

MIL-STD-188C

24 November 1969

SUPERSEDING

MIL-STD-188B

24 February 1964

and Change Notice I

9 August 1966

MILITARY STANDARD

MILITARY COMMUNICATION SYSTEM

TECHNICAL STANDARDS



FSC - MISC

MIL-STD-188C

DEPARTMENT OF DEFENSE
Washington, D.C. 20301

Military Communication System Technical Standards

MIL-STD-188C

1. This standard has been approved by the Department of Defense and is mandatory for use by the Department and Agencies of the Department of Defense, effective 24 November 1969

2. The Standard is to be used in design, installation and operation of new Communication Systems and Equipment. Deviations should only be permitted when there is an overriding necessity and only after the adverse effects of the deviation on such factors as logistics, training, cost and interoperation have been considered. The standards shall be adhered to in development of new equipment, but care should be exercised that the standards do not inhibit advances in communications technology. Revisions of this document and new standards for the future will be generated by such advances in technology.

2.1 It is not intended that existing systems be immediately converted to comply with the requirements of this Standard. New systems and those undergoing major modification or rehabilitation must conform to these Standards.

3. Recommended corrections, additions, or deletions should be addressed to the Commanding General, US Army Electronics Command, ATTN: AMSEL-TD-SS, Fort Monmouth, New Jersey 07703.

FOREWORD

1. The previous issue of MIL-STD-188, "B" revision and change Notice 1 of the "B" revision, contained standards for Global Communications. This issue, the "C" revision, contains only those standards pertaining to tactical communications. Global communication standards are contained in standards publications of the Defense Communication Agency.

2. The "C" revision is being issued to bring standards up to date as a result of improvements in communication technology.

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IDENTIFICATION OF INTERNATIONAL STANDARDIZATION AGREEMENT

Certain provisions of this standard are the subject of international standardization agreement. When revision or cancellation of this standard is proposed, the departmental custodian will inform his respective Departmental Standardization Office so that appropriate action may be taken respecting the international agreement concerned.

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1. SCOPE

1.1 Purpose. The purpose of this standard is to provide technical design standards for military communications systems. These provide the basic technical parameters of communications equipments and systems. The parameters have been chosen for future state-of-the-art values wherever these can be determined with reasonable accuracy as well as to define the minimum acceptable performance values for interim use. The standards are to be used in development of new equipment as well as procurement of production models of standard equipment as stated in the promulgation letter, page ii. Refer to the definitions for STANDARDS, SYSTEM (par. 2.633) and OBJECTIVE, DESIGN (par. 2.434) for their meaning within the context of this standard.

1.2 Objective. The objective of this standard is to enable engineering, installation and operation of military communications systems to be accomplished without undue difficulty from equipment interface problems and problems of incompatibility between systems and equipments. This has been accomplished by the following:

1.2.1 Standardization of operating features of end instruments, not of detail design, but of other factors which govern their interface characteristics with systems in which they will be used. Examples are type of signal, bandwidth, level, etc.

1.2.2 Specifying the maximum extent of the communication system.

1.2.3 Specifying maximum permissible degradation of a signal in the process of transmission and allocating the permissible degradation among various parts of the system.

1.2.4 Standardization of the type of signal at various points in the communication system.

NOTE: In addition to standards, this document contains considerable technical background information to explain how many of the standards were derived and how they are applied. This information is intended as a reference for the user to assist him in determining how the standards are to be applied to his particular problems.

2. TERMS AND DEFINITIONS

2.1 114-LINE WEIGHTING. See WEIGHTING, 114-LINE.

2.2 114-RECEIVER WEIGHTING. See WEIGHTING, 114-RECEIVER.

2.3 ACTIVITY FACTOR. See FACTOR, ACTIVITY.

2.4 ADDRESS. Address in communication usage is the coded representation of the destination of a message. In data processing it is an identification, represented by a name, label or number, for a register or location in storage. Addresses are also a part of an instruction word along with commands, tags and other symbols.

2.5 ADDRESS PATTERN. See PATTERN, ADDRESS.

2.6 ALPHABET. See ALPHABET, DIGITAL.

2.7 ALPHABET, DIGITAL. A table of correspondence between characters and functions and the bit structures which represent them.

2.8 ALPHABET TRANSLATION. See TRANSLATION, ALPHABET.

2.9 ALPHANUMERIC. Alphabetic and numeric, including letters, numbers, and symbols.

2.10 AMPLITUDE MODULATION. See MODULATION, AMPLITUDE.

2.11 AMPLITUDE VS. FREQUENCY DISTORTION. See DISTORTION, AMPLITUDE VS FREQUENCY.

2.12 ANALOG DATA. See DATA.

2.13 ANALOG SIGNAL. See SIGNAL, ANALOG.

2.14 ANTENNA GAIN. See GAIN, ANTENNA.

2.15 AREA, ELEMENTAL (FAX). Any segment of a scanning line of the subject copy the dimension of which along the line is exactly equal to the nominal line width. NOTE: Elemental area is not necessarily the same as the scanning spot.

2.16 ARQ SYSTEM. See SYSTEM, ERROR DETECTING AND FEEDBACK.

2.17 ASSIGNED FREQUENCY. See FREQUENCY, ASSIGNED.

2.18 ASYNCHRONOUS TRANSMISSION. See TRANSMISSION, ASYNCHRONOUS.

2.19 ATTENUATION. The action by which, or the result in which, the power of an electrical signal is decreased; expressed in dB.

2.20 ATTENUATION, ECHO. In a four-wire (or two-wire) circuit in which the two directions of transmission can be separated from each other, the attenuation, R_e , of the echo currents (which return to the input of the circuit under consideration) is determined by the ratio of the transmitted power P_1 , to the echo power received, P_2 ; expressed in dB.

2.21 AVAILABLE LINE. See LINE, AVAILABLE.

2.22 BALANCED. Electrically symmetrical with respect to ground.

2.23 BALANCE, LONGITUDINAL. The electrical symmetry of the two wires of a pair with respect to ground. See BALANCED.

2.24 BALANCED WIRE CIRCUIT. See CIRCUIT, BALANCED WIRE.

2.25 BAND, GUARD. A frequency band between two channels which gives a margin of safety against mutual interference.

2.26 BAND, TIME GUARD. A time interval before or after (or both) the detection/integration interval which may be used to reduce the effects of intersymbol interference in the time domain.

2.27 BANDWIDTH, FACSIMILE. In a given facsimile system, the difference in Hertz between the highest and the lowest frequency components required for adequate transmission of the facsimile signals.

2.28 BANDWIDTH, NECESSARY. For a given class of emission, the minimum value of the occupied bandwidth sufficient to insure the transmission of information at the rate and with the quality required for the system employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth. (This is used for frequency assignment purposes.)

2.29 BANDWIDTH, NOMINAL. The maximum band of frequencies, inclusive of guard bands, assigned to a channel (not to be confused with the term radio frequency emission).

2.30 BANDWIDTH, OCCUPIED (FOR A TRANSMITTER). The frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission. In some cases, for example, multichannel frequency division systems, the percentage of 0.5 percent may lead to certain difficulties in the practical application of the definition of occupied and necessary bandwidth; in such cases a different percentage may prove useful.

2.31 BANDWIDTH, RF (FOR A TRANSMITTER). The difference between the highest and the lowest emission frequencies, in the region of the carrier or principle carrier frequency. NOTE: In practice the region of the carrier or principle carrier frequency beyond which the amplitude of any

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frequency resulting from modulation by signal and/or subcarrier frequencies and their distortion products is less than 5 percent (-26 dB) of the rated peak output amplitude of:

a. The carrier or a single-tone sideband, whichever is greater, for single-channel emission; or

b. Any subcarrier or a single-tone sideband thereof, whichever is greater, for multiplex emission.

2.32 BASEBAND. In the process of modulation, the frequency band occupied by the aggregate of the transmitted signals when first used to modulate a carrier. The term is commonly applied to cases where the ratio of the upper to the lower limit of the frequency band is large compared to unity.

2.33 BASEBAND, MULTIPLEX. The frequency band occupied by the aggregate of the transmitted signals applied to the facility interconnecting the multiplexing and radio or line equipments. The multiplex baseband is also defined as the frequency band occupied by the aggregate of the received signals obtained from the facility interconnecting the radio or line and multiplexing equipment.

2.34 BASEBAND, RADIO. The frequency band available for the transmission of all the combined telephone channels and/or other communication channels.

2.35 BAUD. The unit of modulation rate. One baud corresponds to a rate of one unit interval per second. The modulation rate is expressed as the reciprocal of the duration in seconds of the unit interval. Example: If the duration of the unit interval is 20 milliseconds, the modulation rate is 50 bauds.

2.36 BIAS, INTERNAL (TELETYPEWRITER). That bias, either marking or spacing, that may occur within a start-stop teletypewriter receiving mechanism and which will have the same effect on the margin of operation as bias external to the receiver. See DISTORTION, BIAS.

2.37 BIAS DISTORTION. See DISTORTION, BIAS.

2.38 BINARY CODE. See CODE, BINARY.

2.39 BINARY DIGIT. See DIGIT, BINARY.

2.40 BINARY NOTATION. See NOTATION, BINARY.

2.41 BINARY NUMBER. See NUMBER, BINARY.

2.42 BIT. A contraction of the term binary digit. There are several types of bits.

2.43 BIT, CHECK. See BIT, PARITY.

2.44 BIT, ERRONEOUS. A bit which is not in accordance with that which should have been received.

2.45 BIT, FRAMING. A bit used to denote the beginning or end of a predetermined group of bits.

2.46 BIT, INFORMATION. A bit which is generated by the data source and which is not used by the data transmission system.

2.47 BIT, OVERHEAD. A bit other than an information bit.

2.48 BIT, PARITY. A bit associated with a character, or block, for the purpose of checking the absence of error within the character, or block.

2.49 BIT, SERVICE. An overhead bit which is not a parity bit (i.e., request for repetition, numbering sequence, etc.).

2.50 BIT PAIRING. See PAIRING, BIT.

2.51 BITERNARY TRANSMISSION. See TRANSMISSION, BITERNARY.

2.52 BIT INVERSION. See INVERSION, BIT.

2.53 BLACK FACSIMILE TRANSMISSION. See TRANSMISSION, BLACK FACSIMILE.

2.54 BLOCK. A group of bits, or binary digits, transmitted as a unit over which an encoding procedure is generally applied for error-control purposes.

2.55 BLOCK, ERRONEOUS. A block in which there are one or more erroneous bits.

2.56 BREAK. To break, in a communication circuit, is for the receiving user to interrupt the sending user and take control of the circuit; used especially in connection with half-duplex telegraph circuits and two-way telephone circuits equipped with voice-operated devices.

2.57 BROADCAST OPERATION. See OPERATION, BROADCAST.

2.58 BROADCAST REPEATER. See REPEATER, BROADCAST.

2.59 BUFFER, DATA. A storage device used to compensate for a difference in rate of flow of information or time of occurrence of events.

2.60 BURST, ERROR. A group of bits in which two successive erroneous bits are always separated by less than a given number (X) of correct bits.

2.61 C-MESSAGE WEIGHTING. See WEIGHTING, C-MESSAGE.

2.62 CARRIER. a. A wave suitable for modulation by the intelligence to be transmitted over a communication system. The carrier can be a sinusoidal wave or a recurring series of pulses. See also SUBCARRIER.

b. An unmodulated emission.

2.63 CARRIER FREQUENCY. See FREQUENCY, CARRIER.

2.64 CARRIER NOISE LEVEL. See LEVEL, CARRIER NOISE.

2.65 CARRIER POWER. See POWER, CARRIER (RADIO TRANSMITTER).

2.66 CENTER, SWITCHING. (Also called Switching Facility, Switching Exchange, or Central Office.) An installation in a communication system in which switching equipment is used to interconnect communication circuits on a message or circuit switching basis.

2.67 CENTRAL OFFICE. See CENTER, SWITCHING.

2.68 CHANNEL. The term channel may signify either a one-way path providing transmission in one direction only, or a two-way path providing transmission in two directions. The word "path" is to be interpreted in a broad sense to include separation by frequency division or time division.

2.69 CHARACTER, CODE. The representation of a discrete value or symbol in accordance with a code. See ALPHABET, DIGITAL.

2.70 CHARACTER AND BIT COUNT INTEGRITY. See INTEGRITY, CHARACTER AND BIT COUNT.

2.71 CHARACTER INTERVAL. See INTERVAL, CHARACTER.

2.72 CHARACTER SET. See SET, CHARACTER.

2.73 CHARACTERISTIC, HALFTONE (FAX). A relation between the density of the recorded copy and the density of the subject copy. NOTE: The term may also be used to relate the amplitude of the facsimile signal to the density of the subject copy or the record copy when only a portion of the system is under consideration. In a frequency-modulation system an appropriate parameter is to be used instead of the amplitude.

2.74 CHARACTERISTIC, LOADING (MULTICHANNEL TELEPHONY SYSTEMS). Loading for multi-channel telephony systems indicates for the busy hour the equivalent mean power and the peak power of multi-channel systems as a function of the number of voice channels. The equivalent power of a complex multi-channel signal, referred to zero relative level (0 dBr) is a function of the number of channels and has for its basis a specified mean voice channel power.

2.75 CHARACTERISTIC DISTORTION. See DISTORTION, CHARACTERISTIC.

2.76 CHARACTERISTIC FREQUENCY. See FREQUENCY, CHARACTERISTIC.

2.77 CHECK BIT. See BIT, PARITY.

2.78 CIRCUIT. The complete electrical path between end-terminal instruments over which two-way telecommunications are provided.

2.79 CIRCUIT, BALANCED WIRE. A balanced wire circuit is one whose two sides are electrically alike and symmetrical with respect to ground and other conductors. The term is commonly used to indicate a circuit whose two sides differ only by chance.

2.80 CIRCUIT, COMPOSITED. A composited circuit is a circuit which can be used simultaneously for telephony and direct-current telegraphy, or signaling, separation between the two being accomplished by frequency discrimination.

2.81 CIRCUIT, DUPLEX. A duplex circuit, or system, is a telegraph circuit or system which affords simultaneous independent operation in opposite directions over the same channel.

2.82 CIRCUIT, FOUR-WIRE. A four-wire circuit is a two-way circuit using two paths so arranged that the electric waves are transmitted in one direction only by one path and in the other direction only by the other path. NOTE: The transmission paths may or may not employ four wires.

2.83 CIRCUIT, GROUND-RETURN. A ground return circuit is a circuit which has a conductor (or two or more in parallel) between two points and which is completed through the ground or earth.

2.84 CIRCUIT, HALF-DUPLEX. A circuit designed for duplex operation, but which on account of the nature of the terminal equipment, can be operated alternately only.

2.85 CIRCUIT, METALLIC. A metallic circuit is a circuit of which the ground or earth forms no part.

2.86 CIRCUIT, SIMPLEX. A simplex circuit is a circuit derived from a pair of wires by using the wires in parallel with ground return.

2.87 CIRCUIT, SIMPLEXED. A simplexed circuit is a two-wire metallic circuit from which a simplex circuit is derived, the metallic and simplex circuits being capable of simultaneous use.

2.88 CIRCUIT, TWO-WIRE. A two-wire circuit is a metallic circuit formed by two conductors insulated from each other. NOTE: The term is also used in contrast with four-wire circuit to indicate a circuit using one line or channel for transmission of electric waves in both directions.

2.89 CIRCUIT, UNBALANCED WIRE. An unbalanced wire circuit is one whose two sides are inherently electrically unlike.

2.90 CIRCUIT SWITCHING. See SWITCHING, CIRCUIT.

2.91 CIRCUIT WORKING, CLOSED. A method of single-current operation in which a current flows in the circuit while the transmitting device is at rest.

2.92 CIRCUIT WORKING, OPEN. A method of single current operation in which no current flows in the circuit while the transmitting device is at rest.

2.93 CLOCK. A reference source of timing information for a machine or system.

2.94 CLOSED-CIRCUIT WORKING. See CIRCUIT WORKING, CLOSED.

2.95 CODE. (Telegraph or Data) A system of rules and conventions according to which the telegraph signals forming a message or the data signal forming a block should be formed, transmitted, received and processed.

2.96 CODE, BINARY. A code composed of a combination of entities, each of which can assume one of two possible states.

2.97 CODE, ERROR-CORRECTING. A code in which each telegraph or data signal conforms to specific rules of construction so that departures from this construction in the received signals can be automatically detected, and permits the automatic correction, at the receiving terminal, of some or all of the errors. Such codes require more signal elements than are necessary to convey the basic information.

2.98 CODE, ERROR-DETECTING. A code in which each telegraph or data signal conforms to specific rules of construction, so that departures from this construction in the received signals can be automatically detected. Such codes require more signal elements than are necessary to convey the fundamental information.

2.99 CODE, REDUNDANT. A code using more signal elements than necessary to represent the intrinsic information. For example:

a. A 5-unit code using all the characters of International Telegraph Alphabet No. 2 is not redundant. (See APPENDIX C).

b. A 5-unit code using the digits only in International Telegraph Alphabet No. 2 is redundant.

c. A 7-unit code using only signals made of 4 space and 3 mark digits is redundant.

d. An 8-unit code using one of the bits for parity is redundant.

2.100 CODE CHARACTER. See CHARACTER, CODE.

2.101 CODE CONVERSION. See CONVERSION, CODE.

2.102 CODE ELEMENT. See ELEMENT, CODE.

2.103 CODE SET OR DIGITAL ALPHABET. See ALPHABET, DIGITAL.

2.104 COEFFICIENT, REFLECTION. a. The reflection coefficient at the junction of a uniform transmission line and a mismatched terminating impedance is the vector ratio of the electric field associated with the reflected wave to that associated with the incident wave.

b. At any specified plane in a uniform transmission line between a source of power and an absorber of power, the reflection coefficient is the vector ratio of the electric field associated with the reflected wave to that associated with the incident wave. It is given by the formula

$$(Z_2 - Z_1) / (Z_2 + Z_1) \text{ or } (SWR - 1) / (SWR + 1)$$

where Z_1 is the impedance of the source and Z_2 is the impedance of the load.

2.105 COMMON BATTERY SIGNALING. See SIGNALING, COMMON BATTERY.

2.106 COMMUNICATIONS SINK. See SINK, COMMUNICATIONS.

2.107 COMMUNICATIONS SOURCE. See SOURCE, COMMUNICATIONS.

2.108 COMPANDER. A contraction of the terms compressor and expander. The compressor is used to compress the dynamic range of an analog signal which is to be processed or transmitted. The expander inverts the compressor function to restore the original dynamic range of the processed or transmitted analog signal. The compander may act on the instantaneous amplitude values of the analog signal or on a time average of past amplitudes. Depending on the reaction time, companders are often referred to as slow acting, syllabic, fast acting or instantaneous.

2.109 COMPATIBLE SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND, COMPATIBLE.

2.110 COMPOSITED CIRCUIT. See CIRCUIT, COMPOSITED.

2.111 COMPUTER WORD. See WORD, COMPUTER.

2.112 CONFERENCE OPERATION. See OPERATION, CONFERENCE.

2.113 CONFERENCE REPEATER. See REPEATER, CONFERENCE.

2.114 CONGRUENCY (FAX). The ability of a facsimile transmitter or receiver to perform in an identical manner as an equipment of another facsimile system.

2.115 CONTRAST, SIGNAL (FAX). The ratio expressed in decibels between white signal and black signal.

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2.116 CONTROL EQUIPMENT, REMOTE. The apparatus used for performing monitoring, controlling, supervising, or a combination of these, a prescribed function or functions at a distance by electrical means.

2.117 CONVERSION, CODE. The process by which a code of some predetermined bit structure (for example, 5, 7, 14 bits per character interval) is converted to a second code with more or less bits per character interval. No alphabetical significance is assumed in this process. In certain cases, such as the conversion from start/stop telegraph equipment to synchronous equipment, a code conversion process may only consist of discarding the stop and start element and adding a sixth element to indicate the stop and start condition. In other cases, it may consist of addition or deletion of control and/or parity bits.

2.118 CONVERTER, FACSIMILE. A device which changes the type of modulation.

2.119 CONVERTER, FACSIMILE RECEIVING. (FS TO AM CONVERTER.) A device which changes the type of modulation from frequency shift to amplitude.

2.120 CONVERTER, FACSIMILE TRANSMITTING. (AM TO FS CONVERTER.) A device which changes the type of modulation from amplitude to frequency shift.

2.121 CONVERTER, SIGNAL. A device in which the input and output signals are formed according to the same code, but not according to the same type of electrical modulation.

2.122 COOPERATION, INDEX OF, DIAMETRAL OR INTERNATIONAL (IN FACSIMILE). The product of the drum diameter and the line advance in scanning lines per unit length. The unit length must be the same as that used for expressing the drum diameter.

2.123 COPY, SUBJECT (FAX). The material in graphic form which is to be transmitted for facsimile reproduction.

2.124 CROSSTALK. The phenomenon in which a signal transmitted on one circuit or channel of a transmission system is detectable in another circuit or channel.

2.125 CROSSTALK, FAR-END. Far end crosstalk which is propagated in a disturbed communication channel in the same direction as the propagation in the disturbing channel. The terminals of the disturbed channel and the energized terminal of the disturbing channel are usually remote from each other.

2.126 CROSSTALK, NEAR-END. Near end crosstalk is crosstalk which is propagated in a disturbed channel in the direction opposite to the direction of propagation of the current in the disturbing channel. The terminal of the disturbed channel at which the near end crosstalk is present is ordinarily near or coincides with the energized terminal of the disturbing channel.

2.127 CROSSTALK COUPLING LOSS. See LOSS, CROSSTALK COUPLING.

2.128 CYCLIC DISTORTION. See DISTORTION, CYCLIC.

2.129 DATA. (ANALOG OR DIGITAL.) Material transmitted or processed to provide information, or to control a process.

2.130 DATA BUFFER. See BUFFER, DATA.

2.131 DATA SIGNALING RATE. See RATE, DATA SIGNALING.

2.132 DATA SINK. See SINK, DATA.

2.133 DATA SOURCE. See SOURCE, DATA.

2.134 DATA TERMINAL. See TERMINAL, DATA.

2.135 DB. Decibel. The standard unit for expressing transmission gain or loss and relative power ratios. The decibel is one-tenth the size of a Bel which is too large a unit for convenient use. Both units are expressed in terms of the logarithm to the base 10 of a power ratio, the decibel formula being: $dB = 10 \log_{10} \frac{P_1}{P_2}$

Power ratios may be expressed in terms of voltage or current. If the resistances for both the power measurements are the same, they cancel out in the power ratio so the formulas in terms of voltage or current become as follows:

$$dB = 10 \log \frac{E_1^2}{R_1} / \frac{E_2^2}{R_2} = 10 \log \frac{I_1^2 R_1}{I_2^2 R_2}$$

$$dB = 10 \log \frac{E_1^2}{E_2^2} = 10 \log \frac{I_1^2}{I_2^2}$$

$$dB = 20 \log \frac{E_1}{E_2} = 20 \log \frac{I_1}{I_2} \text{ where } R_1 = R_2$$

2.136 DBa, dBrn ADJUSTED. Weighted circuit noise power, in dB referred to 3.16 picowatts (-85 dbm), which is 0 dba. Use of FLA-line or HAL-receiver weighting shall be indicated in parentheses as required. See WEIGHTING, NOISE. NOTE: A one milliwatt, 1000 cps tone will read +85 dBa, but the same power as white noise, randomly distributed over a 3 kc band (nominally 300 to 3300 cps), will read +82 dBa, due to the frequency weighting.

2.137 DBa (FLA). Weighted circuit noise power in dBa, measured on a line by a noise measuring set with FLA-line weighting. See WEIGHTING, NOISE.

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2.138 DBa (HAL). Weighted circuit noise power in dBa, measured across the receiver of a 302 type or similar subset, by a noise measuring set with HAL-receiver weighting. See WEIGHTING, NOISE.

2.139 DBa0. Circuit noise power in dBa referred to or measured at a point of zero relative transmission level (0 dBr). NOTE: It is preferred to convert circuit noise readings from dBa to DBa0, as this makes it unnecessary to know or state the relative transmission level at point of actual measurement.

2.140 DBm. a. DB referred to one milliwatt; employed in communication work as a measure of absolute power values. Zero dBm equals one milliwatt.

b. In noise power measurement, noise power in dB referred to one milliwatt. NOTE: In American practice unweighted measurement is normally understood, applicable to a certain bandwidth which must be stated or implied. In European practice, psophometric weighting may be implied, as indicated by context; equivalent to dBmOp, which is preferred.

2.141 DBm (Psoph). A unit of noise power in dBm, measured with psophometric weighting. See WEIGHTING, NOISE. NOTE: Conversion regulations with other weighted units:

$$\text{dBm(psoph)} = 10 \log_{10} \text{pWp} - 90 = \text{dBa} - 84$$

2.142 DBm0. In noise power measurement, noise power in dBm, referred to or measured at a point of zero relative transmission level (0 dBr).

2.143 DBm CONVERSION TO VU. $-3.9 \text{ dBm} = 0 \text{ vu}$.

2.144 DBmOp. Circuit noise power in dBm0, measured on a line by a Psophometer or noise measuring set having psophometric weighting. See WEIGHTING, NOISE.

2.145 DBrn. (Decibels Above Reference Noise.) Weighted circuit noise power, in dB referred to 1.0 picowatt (-90 dBm), which is 0 DBrn. Use of 144-line, 144-receiver or C-message weighting, or flat weighting, shall be indicated in parentheses as required. See WEIGHTING, NOISE. NOTE: (1) With C-message weighting, a one milliwatt, 1000 Hertz tone will read $+90 \text{ DBrn}$, but the same power as white noise, randomly distributed over a 3 kHz band (nominally 300 to 3300 Hz) will read approximately $+88.5 \text{ DBrn}$, (rounded off to $+88 \text{ DBrn}$), due to the frequency weighting. (2) With 144 weightings, a one milliwatt, 1000 Hz tone will also read $+90 \text{ DBrn}$, but the same 3kHz white noise power will read only $+82 \text{ DBrn}$, due to the different frequency weighting.

2.146 DBrn (144 LINE). Weighted circuit noise power in DBrn, measured on a line by a noise measuring set with 144-line weighting. See WEIGHTING, NOISE.

2.147 DBrn (144-RECEIVER). Weighted circuit noise power in dBrn, measured across the receiver of a subset with a No. 144-receiver, by a noise measuring set with 144-receiver weighting. See WEIGHTING, NOISE.

2.148 DBrn (C-MESSAGE). Weighted circuit noise power in dBrn, measured on a line by a noise measuring set with C-message weighting.

2.149 DBrn (F1-F2). Flat noise power in dBrn, measured over the frequency band between frequencies f_1 and f_2 . See WEIGHTING, NOISE (FLAT WEIGHTING).

2.150 DECAY TIME, PULSE. The time required for the instantaneous amplitude to go from 90% to 10% of the peak value.

2.151 DEFINITION (FAX). Distinctness or clarity of detail or outline in a record sheet, or other reproduction.

2.152 DEGREE OF DISTORTION. See DISTORTION, DEGREE OF.

2.153 DEGREE OF INDIVIDUAL DISTORTION OF A PARTICULAR SIGNIFICANT INSTANT (OF A MODULATION OR OF A RESTITUTION). See DISTORTION, DEGREE OF INDIVIDUAL.

2.154 DEGREE OF ISOCHRONOUS DISTORTION. See DISTORTION, DEGREE OF ISOCHRONOUS.

2.155 DEGREE OF SIGNIFICANT INSTANT DISTORTION. See DISTORTION, DEGREE OF INDIVIDUAL.

2.156 DEGREE OF START-STOP DISTORTION. See DISTORTION, DEGREE OF START-STOP.

2.157 DELAY, PHASE (FAX). In the transfer of a single frequency wave from one point to another in a system, the time delay of a part of the wave identifying its phase. NOTE: The phase delay is measured by the ratio of the total phase shift in cycles to the frequency in cycles per second.

2.158 DELAY DISTORTION. See DISTORTION, ENVELOPE DELAY.

2.159 DELAY DISTORTION (FAX). See DISTORTION, ENVELOPE DELAY.

2.160 DELTA MODULATION. See MODULATION, DELTA.

2.161 DEMODULATION. A process wherein a wave resulting from previous modulation is employed to derive a wave having substantially the characteristics of the original modulating wave. See RESTITUTION.

2.162 DENSITY (FAX). A measure of the light-transmitting or reflection properties of an area. It is expressed by the common logarithm of the ratio of incident to transmitted or reflected light flux. NOTE: There

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are many types of density which will usually have different numerical values for a given material; e.g. Diffuse Density, Double Diffuse Density; Specular Density. The relevant type of density depends upon the geometry of the optical system in which the material is used.

2.163 DESIGN OBJECTIVE. See OBJECTIVE, DESIGN.

2.164 DESIGNATION, FREQUENCY SPECTRUM. See FREQUENCY, SPECTRUM DESIGNATION OF.

2.165 DEVICE, INPUT-OUTPUT. Any equipment which introduces data into or extracts data from a data communication system.

2.166 DIBIT. A group of two bits. The four possible states for a dibit are 00, 01, 10 and 11.

2.167 DIFFERENTIAL MODULATION. See MODULATION, DIFFERENTIAL.

2.168 DIGIT, BINARY. An information state in binary notation (e.g., 0 or 1).

2.169 DIGITAL ALPHABET OR CODE SET. See ALPHABET, DIGITAL.

2.170 DIGITAL DATA. See DATA.

2.171 DIGITAL SIGNAL. See SIGNAL, DIGITAL.

2.172 DIRECT RECORDING (FAX). See RECORDING, DIRECT. (FAX).

2.173 DIRECTION OF SCANNING (FAX). See SCANNING, DIRECTION OF (FAX).

2.174 DISTORTION, AMPLITUDE VS FREQUENCY (of a transmission system). That distortion caused by the nonuniform attenuation, or gain, of the system with respect to frequency under specified terminal conditions.

2.175 DISTORTION, BIAS. Distortion affecting a two-condition (or binary) modulation in which all the significant intervals corresponding to one of the two significant conditions have uniformly longer or shorter duration than the corresponding theoretical durations.

2.176 DISTORTION, CHARACTERISTIC. Distortion caused by transients which, as a result of modulation, are present in the transmission channel and depend on its transmission qualities.

2.177 DISTORTION, CYCLIC. (Of telegraph signals.) Distortion which is neither characteristic, bias, nor fortuitous and which, in general, has a periodic character. Its causes are, for example, irregularities in the duration of contact time of the brushes of a transmitter distributor or interference by disturbing alternating currents, etc.

2.178 DISTORTION, DEGREE OF. A measurement of the deviation of a digital signal from the theoretically perfect signal. It is expressed as a percent of the theoretically perfect unit interval.

2.179 DISTORTION, DEGREE OF INDIVIDUAL, OF A PARTICULAR SIGNIFICANT INSTANT (OF A MODULATION OR OF A RESTITUTION). Ratio to the unit interval of the displacement, expressed algebraically, of this significant instant from an ideal instant. This displacement is considered positive when a significant instant occurs after the ideal instant. The degree of individual distortion is usually expressed as a percentage.

2.180 DISTORTION, DEGREE OF ISOCHRONOUS. Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and the theoretical intervals separating any two significant instants of modulation (or restitution), these instants being not necessarily consecutive. The degree of distortion (of an isochronous modulation or restitution) is usually expressed as a percentage. NOTE: The result of the measurement should be completed by an indication of the period, usually limited, of the observation. For a prolonged modulation (or restitution) it will be appropriate to consider the probability that an assigned value of the degree of distortion will be exceeded.

2.181 DISTORTION, DEGREE OF SIGNIFICANT INSTANT. See DISTORTION, DEGREE OF INDIVIDUAL.

2.182 DISTORTION, DEGREE OF START-STOP. Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and theoretical intervals separating any significant instant of modulation (or of restitution) from the significant instant of the start element immediately preceding it. The degree of distortion of a start-stop modulation (or restitution) is usually expressed as a percentage.

2.183 DISTORTION, DELAY. See DISTORTION, ENVELOPE DELAY.

2.184 DISTORTION, DELAY (OF A TRANSMISSION SYSTEM). The distortion of a complex waveform, made up of two or more different frequencies, caused by the difference in arrival time of each frequency at the output.

2.185 DISTORTION, END (OF START-STOP TELETYPEWRITER SIGNALS). The shifting of the end of all marking pulses from their proper positions in relation to the beginning of the start pulse.

2.186 DISTORTION, ENVELOPE DELAY. Envelope delay distortion is the maximum difference of the envelope delay characteristic in a band between any two specified frequencies. Refer to Delay Distortion in Appendix B for detailed explanation.

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2.187 DISTORTION, FORTUITOUS (OF TELEGRAPH SIGNALS). Distortion resulting from causes generally subject to random laws, for example, accidental irregularities in the operating of the apparatus and moving parts, disturbances affecting the transmission channel, etc.

2.188 DISTORTION, INTERMODULATION. Nonlinear distortion characterized by the appearance of frequencies in the output, equal to the sums and differences of integral multiples of the component frequencies present in the input. NOTE: Harmonic components also present in the output are usually not included as part of the intermodulation distortion. When harmonics are included, a statement to that effect should be made.

2.189 DISTORTION, NONLINEAR. Distortion caused by a deviation from a linear relationship between the input and output of a system or component.

2.190 DISTORTION, PHASE. See DISTORTION, ENVELOPE DELAY.

2.191 DISTORTION, SINGLE-HARMONIC. The ratio of the power at the fundamental frequency, measured at the output of the transmission system considered, to the power of any single harmonic observed at the output of the system because of its nonlinearity, when a single frequency signal of specified power is applied to the input of the system; expressed in dB.

2.192 DISTORTION, START-STOP TTY. The shifting of the transition of the signal pulses from their proper positions relative to the beginning of the start pulse. The magnitude of the distortion is expressed in percent of a perfect unit pulse length.

2.193 DISTORTION, TELETYPEWRITER SIGNAL. See DISTORTION, START-STOP TTY.

2.194 DISTORTION, TOTAL HARMONIC. The ratio of the power at the fundamental frequency, measured at the output of the transmission system considered, to the power of all harmonics observed at the output of the system because of its nonlinearity, when a single frequency signal of specified power is applied to the input of the system; expressed in dB.

2.195 DIVERSITY. That method of transmission and/or reception, whereby, in order to reduce the effects of fading, a single received information signal is derived from a combination of, or selection from, a plurality of signals containing the same information. Improvement gained shall be expressed in dB.

2.196 DIVERSITY, DUAL. The term applied to the simultaneous combining of, or selection from, two signals and their detection through the use of space, frequency, angle, or polarization characteristics.

2.197 DIVERSITY, FREQUENCY. Any method of transmission and reception wherein the same information signal is transmitted and received simultaneously on two or more distinct frequencies.

2.198 DIVERSITY, POLARIZATION. A method of transmission and/or reception of information accomplished by the use of separate vertically and horizontally polarized antennas.

2.199 DIVERSITY, QUADRUPLER. The term applied to the simultaneous combining of, or selection from, four signals and their detection through the use of space, frequency, angle, or polarization characteristics or combinations thereof.

2.200 DIVERSITY, SPACE. Any method of transmission and/or reception which employs antennas having spatial separation.

2.201 DOPPLER EFFECT, See EFFECT, DOPPLER.

2.202 DOUBLE-CURRENT TRANSMISSION. See TRANSMISSION, DOUBLE-CURRENT.

2.203 DOUBLE SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND, DOUBLE, REDUCED OR SUPPRESSED CARRIER and TRANSMISSION, SIDEBAND, DOUBLE.

2.204 DRUM FACTOR (FAX). See FACTOR, DRUM (FAX).

2.205 DRUM SPEED (FAX). See SPEED, DRUM (FAX).

2.206 DUAL DIVERSITY. See DIVERSITY, DUAL.

2.207 DUPLEX CIRCUIT. See CIRCUIT, DUPLEX.

2.208 DUPLEX OPERATION. See OPERATION, DUPLEX.

2.209 DUPLEX SYSTEM OR CIRCUIT. See CIRCUIT, DUPLEX.

2.210 ECHO. The effect of a wave which, having been derived (for example by reflection) from a primary wave, arrives at either end of the same circuit with sufficient magnitude and delay to be distinctly recognized.

2.211 ECHO ATTENUATION. See ATTENUATION, ECHO.

2.212 EFFICIENCY FACTOR, IN TIME (OF A TELEGRAPH COMMUNICATION). See EFFICIENCY, TELEGRAPH COMMUNICATIONS.

2.213 EFFECTIVE RADIATED POWER. See POWER, EFFECTIVE RADIATED.

2.214 EFFECT, DOPPLER. The phenomenon evidenced by the change in the observed frequency of a wave in a transmission system caused by a time rate of change in the effective length of the path of travel between the source and the point of observation.

2.215 EFFECT, KENDALL (FAX). A spurious pattern or other distortion in a facsimile record caused by unwanted modulation products arising from the transmission of a carrier signal and appearing in the form of a rectified baseband that interferes with the lower sideband of the carrier. NOTE: This occurs principally when the single sideband width is greater than half the facsimile carrier frequency.

2.216 EFFICIENCY, TELEGRAPH COMMUNICATION. The efficiency factor of a communication is the ratio of the time to transmit a text automatically and at a specified modulation rate, to the time actually taken to receive the same text with a specified error rate. NOTE: (a) The whole of the apparatus comprising the communication is assumed to be in the normal condition of adjustment and operation. (b) A telegraph communication may have a different efficiency factor in time for the two directions of transmission. (c) The practical conditions of measurement should be specified; in particular, the duration.

2.217 EHF. EXTREMELY HIGH FREQUENCY, 30 to 300 GHZ.

2.218 ELECTRICALLY-POWERED TELEPHONE. See TELEPHONE, ELECTRICALLY-POWERED.

2.219 ELECTROCHEMICAL RECORDING (FAX). See RECORDING, ELECTROCHEMICAL (FAX).

2.220 ELECTROLYTIC RECORDING (FAX). See RECORDING, ELECTROLYTIC (FAX).

2.221 ELECTROMECHANICAL RECORDING (FAX). See RECORDING, ELECTROMECHANICAL (FAX).

2.222 ELECTRONIC LINE SCANNING (FAX). See SCANNING, ELECTRONIC LINE (FAX).

2.223 ELECTROSTATIC RECORDING (FAX). See RECORDING, ELECTROSTATIC (FAX).

2.224 ELECTROTHERMAL RECORDING (FAX). See RECORDING, ELECTROTHERMAL (FAX).

2.225 ELEMENT, CODE. One of a finite set of parts of which the characters in a given code may be composed.

2.226 ELEMENT, SIGNAL. Each of the parts constituting a telegraph or data signal and distinguished from the others by its nature, magnitude, duration, and relative position (or by one or some of these features only).

2.227 ELEMENTAL AREA (FAX). See AREA, ELEMENTAL (FAX).

2.228 ELF. EXTREMELY LOW FREQUENCY, below 300 Hz.

2.229 END DISTORTION. See DISTORTION, END.

2.230 END INSTRUMENT. See INSTRUMENT, END.

2.231 ENVELOPE DELAY DISTORTION. See DISTORTION, ENVELOPE DELAY.

2.232 EQUALIZATION. The process of reducing frequency and/or phase distortion of a circuit by the introduction of networks to compensate for the difference in attenuation and/or time delay at the various frequencies in the transmission band.

2.233 EQUIPMENT, REMOTE CONTROL. See CONTROL EQUIPMENT, REMOTE.

2.234 ERRONEOUS BIT. See BIT, ERRONEOUS.

2.235 ERRONEOUS BLOCK. See BLOCK, ERRONEOUS.

2.236 ERROR. See ERROR; SINGLE, DOUBLE, TRIPLE, ETC.

2.237 ERROR-CORRECTING CODE. See CODE, ERROR-CORRECTING.

2.238 ERROR-CORRECTING SYSTEM. See SYSTEM, ERROR CORRECTING.

2.239 ERROR-DETECTING AND FEEDBACK SYSTEM. See SYSTEM, ERROR-DETECTING AND FEEDBACK.

2.240 ERROR-DETECTING CODE. See CODE, ERROR-DETECTING.

2.241 ERROR-DETECTING SYSTEM. See SYSTEM, ERROR DETECTING.

2.242 ERROR-RATE RESIDUAL. (Undetected error-rate.) The ratio of the number of bits, elements, characters, blocks incorrectly received but undetected or uncorrected by the error-control equipment, to the total number of bits, unit elements, characters, blocks sent.

2.243 ERROR BURST. See BURST, ERROR.

2.244 ERROR RATE. See RATE, ERROR.

2.245 ERROR: SINGLE, DOUBLE, TRIPLE, ETC. A group of 1, 2, 3, etc., consecutive erroneous bits, characters, words, blocks or elements preceded and followed immediately by at least one correct bit, character, word, block or element.

2.246 EXALTED CARRIER RECEPTION. See RECEPTION, EXALTED CARRIER.

2.247 FLA-LINE WEIGHTING. See WEIGHTING, FLA-LINE.

2.248 FACSIMILE-SIGNAL LEVEL. See SIGNAL LEVEL, FACSIMILE.

2.249 FACSIMILE. A line scanning system of telecommunication for the transmission of fixed images, with or without half-tones, with a view to their reproduction in a permanent form. (Wirephoto and telephoto are

facsimile through wire circuits; radiophoto is facsimile via radio).
See GRAPHICS.

2.250 FACSIMILE BANDWIDTH. See BANDWIDTH, FACSIMILE.

2.251 FACSIMILE CONVERTER. See CONVERTER, FACSIMILE.

2.252 FACSIMILE RECEIVER. See RECEIVER, FACSIMILE.

2.253 FACSIMILE RECORDER. See RECORDER, FACSIMILE.

2.254 FACSIMILE SIGNAL. See SIGNAL, FACSIMILE.

2.255 FACSIMILE TRANSMITTER. See TRANSMITTER, FACSIMILE.

2.256 FACTOR, ACTIVITY. Activity factor, for a voice communication channel, is the percentage of the time during the busiest traffic hour when a signal is present in the channel in one direction.

2.257 FACTOR, DRUM (FAX). The drum factor is the ratio of drum length used to drum diameter. Where drums are not used it is the ratio of the equivalent dimensions.

2.258 FADING. The fluctuation in intensity and/or relative phase of any or all frequency components of the received radio signal due to changes in the characteristics of the propagation path.

2.259 FADING, FLAT. That type of fading in which all frequency components of the received radio signal fluctuate in the same proportion simultaneously.

2.260 FADING, SELECTIVE. That type of fading in which the various frequency components of the received radio signal fluctuate independently.

2.261 FAIL TIME. See DECAY TIME, PULSE.

2.262 FAR-END CROSSTALK. See CROSSTALK, FAR-END.

2.263 FAULT. A malfunction that is reproducible, as contrasted to an error, which is defined as a malfunction which is not reproducible. A malfunction is considered reproducible if it occurs consistently under the same circumstances.

2.264 FAX. A shorthand reference to facsimile.

2.265 FIDELITY. See LINEARITY.

2.266 FIXED REFERENCE MODULATION. See MODULATION, FIXED REFERENCE.

2.267 FLAT FADING. See FADING, FLAT.

2.268 FLAT WEIGHTING. See WEIGHTING, FLAT.

2.269 FORMAT. Arrangement of bits or characters within a group, such as a word, message, or language; shape, size and general makeup of a document.

2.270 FORTUITOUS DISTORTION. See DISTORTION, FORTUITOUS.

2.271 FOUR-WIRE CIRCUIT. See CIRCUIT, FOUR-WIRE.

2.272 FRAME (FAX). A rectangular area, the width of which is the available line and the length of which is determined by the service requirements.

2.273 FRAMING (FAX). The adjustment of the picture to a desired position in the direction of line progression.

2.274 FRAMING BIT. See BIT, FRAMING.

2.275 FREQUENCIES, PICTURE (FAX). The frequencies which result solely from scanning subject copy. NOTE: This does not include frequencies which are part of a modulated carrier signal.

2.276 FREQUENCY-CHANGE SIGNALING. See SIGNALING, FREQUENCY CHANGE.

2.277 FREQUENCY-EXCHANGE SIGNALING, TWO-SOURCE FREQUENCY. See SIGNALING, FREQUENCY EXCHANGE.

2.278 FREQUENCY. The number of complete cycles per unit of time. When the unit of time is one second, the measurement unit is Hertz (cycles per second).

2.279 FREQUENCY, ASSIGNED. The frequency of the center of the radiated bandwidth shall be designated the assigned frequency. (The frequency of the RF carrier, whether suppressed or radiated, shall be referred to in parentheses following the assigned frequency and shall be the frequency appearing in the dial settings of RF equipment intended for a single sideband or independent sideband.) NOTE: The frequency of the RF carrier is usually referred to in this standard as f_0 and the assigned frequency as f_c , i.e., in Figures 15 and 16.

2.280 FREQUENCY, CARRIER. The frequency of the unmodulated carrier.

2.281 FREQUENCY, CHARACTERISTIC. A frequency which can be easily identified and measured in a given emission.

2.282 FREQUENCY, MAXIMUM KEYING (FAX). The frequency in cycles per second numerically equal to the spot speed divided by twice the "scanning spot X dimension."

2.283 FREQUENCY, MAXIMUM MODULATING (FAX). The highest picture frequency required for the facsimile transmission system. NOTE: The maximum modulating frequency and the maximum keying frequency are not necessarily equal.

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2.284 **FREQUENCY, REFERENCE.** A frequency having a fixed and specified position with respect to the assigned frequency. The displacement of this frequency with respect to the assigned frequency has the same absolute value and sign that the displacement of the characteristic frequency has with respect to the center of the frequency band occupied by the emission.

2.285 **FREQUENCY, SAMPLING.** The rate at which signals in an individual channel are sampled for subsequent modulation, quantization, and/or coding.

2.286 **FREQUENCY, SCANNING LINE (FAX).** See **SPEED, STROKE (FAX).**

2.287 **FREQUENCY, SPECTRUM DESIGNATION OF.** A method of referring to a range or band of communication frequencies. In American practice the designator is a two or three letter abbreviation of the name. In ITU practice the designator is a numeric. These ranges, or bands are:

American Band	Frequency	ITU Band
ELF	Below 300 Hz	
ILF	300 - 3000 Hz	
VLf	3 - 30 kHz	4
Lf	30 - 300 kHz	5
Mf	300 - 3000 kHz	6
Hf	3 - 30 MHz	7
VHF	30 - 300 MHz	8
UHF	300 - 3000 MHz	9
SHF	3 - 30 GHz	10
EHF	30 - 300 GHz	11

2.288 **FREQUENCY DIVERSITY.** See **DIVERSITY, FREQUENCY.**

2.289 **FREQUENCY DIVISION MULTIPLEX (FDM).** See **MULTIPLEX, FREQUENCY DIVISION (FDM).**

2.290 **FREQUENCY MODULATION.** See **MODULATION, FREQUENCY.**

2.291 **FREQUENCY SHIFT, SIGNAL (FAX).** In a frequency shift facsimile system, the numerical difference between the frequencies corresponding to white signal and black signal at any point in the system.

2.292 **FREQUENCY SHIFT KEYING.** See **KEYING, FREQUENCY SHIFT.**

2.293 **FREQUENCY SHIFT SIGNALING.** See **KEYING, FREQUENCY SHIFT.**

2.294 **FREQUENCY SPECTRUM DESIGNATION.** See **FREQUENCY, SPECTRUM DESIGNATION OF.**

2.295 **FREQUENCY TOLERANCE.** The maximum permissible departure of the center frequency of the frequency band occupied by an emission from the assigned frequency or of the characteristic frequency of an emission from the reference frequency. The frequency tolerance is expressed in parts in 10^n , in Hertz, or in percentages.

2.296 FULL DUPLEX OPERATION. See OPERATION, DUPLEX.

2.297 GAIN. The action by which, or the result in which, the power of an electrical signal is increased; expressed in dB.

2.298 GAIN, ANTENNA. Antenna gain is commonly defined as the ratio of the maximum radiation intensity in a given direction to the maximum radiation intensity produced in the same direction from a reference antenna with the same power input.

2.299 GAIN, INSERTION. The insertion gain of a transmission system (or component thereof) inserted between two impedances Z_e (transmitter) and Z_r (receiver) is the ratio of the power measured at the receiver Z_r , after insertion of the transmission system considered, to the power measured before insertion; expressed in dB. If the resulting number in dB thus obtained is negative, an insertion loss is indicated.

2.300 GAIN, NET. See LOSS, NET.

2.301 GHZ. GIGAHERTZ. 10^9 TO POWER OF 9, HERTZ.

2.302 GRAPHICS. The art or science of conveying intelligence through the use of graphs, letters, lines, drawings, pictures, etc. (Facsimile is a technology for electrically transporting intelligence in graphic form from one point to another.)

2.303 GROUND-RETURN CIRCUIT. See CIRCUIT, GROUND-RETURN.

2.304 GROUP, TRUNK. Two or more trunks between the same two points.

2.305 GROUPING (FAX). Periodic error in the spacing of recorded lines.

2.306 GUARD BAND. See BAND, GUARD.

2.307 GUARD BAND, TIME. See BAND, TIME GUARD.

2.308 HAL-RECEIVER WEIGHTING. See WEIGHTING, HAL-RECEIVER.

2.309 HALF-DUPLEX CIRCUIT. See CIRCUIT, HALF-DUPLEX.

2.310 HALF-DUPLEX OPERATION. See OPERATION, HALF-DUPLEX.

2.311 HALFTONE CHARACTERISTIC (FAX). See CHARACTERISTIC, HALFTONE (FAX).

2.312 HERTZ. A unit of frequency - one cycle per second, 1 Hz.

2.313 HF. High frequency, 3 to 30 MHz.

2.314 HIGH PERFORMANCE EQUIPMENTS. See PERFORMANCE, EQUIPMENTS, HIGH.

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- 2.315 Hz. Hertz.
- 2.316 ILF. Infra low frequency, 300 to 3000 Hz.
- 2.317 IMPEDANCE, TERMINAL. The complex impedance as seen at the unloaded output terminals of a transmission equipment or line which is otherwise in normal operating condition.
- 2.318 INBAND NOISE POWER RATIO (MULTICHANNEL EQUIPMENT). See NOISE POWER RATIO, INBAND (MULTICHANNEL EQUIPMENT).
- 2.319 INBAND SIGNALING. See SIGNALING, INBAND.
- 2.320 IN CHANNEL NOISE POWER RATIO (MULTICHANNEL EQUIPMENT). See NOISE POWER RATIO, IN CHANNEL (MULTICHANNEL EQUIPMENT).
- 2.321 INDEPENDENT SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND, INDEPENDENT.
- 2.322 INDEX OF COOPERATION (FAX). See COOPERATION, INDEX OF (FAX).
- 2.323 INDEX OF COOPERATION, DIAMETRAL OR INTERNATIONAL. See COOPERATION, INDEX OF (FAX).
- 2.324 INFORMATION BIT. See BIT, INFORMATION.
- 2.325 INFORMATION TRANSFER. See TRANSFER, INFORMATION.
- 2.326 INK VAPOR RECORDING (FAX). See RECORDING, INK VAPOR (FAX).
- 2.327 INPUT-OUTPUT DEVICE. See DEVICE, INPUT-OUTPUT.
- 2.328 INSERTION GAIN. See GAIN, INSERTION.
- 2.329 INSERTION LOSS. See LOSS, INSERTION.
- 2.330 INSTANTS, SIGNIFICANT. The instants at which the successive significant conditions recognized by the appropriate device of the modulation or restitution begin. Each of these instants is determined as soon as the appropriate device takes up the significant condition usable for a recording or a processing.
- 2.331 INSTRUMENT, END. A device which is connected to the terminal of a circuit and used to convert usable intelligence into electrical signals or vice-versa.
- 2.332 INTEGRITY, CHARACTER AND BIT COUNT. That condition in which the precise number of characters, or bits, that are originated in a message text (in the case of message communication) or per unit time (in the case of a user to user connection) are preserved.
- 2.333 INTERCHARACTER INTERVAL. See INTERVAL, INTERCHARACTER.

2.334 INTERFACE. A concept involving the specification of the interconnection between two equipments or systems. The specification includes the type, quantity and function of the interconnection circuits and the type and form of signals to be interchanged via those circuits.

2.335 INTERMODULATION DISTORTION. See DISTORTION, INTERMODULATION.

2.336 INTERMODULATION NOISE. See NOISE, INTERMODULATION.

2.337 INTERNAL BIAS. See BIAS, INTERNAL.

2.338 INTERVAL, CHARACTER. The total number of unit intervals (including synchronizing, intelligence, error checking, or control bits) required to transmit any given character in any given communication system. Extra signals which are not associated with individual characters are not included. For example, additional time added between the end of the customary stop element and the beginning of the next start element as a result of a speed change, buffering, etc., is defined as the intercharacter interval. The intercharacter interval may be of any length and is of the same sense on the stop element, i.e., "1" (marking). See INTERCHARACTER INTERVAL.

2.339 INTERVAL, INTERCHARACTER. The intercharacter interval is that time period between the end of the stop element of one character and the beginning of the following character. The signal sense of the intercharacter interval is always the same as the sense of the stop element, i.e., "1" or marking. See INTERVAL, CHARACTER.

2.340 INTERVAL, SIGNIFICANT. Time interval between two consecutive significant instants.

2.341 INTERVAL, UNIT. In a system using an equal-length code or in a system during isochronous modulation (or demodulation), it is the interval of time such that the theoretical durations of the significant intervals of a telegraph modulation are all whole multiples of this interval.

2.342 INVERSION, BIT. The deliberate or fortuitous changing of the state of a bit to the opposite state.

2.343 ISOCRONOUS MODULATION. See MODULATION, ISOCRONOUS.

2.344 JITTER (FAX). Raggedness in the received copy caused by erroneous displacement of recorded spots in the direction of scanning.

2.345 JITTER, PHASE. See PERTUBATION, PHASE.

2.346 KENDALL EFFECT (FAX). See EFFECT, KENDALL (FAX).

2.347 KEYING, FREQUENCY SHIFT, FREQUENCY SHIFT SIGNALING (FSK). A frequency-change signaling method in which the frequency or frequencies are varied in accordance with the signals to be transmitted and characterized by continuity of phase during the transition from one signaling condition to another.

2.348 KEYING, TWO-TONE, TELEGRAPH. A system employing a transmission path comprising two channels in the same direction, one for transmission of the spacing elements of binary modulation, the other for transmitting the marking elements of the same modulation.

2.349 KHZ. KiloHertz. 10 to power of 3, Hertz.

2.350 LENGTH, SCANNING LINE (FAX). The total length of scanning line is equal to the spot speed divided by the scanning line frequency. NOTE: This is generally greater than the length of the available line.

2.351 LEVEL, CARRIER NOISE. The noise level produced by undesired variations of a carrier in the absence of any intended modulation.

2.352 LEVEL, RELATIVE TRANSMISSION. The ratio of the signal power in a transmission system to the signal power at some point chosen as reference. The ratio is usually determined by applying a standard test tone (See TONE, STANDARD TEST) at zero transmission level reference point (or adjusted test tone power at any other reference point) and measuring the gain or loss to the location of interest. Note should be made as to the distinction between the standard test tone power and the expected median power of the actual signal required as the basis for the design of transmission systems.

2.353 LEVEL, SINGLE SIDEBAND EQUIPMENT, REFERENCE. (Voice Frequency Input Power to a Transmitter, One Sideband Only.) The power of one of two equal tones which together cause the transmitter to develop its full rated peak power output.

2.354 LF. Low frequency 30 to 300 kHz.

2.355 LIMITER. A device which reduces the power of an electrical signal when it exceeds a specified value. The amount of reduction or compression increases with increase of the input power.

2.356 LINE, AVAILABLE (FAX). The portion of the scanning line which can be used specifically for picture signals.

2.357 LINE, LOCAL. See LOOP, LINE.

2.358 LINE, USEFUL (FAX). See LINE, AVAILABLE.

2.359 LINE, USER'S. See LOOP, LINE.

2.360 LINEARITY. A constant relationship between signal processing devices' input and output characteristics such as frequency, amplitude, phase and time, over a designated range. See DISTORTION, NONLINEAR.

2.361 LINE LOOP. See LOOP, LINE.

2.362 LINE SIDE. See SIDE, LINE.

2.363 LINE WIDTH, NOMINAL (FAX). The average separation between centers of adjacent scanning or recording lines.

2.364 LINK. a. A portion of a communication circuit.

b. A channel or circuit designed to be connected in tandem with other channels or circuits.

c. A radio path between two points, called a radio link; the resultant circuit may be unidirectional, half-duplex, or duplex. NOTE: The term "link" should be defined or qualified when used. It is generally accepted that the signals at each end of a link are in the same form.

2.365 LISTENERS GRADE OF SERVICE. Listeners grade of service ratings for telephone communications rate the received volume and or other transmission variables by evaluating the circuit performance by listeners judgment into three major categories of "Good," "Fair," and "Poor or worse."

2.366 LOADING CHARACTERISTIC (MULTICHANNEL TELEPHONY SYSTEMS). See CHARACTERISTIC, LOADING.

2.367 LOCAL LINE. See LOOP, LINE.

2.368 LOCAL SIDE. See SIDE, LOCAL.

2.369 LONGITUDINAL BALANCE. See BALANCE, LONGITUDINAL.

2.370 LOOP. A loop is a single message circuit from a switching center and/or individual message distribution point to the terminals of an end instrument.

2.371 LOOP, LINE. The portion of a radio or wire circuit that connects a user's end instrument and a central office. (Synonymous terms are "local line" and "users line.")

2.372 LOSS, CROSSTALK COUPLING. (Between a Disturbing and a Disturbed Circuit.) The ratio of the power in the disturbing circuit to the induced power in the disturbed circuit observed at definite points of the circuits under specified terminal conditions; expressed in dB.

2.373 LOSS, INSERTION. The insertion loss of a transmission system (or component thereof) inserted between two impedances Z_e (transmitter) and Z_r (receiver) is the ratio of the power measured at the receiver Z_r before insertion of the transmission system considered, to the power measured after insertion; expressed in dB. If the resulting number in dB thus obtained is negative, an insertion gain is indicated.

2.374 LOSS, NET (GAIN). Net loss or gain is the loss or gain overall of a transmission circuit. It is measured by applying a test signal of some convenient power at the beginning of the circuit and measuring the power delivered at the other end. The ratio of these powers expressed in dB is the net gain or loss of the circuit under observation.

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2.375 LOSS, RETURN. The return loss at the junction of a transmission line and a terminating impedance is the ratio, expressed in dB, of the reflected wave to the incident wave. More broadly, the return loss is a measure of the dissimilarity between two impedances, being equal to the number of decibels which corresponds to the scalar value of the reciprocal of the reflection coefficient, and hence being expressed by the formula:

$$20 \log_{10} \left| \frac{Z_2 + Z_1}{Z_2 - Z_1} \right| \text{ dB}$$

where Z_1 and Z_2 are the two impedances. See Figure 10, Appendix B.

2.376 LOW PERFORMANCE EQUIPMENTS. See PERFORMANCE, EQUIPMENTS, LOW.

2.377 MARGIN, SINGING. The singing margin of a transmission circuit is defined as the maximum amount by which the net loss of each of the two directions of transmission in a two-wire circuit that has a four-wire portion may be reduced simultaneously before singing occurs.

2.378 MARKING PULSE. See PULSE, MARKING.

2.379 MAXIMUM KEYING FREQUENCY (FAX). See FREQUENCY, MAXIMUM KEYING (FAX).

2.380 MAXIMUM MODULATING FREQUENCY (FAX). See FREQUENCY, MAXIMUM MODULATING (FAX).

2.381 MEAN POWER (RADIO TRANSMITTER). See POWER, MEAN (RADIO TRANSMITTER).

2.382 MEAN POWER OF THE TALKER VOLUME DISTRIBUTION. See TALKER VOLUME DISTRIBUTION, MEAN POWER OF THE.

2.383 MEAN VOLUME TALKER. See TALKER, MEAN VOLUME.

2.384 MEASUREMENT UNITS OF NOISE. See NOISE, MEASUREMENT UNITS.

2.385 MEDIUM, RECORD (FAX). The physical medium on which the facsimile recorder forms an image of the subject copy.

2.386 MEDIUM POWER TALKER. See TALKER, MEDIUM POWER.

2.387 MESSAGE. A communication from a source to one or more destinations in a suitable language.

2.388 MESSAGE SWITCHING. See SWITCHING, MESSAGE.

2.389 METALLIC CIRCUIT. See CIRCUIT, METALLIC.

2.390 MF. Medium frequency, 300 to 3000 kHz.

2.391 MHZ. MegaHertz. 10 to power of 6, Hertz.

2.392 MODEM. Acronym for modulator-demodulator.

2.393 MODULATION. The process of varying some characteristics of the carrier wave in accordance with the instantaneous value of samples of the intelligence to be transmitted. See CARRIER.

2.394 MODULATION, AMPLITUDE (AM). The form of modulation in which the amplitude of the carrier is varied in accordance with the instantaneous value of the modulating signal.

2.395 MODULATION, DELTA. A technique for converting an analog signal to a digital signal. The technique approximates the analog signal with a series of segments. The approximated signal is compared to the original analog wave to determine an increase or decrease in relative amplitude. The decision process for establishing the state of successive binary digits is determined by this comparison. There are several variations to the simple delta modulation system.

2.396 MODULATION, DIFFERENTIAL. A type of modulation in which the choice of the significant condition for any signal element is dependent on the choice for the previous signal element. Delta modulation is an example.

2.397 MODULATION, FIXED REFERENCE. A type of modulation in which the choice of the significant condition for any signal element is based on a fixed reference.

2.398 MODULATION, FREQUENCY (FM). The form of modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous value of the modulating signal.

2.399 MODULATION, ISOCRONOUS. Modulation (or demodulation) in which the time interval separating any two significant instants is theoretically equal to the unit interval or to a multiple of this.

2.400 MODULATION, PHASE (PM). The form of modulation in which the angle relative to the unmodulated carrier angle is varied in accordance with the instantaneous value of the amplitude of the modulating signal.

2.401 MODULATION, PULSE AMPLITUDE (PAM). The form of modulation in which the amplitude of the pulse carrier is varied in accordance with successive samples of the modulating signal.

2.402 MODULATION, PULSE CODE (PCM). The form of modulation in which the modulating signal is sampled, and the sample quantized and coded so that each element of information consists of different kinds and/or numbers of pulses and spaces.

2.403 MODULATION, PULSE FREQUENCY (PFM). The form of modulation in which the pulse repetition frequency of the carrier is varied in accordance with successive samples of the modulating signal.

2.404 MODULATION, PULSE TIME (PTM). The form of modulation in which the time of occurrence of some characteristics of the pulse carrier is varied in accordance with successive samples of the modulating signal. (This includes pulse position and pulse duration or pulse width modulation.)

2.405 MODULATION, SIGNIFICANT CONDITION OF. A condition assumed by the appropriate device corresponding to the quantized value (or values) of the characteristic (or characteristics) chosen to form the modulation. The following equivalent designations are used to identify the significant conditions for binary modulation:

Passive	Active
0	1
Current Off	Current On
Tone Off	Tone On
Space	Mark
-	+
No hole (paper tape)	Hole (paper tape)
Frequency High	Frequency Low

2.406 MODULATION RATE. See RATE, MODULATION.

2.407 MULTIPLE SPOT SCANNING (FAX). See SCANNING, MULTIPLE SPOT.

2.408 MULTIPLEX, FREQUENCY DIVISION (FDM). Frequency division multiplexing is a method of deriving two or more simultaneous, continuous channels from a medium connecting two points by assigning separate portions of the available frequency spectrum to the several channels.

2.409 MULTIPLEX, TIME DIVISION (TDM). Time Division Multiplexing is a method of deriving several channels from a given frequency spectrum, by assigning discrete time intervals in sequence to the different channels. During a given time interval the entire available frequency spectrum can be used by the channel to which it is assigned. In general, time division multiplex systems use pulse transmission. The multiplex pulse train may be considered to be the interleaved pulse trains of the individual channels. The individual channel pulses may be modulated either in an analog or a digital manner.

2.410 MULTIPLEX BASEBAND. See BASEBAND, MULTIPLEX.

2.411 MULTIPLEX BASEBAND RECEIVE TERMINALS. See TERMINALS, MULTIPLEX BASEBAND RECEIVE.

2.412 MULTIPLEX BASEBAND SEND TERMINALS. See TERMINALS, MULTIPLEX BASEBAND SEND.

2.413 MUX. A shorthand reference to multiplex.

2.414 NEAR-END CROSSTALK. See CROSSTALK, NEAR-END.

2.415 NECESSARY BANDWIDTH. See BANDWIDTH, NECESSARY.

2.416 NET OPERATION. See OPERATION, NET.

2.417 NEUTRAL DIRECT CURRENT TELEGRAPH SYSTEM. See SYSTEM, NEUTRAL DIRECT-CURRENT TELEGRAPH.

2.418 NODE. (Also called Junction Point, Branch Point, or Vertex.) A terminal of any branch of a network or a terminal common to two or more branches of a network.

2.419 NOISE, INTERMODULATION. In a transmission path or device, that noise which is contingent upon modulation and results from any non-linear characteristic in the path or device.

2.420 NOISE, MEASUREMENT UNITS. Noise is usually measured in terms of power, either relative or absolute. The decibel is the base unit for these measurements. A suffix is usually added to denote a particular reference base or specific qualities of the measurement. (See WEIGHTING, NOISE.) Noise measurement units defined in this standard are dBa, dBa(FLA), dBa(HAL), dBaO, dBm, dBmO, dBm,Psoph., dBmOp, dBm, dBm(114-line), dBm(114-receiver), dBm(C-message), dBm($f_1 - f_2$), pW and pWp.

2.421 NOISE, QUANTIZING. In a modulation system that employs a quantizing process, quantizing noise is that noise that is caused by the error of approximation. It is an undesirable random distortion signal which is solely dependent on the particular quantization process used and the statistical characteristics of the quantized signal.

2.422 NOISE POWER OF A RADIO TRANSMITTER (PN). See POWER, NOISE, OF A RADIO TRANSMITTER (PN).

2.423 NOISE POWER RATIO, INBAND (NPR) (MULTICHANNEL EQUIPMENT). The noise power ratio, for multichannel equipment, is the ratio of the mean noise power measured in any channel, with all channels loaded with white noise, to the mean noise power measured in the same channel, with all channels but the measured channel loaded with noise.

2.424 NOISE POWER RATIO, IN CHANNEL (NPR) (MULTICHANNEL EQUIPMENT). The noise power ratio, for multichannel equipment, is the ratio of the mean noise power measured in any channel, with no input loading on the channels, to the mean noise power measured in the same channel, with only the measured channel loaded with white noise.

2.425 NOISE POWER RATIO, SINGLE SIDEBAND (NPR) (SSB). NPR (SSB) is the ratio of the mean noise powers measured in the notch filter bandwidth for the notch in and the notch out conditions with total system mean noise power output equal for both conditions. (See Section 9, Methods of Measurement.)

2.426 NOISE RATIO, SIGNAL-PLUS-NOISE TO. The signal plus noise to noise is a ratio of the signal plus noise arriving at a location in a transmission path to the noise normally present when the signal is removed at the sending end and replaced by a termination.

2.427 NOISE WEIGHTING. See WEIGHTING, NOISE.

2.428 NOMINAL BANDWIDTH. See BANDWIDTH, NOMINAL.

2.429 NOMINAL LINE WIDTH (FAX). See LINE WIDTH, NOMINAL (FAX).

2.430 NONLINEAR DISTORTION. See DISTORTION, NONLINEAR.

2.431 NOTATION, BINARY. A scheme for representing numbers characterized by the arrangements of digits in sequence with the understanding that successive digits are interpreted as coefficients of successive powers of the base two.

2.432 NPR. Noise Power Ratio.

2.433 NUMBER, BINARY. A number expressed in binary notation.

2.434 OBJECTIVE, DESIGN. An electrical (or mechanical) performance characteristic for communication circuits and equipments which is based on engineering judgment of performance desired but which for a number of reasons it is not considered feasible to establish as a STANDARD at the time this standard is written. Examples of reasons for designating a performance characteristic as a (DO) rather than as an (S) are: It may be bordering on an advancement in state-of-the-art; the requirement may not have been fully confirmed by measurement or experience with operating circuits; it may not have been demonstrated that it can be met considering other constraints such as cost and size, etc. A (DO) shall be considered as guidance for Department of Defense Agencies in preparation of specifications for development or procurement of new equipment or systems which shall be used if technically and economically practicable at the time such specifications are written. See also STANDARDS, SYSTEM.

2.435 OCCUPIED BANDWIDTH. See BANDWIDTH, OCCUPIED.

2.436 OFFICE, CENTRAL. See CENTER, SWITCHING.

2.437 ONE-WAY REVERSIBLE OPERATION. See OPERATION, ONE-WAY REVERSIBLE.

2.438 OPEN-CIRCUIT WORKING. See CIRCUIT WORKING, OPEN-.

2.439 OPERATION, BROADCAST. That type of operation in which a transmitting point emits information which may be received by one or more stations.

2.440 OPERATION, CONFERENCE. a. In a telephone system, that type of operation in which more than two stations can carry on a conversation.

b. In telegraph or data transmission, that form of simplex or half-duplex operation in which more than two stations may simultaneously exchange information, carry on conversations or pass messages among one another. NOTE: In radio systems, the stations receive simultaneously, but must transmit one at a time. The common modes are "push-to-talk" (telephone) and "push-to-type" (telegraph, data transmission).

2.441 OPERATION, DUPLEX. A type of operation in which simultaneous two-way conversations, messages or information may be passed between any two given points.

2.442 OPERATION, FULL DUPLEX. See OPERATION, DUPLEX.

2.443 OPERATION, HALF-DUPLEX. That type of simplex operation which uses a half-duplex circuit.

2.444 OPERATION, NET. Nets (netted operations) are ordered conferences whose participants have common information in needs or like functions to perform. Nets are characterized by adherence to standard formats. They are responsive to a common supervisor entitled the Net Controller (Net Control Stations) whose functions include permitting access to the Net and maintaining circuit discipline.

2.445 OPERATION, ONE-WAY REVERSIBLE. Similar to half-duplex operation.

2.446 OPERATION, PUSH-TO-TALK. (Press-to-talk) In telephone systems, that method of communication over a speech circuit in which transmission occurs from only one station at a time, the talker being required to keep a switch operated while he is talking.

2.447 OPERATION, PUSH-TO-TYPE. (Press-to-type) In telegraph or data transmission systems, that method of communication, in which the operator must keep a switch operated in order to send from his station. It is generally used in radio systems where the same frequency is employed for transmission and reception. NOTE: This is a derivative form of transmission, and may be used in simplex, half-duplex or duplex operation.

2.448 OPERATION, SIMPLEX. That type of operation which permits the transmission of signals in either direction alternately. NOTE: In radio telegraph or data transmission systems, it may be either (a) the use of a single frequency, time slot or code address for transmission, and another frequency, time slot or code address for reception, or (b) the use of the same frequency, time slot or code address for both transmission and reception. In wire telegraph systems, simplex operation may be employed over either a half-duplex circuit, or over a neutral direct current circuit.

2.449 OPERATION, SPEECH-PLUS-DUPLEX. That method of operation in which speech and telegraphy (duplex or simplex) are transmitted simultaneously over the same circuit, being kept from mutual interference by use of filters.

2.450 OPERATION, UNIDIRECTIONAL (SEND ONLY, RECEIVE ONLY). A method of operation between terminals, one of which is a transmitter and the other a receiver.

2.451 ORDER WIRE. See WIRE, ORDER.

2.452 OUT-OF-BAND SIGNALING. See SIGNALING, OUT-OF-BAND.

2.453 OUTPUT RATING. See POWER.

2.454 OVERHEAD BIT. See BIT, OVERHEAD.

2.455 PAIRING, BIT. The practice of establishing, within a code set, a number of subsets of two characters each that have an identical bit representation except for the state of a specified bit. For example: In the ITA Number 5 and the Military Standard Code for Information Interchange, the upper case letters are related to their respective lower case letters by the state of bit six.

2.456 PARALLEL TRANSMISSION. See TRANSMISSION, PARALLEL.

2.457 PARITY BIT. See BIT, PARITY.

2.458 PATTERN, ADDRESS. In a digital system a prescribed recurring pattern of bits transmitted over a digital transmission system to enable the receiver to achieve frame synchronization.

2.459 PEAK ENVELOPE POWER (RADIO TRANSMITTER). See POWER, PEAK ENVELOPE (RADIO TRANSMITTER).

2.460 PERFORMANCE, EQUIPMENTS, HIGH. Those equipments having sufficiently exacting characteristics to permit their use in trunk or link circuits. Those equipments designed primarily for use in global and tactical service which are required to operate where the maximum performance, minimum electromagnetic interference and capabilities are required for operation in a variety of nets or for fixed point-to-point circuits. NOTE: Requirements for global and tactical high performance equipments may differ.

2.461 PERFORMANCE, EQUIPMENTS, LOW. Those equipments having insufficiently exacting characteristics to permit their use in trunk or link circuits. Such equipments may be employed in loop circuits whenever they meet loop circuit requirements. Those tactical ground and airborne equipments whose size, weight, complexity must be kept to a minimum and where the primary requirement is to operate in nets with similar minimum performance standards.

2.462 PERTURBATION, PHASE (PHASE JITTER). The existence of this phenomenon has long been recognized by telephone transmission engineers, however due to the relative insensitivity of the human ear to this form of channel disturbance, relatively little attention has been paid to it.

Attention is called to this phenomenon because of the serious detrimental impact it can have on data transmission, particularly that type of modulation which is dependent on the signal phase more than the amplitude or frequency. It is not precisely defined since so little, widely understood or agreed technical data exists. For purposes of a working definition, therefore, Phase Perturbation or Phase Jitter is defined as that phenomena from causes known or unknown which results in a relative shifting (often quite rapid) in the phase of the signal.

The shifting in phase may appear to be random, cyclic or both. It is noted that a similar phenomenon related to amplitude perturbation exists which is also not sufficiently understood to be acceptably defined at this time.

The amount of phase perturbation may be expressed in degrees with any cyclic component expressed in Hertz. The instantaneous relative phase may or may not be significant, however, for the sake of clarity it should be assumed a phase perturbation of 36° would be taken to mean $+18^\circ$ relative to a single sine wave signal or $+36^\circ$ would assume leading shifting in phase of 36° .

2.463 PHASE DELAY (FAX). See DELAY, PHASE (FAX).

2.464 PHASE DISTORTION. See DISTORTION, DELAY.

2.465 PHASE MODULATION. See MODULATION, PHASE.

2.466 PHASE PERTURBATION (PHASE JITTER). See PERTURBATION, PHASE.

2.467 PHASING (FAX). The adjustment of picture position along the scanning line.

2.468 PHOTSENSITIVE RECORDING (FAX). See RECORDING, PHOTSENSITIVE (FAX).

2.469 PICTURE FREQUENCIES (FAX). See FREQUENCIES, PICTURE (FAX).

2.470 PILOT. (In a transmission system.) A signal wave, usually a single frequency, transmitted over the system and used for either level control, synchronization, or both.

2.471 PILOT. A signal wave, usually a single frequency transmitted over the system for supervisory, control, synchronization or reference purposes. Sometimes it is necessary to employ several independent pilot frequencies. Most radio relay systems use radio or continuity pilots of their own but transmit also the pilot frequencies belonging to the carrier frequency multiplex system.

2.472 POINT, ZERO TRANSMISSION LEVEL REFERENCE. A point in a circuit to which all relative transmission levels are referred. See also LEVEL, RELATIVE TRANSMISSION. NOTE: The zero point may not be conveniently available in some systems.

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2.473 POLAR DIRECT CURRENT TELEGRAPH SYSTEM. See SYSTEM, POLAR DIRECT-CURRENT TELEGRAPH.

2.474 POLARIZATION DIVERSITY. See DIVERSITY, POLARIZATION.

2.475 POWER, CARRIER (PC) (RADIO TRANSMITTER). The average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle under conditions of no modulation. This definition does not apply to pulse modulated emissions or FSK.

2.476 POWER, EFFECTIVE RADIATED (ERP). The power supplied to the antenna multiplied by the relative gain of the antenna in a given direction.

2.477 POWER, MEAN (PM) (RADIO TRANSMITTER). The power supplied to the antenna transmission line by a transmitter during normal operation, averaged over a time sufficiently long compared with the period of the lowest frequency encountered in the modulation. A time of 1/10 second during which the mean power is greatest will be selected normally.

2.478 POWER, NOISE (PN) (RADIO TRANSMITTER). The mean power supplied to the antenna transmission line by a transmitter when loaded with white noise having a Gaussian amplitude distribution.

2.479 POWER, PEAK ENVELOPE (PEP) (RADIO TRANSMITTER). The power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the highest crest of the modulation envelope, taken under conditions of normal operation.

2.480 POWER RATIO, NOISE, SINGLE SIDEBAND, NPR (SSB). See NOISE POWER RATIO, SINGLE SIDEBAND, NPR (SSB).

2.481 PSOPHOMETRICALLY WEIGHTED DBM. See DBm (Psoph) and DBmOp.

2.482 PSOPHOMETRIC VOLTAGE. See VOLTAGE, PSOPHOMETRIC.

2.483 PSOPHOMETRIC WEIGHTING. See WEIGHTING, PSOPHOMETRIC.

2.484 PULSE. A signal characterized by the rise and decay in time of a quantity whose value is normally constant.

2.485 PULSE, MARKING (TTY). That significant condition of a modulation which results in an active selecting operation in receiving apparatus. See MODULATION, SIGNIFICANT CONDITION OF A.

2.486 PULSE, SPACING (TTY). That significant condition of a modulation which results in a passive selecting operation in a receiving apparatus. See MODULATION, SIGNIFICANT CONDITION OF A.

2.487 PULSE AMPLITUDE MODULATION. See MODULATION, PULSE AMPLITUDE.

2.488 PULSE CODE MODULATION. See MODULATION, PULSE CODE.

- 2.489 PULSE DECAY TIME. See DECAY TIME, PULSE.
- 2.490 PULSE FREQUENCY MODULATION. See MODULATION, PULSE FREQUENCY.
- 2.491 PULSE RISE TIME. See RISE TIME, PULSE.
- 2.492 PULSE TIME MODULATION. See MODULATION, PULSE TIME.
- 2.493 PUSH-TO-TALK OPERATION. See OPERATION, PUSH-TO-TALK.
- 2.494 PUSH-TO-TYPE OPERATION. See OPERATION, PUSH-TO-TYPE.
- 2.495 PW. (Picowatt. Equal to 10^{-12} Watt, or -90 dBm.) A unit of absolute power commonly used for both weighted and unweighted noise. Context must be observed.
- 2.496 Pwp (PW, PSOPHOMETRICALLY WEIGHTED). See PW and WEIGHTING, NOISE.
- 2.497 QUADRUPLE DIVERSITY. See DIVERSITY, QUADRUPLE.
- 2.498 QUANTIZATION. The process of converting the exact sample values of a signal wave to their nearest equivalent in a finite set of discrete values to permit digital encoding.
- 2.499 QUANTIZING NOISE. See NOISE, QUANTIZING.
- 2.500 QUASI-ANALOG SIGNAL. See SIGNAL, QUASI-ANALOG.
- 2.501 RADIO BASEBAND RECEIVE TERMINALS. See TERMINALS, RADIO BASEBAND RECEIVE.
- 2.502 RADIO BASEBAND SEND TERMINALS. See TERMINALS, RADIO BASEBAND SEND.
- 2.503 RADIO BASEBAND. See BASEBAND, RADIO.
- 2.504 RANDOM BINARY BIT STREAM SIGNALING. See SIGNALING, RANDOM BINARY BIT STREAM.
- 2.505 RATE, DATA SIGNALING. Refer to Appendix B, Reference Chart for modulation rates for explanation of Data Signaling Rates.
- 2.506 RATE, ERROR (BIT, BLOCK, CHARACTER, ELEMENT). The ratio of the number of bits, elements, characters, or blocks incorrectly received to the total number of bits, elements, characters, or blocks sent.
- 2.507 RATE, MODULATION. Reciprocal of the unit interval measured in seconds. (This rate is expressed in baud.)
- 2.508 RATING, OUTPUT. See POWER.

2.509 RECEIVER, FACSIMILE. The apparatus employed to translate the signal from the communications channel into a facsimile record of the subject copy.

2.510 RECEIVING CONVERTER, FACSIMILE. See CONVERTER, FACSIMILE RECEIVING.

2.511 RECEPTION, EXALTED CARRIER. A method of receiving either amplitude or phase modulated signals in which the carrier is separated from the sidebands, filtered and amplified, and then combined with the sidebands again at a higher level prior to demodulation.

2.512 RECORD MEDIUM (FAX). See MEDIUM, RECORD (FAX).

2.513 RECORD SHEET (FAX). See SHEET, RECORD (FAX).

2.514 RECORDED SPOT X DIMENSION (FAX). See SPOT, X DIMENSION OF RECORDED (FAX).

2.515 RECORDED SPOT Y DIMENSION (FAX). See SPOT, Y DIMENSION OF RECORDED (FAX).

2.516 RECORDED SPOT (FAX). See SPOT, RECORDED (FAX).

2.517 RECORDER, FACSIMILE. That part of the facsimile receiver which performs the final conversion of electrical picture signal to an image of the subject copy in the record medium.

2.518 RECORDING SPOT (FAX). See SPOT, RECORDING (FAX).

2.519 RECORDING (FAX). The process of converting the electrical signal to an image on the record medium.

2.520 RECORDING, DIRECT (FAX). That type of recording in which a visible record is produced, without subsequent processing, in response to the received signals.

2.521 RECORDING, ELECTROMECHANICAL (FAX). Recording by means of a signal-actuated mechanical device.

2.522 RECORDING, ELECTROCHEMICAL (FAX). Recording by means of a chemical reaction brought about by the passage of signal-controlled current through the sensitized portion of the record sheet.

2.523 RECORDING, ELECTROLYTIC (FAX). That type of electrochemical recording in which the chemical change is made possible by the presence of an electrolyte.

2.524 RECORDING, ELECTROSTATIC (FAX). Recording by means of a signal-controlled electrostatic field.

2.525 RECORDING, ELECTROTHERMAL (FAX). That type of recording which is produced principally by signal-controlled thermal action.

2.526 RECORDING, INK VAPOR (FAX). That type of recording in which vaporized ink particles are directly deposited upon the record sheet.

2.527 RECORDING, PHOTSENSITIVE (FAX). Recording by the exposure of a photosensitive surface to a signal-controlled light beam or spot.

2.528 REDUCED OR SUPPRESSED CARRIER DOUBLE SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND, DOUBLE, REDUCED OR SUPPRESSED CARRIER.

2.529 REDUNDANT CODE. See CODE, REDUNDANT.

2.530 REFERENCE FREQUENCY. See FREQUENCY, REFERENCE.

2.531 REFERENCE POINT, ZERO TRANSMISSION LEVEL. See POINT, ZERO TRANSMISSION LEVEL REFERENCE.

2.532 REFLECTION COEFFICIENT. See COEFFICIENT, REFLECTION.

2.533 REGENERATIVE REPEATER. See REPEATER, REGENERATIVE.

2.534 RELATIVE TRANSMISSION LEVEL. See LEVEL, RELATIVE TRANSMISSION.

2.535 REMOTE CONTROL EQUIPMENT. See CONTROL EQUIPMENT, REMOTE.

2.536 REPEATER. A device which amplifies or reshapes and/or retimes an input signal for further retransmission.

2.537 REPEATER, BROADCAST. A repeater connecting several channels, one incoming and the others outgoing.

2.538 REPEATER, CONFERENCE. A repeater connecting several circuits, which receives telegraph signals from any one of the circuits and automatically retransmits them over all the others.

2.539 REPEATER, REGENERATIVE. A repeater in which the signals retransmitted are reshaped and retimed.

2.540 REPRODUCTION SPEED (FAX). See SPEED, REPRODUCTION (FAX).

2.541 RESIDUAL ERROR-RATE. See ERROR-RATE, RESIDUAL.

2.542 RESTITUTION (DEMODULATION). Series of significant conditions determined by the decisions taken according to the products of the demodulation process. See also DEMODULATION.

2.543 RETURN LOSS. See LOSS, RETURN.

2.544 RF BANDWIDTH. See BANDWIDTH, RF.

2.545 RINGDOWN SIGNALING. See SIGNALING, RINGDOWN.

2.546 RISE TIME, PULSE. The time required for the instantaneous amplitude to go from 10% to 90% of the peak value.

2.547 RTTY. A shorthand reference to radio-teletypewriter.

2.548 SAMPLING FREQUENCY. See FREQUENCY, SAMPLING.

2.549 SCANNER (FAX). That part of the facsimile transmitter which systematically translates the densities of the subject copy into signal-wave form.

2.550 SCANNING (FAX). The process of analyzing successively the densities of the subject copy according to the elements of a predetermined pattern. NOTE: The normal scanning is from left to right and top to bottom of the subject copy as when reading a page of print. Reverse direction is from right to left and top to bottom of the subject copy. The IEEE, ASA, and WMO Standards consider the normal scanning direction to be from left to right.

2.551 SCANNING, DIRECTION OF (FAX). At the transmitting apparatus the plane (developed in the case of a drum transmitter) of the message surface is scanned along lines running from right to left commencing at the top so that scanning commences at the top right-hand corner of the surface and finishes at the bottom left-hand corner; this is equivalent to scanning over a right-hand helix on a drum. The orientation of the message on the scanning plane will depend upon its dimensions and is of no consequence.

At the receiving apparatus scanning takes place from right to left and top to bottom (in the above sense) for "positive" reception and from left to right and top to bottom (in the above sense) for "negative" reception. NOTE: This is the CCITT Standard for Phototelegraphic apparatus. (See SCANNING (FAX))

2.552 SCANNING, ELECTRONIC LINE (FAX). That method of scanning which provides motion of the scanning spot along the scanning line by electronic means.

2.553 SCANNING, MULTIPLE SPOT (FAX). The method in which scanning is carried on simultaneously by two or more scanning spots, each one analyzing its fraction of the total scanned area of the subject copy.

2.554 SCANNING, SIMPLE (FAX). Scanning of only one scanning spot at a time during the scanning process.

2.555 SCANNING LINE FREQUENCY (FAX). See SPEED, STROKE (FAX).

2.556 SCANNING LINE LENGTH (FAX). See LENGTH, SCANNING LINE (FAX).

2.557 SCANNING SPOT X DIMENSION (FAX). See SPOT, X DIMENSION OF SCANNING (FAX).

2.558 SCANNING SPOT Y DIMENSION (FAX). See SPOT, Y DIMENSION OF SCANNING (FAX).

2.559 SCANNING SPOT (FAX). See SPOT, SCANNING (FAX).

2.560 SELECTIVE FADING. See FADING, SELECTIVE.

2.561 SERIAL TRANSMISSION. See TRANSMISSION, SERIAL.

2.562 SERVICE BIT. See BIT, SERVICE.

2.563 SET, CHARACTER. A "character set" as used herein is a basic group of defined numeric, alphabetic, punctuation and special symbol characters of one style. The term is most meaningful when accompanied by a qualifying descriptor. For example: The graphic character set of USASCII.

2.564 SET, CODE. See ALPHABET, DIGITAL.

2.565 SHEET, RECORD (FAX). The medium which is used to produce a visible image of the subject copy in record form. The record medium and the record sheet may be identical.

2.566 SHF. Super high frequency, 3 to 30 GHz.

2.567 SIDE, LINE. That portion of a device which looks toward the transmission path (line circuit, loop, trunk).

2.568 SIDE, LOCAL. That portion of a device which looks toward the internal station facilities.

2.569 SIDEBANDS. The spectral energy distributed above and below a carrier resulting from a modulation process.

2.570 SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND.

2.571 SIDETONE, TELEPHONE. Telephone sidetone is the transmission and reproduction of sounds through a local path from transmitting transducer to the receiving transducer of the same telephone set in order that the talker may hear his voice in the receiver.

2.572 SIGNAL, ANALOG. A nominally continuous electrical signal that varies in some direct correlation to a signal impressed on a transducer. The electrical signal may vary its frequency or amplitude, for instance, in response to change in phenomena or characteristics such as sound, light, heat, position, or pressure.

2.573 SIGNAL, DIGITAL. A nominally discontinuous electrical signal that changes from one state to another in discrete steps. The electrical

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signal could change its amplitude or polarity, for instance, in response to outputs from computers, teletypewriters, etc. Analog signals may be converted to a digital form by quantizing.

2.574 SIGNAL, FACSIMILE (PICTURE SIGNAL). A signal resulting from the scanning process.

2.575 SIGNAL, QUASI-ANALOG. A quasi-analog signal is a digital signal, after conversion to a form suitable for transmission over a specified analog channel. The specification of an analog channel would include frequency range, frequency bandwidth, S/N ratio, and envelope delay distortion. When this form of signaling is used to convey message traffic over dialed-up telephone systems it is often referred to as voice-data.

2.576 SIGNAL, START (FAX). A signal which initiates the transfer of a facsimile equipment condition from standby to active.

2.577 SIGNAL, START RECORD (FAX). A signal used for starting the process of converting the electrical signal to an image on the record sheet.

2.578 SIGNAL, STOP (FAX). A signal which initiates the transfer of a facsimile equipment condition from active to standby.

2.579 SIGNAL, STOP RECORD (FAX). A signal used for stopping the process of converting the electrical signal to an image on the record sheet.

2.580 SIGNAL, SYNCHRONIZING (FAX). Maintenance of predetermined speed relations between the scanning spot and recording spot within each scanning line.

2.581 SIGNAL, VOICE-DATA. See SIGNAL, QUASI-ANALOG.

2.582 SIGNAL CONTRAST (FAX). See CONTRAST, SIGNAL (FAX).

2.583 SIGNAL CONVERTER. See CONVERTER, SIGNAL.

2.584 SIGNAL ELEMENT. See ELEMENT, SIGNAL.

2.585 SIGNAL FREQUENCY SHIFT (FAX). See FREQUENCY SHIFT, SIGNAL (FAX).

2.586 SIGNAL LEVEL, FACSIMILE. The maximum facsimile signal power or voltage (rms or dc) measured at any point in a facsimile system. NOTE: It may be expressed in decibels with respect to some standard value such as 1 milliwatt.

2.587 SIGNAL-PLUS-NOISE TO NOISE RATIO. See NOISE RATIO, SIGNAL-PLUS-NOISE TO.

2.588 SIGNAL TRANSITION. See TRANSITION, SIGNAL.

2.589 SIGNALING, COMMON BATTERY. A method of actuating a line or supervisory signal at the distant end of a telephone line by the closure of a dc circuit.

2.590 SIGNALING, INBAND. Signaling which utilizes frequencies within the voice or intelligence band of a channel.

2.591 SIGNALING, OUT-OF-BAND. Signaling which utilizes frequencies within the guard band between channels or bits other than information bits in a digital system. This term is also used to indicate the use of a portion of the channel bandwidth provided by the medium such as the carrier channel, but denied to the speech or intelligence path by filters. It results in a reduction of the effective available bandwidth.

2.592 SIGNALING, RANDOM BINARY BIT STREAM (INTERMITTENT TIMING). The method of communication that employs bit intermittent transmission of signals on a unit interval basis without regard to the presence or absence of code or alphabet.

2.593 SIGNALING, RINGDOWN. The application of signal to the line for the purpose of bringing in a line signal or supervisory signal at a switchboard or ringing a user's instrument. (Historically, this was a low frequency signal of about 20 Hz from the user on the line for calling the operator or for disconnect.)

2.594 SIGNALING, FREQUENCY CHANGE. A signaling method in which one or more particular frequencies correspond to each desired signaling condition of a code. The transition from one set of frequencies to the other may be either a continuous or a discontinuous change in frequency or in phase.

2.595 SIGNALING, FREQUENCY EXCHANGE (TWO-SOURCE FREQUENCY KEYING). A frequency change signaling method in which the change from one signaling condition to another is accompanied by decay in amplitude of one or more frequencies and by buildup in amplitude of one or more other frequencies.

2.596 SIGNALING, FREQUENCY SHIFT. See KEYING, FREQUENCY SHIFT.

2.597 SIGNIFICANT CONDITION OF A MODULATION. See MODULATION, SIGNIFICANT CONDITION OF.

2.598 SIGNIFICANT INSTANTS. See INSTANTS, SIGNIFICANT.

2.599 SIGNIFICANT INTERVAL. See INTERVAL, SIGNIFICANT.

2.600 SIMPLE SCANNING (FAX). See SCANNING, SIMPLE (FAX).

2.601 SIMPLEX CIRCUIT. See CIRCUIT, SIMPLEX.

2.602 SIMPLEX OPERATION. See OPERATION, SIMPLEX.

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- 2.603 SIMPLEXED CIRCUIT. See CIRCUIT, SIMPLEXED.
- 2.604 SINGING MARGIN. See MARGIN, SINGING.
- 2.605 SINGLE CURRENT TRANSMISSION. See TRANSMISSION, SINGLE-CURRENT.
- 2.606 SINGLE SIDEBAND EQUIPMENT REFERENCE LEVEL. See LEVEL, SINGLE SIDEBAND EQUIPMENT REFERENCE.
- 2.607 SINGLE SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND, SINGLE.
- 2.608 SINGLE-HARMONIC DISTORTION. See DISTORTION, SINGLE-HARMONIC.
- 2.609 SINK, COMMUNICATIONS. A device which receives information, control or other signals from communications source(s).
- 2.610 SINK, DATA. The equipment which accepts data signals after transmission.
- 2.611 SKEW (FAX). The deviation of the received frame from rectangularity due to asynchronism between scanner and recorder. Skew is expressed numerically as the tangent of the angle of this deviation.
- 2.612 SOUND-POWERED TELEPHONE. See TELEPHONE, SOUND-POWERED.
- 2.613 SOURCE, COMMUNICATIONS. A device which generates information, control, or other signals destined for communications sink(s).
- 2.614 SOURCE, DATA. The equipment which supplies data signals to be transmitted.
- 2.615 SPACE DIVERSITY. See DIVERSITY, SPACE.
- 2.616 SPACING PULSE. See PULSE, SPACING (TTY).
- 2.617 SPECTRUM DESIGNATION OF FREQUENCY. See FREQUENCY, SPECTRUM DESIGNATION OF.
- 2.618 SPEECH-PLUS-DUPLEX OPERATION. See OPERATION, SPEECH-PLUS-DUPLEX.
- 2.619 SPEED, DRUM (FAX). The angular speed of the transmitter or recorder drum. NOTE: This speed is measured in revolutions per minute.
- 2.620 SPEED, REPRODUCTION (FAX). The area of copy recorded per unit time.
- 2.621 SPEED, SPOT (FAX). The speed of the scanning or recording spot within the available line. NOTE: This is generally measured on the subject copy or on the record sheet.

