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MILITARY STANDARD

RADAR ENGINEERING DESIGN REQUIREMENTS
ELECTROMAGNETIC COMPATIBILITY

FSC 5800

DEPARTMENT OF DEFENSE

WASHINGTON, D.C. 20301

Radar Engineering Design Requirements, Electromagnetic Compatibility
MIL-STD-469

1. This standard is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to Commander, Naval Ship Engineering Center, Washington, D.C., 20360.

FOREWORD

The expanding application of radar for various military functions and purposes, with attendant expansion of demands on the electromagnetic spectrum, has given rise to serious concern relative to the formulation and application of more effective standards of frequency management for such equipment. As an initial step, adoption of minimum engineering design requirements was considered necessary. The engineering design criteria set forth in this document are considered necessary to achieve electromagnetic compatibility and improve accommodation of expanding radar requirements within the limited spectrum space available.

The design requirements and criteria stated herein are not intended to prohibit or inhibit the free and unrestricted approach of research in the development of new radar systems which promise an increase in effectiveness. It is recognized that certain requirements stated herein are not applicable to all types of radar systems. When these situations exist, the intent of the requirements shall be applied with best engineering judgment and approval by the procuring activity. Contractor's engineering proposals shall contain all information required by the procuring activity pertaining to this standard.

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TABLES

RADAR ENGINEERING DESIGN REQUIREMENTS, ELECTROMAGNETIC COMPATIBILITY

1. SCOPE

1.1 The engineering design requirements set forth herein are established to control the spectral characteristics of all new radar systems operating between 100 and 40,000 megahertz (MHz) in an effort to achieve electromagnetic compatibility and to conserve the frequency spectrum available to Military radar systems.

2. REFERENCE DOCUMENTS

2.1 Not applicable.

3. DEFINITIONS AND SYMBOLS

3.1 Definitions

3.1.1 Antenna. - An antenna is a device employed as a means for radiating or receiving radio-frequency energy.

3.1.1.1 Fixed elevation antenna. - A fixed elevation antenna is one designed for fixed in elevation. In order to operate at other elevations, the antenna must be manually positioned and secured by the use of bolts, retaining pins, and other fasteners.

3.1.1.2 Elevatable antenna. - An elevatable antenna is one designed for operational maneuverability in the vertical plane regardless of the upper or lower mechanical limits.

3.1.1.3 Rotatable antennas. - Rotatable antennas are antennas designed to rotate through 360 degrees in azimuth.

3.1.1.4 Semi-elevatable antennas. - Semi-elevatable antennas are antennas designed to elevate through an angle less than 80 degrees, or stepped in increments in the elevation plane.

3.1.1.5 System antenna. - A system antenna is the antenna whose characteristics are being measured.

3.1.1.6 Test antenna. - The test antenna is the antenna associated with the measurement equipment.

3.1.2 Minimum test site distance. - A minimum test site distance is that distance between two antennas for open-field tests to ensure no near-field or Fresnel Region radiation pattern effects with respect to both antennas. This minimum distance is equal to D^2/λ or 3λ, whichever is larger, where D is the maximum aperture dimension of the largest antenna, and λ is the wavelength at the fundamental frequency. If the test antenna aperture (D_2) is larger than one-tenth of the aperture (D_1) of the antenna being measured, then the minimum test-site distance is $(D_1 + D_2)^2/2\lambda$.

3.1.3 Assigned frequency. - The assigned frequency is the center of the frequency band assigned to a specific equipment or system.

3.1.4 Frequency coverage of test equipment. - Frequency coverage of test equipment is that range (or those ranges) of frequencies over which the test equipment is designed to operate; for example, the frequency coverage of the AN/URM-XX may be 0.15 to 0.4 MHz and 1.5 to 1000 MHz.

3.1.4.1 Tuning band. - The tuning band is that partial range of the tuning frequency range over which a particular configuration of test equipment operates with a given bandswitch setting; for example, tuning band elements of the AN/URM-XX may cover the following tuning bands:

Band 1: 0.15 to 0.4 MHz
Band 2: 0.35 to 0.92 MHz

Band 3: 0.9 to 2.45 MHz
Band 4: 2.4 to 6.3 MHz
Band 5: 6.0 to 15.4 MHz
Band 6: 15.0 to 30.0 MHz

3.1.4.2 Tuning frequency range. - Tuning frequency range is that partial range of the frequency coverage over which a particular configuration of test equipment operates; for example, the AN/URM-XX may have the following tuning frequency range:

0.15 to 30 MHz with head - 1 installed
20 to 200 MHz with head - 2 installed
200 to 410 MHz with head - 3 installed
400 to 1000 MHz with head - 4 installed

3.1.5 Frequency-selective voltmeter (FSVM). - A frequency-selective voltmeter is a frequency selective radio receiver calibrated as a two terminal voltmeter; for example, a field-intensity meter.

3.1.6 Frequency tolerance. - Frequency tolerance is the maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency. The frequency tolerance is expressed in parts in 10^6 or in Hertz.

3.1.7 Mid-pulse-minimum visible signal (MPMVS). - The mid-pulse-minimum visible signal is the minimum input pulse signal power level which permits visibility of the center of the output pulse. This level is obtained in the same manner as the MVS level, with the center of the pulse being the point of reference.

3.1.8 Minimum visible signal (MVS). - The minimum visible signal is the minimum input pulse signal power level which permits visibility of the output pulse. This level is obtained by initially setting the input signal above the detection threshold, and then slowly decreasing the amplitude.

3.1.9 Necessary bandwidth. - For a given class of emission, necessary bandwidth is the minimum value of the occupied bandwidth sufficient to ensure the transmission of information at the rate and with the quality required for the systems employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment, such as the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth.

3.1.10 Occupied bandwidth. - Occupied bandwidth is the frequency bandwidth, such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission. In some cases, for example, multi-channel frequency-division systems, the percentage of 0.5 percent may lead to certain difficulties in the practical application of the definitions of occupied and necessary bandwidth; in such cases a different percentage may prove useful.

3.1.11 Power levels.

3.1.11.1 Db (decibels). - Db = $10 \log_{10} \frac{P_1}{P_2}$, where P_1 and P_2 are the powers compared.

3.1.11.2 Dbm (decibels relative to 1 milliwatt). - Dbm is defined as decibels relative to 1 milliwatt = $10 \log_{10} P$, where P is the power in milliwatts.

3.1.11.3 Dbm/m^2 (decibels relative to 1 milliwatt per square meter). - DBM/m^2 is defined as decibels relative to 1.0 milliwatt/meter^2 = $10 \log_{10} \frac{P}{A}$ where P is as defined in 3.1.11.2 and A is the effective area in square meters over which P is measured.

3.1.12 Pulse width (τ). - Pulse width is the time interval between half power points in the time waveform of a pulsed signal.

3.1.13 Required acceptance bandwidth. - The required acceptance bandwidth is the receiver required acceptance bandwidth which includes the fundamental frequency response and extends from the lowest to the highest frequencies on the selectivity curve outside of which the image response is at least 60 db below the fundamental frequency response and all other responses are at least 80 db below the fundamental frequency response.

3.1.14 Radar emission bandwidth. - The radar emission bandwidth shall be the frequency bandwidth which includes the fundamental frequency and extends from the lowest to the highest frequencies outside of which the levels of spectral power density do not exceed those specified hereinafter. These levels are in the main beam at a reference distance of 1850 meters and may be expressed in terms of energy received on a surface area of the receiving antenna of one square meter, i.e. joules/meter^2. For the purpose of this standard, however, the more conventional dbm/kHz/meter^2 or milliwatts x kHz^{-1} x meter^{-2} will be used.

fo (within frequency range of) MHz	Level of spectral power (Avg) density (in the main beam at a reference distance of 1850 meters)	
	(milliwatts x kHz^{-1} x meter^{-2})	(Dbm/kHz/meter^2)
100 to 400	6.31×10^{-9}	-82
400 to 1215	2.51×10^{-8}	-76
1215 to 2700	1.26×10^{-7}	-69
2700 to 5000	2.51×10^{-6}	-56
5000 to 8500	1.00×10^{-5}	-50
8500 to 40,000	3.16×10^{-5}	-45

3.1.14.1 For the purposes of this standard, values of spectral power density in dBm/kHz/meter^2 may be converted to radiated spectral level (dbm/kHz) as follows:

Radiated Spectral Level = (Spectral Power Density @ 1850 meters)-G_t + 20log 1.85×10^3 meters + 10log 4π. Therefore, Radiated Spectral Level = (Spectral Power Density @ 1850 meters)-G_t + 76.4dB,

Where G_t = Gain of transmitting antenna.

3.1.15 Receiver. - A receiver is an equipment or system specifically designed to respond selectively to radio-frequency energy.

3.1.16 Spurious emission. - Spurious emission is emission on a frequency or frequencies which are outside the necessary band, and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions and intermodulation products, but exclude emissions in the immediate vicinity of the radar emission bandwidth, which are a result of the modulation process for the transmission of information.

3.1.17 Spurious response acceptance. - A spurious response is any response of a receiver to energy outside the receiver bandwidth.

3.1.18 Standard test frequencies. - Standard test frequencies are that group of frequencies to which transmitters or receivers are tuned during the test procedure. Three such frequencies exist in each equipment tuning band, located at approximately the 5 percent, 50 percent and 95 percent points of the tuning range in each band, and called the low, mean, and high test frequencies, respectively.

3.1.19 Transmitter. - Transmitter is defined as an equipment or system specifically designed to generate radio-frequency energy.

3.1.20 Waveguide cutoff frequency. - Waveguide cutoff frequency is that frequency below which wave propagation will not occur in the waveguide transmission line.

3.2 Symbols. - Symbols are defined as follows:

τ = Pulse width at 1/2 power points in microseconds
d = Compression ratio
D = Antenna aperture
f_o = Carrier frequency in megahertz
Δf = Frequency deviation, the peak difference between the instantaneous frequency of the modulated wave and the carrier frequency in megahertz.

fco = waveguide cutoff frequency
λ = wavelength at the fundamental frequency
α = reduction in receiver sensitivity due to CW signal and pulse signal substitution
Erf = error function
β = resolution bandwidth of spectrum analyzer
A = effective area of test antenna
P_D = power density (dBm/m^2)
P_R = received power (dBm)
P_{SD} = Spectral power density (dBm/kHz/m^2)
A_C = measured cable loss
C = Coupling factor
A_1 = Attenuation Inserted
Posc = Oscillator radiation at the plane of reference
W = Rotation speed of antenna
θ = 3dB antenna beamwidth, degrees
Tr = Response time of the FSVM/recorder system (in milliseconds)
do = Open field test site distance
Ai = Insertion loss
Psp = Power level required for MVS at frequency of a spurious response
Dc = Duty cycle.

4. GENERAL REQUIREMENTS

4.1 Design criteria plan. - The primary goal of this standard is to enhance the design of military radar systems to achieve electromagnetic compatibility and to improve accommodation of expending radar requirements within the limited spectrum available. Therefore, when required by the contract or order, the contractor shall submit to the procuring activity for approval, a plan describing how his proposed radar system design will meet the requirements specified herein. The plan shall be submitted 90 days after award, and shall include, but not be limited to, the following unless otherwise specified by the procuring activity:

(a) Name, responsibility and authority of the individual who will implement the contractor's design program.
(b) Number and experience of full-time and part-time radar design and electromagnetic compatibility personnel assigned to the program.
(c) Organizational chart of all program personnel.
(d) Design aspects of the system as related to the requirements specified herein. Specific items to be discussed include:
  (1) general design philosophy and reasons for the proposed approach;
  (2) anticipated problems and proposed methods for solution;
  (3) methods of implementation of design.
(e) Detailed description of facilities, on hand and to be procured (identified separately) that will enable contractor to determine compliance with the requirements stated herein.
(f) Methods of accomplishing design reviews with subcontractor.

4.2 Test plan. - When required by the contract or order, the contractor shall submit a test plan to the procuring activity 45 days prior to the start of testing, detailing the tests he will perform to determine compliance with the requirements specified herein. Any modifications to the test procedures specified in the appendix to this specification for the particular system shall be fully described and justified in the test plan. Approval of the test plan shall precede the start of formal testing. Changes to the test plan occurring after the start of testing will require Government approval, and shall be recorded in the test report (see section 5). The test plan shall be documented and shall include but not be limited to the following:

(a) Test conditions and procedures for the system, and the sequence of operation during the tests.
(b) Implementation and application of test procedures, including modes of operation, control settings, monitored points, and so forth.
(c) Nomenclature and general characteristics of test equipment to be used.
(d) Types and methods of calibration of standards and calculations to show expected accuracy of each.
(e) Dummy loads, filters, dummy antennas, signal samplers, and so forth to be used and their descriptions.
(f) Readout and detector functions to be used.

(g) Details of test setups, test site procedures, and so forth. Maximum use of photographs and drawings is required.
(h) Expected accuracy of measurement.
(i) Nomenclature and description of test sample.
(j) Personnel required, both designated Government representative and the contractor.

4.3 Testing policy. - Radar systems identical to those which were previously tested in accordance with this document, found satisfactory, and accepted, may require retesting. A copy of the previous test report or reference thereto, or the Government's letter of compliance, with an adequate abstract, shall be forwarded by manufacturer's letter to the procuring activity to determine whether testing is required.

