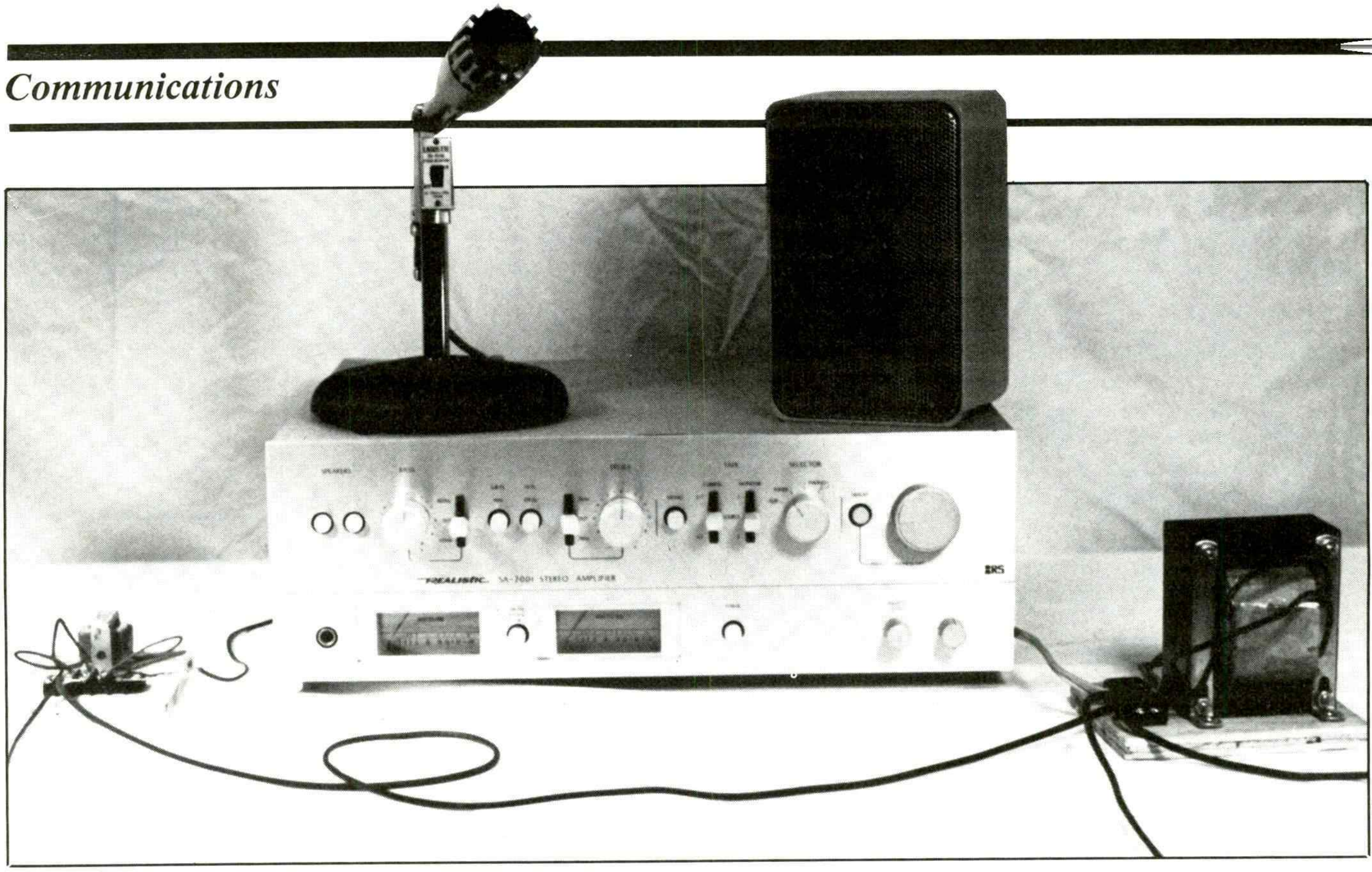

A Ground Communication System

Transmit and receive Morse code and voice signals with this "clandestine" system that uses the earth as the communication medium

By Joseph O'Connell

The technique of communicating through the earth was used to great effect by the French during WWI and amateur radio operators during WWII when they were forced to leave the air. Though through-ground communications came into existence as the result of armed conflict, it has peacetime uses as well and, as a result, never died out. Today, the primary application of underground communication remains as a short-range way to send and receive messages. The very nature of the operation lends an almost-clandestine flavor to the hobby.

