SPELEONICS

SPELEONICS

Number 2

1985

Editorial

One of the problems in building cave communication equipment has been the slow exchange of information, indeed obtaining information of any kind. Nowadays when everbody expects electronic equipment to halve in size and cost, and to double in performance every 5 (or is it 2 ?) years, it is discouraging to find so little information available, and many of the circuits dating back 20 or more years.

Clearly the Cave Communication Section through "Speleonics" can play a role in improving the spread of information, both circuits and ideas. One item in this issue is a Bibliography. To get things rolling I have listed all the articles of interest that I know. The idea is to get all the items into the NSS Library where they will be available for 10 cents a page, or swapped on a page for page basis for new material.

So please send me new listings so we can publish updates to the bibliography. (I. Drummond, 5619 Dalwood Way NW, Calgary, Alberta.T3A 1S6).
Consider sending Bill Torode, NSS Library, 1 Cave Avenue, Huntsville, Ala. 35810 a copy of any articles not already on the list, especially if you want material from the bibliography.

Other ways in which Speleonics can help communication is by suggestion of standards for equipment. Two items in this issue address that topic. One item is from the Eastern Region National Cave Rescue Commission concerning 12 V. power. If all units using 12 V power have the same connector and polarity, then on a rescue there is more chance of sucessful operation and less chance of damaged equipment. It made enough sense to me that I have changed my equipment to conform to the standard.

The second item concerns standardized frequencies. At present two of the more sucessful survey radios operate on frequencies of 3.500 kHz and 3.4956 kHz and are not fully compatible. As Frank Reid explains in his article, neither would work as well in the UK with 50 Hz power noise present. Perhaps a standard frequency could be agreed upon, so that in future radios of a particular type operate on a common frequency. This has been done, for example, with magnetic avalaunche beacons commonly carried by back-country skiers which operate at 2225 Hz world-wide.

Ian Drummond, Editor for Speleonics #2.

Editor for Issue #3 will be Frank Reid, PO Box 5283, Bloomington, IN, 47402

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Needed, A working Cave Radio.

I need to purchase a cave radio system as soon as possible.

Contact Dr. Nicholas C. Crawford
Geography and Geology Dept.
Western Kentucky University
Bowling Green, Ky, 42101 (502)-745-4555

Report on Cave Communication and Electronics Section Meeting at Frankfort, Kentucky. June 24, 1985.

compiled from notes by J. Coward

The meeting started with a series of presentations.

1) Ray Cole talked about his "Organ Cave Radio". It is a narrow-band unit operating at 3.495 kHz for position-finding work only. The receiver has a novel commutating filter. Ray has submitted an article for Speleonics, complete with circuit diagrams.

2) Ian Drummond discussed the bibliography (published in this issue) and gave a little history of cave radio development, pointing out the split in direction between the US and the UK in the late 60's when the US went to narrow-band survey units and the UK went to higher frequency voice units. He also pointed out the US Bureau of Mines work which gives a much better design basis for radios.

3) Julian Coward outlined the ASS cave radio. It is a 2-way voice and tone system operating at 114.28 kHz carrier with 3 kHz upper side-band. A report with circuit diagrams has been published, but improvements have been made and an update will be available. Unlike other radio described at the meeting , the ASS radio antenna has a collapsible frame and stores in a tube for transport.

4) Joe Hruska described his 3.5 kHz survey unit, based on Frank Reid's design. Joe has not concerned himself over ultimate range, but emphasized robust equipment and simplicity.eg. his antenna is mounted in a bicycle tire and is flexible for transport into tight caves.

5) Frank Reid told how he had interconnected cave telephone systems with surface radios for cave rescue use. The first, a simple interconnection of microphone and speaker, worked but required an operator to switch Tx/Rx. The second method was a "Peter-porta", a commercial auto-repeater costing $100. The third, completely sucessful and favoured system was the ICOM radio voice-operated transmit (VOX) switch.

6) Gene Harrison presented ideas on what was needed in a future radio design for cave rescue. a)2-way speech plus emergency location. b)Range of 1000 ft. extendable to 1 mile (horizontally). c)Simple operation d)Standard frequency. e)Easy to build, circuit board with easy to obtain parts. f)Underground <1 cubic ft, <25 lb. g)Power 4-12 V DC.

Discussion

There was general concensus that the narrow-band 3.5 kHz units worked well for survey work.

There was clearly a demand for 2-way voice units. However there was no agreement on frequency or mode of transmission (AM, FM, or SSB). This lead in turn to a discussion of legal requirements. In the US no licence is required below 10 kHz; nor in a band 160-180 kHz for less than 1 watt of power.

One identified problem was lack of test proceedures for cave radios so it was very hard to compare relative performance before deciding what to build.

Good design proceedures now exist (Bureau of Mines work) but are not accesible to non-electrical engineers. There is a need for information on electrical noise-levels and ground conductivity measurments in caving areas.

Remote sensing of caves was briefly mentioned. Electromagnetic conductivity measurements (as opposed to current injection methods) have not been used by cavers. Also radar methods have been used to detect chambers in dolomite to 150 ft. depth, as well as to measure ice thickness on glaciers.

As a result of the discussion a "To do " list was started with names of volunteers to persue the topic.

