ICAS-98-1,11,3

A98-31488

HIRF / EMC TEST TECHNOLOGIES AND METHODOLOGIES

Stefano RIPAMONTI

ALENIA AEROSPAZIO
Progettazione
Torino - Italy

ABSTRACT

The HIRF / EMC testing purpose is to confirm that aircraft specific equipment and subystems can correctly operate both within their own environment and with respect to potential external electromagnetic disturbances.
Test activities are performed to reach the desired degree of confidence in releasing the required aircraft flight clearances, according to international standards.
Alenia Aerospazio has developed test facilities and a EMC test range which are suitable to perform conducted tests and radiated tests, also in a frequency range such that the wavelenghts are in the order of magnitude of the aircraft dimension.
The paper describes the test facilities, mainly including Mobile Test Stations, the EMC Test Range, and fixed/mobile antennas. Some relevant examples of methodology application on actual aircraft are presented.

1. INTRODUCTION

In the paper the test facilities presently available at ALENIA are described, mainly including mobile Test Stations/Instrumentation, fixed Test Range and fixed/mobile antennas. The test facilities capabilities are presented covering relevant frequency ranges, amplifier output power, signal generation, data acquisition systems, and antennas.
For the fixed Test Range the area calibration philosophy is also described, as well as the assessment criteria of the high level radiated electromagnetic fields. In addition, peculiar complementary facilities relevant to the fixed Test Range operation are presented.
The test facilities are specified, designed and developed against state of the art technologies, to support specific test methodologies[1], thus allowing for example Conducted Emissions measurements, Enhanced RF Level tests, Low Level Sweep Frequency / Transferfunction evaluation, Radiated Susceptibility measurements, Bulk Current Injection Test, Armament RF Pick-up Measurement.
Furtherly test facilities are developed in compliance with the requirement of performing some of testing above on aircraft with engine running. Testing is performed in completely automatic mode to reduce test execution times.
Finally some relevant examples of technology and methodology application on actual aircraft are reported, addressing specific test requirements.

2. BACKGROUND

This section outlines the main tests which can be performed at Alenia's facilities.

- **Radiated susceptibility / HIRF**

These tests are used to simulate interferences sources during flight near RF ground stations. Therefore during these tests the aircraft is subjected to RF radiated field strenght increased step by step until the specification limit is achieved.
The system is calibrated in absence of the aircraft, and during the test the RF power generation process is automatically controlled. An acquisition subsystem is used to monitor the parameters under test, by picking them up from digital data bus as well as from analog links. Cockpit parameters are delivered from aircraft to EMC test station via a fiber optic link.

- **Conducted emissions**

The purpose of this test is to analyze the emission spectrum related to the signals on the DC and AC bus bars during the normal operation of the aircraft equipment. The EMC safety margin is established by comparing the test results with the MIL-STD-461/462 conducted susceptibility limits. A fiber optic link and a spectrum analyzer are used in order to transfer and measure the signal. The measurement process is automatically controlled by a dedicated software which allows the definition of the frequency range to be covered and the possibility to lay a susceptibility mask over the final graphic.

- **Enhanced RF level**

The purpose of this test is to verify a 6 dB safety margin increasing the field generated by the aircraft V/UHF transmitting antennas. In order to verify the safety margin with respect to the field radiated during normal operation of on board radios, a high power RF generator is connected to the aircraft V/UHF transmitting antennas. The desired field is obtained increasing by four times the nominal input power of the antenna, and the susceptible aircraft parameters are monitored as in Radiated susceptibility test.

- **Transfer function / Low Level Swept Frequency**

The purpose of this test is to determine the transfer function between an external electric field and the current induced into a bundle of interest, when the aircraft is radiated by means of an external RF transmitter. The test is also referred as Low Level Swept Frequency since it is performed to know the current induced onto the loom by sweeping by steps in frequency across the band under test. From the transfer function it is possible to estimate the structure and harness shielding effectiveness of the complete aircraft. The measurement is performed in two phases: during the first phase the electric field strenght is measured in absence of the aircraft; the power at the input terminal of the transmitting antenna required to establish a low level field (1 V/m for example) is monitored and recorded; during the second phase the same power is applied to the transmitting antenna in presence of the aircraft.

- **Bulk Current Injection**

The purpose of this test is to inject currents with well defined amplitude and frequency on aircraft power or signal lines with the aim to verify if on board equipment are affected by susceptibility. Separate injection chains allow to inject in each point the required current intensity at the required frequency with the advantage of maintaining the real control of the current by means of real time generated power measurement. During the injection the functions of the acquisition system are activated in order to keep under control all the aircraft parameters related with analogic or digital signals.

