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DISCUSSION OF ELECTROMAGNETIC INTERFERENCE



WHITE PAPER

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DISCUSSION OF ELECTROMAGNETIC INTERFERENCE

Andy Chou is a Boyd Market Segment Manager with more than five years of experience working in the area of EMI solutions. He also leads Boyd's New Product Introduction team in developing new and emerging EMI products and applications. With experience as a global technical engineer, key account manager and product manager, Andy is fervently attuned to the management of EMI in the electronic industry and attendant market trends.

INTRODUCTION

Electromagnetic interference (EMI), also known as radio frequency interference (RFI) when in radio frequency, is caused by undesirable radiated electromagnetic fields, or conducted voltages or current from an external source, which interferes with the safe and stable operations of an electronic device. This interference can come from any artificial or natural object that carries rapidly changing electrical currents, like an electrical circuit, the sun or the Northern Lights. This disturbance or interference may interrupt, obstruct, limit or degrade effective electronic device performance. These effects can range from simple performance degradation to a total loss of data or, at worst, device failure.

To avoid these potential performance issues, electronic device design commonly incorporates several materials that promote stable performance in the presence of EMI.

An illustration of this design is the specific installation of a shielding enclosure and grounding gaskets shown in Figure 1.

ORIGIN OF EMI

Electromagnetic interference can come from a number of different sources and be categorized in a number of different ways. EMI sources can be natural or man-made. They can be categorized by duration like continuous interference or impulse "noise" (noise meaning interference), or categorized by bandwidth (narrow or broad band).

How does EMI happen? Normally EMI occurs from a coupling mechanism (or path) caused by one of the following models. The general theory of coupling is shown in Figure 2.

- **Conduction** by electric current effect: Conducted noise is coupled between two or more components through interconnecting wires like a power supply or ground wires. Common impedance coupling is caused when currents from two or more circuits flow through the same component or circuit. Most conducted coupling between pieces of equipment occurs through AC power lines.
- **Radiation** by electromagnetic effect: In the near field condition, E field (electric) and H field (magnetic) coupling are diagnosed separately (mainly for electric field issues). In the far field condition, coupling is treated as a plane wave (mainly for radiated electromagnetic field issues).
- **Induction** by electric field or magnetic field effect:
 - **Inductive Coupling**: Magnetic field coupling is caused by current flow in conductors. The coupling mechanism may be modeled by a transformer.

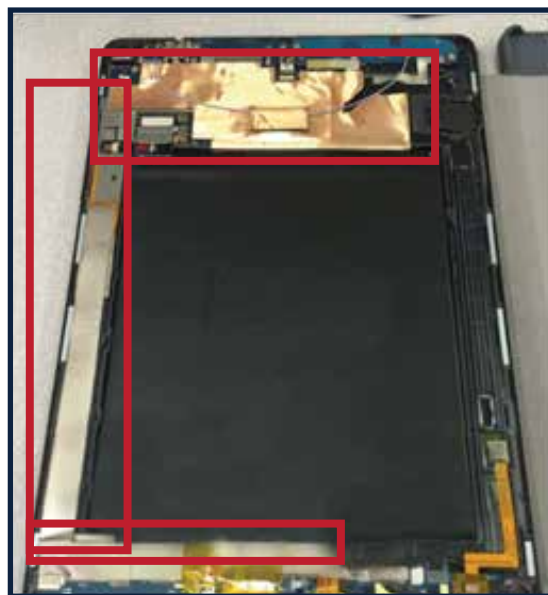


Figure 1: General EMI protection in a mobile phone

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-- **Capacitive Coupling:** Electric field coupling is caused by a voltage difference between conductors. The coupling mechanism may be modeled by a capacitor.