1) FCC Regulations on Cave Radios (USA)	Ray Cole
2) DOC Regulations on Cave Radios (Canada)	Julian Coward
3) European Regulations on Cave Radios	------
4) Standardized tests on Cave Radios	Joe Hruska
5) Theoretical Range calculations	Ian Drummond
6) EM Conductivity Measurements	------
7) EM noise measurements	------
8) Adaptations of commercial equipment to voice communication	------
9) Remote sensing (Radar)	Ian Drummond
10) Design of a "state-of-the-art" survey unit at a frequency near 3.5 kHz.	Ray Cole and Frank Reid

Several people expressed interest in building radios for voice, but ideas were not concrete enough at the meeting to set-up groups to work on specific projects. Some of these people might be identified by the questionaire in this issue, which was also distributed at this meeting. See Speleonics 3# for results of the survey.

If anyone is interested on working on any of these projects, give the person a call, or if no-one is listed, sign-up by giving the new chairman (Ian Drummond) a call at (403)-288-4034.

An election was held at the lunch for the 85-86 period.

Elected	Chairman	Ian Drummond
	Secretary	Frank Reid
	Treasurer	Joe Giddens

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*************************************************
*ACTION ACTION ACTION ACTION ACTION ACTION ACTION*
*C                                              *
*T  If you want your own copy of Speleonics.   A*
*I                                             C*
*O                                             T*
*N   Send $4.00 for a 4 copy subscription to   I*
*                                              O*
*A      J. Giddens, Box 170274                 N*
*C          Arlington, Tx. 76003                *
*T                 USA                         A*
*I                                             T*
*ON ACTION ACTION ACTION ACTION ACTION ACTION ACT*
*************************************************
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Magnetic Moments, Number 2, by Ian Drummond

In this article I want to address the problem of design of loop antennas for transmission.

How big an antenna is needed for a given field, what gauge wire should be used, and how much power can an antenna handle?

In general a designer starts from one of two points. Either he can decide on the maximum size of antenna that can be physically handled in the cave or on the surface, or he starts knowing he must achieve a certain range.In either case he will want the greatest range for a given power.

The type of antenna considered here is the air-cored loop with a tuned secondary winding. I am assuming the designer is familiar with the concepts of transformers and resonant circuits, if not I would recommend reading an article such as The Amateur Radio Handbook, Chapter 2, on Electrical Laws and Circuits to gain an understanding of inductance, capacitance, and concepts such as "Q" of a resonant circuit.

The problem with using these basic concepts to design loop antennas, is that two effects, the skin effect, and the proximity effect, increase the apparent resistance of the wire to AC current over its DC resistance, and so degrade the performance of the antenna.These effects are treated in a very useful book "VLF Radio Engineering" by A D Watt, Pergamon Press, (1971), pages 90-101. I have incorporated the necessary formula into a Basic computer program which seems to work well for 3 very different sized loops, all working at 115.4 kHz, on which I have electrical measurements.

The AC resistance is calculated from the formula

$$R(AC) = R(DC) \times (1 + F + G(K + U)) \text{ Ohms}$$

where

F = Skin Effect

G.K = Proximity effect due to nearby wires.

G.U = Proximity effect due to the magnetic field of the solenoid

These values are part of the output of the program and so allow the designer to estimate their importance in degrading the magnetic moment (NIA) of the loop.

```
CAVE RADIO
ANTENNA DESIGN
BY IAN DRUMMOND

VERSION 3 ; 85-07-02
SELECT ANTENNA SHAPE
 C=CIRCLE  S=SQUARE
 P=PENTAGON
 H=HEXAGON? S
RADIUS OR SPOKE
LENGTH (METRES)0.51
PERIMETER= 2.885
AREA= 0.5202 M^2
FREQUENCY(KHZ)=? 115.4
WIRE SIZE(8-32 AWG)
? 28
SKIN EFFECT=
 9.53E-03 X DC RESISTANCE
#TURNS IN SECONDARY
COIL? 70
LENGTH OF WIRE = 201.9 METRES
MASS OF WIRE =  0.14 Kg
FOR COIL ENTER
# OF LAYERS? 1

WIRE SIZE.
 FOR MAGNET WIRE
 ENTER M ,IF NOT
 ENTER DIA(CM)? M
IS COIL CLOSE-WOUND
(Y/N)? Y
FORMULA FOR WIRE
PROXIMITY EFFECT
WILL ESTIMATE LOW
COIL LENG    2.55 CM
INDUCTANCE
 1.10E-02 H
FOR RESONANCE
C= 1.73E-10 F
NEARBY WIRE EFFECT=
 9.18E-02 X DC RESIST
SOLENOID EFFECT=
 9.32E-02 X DC RESIST.
ENTER CAPACITOR Q
( 200 IF VALUE IS UNKNOWN )
? 200
CAPACITOR EQUIV. SERIES
RESISTANCE = 39.9 OHMS
CALCULATED Q=  87
Q(ACTUAL)? 85
COIL DC OHMS= 43.22
COIL AC OHMS= 91.50
COIL EQUIV OHMS= 93.82
POWER TO ANTENNA
(WATTS)? 10
NIA= 1.19E+01 AMP.M2
AMPS(RMS)= 3.26E-01
VOLTS(P-P)= 7.4E+03
# TURNS IN PRIMARY
? 1
INPUT IMPED. TO
ANTENNA=138.3 OHMS
```

Design of an antenna using this program becomes a question of trying various combinations of antenna size and shape, wire size, # of turns, etc. to find a combination that gives a good value of the magnetic moment (NIA) without exceeding voltage or current capabilities of the capacitors or wire.

