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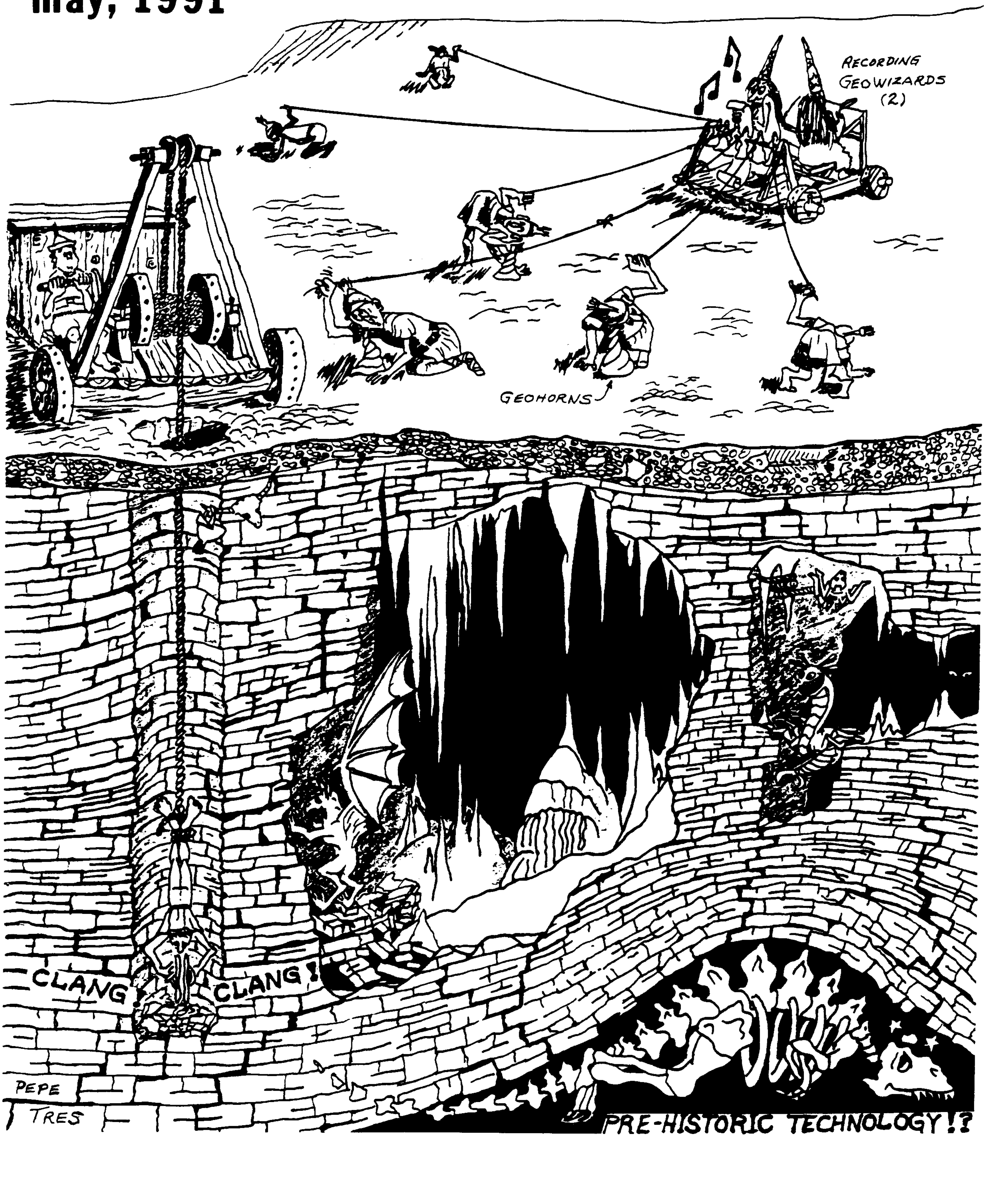

SPELEONICS 16

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.

