speleonics 5

summer 1986

VOLUME II NUMBER 1

CONTENTS

From Canada...

SSB 2-WAY VOICE CAVE RADIO

Schematics !

SPELEONICS 5

Volume II, No. 1, Summer, 1986

SPELEONICS is the quarterly newsletter of the Communication and Electronics 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.

Complimentary copies of SPELEONICS are mailed to NSS offices and sections, the U.S. Bureau of Mines, U.S. Geological Survey, and the Longwave Club of America.

Chairman (and editor of this issue):
Ian Drummond
5619 Dalwood Way NW
Calgary, Alberta
Canada T3A 1S6

Treasurer
Joe Giddens, N5IOZ
PO Box 170274
Arlington, TX 76003

Secretary (and editor of the next issue):
Frank Reid, W9MKV
PO Box 5283
Bloomington, IN 47402

Publisher:
Diana George, N9DEJ
1869 Trevilian Way
Louisville, KY 40205

EDITORIAL

The editorial of Speleonics #1 listed 7 projects that the Communication and Electronics Section thought were important. We have done well on 5 projects.

-We have a quarterly publication, it is on-time and well-received by our members.
-We have our own session at the NSS Convention. Both at Frankfort, Kentucky and at Tularosa, New Mexico we had lively sessions attended by about 40 people each time.
-We have a bibliography of cave-radio articles which is growing.
-We are developing a netowrk of contacts internationally to report on developments.
-We have updated the NSS "Caving Information Series" on Communication.

Where then do we need to look, to review last year's projects to see if they are still important to us? The two projects of the original seven are "Designing high-performance, easily reproduced cave-radios" and "Working with the National Cave Rescue Commission to...(improve the utility of communication equipment)".

I feel both of these items are still key objectives. I feel cave radios can make caving safer, and rescues more efficient but to do this, high-performance, cheap radios are needed.

This issue carries a description of the Alberta Speleological Society radio which developed from early work by Pete Hart of the Westminster Speleological Society in England. The unit has high performance; two-way voice to over 220 metres depth on 10 watts PEP, with small portable antennas; but cheap and easily built it is not.

Surely one way to approach high-performance <u>and</u> easy construction is to utilize commercially available radio systems. One method for licensed amateurs would be to experiment on the 160 metre band which Nevin Davis predicted could be useful for voice[1]; A conclusion supported by experiments by Larry Jack[2]. A second approach would be to build a converter to change the commercial radio signals to lower frequencies for cave-radio use. I am currently working on such a system to use CB radios at 115.2 kHz (to be compatible with existing ASS cave-radios).

Affordable voice-communication is the next challenge for the Cave Communication and Electronics Section.

Let's rise to the bait!

--Ian Drummond

[1] Optimum Frequencies for Underground Radio Communication. N. Davis, Nat.Speleo.Soc.Bull. Vol 32, #1, 11-26, (1970)

[2] Underground Radio is a Dirty Business. L. Jack, <u>73</u> Magazine, 57-59, Sept. 1975.

speleonics 5
v. II no. 1 Summer 1986

Dear Ian,

Frank Reid, in his editorial in Speleonics (4) 1 (1985-86) mentions my early statistical study in which I predicted the number of entranceless caves in Pennsylvania and West Virginia, and implies that my finding that entranceless caves "are numerous but very short" is in contradiction to the fact that Indiana's two longest caves were once both entranceless.

First, I extended my study to many other areas, including Indiana, in another paper (J. Geol, 74 (5) Part 2 798-830 (1966)). Based upon the data then available, the finding for Indiana was that there were expected to be between 85 and 281 (95% Confidence Interval) entranceless caves in Indiana over 1000 feet long, with an expected mean length of 2159 feet. At the time, 41 caves over 1000 feet long with natural entrances were known.

The lengths of caves were also studied, and were found to be hyperbolically distributed. With the parameters for this found then, one can predict that there are expected to be from 0.6 to 1.5 (95% C.I.) caves over 100,000 feet long, with or without entrances. That two are known is therefore not surprising.

More complete data available today, analyzed as was done in 1966, would undoubtedly increase these estimates. However, the possible data base for a reanalysis is being degraded as more caves are discovered or extended by digging, unless such alterations are recorded and always accompany published data.

Sincerely,

Rane L. Curl
Department of Chemical Engineering
University of Michigan
Ann Arbor, MI 48109-2383

REPLY

Dear Ian,

Academic paranoia is an occupational hazard of theoreticians. By citing spontaneous formation of entrances in recent history, I intended to support Curl's finding that the probability of having an entrance increases with a cave's length. (Paradoxically, formation of entrances tends to fragment long caves into short ones.)

Actually, the entrancelessness of the caves in question is a matter of semantics; both were subsequently found to "connect" to "smaller" known caves.

Someday I hope the good professor will allow me to photograph him operating a cave radio, to illustrate the esoteric technique of using the curl to find the divergence!

73,

Frank Reid

Dear Frank,

It would probably be worthwhile to print the provisions of (FCC Rules and Regulations) Part 15 that apply to cave radio and 1750 M.
The provisions of 15.111 for operation between 10 and 490 kHz:

Field Strength (Microvolts per meter measured at 300 meters) not to exceed 2400 / f(kHz).

13 microvolts at 180 kHz, 27 microvolts at 90 kHz, etc. Small signals, but it seems unlikely to me that these levels will be exceeded by portable equipment operated underground.

The 160-190 kHz area might be interesting for "guide wire" work. The railroads used to have transmitters in this region that coupled to the adjacent telegraph lines providing communications between stations and trains in motion. I think this has been completely replaced by radio (UHF/VHF) now. My first experience of LF reception occurred when I was a child riding in a car equipped with an AM receiver. The car stopped at a rail crossing and very clearly over the radio came the sound of a steam locomotive! None of the adults could even attempt an explanation of this odd event and it was not until many years later, talking Longwave with a retired railroad man on 160 M that the mystery was solved.

I don't know whether LF would have any advantage over 27 MHz with a guide wire underground but it seems like the system could be quite sensitive, particularly if the wire were tuned. FM might be used to reduce noise problems. FM systems exist that utilize wire loops around the coverage area, either for intercom or one-way use as in museums and exhibits.

Really long-haul guidewires could have little booster amps - possibly bridging some physical gaps by radio.

A letter from Jim Borglum (which I cannot find now) indicated that some would-be Lowfers working below 10 kHz in Great Britain ran into some fairly serious trouble with the law. Apparently licenses are required (in GB) and in general will not be issued for work in the AF region. I believe the problem may be that in Europe the power line carriers which we find so extensively in the 160-190 kHz region are down in the 2.5 to 15 kHz area (LF BC band occupying the higher frequencies). Considering there must be thousands of PLCs packed into a very narrow region, there may be real interference potential, particularly if experimenters are working with earth current modes and using power mains grounds as part of the loop.

Michael Mideke
PO Box 123
San Simeon, CA 93452

[ed note: Mike no longer publishes 1750 Meters: Western Update as noted in Speleonics 4; the new editor is Jim Ericson, 226 Charles St., Sunnyvale, CA 94086. The only acceptable form of subscription will be business-size SASEs.]

Mike enclosed a copy of ELF/VLF Communications Through the Earth Project Report for Calendar Year 1984 from Lawrence Livermore National Laboratory, prepared for an Air Force study of deep-based ballistic missiles. This 80-page report contains theory of buried electric and magnetic dipoles, plus summaries of experiments performed in a tunnel at Yosemite National Park, and at Lake Lynn Laboratory, USBM mining research station south of Uniontown, PA, near the WV border. A copy of the document will be donated to the NSS Library.

