



The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Équipement de l'Aviation Civile

RADIO FREQUENCY SUSCEPTIBILITY TEST PROCEDURES

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ED-90B

May 2010

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FOREWORD

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3. The findings of EUROCAE are resolved after discussion amongst its members and in co-operation with RTCA Inc., Washington D.C., U.S.A., and/or the Society of Automotive Engineers (SAE), Warrendale PA, USA through their appropriate committees.
4. This document provides information which supplements the Radio Frequency test procedures described in Sections 20 and 21 of the document ED-14F "Environmental Conditions and Test Procedures for Airborne Equipment". The guidance provided in this document applies for any further issue of ED-14 as long as it does not contradict any requirement but clarifies parts that were authorising interpretation.
5. This document supersedes ED-90A. The main difference is simplification of susceptibility chapters due to improvement introduced in ED-14 F and the addition of two chapters providing guidance for the conducted and radiated RF emission measurements procedures. Some subsections are added to Chapter 3, "General Test Requirements" and all information that is provided in ED-14F is not repeated in this document unless it is necessary for understanding.
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CHAPTER 1

GENERAL

1.1 INTRODUCTION

The new certification requirements for civil aircraft to demonstrate that they can operate safely in a high intensity external RF environment (HIRF), have had implications for equipment level EMC qualification susceptibility testing. As a result over the past 10 years, EUROCAE WG-14 and RTCA SC-135 have been revising the environmental specifications ED-14/DO-160, which covers all environmental testing including EMC. The work of both committees has ensured that ED-14 and DO-160 are identical and therefore only ED-14 will be referred to in the remainder of this Users Guide. The most recent revision "F" of ED-14 was published in March 2008.

The result of the work is that Section 20 and 21 of ED-14 has undergone major revisions during this period with the definition of new categories and extensive modifications to the susceptibility and emission test procedures.

This document discusses in greater detail the test procedures and highlights problem areas that could lead to test errors.

1.2 PURPOSE AND SCOPE

The purpose and scope of this Users Guide is to provide additional information and clarification on the test procedures for section 20 and 21. To this end, ED-14 should be read in conjunction with this document.

The purpose of testing to Section 20 of ED-14 is to ensure that equipment will continue to operate within its performance specification when the equipment and its interconnecting wiring are exposed to levels of RF current and RF fields of defined levels. Two test procedures are used. First: the injection of RF currents by means of specially designed injection probes into the interconnecting bulk cables or individual power lines of the equipment. Second: electric field illumination of the equipment and its interconnecting wiring by means of an antenna placed 1 metre away or by the use of a reverberation chamber.

The tests are designed to simulate the effects of high power onboard or external RF transmitters e.g. radar or communications transmitters.

Categories were introduced since Change 1 of Section 20 of ED-14D directly related to the aircraft HIRF environments and have been simplified in the F revision. The use of the test categories is discussed in the appropriate sections of this document.

The purpose of testing to Section 21 of ED-14 is to ensure that equipment will not emit undesired noise in excess of the specified levels. Two set of measurement are performed, one addressing the conducted emission on wiring, by means of measurement probes, and the other the radiated emission of the whole installation including the equipment box and its wiring, by means of a receiving antenna.

For the radiated emission measurement, a major change has occurred in issue F of ED14 by the introduction of reverberation chamber techniques.

1.3 REFERENCES

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- [2] "The Development of a Revised Susceptibility Test for Avionic Equipment", CARTER, N.J., IERE EMC Conference, University of Surrey, September 1982

- [3] "Design, Evaluation, and Use of a Reverberation Chamber for Performing Susceptibility/Vulnerability Measurements", CRAWFORD, M.L. and KOEPKE, G.H. NBS Technical Note 1092, April 1986.
- [4] "System Design and Analysis", AC/AMJ 25.1309
- [5] "The Certification of Aircraft Electronic Systems for Operation in the High Intensity Radiated Fields (HIRF) Environment", AC 20.158
- [6] "The HIRF Users Guide", EUROCAE ED107
- [7] "Measurement Uncertainty of Emission Measurements according to RTCA/DO-160 E", H. Stöfen, 12/2005
- [8] "Requirements for the Control of Electromagnetic Interference Characteristic of Subsystems and Equipment", MIL-STD-461E, Department of Defence-United States of America. August 1999
- [9] "Radio disturbance and immunity measuring apparatus – Ancillary equipment - Radiated disturbances", CISPR16-1-4, IEC. February 2005
- [10] "CISPR 25 2002 - Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices - Limits and methods of measurement" IEC, August 2002
- [11] "Guidance for the Use of Portable Electronic Devices (PEDs) on Board Aircraft", EUROCAE, December 2006
- [12] "Analysis of the CISPR25 Component Test Setup", 2003
- [13] "Some implication of a single aspect angle electromagnetic compatibility test" Gustav J .Freyer and Mats G. Bäckstrom

