7 Electromagnetic Interference

7.1 INTRODUCTION

Electricity and magnetism are interrelated and exist in a complementary fashion. Any conductor carrying electrical current has an associated magnetic field. A magnetic field can induce voltages or currents in a conductive medium exposed to the field. Altering one changes the other consistent with certain principles of electromagnetic dependency. Electrical circuits are carriers of electricity as well as propagators of magnetic fields. In many pieces of electrical apparatus, the relationship between electrical current and magnetic field is put to productive use. Some examples of utilizing the electromagnetic principle are generators, motors, transformers, induction heating furnaces, electromagnets, and relays, to mention just a few. Everyday lives depend heavily on electromagnetism. In the area of power quality, the useful properties of electromagnetism are not a concern; rather, the interest is in how electromagnetic phenomena affect electrical and electronic devices in an adverse manner. The effect of electromagnetism on sensitive devices is called electromagnetic interference (EMI) and is a rather complex subject. Many voluminous books are available on this subject, and each aspect of EMI is covered in depth in some of them. Here, some of the essential elements of EMI will be discussed in order to give the reader the basic understanding necessary to be able to identify problems relating to this phenomenon.

7.2 FREQUENCY CLASSIFICATION

Table 7.1 shows how the frequency spectrum is classified and primary uses of each type of frequency. While some level of overlapping of frequencies may be found in various books, the frequency classification provided here is generally agreed upon. The mode of interference coupling may not be significantly different for two adjacent frequency bands. But, if the frequency spectrums of interest are two or three bands removed, the interference coupling mode and treatment of the EMI problem could be radically different. One advantage of knowing the frequency bands used by any particular group or agency is that once the offending frequency band is determined (usually by tests), the source of the EMI may be determined with reasonable accuracy. While the problem of EMI is more readily associated with signals in the low-frequency range and beyond, in this book all frequency bands are considered for discussion, as all of the frequency bands — from DC to extremely high frequency (EHF) — can be a source of power quality problems.

7.3 ELECTRICAL FIELDS

Two important properties of electromagnetism — electrical and magnetic fields — will be briefly discussed here; it is not the intent of this book to include an in-depth discussion of the two quantities, but rather to provide an understanding of each phenomenon. An electrical field is present whenever an electrical charge (q) placed in a dielectric or insulating medium experiences a force acting upon it. From this definition, conclude that electrical fields are forces. The field exists whenever a charge differential exists between two points in a medium. The force is proportional to the product of the two charges and inversely proportional to the square of the distance between the two points.

If two charges, q_1 and q_2, are placed at a distance of d meters apart in a dielectric medium of relative permittivity equal to ε_R, the force (F) acting between the two charges is given by Coulomb's law:

$$\mathrm{F} = q_1 q_2 / \varepsilon_O \varepsilon_R d^2 \tag{7.1}$$

where ε_O is the permittivity of free space and is equal to 8.854×10^{-12} F/m. If the medium is free space then ε_R is equal to 1.

Electrical forces may be visualized as lines of force between two points, between which exists a charge differential (Figure 7.1). Two quantities describe the electrical field: electrical field intensity (**E**) and electrical flux density (D). Electrical field intensity is the force experienced by a unit charge placed in the field. A unit charge has an absolute charge equal to 1.602×10^{-19} C; therefore,

$$\mathbf{E} = F/q \tag{7.2}$$

where q is the total charge. The unit of electrical field intensity is volts per meter (V/m) or newtons per coulomb (N/C). Electric field intensity (**E**) is a vector quantity, meaning it has both magnitude and direction (vector quantities are usually described by bold letters and numbers). If q_2 in Eq. (7.1) is a unit charge, then from Eqs. (7.1) and (7.2):

$$\mathbf{E} = q_1 / \varepsilon_O \varepsilon_R d^2 \tag{7.3}$$

Equation (7.3) states that the electric field intensity varies as the square of the distance from the location of the charge. The farther q_1 is located away from q_2, the lower the field intensity experienced at q_2 due to q_1.

Electric flux density is the number of electric lines of flux passing through a unit area. If ψ number of electric flux lines pass through an area A (m^2), then electric flux density is given by:

$$D = \psi / A \tag{7.4}$$

The ratio between the electric flux density and the field intensity is the permittivity of free space or ε_O; therefore,

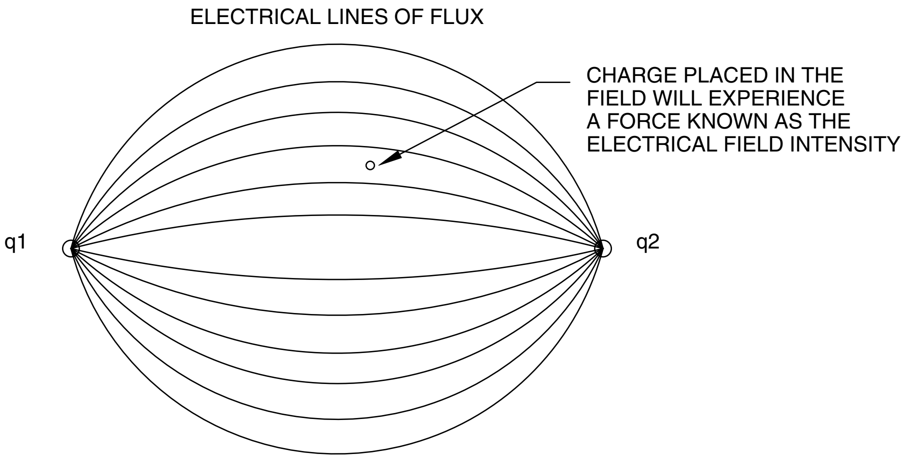

FIGURE 7.1 Electrical lines of flux between two charged bodies.

$$\varepsilon_O = D/\mathbf{E} = 8.854 \times 10^{-12} \text{ F/m}$$

In other mediums besides free space, **E** reduces in proportion to the relative permittivity of the medium. This means that the electric flux density *D* is independent of the medium.

