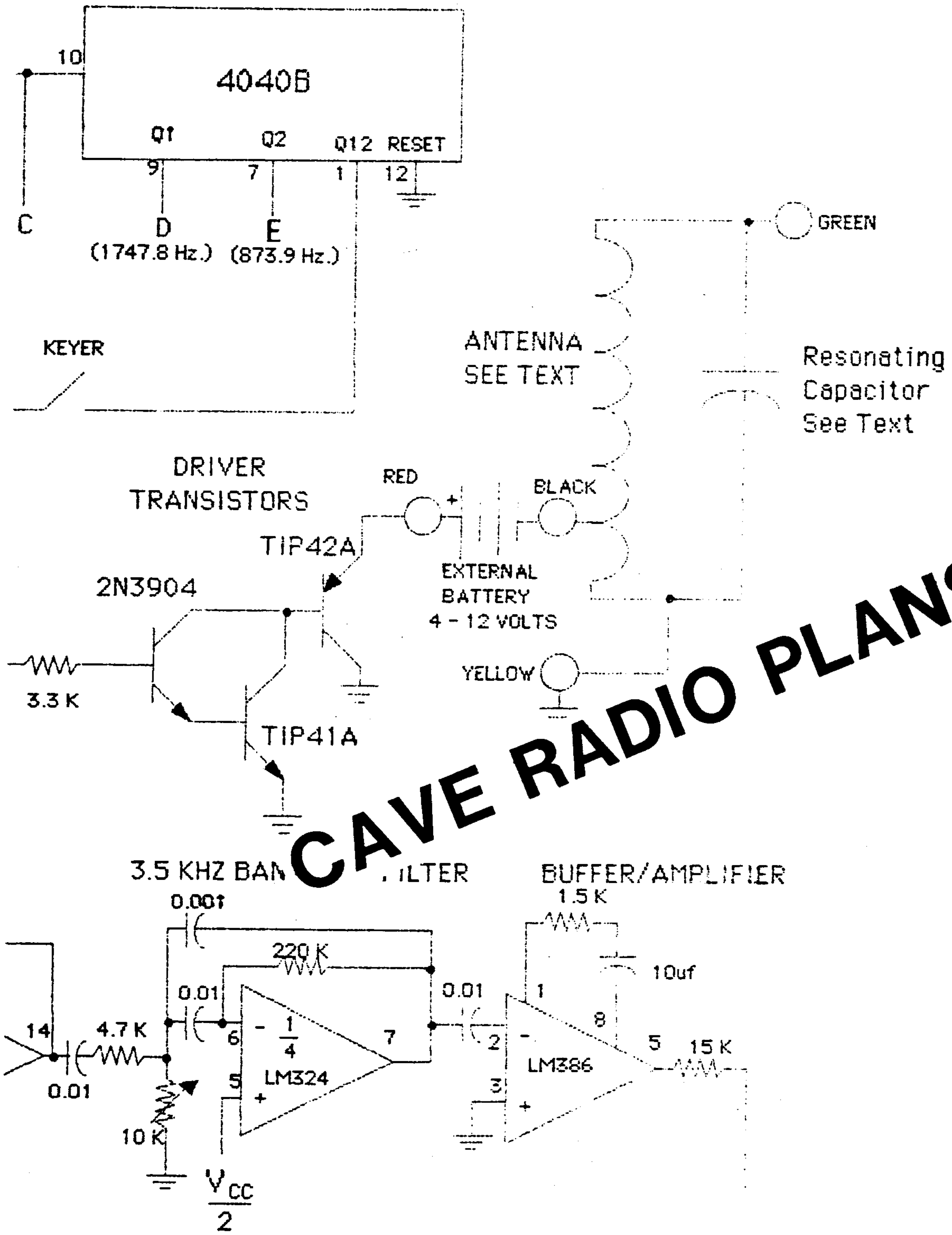
speleonics 3

FALL 1985



CAVE RADIO PLANS!

VOL.1, NO.3

SPELEONICS 3

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SPELEONICS is the quarterly newsletter of the Electronics and Communications Section of the National Speleological Society. Primary interests include cave radio, underground communications and instrumentation, and cave-related applications of amateur radio. Membership is unrestricted (NSS membership not required). Membership, which includes four issues of SPELEONICS, is $4.00 in USA/Canada, $6.00 elsewhere. Send subscriptions to section treasurer **Joe Giddens** at the address below.

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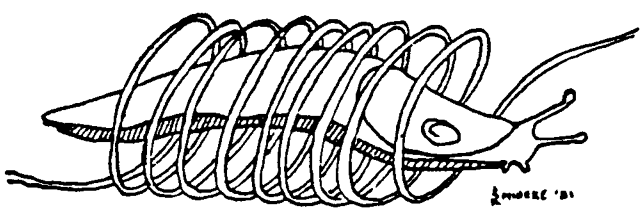


SLUG TUNED COIL

Editorial:

Cave Radio Ethics: Artificial Entrances

Cave radio has located vital water wells for Texas ranchers, aided antipollution projects and cave rescues, surveyed property boundaries, and increased the accuracy of countless cave maps.

Cave radio is the ideal way to locate artificial entrances to known caves. Like dynamite and other powerful tools, its misuse can damage caves and owner relations.

Cavers like to dig! Entrances which conveniently bypass nasty passage and unfriendly landowners are easily rationalized from safety arguments. Purists aside, there are valid objections to cave modification for the sake of convenience. A new entrance can upset cave ecology by modifying airflow and introducing harmful agents (including excessive numbers of cavers). The distinction between convenience and necessity is arguable, to say the least.

New entrances for potential rescue needn't actually be dug; they could be located for future reference, to be excavated by heavy machinery in case of emergency. But who can resist the temptation to dig with success guaranteed?

Cave and owner-relation damage are obviously to be avoided. Individual circumstances will vary; bypassing an unfriendly landowner might cause him no loss, and might even be a favor to him.

Consequences aren't always obvious. I take righteous pride in having refused a request to use cave radio to circumvent a commercial cave operator. The same year, however, I naively made a radiolocation which resulted in an entrance being dug without the landowner's permission. The easier access resulted in significant damage to a small but beautiful cave.

How would one resolve the dilemma of being offered money to do cave radio work for probably-harmful purposes but breaking no laws, and knowing that if he refuses, the job will be done by someone else? Is arming "cave war" combatants morally equivalent to participating directly?

On this 25th anniversary of American cave radio, it is ready to become standard caving equipment instead of the domain of a few specialists. Now is the time to ponder the consequences of irresponsible use of cave radio, lest this valuable tool fall into the same disfavor as the once-popular practice of publishing state cave books.

F.R.

