Security of Aircraft in the Future European Environment « SAFEE »

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Abstract— **Presented work is undertaken in the frame of the on course "SAFEE" EUROPEAN Integrated Project of the 6th European Framework Program. This is a large project designed to restore full confidence in the air transport industry, constructing an advanced aircraft security system designed to prevent on-board threats. To reach this objective SAFEE deals with onboard threat detection, studying an integrated threat detection system based on multiple sensor information. Among project's objectives is the protection of voice and data communications which are daily used for exploitation of aircraft from misuse that may lead to a dramatic situation like direct or indirect control of the aircraft by hijackers or use of false data that can endanger the flight safety. Characterization of Electromagnetic threats coupling with on-board antennas is the presented work.**

This is carried out taking different front door threats scenarios into account and looking for interference results by modeling and testing Electromagnetic intrusive signals.

***Index Terms*—Antenna measurements & modeling.**

I. INTRODUCTION

The SAFEE IP EUROPEAN project is a large Integrated Project designed to restore full confidence in the air transport industry by constructing an advanced aircraft security system designed to prevent on-board threats. The main goal of this system is to ensure a fully secure flight from departure to arrival destination whatever the identified threats are. One focuses on the implementation of a wide spectrum of threat sensing systems, and the corresponding response actions against electronic intruders. A key aspect is an integrated information management system underpinned by a secure communication system. To reach this objective SAFEE deals with onboard threat detection, studying an integrated threat detection system based on multiple sensor information. The objective is to protect communications and data that are daily used for exploitation of aircraft from misuse that may lead to a dramatic situation like direct or indirect control of the aircraft by hijackers or use of false data that can endanger the flight safety. Characterization of the Electromagnetic Threats coupling with on board antennas is the frame of the work.

This is carried out taking into account different front door threats scenarios and looking for solutions by modeling Electromagnetic intrusive signals for the Electromagnetic Threats Detection System.

II. PROBLEM OVERWIEW AND GENERAL APPROACH

The work exposed in the current paper is the determination and the analysis of the effect of an intentional electromagnetic threat coupling with on board operational antennas. Result of this work should be an important helpful element of decision on the feasibility and of such a scenario attack of the aircraft.

To deal with this it is decided to use numerical approach involving high advanced level numerical tools. This enables us to consider a large amount of scenarios test cases, which is of a great interest of our problem.

The choice of a "generic" aircraft description is also done. As we are dealing with front door coupling, which is obviously the most critical coupling path considering threat possible scenarios, one have considered different antennas on board the aircraft, mainly of communication type.

Figure below shows al the general organisation chart leading to the assessment of the threat scenario.

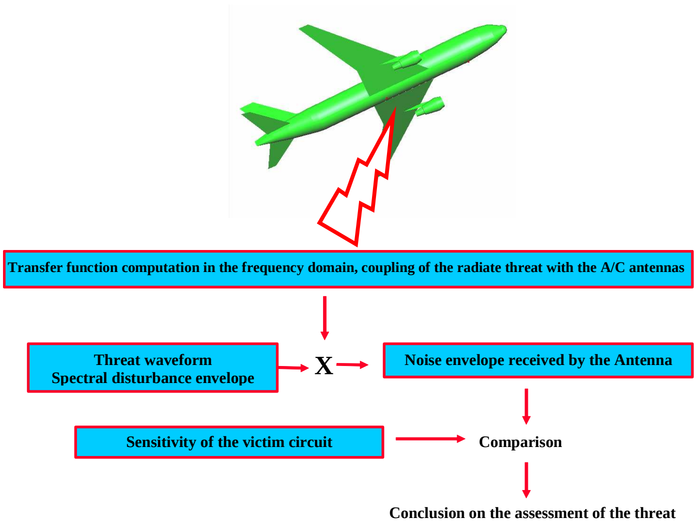


Figure 1: General organization chart

III. ANTENNAS

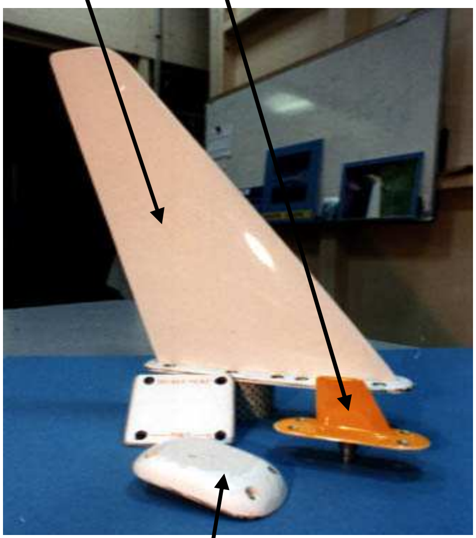
One considers omni directional and directive types of antennas with the following technologies implemented on a generic aircraft.