1.4

ABBREVIATIONS

A/C	Aircraft
AC	Advisory Circular
AMC	Acceptable Means of Compliance
BB	Broadband
BCI	Bulk Current Injection
BIT	Built-in-Test
CISPR	Comité International Spécial des Perturbations Radioélectriques (Special International Committee on Radio Interference)
CE	Conducted Emission
CF	Calibration Factor
CM	Common Mode
CRT	Cathode Ray Tube
CS	Conducted Susceptibility
CW	Continuous Wave
dB	Decibel
DM	Differential Mode
EED	Electro Explosive Device
EMC	Electromagnetic Compatibility
EME	Electromagnetic Envelope
EMI	Electromagnetic Interference
EMV	Electromagnetic Vulnerability
EUROCAE	European Organization for Civil Aviation Equipment
EUT	Equipment Under Test

FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FOL	Fibre Optic Link
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HERO	Hazards of Electromagnetic Radiation to Ordnance
HF	High Frequency
HIRF	High Intensity Radiated Fields
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IERE	Institution of Electronics and Radio Engineers
IF	Intermediate Frequency
IFR	Instrument Flight Rules
JAR	Joint Airworthiness Requirements
JAA	Joint Aviation Authorities
LISN	Line Impedance Stabilising Network.
LLC	Low Level Coupling
LLDD	Low Level Direct Drive
LLSC	Low Level Swept Current
LLSF	Low Level Swept Field
LRU	Line Replaceable Unit
MIL-HBK	Military Handbook
MIL-STD	Military Standard
NB	Narrowband
NBS	National Bureau of Standards
PED	Portable Electronic Device
PRF	Pulse Repetition Frequency
PW	Pulse Width
QC	Quality Control
RE	Radiated Emission
RF	Radio Frequency
RMS	Root Mean Square
RS	Radiated Susceptibility
RTCA	Radio Technical Commission for Aeronautics
SSB	Single Sideband
SW	Square Wave
TWT	Travelling Wave Tube
UHF	Ultra High Frequency
VFR	Visual Flight Rules
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio

CHAPTER 2

EQUIPMENT CATEGORIES

2.1 ED-14 SECTION 20 CATEGORIES

The various equipment categories and associated test limits defined in ED-14D have been extended in recognition of the HIRF requirements in ED-14E, but simplified in ED-14F. The equipment categories define the RF test levels and establish the minimum RF susceptibility level for the equipment under test (EUT). The category to be chosen may be defined in the Equipment Minimum Operational Performance Specification or an Airframe Manufacturer's Performance or Procurement Specification.

The choice of category must frequently be made before the airframe is sufficiently detailed to predict or measure the "internal RF environment" in which the equipment will be located. Furthermore the equipment will probably be installed in several different aircraft. Therefore if a category is not defined in the equipment specification, the equipment manufacturer should design, test and qualify the equipment to the category level consistent with the worst expected location and exposure.

Category designation for equipment consists of two characters. Conducted susceptibility test levels are designated with the first category character. Radiated susceptibility test levels are designated with the second category character.

To aid the equipment manufacturer in selecting appropriate test limits for the equipment and its interconnecting wiring, categories have been defined below. The descriptions are for guidance only. Equipment location, anticipated exposure and location of interconnecting wiring, aircraft size and construction determine the test level.

Categories "B, D, F, G, L, M, Y, W and O" are intended to provide test levels which allow covering the various HIRF external field environments as defined in the HIRF certification advisory documentation. The category selection for the conducted susceptibility test is given in terms of expected aircraft type, dimensions, and the appropriate HIRF environments as shown in Table 2-1 below. The category selection for the radiated susceptibility test is given in terms of the expected level of aircraft attenuation at the equipment installation location and the appropriate HIRF environment as shown in Table 2-2 below.

Category "R" is intended to provide test levels for bench testing systems whose criticality is defined as Level B for compliance to minimum HIRF rules.

Category "S" is intended as a minimum test level where aircraft effects from the external electromagnetic environment are minor and where interference free operation on the aircraft is desirable but not required.

Category "T" is intended to provide test levels for bench testing systems whose criticality is defined as Level C for compliance to minimum HIRF rules.

Categories "W" and "Y" also provide test levels for bench testing to show compliance to interim high intensity radiated fields (HIRF) rules.

Category "Q" is intended to indicate tests conducted at test limits or with modulations other than those specified in these procedures.

For equipment that are part of systems performing functions defined as Level A other than Display, testing to ED-14 may not be sufficient for HIRF certification. However the additional considerations described in ED-90 below that include the test set-up requirements of the HIRF Users Guide (ED-107) allow a useful equipment level test which may reduce the need for system or aircraft immunity testing providing the measured aircraft environment is less than the test levels chosen.

However Level A Display Systems are catered for in this latest revision to ED-14 as discussed in Section 2.2.

2.2 CATEGORIES FOR SYSTEMS PERFORMING LEVEL A DISPLAY FUNCTIONS

2.2.1 Introduction

Categories "B, D, F, G, L, M and O" are based on the environments given in Appendix A which are copied from AC 20.158. One purpose of these categories is to provide adequate certification evidence for systems performing a Level A Display function.

It is important to note that there is a change in how the test limits are used for the conducted susceptibility test. The new limit definition is that the primary limit is in terms of induced current on the wiring bundle under test with the secondary limit being in terms of the forward power to the injection probe. The reason for the change is to allow an easier comparison with induced cable bundle current measurements on aircraft.

