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Way Cool Rocket Project, Part 1

This 70cm rocketborne radio telemetry system is strictly for kids — NOT!

This is the first in a series of three articles that will describe the construction and flight operation of a basic single-channel 70cm (433 MHz) rocketborne radio telemetry system, or rocketsonde.

The transmitter portion of this system is mounted in a small sounding rocket and used to telemeter air temperature of an atmospheric air column to 2,000 meters (about 6,000 feet). The ground-mounted receiver portion of the system is used with a fully steerable antenna array consisting of two stacked Ramsey Electronics four-element 433 MHz yagi antennas. Receiver output is supplied to a strip chart recorder.

This telemetry system is currently being utilized as an instructional tool in a volunteer-led, after hours, high school science enrichment program called "Sounding Rocket 101." The primary purpose of the program is to provide a hands-on science activity to high school science clubs that will provide additional learning opportunities in the areas of: electronics, communications, atmospheric science, and applied physics. The Sounding Rocket 101 program is presented in a way that ignites student interest (no pun intended!).

One of the primary design goals for the telemetry electronics was to produce an easy-to-build, low-cost, single-channel radio telemetry system that could be easily duplicated by an electronically inclined high school student. The purpose of this series of articles is to encourage other radio amateurs to duplicate the system and become involved with providing additional advanced learning opportunities for high school students.

In keeping with the low-cost design objective, the core elements in the radio telemetry system are 433 MHz AM transmitter and receiver modules

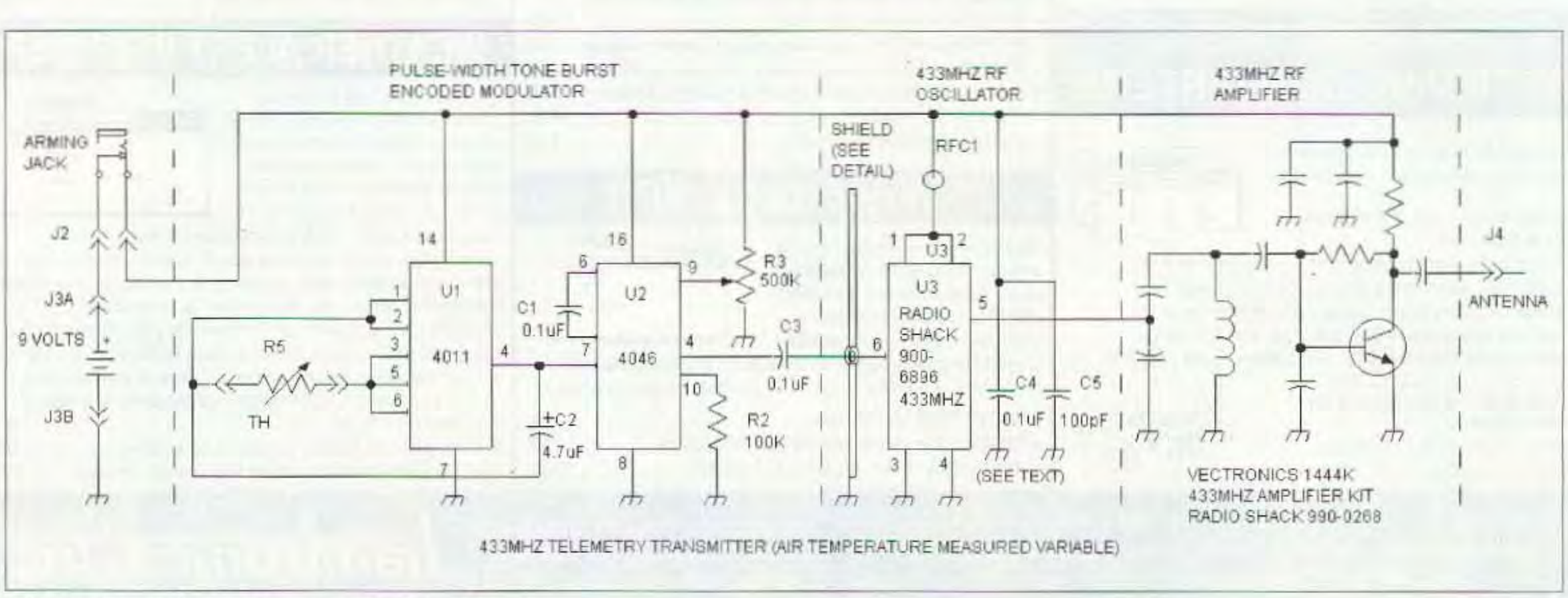

Fig. 1. *Transmitter schematic (see also Fig. 8).*

available from Radio Shack. Although the Radio Shack UHF modules are designed for short-range (several hundred feet) remote control use, through the use of external circuitry their effective communication range can be extended to a little over a mile. The total cost for both modules is less than twenty dollars. To further minimize cost, off-the-shelf circuit assemblies are used were possible. Total cost for all three of the electronic modules used in this project is less than fifty dollars.

The transmitter

Figure 1 — Transmitter schematic. A Radio Shack 8 milliwatt RF output, SAW-device-controlled, 433 MHz AM transmitter module (Radio Shack #900-6896) is used as the core element for the telemetry transmitter. A 4011 quad 2-input NAND gate is used as a variable pulsewidth oscillator. The resistance of the thermistor, R1, determines the width of the output pulse. Output from the 4011 is supplied to the input of a 4046 phase locked loop integrated circuit. Here, the pulse provided by the 4011 is converted to a tone pulse. Potentiometer R3 is adjusted for a tone frequency of about 2 kHz. This 2 kHz tone pulse is capacitively coupled to pin 6 of the transmitter module ("Code in" or modulation input).

RF output from the transmitter is taken from pin 5 of the transmitter module and supplied to the input of a Vectronics 1444K 433 MHz RF amplifier. Although this amplifier is primarily designed as a preamplifier for receivers, in low power applications it also works very well as an RF power amplifier.

Using the RF amplifier, output from the transmitter module is increased from 8 milliwatts to about 80 milliwatts. Using an impedance matching network at the output of the amplifier was experimentally determined to be unnecessary at the power levels being considered in this application. This RF output level is sufficient to ensure reliable data collection from the design altitude of 2,000 meters. Power for the transmitter is provided by a standard Duracell 6LR61 alkaline 9-volt battery. A closed circuit two conductor jack, J1, is used as an on/off switch when the transmitter package is installed in the rocket airframe. A blank plug is inserted in the jack to remove power from the transmitter.