A. *Antennas retained technologies are:*

Blade, Monopole, Patch, Loops

B. *Considered antennas are:*

- VHF 118 MHz – 136.975 MHz
- ATC 1.09 GHz



- IRIDIUM/GPS 1.57542 GHz
- MLS 5.031 GHz – 5.0907 GHz

IV. CALCULATION TECHNIQUE

A. *Antennas intrinsic susceptibility*

In all cases the antennas are studied using the Method of Moments “MoM” technique.

B. *Calculation technique of antennas implanted on an Aircraft*

The influence of the structure on the pattern is calculated by one of the two following techniques depending on the frequency:

Up to 1 GHz:
Method of Moments “MoM”+ Fast Multipole Method “FMM”

Upper 1 GHz:
Asymptotic Method
Frequency domains overlap at around 500 MHz.
“Fast Multipole Method” [1] computations are performed using global model including the antennas implemented on the structure.
Source model: voltage sources are placed at the antennas feeding points allowing obtaining their input impedances.

V. MEASUREMENTS TECHNIQUES

The antenna radiation pattern is the display of the radiation properties as a function of the spherical coordinates. In most cases, and more specifically in the case of our antenna under test, the radiation pattern is determined in the Far Field region. One determines the amplitude and the phase characteristic of the AUT (Antenna Under Test). Transmitter and receiver antennas are separated by a large enough distance in order to simulate free space propagation. The AUT is illuminated by a source antenna (horn bi polarisation) at a distance enough to create a near planar phase front over the aperture of the AUT (Antenna + ground plane). The criteria commonly used to determine the minimum separation distance limits the phase taper < 22.5 °, measured from the centre to the edge of the ATU. The mathematical expression is given by:

$$R > 2D^2/l$$

- R is the distance between transmit and receive antennas,
- D is the aperture of the antenna under test
- L is the measurement wavelength.

In our configurations, the maximal frequency is 6 GHz (5 cm), and the total aperture is 300 or 600 mm (size of ground plane user during the test). R must be greater than 3,6 m. in the anechoic chamber of EADS CRC, R is equal to 8,5 m, large enough to obtain a plane wave.

Antenna radiation patterns are measured at the nominal frequency Fo, and in a specific case, at 2Fo and 3Fo.

A. *Input Impedance and VSWR*

Input impedance is defined as the impedance presented by the antenna at its terminals. If the antenna is not matched to the transmission line, a standing wave is induced along the transmission line. Input impedance are measured on a wide band of frequency, specifically to verify the matching at 2Fo and 3 Fo (Fo nominal frequency).

B. *Instrumentation*

The Antenna under Test is mounted on a two axes positioner, with two orthogonal rotational axes. Hyper frequency instrumentation is coming from “Agilent Technology” with a RF synthesizer and a Microwave receiver HP8530. Pre calibrated Standard Gain Antennas (NARDA Horn) are used to determine the absolute gain of the AUT. The polarization measurement requires a bi polar horn as transmitting source. In this case, no rotation of the source is necessary.

Comparison with suppliers "datasheets" for both input impedance "Zin" & far field pattern.

The antenna "phase centre" is a parameter of interest. Special attention should be dedicated to it.

Note:
- o Get the E field pattern at the central frequency
- o Zin + E field pattern are obtained at the central frequency and at higher harmonics in order to provide all the data necessary to estimate the coupling of these antennas with an external incident plane wave (in band and out of band).

The aim of calculation is to establish the input signal at the antenna phase centre.
Validations between measurements and modeling are done by comparison at the operating frequency with the SWR and "Zin" values specified on the corresponding data sheets. Then one ingests antenna characteristics (S21 & pattern) in the calculation.

VI. Considered Configurations

Once antenna models are validated one implement the considered antennas on the generic aircraft as shown in the figure below.

