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Recommended Measurement Practices and Procedures
for EMC Testing

RATIONALE

The document is still a valid standard which may benefit from a future update. The basic technology described in the document is still valid. The subcommittee designated to update the document is not currently active, so stabilization of the document is the best approach until such time as a committee can be established to open a WIP.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE AE-4 Electromagnetic Environmental Effects (E3) Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
L	MEASUREMENT RECEIVER BANDWIDTHS	3
A	CONDUCTED EMISSIONS, POWER LEADS	6
B	CONDUCTED EMISSIONS, SIGNAL LEADS.....	15
C	CONDUCTED EMISSIONS, SIGNAL CABLES	19
D	CONDUCTED EMISSIONS, TIME DOMAIN.....	28
E	CONDUCTED SUSCEPTIBILITY, POWER LEADS, 30HZ-50KHZ	31
F	CONDUCTED SUSCEPTIBILITY, 50KHZ-400MHZ	36
G	CONDUCTED SUSCEPTIBILITY, TRANSIENT	42
H	RECEIVER INTERMODULATION, THIRD ORDER INTERCEPT	50
I	FRONT END REJECTION	55
J	RADIATED EMISSIONS	61
K	RADIATED SUSCEPTIBILITY.....	65
M	CONDUCTED EMISSIONS, RF TERMINAL.....	69
N	RADIATED MAGNETIC EMISSIONS	73

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A general EMC test method is difficult to prepare. A group of specialists can prepare a specific document, as an example, for airplanes, or satellites, etc. This will take a significant effort but with adequate time and expertise can be accomplished. The problem arises in that unique characteristics associated with ships or ground vehicles, or specialized equipment may not be addressed.

The SAE AE-4 EMC Committee is in a unique position to solve this problem. The specialists in each area are available and with the large number of participants, most perspectives of EMC testing on various products have been presented. This document represents the results of such an effort started in 1978.

Thus, the test methods presented in this document do not represent a modification of an existing set of test methods. Rather, they represent a series of test methods which the committee felt would provide the basic information for any type equipment. A system integrator will need to determine which tests are meaningful to his application.

An effort has been made to establish shield room test methods that give results that will approximate those made in an actual installation.

A major concern of those involved in preparation of this document is the need to establish meaningful limits for the tests. Measuring emissions on a signal line is only meaningful in conjunction with the susceptibility levels. And these levels are highly dependent on the equipment operating scenario. This area needs to be addressed in the future.

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Section L

MEASUREMENT RECEIVER BANDWIDTHS

Background and Philosophy: Those who want to analyze a system for its EMC performance need to do specialized tests and scans to get the detailed resolution desired. This detail differs significantly between equipment types. It is not feasible to provide this detail in a generalized EMI test. The EMI test should provide a general criteria to overall levels. It should be specifically noted that a distinction is thus being made between running a qualification test and doing a performance evaluation. Thus, to evaluate individual equipment performance will require scans with a receiver or an analyzer to determine the type of emission. This may be a random noise signal, impulsive noise, or a CW signal which will each react differently with different receiver bandwidths. This identification is needed in order to appropriately identify the source for possible corrective action.

The concept presented in this test method is to set a limit such that a worst case condition is evaluated. If there is a failure, then further analysis, as discussed above, may be performed to determine the degree of possible corrective action.

Actual bandwidths for the qualification test need to be selected as a trade-off between signal selectivity, scan time, etc. The attached list considers the following criteria:

AF Application Note ASD/ENA-TR-80-3 so that there is not a vast disparity between these results and those taken previously.

ANSI C63.2-1980 so that those chosen agree with the options.

Availability on receiving systems of the major manufacturers.

Coordination with those used in the European community.

Recommendation: The subcommittee's recommendation is that a single scan with a specified bandwidth be used with one set of limits. The topic of broadband - narrowband should be removed from the specifications.

<u>Tuned Frequency</u>	<u>Bandwidth</u>	<u>Type</u>
20Hz - 1kHz	20Hz or less	*
1kHz - 10kHz	200Hz or less	*
10kHz - 1 MHz	1kHz \pm 10%	(Impulse)
1MHz - 30MHz	10kHz \pm 10%	"
30MHz - 1GHz	100kHz \pm 10%	"
1GHz - 18GHz	1Hz \pm 10%	"
18GHz - Open	Not Decided	"

* The impulse bandwidth is recommended, but because of the difficulties in measuring it and the fact that the 6dB bandwidth is not much different, the 6dB bandwidth may be used.

There will be situations where older equipment with non-standard bandwidths must be used. In this situation, the nearest bandwidth greater than the specified value shall be used. A 20 log bandwidth correction factor shall be used if the receiver reading in the average detector function is 6dB or more below the level in the peak detector function. Where the difference is less than 6dB, no correction factor is needed.

JUSTIFICATION AND RATIONALE:

Bandwidth Type: In addition to picking the suggested measurement bandwidth, considerable discussion was held concerning the "type" of bandwidth, i.e. 3dB, 6dB, or impulse bandwidth.

The advantage of a 3 or 6dB bandwidth is the ease of understanding and measuring them. For users of receivers of standard intentional information, this is worthwhile. The limiting problem is that the shape factor is not defined by these terms alone. For a narrowly tuned intentional source, this is not critical. The same reading will be obtained with any of the bandwidth types. However, in EMC work, the signal to be measured extends past the band edges. The bandwidth shape will influence the detected signal levels. Thus, an impulse bandwidth is recommended as being the most technically correct for performing EMI measurements. With a bandwidth so defined, readings of EMC noise by different receivers (and shape factors) can be compared.

Receiver (and analyzer) manufacturers have agreed that this B.W. definition is the most technically correct for the EMC community. The British EMC specification also calls out the impulse bandwidth as their standard and the trend seems to be this way in the European military work.

Measuring Impulse Bandwidth (BW_i): The Impulse Bandwidth, BW_i , of a system is defined as the bandwidth of a rectangular filter having the same voltage response as the system measurement bandwidth. In general, a receiver's equivalent BW_i is dependent on the bandwidth and shape of the receiver bandpass filter (IF filter) and the effects of post detection filtering (video filtering). Receivers having a particular shape of IF bandwidth filters (i.e. rectangular) may or may not have the same equivalent BW_i (i.e. the 6dB BW is not necessarily $+ BW_i$). Fortunately, the equivalent BW_i of receivers having a variety of filter shapes can be easily measured.

A simple method of determining a receiver's equivalent BW_i involves making two measurements on an impulsive signal of a known Pulse Repetition Frequency (PRF) peak voltage (V_p) and duration (τ). The first measurement uses peak detection and the second uses average detection, both in linear.

Measure the impulsive signal's peak voltage V_1 , using a receiver IF bandwidth wider than the signal PRF. The post detection filter should be set at least 10 times wider than the IF bandwidth so no averaging occurs.

Next, reduce the post detection filter (video filter) to be narrower than the signal PRF. The measured voltage (V_2) will be the average value of the impulsive signal.

The receiver's equivalent impulse bandwidth, BW_i can then be determined from the expression:

$$BW_i = (PRF) (V_1/V_2)$$

as shown in Figure L-1.

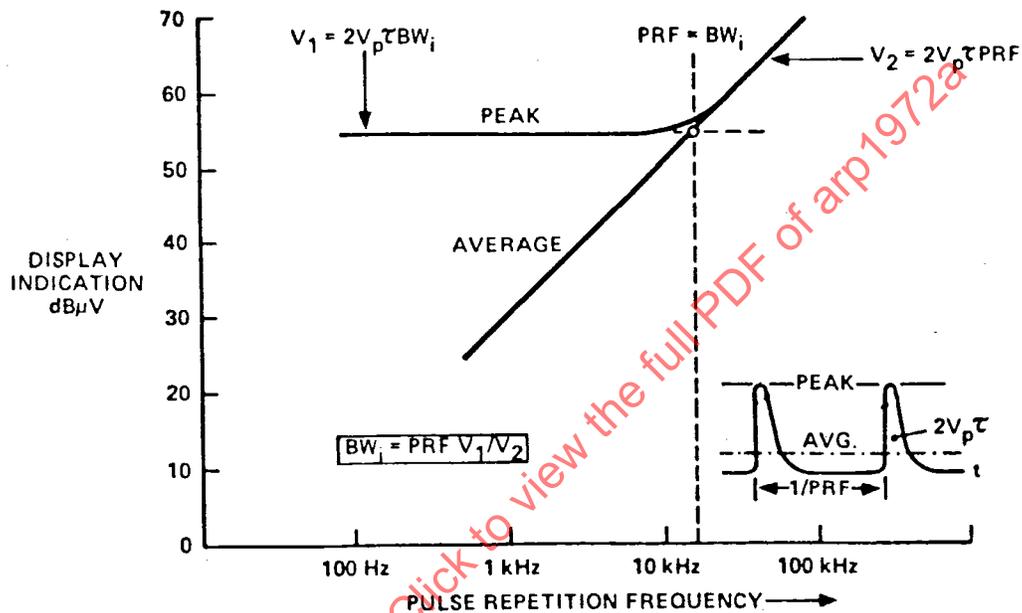


Figure L-1

Section A

CONDUCTED EMISSIONS, POWER LEADS

Background and Philosophy: The SAE subcommittee working on MIL-STD-461 test methods and procedures has studied numerous methods of performing conducted emission measurements. The committee has met many times over the last few years and discussed various methods for measuring conducted emissions. Various test methods with their pros and cons have been presented in these meetings. Questionnaires have been submitted by others listing pros and cons to various methods. A wide variety of commercial and military specifications have been submitted and reviewed. These have been combined and summarized.

Depending on the need of the user one method or another may be most useful. However, the majority of people in responding to questionnaires indicated they favored a method of measurement that gave absolute levels as opposed to levels dependent on a specific test setup or line impedance. A specific concern was that the method provide information that could be used in susceptibility testing and in design.

Recommendation: This subcommittee has decided on a recommended test procedure which consists of using the 5uH LISN in the line to standardize the impedance. The measurements are made with a standard current probe between the LISN and the test sample.

Justification and Rationale: The following paragraphs discuss the rationale and justification for this test method.

Measurements of conducted emissions need to provide absolute levels in terms such as maximum noise power. Various proposals of measuring both voltage and current, measuring current with two different line impedances, measuring the line impedance and current, etc. have been put forth to accomplish this. The consensus was that the most practical method was to use an LISN to define the line impedance and a current probe to measure the current. This uses standard equipment items and requires only one test scan. This paper will, therefore, recommend this method.

A number of studies have been made which have determined the typical power line impedance. The use of the 5uH LISN appeared to be a realistic approximation to these values prior to MIL-STD-826 or MIL-STD-461. The characteristic established about 1940 was based on measurements taken on several typical aircraft and ships of that period. An October 1960 report by Stoddart under contract NY 3139 presents the average of measurements on 5 aircraft with the results. Figures A-1 and A-2 present some of this statistical data of typical power line impedances. Figure A-3 shows the curves for various LISN's that are on the market. The 5uH unit still appears a good choice since it allows for the additional inductance of the test configuration. Measured data indicate that the upper amplitude limit is more closely approximated by 100 ohms than 50 ohms. The objective of this whole analysis is to pick an impedance that approximates actual values. While actual values vary, the chosen value is close enough for most applications to give good results.

If the LISN using 5uH is placed in the power line, the current measured with a current probe would be indicative of that measured in a real system installation: A review of the accuracy of this method is made by an example. If the current measured with the LISN (100 ohms) in the line is 1 mA it would mean that the noise source generated 100u watts. If R changes to 200 ohms or to 50 ohms, the value would be 200u watts or 50u watts, respectively. This is within 3 dB.

At the low frequencies the source impedance of the power supply must be less than 1/10 of the load impedance for it to provide adequate regulation. The error associated with the source impedance will be less than ± 1 dB. Thus, the noise current will be essentially independent of the source impedance. For dc sources, a large capacitance (30,000uF) will be used to assure this low impedance source.

Current probes provide an easy way to perform the measurement. There is freedom from low frequency ground currents and they can be used on both signal and power leads.

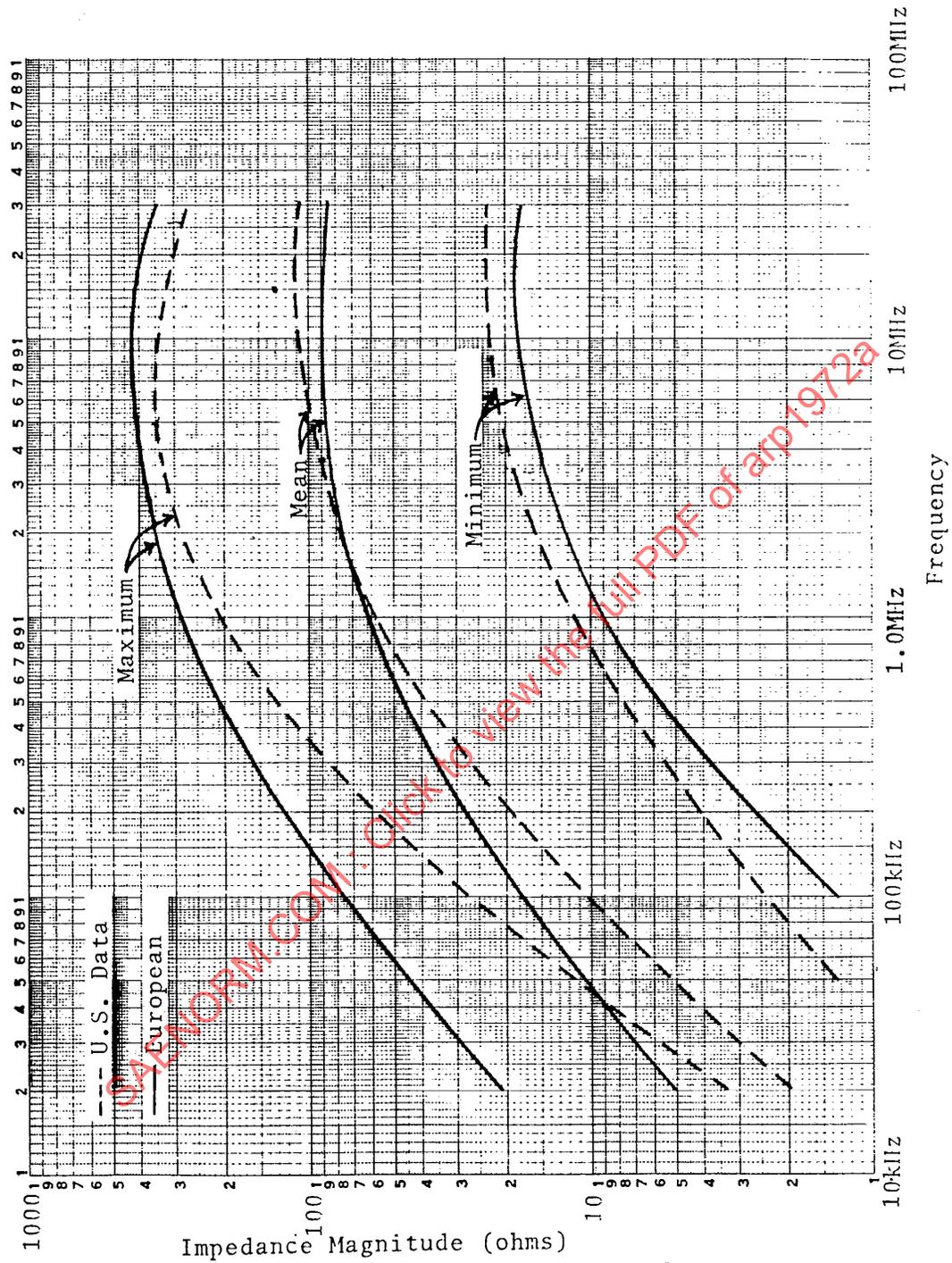
Measurements taken in this manner can be used to relate susceptibility and emission levels. The emission current levels represent that which will exist in an actual system. If the generator impedance is known, then the noise voltage appearing across it can be calculated. This voltage then represents the level that can be transferred as a susceptibility signal to some other equipment. A typical generator impedance is $.03 + j.07$. By knowing this or the impedance for a specific power source, system susceptibility requirements can be established knowing the emission levels. In reverse, the emission limits can be set by knowing the susceptibility levels. The upper frequency was selected at 100MHz to correlate with the lower range of radiated emission measurements.

CONSIDERATION FOR HIGH CURRENT SITUATIONS

High Current Sources: Let us assume a power source of 100 amperes dedicated to one load. The measurement in this case is more of a control and signal lead type than a straight forward power lead measurement. The only impedance in the circuit should be a simulation of the actual dedicated load impedance.

When the same power source is to be used with several loads, as is typical, there will be some length of heavy bus and then a point of divergence. It is hard to picture this common bus as having the 100 ohms impedance characteristic. A realistic approach might be to split a high current source into two or more 50 ampere identical loads with an LISN in each 60cm lead from either a short length of common bus or directly from the output terminal of the source. The conducted emissions could then be measured either on the common bus or on one individual line to an LISN. This latter method would permit realistic EMI outputs from high current supplies, while using the standard limits. It would seem logical that the purpose of the measurement would be to indicate the magnitude of the EMI current injected by the source into one of these individual branches.

High Current Loads: Conversely, if a very high current load exists, it may well have its own dedicated source. The source and the load should again be tested together as a system and special limits employed. If an auxiliary low current load is to be tapped off this system, an LISN should be inserted in series with the load and the EMI measured in this branch.