4.3.1 When a system requires modifications to comply with this standard, retesting shall be required to the extent necessary to determine compliance with the requirements of this standard. Modifications to that system which are necessary so as to conform to the requirements of this standard shall be incorporated into all radars of the lot.

4.4 Furnished equipment. - Unless otherwise specified in the equipment specification. When Government-Furnished Equipment (GFE) contractor-furnished equipment, or commercial "off-the-shelf" equipment is used in a radar system, the contractor shall make the necessary modifications to these items to assure compliance of the final system and for end product with the requirements of this standard.

4.5 Responsibility for testing. - Unless otherwise specified, the contractor is responsible for the performance of all tests and compliance to the requirements in this standard. The contractor may utilize his own facilities or those of any commercial laboratory acceptable to the Government. The Government reserves the right to perform any tests in this standard when necessary to assure supplies and services conform to the requirements. The test shall be witnessed and verified by a Government representative. Evidence of its verification shall be included in the test report.

4.6 Design control parts. - When additional parts are required so that the radar system will conform to the requirements stated herein, even after careful design procedures, parts shall be used that conform to the environmental requirements for the system as specified in the contract. Separately installed and external components shall not be used, unless specifically authorized by the procuring activity.

5. REPORTING FORMAT

5.1 Standardization formats for data reporting are shown in the appendix. The formats embody the minimum data that are required for each measurement delineated within this document. The data sheets serve as a guide only. Other information to be included in the test report is specified hereinafter.

5.1.1 Nominal radar data. - The nominal radar characteristics shall be included in the test report. The data to be included is shown in table I.

5.2 Detailed identification of all measurement and calibration instruments, and pertinent auxiliary equipment used in the performance of these tests, including data on instrumentation accuracies, calibration dates, stabilities, bandwidth, measured filter insertion loss vs frequency, and attenuator and coupler characteristics across the applicable frequency range shall be provided.

5.3 A description of all laboratory test layouts, and all field test deployments, including plans, drawings, and photographs, where applicable, shall be presented in the report preceding the tabulated data. Input and output terminals and all test points used for these measurements shall be identified.

5.4 A description of the measurement location terrain by topographical map, and any pertinent features (mountains, buildings, and so forth) which may influence the measured data shall be provided. The geographical location of the measurement site shall be recorded on the topographical map. Photographs presenting a 360-degree panoramic view taken from the location of the equipment under test shall be presented.

5.5 All initially recorded test data, plus sample calculations employing actual measured data to show how the derived data were obtained shall be presented with each measurement. Comparison of measured data with theoretical calculations (see sample calculation sheet, table II) and explanation of variations shall also be included.

5.6 A list of all failures that occurred to the equipment involved in the measurement program during the test period, and a description of the checks made to determine the condition of equipment performance following repairs shall be presented.

5.7 Other information relevant to the test program which may affect measurements, such as peculiarities encountered in equipment performance, difficulties in performing tests, general weather conditions, and descriptions of measurement procedures, shall be presented. If any measurement cannot be carried out, reasons why and efforts to surmount the problem shall be discussed fully.

Table I - Nominal radar data.

TRANSMITTER NOMENCLATURE: ____________________

SERIAL NO. ____________ MANUFACTURER: ____________

POWER OUTPUT: (Avg.) ________ watts, (Peak) ________ watts

FREQUENCY BAND: ________ to ________ MHz

PULSEWIDTH: ________ μs PULSE REPETITION FREQUENCY ________ pps

REMARKS: ____________________

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RECEIVER NOMENCLATURE: ____________________

SERIAL NO. ____________ TYPE: ____________

SENSITIVITY: ________ dbm, NOISE FIGURE: ________ db

RF PRESELECTOR 3-db BANDWIDTH: ________ MHz

LOCAL OSCILLATOR FREQUENCY: First Conversion ________ MHz

Second Conversion ________ MHz

Third Conversion ________ MHz

INTERMEDIATE FREQUENCY: First Conversion ________ MHz

Second Conversion ________ MHz

Third Conversion ________ MHz

IF 3 db BANDWIDTH: ________ MHz

ANTENNA NOMENCLATURE: ____________________

SERIAL NO. ____________ TYPE: ____________

DIMENSIONS: Horiz. ______ feet, Vertical ________ feet

BEAMWIDTH: Horiz. ______ degrees, Vertical ________ degrees

POLARIZATION ________; Gain (@ mid-band freq.) ________ db

ANTENNA MOVEMENT: Horizontal ________ rpm

ANGULAR LIMITS: Horiz. ________ Vertical ________

Table II - Theoretical calculation sheet.

Equipment Nomenclature ______________________________

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

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

Peak Power (P_p) ______________ Average Power (P_a) ______________

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

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

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

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

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

= ______________

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

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

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

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

= ______________

REMARKS:

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____

____

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

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

6 LIMITS

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

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

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

6.2.1 All other radars shall meet the following frequency tolerances:

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

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

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

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

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

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

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

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

6.7 Radar receiving system. -

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

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

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

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

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

7. NOTES

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

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

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

Custodians:
Army - EL
Navy - SH
Air Force - 11

Preparing activity:
Navy - SH
(Project 5800-0001)

Review activities:
Army - EL
Navy - SH, AS, OS
Air Force - 11

APPENDIX

MEASUREMENTS

10. GENERAL MEASUREMENT REQUIREMENTS

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

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

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

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

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

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

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

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

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

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

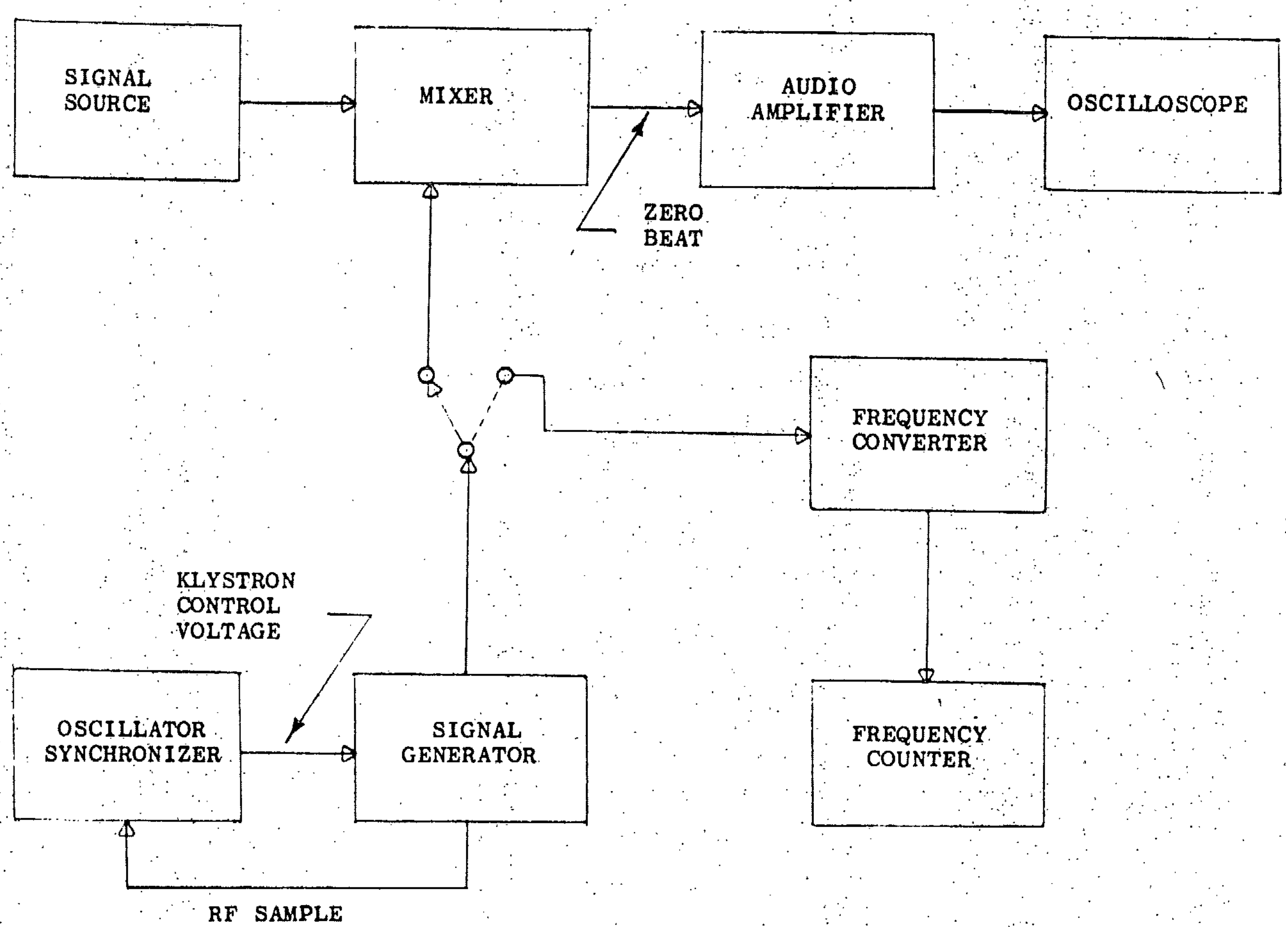

Figure 1 – Frequency measuring equipment block diagram, 10.0 to 40 GHz.

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

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

20. INSTRUMENTATION

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

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

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

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

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

Table III - Recommended test equipment, or equivalent.

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

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

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

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

Equipment	Model	Frequency range
FREQUENCY MEASURING EQUIPMENT		
Hewlett-Packard	540B	10 MHz to 12.4 GHz (100 to 220 MHz Base Freq.)
Hewlett-Packard	2590A	10 MHz to 12.4 GHz
Hewlett-Packard	5245L	DC to 50 MHz
Hewlett-Packard	5253B	50 to 500 MHz
FREQUENCY DOUBLERS		
Hewlett-Packard	938A	18 to 26.5 GHz
Hewlett-Packard	940A	26.5 to 40 GHz
MIXER		
Narda	519	12.4 to 18 GHz
Narda	518	18 to 26.5 GHz
Narda	517	26.5 to 40 GHz
Hewlett-Packard	11521A	10 to 12.4 GHz
Hewlett-Packard	11517A	12.4 to 40 GHz
MODULATOR		
Hewlett-Packard	8403A	
MODULATOR - PIN		
Hewlett-Packard	8730 Series	0.8 to 12.4 GHz
OSCILLOSCOPE		
Tektronix	545	Basic Unit
Tektronix	CA Plug-in	Dual Trace, DC-24 MHz
Tektronix	53/54K	Single Trace, DC-30 MHz
POWER METER		
Hewlett-Packard	431B	Basic Unit
General Microwave	454A	Basic Unit
RECORDER		
Sanborn	151	With 150/400 Power Supply and 150/1400 Pre-Amp
Scientific Atlanta	APR-20	
Esterline-Angus	AW	
SIGNAL GENERATOR		
Hewlett-Packard	608D	10 to 480 MHz
Hewlett-Packard	612A	450 to 1230 MHz
Hewlett-Packard	8614A	0.8 to 2.4 GHz
Hewlett-Packard	8616A	1.8 to 4.5 GHz

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

Equipment	Model	Frequency range
SIGNAL GENERATOR (cont'd)		
Hewlett-Packard	618B	3.8 to 7.6 GHz
Hewlett-Packard	620A	7 to 11 GHz
Hewlett-Packard	626A	10 to 15.5 GHz
Hewlett-Packard	628A	15 to 21.0 GHz
SPECTRUM ANALYZER		
Hewlett-Packard	851B/8551B	10 MHz to 40 GHz
Polarad	SA-84 WAW	10 MHz tc 40 GHz
WAVEGUIDE ADAPTERS		
FXR	L600B	1.12 to 1.7 GHz
FXR	R601B	1.7 to 2.6 GHz
FXR	S601B	2.6 to 3.95 GHz
FXR	H601B	3.95 to 5.85 GHz
FXR	C601B	5.85 to 8.2 GHz
FXR	W601B	7.05 to 10.0 GHz
FXR	X601B	8.2 to 12.4 GHz
WAVEGUIDE SECTIONS		
FXR	R634A	1.7 to 2.6 GHz
FXR	S634A	2.6 to 3.95 GHz
FXR	H634A	3.95 to 5.85 GHz
FXR	C634A	5.85 to 8.2 GHz
Aircom	106X00	8.2 to 12.4 GHz
Aircom	106KU00	12.4 to 18 GHz
Aircom	106K00	18 to 26.5 GHz
Aircom	106KA00	26.5 to 40 GHz
WAVEGUIDE TRANSITIONS		
Aircom	195-L-LS	1.2 to 1.7 GHz 1.7 to 2.6 GHz
Aircom	195-LS-S	1.7 to 2.6 GHz 2.6 to 3.95 Ghz
Aircom	195-S-C	2.6 to 3.95 GHz 3.95 to 5.85 GHz
Aircom	195-C-XC	3.95 to 5.85 GHz 5.85 to 8.2 GHz
Aircom	195-XC-BL	5.85 to 8.2 GHz 7.05 to 10 GHz
Aircom	195-BL-X	7.05 to 10 GHz 8.2 to 12.4 GHz
Hewlett-Packard	HX-292B	7.05 to 10 GHz 8.2 to 12.4 GHz
Hewlett-Packard	MX-292A	8.2 to 12.4 GHz 10.0 to 15 GHz
Aircom	195-X-KU	8.2 to 12.4 GHz 12.4 to 18 GHz
Hewlett-Packard	MP-292	10 to 15 GHz 12.4 to 18 GHz