In power quality studies, we are mainly concerned with the propagation of EMI in space (or air) and as such we are only concerned with the properties applicable to free space. Electrical field intensity is the primary measure of electrical fields applicable to power quality. Most field measuring devices indicate electric fields in the units of volts/meter, and standards and specifications for susceptibility criteria for electrical fields also define the field intensity in volts/meter, which is the unit used in this book.

7.4 MAGNETIC FIELDS

Magnetic fields exist when two poles of the opposite orientation are present: the north pole and the south pole. Two magnetic poles of strengths m_1 and m_2 placed at a distance of d meters apart in a medium of relative permeability equal to μ_R will exert a force (F) on each other given by Coulomb's law, which states:

$$F = m_1 m_2 / \mu_O \mu_R d^2 \tag{7.5}$$

where μ_O is the permeability of free space = $4\pi \times 10^{-7}$ $\mathbf{H}/m$.

Magnetic field intensity, **H**, is the force experienced by a unit pole placed in a magnetic field; therefore,

$$\mathbf{H} = F/m$$

If m_2 is a unit pole, the field intensity at m_2 due to m_1 is obtained from Eq. (7.5) as:

$$\mathbf{H} = m_1/\mu_O\mu_R d^2 \tag{7.6}$$

Equation (7.6) points out that the magnetic field intensity varies as the square of the distance from the source of the magnetic field. As the distance between m_1 and m_2 increases, the field intensity decreases.

Magnetic fields are associated with the flow of electrical current in a conductor. Permanent magnets are a source of magnetic fields, but in the discussion of electromagnetic fields these are not going to be included as a source of magnetic fields. When current flows in a conductor, magnetic flux lines are established. Unlike electrical fields, which start and terminate between two charges, magnetic flux lines form concentric tubes around the conductor carrying the electrical current (Figure 7.2).

Magnetic flux density (B) is the number of flux lines per unit area of the medium. If Ø number of magnetic lines of flux pass through an area of A (m^2), the flux density B = Ø/A. The relationship between the magnetic flux density and the magnetic field intensity is known as the permeability of the magnetic medium, which is indicated by μ. In a linear magnetic medium undistorted by external factors,

$$\mu = \mu_R \times \mu_O \tag{7.7}$$

where μ_O is the permeability of free space and μ_R is the relative permeability of the magnetic medium with respect to free space. In free space, $\mu_R = 1$; therefore, $\mu = \mu_O = 4\pi \times 10^{-7}$ H/m. In a linear medium,

$$\mu = B/H \tag{7.8}$$

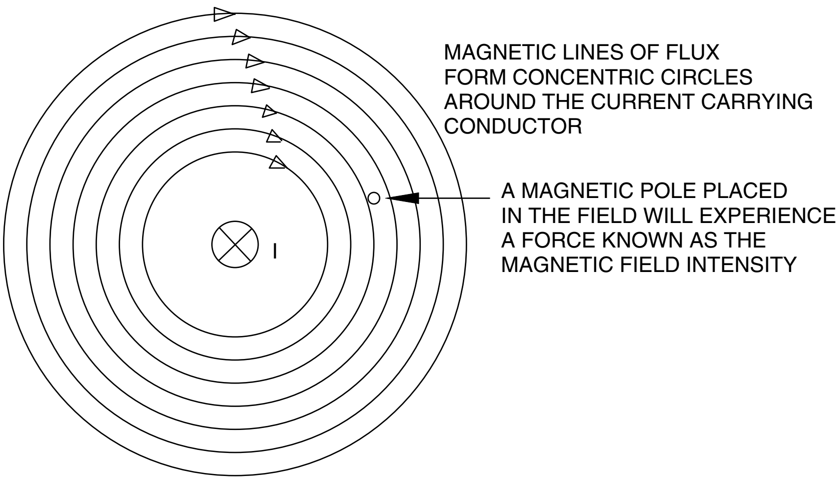

FIGURE 7.2 Magnetic flux lines due to a current-carrying conductor.

In free space,

$$\mu_O = B/H \tag{7.9}$$

Magnetic field intensity is expressed in units of ampere-turns per meter, and flux density is expressed in units of tesla (T). One tesla is equal to the flux density when 10^8 lines of flux lines pass through an area of 1 m^2. A more practical unit for measuring magnetic flux density is a gauss (G), which is equal to one magnetic line of flux passing through an area of 1 cm^2. In many applications, flux density is expressed in milligauss (mG): 1 mG = 10^{-3} G.

Both electrical and magnetic fields are capable of producing interference in sensitive electrical and electronic devices. The means of interference coupling for each is different. Electrical fields are due to potential or charge difference between two points in a dielectric medium. Magnetic fields (of concern here) are due to the flow of electrical current in a conducting medium. Electrical fields exert a force on any electrical charge (or signal) in its path and tend to alter its amplitude or direction or both. Magnetic fields induce currents in an electrical circuit placed in their path, which can alter the signal level or its phase angle or both. Either of these effects is an unwanted phenomenon that comes under the category of EMI.

7.5 ELECTROMAGNETIC INTERFERENCE TERMINOLOGY

Several terms unique to electromagnetic phenomena and not commonly used in other power quality issues are explained in this section.

