

# Solving the Clash of Electronics Technologies

## Background

Fifty or so years ago, magnetic ballasts and fluorescent lamps began to replace incandescent lamps in large buildings. Eventually, this technology made its way into the typical American household. Although the magnetically ballasted lamp was much more efficient than the incandescent lamp—up to four times as efficient—it sometimes produced an audible hum and included expensive components, such as a bulky step-up transformer.

In the 1980s, designers once again improved upon lighting technology by replacing the step-up transformer in magnetic ballasts with electronic components. The electronic ballast converts the incoming 60-Hz ac voltage into a dc voltage and then back into a higher-frequency ac voltage, anywhere from 20 to 80 kHz. Fluorescent lamps operating at the higher frequencies produce light more efficiently, last longer, and start faster than the magnetic-ballast lamps. And because silicon is much cheaper than iron and copper, manufacturers of ballasts are motivated to produce all-electronic ballasts, the discrete components of which may ultimately be integrated into a low-cost, reliable chip.

As with most technologies, improvement in lighting technology came at a cost. The nonlinear dc-to-ac converters in electronic ballasts, especially in ballasts that power compact fluorescent lamps, create harmonic currents, sometimes as high as 200 percent. Moreover, electric utility customers began to report cases of electronic ballasts interfering with other electronic appliances such as infrared remote controls, book-detection systems, and hearing aids.

## The Problem

In 1990, the New York Power Authority (NYPA) began to install high-efficiency lighting in the facilities of participating NYPA customers. Since then, NYPA has installed almost half a million electronic ballasts in public buildings throughout the State of New York, including many schools.

In an elementary school in the Great Neck School District, a student wearing a hearing aid experienced discomfort when her classroom was retrofitted with high-efficiency lighting. Bob Schwabe, a NYPA research and development engineer, attributed the sensations she experienced, a vibration in her jaw, to the sensitivity of her hearing aid to emissions from the new electronic ballasts. Therefore, the ballast retrofit operation was suspended until the exact source of the problem could be determined and a solution proposed.

None of the eleven research organizations contacted by NYPA were aware of a similar occurrence involving a hearing aid and electronic ballasts. Schwabe created his own research team of power quality consultants who performed studies at various locations in the school, made on-site calibrated measurements of radiated electromagnetic interference (EMI) and radio-

frequency interference (RFI), and interviewed the hearing-aid manufacturer about the operation of the analog model worn by the student. These studies indicated that the hearing aid was not affected by power-line harmonics and that harmonics produced by the electronic ballasts were within IEEE standards and FCC requirements.

Part of Schwabe's research team, the EPRI Power Electronics Application Center (PEAC) performed laboratory studies with four main tasks: (1) characterize the ability of the hearing aid to amplify discrete frequencies, (2) expose the hearing aid to ballast emissions similar to emissions of the school's new lighting system, (3) determine the interference mechanism, and (4) establish ways to make the hearing aid immune to those ballast emissions.

## The Investigation

**L**ABORATORY STUDY A typical analog hearing aid, not unlike a telephone handset, basically consists of a microphone, which picks up sounds in the user's environment; an amplifier, which amplifies the sounds from the microphone; and a speaker, which is usually a tiny device placed very close to the user's ear. Figure 1 shows a simple schematic diagram of the hearing aid worn by the student.

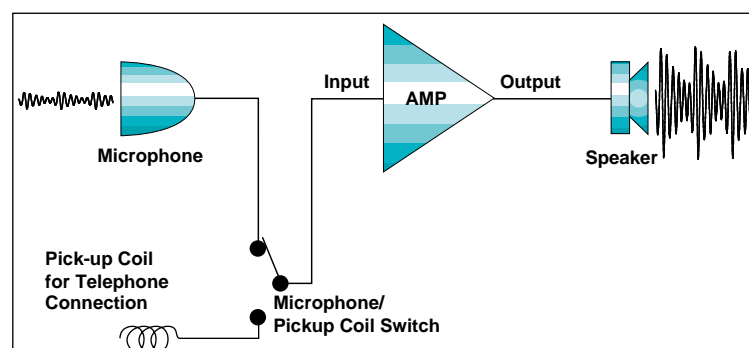


Figure 1.  
Simple Schematic  
Diagram of the  
Analog Hearing  
Aid Worn by the  
Student

PEAC power quality engineers first characterized the bandwidth of the hearing-aid amplifier and discovered that it passed signals from 150 Hz to 120 kHz. However, the speaker would probably limit the high-frequency end of the hearing aid bandwidth to about 6 kHz. Figure 2 shows the bandwidth of the hearing-aid amplifier only.

