

Lighting *Answers*

Electromagnetic Interference Involving Fluorescent Lighting Systems

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NATIONAL
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Introduction

The modern office often is referred to as the electronic office: it routinely includes computers and printers, photocopiers and facsimile machines, security and building energy management systems, and fluorescent lighting systems. These electronic devices can generate interfering *electromagnetic waves*. * The effects of these waves vary, based on their strength and the susceptibility of nearby equipment.

Although the hundreds of thousands of electronic ballasts installed in North America have been associated with few documented cases of electromagnetic interference (EMI), these cases attract attention and diminish the reputation of an important component of energy-efficient lighting systems. The National Lighting Product Information Program (NLPIP) prepared this issue of *Lighting Answers* to

- identify applications where EMI involving fluorescent lighting systems may cause problems
- help specifiers troubleshoot existing EMI problems involving fluorescent lighting systems
- describe how to avoid EMI involving fluorescent lighting systems
- educate specifiers of lighting equipment about EMI in commercial offices

What causes EMI?

Electromagnetic waves of various wavelengths and frequencies make up the electromagnetic spectrum. The spectrum includes all forms of radiant energy: x-rays, gamma rays, infrared radiation, light, ultraviolet radiation, and television and radio waves. EMI occurs when electromagnetic waves affect the performance of an electronic device.

A poorly shielded power supply, poor wiring layout, or improper grounding may allow the transmission of electromagnetic waves. Alternating current in an electronic device produces a magnetic field, which in turn can induce an alternating current and voltage in another

device. A device may generate this current and voltage as an intended part of its design (for example, recording information on magnetic tape) or as undesirable artifacts of the device's design or installation.

EMI can take two forms: conducted or radiated. Conducted EMI occurs when electronic devices induce currents in the local power network that adversely affect an electronic device on the same power network. Radiated EMI is associated with solar flares, for example and the electric and magnetic fields inherent in electronic devices.

How can a specifier determine if the lighting system is causing EMI?

A specifier who suspects that EMI is affecting the performance of a piece of equipment can identify the source using the following procedure. First turn off all the luminaires and all the electrical equipment in the room except the affected equipment. The malfunctions should cease if the lighting system or any of the other electrical equipment is the cause of the EMI. Next turn the luminaires back on, one at a time if possible, while checking the functions of the affected equipment. If the malfunctions reoccur when a luminaire is turned on, that luminaire probably is the source of the EMI. Users should also check the compatibility of the affected equipment with other devices in the space by turning them on one at a time and checking the functions of the affected equipment.

What are some potential EMI problems and solutions with fluorescent lighting?

Table 1 lists examples of products susceptible to EMI, potential problems, and possible solutions that the installer or user can implement if a fluorescent lighting system is involved. The methods used to minimize EMI from high-frequency fluorescent lighting systems depend on the susceptibility of the product and whether the EMI is conducted or radiated. Specific solutions to specific problems depend on the application, but

* Terms in *italics* are defined in the glossary on p. 7.

Table 1
Examples of EMI involving fluorescent lighting systems and possible solutions

Susceptible Product	Problem	Cause
antitheft tag detection systems (in libraries, retail stores, etc.)	system fails to detect passing tag	Within 10–20 feet (ft) of the detector in all directions (including through the ceiling and floor to adjacent floors) magnetic fields from the fluorescent lamps, from the wires to the electronic ballasts, or from computer monitors or TVs can cause the antitheft detection system to fail.
control devices that use communication wiring (such as occupancy sensors, photosensors, programmable thermostats)	controls do not respond correctly to settings	The signal's information is altered by electromagnetic waves before reaching its destination.
cordless and cellular phones	screeching sound	Electromagnetic waves induce currents in the phone's antenna, which distort or overpower the desired signal.
infrared remote controllers for TV, audio, video, and lighting equipment	receiver does not respond to the controller; device may turn on when luminaire is switched on; TV may cycle through channels	High-frequency pulses of infrared energy from a fluorescent lamp may interfere with the infrared signal transmitted by the remote controller. See Figure 3 on p. 4.
intercoms	screeching sound	For <i>power line carrier</i> types of intercoms, conducted currents distort the signal. For cable types, radiated electromagnetic waves induce currents in the cable, which also distort the signal.
power line carrier control systems (commercial and residential)	controls do not operate	Some filters inside electronic ballasts, which are installed to reduce conducted currents from the ballast, can act as a short circuit for the power line carrier control system's signals.
radios	screeching sound or static	Electromagnetic waves induce currents in the radio's antenna, which distort or overpower the desired signal from the radio station.
special equipment commonly found in hospitals and research labs, such as electrocardiograph and MRI equipment, oscilloscopes, and computers	faulty readings and errors in memory storage	The signal that the device is detecting or working with is lost in the noise of electromagnetic waves.

