

**METRIC**

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# **DEPARTMENT OF DEFENSE INTERFACE STANDARD FOR**

## **RADAR ENGINEERING INTERFACE REQUIREMENTS, ELECTROMAGNETIC COMPATIBILITY**

**METRIC**



**AMSC N7193**

**AREA EMCS**

**FOREWORD**

1. This military standard is approved for use by all departments and agencies of the Department of Defense.

2. This standard covers the interface requirements necessary to ensure control of the electromagnetic emission and susceptibility characteristics of military radar equipment and systems operating in all intended electromagnetic environments (EMEs). The engineering interface characteristics set forth in this document are considered necessary for electromagnetic (EM) spectrum conservation and electromagnetic compatibility (EMC).

3. The expanding application of radar for various military functions and purposes places increased demands upon the occupancy of the electromagnetic spectrum. Control of the electromagnetic emission and susceptibility characteristics of radar equipment and systems is essential for conserving the limited EM spectrum that is available.

4. The interface requirements stated herein are not intended to prohibit or inhibit the free and unrestricted research in the development of new radar systems which promise an increase in effectiveness. The minimum interface requirements given herein satisfy the Radar Spectrum Engineering Criteria; Section 5.3 in the National Telecommunications and Information Administration (NTIA) Manual of Regulations and Procedures for Federal Radio Frequency Management. The NTIA standards are approved for use by agencies and establishments of the Federal Government and constitute the minimum acceptable standards for electromagnetic spectrum management. Interface requirements more stringent than the NTIA standards are provided herein for radar equipment and systems that operate in critical EMEs. When these situations exist, the intent of the requirements shall be applied with best engineering judgement and with the approval of the contracting activity.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 03R42, 2531 Jefferson Davis Highway, Arlington, VA 22242-5160 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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## 1. SCOPE

**1.1 Scope.** This standard establishes the engineering interface requirements to control the electromagnetic emission and susceptibility characteristics of all new military radar equipment and systems operating between 100 megahertz (MHz) and 100 gigahertz (GHz), to ensure EMC in all intended operational environments, and to conserve the frequency spectrum available to military radar systems.

**1.2 Application.** The interface requirements presented herein apply to radar equipment and systems designed or acquired for use by activities and agencies of the Department of Defense (DoD). The applicable portions of this standard are mandatory for use by all departments and agencies of the Department of Defense unless waived by the cognizant project office with recommendation from the EMC organization within the procuring activity's command. The applicability of the emission and susceptibility requirements are dependent upon the type of equipment or subsystem, its mission and intended installation.

## 2. APPLICABLE DOCUMENTS

**2.1 General.** The documents listed in this section are specified in sections 3, 4, and 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

### 2.2 Government documents.

**2.2.1 Specifications, standards, and handbooks.** The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issue of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

### STANDARDS

#### MILITARY

MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
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### HANDBOOK

#### MILITARY

MIL-HDBK-237	Electromagnetic Compatibility Management Guide for Platforms, Systems and Equipment
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(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

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**2.3 Non-government publications.** The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

### AMERICAN NATIONAL STANDARD INSTITUTE (ANSI)

ANSI C63.14 American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD).

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

**2.4 Order of precedence.** In the event of a conflict between the text of this document and the references cited herein the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

## 3. DEFINITIONS

**3.1 Definitions.** The terms used in this standard are defined in ANSI C63.14. In addition, the following terms shall be defined as specified herein.

**3.1.1 Active spaceborne sensor.** Active spaceborne sensor is a measuring instrument in the earth exploration service, or in the space research service, by means of which physical measurements of various phenomena are obtained through transmission and reception of radio waves.

**3.1.2 Circular aperture array.** A circular aperture is defined as the shape of the array configuration of a planar-array antenna in which the elements are located within a circular area.

**3.1.3 Planar phased array.** A planar array is a phased-array antenna in which the array elements are in one plane.

**3.1.4 Plane of reference.** A plane of reference is a location in the radio frequency (RF) transmission path, established as close to the antenna as is practicable, where the antenna transmission line is disconnected from the transmitter or receiver, when necessary, for insertion of couplers, adapters, or transitions to be connected to measurement instrumentation.

**3.1.5 Primary radar.** A radiodetermination system based on the comparison of reference signals with radio signals reflected from the position to be determined.

**3.1.6 Receiver.** A receiver is equipment necessary for receiving modulated RF signals and converting them to a form that is suitable for signal processing, visual display, or audio presentation.

**3.1.7 Rectangular aperture array.** A rectangular aperture is defined as the shape of the array configuration of a planar-array antenna in which the elements are located within a rectangular area.

**3.1.8 Selectivity.** Selectivity is a measure of a receiver's ability to discriminate against signals on adjacent frequencies (usually expressed as a curve in which the input signal power at an adjacent frequency, relative to the on-tune power that produces the same response, is plotted against frequency).

**3.1.9 Sensitivity.** Sensitivity is the minimum input signal required to produce an output signal or indication that satisfies a specified requirement.

**3.1.10 Signal processor.** Signal processor is a device that processes the output signal of a receiver to utilize the information contained in the signal for such purposes as supplying tracking error signals, complex waveform decoding, automatic gain control (AGC) for its systems, target identification, electronic counter-countermeasures (ECCM), and clutter mapping.

**3.1.11 Signal substitution.** Signal substitution is a method of measuring signals by using a calibrated signal generator whose output is similar to that of the unknown signal and substitutes for the unknown signal to produce an identical response.

**3.1.12 Spacebased radiolocation system, class 1.** Spacebased radiolocation system, class 1, is a radiolocation system in space, the primary function of which is the detection and location of objects on or near the surface of the earth.

**3.1.13 Spacebased radiolocation system, class 2.** Spacebased radiolocation system, class 2, is a radiolocation system installed aboard a spacecraft for the purpose of determining the relative positions or velocities of one or more extravehicular objects.

**3.1.14 Spurious emission, inband.** A spurious emission inband is any spurious emission of a transmitter or system that is within the assigned frequency tuning range for the system.

**3.1.15 Standard response.** Standard response is a repeatable indication of radar operational performance (as specified in the radar system procurement specification) that is accessible through the receiver or signal processor for use in measurement of receiver selectivity or sensitivity.

**3.1.16 Standard test frequencies.** Standard test frequencies are that set of frequencies to which transmitters or receivers are tuned during the test procedures. At least three such frequencies exist in the tuning band designated for each equipment and are located at the lower limit, center, and upper limit of the tuning range in each band, and designated to low ( $F_L$ ), mean ( $F_M$ ), and high ( $F_H$ ), standard test frequencies, respectively.

**3.1.17 Transmitter.** A transmitter is equipment needed to generate a modulated RF signal and feed the modulated signal to an antenna for radiation into space as electromagnetic waves.

**3.1.18 Tunability.** Tunability is the ability of a radar system to perform its specified acquisition or tracking functions or both by maintaining adequate transmitter power output and receiver sensitivity over the designated tuning range.

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**3.2 Acronyms.** The acronyms used in this standard are defined as specified below:

ACF	Antenna Coupling Factor (dB)
AFC	Automatic Frequency Control
AGC	Automatic Gain Control
AMSDL	Acquisition Management Systems and Data Requirements Control List
ANSI	American National Standards Institute
COTS	Commercial-Off-The-Shelf
CW	Continuous Wave
DoD	Department of Defense
DoDISS	Department of Defense Index of Specifications and Standards
ECCM	Electronic Counter-Countermeasures
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EMR	Electromagnetic Radiation
FM	Frequency Modulation
FSVM	Frequency Selective Voltmeter Receiver
IF	Intermediate Frequency
MPMVS	Mid pulse minimum visible signal (dBm)

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MVS (MDS)	Minimum visible signal (minimum discernable signal) (dBm)
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems Command
NDI	Non-developmental Item
NTIA	National Telecommunications and Information Administration
PRF	Pulse repetition frequency (Hz)
RF	Radio Frequency
RSM	Radar Spectrum Management
STANAG	Standardization Agreement
VSWR	Voltage standing-wave ratio

**3.3 Symbols.** The symbols used in this standard are defined as specified below:

A	Attenuation (dB)
$\alpha$	Alpha factor = pulse versus CW sensitivity of a receiver (dB)
$\alpha_R$	Alpha factor for radar signal received (dB)
$A_S$	Attenuation of signal sampling device, main line to sample port, (dB)
B	Frequency bandwidth (MHz)
$B_{-(x)\text{dB}}$	Bandwidth at (-x) dB response level (MHz)
$B_c$	Bandwidth of the frequency deviation. (The total frequency shift during the pulse duration in MHz)
$B_d$	Bandwidth of the frequency deviation (peak difference between instantaneous frequency of the modulated wave and the carrier frequency) - (FM/CW radar systems), in MHz
$B_{\text{FSVM}}$	Frequency selective voltmeters bandwidth (MHz)

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$B_{\text{NOM}}$	Nominal bandwidth (spectrum analyzer) at 3 dB points (Hz)
$B_s$	Maximum range over which the carrier frequency will be shifted for a frequency hopping radar (MHz)
BW	Bandwidth of test instrument (MHz)
d	Pulse compression ratio
dB	Decibels
dBm	Decibels referenced to one milliwatt
dBi	Decibels gain referenced to isotropic radiator
D	Antenna aperture dimension (meters)
erf	Error function
F	Frequency
$F_{\text{co}}$	Waveguide cutoff frequency (MHz)
$F_{\text{LO}}$	Receiver local oscillator frequency (MHz)
$f_{\text{MOD}}$	Modulation rate (in frequency modulation) (MHz/sec)
$f_{\text{N}}$	Frequency separation between first null points, above and below $f_o$ , in radar signal frequency spectrum (MHz)
$F_{\text{H}}$	High standard test frequency (MHz)
$F_{\text{L}}$	Low standard test frequency (MHz)
$F_{\text{M}}$	Mean standard test frequency (MHz)
$F_{\text{MAX}}$	Maximum test frequency (GHz)
$F_{\text{MIN}}$	Minimum test frequency (GHz)
$F_o$	Radar fundamental frequency (MHz)
$F_s$	Sweep width (Hz)

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G	Radar antenna main beam gain (dBi)
$G_T$	Transmit antenna gain (dBi)
k	Correction factor (dB)
$\lambda$	Wavelength (meters)
N	Number of subpulses within the radar total pulse output time (N =1 for non-FM and FM pulse radars)
$N_e$	Number of antenna elements (phased array)
$P_{avg}$	Radar average power output (peak power output x duty cycle) (dBm)
$P_{ANT}$	Power level at antenna terminals (dBm)
$P_{CW}$	CW signal level (dBm)
$P_D$	Power density at test antenna (dBm/m <sup>2</sup> )
$P_{DN}$	Power density at one nautical mile (dBm/m <sup>2</sup> )
$P_{GEN}$	Power output from signal generator (dBm)
PG	Processing gain (dB)
$P_M$	Power meter reading (dBm)
$P_{MEAS}$	Power (measured) (dBm)
$P_P$	Peak power output of radar (dBm)
$P_{PULSE}$	Pulsed RF signal level (dBm)
$P_R$	Power received at test antenna terminal (dBm)
$P_S$	Radar signal level (sampled) (dBm)
$P_t$	Maximum spectral level (dBm/kHz)
$P_T$	Peak power transmitted (dBm)
PW	Pulse width ( $\mu$ sec)

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R	Distance, radar antenna to test antenna (meters)
$R_{NM}$	Distance (nautical miles)
SF	Pulse width of single step of frequency, (seconds)
t	Emitted pulse duration in seconds at 50 percent amplitude (voltage) points. For coded pulses, the pulse duration is the interval between 50 percent amplitude points of one chip (sub-pulse). The 100 percent amplitude is the nominal flat top level of the pulse.
T	Period between a given reference point on consecutive pulses (seconds)
$T_a$	Oscilloscope vertical display rise time (seconds)
$t_{eff}$	Effective pulse width ( $\mu\text{sec}$ )
$t_f$	Pulse fall time (90 percent amplitude to 10 percent amplitude, in $\mu\text{sec}$ )
$\Theta_{3dB}$	Antenna main lobe width at 3 dB points (degrees)
$T_i$	Rise time indicated on oscilloscope display (seconds)
$T_O$	Transmitter turn-on time (seconds)
$T_S$	Sweep time (seconds)
$t_r$	Emitted pulse rise time in microseconds ( $\mu\text{sec}$ ) from the 10 percent to the 90 percent amplitude points on the leading edge. For coded pulses it is the rise time of a sub-pulse; if the sub-pulse rise time is not discernible, assume that it is 40 percent of the time to switch from one phase or sub-pulse to the next.
$T_r$	Response time of test receiver and recorder (milliseconds)
W	Rotational speed (r/min)
XPW	Expanded pulse width (pulse compression radars) ( $\mu\text{sec}$ ).

### 4. GENERAL REQUIREMENTS

**4.1 Radar equipment and subsystems.** Radar equipment and subsystems acquisitions shall comply with the applicable requirements (see 4.1.1 through 4.1.6). These requirements shall be in addition to the applicable emission and susceptibility requirements and limits as specified in MIL-STD-461.



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**4.1.1 Joint acquisitions.** Equipment or subsystems acquired by one DoD activity for multi-agency use shall comply with the requirements of the user agencies.

**4.1.2 North Atlantic Treaty Organization (NATO) acquisitions.** Equipment or subsystems acquired by a DoD activity in support of NATO shall comply with the applicable requirements of this standard and any applicable NATO standardization agreement (STAN AG). The NATO STANAGs shall not be waived, deviated from, or tailored unless specific authority has been granted by the contracting activity.

**4.1.3 Self-compatibility.** The operational performance of a piece of equipment or subsystem shall not be degraded nor shall it malfunction when all of the units or devices in the equipment or subsystem are operating together at their designed levels of efficiency or normal design capability.

**4.1.4 Radar spectrum management (RSM).** The primary goal of this standard is to promote the effective conservation of the limited electromagnetic spectrum through the implementation of EMC interface requirements for military radar systems. For this goal to be realized, careful attention to EMC is required in all phases of the design, development, and final production of a radar system.

**4.1.5 Radar spectrum management (RSM) test plan.** Unless otherwise specified by the contracting activity, (except for primary radars in Group A (see Table I in 5.1)), an RSM test plan shall be prepared (see 6.3).

The following data shall be reported in the RSM test plan:

- Transmitter emission bandwidth
- Transmitter emission levels
- Transmitter frequency tolerance
- Transmitter tunability
- Antenna pattern and gain characteristics
- Receiver acceptance bandwidth
- Receiver susceptibility characteristics
- Receiver tunability
- Receiver frequency tolerance
- Receiver oscillator radiation

**4.1.6 Test procedures.** Measurements shall be performed using the test procedures specified in Appendix A of this standard or by fully described and justified alternate procedures presented in the RSM test plan. The test procedures presented in Appendix A should be used as guidance to determine compliance with the applicable emission and susceptibility requirements of section 5 (see 6.3). Data gathered as a result of performing tests in one electromagnetic discipline may satisfy requirements in another. To avoid unnecessary duplication, a single test program should be established with similar tests conducted concurrently whenever possible. Equipment intended to be operated as a subsystem shall be tested as such to the applicable emission and susceptibility requirements and limits whenever practical.

**4.2 Tailoring of this standard.** The Contracting Authority shall be advised when engineering analyses on equipment or subsystems being acquired for use in specified systems or installations reveal that the requirements in this standard are not suitable or stringent enough for the acquisition. A detailed description of the inadequate EMC equipment or subsystem specification(s) and recommended changes or corrections

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to the electromagnetic interference (EMI), electromagnetic pulse (EMP) and electromagnetic radiation (EMR) hazards control measures as needed to achieve overall required system or installation performance should be included. In no case shall the recommended requirements be less stringent than those in the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management.

**5. DETAILED REQUIREMENTS**

**5.1 Scope.** The radar categories and groups for the emission and susceptibility requirements established by this standard are defined in table I. All primary radars shall be classified in one of the four groups under one of the two categories in table I and shall meet the requirements specified for the classification category and group. Emission and susceptibility requirements for radars defined as group A in each category have not been established. Table II shall be the reference index for individual parameters under the emission and susceptibility requirements.

**TABLE I. *Definitions of radar categories.***

Radar category	Group	Description
1	A <sup>1</sup>	Pulsed radars of 1 kW or less rated peak power; or radars with an operating frequency above 40 GHz; or man-portable <sup>2</sup> radars; or man-transportable <sup>3</sup> radars; or radio navigation <sup>4</sup> radar in the band of 9300 to 9500 MHz; or expendable, nonrecoverable radars on missiles.
	B	Radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 40 GHz
	C	Radars operating below 40 GHz not included in groups A, B, or D
	D	All fixed radars in the 2700 to 2900 MHz band
2	A <sup>1</sup>	Pulsed radars of 1 kW or less rated peak power; or radars with an operating frequency above 100 GHz; or man-portable <sup>2</sup> radars; or man-transportable <sup>3</sup> radars
	B	Radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 100 GHz
	C	Radars operating below 100 GHz not included in groups A, B, or D
	D	All fixed radars in the 2700 to 2900 MHz band

<sup>1</sup>Presently exempt from any requirements specified herein.

<sup>2</sup>Man-portable: Items which are designed to be carried as a component part of individual, crew-served, or team equipment in conjunction with assigned duties. Upper weight limit is approximately 30 pounds per individual.

<sup>3</sup>Man-transportable: Items which are usually transported on wheeled, tracked, or air vehicles but have integral provisions to allow periodic handling by one or more individuals for limited distances, that is, 100 to 500 meters. Upper weight limits; approximately 65 pounds per individual.

<sup>4</sup>See 5.2.1.

TABLE II. *Radar emission and susceptibility requirements summary.*

Parameters	Paragraph	Table
<b><i>Transmitter</i></b>		
Emission characteristics:		
Maximum bandwidth, -40 dB	5.3.1	IV
Maximum levels (beyond B <sub>-40 dB</sub> )	5.3.2	V
Frequency range	-	VI
Frequency tolerance	5.3.3	VII
System tunability	5.3.4	-
Special EMC requirements (Group D)	5.3.5	-
<b><i>Antenna</i></b>		
Antenna pattern and gain characteristics	5.4	VIII
<b><i>Receiver</i></b>		
Acceptance bandwidth	5.5.1	IX
Susceptibility characteristics	5.5.2	IX
Tunability	5.5.3	-
Frequency tolerance	5.5.4	VII
Oscillator radiation	5.5.5	X

**5.2 Application.** Category 1 of table I provides the minimum radar engineering interface requirements that are acceptable for radars within the Federal Government. The Category 2 requirements exceed those in Category 1. Category 2 requirements shall be applied for radars operating in critical EMC environments such as aboard surface ships. Determination of the radar category is the responsibility of the program manager. This decision shall be made in the process of tailoring of standards on the basis of mission requirements, including the intended electromagnetic operational environment. MIL-HDBK-237 shall be used as a guide in the determination of radar categories and tailoring of specific criteria within categories. In no case shall the tailored requirements be less stringent than those under category 1. For radars employing more than a single emitter (excluding planar phased array radars), variable PRF radars, or radars for which requirements herein can not be directly applied, special methods are necessary. Special methods shall be fully documented (see 6.3). Unless otherwise specified by the contracting activity, the requirements and limits specified herein shall be required for all new radar equipment and subsystems.

**5.2.1 Special application.** In the special case where government radio navigation radars operate in the shared government/non-government band 9300-9500 MHz, an acceptable degree of EMC is deemed to be that degree of compatibility associated with commercial-off-the-shelf (COTS) or non-developmental item (NDI) radar equipment. The vast preponderance of the use of this band by non-government domestic and foreign ships and aircraft creates a situation where relatively inexpensive COTS or NDI equipment is available and at the same time equipment improvements which might be incorporated unilaterally by small numbers of government stations would have little effect on the band as a whole. Accordingly, government radio navigation radars to be operated in this band, having a rated peak power of 100 kW or less, are placed in group A with the understanding that government agencies would procure COTS or NDI equipment and that this exemption will be re-examined should the situation in this band change.

**5.2.2 Application determination.** The requirements under group B shall be applied to class 1 Spacebased radar systems on a case by case basis as determined by the contracting activity. The requirements under group B or group C shall be determined by the contracting activity for application, on a case by case basis, to class 2 Spacebased radar systems and active spaceborne sensors.

**5.2.3 Test parameters.** Radar equipment and systems shall be tested under operation at tuned frequencies as specified in table III.

TABLE III. *Test parameters and radar tuned frequencies.*

Test parameter	Radar tuned frequencies <sup>1</sup>
<b>Transmitter</b>	
Power output	$F_L, F_M, F_H^2$
Pulse width and rise time	$F_L, F_M, F_H$
Emission bandwidth	$F_L, F_M, F_H$
Spurious emission	$F_L, F_M, F_H$
Frequency tolerance	$F_L, F_M, F_H$
Transmitter tunability	$F_L, F_M, F_H^2$
<b>Antenna</b>	
Antenna gain sidelobe suppression	$F_M$
<b>Receiver</b>	
Overall selectivity	$F_M$
Spurious response	$F_L, F_M, F_H$
Tunability	$F_L, F_M, F_H^2$
Frequency tolerance	$F_L, F_M, F_H$
Oscillator radiation	$F_L, F_M, F_H^2$

<sup>1</sup>These radar tuned frequencies represent the minimum number to be used.

<sup>2</sup>In addition to  $F_L$ ,  $F_M$ , and  $F_H$ , eight more radar tuned frequencies are required for Category 2 radars: four frequencies approximately evenly-spaced between  $F_L$  and  $F_M$  plus four frequencies approximately evenly-spaced between  $F_M$  and  $F_H$ .

<sup>3</sup> $F_L$  = lowest frequency for operation in each band.

$F_M$  = mean frequency for each operating band.

$F_H$  = highest frequency for operation in each band.

**5.3 Transmitter limits.**

**5.3.1 Transmitter emission bandwidth.** The maximum emission bandwidth for radars at the antenna input shall not exceed the limits as specified in table IV.

**5.3.2 Transmitter emission levels.** The transmitter maximum emission levels, outside the maximum emission bandwidth ( $B_{-40dB}$ ) specified in 5.3.1, shall not exceed the values as specified in table V. The  $F_{MIN}$  and  $F_{MAX}$  range over which the maximum emission level applies shall be as specified in table VI. The value for  $P_t$  as specified in table V shall be determined by applying the radar parameters using the following equation:

$$P_t = P_p + 20 \log [(N)(t)] + 10 \log (PRF) - PG - 90$$

where:

- PG = 0, for non-FM, non-coded pulse radars
- PG = 10 log(d), for FM pulse radars
- PG = 10 log(N), for coded pulse radars.