7.5.1 Decibel (dB)

The decibel is used to express the ratio between two quantities. The quantities may be voltage, current, or power. For voltages and currents,

$$\text{dB} = 20 \log (V_1/V_2) \text{ or } 20 \log (I_1/I_2)$$

where V = voltage and I = current. For ratios involving power,

$$\text{dB} = 10 \log (P_1/P_2)$$

where P = active power. For example, if a filter can attenuate a noise of 10 V to a level of 100 mV, then:

$$\text{Voltage attenuation} = V_1/V_2 = 10/0.1 = 100$$

$$\text{Attenuation (dB)} = 20 \log 100 = 40$$

Also, if the power input into an amplifier is 1 W and the power output is 10 W, the power gain (in dB) is equal to 10 log 10 = 10.

7.5.2 Radiated Emission

Radiated emission is a measure of the level of EMI propagated in air by the source. Radiated emission requires a carrier medium such as air or other gases and is usually expressed in volts/meter (V/m) or microvolts per meter (μV/m).

7.5.3 Conducted Emission

Conducted emission is a measure of the level of EMI propagated via a conducting medium such as power, signal, or ground wires. Conducted emission is expressed in millivolts (mV) or microvolts (μV).

7.5.4 Attenuation

Attenuation is the ratio by which unwanted noise or signal is reduced in amplitude, usually expressed in decibels (dB).

7.5.5 Common Mode Rejection Ratio

The common mode rejection ratio (CMRR) is the ratio (usually expressed in decibels) between the common mode noise at the input of a power handling device and the transverse mode noise at the output of the device. Figure 7.3 illustrates the distinction between the two modes of noise. Common mode noise is typically due to either coupling of propagated noise from an external source or stray ground potentials, and it affects the line and neutral (or return) wires of a circuit equally.

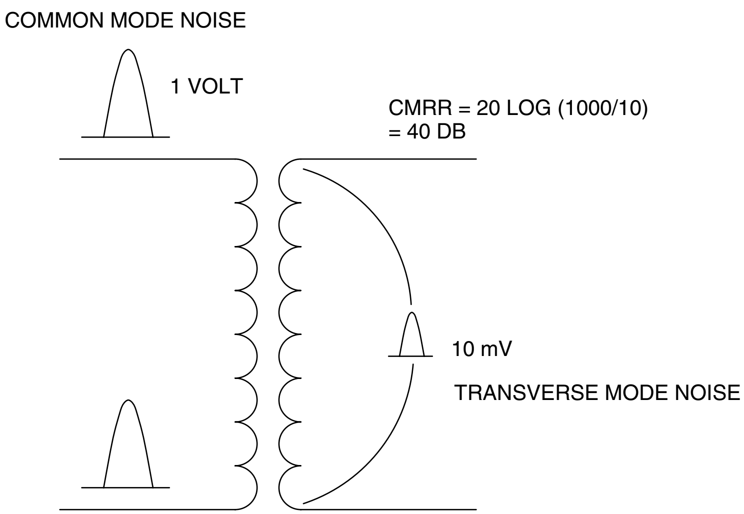

FIGURE 7.3 Example of common-mode rejection ratio.

Common mode noise is converted to transverse mode noise in the impedance associated with the lines. Common mode noise when converted to transverse mode noise can be quite troublesome in sensitive, low-power devices. Filters or shielded isolation transformers reduce the amount by which common mode noise is converted to transverse mode noise.

7.5.6 Noise

Electrical noise, or noise, is unwanted electrical signals that produce undesirable effects in the circuits in which they occur.

7.5.7 Common Mode Noise

Common mode noise is present equally and in phase in each current carrying wire with respect to a ground plane or circuit. Common mode noise can be caused by radiated emission from a source of EMI. Common mode noise can also couple from one circuit to another by inductive or capacitive means. Lightning discharges may also produce common mode noise in power wiring,

7.5.8 Transverse Mode Noise

Transverse mode noise is noise present across the power wires to a load. The noise is referenced from one power conductor to another including the neutral wire of a circuit. Figure 7.4 depicts common and transverse mode noises. Transverse mode noise is produced due to power system faults or disturbances produced by other loads. Transverse mode noise can also be due to conversion of common mode noise in power equipment or power lines. Some electrical loads are also known to generate their own transverse mode noise due to their operating peculiarities.

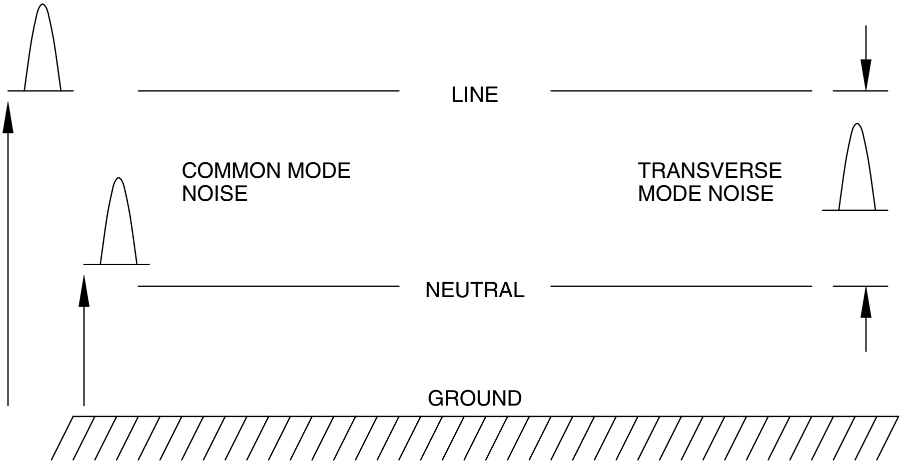

FIGURE 7.4 Common and transverse mode noise.

