Tolosan Method: A transformation between real HIRF illumination and Aircraft sized Reverberation Chamber Environment

A. Saïdani[1], L. Lachater[1], A. Laisne[1]

1 : DGA/CEAT, 47 rue Saint Jean 31131 BALMA

Abstract: The use of reverberation chambers, for governmental HIRF evaluation of warfare systems, has great advantages. On one hand, it permits to increase severity and exhaustiveness of the test, but on the other hand, and because of nowadays lacks of understanding in reverb chamber's mechanism, the test is considered as non-representative of reality and difficult to correlate to classic anechoic chamber tests. This paper presents a French new step into making aircraft sized reverb chamber the most intelligent and efficient may to evaluate warfare systems to HIRF. The methodology is named as "The Tolosan Method". This paper is dedicated to part 4 of the method.

Keywords: HIRF, reverberation chamber, governmental experts

1. Introduction

The increasing use of reverb chambers into EMC and especially HIRF community illustrate the great advantages obtained with this test. This test facility is easily accessible and generates great debates into EMC community about comparison with classic HIRF tests into anechoic chambers. Lots of scientific publications and numerical works deal with this subject. The Aeronautical Test Centre of Toulouse has begun, as HIRF expert of the French MoD, some works about the reverb chamber/ anechoic chamber/ OATS/ real HIRF Environment transformation some years ago. Those works are conducted under a research program named KLIFOR which is financed by DGA Electronic Warfare department and will define a methodology for over HIRF qualification of warfare systems. The expected methodology is divided in 6 parts and the fourth one is presented in the following lines. Firstly presenting some elements about difficulties to compare different classic test techniques, secondly describing a way to assess a relation between aircraft sized reverb chamber environment and real HIRF environment, this paper defines the justification for French MoD to use aircraft sized reverb chamber as a reliable HIRF evaluation test facility.

2. Comparison between anechoic and reverb chamber

2.1 Difficulties

The reverb chamber radiated susceptibility test technique as been introduced into EMC standards as MIL STD 461E and Eurocaé DO160D some years ago. This new technique is now considered as an alternative to the anechoic radiated susceptibility test only for equipment. Nevertheless, only very few international elements and results present a comparison of susceptibility test with both techniques.

The 30 years experience of CEAT with radiated susceptibility test on equipments and complete warfare systems as aircraft, missile or army vehicle, make us considered different types and levels of susceptibilities to HIRF. The facts show that an electronic susceptibility is usually depending on test facility, metrology quality, test laboratory, time of the test. In our opinion, the influence of these parameters cannot help studies concluding about the equivalence between anechoic and reverb chamber tests.

Some subjective arguments are also taken into account. Firstly, the anechoic chamber test is the oldest one; and many electronic equipment have already been qualified this way. Actually, people claim from reverb chamber methodology strong requirements to be considered as an alternative to classic anechoic test. Secondly, the anechoic chamber test is often done with only one threat incidence and then considered as a faster radiated susceptibility test.

However, mysterious equipment's susceptibilities that only occurred inside reverb chamber and higher reached EMC levels obtained inside reverb chamber expose undoubted advantages of exhaustiveness and severity in the vicinity of flight clearance in HIRF environment for governmental experts.

The difficulties encountered by different test centres and scientific team to compare the both techniques made us think that advantages of reverb chambers should be kept in mind for complete warfare systems and studied in a different way to establish a link between a real HIRF illumination and reverb chambers' environment.

2.2. A new way to make MoD experts confident with reverb chambers

This objective should establish that reverb chamber technique is not only exhaustiveness and severe but also representative of a real HIRF illumination and then is one of the excellent means for a governmental expert to assess elements for flight clearance in HIRF environment.

Because of the difficulties previously encountered with anechoic versus reverb chamber comparison, we decided to search a demonstration for use of reverb chamber environment by comparison of:

- Anechoic chamber test environment vs. real HIRF in-flight illumination

- Reverb chamber test environment vs. real HIRF in-flight illumination

The work is foreseen with the help of numerical simulation tools and modelling of the problem and completed by measurements.

