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In today's hectic and noisy world, we are all searching for a little peace and quiet. Well, you might not be able to slip off to a tranquil forest for an hour or two, but you can block out background noise with the Noise-Canceling Headphones. The theory behind this project is that by picking up ambient sound with a microphone and reproducing it out of phase, we can actively cancel or "null" out background noise. In fact, several commercially available devices perform the same function. However, by building your own headset, you can add features not otherwise available and have fun while doing it! Along with noise-canceling features, the Active Noise-Canceling Headphones let you mix in an auxiliary line-level signal from a CD or tape player. That allows you to minimize background noise while quietly listening to music. The project also has a phase switch that will let you keep the microphone signals in phase, thus amplifying background sound. In addition, the design of the Noise-Canceling Headphones lends itself to several other interesting functions, which we will look at later.

**How It Works.** The electronics consist of three op-amp circuits, each built around one half of an NE5532 dual op-amp. Each circuit uses that op-amp in a different configuration. The first circuit is a non-inverting pre-amp, the second is a unity-gain phase-inverter, and the third is an inverting headphone amplifier. Since the Noise-Canceling Headphones is a stereo device, the circuit is actually two identical circuits side-by-side. Only one channel will be described; the second channel works in exactly the same way.

The schematic diagram in Fig. 1 shows the design of the electronics portion of the project. A headset-mounted microphone is connected to J1,

# BUILD THESE NOISE-CANCELING HEADPHONES!

*Muzzle the din and relax to the sounds of silence with headphones that combat the uproar with "anti-noise."*



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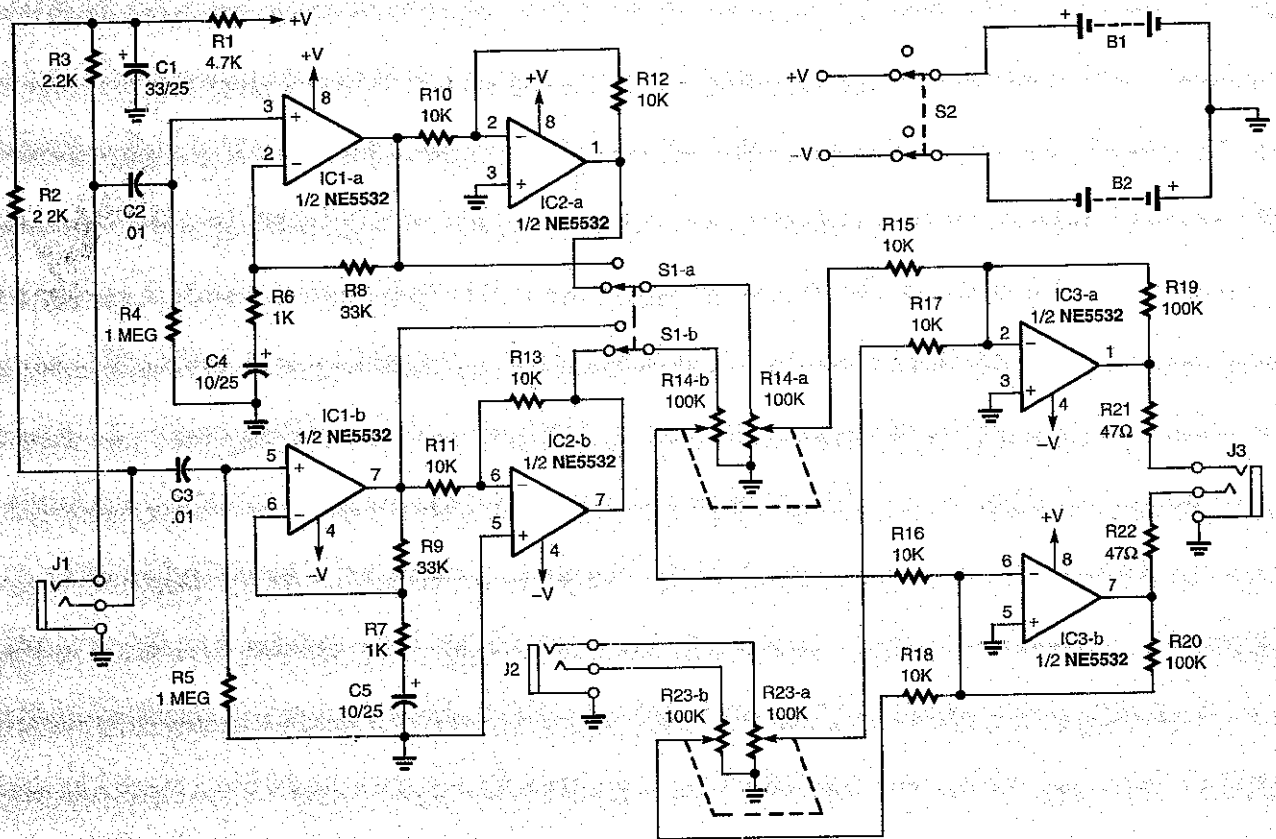


