speleonics 10

JUNE 1988

"BETTER CAVING THROUGH ELECTRICAL STUFF"

volume III number 2

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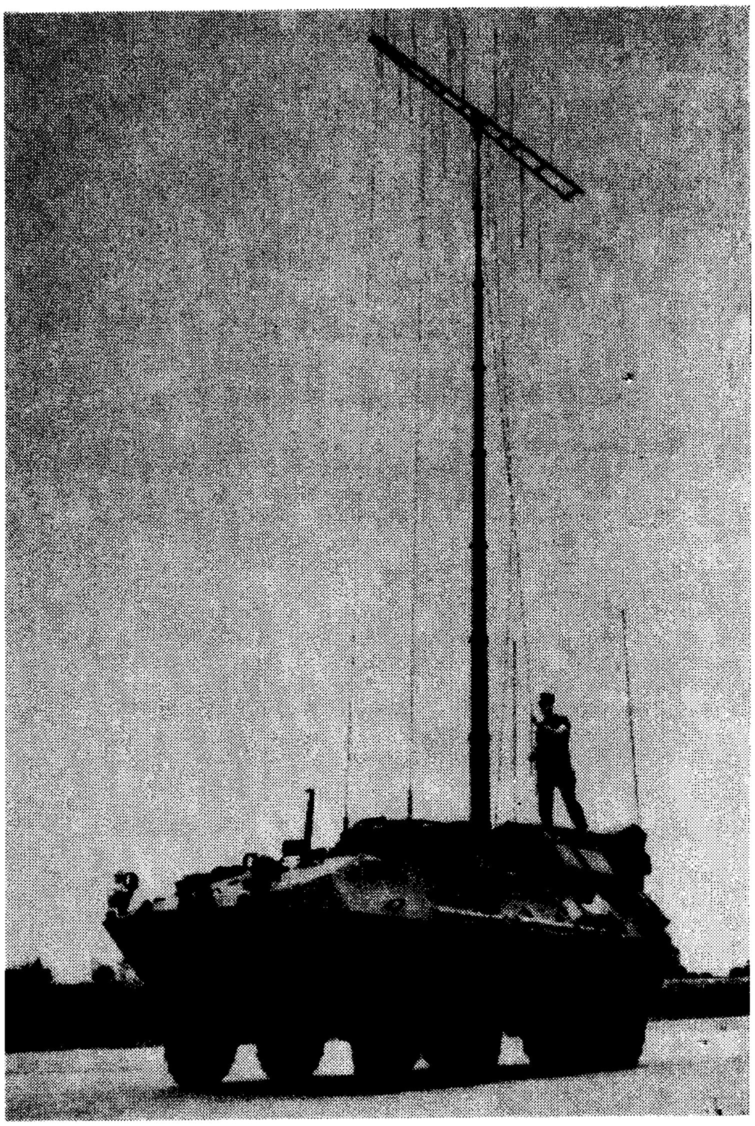

THE ULTIMATE CAVE-RESCUE VEHICLE?

Photo from an ad in DEFENSE ELECTRONICS magazine, October 1987, for GTE Government Systems Corp's "Magic Mast" mobile antenna tower. The vehicle, reminiscent of a Soviet BTR amphibious armored personnel carrier, is unidentified.

SPELEONICS 10

Volume III, Number 2. June 1988

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, $6.00 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. 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 are mailed 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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-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-= NEWS AND ANNOUNCEMENTS -=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-

CAVE RADIO FEATURED IN CANADIAN VIDEO

Ian Drummond reports that video-tape recorded during the April, 1988 expedition to **Castleguard Cave** is now being edited. Ian hopes to show the finished product at the NSS Convention in South Dakota in June. The video shows details of the cave-radiolocation process, using Ian's 2-way SSB voice equipment. The camera was taken underground in this famous cave system which extends beneath a glacier in the Canadian Rockies, and there are surface views from a helicopter. The video will eventually be available through the NSS Library, and the Communications and Electronics Section intends to make it available to our members who are not NSS-affiliated. More details later!

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CAVERS' COMPUTER-MAILING LIST GETS NEW MANAGER

Ron Lussier, founder of the 'caver net' (see SPELEONICS 9, p. 3), regrets that he is no longer able to distribute messages, due to employment change. **John Sutter** has agreed to take over administration of the Cavers'mailing list.

New mailing-list addresses:
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cavers@m2c.org
harvard!m2c!cavers : for the list

cavers-request@m2c.org
harvard!m2c!cavers-request : for admin requests

cavers-archive@m2c.org
harvard!m2c!cavers-archive : for archive requests

The new addresses allow for both **Usenet** and **ARPA** access, and hopefully will increase the membership.

