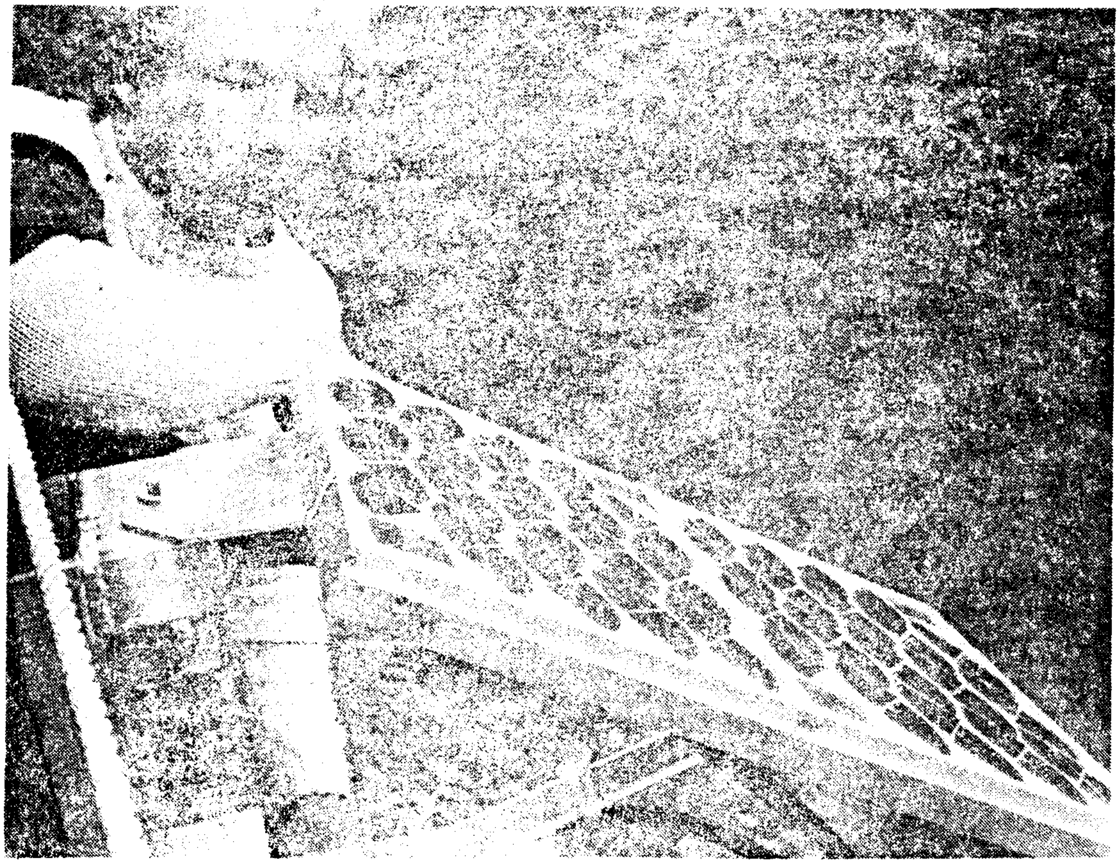
speleonics 7

SPRING 1987

"BETTER CAVING THROUGH ELECTRICAL STUFF"

volume II number 3



SOLAR POWER AT A CAVE RESEARCH FIELD STATION

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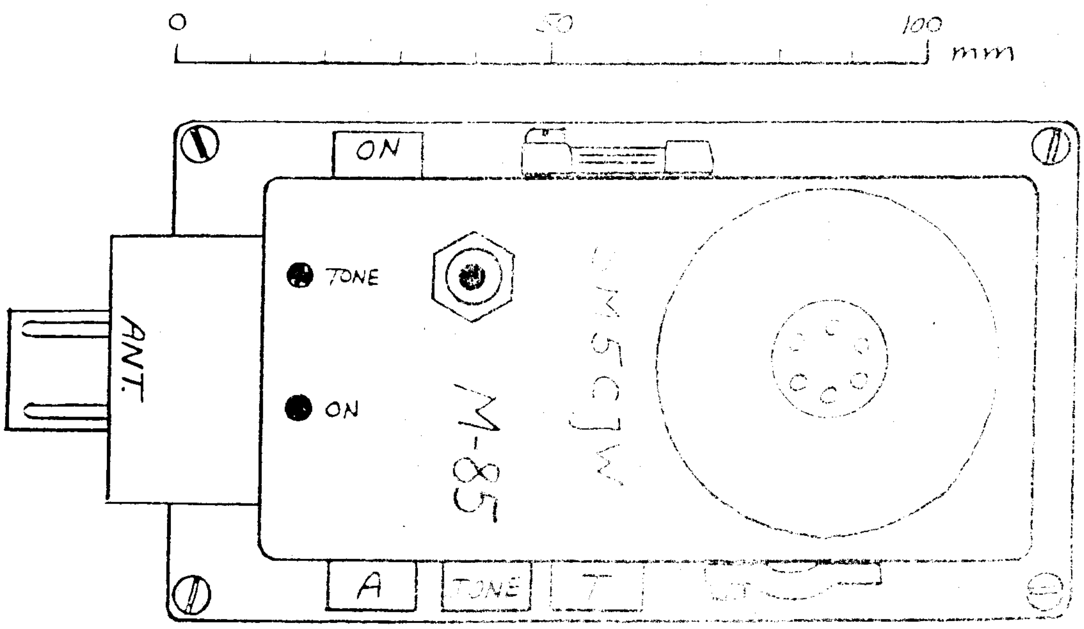

DOUBLE-SIDEBAND VOICE CAVE RADIO TRANSCEIVER FROM SWEDEN

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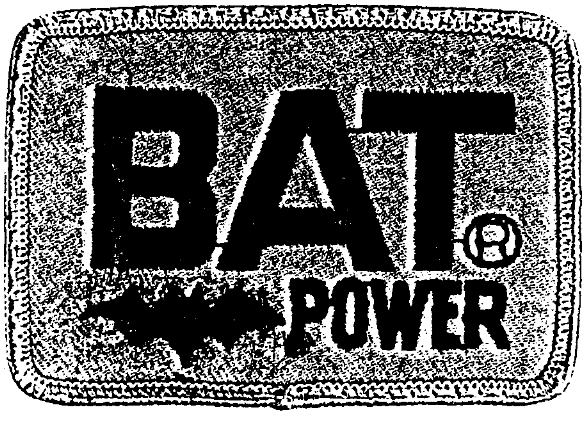

Modified "CAT DIESEL POWER" patch

(originator unknown)

ANNOUNCEMENTS

Information Wanted: CAVEMOBILE ELECTRONICS

Many cavers spend more time travelling to and from caves than they spend underground. If you have unique ways for making this most dangerous phase of caving safer or more pleasant, please write an article or send a letter to the editor. We'd like to hear about radios, sound systems, lights, radar detectors, navigation, heaters, coolers, auxiliary power systems, anti-theft systems, also ingenious nonelectric devices or strategies (tools, safety equipment, ways to hide valuables, etc.).