If you and a friend live within about a quarter of a mile or so of each other, you can communicate through the earth. This method of communicating does not use radio frequencies and does not propagate through the air as r-f does; thus, it requires no license and no expensive radio gear. In fact, you probably already have all the equipment needed to communicate through the earth on hand. All you need to do is to adapt it for this exciting hobby.

Setting Up a Station

To be able to communicate through the earth, at least two stations must be established. Furthermore, two conductive paths are required to carry voice or code signals between stations.

One conductive path can be the cold-water pipe at the station location, assuming all stations are connected to the municipal water-delivery system and are in common electrical contact with each other. If you live in an area where there is no municipal water system, you can still use

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this method of communicating, but you will have to establish a good ground system yourself. Later on, we will give full details on how to go about this.

The second conductive path is formed by driving a metal stake into the ground at each station's location. The conductive path then exists between the stations, through the earth.

A third conductive path can be added to each station, in the form of an extra stake driven into the ground to eliminate the push-to-talk arrangement encountered in simplex communication techniques.

Shown in Fig. 1 is an illustration of the simplest ground-communication arrangement. This particular setup offers the easiest way to try out this communication technique. It uses only a cold-water pipe for ground and one additional stake.

When setting up a ground system, you can use the cold-water pipe in your home if it goes to a municipal water-delivery system. If there is no municipal water system in your community, you must drive a separate stake to make the required ground connection. If you must use a separate ground stake, drive it into the ground so that it goes as deep and touches as much earth as possible. Typically, a 4-foot length of galvanized steel pipe, rod or angle iron should be minimum length for the stake. Drive the stake all the way into the ground with a heavy hammer.

For an even better ground, it is advisable that you dig a hole and bury some sheet metal or other conductive materials at the bottom of the hole, touching moist earth to provide a large surface contact area. Thoroughly wet down the hole and refill it with the removed soil. Solidly tamp down the soil and saturate it with water. Then drive the stake into the midst of the buried conductive material to obtain good electrical contact.

If you use a steel rod or pipe, be sure to fasten a cross-piece to the top of it, as shown in Fig. 2. This cross-

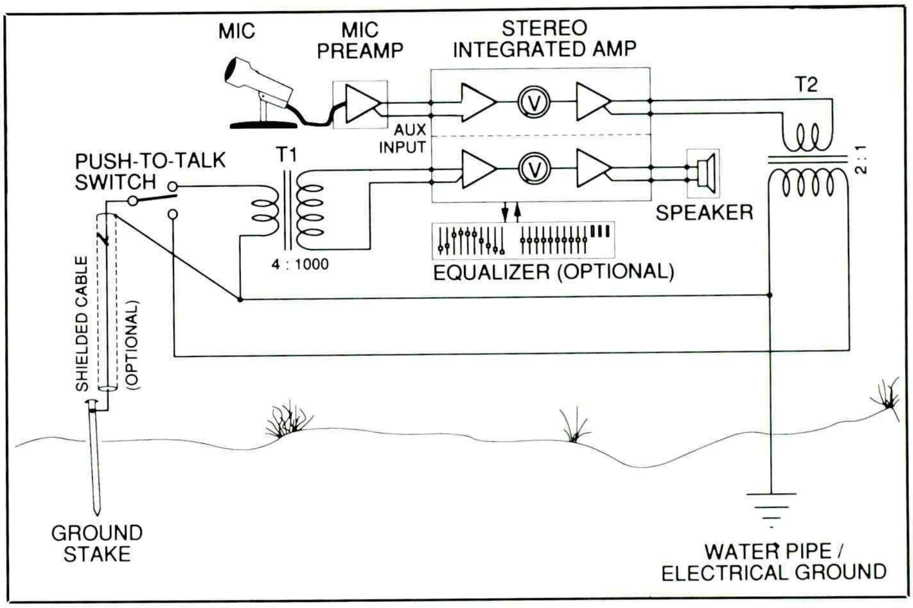

Fig. 1. How to set up an earth station using a one "hot" stake approach.

piece has nothing to do with the communicating ability of the system. Rather, it provides a convenient handle for pulling up the stake if you relocate it in the event you encounter buried rock or other obstacles that cannot be penetrated while driving the stake. Do not be surprised if you have to make two or more tries at driving the stake to have it go all the way into the ground. In most locations, especially where the soil is tightly packed and has a high clay content, more than one try is to be expected.