2.622 SPEED, STROKE (FAX). (SCANNING OR RECORDING LINE FREQUENCY.) The number of times per minute, unless otherwise stated, that a fixed line perpendicular to the direction of scanning is crossed in one direction by a scanning or recording spot. NOTE: In most conventional mechanical systems this is equivalent to drum speed. In systems in which the picture signal is used while scanning in both directions, the stroke speed is twice the above figure.

2.623 SPOT, RECORDED (FAX). The image of the recording spot on the record sheet.

2.624 SPOT, RECORDING (FAX). The image area formed at the record medium by the facsimile recorder.

2.625 SPOT, SCANNING (FAX) The area on the subject copy viewed instantaneously by the pickup system of the scanner.

2.626 SPOT, X DIMENSION OF SCANNING (FAX). The effective scanning spot dimension measured in the direction of the scanning line on the subject copy. NOTE: The numerical value of this will depend upon the type of system used.

2.627 SPOT, X DIMENSION OF RECORDED (FAX). The effective recorded spot dimension measured in the direction of the recorded line. NOTE 1: By effective dimension is meant the largest center-to-center spacing between recorded spots which gives minimum peak-to-peak variation of density of the recorded line. NOTE 2: This term applies to that type of equipment which responds to a constant density in the subject copy by a succession of discrete recorded spots.

2.628 SPOT, Y DIMENSION OF SCANNING (FAX). The effective scanning spot dimension measured perpendicularly to the scanning line on the subject copy. NOTE: The numerical value of this will depend upon the type of system used.

2.629 SPOT, Y DIMENSION OF, RECORDED (FAX). The effective recorded spot dimension measured perpendicularly to the recorded line. NOTE: By effective dimension is meant the largest center-to-center distance between recorded lines which gives minimum peak-to-peak variation of density across the recorded lines.

2.630 SPOT SPEED (FAX). See SPEED, SPOT (FAX).

2.631 STAGGER (FAX). Periodic error in the position of the recorded spot along the recorded line.

2.632 STANDARDS. See STANDARDS, SYSTEM.

2.633 STANDARDS, SYSTEM. a. The minimum required electrical performance characteristics of communication circuits which are based on measured performance of developed circuits under the various operating conditions for which the circuits were designed.

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b. The specified characteristics not dictated by electrical performance requirements but necessary in order to permit interoperation. (For example, the values for center frequencies for telegraph channels, test tone, etc.) See also OBJECTIVE, DESIGN.

2.634 STANDARD TEST TONE. See TONE, STANDARD TEST.

2.635 START-STOP TTY DISTORTION. See DISTORTION, START-STOP TTY.

2.636 START RECORD SIGNAL (FAX). See SIGNAL, START RECORD (FAX).

2.637 START SIGNAL (FAX). See SIGNAL, START (FAX).

2.638 STOP RECORD SIGNAL (FAX). See SIGNAL, STOP RECORD (FAX).

2.639 STOP SIGNAL (FAX). See SIGNAL, STOP (FAX).

2.640 STORE-AND-FORWARD. See SWITCHING, MESSAGE.

2.641 STROKE SPEED (FAX). See SPEED, STROKE (FAX).

2.642 SUBCARRIER. A carrier which is applied as modulation on another carrier, or on an intermediate subcarrier. See also CARRIER.

2.643 SUBJECT COPY (FAX). See COPY, SUBJECT (FAX).

2.644 SWITCHING, CIRCUIT. The term applied to the method of handling traffic through a switching center, either from local users, or from other switching centers, whereby a distant electrical connection is established between the calling and called stations.

2.645 SWITCHING, MESSAGE. The term applied to any indirect or store-and-forward (S/F) traffic through a switching center, either from local users or from other switching centers. Message switching, or store-and-forward, is the technique whereby messages are transmitted link by link through the communication network of switching centers.

2.646 SWITCHING CENTER. See CENTER, SWITCHING.

2.647 SYNCHRONIZING (FAX). The maintenance of predetermined speed relations between the scanning spot and the recording spot within each scanning line.

2.648 SYNCHRONIZING SIGNAL (FAX). See SIGNAL, SYNCHRONIZING (FAX).

2.649 SYNCHRONOUS. See SYSTEM, SYNCHRONOUS and TRANSMISSION, SYNCHRONOUS.

2.650 SYNCHRONOUS SYSTEM. See SYSTEM, SYNCHRONOUS.

2.651 SYNCHRONOUS TRANSMISSION. See TRANSMISSION, SYNCHRONOUS.

2.652 SYSTEM, ARQ. See SYSTEM, ERROR-DETECTING AND FEEDBACK.

2.653 SYSTEM, DUPLEX. See CIRCUIT, DUPLEX.

2.654 SYSTEM, ERROR DETECTING. A system employing an error-detecting code and so arranged that any signal detected as being in error is -

a. Either deleted from the data delivered to the data sink, in some cases with an indication that such deletion has taken place;

b. Or delivered to the data sink together with an indication that it has been detected as being in error.

2.655 SYSTEM, ERROR-CORRECTING. A system employing an error-correcting code and so arranged that some or all signals detected as being in error are automatically corrected at the receiving terminal before delivery to the data sink or to the telegraph receiver.

2.656 SYSTEM, ERROR-DETECTING AND FEEDBACK (DECISION FEEDBACK SYSTEM, REQUEST REPEAT SYSTEM, ARQ SYSTEM). A system employing an error-detecting code and so arranged that a signal detected as being in error automatically initiates a request for retransmission of the signal detected as being in error.

2.657 SYSTEM, NEUTRAL DIRECT-CURRENT TELEGRAPH (SINGLE-CURRENT SYSTEM, SINGLE MORSE SYSTEM). A neutral direct-current telegraph system is a telegraph system employing current during marking intervals and zero current during spacing intervals for transmission of signals over the line.

2.658 SYSTEM, POLAR DIRECT-CURRENT TELEGRAPH. A polar direct-current telegraph system is one which employs positive and negative currents for transmission of signals over the line.

2.659 SYSTEM, SYNCHRONOUS. A system in which the sending and receiving instruments are operating continuously at substantially the same frequency and are maintained, by means of correction if necessary, in a desired phase relationship.

2.660 SYSTEM STANDARDS. See STANDARDS, SYSTEM.

2.661 TAILING (HANGOVER) (FAX). The excessive prolongation of the decay of the signal.

2.662 TALKER, MEAN VOLUME. The mean-volume-talker is one represented by the mean volume of a group of talkers measured at a given location. It is the value in an ordered set of values below and above which there are an equal number of values.

2.663 TALKER, MEDIUM POWER. The medium-power-talker of a log normal distribution is that value of talker volumes which lies at the medium power of all talkers determining the volume distribution at the point of

interest. When the distribution follows a log-normal curve (values expressed in dB) the mean and standard deviation can be used to compute the medium-power-talker. The talker volume distribution follows a log normal curve and the medium-power-talker is uniquely determined by the average talker volume and the standard deviation as given in the following equation:

$$\bar{V}_{avpw} = \bar{V}_0 + 0.115\sigma^2 vu$$

Where \bar{V}_0 is the average of the talker volume distribution, \bar{V}_{avpw} is the volume corresponding to the average-power-talker expressed in vu and σ is the standard deviation of the distribution.

2.664 TALKER VOLUME DISTRIBUTION, MEAN POWER OF THE. The mean power of the talker volume distribution is the mean-power-talker volume less a conversion factor to convert from vu to dBm. NOTE: The factor is taken as 3.9 dB by some authorities and 1.4 dB by others. This standard uses 2.9 dB as the conversion factor.

2.665 TELECOMMUNICATIONS. Any transmission, emission, or reception of signs, signals, writings, images and sounds or information of any nature by wire, radio, visual, or other electromagnetic means.

2.666 TELEGRAPH, TWO-TONE. See KEYING, TWO-TONE.

2.667 TELEGRAPH COMMUNICATION EFFICIENCY. See EFFICIENCY, TELEGRAPH COMMUNICATION.

2.668 TELEPHONE, ELECTRICALLY-POWERED. A telephone in which the operating power is obtained either from batteries located at the telephone (local battery) or from a telephone central office (common battery).

2.669 TELEPHONE, SOUND-POWERED. A telephone in which the operating power is derived from the speech input only.

2.670 TELEPHONE SIDETONE. See SIDETONE, TELEPHONE.

2.671 TELETYPEWRITER SIGNAL DISTORTION. See DISTORTION, START-STOP TTY.

2.672 TERMINAL, DATA. Equipment employed at the end of a transmission circuit for the transmission and reception of data. It may include end instruments or signal converters or both.

2.673 TERMINALS, MULTIPLEX BASEBAND RECEIVE. The point in the baseband circuit nearest the multiplex equipment from which connection is normally made to the radio baseband receive terminals or intermediate facility.

2.674 TERMINALS, MULTIPLEX BASEBAND SEND. The point in the baseband circuit nearest the multiplex equipment from which connection is normally made to the radio baseband send terminals or intermediate facility.

2.675 TERMINALS, RADIO BASEBAND RECEIVE. The point in the baseband circuit nearest the radio receiver from which connection is normally made to the multiplex baseband receive terminals or intermediate facility.

2.676 TERMINALS, RADIO BASEBAND SEND. The point in the baseband circuit nearest the radio transmitter from which connection is normally made to the multiplex baseband send terminal or intermediate facility.

2.677 TERMINAL IMPEDANCE. See IMPEDANCE, TERMINAL.

2.678 THZ. THz. TeraHertz. 10^{12} Hertz.

2.679 TIME, FALL. See DECAY TIME, PULSE.

2.680 TIME DIVISION MULTIPLEX (TDM). See MULTIPLEX, TIME DIVISION (TDM).

2.681 TIME GUARD BAND. See BAND, TIME GUARD.

2.682 TONE, STANDARD TEST. For use at the 600 Ohms audio portions of a circuit; shall be one mW (0 dBm) with a frequency of 1000 Hz and shall be applied at a zero transmission level reference point. NOTE: The Standard Test Tone in CCITT recommendations is 800 Hz.

2.683 TOTAL HARMONIC DISTORTION. See DISTORTION, TOTAL HARMONIC.

2.684 TRANSFER, INFORMATION. (USER) The final result of a data transmission from a data source to a data sink. The information transfer rate may or may not be equal to the transmission modulation rate.

2.685 TRANSITION, SIGNAL. The change from one signaling condition to another; for example, the change from mark to space or from space to mark. See also PULSE, MARKING, TELETYPEWRITER.

2.686 TRANSLATION, ALPHABET. That process whereby the meaning in a particular bit structure in a particular code is conveyed to one or more different alphabets in the same or different code.

2.687 TRANSMISSION, ASYNCHRONOUS. A transmission process such that between any two significant instants in the same group,* there is always an integral number of unit intervals. Between two significant instants located in different groups, there is not always an integral number of unit intervals. *In data transmission this group is a block or a character. In telegraphy this group is a character.

2.688 TRANSMISSION, BITERNARY. A method of digital transmission in which two binary pulse trains are combined for transmission over a system in which the available bandwidth is only sufficient for transmission of one of the two pulse trains when in binary form. The biternary signal is generated from two synchronous binary signals, operating at the same bit

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rate. The two binary signals are adjusted in time to have a relative time difference of one-half the binary interval and are combined by linear addition to form the biternary signal. Each biternary signal element can assume any one of three possible states, i.e., +1, 0, or -1. Each biternary signaling element contains information on the state of the two binary signaling elements as defined in the following truth table:

B1	B2	Biternary
0	0	-1
0	1	0
1	0	0
1	1	+1

The method of addition of B1 and B2 as described above does not permit the biternary signal to change from -1 to +1 or +1 to -1 without an intermediate biternary signal of 0. Since there is half a unit interval time difference between the binary signals B1 and B2 only one of them can change its state during the biternary unit interval. This makes it possible in the decoding process to ascertain the state of the binary signal that has not changed its state and thus avoid ambiguity in decoding a biternary signal of 0.

2.689 TRANSMISSION, BLACK FACSIMILE. In an amplitude-modulation system, that form of transmission in which the maximum transmitted power corresponds to the maximum density of the subject copy. In a frequency-modulation system, that form of transmission in which the lowest transmitted frequency corresponds to the maximum density of the subject copy.

2.690 TRANSMISSION, DOUBLE-CURRENT (POLAR DIRECT-CURRENT SYSTEM). A form of binary telegraph transmission in which positive and negative direct currents denote the significant conditions.

2.691 TRANSMISSION, PARALLEL. The simultaneous transmission of a certain number of signal elements.

Example A: Use of a code according to which each signal element is characterized by a combination of 3 out of 12 frequencies simultaneously transmitted over the channel.

Example B: Use of a separate wire or circuit for each signal element of a character, or word, so that the signal elements of a character, or word, are simultaneously transmitted.

2.692 TRANSMISSION, SERIAL (SEQUENTIAL TRANSMISSION). Transmission at successive intervals of signal elements constituting a data or telegraph signal. NOTE: The sequential elements may be transmitted with or without interruption, provided that they are not transmitted simultaneously.

2.693 TRANSMISSION, SIDEBAND. When a carrier frequency is modulated by a modulating signal, the band of frequencies produced on either side of the carrier frequency include components whose frequencies are,

respectively the sum or difference of the carrier and the modulating frequencies. The sum frequencies form the "upper sideband," and the difference frequencies form the "lower sideband." Several forms of sideband transmission are also defined.

2.694 TRANSMISSION, SIDEBAND, COMPATIBLE. That method of transmission in which the carrier is deliberately reinserted at a lower level after its normal suppression to permit reception by conventional amplitude modulation receivers. This method of transmission is often referred to as Compatible SSB or Amplitude Modulation Equivalent (AME). The normal method of transmitting compatible SSB or AME is the carrier plus upper-sideband.

2.695 TRANSMISSION, SIDEBAND, DOUBLE. In double sideband transmission both the upper and lower sidebands and the carrier are transmitted without reduction or suppression.

2.696 TRANSMISSION, SIDEBAND, DOUBLE, REDUCED OR SUPPRESSED CARRIER. That method of double sideband transmission in which the carrier may be reduced or suppressed.

2.697 TRANSMISSION, SIDEBAND, INDEPENDENT. In independent sideband transmission the modulation products in the upper and lower sidebands are not related to each other, but represent two or more separate sets of modulating signals. The carrier frequency may be either transmitted fully, reduced or suppressed.

2.698 TRANSMISSION, SIDEBAND, SINGLE. In single sideband transmission only one of the sidebands are transmitted. The other sideband is suppressed to the maximum extent possible. The carrier may be transmitted fully, reduced or suppressed.

2.699 TRANSMISSION, SIDEBAND, VESTIGIAL. In vestigial sideband transmission, partial transmission of one sideband (the "vestigial sideband") in the neighborhood of the carrier is exactly compensated by partial suppression of the corresponding part of the other sideband (the "transmitted sideband"). The carrier may be transmitted fully or reduced, or it may be suppressed.

2.700 TRANSMISSION, SINGLE-CURRENT (NEUTRAL DIRECT-CURRENT SYSTEM). A form of telegraph transmission effected by means of unidirectional currents.

2.701 TRANSMISSION, SYNCHRONOUS. A transmission process such that between any two significant instants in the overall stream, there is always an integral number of unit intervals.

2.702 TRANSMISSION, WHITE (FAX). In an amplitude-modulation system, that form of transmission in which the maximum transmitted power corresponds to the minimum density of the subject copy. In a frequency-modulation system, that form of transmission in which the lowest transmitted frequency corresponds to the minimum density of the subject copy.

2.703 TRANSMITTER, FACSIMILE. The apparatus employed to translate the subject copy into signals suitable for delivery to the communication system.

2.704 TRANSMITTING CONVERTER, FACSIMILE. See CONVERTER, TRANSMITTING, FACSIMILE.

2.705 TRANSPOSITION (DATA OR TELEGRAPH TRANSMISSION). A transmission defect in which, during one character period, one or more signal elements are changed from one significant condition to the other, and an equal number of elements are changed in the opposite sense.

2.706 TRUNK. A single circuit between two points, both of which are switching centers and/or individual distribution points.

2.707 TRUNK GROUP. See GROUP, TRUNK.

2.708 TTY. A shorthand reference to teletypewriter.

2.709 TWO-TONE KEYING. See KEYING, TWO-TONE.

2.710 TWO-TONE TELEGRAPH. See KEYING, TWO-TONE.

2.711 TWO-WIRE CIRCUIT. See CIRCUIT, TWO-WIRE.

2.712 UHF. Ultra high frequency, 300 to 3000 MHz.

2.713 UNBALANCED WIRE CIRCUIT. See CIRCUIT, UNBALANCED WIRE.

2.714 UNIDIRECTIONAL OPERATION. See OPERATION, UNIDIRECTIONAL.

2.715 UNIT INTERVAL. See INTERVAL, UNIT.

2.716 USEFUL LINE (FAX). See LINE, AVAILABLE (FAX).

2.717 USER'S LINE. See LOOP, LINE.

2.718 VESTIGIAL SIDEBAND TRANSMISSION. See TRANSMISSION, SIDEBAND, VESTIGIAL.

2.719 VHF. Very high frequency, 30 to 300 MHz.

2.720 VLF. Very low frequency, 3 to 30 kHz.

2.721 VOICE-DATA SIGNAL. See SIGNAL, QUASI-ANALOG.

2.722 VOLTAGE, PSOPHOMETRIC (PSOPHOMETRIC P.D.). Circuit noise voltage measured in a line with Psophometer which includes a CCIF-1951 weighting network. See NOISE WEIGHTING. NOTE: 1. Do not confuse with psophometric emf, conceived of as the emf in a generator (or line) with 600 ohms internal resistance, and hence, for practical purposes, numerically

double the corresponding psophometric voltage. 2. Psophometric voltage readings are commonly converted to dBm (psoph) by the relation:

$$\text{dBm (psoph)} + 20 \log_{10} V - 57.78 \text{ (V in psophometric millivolts).}$$

2.723 VU. VOLUME UNIT. The unit of measurement for electrical speech power in communication work as measured by a vu meter in the prescribed manner. The vu meter is a volume indicator in accordance with American Standards Association c 16.5-1942. It has a dB scale and specified dynamic and other characteristics in order to obtain correlated readings of speech power necessitated by the rapid fluctuation in level of voice currents. Zero vu equals zero dBm in measurement of sine wave test tone power.

2.724 VU CONVERSION FACTOR FROM VOLUME UNITS TO POWER IN dBm. To convert the volume of analog signal from volume units (vu) to dBm, 3.9 dB must be subtracted from the volume reading to obtain dBm, i.e., $0\text{vu} = -3.9\text{ dBm}$.

2.725 WEIGHTING, 1144-LINE. A noise weighting used in a noise measuring set to measure noise on a line that would be terminated by an instrument with No. 1144-receiver, or a similar instrument. The meter scale readings are in dBrn (1144-line).

2.726 WEIGHTING, 1144-RECEIVER. A noise weighting used in a noise measuring set to measure noise across the receiver of an instrument equipped with No. 1144 receiver. The meter scale readings are in dBrn (1144-receiver). NOTE: This type of subset, deskstand with hand receiver, is obsolete.

2.727 WEIGHTING, C-MESSAGE. A noise weighting used in a noise measuring set to measure noise on a line that would be terminated by a 500 type or similar instrument. The meter scale readings are in dBrn (C-message).

2.728 WEIGHTING, FLA-LINE. A noise weighting used in a noise measuring set to measure noise on a line that would be terminated by a 302 type or similar instrument. The meter scale readings are in dBa (FLA).

2.729 WEIGHTING, FLAT. A noise measuring set amplitude-frequency characteristic which is flat over a specified frequency range, which must be stated. Flat noise power may be expressed in dBrn (f_1-f_2), or in dBm (f_1-f_2). The terms 3 kc flat weighting and 15 kc flat weighting are also used for characteristics flat from 30 Hz to the upper frequency indicated.

2.730 WEIGHTING, HAL-RECEIVER. A noise weighting used in a noise measuring set to measure noise across the HAL-receiver of a 302 type or similar instrument. The meter scale readings in dBa (HAL).

2.731 WEIGHTING, NOISE. In a measuring set designed to measure circuit noise a specific amplitude-frequency characteristic or noise weighting

characteristic is included to respond to amplitude and frequency of an interference voltage and permit the measuring set to give numerical readings which approximate the interfering effects to an average listener using a particular class of telephone instrument and receiver. Noise weighting measurements are made on lines terminated either by the measuring set or the class of instrument. NOTE: The noise weightings generally used were established by agencies concerned with public telephone service, and are based on characteristics of specific commercial telephone instruments, representing successive stages of technological development. The coding of commercial apparatus appears in the nomenclature of certain weightings. The same weighting nomenclature and units are used in military versions of commercial noise measuring sets. For weighting curves see APPENDIX B.

2.732 WEIGHTING, PSOPHOMETRIC. A noise weighting established by the International Consultative Committee for Telephony (CCIF, now CCITT), designated as CCIF-1951 weighting, for use in a noise measuring set or Psophometer. The shape of this characteristic is virtually identical to that of FLA weighting. The psophometer is, however, calibrated with a tone of 800 Hz, 0 dBm, so that the corresponding voltage across 600 ohms produces a reading called 0.775 volt. This introduces a 1 dB adjustment in the formulas for conversion with dBa. See DBM, PSOPHOMETRICALLY WEIGHTED.

2.733 WHITE TRANSMISSION (FAX). See TRANSMISSION, WHITE (FAX).

2.734 WIRE, ORDER. (Also called Service Wire, Engineering Circuit, or Speaker Circuit.) A circuit for use by maintenance personnel for communication incident to lineup and maintenance of communication facilities.

2.735 WORD (TELEGRAPH). By definition a telegraph word shall consist of six character intervals when computing traffic capacity in words per minute.

$$\text{wpm} = \frac{\text{Mod rate} \times 10}{\text{Units per character interval}}$$

2.736 WORD, COMPUTER. In computing, a sequence of bits or characters which occupies one storage location and are treated by the computer circuits as a unit and transferred as such.

2.737 ZERO TRANSMISSION LEVEL REFERENCE POINT. See POINT, ZERO TRANSMISSION LEVEL REFERENCE.

3. OVERALL TACTICAL SYSTEM PLAN

3.1 General. The standards contained in this document are applicable to communications systems used primarily by tactical military forces for support of their military operations. Normally these communication systems are installed and operated by tactical military personnel. They include types of systems that range from tactical radio nets to large transportable communication complexes and fixed station installations. The standards may in some cases not be applicable to highly specialized systems with unique requirements. Such systems should, however, follow these standards at any interface with other tactical systems.

3.1.1 Scope. The conditions under which tactical equipment will operate are subject to wide variability. This may include communications for highly maneuverable forces as well as relatively stable tactical installations.

In general, for highly maneuverable tactical forces, little historical data on the desired circuit path characteristics is available, and it is not known beforehand precisely what sites, distances, terrain, etc., will be encountered. Thus, no particular system configuration may be specified. Instead, emphasis is placed on weight, size, portability, ruggedness, quick installation time, vehicular installation, ability to operate at extremes of ambient temperature and humidity, and power drain within the capability of mobile motor-generator sets. Furthermore, human engineering is an extremely important aspect of equipment design to compensate for minimal technical training on the part of users or operators.

On the other hand, where relatively stable tactical installations are involved, the constraints on equipment design due to mobility requirements can be relaxed to some extent. In general, however, the equipment installations are required to be air transportable. More time is usually available for installation and frequent relocation is not usually required. These installations are able to employ larger antenna sizes, more power and frequently have available to them a reliable source of primary ac power. Human engineering of equipment design is an important requirement.

3.1.2 Interconnection of Global and Tactical Systems. Tactical systems that have interconnections with global systems shall follow the interface standards referenced in Section 8 of this standard.

3.2 General Description of Tactical Systems.

3.2.1 Types of Traffic. The tactical military communication system shall provide communications service in every essential functional area: command and control, logistics, intelligence, weather, and administration. Traffic in the system may be in the form of voice, graphics, teletype-writer, and data, and may be transmitted either as analog signals or as digital signals. The system shall accept traffic from and deliver to individual user stations and other systems.

3.2.2 Network. An electrical communication network consists of a number of user stations equipped with various end instruments interconnected by transmission facilities which may be carried through one or more nodes or centers where such functions as switching, processing, service supervision and technical control may be provided. The transmission system consists of all the transmission circuits between user stations and nodes, and between nodes. It may make use of any means of electrical signaling over metallic or radio media. Extensive use is made of multiplexing to obtain various numbers of channels by providing parallel, simultaneous paths of various bandwidths, or by successively assigning the entire bandwidth of a facility to each of a number of channels in rapid time sequence to give the effect of parallel continuous channels. Transmission circuits may be used in a variety of ways, and may be considered with respect to their functions, the signal modes handled, kind of multiplexing used, and the type of transmission medium over which they are provided.

3.2.3 Functions of Transmission Circuits. A transmission circuit may be classified as a loop (or a line), a trunk, or a link, depending on the function it performs in the system. See definitions for CIRCUIT, LOOP, TRUNK, and LINK.

3.2.4 Signal Modes. A transmission circuit can be classified by the mode of signal it is designed to handle. Accepted signals may be continuous or discrete signals (frequently called "analog" and "digital" signals respectively). In general, the transmission requirements for these two signal modes vary widely.

3.2.4.1 Analog Signals. Transmission circuits for analog signals must be able to transmit, with acceptable fidelity, signals that may take any value within specified ranges of amplitude, frequency and phase. They cannot be provided with signal regeneration, since there is no physical way to distinguish the desired signal from noise and distortion at intermediate or receiving points. However, its amplitude may be restored by amplification.

3.2.4.2 Digital Signals. Transmission circuits for digital signals are only required to transmit signals constrained to two or more defined and discrete states. For example, a binary digital link can only handle signals which alternate between two states, such as marking and spacing, 1 and 0, on and off, etc. The signal which is transmitted between transitions from one state to another is a "signal element." In a binary system a signal element represents one bit, that is, either 1 or 0. In a quaternary digital system, four discrete states may be transmitted, therefore, each signal element represents two bits. That is, for the first and second of a pair of adjacent bits in the input, the four available signals are assigned values of 1, 1; 1, 0; 0, 1; and 0, 0. Due to the discrete nature of signals, digital circuits can be provided with signal regeneration, because, in general, the receiving device selects the output state which most closely corresponds with the signal state received. If, in addition, the digital signal conforms to a known timing pattern, the received signal may also be retimed.

3.2.4.3 Quasi-analog Signals. Because an analog circuit, within its amplitude, frequency and phase limits, imposes no limitations on the signals which it can handle, it can be the medium for the transmission of digital signals if they are converted into a form which meets its qualifications. Therefore, a signal may be designed to transmit digital signals over an analog circuit, by choosing a suitable frequency, modulation principle, and power level appropriate to the characteristics of the medium providing the analog circuit. For example, physical wire circuits working at audio frequency throughout, will allow almost any modulation principle to be used. Analog circuits provided over frequency division systems with independent carrier generation may suffer audio frequency displacement; the modulation scheme for the quasi-analog equipment must allow for this. Some radio transmission systems suffer multipath effects which may persist for a number of milliseconds; in such cases, signal element durations longer than the multipath delays offer one method of coping with the problem, and this may, in turn, require transmission on a number of parallel frequency channels.

An important consideration in the use of quasi-analog signal transmission is that as long as digital signals remain in the quasi-analog form, no full regeneration (retiming and reshaping) can be performed on them. Should regeneration be required the signal is usually demodulated and restored to digital form. Also, all the anomalies of the analog media such as thermal, impulse, and fading-connected noise, jitter due to envelope delay distortion, frequency bandwidth cutting, and level variations, tend to accumulate along the circuit. Over a sufficiently long analog circuit, these effects may cause the receiving device to make a large number of errors.

3.2.5 Multiplexing Systems. Transmission links may be provided by nonmultiplexed facilities, by frequency division multiplexing systems, and by time division multiplexing systems. Each method has distinctive characteristics affecting the objectives and use of circuits so derived.

3.2.5.1 Nonmultiplexed Circuits. Multi-pair cables provide parallel pairs for simultaneous transmission of signals along the route.

3.2.5.2 Frequency Division Multiplexing Systems. Frequency division multiplexing is a method of deriving two or more simultaneous, continuous channels from a medium connecting two points by assigning separate portions of the available frequency spectrum to the several individual channels. The most extensive exploitation of this principle is the transmission plant which provides message quality telephone circuits occupying adjacent 4 kHz slots in wideband media, both metallic and radio, and provides an effective bandwidth from about 300 to 3500 Hz. The procedures for placing many telephone channels in adjacent positions in multiplex basebands extending as high as 8 to 12 MHz have become highly standardized, and the practices for utilizing the available spectrum, which are followed by the North American companies and those recommended by the CCITT and CCIR, follow similar principles.

Military practice is characterized by a great use of modular principles, resulting from the relatively high cost of electric wave filters which

provide the separation between channels and groups of channels. Common practice is to assemble twelve voice channels by modulation processes in the basic group frequency band 60 kHz to 108 kHz, where they appear as lower sidebands of twelve carrier frequencies. This group is the basic building block of larger systems. Five such groups are assembled by further modulation processes to adjacent positions in the basic super-group frequency band, 312 to 552 kHz. Large systems extend this principle by further higher order groupings, such as master-groups and supermaster-groups, to provide a current maximum of 2700 voice channels in a nominal 12 MHz band.

3.2.5.3 Time Division Multiplexing Systems. A time division multiplexing system is a method of deriving two or more apparently simultaneous channels from a given frequency spectrum of a transmission medium connecting two points by assigning the entire spectrum to the different channels at different times (usually at regular intervals and by automatic distribution). In general, time division multiplex systems use pulse transmission. The multiplex pulse train may be considered to be the interleaved pulse trains of the individual channels. The individual channel pulses may be modulated either in an analog or a digital manner.

3.2.5.3.1 TDM Systems with Analog Modulation. The stream of pulses representing a given channel may be modulated to carry analog information by changing a selected parameter of each pulse over a continuous range of values within specified limits. The pulse rate must be adequate to preserve all of the analog information. This is achieved by using a sampling rate at least twice as high as the highest frequency in the analog baseband. The selected parameter may be pulse amplitude, duration, or timing. In pulse amplitude modulation (PAM) the amplitude is varied in an analog manner while the duration and timing are constant; in pulse duration modulation (PDM) the amplitude and timing remain constant while the duration varies according to the sampling information; in pulse position modulation (PPM) the amplitude and duration of pulses are constant, while the relative time of arrival of each pulse with respect to a nominal time is varied. Transmissions with analog pulse modulation are not digital; that is, they cannot be regenerated since the receiver has no way to distinguish the desired signal modulation from the effects of distortion and noise, although the unmodulated characteristics of pulses can be restored. An analog TDM system can handle both analog signals and quasi-analog signals, the latter representing digital data.

3.2.5.3.2 TDM Systems with Digital Modulation. In a time division multiplex system with digital modulation, a selected parameter of each pulse is varied in a digital manner. That is, each pulse is constrained to assume one state out of a set of two or more defined and discrete states. Such a signal may be regenerated because the receiving device can be designed so that it is limited to assume a set of output states which correspond to the states of the transmission signal. If noise or distortion, or both, cause the receiver to select an erroneous output state, the analog causes of the digital error are liquidated; the error is "clean". Therefore, the noise and distortion do not have cumulative effects as such; only the errors add up. The same parameters used in analog pulse modulation may also be used for digital modulation. The amplitude may be varied

in steps (this includes reversal in polarity or phase), the duration may be varied in steps, or the pulse position may be discretely varied. In radio systems, pulses are represented by groups of carrier frequency oscillations; in metallic systems, either carrier or "direct current" pulses may be used.

Digital information transmitted over the TDM system on an element for element basis requires either that the contributing individual channels be held in bit synchronism with the TDM system or that some form of buffering be employed. Analog information may be transmitted over a digital system if it is first placed in digital form. This requires that the analog values be quantized and coded. In pulse code modulation (PCM) the designation of the quantum level is generally expressed in binary code. Since the stairstep nature of a quantized signal prevents it from perfectly representing a smooth wave, quantizing error or distortion is produced. This is minimized by adopting a relatively large number of quantizing levels. Differential PCM and delta modulation operate on similar principles except that the digital code transmitted is based on the change from the preceding sampling time rather than the total amplitude value. Speech transmitted in coded digital form does not suffer directly from analog noise and distortion of the transmission medium. The errors in the received code will have a random noise effect on the recovered speech, as opposed to the progressive analog degradation in bandwidth and speech-to-noise ratio which occurs in very long analog circuits.

3.2.6 Transmission Media. The transmission facilities of transmission links may be provided over metallic lines or over radio. The latter may be divided into relatively stable media such as millimeter and microwave; varying media such as tropospheric scatter and ionospheric scatter and those media subject to wide and often prolonged variations, such as high frequency (HF) radio systems.

3.2.6.1 Metallic Lines. The term metallic lines includes all facilities obtained by use of twisted pair and coaxial cable. Characteristics of these lines which affect the parameters of transmission systems designed to operate over them include attenuation, noise and mutual coupling. Attenuation which increases continuously and smoothly with increase of frequency but is relatively stable with temperature. Noise on metallic lines tends to be fairly continuous, comprising induction from electric power systems, and crosstalk from other similar parallel circuits, the latter tending to rise with volume of traffic. Impulsive noise may also be introduced by natural static, transients from signaling circuits, and switching transients from power systems. In some areas, electric railways and local rail services may introduce noise. The fact that attenuation of both paired and coaxial facilities rises progressively with frequency has led to very extensive use of FDM systems with a nominal channel width of 4 kHz.

3.2.6.2 Radio Relay Systems. The term radio relay is generally applied to radio systems which are suitable for the application of either frequency or time division multiplexing and which operate in radio frequency bands where transmission, while varying continually within a restricted range, is relatively stable. The radio spectrum classified as VHF, UHF, and SHF is

currently exploited by radio relay systems of various types. The channel capacity of these systems varies from about 12 to several hundred channels. The loosely defined term "microwave" is also commonly applied to such systems.

Although several types of transmission may be present at the same time on a given link, radio paths for radio relay systems may generally be classified as line of sight, forward scatter, and satellite relay. An important characteristic of radio relay systems is the use of highly directional antenna systems, which may allow extensive duplication of radio frequency channel assignments on a geographical basis.

3.2.6.3 High Frequency (HF) Radio Systems. Radio systems using frequencies lower than about 30 MHz are subject to wide level changes due to slow and rapid fading. This may affect different frequencies, even in the same telephone channel band, differently. Offsetting this handicap is their range, made possible by the reflection or refraction properties of the ionosphere, when frequencies appropriate to the time of day, season, and distance are chosen. The range of such HF systems makes them useful for maintaining contact with tactical forces with wide operating radii, although such circuits are frequently of low performance. Due to congested spectrum conditions, telephone channels are limited to a 3 kHz maximum audio input, and single sideband and independent sideband techniques are widely used for efficiency.

3.2.6.4 Radio Systems Below HF. Radio systems using waves classified as MF, LF, VLF, and ILF have propagation characteristics which are relatively stable, and which may cover long distances. They are used for special purposes, such as reaching tactical vehicles capable of being located anywhere in the world. Due to their limited bandwidths, their large power and extensive antenna system requirements, and their one-way only transmission capabilities, such systems are of limited interest in a tactical system intended to serve a large number of diverse users.

3.3 Basic System Characteristics. In paragraph 3.1.1 the wide variability in tactical communication system requirements and the conditions under which the systems must operate were discussed. In order to meet these widely different conditions it is necessary that the basic reference tactical transmission system for the highly maneuverable requirement be different than the reference system for the more stable system requirement. In a highly maneuverable system the maximum distances over which switched telecommunications are required has been taken as 200 miles and a hypothetical reference system with transmission performance for such a system is given. The more stable system would be expected to meet much longer distance requirements and a hypothetical reference system for 1000 miles is given.

3.3.1 Basic 200 Mile Hypothetical Reference System. This system is based on the probable maximum requirements of a system in which the communication centers are highly maneuverable and subject at times to very frequent relocation. Experience indicates that 7 switches connected in tandem will satisfy the maximum needs of such a communication system. A connection involving 7 switches in tandem will require 6 reference trunks and subscribers loops at each end of the connection as shown in Figure 1.

The reference trunks are assumed to be 30 miles in length obtained from line of sight radio relay. Long trunk circuits obtained from tropospheric scatter or repeatered line of sight radio relay may also be used providing the transmission requirements of the reference trunk are met. Cable systems may also be used if the transmission requirements are met. The transmission standards of Section 4 will meet the transmission requirements of the 200 mile reference system.

3.3.1.1 System Layout. In a geographical area where from the standpoint of military command and organization it is possible to engineer a communication system layout the following general ground rules shall be followed:

a. Between most of the subscribers in the system it shall be possible to place a call involving not more than three intermediate switches providing there is not some blocking encountered in this first choice route.

b. In case blocking is encountered, alternate routes shall be provided. The system shall be designed to provide at least a talking circuit that can be rated as "Fair" when as many as five intermediate switches are required to set up the call using alternate routes. In a small percentage of calls where the tactical systems are extensive it may be that five intermediate switches are required for first choice routes.

c. The system shall be capable of providing a "Poor" but usable connection when as many as seven intermediate switches are involved in setting up the connection.

d. Constraints shall be placed on the number of subscribers authorized to place calls through gateways or over tie trunks to other systems. This is particularly necessary for interconnection into the Switched Global Communication System (AUTOVON). The 200 mile reference system shall be designed in such a manner that subscribers authorized such calls will not have to go through more than three switches to enter another system. It may be necessary in some cases to provide special direct trunks to permit certain groups of users such access.

3.3.1.2 Performance Objectives, 200 Mile Reference System. The quality of voice transmission is determined by subjective tests employing actual talkers and the judgment of actual listeners. A substantial sample of talkers and listeners is required to obtain a distribution of values for the output of telephone instruments and the judgment of listeners as to circuit quality or listeners grade of service under varying conditions of attenuation and noise. Listeners "grade of service" ratings for telephone communication rate the received volume and/or other transmission variables by evaluating the circuit performance by listeners judgment into three major categories of "Good", "Fair", and "Poor or Worse". The transmission factors which influence the listeners grade of service for the 200 mile reference system are shown in Table I. Subjective listener tests for voice transmission have indicated that a signal to noise ratio, S/N, of 13 dB will provide a "Poor" quality but usable circuit. The tandem connections listed in Table I, if met, will provide Good, Fair or Poor

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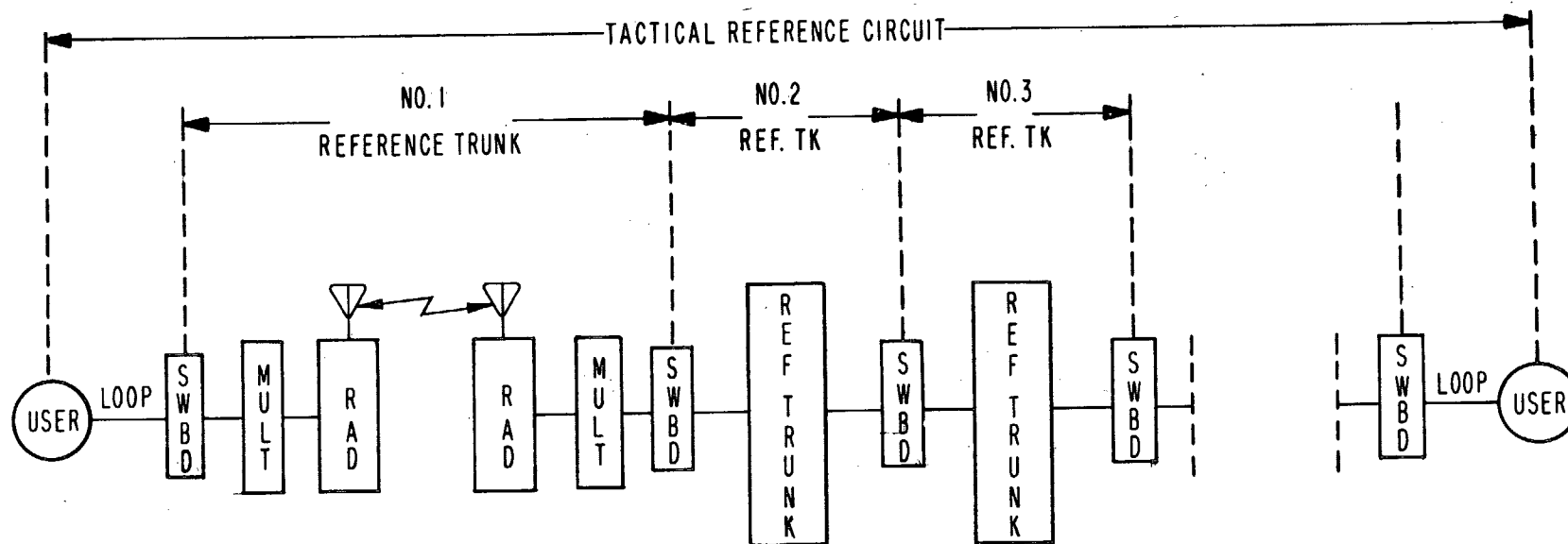


FIGURE 1

HYPOTHETICAL, 200 MILE, REFERENCE CIRCUIT (TOTAL 6 TRUNKS)

Number of Switches	Telephone Output Volume \bar{V}_u	Loss in Loops dB	Loss in Trunks dB	Loss in Switches dB	Noise per Trunk dBa0	Noise at Receiving Subscriber dBa	Volume at Receiving Subscriber		S/N at Receiving Subscriber dB
							Vu	dBa*	
FOUR-WIRE SYSTEMS									
3	-10,05	7,04	0	0	38	34	-17,06.4	65	31
5	-10,05	7,04	0	0	38	37	-17,06.4	65	28
7	-10,05	7,04	0	0	38	39	-17,06.4	65	26
FOUR-WIRE SYSTEMS WITH TWO-WIRE LOCAL SWITCHES AND TWO-WIRE TELEPHONES									
3	-13,05	7,04	3	4	38	32	-27,06.4	55	23
5	-13,05	7,04	3	4	38	35	-27,06.4	55	20
7	-13,05	7,04	3	4	38	37	-27,06.4	55	18
TWO-WIRE SYSTEMS									
3	-13,05	7,04	6	6	38	33	-32,06.4	50	17
5	-13,05	7,04	12	10	38	34	-42,06.4	40	6
FOUR-WIRE SYSTEM WITH A MOBILE RADIO SUBSCRIBER									
3	-10,05	3.5,03	0	0	52 Radio Loop	52 Radio Subs.	-14,05.8	68	16

* dBa equivalent to \bar{V}_u is taken as 0 $\bar{V}_u = 82$ dBa. σ is standard deviation of median value given.

TABLE I

TACTICAL 200 MILE HYPOTHETICAL REFERENCE SYSTEM

MIL-STD-188C

grade of service depending on the number of trunks in tandem, the distribution of values and whether the system is 2-wire or 4-wire. See Section 4 for details of transmission characteristics of telephones, loops, switches, trunks, etc. that make up the system.

3.3.2 Basic 1000 Mile Hypothetical Reference System. In order to systematize the characteristics of the 1000 mile tactical hypothetical reference system, the parameters of a reference circuit **meeting such** distance requirements are defined. It is assumed that tandem connections of 7 switches with 6 switched trunks, and with subscriber loops at each end of the connection, in a network configuration, will result in an end-to-end circuit distance in the order of 1000 miles (length of loops not included). Alternate routing capability is included. Systems which observe the standards of Section 4 will obtain satisfactory service under these conditions.

3.3.2.1 Four-Wire Transmission Diagram. To exemplify the characteristics of the system, a transmission diagram is delineated (refer to Figure 2 and Tables II and III). This diagram, Figure 2, applies to a 4-wire switched FDM system with 6 trunks (modulation sections) in tandem, making up the 1000 mile hypothetical reference circuit. For planning purposes each modulation section of 167 miles can be assumed to comprise six radio or repeater links of corresponding average length of 27.8 miles, properly sited. The tandem trunks are adjusted for a zero dB net loss between switchboards which are at a -4 dBr system reference transmission level point. It is assumed that a 6 dB loss between the -4 dBr T.L.P. and the 4-wire telephone instrument is made up of external cable and/or pad to constitute a fixed value of loop loss for control of overall net loss in the user loops. The end-to-end overall net circuit loss shall be 17 dB minimum and 21 dB maximum to ensure speech signal levels within the range of -21.5 vu to -33.5 vu for an average of -28.0 vu at the telephone receiver, for a 85% "good or better" grade of service.

The composite transmission level from any 4-wire end instrument shall provide or be adjusted for a mean power $N(p)$ of -10 dBm0.

Switchboard insertion loss shall be of the order of 0.5 dB.

The accepted value for noise performance for satisfactory service has been set at 38 dBa0 (44 dBm0) for a 4000-mile circuit. This is the total noise contribution from all sources, e.g., power hum, radio receiver noise, modulator noise, intermodulation and atmospheric, if any. The figure of 38 dBa0 is then divided among the many pieces of electronic hardware so that each section of the total 4000-mile circuit has a particular noise specification. As a consequence of the application of the design criteria, the measure of satisfactory communications is gauged by a specified minimum requirement for the signal-to-noise ratio at the end instrument.

The signal-to-noise (S/N) performance of the transmission subsystem is actually determined by two criteria. One is the noise contribution of intermodulation, which results from the multiplicity of signals that the electronic equipments must process and the other is the thermal or fluctu-

No. of Switches	Hypothetical Overall Distance (Miles)	Telephone Set Output Volume (Vu)	Access Loop Loss (dB) (1)		Recommended Circuit Net Loss (dB) (3)		6 Trunks (Modulation Sections)		Noise at Far End of Circuit (dBa0)	Noise at Telephone Receiver (dBa)	Speech Volume at Telephone Receiver (4,5)		S/N at Telephone Receiver (dB) (4)
			Min(2)	Max.	Min.	Max.	Loss/Trunk (dB)	Noise/Trunk (dBa0)			(Vu)	(dBa)	
4-WIRE SYSTEMS (Multichannel Line-of-Sight FM-Radio-Relay)													
3	334	-9,05	6.5	8.5	17	21	0	25	29.2	13.7	-28	54	40.3
5	668	-9,05	6.5	8.5	17	21	0	25	31.7	16.2	-28	54	37.8
7	1000	-9,05	6.5	8.5	17	21	0	25	33.2	17.7	-28	54	36.3
4-WIRE SYSTEMS with 2-WIRE local Switches and 2-Wire Telephones													
3	334	-9,05	6.5*	12.5*	13	25	0	25	29.75	16.25	-28	54	37.75
5	668	-9,05	6.5*	12.5*	13	25	0	25	32	18.5	-28	54	35.5
7	1000	-9,05	6.5*	12.5*	13	25	0	25	33.5	20.0	-28	54	34

* Includes hybrid and 2-wire switch losses.

- NOTES: (1) Noise output of near end loop 23 dBa for the 4-Wire System and 25 dBa with 2-wire access lines.
- (2) Assume 4-Wire Telephone handset with efficiency equal to that of 2-wire instrument. If higher efficiency instruments are used, additional losses up to 3 dB may be required.
- (3) 4 dB pad or equivalent inserted at 4-Wire receiver element to offset hybrid loss in 2-wire type handset.
- (4) Values given are for median over-all circuit loss (19 dB) and a telephone set median output speech volume.
- (5) dBa equivalent to \bar{V}_u is taken as 0 \bar{V}_u = 82 dBa.
 σ is standard deviation of median value given.

TABLE II
 TACTICAL 1000 MILE HYPOTHETICAL REFERENCE SYSTEM

99

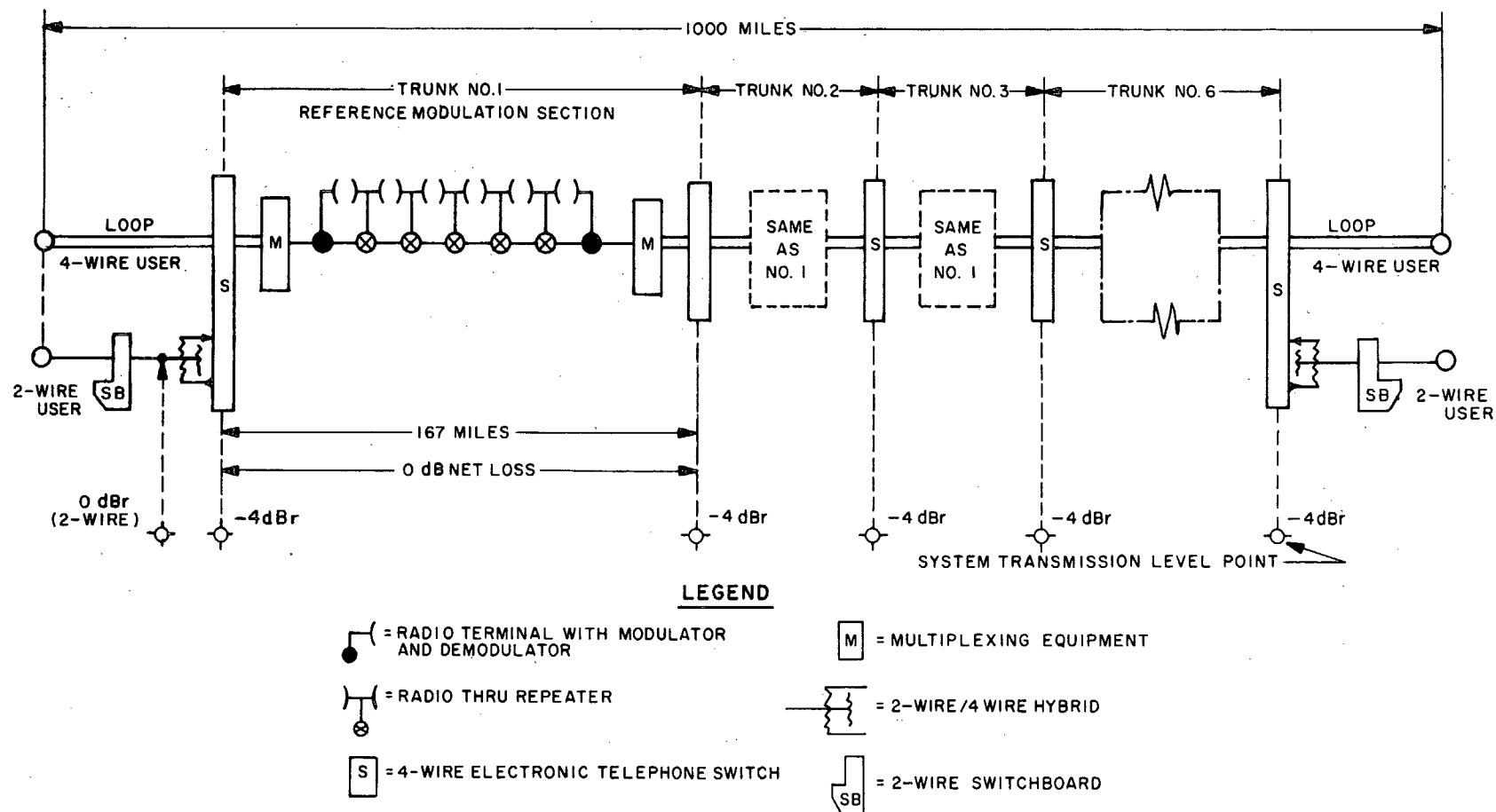


FIG. 2 TACTICAL 1000 MILE HYPOTHETICAL REFERENCE CIRCUIT (4-WIRE TRUNKS)

ation noise which is essentially a function of the received signal strength.

For the case of a multi-channel transmission system utilizing a microwave radio-relay consisting of a series of hops, the overall S/N performance is a function of each individual repeater section.

The hypothetical 1000 mile reference circuit for tactical system applications as delineated in Figure 2, provides for an end-to-end circuit distance of 1000 miles, subdivided into six switched links, each of about 167 miles. Each of these links is designated a "modulation section" and is used as a reference unit for system planning purposes. The noise in the single modulation sections is generally added powerwise and can be taken as representative for the whole reference circuit.

The subdivision of the noise as contributed by each of the single radio repeater sections within the 167 mile modulation section depends on the type of modulation employed and the method of signal through-connection at each repeater station. Baseband, intermediate or radio frequency inter-connection each give a different weight to the various sources of noise. For planning purposes 6 radio or repeater sections can be assumed with an average length of 27.8 miles.

As noted generally above, the noise specifically in a radio relay system is caused by thermal noise of the receivers, jitter of self-excited pulse transmitters, equipment hum and impulse noise, semi-conductor noise, distortion noise and finally outside interference. The latter influence of outside interference is not fully predictable but has to be kept at the lowest possible minimum by careful equipment design and appropriate frequency selection.

In the allocation of the overall noise limits, the main sources of noise are thermal noise, and distortion or intermodulation noise.

Two basic arrangements are of importance in the treatment of the noise power in the reference modulation section, namely intermediate or radio-frequency through-connection at the repeater or demodulation down to baseband and baseband through-connection on all stations of the system.

With IF or RF through-connection, modulation and demodulation are required only once within the modulation section. For the case of baseband through-connection, modulation and demodulation are involved six times. For the latter arrangement, Table III exemplifies the Noise Distribution applicable to a 167-mile modulation section. These figures should only be taken as an example of the order of magnitude for the various contributions involved.

Independently of the system layout an accounting should be made of the noise dependence on the position of the telephone channel within the baseband. At the higher baseband frequencies thermal noise predominates even if pre-emphasis is employed, while at the lower frequencies it is distortion, semi-conductor noise and where applicable, shot effect of modulator tubes.

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It can be noted that the total noise in the weighted telephone channel of 1260 pWp0 corresponds to 25 dBa0 and that a 6 dB simultaneous fading margin assumption is made in all repeater hops of the reference modulation section, wherein this is feasible with reasonable technical effort.

In general for systems longer than 200 miles, the allowable noise can be treated as directly proportional to length. Current telephone practice allows 4.8 picowatts per mile for the microwave transmission system alone and 6.4 picowatts per mile for the microwave plus multiplex.

3.4 Quasi-Analog Data. A signal-to-noise ratio (R.M.S. signal to R.M. S. noise) of 26 dB or better is required for high performance quasi-analog data transmission. A 4-wire system engineered for switched voice service should meet this requirement on either dedicated or switched connections. A possible exception may be in the case of mobile radio loops where special precautions may be required to reduce the noise level.

3.5 Communication Security. Most tactical communication systems have requirements for handling traffic on a secure basis. This has increased the use of digital transmission and switching in tactical communications. Both end-to-end and link encryption methods are used. Character and bit count integrity must be ensured. Many of the standards contained in this document have been established to facilitate encryption, however, due to the security classification that would be involved no standards are contained herein for security devices.

3.6 Precedence Recognition. The Systems shall handle traffic in accordance with several precedence levels as dictated by military operational requirements. It shall be an objective to reduce the number of precedence levels employed to the minimum necessary to meet user and system requirements. Precedence levels are recognized by switching systems and handled accordingly.

3.7 Point to Point, Full Time Allocated Circuits. Circuits which are provided tactical users on a full time, nonswitched basis, are in great demand and frequently occupy a high percentage of the multiplexed trunks between centers. This results in a highly inefficient use of the communication system. The demand for these circuits can be reduced by a better grade of service in switching centers and higher quality transmission. The standards have been established with such improvements as an objective.

Noise Distribution in a 167 mile Modulation Section of a multi-channel FM - Radio - Relay System with Baseband through-connection at Repeaters (See Figure 2)

<u>Multiplexer</u>	<u>pwp0</u>
Total loaded noise contribution of channel translating equipment in any nominal 4 kHz channel	320
<u>Transmission Subsystem</u>	
Noise, 6 Modulator/Demodulator	245
Thermal noise, RF equipment 6 repeater sections	170
Distortion noise, RF equipment 6 repeater sections	200
Distortion noise, Antennas, feeders, margin, 6 repeater sections	325
<hr/>	
Total Noise in the telephone channel, weighted, at zero relative level	1260 pwp (25 dBa0)

TABLE III

4. TACTICAL TRANSMISSION SYSTEMS

4.1 Performance Objectives.

4.1.1 Voice. In switched telecommunication systems the design of the various parts of the system, loops, switches, trunks, etc., is arranged to provide a usable connection between subscribers for the most extreme condition the system will be required to meet in terms of distance and number of tandem switches, trunks, etc. Constraints, such as size, weight, mobility, cost, etc., must be considered and "trade offs" must be made between these constraints and the grade of service that can be given.

4.1.1.1 Listeners Grade of Service. The telephone set volume, loop losses, switch losses and interoffice trunks shall be engineered to provide the following listeners preference ratings in terms of listeners preferences:

- 85% of the users will rate the circuit "Good."
- 10% of the users will rate the circuit "Fair."
- 5% of the users will rate the circuit "Poor" or "Worse."

4.1.2 Data. For high performance quasi-analog data transmission a signal to noise ratio (R.M.S. signal to R.M.S. noise) of 26 dB or better is required. Other performance standards for envelope delay distortion, harmonic distortion, phase jitter, frequency translation, etc., have been established for circuits to facilitate high performance quasi-analog data transmission.

4.1.3 Line-of-Sight Radio Relay Trunks. The fade margin of radio relay trunks shall be such as to insure that noise on trunks shall not exceed trunk noise standards more than 1% of the time.

4.1.4 Tropospheric Scatter Radio Relay Trunks. The fade margin of tropospheric scatter trunks shall be such as to ensure that noise on trunks shall not exceed trunk noise standards more than 1% of the time during the worst propagation month.

4.1.5 Interference Control. All electrical-electronic tactical equipments shall be designed, constructed and installed to conform to limits specified in MIL-STD-461 and MIL-STD-462. Provisions shall be incorporated in tactical equipments to reduce to a minimum the effects of interference likely to be encountered in friendly environments.

4.1.6 Circuit Loading. Frequency division multiplex (FDM) carrier derived trunks shall be engineered to not overload more than 1% of the busy hour for voice traffic. The assumption shall be made that during the busy hour all trunks busy conditions will be frequently encountered. For design purposes an activity factor of 25% shall be used. As many as 10% of the channels shall be considered as carrying quasi-analog message or data traffic. It shall be a Design Objective that all multichannel communication equipment be designed for 100% digital data loading.

Time division derived trunks employing pulse code modulation (PCM) (para 4.4.2) are not subject to multichannel overloading problems. Overloading individual channels does not affect other channels. The standards for volume of voice signals and power of quasi-analog and control signals if followed will not overload individual channels and will provide the best quality of transmission.

4.1.7 Echo Attenuation in Two-Wire Circuits and Return Loss in Four-Wire Circuits. Time delays in transmission over two-wire and return loss in four-wire circuits are usually so small that echos resulting from two-wire terminations and coupling from the receiver to the transmitting transducer are not disturbing to the near end users. If the tactical circuits are extended by world wide trunks and satellite circuits the overall circuit should meet DCA requirements as covered by DCAC 330-175-1.

4.2 Telephone Set Volumes. The telephone instruments used in the 200 mile reference system and in the 1000 mile reference system (see para 3.3) have somewhat different output volume characteristics due to the environments in which they are used.

4.2.1 Telephone Instruments Used in the 200 Mile Reference System. The average of the talker volume distribution for military talkers over two-wire field telephones is -13 VU with a standard deviation (sigma) of 5 VU. In four-wire systems the average of the talker volume distribution for four-wire telephones is -10 VU with 5 VU sigma. In both cases the distribution is considered to be normal or Gaussian.

4.2.2 Telephone Instruments Used in the 1000 Mile Reference System.

4.2.2.1 Two-Wire Field Type. A two-wire telephone set supplied with 100 milliamperes of talking battery current, for a mean sound pressure voice directly into the transducer, delivers a mean volume of about -13 VU into a 600 Ohm load. A universe of talkers will have a log normal distribution of talker volumes with a standard deviation of about 5 VU about the mean. This means a variation of ± 15 VU (3 sigma). Talker volumes will increase directly with a reasonable increase in ambient noise.

4.2.2.2 Four-Wire Field Type. A four-wire telephone set using essentially the same circuit elements as for the two-wire telephone set arranged to operate four-wire will deliver about -10 VU into a 600 Ohm load. A universe of talkers will have a log normal distribution with a standard deviation of about 5 VU. This means a normal variation of ± 15 VU (3 sigma) about the mean. Talker volumes will increase with a reasonable increase in ambient noise. NOTE: See definitions for TALKER, MEAN VOLUME; TALKER, MEDIUM POWER; TALKER VOLUME DISTRIBUTION, MEAN POWER OF THE; for conversion of VU values to dBm.

4.3 Characteristics of Tactical Transmission Circuits.

4.3.1 Loops.

4.3.1.1 Transmission Losses in Loops.

4.3.1.1.1 Loops in the 200 Mile Reference System. (Refer to para 3.3) The losses for both two-wire and four-wire loops at 1000 Hz shall be 3.5 dB mean per loop with a standard deviation (sigma) of 2.9 dB. This is considered to be a normal or Gaussian distribution.

4.3.1.1.2 Loops in the 1000 Mile Reference System. (Refer to para 3.3.2.1 and Table II) The specifications for loop loss are not stated in statistical form, rather minimum values are given with recommended maxima. The recommended maximum loop loss at 1000 Hz for the 4-wire systems shall be 8.5 dB and a minimum loss of 6.5 dB. It is to be noted that an added 4 dB pad or equivalent means is associated with the 4-wire telephone set (receiver) on the basis of presuming 2-wire telephone sets are presently to be accommodated in the 4-wire system and an equivalent grade-of-service is to be provided to each type of telephone instrument. For the 2-wire access loops the recommended limits are 12.5 dB maximum and 6.5 dB minimum, which losses include the hybrid 2/4 wire terminating set and 2-wire switch losses where applicable.

Since it is not practical to adjust each individual loop on the basis of loss measurements, loop loss pads shall be provided as part of switching circuits and/or multiplex terminal equipment. When the user is connected to the switch, alternate terminals shall be provided to adjust for the length falling within the four distance ranges of 0-1,000 ft., 1000-5000 ft., 5000-10,000 ft. and greater than 10,000 ft. Each of these connections to approximate the minimum loss of 6.5 dB at 1000 Hz for the range indicated, wherein the effective loss of the access loop itself at the 4-wire switch is less than the minimum.

4.3.1.1.3 Radio Loops. Radio loops shall be four-wire and operated at 0 dB \pm 2 dB loss (measured at 1000 Hz).

4.3.1.2 Noise. Noise on wire and cable loops is usually so much lower than noise on trunks that its effect on a subscriber to subscriber circuit may be neglected. Trouble conditions may, however, produce excessive noise and should be cleared for satisfactory operation.

The noise measured at the receiving end of radio loops, operating below 30 MHz, shall not exceed 52 dBa (D0, 50 dBa). Above 30 MHz radio loops shall have 38 dBa0 as a Design Objective. The noise shall be measured with a transmission measuring set TS-559()FT, or equal, using FLA line weighting.

4.3.1.3 Terminal Impedance. The terminal impedance of four-wire radio loops shall be a nominal 600 Ohms in the band between 300 and 3040 Hz for a 3 kHz channel and between 300 and 3500 Hz for a 4 kHz channel. This impedance shall have a return loss of 26 dB or more against a 600 Ohm resistance across the specified band.

The impedance of wire and cable loops varies widely with frequency, temperature, moisture and length and is not specified as a standard.

4.3.1.4 Test Tone. The signal used for transmission testing on loops shall have a frequency of 1000 Hz \pm 25 Hz and shall be at a power of 0 dBm0. Test tone power of -10 dBm0 may be used as an option providing it does not cause operational problems.

4.3.1.5 Loop Circuits, Two-Wire. Two-wire loops will be used as long as two-wire switchboards continue to be used in tactical systems. Two-wire radio loops shall be operated in one of the following two ways: (1) Four-wire at the subscriber end and two-wire at the switchboard end, or (2) push-to-talk (one-way-at-a-time) employing radio-wire integration devices. Two-wire loop circuits shall meet the same standards as four-wire loop circuits.

4.3.2 Channel Characteristics. The normal "voice" channel used for voice and data communications shall have a nominal bandwidth of 4 kHz. A special nominal 3 kHz channel shall be utilized for voice and data communications when the channel is derived from radio circuits operating below about 30 MHz.

4.3.2.1 Three kHz Channel. The following channel characteristics are for a single transmission link which is properly terminated. A single link comprises a circuit which joins two points wherein the signal is modulated and demodulated to/from the nominal frequency band of the link under consideration. Unless otherwise specified a link will be understood to include only four-wire, or equivalent four-wire, portions of a circuit and will not include hybrids.

4.3.2.1.1 Channel Audio Input/Output Impedance. The audio input and output impedance of the three kHz channel shall be 600 Ohms, balanced to ground, with a minimum return loss of 20 dB (DO 26 dB) against a 600 Ohm resistance over the frequency range of 300 Hz to 3020 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level.

4.3.2.1.2 Attenuation vs Frequency. The nominal 3 dB points for the band shall be at 300 and 3020 Hz. For all frequencies between 1000 Hz and 350 Hz, the attenuation shall be within the limits of -1 dB and +2 dB, with respect to the attenuation at 1000 Hz. For all frequencies between 1000 Hz and 3000 Hz, the attenuation shall be within the limits of +1.5 dB, with respect to the attenuation at 1000 Hz.

It shall be a Design Objective that the attenuation shall be within +1 dB for all frequencies between 350 and 3000 Hz with respect to the attenuation at 1000 Hz.

4.3.2.1.3 Envelope Delay Distortion. The envelope delay distortion shall not exceed 500 microseconds in the frequency band between 600 and 3020 Hz.

4.3.2.1.4 Total Harmonic Distortion. The total harmonic distortion within the band between 300 and 3020 Hz, produced by any single frequency test signal, shall be at least 30 dB below reference (-30 dBm0). The test signal shall be introduced into the link at the zero transmission level reference point at 0 dBm. The power of the test signal shall be adjusted when introduced at transmission level points other than the zero point.

The Design Objective shall be at least 40 dB below reference (-40 dBm0).

4.3.2.1.5 Intermodulation Distortion. The individual intermodulation distortion products, within the band between 300 and 3400 Hz produced by any two equal level tones introduced at -3 dBm0 in that band, shall be no greater than -38 dBm0 (DO 40 dB).

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4.3.2.2 Four kHz Channel. The following channel characteristics are for a single transmission link which is properly terminated. A single link comprises a circuit which joins two points wherein the signal is modulated and demodulated to/from the nominal frequency band of the link under consideration. Unless otherwise specified, a link will be understood to include only four-wire, or equivalent four-wire, portions of a circuit and will not include hybrids.

4.3.2.2.1 Attenuation vs Frequency. The nominal 3 dB points for the band shall be at 300 and 3500 Hz. For all frequencies between 1000 Hz and 325 Hz, the attenuation shall be within the limits of -1 dB and +2 dB with respect to the attenuation at 1000 Hz. For all frequencies between 1000 Hz and 3450 Hz, the attenuation shall be within the limits of ± 1.5 dB with respect to the attenuation at 1000 Hz.

As a Design Objective the attenuation shall be within ± 1 dB for all frequencies between 325 and 3450 Hz with respect to the attenuation at 1000 Hz. (See Fig 3)

4.3.2.2.2 Envelope Delay Distortion. The envelope delay distortion in the frequency band between 600 and 3200 Hz shall not exceed 175 microseconds, and in the frequency band between 1000 and 2500 Hz shall not exceed 100 microseconds.

4.3.2.2.3 Total Harmonic Distortion. The total harmonic distortion, within the band between 300 and 3500 Hz produced by any single frequency test signal shall be at least 30 dB below reference (-30 dBm0). The test signal shall be introduced into the link at the zero transmission level reference point at 0 dBm. The power of the test signal shall be adjusted when introduced at transmission level points other than the zero point, i.e., -4 dBm if at the -4 dBm point.

The Design Objective shall be at least 40 dB below reference (-40 dBm0).

4.3.2.2.4 Intermodulation Distortion. The individual intermodulation distortion products within the band between 300 and 3500 Hz produced by any two equal level tones introduced at -3 dBm0 in that band shall be no greater than -38 dBm0 (Design Objective -45 dBm0).

4.3.2.2.5 Frequency Translation. The frequency translation introduced by any link due to the difference in carrier frequencies at each end of the link shall not exceed 0.2 Hz.

4.3.2.2.6 Channel Audio Input/Output Impedances. The audio input and output impedances of the 4 kHz channel shall be 600 Ohms, balanced to ground, with a minimum return loss of 26 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB.

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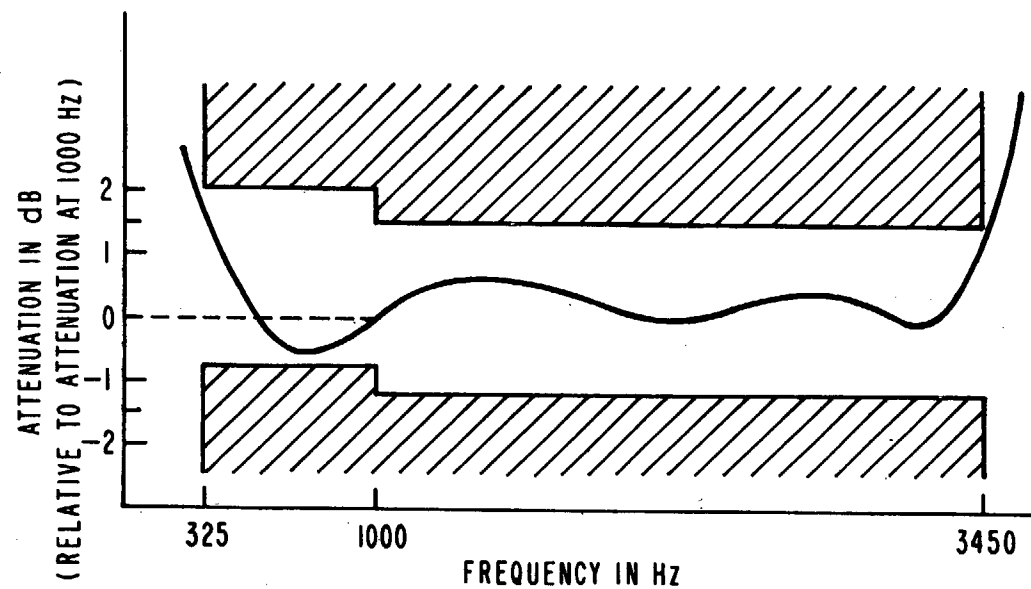


FIGURE 3
ATTENUATION VS FREQUENCY - 4 kHz CHANNEL

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4.3.2.2.7 Voice Frequency Ringing. The use of voice frequency ringing or supervisory signals shall not cause the characteristics of the 4 kHz channel to fall outside the limits specified in paragraphs 4.3.2.2.1 and 4.3.2.2.2.

4.3.2.3 Forty-Eight kHz Channel. The following channel characteristics are for a single transmission link which is properly terminated. A single link comprises a circuit which joins two points wherein the signal is modulated and demodulated to/from the nominal frequency band of the link under consideration.

4.3.2.3.1 Channel Input/Output Impedances. The input and output impedances of the forty-eight kHz channel shall be nominally 135 Ohms, balanced to ground, with a minimum return loss of 20 dB (DO 26 dB) against a 135 Ohm resistance over the frequency range of 12 kHz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level.

It shall be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.3.2.3.2 Channel Input Signal Power.

4.3.2.3.2.1 Four kHz Channel or Equivalent. The test tone input (per 4 kHz channel) shall be -34.5 dBm, +.75 dBm. The composite audio input of speech (for each 4 kHz channel) shall have a mean power of -10 dBm0, when active. The multitone input power (for each 4 kHz channel) shall be -13 dBm0.

4.3.2.3.2.2 Forty-Eight kHz Channel Input Loading. The equivalent gaussian noise test signal for simulating the loading of the channel shall be equal to -10 dBm + 10 log N or 0.8 dBm0, when all 4 kHz channels are loaded with data. When all 4 kHz channels are loaded with voice, -1 + 4 log N may be used.

4.3.2.3.3 Channel Output Signal Power.

4.3.2.3.3.1 Four kHz Channel or Equivalent. The test tone output (per 4 kHz channel) shall be -12 dBm. The composite audio output of speech (for each 4 kHz channel) shall have a mean power of -10 dBm0. The multitone output power (for each 4 kHz channel) shall be -13 dBm0.

4.3.2.3.4 Attenuation vs Frequency. The insertion loss over the frequency band shall have a maximum spread of 1.0 dB and over a band of frequencies corresponding to any 4 kHz channel, the maximum spread shall not exceed 0.3 dB.

4.3.2.3.5 Envelop Delay Distortion. The total envelope delay distortion over the band 60 to 108 kHz shall not exceed 15 microseconds and, over a band of frequencies corresponding to any 4 kHz channel, the total delay shall not exceed 2 microseconds.

4.3.2.3.6 Noise. The basic noise occurring in a band of frequencies corresponding to any 4 kHz channel, shall not exceed 50 pWp0. The total noise in a band of frequencies, corresponding to any 4 kHz channel, shall not exceed 100 pWp0 when all the remaining 4 kHz channels are loaded.

4.3.3 Four-Wire Trunks.

4.3.3.1 Transmission Level Reference Point. The four-wire transmission level reference point shall be at the four-wire switch, and the relative level there shall be -4 dBr for both transmitting and receiving.

4.3.3.2 Test Tone. The signal used for transmission testing on 4 kHz channels shall have a frequency of 1000 Hz +25 Hz and shall be at a power of 0 dBm0 (i.e., when introduced at the -4 dBr point it shall be a power of -4 dBm). As an option, a test tone power of -10 dBm0 may be used providing it does not cause operational problems.

4.3.3.3 Terminal Impedance. The terminal impedance shall be nominally 600 Ohms in the band between 300 and 3040 Hz for a 3 kHz channel and between 300 and 3500 Hz for a 4 kHz channel. This impedance shall have a return loss of 26 dB or more against a 600 Ohm resistance across the specified band.

4.3.3.4 Insertion Loss of Single Trunk. The nominal insertion loss of a single trunk circuit at 1000 Hz shall be 0 dB + 0.5 dB. Permissible regulation variations shall not exceed ± 2 dB or a standard deviation of 0.7 dB.

4.3.3.5 Crosstalk. The crosstalk coupling loss between any two trunks shall be at least 55 dB (65 dB as a Design Objective) when measured at or referred to equal transmission level points. The near end crosstalk coupling loss of a trunk circuit shall be numerically greater than 50 dB in the frequency band transmitted when measured at or referred to equal transmission level points.

The near end crosstalk coupling loss in cable systems where go and return circuits are in close proximity (i.e., spiral-four cable) shall be numerically greater than 25 dB at equal level points.

4.3.3.6 Noise on Trunks. Noise on trunk circuits shall be low enough to permit performance objectives of the 200 mile tactical reference system and the 1000 mile tactical reference system to be met. Permissible noise on trunks for these systems are given in paragraph 3.3 and Tables I, II and III.

4.3.3.6.1 Three kHz Trunks Derived from SSB HF Radio Circuits. These trunks have limited use in special cases for very long haul trunk circuits. They generally cannot meet standards for general purpose trunk circuits. Noise on these circuits when used as trunks shall not exceed 50 dBm0.

4.3.3.6.2 Wire and Cable Trunks. Tactical systems normally do not employ long wire and cable systems for communications and noise on wire and cable trunks is seldom a problem. Noise on these trunk circuits shall not exceed the standards given in paragraph 3.3 and Tables I, II and III.

4.3.3.6.3 Trunks Derived from PCM or Other Time Division Multiplex Systems. These systems are characterized as having very low noise when signals are not present but having noise that accompanies the signal when present. Noise in PCM systems is due to the process of "quantization" and the interfering effect on transmissions of speech and other signals is quite different from that occurring in frequency division systems. Quantizing noise standards are covered in paragraph 4.4.2.1.11 for PCM multiplex trunks.

4.3.3.7 Limiting on Trunks. The limiting action on the trunk circuits shall be such as to compress test tone power inserted at or referred to the zero transmission level reference point as follows:

Input Power - dBm0	Compression - dB
-10.....	None
0.0.....	None
+3	None
+5	1
+8	5

4.3.4 Two-Wire Trunks. The standards for two-wire trunks include the effect of the hybrids.

4.3.4.1 Transmission Level Reference Point. The zero transmission level reference point shall be taken at the two-wire switchboard terminal of the trunk circuit in the transmitting direction. The relative transmission level at this point is 0 dBr.

4.3.4.2 Test Tone. The signal used for transmission testing on the channel shall have a frequency of 1000 Hz \pm 25 Hz and shall be at a level of 0 dBm0.

4.3.4.3 Terminal Impedance. The terminal impedance of all two-wire trunks shall be nominally 600 Ohms in the band between 300 and 3040 Hz for a 3 kHz channel and between 300 and 3500 Hz for a 4 kHz channel. This impedance shall have a return loss of 26 dB or more against a 600 Ohm resistance across the specified band.

4.3.4.4 Insertion Loss of Single Trunks. The nominal insertion loss of a single trunk circuit at 1000 Hz shall be 3 dB \pm 0.5 dB. Permissible regulation variations shall not exceed \pm 2 dB.

4.3.4.5 Echo Attenuation. The time delays in transmissions over tactical two-wire circuits are usually so small that echoes resulting from two-wire terminations are not disturbing to talkers using the circuits.

4.3.4.6 Crosstalk. The crosstalk coupling loss between any two two-wire trunks shall be at least 55 dB when referred to equal level points.

4.3.4.7 Noise on Trunks. The same standards apply as for four-wire trunks.

4.3.4.8 Limiting on Trunks. The limiting on two-wire trunk circuits shall follow the same standards as for four-wire trunks. Refer to paragraph 4.3.3.7.

4.3.5 Transmission Levels.

4.3.5.1 Four-Wire Systems. The transmission levels at the four-wire switch shall be -4 dBr for both directions of transmission. At multiplexers the transmission levels shall be -4 dBr for both directions of transmission. As an option, transmission levels at multiplexers may be -16 dBr at the input to the multiplexer and +7 dBr at the output. Means shall be provided for adjusting these optional levels to the -4 dBr level at the switch.

4.3.5.1 Two-Wire Systems. The transmission level at two-wire switchboards in a two-wire system shall be 0dBr in the transmitting direction toward the trunk. In multiplexers with two-wire terminations (hybrids) the transmission levels at the four-wire point of connection to the hybrid shall be -4 dBr transmitting into the multiplexer and +1 dBr receiving from the multiplexer. As an option, levels of -16 dBr into the multiplexer at the four-wire point and +7 dBr receiving from the multiplexer at the four-wire point may be provided.

4.3.6 Signal Power.

4.3.6.1 Voice Loading. Carrier derived trunk circuits are designed to operate at a specific mean power with a variation about the mean as indicated by the standard deviation used in the design. The users circuits must be arranged as far as possible to apply the design for either two-wire or four-wire operation. The usual mean power talker applied at the modulator input must correspond to the transmission level assigned which may be either -4 dBr or -16 dBr. The mean signal powers applied at these transmission levels are -14 dBm and -26 dBm respectively. Loops must be adjusted to give these mean signal powers at the modulator input (except in the case of the 200 mile reference system where adjustment of loop attenuation is not feasible). (See also para 4.4.1.3.3.2.1 for FDM channel loading.)

4.3.6.2 Data Loading. Quasi-analog data signals shall be transmitted at a total power of -13 dBm for the composite of all tones applied to one voice channel. (Refer also to paragraphs 4.4.1.1.4.1 and 4.4.1.3.3.2.2)

4.4 Multiplexing. Extensive use is made of multiplexing techniques to obtain various numbers of channels by providing parallel, simultaneous paths of various bandwidths (frequency division) or by successively assigning the entire bandwidth of a facility to each of a number of channels in

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rapid sequence to give the effect of parallel continuous channels (time division).

4.4.1 Frequency Division Multiplexing (FDM) Systems. Frequency division multiplexing is a method of deriving two or more simultaneous, continuous channels from a transmission medium (metallic lines or radio) connecting two points.

4.4.1.1 Telegraph Channels, FDM Systems. Several telegraph channels may be multiplexed, on a frequency basis, into a 3 kHz or 4 kHz message circuit, which is analogue in nature. The standards for 12 and 16 multiplexed telegraph channel systems appear below, however they are not intended to inhibit the development or use of systems with larger or smaller numbers of channels.

4.4.1.1.1 Twelve Channel System. The twelve channel system shall follow the same standards as the sixteen channel system with the following exceptions:

4.4.1.1.1.1 Center Frequencies. The nominal center frequencies of the telegraph channels shall be at: 425, 595, 765, 935, 1105, 1275, 1445, 1615, 1955, 2380, 2805 and 3230 Hz.

4.4.1.1.1.2 Signal Type and Sense. Frequency shift modulation shall be employed. The mark signal shall be at the center frequency minus the shift ($f_c - \Delta f$) and the space signal shall be at the center frequency plus the shift ($f_c + \Delta f$).

4.4.1.1.1.3 170 Hz Telegraph Channel, Frequency Shift. The frequency shift in the 170 Hz telegraph channel shall be 42.5 Hz below and above the center frequency.

4.4.1.1.1.4 425 Hz Telegraph Channel, Frequency Shift. The frequency shift in the 425 Hz telegraph channel shall be 85 Hz below and above the center frequency.

4.4.1.1.2 Sixteen Channel System.

4.4.1.1.2.1 Center Frequencies. The nominal center frequencies of the telegraph channels shall be at: 425, 595, 765, 935, 1105, 1275, 1445, 1615, 1785, 1955, 2125, 2295, 2465, 2635, 2805 and 2975 Hz.

4.4.1.1.2.2 Signal Type and Sense. Frequency shift modulation shall be employed. The mark signal shall be at the center frequency minus 42.5 Hz ($f_c - 42.5$ Hz) and the space frequency shall be at the center frequency plus 42.5 Hz ($f_c + 42.5$ Hz).

4.4.1.1.2.3 Frequency Tolerance. The tolerance allowed on the "mark" and "space"-frequencies, as generated, shall be plus or minus 4 Hz.

4.4.1.1.3 Audio Input/Output Impedances. The audio input and output impedances of the telegraph channel multiplexer and demultiplexer on the

carrier line side shall be nominally 600 Ohms with a minimum return loss of 26 dB against a 600 Ohm resistance over the frequency bandwidth of the analog channel.

4.4.1.1.4 Telegraph Channel Multiplexer.

4.4.1.1.4.1 Audio Multitone Output Power. The audio multitone output power, that is fed to the analog channel, shall be -13 dBmO. The output power, per telegraph channel shall be equal to $-13 \text{ dBm} - 10 \log t$, where t is the number of telegraph channels. The multitone output power shall be adjustable over a minimum range of -20 dBm to 0 dBm. NOTE: Higher multitone output power may be used on analog channels that are not subject to the multichannel overloading problems encountered in frequency division multiplex systems. For example, any number of analog channels derived from pulse code modulated multiplexed systems may be loaded with multitone signals or data without causing intermodulation between the analog channels.

4.4.1.1.5 Telegraph Channel Demultiplexer.

4.4.1.1.5.1 Audio Multitone Input Power. The audio input power, that is received from the analog channel, shall be a nominal -13 dBmO. The sensitivity of the demultiplexer shall be such as to accommodate audio input powers over a minimum range of -25 dBm to 0 dBm.

4.4.1.1.6 Crosstalk. The crosstalk coupling loss between telegraph channels, on a single transmission link, shall be numerically greater than 50 dB, when referred to equal level points.

4.4.1.1.7 Distortion. With the transmit and receive terminals connected back to back, sending and receiving loops properly terminated, and all transmit tones activated at proper levels, random undistorted signals keyed simultaneously into each sending loop at the maximum modulation rate of the terminal design; the maximum distortion, as measured in the receiving loops, shall not exceed $4\% M - 0 - 4\% S$. This distortion shall not increase more than 1% for lower modulation rates.

4.4.1.1.8 Telegraph Channel Loop Circuits. It is the usual practice to terminate the individual telegraph channels in a dc loop circuit. The standard "low level interface" (Figure 5, Appendix B) shall be provided for dc telegraph loops.

4.4.1.2 Three kHz Channels, FDM System. Several 3 kHz channels may be multiplexed, on a frequency basis, onto the transmission medium connecting two points. In a tactical environment, the transmission medium will normally be HF SSB radio circuit, operating below 30 MHz. In this case, the frequency division multiplexing equipment is an integral part of the HF radio equipment. (See paragraph 4.5.7)

4.4.1.3 Four kHz Channels, FDM Systems.

4.4.1.3.1 General. The standardized types of frequency division

multiplex equipment, used in the tactical environment provides for multiplexing of 4 kHz or message circuits which are analog in nature. Analog signals such as telephone and facsimile are transmitted without need for signal conversion. By converting digital data signals into quasi-analog form, they may also be transmitted over these circuits. The modular principles employed make it possible to derive wider analog circuits from the multiplex equipment, as described below. The through routing of group and supergroup channels allows the buildup of longer circuits without incurring penalties of bandwidth narrowing and increased envelope delay distortion and noise introduced by the channel translating equipment. It is also anticipated that in the future extensive use will be made of group and supergroup channels and even wider bandwidths to handle the output signals of high speed digital data modems designed for such use.

4.4.1.3.2 Four Channel System.

4.4.1.3.2.1 Order Wire. An order wire or supervisory channel is normally provided by the transmission medium (metallic lines or radio circuits) through the use of the 0.3 kHz to 4 kHz frequency band. One of the 4 channels may also be used for the order wire channel.

4.4.1.3.2.2 Message Baseband.

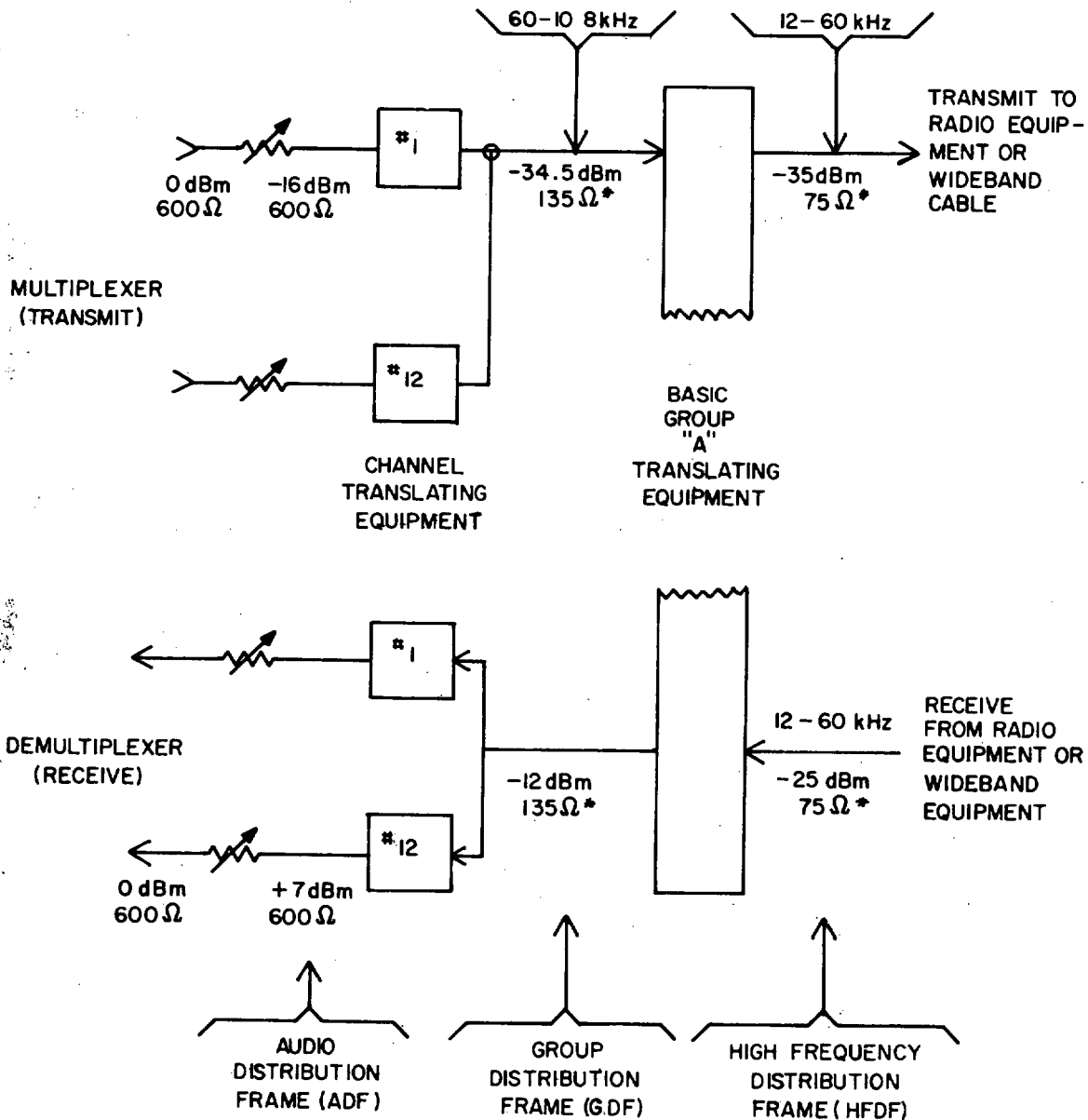
4.4.1.3.2.2.1 Multiplexer. Four each 4 kHz channels are translated, by frequency modulation process, to adjacent positions in the frequency band of 4 kHz to 20 kHz. Four channel carriers are used to do this, spaced every 4 kHz from 8 kHz to 20 kHz. The carriers are suppressed in the channel modulator circuits, and the lower sideband of each channel is selected by a channel sideband filter. A channel sideband in this position is said to be "inverted."

4.4.1.3.2.2.2 Channel Characteristics. The four message channels shall meet the standards for 4 kHz channels as specified in paragraph 4.3.2.2.

4.4.1.3.3 Twelve Channel System. The nominal bandwidth of a twelve channel multiplexed system shall be 48 kHz. The twelve channel system forms a basic group channel and building block for multichannel systems. The multiplexed basic group frequency band shall be translated to 60 kHz to 108 kHz and designated as basic group "B." The basic group B, by further frequency modulation process, is translated to a frequency band of 12 kHz to 60 kHz and is then designated as basic group "A."

Basic group "A" is widely used for 12 channel tactical multiplexed systems. Basic group "B" is widely used in those tactical multiplexed systems, that have more than 24 channels. A basic group "A" and a basic group "B" are sometimes combined in a tactical multiplexed system to provide a 24 channel capability.

4.4.1.3.3.1 Transmission Levels. Tactical FDM equipment for 12 channels and larger systems are arranged as shown in Figure 4 where input and output transmission levels of 0 dBm are available. Transmission



*DO - 135 Ohm AND 150 Ohm IMPEDANCE TERMINATIONS
 BE PROVIDED AS STRAPPING OPTIONS

TEST TONE LEVEL FOR SINGLE CHANNEL FDM BASIC GROUP "A" EQUIPMENT

FIGURE 4

levels of -16 dBr input and +7 dBr output which correspond to Global standards are also available. In order that the transmission levels for tactical systems should be provided, internal pads, or other appropriate means, shall be used to adjust the transmission levels to -4 dBr in and out which are standard for tactical four-wire switched systems.

4.4.1.3.3.2 Loading.

4.4.1.3.3.2.1 Voice Loading (Analog). The total load applied to a multichannel amplifier is the sum of the loads in the individual channels. There are certain factors about speech transmission that tend to reduce and stabilize the total load as the number of channels increases. These factors are:

- a. The number and distribution of channels actively transmitting speech.
- b. The volumes of speech in the individual channels.

In determining the channel loading of a multichannel voice system, considerable advantage may be taken of the statistical distribution of the speech signals. For example, the activity factor for a channel or the percentage of time in the busiest traffic hour a channel might be active in multichannel systems, is about 25%.

For smaller groups of channels this percentage may be larger, but it is highly unlikely that any increase in group size would change it appreciably. Utilization of this activity factor, results in a decrease of the mean power (-10 dBmO) of a voice channel (short term average channel active) to a mean power of -16 dBmO for a voice channel (long term average).

The volumes of speech in active voice channels will also affect the total load. Speech volumes are not constant in a channel, but vary considerably, depending on the characteristics of the talker's speech and the loudness of his voice.

The changes in active channels and in speech volumes concern only the maximum rms load on a multichannel amplifier; causing more and more gradual variations as the number of channels increases.

