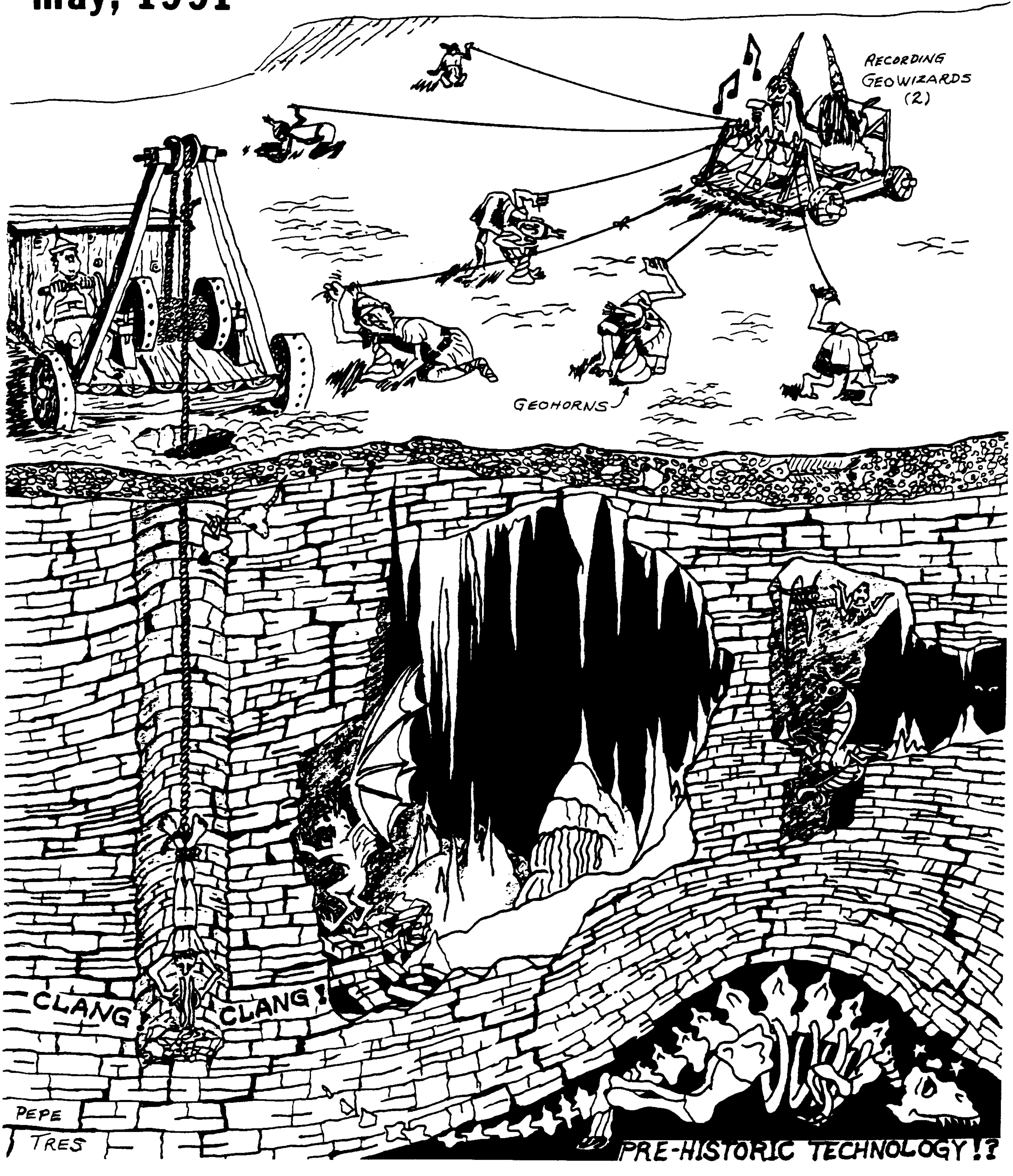
SPELEONICS #16

Volume IV number 4

may, 1991



SPELEONICS 16

Volume IV, Number 4 May, 1991

SPELEONICS is published approximately four times per year by the Communication and Electronics Section of the National Speleological Society (NSS). 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.