From: **John D. Sutter** <jds at ODIN.M2C.ORG>

I will be maintaining an archive of the Cavers mailing list here at M2C. For the time being I will handle the archives manually but will be going to an automated server as soon as possible.

The address of the list is:

Internet: cavers-archive@m2c.org
Usenet: harvard!m2c!cavers-archive

Requests should be stated in simple terms as follows:

HELP	will return help file to user.
INDEX	will return index of articles in archive.
ARTICLE ###	will return article number ### to user.

The archive will also be available via anonymous ftp in pub/cavers-archive on m2c.m2c.org [128.188.1.2].

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NSS 29355

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PRODUCTION IRREGULARITIES

We try to publish quarterly but sometimes miss a season (a hazard of volunteer-produced newsletters). For this reason, SPELEONICS issues are numbered consecutively, and subscriptions are for a certain number of issues rather than per year. This and future issues will be dated only with the month and year of publication; some confusion has resulted in complaints that people didn't receive the (nonexistent) Fall 1987 issue.

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NSS BULLETIN PUBLISHES CAVE RADIO PLANS

The NSS Bulletin, v.49 no.1, June 1987 (received April 1988-- other publications have schedule problems too!) published "A New Radio Location Device" by **Anne and Andrew Bell** of Wales, United Kingdom. The article (previously published in UK) fully describes the "Ogof Beacon," a 38.4-kHz CW cave-radiolocation device of design different from most U.S. cave radios, and having a very successful history of operation. The name comes from Wales' famous Ogof Ffynnon Ddu cave system.

The easily-built transmitter features CMOS circuitry, crystal control, power-FET output stage, antenna coupling which accepts coils of different sizes, and a keyer circuit which is programmable for Morse-code characters (useful for identifying multiple transmitters used on a single cave trip). The superheterodyne receiver has an i-f filter made from inexpensive 4.469896-MHz crystals (the color-burst frequency of UK television). The design is adaptable to 3.597545-MHz US color-tv crystals.

A license would be required to operate the Ogof Beacon in the U.S. if its output exceeds the specifications of FCC Rules and Regulations Part 15 which apply to license-free operation between 10 and 490 kHz (reprinted from SPELEONICS 5):

> **15.111: Field strength (microvolts per meter measured at 300 meters) not to exceed 2400 / f(kHz).** [62.5 uV/m at 38.4 kHz].

An experimental license is easy to get; **Ray Cole** (NSS 12460) has studied the procedure and can provide advice.

NSS Bulletin is the scientific journal of the National Speleological Society. Copies of the 9-page article are available from Frank Reid (address in masthead) for SASE with 2-ounce postage.

--

MEMBERS MEET AT DAYTON HAMVENTION

Twelve people attended our group's first informal meeting at the world's largest hamfest, in Dayton, Ohio, April 30 (see announcement in SPELEONICS 9). Next year we intend to find a meeting place with chairs, and schedule the meeting in the afternoon so that people will have time to scout the vast flea market and record locations of items especially interesting to cavers and low-frequency experimenters. (This year, one caver bought a plane-table alidade with telescope for $100!)

Members and friends attending:

Dick Blenz	Lance Lide
Don Conover	David Martin WA4TRW
Rick Davis K8DOC	Joe Morgan
Angelo George	Frank Reid W9MKV
Diana George N9DEJ	John Sowers WB2YJN
Randy Jackson	Gary Taylor N8HRE

News and notes were shared. Interest was expressed in organizing a Midwest weekend meeting for enthusiasts in cave radio, LF, VLF, metal detectors, etc., similar to the annual events in California hosted by **Jim Ericson**, publisher of 1750 Meters: Western Update. The ideal spot would be an isolated area (away from power lines and electric fences) with caves, enough room for antennas, a picnic shelter and camping facilities, and motels within reach.

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MORE RADIO MODIFICATIONS

Danny Britton KB4TEP has sent instructions for out-of-band modification of the **Kenwood TH-215A** 2-meter handheld transceiver, expanding our file of similar information (see SPELEONICS 9). Copies are available from Frank Reid for SASE.

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REPRODUCTION OF SPELEONICS ARTICLES

Caving publications are traditionally not copyrighted (SPELEONICS authors may copyright their work if so desired). Our purpose is to spread information; we are honored when other newsletters reprint articles. Unless otherwise noted, material originally published in SPELEONICS may be reprinted without prior permission, provided that the author is credited and SPELEONICS is identified as the source. The editors would appreciate receiving a copy of the reprinting publication.

