



AEROSPACE RECOMMENDED PRACTICE

ARP 937

Society of Automotive Engineers, Inc.

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Revised

JET ENGINE ELECTROMAGNETIC INTERFERENCE TEST REQUIREMENTS AND TEST METHODS

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PREPARED BY
COMMITTEE AE-4, ELECTROMAGNETIC COMPATIBILITY

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INTRODUCTION

This document applies to jet engine electrical systems and accessories such as ignition, actuators, fuel controls, solenoids, servos, control alternators, amplifiers and switches. Generators or alternators for powering airframe or non-engine electrical equipment or engine temperature measuring systems utilizing thermocouples as a source of emf are not included.

This document also applies to jet engines used as "prime movers" for generation of power in ground based or marine equipment.

1. SCOPE, NUMBERING, AND FORM

1.1 Scope: This Aerospace Recommended Practice (ARP) establishes uniform test methods for testing equipment, systems, and subsystems to determine their electromagnetic interference and susceptibility characteristics. These test methods have been prepared for several purposes:

- a. To insure that interference control design is incorporated into equipment, systems, and subsystems, and that applicable limits are not exceeded by performing tests under simulated situations obtainable in the laboratory similar to those existing in the operational environment. The tests described are not to be interpreted as an exact or conclusive representation of actual service conditions because the only true test is operation in the intrasystem electromagnetic environment under actual service conditions.
- b. To specify general levels of electromagnetic interference emanation and interference susceptibility for systems, equipments, and subsystems that enable compatible operation in a complex electromagnetic environment. The limits and tests specified herein are established to increase the probability that operational systems will meet the requirements of MIL-E-6051 or other similar system requirements.
- c. To describe in one ARP all test methods of a similar character so that these methods can be kept uniform and thus result in conservation of equipment, manhours, and test facilities. The test methods permit use of automatic and high speed techniques.

1.2 Numbering System: The test methods are designated by numbers assigned in accordance with the following system:

- 1.2.1 Classes of Tests: The tests are divided into several classes, for example, 3000-series test methods cover conducted interference measurements. Within each class, test methods are numbered serially in the order in which they are introduced into this document.
- 1.2.2 Revision of Test Methods: Revisions of test methods are indicated by a decimal notation. For example, if the original number was 4025, the first revision would be 4025.1, the second revision 4025.2, and the tenth revision 4025.10.
- 1.2.3 Obsolete Test Methods: When a test method is made obsolete, the test method will be removed from this document, but the index will retain the number and specify that it is obsolete. To avoid confusion, a number assigned to an obsolete test method will not be reassigned.
- 1.2.4 Page Revisions: Normally, minor changes in this document may be made by issuing completely revised pages to replace the old pages. If the additional pages are inserted in a revision, they will be identified by the page number followed by a letter: for example, page 8a follows page 8 as an inserted page. Each revised page will carry a supersession notice. For example: Supersedes page (No.) of (date).
- 1.2.5 Tentative Test Methods: Whenever possible, new or modified test methods may be issued as tentative test methods prior to issue. A tentative test method may be submitted by any activity. The tentative methods are not mandatory for use. Tentative test methods provide an opportunity for trial use without affecting the status of standard methods.

- 1.2.5.1 Numbering of Tentative Test Methods: Tentative test methods are numbered in accordance with 1.2. In addition to this number, a capital T is prefixed: for example, the basic issue might be T7080, the first revision would be T7080.1. When issued, the test method shows the next revision number. For example, tentative test method T7080.1 would be issued as 7080.2.
- 1.3 Method of Reference: Test methods in this ARP should be referenced in other documents by specifying this document, the applicable test methods, and any details called out in the summary of the individual methods. Do not reference revision numbers: for example, call out 2022 not 2022.11.
- 1.4 Applicable Documents: The following documents should form a part of this specification, to the extent specified herein. The applicable issue of each should be that in effect on the date of this recommended practice unless otherwise specified in the manufacturer's Model (Detail) Specifications. Supplementary specifications, standards, or the like, which by reference in any of the following publications are indicated to be part thereof, should not be considered as effective except as specifically stated in the manufacturer's Model (Detail) Specification or as may be otherwise mutually agreed upon between the vendor and the purchaser.