Locate the signal or "hot" stake as far away from the cold-water pipe (or stake) ground as possible. Consider not only where the water pipe enters your house from the municipal supply, but also how it runs out to the pipe in the street. In addition, when

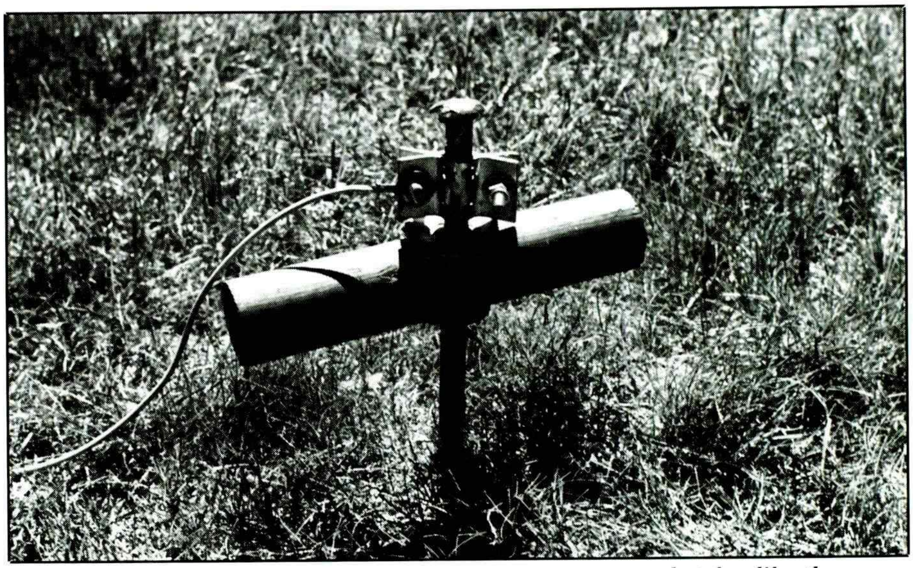

Fig. 2. Be sure to provide some way to remove your ground stake, like the cross-piece shown at the top of the stake in this photo, in case it must be relocated.

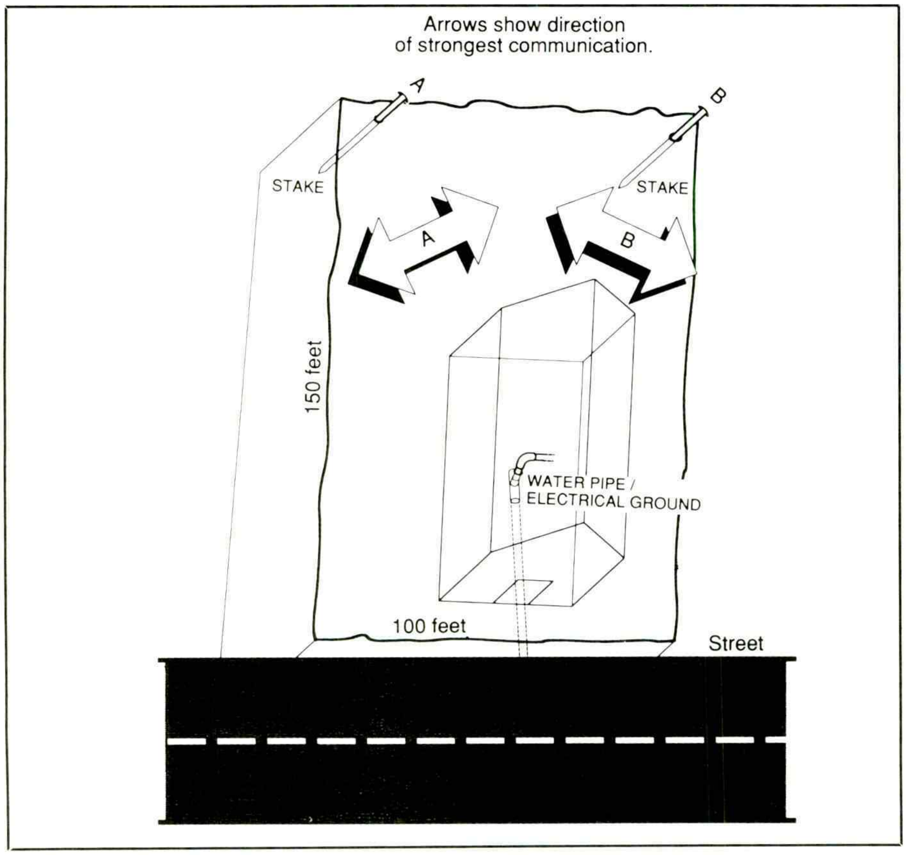

Fig. 3. Aerial view diagram of a typical suburban plot shows direction of strongest communication for two different "hot" stake positions relative to the ground used in the system.