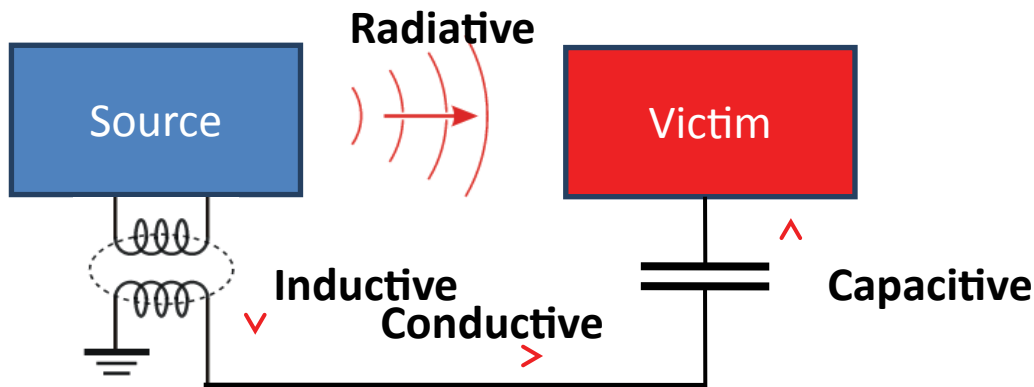


Figure 2: Basic EMI coupling mechanism

When analyzing an EMI coupling mechanism that is or could hinder device performance, it is critical to identify the root cause of interference. The right solution optimizes design for electromagnetic compatibility (EMC) compliance without compromising other design requirements like dimension, cost and aesthetics. Appropriate solutions are also impacted when the interference performance challenge is identified.

- **Circuit Design / Circuit Partitioning:** The idea is to avoid circuit interference through design. Avoid a circuit design loop that causes a current field (also known as antenna effect) and engineer proper capacitor and transformer components in the design to minimize coupling issues.

- **EMC Filters:** Design a filter at a specific location in the PCB circuit to screen “noise” as shown in Figure 3.

- **Grounding:** Design the proper electrical grounding system with appropriate current-carrying capability to serve as an adequate zero-voltage reference level. A general grounding product is shown in Figure 4.

- **Screened Enclosure:** There is a basic theory that when frequency is lower than 200MHz, grounding might be a viable solution, but when frequency is higher than 200MHz it creates radiation and the best solution becomes a shielding enclosure or conductive foam to manage the frequency and subsequent radiation. Shielding enclosures are commonly seen in electronic devices as shown in Figure 5. We also see conductive foam for shielding frequency and radiation, or a combination of conductive foam and shielding enclosures, as shown in Figure 6.



Figure 3: Filter / capacitor / transformer components on a printed circuit board



Figure 4: Grounding pads

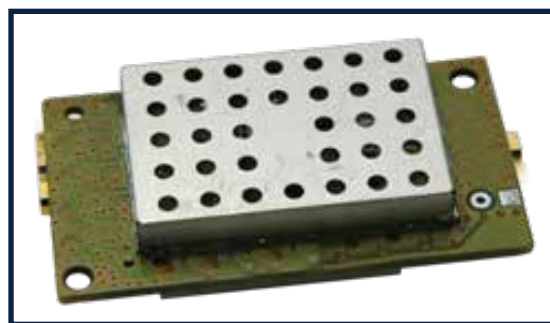


Figure 5: Shielding cans / cages in an electronic device

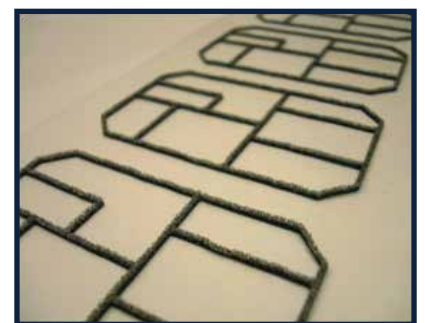


Figure 6: Conductive gaskets for EMI shielding

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- **Screened Lines and Cables:** Due to unbalanced current that occurs when a device is “plugged-in” to power or supplying voltage, it is best to design a ferrite core or flexible ferrite ribbon wrap on the cable to shield radiated “noise,” as shown in Figure 7.