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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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-=-=-=-=-=-=-=-=-=-=-=- **ANNOUNCEMENTS** -=-=-=-=-=-=-=-=-=-=-=-

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

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

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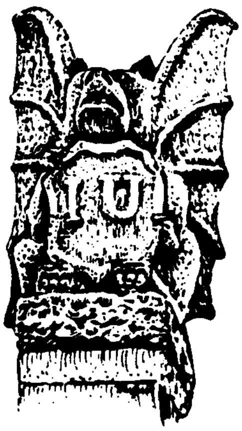

Bat gargoyle at Indiana University

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.

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

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

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,
$\mu_o = 4\pi \times 10^{-7}$ 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 σ = .0031 mhos/m.

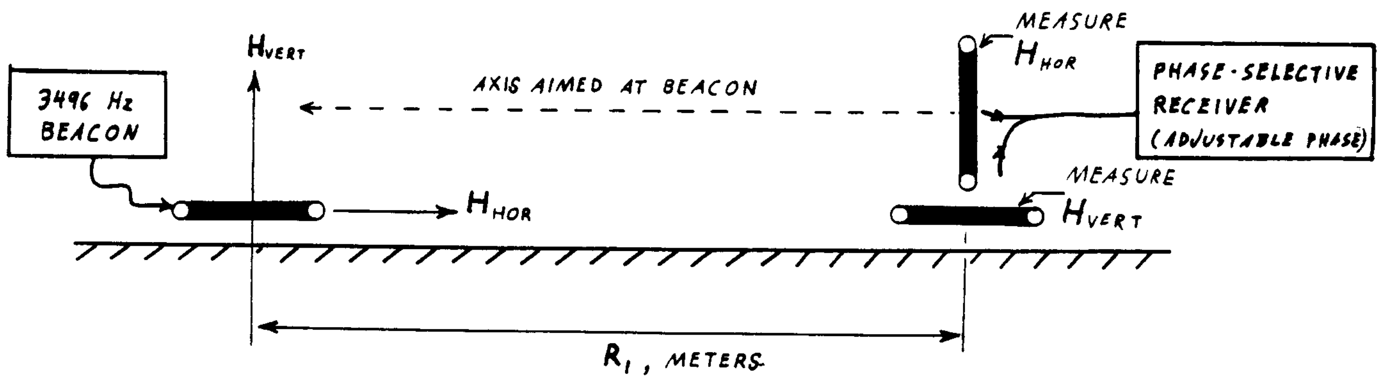

Figure 1.

Stated another way, the limit on maximum range for an <u>accurate</u> 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.

The tricky part is measuring the secondary field where you must carefully find the bottom of the null of the main field and then record its level. I recommend trying this at higher frequency or greater distance than I used, so that the secondary field is only 10 dB or less weaker than the primary. The disadvantage of doing so is that then the Hhor/Hver ratio begins to vary as the square root of conductivity, and so may be much less sensitive as a cave-hunting device.

References

Author's address: 567 Fire St., Oakdale, Connecticut 06370 USA. Home phone: 203-447-9497

1. Williams, R. and Benning, C. "Conductivity Measurements of the Earth at ELF" IEEE Transactions on Antennas and Propagation May 1963

2. Bannister, P. "Some Notes on the Utilization of a Vertical Magnetic Dipole to Determine the Properties of a Stratified Earth" USL Report 695, 5 Oct. 1965.

3. Bannister, P. "The Quasi-Static Fields of Dipole Antennas - Part 1" USL Report 701, 3 Jan 1966.

4. Drummond, Ian "Ground Conductivity by Electro-Magnetic Methods" Speleonics 12, Apr. 1989

5. Cole, Ray "Organ Cave Radio" Speleonics 3, Fall 1985 (corrections in Speleonics 4).

6. Stevens, Paul. Caves of the Organ Cave Plateau, WVSS Bulletin 9, 1988. Appendix G contains description and schematics of Cole's equipment.