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SUBSCRIPTION COST HELD CONSTANT

The April, 1988 increase in US postal rates has not destroyed our budget, since we currently enjoy economical printing arrangements. We presently plan NO increase in subscription costs, though it will probably become necessary someday. Members may, of course, extend subscriptions for any number of future issues at current rates.

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SECTION LOGO REVISED

Our "Better Caving Through Electrical Stuff" emblem ('borrowed' from an ad in a very old electronics trade-journal) has been modified. **Diana George** added artwork to make it more "cavey" and further symbolize connection.

LETTERS

...What? No FAX for the Communications Section!

Graeme Pattison
58 Mary Street
Leichhardt, NSW 2040
AUSTRALIA

We've thought of making SPELEONICS available by electronic transmission via computer bulletin-board, TCP-IP, etc. Facsimile transmission (FAX) would allow easy transfer of pictures and diagrams. What FAX formats are our readers equipped to transmit and receive?

Don Lancaster says in his "Hardware Hacker" column in **Radio Electronics**, May 1988, p. 71: "PostScript is new industry-standard page-description language that is also making strong bids to become a screen-description standard, a fax standard, a BBS graphics-interchange standard, a sign-making and engraving standard, and even a printed-circuit layout standard." For more information on PostScript, contact Don at Synergetics, Box 809, Thatcher, Arizona 85552. tel: (602) 428-4073.

Don gave SPELEONICS a nice mention in the same issue-- THANKS!

--

Dear Frank!

The last Speleonics was very interesting and I have to write something about it. First, the avalanche beacons only work up to 130 feet distance and only in an environment without electromagnetic noise. Three brands are available here. The Ortovox, which you know, is Swiss made and the best one. The Austrian Pieps 3 is now nearly as good. The third is the Mips; it is very cheap and small and comes in two parts-- The transmitter works alone, the receiver module works only in connection with the transmitter. Each part of the Mips is about twice matchbox size. The Ortovox has an accessory called Visovox which contains a VU-meter for using in loud environment (helicopter!). All the others work only with earphones... The Austrian mountain rescue has several large receiving units which have more sensitivity, called the Pieps Langohr (long-ear).

Swiss cavers used avalanche beacons for finding the third entrance of the Holloch. The reason for the double frequency, which all the new ones have, is that it was not possible to decide between the Austrian (2275 Hz) and the Swiss (457 kHz) frequency; there is no technical reason for it.

The Yugoslavians developed a unit many years ago which transmitted at a broadcast frequency. A standard broadcast receiver was used for search. These units were never mass-produced.

Many years ago, a unit was developed which transmitted a different signal on the Pieps frequency and was intended to be used as a "shelter sniffer" in misty weather (a standard situation in our mountains). The signal was transmitted by a long wire loop or a long wire (up to 2.5 miles) which had to be laid in the hut's environment and leading to the hut. The tourist, who has his Pieps with him, switches to Rx and follows the "electronic trail" to the hut. I know no case where this thing was used. One problem is, you have to switch your unit to Rx and so have no avalanche protection for this time. Avalanche beacons are well known in Austria. I have one and I know a lot of people having one or more. It is also possible to rent them cheaply at the alpine clubs. Their use (not so easy as it seems, for efficient operation) is taught at the alpine courses and club meetings.

In your article about the Mini Maglite is a wrong unit conversion (the terminal measurements). Is it possible to use both unit systems in every article? I always prevent bad contact with contact-grease (available in car outfit stores).

Batteries have no date codes here. Duracell is made in Belgium.

Wristwatch bulbs are available here for $1 a package of 5. They are not made for 1.5V because they are a relatively high load for the tiny wristwatch batteries. They are made for 1.2-1.3V and have a current of 10-15mA.

About "Taking Data Underground": I had a similar idea many years ago, but I wanted to use readily available Morse or RTTY de/encoders wth a low frequency transceiver. The Morse system has the advantage that if one unit fails partly, it is still possible communicate if someone knows Morse.

About the slave-flash article: I have a lot of experience with slave-flashes and built many of them. The voltage at the trigger terminals can be up to 150V and is very sensitive to humidity. I always use a small thyristor instead of the transistor. Often the flash's power supply is reversed in polarity from the high voltage, so the power supply shown in the circuit is not possible without additional battery. I always use the voltage at the trigger terminals for the release unit, but you have to remove the LED and decrease the capacitor from 6.8 uF to 0.68 uF. For cave photography it will be an advantage to have more than one photocell in different directions. I want to make a special hardhat with a built-in flash unit and several (3-4) photocells around, so it will be possible to use inexperienced people or other cavers in situations where both hands are necessary. It also will give a natural way of illumination, like a headlamp.

