EMI/RFI Radiation and Susceptibility from Cables and Enclosures

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Here are a number of notes on the control of unwanted radiation from electronic equipment as well as protecting that equipment from the effects of outside interference. In the U.S., FCC regulations place limits on the field strength of radiation from electronic devices of all types. In Europe, additional regulations specify that equipment should operate properly when exposed to fields of 1 V/m to 3 V/m.

Compliance with regulations can require significant investment in manpower, test equipment or services, EMI shielding and other components. Time-to-market can suffer greatly if the initial design is not robust from an EMI standpoint. A friend who designs high-speed DSP-based products claims that achieving regulatory compliance takes longer than the functional design. As he has learned methods for reducing radiation at the component, board and system level, the extensive testing and rework time is gradually diminishing.

Cables and connectors

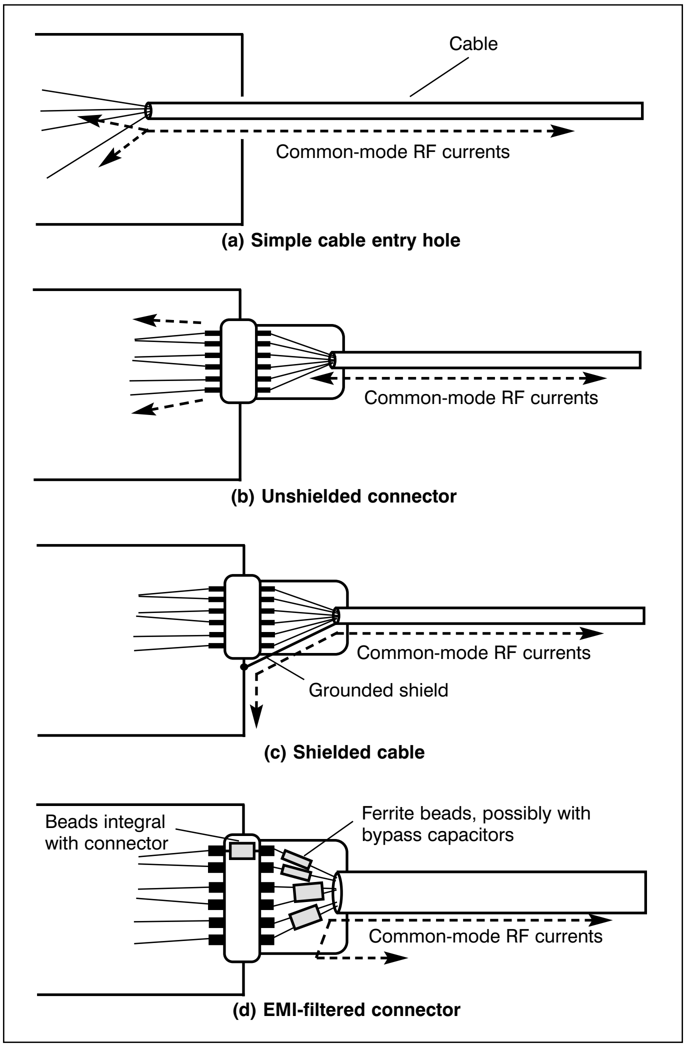
Cables bear a similarity to antennas, which is both a problem and the key to understanding their radiation and susceptibility. These interconnections between modules or enclosures, from power sources and to antenna systems are extremely important, as they represent one of the main ways that unwanted energy gets radiated from within an otherwise "shielded" enclosure.

Common-mode currents are the primary issue in cables. These are the currents that flow on the outside of a shield, or along with an unshielded "twisted pair" cable. The desired signals carried by the cable are in differential mode, and unless the conductors of the cables are somehow separated to interrupt their transmission line behavior, they will not be radiated.

Common-mode currents must be dealt with at the point where they enter or leave an enclosure. Figure 1 illustrates the most common problems and possible solutions. In (a), which is the worst case, a cable simply enters an enclosure through an access hole. The cable can easily couple to energy contained in the enclosure and carry it outside where it can radiate, or bring currents generated by external fields into the enclosure to cause interference.