In general for my own applications I have found all parameters except the input impedence to match well. The input impedence was too high by a factor of 2 or so. Frank Reid compared calculations with the actual values for some of his 3.5 kHz loops and found results within a factor of two also. So the program is not perfect, but I believe it is helpful in designing efficient antenna.

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All these examples are for a square antenna with a spoke length of 0.5 m. operating at a frequency of 115.4 kHz and with a single turn primary.

# Turns	Wire(AWG)	NIA(10 watts)	Peak Volts	Q
70	28	11.7	7.4 kV	87

(This is the calculation for one of our field antennas and matches well.)

# Turns	Wire(AWG)	NIA(10 watts)	Peak Volts	Q
140	28	14.5	15 kV	113

(Doubling the turns only increases NIA by 24% but fries the 6 kV capacitors and the bandwidth is too small)

# Turns	Wire(AWG)	NIA(10 watts)	Peak Volts	Q
70	22	13.9	7.5 kV	115

(Same # turns but thicker wire increases NIA by 19% only and the bandwidth is still too narrow)

# Turns	Wire(AWG)	NIA(10 watts)	Peak Volts	Q
35	22	11.2	3.5 kV	80

(Maybe this would have been a better choice than our original one, less work to make, anyway).

Julian tried an empirical approach to antenna design. A square antenna with 1.1 m spokes,and a one turn primary.

# Turns	Wire(AWG)	NIA(10 watts)	Peak Volts	Q
4	16	21.1	0.48 kV	39

(Not bad, certainly a lot easier to make, but big for handling in the bush)