Next, the engineers in the PEAC laboratory characterized the operation and emissions of the same electronic ballast installed in the student's school, which had a switching frequency of 27 kHz. To determine whether the combination of an electronic ballast and fluorescent lamps could emit the 27-kHz switching frequency during normal operation, engineers measured the current flowing through one of the four-foot lamps. Figure 3 shows the recorded high-end frequency spectrum featuring a prominent 27-kHz spectral component and an 81-kHz sideband.

Engineers did not suspect this high-frequency component as the culprit of the interference mechanism for three reasons. First, because the student sensed the emissions as a vibration, engineers suspected a much lower frequency than 27 kHz. Second, they assumed that the hearing-aid speaker could pass only frequencies less than about 6 kHz and therefore could not pass the 27-kHz switching frequency of the ballast. Third, even if the speaker could pass such a high frequency, a person can only sense audio waves between about 20 Hz and 20 kHz.

Searching for a spectral component low enough to be sensed as a vibration, the engineers analyzed the low-frequency spectrum and discovered a prominent 120-Hz spectral component. When viewed on an oscilloscope, the current through the lamp appeared to be a classic amplitude-modulated (AM) signal, with the 27-kHz component functioning as a carrier, and the 120-Hz component functioning as a modulation signal. Figure 4 shows the AM waveform of the lamp current. Finally, the engineers brought the two clashing technologies together, characterizing the operation of the hearing aid when it was close enough to the electronic

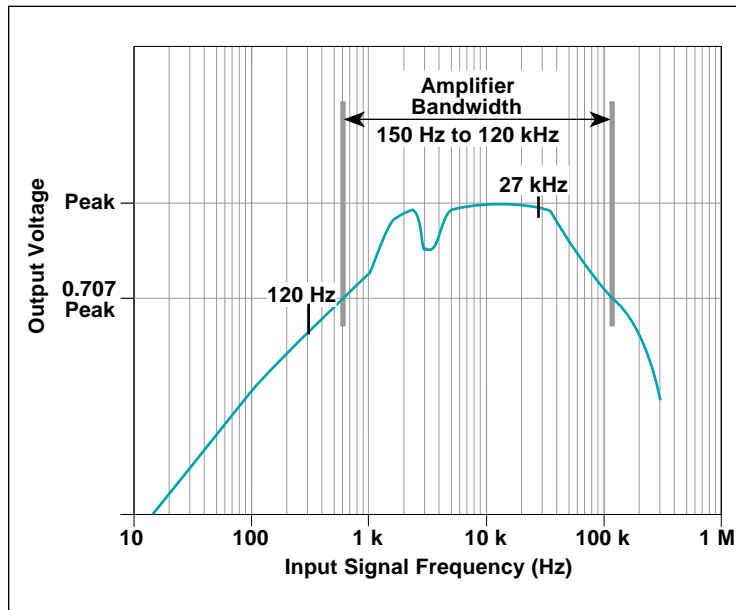


Figure 2.