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

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

30. RADAR TRANSMITTER MEASUREMENTS

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

30.2 Radar transmitter frequency tolerance. -

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

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

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

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

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

30.3 Radar systems tunability. -

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

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

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

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

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

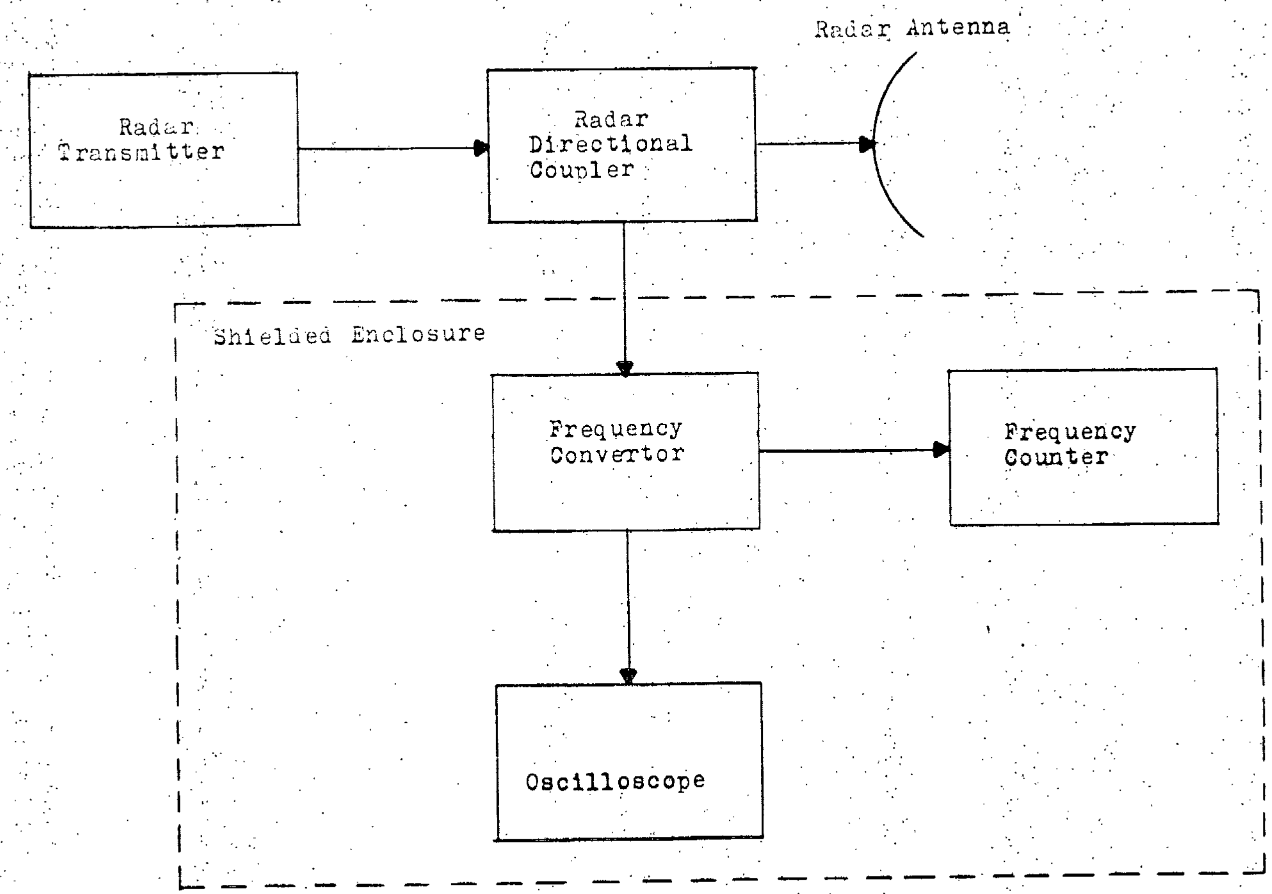

Figure 2-1 – Radar transmitter frequency tolerance measurement block diagram (below 10 GHz).

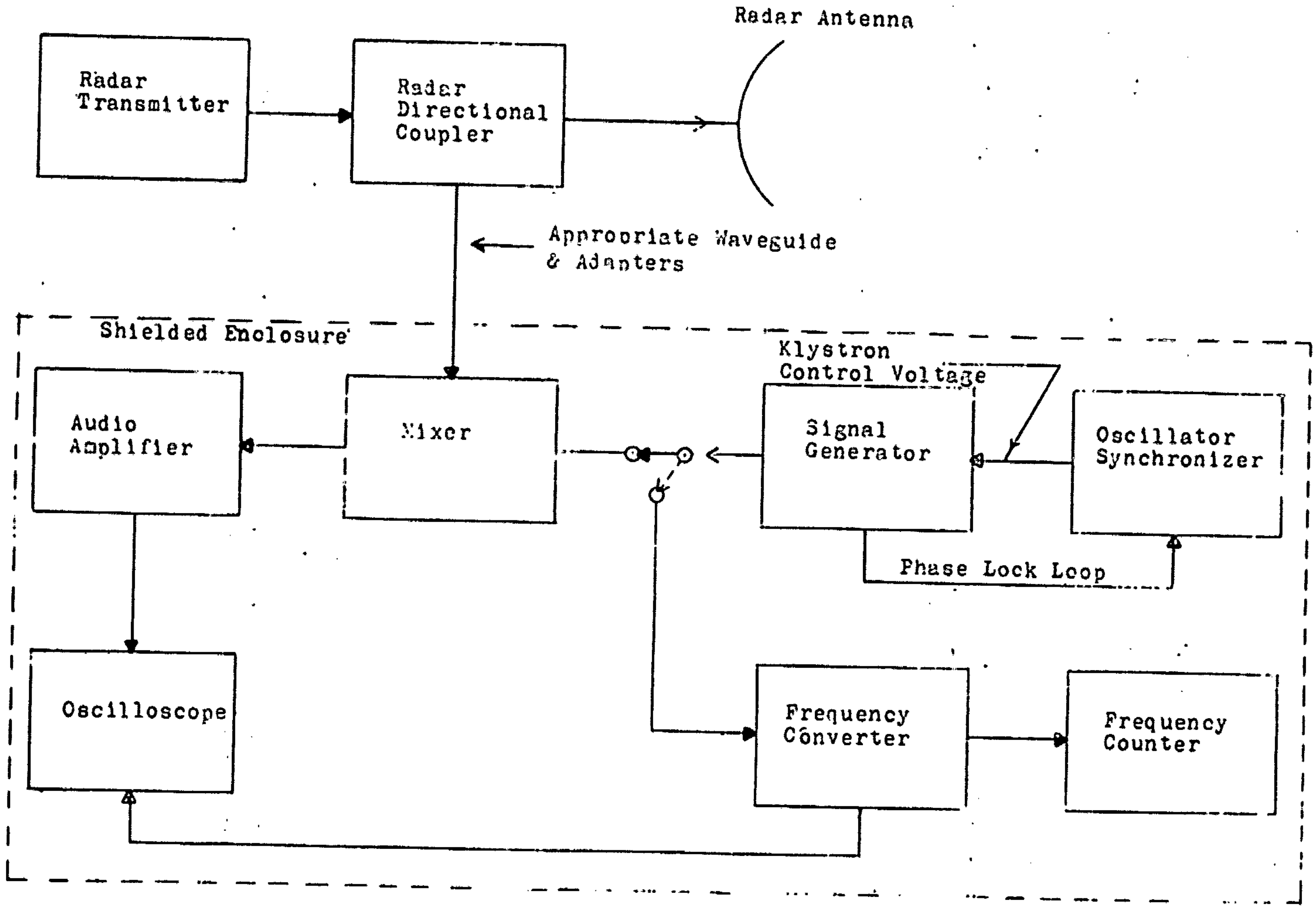

Figure 2-2 – Radar transmitter frequency tolerance measurement block diagram (10–40 GHz).

RADAR TRANSMITTER FREQUENCY TOLERANCES.

DATE ____________________ TIME ____________________

PULSEWIDTH ____________________ μs PULSE REPETITION FREQ. ____________________ pps

Measured Frequency (MHz)	Nominal tuned frequency MHz	ΔT (Minutes)	± Δ f (MHz)

Figure 3 — Sample data sheet
(Radar transmitter frequency tolerances).

incident port, using additional attenuation in the line, if required, to protect the test equipment. Measure and record the tuned frequency of the radar transmitter. If the system employs a dummy load, it may be necessary to connect the test equipment to it to perform this test.

30.3.4.2 Power output. - Remove the frequency measuring equipment and connect a calibrated thermal-type power meter to the incident port of the system directional coupler, inserting additional precision attenuators, as required, to protect the measurement equipment. Measure and record the power meter reading, the coupling factor of the system coupler, and the attenuation inserted in the line. If measurements are made from a dummy load, record its attenuation. Repeat the above measurements for each of the operating frequencies or for the three standard test frequencies if the system is continuously tunable.

30.3.4.3 Sensitivity. - Tune the radar receiver to one of the operating frequencies specified in 30.3.3. Measure the sensitivity of the system using the test equipment and procedures specified in 30.4. The test signal shall be modulated using the system pulsewidth, and shall be triggered by the system trigger. The standard response shall be MVS. Repeat the sensitivity measurements for each of the test frequencies specified herein.

30.3.5 Data. - The data obtained in this measurement shall consist of power meter reading, signal sampler coupling factor, attenuation inserted, and measurement frequency for the power output portion; and signal generator output level, attenuation inserted, cable loss and measurement frequency for the sensitivity portion of the measurement. All data shall be entered on data sheets of the form illustrated in figures 4 and 5. Sample calculations to obtain the transmitter output power and receiver sensitivity follow:

Sample Calculation - Power Output

Measured Data:

Transmitter tuned frequency: 3650 MHz
Pulsewidth (PW): 2.0 microseconds
PRF: 300 pps
Power meter reading (P_m): -5.5 dBm
Coupling factor (A_c): 52.0 dB
Attenuation inserted (A_1): 10.0 dB

The average power output is calculated as follows:

$$P_{avg} = P_m + A_c + A_1$$
$$= -5.5 \text{ dBm} + 52.0 \text{ dB} + 10.0 \text{ dB}$$
$$= 56.5 \text{ dBm}$$

The peak power output is determined from the duty cycle using the relationship:

$$P_{pk} = P_{avg} + 10 \log \frac{1}{(PW)\ (PRF)}$$

where P_{pk} = peak power output, dBm,

$$P_{pk} = 56.5 \text{ dBm} + 10 \log \frac{1}{(2.0 \times 10^{-6})\ (300)}$$

$$= 56.5 \text{ dBm} + 32.2 \text{ dB}$$

$$= 88.7 \text{ dBm}$$

Sample Calculations - Receiver

Measured Data:

Receiver tuned frequency: 3650 MHz
Pulsewidth: 2.0 microseconds
PRF: 300 pps
Signal generator level (P_{sg}): -55.3 dBm
Attenuation Inserted (A_1): 50.0 db
Cable loss (A_c): 3.5 db

The receiver sensitivity (MVS) is calculated as follows:

$$MVS = P_{sg} - A_1 - A_c \quad \text{dBm}$$

$$= -55.3 - 50.0 - 3.5 \text{ dBm}$$

$$= -108.8 \text{ dBm}$$

SYSTEM TUNABILITY

Power output

DATE ______________________ TIME ______________________

PULSEWIDTH ______________________ μs PULSE REPETITION FREQUENCY ____________ pps

Frequency (MHz)	Power Meter Reading (dBm)	Coupling Factor (dB)	Attenuation inserted (dB)	Power Output (dBm)	
				Avg.	Peak

Figure 4 — Sample data sheet
(System tunability, power output).

SYSTEM TUNABILITY

Sensitivity

DATE ______________________ TIME ______________________

PULSEWIDTH ______________________ μs PULSE REPETITION FREQUENCY ____________ pps

Frequency (MHz)	Signal Generator Output (dBm)	Cable Loss (dB)	Attenuation Inserted (dB)	Sensitivity (MVS) (dBm)

Figure 5 - sample data sheet.
(System tunability, sensitivity).

30.4 Radar emission bandwidth. -

30.4.1 Objective. - The objective of this test is to determine the radar emission bandwidth as defined in 3.1.14 by measuring the spectral power density at the acceptable test site and test site distance and extrapolating this level to a distance of 1850 meters from the radar.

30.4.2 Requirements. - The spectral power density at a distance of 1850 meters from the radar antenna shall be not greater than those values specified in 3.1.14 at frequencies removed from the radar operating frequency corresponding to the ends of the maximum emission allowable bandwidth specified in 6.3.

30.4.3 Procedure. - The procedures for this test shall be as follows: Refer to figures 6-1 and 6-2 for a typical block diagram for this test. This test shall be performed as an open-field test, with the test antenna located at a distance, as defined in 3.1.2.

30.4.3.1 Tune the radar to a standard test frequency and adjust its output to the nominal level. Measure and record the transmitter power at the start of this test and at intervals of 30 minutes or less. The output power shall be measured using a thermal-type power meter and an appropriate signal sampler. The system directional coupler shall be used, if available. A power meter with a recorder output is desirable to permit recording the level of the transmitter power output providing a permanent record of any power fluctuations occurring during this test.