I've bought a new gasmantle-kerosene pressure-lamp. It works excellently on Diesel fuel too. It's made in Germany and very nice. The whole lantern is made from brass and polished. It has light output like a 100 W bulb and heat output of 500 W. It weighs less than 3 pounds and is one foot high. One gallon of kerosene lasts for 84 hours, or 70 for one of Diesel. It has built-in rapid priming, so no alcohol is needed. A pressure gauge and a deflate screw are built in too. It will be a nice heat source for a Silent-Generator [thermoelectric generator]. I used it for making coffee (of course real coffee, not the so-called brown water sold in the States) with an Italian coffee-machine. Have you ever thought of a Stirling engine with generator driven by such a heat source, or other?

I've seen in an electronics magazine a device for an automatic radio repeater which needs only one transceiver unit. It fits into the mike-plug and contains a digital memory for 10 seconds of sound. So the unit switches at least every 10 seconds between Rx and Tx, on the same frequency. It is very small, about the size of a cigarette pack, I think. Here it costs $150. The digital speech store alone costs $24 and is able to store 16 seconds of sound in a 256k memory.

I've bought 10 electronic thermometers in Munich. They have a resolution of 0.1° (C or F) and cost $12. They have one sensor built in and one on a 10' wire. It will be very nice for observing a rescue victim's body temperature. The size is about twice a matchbox. There is also a model available which has an alarm with adjustable threshold, and minimum/maximum memory.

There is a new Portasol butane-powered soldering iron available. It's called Portasol Professional and comes with 4 different tips: a standard soldering tip, a hot-air gun, an open flame, and a hot knife. I've used mine (standard) very much. It's now my favorite soldering iron (not only outdoors).

I've found an article in an electronics magazine about a dissertation called Underground Radio Waves written in the sixties. Their longest distance was about 8 miles underground between two mines! They used a 53' x 53' square antenna. They also made experiments with receiving the time-signal transmitter near Frankfurt, W. Germany, on 77kHz.

Good caving and dark moments,

Peter Ludwig
Gfollnerstrasse 6
A-4020 Linz
AUSTRIA

[The Austrian government subsidizes organized sports. A tax on commercial caves helps support caving clubs.(!) Peter procures equipment for his caving club. He plans to attend the NSS Convention again this year, and present several talks on European caves and caving techniques. Copies of the abovementioned 7-page German-language article, "Radiowellen Under der Erde" by Dr. Norbert Nessler, are available from Frank Reid for 2-ounce SASE.]

-=-

CAVE-RESCUE COMMUNICATIONS SECURITY

Frank Reid NSS 9086, W9MKV

Development and evaluation of equipment and techniques for cave-rescue communication is an ongoing project of the NSS Communications and Electronics Section.

Cave rescuers seek to avoid publicity because reporters aggravate crowd-control problems and because even the most favorable news report can cause owners to close caves for fear of liability.

Communications security during a rescue is essential to prevent bystanders' drawing erroneous conclusions from fragments of conversation. Radio procedures vary among U.S. cave rescue groups; some are licensed to use emergency frequencies, others rely primarily on amateur (ham) radio.

Problems have occurred when well-meaning hams alerted news media about rescues, seeking the recognition for public service upon which ham radio thrives. A positive solution is to present a program on cave rescue to your local ham club, stressing the need for low-profile operations, after which you will strongly praise the hams in any news interviews. The best situation exists where the cavers are the local hams, thus are familiar with both worlds.

Radio is intrinsically nonprivate. A few simple procedures will minimize eavesdropping. (Of course, communications security measures must not interfere with the primary goal of the rescue.)

Basic:

1. Avoid Citizens' Band (CB) radio.
2. Use telephones instead of radios whenever possible.
3. Use earphones or headsets.
4. Keep radios hidden under clothing except when expedient to use them as badges of authority.
5. Use minimum antennas and power necessary for on-site communication.
6. Keep frequency readouts covered.
7. Tactfully decline to disclose frequencies to reporters.
8. Do not broadcast names and locations unnecessarily.

Advanced:

1. Change frequencies by pre-planned agreement, e.g., code words injected into conversation. (This may confuse inexperienced operators, and is not strictly legal on ham radio.)

2. Use frequencies and modes unlikely to be intercepted by scanners, e.g., packet, SSB, 220 MHz. Many scanners will not receive the portion of the 2-meter ham band below 146 MHz.