[Manuscript received 17 Nov. 1990. --Ed.]
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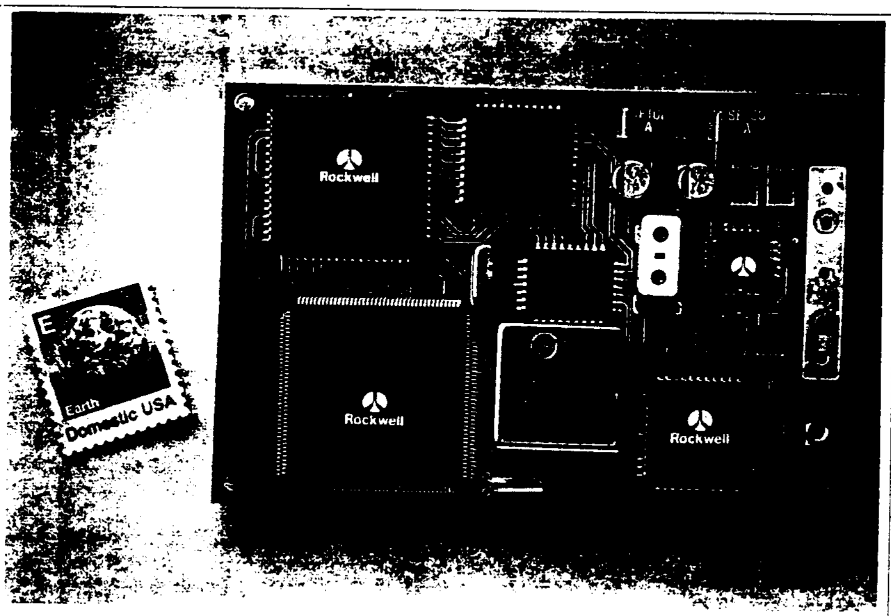
SEE NEXT PAGE--

Rockwell Produces World's Smallest 5-Channel Global Positioning System Receiver

WASHINGTON

Rockwell International says it has developed the world's smallest 5-channel Global Positioning System receiver with its new NavCore V, a 2½ x 4-in. module. The five channels allow the GPS receiver to obtain an accurate three-dimensional position in 30 sec., compared with 2 min. for a 2-channel receiver. NavCore V is based on the Miniaturized Airborne GPS Receiver developed for the military. The receiver is intended for commercial aerospace applications in any original equipment manufacturer's products. Initially, it will sell for $450, but that price could drop as low as $225 for volume orders. □



... SPACE TECHNOLOGY April 1?, 1991

CAVERS GET HANDS-ON EXPERIENCE WITH GPS NAVIGATION

Frank Reid

This article was originally posted to the cavers' computer-mailing list. Here it is abridged and updated.

Global Positioning System (GPS) is a U.S. military satellite-based navigation system, accurate within 25 meters worldwide; special procedures can refine accuracy to 3-5 meters. GPS is superior to the older LORAN-C system, and will be valuable for surface karst studies.

Ammar Mirza, Randy Jackson, Larry Mullens, Bob Armstrong and **Frank Reid** attended a 1.5-day GPS training session sponsored by the U.S. Dept. of Agriculture Forest Service office at Bedford, Indiana. We were invited because cavers have agreed to help the Forest Service make an inventory of caves and karst features on government land, for conservation purposes. Our instructor is with a Forest Service engineering section in Montana which develops and evaluates new technology. The Forest Service is using GPS extensively for land-surveying, and finding it a very cost-effective supplement to conventional labor-intensive optical methods.

The part of GPS available to civilians includes a "feature" called Selective Availability (SA) which introduces intentional errors which degrade accuracy to 100-300 meters, ostensibly to prevent an enemy from using the system. Military receivers remove the encrypted error.

SA was turned OFF when the "Gulf Crisis" began, allegedly because insufficient quantities of military-grade receivers were available, so many civilian-type receivers were in military service. Hopefully, they will be available as war-surplus! GPS receivers presently cost $2500-3500, predicted to ultimately reach $500.

Our instructor has worked closely with other government agencies and GPS-receiver manufacturers, and offered the prediction that political pressure from private and nonmilitary government GPS-users will result in SA being permanently turned off.