TABLE 7.1
Frequency Classification

Frequency Classification	Frequency Range	Application
ELF	3–30 Hz	Detection of buried objects
SLF	30–300 Hz	Communication with submarines, electrical power
ULF	300–3000 Hz	Telephone audio range
VLF	3–30 kHz	Navigation, sonar
LF	30–300 kHz	Navigation, radio beacon
MF	300–3000 kHz	AM, maritime radio
HF	3–30 MHz	Shortwave radio, citizen's band
VHF	30–300 MHz	Television, FM, police, mobile
UHF	300–3000 MHz	Radar, television, navigation
SHF	3–30 GHz	Radar, satellite
EHF	30–300 GHz	Radar, space exploration

Source: Cheng, D. K., *Fundamentals of Engineering Electromagnetics* 1st ed., Prentice Hall, Upper Saddle River, N.J., 1993. With permission.

7.5.9 Bandwidth

Bandwidth commonly refers to a range of frequencies. For example, in Table 7.1, a bandwidth of 300 kHz to 300 MHz is assigned to radio broadcast and marine communication. Any filter intended to filter out the noise due to these sources must be designed for this particular bandwidth.

7.5.10 Filter

A filter consists of passive components such as R, L, and C to divert noise away from susceptible equipment. Filters may be applied at the source of the noise to prevent noise propagation to other loads present in the system. Filters may also be applied at the load to protect a specific piece of equipment. The choice of the type of filter would depend on the location of the noise source, the susceptibility of the equipment, and the presence of more than one noise source.

7.5.11 Shielding

A metal enclosure or surface intended to prevent noise from interacting with a susceptible piece of equipment. Shielding may be applied at the source (if the source is known) or at the susceptible equipment. Figure 7.5 illustrates the two modes of shielding.

7.6 POWER FREQUENCY FIELDS

Power frequency fields fall in the category of super low frequency (SLF) fields and are generated by the fundamental power frequency voltage and currents and their harmonics. Because of the low frequency content, these fields do not easily interact with other power, control, or signal circuits. Power frequency electrical fields do not

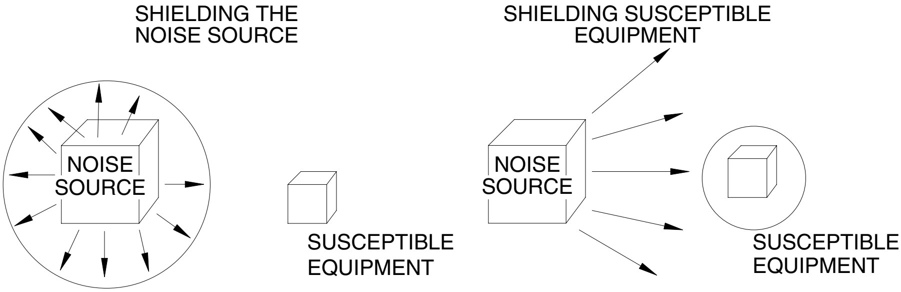

FIGURE 7.5 Radiated noise can be shielded by either shielding the source of noise or by shielding susceptible equipment.

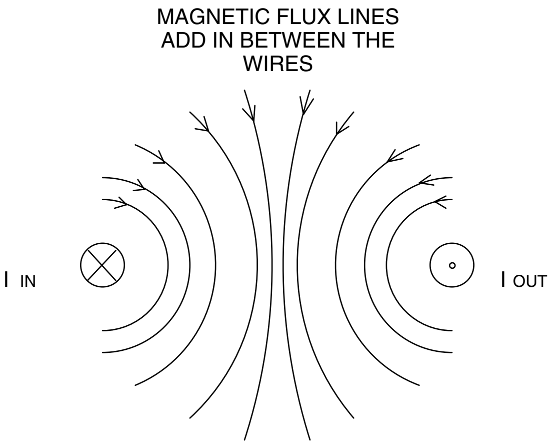

FIGURE 7.6 Magnetic field due to supply and return wires.

easily couple to other circuits through stray capacitance between the circuits. Power frequency magnetic fields tend to be confined to low reluctance paths that consist of ferromagnetic materials. Power frequency currents set up magnetic fields that are free to interact with other electrical circuits and can induce noise voltages at the power frequency.

In a power circuit, magnetic fields caused by the currents in the supply and return wires essentially cancel out outside the space occupied by the wires; however, magnetic fields can exist in the space between the wires (Figure 7.6). Residual electromagnetic force (EMF) attributed to power wiring is rarely a problem if proper wiring methods are used. Typically, power wiring to a piece of equipment is self-contained, with the line, neutral, and ground wires all installed within the same conduit. The net EMF outside the conduit with this arrangement is negligible. Once the power wires enter an enclosure containing sensitive devices, special care should be exercised in the routing of the wires. Figure 7.7 shows the proper and improper ways to route wires within an enclosure. Besides keeping the supply and return wires

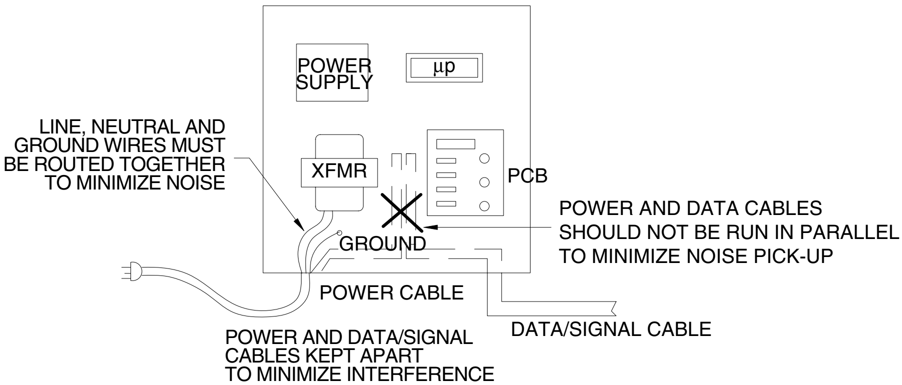

FIGURE 7.7 Equipment wiring to minimize coupling of noise.