The reader must be familiar with the HIRF requirements before selecting test levels from this section.

2.2.2 The HIRF Environments

The HIRF requirements in AC20.158 are defined in terms of three environments.

The HIRF environments are a composite of transmitters that are airborne, land-based, off-shore platforms, and ship-based. The emitters cover the entire RF spectrum and their radiated fields vary greatly in energy levels and signal characteristics.

The EUROCAE WG-33/SAE AE4R environmental subcommittee initially established two environments:

1. The Severe HIRF environment is based on the worst case estimate of electromagnetic field strengths that a civil aircraft might encounter.
2. A subset of this environment was then created and called the Normal HIRF environment. The Normal environment contains just those emitters in the vicinity of representative airports in the United States and Europe. This Normal environment is considered to be the environment which civil aircraft encounter during normal flight operations.

At a second step, two considerations resulted in the establishment of two other environments.

First, the difference between flying equipment qualification levels and the estimated electromagnetic environment the aircraft will operate in resulted in concern over actual HIRF levels encountered by Aircraft during their operations. The subcommittee therefore developed a reduced environment suitable for the certification of Part 23 and 25 aircraft based of IFR flight rules. This new environment was called the Certification Environment.

The second consideration, which needed to be taken into account, was the flight profiles used by rotorcraft. The ICAO fixed wing standard on height above the ground no longer applies. In addition, they can hover. This resulted in the subcommittee establishing two severe environments, one for fixed wing aircraft and one for rotorcraft.

The Certification environment was only deemed to be suitable for rotorcraft IFR Level A functions. For rotorcraft VFR Level A functions the Rotorcraft Severe environment is appropriate.

Among the four following environments established only three were retained for the rules and reported in AC 20.158:

- Rotorcraft Severe now renamed Environment III
- Certification now renamed Environment I

- Normal now renamed Environment II

APPENDIX A gives the field strengths for the three environments.

In addition there are four categories of aircraft covered by the HIRF requirements:

Parts 23 and 25 fixed wing

Parts 27 and 29 rotorcraft

2.2.3 Definition of the HIRF Related Categories

As there are 3 different environments and 4 different aircraft categories, it is very difficult to define categories applicable to the whole frequency band for each type of aircraft in every configuration.

In order to simplify the use of defined categories, the different categories have been defined from the environments but with a certain level of simplification.

The following tables should be used as guidelines for the selection of categories for the conducted and radiated test and to define applicable test levels. The old and new environment terminology is given e.g. HIRF Environment I was formerly known as the Certification Environment.

2.2.3.1 HIRF Related Conducted Susceptibility Categories

For the conducted susceptibility test of level A displays the category selection is given in terms of expected aircraft type and related environment as shown in Table 2-1. The aircraft type is broken down into rotorcraft and three types of fixed wing aircraft broken down in terms of their fuselage length. The category applicable to "all types" is defined as this may be of use to equipment suppliers who make a product, which covers a wide range of types. The category "all types" is a worst-case composite of all the individual aircraft types. Categories given between parentheses are also suitable to cover the case although they were not defined for that purpose.

Aircraft	Rotorcraft Severe Environment (HIRF Environment III)	Certification Environment (HIRF Environment I)	Normal Environment (HIRF Environment II)
Rotorcrafts	Y	O (Y)	O (Y)
AC<25m	Not applicable	M (W)	M (W)
AC <50m, >25m	Not applicable	M (W)	M (W)
AC>50m	Not applicable	O (Y)	O (Y)
All types	Not applicable	O (Y)	O (Y)

TABLE 2-1: CATEGORY DEFINITION FOR THE CONDUCTED SUSCEPTIBILITY TEST IN TERMS OF AIRCRAFT TYPE AND HIRF ENVIRONMENT

2.2.3.2 HIRF Related Radiated Susceptibility Categories

These radiated susceptibility categories are defined in terms of the various HIRF environments and the expected level of attenuation at the location of the equipment on the aircraft (Table 2-2). Again, as for the conducted susceptibility test, for simplification the limits have been combined resulting in some over testing in some frequency bands.

When dealing with the categories for radiated susceptibility testing which are derived from constant attenuation figures, it is permissible to select different categories for different frequency bands depending on the expected (or measured) attenuation of the aircraft location where the equipment is to be installed.

Expected attenuation	Rotorcraft Severe Environment (HIRF Environment III)	Certification Environment (HIRF Environment I)	Normal Environment (HIRF Environment II)
0dB	L	G	G
6dB	L	F	F
12dB	G	D	D
18dB	F	B	B

TABLE 2-2: CATEGORY DEFINITION FOR THE RADIATED SUSCEPTIBILITY TEST IN TERMS OF LOCATION ON THE AIRCRAFT AND THE HIRF ENVIRONMENT

2.3 PED AND T-PED

New threats for avionics that have been recently studied are Portable Electronic Devices (PED) and Transmitting PED's. These are specific in the fact that these sources of disturbances can be brought internally to the aircraft with high difficulties for the aircraft manufacturer to manage the number, the location and the type of these when assessing the protection of its aircraft systems.