Table 1 lists examples of EMI involving fluorescent lighting systems and possible solutions.

Most of the solutions described in Table 1 require electrical wiring changes, except for shielding and moving the equipment apart. Lamp shielding warrants special explanation,

however. Conductive glass or copper mesh can be placed in a luminaire's lens to block electromagnetic waves that originate in fluorescent lamps. The incident electromagnetic wave induces a current in the conductive glass or mesh. That current in turn induces an opposite electromagnetic wave, which

Possible Solutions

Add a *filter* to the detection system. This may not be possible, depending on the detection system.
Replace electronic ballasts that are within 10–20 ft of the detector with low-frequency ballasts (such as energy-efficient magnetic or *cathode-disconnect ballasts*)
Replace the detection system with a new one that uses a digital code interpreter to detect the tags.

Do not run low-voltage wires used for communication next to higher-voltage wires, such as main power wires for fluorescent lamps. If they must be adjacent to one another:

Use twisted-pair wire for the low-voltage wiring. See Figure 1 on p. 4.

Depending on the device's susceptibility:

Be sure the luminaire is *grounded*.

Alter the luminaire's internal wiring layout. See Figure 2 on p. 4.

Shield the ballast wires or the low-voltage wires.

Add a filter to the control device.

Use only low-frequency ballasts in the immediate vicinity and shield the fluorescent lamps.

If the phone has multiple channels, change the channel.
Move away from the luminaire.

Move the lamp away from the field of view of the receiver by moving it behind the receiver, for example.
Use incandescent lamps or low-frequency (60-hertz) ballasts in troublesome luminaires.
Install fresh alkaline batteries in the controller as a short-term solution.

For power line carrier types of intercoms, add a filter to the intercom to separate the wanted and unwanted frequencies.
For cable types:

Use twisted-pair wires.

Change the wiring layout to increase the distance between the luminaire and the intercom's wiring.

Place a filter with a high *impedance* for the signal frequencies on the power line before each ballast.
Use low-frequency ballasts in luminaires that are connected to any power line used by the control system.
Install a different control system.

Move the radio as far from luminaires, including desktop fluorescent task lights, as possible.
Consider an outside antenna wired to the radio.

Depending on the device's susceptibility:

Be sure the luminaire is grounded.

Alter the luminaire's internal wiring layout. See Figure 2 on p. 4.

Shield the ballast wires.

Add a filter.

For extremely sensitive equipment, use only low-frequency ballasts in the immediate vicinity and shield the fluorescent lamps.
Consider installing an alternative lighting system such as a light pipe, a fiber optic lighting system, or incandescent lamps.

negates the effect of the incident wave. Both materials reduce the electromagnetic waves from the lamp, but they also reduce light transmission from the luminaire's lens. Specifiers should consult product literature for information regarding the percentage of light lost because of the mesh or conductive

glass. Effective shielding material may reduce light transmission by more than 20%, so specifiers may want to install additional luminaires to compensate or consider alternatives to shielding.

Figure 1
Twisted wires reduce susceptibility to induced currents

Figure 1a illustrates the induced current that results from a straight wire in a magnetic field. As the magnetic field alternates, the induced current reverses direction, creating an alternating current flow in the wires.

In Figure 1b, the wires have been twisted so that the induced currents in adjacent loops cancel one another out. As the magnetic field alternates, the induced current in each loop reverses direction, still cancelling each other out.

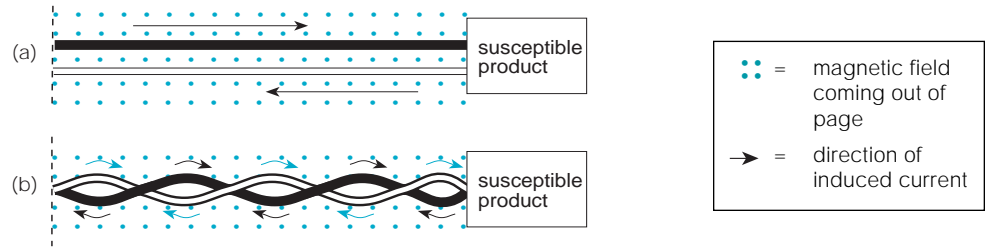


Figure 2
Rewiring ballast connections to minimize EMI

The wiring configurations on the left are more likely to cause problems associated with EMI than those on the right. Minimizing the distance between wires and between wires and lamps or ballasts decreases the intensity of the fields, which minimizes EMI. Note that in the figure in the upper right, the yellow wires are connected to opposite ends of the two lamps. This configuration also helps minimize EMI.

