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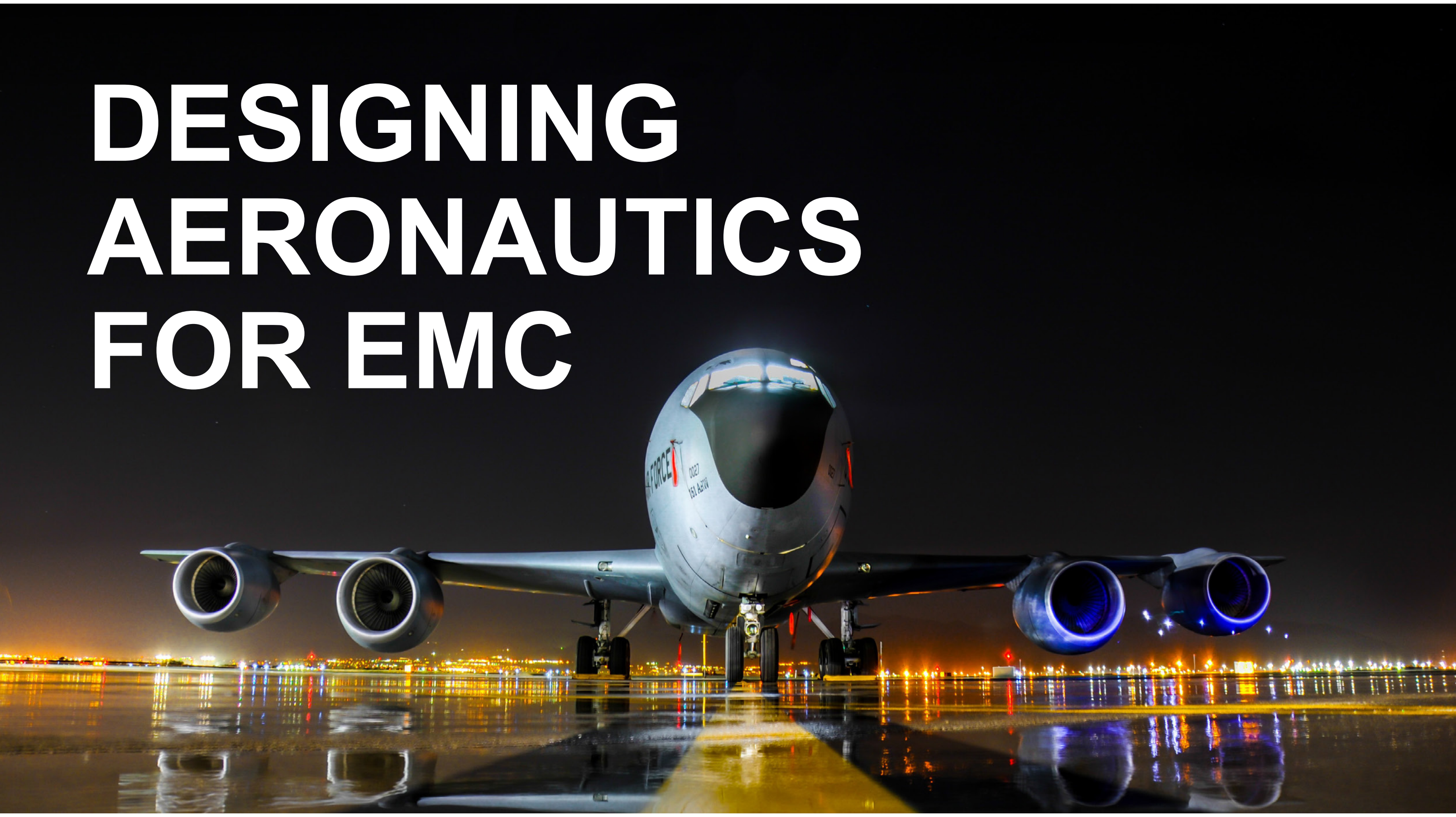
DESIGNING AERONAUTICS FOR EMC