1. MIL-C-5
2. MIL-C-25
3. MIL-C-91
4. MIL-C-11693
5. MIL-C-12889
6. MIL-C-45662
7. MIL-E-6051
8. MIL-F-15733
9. MIL-STD-704
10. Federal Test Method 151
11. SAE ARP 936

2. GENERAL REQUIREMENTS

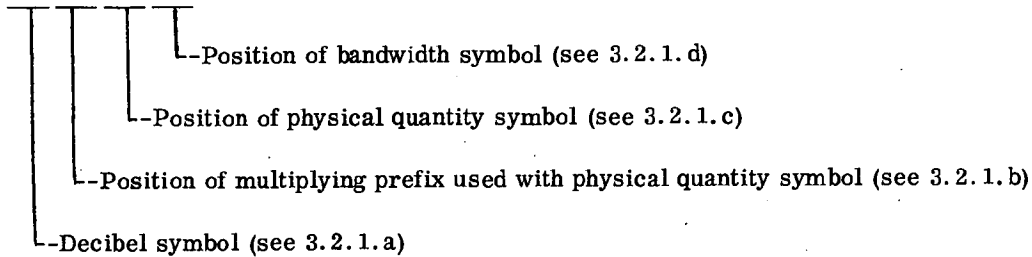
- 2.1 Test Requirements: The electromagnetic interference emanation and interference susceptibility limits should be as specified in the contract. If the contract does not specify such limits but requires compliance with this ARP, the limits and test methods shown in the applicable test methods in the 1000 series should be applicable. Exceptions to the applicable limits may be considered by the purchaser if the contractor can show that system performance margins will be maintained.
- 2.1.1 Detail Documents: Normally, the applicable requirements for a contract will be in a document such as a system interference test plan, a weapon system specification, or an equipment or subsystem specification.
- 2.2 Atmospheric Conditions: Unless otherwise specified herein or in the detail specification, measurements and tests should be made at room ambient temperature, atmospheric pressure, and relative humidity.
- 2.3 Subsystems: This ARP should be applied to a group of units or equipments that are intended to operate together, that can be tested as a subsystem, and individual items that do not have to be tested separately. However, when individual parts of a subsystem are designed to operate separately, each such unit or part should be tested separately.
- 2.4 Quality Assurance Provisions
- a. Qualification tests and test reports specified herein should be accomplished by the contractor and be subject to approval and verification by the purchaser. When the purchaser waives verification, the tests and test reports should be approved and verified by a qualified representative of the contractor's engineering department. Evidence of quality control verification and approval, either by the Government or the contractor, should be contained in the test report.

- b. Production Testing: The detail specification for the system, equipment, or subsystem should specify the requirements for production testing. When the procuring activity waives verification, the tests and test reports should be verified by a qualified representative of the vendors quality control department. If specific requirements are not specified, the general sampling and inspection provisions called out in the contract should govern.
- 2.5 Off-The-Shelf Equipment: When commercial "off-the-shelf" equipment, either airborne or ground, is considered for use in a system, the following rules should be used in selecting applicable tests from this ARP:
 - a. A complete test and test report is necessary to evaluate the equipment.
 - b. The data in the test report should be used to determine suitability of the commercial equipment for the particular application. If an analysis of the submitted data shows that the commercial equipment cannot perform its function because of the mission electromagnetic interference environment, either modifications to correct the problem areas in the environment will be necessary, or another equipment should be selected that will operate satisfactorily.
 - c. Interference requirements for commercial equipments should be described in the interference test plan for the system, and interference data should be reviewed before selecting commercial equipment for use with the system.
- 2.6 Prior Interference Tests: If the system, equipment or subsystem has met the interference specification of a Government agency, that data may be accepted as evidence of meeting equivalent portions of this ARP. If required by the contract, test methods in this ARP that are substantially more stringent should be rerun to verify compliance.
- 2.7 Suppression Parts: Any suppression part that is added to the test sample to meet the tests herein should meet the environmental requirements for the test sample or, when approved by the purchaser, a component in accordance with MIL-C-5, MIL-C-25, MIL-C-91, MIL-C-11693, MIL-C-12889, MIL-F-15733, or Federal Test Method 151 may be used.
- 2.8 Test Policy: The sole purpose of the testing required by this ARP is to verify adequacy of design. Testing for its own sake is highly undesirable. There is no reason to waste resources in formal testing or writing reports on equipment that is many dB above specification limits until fixes are installed. No time should be spent in trying to achieve a high degree of accuracy on very high (30 dB above specification limits) or very low (10 dB below specification limits) readings. For example, it is of little interest to determine whether a 100-dB out-of-specification reading is actually 101, 106, or 92 dB. The witnessing official, Government or contractor, should ensure that formal testing is stopped if high out-of-specification readings are recorded and a fix program started; however, informal survey measurements are permitted to identify problem areas. The purchaser should be notified immediately when this situation occurs or when a decision is required on a marginal condition. In general, tests should be stopped when readings obtained are 40dB higher than those called out in the specification.

