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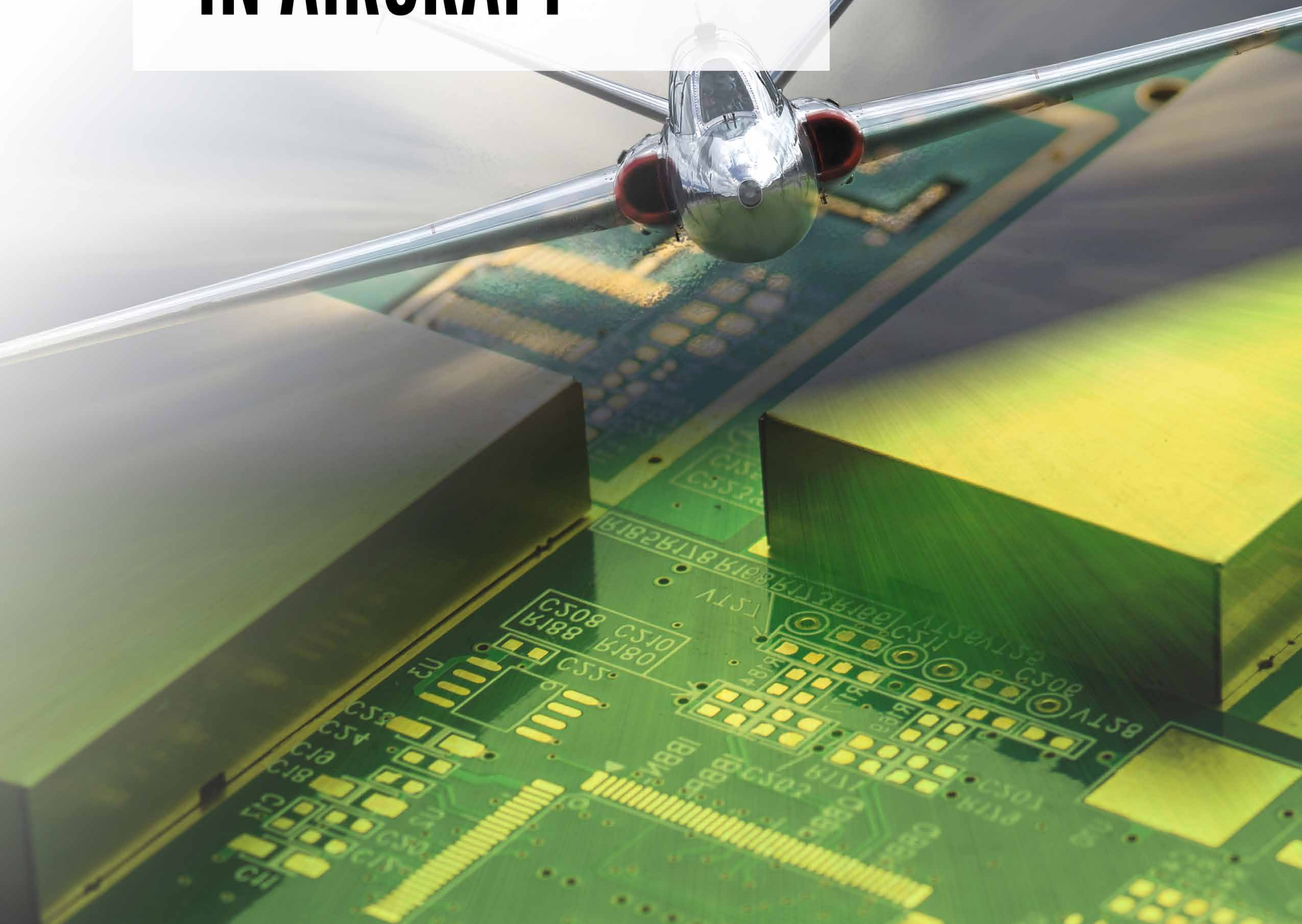
CONTROLLING THE EMI EFFECTS OF AVIONIC EQUIPMENT IN AIRCRAFT



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Not protecting avionic equipment from electromagnetic interference (EMI) can result in detrimental consequences such as degradation or even malfunctioning. EMI can affect cockpit radios and radar signals, interfering with communication between pilot and control tower. Devices that can cause interference in aircraft include laptop computers, electronic games, cell phones, and electronic toys, and all have been suspected of causing events such as autopilot disconnects, erratic flight deck indications, and airplanes turning off course. EMI effects can also come from lightning, solar flares, electrostatic discharge, and high-intensity radiated fields (HIRF) from radar and various kinds of transmitters/communications equipment—these have all also resulted in numerous aviation incidents over the years and as a result are now considered in all aspects of design and certification of avionics.