And so it goes...............

```
10  PRINT"CAVE RADIO"
20 PRINT"ANTENNA DESIGN"
40  PRINT"BY IAN DRUMMOND":PRI
NT
60  PRINT"VERSION 3 ; 85-07-02
":PRINT
70 PRINT"PROGRAM WORKS BEST":P
RINT"WITH SINGLE LAYER":PRINT"
SPACED WIRE-COILS":PRINT"WILL
OVERESTIMATE":PRINT"OTHERWISE"

80 PI=3.1416
100 PRINT"SELECT ANTENNA SHAPE
"
110 PRINT" C=CIRCLE  ";
120 PRINT"S=SQUARE"
130 PRINT" P=PENTAGON"
140 PRINT" H=HEXAGON";
150 INPUT SHAPE$
160 PRINT "RADIUS OR SPOKE"
170 INPUT "LENGTH (METRES)",RA
D
180 IF(SHAPE$="C")THEN 230
190 IF(SHAPE$="S")THEN 260
200 IF(SHAPE$="P")THEN 290
210 IF(SHAPE$="H")THEN 320
220 GOTO 100
230 PERIM=2*PI*RAD
240 AREA=PI*RAD*RAD
250 GOTO 340
260 PERIM=SQR(2)*4*RAD
270 AREA=(PERIM/4)^2
280 GOTO 340
290 PERIM=SIN(PI/5)*10*RAD
300 AREA=1.72*(PERIM/5)^2
310 GOTO 340
320 PERIM=6*RAD
330 AREA=2.598*RAD^2
340 PRINT USING"PERIMETER=##.#
##";PERIM
350 PRINT USING"AREA=##.#### M
^2";AREA
360 ERAD=SQR(AREA/PI)
380 INPUT "FREQUENCY(KHZ)=";FR
Q
390 SKIN=1/(SQR(PI*23.2*PI*FRQ
*1000))
400 PRINT"WIRE SIZE(8-32 AWG)"
:INPUT AWG
410 IF AWG<8 OR AWG>32 OR (AWG
/2<>INT(AWG/2))THEN 400
420 RESTORE
430 FOR I=1 TO (AWG/2-3)
440 READ DIA,RESDC:NEXT I
450 DATA .326,.00206,.259,.003
28,.205,.00522,.163,.00827,.12
9,.0132,.102,.021,.0813,.0331,
.0643,.0531,.0511,.0843,.0404,
.135,.032,.214,.0254,.341,.020
3,.531
```

```
460 IF(DIA>(400*SKIN))THEN 490

470 RESAC=RESDC*(1+((((DIA/(40
0*SKIN))^2)^2)/3)):GOTO 520
490 IF(DIA>1000*SKIN)THEN 510
500 RESAC=RESDC*(.55+.00195*DI
A/SKIN):GOTO 520
510 RESAC=RESDC*DIA/(400*SKIN)

520 PRINT"SKIN EFFECT="
540 PRINT USING"##.##^^^^ X DC
 RESISTANCE";RESAC/RESDC-1
560 PRINT"#TURNS IN SECONDARY"

570 INPUT"COIL";N
572 RESTORE 574:FOR I= 1 TO (A
WG/2-3)
573 READ MASS:NEXT I
574 DATA .0745,.0469,.0295,.01
85,.01165,.00734,.00462,.00289
,.00182,.00114,.000716,.000452
,.000289
575 PRINT USING"LENGTH OF WIRE
 =####.# METRES";N*PERIM
576 PRINT USING"MASS OF WIRE =
 ##.## Kg";N*PERIM*MASS
580 PRINT"FOR COIL ENTER"
590 INPUT"# OF LAYERS";NL:PRIN
T
600 CLS:PRINT"WIRE SIZE."
610 PRINT" FOR MAGNET WIRE"
620 PRINT" ENTER M ,IF NOT"
630 INPUT" ENTER DIA(CM)";DIA$

640 IF(DIA$="M")THEN 670
650 WDIA=VAL(DIA$)
660 GOTO 680
670 WDIA=DIA*(1+AWG/200)
680 PRINT"IS COIL CLOSE-WOUND"

690 INPUT"(Y/N)";A$
700 IF A$="Y" THEN 730 :IF A$<
>"N"THEN 680
710 INPUT"# TURNS/CM";TURNS:IF
 TURNS>1/WDIA GOTO 710
720 L=N*.01/(TURNS*NL):GOTO 77
0
730 IF WDIA/DIA>1.7 GOTO 760
740 PRINT"FORMULA FOR WIRE":PR
INT"PROXIMITY EFFECT"
750 PRINT"WILL ESTIMATE LOW"
760 L=.01*N*WDIA/NL
770 PRINT USING"COIL LENG ####
.## CM";L*100
780 MU=1
790 GOSUB 2160
800 PRINT"INDUCTANCE"
810 PRINT USING"##.##^^^^ H";I
ND*.000001
830 CAP=IND/((IND*2*PI*FRQ)^2)
840 PRINT"FOR RESONANCE"
850 PRINT USING"C=##.##^^^^ F"
;CAP
855 REM CALC WIRE PROXIMITY EF
FECT
860 IF DIA*.01/SKIN>2 THEN 870

865 GBAR=(DIA*.0025/SKIN)^4:GO
TO 890
870 IF DIA*.01/SKIN>4 THEN 880

875 GBAR=.0015*DIA/SKIN-.238:G
OTO 890
880 GBAR=.12*(.01*DIA/SKIN-1)
890 REM NEARBY WIRE EFFECT ONL
Y ACCURATE IF (CENTRE TO CENTR
E)/DIA>1.7
900 IF N<100 THEN 910
905 K=3.3:GOTO 920
910 K=1.58*LOG(N)-.194*(LOG(N)
^2)
920 PRINT"NEARBY WIRE EFFECT="
:PRINT USING "##.##^^^^ X DC R
ESIST";K*GBAR
930 REM SOLENOID EFFECT
935 U=3.19+1.1*L/ERAD-.065*((L
/ERAD)^2)
940 PRINT"SOLENOID EFFECT=":PR
INT USING "##.##^^^^ X DC RESI
ST.";U*GBAR
945 PRINT "ENTER CAPACITOR Q":
PRINT"( 200 IF VALUE IS UNKNOW
N )"
947 INPUT CAPQ
949 RCAP=1/(2000*PI*FRQ*CAP*CA
PQ)
951 PRINT USING "CAPACITOR EQU
IV. SERIES RESISTANCE =###.# O
HMS ";RCAP
960 PRINT"CALCULATED Q";
970 R=N*PERIM*RESDC*((RESAC/RE
SDC)+K*GBAR+U*GBAR)+RCAP:Q=.00
2*PI*FRQ*IND/R
980 PRINT USING"=####";Q
990 INPUT"Q(ACTUAL)";QA
1000 PRINT USING"COIL DC OHMS=
###.##";N*RESDC*PERIM
1010 PRINT USING"COIL AC OHMS=
###.##";R
1015 REFF=(.002*PI*FRQ*IND/QA)

1020 PRINT USING"COIL EQUIV OH
MS=###.##";REFF
1040 PRINT"POWER TO ANTENNA":I
NPUT"(WATTS)";WATTS
1050 AMPS=SQR(WATTS/REFF)
1060 VPP=.00566*AMPS*PI*FRQ*IN
D
1070 NIA=N*AMPS*AREA
1080 PRINT USING"NIA=##.##^^^^
 AMP.M2";NIA
1090 PRINT USING"AMPS(RMS)=##.
##^^^^";AMPS
1100 PRINT USING"VOLTS(P-P)=##
.#^^^^";VPP
1120 SECIMP=QA*.002*PI*FRQ*IND

1130 PRINT"# TURNS IN PRIMARY"
:INPUT PN
1140 PRINT"INPUT IMPED. TO":PR
INT USING"ANTENNA=###.# OHMS";
SECIMP*((PN/N)^2)
1160 PRINT"TO RECALC,ENTER #"
1170 PRINT"1-PRI.TURNS 4-POWER
"
1180 PRINT"2-SEC.TURNS 5-AWG"
1190 PRINT"3-ACTUAL Q  6-FREQ"

1192 PRINT"     7-SIZE"
1200 A$=INKEY$:IF A$="" THEN 1
200 ELSE 1210
1210 CLS:A%=VAL(A$):ON A% GOTO
 1130,560,990,1040,400,380,100

2000 GOTO 2310
2160 REM CALC INDUCTANCE
2170 RATIO=2*ERAD/L
2180 IF(RATIO<.01 OR RATIO>100
0)THEN 2250
2190 IF(RATIO>1)THEN 2220
2200 FBAR=RATIO*(.025-8.999999
E-03*RATIO)
2210 GOTO 2230
2220 FBAR=.016+.0156*LOG(RATIO
)
2230 IND=MU*78.8*FBAR*N*N*ERAD

2240 RETURN
2250 CLS:PRINT"COIL DIMENSIONS
":PRINT"OUTSIDE RANGE"
2260 GOTO 2310
2310 END
```

Cave Communications Bibliography

A list of articles, books, and data useful to those people using, designing, and building communication equipment for use underground.
Most items should eventually be in the NSS Library where they will be available at a charge of 10 cents a page, or available through normal technical library sources.