The most advanced synthesis published on that topic is likely to be ED-130 document. One of its conclusions is that although the present issue of ED-14F section 20 can be used in terms of categories and procedure, it is by far not well adapted to this particular threat, thus resulting in some over testing in terms of levels in some frequency ranges and inaccurate testing in general from set-up and modulation point of view.

Two alternate approaches are introduced in ED-130. The first is based on field strengths and a test distance of 1m. In this field based test cumulative effects must be considered using a multi equipment factor – MEF. The second approach is based on net input power into a quasi-isotropic test antenna and a test distance of 10cm. Here, no MEF needs to be taken into account because of the local nature of the threat. Because for real PED's this near field test represents the most realistic scenario, this test is presently used for equipment certification purposes (see ED-130, [11]).

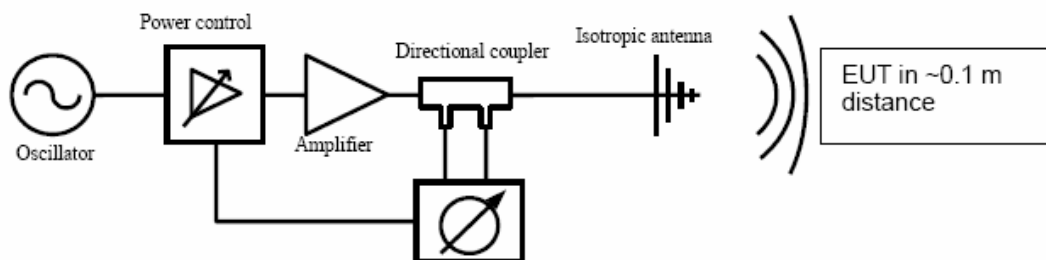


FIGURE 2-1: TEST SETUP FOR NET POWER BASED TEST (REF. ED130, [11])

Some mobile phone standards are best represented by a CW test signal (e.g. CDMA, UMTS). Some are best represented by a pulse modulated test signal (e.g. GSM, PDC). The modulations used are CW and a pulse modulation with 200Hz pulse repetition frequency and a duty cycle of 12.5% (625µs).

However, comparing field strength levels from the investigated mobile communication standards against ED-14F section 20, one can derive that cat. R may cover the qualification against T-PED's onboard aircraft.

2.4

EED

Such specific devices, that are sensitive to the energy induced by HIRF into heating components and will further create a reaction to fuse or explode a media, exist on helicopters or aircraft for safety related function such as fire extinguisher, hoist cable cutter, flotation system...

These devices have their sensitivity to the induced energy that varies a lot due to physical and chemical characteristics production scatter. There is therefore a need for particular consideration when applying an ED-14 test in order to clear these devices for a given level. This particular consideration aims at covering the production scatter and both the proposed approaches result in fact in introducing some margin in the process. The usual necessary margin has been established at a value of 16.5 dB in the military process.

The first method is indeed the direct application of the HERO method and consists in performing a measurement during the injection of RF energy according to ED-14 section 20 procedures. The induced power into the EED during the test is then translated in equivalent induced current and compared to the no-fire current that has been established by the supplier on the base of a statistic method. The pass fail criteria would then be that the induced current is at least 16,5dB lower than the no-fire current. This necessitates a very specific instrumentation with deactivated EED and may not be the simplest way to test in civil laboratory. Detail of this method can be found in MIL HDBK 240.

The second method is to use EUT equipped with EED whose no fire characteristics has been reduced by at least 16,5dB in comparison to the nominal EED of the EUT. With such a device, a go-nogo test as per ED-14 section 20 would be directly suitable.

For that method, the pass fail criteria is that the EED shall not be activated during the test and that it can be activated after the test when injecting the minimum fire current guaranteed by the supplier.

2.5

GPS/GNSS

There has been recent development in the application of GPS/GNSS receivers for aircraft landing operation. As a consequence the correct functioning of this equipment is becoming more critical and it has been considered a need to increase the requirement for emission of the avionics in that frequency range. A reasonable increased requirement has been introduced in the new P radiated curve limit of ED-14 section 21 to anticipate that issue but this may not cover all the effects of avionics on the front door coupling to GPS/GNSS antennas.

CHAPTER 3

GENERAL TEST REQUIREMENTS

Section 20.3 of ED-14 provides some guide-lines on the general test set-up. These are intended to aid test repeatability but are somewhat brief and are therefore expanded in this section.

3.1 EQUIPMENT UNDER TEST (EUT)

The EUT should be mounted on the test bench in a manner that would cover the worst aircraft configuration from the aspects RF coupling to the equipment. This is particularly important when the results of the conducted and radiated susceptibility test are to be used to aid aircraft certification.

