Application Note AN37-0015

An Introduction to Electromagnetic Compatibility

1. Introduction

By definition, Electromagnetic Compatibility (EMC) describes the ability of a system, a piece of equipment, or some other electrical device that utilizes electromagnetic energy, to operate in its intended environment without suffering an unacceptable degradation in its performance, or negatively impacting the ability of another device to perform its intended function.

This paper is intended to provide the reader with a basic understanding of Electromagnetic Interference and Compatibility, the various standards and specifications associated with being compliant, the types of testing available to help the engineer quantify the performance of his equipment and some of the basic approaches utilized to help him meet his requirements.

2. Electromagnetic Interference

Electromagnetic Interference (EMI) is either a continuous or intermittent electromagnetic disturbance or electrical signal that, if not properly addressed, can be transmitted into, or out of, electronic equipment and can disturb the normal and intended operation of electronic systems. EMI is discernible across the entire electromagnetic spectrum and can be generated across either a narrow band or a broad spectrum of frequencies, with the more typical areas of interest extending from the low kHz range to the upper GHz range.

Continuous noise is generally characterized as being low voltage in nature and common low frequency sources would be Switch Mode Power Supplies (SMPS), electric brush motors, ignition systems and fluorescent lighting. Radio Frequency Interference is a common term that generally defines a wide range of continuous higher frequency sources, ranging from high power radio transmitters to computer clock oscillators.

Intermittent or transient noise is generally distinguished from continuous noise as having duration of less than 16.667 milliseconds, or 60 Hertz. Intermittent signals are further classified as being either repeatable or random in nature. Repeatable transients are internally generated within the circuit, are predictable and can be quantified in terms of amplitude, energy and duration, which typically allows the designer to safeguard the system thru selection of a suitable transient protection device. Repeatable transients for example can be generated during the switching cycles of inductive loads utilized in welding equipment and motors.

Random noise on the other hand, is not predictable and cannot be quantified. Examples of random noise would be an electromagnetic pulse in the form of lightning, solar flares, cosmic noise, or a nuclear reaction, or an electrostatic discharge and as such, the selection of a suitable safeguard is generally tied to the use of statistical data and trend analysis.

3. Transmission / Propagation of EMI

For EMI to occur, three essential components have to exist, the emission source, which was discussed in Section 2 above, the receptor and the coupling mechanism. The receptor or victim source can be any apparatus, that when exposed to electromagnetic energy from an emission source, will exhibit degradation or malfunction in performance. In fact, many devices can behave as both receptors and emitters of electromagnetic interference. Communication systems like cell phones for example, utilize both transmitters and receivers, which can emit an EMI signal that has the potential to not only affect other systems, it can also couple back onto itself.

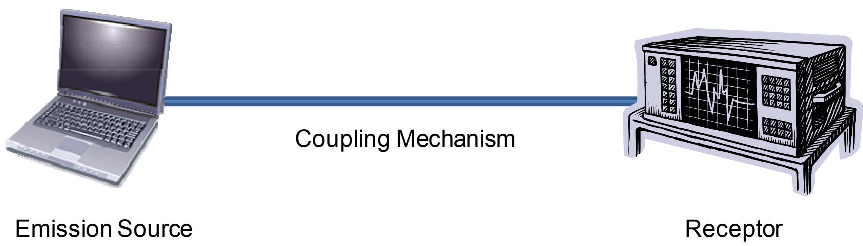


Figure 1 – EMI Components

The means by which EMI is coupled between pieces of equipment are generalized as being either conducted or radiated in nature, or a combination of both. Conduction refers to a type of transmission whereby a signal is conveyed along a lead wire or cable that is leaving and entering a piece of equipment. EMI within this classification is usually considered to be low frequency in nature, with 30 MHz generally acknowledged as the upper limit.

Radiated emissions are higher frequency signals coupled from one device to another without a direct electrical connection. The transmission mechanism is wireless and capable of traveling through non-conductive materials such as air, space, plastic and insulators.