Today, it has become evident that new digital flight control systems need to be hardened to all these effects of EMI. EMI standards such as RTCA DO-160 to standardize environmental conditions and test procedures for airborne equipment or DoD’s MIL-STD-461 exist to control EMI issues. These standards limit unnecessary electronic emissions and require susceptibility requirements.

One major way to combat EMI is to provide EMI shielding of various Line Replaceable Units (LRUs). Without shielding of LRUs and harnesses, an aircraft could be at risk and become unsafe and unfit for both pilots and passengers. Shielding a device or system not only reduces EMI emissions, but also improves its susceptibility performance. With advances in wireless technology and increased signal sensitivity of devices, shielding becomes even more important to maintain the functionality and safety of avionic equipment. In most cases, manufacturers rely on shielding suppliers such as Orbel Corporation to deliver the technical capabilities and knowledge needed to suppress EMI.

What is an Electromagnetic Field?

When electrical charges are present, either moving or stationary, they generate an electric field (E-field) between these charges. If these charges are oscillating or moving, it is called a time-varying current. If there is a current flowing, then there will be a magnetic field (H-field) generated. The direction of the magnetic field can be determined by the “right hand rule” (Fig. 1). Maxwell equations tell us that these moving charges (i.e., a current flow) will not only have a time-varying H-field, but will generate a time-varying E-field. This is then an electromagnetic field. The E-field and H-field components are mutually dependent and are transverse to each other (Fig. 2).

This electromagnetic field or potential EMI is unwanted energy that can disturb other nearby electronic devices, especially important with sensitive signal levels such as GPS and the increasing use of digital communications between subsystems and systems. Because of this, there is a critical need for EMI shielding materials and their applications. These electromagnetic fields are classified by frequency. Figure 3 illustrates some of these bands. One can see how important it is to shield LRUs.

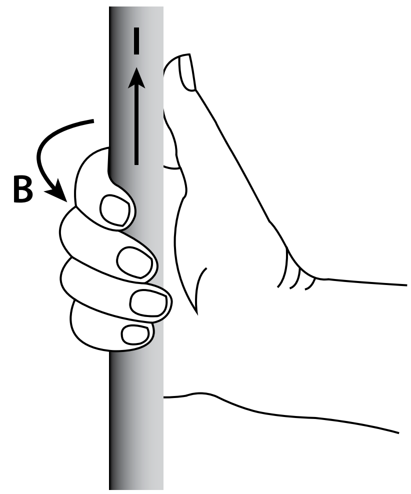

Figure 1: *The thumb points in the direction of the current flow and the fingers curl in the direction of the magnetic field.*

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Category	Frequency	Name	Usage
Radio Frequency	3 kHz - 30 kHz	VLF	Beacon
	30 kHz - 300 kHz	LF	Marine Communication
	300 kHz - 3 MHz	MF	AM Radio Broadcast
	3 MHz - 30 MHz	HF	Shortwave Broadcast, RFID
	30 MHz - 300 MHz	VHF	FM, Televison
Microwave	300 MHz - 1 GHz	UHF	Television, Microwave Oven, Mobile Phones
	1 GHz - 2 GHz	L Band	Mobile Phones, Wireless LAN, Radars, GPS
	2 GHz - 4 GHz	S Band	Bluetooth
	4 GHz - 8 GHz	C Band	Satellite Communication, Cordless Telephone, Wi-Fi

Figure 3: *Typical frequency ranges and their applications.*

Spectrum Control and System Level Planning

Avionic systems contain a large number of on-board frequency-generating systems including frequency synthesizers, digital circuits, telemetry, and switching power supplies. Effective frequency management begins with a good tracking system or compilation list of all the frequencies and their significant harmonics, signal rates, rise/fall times, and power levels. Use of this spectrum information during EMI analysis enables designers to avoid problems in establishing new frequencies and minimize incompatibilities among components based on their existing frequencies.

