MIL-STD-469
NOTICE - 1
30 March 1967

MILITARY STANDARD

RADAR ENGINEERING DESIGN REQUIREMENTS

ELECTROMAGNETIC COMPATIBILITY

TO ALL HOLDERS OF MIL-STD-469:

1. The following pages of MIL-STD-469 have been revised and supersede the pages listed:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
7	30 March 1967	7	1 December 1966
8	1 December 1967	(Reprinted without change)	
9	30 March 1967	9	1 December 1966
10	30 March 1967	10	1 December 1966
11	30 March 1967	11	1 December 1966
12	1 December 1966	(Reprinted without change)	
13	30 March 1967	13	1 December 1966
14	1 December 1966	(Reprinted without change)	
17	30 March 1967	17	1 December 1966
18	1 December 1966	(Reprinted without change)	
27	30 March 1967	27	1 December 1966
28	1 December 1967	(Reprinted without change)	
43	30 March 1967	43	1 December 1966
44	1 December 1966	(Reprinted without change)	

2. Retain this notice and insert before table of contents.

Custodians:
Army - EL
Navy - SH
Air Force - 17

Review activities:
Army - EL
Navy - SH, AS, OS
Air Force - 17

Preparing activity:
Navy - SH
(Project MISC-0438)

FSC MISC

Table II - Theoretical calculation sheet.

Equipment Nomenclature ______________________

Type of Output Tube (Magnetron, Tetrode, and so forth) ______________________

Fundamental Frequency (MHz) ____________ Pulse Repetition Rate (PRF) ____________

Peak Power (P_p) ____________ Average Power (P_a) ____________

Pulse Compression Ratio (d) ____________ Pulse Width at 1/2 power points ____________

Duty Cycle (D_c) = $\frac{P_a}{P_p}$ = ____________ Gain of Antenna (G_a) ____________

Peak Power (dBm) = 10 log (P_p/10-3) = ____________ dBm

dBm/line at f_o = (Conventional Pulse) = $P_p \times D_c^2$ = P_p (dBm) + 20 log D_c = ____________

(Compressed Pulse) = $\frac{P_p \times D_c^2}{d}$ = P_p (dBm) - 20 log D_c - 10 log d

= ____________

Lines/kHz bandwidth = 1 kHz/PRF = ____________ lines = 10 log (1kHz/PRF) = ______ dB

dBm/kHz (Spectral Density) = dBm/line + lines/kHz(dB) = ____________

dBm/kHz/m^2 at 1850 meters for an isotropic antenna = dBm/kHz - 76.4 dB = ____________

dBm/kHz/m^2 at 1850 meters for equipment antenna = dBm/kHz/m^2 (isotropic) + G_a

= ____________

REMARKS:

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5.8 A system block diagram should be furnished, identifying the plane of reference employed for the tests, as well as all other signal injection and monitoring points. Those controls whose settings are significant to a particular test shall be identified and the control positions during the test shall be designated, such as "set to position 5," "turned fully clockwise," and so forth. An adequate description of the system operation shall be included, along with peculiarities that are not normally encountered. The setup for each measurement shall be presented in block diagram form, depicting the specific input terminals, output terminals, and test equipment interconnections.

5.9 All measurement photographs shall be at least 2-1/2 by 3 inches with the recticle lines clearly visible and with each line accurately calibrated. Where measured data are not clear, larger photographs or higher resolution photographs are required.

6 LIMITS

6.1 Unless otherwise specified by the procuring activity, the requirements specified hereinafter shall be adhered to for all new military radar systems.

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6.2 Radar transmitter frequency tolerances. - Radars that are controlled by crystals or equivalent methods:

Frequency range (MHz)	Tolerance (parts per 10^6)
100 to 960	± 50
960 to 4,000	± 100
4,000 to 10,000	± 250
10,000 to 30,000	± 500
30,000 to 40,000	± 1,000

6.2.1 All other radars shall meet the following frequency tolerances:

Frequency range (MHz)	Tolerance (parts per 10^6)
100 to 960	± 250
960 to 4,000	± 500
4,000 to 10,500	± 1,250
10,500 to 30,000	± 2,500
30,000 to 40,000	± 5,000

Frequency or phase shift radars shall meet the above tolerance requirements as appropriate at the upper and lower extremes of the frequency - band shift.

6.3 Maximum allowable radar emission bandwidth. - The radar emission bandwidth (as defined in 3.1.14) employing the following types of modulation shall not exceed the limits indicated:

Type modulation	Maximum allowable Radar emission bandwidth (MHz)	
Pulse	$\frac{20}{t}$	or 1/4 percent of f_o (whichever is greater)
Modified Pulse (chirp, matched filter, pulse compression and pulse stretch type radars)	$\frac{20d}{t}$	
Pulse Doppler	$\frac{20}{t}$	
CW	$3 \times 10^{-4} f_o$	
FM/CW	$2\Delta f + 3 \times 10^{-4} f_o$	

6.4 Radar systems tunability. - The frequency band of the radar shall be the band approved for the specific equipment by the Joint Frequency Panel, United States Military Communication Electronics Board and shall be specified in the contract. Radar systems shall be capable of being tuned over this approved band or a band of frequencies at least as great as 10 percent of the midband frequency. Radar systems may be continuously tunable, or have the capability to tune in discrete steps of no more than 2 percent of the operating frequency.