TABLE IV. *Transmitter emission bandwidth limits for  $B_{-40 dB}$*

Type of radar emission	Maximum $B_{-40 dB}$ for Category 1 and 2 radars	
	Group B (MHz)	Groups C and D (MHz)
Pulse, non-FM <sup>1,2,5</sup>	$7.6/(t_r t)^{1/2}$	$6.2/(t_r t)^{1/2}$
Pulse, FM <sup>3,5</sup>	$7.6/(t_r t)^{1/2} + 2B_c$	$6.2/(t_r t)^{1/2} + 2B_c$
Pulse, frequency-hopping <sup>4,5</sup>	$7.6/(t_r t)^{1/2} + 2B_c + B_s$	$6.2/(t_r t)^{1/2} + 2B_c + B_s$
CW	$0.0003 F_o$	$0.0003 F_o$
FM/CW	$0.0003 F_o + 2B_d$	$0.0003 F_o + 2B_d$

m or coded-pulse radars.

<sup>1</sup>Including spread spectrum

<sup>2</sup>Up to maximum of 64/t for group B and group C.

<sup>3</sup>For FM-pulse radars with pulse rise time of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

<sup>4</sup>For frequency-hopping radars; with pulse compression but with pulse rise time of less than 0.1 microsecond or without pulse compression but with pulse rise of less than 0.01 microsecond, an operational justification for the short rise time shall be provided. The radar spectrum shall not intrude into adjacent spectrum regions on the high or low side of the band, defined by  $B_s$ , more than would occur if the radar was fixed-tuned at carrier frequencies equivalent to the end values of  $B_s$  and was complying with the requirements for FM and non-FM pulse radars.

<sup>5</sup>If  $t_r$  is less than  $t_r$ , then  $t_r$  shall be used in place of  $t_r$ .

**5.3.3 Transmitter frequency tolerance.** The maximum frequency tolerance for radar transmitters shall not exceed the limits as specified in table VII.

**5.3.4 Transmitter tunability.** The frequency tuning band of the radar shall be the band approved for the specified equipment by the Joint Frequency Panel, United States Communication Electronics Board and shall be specified in the contract or order. Each radar shall be tunable in an essentially continuous manner over the approved frequency band or over a band which is 10 percent of the mid-band frequency. Crystal

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controlled radars conform to this requirement if operation at any f frequency across the band can be achieved with a crystal change. Radar systems under group D shall be tunable continuously over the entire 2700 to 2900 MHz band.

**TABLE V. Transmitter maximum emission levels outside  $B_{-40\text{ dB}}$  range.**

<p>1. Reference diagram:</p>
<p>2. For Category 1 and 2 radars, the maximum level of emissions outside the <math>B_{-x\text{ dB}}</math> frequency range and within the <math>F_{\text{MIN}}</math> to <math>F_{\text{MAX}}</math> frequency range shall be as follows:</p> <p>Groups B and C: <math>(P_t - 60)</math> dBm/kHz or <math>-30</math> dBm/kHz, whichever is less  Group D: <math>(P_t - 80)</math> dBm/kHz</p>
<p>3. The <math>B_{-x\text{ dB}}</math> range shall be obtained from the following relationships:</p> <p>Category 1; Groups B and C:</p> <p><math>B_{-x\text{ dB}} = 10^a (B_{-40\text{ dB}})</math>; where <math>a = 1</math> or <math>(P_t - 10)/20</math>, whichever is greater.  <math>x\text{ dB} = 60</math> or <math>(P_t + 30)</math>, whichever is greater.</p> <p>Category 2; Groups B and C:</p> <p><math>B_{-x\text{ dB}} = 10^a (B_{-40\text{ dB}})</math>; where <math>a = 2/3</math> or <math>(P_t - 10)/30</math>, whichever is greater.  <math>x\text{ dB} = 60</math> or <math>(P_t + 30)</math>, whichever is greater.</p> <p>Categories 1 and 2, Group D:  <math>B_{-x\text{ dB}} = 10 (B_{-40\text{ dB}})</math>, <math>x\text{ dB} = 80</math>, special group D requirements are given in 5.3.5.</p>
<p>4. Emission levels at frequencies <math>F</math> within the regions where</p> <p><math>0.5 B_{-40\text{ dB}} \leq  F - F_0  \leq 0.5 B_{-x\text{ dB}}</math>, shall be equal to or lower than the values obtained from the following equations:</p> <p>Category 1; Groups B and C:  Maximum emission level = <math>P_t - 40 - 20 \log (F - F_0) / (0.5 B_{-40\text{ dB}}) </math></p> <p>Category 2; Groups B and C:  Maximum emission level = <math>P_t - 40 - 30 \log (F - F_0) / (0.5 B_{-40\text{ dB}}) </math></p> <p>Categories 1 and 2; Groups D:  Maximum emission level = <math>P_t - 40 - 40 \log (F - F_0) / (0.5 B_{-40\text{ dB}}) </math></p> <p>Special group D requirements are given in 3.3.3.</p>
<p>5. <math>F_{\text{MIN}}</math> and <math>F_{\text{MAX}}</math> are defined in table VI.</p>

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TABLE VI. *Frequency range for emission level requirements.*

Radar tuned frequency (GHz)	Minimum test frequency ( $F_{MIN}$ )		Maximum test frequency ( $F_{MAX}$ )
	Waveguide (Select larger value)	Coaxial <sup>1</sup>	
	(Select larger value)		
Categories 1 and 2, groups B, C, and D:			
Below 2	0.5 $F_o$ or 0.9 $F_{co}$	0.5 $F_o$	10 $F_o$ or 10 GHz
2 to 5	0.5 $F_o$ or 0.9 $F_{co}$	0.5 $F_o$	5 $F_o$ or 18 GHz
5 to 12	0.5 $F_o$ or 0.9 $F_{co}$	0.5 $F_o$	4 $F_o$ or 26.5 GHz
12 to 18	0.5 $F_o$ or 0.9 $F_{co}$	0.5 $F_o$	3 $F_o$ or 40 GHz
18 to 40	0.5 $F_o$ or 0.9 $F_{co}$	0.5 $F_o$	2 $F_o$ or 40 GHz
Category 2, groups B and C:			
40 to 100	0.5 $F_o$ or 0.9 $F_{co}$	0.5 $F_o$	See Note 2

<sup>1</sup>For transmitters employing frequency synthesis (mixers, multipliers, etc.) to generate  $F_o$  from base frequencies lower than 0.5  $F_o$ , the minimum test frequency shall be extended to include the lowest base frequency.

<sup>2</sup>Frequency where emission level is ( $P_i - 60$ ) or -30 dBm/kHz, whichever is lower. However, the frequency range covered shall include bands for satellite communications between 40 GHz and 100 GHz.

TABLE VII. *Frequency tolerance limits.*

Radar tuned frequency (MHz)	Maximum frequency tolerance (plus or minus parts per million)					
	Category 1			Category 2		Group D
				Groups B and C		
	Group A	Group C	Group D	Crystal <sup>1</sup>	Other	
Below 960	-	400	-	50	250	-
960 to 4,000	-	800	-	100	500	-
2,700 to 2,900	-	-	800	-	-	800
2,900 to 4,000	800	-	-	-	-	-
4,000 to 10,500	1,250	1,250	-	160	800	-
10,500 to 30,000	2,500	2,500	-	275	1,400	-
30,000 to 40,000	5,000	5,000	-	500	2,500	-
40,000 to 100,000	-	-	-	500	2,500	-

<sup>1</sup>Radars controlled by crystals or other precise methods of frequency control.

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**5.3.5 Special EMC requirements, group D radars.** Radar systems in the 2700 to 2900 MHz band (Group D) which operate in close proximity to other equipment in this band or operate in areas specified in Annex D of the NTIA Manual shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of system EMC provisions. These provisions include the following requirements and recommendations:

- a. **Emission levels.** The radar emission levels at the antenna input shall be not greater than the values obtainable from the curves in table V. At the frequency  $\pm B_{(-40 \text{ dB})/2}$  displaced from  $F_o$ , the level shall be at least 40 dB below the maximum value. Beyond the frequencies  $\pm B_{(-40 \text{ dB})/2}$  from  $F_o$ , the equipment shall have the capability to achieve at least the 80 dB per decade roll-off lines of table V. The emission levels shall be below the appropriate dB per decade roll-off lines of table V down to a  $-x$  dB level that is 80 dB below the maximum power density.
- b. **Radar system PRF.** The radar system shall be designed to operate with an adjustable pulse repetition frequency(s) (PRFs), with a nominal difference of plus or minus 1 percent (minimum). This will permit the selection of PRF's to allow certain types of receiver interference suppression circuitry to be effective.
- c. **Receiver interference suppression circuitry.** Radar systems in this band shall have provisions incorporated into the system to suppress pulsed interference. The following information is intended for use as an aid in the design and development of receiver signal processing circuitry or software to suppress ac pulsed interference. A description of the parametric range of the expected environmental signal characteristics at the receiver IF output is:

Peak interference-to-noise ratio:  $\leq 50$  dB

Pulse width: 0.5 to 4.0  $\mu\text{sec}$

PRF: 100 to 2000 pps

**5.4 Antenna limits.** The radar antenna characteristics shall satisfy the requirements as specified in table VIII.

### 5.5 Receiver limits.

**5.5.1 Receiver acceptance bandwidth.** The radar receiving system required acceptance bandwidths shall be as specified in table IX.

**5.5.2 Receiver susceptibility characteristics.** The rejection of signals outside the required receiver acceptance bandwidth shall be equal to or greater than the values as specified in table IX for the designated radar category and group.

**5.5.3 Receiver tunability.** The tunability of the radar receiver shall be commensurate with that of the associated radar transmitter. Requirements for radar transmitters shall be as specified in 5.3.4.



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TABLE VIII. *Antenna characteristics limits.*

Category	Group	Requirements
1	B	No requirement is specified at the present time
1 2	C and D D	Antennas operated by their rotation through 360 degrees for the horizontal plane shall have a median gain <sup>1</sup> of -10 dBi or less, as measured on an antenna test range, in the principal horizontal plane. For all other antennas, suppression on lobes other than the antenna main beam shall be provided to the following levels, referred to the main beam: <ol style="list-style-type: none"> <li>1. First three sidelobes, 17 dB;</li> <li>2. All other lobes, 26 dB.</li> </ol>
2	B and C	For non-electronically steered antennas, the first major sidelobe shall be down at least 20 dB from the main beam and all other lobes shall be down at least 30 dB from the main beam. Additionally, antennas operated by their rotation through 360 degrees of the horizontal shall have a median gain <sup>1</sup> of -10 dBi or less, as measured on an antenna test range, in the principal horizontal plane. For electronically-steered antennas with the main beam positioned to the array normal and without adaptive features operating, the first major transmitter antenna sidelobes, relative to the main beam, shall be down at least 13 dB for rectangular aperture arrays and at least 17 dB for circular aperture arrays. The first major receiver antenna sidelobes shall be down at least 20 dB from the main beam. All other lobes beyond the first major sidelobe shall be down by 16 dB for rectangular aperture transmitter arrays, 24 dB for circular aperture transmitter arrays and 30 dB for receiver antenna arrays.

<sup>1</sup>Median gain is defined as that level over an angular region at which the probability is 0.5 that the observed or measured gain at any position of the antenna will be less than or equal to that level.

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TABLE IX. Receiver acceptance bandwidth and susceptibility limits.

Radar category	Group	Requirements										
1	B, C, D	The overall receiver selectivity characteristics shall be more narrow than the transmitter bandwidth described in tables IV, V, and VI for the respective group. The minimum frequency range over which the receiver acceptance bandwidth and susceptibility requirements apply shall be the $F_{MIN}$ to $F_{MAX}$ range in table VI.										
1	B	Receiver rejection of spurious responses, other than image responses, shall be 50 dB or better except where broadband front ends are required operationally.										
1	C, D	Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver image rejection shall be at least 50 dB; rejection of all other spurious responses shall be at least 60 dB.										
2	B,C	<p>The required acceptance bandwidth is the receiver acceptance bandwidth which includes the fundamental frequency response and extends from the lowest to the highest frequencies on the selectivity curve outside of which all other responses are at least 80 dB below the fundamental frequency response. Required acceptance bandwidths are listed:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Type modulation</th> <th>Required acceptance bandwidth (MHz)</th> </tr> </thead> <tbody> <tr> <td>Non-FM pulse</td> <td><math>20/t</math></td> </tr> <tr> <td>FM pulse</td> <td><math>20d/t</math></td> </tr> <tr> <td>CW</td> <td><math>3 \times 10^{-4} F_o</math></td> </tr> <tr> <td>FM/CW</td> <td><math>3 \times 10^{-4} F_o + B_d</math></td> </tr> </tbody> </table> <p>The radar receiver shall not exhibit any undesired response when subjected to signals outside the acceptance bandwidth. RF preselection shall be employed except where broadband front ends are required operationally. The requirement for broadband front ends will be determined by the contracting activity and incorporated into the equipment or subsystem request-for-proposal, specification, contract, or order. The minimum frequency range over which the receiver susceptibility characteristics apply shall be the <math>F_{MIN}</math> to <math>F_{MAX}</math> range in table VI for Category 2 radars.</p>	Type modulation	Required acceptance bandwidth (MHz)	Non-FM pulse	$20/t$	FM pulse	$20d/t$	CW	$3 \times 10^{-4} F_o$	FM/CW	$3 \times 10^{-4} F_o + B_d$
Type modulation	Required acceptance bandwidth (MHz)											
Non-FM pulse	$20/t$											
FM pulse	$20d/t$											
CW	$3 \times 10^{-4} F_o$											
FM/CW	$3 \times 10^{-4} F_o + B_d$											

**5.5.4 Receiver frequency tolerance.** The frequency stability of radar receivers shall be equal to or better than the frequency tolerance of the associated transmitter (see 5.3.3).

**5.5.5 Receiver oscillator radiation.** The radiation of signals produced within the radar receiver shall not exceed the limits as specified in table X.

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TABLE X. *Receiver radiation limits.*

Category	Group	Requirements
1 2	B, C, D	<p>a. The maximum radiation for both coaxial and waveguide systems shall be -40 dBm at the receiver input terminals.</p> <p>b. The frequency range for coaxial systems shall extend from 0.5 F (note 1) to and including <math>F_{LO}</math> with a maximum frequency of 40 GHz.</p> <p>c. The frequency range for waveguide systems shall extend from 0.5 F or <math>0.9 F_{CO}</math>, whichever is greater, to and including <math>2F_{LO}</math> with a maximum frequency of 40 GHz.</p>
2	B, C	<p>a. The maximum radiation from nonphased-array radars shall be -67 dBm at the receiver input terminals.</p> <p>b. For phased-array radars, the maximum radiation at the feed point of a discrete antenna element shall be -67 dBm. When the feed points to discrete antenna elements are not accessible, the radiated nonmain-lobe power density shall not exceed <math>P_{DN}</math> (see note 2).</p> <p>c. For radars employing coaxial transmission line and operating at frequencies <math>\leq 20</math> GHz, the receiver radiation limit applies over the frequency range of 0.5 F to and including <math>2F_{LO}</math>. For coaxial systems operating between 20 GHz and 100 GHz, the frequency range shall be from 0.5 F to and including <math>F_{LO}</math>.</p> <p>d. For radars employing waveguide and operating at frequencies <math>\leq 20</math> GHz, the receiver radiation limits apply over the range from 0.5 F or <math>0.9 F_{CO}</math>, whichever is greater, to and including <math>2F_{LO}</math>. For waveguide systems operating between 20 GHz and 100 GHz, the frequency range shall be from 0.5 F or <math>0.9 F_{CO}</math>, whichever is greater, to and including <math>F_{LO}</math>.</p>
<p>NOTES: 1. The value for F is determined as the lowest frequency used in developing the local oscillator frequency, <math>F_{LO}</math>.</p> <p>2. The value for <math>P_{DN}</math>, in dBm/m<sup>2</sup>, shall be determined from:</p> $P_{DN} = -177 + 20 \log N_e - 20 \log R_{NM} \text{ or}$ $P_{DN} = -144 - 20 \log R_{NM}, \text{ whichever is less.}$ <p>The term <math>N_e</math> refers to the number of antenna elements and <math>R_{NM}</math> is the distance in nautical miles, to radar antenna.</p>		

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

**6.1 Intended use.** This standard is intended to establish the engineering interface requirements to control the electromagnetic emission and susceptibility characteristics of new military radar equipment and systems within specified ranges, to promote EMC, and to conserve the frequency spectrum available to radar systems.

6.2 Issue.

**6.2.1 Issue of DoDISS.** When this standard is used in acquisition, the applicable issue of the DoDISS must be cited in the solicitation (see 2.2.1).

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**6.3 Associated Data Item Descriptions (DIDs).** This standard is cited in DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), as the source document for the following DIDs. When it is necessary to obtain the data, the applicable DIDs must be listed on the Contract Data Requirements List (DD Form 1423), except where the DoD Federal Acquisition Regulation Supplement exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
4.1.5, 4.1.6 5.2	DI-MISC-81113	Radar Spectrum Management Test Plan	-

The above DIDs were current as of the date of this standard. The current issue of the AMSDL must be researched to ensure that only current, cleared DIDs are cited on the DD Form 1423.

**6.4 International standardization agreements.** Certain provisions of this standard are the subject of international standardization agreements (STANAGs -3516, -3614, and -3659). When change notice, revision, or cancellation of this standard is proposed which will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.

### 6.5 Subject term (key word) listing.

Array  
Attenuation  
Bandwidth  
Emission levels  
Frequency  
Planar phased array  
Receiver  
Spectrum  
Waveguide

**6.6 Changes from previous issue.** Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:  
Army - ER  
Navy - SH  
Air Force - 99

Preparing activity:  
Navy - SH  
(Project EMCS-0158)

Review activity:  
Navy - EC

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## APPENDIX A

### MEASUREMENTS

#### 10. SCOPE AND APPLICATION

**10.1 Scope.** This appendix should be used as guidance to determine compliance with the emission and susceptibility requirements of section 5 of this standard. New radar designs may require alternate test procedures to determine compliance (see 4.1.6).

**10.2 Application.** The measured data obtained from applying the test procedures or the alternate procedures herein (see 10.1), should provide the emission and susceptibility characteristics of the radar, referenced to the terminals of the radar antenna. The test procedures should provide the antenna characteristics at a point which describes the far field radiation. The measurements of certain radar parameters provide data which are interrelated. The transmitter emission spectrum characteristics for a pulsed output, for example, are a function of power output, pulse width and pulse rise time parameters and to some extent, the frequency stability. The measurements of these interrelated parameters should be made as close in time as practical.

#### 20. APPLICABLE DOCUMENTS

##### 20.1 Government documents.

**20.1.1 Specifications, standards, and handbooks.** The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

#### STANDARDS

##### MILITARY

MIL-STD-449 Radio Frequency Spectrum Characteristics, Measurement of  
MIL-STD-810 Environmental Test Methods and Engineering Guidelines

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

#### 30. INSTRUMENTATION

**30.1** The test instruments required for measurement of specific equipment parameters are shown in the sample block diagrams for individual test procedures in Appendix A. These instruments should be capable of producing the test results described for each test procedure. Detailed identification of all measurement and calibration instruments and calibration charts for all equipment used in the performance of these tests should be provided in the test report.

**30.2** The frequency of test signal generators should be determined during the measurement procedures with a frequency meter or counter assuring the desired degree of accuracy. The signal generator output impedance should be unbalanced 50 ohm, resistive, with a VSWR less than 1.3:1. For measurements where modulation or deviation is required, the percentage of modulation or deviation should be known within 5 percent.

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**30.3** Signal generator outputs contain harmonics of the fundamental frequency. These harmonic outputs should be attenuated in order that false receiver responses will not be produced. In particular, low pass or bandpass filters of known insertion loss at the fundamental frequency of the generator should be used when spurious responses are being measured at frequencies well below the receiver tuned frequency. This technique is used to attenuate generator harmonics to levels below the sensitivity of the receiver.

**30.4** Many signal generators exhibit some leakage that is particularly noticeable when the attenuator is near its maximum attenuation setting. Low-leakage signal generators should be used to perform measurements. Adequate shielding, separation and power line filtering should be employed to eliminate the possibility of erroneous results caused by improper coupling of the signal generator. The signal generator leakage signal level should be at least 6 dB below the indicated attenuator setting.

**30.5** For receiver measurements, the receiver input coupler should be a shielded network whose insertion loss is known to within 1 dB at the measurement frequency when it is terminated in its nominal impedance. The coupler input impedance should properly terminate the signal source (VSWR less than 1.3:1) independent of load.

**30.6** The frequency of signal generators supplying test signals should be determined to an accuracy of plus or minus 2 parts in  $10^6$  unless other accuracy requirements are given in a specific test. The overall output calibration of the signal generator should be correct within plus or minus 2 dB at any attenuator setting.

**30.7** The calibration of attenuators external to signal generator should be known within 1 dB at each measuring frequency when it is terminated in its nominal impedance. The attenuator should have a VSWR less than 1.3:1 independent of load when driven by a 50 ohm source. The requirement of attenuator calibration may be waived if, in the calibration process, the attenuator insertion loss is included as part of the signal substitution source.

**30.8** Frequency selective voltmeters should be calibrated as two terminal voltmeters at all measurement frequencies by reference to standard signal generators. Frequency selective voltmeters used in these measurements should be monitored by aural as well as visual indicators. An oscilloscope should be used as a visual indication device to ensure that the frequency selective voltmeter indications are due to signals and not noise (especially applicable to pulse measurements).

**30.9** When making measurements requiring recovery of pulse characteristics on non-pulse compression radars, the instrumentation 3 dB bandwidth in MHz should be at least  $2/t$  where  $t$  is the pulse width, in microseconds. For a pulse compression system, this bandwidth should be at least  $2d/XPW$  where  $d$  is the pulse compression ratio and  $XPW$  refers to the expanded pulse width, in microseconds.

**30.10** Spectrum analyzers should be calibrated to an amplitude accuracy of 0.5 dB to 1 dB.

**30.11** When making measurements involving acquisition of fine grain spectrum details, the instrumentation 3 dB bandwidth in MHz should be less than  $1/10t$  or  $d/10XPW$ .

**30.12** When making measurement involving recovery of the time waveform of a pulse signal, the instrumentation 3 dB bandwidth in MHz should be greater than  $3/t_r$  where  $t_r$  is the pulse rise time in microseconds. A measurement objective should be a bandwidth of approximately  $10/t_r$ .

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**30.13** For transmitter testing a sampling device should be used, where needed, to measure the output level of each signal component emitted. The coupling factor of the device should be known within 1 dB at each measurement frequency. The requirement for sampling device calibration should be waived if the device coupling loss is included when signal levels are substituted for calibration levels.

