

# **Simple HF Digi-Radios for Through-Earth Communications**

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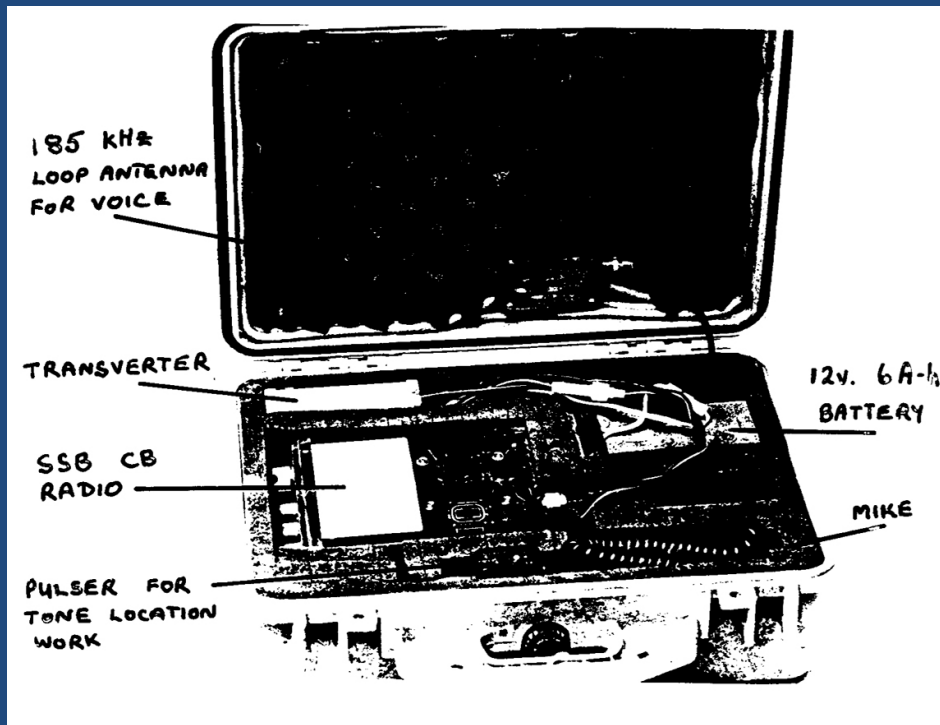
**TAPR DCC, Albuquerque, NM**

**September 14, 2018**

# Compelling Need for Underground to Surface Comms

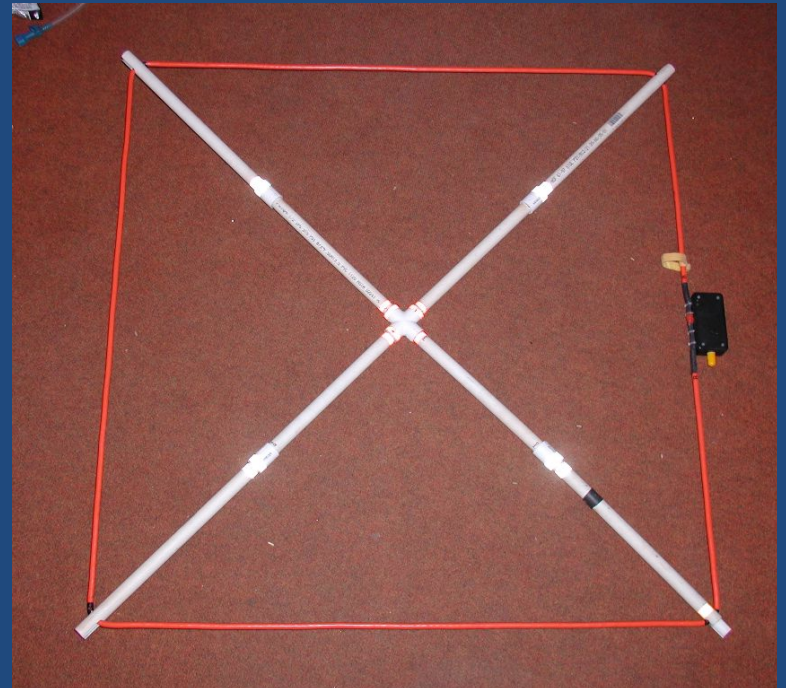
- Cave exploration in very long underground passageways requires teams to travel as much as 8 hours from the entrance portal
- Some caves require underground camping for days or weeks
- All would benefit from a simple communication device with the surface. Safety information, messaging from families, needs for supplies, and efficient rescues need real time communications
- Voice is OK, but for best s/n, digital text mode is best

# Analog (Voice) Systems





# Cave Voice Radio-185kHz













# The 'HeyPhone' to the Rescue

THROUGHOUT the UK, a band of enthusiasts spends its weekends

By Mike Bedford, G4AEE \*

After 15 years of yeoman service, the 'Molefone', caving's standard transceiver, was approaching the end of its useful life. This is the story of its replacement - the 'HeyPhone'.

and talk about a personal voyage of discovery. I would enthuse over the beauty of pure white straw stalactites and the awesome grandeur of thundering subterranean waterfalls. I might even tell tales of exploration and heroism, and bandy around names such as that of the Victorian cave explorer, Edouard Martel. But, despite my enthusiasm over this world of darkness, I would have to admit to the commonly-held view that potholing is dangerous, or at least potentially so, to those who are inexperienced, careless or plain unlucky. And when accidents happen, members of the volunteer cave rescue teams are called out to help those who are lost, cut off by rising water, have fallen, or are the victims of some other catastrophe.