Fig. 1. The Noise-Canceling Headphones is a simple phase-inverting amplifier. All inverted sounds played back through the headphones cancel out the original sounds, leaving nothing but silence. The amount of canceling can be adjusted for different situations. A CD player or cassette tape can be listened to if you want to "fill the quiet."

a 1/8-inch stereo jack. Electret-condenser microphones need a 2- to 10-volt bias voltage for their internal FET pre-amps that is supplied by R2. A voltage-dividing network, which also decouples the bias voltage from the power supply, is provided by R1 and C1. That is necessary due to the high gain of the entire signal chain.

The signals from the microphone then go to IC1-a, an NE5532 set up as a standard non-inverting pre-amp. The gain is set to one plus the ratio of R8/R6 in the feedback path. The total gain for that stage is about 31 dB. Resistor R4 provides a ground reference for the pre-amp. A pair of high-pass filters is formed by C2/R4 and C4/R6. Those filters block any DC that tries to slip through the pre-amp.

From the output of the pre-amp, the microphone signal is sent down two different paths. It feeds both one pole of S1-a and the phase-

inverter. The phase inverter is nothing more than a second NE5532 configured as a unity-gain inverting op-amp (IC2-a). The output of IC2-a is connected to the other pole of S1-a. That way, S1-a can select either the inverted or the non-inverted signal. The selected signal on S1-a's common pole goes to potentiometer R14-a. That potentiometer sets the level of the microphone signal feeding the headphone amplifier.

The headphone amplifier is built around IC3-a, a third NE5532 wired as an inverting op-amp stage. The gain here is set by the ratio of R19/R15. That type of op-amp configuration can be easily modified to add a summing feature by the inclusion of R17. The second input comes from an auxiliary line-level input that is attenuated by potentiometer R23-a.

There is a reason why 10,000 ohms was chosen for the value of

R15 and R17. Besides keeping the values of R19 manageable, the 10,000-ohm resistors interact with the 100,000-ohm linear potentiometers. The potentiometers then behave in a logarithmic fashion. This is how that feature works: One end of the potentiometer is tied to ground because we are using it as a voltage divider. Because the summing junction of an op-amp is at a virtual ground, the 10,000-ohm resistor is also essentially tied to ground. That affects the response of the potentiometer. As the potentiometer is rotated, there is a more pronounced increase in the output as the end of the potentiometer's travel is reached that causes a smooth increase in perceived loudness of the signal. Potentiometers with an audio taper are, of course, available, but a linear-taper unit is easier to obtain and costs less.