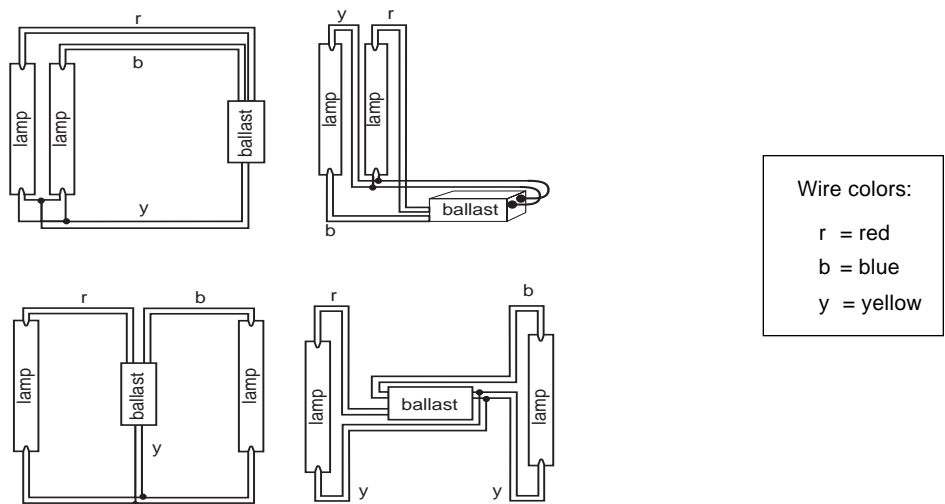
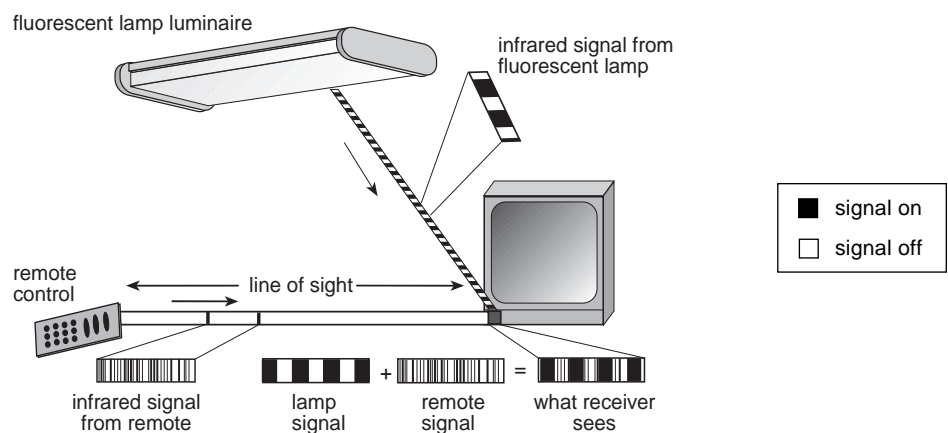


Figure 3
Infrared interference with remote controllers

The constant background infrared signal from the fluorescent lamp interferes with an infrared signal from the remote controller. The receiver sees a combination of the two signals in which the remote controller's signal is obscured by the background signal, so the receiver does not respond to the controller. In other instances, the signal from the fluorescent lamp causes the receiver to respond, even though the remote control was not sending a signal.



Minimizing EMI

Electromagnetic waves from electronic equipment and the equipment's susceptibility to electromagnetic waves can be minimized at the component, circuit, equipment, and system levels.

- Components (such as diodes, resistors, and capacitors) are the basic elements of an electric circuit.
- The circuit connects these elements to perform a specific function, usually using circuit boards.
- The equipment is the assembled device itself, such as a ballast.
- The system comprises the various pieces of equipment used within a space, including those that are connected to one another directly and those that merely share a power line.

Typically the manufacturer controls the emission of and susceptibility to electromagnetic waves at the component, circuit, and equipment levels. The installer or the user can limit electromagnetic waves at the system level.

Manufacturers or users can minimize EMI by changing wiring layouts, improving grounding of wires and equipment, adding filters to wires, shielding wires and equipment, moving equipment further apart, or moving equipment to a different circuit. The table below lists the methods that can be used at each level to minimize EMI, both for equipment that is susceptible to electromagnetic waves and for equipment that acts as a source of electromagnetic waves.

