Exploring for Electromagnetic Fields With a Telephone Induction Coil

By Forrest M. Mims III

For those of us who sometimes experiment with high-voltage coils and transformers, the phrase "induction coil" might conjure up an image of a crackling, popping transformer or a coil generating bluish arcs and copious quantities of ozone. While induction coils are certainly capable of such feats, it's important to remember that all coils are inductors. That some inductors serve as resonators for radio-frequency signals and others as high-voltage generators illustrates the remarkable versatility of one of the simplest and oldest of all electronic components.

The telephone induction coil was developed so that telephone conversations could be conveniently recorded without having to make a direct electronic connection to the telephone line. Later in this column, I'll explore this topic and its legal ramifications. But first let's examine some of the many other fascinating applications for this simple, inexpensive device.

Telephone Induction Coil

Shown in Fig. 1 is a drawing of a typical telephone induction coil. This device consists of a coil of very fine wire wound round an iron core. The coil is installed in a protective plastic housing fitted with a suction cup to permit it to be conveniently attached to the receiver end of a telephone handset. While the suction cup is handy for this purpose, it does impose additional separation between coil and receiver.

Most telephone receivers incorporate an electromagnetic audio transducer that contains a wire coil and an iron core. The combination of a telephone receiver and the induction coil forms a transformer. Audio-frequency signals circulating in the receiver's coil induce an identical signal in the nearby induction coil. This principle is illustrated in Fig. 2. The signal in the induction coil can then be amplified and recorded.

It's important to note that some newer telephone receivers use a piezoelectric receiver element instead of the older electromagnetic type. The signal passing through this kind of receiver won't be coupled into a telephone induction coil.

Knowing that the feeble signals radiated by a telephone receiver can be easily coupled into a telephone induction coil, it's simple to conclude that electromagnetic fields from other sources can also be coupled into such a coil. This is certainly the case. Connect an induction coil to any audio amplifier, and you'll have a highly sensitive electromagnetic probe that transforms oscillatory, audio-frequency magnetic fields into their respective sound frequency.

Induction-Coil Amplifier

Virtually any audio-frequency amplifier can be used to transform into sound the signals induced into a telephone induction coil. If you wish to build your own, the schematic diagram for a suitable circuit is shown in Fig. 3. If you build this circuit, keep the battery leads reasonably short to prevent oscillation. Although the circuit doesn't show any bypass capacitors, it's usually best to connect a 0.1-microfarad bypass capacitor between each of the power supply pins of the two integrated circuits and ground. Be sure to keep the speaker and its leads away from the circuit's input leads. Otherwise, oscillation might occur.

You can replace the speaker with an earphone, if you prefer. Be sure to keep the earphone cord away from the input of the circuit and the induction coil to prevent possible oscillation.

Whether you build your own amplifier or use a commercial unit, be especially careful when using an earphone to listen to the signals detected by the coil. If the

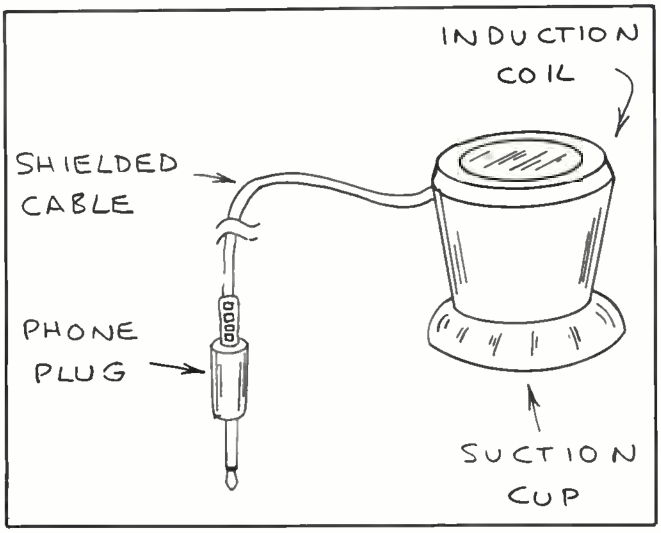

Fig. 1. Details of a typical telephone induction coil.