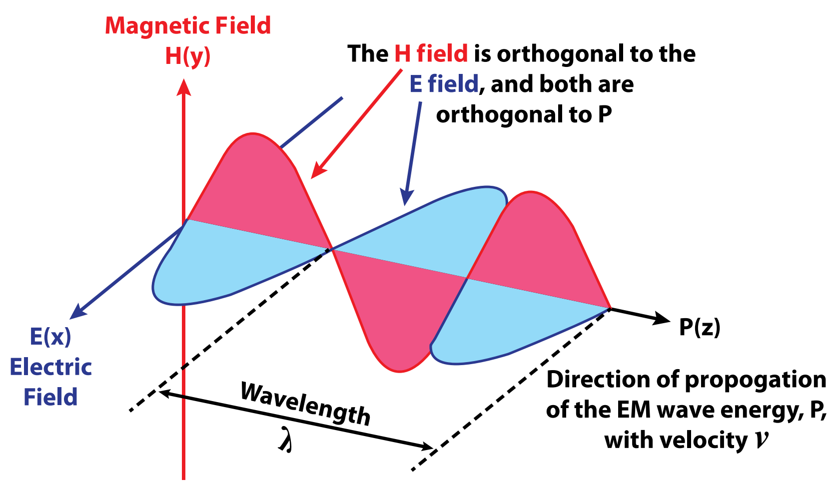

Figure 2: *Radiation or propagation of an electromagnetic wave.*

A good grounding plan, shield termination and interconnects, proper wiring classification and harnessing, and shielding are the main means of controlling system EMI. With the increasing number of frequencies and low sensitivity levels, it becomes even more necessary to have effective shielding. Many system requirements demand high levels of shielding effectiveness with values of enclosures, connectors, and harnessing that are on the order of 60 to 100 dB or more. Methods for achieving such levels include:

1. Proper selection of enclosure material
2. Effective printed circuit board layout and design
3. Ensuring resistance across enclosure continuities
4. Proper use of conductive mating surfaces
5. Effective use of gasketing between mating surfaces
6. Properly terminating cable shields

What is Shielding?

For effective shielding, the LRU should be completely surrounded by an electrically conductive material (Fig. 4). Shielding effectiveness is dependent on the conductivity and thickness of the material and the frequency and amplitude of the electromagnetic field. However, shields have their own shortcomings such as weight, susceptibility to corrosion, wear, apertures and seams, and physical rigidity. Apertures and seams are especially critical as they allow leakage of electromagnetic energy and lower the shielding capability of the enclosure design. The bigger the size of the aperture or seam, the less shielding (especially at higher frequencies).

There are essentially two basic approaches for reducing or shielding electromagnetic emissions from a device or system as well as improving its susceptibility performance. One is shielding at the printed circuit board level utilizing proper design techniques. The second is to place the device or system in a shielded enclosure where gaskets can be used to improve shielding of the enclosure. Shielding solutions are applicable for avionics packaging, enclosure shielding, radio packaging, canopy/window perimeters, structure gaps, and access cover plates.

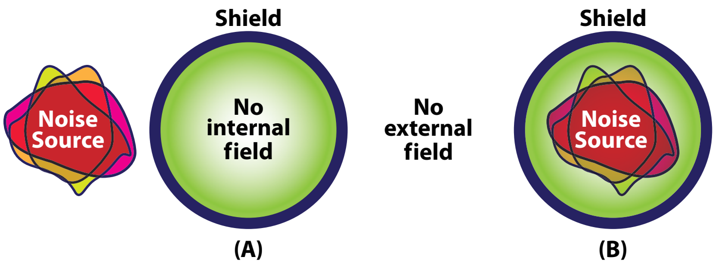

Figure 4: *(A) Shielding noise from the outside. (B) Shielding noise from the inside.*

Board Level Shielding (BLS)

Board level shielding (BLS) is available in a variety of sizes and heights and can be specified with any number of compartments (Fig. 5). Board level shields are placed around the component or circuit(s) on the printed circuit board. They are used to attenuate the amount of electromagnetic energy directly propagating from digital devices themselves.

The effectiveness of BLS is dependent on the design of the printed circuit board. Normally, the sixth side of this "box" will be a ground plane on the board. The number and spacing of vias and/or traces running from this shielded area to other board components can affect the effectiveness of BLS. With higher frequencies and shorter wavelengths, the size and number of holes can become issues. Capacitive and inductive coupling are more significant than aperture size for shielding.