Bandwidth of the Hearing-Aid Amplifier

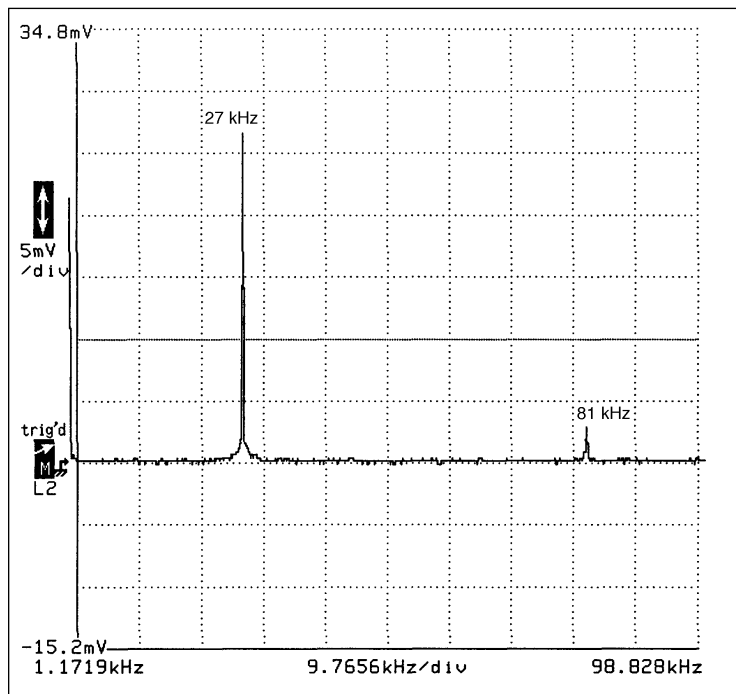


Figure 3.

High-End Frequency Spectrum of the Lamp Current

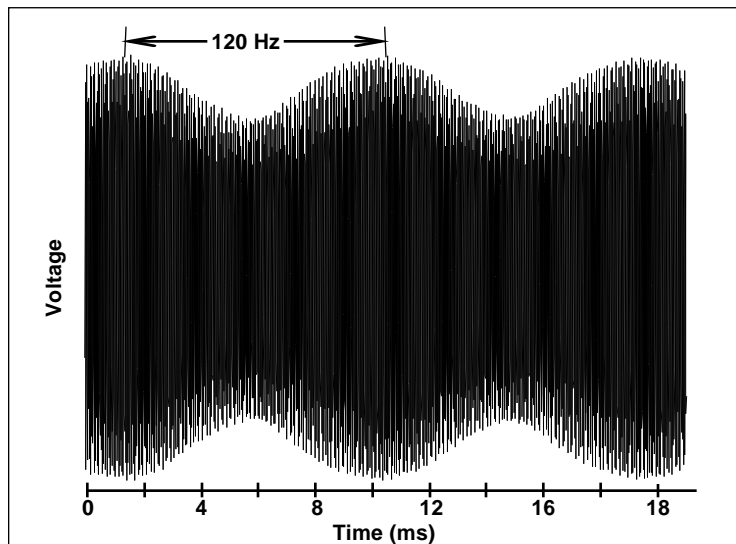


Figure 4.

Amplitude-Modulated Current in the Lamp

lighting to pick up the AM emissions. As a result of these tests, they arrived at an explanation for the incompatibility between the hearing aid and the electronic lighting.

**INTERFERENCE MECHANISM**

The student’s hearing aid was receiving and amplifying the amplitude-modulated 27-kHz emissions just as an AM radio would receive a station broadcasting on a certain frequency—in this case, 27 kHz. Although it could not pass frequencies above 6 kHz or so, the hearing-aid speaker could pass the audible 120-Hz signal from the 27-kHz carrier. The student felt rather than heard the resulting 120-Hz signal at the speaker output as an uncomfortable vibration in her jaw. Figure 5 shows the interference mechanism.

**The Solution**

Armed with a basic understanding of the problem, Schwabe asked PEAC to develop a low-cost shield for the hearing aid that effectively eliminates the interference. Meanwhile, he proceeded with a parallel approach suggested by the manufacturer: replace the student’s hearing aid with a digital model immune to emissions from electronic ballasts. The digital model had an active filter that passed only the frequencies in the range of human hearing and blocked the 27-kHz carrier frequency of the ballast emissions.

In the laboratory, PEAC tested two basic shielding methods—brass foil and a combination of conductive paint and foil—to reduce the amplitude of the ballast emissions reaching the metal parts of the hearing aid, which functioned as an antenna. Modified with the brass foil shields and cellophane insulators, the hearing aid was exposed to high and low levels of RFI emissions, which the shield reduced by about 70 percent.