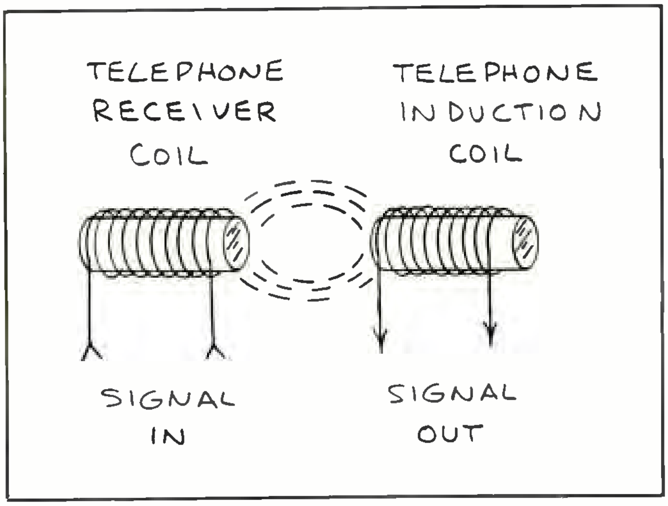

Fig. 2. How an induction coil picks up field from a telephone receiver.

volume is set too high, the sound level caused by some sources may damage your hearing.

Exploring the 60-Hz Electromagnetic Environment

Once you've acquired an amplifier for your induction coil, it's time to go exploring. For starters, find a utility pole outdoors and explore the region around it with your probe. You should hear a constant background hum that grows in intensity as you approach the pole or the power line. The pole near my office and home serves as a terminal for several underground power lines. Therefore, it radiates a particularly strong 60-Hz field. The 60-Hz field from the power line itself is induced into a nearby metal farm gate, barbed wire fence and metal mail box. A 60-Hz field will also be induced into the metal body of an automobile that is parked near the line.

While you're below a power line, rotate the induction coil to notice its directional response. When the coil's iron core is parallel to the power line, the hum should be very weak. Rotate the coil 90° so its core is perpendicular to the line, and the level of the hum will increase substantially. If your results differ, check your surroundings. Maybe you're too close too a power line in a nearby building.

Next, go indoors and place the induction coil next to a light switch. When the switch is off, you may or may not hear a very weak 60-Hz hum. Flip the switch, and you should hear a hum. The hum produced by a fluorescent lamp should be considerably louder than that produced by an incandescent lamp.

Listen carefully, and you should hear a weak 60-Hz hum inside virtually any building that contains electrical wiring. As you move the probe along walls, the hum will rapidly increase in intensity as it passes near power lines. The level of the hum may suddenly increase or decrease if an appliance is switched on or off while you're listening. The 60-Hz field may even be induced into various metal objects and fixtures, like cabinets and desks. Just place the probe near such objects to see if the hum level increases.

You'll find that fluorescent lamp fixtures radiate exceptionally strong 60-Hz fields. Move the induction coil along the fixture; you'll discover that the sound is loudest when the probe is directly over the ballast transformer.

Line-powered appliances are also good 60-Hz radiators, especially those that have power transformers. You can find out for yourself by placing the probe anywhere near a switched-on microwave oven, TV receiver or radio.

Do you have an electric blanket? Switch it on and try using the induction coil to trace the wiring inside the blanket.

As you may know, in recent years there has been considerable controversy over the possible adverse effects of low-frequency electromagnetic fields on human health. The Earth's magnetic field is many times stronger than the average 60-Hz field received by most people. Therefore, it was generally assumed that man-made fields were perfectly safe.

Recently, however, the Environmental Protection Agency released the results of a two-year study that showed a possible linkage between fields from transmission lines and even household appliances with cancer. Many scientific papers have recently been published on this same subject. While the combination of an induction coil probe and an amplifier doesn't provide a quantitative measurement of the intensity of such fields, it does give accurate information about their location. If you're concerned about the possible effect on a sleeping child of the field from wiring concealed inside a wall, you can easily determine if such a field exists with the simple system described here.