Powerline Impedance
Figure A-1

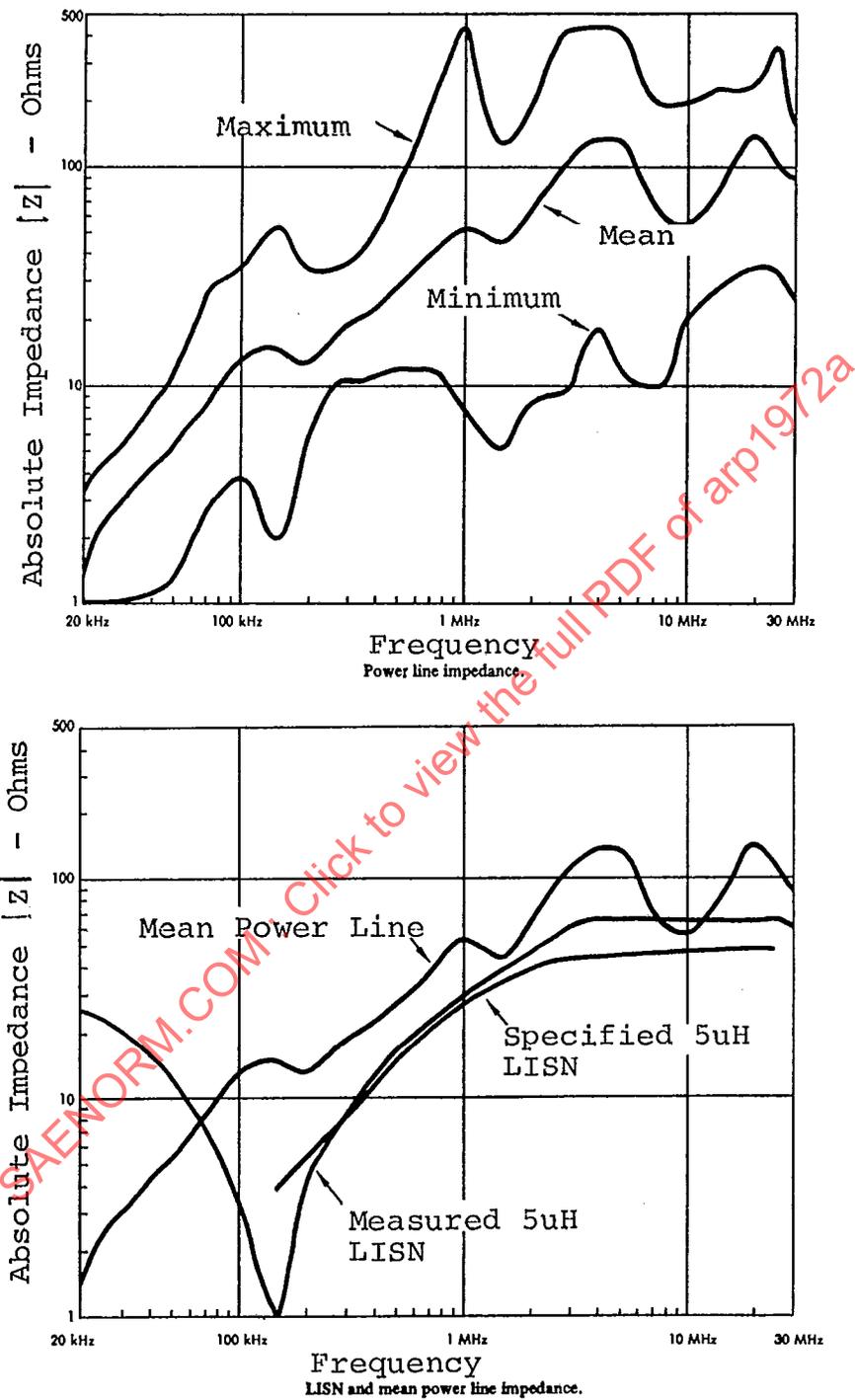
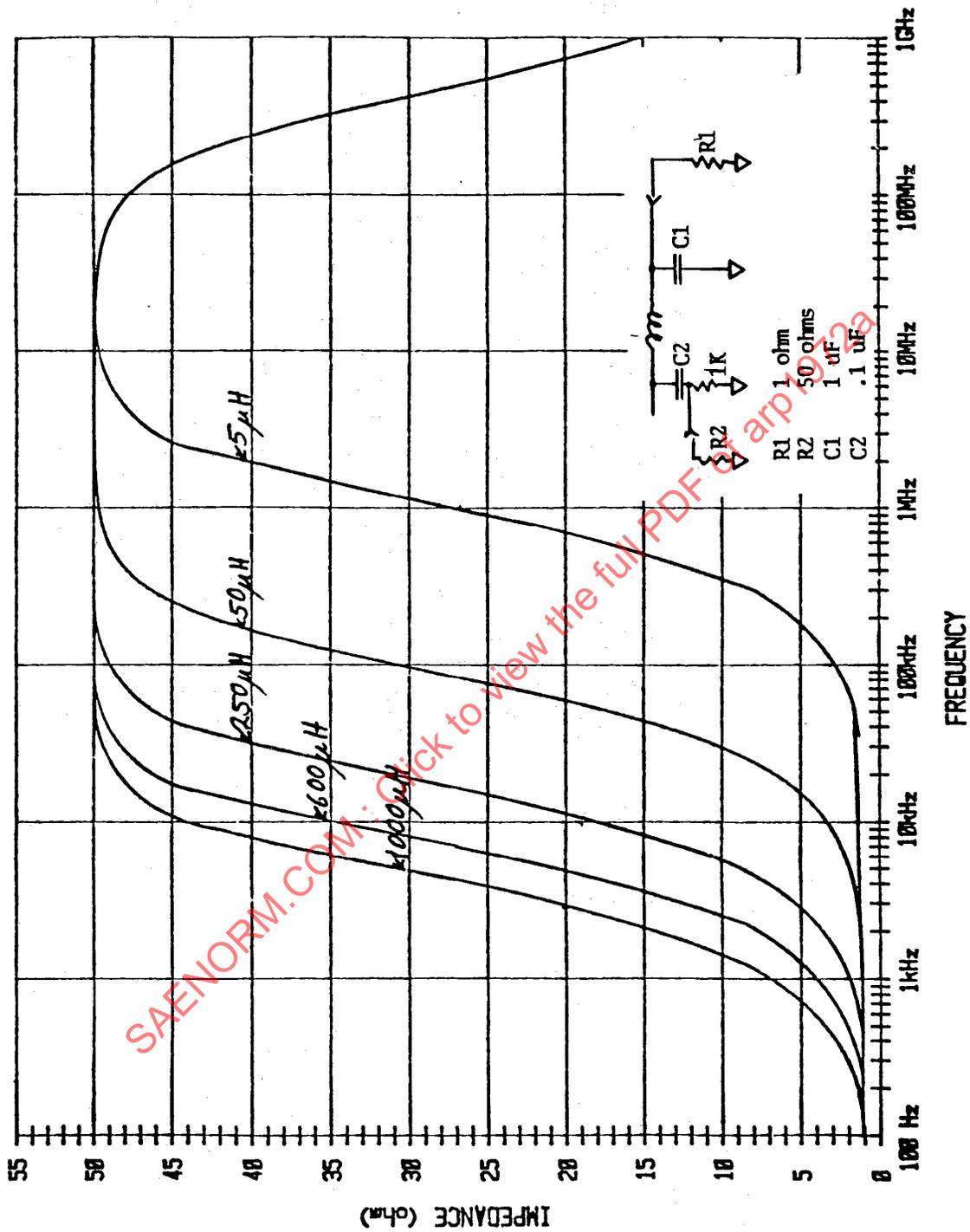


Figure A-2



Background and Rationale
Figure A-3

CONDUCTED EMISSIONS, POWER LEADS

- A1. REQUIREMENT: Conducted emissions shall be measured on the power leads over the frequency range of 30Hz to 100MHz. The allowable limits are presented in Figure A1.-1.
- A2. APPLICABILITY:
- a. General: This test method is applicable for measuring conducted emissions on ac or dc power input leads, including neutrals which are grounded external to the equipment.
 - b. High Current and High Frequency Requirements: This method is applicable to lines up to 100 amps per phase and up to and including 400Hz. An alternate method will be proposed in the test procedure for equipment drawing over 100 Amps or for those systems using "wild frequency" power (above 400Hz).
 - c. Transients: Transients occurring less than once every 10 seconds will be measured at 3 frequencies per decade to provide the general emission envelope.
 - d. Fractional kVA High Frequency Power Sources, Small Alternators and Inverters: Connecting large values of capacity across the output of 400Hz, or higher frequency, power sources can result in abnormal load conditions and errors in conducted EMI data. This problem is very severe when attempting to use a 10uF feed thru capacitor, but it occurs to a lesser degree with the lufd in an LISN. Even if the reactance of the capacitor is tuned out by a suitable power factor correction inductor at the primary or fundamental frequency, the loading impedance becomes less and less as the order of the harmonic is increased.

In actual use, the amount of capacity connected across the AC line by the utilization equipment is limited by the power quality specification (usually as a 0.95 minimum leading power factor). Prior to measurements and preferably in the test plan writing stage, a calculation will be made to insure that the value of capacity to be used in the test setup does not result in a power factor less than 0.95 leading without compensation (power factor correction), or that specified by the power quality specifications.

TEST DATA SHEET

UNIT UNDER TEST _____
TYPE OF MEASUREMENT CONDUCTED EMISSIONS
TEST BY _____ DATE _____
LINE OR CONDITION _____

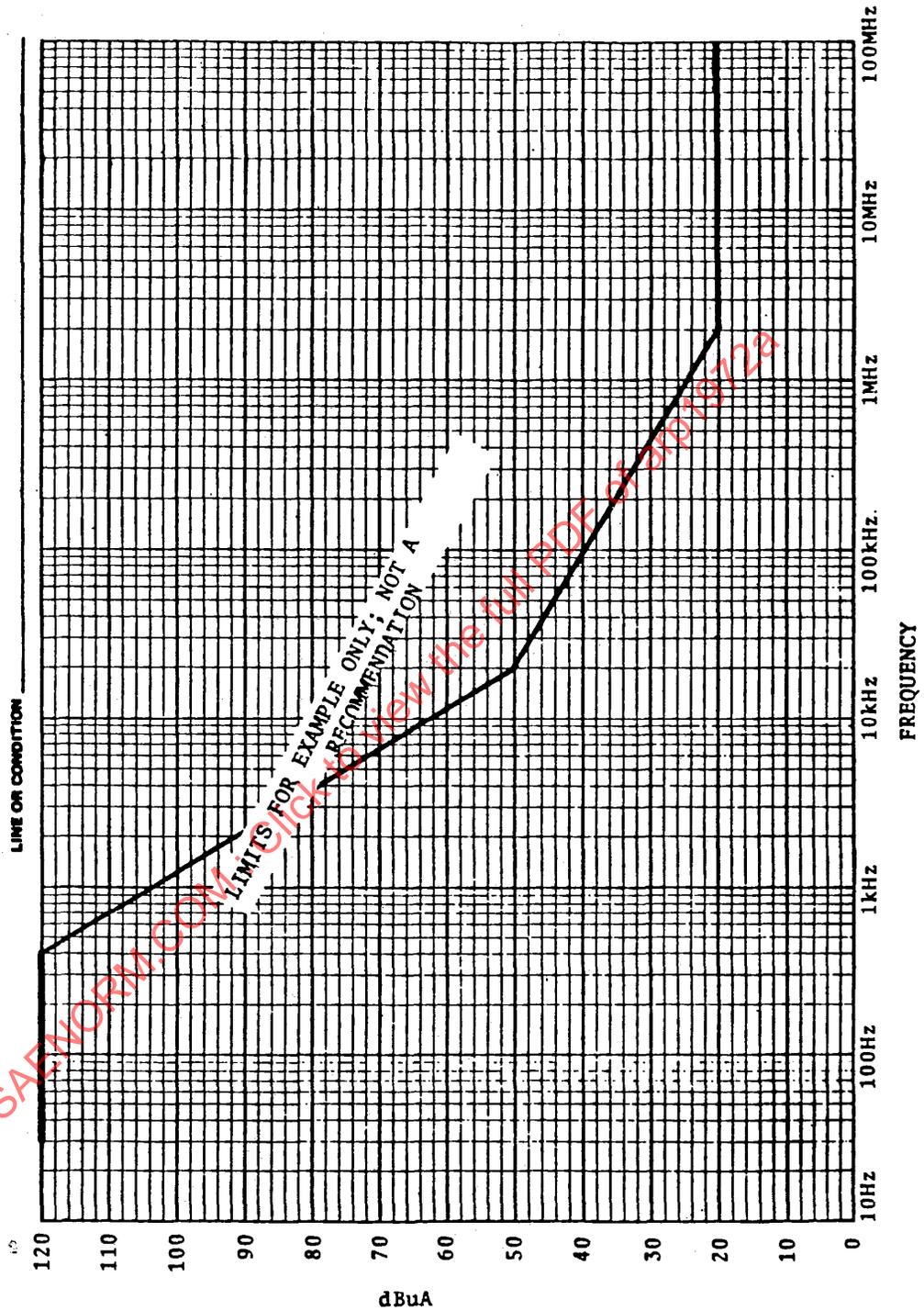


Figure A1.-1

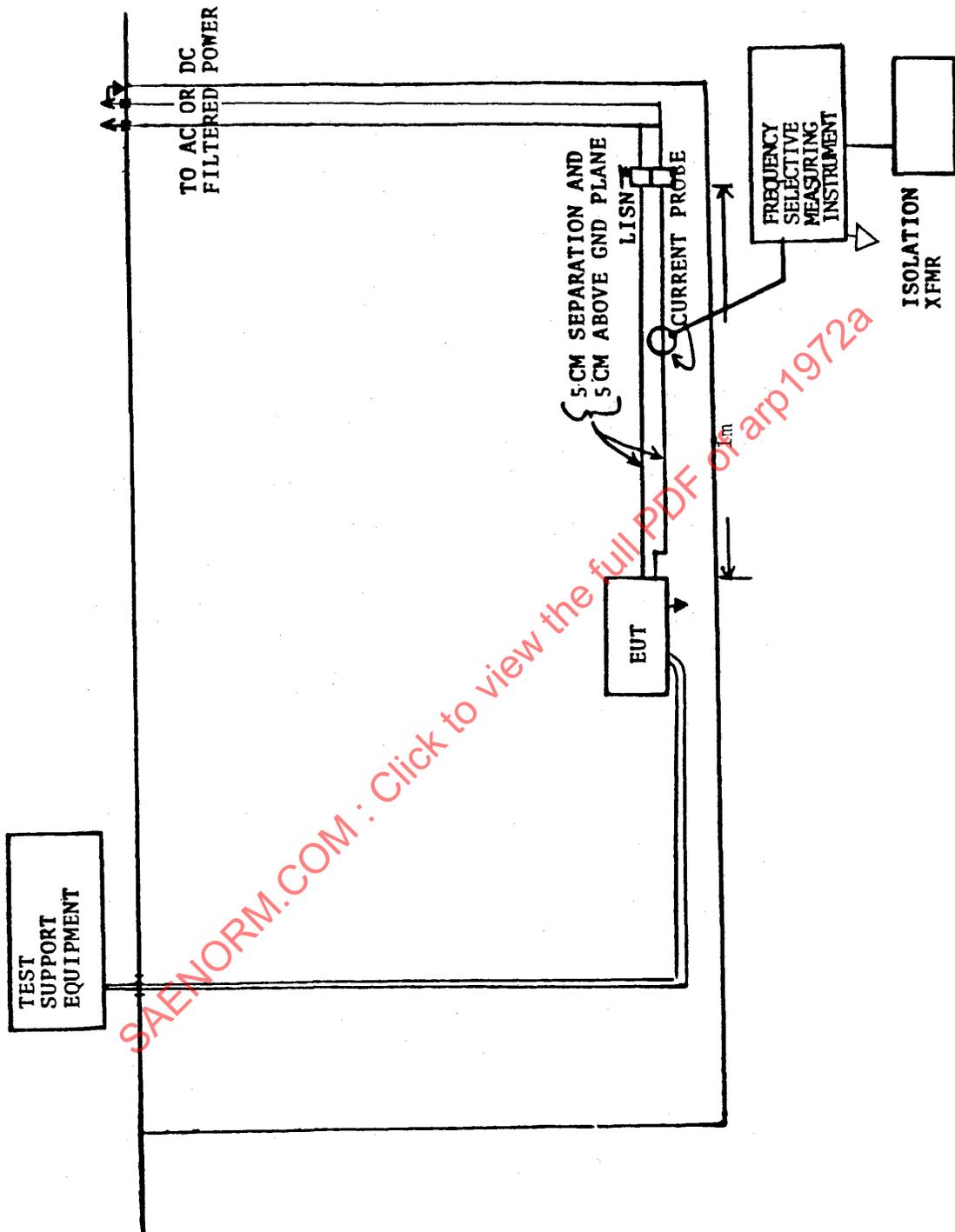
A3. APPARATUS:

- a. Current Probe.
- b. Line impedance stabilization network (see Figures for the schematic and frequency response characteristics).
- c. Frequency selective measuring instrument. Shall use the peak detection capability.
- d. 100 ohm terminations for LISN's.

