



**SPECTRUM  
CONTROL**

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# **Fundamentals of Electromagnetic Compatibility**

## EMI/EMC Filter Basics

### Introduction

Electromagnetic Compatibility (EMC) ensures that multiple electronic devices can function acceptably within the same electromagnetic environment by not interfering with each other. This paper is intended to provide the reader with a basic understanding of EMC standards, test methods, and mitigation techniques.

### Electromagnetic Interference

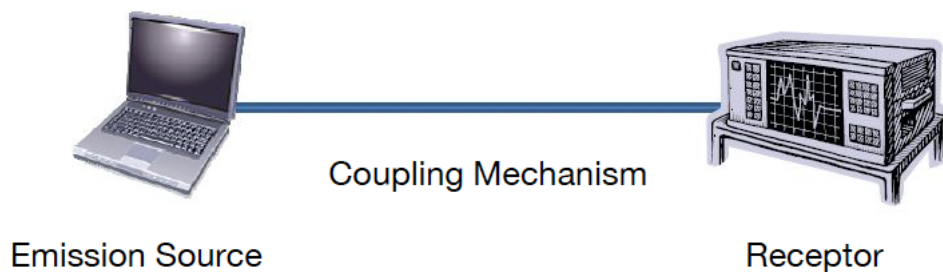
Electromagnetic Interference (EMI) is an electromagnetic emission that causes interference in another electronic device. EMI encompasses the entire electromagnetic spectrum but is most applicable to modern electronic devices over the frequency range of 10 kHz to 10 GHz. EMI can be from intentional or unintentional sources, continuous or intermittent, and at a single frequency or across a broad range of frequencies.

Unintentional EMI sources include switch-mode power supplies (SMPS), digital devices, brushed DC motors, high-voltage ignition systems, and fluorescent lighting. SMPS are the most common unintentional EMI source; since they are now used almost exclusively in LED light bulbs, digital devices, and battery chargers for cell phones and laptops.

Intentional EMI sources are most commonly radio frequency transmitters, whose emissions are often referred to as Radio Frequency Interference (RFI). This includes AM radio, FM radio, television, cell phones, Wi-Fi, Bluetooth, and many other fixed and mobile radio communication systems used by aviation, emergency services, police, and the military.

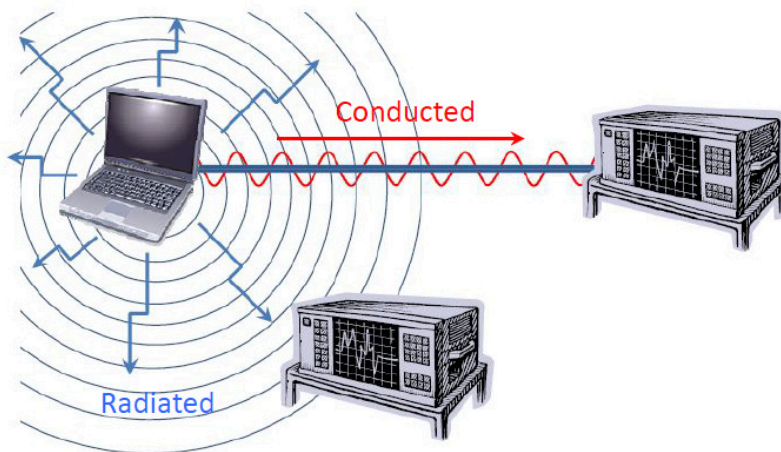
Intermittent EMI includes transients that can cause catastrophic damage to electronics including electrostatic discharge, lightning, inductive kickback, and electromagnetic pulse events (EMP).