6.5 Antenna side lobe suppression. - The first major antenna side lobes shall be down at least 20 db from the main beam, and all other lobes shall be at least 30 db down from the main beam.

6.6 Radar transmission spurious radiations. - All radiated emissions not required by the radar to provide its services shall be held to a minimum. In no instance shall the spectral level outside of the maximum allowable radar emission bandwidth (see 6.3) exceed the following values, when the center of the carrier frequency, f_o is within the frequency range shown:

f_o (within frequency range of) (MHz)	Limit of spectral level (at the transmitter antenna input) (milliwatts/kHz)	(dBm/kHz)
100 to 400	6.31×10^{-5}	-42
400 to 1,215	2.51×10^{-4}	-36
1,215 to 2,700	1.26×10^{-3}	-29
2,700 to 5,000	2.51×10^{-2}	-16
5,000 to 8,500	1.00×10^{-1}	-10
8,500 to 40,000	3.16×10^{-1}	- 5

6.7 Radar receiving system. -

6.7.1 The radar receiving system required acceptance bandwidths are specified hereinafter:

Type modulation	Required acceptance bandwidth
Pulse	20/t
Modified Pulse	20d/t
Pulse Doppler	20/t
CW	$3 \times 10^{-4} f_o$
FM/CW	$2\Delta f + 3 \times 10^{-4} f_o$

6.7.2 R.f. preselection shall be employed except where broadband front ends are requisite operationally.

6.7.3 The stability of receivers shall be commensurate with that of associated transmitters.

6.7.4 Radar receivers shall not exhibit any radiation in excess of -67 dBm, measured at the receiver input terminals.

7. NOTES

7.1 Intended use. - When this standard is referenced, the following data will be required to be furnished in order to comply with the requirements specified in the standard.

(a) Requests for proposal should contain all information required by the procuring activity to be furnished in accordance with this standard.
(b) The contractor will furnish a design criteria plan 90 days after contract award describing how his proposed radar system design will meet the requirements of this standard (see 4.1).
(c) The contractor will submit a test plan 45 days prior to the start of testing, detailing tests to be performed.
(d) Previous test reports or Government letter of compliance will be furnished when required to determine whether identical systems require retesting.
(e) A test report will be submitted for evaluation by the procuring activity to determine conformance with this standard.

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7.2 International standardization agreements. - Certain provisions of this standard are the subject of international standardization agreement (International Telecommunications Union Radio Regulations). When amendment, revision, or cancellation of this standard is proposed which will affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental standardization offices, if required.

Custodians:
Army - EL
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Review activities:
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Preparing activity:
Navy - SH
(Project MISC-0438)

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APPENDIX

MEASUREMENTS

10. GENERAL MEASUREMENT REQUIREMENTS

10.1 All measurements described herein shall be performed using the procedures specified herein or by fully described and justified alternate procedures presented in the approved test plan.

10.2 Measurement frequencies. - Measurements shall be made at each of the three standard test frequencies in each tuning band or the operating frequency closest to the standard test frequency.

10.3 Test sites. - Tests shall be performed at locations meeting the requirements specified in 10.3.1.

10.3.1 Test site criteria. - An open field or anechoic chamber measurement site shall approximate free space conditions such that the power density (P_D) measured at the test site should be within ± 2 dB of the calculated P_D using Friis equation

$$P_D = \frac{G_T P_T}{4 \pi R^2}$$

where R is the horizontal separation between the equipment antenna and the test antenna. Any variations from the calculated power density shall be explained in the test report. If the variation is greater than ± 3 dB, tests shall not be continued without the approval of the contracting officer.

10.4 Determination of signal power level and frequencies. - A standard procedure is recommended for determining signal power levels and frequencies which reduce, to a large extent, the effects of component changes with time and inherent inaccuracies or instabilities or both of some of the test equipment.

10.4.1 Signal substitution technique. - The technique used is referred to as "signal substitution" and is performed as follows: In determining the level of a signal being measured on a spectrum analyzer or frequency selective voltmeter (FSVM), the indication on the instrument (either a vertical deflection or meter reading) is noted. The source of the signal is then replaced by a signal generator whose output has been referenced to a secondary standard thermal power meter. For measurements made with the spectrum analyzer, the signal generator shall be unmodulated (CW). For those measurements made with a FSVM (primarily those in the appendix 40.3 and 40.5), the signal generator shall be modulated with a pulsewidth corresponding to that of the system under test and shall be triggered with the pulse repetition frequency of the system. In either case, tune the signal generator to the frequency of the signal being measured and adjust for a maximum response on the receiver. Adjust the level of the generator until the response previously noted has been regained. The level of the calibrated generator is then read off the attenuator dial. In cases where an external variable attenuator is used, the level of the signal source is determined from the external attenuator.