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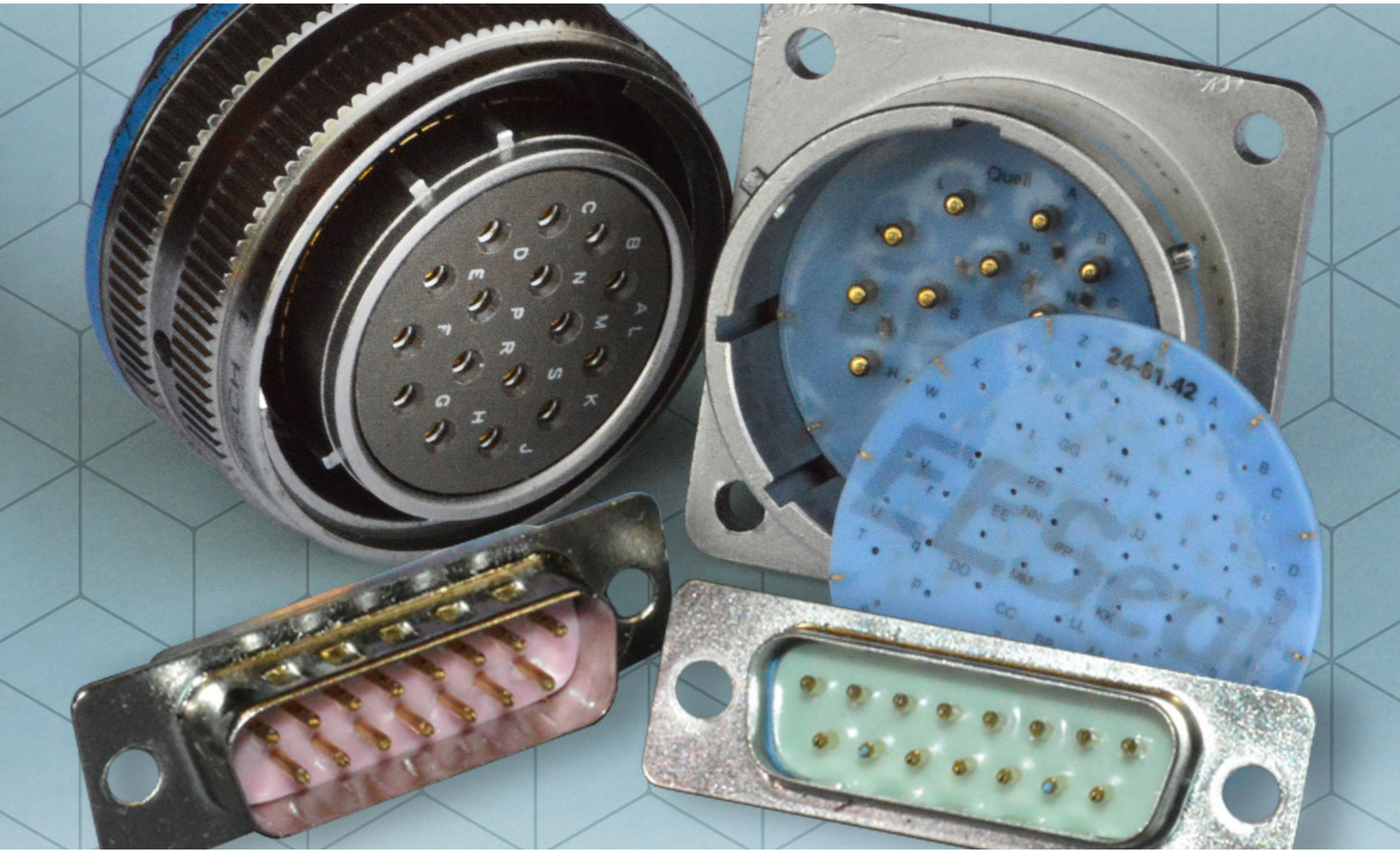
RTCA DO-160, and its international twin, EUROCAE ED-14, is an aerospace environmental standard for testing avionics hardware. It was first used in the 1940s and 1950s when testing aircraft radio equipment. An example of this is the 1954's DO-60, Environmental Test Procedures, Airborne Radio Equipment.