Non-60-Hz AC Fields

The picture tube in a TV receiver or computer video monitor radiates a very strong field. If you place a telephone induction coil near the edge of the tube, you'll hear a very strong buzz. Move the coil to the center of the screen, and the amplitude of the buzz will fall sharply.

You may be able to detect this signal at a considerable distance from a TV receiver or video monitor. Notice how the position of the coil influences the amplitude of the buzz.

When you place the induction coil near line-powered appliances that incorporate digital circuitry, you'll usually hear tones of various frequencies superimposed over the ever-present 60-Hz hum. The segments or digits of electrofluorescent displays are driven in rapid sequence, and this multiplexed signal provides one characteristic signal. The clock circuit that provides timing for microprocessors and other controllers also generates a signal. Even if the clock frequency is above the range of human hearing, you may hear harmonics of the fundamental clock frequency or various other frequencies that have been divided from the original.

You can use an induction coil to quickly find the location of the power transformer inside a sealed, unshielded enclosure. You can also make a map of the field radiated by an instrument such as a computer.

Battery-Powered Devices

Figure 4 is an outline view of the top of the laptop computer into which this column was typed. Note how a scan with the induction coil probe reveals that particular portions of the computer radiate exceptionally strong signals. The signal can be easily picked up when the induction coil is a meter or more away from the computer. One reason for the sharp changes in the signal level is the fact that computers must be shielded to meet the requirements of the Federal Communications Commission.

While making the field map of the computer shown in Fig. 4, it was necessary to move the computer some distance away from the nearby VGA monitor. The monitor generates a much stronger field, which swamps out most of the signals emitted by the laptop.

Many other battery-powered circuits and instruments also radiate signals that can be intercepted by an induction coil. A quartz-regulated clock on my wall incorporates a low-power motor that kicks the second hand once each second. When an