The receiver

Figure 2 — Receiver schematic. A Radio Shack 433 MHz AM receiver module (Radio Shack #900-6895) is used as the core element for the telemetry receiver. Radio Shack does not provide a schematic of the receiver. However, from an examination of the component layout on the miniature circuit board, the receiver appears to be of the super-regen type. A 7805 five-volt regulator is used to provide power to the receiver. The same Vectronics kit used as an RF power amplifier for the transmitter is also used with the receiver as an RF amplifier at the front end of the receiver. A Rainbow Kits AA1 audio amplifier kit (Radio Shack #900-6895) is used on the back end of the receiver. A two-conductor open circuit phone jack is placed in parallel with the speaker to supply audio to a small tape recorder.

The telemetry decoder

Figure 3 — Decoder schematic. An LM555 timer IC is connected as a frequency-to-voltage converter. The values of resistance and capacitance used with the IC are selected for a pulse tone frequency of about 2 kHz. Voltage output from the decoder varies from 0 volts with no pulse input to about +5 volts with a 2 kHz tone input. A 5 megohm potentiometer is used to attenuate output of the decoder for use with a strip chart recorder.

An SPDT switch (SW2) is used to bypass the 5 meg pot for output to a computer or other recording device. Before the telemetry system is used to gather data in flight, the entire rocketsonde transmitter payload package is enclosed in a sealed chamber and exposed to a range of temperatures. Output from the received and decoded signals are recorded and used as calibration data. The participating students use the calibration data to

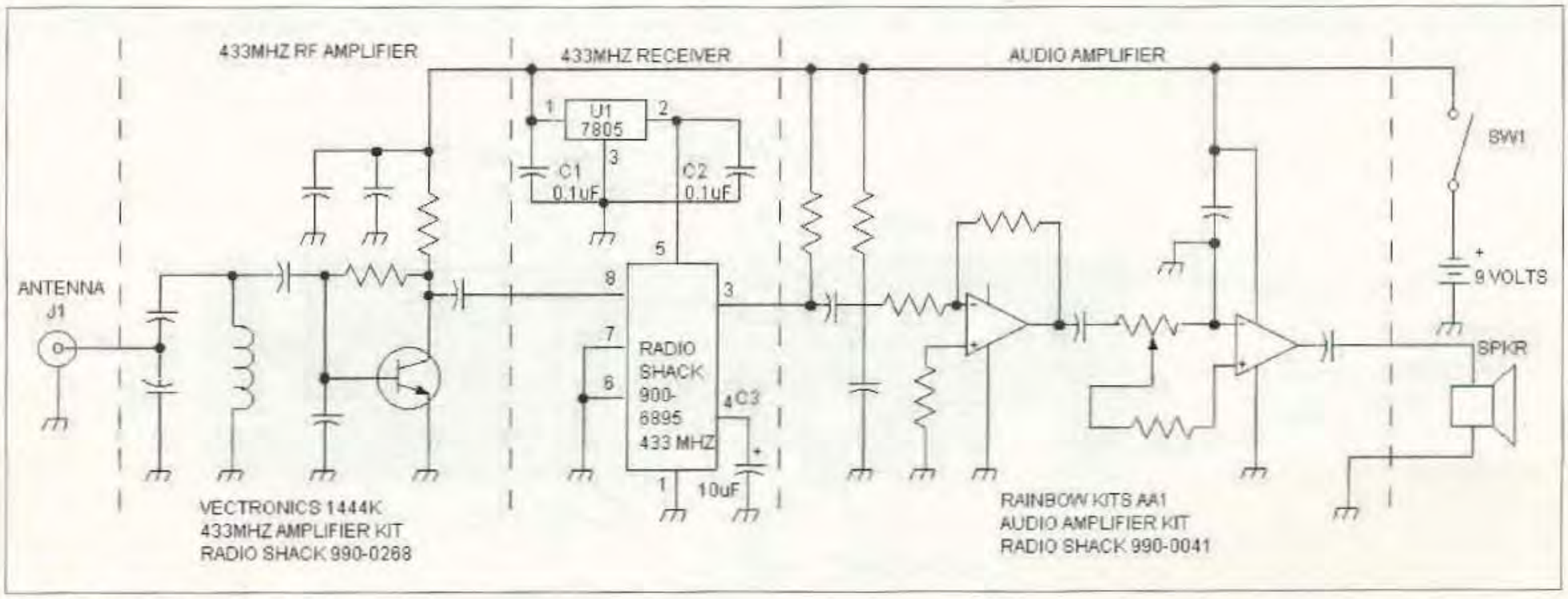

Fig. 2. Receiver schematic.