The physical distance between pieces of equipment can be critical if EMI occurs at the system level. The intensities of the electric and magnetic fields at any given point are directly proportional to their frequencies and inversely proportional to the square of the distance from the source of the field. As a result, the effects of low-frequency fields decrease more rapidly with distance than those of high-frequency fields. Therefore, equipment that is far from the source of the electromagnetic waves is predominantly susceptible to higher frequencies of interference. If the equipment is close to the source, it is susceptible to all frequencies. The definitions of "close" and "far" depend on the particular pieces of equipment.

Methods of minimizing EMI at different levels

Level	Minimize EMI by:*	
	(for susceptible equipment)	(for sources of EMI)
Component	shielding	changing components
Circuit	grounding adding filters changing wire layout	changing wire layout grounding adding filters
Equipment	grounding shielding	grounding changing wire layout shielding
System	moving equipment apart moving equipment to another circuit shielding wires adding filters	moving equipment apart shielding equipment shielding wires adding filters

* Methods are listed in the order that is most likely to minimize the EMI.

Should fluorescent lighting systems be avoided in certain installations?

Usually not. EMI from fluorescent lighting systems occurs infrequently. A specifier who wants the benefits of electronic ballasts can greatly decrease the possibility of an EMI problem through careful planning.

When planning an installation, evaluate what kinds of equipment will be used in the room. Use Table 1 as a guide to preventing EMI by taking the steps in the “Possible Solutions” column. Consult the manufacturer of the equipment or an electrical consultant for specific applications.

How can a fluorescent lighting system cause EMI?

A fluorescent lighting system that includes an electronic ballast (see *Specifier Reports: Electronic Ballasts*) can generate electromagnetic waves in four different ways (see Figure 4), each of which can be a source of EMI in another device:

- Fluorescent lamps operated by an electronic ballast radiate electromagnetic waves at frequencies from 10 kilohertz (kHz) to 100 megahertz (MHz). See number 1 in Figure 4.
- The wires that connect the electronic ballast to the lamps generate magnetic fields at frequencies from 10 kHz to 100 MHz. See number 2 in Figure 4.
- The *switch mode power supply* within the electronic ballast also radiates electromagnetic waves at frequencies from 10 kHz to 100 MHz. See number 3 in Figure 4.
- The wires from the electronic ballast to the main power system conduct currents to the power system at frequencies from 10 kHz to 100 MHz. See number 4 in Figure 4.

Are there government regulations concerning EMI?

In the United States, the Federal Communications Commission (FCC) regulates radio and wire communications, including interference. The FCC regulates conducted electromagnetic emissions with frequencies from 450 kHz to 30 MHz, and radiated electromagnetic emissions with frequencies from 30 MHz to more than 960 MHz. Most of the radiated electromagnetic waves from both electronic ballasts and fluorescent lamps are not covered by FCC restrictions because their frequencies are outside the regulated range (the portion below 30 MHz).

It is illegal to sell electronic equipment in the United States unless its radiated and conducted emissions have been measured and are within FCC limits. Manufacturers must test their own electronic equipment, although the FCC does not require them to submit test data. However, the FCC performs random sampling to verify manufacturer compliance. Products that comply with FCC regulations typically include a statement to that effect in their marketing literature or in installation guides.

Canada regulates electromagnetic emissions over the same frequencies as the United States (450 kHz to 30 MHz for conducted and 30 MHz to more than 960 MHz for radiated).

Many manufacturers design their products to comply with the more-stringent regulations that have been adopted by other countries, such as those developed by the International Special Committee on Radio Interference (Comité International Spécial des Perturbations Radioélectriques or CISPR).

Figure 4 Sources of electromagnetic waves from electronically ballasted fluorescent lighting systems

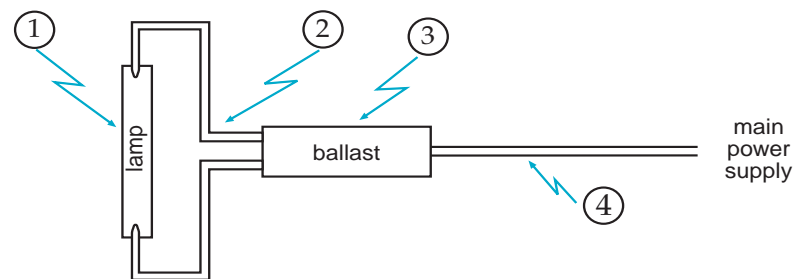
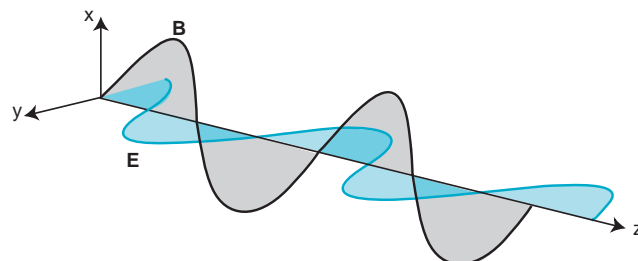


Figure 5 An electromagnetic wave

As the amplitude of a magnetic field (B) decreases, it induces an increasing perpendicular electric field (E). The result is an electromagnetic wave traveling along the z axis.