**30.14** Power meters used for measuring the sampled output from transmitters, measuring reference outputs from signal generators, or other power measurements, should have a full scale accuracy within 5 percent of the indicated power.

#### **30.15 Radar operation.**

**30.15.1 Condition for measurements.** The equipment to be measured should be set up so that it closely approximates the normal operating conditions. The steps specified in the operation and maintenance portions of the radar technical manual should be performed prior to the measurements. The equipment should be aligned in accordance with the pertinent instructions, such that it is represented under normal operating conditions, not deliberately optimized at specific operating frequencies used in the measurements.

**30.15.2 Radar tuned frequencies.** Measurements should be made with the radar tuned to each of the frequencies as specified in table III for the appropriate radar category. If the radar operates over more than one frequency band, that is, multiple bands, the criteria for selecting radar tuned frequencies should be applied to each band.

#### **30.16 Test sites.**

**30.16.1 Selection criteria.** In the receiver measurements for both coaxial and waveguide systems, the test site should normally be in the vicinity of the radar system. This location provides for convenient injection of test signals and extraction of signal outputs during the measurement of receiver parameters. The transmitter requirements refer to the radar antenna terminals. Therefore, the measurement of transmitter signals should be made as close as practical to the antenna terminals. The transmitter output test points should be selected as the plane of reference for transmitter measurements in the following order of preference:

- a. Closed system with system signal sampler at the antenna input
- b. Closed system with test signal sampler inserted at the antenna input
- c. Closed system with radar signal sampler or test signal sampler located at or beyond the transmitter output and before the radar antenna input
- d. Open-field reception of the radiated radar emission with a calibrated test antenna.

A near field antenna test range may be used in lieu of an open field test site for phased array antennas. The upper end of the test frequency range for closed system transmitter measurements will be limited by the characteristics of the device used to sample the radar output signal and by the characteristics of the transmission line between the sampling device and the radar antenna feed. Open field measurements should be used for determining transmitter characteristics beyond the upper end of the range for closed system measurements. Antenna characteristics should be measured from an open field test site. An anechoic chamber may be used in lieu of an open field test site, providing the chamber will approximate free space conditions over the range of measurement frequencies.

**30.16.2 Closed system test sites.** Receiver tests should be made closed system. Transmitters using coaxial systems should be made closed system up to the frequency where the device for sampling the radar signal cannot provide a reliable correlation of the measured data to radar antenna input levels. Transmitters using

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waveguide systems should be tested up to the frequency where the device for sampling the in-guide signal fails to provide a reliable correlation of the measured data to the radar antenna input levels. The maximum frequency for making closed system measurements on radars employing waveguide transmission line should be the cutoff frequency for the first higher order mode of propagation in the waveguide.

**30.16.3 Open field test site.** Radar emissions at frequencies exceeding the upper values specified (see 30.16.2) and radar antenna characteristics should be measured in the open field or an anechoic chamber which approximates free space conditions. Unless otherwise specified, the minimum separation between the radar antenna and the test antenna at the open field site should be  $D_1^2/\lambda$  or  $3\lambda$ , whichever is larger, where  $D_1$  is the maximum aperture dimension of the radar antenna and  $\lambda$  is the wavelength at the radar  $F_o$ . If the test antenna aperture ( $D_2$ ) is larger than  $D_1/10$ , then the minimum radar antenna-to-test site separation should be  $(D_1 + D_2)^2/\lambda$ . The expected power density ( $P_D$ ) at the test site should be calculated using the equation:

$$P_D = P_T + G_T - (20 \log R) - 11.0$$

where  $R$  is the horizontal separation between the equipment antenna and the test antenna. The measured power density should be no more than 2 dB below the calculated value. If the variation is greater than plus or minus 3 dB, tests should not be continued without the approval of the contracting activity.

**30.17 Radar receiver standard response.** The standard response for pulsed receivers should be the minimum visible signal (MVS) except for the overall selectivity test, where the standard response will be the mid-pulse minimum visible signal (MPMVS). The standard response will normally be measured at the receiver video output with a test oscilloscope. Where a particular piece of equipment or system (because of its unique configuration or type of modulation) cannot be measured in accordance with this definition, a different definition that is representative of the operational performance requirements of that equipment or system should be designated and employed upon approval of the contracting activity's technical representative or other designated technical authority.

### 40. RADAR TRANSMITTER MEASUREMENTS

**40.1 Requirements summary.** The radar transmitter measurement and procedures described in this section provide data for comparison to emission characteristics, frequency tolerance and system tunability requirements and limits (see 5.3).

#### 40.2 Power output.

**40.2.1 Objective.** The objective of this test is to determine the ability of a radar system to deliver the minimum rated power output over the approved frequency band.

**40.2.2 Requirements.** Radar systems should produce the minimum rated power output when tuned over the approved frequency band.

#### 40.2.3 Application notes.

**40.2.3.1** The radar power output should be measured with the radar tuned to each operating frequency as specified in table III.



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**40.2.3.2** For radar systems having multiple modulation modes or frequency bands, the power output measurements should be performed for each mode and band combination. The transmitter frequency stability (see 40.6) and tunability (see 40.7) should be performed at the same time as the power output tests.

**40.2.3.3** For phased array systems with less than fifteen transmitters/tubes the power output of each transmitter/tube should be measured. For phased array systems with fifteen or more transmitters/tubes, the power should be either measured in the far-field or statistically determined by measuring the power outputs of a selected number of transmitters/tubes. The transmitters/tubes to be tested should be determined using a table of random numbers for selection. Initially fifteen of the transmitters/tubes should be selected for measurements purposes. The standard deviation of the measured data, corrected for any antenna amplitude weighting factor, should be calculated. If the standard deviation is greater than 2.0 dB, additional transmitters/tubes should be measured. The number of transmitters/tubes to be measured should be determined using the student  $t$ -distribution. The mean of the measured data should be calculated giving the power output per transmitter. The total power output should then be the mean power output in watts, corrected for antenna weighting, times the total number of transmitters.

**40.2.3.4** If the pulse shape of the transmitter output pulse is essentially rectangular, i.e.,  $t_r$  and  $t_f$  are less than  $t/10$ , and the pulse width and PRF values are known or measured, the radar peak output should be determined by measuring the average power output and converting the measured value to peak power output using the radar duty cycle factor.

**40.2.3.5** If the radar modulation is complex, for example, the pulse width or PRF parameters are not easily determined, the radar peak power output should be measured.

**40.2.3.6** The test receiver for direct measurement of the radar peak power output should be a frequency selective voltmeter (FSVM) or broadband crystal detector, depending upon the bandwidth required for reproducing the radar pulse envelope. The criteria for determining the bandwidth required is  $BW = 2/t$ .

**40.2.4 Procedure.** The test setup block diagram for transmitter power output measurement is shown on figure 1. The procedures for this test should be as specified in 40.2.4.1 through 40.2.4.4.

**40.2.4.1** The radar should be tuned to one of the specified operating frequencies and adjusted for its normal operating conditions. Attenuators, if necessary, should be connected to the signal sampler as shown on figure 1.

**40.2.4.2** For average power measurements, the power meter reading ( $P_M$ ) should be noted. Pulse width ( $t$ ) and PRF measured values should be obtained as described in 40.3.

**40.2.4.3** For peak power measurements with the FSVM as the test receiver, attenuation should be inserted at the signal sampler to yield a peak level of minus 10 dBm or less at the FSVM input. After tuning the FSVM for maximum response, the meter reading should be noted for reference. Tune the test signal generator to the FSVM frequency. With the test signal generator set for CW output, reference the output level (set for minus 10 dBm or less) to a selected value on the power meter. Set the test signal generator to pulsed output. The width of the output pulse should be adjusted to the value obtained from the following equation:

$$PW_{TEST} = t; \text{ non-pulse compression radar}$$

or

$$PW_{TEST} = XPW; \text{ pulse compression radar}$$

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Signal substitute the test signal generator to the FSVM input. The output level should be adjusted to regain the reference FSVM reading obtained with the radar signal. Note the resulting level as  $P_{GEN}$ .

**40.2.4.4** If the broadband crystal detector with oscilloscope is used for the test receiver, the attenuator at the signal sampler should be adjusted to yield a level within the detector linear range. With the oscilloscope adjusted for a stable pulse display, note maximum display amplitude for reference. Adjust the test signal generator pulse width and reference the signal generator power level to the power meter as described for the measurements with the FSVM test receiver. Signal substitute the test signal generator output to the broadband crystal detector and adjust the output level to regain the reference oscilloscope display amplitude. Note the resulting level as  $P_{GEN}$ .

### 40.2.5 Sample calculations.

**40.2.5.1** A sample calculation of the peak power output, using the measured average power, is as follows:

Measured data:

- Transmitter tuned frequency ( $F_o$ ): 5000 MHz
- Pulse width ( $t$ ): 1.3 microseconds
- PRF: 650 pps
- Power meter reading ( $P_M$ ): -1.7 dBm
- Attenuation inserted ( $A_1$ ): 0.0 dB
- Signal sampler coupling factor ( $A_s$ ): 50.0 dB
- Transmission line attenuation, signal sampler to antenna ( $A_2$ ): 1.0 dB

The average power output is calculated as follows:

$$\begin{aligned} P_{avg} &= P_M + A_s + A_1 - A_2 \\ &= -1.7 \text{ dBm} + 50.0 \text{ dB} + 0.0 \text{ dB} - 1.0 \text{ dB} \\ &= 47.3 \text{ dBm} \end{aligned}$$

The peak power output ( $P_p$ , in dBm) is determined from the duty cycle ( $t$ )(PRF) using the following relationship:

$$P_p = P_{avg} + 60.0 - 10 \log(t \times \text{PRF})$$

therefore,

$$\begin{aligned} P_p &= 47.3 \text{ dBm} + 60.0 - \\ &\quad 10 \log(1.3 \times 650) \\ &= 47.3 \text{ dBm} + 30.7 \text{ dB} \\ &= 78.0 \text{ dBm.} \end{aligned}$$

**40.2.5.2** A sample calculation of peak power output from measured peak power data follows:

Measured data:

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- Transmitter frequency ( $F_o$ ): 500<sup>0</sup> MHz
- Signal generator substitution level ( $P_{GEN}$ ): -11.0 dBm
- Attenuation inserted ( $A_1$ ): 40.0 dB
- Signal sampler coupler factor ( $A_2$ ): 50.0 dB
- Transmission line attenuation, signal sampler to antenna ( $A_3$ ): 1.0 dB

The peak power output at the radar antenna is calculated as follows:

$$\begin{aligned} P_p &= P_{GEN} + A_s + A_1 - A_2 \\ &= -11.0 \text{ dBm} + 50.0 \text{ dB} + 40.0 \text{ dB} - 1.0 \text{ dB} \\ &= 78.0 \text{ dBm.} \end{aligned}$$

**40.2.5.3** Sample data forms for recording peak or average power output data are shown on figures 2 and 3.

### **40.3 Pulse width and rise time.**

**40.3.1 Objective.** The objective of this test is to determine the amplitude versus time characteristics of the RF pulse at the transmitter output.

**40.3.2 Requirements.** This procedure should be used to determine pulse width and rise time whenever those values must be experimentally determined for use in other tests required by this standard.

**40.3.3 Application notes.** The results from this test have a number of essential applications, as follows: (1) verifying that the pulse width is within specified equipment tolerances, (2) converting measured transmitter average power output levels to peak power output levels and (3) calculations which determine the radar emission bandwidth and emission level.

**40.3.3.1** The pulse width test procedure should include any measurements that are needed for determining the radar pulse envelope, in the time domain, at the radar output. The response of the test setup and any factors needed for relating the test point level to the antenna input level must be known.

**40.3.3.2** The 3 dB bandwidth of the instrumentation used for recovering the time waveform of the pulse width and rise time should be greater than  $3/t_r$  where  $t_r$  is the pulse rise time in microseconds. A measurement objective should be  $10/t_r$ .

**40.3.3.3** The points used for determining the pulse width should be as shown on figure 4. Rise time should be determined from the 10 to 90 percent points, relative to the nominal flat top level.

**40.3.3.4** The test oscilloscope is the basic instrument for measuring the amplitude versus time characteristics of the transmitter's pulsed emission. The test procedure consists of detecting the RF pulse with a crystal detector and measuring the resultant pulse envelope with the test oscilloscope. One advantage of this method is that the oscilloscope frequency response must accommodate only the video frequencies comprising the pulse envelope rather than frequency components near the transmitter fundamental. The disadvantages are that the detector input level should approach the upper end of the detector linear dynamic range and the

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detector conversion efficiency must be known or obtained through supplemental calibrations. If attenuators are necessary for reducing the signal level at the crystal detector input, the least attenuation that prevents detector overload and maintains the level within the linear range characteristic of the detector should be used.

**40.3.3.5** A typical block diagram of the test setup for pulse width and risetime measurements is shown on figure 5. When the crystal detector and oscilloscope are used for recovering the RF pulse the following precautions should be observed:

- a. The characteristic impedance of all interconnecting cables should match the impedance of the devices being connected.
- b. The test oscilloscope input should be terminated to match the detector output and interconnecting cable impedance.
- c. The bandwidth of the crystal detector system should be greater than  $3/t_r$ , where  $t_r$  is the transmitter pulse rise time, with the transmitter fundamental as the mid-bandwidth frequency. The oscilloscope bandwidth should be greater than  $3/t_r$ . A measurement objective for both the crystal detector system and test oscilloscope should be a bandwidth of approximately  $10/t_r$ .

**40.3.3.6** The linearity of the crystal detector or test oscilloscope assembly should be checked to ensure adequate definition of the amplitude points where the level is 10 to 90 percent of the nominal flat top level. To perform this check, increase the attenuation inserted, in selected steps, and note the oscilloscope response obtained after each step. The data from the rise time tests should provide definition of voltage points which are one-tenth of the nominal flat top level (see figure 4). The dynamic range of the test set up should be at least 26 dB (1/20 voltage) below the nominal flat top level.

**40.3.4 Procedure.** The block diagram of the equipment setup should be as shown on figure 5.

**40.3.4.1** Pulse width measurements: Set the test oscilloscope for a direct current (dc) input and adjust the synchronization (trigger threshold) for a stable single pulse display. Set the oscilloscope sweep rate to the value that displays a complete pulse and covers as much calibrated horizontal scale as possible. The pulse envelope at the baseline should cover at least 1/3 of the horizontal scale. Set the oscilloscope vertical sensitivity to obtain a pulse height which covers more than 1/3 of the calibrated vertical range to obtain good readability, then photograph the display.

**40.3.4.2** Rise time measurement: Increase the sweep rate of the oscilloscope time base to display the rise time (10 to 90 percent point) over at least 1/3 of the oscilloscope horizontal width. Photograph the display and note oscilloscope control setting.

**40.3.4.3** Pulse repetition frequency (PRF) measurements: Slow the test oscilloscope sweep rate until two pulses are seen on the display. Note the time (T), in seconds, between corresponding points on the two pulses. The radar PRF should be calculated as  $PRF = 1/T$ . For radars having more than one interpulse period, each different interpulse time should be measured.

**40.3.5 Sample calculation.**

**40.3.5.1** The data in the rise time photographs should be compared to the rise time capability of the test oscilloscope. The rise time of the test oscilloscope ( $T_a$ ) should be less than 1/3 times the indicated rise time shown in the photograph ( $T_i$ ) i.e.:

$$T_a < 1/3 T_i.$$

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**40.3.5.2** Sample data forms for pulse width, risetime, and PRF measurements are shown on figures 6 through 8.

#### **40.4 Emission bandwidth.**

**40.4.1 Objective.** The objective of this test is to determine the radar emission characteristics for comparison to the emission limits specified in 5.3.1.

**40.4.2 Requirements.** The radar emission bandwidth at the  $B_{-40\text{dB}}$  points and over the rolloff region extending beyond each  $B_{-40\text{dB}}$  point should not exceed the values as specified in table IV and the emission limits as specified in table V for the applicable radar category.

**40.4.3 Application notes.** The pulse width and rise time should be measured for each transmitter modulation mode and tuned frequency used in the radar emission bandwidth test. For phased array systems with less than fifteen transmitters or tubes, the power output of each transmitter or tube should be measured. For phased-array systems with fifteen or more transmitters or tubes, the power should be either measured in the far-field or statistically determined by measuring the power outputs (corrected for any antenna weighing) of a selected number of transmitters or tubes. The transmitters or tubes to be tested should be determined using a table of random numbers for selection. Initially, fifteen of the transmitters or tubes should be selected for measurement purposes. The standard deviation of measured data should be calculated. If the standard deviation is greater than 2.0 dB, additional transmitters or tubes should be measured. The number of transmitters or tubes to be measured can be determined using the student-t distribution. The mean of the measured data should be calculated giving the power output per transmitter or tube. The total power output is then the mean power output in watts, corrected for any antenna weighing, times the total number of transmitters or tubes. A power meter with a recorder output is desirable to permit recording a sample level of the transmitter power output providing a permanent record of any power fluctuation occurring during this test.

**40.4.3.1** For certain radars such as frequency hopping or pulse compression radars, it may be necessary to supplement the data which shows the  $B_{-40\text{dB}}$  points on a single photograph with additional analyzer presentations in which the frequency sweep width is narrowed to show greater rolloff detail. The additional data is needed to show the relationship between the 40 dB emission bandwidth frequencies and the lowest and highest transmit frequencies (frequency hopping radars) or the end points of the frequency deviation (pulse compression radars).

**40.4.3.2** To obtain the power spectral level at the signal sampler (or antenna) output of a pulse type radar, it is essential to know the IF bandwidth of the spectrum analyzer. With all analyzer controls unchanged, connect the signal generator to the analyzer and tune it for a centered frequency display. With a CW output, determine the signal generator output level required for a mid-scale vertical display. Record this value as  $P_1$ . Repeat this procedure except with the signal generator output pulse-modulated with a 2.0 microseconds width at the radar PRF (pulse repetition frequency). Record this value as  $P_2$ . Calculate the alpha factor from the relationship, alpha factor (dB) =  $P_1(\text{dBm}) - P_2(\text{dBm})$ . Using the alpha factor, the bandwidth-pulsewidth ( $B \times t$ ) product is determined (see figure 9). The ( $B \times t$ ) product divided by  $2 \times 10^{-6}$  yields the analyzer IF bandwidth (B). The IF bandwidth of the spectrum analyzer must be determined for each frequency used in the radar emission bandwidth test.

**40.4.3.3** In the data reduction, the signal sampler coupler factor is required for converting the power spectral levels of the sampled signal into the equivalent levels at the radar antenna input. If the signal sampler is not located at the antenna input, the attenuation of the transmission line components between the sampler and the antenna should be determined for use in the data reduction. When emission spectrum data are

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obtained in the open field, the overall coupling from the radar antenna terminals to the test antenna terminals is required for application in the data reduction. The coupling factors and attenuation values are required over the entire frequency range covered by the emission spectrum measurements.

**40.4.4 Procedure.** The block diagram for the transmitter emission test is shown on figure 10. This test should normally be performed as a closed system test in accordance with the test point selection priority list (see 30.16.1).

**40.4.4.1** The test procedure for closed system measurements applies to open-field measurements except that the point of measurement is the test antenna terminals rather than signal sampler output. Therefore, the antenna-to-antenna coupler factor replaces the signal sampler coupling factor in the data reduction process. In either case, the radar signal level at the sample point is termed  $P_2$ .

**40.4.4.2** If open-field measurements are necessary, the test antenna should be located as described (see 50.2). With the radar antenna scan stopped, the alignment of the radar and test antenna should be adjusted for maximum signal at the test antenna terminals. The test antenna polarization should be the same as that of the radar antenna.

**40.4.4.3** With the sample point connected to the spectrum analyzer through the appropriate transmission line and calibrated attenuators, the analyzer should be tuned until the radar signal spectrum appears centered on the analyzer display. This adjustment is performed using the maximum analyzer bandwidth. The final analyzer bandwidth should be selected using the following procedure:

- a. Adjust external attenuators for an on-scale display.
- b. Decrease the analyzer bandwidth in increments (a 1:3:10 sequence is normally available) and photograph the resulting displays.
- c. Determine the maximum analyzer bandwidth for which the shape of the spectrum display (envelope) is independent of the bandwidth setting (i.e., no longer changes as bandwidth is reduced).
- d. The analyzer bandwidth determined in step c. should be used for obtaining emission spectrum data (photographs) at the radar  $F_o$  and required points in the spectrum away from  $F_o$  (e.g.  $B_{-40dB}$ ).

The analyzer IF bandwidth (3 dB) determined in step c. should satisfy the relationship  $B_{NOM} > 1.7 PRF$  for pulse radars. The analyzer controls and external attenuators should be adjusted to provide the maximum amplitude on-scale display that does not result in overloading the analyzer input. The analyzer should be checked for signal overload as follows. After the analyzer controls and external attenuators are set, a 10 dB external attenuator should be added at the analyzer input. The amplitude of the spectrum envelope should decrease by a corresponding 10dB over all parts of the display. If a 10dB decrease is not noted, the analyzer controls and external attenuators should be changed as required to produce the desired 10 dB decrease when the overload check is performed. After verifying that overload is not occurring, the 10 dB attenuator added for the check should be removed.

**40.4.4.4** The analyzer sweep width should be adjusted for an optimum display showing the first null points on each side of the maximum emission at  $F_o$ . The sweep time should be selected to satisfy the following inequality:

$$(B_{NOM})^2(T_s/F_s) > 5$$

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where:

$B_{\text{NOM}}$  = spectrum analyzer IF bandwidth (3 dB), in Hz

$T_s$  = sweep time, seconds

$F_s$  = sweep width, in Hz .

Other controls should be set in accordance with the analyzer operating manual, the control settings recorded, and then the display should be photographed.

**40.4.4.5** The analyzer display should be calibrated as follows: Connect a calibrated CW signal generator to the spectrum analyzer, then tune it to the center of the analyzer display. Adjust the generator level to produce a display at the top horizontal graticule line. Record the signal generator frequency and output level. Adjust and record the generator level for each horizontal line. Tune the signal generator frequency so that the display is coincident with the right-hand end of the analyzer display. Increase or decrease the signal generator output as required to attain a display at the middle horizontal graticule line. Note the generator output level and frequency at this point, then tune the generator to the left-hand end of the display and repeat the process. If the levels at the analyzer display end points differ by greater than 2 dB from the mid-frequency level, select additional points across the display frequency range as necessary to describe the overall linearity characteristics.