3. EXPLANATION OF TERMS AND ABBREVIATIONS

- 3.1 Purpose: This section specifies the abbreviations and explanation of terms for use with this ARP. An understanding of these terms is required before reading detailed test procedures.
- 3.2 Compendium
 - 3.2.1 Abbreviations: All abbreviations used to designate physical units in this ARP and in associated test reports should be constructed in accordance with the following rules. The abbreviations should use the symbols shown in subsequent paragraphs and should always be in the sequence shown. Reference is made to IEEE Standard "Symbols For Units" No. 260, January 1965, effective January 15, 1965.

dB ____ / ____



- a. Decibel notations should always be used. The reference level should be one of the units obtained by applying the multiplying prefix to the physical quantity involved.
- b. The following symbols should be used to indicate the applicable multiplying prefix:

<u>Prefix</u>	<u>Symbol</u>
tera (10^{12})	T
giga (10^9)	G
mega (10^6)	M
kilo (10^3)	k
None (10^0)	-
milli (10^{-3})	m
micro (10^{-6})	μ
nano (10^{-9})	n
pico (10^{-12})	p

- c. The following symbols should be used to indicate the applicable physical quantity:

<u>Physical Quantity</u>	<u>MKS Unit</u>	<u>Symbol</u>
Current	amperes	A
Electric field strength (E vector)	volts/meter	V/m
Magnetic flux density	weber/meter ²	Wb/m ²
Magnetic field strength (H vector)	ampere/meter	A/m
Electric potential	volts	V
Power	watts	W

- d. The following symbols should be used to indicate the applicable bandwidth-normalizing factor. The megahertz factor is preferred:

<u>Bandwidth factor</u>	<u>Symbol</u>
gigahertz	GH _Z
megahertz	MH _Z
kilohertz	KH _Z