COMMERCIAL AEROSPACE EMC STANDARDS

Through DO-138 to the early versions of DO-160, many of the tests for electromagnetic interference (previously called radio frequency interference, or RFI) were benign and not difficult to pass. However, with the advent of semiconductors, computer software controls, and highly complex aircraft systems – paired with high power and high frequency transmitters – the tests have become robust and elaborate. In fact, the standards now often rival those found in military standards, and in some cases, exceed them.

The current electromagnetic tests found in DO-160G (the latest version as of this writing) are listed below:

- Section 15 - Magnetic Effects
- Section 16 - Power Input
- Section 17 - Voltage Spike
- Section 18 - Audio Frequency Conducted Susceptibility – Power Inputs
- Section 19 - Induced Signal Susceptibility
- Section 20 - Radio Frequency Susceptibility (Radiated and Conducted)
- Section 21 - Emission of Radio Frequency Energy
- Section 22 - Lightning Induced Transient Susceptibility
- Section 23 - Lightning Direct Effects
- Section 25 - Electrostatic Discharge (ESD)

Some of these tests are performed only on aircraft supplied power lines (Section 16, 17, 18), while one is strictly performed on non-power lines and the chassis (Section 19). However, the rest require testing on all lines of the equipment except the Magnetic Effects (Section 15) and ESD tests (Section 25). The latter is performed on the equipment case, buttons, connectors, and other points of physical contact.

COUPLED ENERGY

Since interference can be induced into any line, and emissions are measured from every line, electromagnetic energy includes that which is generated inside the equipment, as well as energy induced from outside to inside. This induced energy may occur in voltage spikes, current surges (Sections 17 and 22), or as a continuous signal coupled onto the power or signal lines (Sections 18-20). In each case, the test method is designed to replicate a worst-case aircraft environment.

FILTER DESIGN CONSIDERATIONS

To meet the requirements, each line connected to the equipment must be filtered, shielded, or both. For induced lightning testing, transient protection may be needed. For other signals, inductive and capacitive elements in filters are needed. However, for lower frequency signals, inductors may be very large and very heavy, making them inconducive for use on the aircraft where size and weight must be minimized.

To assure the quality of the filters and protection of the equipment, several aspects require consideration. These include the location of the filters, the types and quality of components used in the filters, and the symmetry of the filter itself. For example, electrolytic capacitors do not have the high frequency bandwidth needed for most environments. As for location inside a shielded enclosure, the filters need to be placed as close to the point of penetration as possible (as described in the next section).

LOCATION LOCATION LOCATION

If the filter is located at fair distance from the connector (the penetration into the equipment) it is possible for the energy induced onto the lines outside the equipment could cross-couple into sensitive electronics before reaching the filtering components. This may result in susceptibility of the equipment. Additionally, lines already cleansed of RF energy before leaving the equipment could pick up new energy from surrounding electronics before leaving the chassis. The result: filtering components are bypassed and become less effective. The lines will then radiate this energy outside the equipment, and the emissions test results will be in jeopardy.

To avoid such consequences, the location of the filter must be as close to the penetration as physically possible. This may be accomplished by using a dedicated circuit board into which the connector pins are soldered.

The mounting screws for the circuit board may be directly connected to the chassis, allowing bypass capacitors to be placed near the pins, coupling energy to a reference place, that is bonded to the chassis. The short distance between the pin, plane, and chassis helps minimize the cross-coupled energy described earlier.

COMPONENTS USED

For power lines and other DC reference signals, the use of capacitors to chassis and series inductance may be of little concern. However, the use of bypass capacitors on data lines (or other AC signals) may result in attenuation of the desired signal. To avoid this, it is important to ensure the signal is well balanced (the signal and its return are paired), and that the signal and its return are closely coupled with minimal loop area between the two lines.