### EMI Coupling



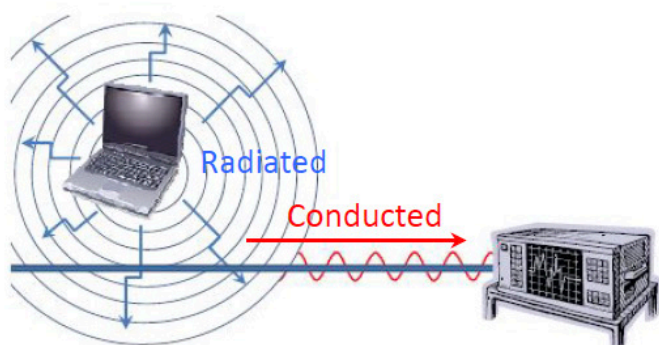
**Figure 1 – EMC Components**

EMI coupling from the source to the receptor can be conducted through wires, radiated through the air, or both. Radiated emissions become more difficult to mitigate at higher frequencies because higher frequencies have shorter wavelengths that are more effectively radiated by typical wire lengths. Radiated emissions readily penetrate non-conductive materials such as air, space, plastic, wood, and insulators.

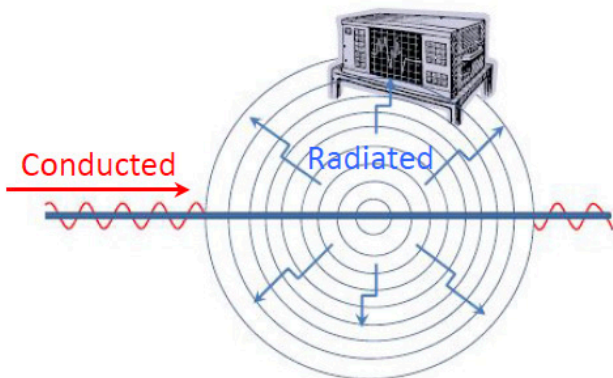


**Figure 2 – Coupling Mechanisms**

Real-world EMI situations are often a combination of both conducted and radiated emissions, with any or all wires and cables acting as receiving or transmitting antennas.



**Figure 3 – Radiation → Conduction**

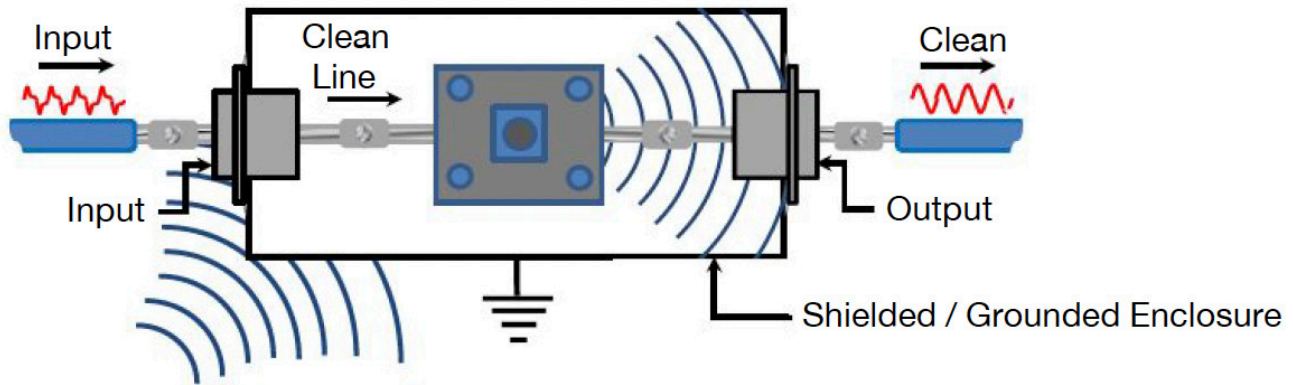


**Figure 4 – Conduction → Radiation**

EMC requires proper grounding, filtering, and shielding, i.e. you can't simply increase filtering to make up for a bad ground or ineffective shielding.

Radiated EMI often requires shielding electronic components inside a metallic enclosure, and maintaining that shield requires cables and wires to be filtered at the point of entry. Filters reduce conducted EMI on wires and cables into and out of the enclosure. Point of entry feedthrough filters require low-impedance coaxial connections to the metal enclosure to function correctly.

## Basic EMI Compliant System



## Compliance Testing

The two types of EMC testing are emissions and immunity. Emission testing verifies the frequency and amplitude of a device's emissions are below standardized limits. Immunity testing verifies the acceptable functionality of a device when exposed to standardized EMI levels.