Section membership, which includes four issues of SPELEONICS, is $4.00 in USA/Canada/Mexico, $6 overseas. Send subscriptions to section treasurer Joe Giddens at the address below (make checks payable to SPELEONICS.) If you have a ham-radio callsign or NSS membership number, please include them when subscribing.

Foreign subscriptions can be paid in U.S. "paper" dollars in the mail; an international money-order may cost as much as the subscription itself. Many members have sent cash without problems. (No foreign currency, please.)

Editorship rotates among the officers. Volunteers are encouraged to guest-edit or produce an issue. A technical session, followed by election of officers, is an annual event held during the NSS Convention.

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

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IMPORTANT NOTICE: DUES INCREASE

Postage is our largest expense. Thanks mostly to our publisher, **Diana George**, we have held subscription costs constant since our first issue in 1985, meanwhile surviving one postal-rate increase. The new increase in January forces us to raise dues to **$1.50 per issue** (US/Canada/Mexico) and **$2.00 overseas**, effective August 1, 1991. Old and new members may subscribe for any number of future issues at the old rate until then.

ERRATUM

Speleonics 15, p.9, column 2, paragraph 3, line 1 should read: "... Detecting Lesser Wax Moths Acoustically."

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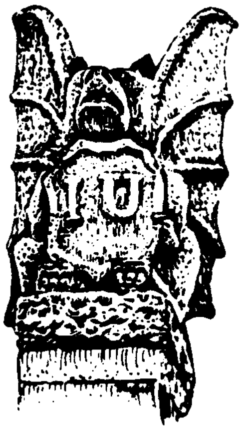

Bat gargoyle at Indiana University

1991 NSS CONVENTION ELECTRONICS SESSION ABSTRACTS

This year's session at the convention in Cobleskill, New York is scheduled for 9:30AM on Monday, July 1. Informal show-and-tell and general discussion follows the scheduled papers, so bring your favorite project!

BATTERIES FOR CAVING

Chuck Heller NSS 6618

A survey of different types of batteries and lighting systems for dry caving includes building a simple charging system which one can use from AC or car battery.

Costs, advantages and disadvantages of standard D, C, A and AA cells, nickel-cadmium dry and wet cells, gel cells, lithium batteries and mercury batteries will be covered.

Care and feeding of gel-cells and nickel-cadmium batteries, along with memory-restoration and depletion of ni-cads will be discussed. Shelf-lives of all the above batteries will be covered.

An inexpensive charging system which is easy to build and can charge all types of batteries will be demonstrated, along with examples of different types of batteries and lights.

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AN EXPERIMENTAL SYNCHRONOUS CAVE-RADIO

Brian Pease NSS 7476

A synchronous cave-radio operating at 3496 Hz has been developed and tested in several different applications. It was originally built as the simplest device that could provide a steady meter-readout of received relative magnetic-field strength from an in-cave beacon to determine depth by field strength for survey applications. The zero-centered meter provides left-right or up-down indications for homing in on "ground zero." The phase-sensitive detector provides deep nulls by rejecting out-of-phase secondary signals generated in the rock. A simple method of measuring ground conductivity without probes, using these secondary signals, has been tested. This conductivity technique shows promise as a way to do "cave hunting" from the surface with the same survey gear. Maximum horizontal range is the usual 1500 feet (457 meters) or so, in quiet conditions.

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CAVE RADIOS AND THE LAW

Brian Pease NSS 7476

Federal Communications Commission regulations currently allow homebuilt cave-radios employing loop antennas to be legally operated in the USA without license or approval of any kind. The weak electric fields actually generated by loops at low frequencies allow cave radios to legally operate at much higher power levels (and higher frequencies) than commonly used. In particular, this will allow the development of high power two-way voice cave-radios in the optimum 15-30 kHz range. Units offered for sale in quantity are supposed to pass a certification test and would carry warning stickers saying that they must not cause harmful interference, etc., such as those found on cordless telephones.

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THE RIGHT TEST EQUIPMENT

Ray Cole NSS 12460

The newcomer to caving-related electronics may be a little frustrated without the right type of electronic test-equipment. The basic tool needed is a method of measuring voltage, current, and resistance. This is called a volt-ohm-milliammeter (VOM). Useable models can be found at electronics parts stores including Radio Shack. More sophisticated equipment including signal generators and oscilloscopes is needed for building your own cave radios. A good place to find electronic test equipment is at amateur-radio fleamarkets called Hamfests. Other useful items include electronic breadboards, and capacitance and resistance-substitution boxes.

