APPENDIX A

EMC/RADHAZ PROGRAM PLAN OUTLINE

This appendix presents an outline for the EMC/RADHAZ Program Plan discussed in the basic portion of this handbook. Applicable portions of the outline are to be used as a basis for the content of the plan which is to be integrated with and become part of the BESEP.

A.1 INTRODUCTION

A.1.1 Purpose of Plan

The purpose of the plan shall be stated. This should in effect be a summary of the program required to achieve an EMC and RADHAZ free installation or system.

A.1.2 Purpose of Installation/System

The overall installation or system shall be summarized.

A.1.3 Requirements

Specific operational and installation requirements shall be stated. Particular requirements and actions of the NAVELEX Field Activity or Division shall be included.

A.2 APPLICABLE DOCUMENTS

A.2.1 Military Standards and Specifications

List of military standards and specifications which are to be imposed on the installation or system, and associated subsystems. For example, MIL-STD-461/462/469/449.

A.2.2 Other Manuals, Handbooks and Documents

List of manuals, handbooks and other documents containing requirements which are to be invoked shall be included. For example, other documents of the Naval Shore Electronics Criteria Handbook series, ANSI standards on RADHAZ (i.e., Warning Sign), other SYSCOM and Navy publications containing siting or installation criteria and EMI suppression techniques, etc.

A.3 DESCRIPTION OF INSTALLATION/SYSTEM

A.3.1 Intended Function

A brief description of the intended function of the installation or system shall be given. In addition the following should be addressed.

a. Is intelligence to be transmitted? If so, what type? How will it be used? For what purpose?

b. What is the allowable maintenance or down-time?

c. Will the system operate continuously?

d. If a back-up is required, will it operate exactly as the primary?

e. Do any equipments or subsystems perform critical operations which can effect mission success or safety?

f. What is the transmission medium?

g. Is signal processing equipment to be used?

h. Will all the equipments and subsystems be manned during operation?

A.3.2 Specific Operational or Environmental Characteristics

The following items should be addressed if known:

a. What is the electromagnetic environment in which the installation will be sited?

b. What environmental factors are there that may adversely affect radiation?

c. Will environmental conditions require special parts and materials in order to maintain reliable operation?

d. What effects do environmental conditions have on the installation of the equipment required to generate, radiate or receive the electromagnetic energy?

e. How will environmental conditions effect the signal-to-noise ratio?

f. Are the operating frequencies vulnerable to atmospheric, natural, or man-made noise at the intended installation?

g. Will the antenna patterns be affected by objects in the vicinity or local terrain?

h. Will there be any other devices in the area that could cause interference to your equipment? If so, what are the functions and characteristics of these other devices? Are there any coupling mechanisms? Have emission or susceptibility measurements been made on these other devices?

i. What effect would interference have on transmissions?

j. What would be the effect of poor ground conductivity?

k. Is real estate available at ground station locations?

l. Is there sufficient space available to house necessary equipment or subsystem for all of the possible operating frequencies?

A.3.3 Type and Characteristics of Equipments/Subsystems to be Installed on Site

A brief description of the devices to be used in the installation should be included, with specific attention to electronic warfare, cryptographic, nuclear detection and ordnance equipment, and the required sensitivities of receiving equipments and operating frequencies of all equipments.

A.4 DESIGN CRITERIA

The overall EMC and RADHAZ control approaches to be taken and the basis for them should be discussed. Shielding, bonding, grounding, cable routing, location of potential hazard, warning signs/alarms, special hazard reduction equipment or techniques (i.e., fuel nozzles, antenna location, use of protective clothing, etc.) should be covered.

Mechanical design considerations shall be described including construction techniques and materials to be used to provide inherent attenuation to EMR.

A.5 ANALYSIS

Prediction and analysis techniques employed to determine potential RADHAZ and EMI problems should be described and predictions performed to date included. Potential problems should be identified as well as the steps to be taken to eliminate each problem.

A.6 TEST AND EVALUATION

The test program deemed necessary to demonstrate EMC and identify possible RADHAZ after installation of all equipments subsystems and systems shall be described. Detailed tests are to be included in the test plan.

A.7 FREQUENCY MANAGEMENT

Statements should be included addressing frequency management aspects of the program including frequency assignment and allocations. Consideration must be given to obtaining frequency allocations for the equipments and subsystems operation, as well as for testing purposes.

A.8 MANAGEMENT

A.8.1 Organization

A description of the organizational responsibilities,lines of authority and control in the activity's organization to show how the EMC/RADHAZ program is to be managed within the overall program framework.

This shall include a definition of responsibility for the program for items and for services which are contracted.

A.8.2 Program Control

A description of installation design reviews and other means of control shall be given.

A.8.3 Schedules

A schedule shall be given describing the milestones for the EMC/RADHAZ program and it shall show how these milestones fit with key overall project.

APPENDIX B

EMC/RADHAZ MEASUREMENT PROGRAM

B.1 SCOPE OF APPENDIX

Various aspects of EMC and RADHAZ have been presented in the basic portion of this handbook. One exception concerns the measurement program required to actually demonstrate EMC or to identify the presence of RADHAZ. Due to the constantly changing technology associated with such measurements, discussion of the overall measurement program has been included as a separate appendix. This will facilitate the updating of the measurement portion of the handbook as the technology advances. The following paragraphs outline general and specific considerations associated with measurements for EMC and RADHAZ. All portions of this appendix will not be applicable for all measurement programs. Therefore, prior to embarking on a measurement program this appendix should be reviewed and applicable portions selected for implementation.

It is also noted that NAVELEXINST 5100.4 indicates that NAVELECSYSCOM field divisions and activities may be required to provide field strength measurements of the electromagnetic environment for RADHAZ evaluations. Applicable portions of this Appendix should also be used for these measurements.

In approaching the measurement program for EMC it is assumed that individual equipments and subsystems which are to be located on the shore station in question have complied with the applicable emission and susceptibility criteria in MIL-STD-461/462 as well as the requirements in MIL-STD-469 for radars. If such is not the case, these equipments should be examined initially when the installation measurements reveal electromagnetic incompatibility.

B.2 GENERAL CONSIDERATIONS FOR INSTALLATION TESTING

Standards for evaluating installations or systems for EMC and RADHAZ are not, generally, available. Therefore, accurate evaluations require a great deal of judgement in predicting or anticipating the operational electromagnetic environment. Thorough evaluations must also consider the required performance characteristics and missions of the installation or system, and associated subsystems. Information gathered from the MIL-STD-461/462 type evaluations of individual equipments to be installed will be useful in evaluating overall system or installation operation and performance.

In order to clarify the system or installation evaluations to be discussed herein, it is necessary to distinguish between "intra" and "inter"-system or installation EMC/RADHAZ evaluations. The former refers to determinations of potential RADHAZ or degradation of the intended performance or mission of equipments or subsystems in a given installation or system as a result of emissions generated by devices internal to, or within that installation or system. Use is made of data obtained from MIL-STD-461/462 measurements of conducted and radiated emission and susceptibility characteristics of the various equipments. Knowledge of the general layout of the final installation or system will enable predictions, as described in Chapter 6 of this handbook, to be performed for intra- and inter-system or installation of EMC and RADHAZ. Evaluations for inter-system or installation of EMC and RADHAZ must be made in the intended operational environment. Emissions must be anticipated from all (i.e., Navy, DOD, other government agencies, and commercial) electronic and electrical emitters in the vicinity, as well as nearby power lines. With this information and the susceptibility characteristics of devices installed in the system or installation, it is possible to determine the presence of RADHAZ as well as performance or emission degradation. The extent, level, and identity of emissions associated with shore electronic installations will vary greatly. If, at a specific planned site all emitters on, or in the vicinity of, the installations are known, or can be predicted from information obtainable from ECAC (see Chapter 1), along with the electrical characteristics, actual surveys or measurements may not be needed. Knowing the above information, field intensities and power densities can be predicted. If, however, measurements are necessary, they should be approached in an orderly manner, starting with preparation of a test plan to describe the testing procedures that will be used to demonstrate EMC or determine the existence of RADHAZ. In general, the test plans indicate measurement objectives, test configurations, test frequencies and points, detailed measuring procedures and the format for recording data. Test procedures should be described in sufficient detail to enable duplication of the proposed methods since data obtained from the measurements may necessitate corrective actions to eliminate or minimize hazards or interference. Finally, upon completion of the testing programs, test reports are to be prepared in sufficient detail to permit the required analyses for EMC or RADHAZ.

Additional details on various aspects of EMC and RADHAZ measurements are discussed below. It is noted that details for RADHAZ measurement evaluations are also applicable for EMC evaluations.