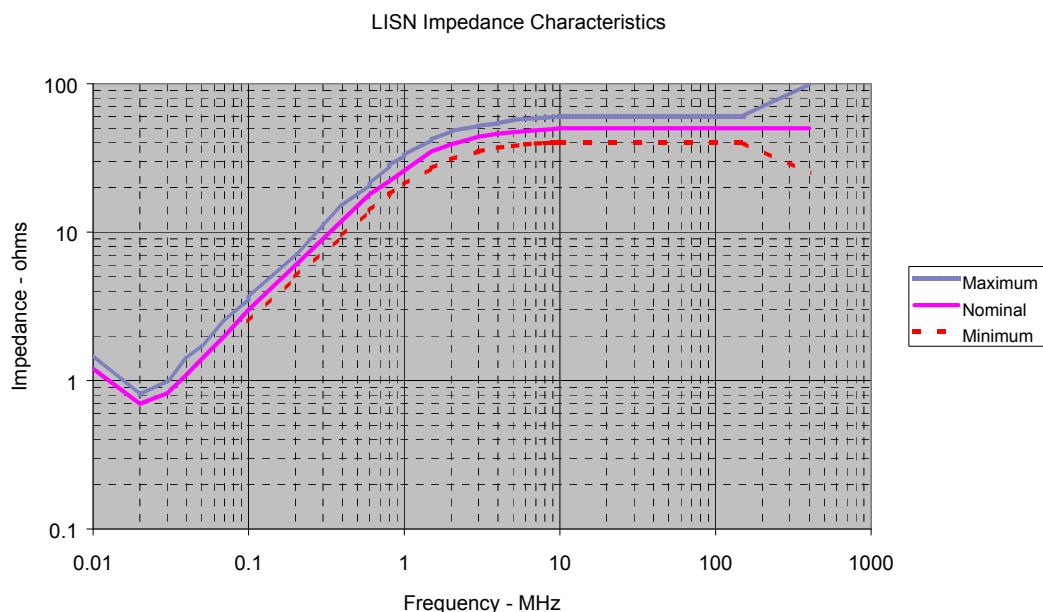
It is first necessary to verify that the bonding of the EUT to the ground is at least, from a resistive and inductive point of view, not better than what can be achieved on the aircraft installation. This will insure that all filtering and surge suppressors are not able to evacuate to the ground the RF common mode coupled current better than what they will be able to achieve on the actual aircraft installation.

It is then necessary to verify that the wiring harness lay-up is not providing excessive shielding protection in regard of what can be achieved on the aircraft. This is of course concerning the nature of the wiring and same type of wiring should be used in terms of twisted pairs (number of twist per meter, dielectrics and gauge) twisted shielded pairs (type of shield), coaxial cables.... This is also concerning the connection of the shield that shall not be better than what will be achieved on aircraft according to the equipment manufacturer's recommended installation guidelines. A typical example is length of pig tail shield connection when used.

If the final aircraft installation is not known or the equipment is to be installed on a variety of aircraft, the test installation shall be as weak as allowed by the equipment manufacturer's recommended installation guidelines. The EUT arrangement used for the test must be accurately described in the test report. This includes management of the configuration of the equipment in such a way that modification status of the equipment, cable lay-up and shielding arrangements are accurately traced. This is important to enable the airframe manufacturer to ensure the intended aircraft installation is adequate. A photograph of the test set-up in the test report is helpful in determining the test conditions and aiding repeatability if a re-test is required, and should be included where practical.

3.2 LINE IMPEDANCE STABILISING NETWORK (LISN)

A Line Impedance Stabilising Network (LISN) is placed in each primary power line. The purpose of the LISN is to provide defined RF source impedance for the test house power supply. The design of the LISN was removed from ED-14 since the "E" revision although the impedance characteristic definition has not changed:



NOTE: No minimum impedance limit is specified below 100kHz.

FIGURE 3-1: LISN INPUT IMPEDANCE

The design provided in ED-14C is still valid and there is no basic change in the required design other than the removal of the lower limit at low frequencies. The inductor used is $5\mu\text{H}$ not $50\mu\text{H}$ as specified in MIL-STD-461/462D.

The 50 ohm coaxial load for all Section 20 tests should have a power rating of at least 100 watts for the higher equipment categories during the bulk current injection (BCI) test.