in close proximity, it is also important to avoid long parallel runs of power and signal circuits. Such an arrangement is prone to noise pickup by the signal circuit. Also, power and signal circuits should be brought into the enclosure via separate raceways or conduits. These steps help to minimize the possibility of low-frequency noise coupling between the power and the signal circuits.

One problem due to low-frequency electromagnetic fields and observed often in commercial buildings and healthcare facilities is the interaction between the fields and computer video monitors. Such buildings contain electrical vaults, which in some cases are close to areas or rooms containing computer video monitors. The net electromagnetic fields due to the high current bus or cable contained in the vault can interact with computer video monitors and produce severe distortions. The distortions might include ghosting, skewed lines, or images that are unsteady. For personnel that use computers for a large part of the workday, these distortions can be disconcerting. In the high-current electrical vault, it is almost impossible to balance the wiring or bus so that the residual magnetic field is very low. A practical solution is to provide a shielding between the electrical vault and the affected workspaces. The shielding may be in the form of sheets of high conductivity metal such as aluminum. When a low-frequency magnetic field penetrates a high-conductivity material, eddy currents are induced in the material. The eddy currents, which set up magnetic fields that oppose the impinging magnetic field, create a phenomenon called reflection. When a material such as low carbon steel is used for shielding low-frequency magnetic fields, the magnetic fields are absorbed as losses in the ferrous metal. High-permeability material such as Mu-metal is highly effective in shielding low-frequency magnetic fields; however, such metals are very expensive and not very economical for covering large surfaces.

Anomalies in the power wiring are a common cause of stray magnetic fields in commercial buildings and hospitals. Neutral-to-ground connections downstream of the main bonding connection cause some of the neutral current to return via the ground path. This path is not predictable and results in residual magnetic fields due to mismatch in the supply and return currents to the various electrical circuits in the

FIGURE 7.8 Low-frequency electromagnetic field meter used to measure magnetic and electric fields.

facility. While low-frequency electromagnetic fields can interact with computer video monitors or cause hum in radio reception, they do not directly interact with high-speed digital data or communication circuits, which operate at considerably higher frequencies. Figure 7.8 shows how low-frequency electromagnetic fields are measured using an EMF probe, which indicates magnetic fields in milligauss (mG). Magnetic fields as low as 10 mG can interact with a computer video monitor and produce distortion. In typical commercial buildings, low-frequency magnetic fields range between 2 and 5 mG. Levels higher than 10 mG could indicate the presence of electrical rooms or vaults nearby. Higher levels of EMF could also be due to improper wiring practices, as discussed earlier.

7.7 HIGH-FREQUENCY INTERFERENCE

The term EMI is commonly associated with high-frequency noise, which has several possible causes. Figure 7.9 depicts how EMI may be generated and propagated to equipment. Some more common high-frequency EMI sources are radio, television, and microwave communication towers; marine or land communication; atmospheric discharges; radiofrequency heating equipment; adjustable speed drives; fluorescent lighting; and electronic dimmers. These devices produce interference ranging from a few kilohertz to hundreds of megahertz and perhaps higher. Due to their remote

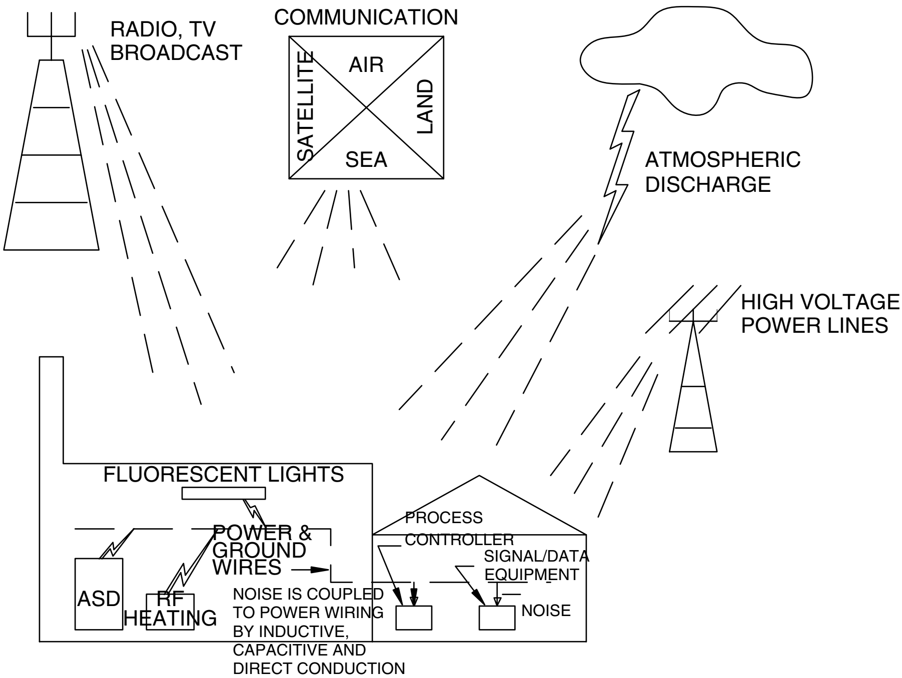

FIGURE 7.9 Common electromagnetic interference (EMI) sources.