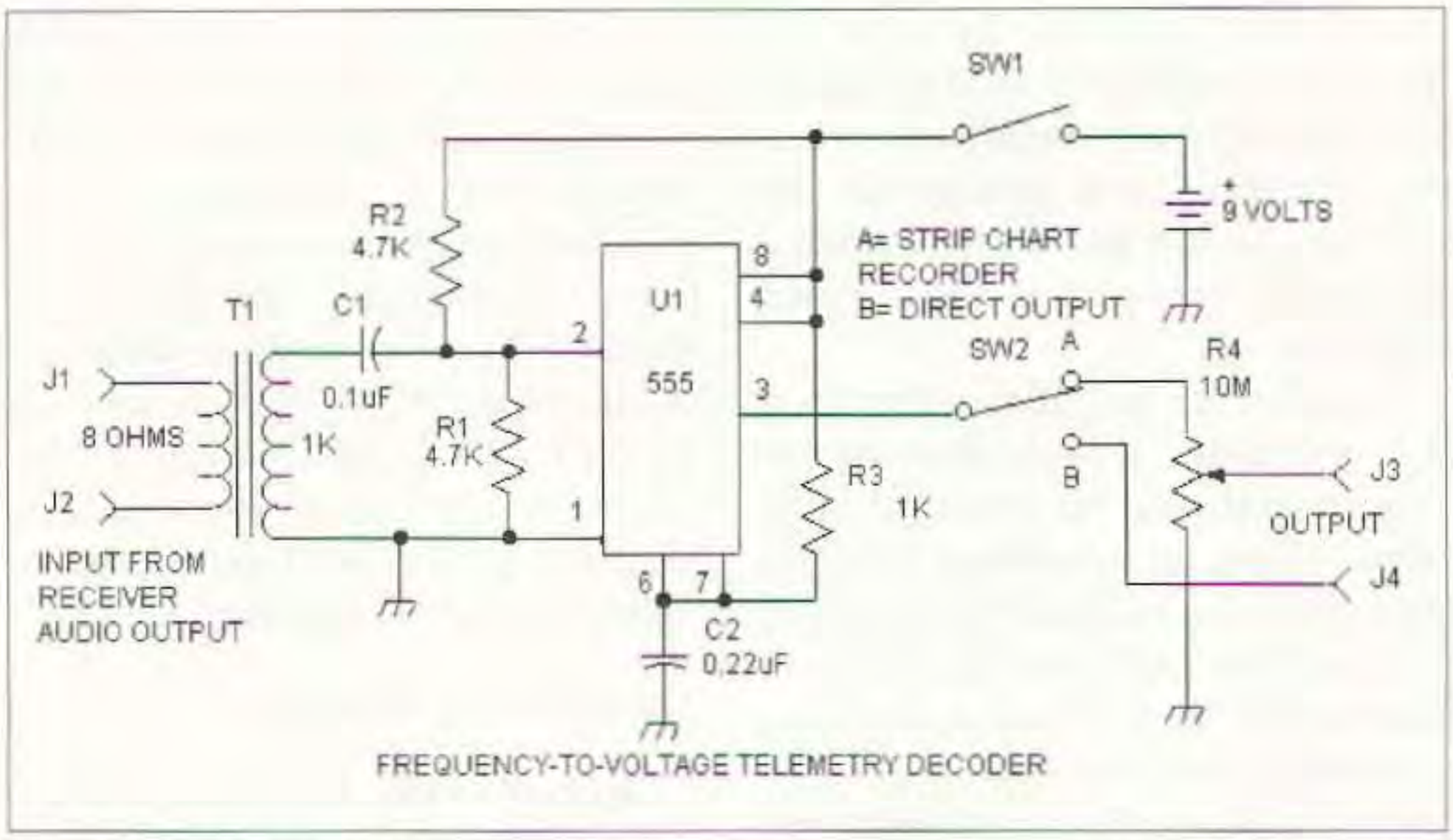

Fig. 3. Decoder schematic.

construct pulsewidth vs. temperature templates. After the flight telemetry data is recorded, the students then use the templates to "reduce" the telemetry data by converting pulsewidth to temperature. During the flight of the rocketsonde, some of the students use theodolites to shoot angles on the rocket in flight. Later, the students use trigonometry to calculate the altitude of the rocketsonde vs. time. The students then combine the two sets of data to construct a graph of air temperature vs. altitude.

Construction of the transmitter

An approximately six-inch by one-inch printed circuit board is used for the transmitter. A full-size reproduction of the circuit board foil pattern is shown in **Fig. 5**. The first steps are to assemble all the modulator components on the board.

Figure 4 — Component placement diagram (transmitter). Make sure to save all of the component lead cuttings, as you will need some of them a bit later. Note that the leads of capacitor C2 (4.7 µF electrolytic) are left a bit long so that it can be bent over the integrated circuit U2. This is necessary to allow the assembled unit to fit into the rocket payload housing.

A short piece of hookup wire is connected to the free lead of capacitor C3 (0.1 µF disc ceramic), and the other end of the wire is soldered to the PC board as shown in the component location diagram. Take one of the longer component lead cuttings and slip the ferrite bead over the wire. Shape as shown in the component location diagram, and solder in place. It is important that the ferrite bead be placed close to the positive bus end of the wire, and the remaining wire is dressed close to the surface of the board.

The next step is to install the transmitter module. This module must be installed with the large round can on the board facing away from the modulator section. This will ensure the correct pin sequence on the board. Make sure that the bare power lead with the ferrite bead does not contact any part of the transmitter module.

Turn the PC board over to the foil side. Solder capacitors C4 and C5 (0.1 µF and 100 pF disc ceramic) between the positive power pad and the ground bus. It is important that you use zero lead length when soldering the capacitors in place. The next step is to fabricate the RF shield. Cut a 17mm by 19mm rectangle from a sheet of .005 brass. Solder three of the scrap component leads to the brass plate as shown in the shield detail. Mount the shield to the board and solder in place. Ensure that the plate does not contact the transmitter module.

The Vectronics 1444K RF amplifier kit is assembled per the instructions supplied with the kit. When winding the three-turn coil, make sure to keep the turns close together. Once the Vectronics kit is assembled, scrap component leads will be soldered to the Vectronics kit to convert it to a module that can be mounted on the transmitter PC board. You will need five lengths of scrap lead material.

Solder the leads in place so that most of the lead projects below the foil side of the Vectronics PC board. Make sure to cut off any small excess lead lengths

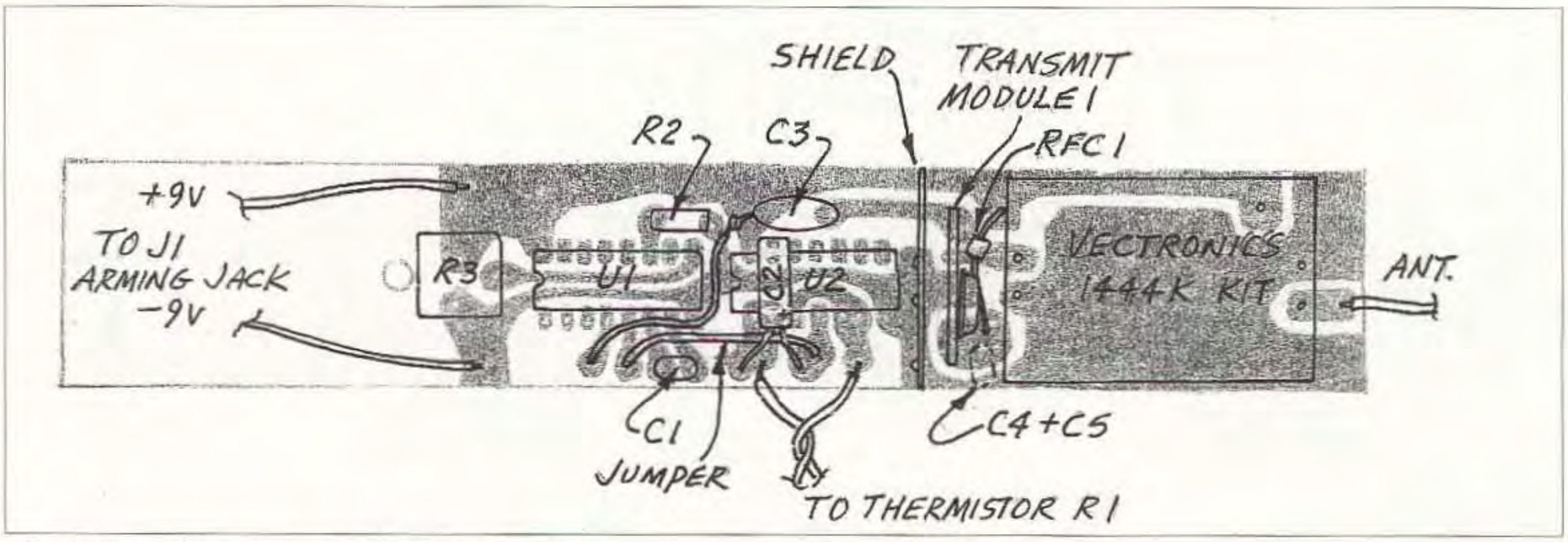

Fig. 4. Transmitter component placement diagram.