B.3 EMC MEASUREMENTS

B.3.1 Testing Concepts

The complete EMC survey may cover the frequency range of 30 Hz to above 40 GHz, depending on the equipment used in the installation and will consider both inter- and intra-installation or system of EMC, with the major objective to demonstrate total installation EMC under operational conditions. Tests should be designed to investigate and locate every potential source and victim of EMI via the mechanism inherent in the actual operational environment. Because the tests include basic equipments and subsystems in the installation, as well as all of the electrical and other electronic equipments in the system or installation, the EMC survey is quite lengthy in both preparation and implementation.

Test procedures and instrumentation required to perform realistic EMC tests are to be detailed in the test plan. There are several basic approaches that may be followed, either singly or collectively to demonstrate EMC.

a. Emissions may be injected into the system or installation at critical points. Injected conducted emissions must be at a level somewhat higher (for example 6dB) than pre-determined ambient environment levels. Appropriate test points must then be monitored for malfunction indications.

b. A second approach that may be used to test for a safety margin (i.e., 6 dB) between equipment susceptibility and emission levels generated within the system or installation, is to increase the system or installation sensitivity level so that its susceptibility level to interference is increased by the required safety margin. With this approach, it is also necessary to monitor test points for malfunctions. The increase in sensitivity is often difficult to achieve and therefore this approach is seldom used.

c. A third approach that may be used is to measure susceptibilities of key subsystems or equipments and compare these measured levels with existing or predicted emission levels to determine if the required safety or interference margin exists.

Each of the above approaches has certain advantages and disadvantages. The best approach will depend on the particular installation or system under consideration and should be documented in the test plan.

B.3.2 Degradation/Malfunction Criteria

In order to evaluate the effectiveness of a system or installation it is necessary to evaluate how the various associated subsystems and equipments are affected by emissions. This necessitates defining what constitutes a malfunction or degradation of performance and measurement techniques.

To do this, it must be indicated how the degradation will affect the operational performance. In some cases, the environmental conditions must be designated under which the presence of potentially interfering (undesired) emissions or other forms of electromagnetic energy will be barely detectable in the output of the various equipments and subsystems. In many instances, the system of design is such that substantially more than barely detectable signals must be impressed before degradation of performance occurs. This is because the associated subsystems and equipments if designed to MIL-STD-461 have a certain amount of immunity. Some judgement will, therefore, have to be exercised in specifying the emission levels at which actual degradation of performance will occur. Presumably, a technician with adequate experience can make a fair estimate of such things as when data transmission circuits will begin to produce errors, when target indicators will begin to become confused by extraneous indications, and when communications circuits are sufficiently degraded that information transmission is difficult to maintain or is otherwise unsatisfactory. Accordingly, the 6 dB figure cited above should not be construed as the sole criteria to use.

Eventually, it is expected that performance and malfunction criteria pertaining to overall operation will become more explicit and quantitative than at the present time.

B.3.3 Installation/System Operation

To meaningfully test for EMC, it is necessary to operate all equipments and subsystems in the installation or system as expected during the execution of all of its intended missions. It should be operated under load as in "real-life" - at least to the extent economically permissible. Time-dependent operations of the various equipments one at a time and recording EMI malfunctions, if any, may have little resemblance to real-life situations since an installation generally has a number of devices actuated at any one time. On the other hand, turning on all devices simultaneously will probably create a situation which also will never occur in real life. Accordingly, the off-on modes of operation of the devices and equipments of an installation or system should be documented in the test plan and followed. Aside from the basically required interference measuring equipment (which sometimes can be minimized if adequate secondary instrumentation usage is approved), test equipment such as signal generators, oscilloscopes, spectrum analyzers, frequency meters or counters, cameras, audio amplifiers, and/or special receivers may be required. Included in the signal generator class are those special signal sources needed to provide simulation of the subsystems or equipments be they random pulse, function, sine, square, video, transient, or audio devices. The use of amateur radio or military surplus transmitters can sometimes even be used as EM energy sources instead of more costly high power signal generators (provided that radiated spectrum is relatively clean). The audio amplifiers need not be special.

Of particular concern is the choice of measuring antennas for radiated emission tests. The following antennas are commonly used and are acceptable for the EMC testing described herein (See Table B - 1).

Antenna factors are to be included in the test plan or test report. Procedures for antenna calibration are included in MIL-STD-461/462 and the SAE ARP 958.

B.3.4 Monitoring the Installation or System

Malfunctions may be sensed and recorded using personnel to man the stations of output display devices, such as panel meters, recorders, scope displays, digital presentations, etc., in which the outputs are intended for human consumption. Malfunctions may also be monitored automatically by sensors which record a voltage or current which is an analog of the sensed parameter. This technique is especially important where events are occurring too rapidly for humans to follow or where more automation of malfunction versus mission time sequence is desired for economic reasons. Concurrently with the latter approach, certain auxiliary instruments may be used to help locate victims and sources of EMI. For example, current probes on one or more busses or wiring harnesses may be used, as may electric field antennas for probing certain areas. For these data recordings, plots of amplitude (usually peak readings) versus time are made to permit all data to be presented on an event-reaction versus time basis. This allows cause and effect analyses to be made.

B.3.5 Instrumentation Considerations

As previously stated, EMC testing involves instrumentation to record emission levels of voltage or current on critical circuits and the effects of the emissions in outputs of critical devices. In most instances, these tests are performed over a period of time during which continuous recordings may be required. As a result, a wide range of test equipments may be required. EMC instrumentation requirements are covered in many of the referenced documents as well as several military standards, such as MIL-STD-461/462/449 and 469, and therefore will not be detailed herein. General factors to consider when selecting instrumentation, however, are presented in the following paragraphs. Oscilloscopes and spectrum analyzers are fast becoming favorite test tools. A camera may be added to these units to provide a permanent record. For transient amplitude measurements and analysis this is one of the only ways to record the events as they occur. The use of current probes with these instruments further increases their utility. Logarithmic sweep adapters are available for many oscilloscopes making possible the display of information normally presented on graph paper.

The instrumentation to be used should be described in the test plan.

B.3.6 Test-Site Ambient Electromagnetic Environment

The ambient electromagnetic during testing must be monitored, measured, analyzed, and perhaps controlled, to ensure that it does not degrade test results or mask EMI. When possible, all support or site equipment that generates EMI should be suppressed, removed or not operated. Ambient signals that degrade test results should be identified. For signals that may be present only randomly, such as from commercial or mobile communications stations, it may be possible to perform EMC testing while the signals are not broadcasting.

Some emissions may be arriving at the test site by ionospheric propagation. Such signals will usually be below 30 MHz. These emissions may be present for 24 hours. However, due to the daily changes in ionospheric propagation, tests in this frequency range may be scheduled for times when the offending emissions are relatively quiet. CCIR 322 can be used to estimate these levels.

Certain frequencies in the broadcast FM and TV bands may cause problems. The approach in this case is to postpone measurements in these frequency ranges until the offending stations sign off. This approach may also be used where certain noncommercial ambient emissions are on only during the normal work day. For example, the checkout of an engine-generator set can be arranged outside normal working hours so that such industrial equipment as welders, milling machines, lathes, reproduction machines, etc., can be turned off without disturbing normal operation.

The characteristics of certain ambient emissions allow the human ear to discriminate between them and the emission from the test sample. This approach may be used where the ambient emissions are clicks caused by a switching device and the emission of interest is a pulse with a steady repetition rate. The level of the ambient emission should not be too far above the emission of interest, lest the emission of interest be inaudible.

EMC measurements at times must be made in areas where other electronic tests are being performed. Managers of these areas can do much toward ensuring that the ambient is kept within reason, providing it is handled in a timely manner. Some offending items that should be kept out of the test area during EMC tests provided with appropriate means of suppression are:

a. Vehicles with ignition systems. These may be replaced with diesel units or suppressed.

b. Motor-generator sets. These units may be of brushless design, or located in shielded enclosures with filtered input and output lines.

c. Facility appliances (switching units, such as heater or elevator switches, and many motor units such as refrigeration units, fans, etc.).

When considering ambients, the conducted ambient level should not be overlooked. Ambient emissions can be conducted to the test area and critical devices via power lines. They can be conducted a considerable distance. Therefore, when evaluating the ambient electromagnetic levels, the following should be considered: power lines; telephone lines; commercial radio relay lines; nearby industrial activity; and equipments operated on the installation.

B.4 EMR HAZARDS MEASUREMENTS

Measurement procedures to determine hazardous levels of EMR at shore installations have been developed and used for some time. Various aspects of these procedures are included herein to facilitate and standardize to some extent EMR measurements at shore sites.

