DIGITAL AVIONICS SUSCEPTIBILITY TO HIGH ENERGY RADIO FREQUENCY FIELDS

WILLIAM E. LARSEN
FEDERAL AVIATION ADMINISTRATION
NASA AMES RESEARCH CENTER
MOFFETT FIELD, CA

ABSTRACT

Generally, noncritical avionic systems for transport category aircraft have been designed to meet radio frequency (RF) susceptibility requirements set forth in RTCA DO 160B, Environmental Conditions and Test Procedures for Airborne Equipment. Section 20 of this document controls the Electromagnetic Interference (EMI) hardening for avionics equipment to levels of 1 and 2 V/m. Currently, United States equipment manufacturers are designing flight critical fly-by-wire avionics to a much higher level.

Since early 1986 the FAA has recognized that new standards were required for the protection of critical electronic control systems from high energy RF fields. This came about from reports of military accidents attributed to RF fields by civil transmitters, the increased use of composite materials and the introduction of electronic control systems.

The criteria used for certification of aircraft by the FAA for protection of critical electronic control systems is: each system, whose failure to function properly would prevent the continued safe flight and landing of an airplane, must be designed and installed to ensure that its operation and operational capabilities are not adversely affected when the airplane is exposed to externally radiated radio frequency energy envelope contained herein.

This environmental standard does not address modulation nor specific equipment test frequencies. The critical susceptibility frequencies and modulation factors for the particular aircraft configuration must be included in the certification test plan submitted by the applicant.

When making an assessment of a system as to whether or not it is flight critical the basic safety level in the airworthiness standards must be used. Also considered in the assessment is whether the system is momentarily interrupted or fails to continue its intended function. Another significant consideration is the continued airworthiness of these flight critical systems; therefore, a surveillance method must be considered.

INTRODUCTION

The next generation of commercial aircraft will be constructed with a greater percentage of composite materials and flight critical fly-by-wire control systems thus requiring protection from high-energy electromagnetic fields to an extent not seen in aircraft now in service (Ref. 1). The principal threat to these new systems will be from radiated electromagnetic energy from very high power broadcast, communication, and radar facilities. Today these radio frequency (RF) generating sources reach power levels of 30 MW effective radiated power and more (FPS-85 radar systems).

By the year 2000, magnetocumulative generators will be coming on line with capabilities up to 500 MW at frequencies below 100 MHz. Within this same time frame avionics systems employing VHSIC/VLSIC devices will be in wide use. Overall system hardness exceeding 100 dB will be necessary over much of the microwave region where these devices are subject to upset (Ref. 2).

Modern avionics systems using VHSIC/VLSIC technology will have a noted increase in system susceptibility as the integrated circuit devices become more dense. The electromagnetic susceptibility of these devices to upset is caused by transient electrical voltages which create a nonpermanent and undesirable logic state which shows up in the output as systems error. This form of system upset occurs at far lower levels than to cause damage, leaves no trace and most often is not repeatable. In general, integrated circuit electromagnetic interference will be dependent not only upon the incident disturbance amplitude, modulation and frequency, but also on the devices clock rate, pulse width, pulse repetition frequency, and the flow of information processed (Ref. 3).

These modern systems must be designed and constructed electromagnetically hard not only at the time of manufacture, but also throughout their lifespan. Although electromagnetic hardness degrades with time in many ways, experience suggests that only a few coupling mechanisms are involved in any significant degradation. The
These standards are only to address susceptibility advanced technology airframe and flight systems criteria related to high-power broadcast, communication, and radar threats. This action is being appropriate electromagnetic susceptibility standards and guidance material for industry to define higher standard for the high-frequency band between 2 and 30 MHz.

In light of the need to upgrade these specifications, the FAA has provided technical information for frequencies between 15 kHz to 35 MHz but Category Z equipment qualified to this standard band from 118 to 136 MHz. A similar standard is imposed for the VHF communications capability of airborne equipment is contained in the FAA has provided technical information for both internally and externally radiated source control problems have been attributed to this threat. Since flight control systems in use in the commercial fleet are considered nonflight critical, no concern has been paid to EM energy radiated from nonaircraft sources other than lightning. Secondly, there has not been until very recently a data base of radiated RF energy for broadcast, communication, or radar sources available to the civil community.