30.4.3.2 After adjusting the radar transmitter and measuring its output power, align the system and test antennas for maximum signal transfer as follows. The test antenna shall be elevated to a height at which the electrical centers of the two antennas are aligned. Polarization of the test antenna shall be the same as that of the system antenna. With the test antenna connected to the spectrum analyzer through the appropriate transmission line and calibrated attenuators, as required, tune the analyzer until the radar signal spectrum appears centered on the analyzer display. Adjust the analyzer controls and external attenuators to provide an on-scale indication. Once this is accomplished, ascertain that the system and test antennas are aligned in azimuth, elevation, and polarization for maximum signal transfer.

30.4.3.3 Adjust the analyzer bandwidth control to a value in accordance with this appendix, paragraph 20. Adjust the dispersion control of the analyzer to a value corresponding to the maximum allowable radar emission bandwidth, as specified in 6.3.

30.4.3.4 With all other analyzer controls set in accordance with the operating manual of the instrument, photograph the spectrum analyzer display using an oscilloscope camera.

30.4.3.5 Remove attenuation from the line and re-center the display, if required. Photograph the display. Remove only enough attenuation to provide a signal of approximately 6 dB (linear analyzer display) or 10 dB (logarithmic display) above the noise at the portions of the display corresponding to the end frequencies of the radar emission bandwidth.

30.4.3.6 After the photographs are taken, calibrate the display of the analyzer as follows. Connect a calibrated signal generator to the spectrum analyzer and with the generator set for a CW output, tune the generator to the center of the analyzer display. Adjust the output level of the signal generator to produce a display with an amplitude at the top horizontal graticule line. Record the signal generator output level. Repeat this procedure for each horizontal line. Measure and record the signal generator frequency using the procedure specified in this appendix, section 10.

30.4.3.7 Retune the signal generator to the center of the analyzer display and adjust the output level for an amplitude corresponding to the center 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 regain a mid-scale vertical deflection. Record the generator output and frequency at this point, then tune the generator to the left-hand end of the display and repeat the process.

30.4.3.8 The values thus obtained will enable calibration of the photograph for amplitude, frequency, and spectrum analyzer gain linearity at the center and either end of the display. In order to obtain the spectral power density of the signal as measured on the spectrum analyzer, in $dBm/kHz/m^2$, it is necessary to know the resolution bandwidth of the analyzer. This may be obtained with sufficient accuracy as follows. With all analyzer controls unchanged, connect the signal generator to the analyzer and tune it to the center of the display. With a CW output, obtain the signal generator output level required for a mid-scale vertical display. Record this value. Modulate the original generator output with a 2.0-microsecond pulse at the system PRF and center the display on the analyzer. Increase the output of the signal generator until the display is at the same amplitude as was measured with the CW signal. Record this level. The resolution bandwidth may then be obtained from the following relationship:

$$\alpha \text{ (dB)} = 20 \text{ Log} \left[\text{Erf } 1.33 \, (\beta\tau) \right]$$

$$\text{Erf } 1.33 \, (\beta \quad) = \text{Log}^{-1} \, \alpha/20$$

where:

α (dB) = reduction in sensitivity between CW signal (P_1) and pulse signal (P_2); that is $P_1 - P_2$, dB. This will be a negative number.

Erf = error function

β = resolution bandwidth, Hertz

τ = pulsewidth, 2 X 10^{-6} seconds

Once the resolution bandwidth is known, the spectral power density may be determined per kHz of bandwidth.

30.4.4 Data. - The data obtained in this test shall consist of signal generator output level, insertion loss and test antenna effective area, orientation of system and test antennas. Photographs of the fundamental signal spectrum shall be calibrated and presented with the data. All data will be entered on data sheets of the form shown in figure 7. A sample calculation to obtain the spectral power density in dbm/kHz/m^2 follows:

Sample calculation

Measured data:

Transmitter tuned frequency: 3650 MHz
Pulsewidth: 2.0 microseconds
PRF: 300 pps
Frequency at high end of allowable emission bandwidth ($f_o + \frac{10}{\tau}$) 3655 MHz
Signal generator level (P_{sg}) measured at 3655 MHz: -80.0 dbm
Measured cable loss (A_c): 3.5 db
Attenuation inserted (A_1): 60.0 db
Spectrum analyzer resolution bandwidth: 10 kHz

The signal power density (in a 10-kHz bandwidth) is found from the relation:

$$P_D = P_R - A$$

where:

P_D = power density, dbm/m^2

P_R = received power (dbm) = $P_{sg} + A_1 + A_c$

A = effective area of test antenna, dB/m^2

$$= \frac{\lambda^2 G_T}{4\pi}$$

$\lambda = 300/f_{MHz}$

$A = 20 \log 300 + G_T - 20 \log f_{MHz} - 10 \log 4\pi$

where:

G_T = gain of test antenna over an isotropic antenna, db

f_{MHz} = frequency of signal, megahertz

Simplifying this equation,

$$A = G_T - 20 \log f_{MHz} + 38.5 \text{ dB/m}^2$$

Using these data with G_T = 19.0 dB,

$$A = 19.0 \text{ dB} - 71.3 \text{ dB} + 38.5 \text{ dB/m}^2$$

$$= -13.8 \text{ dB/m}^2$$

$$P_D = P_R - A \text{ dBm/m}^2$$

and

$$P_R = -80.0 \text{ dBm} + 60.0 \text{ dB} + 3.5 \text{ dB}$$

$$= -16.5 \text{ dBm}$$

$$P_D = -16.5 \text{ dBm} - (-13.8 \text{ dB/m}^2)$$

$$= -2.7 \text{ dBm/m}^2$$

To convert this value to spectral power density in units of dBm/kHz/m^2, the relationship

$$P_{SD} = P_D - 10 \log \beta \text{ is used}$$

where:

P_{SD} = spectral power density, dBm/kHz/m^2

β = resolution bandwidth of spectrum analyzer, kHz

$$P_{SD} = -2.7 \text{ dBm/m}^2 - (10 \log 10)\text{dB}$$

$$= -12.7 \text{ dBm/kHz/m}^2$$

This value is for the spectral power density as measured at the open-field test site. To refer this value to a distance of 1850 meters, the following correction shall be used:

$$P_{SD} \text{ (test site)} = P_{SD} \text{ (1 naut. mile)} + D$$

where D is the correction factor, in dB

$$D = 20 \log do/1850$$

where d is the open-field test site distance in meters (200 meters for this example)

$$D = 20 \log 200/1850 \text{ dB}$$

$$= -19.4 \text{ dB}$$

The corrected spectral power density at $f_o + 10/\tau$ is, therefore,

$$P_{SD}\,(1\text{ naut. mile}) = -12.7\text{ dBm/kHz/m}^2 + (-19.4)\text{ dB}$$

$$= -32.1\text{ dBm/kHz/m}^2$$

This value shall be recorded in the spectral power density column on the date form.

30.5 Radar transmitter spurious radiations. -

30.5.1 Objective. - The objective of this test is to measure all radiations emitted by the radar transmitter under test over the frequency range specified.

30.5.2 Requirements. - All emissions outside of the maximum allowable radar emission bandwidth specified in 6.3 shall have a spectral level below the maximum values specified in 6.6 for carrier frequencies within the ranges shown at the transmitter antenna input.

30.5.3 The radar transmitter spurious radiations test involves a determination of the power versus frequency characteristics of a transmitter throughout its frequency range with the exception of that portion of the spectrum covered in 30.4.

30.5.4 Procedure. - Measurements shall be made as follows: Refer to figures 8-1 and 8-2 for typical block diagrams of this test. This test is to be performed in-line. Tune the radar transmitter to a standard test frequency and adjust its output power to the nominal level. Measure and record the transmitter power at the start of this test and at intervals of 30 minutes or less (more frequently if a noticeable change occurs). The output power shall be measured using a thermal-type power meter and an appropriate signal sampler. The system directional coupler shall be used, if available, and shall be calibrated over the range of frequencies measured.

30.5.4.1 After measuring and recording the output power, connect a spectrum analyzer to the incident port of the directional coupler through the appropriate transmission line and calibrated attenuators, as required. Adjust the analyzer bandwidth control so it is less than $1/10\tau$ where τ is the pulsewidth ($2d/10\tau$ for pulse compression), and the other controls in accordance with the instrument operating instructions. Tune the analyzer until a maximum indication is achieved on the CRT. Measure and record the level and frequency of the fundamental output signal of the radar using the substitution techniques, as described herein.

30.5.4.2 Tune the analyzer above the radar tuned frequency to a frequency corresponding to the upper end of the emission bandwidth. Remove all external attenuation and insert the appropriate filters (notch rejection, high-pass or bandpass) preferably waveguide sections with f_{c_o} above f_o to reduce the possibility of the radar's fundamental frequency power causing spurious responses in the analyzer.

30.5.4.3 After this has been accomplished, tune the analyzer above the radar frequency. Each time a spurious transmitter output is found, adjust the input attenuation and/or analyzer sensitivity to produce a convenient indication. Measure and record the level and frequency of each spurious emission, as specified herein.

30.5.4.4 Once the upper frequency limit has been reached (40 GHz unless otherwise specified), tune the analyzer to the frequency corresponding to the lower frequency of the maximum allowable emission bandwidth and begin the scan for spurious emissions below the radar operating frequency. The entire scan will be performed for each of the three standard test frequencies.

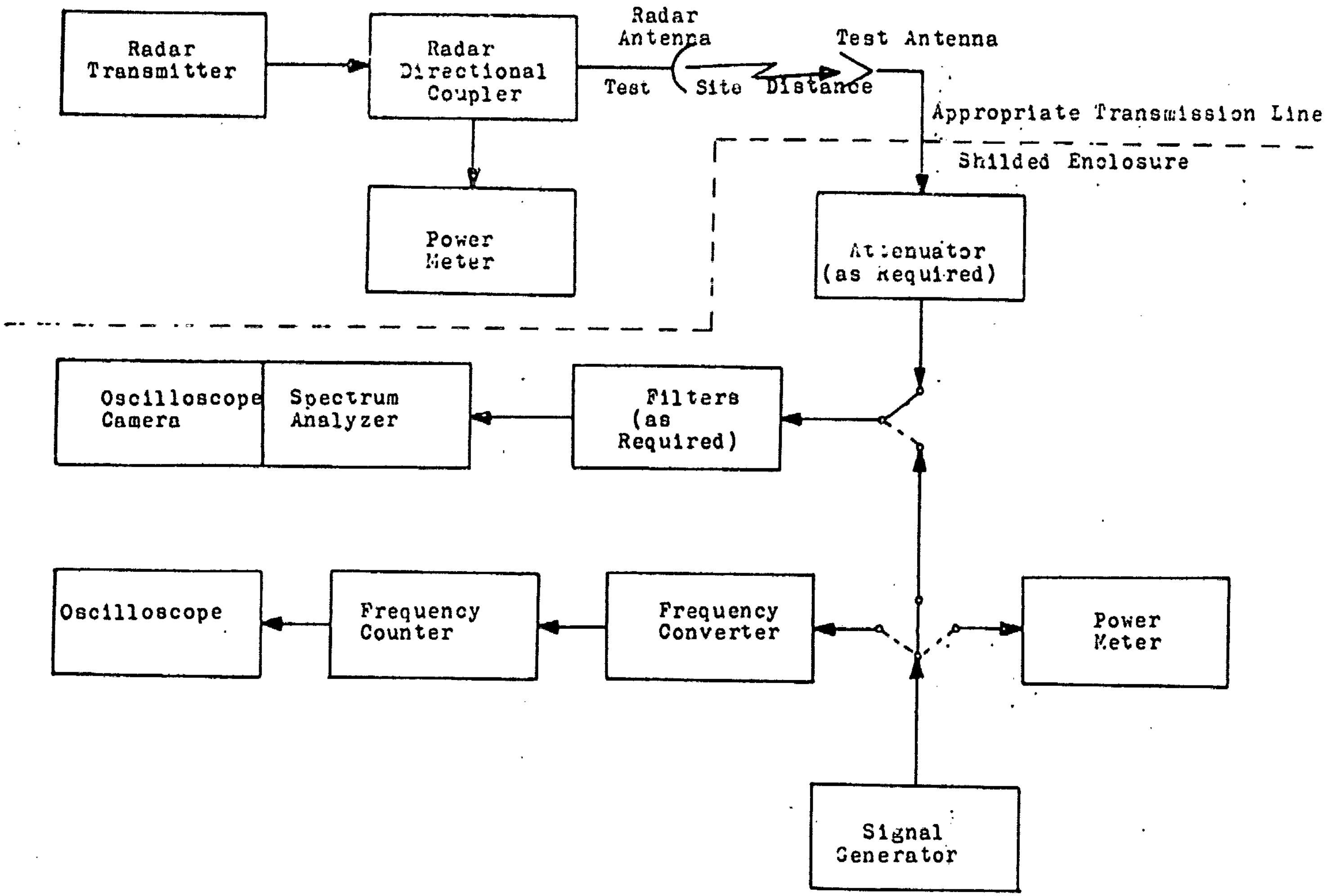

Figure 6-1—Radar emission bandwidth measurement block diagram (below 10 GHz).