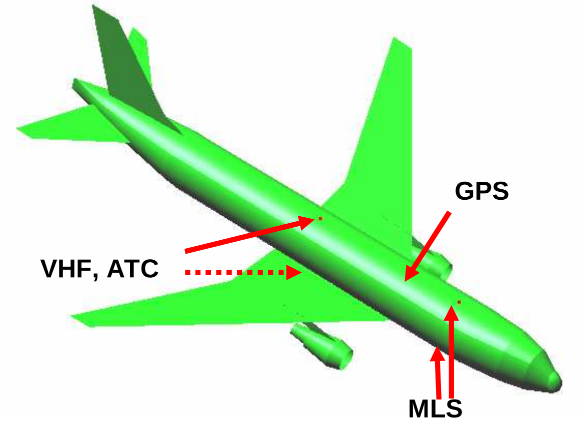


Figure 2: Antennas implantation on the aircraft

Finally the aircraft with on board antennas computation gives the constraints levels obtained at the antennas levels. One may establish the output as the result of the product of the previous computed function transfer and the threat Fourier transform. Lastly one may establish if a jamming and/or hacking attempt has been performed and if it is, use the Electromagnetic Threats Detection System to send a flag alarm.

Considered scenarios of threats are presented below:
- OXY Horizontal plan Θ=90°
- OXZ Longitudinal plan φ =0°
- OYZ Transverse plan φ =90°
- Θ inside Longitudinal plan OXZ varies from 90° -> 180°
- Φ inside Horizontal plan OXY varies from 0° -> 180°

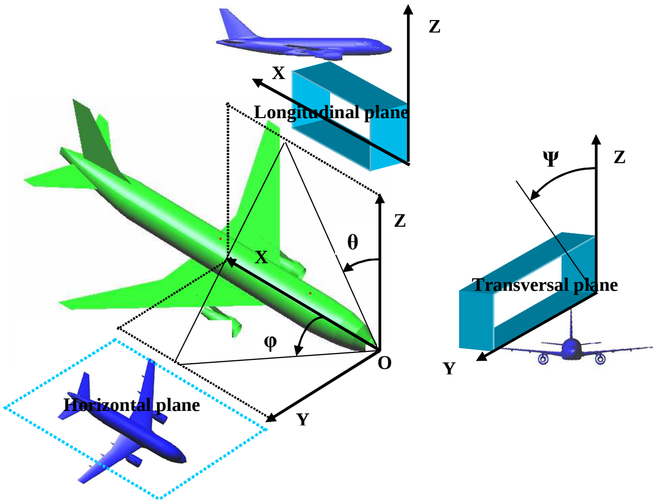


Figure 3: Definition of the axis on the aircraft

<u>450 considered configurations cases</u> have been studied:

φ	Θ : 90° -> Step variation : 2° -> 180°
0°	E field Horizontal polarisation, Vertical polarisation
45°	//
90°	//
135°	//
180°	//

Table 1: Definition of threats scenarios configurations

VII. Modeling of Antennas & Their Susceptibility When on Aircraft

A. Computed obtained results

One presents in the following antennas pattern computation according to the descriptions below, at the nominal frequency of F0: (Etheta : Ez; Ephi: Ey)