A4. TEST PROCEDURE:

- a. The test setup will be as shown in Figure A4.-1.
- b. A receiver bandwidth as indicated under "measurement receiver bandwidths" will be used.
- c. The receiver will receive power through an isolation transformer to break the ground path. Ground the receiver at only one point. This shall be either at the shield room coaxial penetration between receiver and the current probe or by bonding the receiver to the ground plane.
- d. Power lead length between the equipment under test and the LISN's will be 1 meter unless specific equipment specifications indicate differently.
- e. The current probe will be positioned 10cm from the LISN.

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Conducted Emissions, Power Leads Set Up
Figure A4.-1

Section B

CONDUCTED EMISSIONS, SIGNAL & CONTROL LEADS

Background and Philosophy: Unwanted electromagnetic energy on signal, control, and rf lines can create interference conditions by two mechanisms: 1) conducting interference directly into another equipment, and 2) radiating from the cable onto other cables.

- 1) The objective of the first test is to determine the signals being conducted on a single wire from one box into another. The intentional signal on a given line is exempt from the limits for this test.
- 2) The objective of the second test is to ensure that a wire, or cable bundle, does not have emissions that could couple into an adjacent bundle. In this case the intentional signal on a line is not exempt from the limits, since if it couples onto an adjacent line, it is as much a source of interference as any other signal.

The procedure addresses the first method listed above.

Recommendation: The conducted emissions measurements will be made with a standard power lead probe around each lead to be tested.

Justification and Rationale: Interference on a line is directly a function of the source and load impedance. Use of the current probe is the most practical way of measuring the interference on the line without having to break into the cable or wire.

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CONDUCTED EMISSIONS, SIGNAL LEADS

- B1. REQUIREMENT: Conducted emissions shall be measured on the control and signal lines over the frequency range of 30Hz to 100MHz. The allowable limits are presented in Figure B1.-1.
- B2. APPLICABILITY:
- Applies to interconnecting control and signal lines as individual wires.
 - Power leads which are derived from other equipment, i.e. secondary power, are subject to this test method.
 - The limits do not apply to the intentional signal on the line.
- B3. APPARATUS:
- Current probe.
 - Frequency selective measuring instrument, using the peak detection capability.
- B4. TEST PROCEDURE:
- The typical test setup is shown in Figure B4.-1.
 - A receiver bandwidth as indicated under "measurement receiver bandwidths" will be used.
 - The receiver will receive power through an isolation transformer to break the ground path. Ground the receiver at only one point. This shall be either at the shield room coaxial penetration between receiver and the current probe, or by bonding the receiver to the ground plane.
 - The test sample shall be bonded to the ground plane in a manner representative of that used in service.
 - The interconnecting wire lengths specified in B4.f shall be supported on insulated standoffs of 5cm height to maintain the capacitance effects between cables and ground plane constant.
 - The interconnecting wires shall be one meter in length unless the actual system installation configuration is known and can be used.
 - All interconnecting wires shall be terminated in loads that simulate those of the actual installation.
 - The receiver shall use a peak detector function for all measurements.

TEST DATA SHEET

UNIT UNDER TEST _____
TYPE OF MEASUREMENT CONDUCTED EMISSIONS
TEST BY _____ DATE _____
LINE OR CONDITION _____

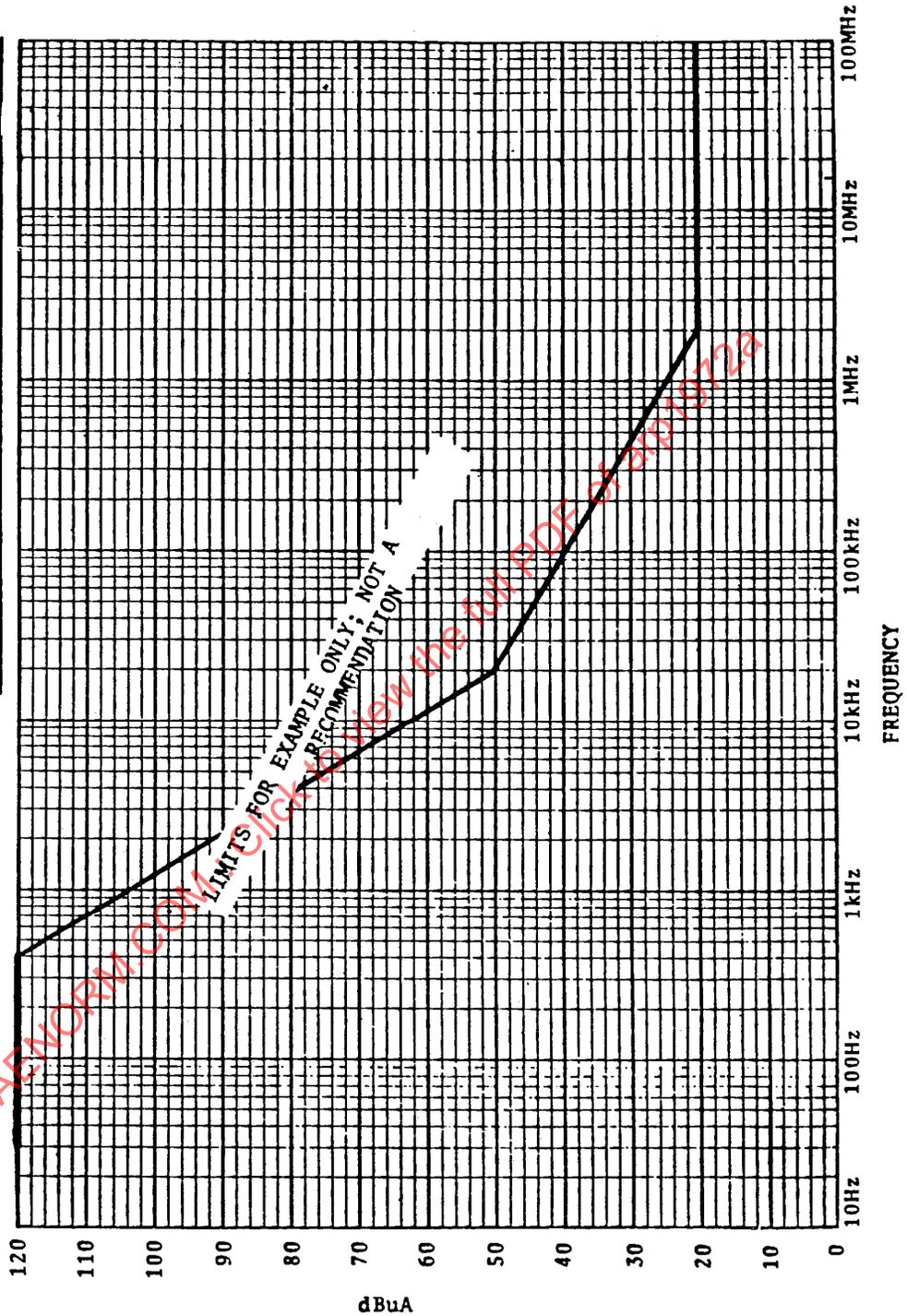
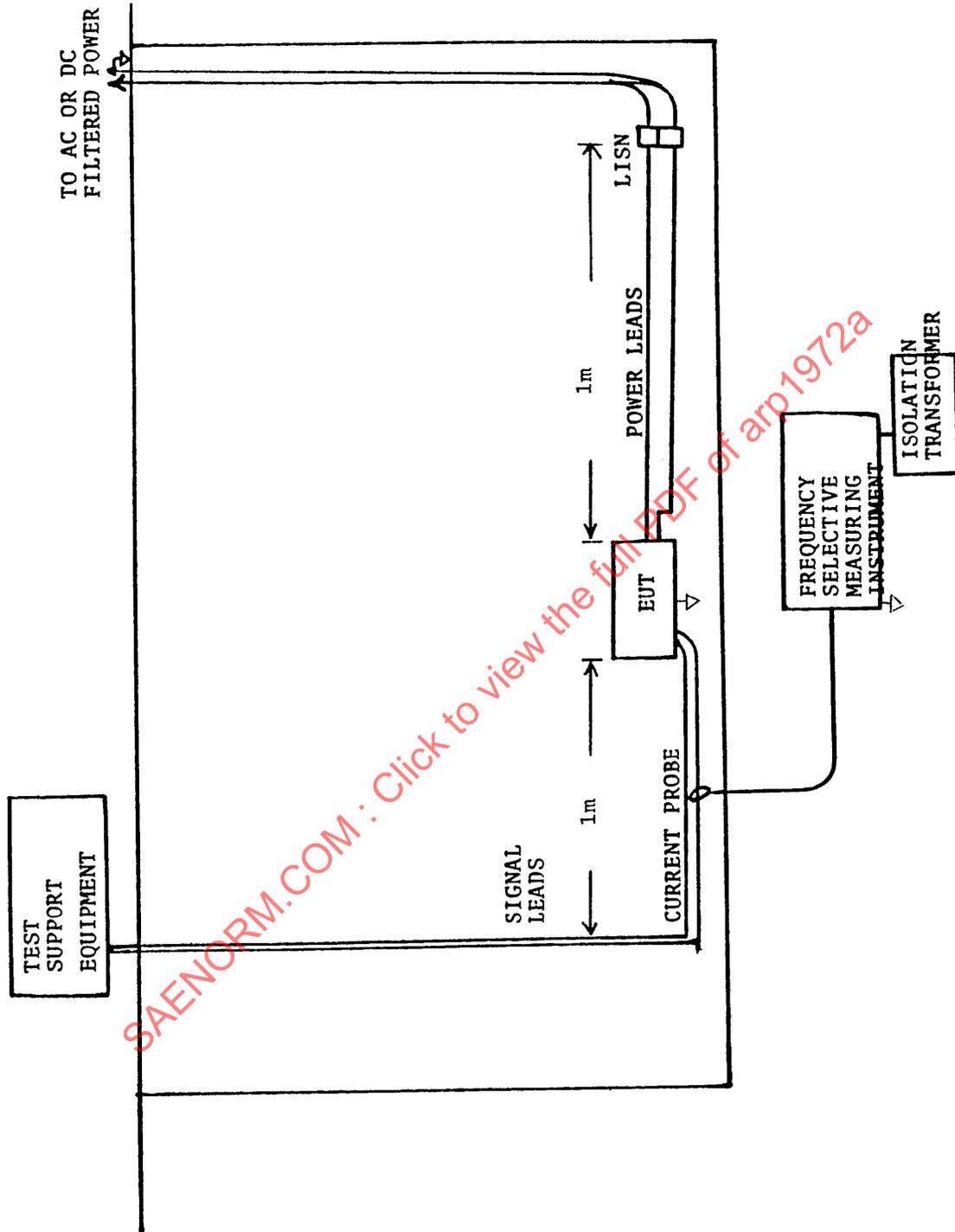


Figure B1.-1



Coconducted Emissions, Signal Lead, Set Up
Figure B4.-1

Section C

CONDUCTED EMISSIONS, SIGNAL CABLES

Background and Philosophy: Unwanted electromagnetic energy on signal and rf lines can create interference conditions by two mechanisms: 1) conducting interference directly into other equipment and 2) radiating from the cable onto other cable lines.

- 1) The objective of the first test is to determine the signals being conducted on a single wire from one box into another. The intentional signal on a given line is exempt from the limits for this test.
- 2) The objective of the second test is to ensure that a wire/conductor, or cable bundle, does not have emissions that could couple into an adjacent bundle. In this case the intentional signal on a line is not exempt from the limits, since if it couples onto an adjacent line, it is as much a source of interference as any other signal.

This procedure addresses the second method listed above.

Recommendation: Conducted emissions will be measured on the overall cable bundle with a standard current probe.

Justification and Rationale: Some test specifications have developed a test fixture as shown in Figure C-1. The copper wire/conductor can be open or short circuited at one end, and the level coupled from the cable under test onto the tube can be measured with an EMI receiver.

Since most testing is done with current probes, it was desirable to determine if comparable results to the parallel rod could be obtained with a current probe to promote a common test method. Use of the current probe was also desirable since the method can be used in actual installation conditions where the cables cannot be placed in a fixture.

Tests described in the following paragraphs were performed to determine the applicability of the current probe.

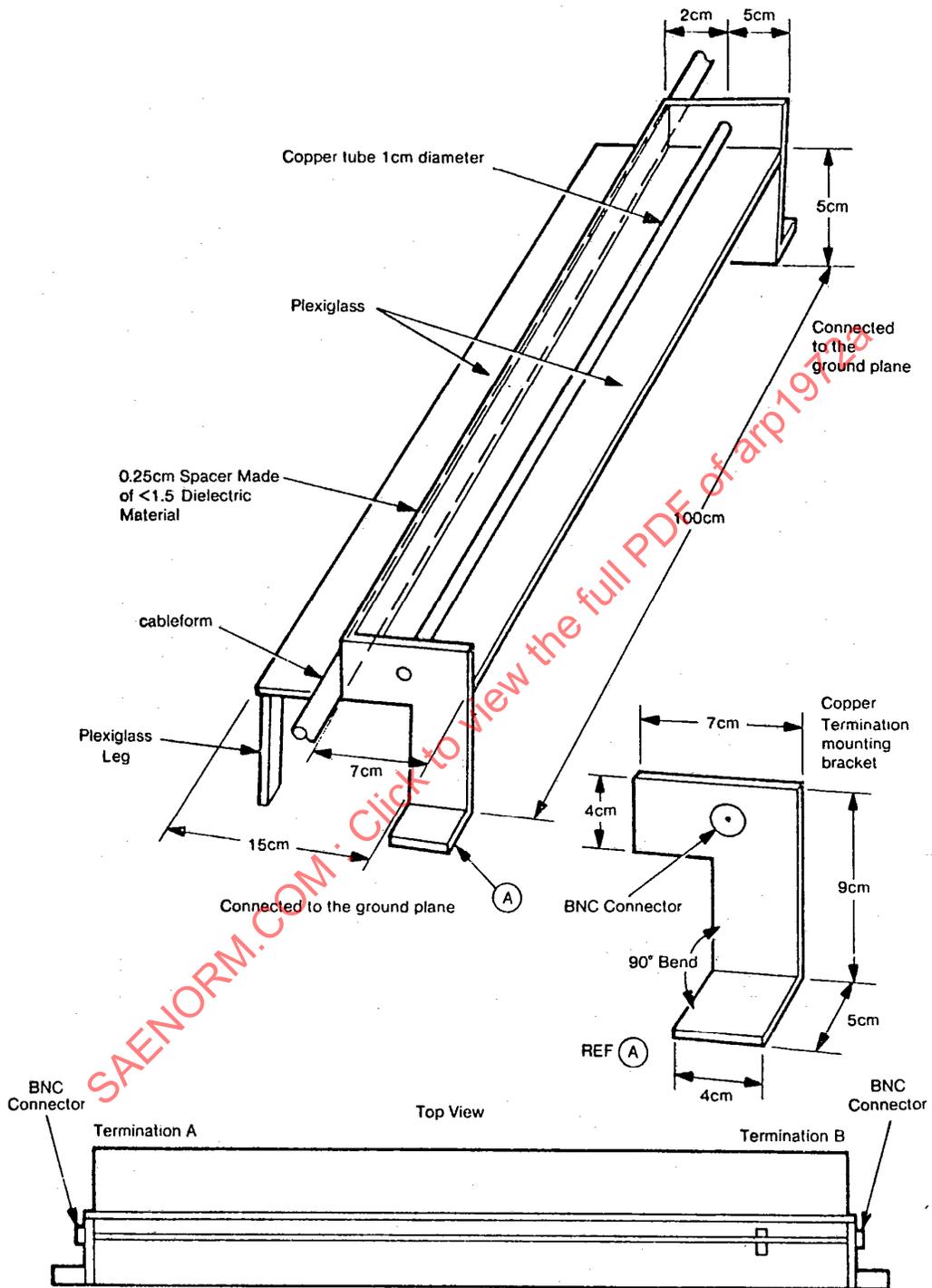
A digital signal was applied to the source wire. The load on this wire was varied between 10 Ω , 50 Ω , 600 Ω , 1K Ω , and 10k Ω as typical of most source resistances. A current probe reading was taken for each of these loads. A measurement on the pickup wire with it shorted at one end and then open on one end was also taken to correspond with each of the source loads.

A comparison of the current probe readings with those of the pickup line under the shorted condition showed a fixed difference regardless of the load. This is plotted as Figure C-2. This indicates the two methods have a direct relationship as a function of current flow in the source wire.

A comparison of the current probe readings with those of the pickup line under the open condition showed a difference roughly inversely proportional to the source line impedance (Figure C-3).

It is concluded that a cable bundle reading as measured with a clamp-on current probe can be directly correlated to cable induced interference. When used with appropriate limits it can be used to establish compatible conditions for cable coupled interference.