## RESCUE COMMUNICATIONS

NOT ALL CAVING trips are as quick or as easy as a jaunt into a tourist cave. Some cave systems contain tens of kilometres of passages, progress is often barred by vertical pitches which have to be abseiled down, and even horizontal motion can be a mixture of crawling and squeezing rather than walking. It's not surprising, therefore, that it can often take rescuers many hours to reach a casualty, and even longer to return to the surface with the hapless caver strapped on a stretcher.

Traditionally, therefore, the

rescue team could be out of contact with the surface controller for hours on end. And if additional equipment or personnel were required, the only option would be to send a 'runner' back to the surface. This delay could easily cost lives. Cave rescue made a giant leap forward, therefore, when the 'Molefone' was introduced in the early 80s. Developed by Bob Mackin of Lancaster University, a member of the Cave Rescue Organisation in Clapham, North Yorkshire,

it revolutionised cave rescue. Operating at a low frequency of 87kHz in order to penetrate the rock, and employing the principle of induction rather than radiation to avoid the need for huge antennas, the Molefone allowed underground rescue teams to talk directly to rescuers above ground. Operating in the inductive near field doesn't provide long range communication, as the signal strength decays with the cube of the distance. However, it does penetrate limestone to a depth of a few hundred metres which is perfectly adequate for most British caves. There are undoubtedly people walking around today who owe their survival to the Molefone.

## NEEDED - A NEW CAVE RADIO

BUT TIME moves on and a couple of years ago, the British Cave Rescue Council (BCRC) recognised that they had a problem. Although the Molefone had done sterling service, fifteen years is a long time to expect electronic equipment to survive in what must be one of the most hostile of environments. Being dragged along cave floors, being subjected to the occasional dunking, being dropped and generally abused for this length of time had taken its toll on the Molefones and the BCRC's member teams were starting to report failures.

To make matters worse, repair was difficult, if not impossible, because the PCBs had been potted in epoxy resin to improve their immunity to physical shock and some of the components were obsolete. It looked as if the Molefone was coming to the end of its useful life.

## RADIO AMATEURS TO THE RESCUE

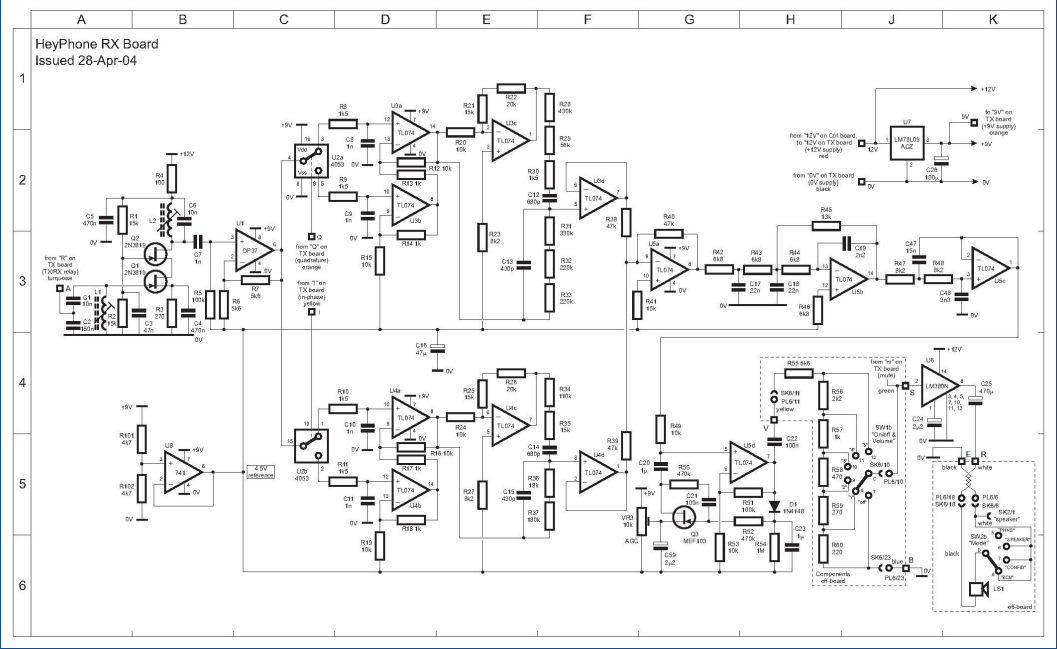
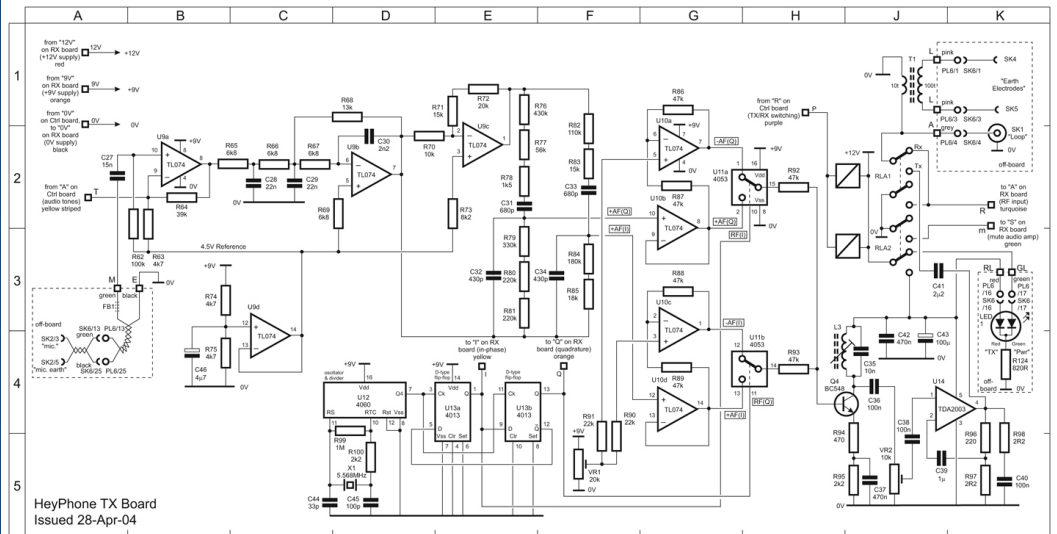
WITH A LOSS of communications capability looking ever