B.4.1 Near and Far Field Measurement Considerations

The electric field radiated by a particular transmitting antenna can be measured in either the near field or far field as discussed in other chapters of this handbook. There is no sharp dividing line between the two regions and the somewhat arbitrary limits set for each region are based on the way in which the energy spreads as the distance from the antenna increases since the energy is not spread uniformly across the antenna in the near field region and does not have a fixed density value with distance from the antenna as it does in the far field region. This being the case, the far field region is normally selected to perform measurements. The far field regions appear at a substantial distance from the transmitting antenna. At this point the power density begins to decrease in proportion to the inverse square of the distance from the antenna. The far field region begins at a distance $d = 2(D_t + D_m)^2/\lambda$ where D_t = diameter of the transmitting antenna, D_m = diameter of measuring antenna, and λ= wavelength.

B.4.2 Equipment Selection

Factors are now covered for measuring and identifying the extent of electromagnetic radiation in a field created by an unknown source or sources of radiation at a specific site on or around an installation. Power meters, field intensity meters, and spectrum analyzers can be used as measuring instruments. The power meter is a broadband device from which levels of power density can be determined, but in order to identify the frequency of the sources of the electromagnetic radiation, a frequency selective device such as the Field Intensity Meter (FIM) or spectrum analyzer must be used. Regardless of which test instrument is used to measure an unknown field, the proper receiving antenna or antennas must be selected and properly oriented. For example, the possible radiation may originate from a directional type antenna or antennas. In this case the receiving antenna must be rotated 360° in azimuth in order to maximize on the radiated emission or emissions. The spectrum analyzer has the capability as a frequency selective device or broadband measuring device with varying spectrum widths. Many FIM have automated sweep frequency capability along with an X-Y recorder output. For devices without the automatic sweep capability, manual sweeping can obtain acceptable results. When using an FIM, which is a frequency selective device to scan the frequency field in question, several frequency scans may be required along with different orientation of the proper receiving antenna or antennas, in order to investigate the frequency operation properly. Once the presence of an emission or emissions and the approximate level or levels determined, then the selected emissions can be measured and power density levels determined and identified by frequency if required.

B.4.3 Measurements in High Level Fields

In performing measurements close in or in the near field, there exists the possibility of obtaining erroneous reading on the monitoring device due to the presence of a high level radiation field which exceeds the shielding capability of the measuring device. To determine if case penetration is present, terminate the signal input of the monitoring device, and with minimum attenuation settings, observe the meter indication, if any. In the event there is a meter indication then case penetration is considered. To counteract this situation a shielded enclosure must be used which provides sufficient shielding in order to obtain valid data, or move the instrument away from the beam of the radiator.

B.4.4 Multiple Sources

The superimposed fields of multiple frequencies (several transmitters) may be strong enough to cause a radiation hazard even though each individual transmitter cannot. In this situation a frequency selective measuring instrument is necessary such as a spectrum analyzer or RIFI meter. Each transmitter is treated as a single source. After the results are obtained for each individual transmitter then:

a. Determine the ratio (EM/EC) for each transmitter. EC is equal to the hazard requirement for the particular situation and EM is equal to either the calculated or the measured power of the individual transmitter.

b. Square the ratios (one for each transmitter) and add them:

$\left(\frac{EM_1}{EC_1}\right)^2 + \left(\frac{EM_2}{EC_2}\right)^2 + \ldots\ldots$ (10). If they are equal to or greater than 1, a hazard exists.

If the ratio is less than 1, no hazard exists.

B.4.5 Calculations

B.4.5.1 Converting Field Intensities to Power Densities

Some relationships that are quite useful in converting field intensity measurements are presented below:

$$P = \frac{E^2}{120\pi} \qquad \text{(B-1)}$$

P = Power density in watt/meter^2

E = Electric field intensity in volts/meter

120π = Resistance of free space

For convenience this can be expressed in logarithmic form for watts, milliwatts, volts, and microvolts.

dBW/m^2	=	dBV/m	–	25.8	(B-2)
dBW/m^2	=	dBμV/m	–	145.8	(B-3)
dBm/m^2	=	dBμV/m	–	115.8	(B-4)
dBm/cm^2	=	dBμV/m	–	155.8	(B-5)
dBm/cm^2	=	dBV/m	–	35.8	(B-6)
dBW/m^2	=	dBm/m^2	–	30	(B-7)
dBW/m^2	=	dBW/cm^2	+	40	(B-8)
dBW/m^2	=	dBm/cm^2	+	10	(B-9)

B.4.5.2 Received Power

Calculations of received power can be made as follows:

$$P_r = \frac{A_r A_t P_t}{(\lambda R)^2} \qquad \text{(B-10)}$$

where:

P_r = received power in watts
A_r = receiving antenna effective area in meters
A_t = transmitting antenna effective area in meters
P_t = transmitter average radiated power in watts
λ = wavelength of transmitted signal in meters
R = distance between transmitting and receiving antennas in meters.

In addition,

$$P_r = \frac{G_r G_t P_t \lambda^2}{(4\pi R^2)} \qquad \text{(B-11)}$$

$$P_r = \left(\frac{G_r G_t P_t}{f\,[\,\mathrm{MHz}\,]\,R^2}\right)\left(\frac{984}{4\pi}\right)^2 \qquad \text{(B-12)}$$

where:

f = transmitter frequency in MHz and R = distance in feet
If P_t is in watts, then P_r is also in watts.
Written in logarithmic form equation (B-12) becomes:

$$P_r = 37 + G_r + G_t + P_t - 20 \text{ Log } R - 20 \text{ Log } f \qquad \text{(B-13)}$$

where:

P_r = received power in dBm if P_t is also in dBm.

Equation (B-13) enables simple addition and subtraction of the factors needed to predict received power.

An alternate method of prediction for power density of an emission at a given distance from the transmitting antenna utilizes the following equation:

$$P_d = \frac{P_t G_t}{4\pi R^2} \qquad \text{(B-14)}$$

where:

P_d = power density in watts/m^2 (milliwatts/m^2)
P_t = transmitter average power output in watts (milliwatts)
R = distance between site of interest and transmitter antenna in meters
G_t = transmitter antenna gain

$$P_d = P_t + G_t - 11 - 20 \text{ Log } R, \qquad \text{(B-15)}$$

where:

P_d is in dBW (dBm)/m^2, P_t is in dBW (dBm) and G_t is in dB, which reduced the math to simple addition and subtraction.

To obtain power density from the received power, we can use the following relations:

$$P_d = \frac{P_r}{A_r} \quad \text{Where } A_r = \text{effective area } (m^2) \qquad \text{(B-16)}$$

$$A_r = \frac{G_r \lambda^2}{4\pi} \qquad \text{(B-17)}$$

$$\text{Hence,} \quad P_d = \frac{4\pi P_r}{G_r \lambda^2} \qquad \text{(B-18)}$$

or expressed logarithmically:

$$P_d\ (\text{dBm/m}^2) = 11 + P_r\ (\text{dBm}) - G_r\ (\text{dB}) - 20 \text{ Log } \lambda \qquad \textbf{(B-19)}$$

Correcting for cable loss (A_o) from the antenna, we now have:

$$P_d\ (\text{dBm/m}^2) = 11 + P_r\ (\text{dBm}) + A_o\ (\text{dB}) - G_r\ (\text{dB}) - 20 \text{ Log } \lambda \qquad \textbf{(B-20)}$$

B.4.5.3 Comparisons With Predicted EMR Levels

In order to compare the measured EMR levels with predicted levels, refer to the Power Density nomogram in figure B-1 of this Appendix and use the following procedure:

a. Locate the transmitter output on the P_t scale.
b. Locate the gain of the transmitting antenna on the G_t scale.
c. Connect a straightedge between these two points and note the reading on the P_t G_t scale.
d. From this point on the P_t G_t scale connect a straightedge to the distance which is the antenna separation located on the R scale.
e. Note the reading on the P_d scale. This level is the predicted power density at the point of interest.

To determine the power that one's instruments should measure at this point, refer to the Effective Area and Received Power nomogram in figure B-2 of this Appendix.

a. Locate the gain of the receiving antenna on the G_r scale.
b. Locate the transmitting frequency on the frequency scale.
c. Connect a straightedge between the two points and note the reading on the A_e scale.
d. Connect a straightedge from the reading on the A_e scale to a point on the P_d scale which represents the approximated power density obtained from the Power Density Nomogram.
e. Note the reading in dBm on the P_r scale.
f. Correct for cable loss by adding the attenuation of the receiving cable to the value obtained in (e.) and determine what the measuring instrument should read. This predicted value should be very close to the actual measured value. If the result is desired in dB volts/meter instead of dBm/m² scale, refer to paragraph B.4.5.2.