The output of the headphone amplifiers is coupled to output jack

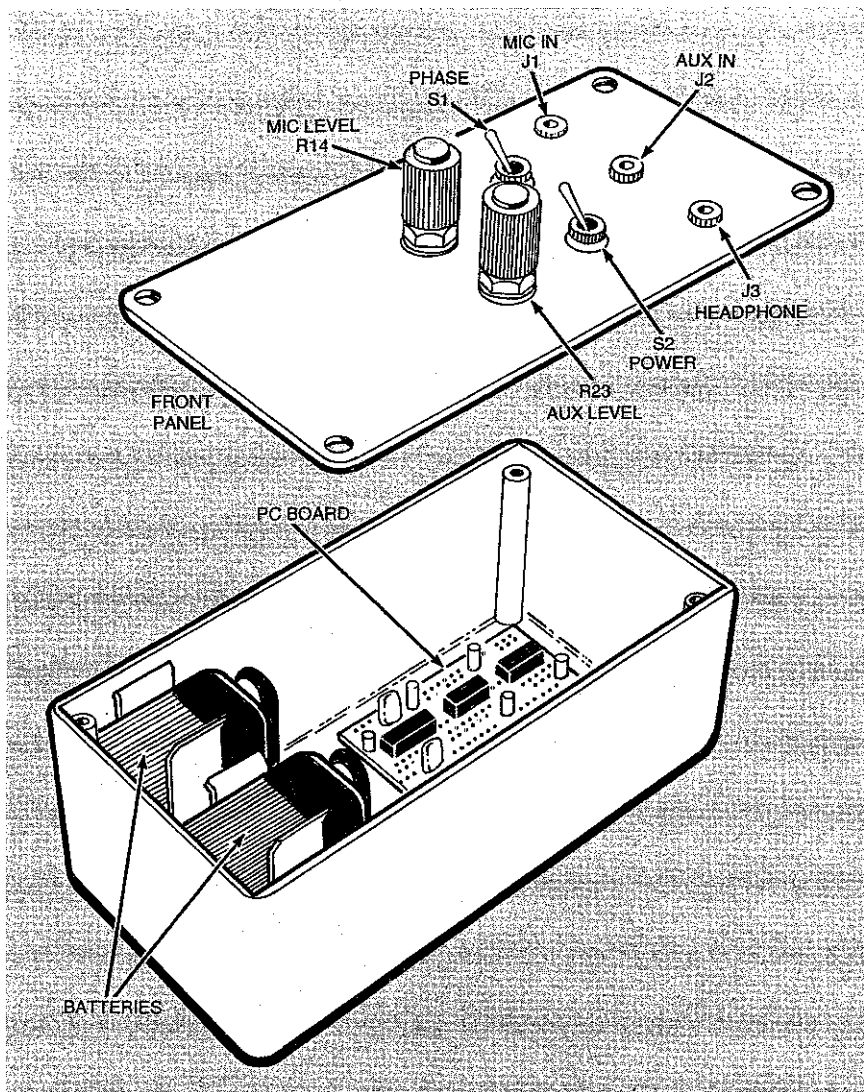


Fig. 2 The circuit board and batteries fit neatly into a simple project box. Keeping the wiring neat and following the layout shown here makes assembling the unit and changing the batteries easier.

J3 through R21. That resistor provides overload protection to IC3—in case the output is shorted. If you have never used an op-amp for driving headphones before you are in for a nice surprise. The NE5532 will supply a 10-volt rms signal into a 600-ohm load with very little distortion. That works out to 166 mW of power. Most personal stereos only supply 20 to 30 mW of power to headphones. A final note on using operational amplifiers as headphone amps: Most generic ones will not supply enough current to function properly. Some substitutes for the NE5532 that are known to work include the OP275 from Analog Devices, the OPA2604 from Burr Brown, and the LM833 from National Semiconductor. Those components are available from

several sources, including Digi-Key, Allied Electronics, and Jameco.

**Construction.** There are two parts to this project: building the electronics and modifying a pair of headphones. The circuit is relatively simple and can easily be assembled on a perfboard. One style of perfboard that simplifies construction is one having a pre-etched copper pattern on its solder side that connects groups of holes together. One example of that type of perfboard is RadioShack #276-150. The etched pattern on that board has a pair of buses that run the length of the board. Those buses are very convenient for power distribution. If you use that type of board for the Noise-Canceling Headphones, it is best to

start by spacing out the three ICs on the board so that they straddle the buses. Then attach the power supply leads from each chip to the buses. It is then a simple matter of point-to-point wiring the rest of the circuit.

Check your work often while building the circuit. A common mistake many hobbyists make is not checking their work thoroughly enough. Often a few components are accidentally wired in backwards. The usual result is that the cir-

### PARTS LIST FOR THE NOISE-CANCELING HEADPHONES

#### RESISTORS

(All resistors are 1/4-watt, 1% metal-film units unless otherwise noted.)