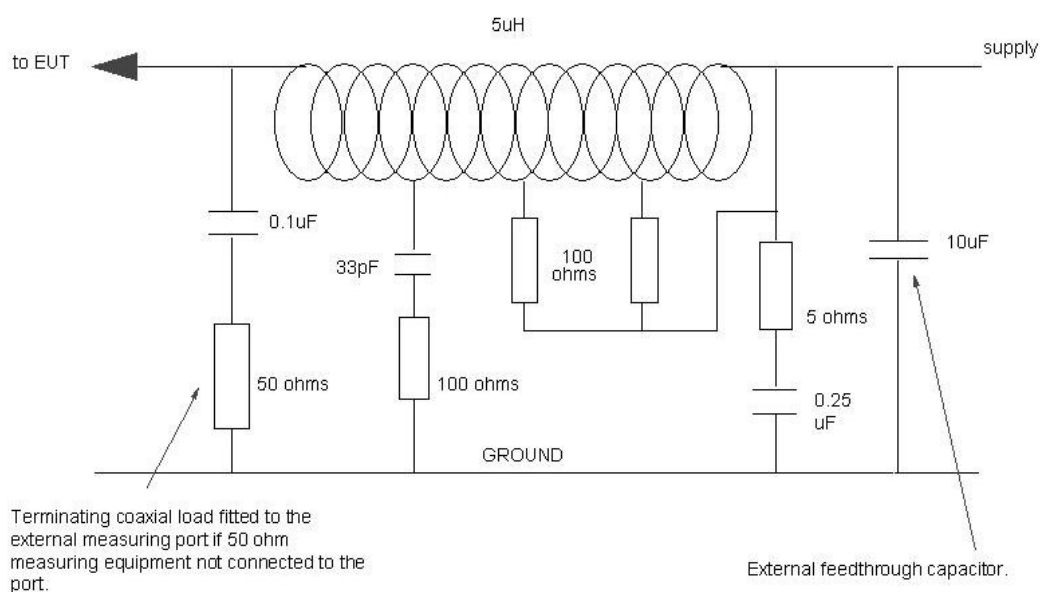


FIGURE 3-2: SCHEMATIC DIAGRAM FOR THE LINE IMPEDANCE STABILISING NETWORK

The coaxial load is shown connected in this drawing. The 10 μ F capacitor shown on the supply side of the LISN, as required in ED-14, will provide for more repeatable results as the length of cable from the LISN to the shielded room wall is not specified. It also reduces the RF currents induced during the BCI test flowing into the shielded room supplies or onto other power supply lines. If this capacitor is not embedded in the LISN circuits itself, it would be recommended to use an external feed through capacitor in order to maintain high performance at high frequencies. The various components in the LISN need to be capable of handling the RF power which they will dissipate during the bulk current injection (BCI) test. The resistors in the unit need to be at least two watts.

3.3 TEST EQUIPMENT

Any test equipment and sensors which are implemented in the set-up for monitoring purpose only should be interfaced to the EUT by fibre optics. This helps to provide susceptibility-free monitoring of the EUT and prevents spurious resonances in the coupling of RF to the EUT's wiring bundles. Any test loads or simulated test signals should reflect the final installation in terms of signal type and impedance. This will have to include all impedances from load filtering or protection devices. They must not contribute to the overall susceptibility of the EUT and therefore may need hardening.

3.4 ANECHOIC LINING

When reverberation chamber techniques are not used, the use of RF absorber material is mandatory in the specification during radiated testing in order to reduce reflections and aid in test consistency. As a minimum it shall line the shielded room walls above, behind and on both sides of the EUT and the walls behind and to each side of the radiating antenna. The minimum requirement for the anechoic lining used is defined in ED-14.

This requirement is based on MIL-STD-461/462D and is not particularly onerous. During radiated susceptibility testing it has been found that by "hooding" the antenna, by placing multi layered anechoic slabs such as AN 79 around the antenna, a more consistent load is presented to the driving power amplifier. This is because the coupling of the antenna to the shielded room is minimised. This coupling manifests itself in resonances in the VSWR characteristics of the antenna.

3.5 BONDING OF GROUND PLANE

For the bonding of the ground plane to the shielded enclosure, not only the distance between the bonding strips and their resistance are important. As is hinted at in [7], the position and the orientation of these strips contribute considerably to field distribution into the room. Influences up to 20dB at some frequencies were measured during radiated emission test.

It is suggested, when testing in anechoic chamber, that the bonding strips at the back and on both sides of the test table be lead horizontally to the sidewalls of the shielded enclosure in order to minimize reflections.

3.6 HEIGHT OF TEST TABLE

The height of the test table is not quoted in ED-14. Nevertheless this plays a role in particular for the comparability of the measurement results of varying laboratories. However in CISPR 25 and in MIL-STD-461E [8], a table height of 90 cm is used. Therefore also the ground planes for ED-14 testing are usually 90 cm above the conducting floor of the SAR.

In order to reduce variability between test sites and increase comparability, a height of the ground plane of 90cm is suggested.

3.7 TEST FREQUENCIES

When using test equipment that generates discrete frequencies, ED-14 defines the minimum number of test frequencies as 100 frequencies per decade. The test frequencies shall be logarithmically spaced. ED-14 gives an example of a formula that can be used to calculate these frequencies in ascending order:

$$f_{(n+1)} = f_n * 10^{\left(\frac{1}{100}\right)}$$

where f_n is the test frequency and $n = 1$ to m

f_1 is the start frequency

f_{100} is the end frequency

$m = 1 + 100 * \log(f_m / f_1)$ rounded up to the nearest integer

If the last test step for f_{n+1} yields a frequency greater than f_m , then set the last frequency to f_m

For ease of use, the following table shows the results of this calculation assuming a start frequency of 1, e.g. the results are in MHz if the start frequency is 1MHz. In this instance the first start frequency is 1MHz and the final 100th test frequency in the decade is 10MHz.

If the start frequency of the decade is 100MHz, multiply the frequency given in the table by 100 and the result will be in MHz.