B.4.6 Testing for RADHAZ to Fuels

B.4.6.1 Necessity for Testing

Many factors affect the creation of an environment favorable to the ignition of fuel vapor by RF-induced arcs. Some of these have been discussed in other portions of this handbook, but are also listed.

a. Fuel
   (1) Fuel/air mixture ratio
   (2) Type of fuel (aviation gasoline, jet fuel, etc.)

b. Electromagnetic Environment
   (1) Transmitter power
   (2) Frequency
   (3) Type and characteristics of antenna (gain, polarization, etc.)
   (4) Ground conductivity

c. Installation or System Geometry
   (1) Aircraft or vehicle orientation with reference to antenna
   (2) Distance from antenna
   (3) Type of aircraft (wing span, location of filler vents on wing, etc.) or vehicle
   (4) Presence of nearby reflecting bodies
   (5) Length and orientation of nozzle and filler hose with reference to both aircraft or vehicle and transmitting antennas
   (6) Ambient winds.

B.4.6.2 Measurements

The purpose of the measurements are to determine several of the more important fuel-hazard parameters at a Naval Shore Station where such a hazard is known to exist and, on the basis of these measurements, to establish general distance separation and transmitter power criteria for the planning at other Naval Shore Stations. The effectiveness of several proposed corrective measures will be determined.

The major part of the measurements required are outlined below. Details on the particular type of instrumentation employed (type, serial number, manufacturer), lead lengths, provisions for shielding and grounding, and the physical environment (wind, temperature, humidity, etc.) should be recorded.

a. Field Intensity Measurements. For a specified transmitter power output and for several frequencies across the HF band (i.e., 2, 8, 30 MHz), the field intensity will be measured at various selected points within the normal refueling area and adjacent to the antenna complex. Both vertical–and horizontal-polarized components of the electric field will be measured at specified heights above the ground. The pickup antenna will be oriented in the horizontal plane to obtain a maximum reading. Its direction will also be noted. Distances from these points to the transmitting antenna should be recorded.

Because of mismatch problems between the antenna, transmission line, and transmitter, the degree of mismatch, evidenced by VSWR on the line, should also be recorded at both ends of the transmission line. The type and length of both the transmission line and the antenna are to be noted. The transmitter need not be modulated for these tests, since correction factors can be applied later to determine peak instantaneous powers at the modulation crests; i.e., for 100% AM modulation, the peak instantaneous power is eight times the average unmodulated power. Average ground conductivity should also be noted.

To minimize the influence of reflecting bodies such as nearby aircraft, personnel, trucks, etc., these measurements should be made in a roped-off area. Proximity effects due to personnel taking the readings may cause erroneous data, so remote readings via a telescope may be necessary. Providing adequate shielding of the instrumentation, signal, and power leads will likely be a problem before repeatable data can be taken. Calibration of the field intensity meters both prior to and immediately after these tests is desirable to insure accurate data.

b. RF Voltage and Current. When evaluating RADHAZ to fuels for air stations, measurements on several typical Naval aircraft (fighters, patrol, training, etc.) should be made of the RF-induced voltages and current between selected points along the aircraft wing (both sides) and the nozzle of a purged fuel truck. These aircraft should be located at the same points in the refueling area as in (a.) above, and for the aircraft axis, both transverse and longitudinal, to the direction of the transmitting antenna. These measurements will be performed for the specified frequencies as in (a.) above. A simple jig made from plastic or wood to maintain the refueling nozzle, and line in a realistic but fixed orientation, will be required. Variable spacing of the nozzle lip from the aircraft skin will be provided, with these data being recorded. Some consideration should be given for providing a simple mechanism that will simulate the nozzle being lifted from the skin. The configuration of the nozzle lip (its radius of curvature and diameter) should be recorded. Because of high RF-induced currents on all metallic structures and test gear in the near field of the antenna, efforts will be required to provide adequate shielding of the RF voltmeter, its leads, input power lines, etc. Battery-powered instrumentation would eliminate coupled interference through the power cords. It is essential that the voltage and current at the point where the arc is formed be measured. To provide measurement of RF current a low-resistance (1 ohm or less) resistor across the electrodes may be necessary.

c. Hazardous Atmosphere. For various types of fuels (aviation gasoline, JP-4, JP-5, etc.) the fuel-air mixtures should be sampled at and near the refueling vents on several typical aircraft and the ratios measured. Fuel should be spilled intentionally on the wing and the resulting gaseous mixture ratios measured. Instrumentation required will be a vapor-detector unit. Attention in the measurements will be given to the time-lag (if any) in the detector response and its capability to spatially resolve the volume of fuel-air mixture (whether the sampled volume is 1 cm^3 or 1 m^3). A time history of the fuel-air mixture at several specified points is desired, if such can be made. Winds, temperature, humidity, etc., are factors which will affect the dispersal of hazardous mixtures so that such data should be recorded.

d. Effectiveness of Proposed Corrective Measures. The effectiveness of several proposed corrective techniques should be determined. Short grounding straps or braid between a point on the refueling nozzle and the aircraft may provide a low reactance path to ground and prevent any arc buildup at the nozzle when it is pulled away from the aircraft. Another suggested technique is the use of an insulated sleeve. These techniques will be evaluated by measuring the RF voltages and currents as in (b.). Tests will be made for the worst case found in (b.). Tests at night make arc detection easier.

e. Problems in HF Measurements. For E-Field measurements, at least a 9-foot square (per side) ground plane should be used to reduce variations to plus or minus 0.5 dB. With smaller ground planes (such as those normally supplied with an equipment by the manufacturer) variations up to plus or minus 10 dB were found. For convenience it is recommended that a loop antenna be used for measurements in the HF range and below.

Because there are such a multitude of factors, attempts to treat this problem analytically are not feasible. A carefully controlled measurement program must be used which hopefully will provide some basis for deciding if potentially hazardous situations exist at Naval Shore Stations. In addition, it is essential that a sufficient number of tests be performed for each condition to provide some degree of statistical repeatability. "Sufficient tests" represents a compromise between time and cost limitations on one hand, and the desire to reduce data variance on the other.

B.4.6.3 Correlation of Test Data with Theory

An effort should be made to correlate the field intensity data from B.4.6.2 with predictions of the field in the near-zone based on a mathematical model which adequately simulates the antenna and its environment. Since typical Naval aircraft have dimensions comparable to wavelengths at HF, they represent resonant structures with standing waves of voltages and currents over their surfaces. From the data in B.4.6.2b an effort should be made to compare positions along the wing where the observed voltages and currents are maximum with their predicted positions (antinodes) based on thick cylindrical antenna theory. Other comparisons may be suggested during the course of the tests to make the data more meaningful and useful.

B.4.6.4 Final Report

A comprehensive report on the entire test program, its results and conclusions, as well as those theoretical confirmations that are possible should be prepared. Recommendations as to minimum distances between transmitting antennas and refueling areas should be made if sufficient confidence and reliability in the data can be had.

B.4.7 Testing for X-ray Radiation Hazards from Electronic Equipment

The detection of X-radiation which is produced by electron tubes is more difficult than is the detection of radiation intentionally produced by X-ray equipment or by radioactive materials. One reason for this added difficulty is that an extremely strong electromagnetic radiation field is present along with the X-radiation. This electromagnetic field may result in the production of large gradients of potential within the particular detector and its circuitry, which could be responsible for considerable error in the indicated value of X-radiation intensity. Proper shielding of the detector and its circuitry against electromagnetic radiation may substantially reduce the error, but the amount of shielding required may attenuate lower-energy X-radiation, before it reaches the detector, to such an extent that the detector may be insensitive to the lower-energy X-rays. In the detection of X-radiation from electronic tubes this consideration is particularly important because energy values of X-radiation as low as 20 kiloelectronvolts must be detected.

Another reason for the additional difficulty of X-radiation from electron tubes lies in the fact that this radiation is generated in extremely high intensity pulses of very short time duration. The average value of X-radiation intensity is therefore relatively low. For example, a klystron operating at a duty cycle of 0.001 may produce an average dose rate of X-radiation of 1 roentgen per hour, at a distance of a few feet from the tube. The actual intensity in a single pulse of klystron operation may be in the order of 1000 roentgens per hour at the same distance, if the klystron operation were continuous instead of being pulsed. Such high instantaneous intensities result in erroneous indications from conventional gas-filled detectors of X-radiation, such as ionization chambers, rendering reliable operation difficult, if not impossible.

Additional difficulties which are encountered in the detection of X-radiation from RF tubes are caused by the size of the radiated beam, the resolution of the beam, and the energy response of the detector. The radiated beam from most electron tubes which emit X-radiation is small and well collimated, especially when the tubes are shielded. The beam escapes through small openings or faults in the tube body or shielding. If the beam is of high intensity but only 0.5 inch in diameter, it would obviously not completely cover the area of a 3-inch diameter ionization chamber. The roentgen has been defined as that amount of X-radiation which will produce, in one cubic centimeter of air at standard pressure and temperature, ions carrying one electrostatic unit (esu) of charge of either sign. The scale of the ionization chamber has been calibrated in accordance with this definition of the roentgen and, therefore, requires an X-radiation field which is uniform and which completely fills the cross-sectional area of the ionization chamber. Since a small beam will ionize only a small portion of the cross-sectional area, resulting in a much lower and, therefore, erroneous indication of measured intensity.