Editor:

I'm not up on electronics but still wade through the kHz's, etc.

I'm looking for a large cave in the southwest with a treasure in it. I think the cave could be over a mile long. The cave is in a fractured layer of caleche (chalk) that forms the bottom of an old volcanic caldron and is maybe over 400 feet deep, but should be dry.

The "Michie Phone System" [SPELEONICS 4] seems to be about the best I've seen so far. What problems do you foresee in a mile run using this system? What would a mile of 7 / .0076" wire weigh? Is there someone I could contact to build this system for me?

R. G. (Jerry) Babcock
601 Briarwood
Marshall, Missouri 65340

The Michie Phone, which uses a single wire and ground, with high-impedance amplifiers (about 60k ohms), should work well over a 1-mile range. I do not speak from experience; there could be problems in an extremely dry environment. Seven strands of .0076" diameter copper wire weighs about 3 kilograms, plus the weight of insulation, perhaps 30%, for a total of 3.8 kg, or 8.5 pounds. Anyone interested in Jerry's project? --F.R.

ANNOUNCEMENTS

WIRE SIZE PROBLEMS

Numbered wire sizes cause considerable international confusion. Several different systems are used among non-metric nations. The only system commonly used in the U.S. is "AWG" (American Wire Gauge), which is the same as B&S (Browne & Sharpe). Particularly confusing is the "circular mil" unit used to measure the cross-section of wire. A circular mil is the area of a circle with a diameter 0.001 inch (7.85×10^{-7} in ^{2}). The Radio Amateur's Handbook and the Handbook of Chemistry and Physics contain wire tables with metric dimensions. Authors should specify actual diameters of wires.

NSS CAVING INFORMATION SERIES #18 REVISED

Use of the Cave Radio in Mapping, by cave radio pioneer Bill Mixon, has been updated and expanded by Frank Reid and sent to NSS Caving Information Series coordinator Chris Amundson. Publication date is unknown at this time.

The revised version includes a section on weak-signal techniques, and a programmable-calculator solution to the depth equation.

Caving Information Series #19, How to Build a Cave Radio, needs modernization. Any volunteers?

NOTICE TO HAMS AND RESCUERS

Gene Harrison has Larsen VHF and UHF mobile antennas available at discount prices. Contact him at Box 1584, Leesburg, VA 22075.

Communications equipment interchangability is important in emergency service; Eastern cave-rescue groups have standardized on Larsen-type mobile antennas, whose screw-on mounts are the same as ordinary SO-239 "UHF" coaxial connectors. (See also Gene's article about standardized 12-volt dc power connectors in SPELEONICS 2.)

SPECIAL ISSUE ON LIGHTING

The next SPELEONICS will be devoted to electric lights for caving. Send **your** article to Joe Giddens or Frank Reid. Hoping to include a bibliography, we're also looking for lists and copies of published articles about cave lights, batteries, chargers, bulbs, modifications for existing systems, etc.

CIRCUIT DESCRIPTION, ALBERTA SPELEOLOGICAL SOCIETY CAVE RADIO

by Ian Drummond and Julian Coward, January, 1985

4.1 Power Supply. The power supply uses a uA723 voltage regulator to reduce the 12v battery voltage to a regulated 9v for most of the low-power circuits. The LED (D102) extinguishes if the battery voltage drops below about 11v. D103 is a reverse polarity protector, and will cause the fuse to blow if the battery is connected the wrong way. The exact output voltage is controlled by the ratio of R102/R103 and either can be trimmed if necessary. Current limiting of the 9v supply is controlled by R101 at about 65 ma and will protect the circuit in case of a short-circuit.

4.2 Oscillator and Divider Circuits. The carrier frequency, 114.3 kHz, is obtained by dividing the output of a crystal oscillator. Further division is used to obtain an audio tone of 1143 Hz. In this circuit a separate pulser is used to switch the audio tone on and off, but for future circuits, further division to obtain the pulse signal is recommended.

The oscillator uses a 4.0 MHz crystal in a standard circuit using a CMOS NOR gate connected as an inverter. The exact frequency can be adjusted about 100 Hz using C203. The frequency of all units should be adjusted to the same value by beating the 4 MHz signal from the units while listening on a wideband or communications receiver.

The 4569 (Q202) is a programmable two-stage frequency divider, and is connected here to give a 35-to-1 division. The output from pin 1 consists of short positive-going pulses, and the pulse shaper D201, C208 and R204 squares-up the waveform, increasing the output from the tuned circuit L201/C210. L201 is an approx. 14 mH inductor made by winding 190 turns on a Siemens B65541-L0400-A048 pot core.

The pulses from the 114.3 kHz circuit are also fed to a 100:1 frequency divider Q203. Q203 is a 4518, a two-stage divide-by-ten, with each stage having reset and inhibit lines. All pins not shown connected in Fig. 4.4 must be left open, as they are outputs.

L202 is a surplus 720 mH inductor. C205 and C206 in series tune L202 to resonance at 1143 Hz and either capacitor can be padded as necessary. Tuning is not too critical in this circuit.

The pulser uses two gates of a 4001 (Q201) connected to oscillate at about 1 Hz. D202, R207 and R208 are connected to control the duty cycle of the pulser, with the output at pin 11 going low for about 30% of the cycle. The pulse can be suppressed if pin 13 is held high, which occurs if S202 is open. Continuous tone would then be transmitted, or if S4 is operated, morse code can be sent.

4.3 Audio Amplifier and Modulator. The tone and speech signals are amplified and fed to the balanced modulator, which produces a double-sideband signal with the carrier suppressed.

A carbon microphone is used, powered through the trimmer R301 which controls the level of speech clipping (elimination of transient highs which would cause overmodulation if not removed). The two diodes D301 and D302, and R303, R302 and R304 limit the audio output of the mike to about 1200 mv peak-to-peak.

The op-amp Q301 is a uA741 connected as a summing amplifier to amplify either tone or speech signals before filtering out the lower sideband and feeding the output power amplifier. R308 controls the gain and consequently the drive level applied to the output stage. C308 is used to limit the high-frequency response of Q301.

To set up the audio system, a 1140 Hz signal should be injected at C301 and the level increased until the signal between C302 and R305 just shows clipping on an oscilloscope. The RMS voltage is then measured at this point (S volts). The tone input voltage is also measured at R309 (T volts). R305 value is then calculated as 10xS/T k-ohms. This insures speech and tone will be equally amplified by Q301. R301 is adjusted so that moderate clipping occurs (as observed by scope on the input side of R305) when speaking normally into the mike.

The balanced modulator is a 1496 chip used in a standard circuit. Good decoupling is required at pin 8 and components should be placed to minimize feedthrough from the carrier input (C308) to the output on C310, R312 or R311. The balance control (R320) is adjusted for minimum output when the tone is off and the mike disconnected. Details of setting-up single sideband systems can be found in many books, such as The Radio Amateur's Handbook.

4.4 The Sideband Filter. The sideband filter is tuned to a frequency of 115.4 kHz to select the upper sideband. The 3db bandwidth is 1.3 kHz and output is 80-100% of the input voltage at 115.4 kHz. The inductors were all wound with 28 AWG wire on Siemens pot-cores, B65661-L0400-A022. The windings were tightly taped and the bobbins held in place in the cores with wax, also, no slugs were used, in the interest of mechanical stability and consequently stable inductance. The tuning capacitors were silver-mica for stability and high Q.

