

# speleonics 8

summer  
1987

"BETTER CAVING THROUGH ELECTRICAL STUFF"

volume II number 4

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## SPELEONICS 8

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**SPELEONICS** is the quarterly newsletter of the Communication and Electronics Section of the National Speleological Society. Primary interests include cave radio, underground communication and instrumentation, cave rescue communications, cave lighting, and cave-related applications of amateur radio. NSS membership is encouraged but not required.

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### EDITORIAL

Much effort has been expended by cavers in trying to locate underground passage by the method of electrical resistivity. The effort has been both mental and physical. The mental effort arose from the disappointing results; the simple model of a uniform earth pierced by circular cave passage did not work very well. Hence more complex models were developed, none, it must be said, overwhelmingly successful. The physical effort required arose from dragging cables, power supplies and other equipment through the bush to inject electrical currents and measure voltages.

Since the early days of cave-hunting by resistivity, the geophysicists have greatly improved both the models for interpretation of data and the methods of measuring resistivity. Many of the new methods are electromagnetic in nature and do not require the awkward equipment and cables of the old current-injection methods. Unfortunately, the geophysicists are usually looking for areas of high conductivity (ore bodies), rather than areas of low conductivity (caves), so their methods may not be directly applicable to cave hunting. Even so, perhaps the time has come to reappraise conductivity as a method for detecting caves. The challenge is to adapt modern commercially-available equipment (which can be rented or borrowed, as well as bought) to allow reliable detection of cave passage.

--Ian Drummond

### COVER

**Danny Britton** operates British MOLEPHONE underground voice transceiver at 1987 NCRC Seminar. Story on page 4.

### 1987 NSS CONVENTION ELECTRONICS SESSION REPORT

**Ray Cole** presented "Improving the Organ Cave Radio" (See *Speleonics* 3). **Frank Reid** presented "Improvised Telephones for Cave Rescue," followed by an unscheduled test report on the British "Molefone" (see this issue). Abstracts of Cole and Reid papers are in *Speleonics* 7. *Speleonics* will publish both papers pending further development.

#### Informal presentations:

**Ray Cole** discussed Mollicell™ rechargeable lithium cells (see *Resources*, this issue) and a micro-processor-controlled battery charger. **Gary Taylor** demonstrated the Portasol™ butane-fueled soldering iron, and **Frank Reid** showed a mobile microwave source which triggers radar detectors in nearby cars (see "Information wanted: Cavemobile Electronics," *Speleonics* 7.) Austrian caver **Peter Ludwig** reported that cave radio is very difficult to use in the alpine karst of his homeland because of rugged surface terrain and the extreme depths of the primarily-vertical caves. Peter's demonstration of his Unique Self-Climbing Ladder (*Speleonics* 4) was well received at the vertical session.

#### Business:

The planned cave-radio video taping session did not materialize. Production of a video for the NSS Library, on how to use cave radio, remains a goal of the Section.

31 people attended the session. 10 new members joined, 5 memberships were renewed, 24 newsletters were sold. Incumbent officers were re-elected.

LETTERS

We are fortunate to have a growing membership of LF/VLF enthusiasts from outside the caving community. Their expertise and insight continue to yield new ideas for cave radio. Below is a digest of correspondence from a designer of metal-detectors:

Dear Frank,

...You have confirmed several ideas I had about operation below 10 kHz. I am now trying to figure out if there is any application of your field angle graph to problems in pipe locating (an important part of Fisher's business). Usually the field from a pipe is concentric about the (horizontal) pipe, but there may be some configuration where your chart would be useful to us.

In basement-band communications apparatus, I am leaning heavily toward transmitting on frequencies 30 Hz removed from powerline harmonics, and using a local oscillator which is a multiple of the powerline. This produces an I.F. of 30 Hz, which makes it easy to build a narrowband system and to filter out the powerline noise. Unfortunately I do not yet have a receiver built, though I do have a transmitter at 8.192 kHz...

In reading through my issues of Speleonics 1 and 2 and your "Caveman Radio" article in 73 Magazine, it appears that the time is ripe for someone to declare a standard VLF frequency for induction-type communications and locating apparatus. There seems to be a consensus that frequencies around 3.5 kHz are best, and that 3.2768 kHz is easily obtained by dividing a standard timekeeping crystal. I have used this frequency myself in metal detector experiments, and believe that it would make a good standard frequency for underground communications and locating work. Unfortunately, the receiver must use a local oscillator of 3.300 kHz-- not easily obtainable by any combination of division and standard crystals that I have found. I hope that Statek (or another crystal manufacturer) can eventually be persuaded to stock 33 kHz as a standard item. Persuading them to do so will be easier if an "industry" standard for this frequency exists. So-- I propose that Mr. Frank Reid declare by fiat that the aforementioned transmit and local oscillator frequencies are hereafter Genuine Caveman Standard Frequencies.

The existence of this standard will obviously not preclude the development of other standards if a need surfaces, but the existence of this standard will bring about the availability of the necessary crystals so that the various people building equipment can produce compatible equipment.

Sincerely,

**David E. Johnson** Fisher Research Laboratory  
1005 I Street  
Los Banos, California 93635

--

Dear Dave,

Cavers are notoriously independent and will hate me if I dictate a standard! 3276.8 Hz is an excellent frequency, especially for countries with 50-Hz power, since it falls almost exactly between power line harmonics. Below is a list of known rigs, ranked by frequency.

Your expertise in metal-detector design must include many good techniques applicable to cave radio. For example, a 30-Hz i.f. has many advantages but how do you eliminate the image frequency, 30 Hz on the other side of the local oscillator?