- R1—4,700-ohm
- R2, R3—2,200-ohm
- R4, R5—1-megohm
- R6, R7—1000-ohm
- R8, R9—33,000-ohm
- R10-R13, R15-R18—10,000-ohm
- R14, R23—100,000-ohm potentiometer, dual-gang, linear-taper
- R19, R20—100,000-ohm
- R21, R22—47-ohm

#### ADDITIONAL PARTS AND MATERIALS

- IC1-IC3—NE5532 dual audio op-amp, integrated circuit
- C1—33- $\mu$ F, 25WVDC, electrolytic capacitor
- C2, C3—0.01- $\mu$ F, Mylar capacitor
- C4, C5—10- $\mu$ F, 25WVDC, electrolytic capacitor
- J1-J3—Audio jacks, 1/8-inch, stereo
- S1, S2—Toggle switch, double-pole, double-throw
- B1, B2—Battery, 9-volt
- Microphones (Digi-Key P9967-ND or similar), headphones, PC board, case, wire, hardware, etc.

cuit will probably not work: the ICs could be damaged, and the electrolytic capacitors might explode!

When wiring the jacks, it is a good idea to follow the audio industry standards as to which jack connection is for which stereo channel. Normal standards for stereo connections are to connect the right channel to the ring and the left channel to the tip.

The board and batteries are mounted in a suitable enclosure. A suggested layout for the components and control panel is shown in

Fig. 2 When selecting a case for the project, be sure that it is large enough to hold the circuit board and the two 9-volt batteries comfortably. After the front panel is laid out and drilled, check to make sure all the controls and jacks will fit. One method for labeling the front panel is to spray the entire panel with a flat color such as white or yellow. After applying transfer letters, seal the panel. Use several thin coats of a clear coating such as Crystal Clear by Krylon. The results are worth the effort. While the front panel is drying, we can start on the headphones

**Headphones with Ears.** The headphones are a standard pair of aftermarket Walkman-type units. They sell for about \$20 at most record or electronics stores. The headphones are modified by mounting two small electret-condenser microphones on the headphones, one on each earpiece. That modification is shown in Fig. 3.

The key to making the headphones wearable is to use thin wires running to the microphones. An excellent source of thin audio cable is to buy another set of cheap headphones—the cheapest you can find. Cutting the wire off them will yield a shielded stereo cable that is thin and flexible. As an added bonus, the wire will have a 1/8-inch stereo plug molded on to it already!

The best way to strip that type of wire is to roll a razor blade very carefully over the insulation without cutting the wire underneath. Once the insulation is cut, carefully pull it away from the wire. That method works especially well on Teflon-insulated wire. After you have prepped the wire, mark the wire that is connected to the ring and the one that goes to the tip of the jack. An ohmmeter makes that task easy.

Carefully solder the wires to the microphone elements. The easiest way to do that is to pre-ffin the wires and melt the little dab of solder on the microphone element with the tinned wire beneath the soldering iron tip. Look carefully at the microphone. As shown in Fig. 3C, the terminal that is connected to the case of the microphone is the ground