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---------------- Postdisaster Survival and rescue Research.
Bureau of Mines Information Circular 8907, (1982).

---------------- Underground Mine Communications. Four parts 1)Mine telephone systems. 2)Paging systens. 3)Haulage systems. 4)Section-to-place communications. Bureau of Mines Information Circulars #8742,8743,8744,8745. 1977.

Birchenough W. Electromagnetic Induction as an aid to cave surveying.
Trans. Cave Research Group. vol.12, p135-8, (1970)

Bishop CS, Reid FS. Accuracy evaluation of electromagnetic locating.
Nat. Speleo. Soc. News. p70-71, (1975)

Bowles B, Austin B, Attwell C. Components of electrically small loop antennae.
Electronic Engineering. Part 1 48-57, Nov 1978; part 2, 39-48, Dec 1978

Charlton R E. Cave to surface magnetic induction direction finding and communication.
Nat. Speleo. Soc. Bulletin. Vol 28, #2, p70-79 (1966)

Christopher NSJ. The application of electromagnetic position finding devices to cave surveying.
CRG Newsletter #110, 17-20, March 1968

Chufo RL. Medium frequency mine communication.
28 th. IEEE Vehicular Technology Conference. 261-266 (1978)

Coward J, Drummond I. Construction and testing of an underground radio.
A report to the Alberta Govt. Workers' Health, Safety and Compensation Dept.1983.
(Includes circuits for a two-way speech device (SSB) operating at 115.4 kHz)

Davis N. Optimum frequencies for underground radio communication.
Nat. Speleo. Soc. Bulletin. Vol 32, #1, p11-26. (1970)

Delogne P. Chapter 4. Subsurface radio communication in the HF and lower frequency bands. in Leaky Feeders and subsurface radio communication. Published by IEEE

Drummond I. Cave Radio Update.
Nat. Speleo. Soc. News. vol 42, #12, p366-368, (1984)

Eve AS, Keys DA, Lee FW. The penetration of rock by electromagnetic waves and audio frequencies.
Proc. IRE 17, #11, 2072-2074 (1929)

Flack R. Electronic determination of depth and ground-zero of caves.
Spel. Assoc. South Africa Speleo. p30-4, (1966)

Geyer RG (Editor). Thru-the-Earth Electromagnetic Workshop at the Colorado School of Mines. Aug 15-17 1973. National Technical Information Service report PB 231 154. (also Bureau of Mines Report # OFR 16-74)

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

Glover RR. Ingleborough Field Meet Report.
CRG Newsletter #107, 4-6, Sept 1967
(First report on performance of equipment operating at 100 kHz)

Glover RR. Cave Surveying by Magnetic Induction.
A chapter in Surveying Caves. Ellis B. (Editor) British Cave Research Association (1976)
(A very clear account of use of the equipment for surveying)

Hart PJ. Mark 1 Induction loop radio equipment.
Unpublished report 1978
(125 kHz SSB unit which formed the basis for the ASS Cave Radio by Coward and Drummond)

Jones N, Birchenough W. A magnetic position-finding device.
CRG publication #11, Some technical aids for cave exploration.
p89-102, Nov. 1962.

Kraus JD. Antennas. McGraw-Hill (1950)
(Theory of loop antennas in free-space)

Lord H. Communication underground - Inductive systems.
A chapter in Manual of Caving Technique. Cullingford C (Editor) Routledge and Kegan Paul (1969)
(Visionary stuff by one of the original workers in the field)

Lord H. A device for surveying and speech communication underground.
Proceedings of the British Speleological Association #1, Aug 1963.
(A clear account of early work with audio frequency equipment)

Mixon W, Blenz R. Locating an underground transmitter by surface measurements.
The Windy City Speleonews, vol 4, #6, 47-53.
Reprinted in Speleo Digest 1964, Page 3-1

Murphy JN, Parkinson HE. Underground Mine Communication.
Proc IEEE 66, #1, 26-50 (1978)

Phillips J A, Standing I J. The detection of caves by equipotential surveying and electromagnetic induction location using a thyristor pulse generator.
Proc Brit Spel Assoc. vol 7, p31-52, (1969)

Plummer W. A two-way cave radio.
Baltimore Grotto News, vol 7, p162, June 1964

Plummer W. Depth measurement with the cave radio.
Baltimore Grotto News, vol 7, p259, Aug 1964

Reid FS. Caveman Radio
73 Magazine, Feb 1984, 42-49.

Reid FS. Long-range Cave Radio.
Unpublished, presented at the 1981 International Congress of Speleology.
(Detailed circuits of 3.5 kHz pulse transmission/receiver, and high power surface-to cave voice units)

Reid FS. Cave Radio revisits James Cave.
The Windy City Speleonews, vol 19, p8, Feb. 1979

Roberts RS. Ferrite Aerial Receivers.
Wireless World p701, Feb 1968

Roeschlein ER. Mapping caves magnetically.
Electronics. Sept.23 1960 p61

Saveskie PN. Radio Propagation Handbook
TAB Books, Blue Ridge Summit, Pa 17214
(A very strange book, but does contain useful info on soil and rock conductivities, and on EM noise contours by frequency and time).