- **Armament RF pick-up**

This test consists in the measurement of the spurious energy picked up on the Electro Explosive Device bridgewires during the electromagnetic field exposition or during the activation of emissive aircraft equipment. The energy level reading is based on the fluoroptic thermometry measure method. It is based on the precise relationship between the decay time of the fluorescence of a selected phosphor and the temperature. The measurement software is able to perform the calculation of the safety margins in accordance with the applicable specifications.

3. ALENIA AEROSPAZIO TEST FACILITIES

In this section a detailed description of all the EMC facilities available at the Alenia Caselle plant is reported, including EMC Test Range, Antennas, and Mobile Test Stations.

3.1 EMC Test Range

The EMC Test Range was suitably designed to perform the radiated tests in the best conditions, considering the external electromagnetic environment; the following considerations were done: the external electromagnetic field that can generate resonance phenomena on aircraft, and then susceptibility of its systems, is in the frequency range such that the wavelenghts are in the order of magnitude of the aircraft dimensions; typically for a fighter aircraft the critical frequency range is in the HF range: therefore the design of the EMC Test Range had to cope with difficulties related to this frequency range, that are the large antenna dimensions required and the zero field strenght in horizontal polarization on ground level.
The area was designed according to the following major requirements:

* test area suitable for testing a medium size aircraft;
* rotation of the aircraft around 360°;
* performance of some tests with aircraft engines running.

The result is a dedicated open area (around 5400 square meters) including two circular test areas of 15 m diameter for vertical and horizontal polarization radiation; inside these areas the radiation of the electromagnetic field is performed with the fulfillment of requirements of field strenght, field uniformity, and cross polarization.

A general not scaled view of the EMC Test Range is shown in Fig.1(*).

- **General facilities**

The following general facilities are available at the EMC Test Range:
Ground plane: under the whole test range a metal wire fence is placed as the ground plane which antennas ground is referred to.
Aircraft supplies: aircraft electrical and hydraulic supplies are available in both test areas, by means of underground connection from a service house.
Antennas supplies: the two main antennas are supplied by means of dedicated underground RF power lines, which are pressurized by a dry air compressor.
Wire fence: due to the use of high power antennas, a wire fence is used to avoid radiation towards Test Range external areas.

- **Instrumentation**

The following instrumentation is available at the EMC Test Range:
Turntable: since a strong correlation between aircraft susceptibility and the radiation direction has been demonstrated, a metal turntable moving on circular rails is installed inside the horizontal polarization area in order to rotate the aircraft by 360°.
Plinths: some plinths to arrest the aircraft by means of the Arrestor Hook are provided to allow test with engines running at ratings different from idle.
Lifting platform: a wooden made lifting platform is available to lift the aircraft above ground, where the best horizontal polarized field is radiated by an inverted V antenna. The platform has suitable dimensions to allow its placement on the turntable and the aircraft rotation.
Crane: a crane is available to lift the aircraft on the lifting platform. The crane is movable outside the test area by means of rails.
Shielded suites: two RF shielded suites are available to guarantee safety during RF field radiation phase when on board aircrew is required.

3.2 Antennas

The following antennas were specifically designed and built to be operated at the EMC Test Range:

Antenna	Polarization	Max Power	Figure n.
Inverted V	H	20 KW	2
Multiwire	V	20 KW	3
Monocone	V	500 W	4
Dipole	H	500 W	5

(*) See Figures at end of paper

Inverted V and Multiwire antennas are suitable to deliver high RF field strenght as required by Radiated Susceptibility tests in the 5 to 30 MHz frequency range; the monocone and dipole antennas are dedicated to perform Transferfunction test and Bulk Current Injection in the same frequency range, but these tests require low intensity RF field, just enough to measure coupled currents on defined aircraft bundles.
For radiated tests at higher frequencies (30 MHz - 40 GHz) a dedicated trolley, on which antennas as needed by the test can be installed, was designed and built. The trolley is a battery powered mobile device with a telescopic rotating arm such that all antennas can be displaced in any relative position and polarization with respect to the aircraft under test. The following antennas can be installed on the trolley:

Antenna	Polarization	Freq. Range
Log-Periodic	H/V	30-200 MHz
Log-Periodic	H/V	200-1000 MHz
Horn antennas	H/V	1-40 GHz

3.3 Mobile Test Stations

Field generation and control test instrumentation used to perform EMC / HIRF tests is installed on mobile test stations which allow quick EMC area reconfiguration if needed, and the execution of many of the tests described above outside the EMC Test Range, thus making possible testing more than one aircraft at the same time.
Due to their transportation features, test stations can be operated outside Alenia facilities as well, for example in military air fields, according to particular requirements.
When power supplies are not available, dedicated transportable generators can supply power to the stations.
The following test stations types are available at the present time at Alenia:

- **High Power Generation Test Station**

The High Power Generation Test Station is a mobile shielded shelter that contains the high power RF amplifiers to be used as generation systems to perform HIRF tests in the HF range. The available power is 20 KW, generated by solid state amplifiers. The choice of solid state amplifiers is due to very high harmonic suppressions; this is very important in case of susceptibilities in order to correlate the susceptibility itself with the exact frequency at which occurs, that otherwise could be generated by harmonics of the frequency under test.