using a cold-water pipe as a ground, take into consideration your neighbors' cold-water pipes and treat them in the same manner, since they are in electrical contact with your own. You also want the stake and water-pipe ground arranged so that a line connecting the two will be perpendicular to an an imaginary line between your and your friends' houses. Figure 2 shows how the direction of strongest communication depends on the location of the stake and cold-water pipe.

Check the quality of the ground stake by measuring the impedance between it and the water-pipe (or stake) ground. The measured impedance should be between 20 and 60 ohms at 1 kHz. The lower the impedance figure, of course, the better the ground. Measure the impedance in *both* directions (that is, take a reading and then reverse the meter leads to obtain a second reading) and take the average of the two readings. This two-reading cancels out the effect of any direct current flowing between the two grounds.

Owing to the fact that ground communication is at low audio frequencies, no fancy transmission line is required. You can run ordinary heavy-duty speaker-type zip cord between the "hot" stake and your house; likewise if you had to drive a separate ground stake in lieu of using a cold-water pipe as a ground. Because you will be pumping 40 watts or more of power into the earth, use at least 18-gauge zip cord.

The line between the "hot" stake and your house will be at nearly ground potential and is not likely to pick up interference, unless it passes near a very powerful source of r-f or other electromagnetic radiation. If you encounter excessive electrical interference, use heavy-duty shielded cable between the "hot" stake and your house.

In addition to the stake(s) and transmission line, you need a stereo integrated amplifier and a few other components to complete your station, as illustrated in Fig. 1 and specified in the Bill of Materials. One amplifier channel is used to amplify the output from a microphone for transmission, the other to amplify the signal from the ground during reception.

The best amplifiers to use for ground communication have separate left- and right-channel volume controls that permit you to leave transmission volume at maximum while allowing you to adjust receive volume as needed. In the absence of separate volume controls, you can use the balance and volume controls to obtain roughly the same effect. Of course, for maximum communication distance, use the most powerful amplifier you can get your hands on.

Both transmission and reception require impedance-matching transformers. These increase communication range and isolate the electronic equipment from the small dc current that almost always flows between earth grounds.

For reception, you must match the low impedance of the ground to the high input impedance of most amplifiers. Use a transformer that offers good fidelity, such as a small speaker output transformer. Connect its 4- or 8-ohm secondary winding across the tie points to the earth and its 1,000-ohm primary winding across the input to the amplifier.

For transmission, the transformer needed has less of an impedance difference to contend with. However, this transformer must be able to safely handle the high output power of the amplifier being used. Though a transmit transformer is not absolutely essential, it helps the amplifier develop its full rated power into the