2.2 The expected methodology

The methodology developed compare evolution and characteristics of electric field in a close area of a flying aircraft when it is under HIRF illumination and inside reverb chamber's environment.

The results presented in the next paragraphs concern one of the first steps of the study. The numerical simulations are realised on a simple missile to estimate future requirements to apply the calculations to a whole aircraft.

3. Real HIRF illumination

3.1 Problem modelling

Several remarks, results, and industrial analyses to cover HIRF susceptibilities obtained during complete HIRF tests on fighter aircrafts and helicopters, made me think that classic anechoic HIRF test with local illumination and high powered magnetrons and TWT amplifiers is some times far away from what happened near an aircraft under global HIRF illumination.

A first point was to see what happened when a system like a missile is experiencing a real HIRF far field illumination (see fig.1).

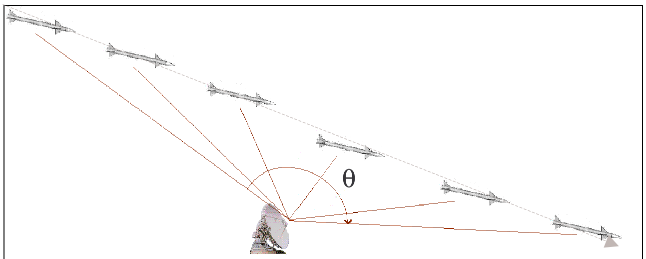

Figure 1: missile under HIRF (-90 to 90° incidence)

In the entire study, different cases of illumination are considered in order to get an increasing understanding of the phenomenon:

- unique incidence in far-field region,
- several successive incidences in far-field,
- several successive incidences in near-field,

The case of successive plane wave illumination of the missile is presented here. The numerical calculation of the total electric field is computed at any point of a regular volume around the missile (see fig.2). The total electric field is the result of superposition of the incident field, the reflected and the scattered field. The calculation is done for each threat incident every 5° with an incident plane wave (amplitude = 1 V/m, frequency = 1.3 GHz)

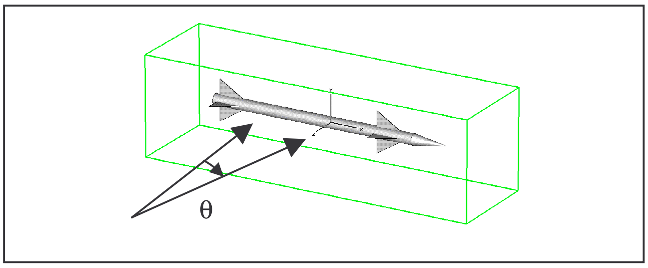

Figure 2: calculation volume for each threat incidence

The idea is to imagine a missile coming from far away, then passing near a radar a going far away again. In the reality missile is going very fast and the radar is rotating. That creates several cases of illumination during the time during which the missile is illuminate by the radar.

3.2 Single incidence result

A single result (incidence = -45° in horizontal plan) shows the existing standing waves around the missile composed by scattered, reflected and incident field(see fig.3).

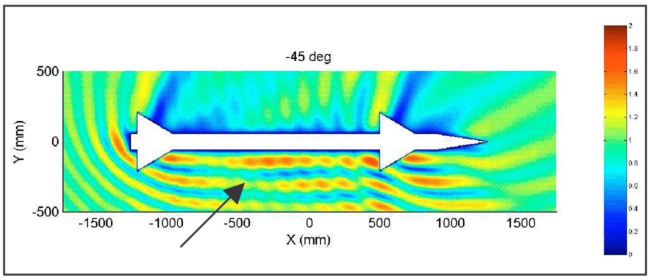

Figure 3: single result for -45° threat incidence

This first result shows the complex nature of the local E field around the missile during HIRF illumination because of geometric details of the missile. This effect should be amplified in the case of a complete fighter aircraft modelling.

The next result is obtained for the -90° incidence (front incidence, see fig.4). Effects of the missile geometry make results as complex as possible.