- 3.2.2 Ambient Interference: Ambient interference is that interference level emanating from sources other than the test sample, including the internal background noise of the interference-measuring instrument.
- 3.2.3 Antenna Factor: The antenna factor is that factor which, when applied to the voltage appearing at the input terminal of the measurement instrument, yields the interference electric field strength in volts/meter, magnetic field strength in amperes/meter. It should be expressed in decibels (dB).
- 3.2.4 Antennas: Because of the unknown nature of the electromagnetic field, which usually exists close to a test sample, it is imperative that tests for radiated interference be conducted with antennas identical to those specified in the detailed test methods. Attempts to correlate results obtained with other antennas by reducing the results to microvolts per meter, based upon plane-wave calculations and antenna-free space characteristics, may be erroneous and should not be accepted as an indication of compliance with this recommended practice.
- 3.2.5 Broadband Interference: Broadband interference is a continuous spectrum of energy covering a wide frequency range.
- 3.2.6 Deviations From Normal: This term refers to an undesired change in the standard reference output occurring during a susceptibility test. Specific criteria for allowable deviations from normal should be called out in the detail specification or in the interference test plan.
- 3.2.7 Impulse Bandwidth: The impulse bandwidth of an interference-measuring instrument is the area divided by the height of the voltage response versus frequency selectivity curve from the antenna through the peak detector.
- 3.2.8 Interference: Interference is defined as any electromagnetic disturbance, phenomenon, signal or emission, man-made or natural, which causes or can cause undesired response, malfunctioning, or degradation of performance of electrical and electronic equipment, or premature and undesired location, detection, or discovery by enemy forces except deliberately generated interference (electronic counter-measures).
- 3.2.9 Interference Types: For the purposes of this ARP, interference is arbitrarily categorized into the following types:
- Narrowband
 - Broadband
 - Pulsed CW
- 3.2.10 Microvolts Per Megahertz: Interference intensity in microvolts per megahertz is equal to the number of root-mean-square sine-wave microvolts (unmodulated) applied to the input of the measuring circuit at its center frequency that will result in peak detector response in the circuit equal to that resulting from the interference pulse being measured, divided by the impulse bandwidth of the circuit in megahertz.
- 3.2.11 Narrowband Interference: Narrowband interference is, ideally, energy at a single frequency with zero bandwidth. Emission has a spectrum extending over a frequency range which is significantly narrower than the bandwidth of the measuring instrument. Unmodulated and amplitude-modulated sine-wave carriers are typical examples.

- 3.2.12 No Malfunction: This term means that the performance of the test sample is not degraded to the point where mission capability is affected. Usually, this term cannot be interpreted by an equipment or sub-system contractor and must be interpreted by the purchaser or the system contractor. Criteria and interpretations should be specified in documents such as the detail specifications and interference test plan.
- 3.2.13 Octave: An octave is a frequency ratio of 2 to 1: that is, from 1 to 2, 2 to 4, 500 to 1000 megahertz, etc.
- 3.2.14 Open Space: This term, as used herein, is intended to designate an ideal site for radiated interference measurements. This ideal site should be open, flat terrain at a considerable distance from buildings, electric power lines, fences, trees, underground cables, and pipe lines. This site should have a sufficiently low ambient level of radiated interference and signals to permit testing to the radiated interference limit at any test frequency selected. Since such ideal locations do not exist, a site should be selected as close to the ideal as practicable. Characteristics of the test site that can affect the data should be recorded.
- 3.2.15 Precalibrated Measurement Techniques: This term describes an old technique of measuring interference. The technique requires that the gain of the instrument be adjusted so that the instrument indicates the correct value. The gain is generally adjusted by use of calibration charts that specify readings from a built-in transfer standard such as impulse generators and white-noise generators. The calibration must be checked periodically to ensure correct readings.
- 3.2.16 Pulsed CW: Pulsed CW is a narrowband carrier modulated by one of several types of pulse trains. This type of interference has a spectrum but can have the characteristics of either narrowband or broadband interference depending upon pulse shape, repetition rate, and the bandwidth of the measurement equipment.
- 3.2.17 Radiated: This term as used herein, does not imply that measurements are taken in the far field, the Fraunhofer Zone, or that normally used propagation laws apply. The term implies only that the electromagnetic fields in the vicinity of the test sample are being investigated. The energy is propagated in space either by induction or radiation.
- 3.2.18 Random Noise: Random noise is characterized by random amplitudes, frequencies, and phases.
- 3.2.19 Transient Interference: Transient interference (single occurrence impulse) is characterized by coherent amplitude, frequencies, and phases which are related by a Fourier integral to a discrete function of time. In this ARP, this term is also used for low repetition-rate signals that must be measured by using specialized procedures.
- 3.2.20 Semiautomatic Measurement Techniques: This term refers to a method of using interference measurement instruments which translate specification limits and applicable correction factors into an equivalent meter reading for a specific instrument. It may be used with X-Y recorders, oscilloscopes, and other equipment to reduce repetitive application of correction factors, and enables immediate determination of an out-of-specification condition.
- 3.2.21 Standard Reference Output: This term refers to a condition for a particular test sample that defines normal operation and is used in measuring any deviation from standard performance which occurs during susceptibility testing. This term should be defined in the detail equipment specification.
- 3.2.22 Substitution Technique: This term describes a method of measuring interference. The method depends upon availability of a calibrated signal source the output of which is similar to that of the unknown signal: that is, an impulse generator for broadband measurements and a sine-wave generator for narrowband measurements.