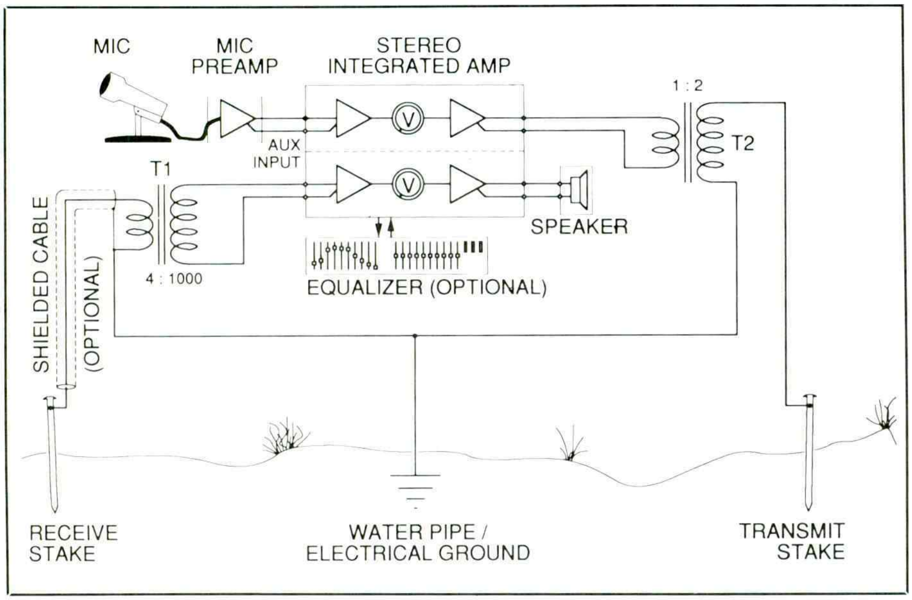

Fig. 4. How to set up an earth station using two "hot" stakes to provide simultaneous transmit/receive operation.

higher impedance of the earth.

This author has had a great deal of success using power transformers with 50- to 70-volt secondary windings. With their 117-volt primaries, such transformers offer an impedance ratio of about 1:2, which is almost ideal for matching the 8-ohm output of the amplifier to the 30-ohm impedance of the earth. Regardless of its secondary voltage rating, the transformer must be able to safely handle the power developed by the amplifier. Any transformer with a secondary current rating of 5 amperes or more should work. However, be sure you can connect an oscilloscope across the output while you are transmitting so that you can check to make sure the transformer is not saturating on signal peaks.

So far, only the one "hot" stake configuration has been discussed. This approach requires a push-to-talk switch that alternately connects a single "hot" stake between the transmitting and receiving transformers, as shown in Fig. 1. Without this switch to disconnect the receiving section when you transmit, the amplifier would be damaged or you would get tremendous feedback.

Good switches for this application are spdt microswitches that require very little effort for switching and have contacts that can safely carry the full transmitting power developed by your amplifier. You can use such a switch as-is or connect to it a lever that is easier to press than is the tiny button typically supplied on these switches.

Use of separate transmit and receive "hot" stakes allows you to communicate without having to constantly push a switch to talk and release it to listen. Such an arrangement is illustrated in Fig. 4.

Having more than one "hot" stake also allows you to orient your stakes in relation to the water pipe to permit you to transmit and receive in different directions. The two stakes shown in Fig. 3 have different optimal directions for communication, based on their positions in relation to the water-pipe ground. Either stake could be used with the one "hot" stake method to communicate in its own optimal direction. Alternatively, both stakes could be used with the two-stake method to communicate with an earth station located straight behind them.

You may be able to improve reception by installing tone controls or a graphic equalizer in the receiving half of the system. Even with just simple bass and treble tone controls, it should be possible to reduce much of

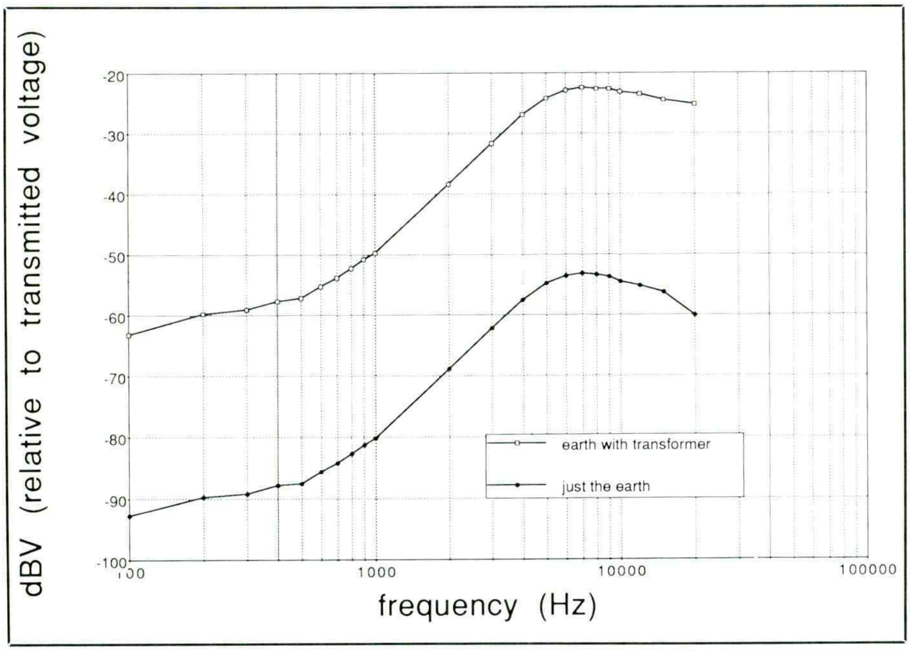

Fig. 5. Frequency-response plots of the earth made during tests.