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WHEAT LAMP NOTES

from cavers' computer-mail list

FOR STORAGE: There is a Rubbermaid(tm) food/beverage container which is perfect for the lamp. It's roughly rectangular, with a vertical depression for a handle. It sits vertically, with a long, narrow lid. I don't know the capacity; it's about 9" [23cm] high. There are two sizes available; measure your lamp to make sure it fits. You can coil the cord next to the battery and put the headpiece in there too. -- **Phil Okunewick**

Re: diffusing lenses: I've sanded the inside surface of clear lenses, and that works very well. If you give the lens a grain, you can shape your patch of light! By mounting the lens with the grain running horizontally, you will cast a tall and narrow oval of light.

--**Bob Warshow**

I strongly recommend that anyone buying/replacing a Wheat battery consider a sealed Gel-Cell instead of vented lead acid (VLA). Kohler does not make a Gel-cell, but Bob&Bob and others carry them at prices similar to the vented ones (made by NiteLite, I believe).

The problem with VLAs are:

1. If you seal them with stainless sheet-metal screws, they will rupture or explode (depending on charge rate) if you forget to take the screws out. This is remarkably easy to do, especially if you put the lamp on charge in those dazed pre-dawn hours.

2. If you try to get by with lots of duct tape, there is still the chance that the thing will leak. I was a little lazy about using fresh tape a while back, and had acid all over my elbow as a reward.

Battery acid will destroy nylon, of course, so there are all kinds of opportunities for disaster when batteries are charged in vehicles, thrown in the back to go up the mountain, backpacked into caving areas, etc.

To conclude, my two vented Wheats make me very nervous and I wish that I had bought Gell-Cells. Rumors during 1984-85 notwithstanding, they now seem to be quite reliable. --**John Ganter**

THE STANLEY ESTIMATOR AND OTHER MISCELLANEOUS RAMBLINGS

by Jim McConkey *

The Estimator

I have been interested in ultrasonic tape measures for several years now. Several times I have started to design and build one but my attempts have always been interrupted by other, more important projects. When a local hardware store recently had a sale on ultrasonic tape measures for the incredible price of just $12.99, I just had to pick one up and check it out.

What I got was the Stanley "Estimator," a 2 3/4" by 4 3/4" by 7/8" [70 x 2 x 2.2 cm] plastic case with a large ultrasonic transducer, an LCD display and two bright yellow buttons. The unit is definitely NOT water (or mud) proof, even in its hard belt carrying case (included). The unit measures 2 to 33 feet 0.1' increments.

Naturally, I've taken it apart and examined it. The Estimator is powered by two button-batteries, which do not look like they were designed to be replaced (but at $13 for the whole thing, replacement batteries would probably cost more than a new Estimator, anyway!) There is apparently some sort of custom processor hidden in black epoxy under the LCD display, making hacking difficult at best. The pulse-sending and receiving sections are accessible, though. The unit sends bursts of 14 pulses of about 48 KHz. The pulses are amplified in a small transformer to several hundred volts before being sent to the electrostatic transducer. Several pulse bursts are sent, until the unit gets a steady reading, though it never seems to do less than about 3. It apparently averages a number of readings before displaying the distance. There is no on/off switch. Pressing either (or both) of the two yellow buttons on the sides starts the measuring. The unit beeps to tell you when it has a stable distance, and the distance appears on the LCD display. It automatically powers off after about 20 seconds if not used again. There is a small trimpot accessible through a hole in the side, but there is no mention of what its for. I would assume it could be used to compensate for temperature.

I have taken the Estimator caving several times. One time I also had a surveying tape along and was able to compare readings. Every measurement I took (admittedly less than 10) agreed to within 0.1'. I should note that ALL readings were consistently high by 0.1', so this may be a temperature calibration problem. On the last trip, I tried it in a room with a large waterfall (which are notorious for screwing up ultrasonic devices) with no problems.

