Important and Interesting Aspects of Electromagnetic Compatibility

Learning by doing in avionics

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Safe flight and landing for aircraft is the goal of aircraft electronics, referred to as avionics. The pilot needs information from instrumentation that will not be lost regardless of the hardships it may face in the flight environment. The environmental testing for these systems is quite extensive and ensures that the instrumentation is immune to many elements. Some of these are extremes of temperature, pressure, humidity, vibration, fluids and corrosive compounds, electrostatic discharge (ESD), several kinds of electromagnetic interference (EMI) from various sources, and power supply voltage (including spikes, interruptions, and induced signals). This article describes the author's first industrial experience with electromagnetic compatibility (EMC) testing and certification for avionics.

My university education did not include specific courses on the subject of EMC. The concepts in my electromagnetic theory studies formed the foundation of this subject but were not applied to its specific problems. The academic experiences I had with EMC were manifested as befuddling and untimely frustrations in my laboratory classes. These were usually discovered uncomfortably near a deadline or demonstration.

Industry does not leave EMC and EMI to last minute troubleshooting. I was introduced to these concerns after graduation when I began work with a company that designs and manufactures electronics for navigation, communication, and sensor instrumentation for general aviation aircraft. General aviation refers to civilian aircraft that are not used commercially for the passenger transport or cargo industry. These aircraft include single and twin propeller planes and even some light jets.

Avionics

A modern general aviation aircraft has a surprisingly plentiful assortment of instrumentation. Setting aside the radio navigation and communication systems, the primary instrumentation needs for flight are attitude, altitude, and airspeed. Diverse engine and airframe sensors are also necessary to insure that the pilot will have the power and fuel to maintain control of these properties. Often, complementary or purely redundant sources of information are compared to check for integrity and combined for greater accuracy.

A good example of this data combining occurs in an integrated attitude, altitude, and airspeed system. In the past, these systems have

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been separate. Altitude and airspeed have been derived from clever static and differential pressure sensors. Attitude has been provided by a spinning-mass gyro driven from a vacuum pump or electrical motor. With advances in technology, electronic rate-gyros and accelerometers may also be used to perform these measurements. These data may be integrated and compared with traditional barometric (pressure) altitude, pressure/temperature derived true airspeed, and magnetic heading. The combination offers a three-dimensional picture of the aircraft's translation and rotation complete with position, velocity, and acceleration stabilized by multiple sources of data. For additional positional awareness, this may be combined with GPS and other radio navigation tools.

An RF signal must be generated, amplified to the proper level, which is frequency and modulation dependent, and transmitted toward the EUT for the appropriate dwell time before stepping to the next frequency.

It may seem like a lot of overhead to make an artificial horizon when you can look out the window and get the real thing for free. This is true if you only plan to fly when there is sufficient light and clear visibility. Under such favorable conditions, pilots operate under visual flight rules (VFRs).

However, weather and lighting conditions may obfuscate the horizon and other ground based landmarks. In these circumstances, pilots must observe instrument flight rules (IFRs). An IFR certified aircraft must meet many requirements. Among the requirements is to have instruments to replace the lost situational information and to include attitude, altitude, and airspeed. These requirements point out why environmental testing is so important for these systems.

Fig. 1. Radio frequency sniffers.

Constructing an RF Sniffer

EMI is a somewhat mysterious environmental property. Unlike most other categories of the environmental testing, it is not directly observable by physical senses. One way to observe EMI within radio frequency (RF) is to connect an RF sniffer to a spectrum analyzer (or network analyzer, if you are looking for higher frequencies) and examine a signal that is being received.

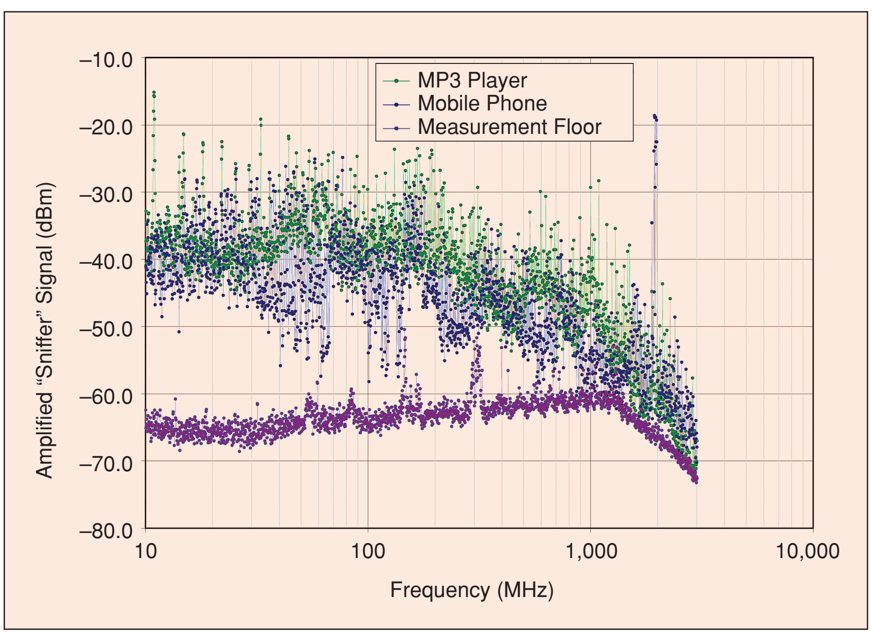

Fig. 2. Sample plot of a sniffer output.