ERRATUM

We apologize for omitting **Mexico** from the list of countries represented by our foreign members [SPELEONICS 6].

COVER

(Top): **Dave Zoldoske** inspects the photovoltaic array that powers radio, cave telephone, and instrumentation at the Cave Research Foundation's study site at Lilburn Cave in Kings Canyon National Park, California. The installation is 130 feet up in a fir tree. [See article by **Howard Hurtt**]

(Bottom:) Swedish caver **Bo Lenander's** 32-kHz double-sideband cave radio (top view, actual size). The 6.4cm-thick unit contains the battery. Complete plans in this issue!

LETTERS

Dear Frank, 87-01-20

...Julian Coward and myself are about to make some more ASS Cave Radios [SPELEONICS 5], so we will be getting a batch of PC boards made-up. We will sell extra sets at cost, so if you know of anyone who is interested, tell them to write.

I tested my "giant" antennas last weekend. Using 10 watts PEP, we were able to get two-way speech between two points on the surface, one 480 m above the other with 1100 m separating the two sites. The 13 m square antennas are not moveable, of course, so there was no rotation to try and get an optimum orientation. We just slapped them down and turned on. I am hoping to try them in Castleguard this spring. We can get about 550 m depth at one point in the cave. At this range and frequency we will have lost the classic directional properties of the magnetic field, so the giant antennas are only of use for communication and not for surveying.

Ian Drummond
5619 Dalwood Way NW
Calgary, Alberta
CANADA T3A 1S6

Dear Ian, 28-Jan-87

As you know, I have been interested in the development of reliable and "idiot-proof" cave radio systems for over 20 years, but it is only within the last 10 years that advances in microelectronics have resulted in the availability of small, light-weight and cheap integrated circuits for use in low frequency magnetic induction two-way speech systems.

While working at Lancaster University in the 1970's, I collaborated with... Bob Mackin to design and build a prototype SSB system operating at 102.4 kHz, and generating 10w of transmitter power. We used 12-way ribbon cable, mounted on collapsible X-shaped perspex frames, to give 1m by 1m square loop antennae, for both underground and surface sets. We experimented with this equipment, which we called the SPELEOPHONE, mainly in the Gaping Gill system, and found that the range for both speech and tone... was in excess of 350 feet, except where the surface was covered with an appreciable (10m) thickness of peat bog and glacial drift. This reduced the range significantly, to about 100-150 feet, due to the relatively high conductivity of the boggy ground cover... The other major limitation on range that we found was the occasional very high level of LRF signal we encountered with the surface set, particularly when operating on top of the limestone benches in certain south-westerly facing Dales. We never positively identified the source of the interference, but assumed it to be some sort of aircraft navigation beacon system, or VLF radar. The curious feature was the way the shape of the valley appeared to focus the interference, almost as if the valley was acting as half a horn antenna!

In the late 70's, Bob Mackin and I parted company... He was grant aided by Yorkshire Television to produce a version of the Speleophone for use by cave divers, to enable Geoff Yeadon and Oliver Statham to talk to the surface, and their position followed on the surface, while they completed the Kingsdale Master Cave - Keld Head through dive. The dive was filmed by Yorkshire Television as it happened, and later broadcast as "The Underground Eiger." ...We never published any details of the Speleophone, other than a brief abstract in the Proceedings of the 1977 Sheffield ISU Conference.

Subsequently, Bob Mackin moved to the Engineering Department at Lancaster, and enlisted their aid to further develop the system and market it, under the name of the MOLEPHONE. This, I am told, can be purchased from the Engineering Dept, for 1300-1400 Pounds + VAT, for a pair of sets, batteries and loop aerials. At this price, only the grant-aided Northern Cave Rescue Organizations have been able to buy it. However, both the Settle-Ingleton CRO and the Upper Wharfedale Cave and Fell Rescue Organization now have several systems each, and use them regularly both on practice and actual rescues. I am told that the equipment is so ruggedized and reliable that it is taken for granted, and that the rescue teams have pre-prepared lists of correlated surface and underground locations for all the major cave systems in their respective areas. There is no doubt that the Molephone now regularly plays an important and time (and life) saving role in cave rescues in the Yorkshire Dales.

I know of three recent British expeditions which used... cave radios. Two were cave diving expeditions to Greece and Norway, both made in 1985, and documented in the Cave Diving Group Newsletter No. 78, January 1986. Filmed reports of both were shown on TV in this country late last year. The third expedition was last summer's CRO/Army visit to the Gouffre Berger and the Scialet de la Fromagere. I... will enquire as to what use was made of the Molephone during the expedition.

As far as I am aware, no use is being made in Britain of cave radio techniques for data transfer from underground equipment or for measuring ground conductivity.

In May, June and July 1986, 3 parts of an article describing the TROGLOGRAPH, a CW cave radio system transmitting at 3.2768 kHz, and designed by Mike Bedford, appeared in the British hobby electronics magazine ELECTRONICS TODAY INTERNATIONAL, published by Argosy Specialist Publications Ltd., 1 Golden Square London W1R 3AB. I contacted Mike through the editor, and found that he was a microelectronics software/hardware engineer working... on CAD graphics display terminals... We have met several times since then, and I have given him copies of all my articles etc., together with SPELEONICS Nos. 1-6. He is trying to re-create your A.S.S. system using ICs currently available in Britain, and operating at the Molephone frequency... We hope to commence prototype tests sometime this year. In particular, we want to examine the spectrum in the 100-200 kHz band to find the frequency with the least RF noise consistent with acceptable attenuation through limestone with 5-10m bog and drift cover, and to experiment with ribbon cable loop antennae to find a design giving a depth range of 200m+ without being too cumbersome. We will keep you posted...