Small, battery-operated radiation meters are available which have been designed to measure X-radiation having energies from about 12 to 40 kiloelectronvolts in electromagnetic fields up to 10 milliwatts/cm^2.

Photographic dosimetry is an extensive use as a form of detection of X-radiation. Certain types of photographic films, when enclosed in a badge-type holder, may be used for personnel monitoring. Large films located in the vicinity of high power generators of X-radiation will indicate not only intensity levels, but also the distribution pattern of the radiation. Energy level measurements may be readily made by trained personnel if sufficient time and auxiliary equipment is available. Photographic films, particularly those types used in dosimeters, are insensitive to electromagnetic radiation. Detailed techniques and instrumentation for X-radiation detection and measurements may be found in NAVMED P-5055.

B.4.8 Testing for Hazards of EMR to Ordnance

Specific procedures have been developed by NAVORD and NAVAIR to evaluate the possibility of hazards to ordnance. The procedures detailed in NAVORD OP-3565/NAVAIR 16-1-529 NAVORD OD-30393, and OP-3565 shall be used to determine the presence of RADHAZ to ordnance.

B.4.9 Testing for Hazards from Lasers

The procedures in NAVMED P-5052-35 shall be used to determine the existence of possible hazards from lasers.

TEST REPORT

A test report should be prepared detailing results of the EMC survey. The test report should include the following details of testing:

a. Test plan.
b. Nomenclature of interference measuring equipment.
c. Date of last calibration of interference measuring equipment.
d. Detector functions used on interference measuring equipment.
e. Internal noise level of instrument at each detector function used at each test frequency.
f. Descriptions of procedures used.
g. Measured line voltages to test sample.
h. Test frequencies.
i. Method of selection of test frequencies.
j. Type of emissions measured.
k. Measured level of emission and susceptibility at each test frequency and test point.
l. Description and ambient profile data of interference free area.
m. Graphs showing items e., h., k., and l.
n. Photographs of test set ups and test sample.
o. Sample calculations (showing how item k. was obtained for each antenna used).
p. The system/installation should be completely identified in the test report. All suppression work performed during the tests should be fully described in words as well as by the test data in the report.

Figures B-3, B-4, and B-5 depict sample formats which may be used in the preparation of the report.

Table B-1. Antenna Types Used for EMC Testing

FREQUENCY RANGE	ANTENNA TYPE
14 kHz to 30 MHz	41 in. rod antenna with matching network
20 MHz to 200 MHz	Biconical, discone and dipole antennas
200 MHz to 10 GHz	Conical log-spiral, cavity-backed spiral and horn antenna
10 GHz to 40 GHz	Cavity-backed spiral and horn antennas

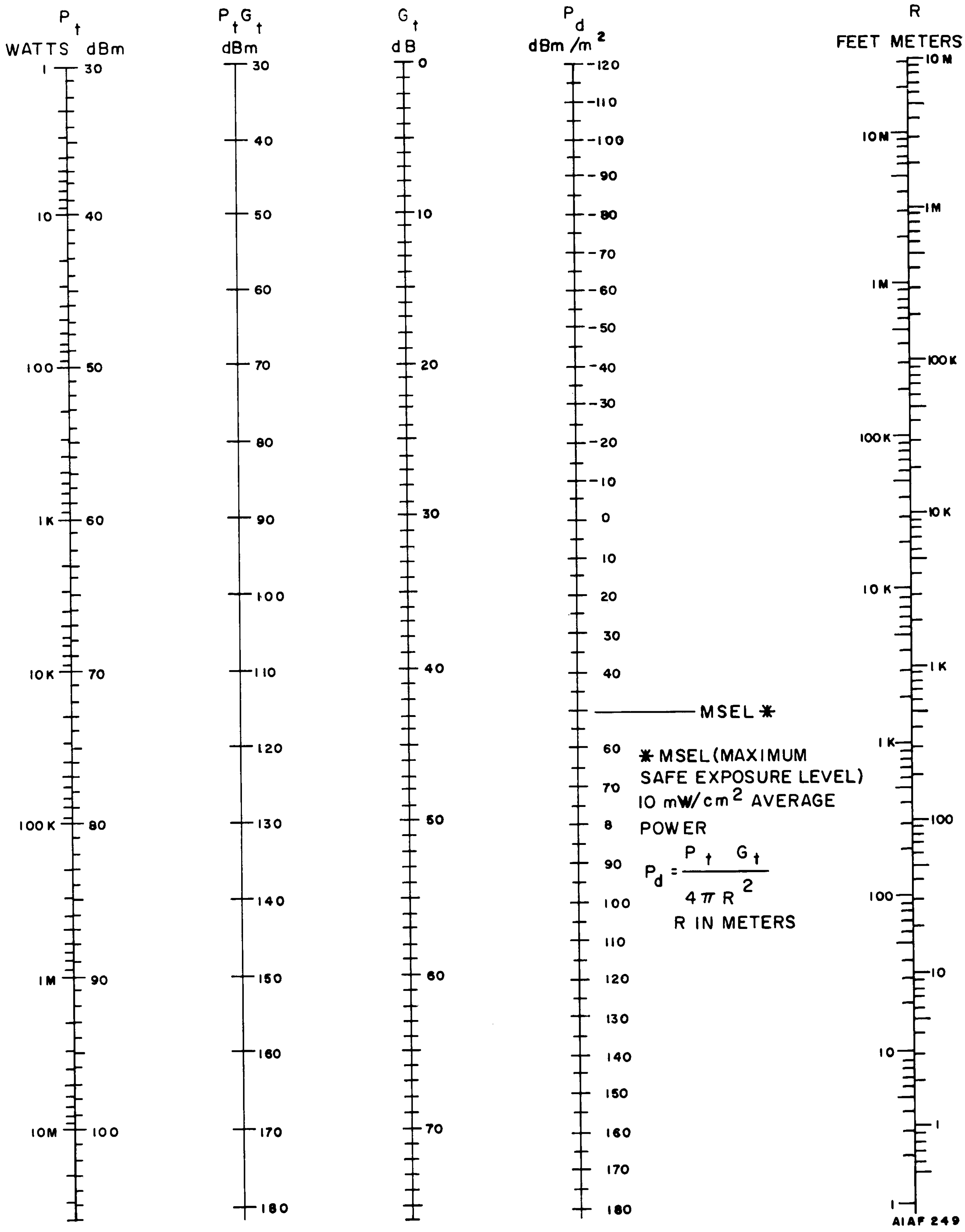

Figure B - 1. Power Density Nomogram (1 of 3)