However, it is the total input voltage applied to the amplifier, and not just the rms portion, that determines whether the amplifier will overload. This total voltage is the vector sum of the instantaneous voltages in the separate channels and is a function of both the phase and amplitude of each speech signal.

In consideration of the above statistical aspects of voice and the associated probabilities, loading formulas were established by Holbrook and Dixon and are recommended by CCITT. These formulas give the mean absolute power (P_m) of the distributed speech signals that the system must be capable of carrying. The signal power depends on the number of channels involved, and is calculated from one of the two formulas: (See Figure 30.)

$$P_m = -1 + 4 \log N, \text{ (for } N \text{ less than 240 channels) dBmO}$$

or

$$P_m = -15 + 10 \log N, \text{ (for } N \text{ greater than 240 channels) dBmO}$$

The formulas include a small margin for loads caused by signaling tones, pilot signals, and carrier leak.

4.4.1.3.3.2.2 Digital Data Loading. Data signals are, more or less, of constant amplitude; in contrast to the wide variations of speech. Thus, the average power of a data signal is continuous and imposes greater loads on the multichannel amplifier than that of a voice signal which is present part of the time. The loading, imposed by telegraph and data signals, is calculated from the following formula: (See Figure 30.)

$$P_m = P_C + 10 \log N$$

where P_m = rms power of the multichannel signal (dBmO)
 P_C = rms power of the input telegraph or data signal
 N = number of channels carrying telegraph or data signals

It shall be a Design Objective that all multichannel communication equipment be designed for 100% digital data loading.

NOTE: In the application of the digital data loading value of -10 dBmO mean power per channel $(-10 + 10 \log N \text{ dBmO for power summation})$ to contemporary multichannel systems (switched) carrying (1) voice, (2) teletype, and (3) data traffic; that the combination of the applicable values for (1), (2), (3) of voice channel loading together with the number of channels so allocated, produces a resultant transmission level that is compatible with the specific overload characteristics of the multiplex equipment, the emission bandwidth of the FM system, etc. Otherwise a reduction in the digital data loading to -13 dBmO mean power per channel may be necessary to meet the required noise performance.

4.4.1.3.3.3 Channel Equipment. (See Figures 4, 5 and 6.)

4.4.1.3.3.3.1 Channel Translating Equipment. The channel translating equipment shall translate 12 each 4 kHz channels to/from a basic group "B" channel (48 kHz).

4.4.1.3.3.3.1.1 Channel Modulation and Demodulation Plan. The Channel Translating Equipment shall modulate and demodulate twelve, four-wire, audio channels to the 60 to 108 kHz frequency spectrum as shown in Figure 7(a). The translated channels shall appear at the Group Distribution Frame (GDF) or equivalent point as single sideband suppressed-carrier 4 kHz-spaced channels with lower sideband orientation for all channels. The translated channels are identified as a Basic Group "B" at the GDF point.

4.4.1.3.3.3.1.2 Channel Input/Output Power. The input and output levels specified apply to channel translating equipment and provide a net gain of 23 dB in each oneway path. These power levels shall apply to all channels of the multiplex equipment, without regard for the net loss to be provided for any particular trunk, whether terminated on a two-wire or a four-wire basis. All channels shall be maintained on the same basis so that a -16 dBm test tone at any input to the channel translating equipment shall result in a +7 dBm level at the corresponding channel output of the demodulator, insuring that all channels are interchangeable and may be freely patch at multiplex access points without need to change adjustments

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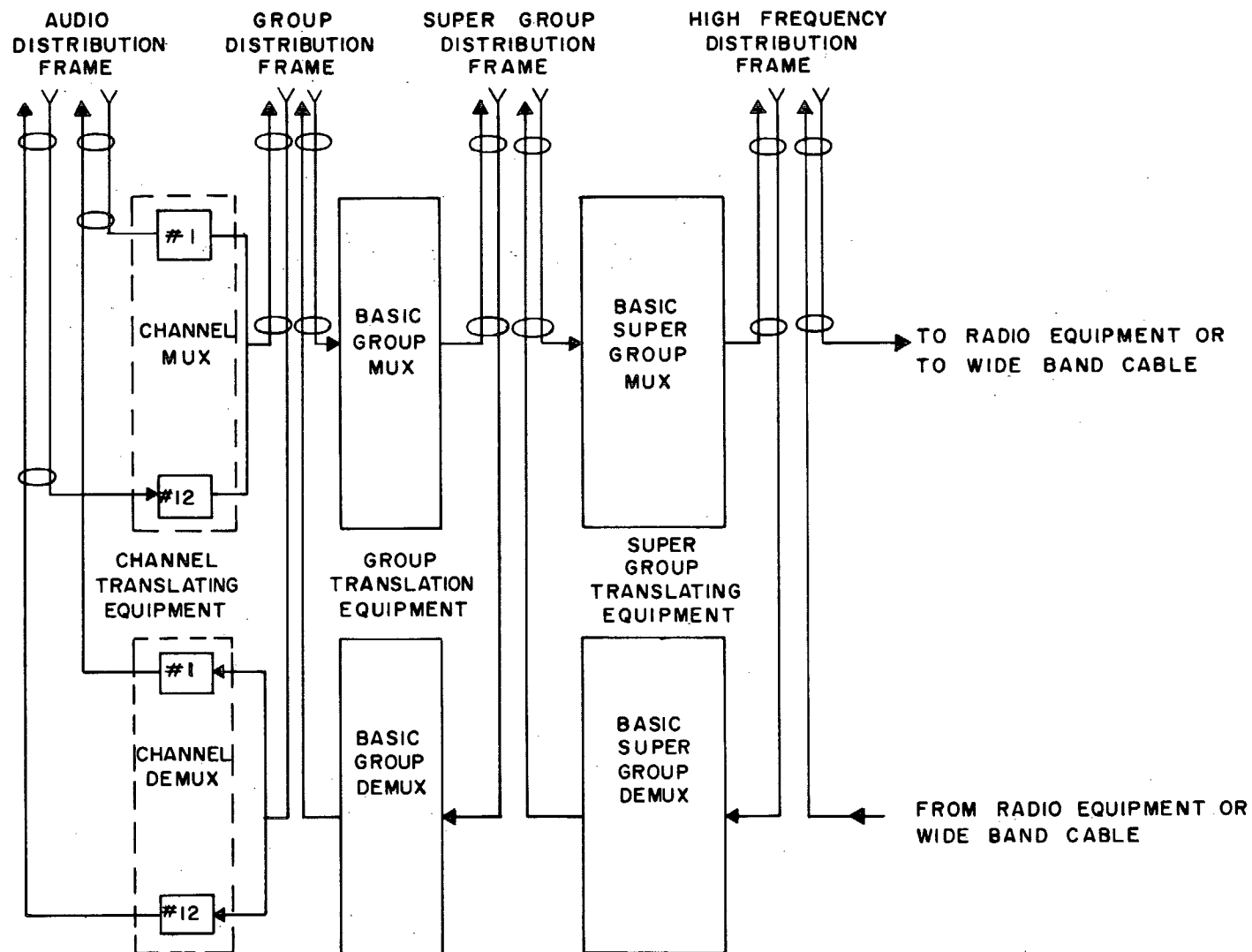
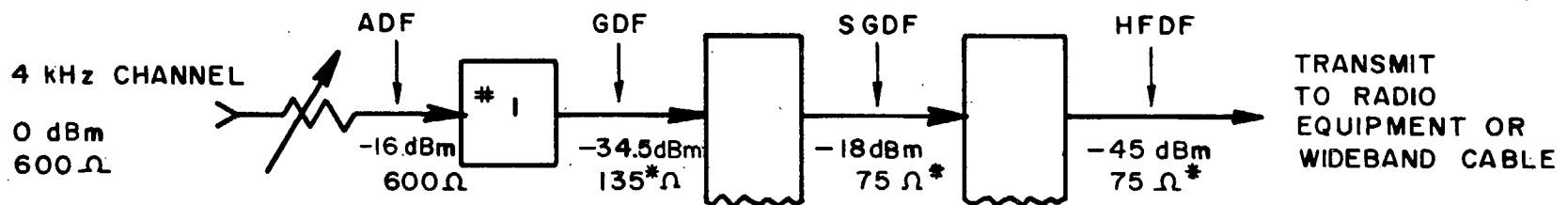


FIGURE 5

FREQUENCY DIVISION MULTIPLEXING (FDM) EQUIPMENT

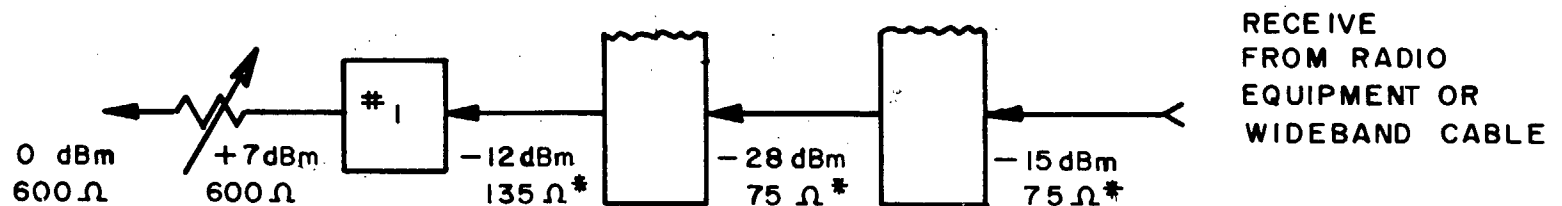
TEST TONE, SINGLE CHANNEL FDM EQUIPMENT



CHANNEL
 TRANSLATING
 EQUIPMENT

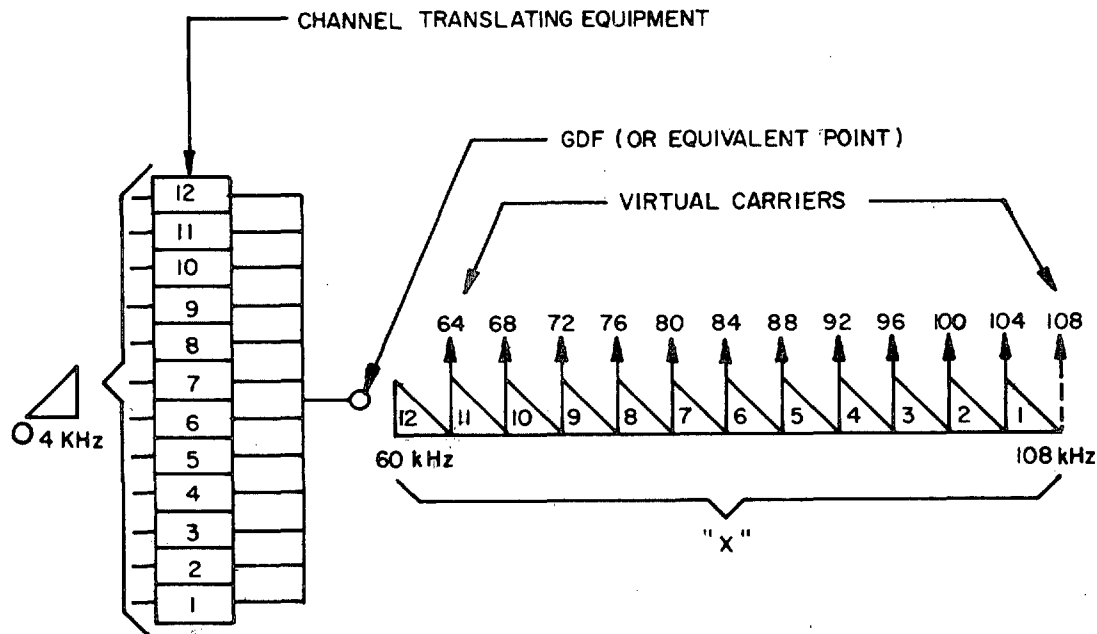
BASIC
 GROUP
 TRANSLATING
 EQUIPMENT

BASIC
 SUPER
 GROUP
 TRANSLATING
 EQUIPMENT

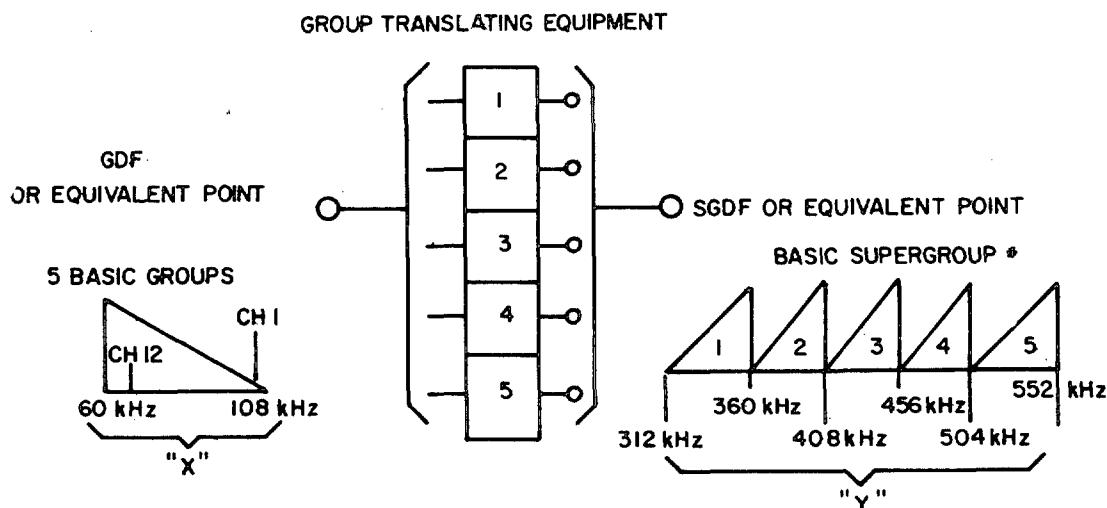


* DO - 135 Ohms AND 150 Ohms SHALL BE PROVIDED AS STRAPPING OPTIONS

FIGURE 6



A. Channel Modulation and DeModulation Plan: Formation of the 12-Channel Basic Group



"X" represents a group of 12 channels in which the audio frequencies are inverted.

"Y" represents 5 groups of 12 channels in which the audio frequencies are upright.

* The basic supergroup (Y) is formed by modulating 5 groups (X) with the following carrier frequencies, respectively: 420, 468, 516, 564 and 612 kHz.

B. Group Modulation Plan: Formation of 5 Group Basic Supergroup.

GROUP MODULATION PLAN (F D M)

FIGURE 7

integral to the multiplex equipment.

a. The test tone, at the audio input to the channel translating equipment, shall be -16 dBm.

b. The test tone, at the audio output from the channeling equipment, shall be +7 dBm + 0.1 dB with an adjustment range of not less than + 3 dB to accommodate variations in the receive direction at the GDF or equivalent point.

c. The test tone level, at the GDF or equivalent point in the transmit direction, shall be -34.5 dBm, + .75 dBm.

d. The test tone level, in the receive direction at the GDF or equivalent point, shall be -12 dBm.

4.4.1.3.3.1.3 Channel Impedances.

a. Audio Input and Output. The impedance at the audio input and output, measured over the frequency band of 300 to 3400 Hz, shall be 600 Ohms with a longitudinal balance of not less than 40 dB. The return loss shall be not less than 26 dB when compared against a nonreactive impedance of 600 Ohms. For this requirement, the test tone level shall be used.

b. GDF Input and Output. The impedance of the channel translating equipment at the GDF shall be 135 Ohms balanced with a return loss of not less than 20 dB (DO 26 dB) when compared with a nonreactive impedance of 135 Ohms. It shall also be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.3.1.4 Channel Insertion Loss-Frequency Characteristic. The individual transmitting and receiving branch insertion loss-frequency characteristics, i.e., audio to GDF or GDF to audio, shall be within the following values:

Frequency Band	Insertion Loss
600 - 2400 Hz	+ 0.35 dB
400 - 3000 Hz	- 0.35 dB + 0.75 dB
300 - 3400 Hz	- 0.35 dB + 1.50 dB

Positive figures indicate a loss, and negative figures indicate a gain, relative to the insertion loss at 1000 Hz.

4.4.1.3.3.1.5 Channel Envelope Delay Distortion. The envelope delay distortion of a channel from audio to GDF in the transmit direction and from GDF to audio in the receive direction, taken individually, shall not exceed 90 microseconds over the 600 to 3200 Hz portion of a channel and 55 microseconds over the 1000 to 2500 Hz portion of a channel.

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4.4.1.3.3.3.1.6 Channel In Band Noise. With the channel translating equipment properly looped at the GDF and the VF leads terminated in 600 Ohms, the idle channel noise shall not exceed 35 pWp0.

4.4.1.3.3.3.1.7 Channel Out of Band Noise. With the channel bank properly looped at the GDF through suitable level correcting equipment, the total intrinsic and intermodulation noise occurring in any channel shall not exceed 200 pWp0 when all other channels are loaded with (300 to 3400 Hertz band) Gaussian noise at an input power level equivalent to -5 dBm0 per channel.

4.4.1.3.3.3.1.8 Channel Level Stability. With the channel bank properly looped at the GDF through suitable level-correcting equipment, the channel level stability measured at the channel demodulator output shall be ± 0.5 dB or better over a 30 day period. This measurement shall be made at the test tone frequency and level.

4.4.1.3.3.3.1.9 Channel Limiting. The channel translating equipment shall provide limiting in the transmit direction such that the level at the GDF or equivalent point cannot exceed +9 dBm0 per channel. The limiting shall be such that if a 1000 Hz tone is applied to the channel input at a level of -16 dBm and the level of this tone is increased in a linear manner for 3.5 dB above -16 dBm, the output level at the GDF or equivalent point will increase in a linear manner with a maximum departure not exceeding ± 0.3 dB. For an increase in level up to 16 dB above the initial setting, the limiting shall come into play such that the transmit level will not exceed +9 dBm0 per channel.

4.4.1.3.3.4 Basic Group "A" Equipment (12 kHz to 60 kHz). (See Figure 4.)

4.4.1.3.3.4.1 Group "A" Translating Equipment. The basic Group "A" equipment shall translate the basic group "B" channel to/from a basic group "A" channel.

4.4.1.3.3.4.1.1 Group Modulation and Demodulation Plan. The basic group equipment shall translate the frequency of the basic group "B" channel (60 kHz to 108 kHz) to/from the basic group "A" channel (12 kHz to 60 kHz). The translated channel shall be single sideband, suppressed carrier, with upper sideband orientation. The quality of the basic group "A" channel will be lower than that of basic group "B" channel, because of the frequency translation process.

4.4.1.3.3.4.2 Group Multiplexer.

4.4.1.3.3.4.2.1 Group Input/Output Power. The group test tone input (per 4 kHz channel) shall be -34.5 dBm. The group test tone output shall be -35 dBm (per 4 kHz channel).

4.4.1.3.3.4.2.2 Group Input/Output Impedances. The group input impedance shall be 135 Ohms, balanced to ground, with a return loss of 20 dB (26 dB) against a 135 Ohm resistance over the frequency band of interest.

The group output impedance shall be 75 Ohms, unbalanced, with a return loss of 20 dB (DO 26 dB) against a 75 Ohm resistance over the frequency band of interest. It shall be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.3.4.3 Group Demultiplexer.

4.4.1.3.3.4.3.1 Group Input/Output Power. The group test tone input (per 4 kHz channel) shall be -25 dBm. The group test tone output shall be -12 dBm.

4.4.1.3.3.4.3.2 Group Input/Output Impedances. The group input impedance shall be 75 Ohms, unbalanced, with a return loss of 20 dB (DO 26 dB) against a 75 Ohm resistance over the frequency range of interest. The group output impedance shall be 135 Ohms, balanced to ground, with a return loss of 20 dB (DO 26 dB) against a 135 Ohm resistance over the frequency range of interest. It shall be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.3.4.4. Group Insertion Loss and Frequency Response Characteristics.

a. Transmit Direction. In the transmit direction, the insertion loss characteristics shall have a maximum spread of 0.5 dB. The test frequencies shall be sent at the test tone level at the GDF in the frequency range of 60.6 to 107.7 kHz and measurements made at the HFDF or equivalent point at the corresponding sideband frequencies.

Over any band of frequencies corresponding to a 4 kHz channel, the spread shall not exceed 0.3 dB.

b. Receive Direction. In the receive direction the insertion loss characteristic shall have a maximum spread of 0.5 dB. The test frequencies shall be sent at the test tone level at the HFDF or equivalent point and measured at the GDF or equivalent point in the 60.6 to 107.7 kHz band.

Over any band of frequencies corresponding to a 4 kHz channel the spread shall not exceed 0.3 dB.

4.4.1.3.3.4.5 Group Envelope Delay Distortion.

a. Transmit. In the transmit direction the envelope delay distortion over the band of frequencies corresponding to a 4 kHz channel in the range of 64 to 104 kHz shall not exceed 15 microseconds. The delay distortion over the 64 to 104 kHz band shall not exceed 50 microseconds. These measurements shall be made at the HFDF when sending at the GDF.

b. Receive. In the receive direction the envelope delay distortion over the band of frequencies corresponding to any 4 kHz channel in the range of 16 to 56 kHz shall not exceed 15 microseconds. The delay distortion over the 64 to 104 kHz band shall not exceed 50 microseconds. This measurement shall be made at the GDF when sending at the HFDF.

4.4.1.3.3.4.6 Group In Band Noise. With the group translating equipment correctly looped at the 12-60 kHz side, the noise occurring in any nominal 4 kHz band, corresponding to any channel, shall not exceed 50 pWp0.

4.4.1.3.3.4.7 Group Out of Band Noise. With the group translating equipment correctly looped at the 12-60 kHz side, the total loaded noise contribution, of the group translating equipment including group regulating equipment, in any slot corresponding to any nominal 4 kHz channel shall not exceed 200 pWp0. The noise source shall be band-limited to the 60-108 kHz spectrum and the input level to the group translating equipment shall be equivalent to -5 dBm0 per channel.

4.4.1.3.3.4.8 Group Level Stability. With the group translating equipment correctly looped at the HFDF or equivalent point, the group level stability measured at the GDF or equivalent point shall be ± 0.5 dB over any 30 day period.

4.4.1.3.4 Sixty Channel System. (See Figures 5, 6 and 7 (B).)

4.4.1.3.4.1 Group "B" Translating Equipment. The basic group "B" translating equipment shall translate 5 each 48 kHz channels (60 kHz to 108 kHz) to/from a basic supergroup channel (312 kHz to 552 kHz).

4.4.1.3.4.2 Group "B" Modulation and Demodulation Plan. In systems consisting of a large number of channels, five basic groups (B) are translated, by a second modulation process, to adjacent positions in the basic supergroup frequency band 312 to 552 kHz. The process is indicated in Figure 7, part B. Five group modulating carriers are required, from 420 to 612 kHz. These are suppressed, and the lower sidebands, formed by modulation of the basic group band, are selected by filters. In this process, the sidebands of the individual channels are turned over in frequency from the inverted position they occupy in the basic group (Figure 7, part A) so that they are "erect," with the higher audio frequencies located in the higher frequency portion of the 4 kHz slot occupied in the supergroup.

4.4.1.3.4.3. Group Multiplexer.

4.4.1.3.4.3.1. Group Input/Output Power. The group test tone input (per 4 kHz channel) shall be -34.5 dBm. The group test tone output shall be -18 dBm (per 4 kHz channel).

4.4.1.3.4.3.2 Group Input/Output Impedances. The group input impedance shall be 135 Ohms, balanced to ground, with a minimum return loss of 20 dB (DO 26 dB) against a 135 Ohm resistance over the frequency band of interest. The group output impedance shall be 75 Ohms, unbalanced, with a minimum return loss of 20 dB (DO 26 dB) against a 75 Ohm resistance over the frequency band of interest.

It shall be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.4.4 Group Demultiplexer.

4.4.1.3.4.4.1 Group Input/Output Power. The group test tone input (per 4 kHz channel) shall be -28 dBm. The group test tone output shall be -12 dBm (per 4 kHz channel).

4.4.1.3.4.4.2 Group Input/Output Impedance. The group input impedance shall be 75 Ohms, unbalanced, with a minimum return loss of 20 dB (D0 26 dB) against a 75 Ohm resistance over the frequency band of interest. The group output impedance shall be 135 Ohms, balanced to ground, with a minimum return loss of 20 dB (D0 26 dB) against a 135 Ohm resistance over the frequency band of interest.

It shall also be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.4.4.3 Group Insertion Loss and Frequency Response Characteristics.

a. Transmit Direction. In the transmit direction the insertion loss characteristic shall have a maximum spread of 0.5 dB. The test frequencies shall be sent at the test tone level at the GDF in the frequency range of 60-108 kHz and shall be measured at the SGDF or equivalent point at the corresponding sideband frequency. Over the band of frequencies corresponding to the 4 kHz nominal bandwidth of any channel, the spread shall not exceed 0.15 dB.

b. Receive Direction. In the receive direction the insertion loss characteristic shall have a maximum spread of 0.5 dB. The test frequencies shall be sent at the test tone level at the SGDF at the sideband frequencies corresponding to the demodulated range of 60-108 kHz for each group and measured at the GDF or equivalent point. Over the band of frequencies corresponding to the 4 kHz nominal bandwidth of any channel, the spread shall not exceed 0.15 dB.

4.4.1.3.4.4.4 Group Envelope Delay Distortion.

a. The total delay distortion over the band 60 to 108 kHz shall not exceed 15 microseconds. These measurements shall be made with the equipment looped at the SGDF, sending at GDF and measuring at the GDF, receive direction.

b. The total delay distortion over the band 68 to 100 kHz shall not exceed 5 microseconds when transmitting at the GDF and measuring at the SGDF, or when receiving at the SGDF and measuring at the GDF.

c. In the transmit or receive direction, the delay distortion over any 4 kHz segment corresponding to a channel in the range 60 to 108 kHz shall not exceed 2 microseconds.

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4.4.1.3.4.4.5 Group In Band Noise. With the group translating equipment correctly looped at the SGDF, the basic noise occurring in any nominal 4 kHz band, corresponding to any channel shall not exceed 50 pWp0.

4.4.1.3.4.4.6 Group Out of Band Noise. The total noise in any slot corresponding to a channel shall not exceed 100 pWp0 when the group translating equipment is correctly looped at the SGDF and when:

a. One of the groups, including group regulation equipment is loaded with a 60-108 kHz bandlimited spectrum of white noise at a power level of -5.0 dBm0, per channel (combined load of +5.8 dBm0) or when

b. All five groups are each simultaneously loaded with a 60-108 kHz bandlimited spectrum of white noise at a power level of -5.0 dBm0 per channel (combined load of +12.8 dBm0).

4.4.1.3.4.4.7 Group Level Stability. With the group translating equipment properly looped at the SGDF through suitable level-correcting equipment, excluding group regulation, the group level stability measured at the GDF or equivalent shall be ± 0.5 dB or better over any 30 day period. This measurement shall be made using test tone level input to GDF (transmit direction) at a frequency of 83 kHz.

4.4.1.3.4.4.8 Group Pilot. When the multiplex equipment is required to provide a group reference and control monitoring pilot, this pilot will always be associated either with the channel or the group translating equipment. The group pilot shall be injected in such a manner as to be present at the input to each group except when groups are patched or switched in tandem. Means shall be provided for manually disabling the group pilot, regulators and alarms.

4.4.1.3.4.4.8.1 Pilot Frequency. The group reference and control monitoring pilot frequency shall be 104.080 kHz ± 1 Hz.

4.4.1.3.4.4.8.2 Frequency Stability. The pilot frequency shall remain within limits for at least ninety days without adjustment.

4.4.1.3.4.4.8.3 Pilot Level. The pilot level of the group reference and control monitoring pilot at the GDF or equivalent point shall be -20 dBm0 with an adjustment accuracy of ± 0.1 dB.

4.4.1.3.4.4.8.4 Pilot Level Stability. The level stability of the group pilot generator shall be ± 0.3 dB for any thirty day period.

4.4.1.3.4.4.8.5 Group Alarm. In addition to the group alarm feature specified in 4.4.1.3.4.4.8, a group alarm shall be provided. This alarm shall always be associated with either the channel or group translating equipment. This alarm shall be activated when the level of the group reference pilot varies by more than ± 5.0 dB from its nominal level.

4.4.1.3.4.5 Through Group Equipment. The through group equipment shall enable the patching of a basic group "B" demultiplexer output (receive) to the input of a basic group "B" multiplexer (transmit). This patching ability shall provide the capability of relaying without demodulating to the 4 kHz channels and minimizing the channel degradation.

4.4.1.3.4.5.1 Level and Insertion Loss. The channel test tone level at the input to the through group equipment shall be -12 dBm. The channel test tone level at the output of the through group equipment shall be -34.5 dBm. The insertion loss measured at 83 kHz shall be $22.5 \text{ dB} \pm 0.5 \text{ dB}$.

4.4.1.3.4.5.2 Impedances. The impedance at the input and output of the through group equipment, measured over the frequency band of 60.6 kHz to 107.7 kHz, shall be 135 Ohms balanced with a return loss of not less than 20 dB when measured against a nonreactive impedance of 135 Ohms. Longitudinal balance shall not be less than 40 dB.

4.4.1.3.4.5.3 Insertion Loss Characteristic. The spread of the insertion loss characteristic over the frequency band of 60.6 kHz to 107.7 kHz shall be 1.0 dB maximum. The spread over any 4 kHz channel shall not exceed 0.5 dB between 64 kHz and 104 kHz. In addition, the spread in the band of 103.7 to 104.6 kHz shall not exceed 0.3 dB.

4.4.1.3.4.5.4 Envelope Delay Distortion. The envelope delay distortion over any 4 kHz segment corresponding to a channel in the range of 68 - 100 kHz shall be not more than 20 microseconds. The envelope delay distortion over the 68 kHz to 100 kHz band shall not exceed 40 microseconds. The envelope delay distortion over the 60.6 kHz to 107.7 kHz band shall not exceed 170 microseconds. The envelope delay distortion corresponding to the 600 - 3200 Hz portions of Channels 2 to 11 shall not exceed 40 microseconds. The envelope delay distortion corresponding to the 600 - 3200 Hz portions of Channels 1 or 12 shall not exceed 90 microseconds.

4.4.1.3.4.5.5 Noise and Crosstalk. The total noise and crosstalk in any slot, corresponding to a channel, shall be not more than 10 pWp0 with the through group equipment loaded with noise at a level of -5.0 dBm0 per channel (except for the channel being measured).

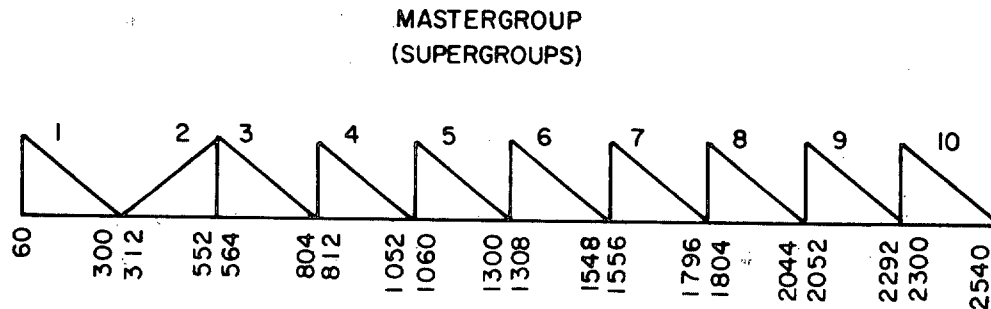
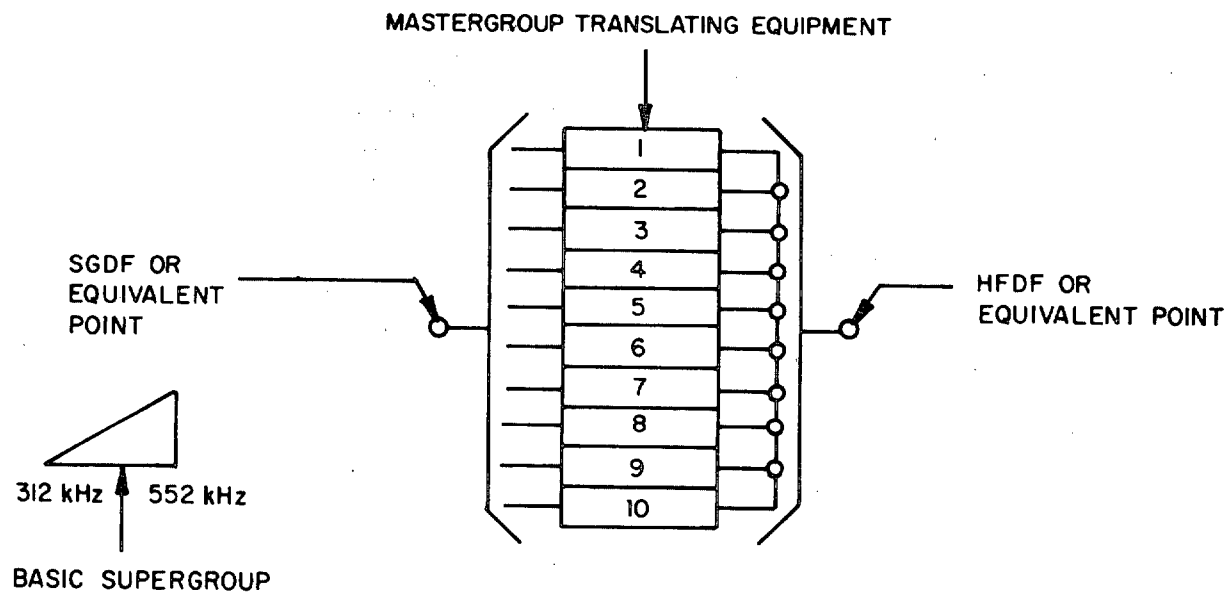
4.4.1.3.4.5.6 Level Stability. The level stability shall be $+ 0.2 \text{ dB}$ for any frequency in the 60.6 to 107.7 kHz range for any 30 day period.

4.4.1.3.5 Up to 600 Channel System. (See Figures 5, 6 and 8.)

4.4.1.3.5.1 Supergroup Translating Equipment. The basic supergroup translating equipment shall translate up to 10 each basic supergroup channels (312 kHz to 552 kHz) to/from a master group.

4.4.1.3.5.2 Supergroup Modulation and Demodulation Plan. In the transmit direction, the supergroup translating equipment shall modulate the 60-channel basic supergroup (312 to 552 kHz) to one of the ten supergroup line frequency allocations shown in Figure 8. Except for supergroup 2, all supergroups are again reversed in frequency sense by the modulation

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Frequency in kHz

Represents a supergroup (60 channels) in which the audio frequencies are upright.

Represents a supergroup (60 channels) in which the audio frequencies are inverted.

Formation of the Line Frequency Allocation, One to Ten Supergroups.

MASTERGROUP MODULATION PLAN (FDM)

FIGURE 8

processes, thus making the individual channel sidebands become inverted. Supergroup 2 is already in the correct position and is transmitted without further modulation at this stage. Its individual channels therefore remain erect. In the receive direction, the supergroup translating equipment shall demodulate the 60-channel basic supergroups (312 to 552 kHz) from the supergroup line frequency allocations shown in Figure 8.

4.4.1.3.5.3 Basic Supergroup Multiplexer.

4.4.1.3.5.3.1 Basic Supergroup Input/Output Power. The test tone input power to the supergroup (per each 4 kHz channel of the basic group) shall be -18 dBm. The test tone output power from the supergroup (per each 4 kHz channel) shall be -45 dBm.

4.4.1.3.5.3.2 Basic Supergroup Input/Output Impedances. The supergroup input/output impedances shall be 75 Ohms, unbalanced, with a minimum return loss of 20 dB (D0 26 dB) against a 75 Ohm resistance over the frequency band of interest.

It shall also be a Design Objective that 130 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.5.4 Basic Supergroup Demultiplexer.

4.4.1.3.5.4.1 Supergroup Input/Output Power. The supergroup test tone input (per 4 kHz channel) shall be -15 dBm. The supergroup test tone output (per 4 kHz channel) shall be -28 dBm.

4.4.1.3.5.4.2 Supergroup Input/Output Impedances. The supergroup input/output impedances shall be 75 Ohms, unbalanced, with a minimum return loss of 20 dB (D0 26 dB) against a 75 Ohm resistance over the frequency band of interest.

It shall also be a Design Objective that 135 Ohm and 150 Ohm impedance terminations be provided as strapping options.

4.4.1.3.5.5 Basic Supergroup - Insertion Loss Characteristic.

a. Transmit Direction. The maximum spread in the insertion loss characteristic in the transmit direction shall not exceed 1.0 dB. The test frequencies shall be sent at the test tone level at the SGDF or equivalent point in the frequency range of 312 to 552 kHz and shall be measured at the HFDF or equivalent point at the corresponding sideband frequencies. The maximum spread over the band of frequencies corresponding to a 48 kHz group allocation shall not exceed 0.5 dB. The maximum spread over the band of frequencies corresponding to a 4 kHz channel allocation shall not exceed 0.25 dB when interpolated from the above measurement.

b. Receive Direction. The maximum spread of the insertion loss characteristic in the receive direction shall not exceed 1.0 dB. The test frequencies shall be sent at the test tone level at the HFDF or equivalent

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point at the sideband frequencies corresponding to the basic supergroup frequencies of 312 to 552 kHz for each supergroup and measured at the SGDF or equivalent point.

The maximum spread over the band of frequencies corresponding to a 48 kHz group allocation shall not exceed 0.5 dB.

The maximum spread over the band of frequencies corresponding to a 4 kHz channel allocation shall not exceed 0.25 dB when interpolated from the above measurement.

4.4.1.3.5.6 Basic Supergroup Envelope Delay Distortion.

a. Transmit Direction. For supergroup 2 and supergroups 4 through 10, the envelope delay distortion over any 4 kHz segment corresponding to a channel in the range 312 to 552 kHz shall not exceed 1.5 microseconds. The envelope delay distortion over the 312-552 kHz band shall not exceed 5 microseconds.

For supergroup 1, the envelope delay distortion over any 4 kHz segment corresponding to a channel in the range 316 to 552 kHz shall not exceed 4 microseconds. The envelope delay distortion over the 316 to 552 kHz band shall not exceed 30 microseconds.

For supergroup 3, the envelope delay distortion over any 4 kHz segment corresponding to a channel in the range 312 to 544 kHz shall not exceed 20 microseconds. The envelope delay distortion over the 312-544 kHz band shall not exceed 28 microseconds.

These measurements shall be made at the HFDF when transmitted at the SGDF.

b. Receive Direction. The envelope delay distortion for supergroup 1, 2, 3 and 4 through 10, respectively, in the receive direction, shall not exceed the values specified above for the transmit direction. These measurements shall be made at the SGDF when transmitting at the HFDF.

4.4.1.3.5.7 Basic Supergroup In-Band Noise. With the supergroup correctly looped at the HFDF, the idle noise measured in a 4 kHz slot corresponding to a channel allocation shall not exceed 50 pWp0.

4.4.1.3.5.8 Basic Supergroup Out-of-Band Noise. With the supergroup correctly looped at the HFDF or equivalent point, the total loaded noise contribution of the supergroup translating equipment, including supergroup regulation equipment, if any, in a 4 kHz slot corresponding to a channel allocation shall not exceed 100 pWp0. The noise source shall be band-limited to the 312 to 552 kHz and the noise input level to the supergroup translating equipment shall be equivalent to -5.0 dBm0 per channel (combined load of +12.8 dBm0).

4.4.1.3.5.9 Basic Supergroup Level Stability. With the supergroup translating equipment correctly looped at the HFDF, the supergroup level

stability measured at the SGDF or equivalent point (receive direction) shall be ± 0.5 dB or better over any 30 day period.

4.4.1.3.5.10 Pilot Frequency. The supergroup reference and control monitoring pilot frequency shall be 315.920 kHz ± 1 Hz. The group one pilot (104.080 kHz) translated to 315.920 kHz in the group modulator shall be used for this pilot.

4.4.1.3.5.10.1 Pilot Level. The pilot level of the supergroup reference and control monitoring pilot at the HFDF or equivalent point shall be -20 dBm0 with an adjustment accuracy of ± 0.1 dB.

4.4.1.3.5.11 Through Supergroup Equipment. The through supergroup equipment shall enable the patching of a basic supergroup demodulator output (receive) to the input of a basic supergroup multiplexer (transmit). This patching ability shall provide the capability of relaying without demodulating to either the group or 4 kHz channels and minimizing the channel degradation.

4.4.1.3.5.11.1 Test Tone Power Level and Insertion Gain. The channel test tone power level at the input to the through super group equipment shall be -28 dBm. The channel test tone power level at the output of the through supergroup equipment shall be -18 dBm. The insertion gain, measured at 433 kHz, shall be 10 dB ± 0.3 dB.

4.4.1.3.5.11.2 Impedances. The impedance at the input and output of the through supergroup equipment, measured over the band 312 to 552 kHz, shall be 75 Ohms unbalanced. The return loss measured at the input and output shall be not less than 20 dB.

4.4.1.3.5.11.3 Insertion Loss Characteristic. The spread of the insertion loss characteristic over the frequency band of 312 kHz to 552 kHz shall be 1.4 dB maximum. The spread over any 4 kHz channel shall not exceed 0.5 dB maximum, from 316 kHz to 548 kHz.

4.4.1.3.5.11.4 Envelope Delay Distortion. The envelope delay distortion over any 4 kHz segment corresponding to a channel in the range of 316 kHz to 548 kHz shall not exceed 30 microseconds. The envelope delay distortion over the 316 kHz to 548 kHz band shall not exceed 70 microseconds. The envelope delay distortion over the 312 kHz to 552 kHz band shall not exceed 170 microseconds.

4.4.1.3.5.11.5 Noise and Crosstalk. The total noise and crosstalk in any slot corresponding to a channel shall be not more than 50 pWp0 with the through supergroup equipment loaded with noise at a power level of -5.0 dBm0 per channel (combined load of +12.8 dBm0).

4.4.1.3.5.11.6 Level Stability. The level stability shall be ± 0.2 dB for any frequency in the 312 to 552 kHz range for any 30 day period.

4.4.1.3.6 Overall FDM Performance Requirements. (See Figures 5 and 6.)

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4.4.1.3.6.1 General. The term "set" used in these performance requirements refers to a complete set of multiplex equipment, including channel, group and supergroup modulator and demodulator equipment with associated carrier generation and distribution equipment and power supply equipment. The performance specified herein shall be demonstrated with the set correctly adjusted for test tone levels indicated in Figure 6.

a. With the set looped back at the High Frequency Distributing Frame or equivalent point through appropriate looping equipment and with tests performed on a back-to-back basis.

b. In those cases where sets having only one supergroup, the tests specified in (a) above shall be conducted with the equipment looped back at the Group Distributing Frame. (See Figure 5.)

4.4.1.3.6.2 Insertion Loss Referenced to 1 kHz

Frequency Band, Hz	Insertion Loss, dB	
	Looped at HFDF	Looped at GDF
	dB	dB
600-2400	+ 1.0	+ .7
400-3000	- 1.0, + 2.0	- .7, + 1.5
300-3400	- 1.0, + 3.5	- .7, + 3.0

4.4.1.3.6.3 Envelope Delay Distortion (microseconds) Relative to Any Single Frequency Between 1000 and 2500 Hz.

	Freq band, Hz	Microseconds
Any channel, looped at GDF	1000-2500	≤110
	600-3200	≤180
Looped at HFDF		
Any channel, SG2 & SG4-10	1000-2500	≤117
	600-3200	≤187
Any channel, SG 1 & 3, Except Channel 1, Gr 1, of SG1 and Channel 11 & 12, GR5, SG3	1000-2500	≤130
	600-3200	≤200

4.4.1.3.6.4 Accuracy of a Single Frequency. Any single frequency between 300 and 3400 Hz injected into any channel at a level of -16 dBm shall be received at the corresponding channel output with an accuracy of ± 0.10 Hz.

4.4.1.3.6.5 Loaded Noise. This test shall be made with all channels, but one, loaded with a uniform 300-3400 Hz Gaussian noise signal at a level of -10 dBm 0. The nonloaded channel shall be terminated in its characteristic impedance. The noise, measured in the nonloaded channel output,

using an appropriately calibrated noise measuring instrument, shall not exceed 20 dBA for sets looped at the HFDF or 17 dBA for sets looped at the GDF. Four channels in each group shall be tested sequentially for loaded noise, with only one channel unloaded at a time and the remaining channels in the terminal loaded.

4.4.2 Pulse Code Modulation - Time Division Multiplexing Systems. The following characteristics apply to time division multiplexed (TDM) circuits using pulse code modulation (PCM) for transmission of voice and digital information in quasi-analog form. These standards shall be followed for TDM-PCM equipments designed for use in tactical communication systems. (Additional standards will be developed in the future for new digital modulation techniques where the specific application warrants a deviation from these standards.)

4.4.2.1 4 kHz Channel. The following characteristics are for a single link when properly terminated. (A single link in this context comprises a channel which joins two points and wherein the analog signal is coded into digital form at the originating end of the channel, for transmission over the entire channel under consideration, and decoded into analog at the terminating end of the channel.) The characteristics of this 4 kHz channel are specified for the four-wire analog input and output terminals of the link.

4.4.2.1.1 Transmission Levels. See paragraph 4.3.5.

4.4.2.1.2 Test Tone. Same as paragraphs 4.3.3.2 and 4.3.4.2.

4.4.2.1.3 Insertion Loss of Single Link. The nominal insertion loss of a single 4 kHz link at 1000 Hz shall be 0 dB plus or minus 0.5 dB.

4.4.2.1.4 Terminal Impedance. Same as paragraph 4.3.3.3.

4.4.2.1.5 Crosstalk. The near end or far end signal-to-noise plus crosstalk ratio in any idle channel due to full test tone modulation of any other channel shall be at least 53 dB.

4.4.2.1.6 Idle Channel Noise. The noise measured at the receiving end, when converted to the zero transmission level reference point on 4 kHz channel, shall not exceed 30 dBA0 per link using FLA line weighting.

4.4.2.1.7 Random Noise. The characteristic of the idle channel noise shall be as close to white noise as possible. This can be accomplished by the injection of an appropriate, random noise source into the common PAM signals before the PCM coder, at a level which will cause a variation of one coder level.

4.4.2.1.8 Input/Output Linearity. The input/output characteristics of a 4 kHz channel shall be linear within plus or minus 0.5 dB (with a mean of zero) for input signal levels from minus 40 dBm to minus 4 dBm, four-wire. (DO)

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4.4.2.1.9 Attenuation vs Frequency. For all frequencies between 200 and 1000 Hz, the attenuation shall be within the limits of -0.5 to + 0.5 dB with respect to the attenuation at 1000 Hz. For all frequencies between 1000 and 3500 Hz, the attenuation shall be within the limits of -1.0 to + 0.25 dB with respect to the attenuation at 1000 Hz. For all frequencies between 3500 and 3640 Hz, the attenuation shall be between the limits of -3.0 to + 0.25 dB with respect to the attenuation at 1000 Hz.

4.4.2.1.10 Envelope Delay Distortion. The envelope delay distortion in the frequency band between 600 and 3200 Hz shall not exceed 200 microseconds (150 microseconds Design Objective), and in the frequency band between 1000 and 2500 Hz shall not exceed 100 microseconds.

4.4.2.1.11 Signal-to-Noise (Quantized), (S/N_q) Ratio. With two multiplex terminals connected together at the transmission medium interfaces, the total signal-to-noise (quantized) (S/N_q) ratio of a sine wave signal at any frequency between 300 and 3400 Hz, when measured between the four-wire transmit and the four-wire receive points, shall be as follows: (See Figure 10)

Input Signal dBm	Minimum Signal to Quantizing Noise Ratio, dB	
	DO	Interim Standard
-4	30	30
-4 to -20	30	17
-20 to -30	25	15
-30 to -40	16	14

4.4.2.1.12 Longitudinal Balance. The longitudinal balance on a 4 kHz channel shall be at least 40 dB.

4.4.2.1.13 Total Harmonic Distortion and Intermodulation Distortion. The multiplexed channels shall meet the requirements of paragraphs 4.3.2.2.3 and 4.3.2.2.4 except that in paragraph 4.3.2.2.4 the intermodulation distortion products in the specified band shall not exceed -30 dBmO. (D.O. - 38 dBmO).

4.4.2.2 Characteristics of the Multiplex Signal. The following characteristics apply to the functions of the PCM multiplexer and to the multi-channel group signal at the interface between the PCM multiplexer and the transmission unit. (See Figure 9.)

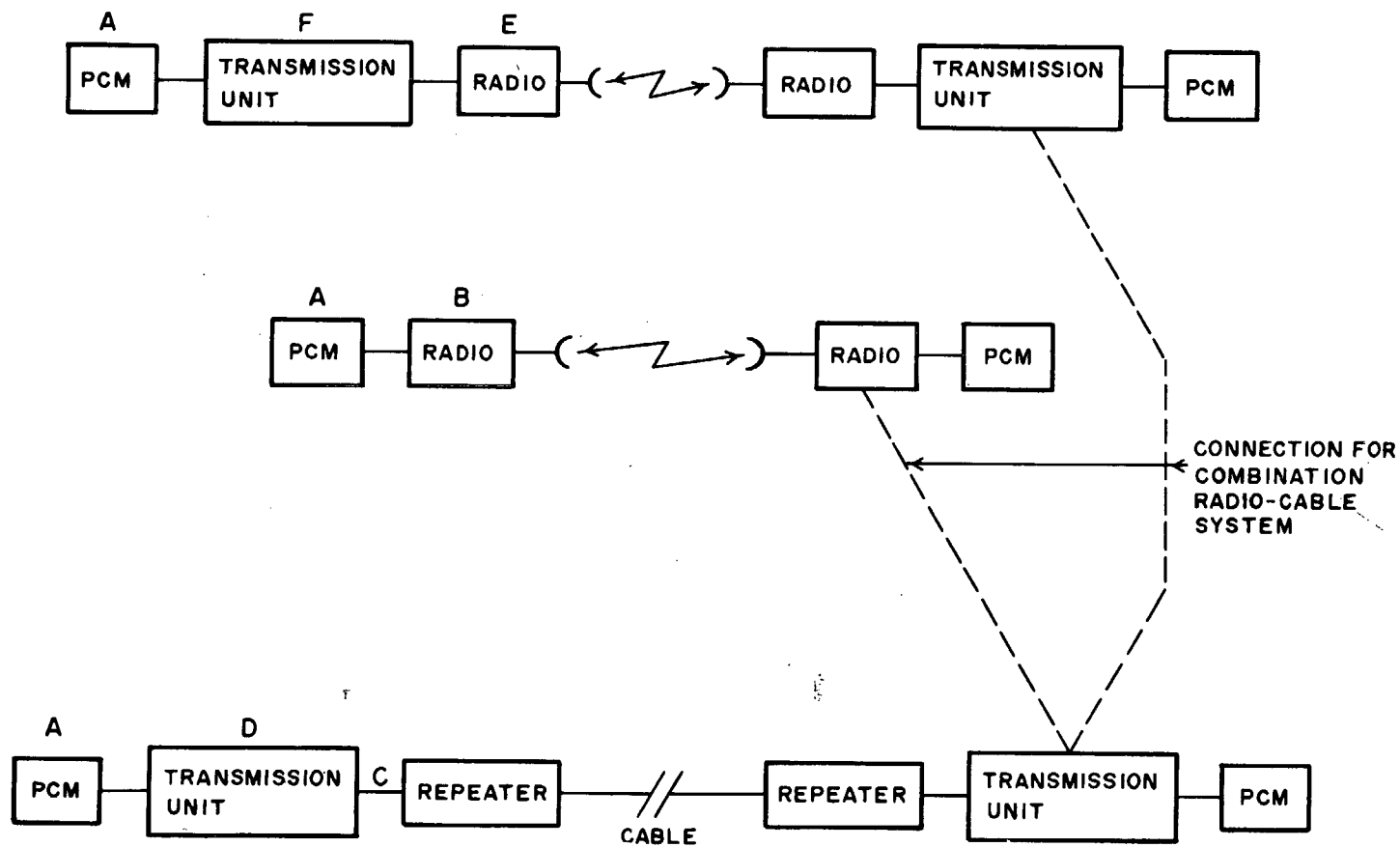
4.4.2.2.1 Sampling Rate. Each 4 kHz channel shall be sampled at a nominal 8 kHz rate.

4.4.2.2.2 Number of Digits per Channel. Each sampled 4 kHz channel shall be encoded into a 6-digit binary code with the most significant digit transmitted first.

4.4.2.2.3 Compander Characteristics. An instantaneous compander shall be used. The compressor shall have a 3-segment, straight-line, transfer

PULSE CODE MODULATION SYSTEMS

FIGURE 9



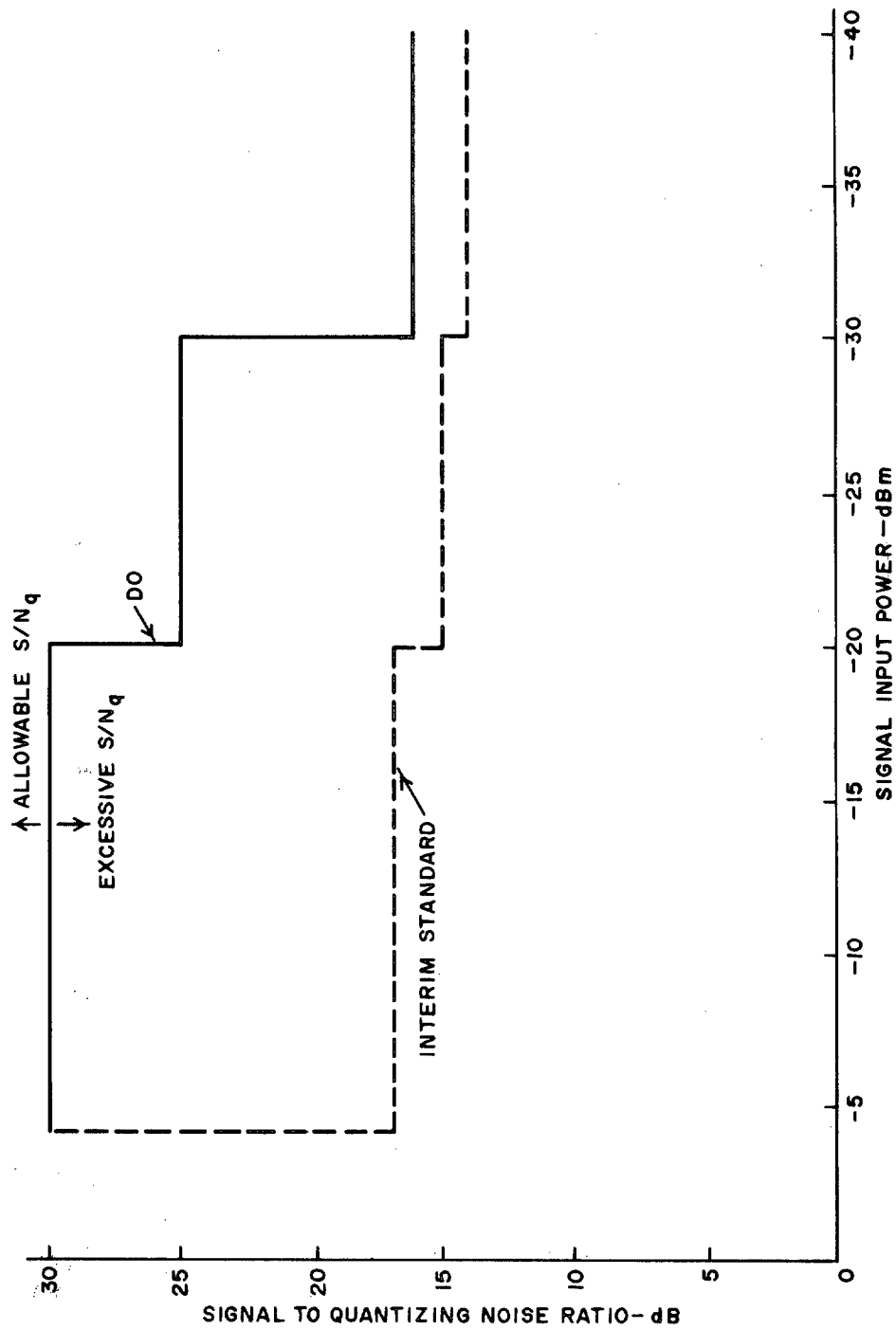
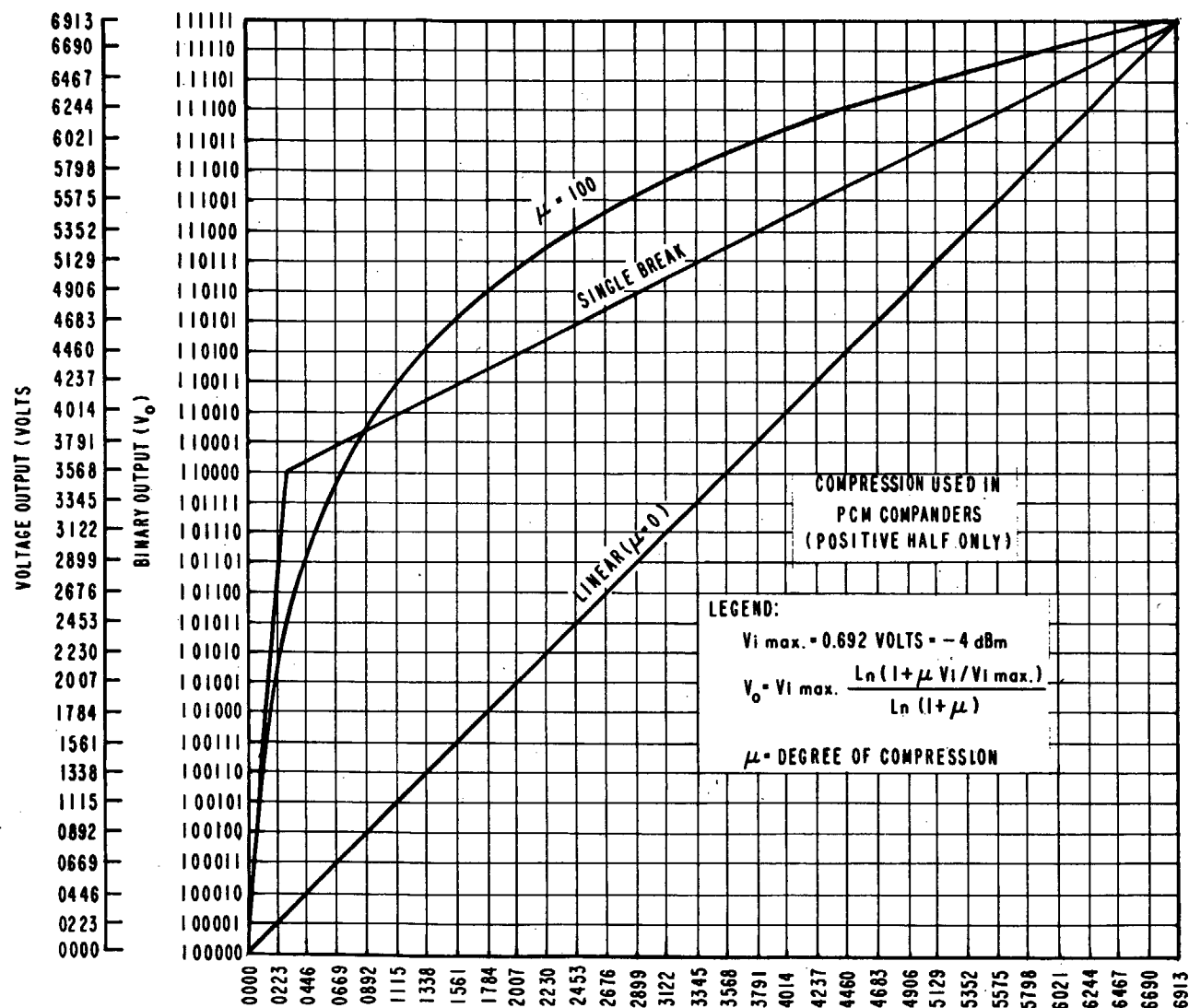


FIGURE 10

ALLOWABLE SIGNAL TO QUANTIZING NOISE RATIO
FOR TACTICAL TIME DIVISION LINKS

501



V_i - ABSOLUTE INSTANTANEOUS INPUT VOLTAGE ACROSS 600 OHMS

FIGURE 11

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characteristic, with breakpoints at levels 15-16 and 47-48. The expander shall have the complementary transfer characteristic. The compression ratio, defined as the initial to average slope, shall be 20 dB plus or minus 1.0 dB. The characteristics of this compander are shown in Figure 11 (single break, positive half only).

The straight line transfer characteristic shown in Figure 11 has been used in a considerable inventory of equipment. It is, however, a compromise used to simplify network design. Considerable reduction in quantizing noise over a wider dynamic range can be achieved if a logarithmic curve is used as shown in Figure 11. It shall be a Design Objective for future equipment design to employ the $\mu = 100$ curve of Figure 11. The $\mu = 100$ curve may be approximated by sufficient linear segments to achieve the S/Nq performance of 4.4.2.1.11.

4.4.2.2.4 Stability of Idle Code. The nominal code level corresponding to zero modulation of a channel shall be midway between levels 31 and 32. The channel to channel variation of code level centering at zero modulation shall not exceed plus or minus 3 levels. The zero modulation code level of any channel shall not vary more than plus or minus 2 levels in a 24 hour period.

4.4.2.2.5 Frame Synchronization. Frame synchronization information shall be added to the PCM output of the multiplexer. This information shall consist of 1 address pulse substituted for the least weight pulse of the last channel of the channel group. The address pulse shall have the same shape and amplitude characteristics as the remaining code pulses.

4.4.2.2.5.1 Address Patterns. Operation with either one of two address patterns shall be provided. One pattern is the binary signal 10101010----- and is referred to as a 4 kHz address, as it repeats after two frames or at half the frame rate of 8 kHz. The other pattern is the binary signal 11001100----- and is referred to as the 2 kHz address as it repeats after four frames or at one-fourth the frame rate of 8 kHz.

4.4.2.2.6 Alarms. Alarms shall be provided which will indicate loss of frame at the receive terminal.

4.4.2.2.7 Order Wire. An order wire, if used, shall occupy the frequency band below 4 kHz. It shall provide a signal-to-noise ratio of 30 dB or better for video signal to noise ratios specified in paragraph 4.4.2.2.8. The maximum peak-to-peak deviation of the radio carrier due to operation of the order wire shall be 18% of the total traffic deviation. A signaling frequency of 1600 Hz shall be employed.

4.4.2.2.8 Signal-to-noise Ratio to Meet Idle Channel Noise Requirements. Idle channel noise requirements (paragraph 4.4.2.1.6) shall be met with a peak-to-peak video-to-RMS noise ratio at the output of the transmission channel as low as 25 dB for binary transmission and 33.5 dB for biternary transmission.

4.4.2.2.9 Signal-to-Noise Ratio to Meet Frame Synchronization Acquisition Time. Frame synchronization acquisition time shall be achieved and maintained with a peak-to-peak video-to-RMS noise ratio at the output of the transmission link as low as 18.5 dB for binary transmission and as low as 24.5 dB for biternary transmission. (Paragraphs 4.4.2.3.3, 4.3, 5.3, 6.3, 7.3).

4.4.2.3 6 Channel Multiplex System.

4.4.2.3.1 Transmission Rate. The transmission rate for the 6 channel system shall be 288 kilobits per second.

4.4.2.3.2 Composition of Channels. In a frame of 125 microseconds comprising 36 pulses, each channel of the 6 channel system except channel 6 shall be allotted 6 consecutive pulses. The first 6 pulses in the frame shall be allotted to channel 1, the second 6 pulses to channel 2, etc. Pulses 31, 32, 33, 34 and 35 shall be allotted to channel 6, and pulse 36 shall be reserved for framing information. The first pulse in each channel shall be the most significant bit of the binary code with subsequent pulses weighted in descending order.

4.4.2.3.3. Frame Synchronization Acquisition Time. The nominal frame-in time for the multiplexer receive circuits in a 6 channel terminal shall be 150 milliseconds or less. As a Design Objective a frame-in time of 10 milliseconds is desirable.

4.4.2.3.4 Frame Synchronization Hold Time. Nominal frame hold time following complete loss of signal shall be at least 1 millisecond. As a Design Objective a frame hold time of 100 milliseconds is desirable.

4.4.2.4 12 Channel Multiplex System.

4.4.2.4.1 Transmission Rate. The transmission rate for the 12 channel system shall be 576 kilobits per second.

4.4.2.4.2 Composition of Channels. In a frame of 125 microseconds comprising 72 pulses, each channel of the 12 channel system except channel 12 shall be allotted 6 consecutive pulses. The first 6 pulses in the frame shall be allotted to channel 1, the second 6 pulses to channel 2, etc. Pulses 67, 68, 69, 70 and 71 shall be allotted to channel 12, and pulse 72 shall be reserved for framing information. The first pulse in each channel shall be the most significant bit of the binary code with subsequent pulses weighted in descending order.

4.4.2.4.3 Frame Synchronization Acquisition Time. The nominal frame in time for the multiplexer receive circuits in a 12 channel terminal shall be 150 milliseconds or less. As a Design Objective a frame-in time of 10 milliseconds is desirable.

4.4.2.4.4 Frame Synchronization Hold Time. Nominal frame hold time following complete loss of signal shall be at least 1 millisecond. As a Design Objective a frame hold time of 100 milliseconds is desirable.

4.4.2.5 24 Channel Multiplex System.

4.4.2.5.1 Transmission Rate. The transmission rate for the 24 channel system shall be 1152 kilobits per second, or two parallel and bit synchronous 576 kilobits per second pulse streams at the multichannel group interface with the transmission unit.

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4.4.2.5.2 Composition of Channels. The 24 channel system shall be made up of two 12 channel systems interleaved on a bit-by-bit basis. Each 12 channel system shall be composed as described in paragraph 4.4.2.4.2.

4.4.2.5.3 Frame Synchronization Acquisition Time. The nominal frame-in time for the 24 channel terminal shall be 300 milliseconds or less. As a Design Objective a frame-in time of 10 milliseconds is desirable.

4.4.2.5.4 Frame Synchronization Hold Time. Nominal frame hold time following complete loss of signal shall be at least 1 millisecond. As a Design Objective a frame hold time of 100 milliseconds is desirable.

4.4.2.6 48 Channel Multiplex System.

4.4.2.6.1 Transmission Rate. The transmission rate for the 48 channel system shall be 2304 kilobits per second.

4.4.2.6.2 Composition of Channels. In a frame of 125 microseconds comprising 288 pulses, each channel of the 48 channel system except channel 48 shall be allotted 6 consecutive pulses. The first 6 pulses in the frame shall be allotted to channel 1, the second 6 pulses to channel 2, etc. Pulses 283, 284, 285, 286 and 287 shall be allotted to channel 48, and pulse 288 shall be reserved for framing information. The first pulse in each channel shall be the most significant bit of the binary code with subsequent pulses weighted in descending order.

4.4.2.6.3 Frame Synchronization Acquisition Time. The nominal frame-in time for the multiplexer receive circuits in a 48 channel terminal shall be 400 milliseconds or less. As a Design Objective a frame-in time of 10 milliseconds is desirable.

4.4.2.6.4 Frame Synchronization Hold Time. Nominal frame hold time following complete loss of signal shall be at least 1 millisecond. As a Design Objective a frame hold time of 100 milliseconds is desirable.

4.4.2.7 96 Channel Multiplex System.

4.4.2.7.1 Transmission Rate. The transmission rate for the 96 channel system shall be 4608 kilobits per second, or two parallel and bit synchronous 2304 kilobit per second pulse streams at the video group interface with the transmission unit.

4.4.2.7.2 Composition of Channels. The 96 channel system frame shall be made up of two 48 channel systems interleaved on a bit-by-bit basis. Each 48 channel system shall be composed as described in paragraph 4.4.2.6.

4.4.2.7.3 Frame Synchronization Acquisition Time. The nominal frame in time for the 96 channel terminal shall be 800 milliseconds or less. As a Design Objective a frame-in time of 10 milliseconds is desirable.

4.4.2.7.4 Frame Synchronization Hold Time. The nominal frame hold time following complete loss of signal shall be at least 1 millisecond.

As a Design Objective a frame-in time of 10 milliseconds is desirable.

4.4.2.8 **Transmission Channels for Multichannel PCM Groups.** The following characteristics apply to the wideband input and output terminals of the transmission facility (see Figure 9). These characteristics are dependent upon the transmission medium employed.

4.4.2.8.1 **Radio Transmission of PCM Groups.** The following standards refer to the interface between the transmission unit if used or the PCM equipment if a transmission unit is not employed as shown in Figure 9 and the radio. Outputs and inputs refer to the transmission unit or the PCM equipment.

4.4.2.8.1.1 **Amplitude vs Frequency Response Characteristic.** The overall baseband frequency response of the radio shall have a gaussian characteristic to at least the 40 dB point. The nominal system 3 dB bandwidth shall be as given in the following table:

VIDEO BANDWIDTH

Number of Channels	225-1000 MHz	4500-5000 MHz, LOS	4400-5000 MHz, Tropo.
6	235 kHz ²	-	-
12	235 kHz ²	210 kHz ²	210 kHz ²
24	235 kHz ¹	240 kHz ¹	420 kHz ²
48	-	950 kHz ²	950 kHz ²
96	-	950 kHz ¹	-

NOTES: 1 - Biternary transmission
 2 - Binary transmission

4.4.2.8.1.2 **Phase Response of Video Channel.** The baseband phase response shall be 40 degrees plus or minus 10 degrees at 300 Hz, relative to 1000 Hz.

4.4.2.8.1.3 **Input and Output Terminating Impedance.** The output circuits shall be designed to drive a load of 51 Ohms plus or minus 10 percent.

4.4.2.8.1.4 **PCM Signal Characteristics.** The characteristics of PCM pulses shall be in accordance with TABLE IV and Figures 12 and 13.

4.4.2.8.2 **6/12/24/48 Channel Cable Transmission.** The following standards refer to the interface between the transmission unit and the cable (see Figure 9). Outputs and inputs refer to the transmission unit.

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Equipment** Interface (See Fig 9)	PCM			TIMING				PCM and Timing
	Rise and Fall Times (nsec)	Peak Amplitude (Volts)		Rise and Fall Times (nsec)	Pulse Widths (nsec)	Peak Amplitude (Volts)		Ripple (Volts)
		Logic "1" Relative to Baseline	Logic "0" Relative to Ground			Logic "1" Relative to Baseline	Logic "0" Relative to Ground	"1" & "0"
A to F, A to D	10	1.7	-2.2	10	80	1.7	-3.0	± 0.3
F to A, D to A	to	to	to	to	to	to	to	
A to B, B to A	120	2.3	-1.8	120	150	2.3	-1.0	

* Timing Pulses Lead PCM Pulses by 0 - 80 nsec
 See Figure 12

** a. D to C: Dipulse, Peak Amplitude 1.6 - 2.0 Volts,
 Pulse Width 180 - 230 nsec

b. C to D: 20 - 50 Millivolts peak-to-peak

c. E to F: 0.5 - 3.0 Volts peak-to-peak

PCM	Pulse	Widths
No. of Channels	Modulation Rate (kHz)	Pulse Widths(μs)
6	288	3.472
12	576	1.736
24	1152	0.868
48	2304	0.434
96	4608	0.217

PCM PULSE CHARACTERISTICS
 TABLE IV

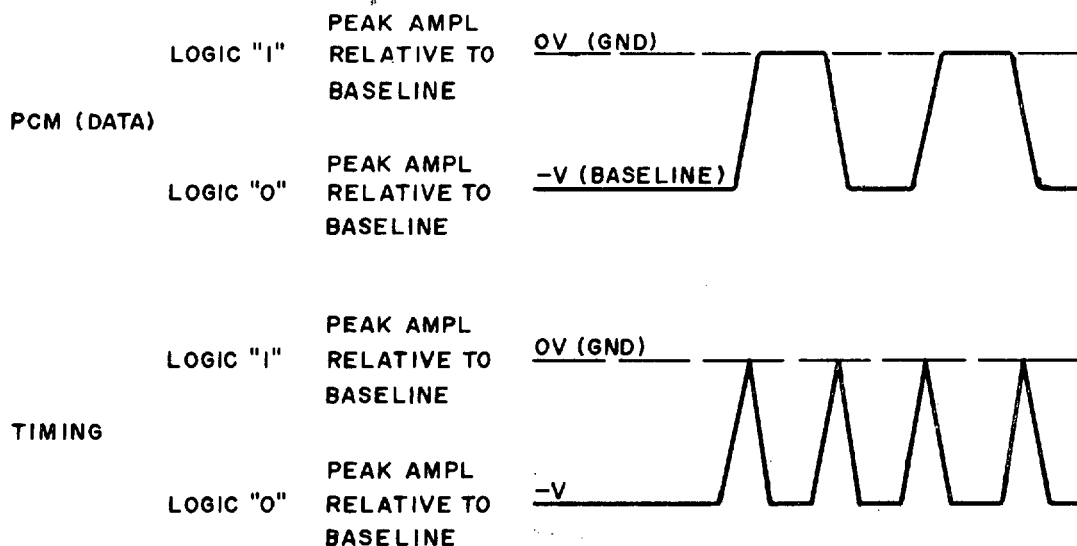


FIGURE PCM AND TIMING PULSES

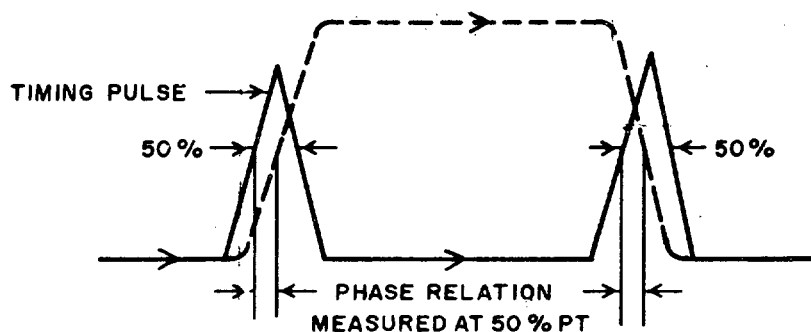


FIGURE PCM - TIMING PHASE RELATIONSHIP

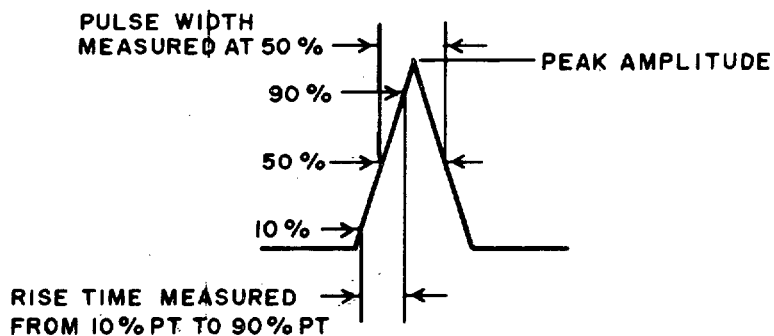
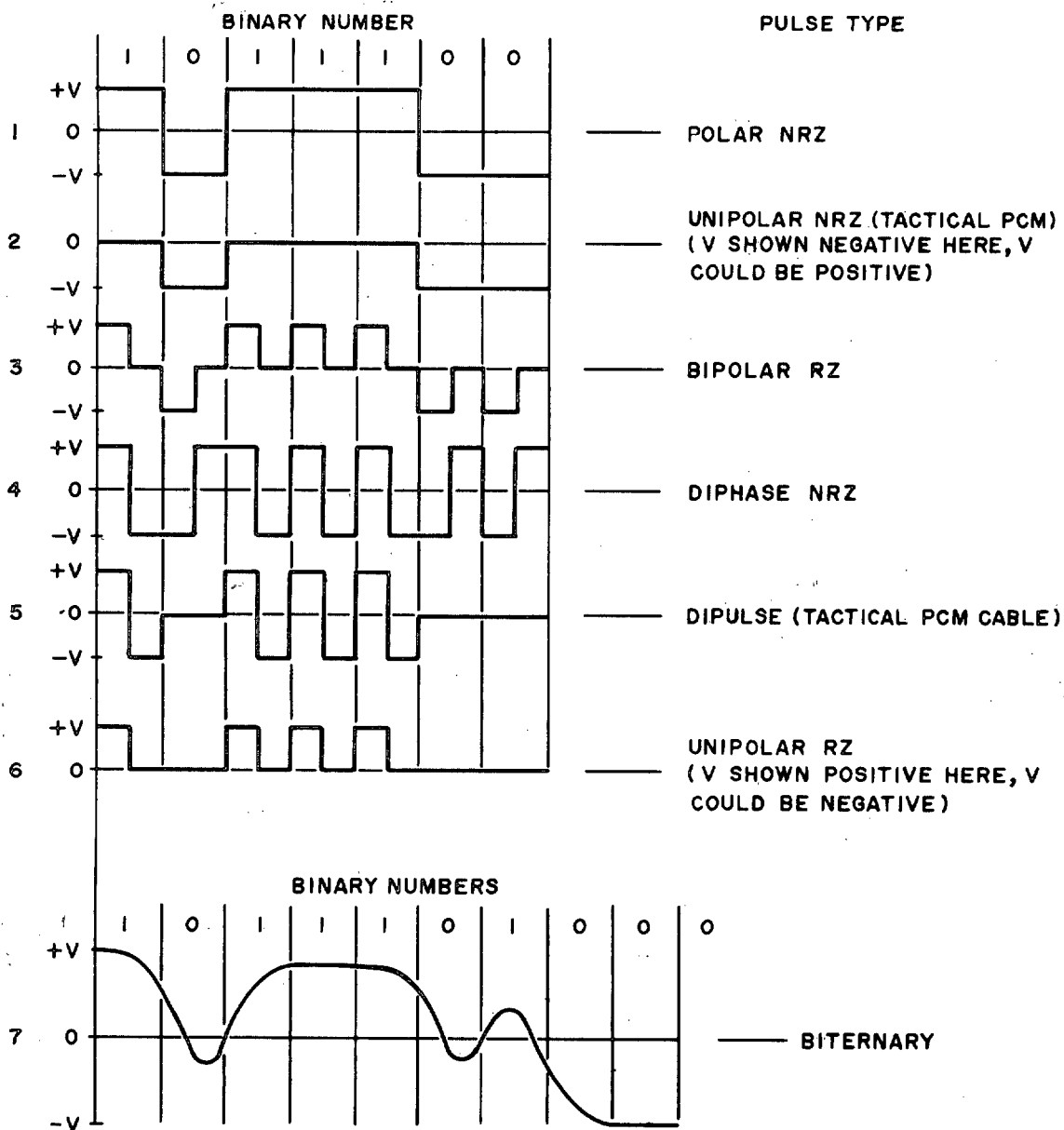


FIGURE 12

PCM - TIMING PULSE WIDTH MEASUREMENTS

**NOTES**

- 1 NUMBERS 1 THROUGH 6 ARE ALL BINARY SIGNALS
- 2 NUMBER 7 IS A TERNARY SIGNAL

FIGURE 13
VARIOUS TYPES OF SIGNALS

4.4.2.8.2.1 Input and Output Terminating Impedance. The output circuits shall be designed to drive a load of 56 Ohms plus or minus 10 percent over the band from 500 kHz to 3 MHz.

4.4.2.8.2.2 PCM Signal Characteristics. Dipulse transmission (see Figure 13) at the 230k kilobit per second rate shall be used for cable transmission. In dipulse transmission a signal is sent only when a "one" is present, no signal is sent for a "zero." The dipulse signal after equalization resembles a complete cycle of a sinusoidal wave, whose duration is equal to one unit interval in binary modulation. The first half cycle is positive in this case. The characteristics of the PCM pulses shall be in accordance with TABLE IV and Figures 12 and 13.

4.4.3 Other Time Division Multiplexing Systems. There is already a considerable inventory of the foregoing 6-bit PCM system in military use. The application of TDM systems for military use is, however, in early stages and is expected to increase rapidly in the future. The foregoing PCM standards are not intended to inhibit advancements in TDM technology for military applications and development of new and improved TIM systems should be pursued. Standards for other TIM systems will be included when available in future issues of this standard.

4.5 Radio Circuits.

4.5.1 General. The radio circuits defined herein are treated from several points of view, i.e., on the basis of functional employment and on a frequency band allocation.

4.5.1.1 Radio Regulations. The use of the frequency spectrum is regulated by international agreements embodied in "Radio Regulations, General Secretariat of the International Telecommunications Union," Geneva, 1959. These regulations are further qualified at the national level through Government (Interdepartment Radio Advisory Committee, IRAC) and military agencies (Joint Chiefs of Staff, JCS, and Military Communication Electronics Board, MCEB).

For normal peacetime use, the choice and performance of equipment, as well as frequencies and emissions of any radio system, shall satisfy the provision of those regulations. Adequate familiarity with the latter is, therefore, required of designers and users of radio systems.

Military frequency planning, including joint function frequency allocation tables, is established as a joint military action area under the MCEB. Final approval of frequency bands, operating modes and equipment characteristics rests with the MCEB.

4.5.1.2 Radio Employment. Radio transmitters and receivers are employed in three general types of tactical radio systems: Single channel, point-to-point systems; single channel, radio net systems; and multichannel systems. The radio system may be used in tactical loop, link or trunk circuits, where the characteristics of the radio equipment meet the requirements for such circuits.

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4.5.1.2.1 Single Channel, Point-to-Point Systems. This general class of tactical radio systems provides for the transmission/reception of voice, teletype, data, facsimile or any other type of signals for which it is suitable. Simplex/duplex operation may be employed.

4.5.1.2.2 Single Channel, Radio Net Systems. This general class of tactical radio systems includes radio equipments used for net operations and transmission/reception of voice, teletype, data, facsimile or any other type of signals for which it is suitable. These systems usually operate on the same frequency for send and receive on a push-to-talk or push-to-type basis.

4.5.1.2.3 Multichannel Systems. This general class of tactical radio systems includes radio equipments used for transmission/reception of multiplexed audio channels. This class is subdivided into two general types; four or less audio channels, for example, high frequency single sideband equipment, and more than four audio channels, radio relay equipment.

4.5.1.3 Interconnection of Wire and Single Channel Radio Equipments. The following requirements apply to radio equipments which are to be connected in tandem to other communication facilities.

4.5.1.3.1 Control Circuits.

4.5.1.3.1.1 Transmitter Input. When the modulation input circuit is closed through an external circuit having a dc resistance within the range of 0 Ohms to at least 1000 Ohms, the transmitter carrier shall be turned on within 1 second of such closure (DO-100 milliseconds). If security equipment is to be used, the transmitter carrier shall be turned on and shall reach 50% of full rated power within 20 milliseconds (DO-4 milliseconds) and full rated power within 50 milliseconds (DO-7 milliseconds) of such closure.

4.5.1.3.1.2 Remote Control Applique. The remote control applique (or radio set incorporating equivalent features) designed to provide a two-wire connection for radio transmitter and receiver operation shall conform to the following requirements.

4.5.1.3.1.2.1 Push-to-Talk Operation (Alternate Transmit-Receive Operation).

4.5.1.3.1.2.1.1 Impedance. When in the transmit or receive condition, the input and output circuits shall be balanced and have the same terminal impedance as that specified for single link or trunk circuits of the same bandwidth. The return loss shall be a minimum of 20 dB against the nominal impedance over the bandwidth of interest.

4.5.1.3.1.2.1.2 Transmitter Control. A DC closure placed across the two-wire line connected to the remote control applique shall provide a dc closure to the transmitter input circuit. The impedance of the two-wire line permitting suitable operation shall include at least the range 0 to 1000 Ohms DC resistance.

4.5.1.3.1.2.1.3 Wire-to-Radio Ringdown Signaling. Upon receiving a 15 to 25 Hz signal of from 15 to 110 Volts rms via the two-wire line, it shall provide a dc closure to the transmitter input circuit and shall furnish a 1600 Hz, +30 Hz, signal of -12 dBm, +2 dB to the modulation input terminals of the radio transmitter.

4.5.1.3.1.2.1.4 Radio-to-Wire Ringdown Signaling. Upon receiving a 1600 Hz, +30 Hz, signal within the range of -15 to +10 dBm from the connected radio receiver, the remote control applique shall provide a 20 Hz +5 Hz signal of not more than 110 Volts rms to the two-wire line. The 20 Hz power source shall be capable of delivering 1.75 W to a 2000 Ohm load.

4.5.1.3.1.2.2 Full-duplex Operation.

4.5.1.3.1.2.2.1 Impedance. The input and output circuits shall be balanced and have the same terminal impedance as that specified for single link or trunk circuits of the same bandwidth. The return loss shall be a minimum of 20 dB against the nominal impedance over the bandwidth of interest.

4.5.1.3.1.2.2.2 Transmitter Control and Common Battery Signaling. When a common battery telephone instrument is connected to the two-wire line terminals of the remote control applique, the dc closure provided by the telephone instrument shall cause the remote control applique to provide a dc closure to the transmitter input circuit, and the remote control applique shall generate and furnish a 1600 Hz +30 Hz signal of -12 dBm, +2 dB to the modulation input terminals of the radio transmitter for a duration of at least 3 seconds but not more than 5 seconds. The impedance of the two-wire line permitting suitable operation shall include, at least, the range 0 to 1000 Ohms dc resistance.

4.5.1.3.1.2.2.3 Wire-to-Radio Transmitter Control Ringdown Signaling. When the remote control applique is connected to a telephone or switchboard which originates ringdown signals, a 15 to 25 Hz signal of from 15 to 110 Volts rms applied to the two-wire line shall provide a dc closure to the transmitter input circuit and the remote control applique shall simultaneously generate and furnish a 1600 Hz signal of -12 dBm +2 dB to the modulation input terminals of the radio transmitter for a duration of at least 3 seconds but not more than 5 seconds.

4.5.1.3.1.2.2.4 Radio-to-Wire Transmitter Control and Common Battery Signaling. When connected to a common battery switchboard line circuit and upon receiving a 1600 Hz, +30 Hz, signal within the range of -15 dBm to +10 dBm from the connected radio receiver, the remote control applique shall provide a dc closure across the two-wire line and shall provide a dc closure to the connected transmitter input circuit.

4.5.1.3.1.2.2.5 Radio-to-Wire Transmitter Control and Ringdown Signaling. When connected to a telephone or switchboard which responds to ringdown signals and upon receiving a 1600 Hz, +30 Hz signal within the range of -15 to +10 dBm from the connected radio receiver, the remote control applique shall provide a 20 Hz +5 Hz signal of not more than 110 Volts rms

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to the two-wire line and shall provide a dc closure to the connected transmitter input circuit. The 20 Hz power source shall be capable of delivering 1.75 W to a 2000 Ohm load.

4.5.1.4 Order Wire (Multichannel Equipment). Communication channels may in some cases be used for order wire purposes. If a separate order wire is provided and brought out at the radio relay terminals and repeaters, the following design practices are recommended:

4.5.1.4.1 Frequency Division Multiplex Systems (FDM). The order wire should be inserted and transmitted at audio frequencies (below 4 kHz). Low pass filters are required to prevent the order wire channel from interfering with the other channels.

4.5.1.4.2 Time Division Multiplex Systems (TDM). The order wire shall be inserted as an amplitude modulation of the TDM pulse train. The video channel provided by the TDM radio relay, as measured at the receiver output, shall have a roll off below 300 Hz and the phase angle at 300 Hz shall be $40^\circ \pm 10^\circ$ with respect to the phase angle at 1000 Hz. The bandwidth of the TDM order wire shall be limited to the band between 300 Hz and 1800 Hz.

4.5.1.4.3 Audio and Baseband Characteristics. Order wires are required to provide the minimum transmission quality for reliable maintenance of the terminals and repeaters. Input and output powers and impedances should in general follow those specified for narrow band, radio net systems. The bandwidths should be reduced to a nominal 300 to 1800 Hz for time division multiplex systems. NOTE: Where order wires are required to be extended over long distances from the radio relay terminal or where a large number of radio relay repeaters are required between terminals the standards given for Time Division Multiplex Systems may not provide satisfactory transmission. In such cases order wires shall be specially engineered to fulfill the maximum system requirements.

4.5.1.4.4 Input Characteristics.

4.5.1.4.4.1 Input Impedance. An input circuit, with a nominal impedance of 150 Ohms over the frequency range of 300 to 3400 Hz, shall be provided. It may be unbalanced to ground. The return loss shall be a minimum of 20 dB against a 150 Ohm resistance over the frequency range. When the audio input is removed from the radio set, the preferred input impedance shall be 600 Ohms, balanced, over the frequency range of 300 Hz to 3400 Hz. The return loss shall be a minimum of 20 dB against the nominal impedance over the frequency range.

4.5.1.4.4.2 Audio Input Signal Power. The nominal input level, when a microphone is connected directly to the radio set, shall be the mean power output of the associated microphone. (For dynamic microphones, the output power is approximately -56 dBm). When the microphone is removed from the radio set, the composite audio input of speech shall have a mean power of -10 dBm, obtained from a distribution with a mean volume of -10 vu with a standard deviation of 5 vu.

4.5.1.4.5 Output Characteristics.

4.5.1.4.5.1 Output Impedance. The output impedance of receivers shall be 600 Ohms, balanced to ground, with a minimum return loss of 20 dB, against a 600 Ohm resistance, over the frequency range.

4.5.1.4.5.2 Output Power. The output power that the receivers deliver to headsets, handsets and/or for purposes of remoting shall be continuously variable from -20 dBm to 0 dBm. The output power that the receivers deliver to loudspeakers, shall be continuously variable from 10 dBm to 30 dBm.

4.5.1.5 Single Channel Radio, Frequency Shift Keying.

4.5.1.5.1 Frequency Shift Facsimile. The radio frequency shift shall be 800 Hz. The white (maximum) signal shall shift the radio carrier frequency by 400 Hz in a lower direction and the black (minimum) signal shall shift the radio carrier frequency by 400 Hz in a higher direction. The shift in frequency shall be linear with respect to the voltage or amplitude of the modulating signal.

4.5.1.5.2 Frequency Shift Keyed Teletypewriter, 850 Hz. The mark frequency shall be 1575 Hz, plus/minus 50 Hz (DO plus/minus 25 Hz). The space frequency shall be 2425 Hz, plus/minus 50 Hz (DO plus/minus 25 Hz).

4.5.1.5.3 Frequency Shift Keyed Teletypewriter, 85 Hz. For speech plus single channel TTY operation, the 2805 Hz center frequency shall be used. For in band frequency diversity operation, the 1445 Hz and the 2805 Hz center frequencies shall be used. For multichannel teletype operation refer to 4.4.1.1.

4.5.1.5.4 Double Frequency Shift Keying. For double frequency shift or similar systems, the following signaling sense shall be employed:

CHANNEL A	S	F_1 or highest frequency
CHANNEL B	S	
CHANNEL A	S	F_2
CHANNEL B	M	
CHANNEL A	M	F_3
CHANNEL B	S	
CHANNEL A	M	F_4 or lowest frequency
CHANNEL B	M	

4.5.1.6 Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC) Requirements.

4.5.1.6.1 Equipment. Any item including subassemblies and parts, serving functionally in electromagnetically generating, transmitting, conveying, acquiring, receiving, storing, processing or utilizing

information in the broadest sense shall meet the appropriate requirements of MIL-STD-461 except as specified herein.

4.5.1.6.2 Subsystems and Systems. Systems and associated subsystems shall be designed to achieve intra and inter system electromagnetic compatibility. There shall be neither unacceptable responses nor malfunctions in any item of the system or subsystem beyond the tolerances established by the individual material specifications.

4.5.2 Extremely Low Frequency Band (Below 300 Hz). Formulation deferred pending establishment of a need for technical standards.

4.5.3 Infra Low Frequency Band (300 Hz - 3000 Hz). Formulation deferred pending establishment of a need for technical standards.

4.5.4 Very Low Frequency Band. VLF (3 kHz - 30 kHz). The very low frequency (VLF) band is employed primarily for broadcast in the Maritime Mobile Service and for limited long haul communications of a tactical basis.

4.5.4.1 Frequency Coverage. Equipment shall be capable of having its carrier tuned and aligned, over the frequency range of the equipment, in steps of 10 Hz at integral 10 Hz frequency increments.

4.5.4.2 Frequency Tolerance.

4.5.4.2.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^9 of any designated frequency.

4.5.4.2.2 Frequency Stability. The frequency stability of the equipment, with respect to the initial frequency, shall be within 1 part in 10^8 per day, 5 parts in 10^8 during the first 30 days after calibration. The stability shall not be degraded by more than 4 parts in 10^8 per each 30 day period thereafter.

4.5.4.2.3 Phase Jitter. The phase difference averaged over any two successive 10 millisecond periods (13.33 millisecond periods may also be used) shall not exceed 20 degrees for noncoherent systems and 3 degrees for coherent systems when measured between the signal input and output terminals of a transmitter or a receiver. Measurements shall be performed for at least 100 sample time periods.

4.5.4.3 Carrier Noise Level. Hum, ripple or other extraneous noise on the carrier shall be at least 40 dB below the unmodulated or CW carrier level.

4.5.4.4 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.4.5 DC Digital Interface Characteristics. The information bandwidth is limited in this frequency band. The transmissions/receptions are generally FSK or CW. The radio equipment shall interface with the DC digital transmitter/receiver in accordance with the requirements of the Standard Interface (Low Level), paragraph 7.2.1.