One of the problems we face in this country which does not appear to trouble you so much in North America is one of licencing. It took me a lot of time and a visit to London to get even a develop-

(**LETTERS** continued)

ment licence for the Speleophone, and I do not know what licencing arrangements are necessary for the Molephone. Once I find out, I will let you know so that the details can be published in Speleonics. In addition, I will try to get a general article published in the BCRA Caves and Caving Bulletin mentioning Speleonics, and requesting all interested British cavers to get in touch with you and I and suggesting they become subscribers. We might end up with our own specialist BCRA Communications Section!

Regards,

Dick Glover

258 CROSS FLATTS GROVE,
BEESTON,
LEEDS LS11 7BS.
United Kingdom
Phone: (0523) 701062

[Sidebands of the 100.0-kHz LORAN-C navigation system (see SPELEONICS 5) might cause interference. The LORAN transmitter nearest the British Isles is in West Germany. There are 14 LORAN stations in continental US (more are planned) and 11 in Canada and Alaska. --F. Reid

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Dear Frank,

Thanks for the Smart Compass plans [see SPELEONICS 6]. I've ordered one of the coils to experiment with. I disassembled the code and found out how it works: T and L are sin θ and cos θ. They are divided in software to give tan θ over 0-45°. An arctan is done via table lookup, corrected for quadrant, and displayed. The accuracy is ultimately limited by the coil winding accuracy (i.e., T & L are exactly 90° to each other). To get sub-degree accuracy will require a better A/D and bigger arctan lookup table, but that's easy. I'll keep you posted.

Jim McConkey

7304 Centennial Rd.
Rockville, MD 20855

Someone requested information on WWVB receivers. We lost the letter, but here are some references:

WWVB is a time/frequency-standard station operated by the National Bureau of Standards at Fort Collins, Colorado. The 60-kHz frequency is relatively free of propagation-anomaly errors. Time information is digitally encoded; see [2] below:

1. "A WWVB 60 kHz Frequency Comparator Receiver" by Ernest P. Manly appared in 73 Magazine, Sept. 1972. The now-obsolete RTL integrated circuits in this design can probably be replaced with CMOS. It's similar in function to the Hewlett-Packard 117A VLF Comparator but has no phase-locked oscillator output.

2. Don Lancaster published plans for a 60-kHz WWVB receiver with time-code output, in Radio Electronics magazine, August 1973, p. 48. Methods of phase-locking are discussed.

3. "Low-Frequency Receiving Techniques," a series of articles by R. W. Burhans in Radio Electronics, March-July 1983, describes state-of-the-art LF/VLF active antennas, and a method for using LORAN-C (100 kHz) for time and frequency calibration. These are valuable references for cave-radio experimenters. A set of reprints, with errata/addenda, is available from the author for $4.00 postpaid:

Burhans Electronics
161 Grosvenor St.
Athens, Ohio 45701

Send SASE for catalog. See also Dr. Burhans' three-part article about Omega navigation receivers (10-14 kHz) in Byte magazine, February, March, April, 1977.

EMERGENCY WATCH-REPAIR FOR CAVERS

Frank Reid

I've successfully repaired several cavers' digital watches which failed after taking water during cave trips, just by opening the cases (as soon as possible), removing and drying the batteries, and putting the watch guts in a warm (not hot) place for a few hours. An electric hand-dryer also works-- A National Cave Rescue Seminar participant was amazed to see an electronic watch repaired in a National Park campground bathroom, using only a Swiss Army knife!

Clean all battery terminals and contacts before reassembly (I use a pencil eraser). The only difficult part is making sure that pushbutton contacts are not bent during reassembly.

Here's more watch-repair advice, received through <rec.ham-radio> an international computer-mail distribution. It was signed "Joe N2XS":

When taking-apart digital watches it is important not to touch anything inside with your bare hands. The DNA from your skin is enough to cause a bad contact. Almost all problems with digital watches are contact or battery problems. Dampen a VCR cleaner swab or lint-free cloth with tuner-spray and clean all visible contacts. Do not spray the inside directly from the can. Also, look for bent contacts; they are very small and easily damaged.

YOU, TOO, CAN BE A BIG-NAME CAVER!

Just Xerox the above emblem on colored paper, cut out, glue onto an old political campaign button, an wear it at the NSS Convention!

WHERE THE SUN SOMETIMES SHINES: SOLAR POWER AT A CAVE RESEARCH FIELD STATION

Howard A. Hurtt, KB6KSO

Lilburn Cave in Kings Canyon National Park, California, has been known to cavers since the mid-Fifties, and has been the subject of intense mapping and baseline scientific studies by the Cave Research Foundation (CRF) since 1980. Lilburn boasts 12 km of passage and a resurgence with bizarre chaotic ebb-and-flow characteristics.

The cave system's unusual hydrology was discovered in 1968, and instrumentation was completed at the resurgence and at the terminal siphon in the cave in 1973. The equipment consisted of potentiometric pressure sensors controlling VCO's at each location to convert water depth to frequency. This was landlined to a dual-track tape recorder at the fieldhouse. Segments of the seven-day record obtained were treated with a 2-channel F/V converter to produce synchrograms of siphon and resurgence water levels.

Although the project was beset by problems, including lightning damage, destruction of surface lines by animals and limb-fall, washing away of the resurgence instrumentation by record floods, and subsequent loss of the data tape, the siphon and resurgence water levels were proven to mirror each other. In the bargain, the roughly 6,000 feet of quad D (indoor telephone wire) running from the siphon to the surface has remained in excellent condition for 13 years.

The telemetry line has been used since 1975 as part of a dry-line telephone system, and has failed only twice: once from corrosion at a twist-splice, and once from being mashed by a rock kicked loose by a caver high above. After a string of interim phone systems proved their merit in improving organization and safety in this hostile cave, it was decided that something more substantial and permanent be built.