EMC COMPLIANCE

EMC is the ability of electrical or electronic equipment and systems to function in the intended operating environment without causing or experiencing performance degradation due to unintentional EMI. Electronic devices should be able to operate in a shared environment without interfering with one another’s stable performance. This is not an easy measurement because there are a lot of potential EMI “noise” factors in a given environment, as previously discussed. Normally, it is better to measure EMC performance in isolated conditions or a shielding room to be certain there are no unexpected “noise” effects coming from external sources (as shown in Figure 8).



Figure 7: Ferrite core on cable

For finished products, three meter and ten meter tests are the most common to certify a product to specific EMC requirements. A test facility provides certifications to radiated emissions and radiated immunity requirements to various international standards specified in ANSI C63.4, EN50147 part 2 (emissions) and EN61000-4-3 (immunity).

For RF modules or semi-finished components, a “noise” scanner (shown in Figure 9) or Spectrum Analyzer (shown in Figure 10) can be used to measure the “noise” before final product assembly testing. It is ideal to detect the “noise” at the component level, identify the source of the “noise” and adjust design to correct interference before finalizing product design and proceeding with EMC compliance testing.



Figure 8: Shielding room



Figure 9: EMI noise scanning



Figure 10: Spectrum Analyzer

EMI SOLUTIONS

When a design is fixed and an EMI problem is identified, there are still ways to solve EMI performance challenges. Proper EMI materials can solve EMI problems without making device design changes. The first step is to identify major performance issues then recommend “fix-it” solutions like absorbers, grounding, shielding or other special materials to eliminate the “noise.”

There are three basic steps to investigate EMI performance concerns. The concept is shown in Figure 11.

- **Grounding Check:** This is the most common diagnostic tool for EMI “noise.” Avoid creating “bias” voltage that can act as a signal transmitter by inserting an electrically conductive product that acts as an interconnect that will optimize grounding. A grounding product could be conductive foam, conductive adhesive, conductive polymer, fabric over foam, etc.

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- **Shielding Check:** The basic theory is to isolate “noise” from external (immunity) or internal radiation (emission) sources that affect data transmission and avoid radiation leakage from poor shielding material installation. A shielding product could be conductive foam, a conductive pad, a metal enclosure, metal foil, metalized cloth or conductive glue. The best solution depends on dimensions available, performance required, and additional needed characteristics.

- **Absorber Lamination:** If grounding and / or shielding solutions have been designed into the device but the “noise” issue persists, absorber materials need to be evaluated. This is a relatively new concept for “noise” elimination. It is critical to understand the frequency range causing the “noise” to select the proper absorber solution. Common materials are magnetic noise suppression sheets, electric noise suppression sheets or the combination of the two.

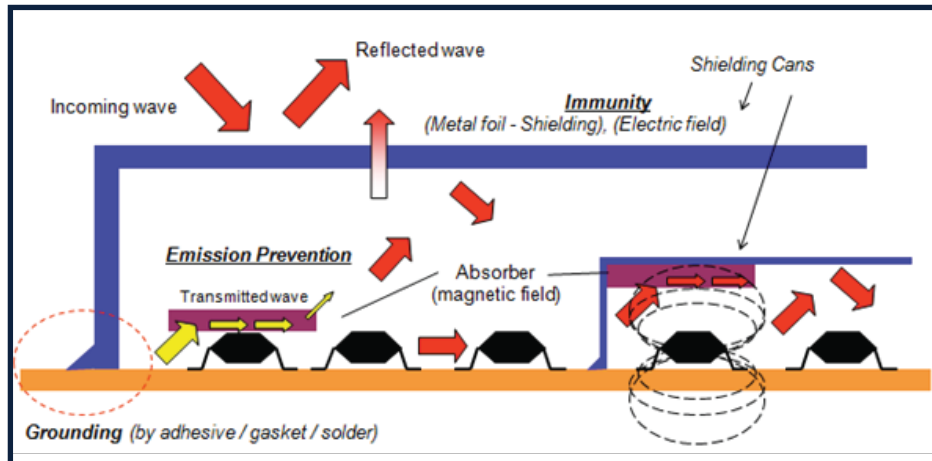


Figure 11: Major EMI material installation

EMI SOLUTION DRIVERS

There are key performance characteristics that can help identify the best “fix it” solution:

- **Lower Surface Resistance (ohm/sq) / Lower Contact Resistance (ohm/in²)** (general model shown in Figure 12): This is based on MIL-DTL-83258C (MIL-STL202.307), or equivalent standards, to measure surface and contact resistance. It is important to note that the unit for surface resistance is ohm/sq. This unit is not related to the contact area size nor does contact area size correlate to performance -- a product with a larger footprint will not have higher performance. Contact resistance is the measure of Z-axis resistance. This is a very critical measurement that shows grounding performance and the common unit is ohm/in². Contact area will affect conductivity performance. The same material with a larger contact area will offer better grounding performance. If higher performance is required but larger contact area is not available, a higher conductivity material may be needed to achieve improved grounding performance.

- **Better Shielding Capability (dB):** A shielding enclosure is a good way to provide immunity or prevent emission internally and it is common to see this design in electronic devices. The general test set up is shown in Figure 13.

Material shielding effectiveness is measured according to ASTM D4935 and the data generated is shown in Figure 14.



Figure 12: Electrical resistance testers

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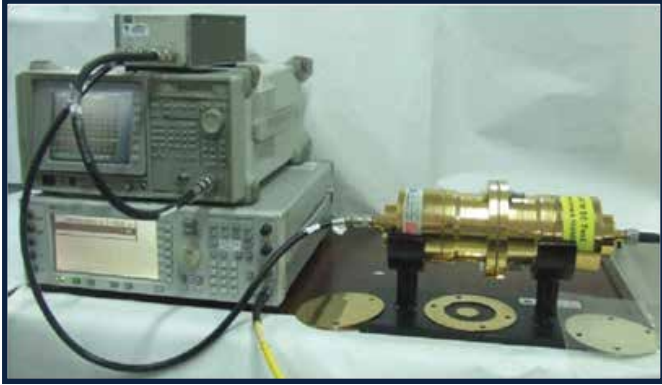


Figure 13: ASTM D4935 Shielding effectiveness tester

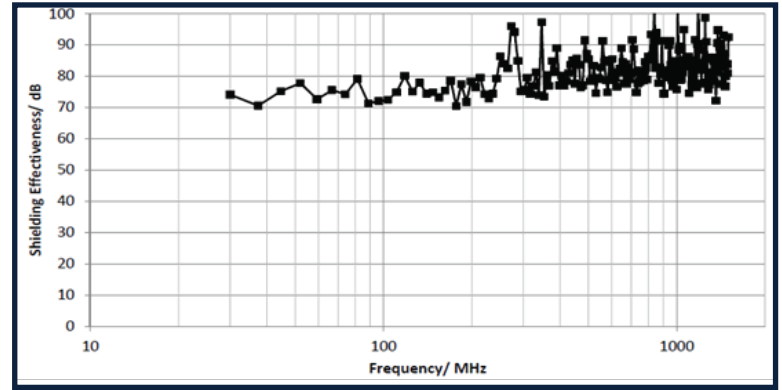


Figure 14: Shielding effectiveness test at 30MHz to 1.5GHz

How to interpret the shielding effectiveness data?

The lowest point in the data offers the least protection for shielding effectiveness.

- 60dB equals 1000 times reduction,
- 70dB equals 3160 times reduction,
- 80dB equals 10000 times reduction

Shielding Effectiveness:

- 60dB shield will reduce by 1mV,
- 70dB shield will reduce by 0.3mV,
- 80dB shield will reduce by 0.1mV,

This means devices with a higher shielding effect will experience less signal loss. Generally, shielding in thinner materials is lower than thicker materials.

- **Select Proper Frequency Range Absorber for EMI Noise Absorption (permeability u' , u''):** EMI absorbers are used in a wide range of applications to eliminate stray or unwanted radiation that could interfere with a system's operation. Absorbers can be used externally to reduce the reflection from or transmission to particular objects and can be used internally to reduce oscillations caused by cavity resonance (enclosed space).