A HeyPhone in use on the surface above Carlswalk Caverns in Derbyshire.

Reflex • January 2002

Reflex • January 2002



87 KHz SSB or DSB, Earth current

# Digital (Text) Systems

# Digital Modulations of Interest

Category	Mode Designation	Baud Rate (Hz)	Phases / Frequencies	Data Throughput		Bandwidth (Hz)	Forward Error Correction	Minimum Signal-to-Noise Ratio (dB)
				Upper Case Only	Full ASCII			
Phase Shift Keying	BPSK31	31.25	2	51	37	80	N	-11.5
	QPSK31	31.25	4	51	37	80	Y	-11.5
	BPSK63	62.5	2	102	74	160	N	-7
	QPSK63	62.5	4	102	74	160	Y	-8
	PSK63F	62.5	2	42	N/A	160	Y	-12
	PSKFEC63	62.5	2	28	N/A	160	Y	-14.5
MFSK	MFSK8	7.8125	16	N/A	26	316	Y	-15.5
	MFSK16	15.625	16	N/A	42	316	Y	-13.5
	WSPR	1.4648	4	5.4	N/A	6	Y	-28
	JT65	2.69	64	3	N/A	180	Y	-24
Reference Modes	SSB (speech)	N/A	N/A	N/A	N/A	2,500	N/A	+6
	CW (Morse)	10	2 levels	12	N/A	48	N/A	-12
	QRSS (Slow Morse)	0.008	2 levels	0.02	N/A	0.017	N/A	-33

**LOCKHEED MARTIN**

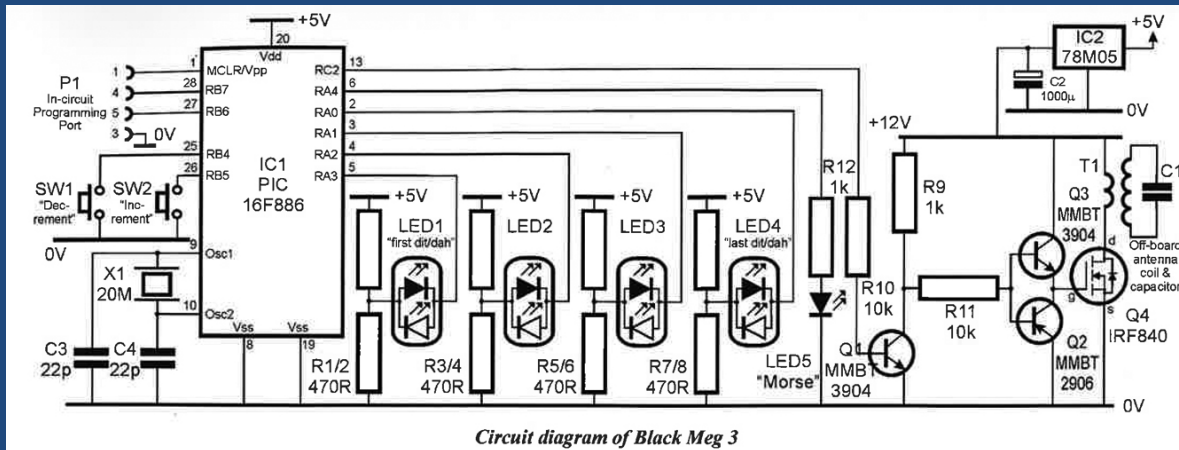
*We never forget who we're working for®*



## **MagneLink® Magnetic Communication System (MCS)** Through-The-Earth Two-Way Emergency Wireless Communications for Mine Industry Safety