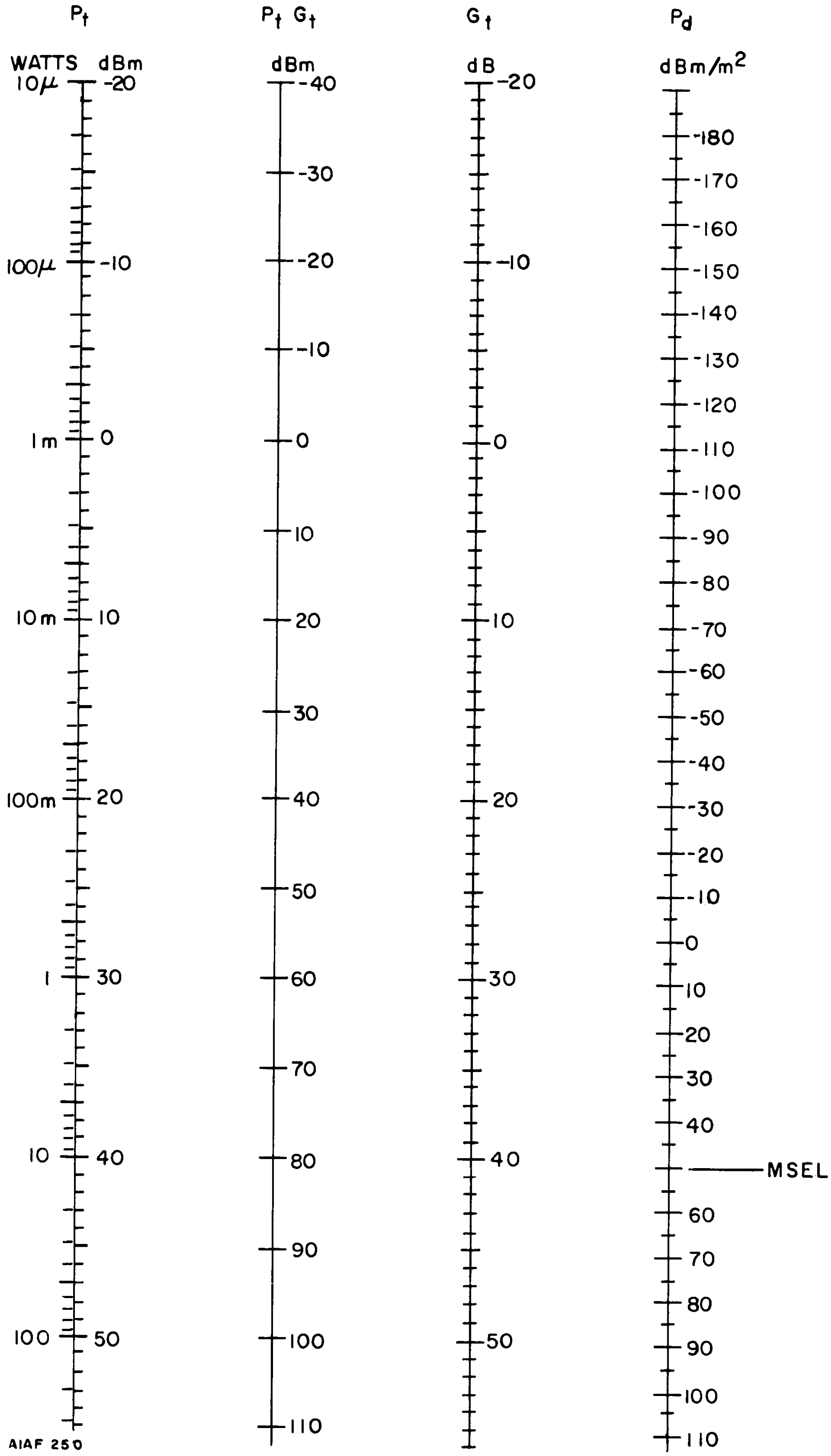

Figure B-1. Power Density Nomogram (2 of 3)

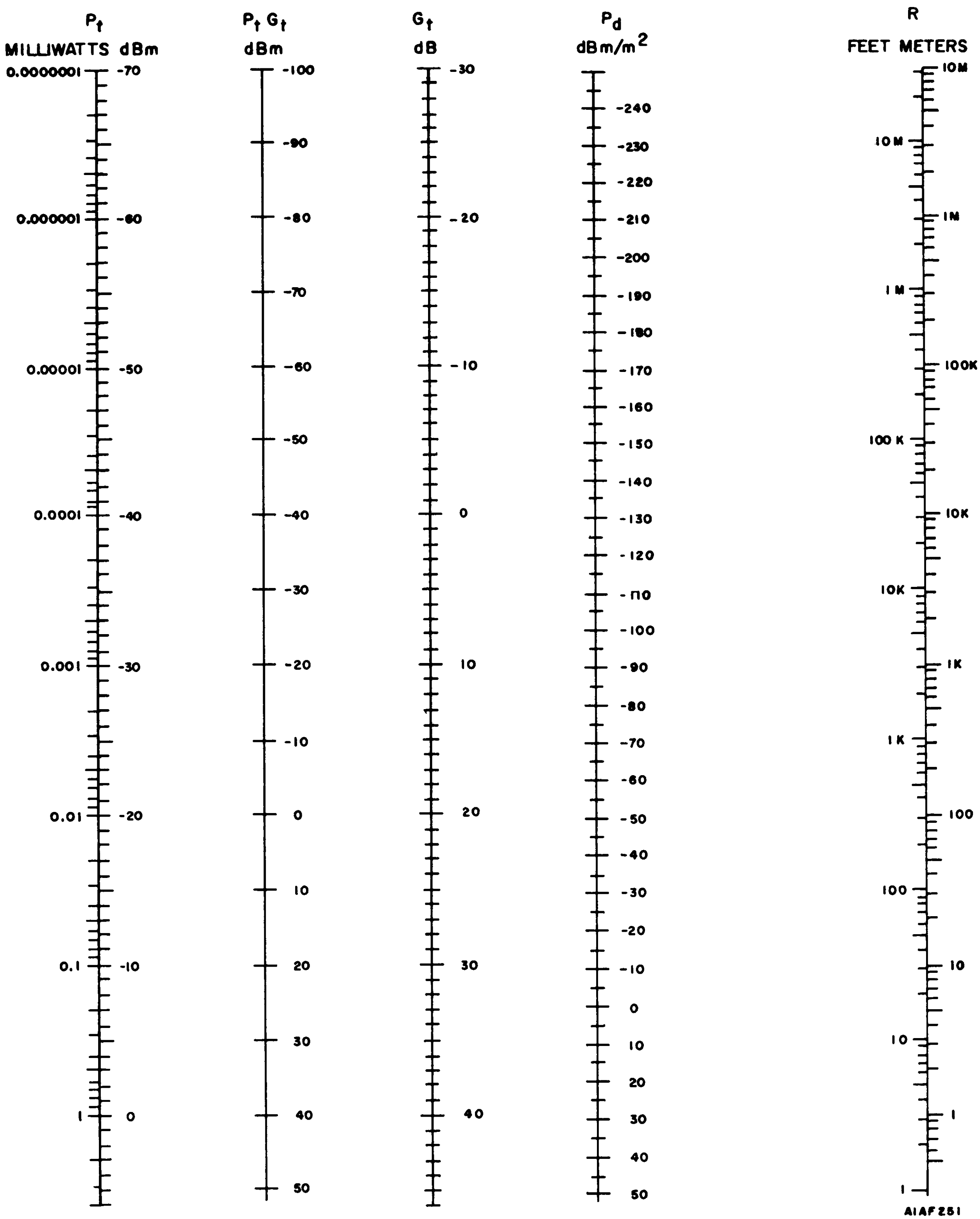

Figure B - 1. Power Density Nomogram (3 of 3)