Sincerely,

**Frank Reid**

--

Dear Frank,

Using a full quadrature mixer to obtain image rejection in a superheterodyne is very easy in a receiver that receives at only one frequency, or within a frequency band that is less than 1.5:1 from its highest to lowest frequency. It's easier than having to tune the RF stage and make it track the local oscillator, and it allows you to use any IF frequency you want (especially, low frequencies that allow you to get narrow bandwidth easily). The difficulty in using a full quadrature mixer in order to obtain image rejection is when you have to cover a wide range of frequencies-- for instance, in a voice SSB mixer where in order to cover a 300-3000 Hz (10:1) frequency range requires at least four phaseshift circuits (preferably six) in order to obtain good sideband suppression, and the circuits must be constructed of 1% precision components. For low frequency, ultra narrow bandwidth, high sensitivity receivers, the quadrature technique is vastly superior to conventional technique, in my opinion-- better performance and simpler construction.

Using a 30 Hz IF allows you to get narrow bandwidth cheap, and to easily eliminate power line harmonics. If you intend to actually hear a 30 Hz signal, you gotta rectify it (you do this anyway to drive the S-meter) and use the resulting DC signal to actuate a tone generating circuit of some kind. In our pipe locators we proportion both the audio magnitude and the audio pitch so that you have good sensitivity for weak signals and good proportionality on strong signals. It's very effective-- but you gotta watch out that the audio "display" doesn't work its way back into the receiving system. In a receiver with a total gain of a million or so, the latter is not a trivial problem.

If people will agree on transmitters that work on 3.2768 kHz, nobody has to agree on what crystal to use in the receiver, just as nobody has to agree to use an ultra-low-frequency IF.

Point of interest-- If a transmitter could be switched from 3.2768 to 3.323 kHz, or if the latter frequency was an "auxiliary" transmit frequency available from a different manufacturer or by special order, then a receiver utilizing a local oscillator frequency of 3.300 kHz could receive either of the two transmit frequencies by flipping a switch in the mixer to go from "lower sideband" to "upper sideband."

I understand your reluctance to declare a standard frequency, but perhaps someone else will take it upon themselves to establish a de facto standard. I can't be the one to do this since I have not actually built any caving equipment and have no definite plans to do so (though I wouldn't rule out the possibility of manufacturing something sometime.)

(LETTERS cont.)

I think that longwave voice communications (SSB) should, in the long run, be moved up into the 1750 meter band in order to minimize the possibility of running afoul of FCC regulations. Also, since there are quite a few legal experimenters in this

band, it'd make it easier to compare R&D notes and make joint use of more than one person's equipment.

David E. Johnson

**Partial list of past and present cave-radio frequencies:**

Freq.	Name	Designer	Country	Reference/comments
<b>Continuous Wave:</b>				
630.0 Hz (and others)		US Bur. of Mines	USA	Mine emerg. beacons
900 Hz		A. Delpy	France	<b>Speleunia</b> no. 17 Jan-Mar 85
1800 Hz		Ron Allum	Australia	<b>Speleonics 4</b>
2000 Hz		E. R. Roeschlein	USA	<b>Electronics</b> Sep 23, 1960
2000 Hz	MIDAC	Royce Charlton	USA	<b>NSS Bulletin</b> 28:2 1966
2000 Hz		Smith & Stevens	England	<b>Trans. BCRA</b> 1:1 Jan 74
3276.8 Hz	Troglograph	Mike Bedford	England	<b>Electronics Today Internat'</b> 1 May 86
3495.6 Hz	Organ Cave Radio	Ray Cole	USA	<b>Speleonics 3</b>
3500.0 Hz		Frank Reid	USA	<b>73 magazine</b> Feb. 84
7305.0 Hz		Richard Blenz	USA	unpublished; no longer used
38.4 kHz	Ogof Beacon	A. & A. Bell	Wales	<b>S. Wales Caving Club Newstr</b> #101
<b>Voice/CW:</b>				
baseband af		various		
32.768 kHz	M-85	Bo Lenander	Sweden	<b>Speleonics 7</b>
87.5 kHz	Ogofone	Williams & Todd	Wales	<b>Caves &amp; Caving</b> Spring '87
102.4 kHz	Molefone	Bob Makin	England	commercially prod. (review: Splncs 8)
114.3 kHz	ASS Cave Radio	Drummond & Coward	Canada	<b>Speleonics 5</b>
125.0 kHz	Ogofone	Williams & Todd	Wales	<b>Caves &amp; Caving</b> Spring '87

**DECCA NAVIGATION SYSTEM INFORMATION**

Frank Reid

Information request posted on USENET computer network:

How does the DECCA navigation system work? My understanding is that it's a British or European system similar to LORAN-A. There are several "chains" of transmitters 70 and 130 kHz. What is DECCA's range, coverage area, and signal format? I have seen no DECCA equipment advertised in marine electronics catalogs in the U.S. Is it used in the Western or Southern hemispheres? Is DECCA considered a modern system? Ian Fleming mentions it in "Thunderball," aboard the bad guy's yacht.

Frank Reid  
reid@gold.bacs.indiana.edu

Unisigned reply:

As a technician who worked for Decca Marine for several years I can tell you a little about the Decca Navigation system. You are right about the frequency range. It is a continuous wave system where as LORAN is a pulse system. The transmitters (3 or more) transmit signal on a specific frequency and the receiver measures the phase difference between the signals. Each transmitter is on a different frequency, but they are locked to a frequency standard such as a cesium-beam clock. The Decca system is very popular in Europe, and is (claimed to be) more accurate than LORAN. But

Decca makes money by leasing the receivers to ships, and since LORAN is free, there is no market in the USA for the Decca system. I think there is a Decca chain on the east coast of Canada.

Also the system is not pure cw, some type of info is encoded but I'm not sure what. (The techs from the UK told us about a European fellow who decided he was going to get rich, he designed a digital receiver that used the Decca system. The Decca receivers used big dials like analog clocks, kinda looked like the altimeters in old crashing airplane movies, the hands would spin wildly until it locked onto the signal. Anyway, this fellow's receiver worked real well and sold for the price of about a 6 month Decca lease. After many canceled leases the boys at Decca found out what was going on and they got one of his receivers, analyzed it and found that by slightly changing the signal the bogus receiver doesn't track anymore. But it didn't effect the mechanical works in a "real" Decca receiver.