Packet-radio data communication can send relatively secure, error-free written messages for hundreds of miles. Packet has great potential for cave-rescue communications between the rescue site and the outside world. Scanner enthusiasts and news media are unlikely to have the equipment necessary to decode packets. Packet technology and networking are still evolving. Computers used with packet radio are ill-suited for the battlefield-like cave rescue environment but the annual ham radio Field Day contest has proven that packet radio is viable under field conditions.

Reporters are unavoidable if professional emergency services are involved. Reporters will concentrate their listening on well-known police, fire and ambulance frequencies, and cavers can coordinate the rescue with their own radios, selecting from the thousands of channels on VHF and UHF ham bands.

In a long-duration rescue, long-range portable or mobile ham equipment may be brought to the staging area or nearby shelter. Alternatively, a fixed station within VHF range may provide long-range communication. Autopatch repeaters, which provide access to the telephone system via radio, have proven invaluable in numerous cave rescues. Although not routinely monitored by the press, they are perhaps the least private form of ham communication. Most autopatches disallow long-distance calls; rescue pre-planning should consider availability of manually-operated phone patches for interconnecting radios and telephones.

EARLY RADIO EXPERIMENTS IN CAVES

Angelo I. George, NSS 7149F *

When radio was still new in the households of America, commercial radio stations were pushing the frontier in radio transmission and reception. The limits of radio broadcasting were not known nor was there a practical understanding as to why certain geographic areas could not receive radio transmission. These areas, called "dead spots" were an embarrassment to radio stations; there were communities just 90 miles (144km) south of Louisville, Kentucky, that could not receive even the carrier of Louisville station WHAS (Harris, 1937, p. 239, 241). Experiments and media events conducted in Mammoth Cave by WHAS furthered understanding of the limitations of early radio use in caves. radio use in caves.

Since the time of William Gilbert (c. 1600) with his theory of magnetism in De Magnete, we have known that magnetic lines of force are transmitted through the earth. Nathan B. Stubblefield in 1892 and Nikola Tesla in 1893 experimented with low frequency radio transmission and reception. Tesla's associates through U. S. Supreme Court action ruled against Marchese Guglielmo Marconi's 1895 invention, and credited Tesla as the inventor of radio.

In the early 1890's, Tesla was experimenting with ground-to-ground transmission and reception with a device he called "the wireless telephone - or simply wireless - and later by its modern name, radio" (Cheney, 1981, p. 62). Tesla said, "I had produced a striking phenomenon with my grounded transmitter...and was endeavoring to ascertain its true significance in relation to currents propagated through the earth." Tesla's experiments and the evolution of induction cave-radios are clearly connected.

When Alexander Graham Bell invented the telephone in 1875, speleologists quickly applied it to underground exploration. In 1889, Edward A. Martel and "...Gaupillet were the first to use telephones in cave[s]..." (Shaw, 1979, p. 61). Martel showed the practicality of using these devices in pit caves over 300 feet (91m) deep. The telephone and wires connecting to the outside were used for early radio broadcasting from Mammoth Cave and Great Saltpetre Cave.

The first radio broadcast station, KDKA in Pittsburgh, went on the air on November 2, 1920. WHAS, Louisville, Kentucky, began broadcasting on July 18, 1922.

Harris (1937, p. 243) describes an early and probably the first attempt to receive radio transmission underground. He says there "had been speculations expressed in a scientific radio magazine concerning an electromagnetic wave's ability to penetrate the earth but, no cavern being handy, field experiments lagged - except for a try by a New York broadcaster to reach inside the subway, which did not turn out convincingly."

On August 19, 1922, one month after WHAS started broadcasting, someone though of trying to receive radio signals in Mammoth Cave. The first successful test was conducted in Roosevelt's Dome, 195 feet (59m) underground. A radio was placed in the cave by the Radio Equipment Company of Cave City. WHAS and "some of the large Eastern stations were heard plainly."[1]

The second and often-quoted "first" radio reception took place in Mammoth Cave on July 21, 1923. Variation on this date often appears in print as July 19 or July 23. Inspection of primary documentation could resolve this discrepancy. Fred G. Harlow, junior operator for WHAS, W. A. Mivelez (a volunteer assistant from Louisville) and a Mammoth Cave guide were present for this historic occasion. The object of the experiment was to establish if radio waves can penetrate great depths into the earth and to better assess the concept of dead spots.[2] The newspaper article says a "tentative experiment was made last fall by testing signals while going through a tunnel on the L. & N. road. It was impossible to determine accurately in this experiment, however, due to the possibility that the signals, which were received distinctly though with reduced volume, might have followed the train through the tunnel mouth instead of penetrating directly through the soil above."