Because PEAC considered that a 70 percent reduction in the emissions might not be adequate to mitigate the physical effects on the student, the inside of the hearing-aid case was double-coated with a spray of conduc-

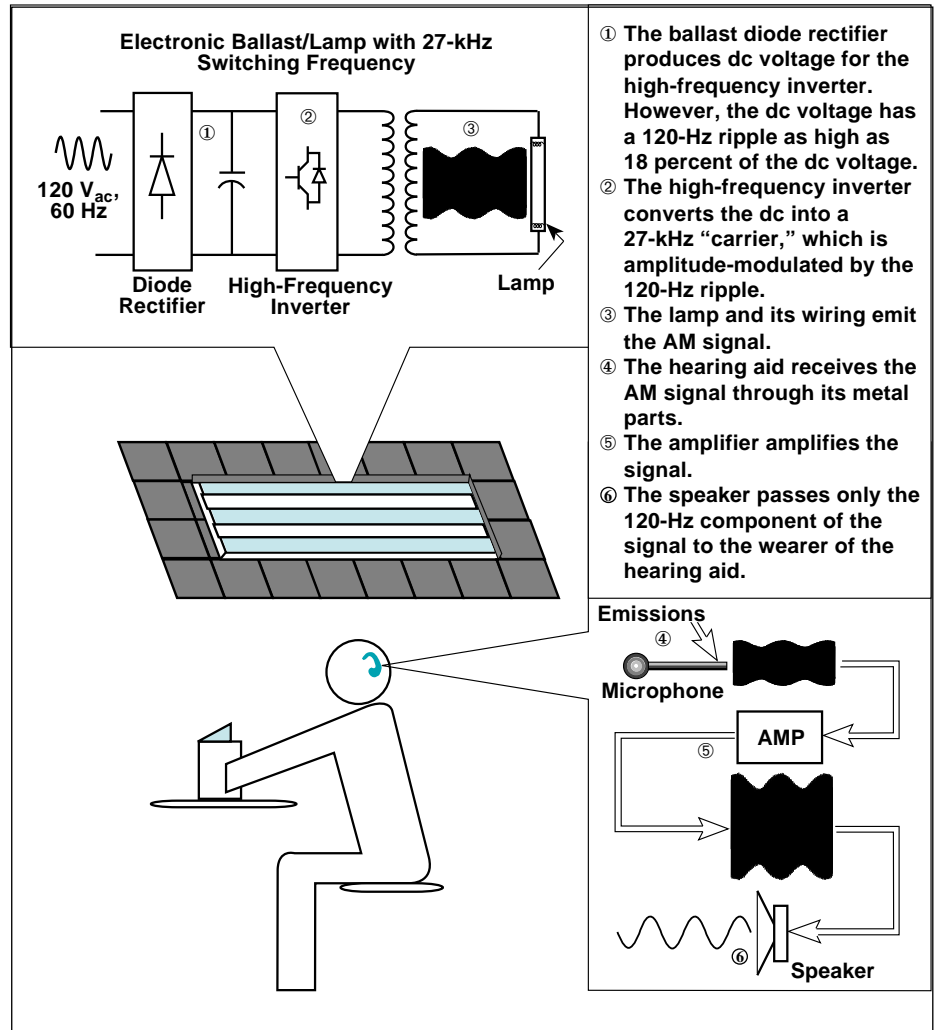


Figure 5. The Mechanism of Interference Between Electronic Lighting and the Analog Hearing Aid

tive paint. The brass foil and cellophane were installed as before, and the device was again subjected to high and low levels of RFI emissions. This combination of shielding techniques reduced the emissions by about 95 percent. The shielded model was then worn by the student, who confirmed that the shield had eliminated the ballast interference.

**Significance**

The hearing-aid incident illustrates how a concentration of electronic ballasts and fluorescent lamps is in effect a low-power AM transmitter, very similar to an AM radio station. As the switching frequencies of electronic ballasts increase, different interference problems will emerge. Therefore, application engineers will be challenged to consider compatibility issues when appliances capable of receiving AM

radio signals clash with new installations of electronic lighting. Moreover, field studies indicate that electronic ballasts can attenuate radiated and conducted power-line carrier signals, as well as produce harmonic distortion and other types of electromagnetic interference that may affect the performance of other electronic appliances, such as infrared remote controls.

Conversely, electronic lighting itself may be susceptible to electrical disturbances such as voltage fluctuations and surges. Given the increased complexity of the typical electrical environment, more design challenges involving electromagnetic compatibility are likely. Design engineers must ensure the compatibility between old and new technologies (see Tutorial, back page). And manufacturers must be willing to modify the designs of their products based upon reported incompatibilities.