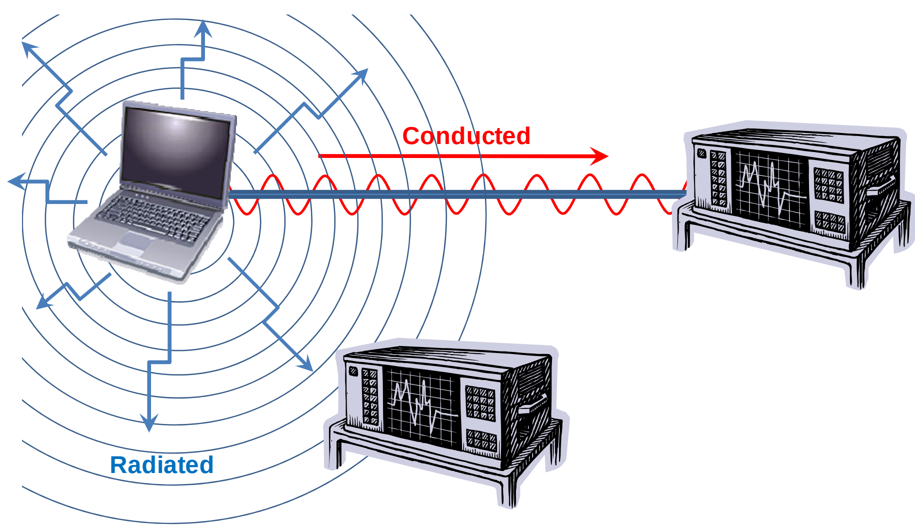


Figure 2 – Coupling Mechanisms

In situations where a combination of both conducted and radiated emissions are at work, signal, power and ground cables can act like receiving or transmitting antennas.

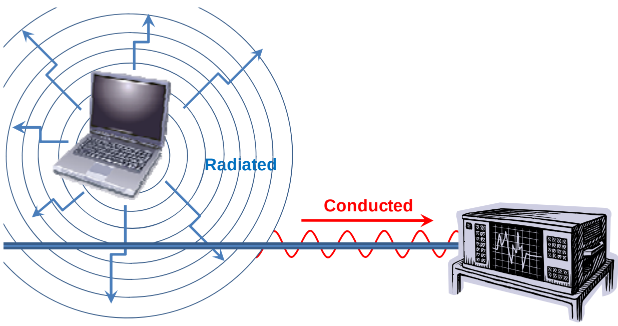


Figure 3 – Radiation ⟹ Conduction ⟹

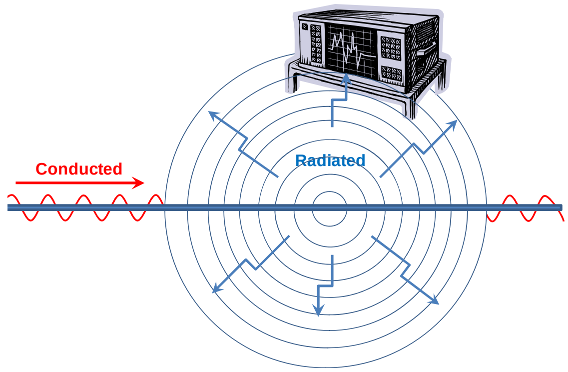


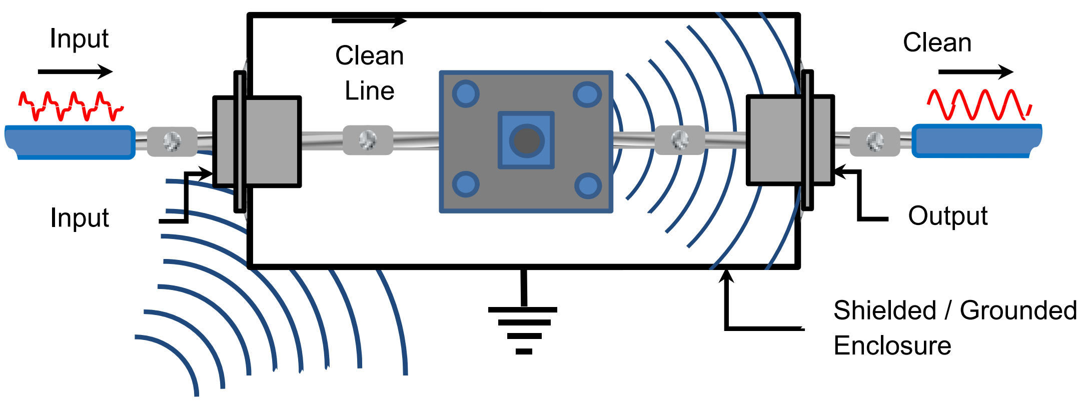
Figure 4 – Conduction ⟹ Radiation ⟹

4. EMI Suppression

Depending on the means of propagation, unwanted electromagnetic signals can generally be suppressed through the use of proper shielding, filtering and grounding techniques, or a combination thereof.