The radio apparatus used in the Mammoth Cave experiment "...consisted of a non-regenerative type of receiver with one stage of radio frequency and two stages of audio frequency amplification. The tubes consumed a filament current of three, and a very low amperage consumption rate (sic). A two-foot loop holding forty feet of wire acted as the aerial, and the ground was a three-foot iron bar to be driven at desired places."[3] A compass was also used to orient the loop antenna.

Experiments conducted in the Rotunda failed. Lack of moisture in the cave soils for good contact of the ground probe was deemed responsible for the failure. The team went about a mile upstream on Echo River from the Dead Sea. They put their ground probe in the river. They received the carrier from WHAS, but could not discern the audio. This time, too much water was deemed the problem. They walked another mile and found a moist spot on the ground, where they set up the equipment again. At 4:00 p.m., WHAS went on the air and the cave radio team could clearly hear Credo F. Harris announce, "This is WHAS, the radiophone broadcasting station of the Courier-Journal and the Louisville Times, at Louisville Ky. WHAS, at Louisville, Ky., is sending out its usual afternoon concert." Depth of this spot was presumed to be 370 feet (113m) and over a mile (1.6km) from the Historic Entrance.

The fourth and often-quoted "second" radio reception occurred on July 14, 1924. By this time, interest in listening to the radio inside Mammoth Cave became a tourist event. The Courier-Journal, Louisville Times newspaper and WHAS used all the hype at their disposal to generate publicity. They rented a special train and allocated 150 tickets for those wishing to attend. This included a round-trip train ticket, two box lunches, and the trip into the cave to listen to the radio. The Radio Special, as it was advertised, "to the cave, will be the first persons to attend such a public demonstration of the weird power of radio."[4] Members of the Radio Party "will be the first persons, other than those who conducted this test, to hear a radio program that will have literally burrowed its way 370 feet through rock and earth to the banks of Echo River, in the depth of Mam-

* 1869 Trevilian Way
Louisville, Kentukcy 40205

moth Cave."[5] A special bronze commemorative tablet is to be dedicated on the spot of this "first" radio reception.

During all this hype, Mammoth Cave competitor George D. Morrison upstaged the Radio Party event. The Louisville Herald reports on July 17, 1924, of radio reception at the New Entrance (Frozen Niagara) to Mammoth Cave. In a place now called the Radio Room, radio reception, "was successful when a party of forty persons, with C. M. Caldwell, manager of the Radio Equipment Company of Cave City, Ky., took a super heterodyne type receiver 360 feet beneath the surface and clearly heard WDAP Chicago, WHAA Iowa City, WOS Jefferson City, and WLW Cincinnati... A remarkable feature was the fact that no antenna was used."[6] This same type of receiver had been "used in a successful experiment in the Hudson River tunnel, New York City."[7] This becomes a double triumph for the Radio Equipment Company, because this company had achieved the first radio broadcast reception in 1922 at Mammoth Cave. The Courier-Journal and Louisville Times did not report this event in their papers. WHAS was owned by that newspaper organization and they were promoting their own event. Balanced journalism was achieved by the Louisville Post and the Louisville Herald.[8] Cave promoter George D. Morrison stole some of the thunder from WHAS's media event with this third known broadcast reception in a cave. Everyone with the exception of the Mammoth Cave management seems to have forgotten the 1922 event.

The Radio Party Train Special with 5 rented cars left Louisville at 8 A.M. for the 4 P.M., July 19, 1924, historic re-enactment of the "first radio reception". Kenneth S. Bixby used his own 10-tube radio set with a speaker for this event.[9] The party would break into six separate groups, tour the cave and visit the spot on Echo River where the actual event occurred a year before. The actual broadcast radio reception would take place in the Rotunda to an audience of 272 persons. An outline of the complete special radio broadcast is found in the Courier-Journal article on July 20, 1924. The commemorative tablet reads:

AT THIS SPOT
JULY 21, 1923
WAS HEARD
FOR THE FIRST TIME IN
MAMMOTH CAVE A VOICE
BY RADIO TRANSMISSION

BROADCAST FROM
WHAS
THE COURIER-JOURNAL
THE LOUISVILLE TIMES
LOUISVILLE

The 1925 Floyd Collins entrapment in Sand Cave does not belong in the category of cave communication. A shortwave 500-watt radio transmitter (call letters 9BRK) was used outside the cave to communicate with a base station (9CHG) in Cave City (Murray and Brucker, 1979, p. 154). H. E. Ogden directed the ham operation for a short time. The transmitter was not taken into the cave, nor was a microphone. Remote broadcast of tragedy was gaining popularity, for example, the terrible destruction of the Hindenburg with Herb Morrison's eyewitness announcement of the disaster.