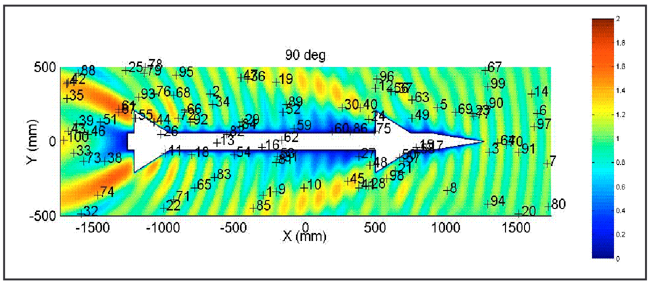

Figure 4: front threat incidence

3.3 Successive incidences results

The same calculation is made at each incidence from -90° to 90°. It gives the possibility to see the variation of the E field on a single missile relative point during the successive illumination. The fig.5 gives the result for the point n°34 in the horizontal plan (see fig.4).

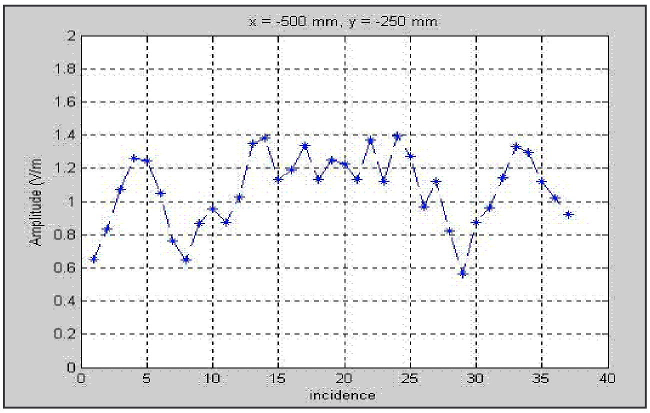

Figure 5: E field evolution with threat incidence

As a first remark, E field evolution at a single point seems to take some random values. Auto-correlation calculations over a complete set of threat incidence show that E field values do not seem to be correlated.

A statistical analysis of the E field's evolution at each point of the volume shows that electric field components follow a known statistical law. The application of the Kolmogorov test confirms that E field components values follow a Chi² law (see fig.6).

For:

$$Dn = \sup |CDF_{Chi^2} - CDF_{Efield}| \qquad [1]$$

CDF: Cumulative Distribution

For a 95% confidence level and 37 incidences, the Kolmogorov test predicts adequate statistical law for:

$$Dn < 0.218 \qquad [2]$$

Calculation at point n°34, for example, shows that: **$Dn_{pt\ n°34}$ = 0.0667**. Same kind of conclusion can be made for every point of the regular volume.

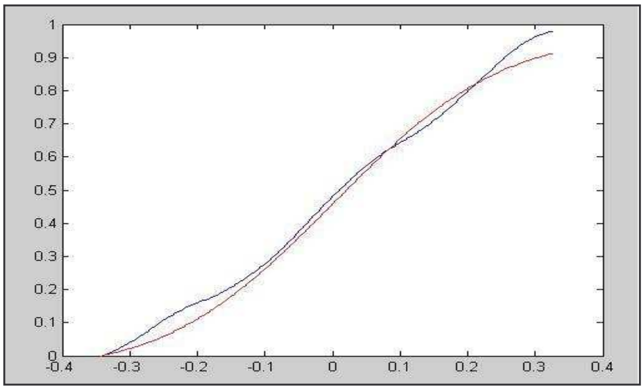

Figure 6: Kolomogorv test result at point n°34

3.4 Evolution of the maximum E field over the incidence

The study of the distribution of the maximum E field values over the different threat incidences give a new specific information (see fig.7).