4.5.4.6 Modulation. The transmissions are generally FSK (binary narrow band frequency modulation (NBFM)) where data may correlate with either frequency state or RF signal phase, such that the waveform is always continuous, although CW (amplitude modulation) may be employed. It is anticipated that analog NBFM techniques will be used in future communication systems.

4.5.4.6.1 FSK Modulation Index. The modulation index shall be 1.0 for phase coherent transmission (0.5 Design Objective).

4.5.4.6.2 FSK Response vs Frequency. The frequency response of the radio set (back to back) shall be plus or minus 1.5 dB over the FSK modulation range.

4.5.4.6.3 FSK Frequency Accuracy. The FSK frequency accuracy for a phase coherent transmission shall correspond to the frequency tolerance requirements of 4.5.4.2 and for noncoherent transmission shall not exceed +10%.

4.5.4.6.4 Modulation Rate. The standard modulation rate shall be 50 baud. (100, 200 and 800 baud shall be a Design Objective.)

4.5.4.7 Necessary Bandwidth. The necessary bandwidth in Hz for FSK transmission shall be twice the transmission rate in bauds for a modulation index of 1.0 and equal to the transmission rate in bauds for a modulation index of 0.5.

4.5.5 Low Frequency Band (30 kHz - 300 kHz). The low frequency (LF) band is employed for a limited amount of tactical communication services. This usage is restricted by the limited information bandwidth inherent to this frequency band.

It is common for military LF communication receivers to cover a portion of the LF band as well as to cover a portion of the VLF band. The military LF communication transmitter generally covers a narrower range of frequencies than does the LF communication receiver.

4.5.5.1 Frequency Coverage. Equipment shall be capable of having its carrier tuned and aligned, over the frequency range of the equipment, in steps of 10 Hz at integral 10 Hz frequency increments.

4.5.5.2 Frequency Tolerance.

4.5.5.2.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^9 of any designated frequency.

4.5.5.2.2 Frequency Stability. The frequency stability of the equipment, with respect to the initial frequency, shall be within 1 part in 10^8 per day, 5 parts in 10^8 during the first 30 days after calibration. The stability shall not be degraded by more than 4 parts in 10^8 per each 30 day period thereafter.

4.5.5.2.3 Phase Jitter. The phase differences averaged over any two successive 10 millisecond periods (13.33 millisecond period may also be used) shall not exceed 20 degrees for noncoherent systems and 3 degrees for coherent systems when measured between the signal input and output terminals of a transmitter or a receiver. Measurements shall be performed for at least 100 sample periods.

4.5.5.3 Carrier Noise Level. Hum, ripple or other extraneous noise on the carrier shall be at least 40 dB (50 dB DO) below the unmodulated or CW carrier level.

4.5.5.4 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.5.5 DC Digital Interface Characteristics. The information bandwidth is limited in this frequency band. The transmissions/receptions are generally FSK or CW. The radio equipment shall interface with the DC digital transmitter/receiver in accordance with the requirements of the standard interface (low level), paragraph 7.2.1.

4.5.5.6 Modulation. The single channel transmissions are generally FSK (binary narrow band frequency modulation (NBFM)) where data may correlate with either frequency state or RF signal phase such that the waveform is always continuous, although CW (amplitude modulation) may be employed. Up to eight FSK channels may be multiplexed onto the carrier, using single sideband (SSB) techniques, at the high end of the frequency band. The current type of multiplexing is Frequency Division Multiplexing (FDM). It is anticipated that analog NBFM techniques will be used in future communication systems.

4.5.5.6.1 FSK Modulation Index. The modulation index shall be 1.0 (0.5 DO) for phase coherent transmission.

4.5.5.6.2 FSK Modulation Deviation. The modulation deviation shall be from plus or minus 10 Hz to plus or minus 200 Hz for noncoherent modems.

4.5.5.6.3 FSK Response vs Frequency. The frequency response of the radio set shall be plus or minus 1.5 dB over the FSK modulation range.

4.5.5.6.4 Modulation Rate. The equipment shall have the capability of modulation rates of 50 and 75 baud per channel. (100, 200 and 800 baud Design Objective.)

4.5.5.7 Necessary Bandwidth. The necessary bandwidth for single channel IF transmission shall be 500 Hz, maximum. The necessary bandwidth

for 8 channel SSB transmissions shall be 1500 Hz, maximum.

4.5.6 Medium Frequency Band (0.3 MHz - 3 MHz). The medium frequency (MF) band is primarily utilized for broadcasting purposes. However, certain segments of this band are used in military communication services. Assigned bandwidths, in accordance with Appendix A, may be up to 12 kHz.

It is common for military high frequency (HF) communication equipment to cover the 2 MHz to 3 MHz portion of the MF band. In this event, the performance standards of the high frequency band shall apply to the extended frequency coverage.

4.5.6.1 High-Low Performance Equipment. High performance MF equipment can be utilized in radio loops or in radio nets, where the characteristics of the equipment meet the communication circuit requirements. Low performance MF equipment may be employed in radio loop circuits or in those tactical radio communication facilities which are self supporting. The low performance equipment must be able to operate with high performance equipment in a radio loop circuit or radio net; although the channel quality of the communication circuit may be degraded. It is a Design Objective that all multichannel MF equipment shall meet the high performance requirements.

4.5.6.2 Frequency Coverage. Equipments shall be capable of having its carrier tuned and aligned over the frequency range of 0.3 MHz to 2 MHz, or its operating frequency range, in steps not greater than 10 Hz at integral 10 Hz frequency increments. Equipments shall be capable of having its carrier tuned and aligned over the frequency range of 2 MHz to 3 MHz in steps of 100 Hz at integral 100 Hz frequency increments for high performance equipment. Steps of 1 kHz shall be optional in lieu of 100 Hz for low performance tactical equipments where size and weight constraints make the 100 Hz steps impractical.

4.5.6.3 Frequency Tolerance.

4.5.6.3.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^8 for high performance equipment and 5 parts in 10^7 for low performance equipment of any designated frequency.

4.5.6.3.2 Frequency Stability.

4.5.6.3.2.1 High Performance Equipment. The frequency stability of the high performance equipment, with respect to the initial frequency, shall be within 1 part in 10^7 per day, 5 parts in 10^7 during the first 30 days after calibration. The stability shall not be degraded by more than 4 parts in 10^8 per each 30 day period thereafter.

4.5.6.3.2.2 Low Performance Equipment. The frequency stability of the low performance equipment, with respect to the initial frequency, shall be within 5 parts in 10^6 per day, 1 part in 10^5 during the first 30 days after calibration. The stability shall not be degraded by more than 4 parts in

10^6 per each 30 day period thereafter.

4.5.6.3.3 Phase Jitter. The phase difference averaged over any two successive 10 millisecond periods (13.33 millisecond periods may also be used) shall not exceed 5 degrees (DO - 2.5 degrees) when measured between the signal input and output terminals of a transmitter or a receiver. Measurements shall be performed for at least 100 sample time periods.

4.5.6.4 Electromagnetic Compatibility requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.6.5 Microphone/Headset Circuit. The input and output characteristics of the microphone and headset circuit, when required, shall be in accordance with the requirements of paragraphs 4.5.1.4.4 and 4.5.1.4.5.

4.5.6.6 Audio Input/Output Impedance. The audio input and output impedances of the MF equipment shall be nominally 600 Ohms balanced to ground with a minimum return loss of 26 dB (20 dB for low performance equipment (DO - 26 dB)) against a 600 Ohm resistance over the frequency range of 300 Hz to 3000 Hz on nominal 3 kHz channels. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level.

4.5.6.7 Audio Input Signal Power. The test tone input to each audio channel shall be -10 dBm. The composite audio input of speech to each audio channel shall have a mean power of -10 dBm, obtained from a distribution with a mean volume of -10 vu with a standard deviation of 5 vu. The multitone power, from multichannel carrier telegraph, fed to each audio channel shall be -10 dBm. The audio input of each tone shall be equal to -10 dBm -10 log t, where t is the number of tones.

4.5.6.8 Audio Output Signal Power. Refer to paragraph 4.5.7.8.

4.5.6.9 RF Output/Input Impedances. The radio frequency (RF) output and input impedance for the high performance MF radio set shall be a nominal 50 Ohms, unbalanced (optional for low performance MF radio set).

4.5.6.10 Modulation.

4.5.6.10.1 Amplitude Modulation.

4.5.6.10.1.1 Carrier Noise Level. The detected output voltage obtained from an unmodulated carrier shall be at least 50 dB (60 dB DO) below the detected output voltage obtained from the carrier 90% modulated with a 1000 Hz tone. Low performance equipment shall be at least 40 dB (50 dB DO).

4.5.6.10.1.2 Modulation. When a zero dBm audio signal at any frequency between 300 Hz and 3000 Hz is applied to the audio input circuit, the RF carrier output at rated output level, shall be modulated at least 95%.

4.5.6.10.1.3 Harmonic Distortion. With any audio input frequency between 300 Hz and 3000 Hz, and with the audio input adjusted for 90% modulation, the total harmonic distortion at rated power output (RF - transmitter, Audio - receiver) shall not exceed -25 dB (-20 dB for low performance equipment) with reference to a detected output voltage obtained from the carrier, 90% modulated with a 1000 Hz tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.6.10.1.4 Intermodulation Distortion. With any two equal level audio input frequencies between 300 Hz and 3000 Hz, and with the audio input adjusted for 90% modulation, the intermodulation distortion products at rated power output (RF - Transmitter, Audio - receiver) shall not exceed -38 dB (-30 dB for low performance equipment), with reference to a detected output voltage obtained from the carrier, 90% modulated with a 1000 Hz tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.6.10.1.5 Attenuation vs Frequency (Audio). The nominal 3 dB points for the radio channel shall be at 300 Hz and 3000 Hz. For all frequencies between 325 Hz and 1000 Hz, the attenuation shall be within the limits of -1 dB and +2 dB, with respect to the attenuation at 1000 Hz. For all frequencies between 1000 Hz and 2950 Hz, the attenuation shall be within the limits of + 1.5 dB, with respect to the attenuation at 1000 Hz. It shall be a Design Objective that the attenuation be within + 1 dB for all frequencies between 325 Hz and 2950 Hz, with respect to the attenuation at 1000 Hz.

4.5.6.10.2 Single Sideband.

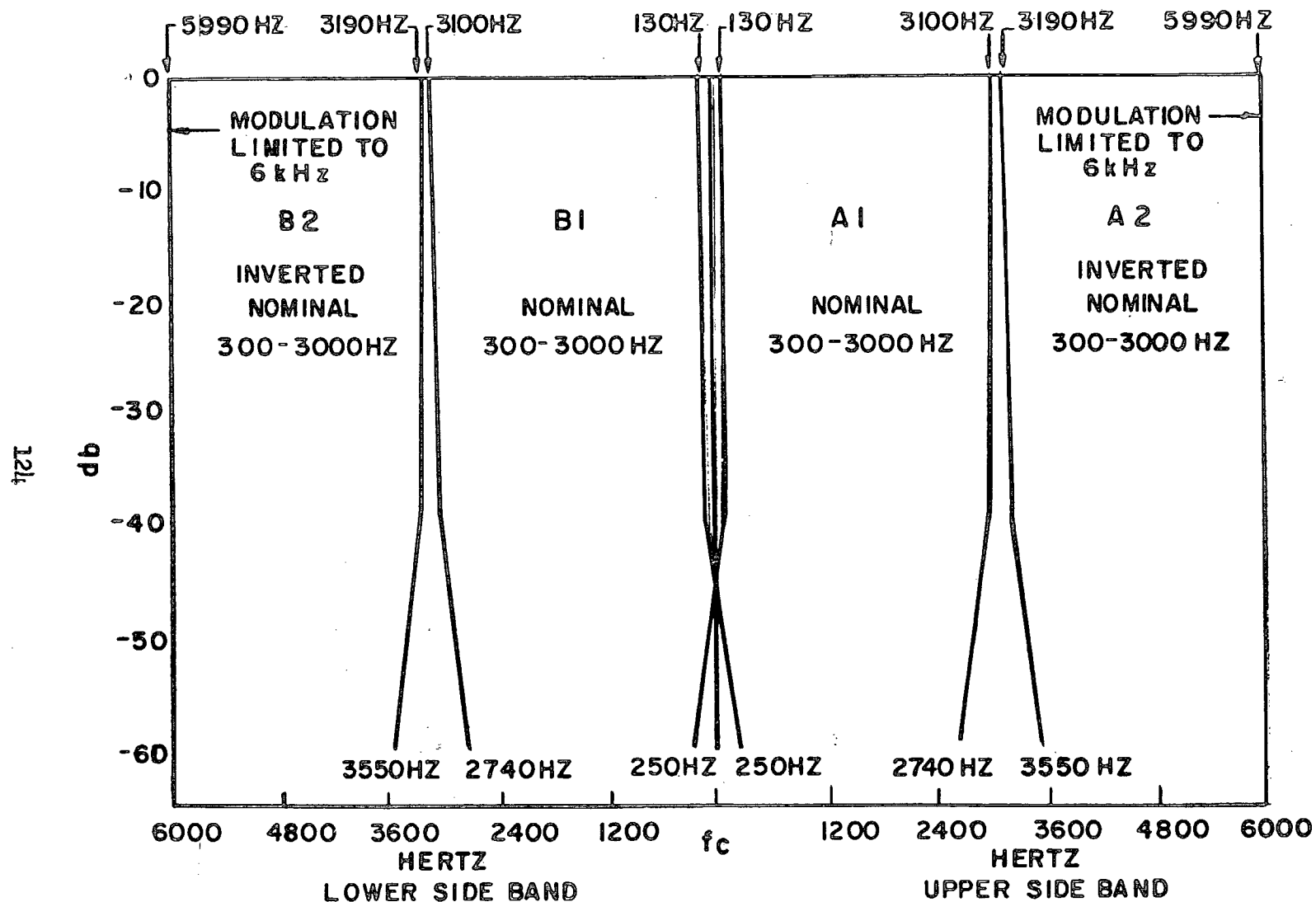
4.5.6.10.2.1 Single Sideband Emissions. The designation of single sideband (SSB) emissions and bandwidth characteristics shall be in accordance with Appendix A. The displayed frequency shall be that of the carrier, whether suppressed or not.

4.5.6.10.2.2 Operating Modes.

4.5.6.10.2.2.1 High Performance Equipment. The equipment may accommodate up to a maximum of four nominal 3 kHz channels by using multiplexing techniques. Figure 14 shows four channel operation that has equal bandwidths and is compatible with the phase delay and amplitude characteristics specified for high performance equipment.

4.5.6.10.2.2.2 Low Performance Equipment. Low performance equipment shall have the capability of single channel, upper sideband operation. The equipment may also have the capability of both upper and lower sideband operation. (With the option of simultaneous operation.)

4.5.6.10.2.2.3 Carrier Level Control, SSB. The carrier level control shall provide for a minimum selection of the following levels of the re-inserted carrier: + 1 dB, 10 dB, 20 dB; and maximum suppression with reference to the output level of a single tone modulating the equipment to rated noise power (pn) output.



NOTE: For Voice Operation, A Low Pass Filter (2740 HZ, 40db DOWN) IS REQUIRED.

FOUR CHANNEL OPERATION

FIGURE 14.

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4.5.6.10.2.2.3.1 Reduced Carrier Level (A3A, for example). The reduced carrier level shall be either 10 or 20 dB (selectable) below the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.6.10.2.2.3.2 Suppressed Carrier Level (A3J, for example). The suppressed carrier level shall be at least 50 dB (60 dB D0) for high performance equipment and at least 40 dB (50 dB D0) for low performance equipment below the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.6.10.2.2.3.3 Full Carrier Level (A3H, for example). The full carrier level shall be approximately plus 1 dB above a single tone modulating the equipment to rated, noise power (pn) output.

4.5.6.10.2.2.3.4 AM Compatibility. The capability of the equipment for compatible AM operation is required for high performance equipment (optional for low performance equipment).

4.5.6.10.2.2.4 Independent Sideband. Equipment, that has the capability of simultaneous independent sideband operation, shall be required for all high performance equipment.

4.5.6.10.2.3 In Band Distortion.

4.5.6.10.2.3.1 High Performance Equipment. The noise power ratio (NPR (SSB)) shall be at least 40 dB (43 dB D0) when the equipment is loaded to rated noise power (pn) output with the specified noise signal (s). (See paragraph 9.3).

4.5.6.10.2.3.2 Low Performance Equipment. The noise power ratio (NPR (SSB)) shall be at least 30 dB, when the equipment is loaded to rated noise power (pn) output with the specified noise signal(s). (See paragraph 9.3)

4.5.6.10.2.4 Out-of-Band Spectral Emissions. When the transmitter is loaded to rated noise power (pn) output with the specified noise signal(s) (see paragraph 9.3) in each audio channel, the power spectral density of the out-of-band emission shall not exceed the level established by straight lines connecting the points given in the following table:

Frequency Measurement	Attenuation Below In-band Power Density	
	Standard	D0
High Performance Equipment: (See Figure 15)		
$f_m = f_c - \frac{(1.0 B)}{2} + 500 \text{ Hz}$	40 dB	43 dB
$f_m = f_c + 1.0 B$	45 dB	48 dB
$f_m = f_c + 2.5 B$	60 dB	65 dB

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Frequency Measurement		Attenuation Below In-band Power Density	
High Performance Equipment: (See Figure 15)		Standard	D0
or	$f_c + 4.0 B < f_m < 1.05 f_c$	70 dB	80 dB
	$.95 f_c > f_m > f_c - 4.0 B$		
Low Performance Equipment: (See Figure 16)			
	$f_m = f_c \pm \frac{(1.0 B + 500 \text{ Hz})}{2}$	30 dB	30 dB
	$f_m = f_c \pm 1.0 B$	35 dB	35 dB
	$f_m = f_c \pm 2.5 b$	45 dB	50 dB
or	$f_c + 4.0B < f_m < 1.05 f_c$	50 dB	60 dB
	$0.95 f_c > f_m > f_c - 4.0 B$		

where

f_m = frequency of measurement

f_c = center frequency of necessary bandwidths

B = necessary bandwidth

4.5.6.10.2.5 Discrete Frequency Spurious Emissions. When the transmitter is loaded with a single tone in each audio channel to rated noise power (pn), output, the in-band and out-of-band ($f_0 \pm 5\% f_0$) discrete frequency spurious emissions shall be at least 80 dB below the reference single tone output for high performance equipment, and at least 60 dB below the reference single tone output for low performance equipment. NOTE: MIL-STD-461 specified the out-of-band emissions for bandwidths greater than $f_0 \pm 5\%$.

4.5.6.10.2.6 Amplitude - Frequency Response (Audio).

4.5.6.10.2.6.1 High Performance Equipment (Transmitter and Receiver, Respectively). The maximum variation between 250 Hz and 3100 Hz shall be 1 dB. The attenuation shall be not less than 40 dB at 50 Hz and 3250 Hz. The attenuation shall be not less than 60 dB at 3550 Hz and higher frequencies and at $f_0 - 250$ Hz and lower frequencies. See Figure 17.

4.5.6.10.2.6.2 Low Performance Equipment (Transmitter and Receiver, Respectively). The maximum variation between 530 Hz and 3050 Hz shall be

2 dB and from 350 Hz to 530 Hz shall be 3 dB. The attenuation shall be at least 30 dB from 0 Hz (f_0) to $f_0 - 300$ Hz. The attenuation shall not be less than 60 dB at 4000 Hz and higher frequencies and at $f_0 - 300$ Hz and lower frequencies. See Figure 18.

4.5.6.10.2.6.3 One/Two Channel Equipment (Digital). The maximum variation between 300 Hz and 3050 Hz shall be 1.5 dB and from 3050 Hz to 3200 Hz shall be 3 dB. The attenuation shall be at least 20 dB from (f_0) to $f_0 - 415$ Hz. The attenuation shall be at least 40 dB from $f_0 - 415$ Hz to $f_0 - 1500$ Hz and at least 60 dB below $f_0 - 1500$ Hz. The attenuation shall be at least 30 dB from 4000 Hz to 5000 Hz and at least 60 dB above 5000 Hz. See Figure 20.

4.5.6.10.2.7 Envelope Delay Distortion.

4.5.6.10.2.7.1 High Performance Equipment (Transmitter and Receiver, Respectively). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 17.)

a. Maximum envelope delay distortion of 500 microseconds from 300 Hz to 3020 Hz.

b. Maximum envelope delay distortion of 100 microseconds for any 100 Hz frequency increment between 300 Hz to 3100 Hz.

c. The absolute delay is not to exceed 8 milliseconds (DO - 4 milliseconds) over the frequency range of 300 Hz to 3020 Hz (relative to the carrier frequency).

4.5.6.10.2.7.2 Low Performance Equipment (Transmitter and Receiver, Respectively). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 18.)

a. The envelope delay distortion, with reference to the delay at 825 Hz, shall not vary more than minus 300 microseconds to plus 500 microseconds from 825 Hz to 2750 Hz.

b. Maximum envelope delay distortion of 150 microseconds for any 100 Hz frequency increment between 750 Hz to 2750 Hz.

c. Maximum envelope delay distortion of 250 microseconds from 2750 Hz to 2850 Hz.

d. Maximum envelope delay distortion of 350 microseconds from 600 Hz to 750 Hz.

e. The absolute delay is not to exceed 6 milliseconds (DO - 2 milliseconds) over the frequency range of 600 Hz to 2750 Hz.

4.5.6.10.2.7.3 One/Two Channel Equipment (Digital). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 20.)

HIGH PERFORMANCE EQUIPMENT:

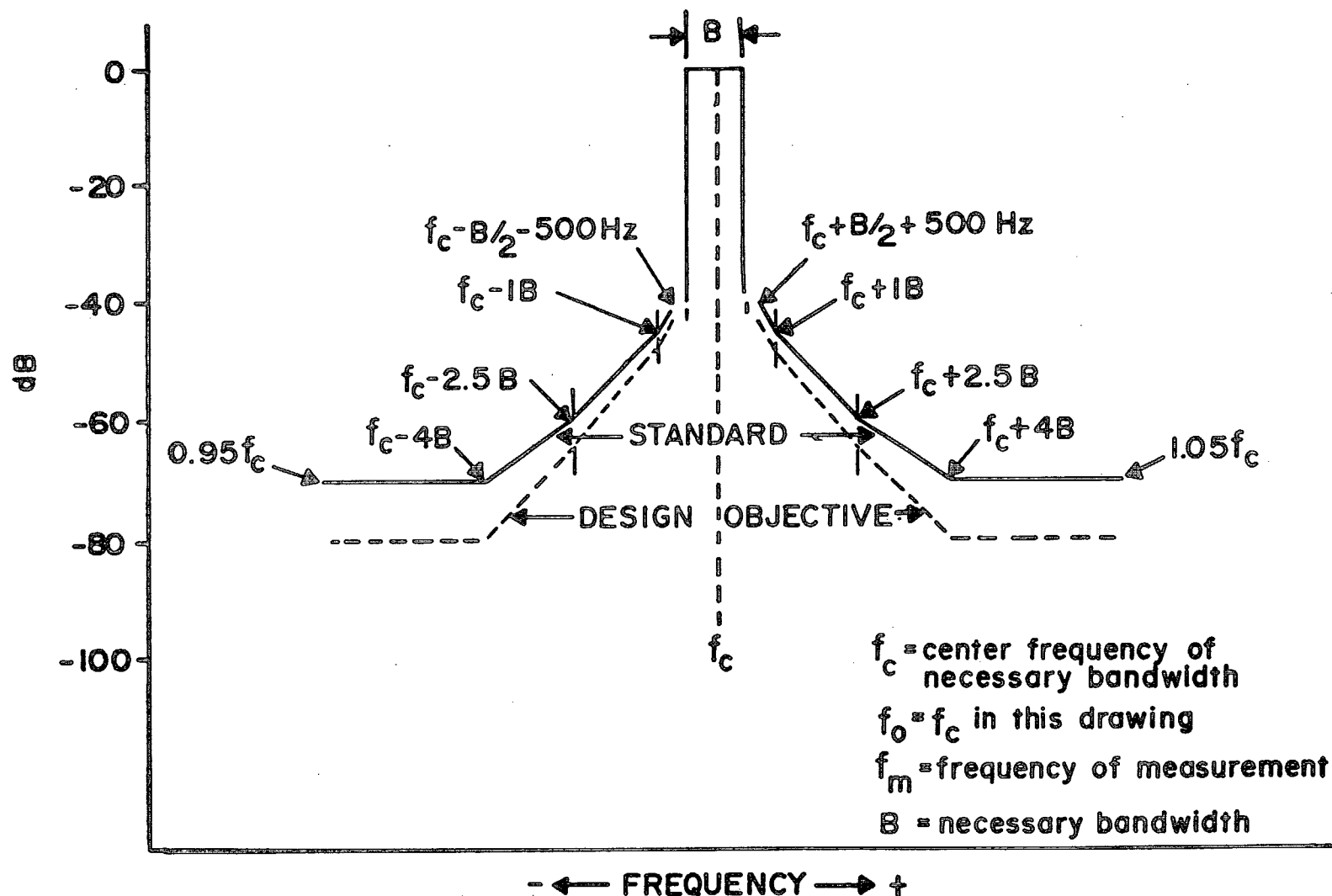


FIG. 15 OUT-OF-BAND POWER SPECTRAL DENSITY LIMITS

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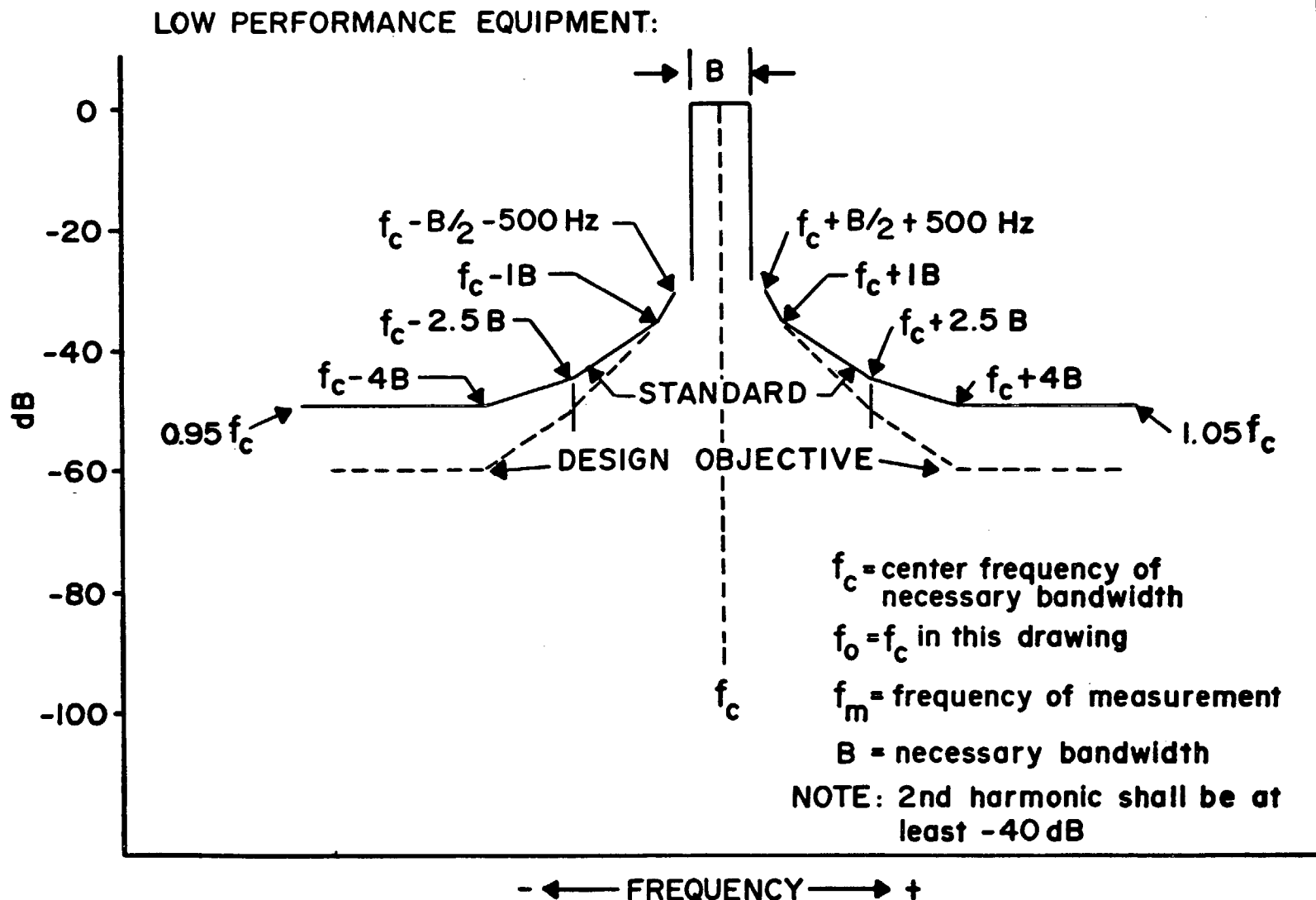
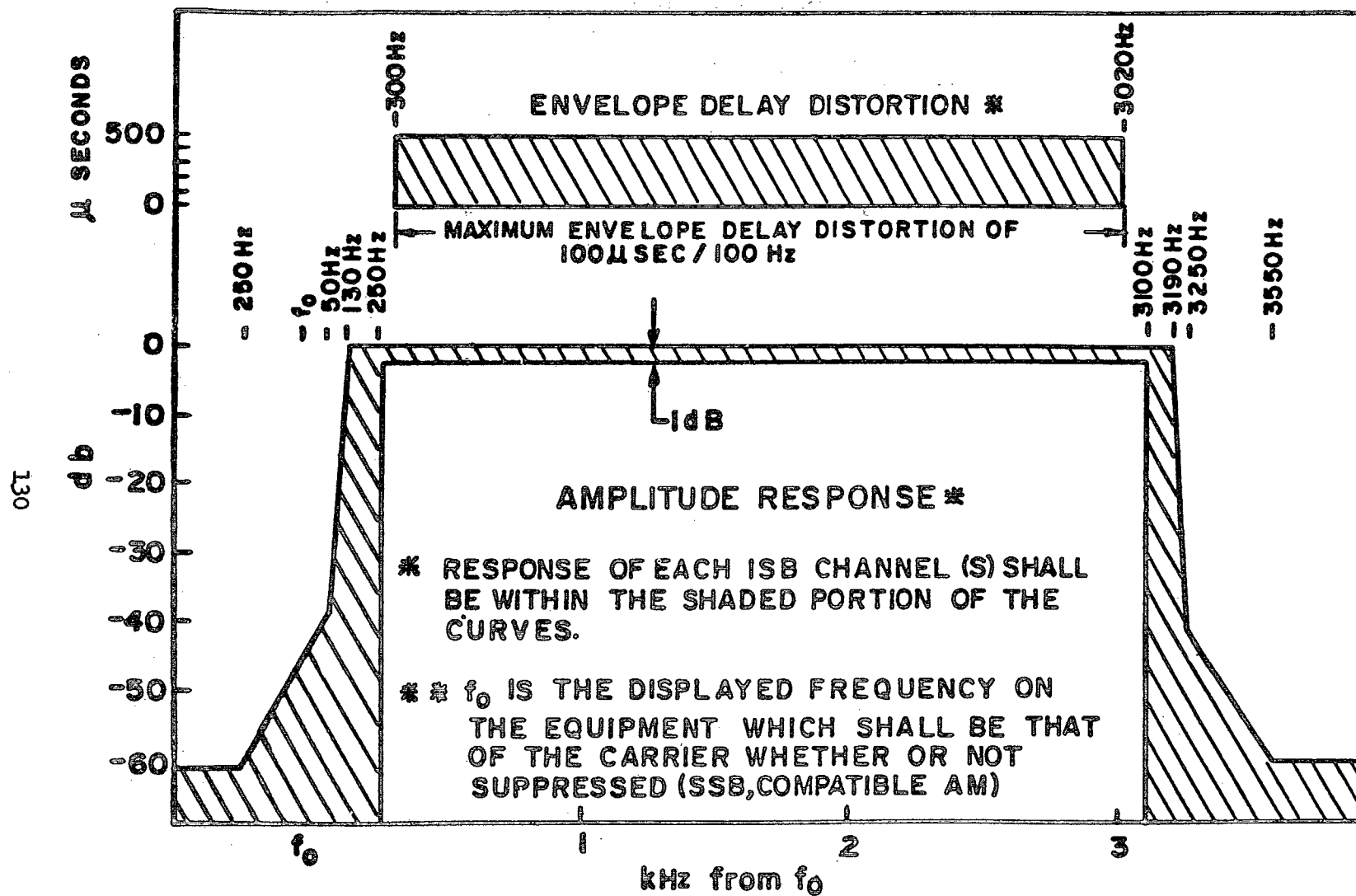


FIG.16 OUT-OF - BAND POWER SPECTRAL DENSITY LIMITS

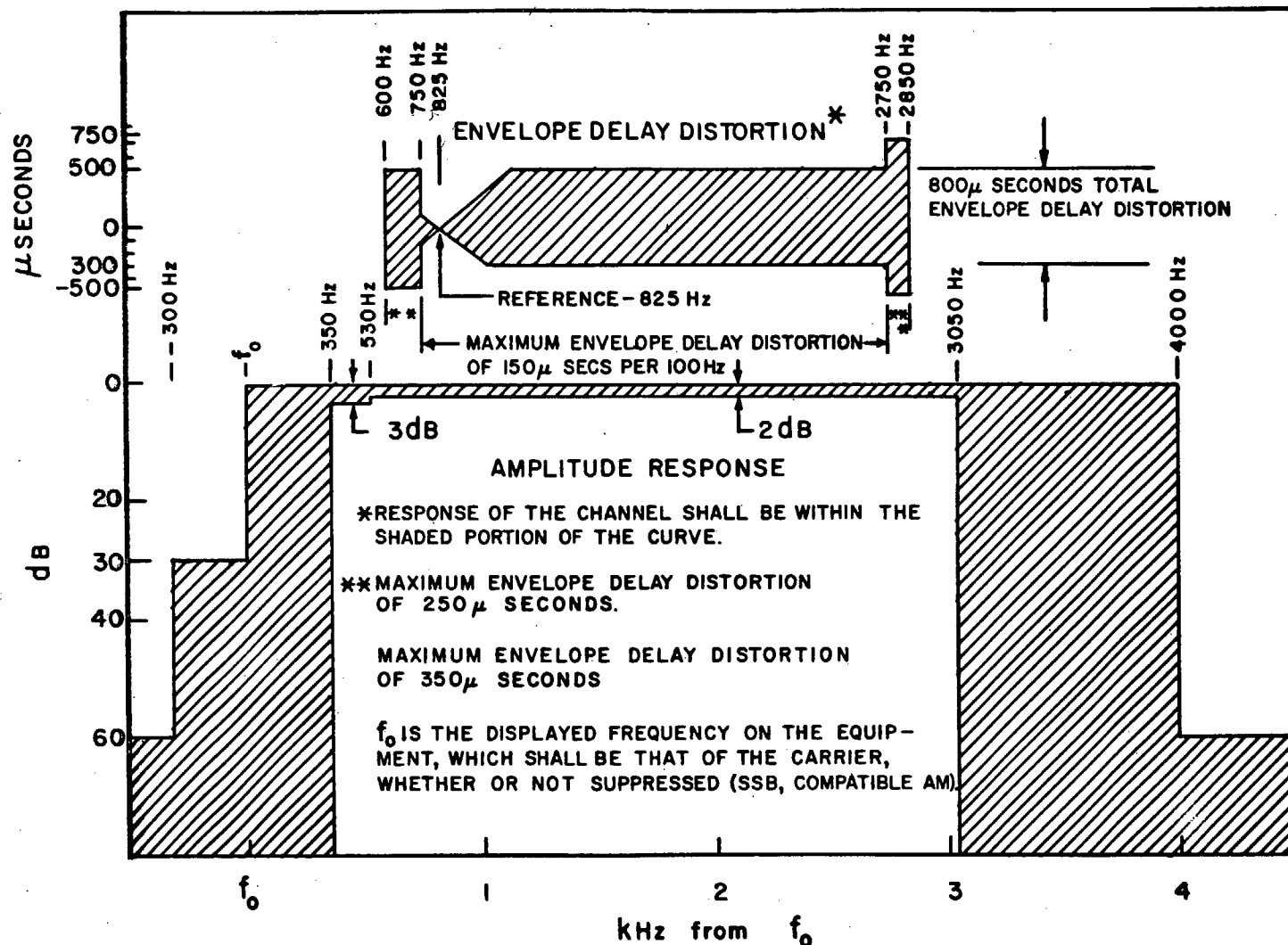
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HIGH PERFORMANCE CHARACTERISTICS

FIGURE 17

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LOW PERFORMANCE CHARACTERISTICS

FIGURE 18

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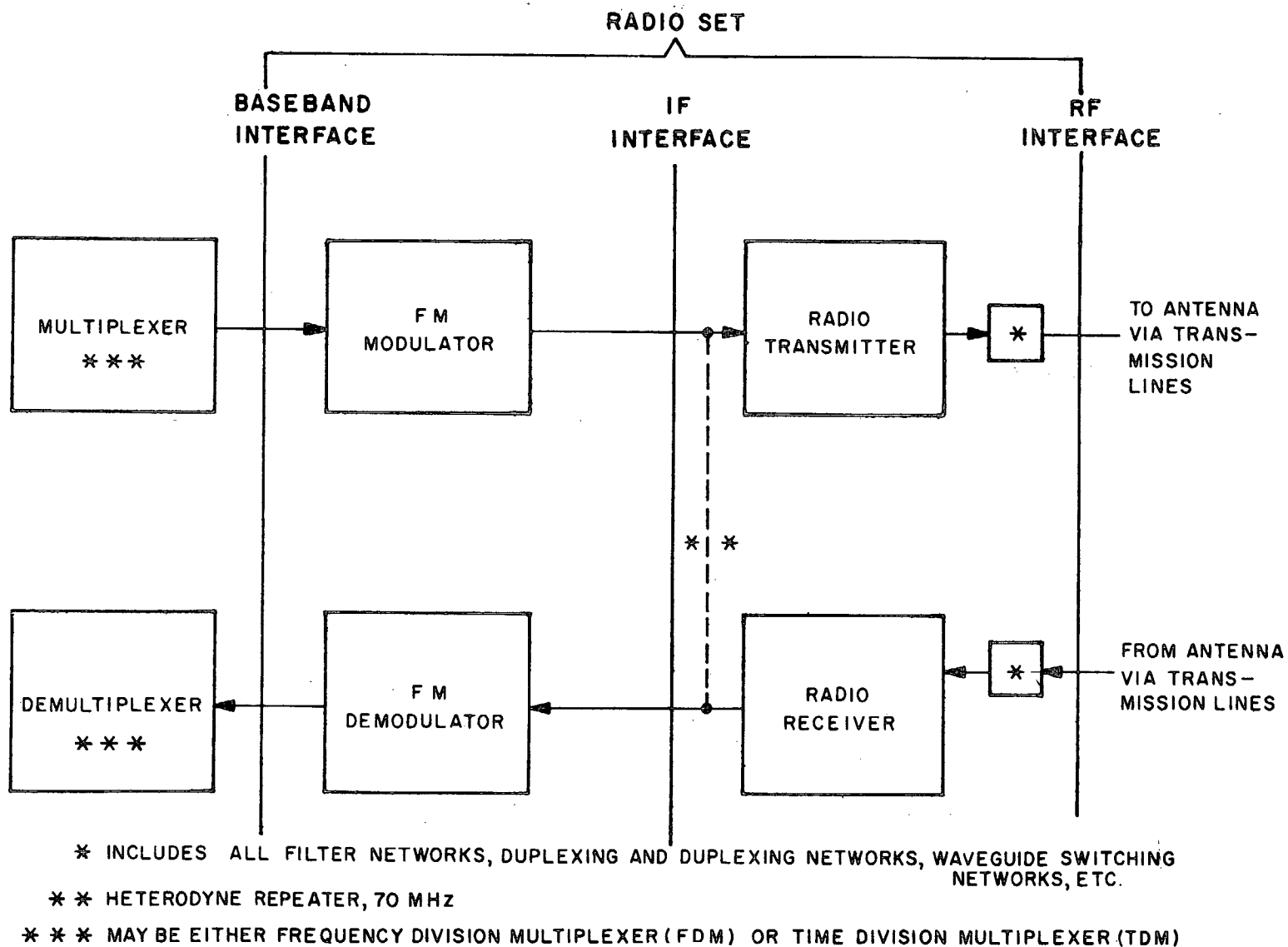


FIGURE 19: RADIO RELAY SYSTEMS

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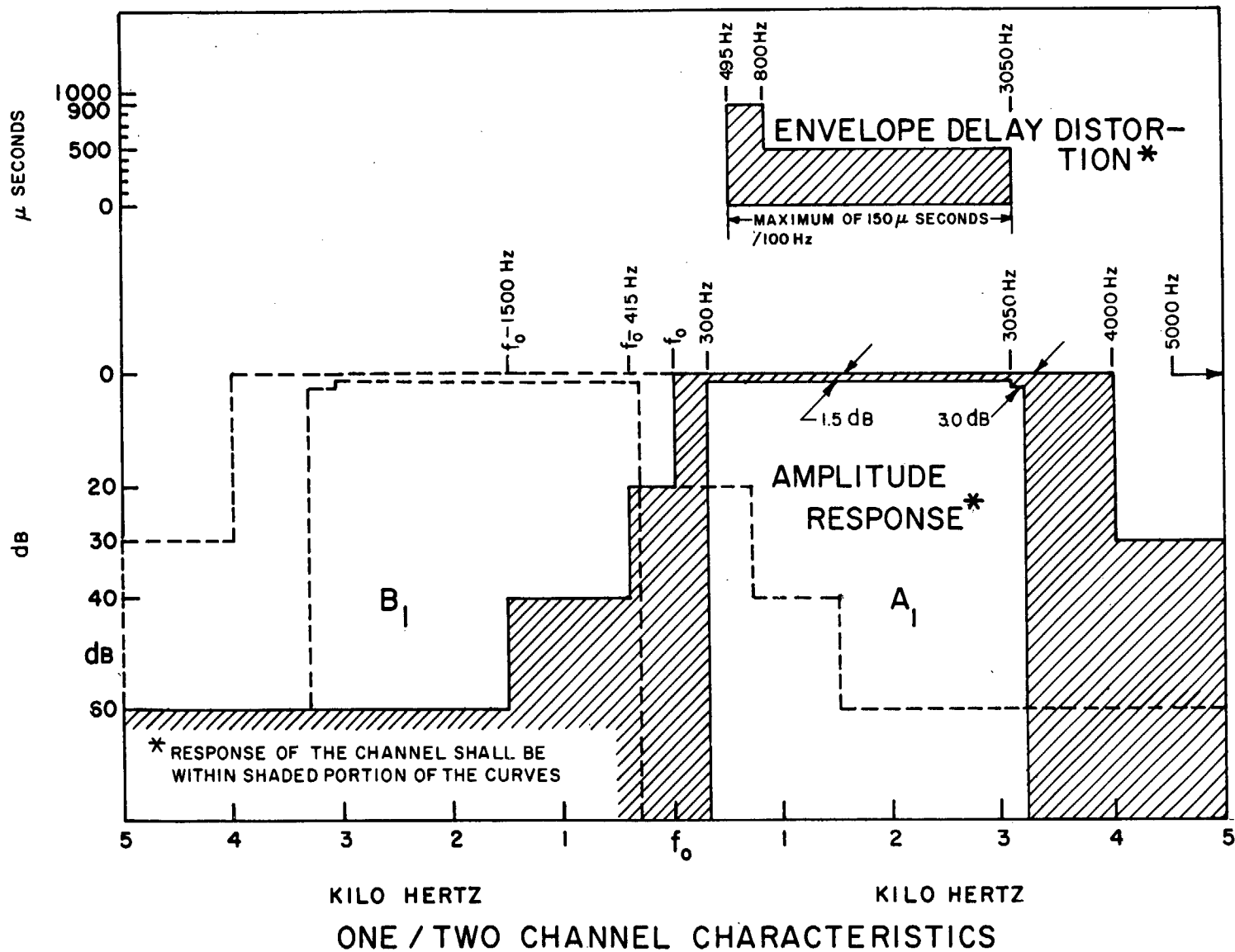


FIGURE 20

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- a. Maximum envelope delay distortion of 500 microseconds from 800 Hz to 3050 Hz.
- b. Maximum envelope delay distortion of 900 microseconds from 495 Hz to 800 Hz.
- c. The absolute delay is not to exceed 2.5 milliseconds (DO - 2 milliseconds) over the frequency range of 495 Hz to 3050 Hz.

4.5.6.11 Necessary Bandwidth. The necessary bandwidths for medium frequency band emissions shall be as follows:

Amplitude Modulation:

Single Channel Voice 6 kHz, maximum

Single Sideband Modulation:

Single Channel	3 kHz or 6 kHz, maximum
Two Channels	6 kHz or 12 kHz, maximum
Four Channels	12 kHz, maximum

4.5.7 High Frequency Band (3 MHz - 30 MHz). The high frequency (HF) band is utilized for point-to-point, and ground-to-air tactical military communications. In military equipment extension of the frequency coverage to 2 MHz is common. Several modes of propagation are utilized: The ionospheric refraction mode (single or multi-hop) is capable of sustaining service of up to 5,000 miles in range, but varies due to such natural phenomena as sunspot activity and auroras. The ground wave mode is used for short range communications up to several hundred miles. Ground equipment for ground-to-air service is fundamentally identical to other HF equipment. In the military, the preferred form of emission in this band is SSB.

4.5.7.1 High/Low Performance Equipment. In the high frequency (HF) band, channel assignments are nominal 3 kHz bandwidths. High performance HF equipment can be utilized in radio loop, link, or trunk circuits where the characteristics of the nominal 3 kHz channel will meet the communication circuit requirements. Low performance HF equipment may be employed in radio loop circuits or in those tactical radio communication facilities which are self-supporting in the sense that they rarely connect into other communication systems. The low performance equipment must be able to operate with high performance equipment in a radio loop circuit or radio net; although the channel quality of the communication circuit may be degraded. All HF transmitter, whose rated noise power (pn) output exceeds 51.75 dBm (150 Watts) (DO - 43 dBm (20 Watts)), shall meet the out-of-band spectral emission limits of the high performance equipment. Where CW compatible operation is required, HF transmitters shall also have a single tone power (pc) output capability of 6 to 7 dB above the output level of

a single tone modulating the equipment to rated noise power (pn) output when the rated noise power is less than 60 dBm (1 KW) and 3 to 6 dB when the rated noise power (pn) is greater than 60 dBm (1 KW).

4.5.7.2 Frequency Coverage.

4.5.7.2.1 High Performance Equipment. The high performance equipment shall be capable of having its carrier tuned and aligned over the entire frequency range of 2.0000 MHz to 29.9999 MHz in steps of 100 Hz at integral 100 Hz frequency increments.

4.5.7.2.2 Low Performance Equipment. Low performance equipment shall be capable of having its carrier tuned and aligned over its operating frequency range in steps of 100 Hz at integral 100 Hz frequency increments. Steps of 1 kHz shall be optional in lieu of 100 Hz for tactical equipment only where size and weight constraints make the 100 Hz steps impractical. It shall be a Design Objective that the low performance equipment operating range covers the entire 2.0000 MHz to 29.9999 MHz frequency band.

4.5.7.3 Frequency Tolerance.

4.5.7.3.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^9 for high performance equipment and 5 parts in 10^8 for low performance equipment of any designated frequency.

4.5.7.3.2 Frequency Stability.

4.5.7.3.2.1 High Performance Equipment. The frequency stability of the high performance equipment, with respect to the initial frequency, shall be within 1 part in 10^8 per day, 5 parts in 10^8 during the first 30 days after calibration. The stability shall not be degraded by more than 4 parts in 10^8 per each 30 day period thereafter.

4.5.7.3.2.2 Low Performance Equipment. The frequency stability of the low performance equipment, with respect to the initial frequency, shall be within 5 parts in 10^7 per day, 1 part in 10^6 during the first 30 days after calibration. The stability shall not be degraded by more than 2 parts in 10^7 per each 30 day period thereafter. It shall be a Design Objective that the frequency stability shall be 5.5 parts in 10^7 during the first 30 days after calibration, and that the stability shall not be degraded by more than 4 parts in 10^8 per each 30 day period thereafter.

4.5.7.3.2.3 Phase Jitter. The phase difference averaged over any two successive 10 millisecond periods (13.33 millisecond periods may also be used) shall not exceed 5 degrees (DO - 2.5 degrees) when measured between the signal input and output terminals of a transmitter or a receiver. Measurements shall be performed for at least 100 sample time periods.

4.5.7.4 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

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4.5.7.5 Microphone/Headset Circuit. The input/output characteristics of the microphone and headset circuits, when required, shall be in accordance with the requirements of paragraphs 4.5.1.4.4 and 4.5.1.4.5.

4.5.7.6 Audio Input/Output Impedances (Message Baseband). The audio input and output impedances of the HF equipment shall be nominally 600 Ohms balanced to ground with a minimum return loss of 26 dB against a 600 Ohm resistance over the frequency range of 300 Hz to 3020 Hz on nominal 3 kHz channels. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level.

4.5.7.7 Audio Input Signal Power (Message Baseband). The test tone input to each audio channel shall be -10 dBm. The composite audio input of speech to each audio channel shall have a mean power of -10 dBm, obtained from a distribution with a mean volume of -10 vu with a standard deviation of 5 vu. The multitone power, from multichannel carrier telegraph, fed to each audio channel shall be -10 dBm. The audio input of each tone shall be equal to $-10 \text{ dBm} - 10 \log t$, where t is the number of tones.

4.5.7.8 Audio Output Signal Power (Message Baseband). The test tone output of the receiver shall be adjusted to conform to the transmission level of the equipment or the transmission facility to which the receiver output is to be connected. If the standard test tone of -10 dBm (as specified in paragraph 4.5.7.7) has been inserted into the audio channel of the transmitter at 0 dBr transmission level point, the following examples are given for correct measurements of test tone at the receiver audio channel output for different transmission levels:

Transmission Level at Audio Channel Output of Receiver (dBr)	Test Tone Measured (dBm)
+7	-3
0	-10
-4	-14
-16	-26

The mean audio output power of speech signals or the composite multitone signal power, when inserted in the audio channel as specified in paragraph 4.5.7.7 will then have the same output powers in dBm as listed above for test tones at the +7, 0, -4 and -16 dBr transmission levels. The receiver audio output channel shall be adjustable to cover the above range of transmission levels.

4.5.7.9 RF Output/Input Impedances. The radio frequency (RF) output and input impedance for a high performance HF radio set shall be a nominal 50 Ohms, unbalanced (optional for low performance HF radio set).

4.5.7.10 Single Sideband Emissions. The designation of single sideband emissions and bandwidth characteristics shall be in accordance with Appendix A. The displayed frequency shall be that of the carrier, whether suppressed or not.

4.5.7.10.1 The classification of typical emissions is tabulated as follows:

Type of Modulation	Type of Transmission	Supplementary Characteristics	Symbol
Amplitude Modulation	Single channel voice frequency telegraphy	Single sideband, suppressed carrier	*A2J
Amplitude Modulation	Single channel telephony	Single sideband, reduced carrier	3A3A
Amplitude Modulation	Multichannel telephony	Two independent sidebands	**A3B
Amplitude Modulation	Single channel telephony	Single sideband, suppressed carrier	3A3J
Amplitude Modulation	Single channel telephony	Single sideband, full carrier	3A3H
Amplitude Modulation	Facsimile	Single sideband, reduced carrier	*A4A
Amplitude Modulation	Multichannel voice - frequency telegraphy	Single sideband, reduced carrier	3A7A
Amplitude Modulation	Combination of telephony and telegraphy	Two independent sidebands	**A9B

* determined by communication system requirements.

** by using multiplexing techniques, the available bandwidth (up to a maximum of 12 kHz) can accommodate multiple nominal 3 kHz channels. (See Figure 14.)

4.5.7.10.2 Operating Modes.

4.5.7.10.2.1 High Performance Equipment. High performance equipment shall have the capability of single channel, upper sideband operation. The equipment may also accommodate up to a maximum of four nominal 3 kHz channels by using multiplexing techniques. Figure 14 shows four channel operation that has equal bandwidths and is compatible with the phase delay and amplitude characteristics specified for high performance equipment.

4.5.7.10.2.2 Low Performance Equipment. Low performance equipment shall have the capability of single channel, upper sideband operation. The

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equipment may also have the capability of both upper and lower sideband operation. (With the option of simultaneous operation.)

4.5.7.10.2.3 Carrier Level Control, SSB. The carrier level control shall provide for a minimum selection of the following levels of the reinserted carrier: +1 dB, 10 dB, 20 dB; and maximum suppression with reference to the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.7.10.2.3.1 Reduced Carrier Level (A3A, for example). The reduced carrier level shall be either 10 or 20 dB (selectable) below the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.7.10.2.3.2 Suppressed Carrier Level (A3J, for example) The suppressed carrier level shall be at least 50 dB (60 dB DO) for high performance equipment and at least 40 dB (50 dB DO) for low performance equipment below the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.7.10.2.3.3 Full Carrier Level (A3H, for example). The full carrier level shall be approximately plus 1 dB above a single tone modulating the equipment to rated noise power (pn) output.

4.5.7.10.2.3.4 AM Compatibility. The capability of the equipment for compatible AM operation is required for high performance equipment (optional for low performance equipment).

4.5.7.10.2.4 Independent Sideband. Equipment, that has the capability of simultaneous independent sideband operation, shall be required for all high performance equipment.

4.5.7.10.3 In Band Distortion.

4.5.7.10.3.1 High Performance Equipment. The noise power ratio (NPR (SSB)) shall be at least 40 dB (43 dB DO), when the equipment is loaded to rated noise power (pn) output with the specified noise signal(s). See paragraph 9.3.

4.5.7.10.3.2 Low Performance Equipment. The noise power ratio (NPR SSB)) shall be at least 30 dB, when the equipment is loaded to rated noise power (pn) output with the specified noise signal(s). (See paragraph 9.3.)

4.5.7.10.4 Out-of-Band Spectral Emissions. When the transmitter is loaded to rated noise power (pn) output with the specified noise signal(s) (see paragraph 9.3) in each audio channel, the power spectral density of the out-of-band emission shall not exceed the level established by straight lines connecting the points given in the following table:

Frequency of Measurement		Attenuation Below In-Band Power Spectral Density	
High Performance Equipment: (See Figure 15)		Standard	DO
$f_m = f_c \pm \frac{(1.0 B + 500 \text{ Hz})}{2}$		40 dB	43 dB
$f_m = f_c \pm 1.0 B$		45 dB	48 dB
$f_m = f_c \pm 2.5 B$		60 dB	65 dB
or	$f_c + 4.0 B < f_m < 1.05 f_c$	70 dB	80 dB
	$0.95 f_c > f_m > f_c - 4.0 B$		
Low Performance Equipment: (See Figure 16)			
$f_m = f_c \pm \frac{(1.0 B + 500 \text{ Hz})}{2}$		30 dB	30 dB
$f_m = f_c \pm 1.0 B$		35 dB	35 dB
$f_m = f_c \pm 2.5 B$		45 dB	50 dB
or	$f_c + 4.0 B < f_m < 1.05 f_c$	50 dB	60 dB
	$0.95 f_c > f_m > f_c - 4.0 B$		

where

f_m = frequency of measurement

f_c = center frequency of necessary bandwidth

B = necessary bandwidth

4.5.7.10.5 Discrete Frequency Spurious Emissions. When the transmitter is loaded with a single tone in each audio channel to rated noise power, (pn) output, the in-band and out-of-band ($f_o + 5\% f_o$) discrete frequency spurious emissions shall be at least 80 dB below the reference single tone output for high performance equipment, and at least 60 dB below the reference single tone output for low performance equipment. NOTE: MIL-STD-461 specifies the out-of-band emissions for bandwidths greater than $f_o \pm 5\%$.

4.5.7.10.6 Amplitude - Frequency Response (Audio).

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4.5.7.10.6.1 High Performance Equipment (Transmitter and Receiver, Respectively). The maximum variation between 250 Hz and 3100 Hz shall be 1 dB. The attenuation shall be not less than 40 dB at 50 Hz and 3250 Hz. The attenuation shall be not less than 60 dB at 3550 Hz and higher frequencies and at $f_0 - 250$ Hz and lower frequencies. See Figure 17.

4.5.7.10.6.2 Low Performance Equipment (Transmitter and Receiver, Respectively). The maximum variation between 530 Hz and 3050 Hz shall be 2 dB and from 350 Hz to 530 Hz shall be 3 dB. The attenuation shall be at least 30 dB from 0 Hz (f_0) to $f_0 - 300$ Hz. The attenuation shall not be less than 60 dB at 4000 Hz and higher frequencies and at $f_0 - 300$ Hz and lower frequencies. See Figure 18.

4.5.7.10.6.3 One/Two Channel Equipment (Digital). The maximum variation between 300 Hz and 3050 Hz shall be 1.5 dB and from 3050 Hz to 3200 Hz shall be 3 dB. The attenuation shall be at least 20 dB from (f_0) to $f_0 - 415$ Hz. The attenuation shall be at least 40 dB from $f_0 - 415$ Hz to $f_0 - 1500$ Hz and at least 60 dB below $f_0 - 1500$ Hz. The attenuation shall be at least 30 dB from 4000 Hz to 5000 Hz and at least 60 dB above 5000 Hz. See Figure 20.

4.5.7.10.7 Envelope Delay Distortion.

4.5.7.10.7.1 High Performance Equipment (Transmitter and Receiver, Respectively). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 17)

a. Maximum envelope delay distortion of 500 microseconds from 300 Hz to 3020 Hz.

b. Maximum envelope delay distortion of 100 microseconds for any 100 Hz frequency increment between 300 Hz to 3100 Hz.

c. The absolute delay is not to exceed 8 milliseconds (DO - 4 milliseconds) over the frequency range of 300 Hz to 3020 Hz (relative to the carrier frequency).

4.5.7.10.7.2 Low Performance Equipment (Transmitter and Receiver, Respectively). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 18)

a. The envelope delay distortion with reference to the delay at 825 Hz, shall not vary more than minus 300 microseconds to plus 500 microseconds from 825 Hz to 2750 Hz.

b. Maximum envelope delay distortion of 150 microseconds for any 100 Hz frequency increment between 750 Hz to 2750 Hz.

c. Maximum envelope delay distortion of 250 microseconds from 2750 Hz to 2850 Hz.

d. Maximum envelope delay distortion of 350 microseconds from 600 Hz to 750 Hz.

e. The absolute delay is not to exceed 6 milliseconds (DO - 2 milliseconds) over the frequency range of 600 Hz to 2750 Hz.

4.5.7.10.7.3 One/Two Channel Equipment (Digital). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 20)

a. Maximum envelope delay distortion of 500 microseconds from 800 Hz to 3050 Hz.

b. Maximum envelope delay distortion of 900 microseconds from 495 Hz to 800 Hz.

c. The absolute delay is not to exceed 2.5 milliseconds (DO - 2 milliseconds) over the frequency range of 495 Hz to 3050 Hz.

4.5.7.11 Necessary Bandwidth. The necessary bandwidths for high frequency band emissions shall be as follows:

Single Sideband Modulation

Single channel	3 kHz or 6 kHz maximum
Two channels	6 kHz or 12 kHz maximum
Four channels	12 kHz maximum

4.5.8 Very High Frequency Band (30 MHz - 300 MHz). The very high frequency (VHF) band is used by both military and nonmilitary services. A portion of this band is allocated to commercial FM and TV broadcasting. However, certain segments of this band are used in military communication systems. From a military tactical communications viewpoint, this band is primarily employed for ground-ground, ground-aerospace and limited extended range beyond line-of-sight applications. The radio equipment, through multiplexing techniques, can provide multichannel capability.

It is common for Ultra High Frequency (UHF) military equipment to extend the UHF frequency coverage to 225 MHz, resulting in a UHF military communication band of 225 MHz to 400 MHz. This coverage is discussed further in the ultra high frequency band section.

4.5.8.1 High/Low Performance Equipment. High performance VHF equipment can be utilized in radio loops or radio nets, where the characteristics of the equipment meet the communication circuit requirements. Low performance VHF equipment may be employed in those tactical radio communications facilities which are self-supporting; in the sense that they rarely interconnect with other communication systems. The low performance equipment however, must be able to operate with high performance equipment when used in a radio loop circuit or radio net; although the channel quality of the communication circuit may be degraded.

4.5.8.2 Frequency Coverage. The equipment shall be capable of having its carrier tuned and aligned over its frequency range in steps which allow operation in conformance with the channeling plans promulgated or approved by the MCEB. Receiver selectivity shall be such as to allow single channel equipments to operate within a single channel as outlined in these channeling plans.

4.5.8.3 Frequency Tolerance.

4.5.8.3.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned between the following:

a. High Performance Equipment

- | | |
|--------------------|-------------------|
| 1. AM (30-76 MHz) | 5 parts in 10^6 |
| 2. AM (76-300 MHz) | 1 part in 10^7 |
| 3. FM | 5 parts in 10^6 |
| 4. SSB | 1 part in 10^9 |

b. Low Performance Equipment

- | | |
|--------------------|-------------------|
| 1. AM (30-76 MHz) | 5 parts in 10^6 |
| 2. AM (76-300 MHz) | 1 part in 10^6 |
| 3. FM | 5 parts in 10^6 |
| 4. SSB | 5 parts in 10^8 |

4.5.8.3.2 Frequency Stability.

4.5.8.3.2.1 High Performance Equipment. The frequency stability of the high performance equipment, with respect to the initial frequency, shall be within the following:

Requirement	MHz AM(30-76)	MHz FM(30-76)	MHz AM(76-300)	MHz FM(162-174)	SSB
per day	5 parts in 10^5	2 parts in 10^5	1 part in 10^6	5 parts in 10^6	1 part in 10^8
first 30 days	5.5 parts in 10^5	2 parts in 10^5	2 parts in 10^6	5 parts in 10^6	5 parts in 10^8
each 30 days thereafter	5 parts in 10^6	2 parts in 10^5	1 part in 10^6	5 parts in 10^6	4 parts in 10^8

For mobile FM equipments with a power output of less than 3 Watts, a stability of 5 parts in 10^5 is allowed except as provided in para 4.5.9.1.3.1.2.

4.5.8.3.2.2 Low Performance Equipment. The frequency stability of the low performance equipment, with respect to the initial frequency, shall be within the following:

Requirement	MHz AM(30-76)	MHz FM(30-76)	MHz AM(76-300)	MHz FM(162-174)	SSB
per day	5 parts in 10^5	2 parts in 10^5	1 part in 10^5	5 parts in 10^6	5 parts in 10^6
first 30 days	5.5 parts in 10^5	2 parts in 10^5	1.5 parts in 10^5	5 parts in 10^6	1 part in 10^6
each 30 days thereafter	5 parts in 10^6	2 parts in 10^5	1 part in 10^6	5 parts in 10^6	2 parts in 10^7

For mobile FM equipments with a power output of less than 3 Watts, a stability of 5 parts in 10^5 is allowed except as provided in para 4.5.9.1.3.1.2. For SSB the Design Objective shall be 5.5 parts in 10^7 for the first 30 days and 4 parts in 10^8 for each 30 day period thereafter.

4.5.8.4 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.8.5 Microphone/Headset Circuit. The input/output characteristics of the microphone and headset circuits, when required, shall be in accordance with the requirements of paragraphs 4.5.1.4.4 and 4.5.1.4.5.

4.5.8.6 Audio Input/Output Impedances (Message Baseband). The audio input and output impedances of the VHF equipment shall be nominally 600 Ohms, balanced to ground, with a minimum return loss of 26 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level. When multiplexed VHF equipment is used, the input/output impedances shall be compatible with the multiplexed equipment. The characteristics of the multiplexed equipment shall be in accordance with the requirements of paragraph 4.5.9.2.5.

4.5.8.7 Audio Input Signal Power (Message Baseband). The test tone input to each audio channel shall be -10 dBm. The composite audio input of speech to each audio channel shall have a mean power of -10 dBm, obtained from a distribution with a mean volume of -10 vu with a standard deviation of 5 vu. The multitone power, from multichannel carrier telegraph, fed to each audio channel shall be -10 dBm. The audio input of each tone shall be equal to -10 dBm - 10 log t, where t is the number of tones. The characteristics of the multiplexed equipment when used shall be in accordance with the requirements of paragraph 4.5.9.2.5.

4.5.8.8 Audio Output Signal Power (Message Baseband). Refer to paragraph 4.5.7.8.

4.5.8.9 RF Output/Input Impedances. The radio frequency (RF) output and input impedance for the high performance VHF radio set shall be a nominal 50 Ohms, unbalanced (optional for the low performance VHF radio set).

4.5.8.10 Modulation. The modulation technique currently used is either frequency or phase modulation or amplitude modulation. The use of single sideband modulation in these frequency ranges is a Design Objective.

4.5.8.10.1 Amplitude Modulation.

4.5.8.10.1.1 Carrier Noise Level. The detected output voltage obtained from an unmodulated carrier shall be at least 50 dB (60 dB DO) below the detected output voltage obtained from the carrier 90% modulated with a 1000 Hz tone. Low performance equipment shall be at least 40 dB (50 dB DO).

4.5.8.10.1.2 Modulation. When a zero dBm audio signal at any frequency between 300 Hz and 3500 Hz is applied to the audio input circuit, the RF carrier output, at rated output level, shall be modulated at least 95%.

4.5.8.10.1.3 Harmonic Distortion. With any audio input frequency between 300 Hz and 3500 Hz, and with the audio input adjusted for 90% modulation, the total harmonic distortion at rated power output (RF-Transmitter, Audio-Receiver) shall not exceed -30 dB (-20 dB for low performance equipment) with reference to a detected output voltage obtained from the carrier, 90% modulated with a 1000 Hz tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.8.10.1.4 Intermodulation Distortion. With any two equal level audio input frequencies between 300 Hz and 3500 Hz, and with the audio input adjusted for 90% modulation, the intermodulation distortion products at rated power output (RF-Transmitter, Audio-Receiver) shall not exceed -38 dB (-30 dB for low performance equipment) with reference to a detected output voltage obtained from the carrier, 90% modulated with a 1000 Hz tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.8.10.1.5 Attenuation vs Frequency (Audio). The nominal 3 dB points for the radio channel shall be at 300 Hz and 3500 Hz. For all frequencies between 325 Hz and 1000 Hz, the attenuation shall be within the limits of -1 dB and +2 dB, with respect to the attenuation at 1000 Hz. For all frequencies between 1000 Hz and 3450 Hz, the attenuation shall be within the limits of +1.5 dB, with respect to the attenuation at 1000 Hz. It shall be a Design Objective that the attenuation be within +1 dB for all frequencies between 325 Hz and 3450 Hz with respect to the attenuation at 1000 Hz.

4.5.8.10.1.6 Wideband Mode (Diphase). The radio equipment shall have an auxilliary wideband mode with the following characteristics:

- a. Audio Input Impedance - 600 Ohms.

- b. Audio Input Signal Levels - 0 dBm.
- c. Audio Output Impedance 600 Ohms.
- d. Audio Output Signal Level 0 dBm.
- e. Attenuation versus Frequency (Audio) (Input and Output). Nominal 3 dB points for the radio channel shall be at 300 Hz and 23 kHz. With reference to attenuation at 19.2 kHz, the attenuation shall be at least 20 dB greater at 32 kHz and at least 30 dB greater at 37 kHz.

4.5.8.10.2 Frequency or Phase Modulation.

4.5.8.10.2.1 Noise Level. The detected output voltage obtained from an unmodulated carrier shall be at least 40 dB (DO 50 dB) below the detected output voltage obtained from the carrier fully modulated at 1000 Hz with rated deviation.

4.5.8.10.2.2 Deviation. When a zero dBm audio signal, between 300 Hz and 3500 Hz, is applied to the audio input circuit, the RF carrier shall be frequency modulated to the rated deviation. For single channel analog voice equipments, the capability to operate with a frequency deviation not to exceed +5 kHz must be provided.

4.5.8.10.2.3 Harmonic Distortion. With any audio input frequency, between 300 Hz and 3500 Hz, and with the audio input level adjusted for rated deviation, the total harmonic distortion at rated output (RF-Transmitter, Audio-Receiver) shall not exceed -30 dB (-20 dB for low performance equipment) with reference to the output level of the input audio tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.8.10.2.4 Intermodulation Distortion. With any two equal level audio input frequencies between 300 Hz and 3500 Hz, and with the audio input adjusted for rated deviation, the intermodulation products at rated power output (RF-Transmitter, Audio-Receiver) shall not exceed -38 dB (-30 dB for low performance equipment) with reference to the output level of either input audio tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.8.10.2.5 Attenuation vs Frequency (Audio). The nominal 3 dB points for the radio channel shall be at 300 Hz and 3500 Hz. For all frequencies between 325 Hz and 1000 Hz, the attenuation shall be within the limits of -1 dB and +2 dB, with respect to the attenuation at 1000 Hz. For all frequencies between 1000 Hz and 3450 Hz, the attenuation shall be within the limits of +1.5 dB, with respect to the attenuation at 1000 Hz. It shall be a Design Objective that the attenuation be within +1 dB for all frequencies between 325 Hz and 3450 Hz with respect to the attenuation at 1000 Hz. The transmitter shall be provided with an audio low pass filter installed between the modulator limiter and the modulator stage to insure that at frequencies above 12.5 kHz, the attenuation shall be at least 25 dB greater than the attenuation at 1 kHz.

4.5.8.10.2.5.1 Pre-emphasis and De-emphasis. The use of pre-emphasis and de-emphasis circuitry is an optional requirement.

4.5.8.10.2.6 Wideband Mode (Conditioned Baseband). The radio equipment shall have an auxiliary wideband mode with the following characteristics:

- a. Digital Input Impedance: 2 k Ohms (DO - 50 K Ohms).
- b. Digital Input Signal Levels: Plus and minus 6 Volts.
- c. Digital Output Impedance: 100 Ohms (DO - 50 Ohms).
- d. Digital Output Signal Levels: 1 Volt, peak to peak.
- e. Attenuation vs Frequency (Audio). The nominal 3 dB points for the radio channel shall be at 10 Hz and 13 kHz with reference to the attenuation at 1000 Hz, the attenuation shall be less than 10 dB at 14 kHz; 20 dB at 21 kHz; 30 dB at 23 kHz.

4.5.8.10.3 Single Sideband.

4.5.8.10.3.1 Single Sideband Emissions. The designations of single sideband (SSB) emissions and bandwidth characteristics shall be in accordance with Appendix A. The displayed frequency shall be that of the carrier, whether suppressed or not.

4.5.8.10.3.2 Operating Modes.

4.5.8.10.3.2.1 High Performance Equipment. The equipment may accommodate up to a maximum of four nominal 3 kHz channels by using multiplexing techniques. Figure 14 shows four channel operation that has equal bandwidths of 300 Hz to 3000 Hz and is compatible with the phase delay and amplitude characteristics specified for high performance equipment.

4.5.8.10.3.2.2 Low Performance Equipment. Low performance equipment shall have the capability of single channel, upper sideband operation. The equipment may also have the capability of both upper and lower sideband operation but not simultaneous operation.

4.5.8.10.3.2.3 Carrier Level Control, SSB. The carrier level control shall provide for a minimum selection of the following levels of the re-inserted carrier: +1 dB, 10 dB, 20 dB; and maximum suppression with reference to the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.8.10.3.2.3.1 Reduced Carrier Level (A3A, for example). The reduced carrier level shall be either 10 or 20 dB (selectable) below the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.8.10.3.2.3.2 Suppressed Carrier Level (A3J, for example). The suppressed carrier level shall be at least 50 dB (60 dB DO) for high performance equipment and at least 40 dB (50 dB DO) for low performance equipment below the output level of a single tone modulating the equipment to rated noise power (pn) output.

4.5.8.10.3.2.3.3 Full Carrier Level (A3H, for example). The full

carrier level shall be approximately plus 1 dB above a single tone modulating the equipment to rated noise power (pn) output.

4.5.8.10.3.2.3.4 AM Compatibility. The capability of the equipment for compatible AM operation is an optional requirement.

4.5.8.10.3.2.4 Independent Sideband. Equipment, that has the capability of simultaneous independent sideband operation, shall meet the requirements of high performance equipment.

4.5.8.10.3.3 In Band Distortion.

4.5.8.10.3.3.1 High Performance Equipment. The noise power ratio (NPR (SSB)) shall be at least 35 dB (43 dB DO) when the equipment is loaded to rated noise power (pn) output with the specified noise signal(s). (See paragraph 9.3)

4.5.8.10.3.3.2 Low Performance Equipment. The noise power ratio (NPR (SSB)) shall be at least 30 dB, when the equipment is loaded to rated noise power (pn) output with the specified noise signal(s). (See paragraph 9.3)

4.5.8.10.3.4 Out-of-Band Spectral Emissions. When the transmitter is loaded to rated noise power (pn) output with the specified noise signal(s), (see paragraph 9.3) in each audio channel, the power spectral density of the out-of-band emission shall not exceed the level established by straight lines connecting the points given in the following table:

Frequency of Measurement	Attenuation Below In-Band Power Spectral Density	
	Standard	DO
High Performance Equipment: (See Figure 15)		
$f_m = f_c \pm \frac{(1.0 B + 500 \text{ Hz})}{2}$	40 dB	43 dB
$f_m = f_c \pm 1.0 B$	45 dB	48 dB
$f_m = f_c \pm 2.5 B$	60 dB	65 dB
or $f_c + 4.0 B < f_m < 1.05 f_c$ $0.95 f_c > f_m > f_c - 4.0 B$	70 dB	80 dB
Low Performance Equipment: (See Figure 16)		
$f_m = f_c \pm \frac{(1.0 B + 500 \text{ Hz})}{2}$	30 dB	30 dB
$f_m = f_c \pm 1.0 B$	35 dB	35 dB

Low Performance Equipment: (See Figure 16)

Standard DO

$$f_m = f_c \pm 2.5 B$$

45 dB 50 dB

or

$$f_c + 4.0 B < f_m < 1.05 f_c$$

$$0.95 f_c > f_m > f_c - 4.0 B$$

50 dB 60 dB

where

f_m = frequency of measurement

f_c = center frequency of necessary bandwidth

B = necessary bandwidth

4.5.8.10.4 Discrete Frequency Spurious Emissions. When the transmitter is loaded with a single tone in each audio channel to rated noise power (pn), output, the in-band and out-of-band ($f_o \pm 5\% f_o$) discrete frequency spurious emissions shall be at least 80 dB below the reference single tone output for high performance equipment, and at least 60 dB below the reference single tone output for low performance equipment. NOTE: MIL-STD-461 specifies the out-of-band emission for bandwidth greater than $f_o \pm 5\%$.

4.5.8.10.5 Amplitude - Frequency Response (Audio).

4.5.8.10.5.1 High Performance Equipment (Transmitter and Receiver, Respectively). The maximum variation between 250 Hz and 3100 Hz shall be 1 dB. The attenuation shall be not less than 40 dB at 50 Hz and 3250 Hz. The attenuation shall be not less than 60 dB at 3550 Hz and higher frequencies and at $f_o - 250$ Hz and lower frequencies. See Figure 17.

4.5.8.10.5.2 Low Performance Equipment (Transmitter and Receiver, Respectively). The maximum variation between 530 Hz and 3050 Hz shall be 2 dB and from 350 Hz to 530 Hz shall be 3 dB. The attenuation shall be at least 30 dB from 0 Hz (f_o) to $f_o - 300$ Hz. The attenuation shall not be less than 60 dB at 4000 Hz and higher frequencies and at $f_o - 300$ Hz and lower frequencies. See Figure 18.

4.5.8.10.5.3 One/Two Channel Equipment (Digital). The maximum variation between 300 Hz and 3050 Hz shall be 1.5 dB and from 3050 Hz to 3200 Hz shall be 3 dB. The attenuation shall be at least 20 dB from (f_o) to $f_o - 415$ Hz. The attenuation shall be at least 40 dB from $f_o - 415$ Hz to $f_o - 1500$ Hz and at least 60 dB below $f_o - 1500$ Hz. The attenuation shall be at least 30 dB from 4000 Hz to 5000 Hz and at least 60 dB above 5000 Hz. See Figure 20.

4.5.8.10.6 Envelope Delay Distortion.

4.5.8.10.6.1 High Performance Equipment (Transmitter and Receiver, Respectively). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 17)

a. Maximum envelope delay distortion of 500 microseconds from 300 Hz to 3020 Hz.

b. Maximum envelope delay distortion of 100 microseconds for any 100 Hz frequency increment between 300 Hz to 3100 Hz.

c. The absolute delay is not to exceed 8 milliseconds (DO - 4 milliseconds) over the frequency range of 300 Hz to 3020 Hz (relative to the carrier frequency).

4.5.8.10.6.2 Low Performance Equipment (Transmitter and Receiver, Respectively). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 18)

a. The envelope delay distortion with reference to the delay at 825 Hz shall not vary more than minus 300 microseconds to plus 500 microseconds from 825 Hz to 2750 Hz.

b. Maximum envelope delay distortion of 150 microseconds for any 100 Hz frequency increment between 750 Hz to 2750 Hz.

c. Maximum envelope delay distortion of 250 microseconds from 2750 Hz to 2850 Hz.

d. Maximum envelope delay distortion of 350 microseconds from 600 Hz to 750 Hz.

e. The absolute delay is not to exceed 6 milliseconds (DO - 2 milliseconds) over the frequency range of 600 Hz to 2750 Hz.

4.5.8.10.6.3 One/Two Channel Equipment (Digital). The envelope delay distortion characteristics shall be in accordance with the following: (See Figure 20)

a. Maximum envelope delay distortion of 500 microseconds from 800 Hz to 3050 Hz.

b. Maximum envelope delay distortion of 900 microseconds from 495 Hz to 800 Hz.

c. The absolute delay is not to exceed 2.5 milliseconds (DO-2 milliseconds) over the frequency range of 495 Hz to 3050 Hz.

4.5.8.11 Necessary Bandwidth. The necessary bandwidths for very high frequency band emissions shall be as follows:

8 kHz, maximum

Amplitude Modulation

Single Channel

8 kHz, maximum

Frequency Modulation

Single Channel (analog voice)

Up to 40 kHz (normally 16 Hz)

Line-of-Sight and Radio Relay Service

Dependent upon number of multiplexed 4 kHz channels and deviation index.

Single Sideband Modulation

Single Channel

3 kHz or 6 kHz, maximum

Two Channels

6 kHz or 12 kHz, maximum

Four Channels

12 kHz maximum

4.5.9 Ultra High Frequency Band (300 MHz - 3000 MHz). The ultra high frequency (UHF) band is extensively employed for tactical communications service in such general use as line-of-sight radio relay, tropospheric scatter, ground-aerospace and for tactical satellite communications.

It is common for military communication equipment to cover certain segments of this band. One segment is 300 MHz - 400 MHz (this segment is extended into the VHF frequency band to include 225 MHz to 300 MHz, resulting in a UHF military communication band of 225 MHz - 400 MHz). The 225 MHz to 400 MHz band is currently used for single channel tactical applications and in tactical radio relay for multichannel applications. Other segments of the UHF frequency band are currently used for multichannel tactical applications. It is also common for multichannel FDM equipment to be installed with a "supergroup multiplexer," even though initially only one "group multiplexer" is required. This design allows for expansion of the radio relay system.

4.5.9.1 225 MHz - 400 UHF Equipment.

4.5.9.1.1 High/Low Performance Equipment. High performance UHF equipment can be utilized in radio loops, links, or trunk circuits or radio nets, where the characteristics of the equipment meet the communication circuit requirements. Low performance UHF equipment may be employed in radio loop circuits or in those tactical radio communications facilities which are self-supporting; in the sense that they rarely interconnect with other communication systems. The low performance equipment, however, must be able to operate with high performance equipment when used in a radio loop circuit or radio net; although the channel quality of the communication may be degraded.

4.5.9.1.2 Frequency Coverage.

4.5.9.1.2.1 Single Channel. The single channel 225 MHz - 400 MHz UHF equipment shall be capable of having its carrier tuned and aligned over

the entire frequency range of 225.00 MHz to 399.95 MHz in steps of 50 kHz at integral 50 kHz frequency increments (DO 25 kHz at integral 25 kHz frequency increments).

4.5.9.1.2.2 Multichannel. The multichannel 225 MHz - 400 MHz UHF equipment shall be capable of having its carrier tuned and aligned over the entire frequency range of 225.0 to 399.5 MHz in steps of 500 kHz at integral 500 kHz frequency increments.

4.5.9.1.3 Frequency Tolerance.

4.5.9.1.3.1 225 MHz - 400 MHz UHF Equipment.

4.5.9.1.3.1.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^7 for high performance equipment and 1 part in 10^6 for low performance equipment of any designated frequency.

4.5.9.1.3.1.2 Frequency Stability.

4.5.9.1.3.1.2.1 High Performance Equipment. The frequency stability of the high performance equipment, with respect to the initial frequency, shall be within 1 part in 10^6 per day, 2 parts in 10^6 during the first 30 days after calibration. The stability shall not be degraded by more than 1 part in 10^6 per each 30 day period thereafter.

4.5.9.1.3.1.2.2 Low Performance Equipment. The frequency stability of the low performance equipment, with respect to the initial frequency, shall be within 1 part in 10^5 per day, 1.5 parts in 10^5 during the first 30 days after calibration. The stability shall not be degraded by more than 1 part in 10^6 per each 30 day period thereafter.

4.5.9.1.4 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.9.1.5 Microphone/Headset Circuit. The input/output characteristics of the microphone and headset circuits shall, when required, be in accordance with the requirements of paragraphs 4.5.1.4.4 and 4.5.1.4.5.

4.5.9.1.6 Audio Input/Output Impedance (Message Baseband).

4.5.9.1.6.1 Single Channel. The audio/output impedances of the UHF equipment shall be nominally 600 Ohms, balanced to ground, with a minimum return loss of 26 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level.

4.5.9.1.6.2 Multichannel. The characteristics of the multiplexed equipment shall be in accordance with the requirements of paragraph 4.5.9.2.5.

4.5.9.1.7 Audio Input Signal Levels (Message Baseband).

4.5.9.1.7.1 Single Channel. The test tone input level to the audio channel shall be -10 dBm. The composite audio input of speech to each audio channel shall have a mean power of -10 dBm, obtained from a distribution with a mean volume of -10 vu with a standard deviation of 5 vu. The multitone power, from multichannel carrier telegraph, fed to each audio channel shall be -10 dBm. The audio input of each tone shall be equal to -10 dBm -10 log t, where t is the number of tones.

4.5.9.1.7.2 Multichannel. The characteristics of the multiplexed equipment shall be in accordance with the requirements of paragraph 4.5.9.2.5.

4.5.9.1.8 Audio Output Signal Power (Message Baseband).

4.5.9.1.8.1 Single Channel. Refer to paragraph 4.5.7.8.

4.5.9.1.8.2 Multichannel. The characteristics of the multiplexed equipment shall be in accordance with the requirements of paragraph 4.5.9.2.5.

4.5.9.1.9 RF Output/Input Impedances. The radio frequency (RF) output/input impedances for the high performance UHF radio set shall be a nominal 50 Ohms, unbalanced and optional for the low performance UHF radio set.

4.5.9.1.10 Modulation. The modulation technique currently used in the 225 MHz to 400 MHz frequency range is amplitude modulation (AM) and narrow band frequency modulation (NBFM).

4.5.9.1.10.1 Amplitude Modulation.

4.5.9.1.10.1.1 Carrier Noise Level. The detected output voltage obtained from an unmodulated carrier shall be at least 50 dB (60 dB DO) below the detected output voltage obtained from the carrier 90% modulated with a 1000 Hz tone. Low performance equipment shall be at least 40 dB (50 dB DO).

4.5.9.1.10.1.2 Modulation. When a zero dBm audio signal at any frequency between 300 Hz and 3500 Hz is applied to the audio input circuit, the RF carrier output, at rated output level, shall be modulated at least 95%.

4.5.9.1.10.1.3 Harmonic Distortion. With any audio input frequency between 300 Hz and 3500 Hz, and with the audio input adjusted for 90% modulation, the total harmonic distortion at rated power output (RF-Transmitter, Audio-Receiver) shall not exceed -30 dB (-20 dB for low performance equipment) with reference to a detected output voltage obtained from the carrier, 90% modulated with a 1000 Hz tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.9.1.10.1.4 Intermodulation Distortion. With any two equal level audio input frequencies between 300 Hz and 3500 Hz, and with the audio input

adjusted for 90% modulation, the intermodulation distortion products at rated power output (RF-Transmitter, Audio-Receiver) shall not exceed -38 dB (-30 dB for low performance equipment) with reference to a detected output voltage obtained from the carrier, 90% modulated with a 1000 Hz tone. The Design Objective shall be at least 40 dB below the reference level.

4.5.9.1.10.1.5 Attenuation vs Frequency (Audio). The nominal 3 dB points for the radio channel shall be at 300 Hz and 3500 Hz. For all frequencies between 325 Hz and 1000 Hz, the attenuation shall be within the limits of -1 dB and +2 dB, with respect to the attenuation at 1000 Hz. For all frequencies between 1000 Hz and 3450 Hz, the attenuation shall be within the limits of +1.5 dB, with respect to the attenuation at 1000 Hz. It shall be a Design Objective that the attenuation be within +1 dB for all frequencies between 325 Hz and 3450 Hz with respect to the attenuation at 1000 Hz.

4.5.9.1.10.1.6 Wideband Mode (Diphase). The radio equipment shall have an auxiliary wideband mode with the following characteristics:

- a. Audio Input Impedance - 600 Ohms.
- b. Audio Input Signal Levels - 0 dBm.
- c. Audio Output Impedance - 600 Ohms.
- d. Audio Output Signal Level - 0 dBm.
- e. Attenuation vs Frequency (Audio) (Input and Output). Nominal 3 dB points for the radio channel shall be at 300 Hz and 23 kHz, with reference to attenuation at 19.2 kHz, the attenuation shall be at least -20 dB at 32 kHz and at least -30 dB at 37 kHz.

4.5.9.1.10.2 Frequency Modulation.

4.5.9.1.10.2.1 Narrowband Frequency Modulation (225 MHz - 400 MHz).

4.5.9.1.10.2.1.1 FSK Modulation Index. The modulation index shall be 1.0.

4.5.9.1.10.2.1.2 FSK Modulation Deviation. The modulation deviation shall be plus or minus 20 kHz.

4.5.9.1.10.2.1.3 FSK Response vs Frequency. The frequency response of the radio set (back to back) shall be plus or minus 3 dB (DO 1 dB) over the FSK modulation range.

4.5.9.1.10.2.1.4 FSK Frequency Accuracy. The FSK frequency accuracy, for the fixed modulation deviation, shall be within plus or minus 1 kHz.

4.5.9.1.10.2.1.5 Signaling Rate. The equipment shall have the capability of signaling rate of 5 k bits per second.

4.5.9.2 Multichannel UHF (300 MHz - 3000 MHz).

4.5.9.2.1 Frequency Coverage. The equipment shall be capable of having its carrier tuned and aligned over its entire frequency range in steps of 100 kHz at integral 100 kHz frequency increments (XTAL controlled equipment) and 500 kHz steps at integral 500 kHz frequency increments (synthesizer controlled).

4.5.9.2.2 Frequency Tolerance.

4.5.9.2.2.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^8 of any designated frequency.

4.5.9.2.2.2 Frequency Stability. The frequency stability of the equipment, with respect to the initial frequency, shall be within 1 part in 10^7 per day, 5 parts in 10^7 during the first 30 days after calibration. The stability shall not be degraded by more than 1 part in 10^7 per each 30 day period thereafter.

4.5.9.2.3 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.9.2.4 Supervisory Channel.

4.5.9.2.4.1 Audio Input/Output Impedance. The multichannel radio equipment shall have, in addition to the message baseband circuitry, a supervisory channel whose audio input/output impedances shall be nominally 600 Ohms, balanced to ground, with a minimum return loss of 20 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz.

4.5.9.2.4.2 Audio Input Signal Levels. The test tone input level to the supervisory channel shall be 0 dBm. The composite audio input level of speech or multitone power fed to the supervisory channel shall be -10 dBm. The audio input level of each tone shall be equal to $-10 \text{ dBm} - 10 \log t$, where t is the number of tones.

4.5.9.2.4.3 Audio Output Signal Levels. The test tone output of the supervisory channel shall be 0 dBm. The composite audio output level of speech or multitone power shall be -10 dBm.

4.5.9.2.5 Message Baseband.

4.5.9.2.5.1 Frequency Division Multiplex (FDM). (See Figure 19.) Refer to paragraphs 4.4.1.3.2, 4.4.1.3.3, 4.4.1.3.4, 4.4.1.3.5, and 4.4.1.3.6 for FDM standards.

4.5.9.2.5.1.1 FM Modulator Input/Demodulator Output Impedances. The message baseband input/output impedances shall be 75 Ohms, unbalanced, with

a minimum return loss of 20 dB (DO 26 dB) over the frequency range. It shall also be a Design Objective that 130 Ohms and 150 Ohms, balanced, be provided as strapping options.

4.5.9.2.5.1.2 FM Modulator Input Levels. The per channel test tone level at the input to the FM modulator shall be -45 dBm (-45 dBr T.L.P.). (DO - the FM modulator shall have the capability to accommodate input test tone levels over a range of -15 dBm to -48 dBm for baseband interfacing the modulator at the GDF, SGDF or HFDF multiplex output transmission level points.) The composite multichannel power input to the FM modulator shall be equal to -55 to +10 log N dBm, where N = number of 4 kHz channels (for systems where all multiplexed channels are loaded with digital data). For systems where all multiplexed channels are loaded with voice, then the input power shall be equal to -45 + (-1 + 4 log N) dBm, where N = up to 240 channels and shall be equal to -45 + (-15 + 10 log N) dBm, where N = number of channels greater than 240 channels. Refer to Figure 30.

4.5.9.2.5.1.3 FM Demodulator Output Levels. The per channel test tone level at the output of the FM Demodulator shall be -15 dBm + 0.5 dB (DO + 0.1 dB) (-15 dBr T.L.P.). (DO - The FM demodulator shall have the capability to accommodate output test tone levels over a range of -9 dBm to -31 dBm; for interfacing with the FDM multiplex equipment at the HFDF, SGDF or GDF interface transmission level points.) The per channel composite audio output level of speech or multitone power shall be -25 dBm.

4.5.9.2.5.1.4 Bandwidths. The message baseband bandwidth shall be capable of interfacing with the FDM multiplexer sets by the use of filters which shall narrow the 0.1 dB reference points to the following:

- a. 12 channel operation: 12 kHz to 60 kHz
- b. 24 channel operation: 12 kHz to 108 kHz
- c. 60 channel operation: 12 kHz to 252 kHz or 60 kHz to 300 kHz
- d. 120 channel operation: 60 kHz to 552 kHz
- e. 240 channel operation: 60 kHz to 1052 kHz
- f. 300 channel operation: 50 kHz to 1300 kHz

4.5.9.2.5.2 Time Division Multiplex (TDM). Standards for radio transmission of TDM (PCM) pulse groups are covered in paragraph 4.4.2.8.1.

4.5.9.2.6 RF Output/Input Impedances. (See Figure 19) The radio frequency (RF) output/input impedances for the UHF radio set when coaxial cable is used, shall be a nominal 50 Ohms, unbalanced. Wave guide may also be used.

4.5.9.2.6.1 Return Loss. The return loss, as measured in either direction from the RF interface points, shall be at least 32 dB (VSWR not greater than 1.05:1) as measured over a frequency band centered at the carrier frequency (or frequencies) with the band limits determined by the required minimum 3 dB bandwidth.

4.5.9.2.7 Modulation. Frequency modulation is currently used in this band. The baseband input signals may be either Frequency Division Multiplexed (FDM) signals or Time Division Multiplexed (TDM) signals.

4.5.9.2.7.1 FDM/Frequency Modulation.

4.5.9.2.7.1.1 Carrier Noise Level. The residual AM in the baseband for FM service shall be at least 50 dB below the level of the unmodulated carrier operating at its rated power output. Residual FM shall be at least -70 dBm0 in any 4 kHz slot in the baseband above 12 kHz.

4.5.9.2.7.1.2 Deviation Capability. The test tone signal deviation (RMS) (without pre-emphasis) shall be adjustable from 35 kHz to 200 kHz per channel. All performance characteristics specified herein shall be met when using a test tone signal per channel deviation of 140 kHz and 200 kHz. The peak deviation capability shall be at least 5.0 MHz. If pre-emphasis is employed the per channel test tone RMS deviation requirements shall apply to the mean baseband frequency, i.e., that frequency at which the deviation is the same with or without pre-emphasis.

4.5.9.2.7.1.3 Deviation Ratio. The deviation ratio shall be adjustable from 0.5 to 10. This ratio is the ratio of carrier deviation to the highest baseband frequency.

4.5.9.2.7.1.4 Pre-emphasis and De-emphasis. Circuitry shall be provided for greater deviations at higher baseband frequencies in order to compensate for triangular noise at the discriminator outputs and to maintain a constant baseband output signal to noise ratio (SNR) across the entire baseband frequency spectrum. The preferred emphasis characteristics and insertion loss of the network is described in CCIR Reports 275 and 404.