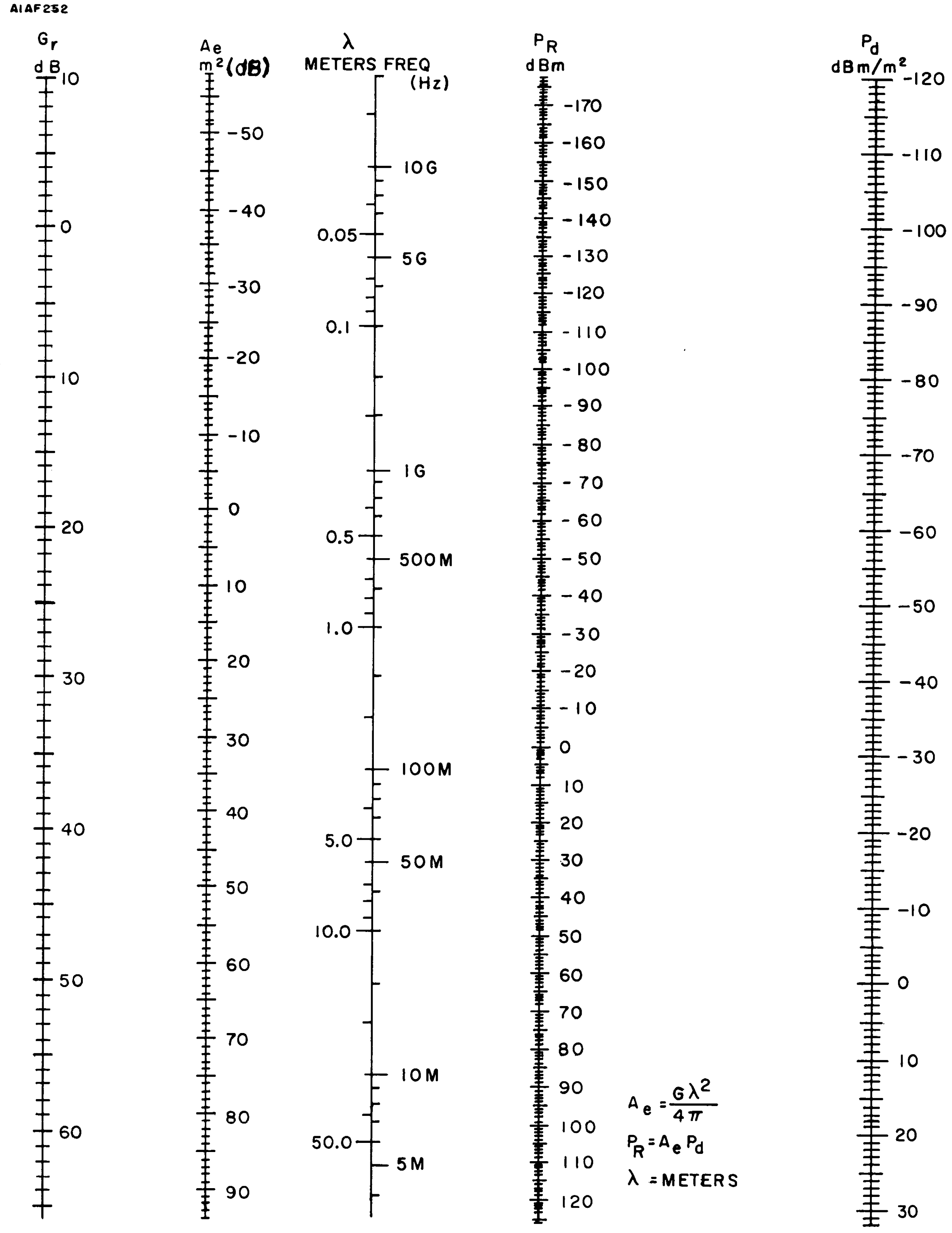

Figure B - 2. Effective Area and Received Power Nomogram

TEST EQUIPMENT LIST

DATA SHEET NO. __________

TEST PERFORMED	EQUIPMENT USED	SERIAL NO.	CALIBRATION DATA

AIAF253

Figure B - 3. Susceptibility Sheet

SUSCEPTIBILITY DATA
SHEET NO. ________

EQUIPMENT UNDER TEST ____________
SERIAL NUMBER ____________
MODE OF OPERATION ____________
SIGNAL GENERATOR USED ____________
SERIAL NUMBER ____________
FREQUENCY RANGE ____________

TEST DATE ____________
OPERATOR ____________
WITNESS ____________
TYPE OF TEST
RADIATED ☐
CONDUCTED ☐
LINE ____________
TEST CONDITION ____________

TEST FREQUENCIES	THRESHOLD SIGNAL LEVELS	OUTPUT LEVEL	DESCRIPTION OF RESPONSE

REFERENCE:
FIG. NO. ____________

AIAF 254

Figure B - 4. Equipment List

EMISSION DATA
SHEET NO.______

EQUIPMENT UNDER TEST ____________________
SERIAL NUMBER ____________ TEST DATE ____________
MODE OF OPERATION ____________ OPERATOR ____________
TEST SET USED ____________ TYPE OF TEST ____________
SERIAL NUMBER ____________ RADIATED ☐
MEASUREMENT TECHNIQUE ____________ CONDUCTED ☐
DETECTOR FUNCTION ____________ LINE ____________
FREQUENCY RANGE ____________ TEST CONDITION ____________
CORRECTION FACTOR =

TEST FREQ. MC	METER READING DB	CORRECTION FACTOR DB	FINAL READING DB	REMARKS

REFERENCE:

FIG. NO.______

AIAF 255

Figure B - 5. Emission Data Sheet

APPENDIX C

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56. USA Standard Safety Level of EMR with Respect to Personnel, USAS C95.1, 1966, American National Standards Institute.
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GLOSSARY

Following are the definitions of some of the more commonly used terms in the areas of Electromagnetic Compatibility and Electromagnetic Radiation Hazards.

Arc. An electrical discharge of relatively long duration which may be brought about by separating current-carrying electrodes or may result from a spark discharge between initially separated electrodes, provided that the energy source is sufficient to maintain the arc.

Athermal Effect. Any effect of electromagnetic absorption, exclusive of the production of heat.

BESEP. Acronym for "The Base Electronics System Engineering Plan," a planning tool used in the integration of electronic systems and shore/site facilities. One of the plan's considerations includes electromagnetic compatibility-radiation hazards.

Bonding. The process of physically connecting two metallic surfaces to provide a low impedance path for RF current.

Breakdown Voltage. The minimum potential necessary to produce an electrical discharge in a gaseous medium under stated conditions.

Direct Wave. See Ground Wave Propagation.

Distillation Range. Difference between the End Boiling Point and Initial Boiling Point of fuels; an indication of relative fuel volatility.

Dose. The amount of absorbed electromagnetic energy.

Electrical Equipment. Equipments which do not produce useful internal signals, or in which the electrical energy is not used for information purposes. Examples are electric motors, fluorescent lamps, office equipment, etc.

Electrolyte. A chemical compound which when fused or dissolved in certain solvents, usually water, will conduct an electric current. All acids, bases, and salts are electrolytes.

Electroexplosive Device (EED). Any single discrete unit, device, or subassembly whose actuation is caused by the application of electric energy which, in turn, initiates an explosive propellant, or pyrotechnic material contained therein. The term electro-explosive device does not include complete assemblies which have electric initiators as subassemblies, but includes only subassemblies themselves. The term is synonymous with electric initiator.

Electromagnetic Compatibility (EMC). The ability of communications-electronics (C-E) equipment, subsystems and systems to operate in their intended operational environments without suffering or causing unacceptable degradation because of unintentional electromagnetic radiation or response. It does not involve a separate branch of engineering, but directs attention to improvement of electrical and electronic engineering knowledge and techniques to include all aspects of electromagnetic effects.

Electromagnetic Environment. The composite electromagnetic field generated by natural and man-made sources existing in a transmission medium or in operational areas.

Electromagnetic Interference. Any emission, radiation, or induction which degrades, obstructs, or repeatedly interrupts the designed performance of electronic equipments.

Electronic Equipment. Equipments which produce useful internal signals, or serve functionally by generating, transmitting, receiving, storing, processing or utilizing information in the broadest sense. Examples are communications, radar, sonar, countermeasures, navigation, computers, test equipment, etc.

Electromagnetic Radiation. Emission of energy from a source in the form of electromagnetic waves.

Electromagnetic Susceptibility (EMS). The characteristic of electronic equipment that permits undesirable responses when subjected to electromagnetic energy.

EMC/EMR Hazard Program Plan. The guiding document outlining control, reduction, techniques and procedures to achieve EMC/EMR Hazard free operation and is included as part of the BESEP.

EMC/EMR Hazard Predictions. The process of determining potential interference conditions, or potential hazards by calculation and/or measurement of field strengths, equipment susceptibilities, propagation losses, frequency response characteristics, etc., as applicable.

Emission. Electromagnetic energy propagated from a source by radiation or conduction.

Emission, Broadband. That which has a spectral energy distribution sufficiently broad, uniform, and continuous so that the response of the measuring receiver in use does not vary significantly when tuned over a specified number of receiver impulse bandwidths.

Emission, Conducted. Desired or undesired electromagnetic energy which is propagated along a conductor. Such an emission is called "conducted interference" if it is undesired.

Emission, Counterpoise. The reference-plane portion (grounded or ungrounded) of an unbalanced antenna.

Emission, Narrowband. That which has its principal spectral energy lying within the bandpass of the measuring receiver in use.

Emission, Radiated. Radiation and induction field components in space.

Emission Spectrum. The power vs. frequency distribution of a signal about its fundamental frequency which includes the fundamental frequency, the associated modulation sidebands, as well as non-harmonic and harmonic spurious emissions and their associated sidebands.

Field Strength. The term "Field Strength" is applied only to measurements made in the far field. The measurement may be of either the electric or the magnetic component of the field, and may be expressed as V/m, A/m, or W/m^2; any one of these may be converted to others. It is abbreviated as FS. For measurements made in the near field, the term "Electric Field Strength" (EFS) or "Magnetic Field Strength" (MFS) is used, according to whether the resultant electric or magnetic field, respectively, is measured. The EFS is expressed as V/m, and the MFS as A/m. In this field region, the field measured will be the resultant of the radiation, induction and quasi static ($1/r$, $1/r^2$ and, if present, the $1/r^3$) components, respectively, of the field where r is the distance from the source. Inasmuch as it is not generally feasible to determine the time and space phase relationships of the various components of this complex field, the energy in the field is similarly indeterminate.

Fraunhofer Region or Zone. That volume of space extending beyond the far-field distance. The far-field distance is defined as equal to $2D^2/\lambda$ where D is the maximum antenna aperture dimension and λ is the fundamental frequency wavelength. In the Fraunhofer region, antenna radiation patterns are essentially independent of the distance r from the aperture, the field strength decays as $1/r$, power density decays as $1/r^2$ and for all practical purposes, the electromagnetic field may be regarded as composed of plane waves.

Free Space Transmission. An idealized state in which both transmitting and receiving antennas are isolated in unbounded, empty space.

Frequency Allocation. The term, frequency allocation, generally refers to the apportionment or sectioning of the radio frequency spectrum into bands or blocks, with each band being reserved for a specific use category.

Frequency Assignment. The term, frequency assignment, generally refers to the assignment of a specific frequency within a band or block to an individual user.

Frequency Management. The application of technical criteria, management techniques, options, etc., to the optimization of the supply and demand on the frequency spectrum.

Frequency Spectrum. The range of frequencies of electromagnetic energy encountered by man from both natural phenomena and man-made sources; generally extends from less than .001 hertz to greater than 10^{22} hertz. The Radio Frequency Spectrum is, loosely, that portion of the total spectrum used for information communication.