10.4.2 Frequency of the signal generator may be obtained by connecting the output of the generator to a frequency counter. In cases where the signal to be measured is above the frequency limits of the counter, it is necessary to convert this frequency to one which falls within the counter limits. This may be done using a transfer oscillator, frequency converter, and mixers.

10.4.2.1 For frequencies which lie within the limits of the transfer oscillator or frequency counter, usually between 10 MHz and 12.4 GHz, the procedures for determining frequency shall be as described in the operating instructions for the instrument. For frequencies above 12.4 GHz, it will be necessary to mix the signal source frequency with a harmonic from a signal generator whose fundamental frequency lies within the frequency limits of the transfer oscillator/frequency converter. Figure 1 is a block diagram of a typical setup for frequency measurement. With this method, the mixer output is fed to an audio amplifier to provide sufficient signal level to be observed on an oscilloscope. The frequency of the signal generator is varied until one of its harmonics (predetermined) mixes with the signal source, providing a zero beat as observed on the oscilloscope.

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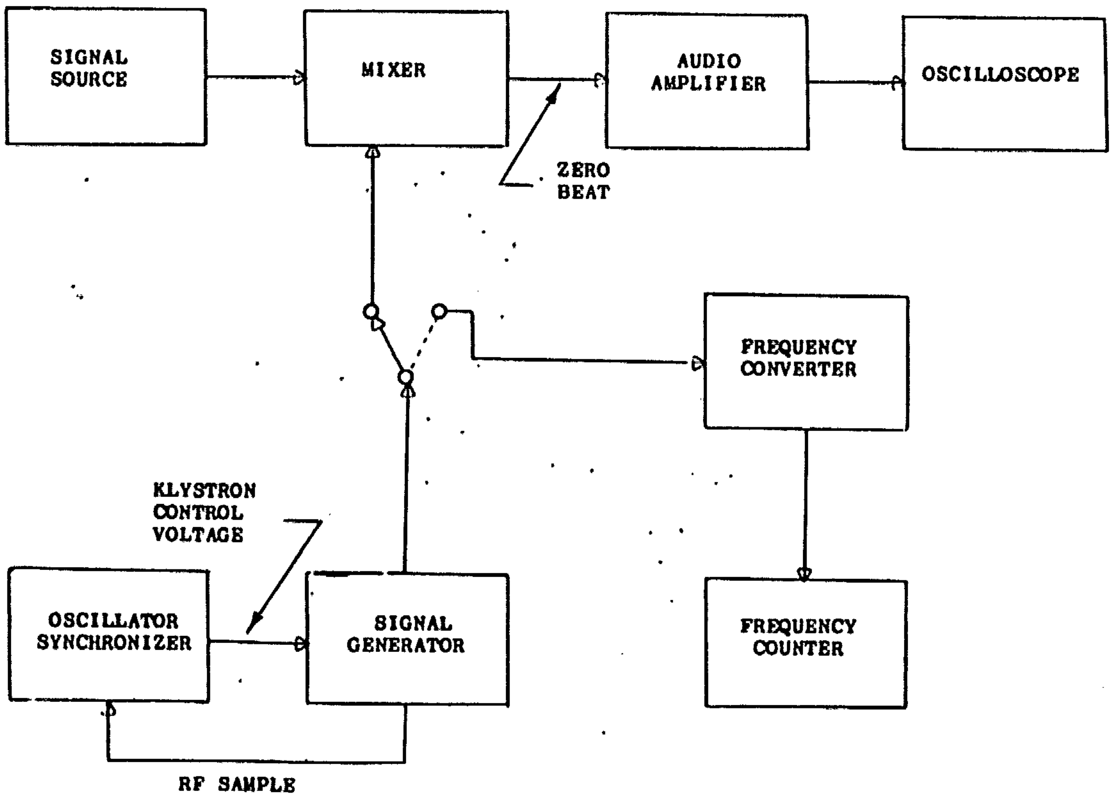

Figure 1 — Frequency measuring equipment block diagram, 10.0 to 40 GHz.

10.4.2.2 After this has been done, switch the output of the signal generator to the transfer oscillator/frequency converter and determine the frequency of its fundamental signal. This value multiplied by the appropriate harmonic number, will provide the frequency of the signal source.

10.4.3 An alternate method, which may be used if an audio amplifier is unavailable, is to replace the amplifier by an FSVM (e.g., an NF-105) and tune it to a specific frequency (e.g., 100 MHz). By adjusting the frequency of the signal generator for a peak indication on the FSVM, the frequency of the signal source may be determined by measuring the signal generator frequency as above. Care must be taken to assure that the difference frequency, as set up on the FSVM, is added to or subtracted from the signal generator harmonic frequency, as appropriate.

20. INSTRUMENTATION

20.1 Choice of instrumentation shall be in accordance with good engineering judgement, employing equipment that is in keeping with the state of the art and which has been calibrated within preceding 6 months with calibrations traceable to the National Bureau of Standards. Power level readings shall be within ± 2 db. Frequency measurements shall be within 1 part in 10^6. All external attenuators used shall be accurate to 1 db. The insertion losses of filters, directional couplers, or other signal sampling devices shall be known to ± 1 db.