Cartoon by **Elea Mideke** originally appeared in The Lowdown, vol. 8, no. 7, July 1981. Reprinted by artist's permission.

ORGAN CAVE RADIO

by Ray Cole NSS 12460

INTRODUCTION. The cave radio used in the Organ Cave System project needed a range greater than 516 feet, the cave's maximum depth. Information was initially available on cave radio equipment built by Frank Reid, Richard Blenz, Bill Plummer, Lew Bicking, and the Charltons. It was not desired to build the highest-performance equipment possible, but something that could be easily constructed from readily-available electronic components.

THE TRANSMITTER. The transmitter was easiest. A prototype constructed in 1977 worked well. The transmitter is a frequency source which drives a power switching transistor which supplies energy to the antenna. The final design employed a crystal oscillator with CMOS dividers to produce the operating frequency. The design also used a PNP driver transistor which simplified construction by allowing the transistor collector to be directly connected to the aluminum case. This was the first use noted for this driver arrangement, which increased the reliability of the equipment. Several driver transistors in previous circuits had been destroyed in testing. Thus far, none of the PNP drivers have failed in testing or in use even though the underground antenna draws six amperes peak current. The output driver transistor is driven by a waveform with a 25% duty cycle. This was found experimentally to yield the maximum radiated field with minimum RMS battery current. A vital part of any cave radio equipment is a circuit that will turn the signal on and off to allow it to be discerned from background noise, making it easier to initially detect the signal. Of course, a key jack should be included for morse code communication. Communication is not essential in surveying. **Figure 1** is a block diagram of the transmitter. While voice communication has frequently been requested by potential users, the morse code systems are more efficient due to the narrow bandwidths of the antennas at these frequencies. Ian Drummond and others have built equipment suitable for voice use.

ANTENNAS. The transmitting antenna is an autotransformer with the driving current applied to a low-impedance tap. A capacitor in parallel with the main coil produces a resonant circuit at the operating frequency. The autotransformer steps up the voltage applied to the tap, based on the turns ratio. The first antenna constructed was 400 turns of number 24 wire with a 20-inch diameter, resulting in an inductance of 188 mh with a Q of 77. An 11000 picofarad capacitor resonated the loop to 3495.6 Hz. The taps were placed at 2, 4, 6, and 12 turns. The 4 and 6-turn taps were used with 5 and 6 volt batteries while the 12-turn tap was used with 12-volt batteries. This antenna was capable of producing more than 1000 volts at its terminals. There was some safety concern for both the caver and the resonating capacitors. The underground transmit antenna has a lower terminal voltage with higher currents, using seventeen turns of number 18 stranded wire in a six-foot-diameter loop. This loop has an inductance of 1 mh. and a Q of 11.5 at 3495.6 Hz. A 2.0 microfarad capacitor is required for resonance. A tap at two turns is used for 6-volt operation. This flexible antenna is laid on a plastic sheet placed on the cave floor. Rocks and gravel are placed under the plastic sheet to obtain a level loop as measured with a bubble level on a string. Accurate leveling is essential; an error of one degree would produce an error of over eight feet on the surface at the 500-foot depth.

FREQUENCY. After reviewing the literature, 3495.65 Hz was decided upon. While no one was using this exact frequency, it is easily obtained by dividing a TV color-burst crystal (3.579545 MHz) by 1024. This can be done with a single CMOS integrated circuit. Operating frequency is a compromise between antenna efficiency and attenuation due to the conductivity of the limestone and soil. The antennas have a higher efficiency at higher frequencies, while attenuation increases with frequency. The optimum frequency would thus vary with required range and overburden conductivity. The author picked a frequency near that which others had used successfully.

RADIO RECEIVER. It was initially thought that, for the 516-foot range desired, a receiver consisting of simple high-pass and band-pass filters followed by enough gain to drive headphones would be adequate. Testing with the transmitter in the basement showed that the signal was very weak at 150 feet. Cave radios work poorly in the city due to 60-Hz harmonics radiated by electrical wiring, and other man-made noise sources. Greater range could have been obtained away from city noise. The 150-foot range was much less than required, since magnetic field signal level reduces in amplitude as a function of the cube of the distance. The problem with the receiver just described is that high gain produces feedback between the headphone output and the receive antenna. Performance would vary depending on the relative position of the receiver, antenna, or headphones. Crystal-element headphones reduced coupling to the antenna that would have occurred with conventional magnetic headphones. A single-conversion receiver was needed to distribute the gain between two frequencies to reduce or eliminate feedback. Frank Reid's design looked great but used a specially-ordered electronic tuning fork as well as analog components that require careful alignment. A telephone conversation with Brian Pease turned up an idea he had generated with one of his colleagues, which was a digital commutator filter combined with another commutator stage to resynthesize the signal at a different frequency. This is just what was needed; it simultaneously provided single conversion and very small bandwidth (less than 30 Hz). The frequencies to control the commutator filter and commutator synthesizer are available in the crystal-controlled transmitter. This type of filter is easily built with currently-available analog CMOS integrated circuits. It was necessary to add another board to accommodate the additional circuitry but the results were immediately encouraging. It took a few weeks of experiment to determine the appropriate gain settings for each stage. The resulting receiver block diagram is shown in **Figure 2.** This receiver provided good signal levels at 500-foot ranges in the city. For the frequency used, surface testing gives a good idea of range since the losses due to the limestone conductivity are much less than the loss due to range.

CONSTRUCTION. Components were procured, and about six D.C.- area cavers spent a long day in the author's basement on March 29, 1981. The group did the chassis work, started wiring the circuit boards, and wound several antennas. At this work meeting, Dick Sanford provided the author with a recent letter from Brian Pease containing some of his ideas on cave radios.

The radios were constructed in 2x3x6-inch aluminum enclosures which contained the necessary jacks, potentiometer, 9-volt battery, and a single circuit board. The box became very crowded when the second board was added. The electronic circuitry draws 12 ma from the 9-volt battery. Only two units of this type have been constructed. Each works a little differently. Since the layout is sensitive, it is not recommended that the exact circuit be duplicated. The complete schematic is included here (**Figure 3**) to aid others who may wish to build or experiment with cave radios.

NEXT EQUIPMENT. A major compromise in the implementation described was the integrated circuit used for the commutator. This device produced a current spike at each sample. A number of techniques were tried to reduce this effect with no success. In order to use these devices, much of the required gain was placed before the commutator filter. That provided an adequate signal-to-noise ratio after the commutator filter. Future designs should investigate the use of other devices for the commutator. After using the equipment described, some general ideas to improve the performance of the cave radio receiver were developed. The basic approach would be to use the extremely stable phase information available to provide a coherent matched filter demodulator. This would increase the effective signal-to-noise ratio by demodulating the signal in the smallest possible bandwidth. It would also be possible to transmit information using phase-shift modulation. This could be done for both morse code and analog voice. Analog voice would probably require a higher operating frequency to enable an acceptable antenna bandwidth of 1.7 kHz. minimum. Frequency or phase modulation transmission would still allow the simple and efficient antenna driver circuits to be used.