**40.4.4.6** The test setup should be reconnected to the radar signal sample point. The analyzer sweep width should be increased for an optimum display of the radar emission at the 40 dB points below the maximum level at  $F_o$ . The analyzer sweep rate should be changed as necessary to satisfy the  $(B_{\text{NOM}})^2(T_s/F_s) > 5$  requirement. The display should be photographed and the calibration procedure performed as described for the first photograph.

**40.4.4.7** The next part of the procedure requires a tunable preselector which tracks with the sweep frequency of the spectrum analyzer inserted at the analyzer input. After reconnecting the test setup to the radar signal sample point, the spectrum analyzer should be tuned above the radar  $F_o$  until the 40 dB down amplitude point appears near the low frequency end of the display. Remove part of the calibrated input attenuation to raise the entire spectrum display higher on the analyzer screen. In removing the attenuation, the level applied to the preselector and analyzer should be maintained below the value which produces overload or signal compression in the display. The amplitude of the overall spectrum envelope, at the minus 40 dB amplitude and lower, should be raised on the display by an amount equal to the attenuation removed. The level at the minus 40 dB amplitude point should remain on scale. The analyzer sweep width which will show the upper end-point of the spectrum rolloff region should be selected. The analyzer sweep rate should be adjusted to satisfy the criteria given for the first two photographs. The display should be photographed and calibrated using the procedure given for the first photograph. The procedure described should be repeated with the spectrum analyzer tuned below the radar  $F_o$ .

**40.4.4.8** The procedure for CW and FM/CW radars is similar to that for pulsed radars described above except that it is not necessary to determine the alpha factor and the criteria for selecting the analyzer bandwidth is as follows:

- a. For a CW radar, select the analyzer IF bandwidth (B) such that  $B < (3 \times 10^{-5}) F_o$ , where  $F_o$  is the radar tuned frequency, in Hz.
- b. For FM/CW radars, select the analyzer IF bandwidth (B) such that  $B < (3 \times 10^{-5}) F_o$  or  $B < 0.5 F_{\text{MOD}}$ , whichever is less.  $F_{\text{MOD}}$  is the modulation rate for the FM.

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For non-pulse radars, the tracking preselector can be replaced with a passive rejection filter, tuned to the radar  $F_o$ , when measuring emission levels in the rolloff region.

**40.4.4.9** For phased array systems, procedures should be repeated (see 40.4.4 through 40.4.4.8) with the system operating in its normal search mode.

**40.4.5 Sampling calculations.** The emission spectrum measurement results consist of the emission spectrum photographs and the associated frequency and amplitude calibration data together with insertion loss, coupling factor, and other calibrations as needed to obtain the power spectral level, in dBm/kHz, at the input to the radar antenna. Sample emission spectrum data forms are shown on figures 11 through 13. Data reduction is required to yield a direct comparison of the radar performance to the specification limits.

**40.4.5.1** Sample calculations which obtain the power spectral level in dBm/kHz from the measured data should follow. Calculations are based on pulse radar having the measured characteristics, listed below, and a nearly rectangular RF pulse envelope. Other conditions are that there are no sub-pulses within the pulse, and that the pulses are not FM or otherwise encoded.

Measured data at transmitter  $F_o$ :

- Transmitter tuned frequency ( $F_o$ ): 500<sup>0</sup> MHz
- Frequency separation, first spectrum nulls (from photo): 1.54 MHz
- Radar PRF: 650 pps
- Spectrum analyzer alpha factor, -20.0 dB ( $2 \times 10^{-6}$  second pulsewidth)
- Measured signal sampler coupling factor ( $A_s$ ): 50<sup>0</sup> dB
- Attenuation inserted at analyzer input ( $A_1$ ): 30<sup>0</sup> dB
- Signal generator CW calibration level ( $P_{cw}$ ) at emission spectrum peak: -24.7 dBm ( $A_1$  removed)
- Attenuation, signal sampler to radar antenna ( $A_2$ ): 0 dB.

**40.4.5.2** The first step in the data reduction calculates the spectrum analyzer IF bandwidth B from the measurement with the 2 microsecond test pulsewidth described (see 40.4.3.2). An alpha factor of minus 20 dB provides  $B \times t = 0.067$  (see figure 9). Therefore,  $(B)(2 \times 10^{-6}) = 0.067$  which gives  $B = 33.5$  kHz.

**40.4.5.3** The effective radar pulsewidth ( $t_{eff}$ ) is determined from the equation  $t_{eff} = 2/f_N$ , where  $f_N$  is the frequency between the upper and lower first null points of the emission spectrum. Where  $f_N = 1.545$  MHz,

$$t_{eff} = 2/(1.54 \times 10^6) = 1.3 \times 10^{-6} \text{ seconds.}$$

**40.4.5.4** With the spectrum analyzer bandwidth and the effective radar pulsewidth known, the product is:  
 $B \times t_{eff} = (33.5 \times 10^3) (1.3 \times 10^{-6}) = 0.044.$

Applying  $B \times t_{eff}$  (see figure 10), the pulse versus CW sensitivity for the radar signal (alpha R) is -23.6 dB.

**40.4.5.5** The peak level  $P_p$  of the radar emission at the radar antenna input is given by:

$$P_p = P_{CW} + A_1 + A_s - A_2 - \text{alpha R.}$$



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Substituting alpha R and the measured values for the remaining factors in the equation gives:

$$\begin{aligned} P_p &= -24.7 + 30.0 - 0.0 + 50.0 + 23.6 \\ &= 78.9 \text{ dBm.} \end{aligned}$$

**40.4.5.6** The last step consists of calculating the maximum power spectral level ( $P_t$ ), in dBm/kHz as follows:

$$P_t = P_p + 20 \log (N \times t) + 10 \log \text{PRF} - \text{PG} - 90$$

where:

$P_t$	=	maximum power spectral level, dBm/kHz
$P_p$	=	peak power, dBm
$N$	=	number of subpulses in the pulse
$t$	=	emitted pulse duration, microseconds
PRF	=	pulse repetition frequency, Hz
PG	=	processing gain.

The conditions for this example are: (1) no subpulses contained in the pulse ( $N = 1$ ), and (2) non-FM, non-encoded pulses ( $\text{PG} = 0$ ). Therefore, the calculation of  $P_t$  gives:

$$\begin{aligned} P_t &= 78.9 + 20 \log (1 \times 1.3) + 10 \log 650 - 0 - 90 \\ &= 19.3 \text{ dBm/kHz.} \end{aligned}$$

The value for  $P_t$  is needed for evaluating the end points of the emissions levels in the rolloff region. The criteria for determining the dB below  $F_o$  level at the end point of each rolloff region is 60 dB or ( $P_t + 30$ ) dB, whichever is greater. Evaluating ( $P_t + 30$ ) dB gives 49.3 dB. Therefore, the 60 dB value applies to the radar in this example since ( $P_t + 30$ ) is less than 60 dB.

### 40.5 Spurious emission.

**40.5.1 Objective.** The objective of this test is to measure the power spectral level of all emissions outside the  $B_{-40\text{dB}}$  frequency range; these emissions are not determined by the radar emission bandwidth test.

**40.5.2 Requirements.** Emissions outside the  $B_{-40\text{dB}}$  frequency range should have a power spectral level below the maximum values (see 5.3.2).

**40.5.3 Application notes.** For groups B and C radars, this test defines the radar emissions characteristics down to levels 60 dB or ( $P_t + 30$ ) dB, whichever is greater, below the maximum emission level of the radar fundamental ( $F_o$ ). For group D radars, the radar emission characteristics are defined down to levels 80 dB below the maximum  $F_o$  level. These regions above and below  $F_o$  are referenced herein as the rolloff frequency region. The spurious emission tests should extend from the end points of the measured rolloff frequency regions to the limits of the applicable test frequency range specified (see table VI). The test results should provide the power spectral level, in dBm/kHz, referenced to the terminals of the radar antenna. The spurious emission test procedure should be applied over those portions of the required test frequency range where the radar emission bandwidth test procedure has insufficient sensitivity to verify compliance with the dynamic range, 60 dB or ( $P_t + 30$ ) dB below the maximum spectral level of  $F_o$  over the specified test frequency range.

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**40.5.3.1** The spurious emission test should be performed for each radar tuned frequency and operating mode specified for emission bandwidth tests (see 5.3.2).

**40.5.3.2** The output power should be measured using a thermal-type power meter and an appropriate signal sampler. The system directional coupler should be used, if available, and should be calibrated over the range of frequencies measured. For phased arrays the output power should be measured as specified in 40.2.33. The number of transmitters selected should be determined using a table of random numbers. Initially fifteen of the transmitters should be selected for measurement purposes. The standard deviation of the measured data should be calculated. If the standard deviation is greater than 2.0 dB, additional transmitters should be measured. The number of transmitters to be measured can be determined using the student-t distribution. The mean of the measured data should be calculated giving the power output per transmitter. The total power output is then the mean power output in watts, corrected for any antenna weighing function times the total number of transmitters.

**40.5.3.3** The first part of the spurious emission test procedure supplements the emission bandwidth, as necessary, for defining the power spectral level in the rolloff region. The procedure consists of increasing the spectrum analyzer IF bandwidth to capture more spectral power in frequency regions away from the radar fundamental but with a loss in the detail for the spectrum lobes. The result is an increase in the amplitude of the spectrum envelope relative to the analyzer noise level. A correction factor (k) should be determined for relating the data measured with the increased analyzer IF bandwidth to the data from the radar emission bandwidth test.

**40.5.3.4** The second part of the spurious emission test procedure should be applied only when the spectrum analyzer, at maximum IF bandwidth, produces insufficient dynamic range in the measured data; that is, dynamic range is less than the 60 dB or  $(P_i + 30)$  dB, whichever is required. The second part of the procedure should be required for adequate measurement sensitivity between the end points of the spectrum rolloff regions and the limits of the required test frequency range. In the second part of the test procedure, the spectrum analyzer in the test setup should be replaced with a tunable receiver (frequency selective RF voltmeter, FSVM). A correction factor (k) should be used for relating the data measured with FSVM to radar emission bandwidth data.

**40.5.3.5** The spurious emission test should be performed for each radar transmitter tuned frequency and operational mode used in the emission spectrum test (see 40.4).

**40.5.4 Procedures.** Refer to procedures as shown on figure 10 for a typical block diagram of this test. Tune the radar transmitter to a standard test frequency and most used operating mode. Adjust the output power to the nominal level. Record the measured transmitter power at the start of this test and at intervals of 30 minutes or less (more frequently if a noticeable change occurs). A power meter with a recorder output is desirable to permit recording a sample level of the transmitter radiated power output providing a permanent record of any power fluctuations occurring during this test.

**40.5.4.1** The procedure should be described for spurious emissions above the radar tuned frequency ( $F_o$ ). It should be assumed that the radar emission bandwidth procedure has been completed to a frequency above  $F_o$  where the emission level is less than 5 dB above the spectrum analyzer noise level. The analyzer IF bandwidth should be increased and the frequency sweep range should be tuned for a spectrum display which overlaps the upper end of the sweep range of the previous spectrum photograph. The overlap region should include amplitudes which are at least 15 dB above the analyzer noise presentation in the previous photograph. The results from the process of changing the bandwidth and overlapping sweep ranges should be as shown on

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figure 13. Note the increase (k, in dB) of the spectrum envelope produced by increasing the analyzer IF bandwidth for identical frequency sectors. In the example as shown on figure 13, k equals 19.5 dB. Photograph the display and calibrate the analyzer frequency and amplitude scales using the procedure given (see 40.4.4.5).

**40.5.4.2** When it is necessary to employ the second part of the spurious emission test procedure (where the FSVM replaces the spectrum analyzer), the process for obtaining the k factor should be modified slightly. Using the radar emission bandwidth photograph which shows the rolloff spectrum region for reference, a frequency toward the end of the rolloff where the display amplitude is 10 to 15 dB above the noise should be selected. The FSVM should be tuned about this frequency for a maximum response, and the amplitude for reference noted. A calibrated pulsed RF signal should be substituted at the input to the FSVM. The PRF of the pulsed RF signal should be set to equal the radar PRF. The RF pulsewidth (t) should be adjusted to satisfy the following:

$$t > 2/B_{FSVM}$$

where  $B_{FSVM}$  is the nominal instrument bandwidth. The frequency of the pulsed RF signal should be adjusted for maximum response on the FSVM, then the signal level adjusted to obtain the reference FSVM response. The frequency of the pulsed RF signal should be measured and the value along with the signal level noted. The CW signal level corresponding to the amplitude of the spectrum envelope should be determined in the photograph at the frequency noted. The k factor, in dB, should be determined by comparing the CW signal level (from the photograph),  $P_{CW}$ , to the pulsed RF signal level,  $P_{PULSE}$ , as follows:

$$k = P_{PULSE} - P_{CW}$$

where:

$$P_{PULSE} \text{ and } P_{CW} \text{ are in dBm.}$$

**40.5.4.3** When spurious emissions, which are 20 dB or more above the test receiver noise level, are found the spectrum analyzer test receiver should be used to determine the power spectral level. The analyzer bandwidth should be returned to the original value used in the radar emission bandwidth test.

**40.5.4.4** After the upper frequency limit has been reached (see table VI), the analyzer should be tuned to the frequency corresponding to the lower frequency of the maximum allowable emission bandwidth and the scan for spurious emission should begin below the operating frequency. The entire scan should be performed for each of the three standard test frequencies and at the maximum duty cycle. The same tests should be performed at the mid-standard test frequency using the mean pulsewidth and repetition rate of the system.

**40.5.4.5** Spurious emissions measurement test procedures in the open field should be the same as those for the closed system tests except that additional measurements should be made to determine the antenna coupling factor (ACF) from the terminals of the radar antenna to the terminals of the test antenna in the open field over the test frequency range. When the ACF coupling factor is known, it should not be essential for the radar-to-test antenna distance to satisfy the minimum distance requirement given for the radar antenna pattern test. The polarization, bearing, and elevation of the radar and test antennas should be adjusted for maximum signal transfer over each portion of the test frequency range.

**40.5.4.6** For the antenna coupling measurement at each frequency, a calibrated CW signal should be applied to the radar antenna input. The level received at the test antenna terminals should be measured with the spectrum analyzer or FSVM. Signal substitution with a calibrated CW signal generator should be used for

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determining reference response readings obtained on the analyzer or FSVM. When the antenna coupling is measured for radar antennas having waveguide transmission line input, adapters and transition sections should be employed over appropriate portions of the measurement frequency range.

**40.5.5 Sample calculations.** The results from the spurious emission measurements will consist of spectrum analyzer photograph or FSVM readings with associated calibration data, measured k factors as necessary plus additional test data such as signal sampler or radar-to-test antenna coupling and insertion losses preceding the point for substituting the calibration signals. Sample spurious emission data forms are shown (see figures 14 through 19).

**40.5.5.1** To determine the power spectral level in dBm/kHz from the measured data, use the following sample calculations as a guide:

Measured data at transmitter  $F_o$  (5000 MHz):

- Frequency separation, first spectrum nulls (from photo): 1.54 MHz
- Radar PRF: 650 pps
- Spectrum analyzer alpha factor for a 2-microsecond pulsewidth: -20.0 dB
- Measured signal sampler coupling factor ( $A_s$ ): 50.0 dB
- Attenuation inserted at analyzer input ( $A_1$ ): 30.0 dB
- Signal generator CW calibration level ( $P_{CW}$ ) at emission spectrum peak: -24.7 dBm ( $A_1$  removed)
- Attenuation, signal sampler to radar antenna ( $A_2$ ): 0 dB
- Nominal spectrum analyzer IF bandwidth ( $B_{NOM}$ ): 30 kHz.

First, apply the data analysis procedures given (see 40.4.5) to obtain the maximum spectral level at  $F_o$  which is 19.3 dBm/kHz. Next consider that the power spectral level at 40 MHz above  $F_o$  is desired but the spectrum envelope is only 4 dB above the noise level, which also increases when the bandwidth is changed. Assume that the k factor resulting from the change in bandwidth (see 40.5.4.1) is analyzed at 15 MHz above  $F_o$  (where the power spectral level is 35 dB below the maximum spectral level at  $F_o$ ). With the following data obtained:

- Signal generator (SG) CW level ( $P_{CW}$ ) at  $F_o$  (frequency of spectrum peak),  $A_1$  removed and 30 kHz  $B_{NOM}$ : -24.7 dBm
- SG CW level ( $P_{CW,A}$ ) at  $F_o + 15$  MHz,  $A_1$  removed and 30 kHz  $B_{NOM}$ : -59.7 dBm
- SG CW level ( $P_{CW,B}$ ) at  $F_o + 15$  MHz,  $A_1$  removed and 100 kHz  $B_{NOM}$ : -49.2 dBm
- SG CW level ( $P_{CW,C}$ ) at  $F_o + 40$  MHz,  $A_1$  removed and 100 kHz  $B_{NOM}$ : -58.5 dBm.

The k factor should be determined as:

$$\begin{aligned} k &= P_{CW,A} - P_{CW,B} \\ &= -59.7 \text{ dBm} - (-49.2 \text{ dBm}) \\ &= -10.5 \text{ dB.} \end{aligned}$$

With the analyzer bandwidth of 100 kHz, the CW level at  $F_o + 40$  MHz ( $P_{CW,C}$ ) is measured -58.5 dBm. Adding the k factor to compensate for the increase of analyzer bandwidth, the equivalent CW level ( $P_{CW,D}$ ) for  $B_{NOM} = 30$  kHz is:

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$$\begin{aligned} P_{CW,D} &= P_{CW,C} + k \\ &= -58.5 \text{ dBm} + (-10.5 \text{ dB}) \\ &= -69.0 \text{ dBm}. \end{aligned}$$

Comparing the resulting level to the CW level at the spectrum maximum obtains  $-24.7 \text{ dBm} - (-69.0 \text{ dBm}) = 44.3 \text{ dB}$  below maximum power spectral level. The power spectral level at  $F_o$  was  $19.3 \text{ dBm/kHz}$ . Therefore, the power spectral level at  $F_o + 40 \text{ MHz}$  is  $19.3 \text{ dBm/kHz} - 44.3 \text{ dB} = -25.0 \text{ dBm/kHz}$ .

#### **40.6 Frequency stability.**

**40.6.1 Objective.** The objective of this test should be to determine the frequency stability of the radar transmitter.

**40.6.2 Requirements.** Radar transmitters should achieve a frequency tolerance no larger than that given (see 5.3.3) for the appropriate radar category.

**40.6.3 Application notes.** This test should be performed in-line using the system directional coupler or other suitable coupling devices. The radar transmitter should be tuned to an operating frequency near the midpoint of the tuning band. If the radar system operates on more than one band, the tests should be performed for each band. The preferred test technique should be to automatically measure and record the frequency.

**40.6.3.1** The transmitter output signal should be obtained from the transmitter signal sampler or a test signal sampler inserted between the transmitter output and antenna input. Alternative test points between the transmitter frequency determining circuits and the final output should be used providing that (1) the frequency at the point of measurement equals the final output frequency and (2) connection of the test instrumentation should not alter the transmitter operation. The attenuators in the diagram should be needed to reduce the signal levels to within the input level capabilities of the test instrumentation.

**40.6.3.2** The test instrumentation should provide a measurement accuracy which is equal to or better than 5 percent of the specified maximum frequency tolerance. For example, a group C, category 1, radar operating at 100 MHz would have a maximum tolerance of:  $(400/10^6) (100 \times 10^6 \text{ Hz}) = 0.04 \text{ MHz}$ . For a measurement accuracy of 5 percent, the frequency should be determined within 5 percent of  $0.04 \text{ MHz} = 2000 \text{ Hz}$  or 20 parts per  $10^6$  at the operating frequency of 100 MHz.

**40.6.3.3** The transmitter frequency stability should be measured at the highest and lowest temperature for which the equipment is designed to operate. Temperatures should be established and maintained in accordance with procedures specified in MIL-STD-810, methods 501.1 and 502.1.

**40.6.4 Procedure.** The frequency stability measurement block diagram should be as shown on figure 20. The test duration should be a minimum of 4 hours with the following measurement intervals:

- a. Within first hour: After transmitter turn-on, at time  $T_o$ , measure frequency at 10-second intervals during first 2 minutes of operation. Beginning at times of  $T_o + n$  minutes, where  $n = 5, 10, 15...$  up to 60, measure frequency at 10-second intervals for a period of 1 minute.
- b. Over next 3 hours: Measure frequency at times of  $T_o + 60 + n$  minutes where  $n = 0, 10, 20, 30...$  up to and including  $n = 180$ .

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**40.6.5 Sample calculations.** The results from the frequency stability measurements consist of the transmitter frequency and times of measurement plus test particulars such as mode of transmitter operation, ambient temperature, and time from cold start to first frequency measurement. It is possible that a given system may be intended to be kept at a condition other than cold as its normal off mode. An explanation should be provided when the system under test is not operated from a cold start. Sample data sheets to be used for reporting test details and measurement results are shown on figures 21 and 22.

**40.6.5.1** A sample calculation to determine the frequency stability at one measurement follows:

Frequency at transmitter cold start ( $T_o$ ) = 2100.031 Mhz

Frequency after 5 minutes of operation ( $T_o + 5$ ) = 2100.014 MHz

$$\begin{aligned}\text{Frequency tolerance} &= |F(T_o) - F(T_o + 5)| \\ &= |2100.031 - 2100.014| \\ &= 0.017 \text{ MHz.}\end{aligned}$$

### **40.7 Transmitter tunability.**

**40.7.1 Objective.** The objective of this test is to determine the ability of the radar transmitter to tune over its approved frequency band.

**40.7.2 Requirements.** Each radar should be tunable in an essentially continuous manner (see 5.3.4).

**40.7.3 Application notes.** The procedure for the transmitter tunability test consists of performing the transmitter power output and output frequency test with the transmitter tuned, in turn, to each of the required test frequencies. The test procedures for measuring the transmitter power output and operating frequency are described (see 40.2 and 40.6). Refer to 40.2 and 40.6 for the individual test procedures; the selection of the required test frequencies is described in 40.7.4. In the initial selection for each radar band, at least 11 test frequencies should be used, as specified herein:  $F_L$ ,  $F_M$ ,  $F_H$ ; four frequencies approximately evenly spaced between  $F_L$  and  $F_M$ , and four frequencies approximately evenly spaced between  $F_M$  and  $F_H$ . In the absence of specific requirements for power output in the radar procurement specification, test criteria for radar system tunability should be derived from system specifications that define operational performance requirements.

**40.7.4 Procedure.** At each tuned frequency, the transmitter should be adjusted for normal operation as described by the system operating manual. Any efforts to optimize the equipment operation at a particular frequency should not be attempted unless the procedure is described in the manual.