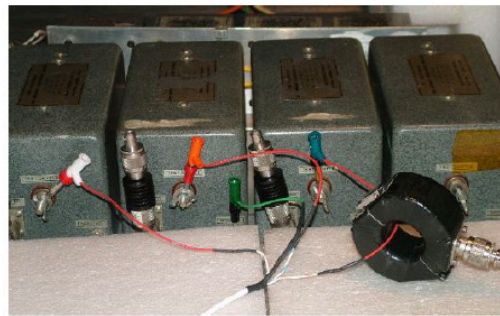
Emissions are measured using a Line Impedance Stabilization Network (LISN), current probe, or antenna connected to an EMI receiver that scans the desired frequency range. Emissions under the limit are passing and emissions over the limit are failing.

## Emissions Testing

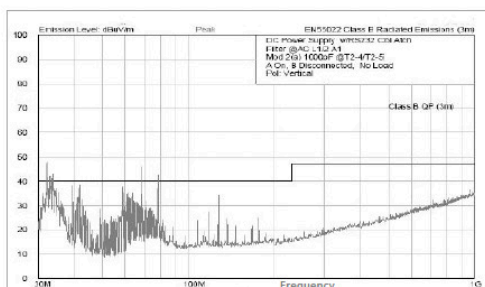
### Emissions Testing



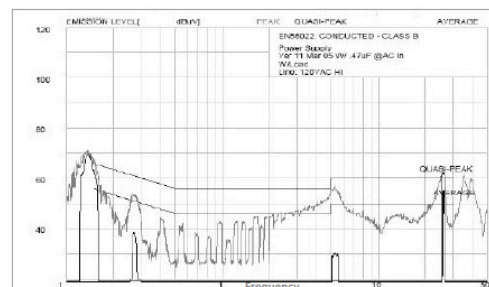
**Radiated Emissions Test Setup**



**Conducted Emissions Test Setup**



**Radiated Emissions Test Data**



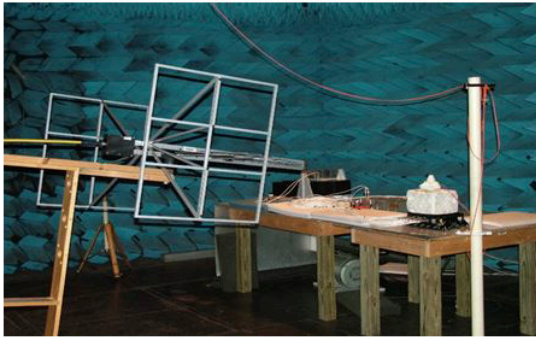
**Conducted Emissions Test Data**



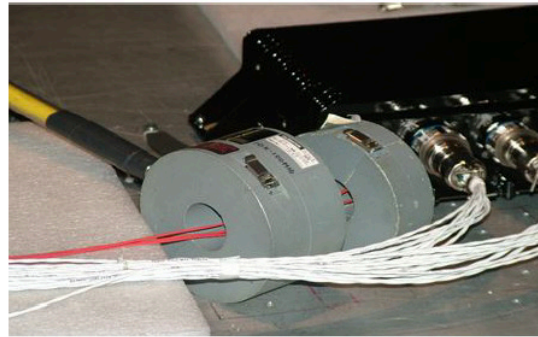
Immunity is performed by injecting EMI through a Coupling/Decoupling Network (CDN), current probe, or antenna and verifying the functionality of the device under test. The pass and fail indications are not seen on the EMC test equipment but are determined by monitoring the functionality of the device being tested while it is exposed to EMI.

Emission and immunity testing are further broken down into the four basic EMC tests 1) Conducted Emissions, 2) Radiated Emissions, 3) Conducted Immunity, and 4) Radiated Immunity. Conducted emissions and conducted immunity testing does not use an antenna, whereas radiated emissions and radiated immunity testing use antennas. If there is an antenna in the setup radiated emissions or radiated immunity test is being performed.