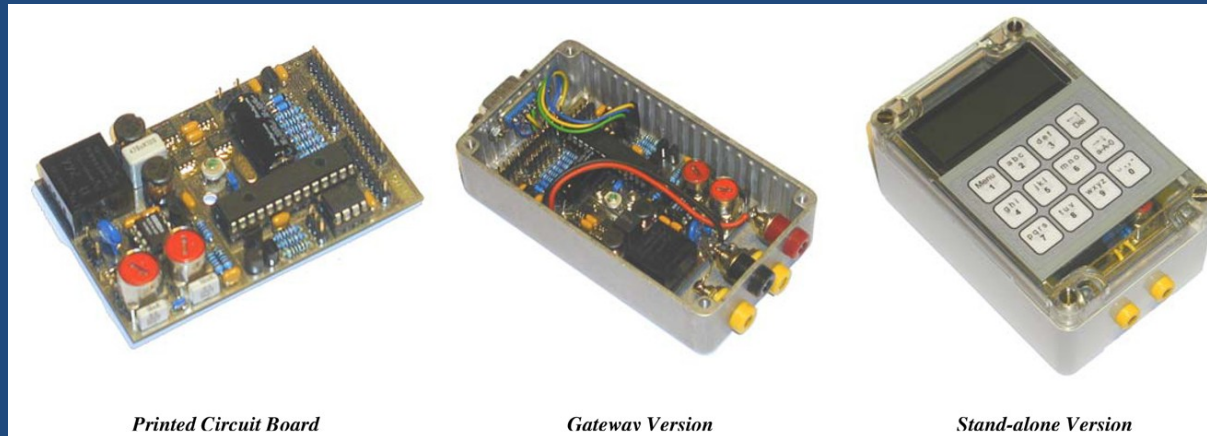
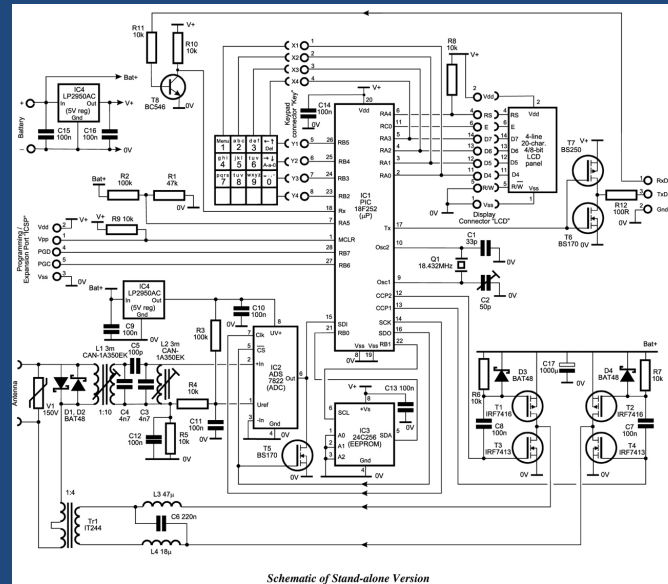


- VLF
- Precoded Messages
- One way only

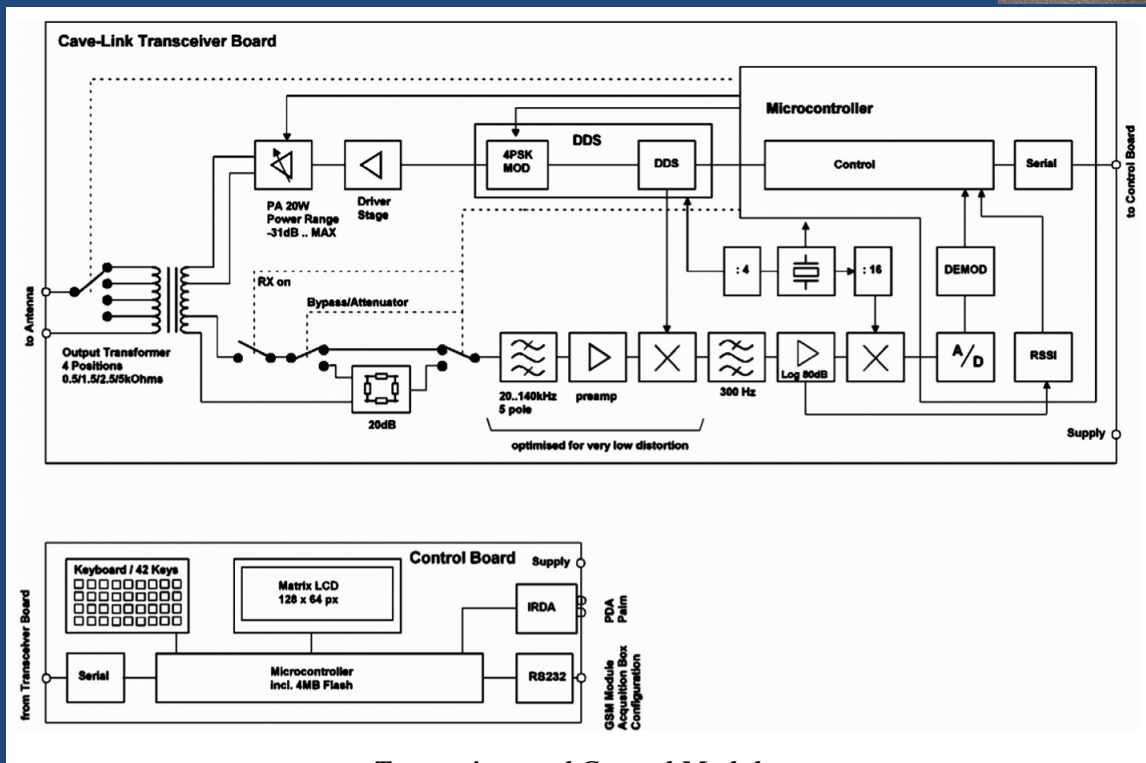
Msg No.	Binary	Message Code				Message
0	0000	DIT	DIT	DIT	DIT	2 Divers reached Tipperary OK
1	0001	DIT	DIT	DIT	DAH	3 Divers reached Tipperary OK
2	0010	DIT	DIT	DAH	DIT	4 Divers reached Tipperary OK
3	0011	DIT	DIT	DAH	DAH	Air bad in Tipperary heading out in morning
4	0100	DIT	DAH	DIT	DIT	Air bad in Tipperary heading out ASAP
5	0101	DIT	DAH	DIT	DAH	All OK - Sleep tonight - Dive tomorrow
6	0110	DIT	DAH	DAH	DIT	Divers back at Tipperary after dives in Sump 3
7	0111	DIT	DAH	DAH	DAH	Exiting Sump 2 today/tonight
8	1000	DAH	DIT	DIT	DIT	Exiting Sump 2 as planned on time
9	1001	DAH	DIT	DIT	DAH	Exiting Sump 2 as planned – 2 hours later
10	1010	DAH	DIT	DAH	DIT	Exiting Sump 2 as planned – 4 hours later
11	1011	DAH	DIT	DAH	DAH	Exiting Sump 2 24hours later than planned
12	1100	DAH	DAH	DIT	DIT	Will need to return to Tipperary in 1,2 or 3 days
13	1101	DAH	DAH	DIT	DAH	Significant dry passage found
14	1110	DAH	DAH	DAH	DIT	Batteries are low – may lose contact soon
15	1111	DAH	DAH	DAH	DAH	Transmitting Locating Pulses