20.2 The waveguide transitions and coax-to-waveguide adapters used in the receiver tests specified in Section 30 of this appendix shall have input impedances of 50 ohms and VSWR less than 1.3:1 independent of load. The insertion loss of the device shall be known within 1 db over the frequency range of the device when it is terminated in the nominal impedance.

20.3 Frequency selective voltmeters shall be calibrated using the signal substitution method specified herein. All FSVM's used in these measurements shall be monitored by aural and visual methods. An oscilloscope shall be used as a visual indication device in addition to instrument meters. When using an FSVM with different detector functions (e.g., Pulse Peak, Direct Peak, CW, Field Intensity, Quasi-Peak, CW Peak, and so forth), the appropriate detector function shall be utilized. For pulsed radar systems, a peak detecting function shall be used.

20.4 When making measurements requiring recovery of the pulse envelope (see 50.2 of this appendix), the 3-dB bandwidth of the FSVM shall be sufficient to recover at least 90 percent of the energy contained within the pulse. For fixed frequency pulses, the bandwidth, in megahertz, shall be at least $2/\tau$, where τ is the nominal system pulsewidth in microseconds. For frequency deviated pulses (pulse compression systems), the bandwidth shall be at least $2d/\tau$ where d is the pulse compression ratio. Where fine grain spectrum details are to be observed (as in 30.4 and 30.5 of this appendix, the 3-dB bandwidth shall be less than $1/10\tau$ or $2d/10\tau$ for fixed frequency pulses or frequency deviated pulses, respectively. At present, the spectrum analyzer is the only widely available instrument with a bandwidth narrow enough to meet the above requirements.

20.5 Typical block diagrams showing test setups recommended for the performance of these measurements are contained in each measurement section. Instrumentation is listed by equipment type. A table of recommended equipment is presented in table III. This equipment, or equivalent substitutes, shall be used whenever possible. As new equipment becomes available, the equipment list will be changed accordingly.

Table III - Recommended test equipment, or equivalent.

Equipment	Model	Frequency range
ANTENNA		
Stoddart	91280-1	20 to 1000 MHz
Empire Devices	NF-105	15 kHz to 1.0 GHz
Polarad	CA-L	1 to 2.24 GHz
Polarad	CA-S	2.14 to 4.34 GHz
Polarad	CA-M	4.19 to 7.74 GHz
Polarad	CA-X	7.36 to 10.0 GHz
Microline	56X1	8.2 to 12.4 GHz
Microline	56U1	12.4 to 18.0 GHz

Table III - Recommended test equipment, or equivalent (cont'd).

Equipment	Model	Frequency range
ANTENNA (cont'd)		
Microline	56K1	18 to 26.5 GHz
Microline	56V1	26.5 to 40.0 GHz
Polarad	CA-R	For Use with CA-M, CA-X
ATTENUATOR		
Weinschel	210-5	1 to 10 GHz
Weinschel	210-10	1 to 10 GHz
Weinschel	210-20	1 to 10 GHz
Weinschel	210-20	1 to 10 GHz
Weinschel	50-5	DC to 3.0 GHz
Weinschel	50-10	DC to 3.0 GHz
Weinschel	50-20	DC to 3.0 GHz
Weinschel	50-40	DC to 3.0 GHz
ATTENUATOR - VARIABLE		
Hewlett-Packard	P382A	12.4 to 18 GHz
Hewlett-Packard	K382A	18 to 20.5 GHz
Hewlett-Packard	R382A	26.5 to 40 GHz
BOLOMETER		
Hewlett-Packard	478A	10 MHz to 10 GHz
General Microwave	N420, 421, 422	10 MHz to 10 GHz
Hewlett-Packard	M486A	10.0 to 15.0 GHz
Hewlett-Packard	X486A	8.2 to 12.4 GHz
General Microwave	X420	8.2 to 12.4 GHz
Hewlett-Packard	P486A	12.4 to 18 GHz
General Microwave	U420	12.4 to 18 GHz
Hewlett-Packard	K486A	18 to 26.5 GHz
General Microwave	K420	18 to 26.5 GHz
Hewlett-Packard	R486A	26.5 to 40 GHz
General Microwave	A420	26.5 to 40 GHz
FIELD INTENSITY METER		
Empire Devices	BA/NF-105	Basic Unit
Empire Devices	T-1/NF-105	20 to 200.0 MHz
Empire Devices	T-2/NF-105	200 to 400 MHz
Empire Devices	T-3/NF-105	400 to 1000 MHz
Empire Devices	BA/NF-112	Basic Unit
Empire Devices	T-1/NF-112	0.9 to 2.1 GHz
Stoddart	NM-30A	10 to 400 MHz
Stoddart	NM-52A	375 to 1000 MHz
Polarad	R-BI	Basic Unit
Polarad	RR-5(plug-in)	400 to 1000 MHz
Empire Devices	T-2/NF-112	2 to 4 GHz
Empire Devices	T-3/NF-112	3.9 to 7.2 GHz
Empire Devices	T-4/NF-112	4.0 to 10.2 GHz
Empire Devices	T-5/NF-112	10 to 15 GHz
Stoddart	NM-62A	1 to 10 GHz
EMC	EMA-910A	1 to 10 GHz
Polarad	FIM	1 to 10 GHz

Table III - Recommended test equipment, or equivalent (cont'd).