Figure 1(b) is a more subtle case where a connector is used for unshielded cables, or with shielded cables that do not have their shields grounded at the connector. This installation gives the appearance of being robust, and the connector may even have a metal shell that provides shielding. However, common-mode currents will not be impeded and the performance is the same as that shown in Figure 1(a).

The first, and simplest solution is the use of a shielded cable, typically a braid that encompasses the entire bundle of individual cables. This overall shield is bonded



▲ **Figure 1. EMI/RFI performance of common cable entry methods.**

to ground at the entrance to the enclosure, keeping currents on the shield from entering the box. Figure 1(c) is a sketch of this technique.

A more elaborate technique is shown in Figure 1(d). Here, the individual cables within the bundle are filtered at the connector. Special connectors are available that include ferrite materials, or even L-C decoupling circuits, avoiding the need to hand-assemble filters adjacent to the connector.

Figure 1 is a simplified description of the general problem of cable entry, which applies to signal lines, AC and DC power connections and all other cables that are attached to the enclosure. There are also other methods for reducing the radiation and susceptibility of cables outside the enclosures that they are serving.

One simple, yet effective practice is routing the cables along a grounded metal surface, such as a metal equipment rack. Cables that simply cross open areas between rack systems will be much more prone to unwanted radiation and pickup. If they are routed along the metal support members or flat sides of a rack, common-mode behavior is reduced, since the combination of cable and surface acts like a transmission line, just like a microstrip's conductor-over-ground plane configuration. Thus, the interconnecting cable is no longer an "antenna" since currents are contained between the "transmission line" conductors.

EMI control inside enclosures

These same rules apply to the circuit elements within an enclosure, especially the interconnections between circuit boards, power supplies, etc. Similar techniques regarding shielded cables, grounding at the point where the cable leaves a p.c. board or applying EMI filtering will reduce the energy circulating within the enclosure. This may not change the external radiation that is measured for regulatory compliance, but it will reduce the possibility of self-interference.

In addition, enclosures require attention to the interruptions in their shielding, including all openings, gaps, panels, doors and mechanical bonds. Put simply, any gap in a metal surface is a slot antenna that can couple energy between the inside and outside of an enclosure. The size and shape of the gap determine its frequency response. A 6-inch long slot will pass 900 MHz cellular energy with very little attenuation!

Be careful with painted enclosures. The layer of paint may be an insulator that prevents conductive contact between panels, resulting in an unexpected "slot antenna" that is 12 or 18 inches long.

At a minimum, removable or assembled metal parts should have clean, bare metal surfaces where they contact one another. Access doors or panels that may be removed regularly should have EMI control gaskets that are designed to maintain electrical contact after repeated operations.

Why worry so much about RFI?

The most obvious reason for EMI/RFI control is to meet the regulatory requirements of various governmental bodies. For the past ten years, interest in standards and regulations has increased as the European Union implemented some of the world's most stringent standards.

Presently, all industrialized countries, plus many developing nations, are working toward "harmonization" to avoid dramatically different standards. The global economy is dependent on access to many different markets. If products must be built to meet widely varied EMI standards, then it may not be feasible to offer them in all markets.

These regulatory requirements are neither arbitrary nor designed to restrict market access. They have a solid practical basis: the reduction of interference. Interference among electronic devices is regulated for reasons ranging from simple consumer protection to public safety. Not only do we want to assure a minimum level of protection against products that are poorly designed and constructed, we also want to avoid interference with communications.

The European Union has added a protection factor that is not yet present in the U.S. — immunity to interference from external RF fields. There are many sources of significant RF energy in our environment, and the EU has determined that it is important to assure that electronic products have a reasonable level of protection from their effects.

For example, in the U.S., the single largest source of interference complaints to the Federal Communications Commission is interference to telephones by radio and television stations, CB operators, two-way radio, ham operators and other licensed radio services. Telephones are not intended to be radio receivers, and if they were required to comply with EU standards for immunity to interference from radio signals, the complaints would almost completely cease.

Summary

As more wireless communication services are offered to the public, the potential for interference will increase. The growth in other types of electronic equipment such as computers adds many more possible sources and victims of interference. It is both in the public interest and good business to design and build equipment that does not radiate unwanted signals and is robust enough to avoid being an unwanted "receiver" of interference. ■