[The above was printed in 1750 Meters: Western Update #46, July 6, 1987. Subsequent correspondence disputes the part about Decca's intentional interference with competing receivers. The different frequencies used in Decca chains are subharmonically related. The Decca chain on the east coast of Canada uses 114.3 kHz, the same frequency as Ian Drummond and Julian Coward's ASS Cave Radio (Speleonics 5). No interference has been reported.

Frank Reid

The National Cave Rescue Commission (NCRC) was fortunate to have Dr. John C. Frankland, noted British cave-rescue physician, as an instructor at the 1987 week-long training seminar at Abingdon, Virginia. Dr. Frankland brought a pair of the Molephone underground voice transceivers which have replaced wired telephones for underground communication in most British cave rescues (see Letters, SPELEONICS 7). The units were lent by the manufacturer, and are the first Molephones ever brought to the U.S.

All who used the Molephones were impressed by their small size, light weight, ease of operation, durability and performance. We were disappointed that there were no accompanying schematic diagrams or technical specifications (other than those reproduced below), and that the units are plastic-encapsulated, thus nonrepairable.

Tests on the surface yielded intelligible voice range of 600-700 feet (183-213m), using 1-meter-square loop antennas made of 24-conductor ribbon cable. Horizontal or vertical polarization of both coils had little effect on range. One Molephone unit seemed to perform better than the other.

British sources tell us that Molephones operate at 102.4 kHz, single sideband. Range was limited by strong interference from the LORAN-C navigation system (100.0 kHz), and an even stronger unidentified low-speed data transmission of the type used by military communications systems. The test area lies midway between the two nearest LORAN-C transmitters, approximately 300 miles from each. LORAN interference (a rhythmic clattering sound) could be nulled by rotating the antenna but the data signal could not. An underground operator (approx. 100 feet deep) reported that interference diminished only slightly inside the cave. There was minor interference near large power lines. During the approach of a thunderstorm, receivers detected static crashes from visible lightning. Molephones were not affected by a nearby handheld VHF transceiver. They were not tested near AM broadcast stations.

Despite interference, the Molephones performed well within minimum specifications. Audio quality was good, with no "Donald Duck" SSB sound. Female voices gave superior penetration of noise and interference.

Inexperienced people can easily operate Molephones. There are only three controls; on/off, push-to-talk, and a button which, when held down, transmits tone bursts for direction-finding. The tone feature was not useful, as its frequency is nearly the same as that of the interfering data signal.

The receiver automatic gain control (AGC) circuit seems to work exceptionally well, with the wide range, fast attack and slow release characteristics needed for good SSB reception. AGC makes direction-finding difficult, especially with strong signals, as it tries to maintain constant level through a null (the optional signal-strength meter was not included in the kit). The microphone amplifier also appears to have AGC, which is probably necessary but causes increased background noise pickup between words.

The equipment set included two handheld speaker-

microphones and one boom-mike headset. The battery charger will charge four batteries simultaneously, and readily converts from 230 to 115-volt operation by changing transformer taps and wall-plug. The charger uses a common voltage-regulator IC, and incorporates an ingenious current-meter shunt as part of the printed circuit board.

Antenna and microphone/speaker are connected by 5-pin locking DIN plugs. No harm is done if they are accidentally interchanged (I did it!). The specially-made battery packs have standard Molex™ connectors. Batteries should be removed when the units are not in use; it's very easy to accidentally switch them ON.

Of course, I tried to look inside the Mo-Fo's but their insides are filled with plastic foam, and no parts are visible. We assume the potting is for protection from water and mechanical shock...

A Molephone transceiver with accessories and extra battery fits easily inside a small (.30-cal) ammo box. The underground antenna is spread on the cave floor; the surface unit has a folding plastic spreader which holds the loop in a rigid square. There is also a ferrite antenna which can be used in motion underground. It fits into very tight passages, and works underwater. The ferrite antenna has about 20% the range of the one-square-meter loops.

The 25 LORAN-C transmitters in continental US, Canada and Alaska (with 400-800 kW outputs) could make Molephones unusable in much of North America. Several new stations are planned for mid-continent. The LORAN-C transmitter nearest the British Isles is at Sylt, W. Germany.<sup>1</sup>

Had a digitally-tuned receiver of known sensitivity been available, we could have learned many technical details of the Molephone. Without test equipment, we were unable to verify the frequency of Dr. Frankland's units. If they are indeed at 102.4 kHz, then the interfering FSK signal may have been an image response or intermodulation product of the Molephone receiver. Back home in Indiana, LORAN-C is especially strong but no other signal is detectable at 102.4 kHz, using an Icom IC-720 HF transceiver with Burhans VLF converter and Burhans E- and H-field antenna preamplifiers. Very strong signals at 88.0 and 134.9 kHz, with characteristics similar to the unidentified interference, come from U.S. Navy station NSS (!) at Annapolis, Maryland, 336 miles (540 km) from Abingdon.

Europe and North America, especially the U.S. East Coast, are crowded with very powerful transmitters between 10 and 200 kHz.<sup>2</sup> Designers should consider frequency-agile cave radios and receivers which, like the Burhans circuits<sup>3</sup>, include special features to suppress spurious response (and thereby achieve greater gain).

America needs long-range voice "cave radios" for rescue application<sup>4</sup>. NCRC instructors and students who used Molephones agreed that they are a superior and viable alternative to wired telephones underground. Most considered the problems of cost, nonrepairability and potential interference unacceptable but a few with immediate needs indicated an interest in buying them.



Department of Engineering  
Bailrigg  
Lancaster, LA1 4YR  
Telephone Lancaster 65201 (STD 0524)

MOLEPHONE EQUIPMENT

One set normally includes the following items:-

Quantity	Description
2	Transmitter/recievers.
2	Handsets.
2	Loop Aerials.
1	Aerial Frame.
1	Small Cylindrical Aerial.
1	Set Headphones with Pendant Switch.
4	Battery Packs.
1	240V mains Battery Charger.
2	Carrying Bags and belts.

The price of these items is £1650.00 Sterling inclusive of packing. Freight, insurance and documentation are charged in addition but will not exceed £250 + VAT.