N	Freq	N	Freq	N	Freq	N	Freq	N	Freq
1	1	21	1.5848	41	2.5118	61	3.98107	81	6.3095
2	1.0232	22	1.6218	42	2.5703	62	4.07380	82	6.4565
3	1.0471	23	1.6595	43	2.6302	63	4.16869	83	6.6069
4	1.0715	24	1.6982	44	2.6915	64	4.26579	84	6.7608
5	1.0964	25	1.7378	45	2.7542	65	4.36515	85	6.9183
6	1.1220	26	1.7782	46	2.8183	66	4.46683	86	7.0794
7	1.1481	27	1.8197	47	2.8840	67	4.57088	87	7.2443
8	1.1748	28	1.8620	48	2.9512	68	4.67735	88	7.4131
9	1.2022	29	1.9054	49	3.0199	69	4.78630	89	7.5857
10	1.2302	30	1.9498	50	3.0902	70	4.89778	90	7.7624
11	1.2589	31	1.9952	51	3.1622	71	5.01187	91	7.9432
12	1.2882	32	2.0417	52	3.2359	72	5.12861	92	8.1283
13	1.3182	33	2.0892	53	3.3113	73	5.24807	93	8.3176
14	1.3489	34	2.1379	54	3.3884	74	5.37031	94	8.5113
15	1.3803	35	2.1877	55	3.4673	75	5.49540	95	8.7096
16	1.4125	36	2.2387	56	3.5481	76	5.62341	96	8.9125
17	1.4454	37	2.2908	57	3.6307	77	5.75439	97	9.1201
18	1.4791	38	2.3442	58	3.7153	78	5.88843	98	9.3325
19	1.5135	39	2.3988	59	3.8018	79	6.02559	99	9.5499
20	1.5488	40	2.4547	60	3.8904	80	6.16595	100	9.7723

TABLE 3-1: TEST FREQUENCIES FOR 1 DECADE

CHAPTER 4

AMPLITUDE MEASUREMENT

Confusion has existed amongst some engineers as to the definition of the test limits when dealing with modulated signals. This confusion has also surrounded the measurement units used to define the field strength of the HIRF environment.

Since ED-14E and in the HIRF Users Guide, amplitude measurement in the presence of modulated signals has been hopefully better defined to prevent this confusion.

The various HIRF environments and associated susceptibility test levels are defined in terms of the "peak of the RMS envelope" (peak RMS) of the signal. This is in terms of electric field strength (V/m) for both the environment and the radiated susceptibility test levels.

The electric field strength values of the HIRF environment have been determined from the measured or calculated values of the power density produced by the various transmitters, either average for CW fields or peak for modulated fields:

The field strength (E) from the transmitter assuming far field conditions:

$$E = (Pd \cdot 377)^{1/2} \text{ [V/m]}$$

where Pd = power density.

The Power Density [W/m²]:

$$Pd = (\text{Transmitter Power} \cdot \text{Antenna Gain}) / (4 \cdot \pi \cdot \text{Distance}^2)$$

4.1 CW FIELDS

The field generated by an unmodulated transmitter is expressed in terms of power density and the peak and average values are the same. In plane wave conditions, this is equal to the product of the electric and magnetic fields. In all cases we are talking about the rms values which, as in all forms of electrical engineering, have always been true electrical peak divided by root 2.

4.2 MODULATED FIELDS

When dealing with modulated signals such as pulse modulated fields from a radar, there is obviously a difference between peak and average values of power density. The ratio between the peak and average values is a function of the duty cycle with pulse modulated or gated signals. For instance with a duty cycle of 50%, e.g. on for 50% of the time and off for 50% of the time, the average value of field strength is 3dB lower than the peak value.

Under plane wave conditions, the power density is still a function of the product of the electric and magnetic field strengths. In the case of the peak field it is the product of the rms value of the electric and magnetic field strengths for the time that the signal is on (Figure 4-1). When the signal is off, the field strength is obviously zero.

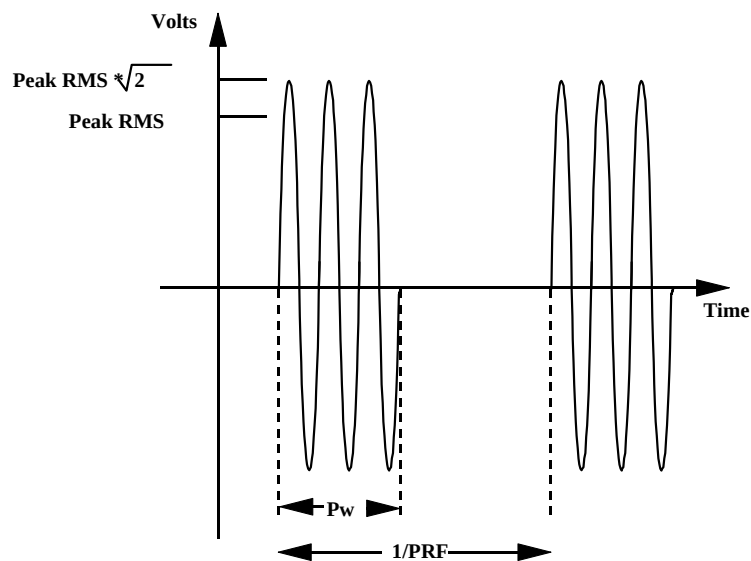


FIGURE 4-1: PULSE MODULATED OR GATED SIGNAL

When dealing with more complex amplitude modulated signals, the peak field strength is expressed in terms of the maximum instantaneous value of power density, which equates to the product of the maximum instantaneous rms values of the electric and magnetic field.