- 42.6 KHz BPSK
- Earth Current
- 3300 ft depth



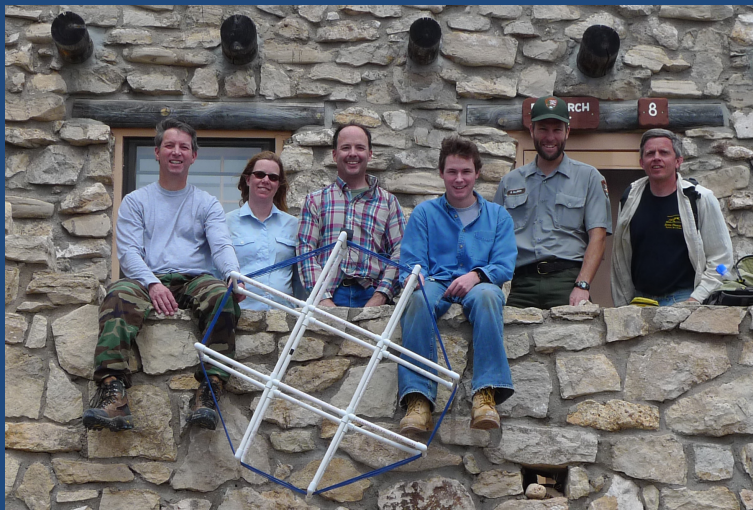
- 20-140 KHz QPSK
- Earth current
- 3160 ft depth