Another issue with higher frequencies is resonance effect. These structures behave as cavity resonators. A 2-inch by ½-inch enclosure resonates at a first order mode of around 12 GHz. Even weak coupling at these extremely high frequencies can induce strong oscillations than can then couple to any other point in the enclosure.

As devices become faster in frequency, they generate more heat. So, thermal management is also a design factor. Thermal management can be achieved through the use of thermal pads and heat sink.

Figure 5: *Various configurations of board level shielding (BLS) available from Orbel Corporation.*

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Gasketing

Gaskets are used to maintain shielding by proper seam treatment. It is the effect of these seams and discontinuities, in general, that accounts for most of the leakages of the enclosure. The shielding effectiveness of a seam is dependent on the materials, contact pressure, and surface area. If there is no continuity between metal pieces, then it will become a radiating aperture. Although close spaced fasteners (approximately 25mm or 1 inch) can be used alone, gasketing is preferred in order to reduce the number of fasteners and compensate for mechanical variations or joint unevenness.

Beryllium copper gaskets offer the highest level of attenuation over the widest frequency range and are useable in both compression and shear-type applications (Fig. 6). Solid fingers have a greater cross-sectional area, hence higher conductivity. In addition, the finger shape has the characteristics of an interconnecting ground plane with a large contact area. The inductance will therefore be low as well. The movement of the finger shape will also provide a "wiping" action that aids in penetrating or removing any oxide buildup in the contact area. Finger-stock gaskets are very forgiving to compression, meaning it is very difficult to overcompress them causing compression set or breakage. Potential problem areas are the slots between the fingers. At sufficiently high frequencies, these slots begin to permit RF energy transmission through the bounded slot configuration.

Important factors that must be considered during gasket selection are RF impedance, shielding effectiveness, material compatibility, corrosion control, gasket height, compression force, compressibility, compression range, compression set, and environment. For RF impedance control, high conductivity and low inductance is desired. Beryllium copper has the highest conductivity.

Corrosion is also a concern because it leads to reduced shielding effectiveness due to causing the gasket material to become insulative or creating new problem frequencies through nonlinear mixing. There are two types of corrosion. The most common type is galvanic corrosion due to contact between two dissimilar metals in the presence of moisture. The second type is electrolytic corrosion due to current flow between two metals in the presence of an electrolyte (which could be just slightly acidic ambient moisture).

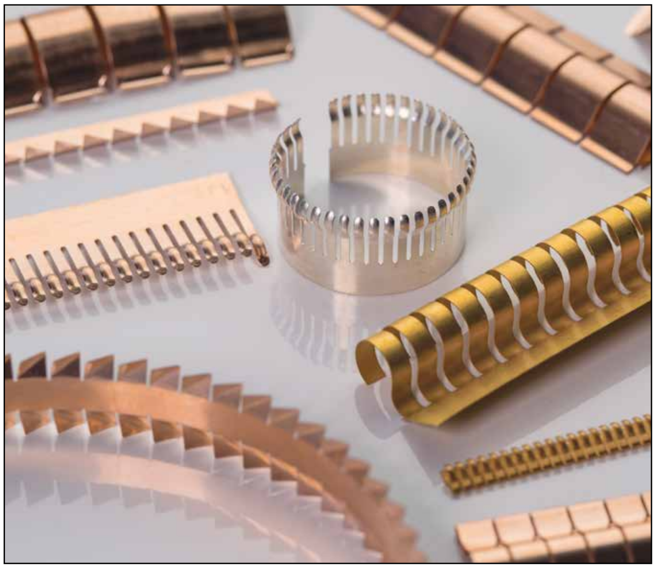

Figure 6: *BeCu gaskets from Orbel are available in a variety of finishes.*

About Orbel Corporation

Since 1961, Orbel's custom design and manufacturing process has enabled unique engineered solutions for a variety of applications and industries. From conception through delivery, Orbel offers today's most effective EMI/RFI shielding, photo-etched precision metal parts, precision metal stampings, and electroplated metal foils. Areas of specialization include aerospace, telecommunications, electronics, microwave/RF, medical, automotive, and manufacturing. For more information, visit **Orbel.com** or call **610-829-5000**.

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