The High Power Generation Test Station is connected to the Inverted V antenna or to the Multiwire antenna to generate the High intensity electromagnetic field in the HF range. The field calibration phase and the field generation during the test are controlled by a workstation; the calibration data are stored as power as a function of frequency: during the test a scaled power is radiated by the antenna in order to generate the desired field level.
Field calibration and generation are performed using the High Power Generation Test Station linked to the Acquisition Test Station.

- **Acquisition Test Station**

The Acquisition Test Station is a mobile shielded shelter that contains an analog signal acquisition subsystem and a field generation subsystem. The subsystems are automatically computer controlled by a dedicated workstation which also controls the power amplifiers on the High Power Generation Test Station via a fiber optic link.
A maximum of 64 analog signals can be monitored in real-time, and parameters out of a selected range are automatically stored in a database.

- **EMC Test Stations**

The EMC Test Stations were developped to perform EMC tests on prevailingly military aircraft.
Figure 6 shows the typical subsystems constituting the test station.

Computer subsystem

A workstation provides:
* control of the instrumentation during the measurements via IEEE-488 bus;
* setting of the instrumentation configuration;
* test results storage;
* generation of test reports.

Generation subsystem

The generation subsystem includes three chains:
* External field radiation (1 MHz - 18 GHz);
* BCI (4 indipendent lines, 1 - 400 MHz);
* Defensive Aids Subsystem stimulation.

Audio-Video subsystem

The audio-video subsystem includes:
* headphone system linked to aircraft interphonic system by fiber optics;
* speaker diffusion of the interphonic signal inside the test station;
* colour video camera with remote control (pan, tilt, phocus) by means of fiber optic link;
* video recorder and video hard copy printer;
* colour monitor.

Acquisition subsystem

The acquisition subsystem includes:
* electric and magnetic field sensors and repeater (8 simultaneous readings);
* 8 channels 1 KHz - 1 GHz fibre optic link (used in LLSF, BCI, Armament transients, AC bus bars steady state, Spikes and Transients measurements);
* 8 channels DC - 1 MHz fibre optic link;
* Armament system analyzer;
* EMI receiver;
* Radio communications test-set;
* Aircraft Signal Handling (ASH). This signal real-time acquisition system performs the following functions:
* 2 military standard bus real time data acquisition and storage;
* 2 fiber optic military standard bus real time data acquisition and storage;
* 64 analog channels data acquisition and storage;
* 100 bus/analog parameter verification in real time;
* 10 parameters graphically displayed in real time;
* Data Base functions;
* Post acquisition data analysis.

Due to its complexity the ASH is implemented by a workstation remotely controlled by the computer subsystem.

The EMC Test Stations can be used in conjunction with the High Power Generation Test Station to allow avionic parameters acquisition, during field radiation phase, in addition to visual observation of susceptibilities: this way susceptibilities can be exactly defined avoiding errors due to human factor, i.e. control surfaces movements that human eyes cannot appreciate.

4. HIRF TEST METHODOLOGIES

This section provides an example of application of test methodologies adopted in Alenia to perform HIRF test in the HF frequency range. The main purpose of this section is to describe the whole sequence of activities related to a HIRF test, therefore, for completeness reasons, some data about results of the tests are included: these results represent an exemplification, are no way related to an actual aircraft, and cannot be addressed to a specific requirement.

4.1 Test Requirements

An Engineering Department issues test requirement applicable to an aircraft which may be a prototype or a version fully representative of a serial production.
A first requirement defines Test Area Calibration features, with two main objectives:

* to reach a deep knowledge of the characteristics of the electromagnetic field which will be radiated during the test;
* to define the RF amplifier power output to be delivered to the antenna in order to reach the desired field level during test.

Other main requirements for a typical HIRF test are:
* *Frequency range*: a sweep can be performed during test starting from 1 MHz;
* *Frequency step*: is the frequency resolution to be applied during the sweep;
* *Field levels*: testing at more than one field level can be required, typicall from 5 V/m to the maximum allowed by instrumentation depending on the selected frequency range, polarization, etc.
* *Field polarization*: typically both vertical and horizontal;
* *Wave modulation*: CW or amplitude / frequency / pulse modulated signals can be radiated;
* *Aspect angle*: due to the aircraft rotation capabilities on the turntable in front of the antenna, every aspect angle from 0° to 360° can be required in order to simulate the radiation of the aircraft from well defined directions, and therefore to detect the susceptibility profile of the aircraft with respect to the position of the interfering transmitter;
* *Aircraft configuration*: defines the configuration to be tested (surface positions, external loads, etc.);
* *Parameter list*: the list of analog/digital parameters to be kept under control during test, including ranges, validity range, tolerances.