3.2.23 Subsystem: As used herein, this term refers to the lowest functional breakdown possible on a group of equipments: for example, a complete missile would not usually be considered a subsystem. An ignition system consists of exciters, ignition output leads, igniters, and an input wiring harness if one is used. Power sources solely for ignition systems and automatic restart switches when used should be considered as part of the ignition system.

3.2.24 Susceptibility: Susceptibility is defined as that characteristic which causes an equipment to malfunction or exhibit an undesirable response when its case or any external lead or circuit is subjected to electromagnetic voltages or fields.

4. REPORTING FORMAT

4.1 Purpose: A test report should be prepared by the organization performing the compliance tests. The report should be submitted to the purchaser for review.

4.2 Format: The reporting format should be specified by the purchaser.

5. MEASUREMENT INSTRUMENTS

5.1 Purpose: This section provides general information for measuring instruments.

5.2 Interference Measurement Instruments: Interference measuring instruments approved by the purchaser in the procurement contract should be used for a particular test. A list of approved instruments has not been included in this recommended practice because of the changes that occur in lists of approved instruments as new instruments become available.

5.3 Signal Sources

5.3.1 Any commercially available signal source may be used that can supply the necessary levels with the proper modulation. In some cases, these sources would not have calibrated output. When this occurs, use power meters, voltmeters, and external attenuators to set the required output levels.

5.3.2 When procuring signal sources, it is suggested that equipment be purchased capable of generating levels higher than those prescribed. It is required that the available margin of safety be determined for some tests. A reasonable amount of reserve signal power should be available for this purpose.

5.3.3 Signal sources with features to minimize manual operations should be utilized to the maximum possible extent so that minimum test time will be used.

5.4 Antennas

5.4.1 Standard Antennas: Because of the unknown nature of the electromagnetic field which exists close to a test sample, it is imperative that tests for radiated interference be conducted with antennas identical to those specified. Attempts to correlate results obtained with other antennas and reducing the results to microvolts per meter, based upon plane-wave calculations and antenna free-space characteristics, may be erroneous.

5.4.2 Test Antennas: When antennas are not specified in the procurement contract, the following antennas should be used for radiated interference and susceptibility tests: (See instrument manufacturers manuals for additional information.)

- a. 14 KHz to 25 MHz - 41 inch rod (electrical length = 1/2 meter).
- b. 25 to 35 MHz - dipole tuned to 35 MHz
- c. 35 to 200 MHz - tuned dipole (dipole can be tuned to preselected fixed frequencies with a correction factor applied to obtain the equivalent meter reading at other frequencies.)
- d. 200 MHz to 1 GHz - conical logarithmic spiral antenna in accordance with ARP 958
- e. Refer to manufacturer's instructions for tuning antennas for particular frequencies.

- 5.5 Impulse Generators: By definition, the calibration for broadband measurements must be referenced to the rms value of an equivalent sine-wave. Calibration of impulse generators should be verified by a certificate of traceability or other data.
- 5.6 Advertising Policy on Approved Equipment: Commercial sales literature should not state or imply that SAE has approved or endorsed the product.
- 5.7 Detector Function: A peak detector should be used for all measurements required by this recommended practice. Detector functions used for other specifications or standards such as "field intensity, quasi-peak, average, and carrier" should not be used for this recommended practice.
- 5.7.1 Peak Detector Characteristics
- 5.7.1.1 Manual Operation: The peak detector for manually tuned instruments may be either the direct-reading meter type or the slideback type with aural cutoff. Calibration may be by the substitution method.
- a. The direct-reading type should have a response vs. impulse repetition rate such that it will read no more than 1 dB below true peak for rates down to 10 impulses/ sec. at the widest bandwidth setting of the instrument.
 - b. The slideback type should have ample post-detector audio gain to assure an accurate cutoff.
- 5.7.1.2 Automatically Scanned Operation: For automatically scanned operation, where the output of the detector is recorded on an X-Y chart or applied to a digital memory for recording and printout, the peak detector should have response and release times sufficiently fast so that at the scanning rate and bandwidth used, the detector will not limit the accuracy of the recorded data.