BIBLIOGRAPHY

1. Letter from Brian Pease to Dick Sanford dated 20 March 1981.
2. Charles Bishop and Frank Reid, "Accuracy Evaluation of Electromagnetic Locating" 1981, Eighth International Congress of Speleology, Bowling Green, Kentucky.
3. Frank Reid, "Caveman Radio", 73 Magazine, February 1984, pp. 42-49.
4. William Mixon and Richard Blenz, "Locating an Underground Transmitter by Surface Measurements", The Windy City Speleonews, Vol. IV, no. 6, pp. 47-53, 1964 Speleo Digest, pp. 3-1 thru 3-13.
5. Bill Plummer, "Direction Finding in the Horizontal Plane", The Baltimore Grotto News, Vol. VII, No. 12, pp. 360-62, 1964 Speleo Digest, pp. 3-31 thru 3-33.
6. Harry Pemble, "Report on Experiments in Subterranean Radio Propagation at Walli Caves", The Texas Caver, Vol. 11, No. 11,pp. 132, 138, 142, 1966 Speleo Digest, pp. 3-19.
7. Lew Bicking, "The Cave Radio Revisited", 1966 Speleo Digest, pp. 3-20 thru 3-23.
8. Letter from Ian Drummond to Ron Simmons describing a voice cave radio constructed by the Canadians, letter dated 26 May 1982.
9. Bud Broeker, "Want a bandpass filter? (Commutating filter)", Electronic Design, October 25, 1970, pp. 76-78.
10. W. R. LePage et. al, "Analysis of a Comb Filter Using Synchronously Commutated Capacitors", AIEE Part 1 Vol. 72, March 1953, pp. 63-68.
11. Roy and Ray Charlton, Personal observations of their equipment, 1970 NSS Convention at Blacksburg, VA and at the Simmons Mingo Expedition in 1972.

Organ Cave Trip Report

by Ray Cole NSS 12460

(Condensed from original article to be published in the DC Speleograph.)

On August 17, 1985 The Organ cave radio was used to determine the relative position between two stream passages. The latest map showed the Upper Level Organ (ULO) passage running through the middle of the larger Hendricks passage. Bob Handley, Charley Maus, Alan Stubbes, Alice Cruse and Ray Cole first went to ULO to place the transmit equipment, then Ray and Alice went to Hendricks with the other cave radio.

Seven radio location stations were placed in Hendricks. A bearing and magnetic field slope were measured from each of these, and the points were tied into the existing survey. From this data, the ULO passage was calculated to be 15 feet east of Hendricks and 30 feet higher. During the morse code communication between Alan and Ray, the ULO team was asked to listen for a whistle. They heard the whistle, as well as rock pounding in some of the leads Alice tried, heading in the general direction of ULO.

This use of the cave radio from underground to underground was the first known use in any cave. While more awkward underground due to the limited physical access, it still proved possible. Voice communication with the cave radio would have been helpful. The Hendricks team did not know that sounds were heard until they met on the surface. The ULO team didn't copy the message that the Hendricks team was still underground. Travel time with the 22-inch square receive antenna was slower than planned. The large breakdown in Hendricks required more time to make the necessary measurements and tie-in the radio stations.

The map was accurate at this point with a relative error of less than 30 feet between the two passages. The success of this trip suggests that cave radios could be useful tools in connecting caves and cave passages.