Where the designer is dealing with radiated emissions, suitable shielding, through the use of tightly sealed metal or metalized housings, will help to mitigate transmission of unwanted EMI into and out of the enclosure. Unfortunately, this approach is not considered practical, as some openings are obviously needed to accommodate conductors that connect to external sources and loads. In this case, the selection of a suitable electrical filter, placed in line with these conductors, and properly grounded at the housing access or egress point, will not only provide for further shielding, but will also allow for elimination of conducted EMI. A combination of these two methodologies and use of a low resistance connection to ground, will normally provide adequate isolation, eliminate unintended electromagnetic signals, both radiated and conducted, and allow all associated equipment to operate as intended.

Basic EMI Compliant System



5. Compliance Testing

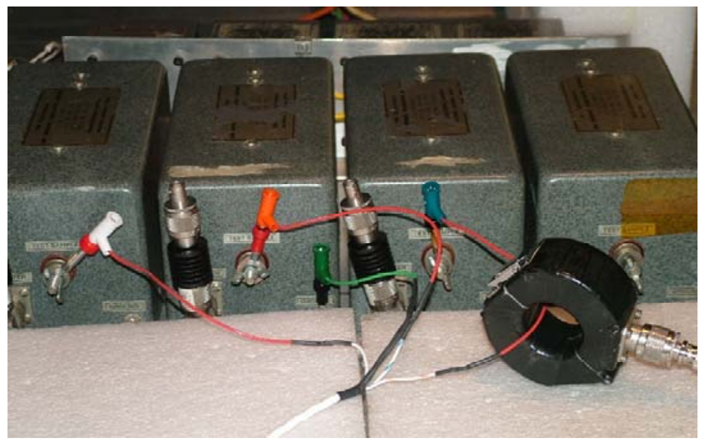
Electromagnetic Compatibility or EMC is established through the performance of 1) Emissions testing, which identifies the frequency and amplitude of EMI generated by a device and / or 2)

Immunity testing, which verifies the performance of a device or system, when subjected to known levels of EMI.

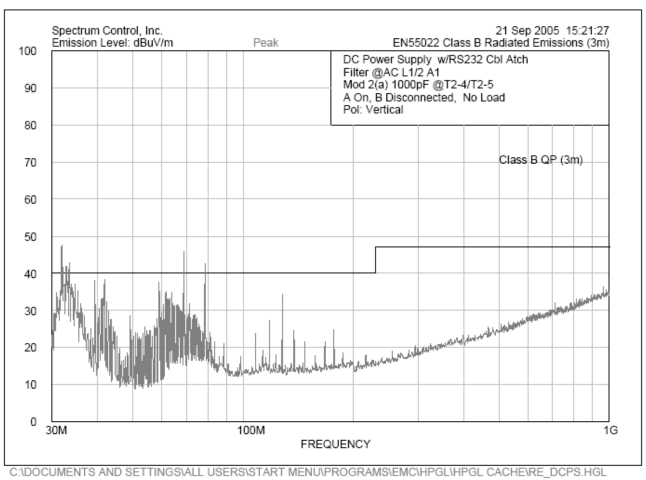
Emissions are measured by connecting a Line Impedance Stabilization Network (LISN), a current probe, or an antenna to an EMI receiver, scanning the desired frequency range and measuring the amplitude of the signals detected. This procedure would act much in the same way as the 'scan" button on an FM radio.