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Conducted Emission Signal Leads, Test Fixture
Figure C-1

ELECTROMAGNETIC INTERFERENCE

UNIT UNDER TEST _____
TYPE OF MEASUREMENT Current Probe Reading (-) Pickup Line Shorted Reading
TEST BY _____ DATE _____
APPLICABLE SPECIFICATION _____
LINE OR CONDITION _____

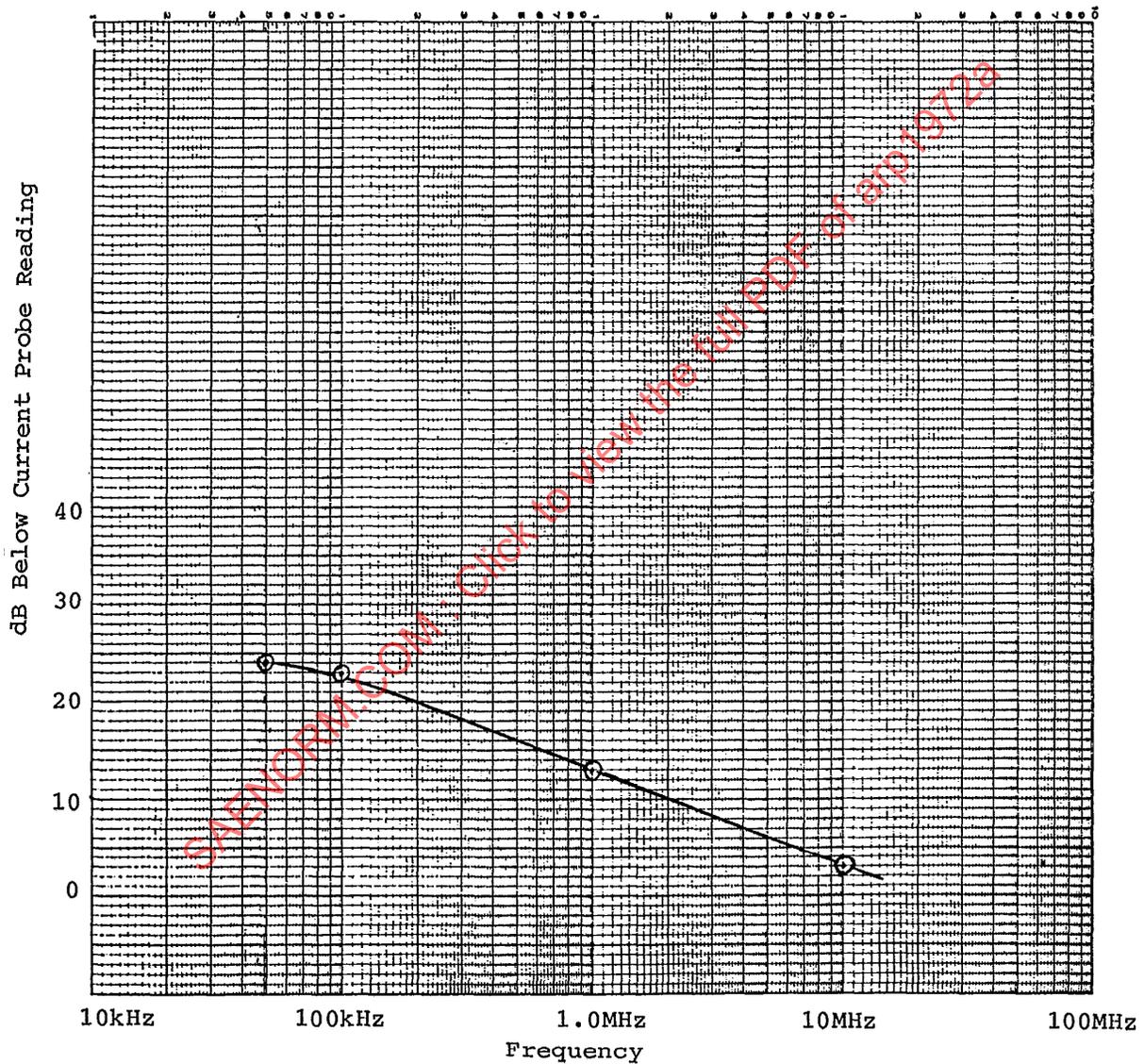


Figure C-2

ELECTROMAGNETIC INTERFERENCE

UNIT UNDER TEST _____
TYPE OF MEASUREMENT Current Probe Reading - Pickup Line Open Reading
TEST BY _____ DATE _____
APPLICABLE SPECIFICATION _____
LINE OR CONDITION _____

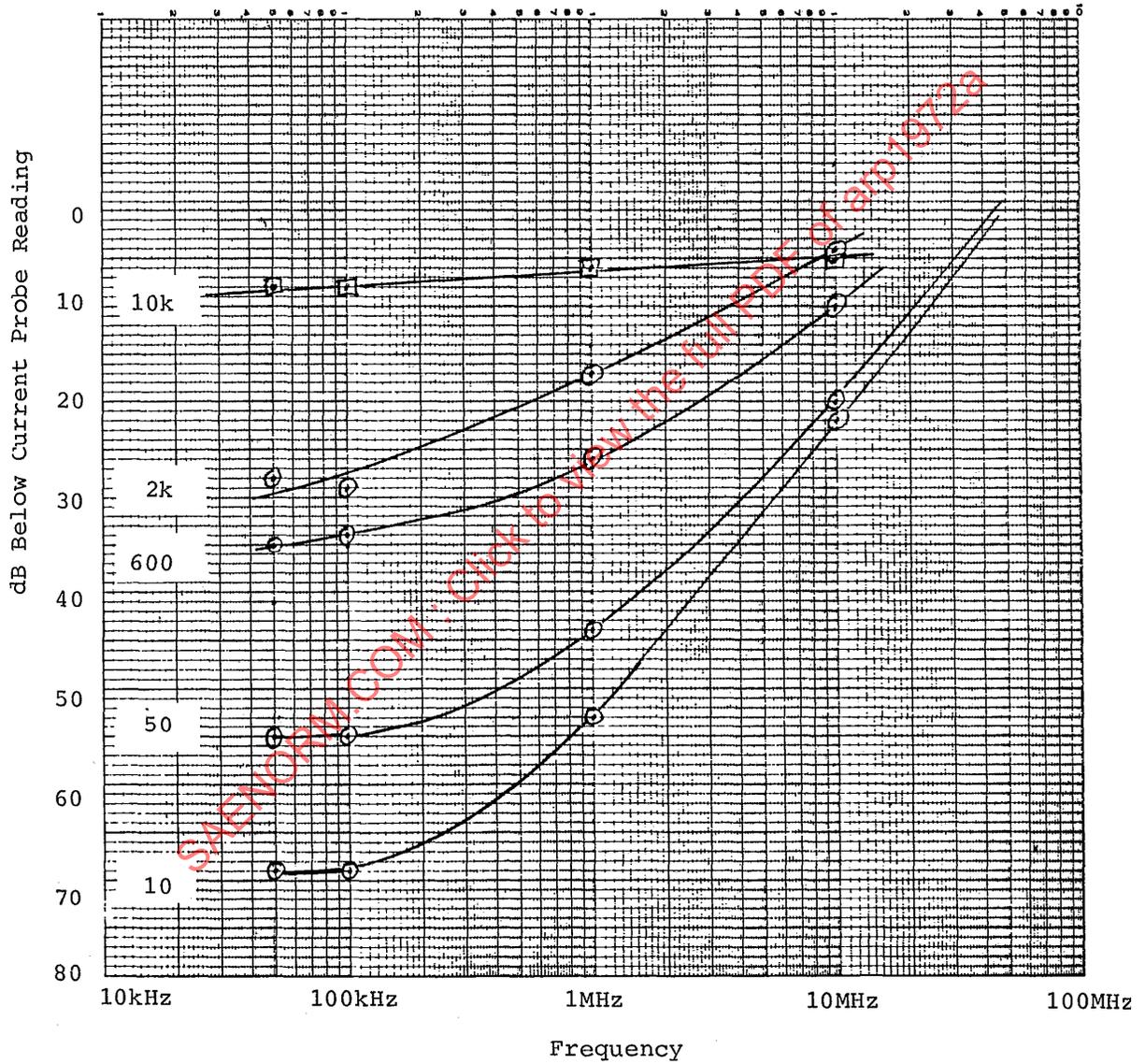


Figure C-3

CONDUCTED EMISSIONS, SIGNAL CABLES

- C1. REQUIREMENT: Conducted emissions shall be measured on control and signal cables over the frequency range of 30Hz to 100MHz. The allowable limits are presented on the attached graphs.
- C2. APPLICABILITY:
- C2.1 Applies to interconnecting control and signal cables as a cable bundle.
- C2.2 Control and signal cables which will be definitely routed as a separate bundle from any others are not subject to this test method.
- C2.3 Cables carrying regulated power which is derived from other equipment are subject to this test method.
- C3. APPARATUS:
- a. Current probe.
- b. Frequency selective measuring instrument.

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TEST DATA SHEET

UNIT UNDER TEST _____
TYPE OF MEASUREMENT CONDUCTED EMISSIONS, NARROWBAND
TEST BY _____ DATE _____
LINE OR CONDITION _____

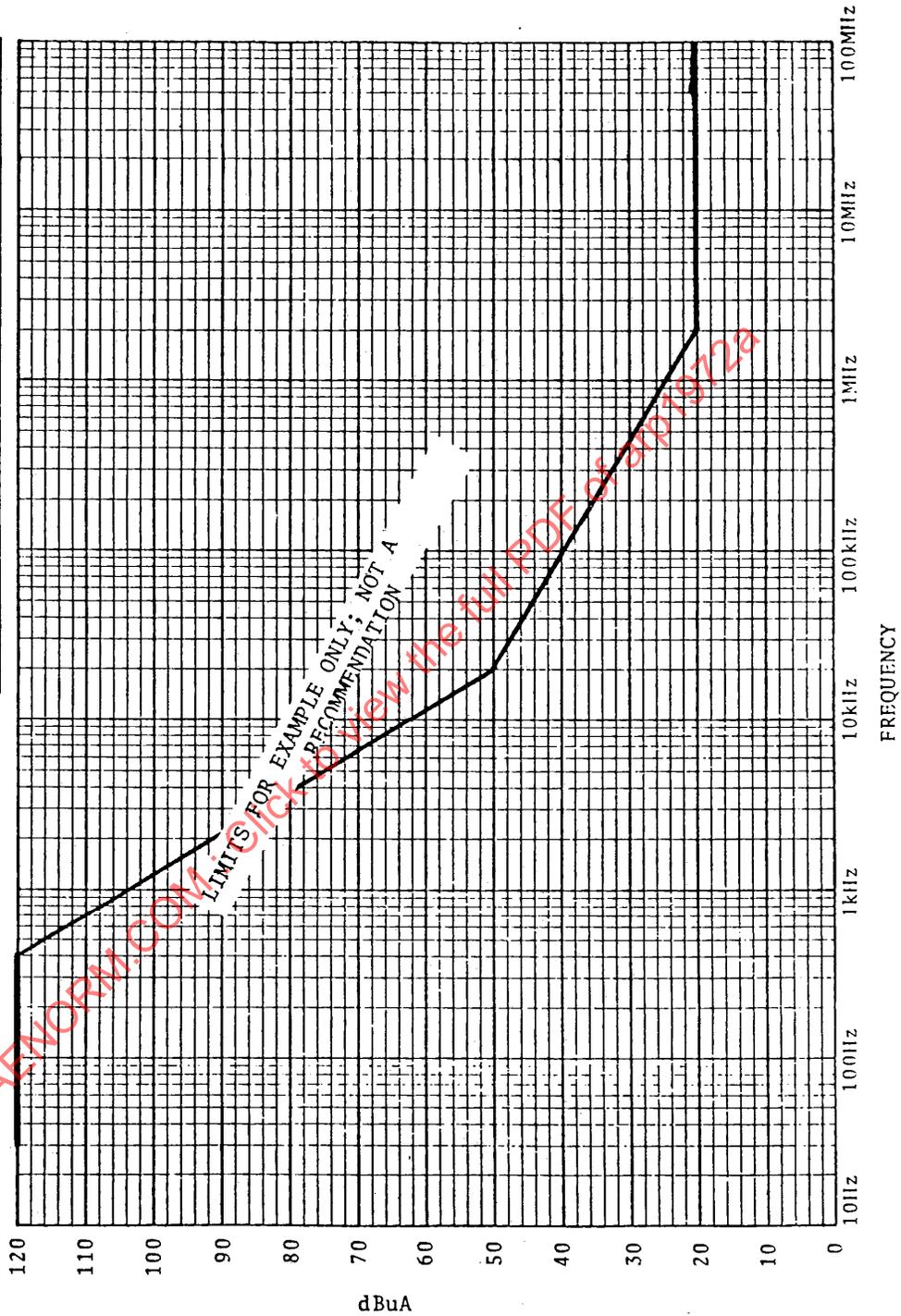
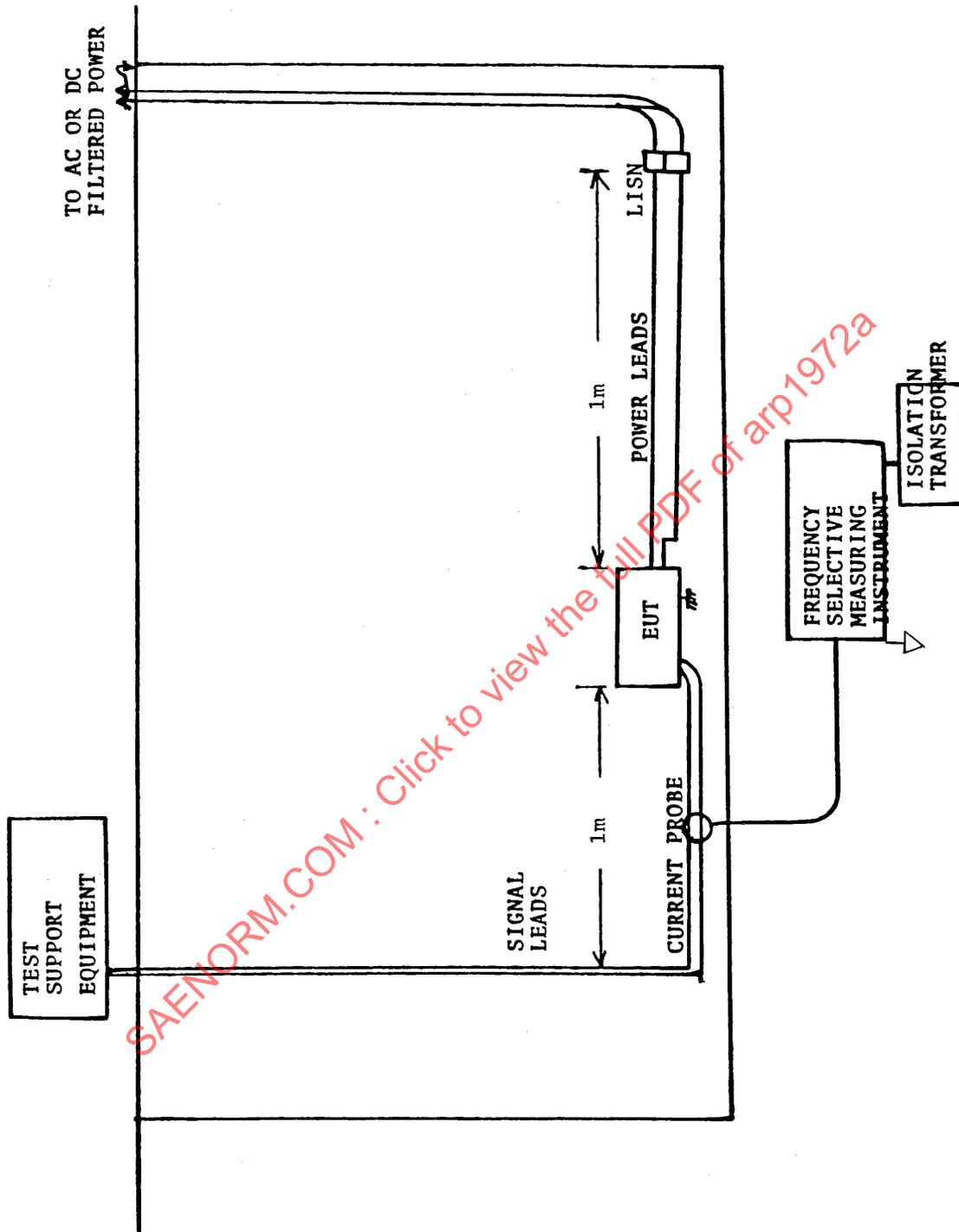


Figure C1.-1

C4. TEST PROCEDURE:

- a. The typical test setup is shown in Figure C4.-1.
- b. A receiver bandwidth as indicated under "measurement receiver bandwidths" will be used.
- c. The receiver will receive power through an isolation transformer to break the ground path. Ground the receiver at only one point. This shall be either at the shield room coaxial penetration between receiver and the current probe, or by bonding the receiver to the ground plane.
- d. The test sample shall be bonded to the ground plane in a manner representative of that used in service.
- e. The interconnecting cables shall be constructed in the same manner as the actual cables with special attention given to lead lengths, shielded leads, lengths of shield pigtailed, and division of cables as in the installation.
- f. One meter of the interconnecting cables shall be supported on insulated stand-offs of 5cm height to maintain the capacitance effects between cables and ground plane constant.
- g. The receiver shall use a peak detector function for all measurements.
- h. If a group of leads exceeds the test limits, the offending lead may be identified and measured separately.

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Conducted Emissions, Signal Cable, Test Set Up
Figure C4.-1

Section D

CONDUCTED EMISSIONS, TIME DOMAIN

Background and Philosophy: Power line transients are generated by switching of loads. Often, the time domain characteristics are more useful for analysis than the frequency domain information. Accordingly, a requirement has been developed to obtain these characteristics using a standard method.

Recommendation: A review of standardizing the effect of power line source impedances indicates the LISN is a worthwhile instrument to use for the performance of this test. The time domain voltage waveshape generated by the eut into the simulated load can be obtained with an oscilloscope.