Figure 1. Cave Radio Transmitter Functional Diagram

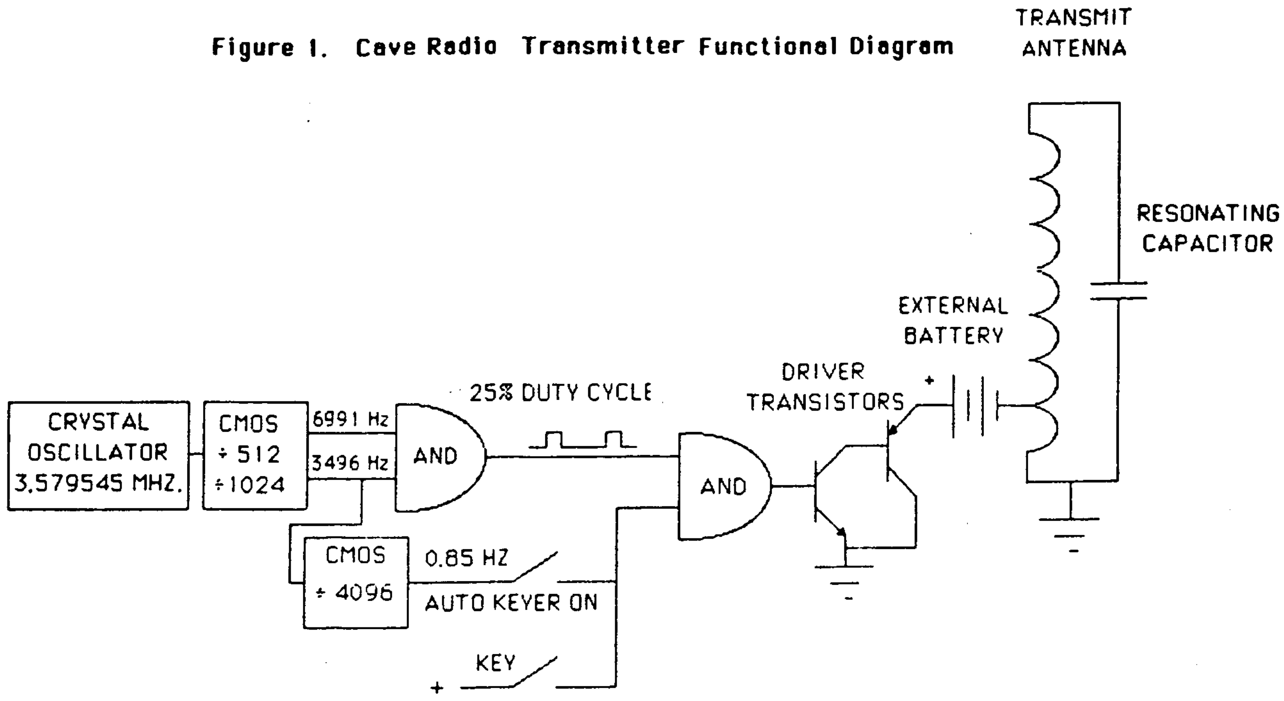
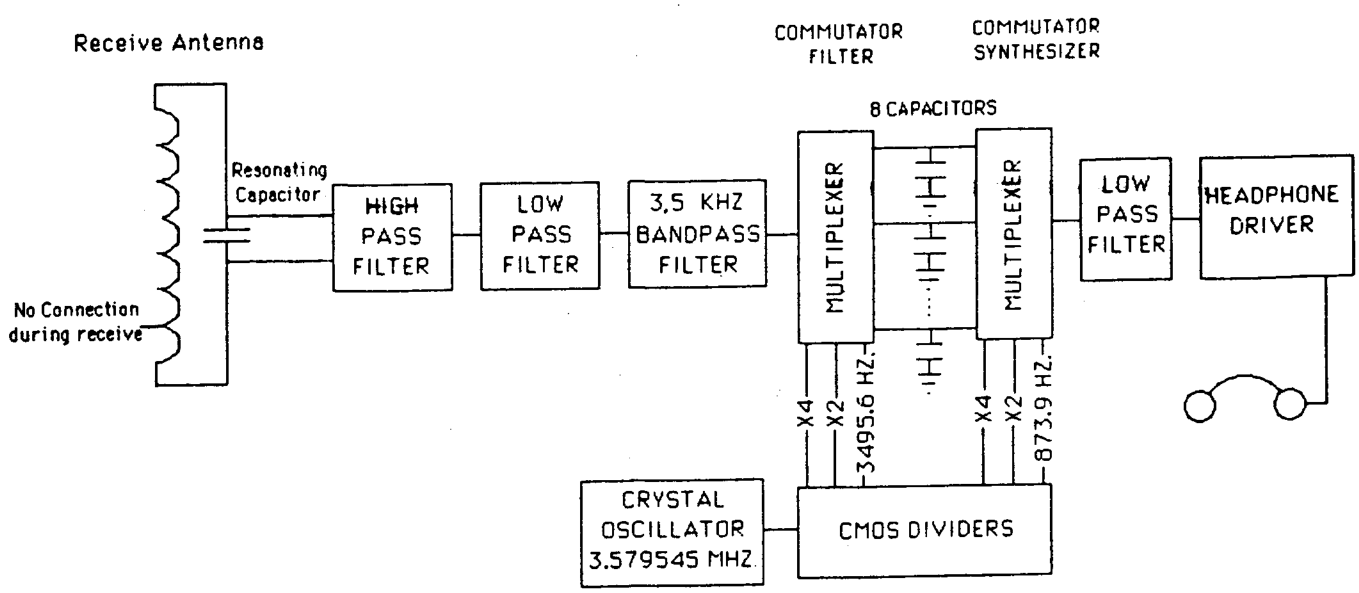
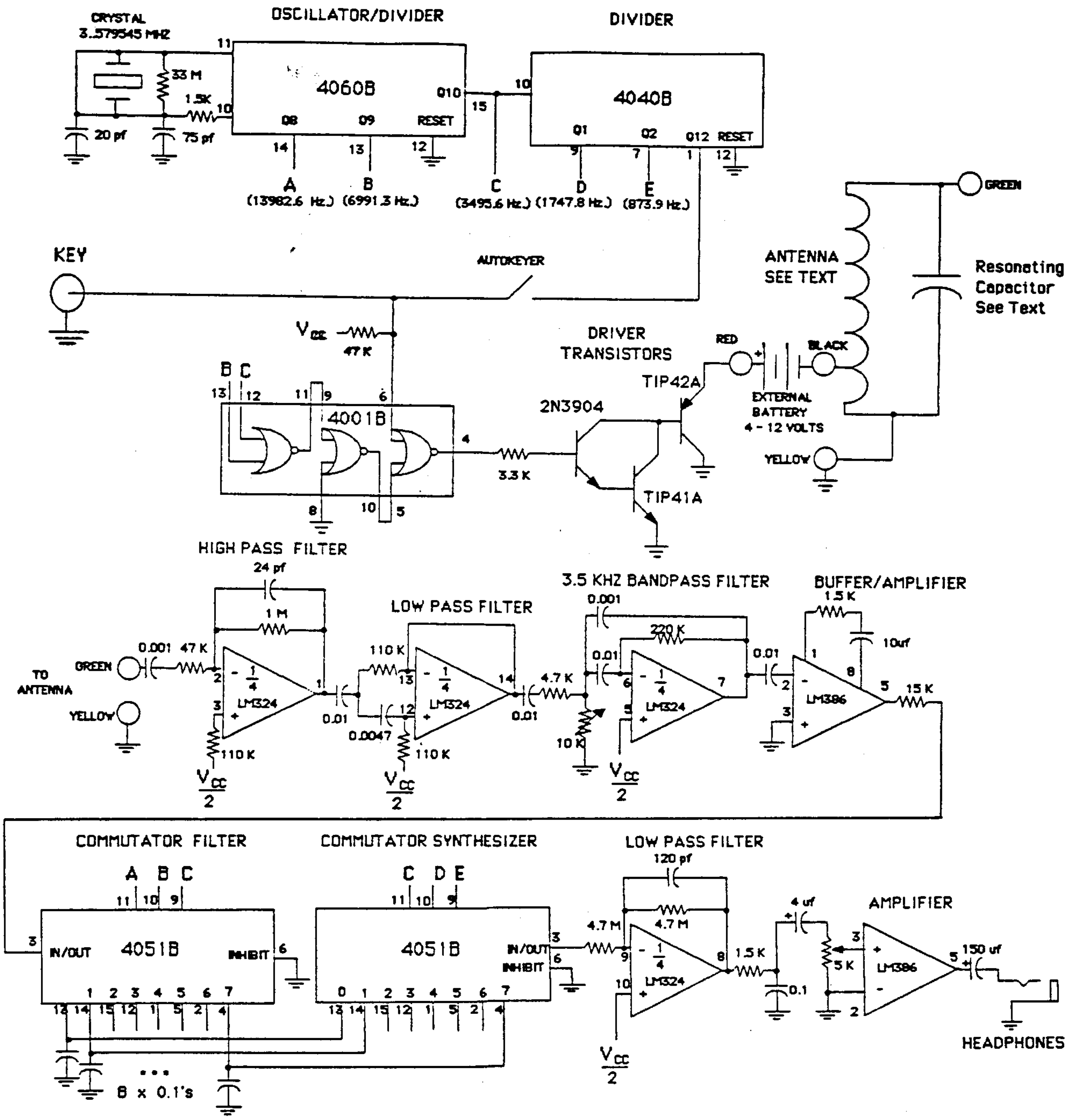
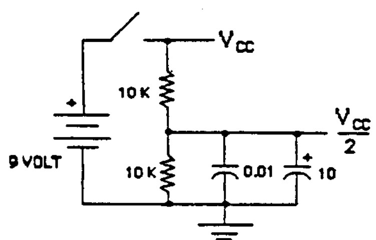


Figure 2. Cave Radio Receiver Functional Diagram





POWER



Notes:

1. Capacitance values are microfarads unless otherwise stated
2. A bypass capacitor should be used at each IC
3. Disconnect green antenna lead during transmit

SUPPLY AND GROUND PINS

IC TYPE	V_{cc}	GROUND
LM324	4	11
LM386	6	4
CD4001B	14	7
CD4040B	16	8
CD4051B	16	8
CD4060B	16	8

Figure 3. Cave Radio Schematic

CAVE RESCUE COMMUNICATIONS: LINKED SYSTEMS

This double article describes independently-developed but complimentary solutions to cave rescue communications problems.