Until 1980, reasonably stout vehicles could be driven from the nearest paved road down seven miles of ruts leading to the door of the field station. At this time, the NPS wisely began managing the area as wilderness, a policy which, among other things, excluded motors. This caused an immediate communication crisis. The project had been clipped into handy car batteries to run the cave phone and also the re-tuned Systcoms VTR3 mobile phones with which radio contact was maintained with Park HQ. The cave phone was quickly adapted to a 6V headlamp battery, which would run it all season. The mobile phone, however, with its 30W all-tube transmitter, drained a motorcycle battery every trip, which had to be packed in and out. Electric cavers had also become accustomed to recharging their headlamp batteries on the site. We decided we had to either junk the dinosaur radio or learn to make our own electricity, or both.

POWERING DOWN

Project management cast about for proposals to solve the problem of the power-hungry radio. A mini-hydroelectric plant operating at the resurgence was seriously considered until the fate of the telemetry line across the same route was recollected. There was also some concern about what NPS would think of the idea in a wilderness. The outcome of that meeting was that we should think in terms of powering-down so that at least batteries wouldn't have to be carried in as often.

Chris Royce, KF6IO, donated a Regency HR-2B to the cause, expressing some doubt whether it could be tuned upward 20 MHz to the NPS frequency. It could, and the Systcoms was retired. A 3-element Yagi was assembled from 12-gauge (2.053 mm dia.) solid wire hidden in 3/4" Schedule-40 PVC. In the 1.5 W low power mode, the Regency easily brings up the NPS repeater on a ridge 9 miles away.

The radio was mated to the cave phone so that they shared a common power supply. The phone line was matched to the receiver's audio amplifier input and also to the microphone input, and receiver audio was superimposed on the phone line (Figure 1). This provided something very much like a continuous phone patch. Although it has not been used in an emergency, the patch has been tested, and work well.

Eight taps were provided along the line in the cave, either at important intersections or near particularly obnoxious spots on main routes. When a cave party clips a conventional phone handset onto the parallel wire pair, a 40 mA current loop is completed which latches an SCR. This powers a ring generator (Figure 2), which produces a high-low tone with about a 10 Hz shift rate, interrupted about every 2 seconds. This is heard loudly at the receiver speaker, and stays latched until the field station handset is picked up. Picking up the field station handset completes the speech loop, and also enables the transmitter and starts a logging recorder.

The phone system uses two of the 4 conductors in the D wire. The other two are reserved for instrumentation.

THE POWER SUPPLY

The only sane power supply for the project appeared to be solar. But where would we find sun in a mature forest where most of the trees were pushing 200 feet? The Lilburn field station is on the flank of Redwood Mountain, home of the largest of the Giant Sequoia groves. Even a small tree in these parts can be damn big, and cast a big shadow. So why not put a solar collector up in a tree? Ridiculous! You'd have to go up a hundred feet or more, and the voltage drop in the down-leads would be unacceptable. Furthermore, the mounting bracket would mutilate the tree.

"Not so," said Dave Zoldoske, who just happened to know where he could get his hands on 200 feet of 6-gauge (4.115 mm) 2-conductor street light wire. "Not so," added Mike Spiess, a master welder and former treetopper, who would build and install the gentlest of brackets, with turnbuckles to adjust for the growth of the tree.

With binoculars, clinometers, and well-tempered enthusiasm, we surveyed the five or six most likely trees near the field station. The winner jumped out at us. On a slope about 20 feet south of the cabin was a majestic white fir with a 41 inch diameter trunk. The tree had a distinctive compensation curve from the creeping of the soil of the slope, but above was sound and straight. At about a hundred feet up, it looked as though a gap in the canopy was illuminated over the tops of adjacent shorter trees to the south for most of the day. We would have to climb it to be sure.

Spiess, dragging a measuring string and free-climbing the bark, got into the lowest branches 55 feet off the ground. Here, at last, he could put sling loops around limbs for protection. He attained the gap in the canopy at 130 feet, and surveyed the solar window. With the trimming of a few small interfering branches, it would be nearly perfect. The trunk was 26 inches in diameter at that point, and the top of the tree looked to be another 60 to 70 feet higher. He put in a permanent anchor and retreated.

While the tree search was going on, I had been investigating solar collectors. The first price sheet I saw convinced me that we would have to charm someone out of a collector. I put out several feelers, offering publicity in exchange for samples. In January of 1983, Gabe Amaro of ARCO Solar International, Inc, responded. ARCO Solar publishes ARCO Solar News, a review of novel photovoltaic applications. Ours sounded novel enough, and a week later we were caressing two shiny new ARCO M-81 modules. These are half-amp collectors designed to charge deep-cycle lead-acid batteries. Amaro had also included plenty of advice on mounting, charge regulation, and lightning protection. I turned over the collectors to Spiess for bracket fitting, and began work on the charging circuitry.

We had bought a Donley 45 AH deep-cycle battery and packed it, fully charged, to the field station in hopes of never having to carry it out again. It ran the communication gear for six months without recharging, then promptly came up to full charge when the photovoltaic system was attached. Since then, we have added a 105 AH battery, and both seem to be faring well.

The charging circuit (Figure 3) consists of a 1N6096 Schottky as a blocking diode (Solar Power Corp. 1980), and a comparator that pulls in a relay to add 5 ohms to the circuit to drop the charge rate to a maintenance level of about 300 mA when the battery reaches 12.6 V (Byers 1984). The normal rate is about 900 mA.

As can be seen in Figure 4, most of the system wiring is devoted to distribution and lightning protection. There is a 12 V 20 A utility outlet on the main panel, and also a 2A instrument power outlet with supplementary transient protection. In addition to the communication package, the 12 V bus also runs two simple headlamp battery chargers and a 30 W self-inverting fluorescent light of the sort used in RV's. The fluorescent was an almost absurd afterthought. It had been found in a trash bin behind a Winnebago dealership, tubes intact, with its switching transistor burned up from inadequate heat dissipation. The transistor was just pop-riveted to the thin aluminum reflector. For the investment of a more substantial heat sink and a cheap generic transistor, we had acquired a very efficient way to light the interior of the fieldhouse.

Lightning is a big problem on Redwood Mountain. Warm, wet Pacific air is cooled as it goes up the west slope of the Sierra Nevada, generating a line of thunderstorms that can sometimes last for weeks. These storms often produce more electricity than water, resulting in frequent fires. One reason NPS insists that we man a radio at the field station is for reporting fires. We learned our lesson about lightning in 1974 when the surface telemetry line got blitzed, but instead of retreating we went for technical countermeasures.