This practice includes the lines inside and outside of the equipment. Often, this is best performed using a twisted pair. Finally, the use of common mode inductance should be considered, where the signal and its return are wound on a common ferrite core. This should not affect the signal but can add impedance to any energy entering or leaving the equipment.

For transient protection, the line under test must be understood before considering the size of suppression to use. In the case of power lines, the lightning impulses will be coupled directly to each line, as well as common on all lines. The resulting currents and voltages may be very high. The transient protection will often be from line to chassis, and possibly from line to line, depending on the circuit.

In the case of transients on signal and data lines, the induced signal will likely only be common mode. If the circuit is isolated, the induced currents may be relatively small, despite a high voltage impulse. Transient protection may be needed from line to line. Again, remember to choose transient suppression carefully to avoid attenuating the desired signals.

SHIELDING

Another control method is to attenuate the coupling path itself. This is accomplished using a shield. Shielding works by having the coupled energy generate a current in the shield. Currents must flow in complete loops, where the source of the current is able to flow through the path back to source.

For this to work, a shielded cable must have the shield bonded to both ends. Note that high frequency (radio frequency) currents are very sensitive to impedances, and impedance changes. These may be in the form of termination wires (sometimes called pigtails). Wires, and the loops they create, are inductive and can add significant impedance to the shield. However, a direct contact with the chassis for the termination of the shield may not be available, and the wire may be the only solution. When possible, avoid terminating the shield inside the chassis. Due to the requirement of energy into the equipment, likely through a connector, it can capacitively and inductively cross-couple into the lines being protected.

DIFFICULT ENVIRONMENTS

In avionics, the environment in which the equipment is placed may result in test levels which are very high. The environment for helicopters can require designs to meet fields of 7,200 V/m. If the equipment to be tested is sensitive to these fields and frequencies, multiple solutions will need to be considered. The installed equipment may be located near an antenna used for communication or navigation. In both cases, the equipment must include robust filtering. The lines outside of the equipment will likely need shielding. Even if both are done, further mitigation may need to be considered.

GETTING THROUGH QUALIFICATION TESTING

Laboratory testing may be costly and repetitive tests are time consuming. Deadlines may mandate more rapid solutions – and such solutions can be very difficult to discover.

To solve these issues, a very effective method is to have capacitive coupling of sensitive lines from line to chassis inside the connector. These are called filter pin connectors. The use of these capacitors can shunt the energy from the line back to the source before it couples outside or inside the equipment. These filters have minimal high frequency impedance, making the bandwidth of the solution very wide, and very effective. Although effective, the use of filter pin connectors can be very expensive, and result in long delays for design and manufacturing.

Very similar to filter pin connectors are insert style filters, which slip over the connector pins inside the connector itself. Implementation is fast and easy. They then create a capacitive path from each pin to the chassis. The results can be observed immediately. In a 50Ω system, the ratings can be up to 40 dB of attenuation. However, on high impedance lines, the use of bypass capacitance can exceed these values, providing highly effective protection and filtering for the equipment. Even late in the development cycle, where a design may be frozen, the use of these insert filters may bring the equipment into compliance with minimal time and effort expended.

If additional effectiveness is desired, consider adding any inductance onto the line, such as a common mode inductor. If the issue is emissions, then place the inductance or ferrite outside the equipment, so the path from line to chassis is low and the impedance to the line is increased. This will help to push the currents back to the chassis and return them to the source. If the issue is susceptibility, then the inductance or ferrite can be placed inside the equipment.

Quell's EESeal is an excellent device to use in these situations. When using connector pin filtering, not all lines will need the same value of capacitance. Utilizing the EESeal, smaller capacitors may be used on higher impedance and less sensitive lines. Some lines may not need filtering at all. The ability to choose these values and positions makes the filters a more valuable solution for any challenge. [i]

REFERENCES:

[i] RTCA DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment, December 8,2010

SAE Aerospace ARP5583 Rev. A, Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment, June 2006