4.5.9.2.7.1.5 Transfer Function Parameters. (See Figure 19) With the radio set connected back-to-back, at the RF interface with appropriate frequency translation devices and attenuators to provide a received signal level of -30 dBm when the transmitter is operated at full power output. The overall performance, when measured between the baseband interface points shall be as follows:

4.5.9.2.7.1.5.1 In Band Noise. The back-to-back equipment noise power ratio (NPR) shall be at least 55 dB (DO - 60 dB) for any 4 kHz channel slot in the message baseband and 50 dB (DO - 55 dB) in the supervisory channel. The gaussian noise power input level shall be defined by the equation: $\text{Power (dBm)} = -55 \text{ dBm} + 10 \log N$ where N = number of channels and the minimum input level per channel = -45 dBm.

4.5.9.2.7.1.5.2 In Channel Noise. The ratio of any channel noise power (residual noise power), with no input noise loading, to the same channel noise power, when the channel is loaded with rated gaussian noise, shall be 57 dB (DO - 62 dB) in the message baseband and 52 dB (DO - 57 dB) in the supervisory baseband.

4.5.9.2.7.1.5.3 Attenuation vs Frequency. The back-to-back baseband frequency response of the radio set shall be + 0.5 dB in the message band and + 1 dB in the supervisory channel. The nominal 0.1 dB bandwidths shall be in accordance with the filters used to accommodate the different number of channel operational capability.

4.5.9.2.7.1.5.4 Receiver Automatic Gain Control. The receiver shall employ automatic gain control circuitry such that the output will not vary by more than 0.5 dB as the received signal level varies from 5 dB to 60 dB above threshold. (DO 5 dB to 75 dB)

4.5.9.2.7.1.5.5 Level Stability. The radio set shall be designed with sufficient regulation and feedback to provide long time stability such that for a constant level input, the output will not vary by more than ± 0.5 dB during a 30 day period without adjustments.

4.5.9.2.7.1.5.6 Spurious Emission. All spurious emissions between $f_0 + 5$ MHz and $f_0 + (5\% f_0)$ shall be suppressed below a -50 dBm power level, as measured at the RF interface, with gaussian noise loading of the baseband and with full transmitter output power. For frequencies beyond $f_0 + 5\% f_0$ the spurious emission requirements of MIL-STD-461 shall apply.

4.5.9.2.7.1.5.7 Envelope Delay Distortion. The back-to-back envelope delay distortion of the radio set shall not exceed 200 nanoseconds over the message baseband.

4.5.9.2.7.2. TDM/Frequency Modulation. Formulation deferred pending the establishment of technical standards.

4.5.9.2.8 Radio Relay Operation. The IF portion of the multichannel radio set shall meet the following: (See Figure 19)

ITEM	REQUIREMENT
Frequency	70 MHz, ± 0.070 MHz
Impedance and Return Loss	The impedance shall be 75 Ohms, unbalanced, and shall have a return loss against the nominal impedance of at least 20 dB.
Signal Levels	The nominal 70 MHz signal level at the IF interface shall be + 1 dBm. At each source (FM modulator output and radio receiver output), the level shall be continuously adjustable over a range of + 1 to + 5 dBm. The required radio transmitter and FM demodulator IF inputs shall be within ± 0.5 dB of the nominal signal level.

4.5.9.3 Necessary Bandwidth. The necessary bandwidths for the ultra high frequency band emissions shall be as follows:

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Amplitude Modulation

Single channel, 225 - 400 MHz 8 kHz, maximum

Frequency Modulation

Single channel, 225 - 400 MHz 40 kHz
 Line-of-Sight, Multiplex and Video; up to 20 MHz
 300 - 3000 MHz
 Radio Relay, Multiplex; 300 - 3000 MHz up to 10 MHz
 (Tropospheric Scatter)

4.5.10 Super High Frequency Band (3-30 GHz). The super high frequency band is employed in tactical military communications primarily in line-of-sight relay, for tactical satellite communications and for other limited applications.

It is common for military communication equipment to cover segments of this band. It is also common for multichannel FDM equipment to be installed with a super "group multiplexer," even though initially only one "group multiplexer" is required. This design allows for expansion of the radio relay system.

4.5.10.1 Frequency Coverage. The radio set shall be capable of having its carrier tuned and aligned over its entire frequency range. The frequency generating source for the frequency band 4400-4990 MHz shall be in increments of 100 kHz (50 kHz DO). The generating source for the frequency band 7125-8400 MHz shall be in increments of 1 MHz.

4.5.10.2 Frequency Tolerance.

4.5.10.2.1 Frequency Calibration Resolution. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated or aligned within 1 part in 10^8 for high performance equipment and 5 parts in 10^8 for low performance equipment of any designated frequency.

4.5.10.2.2 Frequency Stability.

4.5.10.2.2.1 High Performance Equipment. The frequency stability of the high performance equipment, with respect to the initial frequency, shall be within 1 part in 10^7 per day, 5 parts in 10^7 during the first 30 days after calibration. The stability shall not be degraded by more than 1 part in 10^7 per each 30 day period thereafter.

4.5.10.2.2.2 Low Performance Equipment. The frequency stability of the low performance equipment, with respect to the initial frequency, shall be within 5 parts in 10^7 per day, 1 part in 10^6 during the first 30 days after calibration. The stability shall not be degraded by more than 2 parts in 10^7 per each 30 day period thereafter.

4.5.10.3 Electromagnetic Compatibility Requirements. The equipment shall meet the electromagnetic compatibility requirements of paragraph 4.5.1.6.

4.5.10.4 Single Channel Radio Equipment. It is anticipated that single channel radio equipment may be used for tactical satellite communication circuits at the mobile end, i.e., team pack, jeep, submarine, or aircraft.

4.5.10.4.1 Audio Input/Output Impedances. The audio input/output impedances of the SHF equipment shall be nominally 600 Ohms, balanced to ground, with a minimum return loss of 26 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below the reference level.

4.5.10.4.2 Audio Input Signal Levels. The test tone input level to the audio channel shall be 0 dBm. The composite audio input level of speech fed to the audio channel shall be -10 dBm. The composite audio input level of multitone power fed to the audio channel shall be -10 dBm. The audio input level of each tone shall be equal to $-10 \text{ dBm} - 10 \log t$, where t is the number of tones.

4.5.10.4.3 Audio Output Signal Levels. Refer to paragraph 4.5.7.8.

4.5.10.5 Multichannel Radio Equipment.

4.5.10.5.1 Supervisory Channel.

4.5.10.5.1.1 Audio Input/Output Impedance. The multichannel radio equipment shall have, in addition to the message baseband circuitry, a supervisory channel whose audio input/output impedances shall be nominally 600 Ohms, balanced to ground, with a minimum return loss of 20 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz.

4.5.10.5.1.2 Audio Input Signal Levels. The test tone input level to the supervisory channel shall be 0 dBm. The composite audio input level of speech or multitone power fed to the supervisory channel shall be -10 dBm. The audio input level of each tone shall be equal to $-10 \text{ dBm} - 10 \log t$, where t = number of tones.

4.5.10.5.1.3 Audio Output Signal Levels. The test tone output of the supervisory channel shall be 0 dBm. The composite audio output level of speech or multitone power shall be -10 dBm.

4.5.10.5.2 Message Baseband.

4.5.10.5.2.1 Frequency Division Multiplex (FDM). (See Figure 19) Refer to paragraphs 4.4.1.3.3, 4.4.1.3.4, 4.4.1.3.5 and 4.4.1.3.6 for FDM standards.

4.5.10.5.2.1.1 FM Modulator Input/Demodulator Output Impedances. The message baseband input/output impedances shall be 75 Ohms, unbalanced, with a minimum return loss of 20 dB (DO 26 dB) over the frequency range. It shall be a Design Objective that 130 Ohms and 150 Ohms, balanced, be provided as strapping options.

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4.5.10.5.2.1.2 FM Modulator Input Levels. The per channel test tone level at the input to the FM modulator shall be -45 dBm (-45 dBr T.L.P.). (DO - the FM modulator shall have the capability to accommodate input test tone levels over a range of -15 dBm to -48 dBm for baseband interfacing the modulator at the GDF, SGDF or HFDF multiplex output transmission level points.) The composite multichannel power input to the FM modulator shall be equal to -55 to +10 log N dBm, where N = number of 4 kHz channels (for systems where all multiplexed channels are loaded with digital data). For systems where all multiplexed channels are loaded with voice, then the input power shall be equal to -45 + (-1 + 4 log N) dBm, where N = up to 240 channels and shall be equal to -45 + (-15 + 10 log N) dBm, where N = number of channels greater than 240 channels. Refer to Figure 30.

4.5.10.5.2.1.3 FM Demodulator Output Levels. The per channel test tone level at the output of the FM Demodulator shall be -15 dBm + 0.5 dB (DO + 0.1 dB) (-15 dBr T.L.P.). (DO - The FM demodulator shall have the capability to accommodate output test tone levels over a range of -9 dBm to -31 dBm; for interfacing with the FDM multiplex equipment at the HFDF, SGDF or GDF interface transmission level points.) The per channel composite audio output level of speech or multitone power shall be -25 dBm.

4.5.10.5.2.1.4 Bandwidths. The message baseband bandwidths shall be capable of interfacing with the FDM multiplexer sets by the use of appropriate filters. The actual bandwidth is a function of the communication system requirements. Typical line-of-sight relay systems may contain up to 5 super groups (300 voice channels), having a 1.3 MHz baseband, or may contain both supergroups and a TV/radar video channel or may only contain a TV/radar video channel.

4.5.10.5.2.2 Time Division Multiplex (TDM). (See Figure 19) Standards for radio transmission of TDM (PCM) pulse groups are covered in paragraph 4.4.2.8.1.

4.5.10.6 RF Output/Input Impedances (See Figure 19). The radio frequency (RF) output/input impedances for the SHF Radio set when coaxial cable is used, shall be a nominal 50 Ohms, unbalanced. Wave guide may also be used.

4.5.10.6.1 Return Loss. The return loss, as measured in either direction from the RF interface points, shall be at least 32 dB (VSWR not greater than 1.05:1) as measured over a frequency band centered at the carrier frequency (or frequencies) with the band limits determined by the required minimum 3 dB bandwidth.

4.5.10.7 Modulation. Frequency modulation is currently used in this band. The baseband input signals may be either Frequency Division Multiplexed (FDM) signals or Time Division Multiplexed (TDM) signals.

4.5.10.7.1 FDM/Frequency Modulation.

4.5.10.7.1.1 Carrier Noise Level. The Residual AM in the baseband for FM service shall be at least 50 dB below the level of the unmodulated carrier operating at its rated power output. Residual FM shall be at least -70 dBm0 in any 4 kHz slot in the baseband above 12 kHz.

4.5.10.7.1.2 Deviation Capability. The test tone signal deviation (RMS) (without pre-emphasis) shall be adjustable from 35 kHz to 200 kHz per channel. All performance characteristics specified herein shall be met when using a test tone signal per channel deviation of 140 kHz and 200 kHz. The peak deviation capability shall be at least 5.0 MHz. If pre-emphasis is employed the per channel test tone RMS deviation requirements shall apply to the mean baseband frequency, i.e. that frequency at which the deviation is the same with or without pre-emphasis.

4.5.10.7.1.3 Deviation Ratio. The deviation ratio shall be adjustable from 0.5 to 10. This ratio is the ratio of carrier deviation to the highest baseband frequency.

4.5.10.7.1.4 Pre-Emphasis and De-Emphasis. Circuitry shall be provided for greater deviations at higher baseband frequencies in order to compensate for triangular noise at the discriminator outputs and to maintain a constant baseband output signal to noise ratio (SNR) across the entire baseband frequency spectrum. The preferred emphasis characteristics and insertion loss of the network is described in CCIR Reports 275 and 404.

4.5.10.7.1.5 Transfer Function Parameters. (See Figure 19). With the radio set connected back-to-back, at the RF interface with appropriate frequency translation devices and attenuators to provide a received signal level of - 30 dBm when the transmitter is operated at full power output, the overall performance, when measured between the baseband interface points shall be as follows:

4.5.10.7.1.5.1 In Band Noise. The back-to-back equipment noise power ratio (NPR) shall be at least 55 dB (DO - 60 dB) for any 4 kHz channel slot in the message baseband and minus 50 dB (DO -55 dB) in the supervisory channel. The gaussian noise power input level shall be defined by the equation: Power (dBm) = -55 dBm + 10 log N where N = number of channels and the minimum input level per channel = -45dBm.

4.5.10.7.1.5.2 In Channel Noise. The ratio of any channel noise power (residual noise power), with no input noise loading, to the same channel noise power, when the channel is loaded with rated gaussian noise, shall be minus 57 dB (DO - minus 62 dB) in the message baseband and minus 52 dB (DO - minus 62 dB) in the message baseband and minus 52 dB (DO - minus 57 dB) in the supervisory baseband.

4.5.10.7.1.5.3 Attenuation Vs Frequency. The back-to-back baseband frequency response of the radio set shall be + 0.5 dB in the message band and + 1 dB in the supervisory channel. The nominal 0.1 dB bandwidths shall be in accordance with the filters used to accomodate the different number of channel operational capability.

4.5.10.7.1.5.4 Receiver Automatic Gain Control. The receiver shall employ automatic gain control circuitry such that the output will not vary by more than 0.5 dB as the received signal level varies from 5 dB to 60 dB above threshold. (DO 5 dB to 75 dB).

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4.5.10.7.1.5.5 Level Stability. The radio set shall be designed with sufficient regulation and feedback to provide long time stability such that for a constant level input, the output will not vary by more than ± 0.5 dB during a 30 day period without adjustments.

4.5.10.7.1.5.6 Spurious Emission. All spurious emissions between $f_0 + 5$ MHz and $f_0 + (5\% f_0)$ shall be suppressed below a -50 dBm power level, as measured at the RF interface, with gaussian noise loading of the baseband and with full transmitter output power.

4.5.10.7.1.5.7 Envelope Delay Distortion. The back-to-back envelope delay distortion of the radio set shall not exceed 200 nanoseconds over the message baseband.

4.5.10.7.2 TDM/Frequency Modulation. Formulation deferred pending the establishment of technical standards.

4.5.10.8 Radio Relay Operation. The IF portion of the multichannel radio set shall meet the following: (See Figure 19)

<u>ITEM</u>	<u>REQUIREMENT</u>
Frequency	70 MHz, ± 0.070 MHz
Impedance and Return Loss	The impedance shall be 75 Ohms, unbalanced, and shall have a return loss against the nominal impedance of at least 20 dB.
Signal Levels	The nominal 70 MHz signal level at the IF interface shall be + 1 dBm. (DO - At each source (FM modulator output and radio receiver output), the level shall be continuously adjustable over a range of + 1 to + 5 dBm). The required radio transmitter and FM demodulator IF inputs shall be within ± 0.5 dB of the nominal signal level.

4.5.10.9 Necessary Bandwidth. The necessary bandwidths for the super high frequency band emission shall be as follows:

Frequency Modulation

Line-of-Sight Service

Single Channel	up to 3 MHz
Multiplex and Video	up to 20 MHz
Tactical Satellite Radio Relay Service	up to 7 MHz

4.5.11 Extremely High Frequency Band Range (30-300 GHz). The present state-of-the-art and the limited experience with equipment for communication purposes in the EHF range do not permit the establishment of reason-

able standards at this time. Equipment designed for operation in the EHF range shall be compatible with the existing standards for communication circuits and shall be capable of interoperation with telephone and telegraph multiplexed carrier equipment designed in accordance with their standards.

4.6 Radio Sets, Manpacked, Handheld or Helmet-mounted. Radio sets that must be carried by one individual in field operations have severe constraints in their design from the standpoint of size, weight, ruggedness, reliability and ease of operation by non-technical personnel. There may also be severe constraints on cost due to the extremely large quantities required. Where, due to their employment, it is possible to relax certain of the standards for radio circuits given in paragraph 4.5 "Radio Circuits", the following standards shall apply as exceptions.

4.6.1 Frequency Tolerance and Calibration. The applicable low performance requirements set forth in paragraph 4.5 "Radio Circuits" shall apply for HF equipment with SSB service and for all UHF and VHF equipment. For HF equipment with AM, CW, MCW service, the following shall apply.

4.6.1.1 Calibration Accuracy. The frequency adjustment control of a transmitter and receiver shall permit either equipment to be periodically calibrated to be within 50 Hz of any operating frequency.

4.6.1.2 Accuracy after Calibration. The frequency stability and accuracy of the equipment with respect to the designated operating frequency shall be within ± 5.5 parts in 10^5 during the first 30 days after calibration. This accuracy may be progressively degraded by an additional ± 5 parts in 10^6 for each month thereafter.

4.6.2 Audio Input/Output Interfaces. The audio input/output interface requirements covered under paragraphs, 4.5.7.6, 4.5.7.7, 4.5.7.8, 4.5.8.6, 4.5.8.7, 4.5.8.8, 4.5.8.10.1.2, and 4.5.8.10.2.2 need not apply. The following requirements shall apply.

4.6.2.1 Microphone Input Impedance. A microphone input circuit, if required, shall have a nominal impedance of 150 Ohms over the frequency range of 300 to 3000 Hz. This shall be as close to pure resistance as possible and may be unbalanced to ground.

4.6.2.2 Audio Input Level (for microphone input). The nominal input power level shall be as such as to accept the nominal output range of the microphone. (For dynamic microphones, this is approximately -56 dBm.)

4.6.2.3 Output Circuitry of Suitable Impedances for Connection to Headsets and/or Loudspeakers. The output impedance of receivers shall be suitable for connection of the following audio accessories: A single earpiece headset or handset with an impedance of 1000 Ohms $\pm 20\%$ and a dual earpiece headset with an impedance of 500 Ohms $\pm 20\%$ and loudspeakers with an impedance of 6000 Ohms $\pm 20\%$.

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4.6.2.4 Audio Output Power. The maximum output power which a receiver shall deliver to a headset and/or handset shall be at least 1 milliwatt. A continuous adjustment shall be capable of reducing this power to 0.01 milliwatt.

4.6.3 RF Output/Input Impedances. The RF output/input impedances that are required under paragraphs 4.5.7.9 and 4.5.8.9 are not required. It is a design objective to provide RF input and/or output terminals with 50 Ohms impedance for test purposes.

4.6.4 Attenuation vs Frequency (Audio). The responses described under paragraph 4.5.7.10.6.2, 4.5.8.10.1.5, 4.5.8.10.2.5 and 4.5.8.10.6, are not required for those equipments whose only mode is analog voice. For those equipments the nominal 3 dB points shall be at 500 Hz and 3000 Hz. The maximum attenuation between 500 and 3000 Hz shall be within + 3 dB with respect to the attenuation at 1000 Hz. Attenuation below 300 Hz and beyond 3000 Hz shall increase as rapidly as possible.

4.6.5 Envelope Delay Distortion. The requirements described by paragraphs 4.5.7.10.7 and 4.5.8.10.7 for envelope delay distortion are not required for those equipments whose only mode is analog voice.

4.7 Radio Sets, Airborne, for Low Performance Aircraft. Radio sets for such aircraft shall meet the standards for "low performance" radio circuits as contained in Section 4.5 "Radio Circuits" of this standard with the following exception:

4.7.1 Audio Input/Output Impedance. The audio input and output impedance for such aircraft shall be 150 Ohms over the frequency range of 300 to 3000 Hz. They shall be as close to a pure resistance as possible and balanced with respect to ground.

4.8 Speech Plus Half-Duplex.

4.8.1 Speech Channel. Speech plus half-duplex shall not be used as a trunk circuit because it causes degradation to speech and also precludes the use of the channel for high speed data.

4.8.1.1 Amplitude vs Frequency Distortion. The amplitude vs frequency distortion shall not be greater than 3 dB with respect to the minimum attenuation within the bands from 300 to 1000 Hz and from 1600 to 3500 Hz.

4.8.1.2 Single Harmonic Distortion. The single harmonic distortion within the bands between 300 to 1000 Hz and 1600 to 3500 Hz produced by any single frequency test signal shall be at least 25 dB below reference (-25 dBm0). The test signal is introduced into the link at the transmission level reference point at 0 dBm. The power of the test signal is adjusted when introduced at transmission level points other than the zero point.

4.8.1.3 Frequency Translation. The frequency translation introduced by any single link due to the difference in carrier frequencies at each end of the link shall not exceed 2 Hz.

4.8.2 Telegraph Channel. The telegraph channel shall employ the tactical modem for 150 baud or less covered by paragraph 7.3.8.

4.8.2.1 Amplitude vs Frequency Distortion. There shall not be a greater difference between the maximum and minimum attenuation than 4 dB for frequencies in the band between 1200 and 1350 Hz.

4.8.2.2 Crosstalk Coupling Loss. The crosstalk coupling loss from the telephone channel into the telegraph channel shall be greater than 80 dB for any frequency between 300 Hz and 3500 Hz.

4.9 Speech Plus Full-Duplex. Speech plus full duplex shall follow the same standards as for speech plus half-duplex.

5. SWITCHING SYSTEMS

5.1 Automatic Switching Equipment (Analog Voice Band). Tactical automatic switching equipment shall be designed for switching 4 kHz circuits (trunks and loops) on a 4-wire basis. It is recognized that some switch designs have transmission characteristics that permit the switching of wideband circuits (greater than 4 kHz), however the transmission characteristics of switching equipment for circuits greater than 4 kHz in band width shall be considered as optional and are not specified as standards herein. It is also recognized that automatic 4-wire switches must frequently interface with a large inventory of 2-wire systems. Conversion equipment should be provided in the automatic switches where such requirements exist. For interfaces with AUTOVON, the DCS Global Switching System, refer to the DCS-NON-DCS interface standards, Section 8 of this standard.

5.1.1 Transmission Characteristics.

5.1.1.1 Insertion Loss. The insertion loss of any 4-wire connection thru a switch shall be $0 \text{ dB} \pm 0.5 \text{ dB}$ when measured with a 1 kHz test tone.

5.1.1.2 Transmission Levels. The transmission levels for 4-wire automatic switches shall be -4 dBr for both transmitting and receiving.

5.1.1.3 Limiting. The 4-wire connections thru a switch shall not overload and start limiting when a 1 kHz test tone at a power of +4 dBm is transmitted thru the connection. The test tone shall be introduced at the -4 dBr transmission level point. (In effect this means that switches shall not start limiting for signal powers that are 8 dB higher than the standard test tone power used to establish the -4 dBr transmission levels.)

5.1.1.4 Amplitude vs Frequency Distortion. For all frequencies between 300 Hz and 3500 Hz the attenuation shall be within the limits of +1.0 dB (+0.5 dB D.O.) with respect to the attenuation at 1000 Hz. The 3 dB points shall be below 275 Hz and above 3600 Hz.

5.1.1.5 Harmonic Distortion. The total harmonic distortion produced by the transmission of any single test frequency between 300 Hz and 3500 Hz thru any of the 4-wire connections of a switch shall be at least 35 dB (40 dB D.O.) below the power of the test frequency. The test frequency shall be at a power of -4 dBm and be introduced into the switch at the -4 dBr transmission level point.

5.1.1.6 Envelope Delay Distortion. The envelope delay distortion for a single 4-wire connection thru a switch shall not exceed 25 microseconds in the frequency band between 600 Hz and 3200 Hz.

5.1.1.7 Noise. The noise on any connection thru the switch, when idle and properly terminated, caused by the switch itself shall not exceed

16 dBa when measured at the -4 dBr transmission level point. Impulse noise on any connection, when idle and properly terminated, due to switching on another connection or due to any other switch functions not associated with the connection measured shall not exceed .004 volts peak amplitude measured across a 600 Ohm termination at the -4 dBr transmission level point.

5.1.1.8 Crosstalk. The crosstalk coupling loss between any two connections thru the switch shall be not less than 60 dB (70 dB D.O.) when measured at the -4 dBr transmission level points.

5.1.1.9 Terminal Impedance. The input and output impedance of the switch in the frequency band between 300 Hz and 3500 Hz shall have a return loss of 20 dB or more when referred to a 600 Ohm resistance.

5.1.1.10 Longitudinal Balance. The longitudinal balance of any 4-wire connection thru the switch shall be at least 40 dB for each direction of transmission over the frequency band between 300 Hz and 3500 Hz.

5.1.1.11 Test Tone. The standard test tone frequency of 1000 Hz + 25 Hz shall be used for measuring transmission levels within the switch. When introduced at an input to a switch connection it shall be at the -4 dBr transmission level point and the power of the test tone shall be -4 dBm.

5.1.2 Numbering Plan. The following numbering plan shall be used: Each local termination (i.e. subscriber) located at an automatic electronic switchboard shall be identified by a 7-digit number (PRSLIXX) and by a 3-digit abbreviated dialing number. The numbers and explanations are shown in Table V. Each automatic central office can be located by PRSL while each manual switchboard (see para 5.2) is designated IXX. The PRSL will identify the automatic trunk route to the manual switchboard. When a call is placed to a subscriber or attendant at some other automatic switchboard, either the 7-digit number or the abbreviated 3-digit local calling code may be used. When a call is placed to a subscriber or attendant at some other manual switchboard, the appropriate 7-digit number must be keyed. The local attendant at an automatic switchboard should be reached by keying 0 or the 7-digit number PRSLOO0. It should be noted that the SL designate may be used to describe some manual switchboard until substantial numbers of automatic equipments are fielded.

Digit Position	Identification	Available Numbers
PR	Primary Area	70 - 99
SL	Automatic Switchboard Identification	00 - 99
IXX	3 digit subscriber Identification	1XX, 2XX, 3XX 4XX, 5XX, 6XX
	Abbreviated Local Dialing	0, 1XX, 2XX, 3XX 4XX, 5XX, 6XX
<u>Centrals which are Manual:</u>		7XX, 8XX, 9XX

TABLE V

CENTRALS WHICH ARE AUTOMATIC: PRSLIXX

5.1.3 Control and Signalling Supervision Procedures. Control and signalling supervision procedures shall be as follows:

a. The seizure signal shall be an untimed signal transmitted in the forward direction (calling to called switching center).

b. The called switching center after proper detection and identification of the seizure signal shall initiate instructions for connecting an available idle register receiver to the trunk requesting service.

c. When the register is ready to receive address and routing information a DTMF Re-Start Signal (R, start sending) shall be sent to the calling switching center.

d. The calling switching center upon detection of the (R) signal shall cease transmitting the seizure signal to the called switching center.

e. The called switching center shall continue to transmit the (R) signal until the calling switching center starts sending the first DTMF digit signal in the address sequence.

f. When the called switching center receives this digit signal, it shall confirm its receipt by sending the complement of the received address digit signal to the calling switching center.

g. The calling switching center upon detection and verification of the complementary signal shall proceed to send the interdigit signal (X).

h. The called switching center, upon receipt of the (X) signal shall return a Proceed Signal (P) to the calling switching center as an instruction to send the next digit in the address sequence.

i. This procedure between the calling and called switching center shall be repeated until the last digit in the office code (PRSL) is sent and confirmed.

j. When the called switching center register receives the next inter-digit signal, after the office code, the called switching center shall examine the received office code digits.

k. If it determines the call has to be transferred to another switching center, it shall seize an idle trunk and proceed to send to the next switching center the trunk seizure signal.

l. Once this seizure is accomplished, in the same manner as it was accomplished between the calling and the first called switching center, a register receiver in the third switching center shall be connected to the calling trunk circuit.

m. An (R) signal shall then be sent in the reverse direction from the third to the second switching center.

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n. When this (R) signal is received in the second switching center the register in this office shall be released, and a connection shall be established between the two trunks (switching centers 1 and 3).

o. The (R) signal which is still being sent from the third switching center shall now be received in the first switching center and this shall be interpreted as a start (R) signal to restart sending the called address.

p. Therefore, the first office shall start anew to send the first digit in the address sequence, and the entire procedure shall be repeated between the first and the third switching center instead of the first and second.

q. When the office code and the (X) signal is sent, the digits shall now be examined, but this time by the third switching center. This procedure can be repeated for establishing trunk (tandem) connections through a number of switching centers.

r. When a switching center discovers that the received office code is its own, the address sending shall continue until the receiving register detects that the last digit is received.

s. The last (X) signal sent forward shall stop the sending of the last complement in the reverse direction. Then the register in the calling switching center shall be released and the called switching center shall then proceed to process the call to the subscriber corresponding to the received address.

5.1.4 Confirmation Signaling. For each digit or precedence signal sent over a trunk, a confirmation signal shall be returned. The following lists the frequencies and their confirmation frequencies:

	Hz	Hz
(	697	941
Low (	770	852
Group (	852	770
(	941	697
(	1209	1633
High (	1336	1477
Group (	1477	1336
(	1633	1209

5.1.5 Voice Guard. The design of the equipment shall be such that not more than one release signal in 1000 shall fail to be recognized by single or tandem connections. Not more than one call in 10,000 four minute calls shall be falsely released as a result of voice simulations.

5.1.6 Signaling and Supervision. Signaling and supervision shall be DTMF and SF in accordance with Table VI.

Function	Freq Hz	From Automatic Switchboard		Remarks
		Single	Duration	
		Tone Level dBm		
Digits	1 697/1209 2 697/1336 3 697/1477 4 770/1209 5 770/1336 6 770/1477 7 852/1209 8 852/1336 9 852/1477 0 941/1336	-14 <u>+1</u>	The total time from the beginning of transmission of one digit until the beginning of transmission of the next, including confirmation signalling and interdigit plus proceed or restart shall not exceed 200 millisecond. No digit tone shall be transmitted for over one (1) second.	
Seize	2250	-14 <u>+1</u>	Continuous up to 1.5 sec	min of 250 msec cutoff by seize ack
Seize Acknowledge (Lines)	570	-14 <u>+1</u>	Continuous up to 1.5 sec	until seize stops plus 250 msec
Seize Acknowledge (Trunks) Restart Signal (R)	852/1209	-14 <u>+1</u>	Continuous up to 1.5 sec	until seize stops plus 250 msec
Dial Tone	425	-14 <u>+1</u>	Continuous max 10 sec	shutoff by first digit
Ring Loop (Normal)	570	0 <u>+1</u>	3 min $\pm \frac{1}{2}$ Min Cutoff by ring trip	50 msec on 50 msec off 2 sec on 4 sec off
Ring Loop (Priority)	570/425 Freq Shift	0 <u>+1</u>	3 min $\pm \frac{1}{2}$ Min Cutoff by ring trip	50 msec 570, 50 msec 425 1 sec on, 1 sec off
Line Busy Tone	425	-14 <u>+1</u>	10 sec <u>+3</u> sec	$\frac{1}{4}$ sec on $\frac{1}{4}$ sec off
Trunk Busy Tone	425	-14 <u>+1</u>	10 sec <u>+3</u> sec	$\frac{1}{4}$ sec on $\frac{1}{4}$ sec off
Ring Back Tone	Same as Ring	-14 <u>+1</u>	3 min $\pm \frac{1}{2}$ min or until ring stops	Same as Ring

TABLE VI

AUTOMATIC SWITCHBOARD SIGNALS

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Function	Freq Hz	From Automatic Switchboard		Remarks
		Single	Duration	
Ring Trip-Trip Tone	570	Tone Level dBm	Continuous up to 15 sec	until ring trip stops. Min of 250 msec
Released Party Preempt Tone	570	-14 \pm 1	1 $\frac{1}{4}$ sec \pm $\frac{1}{4}$ sec	
Preempt Tone	570/425 Freq Shift	-14 \pm 1	1 $\frac{1}{4}$ sec \pm $\frac{1}{4}$ sec	50 msec 570, 50 msec 425
Precedence Levels	FO-697/1633 F -770/1633 I -852/1633 P -941/1633	-14 \pm 1	Same as Digit Duration	
Release	2600	-14 \pm 1	Continuous up to 3 sec	Cutoff by re-release acknowledge
Release Acknowledge (Trunks)	2600	-14 \pm 1	Continuous up to 3 sec	Cutoff by the end of release. Min of 250 msec
Test Tone	1000	-4 \pm $\frac{1}{2}$	Continuous	
Recall Response	570	-14 \pm 1	Until Recall Stops	
Proceed Signal	941/1209	-14 \pm 1	Same as Digit Duration	Cutoff by digit signal
Interdigit Signal	941/1477	-14 \pm 1	Same as Digit Duration	Cutoff by Proceed or Restart signals
<u>THE FOLLOWING THREE SIGNALS PERTAIN TO SPECIAL CIRCUITS ONLY</u>				
Idle Tone	1000	-14 \pm 1		Sent to Ringdown trunks when idle
Trunk Signal Tone	1600	-14 \pm 1	1.25 \pm .25 sec	If idle tone is on, shut off. If idle tone is off, turn on.
Trunk Signal	20 Hz \pm 5 Hz	90 Volts \pm 10% into 5000 Ohm load	1.25 \pm .25 sec	

TABLE VI

AUTOMATIC SWITCHBOARD SIGNALS (CONT'D)

5.2 Semi-Automatic, Manual Cordless Switching Equipment. Semi-automatic manual cordless switching equipment shall be designed for switching 4 kHz circuits (trunks and loops) on a 4-wire basis. These switches shall be designed to operate with tactical automatic switching equipment, paragraph 5.1. Where requirements exist it shall be provided with conversion equipment for an AUTOVON interface or for interfaces with 2-wire systems.

5.2.1 Transmission Characteristics. Same as paragraph 5.1.1.

5.2.2 Numbering Plan. Same as paragraph 5.1.2.

5.2.3 Control and Signaling Supervision Procedures. Same as paragraph 5.1.3.

5.2.4 Confirmation Signaling. Same as paragraph 5.1.4.

5.2.5 Voice Guard. Same as paragraph 5.1.6.

5.2.6 Signaling and Supervision. Signaling and supervision shall be DTMF and SF in accordance with Table VII.

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Function	Freq Hz	Single Tone Level (dBm)	Duration	Remarks
Digits 1	697/1209	-14 \pm 1	Operator controlled	Operator originated
2	697/1336			
3	697/1477			
4	770/1209			
5	770/1336			
6	770/1477			
7	852/1209			
8	852/1336			
9	852/1477			
0	941/1336			
Seize	2250	-14 \pm 1	Continuous	Min of 250 msec cut-off by Seize Ack.
Seize Acknowledge	570	-14 \pm 1	Continuous until seize stops	
Dial Tone (into Auto Swbd)	425	-14 \pm 1	Continuous Max 10 sec	Shutoff by first digit
Ring, Loop (Normal)	570	0 \pm 1	3 min \pm $\frac{1}{2}$ min Cutoff by Ring-trip	50 msec on, 50 msec off, 2 sec on, 4 sec off
Ring, Loop (Priority)	570/425 freq. shift	0 \pm 1	3 min \pm $\frac{1}{2}$ min Cutoff by Ring-trip	50 msec on, 50 msec off, 1 sec on, 1 sec off
Ringback Tone	Same as Ring	-14 \pm 1	Same as Ring	Same as Ring
Ring Trip-Trip	570	-14 \pm 1	Min of 250 msec	Cutoff by end of Ring Trip
Preempt Tone	1000	-14 \pm 1	Operator Controlled or Timed	$\frac{1}{4}$ sec on, $\frac{1}{4}$ sec off
Precedence Levels	FO 697/1633 F 770/1633 I 852/1633 P 941/1633	-14 \pm 1	Operator Controlled	
All Links Busy	1000	-14 \pm 1	Subscriber Contr.	$\frac{1}{4}$ sec on, $\frac{1}{4}$ sec off

TABLE VII

MANUAL CORDLESS SWITCHBOARD AND CONVERTER SIGNALING

Function	Freq Hz	Single Tone Level (dBm)	Duration	Remarks
Recall/Line Priority	941/1209	-14 \pm 1	Operator Control	
Recall Response	570	-14 \pm 1	Until Recall Stops	
Release	2600	-14 \pm 1	Continuous to 3 to 10 sec.	Cutoff by Release
Release Ack	570	-14 \pm 1	Continuous to 10 sec.	Cutoff by end of Release. Min 250 msec
Test Tone	1000	-4 \pm 1/2	Continuous	
Trunk Signal Tone	1600	-14 \pm 1	1.25 \pm .25 sec	If idle tone is on shut off. If idle tone is off turn on.
Trunk Signal	20 Hz \pm 5 Hz	90 volts + 10% into 5000 Ohm load	1.25 \pm .25 sec	

TABLE VII

MANUAL CORDLESS SWITCHING AND CONVERTER SIGNALING (CONT'D)

5.3 Manual Switchboards.

5.3.1 Trunk Signaling.

5.3.1.1 Metallic Trunks. Switchboards shall transmit a 90 Volt rms $\pm 10\%$ ringing signal across a 5000 Ohm load, at a frequency of 20 Hz $\pm 10\%$. The ringing signal shall have a duration governed by manual operation of a key, or equivalent device. A 20 Hz ringing signal from a 12 Volt rms 4000 Ohm source shall operate the signal receiving devices in the switchboard.

5.3.1.2 Repeatered, Carrier Derived and Radio Trunks. Switchboards shall employ the same signals as for metallic trunks. The 20 Hz signals shall be converted to 1600 Hz signals for transmission over the trunk. The 1600 Hz transmitting power shall -8 dBm ± 4 dB. The receiving sensitivity shall be at least sufficient for satisfactory operation on a 1600 Hz (± 30 Hz) received signal of -25 dBm.

5.3.2 Loop Signaling. Loop signaling shall be one of two types, i.e., common battery or ringdown, or shall be compatible therewith.

5.3.2.1 Common Battery Signaling. Common battery signaling shall employ a dc closure at the user's telephone to signify to the switchboard that the telephone is off hook. A dc open circuit at the user's telephone shall indicate to the switchboard that the user's telephone is on the hook. The switchboard shall employ a 20 Hz ringing signal of 90 Volts rms to the user's telephone.

5.3.2.2 Ringdown Signaling. Ringdown signaling shall employ 20 Hz signals for signaling both the switchboard and the user. The switchboard shall transmit a signal of at least 90 Volts rms at 20 Hz and shall operate satisfactorily on a received signal of 12 Volts rms, or higher, in the range of 16 Hz to 25 Hz.

5.3.3 Loss Caused by Signaling Device. At frequencies between 300 and 3500 Hz, the loss caused by trunk signaling equipment bridged across the 4 kHz trunk shall be less than 0.5 dB.

6. END INSTRUMENTS

6.1 Teletypewriter and Data Equipment.

6.1.1 Standard Coded Character Set. The standard code and alphabet for teleprinter and digital data, character conscious communications equipment shall be the USA Standard Code for Information Interchange (USASCII) X3.4-1967 as presented in Appendix C of this standard. International Telegraph Alphabet No. 5 (ITA No. 5) is the international version of USASCII.

USASCII does not necessarily apply to equipment or systems such as central processors, peripheral or other related equipment used substantially full time as part of the control element in a larger system, where that larger system (weapons control for instance) is not itself primarily concerned with information activities. Neither does it apply to such established specialized functions as telephone signaling, telemetry, pulse code modulation, vocoded speech, brevity code systems, etc.

6.1.1.1 Basic Code. This code is composed of seven units (bits) as provided for in USA Standard (USAS) X3.4-1967 and one parity unit as provided for in USAS X3.16-1966. However, the parity unit as discussed in paragraph 6.1.1.3 below differs in its use for asynchronous transmission as specified in USAS X3.16-1966. The parity bit shall follow the most significant bit, b_7 , of the character to which it applies as provided for in USAS X3.15-1966. The coded character set is to be transmitted low order first as also provided for in X3.15-1966; thus b_1 will appear on-line first and b_7 last, followed by the parity bit.

6.1.1.2 Character Substitutions. Character substitutions in the USASCII (FIPS 1) character sets are not permissible without specific approval of US Department of Commerce/National Bureau of Standards as specified in FIPS Pub 7, Section 9, Waivers.

6.1.1.3 Parity Bit. For transmission from end instruments, the eighth bit, when used for parity or control purposes, is set so that the sum of the binary ones of the eight-bit code character is always odd (odd parity). At reception, the detection of an even sum of the binary ones indicates a character error. For recording on paper tape and edge-punched cards the parity bit is inverted so that the sum of the binary ones is even (even parity). (In AUTODIN odd/even techniques are employed for internal system controls, error detection/correction, etc., wherein communication terminal equipments will transmit those control characters for channel control and coordination using even parity.)

6.1.1.4 Application of Standard Coded Character Set. The standard set defined above will be used in the applications listed below.

6.1.1.4.1 It will be the alphabet used for transmission of switching and supervisory information in data communications systems of the character conscious type.

6.1.1.4.2 It will be the common user alphabet of input-output devices interchanging information.

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6.1.1.5 Character Interval.

6.1.1.5.1 Transmitting, Start/Stop. The preferred standard start/stop character interval shall consist of ten signal elements having equal time intervals; one "O" (spacing) start element, seven USASCII elements, one character parity element, and one (marking) stop element. The inter-character interval (the time between the end of the stop element and the beginning of the next start element) may be any length, and is of the same sense as the stop element, i.e., marking. An eleven-unit character interval is permissible where such operation is technically more satisfactory, provided that one of the standard modulation rates is employed.

6.1.1.5.2 Receiving, Start/Stop. The standard start/stop character interval (as regards functioning of the receiver apparatus) shall be 9.6 units, i.e., the receive device shall be prepared to correctly accept the next character interval by not more than 9.6 unit intervals from the beginning of the start pulse. The receiver device shall be capable of operating with an inter-character interval of any length.

6.1.1.5.3 Synchronous. An eight-unit character interval shall be standard for synchronous transmission as provided for in USAS X3.16-1966.

6.1.1.6 Modulation Rate. The modulation formula for tactical equipments shall be 75×2^m baud, where m is a positive integer. For low speed serial start/stop equipments, m shall be 0 or 1. For high speed serial start/stop equipments, m may have any of the values 0,...,7, (i.e., the values that may be assigned to m are specified as opposed to the number of values of m to be provided in an equipment).

6.1.1.7 Interface Characteristics. Equipment which utilizes the Standard Coded Character Set shall provide the Standard Interface (para 7.2.1).

6.1.1.8 Keyboards. Standards for keyboards used in tactical end instruments shall be in accordance with MIL-STD-1280, Military Standard Keyboard Arrangements.

6.1.1.8.1 Communication Service. The arrangement of the MIL-STD-1280 keyboard used for tactical communication service is shown for information purposes in Appendix C.

6.1.1.8.2 Weather Data Service. The present indication is that a keyboard with special weather symbols will not be required in the future for this service.

6.1.1.8.3 Data Service. The numeric cluster arrangement of the MIL-STD-1280 keyboard used for data service is shown for information purposes in Appendix C.

6.1.1.8.4 System Application. MIL-STD-1280 includes a notation system to be used in adopting the general purpose arrangements to particular systems. The notation diagram is shown for information purposes in Appendix C.

6.1.2 Interim Standard Coded Character Set. The interim standard code and alphabet for teleprinter and digital data communications equipment shall be the International Telegraph Alphabet No. 2 (ITA No. 2), American Version, reproduced in Appendix C. Its use is currently widespread and it will continue to be used for an indeterminate period. During this period the following standards shall govern in those areas where a changeover to ITA No. 5 is not advisable or feasible.

6.1.2.1 Basic Code. This code is composed of five units as indicated in Appendix C. The coded character set is to be transmitted low order first; thus b_1 will appear on-line first and b_5 last.

6.1.2.2 Character Interval.

6.1.2.2.1 Transmitting, Start/Stop. The standard start/stop character interval for 5-unit code, printing telegraph, transmitting equipment shall be 7 units; i.e., a 1-unit start element, 5 1-unit intelligence elements and a 1-unit stop element. (The designer is reminded that there is currently in widespread use transmitting equipment which uses a 7.42 character interval.)

6.1.2.2.2 Receiving, Start/Stop. The standard start/stop character interval (as regards the functioning of the receiver apparatus) shall be 6.6 units, i.e., the receive device shall be prepared to correctly accept the next character interval by not more than 6.6 unit intervals from the beginning of the start pulse. The receive device shall be capable of operating with an intercharacter interval of any length.

6.1.2.3 Modulation Rate. The modulation rate for new equipment which incorporates electronic input/output is 50 and 75 baud. (The designer is reminded that the equipment currently in widespread use has modulation rates of 45.45, 50, 56.9 and 74.2 baud.)

6.1.2.4 Modulation Rate Accuracy. See paragraph 6.1.4.2.

6.1.2.5 Interface Characteristics. See paragraph 7.2.2. New equipment shall provide both interfaces during the period when high level interface equipment is being phased out.

6.1.2.6 Keyboards. See Appendix C.

6.1.3 Printing Telegraph Equipment, Functional Description.

6.1.3.1 Page Printing Equipment. The basic unit employed in printing telegraphy is the page printer. This is a device which generally types, on paper fed from a roll, a line of printed characters. Some machines also use fanfold paper. The paper may be fed by friction, or sprockets or both. There are two standard character sets in use within the DCS, weather symbols and communication symbols. (See Appendix C.)

6.1.3.1.2 Line Length, Page Copy. In AUTODIN, 80 characters (printing positions) per line is standard. This was chosen so that an 80 character unit record card will fit on one line of a printed page. In the weather service, 76 characters per line is standard. In CONUS messages, 72 characters per line is common practice. In US/NATO military circles, 69 characters per line is the agreed upon standard.

6.1.3.2 Tape Readers. There are two basic classes of mechanical tape readers: (1) Coincident selection in which all pins of the tape reader sense the tape simultaneously; and (2) sequential selection readers in which pins 1, 2, 3, 4 and 5 are successively presented to the tape to determine the presence or absence of a perforation. Each method of selection has certain mechanical design advantages. Some of the tape readers appearing in the DCS inventory have provision for reading additional tracks in the tape as future requirements develop for 6, 7 or 8 track tape.

Many of the modern tape readers employ a photosensitive technique for determining the presence or absence of a perforation. Some of these readers operate on the "sequential selection" principal but operation on the "coincident selection" principal is more predominant.

There are no standards established at this time for the method of sensing punched tape beyond that the reader can correctly sense the standard tape without modification of, or damage to, the standard tape.

6.1.3.3 Tape Punches. There are two basic types of punches:

- (1) Nonprinting punches in which only data and feed holes are punched in the tape.
- (2) Printing punches in which, in addition to punching data and feed holes, the characters are printed on the tape.

There are two methods of printing on the tape:

- (1) The printing is in line with the feed holes and six characters behind the corresponding data holes.
- (2) The printing is between the sixth and seventh feed holes following the corresponding data holes.

In each type of punch there are two methods of punching the holes:

- (1) Chadless or partially punched holes.
- (2) Chadded or fully punched holes.

Each punching method has its advantages but the chadded or fully punched method is standard in military equipment.

6.1.4 Performance Characteristic of Printing Telegraph Equipment.

6.1.4.1 Distortion Characteristics. The distortion percentages specified are applicable at the modulation rate employed by the equipment.

6.1.4.1.1 Transmitting Devices. Electromechanical sequential selection transmitting (keyboard, tape readers).

6.1.4.1.1.1 High Performance Equipment Output Distortion, All Types. 1.0% Mark-0-1.0% Space.

6.1.4.1.1.2 Low Performance Equipment Output Distortion, All Types. 4% Mark-0-4% Space.

6.1.4.1.2 Electromechanical Coincident Selection Transmitting Devices (keyboard, tape readers).

6.1.4.1.2.1 High Performance Equipment Output Distortion, All Types. 1% Mark-0-1% Space.

6.1.4.1.2.2 Low Performance Equipment Output Distortion, All Types. 3% Mark-0-3% Space.

6.1.4.1.3 Transmitting devices, electromechanical, electronic, or composite, incorporating electronic outputs (either sequential or coincident selection), output distortion all types not to exceed 1% Mark, 0, 1% Space.

6.1.4.1.4 Receiving Devices, Electromechanical.

6.1.4.1.4.1 High Performance Equipment Distortion Tolerance. Switch Bias Distortion: 45% Mark-0-45% Space. Bias Distortion: 45% Mark-0-45% Space. End Distortion: 45% Mark-0-45% Space. Cyclic Distortion: 22.5% Mark-0-22.5% Space.

6.1.4.1.4.2 Low Performance Equipment Distortion Tolerance. Switched Bias Distortion: 30% Mark-0-30% Space. Bias Distortion: 30% Mark-0-30% Space. End Distortion: 30% Mark-0-30% Space. Cyclic Distortion: 15% Mark-0-15% Space.

6.1.4.1.5 Receiving Devices, Electronic Input. Switched Bias Distortion: 49% Mark-0-49% Space. Bias Distortion: 49% Mark-0-49% Space. End Distortion: 49% Mark-0-49% Space. Cyclic Distortion: 24.5% Mark-0-24.5% Space.

6.1.4.2 Modulation Rate Accuracy, Start/Stop Transmission. The transmitting equipment shall maintain a modulation rate accuracy so that, in any given character interval, every transition shall be within 1% of the theoretically correct transition point measured with reference to the stop-to-start transition of that character at the given modulation rate for high performance equipment; for low performance equipment the tolerance shall be 5%.

6.1.4.3 Clutch Magnet Sensitivity. At modulation rates up to 100 bauds the sensitivity of the clutch magnet of electromechanical equipment shall be such that a 25 ± 5 millisecond DC pulse not in excess of 130 volts and 60 milliamperes shall cause correct operation of the transmit device. For electromechanical devices incorporating electronic input/output and/or stepping circuits, the dc digital interface characteristics apply (see para 7.2.1).

6.1.4.4 Words Per Minute. The use of this term in technical description is deprecated. However, words per minute for printing telegraphy is expressed by the formula:

$$\text{WPM} = \frac{10 \times \text{Mod Rate (in baud)}}{\text{Units per character interval}}$$

$$\text{e.g. } 150 \text{ WPM} = \frac{10 \times 150}{10}$$

when a ten-unit character interval USASCII machine operates at 150 baud.

6.1.4.5 Paper Line Feed Operation. New start/stop receiving equipment for 15 characters per second or less, shall be capable of, in one character interval, returning the printing point to the left side of the page and advancing the page one step (1 or 2 lines) in response to the code combination for Line Feed. (For higher speed equipment appropriate techniques may be applied.) (See also par 2.6.5 Special Considerations in Appendix C.)

6.1.4.6 Clock Operation. New start/stop equipment employing electronic input/output shall be capable of operating under external (master or station) clock control at the applicable modulation rate in the bit synchronous transmission mode with 7 thru 16 units per character interval. (Refer to para 7.2.10 and Clock-Data Phase Relationships, Appendix B.)

6.1.4.7 Character Stepped Operation. New start/stop equipment shall be capable of operating under step control where the step interval is equal to or greater than the character interval at the applicable modulation rate.

6.1.4.8 Remoted Controls Exclusive of Clock or Data. An open remote control line shall have no effect on the device to be controlled and a closed remote control line shall cause the device to be controlled to execute the applicable function. The controlling device shall provide only the switch. There shall be a maximum of 6 volts and 1 milliamperes on a remote control line.

6.1.4.9 Electromagnetic Interference Characteristics. Refer to MIL-STD-461.

6.1.4.10 Reliability Characteristics. The theoretical reliability characteristics for electromechanical printing telegraph equipment are difficult to achieve in practice due to the wide range of environmental and maintenance skills to which the equipment is subjected. Mechanical printing telegraph equipment should be considered high performance if it

operates correctly (essentially continuously) for 1500 hours at 75 baud, 7-unit code or 150 baud 10-unit code. NOTE: The changing of paper or ribbons is not considered maintenance. The failure of equipment associated with, but not a part of, the actual typing, punching or reading units shall not be considered in the 1500 hour characteristic.

6.1.5 Teletypewriter Recording Media.

6.1.5.1 Teletypewriter Roll Paper. The standard roll paper is for friction feed, is $8\frac{1}{2}$ inches wide, and is in accordance with Federal Specification UU-P-547.

6.1.5.2 Teletypewriter $8\frac{1}{2}$ Fanfold Paper. The standard $8\frac{1}{2}$ fanfold paper is for sprocket feed and is in accordance with Military Specification MIL-P-40023. The paper colors and the number of parts may be varied since these parameters do not adversely affect the standardization of the printing machines.

6.1.5.3 Paper Tape.

6.1.5.3.1 Information Tracks. The standard for identifying information tracks is established as a two part standard for the following machine systems:

a. For machine systems with the capability of utilizing three information tracks between the guiding edge and feed hole, in accordance with Figure 2, Appendix B.

b. For machine systems with the capability of utilizing two information tracks between the guiding edge and feed hole, in accordance with Figure 2, Appendix B. This standard is not to be used in future design. NOTE: When preparing punch instructions, the symbol O will represent an information element. Therefore, when denoting the feed hole use the symbol F rather than O.

6.1.5.3.2 Tape Width.

6.1.5.3.2.1 A minimum tape width of one inch (with tolerances as specified in Federal Specification UU-T-120) is established for systems with the capability of utilizing three information tracks between the guiding edge and the feed hole (Figs 2 and 3, Appendix B).

6.1.5.3.2.2 Minimum tape widths of $11/16$ inch and $7/8$ inch (with tolerances as specified in Federal Specification UU-T-120) are established for systems with the capability of utilizing two information tracks only between the guiding edge and the feed hole (Figs 2 and 3, Appendix B).

6.1.5.3.2.3 Chadded Tape. Where perforated tape is used, holes shall be completely perforated (chadded).

6.1.6 Polar Relays.

6.1.6.1 Electromechanical Polar Relays. There are no standard electromechanical polar relays specified for US military applications. The minimum required performance characteristic for electromechanical polar relays are:

6.1.6.1.1 Side Stable. The relays shall be side stable, i.e., they shall remain in the last signaled contact position.

6.1.6.1.2 Operating Differential. Not in excess of 5 mA.

6.1.6.1.3 Distortion. Modulation rates up to 75 baud shall be handled with less than 2% distortion (all types) introduced by the relay performance.

6.1.6.1.4 Winding Current. Maximum operating current per winding shall not exceed 80 mA.

6.1.6.1.5 Winding dc resistance: 100-200 Ohms.

6.1.6.1.6 Reactance not specified.

6.1.6.1.7 Contact material is not specified. Extreme operating conditions: 150 mA; 260 Volts. Typical battery source impedance 160 Ohms.

6.1.6.1.8 International Octal Base Pin Connections. (Pins viewed from bottom of socket.)

Pin #1, Coil #1 positive (potential causing relay armature to make marking contact) termination.

Pin #2, Coil #2 negative termination.

Pin #3, Coil #2 positive termination.

Pin #4, Space contact.

Pin #5, Ground of relay case if applicable.

Pin #6, Armature (tongue) of relay.

Pin #7, Marking contact.

Pin #8, Coil #1 negative termination.

6.1.6.2 Electronic Polar Relays. Great care must be made in accepting an electronic (solid state) substitute for the electromechanical polar relay. It shall meet the following minimum required performance standards.

6.1.6.2.1 Side Stable. The relays shall be side stable, i.e., they shall remain in the last signaled contact position.

6.1.6.2.2 Operating Differential: 2 mA (maximum).

6.1.6.2.3 Modulation Rates. Modulation rates up to 4800 baud are considered desirable. However, to minimize the relay's response to transients, it may be useful to dampen the relay in a manner that limits its operation in a given application to ranges under 100, 500, 1000, 1500, 2500, 5000, etc. baud.

6.1.6.2.4 Distortion. The relay shall not introduce distortion (all types) in excess of 1% at the applicable modulation rate.

6.1.6.2.5 Number of Windings (or equivalent): Two. Maximum operating current: 80 mA.

6.1.6.2.6 Winding dc Resistance (or equivalent): Not in excess of 200 Ohms.

6.1.6.2.7 Reactance of input/output essentially 0 Ohms with regard to the applicable modulation rate.

6.1.6.2.8 Output Impedance: Less than 50 Ohms. Maximum signal current: 150 mA. Maximum potential applied across the mark and tongue or space and tongue: 260 Volts. Maximum voltage referenced to signal ground: 130 Volts.

6.1.6.2.9 International Octal Base Pin Connections. (Pins viewed from bottom of socket.)

Pin #1, Coil #1 positive (potential causing relay armature to make marking contact) termination.

Pin #2, Coil #2 negative termination.

Pin #3, Coil #2 positive termination.

Pin #4, Space contact.

Pin #5, Ground of relay case if applicable.

Pin #6, Armature (tongue) of relay.

Pin #7, Marking contact.

Pin #8, Coil #1 negative termination.

6.2 Telephone Instruments.

6.2.1 Two-Wire Field Type. Standards for two-wire field type telephones apply to a large inventory of telephone instruments that are in widespread use for tactical field applications. It is to be expected that they will be used for many years until phased out by four-wire instruments or other more modern designs.

6.2.1.1 Terminal Impedance. The terminal impedance of the telephone set shall be 600 Ohms \pm 10%. Permissible phase shift shall lie between the limits of 0° and $\pm 20^{\circ}$.

6.2.1.2 Sidetone. A sound pressure of 28 dynes per square centimeter from a 1000 Hz source into the transmitter shall produce a sound pressure of 6 dynes per square centimeter from the receiver in conjunction with a six cubic centimeter coupler.

6.2.1.3 Electromagnetic Interference Characteristics. Refer to MIL-STD-461.

6.2.1.4 Transmit Direction.

6.2.1.4.1 Output Power Level. A 1000 Hz signal with a sound pressure of 28 dynes per square centimeter at the grid of the transmitter shall produce -6 dBm \pm 2 dB into a 600 Ohm load measured at the 2-wire output of the telephone set.

6.2.1.4.2 Amplitude Clipping Level. No amplitude clipping shall occur below a sound pressure corresponding to +3 dBm.

6.2.1.4.3 Amplitude vs Frequency Characteristic. The output in the transmit direction shall have a 2 dB per octave slope rising from 500 Hz to 3000 Hz. The output at 300 Hz and 3500 Hz shall not be more than 3 dB down relative to the extrapolated value of the slope.

6.2.1.4.4 Noise. The noise output in the transmit direction shall be not greater than -40 dBm with no input sound pressure.

6.2.1.4.5 Signaling Generator Output.

6.2.1.4.5.1 Level. The output power available from the signaling generator shall be 1.75 Watts into 1500 Ohms.

6.2.1.4.5.2 Frequency. A crank speed of 200 rpm \pm 5 rpm shall produce a frequency of 20 Hz.

6.2.1.5 Receive Direction.

6.2.1.5.1 Sensitivity. A 1000 Hz input to the telephone set at a level of -32 dBm at the 2-wire input to the telephone set, shall produce a sound pressure from the receiver, in conjunction with a six cubic centimeter coupler, of 2 dynes per square centimeter.

6.2.1.5.2 Amplitude Clipping Level. No amplitude clipping shall occur with inputs of +3 dBm or less.

6.2.1.5.3 Amplitude vs Frequency Characteristic. Relative to the response at 1000 Hz, equal input power at frequencies from 500 to 3000 Hz shall produce an output sound pressure within 3 dB of the sound pressure at 1000 Hz.

6.2.1.5.4 Harmonic Distortion. The total harmonic distortion in the receiver direction shall be less than 5% for all input signals within the band 300 to 3500 Hz with input level at 0 dBm.

6.2.1.6 Ringer.

6.2.1.6.1 Impedance. The impedance of the ringer shall be not less than 6000 Ohms at 20 Hz and 35 Volts, and the inductance of the ringer shall be not less than 15 Henries at 2 Volts and 900 Hz.

6.2.1.6.2 Input Sensitivity. The ringer shall be actuated by an input to the ringer of 25 Volts at 15 Hz, and 38 Volts and 25 Hz.

6.2.1.7 Control and Supervision.

6.2.1.7.1 Local Battery. For the local battery mode of operation, microphone power shall be integral with the telephone set. Signaling to the other end of the line (magneto switchboard or other telephone) shall be achieved by a hand driven 20 Hz generator integral to the telephone set. A 20 Hz ringing signal introduced at the far end of the line (magneto switchboard or other telephone) shall actuate an alarm integral to the telephone set. This alarm shall be visual or audible or both.

6.2.1.7.2 Common Battery Supervision. In the common battery supervision mode of operation, microphone power shall be integral with the telephone set. Signaling to other end of the line (switchboard only) shall be achieved by dc closure. Ringing from the far end of the line shall be an integral alarm actuated by a 20 Hz signal.

6.2.1.7.3 Common Battery. In the common battery mode of operation, microphone power shall be provided by the switchboard over the line. Signaling to the switchboard shall be by dc closure. Ringing from the switchboard shall be by an integral alarm actuated by a 20 Hz signal.

6.2.2 Two-wire and Four-wire Commercial. When necessary to employ commercial telephones in the military communication system, these telephones shall meet the applicable electrical requirements for field telephones insofar as practicable. A military version of a commercial telephone is used in some tactical systems. For a description of its electrical characteristics refer to DCAC 370-V165-1. For further information on use of this telephone in tactical systems refer to paragraph 4.2.2.

6.2.3 Four-wire Field Type.

6.2.3.1 Transmission Characteristics.

6.2.3.1.1 Output (Transmitting Direction). A 1000 Hz acoustic tone, with a sound pressure of 28 dynes per square centimeter, applied at a distance of $\frac{1}{4}$ inch from the mouthpiece of the microphone, shall produce an electrical output power of -4 dBm into a 600 Ohm load measured at the 4-wire output of the telephone set. Permissible variations shall be within the limits of -2 dBm and -9 dBm.

6.2.3.1.2 Limiting, Transmitting Direction. Limiting shall not occur for outputs (para 6.2.3.1.1) below +3 dBm.

6.2.3.1.3 Receiver Sensitivity. A 1000 Hz signal at a power of -32 dBm inserted at the 4-wire receive terminals of the telephone set shall produce a sound pressure from the receiver, in conjunction with a 6 cubic centimeter coupler, of at least 2 dynes per square centimeter. (In 4-wire transmission it is permissible for the acoustical volume of the receiver to be adjustable to suit the listeners preference for loudness.)

6.2.3.1.4 Limiting, Receiving Direction. Limiting shall not occur for inputs to the 4-wire terminals of the receiver of +3 dBm or less.

6.2.3.1.5 Harmonic Distortion, Transmitter or Receiver. The total harmonic distortion within the band between 300 Hz and 3500 Hz produced by any single test frequency, of less power than that which would cause limiting to occur, shall be at least 25 dB below the power of the test frequency.

6.2.3.1.6 Sidetone. Sidetone coupling within the telephone set shall be provided. The coupling loss from transmitter input to receiver output should be approximately 16 dB. The value is not critical, but should not be so low as to cause singing nor so high as to be ineffective.

6.2.3.1.7 Audible Signal. The audible ringing signal produced by telephone sets shall be at least 80 dB for field telephones and 50 dB for desk telephones above a sound pressure of .0002 dynes per square centimeter measured at a distance of 3 feet in any direction from the telephone set.

6.2.3.1.8 Input and Output Impedance. The input and output impedances shall be 600 Ohms, balanced to ground, with a minimum return loss of 20 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB.

6.2.3.1.9 Noise. The noise output in the transmit direction shall be not greater than -30 dBm with no input sound pressure.

6.2.3.2 Signaling. Signaling shall be in accordance with Table VIII.

6.3 Facsimile Equipment.

6.3.1 Meteorological Facsimile Equipment. Facsimile is extensively employed throughout the world for meteorological communications. The majority of the systems in use are scheduled blind broadcasts employing wire or radio facilities. When employing wire, amplitude modulation is employed and when radio facilities are used, an ancilliary amplitude/frequency modulation conversion device is required.

6.3.1.1 Meteorological Facsimile Transmitter.

6.3.1.1.1 Original Copy Size.

Function	Freq. Hz	From Telephones Single Tone Level -dBm	Duration	Remarks
Digits 1	697/1209	-7 ± 2	Subscriber Controlled	
2	697/1336			
3	697/1477			
4	770/1209			
5	770/1336			
6	770/1477			
7	852/1209			
8	852/1336			
9	852/1477			
0	941/1336			
Seize	2250	-4 ± 2	Continuous	Min of 250 msec cutoff by Seize Ack
Ring Trip Tone	2250	-4 ± 2	Continuous	Min of 250 msec cutoff by Ring- trip-trip
Recall/Line Priority	941/1209	-7 ± 2	Subscriber Controlled	
Release	2600	-4 ± 2	Continuous with maximum of 3 to 10 sec.	Cutoff by Release Ack.
Conference	941/1477	-7 ± 2	Subscriber Controlled	
Conference Release	941/1209	-7 ± 2	Subscriber Controlled	

NOTE: The tolerance on all frequencies is $\pm 1.3\%$ unless otherwise noted.

TABLE VIII
TELEPHONE SIGNALS

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6.3.1.1.1.1 Drum Scanners. The scanning system of the transmitter shall accept an original copy 18 5/8 inches wide (473 mm) with tolerances not to exceed +1/16 to -3/32 inches and 12 inches (305 mm) (or integral multiples thereof) in length and of thickness no greater than 0.010 inch.

6.3.1.1.1.2 Continuous Scanners. A continuous (flat bed scanner) shall accept and properly scan an original copy 18 5/8 inches (473 mm) wide and at least 2 inches long. The copy need not be precisely sized or have square edges. NOTE: It is desirable that flat bed scanning devices accept, but not necessarily scan, originals of greater width than 18 5/8 inches and of indefinite length.

6.3.1.1.2 Original Copy Characteristics. The facsimile scanner shall be designed to accept any original copy normally used for meteorological charts and shall have a spectral sensitivity corresponding to the RMA S-4 photo-surface. It shall transmit marks on the copy made by any visible color used for printing. NOTE: The inclusion of an automatic level control system capable of compensating for variations in the background density or color of the original copy is desirable to eliminate manual adjustments between copies.

6.3.1.1.3 Scanning Line Length. The total length of the scanning line shall be 18.85 inches (478.8 mm).

6.3.1.1.4 Scanning Direction. The scanning direction shall be normal (corresponding to a left-hand Helix).

6.3.1.1.5 Dead Sector. A sector at the end of the scanning line 0.5 inches in length shall be provided which shall not be optically scanned. This dead sector shall coincide with the time position of the phasing signal (see para 6.3.1.1.3.2) when the phasing signal is transmitted. The signal transmitted by the transmitter when scanning the dead sector shall be the equivalent of scanning 1/4 inch of full black and then 1/4 inch of full white. NOTE: This characteristic signal is specified to permit manually phasing a facsimile recorder under adverse transmission conditions and to provide information for an automatic control system for the recorder.

6.3.1.1.6 Scanning Speeds. The scanning speed shall be 60, 90, and 120 strokes per minute. The selection of the scanning speed shall be by means of a suitable control on the device and rapidly made by the machine operator.

6.3.1.1.7 Line Advance. The line advance shall be 1/96 inch (0.25 mm).

6.3.1.1.8 Scanning Spot Size. The scanning spot size shall be .010 inch x 0.010 inch, and be constant along the scanning line.

6.3.1.1.9 Index of Cooperation. The index of cooperation shall be 576.

6.3.1.1.10 Scanning Linearity. To protect the dimensional fidelity of the system, the physical position of the scanning spot shall not depart from the theoretical position thereof by more than 1/96 inch per inch of scanned copy. This relation applies in the direction of the scanning line as well as perpendicular to it.

6.3.1.1.11 Signal Characteristics.

6.3.1.1.11.1 Signal Output Characteristics. The signal output of the facsimile transmitter shall be adjustable between +10 dBm and -10 dBm. The output impedance shall be 600 Ohms, balanced to ground, with a minimum return loss of 20 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB. No signal shall be transmitted when the transmitter is in standby or idle condition. A suitable output signal level monitor will be provided. The carrier frequency shall be a sinusoidal voltage of 2400 Hz maintained at an accuracy of at least 3 parts per 10^6 .

6.3.1.1.11.2 Signal Contrast. The signal contrast shall be 20 dB + 2 dB and black transmission shall be employed. NOTE: It is desirable that either black or white transmission be provided on a selectable basis.

6.3.1.1.11.3 Halftone Characteristic. The voltage output/copy density relation of the transmitted signal shall be nominally linear.

6.3.1.1.12 Synchronization. The scanning rates of the transmitter shall be controlled by a self-contained frequency standard maintained at the assigned frequency within 3 parts per million. The frequency driving the synchronous drive system of the scanner shall be 300 Hz or an integral multiple thereof.

6.3.1.1.13 Control Functions. To effect automatic operation, it is necessary to transmit to a facsimile recorder a start command, a signal to permit recorder phasing, and a stop command. The transmitter operating cycle shall conform to this cycle as follows:

6.3.1.1.13.1 Start Tone. When activated, the transmitter shall transmit alternate black and white levels modulated at a rate of 300 \pm 0.1 times per second for a period of five seconds.

6.3.1.1.13.2 Phasing Signal. Immediately after cessation of the start signal, a black signal, interrupted by a white pulse of duration of not less than 2.5% and not more than 5% of the scanning line and coincident with the leading edge of the dead sector (see para 6.3.1.1.5) shall be transmitted. This signal shall be transmitted for between 15 and 20 seconds. Upon termination of this signal the transmitter shall initiate scanning of the copy.

6.3.1.1.13.3 Stop Tone. Upon completion of the scanning, the transmitter shall automatically transmit an alternate black and white signal

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interrupted at a rate of 450 ± 0.1 times per second for a period of not less than 4 nor more than 10 seconds.

6.3.1.1.13.4 Manual Operation. Controls shall be provided on the transmitter to permit the operator to start, or stop the transmitter, or transmit phasing signals manually. Provisions shall also be included within the transmitter to permit the operator to transmit unmodulated black or white signals indefinitely for circuit adjustment purposes.

6.3.1.1.14 Power Requirements. No power requirements are stipulated in these standards, however, no information or frequency obtained from the power source shall be utilized to derive any frequency or timing rates within the transmitter.

6.3.1.2 Meteorological Facsimile Receiver.

6.3.1.2.1 Recorded Copy Size.

6.3.1.2.1.1 Drum Recorders. The drum of these recorders shall accept recording media 18 5/8 inches wide with tolerances not to exceed $+1/16$ to $-3/32$ inches and 12 (or integral multiples thereof) inches long.

6.3.1.2.1.2 Continuous Recorders. The continuous recorder shall accept a 400 foot roll of recording media, wound on a core of 1 inch, $+1/4$ inch, inside diameter, 18 5/8 ($+1/16$ to $-3/32$) inches wide. If pressure sensitive recording techniques are employed, the transfer tissue shall be supplied from a spool 400 feet in length, wound on a core of 1 inch $+1/4$ inch inside diameter, and 18 5/8 inches ($+3/8$ to -0 inches) wide.

6.3.1.2.2 Scanning Line Length. The total length of the scanning line shall be 18.85 inches (478 mm).

6.3.1.2.3 Scanning Direction. The scanning direction shall be normal (corresponding to a left-hand Helix).

6.3.1.2.4 Scanning Speed. The scanning speed shall be 60, 90, and 120 strokes per minute. The selection of the scanning speed shall be by means of a suitable control on the receiver and made by the machine operator.

6.3.1.2.5 Line Advance. The line advance shall be 1/96 inch (0.25 mm).

6.3.1.2.6 Recording Spot Size. The recorded spot shall be 0.010 x 0.010 inches.

6.3.1.2.7 Index of Cooperation. The index of cooperation shall be 576.

6.3.1.2.8 Dead Sector. The signal transmitted during the interval the transmitter is scanning the dead sector may be blanked within the recorder if operationally desirable.

6.3.1.2.9 Dimensional Stability. Dimensional distortion between the transmitted and received copy shall not exceed 0.010 inch per linear inch when measured along the scanning line or perpendicular to the scanning line.

6.3.1.2.10 Signal Characteristics.

6.3.1.2.10.1 Input Circuit. The input circuit shall have nominal impedance of 600 Ohms, balanced to ground, with a minimum return loss of 20 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB. The input circuit shall be designed to withstand the ringing voltage impressed on a telephone circuit.

6.3.1.2.10.2 Input Power Level. The receiver shall operate properly when input signal corresponding to white signal power levels between -10 dBm and -56 dBm is received.

6.3.1.2.11 Operating Controls. A gain control, an independent density control, a manual phasing control, and a start and stop control shall be provided in a convenient location on the receiver. A white/black transmission selector is desirable.

6.3.1.2.12 Synchronization. The scanning rates of the recorder shall be controlled by a self-contained frequency standard maintained at the assigned frequency within 3 parts per million. The frequency driving the synchronous drive system of the receiver shall be 300 Hz or an integral multiple thereof.

6.3.1.2.13 Control Functions. The facsimile recorder shall reliably start, phase, and stop when signals are received from the transmitter. It shall be possible for the operator to override any automatic function with operating controls described above.

6.3.1.2.14 Power Requirements. No power requirements are stipulated in these standards, however, no information or frequency obtained from the power source shall be utilized to derive any frequency or timing rate with the receiver.

6.3.2 Meteorological Facsimile Receiver (Small Format).

6.3.2.1 General. The facsimile receiver shall employ continuous recording techniques and a recording medium capable of resolving at least 200 lines per inch. The receiver shall employ a recording medium that is stable in its operating environment, has indefinite storage life, and does not fade upon exposure to light. The capability of the receiver to produce multiple copies and reproducible on office type duplicators is desired.

6.3.2.2 Recorded Copy Size. The recorded copy shall be $8\frac{1}{2}$ inches wide. The length is dependent on the duration of the transmission. The

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recorder shall accept a 400 foot roll of recording medium spooled on a $1 + \frac{1}{4}$ inch inside diameter core and if carbon tissue is employed, the carbon tissue shall be supplied from a separate roll of 400 feet spooled on a core $1 + \frac{1}{4}$ inch inside diameter.

6.3.2.3 Scanning Line Length. The total scanning line length shall be 8.64 inches (220 mm).

6.3.2.4 Scanning Direction. The scanning direction shall be normal (corresponding to a left-hand helix).

6.3.2.5 Scanning Speed. The scanning speed shall be 60, 90, 120, and 180 strokes per minute. The selection of the scanning speed shall be by means of a suitable control on the receiver and made by the machine operator.

6.3.2.6 Index of Cooperation. The indices of cooperation shall be 576 and 264. Selection of the index shall be accomplished by a suitable control on the receiver and made by the machine operator. NOTE: Certain meteorological charts are transmitted at an index of 288. Operation using an index of 264 when recording these transmissions will result in negligible dimensional distortion. The capability to operate at an index of cooperation of 264 standard affords interoperability with other facsimile systems without dimensional distortion.

6.3.2.7 Line Advance. The line advance shall be $1/209.5$ or $1/96$ inch (selected by the index of cooperation control).

6.3.2.8 Recording Spot Size. The recorded spot size shall be $1/200$ inch X $1/200$ inch.

6.3.2.9 Dead Sector. The signal transmitted during the interval the transmitter is scanning the dead sector may be blanked if operationally desirable.

6.3.2.10 Signal Characteristics.

6.3.2.10.1 Input Circuit. The input circuit shall have a nominal impedance of 600 Ohms, balanced to ground, with a maximum return loss of 20 dB against a 600 Ohm resistance over the frequency range of 300 to 3500 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB. A high impedance bridging input of at least 2500 Ohms shall also be provided. The input circuits shall be designed to withstand the ringing voltage normally impressed on a telephone circuit for signaling.

6.3.2.10.2 Input Power Level. The receiver shall operate properly when an input signal corresponding to white signal power levels between -10 dBm and -56 dBm is received.

6.3.2.11 Operating Controls. A gain control, an independent density control, a manual phasing control, a start/stop control and a white/black

transmission selector shall be provided in a convenient location on the receiver.

6.3.2.12 Synchronization. The scanning rates of the recorder shall be controlled by a self-contained frequency standard maintained at the assigned frequency within 3 parts per million. The frequency driving the synchronous drive system of the receiver shall be 300 Hz or an integral multiple thereof.

6.3.2.13 Control Functions. The facsimile recorder shall reliably start, phase, and stop when activated by the transmitted signal. It shall be possible for the operator to override any automatic function with the operating controls described in "Operating Controls" above. The receiver shall start one to three seconds after receipt of a 2400 Hz signal from the transmitter; automatically switch into a phasing mode for 10-12 seconds; and then automatically switch into the recording mode. The receiver shall stop three to five seconds after the 2400 Hz signal disappears and shall then be capable of immediate recycling.

6.3.2.14 Power Requirements. No power requirements are stipulated in these standards, however, no information or frequency obtained from the power source shall be utilized to derive any frequency or timing rate within the receiver.

6.3.3 General Purpose (Black/White) Facsimile Equipment. This type of equipment is intended for transmission of message, sketches, maps, handwritten information and other essentially black and white graphical information.

6.3.3.1 Original Copy Size. The copy shall be any width up to 8½ inches and of any length (continuous scanning). Due to man-machine problems of aligning long copy practical limits may have to be applied as determined by user's requirements. For example a five foot length may satisfy the requirement to send overlays.

6.3.3.2 Scanning Direction. The scanning direction shall be normal, that is at the transmitter, the plane of the original copy shall be scanned at a uniform rate along lines running from the upper left to the upper right, commencing at the top left-hand corner of the scanned area and finishing at the bottom right-hand corner (left hand helix).

6.3.3.3 Scanning Line Length. The Total Scanning Line Length shall be 8.64 inches. The Total Line Length is defined as the scanning spot velocity divided by the scanning line frequency (lines per unit time) and therefore includes a pseudo length corresponding to a dead sector or the flyback time of flatbed scanners.

6.3.3.4 Dead Sector. Between the end of the scanning of the available line and the start of the scanning of the following line there shall be a dead sector or non scanning period during which black signal shall be transmitted. The duration of the dead sector signal shall be 2% of the total scan line duration.

6.3.3.5 Scanning Speeds. The normal scanning speeds shall be 90 and 180 strokes or lines per minute (LPM). These permit operation over voice bandwidth wire or radio circuits or over 2400 bit/sec digital circuits. For wider band circuits higher scanning speeds are possible and these shall be selected as multiples of 180 LPM.

6.3.3.6 Line Advance. The line advance shall be 1/96 inch (0.26 mm) per line of copy.

6.3.3.7 Resolution. There shall be 800 or more elements in the Total Scanning Line Length.

6.3.3.8 Index of Cooperation. The index of cooperation shall be 264.

6.3.3.9 Signal Characteristics.

6.3.3.9.1 Signal Types. The facsimile equipment shall be capable of operating with three types of signals, AM, FM, and Digital as follows:

a. AM. The transmitted output shall be a 2400 Hz carrier amplitude-modulated in accord with the density of the graphical material being scanned. Operation will be over voice bandwidth or 2400 bit/sec circuits. White level shall be 0 dBm + 1 dB. Impedance shall be 600 Ohms + 30% balanced to ground within 1%. Voltage output vs copy density shall be nominally linear. The receiver shall be capable of operating from the transmitter via circuits with a gain-attenuation characteristic between + 10 dB and -36 dB. Receiver impedance shall be at least 2500 Ohms for bridging. Input circuits shall be designed to withstand ringing voltages normally impressed on a telephone circuit for signaling.

b. FM. The transmitter output shall be a constant level of 0 dBm + 1 dB into 600 Ohms with a frequency that varies from 1500 Hz for white to 2300 Hz for black copy.

The receiver shall be capable of operating from the transmitter via circuits with a gain-loss characteristic between + 10 dB and -36 dB. Receiver impedance shall be at least 2500 Ohms for bridging. Input circuits shall be designed to withstand ringing voltages normally impressed on a telephone circuit for signaling.

c. Digital. The graphical information being scanned shall be resolved into white, light gray, dark gray, and black digital signals as follows:

White	-	11
Light gray	-	10
Dark gray	-	01
Black	-	00

Output levels shall be +6 volts for "1" condition and -6 volts for "0" condition. Transmitter and receiver shall match the Digital Standard Interface (low level), paragraph 7.2.1.

6.3.3.10 Recording. Recording shall be of the continuous type and preferably be on plain paper 8 $\frac{1}{2}$ " wide (nominal) at least 150 feet long. Paper supply shall be rolled on a core with inside diameter of 3/8 to 1 3/8 inches. It is desirable that, by a change in stock to a transparent material, recordings be made which can be used for display by projection. Through use of other recording media it is desirable that reproducible masters be obtained directly for use on reproduction equipment common to user elements.

6.3.3.11 Synchronization. The scanning rates of the transmitter and recorder shall be controlled by a frequency standard contained in each set and maintained at the assigned frequency within 3 parts per million. The scanning rate shall also be capable of being controlled by an external clock. For digital operation the transmitted bit rate shall be controlled by the internal standard or by the clock of the external system.

6.3.3.12 Control Functions. Manual and automatic control of the facsimile equipment shall be provided.

6.3.3.12.1 Manual Operation. Controls shall be provided on the transmitter to permit the operator to start or stop the transmitter. Using a hold-down switch the operator shall also be able to transmit steady black or white signals indefinitely to permit circuit or equipment adjustment. The receiver shall have a gain control, an independent density control, a manual phasing control a start/stop control and a black/white-transmission selector. These controls shall permit the operator to override any automatic function.

6.3.3.12.2 Automatic Operation. Upon insertion of a copy to be sent or upon operation of a "send" control the transmitter shall automatically send the start, phasing, information (picture) and stop signals as follows:

a. AM.

Start	Transmitter sends 2400 Hz carrier for 5 seconds. Receiver starts in one to 3 seconds then switches to phasing mode.
Phasing	White signal interrupted by black level for 2% of scan line time prior to start of each line and in line with dead sector. Phasing signal is sent for 15 seconds. Receiver automatically phases.
Information	Modulated carrier.
Stop	No carrier sent. Receiver is ready for restart within 2 to 3 seconds.

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b. FM.

Initial Condition	Send steady white signal. Receiving converter looks for phasing signals then provides 2400 Hz to facsimile receiver for 5 seconds.
Phase	Send white interrupted by black frequency for 2% of scan line time prior to start of each line and in line with dead sector. Signal sent for 15 seconds. Receiver automatically starts and phases.
Information	Frequency Shift
Stop	Transmitter reverts to initial condition. Receiver stops and is in readiness for next cycle.

c. Digital

Initial Condition	Send steady white (mark). Receiver looks for phasing signal.
Phasing	White interrupted by black signal for 2% of scan line time prior to start of each line and in line with dead sector. Send for 15 seconds for speeds up to 180 LPM and for 15 scan lines for higher speeds. Receiver starts and phases.
Information	Digital stream of 0's and 1's (spaces and marks).
Stop	Transmitter reverts to initial condition (steady white). Receiver stops and is in readiness for next phasing signal.

6.3.4 Commonality between Meteorological and General Purpose Facsimile Equipment. In practice it is feasible to construct single equipments meeting the interoperability requirement of the meteorological and general purpose equipments. In a specific instance the general purpose receiver capable of recording 8½" wide copy at 90 and 180 LPM and an Index of Cooperation of 264 can by means of operator controls also operate at the meteorological speeds of 60, 90 and 120 LPM with an Index of Cooperation of 576. Signal sense must also be reversed since white is maximum level for the general purpose set and black is maximum for meteorological facsimile. Recording in this case is 8½ for both types of recording but to accommodate the Index of Cooperation change the number of lines per inch is changed from 96 to 209.5. There is less requirement for the transmitter to accommodate both standards than for the recorder since most original copy must be utilized in its original size.

7. TELEGRAPH AND DATA TRANSMISSION

7.1 General. This section deals with standards for single channel and multichannel binary circuits that provide for transmission of binary dc signals between end instruments or between switches to which such end instruments may be connected by loops. Transmission is usually accomplished by converting the binary dc signal into a quasi-analog form for transmission over channels that will not transmit signals in dc digital form. Characteristics of a number of conversion devices (modems) are standardized in order to accommodate the variety of data to be transmitted and the different types of transmission media available. For wire and cable transmission media, signals may be transmitted in dc digital form (without conversion to quasi-analog form) over relatively short distances.

7.2 DC Digital Transmission Reference Systems.

7.2.1 Standard Interface (Low Level). The following characteristics shall be applicable to signal, clock, and control circuits for all military digital dc communication equipment where a binary interface appears. The standard interface shall apply to all equipment other than equipment in a controlled environment. For these purposes a controlled environment is defined as equipment which will not normally interface with the equipment of other services, or which is packaged so as to form a completely functioning unit which will not normally have its internal stages or components connect directly into the communications network. Where this complex interfaces with the transmission medium, it will observe the standard. Equipment specifically included where the interface is applied shall be teletypewriter, data terminal, the local side of signal conversion (modem) equipment, and both the loop and line side of cryptographic or cryptographic control equipment, as applicable. The standard interface shall be applicable to remotely operated equipment where the interface is at the dc baseband. This standard interface shall apply to equipment with modulation rates suitable for transmission over 4 kHz analog channels, and may be employed at transmission rates higher than this. Alarm and control circuits not directly related to the data or clock timing may be excluded. This standard shall not be construed to imply that equipment operating over a modulation rate range in excess of that suitable for 4 kHz analog channels must have different input characteristics over different portions of its operating range. The standard low level interface is specified in Figure 5, Appendix B.

7.2.1.1 Transmitter Output Voltage. The open circuit transmitting voltage shall be positive and negative 6 ± 1 Volts. Ripple shall be less than 0.5% under normal operating conditions. The balance between the marking and spacing voltages shall be within 10% of each other.

7.2.1.2 Transmitter Source Impedance. The transmitting source impedance shall not exceed 100 Ohms (50 Ohms DO) for currents whose magnitude is less than 0.01 Amperes. The maximum short circuit current delivered to the interface shall not exceed 0.1 Amperes.

7.2.1.3 Transmitter Wave Shape. The wave shape delivered to the interface shall have a rise time no faster than 5% of the duration of the

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Unit interval. The waveshape shall be such that the rise and fall times, (defined as the time required for the pulse to go from 10% to 90% of its peak-to-peak value) shall be within 5% to 15% of the unit interval at the applicable modulation rate. (See paragraph 7.10.4 for an exception to the 15% maximum waveshape limit on clock signals.) Transitions in both directions shall be reasonably equal within the limits specified above and be equally affected by shunt capacitance across the line. Properly shaped waveforms shall exhibit smooth exponential curves and contain no points of inflection prior to obtaining maximum amplitudes. (See Fig 21.) For those devices which operate at one specific rate, the waveshaping network shall be selected to meet the 5 to 15% requirements for that rate. For those devices which may be manually or automatically shifted to different modulation rates, the required waveshaping shall be accomplished at least at the highest modulation rate. The waveshape shall be measured at the output terminals of the transmit device if waveshaping is provided internally. If waveshaping is accomplished externally, interconnecting leads between transmit device and waveshaping unit shall not exceed 8 inches in length. The measurement shall be accomplished at the output terminals which shall be terminated in 47 to 68 kOhms resistive load for the purpose of the test.

7.2.1.4 Receiver Input Resistance. The minimum input resistance of a single receiver device shall be 6000 Ohms. (DO, 45 kOhms to 68 kOhms.) The input resistance of devices to operate at modulation rates in excess of 200 kilobaud is not defined at this time due to the limited data available for standardization purposes.

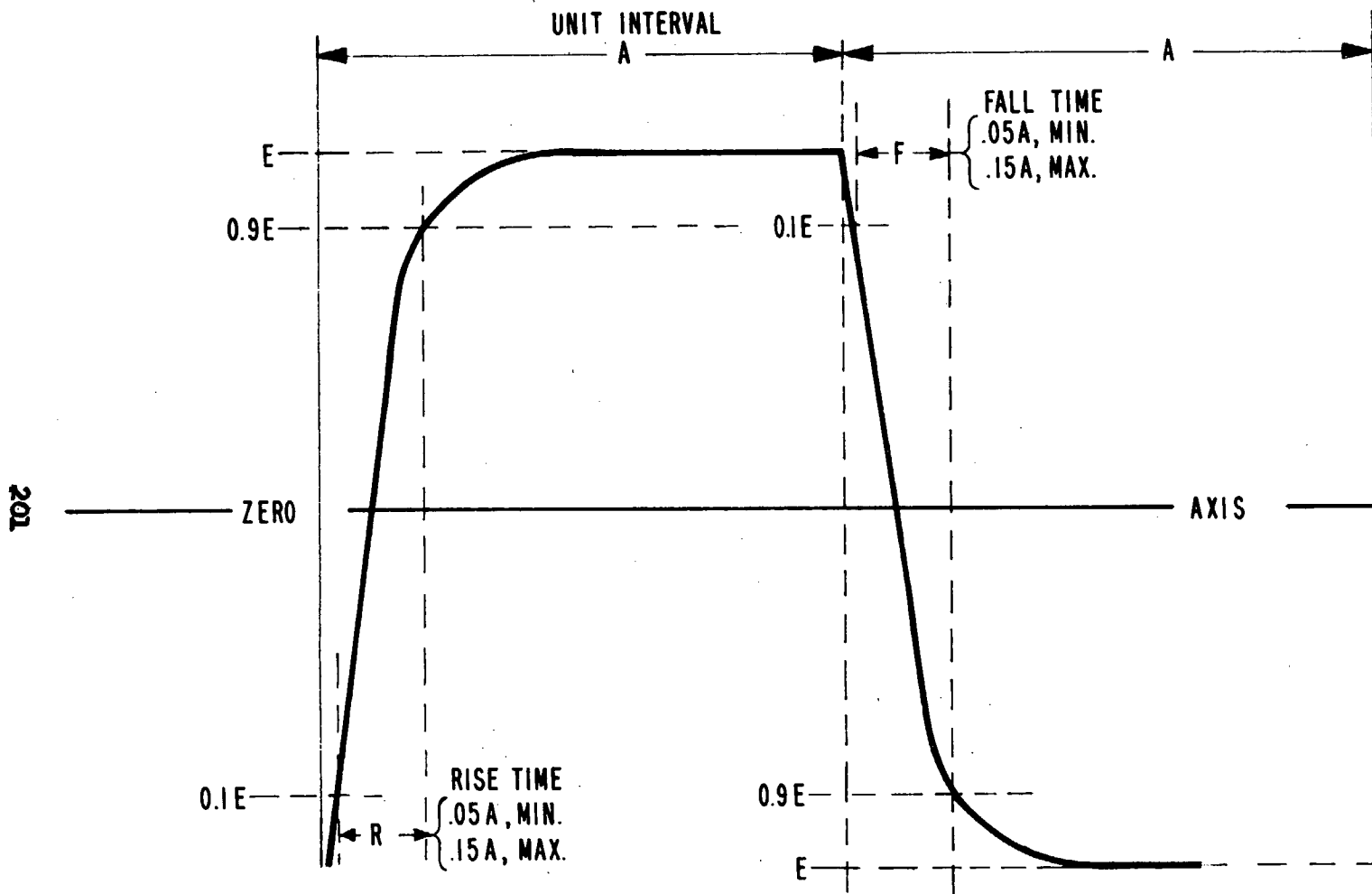
7.2.1.5 Receiver Input Capacitance. The input capacitance of the receiver device shall not exceed 2500 picofarads.

7.2.1.6 Receiver Sensitivity. Maximum operating current required (that current at which the device changes its state from mark to space or vice versa) shall be .0001 Amperes with a minimum input resistance of 6000 Ohms. (DO, 45 kOhms to 68 kOhms is 15.6 to 7.4 microAmperes over a Voltage range of 5 to 7 Volts.) Minimum input circuit sensitivity required shall be such that correct operation of the device shall be effected on current levels of these magnitudes. A marking current not in excess of .0001 Amperes (DO, 15.6 to 7.4 microAmperes) shall cause the receive device to correctly assume the marking (one) state, while a spacing current of the same magnitude shall cause the receive device to correctly assume the spacing (zero) state. The balance between the marking and spacing current actually required shall be within 10% of each other.

7.2.1.7 Signaling Sense. A positive voltage between line and signal ground shall be used to indicate a marking state; a negative voltage shall be used to indicate a spacing state.

7.2.1.8 Signal Connection. The primary standard for connection between end instruments and communication links shall be by serial transfer or bits on a single data line.

7.2.1.8.1 Serial Connection. The primary standard for connecting sources to sinks shall be by a serial transfer of bits on a single data line (one pair of wires). When the source is connected to several sinks



Rise and Fall Times (0.1 to 0.9 of the peak-to-peak voltage, E) shall be approximately equal and shall exceed 5% but shall not exceed 15% of the unit interval, A, at the applicable modulation rate.

FIGURE 21. STANDARD WAVESHAPE

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simultaneously, the number of such sinks shall not cause the steady state line current at the source to exceed 0.001 Amperes, plus/minus 20%, and all sinks shall be connected in parallel.

7.2.1.8.2 Parallel Connection. As an optional method, parallel data lines may be used to connect sources to sinks. The information transfer in this connection is serial-by-character, parallel-by-bit. The modulation rates specified in paragraph 7.2.6.

7.2.2 Interim Standard Interface (High Level). In the following paragraphs the interim standard interface for military systems is defined. However, the user is cautioned that telegraph systems of different characteristics are encountered. The following is provided for guidance:

In the United States:

Voltages: 24, 48, 60, 75, 130 V.

Currents: 20, 60, 65, 75 milliAmperes.

Sense: Positive and negative in neutral, polar and polarential circuits.

Battery Source Impedance: High and low.

In Other Countries:

	Volts	MilliAmperes	Sense (Mark)
United Kingdom	80	20	-
France	48	20	+
Spain	80	20	+
Norway	60	20	-
Germany	60 & 24	20	- & +

International: The standard for international boundary crossing purposes is 48 Vdc polar, 20 mA, positive marking. (See Fig 4, Appendix B.)

All normally utilize polar and low impedance battery sources.

7.2.2.1 Transmitter Output Current. The interface (high level) shall be a polar signal at 20 mA (+ 10%). A neutral interface (high level) is acceptable and may be either a current of 20 mA (+ 3%) or 60 mA (+ 3%).