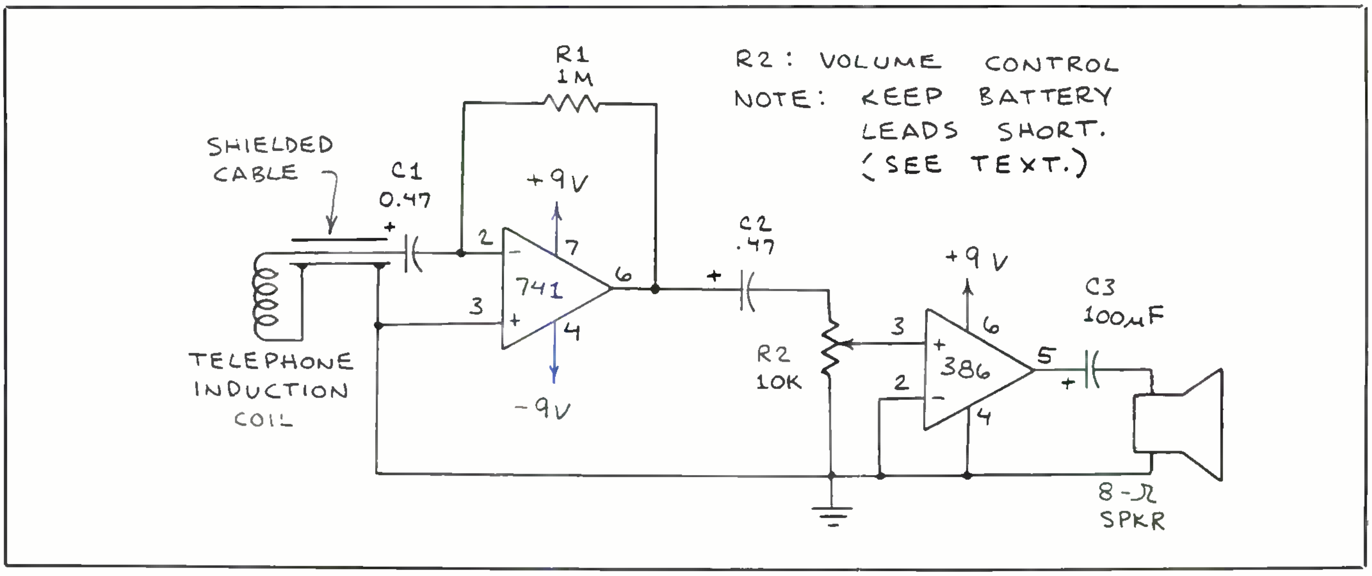

Fig. 3. Schematic details of a telephone induction coil amplifier.

induction coil is placed near the center of the clock, a very closely spaced pair of "pocks" is heard once each second. Presumably, the first pock represents the rising edge of the pulse that drives the motor, the second pock the falling edge of the same pulse. The radiated signal is much stronger than that from a clock or watch with a liquid-crystal display since the pulsating signal flows through the motor's coil, which, in turn, emits a magnetic field.

The motor in a tape recorder produces a very characteristic sound when the induction coil is placed nearby. You can even locate the motor's position by moving the coil around the recorder's case.

Digital calculators include a clock circuit that synchronizes the central processor, display and keyboard scanner. The signal radiated by a Hewlett-Packard HP-28 scientific calculator is quite strong. That radiated by a tiny solar-powered Texas Instruments TI-25 scientific calculator is considerably weaker but easily detectable.

Most remote-control transmitters for TV receivers, radios and Compact Disk players transmit a beam of near-infrared radiation. They also radiate an electromagnetic field that can be easily heard by placing an induction coil near the transmitter while its buttons are pressed.

Some Experiments

One of the first things you'll discover when you go searching for magnetic fields is that the amplifier produces a loud, pure tone when the induction coil is placed near the amplifier's speaker. If you're using an earphone, the same thing will occur if the coil is placed near the phone or, in some cases, the phone's cord. The origin of this tone is the same kind of positive feedback that causes audio amplifiers to squeal and howl when a microphone is placed too close to a speaker or when the gain is set too high. Feedback produced by an induction coil, however, results in a much purer tone. The feedback takes place because of the inductive coupling between the induction coil and the voice coil of the speaker (or the coil of the earphone).

An interesting demonstration that capitalizes on the feedback phenomenon is to swing the induction coil back-and-forth over the amplifier's speaker. Each time the coil swings past the amplifier, a loud chirp will be produced. A similar effect can be obtained by swinging an earphone past the induction coil.

You can make a simple musical instrument by installing a magnet under a taut steel wire and placing an induction coil on the other side of the wire. Pluck the wire and it will slice through the magnet's field at an audio-frequency rate. This induces an identical audio-frequency signal into the coil. Voila, a one-string steel guitar.

Want an electronic drum? Place a small magnet on a table a few centimeters away from the induction coil. Stretch out a steel paper clip and hold one end of the wire on the surface of the table so the wire is between the magnet and the coil. When you pluck the free end of the wire, you'll hear very realistic drum-like thumps. You can alter the sounds by changing the free length of the wire.

If the magnet jumps over and clings to the wire, use tape or a clamp to hold it to the table. But first experiment with this new arrangement. When the magnet rotates around the wire or swings back and forth, you'll hear various kinds of interesting sounds.

You might want to try this experiment with several pieces of steel piano wire cut to different lengths and tightly clamped into place. Some hobby and craft shops sell piano wire. You might also want to experiment with different magnets. Plucking the free ends of the wires should result in a wide range of musical sounds.

Tape Recording

Telephone induction coils are ideally suited for taping radio broadcasts and recordings from other recorders when it's not possible to make a direct electrical connection between the tape recorder and the instrument being recorded. Usually, a microphone is used when a direct connection isn't possible. But a microphone will pick up any room noise that's present and superimpose it on the signal being recorded.