**40.7.4.1** The measured power output values should be compared to the radar specifications. If measured values differ by more than 2 dB from the specification values, additional frequencies should be tested near the frequency where the discrepancy is noted in order to describe the problem. For systems which are fixed-tuned or have less than 11 operating frequencies, the number of test frequencies should be reduced to the maximum available.

**40.7.5 Sample calculations.** The sample calculations for obtaining the transmitter power output from measured data are described (see 40.2). Sample data forms for recording the power output results are shown (see figures 2 and 3).

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**50. RADAR ANTENNA MEASUREMENTS**

**50.1 Requirements summary.** The radar antenna measurements and procedures described in this section should provide data to be compared to the radar antenna characteristics, requirements, and limits specified in 5.4.

**50.2 Antenna characteristics.**

**50.2.1 Objective.** For antennas operated by their rotation through 360 degrees of the horizontal plane, the objective should be to determine the median gain of the antenna, in the principal horizontal plane, by measurement of the antenna pattern. Median gain should be defined as that level over an angular region at which the probability is 50 percent that the observed or measured gain at any position of the antenna will be less than or equal to that level. For other antennas, the objective should be to determine the antenna pattern, including the sidelobe levels, relative to the main lobe.

**50.2.2 Requirements.** The radar antenna should provide sidelobe characteristics within the limits (see 5.4) for the appropriate radar category.

**50.2.3 Application notes.** For radar systems other than the types described, appropriate test procedures should be determined and described in a test plan developed for the cognizant activity directing the test. Upon approval of the test plan and subsequent execution of the tests, any departure from the test plan should require approval. Guidance in planning antenna pattern and median gain tests on these types of systems should be provided as specified in MIL-STD-449.

**50.2.3.1** The spatial distribution of power radiated into space, if site effects are minimized, should describe the amount of relative antenna gain existing in directions removed from the main beams of an antenna. The recorded information, commonly referred to as antenna patterns, presents a graphical representation of the energy distribution about the system antenna.

**50.2.3.2** The primary procedure uses the radar transmitter, operating in its normal mode with the rated power output, as the transmit signal source. A secondary procedure, which replaces the radar transmitter with a substitute signal source such as a high level CW signal generator is acceptable. With either transmit signal source, the power level delivered to the radar antenna terminals should be measured and the results noted in the test data.

**50.2.3.3** Mechanically rotatable antennas should be tested (see 50.2.4 through 50.2.4.5). Systems with electronic beam-scanning and limited or no mechanical rotational ability, yet with antennas small and light enough for mounting on a mechanically-rotatable platform, should use the procedure (see 50.2.4 through 50.2.4.5). Electronic beam-scanning antennas which cannot be mechanically rotated should use the procedures listed (see 50.2.4.6 and 50.2.4.7).

**50.2.3.4** The receiving test antenna should be positioned at a location which is separated from the radar antenna by a distance (R) determined from the following equation.

$$R > (D_1^2 + D_2^2)/\text{wavelength of test frequency}$$

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where  $D_1$  and  $D_2$  are the maximum aperture dimensions for the radar and test antennas respectively, and all parameters are in the same dimensional units. The test antenna height should coincide with a horizontal plane through the radar antenna. Both the test antenna site and the path to the radar antenna should be free from obstructions and objects which could cause reflections. Elevate the test antenna for the maximum received signal level.

**50.2.3.5** For those systems where the test antenna cannot be located in the radar main beam maximum, this measurement should be performed using near-field measurement techniques. If near-field techniques are employed, the equivalent far-field patterns should be determined using appropriate techniques before comparing the results to the requirements (see 5.4).

**50.2.3.6** The antenna pattern recording system (test receiver plus recorder) should have a dynamic range of at least  $(G + 20)$ dB where  $G$  is the gain, in dB, of the radar antenna main beam, with a minimum of 40 dB for the system. The dynamic range can be expanded by removing attenuation at the test receiver input, then obtaining a second antenna pattern recording. With this procedure, the second recording should show the higher pattern levels off-scale but the lower levels should be reproduced. The calibration procedure should be as described for the initial antenna pattern recording which shows the main lobe on-scale.

**50.2.3.7** Statistical measurements of the transmitted beam should be taken with the main beam scanning the solid sector in the normal scanning mode. Time should be allowed at each test position and frequency for at least 10 complete scan cycles of the solid scan sector to be made by the main beam. Where possible, the scanning measurements should be synchronized in time so that the outputs of each complete scan cycle should be correlated with the other scan cycles. The output data should be used to determine the statistical mean and the deviation from the mean of the power density for the fundamental frequency at each test point. For frequency-scanning or frequency-agile radars, either a receiver bandwidth wide enough to encompass the radar scanning bandwidth or a number of receivers, each tuned to a separate frequency employed in the agile mode, should be used. As an alternate, for frequency agile radars with a limited number of discrete frequencies, one receiver should be used. The receiver can be tuned successively to each frequency and statistics collected.

**50.2.3.8** The procedures for measuring the receiver antenna patterns should be similar to those specified for the transmit pattern, except that the test signal is radiated from each test site location to the array antenna.

**50.2.4 Procedure.** The block diagram for the antenna pattern test should be as shown on figure 23. This test should be performed at the mid-band test frequency, or at the horizon frequency for frequency-to-elevation scanning radars.

**50.2.4.1** The output of the test antenna should be connected to the input of the test receiver via a length of transmission line with attenuators as required to prevent overloading. The test receiver should be adjusted as described for measuring the peak level of the radar signal (see 40.2).

**50.2.4.2** With the radar and test antennas aligned for maximum power transfer, the test receiver should be tuned for maximum response at the radar fundamental frequency ( $F_o$ ). For frequency-to-elevation scanning radars, the test receiver should be tuned to the horizon beam frequency. The recorder should connect to the test receiver. The recorder gain controls should be adjusted for nearly full scale deflection of the recorder pen. The level and frequency of the radar  $F_o$  should be measured using the procedure given for measuring peak power output (see 40.2). In this test the signal sample should be provided by the test antennas rather than from a signal sampler. Calculate the radar power density using the following equation:



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$$P_D = P_R - 20 \log (\lambda) - GR + 11.0$$

where:

- $P_D$  = power density at test antenna, dBm/m<sup>2</sup>
- $P_R$  = radar F<sub>o</sub> level at test antenna terminals, dBm
- $G_R$  = test antenna gain, dB, and  $\lambda = 300/f_{\text{MHz}}$ , meters.

The power density at the test antenna should be compared to the expected F<sub>o</sub> power density level. The measured power density (equation on previous page) should agree within 2 dB of the expected power density (equation below). The equation for the main beam power density is:

$$P_D = P_T + G_T - 20 \log R - 11.0$$

where:

- $P_D$  = power density at test antenna, dBm/m<sup>2</sup>
- $P_T$  = radar peak transmitted power, dBm
- $G_T$  = radar antenna nominal main beam gain, dB
- $R$  = distance from radar antenna to test antenna, meters.

**50.2.4.3** With all instrumentation set as specified, rotate the system antenna and start the recorder. The recorder should be operated to obtain two complete 360 degree sweeps of the system antenna on the recording. The recorder response times and antenna rotational speeds necessary to give at least 1 dB accuracy in the antenna pattern recording should be obtained from the following equation:

$$W < 50 \Theta_{3\text{dB}}/T_r$$

where:

- $W$  = rotational speed, r/min
- $\Theta_{3\text{dB}}$  = 3-dB width of antenna main lobe, degrees
- $T_r$  = response time of the test receiver and instrumentation, milliseconds.

**50.2.4.4** To calibrate the antenna pattern recording, the main beam of the radar antenna should be re-aligned for a maximum received level on the test antenna. Additional attenuation should be inserted in the line from the test antenna, in 5 dB steps. After each 5 dB increase, the resulting deflection of the recorder pen should be marked.

**50.2.4.5** For antennas that can be elevated, an antenna pattern measurement should be performed in the vertical plane using the procedure described for the azimuthal pattern recording.

**50.2.4.6** For electronic beam-scanning antenna which cannot be mechanically rotated, the following procedures should be used. The test antenna should be placed sequentially at 10 equally spaced angular positions, with the test antenna positioned as high as possible but not above the lowest elevation of the system antenna main beam maximum for the following tests. The test antenna positions should be on a semi-circular arc starting at the azimuth boresight location and ending 180 degrees offset in azimuth. One each of the test positions should be at each end of the specified arc. (Phased array systems are usually symmetrical by design; the mirror image of the test positions with associated data should be reflected to the other side of the antenna.)

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**50.2.4.7** The azimuthal beam-scanning measurement should be performed if the main beam can be easily steered at will. The main beam of the phased array should be steered as close as possible to the elevation of the test antenna and, with the elevation constant, should be sequentially stepped in azimuth through the complete scan sector. The azimuthal beam-scanning measurement should be taken with the test antenna at the azimuthal array normal test position, at the test position nearest the maximum angle of the scan sector, at an optional test position, and at the test position 180 degrees in azimuth from the array normal test position.

**50.2.5 Sample calculations.** The results from the antenna characteristics measurements consist of antenna pattern recording (strip chart or polar format) and associated calibration data such as attenuation inserted, cable loss, system antenna rotation rate, relative amplitude level, and test receiver and recorder response times. A sample antenna pattern recording (strip chart format) is shown (see figure 24).

**50.2.5.1** A sample calculation to determine the power density measured at the test site from measured data follows:

- Transmitter tuned frequency ( $F_o$ ): 3000 MHz
- Signal generator calibration level at peak of antenna pattern mainlobe ( $P_{GEN}$ ):  $-13.0$  dBm
- Attenuation inserted at test receiver input ( $A_1$ ):  $50.0$  dB
- Attenuation, coax to test antenna ( $A_2$ ):  $1.5$  dB
- Test antenna gain ( $G_R$ ):  $16$  dBi
- Wavelength =  $300/3000 = 0.10$  meters.

The received level at the test antenna is determined from:

$$\begin{aligned}P_R &= P_{GEN} + A_1 + A_2 \\ &= -13.0 + 50.0 + 1.5 \\ &= 38.5 \text{ dBm.}\end{aligned}$$

Next, the power density at the test antenna is calculated (see 50.2.4.2) as follows:

$$\begin{aligned}P_D &= P_R - 20 \log(\lambda) - G_R + 11.0 \\ &= 38.5 - 20 \log(0.1) - 16.0 + 11.0 \\ &= 53.5 \text{ dBm/m}^2.\end{aligned}$$

The sample calculation for the expected power density assumes the following parameters:

- Radar antenna power input ( $P_T$ ):  $90.0$  dBm
- Radar antenna gain ( $G_T$ ):  $25.0$  dBi
- Distance from radar antenna to test antenna (R):  $316$  meters.

Using the equation (see 50.2.4.2) the expected power density at the test site is calculated as follows:

$$\begin{aligned}P_D &= P_T + G_T - 20 \log(R) - 11.0 \\ &= 90.0 + 25.0 - 20 \log(316) - 11.0 \\ &= 54.0 \text{ dBm/m}^2.\end{aligned}$$

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**60. RADAR RECEIVER MEASUREMENTS**

**60.1 Requirements summary.** The radar receiver measurements and procedures described in this section provide data for comparison to the acceptance bandwidth, susceptibility characteristics, frequency tolerance, tunability and oscillator radiation requirements and limits (see 5.5).

**60.2 Overall selectivity.**

**60.2.1 Objective.** The objective of this test is to determine the receiver response characteristics at and near the receiver tuned and image frequencies.

**60.2.2 Requirements.** The overall receiver selectivity characteristics should satisfy the requirements (see 5.5) for the appropriate category of radar.

**60.2.3 Application notes.** In the first part of the test, the receiver response to test signals at and near the radar tuned frequency should be determined. In the second part, the response to test signals at and near the receiver image frequency should be determined. Both parts should be performed with the radar receiver tuned to the mid-frequency of its tuning range ( $F_M$ ). If the receiver switches bandwidth during its operation, this test should be repeated for each bandwidth used in the radar operation.

**60.2.3.1** The receiver selectivity characteristics give an indication of the overall gain and sensitivity of the receiver at its tuned frequency as well as its responses at frequencies slightly removed from the tuned frequency. The selectivity characteristics are mostly determined by the IF amplifier tuned circuits and should be fairly symmetrical about the center frequency. The level of these responses near the fundamental and image frequency indicate the ability of the receiver to discriminate against off-channel radiation through the acceptance bandwidth or selectivity.

**60.2.3.2** The radar receiver measurements specified herein should be performed on all receivers of the same radar except in the case of phased array radars with more than fifteen identical parallel receivers. For these radars fifteen of the receivers should be selected through the use of a table of random numbers. The standard deviation of the measured data, corrected for any antenna weighing, should be calculated. If the standard deviation is greater than 2.0 dB, additional receivers should be measured. The number of receivers to be measured should be determined using the student-t distribution. The total receiver response (all receivers) should then be determined statistically.

**60.2.3.3** For pulsed radar receivers, the test signal generator should be modulated with a pulsed signal which is approximately 10 times the longest operating pulsewidth for the tuned circuit being measured. The wide pulsewidth produces a relatively narrow energy spectrum in comparison to the receiver bandwidth. This narrow spectrum avoids erroneous bias buildup in the receiver's gain control circuits. In addition, the narrow spectrum provides a close approximation of the CW selectivity characteristics of the receiver.

**60.2.3.4** For nonpulsed receivers, the test signal should be unmodulated (CW). The point for measuring the receiver output should be past the receiver second detector, if possible, and should give a signal which represents normal operation of the system.

**60.2.4 Procedure.** The block diagram of the test setup should be as shown on figures 25 and 26.

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**60.2.4.1** The test frequency should be tuned about  $F_M$  for an optimum response at the receiver output. The test signal level should be reduced to obtain midpulse minimum visible signal (MPMVS) at the receiver output. The receiver video output should be observed at the output of the video detector using a wide bandwidth oscilloscope. With the MPMVS output established, the frequency and level of the test signal generator should be recorded. The insertion loss of test devices between the point where power level is referenced and the receiver input should be determined.

**60.2.4.2** The test signal generator level should be increased to 3 dB above the tuned frequency ( $F_o$ ) MPMVS level. The generator frequency should be tuned above  $F_o$  to regain the MPMVS response at the receiver output. This test signal frequency should be measured and noted. This procedure should be repeated with the generator frequency tuned below  $F_o$ . The procedure should be repeated above and below  $F_o$  with the test signal level increased in steps to 6, 12, 20, 40, 60 and, if possible, 80 and 100 dB above the MPMVS sensitivity level at  $F_o$ .

**60.2.4.3** The procedure should be repeated for frequencies at and near the receiver image response. In this case, the maximum test signal level should not be required to exceed 60 dB above the MPMVS sensitivity level measured at  $F_o$ .

**60.2.5 Sample calculations.** The selectivity measurement results consist of frequencies corresponding to specified amplitude response levels and associated information such as receiver operating mode, bandwidth and test point. Sample selectivity data forms are shown (see figures 27 through 30).

**60.2.5.1** A sample calculation to illustrate the procedure to determine the incremental frequency values and bandwidth follows:

Measured data:

- Radar tuned frequency ( $F_o$ ): 3001.868 MHz
- Frequency at 6 dB response above  $F_o$ : 3003.655 MHz
- Frequency at 6 dB response below  $F_o$ : 2999.997 MHz

The incremental frequency above  $F_o$  ( $+\Delta F$ ) is calculated as

$$\begin{aligned} +\Delta F &= 3003.655 \text{ MHz} - 3001.868 \text{ MHz} \\ &= 1.787 \text{ MHz} \\ -\Delta F &= 3001.868 \text{ MHz} - 2999.997 \text{ MHz} \\ &= 1.871 \text{ MHz} \end{aligned}$$

The 6 dB bandwidth (BW) is calculated from

$$\begin{aligned} \text{BW} &= |+\Delta F| + |-\Delta F| \\ &= 1.787 + 1.871 \\ &= 3.658 \text{ MHz} \end{aligned}$$

### 60.3 Spurious response.

**60.3.1 Objective.** The objective of this test is to determine the response characteristics of the radar receiver to signals at frequencies outside the range of the selectivity test.

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**60.3.2 Requirements.** The required spurious response characteristics of radar receivers should be as specified (see 5.5).

**60.3.3 Application notes.** The receiver input reference point should be selected at, or as close as possible to, the connection point of the transmission line to the system antenna (antenna terminals). Where it is not practical to establish the receiver input reference point at the system antenna, additional measurements should be obtained to describe the transmission line loss between the point which is used and the system antenna terminals.

**60.3.3.1** The range of test signal frequencies are specified in 5.5. The test signal generator should be modulated with a pulse of the same width as the system pulse and triggered by the system trigger. For systems using waveguide transmission line, the signal generator output should be applied at the receiver input through appropriate waveguide transitions and adapters to ensure, as much as possible, dominant mode incidence to the receiver. Adapters and transitions should be changed as necessary to correspond with the test signal frequency. Filters should be used to prevent unwanted signal generator outputs from entering the receiver. Attenuators should be inserted at the receiver input to provide a better match between the test signal source and the plane of reference.

**60.3.4 Procedure.** Typical block diagrams of the test setup for spurious response measurements should be as shown on figures 25 and 26.

**60.3.4.1** The receiver should be tuned to  $F_M$  and adjusted for normal operation in the selected mode. With the test signal generator set to the low end of the required frequency range, the test signal level should be adjusted at the receiver input such that the value exceeds the measured receiver sensitivity level by at least 10 dB plus the spurious response rejection value specified in table IX for the appropriate radar category. Starting at the low end of the required frequency range, the frequency of the test signal generator should be increased until a response is observed on the receiver output monitor. The receiver response and point for monitoring should be the same (see 60.2) as that used for measuring the overall selectivity. With the frequency of the test signal adjusted for a maximum response, the test signal level should be reduced to obtain the MPMVS response (see 60.2) (MDS for pulse radars). The test signal generator output level and frequency should be noted. After adjusting the test signal generator level to be value described for the start of the test, the test signal frequency should be increased until another spurious response is located. The scan and measurement procedure should be repeated for all spurious responses up to the maximum test frequency as specified (see table VI) for the emission bandwidth test.

**60.3.4.2** The spurious response test procedure should be repeated for each receiver tuned frequency specified and each mode and band of receiver operation.

**60.3.5 Sample calculation.** The results from the spurious response measurements typically consist of test signal generator level and frequency at each spurious frequency point plus associated information such as attenuation inserted and insertion losses of adapters transitions and cables. Sample data forms are shown (see figures 31 and 32).

**60.3.5.1** A sample calculation to obtain the spurious response level follows:

Measured data:

Receiver tuned frequency: 3650 MHz

Test pulse width: 5.0 microseconds

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PRF: 650 pps  
Signal generator level ( $P_{GEN}$ ): -20.0 dBm  
Signal generator frequency: 4203.615 MHz  
Attenuation inserted ( $A_1$ ): 5.<sup>0</sup> dB  
Cable loss ( $A_2$ ): 2.<sup>2</sup> dB  
Adapter loss ( $A_3$ ): 0.<sup>8</sup> dB.

The power input at the receiver input plane of reference ( $P_R$ ) is calculated as follows:

$$\begin{aligned} P_R &= P_{GEN} - A_1 - A_2 - A_3 \\ &= -20.0 - 5.0 - 2.2 - 0.8 \\ &= -28.0 \text{ dBm.} \end{aligned}$$

#### **60.4 Receiver tunability and frequency stability.**

**60.4.1 Objective.** The objectives of this test should be to verify that the radar receiver is tunable over the required frequency range and that the frequency stability is within the frequency tolerance specified. This test should also verify that crystal controlled receivers achieve the tunability requirements of operation at essentially any frequency across the band with a crystal change.

**60.4.2 Requirements.** The frequency stability of receivers should be commensurate with or better than the frequency tolerance of the associated transmitter. The frequency tolerance requirements for radar transmitters, which apply to radar receivers should be as specified (see 5.3.3 and 5.5.4) and tunability requirements should be as specified (see 5.3.4 and 5.5.3). The frequencies to be measured for the tunability test should be selected in accordance with 40.7 for transmitter tunability. The frequencies to be selected for the frequency stability test should be  $F_L$ ,  $F_M$ , and  $F_H$  as specified in table III. The receiver frequency stability test requirement should be waived for radar systems which normally employ automatic frequency control (AFC) or similar means for maintaining the receiver tuned frequency equal to the transmitter frequency. The receiver tunability and frequency stability test should be performed with the radar system or equipment operating at nominal environmental temperatures as specified and the minimum and maximum environmental temperatures as specified.

**60.4.3 Application notes.** A measure of the tunability of a radar receiver is its ability to attain rated sensitivity over its operating band. The receiver tunability should be determined from measurements of the receiver sensitivity at each test frequency as specified. Unless otherwise specified for the receiver nominal parameters, the standard output response should be minimum discernable signal (MDS) observed on the test oscilloscope display. If the required sensitivity of the receiver is not specified over the operating band, the minimum signal level and corresponding receiver standard response should be established by the contracting activity and included in the test plan.

**60.4.3.1** A measure of the frequency stability of a radar receiver is the ability of its frequency producing circuits to maintain the receiver tuned frequency within the frequency tolerance specified.

**60.4.4 Procedure.** The receiver tunability and frequency stability measurements should be performed as a closed system test. The block diagram is shown on figure 33.

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**60.4.4.1** The tunability test should begin by tuning the radar receiver for normal operation on one of the test frequencies specified. The test signal should be modulated to equal the nominal characteristics for which the radar system or equipment specifications are given. The test signal should be triggered from the radar modulation trigger, with a delay to place the signal at an equivalent range such that any sensitivity time control (STC) is not activated (unless allowance for the effect of STC has been made in establishing the standard response). The test signal should be tuned to the receiver frequency. The receiver output should be monitored with the oscilloscope. The generator level should be adjusted to obtain the standard response at the receiver output. The generator frequency should be measured with the frequency counter and the value recorded along with the receiver output level required for the receiver output standard response. The procedure should be repeated for the remaining receiver test frequencies as specified. The entire procedure should be performed with the radar system or equipment operating under the environmental temperature conditions as specified.

**60.4.4.2** The receiver frequency stability should be determined by accurately measuring the frequency stability of the local oscillator frequency with the frequency counter. In case of the multiple conversion receiver, the frequency of all local oscillators should be measured. The time over which the receiver stability is measured should include the stability requirements specified by the contracting activity or contract. The frequency stability test should also include the frequency measurement over a period of 4 hours at the following intervals:

- a. Within first hour: After receiver turn-on, at time  $T_o$ , measure frequency at 10-second intervals during first 2 minutes of operation. Beginning at times of  $T_o + n$  minutes, where  $n = 5, 10, 15... up to 60$ , measure frequency at 10-second intervals for a period of 1 minute.
- b. Over the next 3 hours: Measure frequency at time of  $T_o + 60 + n$  minutes where  $n = 0, 10, 20, 30... up to and including n = 180$ .