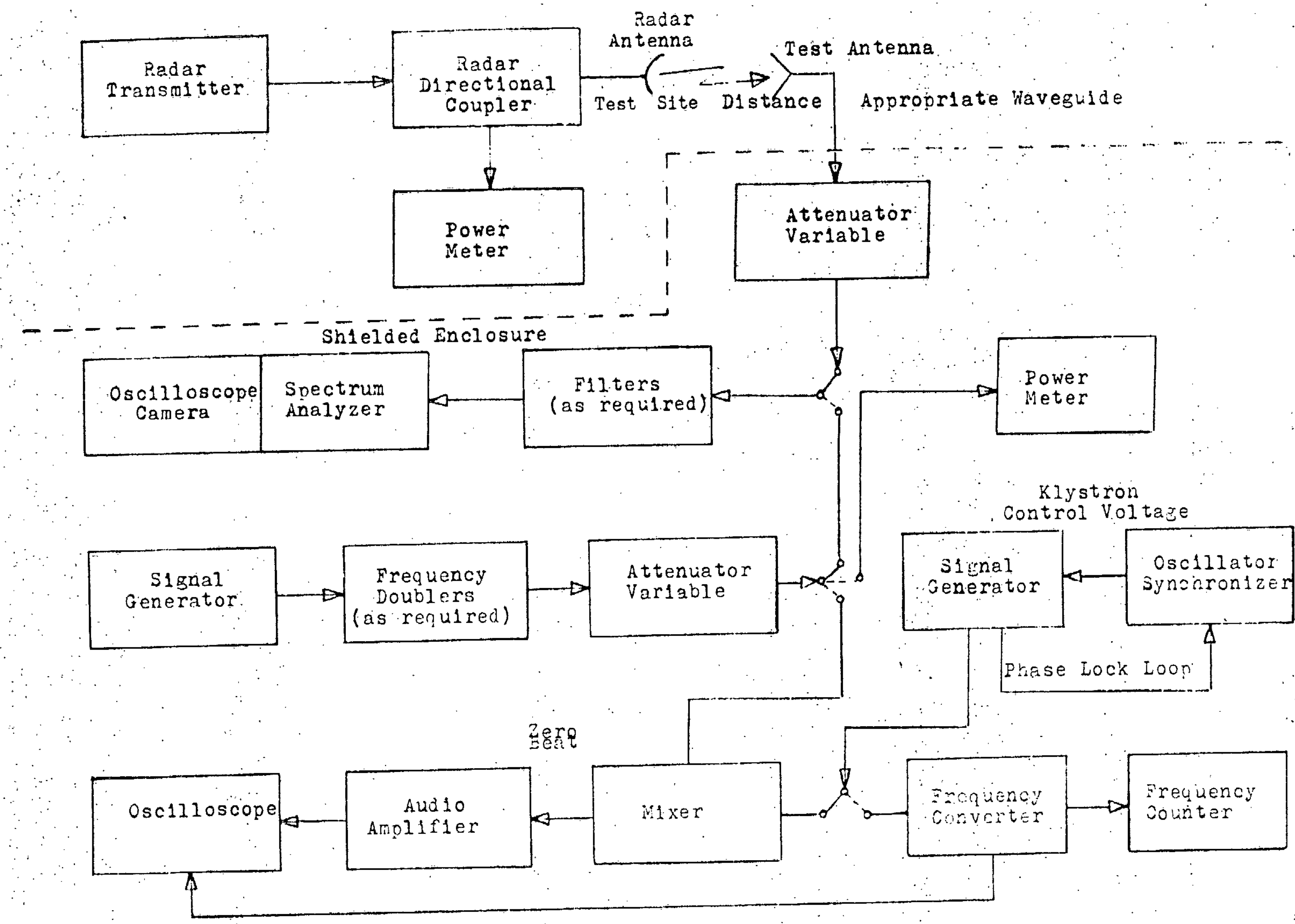

Figure 6-2—Radar emission bandwidth measurement block diagram (10 to 40 GHz).

RADAR EMISSION BANDWIDTH

DATE ____________ TIME ____________ TRANSMITTER TUNED FREQUENCY ____________

Peak Power Output ________ dbm Pulsewidth ________ μsec Pulse Repetition Freq. ________ pps

Modulation ____________ Compression Ratio ____________

Spectrum Analyzer Resolution Bandwidth ____________ kHz

Test Antenna Orientation: θ ______°, φ ______°, ω ______°, gain ____________

Height Above Ground ____________ Test Site Distance (feet) ____________

Test antenna polarization ____________

Frequency (MHz)	Δf (± MHz)	Signal Generator Level (dbm)	Measured Cable Loss (db)	Atten. Inserted (db)	Test. Ant. Effective area (db/m^2)	Spectral Power Density*1/ ($dbm/kHz/m^2$)

1/ At 1850 meters.

Figure 7 – Sample data sheet (radar emission bandwidth).

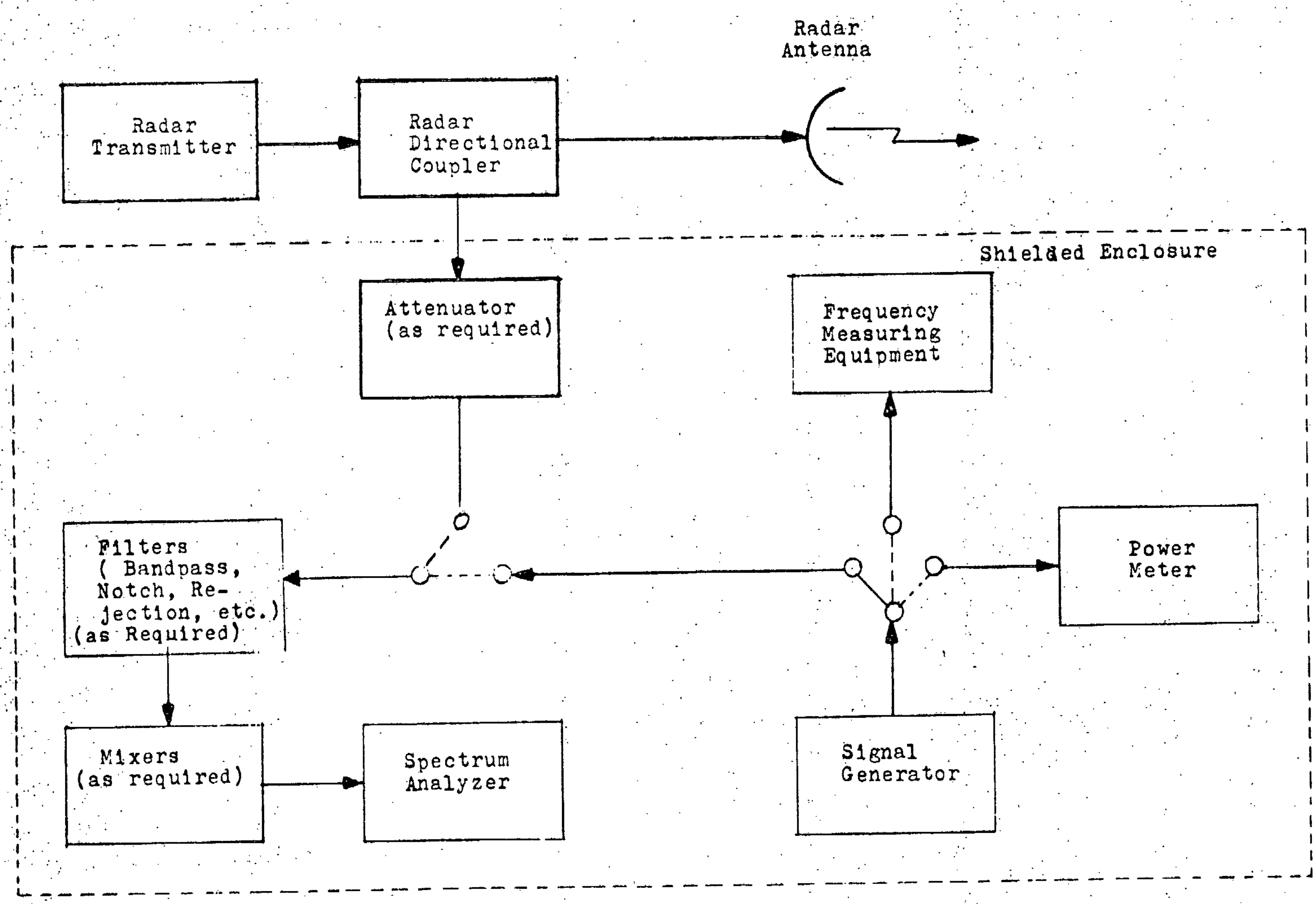

Figure 8-1—Radar transmitter spurious radiation block diagram (below 10.0 GHz).

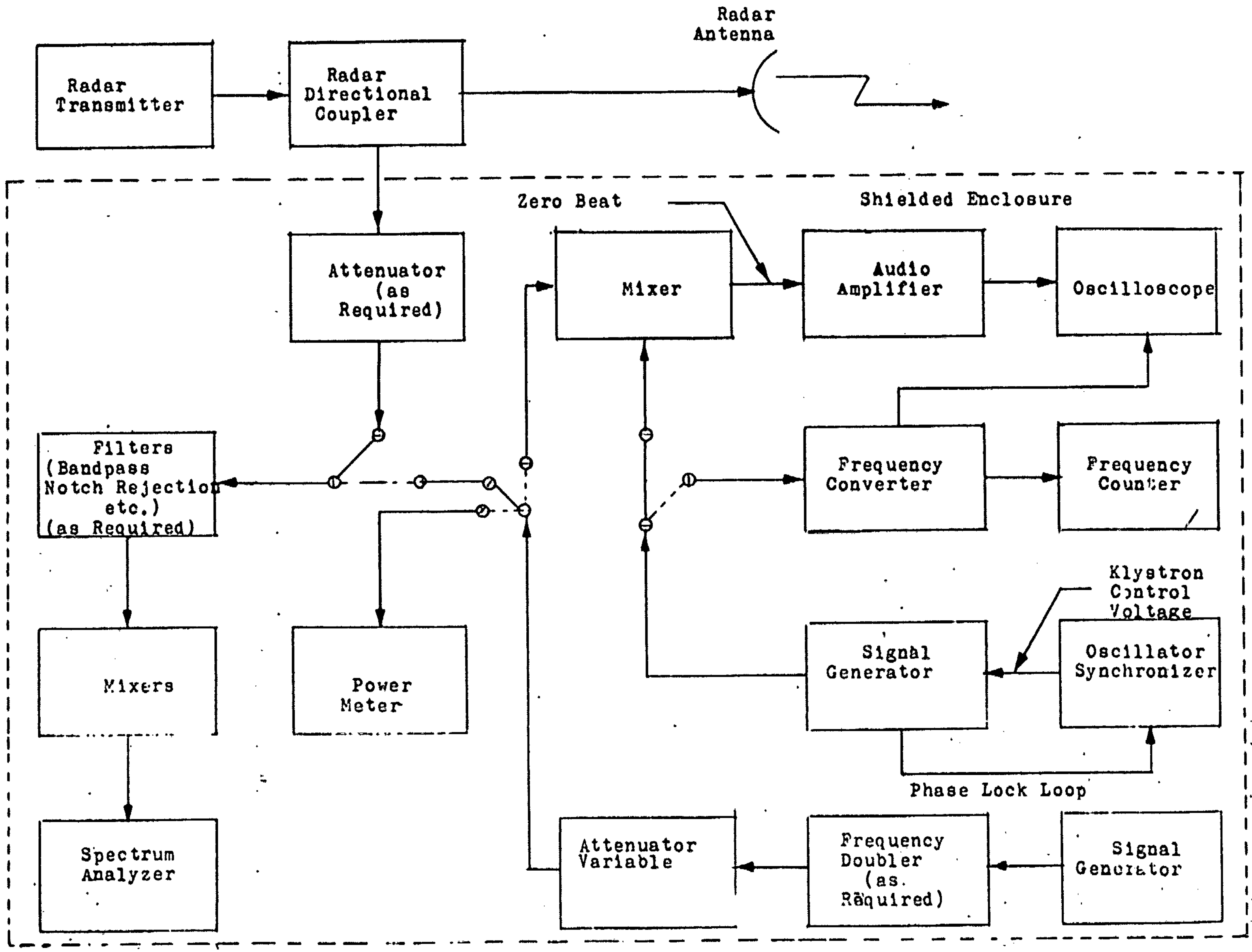

Figure 8-2—Radar transmitter spurious radiation, block diagram (10 to 40 GHz).

30.5.5 Data. - The data obtained in this test shall consist of signal generator output, insertion loss, coupling factor. All data shall be entered on a data sheet of the form shown in figure 9. A sample calculation to obtain the spectral level in dbm/kHz follows:

Sample calculation

Measured Data:

Transmitted tuned frequency: 3650 MHz
Pulsewidth: 2.0 microseconds
PRF: 300 pps
Spurious frequency: 5225.1 MHz
Signal generator level (P_{sg}): -50 dBm
Measured cable loss (A_c): 5.5 dB
Attenuation inserted (A_1): 0 dB
Coupling factor (C): 55 dB
Spectrum analyzer resolution bandwidth: 10 kHz

The signal power level in dBm, is:

$$P = Psg + Ac - A + C$$

$$= -50.0 + 5.5 + 0 + 55.0$$

$$= 10.5 \text{ dBm}$$

This is the level measured with a receiver bandwidth of 10kHz. To convert this level into peak spectral level in dBm/kHz, the following relation shall be used:

$$Ps = P - 10 \log$$

$$= 10.5\text{dBm} - 10 \log 10 \text{ dB}$$

$$= 0.5 \text{ dBm/kHz}$$

This value shall be recorded on the data sheet with the corresponding spurious frequency.