Justification:

- 1) The oscilloscope is loaded with 100 ohms so that the LISN reflects the proper load back to the eut.
- 2) A clarification of the transient level is used. The level is set so that it is independent of its position on the sine wave. The transient level can couple through an input transformer or power supply equally well at various positions on the wave shape.
- 3) Power quality specifications allow some high levels of emergency operating levels. It is not feasible to use devices to clip short duration spikes to a lower level than the surge levels of the fundamental power frequency. The spike level is set with consideration of this problem.
- 4) The question of responsibility of a transient from a power on-off switch is established. The test needs to be performed, but designers are not responsible for complying with limits outside their design responsibility.

CONDUCTED EMISSIONS, TIME DOMAIN

D1. REQUIREMENT: Switching transients will not exceed the following, as applicable:

AC: Max. transient $\leq 1.5 \times V_{pk}$ at any point on the sine wave.

DC: +50%, -150% of nominal line voltage

D2. APPLICABILITY: This test includes on-off switching transients, which, if the switch is external to the unit, is to provide data for information. Since the switch, arcing, etc. causes much of the transient and it is beyond the control of the EUT designer, the information is for the system integrator use.

All internal switching must meet the limits.

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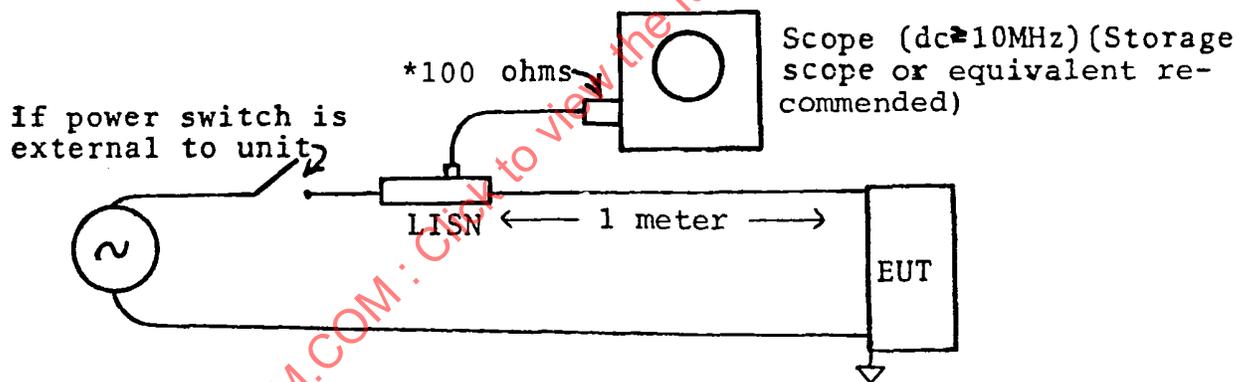
D3. APPARATUS:

- a. Line impedance stabilization network (LISN)
- b. Oscilloscope (dc \geq 10MHz) (Storage scope recommended)

D4. TEST PROCEDURE:

- a. The typical test setup is shown in Figure D4.-1.
- b. An oscilloscope of at least 10MHz BW will be used.
- c. Activate the switch under test and photograph the resulting display on the oscilloscope.
- d. Repeat the test five times to obtain a worst case representation of the transient.

The following figure shall be used as reference for describing the test method in the case of on-off transients.



The LISN shall be used to standardize the source impedance of the generator.

*Note: High pass filter may be necessary to get rid of power frequency feed through.

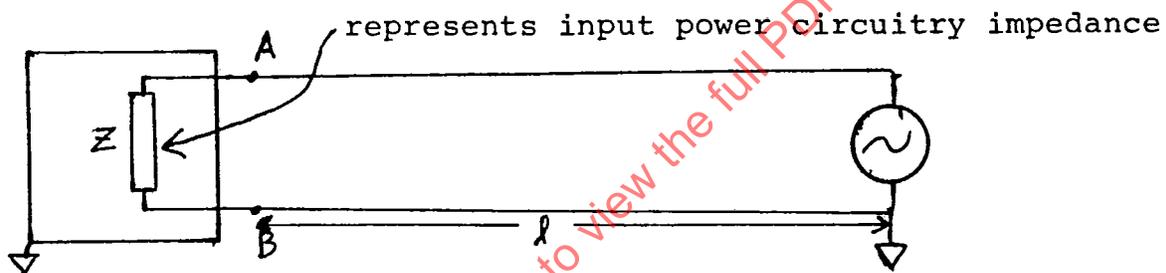
Conducted Emissions, Time Domain Test Setup
Figure D4.-1

Section ECONDUCTED SUSCEPTIBILITY, POWER LEADS, 30HZ-50KHZ

Background and Philosophy: An existing test method is specified in MIL-STD-461. The primary concern was to be able to relate the levels to conducted emissions. This will be possible with the proposed method of measuring conducted emissions. An attempt was made to standardize on using current probe techniques where possible. The poor efficiency of current probes at this frequency range dictated that another method was needed.

Recommendation: A procedure using a transformer to couple the interfering signal onto the power lines is proposed.

Justification and Rationale: The signal will be injected by a transformer into the power line and the voltage measured line to line at points A to B. It will be observed that point B is at ground via the impedance of the line length l .



At the frequency range of this test, this impedance will be low enough to be neglected. Since the power line will, in general, be isolated from the chassis internal to the EUT, the injection transformer could be placed in either power lead. However, to preclude problems with those units where there is a ground reference, the injection transformer should be placed in the positive or hot power lead and then the return lead in turn.

CONDUCTED SUSCEPTIBILITY, POWER LEADS 30HZ - 50KHZ

- E1. **REQUIREMENT:** The performance characteristics of equipment shall not be degraded beyond system specifications due to the injection of an interference signal on each of the power leads. The frequency range covered by this test method is 30Hz to 50kHz. The injected test level will be as indicated in Figure E-1. The test signal will not be modulated.
- E2. **APPLICABILITY:** This test applies to the primary input power leads to the equipment under test. This test applies to power and return lines. It does not apply to the safety (or green) ground lead. It does not apply to output power as these leads are tested under "signal lead conducted susceptibility." The purpose of the test is to confirm that extraneous signals coupled onto the test sample's input power leads will not cause an unacceptable degradation in performance.
- E3. **APPARATUS:** The basic test setup is shown in Figure E-2. The following items of test equipment are needed:
- a) isolation transformer
 - b) VTVM
 - c) oscilloscope
 - d) phase shift network
 - e) signal generator
 - f) power amplifier
 - g) coupling transformer
- E.4 **TEST PROCEDURE:**
- E4.1 **Calibration:** The voltage levels of Figure E-1 will be applied. The requirement is satisfied if the test voltage cannot be generated by a source adjusted to dissipate 50 watts in a 0.5 ohm load ($V = 5$ volts across the 0.5 ohms). This is measured with the 0.5 ohm load across the output of the transformer with the power line disconnected.
- E4.2 **Test Set Up:**
- a) This test setup will be as shown in Figure E-2.
 - b) The test sample shall be bonded to the ground plane in a manner representative of that used in service. Special attention shall be given to simulating the length to width ratio of actual bonding straps.
 - c) The injection transformer will be approximately 10 cm (or as close as possible) from the test sample.
 - d) The power line will have an LISN installed using a 100 ohm termination. Additionally, DC sources will be shunted with a 30,000uF capacitor on the power supply side of the LISN.

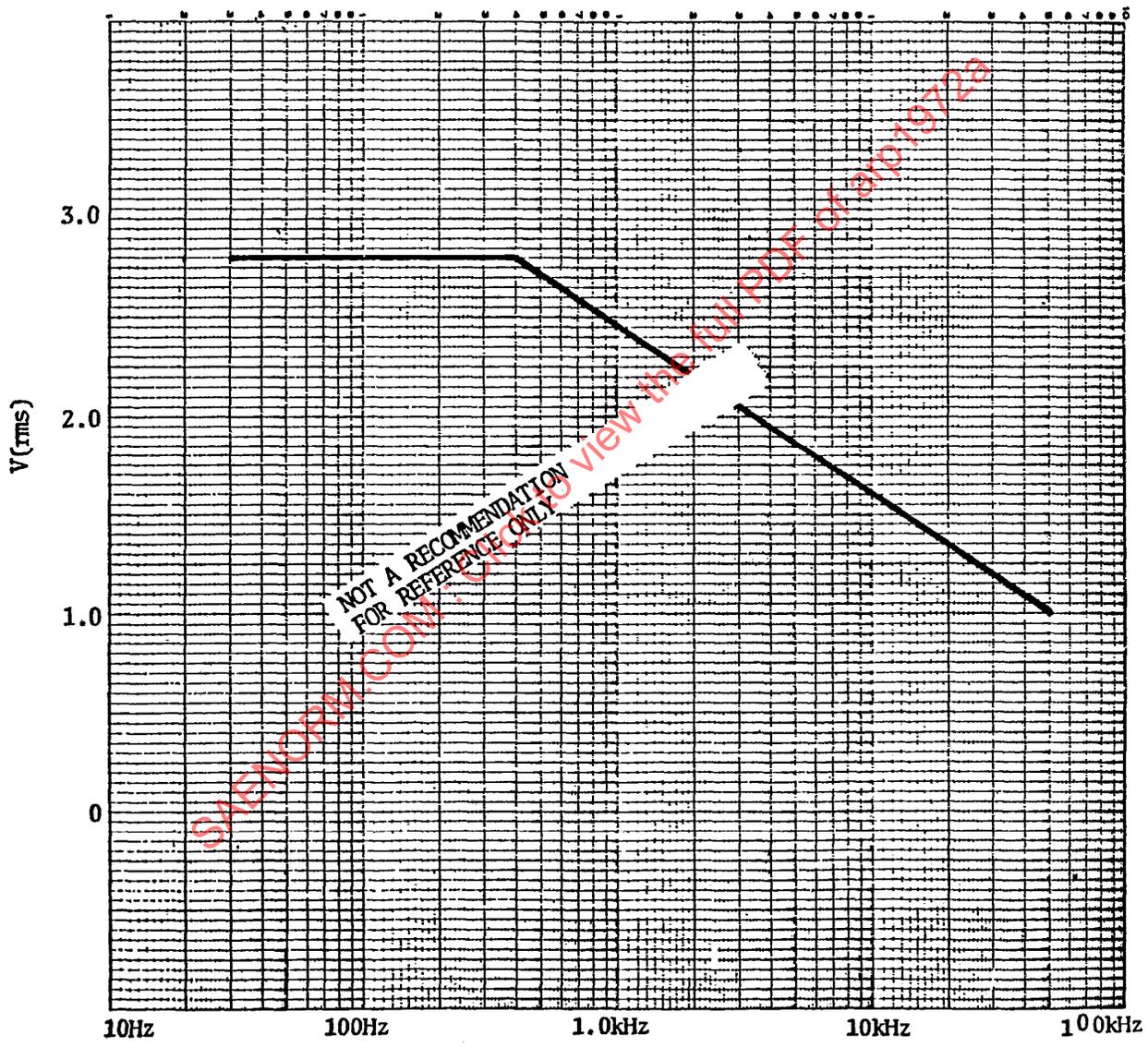
E4.3 Test Procedure:

- a) The approximate levels out of the signal generator will be evaluated as described in Section E4.1.
- b) The injection transformer will be connected to the power line at a distance of 10 cm from the connector of the equipment under test.
- c) A VTVM or oscilloscope will be used to monitor the injected level on the power lines. For AC line, use a phase shift network to cancel the 60Hz or 400Hz signals.
- d) Slowly tune the signal source through the frequency range.
- e) At frequencies where the test sample is susceptible, the signal amplitude will be reduced until a threshold of susceptibility is determined.
- f) Record the frequency of any signal causing an unacceptable indication. The threshold level will be recorded as well as the degree of improper response with the signal at the required amplitude.
- g) Repeat the above steps for each power line.

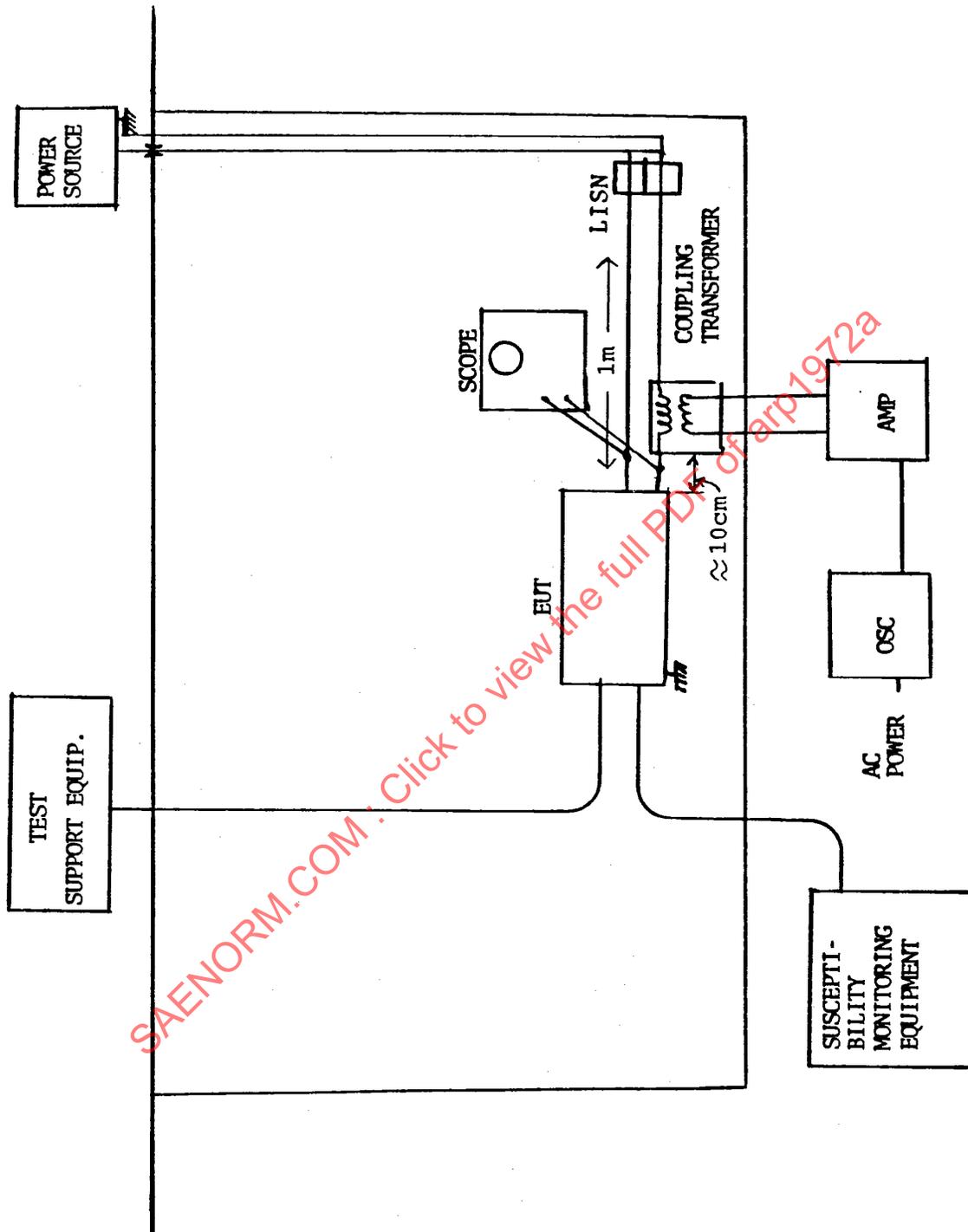
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ELECTROMAGNETIC INTERFERENCE

UNIT UNDER TEST _____
TYPE OF MEASUREMENT CONDUCTED SUSCEPTIBILITY
TEST BY _____ DATE _____
APPLICABLE SPECIFICATION _____
LINE OR CONDITION _____



Frequency
Figure E-1



Conducted Susceptibility, Power Leads, 30Hz - 50kHz, Test Setup
Figure E-2

Section FCONDUCTED SUSCEPTIBILITY, 50KHZ - 400MHZ

Background and Philosophy: One of the primary sources of system interference enters by wire coupling to signal and control leads as well as by the power leads. There is no test specified in MIL-STD-461 that addresses the issue of signal and control leads. A test procedure is recommended to evaluate the equipment performance in this area.

Recommendation: The subcommittee recommends a procedure which consists of using an injection current probe to induce noise currents in an overall cable bundle. Shielding, twisting, and filtering are techniques which can be used to minimize susceptibility effects. This same technique will apply to power leads.

Justification and Rationale: Susceptibility conditions are dependent on source and load conditions. For proper test results, the normal loads and cable configuration, including shielding, need to be used. Thus, a current probe injection technique was determined to be the proper test method.

Over the years, coupling of an rf susceptibility signal onto power leads has created testing problems. The necessity to break into power leads near equipment under test and the requirement to have adequate capacitive coupling are but two. Also, the acceptance of using a current probe injection test on signal lines makes it desirable to use the same approach on power lines.

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CONDUCTED SUSCEPTIBILITY, 50KHZ - 400MHZ

- F1. **REQUIREMENT:** The performance characteristics of equipment shall not be degraded beyond system specifications due to the injection of cable coupled current over the frequency range of 50kHz to 400MHz. The injected test level will be as indicated in the table below. The test signal will be modulated with a signal to which the unit under test is most susceptible.* These levels are based on those found to be present on typical installations. They should be set up in the calibration fixture as a pre-test calibration.