Part I:

Thomas M. Whitehurst, NSS 12919, KC5UN
3912 Case
Houston, TX 77005

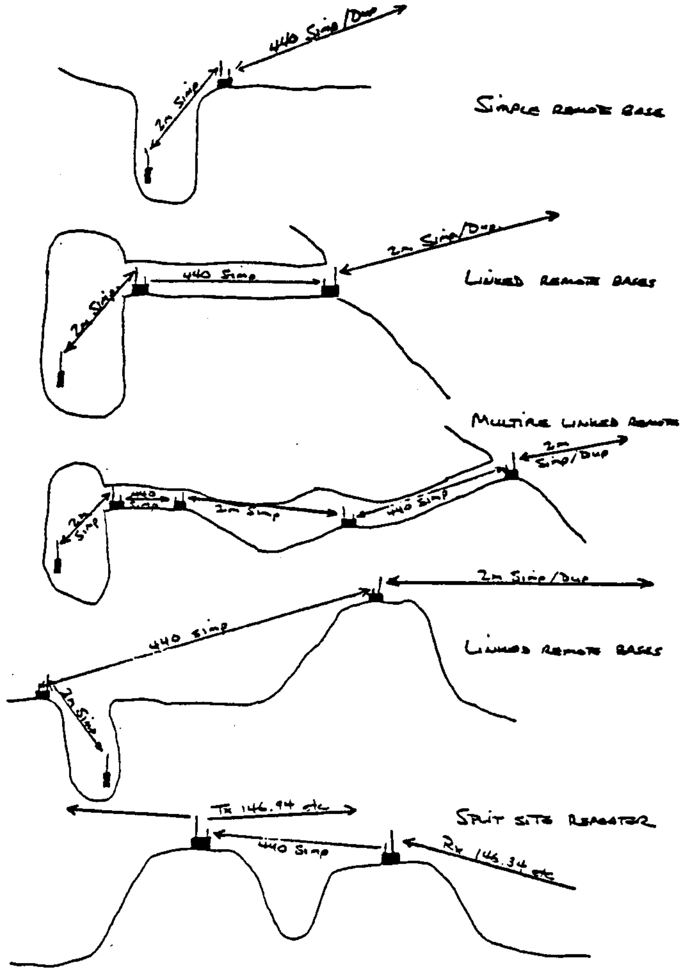
In response to your call for cave-related applications of amateur radio, I am enclosing a copy of an article from <u>220 NOTES*WEST</u>. The article describes interfacing two ICOM handhelds (on different bands) to make a portable remote base. (I understand that this has been done with Tempo S-1 and S-2 rigs too.) This system transmits on 440MHz (or 220 MHz) what it hears on 2m, and vice-versa.

The circuit works beautifully. There is no noticeable de-sense using IC-2AT and 4AT (2m and 440MHz) radios. The interface fits into a 35mm film can, therefore, the unit is essentially no larger than the two radios. I was doing some transmitter hunting at the time, so I put the equipment in a surplus ammo can along with a 12v 4.5 amp-hour gel-cell and had room left over for a 30w 2m amplifier. Antennas were attached to waterproof BNC feed-throughs on top of the can. This is a very rugged piece of equipment. It has been blown around in treetops and buried up to its antennas for transmitter hunts. With no amplifier and a 50% duty cycle, the life of a 4.5 amp-hour battery is calculated to be over 11 hours. Without the amplifier, there is room for a 9 amp-hour battery.

The true utility of this system can be realized when two or more of these remote base units are used. Operators working at the point of rescue can use 2m handhelds; their signals will be picked up by the first remote and retransmitted on 440 MHz to the second remote which retransmits on 2m to a local repeater or a third remote, or a phone patch, etc.

Either radio can be set to any frequency in its range, in either simplex or (half-) duplex modes. This frequency agility, and no need for duplexers, makes it a very flexible system. It can act as a conventional remote base (simplex on one band--duplex on the other, or simplex on both bands). It can link two repeaters on different bands by operating both radios in duplex mode, or <u>two remotes can act as a split-site repeater</u> for searches or conventions. Other advantages are wide availability, and ease of modification of inexpensive equipment.

An obvious drawback of using such a system in cave rescue is that 440 or 220 Mhz gear may be hard to find in areas where there is little activity on those bands. Amateurs always seem eager to help with emergencies. Obviously, cave rescue is not the only use for these things, so rather than going out and buying dedicated radios for remotes, get a large number of hams in the area to make the modification. This way, the equipment could be borrowed when it is needed. The mod to the handhelds only takes 15 minutes per radio, and normal operation of the radio is not affected in any way. Ammo cans are cheap and the circuit components can be had for a couple bucks.



The basic remote could be enhanced by providing an external power plug, a local microphone connection, and cw-id. Running the system directly from a 9v rather than a 12v battery would eliminate the need for the regulator units that step-down the voltage to 8.4v. This would be more efficient and either make the package smaller, or allow room for more battery.