The turn-on time in a. from a cold start may vary from one piece of equipment to another. Turn-on time will be defined as "the earliest time, from a cold start, that the equipment is intended to radiate and receive signals". The receiver tuned frequencies at each point over the required time interval should be determined from the measured local oscillator frequency and the receiver intermediate frequency. The variation in the receiver tuned frequency at times  $T_o + n$  compared to the tuned frequency at time  $T_o$  should not exceed the frequency tolerance as specified.

**60.4.4.3** Sample data forms for recording receiver tunability and frequency stability measurements results are shown on figures 34, 35, and 36.

**60.4.5 Sample calculations.** The results from the receiver tunability measurements typically consist of the receiver sensitivity measured at the required test frequency (see 60.4.2). Sample calculations for spurious response (see 60.3.5) are applicable for sensitivity measurements. The results from the receiver frequency stability test consist of receiver local oscillator(s) frequency measurements and associated information such as mode of receiver operation, cold start time, turn-on time, and time for each frequency measurement point.

**60.4.5.1** In the stability data reduction, the measured local oscillator frequency is first converted to the equivalent frequency at the receiver input.

Measured data:

Local oscillator frequency at start of test ( $F_{lo}, T_o$ ): 1250.764 MHz

Local oscillator frequency at time  $T_1$  ( $F_{lo}, T_1$ ): 1250.748 MHz

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Receiver intermediate frequency ( $F_{IF}$ ): 30 MHz

Local oscillator frequency relative to receiver tuned frequency: above.

Receiver tuned frequency is determined as follows:

$$F_o = F_{lo} - F_{IF}$$

therefore,

$$\begin{aligned} F_{o,T_0} &= 1250.764 - 30 \\ &= 1220.764 \text{ MHz} \end{aligned}$$

$$\begin{aligned} F_{o,T_1} &= 1250.748 - 30 \\ &= 1220.748 \text{ MHz.} \end{aligned}$$

The frequency tolerance at time  $T_1$  is calculated as follows:

$$\begin{aligned} \text{Frequency tolerance} &= |F_{o,T_0} - F_{o,T_1}| \\ &= 1220.764 - 1220.748 \\ &= 0.016 \text{ MHz.} \end{aligned}$$

## **60.5 Receiver radiation.**

**60.5.1 Objective.** The objective of this test is to determine the level of receiver radiated signals at the receiver input terminals.

**60.5.2 Requirements.** No receiver radiations should exceed the maximum values as specified in table X for the appropriate radar category.

**60.5.3 Application notes.** Energy that is generated within the radar receiver by local oscillators and other signal producing circuits may be radiated from the radar system antenna. In this manner, the receiver acts as a transmitter and may emit energy which becomes interference to nearby equipment.

**60.5.3.1** To provide assurance that the receiver oscillator radiation meets the requirement, the level of the local oscillator fundamental signal should be determined for all transmitter frequencies which are selected for use in the transmitter tunability test (see 40.7).

**60.5.3.2** The test receiver should be a spectrum analyzer or a frequency selective voltmeter (FSVM). The sensitivity of the test receiver should be at least 5 dB greater than the specification limit, measured at the input to the transmission line leading to the test receiver.

**60.5.3.3** If numerous oscillator emissions are found in the frequency scan, it may be advantageous to display sequential frequency sectors on the spectrum analyzer, photograph each display and perform the calibration procedure as described for spurious emission (see 40.5). This alternate procedure is especially applicable to frequency scanning or frequency hopping radars where the scan sequence cannot be stopped for single frequency analysis.

**60.5.3.4** Over frequency regions where no oscillator radiations are detected, the sensitivity of the test receiver setup should be checked at points over the scan range to demonstrate the required measurement sensitivity. The insertion loss of the adapter used at the receiver input should be determined for each frequency where oscillator radiation is measured.



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**60.5.4 Procedure.** This test should be performed as a closed system test. A typical block diagram of the test setup is shown on figure 37. Disconnect the transmission line to the system antenna at the nearest available breakpoint external to the equipment enclosure. Terminate the transmission line on the receiver side of the disconnect point in an adapter as necessary to match the transmission line to the test receiver.

**60.5.4.1** For each of the test frequencies as specified in table III, start at the low extreme of the frequency range as specified in table X and increase the test receiver frequency until a signal is detected. Tune the test receiver for maximum response and record the response level on the data sheet as shown on figure 38. Connect the coaxial cable leading to the test receiver to a CW signal generator. Tune generator to obtain a frequency matching that of the reference analyzer response. Adjust the generator level to duplicate the reference response level. Record the generator frequency (measured with the frequency counter) and level readings. Continue the frequency scan until the next oscillator emission is found. Repeat entire procedure just described for each oscillator emission encountered in the frequency range as specified in table X.

**60.5.5 Sample calculations.** The results from receiver oscillator radiation measurements consist of signal generator CW substitution level and frequency and associated test data such as adapter loss. Sample oscillator radiation data forms are shown (see figures 38 and 39).

**60.5.5.1** A sample calculation to obtain the receiver oscillator radiation level follows:

Measured data:

Signal generator frequency: 1250.764 MHz

Signal generator level ( $P_{\text{GEN}}$ ): -38.0 dBm

Adaptor loss ( $A_1$ ) = 1.4 dB.

The oscillator radiation level ( $P_{\text{CW}}$ ) is calculated

$$\begin{aligned} P_{\text{CW}} &= P_{\text{GEN}} + A_1 \\ &= -38.0 + 1.4 \\ &= 36.6 \text{ dBm.} \end{aligned}$$

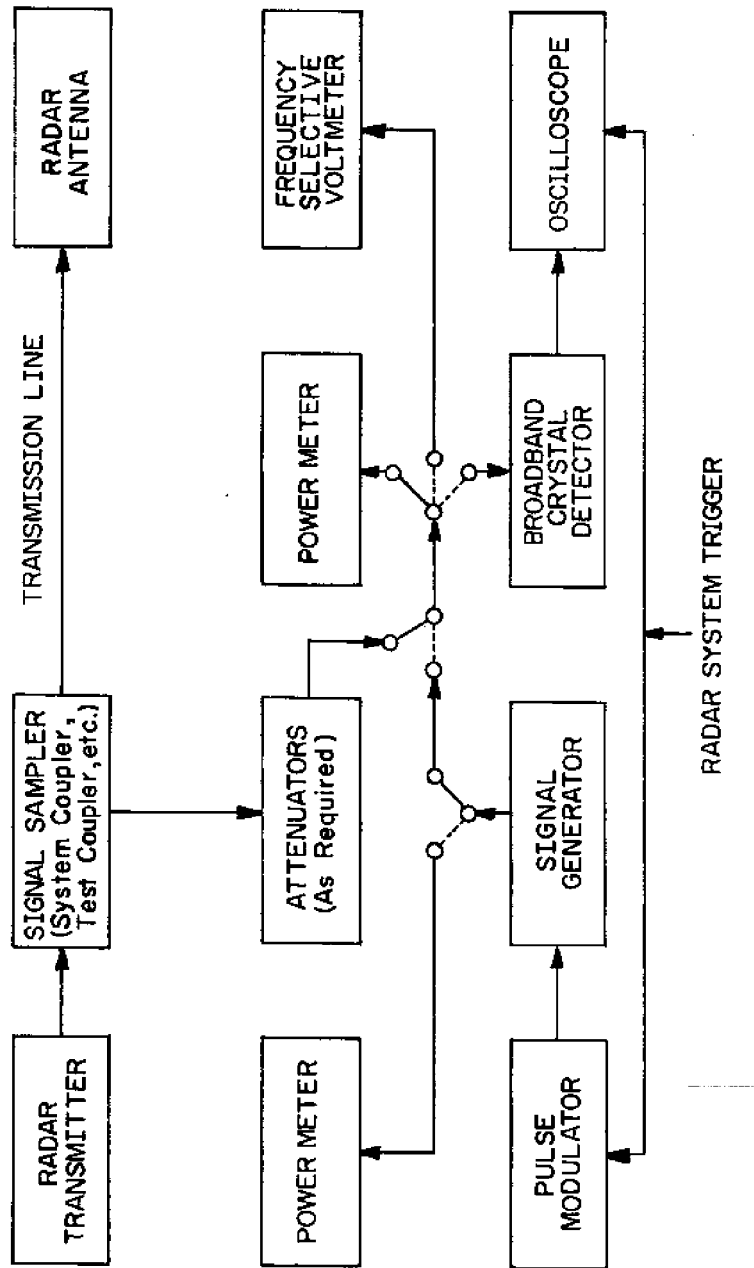


FIGURE 1. *Transmitter power output measurement block diagram.*

**TRANSMITTER MEASUREMENTS  
POWER OUTPUT  
INTERNALLY MODULATED PULSED TRANSMITTERS**

**Equipment under test**

Transmitter nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuning range or band \_\_\_\_\_  
Rated power output (indicate average, peak or PEP) \_\_\_\_\_ dBm  
Configuration \_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Point of signal injection \_\_\_\_\_  
Point of measurement \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

FIGURE 2. *Sample transmitter power output data form A.*

**TRANSMITTER MEASUREMENTS  
POWER OUTPUT**

Xmtr. Nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
Date. \_\_\_\_\_

Frequency (MHz)	Pulse width <sup>1</sup>		PRF		Measured power		Losses (dB) <sup>2</sup>	Power out	
	Nom ( $\mu$ sec)	Meas ( $\mu$ sec)	Nom (pps)	Meas (pps)	P <sub>Avg</sub> (dBm)	P <sub>p</sub> (dBm)		P <sub>Avg</sub> (dBm)	P <sub>p</sub> (dBm)

<sup>1</sup>1/2 Voltage.

<sup>2</sup>Signal sampler, attenuation inserted and transmission line components combined.

FIGURE 3. *Sample transmitter power output data form B.*

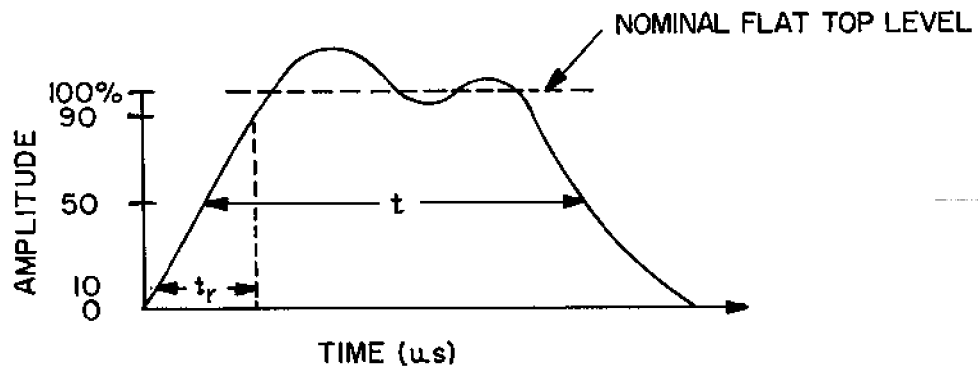
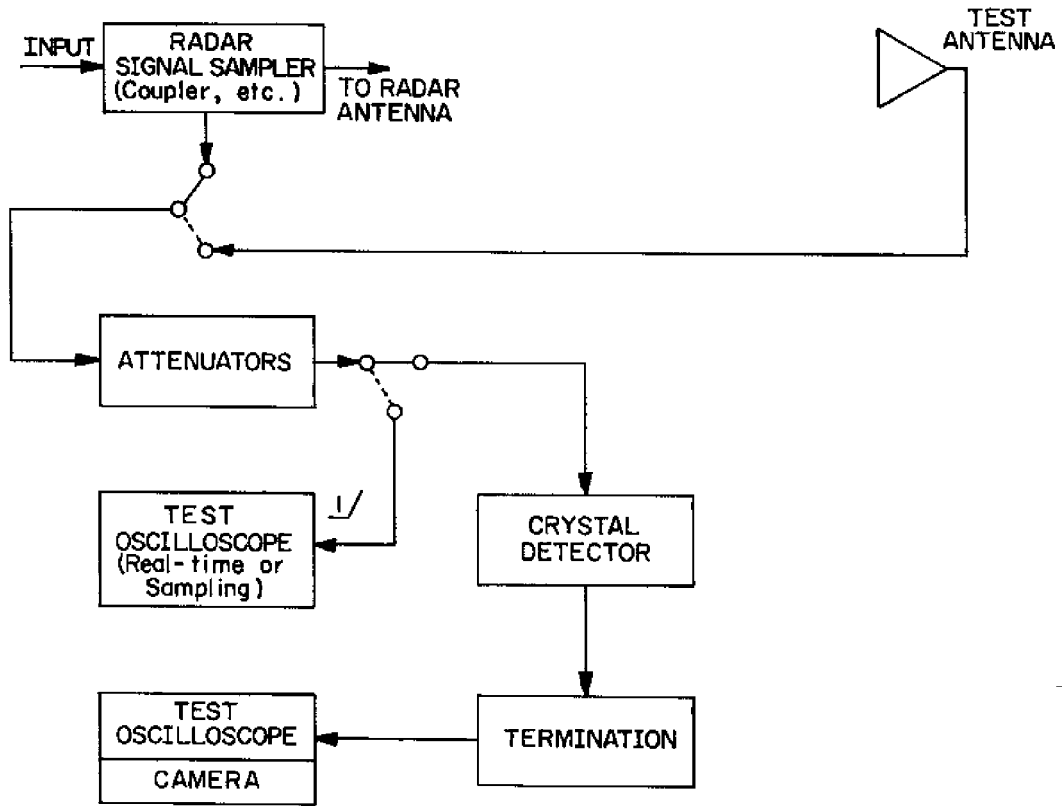


FIGURE 4. *Determination of  $t$  and  $t_r$  (pulse waveform).*



<sup>1</sup>Termination will be required if the input impedance is high.

FIGURE 5. *Transmitter pulse width, rise time and PRF measurement block diagram.*

**Equipment under test**

Transmitter nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuning range or band \_\_\_\_\_  
Modulation \_\_\_\_\_ Mod. BW \_\_\_\_\_  
Pulse width \_\_\_\_\_  $\mu$ sec, PRF \_\_\_\_\_ pps  
Configuration \_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Point of signal injection \_\_\_\_\_  
Point of measurement \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

FIGURE 6. *Sample transmitter pulse width data form A.*

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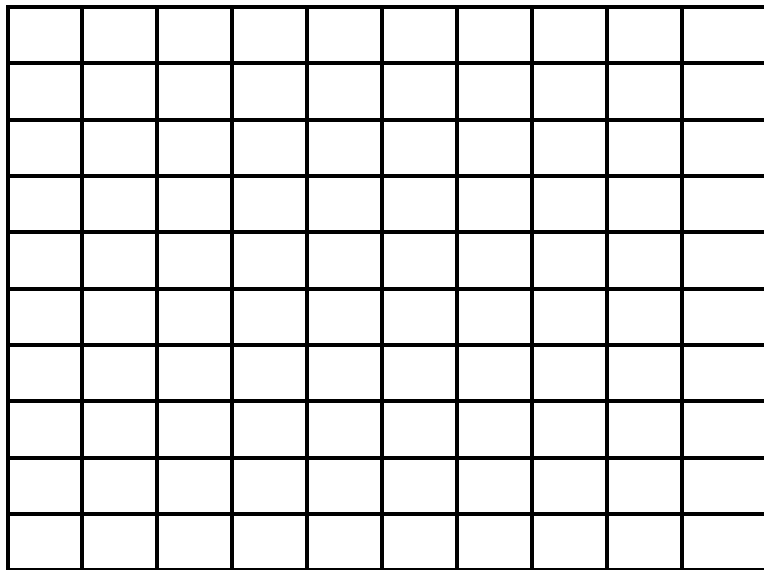
Xmtr. nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
Date. \_\_\_\_\_

Transmitter tuned freq. (MHz)	Photo No.	Time (24 hour base)	Pulse width of fund. ( $\mu$ sec)

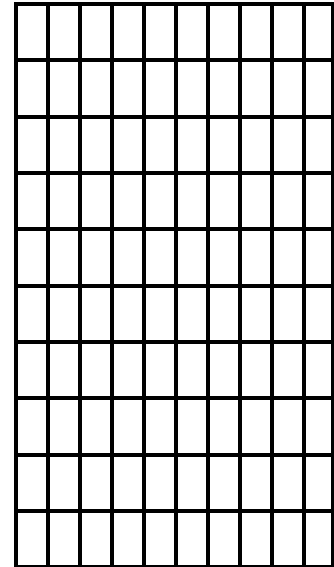
FIGURE 7. *Sample transmitter pulse width data form B.*



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Time  $\mu\text{sec}/\text{cm}$



Volts

Photo No. \_\_\_\_\_

Equipment nomenclature \_\_\_\_\_

Serial No. \_\_\_\_\_ Test equipment bandwidth \_\_\_\_\_

Tuned frequency ( $f_o$ ) \_\_\_\_\_ MHz

Test frequency \_\_\_\_\_ MHz

Measured values (from photograph)

Pulsewidth \_\_\_\_\_  $\mu\text{sec}$ <sup>1</sup> PRF \_\_\_\_\_ pps

Rise time \_\_\_\_\_  $\mu\text{sec}$ <sup>2</sup> Fall time \_\_\_\_\_  $\mu\text{sec}$

Comments \_\_\_\_\_

<sup>1</sup>50 Percent peak voltage point.

<sup>2</sup>10 to 90 Percent of peak voltage (fall time: vice versa).

FIGURE 8. *Sample transmitter pulse width or rise time data form.*

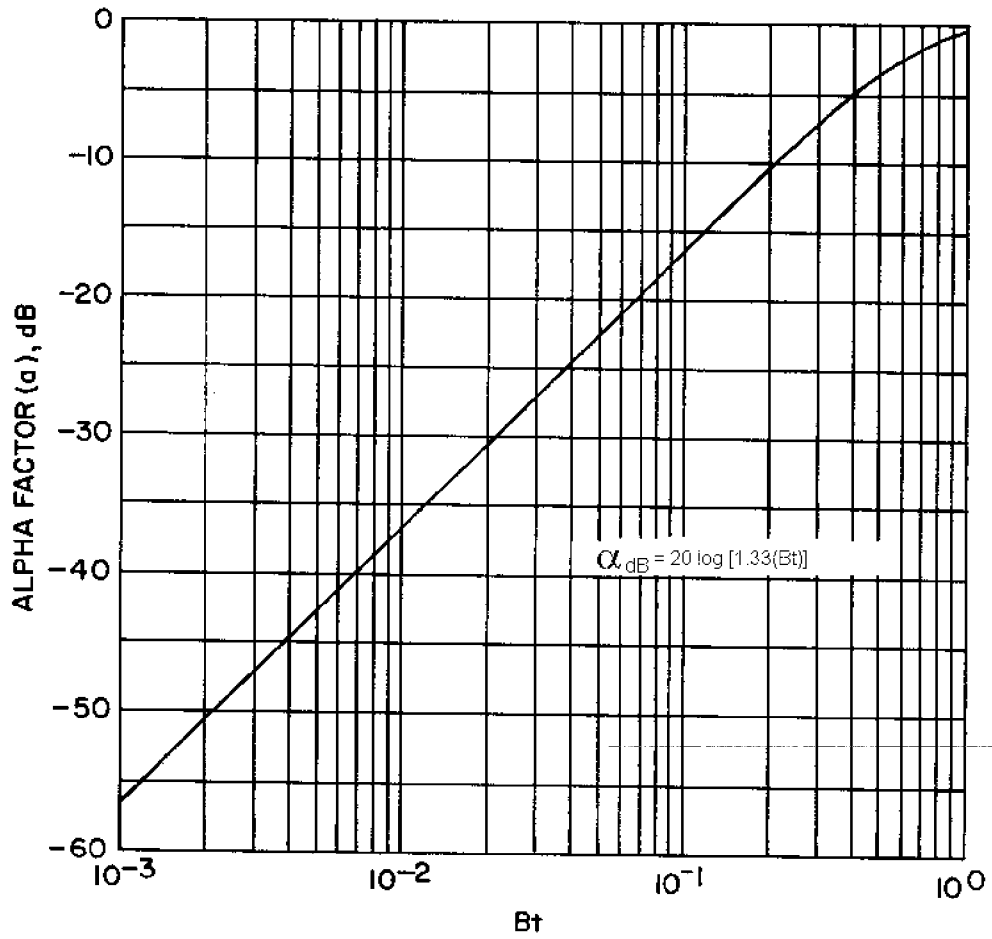


FIGURE 9. *Spectrum analyzer alpha factor (a) versus bandwidth (b) - pulse width (t) product.*

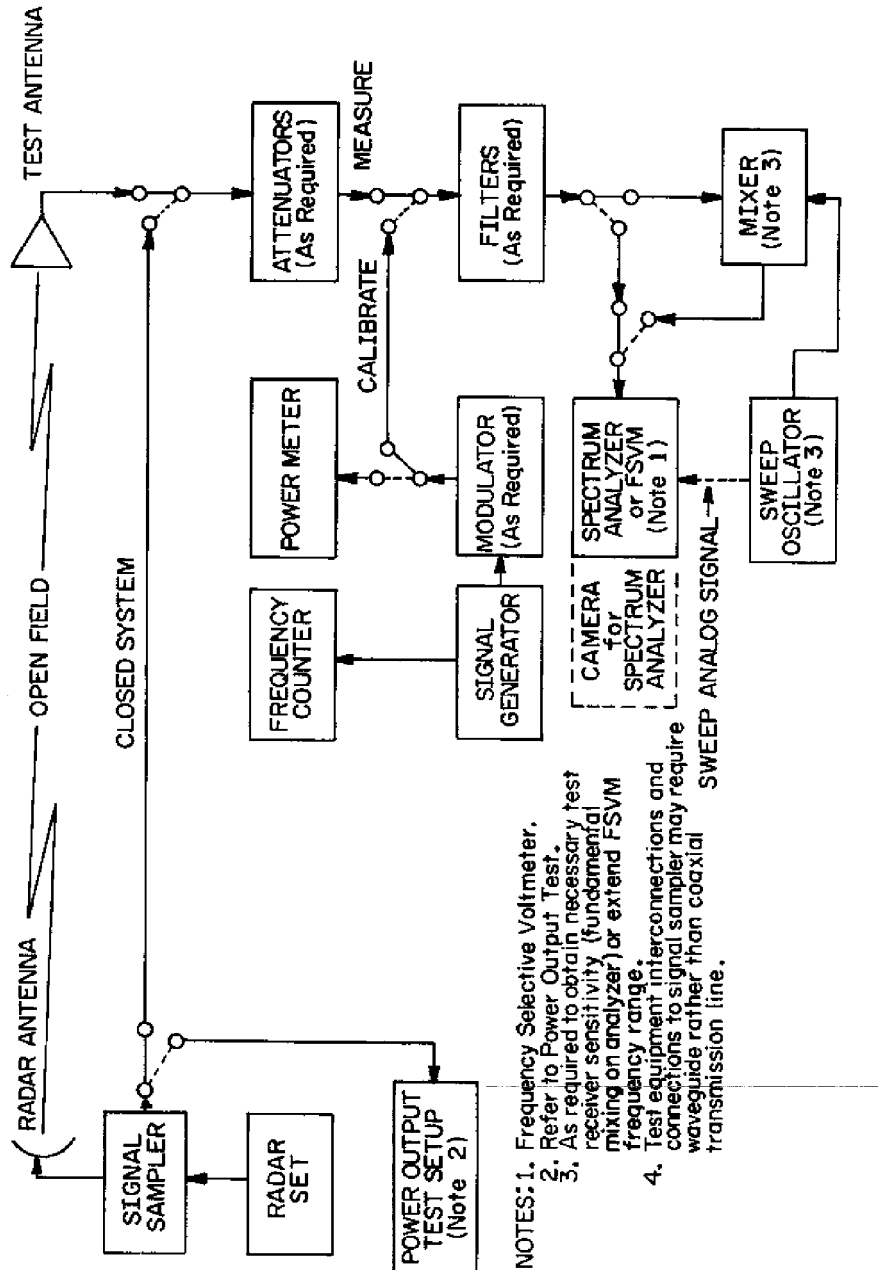


FIGURE 10. Transmitter emission characteristics measurement block diagram.