Additional items are available as follows:  
Extra batteries £50 each  
Signal strength meter £50  
Attenuator £65

TERMS

Delivery will be made to the shipper on receipt of an irrevocable letter of credit payable at 30 days and made out to The University of Lancaster.



(One British Pound Sterling equals approximately \$1.60 US.)

**Molephone Specifications**

(Reproduced from instruction manual. The remainder of the 17-page booklet describes equipment operation, and standard methods of radiolocating and depth measurement.)

**Size:**

(Transmitter-receiver unit,  
excluding aerial) 150 x 100 x 75 mm

**Weights:**

transmitter-receiver and battery pack	950 g
additional battery packs, each	400 g
tape aerial and spreader	1250 g
cylindrical aerial	1057 g
headset	475 g

**Power Supply:**

Detachable battery pack. Rechargeable. 12 volts, 1/2 amp. hour capacity giving approximately 4 hours endurance under intermittent use.

**Effective Range:**

Normally up to 500 feet through rock and soil. In favourable conditions 1000 feet may be achieved.

**General Detail:**

System has facility for hand microphone and external speaker or hand-free operation using boom microphone and earphones. Transmission is simplex. Speech or alternatively a locating tone may be transmitted.

In the locating mode, the directionality of the system is such as to enable locations to be determined to within 1 foot plan position error at depths of up to 400 feet in favourable ground. Instrument case is normally water resistant, but a waterproof version (suitable for diving at up to specified limits) can be made available by the addition of a waterproof housing and specialized components.

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Bill Torode, NSS Librarian

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### THE PBR FLASH GUN

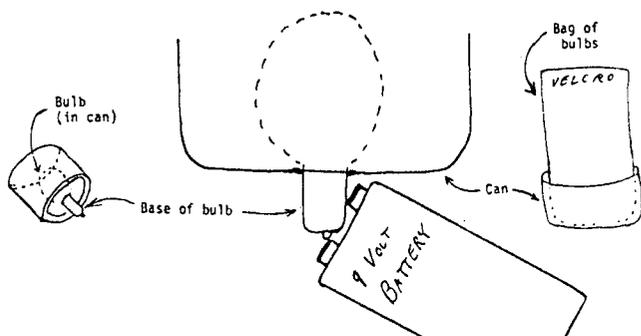
by Bill Baus

[Reprinted from Bloomington Indiana Grotto Newsletter 19:2 June 1987]

In cave photography, the need for a compact and powerful light source makes the M3 and M3B flash bulbs highly desirable. Unfortunately, the only flash gun for these bulbs still being manufactured is a unit made by Ron Simmons, which sells for \$70. For those who want a more economical unit or who want a secondary flash unit, I highly recommend the PBR flash as the ultimate in compactness and economy.

#### MATERIALS REQUIRED:

- 1 can of Pabst Blue Ribbon Beer. (Other impact-molded aluminum cans will probably work, but you wouldn't have a genuine PBR flash.)
- 1 free 9-volt transistor battery from Radio Shack.
- 1 small cloth bag (preferably heavy nylon) with Velcro, drawstring, or button closure, large enough to hold a dozen bulbs and the battery, but small enough to fit into the beer can.



#### MANUFACTURING PROCESS:

1. Drink the beer.
2. Cut the can so that about 1-1/2 inches (4 cm) of sidewall remains with the bottom of the can. Discard the top.
3. Tape the edge of the can to prevent cutting yourself or your gear.
4. Make a hole in the center of the bottom of the can, just large enough to fit the base of an M3 bulb. It should fit tightly. Mash the edges of the hole so that there are no sharp places.
5. In case you make a mistake in cutting or punching the hole, start step 1 with a new beer. After 5 or 6 failures, however, I recommend delaying the manufacturing process until the next day unless you have help drinking the beer.

#### OPERATING INSTRUCTIONS:

1. Place an M3 bulb in the hole with the bulb on the inside of the can and the base on the outside.
2. Aim away from your eyes.
3. Place one of the snap-type terminals of the battery against the cylindrical base of the bulb (not the can) and tilt the battery until the other terminal comes against the contact in the center of the tip of the bulb base. The bulb will flash.

## LONG-RANGE CAVE RADIO

Frank Reid

This article is revised and condensed from a booklet (same title and author) sold at the 1981 International Congress of Speleology. See references 1, 2 and 3 for detailed cave radio theory and practice.

Originally built in 1973, this equipment has an excellent service record and maximum detectable range of 600-800 m. Using parts values as shown, receiver gain is so high that layout, shielding and decoupling are critical. Alignment and operating procedures are somewhat complex, and some parts are difficult to obtain. These circuits are offered as reference material rather than as plans for new construction.

### General Notes On Cave Radio

1. Power lines are the main source of interference. Strong 60-Hz harmonics (50 Hz in some countries) extend well into ultrasonic frequencies. Choose a frequency between two harmonics, and use a receiving filter sharp enough to reject the adjacent harmonics<sup>7</sup>. Such narrow bandwidths require precise frequency control and very slow Morse-code speeds. Reference 8 presents an ingenious solution to frequency-stability problems, using a swept-frequency transmitter.

My early equipment operated at 7300 Hz; Dick Blenz had gone to that frequency from 2000 Hz to escape power line harmonics. I later converted to 3500 Hz because of a fortunate coincidence of available parts. Performance improved significantly at the lower frequency; transmitter coil current was greater and, as predicted by Davis<sup>6</sup>, atmospheric noise is less intense.

2. Atmospheric noise from thunderstorms can produce major interference in summer. It is strongest at night<sup>6</sup>. Atmospheric noise is polarized such that it nulls when the receive coil's plane is horizontal.

3. Receiver gain is limited by feedback from the output back to the antenna. Receiver gain can be enormously increased without feedback problems by using a **balanced mixer** and local oscillator to convert the input frequency to a different frequency, then filtering and amplifying that frequency, keeping the original signal at low level. Receivers using frequency-conversion require careful design to suppress image response.