Transceiver and Control Modules



# Alex Kendrick's digital radio (2009)

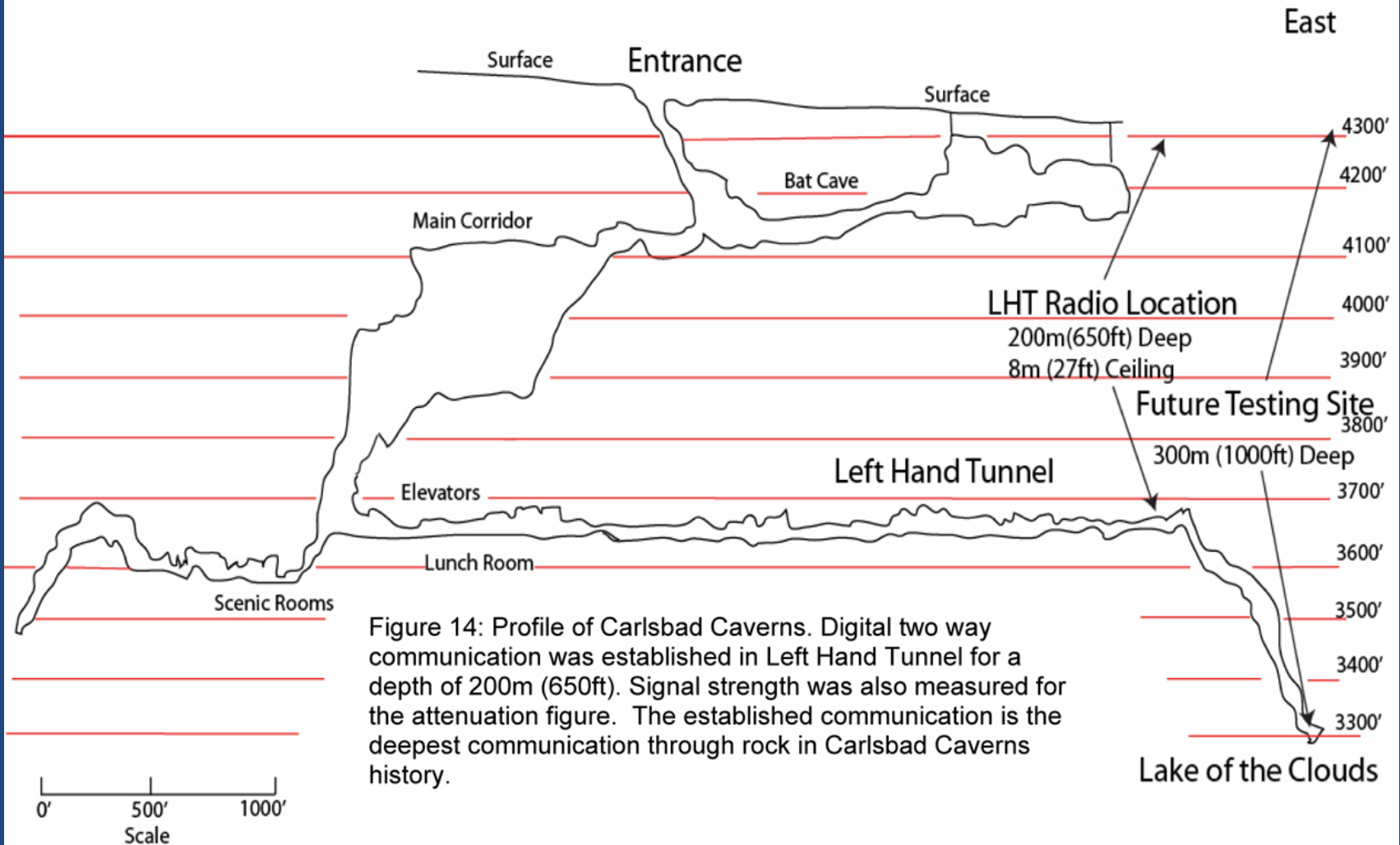


- 23.4 KHz prototype
- 25 turn loop
- Simple on/off keying
- Custom alpha code using PWM



# Profile Map of Carlsbad Caverns

Eddy County, NM



- High frequencies are intriguing. Radios could be COTS units
- Work by others has suggested that HF attenuation through rock in arid regions is not as severe as thought
- The increased efficiency of tuned half-wave dipoles and loops at HF has advantage over electrically short LF antennas



- Work by Paul Jorgensen, KE7HR, proved that HF frequencies had some potential for underground to surface communication and vice versa\*.
- Tests at Carlsbad Cavern using FT817-ND with 3.9 MHz SSB and 5 watts demonstrated reliable voice communications to 780 feet.



\*Speleomics 27, June, 2011

In 2015, the UK Cave Radio and Electronics Group published HF communications testing with 7.135 MHz SSB using FT706 and 20 watts with half wave dipole antennas. Depth was about 330 feet, and slant distance between radios was about 1270 feet.



BCRA Cave Radio and Electronics Group,  
Journal 95, Sept. 2016



BCRA Cave Radio and Electronics Group,  
Journal 92, Dec. 2015



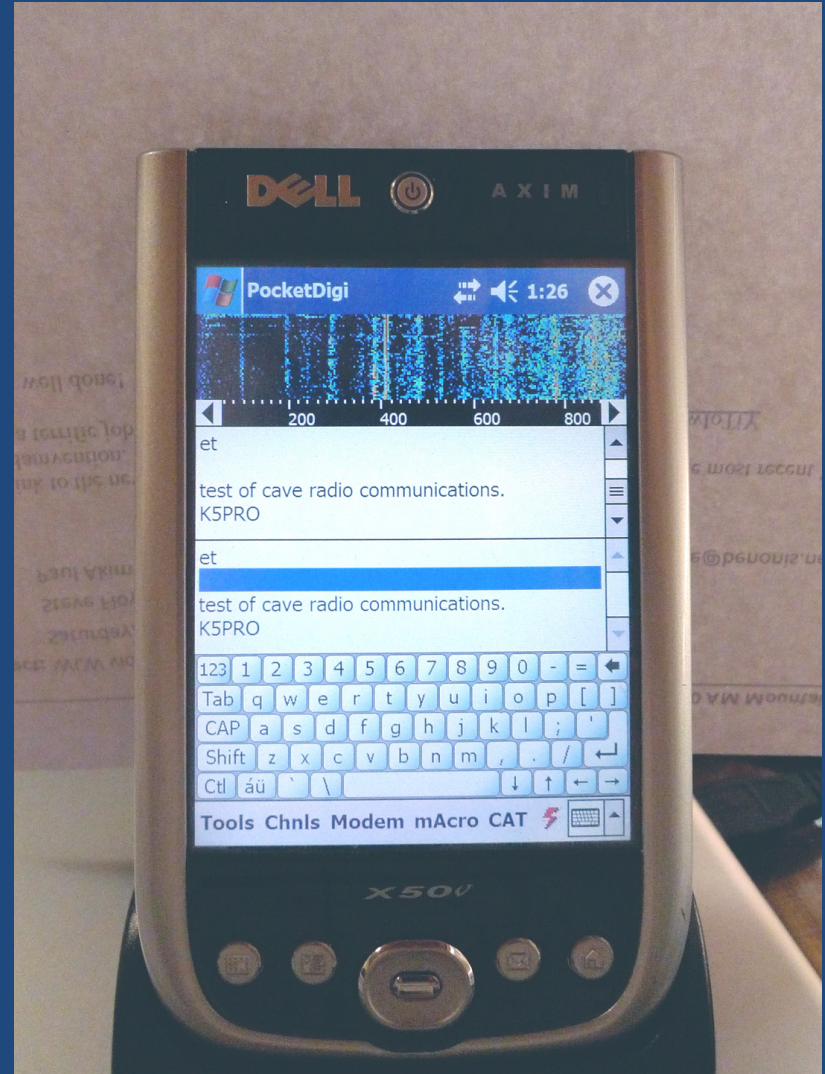


*7MHz WSPR transmissions from nine countries were received 100m underground. Map Data ©2016 Geo-Basis/DE-BKG (©2009), Google Inst. Geogr. Nacional)*