4.5 Power Amplifier. The final output amplifier is a standard linear class-AB design, giving up to 10 w continuous output. L501 is wound on Siemens B65661-L0400-A022 pot core and C503 is chosen to resonate the 35-turn primary at 115.4 kHz (loaded Q is approx. 20). L502 was wound on a Siemens B65661-K0000-R030 pot core. The number of secondary turns requires a knowledge of the impedance of the antenna at 115.4 kHz and is equal to $\sqrt{II.I}$ Where I is the impedance in ohms. Practically, the secondary is wound with several taps around the calculated value, and the tap giving maximum power output is used.

The driver transistor Q501 requires a push-on heat sink. The final stage transistors were mounted on Wakefield 601 heat sinks.

As the gain of the audio section (R308) is increased, the antenna power will increase until it reaches a plateau. The gain should be set near the top of the linear portion of the curve.

4.6 RF Amplifier. The receiver preamplifier is a key component and has been modified several times by us. Key features are a low-input-impedance first stage to match the antenna impedance, and narrow-band coupling transformers between stages to reduce noise and interference. Two circuits are shown here. Fig. 4.9 shows the narrow-band transformer in the second stage collector. C516A is selected to tune L503A to 115.4 kHz (Siemens B65661-L0400-A022 pot core). A gain control was added on the front panel although it is probably not necessary. Gain at 115.4 kHz is 35 db on "low" and 60 db on "high." In the field, high gain can only be used under very quiet electrical conditions and is only useful at extreme range (greater than 200 m).

Because the first stages are the most critical for noise reduction, a second modification was made, Fig. 4.9A. A FET first stage with narrow-band transformer was added and the gain control removed. Overall gain is 80 db with acceptably low noise. This circuit has only been used in the field with the large antenna (see later) and the greater range of this unit is due in part to the RF preamp, and in part to the antenna.

4.7 Demodulator and Audio Amp. The demodulator uses a LM373 chip which mixes a local carrier with the single-sideband signal and extracts the audio signal. The LM373 has two stages, the first is an amplifier which can provide from 40 db gain to 20 db attenuation. The gain is controlled either manually (which we do not use here) or by the level of the audio signal from the second stage. The use of the automatic gain control is convenient for speech and does not cause problems for null location at depths of up to 100 m. The circuit is a standard one except for the addition of a filter network (R406A, R407A, C422, C422A and C423A) on the audio output to remove carrier frequencies. The audio amplifier Q405 has sufficient gain at 114 kHz to cause feedback and oscillation if the carrier leakage is not removed.

The LM373 chip is reported to be no longer available, but the ECG 800 is supposed to be a direct replacement.

The audio amp, Fig. 4.12, uses a standard integrated circuit to power the 8-ohm headphones.

4.8 Audio Filter. The filter enhances reception of tone in electrically noisy areas. It consists of a standard design (see Amateur Radio Handbook) using a quad op-amp connected as a four-stage twin-T circuit. Each stage has a Q of 5 and a gain of 1.5 with a centre frequency of 1143 Hz. The capacitors should be polystyrene and the resistors all 5%.

4.9 Alarm If a radio is left on "receive" with the alarm on, a tone signal from another radio will give an audible alarm. This feature is useful for underground camps and allows contact at other than prearranged times. The circuit is based on a uA456 tone decoder. C493, R495 and R496 determine the frequency which is detected (1143 Hz) and the capacitors on pins 1 and 2 control the number of cycles before alarm. They are set fairly large to give noise immunity but still trigger on a pulsed tone signal.

5.1 The Antennas. The antenna is used for both transmission and reception. The original antennas worked, were not too large to use in overgrown surface areas, but had little else to recommend them, being expensive, time-consuming to make, and subject to very high electrical voltages. They consisted of a single-turn primary coil and a 70-turn tuned secondary. The coil is wound as a 0.71 m square loop, held fairly rigid by a wooden frame but can be folded up for transportation.

A second type of antenna was made which is cheaper, easier to make, and while larger and somewhat more awkward to handle, has far superior performance. At a given distance the magnetic field in transmission is 20x as large and in reception it absorbs 3x the power from the field. (The design of antennas is the subject of a series of articles in SPELEONICS.)

The original antenna consisted of plexiglass and ABS plastic spider and four wooden spreaders, well-varnished as waterproofing. The 70 turns of 28 AWG magnet wire were wound on the assembled frame in the form of a flat ribbon (important!). The completed ribbon was liberally coated with contact cement to keep its shape and when thoroughly dry, wrapped with butyl rubber self-sealing tape using a 50% overlap. The termination and capacitor box was then constructed by epoxy-gluing together PC board material to form a box 1x1x3 inches. The box was taped to the secondary coil and the single turn primary of 18 AWG PVC-insulated wire added and connected to the BNC connector in the box. The ends of the secondary coil are brought into the box and the coil finished with a second wrap of butyl tape followed by a final wrap of zinc oxide adhesive bandage.

To tune the antenna a 115.4 kHz signal is fed to the primary and the necessary capacitors added across the secondary windings. The capacitors must be 6-kv types with low temperature coefficients. We used S2L types of 4.7 to 15 pf connected in parallel to give a total of about 80 pf.

The Q of the antenna is about 80, so the tuning is quite critical and final tuning must be done with the capacitors installed in the box and the indicating neon lamp connected. The neon is only connected to one lead, as stray capacitance is enough to strike it when transmitting. After final tuning, the box is filled with wax.

The larger antenna has similar framework of spider and four spreaders but is 1.6 m square. The coil consists of 2 turns of two-conductor zip-cord 16 AWG wire connected to give a four-turn winding, tapped one turn from the bottom. The main tuning capacitor is a 500-v, 0.05 uf unit selected to give a high Q. A DIP switch can be used to select trimming capacitors, allowing some tuning to be done in the field if necessary. An indicator neon is connected (at both terminals) via a 220 k resistor across the secondary coil.

References:

Coward, J, Drummond, I. Construction and testing of an underground radio. A report to the Alberta Gov't Workers' Health, Safety and Compensation Dept. 1983.

Drummond, Ian, Cave Radio Update. NSS News. vol 42, #12, p366-368, (1984)