4. Strong interfering signals can intermodulate with the desired signal in active filters, producing even worse interference. Active filters use power and produce noise. Although physically smaller, they are more complex than L-C filters of equivalent performance. L-C filters are easy to design from cookbook tables and are often the best solution for the high-performance filters required by cave radio receivers.

### Transmitter Notes (see diagram)

1. R1 is a meter shunt (2 amps full scale). R2 is a voltmeter resistor (12 volts full scale).

2. Voltage regulator may be omitted if CMOS logic circuits are used.

3. Transistor types are noncritical. The final amplifier should be a high-current, high-frequency type. A 2N3055 or a power FET should work.

4. Large bypass needed here.

5. The keying circuit is essential: Pulsing the signal saves battery power and simultaneously increases range because the receiver operator can more easily discriminate a pulsed signal against background noise and interference. A low output on pin 3 keys the transmitter. The diodes in the keyer circuit (1N914 or equiv.) allow a greater-than-50% duty cycle (Electronics, June 21, 1973, p. 129). Keyer as shown pulses transmitter at 2 Hz, 10% duty cycle. Duty cycle was later raised to 20% for better performance with narrow receiving filter. Some designs derive the keying signal by further dividing the output frequency.<sup>4</sup>

6. The driver simulates a class-C amplifier. Once each cycle, the pulse from the 555 replenishes the energy lost in the resonant circuit. The duty cycle can be adjusted for either highest coil current or best efficiency. Duty cycle affects antenna tuning because a longer on-period lowers the coil's Q. Period is adjustable 20 to 70 microseconds. Final input power is 15 watts or less, depending on the antenna coil used.

See ref. 4 for an alternative design. There's much opportunity to experiment in this area; the complimentary outputs of the frequency divider could, for example, be used to drive a bridge-inverter final amplifier.

7. Crystal frequency is divided by 36.

8. Crystals in this frequency range are series-mode, and may not work in all oscillator circuits. I chose 126 kHz because the crystals were available, and because they work in both transmitter and receiver. C3 is as needed to trim crystal frequency.

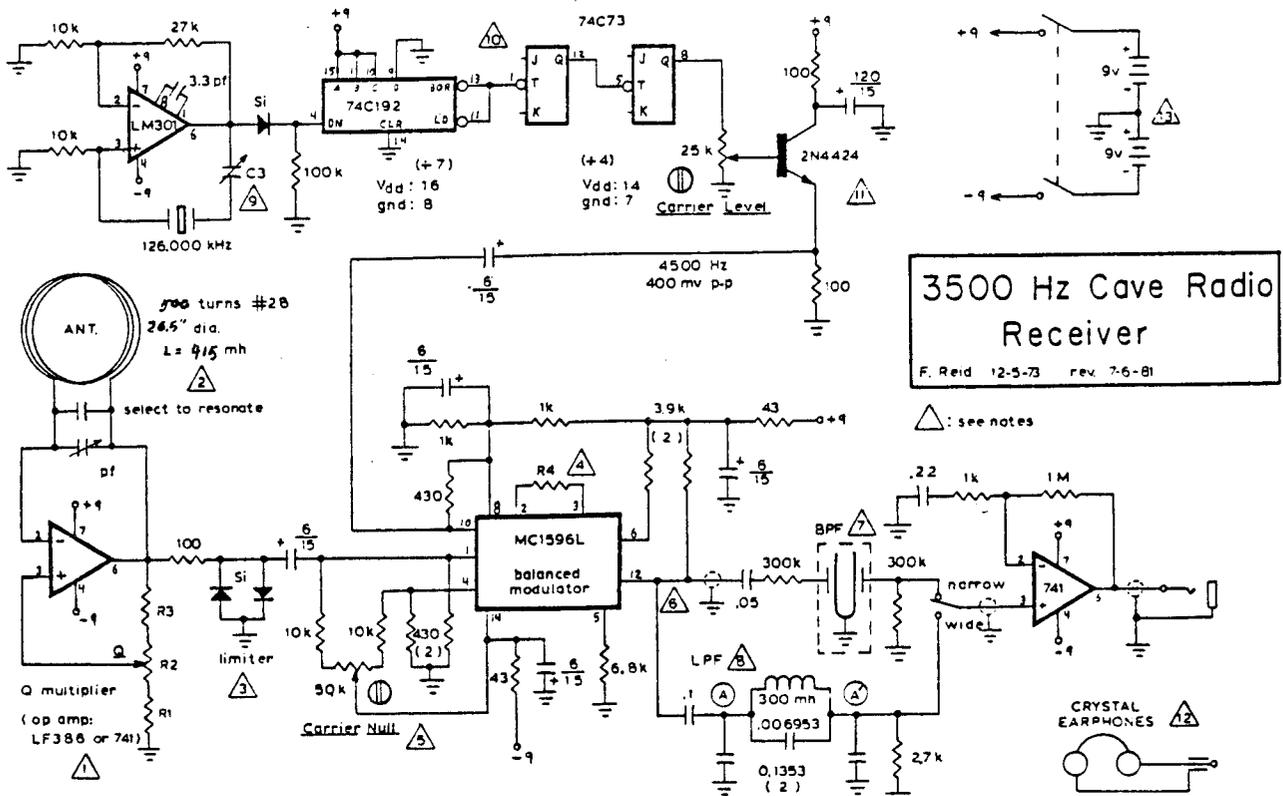
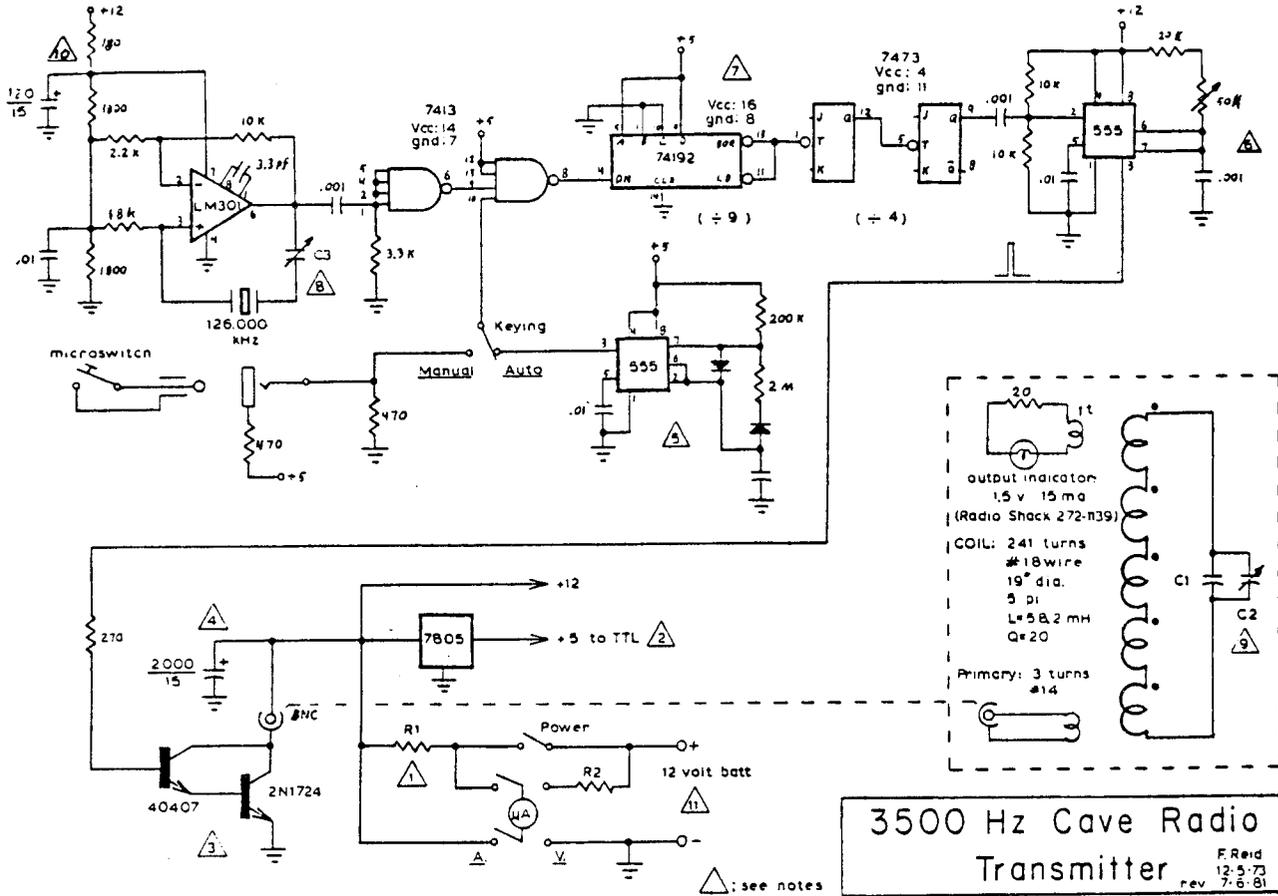
9. C1: 1500-volt mica, about .035 uf. Select carefully for resonance. C2: 200 pf or more, fine-tuning control. (Receiver-type variable capacitors cannot withstand high voltage.)