4.2 Area Calibration

Calibration is performed inside the area where the aircraft is located during the test. Eight electric field and four magnetic field sensors are used in subsequent calibration sessions to measure the level of electric and magnetic field in many locations inside the area. Typically 13 points are measured inside a circular area (see Figure 7) at 4 different heights over ground.
During a preliminary field calibration the output of RF power amplifiers is increased until the selected target field level is reached by all the sensors involved. At this point output power and field level are stored to be used both for a subsequent single calibration session to measure module and components of the electric field or module of magnetic field, and as source data for field generation during test.
From the data recorded the following results are calculated:
* electric field uniformity: should be ± 3 dB inside calibration volume (see an example in Fig. 8);
* cross polarization: main to undesired electric field component ratio.
* wave impedance: electric to magnetic field ratio.

4.3 Test Execution

Test is performed according to a test procedure issued with the objective of fulfillment of requirements as the ones described above.
A typical HIRF test is performed in three phases as follows:

- **Preliminary investigation phase**

In this test phase the aircraft is tested by radiating it in at least 24 different aspect angles with steps of 15°; aspect angle is defined as the angle between aircraft axis and the incident radiation direction; a typical frequency step in this phase is 300 KHz in the 5 to 30 MHz frequency range; several different field levels are generated starting from a very low one (10 V/m for instance); no modulation is applied to the RF carrier; all the configuration foreseen are tested in this phase.
This massive approach takes to the detection of most critical aspect angles and aircraft configurations.

- **Fine investigation phase**

This phase is performed detailing critical aspect angles (e.g. testing the aircraft at the critical aspect angles found in preliminary phase and at ±5° adjacent angles), increasing test frequencies, and applying different transmission patterns. The above refining is applied only to configurations identified as critical in the preliminary phase.

- **Susceptibility threshold determining phase**

At most critical aspect angles as resulting from the above automatic measurements, the exact susceptibility level is found in manual mode slowly increasing the external RF field level.

4.4 Data Analysis and Result Assessment

Any susceptibility occurred during the three test phases is stored in a data base which allows aggregation of data for post run processing.

Many kinds of graph can be plotted, referred to a single parameter, to an aircraft subsystem or to the whole aircraft.
Source data can be selected to separate the results of different test conditions: for instance a dedicated analysis can be performed on an aspect angle, vertical or horizontal polarization data, a field level, a parameter, an aircraft configuration, or their combinations.
The higher level of synthesis can be obtained using all the susceptibility records to produce graphs which show the most critical susceptibility level in V/m as a function of the radiation direction (Fig. 9) and susceptibility profile plots including susceptibility level as a function of frequency (Fig. 10).

5. CONCLUSIONS

The application of state of the art technologies has taken to the design and development of test facilities which are suitable for the performance of all EMC/HIRF tests that are necessary to obtain aircraft qualification according to military standards or customer requirements.
In particular, the objective of performing accurate HIRF testing on the whole aircraft has been achieved.