To record a radio signal, simply place the induction coil near the radio's speaker. If you don't want to hear the broadcast being recorded until later, just place the coil near an earphone connected to the radio. Use the same technique to copy a tape recording. First, however, be sure the coil doesn't pick up the source recorder's motor noise. If this is a problem, connect an earphone to the source recorder and place it and the induction coil together some distance away from the recorder.

Now we have come full circle, for the taping of telephone conversations is the purpose for which telephone induction coils are sold. The process is simple: just attach the suction cup to the receiver end of the telephone handset and press RECORD. But is it legal?

During my 20 years as a free-lance writer, I've only rarely used a tape recorder to record an interview. In each of those few cases, I asked permission to record the conversation. I've also recorded a number of radio talk shows on which I was a guest. Other than these instances, I've never recorded anyone's conversation over the telephone, with or without their knowledge.

However, while working on an assignment for a major magazine a year or so ago, I found myself in an emergency situation in which it seemed only prudent to be prepared to record conversations without first asking permission. It also seemed prudent to first visit a library to find out what the law said about taping telephone conversations.

According to the United States Code ("Wire and Electronic Communications Interception and Interception of Oral Communications," Title 18, Chapter 119, Section 2511, (d), "It shall not be unlawful under this chapter for a person not acting under color of law to intercept a wire, oral, or electronic communication where such person is a party to the communication or where one of the parties to the communication has given prior consent to such interception unless such communication is intercepted for the purpose of committing any criminal or tortious act in violation of the Constitution or laws of the United States or of any State."

Simply put, this 80-word sentence says it's okay to record a conversation if at least one party knows the recording is being made or has given permission. The recording cannot be made for unlawful purposes.

Since this law clearly permits the practice, my recorder was ready when the anticipated emergency did indeed occur. Later, however, I found the following passage in a telephone directory: "It is a crime under federal and state law for any person, including a telephone subscriber, to unlawfully wiretap or otherwise intercept a telephone call . . . Under federal law, the penalty for illegal wiretapping can be imprisonment for 2-20 years, a $10,000 fine or both."

This warning seems fairly clear and blunt. But it clashes with the United States Code. Not wanting to risk violating any laws, I decided it would be best to erase the important ferrous-oxide record produced by the recorder. First, I was curious to find out more about the obvious contradiction between the U.S. Code and the warning in the telephone directory. Therefore, I telephoned the Federal Communications Commission and spoke with an attorney with the Common Car-