10. Decoupling network.

11. Use battery with low internal resistance; Ni-Cd or GeI-Cell.

### Receiver Notes (see diagram)

1. The Q-multiplier has been a very successful cave radio circuit. It can be a transceiver all by itself. Any 741-type op-amp will work; low-noise types are preferable. The op-amp's negative-feedback loop forms a negative resistance which cancels the resistance of the coil. As the Q (regeneration) control is advanced, sensitivity and selectivity increase until oscillation occurs (infinite Q). The value of (R1 + R2 + R3) is not critical and may range from 10k to 1M. Choose R1 and R3 such that R2 provides useful control throughout its range. A large tuning capacitor is needed because Q affects resonant frequency.



2. A wide variety of coils will work. No electrostatic shield is needed. A coil used for direction-finding must be mounted on a flat, rigid board or framework equipped with an inclinometer.

3. Limiter protects input of next stage. Diodes are 1N914 or equivalent.

4. The mixer IC would work better in a double-balanced configuration; see ref. 5, also Motorola data sheet and application notes.

MC1496L is a less-expensive chip which works as well as the military-temperature-range 1596. The "L" suffix designates DIP package; other packages have different pinouts. R4 sets conversion gain, and may range from 0 (max. gain) to 1k. R4 interacts with carrier null.

5. Use metal-film-type trimmer resistor; wire-wound types lack sufficient resolution.

6. When adjusting mixer output, observe for symmetrical waveform here. Both input signals must be nulled. Adjust carrier level for best results. If you use a transformer here, use a shielded toroid type. To set carrier null: Place jumpers across antenna coil and low-pass filter (points A - A'), switch to wide filter, adjust null control until local oscillator signal is inaudible in earphones.

7. Murata EFM-R 1000-Hz tuning-fork mechanical filter. Bandwidth is 3 Hz. Filter requires 300k termination (termination resistance affects resonant frequency and bandwidth). The filter is suspended on rubber bands to suppress microphonics. Similar filters are used in some Motorola paging receivers. The fork is about 1.5 cm long, with piezoelectric transducers on its tines. Filter frequency reportedly can be changed by grinding or adding solder to the fork tines.

8. Low-pass filter designed from cookbook tables:  $Z_0 = 2166$  ohms,  $f_c = 1067$  Hz. Attenuation > 45 dB above 3048 Hz. Notch at 3500 Hz. Capacitors are selected and paralleled for correct values. The wide filter is used for receiving Morse code, and when signals are strong and interference-free.