6. REFERENCES

1) **B. Audone** - *Compatibilità elettromagnetica*, McGraw-Hill, 1992

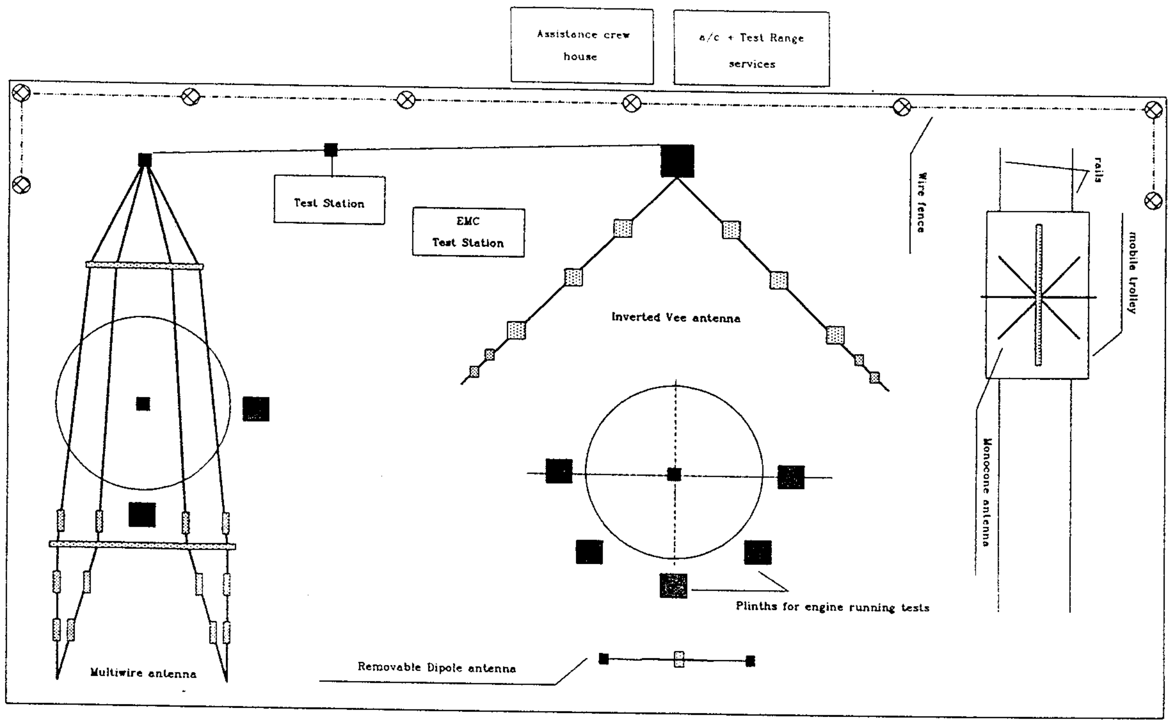

Fig. 1 - General view of the EMC Test Range

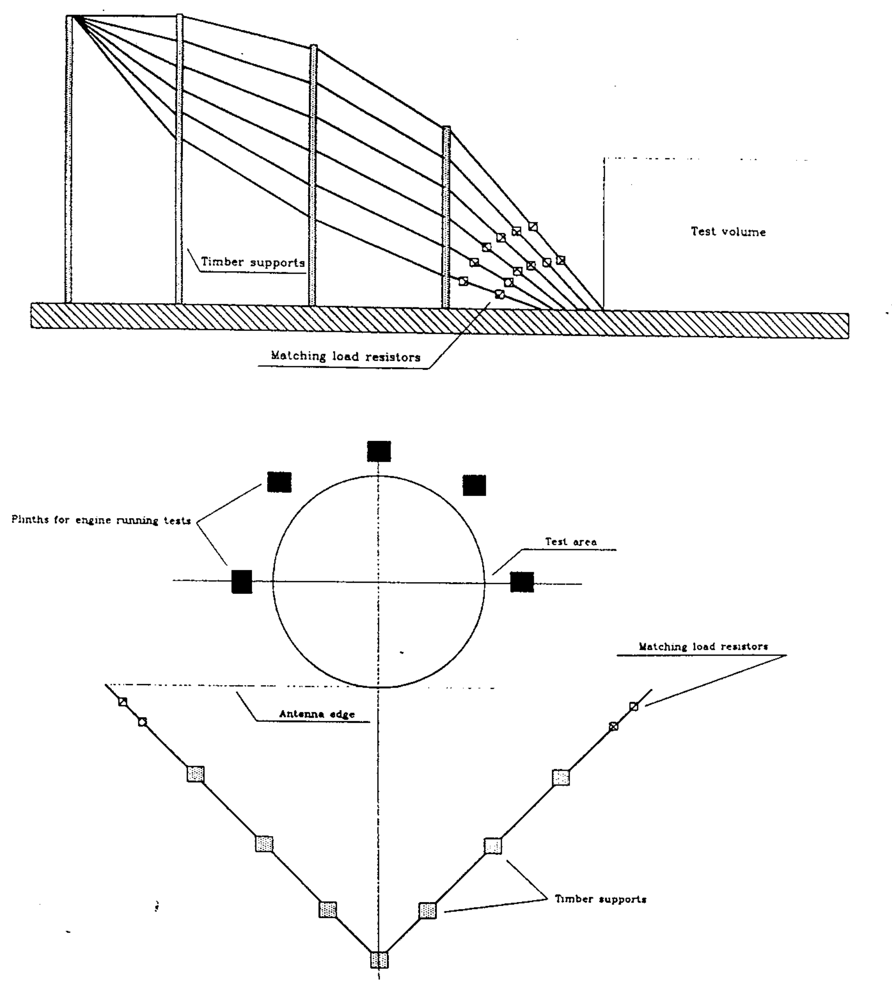

Fig. 2 - Inverted V antenna