Emissions Testing

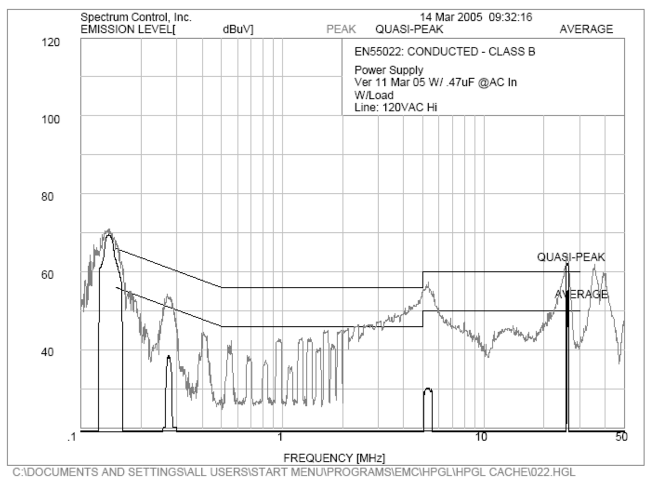
Radiated Emissions Test Setup



Conducted Emissions Test Setup



Radiated Emissions Test Data

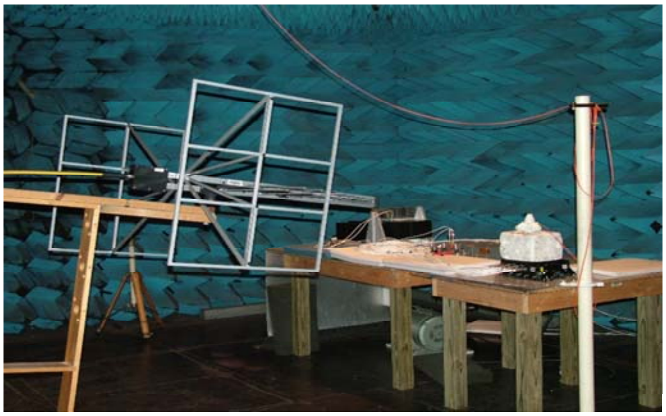


Conducted Emissions Test Data

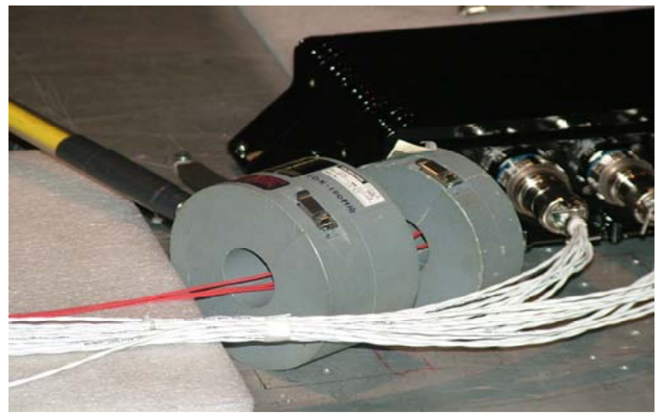
Immunity / Susceptibility testing by comparison, connects the LISN, a current probe or antenna to an RF amplifier and injects a signal into the system being evaluated. For this analysis, the equipment still scans for EMI signals, but now the intention is to monitor the performance of the DUT while subjected to the energy and determine what sort of response if any, the equipment exhibits.

Emissions and Immunity testing are further broken down into four basic EMC tests 1) Radiated Emissions, 2) Conducted Emissions, 3) Radiated Immunity and 4) Conducted Immunity. Radiated tests utilize an antenna in the test setup, whereas conducted tests deal specifically with wires and cables and are easy to identify as there are no antennas used.