METHOD 1001

TEST LIMITS AND TEST METHODS

1. Purpose: The purpose of this method is to describe the test methods and test limits applicable to this recommended practice.
2. Interference Test Plan: When required by the contract, the contractor should prepare a detailed test plan showing the means of implementation and the application of the test methods in this ARP to the equipment being procured. Prior to formal testing, this test plan should be approved by the purchaser. The test plan should be sufficiently complete so that a qualified technician can, with a little additional information, use the plan to conduct tests. The proposed method of testing for the requirements should be included as well as additional details such as:
 - a. Nomenclature and serial numbers of measuring instruments to be used.
 - b. Methods of measurement to be used.
 - c. Detector functions to be used on measuring instruments.
 - d. Methods of loading and triggering.
 - e. Operation of test sample.
 - f. Control settings on test sample.
 - g. Frequencies at which interference might be expected.
3. Applicable Test Methods: The test methods shown in Table I should be applicable unless the contract contains other requirements.

TABLE I - APPLICABILITY OF REQUIREMENTS

Test Method or Series	Am	Au	Gp	C
2000	Y	Y	Y	Y
3001	Y ₁	Y ₁	Y ₁ +10	Y ₁
3002	Y	Y	+10	Y
4000	Y	Y	+10	Y
5000	Y ₂	Y	Y	Y ₂

Y = Yes, requirement is applicable

Y₁ = Is not applicable unless specifically required by the contract

Y₂ = Applicable for equipment containing transistors and/or semi-conductors other than diodes