Even with SA turned on, measurements with error radius 2-5 meters can be made by "differential post-processing": One GPS receiver is placed at a known location, e.g., a first-order benchmark for which GPS coordinates are known. This "base" unit records its own GPS-indicated locations (including time) while a "remote" unit is taken into the field. The remote unit records a file of several minutes of data at each position of interest. The base and remote data are subsequently downloaded into an IBM-PC-compatible computer which compares the remote and base data at matching times, and subtracts the errors from the remote data. The base and remote units may be separated by as much as 250 miles (400km).

A "survey grade" GPS receiver is accurate within a few centimeters. It costs about 10 times more than ordinary GPS receivers. Some survey-grade receivers contain their own atomic clocks.

Certain nuances and oddities must be observed in using GPS effectively: One problem could be called proliferation of coordinate systems: GPS uses a mathematical model of the earth's shape called WGS 84, which is more accurate than the 1927 model upon which most topographic maps are based. Discrepancies range from negligible to as much as 200 feet (60m) horizontally. It is recommended that GPS coordinates be considered absolute, rather than "calibrated" against latitude/longitude measurements taken from topographic maps.

GPS elevation is given in "height above ellipsoid," which is different from sea level; in continental U.S., the ellipsoid (abovementioned mathematical model) is 16 - 40 meters below sea level.

Elevation accuracy is usually somewhat less than horizontal accuracy. Four satellites must be simultaneously visible in order to compute a 3-dimensional (latitude/longitude/elevation) fix. If only three satellites are visible, the fix degrades to "2D"; elevation is not computed, and there is some attendant loss of horizontal accuracy.

Accuracy varies with a parameter called "PDOP" (Position Dilution Of Precision). PDOP is continuously indicated on the display, and is a funciton of satellite position: PDOP is poor if all the satellites are close together in the sky; ideal PDOP occurs when three satellites are 120 degrees apart in azimuth and about 20 degrees above the horizon, with a fourth satellite directly overhead. PDOP is analogous to "strength of figure" in triangulation.

GPS is not usable at all times of day because he full "constellation" of satellites, providing 24-hour coverage, will not be in orbit until 1993, The PC software which comes with the units will produce tables and graphs which show windows of good conditions.

GPS does not work underground: The satellite radio-signals are about 1.4 Gigahertz. GPS <u>is</u> usable under a full forest canopy.

We used "TANS" GPS receivers made by Trimble Navigation of Sunnyvale, California (see <u>Resources</u> column). The receiver and external 12-volt battery combined are about the size of two bricks. The antenna is about the size and shape of the upper half of a plastic "Big Mac"(tm) container. Its base is threaded to fit a surveyor's range-pole. It is also supplied with a magnet for temporary mobile mounting. The antenna should be kept level so that its hemispheric field of view does not miss satellites near the horizon. The antenna should be kept about 2m above the ground. Reception problems may arise if deep valleys or tall buildings obscure satellites, or if the antenna is near a vertical metal surface which reflects the signals, causing multipath distortion, the same effect which produces "ghosts" on a TV screen).

The Trimble units are 2-channel receivers: The significance of number of channels is in speed of response and immunity from "dead spots" where satellite radio-signals are momentarily shielded, and from multipath problems. A single-channel receiver must divide its time between 3 or 4 satellites and "housekeeping" functions (which include looking for other satellites). A 2-channel receiver is significantly better than a 1-channel receiver (e.g., the handheld Magellan (tm), which our instructor does not recommend). Six to eight channels are optimum.

The TANS reciever is attached by RS-232 cable to an Omnitech "Polycorder" (handheld general-purpose computer/keyboard/display unit which the Forest Service uses for many applications). It stores data, waypoints, etc. and can be programmed, up/downloaded, etc. independently of the GPS receiver.

GPS indicates positions to the nearest 0.1 second of latitude/longitude (about 3.3 meters). Its internal resolution is 0.01 second (about 33cm [1 foot]). We recorded data once per second (of time) while carrying a receiver around the periphery of a parking lot, and were amazed by the detailed computer-plot of our trip.

To survey a point, e.g., a karst featrue, the antenna is placed at the spot and data are recorded once per second for three minutes. The file is later downloaded to a PC which calculates the mean location and produces a scatter-plot of the data with a standard-deviation circle around the mean lat/lon. We achieved standard deviations of 3-5 meters. Data can also be gathered while traversing around an area (e.g., a sinkhole). The computer can calculate the enclosed area and the mean location of its centroid.