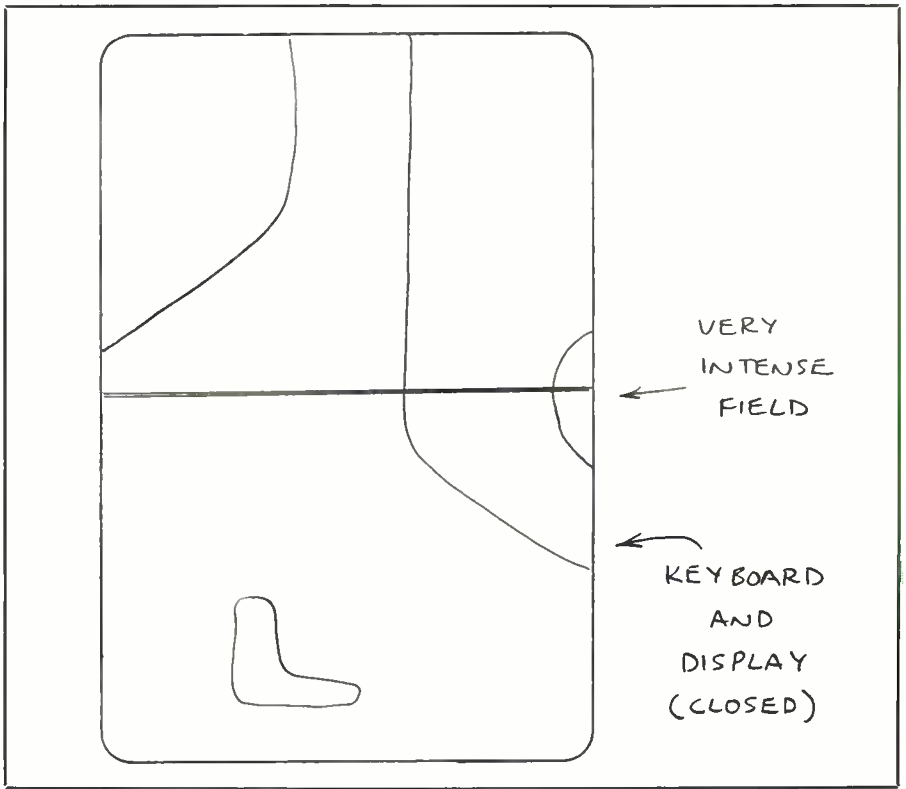

Fig. 4. Magnetic-field map of a laptop computer.

rier Bureau. He sent me a report titled "Use of Recording Devices in Connection with Telephone Service" from Federal Communications Record (FCC 86-570, Docket No. 20840, pp. 502-506).

Adopted December 23, 1986, this report explains how the telephone company tariff requires subscribers to use a beep tone device or to request prior consent before a telephone conversation is recorded. "In other words," the report observes, "our telephone recording policies are applied to the general public through a tariff mechanism and to the telephone company itself through a Commission rule."

This report goes on to observe that "... Congress has placed responsibility for enforcing telephone privacy in the courts and that the courts have found that one party consent recordings are not unlawful." The report also notes then "even if a recording does violate the tariff and the tariff is subsequently enforced, the recording may still be admissible in court."

The report also observes that "In many instances, the mere threat of service suspension will be enough to deter future misconduct . . . the very existence of a regulation, albeit largely unenforceable, is enough to induce compliance." The report notes that "The penalty for violation of the tariff provision is possible discontinuance of telephone service." It concludes with a statement in which the FCC retains the mutual consent and beep-tone requirements in the tariff.

Confused? So was I. Therefore, I asked some attorneys to explain the apparent contradiction between a law that permits a practice restricted by a regulation and the warning in the telephone directory. The key word in the telephone directory warning is "unlawful." The attorneys said that the United States Code prevailed and that it's lawful to tape a conversation without informing the other party. However, the telephone company might threaten to discontinue service if it learned of the practice. Also, a party whose conversation is recorded might take legal action if the recording is used in an unlawful manner.

Since *Modern Electronics* and I aren't attorneys, you shouldn't consider any of this as legal advice. Furthermore, it's especially important to remember that the laws of some States prohibit the recording of any telephone conversations without mutual notification. My personal opinion is that one should never record a telephone conversation without informing the other party unless there's a clear emergency and an attorney has approved the procedure. In my case, the ferrous-oxide record saved by a tape recorder, coupled with good legal advice, made possible the publication of three of the most important magazine articles of my career.

Going Further

One can only wonder if the companies that make telephone induction coils realize just how versatile are these devices. The applications and experiments described here are only some of the many possibilities. No doubt you'll think of and discover many others once you begin experimenting and exploring.

Calvin R. Graf, a friend of mine, wrote *Listen to Radio Energy, Light and Sound* (Howard W. Sams & Co., Inc., 1978), a book that included a section on uses for telephone induction coils. This book may be out of print, but it's worth looking it up in a library. In addition to some of the applications described here, Cal describes how to use an induction coil to "hear" flashlight switches, neon lamps and pilot lights. He also describes how to monitor various electrical devices on an automobile with a telephone induction coil and how to communicate through a wall by means of an earphone for a transmitter and an induction coil for a receiver.

If you want to find out more about the possible hazards of low-frequency electric and magnetic fields, see "Power Play" by David Noland in *Discover* (December 1989, pp. 62-68) and "Power Lines and Cancer: The Evidence Grows" by Louis Slesin in *Technology Review* (October 1987, pp. 53-59). Dozens of technical papers on the subject have been published in the scientific literature. **ME**