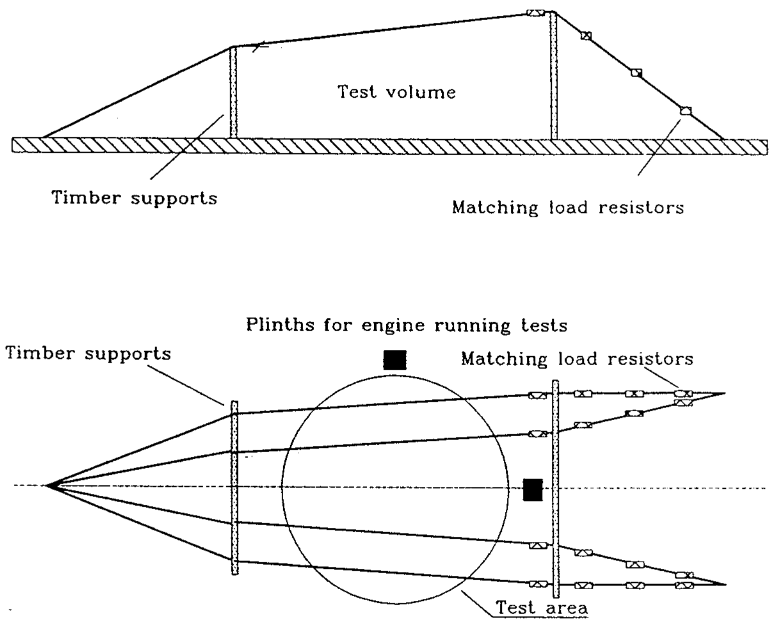

Fig. 3 - Multiwire antenna

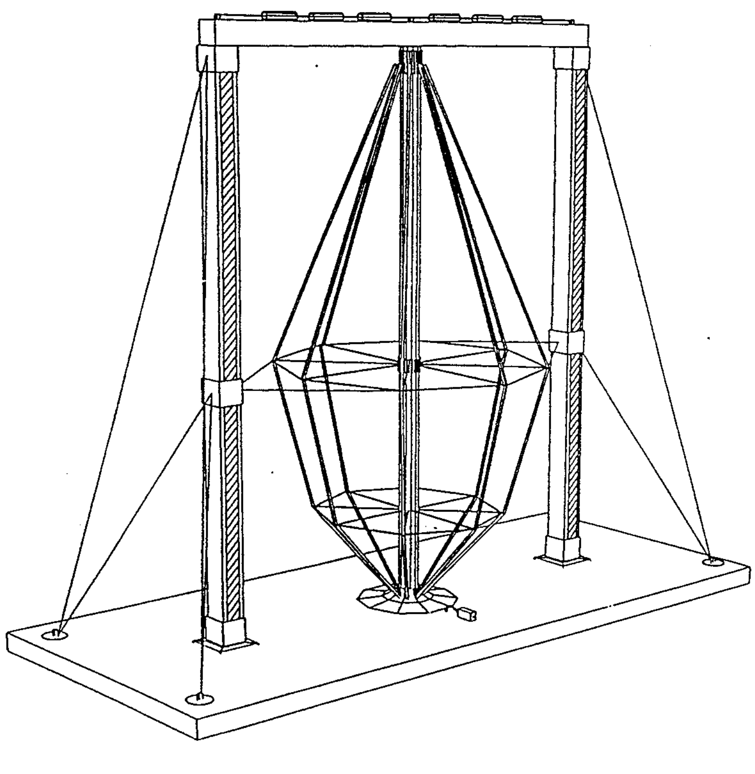

Fig. 4 -Monocone antenna

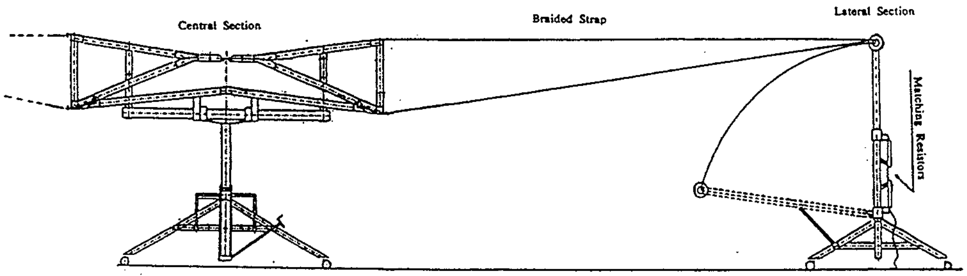

Fig. 5 -Dipole antenna

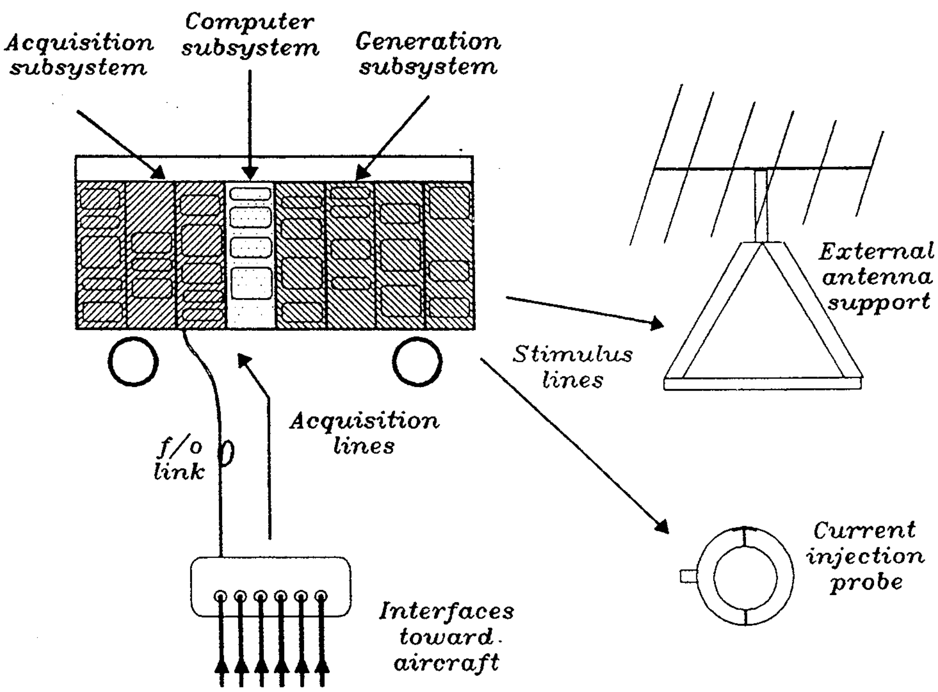

Fig. 6 - Typical EMC Test Station subsystems