Article reprinted by author's permission from:

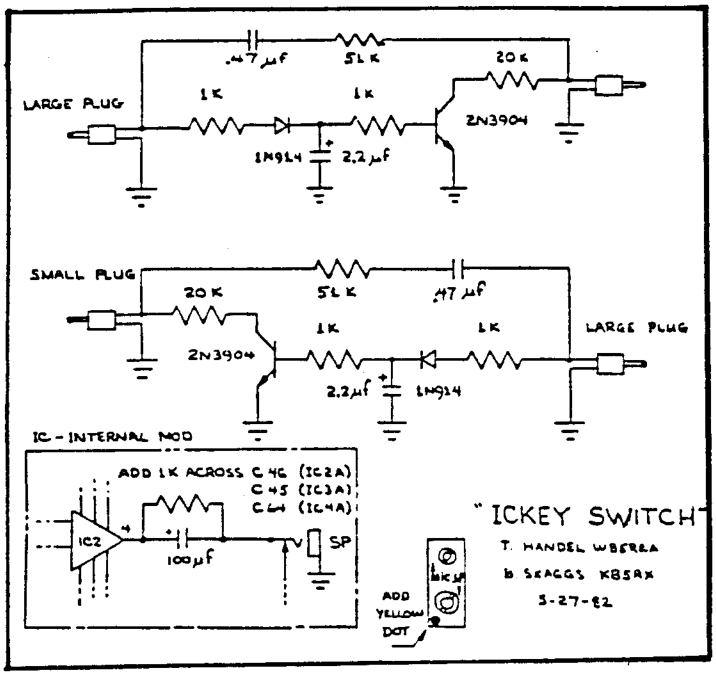
<u>220 NOTES*WEST</u>
Box 15186, Tucson AZ 85708

August, 1982

Ted Handel, WB5REA and Bob Skaggs, KB5RX

(Condensed)

We sat around one day and dreamed of a way to put an IC-2AT back-to-back with an IC-3AT to make a remote base. If you could get a signal out of the audio and rectify it to turn on the other radio transmitter, you would have the COR (carrier-operated relay) and the voice could be passed through a capacitor to the speaker-mic circuit. The following circuit does the job. We have used it to pick up signals from a guy out searching for some of his buddies who were lost, and pass them back to his base camp via the 220 repeater. Works like a horse!



With the addition of a 1k resistor across the speaker output capacitor in your IC-2, 3, or 4, you can hook it back-to-back with another handheld not of the same band, and make a remote base. The voltage on pin 4 comes up to about 3.5 vdc when audio is coming out of the speaker. The 1k resistor allows a small DC current to be multiplexed on the audio. Both signals are carried into the ICKEY switch where they are split. The DC current is passed through a diode to prevent chatter of the switch which then turns-on the push-to-talk circuit of the other handheld. The audio goes around the switch, thence into the microphone circuit of the radio that is transmitting.

The audio levels are set to normal listening volume on the radio and the 51k resistors are just about right for good gain in the transmitter. The .47 uf can be varied by a factor of two, either way, to equalize the audio to suit. This value makes it sound about natural. Hang-time and squelch time are set in front of the 2N3904.

Ed. note: The original article advertises a printed-circuit board. Author Skaggs advises that these are no longer available. Tom Whitehurst says that the ICKEY switch also works with Icom IC-02AT and IC-04AT transceivers.

Part II:

"HANDHELD" REPEATER LINKS FIELD PHONES AND RADIOS

Frank Reid, NSS 9086, W9MKV

(original publication)

Icom's HS-10SA VOX (voice-operated switch) unit allows hands-free headset operation with the IC-02AT and IC-04AT handheld 2m and 440-Mhz transceivers. An easy modification allows the HS-10SA to accept telephone line input, thus making a portable repeater controller. The transmitter is activated whenever audio is present, and for a short period after talking stops. The modified VOX retains its normal headset function.

The repeater-adapted VOX unit automatically links underground and surface communications systems (Fig. 1). Wires connecting the receiver and transmitter extend into the cave, and are connected to field telephones underground and on the surface. Telephone conversations are transmitted by radio. Received radio traffic enters the phone line and is retransmitted on the repeater output frequency, thus increasing the range of portable radios.

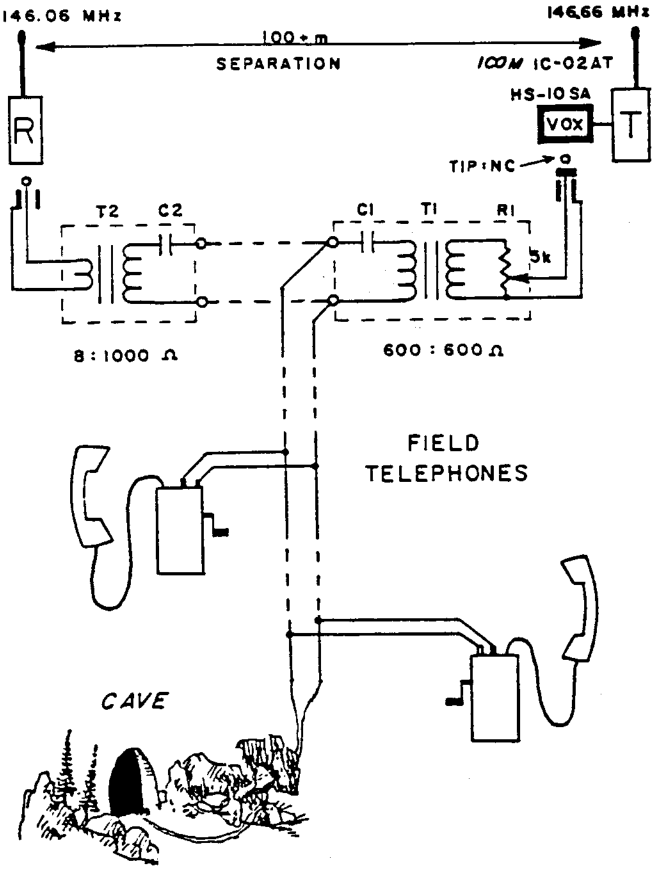


Fig. 1. "Handheld" VOX-controlled repeater separates receiver and transmitter by several hundred feet, to avoid receiver overload. If possible, the wires from the receiver should go directly to the repeater controller, thence to the telephone network, so that the phone-to-radio link may be broken without disabling the radio repeater function. Small audio transformers provide isolation and impedance matching. 1-microfarad capacitors block low-frequency telephone-ringing current. The Icom HS-10SA VOX unit's microphone input is the ring of a 3-conductor miniature phone plug.

The 7-transistor HS-1ØSA is sensitive, fast-acting, and contains no mechanical relays. It never misses a syllable; VOX repeater control is seldom distinguishable from the preferable but more complex COR configuration. The HS-1ØSA costs about $2Ø, and is intended for use with Icom's HS-1Ø headset. It also works with certain other headsets, e.g., an unmodified Plantronics StarSet with preamplifier.

The repeater configuration is simpler, so to speak, than a simplex autopatch, and has the advantages of a full-duplex repeater.

Many variations are possible; the handheld repeater could easily be given autopatch capability, including "reverse autopatch," since it is already designed to connect to telephone lines.

NOTE: The Icom HS-1ØSA VOX unit is intended only for the IC-Ø2AT and IC-Ø4AT transceivers. It does not work with the older IC-2AT family, whose external-microphone jacks lack the third conductor which provides power for the VOX unit. The HS-1ØSA presumably can be modified to use an independent power source; it requires approximately 7 volts. I have not tested voltage tolerance or current requirement. Radio Shack sells a 7-volt mercury battery ($5) that is small enough to fit inside the VOX unit. No schematic diagram is supplied with the HS-1ØSA, however, Gene Harrison has obtained a schematic from Icom. Copies are available from the author for SASE.