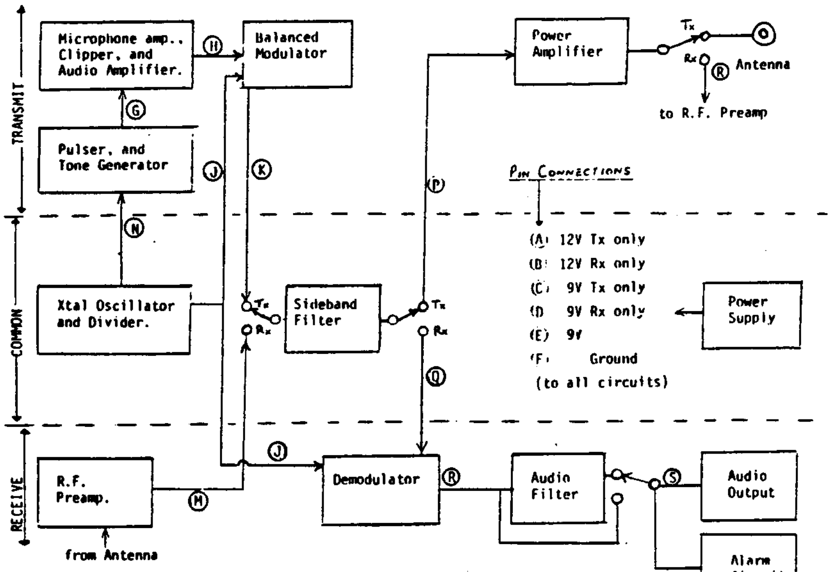


FIGURE 4.1 BLOCK DIAGRAM

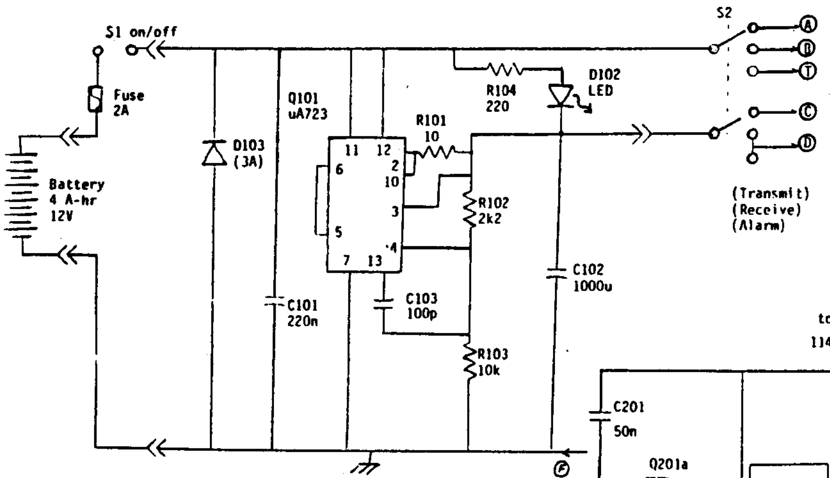


FIGURE 4.2. Power Supply

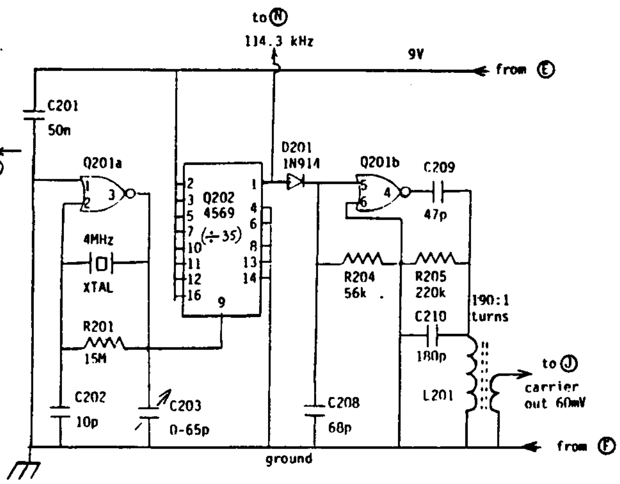


FIGURE 4.3. XTAL OSCILLATOR and DIVIDER

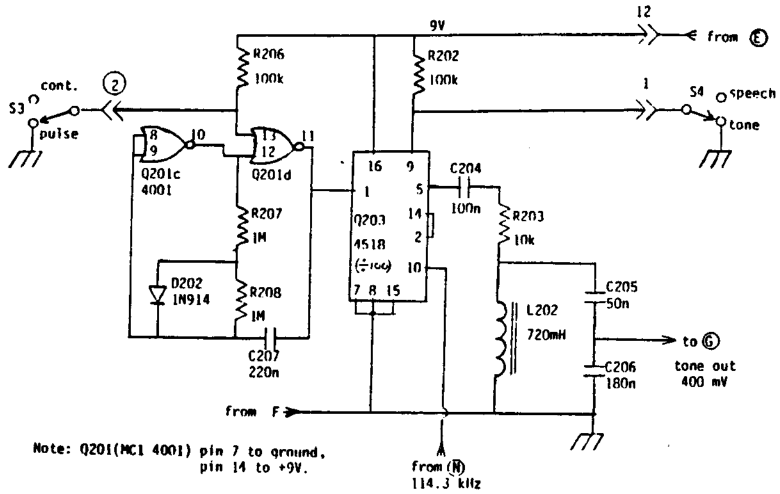


FIGURE 4.4. PULSER and TONE GENERATOR

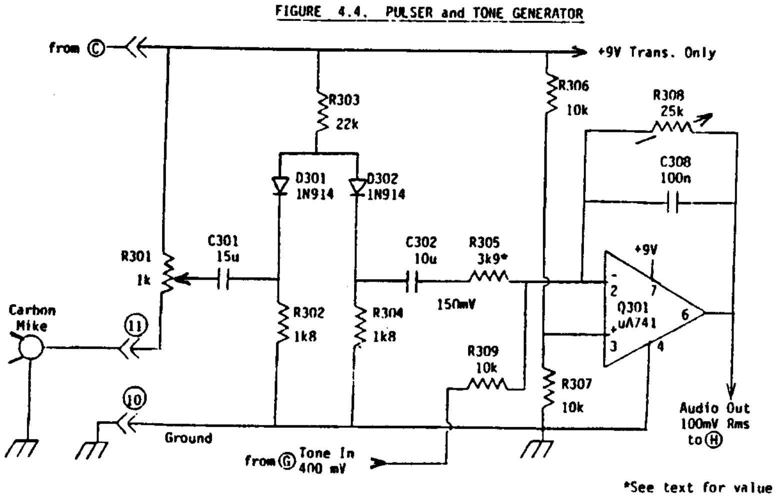


FIGURE 4.5. Microphone, Clipper and Audio Amplifier

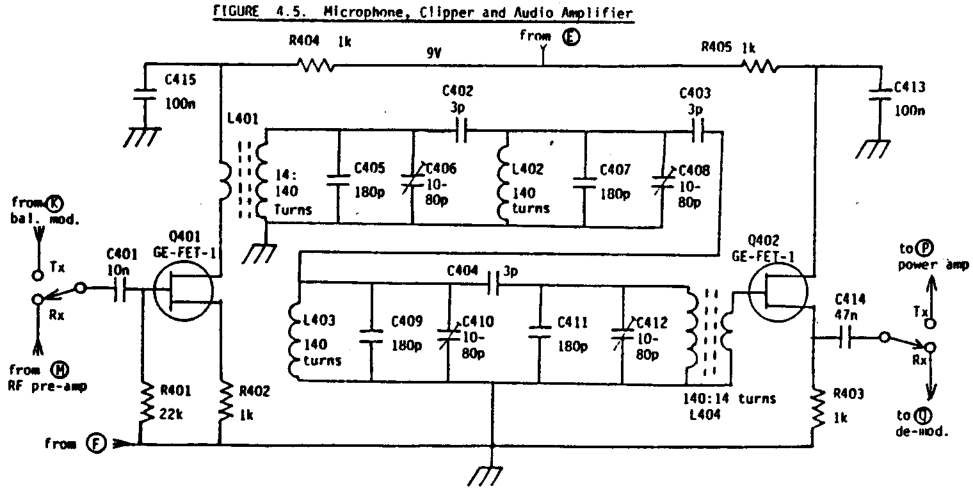