40. RADAR RECEIVER MEASUREMENTS

40.1 The radar receiver measurements specified hereinafter shall be performed on all receivers of the same radar.

40.2 Receiver response characteristics

40.2.1 Objective. - The objective of this test is to determine the receiver response characteristics to frequencies within and outside its bandpass.

40.2.2 Requirements. - All receiver responses outside the required acceptance bandwidth shall meet the limits in 6.7.

40.2.3 The receiver response characteristics, as measured by this test, give an indication of the overall gain and sensitivity of the receiver at its tuned frequency, as well as its responses at frequencies removed from the tuned frequency. Those responses at frequencies slightly removed from the tuned frequency are determined, for the most part, by the IF amplifier-tuned circuits, and should be fairly symmetrical about the center frequency. The level of these responses indicate the ability of the receiver to discriminate against off-channel radiations and, in reality, is a measure of the receiver's acceptance bandwidth or its selectivity. Receivers of the heterodyne type are also capable of responding to signals at frequencies that are relatively far removed from the receiver tuned frequency. These responses are often functions of internal frequencies inherent within the receiver, combining with an external signal in such a manner as to cause a spurious response. To determine the receiver response characteristics to frequencies within the range specified, the following procedures shall be followed.

RADAR TRANSMISSION SPURIOUS RADIATION

DATE ____________ TIME ____________ TRANSMITTER TUNED FREQUENCY ____________

Power Output: (Peak) ________ dBm ______ (Avg) ________ dBm ______ Modulation ____________

Pulsewidth ________ μsec Pulse Repetition Freq. ________ pps Compression Ratio ____________

Bandwidth (Frequency Selective Voltmeter/Spectrum Analyzer) ____________ kHz

Frequency (MHz)	Signal Generator Level (dBm)	Measured Cable Loss (dB)	Coupling Factor (dB)	Attenuation Inserted (dB)	Spectral Level (dBm/kHz)

Figure 9 – Sample data sheet (radar transmission spurious radiation).

40.2.4 Procedure. - Refer to figures 10-1 and 10-2 for a typical block diagram for this test. This test is performed in two parts. In the first part, the receiver's response to signals at the tuned and image frequencies and those slightly removed will be determined (Selectivity). In the second section, the receiver's response to signals at frequencies within the range specified will be determined (Spurious Response). Both parts are to be performed for each of the three test frequencies.

40.2.4.1 Selectivity. - In these measurements, the signal generator used shall be modulated with a pulsed signal that is approximately ten times the normal operating pulsewidth. This is done in order to determine the CW selectivity of the system. The wide pulsewidth produces a relatively narrow energy spectrum in comparison with the receiver bandwidth. This narrow spectrum avoids erroneous bias buildup in the receiver's gain control circuits. The signal generator is triggered by the system trigger of the radar under test.

40.2.4.1.1 The signal generator shall be tuned to the receiver frequency and the output is adjusted for a mid-pulse MVS, as defined in 3.1.7. The receiver video output is observed at the output of the video second detector, using a wide bandwidth high-frequency oscilloscope; e.g., Tektronix 545 or equivalent. Once mid-pulse MVS has been obtained, the frequency and level of the signal generator is measured as described herein, and recorded along with any attenuators, cable losses, etc.

40.2.4.1.2 The output of the generator shall then be increased by 3.0 dB and the signal generator tuned above the receiver frequency until mid-pulse MVS again is obtained. Signal generator frequency again is measured. This is repeated for 6, 12, 20, 40, 60 and 80 dB increases above the receiver mid-pulse MVS sensitivity; recording signal generator frequency for each step. If possible, the measurement is to be extended beyond the -80 dB response frequency in steps of 10 dB down to the -100 dB level. The foregoing procedure is then repeated with the signal generator tuned below the receiver tuned frequency. Range of the measurement will be such to include the image response of the receiver.

40.2.4.2 Spurious response. - For this portion of the receiver response test, the signal generator shall be modulated with a pulse of the same width as the system pulse and triggered by the system trigger. The signal generator output shall be applied to the plane of reference through appropriate waveguide transitions and adapters to insure, as much as possible, dominant mode incidence to the receiver. The adapters and transitions will be changed to correspond with the frequency being injected into the receiver. Filters shall be used to prevent unwanted signal generator outputs from entering the receiver. Attenuator(s) shall be used at the input to the adapters to provide a better impedance match between the source and the plane of reference. The receiver is first tuned to one of the test frequencies and adjusted to produce the maximum usable sensitivity. Starting at $0.9f_{co}$ for waveguide systems, or 14.0 kHz for coaxial systems, adjust the signal generator output to its maximum setting (at least 0 dBm). Increase the frequency of the signal generator level until a response is noted, using care not to pass over weak signals. The signal generator is tuned for a maximum video response. The signal generator is then lowered until MVS is obtained. After obtaining MVS, the signal generator output level and frequency are measured and recorded.

40.2.4.2.1 With the receiver setting unchanged, again adjust the signal generator output to the previous maximum output level. Tune the generator to a higher frequency until another response is noted. Measure and record each response, continuing until the generator frequency has reached 40.0 GHz. The maximum signal generator frequency shall not exceed 10 times the receiver tuned frequency.

40.2.4.2.2 For systems incorporating r.f. selectivity preceding the first mixer, spurious response measurements shall be limited to the range of frequencies defined by the 60 dB r.f. bandwidth of the receiver.

40.2.5 Data. - Measurement data obtained from the receiver response measurement is presented in two parts: Part I, the selectivity data shall consist of signal generator frequency and level relative to mid-pulse MVS. In Part II, spurious response data shall consist of signal generator output level, attenuation inserted, cable losses, insertion losses, and signal generator frequency. All data shall be entered on forms of the type illustrated in figures 11 and 12 for the selectivity and spurious response tests, respectively. Sample calculations for obtaining the above information follows.

Sample calculation - Selectivity

Measured Data:

Receiver tuned frequency (f_0): 3650.105 MHz
Test pulsewidth: 20.0 microseconds
PRF: 300 pps

Sample calculation - Selectivity (cont'd)

Measured Data: (cont'd)

Signal generator relative level: + 3.0 dB
Signal generator frequency above receiver tuned frequency (f_1) = 3650.405 MHz
Signal generator frequency below receiver tuned frequency (f_2) = 3649.700 MHz

The 3 dB bandwidth is computed as follows:

$$BW_{3\ dB} = |+\Delta f| + |-\Delta f|$$

where

$$|+\Delta f| = (f_1 - fo)\ MHz$$

and

$$|-\Delta f| = (fo - f_2)\ MHz$$

$$|+\Delta f| = 3650.405 - 3650.105$$

$$= 0.300\ MHz$$

$$|-\Delta f| = 3650.105 - 3649.700$$

$$= 0.405\ MHz$$

$$BW_{3\ dB} = 0.300 + 0.405$$

$$= 0.705\ MHz$$

Sample calculation - Spurious response

Measurement Data:

Receiver tuned frequency: 3650 MHz
Test pulsewidth: 2.0 microseconds
PRF: 300 pps
Signal generator level (P_{sg}): -25 dBm
Signal generator frequency: 4203.615 MHz
Attenuation inserted (A_1): 0 dB
Cable loss (A_c): 4.1 dB
Insertion losses (A_i): 1.1 dB

The power input to the receiver at the plane of reference is

$$P_{sp} = P_{sg} - A_1 - A_c - A_i\ dBm$$

where

P_{sp} = power level required for MVS at frequency of the spurious response

$$P_{sp} = -25.0\ dBm - 4.1\ dB - 1.1\ dB$$

$$= -30.2\ dBm$$

This value shall be recorded in the last column of the data sheet.

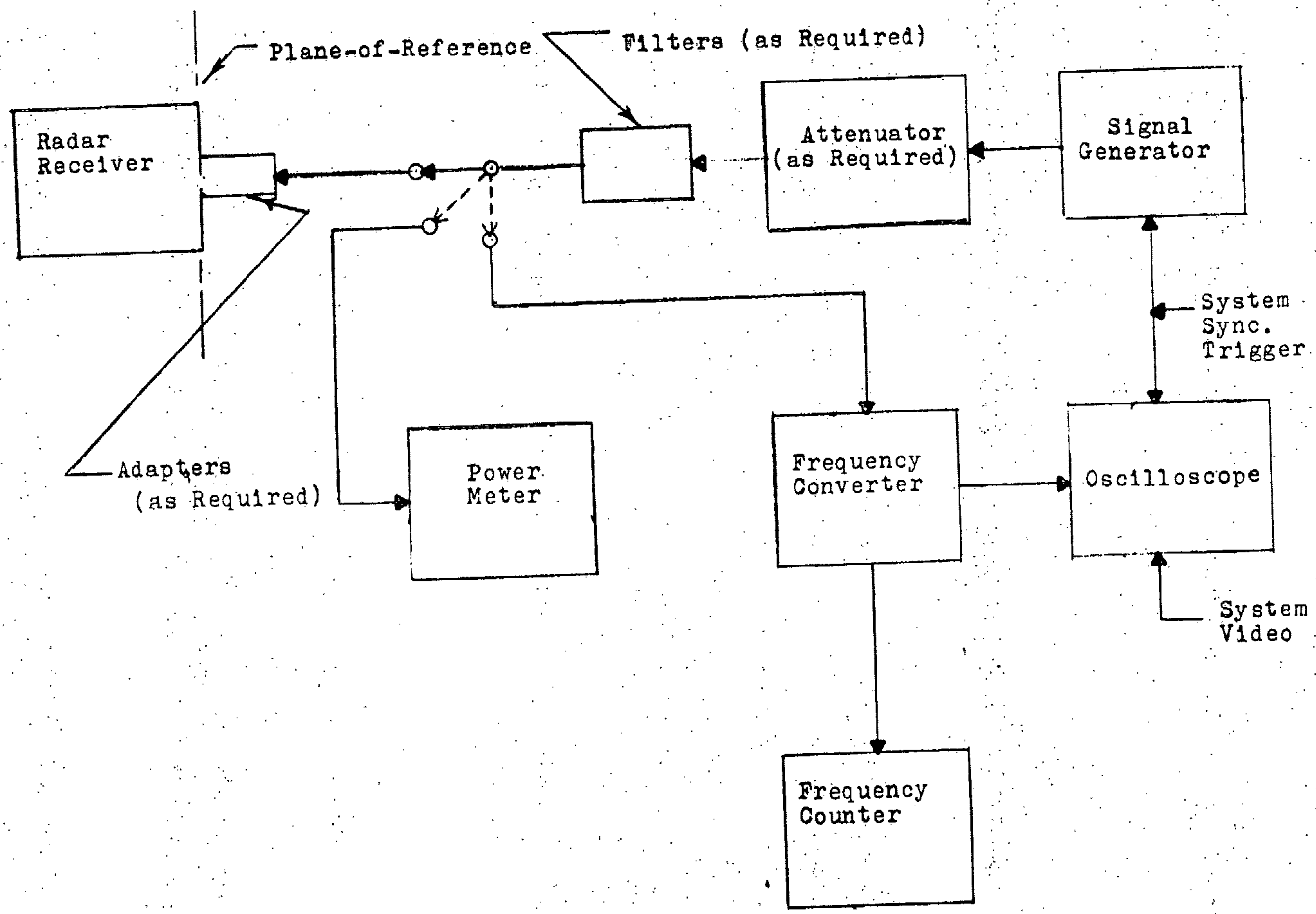

Figure 10-1—Receiver response characteristics measurements block diagram (below 10 GHz).

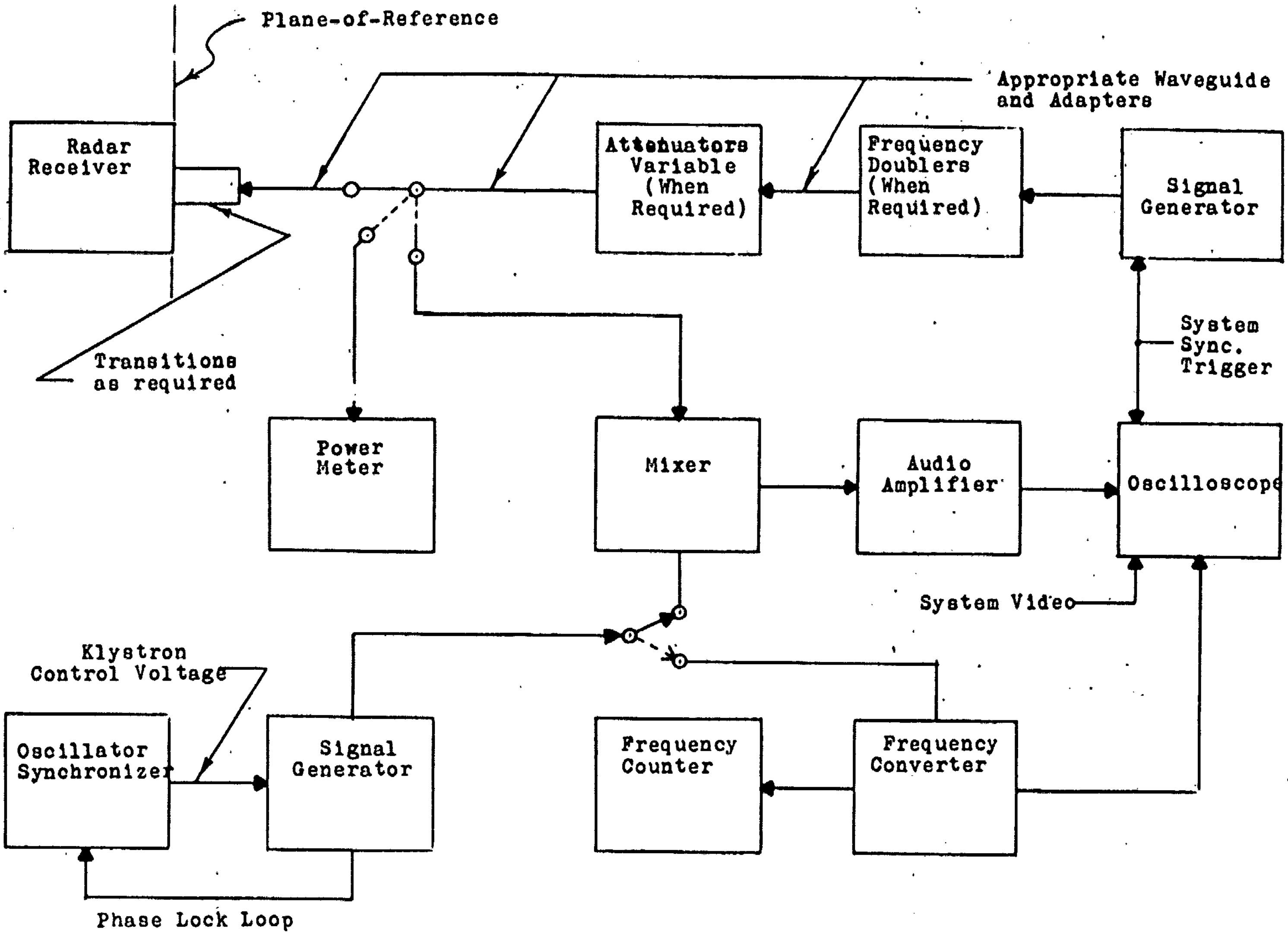

Figure 10-2—Receiver response characteristics measurements block diagram (12.4 - 40 GHz).