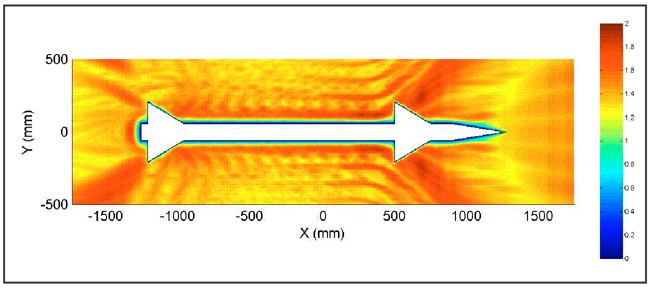

Figure 7: max E field over a complete illumination

Considering the maximum E field at every point of the volume, over a complete illumination (from -90° to 90°), the max E field is driven by the same known statistical law (see fig.8) and the standard deviation of max E field values do not exceed 1.5 dB.

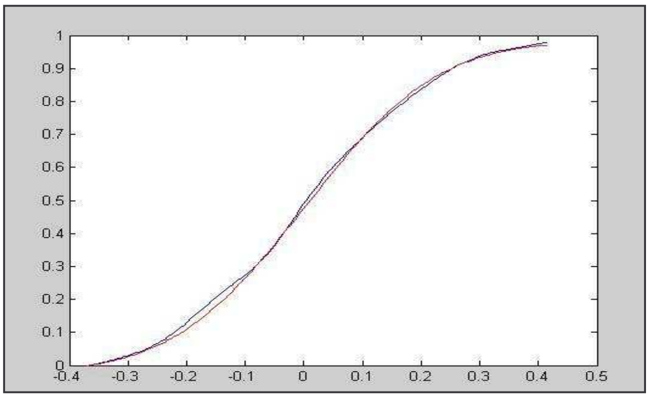

Figure 8: CDF for max E field (complete illumination)

These different results present a new possibility to link real HIRF illumination with reverb chamber illumination by the description of a specific scenario and the identification of common E field distribution.

4. From reverb chamber to reality

Components of electric field inside reverb chamber follow Chi² statistical law over a complete turn of the stirrer. These characteristics propose us a way to derive the real HIRF **perimeter** covered by an evaluation/qualification of a complete system into an aircraft sized reverb chamber.

The on going complete study will execute numerical calculations on a real fighter aircraft as Rafale. Dimensions and irregular forms will amplify scattered field effects and maximised statistical dependency.

First results show us that evaluation in reverb chamber of an aircraft can cover a perimeter of HIRF illumination by plane wave in the far-field region. Scattered effects seem to drive statistical phenomenon, and following steps of the study with introduction of near-field effects (correction factor, irregular free space impedance, E field variation on short distance) will manage a more and more accurate description of relations that promote the reverb chamber as a representative test facility.

As a connection with coaxial-return techniques and the low frequencies HIRF qualification methodology developed in the KLIFOR project, a measurements campaign of skin magnetic field will be done on an aircraft in the aircraft sized reverb chamber named "EMILIE" at CEAT in Toulouse. The distribution of skin magnetic field seems to be a good parameter to find measurable relations to derive conclusions about the reverb chamber E field amplitude controversy between MILSTD 461E and DO160D.

5. Conclusion

Numerical simulation helps us to describe what happened near an aircraft during HIRF global illumination. This methodology to link reverb chamber's environment and real HIRF illumination is known as the "Tolosan method part 4".

The aim of this study is to find elements to quantify the HIRF perimeter covered by a full test into an aircraft sized reverb chamber. Different links have to be quantified:

- Reverb chamber vs. Real illumination
- Reverb chamber vs. several incidence classic test

6. Aknowledgment

In addition to coaxial-return techniques [1] for HIRF evaluation, aircraft sized reverb chambers offer the possibility to automate in different ways a complete HIRF test. It gives the possibility to execute global illumination testing with excitation of all weak points of a complete system at the same time. For a same test time, reverb chambers offer the possibility to achieved more numerous and accurate results. Everybody in aeronautics EMC community is aware of saving test time, and aircraft sized reverb chambers give us an opportunity to make it in a smart way. It is quite sure, that such a test will stay difficult to understand and long to convince for some of us. Same was for other previous technique…

7. References

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8. Glossary

HIRF: High Intensity Radiated Field

EMC: Electromagnetic Compatibility

CEAT: Aeronautical Testing Centre of Toulouse