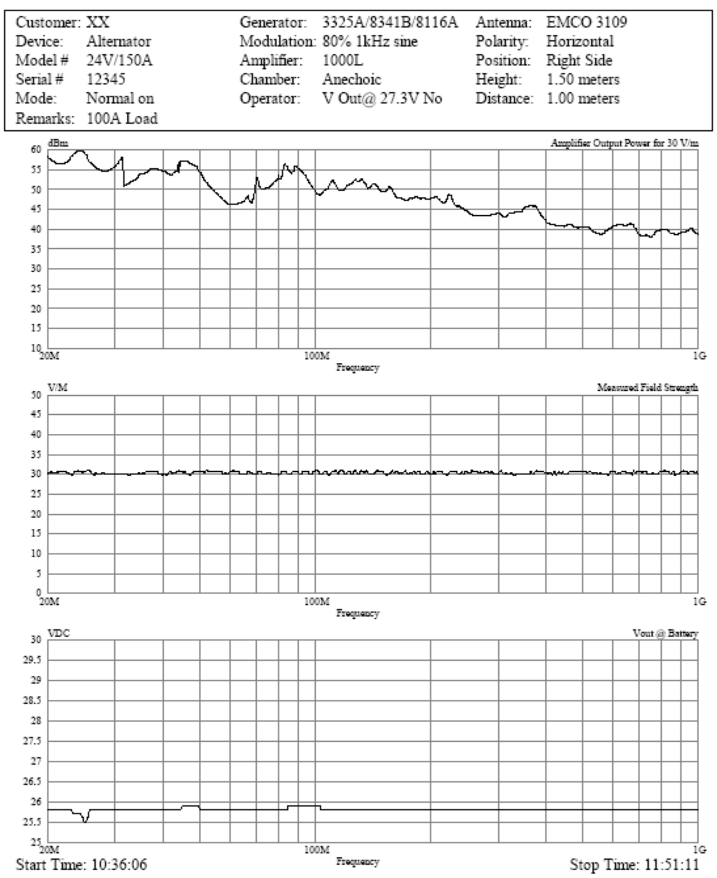
Immunity Testing



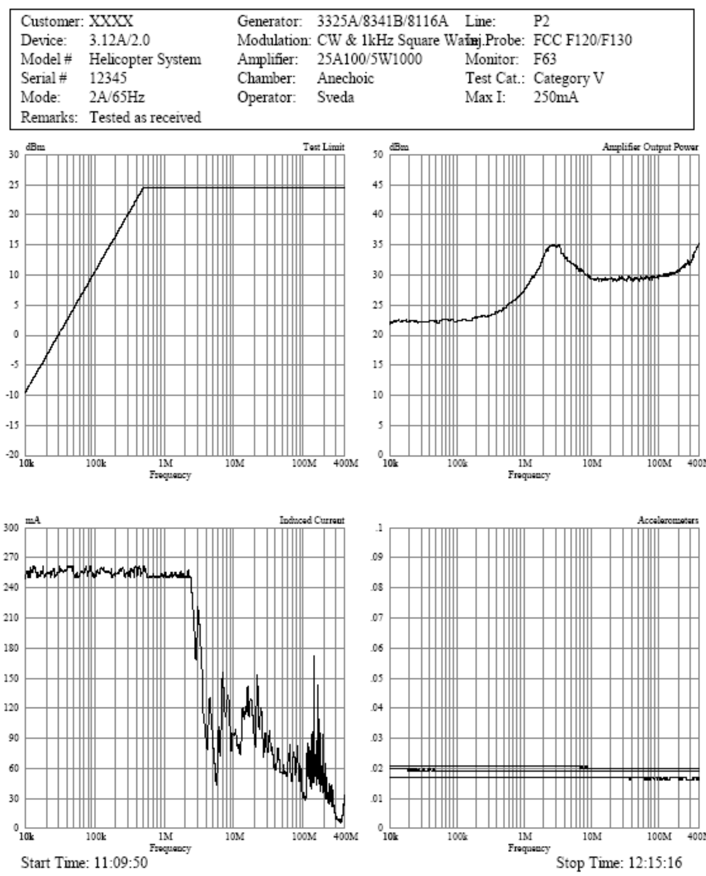
Radiated Immunity Test Setup



Conducted Immunity Test Setup



Radiated Immunity Test Data



Conducted Immunity Test Data

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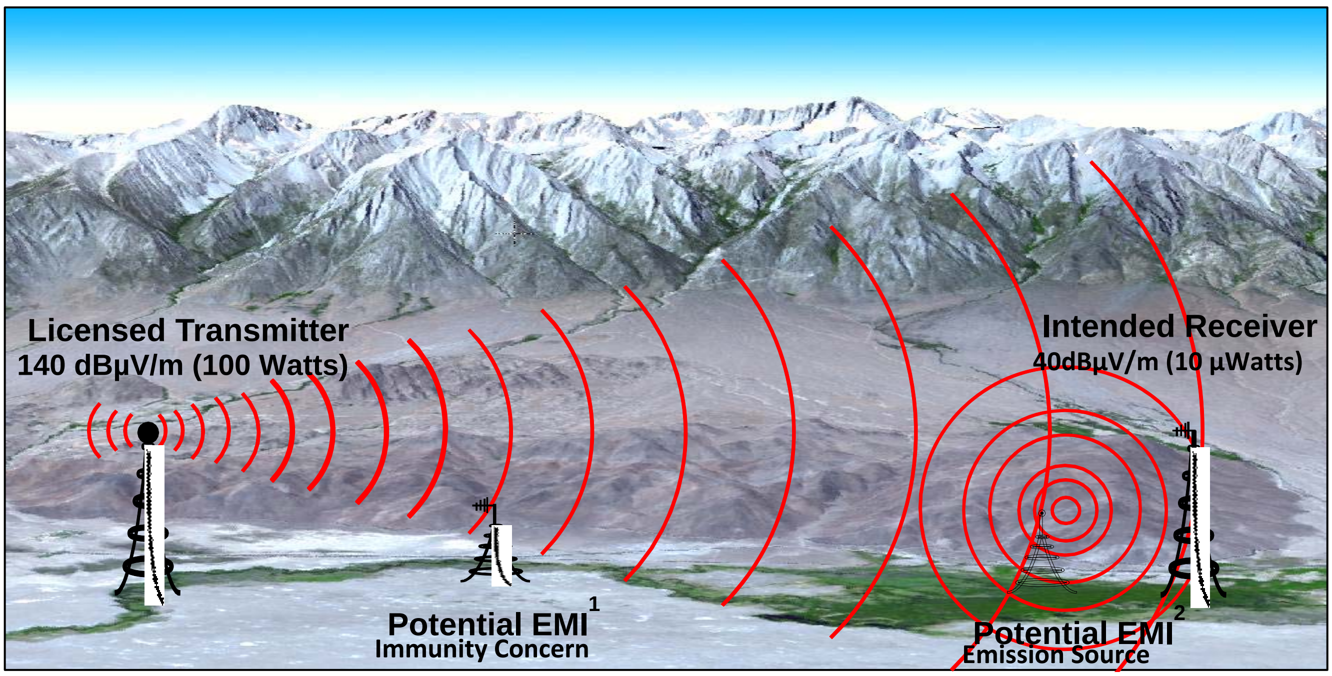
6. Real World Considerations