FIGURE 4.7 SINGLE SIDEBAND FILTER

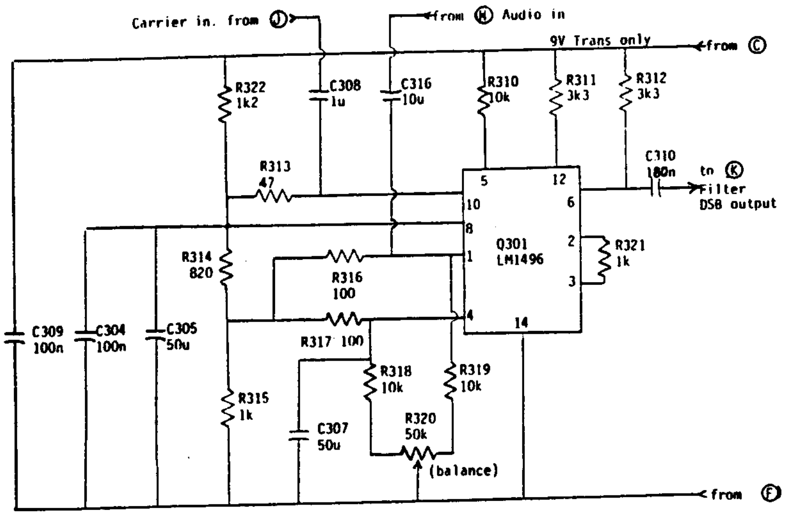
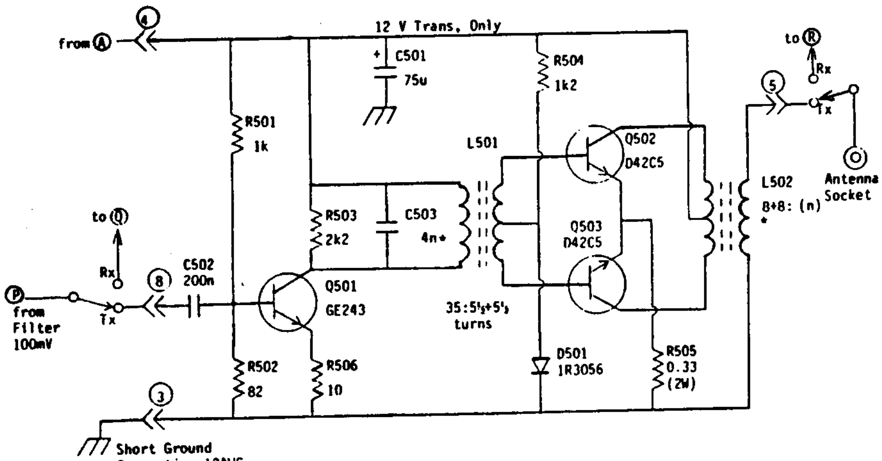


FIGURE 4.6. BALANCED MODULATOR



*See text for Values

FIGURE 4.8. POWER AMPLIFIER

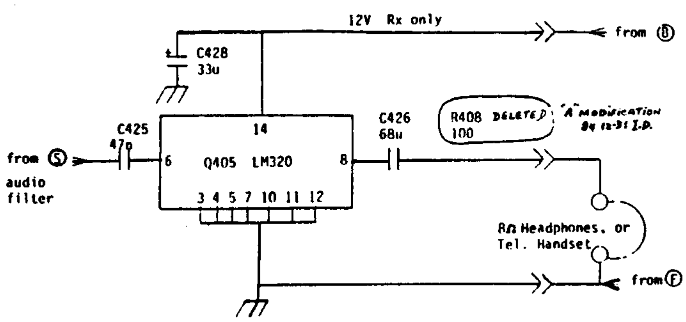


FIGURE 4.12. AUDIO OUTPUT

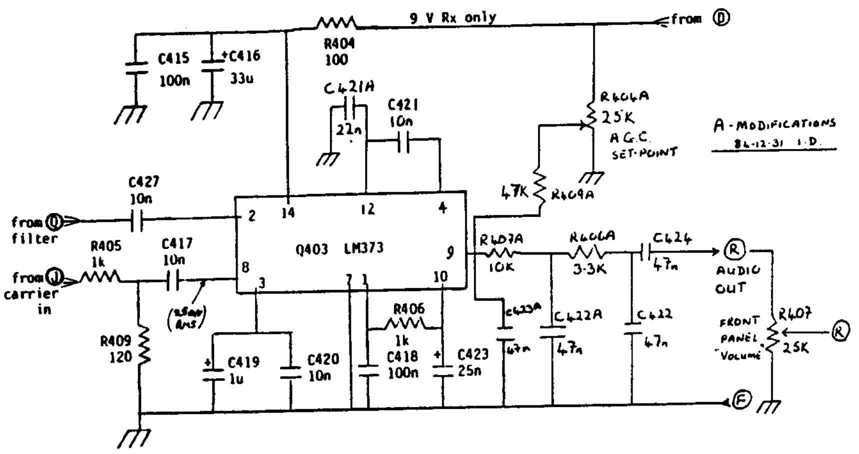
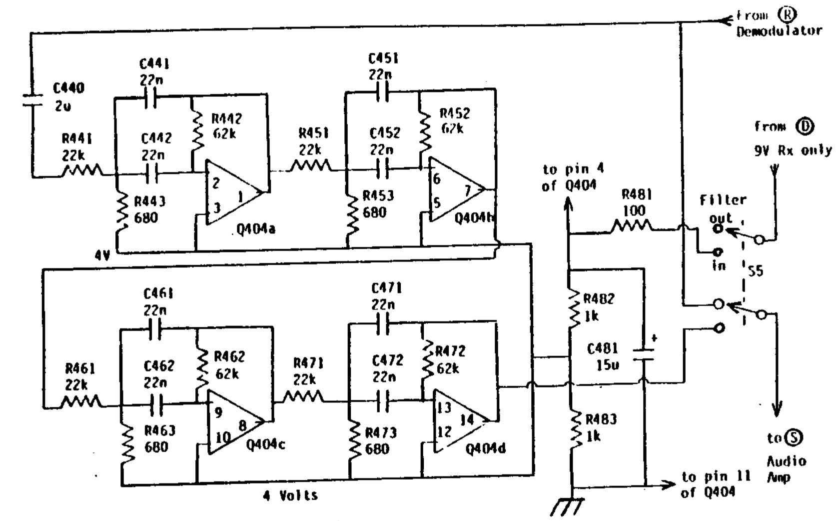


FIGURE 4.10. DEMODULATOR



Notes: Q404 is a 474 quad op-amp (dip)