The older LORAN-C radionavigation system uses ground-based transmitters. Its repeatable accuracy can sometimes exceed that of GPS but only in relatively small regions of favorable geometry relative to transmitting stations. LORAN-C covers most of the U.S. but is not worldwide. Good LORAN-C receivers are now available for less than $300. LORAN-C has a resolution of 0.01 minute of lat/lon, which is about 50x60 feet [15x18m] at mid-latitudes. It is excellent for long trips and cave-rescue operations, but nonideal for cataloging karst features: LORAN-C operates at low frequency (100 kHz) and propagates around the curvature of the earth by "ground wave." Variations in ground conductivity (e.g., near sinks and escarpments) cause propagation anomalies manifest as position errors. Cavers have also discovered that LORAN-C is unreliable in very deep valleys.

References:
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"LORAN-C for Cavers," Speleonics 5 p. 12.
"New LORAN-C transmitters to fill Mid-Continent Gap" Speleonics 9 p. 13.
"The Global Positioning System" Speleonics 11 p.13.
"GPS Update" Speleonics 13 p.6.
"Radionavigation System Devleopments" Speleonics 14 p.12.
Reprinted Trimble Navigation ad, Speleonics 14 p. 14.

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RESOURCES, REFERENCES, NEW PRODUCTS

GPS Info from rec.ham-radio, October 1990

An excellent GPS receiver is the TANS from Trimble Navigation. It's very small, low-power, and easy to use. Antenna is about 5x5 inches, low-profile phased array. The best part is that unlike some of the models made for the boating world (like Magellan), the TANS has an RS-422 port and transmits latitude, longitude, elevation, speed, time, and diagnostic data. Easy to interface. I'm putting one on my bicycle for nav, mapping, and security.

Contact the company at 800-TRIMBLE or 408-730-2900 (they're in Sunnyvale).

Steve Roberts N4RVE
Nomadic Research Labs

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For subscriptions to GPS World magazine, write to:

P.O. Box 10955
Eugene, Oregon 97440-2955 or call 503-343-1200

European offices:

Unit 4E, Bridgegate Pavilion
Chester Business Park,
Wrexham Road,
Chester CH4 9QH, UK
Telephone: 0244-680606
Fax: 0244-680094

Free subscriptions to the magazine are available to the engineering community; for others the subscription price is $54/yr in the U.S. and $97/yr outside the U.S.

Two GPS receiver suppliers that I have had good experiences with are:

Trimble Navigation
Sunnyvale, CA telephone: 800-TRIMBLE

Ashtech
390 Potrero Ave.
Sunnyvale, CA telephone: 800-229-2400 or 408-737-2400

Global Positioning System status report on WWV/WWVH

WWV and WWVH broadcast reports on the status of the Global Positioning System. The WWV broadcast is at 14 minutes past the hour and is repeated during the following minute. The Omega navigation system status report continues to be broadcast at 16 minutes past the hour. The GPS report on WWVH is given at 43 minutes past the hour with a repeat at 44 minutes past. This is followed at 45 minutes past with the solar activity report.

Richard B. Langley BITnet: LANG@UNB.CA or SE@UNB.CA
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A WHISTLER HUNTER'S GUIDE by **Michael Mideke** is a 14-page introduction to the study of "whistlers" and other natural radio phenomena in the audio-frequency range, by a leading experimenter. It includes plans for an easy-to-build portable receiver. This is essential reading for anyone working with cave radio at frequencies below 10 kHz. Available for $2.00 and SASE (with postage for 2 ounces) from Mike Mideke, Box 123, San Simeon, California 93452.
..

Battery Charger References

The July '86 issue of Radio Electronics magazine has a construction article for a "Universal Battery Charger" intended for gel-cells.

It uses a LM317 in constant-current mode. When the terminal voltage approaches full charge, it trips an SCR that changes the circuit to a voltage regulator for constant-voltage trickle ("float") charge.