Homespun sniffers like those pictured in Figure 1 are easy and affordable to fabricate. Take your favorite RF bulkhead connector (or spare end of a coax cable) and solder a loop (or loops) of wire to the end. Loop diameter is inversely proportional to the frequency of efficient reception. Try putting a low noise amplifier (LNA) in the line to increase sensitivity. While they are not precision devices, sniffers offer excellent qualitative insight to the RF presence in a general area. They can help you pinpoint a specific chip, PCB trace, or rogue piece of lab equipment that may be an EMI offender. They can even save rework on a prototype if, for example, you forgot to add a probe point to an oscillator and you want to verify the frequency.

Using your new sniffers, run some tests on the RF emissions of some popular consumer electronic devices. How much RF can you see coming out of a portable music player, notebook computer, or CRT monitor? Test a mobile phone when idle, receiving, placing a call, and holding a conversation. Are there different emissions during various modes of operation (including backlight operation)? Probe an unenclosed switching power supply and watch the graph come to life.

Figure 2 shows some sniffer sweeps that I took at close range of a mobile phone and an MP3 player. The plot represents relative data and not the exact power present. The sniffer probe would have to be calibrated to read the exact power but it is not intended for precision measurement. Because of this uncertainty, I also made no attempt to calibrate out the gain profile of the LNA I used for this plot.

At high powers, the amplifiers often compress the signal and cause significant distortion.

Cell Phones and EMI

The FCC has planned frequency use very well so avionics systems are not affected by typical cell phone EMI, but high sensitivity radios can be affected. Almost all aviation radios qualify as high-sensitivity. The relatively strong off-channel signals from cell phones and similar emissions from other electronic devices may degrade radio performance in the sensitive RF receivers. They can also cause glitches in both analog and digital circuits that are not designed to be RF receivers. Because of these potential problems, the tradition is to disallow the use of cell phones in aircraft to decrease the risk of interference. Always comply with your flight attendant when you are asked to turn off cell phones and electronic devices.

EMI threats to avionics also come from outside the plane. There are many high-power transmitters of various frequencies and modulations, and most are ground based. During certain stages of flight, aircraft may fly relatively close to antennas for television, communication, radar, or military use.

RF Testing for Problem EMI

Avionics must be tested to prove they will not fall prey to these problematic EMI hurdles. This RF testing is chiefly divided into two categories, emissions and susceptibility. Emissions testing assures that the equipment does not radiate an amount of RF energy that would interfere with the other aircraft systems. Susceptibility assures the equipment is immune to RF signals of various levels, frequencies, and modulations that it may see in the flight environment. Both emissions and susceptibility are further divided into radiated signals and signals conducted in the interconnecting cables and power lines. This article discusses radiated testing.

Emissions testing requires less instrumentation coordination than susceptibility. Usually, the challenge becomes how to achieve a low enough noise environment in which to make the measurements. An anechoic chamber (a sealed chamber lined with RF absorbing material) like the one in Figure 3 is often employed to conduct the test. An assortment of sensitive antennas and LNAs must be used to cover the frequency range. In turn, each is connected to a spectrum analyzer for data collection. The calibration data for the antenna, LNA, and cables under use for the frequency band are applied. This results in a field strength measurement that must be lower than the limit for the particular requirement. Figure 4, which is adapted from [1], shows the RF emission limits for equipment in direct view of a general aviation aircraft's radio antennas [1].

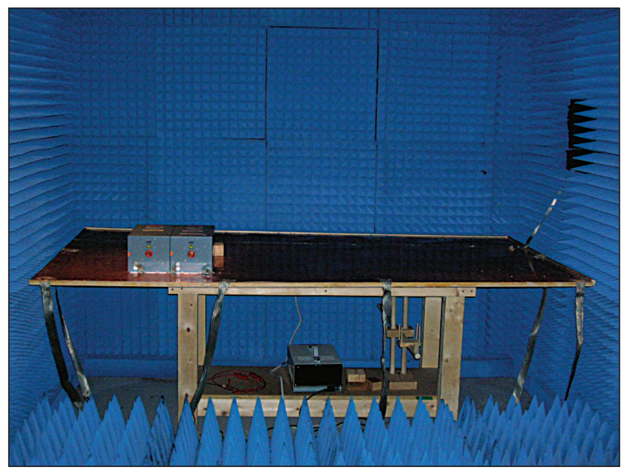

Fig. 3. Inside an anechoic test chamber.