For surveying use, the Estimator will, of course, have the inherent problems of ultrasonic tapes. The range is somewhat limiting (though around here, shots average maybe 15' at best) and they are easily confused by obstructions (a column, for example) between the device and the target. Oh, and did I mention the target must be a wall approximately perpendicular to the line of sight? I already mentioned that the Estimator is less mud and waterproof than would be desirable. While I doubt the Estimator will find much use in surveying, it seems to be ideally suited to sketching. How many times have you tried estimating a ceiling height out of reach? And how many sketchers actually measure the distances to the walls? The Estimator would make this an easy and accurate one-hand job.

Ultrasonic tapes in general

Ultrasonic tapes have several disadvantages which I have already mentioned. We need to remember that they work on the same principle as bat's echolocation. Indeed, bats can easily hear the frequencies these devices use. The transmitted signal is very short, so they they will just hear a couple 'clicks', but they could be loud. The use of such devices can conceivably also affect their echolocation and therefore, flight. Ultrasonic rangers should never be used near bats, especially hibernating ones (but surveying should never be done near hibernating bats, anyway).

The best way around some of these problems is to use an active target and direct measurement. The Estimator and virtually all other rangers that I am familiar with use echo distancing: The time the sound takes to reach the target and bounce back is measured. Knowing the speed of sound through air (roughly 0.9 ms per foot [2.95 ms/meter], temperature dependent), the round-trip distance is easily calculated. This is divided by two to get the actual distance. In an active-target system, the master unit tells the slave target to transmit a sound pulse by light flash, radio or other instantaneous means. The time that it takes the pulse to return directly gives the distance. This removes the obstacle and perpendicular wall target restrictions. Also, since intensity falls off with the square of distance and we are only measuring half the distance now, we only need a quarter of the transmitted power (less annoying to bats!) to measure the same distance. Conversely, we can measure 4 times farther with the same power (actually more, since we have no absorption by the target).

I may try to pursue this approach further using Estimators for their transceiver sections, and building my own optical trigger (which could also double as a photoflash slave trigger!) and counter. Thanks to the epoxy covered SMT parts, I don't think the Estimator can be altered to count twice as fast. I could rig one with an optical trigger so that I only got a reading of half the distance, but then the accuracy would only be 0.2', which is not enough for most modern cave surveyors.

A total surveying instrument

My interest in ultrasonic rangers is just part of a pipe-dream (for now, at least) of a complete point-and-shoot surveying instrument/data logger using an active target. Just set the target, point the device at it, and the unit would measure distance ultrasonically, temperature (to compensate distance), angle by capacitive tilt transducer, and bearing by fluxgate magnetometer (Radio Shack has one on sale for $50 here - has anyone hacked this thing yet?) instantly and log it. When you get back home, dump the data via RS-232 to SMAPS and, voila, instant map! Anyone interested? Any questions, comments or experiences with any of these devices are welcomed!

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MEASURING GROUND CONDUCTIVITY WITH A CAVE RADIO

by
Brian Pease NSS 7476 W1IR

In fall of 1990 I successfully measured the electrical conductivity of limestone in eastern U.S., using my unmodified 3496 Hz phase-selective cave radio set. This work was essentially a follow-on to Ian Drummond's article in Speleonics 12 [4] which suggested it as a viable method but, being out of touch at the time, I did it independently without knowledge of Ian's work, based on papers by Bannister[2,3], and by Williams and Benning.[1]

Knowing conductivity of a new area prior to doing radiolocations can be helpful in making decisions about whether to use high or low frequency gear, estimating sharpness of nulls for depth measurement, and even cave hunting.

THEORY

My technique, like Ian's, is based upon measuring the ratio of the primary (vertical) and secondary (horizontal) field strengths at a distance from a horizontal loop located on the surface, which transmits a continuous carrier (see Fig. 1). The equations for these fields are complex but can be expressed in simple quasi-static approximations over a limited range of values. Note that the two fields are 90° out of phase in this range, which is the key to the technique. H_{hor} is generated by currents induced into conductive rock; it "fills in" the nulls of the conventional depth-measuring process, making them less distinct with greater distance from the surface point directly above an underground transmitter.

$$H_{ver} = -\frac{IA}{4\pi R_1^3} \text{ amps/meter;} \qquad [1]$$

$$H_{hor} = -i\,\frac{IA\sigma_1 \mu_0 \omega}{16\pi R_1} \text{ amps/meter} \qquad [2]$$

Where: I is the beacon loop current in amps,
A is the loop area in meters squared,
$\omega = 2\pi f$ where f is in Hertz,
R_1 is the distance to the receiver in meters,
$\mu_0 = 4\pi \times 10^{-7}$ henries/meter,
σ_1 is the conductivity of the rock in mhos/meter,
H_{ver} is the primary (vertical) magnetic field,
H_{hor} is the secondary (horizontal) magnetic field.
i simply indicates that H_{hor} is shifted 90 electrical degrees from H_{ver}.