See also Sky & Telescope magazine, July 1989, p.97 for a similar automatic gel-cell charger circuit.
..

Coon Dog Catalog

Nite Lite Co.
P.O. Box 8210
Little Rock, Arkansas 72221
ph: (800) 648-5483

Actually a supplier of hunting equipment, their catalog includes Wheat(tm) Lamps and parts, and other powerful lamps and bulbs suitable for caving. Prices appear competitive. [contributed by **Randy Jackson**]
..

Pocket-Sized pH Meters Affordable by Nonsubsidized Pollution-Fighters.

Cole-Palmer is marketing portable electrochemical test instruments for less than $100. In addition to pH meters, there are similar testers for sodium, salinity, and oxidation-reduction potential (ORP). There are also conductivity and dissolved-oxygen meters ($258.50 and $399 respectively) and a "Water Tester" which measures pH, ORP, conductivity and temperature, all in a single instrument for $121.

Cole-Palmer Instruments Co.
7425 N. Oak Park Avenue
Chicago, IL 60648 800-323-4340 or 312-647-7600
..

Underwater Communications Reference

The January 91 issue of the IEEE journal of Oceanic Engineering was a special issue on ocean acoustic data telemetry (Volume 16, Number 1 ISSN 0364-9059)

--**Dale Chayes** (dale@lamont.ldgo.columbia.edu)

EARLY ADVANCES IN UNDERGROUND RADIO COMMUNICATION

by Angelo I. George, NSS 7149RF
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Introduction

Communication without wires, that was the dream of early inventors. With understanding of electromagnetic waves, radio grew out of induction and ground-to-ground experiments of Nathan B. Stubblefield in 1892 and Nikola Tesla in 1893. Reid (1990) has profiled in part the accomplishments of Stubblefield. By 1913, the principal of inductive communication was being popularized in a children's electronic book by Alfred P. Morgan (1913, p. 290-295). All were then hi-tech toys beyond the reach of most people. Commercial broadcast radio started in 1920. Soon after, radio receivers became a household appliance. There were more radios than indoor plumbing in homes (Archer, 1938).

Experiments were conducted in faraway places to discover the range and effectiveness of radio reception. Some of these experiments were conducted in caves (George, 1988). Since that article, new information has been assembled on Endless Caverns, Carlsbad Caverns, Wyandotte Cave, Fishers Cave, Meramec Caverns, Howe Caverns, Hudson River Tunnel, and several international sites.

Hudson River Tunnel

In January 1924, radio-wave penetration experiments were conducted in the south tube of the Hudson River Tunnel. The experiment was the outgrowth of a request made by Morris M. Frohlich, secretary of the New York Tunnel Commission. Frohlich wanted to know if radio transmitter could be used to communicate with workmen underground in case of an accident or danger during tunnel construction (Anon. 1924a).

The site was located over 1000 feet (300 meters) from the south entrance and 80 feet (24m) below the surface of the Hudson River. The project was under the direction of pioneer radio engineers G. Y. Allen and G. L. Beers of Westinghouse Electric and Manufacturing Company. They used "a six-tube loop receiver" (Anon. 1924ab). Alan S. Douglas, antique radio historian (personal communication, 6 December 1990) said "the radio that Westinghouse used in 1924 appears to be a prototype of the superhet that they had just helped to develop for RCA..." The radio used a small, square directional antenna.

The Westinghouse radio received the following stations: WOR, Newark; WEAF, WHN, and WJZ, New York (Anon. 1924a, p. 1224, 1327).

Frohlich said (Anon. 1924a), "We are working on a portable sending-set for the use of those engaged in dangerous underground work... It has now been proven that radio waves can enter anywhere, and the only thing now needed is a portable transmitter."

The realization of this underground portable transmitter was exceptionally slow in development. The U. S. Bureau of Mines did transmission and antenna experiments in mines during 1924 using the "wired-wireless principle, which makes use of the mine trolley and eliminates the need for high-powered sets" (Anon. 1925a, p. 149). From photographs in Popular Mechanics, the transmission device is a room-sized base station needed for surface-to-underground voice communication. From a practical point of view, I must presume these experiments were not very successful because Eve and Keys were still working on the transmission and reception problem in June 1929 in Mammoth Cave (George, 1988). The technique did not become practical until the late 1950s and early 1960s with the advent of induction cave-radios, and perhaps later with U.S. Navy developments used in the detection of submarines and in military communication using the same principal.