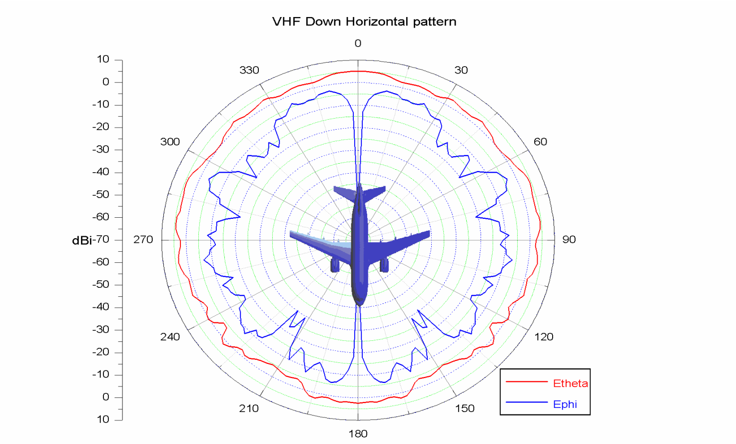


Figure 4: VHF down antenna pattern in horizontal plan

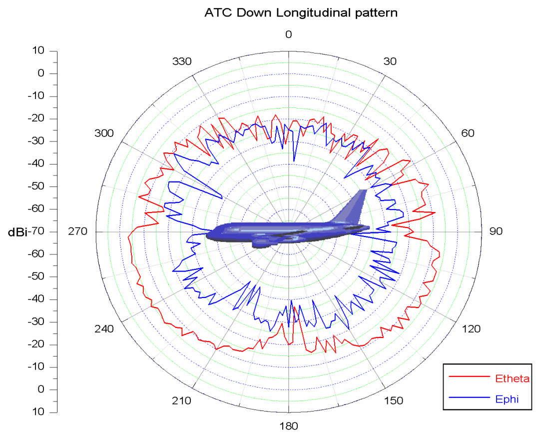


Figure 5: ATC down antenna pattern in longitudinal plan

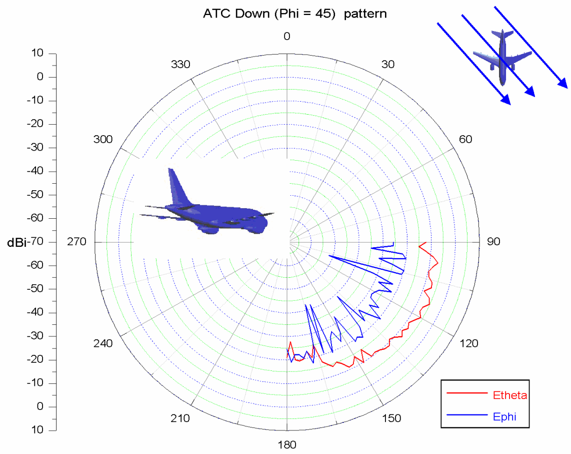


Figure 8: ATC down antenna pattern in plan φ=45°

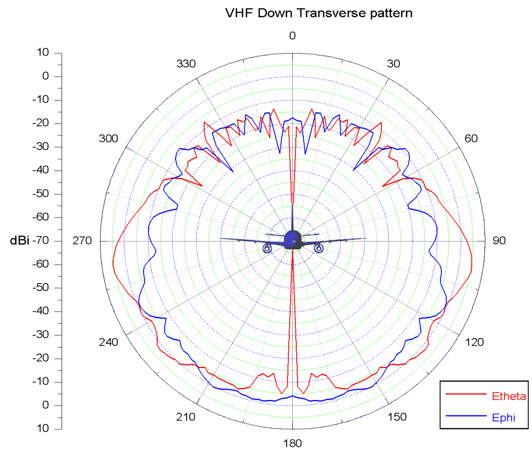


Figure 6: VHF down antenna pattern in transversal plan

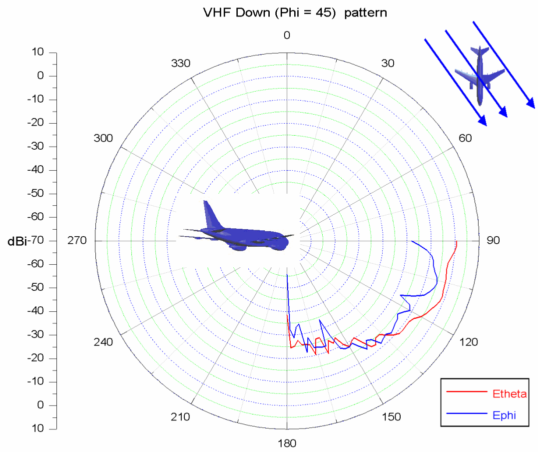


Figure 7: VHF down antenna pattern in plan φ=45°

B. Analysis of the results

Obtained computed antennas patterns at the nominal frequencies (F0) well correspond to classical obtained one when measured on a metallic scale aircraft in an anechoic chamber. Same kinds of results have been obtained out of band in particular cases of 2F0 and 3F0. One may observe that at the frequency of 3F0 antennas susceptibilities are of the same out of order as the nominal frequency ones.

VIII. MEASUREMENTS OF THE VHF ANTENNA

A scaled generic aircraft (1/18) & a VHF implemented antenna mock-up was used for the measurements. The coupling to an antenna depends both on its input impedance (S11 parameter) and on its antenna gain in a specific direction. The far field pattern is consequently required to quantify the coupling. This far field pattern was measured as indicated below:

- frequency range [2GHz-20GHz] (801 pts) covering F0 up to 10*F0
- "H" horizontal & "V" vertical polarisations

The test cases configurations are the following (see figure 2).

VHF2 Configuration «in flight» (no landing gear & flaps outside)

- longitudinal plan (φ=0°) θ varies from -110° up to 110°
- transverse plan (φ=90°) Ψ varies from -110° up to 110°
- Plan(φ=30°) θ varies from -110° up to 110°

VHF2 Configuration «take or landing» (landing gear & flaps outside)

- longitudinal plan (φ=0°) θ varies from -110° up to 110°
- Plan(φ=30°) θ varies from -110° up to 110°