7.2.2.2 Transmitter Output Magnitude. The standard polar circuit shall be ± 60 V ($\pm 2\%$) for high performance facilities and ± 60 V ($\pm 4\%$)

for low performance facilities. The standard neutral circuit shall be 130 Volts (+ 2%) for high performance facilities and 130 Volts (+ 4%) for low performance facilities. NOTE: Certain US Military electronic telegraph terminal equipments utilize upwards of 30 Vdc (referenced to the signal ground) in their output circuit. Such equipment shall be isolated from the cable plant by suitable relays or other isolation devices to prevent destruction of the cable or hazard to human life.

7.2.2.3 Source Impedance. The battery (or equivalent) source impedance at the transmit contacts, or equivalents) should not exceed 150 Ohms, essentially resistive.

7.2.2.4 Waveshaper. The standard polar waveshaper for dc telegraph signals with modulation rates up to 150 baud shall be 200 Ohm, 10 Watt wire-wound, + 10% resistor connected between the transmitting device and the line (see Fig 4, Appendix B). The line side of the resistor shall be shunted to the signal ground by a 1 microfarad capacitor, 10% tolerance, with a capacitor working voltage of 200 Volts. Local circumstances may dictate a reduction in the size of the capacitor on long lines (in excess of 10 miles) or on lines exhibiting high capacity. The objective is to provide the maximum waveshaping possible at the transmitting point to reduce or eliminate near end crosstalk and/or to minimize the tendency of the receive relay to bounce. The RC network indicated above has been shown adequate in almost all cases within and outside of the US. The waveshaper for neutral signals is not specified.

7.2.2.5 Contact Protection. Transmit contacts (or equivalents) shall be protected by fuses, ballast lamps (such as FSN 5905-335-0644) and/or resistors (not to exceed 150 Ohms in each mark and space contact lead).

7.2.2.6 Receiver Sensitivity. The input sensitivity of mechanical or electronic, polar relay driven, printing telegraph equipment shall be in the 2 to 4 mA operating differential region. That is, a change from 32 mA to 28 mA on a 60 mA neutral signal shall cause correct operation of the receive device, or, in the case of a polar signal, a change from +2 mA through 0 to -2 mA should cause correct operation of the receive device.

7.2.2.7 Signaling Sense. A positive voltage between the line and signal ground or the lower frequency of a two-tone FSK signal shall be the marking state.

7.2.3 Signal Paths. The standard dc signal path shall be either 2-wire with metallic ground or earth return or 4-wire full metallic for a single full-duplex circuit. It is to be noted that a distinction is implied between ground and earth return. Use of the first term is meant to imply that a single metallic path, either insulated or not insulated from the earth is employed for the return path of one or more dc circuits; whereas use of the term earth return is meant to imply that the signal current literally flows through the earth on a nonmetallic basis.

7.2.4 Communication Path Performance. The quality of a circuit shall be expressed by the following formulas:

$$a. \text{ Path Error Rate } \% = \frac{\text{number of incorrect characters or bits}}{\text{number of characters or bits sent}} \times 100$$

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- b. Path Utilization % = $\frac{\text{number of characters or bits sent}}{\text{theoretical \# of characters or bits that could be sent with error detection/correction systems}} \times 100$
- c. Path Efficiency % = $\frac{\text{number of correctly received characters or bits}}{\text{total number (including repeated and/or control characters) sent}} \times 100$

7.2.5 Distortion Introduced by a Line or Loop (dc Digital). The maximum total distortion introduced by the line, or loop, due to any combination of causes (bias, fortuitous, cyclic or characteristic) shall not exceed 1%. (There are a number of titles applied to various types of distortion. To avoid confusion, the usage of the titles listed above together with their interpretation as defined in Section 2 is encouraged.)

7.2.6 Modulation Rates. The preferred modulation rates at the standard digital interface shall be:

- (1) 25×2^{-m} baud
- (2) 50.0 baud
- (3) 75.0×2^m baud

Where m is the positive integers 0, 1, 2, ..., etc.

7.3 Digital Data Modems. Digital transducers or modems (modulator-demodulators) employ a variety of techniques for converting binary data signals into a form suitable for transmission over an analog communication channel. Various modulation techniques are in common use in military communication systems, and no single technique has been found to be optimum for all applications. The following general standards are applicable to all digital data modem equipments:

7.3.1 Standard Interface (Low Level). See paragraph 7.2.1.

7.3.2 Modulation Rates. See paragraph 7.2.6.

7.3.3 Timing Characteristics. See paragraph 7.10.

7.3.4 Signal Interval. The device shall accept and deliver unit interval signals.

7.3.5 HF Data Modems. For those applications where 16 data tone, differential phase shift keying is used as the modulation technique for general bit synchronous data transmission over HF radio paths at data signaling rates up to 2400 bits per second, the following standards apply:

7.3.5.1 Frequencies. The modulator shall transmit sixteen differentially-coherent phase shift keyed (DPSK) tones. The 16 tones shall be simultaneously keyed to produce a signal element interval of 13.33 milliseconds for each tone. In addition, a separate tone for doppler correction shall be provided when required. The tone frequencies and spacing shall be in accordance with Table IX. Tone frequencies shall maintain an accuracy of 0.1 Hz.

TONE FREQUENCY (Hz)	FUNCTION	<u>2400 b/s</u>	<u>1200 b/s</u>	<u>600 b/s</u>	<u>300 b/s</u>	<u>150 b/s</u>	<u>75 b/s</u>
605	Continuous Doppler tone						
825	Synchronization Slot						
935	DATA 1	0 & 1	0 & 1	0	0	0	0
1045	DATA 2	2 & 3	2 & 3	1	1	1	1
1155	DATA 3	4 & 5	4 & 5	2	2	0	0
1265	DATA 4	6 & 7	6 & 7	3	3	1	0
1375	DATA 5	8 & 9	8 & 9	4	0	0	0
1485	DATA 6	10 & 11	10 & 11	5	1	1	0
1595	DATA 7	12 & 13	12 & 13	6	2	0	0
1705	DATA 8	14 & 15	14 & 15	7	3	1	0
1815	DATA 9	16 & 17	0 & 1	0	0	0	0
1925	DATA 10	18 & 19	2 & 3	1	1	1	0
2035	DATA 11	20 & 21	4 & 5	2	2	0	0
2145	DATA 12	22 & 23	6 & 7	3	3	1	0
2255	DATA 13	24 & 25	8 & 9	4	0	0	0
2365	DATA 14	26 & 27	10 & 11	5	1	1	0
2475	DATA 15	27 & 29	12 & 13	6	2	0	0
2585	DATA 16	30 & 31	14 & 15	7	3	1	0

*NOTE: For 600 b/s and lower rates, two phase modulation shall be used.

TABLE IX

BIT PLACEMENT FOR VARIOUS DATA SIGNALING RATES

7.3.5.2 Modulation Encoding. The modulation scheme shall employ four phase encoding for 2400 and 1200 bit per second data signaling rates and two phase encoding for 600, 300, 150 and 75 bit per second data signaling rates in accordance with the following diagram:

For two phase encoding the -45° and -225° vectors shall be used

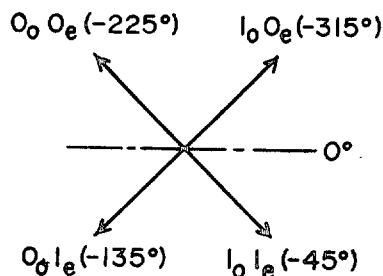


FIGURE 22

The subscripts refer to the odd and even bit numbers and the phase in degrees is with regard to the previous signal element.

7.3.5.3 Modulation Rate. The modulation rate of the composite audio signal shall be 75 baud. The modulation rate shall be constant for all input data signaling rates up to 2400 bits per second.

7.3.5.4 Modulator Output Level. The output level of the modulator shall be adjustable between minus 20 and 0 dBm.

7.3.5.5 Impedance. The transmit and receive impedance on the transmission channel side of the modem shall be 600 Ohms, $\pm 10\%$ resistive and balanced.

7.3.5.6 Demodulator Input Level. The demodulator shall have a dynamic range sufficient to accept and process, with uniform performance, input signals from minus 40 dBm to 0 dBm.

7.3.5.7 Synchronization. Upon receipt of a "transmit" command, the modem shall initiate a synchronization preamble consisting of two tones, 605 Hz and 1705 Hz for a duration of five signal elements (66.65 milliseconds). The 605 Hz tone shall be unmodulated and used for doppler correction when required. The 1705 Hz tone shall be phase shifted 180° for each signal element and used to obtain proper modem synchronization by the receiver. During the preamble, the level of the 605 Hz tone shall be 7 ± 1 dB higher than the level of the 1705 Hz tone. The RMS value of the composite audio output during the preamble shall be within 1 dB of the RMS value of the transmitter output during normal data transmission when all data tones are transmitted. At the completion of the preamble all data tones will be turned on for a time equivalent to one signal element (13.33 milliseconds) prior to transmission of data in order to establish a phase

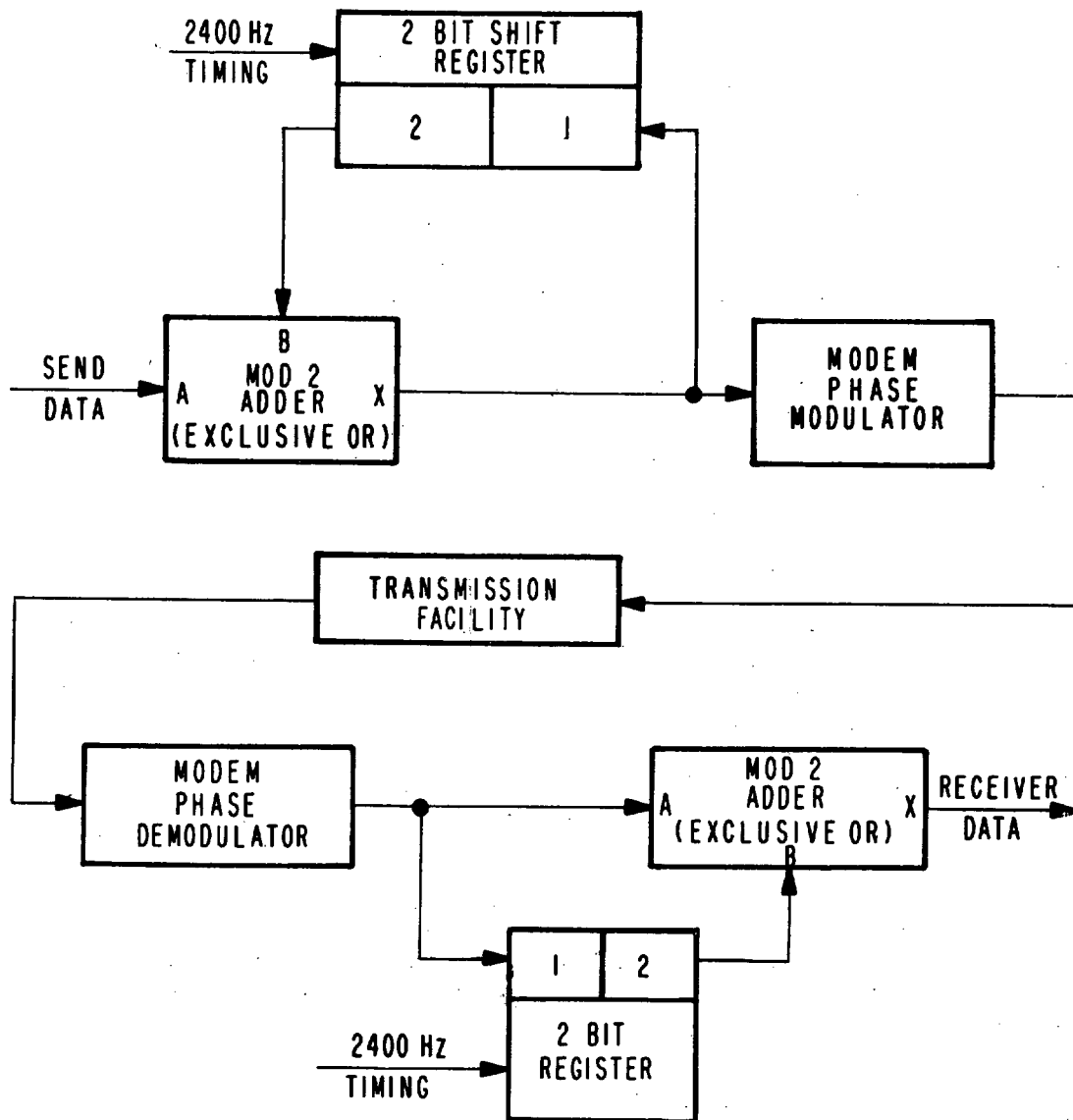


TABLE OF COMBINATIONS FOR EXCLUSIVE OR		
A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

FIGURE 23
DATA ENCODER/DECODER

reference. Following the synchronization sequence, synchronization shall be maintained by sampling the signal energy in the 825 Hz slot. No tone shall be supplied in the modulator at the 825 Hz frequency.

7.3.5.8 Doppler Correction. For those applications where a doppler correction capability is required, the 605 Hz tone shall be used.

7.3.5.9 Inband Diversity Combining. Inband diversity combining shall be accomplished at all data signaling rates lower than 2400 bits per second. The channels shall be combined in accordance with Table IX to provide either ratio squared or linear combining. The degree of diversity combining shall be two times at 600 or 1200 bps, four times at 300 bps, eight times at 150 bps and sixteen times at 75 bps.

7.3.5.10 Demodulator Signal Alarm. Provision shall be made in the demodulator to activate an alarm when the incoming signal from the transmission channel falls below a preset level. The specific techniques and levels to be used will be defined in the applicable modem specifications.

7.3.6 PSK Data Modems. For those applications where differential phase shift keying (DPSK) is used and where a voice channel data interface with the DCS is required over other than HF radio at modulation rates up to 2400 baud (a data signaling rate of 2400 bits per second) the following standards apply:

7.3.6.1 Operating Requirements. The modem shall provide full duplex operation, i.e., it shall be capable of simultaneous conversion of serial digital signals to a modulated analog signal on the transmit channel and demodulation of voice frequency analog representation of independent serial digital signals originating from a distant modulator on the receive channel. The modulator shall accept a serial digital data signal at modulation rates of 1200 or 2400 baud.

7.3.6.2 Modulator Carrier. The carrier frequency of the modulator shall be 1800 Hz and shall be manually adjustable ± 0.5 Hz. The long term frequency stability of the carrier shall be better than 1 part in 10^4 per 24 hour period.

7.3.6.3 Binary Encoder/Decoder. A data encoder shall be provided in the modulator and a corresponding decoder in the demodulator. The encoder/decoder shall consist of a modulo 2 adder and a 2-bit shift register or equivalent as shown in Figure 23. Encoding/decoding shall be accomplished at a data signaling rate of 2400 bits per second for the two data rates. Provision shall be made to employ the encoder/decoder on an optional strapping or switch selectable basis to maintain synchronism during data inputs of steady "ones" or "one-zero" reversals.

7.3.6.4 Modulator Output Signal. The data signal at the output of the modulator shall be a synchronous differentially coherent quaternary phase shift keyed signal. For a data signaling rate of 1200 and 2400 bits per second at the modulator input, the line signal is always 1200 baud. The

line signal shall be obtained by grouping the serial stream of binary digital signals from the binary encoder (or from the data source if the encoder is bypassed) into dibits. Upon determining which of four possible bit sequences are contained in the dibit, the phase of the 1800 Hz carrier is shifted relative to the phase of the carrier at the beginning of the immediately preceding dibit interval. The dibit-phase relationship is shown in the following diagram:

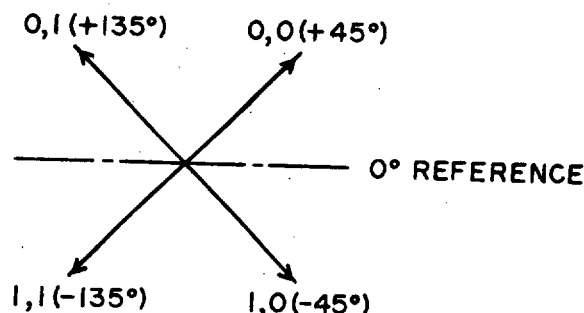


FIGURE 24

Phase vectors denote carrier phase shift relative to the phase of the immediately preceding dibit interval.

7.3.6.5 Modulator Output Level. The output level of the modulator shall be adjustable from -18 dBm to 0 dBm.

7.3.6.6 Demodulator Input Signal. The demodulator shall accept the synchronous quaternary phase shift keyed signal described in paragraph 7.3.6.4 as modified by passage through the transmission channel.

7.3.6.7 Demodulator Dynamic Range. The demodulator shall have a dynamic range sufficient to accept and process, without degradation of performance, input signal levels from -35 dBm to -5 dBm.

7.3.6.8 Impedance Return Loss and Balance. The output impedance of the modulator and the input impedance of the demodulator shall be 600 Ohms balanced with a minimum return loss of at least 26 dB over the frequency range of 370 Hz to 3400 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below prevailing metallic currents.

7.3.6.9 Synchronization. Synchronization between the modulator and demodulator shall be accomplished automatically by the demodulator without the need for transmission of separate synchronization signals from the modulator. The modem shall provide both uncorrected and phase corrected timing output signals at each of the selectable modulation rates.

7.3.6.10 Demodulator Clock Circuits. The timing signal at the output of the demodulator shall be phase corrected to the digital data signal at the output of the demodulator. The rate of phase correction shall be such that no more than 150 serial digital data transitions shall be required to correct for phase differences of up to $\frac{1}{2}$ of a data unit interval. The maximum allowable rate of phase correction shall be limited to a value such that the phase jitter of the corrected timing signal does not exceed $\pm 1\%$ of a data unit interval. The phase correction shall be automatically inhibited if the line signal is interrupted.

7.3.6.11 Demodulator Signal Alarm. Provision shall be made in the demodulator to activate an alarm when the incoming signal to the receiver falls below the preset level. The specific techniques and levels to be used will be defined in the applicable specifications.

7.3.6.12 Transmission Channel Phase Jitter. The modem shall be capable of operation over a voice channel facility where phase jitter is present so that the bit error rate versus Gaussian noise performance shall not experience additional degradation in excess of 1 dB when ± 20 degrees of peak phase jitter at any jitter rate from 20 to 120 Hz is introduced.

7.3.7 FSK Data Modems. In those applications where frequency shift keying (FSK) is used as a modulation technique for bit synchronous data transmission at data signaling rates up to and including 1200 bits per second, the following standards apply:

7.3.7.1 Frequencies. Where modems limited to data signaling rates of 600 bits per second or less are used, they shall employ phase-continuous frequency shift keying at the following frequencies:

Mark frequency	1300 ± 5 Hz.
Center frequency	1500 ± 5 Hz.
Space frequency	1700 ± 5 Hz.

Where modems limited to data signaling rates of 1200 bits per second operation or less are used, they shall employ phase-continuous frequency shift keying at the following frequencies:

Mark frequency	1300 ± 5 Hz.
Center frequency	1700 ± 5 Hz.
Space frequency	2100 ± 5 Hz.

7.3.7.2 Impedance Return Loss and Balance. The output impedance of the modulator and the input impedance of the demodulator shall be 600 Ohms balanced with a minimum return loss of at least 26 dB over the frequency range of 370 Hz to 3400 Hz. The electrical balance shall be sufficient to suppress longitudinal currents at least 40 dB below prevailing metallic currents.

7.3.7.3 Modulator Output Power. The modulator output power to the transmission line shall be adjustable between -16 dBm and +4 dBm.

7.3.7.4 Demodulator Dynamic Range. The receiver (demodulator) shall be capable of providing full operational performance at line inputs to the receiver between -40 dBm and 0 dBm.

7.3.7.5 Modulator Output Spectrum. The transmitted signal energy during maximum speed operation shall be suppressed at least 40 dB for frequencies of 3400 Hz, and above.

7.3.8 Tactical Data Modem for 150 Bauds or Less. For these applications where a requirement exists for data at rates of 150 baud or lower, the following standards shall apply:

7.3.8.1 Modulation. Binary Frequency Shift Keying.

7.3.8.2 Carrier Frequency. 1232.5 Hz for a "1" (Mark)

1317.5 Hz for a "0" (Space)

(tolerance = ± 4 Hz)

NOTE: The above frequencies for mark and space are reversed in a large existing inventory of equipments. New equipments procured should have a ready means of reversing the sense of mark and space in order to operate with the older equipments.

7.3.8.3 Modulation Rate. Any rate up to 150 baud.

7.3.8.4 Modulator Output Level. The modulator output level shall be adjustable from -16 to +4 dBm in steps no greater than 2 dB. The difference in output levels between mark and space frequencies shall be less than 1 dB.

7.3.8.5 Mark Hold. The demodulator output shall be held in a steady "1" condition and an alarm signal provided when the received signal drops below the lower limit of the dynamic range selected.

7.3.8.6 Demodulator Dynamic Range. There shall be two (2) selectable options of demodulator dynamic range. In one option the equipment shall detect signals from 0 + 3 dBm to minus 25 dBm + 3 dBm without adjustment. In the second option, it shall detect signals from 0 + 3 dBm to minus 48 dBm + 3 dBm without adjustment.

7.3.8.7 Carrier Suppression. During periods of no transmission the modulator output shall be removed automatically. The carrier suppression time delay shall be such that the output shall persist for 2.5 \pm 0.5 seconds.

7.3.8.8 One-Way Reversible Operation. The modem shall be capable of operation over either two (2) or four (4) wire circuits. When connected for two-wire operations, the modem shall be capable of generating a break-in signal that stops transmission from the remote modulator and allows the

direction of data flow to be reversed. The break-in frequency shall be $1180 \text{ Hz} + 3 \text{ Hz}$. The normal break-in signal modulator output power shall be 0 dBm . The break-in frequency detector of the demodulator shall operate with signals down to minus 30 dBm .

7.4 Digital Buffering Equipment.

7.4.1 Modulation Rate Converters. A modulation rate conversion process may take place in any number of equipments; however, the equipments referred to in the following paragraphs are devices whose basic purpose is to change the input/output modulation rate relationship.

Modulation rate converters (MRC) find application in such areas as those involving the electrical connection between 45.5 and 75.0 baud teleprinter equipment.

It is to be understood that in connecting a higher to a lower modulation rate device, provision must be made to control the average information rate of the faster equipment in order that the information rate of the slower device is not exceeded: e.g., 100 wpm - 60 wpm operates at an average of 60 wpm , 100 cards per minute to 10 cards per minute operates at an average of 10 cards per minute, etc.

The inherent characteristics of an MRC, regenerative repeater, distortion monitor, and delay line can take on a close resemblance that may be usefully exploited in combining these functional areas.

7.4.1.1 Clocking Methods.

7.4.1.1.1 Start/Stop Input. The input to the MRC input sampling timing should become quiescent and/or ready to commence sampling the character following the one just sampled, at some point after the beginning of the stop interval and in no case in excess of half the duration of the unit interval at the applicable modulation rate. If the start/stop character interval is 10 unit intervals (1 unit start, 8 unit intelligence, and a 1 unit stop element) the input logic should be prepared to correctly accept the following character at any time between 9.6 and 10 unit intervals from the stop/start transition of that character interval.

7.4.1.1.2 Start/Stop Output. The output character interval may not be shorter than the input character interval to circumvent the need for various amounts of storage capabilities.

7.4.1.1.3 Output Character Interval. The output character interval must be equal to or greater than the input character interval to avoid any requirement for storage facilities. There are two situations, depending on whether the modulation rate is increased or decreased by the modulation rate converter.

a. Modulation Rate Increased. In this case the output modulation rate is greater than the input modulation rate. Since the information rate

is controlled by the character rate of the input signal, each output character must consist of a character of the same character structure as the input signal, but with the stop element extended until the time duration is the same as that of the input character. In terms of the output modulation rate, the output character interval must contain at least as many unit intervals as the input character, multiplied by the ratio of the output modulation rate to the input modulation rate. EXAMPLE 1. Given an input with a character interval of 7.0 units, and a modulation rate of 75.0 baud, with the output to be delivered at the rate of 150 baud. The output character interval must then be at least:

$$7.0 \times \frac{150.0}{75.0} = 14.0 \text{ units.}$$

b. Modulation Rate Decreased. In this case the output modulation rate is less than the input modulation rate. The character rate of the input signals must be reduced to that of the output circuit, or lower, so as not to outrun the modulation rate converter capability. A typical way to accomplish this is to use stepped operation, whereby the modulation rate converter, or some external device, generates step impulses causing the input circuit to deliver only the next character. The step impulses are spaced sufficiently to allow the converter to deliver the output signal with the correct character interval. EXAMPLE 2. Given an input with a character interval of 11.0 units, and a modulation rate of 110.0 baud, with the output to be delivered at the rate of 50.0 baud. The stepping impulses must be spaced by an interval, in terms of the input modulation rate, of at least:

$$11.0 \times \frac{110.0}{50.0} = 24.2 \text{ units.}$$

7.4.1.2 Input/Output Signaling Characteristics. See paragraph 7.10 for timing characteristics and paragraph 7.2.1 for interface characteristics.

7.5 Digital Regenerative Devices.

7.5.1 Regenerative Repeaters. Regenerative repeaters reshape and retime digital signals. It is generally accepted that retiming characteristics make a regenerative repeater distinct from a nonregenerative repeater which reshapes but does not retime the signal. There are two basic classes of regenerative repeaters, synchronous and start/stop.

7.5.1.1 DC Input/Output Characteristics. See paragraph 7.2.1.

7.5.1.2 Synchronous Repeaters.

7.5.1.2.1 Modulation Rate Coverage. A range from 25 to 38,400 baud is desirable.

7.5.1.2.2 The device shall accept unit interval signals only.

7.5.1.2.3 An internal equipment propagation delay time of greater than one-half and less than two unit intervals at the applicable modulation rate is desired.

7.5.1.2.4 It is to be assumed that no requirement exists for remote user removal or insertion of the regenerative repeater from or into a channel.

7.5.1.2.5 Distortion. Synchronous repeater input accepting capabilities are:

Switched bias distortion.....49% M-O-49% S

Bias distortion.....49% M-O-49% S

Cyclic distortion.....49% M-O-49% S

Fortuitous distortion.....49% M-O-49% S

These distortion figures assume the input signal modulation rate and the clock signal are within 1% of each other and are applicable to either externally or internally clocked repeaters.

7.5.1.2.5.1 Means shall be incorporated to cause the regenerative repeater to alarm local station attendants if the input signal exceeds a distortion figure of 49% for a three second period. At the same time, the output signal shall be forced to assume a marking state until such time as the input signal can be accepted by the repeater. The purpose of this requirement is to insure that the regenerative repeater will not unnecessarily confuse cryptographic operations.

7.5.1.2.6 Synchronous Repeaters Controlled by Station Clocks.

7.5.1.2.6.1 Timing Source. See paragraph 7.10.1.

7.5.1.2.6.2 When controlled by station or master clocks (external clocks), the input signal clock timing relationship should be arranged so that the phase of the incoming signal may be shifted 270° , early or late, from the center of the unit interval at the applicable modulation rate. The decision as to whether the phase adjustment be manual, semiautomatic, or fully automatic is left to the decision of the equipment designer. The adjustment of the phase of the input signal/clock relationship should be reflected in a similar shift in the phase of the output signal. Rather, the output signal should maintain the phase of the station clock supplied to the regenerative repeater.

7.5.1.2.6.3 The clock modulation rate shall be supplied at twice the applicable signal modulation rate (see para 7.10).

7.5.1.2.7 Synchronous Repeaters Not Controlled by Station Clocks.

7.5.1.2.7.1 Timing Source. Operational experience to date indicates that great care must be made in determining how the clock is derived from synchronous regenerative repeaters operating in systems not employing station clocks. A fundamental operational difference exists between the design of synchronous transmission terminal equipment and synchronous regenerative repeaters. That difference is physical location in the communication plant. The repeater may be several thousand miles from either terminal end of the communication link. In the typical case of stations presently operating multiple synchronous transmission equipment (each operating with its own clock system), it will be found that, generally no two similar links operate closely enough to the same modulation rate to be considered synchronous except with their associate receiving terminal. Highly stable (but without the stability of master clock systems) regenerative repeaters operating under such conditions have been found to drive the synchronous transmission equipment rapidly out of phase, particularly during degraded circuit conditions.

7.5.1.2.7.2 The frequency control signals of synchronous regenerative repeaters not controlled by station clocks should be derived by an integrating process so that the repeater will tend to follow the average signal modulation rate rather than attempt to dictate a rate. Such frequency control would be analogous to the automatic frequency control employed in radio receiver equipment.

7.5.1.2.7.3 The means for setting the modulation rate should incorporate a technique similar to tuning a radio receiver, e.g., setting the control dial to the gross modulation rate would then allow the AFC to lock on to the input signal modulation rate. A five second lock on time is considered adequate. This means that within five seconds of receipt of an initial input signal the correct input signal/clock phase relationship will be established. The stability of the regenerative repeater frequency control should be such that the loss of the input signal for periods of one second or less at 38.4 kilobaud shall not cause the input signal/clock phase relationship to deviate in excess of 5% of the duration of the unit interval upon resumption of input signaling. For lower modulation rates, the hold-in time shall be inversely proportional to the modulation rate.

7.5.1.2.7.4 It is expected that the changes in phase of the input signal/clock phase relationship will appear in the output signal, considerably smoothed or dampened by the integration factor of the AFC equipment.

7.5.1.3 Start/Stop Regenerative Repeaters.

7.5.1.3.1 General. In start/stop regenerative devices it is expected that an equipment propagation delay time equal to the number of bits normally stored, plus one-half the duration of the unit interval will be encountered. (For 8 unit code, start/stop signaling with a unit interval start and a unit interval stop, a propagation delay time of 10.5 would be considered reasonable.)

7.5.1.3.1.1 Normally, start/stop regenerative repeaters cannot regenerate distortion encountered at the stop element. Therefore, the

distortion of the stop element may appear at the output of the regenerative repeater. There are exceptions to this problem, for example, synchronous transmission equipment fitted with start/stop, input/output buffers. In this case, due to the storage and timing functions of the synchronous equipment, the stop element is regenerated. The type of start/stop regenerative repeater covered by this standard is not of this nature.

7.5.1.3.2 Distortion. Start/stop regenerative repeaters should have the capability of accepting:

Switched bias distortion.....49% M-0-49% S

Bias distortion.....49% M-0-49% S

Cyclic distortion.....24.5% M-0-24.5% S

Fortuitous distortion.....24.5% M-0-24.5% S

These distortion figures are applicable assuming that the input signal modulation rate and repeater timing are within 1% of each other. The duration of measurement is not specified, but it is assumed that these figures are normally obtained during routine test either under laboratory or field conditions.

7.5.1.3.3 Alarms. See paragraph 7.5.1.2.5.1.

7.5.1.3.4 Timing. See paragraphs 7.4.1.1 and 7.10.

7.6 Code Converter.

7.6.1 General. Code converters generally are an inherent part of, or at least closely associated with, other equipment, such as the input or output of time division multiple channel transmission equipment. Unfortunately a degree of confusion exists in differentiating between code converters and devices more properly called alphabet translators (see para 7.9). Code converters are those devices whose basic function is to accept a digital signal in one code and convert it to another code. The sixth unit or bit in each character interval might be used to signify the start or stop condition. The code conversion process in this example does not manipulate the five intelligence bits. Rather, these bits are passed to the output in the same physical relationship to each other as they were presented to the converter input.

A code conversion process may also incorporate an alphabet translation process: e.g., the conversion of International Morse to five unit code, start/stop, International Alphabet No. 2.

7.6.2 DC Input/Output Characteristics. See paragraph 7.2.

7.7 Error Control Devices.

7.7.1 General. Automatic error control devices are assembled into three basic types of error control systems, error correcting systems, error detecting systems, and error detecting and feedback systems (see Section 2, Terms and Definitions). The choice of error control system to be used is a function of the particular transmission media employed and the data source and sink requirements of the users. Error control devices to be used in the tactical system must be designed to protect against the particular type of interference encountered in communication systems, such as impulse noise bursts, multipath effects, deep fading, selective fading, etc. No attempt is made to standardize on one type of error technique but the most common technique used in present communication systems is the error detecting and feedback system. Regardless of the type of system used, error control devices used in the system must meet the following standards at the interface points:

7.7.2 Standard Interface. See paragraph 7.2.1.

7.7.3 Modulation Rates. See paragraph 7.2.6.

7.7.4 Timing Characteristics. See paragraph 7.10.

7.7.5 Signal Interval. See paragraph 7.3.4.

7.8 Security Devices.

7.8.1 Current editions of the following documents should be referenced prior to implementing a development or production program in which security restrictions may apply:

DCAC 300-175-1

FED-STD-222

7.9 Alphabet Translators.

7.9.1 General. Alphabet translators in communication systems have tended to be separate devices peculiar to themselves. On the other hand, it has been a fairly common practice in the data processing industry to accomplish alphabet translation as a part of computer programs. There is a basic difference between the communication field and the data processing field. The communication system is intended to convey information from a "source" to a "sink" whereas the primary task of the data processing industry is to manipulate the data in accordance with a desired result. The communication system must take particular care not to arbitrarily mutilate the information flowing in the path. Therefore, it must be assumed that the communication system has no knowledge of the information content of the data.

It is to be presumed that alphabet translators will become widely used to facilitate interconnection of otherwise incompatible equipment.

It is possible to have an alphabet translation process with or without a code conversion process, e.g., 5 unit code, International Alphabet No. 2

translated to 5 unit code, Baudot Alphabet. A code conversion and alphabet translation process takes place when a 5 unit code start/stop International No. 1 Alphabet is changed to an 8 unit code, start/stop, IBM 4 of 8 Alphabet.

7.9.2 Restrictions. There are no restrictions to accomplishing a code conversion process provided all permutations of a code being converted can be processed either to or from the first to the second, or from the second to the first code. On the other hand, there is an absolute restriction that an alphabet translation shall not be accomplished except at the request of the data originator. It is presumed, however, that the originator shall state the alphabet which is to be translated.

7.9.3 DC Input/Output Characteristics. The interface characteristics stated in paragraph 7.2.1 apply.

7.9.4 Modulation Rate for Applicable Modulation Rates and Timing Considerations. See paragraph 7.2.6.

7.10 Clock Equipment. The clock is the device which provides the time base for control of operation in digital equipment. An equipment clock provides the peculiar needs of its equipment and in some cases may control the flow of data at its equipment interface. A master or station clock, regardless of its physical location, controls two or more equipments which are linked together as a system. It is with master or station clocks that these paragraphs are primarily concerned.

7.10.1 Clock Control.

7.10.1.1 Transmission Modes. All future military communication equipment requiring a stable clock or precise character interval control shall make provisions for operating from station clocks in either or both of the following modes.

7.10.1.1.1 Bit Synchronous. In bit synchronous operation, clock timing shall be delivered at twice the data modulation rate. (For this purpose, "data" includes information bits plus all bits added to the stream for whatever purpose they may serve in the system, i.e., error control, framing... etc.) The device shall release, within the duration of one clock signal, one bit. In bit-by-bit operation it is assumed that rapid manual, semi or automatic shifts in the data modulation rate will be accomplished by varying the clock modulation rate. It is possible that equipment may be operated at 50 baud one moment and the next moment at 1200 or 2400 baud. It shall be assumed that, during periods of communication difficulty, a clock signal might be delivered to a send device occasionally or not at all for periods extending to hours. During periods when the sending equipment has no traffic to send, an idle pattern or all "ones" may be transmitted.

7.10.1.1.2 Character Interval Synchronous. In character interval synchronized equipment, any character interval from 4 to 16 unit intervals per character interval shall be permitted. It is assumed that,

having programmed a given facility for a particular character interval, no other character interval operation would be expected except by re-programming. An example of such operation would be a 7.0 units per character interval tape reader being stepped at 8.0 units per character interval.

7.10.2 Clock Modulation Rates. The standard clock modulation rates for compatibility with preferred modulation rates in paragraph 7.2.6 shall be: (1) 50×2^{-m} baud (2) 100.0 baud (3) 150.0×2^m baud where m is the positive integers 0, 1, 2, ... etc.

7.10.3 Clock Modulation Rate Stability. The stability of synchronizing or clock timing supplied in all synchronous digital transmission, switching, terminal, and security equipment shall be sufficient to insure that synchronism is maintained within $\pm 25\%$ of the unit interval between transmitted and received signals for periods of not less than 100,000 consecutive seconds (1 part in $4 \times 10^5 \times \text{mod rate}$). Accuracy of the clock timing shall be such as to assure that the actual modulation rate is within 1 part 10^7 of the nominal rate.

7.10.3.1 Modulation Rate Phase Adjustment. Means shall be provided in all digital transmission, switching, terminal, and security equipment so that, at the applicable modulation rate, a shift in phase of the clocking pulse with relation to the incoming signal stream shall be possible over a period of 3 unit intervals (i.e., a shift of 1.5 unit intervals early or late from a theoretical center of the unit interval at the applicable modulation rate). Whether this adjustment is to be manual or automatic is left to the discretion of the equipment designer.

7.10.4 Clock Output. The output of the clock shall be an alternating symmetrically shaped wave, or sine wave, at the required clock modulation rates and in accordance with paragraph 7.2.1. When the clock is quiescent the clock signal state shall be negative. (In this standard a clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). Thus, in the binary sense, each clock period or cycle is composed of two unit intervals, and it follows that a clock rate of 50 Hz is a clock modulation rate of 100 baud.)

7.10.5 Clock/Data Phase Relationship. Arrangements which may be used to supply clock pulses to sources and sinks are shown in Appendix B. Typical standard arrangements are shown from which one may be selected to meet a specific application. For those digital devices operated at DC baseband which are interconnected by metallic wire (or other equipment which provides in effect the same function as a metallic wire) the following clock/data phase relationships apply if, and only if, interface circuit lengths permit. It is noted that due to signal propagation delay time differences over different DC wire circuits or DC equivalent circuits at data modulation rates higher than 2400 to 4800 baud, there may be a relative clock/data phase shift sufficient to warrant compliance with paragraph 7.10.3.1. Practical operating experience indicates that typical multiple pair paper or PVC insulated telephone exchange cable plant may be expected to function

at modulation rates of 4800 baud data/9600 baud clock at distances up to 3000 cable feet without any need for concern over relative phase shift or noise if the standard low level signaling interface is applied to both clock and data signals in accordance with paragraph 7.2.1.

All data transitions emitted by a source under direct control of external clock shall occur on (be caused by) negative to positive transitions of that clock. The design objective is a minimum delay between the clock transition and the resulting data transition, but in no case shall this delay exceed 12.5% of the duration of the data unit interval. For each equipment, once this delay is fixed in hardware, it shall be consistent within $\pm 1\%$ of itself for each clock transition which causes a data transition. These delay limits shall apply directly at the source interface. See Figure 25.

Sampling of the data signal by the external clock at a sink interface shall occur on (be caused by) positive to negative clock transitions. See Figures 25 and 27.

When the clock is used for controlling intermittent data transmission, data may not change state except when requested by a negative to positive clock transition. The quiescent state of the clock shall be at negative voltage. The quiescent state of the data shall be that state resulting from the last negative to positive clock transition. See Figure 26.

For devices in which the external clock is only related indirectly to source data, to maintain synchronism between a transmitter and a receiver for a constant modulation rate signal for example, the phase relationship between external clock and data is not specified. However, whatever the phase delay, it shall be consistent to within $\pm 1\%$ of the data unit interval at the applicable modulation rate. If clock at twice the modulation rate of the same data is also supplied as an output, then data transitions shall coincide within $\pm 1\%$ of the data unit interval with the negative to positive transitions of the output clock. See Figure 28. Direct control means control of data by a clock signal at twice the modulation rate of the data. Indirect control means use of a clock at some higher standard modulation rate, e.g., 4, 8, 128 times the modulation rate.

For devices in which input data to the sink is sampled from a clock not directly related to the data modulation rate, the phase relationship of data to clock shall be maintained in such a way that each data unit interval shall be sampled within $\pm 1\%$ of the theoretical center of the data unit interval.

In the special case of synchronous devices operating from external clock directly related to data and outputting start/stop format signals, data transitions shall be coincident with negative to positive clock transitions within $\pm 1\%$ of the data unit interval.

For start/stop format devices utilizing internal, low stability sampling sources, it shall be permissible to sample incoming data $\pm 12.5\%$ of the data unit interval away from actual center. This distortion, however, shall not

be passed on to any output interface. Any further transmission of this signal shall be regenerated.

7.10.6 Monitoring. The standard methods of monitoring dc circuits shall be an essentially nonreactive tap with a minimum dc resistance of 10,000 Ohms (DO, 45K to 68K Ohms) for polar signaling and an essentially nonreactive series insertion with a maximum dc resistance of 200 Ohms for neutral signaling.

7.10.7 Controlled Environment Interface. Systems which are autonomous, in the sense that they will rarely interface with the equipments of other systems, or which have overriding military or technical requirements, shall utilize the interconnection method practicable for their application.

7.11 Message Composers.

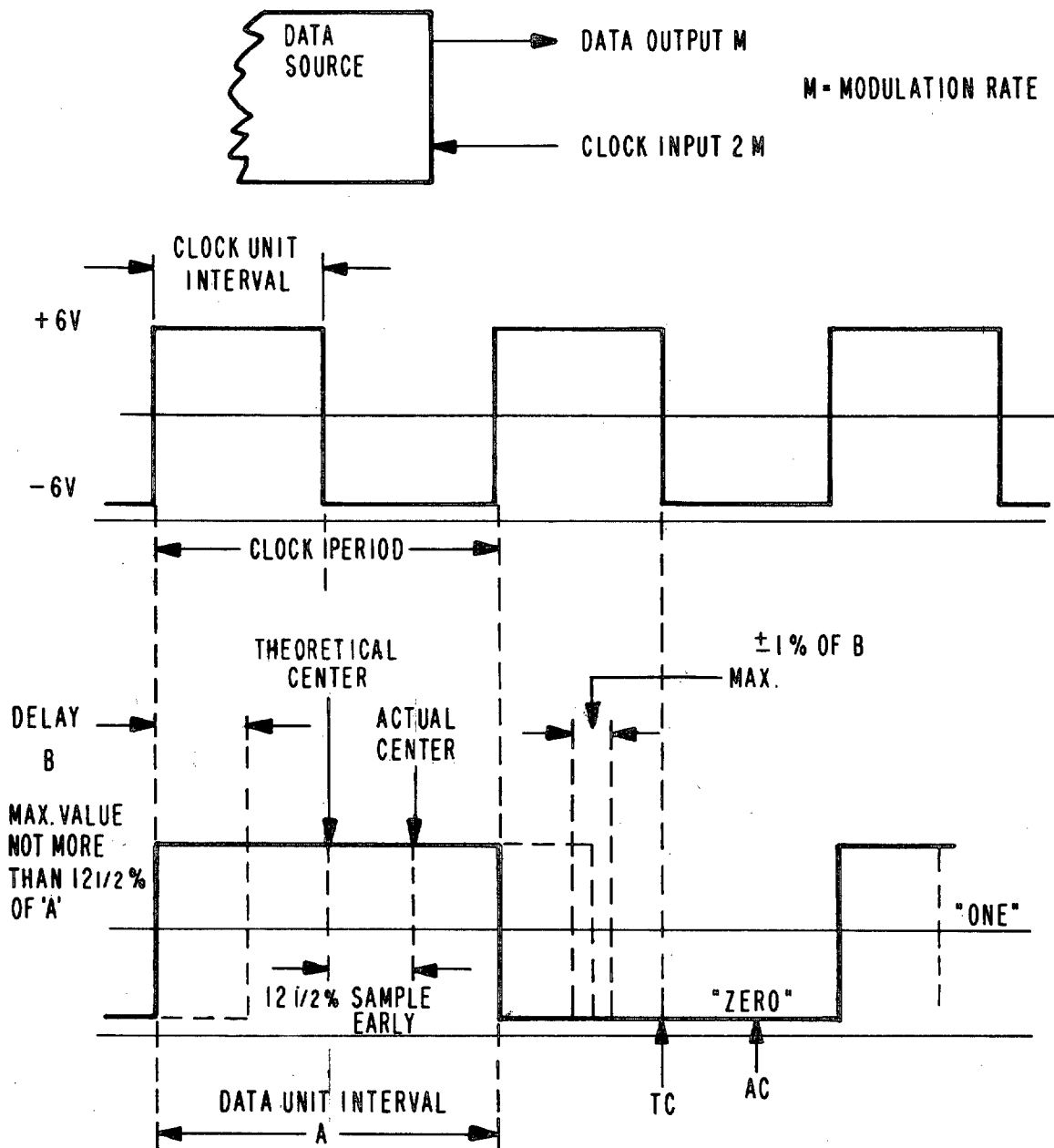
7.11.1 General. Format message composers of the automatic or semi-automatic alpha-numeric type which connect into the global communication system shall meet the applicable requirements of ACP-127 () or JANAP 128 () as appropriate (see Appendix D) for message format and switching instructions and shall meet the following standards at the interface points.

7.11.1.1 Standard Interface. See paragraph 7.2.1.

7.11.1.2 Modulation Rates. See paragraph 7.2.6.

7.11.1.3 Timing Characteristics. See paragraph 7.10.

7.11.1.4 Signal Interval. See paragraph 7.3.4.



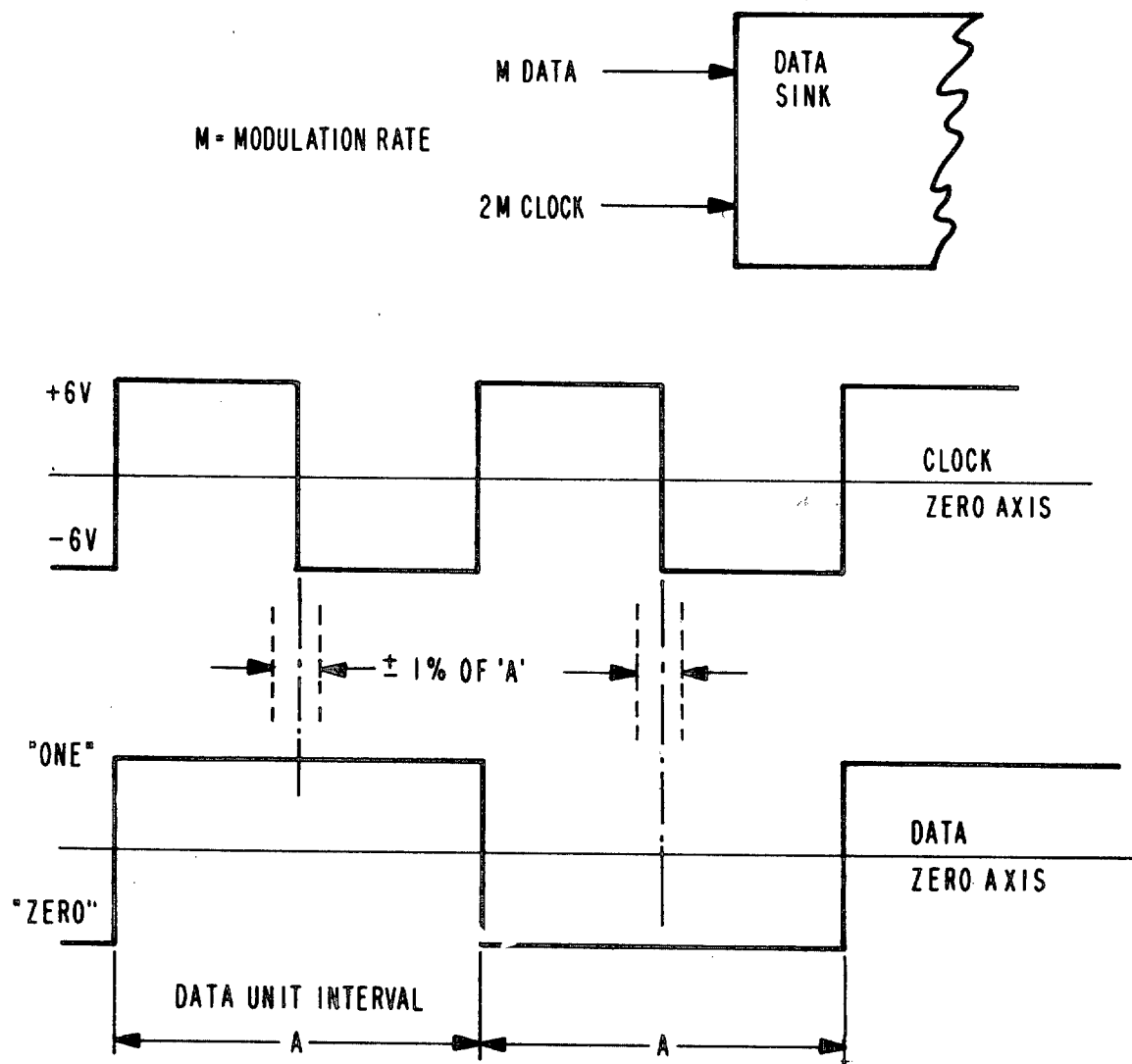
The source data signal transition shall occur consistently within 12 1/2% of the duration of the data unit interval from the clock input transition from negative to positive. Whatever phase delay is chosen, the equipment design shall insure that data transitions are released with a consistent phase delay not to exceed plus or minus one percent of that delay. Measurements shall be made and these limits apply directly at the source interface.

EXTERNAL DIRECTLY RELATED SOURCE CLOCK/DATA RELATIONSHIP

FIGURE 25



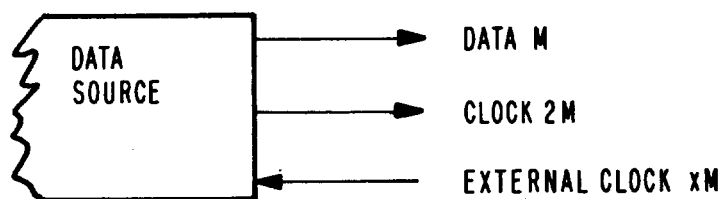
STANDARD INTERFACE CLOCK/DATA PHASE RELATIONSHIP



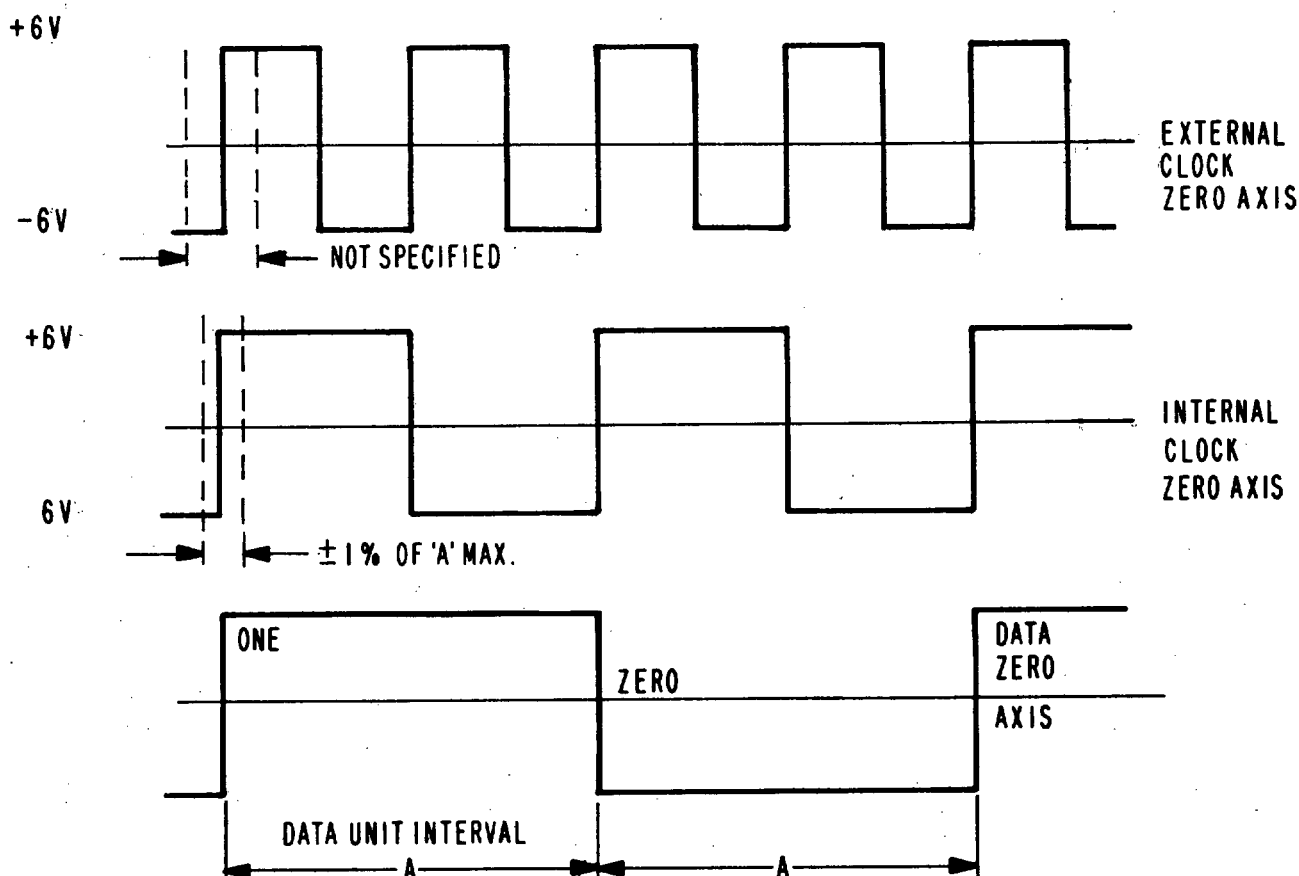
The input data signal to the sink shall be sampled consistently within $\pm 1\%$ of the duration of the unit interval of the data signal assuming the modulation rate of the clock is twice that of the data. Positive to negative clock transitions shall be utilized for sampling of the data.

FIGURE 27

EXTERNAL DIRECTLY RELATED SINK CLOCK/DATA RELATIONSHIP



"X" MAY BE 2,4,8, 128 ETC.



The data transitions shall be coincident within $\pm 1\%$ with the negative transitions of the source clock. No phase relationship between data and external clock is specified except that modulation rate and phase shift of the output clock shall be constant within 1% of the duration of the unit interval of data at the applicable modulation rate.

FIGURE 28

EXTERNAL INDIRECTLY RELATED SOURCE CLOCK/DATA RELATIONSHIP

8. INTERFACE STANDARDS

8.1 General. Tactical communication systems are frequently required to interface with other military systems and with commercial systems. The tactical standards facilitate the establishment of such interface to a large degree, however, due to differences in military requirements, environments and operations, there are differences between tactical standards and standards for other systems in a few specific instances. It may be necessary, in such cases, to provide special conversion circuits at interface points to permit interoperability across the interface. Following are listed other military systems and their standards documents. Interfaces with these systems may be expected to occur with some frequency.

8.1.1 Interface Between Tactical Communication Systems and Global Communication Systems. The standards for interfaces between tactical and global military systems are covered by DCS-Non-DCS (Defense Communications System) interface standards in the Defense Communications Agency Circular 330-175-1. The interface standards for tactical communication systems shall follow the interface standards specified in this DCA Circular.

8.1.2 Tactical Data Link Standards. These standards are for specific tactical command and control applications and include largely standards for modems, message formats, and signaling schemes. Where interfaces may exist there has been a concerted effort to coordinate standards and avoid interface problems. These standards are covered by the Joint Chiefs of Staff Publication JCS PUB 10.

9. METHODS OF MEASUREMENT

9.1 Methods of Measurement of Distortion in DC Digital Signals.

9.1.1 Digital distortion analysis equipment should reveal non-ambiguously the following:

- a. Modulation rate.
- b. Units per character interval.
- c. Bias distortion.
- d. Fortuitous distortion.
- e. Cyclic distortion.
- f. Characteristic distortion.

9.1.2 Digital distortion analyzer equipment should incorporate the following facilities or functions. However, it is not intended to limit such analyzer equipment to the facilities or functions mentioned. (Maintenance or monitoring equipment may or may not incorporate all the functions required for complete distortion analysis.)

- a. A calibrated scale to indicate the signal modulation rate.
- b. A means to set the sampling position on the signal transition (see Fig 12, Appendix B).
- c. A means to set the character interval from 1 to 16 unit intervals.
- d. Provision for operation on positive and negative marking, polar and neutral signals.
- e. The input operating differential should be in accordance with the Standard dc Digital Interface Characteristic (see para 7.2.1).
- f. Means should be provided to display all signal transitions in each character interval. Means may also be provided to display successive signal transitions in each character interval.
- g. The display facilities should have an accuracy of 2% at the applicable modulation rate.
- h. Provision should be made for accepting timing from a station master timing source (see para 7.2.7).
- i. For start/stop transmission modulation rate accuracy, see paragraph 6.1.4.2.

j. Means for generating start/stop signals with 1.0, 1.5, and 2.0 stop elements should be provided.

k. Means for generating start/stop signals with the capability of shifting the stop-to-start transition 70% of marking through 0 to 70% spacing at the applicable modulation rate should be provided. The purpose of this requirement being to permit measuring the range or margin of start/stop receiving devices.

l. Means for generating a test message utilizing the start/stop 5-unit code, International Telegraph Alphabet No. 2, American Version, (see Appendix C) should be provided.

m. Provision for generating a test message utilizing the start/stop 8-unit code, Military Standard Coded Character Set (see Appendix C), should be provided.

n. Means repetitively generating any permutation of a 5-unit or 8-unit code should be provided.

9.2 Noise Measurements on Radio Relay Systems Using Frequency Division Multiplex Equipment.

9.2.1 Noise. Two basic types of noise exist within LOS or tropospheric scatter radio relay systems. Idle noise and Intermodulation noise.

Idle noise, which is always present with or without modulation, consists of thermal noise generated within the equipments by mixer diodes, low level amplifiers, shot noise from klystrons, the noise often generated by semiconductor multiplier chains, etc.

Intermodulation noise is introduced into the system as a result of heavy signal load or increased operating level. The greater the traffic load or the higher the operating level, the more intermodulation noise is introduced. Usually intermodulation increases slowly until a "break point" is reached after which it increases very rapidly. Generally, it is desirable to operate the system at as high a level as possible (but short of the break point) in order to improve the S/N ratio.

In an FM system, higher operating levels cause greater frequency deviation which is very effective in overcoming some of the idle noise. There is a limit, however, to the amount of deviation possible before nonlinearities in the equipment increase the intermodulation noise to an unacceptable value.

If the amount of permissible deviation is shared by only a few channels, the S/N ratio in each channel will be quite good. However, as the number of channels are increased, intermodulation noise limitations demand that the per-channel frequency deviation be reduced, with a consequent increase in idle noise. If the system linearities can be improved, greater deviation can be obtained, thus restoring system quality. (The

wider deviation may affect the FM threshold detection process; however, this may be ignored under the terms being discussed.)

Thus, the equipment used represents an engineering compromise in the degree of idle channel and intermodulation noise that may be economically designed into them.

9.2.2 General Method of Noise Measurement (see Fig 29). The most desirable method of measuring the performance of radio relay systems is by the use of "white noise" loading. It has been long determined that a white noise signal (a signal with a continuous uniform spectrum) has statistical properties similar to those of a multichannel FDM and can, therefore, be effectively used for system and equipment evaluation, testing, or alignment. This is accomplished by using a white noise generator producing a baseband corresponding to the multiplex signal it replaces, but with specified gaps or slots which may be produced by stop filters at the lower, middle and upper edges of the baseband. The filters at the edges may be just within either the IB (inside band) or OB (outside band). These filters are sometimes referred to as band stop, slot, or notch filters. The noise measurements are made in the stop bands through suitable receiving filters, with the stop filters first in and then out of the circuit.

9.2.2.1 White Noise Signal Spectrum. Table X gives the noise bandwidth for systems with 60 to 600 channels, for the allocation starting at 60 kHz at the lower edge.

9.2.2.2 White Noise Signal Power Levels. The power of the white noise signal shall be computed according to the following formulas, relative to 1 mW at a point of zero transmission level, where n is the total number of channels in the circuit.

Within the specified band, the rms noise voltage level measured with a narrow bandwidth of about 2 kHz shall not vary by more than 1 dB. Outside this band, the power shall drop sharply and be more than 25 dB down at all frequencies greater than 10% above and 20% below the band.

9.2.2.2.1 Voice Loading Only.

For systems with from 60 to 240 telephone channels:

$$\text{Power} = (-1 + 4 \log_{10} n) \text{ dBmO}$$

(Provisionally applies down to minimum of 12 channels)

For systems with 240 to 600 channels (or more):

$$\text{Power} = (-15 + 10 \log_{10} n) \text{ dBmO}$$

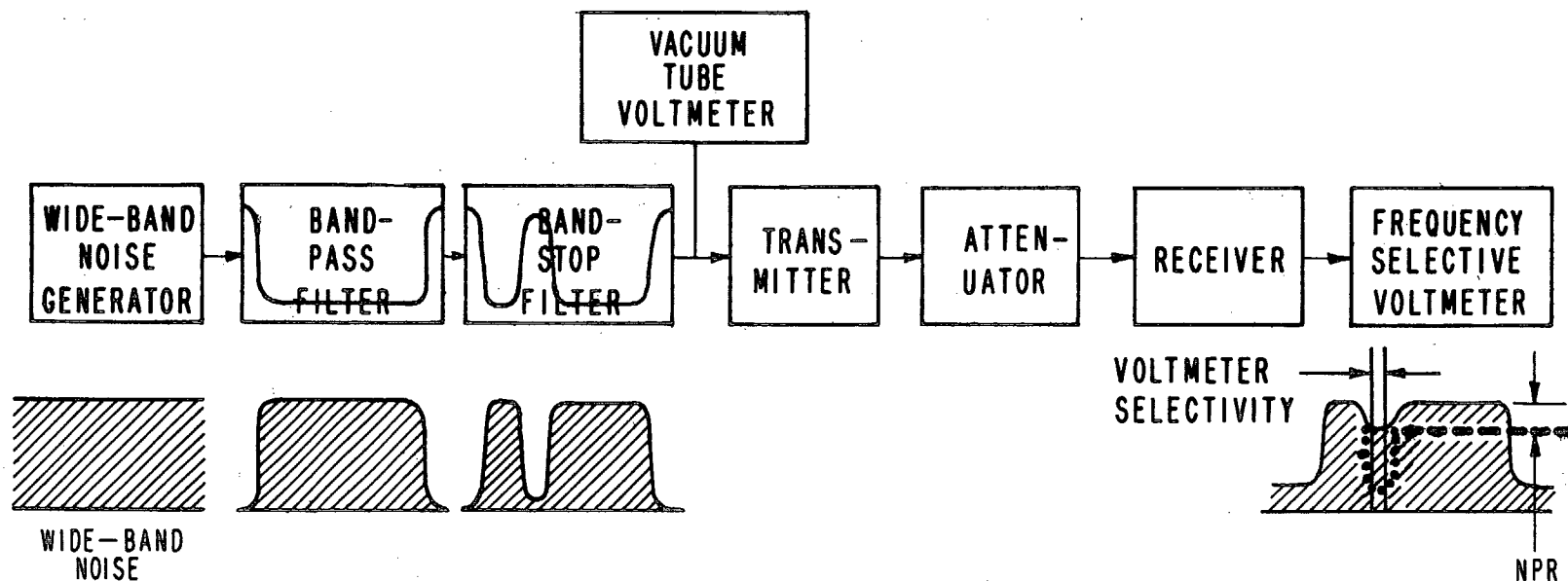
9.2.2.2.2 Data Loading.

For systems with from 12 to 600 telephone channels:

$$\text{Power} = (-10 + 10 \log_{10} n) \text{ dBmO}$$

See Note Paragraph 4.4.1.3.3.2.2

9.2.2.2.3 Stop Band Filters. To clear the measurement channels of white noise, stop band filters are required at the output of the white noise generator. The center frequencies of these filters shall be the



TYPICAL ARRANGEMENT FOR MEASURING INTERMODULATION DISTORTION IN TERMS OF NOISE POWER RATIO. RANDOM NOISE OF THE SAME EFFECTIVE POWER AND BANDWIDTH AS BASEBAND SIGNAL (BUT WITH NARROW "SLOT" REMOVED) IS APPLIED TO TRANSMITTER. ADDED NOISE IN SLOT IS MEASURED AT OUTPUT OF RECEIVER. NOTE THAT ALL NOISE CONTRIBUTIONS BY BOTH TRANSMITTER AND RECEIVER ARE INCLUDED IN A SINGLE FIGURE; PRACTICE OF QUOTING SEPARATE FIGURES FOR TRANSMITTER AND RECEIVER IS MISLEADING.

FIGURE 29

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A	B	C	D	E		F	G	H	I	J	K	L	M	N	O	P
No. Chan.	Freq.Limits Band Occup- ied by Tel. Channels (kHz)	Freq. Limits Baseband (kHz)	Nominal Impedance Baseband (Ohms) (Note 2)	Power Level Per Channel		Continuity Pilot		White Noise Spectrum Bandwidth (kHz)	Noise Measuring Actual Traffic		Channel Center Frequencies(kHz) White Noise (Note 4)					
				Input (dBm0) =	Output (dBm0) =	Frequency (kHz) (Note 1)	Deviation (rms) produced by the pilot (kHz)		Below	Above	Lower Center Upper					
											OB	IB		IB	OB	
24	12-108	12-108	150 bal.	-45	+4.5	116 (or 119)	20	-	10	116(or 119)	-	-	-	-	-	-
60	12-252 60-300	12-252 60-300	150 bal. 75 unbal.	-45 -45	+1.75 -15	304 331	25, 50, 100 (Note 3)	60-300	10 50	304 331	50	70	-	270	331	
120	12-552 60-552	12-552 60-552	150 bal. 75 unbal.	-45 -45	+1.75 -15	607	25,50,100 (Note 3)	60-552	10 50	607 607	50	70	270	534	607	
300	60-1300 64-1296	60-1364	75 unbal.	-45	-15	1499	100	60-1300	50	1499	50	70	534	1248	1499	
600	60-2540 64-2660	60-2792	75 unbal.	-45	-20	3200	140	60-2660	50	3200	50	70	1248	2438	3200	

- NOTES: 1. Frequency stability of continuity pilot shall be better than 5 parts in 10^5 .
2. Some North American commercial systems are 135 Ohms, balanced.
3. Corresponding to the per-channel deviation of the FDM signal of 50, 100 and 200 kHz, respectively.
4. Lower and upper measuring channels may be either outside (OB) or inside (IB) the band of white noise signal.
5. Data shown agree with CCIR Recommendations as follows:

CCIR Recom No.	269	292	293	294
Column of Table	ABCDEF	GH	JK	I,LMNOP

TABLE X
 PARAMETERS FOR RADIO RELAY SYSTEMS USED WITH FREQUENCY DIVISION MULTIPLEX

MTL-37D-138C

MIL-STD-188C

same as for measuring channels shown in table X. Three filters shall be used in a given case: for the center channel, and for either the two outside band (OB) or two inside band (IB) channels. The attenuation of noise in each stop band at the generator output shall exceed 80 dB over a band at least 3 kHz wide, and shall not exceed 3 dB at frequencies of $\pm (0.02 f + 4)$ kHz, where f is the center frequency in kHz. The shape of the filter characteristics shall be such that when all three band filters are simultaneously brought in the circuit, the errors in measurement as compared with a measurement carried out with a perfectly uniform source and an indefinitely narrow stop band shall not exceed 1 dB. Error here means the loss due to insertion of filters, to changes in spectral distribution of thermal and intermodulation noise produced by the insertion, and to other causes.

9.2.2.2.4 Measurement Filters. Intermodulation noise measurements shall be performed on the same bands used for the stop band filters. The use of these channels is preferred for special tests such as acceptance tests, calibration, etc. The effective bandwidth of the measuring filters in the receiving equipment shall be designed to be narrow enough to provide satisfactory measurements, taking into account the possibility of stop band filter attenuation as low as 3 dB at the frequencies $\pm (0.02 F + 4)$ kHz with respect to the center frequencies, as allowed in the stop band filter requirements. Additional or alternative measuring channels may be used as required by circumstances.

9.2.3 Noise Power Ratio (NPR) or Slot Noise Power Ratio. This is the ratio of the noise power appearing in a measured channel with the appropriate stop band filter, first out of, then in the circuit. The change in level is independent of the precise width of the measurement channel. The phrase "notch-to-no-notch ratio" is sometimes used to indicate NPR measurements. The NPR provides a good indication of system performance, since all aspects of equipment performance are taken into account.

Note that in measuring intermodulation distortion, both the transmitter and receiver participate in the test and the resulting NPR pertains to both operating together. It is not proper to assign an NPR separately to the receiver and transmitter, even though the number for each appears to be 3 dB better (higher) than the NPR for the transmitter-receiver combination, i.e., a transmitter that is rated with an NPR of 50 dB and a receiver that is rated with an NPR of 50 dB actually yield a true NPR for the system of 47 dB, twice as noisy as suggested by the split in figures.

9.2.3.1 Converting NPR to Other Rating Scales. Although the NPR provides a good indication of system performance, it is sometimes desirable to rate equipment in terms of the quality of a communications channel, i.e., in terms of dBa. This permits radio channels to be compared directly with those transmitted over wire or cable.

Per-channel noise (expressed as either dBa or S/N ratio, since dBa equals $82 - S/N$) can be derived from the NPR by relating the noise in the slot to a reference level and then applying a weighting factor.

Most commercially available noise test equipment is calibrated to express noise in terms of pico-watts or S/N ratio.

The conversion of the NPR to S/N requires that the bandwidth ratio (BWR) of the system be calculated as follows in order to obtain the proper relationship between the bandwidth of the entire baseband and the bandwidth of the slot or channel:

$$BWR = 10 \log_{10} \frac{\text{Baseband Noise Test Signal}}{\text{Channel Test-Tone Signal}}$$

If the baseband noise test power is expressed in dBm0, the NLR equals dBm0 and no calculation is necessary. Figure 30 shows the noise power equivalent to various numbers of voice channels and tone signals as recommended by CCIR and the US Electronics Industries Association (ETIA).

When the BWR and NLR have been determined, the per-channel S/N ratio may be calculated from the NPR.

$$S/N = NPR + BWR - NLR$$

As an example, figure 31 shows the per-channel S/N of a 300 channel radio system in which the intermodulation is quoted in terms of NPR of 50 dB. It is specified that the NPR was measured in a 3kHz slot and that the baseband was loaded with white noise in the frequency range of 60 to 1300 kHz. Then,

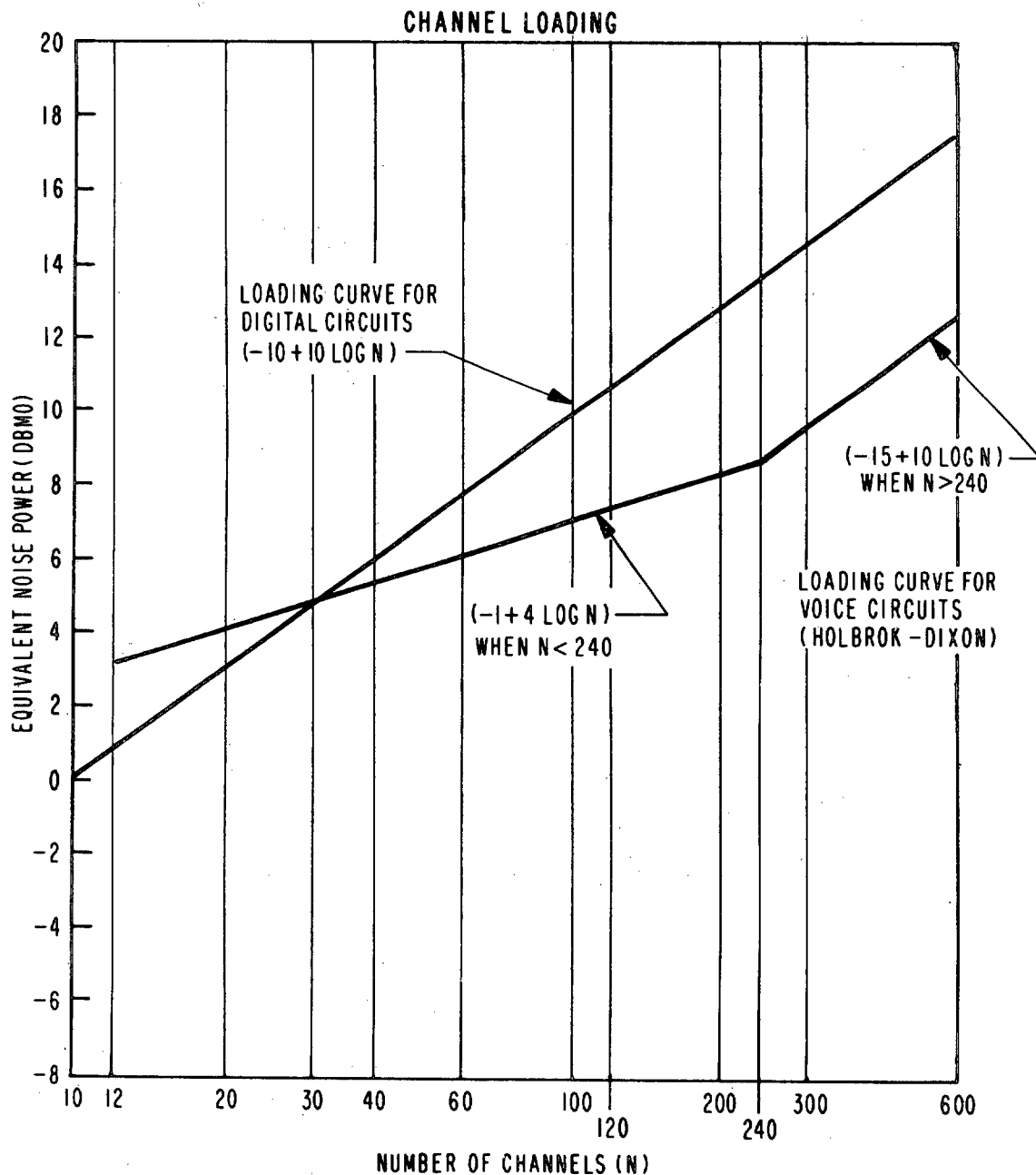
$$\begin{aligned} S/N &= NPR + BWR - NLR \\ &= 50 + 10 \log \frac{1300 - 60}{3} - 9.8 \\ &= 50 + 26.2 - 9.8 \end{aligned}$$

$$S/N = 66.4 \text{ dB}$$

The conversion of NPR to S/N gives the S/N ratio of the channel without weighting or adjustment for the responses of the human communicator or his handset. In systems where the channel response is essentially "flat" and is being measured with an unweighted meter, the FIA weighted S/N ratio may be obtained by adding 3 dB to the unweighted meter reading.

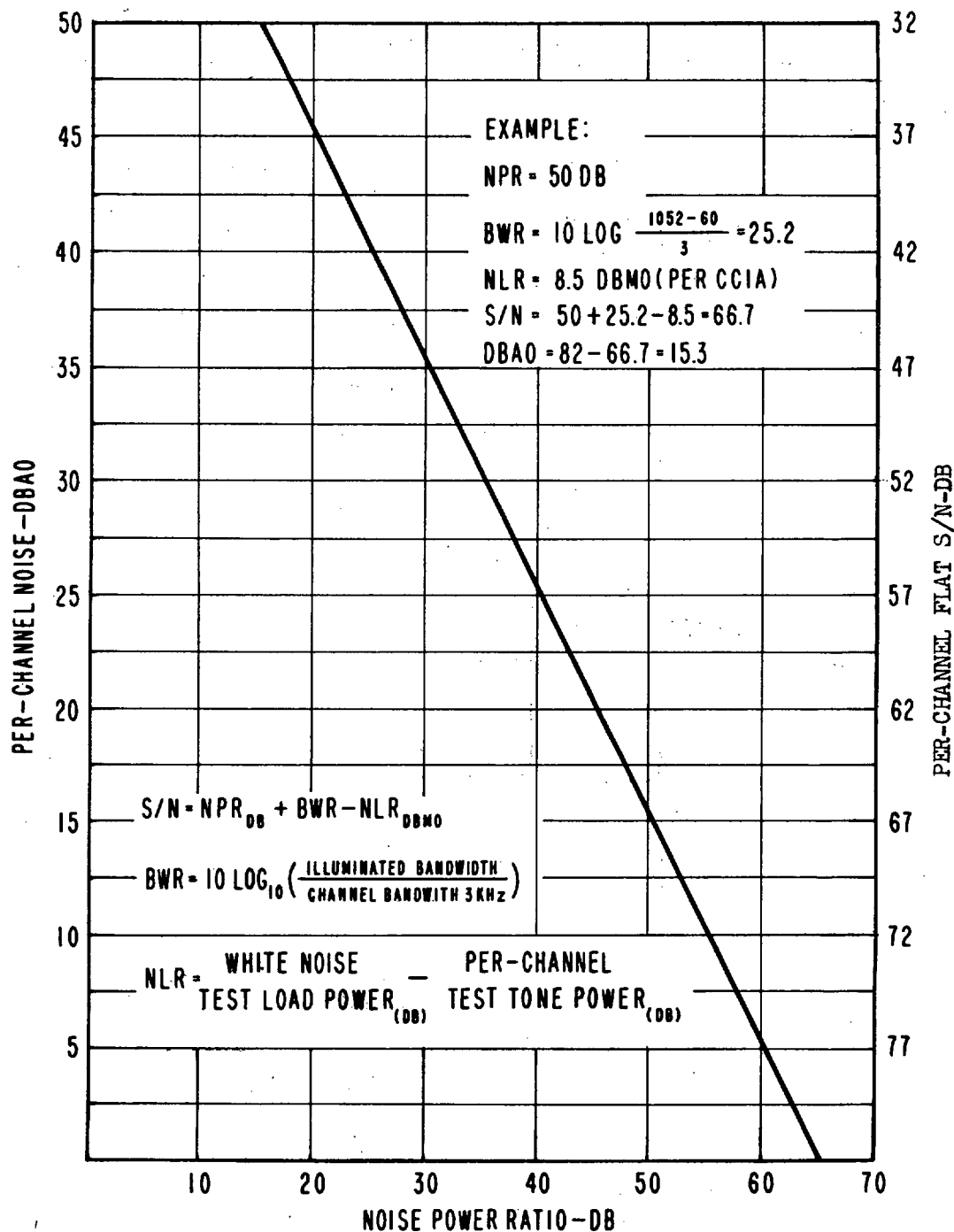
9.2.3.2 Converting S/N to dBa. By definition dBa refers to decibels of noise power above a reference noise power, with an adjustment factor included to compensate for weighting. The reference noise power to which dBa is referred is -85 dBm. To obtain dBa, it is only necessary to calculate how many dB the signal is above the reference power. For flat voice channels, the corrected reference level is -85 + 3 = -82 dBm. Therefore, dBa = 82 - (S/N). Thus, a channel for a S/N ratio of 60 dB exhibits 22 dBa of noise. To convert the per-channel S/N of the hypothetical 300 channel system discussed above (Fig 31) to a value in dBa:

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Equivalent Gaussian Noise test signal for simulating load provided by various numbers of channels. Lower values for simulating voice channels result from lower activity factor. Values shown may be used directly for noise load ratio when converting NPR to S/N and dBa.

FIGURE 30



Relationship between noise power ratio, per-channel signal-to-noise ratio, and dBa is calculated for 240-channel system according to Electronic Industries Association formula.
 NOTE: Per channel S/N ratio is with equipment connected back to back.

FIGURE 31

MIL-STD-188C

$$S/N = 66.4 \text{ dB}$$

$$\text{dB} = 82 - 66.4$$

$$\text{Noise} = 15.6 \text{ dBa (FLA weighted)}$$

9.2.4 Measurement of Noise in Actual Traffic. Once a radio relay system is placed in service, it may be difficult, if not impossible, to withdraw it from traffic to measure its noise by the use of white noise signals. Also, there may be no assurance that the identical standby channels would be available on successive occasions for this purpose. Furthermore, maintenance measurements of the total noise (idle and intermodulation noise) are of use to determine the quality of the system, and must be made during traffic. It is, therefore, desirable to specify measurement channels outside but reasonably close to the total bandwidth of the multiplex signal in order to measure the intermodulation products due to the nonlinearity of the system. Filter cost and design problems, however, require a reasonable separation between the measurement bands and the multiplex signal band. It is desirable to measure noise in a channel just above the multiplex band, since this is generally more sensitive to changes of idle and intermodulation noise in the RF and IF parts of the equipment. On the other hand, measurements in a channel below the multiplex band are more sensitive to changes in the modulators and demodulators. It is usually necessary to use stop band filters at the input of a system to minimize noise on the incoming circuit in the bands occupied by the measuring channels. The following requirements are derived from CCIR Recommendation 293 (Los Angeles, 1959).

9.2.4.1 Stop Band Filters. The attenuation of the stop band filters at the input of the system shall exceed 50 dB over a minimum frequency band $\pm (0.005 f + 2)$ kHz, where f is the center frequency of the measuring channel in kHz. The additional attenuation caused by the insertion of the stop filters at the lower edge and at the upper edge of the total multiplex signal band shall not exceed 0.3 dB referred to the additional attenuation caused in the center of the multiplex signal band. The center frequencies of the noise measuring channels are given in Table X. When the center frequency is 10 kHz minimum frequency band is to be ± 1 kHz instead of the band determined using the formula given above.

9.2.4.2 Measurement Filters. The characteristics of the measurement filters, the center frequencies of which are given in Table X shall be designed to be sufficiently narrow to give satisfactory measurements, taking into account the characteristics of the stop band filters.

9.2.4.3 Continuity Pilots. Frequencies given in Table X for continuity pilots agree with the central frequencies of the noise measuring channels above the multiplex band. It may be of use to combine the evaluation of the power of the continuity pilot with the measurement of the noise around it.

9.2.4.4 Filter Designs. It is desirable that design of band stop and measuring filters should enable them to be used both for maintenance measurements and for measurements of white noise.

9.2.4.5 Disconnection of Certain Channels. In certain telephone channels and in combinations of them, harmonic distortion may be produced. This may make it necessary to leave these channels disconnected (for example, if the second or third harmonics coincide with the central frequencies of the noise measuring channels).

9.2.4.6 Carrier Noise Measurements. Generally, it is impractical to obtain accurate field measurements of the intermodulation noise contributed by the carrier equipment; this would require that all channels be loaded simultaneously by suitable test signals. However, the intermodulation noise contributed by the carrier system may be estimated at periods of peak traffic if the noise performance of the radio has been determined previously. Such estimates may not be very accurate, however, since the load imposed by a large number of voice channels varies from moment to moment and may never reach a value which can be identified as a peak load. For this reason, meaningful evaluations of carrier noise usually consist of back-to-back measurements of idle noise.

Unlike cable or open-wire carrier systems, carrier systems, for use with radio, transmit and receive on the same band of frequencies. This permits the output of the transmit terminal to be connected back into the receive terminal on a back-to-back basis, thus permitting measurements of the carrier residual noise at one terminal.

For the back-to-back measurements of idle noise, the carrier equipment is disconnected from the radio equipment and the input of the channel in which the noise is to be measured (MOD IN) is terminated in its characteristic impedance. If the normal output or transmit level of the carrier terminal is the same as the receive level, it is then only necessary to patch the transmitter output to the receiver input. If different transmit and receive levels are used in the system, it will be necessary to adjust the transmit level to match the required receive level, either by adding or removing attenuators, or by adjusting the transmit line amplifier gain. This may require that a test tone be applied to the channel input before it is terminated; then the line amplifier gain is adjusted until the correct receive level is obtained. A suitable terminated vacuum tube voltmeter connected across the demodulator output (DE-MOD OUT) will provide a direct indication of the channel idle noise power, provided that allowance is made for the difference in levels of the actual measurement point and the zero transmission point.

If the necessary test points are available in the carrier equipment, noise measurements may be made at any modulation step in the system channel, group, or supergroup. As in the case of voice channel measurements, the modulator input must be terminated in its characteristic impedance, and the transmit level adjusted, if necessary, to match the required received level.

9.2.4.7 System Performance. The noise performance of a communication system is the sum of the noise contributed by the carrier equipment and the individual radio sections. In order to add these noise contributions directly, they must first be converted into Watts (or rather, picowatts, 10^{-12} Watt). It may be more convenient to use figure 13, Appendix B to make the addition in deciBels.

The total noise introduced by a system having many repeaters may be easily calculated if the noise contribution of each section is known, and all contribute equally. Total noise equals the number of sections. Accordingly, in a two section system in which each section contributes 18 dBa:

$$\begin{aligned}\text{Total noise} &= 18 + 10 \log 2 \\ &= 18 + 3 \\ &= 21 \text{ dBa}\end{aligned}$$

Assume a system having 16 sections, each section with a radio noise of 18 dBa. The per-channel radio noise would then be:

$$\begin{aligned}\text{Radio noise} &= 18 + 10 \log 16 \\ &= 18 + 12 \\ &= 30 \text{ dBa}\end{aligned}$$

NOTE: Total per-channel noise for a system is computed by adding the carrier multiplex and radio power noise contributions, not the ratios of these values. Thus in a 16 hop system, assuming carrier noise (multiplex, idle back-to-back) of 23 dBa, combined with the 30 dBa radio noise, the per-channel system noise is 30.8 dBa since converting 23 dB and 30 dB to power ratios:

$$\log^{-1} \frac{23}{10} = \log^{-1} 2.3 = 200$$

$$\log^{-1} \frac{30}{10} = \log^{-1} 3.0 = 1000$$

$$\text{Total power ratio} = 1200$$

then converting back to dB

$$10 \log 1200 = 10 \times 3.08 = 30.8 \text{ dB (dBa)}$$

The noise power in dBa is converted to psophometric picowatts by:

$$\text{dBa} + 6 = 10 \log_{10} (\text{pwp})$$

so that

$$30.8 + 6 = 36.8$$

$$\log^{-1} \frac{36.8}{10} = \log^{-1} 3.68 = 4800 \text{ pwp}$$

9.3 Noise Power Ratio (NPR(SSB)) Measurements

9.3.1 Single Sideband and Independent Sideband Equipment. Noise from causes other than noise intermodulation distortion products also contributes to the spectral content within the cleared portion of a notched noise signal in single sideband or independent sideband equipment output.

9.3.1.1 Method of Noise Power Ratio (SSB) Measurement. (See Fig 32). The method of measuring noise power ratio (NPR(SSB)) is to load the transmission channel(s) with a white noise signal of Gaussian amplitude distribution having an insertable narrow notch located near the center of the channel passband. The level of the applied notched noise signal is set to drive the equipment to rated noise power output. A frequency selective voltmeter measures the relative noise power of the output signal in the notch filter bandwidth for the notch in and the notch out conditions.

The relative power may be established either by switching the notch out and readjusting the signal for rated equipment output, by tuning the selective voltmeter to different frequencies, or by any other means that provide an accurate measure of NPR (SSB) as defined in paragraph 2.425.

9.3.1.1.1 Noise Test Signal Per Channel.

9.3.1.1.1.1 Noise Spectrum. The noise generator output shall be flat (constant power per Hertz of bandwidth) ± 1 dB from 100 Hz to 6000 Hz.

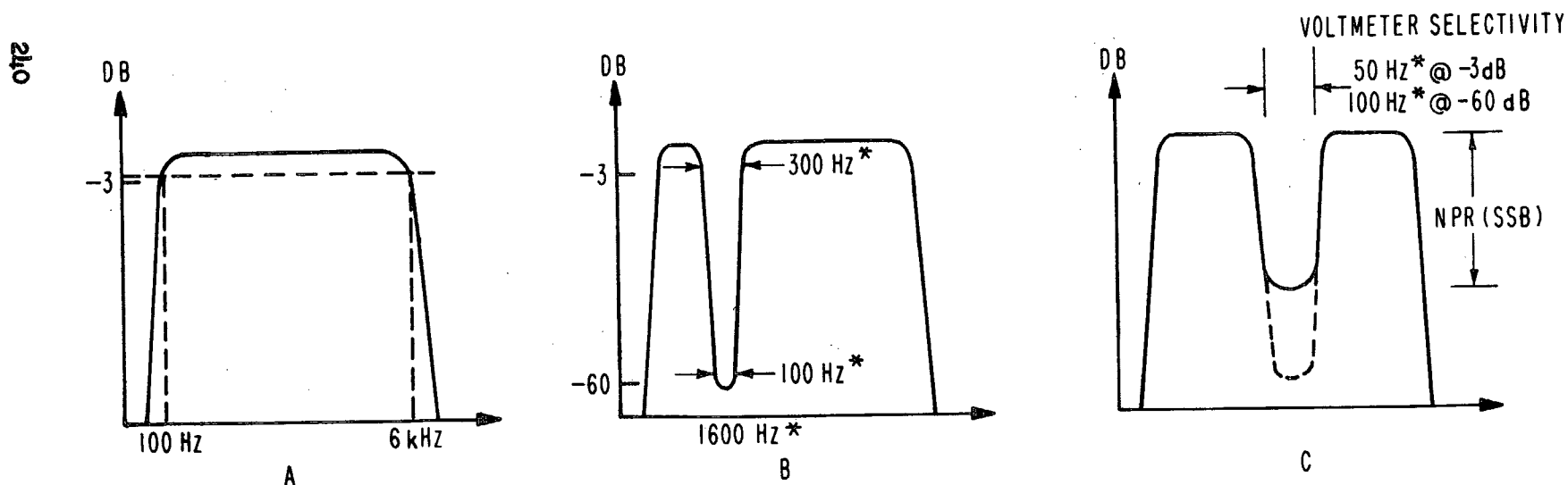
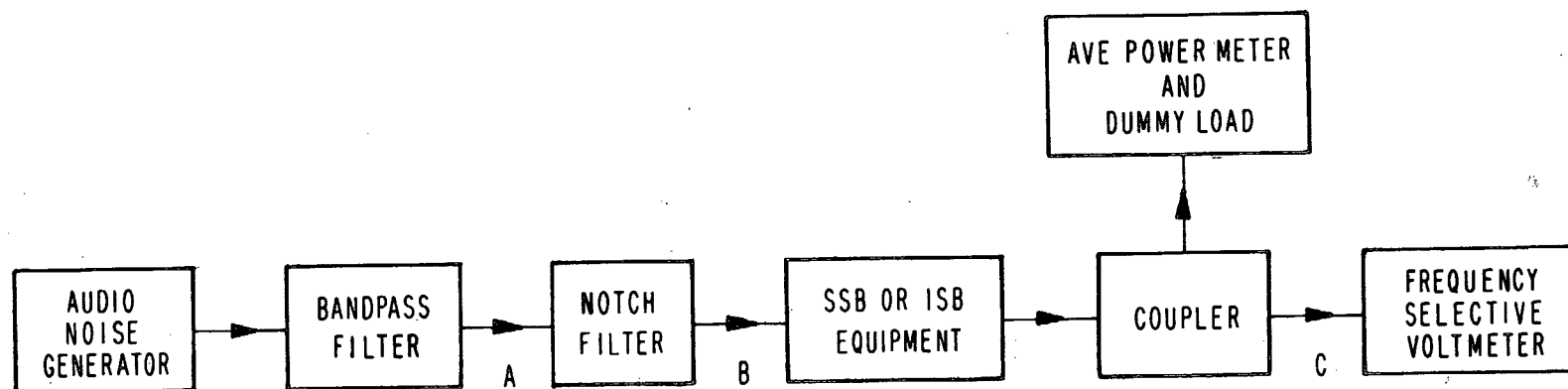
9.3.1.1.1.2 Noise Amplitude Distribution. The noise test signal amplitude density distribution shall be as indicated below when measured in a window of 0.2 (sigma) where sigma is the standard deviation of rms value of the noise voltage.

<u>Voltage (in Sigma)</u>	<u>Amplitude Density Distribution</u>
0	0.0796 \pm 0.005
± 1	0.0484 \pm 0.005
± 2	0.0108 \pm 0.003
± 3	0.000898 \pm 0.0002

9.3.1.1.1.3 Noise Band Limiting. The noise generator output shall be band limited to a 3 dB passband from 100 Hz to 6000 Hz with 6 dB/octave cutoff slopes. The passband tolerance shall be ± 1 dB.

9.3.1.1.1.4 Noise Band Notching. The noise generator output shall be notched by the narrow stop band of a notch filter located near the center of a 3 kHz channel passband to clear a portion of the channel of noise for measuring equipment with 3 kHz or 6 kHz channels.

9.3.1.1.2 Notch Filter.



* DENOTES TYPICAL VALUES

FIGURE 32
 TYPICAL ARRANGEMENT FOR MEASUREMENT OF NPR (SSB)

9.3.1.1.2.1 Stop Band Center Frequency. The stop band center frequency shall be 1600 Hz \pm 150 Hz.

9.3.1.1.2.2 Stop Band Bandwidth. The 3 dB bandwidth of the stop band shall not exceed 350 Hz. The attenuation skirts of the notch filter shall provide sufficient signal rejection when used in conjunction with the narrow bandpass filter in the frequency selective voltmeter to achieve the measurement dynamic range desired (50 dB typical).

9.3.1.1.3 Frequency Selective Voltmeter.

9.3.1.1.3.1 Bandpass Filter. The 3 dB bandwidth of the bandpass filter should be sufficiently wide (50 Hz typical) to minimize integration time required for a reasonably steady (+ 0.5 dB typical) meter indication. The 60 dB bandwidth shall be sufficiently narrow (100 Hz typical) to allow, when used in conjunction with the notch filter, for the measurement dynamic range desired (50 dB typical). NOTE: A 100 kHz crystal filter design can meet these typical characteristics.