distance and because electrical and magnetic fields diminish as the square of the distance from the source, the effects of several of the aforementioned EMI sources are rarely experienced. But, for locations close to the EMI source, the conditions could be serious enough to warrant caution and care. This is why agencies such as the Federal Communications Commission (FCC) have issued maximum limits for radiated and conducted emission for data processing and communication devices using digital information processing. The FCC specifies two categories of devices: class A and class B. Class A devices are intended for use in an industrial or a commercial installation, while class B devices are intended for use in residential environments. Because class B devices are more apt to be installed in close proximity to sensitive equipment, class B limits are more restrictive than class A limits. These standards have to be met by product manufacturers.

It is reasonable to assume that using equipment complying with FCC limits would allow a sensitive device installed next to equipment to function satisfactorily. Unfortunately, this is not always true because internal quirks in the component arrangement or wiring can make a device more sensitive to EMI than a properly designed unit. For example, location and orientation of the ground plane within a device can have a major impact on the equipment functionality. Figure 7.10 indicates the proper and improper ways to provide a ground plane or wire for equipment. In Figure 7.10A, noise coupling is increased due to the large area between the signal

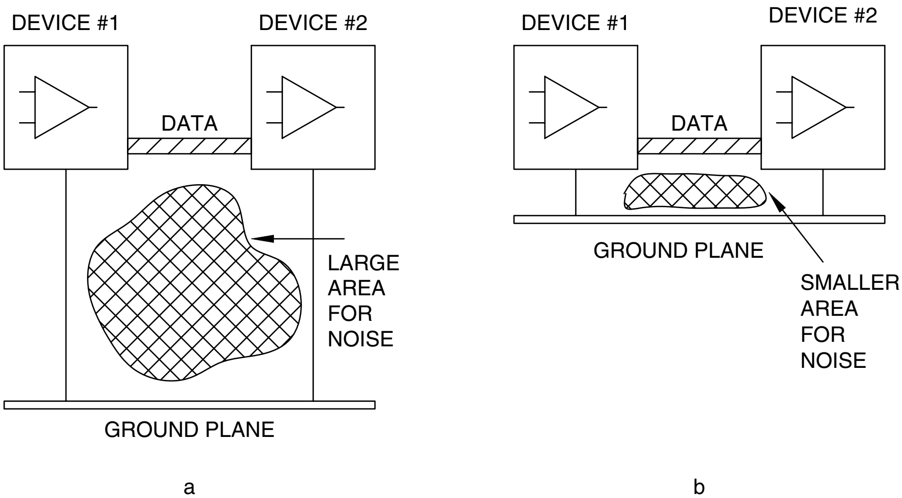

FIGURE 7.10 Location of ground plane or wire can affect noise pickup due to effective ground loop area.

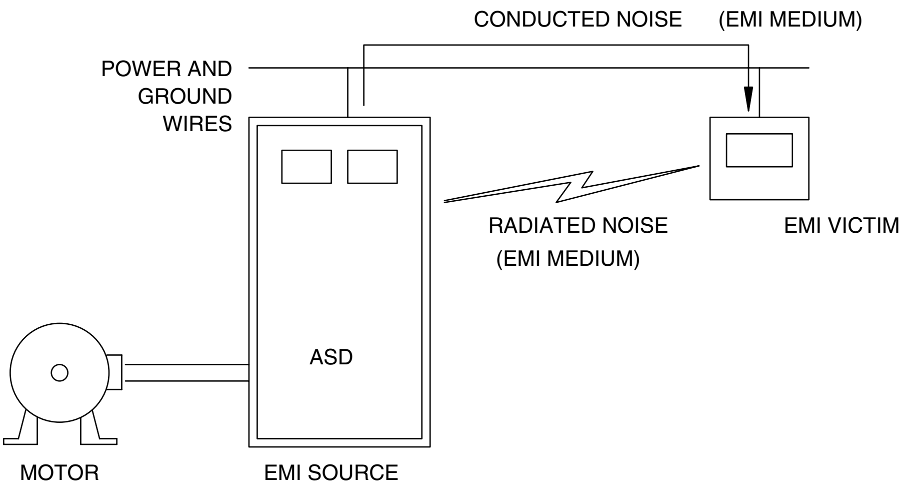

FIGURE 7.11 Criteria for electromagnetic interference (EMI) source, conducting medium, and victim.

and the ground wires. In Figure 7.10B, noise is kept to a minimum by keeping this area small. The same philosophy can be extended to connection of sensitive equipment to power, data, or communication circuits. As much as possible, effective area between the signal wires, between the power wires, and between the wires and the ground should be kept as small as practical.

7.8 ELECTROMAGNETIC INTERFERENCE SUSCEPTIBILITY

To produce electromagnetic interference, three components must exist: (1) a source of interference, (2) a "victim" susceptible to EMI, and (3) a medium for the coupling of EMI between the source and the "victim," which is any device sensitive to the interference. The coupling medium could be inductive or capacitive, radiated through space or transmitted over wires, or a combination of these. Identification of the three elements of EMI as shown in Figure 7.11 allows the EMI to be treated in one of three ways:

- Treatment of the EMI source by isolation, shielding, or application of filters
- Elimination of coupling medium by shielding, use of proper wiring methods, and conductor routing
- Treatment of the "victim" by shielding, application of filters, or location

In some instances, more than one solution may need to be implemented for effective EMI mitigation.