RECEIVER RESPONSE

Selectivity, Part I

DATE ______________________ TIME ______________________

RECEIVER TUNED FREQUENCY ______________ MHz

RECEIVER SENSITIVITY (Mid-Pulse MVS) ______________________ dBm

TEST PULSEWIDTH ______________ μs PULSE REPETITION FREQ. ______________ pps

Relative Response (dB)	+ Frequency (MHz)	$+\Delta f$ (MHz)	- Frequency (MHz)	$-\Delta f$ (MHz)	Bandwidth $\lvert +\Delta f \rvert + \lvert -\Delta f \rvert$ (MHz)

Figure 11 – Sample data sheet (receiver response,) selectivity, Part I.

RECEIVER RESPONSE

Spurious response, Part II

DATE ______________________ TIME ______________________

RECEIVER TUNED FREQUENCY ______________________ MHz

RECEIVER SENSITIVITY (MVS) ______________________ dBm

TEST PULSEWIDTH ______________ μs PULSE REPETITION FREQ ______________ pps

Spurious Frequency (MHz)	Signal Generator Output (dBm)	Atten. Loss (dB)	Cable Loss (dB)	Insertion Loss (filters, etc.) (dB)	Power Input to Receiver MVS (dBm)

Figure 12 – Sample data sheet (spurious response), Part II.

40.3 Receiver radiation. -

40.3.1 Objective. - To determine the level of radiation at the receiver input terminals.

40.3.2 Requirements. - No receiver radiations shall be greater than the value given in 6.7.4.

40.3.3 Energy that is generated within the receiver of a radar by local oscillators and other frequency-producing circuits may be radiated from the antenna terminals. In this manner, the receiver acts as a transmitter, emitting energy which could be a potential source of interference to surrounding equipment. To determine the level and frequency of energy present at the receiver input terminals, the following procedures will be followed.

40.3.4 Procedure. - Refer to figures 13-1 and 13-2 for a typical block diagram for this test. The transmission line from the receiver to the antenna shall be disconnected at the plane of reference as defined in Section 3. The receiver shall be first tuned to the mid-band operating frequency. The transmission line shall be terminated in an adapter of the proper type to connect the plane of reference to a frequency selective voltmeter (FSVM). The connecting transmission line between the adapter and the FSVM shall be kept as short as possible. No attenuators or sampling networks are needed if the nominal impedance of the FSVM matches the receiver (with adapter) under test. Tune the FSVM to a frequency corresponding to $0.9f_{co}$ (see 3.1.20). With this starting point, proceed to tune the FSVM through the frequency range specified.

40.3.4.1 When a signal is detected, the scan shall be stopped and the FSVM tuned for the maximum response. This reference shall be noted. The input to the FSVM shall be then switched to the signal generator (CW output). The generator shall be tuned to the frequency at which the response was noted and its output level adjusted for approximately the same level as obtained from the receiver. The generator output shall be next connected to a thermal power meter and its output referenced to the power meter. Reconnect the generator to the FSVM, re-peak the generator and adjust its output to provide the original reference. Record this level, and any attenuators, signal samplers, and cable losses where applicable.

40.3.4.2 To determine the precise frequency of the detected signal, switch the output of the signal generator to the frequency measuring equipment and measure its frequency as specified in Section 10 herein. Record this frequency, reconnect the FSVM to the plane of reference, and resume the scan. Repeat the above procedures for each detected radiation. The maximum signals measured in this manner should not exceed -67 dBm (see 6.7.4). It may be mandatory to provide filters (high-pass or low-pass) at the input to the FSVM when performing this test, to eliminate possible spurious responses of the FSVM to oscillator radiations of higher or lower frequency than that being measured.

40.3.5 Data. - The data measured in this test shall consist of signal generator output level, cable loss, and radiated frequency. All data shall be entered on forms of the type illustrated in figure 14. A sample calculation to obtain the radiated power level at the receiver input terminals (plane of reference) follows.

Sample calculation

Measured Data:
Receiver tuned frequency: 3650 MHz
Radiated frequency: 3620 MHz
Signal generator level (P_{sg}): -45 dBm
Cable loss (A_c): 3.5 dB

The radiated power level may be obtained as follows:

$$P_{osc} = P_{sg} + A_c$$

where

P_{osc} = the oscillator radiation at the plane of reference

= -45 dBm + 3.5 dB

= -41.5 dBm

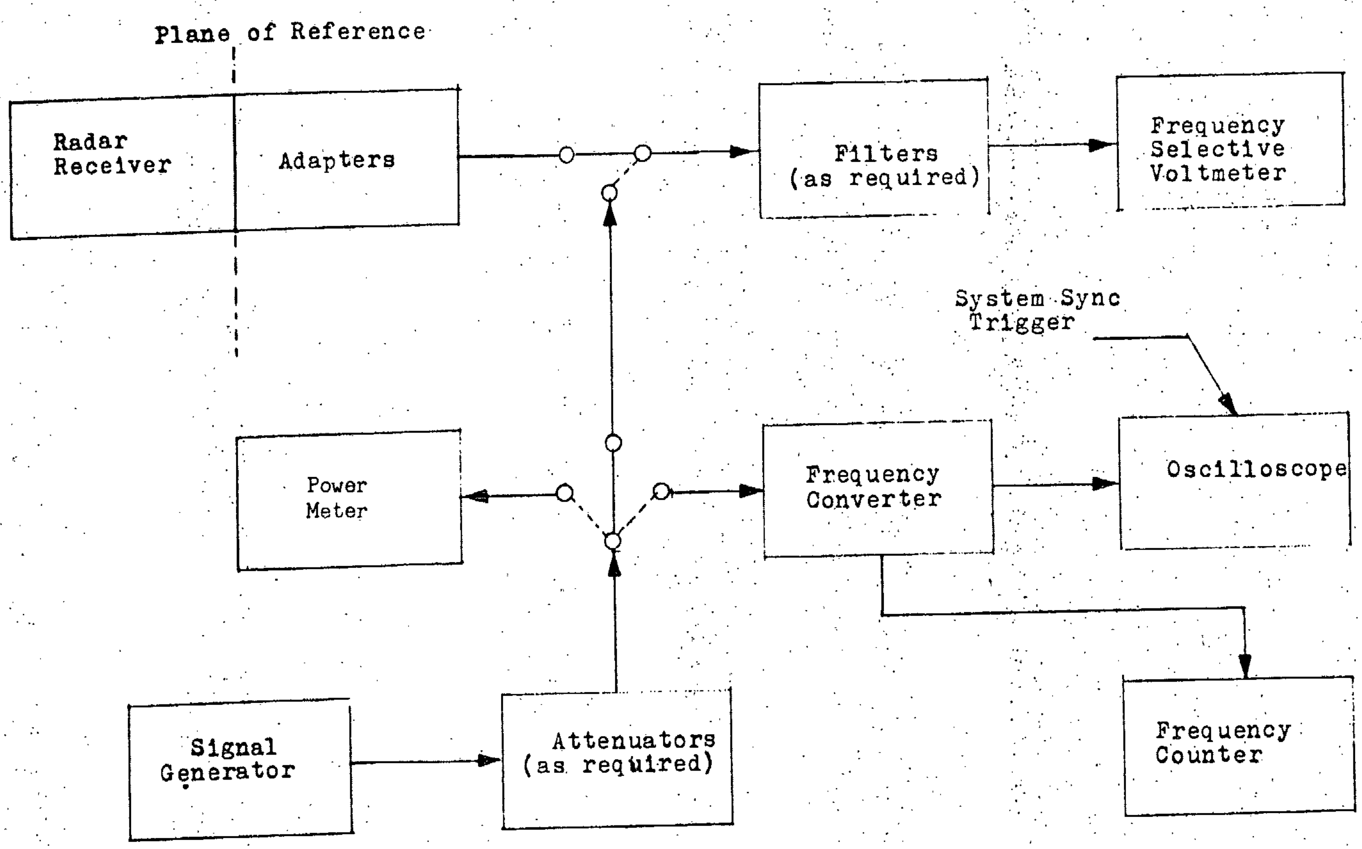

Figure 13-1—Radiation measurement block diagram (below 10 GHz).

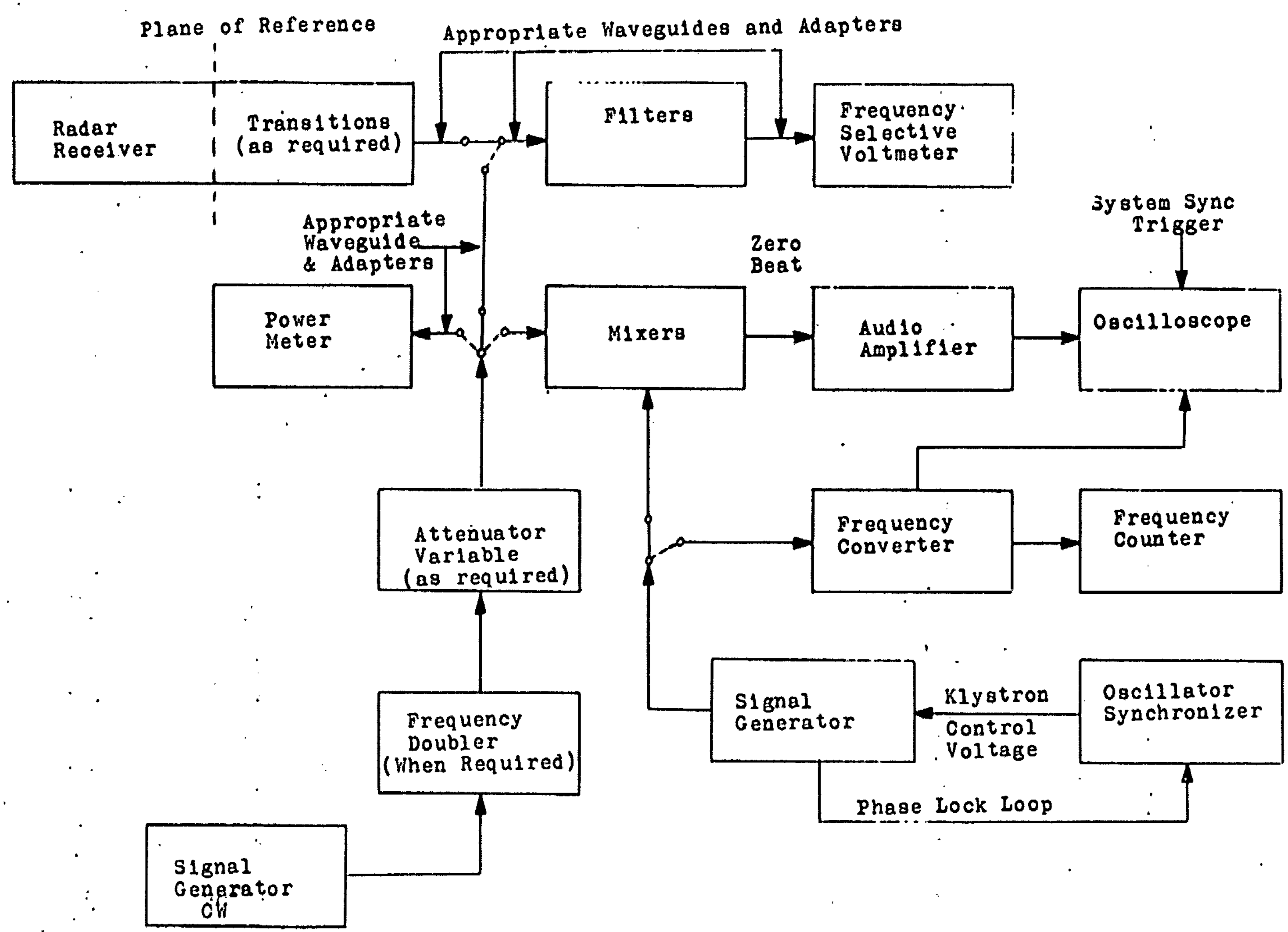

Figure 13-2—Radiation measurement block diagram (10 - 40 GHz).