Glossary

cathode-disconnect ballast An electromagnetic ballast that disconnects the electrode-heating circuit after the lamps are started. Cathode-disconnect ballasts operate lamps at 60 Hz; they sometimes are called “hybrid” or “low-frequency electronic” ballasts. They operate lamps at lower power than magnetic ballasts.

electromagnetic wave A wave composed of perpendicular electric and magnetic fields. The wave propagates in a direction perpendicular to both fields. See Figure 5. The electromagnetic spectrum is shown in Figure 6.

electronic ballast A ballast that uses electronic components instead of a magnetic core and coil to operate fluorescent lamps. Electronic ballasts operate lamps at 20–60 kHz, which results in reduced flicker and noise, and increased efficacy compared with ballasts that operate lamps at 60 Hz.

filter A device that allows currents at certain frequencies to pass while those at other frequencies are blocked. Filters reduce conducted electromagnetic waves by grounding the current or by increasing the impedance to a specific frequency.

grounding To connect a circuit or metal object to the earth at one or more points. Done mostly for safety, grounding also reduces electromagnetic waves.

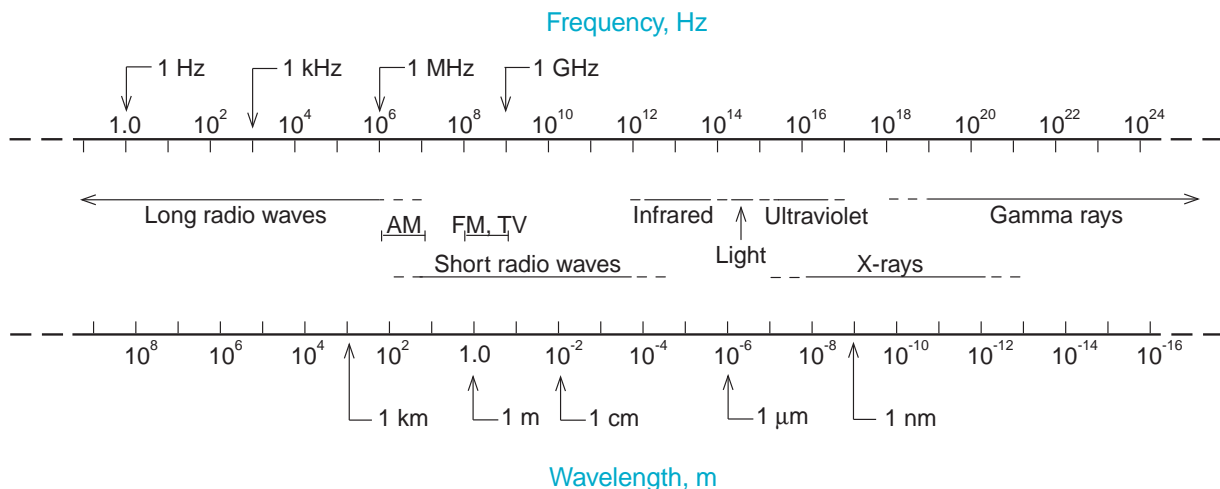
impedance A measure of the total opposition to current flow in an alternating-current circuit. The unit of impedance is the ohm (Ω).

power line carrier A system that transmits high-frequency (50–500 kHz) signals via the power lines of a building. These signals control devices such as luminaires, or contain voice transmissions such as intercom messages. Some commercial and residential energy management systems also use power line carrier systems.

shielding To block an electric or magnetic field with a metallic substance. The incident field induces currents in the metallic substance and these currents induce a field that opposes the incident field. Shielding reduces radiated electromagnetic waves. Electronic components, wires, lamps, and devices can all be shielded.

switch mode power supply A component of many electronic devices that increases or decreases the voltage or current from the main power supply to a level that the device can use. Switch mode power supplies are found in devices such as electronic ballasts, computers, televisions, microwave ovens, audio equipment, printers, photocopiers, and facsimile machines.

Figure 6
The electromagnetic spectrum



Resources

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