Endless Caverns

Two postcard views from Endless Caverns, Virginia, depict radio operation in the cave. Both of the cards show a place in the cave called The Arctic Circle. For successful radio reception, the cave passage must be highly fractured, very close to the surface, adjacent to a valley wall, or a combination of these criteria. Some information has been collected to better target a period when these experiments were conducted.

The Rotograph Company of New York published a sepiatone card of The Arctic Circle (Gordon L. Smith, personal communication, 1 January 1990). The Arctic Circle view was available for sale in the gift shop in 1925. The view shows an artist at work rendering a cave scene. To his right in the foreground is a radio set, curved horn speaker, and large square antenna mounted on a wood frame. The caption reads:

> THE ARCTIC CIRCLE
> Endless Caverns, New Market, Va.
>
> Making a scale Model of one of the rooms in the Endless Caverns. With this model and with color sketches as guides a large group was constructed for the Geological Hall in the Milwaukee Public Museum. The Radio set keeps the artist in touch with the news of the day down here 300 feet underground and over a mile from the entrance.
>
> Photo by Merl LaVoy.

Merl La Voy was an early nature and adventure photojournalist. He joined the Explorers Club in 1923 (Russell Gurnee, personal written communication, 13 June 1989), and accompanied the second expedition of the Explorers Club into Endless Caverns on the evening of 25 May 1925 (Anon., 1925d, p. 12). This was not his first trip into the cave. Apparently he was then living in New Market (Anon., 1925d, p. 12) and as a result was able to photograph the Milwaukee Museum artist at work making wax models of cave formations. His photographs would appear in the Milwaukee Journal, Popular Mechanics, and Endless Caverns brochures and postcard (Anon. 1925cd).

Between 16 and 24 April 1925, Merl La Voy took his Crebe Radio into the cave "and the Milwaukee museum members, though 240 feet below the earth's surface had 'music with their work'" (Anon. 1925d, p. 12). This was not a planned radio experiment; it was done on the spur of the moment for entertainment.

La Voy used a Synchrophase radio manufactured in 1925 by the A. H. Grebe Company. The circuit is tuned radio-frequency. A six-volt storage battery supplied power to vacuum tube filaments. Several dry-cell batteries supplied plate voltage (Lauren A. Peckham, personal communication, 25 May 1990).

Seven hundred feet of motion picture film were shot in the cave, using white magnesium flares for illumination. The film shows part of the Explorers Club expedition, an old-time square dance in the Ball Room, and the artist with radio in the Arctic Circle (Barrett, 1925).

A second radio postcard has proved very elusive and is called Radio Underground. It was issued by the Albertype

Company, Brooklyn, New York. This is a hand colored view showing three men with earphones, four or five boxes of radio equipment, and a square directional antenna. Most of the equipment is placed on a folding field-table in front of the operators who are seated on straight-back chairs. The photograph is taken at the entrance to The Arctic Circle. Caption on the back of the card reads:

> ENGINEERS TESTING RADIO RECEPTION UNDERGROUND
> Endless Caverns New Market, Va.
>
> Far below the surface and nearly a mile from the Caverns Entrance radio reception from distant stations was excellent. Musical reception proving exceptionally good.

Gordon L. Smith (personal communication, 1 January 1990) has been able to establish that the radio postcard was issued at the cave in 1928. The radio equipment looks older. Anon. (1926, p. 24) in a promotional brochure shows a newspaper photograph of this same experiment. With no date for the two newspaper items, no clear information is available as to when or why the experiment was conducted. More research is needed.