The Rothrocks of Wyandotte Cave fame were soon to follow in another epic garnering "first" radio reception in a cave. A photograph in George F. Jackson's book, The Story of Wyandotte Cave shows Jackson (tuning the radio) and three other men. The cut line reads, "This 1926 or 1927 photo at the Throne and Canopy shows what was said to be the first radio reception received underground in a cave. Reception was excellent from WHAS, Louisville, Ky - about 40 air miles [64km] distant."[10] Clearly, the 1922 Mammoth Cave radio reception was the first of its kind.

Between newspaper hype and cave-promoter competition for having the "first" radio reception in their caves, there was actually some very qualitative research on radio communication going on in Mammoth Cave. Classic studies of induction cave-radios and geophysical resistivity surveys at Mammoth Cave begin with experiments by Eve and Keys (1931), Eve, Keys and Lee (1929) and Eve (1930). The experiments were conducted in June 1929, to establish how a propagating electromagnetic wavefront would be received in a cave. This has profound practical and scientific applications in the geophysical search for valuable minerals. A transit survey with vertical control was made from the Historic Entrance to the entrance of Echo River, Mammoth Dome and Little Bat Avenue. Four problems were addressed in the experiment:

Problem 1 established that radio waves in the broadcast range do penetrate the earth. They used a 1925 RCA model No. 26 Portable Radiola superheterodyne, six-tube set with a small loop antenna. In Mammoth Dome they were able to receive WLW from Cincinnati. Thin overburden (70 feet; 21m) and the presence of the sinkhole above the dome led Eve and Keys to say "no doubt the waves were coming through the sides of the sink to us underground near the top of the Dome." [11] Experiments of this nature were also conducted in the entrance to Mammoth Cave. They also went to Bowlegged Bridge beyond River Hall; by stretching a 300-foot [91m] aerial they were able to receive "admirable reception with loud-speaker broadcasting of speech and music from Cincinnati [WLW] and from Nashville [WSN]."[12]

The second and third problem were more quantitative. For these experiments they used a Model RE Low Frequency Receiving Equipment. One question centered upon wavelengths in the range of 17 to 20 thousand meters, or 15 kHz. They were able to receive code messages from ships at sea or across the Atlantic. Static prevented clear reception. A station in Long Island was loud and clear. A properly-oriented vertical loop produced better results than a horizontal loop on the floor. Reception was poorer as the coil neared the damp cave floor.

The third problem was "to compare by actual measurements the relative intensities of the effects, 300 feet (91m) down in the cave, from a current in a horizontal loop above ground, using frequencies 20, 30, 40-100, 110 kilocycles."[13] Using a 40 x 10 foot (12 x 10m) rectangular coil of 3 turns with one side of the coil grounded, they were able to establish clear reception in the cave at 15 and 108 kHz. Poor to very weak reception was made in the range of 35, 65 and 95 kHz. Of this problem, they said "the work this year was to some extent of a pioneer character."[14]

Problem 4 was the watershed experiment that showed the practicality of cave-radio surveying. The object of this investigation was to assess the ability of "penetration of rock using alternating current of audible frequency (500 cycles a second) in a horizontal loop on the ground."[15] Surface equipment consisted of a 500-Hz generator producing 2.35 amps, powered by a gasoline engine. The current was passed through a 100-foot diameter (30.5m) horizontal loop with 10 turns of wire, at a point 303 feet (92m) above River Hall. Equipment used in the cave consisted of:

> Pittsburgh coil, 2 feet by 3 feet [61 x 91 cm], 400 turns, mounted on a transit tripod, so that azimuth and dip could be measured. With this apparatus it was possible to verify the survey of the cave, as the coil, when exactly below the centre of the loop, would give no signal to the head phones when the coil was upright and rotated about a vertical axis.
>
> ..Indeed a coil of this character could be used for surveying purposes to replace the compass when local magnetic disturbances prevent the use of a compass survey.
>
> Clearly, with only a coil and headphones used underground, it would be easy to read code messages from a loop laid on the surface, with a few amperes passing through it. The question of signalling back to the surface is a more difficult one, however. Both theory and experiment indicate clearly enough that the audio frequency electromagnetic effects, whether we deem them due to inductance or radiation, pass through great thicknesses of rock with little or no absorption.[16]

Myers summarizes some of these experiments:

> Conclusion from this and other similar test show that absorption is high with short waves of less than 100 metres wavelength. Better results are obtained with wavelengths in the 400 to 1000 metre range, and wavelengths of over 1000 metres appear to be absorbed only slightly.[17]

These experiments represent the first communication and radiolocation of a position in a cave, and establish that the signal is propagating through the rock and not from a cave entrance along the twists and turns of a cave passage. If electrical generating equipment had been portable enough, true cave-to-surface communication and surface location could have been made.