Absorbers generally consist of filler material inside a material matrix, the fillers consist of one or more constituents that perform the absorption of radiated "noise." To select the correct absorber, permeability at a specific frequency level causing the EMI performance issues must be tested. Figure 15 shows various EMI absorber permeability levels -- the material that correlates to performance requirements is chosen. The basic idea is to select a higher u' permeability with lower u'' (magnetic loss) after the problem frequency range has been identified (e.g. GSM working at 600 - 800MHz, WiFi working frequency at 2.4GHz). A thicker

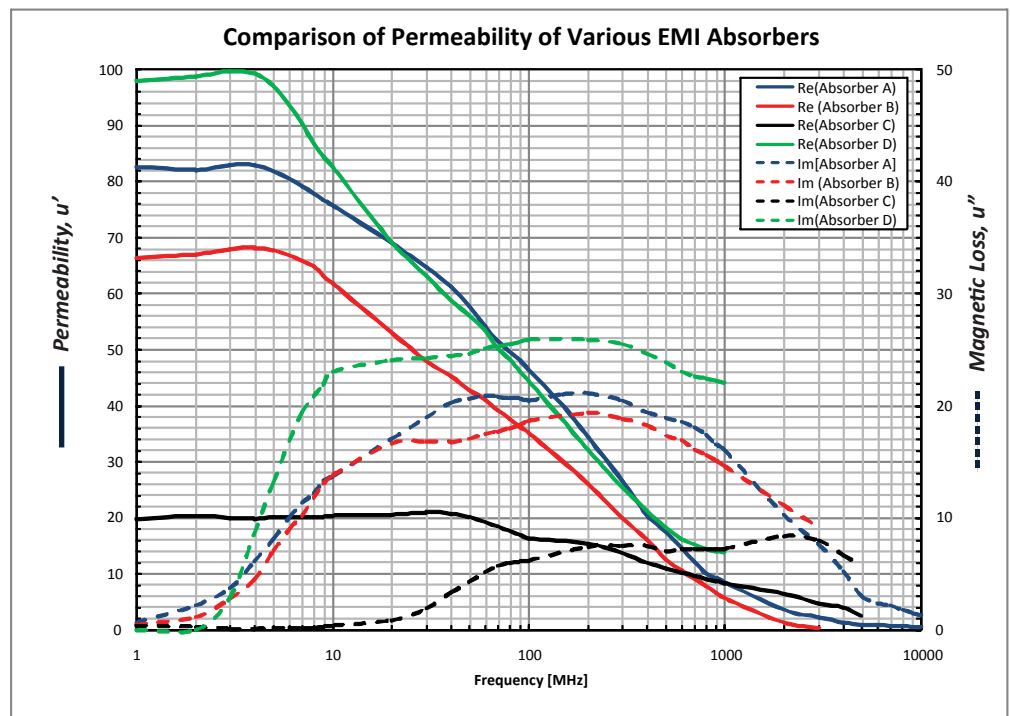


Figure 15: Various absorbers' permeability chart

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absorber has better absorbing capability if dimensional space is available.

EMI APPLICATIONS

For more than 30 years, Boyd has provided EMI solutions for market segments and applications including:

- Networking equipment enclosures featuring fabric over foam compressible shielding gaskets, beryllium-copper fingerstock, conductive foam gaskets and grounding materials designed in and around openings and doors.
- Enterprise electronic server solutions featuring a conductive fabric wrapped input / output gasket designed around entry and exit ports.
- Consumer electronics devices featuring a flexible ferrite absorber strategically wrapped around cables and cords.

Boyd's long history in EMI solutions as well as market experience provides an unmatched ability to assist its OEM customers, EMS partners and suppliers in designing solutions to solve EMI challenges.

For your EMI challenges, engage Boyd early in the design cycle to ensure that the most functional and cost effective designs are in place prior to emergent situations at product launch. Use Boyd's years of experience and engineering support in concert with your engineering / technical expertise to ensure your EMI challenges are solved in a cost effective, leading edge way.

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With decades of experience and a wholly-owned global footprint, Boyd provides best-cost, engineered, specialty material-based energy management and sealing solutions through comprehensive technical materials and design expertise, world-class manufacturing quality and service reliability, and unparalleled supply chain management.

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