Combining equations [1] and [2], then solving for conductivity:

$$\sigma = \left(\frac{H_{hor}}{H_{ver}}\right)\frac{.506 \times 10^6}{f R_1^2} \text{ mhos/meter (or Siemens/m, to use the modern term)} \qquad [3]$$

All three equations are valid only in a limited range as follows:

1) The ratio of conduction to displacement current in the limestone must be greater than 10. This is true for the normal range of radio frequencies and conductivities encountered.

2) The maximum allowable distance to the receiver is approximately

$$r = \sqrt{\frac{.506 \times 10^5}{\sigma_1 f}} \qquad [4]$$

This is 68 meters for f = 3496 Hz and $\sigma = .0031$ mhos/m.

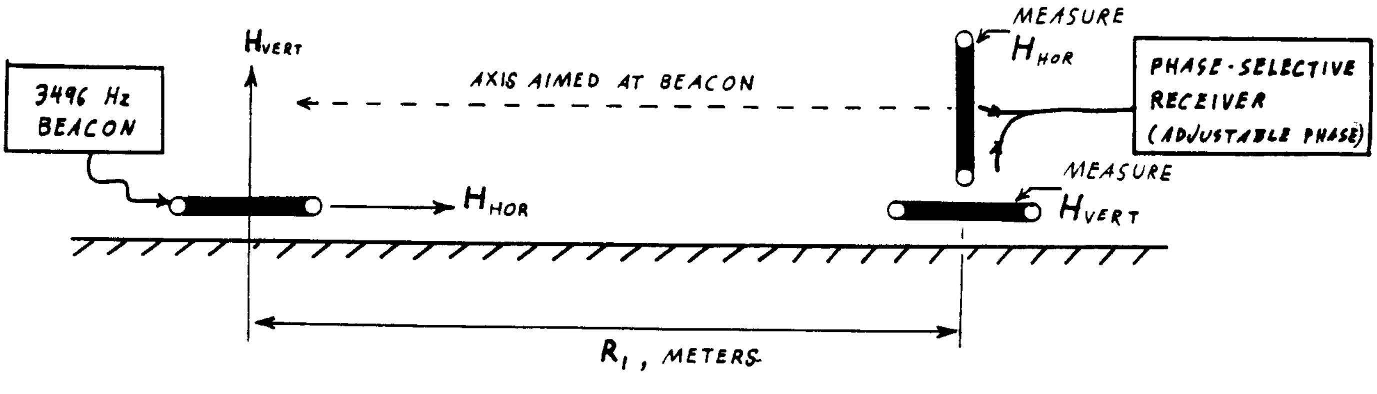

Figure 1.

Stated another way, the limit on maximum range for an accurate measurement is $H_{hor}/H_{ver} < 0.1$, which means that the primary field must be at least 20 dB stronger than the secondary field. In this range, the secondary field drops linearly with distance and the primary field is unaffected by the rock. Conductivity for greater ranges can be found from the plots and tables in Ian's article, which is indeed the necessary method when using conventional receivers (i.e., without phase-sensitive detectors) which probably cannot measure secondary fields which are more than 20 dB weaker than the primary field.

MEASUREMENTS

With the help of my (very) patient wife Bonnie, I used my unmodified cave radio to test the concept. The measurement setup (Fig. 1) consisted of a simple TV-crystal controlled beacon of the type used by Ray Cole[5,6], and a phase-selective (synchronous) receiver controlled by an identical crystal. The oscillators were roughly temperature-compensated. The receiver had a phase-shifting switch for alignment prior to each measurement, and built-in means to precisely match the two frequencies before the units were separated for the measurement. I can adjust the oscillators to nearly one cycle per hour (short term) and have achieved better than one cycle per minute after several hours in actual caving conditions. This stability is adequate for radiolocation and has been used in caves deeper than 300 feet [90m] (the subject of another article), however, such stability is very marginal for measuring the secondary field. The key to successfully measuring the secondary field (H_{hor}) lies in the fact that in the recommended range it is at a physical right angle to the primary field, i.e., in the physical null of H_{ver} and also at 90° electrical phase to it, i.e., in the electrical null as well.