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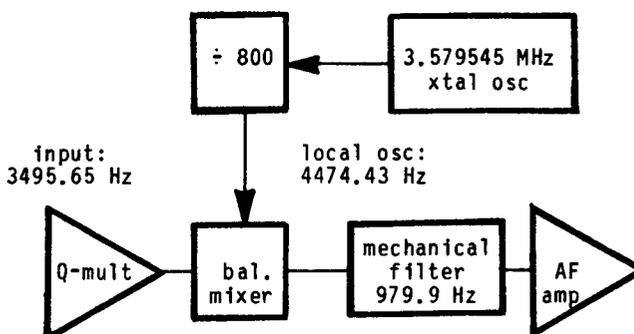
9. Same crystal oscillator circuit as in transmitter, using dual power supply. C3 value as needed to trim crystal frequency.

10. Crystal frequency is divided by 28. Tie unused CMOS inputs to +9 or ground, as required. The same oscillator-divider circuit could be used in a transceiver by switching the programmable divider to divide by either 9 or 7.

11. Emitter follower with decoupling network. Also note decoupling networks around MC1596.

12. 4000-ohm magnetic earphones work in this circuit without feedback problems. Crystal earphones are more sensitive but are easily destroyed by heat and humidity.

13. Battery is twelve AA cells, or a pair of 9-volt alkaline "transistor" batteries. The positive battery supplies more current; rotate batteries periodically.



Block diagram for proposed receiver based on above design, using Ray Cole's frequency (3.579545 MHz / 1024; see ref. 4) and readily-available parts. 979.9 Hz is Motorola's paging tone code "130." Mixer output is within filter bandwidth; see receiver note 7.

8. Allum, Ron, Cave to Surface Communications, Speleonics 4 (v1 #4) winter-spring 1985-86.



MAGNETIC MOMENTS #6: THE TRANSITION ZONE

by Ian Drummond

When any antenna transmits an electromagnetic (EM) field, it is surrounded by three zones; the far field zone, the near field zone and the transition zone between them.

The far field is the zone of conventional radio transmission, more than one wavelength from the antenna, where there is a radiated signal (a propagating EM wave). The EM wave consists of oscillating electric (E) and magnetic (H) fields which are at right angles to each other and the direction of travel. The two fields have a certain ratio of intensity ( $E/H = 120\pi$  ohms in a vacuum) and this intensity decays proportionally to the inverse of the distance from the antenna. Therefore the power of the field decays proportionally to the inverse square of the distance (the well-known inverse square law). Around a loop antenna the radiated field is maximum in the plane of the loop and is essentially zero along the axis of the loop.

The near field is the zone close to the antenna, less than  $1/2\pi$  wavelengths away. Normal cave radio operation takes place in the near field of a loop antenna. In this zone the intensities of the magnetic and electric fields are determined by the shape of the antenna and need not have a particular ratio. The magnetic field around a loop antenna decays with the inverse cube of the distance, and consequently the power of the field decays as the inverse sixth power of distance. Moreover the magnetic field is more intense along the axis of the loop than in the plane and so the greatest range of a cave radio is normally when the receiver is located on the axis of the transmitter loop.

The transition zone is the zone from  $1/2\pi$  to one wavelength from the antenna. In this zone the magnetic field along the axis of a loop antenna continues to decay as the inverse cube of the distance, but the field in the plane of the loop decays less rapidly and so becomes more intense than the magnetic field on the axis (Fig. 1).

The consequences of this information are interesting. If a cave radio system can be built of sufficient range to operate in the transition zone (receiver sensitivity and selectivity; and transmitter power) then **the greatest range will be with the receiver in the plane of the transmitting loop.** Moreover, any further increments in performance will yield much greater benefits in range than for a radio operating in the near field.

Is it practical to build cave radios which might operate into the transition zone? The ASS cave radio operates at 115 kHz, which corresponds to a wavelength of 2.6 km in air. However when the units are used "thru-the-earth" the conductiv-

ity of the medium reduces the wavelength of the EM waves (Fig. 2).

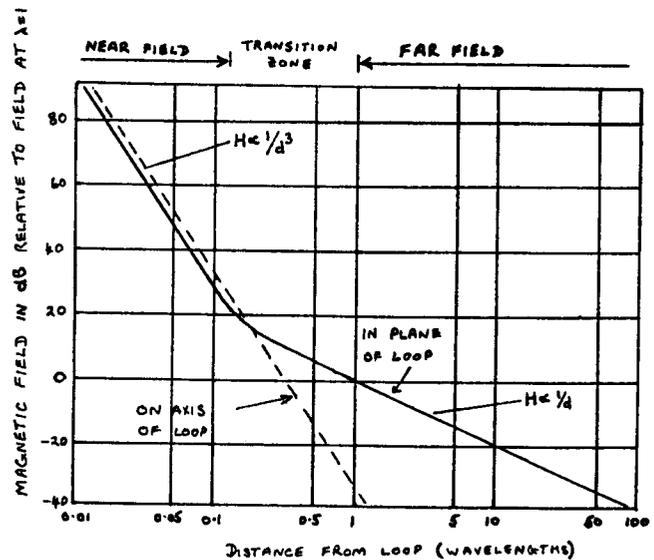


Figure 1. MAGNETIC FIELD AROUND A LOOP ANTENNA

$$\text{Wavelength (m)} = 2\sqrt{\pi/\mu\sigma}$$

in a conductive medium ( $\sigma \gg 2\pi f e_0 e_r$ )

where:  $f$  = frequency (Hz)  
 $\sigma$  = conductivity (mho/m)  
 $\mu$  =  $4\pi \times 10^{-7}$  H/m  
 $e_0$  =  $9 \times 10^{-12}$  F/m  
 $e_r$  = relative dielectric constant  
 (10 for limestone)

Figure 2. SIZE OF TRANSITION ZONE

Conductivity	f = 115 kHz	f = 3.5 kHz	Medium
0 mho/m	410 - 2600m	1400 - 86000m	air
0.001	47 - 300	270 - 1700	dry limestone
0.01	15 - 93	85 - 534	conductive limestone

Clearly the ASS radio with a range exceeding 400m through dry limestone is operating in the transition zone. Indeed I believe these effects are responsible for the practical success of the several radios operating near 100 kHz, whose performance exceeds that predicted on the basis of near-field models.