± = Add or subtract the indicated number of dB to the applicable limits

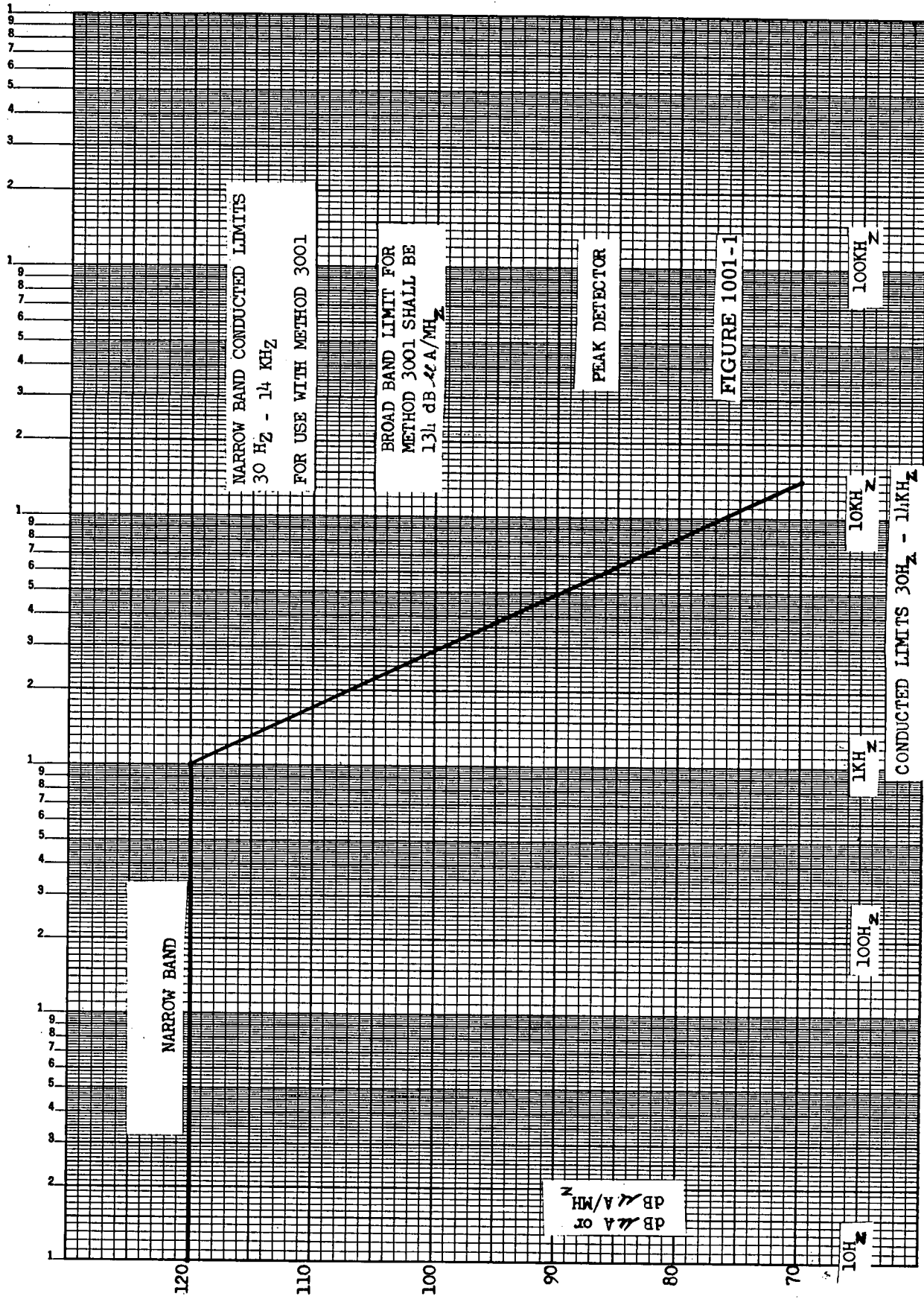
- 3.1 Equipment Classification: The following classification should apply:
 - a. Class Am consists of equipment (including systems and subsystems) installed in manned airborne systems, such as aircraft, and aerospace vehicles.
 - b. Class Au consists of equipment installed in unmanned airborne systems, such as missiles, satellites, and aerospace vehicles.

- c. Class Gp consists of ground equipment intended to operate in close proximity to other sensitive equipment. Ground equipment connected to or used less than 100 ft (30.5 m) of an airborne vehicle falls within this class.
 - d. Class C consists of a collection of ground equipment needed to perform a function or mission that is physically isolated from sensitive equipment by at least 100 ft (30.5m).
4. Transients: All interference resulting from any electrical or any electromechanical systems, subsystems or equipment should not exceed the limits specified for broadband interference. Exceptions to this requirement should be included in the interference test plan for consideration and possible approval by the purchaser.
5. Voltage Spikes: For classes AM, Au, Gp, and C, all voltage spikes should be within the envelopes specified by MIL-STD-704 unless otherwise specified in the contract.
6. Test Limits: The test limits in Table II should apply unless otherwise specified in the contract or approved system interference-control plan and the test plan.
- 6.1 The purchaser should be consulted for any unusual application of this ARP.

TABLE II

<u>Test Method</u>	<u>Applicable Interference Limit</u>
3001, Conducted Interference, 30 H _Z to 14 KHz	See Fig. 1001-1
3002, Conducted Interference, 14 KHz to 100 MHz	See Fig. 1001-2
4001, Radiated Interference, 14 KHz to 400 MHz	See Fig. 1001-3, 4
5001, Conducted Susceptibility, 50 H _Z to 150 KHz	See Fig. 1000-5

7. Short Duration Interference: Short duration transients and impulse interferences are not to be considered as interference if their duration is less than 3 seconds and if they do not occur more than twice per flight or running period. Components used only during engine starting may deviate from the limits by 20 dB. Also, equipment which has a maximum interference duration of 1 second and has a maximum recurrence rate of once in each 3 minutes may deviate from the limits by 20 dB. This paragraph is subject to approval by the purchaser.
8. Spike Susceptibility: Spike susceptibility tests and limits are not specified in this ARP. All electrical accessories for engines are required to withstand the voltage transients of MIL-STD-704.