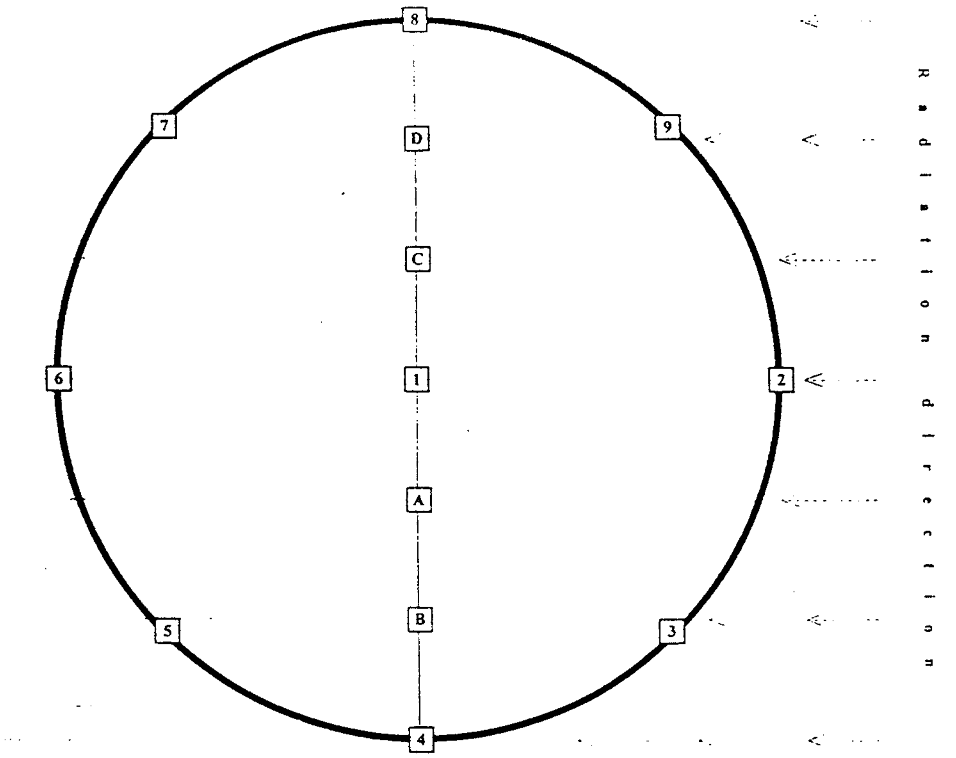

Fig. 7 - Field sensor positions during test area calibration

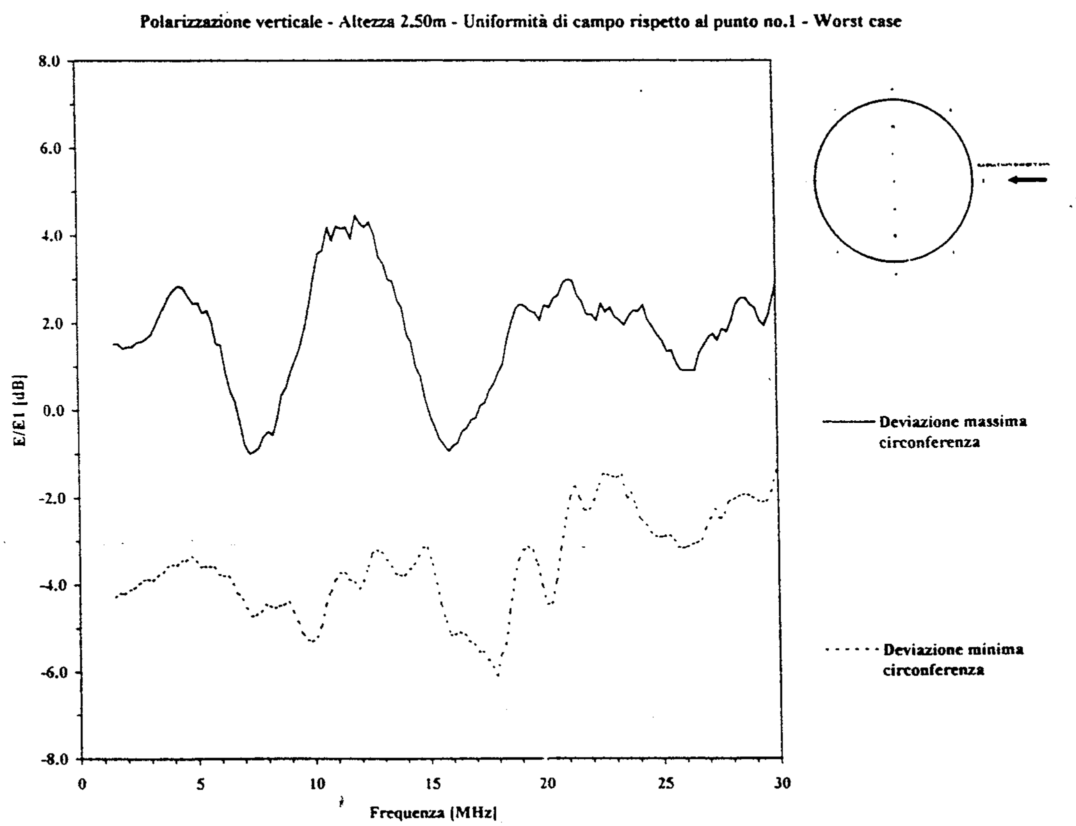

Fig. 8 - Test area "Worst case" field uniformity with respect to central point