It must be noted that the most stringent standard imposed by the FAA for electromagnetic susceptibility of airborne equipment is contained in the previously mentioned RTCA DO 160B, Environmental Conditions and Test Procedures for Airborne Equipment. Sections of this specification control the level of hardening for avionics equipment to RF radiated and conducted energy. Electromagnetic field strengths specified in this document are based on energy levels found within a transport airplane for both internally and externally radiated sources. To date no major commercial aircraft control problems have been attributed to this threat. Since flight control systems in use in the commercial fleet are considered nonflight critical, no concern has been paid to EM energy radiated from nonaircraft sources other than lightning. Secondly, there has not been until very recently a data base of radiated RF energy for broadcast, communication, or radar sources available to the civil community.

Until very recently there has been a general lack of information (in the civilian community) as to the magnitude and frequencies of the radiated electromagnetic threat from broadcast, communication, and radar sources. To fill this void the FAA contracted with the Electromagnetic Compatibility Analysis Center (ECAC) for a description of the electromagnetic environment a typical civil transport aircraft might encounter during normal operation. The ECAC has provided calculated field strengths in the form of an RF envelope for worst-case conditions.

DATA BASE AND CRITERIA

Aircraft avionics is being affected by radiated electromagnetic energy from various sources. Many of these sources are shown in Fig. 1. Figure 2 depicts the frequency and type of RF energy found in the environment. Transport aircraft avionics are particularly susceptible to threats in the range of 1.5 to 300 MHz (Ref. 7, Table 1.1–5), with smaller aircraft and rotorcraft influenced by a slightly higher range of frequencies. To develop an electromagnetic energy envelope of the threat for aircraft near airports the following
criteria were assumed (Fig. 3): 1) 250-ft protection for operations on the airport surface; 2) 2.4% gradient for approach until reaching an altitude of 300 ft; and 3) 300-ft protection between 1.84 nautical mile (n. mi.) and 4.5 n. mi. at which time the protection boundary goes to 500 ft above the altitude of any emitter.

Figure 4 displays the predicted maximum average field strength existing at six U.S. airports assumed to have the worst electromagnetic threat levels. The airport information is then compared with the total possible electromagnetic environment present at 500-ft altitude above any emitter throughout the CONUS. Both maximum and average threats are presented to allow the reader to extract duty cycle of the threat for those frequencies where the signal is pulsed. Figure 5 compares the maximum peak field strength for the same six airports considered to have the most severe threat in the United States. Foreign and domestic airport information is then compared to establish a total possible electromagnetic environment that will be present at altitudes of 500 ft above potential emitters.

The data and criteria have been shared with the European authorities and graphically compared with British, French, and NATO data (Figs. 6-8). The French data have been verified through actual measurement whereas United States and British data to date are analytical. The FAA plans to measure selected sites within the United States for comparison and verification purposes.

CONCLUSION

The FAA has requested that the RTCA SC-135 High-Energy Radio Frequency (HERF) working group develop appropriate testing procedures for Section 20 of RTCA DO 160B for radiated and conducted susceptibility at the box and systems level. The FAA has also requested the SAE ABAR committee to address installed systems testing, airframe shielding effects, and RF environment monitoring.

Emitters of interest include radar (ground, ship, and aircraft) commercial broadcast and TV station, mobile communication, and other transmitter that could possibly affect commercial aircraft.

**ELECTROMAGNETIC ENVIRONMENT**

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>AVERAGE FIELD STRENGTH V/m</th>
<th>PEAK FIELD STRENGTH V/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 KHZ - 3 MHz</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3 MHz - 30 MHz</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>30 MHz - 100 MHz</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>100 MHz - 200 MHz</td>
<td>200</td>
<td>3000</td>
</tr>
<tr>
<td>200 MHz - 1 GHz</td>
<td>2000</td>
<td>6000</td>
</tr>
<tr>
<td>1 GHz - 2 GHz</td>
<td>2000</td>
<td>14000</td>
</tr>
<tr>
<td>2 GHz - 8 GHz</td>
<td>600</td>
<td>14000</td>
</tr>
<tr>
<td>8 GHz - 10 GHz</td>
<td>2000</td>
<td>14000</td>
</tr>
<tr>
<td>10 GHz - 40 GHz</td>
<td>1000</td>
<td>8000</td>
</tr>
</tbody>
</table>

REFERENCES


Fig. 1 Typical electromagnetic environment.

Fig. 2 Radio frequency range.
Fig. 3 Criteria for susceptibility threshold.
Fig. 4 Average field strengths of selected takeoff/landing environments within the United States, United Kingdom, and France.
Fig. 5 Peak field strengths of selected takeoff/landing environments within the United States, United Kingdom, and France.
Fig. 6 Average field strengths for the total worst-case environments of the United States, United Kingdom, and France.
Fig. 7 Peak field strengths for the total worst-case environments of the United States, United Kingdom, and France.
Fig. 8 Predicted maximum average field strength levels comparison of United States composite with NATO STANAG.