FIGURE 4.11 AUDIO FILTER

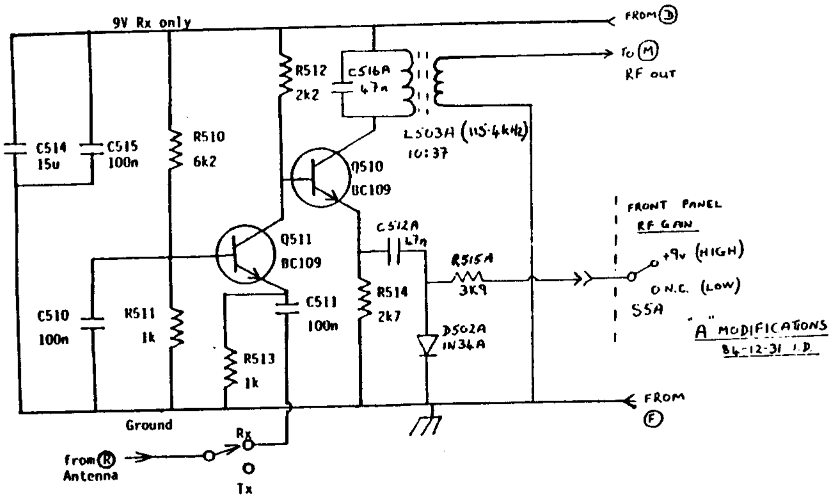


FIGURE 4.9 RADIO FREQUENCY AMPLIFIER

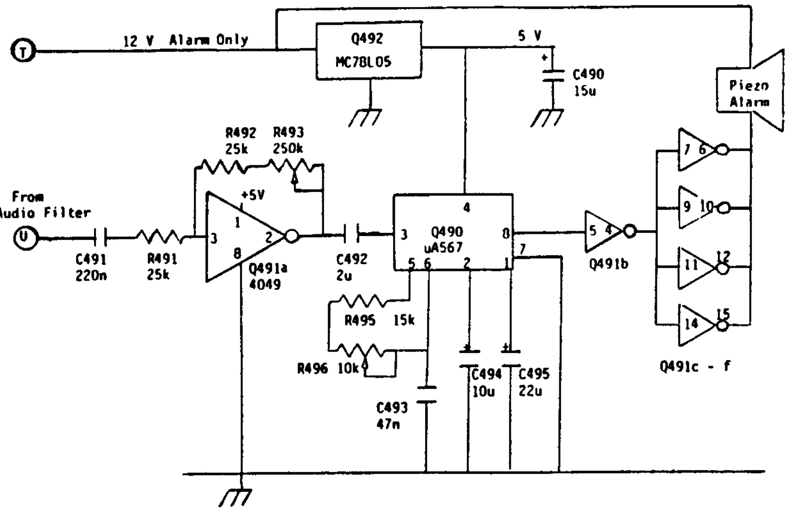


FIGURE 4.13. ALARM

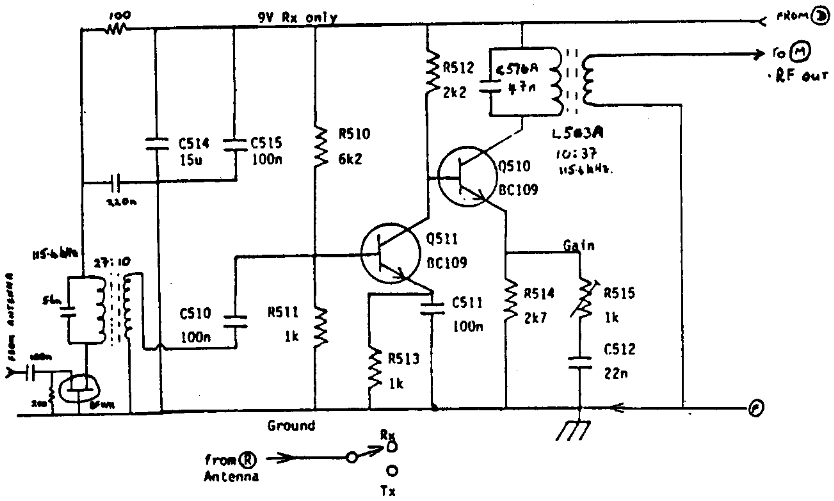
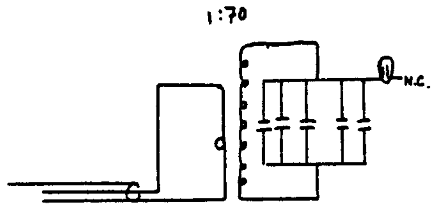
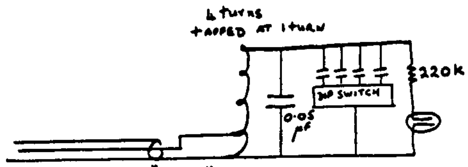


FIGURE 4.9A RADIO FREQUENCY AMPLIFIER



"OLD" ANTENNA



"NEW" ANTENNA

L.E.D. SURVEY TARGET FROM MODIFIED FLASHLIGHT BULB

Richard Market, NSS 17550

This target is much easier to see in the dark cave than a white light, and you cannot get it mixed up with other cavers moving about. It also gives a point source, for better accuracy.

I removed the bulb from a low-cost AA-size flashlight and broke the glass out. Then I soldered a resistor and light-emitting diode inside the brass base and installed it back into the flashlight. With two Ni-Cd cells you can obtain over 24 hour burn time.

Just about any general purpose LED could be used. Spec on the LED I used is:

Fwd volt (max) - 3v @ 20 ma (typ) 2.3v @ 20 ma.
Luminous intensity - 1.2 mcd @ 20 ma.
Lens is red diffused epoxy.

I used about 15 ma on the above diode. I'm also working on lighting the Suunto compass with an LED. I have a sample made and the results look good so far.

1986 NSS CONVENTION ELECTRONICS SESSION

About 40 people attended our annual technical session and Section business meeting at the NSS Convention in Tularosa, New Mexico, June 23. No formal papers were given, there having been no abstracts received, but informal presentations were very interesting!

Joe Hruska displayed an ingenious cave-radio antenna coil wound on a 20-inch plastic bicycle wheel and covered with tape and plastic tool-handle-dip compound. Joe's cave radio features an integrated full-bridge motor-driver chip (Sprague UDN-2952) in its output circuit. Contact Joe about volume purchase of wheels and chips.

Peter Shifflett demonstrated a sophisticated submersible recording fluorometer which is microprocessor-controlled and extremely sensitive. It has commercial possibilities!

Alan Hill, major cave-radio pioneer and theoretician, brought some historic cave radio equipment, and spoke about topics that he has previously suggested but with which cavers have yet to experiment-- underground E-field transmitting antennas (which should dramatically increase cave-radio range), acoustic holography for cave detection, and investigation of the possible use of acoustic holography by bats.

Well-known electronics author **Don Lancaster** spoke about a new microcomputer chip (M50734) which seems well-suited to underground instrumentation, a new small-sized ultraviolet lamp, and a simple but precise electronic vertical-angle sensor made by Sperry. Don theorizes that this variable-capacitance device contains propylene glycol (anti-freeze), which has a dielectric constant of 40.

Frank Reid discussed inexpensive ultraviolet light-sources for cavers (for detecting dye and fluorescent formations), Loran-C navigation, ultrasonic rangefinders (see SPELEONICS 4), and the military-surplus M-57 electrical firing device (which is not recommended for caving, due to low output).

Dick Blenz recounted the value of ham radio in cave rescue.

All incumbent Section officers were re-elected. 13 new memberships and 8 renewals were received. Memberships and sales of newsletter back-issues totalled $157.