Equipment	Model	Frequency range
WAVEGUIDE TRANSITION (cont'd)		
Aircom	195-KU-K	12.4 to 18 GHz 18 to 26.5 GHz
Aircom	195-K-KA	18 to 26.5 GHz 26.5 to 40 GHz

30. RADAR TRANSMITTER MEASUREMENTS

30.1 The radar transmitter measurements described hereinafter shall be performed on all transmitters, unless otherwise indicated.

30.2 Radar transmitter frequency tolerance. -

30.2.1 Objective: The objective of this measurement is to determine the frequency stability of a radar transmitter by evaluating the performance data obtained.

30.2.2 Requirements. - All radar transmitters that are controlled by crystals or equivalent methods shall meet the frequency tolerances specified in 6.2. All other radars shall meet the frequency tolerances specified in 6.2.1.

30.2.3 The ability of a radar transmitter to remain within the frequency tolerances set will provide a more reliable method by which frequency and equipment assignments may be made. This test shall be performed in-line, using the system directional coupler or other suitable coupling devices. The procedures to be used are specified hereinafter.

30.2.4 Procedures. - The measurement shall be made as follows: Refer to figures 2-1 and 2-2 for a typical block diagram of the test setup for this measurement. Turn the radar transmitter on and tune it to a standard test frequency. Adjust it for normal operation. Connect the frequency measuring equipment to the coupling device using attenuation in the line, as required. Measure and record the system frequency immediately after turn-on and at 15-minute intervals thereafter up to 4 hours. Record the time and frequency of each measurement. Repeat the above test for the other two standard test requirements.

30.2.5 Data. - The measurement data obtained shall consist of the transmitter frequency, pulsewidth, and PRF. All data obtained shall be recorded on forms as illustrated by figure 3.

30.3 Radar systems tunability. -

30.3.1 Objective. - The objective of this measurement is to determine the ability of a radar system to tune over its approved frequency band as specified hereinafter.

30.3.2 Requirements. - Radar systems shall be capable of being tuned over their approved frequency band or a band of frequencies specified in 6.4.

30.3.3 A measure of the tunability of a system is the ability of its transmitter to produce a given minimum output and of its receiver to produce a given minimum sensitivity over its operating band. Therefore, the procedures described herein will be to measure the system power output, sensitivity and frequency at each of its operating frequencies. In the case of continuously tunable systems, the frequencies to be measured shall be the low, mid, and high standard test frequencies, as specified in 3.1.18.

30.3.4 Procedures. - The procedures for this test shall be as follows: Refer to the block diagrams, figures 6-1 and 6-2 and 10-1 and 10-2 for typical test setups for power output and sensitivity measurements.

30.3.4.1 Frequency. - Tune the radar transmitter to one of the operating frequencies (or one of the standard test frequencies if continuously tunable) and adjust for its normal operating conditions. If the system employs a directional coupler or other coupling device connect frequency-measuring equipment to its