SUSCEPTIBILITY PROFILE - frequencies: all

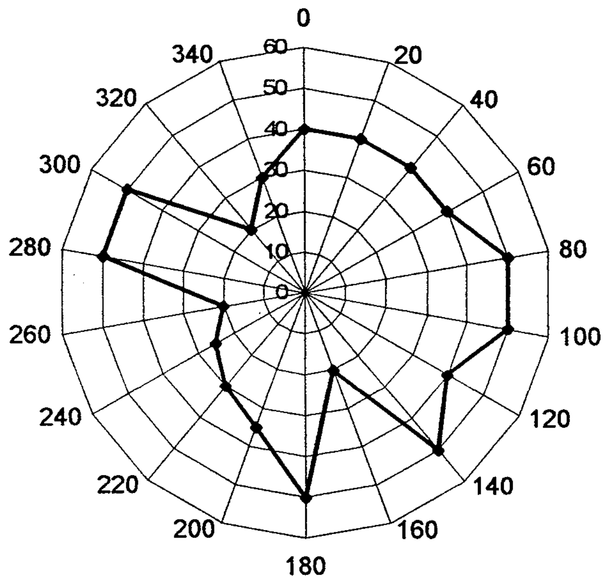

Fig. 9 – Susceptibility level as a function of radiation direction

SUSCEPTIBILITY LEVEL

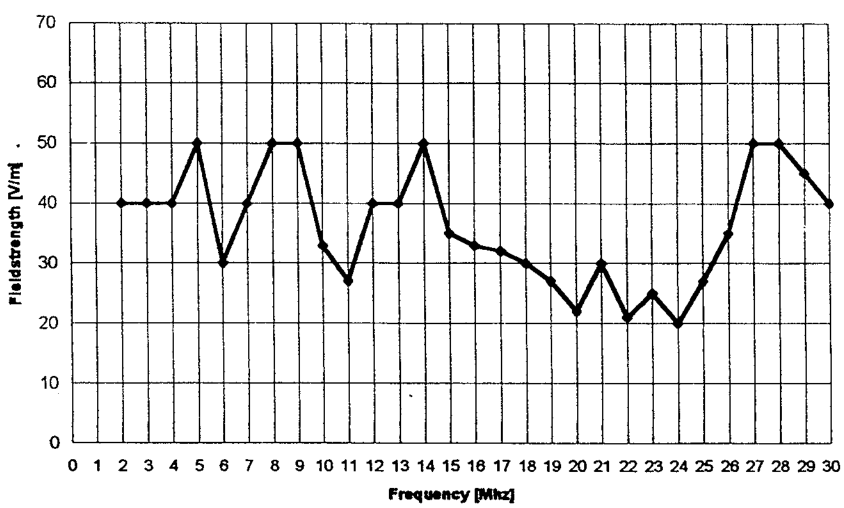

Fig. 10 – Susceptibility level as a function of frequency