BILL OF MATERIALS

Integrated stereo amplifier—Rated to deliver 40 watts or more per channel (see text)
Microphone—With table stand and shielded output cable
Microphone Preamplifier—required only if stereo amplifier does not have a built-in microphone preamplifier (see text)
Graphic Equalizer—useful for eliminating hiss, 60-Hz hum and other noise (optional—see text)
Speaker—to match the receive output of amplifier
T1—Audio impedance-matching transformer (see text)
T2—5-ampere or more power transformer with 50- to 70-volt secondary (see text)
Stakes—Galvanized-steel rod, pipe or angle iron (see text for number required)
Push-to-talk switch—Momentary-action spdt microswitch with retrofitted lever (required only for single "hot" stake setup—see text)
Shielded cable—For reception side of system only if transmission cable picks up excessive electrical interference; otherwise, use ordinary heavy-duty speaker zip cord
Miscellaneous—Interconnects; hardware; solder; etc.

the 60-Hz hum and high-frequency "hash" that the receiving stake will pick up, without compromising the quality of the voice signal.

Notes on Range

Usable range with the methods discussed in this article can be from a few hundred feet to a few miles. Actual range depends on so many factors that no accurate estimate can be given for any specific location. Range depends on type of soil, proximity of water pipes to your stakes, number of water pipes in a network and other electrically grounded objects between stations, transmit power, size and type of earth stakes used, and whether or not you use an equalizer to improve reception clarity.

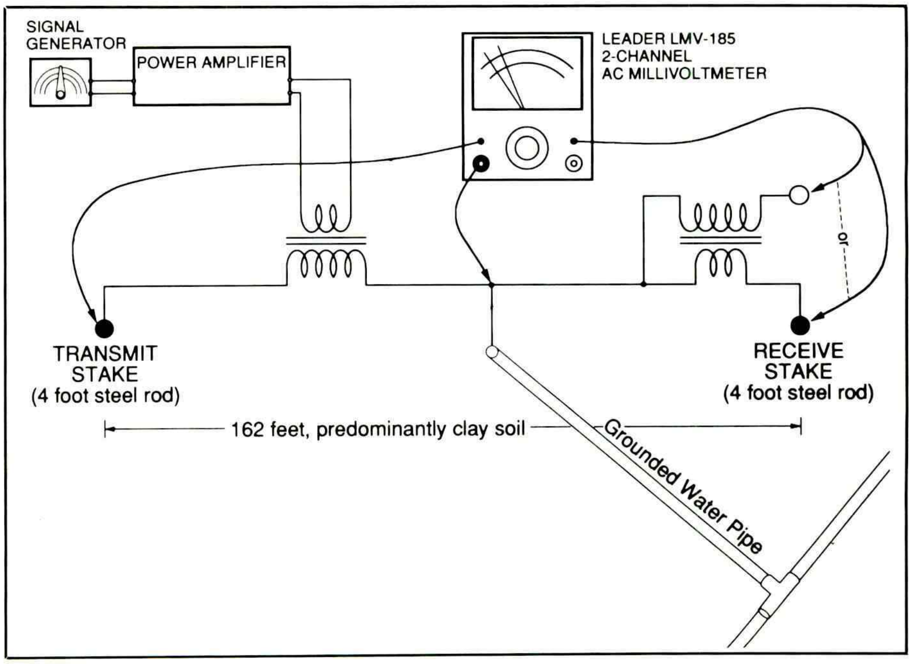

Fig. 6. Arrangement author used to obtain plots shown in Fig. 5.

Range for Morse code transmission is considerably greater than for voice. With code, intelligibility does not suffer so much in the presence of noise. Also, you can select a transmit frequency that corresponds to a peak in the frequency response of the earth.

Different frequencies travel farther through the earth than do others, as illustrated by the plots in Fig. 5. To obtain these plots, transmission of audio frequencies was measured through 162 feet of soil that was predominantly clay, using the setup shown in Fig. 6. There was a water-pipe ground between the two stakes that acted as a partial short-circuit to signals traveling between them.