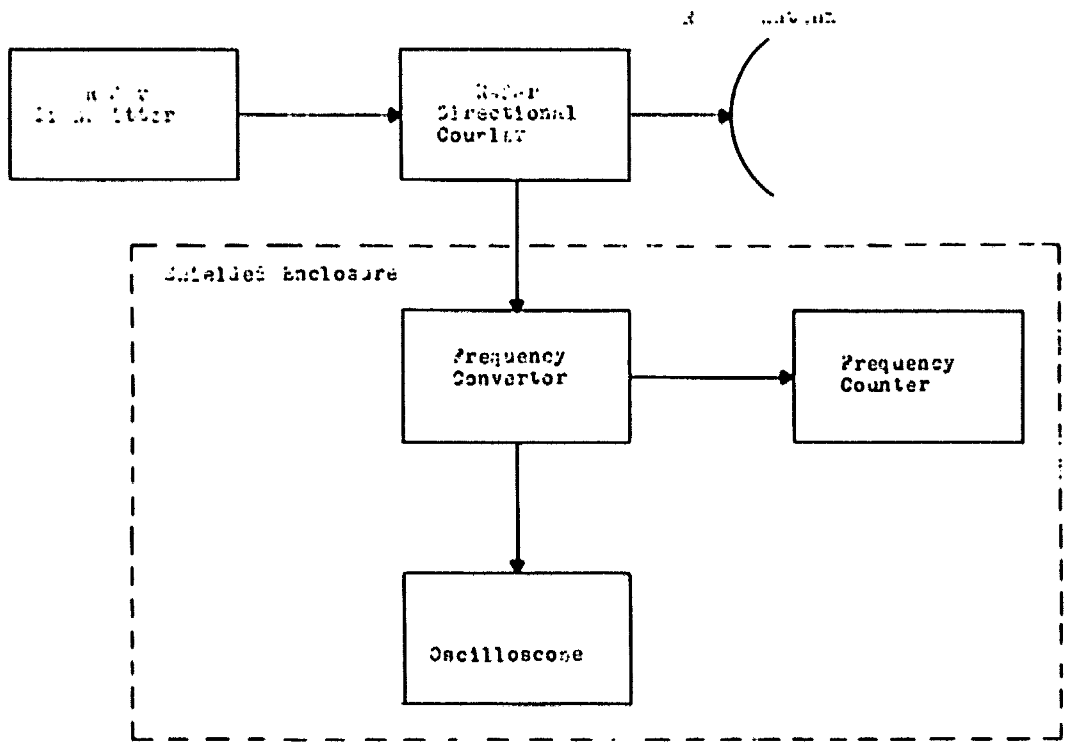

Figure 2-1 — Radar transmitter frequency tolerance measurement block diagram (below 10 GHz).

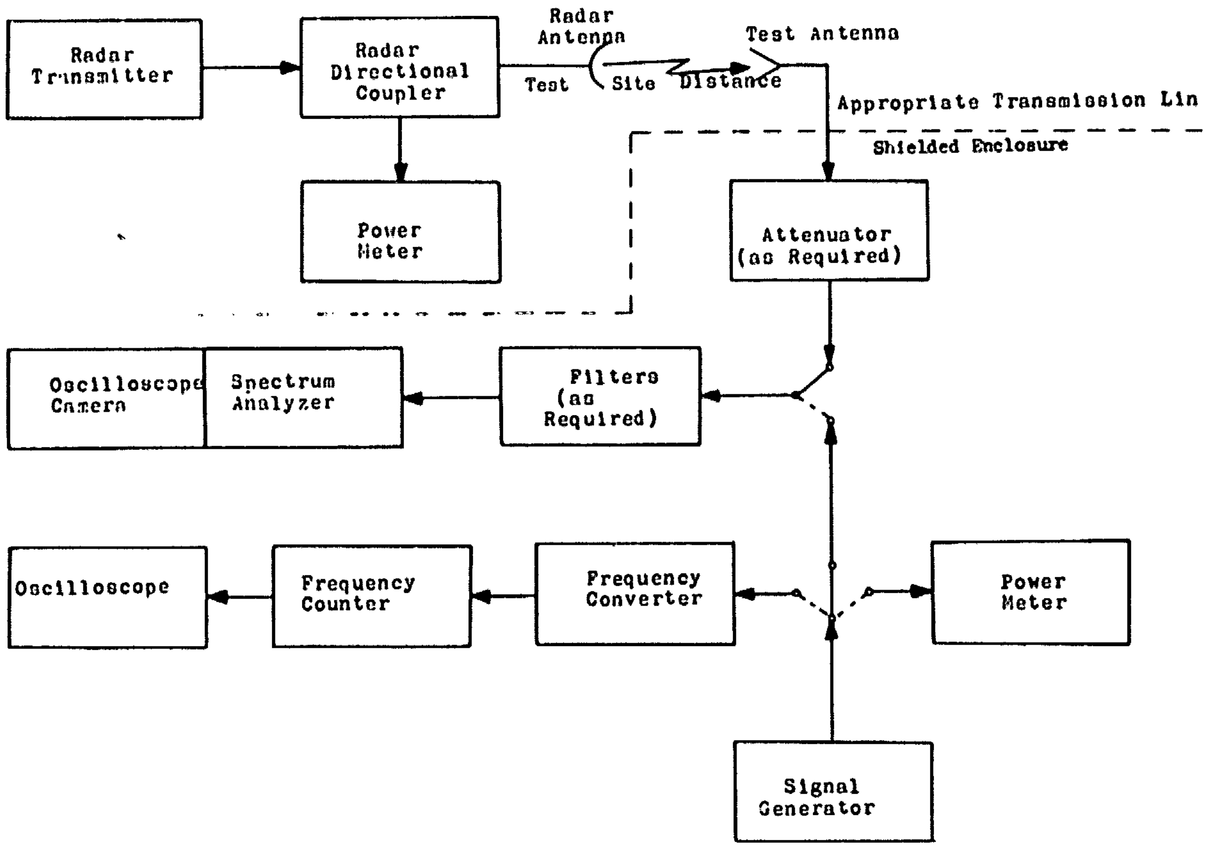

Figure 6-1—Radar emission bandwidth measurement block diagram (below 10 GHz).