Frequency Range	Transmission Line Current Pass/fail level	
50kHz - 2MHz	100 dBuA	} Limits for example only - not a recommendation.
2 - 200MHz	86 dBuA	
200 - 400MHz	86 dBuA	

*This will be specified by the equipment spec. 400Hz squarewave will be used if it is not defined otherwise.

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F2. APPLICABILITY:

- a) This test applies to all interconnecting cables including primary power leads. The purpose of the test is to confirm that rf signals coupled onto the test sample's interconnecting cables will not cause an unacceptable degradation in performance.
- b) The test will be applied to individual power lines. There is a concept that if one side of the power line is tied to chassis the test is not needed. This is not the policy of this procedure. The test will be performed regardless. If one side is connected to chassis by a low impedance, the equipment will pass the test. However, the impedance is often not low enough and the equipment will fail due to noise on this chassis referenced line.

F3. APPARATUS:

- a) injection probe*
- b) signal source 50kHz - 400MHz
- c) power amplifier 100 watts, 50kHz - 400MHz
- d) measuring receiver or spectrum analyzer
- e) directional coupler - 100 watts, 50kHz
- f) LISN (100 ohm)
- g) current probe

F4. TEST PROCEDURE:

- F4.1 Test Calibration:** The following calibration procedure shall be performed prior to the test using the same test equipment layout and injection probe to be used on the test. This shall be used rather than accept a generic manufacturer's curve.

The injection probe shall be placed in the calibration jig shown in Figure F-1. This calibration jig shall be terminated in 50 ohms at one end and a 50 ohm voltmeter or spectrum analyzer at the other.

The test signal supplied to the injection probe shall be increased until the voltmeter or analyzer indicates that the required current for the test method is flowing in the calibration jig. The forward power flow to the injection probe shall then be recorded. This measurement shall be made over the frequency range of 50kHz to 400MHz. The calibration curve obtained shall be shown in the test report. This measured level becomes the pass/fail criteria for the equipment under test.

F4.2 Test Setup:

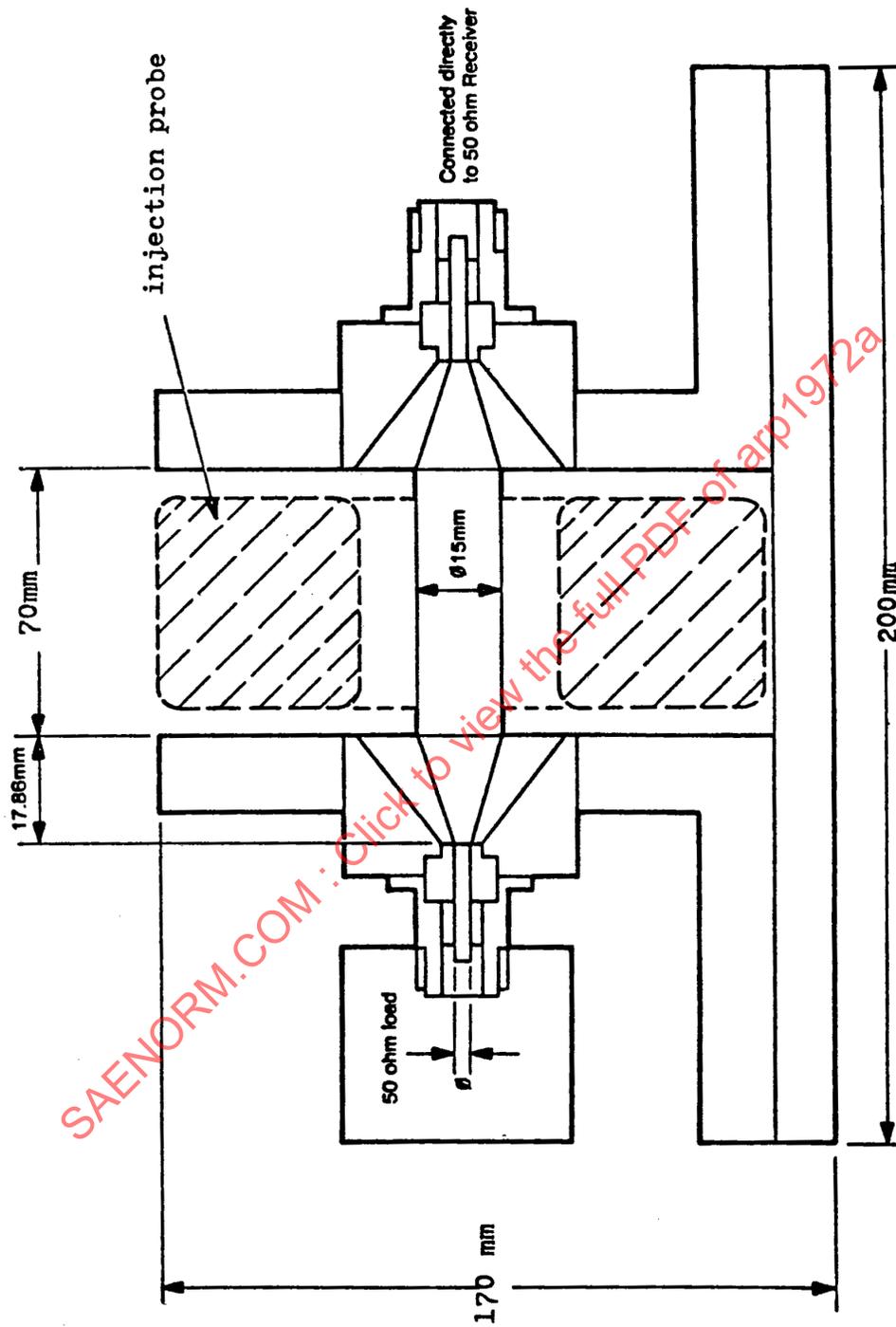
- a) The test set-up will be as shown in Figure F-2.
- b) The test sample shall be bonded to the ground plane in a manner representative of that used in service. Special attention shall be given to simulating the length to width ratio of actual bonding straps.

*Probe needs to be able to handle power without saturating.

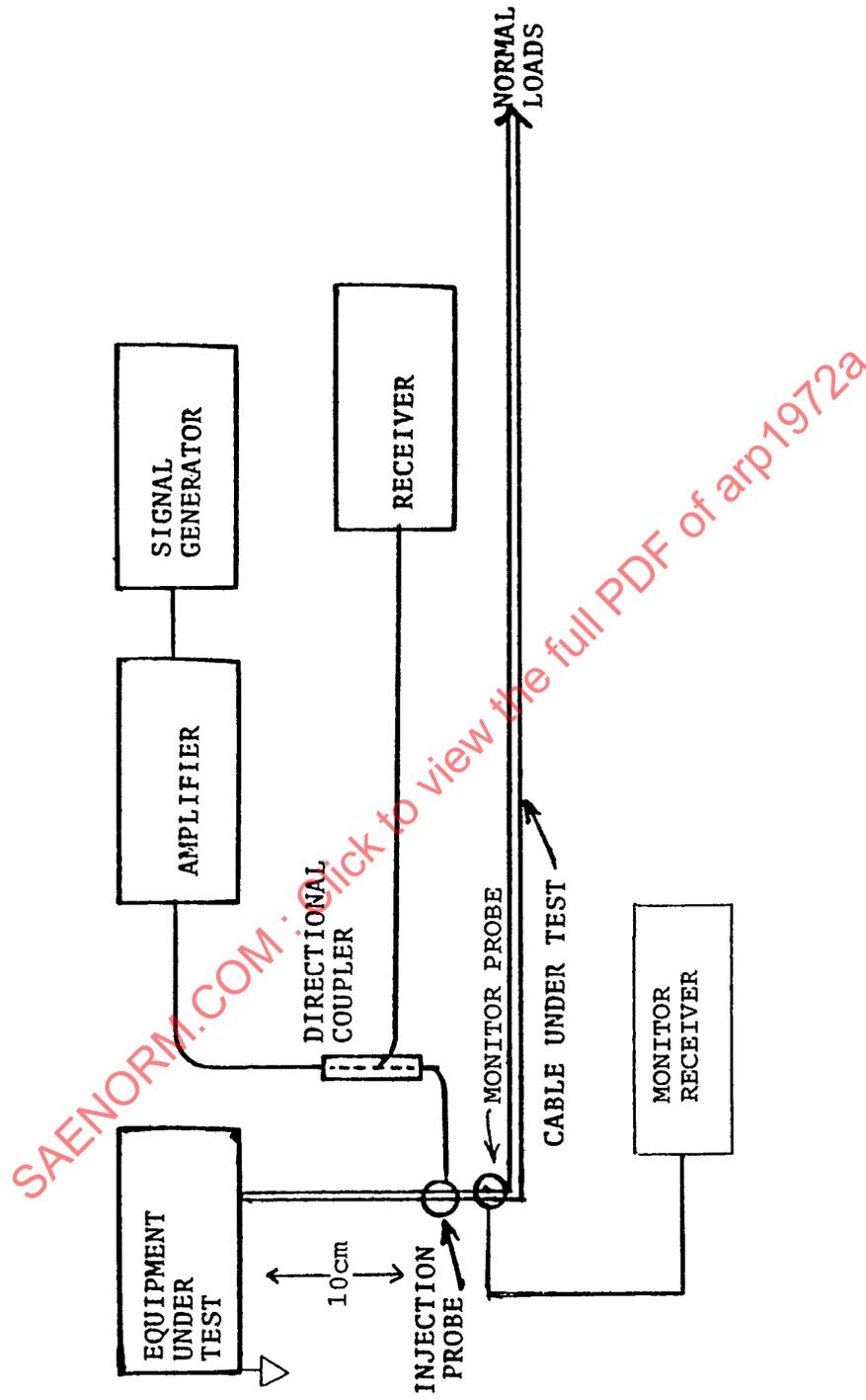
- c) All interconnecting cables shall be constructed and terminated in the same manner as the system cables with special attention given to lead lengths, shielded leads, lengths of shield pigtailed and division of cables as in the actual installation.
- d) The power and interconnecting cables shall be supported on insulated stand-offs of 5 cm height to maintain capacitance effects between cables and ground plane constant.
- e) The interconnecting cables shall be the same length as on the system installation if known, if not they shall be 1 meter long.
- f) If power leads use the same connector as signal cables they shall be included as part of the cable to be encompassed by the current probes.
- g) Intra-system power leads will be tested.
- h) For primary power leads, no shields shall be used.
- i) The power line will have an LISN, using a 100 ohm termination, installed 1 meter from the eut. Additionally, dc sources will be shunted with a 30,000uF capacitor.

F4.3 Test Procedure:

- a) The calibration procedure described in Section F4.1 shall be performed prior to commencement of the test.
- b) The injection probe shall be fitted around the interconnecting cable such that the face adjacent to the nearest face of the test sample is at 10cm (or as close as possible if some obstruction prevents it from being that close).
- c) The signal amplitude shall be set to the test level as monitored via the directional coupler. The signal source shall then be slowly tuned through the frequency range.
- d) At frequencies where the test sample is susceptible, the signal amplitude shall be reduced until a threshold of susceptibility is determined. Check for hysteresis in signal amplitudes by decreasing through the susceptibility threshold and then increasing through the threshold. The lesser of the two shall be recorded.
- e) The forward power to the injection probe shall be recorded.
- f) A second current probe is used on the cable to record the actual induced current. This allows coordination of the results with measurements in an actual system.



Probe Calibration Jig
Figure F-1



Test Set Up
Figure F-2

Section G

CONDUCTED SUSCEPTIBILITY, TRANSIENT

Background and Philosophy:

Conducted Susceptibility, Spike, Power Leads: Spike tests are generally considered a needed susceptibility evaluation tool. Spikes exist on most power distribution systems. A problem exists in defining the spike that represents the real life situation. The following paragraphs discuss several of these spikes along with practical concerns in generating a test spike.

MIL-STD-461A 10usec Spike, CS06: A 100 volt, 10usec spike as measured across a 5 ohm load was specified. No source impedance was defined. Many people used a Solar transient generator which has a measured source resistance of 1.2 ohms in the parallel mode and 2 ohms in the series mode. Thus, by default this became the standard source impedance. This generator also had a built-in bias circuit so that when it was connected across the line under test, the pulse was automatically added "on top of" the line voltage. When a pulse of twice the line voltage (for 28VDC this value is 56 volts) was injected, it measured 84 volts relative to the return or $(28-56=)$ -28 volts relative to the return with an oscilloscope. This test is specified as across the line in Figures CS06-1 and CS06-2.

MIL-STD-1541 Pulse: MIL-STD-1541 instructs us to perform the same CS06 test except change the voltage and amplitude of the pulse. Suddenly the same pulse generator cannot be used and all sorts of conflicts and changes begin to occur.

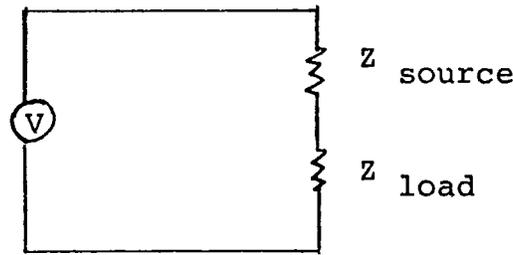
Change #1: The source impedance is still undefined. The following paragraph analyzes the problem that can occur with some generators. As a result of this, a source impedance needs to be defined before the test setup can be resolved.

Change #2: The existing generators do not add the pulse "on-top-of" the line voltage and a higher calibration level needs to be established.

Change #3: The test is now called out as line to line, and each line to chassis.

MIL-STD-1541 Spike Tests:

Amplitude: To produce a rectangular pulse as required by MIL-STD-1541 necessitates the use of a High Voltage Pulse Generator. If the common approach of producing the required spike across a 5 ohm non-inductive load and then applying the spike (at the same generator amplitude setting) to the UUT is used, spike voltages could appear which are of much larger magnitude than required by the test. This is due to the fact that the generator is generally a high impedance device (50 ohm). Let the following simple circuit represent the pulse generator:



We can then use the following equation to represent the voltage generated across Z_{load} :

$$V_{load} = V \cdot \left(\frac{Z_{load}}{Z_{source} + Z_{load}} \right) \quad (1)$$

$$V_{source} = V \cdot \left(\frac{Z_{source}}{Z_{source} + Z_{load}} \right) \quad (2)$$

As can be seen from equations 1 and 2, if Z_{source} is much greater than Z_{load} , $V_{source} \approx V$. Also, if Z_{load} is much greater than Z_{source} , $V_{load} \approx V$. Therefore, if a voltage setting is determined using a 5 ohm load and then used for testing a 300 ohm load, the voltage spike across the 300 ohm load will be approximately 10 times greater than across the 5 ohm load.

DO-160 Pulse: A pulse generated by a "chattering relay" is specified. The reasons given as to why this is a good test is that there is a lot of high frequency noise generated by the irregular shaped transient. This represents real life and the environment to which the equipment will be exposed. Many contend that equipment will fail this test because of the noise on the pulse, whereas it will pass the -461 spike test. However, the equipment will have the same type of failures in the actual installation. Likewise if it passes the test, it functions in the installation.

A problem with this pulse is its definition or energy content. Every pulse is different and somewhat uncontrolled. The exact cause of a failure is therefore hard to determine or repeat at times.

Damped Sinewave: The damped sinewave pulse is an attempt to generate a pulse simulating those present in actual installations. Often the MIL-STD-461A pulse converts to this type when it is applied across power leads. It is a controlled attempt to approximate some of the variations present in DO-160. The standard generators of this pulse ring at 1MHz only, although new equipment is being developed with additional capabilities. Standard power pulse generators with

shaping networks can be used to generate a wide variety of ringing frequencies. Providing a known source impedance at the proper power levels creates significant engineering problems. Also, L-C shaping networks are difficult to construct for pulses with the higher sinewave frequencies.

Source Impedance: The energy content of a surge or spike can be defined if the equivalent source impedance is known. Obviously the value of an actual source impedance is statistical. A defined value presented will merely be a standardization representing an average source impedance. (The proper term should be resistance since we are considering only a fundamental value).

Over the past decade, a number of field studies have attempted to define this source impedance. The table below shows a summary of the results that have been accepted in several areas. The net finding has been that the shorter the spike duration, the higher the source impedance.

<u>Duration</u>	<u>Source Resistance</u>
< 1ms	50 ohms
1ms - 10ms	15 ohms
10ms - 50ms	5 ohms
> 50ms	0.2 ohms

The LISN is used to account for this same general concept of impedance variation with frequency.

Recommendation: A procedure using an arc discharge as the source of the interfering transient is proposed.