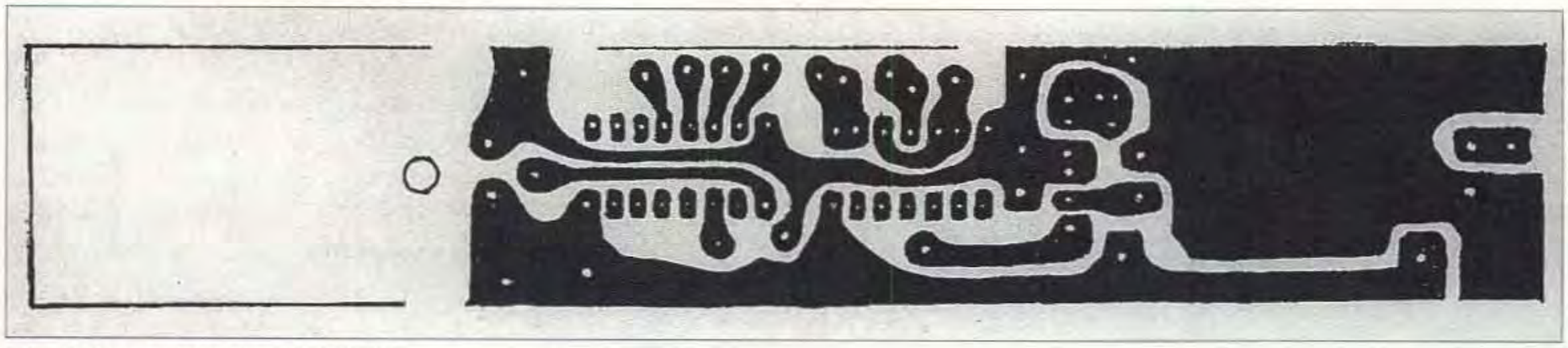

Fig. 5. Transmitter board, foil side.

that project above the component side of the board. Position the Vectronics board in place, inserting all the prefabricated leads in the holes in the transmitter board. Make sure that the Vectronics PC board is as close to the top surface of the transmitter PC board as possible.

Solder all the leads in place and cut off all excess lead length on the foil side of the transmitter board.

Prepare a three-inch length of hookup wire. Solder one end to the RF amplifier output pad on the transmitter PC board. Solder the free end to both pins of a two-pin connector. This is the transmitter antenna connection. As shown on the transmitter board component layout diagram, solder the black wire from the battery snap connector to the negative power bus on the transmitter PC board.

Prepare three-inch and six-inch lengths of red hookup wire. Slip a short length of heat shrink tubing over the shorter length of red hookup wire. Splice one end of the three-inch length of red wire to the red wire from the battery snap connector. Slide the heat shrink tubing over the solder joint and, using the barrel of the soldering iron, heat shrink in place. Solder the free end of the three-inch red wire to one terminal of the arming jack. Solder one end of the six-inch red wire to the switched terminal on the arming jack. If you are not sure which is the switched terminal, use an ohmmeter to check for continuity. When the plug is inserted in the jack, the switched terminal will be open; it will be closed when the plug is removed.

As shown on the transmitter PC board layout diagram, solder the free end of the red wire to the positive power bus on the transmitter PC board. If you wish, you can cut the two red wires from the arming jack and install a two-pin connector. This will make for easier installation of the transmitter package into the payload airframe.

Prepare two seven-inch lengths of green hookup wire. Twist the two wires together to form a "twisted pair" about six inches long. As shown on the transmitter board layout diagram, solder the two wires on one end of the "twisted pair" to the points indicated on the transmitter board layout diagram.

Solder the two free ends of the "twisted pair" to a two-pin connector. This is the connection point for the thermistor temperature sensor. The thermistor will be mounted to the outside of the payload airframe and is connected when the transmitter package is installed in the payload airframe section. This completes assembly of

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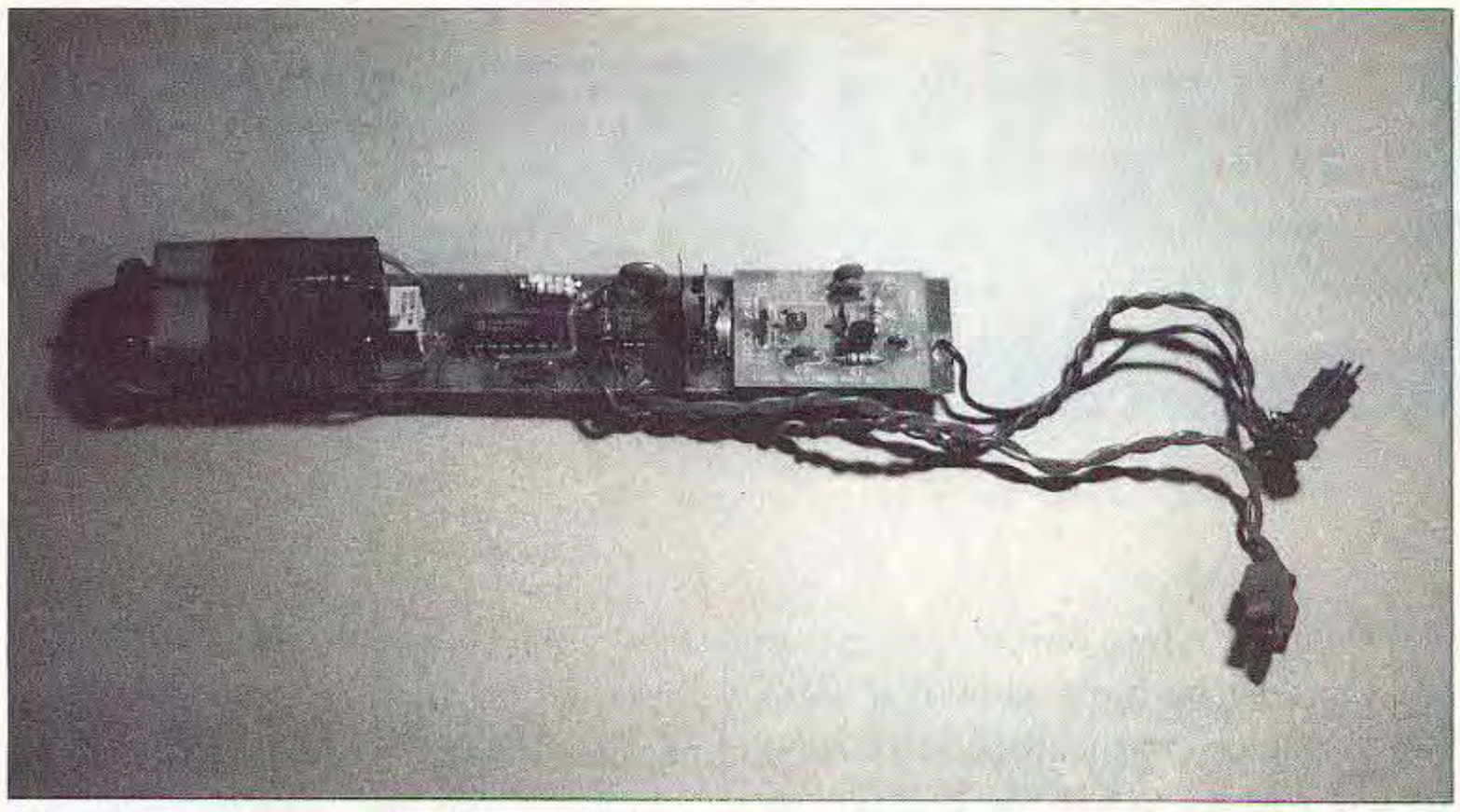

Photo A. *Telemetry transmitter.*

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the telemetry transmitter. **Photo A** shows the telemetry transmitter.