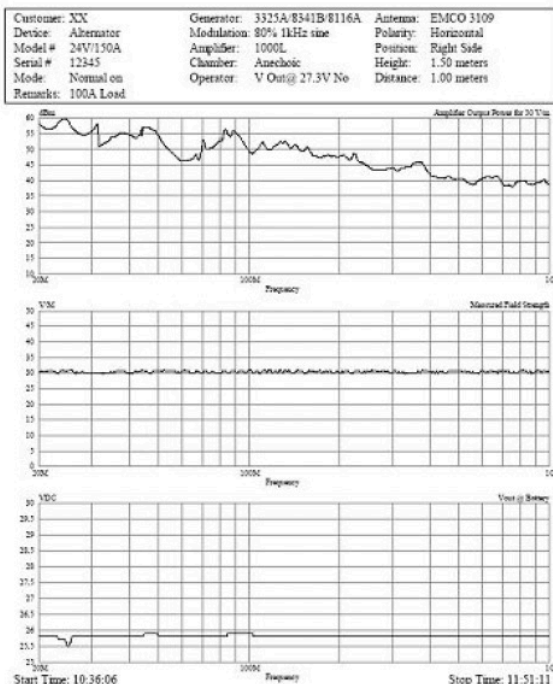
### Immunity Testing



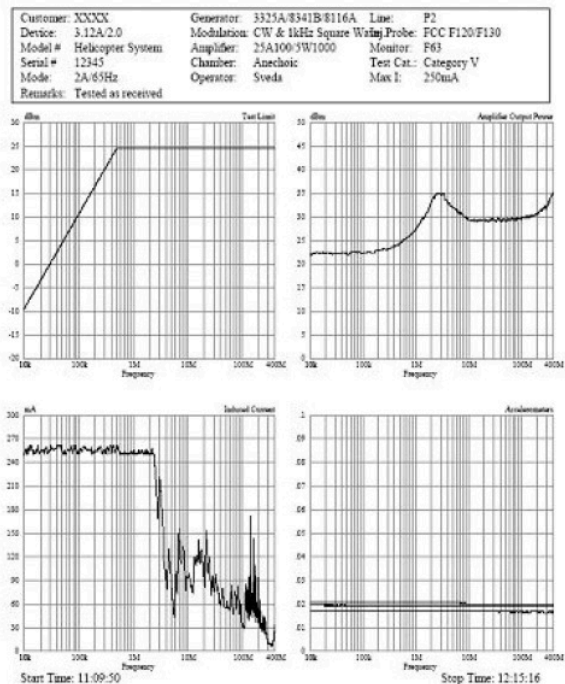
**Radiated Immunity Test Setup**



**Conducted Immunity Test Setup**



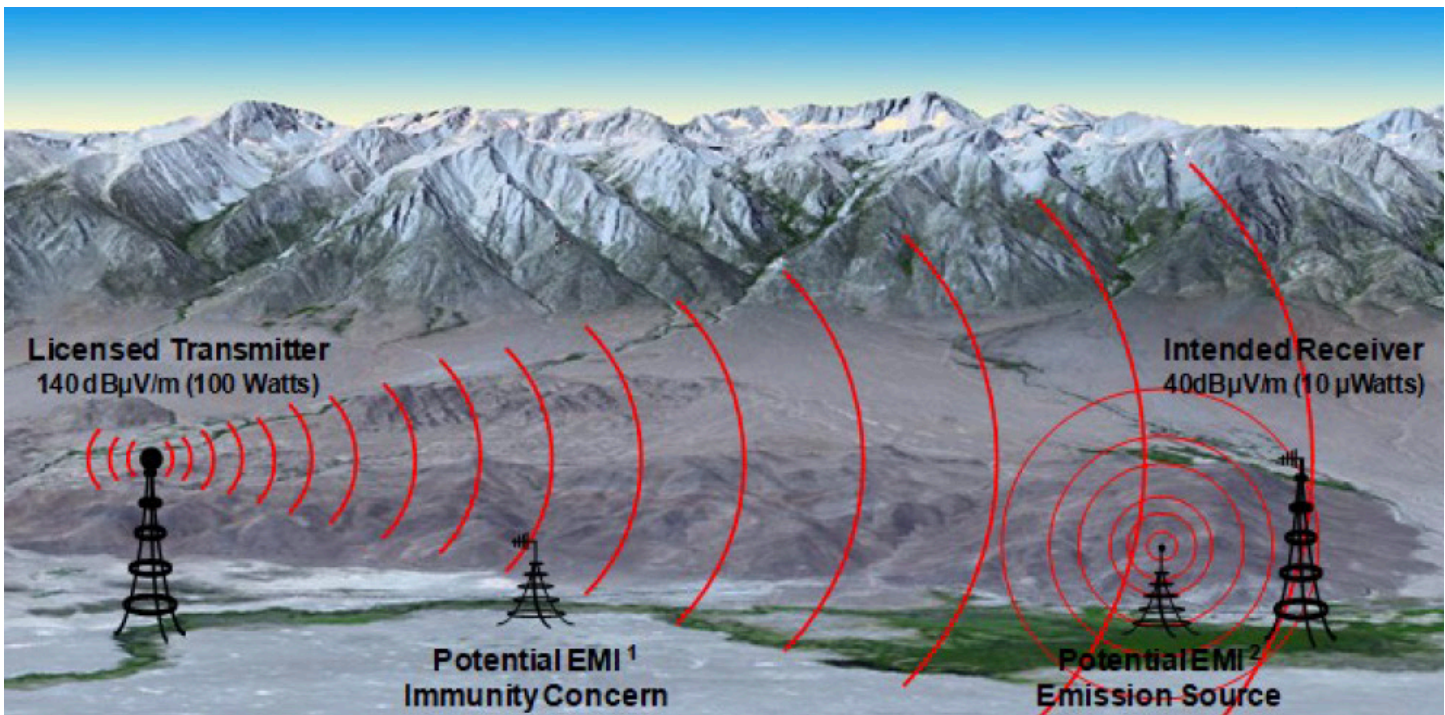
**Radiated Immunity Test Data**



**Conducted Immunity Test Data**

## Real World Considerations

The typical difference between EMI emission limits and immunity test levels is 100,000 to 1 or 100 dB. Is this a 100 dB safety margin? If electronic devices in a given environment are limited to such low levels of emissions, then why are these same devices required to handle such high levels for immunity? The reason is that electronic devices must operate in close proximity to both radio transmitters and radio receivers. Radio transmitters generate high-level RFI to communicate over great distances. Radio receivers are very sensitive in order to detect these signals. Immunity test levels simulate the energy levels that electronic devices will be exposed to when they are operated nearby radio transmitters. Emission limits ensure that a device's EMI emissions will not interfere with the reception of nearby radio receivers.



## Notes

- Equipment expected to operate in close proximity to radio transmitters must be immune to EMI levels in excess of 10 V or 140 dBμV.
- Equipment expected to operate in close proximity to radio receivers typically limit EMI emission levels to less than 0.0001 V or 40 dBμV.