Seggern D. Continuation of electromagnetic survey of Half-mile Cave.
St. Louis University Grotto Newsletter, vol 3, p1, Spring 1964

Sinha AK, Bhattacharya PK. Vertical magnetic dipole buried inside a homogeneous earth.
Radio Science 1, #3, 379-395 (1966)
(The first publication of the full solution to magnetic and electric fields around a buried loop. Very theoretical)

Smith R, Stevens RA. Inductive loops and cave surveying.
Trans. BCRA 1, #1, 55-60 (1974)

Stevens RA. An improved electromagnetic position-finding device.
Trans. CRG 14, #1, 43-47 (1972)

Wait JR. Mutual coupling of loops over a homogeneous ground.
Geophysics 20, #3, 630-637
(Early work on the theory accounting for the effects of a conductive ground)

Wait JR. Electromagnetic induction technique for locating a buried source.
IEEE Transactions on Geoscience Electronics. GE-9, #2, 95-98

Wait JR, Spies KP. Electromagnetic Fields of a small loop buried in a stratified Earth.
IEEE Transactions on Antennas and Propogation. AP-19, #5, 717-718

Wait JR. Criteria for locating an oscillating magnetic dipole buried in the Earth.
Proceedings of IEEE Letters, 59, #6, 1033-1035, (1971)

Watt AD. VLF Radio Engineering. Pergamon Press, (1971)
(A very useful general reference book for designers of equipment)

Wolff EA. Antenna analysis. Wiley and sons. Date unknown.
(Useful only for design of ferrite core antenna)

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Thoughts towards designing an "International" cave radio: Choosing an operating frequency.

by Frank Reid

A primary goal of the NSS Electronics Section is designing high-performance, easily built cave radios. Of the few sets of equipment that now exist, most are on different frequencies. Cave radios on common frequencies (I don't want to use the word "standard" at this time) would be advantageous in cave rescue and other inter-group efforts, and for performance tests. This article applies to CW radios operating at mid range audio frequencies; cave radios which transmit voice will be covered elsewhere.

Nevin Davis (1) has shown that frequencies near 3.5 kHz are optimum for magnetic induction cave radio. Power-line interference is a major problem for radios having carrier frequencies in the audio range. Harmonics of the 60 Hz power-line frequency are strongest below 600 Hz, but extend to higher frequencies. The strongest 60 Hz harmonic is 180 Hz, and is probably caused by a 3-phase effect.

Power-line interference can be limited by choosing an operating frequency that falls between power-line harmonics, and using a receiver bandwidth narrow enough to reject the adjacent harmonics. Europe uses 50 Hz power; a cave radio frequency which falls in between the harmonics of <u>both</u> 50 and 60 Hz would be workable in any country. I have operated a 3500 Hz cave radio for more than 12 years (3); 50 Hz harmonics are not a problem in America. Harmonics of 60 Hz probably would not be detected in Europe.

Harmonics of 50 and 60 Hz coincide every 300 Hz, and the pattern of seperation repeats every 300 Hz.

```
50   100  150  200  250  300  350  400  450  500  550  600  650  700
 60    120    180   240    300   360   420   480   540   600   660   720
```

We can never get more than 25 Hz away from a harmonic of 50 Hz, nor 30 Hz away from a 60 Hz harmonic. The largest "windows" between harmonics are 50 Hz wide, and occur either side of multiples of 300 Hz. Assuming that we wish to avoid any harmonic by at least 20 Hz, the most desirable frequency for an "international " cave radio in the 3.5 kHz region would be 20 to 30 Hz on either side of a multiple of 300 Hz, eg. 2700, 3000, 3300, 3600,or 3900 Hz.

Cave radios having very narrow receiving bandwidths require quartz crystal oscillators for frequency stability. We would like to use commonly available crystals, and use the same crystal frequency in both transmitter and receiver. (Receivers use local oscillators to drive mixers and for clocking digital filters and correlators). We would also prefer that the crystal frequency divisor be an even number, so that the divider output is a symetrical square wave.

The 3.579545 MHz colour-burst crystals used in colour televisions are inexpensive and more readily available than any other crystals. (Are these available in Europe? Editor). 3579.5 Hz (the colour TV frequency divided by 1000) satisfies all the above criteria, being 20.5 Hz away from 3600 Hz, the nearest harmonic of 50 or 60 Hz.

3276.8 Hz, made by dividing an electronic wristwatch oscillator frequency by 10, also fulfills the requirements for harmonic avoidance, easy parts availability and an even-numbered divisor. It is 23.2 Hz from 3300 Hz.

Many other candidates exist.

32768/12 = 2730.67
1 MHz/(21 x 16) = 2976.19
4 MHz/($67 x 16) = 2427.18
4 MHz/($8B x 8) = 2673.80
4 MHz/(21 x 64) = 2976.19
4 MHz/(35 x 32) = 3571.43
4 MHz/(69 x 16 = 3623.19

TV/(41 x 32) = 2728.31
TV/(37 x 32) = 3023.26
TV/(57 x 16) = 3924.94
TV/(53 x 16) = 4221.16

4 MHz/($A5 x 8) = 3030.30
4 MHz/($81 x 8) = 3875.97

Where $ = hexadecimal number instead of a three digit decimal number

It is easy to divide a frequency by any integer, using programmable up/down counters, eg. 74192 or 74193 TTL chips or their CMOS equivalents.(4) Converting decimal divisors to hexadecimal and using full 4-bit counters instead of decade counters sometimes saves chips, eg. decimal numbers from 100 - 255 become 2-place numbers when converted to hexadecimal.