Construction of the Receiver

Like the transmitter, the telemetry receiver is assembled on a printed circuit board. A full-size printed circuit foil pattern for the receiver PC board is given in **Fig. 7.** The first step is assembly of the Vectronics 1444K RF amplifier kit and the Rainbow Kits AA-1 audio amplifier kit. Make sure to save all the scrap component leads.

Figure 6 — Receiver component placement diagram. Assemble the RF amplifier and audio amplifier as detailed in the instructions included with each kit. NOTE: When winding the three-turn coil for the RF amplifier, keep the turns close together.

Using some of the scrap component leads, solder a wire lead to the input, output, and power points on both the RF and audio amplifiers. Make sure that most of the wire lead projects out from the foil side of the PC board. Cut off the exposed end of each lead from the component side of the board. Check to see that the soldered leads match with the holes in the receiver PC board. Install both the RF amplifier

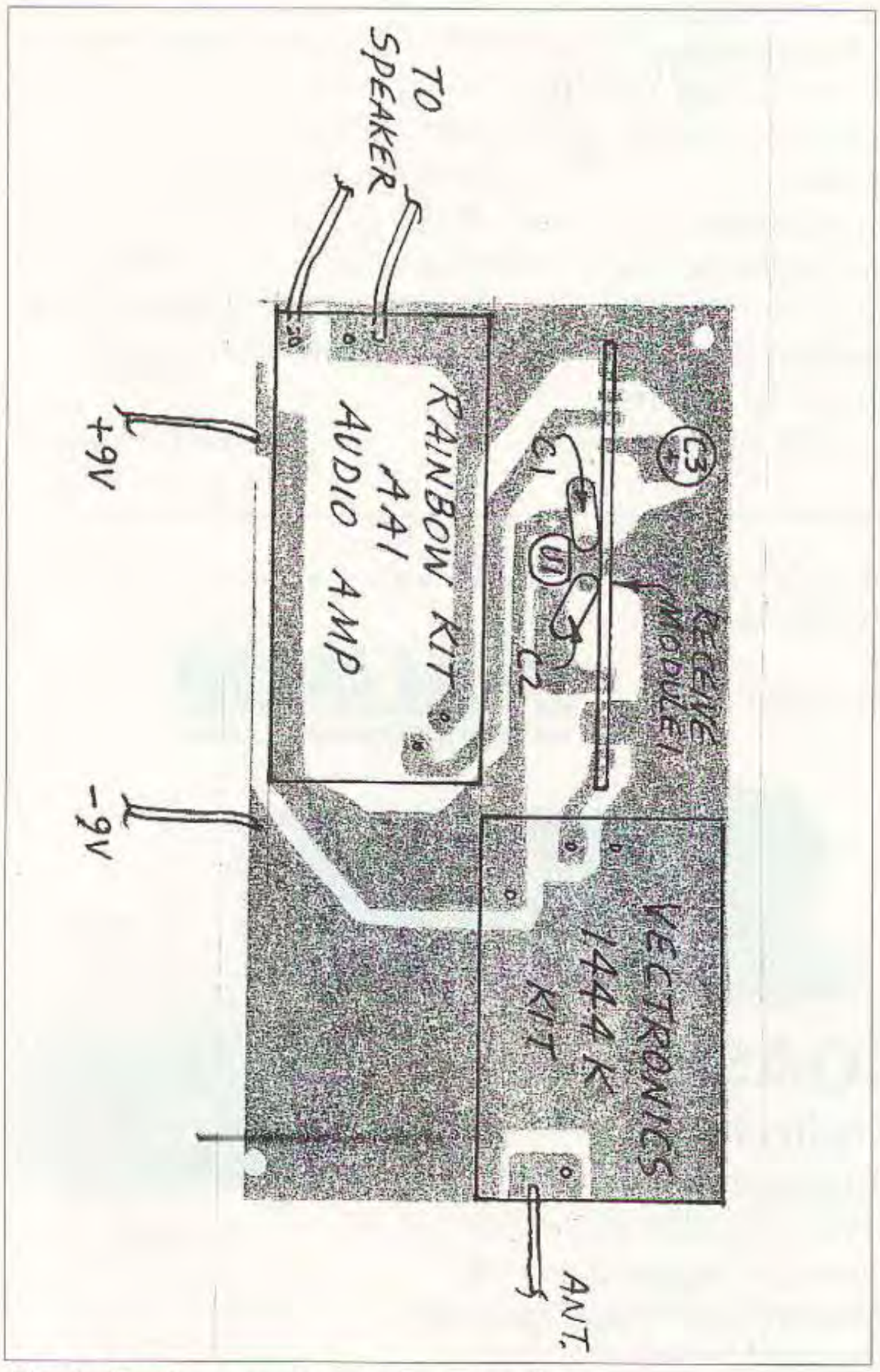

Fig. 6. *Receiver component placement diagram.*

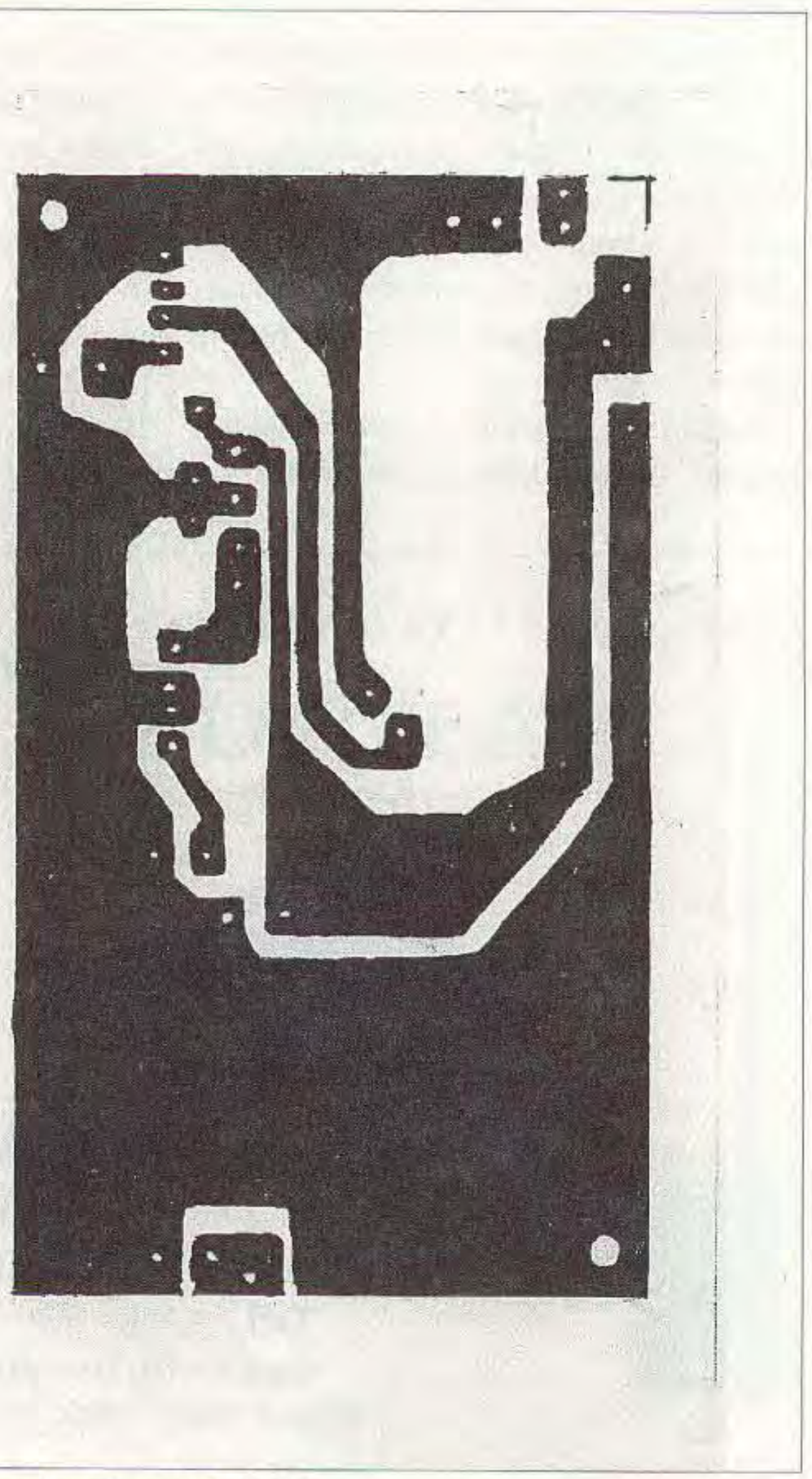

Fig. 7. *Receiver board, foil side.*

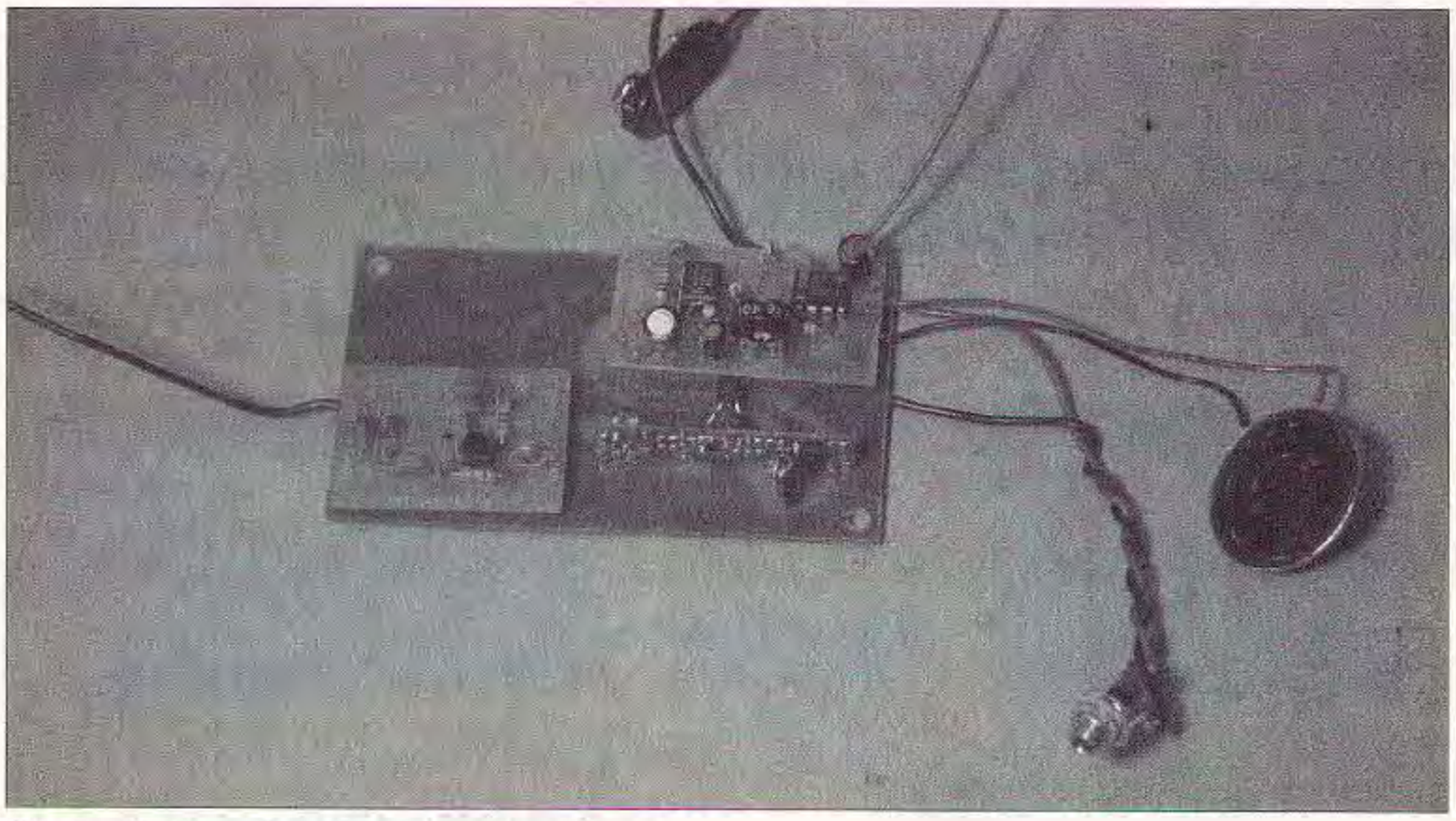

Photo B. *Completed receiver board.*

and the audio amplifier to the receiver PC board. Seat each of the circuit boards as close as possible to the component side of the receiver PC board and solder in place.