The surface line from the field station to the Meyer Entrance, a distance of about half a kilometer, was replaced with two parallel runs of 2-conductor copperclad drop wire. This is the abundant, cheap, and tough material used to bring phone service from pole to house. It is miserable to work with, but holds up well against falling limbs and gnawing forest fauna. Where the surface line enters the fieldhouse, it is attached to Western Electric signal circuit protectors, as is the drop wire that enters homes. These are fuse-like devices that respond to spikes of 200 V or more, shorting the offending line to earth until the element is replaced. Signal circuit protectors are also used at the fieldhouse tiepoints of the solar collector downleads.

Three other types of transient protection are used in the power and landline systems. Where the solar collector leads enter the distribution panel, a TII-317A surge arrestor, provided by ARCO protects both positive and negative leads. This is a gas-filled spark gap which fires at about 60 V, momentarily shorting the lead to ground. Downstream of the 317A is an LC network within buffers any voltage with a risetime shorter than about 2.5 microseconds. As the telemetry lines enter the panel, they pass through quick-blow 250 mA instrumentation fuses, and are then bypassed to ground with 130-V MOV's. Downstream are LC networks. If either the MOV or the bypass capacitor of the LC passes substantial current, the fuse will be opened, and subsequent injury to the system prevented.

Although some parts of the design may seem crude by contemporary standards, this system has been in operation for more than five years, and has yet to suffer even so much as a blown fuse. This testifies either to the robustness of the design or to an unseasonable lack of lightning activity. The ability to recharge caving headlamp batteries using solar power at a long-term cave research project site is, as far as we know, unprecedented. It also lends a prosaic twist to the line in the well-known cave ballad.

I would like to hear from anyone else with experiences or comments on unusual applications of photovoltaics. I believe that, once one gets access to the collectors, the rest is easy. Particularly welcome would be commentary and criticism of this system.

Correspondence should be addressed to:

H.A. Hurtt
4763 E. Illinois Ave.
Fresno, CA 93702

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Byers, T. J. 1984. A photovoltaic battery-charge controller. Mother Earth News 1984 (2):98-100.

Solar Power Corporation. 1980. Solar electric generator systems. Anon. pamph., 11 pp.