WELCOME NEW MEMBERS:

Rick Banning (NSS 8083L), Takoma Park, MD
S. Ray Beach, Jr. (NSS 2687FL), Menlo Park, CA
Lee Blackburn (NSS 4301L), Canyon Country CA
Langford G. Brod, Jr. (NSS 5329RF), Tucson, AZ
Gary Bush (KA8YVE, NSS 17697F), Cincinnati, OH
L. Peter Carron, Easton, PA
Bill Eidson, Jr. (NSS 9612), Valparaiso, IN
Fred K. Gampper, Sierra Vista, AZ
Dennis Green (NSS 20156), Edgewood, KY
Hugh Gregg (N6NIL), Santa Cruz, CA
Dave & Becky Jagnow (NSS 8177 & 10655), Edmond, OK
Joseph M. Jette (NSS 11930) Phoenix, AZ
Jerry Johnson (WA5RON), Austin, TX
Don Lancaster (NSS 10963) Thatcher, AZ
Lance Lide (NSS 25078) Little Rock, AR
Joseph Liebertz, Monrovia, CA
Greg McGill (NSS 17272), Birmingham, AL
Duke McMullan (N5GAX, NSS 13429), Albuquerque, NM
John Schweyen (NSS 24848) Hackensack, NJ
Peter Shifflett (NSS 21467) San Diego, CA
Rick Sparrow (KE7EE), Tucson, AZ
Robert B. Staley, Jr. (NSS 11572), Tucson, AZ
Bob Stucklen (NSS 4752) Montrose, CO
David Weller (NSS 13668), Louisville, KY
Barry Were, Hamilton, New Zealand
James Wolford (WB8FAX, NSS 25818), Indianapolis, IN

BIBLIOGRAPHY SUPPLEMENT

These are additions to the cave-related electronics bibliography published in SPELEONICS 2:

----- Development and prototype production of a trapped miner signalling transmitter/transceiver. General instrument co. government systems division. USBM contract final report J0395017 (1981) (contains schematics)

----- Proposal to improve detection capability of trapped miner EM transceiver. Proposal no. QR-9067 General instrument co. government systems division, Hicksville, NY. Prepared for USBM Bruceton Research Center, Pittsburgh, PA. (1980) (tapped analog delay-line correlator)

----- VLF and geophones help rescue trapped miners Electronic Design #4, Feb 18, 1971.

Bicking L. The cave radio revisited.
Baltimore Grotto News v8 #12 p232-6
reprinted: Speleo Digest 1966 p.3-20 thru 3-24.

Cole R. Organ cave radio.
Speleonics 3 (v1 #3 Fall 1985)
(plans for 3.5-kHz 2-way equipment featuring digital circuitry. Corrections: Speleonics 4.

DeMaw MF. Ferromagnetic core design and application handbook.
Prentice-Hall (1981)

Dobrin MB. Introduction to geophysical prospecting.
McGraw-Hill. 3rd ed. 1976

Geyer RG, Keller GV, Ohya T. Research on the transmission of electromagnetic signals between mine workings and the surface. National Technical Information Service report PB 237 852. (also available as Bureau of Mines report OFR 61-74)

Glover RR. Cave depth measurement by magnetic induction.
Lancaster Univ. Spel. Soc. Jour. v1 #3 Summer 1973 (extensive bibliography)

Hill DA, Wait JR. Analytical investigations of electromagnetic location schemes relevant to mine rescue.
Bureau of Mines summary report, contract H0122061 (1974)
(contains collected reprints)

Jack, L. Underground Radio is a Dirty Business.
73 Magazine, 57-59, Sept. 1975.

Jakosky JJ. Electrical prospecting.
QST June 1928 p9 ff.

Jakosky JJ. Exploration geophysics.
Trija Publ. co., Newport Beach CA. 1940, 1950. 2nd ed. reprinted Oct. 1961.

Mixon, W. NSS Caving Information Series #18: Use of the Cave Radio in Mapping.
National Speleological Society
(revised by F. Reid, 1985)

Plummer W. Depth measurement with the cave radio.
Baltimore Grotto News, vol. 7, p259, Aug 1964
reprinted: Speleo Digest 1964 p 3-23 thru 3-26

Plummer W. Direction finding in the horizontal plane.
Baltimore Grotto News. v7 #12 p360-62
reprinted: Speleo Digest 1964 p3-31 thru 3-33

Plummer W. A cave telephone
Baltimore Grotto News. v8 #5 p116-19
reprinted: Speleo Digest
(theory and practice of earth-current communication. parts believed erroneous.)

Reid FS. Q-multiplier on loop antenna makes selective front-end for cave radio. Bloomington Indiana Grotto Newsletter. v10 #3 p. 53-54.
reprinted: Speleo Digest 1971 p305

Seggern D, Adams WM. Electromagnetic mapping of hawiian lava tubes.
Water resources research center technical report no.8. University of Hawaii, Honolulu HI (1967)

Shope SM. Electromagnetic surface fields due to a magnetic dipole buried in a three-layered earth.
USBM report of investigations RI 8702 (1982)

Stoyer CH, Wait JR. Analysis of source location errors for a magnetic dipole buried in a laterally inhomogenous conducting earth.
Final report, USBM contract J019915 (1980)

Telford W, Geldart L, Sheriff R, Keys D. Applied Geophysics.
Cambridge Univ. Press 1976
(textbook with formulas for EM and resistivity methods)

LORAN-C FOR CAVERS

Frank Reid

[Adapted from an article in The Lowdown, 6-85]

3 years' experimenting with Loran-C for land navigation have shown that its high resolution and repeatable accuracy are adequate for locating and recovering manhole-sized cave entrances in Kentucky and Indiana in dense woods where visibility is 100 feet or less.

16-bit microprocessors made Loran-C navigation receivers affordable. They continue to become smaller, more sophisticated and less expensive. They have great potential as an aid to caving in general, and for cave rescue. LORAN is an acronym for Long Range Navigation. Loran-A has been phased out, Loran-B was never deployed. Loran-C operates at 100 kHz, using widely-spaced ground transmitters. The new Navstar satellite navigation system is superior, providing worldwide coverage with constant accuracy, but receivers for it are not likely to become affordable in the near future.

The Micrologic ML-5000 Loran receiver indicates latitude and longitude to 0.01 minute (roughly 50 by 60 feet). It also indicates raw Loran coordinates in microseconds (for those secret cave locations)! Repeatable accuracy (about 100 feet in Indiana and Kentucky) varies with position relative to transmitting stations; it can be as good as 50 feet.

The ML-5000 is easily portable, requires 8-20 volts and only 0.6 amp with its panel lights off. It requires 3 or more feet of antenna, which must be connected directly to the separate preamplifier. Most Loran-C receivers are made for boats, and compute such useful navigation functions as distance-and-azimuth to destination, true course, ground speed, cross-track error, cumulative distance, ETA, and "velocity made good" (the component of motion toward the destination). When the current year is entered, the ML-5000 knows magnetic variation everywhere.

The device has been altogether satisfactory for automobile use, which must be a worst-case application. I've measured locations of 200-mile-distant road intersections on aeronautical sectional charts, and consistently had the waypoint-arrival alarm sound when within sight of the destination (arrival alarm radius set to 300 feet). I anticipated using my receiver for air navigation to supplement the ratty avionics in rental planes but the unit's size and shape make it unsuitable for temporary mounting in small aircraft. The ML-5000 stores 59 locations, called "waypoints." Its unique ability to store alphanumeric waypoint names is a tremendous advantage, eliminating the need to refer to a separate list. Waypoints are entered as latitudes and longitudes in degrees/minutes/ seconds, or degrees, minutes and decimal fractions of a minute. Present position can be stored with only 3 keystrokes.

It's an excellent companion on long drives. Unlike most radios, you don't have to listen to it. I named mine "CRM-114" after a device in the movie "Dr. Strangelove" (that label also appears in "Back to the Future"). One of my stored waypoints is MECCA, for the convenience of any Moslem passengers.

Another Loran I've used, a II Morrow "Apollo" installed in a friend's airplane, has relatively primitive software. Don't buy one for caving.

Most Loran receivers only display distances and speeds in nautical miles and knots (nm per hour). Nautical miles are practical units for lat/lon navigation-- **A nautical mile is one minute of latitude (6076 feet, 1.15 statute mile).** It is approximately 2 kilometers or 2000 yards. King Radio makes a Loran receiver which will indicate nm, statute miles, or kilometers. (The King 8001 is currently the best deal; about $700.)