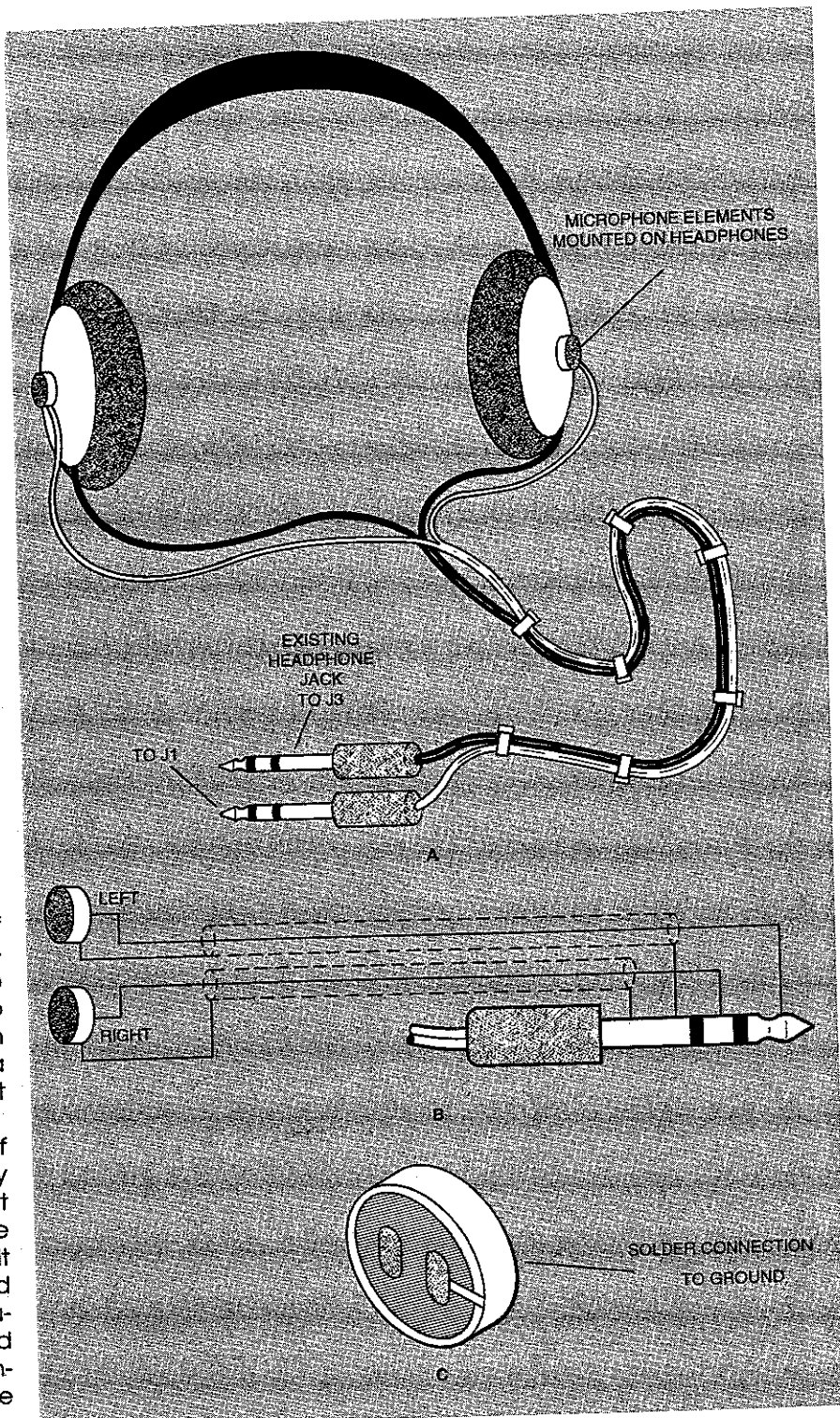


Fig. 3. The microphones are mounted on the earpieces of the headphones with a dab of silicone sealant. Tie both wires together in order to make the headphones more comfortable to wear (A). Follow the diagram in (B) when wiring the microphones. The left mic is connected to the plug's tip and the right is connected to the ring. The ground connection on an electret microphone cartridge is easily identified by the solder connection between the terminal and the mic's case (C)

connection. The other terminal is the actual microphone output. Holding the microphone element in an alligator-clip holder will make the job much easier. After soldering on the microphone elements, it is a

good idea to test them prior to gluing them to the headphones. The wiring should follow Fig. 3B.

Mount the microphones on the headphones as shown in Fig. 3A. One way to attach the micro-

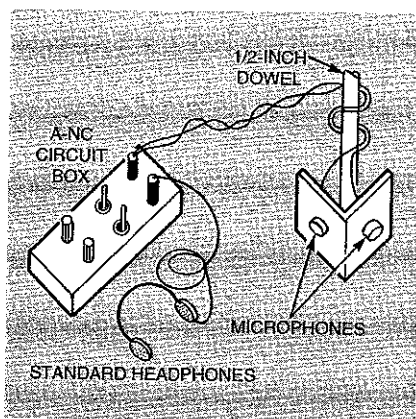


Fig. 4 Mounting both microphones angled apart at the end of a long stick makes an audio probe. It is very useful when you need to listen at a location that you can't reach.

phones to the headphones is to use a dab of silicone sealant. Using a toothpick or other suitable substitute, mold the silicone around the edges of the microphone element to smooth everything off. Be careful not to get any on the black felt surface—that is where the sound enters. Obviously, the left and right microphones should be attached to the left and right sides of the headphones, respectively. Trying to cancel out a sound on the right with a sound from the left will not work.