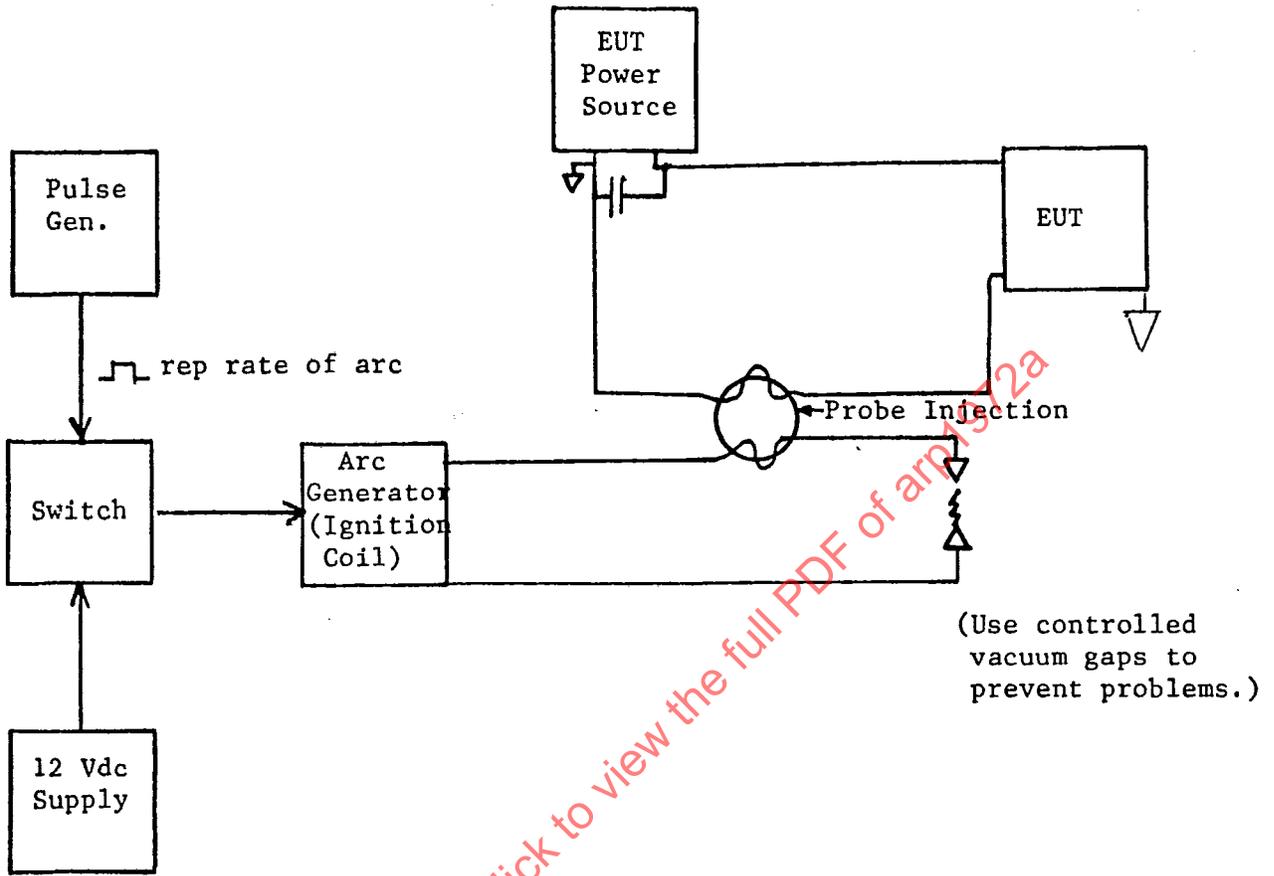
The damped sinewave simulates the induced signal caused by EMP, lightning, and the MIL-STD-461 CS06 spike. Certainly, the suppression components for these pulses need to be more sturdy than for general power line transients. The general attitude is that this needs to be an additional test to the arc discharge presented here. Some additional evaluation is planned to determine whether it is sufficient by itself.

Justification and Rationale: The high frequency components and randomness of these components provide a more effective test of an equipment ability to be nonsusceptible to spikes and transients encountered in operation. Past experience with the "chattering relay" test or similar techniques has shown a significant degree of non-repeatability and general lack of definition of source energy.

The use of an ignition coil with spark gaps set at a specific separation will stabilize the breakdown voltage level. A series resistor can be used to limit the current.

Figure G-1 shows the block diagram of the general setup used for generating the arc. Figures G-2 and G-3 show the radiated and conducted spectrum from the arc. It is reasonably uniform across the frequency spectrum and independent of polarization of the arc.

The injection current probe will have to be well insulated to prevent corona or arcing, which would cause substantial change in the currents being injected.

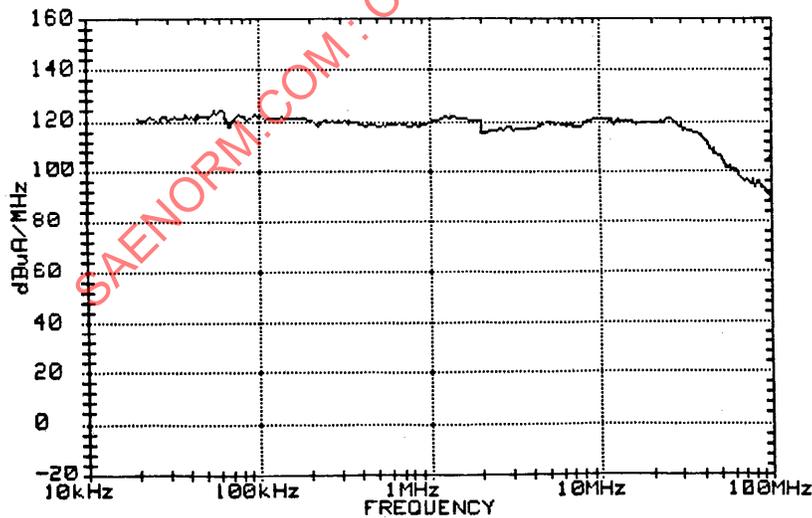
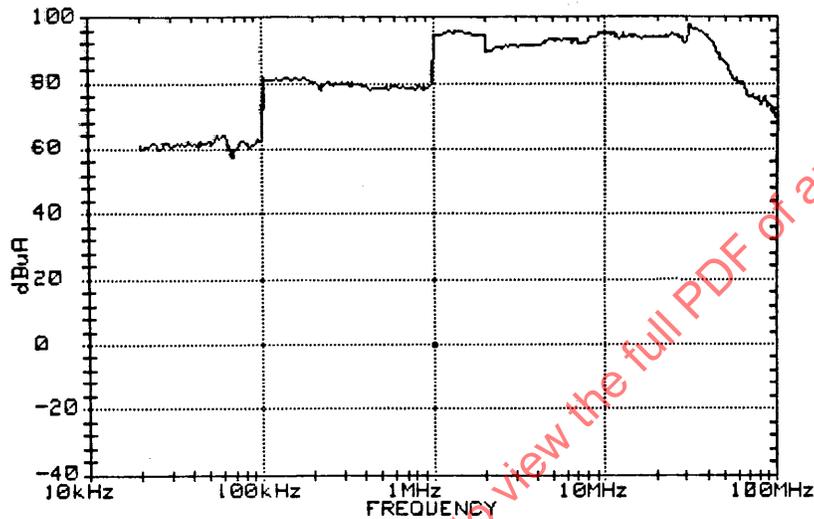


General Test Setup
Figure G-1

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PROJECT: SERIAL No.: SPARK GAP DATE: 10-2-85
 PROJECT No.: TECHNICIAN:
 LINE or CONDITION: 9mm GAP MODE: 15PPS
 SPECIFICATION:
 MEASUREMENT TYPE: CONDUCTED EMISSIONS

SEG.	START FREQ.	STOP FREQ.	IF BW	Rx	TRANS.
1	20kHz	100kHz	1kHz	NM-17/27	T-7020
2	100kHz	1MHz	10kHz	NM-17/27	T-7020
3	1MHz	30MHz	50kHz	NM-17/27	T-7020
4	30MHz	100MHz	100kHz	NM-37/57	T-7020



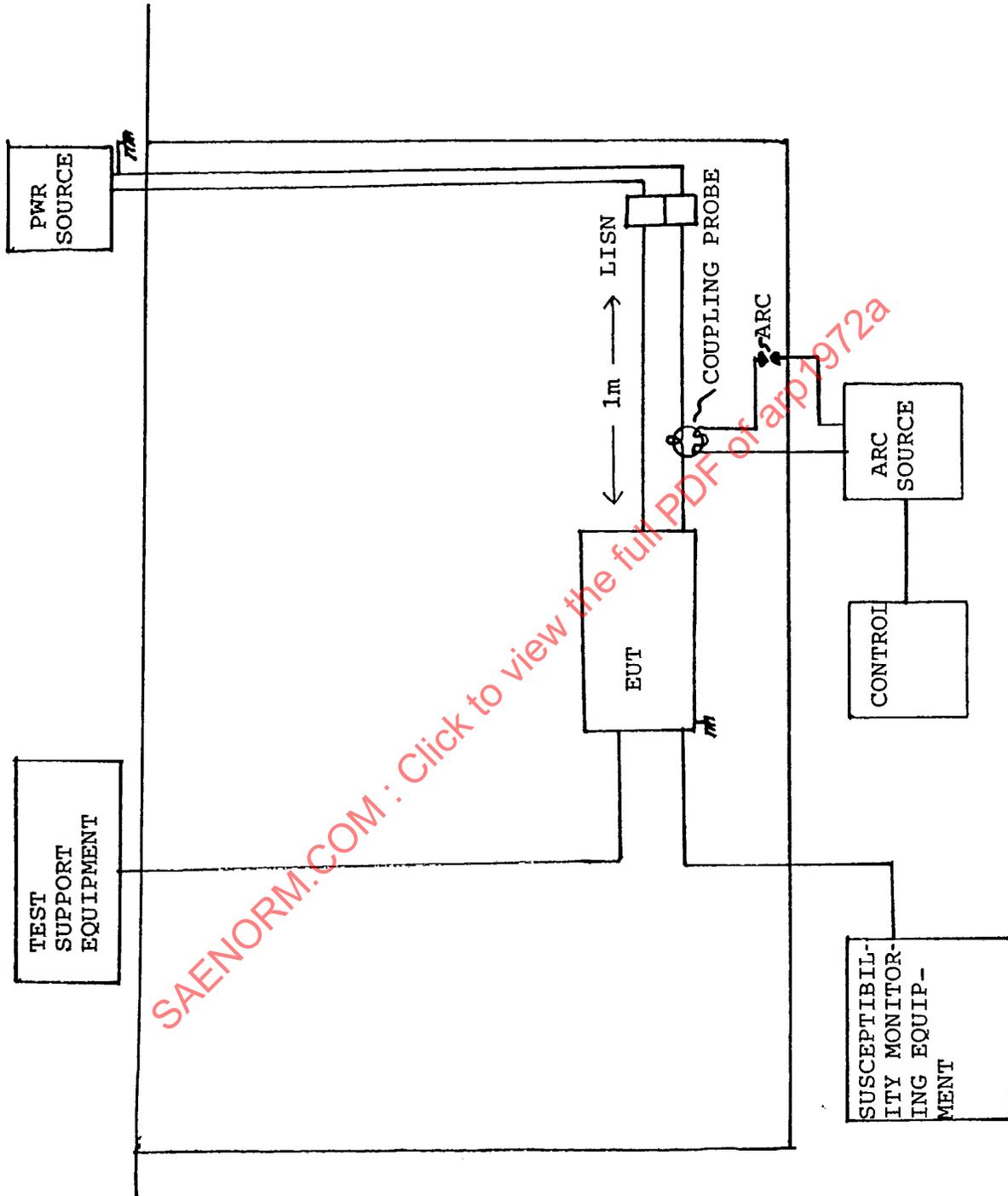
CONDUCTED SUSCEPTIBILITY, TRANSIENT

- G1. **REQUIREMENT**: The performance characteristics of equipment shall not be degraded beyond system specifications due to the injection of a transient interference signal on each of the power leads. The arc level will be 10kV and established by discharge points set at 9mm. Coupling will be via an injection current probe.
- G2. **APPLICABILITY**: This test applies to primary power input lines.
- G3. **APPARATUS**: The basic test setup is shown in Figure G3.-1. The following items of test equipment are needed:
- a) Injection probe
 - b) Arc generator (ignition coil)
 - c) Pulse generator
 - d) Switch
 - e) Power supply (12 volts)
 - f) Controlled vacuum gas gap (such as made by C.P. Claire, Joslyn Reynolds Ind., Seamons, etc.)
- G4. **TEST PROCEDURE**:
- G4.1 **Test Setup**:
- a) This test setup will be as shown in Figure G3.-1.
 - b) The test sample shall be bonded to the ground plane in a manner representative of that used in service.
 - c) The power supply voltage will be referenced to chassis ground at the source.
 - d) The injection probe will be approximately 10cm (or as close as possible) from the test sample.
 - e) The power line will have an LISN installed using a 100 ohm termination. Additionally, dc sources will be shunted with a 30,000uF capacitor on the power supply side of the LISN's.
 - f) Route the arc wiring such that it does not add to the coupling of the probe to the line under test.
- G4.2 **Test Procedure**:
- a) Set up the equipment in accordance with Figure G3.-1.
 - b) Set the spark gap for 9mm which will create a 10kV discharge.

G4.2 Test Procedure (Continued):

- c) Adjust the pulse rate so that the arc occurs at a rate of 2 per second.
- d) Allow the arc to continue firing for a period of 2 minutes.
- e) Record and describe any malfunctions or unacceptable responses of the equipment under test.

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Test Setup
Figure G.3-1

Section H

INTERMODULATION, THIRD ORDER INTERCEPT

Third Order Intercept Background: The existing test method specifies the level of the interfering signals and requires a scan to cover the different possible interfering combinations. If these levels are absolute quantities, such a test will verify proper operation at the specified environmental levels. Another variation of this test can be performed which determines the 3rd order intercept point. This is the most likely point of intermodulation and allows a characterization of the non-linearity in the receiver front end. It can be accomplished by single measurement without sweeping over a band of frequencies. Thus, it serves as a qualification test but the results can also be used to predict performance in any environment.

Third Order Intercept Rationale: The response of a receiver increases linearly with the input level. However, the level of the third order intermod signal increases by a factor of 3 for each unity increase in the applied signals. The objective of this test is to determine a response level for an intentional signal and then determine the level of the intermodulation signals required to generate the same response.

The intermodulation distortion products of a specific receiver may be expressed in dBc, dB below the carriers. However, the problem is that test signal levels may vary widely for different receivers, making figures difficult to compare.

An accepted method to normalize these differences and to avoid excessive scanning and searching for responses is to define "intercept points." Intercept points are the theoretical points at which the fundamentals and intermodulation products have equal amplitude. "Theoretical" because gain compression eventually limits the output power to less than the intercept point. Intercept calculation is only valid when extrapolated from the linear operation range of the receiver under test.

The following information is necessary to determine a receiver's TOI:

1. Device drive level (P). (The level of the intermodulation test levels P_1 and P_2 .)
2. Distortion product suppression at that drive level (S). (The difference between intermodulation test level and receiver mds at f_o .)

The equation below allows a receiver's TOI to be calculated:

$$\text{TOI (dBm)} = (S/2) + P$$

S is the relative suppression (or difference) from carriers (test signals) in dB

P is the power level of the carrier signals (test signals) in dBm.

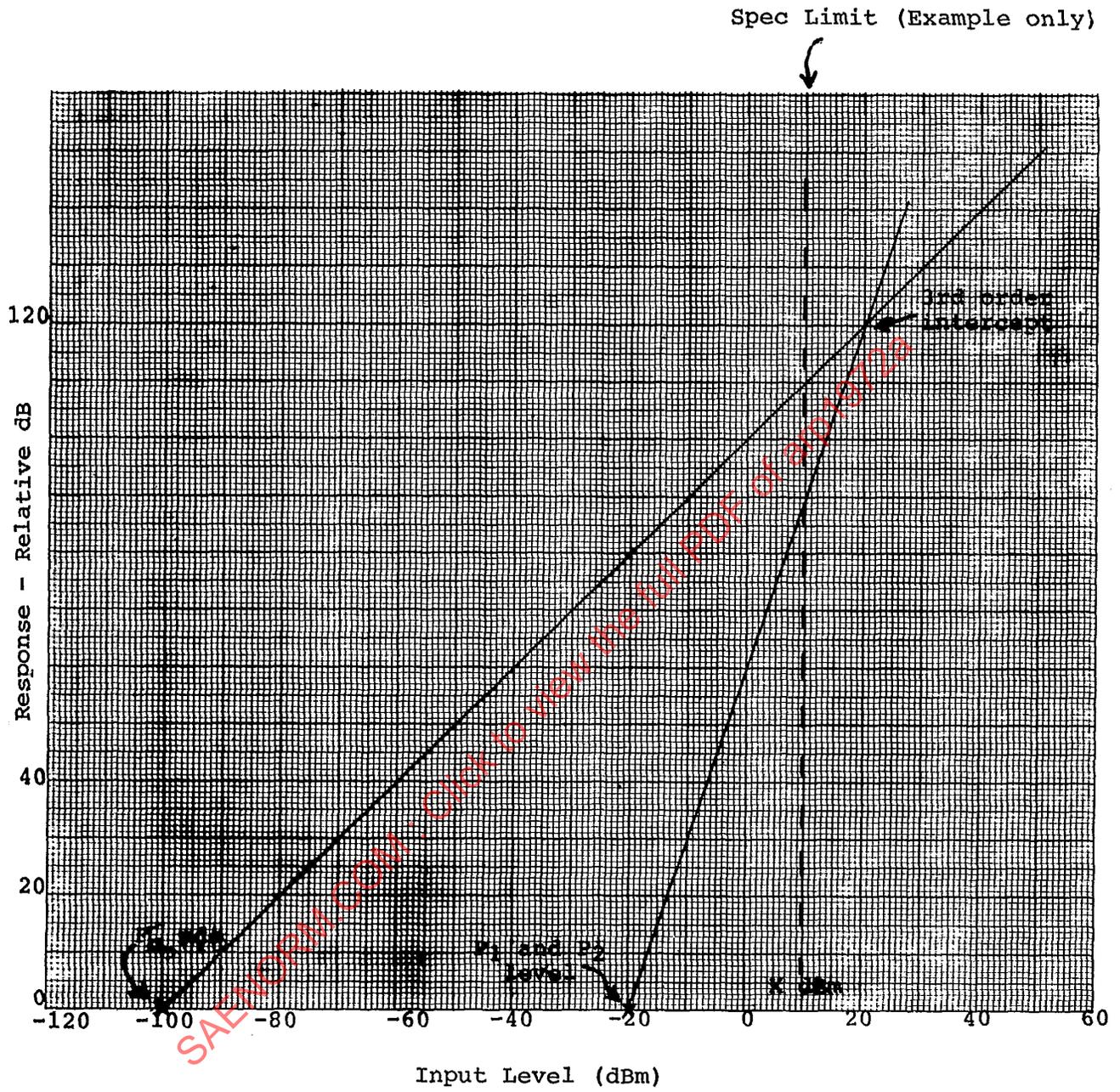
If the intercept point is known, then the relative suppression of distortion products can be determined. The order of the intermodulation product is needed to determine its change in power for a change in the fundamental's power level. The intermodulation products have a slope equal to their order. A plot of relative suppression of an n^{th} order product has a slope of $(n-1):1$. Therefore, the general equation, $I_n(\text{dBm}) = S/(n-1)+P$ gives the intercept point for any order.