Figure 1

COMMUNICATION CONSOLE

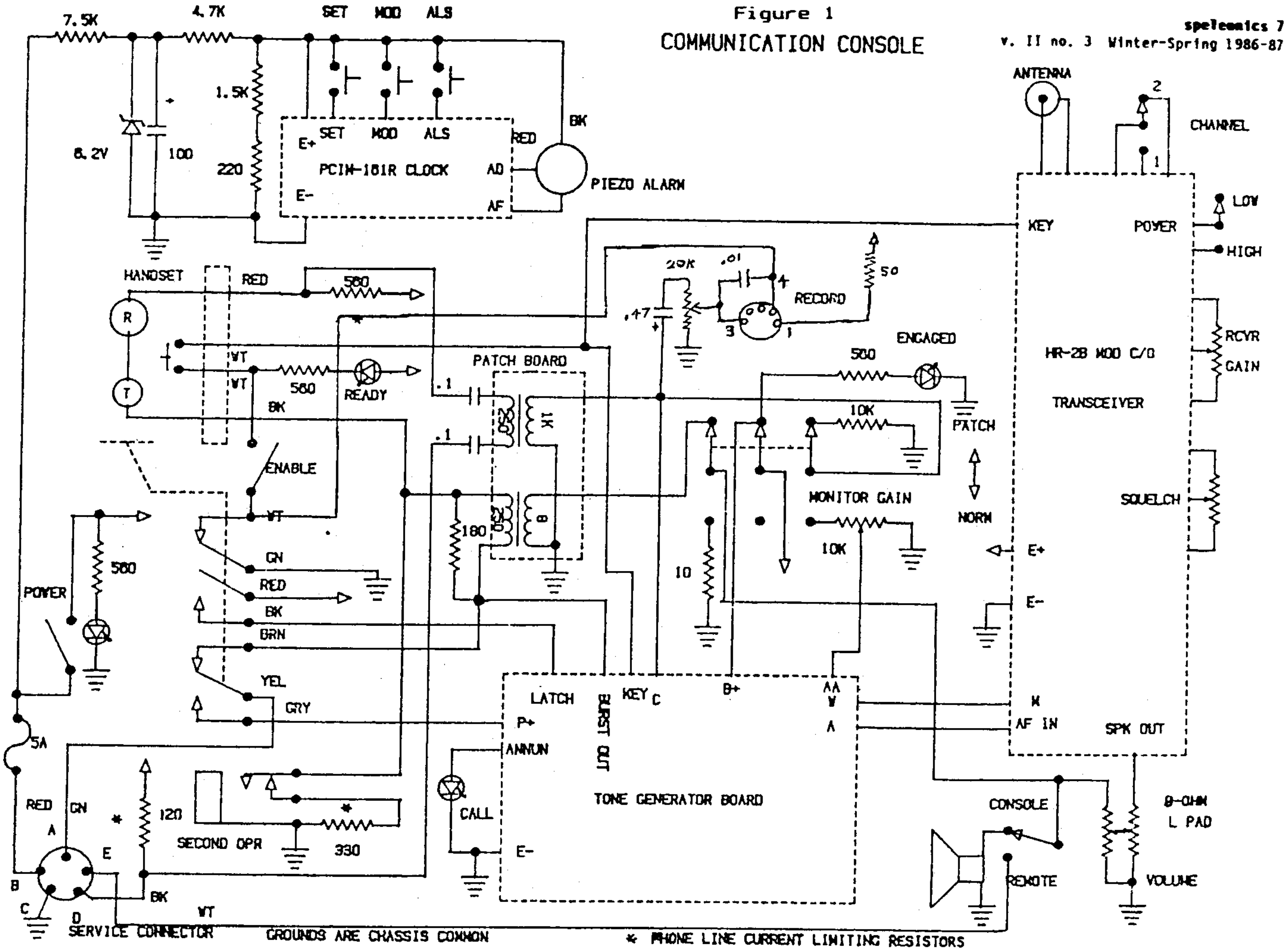


Figure 2

TONE GENERATOR BOARD

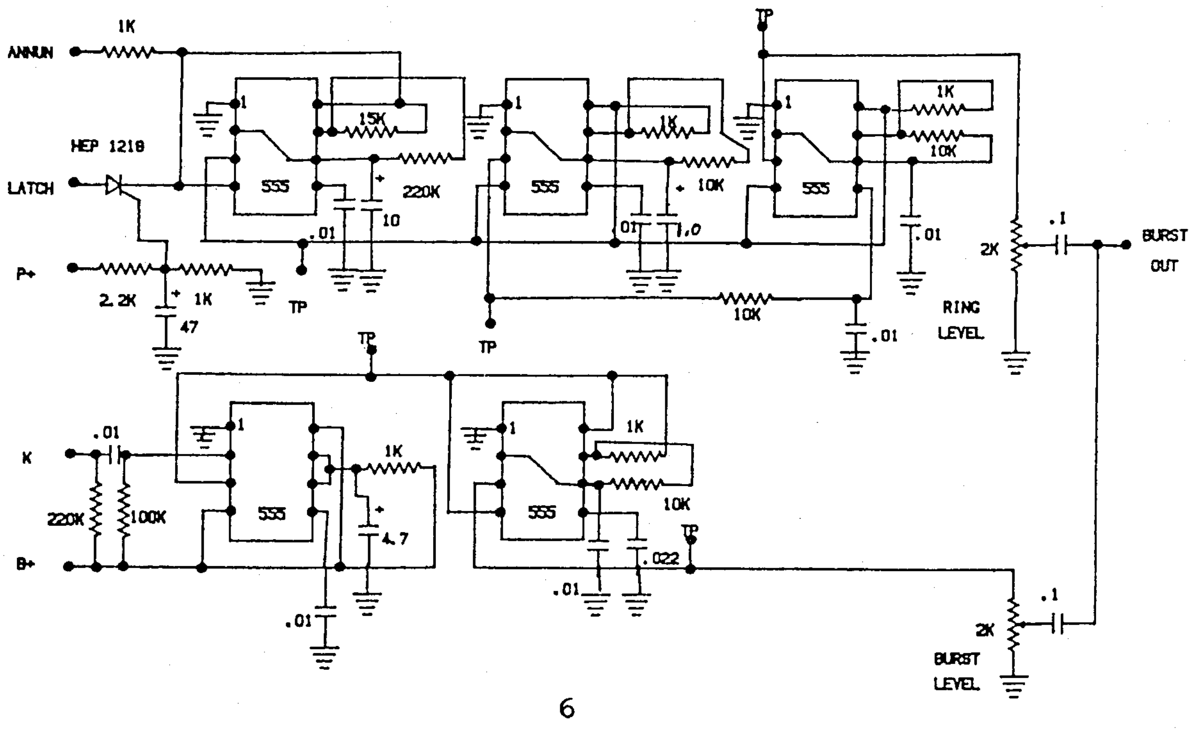


Figure 3

CHARGE REGULATOR

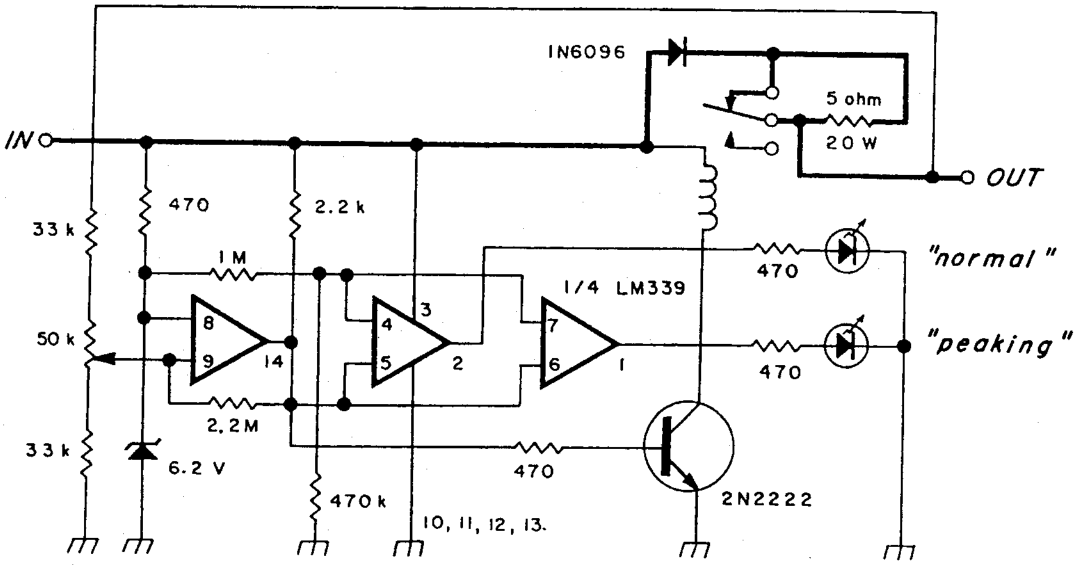
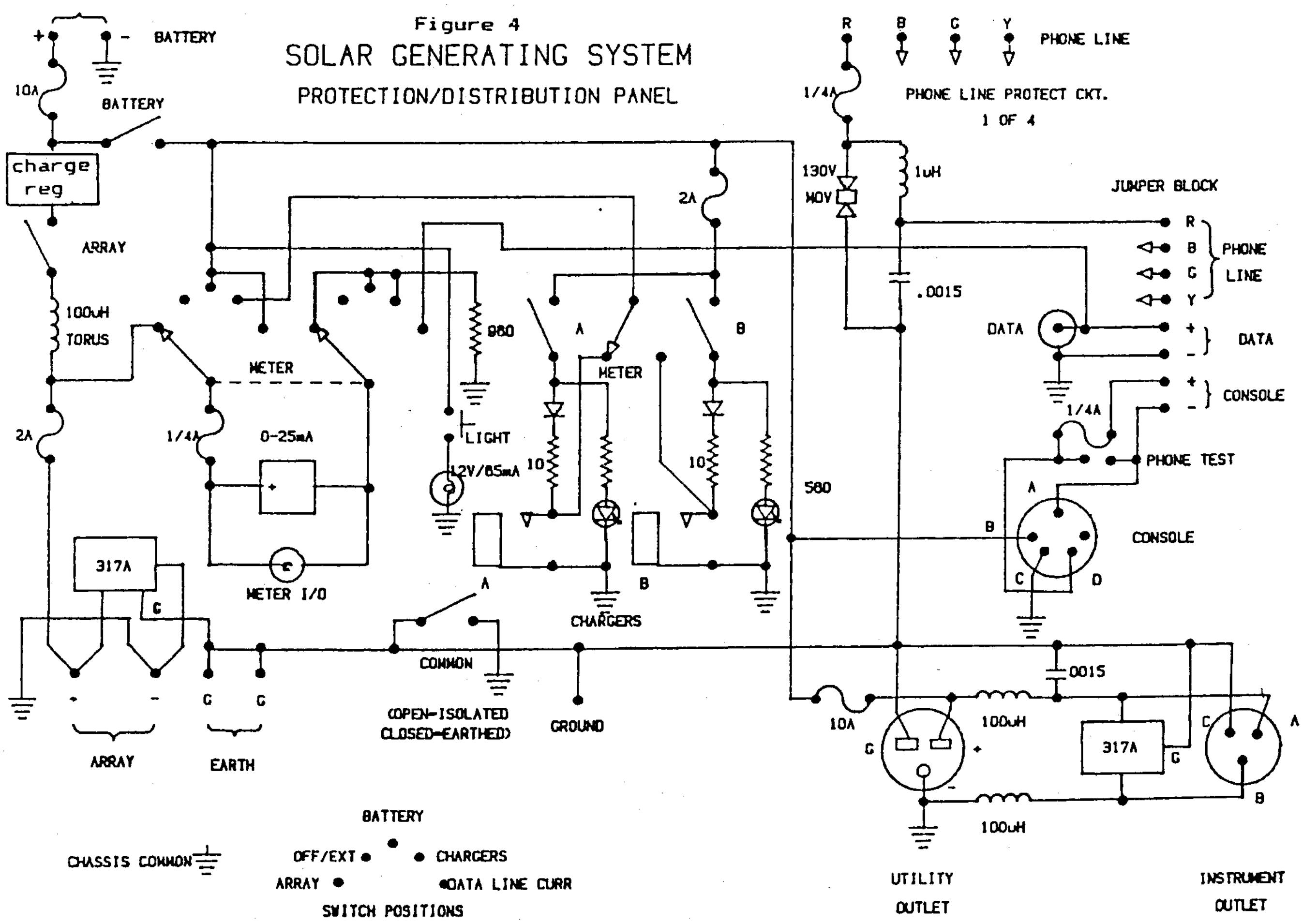