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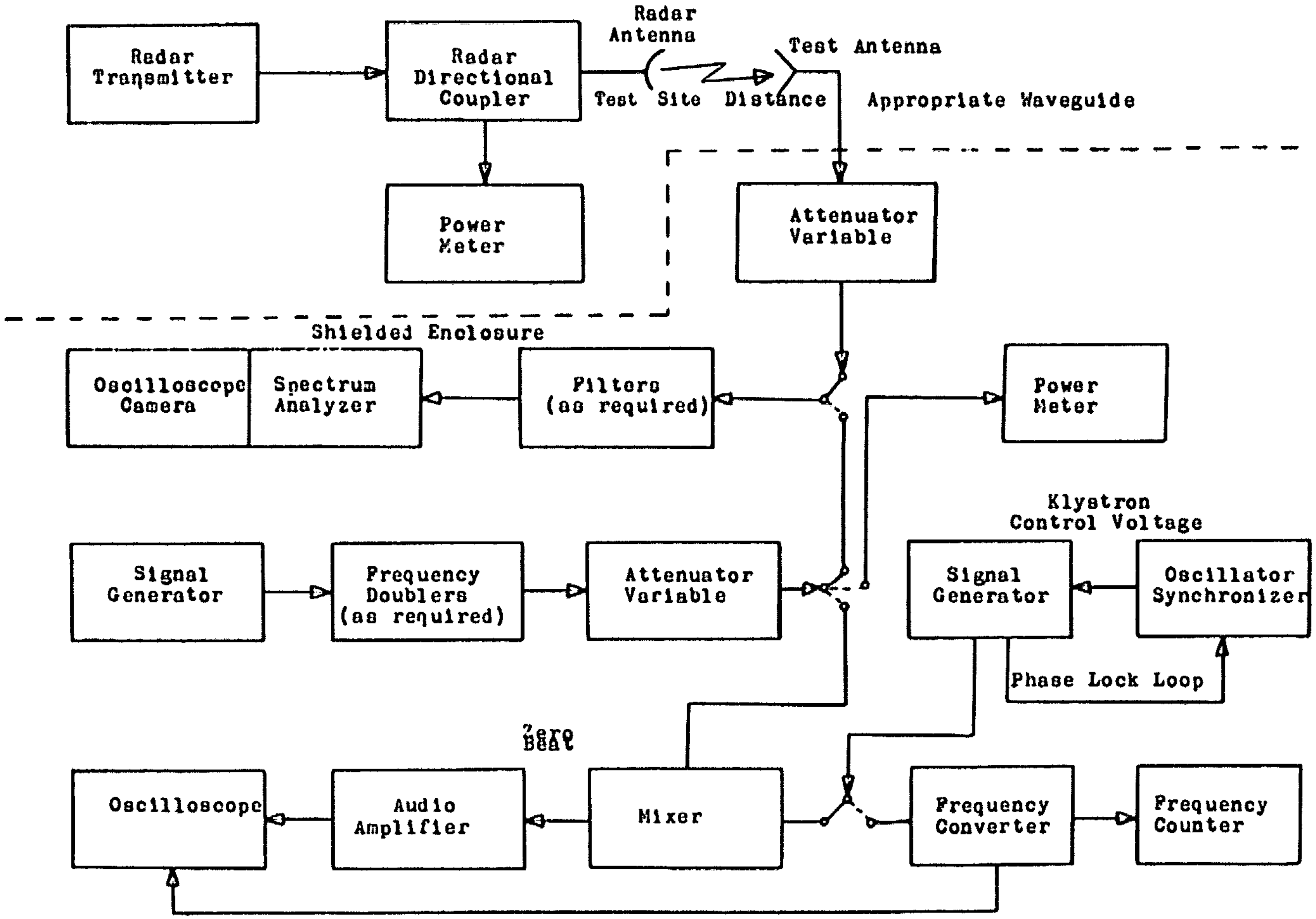

Figure 6-2—Radar emission bandwidth measurement block diagram (10 to 40 GHz).

50.2.4 Procedures. - The test shall be conducted as follows: Refer to figures 15-1 and 15-2 for a typical block diagram of antenna patterns measurements. With the radar transmitter operating in its normal configuration and at rated power output, position the receiving test antenna at a location that meets the test site criteria and is as free as possible from obstructions which could cause reflections. The test antenna shall be located at a minimum test site distance as defined in 3.1.2, and elevated to a height such that the energy received by the test antenna is a maximum.

50.2.4.1 The output of the test antenna shall be connected to the input of an FSVM via a length of transmission line and attenuators, as required. The radar antenna shall be excited by the system transmitter whenever possible. The FSVM shall be operated with the proper detector function and bandwidth.

50.2.4.2 With the system and test antennas aligned, tune the FSVM for maximum response. Adjust the attenuation in the line and the gain and attenuator controls of the FSVM for approximately full-scale deflection. Connect a strip-chart recorder to the recorder output of the FSVM. The gain and attenuator controls should be adjusted for approximately full-scale deflection of the recorder stylus. Measure the level and frequency of the fundamental of the system with the two antennas aligned using the signal substitution method, outlined in this appendix. With all instrumentation set as described, rotate the system antenna and start the recorder. It is required that the rotational speed of the system antenna be slow enough so that the recording equipment will have adequate time to respond to the radar energy as the beam sweeps past the test antenna.

50.2.4.3 For a typical setup with the following parameters, a rotational speed of 5 rpm would yield an accuracy of approximately 3 dB. Reducing the speed to approximately 1 rpm would yield an accuracy greater than 1 dB.