Fresnel Region or Zone. That portion of the radiation field, for large aperture antennas, lying between a wavelength from the antenna and a distance r defined by: $r<KD^2/\lambda$, where D is the maximum antenna aperture dimension, λ is the fundamental frequency wavelength and K is a constant.

Galvanic Corrosion. Galvanic or two-metal corrosion occurs when two dissimilar metals in contact or otherwise connected electrically are exposed to a corrosive electrolyte.

Gamma Radiation. Electromagnetic radiation of nuclear origin, occupying an intermediate position between X-Radiating and Cosmic-Radiation in the frequency spectrum.

Grounding. The process of physically providing a metallic surface with a low resistance or impedance path to ground potential.

Ground Reflected Wave. See Ground Wave Propagation.

Ground Wave Propagation. Generally, ground wave propagation refers to the transmission of energy which does not make use of reflections from the ionosphere. Ground waves may take a direct or reflected course from the transmitter to the receiver, or they may be conducted to the surface of the earth or reflected in the troposphere. The resulting ground wave, therefore, may be composed of one or more of the following components: the direct wave, the ground-reflected wave, the surface wave, and the tropospheric wave.

Insertion Loss. A guide to the use of capacitors in suppression applications. Insertion loss is the ratio of the voltages existing across the circuit load impedance before and after connecting the suppression capacitor into the circuit. Insertion loss data, in decibels (dB), indicates the voltage across the circuit load impedance that will be reduced by the insertion of the suppressor capacitor.

Interference. See Electromagnetic Interference.

Interference Margin. A quantity which represents the amounts of energy by which an undesirable signal exceeds the level required to produce interference. It is calculated by combining source, transmission, antenna, and susceptibility factors, to determine the total contribution to a potential interference condition.

Ionizing Radiation. Electromagnetic waves or particular emanations capable of causing ionization, i.e., the ejection of electrons from atoms.

Isotropic Antenna. A hypothetical antenna which radiates or receives equal energy in all directions.

Magnetic Field. A state or region influenced by a charge or system of charges in which moving charges, or charged bodies, are subject to forces by virtue of both their charges and motion.

Microwaves. A term used loosely to identify radio waves in the frequency range from about 1.0 GHz upwards.

Polarization. Term used to describe the orientation of the time varying electric or magnetic field vector. If the vector is confined to a plane containing the direction of propagation of the wave, the wave is plane polarized. If the vector rotates around the direction of propagation as an axis but remains constant in magnitude, the wave is circularly polarized. If the amplitude does not remain constant, so that the end of the vector traces out an ellipse, the wave is elliptically polarized.

Power Density. The power flow per unit area, usually expressed in milliwatts per square centimeter. Average power density is the quantity relating to the heating properties of electromagnetic radiation and, hence, to personnel and other hazards, while peak power density becomes important in the study of the effects of electromagnetic fields on electrically initiated explosive devices and on fuel hazards.

Propagation. The transmission of electromagnetic energy.

Radiac. Name given to the detection, identification, and computation of nuclear radiation.

Radio Frequency Interference. See Electromagnetic Interference.

Roentgen. The basic unit used to indicate a measured quantity of ionizing radiation. It is a measure of the ionization in air caused by X- or gamma-radiation, and is defined as that amount of radiation that will produce $2.083X10^9$ ion pairs in 1 cc of air under standard conditions.

Shielding or Shield. A housing, screen, or other object which substantially reduces the effect of electromagnetic fields on one side thereof, upon devices or circuits on the other side.

Skin Effect. A phenomenom in which high frequency currents tend to concentrate in a thin layer or skin on the surface of conductors.

Sky-wave Propagation. The transmission of electromagnetic energy which depends upon, and makes use of, reflections from the layers in the ionoshpere.

Spark. An electrical discharge of relatively short duration.

Spectrum Signature. The package of data which describes the electromagnetic radiating and receiving characteristics of electronic equipment.

Spurious Emission. Emissions on a frequency or frequencies which are outside the designed or necessary bandwidth, and the level of which may be reduced without affecting the corresponding transmission of intelligence. These include harmonics, parasitic emissions, and intermodulation products, but exclude unnecessary modulation sidebands of the fundamental frequency.

Spurious Response. Any response of an electronic device to energy outside its designed reception bandwidth.

Squibb. An electro-explosive device.

Susceptibility. See Electromagnetic Susceptibility.

Thermal Effect. Generally refers to the heating effects of electromagnetic radiation on materials and people.

Vapor Pressure. The pressure of a confined body of liquid, e.g., fuel in storage tanks.

X-Radiation. Electromagnetic radiation of short wavelength, usually produced by the bombardment of a metal target by high-energy electrons.

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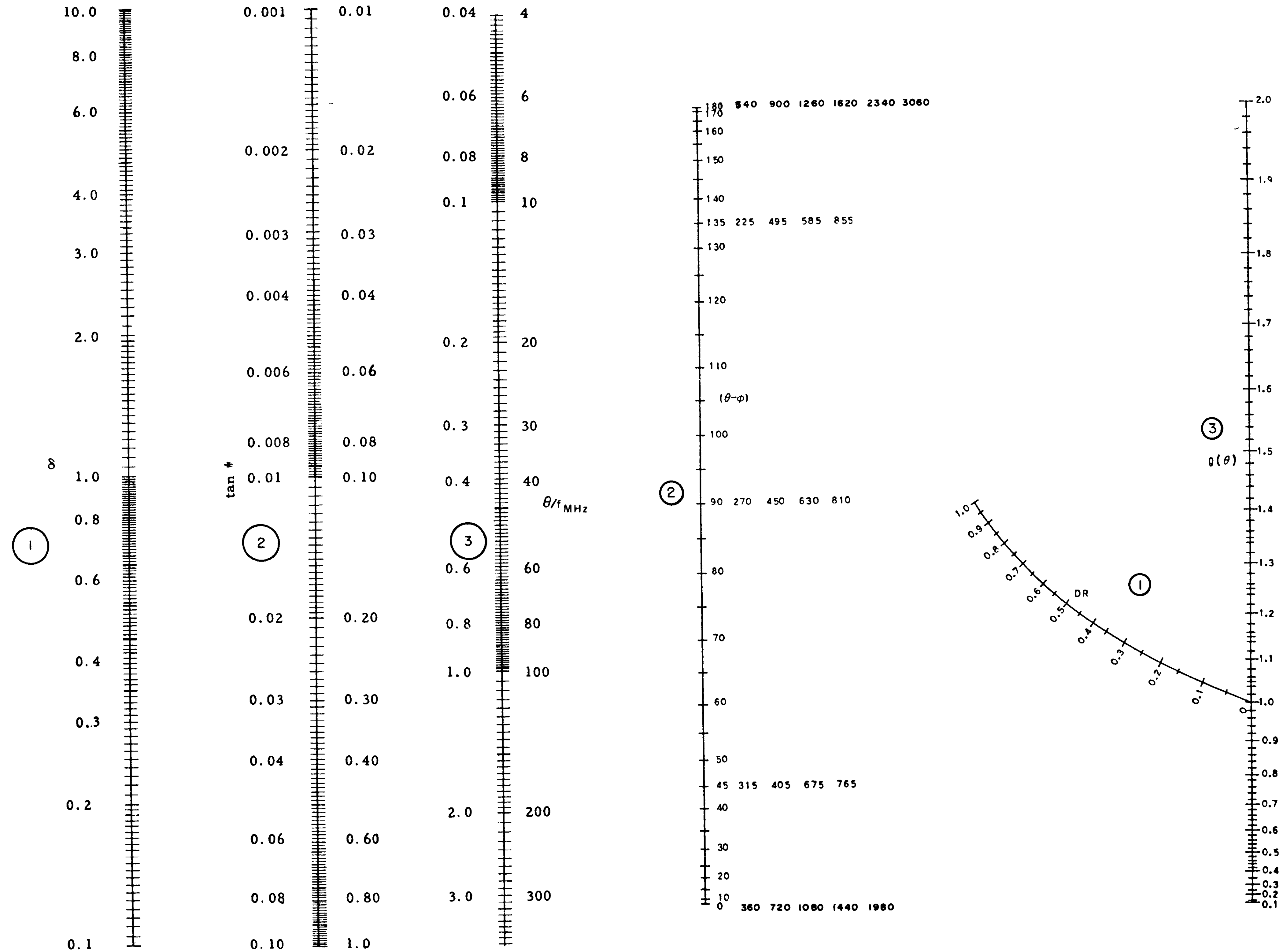

A. Nomogram for Determining θ/f MHz

B. Nomogram for Determining g(θ)

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Figure FO6 - 1. Nomograms, Referenced in Figure 6 - 26, Lines 3.2.1 and 3.4