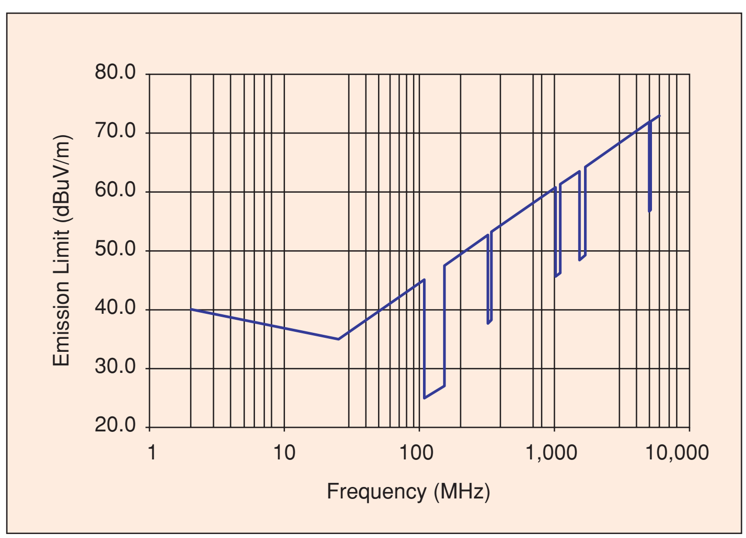

Fig. 4. An example of RF emission limits.

Notice that the requirements are much stricter in several frequency ranges. These notches align with frequencies that the aircraft uses for various navigation and communication radios. If the tests were not more demanding in these regions, various parts of the aircraft could interfere with other parts in the same aircraft.

EMI threats to avionics also come from outside the plane.

High-intensity radiated-field (HIRF) susceptibility testing quickly gets more complicated and expensive. As with emissions, susceptibility testing may be conducted in an anechoic chamber to contain the RF energy; or susceptibility testing may be conducted in a reverberation (reverb) chamber [2]. Reverb chambers are essentially sealed chambers designed to contain and reflect any RF energy within its walls. For this reason, they require less power to attain the same field strengths. However, a large RF reflecting paddle must be stepped at several angles to prevent standing wave nulls from developing in the vicinity of the equipment under test (EUT). Controlling this stepper motor adds complexity to the test procedure.

Regardless of the choice of test chamber, an RF signal must be generated, amplified to the proper level, which is frequency and modulation dependent, and transmitted toward the EUT for the appropriate dwell time before stepping to the next frequency. The EUT must simultaneously be tested for continuous proper operation. Because high-power amplifiers and antennas are, by nature, narrow band, several RF power amplifiers and antennas must be used to cover the frequency range for the entire test.

Closed-loop control of the field strength is best for this application. An open-loop calibrated sweep may not take into account factors such as the loading the EUT may have on the antenna or the drift of the gain in the power amplifier. For closed-loop control, the monitored signal power may be compared to a calibration file and adjustments made as necessary. At high powers, the amplifiers often compress the signal and cause significant distortion. This can cause under-testing if the monitored power is the total signal and not only the power at the frequency under test at the time. This usually dictates the use of a spectrum analyzer instead of a simple power meter.

All these activities must be automated, coordinated, and logged in a flexible fashion. The process requires many articles of test equipment controlled by a central machine. Some software packages exist to help with this task, but many companies and test labs opt to write their own programs to meet their specific testing and troubleshooting needs more efficiently.

Testing the System

These tests need to be performed on avionics such as the integrated system for attitude, altitude, and airspeed, which was discussed earlier. The test requirements are often quite demanding of electronic circuits. Careful planning, protection, and shielding are necessary to build an EMI immunized system.

Time may well show that having the strengths of both electronic and mechanical instruments together are invaluable in an overall system configuration. The old mechanical gauges are inherently robust in their EMI immunity. They are, however, susceptible to wear of moving parts and must pass environmental tests. Both electronic and mechanical instruments are available side by side in the same installation at an affordable price for general aviation.

Conclusions

Many engineers are interested in avoiding EMC problems because of their difficulty to troubleshoot. Having a better understanding of the threat environment and EMI requirements for instrumentation is one of the best ways to avoid troubleshooting in the EMI lab. While the actual testing can be tedious, EMI testing is a field with many intriguing instrumentation challenges. There is great opportunity for innovation in these systems, especially in automating the tests.

References

[1] "Emission of radio frequency energy," in *RTCA DO-160E Environmental Conditions and Test Procedures for Airborne Equipment*, RTCA, Inc., Washington, DC, 2004, sec. 21.

[2] "Radio frequency susceptibility," in *RTCA DO-160E Environmental Conditions and Test Procedures for Airborne Equipment,* RTCA, Inc., 2004, sec. 20.

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