Thus, $S = (I_n - P)(n-1)$ gives the dB down from the carrier signal at which particular intermodulation product will be present. For the example on Figure H1.-1, if the 5th order product is desired: $S = (20 - (-20))(5-1) = 40 \times 4 = 160\text{dB}$ down.

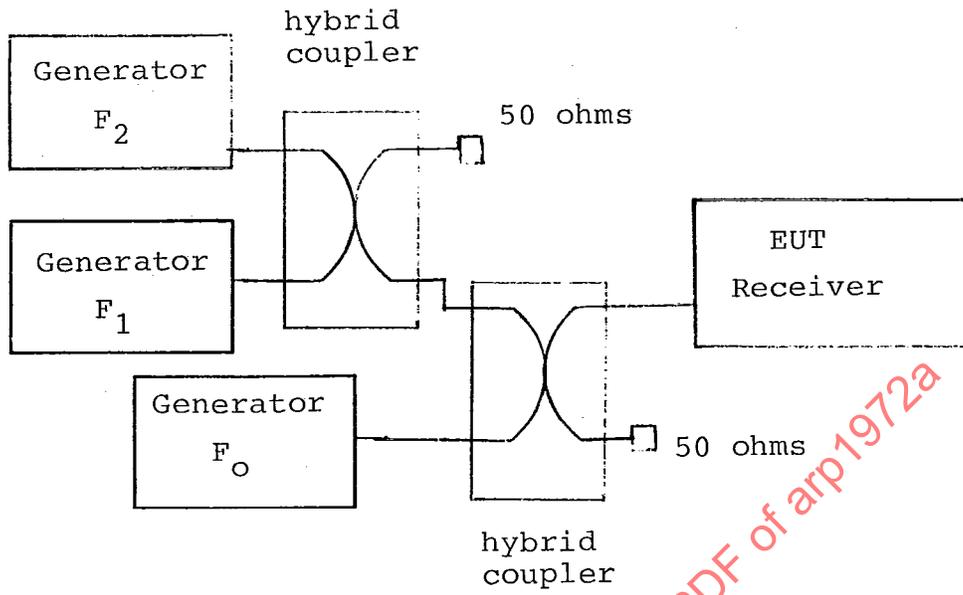
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RECEIVER INTERMODULATION, THIRD ORDER INTERCEPT

- H1. REQUIREMENT: The receiver shall have its third order intercept point on or above X dBm (see Figure H1.-1).
- H2. APPLICABILITY: This test is applicable to all receivers which are capable of responding to an intermodulation product of the two applied signals if the necessary non-linear elements were present.
- H3. APPARATUS:
- Signal sources capable of providing a signal with the proper amplitude, frequency, and modulation characteristics.
 - Filters to eliminate signal generator spurious outputs.
 - Directional couplers to couple the signals into the receiver front-end.
- H4. TEST PROCEDURE:
- The test setup will be as shown in Figure H4.-1.
 - Set the receiver with f_0 at approximately the center of its tuning range.
 - Set an appropriately modulated signal generator at f_0 to determine the receiver specified sensitivity. For standardization, this will be defined as 3dB.
 - Record this level as f_0 mds as shown on Figure H1.-1.
 - Set generator 1 at a frequency Δf , above f_0 . ($\Delta f = 3\text{dB IF BW}$)
 - Set generator 2 at $f_0 + 2\Delta f$.
 - Adjust P_1 and P_2 , at the same level, equally until the standard response is achieved (same criteria as used on step c).
 - Record the level of P_1 and P_2 as shown on Figure H1.-1.
 - The device drive level is (P). (The level of the intermodulation test levels P_1 and P_2 .)
 - The distortion product suppression at that drive level is (S). (The difference between the intermodulation test levels (P) and the receiver mds at f_0 .)
 - The equation below allows a receiver third order intercept (TOI) to be calculated:
$$\text{TOI(dBm)} = S/2+P$$
 - Using Figure H1.-1 as a model, draw curves to determine the third order intercept point. Compare this with the specification level.



Third Order IM Specification Example
Figure H1.-1



Third Order Intercept Intermodulation Test Setup
Figure H4.-1

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Section I

FRONT END REJECTION

Background and Philosophy: The variety of modern receivers dictates that the intent of the front end susceptibility tests be understood so that they can be adapted to the specific receiver being tested.

RECOMMENDATION: The subcommittee proposes that an option of using a single generator test method or a two signal generator test method be available.

JUSTIFICATION AND RATIONALE: The intent of this test is to determine the bandwidth of a receiver and the extent to which it will respond to a signal at the specified levels outside of this bandwidth. For the "traditional" receiver this is best done with a single signal. A number of receivers, such as those using a phase lock system, have essentially no bandwidth. In this case there will be no bandwidth and no out of band responses. However, out of band signals can interfere with the reception by such things as front end overload. In this case the intent of the specification is best met by the two signal generator test methods.

It is recognized that the limits and procedures given herein are general in nature and cannot be directly applied to all types of receivers. The dynamic range of the test requirements should be specifically tailored to the equipment type, application, and expected environment. This dynamic range should be specified prior to testing either in the equipment procurement specification, the control plan, or in the test procedure.

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FRONT END REJECTION SINGLE GENERATOR METHOD

- I1. REQUIREMENT: The receiver shall not exhibit any undesired responses when subjected to the test signals of Figure I1.-1.
- I2. APPLICABILITY: This test shall apply over the frequency range of 30Hz to 18GHz (or 5 times the maximum receiver operating frequency + IF, whichever is lower) to a receiver or tuned amplifier. The receiver shall be the type with a defined bandwidth as indicated in Figure I1.-1. The test can be extended beyond the indicated frequency range, but must be specifically called out in the equipment specification. For systems that have the receiver front end mixing and filtering in an antenna module, the receiver tests should be modified to use antennas. This system is practical above 1GHz. Separation should be 1 meter or more, if necessary, to stay in the far field.
- I3. APPARATUS:
 - a. Signal source capable of providing a signal at the proper amplitude, frequency, and modulation characteristics.
 - b. Filters to eliminate signal generator spurious outputs.
- I4. TEST PROCEDURE:
 - a. The test setup will be as shown in Figure I4.-1.
 - b. Set the EUT at f_0 (approx. the center of its tuning range).
 - c. The signal generator will be modulated as follows:

AM Receivers: 30% at 400Hz sinewave SSB and FM: unmodulated or as specified in equipment procurement specification.

Pulsed Receivers: Pulse width such that 80% of energy falls within the 3dB bandwidth of the receiver.
 - d. Set the signal generator at f_0 and determine the sensitivity threshold level.
 - e. Adjust the generator to define the 80dB bandwidth points (80dB or as specified, above the threshold level of Step c).
 - f. Adjust the generator to define the 0dBm (or the maximum specified input level) bandwidth points.

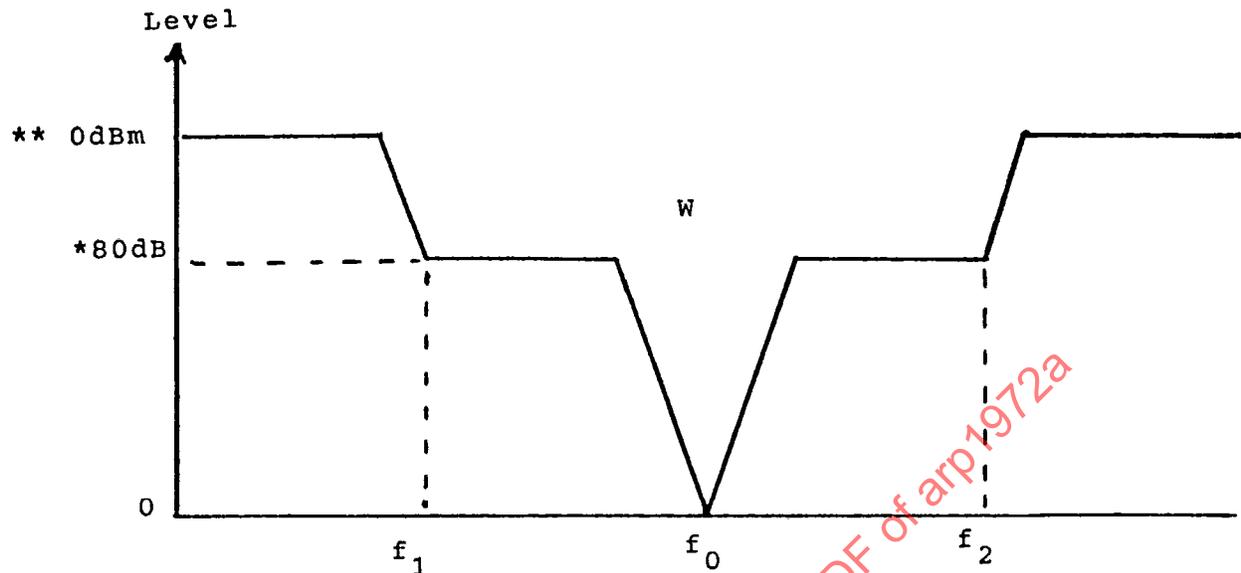
14. TEST PROCEDURE (Continued):

- g. Scan the generator over the maximum range indicated by the formulas.

<u>Lower Frequency</u>	<u>Upper Frequency</u>
$IF/5$	$5f_{i0} + IF$
$.05 f_o$	$20 f_o$
(min. 30Hz)	(max. 18GHz or maximum operating frequency + IF)

- h. Monitor the receiver for any responses and record the frequency of response and the threshold level.

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f_0 = receiver tuned frequency or band center for amplifiers.

f_1 = lowest tunable frequency of receiver band in use or the lowest frequency of amplifier passband.

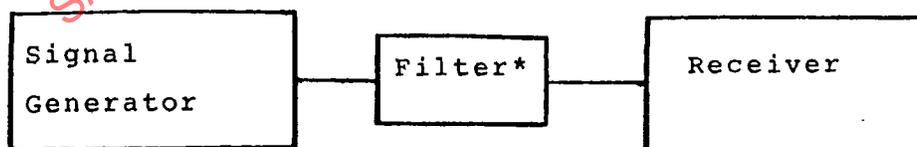
f_2 = highest tunable frequency of receiver band in use or the lowest frequency of amplifier passband.

* = 80dB above the specified sensitivity of the receiver at f_0 or as otherwise specified.

** = 0dBm or the maximum specified level

W = bandwidth at the indicated level

Figure I1-1



* as required

Figure I4-1

FRONT END REJECTION TWO GENERATOR METHOD

11. REQUIREMENT: The receiver shall not exhibit any undesired responses when subjected to the test signals of Figure I1.-1.
12. APPLICABILITY: This test shall apply over the frequency range of 30 Hz to 18GHz to a receiver. The receiver shall be of the type that will not normally respond to any signal except its designated input. This could be caused by phase lock requirements or unique modulation requirements that prevent any response to unauthorized signals. The test can be extended beyond the indicated frequency range, but must be specifically called out in the equipment specification.
13. APPARATUS:
- Signal source capable of providing a signal at the proper amplitude, frequency, and modulation characteristics.
 - Filters to eliminate signal generator spurious outputs.
 - Coupling networks to combine two signals at the receiver input.
14. Test Procedure:
- The test setup will be as shown in Figure I4.-1.
 - Set signal generator 1, appropriately modulated, at f_o . The level will be 10dB above the specified sensitivity.
 - Generator 2 will be set at a level of 0dBm (or as otherwise specified).
 - Generator 2 will be scanned over the frequency range indicated by the formulas.

Lower Frequency

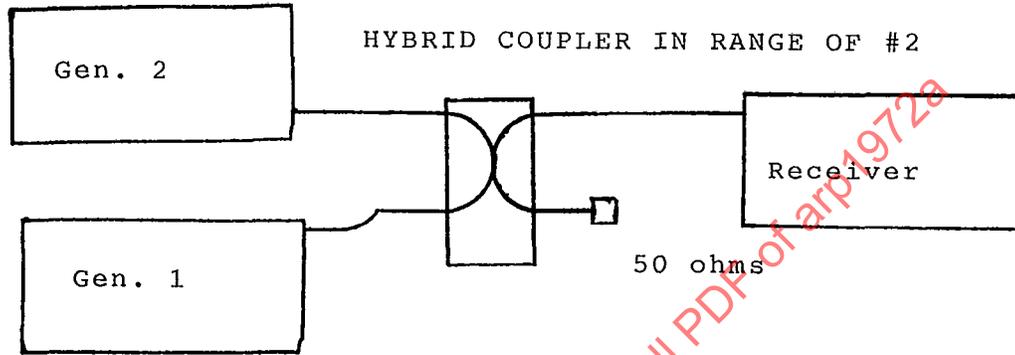
$IF/5$
 $.05f_o$
 (min. 30Hz)
 (min. = $.8f_{co}$ if
 waveguide is used)

Upper Frequency

$5f_{10} + IF$
 $20f_o$
 (max. 18GHz or the maximum
 system operation + IF)

- Monitor the receiver for any degradation of the intentional response and record the frequency response and the threshold level.

Freq. of Generator 1 Less Than #2



Freq. of Generator 1 Greater Than #2

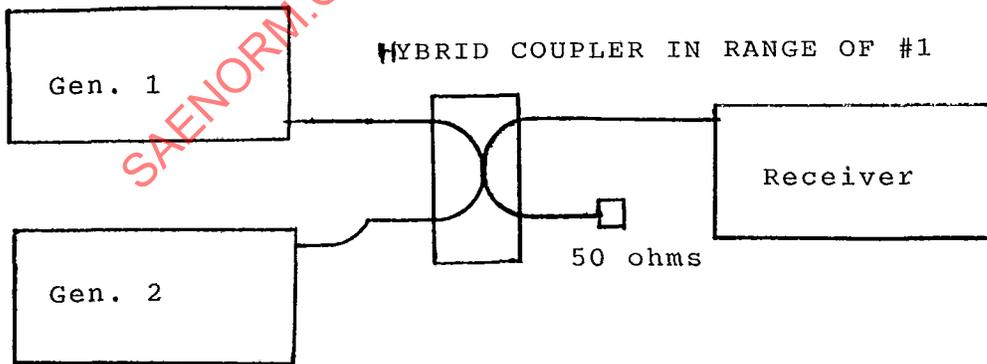


Figure I4-1

Section J

RADIATED EMISSIONS

Background and Philosophy: The consensus of the subcommittee is that it is important to have "standard" results that are free from room resonance characteristics. As such, the use of absorber material, mode stirring, open field, etc. are all acceptable ways to achieve this objective. To obtain "standard" results necessitates the use of a calibration technique.

Spherical dipoles, 10 cm in diameter, have been developed by NBS in Boulder with fundamental frequencies of 10MHz and 30MHz. Units operating up to 700 MHz have been designed on paper. The state-of-the-art still needs to be advanced by getting these items through the "build" stage. The status of the project is that these antennas worked very well in providing the type of function being proposed. Currently an estimated \$200,000 and 6 months is needed to finish the development and produce several units. The subcommittee recommends that this technical advance would provide a significant boost in the radiated emissions measurement technology. The test results thus far obtained indicate that good results can be obtained as low as 10MHz.

Further, the literature needs to be searched and the applicable formulas presented as part of this specification that will indicate the correct level, including tolerances, as measured by the receiving system for a given source.

Recommendation: Radiated measurements will be taken over the frequency range of 100 MHz to 18GHz. The measurements must be obtained in a facility that has been calibrated to provide accurate results.

Justification and Rationale: The proposed method of calibration is to use an isotropic radiator of known output as a standard. This will be located where the equipment under test would be positioned. The levels from this source will be measured using the actual measurement antennas and receiving system proposed for the test. Since the source is a known standard, the theoretical level at the measuring antenna is also known. The difference between this theoretical level and the measured level represents a transfer function for that test site.

Absorbing material, open space, or other techniques will be useful in minimizing the Q of any resonances to give a transfer function curve with less fluctuation.