CONSTRUCTION. I mounted binding posts, switch and variable resistor on the top panel of the VOX unit. I replaced the original metal top panel with a plastic panel, for insulation. Icom uses the same enclosure for their HS-1ØSB push-to-talk switchbox; I used wire cutters and a handheld grinder to remove some of the plastic projections beneath the top panel. I glued the transformer in a space between the binding posts, and wired the circuit in a conventional manner. Alternatively, all the telephone interface components can be housed separately and plugged into an unmodified VOX (Fig. 1).

The 1-microfarad capacitors block dc and low-frequency telephone-ringing current (do not use electrolytic capacitors). Field phones' bells will be disabled if there are no blocking capacitors. C1 is too large to fit inside the VOX housing.

Capacitors can be omitted if no telephones are to be connected to the circuit. The toggle switch may also be eliminated-- The headset jack in the VOX unit is a closed-circuit type, but its switch contacts are unused. Fig. 2 shows a wiring method where an internal line transformer is automatically disconnected whenever a headset is plugged into the VOX unit.

ADJUSTMENT. First, adjust the VOX unit's MIC & VOX GAIN and VOX GAIN controls for proper operation with a headset (the controls interact somewhat; see the HS-1ØSA instruction sheet). Connect the receiver transformer output terminals to a commercial or field telephone line, as if connecting an ordinary phone patch. Call a friend on the phone, and adjust receiver volume for comfortable listening. Starting with R1's arm set at the grounded end, advance R1 until phone line and headset input levels are equal, thus eliminating the need to readjust gain controls on the VOX whenever phone line and headset are interchanged. Set the VOX DELAY control to maximum (about one second) for repeater operation.

The line impedance and audio signal levels used by the repeater are compatible with both commercial and field telephones. Military field telephones, set to "Common Battery" mode, will work on commercial telephone lines; add rotary dials or use tone-dialing via radio.

The handheld repeater allows surface and underground rescue coordinators to converse directly without relay operators (who are freed for other work). The surface coordinator can move freely without having to stay near a telephone. He can monitor and direct underground and surface operations with a single handheld radio.

The repeater allows instructors and students to more easily monitor the progress of practice rescues. People using telephones in the repeater system must remember that they cannot simultaneously talk and listen to someone who is using a radio.

Telephones and radios can remain linked throughout an emergency to give participants a better understanding of the situation, or those in control may elect to break the connection if traffic volume causes confusion, or to avoid broadcasting sensitive information. During a complex mock-rescue involving over 6Ø people, excessive traffic (due partially to inexperienced operators) occasionally forced the telephone talker at the cave entrance to disconnect the repeater from the telephones.

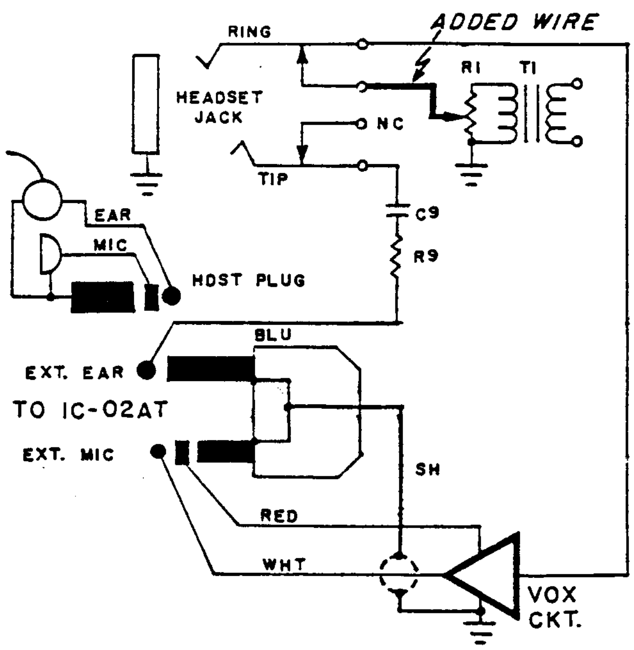


Fig. 2. Alternate wiring method: switch contacts in the closed-circuit headset jack connect the telephone interface to the VOX circuit whenever the headset is unplugged. T1 and R1 are mounted inside the VOX unit.

Real emergencies require communications-security measures, e.g., using earphones, to prevent bystanders' drawing erroneous conclusions from fragments of conversation. The surface telephone operator at a cave rescue often becomes the target of reporters. Repeater components can be hidden, leading bystanders to cluster around a "decoy" telephone which is not the primary communications terminal and is manned by someone with a talent for public relations.

The transmitter and receiver should have weatherproof containers. I have used small ropes to hoist the transmitter and receiver into trees, for greater antenna height and better equipment security. An IC-02AT used as a repeater transmitter will quickly deplete its battery unless it has an external power source or optional high-capacity battery pack. The BP-4 pack with alkaline cells is a good choice for emergency service.

A previous experimental telephone/VOX repeater was based on the "Porta-Peater" circuit made by W.S. Engineering of Pine Hill, NJ (about $100). It makes an "instant repeater" from a wide variety of radio equipment, and includes identifier and timer circuits. The original device is designed to accept speaker-level audio from the receiver. Its local-microphone amplifier was rewired to interface to telephone lines. An electronic telephone ringer was added, wired such that its warbling sound is transmitted by radio when the telephone rings.

The repeater expands radio facilities inexpensively, since any field telephone connected to it functions as a semi-portable radio. People without licenses may participate in amateur radio under the supervision of a license holder. There are no identifier or timeout circuits; users must identify the repeater. The repeater control operator must remain near the equipment in case of malfunction.

Amateur radio has proven invaluable in cave rescue. The Icom IC-02AT is easily modified for operation outside the ham band, up to 165 MHz. Plans will be published in a future issue of SPELEONICS, along with a bibliography of out-of-band conversions for other ham rigs.

References:

1. Danzer, Paul, "A $10 Phone Patch," 73 Magazine, February 1981, p. 68.

2. Macassey, Julian, "Understanding Telephones," Ham Radio, Sept. 1985, p. 38

3. Macassey, Julian, "Building and Using Phone Patches," Ham Radio, Oct. 1985, p. 34.

Parts List:

C1, C2 (optional; see text): 1-microfarad, 400-volt nonelectrolytic capacitors.

R1: 5000-ohm miniature variable resistor.

S1: SPDT subminiature toggle switch (RS 275-625), $1.49.

T1: Audio line isolation transformer, 600-900 ohms, 1:1 turns ratio (Radio Shack 273-1375), $2.49.