The procedure is similar to the one Ian proposed for a "normal" radio:

a) Set up the beacon loop exactly horizontal (or parallel to the slope if measuring uphill). It is operated in continuous-on mode (i.e., not pulsed).

b) Measure a convenient distance, perhaps 200 feet [60m], or use equation [4] if you have a rough guess of the conductivity; .002 mhos/m is a good starting point in Eastern U.S.

c) With the receiver loop exactly horizontal (parallel to the beacon loop) align the phase for maximum primary signal H_{ver} and record the relative level. Now align the phase to completely null the signal.

d) Rotate the receive loop to a vertical position with its axis parallel to the ground and pointed at the beacon. This can be done by hand, since only the H_{hor} signal is present. Record the level of the secondary field. Repeat c) and d) if necessary. Phase drift is a significant problem, especially if H_{hor} is 25 dB or more below H_{ver}.

e) Take the ratio H_{hor}/H_{ver} and calculate the conductivity using equation [3]. If $H_{hor/ver} > 0.1$, then start again with smaller transmitter-receiver spacing. No correction for noise is needed, since noise averages to zero in a phase detector. Bandwidth can be reduced if jitter is a problem (I normally use 1 Hz), or you can return on a quieter day.

Some results are shown in **Table 1:**

	Measured Magnetic Field Strength				Loop Spacing		Calculated Conductivity	
	Primary H_{ver}	Secondary H_{hor}	H_{hor}/H_{ver}	$H_{hor}-H_{ver}$	ft.	mtrs	mhos/mtr	Comments
near McFail's Cave, NY	+60 dB	+26 dB	-34 dB	.02	100	30.5	.0031	H_{hor} hard to get.
" " "	+42	+20	-22	.08	200	61	.0031	No problem.
" " "	+31.5	+15.5	-16	.016**	300	91.4	.0028	Easier to measure.
near Clarksville Cave, NY	+62 *	+30	-32	.0251	150	45.7	.00174	2 other tests were identical.
over Clarksville Cave	+61 *	+22	-39	.0112	150	45.7	.00076	10x15-foot passage 60 ft. down [3 x 5m] [20m]

* Receiver gain was increased prior to these tests. ** This ratio is slightly beyond the range for accurate results.

CONCLUSIONS

This is an easy way to measure conductivity. 3496 Hz allows measurements at reasonable distances, at least in the Eastern U.S. Spacing must be accurately measured because conductivity varies as its square. This seems like a great way to check a new cave area for conductive overburden without entering the cave. Strongly conductive overburden (say, .01 mhos/mtr) can cause errors and broad nulls in depth measurements, and possibly even ground-zero errors. There is definite potential for "cave hunting" with this device as shown by the measurement over Clarksville Cave. This extremely low conductivity was measured perpendicular to the cave passage but cannot be explained by the small cave passage alone unless it has "dried out" all of the nearby limestone. There is no obvious joint visible underground or on the surface. Additional measurements confirmed the effect. Cave hunting from the surface will be the subject of a future article after I have accumulated more experience.

RECOMMENDATIONS

This equipment is actually a large "treasure finder" device optimized for detecting variations in rock conductivity. For cave hunting, only the secondary field need be monitored, since the main field is not affected by conductivity in this short range. As a rough guess, try spacing the receiver two to three times the expected depth of the bottom of the passage.

A practical conductivity-measuring device should have a wire line between transmitter and receiver so that both units can share the same local oscillator, thus eliminating drift. Crystal control would then not be necessary. The connecting wire would also act as a measuring tape to maintain constant spacing. A digital voltmeter could be used for readout.

As Ian speculated, it may be possible to obtain good results with an ordinary continuous beacon and conventional receiver by using an audio voltmeter as a readout and following the procedures outlined in his article.