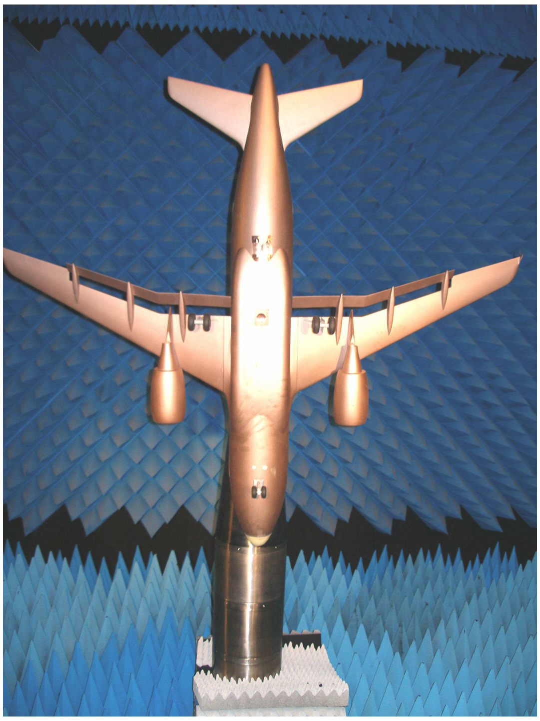


Figure9: Configuration «take or landing» (landing gear & flaps outside)

The results obtained are presented below:

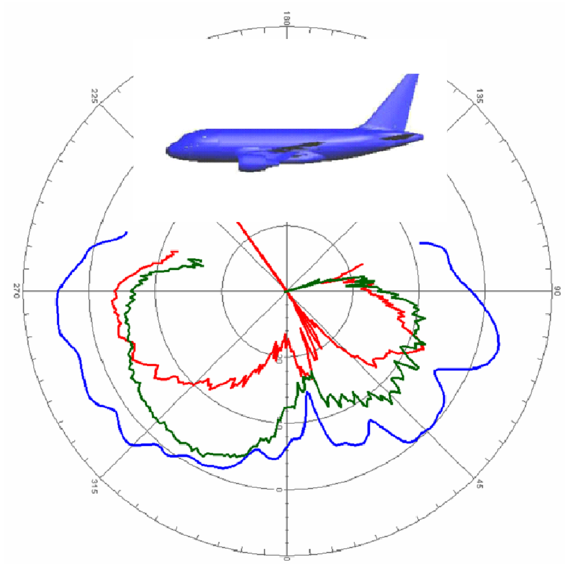


*Figure10: Configuration «in flight» (no landing gear & flaps outside); Longitudinal plan (φ=0°)   θ varies from -110° up to 110°; "H" polarization; blue: F0; red: 2*F0, green: 3*F0*

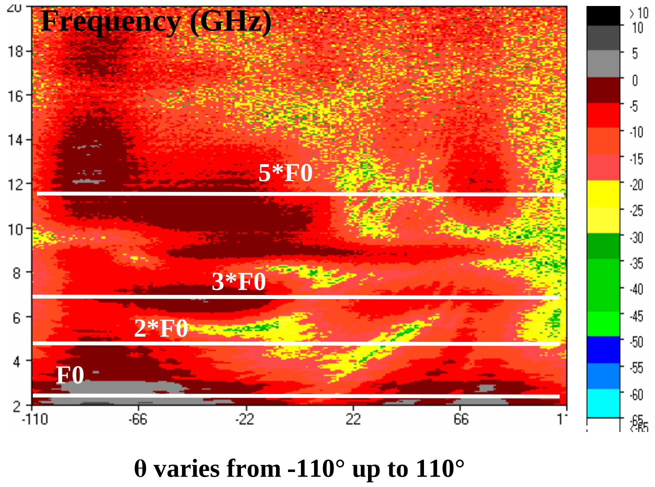


*Figure11: Longitudinal plan (φ=0°); The coupling versus frequency exhibits two more sensible regions, one around F0 (2.34GHz on the plot) and the second one at 3*F0; At higher frequencies (around 5*F0) the coupling looks still acceptable but the antenna is totally mismatched.*

IX. Conclusion

This work was aimed to determine the coupling of an electromagnetic intentional threat on an aircraft. Measurements and computation of antennas mounted on a generic aircraft were performed for the far field pattern and for the S11 parameter at frequencies of F0, 2F0 and 3F0. The most critical directions exhibiting the highest values for the coupling were found. The next step will consist in considering particular threat waveforms to compute the coupling level.

Acknowledgment

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References

[1] G. Sylvand, "La méthode multipôle rapide en électromagnétisme : Performance, parallélisation, applications." Thèse de doctorat de l'Ecole Nationale des Ponts et Chaussées, soutenue le 7 juin 2002.