3 dB Beamwidth (system antenna): 1.6°
Recorder response time: 50 milliseconds

A rotational speed which will give at least 1 db accuracy may be obtained from the equation

$$W < 50 \frac{\theta 3dB}{T_r}$$

where

W = rotation speed, rpm

θ = 3 dB antenna beamwidth, degrees

T_r = response time of the FSVM/recorder system, in milliseconds

After the system antenna has swept past the test antenna a minimum of twice, stop the recorder and calibrate the pattern as follows. Switch the input of the FSVM to a calibrated signal generator and tune the frequency of the generator to the FSVM. Adjust the output level of the generator for a full-scale deflection on the strip-chart recorder. Start the recorder and record this level. Reduce the level of the signal generator in steps of 5 dB, recording each level on the strip chart. Continue reducing the generator output until the noise level of the receiver has been reached. Check the antenna pattern to determine its dynamic range. If it is not at least 35 dB, remove some of the external attenuation in the transmission line and re-run the measurement.

50.2.4.4 For antennas that can be elevated, perform an antenna pattern measurement in the vertical plane using the above procedures.

50.2.5 Data. - The data obtained in this measurement shall consist of signal generator output level, attenuation inserted, cable loss, signal generator frequency, system antenna rotation speed. All data shall be recorded on data forms, as illustrated on figure 16. A sample calculation to determine the power density of the fundamental energy in the main lobe of the antenna is specified in 30.4 of this appendix. In this case, however, the frequency selective voltmeter used to receive the energy has a bandwidth sufficiently wide ($>2/\tau$) to recover the energy generally contained in the pulse. The power density computed, therefore, will be in units of dBm/m^2.

50.2.5.1 In addition to the data recorded on the data sheets, the patterns recorded shall be presented with their calibrations.

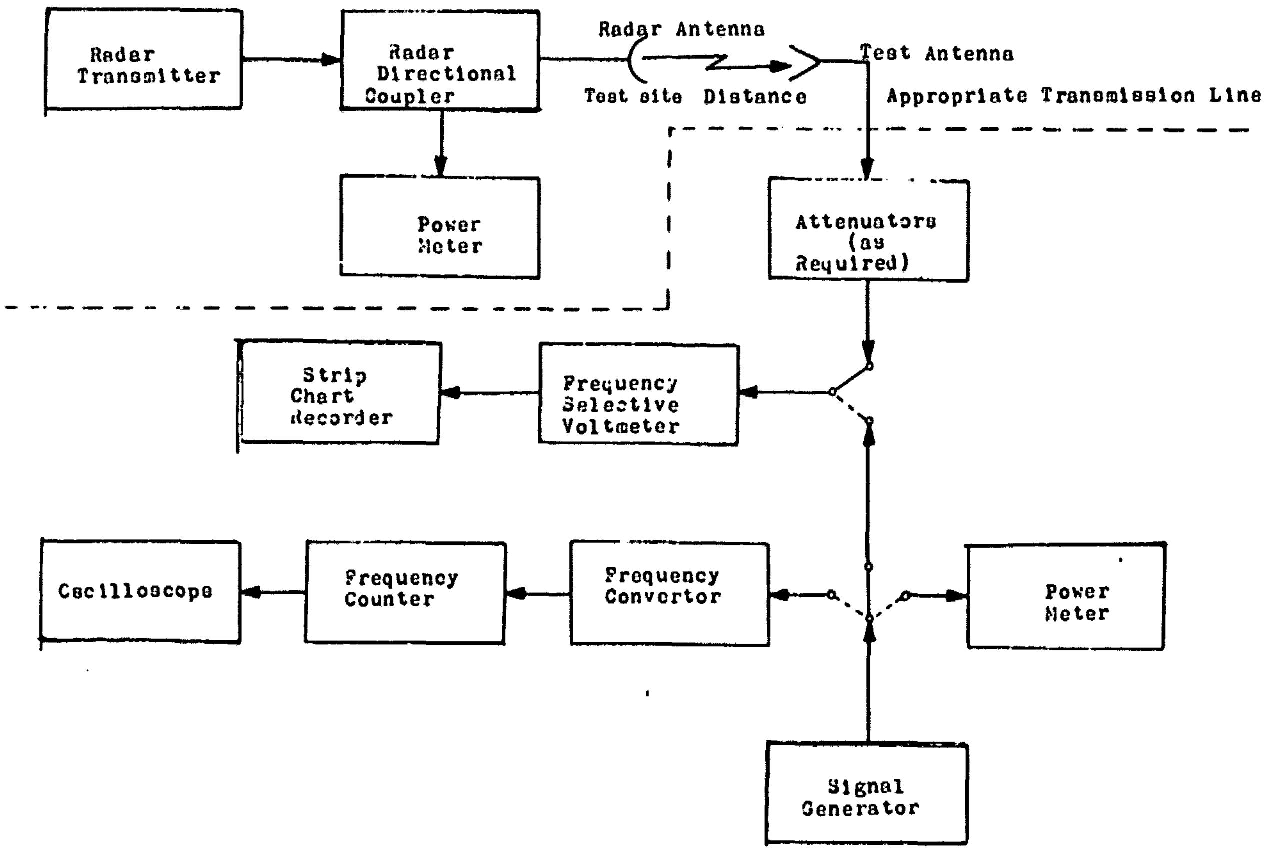

Figure 15-1—Radar antenna lobe suppression measurement block diagram (below 10.0 GHz).