9.3.1.1.3.2 Frequency Translator. The dynamic range of the frequency translator shall be wide (90 dB typical). NOTE: The phase noise associated with the conversion injection signal shall be sufficiently small so as to not affect the NPR measurement.

9.3.1.1.3.3 Voltmeter. The voltmeter shall be of the type to indicate either the average or the rms voltage level.

9.3.1.1.4 Multichannel Equipment. NPR (SSB) testing of multichannel equipment is carried out by successively applying the aforementioned single channel notched-noise test signal to each channel. The unnotched inputs to each of the remaining channels shall consist of uncorrelated noise, having the characteristics specified in 9.3.1.1.1.1, 9.3.1.1.1.2 and 9.3.1.1.1.3. In all cases, each of the channels shall contribute equally to the output noise power and the total output noise power shall be maintained equal to the rated output noise power.

9.3.1.1.5 Equipment Operation During Measurement. The equipment shall be tuned and operated in its normal condition.

9.4 Methods of Measurement of Transmission Performance of Digital Data Modems in Presence of Added Gaussian Noise.

9.4.1 Back to Back Performance Testing with Added Gaussian Noise.
 NOTE: This measurement is not to be construed as a complete indication of the actual performance of a modem when used over actual communications circuits. Other tests for the modem performance in the presence of other circuit phenomena such as phase jitter, envelope delay distortion, impulse noise, etc. are also required.

9.4.1.1 Determining Signal to Noise Ratio. Although this concept of establishing the performance criteria of various digital and quasi-analog data transmission systems is widely accepted, the measurement techniques

used throughout the engineering community often differ to some degree and agreement of results is not always achieved. It is considered appropriate to present a standard method of measurement to alleviate this situation.

Basically, this measurement technique strives to establish a plot of bit error rate (BER) as a function of signal to noise ratio S/N. It is often assumed that S/N in dB taken from the ratio of RMS signal voltage to RMS noise voltage as measured with a true RMS voltmeter is identical to any other equivalent S/N simply measured in the same manner. Difference in the results achieved under apparently equivalent or identical test configurations can often be ascribed to inattention to certain details of the signal and noise characteristics which produce subtle differences. In addition, many test engineers prefer a normalized S/N ratio to facilitate comparison of results with theoretical results which are often presented on a normalized basis using the ratio of bit energy in Joules to noise power density in watts per cycle of effective noise bandwidth (E_o/N_o). This method has become so prevalent while proving to be sufficiently convenient, that it will be presented herein as a preferred method. The S/N measurement easiest to obtain is the RMS signal voltage to RMS noise voltage ratio where the voltage measurements are made with a TRUE RMS Voltmeter. After determining this ratio, a convenient conversion constant (k) to normalize the ratio in terms of E_o/N_o is necessary. The procedure for finding k follows:

9.4.1.2 Finding the k Value

Signal to Noise Measurements. The actual measurements made with TRUE RMS Voltmeters will establish e_s/e_n , the ratio of RMS signal voltage to RMS noise voltage in decibels. In order to convert this dB value to an E_o/N_o dB value it will be necessary to add (or subtract) k decibels.

Calculating the k Value

Since $E_o = \text{Bit Power} \times \text{Signal Element Length}$

$$= \frac{e_s^2}{Z} \times \frac{1}{\text{Bit Rate}} \text{ secs}$$

$$\text{and } N_o = \frac{e_n^2}{Z} \times \frac{1}{\text{ENB}} \quad \text{where ENB is the effective noise bandwidth found below in 9.4.1.3}$$

$$\begin{aligned} \text{then } \frac{E_o}{N_o} &= 10 \log_{10} \frac{e_s^2}{2400} \times \frac{\text{ENB}}{e_n^2} \quad (\text{if the bit rate is 2400 BPS}) \\ &= 10 \log_{10} \frac{\text{ENB}}{2400} + 20 \log_{10} \frac{e_s}{e_n} \end{aligned}$$

$$\text{Therefore } \frac{E_o}{N_o} = k + 20 \log \frac{e_s}{e_n}$$

Example, if the ENB is 2730 Hz

$$k = 10 \log_{10} \frac{2730}{2400} = 10 \log_{10} 1.13$$

$$k = 10 \times 0.05 = 0.5 \text{ db}$$

Therefore, 0.5 dB shall be added to every e_s/e_n deciBel value measured. (e.g. 13.5 dB becomes 14 dB on the E_o/N_o plot.)

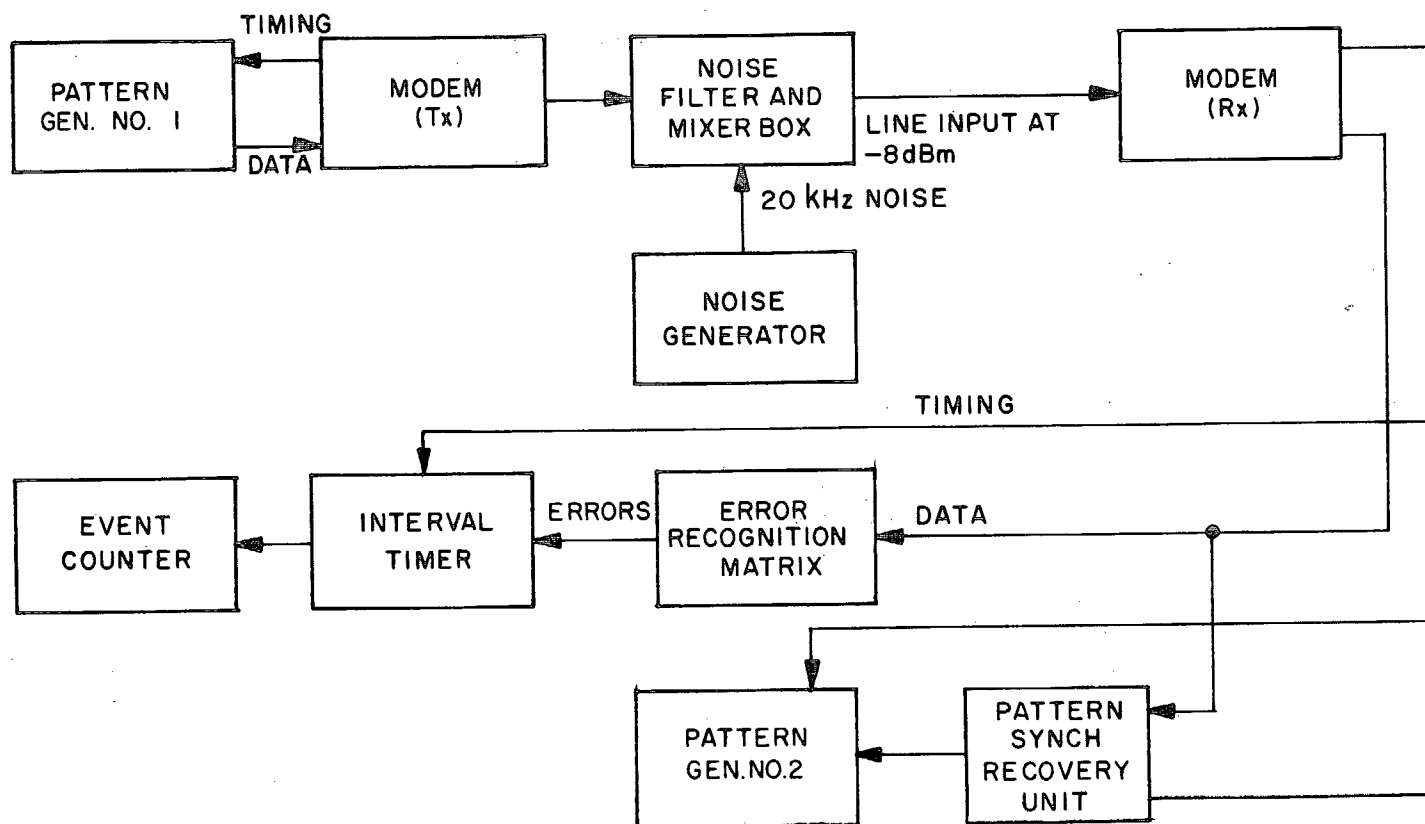
9.4.1.2.1 Finding Effective Noise Bandwidth (ENB). The Effective Noise Bandwidth (ENB) referred to above is the equivalent rectangular bandwidth of a noise band limiting filter placed between the noise source and the signal and noise mixer unit. This bandpass filter is often taken as one with its half power points at 300 and 3000 Hz and its -20 dB power points at approximately 125 Hz and 7500 Hz. The exact roll-off characteristics are not critical since the area under the power plot must be found graphically (out to the -20 dB points) and converted to an equivalent rectangular bandwidth centered around the peak power response of the actual plot. After determining the equivalent rectangular bandwidth (ENB) the noise density N_o is established as shown in 9.4.1.2 above.

9.4.1.3 Performance Measurements. A typical test configuration for determining the performance characteristics of a digital data modem system under laboratory conditions with added Gaussian noise is shown in Figure 33. The 600 Ohm noise filter and mixer box should contain the band limiting noise filter mentioned above in 9.4.1.2.1, attenuators for controlling the S/N ratio and a 600 Ohm bridged "tee" or similar type of linear mixer. The test pattern should be preferably several hundred bits long with a small portion of the sequence (e.g., 16 bits) used for frame synchronization by the pattern synchronization recovery unit which is simply a shift register and multiple input logical "AND" circuit.

Error rates at chosen S/N ratios can be determined by calculating the number of bits of the total transmitted which are in error. Test runs should be of sufficient length to realize several errors (say approximately 10) in order to establish valid probability statistics. Plots should be made on 6 cycle semi-log paper with bit error rate on the log ordinate and E_o/N_o on the abscissa. A typical plot can be realized with E_o/N_o values of approximately 8.5, 10.5, 12.5, 14.5 and 16.5 dB.

9.4.1.4 Setup. The following setup procedure is suggested to facilitate these measurements.

a. Set the signal attenuator at -8dBm (320 millivolts RMS into 600 Ohms) and note the setting. Remove the signal by inserting maximum attenuation (e.g., 30 dB) or substituting a 600 Ohm resistive load for the signal path.



TEST CONFIGURATION FOR BACK TO BACK PERFORMANCE
 WITH ADDED GAUSSIAN NOISE

FIGURE 33

- b. Set the noise at -16 dBm.
- c. Reinsert the signal at its original attenuator setting. (The setting which established the RMS signal level at -8 dBm). The es/en is now set at 8 dB. Make five test runs, average and plot the point.
- d. Insert additional attenuation (in 2 dB steps) in the noise path to raise es/en to 10 dB, 12, 14 and 16 dB and make runs and average at each point as in c.

9.4.1.5 Plotting. The results found above may be plotted directly as RMS signal voltage to RMS noise voltage ratios (es/en) expressed in decibels versus the corresponding bit error rates. If signal to noise is to be expressed in normalized terms of bit energy to noise power density (E_b/N_0) the k value in dB must be algebraically added to the es/en value. (For the positive k value of 0.5 dB given in the example above the initial setup value of 8 dB becomes 8.5 dB etc.) NOTE: K is positive when the ENB in Hz is numerically less than the bit rate in bits per second and acts to degrade the es/en plot when normalizing. A negative k value upgrades the es/en plot.

9.4.1.6 Precautions. In addition, to the procedures outlined in setting up a modem performance test under conditions of added Gaussian noise, there are some other precautions which must be observed if consistent, repeatable results are to be achieved.

- a. It should be verified that only signal and Gaussian distributed noise are entering the ports of the mixer. (i.e., make sure that other extraneous signals, noise, hum or unbalanced currents are not being introduced)
- b. The Gaussian noise source must be reasonably flat and unclipped within the flat portion of the frequency response of the band limiting noise filter.
- c. The presumed Gaussian distribution should be verified as Gaussian by some form of distribution analysis. If verification is not achieved replacement or adjustment of the noise source should be investigated.
- d. Make sure that the driving impedances and load impedance of the bridged "Tee" mixer are properly terminated. (Occasionally a careless double terminations will present confusing results.)
- e. A control modem, the performance characteristics of which are well established, should be used to verify the test configuration.

Custodians:

Army - EL

Navy - EC

Air Force - 17

Preparing Activity:

Army - EL

Project No.: Misc. - 0576

Review Activities:

Army - SC

Navy - AS, SH

Air Force - 13

APPENDIX A

DESIGNATION OF EMISSIONS AND BANDWIDTH

The content of this appendix is derived from ITU Radio Regulations, Geneva, 1959. Emissions are designated according to their classification and their necessary bandwidth.

1. DESIGNATION OF EMISSIONS AND BANDWIDTH

1.1 CLASSIFICATION OF EMISSIONS. Emissions are classified and symbolized according to the following characteristics:

- (a) Type of modulation of main carrier.
- (b) Type of transmission.
- (c) Supplementary characteristics.

1.1.1 Types of modulation of main carrier.

	Symbol
(a) Amplitude.....	A
(b) Frequency (or phase).....	F
(c) Pulse.....	P

1.1.2 Types of transmission.

(a) Absence of any modulation intended to carry information.....	0
(b) Telegraphy without the use of a modulating audio frequency.....	1
(c) Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission (special case: an unkeyed modulated emission).....	2
(d) Telephony (including sound broadcasting).....	3
(e) Facsimile (with modulation of main carrier either directly or by a frequency modulated subcarrier).....	4
(f) Television (vision only).....	5
(g) Four-frequency duplex telegraphy.....	6
(h) Multichannel voice-frequency telegraphy.....	7
(i) Cases not covered by the above.....	9

1.1.3 Supplementary Characteristics.

(a) Double sideband.....	None
(b) Single sideband:	
reduced carrier.....	A
full carrier.....	H
suppressed carrier.....	J
(c) Two independent sidebands.....	B
(d) Vestigial sideband.....	C
(e) Pulse:	
amplitude modulated.....	D
width (or duration) modulated.....	E

phase (or position) modulated..... F
 code modulated..... G

1.1.4 Examples of emissions. The classification of typical emissions is tabulated as follows:

Type of modulation of main carrier	Type of transmission	Supplementary characteristics	Symbol
Amplitude modulation..	With no modulation...	.....	A0
	Telegraphy without the use of a modulating audio frequency (by on-off keying).	.....	A1
	Telegraphy by the on-off keying of an amplitude-modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission (special case: an unkeyed emission amplitude modulated).	.....	A2
	Telephony.....	Double sideband.....	A3
		Single sideband, reduced carrier	A3A
		Single sideband, suppressed carrier	A3J
		Single sideband, full carrier	A3H
		Two independent sidebands	A3B
	Facsimile (with modulation of main carrier either directly or by a frequency modulated subcarrier).	.....	A4
	Television.....	Single sideband, reduced carrier	A4A
	Multichannel voice-frequency telegraphy.	Vestigial sideband	A5C
		Single sideband, reduced carrier	A7A
	Cases not covered by the above, e.g., a combination of telephony and telegraphy.	Two independent sidebands	A9B

Type of modulation of main carrier	Type of transmission	Supplementary characteristics	Symbol
Frequency (or phase) modulation.	Telegraphy by frequency shift keying without the use of a modulating audio frequency: one of two frequencies being emitted at any instant.	.....	F1
	Telegraphy by the on-off keying of a frequency modulating audio frequency or by the on-off keying of a frequency modulated emission (special case: an unkeyed emission, frequency modulated).	.....	F2
	Telephony.....	.....	F3
	Facsimile by direct frequency modulation of the carrier.	.....	F4
	Television.....	.....	F5
	Four-frequency duplex telegraphy.	.....	F6
	Cases not covered by the above, in which the main carrier is frequency modulated.	.....	F9
	A pulsed carrier without any modulation intended to carry information (e.g., radar).	.....	P0
	Telegraphy by the on-off keying of a pulsed carrier without the use of a modulating audio frequency.	.....	PLD
Pulse modulation..	Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by the on-off keying of a modulated pulsed carrier (special case: an unkeyed modulated pulsed carrier).	Audio frequency or audio frequencies modulating the amplitude of the pulses.	P2D

Type of modulation of main carrier	Type of transmission	Supplementary characteristics	Symbol
		Audio frequency or audio frequencies modulating the width (or duration) of the pulses.	P2E
		Audio frequency or audio frequencies modulating the phase (or position) of the pulses.	P2F
	Telephony.....	Amplitude modulated pulses.	P3D
		Width (or duration) modulated pulses.	P3E
		Phase (or position) modulated pulses.	P3F
		Code modulated pulses (after sampling and quantization).	P3G
	Cases not covered by the above in which the main carrier is pulse modulated.	.....	P9

1.2 BANDWIDTHS. Whenever the full designation of an emission is necessary, the symbol for that emission, as given above, shall be preceded by a number indicating in kilo Hertz the necessary bandwidth of the emission. Bandwidths shall generally be expressed to a maximum of three significant figures, the third figure being almost always a nought or a five.

1.2.1 Examples of necessary bandwidths and designations of emission. The necessary bandwidth may be determined by one of the following methods:

- (a) Use of the formulae included in the following table which also gives examples of necessary bandwidths and designation of corresponding emissions.
- (b) Computation in accordance with C.C.I.R. recommendations.
- (c) Measurement, in cases not covered by (a) or (b) above.

The value so determined should be used when the full designation of an emission is required. However, the necessary bandwidth so determined is not the only characteristic of an emission to be considered in evaluating the interference that may be caused by that emission.

In the formulation of the following table, these terms have been employed:

- B_n = Necessary bandwidth in Hz.
 B = Telegraph speed in bauds.
 N = Maximum possible number of black plus white elements to be transmitted per second, in facsimile and television.
 M = Maximum modulation frequency in Hz.
 C = Subcarrier frequency in Hz.
 D = Half the difference between the maximum and minimum values of the instantaneous frequency. Instantaneous frequency is the rate of change of phase.
 t = Pulse duration in seconds.
 K = An overall numerical factor which varies according to the emission and which depends upon the allowable signal distortion.

Description and class of emission	Necessary bandwidth (Hz)	Examples - details	Designation of emission
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I. AMPLITUDE MODULATION

Continuous wave telegraphy, A1	$B_n = BK \dots\dots\dots$	Morse code at 25 words per minute. $B = 20$, $K = 5$; Bandwidths: 100 Hz.....	0.1A1
	$K = 5$ for fading circuits $K = 3$ for non-fading circuits	Four-channel time-division multiplex, 7-unit code, 42.5 bauds per channel, $B = 170$, $K = 5$; Bandwidth: 850 Hz.....	0.85A1
Telegraphy modulated by an audio frequency, A2 Telephony, A3	$B_n = BK + 2M \dots$	Morse code at 25 wpm, $B = 20$, $M = 1000$, $K = 5$; Bandwidth: 2 100 Hz	2.1A2
	$K = 5$ for fading circuits $K = 3$ for nonfading circuits		
	$B_n = M$ for single sideband.	Double sideband telephony, $M = 3000$; Bandwidth: 6000 Hz.....	6A3
	$B_n = 2M$ for double sideband.	Single sideband telephony, reduced carrier, $M = 3000$; Bandwidth: 3000 Hz..... Telephony, two independent sidebands, $M = 3000$; Bandwidth: 6000 Hz.....	3A3A 6A3B

Description and class of emission	Necessary bandwidth (Hz)	Examples - details	Designation of emission
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I. AMPLITUDE MODULATION - Continued

Sound broadcasting, A3	$B_n = 2M$ M may vary between 4000 and 10000 depending on the quality desired.	Speech and music, $M = 4000$; Bandwidth: 8000 Hz.....	8A3
Facsimile, carrier modulated by tone and by keying, A4	$B_n = KN + 2M$ $K = 1.5$	The total number of picture elements (black plus white) transmitted per second is equal to the circumference of the cylinder multiplied by the number of lines per unit length and by the speed of rotation of the cylinder in revolutions per second. Diameter of cylinder = 70 mm, number of lines per mm = 5, speed of rotation = 1 rps, $N = 1100$, $M = 1900$; Bandwidth: 5450 Hz.....	5.45A4
Television (vision and sound), A5 and F3	Refer to relevant C.C.I.R. documents for the bandwidths of the commonly used television systems.	Number of lines = 625; Number of lines per second = 15625; Video bandwidth: 5 MHz Total vision bandwidth 6.25 MHz FM sound bandwidth including guard bands: 0.75 MHz, Total bandwidth: 7 MHz	625OA5C 75OF3

II. FREQUENCY MODULATION

Frequency-shift telegraphy, F1	$B_n = 2.6D + 0.55B$ for $1.5 < \frac{2D}{B} < 5.5$ $B_n = 2.1D + 1.9B$ for $5.5 \leq \frac{2D}{B} \leq 20$	Four-channel time-division multiplex with 7-unit code, 42.5 bauds per channel, $B = 170$, $D = 200$; $\frac{2D}{B} = 2.35$, therefore the first formula in column 2 applies Bandwidth: 613 Hz.....	0.6F1
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Description and class of emission	Necessary bandwidth (Hz)	Examples - details	Designation of emission
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II. FREQUENCY MODULATION - Continued

Commercial telephony, F3	$B_n = 2M+2DK$ K is normally 1 but under certain conditions a higher value may be necessary.	For an average case of commercial telephony, $D = 15000$ $M = 3000$; Bandwidth: 36000 Hz.....	36F3
Sound broadcasting, F3	$B_n = 2M+2DK$	$D = 75000$, $M = 15000$ and assuming $K = 1$; Bandwidth: 180000 Hz....	180F3
Facsimile, F4	$B_n = KN+2M+2D$... $K = 1.5$	(See facsimile, amplitude modulation.) Diameter of cylinder = 70 mm, number of lines per mm = 5 speed of rotation = 1 rps, $N = 1100$, $M = 1900$, $D = 10,000$; Bandwidth: 25450 Hz.....	25.5F4
Four-frequency duplex telegraphy, F6	If the channels are not synchronized, $B_n = 2.6D+2.75B$ where B is the speed of the channel. If the channels are synchronized the bandwidth is as for F1, B being the speed of either channel.	Four-frequency duplex system with 400 Hz spacing between frequencies, channels not synchronized, 170 bauds keying in each channel, $D = 600$, $B = 170$; Bandwidth: 2027 Hz.....	2.05F6

III. PULSE MODULATION

Unmodulated pulse, PO	$B_n = \frac{2K}{t}$ K depends upon the ratio of pulse duration to pulse rise time. Its value usually falls between 1 and 10 and in many cases it does not exceed 6.	$t = 3 \times 10^{-6}$, $K = 6$; Bandwidth: 4×10^6 Hz.....	4000PO
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MIL-STD-188C

Description and class of emission	Necessary bandwidth (Hz)	Examples - details	Designa- tion of emission
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III. PULSE MODULATION - Continued

Modulated pulse, P2 or P3	The bandwidth de- pends on the particular types of modulation used, many of these being still in the develop- ment stage.		
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APPENDIX B
EXPLANATORY NOTES
AND DIAGRAMS

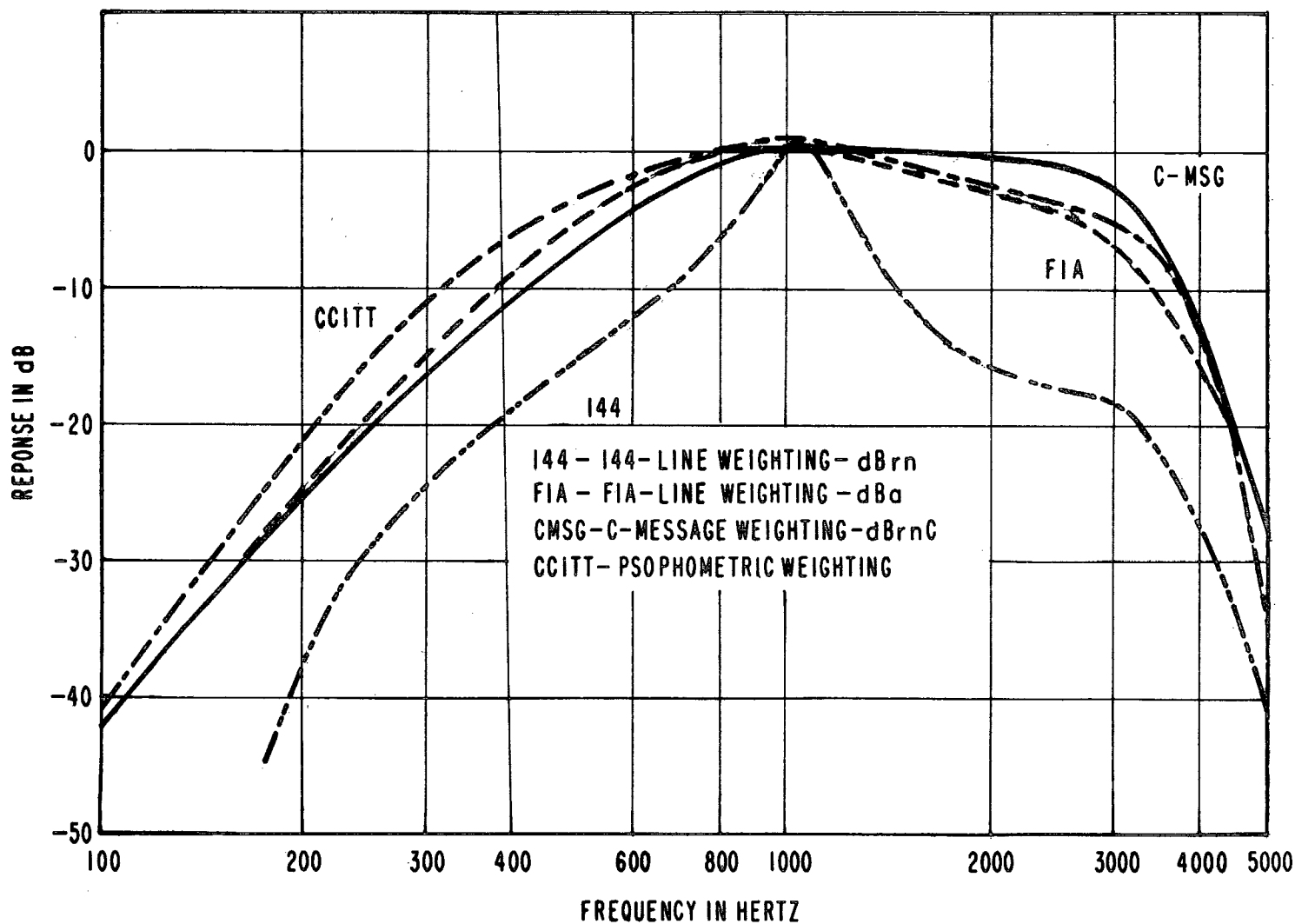


FIGURE 1. Line weightings for telephone message circuit noise

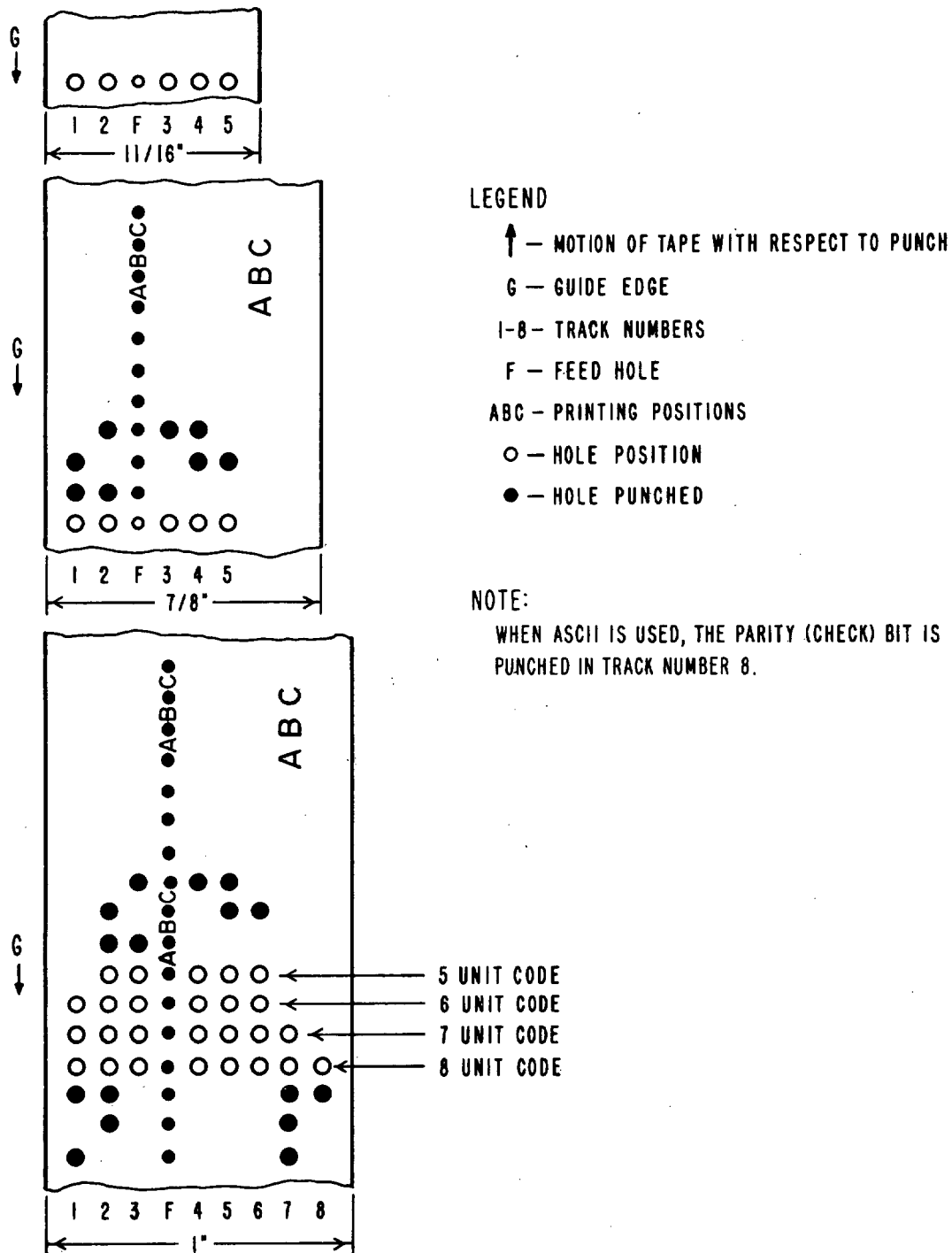
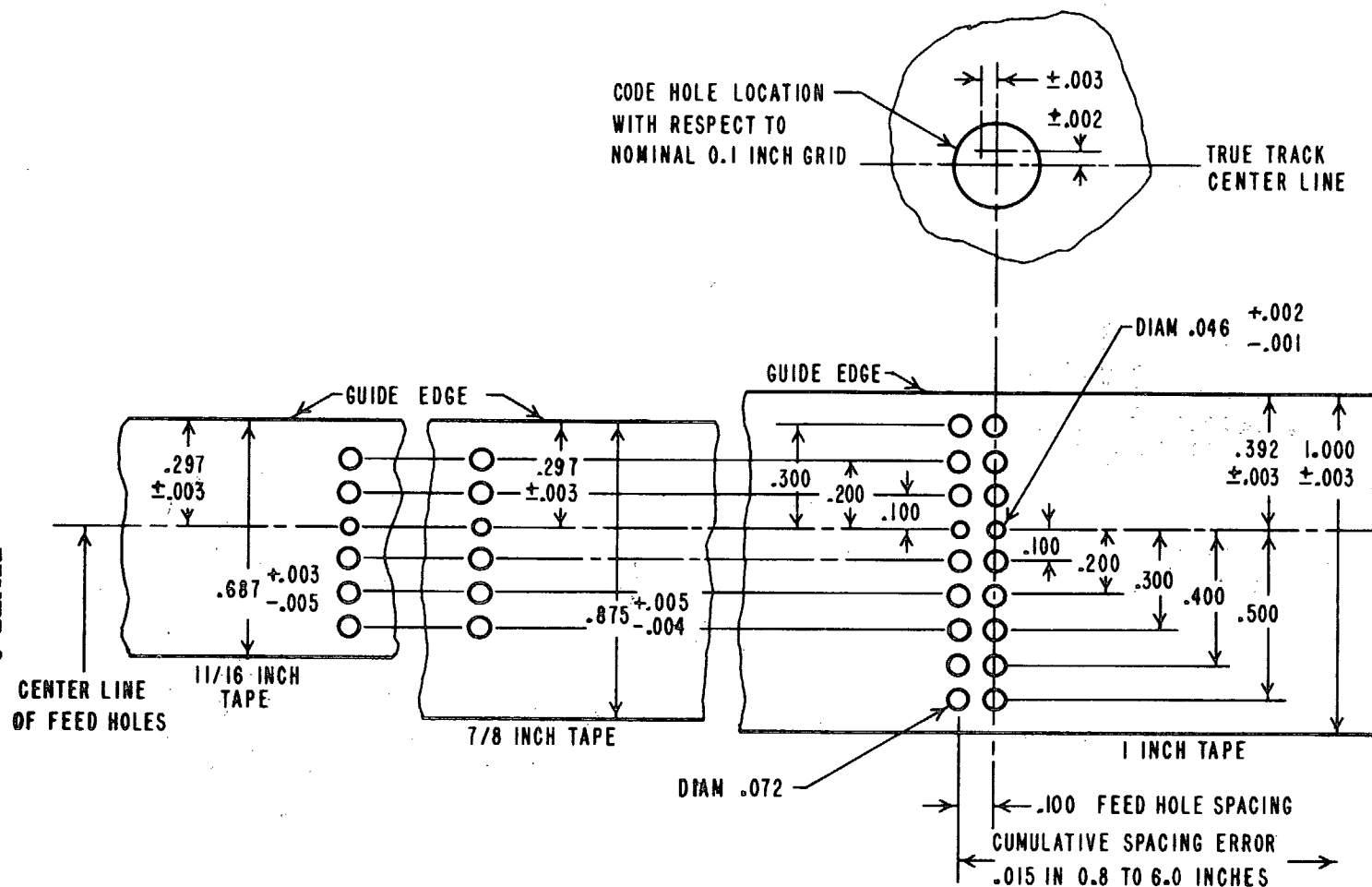


FIGURE 2 STANDARD PRINTING AND PUNCHING PLAN FOR PAPER TAPE

PUNCHING STANDARD FOR PAPER TAPES

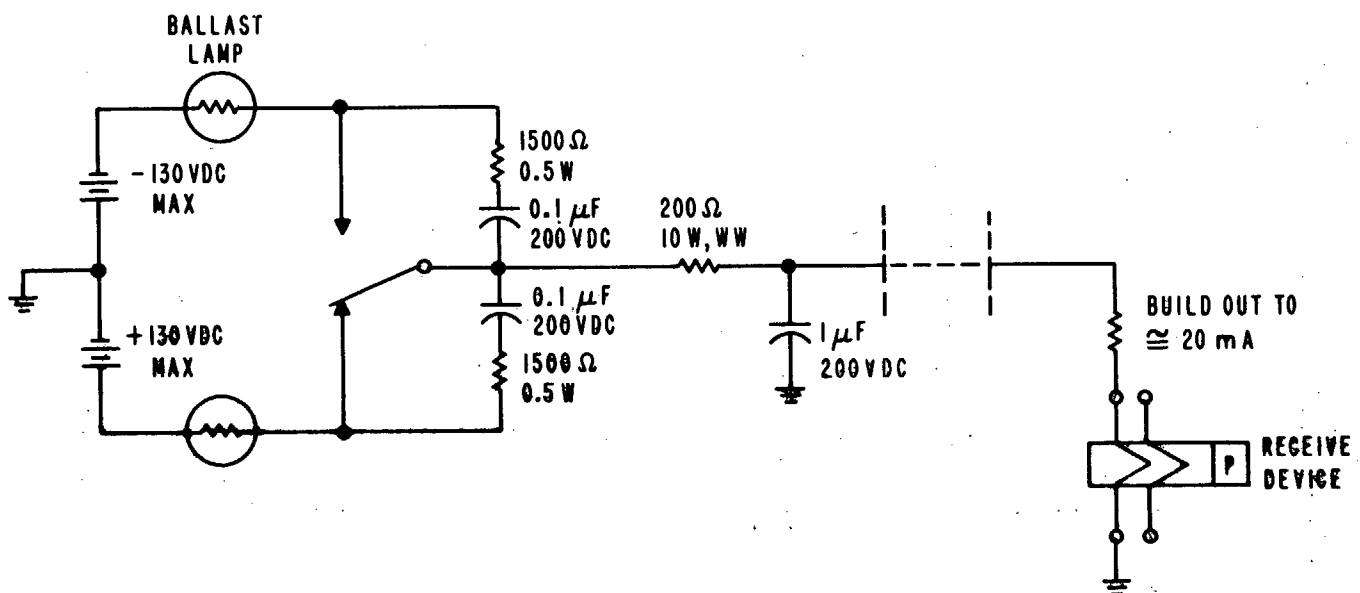
FIGURE 3

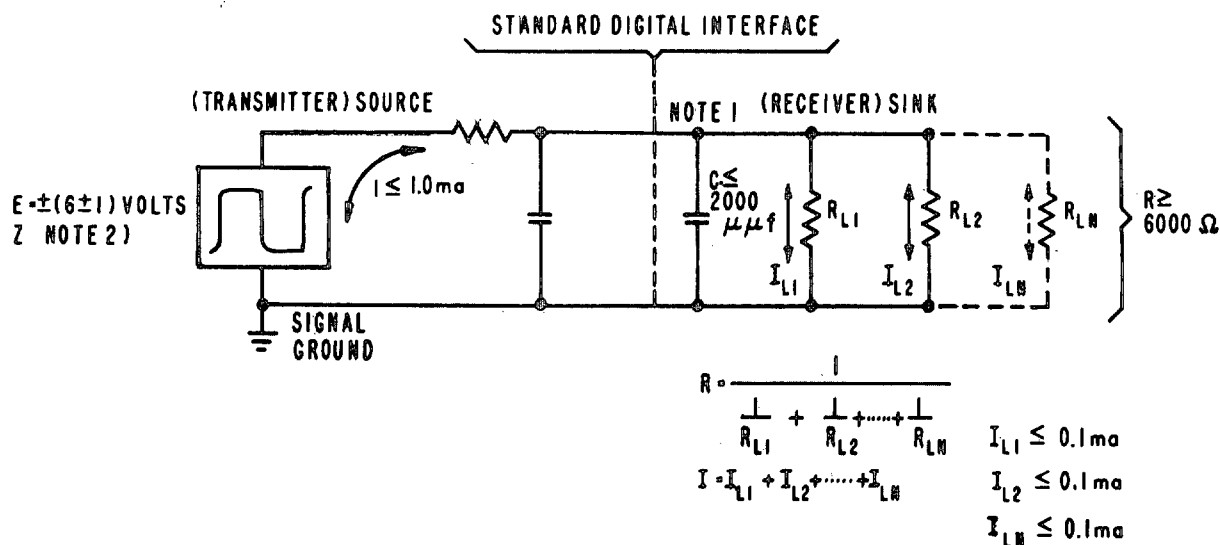


NOTES

1—UNLESS OTHERWISE INDICATED ALL TOLERANCES ARE $\pm .002$

FIGURE 4 INTERIM STANDARD INTERFACE, DC DIGITAL (POLAR HIGH LEVEL, MARKING)



NOTE ONE

There is no technical limit on the number of sinks that may be connected (in parallel) to one source. There is a limit of one milliampere for the steady state current to be utilized for normal operation of the interface. Where more than one sink is connected in parallel, the sum of the currents through all sinks shall not exceed 1.0 ma. The combined input resistance of all sinks shall be 6000 Ohms minimum.

NOTE THREE

Clock and control signals may be sine waves or shaped square waves.

NOTE FOUR

The modulation rate of the control signaling shall not exceed that of the clock.

NOTE TWO

The source impedance shall not exceed 100 Ohms (including the shaping network) for current whose magnitude is less than .01 amperes. It is to be noted that good installation practice should provide suitable protection from excess current per para 7.2.1.2. Whether this protection is incorporated in the logic itself or between the logic output and the line is left to the discretion of the designer.

NOTE FIVE

This interface may be implemented with one side of the line grounded to signal (or circuit) ground (unbalanced), or with neither line grounded to signal (or circuit) ground (balanced). Within an equipment, signal and chassis (or earth) shall be separate and independent. In either implementation, the accidental or intentional chassis (or earth) grounding of one line external to the equipment shall not cause damage to, or malfunction of, the interface logic.

STANDARD DIGITAL INTERFACE (Low Level).

FIGURE 5

CLOCK/DATA PHASE RELATIONSHIP

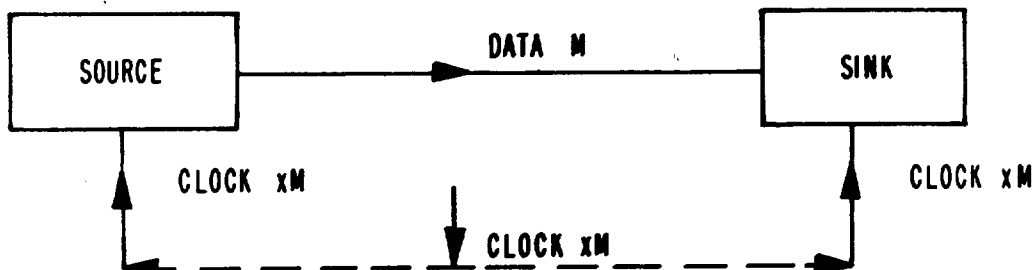
1. The following definitions apply:

a. Data modulation rate = M .

b. Clock modulation rate indirectly related to the data modulation rate = xM . Special case: when $x = 2$, clock is directly related to data modulation rate. External clock, supplied at a higher modulation rate and divided within equipment to provide a data modulation rate of M , would be defined as some number multiplied by the data modulation rate; e.g., 128M designates that clock is 128 times the data modulation rate.

2. There are five typical cases considered in this standard and the user with a unique case should attempt to relate his case to one of the examples given.

CASE ONE: Source to sink data modulation rate is determined by an external clock(s). In some cases the external clock is supplied to the source and sink and in other cases there may be two separate external clocks.



CASE 1

FIGURE 6

For electrically collocated source and sink driven by the same external clock at rate xM , x may equal 2; clock is directly related to data modulation rate and center sampling, within plus/minus 1% of the data unit interval, shall be assured.

For collocated source and sink driven by different clocks, or driven by the same clock when x is greater than 2, or for electrically separated source and sink; phasing techniques shall be employed which permit initial adjustment of sample point to within plus/minus 1% of the theoretical data unit interval measured from the center of the data unit intervals arriving at the sink.

CASE TWO: External clock is supplied to the source device at xM ; divided down to $2M$ to serve as a directly related clock, and determines the data modulation rate; the $2M$ clock is released along with the M data to act as an instruction to the sink that the data lead contains data that

MIL-STD-188C

is to be sensed. The method of gating the 2M clock is considered an equipment design consideration. The phase relationships of M to 2M shall be maintained whether gated or non-gated clock is furnished.

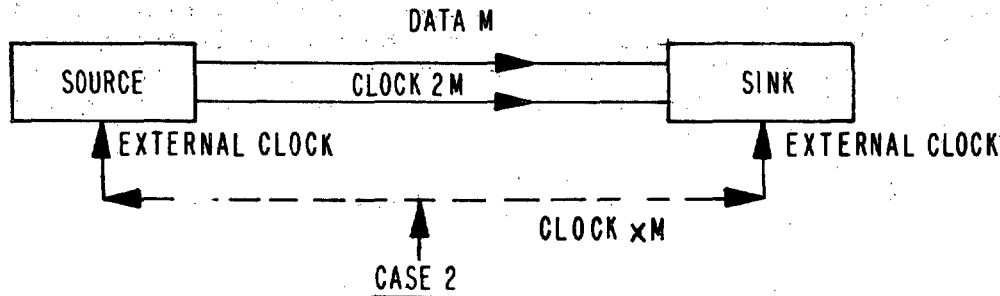


FIGURE 7

There is no specific phase relationship between xM and $2M$ or xM and M defined or implied. There is a specific modulation rate relationship which is determined by the ratio $xM/2M$ or xM/M .

CASE THREE: Case three is similar to case two except the $2M$ clock is supplied from the sink toward the source. This clock may be gated or non-gated; in effect it requests the source to release data. There is no specific phase relationship between xM and $2M$ defined or implied. There is a specific phase relationship defined between M and $2M$ at the source: data transitions can only occur after negative to positive transitions of $2M$. The data line shall not again change state until the next negative to positive transition at the $2M$ lead. The source shall maintain the phase relationship of the data M to clock $2M$ within plus/minus 1%. The $2M$ clock is not permitted to change state except at transitions of a continuous square wave of the same modulation rate. This is intended to preclude data intervals occurring at other than integral multiples of the unit interval.

The duration of the unit interval of the data modulation rate shall be maintained within the accuracy of the external clock to plus/minus 1%.

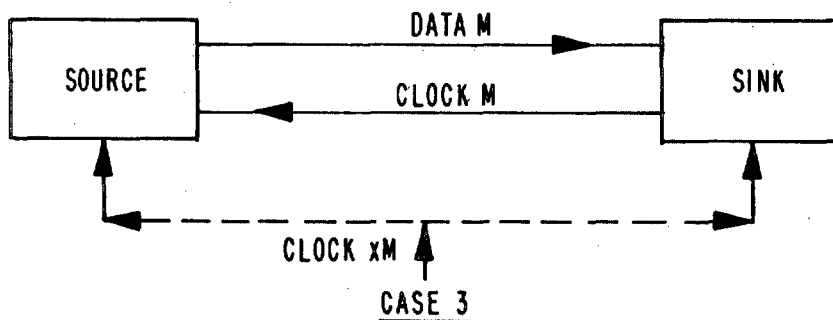


FIGURE 8

CASE FOUR: No external clock is required or implied. The control of the data modulation rate is completely under the control of the source. A 2M clock and M data lead are supplied to the sink. The "state" of the clock lead determines the sensing of the data lead at the sink. The 2M clock shall request (cause) changes in the state of the data only on the negative to positive transitions. The receiver shall determine the state of the data lead only on the positive to negative transitions of the 2M clock.

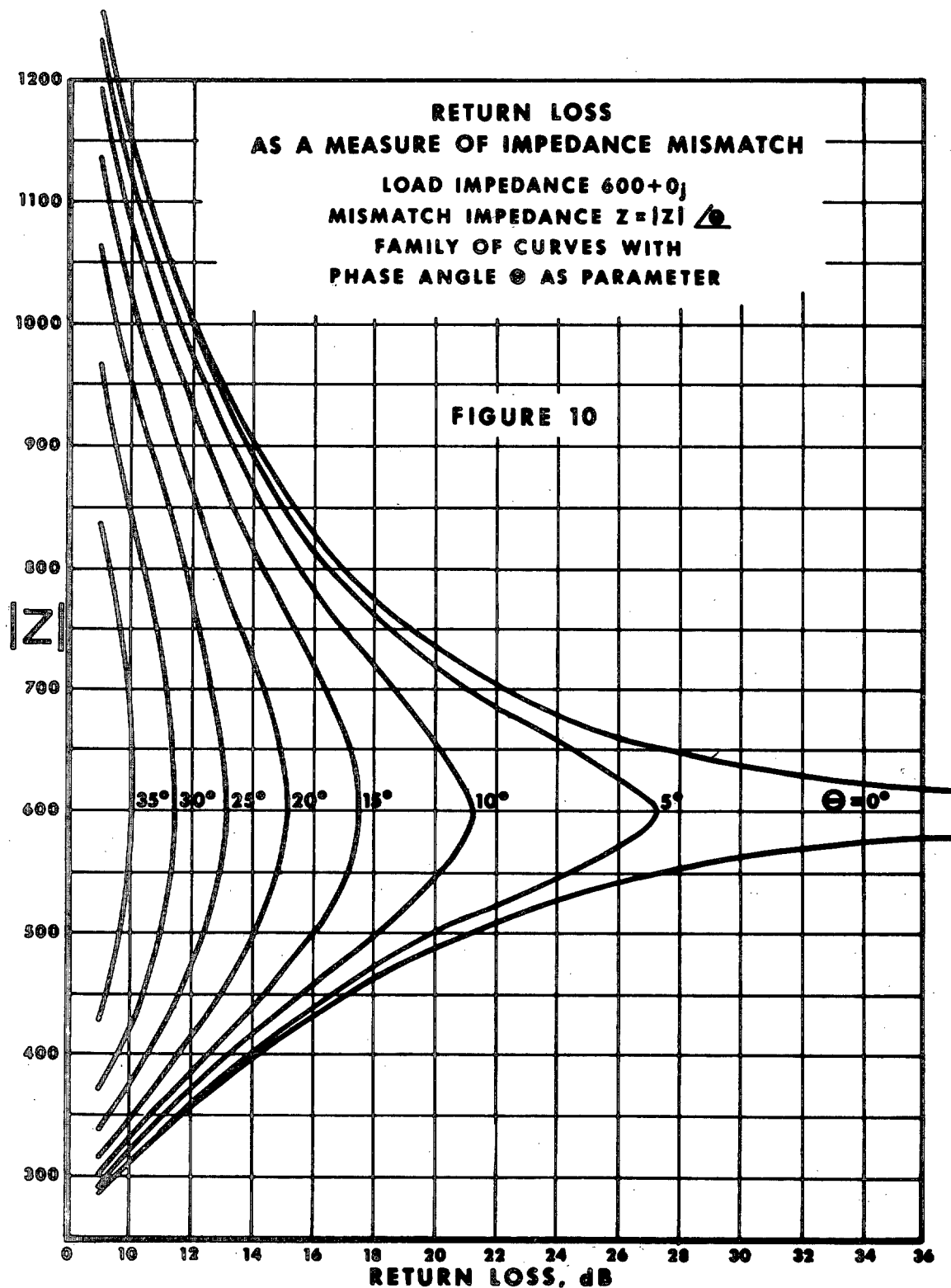


CASE 4

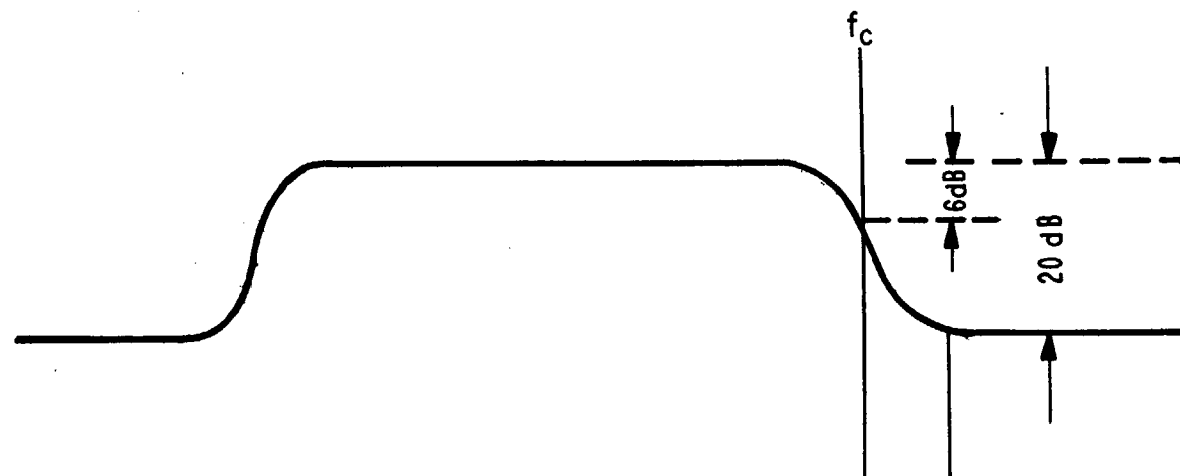
FIGURE 9

CASE FIVE: For start/stop format sinks utilizing internal, low stability, sampling sources or external clock at rate xM ; it shall be permissible to sample incoming data within plus/minus 12.5% of the theoretical data unit interval measured from the actual center of the data unit intervals arriving at the sink. Any data regenerated by this equipment shall be retimed to prevent passing on to any output interface distortion caused by this sampling technique.

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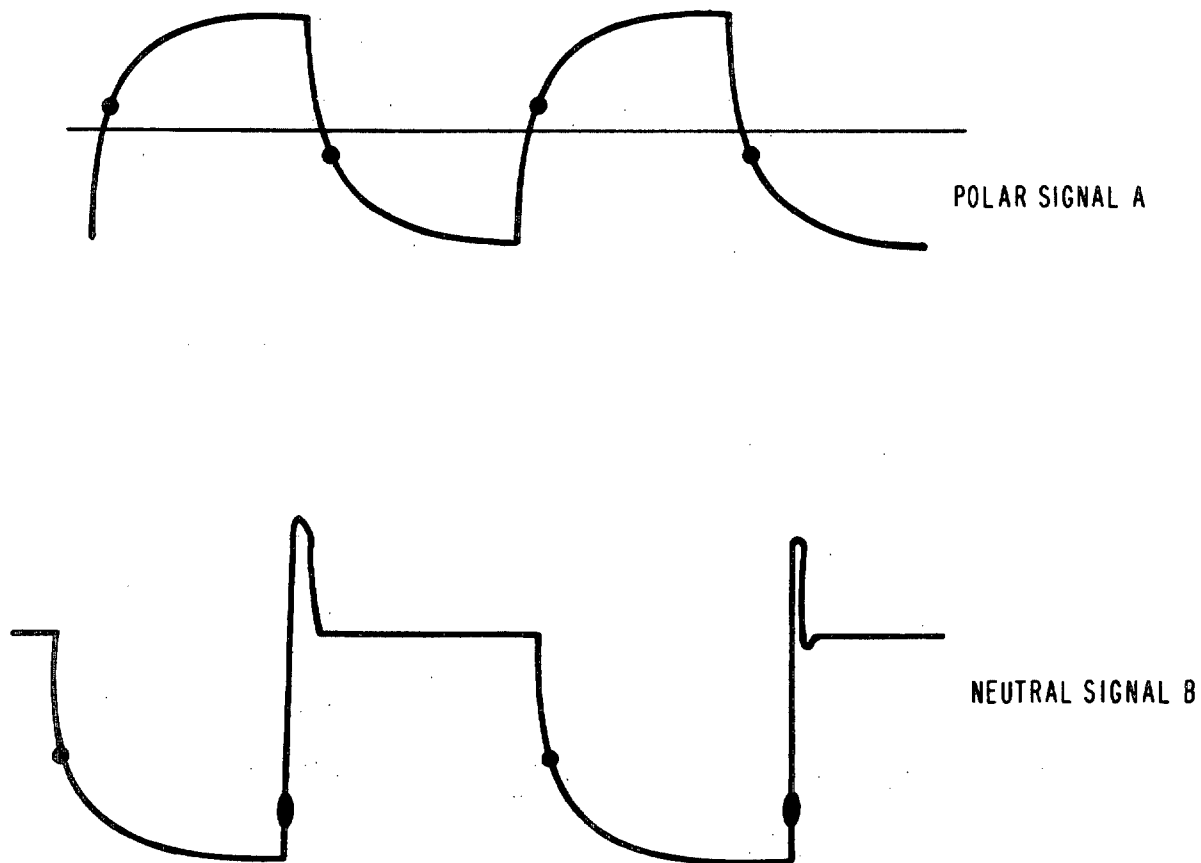
265



NOTE:
 f_c IS THE CARRIER FREQUENCY

FIGURE 11
FACSIMILE EQUIPMENT RESPONSE

MIL-STD-188C



NOTE: Due to the shape of the wave and depending on the actual point on the waveshape that the measurement is made, a signal may be said to be distorted or not distorted. It is further emphasized that when the waveshape becomes degraded at locations remote from the source, distortion can increase.

FIGURE 12

METHOD OF DISPLAY ON A WAVE FROM THE ACTUAL POINT OF MEASUREMENT

Graph for adding noise or signals expressed in decibels or dBa. If signals differ by more than 16 dB, smaller signal makes no significant contribution to total.

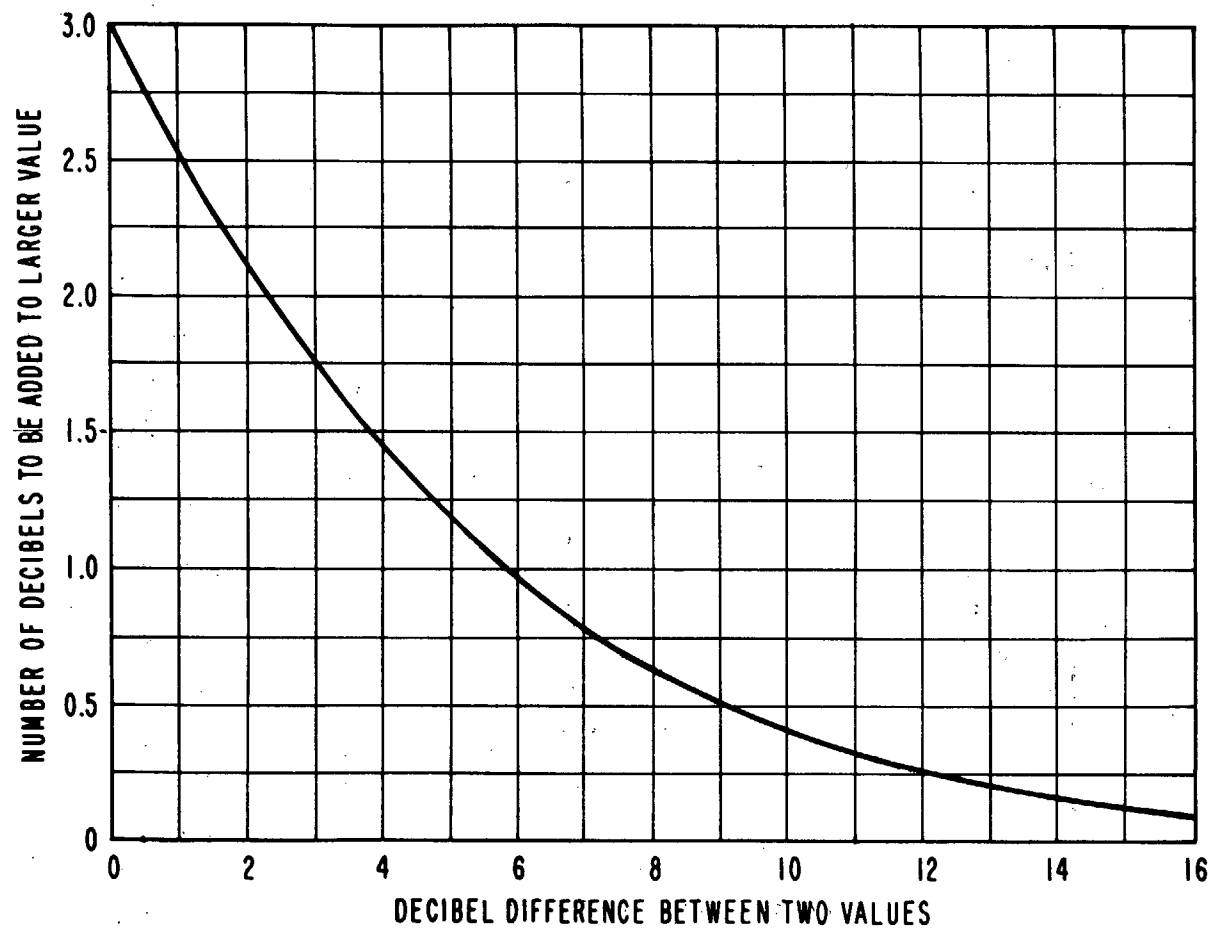


FIGURE 13

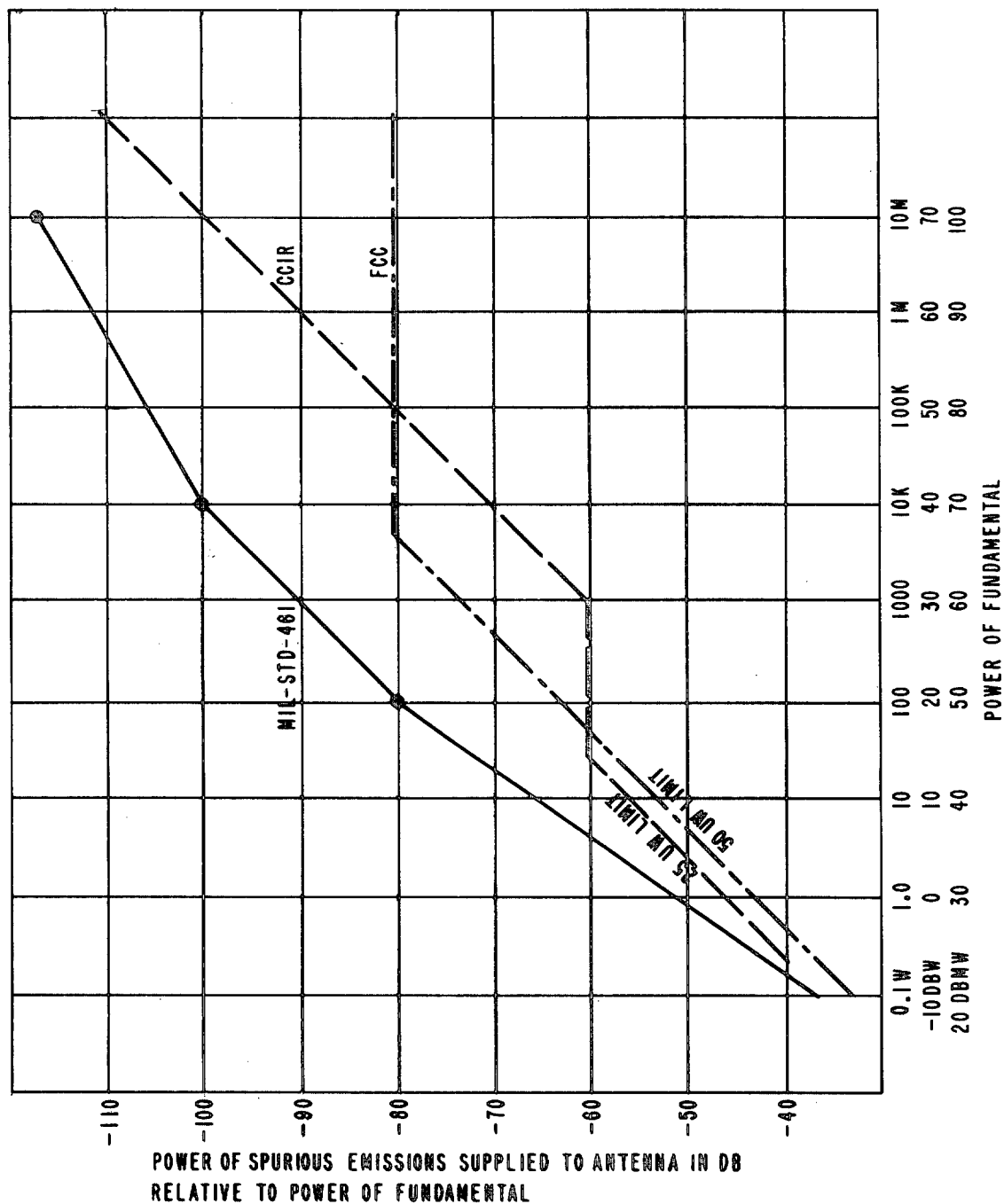


FIGURE 14 EXTRANEEOUS EMISSION OUTPUT LIMITS IN LF-MF-HF-VHF-UHF-SHF SPECTRUM

REFERENCE CHART FOR MODULATION RATES

The following chart, Table 1 and Figure 15, gives the pertinent technical characteristics of military and commercial communication systems planned or commonly in use. It is intended primarily to serve as a handy reference chart for communicators who must interface with other systems. It also points up the difficulties and advantages of standardized modulation rates. These standardized modulation rates are identified in the chart by underlines.

The following definitions apply to symbols used in Table 1, Figure 15 and Formulas:

1. W = Words per minute.
2. C₁ = Characters per second.
3. M = Modulation rate (Band).
4. B = Bits per second.
5. N = Units per character interval, or unit intervals, or character interval.
 N₁ = Whole bits per character interval.
6. U = Unit interval (size in milliseconds).
7. SU = Duration of stop interval in milliseconds.
8. C = Character intervals (size in milliseconds).
9. O = Operations per minute.
10. F = Normal bandwidth to pass 5th harmonic (rounded out from a factor of 2½ to a factor of 3) in Hertz

DATA SIGNALING RATE

$$\text{Data Signaling Rate} = \sum_{i=1}^m \frac{1}{T_i} \log_2 N_i$$

where:

- m = number of parallel channels
 T_i = minimum interval for the i th channel expressed in seconds
 n_i = number of significant conditions of the modulation in the i th channel

Data Signaling Rate is expressed in bits per second

NOTE 1 - For a single channel (serial transmission) it reduces to $\frac{1}{T} \log_2 n$; with a two-condition modulation (n = 2), it is $\frac{1}{T}$.

NOTE 2 - For a parallel transmission with equal minimum intervals and equal number of significant conditions on each channel, it is $\frac{m}{T} \log_2 n$ ($\frac{m}{T}$ in the case of a two-condition modulation).

1 (W)	2 (C ₁)	3 (M)	4 (B)	5 (N)	6 (U)	7 (SU)	8 (C)	9 (O)	10 (F)
(5 Unit)									
35.71	3.57	25	25	7.0	40	40	280	219.2	75
40.0	4.0	28	28	7.0	35.7	35.7	250	240	84
60	6.0	42	42	7.0	23.8	23.8	166	360	126
(10)65	6.5	45.5	45.5	7.0	21.97	21.97	153.7	390(A)	136.5
66	6.6	46	46	7.0	21.7	21.7	151.9	396	138
(1)71.3	7.13	49.9	49.9	7.0	20.	20.	140	427.8	149.73
(9)71.42	7.14	50	50	7.0	20.	20.	140.	428.5(A)	150
75	7.5	52.5	52.5	7.0	19.	19.	133	450	157.5
100	10.0	70	70	7.0	14.2	14.2	99.4	600	210
106	10.6	74.2	74.2	7.0	13.5	13.5	94.5	636	222.6
(9)107.1	10.7	75	75	7.0	13.3	13.3	93.1	642.8(A)	225
112.7	11.27	100	100	7.0	10.0	10.0	70	858.2	300*
(2)600	60.0	420	420	7.0	2.39	2.39	16.73	3600	1260
40	4.0	29.68	28	7.42	33.6	47.7	249.3	240	89
60	6.0	44.52	42	7.42	22.46	31.9	166.6	360	133.5
61.3	6.13	45.5	42.91	7.42	21.97	31.2	163	367.8	136.5
66	6.6	48.97	46.2	7.42	20.4	28.97	151.3	396	146.9
67.4	6.74	50	47.1	7.42	20	28.4	148.4	404	150
75	7.5	55.65	52.5	7.42	17.97	25.5	133.3	450	166.9
100	10	74.2	70	7.42	13.47	19.1	99.9	600	222.6
101	10.1	75	70.7	7.42	13.33	18.9	98.9	606	225
(3)122.7	12.27	91	85.89	7.42	10.98	31.2	80.5	736	273
60	6	45	42	7.5	22.2	33.3	166.5	360	135
(4)66.7	6.67	50	46.69	7.5	20	30	150	400	150
75	7.5	56.25	52.5	7.5	17.6	26.4	132	450	168
100	10	75	70	7.5	13.33	19.99	99.97	600	225
200	20	150	140	7.5	6.66	9.99	49.5	1200	450
600	60	450	420	7.5	1.66	2.49	12.45	3600	1350
800	80	600	560	7.5	1.25	1.87	9.37	4800	1800
1000	100	750	700	7.5	1.	1.5	7.5	6000	2250
1600	160	1200	1120	7.5	0.625	0.937	4.68	9600	3600

(6 Unit)

(5)60	6	48	48	8.0	20.8	20.8	166.4	360	144
(6)61.3	6.13	49.04	49.04	8.0	20.4	20.4	163.2	367.8	147
(7)100	10	85	80	8.5	11.76	17.6	99.96	600	255
(8)100	10	100	100	10.0	10.0	10.	100.	600	300

TABLE 1

REFERENCE CHART FOR MODULATION RATES

1 (W)	2 (C ₁)	3 (M)	4 (B)	5 (N)	6 (U)	7 (SU)	8 (C)	9 (O)	10 (F)
8 Unit (synchronous)									
93.75	9.375	75	75	8	13.33	13.33	196.6	562.5	225
187.5	18.75	150	150	8	6.66	6.66	53.3	1125	450
375	37.5	300	300	8	3.33	3.33	26.6	2250	900
750	75	600	600	8	1.667	1.667	13.3	4500	1800
1500	150	1200	1200	8	0.833	0.833	6.66	9000	3600
3000	300	2400	2400	8	0.416	0.416	3.33	18000	7200

8 Unit (asynchronous)									
42.9	4.29	45	42.9	10.5	22.2	33.3	233.1	257.4	135
53.3	5.33	56	53.3	10.5	18.7	28.1	196.3	319.8	168
71.4	7.14	75	71.4	10.5	13.33	19.99	140	428.4	225
142.8	14.28	150	142.8	10.5	7.	10.5	73.5	856.8	450**
429	42.9	450	429	10.5	2.33	3.49	24.4	2574	1350
571	57.1	600	571	10.5	1.66	2.49	17.4	3426	1800
714	71.4	750	714	10.5	1.33	1.99	13.9	4284	2250
1143	114.3	1200	1143	10.5	0.833	1.24	8.7	6858	3600
1333	133.3	1400	1333	10.5	0.714	1.07	7.488	7998	4200*

8 Unit (asynchronous)									
75	7.5	75	75	10.0	13.33	13.33	133.3	450(A)	225
150	15	150	150	10.0	6.66	6.66	66.6	900(A)	450
300	30	300	300	10.0	3.33	3.33	33.3	1800(A)	900
600	60	600	600	10.0	1.667	1.667	16.67	3600(A)	1800
1200	120	1200	1200	10.0	0.833	0.833	8.33	7200(A)	3600
2400	240	2400	2400	10.0	0.416	0.416	4.16	14400(A)	7200
68.2	6.82	75	75	11.0	13.33	26.66	146.63	409.1(A)	225
136.4	13.64	150	150	11.0	6.66	13.33	73.26	818.2(A)	450

NOTES:

- (1) Telex-Europe.
- (2) TTY Elec. Dist.
- (3) Teletype Diplex.
- (4) CCITT Standard.
- (5) IBM Start-stop.
- (6) Teletypesetter.
- (7) Stock Ticker.
- (8) IBM Start-stop.
- (9) Standard rates for electronic replacements for mechanical teletypewriter equipments.
- (10) Rate provided in new electronic equipments for compatibility with existing 60 WPM mechanical equipments.
- (A) A nominal figure which is not meaningful in the new electronic teletypewriter equipments

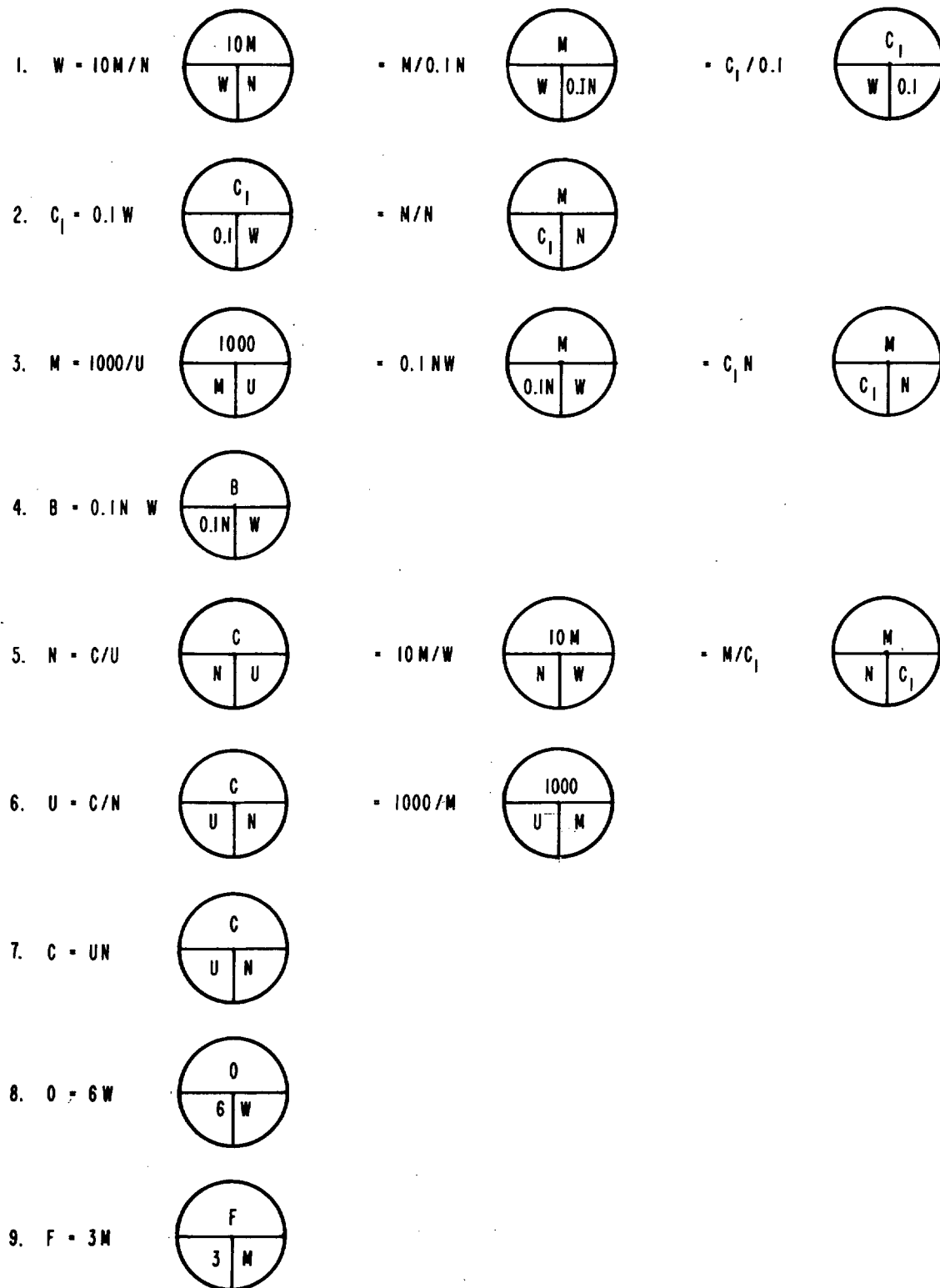
TABLE 1(Cont'd)
 REFERENCE CHART FOR MODULATION RATES

- ** Typical capability of the AN/FGC-61, AN/FGC-29, etc (about 50 cards per minute).
- # Typical 100 cards per minute.
- * Permissive standard rates.

Underlines indicate preferred standard rates.

TABLE 1 (Cont'd)

REFERENCE CHART FOR MODULATION RATES



REFERENCE CHART FOR MODULATION RATES (CONTINUED)-FORMULAS

FIGURE 15

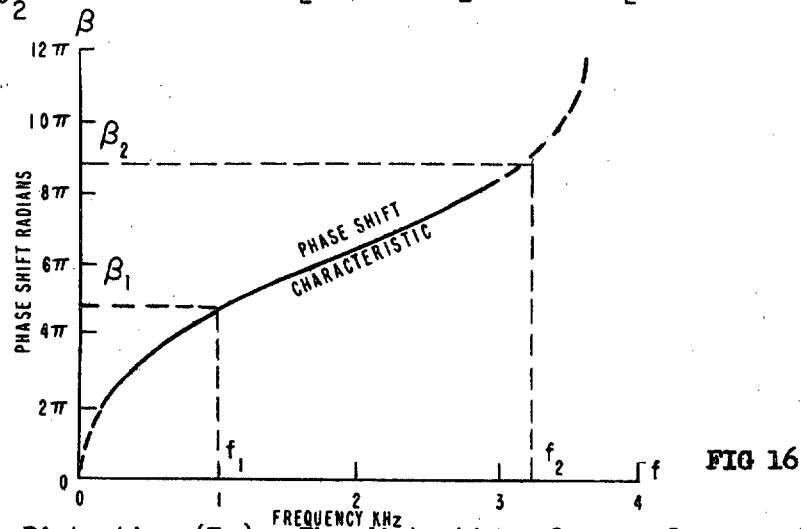
DELAY DISTORTION

1. The following explanatory information is provided for a better understanding of definitions for Delay Distortion, Envelope Delay Distortion, Phase Distortion, and Standards for limits on these distortion phenomena.

1.1 Phase Delay (T_p). The time delay between an input sinusoidal waveform to a circuit or network and the output waveform is called Phase Delay. This may be determined from the phase shift characteristic as shown in the following figure. The phase delay at any frequency (ω_1) can be computed as:

$$T_p = \frac{\beta_1 \text{ radians}}{\omega_1 \text{ radians/second}}, \text{ where } \omega_1 = 2\pi f_1; \text{ also}$$

$$T_p = \frac{\beta_2}{\omega_2} \text{ at frequency } f_2, \text{ where } \omega_2 = 2\pi f_2.$$



1.2 Delay Distortion (T_d). The distortion of a complex waveform, made up of two or more different frequencies, caused by the difference in arrival time of each frequency at the output, is called delay distortion. It is the direct result of a nonlinear phase-shift characteristic in the transmission medium. Delay distortion may be defined as:

$$T_d = \frac{\beta_2}{\omega_2} - \frac{\beta_1}{\omega_1}$$

which is the difference in phase delays at the two frequencies.

1.3 Absolute Envelope Delay (envelope delay) is the amount of delay encountered by the modulating energy in a signal between the input and output of any circuit. It is measured by transmitting a narrowband signal at the frequency(s) of interest and using the same reference at the receiver. It is the derivative of the phase-shift curve (as shown in Fig 16) at the frequency of measurement.

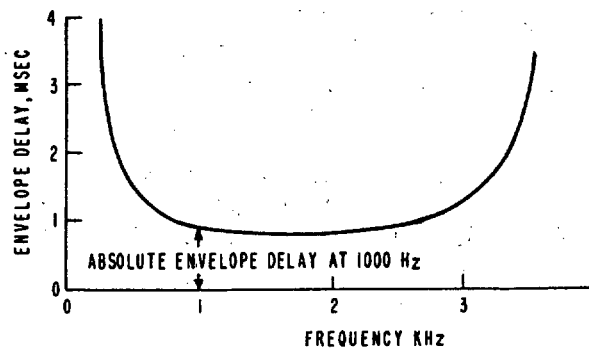


FIG 17

1.4 Relative Envelope Delay. Relative envelope delay is the difference in envelope delay at various frequencies but with a specific frequency selected as a reference point for all other frequencies. The delay at the reference frequency is considered to be 0 microseconds, and all other frequencies will either have more (positive) or less (negative) delay than the reference frequency (Fig 18).

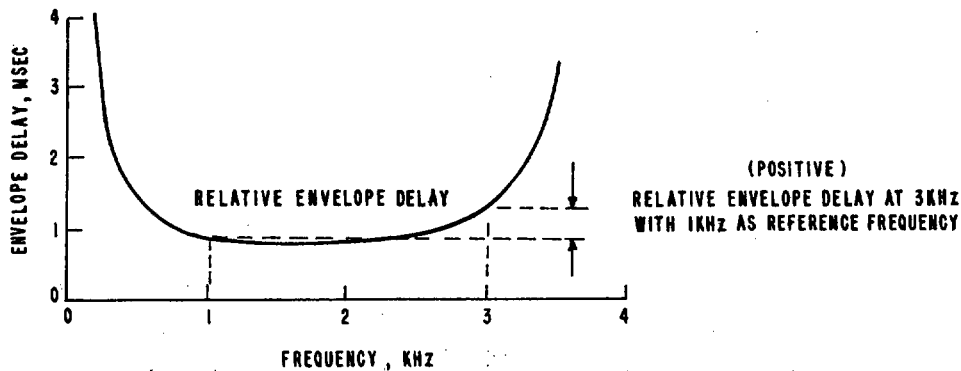
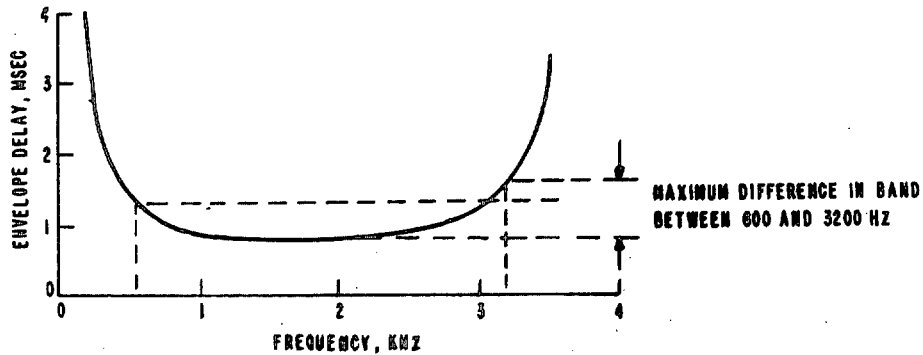
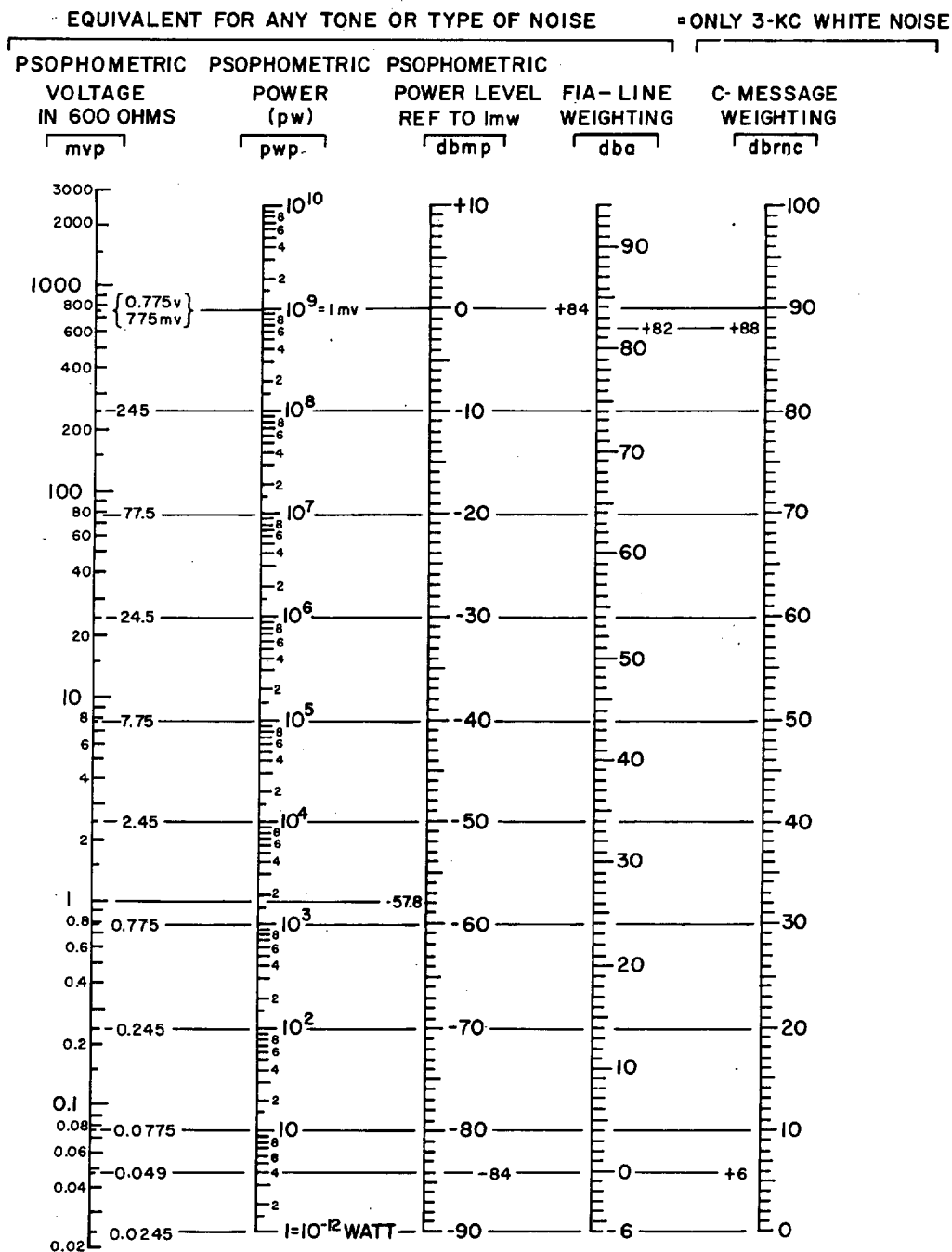


FIG 18

1.5 Envelope Delay Distortion. True delay distortion as determined from the phase characteristic is often confused with envelope delay distortion as determined from the envelope delay characteristic. Envelope delay distortion is the maximum difference of the envelope delay characteristic in a band between any two specified frequencies (Fig 19). It is not directly related to delay distortion (T_d).

**FIG 19**



BASIS FOR CHART CONSTRUCTION

- A. dbm, PSOPH. WTD (dbmp) = dba - 84
- B. ONE mw UNWEIGHTED 3-kc WHITE NOISE
 READS +82 dba = +88.5 dbrnc (C-MESSAGE),
 ROUNDED OFF TO: +88.0 dbrnc
- C. ONE mw INTO 600 OHMS = 775 MILLIVOLTS =
 0 dbm = 10^9 PICOWATTS

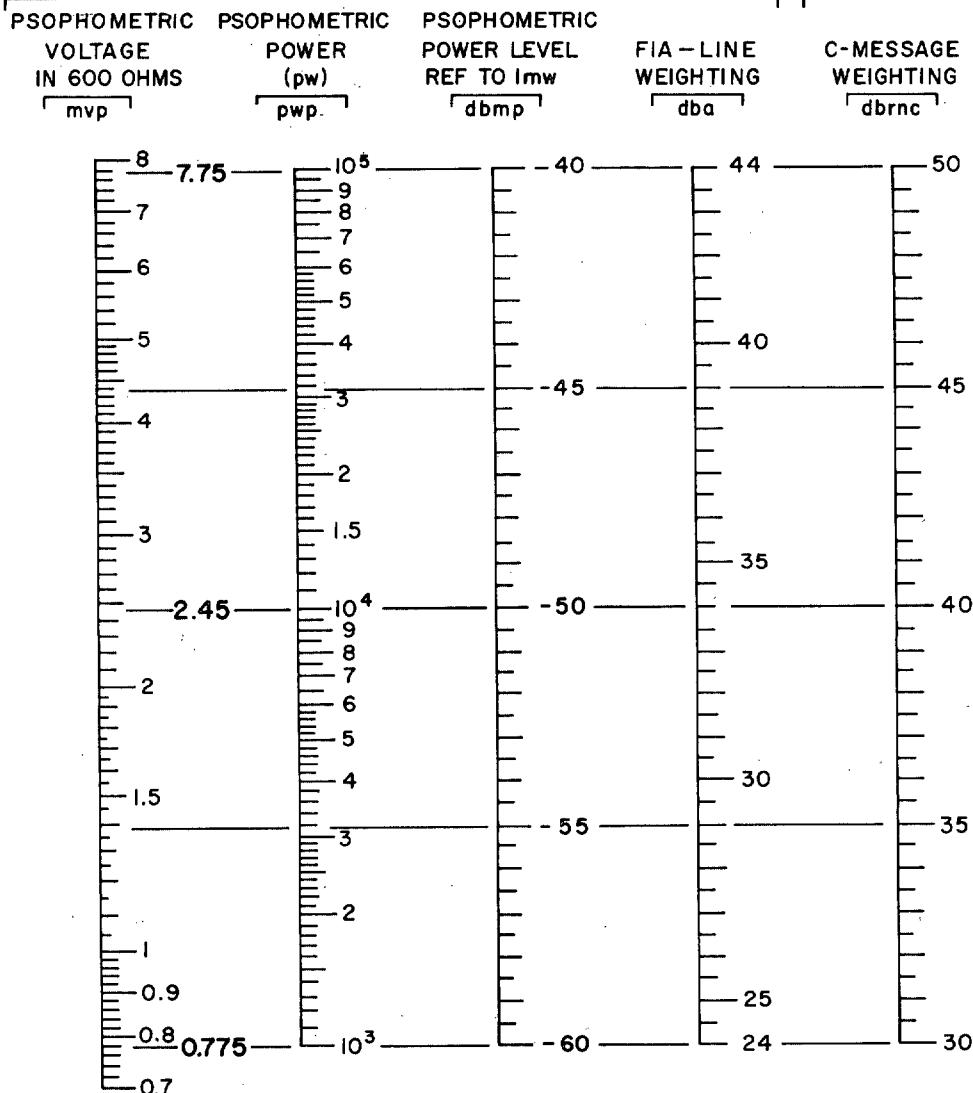
READINGS OF NOISE MEASURING SETS WHEN
 CALIBRATED ON ONE MILLIWATT OF TEST TONE:
 FIA - LINE: AT 1000 Hz READS +85 dba
 C - MESSAGE: AT 1000 Hz READS +90 dbrnc
 PSOPHOMETER (1951), 800 Hz READS 0 dbm

CONVERSION CHART: PSOPHOMETRIC, FIA
 AND C-MESSAGE NOISE UNITS

TABLE II

EQUIVALENT FOR ANY TONE OR TYPE OF NOISE

=ONLY 3-KC WHITE NOISE



$$[20 \log_{10}(\text{mvp}) - 57.8] = [10 \log_{10}(\text{pwp}) - 90] = [\text{dbmp}] = [\text{dba} - 84] = [\text{dbrnc} - 90]$$

BASIS FOR CHART CONSTRUCTION

- A dbm, PSOPH WTD (dbmp) = dba - 84
- B ONE mw UNWEIGHTED 3-kc WHITE NOISE
 READS +82 dbc = +88.5 dbrnc (C-MESSAGE),
 ROUNDED OFF TO: +88.0 dbrnc.
- C. ONE mw INTO 600 OHMS = 775 MILLIVOLTS =
 0 dbm = 10⁹ PICOWATTS.

READINGS OF NOISE MEASURING SETS WHEN
 CALIBRATED ON ONE MILLIWATT OF TEST TONE:
 FIA-LINE: AT 1000 Hz READS +85 dba
 C-MESSAGE: AT 1000 Hz READS +90 dbrnc
 PSOPHOMETER (1951), 800 Hz READS 0 dbm

CHART IS ADAPTABLE TO RANGES A THROUGH E WITH LIMITS AS FOLLOWS:

	mvp	pwp	dbmp	dba	dbrnc
A	775.	10 ⁹	0	+84	90
B	77.5	10 ⁷	-20	+64	70
C	7.75	10 ⁵	-40	+44	50
D	0.775	10 ³	-60	+24	30
E	0.0775	10	-80	+4	10
	0.0245	1	-90	-6	0

TABLE III

APPENDIX C

CODED CHARACTER SETS (ALPHABETS)

1. INTRODUCTION. Teletypewriter message transmission systems have been used in Department of Defense communications for a number of years and are expected to be used for some time. The five unit teletypewriter coded character set (see table 3) used throughout these systems has for many years been established as a standard and is included in this publication as an interim standard since it will remain in use for an undetermined interval. In the past decade, an extensive automatic electronic information processing industry has been developed. Numerous codes and media practices have been developed for input and output use with a great variety of processing equipment.

The coded character set of table 3 has not been extensively used for input or output in automatic information processing for a number of reasons. One reason is the requirement for a case shift to represent the characters in the set; another reason is the lack of order in code assignments from the standpoint of information processing by machine methods.

Recognizing that a standard coded character set was required to transmit data between the various automatic information processing centers and their associated equipment, the Department of the Army developed an eight unit code (FIELDATA) which was approved as a Military Standard in 1960 (see table 4). This code has been used in a number of communications and automatic data systems developed by the Department of Defense as well as in some commercial automatic data processing equipment. The great majority of data processing equipment has; however, used codes; media and recording format chosen by each manufacturer. The problem of information interchange between these equipment has grown more acute as their use has increased, not only in the Government, but in commercial applications as well.

During recent years, through the cooperative effort of representatives of the data processing industry, the communications industry, and the Federal Government, a coded character set has been developed and approved as a USA Standard Code for Information Interchange (USASCI) X3.4-1967, revision of X3.4-1965. This coded character set, in addition to having many of the features of the FIELDATA code, possesses a character order more acceptable for data manipulation and processing purposes. The USASCI is intended to serve as a universal code for input/output purposes and for information interchange in automatic data processing, data transmission and data capture where coded characters are used. The general use of a standard coded character set will minimize requirements for code conversion and related types of intermediate processing operations when exchanging information in machine code form throughout the Department of Defense.

During the past six years, intensive effort has been applied to obtain international agreement on a code for information interchange. The coded character set shown in Table 1 reflects a considerable amount of international consideration before May 1966. At this time the International Standards Organization (ISO) and the International Consultation Committee Telegraph and Telephone (CCITT) of the International Telecommunications Union (ITU), as specialized agency of the United Nations, and the USA Standards Institute (USASI) proposed certain minor changes now incorporated in Table 1. These changes were not reflected in Change Notice No. 1 to MIL-STD-188B because they had not been officially approved by the USASI. The changes were approved, however, on July 7, 1967. In 1966 the CCITT announced that the international version of the code shall be known as the International Telegraph Alphabet No. 5 (ITA No. 5). The international version has reserved code table positions 4/0, 5/11, 5/12, 5/13, 7/11, 7/12 and 7/13 for national use. The USASI has assigned relatively unimportant characters to these positions so that their use may be dispensed within certain international traffic with a minimum of difficulty.