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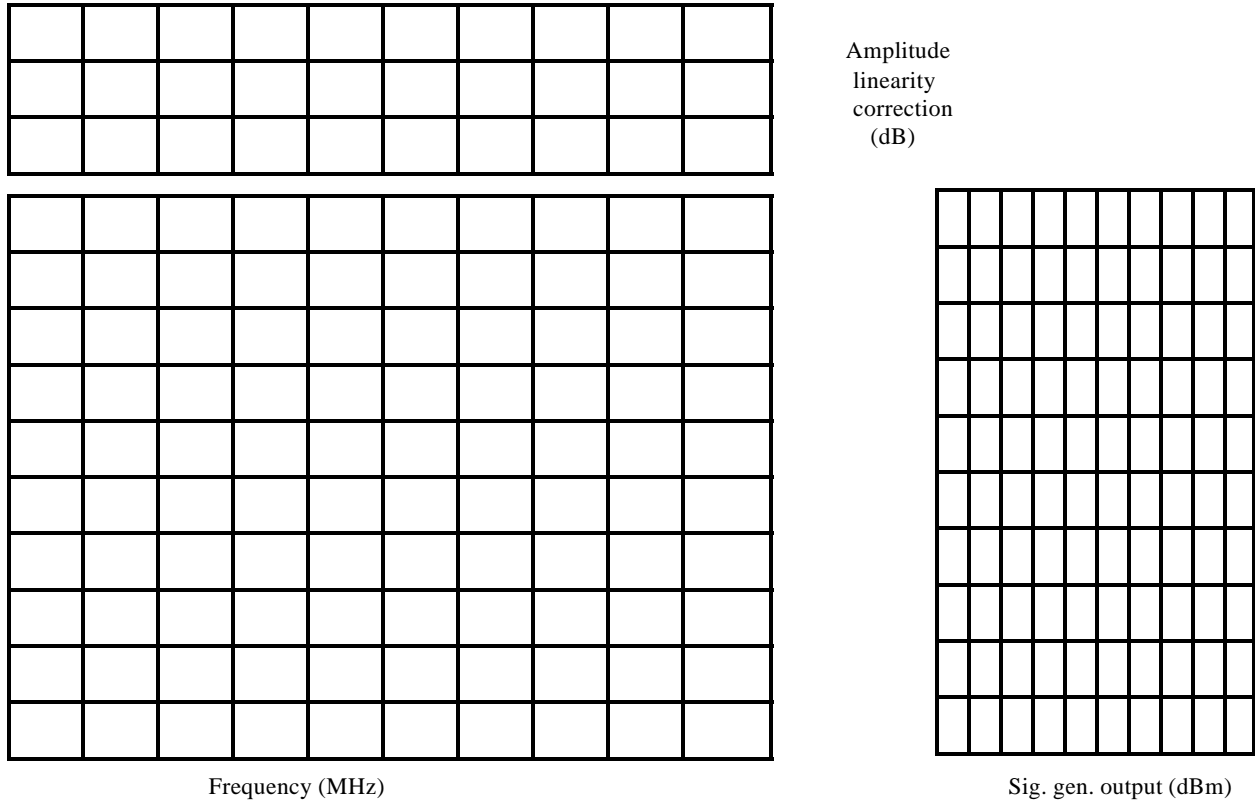


Photo number \_\_\_\_\_ Date \_\_\_\_\_

Transmitter tuned frequency \_\_\_\_\_ MHz Peak power output \_\_\_\_\_ dBm

Spectrum analyzer:

Bandwidth \_\_\_\_\_ kHz

Sweep width \_\_\_\_\_ MHz Sweep rate \_\_\_\_\_ Hz

Comments \_\_\_\_\_

NOTE: Each vertical and horizontal reticle should be calibrated either with an attached calibrated curve or by scaling the photograph.

FIGURE 11. *Sample transmitter emission spectrum photograph data form.*

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Date: \_\_\_\_\_ Time: \_\_\_\_\_ Transmitter tuned frequency: \_\_\_\_\_

Peak power output: \_\_\_\_\_ dBm Pulsewidth: \_\_\_\_\_  $\mu$ sec Pulse repetition frequency: \_\_\_\_\_ pps

Modulation: \_\_\_\_\_ Compression ratio: \_\_\_\_\_

Spectrum analyzer resolution bandwidth: \_\_\_\_\_ kHz

OPEN FIELD TESTS: Test antenna: \_\_\_\_\_ Gain: \_\_\_\_\_ dB Polarization: \_\_\_\_\_

Height above ground: \_\_\_\_\_ feet Alinement (relative to radar antenna): Bearing: \_\_\_\_\_ degrees

Elevation: \_\_\_\_\_ degrees Polarization: \_\_\_\_\_ Coupling (radar-to-test antenna terminals): \_\_\_\_\_ dB

Frequency (MHz)	$\Delta f$ ( $\pm$ MHz) <sup>1</sup>	Signal generator level (dBm)	Measured cable loss (dB)	Attenuation inserted (dB)	Coupling (dB) <sup>2</sup>	Power spectral level (dBm/kHz)

<sup>1</sup>Referenced to transmitter tuned frequency.

<sup>2</sup>Closed system - coupling, sampler attenuated output to radar antenna input.

Open field - coupling, radar antenna input to test antenna terminals.

FIGURE 12. *Sample transmitter emission spectrum data form.*

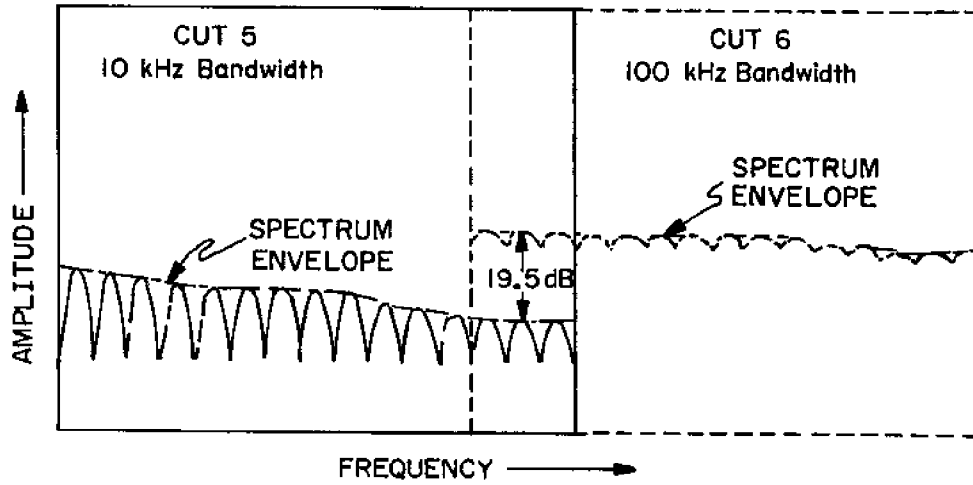


FIGURE 13. *Illustration of emission spectrum photographs, overlap and analyzer bandwidth increased.*

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Pulsed Coax  
Nonpulsed

Waveguide

**Equipment under test**

Xmtr nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Output tube \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

Spectrum analyzer used \_\_\_\_\_ Serial No. \_\_\_\_\_  
3 dB resolution BW \_\_\_\_\_ kHz CW BW \_\_\_\_\_ kHz  
MDS \_\_\_\_\_ dBm  
Modulation description \_\_\_\_\_  
Cable: Type \_\_\_\_\_ Length \_\_\_\_\_ Meters

Significant control positions

**Test information**

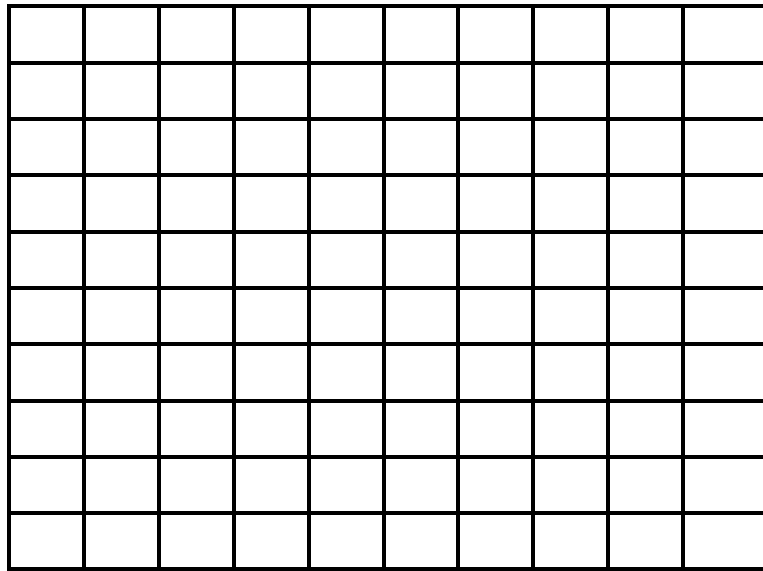
Description of analyzed pulse:

PW <sup>1</sup>	PRF
Rise time	Fall time
Compression ratio	

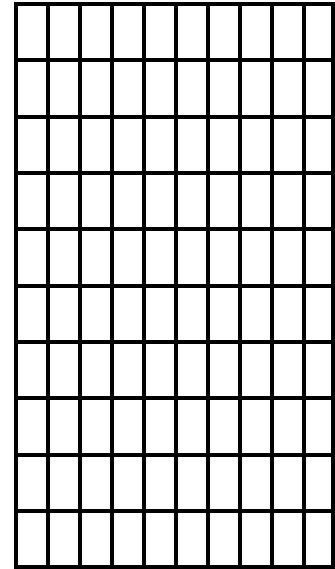
<sup>1</sup>50 percent voltage point, rise time: 10 to 90 percent Peak voltage (fall time vice versa)

FIGURE 14. *Sample transmitter closed system spurious emission data form A.*

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Frequency (MHz)



Sig. gen. output (dBm)

Photo No. \_\_\_\_\_ Date \_\_\_\_\_

Transmitter tuned frequency \_\_\_\_\_ MHz

Spectrum analyzer:

Bandwidth \_\_\_\_\_ kHz

Sweep width \_\_\_\_\_ MHz Sweep rate \_\_\_\_\_ Hz

Comments \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

NOTE: Each vertical and horizontal reticle should be calibrated either with an attached calibrated curve or by scaling the photograph.

FIGURE 15. Sample transmitter closed system spurious emission data form B.



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Pulsed  
Nonpulsed

Date \_\_\_\_\_

Coax  
Waveguide

Frequency		Indent.	Sig. gen. output (dBm)	Losses (dB)	P.S.L. <sup>1</sup> (dBm/kHz)
Xmtr. tuned (MHz)	Spurious (MHz)				

<sup>1</sup>Power spectral level.

FIGURE 16. *Sample transmitter closed system spurious emission data form C.*

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Pulsed  
Nonpulsed

Coax  
Waveguide

**Equipment under test**

Xmtr nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Output tube \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Pwr. out. \_\_\_\_\_ dBm Avg. \_\_\_\_\_ dBm peak  
Modulation \_\_\_\_\_  
Far field distance \_\_\_\_\_ Ft. \_\_\_\_\_ Meters  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

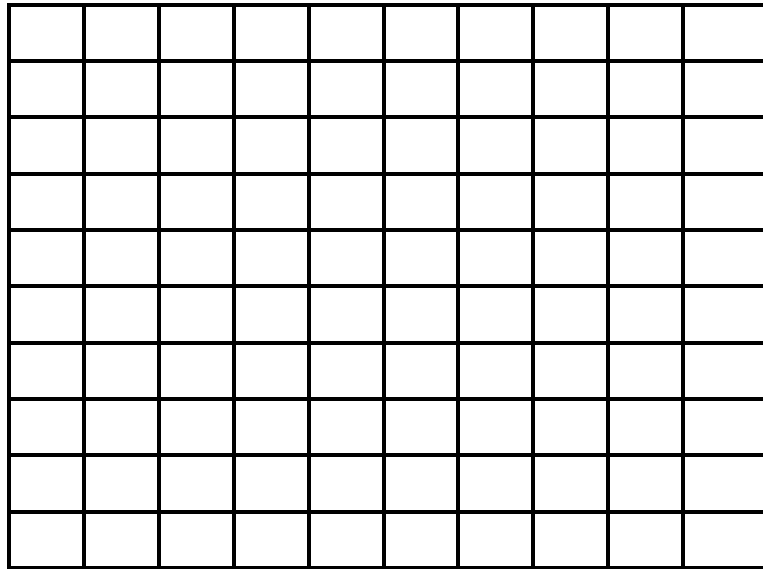
Spectrum analyzer used \_\_\_\_\_ , MDS \_\_\_\_\_ dBm  
3 dB resolution BW \_\_\_\_\_ kHz CW BW \_\_\_\_\_ kHz  
Test antenna: Type \_\_\_\_\_ Polarity \_\_\_\_\_  
Cable: Type \_\_\_\_\_ Length \_\_\_\_\_ Meters  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

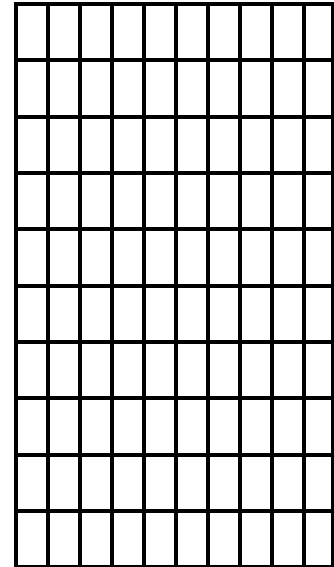
Radar site elevation \_\_\_\_\_ Ft. MSL  
Test site elevation \_\_\_\_\_ Ft. MSL  
Antenna height \_\_\_\_\_ Ft.  
Measurement distance \_\_\_\_\_  
\_\_\_\_\_  
Unusual terrain features or man made objects \_\_\_\_\_  
\_\_\_\_\_

FIGURE 17. *Sample transmitter open field spurious emission data form A.*

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APPENDIX A



Frequency (MHz)



Sig. gen. output (dBm)

Photo No. \_\_\_\_\_ Date \_\_\_\_\_

Transmitter tuned frequency \_\_\_\_\_ MHz Peak power output \_\_\_\_\_ dBm

Spectrum analyzer:

Bandwidth \_\_\_\_\_ kHz

Sweep width \_\_\_\_\_ MHz Sweep rate \_\_\_\_\_ Hz

Comments \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

NOTE: Each vertical and horizontal reticle should be calibrated either with an attached calibrated curve or by scaling the photograph.

FIGURE 18. *Sample transmitter open field spurious emission data form B.*

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Pulsed  
Nonpulsed

Coax  
Waveguide

Xmtr tuned freq \_\_\_\_\_ Peak power output \_\_\_\_\_ dBm  
Nominal PW \_\_\_\_\_ Nominal PRF \_\_\_\_\_

Rise time \_\_\_\_\_ Fall time \_\_\_\_\_  
Modulation \_\_\_\_\_ Compression ratio \_\_\_\_\_

Freq. (MHz)	Date/ time (24 hr base)	Test antenna orientation				S.G. S/A input <sup>1</sup> (dBm)	Measured cable lose		Attenu- ation inserted (dB)	Test ant.- radar ant. coupling (dB)	Power spectral level (dBm/kHz)
		$\theta$ (deg)	$\phi$ (deg)	$\omega$ (deg)	Ht (m)		S.G.-S/A (dB)	Ant.-S/A (dB)			

<sup>1</sup> State type of signal used.

NOTE: Record received energy in units actually measured; if converted to other units, report raw data and calculations on separate sheet.

FIGURE 19. *Sample transmitter open field spurious emission data form C.*

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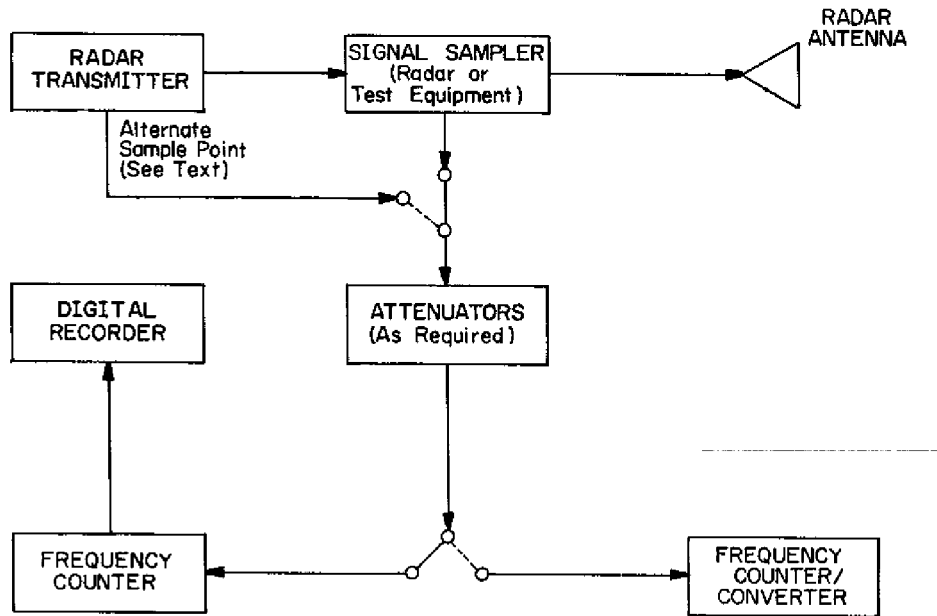


FIGURE 20. *Transmitter frequency stability measurement block diagram.*

**TRANSMITTER MEASUREMENTS  
CARRIER FREQUENCY STABILITY  
INTERNALLY MODULATED PULSED TRANSMITTERS**

**Equipment under test**

Transmitter nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuned freq. \_\_\_\_\_ MHz  
Configuration \_\_\_\_\_  
Date and time equip. last operated \_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Frequency stability \_\_\_\_\_ Parts/million  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Point of signal injection \_\_\_\_\_  
Point of measurement \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

FIGURE 21. *Sample transmitter frequency stability data form A.*

**TRANSMITTER MEASUREMENTS  
CARRIER FREQUENCY STABILITY  
INTERNALLY MODULATED PULSED TRANSMITTERS**

Xmtr. nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuned frequency \_\_\_\_\_ MHz

Date	Time	Frequency (MHz)	Date	Time	Frequency (MHz)

FIGURE 22. *Sample transmitter frequency stability data form B.*

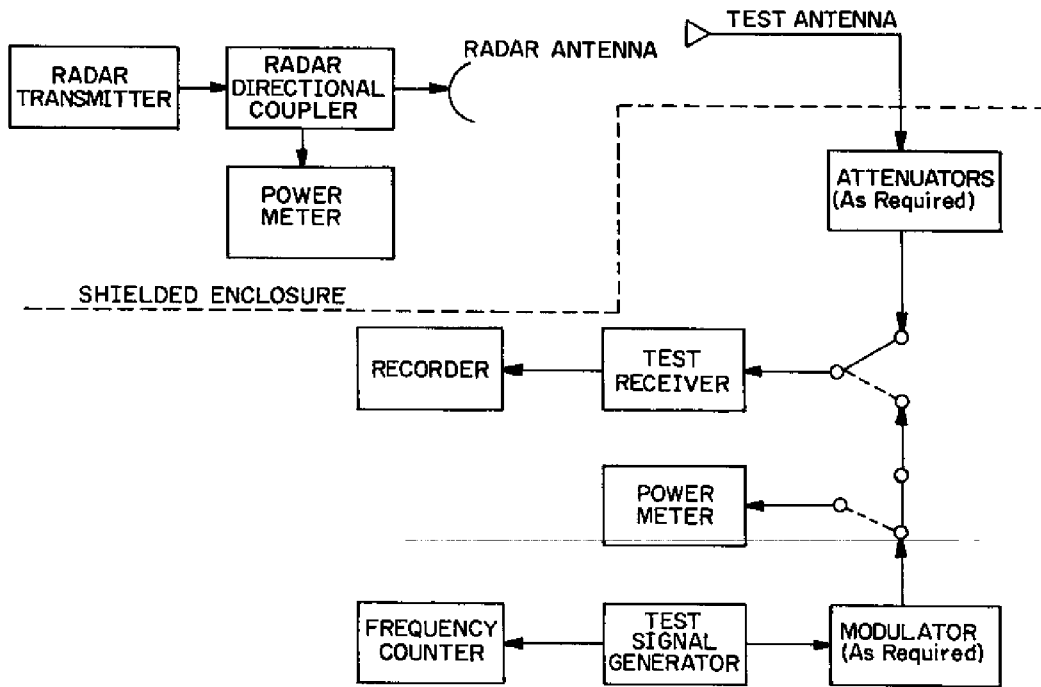


FIGURE 23. *Antenna pattern and median gain measurement block diagram.*



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ANTENNA LOBE SUPPRESSION

Date \_\_\_\_\_ Time \_\_\_\_\_ Transmitter tuned frequency \_\_\_\_\_  
 Peak power output \_\_\_\_\_ dBm Pulsewidth \_\_\_\_\_  $\mu$ s Pulse repetition freq. \_\_\_\_\_ pps  
 Test receiver \_\_\_\_\_ Bandwidth \_\_\_\_\_ MHz Attenuation inserted \_\_\_\_\_ dB  
 Antenna rotation speed \_\_\_\_\_ r/min Recorder speed \_\_\_\_\_  
 Test antenna orientation:  $\theta$  \_\_\_\_\_  $^\circ$ ,  $\phi$  \_\_\_\_\_  $^\circ$ ,  $\omega$  \_\_\_\_\_  $^\circ$ , height \_\_\_\_\_ meters  
 Power density at test antenna \_\_\_\_\_ dBm/m<sup>2</sup>

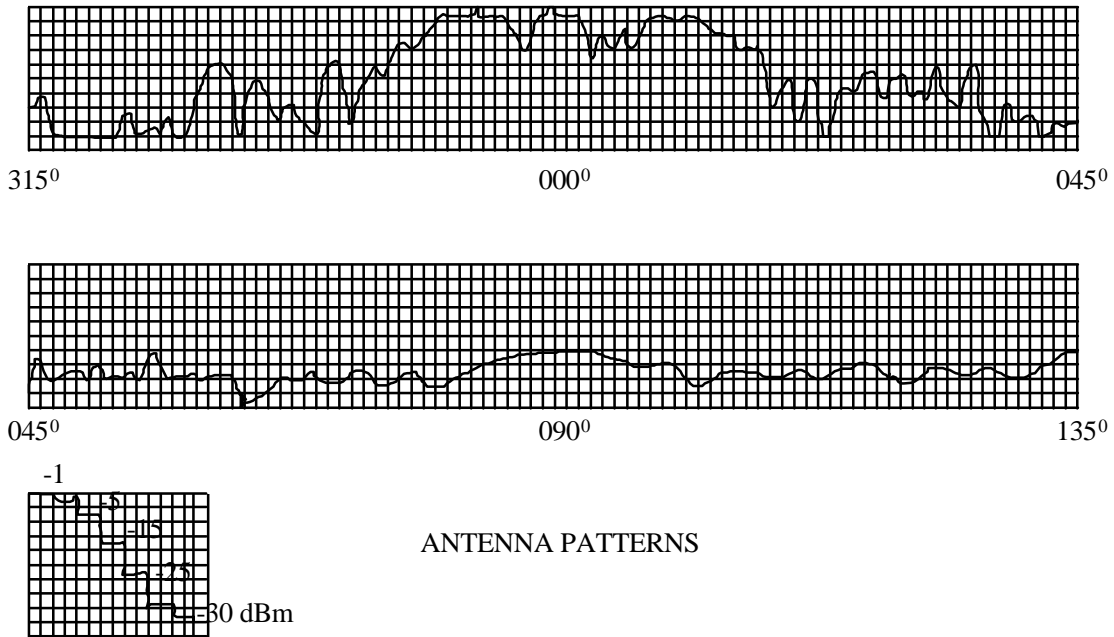


FIGURE 24. Sample antenna pattern data format (sample antenna pattern).