Figure 4

SOLAR GENERATING SYSTEM

PROTECTION/DISTRIBUTION PANEL



CAVE RADIO M-85

Bo Lenander, SM5CJW *

After years of calculation, experiments and just making the equipment, it is ready-- an easy-to-use direction-finding and communicating device! This equipment uses double-sideband (DSB) transmission/reception; the informationless carrier is greatly reduced and takes less energy from the batteries. The cave and surface units are identical and weigh 700 g, including batteries. The antenna weighs an additional 600-1350 g. **Transmitter peak power is about 1.5 W and the frequency is 32768 Hz.** The microphone input has automatic level control with long decay-time so the modulation level will be the same if you are whispering or shouting into the microphone. The receiver also has audio AGC, with a decay time of about 1 second and that is very convenient when using it for direction finding. An external headphone can be used in noisy environments, and then the built-in speaker operates only as a microphone. Speech quality is comparable to MW or LW broadcast stations. Each unit has eight 1.5 V, size R6 (or AA) alkaline cells. The units are not completely waterproof, but water resistant. The p-c board is protected by lacquer and all switches are magnetically controlled and glass-encapsulated. Each unit consists of 13 IC's, 10 transistors and 106 other components on a printed-circuit board, 60 x 115 mm.

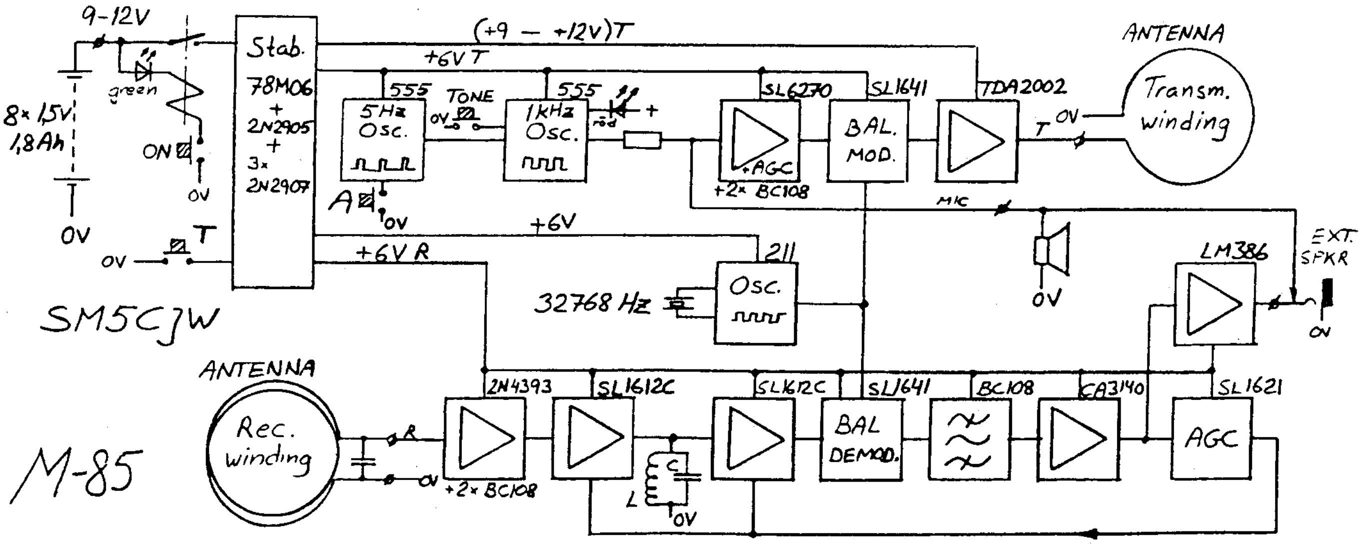
A Short Description of the Function:

ON/OFF is controlled by a relay and indicated by a LED. The high-current double contacts of the relay connect to a 6-volt regulator. A distributing circuit gives voltage to the transmitter when the T-button is pressed, and to the receiver when the T-button is released. Pushbutton **A** activates a pulse-generator controlling a tone generator, making a sequence of short tone bursts. Pushbutton **TONE** is used as a key to send morse code. A microphone amplifier with automatic level control feeds the balanced modulator. The carrier oscillator is built around an electronic watch crystal, and is used for both reception and transmission. The transmitter PA is an audio amplifier IC that has proved useful up to 100 kHz. The receiver input is high-impedance and therefore the Q-value of the antenna is high, giving good sensitivity and good signal/noise ratio. The two following amplifiers are AGC-controlled. A resonant circuit between the amplifiers reduces the HF bandwidth. The demodulator is the same type of circuit as the modulator. An audio bandpass filter with an amplifier drives the audio output stage and the AGC circuit. Microphone input and receiver antenna are not disconnected during transmission, therefore, the transmitter and receiver inputs have protection circuits. All microcircuits of type SL___ are made by Plessey, for professional communication equipment.

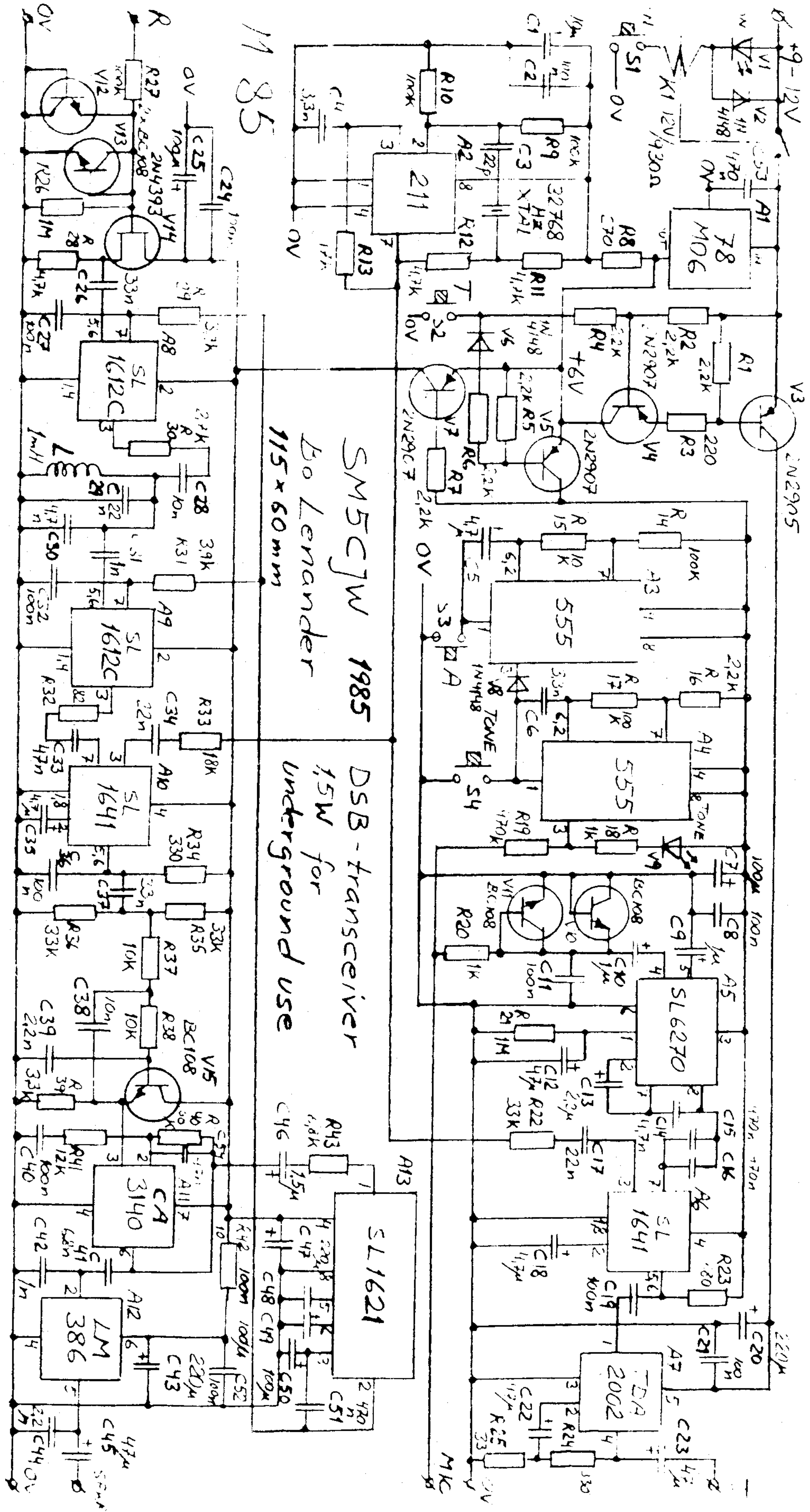
Antennas:

Two antennas have been made for use in caves. One is a shielded 18-wire cable connected as an 18-turn receiver coil with 1 m diameter. The shield (1 turn) is then used as the transmitter coil. This foldable antenna weighs 1000 g and can be used for communication up to 200 m distance. The other underground antenna is made of 12 ferrite rods (D = 10 mm, L = 200 mm) in a bundle with a 300-turn receiver coil and a two-turn transmitter coil wound on it. A spirit bubble level is mounted in the end, making it easy to orient the antenna vertically when using the direction-finding mode. This antenna weighs 1350 g and can be used for communication to 80 m distance. The surface unit has a loop antenna of 420 mm diameter with a 300-turn receiver and 1-turn transmitter coil. The weight of this loop antenna is 600 g and it is very useful for direction finding.

* Kultyxgatan 16
S-723 51
Vasteras, SWEDEN



Block Diagram


SM5CJW 1985
Bo Lenander
115 x 60 mm
DSB-transceiver
1,5W for
underground use

Note that some pins of the ICs have been cut (= not used).