History after this point has forgotten Eve, Keys and Lee's accomplishments. Their published works in the Canada Department of Mines, Geological Survey publications are tedious in technicalities and would make for poor comprehension to the cave guides and their charges touring Mammoth Cave. Being able to listen to WHAS was more thrilling than induction coil experiments. To these pioneers go the first practical cave-radio concepts that would not be again experimented with until McGehee (1954, 1955), Lord (1963), Mixon and Blenz (1964), Charlton (1966), Birchenough (1970) and many others.

J. Wallace Joyce (1931) conducted geophysical experiments to determine the "Electromagnetic absorption by rocks, with some experimental observation taken at Mammoth Cave of Kentucky." [I have not seen this item]. Mammoth Cave management was encouraging original research in their cave; even so, it was easier to bring in another radio for the public to witness the wizardry of modern electricity.

On March 3, 1931, a Columnaire receiver was lowered by rope to the base of Mammoth Dome for a "tough test" publicity experiment conducted by Westinghouse Electric Company. This was one of the best radio reception points established by Eve and Keys in 1929. The "tough test" was designed to reach a submarine off Panama, the Goodyear blimp "Volunteer" flying over Hollywood and deep inside Mammoth Cave.[18] The broadcast was to originate from station KDKA Pittsburgh through affiliates CBS and WHAS. W. P. Short, an engineer with Westinghouse of Newark, New Jersey, was in charge of the experiment. Twenty-five people were in Mammoth Dome to hear the broadcast.[19] The radio for this experiment was provided by Tafel Electric Company of Louisville.

The biggest event in the history of radio broadcast from caves is the first public radio broadcast from Mammoth Cave. The 2:30 p.m. broadcast from inside the cave was to commemorate the official opening of the Historic Entrance to Frozen Niagara tour on July 8, 1935. WHAS installed 2 miles (3.2km) of wire in the cave to a bandstand constructed in the Snowball Dinning Room. Another 2 1/2 miles (4km) of wire outside the cave went to the closest place where the wire could be patched into the telephone line.[20] Equipment from three different telephone companies was used for this event. This feat is described as "the first American broadcast originating below the surface of the earth..."[21] The dedicatory group consisted of 40 superluminaries responsible for making the new tourist trail connection possible. WHAS provided their chief engineer, J. Emmet Graft, and his technician, Karl Schmidt. Dudley Musson and Hugh Sutton were the announcers.

Another early commercial radio broadcast occurred on July 27, 1941 at 3:00 p.m. from Great Saltpetre Cave, Rockcastle County, Kentucky.[22] John Lair's Renfro Valley Barn Dance, an early radio competitor of the Grand Ol' Opry, made the second known remote-broadcast from a cave. WHAS made broadcast arrangements in the cave, and probably used a telephone circuit as in the Mammoth Cave dedication in 1935. A new feature player was introduced on this broadcast; John Jacob Niles, the Bard of Kentucky with his dulcimer made his Barn Dance debut.

CONCLUSION

The first cave radio reception occurred on August 19, 1922, in Mammoth Cave. Since then there are six separate events of this nature in Mammoth Cave and one in Wyandotte Cave. The first remote commercial broadcasts was in Mammoth Cave was on July 8, 1935. A second remote broadcast occurred in Great Saltpetre Cave on July 27, 1941. Both of the transmissions used telephone lines to WHAS's transmitter in Louisville. At present, I know no pre-1940 example of true commercial or experimental radio transmission from a cave. Pioneer induction-radio work by Stubblefield and Tesla needs further investigation. Induction experiments in Mammoth Cave showed that cave-to-surface transmission was possible in 1929. We had to wait for the work of McGehee (1954) and Lord (1963) before practical voice/signal transmitters and receivers were shown to work underground.

I welcome any additional early cave radio reception or transmission information. I am especially interested in the New York Subway and Hudson River Tunnel experiments. The Mammoth Cave and Wyandotte Cave radio reception indicates this was a fairly popular thing for entertaining tourists and generating publicity for the commercial caves and radio stations. Other eastern commercial caves