## Standards and Specifications

From a global perspective, most governments have rules and regulations related to the control of EMI and call out specific standards for testing devices to ensure EMC compliance.

In the U.S., EMC 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-461 and MIL-STD-464.

The International Electrotechnical Commission (IEC), via its International Special Committee on Radio Interference (CISPR), creates globally accepted EMC standards.

Test capability at Spectrum Control is extensive and covers a large number of requirements related to the FCC, US Military, and the IEC. Some test capabilities are listed below, but this list continues to evolve and expanded in support of market expectations.

### **Military**

- MIL-STD-461 A/B/C/D/E/F/G
- MIL-STD-1399 Surge
- MIL-STD-704
- MIL-STD-1275

### **Commercial**

- FCC Part 15 Emissions
- CISPR 11, 14, 22 Emissions
- CISPR 25 Emissions
- IEC 1000 x 4 Immunity

### **Medical**

- EN 55011
- EN55022

### **Conclusion**

Electromagnetic Compatibility has become an important aspect in the design of electronic equipment and systems. Equipment manufacturers must stay up to date with continually evolving EMC legislation. It is important to understand EMC since equipment failures at the compliance level can lead to delayed product deliveries and increased development costs. EMC failures at the user level can mean returned equipment, loss of future business, and potential hazards in critical applications.

Please contact Spectrum Control for additional information.