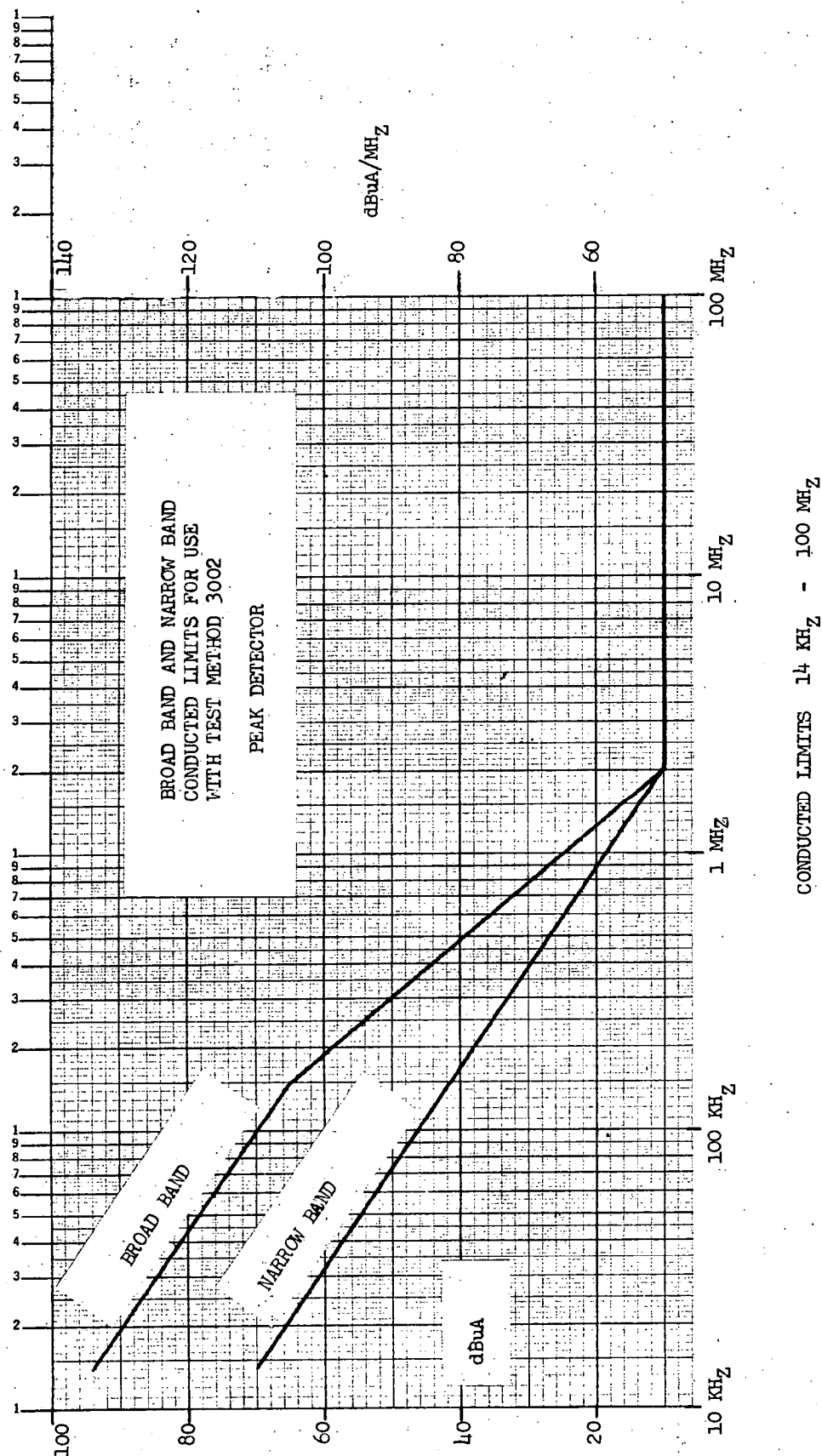


FIGURE 1001-2