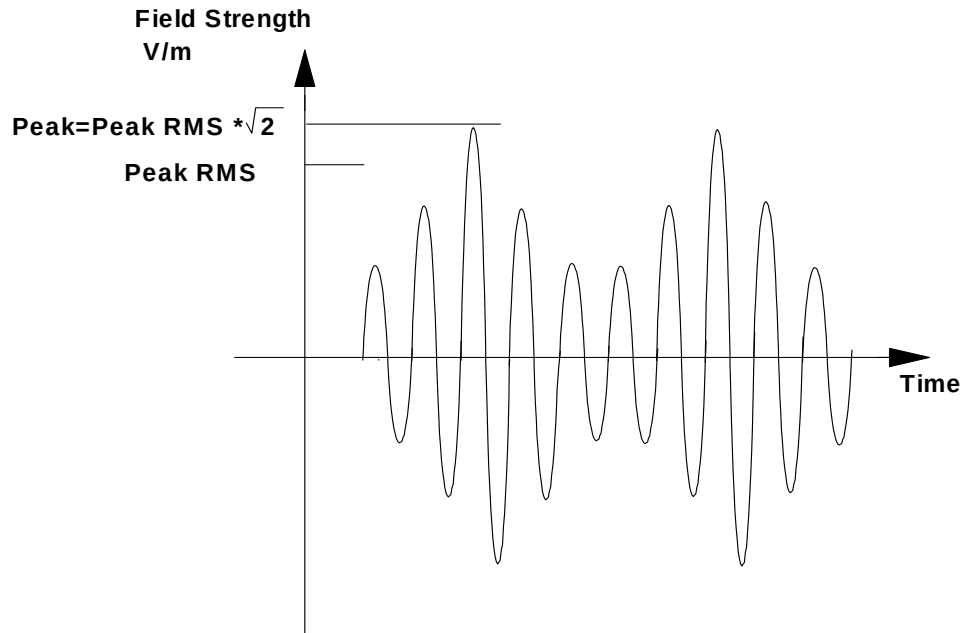


FIGURE 4-2: AMPLITUDE MODULATED WAVEFORM

The term maximum instantaneous rms value has become known as peak rms and is the normal parameter measured during equipment and aircraft EMC tests, hence commonality with the way the peak HIRF environment is expressed.

4.3 MEASUREMENT

All measurements relating to HIRF are made using the peak detector function of the measuring receiver/spectrum analyser. This is calibrated in terms of the equivalent rms value of a sine wave. What does this mean? When measuring a modulated signal, the bandwidth of the measuring receiver should be set wide enough to capture the total energy of the signal. The amplitude reading as measured by the peak detector function is noted. The unknown signal is disconnected and a sine wave signal at the same frequency fed in. Its amplitude is adjusted until the same reading is produced on the measuring receiver. This amplitude is expressed in terms of the rms value of the sine wave e.g. a 1 volt rms sine wave input will give an indicated measurement of 1 volt. This will not change if the signal is switched on and off, the peak reading will still be 1 volt hence the term peak rms. Figure 4-1 shows the relationship between peak and peak rms for a pulse modulated or gated sine wave. Figure 4-2 shows the relationship between peak and peak rms for an amplitude modulated sine wave.

ED-14E and later provide the following guidance on the characteristics of the equipment to be used to measure the amplitude of the applied susceptibility test waveform:

- The amplitudes associated with the test limits are based on the peak of the rms envelope over the complete modulation period.
- Amplitude measurements shall be made in a manner, which clearly establishes the peak amplitude of the modulated waveform.
- The measuring instrument must have a fast enough time response to respond to signal amplitude variations. A spectrum analyser may be used.
- The detection, resolution and video bandwidths of the measuring instrument must be wider than the modulating frequency.
- The measurement bandwidth shall be increased until the amplitude of the measured signal does not change by more than 1dB for a factor of three changes in bandwidth. This bandwidth setting shall then be used for the test. At the proper setting the individual modulation sidebands will not be resolved.

It is important to meet these requirements especially when measuring modulated signals. The use of a spectrum analyser for signal measurement during susceptibility testing does provide advantages over power meters or receivers as it allows a more direct visual check on the quality of the applied signal during the testing. It provides direct indication if the signal source is becoming non-linear, or generating spurious signals. Sometimes, when mismatched, TWT amplifiers have been found to produce parasitic high power oscillations even with no input drive at a frequency, which may be well removed from the required test frequency. Regular checks should be made on the quality of the test signal, and presence of spurious signals.

4.4 USE OF EMC TEST RECEIVERS VS. SPECTRUM ANALYSERS IN EMISSION TESTING

Emission testing according to ED-14 has different priorities. Although spectrum analysers are permitted for the measurement of conducted and radiated emissions, it may be recommended to use a test receiver, as only that way a precise definition of measurement time per frequency is possible. An additional advantage of test receivers is that they have built-in pre-selectors, which make them less susceptible for overloading of the IF-mixer. Much higher dynamic range can be achieved that way.