Given a Loran receiver, thinking in latitude and longitude becomes easy. The spherical coordinate system has many advantages but many cavers consider it cumbersome. Programmable calculators can convert lat/lon to UTM or other coordinate systems. Caver/geologist **Phil O'dell** plans to experiment with Loran for finding locations in areas which have been disturbed by strip mining and no longer match the contours on topographic maps.

Power lines are the major source of interference on land. Briefly driving under one causes no problem because the computer's position-determining process averages a large number of Loran pulses. Driving parallel to a large power line for a mile or so can cause the receiver to lose track. (Loran receivers require 2-5 minutes to initialize, and can do so in motion.) It often becomes unusable in metropolitan areas. With the vehicle not moving, I have noticed large position errors (more than one mile) near power lines even when the receiver displayed no error alarms. Power-line noise may have caused the receiver to cycle-slip (detect the wrong cycle of the Loran pulse).

The prime caving areas of Eastern U.S. are very well-covered, but weak signals and unsuitable station geometry make Loran-C marginal or unusable in parts of the Western Plains and Southwest. I travelled through the "mid-continent gap" enroute to Wyoming in summer, 1984. Driving westward through Iowa and southern South Dakota, the repeatable-accuracy readout slowly increased to over 400 feet, and signal-to-noise ratios decreased but stayed within the usable range. (Decreased accuracy isn't a serious problem Out West where driving visibility is better than flying visibility in the East!) Manufacturers recommend recalibration every 200 miles, or after changing transmitters. Using an aeronautical sectional chart, I recalibrated at a road intersection in South Dakota, my first recalibration since Indiana, and was two minutes off in longitude but perfect in latitude. There were no problems until I reached the Black Hills region. East of the Black Hills, the Loran remained on the Great Lakes chain, changing to the West Coast chain a few miles west, but within the Black Hills geological formation, signals from both chains were unusably weak. In Wyoming, it "derailed" as I drove under a thunderstorm. The unit functioned perfectly during the return trip on I-90, passing just north of the Black Hills. It automatically switched back to the Great Lakes chain near Rapid City, SD. On a trip from Indiana to Texas, my receiver switched from Great Lakes to Southeast chain in Arkansas, and became unusable south of Dallas, near a baseline extension with no alternative stations available.

I just had to see if Loran works underground! I carried the pack-frame-mounted unit (with 3-foot whip antenna) through a large commercial cave in central Kentucky which contains USGS benchmarks, stopping at benchmarks to check position. The average depth was 200 feet. Signal strengths varied enormously-- At many locations, signals from the 400-kw station at Dana, Indiana (173 nautical miles away) remained almost as strong as on the surface but signals from New York and Florida were unusably weak, so fixes could not be computed. 100 feet of extra antenna did not improve reception significantly, nor was cycle-stepping successful. At a place where water enters the cave through a vertical joint, all signals were strong; the computed fix was 1/2 mile east of the true location. Part of the underground route contained power lines for lighting, which are in metal conduit and buried. Their presence or absence had no noticeable effect on Loran signals. The lights were not turned on. I have taken the Loran receiver into two Indiana caves, with similar results.

Although Loran navigation seems not to work underground, there are interesting effects worthy of study; a simplified 100-kHz receiver could be used in caves to search for vertical joints, thin overburden or other anomalies.

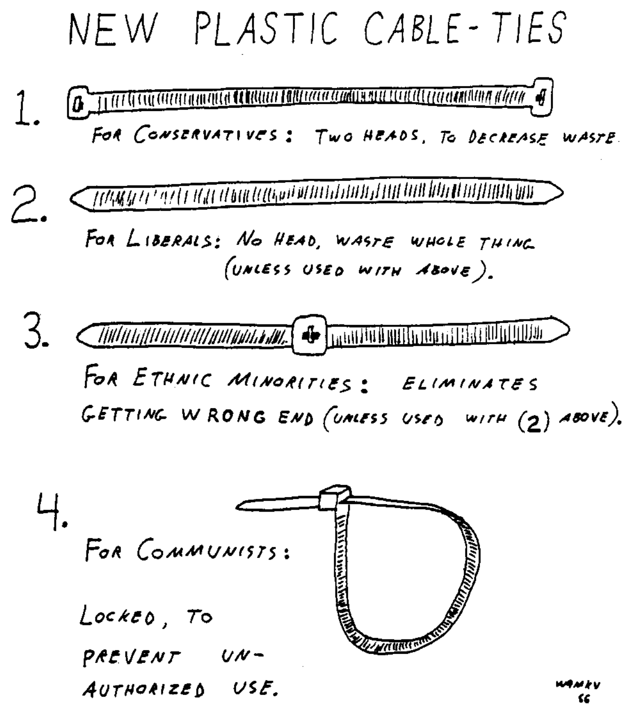
Changes in ground conductivity cause local propagation anomalies, manifest as Loran position errors, near geological features such as sinkholes and escarpments, and probably faults and mineral deposits. Loran in conjunction with optical survey may be usable as a prospecting aid analogous to the ground-resistivity mapping process but without the cumbersome wires and ground rods. (There are a number of geophysical techniques which use signals from U.S. Navy high-powered VLF stations. A useful reference is Applied Geophysics by W. Telford, L. Geldart, R. Sheriff and D. Keys, Cambridge University Press, 1976.)

The highly-stable Loran signal could be used as a reference frequency for a "coherent-CW" cave radio transmitter.

BOOK REVIEW: The Aviator's Guide to Loran-C, John F. Good, 1984, $12.00, available from Aksunai Press, Box 326, Wakefield, MA 01880, or Sporty's Pilot Shop, Clermont Co. Airport, Batavia, OH 45103. [Sporty's free catalog is interesting, whether or not you fly.]

This up-to-date book offers an easy introduction to the principles of Loran, its limitations, how to choose and install a receiver and protect it from interference, plus a review of popular models. There is plenty of more technical material, including hard-to-find data such as a graph of daily and seasonal variations in time difference at a fixed point. The book includes a tour of a Loran station, and a fascinating history of Loran, including a discussion of bureaucratic infighting over present and future navigation systems. The author believes that satellite navigation systems will not replace Loran-C for a long time, and reports that part of the mid-continent gap may be filled by a new station in central Texas, possibly before 1988.

There is an extensive bibliography and glossary. The book is a much better buy than the Loran-C User's Handbook, available from the Government Printing Office for $7.95.



NOTICE TO SUBSCRIBERS

We have passed the break-even point where it is more economical to bulk-mail the minimum 200 copies of SPELEONICS than to send a lesser number by first-class mail. As noted in the masthead, we send the required copies to NSS Headquarters, and we exchange with other organizations. The remaining promotional copies are sent to NSS Grottos, potentially-interested people and random NSS members on a rotating, irregular basis. If you received this issue free, you may not get another for years! If it interests you, please subscribe. If not, please pass it on to others.

MEMBERS: If you know people who might be interested in our Section, let us know and they will receive a free sample.

If your mailing label is marked "LAST ISSUE," it means that your subscription has expired or, if you are not a member, that your name will be removed from the next mailing list, as noted above.

SPELEONICS
Bloomington Indiana Grotto
PO Box 5283
Bloomington, IN 47402-5283

Bulk Rate
U. S. Postage
PAID
Bloomington, IN
Permit No. 2Ø2