The USA Standard Code for Information Interchange, commonly referred to as USASCII or ASCII, was made a Federal Standard by a Memorandum of the President of the United States on 11 March 1968. This Appendix is therefore in accordance with the July 7, 1967 revision of USASCII and the Federal Standard established in the Presidential Memorandum.

Certain major procurements were made based upon the pre-May 1966 version of USASCII. These equipments should not be considered nonstandard unless operational incompatibilities result but a planned effort should be made to convert to Table 1 operation at the earliest necessary date, depending upon operational difficulties. The changes made in the USASCII were:

- a. In position 1/10 the SS (Special Sequence) was replaced with SUB (Substitute).
- b. The "@" was moved from position 6/0 to 4/0 and the "grave accent" from position 4/0 to 6/0.
- c. The "Tilde" in position 5/12 was changed to "reverse slant."
- d. The "overscore" was moved from position 7/12 to 7/14 and represented by the "Tilde" which it doubles for and the "vertical line" was moved from position 7/14 to 7/12 and represented by a two-segment broken vertical line.

The information contained in this appendix is derived from the USA Standard Code for Information Interchange X3.4-1968 and is included in this standard with the permission of the USA Standards Institute.

That portion of X3.4-1968 that concerns the "New Line" (NL) convention has not been adopted as a Federal Standard whereas the provisions of X3.4-1967 have been pursuant to Federal Information Processing Standards Publications 1 and 7 (FIPS PUBS 1 and 7) published by the US Department of Commerce/ National Bureau of Standards.

2. USA STANDARD CODE FOR INFORMATION INTERCHANGE (USASCII).

2.1 The USASCII is to be used for the general interchange of information among information processing systems and communication systems, of a character conscious type, used by the Departments and Agencies of the Department of Defense.

2.2 Table 1 contains Printing Symbols for the 128 characters of USASCII. Where standards for printing symbols for the control characters have not yet been established for USASCII, Table 1 contains recommended symbols for control characters in columns 0 and 1 and for "delete" in position 7/15. Table 1 also has added two noncoded graphics; the diamond (\diamond) as the symbol to indicate a detected error and the heart (\heartsuit) as a general symbol to indicate control characters (see par. 2.5.3).

2.3 Character Representation. The standard 7-bit character representation with b_7 the high-order bit and b_1 the low-order bit, is shown below. (Order of bit transmission is specified in paragraph 2.6.4 of this appendix.)

EXAMPLE: The bit representation for the character "K" (see Table 1) is:

b_7	b_6	b_5	b_4	b_3	b_2	b_1
1	0	0	1	0	1	1

The code table position for the character "K" may also be represented by the notation "column 4, row 11" or alternatively as "4/11." The decimal equivalent of the binary number formed by bits b_7 , b_6 , and b_5 , collectively, forms the column number, and the decimal equivalent of the binary number formed by bits b_4 , b_3 , b_2 and b_1 collectively, forms the row number.

2.4 LEGEND

2.4.1 Control Characters:

NUL	Null	DC3	Device Control 3
SOH	Start of Heading (CC)	DC4	Device Control 4 (Stop)
STX	Start of Text (CC)	NAK	Negative Acknowledge (CC)
ETX	End of Text (CC)	SYN	Synchronous Idle (CC)
EOT	End of Transmission (CC)	ETB	End of Transmission Block (CC)
ENQ	Enquiry (CC)	CAN	Cancel
ACK	Acknowledge (CC)	EM	End of Medium
BEL	Bell (Audible or attention signal)	SUB	Substitute
BS	Backspace (FE)	ESC	Escape
HT	Horizontal Tabulation (punched card skip) (FE)	FS	File Separator (IS)
LF	Line Feed (FE)	GS	Group Separator (IS)
VT	Vertical Tabulation (FE)	RS	Record Separator (IS)
FF	Form Feed (FE)	US	Unit Separator (IS)
CR	Carriage Return (FE)	DEL	Delete ¹
SO	Shift Out	NOTE: (CC) Communication Control (FE) Format Effector (IS) Information Separator (1) In the strict sense, DEL is not a control character.	
SI	Shift In		
DLE	Data Link Escape (CC)		
DC1	Device Control 1		
DC2	Device Control 2		

2.4.1.1 When a control character is represented by a single graphic symbol, the symbol shall be that which appears to the right of the control abbreviation in table 1.

2.4.2 Graphic Characters:

Column/Row	Symbol	Name
2/0	SP	Space (normally non-printing)
2/1	!	Exclamation Point
2/2	"	Quotation Marks (Diaeresis ¹)
2/3	#	Number Sign ²
2/4	\$	Dollar Sign
2/5	%	Percent
2/6	&	Ampersand
2/7	'	Apostrophe (Closing Single Quotation Mark; Acute Accent ¹)
2/8	(	Opening Parenthesis
2/9	)	Closing Parenthesis
2/10	*	Asterisk
2/11	+	Plus
2/12	,	Comma (Cedilla ¹)
2/13	-	Hyphen (Minus)
2/14	.	Period (Decimal Point)
2/15	/	Slant
3/10	:	Colon
3/11	;	Semicolon
3/12	<	Less Than
3/13	=	Equals
3/14	>	Greater Than
3/15	?	Question Mark ²
4/0	@	Commercial At ²
5/11	[	Opening Bracket ²
5/12	\	Reverse Slant ²
5/13	]	Closing Bracket ²
5/14	^	Circumflex ^{1,2}
5/15	_	Underline
6/0	`	Grave Accent ^{1,2} (opening single quotation mark)
7/11	{	Opening Brace ²
7/12	|	Vertical Line
7/13	}	Closing Brace ²
7/14	~	Overline ² (Tilde; General Accent ¹)
Not Coded	◇	Diamond
Not Coded	♡	Heart

¹ The symbols in 2/2, 2/7, 2/12, 5/14, 6/0 and 7/14 may be used as diacritical marks by preceding them with an alphabetic character and BS (Backspace) in that sequence.

² These characters should not be used in international interchange without determining that there is agreement between sender and recipient.

2.5 DEFINITIONS

2.5.1 General:

(CC) Communication Control: A functional character intended to control or facilitate transmission of information over communication networks.

(FE) Format Effector: A functional character which controls the layout or positioning of information in printing or display devices.

(IS) Information Separator: A character which is used to separate and qualify information in a logical sense. There is a group of four such characters, which are to be used in a hierarchical order.

2.5.2 Control Characters:

NUL: The all zeros character.

SOH (Start of Heading): A communication control character used at the beginning of a sequence of characters which constitute a machine-sensible address or routing information. Such a sequence is referred to as the "heading". An STX character has the effect of terminating a heading.

STX (Start of Text): A communication control character which precedes a sequence of characters that is to be treated as an entity and entirely transmitted through to the ultimate destination. Such a sequence is referred to as "text". STX may be used to terminate a sequence of characters started by SOH.

ETX (End of Text): A communication control character used to terminate a sequence of characters started with STX and transmitted as an entity.

EOT (End of Transmission): A communication control character, used to indicate the conclusion of a transmission, which may have contained one or more texts and any associated headings.

ENQ (Enquiry): A communication control character used in data communication systems as a request for a response from a remote station. It may be used as a "Who Are You" (WRU) to obtain identification, or may be used to obtain station status, or both.

ACK (Acknowledge): A communication control character transmitted by a receiver as an affirmative response to a sender.

BEL: A character for use when there is a need to call for human attention. It may control alarm or attention devices.

BS (Backspace): A format effector which controls the movement of the printing position one printing space backward on the same printing line. (Applicable to display devices).

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HT (Horizontal Tabulation): A format effector which controls the movement of the printing position to the next in a series of predetermined positions along the printing line. (Applicable also to display devices and the skip function on punched cards.)

LF (Line Feed): A format effector which controls the movement of the printing position to the next printing line. (Applicable also to display devices.) Where appropriate, this character may have the meaning "New Line" (NL), a format effector which controls the movement of the printing point to the first printing position on the next printing line. Use of this convention requires agreement between sender and recipient of data. (So long as the current operating procedure of ending (or beginning) a line with CR-CR-LF is observed no operational problem arises from interconnecting "NL" and "Non-NL" machines.)

VT (Vertical Tabulation): A format effector which controls the movement of the printing position to the next in a series of predetermined printing lines. (Applicable also to display devices.)

FF (Form Feed): A format effector which controls the movement of the printing position to the first predetermined printing line on the next form or page. (Applicable also to display devices.)

CR (Carriage Return): A format effector which controls the movement of the printing position to the first printing position on the same printing line. (Applicable also to display devices.)

SO (Shift Out): A control character indicating that the code combinations which follow shall be interpreted as outside of the character set of the standard code table until a Shift In character(s) is (are) reached.

SI (Shift In): A control character indicating that the code combinations which follow shall be interpreted according to the standard code table.

DLE (Data Link Escape): A communication control character which will change the meaning of a limited number of contiguously following characters. It is used exclusively to provide supplementary controls in data communication networks. DLE is usually terminated by a Shift In character(s).

DC1, DC2, DC3, DC4 (Device Controls): Characters for the control of ancillary devices associated with data processing or telecommunication systems, more especially switching devices "on" or "off". (If a single "stop" control is required to interrupt or turn off ancillary devices, DC4 is the preferred assignment.)

NAK (Negative Acknowledge): A communication control character transmitted by a receiver as a negative response to the sender.

SYN (Synchronous Idle): A communication control character used by a

synchronous transmission system in the absence of any other character to provide a signal from which synchronism may be achieved or retained.

ETB (End of Transmission Block): A communication control character used to indicate the end of a block of data for communication purposes. ETB is used for blocking data where the block structure is not necessarily related to the processing format.

CAN (Cancel): A control character used to indicate that the data with which it is sent is in error or is to be disregarded.

EM (End of Medium): A control character associated with the sent data which may be used to identify the physical end of the medium, or the end of the used, or wanted, portion of information recorded on a medium. (The position of the character does not necessarily correspond to the physical end of the medium.)

SUB (Substitute): A character that may be substituted for a character which is determined to be invalid or in error.

ESC (Escape): A control character intended to provide code extension (supplementary characters) in general information interchange. The Escape character itself is a prefix affecting the interpretation of a limited number of contiguously following characters. ESC is usually terminated by a Shift In character(s).

FS (File Separator), GS (Group Separator), RS (Record Separator) and US (Unit Separator). These information separators may be used within data in optional fashion, except that their hierarchical relationship shall be: FS is the most inclusive, then GS, then RS, and US is least inclusive. (The content and length of a File, Group, Record, or Unit are not specified).

DEL (Delete): This character is used primarily to "erase" or "obliterate" erroneous or unwanted characters in perforated tape. (In the strict sense DEL is not a control character).

Note: SO, ESC, and DLE are all characters which can be used, at the discretion of the designer, to indicate the beginning of a sequence of digits having special significance.

2.5.3 Graphic Characters:

SP (Space): A normally nonprinting graphic character used to separate words. It is also a format effector which controls the movement of the printing position, one printing position forward. (Applicable also to display devices.)

(Diamond): A noncoded graphic which shall be printed by a printing device to denote the sensing of an error when such an indication is required. As an interim standard, an asterisk (*) may be used for this function.

(Heart): A noncoded graphic which may be printed by a printing device in lieu of the symbols for the control characters shown in columns 0 and 1 in table 1 of this appendix.

2.6 General Considerations

2.6.1 The relative sequence of any two characters of the code table, when used as a basis for collation, is defined by their binary values.

2.6.2 No specific meaning is prescribed for any of the graphics in the code table except that which is understood by the users. Furthermore, this standard does not specify a type style for the printing or display of the various graphic characters.

2.6.3 For military purposes, a parity bit, b_8 is always added to the standard character. Requirements for parity are described in paragraph 6.1.1.3 of the basic Standard.

2.6.4 In serial by bit transmission, the coded character will be transmitted low order first; i.e., the bits will appear on-line in the order $b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8$ (parity).

2.6.5 Special Consideration. An option is available in the use of ASCII to use line feed as new line (see the definition of line feed above). In the Military Systems, the current practice of transmitting two carriage returns and one line feed will be continued. However, it shall be standard to procure new line equipment when available at no increase (or an insignificant increase) in cost and use it in accordance with the old practice. This has the advantage of becoming prepared, at no additional cost, to cutting over to new line operation should this ever be desirable while maintaining compatibility between old and new equipments in the interim.

2.7 Printing Symbols

2.7.1 128-Symbol Set. The complete standard set of 128 printing symbols is given in table 1. There are actually only 127 printing symbols since the space is non-printing.

2.7.2 96-Symbol Set. The standard 96 symbol subset of printing symbols comprises the symbols contained in columns 2 through 7 of table 1. (95 printing symbols plus space). The heart symbol may be printed in lieu of the symbol for the control characters shown in columns 0 and 1 in table 1 of this appendix.

2.7.3 64-Symbol Set. The standard 64-symbol subset of printing symbols for page printer applications is given in table 2. The heart symbol may be printed in lieu of the symbol for the control characters shown in columns 0 and 1 in table 1 of this appendix.

3. FOUR-ROW KEYBOARDS. Four-row keyboards are standard for the implementation of ASCII and for OCR message preparation units. The

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128-SYMBOL PRINTING SET										
COLUMN →	0	1	2	3	4	5	6	7	ROW ↓	
b7 b6 b5	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1		
b4 b3 b2 b1	NON-PRINTING (4)			96-SYMBOL PRINTING SUBSET						
0 0 0 0	NUL \	DLE θ	SP	0	@	P		p	0	
0 0 0 1	SOH Γ	DC1 ①	!	1	A	Q	a	q	1	
0 0 1 0	STX ⊥	DC2 ②	"	2	B	R	b	r	2	
0 0 1 1	ETX J	DC3 ③	™	3	C	S	c	s	3	
0 1 0 0	EOT ⊣	DC4 ④	\$	4	D	T	d	t	4	
0 1 0 1	ENQ †	NAK ⑤	%	5	E	U	e	u	5	
0 1 1 0	ACK ↵	SYN ⑥	8	6	F	V	f	v	6	
0 1 1 1	BEL &	ETB ⑦	' (APOS)	7	G	W	g	w	7	
1 0 0 0	BS ◀	CAN ☒	(	8	H	X	h	x	8
1 0 0 1	HT ▶	EM ☒	)	9	I	Y	i	y	9
1 0 1 0	LF ≡	SUB ☒	* :	J	Z	j	z		10	
1 0 1 1	VT ▽	ESC ☒	+ ;	K	[	k	{		11
1 1 0 0	FF ▹	FS ☒	, <	L	\	l	!		12	
1 1 0 1	CR «	GS ☒	- =	M	]	m	}		13
1 1 1 0	SO ≡	RS ☒	. >	N	^	n	~		14	
1 1 1 1	SI ▾	US ☒	/ ?	O	_	o	DEL ☒		15	

NOTES:

- (1) Columns 0 & 1 show the mnemonic abbreviations and the printing symbols for the control characters.
- (2) The diamond (☒) is printed to indicate the detection of an error.
- (3) The heart (♥) may be printed to indicate a character of the control character sub-set.
- (4) Non-printing codes in the 96-symbol Printing Set.

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Table 1. American Standard Code for Information Interchange

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AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE

64-SYMBOL PAGE PRINTING SUBSET

COLUMN →	0	1	2	3	4	5	6	7	ROW ↓
b7 b6 b5	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1	
b4 b3 b2 b1	NON-PRINTING			PRINTING					
0 0 0 0	NUL ↘	DLE Ⓢ	SP	0	@	P	Ⓢ	P	0
0 0 0 1	SOH ⌈	DC1 Ⓢ	!	1	A	Q	A	Q	1
0 0 1 0	STX ⌋	DC2 Ⓢ	"	2	B	R	B	R	2
0 0 1 1	ETX ⌋	DC3 Ⓢ	#	3	C	S	C	S	3
0 1 0 0	EOT ⌋	DC4 Ⓢ	\$	4	D	T	D	T	4
0 1 0 1	ENQ ⌈	NAK Ⓢ	%	5	E	U	E	U	5
0 1 1 0	ACK ⌈	SYN Ⓢ	&	6	F	V	F	V	6
0 1 1 1	BEL ⌈	ETB Ⓢ	/ (APOS)	7	G	W	G	W	7
1 0 0 0	BS ⌈	CAN Ⓢ	(	8	H	X	H	X	8
1 0 0 1	HT ⌈	EM Ⓢ	)	9	I	Y	I	Y	9
1 0 1 0	LF ≡	SUB Ⓢ	*	:	J	Z	J	Z	10
1 0 1 1	VT ∇	ESC Ⓢ	+	;	K	[	K	[	11
1 1 0 0	FF ∇	FS Ⓢ	,	<	L	\	L	\	12
1 1 0 1	CR «	GS Ⓢ	-	=	M	]	M	]	13
1 1 1 0	SO ⌈	RS Ⓢ	.	>	N	^	N	^	14
1 1 1 1	SI ∇	US Ⓢ	/	?	O	_	O	DEL _	15

The diamond (Ⓢ) is printed to indicate the detection of an error.

The heart (♡) may be printed to indicate a character of the control character sub-set.

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 Rev. 10-14-69

Table 2. 64-Symbol Subset (Page Printer Application)

CHARACTERS			CODE SIGNALS							CCITT NO.2 UPPER CASE *
LOWER CASE	UPPER CASE COMM	UPPER CASE WEATHER	START	1	2	3	4	5	STOP	
A	—	↑		/	/				/	
B	?	⊕		/			/	/	/	
C	:	○			/	/			/	
D	\$	/		/			/		/	WRU
E	3	3		/					/	
F	!	→		/		/			/	UNASSIGNED
G	&	\			/				/	UNASSIGNED
H	STOP	↓			/			/	/	UNASSIGNED
I	8	8			/	/			/	
J	'	/		/			/		/	AUDIBLE SIGNAL
K	(←		/					/	
L)	/			/			/	/	
M	.	.				/	/	/	/	
N	,	⓪				/	/	/	/	
O	9	9					/	/	/	
P	0	0			/		/	/	/	
Q	!	!		/				/	/	
R	4	4			/				/	
S	BELL	BELL		/		/			/	'(APOSTROPHE)
T	5	5						/	/	
U	7	7		/	/			/	/	
V	:	⓪			/	/	/	/	/	=
W	2	2		/				/	/	
X	/	/		/		/	/	/	/	
Y	6	6		/				/	/	
Z	"	+		/				/	/	+
BLANK	—								/	
SPACE						/			/	
CAR. RET.							/		/	
LINE FEED					/				/	
FIGURES				/	/			/	/	
LETTERS				/	/	/	/	/	/	

NOTE: UPPER CASE H (COMM) MAY BE STOP OR #

 MARKING PULSE

 SPACING PULSE

* THIS COLUMN SHOWS
 ONLY THOSE CHARACTERS
 WHICH DIFFER FROM THE
 U. S. A. VARIATION

Table 3 International Telegraph Alphabet No. 2, American Variation

I ₁ - I ₂ - C →				000		100		010		110		001		101		011		111	
D ₀	D ₁	D ₂	D ₃		P		P		P		P		P		P		P		P
↓	↓	↓	↓		↓		↓		↓		↓		↓		↓		↓		↓
0	0	0	0		1		0		0		1	Mast. Sp.	0	K	1	)	1	0	0
1	0	0	0		0		1		1		0	Up. Case	1	L	0	-	0	1	1
0	1	0	0		0		1		1		0	Lwr. Case	1	M	0	+	0	2	1
1	1	0	0		1		0		0		1	Line Feed	0	N	1	<	1	3	0
0	0	1	0		0		1		1		0	Car. Ret.	1	O	0	=	0	4	1
1	0	1	0		1		0		0		1	Space	0	P	1	>	1	5	0
0	1	1	0		1		0		0		1	A	0	Q	1	(underline)	1	6	0
1	1	1	0		0		1		1		0	B	1	R	0	\$	0	7	1
0	0	0	1		0		1		1		0	C	1	S	0	*	0	8	1
1	0	0	1		1		0		0		1	D	0	T	1	(	1	9	0
0	1	0	1		1		0		0		1	E	0	U	1	"	1	'	0
1	1	0	1		0		1		1		0	F	1	V	0	:	0	:	1
0	0	1	1		1		0		0		1	G	0	W	1	?	1	/	0
1	0	1	1		0		1		1		0	H	1	X	0	!	0	.	1
0	1	1	1		0		1		1		0	I	1	Y	0	,	0	Spec. □	1
1	1	1	1		1		0		0		1	J	0	Z	1	+ (Stop)	1	Idle	0
← CONTROL FUNCTIONS (Under Study) →										← ALPHANUMERICS →									

Sequence of Signal Elements for Serial Transmission: D₀ - D₁ - D₂ - D₃ - I₁ - I₂ - C - P

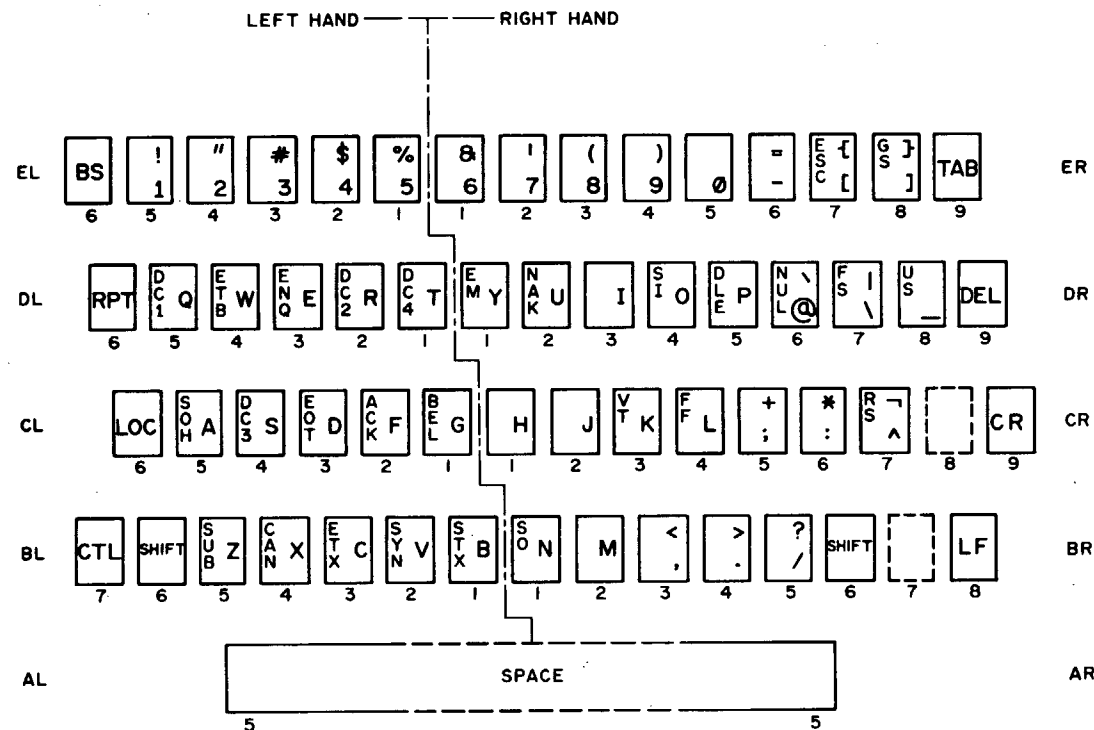
Example: Letter "C": 0 0 0 1 0 0 1 1

P is standard transmission parity bit added to give odd parity for error control.

For punched tape, all parity bits are automatically reversed to give even parity.

TABLE 4. Interim standard coded character set for information interchange (Fieldata)

FIGURE 1 TYPE I, CLASS I STANDARD KEYBOARD ARRANGEMENT

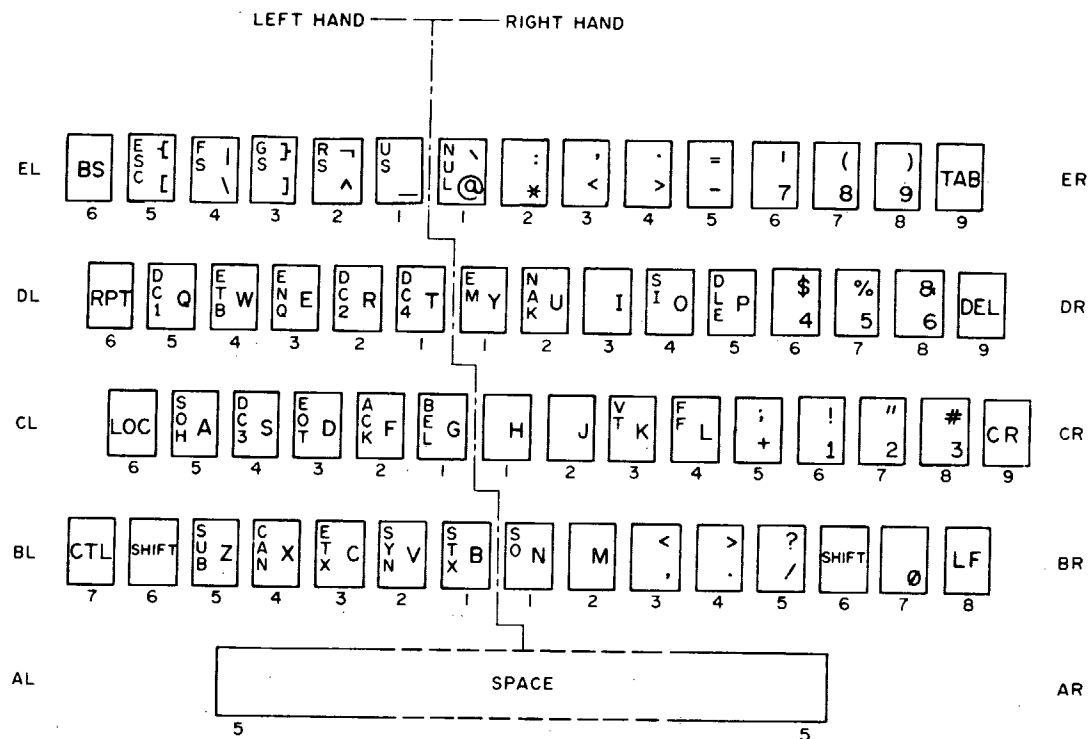


NOTES

- 1 PHYSICAL CHARACTERISTICS AND LOCATIONS (i.e. SIZE, SHAPE, SKEW, ETC) OF SPACE BAR OR KEYS ARE NOT TO BE INFERRED
- 2 ARRANGEMENT TYPE I, CLASS I AS PER MIL-STD-1280

FIGURE 2 TYPE I, CLASS 2 STANDARD KEYBOARD ARRANGEMENT

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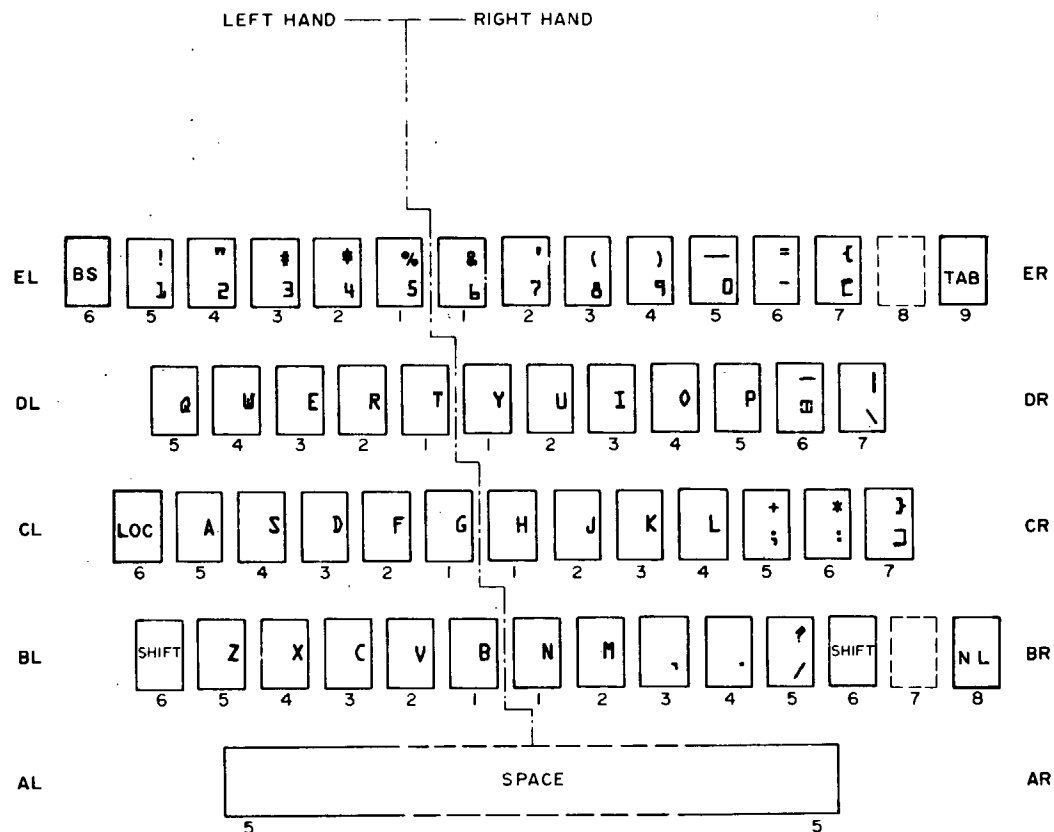


NOTES

- 1 PHYSICAL CHARACTERISTICS AND LOCATIONS (i.e. SIZE, SHAPE, SKEW, ETC) OF SPACE BAR OR KEYS ARE NOT TO BE INFERRED
- 2 ARRANGEMENT TYPE I, CLASS 2 AS PER MIL-STD-1280

FIGURE 3 TYPE II, CLASS I STANDARD KEYBOARD ARRANGEMENT

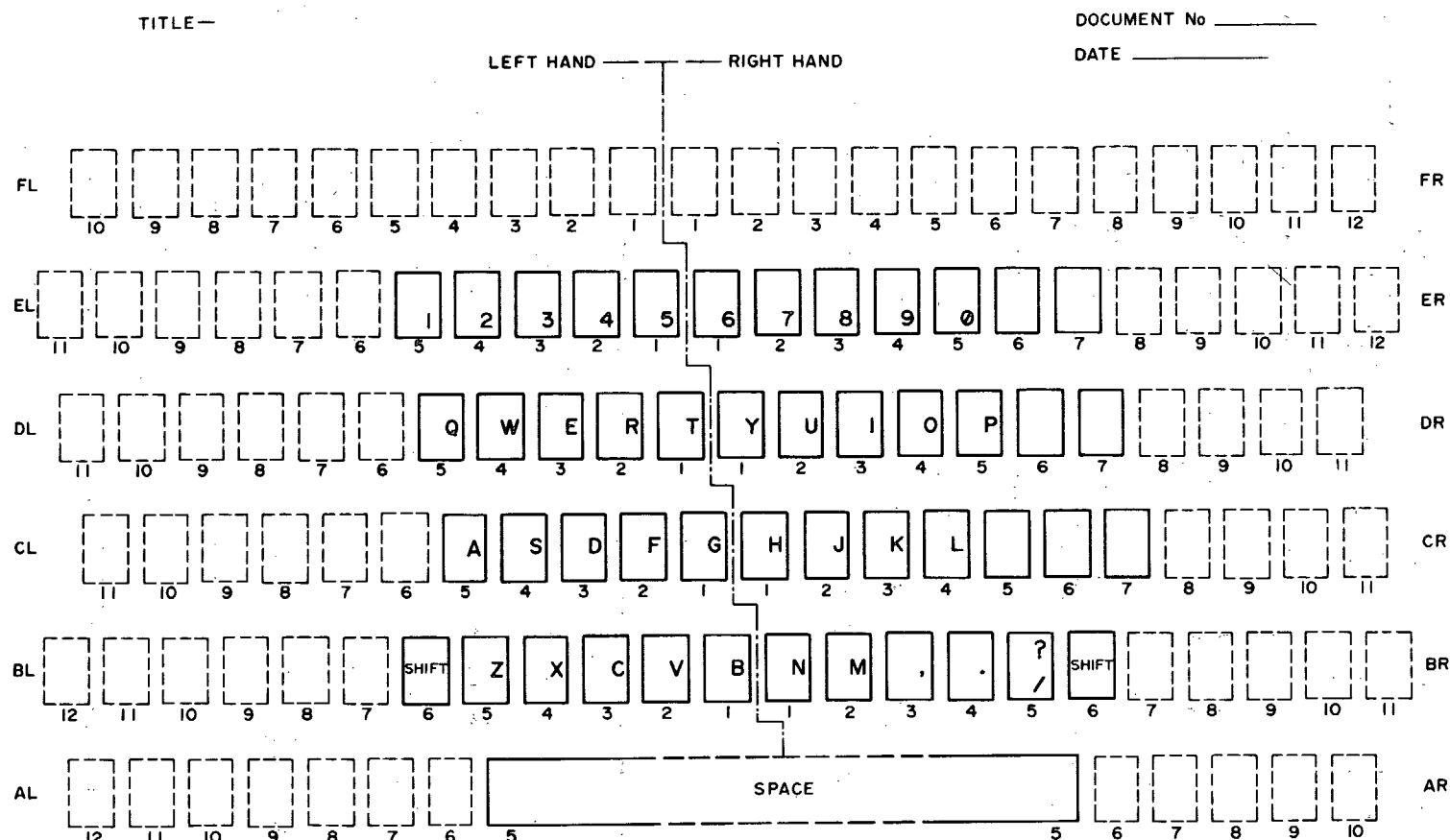
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NOTES

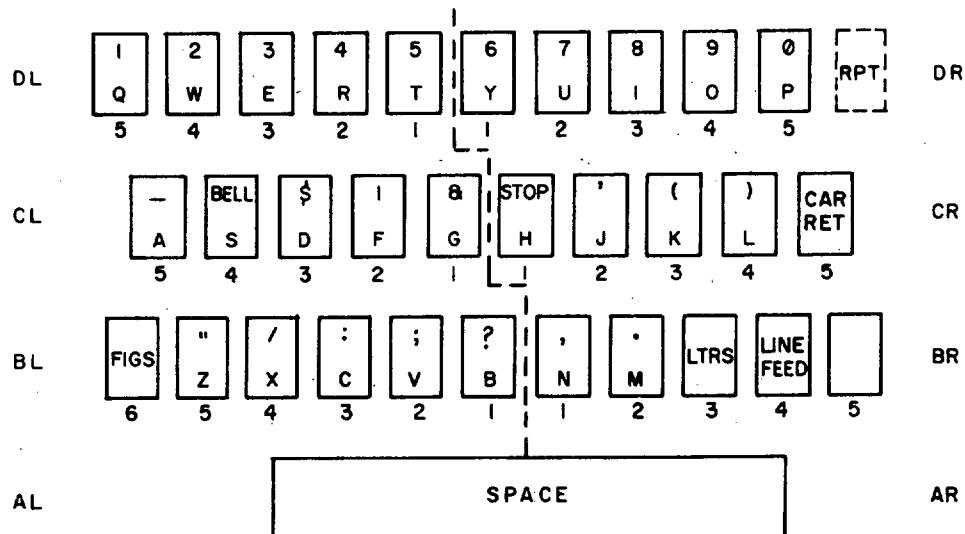
- 1 PHYSICAL CHARACTERISTICS AND LOCATIONS (i.e. SIZE, SHAPE, SKEW, ETC) OF SPACE BAR OR KEYS ARE NOT TO BE INFERRED
- 2 SOLID KEY OUTLINES CORRESPOND TO USAS X4.7-1966
- 3 THE UPPER CHARACTER ON KEY ER5 WILL BE THE "GROUP ERASE" WHICH WILL APPEAR IN A REVISION OF USAS X3.17-1966

FIGURE 4
 KEYBOARD ARRANGEMENT NOTATIONAL SYSTEM



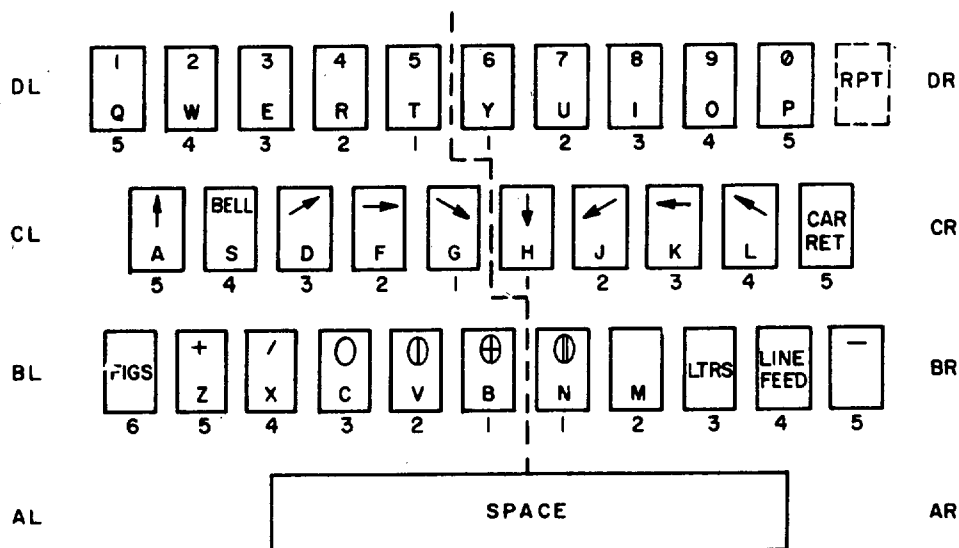
NOTES

- 1 PHYSICAL CHARACTERISTICS AND LOCATIONS (i.e. SIZE, SHAPE, SKEW, ETC) OF SPACE BAR OR KEYS ARE NOT TO BE INFERRED
- 2 SOLID KEY OUTLINES CORRESPOND TO USAS X4.7-1966



NOTE: UPPER CASE H MAY BE STOP OR #

THREE ROW COMMUNICATION KEYBOARD (INTERIM STANDARD)



THREE ROW WEATHER KEYBOARD (INTERIM STANDARD)

FIGURE 5. THREE ROW KEYBOARDS

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standards arrangements are included as Figures 1, 2 and 3. For details on the application of these arrangements, the designer is advised to consult MIL-STD-1280, Keyboard Arrangements. Figure 4 is the standard notation system for keyboard arrangements.

4. THREE-ROW KEYBOARDS. Refer to Figure 5 for three-row communication and weather keyboards.

5. INTERNATIONAL TELEGRAPH ALPHABET NO. 2, USA VARIATION. See Table 3. This is now classified as interim standard.

6. INTERIM STANDARD CODED CHARACTER SET FOR INFORMATION INTERCHANGE (FIELDATA). See Table 4.

7. CODE CORRESPONDENCE. This is a reference paragraph only. It does not in itself establish any code as a standard. It merely establishes the relationship between some commonly used codes so that translations may be made. Although the USASCII is standard the USA Standard Punched Card Code and the EBCDIC is also used. The first eight columns of Table 5 presents the 128 hole-patterns for the 128 characters of USASCII. The last eight columns present the extension of the code to 256 characters. This extension has been approved by USASI and will be published as USASI Standard X3.26-1969. For the present, only the hole-patterns have been assigned to the bit-patterns in the extension. Table 6 is a cross reference from the Hollerith hole-patterns to the USASCII graphic and control characters.

As of March 1968, the AUTODIN Digital Subscriber Terminal Equipment has the capability of operating with 64 hole-patterns. However, only 50 hole-patterns are currently active. Plans for activating the remaining 14 hole-patterns and for aligning the equipment with the Standard Hollerith Punched Card Code are not firm at this time. The correspondence between AUTODIN punched card practice and the Standard Hollerith Punched Card Code for all USASCII graphic characters is presented in Table 7.

The interim standard punched card practice for the Worldwide Military Command and Control System was published in Chapter II, Section 2 of JCS Pub 7 of 3 February 1964. Its correspondence with the Standard Hollerith Punched Card Code and with AUTODIN is also given in Table 7. Note that this interim standard uses characters which are not in USASCII.

The EBCDIC is presented in Table 8. Note that here too in 128 instances, only the hole-patterns have been assigned to the bit-patterns. The other 128 are the assigned positions of the USASCII characters.

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b8 b7b6b5	0 000	0 001	0 010	0 011	0 100	0 101	0 110	0 111	1 000	1 001	1 010	1 011	1 100	1 101	1 110	1 111		
bbbb 4321	COL ROW	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	COL ROW
0000	0	NUL 12-0-9-8-1	DLE 12-11-9-8-1	SP NO PCH	0 0	@ 8-4	P 11-7	p 8-1	12-11-7	11-0-9-8-1	12-11-0-9-8-1	12-0-9-1	12-11-9-8	12-11-0-9-6	12-11-8-7	12-11-0-8	12-11-9-8-4	0
0001	1	SOH 12-9-1	DC1 11-9-1	! 12-8-7	1 1	A 12-1	Q 11-8	a 12-0-1	q 12-11-8	0-9-1	9-1	12-0-9-2	11-8-1	12-11-0-9-7	11-0-8-1	12-11-0-9	12-11-9-8-5	1
0010	2	STX 12-9-2	DC2 11-9-2	" 8-7	2 2	B 12-2	R 11-9	b 12-0-2	r 12-11-9	0-9-2	11-9-8-2	12-0-9-3	11-0-9-2	12-11-0-9-8	11-0-8-2	12-11-0-8-2	12-11-9-8-6	2
0011	3	ETX 12-9-3	DC3 11-9-3	# 8-3	3 3	C 12-3	S 0-2	c 12-0-3	s 11-0-2	0-9-3	9-3	12-0-9-4	11-0-9-3	12-0-8-1	11-0-8-3	12-11-0-8-3	12-11-9-8-7	3
0100	4	EOT 9-7	DC4 9-8-4	\$ 11-8-3	4 4	D 12-4	T 0-3	d 12-0-4	t 11-0-3	0-9-4	9-4	12-0-9-5	11-0-9-4	12-0-8-2	11-0-8-4	12-11-0-8-4	11-0-9-8-2	4
0101	5	ENQ 0-9-8-5	NAK 9-8-5	% 0-8-4	5 5	E 12-5	U 0-4	e 12-0-5	u 11-0-4	11-9-5	9-5	12-0-9-6	11-0-9-5	12-0-8-3	11-0-8-5	12-11-0-8-5	11-0-9-8-3	5
0110	6	ACK 0-9-8-6	SYN 9-2	& 12	6 6	F 12-6	V 0-5	f 12-0-6	v 11-0-5	12-9-6	9-6	12-0-9-7	11-0-9-6	12-0-8-4	11-0-8-6	12-11-0-8-6	11-0-9-8-4	6
0111	7	BEL 0-9-8-7	ETB 0-9-6	' 8-5	7 7	G 12-7	W 0-6	g 12-0-7	w 11-0-6	11-9-7	12-9-8	12-0-9-8	11-0-9-7	12-0-8-5	11-0-8-7	12-11-0-8-7	11-0-9-8-5	7
1000	8	BS 11-9-6	CAN 11-9-8	(12-8-5	8 8	H 12-8	X 0-7	h 12-0-8	x 11-0-7	0-9-8	9-8	12-8-1	11-0-9-8	12-0-8-6	12-11-0-8-1	12-0-9-8-2	11-0-9-8-6	8
1001	9	HT 12-9-5	EM 11-9-8-1	) 11-8-5	9 9	I 12-9	Y 0-8	i 12-0-9	y 11-0-8	0-9-8-1	9-8-1	12-11-9-1	0-8-1	12-0-8-7	12-11-0-1	12-0-9-8-3	11-0-9-8-7	9
1010	10	LF 0-9-5	SUB 9-8-7	* 11-8-4	: 8-2	J 11-1	Z 0-9	j 12-11-1	z 11-0-9	0-9-8-2	9-8-2	12-11-9-2	12-11-0	12-11-8-1	12-11-0-2	12-0-9-8-4	12-11-0-9-8-2	10
1011	11	VT 12-9-8-3	ESC 0-9-7	+ 12-8-6	; 11-8-6	K 11-2	[12-8-2	k 12-11-2	[12-0	0-9-8-3	9-8-3	12-11-9-3	12-11-0-9-1	12-11-8-2	12-11-0-3	12-0-9-8-5	12-11-0-9-8-3	11
1100	12	FF 12-9-8-4	FS 11-9-8-4	, 0-8-3	< 12-8-4	L 11-3	\ 0-8-2	l 12-11-3	l 12-11	0-9-8-4	12-9-4	12-11-9-4	12-11-0-9-2	12-11-8-3	12-11-0-4	12-0-9-8-6	12-11-0-9-8-4	12
1101	13	CR 12-9-8-5	GS 11-9-8-5	- 11	= 8-6	M 11-4	] 11-8-2	m 12-11-4	] 11-0	12-9-8-1	11-9-4	12-11-9-5	12-11-0-9-3	12-11-8-4	12-11-0-5	12-0-9-8-7	12-11-0-9-8-5	13
1110	14	SO 12-9-8-6	RS 11-9-8-6	. 12-8-3	> 0-8-6	N 11-5	^ 11-6-7	n 12-11-5	^ 11-0-1	12-9-8-2	9-8-6	12-11-9-6	12-11-0-9-4	12-11-8-5	12-11-0-6	12-11-9-8-2	12-11-0-9-8-6	14
1111	15	SI 12-9-8-7	US 11-9-8-7	/ 0-1	? 0-8-7	O 11-6	_ 0-8-5	o 12-11-6	DEL 12-9-7	11-9-8-3	11-0-9-1	12-11-9-7	12-11-0-9-5	12-11-8-6	12-11-0-7	12-11-9-8-3	EC 12-11-0-9-8-7	15

Table 5. Standard Hollerith Punched Card Code

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	12				12	12		12		12				12	12		12	
		11				11	11	11			11				11	11	11	
			0		0		0	0			0		0		0	0		
	&	-	0	SP	ƒ	l	J	11/10	10/8	11/1	11/9	12/3	12/10	13/1	13/8	8-1		
1	A	J	/	1	a	j	13/9	13/9	SOH	DC1	8/1	9/1	10/0	10/9	9/15	11/11	9-1	
2	B	K	S	2	b	k	s	13/10	STX	DC2	8/2	SYN	10/1	10/10	11/2	11/12	9-2	
3	C	L	T	3	c	l	t	13/11	ETX	DC3	8/3	9/3	10/2	10/11	11/3	11/13	9-3	
4	D	M	U	4	d	m	u	13/12	9/12	9/13	8/4	9/4	10/3	10/12	11/4	11/14	9-4	
5	E	N	V	5	e	n	v	13/13	HT	8/5	LF	9/5	10/4	10/13	11/5	11/15	9-5	
6	F	O	W	6	f	o	w	13/14	8/6	BS	ETB	9/6	10/5	10/14	11/6	12/0	9-6	
7	G	P	X	7	g	p	x	13/15	DEL	8/7	ESC	EOT	10/6	10/15	11/7	12/1	9-7	
8	H	Q	Y	8	h	q	y	14/0	9/7	CAN	8/8	9/8	10/7	11/0	11/8	12/2	9-8	
9	I	R	Z	9	i	r	z	14/1	8/13	EM	8/9	9/9	NUL	DLE	8/0	9/0	9-8-1	
8-2	ƒ	J	\	:	12/4	12/11	13/2	14/2	8/14	9/2	8/10	9/10	14/8	14/14	15/4	15/10	9-8-2	
8-3	.	\$	,	#	12/5	12/12	13/3	14/3	VT	8/15	8/11	9/11	14/9	14/15	15/5	15/11	9-8-3	
8-4	<	*	%	@	12/6	12/13	13/4	14/4	FF	FS	8/12	DC4	14/10	15/0	15/6	15/12	9-8-4	
8-5	(	)	_	'	12/7	12/14	13/5	14/5	CR	GS	ENQ	NAK	14/11	15/1	15/7	15/13	9-8-5	
8-6	+	;	>	=	12/8	12/15	13/6	14/6	SO	RS	ACK	9/14	14/12	15/2	15/8	15/14	9-8-6	
8-7	!	^	?	"	12/9	13/0	13/7	14/7	SI	US	BEL	SUB	14/13	15/3	15/9	15/15	9-8-7	

Table 6. Hollerith Hole-pattern Cross-reference To ASCII

	12	11	0		12	11	11	12		12	11	0	
	&	-	0	SP	¢	|	}						
	-	/	0	SP	~	na	^						
	+	-	0	Blk	?	na	!						
1	A	J	/	1	a	j	~		8-1				na
	A	J	&	1	na	na	na						na
	A	J	/	1	na	na	na						na
2	B	K	S	2	b	k	s		8-2	[]	\	:
	B	K	S	2	na	na	na			na	na	—	'
	B	K	S	2	na	na	na			na	na	#	b
3	C	L	T	3	c	l	t		8-3	.	\$,	#
	C	L	T	3	na	na	na			.	[,	#
	C	L	T	3	na	na	na			.	\$,	=
4	D	M	U	4	d	m	u		8-4	<	*	%	@
	D	M	U	4	na	na	na			<	*	%	>
	D	M	U	4	na	na	na)	*	('
5	E	N	V	5	e	n	v		8-5	()	—	'
	E	N	V	5	na	na	na			+]	?	:
	E	N	V	5	na	na	na			[]	~	:
6	F	O	W	6	f	o	w		8-6	+	;	>	=
	F	O	W	6	na	na	na			(;	\$)
	F	O	W	6	na	na	na			<	;	\	>
7	G	P	X	7	g	p	x	DEL	8-7	!	^	?	"
	G	P	X	7	na	na	na	na		=	!	~	"
	G	P	X	7	na	na	na	na		≠	^	##	✓
8	H	Q	Y	8	h	q	y						
	H	Q	Y	8	na	na	na						
	H	Q	Y	8	na	na	na						
9	I	R	Z	9	i	r	z						
	I	R	Z	9	na	na	na						
	I	R	Z	9	na	na	na						

← Standard Hollerith

← AUTODIN

← JCS Pub 7

na means not assigned

Table 7. Correspondence of Standard Hollerith, AUTODIN
 and JCS Pub 7 Punched Card Codes.

Bits xxxx 4567	Hexadecimal Row	Digit Punctures	00				01				10				11				Bits x0,x1
			00	01	10	11	00	01	10	11	00	01	10	11	00	01	10	11	Bits x2,x3
			0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	Hex. Col.
			12				12	12		12	12	12		12	12				Zone Punctures
				11				11	11	11		11	11	11		11			Digit Punctures
				0			0		0	0	0		0	0			0		
			9	9	9	9	9	9	9	9									
0000	0	8-1	*1 NUL	*2 DLE	*3	*4	*5 SP	*6 &	*7 -	*8					*9 {	*10 }	*11 /	*12 0	8-1
0001	1	1	SOH	DC1					*13 /		a	j	┐		A	J	*14	1	1
0010	2	2	STX	DC2		SYN					b	k	s		B	K	S	2	2
0011	3	3	ETX	DC3							c	l	t		C	L	T	3	3
0100	4	4									d	m	u		D	M	U	4	4
0101	5	5	HT		LF						e	n	v		E	N	V	5	5
0110	6	6		BS	ETB						f	o	w		F	O	W	6	6
0111	7	7	DEL		ESC	EOT					g	p	x		G	P	X	7	7
1000	8	8		CAN							h	q	y		H	Q	Y	8	8
1001	9	8-1		EM							i	r	z		I	R	Z	9	9
1010	A	8-2							*15 :										8-2
1011	B	8-3	VT						\$	,	#								8-3
1100	C	8-4	FF	FS		DC4	<	°	%	@									8-4
1101	D	8-5	CR	GS	ENQ	NAK	(	)	—	'									8-5
1110	E	8-6	SO	RS	ACK		+	:	>	=									8-6
1111	F	8-7	SI	US	BEL	SUB	!	^	?	"									8-7
			12				12				12	12		12	12	12		12	Zone Punctures
				11				11				11	11			11	11	11	
				0					0		0		0	0	0		0	0	
			9	9	9	9								9	9	9	9		

Card Hole Patterns

*1, 12-0-9-8-1

*2, 12-11-9-8-1

*3, 11-0-9-8-1

*4, 12-11-0-9-8-1

*5, No Punctures

*6, 12

*7, 11

*8, 12-11-0

*9, 12-0

*10, 11-0

*11, 0-8-2

*12, 0

*13, 0-1

*14, 11-0-9-1

*15, 12-11

Table 8. EBCDIC Card Code

APPENDIX D

STANDARD SWITCHING INSTRUCTIONS AND BIT STRUCTURES FOR START/STOP AND SYNCHRONOUS AUTOMATIC TELEPRINTER SWITCHING EQUIPMENT UTILIZING ITA No. 2

This appendix sets forth guidance with regard to switching instructions and bit patterns as they apply (1963) for teletypewriter switching equipment. In case of conflict between any specific instructions in this appendix and any applicable portion of ACP-127 (), the requirements of ACP-127 () shall govern.

NOTE: JANAP 128 () AUTOMATIC DIGITAL NETWORK (AUTODIN) OPERATING PROCEDURES has been published by the Joint Chiefs of Staff and prescribes the standard data communication policies, practices, procedures, and routing doctrine for operation of the Defense Communication System AUTODIN. The latest issue in effect of JANAP 128 () should be referred to for all AUTODIN Operating Procedures.

1. GENERAL

The switching instructions listed in the standard message format permit a subsystem to forward messages without difficulty and in accordance with present world-wide equipment and agreed practices.

- 1.1 Start of message instruction, channel designator and serial number: format line # 1.
- 1.2 Precedence instruction: end of format line # 1, beginning of format line # 2.
- 1.3 Routing Instruction: format line # 2.
- 1.4 End of routing instruction: end of format line # 2, beginning of format line # 3.
- 1.5 Format lines 3 and 4 are not generally utilized by automatic switching equipment at this time except as noted in processing ACP 127 messages into AUTODIN.
- 1.6 Format lines 5 thru 10 are standardized procedurally but are not utilized at this time for automatic switching.
- 1.7 Format line 10 is used to count code groups in the text.
- 1.8 End of address instruction, start of text instruction: format line 11.

1.9 End of message instruction: end of format line 15.

2. Between the channel designator/serial number instructions and the precedence instruction, extraneous bits or instructions may appear provided the total number of bits inserted does not exceed 400 unit bits, and the extraneous bits are not standard switching instructions out of sequence in the standard message format.

3. No extraneous bits or instructions may appear between the precedence instructions and the routing instructions or between the routing instruction and the end of the routing instruction.

4. Additional instructions may be inserted between the end of routing instruction and the end of format line 3 up to a maximum of 400 bits, provided the extraneous bits are not standard switching instructions out of sequence in the standard message format.

5. No extraneous bits or switching instructions shall be recognized in the address or delivery section of the message format. This area of the message format is yet to be standardized for equipment switching purposes.

6. For automatic equipment to effect delivery it is necessary that the routing line contain a routing instruction for each address or two or more addresses if served through the same station. It is required that the routing instruction line will be "segregated" as the message passes through the system.

7. It is presumed that equipment will be developed to effect distribution or delivery once a message has been passed over the world-wide trunk network. It is further presumed that message delivery equipment would accomplish its function by reading the precedence instruction and, having checked the routing instruction to determine that the message was in fact intended for that station, by processing the address portion of the message (format line 7-8) automatically.

8. Standard Switching Instruction Bit Structures. No departures from these bit structures are permissible. All sequences are shown preceded by a one or marking bit which represents the marking or resting state of the line.

8.1 Format Line #1: (1) START OF MESSAGE (SOM)
 VZCZC (See Symbol Schedule, paragraph 8.7)

(2) CHANNEL DESIGNATION AND SERIAL NUMBER (CDSN)

* * * ↑ # # # ↓

Bit Sequence:

1 0011111 0100011 0011101 0100011 0011101 * * * 0110111 # # # 0111111

* Sixth, seventh, and eighth characters (Bits 37 thru 57 inclusive) are the letters which denote the channel designation.

Tenth, eleventh, and twelfth characters (Bits 65 thru 85 inclusive) are the serial number of the message.

8.2 End of Format Line #1 (EOL #1) Beginning of Format Line #2 and PRECEDENCE:

<< ≡ * * >

Bit Sequence:

1 0000101 0000101 0010001 ** 0001001

* Fourth and fifth characters are the precedence of the message and can be either RR, PP, OO, or ZZ, e.g., message with FLASH precedence (ZZ).

1 0000101 0000101 0010001 0100011 0100011 0001001

Other possible Precedences:

<u>PRECEDENCE SYMBOL</u>	<u>BIT SEQUENCE</u>	
RR	0010101	0010101
PP	0011011	0011011
OO	0000111	0000111
ZZ	0100011	0100011

8.3 Format Line # 2: ROUTING INDICATORS

Note: This format line may consist of a number of printed lines all of which constitute format line #2.

At the end of each routing indicator (which may include up to 49 bits) there are seven additional bits denoting a space. At the end of each printed line of nine routing indicators there are twenty-one additional bits (two carriage return and one line feed).

8.4 End of Format Line #2 (EOL #2 and PROSIGN PRECEDING ORIGINATOR'S STATION DESIGNATOR OR END OF FORMAT LINE #1 PILOT

<< ≡ D E >, or << ≡ Z * * >

Bit Sequence:

1 0000101 0000101 0010001 0100101 0100001 0001001 or

1 0000101 0000101 0010001 0100011 * * 0001001

* Fifth and sixth characters may be any two applicable characters (7 bits each) of the Z-signal series.

8.5 Format line #11: START OF TEXT (SOT)

<< ≡ B T << ≡

Bit Sequence:

1 0000101 0000101 0010001 0100111 0000011 0000101 0000101 0010001

8.6 Format Line #13: END OF TEXT (EOT)

<< ≡ B T << ≡

Bit Sequence:

See Paragraph 8.5

8.7 END OF MESSAGE (EOM)

< < ≡ ≡ ≡ ≡ ≡ ≡ ≡ ≡ N N N N ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ *

(Future Switching Equipment shall respond to ≡ ≡ N N N N)

Bit Sequence:

1 0000101 0000101 0010001 0010001 0010001 0010001 0010001 0010001

0010001 0010001 0001101 0001101 0001101 0001101 0111111 0111111, etc.*

* Minimum of twelve letter shifts.

SYMBOL SCHEDULE

↓ Letter Shift	≡ Line Feed
< Carriage Return	> Spare
↑ Figure Shift	

APPENDIX E

OPTICAL CHARACTER RECOGNITION EQUIPMENT {OCRE} FOR PROCESSING MESSAGES

FOREWORD

1. Optical character recognition {OCR} is a comparatively new art. In applying a new art there is a tendency for users to choose their operating parameters in a divergent manner because of a lack of standards. The resulting incompatibilities of the past indicate a requirement for development of standards early in the progress of an art. On the other hand, the application of too rigid a standard tends to limit experimentation in a search for optimum operating conditions. Because the Military Departments and Agencies are still learning how to apply OCR to message handling, this standard has been made permissive in certain instances. As experience is gained it will be possible, in some instances, to be more specific.
2. A standard message format has been developed {see Figure 1}. There are four annexes to the format which constitute instructions to the printer, administrator, COMMCENTER/Message Center, and drafter's typist.
3. A "character set" as used herein is a basic group of defined numeric, alphabetic, punctuation and special symbol characters of one style. A character set is monospace if it contains only upper case alphabetic characters and dual case if it includes both upper and lower case alphabetic characters.
4. From a narrow operational standpoint no standard for OCRE is required as long as each message reader is compatible with the DoD switching system into which it feeds the message read. However, such a narrow viewpoint is unacceptable. There is more to satisfactory use of OCRE than compatibility with the message switching system. These standards involve the following concepts.
 - a. Logistical interchangeability. A reader should be capable of operating satisfactorily in any location within the DoD, not just one.
 - b. Minimum training of personnel. This requires a standard message form for all locations and the preparation of these forms in a standard manner. Thus personnel need not be retrained when reassigned.
 - c. Mutual assistance capability. Two or more headquarters using OCRE in a given building or area should be able to process the other's traffic in case of equipment failure. This requires

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a standard message format, standard processing, and an agreement on at least one character set that all OCR readers will be capable of reading.

d. Minimum cost. This requires standard message forms and OCR-E with a limited character set capability. An increase in the cost of a reader utilizing more than one character set over that of a single character set reader may be sufficient to pay for many new typewriters. Furthermore there are so many character set styles that an OCR-E with a capability of 10 character sets can read the character set of only a small percent of typewriters chosen at random.

5. Standards are of no value if not observed and to a certain extent unenforceable if not accepted by users. Thus a standard must not appear to be arbitrary or illogical. OCR is a new art requiring explanation of certain concepts. For that reason there are explanatory remarks in the following standard, making it more tutorial, than is generally the case for a standard.

6. DoD Policy on Character Sets. Current policy at the time MIL-STD-188C is published is that "DoD should not adopt any standard font at this time." Guidance provided is that "evaluation and selection of potential fonts for communications OCR equipments will be based on cost effectiveness and growth potential analysis of each specific application."

7. Character Sets. Within the scope of this standard {MIL-STD-188C} the OCR-A is established as the minimum capability requirement for all OCR-E. The OCR-A character set for monospace OCR-E is shown in Table II of this Appendix.

APPENDIX E

OPTICAL CHARACTER RECOGNITION EQUIPMENT

{OCRE}

1. Introduction. This Appendix concerning Optical Character Recognition Equipment {OCRE} is applicable to communications only. This OCRE is to be used to generate binary electrical signals in the appropriate code and alphabet by a process of reading {scanning} messages prepared in a standard manner on a standard message format using typewriters suitable for preparation of messages accurately readable by OCRE. The message format is discussed in paragraphs 6.2 of this appendix. Suitable typewriters are discussed in paragraph 5 of this appendix. The OCRE may be used on-line, feeding the generated signals directly to the line or to any of a number of lines as required by the traffic situation; or the OCRE may be used off line by recording on paper tape, magnetic tape, a drum, etc. When used off-line the recorded message is subsequently read to the appropriate line. Which method of operation is used is a matter of command prerogative, but the design should be such that both on-line and off-line operation is possible.

2. OCRE Signals.

2.1 Code and Alphabet. The binary signals generated by the OCRE shall be coded in the International Telegraph Alphabet No. 2 {ITA No. 2} {USA Version} or the International Telegraph Alphabet No. 5 {ITA No. 5} {USA Version} as applicable. These coded character sets {alphabets} are discussed in Appendix C. The latter code was formerly known as ASCII {American Standard Code for Information Interchange} and was later renamed USASCII. ITA No. 5 is the name applied by the CCITT.

2.2 Low Level Signaling. The signals generated by the OCRE shall be in accordance with paragraph 7.2.1 Standard interface {low level} of the basic standard.

2.3 Modulation Rate. Whether used on-line or off-line the modulation rate of the OCRE signal shall be as specified in paragraph 7.2.6 {Modulation rate} of the basic standard.

2.4 Character Reading Rate. The character reading {scanning} rate bears a definite relationship to the rate at which signals are dispersed to the line unless a buffer storage is provided between the two. The maximum scanning rate shall be consistent with the headquarters traffic load, economics, accuracy in reading, and sound engineering practices.

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2.5 Bit Transmission. Bits {per character} transmission between the OCRE and the off-line recorder may be in serial or parallel form. When the OCRE is operating on-line the bit stream must ultimately be serialized before transmission.

2.6 Parity. When the ASCII is used pursuant to paragraph 2.1 of this appendix, the parity bit shall be generated by the OCRE in accordance with paragraph 6.1.1.3 {Parity Bit} of the basic standard.

3. Major Associated Devices.

3.1 Recorders. The paper or magnetic tape, etc. recording devices shall conform to the basic standard.

3.2 Cryptographic Equipment. The OCRE need not be required to operate with off-line cryptographic devices. Ordinarily any off-line encryption required shall be effected after the clear text message is "read" and recorded on the recording media. However, the OCRE may be associated directly with off-line cryptographic equipment for encryption of the body of the message if desired.

3.3 Switching Equipment. The OCRE will not be required to switch messages on the basis of what is in the routing line. Switching will be accomplished in the switching center into which the OCRE {if on-line} or the recording medium {if the OCRE is off-line} operates. However, the OCRE may be assigned the function of forwarding messages to the Local Digital Message Exchange for local distribution.

3.4 Routing Line Segregation Equipment. Routing line segregation shall not be performed by the OCRE. This shall be performed by the switching equipment of other device designed specifically for this function.

3.5 Heading Generator. An appropriate heading must be generated for the message that is in accord with the design of the local switching center, generally JANAP 128. This may be accomplished by one of the following techniques.

3.5.1 Manual Preparation. This method of generation of the heading is not recommended except for emergency operation and small amounts of traffic to seldomly addressed headquarters.

3.5.2 Semiautomatic Generation. By this method the heading is generated from information recorded in a punched card {or equivalent}. One card is prepared for each headquarters ordinarily addressed. When a message is addressed to a headquarters for which no address card has been prepared such a card must be prepared manually. This method is permissible but

automatic generation of the heading should be a design objective.

3.5.3 Automatic Generation. This method, which is preferred over manual or semiautomatic generation, is considered standard. A computer associated with the OCRE generates automatically the appropriate heading, using the information read from the message heading by the OCRE in conjunction with other information stored in the memory of the computer. Fully automatic operation would require sufficient table look-up in the memory to hold a record of all headquarters with the associated routing indicator for each. It shall not be considered non-standard to omit seldomly addressed headquarters from the table look-up and to handle manually certain components of such message headings.

3.6 Distribution Equipment.

3.5.1 Manual Distribution. In order to obtain satisfactory copy for local distribution, reproduction facilities may be employed or one or more page copy machines may be associated with the OCRE.

3.6.2 Automatic Distribution. If Local Digital Message Exchange {LDMX} is employed, the OCRE may be designed to feed the message directly to the LDMX for automatic distribution. {See paragraph 6.2.5.8 of this appendix.}

4. OCRE Capabilities.

4.1 Monocase ASCII OCRE {Preferred standard for message preparation}. The minimum reading capability of monocase OCRE operating in an ASCII communication link shall be the characters given in Table I of this appendix. Any additional character reading capability shall be limited to those characters given in Table I of Appendix C.

4.2 Dualcase ASCII OCRE. Dualcase readers shall have the same capability as monocase readers but with the additional capability of reading lower case alphabetic characters printed in the same font design as the upper case alphabetic characters. Dualcase OCRE is not recommended for ordinary communications use because dualcase receiving teleprinters will not generally be available. The use of dualcase OCRE is appropriate only in properly equipped closed networks, when dualcase receiving teleprinters are generally available and when using ASCII, or the ITA No. 5 Alphabet.

4.3 Monocase ITA No. 2 OCRE {USA Variation}. It shall be standard to design OCRE operating in the ITA No. 2 Alphabet to have a read capability the same as that for monocase ASCII OCRE so that conversion to ASCII operation may be readily

accomplished when required. Five characters of Table I are not included in the ITA No. 2 namely: percent, asterisk, plus-equals and vertical line. In order to maintain character count integrity of the message, these may be transmitted as exclamation point. The software of the OCRE must provide some special handling of these five characters.

4.4 Dualcase ITA No. 2 OCRE {USA Variation}. The use of dualcase OCRE operating in the ITA No. 2 Alphabet is entirely inappropriate because ITA No. 2 is strictly monospace with respect to the alphabetic characters. Only as part of a phased program for changeover to dualcase processing in ASCII can such a use find justification.

4.5 Character Set Capabilities.

4.5.1 Single Character Set OCRE {Monospace}. The use of monospace character set OCRE {upper case only} has the disadvantage of necessitating more complete standardization of message preparation typewriters throughout the headquarters than does OCRE utilizing dualcase and multiple character sets. However, monospace OCRE has an advantage in cost and reliability of reading over dualcase OCRE and it has a very considerable advantage in cost and reliability of reading over multiple character set OCRE. For DoD policy and guidance on fonts refer to the foreword of this appendix.

4.5.2 Multiple Character Set OCRE. OCRE having multiple character set capability allows more flexibility in the use of typewriters but it costs considerably more and is much less reliable in reading than the single character set OCRE. Multiple character set OCRE shall have the capability of the character set described in Table I and paragraph 4.6.

4.6 Minimum Character Set Capability. OCRE shall have the minimum capability of reading a character set defined by Table I when the:

Horizontal character spacing is 10 per inch
Vertical character spacing is 3 per inch
Maximum character height, H , is 0.094 inches
Maximum character width, W , is 0.055 inches
Nominal stroke width, T , is 0.014 inches

The character height and width are defined as centerline height and width. Therefore, the actual maximum height is $H+T$ and the actual maximum width is $W+T$.

4.7 Multiple Character Set Capability. One of the character sets shall be as described in paragraph 4.6. All other character sets are specified only to the extent of having the character spacing of paragraph 4.7.

4.8 Automatic Message Heading. OCRE equipped for automatic message heading generation shall read the heading elements which are typed in the appropriate places on DD Form 173. Using this information, the OCRE shall automatically generate an appropriate message heading as described in paragraph 3.5.3 of this appendix.

4.9 Automatic Message Ending. OCRE equipped for automatic message heading generation shall also automatically generate a compatible and appropriate end of message format.

5. Typewriters.

5.1 General Performance Characteristics. Adequate typing quality is mandatory in order to minimize OCRE reading errors. This requires appropriate typewriters, ribbons, maintenance, and a consistently strong touch. All of this can be obtained most adequately by using electric typewriters and one-time ribbons. Making such practice mandatory will pay dividends in added message reliability.

5.2 Print Quality. Print quality is a combination of the following: Minimum print contrast signal {PCS} within character outline, the maximum PCS outside the character outline, voids, extraneous ink areas, stroke width variation, and conformance of character shapes to nominal character shapes specification. These factors are largely determined by the printing systems employed. The performance of OCR systems depends to a large extent on the print quality. Hence, every effort should be made to provide "good" print quality, i.e.:

a. The printed character should present as high a contrast as possible to the background document.

b. Stroke width should be held as close as possible to the nominal.

c. Insofar as possible, there should be no voids within the stroke outline. When these cannot be prevented, the number of void areas within a stroke should be minimized. The size of individual voids should not exceed half of the nominal stroke width, and the distance between individual voids should be as great as possible.

d. Insofar as possible there should be no extraneous ink within the clear area. When this cannot be prevented, the number of extraneous ink spots should be minimized, the size of the spots should not exceed half the nominal strike width, and the distance between unit spots should be as great as possible.

5.3 Dualcase Typewriters. Dualcase typewriters shall ordinarily be used for message preparation so that they also may be used for other work. The lower case characters may be any suitable style unless the headquarters is equipped with an OCR-E with both an upper and a lower case reading capability. In such a case the lower case characters shall be the appropriate characters as provided in paragraph 4.2 of this appendix.

5.4 Monocase Typewriters. Monocase typewriters shall ordinarily not be used for message preparation even though messages normally will continue to be prepared in upper case letters only.

5.5 Keyboard Arrangement. The standard keyboard arrangement for OCR typewriters is shown for information purposes in Figure 3 of Appendix C. The detail requirements are given in MIL-STD-128D, Military Standard Keyboard Arrangements.

B. Standard Message Form Use.

B.1 Paper Specifications. See Inclosure 1 to Figure 1.

B.2 Printed Format.

B.2.1 First Sheet {DD Form 173}. The joint message form is shown in Figure 1. This sheet includes the heading information required for a computer to generate the appropriate standard format for the message heading in accordance with JANAP-128 {AUTODIN}, ACP-127 {NATO Traffic Only} or other appropriate format as determined by the requirements.

B.2.2 Continuation Sheet. The same form is used as a continuation sheet for those messages that require more than one page.

B.2.3 Printed Details. See Inclosure 1 to Figure 1.

B.2.4 Use of Format. See Inclosures 2, 3 and 4 to Figure 1.

B.2.5 Message Component Symbolization.

B.2.5.1 Orientation {Benchmark} Symbol. It shall be standard not to use a special printed symbol for the OCR-E to orient itself with respect to the printed page. The equipment shall orient itself with respect to edges of the paper by the difference between the paper reflectance and that of machine background, or may be oriented on the first typed character. In the event a reader is used that does not have such a capability, the typist may be instructed to type in a special symbol at an appropriate place on the page. In any event the

OCRE shall be programmed to start its scan at the first line of typing after becoming oriented.

6.2.5.2 Start of Heading {SOH}. No start of Heading {SOH} symbol is used in the interest of economy. Such a symbol would have to be printed in black. A two color form would be more costly than a single color {blue} printed form. To have the typist type in a SOH would complicate her job unnecessarily. The OCRE shall be programmed to recognize the Start of Heading by the message pagination, that is page "1" of "X" pages.

6.2.5.3 Action Addressee Symbol. Not used, handled by software. The first Action Addressee may be recognized by the OCRE as being indented 20 spaces. Subsequent Action Addressees, if any, are also indented 20 spaces. Double spacing is used vertically.

6.2.5.4 Information Addressee Symbol. The sequence "INFO:" shall be used to indicate the first Information Addressee. The colon is used to prevent a random sequence "INFO" in the message from giving a false result. "INFO:" is typed by the drafter's typist two lines below the last Action Addressee, starting immediately to the right of the left blue margin line using no indentation. The Info Addressees are indented 20 spaces as are the Action Addressees and are also double spaced vertically. The OCRE may thus recognize the end of Action Addressees and the beginning of Information Addressees by the typed "INFO:" starting at the margin. If there are no Information Addressees the OCRE will recognize this fact by finding "XMT:" at the left margin line, no indentation, using double spacing from the last Action or Information Addressee as the case may be. The exempted headquarters or routing indicator{s} shall be typed in starting directly under the start of the addressees, namely 20 spaces from the left margin line. If there be more than one line of exempted routing indicators the second line shall also be indented 20 spaces. Thus, the OCRE can recognize the Start of Text by the next nonindented typing.

6.2.5.5 Start of Text {STX} Symbol. Not used, handled by software.

6.2.5.6 End of Text {Message} {ETX} Symbol. Not used, handled by software. The OCRE can recognize the ETX by the end of the printing in the last page of the message. The last page is identified by the pagination in the page block in the first line of typed material. On the last page the page number is the same as the number of pages, such as page 2 of 2.

6.2.5.7 Indentation Symbol. It shall be standard to program the computer to effect indentation and tabulation at the receiver by counting and transmitting the appropriate number of

spaces. This method allows for tabulation without any prearrangement between the originator or drafter and the addressee. When the ASCII is used, however, tabular material can be sent by prearrangement between the transmitter and receiver. This requires sending tabular codes rather than spaces and also employing appropriate page printers at the receiver.

6.2.5.8 Automatic Local Distribution. If the OCRE is used in conjunction with a Local Message Distribution Unit (LDMX) the local distribution may be typed in the appropriate place on the Joint Message form. A vertical line is used to indicate that this data is for local distribution and not part of the message.

6.2.6 Use of Erase Symbols.

6.2.6.1 Group Erase Symbol. It shall be standard to use a long dash (Group Erase Symbol) through the first three characters in a line to indicate that the line is in error and must be omitted by the OCRE. This symbol is shown in Table II.

6.2.6.2 Character Erase Symbol. It shall be standard to use the Character Erase Symbol "E" printed over a character to indicate that the character is in error and should be omitted (ignored) by the OCRE. This symbol is shown in Table II.

6.2.6.3 Alternative to Use of Group Erase and Character Erase Symbols. An alternative to the use of group erase and character erase symbols is the perfect typist or the erasure. Perfect typists are scarce and the use of the erasure, unless done very carefully, will cause OCRE reading errors. Messages destined to be mailed may contain erasures in order to obtain satisfactory copy. The preparation of messages destined for the OCRE, should make use of the group erase and character erase symbols.

TABLE I
 APPENDIX E

Repertoire of Characters to be used in Message Preparation for OCRE Handling (Based on ASCII Table, Appendix C)

COLUMN →	0	1	2	3	4	5	6	7	ROW ↓
b7 b6 b5	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1	
b4 b3 b2 b1	NON-PRINTING		96-SYMBOL PRINTING SUBSET						
0 0 0 0			SP	0		P			0
0 0 0 1				1	A	Q			1
0 0 1 0			"	2	B	R			2
0 0 1 1				3	C	S			3
0 1 0 0			\$	4	D	T			4
0 1 0 1			%	5	E	U			5
0 1 1 0			&	6	F	V			6
0 1 1 1			' (APOS)	7	G	W			7
1 0 0 0			(	8	H	X			8
1 0 0 1			)	9	I	Y			9
1 0 1 0			*	:	J	Z			10
1 0 1 1			+	;	K				11
1 1 0 0			,		L			1	12
1 1 0 1			-	=	M				13
1 1 1 0			.		N				14
1 1 1 1			/	?	O				15

NOTE: ITA #2 (USA version) does not include Percent, Asterisk, Plus, Equal or Vertical Line.

APPENDIX E

TABLE II

OCR-A CHARACTER SET FOR MONOCASE OCR

OCR-A Character Set Representing ASCII Characters

<u>Alphabet</u>		<u>Numerals</u>	<u>Punctuation</u>	
			<u>Symbols</u>	<u>Name</u>
A	N	1	.	Period
B	O	2	,	Comma
C	P	3	:	Colon
D	Q	4	;	Semi-Colon
E	R	5	=	Equals
F	S	6	+	Plus
G	T	7	/	Slant
H	U	8	\$	Dollar Sign
I	V	9	*	Asterisk
J	W	0	"	Quotation Mark
K	X		&	Ampersand
L	Y		'	Apostrophe
M	Z		-	Hyphen
			{	Left Parenthesis
			}	Right Parenthesis
			%	Percent
			?	Question Mark
			|	Vertical Line

Special USASI Symbols

<u>Symbols</u>	<u>Name</u>	<u>Use</u>
⸮	Hook	None
⸮	Fork	None
⸮	Chair	None
⸮	Group Erase	Erase complete line
⸮	Character Erase	Erase character

DATUM LINE

JOINT MESSAGEFORM										SECURITY CLASSIFICATION											
* SEE NOTE 3 0.125 ± 0.05 0.575 3.55 0.7										0.45 0.125 0.9 1.32											
PAGE 1 OF 1		DRAFTER OR RELEASER TIME		PRECEDENCE ACT INFO		LMF		CLASS		CIC		FOR MESSAGE CENTER/COMMUNICATIONS CENTER ONLY									
1.45		1.75		2.05		2.45		3.05		3.55		DATE — TIME				MONTH		YEAR			
5.25		6.25				6.65				5.25				6.25				6.65			
BOOK		MESSAGE HANDLING INSTRUCTIONS																			
0.35		1.566 * SEE NOTE 2 FROM: 1.9 TO: 1.85																			
6.566		6.9 7.233 7.566 7.616 DISTR 7.9 8.233 8.283																			
DRAFTER TYPED NAME, TITLE, OFFICE SYMBOL AND PHONE										SPECIAL INSTRUCTIONS											
8.783										9.283 3.55 9.55 SECURITY CLASSIFICATION											
TYPED NAME, TITLE, OFFICE SYMBOL AND PHONE										9.283 3.55 9.55 SECURITY CLASSIFICATION											
SIGNATURE										9.283 3.55 9.55 SECURITY CLASSIFICATION											
0.2										9.283 3.55 9.55 SECURITY CLASSIFICATION											

DATUM LINE

* SEE NOTE 2

DD FORM 1 JUL 68 173 * SEE NOTE 2

6.9 ± 0.1

FIGURE 1 JOINT MESSAGEFORM FOR OCR PROCESSING

MIL-STD-188C

ENCLOSURE 1 TO FIGURE 1

PRINTING INSTRUCTIONS FOR JOINT MESSAGE FORM (CORE APPLICATION)

1. Essential instructions are as follows:

- a. Sheet size: 8 x 10 1/2 inches.
- b. Line color: Drop out blue, not visible to optical readers {all lines and printing}.
- c. Margin lines:
 - {1} Left and right margins: 1/2 inch from paper edge, plus or minus 1/10 inch, always maintaining sixty-nine typing characters at 10 per inch between margin lines.
 - {2} Top margin 1/8 inch, bottom margin 3/8 inch, from paper edge.
- d. Typewriter line-up lines: Distance between the two short lines in the upper right and left margins: 1/8 inch. These lines delineate the first line of typing and are used to line up the paper in the typewriter. Therefore both pairs of lines should be equidistant from the top of the page and centered about 7/8 inch from the top margin line.
- e. Block spacing on first line: The width of each block in the first line of typing is given below. The numbers are based upon ten typewriter characters per inch. An additional space separates each two adjacent blocks. The separating line between adjacent blocks appears in the center of the space between blocks.

<u>BLOCK</u>	<u>TYPEWRITER CHARACTER SPACES (10 PER INCH)</u>
PAGE	6
DRAFTER OR RELEASER TIME	7
ACT	2
INFO	2
LMF	3
CLASS	5
CIC	4
UNNAMED	16
DATE-TIME	9
MONTH	3
YR	2
TOTAL NUMBER LINE SPACES	10
TOTAL SPACES	69

f. Block spacing on second line:

<u>BLOCK</u>	<u>TYPEWRITER CHARACTER SPACES</u>
BOOK	3
TOTAL NUMBER LINE SPACES	1
MESSAGE HANDLING INSTRUCTIONS	65
TOTAL SPACES	69

g. The bottom line delineating the Message Handling Instructions Block shall be $\frac{3}{8}$ inch below the line above.

h. "FROM" and "TO" lines: The "FROM" and "TO" must be four and six typewriter lines (at six lines per inch) respectively below the first typewritten line as delineated by the aforementioned short lines in the margins. The T in TO should be directly below the O in FROM. The colon following the TO and FROM in each case must be 19 typewritten characters from the left margin, 1.9 inches.

i. The vertical distance between the centers of the numbers in the lower left margin must be $\frac{1}{6}$ inch. The center of the first number (6) must be the center of the 34th typewritten line (at 6 lines per inch), or $5 \frac{2}{3}$ inches, below the first line of typing as delineated in paragraph d above.

j. The upper and lower lines delineating the "DRAFTER TYPED NAME...." and "RELEASER TYPED NAME...." in each instance are spaced $\frac{3}{8}$ inch vertically.

k. The quality of the paper used in message forms must be controlled for OCR applications. A suitable specification for paper quality may be obtained by reference to paragraph 4, Paper Specifications of the "USA Standard Character Set for Optical Character Recognition" (USAS X3.17-1966). This standard is published by the United States of America Standards Institute, 10 East 40th Street, New York, N. Y. 10016. Paragraph 4.5 of this standard defines opacity. A paper of medium opacity is suitable if no writing is to be put on the back. However, if writing of any kind is to be placed on the back of the form, the paper should have high opacity as given in paragraph 1 below.

l. Paper Weight: Recommended paper weights used should be 30, 32, 40 and 48 pounds. These are Federal Standard weights based upon the weight of 1000 17x22 inch sheets. Commercial weights are half these figures based upon 500 17x22 inch sheets. The preferable weights are 40 and 48 in that order. Forty weight paper is the recommended minimum weight to be used when back

printing or writing is used. In such instances the paper must have a minimum opacity of 85 percent and the back-printing must have a minimum surface reflectance of 50 percent.

m. The blue ink used for the forms must be "Drop Out Blue." No attempt has been made to formulate a US Standard that defines this shade of blue. However, ink consisting of 31 parts white and one part of process blue has been found to be satisfactory. Drop Out Blue should have, as should all nonread colors, a defused reflectance reading, based on the reflectance of magnesium oxide, of 72 percent. Any lower reflectance is unacceptable. All readings should be derived in the S4 photo area.

ENCLOSURE 2 TO FIGURE 1

ADMINISTRATIVE INSTRUCTIONS FOR JOINT MESSAGEFORM {OCRE APPLICATION}

1. All stamps, signatures, or initials must remain outside of the blue margin lines that delineate the area reserved for typing to be read by the Optical Character Recognition Equipment {OCRE}. This may require authorities coordinating on the message to initial a block on the cover sheet, the back of the sheet, or elsewhere to be determined by the commander. If the initials of coordinators or any other writing is placed on the back of the form it must be behind the administrative portion at the bottom of the form. Dependence should not be placed upon the inks used being sufficiently reflective or the paper being sufficiently opaque to preclude back writing or printing interfering with the optical reading process. If corrections and changes are made on the typed form in pencil or ink, the form must be retyped before inserting on the OCRE.

2. These instructions may be supplemented as required.

ENCLOSURE 3 TO FIGURE 1MESSAGE CENTER AND/OR COMMUNICATIONS CENTER INSTRUCTIONS FOR
JOINT MESSAGEFORM {OCRE APPLICATION}

1. Examine each Optical Character Recognition Equipment {OCRE} joint message form when received for completeness and neatness. Refer incomplete, mistyped, or smudged forms to the Duty/Watch Officer for coordination and corrective actions with the office originating the message.
2. Only the first page of the messageform will be stamped with the date-time-group, and file time, upside down at the bottom of the back side. To accomplish this, reverse the first page about the horizontal axis and insert the bottom left portion of the form into the time clock for the date-time-group and the bottom right portion of the form for the file time in accordance with local instructions. This procedure will allow typists to read the stamped figures and transcribe them as required into the FOR MESSAGE CENTER/COMMUNICATIONS CENTER ONLY block, after inserting the page in a typewriter, by glancing over the carriage at the bottom part of the backside of the message form. Care should be taken that the size of the time stamp and its position at the bottom of the page is such that the stamped material will all be below the line on the front that delineates the lower message area from the top of the administrative area of the form. This precaution must be taken to preclude ink on the back from showing through the paper and confusing the optical reader.
3. Only character sets approved for OCRE use will be used to type any information on the messageform.
4. The following instructions are for automatic heading preparation. If the message heading, ready for transmission, is prepared manually, existing procedures, modified as required, are suggested.
 - a. The message, after being inserted in the typewriter, will be properly aligned with a minimum of line skew and adjusted vertically so that the characters to be typed in will be even with those already printed between the two short horizontal blue lines on the upper left and right margins of the form.
 - b. The typist in the MESSAGE CENTER and/or the COMMUNICATIONS CENTER will read the date-time-group and file time stamped on the back and, where appropriate, will assign a cite number {if required by service or command instructions}. He will then:

(1) Type the file time and the cite number (if required) in the appropriate blocks.

(2) Type the date-time-group, including the month and year in the appropriate block. Some OCREs and associated computers are programmed to automatically generate the date, time, month and year, but this information must still be typed on the form before return to the office of origin.

(3) Type in the appropriate message handling instructions as required by local procedures.

(4) The area marked "DISTR:" is for local distribution which will be typed in, or omitted, in accordance with service or command instructions. Type a vertical line (|) in front of the first addressee. If only one line of local distribution is needed, it may be placed in the last typing line above the lower blue line with text going down to that line. If no local distribution is needed, the text may be typed down to the last typing line. However, if more than one line of local distribution is needed, the text must not be typed below the first blue line at the bottom of the page.

5. In a completely automated system the OCRE will supply the routing indicator for addressees.

6. In a partially automated system the routing indicator is obtained from the ACP 117 series and annotated on the message-form by Communications Center personnel. The routing indicator and/or operating signals must be typed in front of each addressee, both INFORMATION and ACTION and must begin six spaces from left margin. The originating routing indicator is automatically assigned by the OCRE processor.

7. If one or more characters are typed in error, strike over each such character with the appropriate delete symbol. In some instances there will be no room for additional characters due to typeovers. Thus care must be exercised in typing to avoid errors.

8. These instructions may be supplemented as required.

ENCLOSURE 4 TO FIGURE 1

TYPIST INSTRUCTIONS FOR JOINT MESSAGEFORM (OCRE APPLICATION)

1. This office is serviced by a communication center that is equipped with an Optical Character Recognition Equipment (OCRE) device that reads what you have typed on the standard message-form and, with the assistance of a computer, electronically prepares the message for transmission. The system is programmed with these instructions. If you make any mistakes in formatting the heading or smear the paper with your fingers or by poor erasing, the machine is likely to make a mistake or activate an alarm to get human assistance.
2. Your typewriter is equipped with an approved OCRE type face (character set). Non-approved character sets, if used, will require manual processing of the message.
3. The following instructions must be followed:
 - a. Select an OCRE joint messageform.
 - b. Insure that the form is straight in the typewriter carriage, using horizontal blue lines at the left and right margins.
 - c. Correct the vertical alignment so that characters will print between the horizontal lines in the upper left margin of the form.
 - d. Type all letters (or words) in capital letters.
 - e. Type in the page number and message page count, taking care to locate the page number immediately to the right of the blue left margin line. Adjust the margin set at this point because all non-indented lines of the message must line up under this page number. In some instances the message page count will not be known until later and must be typed in at that time. Considerable care should be exercised in lining up the typewriter both horizontally and vertically as it originally was when typing in the page count.
 - f. In the DRAFTER or RELEASER TIME block type in the DRAFTER's or RELEASER's Date and Time in accordance with local instructions. If this block is filled in after the preceding data is typed, extreme care must be exercised in lining up the typewriter as near to the previous lineup, both horizontally and vertically as possible. This is not the message reference DATE-TIME GROUP which is assigned by the MESSAGE CENTER/COMMUNICATIONS CENTER and written in the upper right hand corner of

the message form which you will leave blank. Your return copy will have the message reference DTG typed in.

g. In the PRECEDENCE blocks type the code characters for the desired message precedence, doing so for both ACTION and INFORMATION addressees as applicable. Leave the INFO block blank if there is no INFORMATION addressee. Proper code characters are as follows:

ZZ for Flash Precedence

00 for Immediate Precedence

PP for Priority Precedence

RR for Routine Precedence

h. The block marked LMF is designed for the Language Media Format of the message. LMFs are listed in JANAP 128 and are not generally used at present. The LMF will be typed in or omitted in accordance with local instructions.

i. In the CLASS block type the characters of the security classification, and/or handling instructions as indicated below. If the message is a Special Category (SPECAT), type AA immediately following the security characters.

Examples follow:

UU Unclassified

EE Encrypt for Transmission Only

CC Confidential

SS Secret

TT Top Secret

CCAA Confidential SPECAT

SSAA Secret SPECAT

TTAA Top Secret SPECAT

j. The block marked CIC is designed for the Content Indicator Code or general subject of the message. CICs are listed in JANAP 128 and are not generally used at present. The CIC will be typed in or omitted in accordance with local instructions.

k. In the BOOK block type in "Yes" if the message is a BOOK MESSAGE and "No" if it is a single or multiple address message.

l. Type the originating organization following the word "FROM" starting 20 spaces over from the left margin line. Space down and type in the first ACTION addressee following the word "TO:", being sure to start the addressee directly under the FROM headquarters. Double space down and type in subsequent ACTION addressees, starting in the space directly below the start of the first ACTION addressee. Continue until all ACTION addressees are typed. If a second sheet is used for additional ACTION or INFORMATION addressees, be sure to start all addressees 20 spaces over from the left margin line. Additional addressees placed on the second page should start after the "FROM:". The reader does not see the FROM and is programmed to consider this an addressee when occurring on a page other than the first. If there are any INFORMATION addressees, double space down and type in "INFO": starting at the left blue margin line. Space over and type in the first INFORMATION addressee, starting directly under the start of the last ACTION addressee. If there is a second INFORMATION addressee, double space down and type in the second addressee, starting directly under the first one, and so on.

m. Never type below the first blue line at the bottom of the page if there is more than one line of internal office distribution symbols to be listed in this space between the blue lines at the bottom (see paragraph p).

n. After completing the INFORMATION addressees there are two possibilities, starting the text or writing in exempted addressees, if any, if an Address Indicating Group has been used as an ACTION or INFORMATION addressee. If there are any exempted addressees type in "XMT:", starting at the left margin line and then type in the name of the exempted addressee, starting directly under the last addressee (20 spaces over from the margin line). If room is available, double space down from the last addressee and start the text. Typing of the text must begin immediately to the right of the left margin line (no indentation for the start of text is permitted). Continue across the page for not more than 69 characters which places the last character at the beginning of the right margin line. The text must be double spaced. The first word of the text must be the classification, or the abbreviation UNCLAS.

o. The numbers in the lower left margin will remind you of how many single spaced lines are left for addressees or text as applicable.

p. The area marked "DISTR:" is for local distribution which will be typed in, or omitted, in accordance with service or command instructions. Type a vertical line (|) in front of the first addressee. If only one line of local distribution is needed, it may be placed in the last typing line above the lower blue line with text going down to that line. If no local

distribution is needed, the text may be typed down to the last typing line. However, if more than one line of local distribution is needed, the text must not be typed below the first blue line at the bottom of the page.

q. The lower part of the OCRE Joint Messageform is reserved for administrative details that are not necessary for the optical reader to consider. All hand writing, special instructions, coordination, initials and signatures must remain in the area below the lower heavy blue line.

r. The Joint Messageform is used as both a first page and a continuation sheet. When used as a continuation sheet, leave blank all of the first line of typing except the "PAGE" and "DRAFTER or RELEASER TIME" blocks. In the "PAGE" block enter the page number and, when determined, the message page count. Fill in the DRAFTER or RELEASER TIME block as on previous pages of the same message. Ignore the "BOOK" "MESSAGE HANDLING INSTRUCTIONS", "FROM:" and "TO:" in blue and type over as required. Do not type below the lower heavy blue line.

s. As on the first page the security classification of the message must be stamped on the top and bottom, in the boxes marked SECURITY CLASSIFICATION of all subsequent pages.

t. If any erasures are made they must be done very carefully and completely in order to preclude chances of erroneous reading by the machine. Erasures are not recommended. If one or more characters are typed in error, strike over each such character with the single delete character symbol. Its use advises the reading machine that the overprinted character(s) must be deleted and its (their) used space filled up with the next character(s) whether printed or a space. When it is desired to delete a whole line of typing use the group(line) delete symbol (a long dash) by typing over the first three characters in the line.

4. These instructions may be supplemented as required.

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