Receiver radiation

DATE ______________________ TIME ______________________

RECEIVER TUNED FREQUENCY ______________________

LOCAL OSCILLATOR FREQUENCY: (1) ________ MHz; (2) ________ MHz; (3) ________ MHz

Radiated Frequency (MHz)	Source Identification	Signal Generator Level (dBm)	Measured Cable Loss (dB)	Radiated Power Level (dBm)

Figure 14 – Sample data sheet, (receiver radiation).

Identification of the radiation, when possible, shall be entered on the data form. In this example, the radiation measured is the local oscillator fundamental frequency (f_{o}).

50. ANTENNA MEASUREMENTS

50.1 The following measurements shall be made of all the radar antenna systems to determine the relative gain between the required lobes and associated side lobes.

50.2 Radar antenna side lobe suppression. -

50.2.1 Objective. - The objective of this test is to determine the relative gain between the operationally required antenna lobes and the associated side and back lobes.

50.2.2 Requirements. - All nonoperationally required antenna lobes shall meet the requirements of 6.5.

50.2.3 The spatial distribution of power radiated into space, with as little site effects as possible, will determine the amount of relative antenna gain existing in directions removed from the main beam(s) of an antenna. The recorded information, commonly referred to as "antenna patterns," presents a graphical representation of the energy distribution about the system antenna. This test shall be performed at the mid-band test frequency or at the horizon frequency in the case of frequency scan radars using the following procedures.

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

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

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

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

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

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

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

where

W = rotation speed, rpm

θ = 3 dB antenna beamwidth, degrees

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

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

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

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

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

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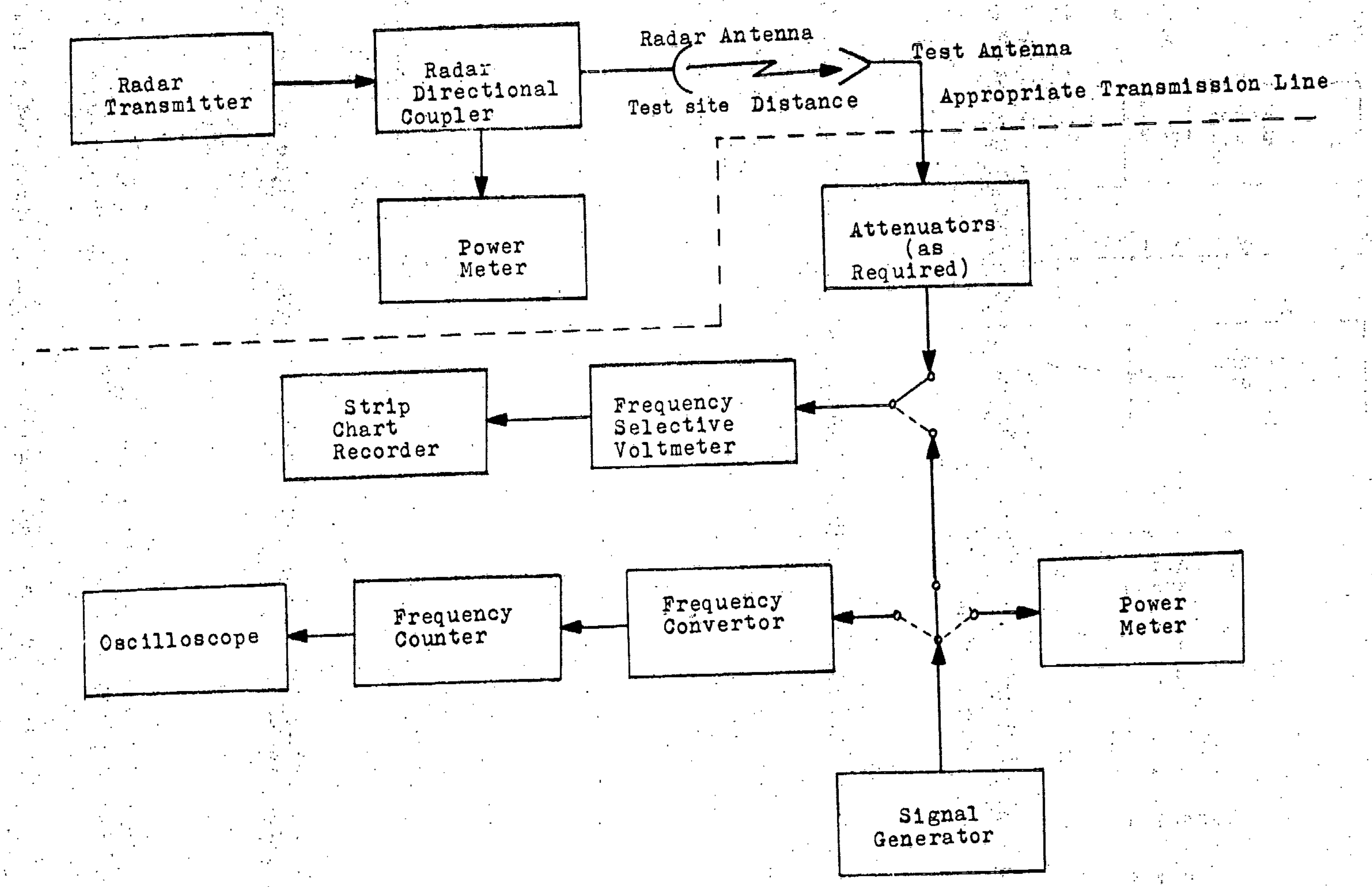


Figure 15-1—Radar antenna lobe suppression measurement block diagram (below 10.0 GHz).

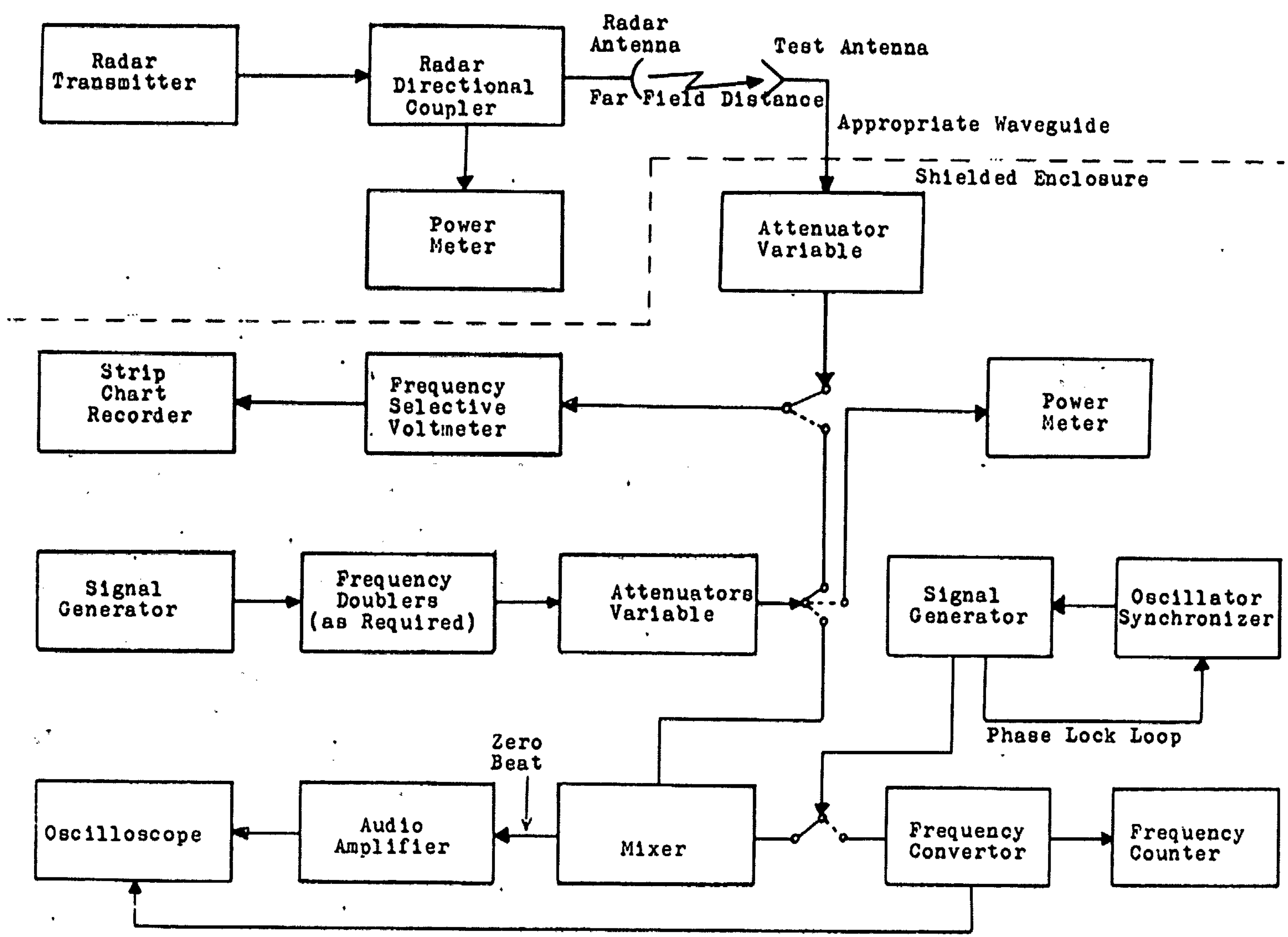


Figure 15-2—Radar antenna lobe suppression measurement block diagram (10 - 40 GHz).

ANTENNA LOBE SUPPRESSION

DATE ____________ TIME ______________ TRANSMITTER TUNED FREQUENCY ____________

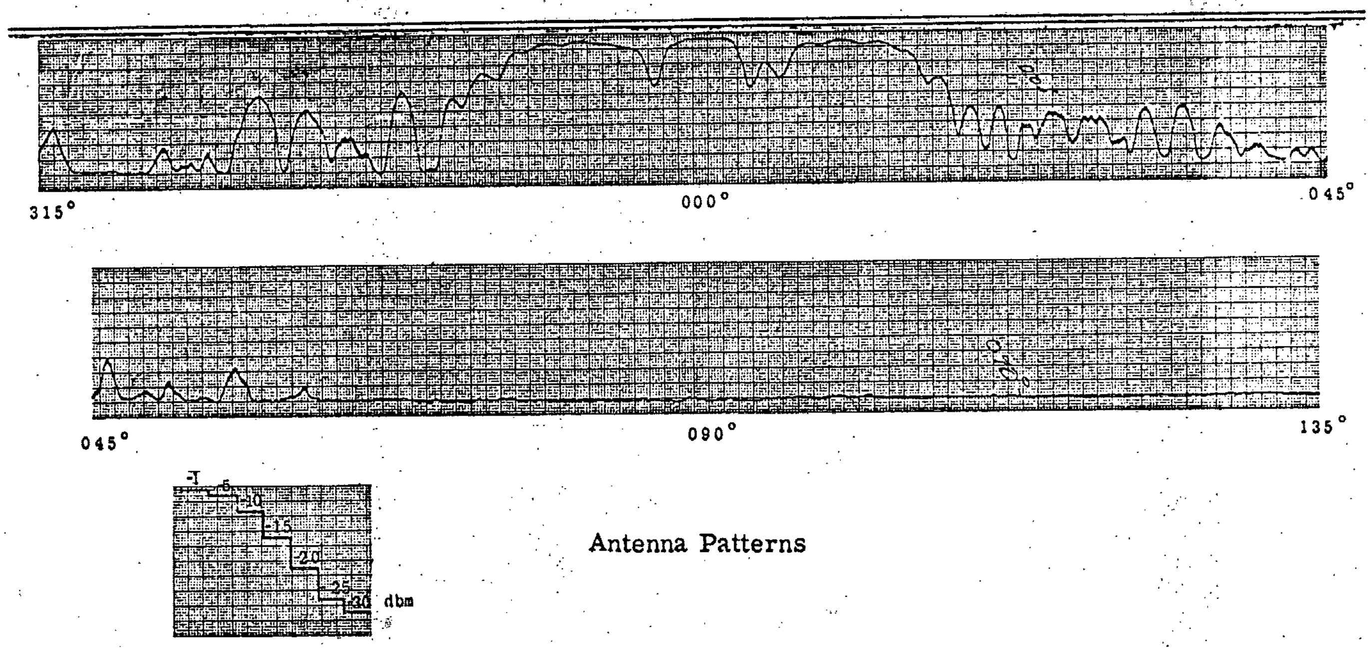
Peak Power Output________dbm Pulsewidth________μs Pulse Repetition Freq. _____pps

Frequency Selective Voltmeter Bandwidth ________MHz Attenuation Inserted_________ db

Antenna Rotation Speed ________rpm Recorder Speed ________

Test Antenna Orientation: θ____°, ϕ____°, ω____°, height ________feet

Power Density at Test Antenna ________ dbm/m^2



Antenna Patterns

Figure 16 — Sample data sheet (antenna lobe suppression).