7.9 EMI MITIGATION

7.9.1 Shielding for Radiated Emission

To control radiated emission, shielding may be applied at the source or at the "victim." Very often it is not practical to shield the source of EMI. Shielding the "victim" involves provision of a continuous metal housing around the device which permits the EMI to be present outside the shield and not within the shield. When the EMI strikes the shield, eddy currents induced in the shield are in a direction that results in field cancellation in the vicinity of the shield. Any device situated within the shield is protected from the EMI. Metals of high conductivity such as copper and aluminum are effective shielding materials in high-frequency EMI applications. In order for the shield to be effective the thickness of the shielding must be greater than the skin depth corresponding to the frequency of the EMI and for the material used as the shield. Table 7.2 provides the skin depths of some typical shielding materials corresponding to frequency. It is evident that for shielding made of copper and aluminum to be effective at low frequencies, considerable metal thickness would be needed. Elimination of air space in the seams of the shielding is very critical to maintaining effectiveness. Special care is necessary when shields are penetrated to allow entry of power or data cables into the shielded enclosure.

7.9.2 Filters for Conducted Emission

Filters are an effective means of providing a certain degree of attenuation of conducted emissions. Filters do not completely eliminate the noise but reduce it to a level that might be tolerated by the susceptible device. Filters use passive components

TABLE 7.2
Skin Depth of Various Materials at Different Frequencies

Frequency	Copper (in.)	Aluminum (in.)	Steel (in.)	Mu-metal (in.)
60 Hz	0.335	0.429	0.034	0.014
100 Hz	0.26	0.333	0.026	0.011
1 kHz	0.082	0.105	0.008	0.003
10 kHz	0.026	0.033	0.003	—
100 kHz	0.008	0.011	0.0008	—
1 MHz	0.003	0.003	0.0003	—
10 MHz	0.0008	0.001	0.0001	—
100 MHz	0.00026	0.0003	0.00008	—
1000 MH	0.00008	0.0001	0.00004	—

Source: Ott., H. W., *Noise Reduction Techniques in Electronic Systems* John Wiley & Sons, Inc., New York, 2002. With permission.

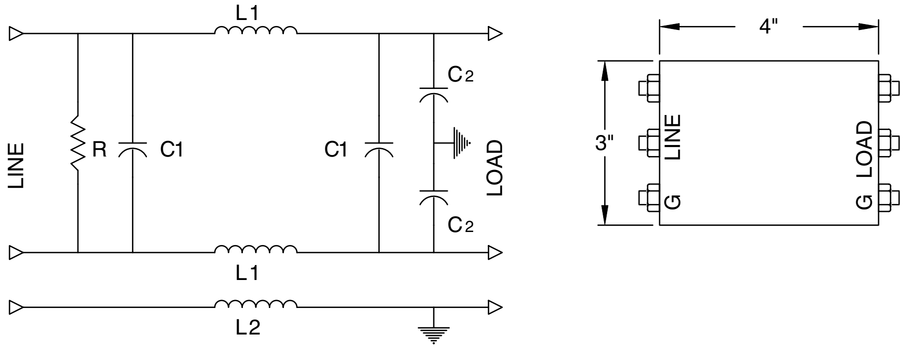

FIGURE 7.12 Typical electromagnetic interference (EMI) filter schematic and outline; the filter yields 60 dB common-mode attenuation and 50 dB transverse mode attenuation between 100 kHz and 1 Mhz.

such as *R*, *L*, and *C* to selectively filter out a certain band of frequencies. A typical passive filter arrangement is shown in Figure 7.12. Passive filters are suitable for filtering a specific frequency band. To filter other bands, a multiband filter or multiple filters are necessary. Filter manufacturers publish frequency vs. attenuation characteristics for each type or model of filter. Prior to application of the filters, it is necessary to determine the range of offending frequencies. Some filter manufacturers will custom engineer and build filters to provide required attenuation at a selected frequency band. For low-level EMI it is sometimes adequate to apply a commercially available filter, which does provide some benefits even though they may be limited. Sometimes filters may be applied in cascade to derive higher attenuation. For instance, two filters each providing 40-dB (100:1) attenuation may be applied in series to derive an attenuation of 80 dB (10,000:1). In reality, the actual attenuation would be less due to parasitic capacitance.

7.9.3 Device Location to Minimize Interference

We saw earlier that electrical and magnetic fields diminish as the square of the distance between the source and the victim. Also, EMI very often is directional. By removing the victim away from the EMI source and by proper orientation, considerable immunity can be obtained. This solution is effective if the relative distance between the source and the victim is small. It is not practical if the source is located far from the victim. For problems involving power frequency EMI this approach is most effective and also most economical.

7.10 CABLE SHIELDING TO MINIMIZE ELECTROMAGNETIC INTERFERENCE

Shielded cables are commonly used for data and signal wires. The configuration of cable shielding and grounding is important to EMI immunity. Even though general guidelines may be provided for shielding cables used for signals or data, each case requires special consideration due to variation in parameters such as cable lengths, noise frequency, signal frequency, and cable termination methodology, each of which can impact the end result. Improperly terminated cable shielding can actually increase noise coupling and make the problem worse. A cable ungrounded at both ends provides no benefits. Generally, shielding at one end also does not increase the attenuation significantly. A cable grounded at both ends, as shown in Figure 7.13, provides reasonable attenuation of the noise; however, with the source and receiver grounded, noise may be coupled to the signal wire when a portion of the signal return current flows through the shields. This current couples to the signal primarily through capacitive means and to a small extent inductively. By using a twisted pair of signal wires, noise coupling can be reduced significantly. As a general rule, it may be necessary to ground the shield at both ends or at multiple points if long lengths are involved. Doing so will reduce the shield impedance to levels low enough to effectively drain any induced noise. At low frequencies, grounding the shield at both ends may not be the best alternative due to the flow of large shield currents. The best shielding for any application is dependent on the application. What is best for one situation may not be the best for a different set of conditions. Sometimes the best solution is determined through actual field experimentation.