After the glue is dry, gather and bundle the wires together with several nylon tie wraps along the length of the wires. With the headphones complete, it is time to experiment with the Noise-Canceling Headphones.

**Creating A Quiet Zone.** For testing purposes, you should be in a quiet room with just a little background sound, such as a heater or air-conditioner fan. Plug in the microphone jack and the headphone jack, and put on the headphones. Turn both controls all the way down and turn the power switch on. Slowly turn up the microphone level. You should either hear the background sound increase or start to fade. If it increases, change the position of the phase switch. At some point, you should reach a "null" point where the background sound is at a minimum. If you adjust beyond the null, background sound will become louder as the out-of-phase signal exceeds the ambient

sound level. Try talking aloud. If it sounds like you have a massive head cold and can barely hear yourself, the circuit is functioning properly.

Note that it is impossible to eliminate all incoming sound. Many things affect the ability to cancel out noise. The loudness of the incoming sound, the specific frequencies involved, and the position of the sound source all play a part in how well the headphones do their job. Feel free to experiment. If everything is working fine, try connecting a CD player to J2. You will need a 1/8-inch-to-1/8-inch patch cord similar to the ones used to connect portable CD players into a car stereo. After connecting the CD player, slowly turn up R23. It should sound clear with no distortion. Experiment with combining low levels on the CD player and canceling out room noise. The Noise-Canceling Headphones is the perfect device for environments that have a loud ambient sound level, such as rooms with loud ventilation systems.

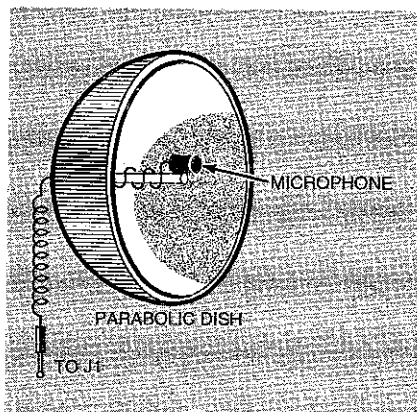


Fig. 5 A parabolic dish or lamp reflector makes a usable "Big Ear" microphone. The microphone is mounted at the focal point facing in towards the dish. Either one or two microphones can be mounted in the dish. If you build two, you can pick up stereo sounds.

**Beyond Peace and Quiet.** This project lends itself to many other uses. Several interesting applications will suggest themselves that do not require any additional hardware. For example, by switching the microphones to "in-phase," the unit can be used to assist hearing or improve hearing. Areas that can benefit include outdoor activities such as hunting or just observing nature.

Another unusual application for the Noise-Canceling Headphones is in binaural recording. Since we already have two microphones mounted in essentially the same place human ears are, all we have to do is send the headphone output to a tape recorder input. Binaural recordings put the listener directly in the sound field. The two microphones capture the exact phase and timing relationships of sound as we hear it. Those are the clues our ears use to determine the location of a sound. Try this little experiment: record a person talking to you while you are wearing the headphones and have them walk around you in a circle. Then listen to the recording on the headphones. You will hear the person walk around you! The microphone elements used in this project feature full 20-Hz to 20-kHz frequency response. They provide a signal with surprisingly high fidelity.

Other interesting tools can be created by building different types of housings for the microphones. If two microphones are mounted on the end of a length of 1/2-inch dowel, an audio probe is the result. It is wired similarly to Fig. 3B. That device lets you listen to things up close that you wouldn't normally hear. It can be used to "sniff" out problems in mechanical equipment or to record things like hamsters chewing on cardboard. With the microphones mounted at an angle between 90° and 120°, you will have a stereo image of the sound source too!

An extension of the shotgun-style microphone is a "Big Ear." The general arrangement is shown in Fig. 5. The main component is a small parabolic dish. Place one or both microphones at the focal point of the dish and experiment away. Sources for parabolic dishes can be as close as a local hardware store. A simple reflector for a light bulb can be found at a very reasonable price. Another source of true parabolic dishes is Edmund Scientific, 101 East Gloucester Pike, Barrington, NJ 08007. For some advanced experimenting, use two dishes (one for the left microphone, one for the right) and experiment with stereo reception of a distant sound. Ω 37