T2: 8-to-1000-ohm audio output transformer (RS 273-1380), $1.29.

Misc. parts: miniature binding posts (4 req'd), miniature phone plug, miniature phone jack, small box to house T2, C2.

Magnetic Moments #3 by Ian Drummond

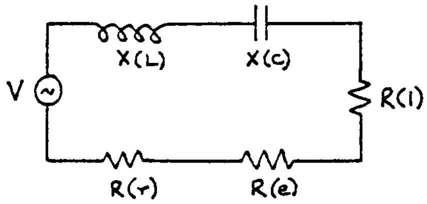
This article deals with reception of the signal. The receiving antenna must absorb some power from the magnetic field set-up by the transmitting antenna. This signal is then amplified (as well as unwanted signals being rejected) so that it can be detected, normally by listening with earphones.

The voltage induced in a loop of wire by a magnetic field is:

$$V = 8 \times 10^{-7} \times \pi f A n \cos \theta H \quad \text{volts}$$

where
- f = frequency (Hertz)
- A = area (m^2)
- n = # of turns of wire
- H = magnetic field (A/m)
- θ = angle of the antenna to the magnetic field

The power the antenna can deliver to the first stage amplifier depends upon the impedance of the antenna and the load. The equivalent circuit of the antenna and load for a directly coupled antenna is as follows.



where V = the induced voltage as given above
X(L) = inductive reactance of the circuit (antenna and first stage)
R(r) = Radiation resistance of the loop
R(e) = Equivalent AC resistance of the loop
R(l) - Load resistance

Then the power dissipated in the load is given by

$$P = \frac{V^2 R(l)}{[R(r) + R(l) + R(e)]^2 + [X(C) + X(L)]^2} \quad \text{watts}$$

For practical low frequency loops, R(r) = 0
For tuned loops, X(C) = -X(L)
and maximum power is transferred to the load when R(e) = R(l)

$$\text{so } P(max) = V^2 / 4 R(e) \quad \text{watts}$$

Since $R(e) = 2 \pi f L / Q$ ohms, where Q = the unloaded antenna Q

Substituting for V gives

$P(max) = 8.\pi^3 \times 10^{-14}\ f\ H^2\ A^2\ n^2\ Q\ L^{-1}$ watts

For an antenna which is transformer coupled to the receiver, maximum power will be the same as in the directly coupled case, but the receiver input must match the transformed impedance of R(e). That is, the receiver input must equal R(e) . (n(p) / n^2 where n(p) = the # of link turns to the antenna.

Example My transceiver uses the same design of antenna for both transmitting and receiving.

When transmitting NIA = 11.3 A.m^2
If the ground has a conductivity of 0.005 mhos/m, using the information in Magnetic Moments #1, at 100m or approx. 5 skin-depths, $H = 1.2 \times 10^{-7}$ A/m
The maximum power which can be delivered to the receiver for

f = 115.4 kHz	A = 0.51 m^2
n = 70	Q = 85
L = 11 mH	

is 4×10^{-14} watts. (This is not going to keep you warm if you are lost in a cave!)

To obtain this power the receiver input impedance must be matched to the antenna, and be equal to R(e) . (1/70)^2 ohms, because of the one turn link transformer.
Input impedance = $(2\pi F\ L) / Q / 70^2$ ohms = 0.02 ohms
That is, this antenna acts as a current source and requires a very low impedance first stage, such as a common base amplifier.

Next time I will discuss the effects of atmospheric noise on the reception of the signal.

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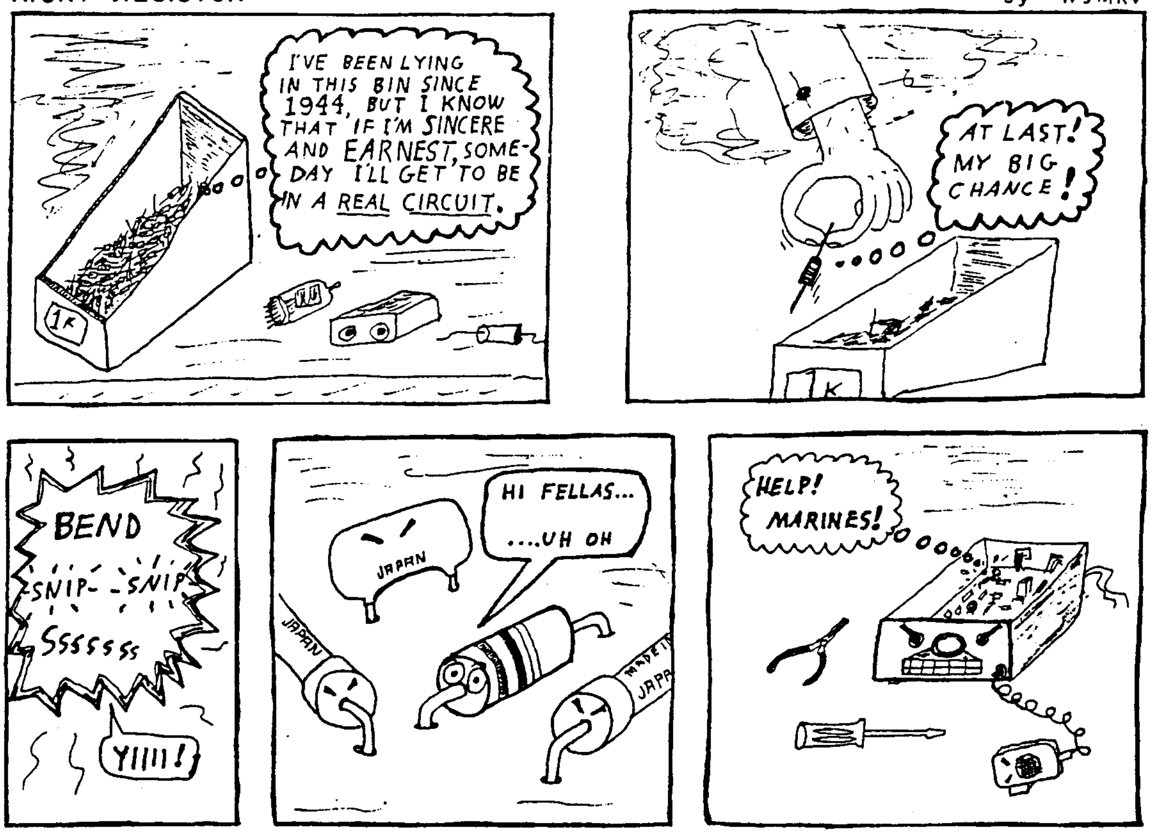

73 Magazine REJECTED this cartoon but I got a nice Christmas card initialed by the staff! - F.R.