7.11 HEALTH CONCERNS OF ELECTROMAGNETIC INTERFERENCE

Electricity and magnetism have been with us since the commercial use of electricity began in the late 1800s, and the demand for electricity has continued to rise since then. Electricity is the primary source of energy at home and at work, and it is not uncommon to see high-voltage transmission lines adjacent to residential areas, which has raised concerns about the effects of electrical and magnetic fields on human health. Engineers, researchers, and physiologists have done considerable work to determine whether any correlation exists between electromagnetic fields and health.

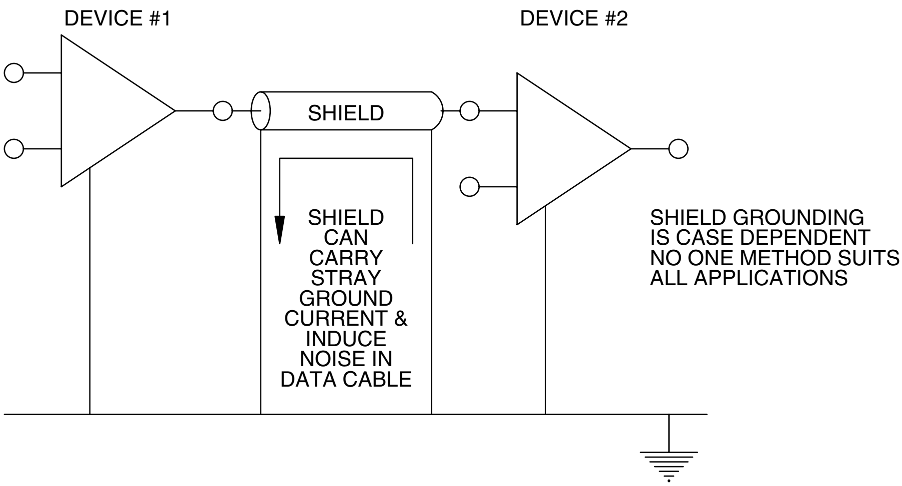

FIGURE 7.13 Cable shield grounding method.

This section provides an overview of the research done in this field so far by the various groups.

Earlier studies on the effects of fields were based on statistical analysis of the incidence of cancer in children and adults who were exposed to electromagnetic fields that were the result of wiring configurations and anomalies found at some of the homes. These studies suggested that the slightly increased risks of cancer in children and adults were due possibly to the fields; however, the risk factors were low. Cancers were reported in homes with slightly higher fields as well as homes with normally expected fields. The number of cases in homes with higher fields was slightly higher, but no overwhelming statistical unbalance between the two scenarios was found.

Later studies involving low-frequency exposure have not clearly demonstrated a correlation between low-level fields and effects on human health. One study observed a slight increase in nervous system tumors for people living within 500 m (≅1600 ft) of overhead power lines, while most recent studies in this field have not found any clear evidence to relate exposure to low-frequency fields with childhood leukemia.

Some experiments on rats and mice show that for continuous exposure at high levels of EMF (400 mG) some physiological changes occur. These EMF levels are well above what humans are normally exposed to at home or at work. One study that exposed humans to high levels of electrical and magnetic fields (greater than 100 times normal) for a short duration found a slowing of heart rate and inhibition of other human response systems.

The studies done so far do not definitively admit or dismiss a correlation between low-frequency magnetic fields and human health. During a typical day, humans are exposed to varying levels of low-frequency electromagnetic fields. This exposure is a byproduct of living in a fast-paced environment. A typical office space will have an ambient low-frequency electromagnetic field ranging between 0.5 and 3 mG.

TABLE 7.3
Low-Frequency Electromagnetic Force Due to Common Household Equipment

Equipment	EMF 6 in. from Surface (mG)
Personal computer	25
Microwave	75
Range	150
Baseboard heater	40
Electric shaver	20
Hair dryer	150
Television	25

Table 7.3 shows the EMFs produced by some common household electrical appliances. While the EMF levels can be considered high, the exposure duration is low in most cases. It is important to realize that the effects of exposure to low-frequency fields are not clearly known, thus it is prudent to exercise caution and avoid prolonged exposure to electrical and magnetic fields. One way to minimize exposure is to maintain sufficient distance between the EMF source and people in the environment. As we saw earlier, electrical and magnetic fields diminish as the square of the distance from the source. For example, instead of sitting 1 ft away from a table lamp, one can move 2 ft away and reduce EMF exposure to approximately one fourth the level found at 1 ft. It is expected that studies conducted in the future will reveal more about the effects, if any, of low-frequency electromagnetic fields.

7.12 CONCLUSIONS

Electromagnetic fields are all around us and are not necessarily evil. For instance, without these fields radios and televisions would not work, and cell phones would be useless. The garage door opener could not be used from the comfort of a car and the door would not automatically open. Electromagnetic energy is needed for day-to-day lives. It just so happens that some electronic devices may be sensitive to the fields. Fortunately, exposure of such devices to the fields can be reduced. As discussed earlier, shields, filters, and isolation techniques are useful tools that allow us to live in the EMI environment. It is a matter of determining the source of the interference, the tolerance level of the "victim," and the medium that is providing a means of interaction between the two. All EMI problems require knowledge of all three factors for an effective solution.