Install the receiver module so that the coil faces the audio amplifier. Position the module so that you have minimum lead length and solder in place. Next, install capacitor C3 (10 µF electrolytic). Make sure to observe proper capacitor polarity. Solder C3 in place. Install U1, the LM7805 voltage regulator IC. Make sure that the flat surface on the IC case faces the receiver module. Leave the leads a bit long so that the component can be bent away from the coil on the receiver board. Solder U1 in place. Install capacitors C1 and C2 in place next to U1. Try to use the minimum lead length on these components and solder in place.

Use hookup wire to connect the speaker and output jack J2 to the audio amplifier output. Solder an SPST switch (SW1) in series with the positive lead from a 9-volt battery snap connector. Solder the battery leads to the appropriate points on the receiver PC board.

Photo B — Completed receiver PC board. I housed the receiver in a 2-inch x 4-inch x 5-inch Bud aluminum minibox. The receiver PC board is mounted on 1/4-inch aluminum standoffs and is positioned as close as possible to the antenna connector. **Photo C** shows the receiver mounted in the enclosure.

Construction of the decoder

The decoder is a simple enough circuit to be easily wired on 1/2 of a Radio Shack #276-159 "Dual General Purpose IC PC Board." Lead length and component placement are not critical in this circuit. The type of attenuator you use will depend on the input requirements of the recording device you are using. I used banana type jacks for the decoder input and output connections. **Photo D** shows the decoder mounted in its housing.

Testing and tuning

Attach a short antenna to the receiver and solder a twelve-inch length of wire to the transmitter RF amplifier output connector. Temporarily connect the thermistor to the transmitter. Plug in a blank plug into jack J1 on the transmitter. This will ensure that power is removed from the transmitter. Temporarily break the positive power lead to the transmitter and install a milliammeter in series with the positive power lead. Install a 9 volt battery to the transmitter battery snap connector. Connect a 9 volt battery to the receiver. Apply power to the receiver. You should hear a rush of static coming from the speaker.

Next, remove the plug from transmitter J1. This will apply power to the transmitter. You should see about 10 milliamps of current to the transmitter. At the same time, you should hear tone pulses in the speaker. Use the point of a wooden toothpick to gently separate the turns on transmitter power amplifier coil. Go easy here, as the adjustment required is small.

Adjust for maximum signal strength from the speaker. Use the same technique to adjust turn spacing on the receiver RF amplifier coil. Again, adjust for maximum signal strength. Power down the transmitter and receiver and reconnect the positive power lead in the transmitter.