The Explorers Club mounted another expedition on 30 October 1940. Well prepared with men, telephones, ropes, candles, balls of twine, and confetti (to mark the way), the expedition was underway. Cowling (1947, p. 42-43), the expedition leader remarked:

> The portable telephone equipment - which we had carried as a contact with the outside world - was heavy so we left it behind as soon as we were certain that, if necessary, we could contact the outside world. We used the equipment several times to communicate with representatives of the press and radio, but luckily we never needed it because of any emergency. Lowell Thomas spoke to each of the members of the expedition in our location far, far underground and commented on these unusual conversations in his October 30 coast to coast broadcast.

It is not clear if this was a remote broadcast via telephone lines from the cave to the surface, or if Lowell Thomas was actually at the cave or in his radio studio. The Explorers Club Journal says (Anon. 1940, p. 3):

Many examples of stalactites, stalagmites and calcite formations were taken out of the new sections. Some of these are being sent to Lowell Thomas in hopes that they may find a spot in his fireplace. Lowell Thomas carried an item about the expedition on his broadcast the first night and that created universal interest in our work.

The Explorers Club Journal implies that Thomas gathered his news over telephone lines and reported later the substance of his conversation with the underground adventurers. Anonymous (1940) suggests this was not a true remote radio broadcast as in those conducted from Mammoth Cave and Great Saltpetre Cave, Kentucky (George, 1988, p. 7).

Carlsbad Cavern

One of the few successes of Frank Ernest Nicholson's 15-man expedition to Carlsbad Cavern was a radio experiment conducted in the cave. A radio test was conceived by Eric Palmer to gauge "the penetration of the earth's crust by radio waves" (Halliday, 1976, p. 125; 1981, p. 2; Nicholson, 1930). At the end of the first expedition day on 20 February 1930, the experiment was declared a success.

Howe Caverns

Bob Addis (personal oral communication 27 May 1990) told me of an experiment conducted in Howe Caverns, New York. The radio site is located to the left of the elevator shaft about 200-300 feet (61 - 91m) in the undeveloped part of the cave. He said there was a lot of wire or chicken wire strung all over the place. The experiment may have been related to national defense prior to World War II. Any information on this event would be most helpful.

A live radio broadcast over WGY was on June 28, 1948 (Cudmore, 1990, p. 146). This broadcast commemorated the one millionth visitor to the cave. I must presume telephone cable connected to the radio studio for this event.

Wyandotte Cave

George F. Jackson (1970, p. 6; 1975, p. 26) wrote extensively on the lore and exploration in Wyandotte Cave. He reports about the first radio reception underground in a cave. This was supposed to have been either in 1926 or 1927. The radio reception site is in the south end of the cave known as the Throne and Canopy. WHAS in Louisville, Kentucky, came in loud and clear. The site is highly decorated with formations and the passage is close to the valley wall. This then is one of the criteria needed for good radio reception underground.

The radio used was a Radiola model 20 manufactured by RCA in 1925. Lauren A. Peckham (personal communication, 25 May 1990) said:

> The circuit is a tuned radio-frequency type with regenerative detector.
> The Radiola 20 set used tubes of special design (at that time) with filaments that could be operated with dry-cell batteries. This was a big advantage over storage batteries which had to be recharged and were heavy and messy.

The first radio reception was actually in Mammoth Cave. This was made on 19 August 1922 (George, 1988, p. 5; 1990, p. 6), four or five years prior to the Wyandotte Cave event.

Fishers Cave

Radio was used as part of a publicity stunt to increase visitation to Fishers Cave in Franklin County, Missouri. This occurred on December 2, 1928 (Anon. 1928; Weaver and Johnson, 1977, p. 63). Lester B. Dill had the concession at the cave, and he devised a radio-reception event to increase tourism to his cave and at the same time garner some free advertisement. He obtained a radio expert by the name of L. E. Johnson from Sullivan. About one quarter of a mile (400m) from the entrance at the Ballroom, the Johnson-Dill party received "clear, distinct reception, entirely free from static or interference of any kind," according to the Sullivan News.

Meramec Caverns

Sometime after the successful Fishers Cave radio reception, Lester B. Dill tried the same advertising stunt in Meramec Caverns (Weaver and Johnson, 1977, p. 83). He had L. E. Johnson bring his new portable Zenith radio into the cave. On a Sunday with perhaps ninety people in the cave, good radio reception was made throughout the