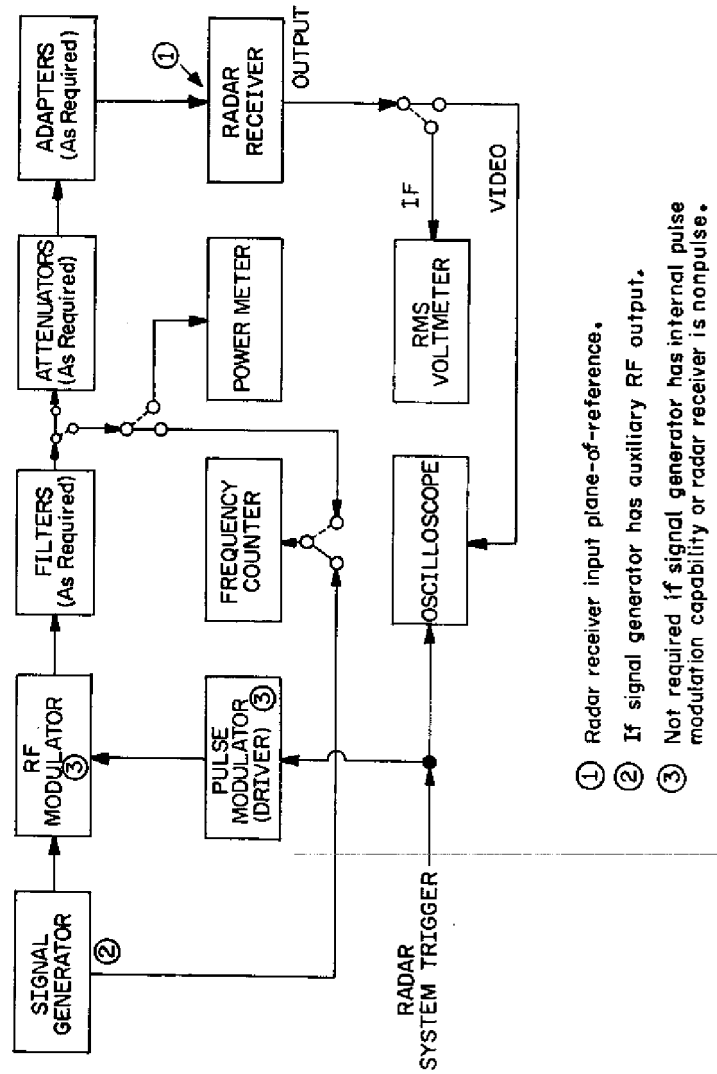


FIGURE 25. Receiver response characteristics measurement block diagram  $\leq 10$  GHz.

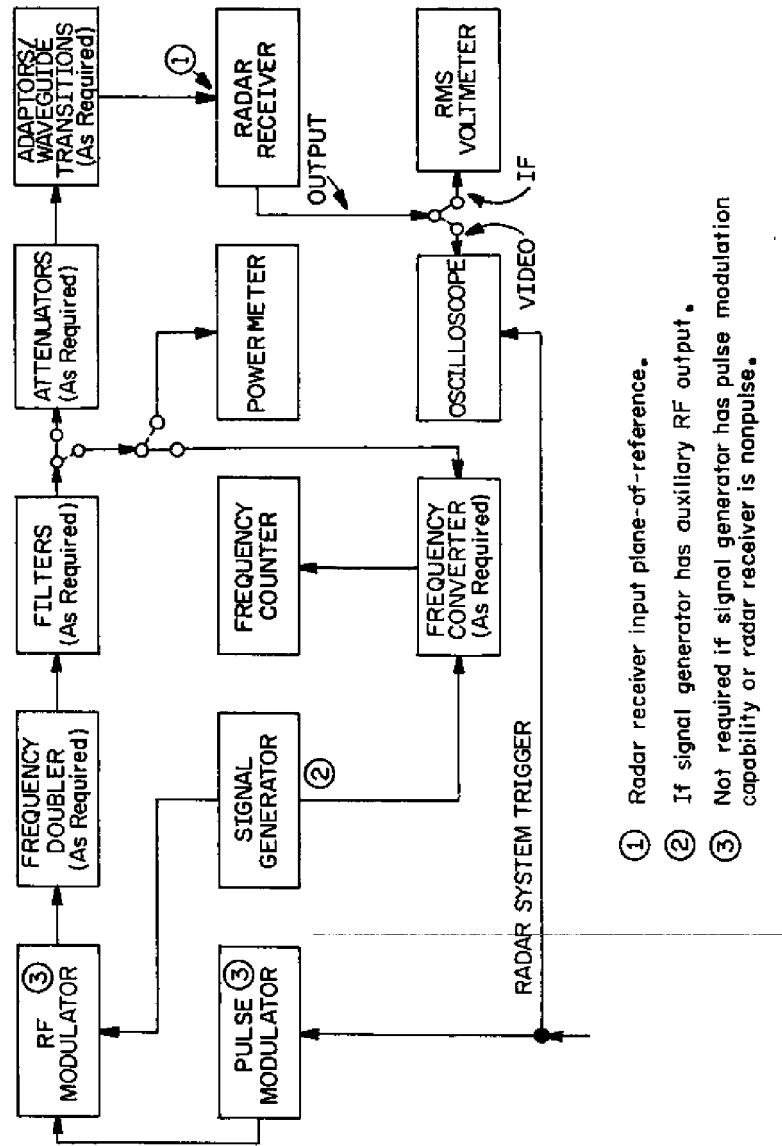


FIGURE 26. *Receiver response characteristics measurement block diagram >10 GHz.*

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**Equipment under test**

Receiver nomenclature \_\_\_\_\_  
Configuration \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuned freq. \_\_\_\_\_ MHz MDS \_\_\_\_\_ dBm  
Nominal characteristics:  
PW \_\_\_\_\_  $\mu$ sec PRF \_\_\_\_\_ pps  
Sensitivity \_\_\_\_\_ dBm Noise figure \_\_\_\_\_  
3 dB Bandwidth \_\_\_\_\_ kHz  
Local osc. freq.  
1. \_\_\_\_\_ , Above, Below  
2. \_\_\_\_\_ , Above, Below  
3. \_\_\_\_\_ , Above, Below  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Test pulse: PW \_\_\_\_\_  $\mu$ sec PRF \_\_\_\_\_ pps  
MDS w/test pulse \_\_\_\_\_ dBm  
Point of signal injection \_\_\_\_\_  
Measurement point \_\_\_\_\_  
Std. response used \_\_\_\_\_

FIGURE 27. *Sample pulsed receiver data form.*

**Equipment under test**

Receiver nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuning range or band \_\_\_\_\_  
Nominal: Bandwidth \_\_\_\_\_ kHz  
Sensitivity \_\_\_\_\_ dBm  
Configuration \_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Test signal modulation:  
Frequency \_\_\_\_\_ Hz, Percentage \_\_\_\_\_ %  
Point of signal injection \_\_\_\_\_  
Point of measurement \_\_\_\_\_  
Std. response used \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

FIGURE 28. *Sample nonpulsed receiver selectivity data form.*

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Receiver nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuned frequency \_\_\_\_\_MHz Date \_\_\_\_\_

Relative response (dB)	Absolute freq. (MHz)	- $\Delta f$ (kHz)	Absolute freq. (MHz)	+ $\Delta f$ (kHz)	Bandwidth (kHz)

FIGURE 29. *Sample receiver selectivity data form A.*

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Rcvr. nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuned frequency \_\_\_\_\_MHz

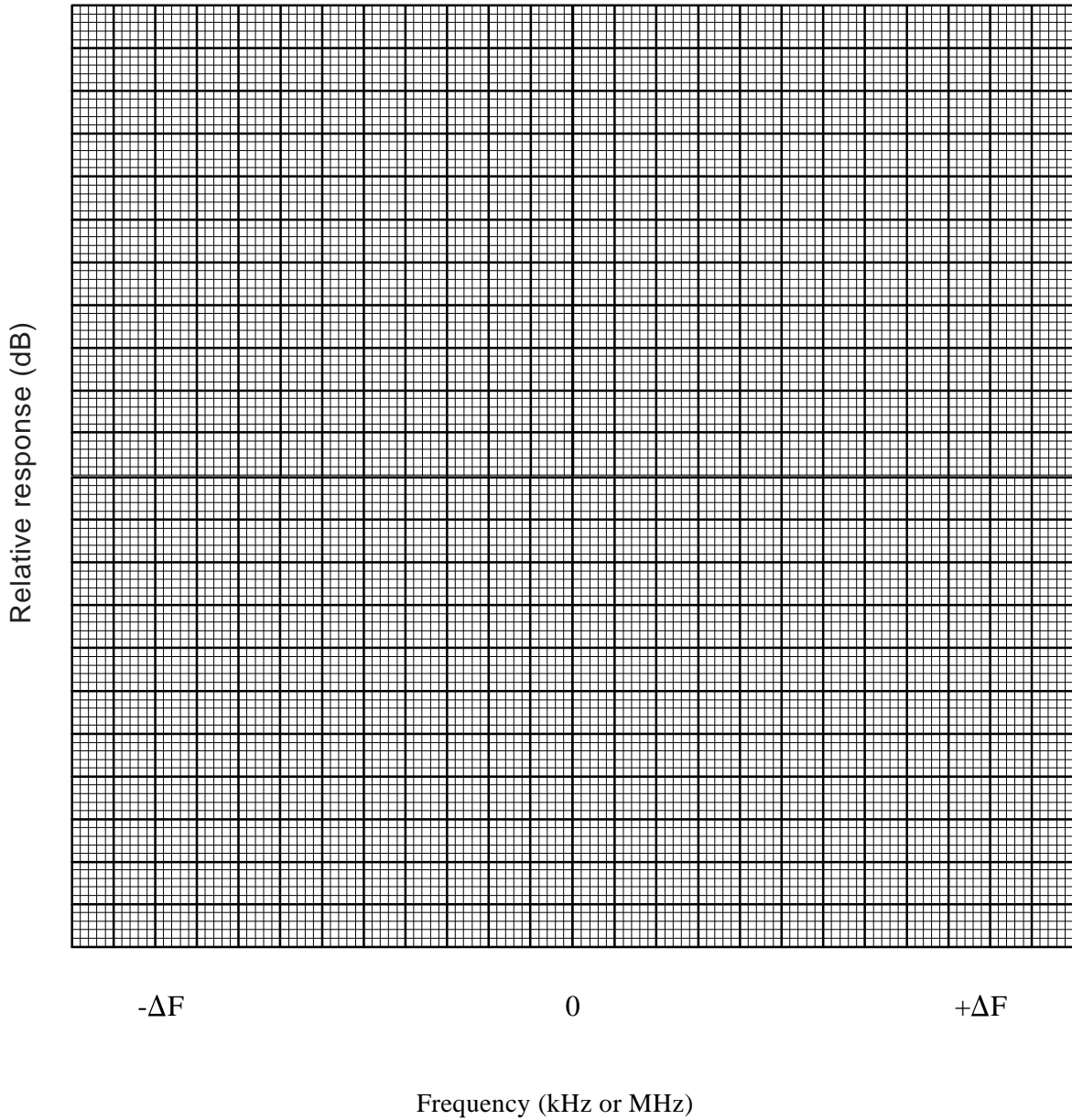


FIGURE 30. *Sample receiver selectivity data form B.*

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**Equipment under test**

Receiver nomenclature \_\_\_\_\_

Type \_\_\_\_\_ Serial No. \_\_\_\_\_

Tuning band \_\_\_\_\_

LO freq.		Injection multiple		IF freq.	
1. _____	MHz	1. _____		1. _____	MHz
2. _____	MHz	2. _____		2. _____	MHz
3. _____	MHz	3. _____		3. _____	MHz

Significant control positions \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Significant control positions \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Test signal modulation:

Frequency \_\_\_\_\_ Hz Percentage \_\_\_\_\_ %

or PW \_\_\_\_\_  $\mu$ sec PRF \_\_\_\_\_ pps

Point of signal injection \_\_\_\_\_

Point of measurement \_\_\_\_\_

Std. response used \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

FIGURE 31. *Sample receiver spurious response data form A.*



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Receiver nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
 Tuned frequency \_\_\_\_\_ MHz Date \_\_\_\_\_  
 Measured LO frequency (1) \_\_\_\_\_ MHz (2) \_\_\_\_\_ MHz (3) \_\_\_\_\_ MHz  
 Injection multiple (1) \_\_\_\_\_ (2) \_\_\_\_\_ (3) \_\_\_\_\_  
 IF frequency (1) \_\_\_\_\_ MHz (2) \_\_\_\_\_ MHz (3) \_\_\_\_\_ MHz

Spurious frequency (MHz)	Sig. gen. output (dBm)	Atten. SG-Rcvr (dB)	Power input (dBm)	Mixer identification									Response
				First			Second			Third			
				P	Q	Sign	P	Q	Sign	P	Q	Sign	

FIGURE 32. Sample receiver spurious response data form B.

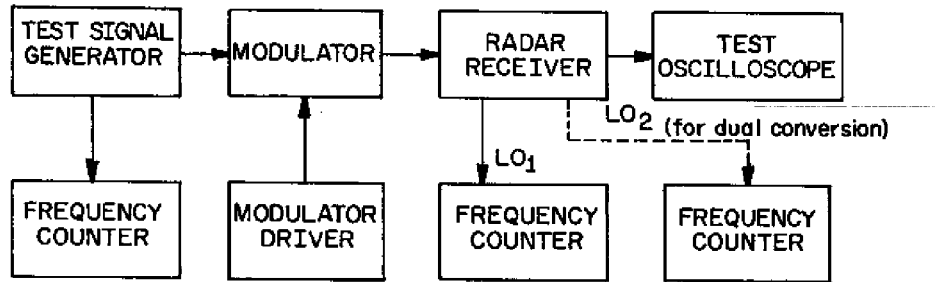


FIGURE 33. Receiver tunability and frequency stability measurement block diagram.

**Equipment under test**

Receiver nomenclature \_\_\_\_\_  
Type \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuning range or band \_\_\_\_\_ MHz  
Nominal sensitivity \_\_\_\_\_ dBm  
3 dB Bandwidth \_\_\_\_\_ kHz  
Configuration \_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test equipment**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
Significant control positions \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Test information**

Test signal modulation:  
Frequency \_\_\_\_\_ Hz Percentage \_\_\_\_\_ %  
or PW \_\_\_\_\_  $\mu$ sec PRF \_\_\_\_\_ pps  
Point of signal injection \_\_\_\_\_  
Point of measurement \_\_\_\_\_  
Std. response used \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

FIGURE 34. *Sample receiver tunability and frequency data form.*

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Receiver nomenclature \_\_\_\_\_  
Test signal modulation \_\_\_\_\_

Serial No. \_\_\_\_\_  
Date \_\_\_\_\_

Tuned frequency (MHz)	Sig. gen. frequency (MHz)	Sig. gen. power (dBm)	Attenuation inserted and cable loss (dB)	Coupling loss (dB)	Power input (dBm)

FIGURE 35. *Sample receiver tunability data form.*

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Receiver nomenclature \_\_\_\_\_  
 Tuned frequency \_\_\_\_\_ MHz  
 No. 1 generator frequency \_\_\_\_\_ MHz

Serial No. \_\_\_\_\_  
 Date \_\_\_\_\_  
 Turn-on time \_\_\_\_\_

<i>Time</i>	<i>No. 2 generator frequency (MHz)</i>	<i>Frequency tolerance (parts/million)</i>	<i>Time</i>	<i>No. 2 generator frequency (MHz)</i>	<i>Frequency tolerance (parts/million)</i>

FIGURE 36. Sample frequency stability data form.

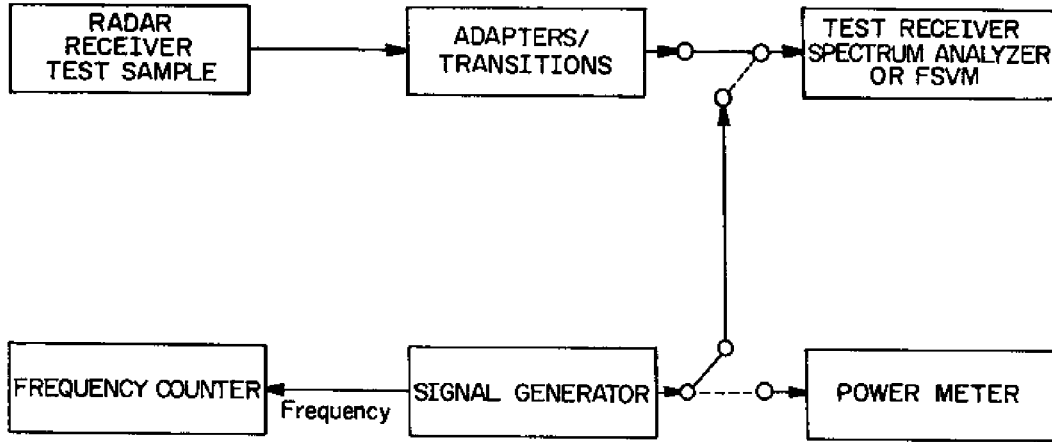


FIGURE 37. Receiver oscillator radiation measurement block diagram.

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Receiver nomenclature \_\_\_\_\_ Serial No. \_\_\_\_\_  
Tuned frequency \_\_\_\_\_ MHz Date \_\_\_\_\_  
LO frequency \_\_\_\_\_ MHz

Radiated frequency	Frequency identification	Sig. gen. output (dBm)	Adapter attenuation (dB)	Power output (dBm)

FIGURE 38. *Sample receiver oscillator radiation data form B.*

***Equipment under test***

*Receiver nomenclature* \_\_\_\_\_  
*Type* \_\_\_\_\_ *Serial No.* \_\_\_\_\_  
*Tuning range or band* \_\_\_\_\_  
*Configuration* \_\_\_\_\_  
*Significant control positions* \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

***Test equipment***

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
*Significant control positions* \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

***Test information***

*Point of signal injection* \_\_\_\_\_  
*Point of measurement* \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

*FIGURE 39. Sample receiver oscillator radiation data form A.*



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Ship: \_\_\_\_\_ Date: \_\_\_\_\_  
System ant: \_\_\_\_\_ Xntr power: \_\_\_\_\_  
Radiation cutouts: A, CW \_\_\_\_\_ CCW \_\_\_\_\_ EL \_\_\_\_\_  
Backlash: AZ CW \_\_\_\_\_ CW \_\_\_\_\_ EL \_\_\_\_\_  
Radiation zone: AZ \_\_\_\_\_ EI \_\_\_\_\_

Power density measurements data sheet (directed beam antennas)					
AZ (degrees)	EL (degrees)	PD mW/cm <sup>2</sup>	Location		Comments
			Deck	Frame	

FIGURE 40. *Sample power density measurements data sheet (directed beam antennas).*

# STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

## INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
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### I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER  
MIL-STD-469B

2. DOCUMENT DATE (YYMMDD)  
960624

3. DOCUMENT TITLE RADAR ENGINEERING INTERFACE REQUIREMENTS, ELECTROMAGNETIC COMPATIBILITY

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

### 5. REASON FOR RECOMMENDATION

### 6. SUBMITTER

a. NAME (Last, First, Middle Initial)

b. ORGANIZATION

c. ADDRESS (Include Zip Code)

d. TELEPHONE (Include Area Code)  
(1) Commercial  
(2) AUTOVON  
(if applicable)

7. DATE SUBMITTED  
(YYMMDD)

### 8. PREPARING ACTIVITY

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703-602-9370 EXT 219  
(2) AUTOVON  
332-9370

c. ADDRESS (Include Zip Code)

COMMANDER, NAVAL SEA SYSTEMS COMMAND  
ATTN: SEA 03R42  
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