ABSTRACTS

RADAR PROBING OF VICTORIO PEAK, NEW MEXICO

L.T. Dolphin, W.B. Beatty, J. D. Tanzi

Geophysics, Vol. 43, no. 7 (Dec. 1978)

Ground-penetrating radar and resistivity measurements were made on 20-31 March 1977 in support of limited exploration and excavation of Victorio Peak, White Sands Missile Range, New Mexico, by Expeditions Unlimited. The survey by SRI International (formerly Stanford Research Institute) confirms the existence of large caverns beneath the mountain as well as tunnels, fissures, and other features of geophysical interest, pertinent to the legends that a treasure cache was discovered within the peak in 1937. The uniqueness of the radar work reported is a result of lower-than-average radio-frequency attenuation in the peak permitting sounding to depths as great as 400 ft.

[contributed by Ian Drummond]

APPLICATION OF A VLF ELECTROMAGNETOMETER TO HYDROGEOLOGY

D.O. Whitemore

Remote Sensing: Applications to Hydrogeology - A Short Course. National Water Well Association, 1987

A very low frequency (VLF) electromagnetometer, the Ronka EM 16, (available from Geonics Limited, Toronto, Ontario) has been qualitatively tested over hydrogeologic features in the local carbonate terrane and has been found useful in certain conditions for detecting caves and lithologic changes. The Ronka EM 16 electromagnetic system utilizes the transmissions of VLF radio stations operated by the U.S. Navy for submarine communications.

Traverses were made perpendicular to the general strike of the feature while recording inclination (in-phase) and quadrature (out-of-phase) values given by the EM 16. Readings were taken at 50 foot, 25 foot, or similar intervals depending on the variation with distance of the readings in the immediate area. The data were plotted as in-phase and quadrature values versus traverse distance. Where differences in ground electrical conductivity were encountered the resulting curves deviate from horizontal lines. It was found that for the instrument to give readings indicative of the hydrogeologic features the immediate area surveyed must be free of such conductive interferences as power lines, buried pipes, and tightly drawn, straight wire fences. Anomalies are best when the hydrogeologic feature is long and linear.

[contributed by Angelo George]

RESOURCES

MOLICEL rechargeable lithium batteries

Moli Energy Limited  
3958 Myrtle Street  
Burnaby,  
British Columbia,  
Canada V5C 4G2

The AA-size Molicel now available is rated 600 ma hr, 1.1 watt-hr (a typical AA nickel-cadmium cell is 500 ma hr at 1.25v.) The voltage decreases steadily with discharge, from 2.4 to 1.3 volts. The sloping discharge curve provides a convenient state-of-charge indication. The varying voltage may be unsuitable for some applications; it's no problem in modern handheld radios which accept any voltage from 6 to 15v.

See QST magazine, June 1987, for greater detail.

Molicel are reported to have produced some "BC" or Beer-Can sized cells for experimental use in vehicles. These could be just the item for use in high-powered cave lights or even underwater propulsion units.

contributed by Ray Cole and Ian Drummond

The **Heyden-Spike EM-200 EAR-MIKE<sup>tm</sup>** is a single-unit transducer which combines the functions of a microphone and speaker, worn in the ear.

The EAR-MIKE converts the voice vibrations present in the ear canal into signals for radio transmission, while also being able to act as a conventional receiver earphone. The EAR-MIKE is usable in environments where conventional voice communications is difficult or impractical, such as high ambient noise areas, while using hearing

protectors, in discreet communication situations, or even while wearing partial or full face masks.

The EAR-MIKE does not rely on bone conduction. Using the otolaryngeal system, transmission is achieved using vibrations in the ear canal created by the voice box and eardrum. Reception is accomplished as with a conventional earphone.

Connected to a compact interface unit with amplifier and sealed Push To Talk switch, the EAR-MIKE can be used with any portable radio equipped with external speaker/microphone capability. The interface unit uses one Size-AA 1.5-volt battery.

In high ambient noise environments, hearing protectors shield both the microphone and speaker from external noise. It is also ideal for extreme cold or wet conditions; all equipment is worn inside clothing. It can be adjusted for optimum voice clarity.

Some work has been done using special EAR-MIKES to depths of 100 feet underwater. Current technology requires the diver to use a full-face mask with a microphone and attendant wires mounted in it. All cave divers I have talked to would not consider a full-face mask in a cave. So the ear-mike might be a vital link in providing diver-to-diver and diver-to-base communication in a cave setting.

-- Ian Drummond

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**We thought that was the end of Uncle Algie – but no! Every few weeks he would ring up from Devil's Island to ask for money. He was a bad lot.**

(Original source unknown. Obtained from Intimate Relations by T.E.B Clarke, 1971, Michael Joseph, London, which is a book using Victorian illustrations taken out of context to give a humorous tale.)

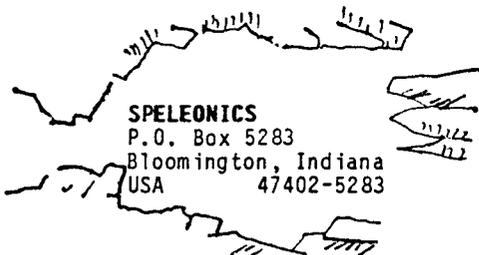
### HUNTING FOR DINOSAUR WITH RADAR

A piece of electronic equipment at Los Alamos National Laboratory is getting its trial runs in some mighty unusual territory.

The device, a subsurface radar, is being trundled across an ancient mesa looking for signals from a fossilized dinosaur. A radar pulse directed into the ground will be turned on and off, and then equipment will listen for the returning echo. Penetration depth is expected to range from a few inches to 100 yards.

The radar-armed scientists are searching for what may be the largest dinosaur yet discovered. The creature's remains lie buried beneath a 144 million year old formation in the Jemez Mountains, NM. Estimates made from vertebrae already unearthed suggest that the creature was about one and a half times larger than the blue whale and may have measured over 100 feet long. In view of its tremendous size, the dinosaur was named *Seismosaurus* or "Earth Shaker."

--Microwave Journal May 1987 p. 204



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