The two plots in Fig. 6 show the response as measured directly at the stake and passing through a transformer. The slight high-frequency

(continued on page 76)

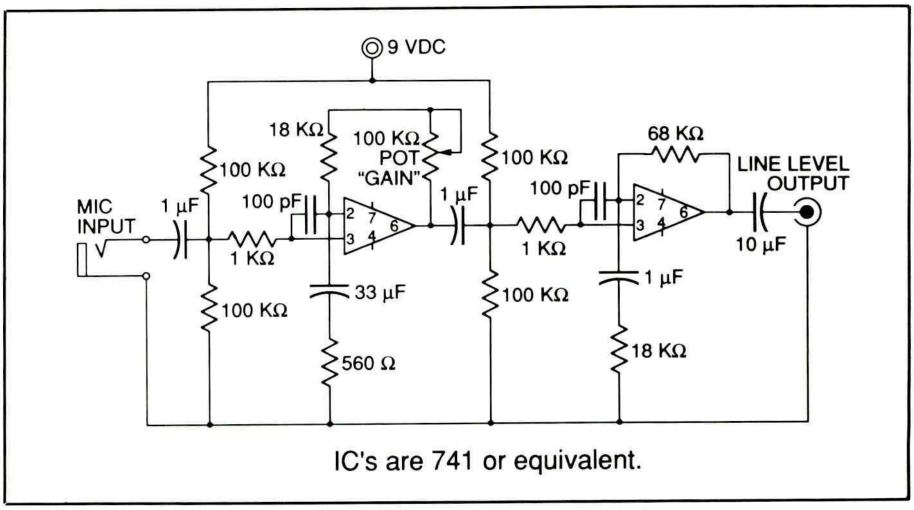

Fig. 7. Schematic diagram of a simple build-it-yourself microphone preamplifier.

boost obtained was due to the transformer's deviation from a flat response. As the plot shows, loss is minimal above about 3 kHz. Best response was obtained at 7 kHz, making this frequency ideal for Morse code transmission.

Noise picked up by the receiving stake in the test setup was at a −63-dB level with a transformer and at a −93-dB level without the transformer. This yielded a S/N of 40 dB at 7 kHz, which would increase with distance but could also be increased with judicial use of tone controls or an equalizer.

Microphone Preamplifier

Twenty and more years ago, almost every audio amplifier and tape recorder used for high-fidelity reproduction came equipped with a built-in microphone preamplifier. This is no longer the case. If you have a fairly recent amplifier that you want to use for communicating through the earth, chances are that it does not have the requisite microphone inputs built into it. If this is the case, you must use an external preamplifier circuit between your microphone and the input to your amplifier.

You can, of course, purchase a commercial mike preamp and use it with this system. However, since this is a hobby pursuit (and perhaps you want to make a minimal monetary investment in materials), you can build a very good mike preamp using the schematic diagram shown in Fig. 7. As you can see, this circuit is built around two popular 741 operational amplifiers (actually, any other op amp will do if you have it on hand). The support components are also very low in cost.

Component layout for the Fig. 7 circuit is not critical, but it is a good idea to locate the input and output at opposite ends of the layout and to use a shielded enclosure for the circuit. The latter is because you want to minimize the effects of induced hum to an absolute minimum.

If you wish, you can design and fabricate a printed-circuit board on which to mount and wire together the mike preamp ccomponents. Otherwise, simply mount the components on perforated board that has holes on 0.1-inch centers with the aid of Wire Wrap or soldering hardware and use a point-to-point wiring technique to interconnect them. Whichever way you go, though, be sure to use sockets for the ICs.

When you are finished assembling the circuit-board assembly, house it inside a small metal enclosure that can accommodate it and a 9-volt battery. Machine the enclosure to provide mounting holes for the circuit-board assembly, input and output jacks and the GAIN control.

When you are finished building the mike preamp, use shielded cable to connect its LINE LEVEL OUTPUT to the AUX input of the channel you are going to use for receiving on your amplifier and connect the shielded cable from your microphone to the MIC INPUT jack on the preamp. Then make all other connections to complete setting up your station.

When you are up and running, try experimenting with other people in your locality to see just how far you can communicate. As a network of communicators is set up, you just might find that "rag chewing" through the earth can be every bit as enjoyable and demanding a hobby as amateur radio through the airwaves.

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