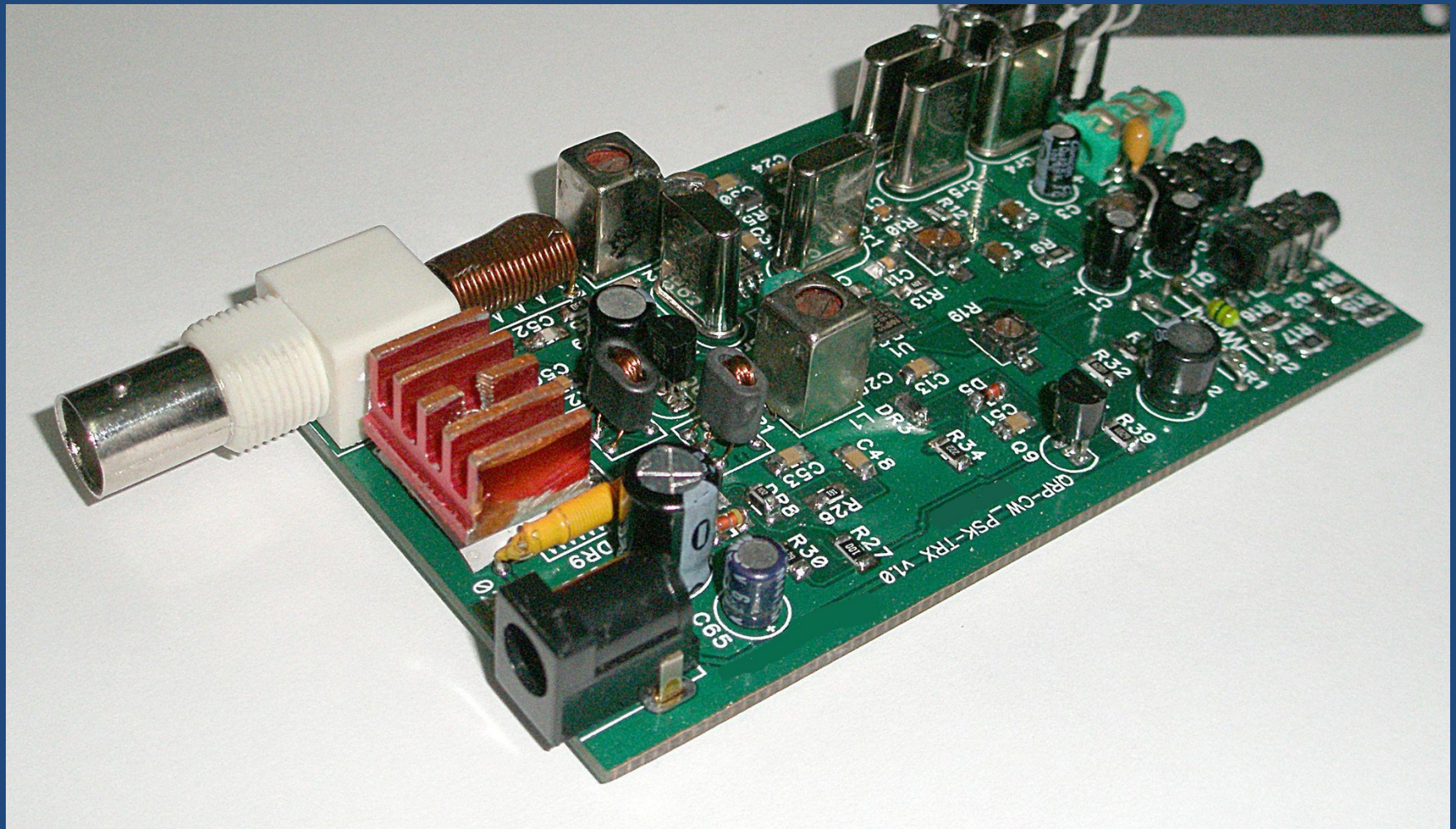


These surplus PDAs provide a convenient all-in-one text terminal and modem



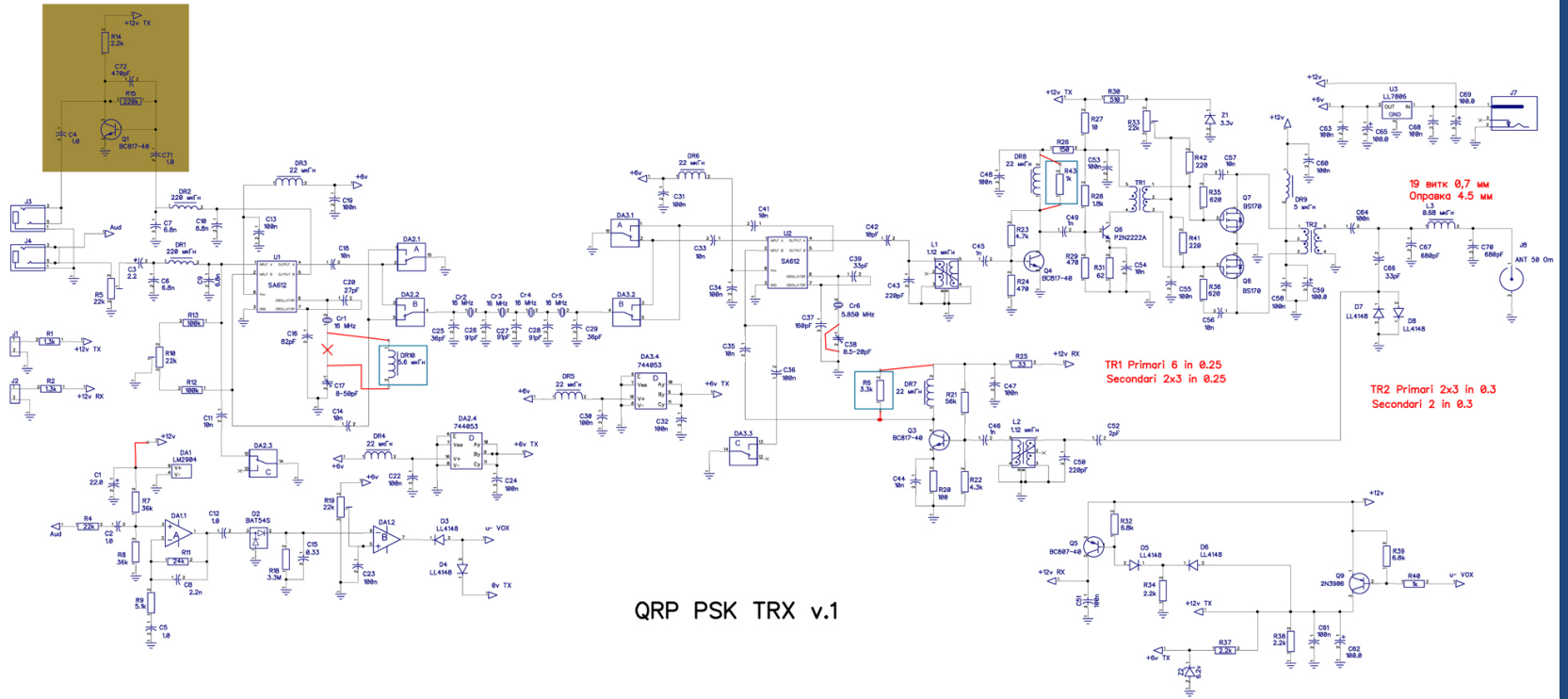
- Commercial HF transceivers such as the Warbler and Small Wonder PSK radios are no longer available
- A Ukrainian source of compact HF PSK radios provides PSK transceivers for 40, 30 and 20 meter amateur bands. Serge, UT5JCW, sells these through the ebay business "transverters-store"



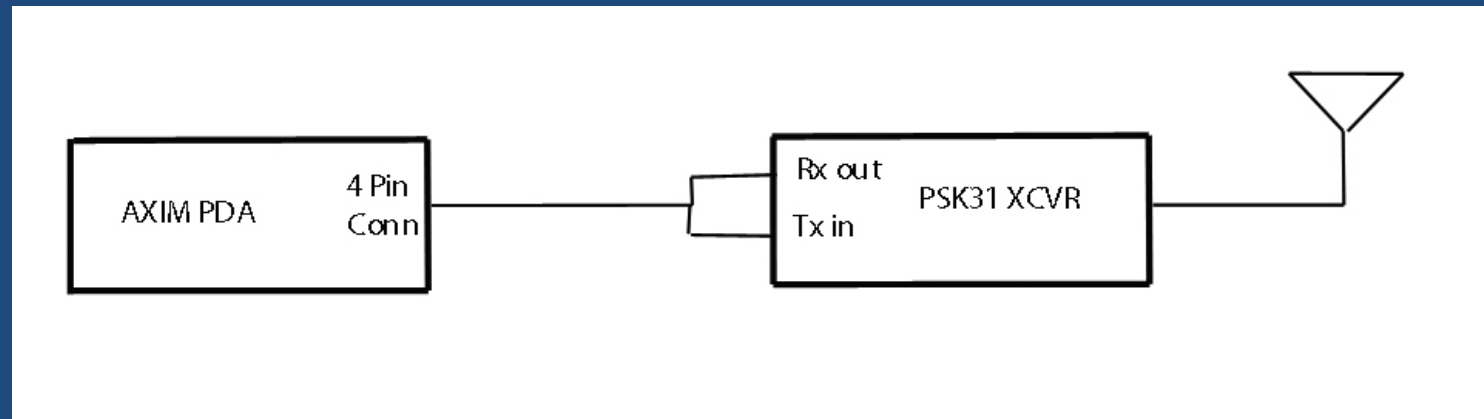


30 meter band (10.148 MHz) was chosen as there is lower usage and radio traffic/noise

# 10.148 Mhz



Very simple setup, audio cable and RF,  
12 V battery for PSK transceiver



Total cost is ~\$200



# Test Antennas



# Status

- 2 Radios and Pocket-Digi terminals are ready for test
- Antennas to be tested are full half wave or shortened loaded dipoles and tuned loops of a few turns, 1m diameter.
- Tuning will be required and is one concern for reliability

# Acknowledgement

British Cave Rescue Association,  
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Carlsbad Caverns National Park

Bob Buecher

Brian and Alex Kendrick

Paul Jorgensen, KE7HR

Ray Cole, K4GAA (SK)