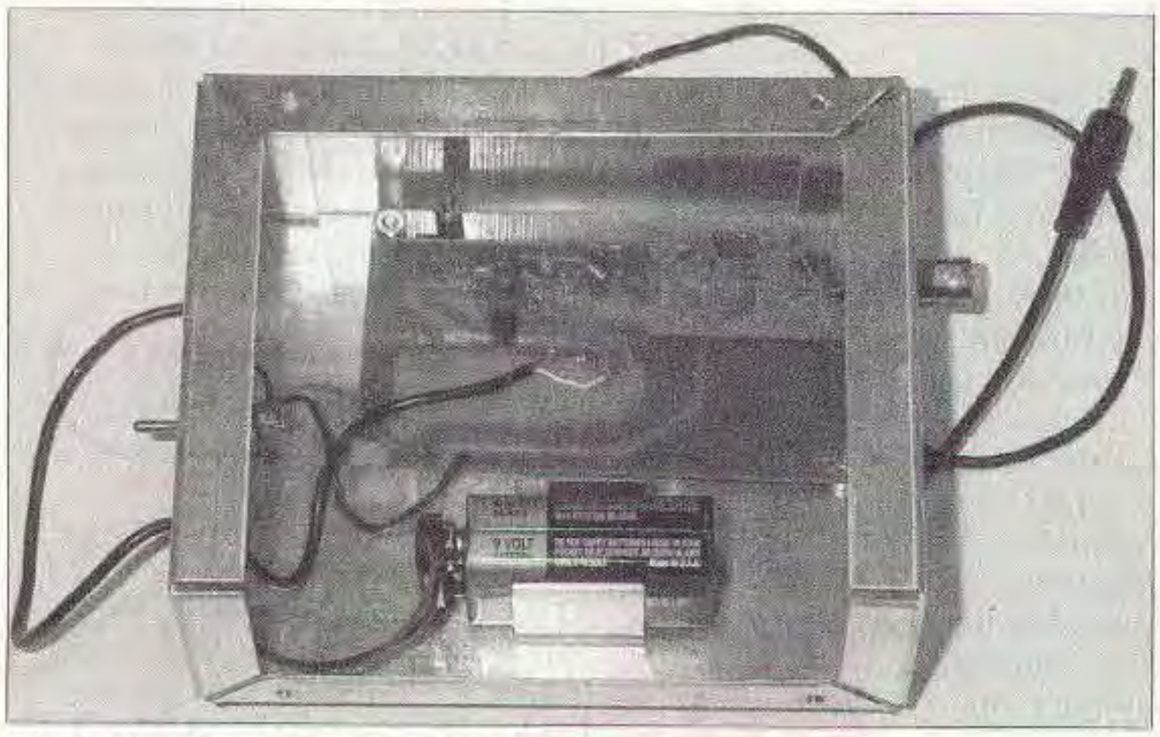

Photo C. *Receiver mounted in the enclosure.*

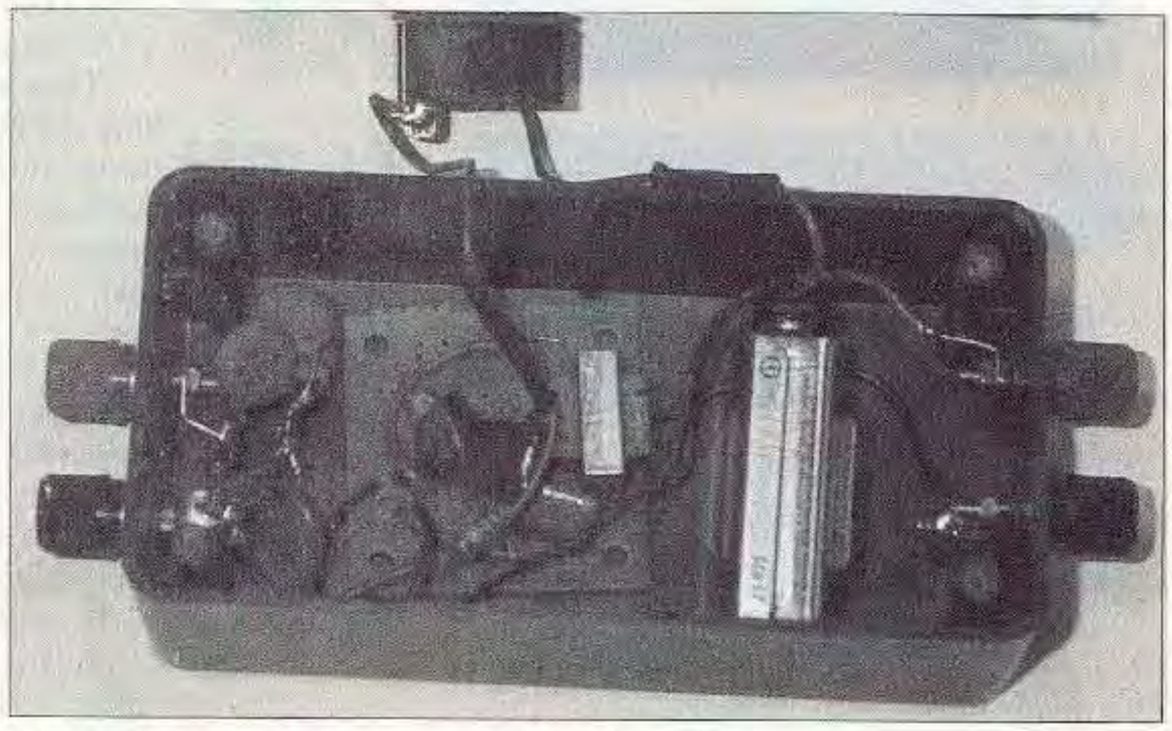

Photo D. *Decoder mounted in its housing.*

NAME	DESCRIPTION
Transmitter Parts List	
C1, C3, C4	0.1 µF disc ceramic cap, RS #272-135
C2	4.7 µF electro cap, RS #272-1024
C5	100 pF disc ceramic cap, RS #272-123
R1	Thermistor, RS #271-110
R2	100k 1/4 W resistor, RS #271-1347
R3	500k pot, Mouser #72-T70YP-500k
J1	1/8-in. open frame closed circuit jack, RS #274-246
J2, J4	Thermistor connector, 2-pin Deans ultraplug, Deans #1300 (available from R/C suppliers)
J3	9 V battery snap connector, RS #270-324
Module 1	433 MHz AM transmitter module, RS #900-6896
Vectronics 1444K RF amp kit	433 MHz, RS #990-0268
U1	4011B CMOS quad NAND gate, Digi-Key #CD4011BCN-ND
U2	4046 micropower PLL, Digi-Key #CD4046BCN-ND
RFC-1	Ferrite bead, Mouser #542-FB64-110
Misc. components: 0.005-in, sheet brass; PC board	
Receiver Parts List	
C1, C2	0.1 µF PC-mount cap, RS #272-1069
C3	10 µF electro cap, RS #RSU11296852
U1	7805 IC +5 V regulator, RS #276-1770
Module 1	433 MHz AM receiver module, RS #900-6895
Vectronics 1444K RF amp kit	433 MHz, RS #990-0268
Rainbow Kits AA1 audio amp kit	RS #990-0041
SW1	SPST mini toggle switch, RS #275-624
J1	BNC chassis-mount jack, RS #278-105
J2	2-conductor open frame jack, RS #174-251
Spkr	1.1-in. mylar mini speaker, Mouser #253-5011
Misc. components: 9 V battery snap (RS #270-324); 9 V battery holder (RS #270-326); aluminum minibox; PC board	
Decoder Parts List	
C1	0.1 µF cap, RS #272-1069
C2	0.22 µF cap, RS #272-1070
R1, R2	4.7k 1/4 W resistor, RS #271-1330
R3	1k 1/4 W resistor, RS #271-1321
R4	5 meg pot, linear taper, Mouser #31VC605
T1	Audio transformer, RS #273-1380
U1	LM555N IC timer, RS #276-1723
SW1	SPST toggle switch, RS #275-624
SW2	SPDT toggle switch, RS #275-625
J1, J2, J3, J4	Banana jacks, RS #274-661
Misc. components: 9 V battery snap (RS #270-324); 9 V battery holder (RS #270-326); small plastic box; PC board (RS #276-159)	

Component Suppliers	
NAME	**URL**
Radio Shack	www.RadioShack.com
Digi-Key	www.digikey.com
Mouser Electronics	www.mouser.com

Part 2 of this three-part series will discuss integration of the transmitter electronics package into the sounding rocket payload section and construction of the telemetry tracking antenna. Have fun! 73

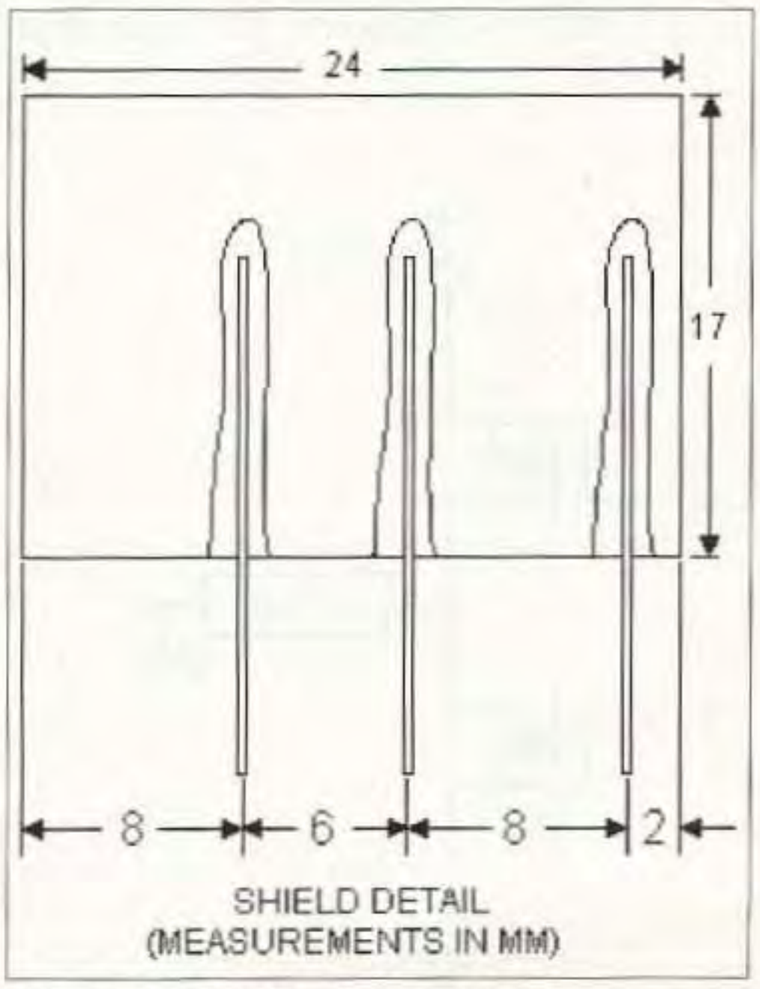

Fig. 8. Shield detail from Fig. 1.

Table 1. Parts lists.