The simplest frequency divider is a cascade of flipflops, which divides frequencies by powers of two. Filter-clocking and local oscillator frequencies are easily obtained by tapping a straight divider chain (available on a single chip). Cave radio experimenter Ray Cole has had excellent results using the TV crystal of 3.579545 MHz and such a chain to provide frequencies of 3.49565 and 6.9913 kHz combined via an "AND" gate for a 25% duty cycle transmit pulse at 3.49565 kHz, and frequencies of 873.9 x 1, x 2, x 4, x 8, x 16 to clock his commutating filter. Unfortunately while his transmitter frequency of 3495.65 Hz fits well between 60 Hz harmonics it is only 4 Hz away from a 50 Hz harmonic.

The US Bureau of Mines tested 630, 1050, 1950 and 3030 Hz for mine-rescue radio location (2). Results were slightly better at lower frequencies. All these frequencies are half-way between 60 Hz harmonics but only 630 and 3030 Hz avoid 50 Hz harmonics by the formula above.

Ideally, local oscillator frequencies and mixer products should also be in between power-line harmonics. Intermodulation could cause interference if the input signal to the mixer contains powerline harmonics near the local oscillator frequency.

References

(1) Davis, Nevin W. Optimum frequencies for underground communication. NSS Bulletin vol 32, #1, (1970)

(2) Durkin, John. Performance evaluation of electromagnetic techniques for the location of trapped miners, US Bureau of Mines, Report of Investigation, RI 8711,(1982).

(3) Reid, Frank Caveman Radio. 73 Magazine, Feb, (1984)

(4) Reid, F and Honeycutt, R K. A digital clock for sidereal time. Sky and Telescope, July, p59, 1976.

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NEEDED

A program for an IBM-PC for drawing electronic circuits.
Preferably cheap and with templates if necessary.
Help your editors give what we all want.......

SHORT ARTICLES AND LONG CIRCUITS
not
LONG ARTICLES AND SHORT CIRCUITS.

Info by letter or phone to Ian Drummond, (403)-288-4034 or see questionaire for address.

Cave Communication Questionaire

Name ______________________________ Are you representing a group? Y/N ___
Address ______________________________ If "yes", who are they, and how many people are there?
______________________________ Group Name ______________________________
______________________________ # of people __________
____

Do you already have or use communication equipment? Y/N ______
If "yes", please give a brief description ______________________________
____
____
____

Is it satisfactory in performance? Y/N ______
If "No" please give brief reasons, if it is satisfactory, are you prepared to loan equipment or to share construction details? ______________
____
____
____

Which techniques are you interested in? Telephone _____ Seismic _____
Radio _____ Other _____

What do you want to use the equipment for primarily?
Survey work __________ Emergency location __________
Voice communication for Rescue ________
Exploration ________
Underwater ________
Data transfer __________ Remote sensing __________
Other, please describe ______________________________
____

What depths are the cave passages in your main caving area? ________metres

What length of time do you need the equipment to operate on an underground trip? __________ hours __________ days

Are you interested in Field testing of equipment? ________
Construction of established designs? ________
Construction of experimental designs? ________
Work on the theory for a better design basis? ________
Organization of this NSS Section? ________
Other? ______________________________

Do you have any books or articles which you would like to add to the bibliography or to the NSS Library on this topic? ______________________
____
____

If you are a Radio Amateur, please include call-sign, preferred frequency, and time of day for contacts.

Please send the completed questionaire to: I. Drummond
5619, Dalwood Way NW
Calgary, Alberta, Canada
T3A 1S6

Any additional correspondence welcome.

APPALACHIAN SEARCH AND RESCUE CONFERENCE, INC.
P.O. BOX 440
NEWCOMB STATION
CHARLOTTESVILLE, VIRGINIA 22901

COMMUNICATIONS STANDARD #1.0
12 VOLT D.C. POWER ("JONES PLUGS")

REVISION 0 P1/2

PURPOSE: STANDARDIZE AND PROMOTE INTERCHANGABILITY OF "12 VOLT" D.C. AUTOMOTIVE-TYPE POWERED DEVICES AMONG EMERGENCY PERSONNEL AND ORGANIZATIONS.

ELECTRICAL: "12 VOLTS" RANGING FROM 11 TO 15, BUT TYPICALLY 13.8 VOLTS DIRECT CURRENT, USUALLY FROM AUTOMOBILES OR BATTERIES, AT UP TO 7.5 AMPS (10 AMPS MAXIMUM).

STANDARD: 2-PIN "JONES PLUG" AS ILLUSTRATED BELOW.