Government agencies tasked with instituting EMC standards have established emission limits of 100 µV or 40 dBµV maximum and immunity levels of 10 V or 140 dBµV minimum as general guidelines for operation of unlicensed equipment. These differences represent a 100,000 to 1 voltage ratio and a 10,000,000,000 to 1 power ratio, which on the surface may seem excessive, but in fact makes perfect sense in "real world" situations. Devices intended to communicate with each other may not necessarily be in close proximity and as such one would expect to see a certain level of signal loss between the transmitter and the receiver. By establishing these EMC guidelines, the agencies are effectively allowing for up to 100 dB in signal loss by mandating that any other piece of equipment operating within the systems realm of influence not produce excessive noise levels that might otherwise interfere with the intended communication. Furthermore, any piece of equipment expected to operate within this area must also be suitably protected and capable of withstanding exposure to signal levels of up to 10 V or 140 dBµV.



Notes:

1. Equipment expected to operate within transmission area must be designated to meet immunity levels in excess of 10 V or 140 dBµV.

2. Equipment intended to operate within transmission area must be designated to limit emission levels below 100 µV or 40 dBµV.

7. Standards and Specifications

From a global perspective, most governments have established very specific rules and regulations related to the control of electromagnetic interference (EMI) and the majority take it a step further by stipulating guidelines for testing systems in an attempt to ensure an acceptable level of electromagnetic compatibility (EMC).

In the U.S., EMI guidelines for commercial equipment are handled by the Federal Communications Commission (FCC). The Code of Federal Regulations (CFR) section 47 Parts 15, 18, and 68 contain relevant information that all engineers should be aware of when designing class A and B devices.

The US Military has its own standards, which are significantly more stringent. These guidelines are detailed in a wide range of military standards, such as MIL-STD-461E, MIL-STD-464.

The International Electrotechnical Commission (IEC), via its International Special Committee on Radio Interference (CISPR), also created globally accepted EMI and electromagnetic compliance (EMC) rules.

Test capability at API Technologies is very extensive and covers a large number of requirements related to FCC, the US Military and the IEC. Test capabilities are listed below, but it should be pointed out that this list continues to evolve and expanded in support of market expectations.

Military
- Mil-Std-461 A/B/C/D/E/G
- Mil-Std-1399 Surge

Automotive
- CISPR 25 Test Methods

Commercial
- FCC Part 15/18 Pre-Compliance
- RTCA/DO – 160 A/B/C/D/E/G
- GR-189-CORE

International
- EN55011/CISPR 11
- EN55014/CISPR 14
- EN55022/CISPR 22
- EN61000-4-2 Electrostatic Discharge
- EN61000-4-3 Radiated RF Immunity
- EN61000-4-4 Electrical Fast Transient
- EN61000-4-5 Surge
- EN61000-4-6 Conducted RF Immunity

8. Conclusions

Electromagnetic Compatibility is becoming more and more significant, especially in light of continually evolving EMC legislation and as such as become an important aspect in the design of electronic equipment and systems. A lack of understanding when it comes to possible sources of Electromagnetic Interference and failure to address those situations, can potentially lead to unwanted and potentially hazardous results in critical applications.

Please contact API Technologies Electromagnetic Integrated Solutions for additional information.