SOURCE AND NUMBERS:	CORD MALE	CORD FEMALE	CHASSIS MALE	CHASSIS FEMALE
RADIO SHACK →	274-201	274-202	—	274-203
TRW CINCH →	P-302-CCT	S-302-CCT	P-302-AB	S-302-AB

(TRW VERSIONS RECOMMENDED: METAL SHELLS, MORE VARIETIES AVAILABLE)

CONNECTION AND ASSEMBLY: SOLDER(!) AND INSULATE CONNECTIONS. (* = TYPICAL)

MALE (PINS) FOR LOADS (RADIOS, LITES...) NARROW FOR "HOT", +12V, RED* WIRES

FEMALE (HOLES) FOR SOURCES (BATTERY...) WIDE FOR "GROUND", -12V, BLACK* WIRES

SAFETY: ALWAYS FUZE-PROTECT WITH RATING APPROPRIATE TO 1) SPECIFIC DEVICE/LOAD, 2) SPECIFIC SOURCE/BATTERY, OR 3) WIRE SIZE, WHICHEVER IS LEAST, OR FUZE CONNECTOR AT 10 AMP (MAX 15).

WIRE SIZES/MAX AMPS: AWG #16 @ 7A ; #14 @ 15A ; #12 @ 20A ; #10 @ 30A

USE HIGH TEMPERATURE AUTOMOTIVE-TYPE WIRE, ESPECIALLY IN CARS OR ROUGH SERVICE.

LIGHT-DUTY CORDS AND ADAPTORS MIGHT USE LAMP (ZIP) CORD.

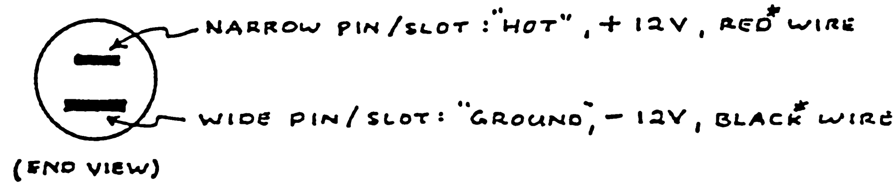
COMMUNICATION STANDARD #1.0

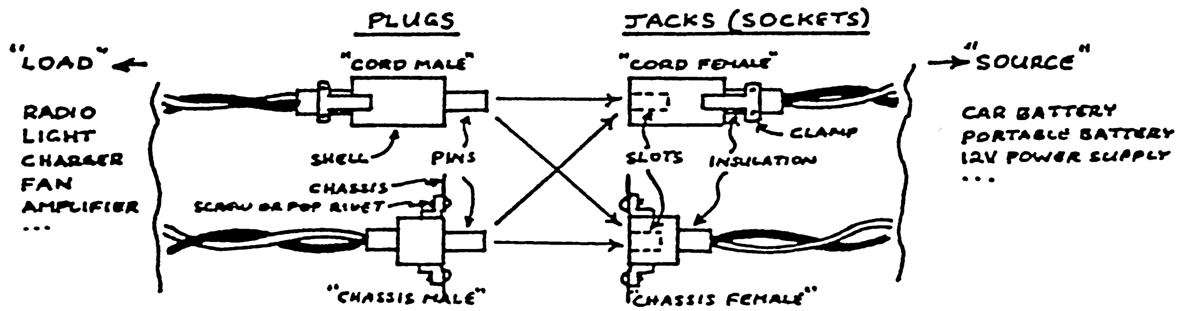
©INOV84GLHARRISON

Revision 0   P2/2

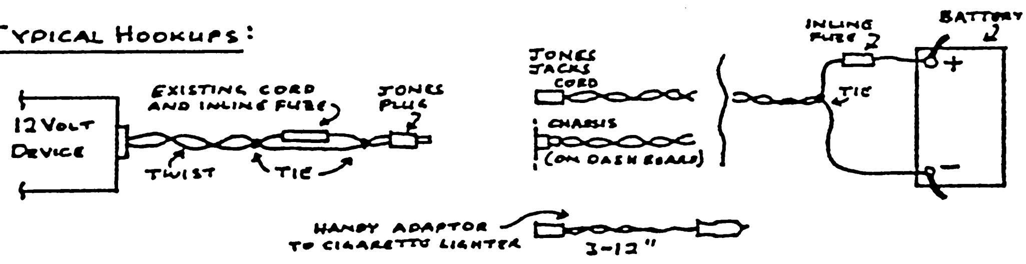
2-Pin Jones Plug:

(* = TYPICAL)

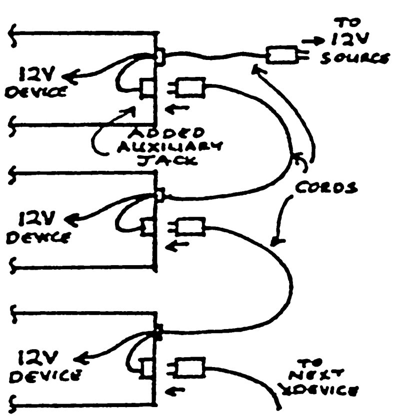


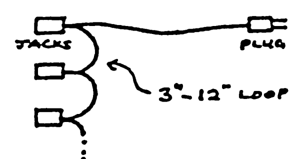


Typical Hookups:

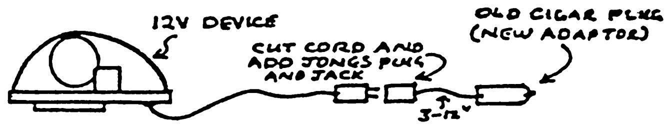


"Daisy Chain" Devices And Cords (Promote Flexibility)





Simple Conversion "Cigar" to "Jones"



Typical Junction Box