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A subterranean innovation

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A subterranean

Above ground, we have come to take communication for granted, but one man's invention will long be appreciated below ground. By **Mike Bedford**.

The sport of caving, or potholing if you prefer, only ever comes into the limelight when something goes badly wrong. The Cuetzalan Tiger 2004 caving expedition to Mexico was no exception. The first most of us heard about it was when six British cavers became trapped by rising waters. Media attention reached fever pitch as the Mexican government accused these hapless cavers first of being on an unauthorised military exercise and then of prospecting for Uranium. After a week of incarceration the six were eventually rescued by a team of British cave divers before being expelled from the country for alleged visa violations. Those with a technical turn of mind can't help but to have noticed mention of a so called 'high tech mobile phone' which, according to the news reports, the trapped cavers used to maintain contact with their colleagues on the surface. The equipment in question was a through rock communication system called the HeyPhone, designed by retired electronics engineer John Hey.

Rescue communications

Throughout the UK, teams of volunteer cavers are on constant standby to provide assistance to those who get into difficulty underground. But extricating an injured caver from a deep cave is rarely easy. If the casualty isn't able to walk, it can take many hours for a rescue team to manhandle a stretcher through tortuous passages and up vertical pitches, during which time rescuers would invariably be out of touch with support on the ground for extended periods. However, cave rescue was revolutionised in the 1970s with the development, by Bob Mackin of Lancaster University, of the Molefone, a radio which could transmit through solid rock. For the first time the underground team could call in additional support or specialist equipment when necessary. Undoubtedly, the new technology saved lives.

In order to penetrate rock, the Molefone operated in the LF portion of the radio spectrum at 87kHz. But because an efficient radio antenna at this frequency would have been so large (the wavelength is more than 3km) it employed induction rather than radiation. Transmit and receive

antennas were small multi-turn loops and, although the range of an induction system is severely limited by inverse cube law attenuation, it could achieve the hundred metres necessary to reach most points in British caves.

The Molefone was built to a high standard of mechanical engineering, however, caves are particularly hostile to sensitive electronic equipment and cavers are not renowned for their careful handling of gear. By the mid 90s, many of the rescue teams were reporting failures and, to make matters worse, repair was difficult since the Molefone used a number of analogue ics which were now obsolete. With the rescue teams facing a return to the dark ages, the British Cave Rescue Council (BCRC) – the national body responsible for cave rescue – starting looking for a replacement. Their search led them to CREG (the Cave Radio and Electronics Group), a special interest group of the British Cave Research Association (BCRA). Fortuitously, CREG member John Hey had recently designed a new cave radio and CREG had been experimenting with methods of improving the range beyond that of the Molefone. The BCRC decided to base its new rescue radio on John's design and to call it the HeyPhone.

Cave Radio: the Next Generation

Asked what led him to develop a cave radio, Hey said: "I became interested in cave radio as an outlet for experimentation I was doing, using cmos switches and multiplexers as mixers and the use of tuned filters in place of LC tuned circuits. Hearing that cave radios used low frequencies, it seemed that here was a means to try out some ideas. By chance I was introduced to CREG, who I'd never heard of before, and soon entered my very first cave."

Although based on John's circuit, the design of HeyPhone was influenced by the needs and aspirations of the rescue community. Unlike consumer electronic equipment, a cave radio is expected to remain in service for many years. So it was important to make sure that units could be repaired and replacements built well into the future. This had an impact on the choice of components. Programmable parts such as PIC processors were discounted in favour of simple components which were unlikely to be discontinued in the foreseeable future. All ics are either 4000 series logic chips, common op amps or the audio amplifiers.

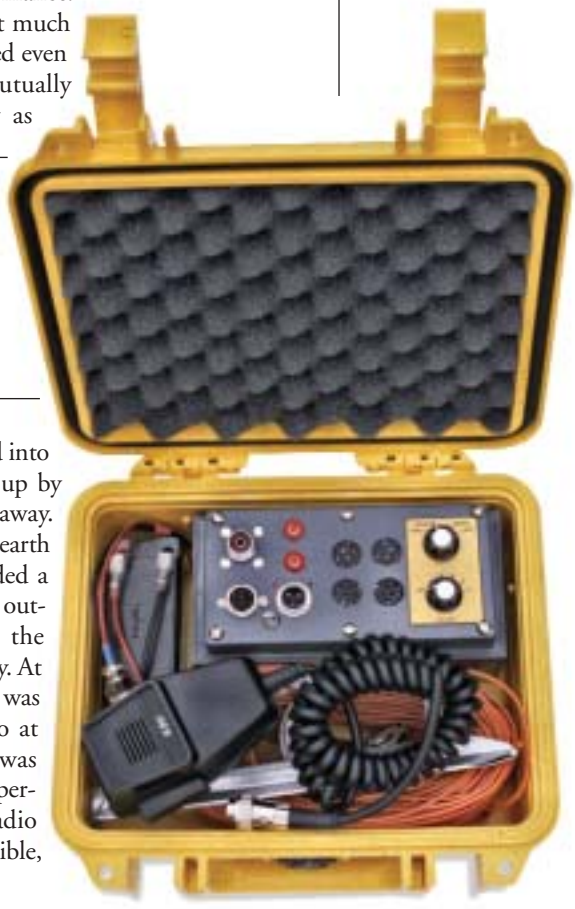
Making the units cave proof was also a major consideration. The Molefone had been potted in epoxy resin to provide the maximum protection against mechanical shock and the ingress of water. Ironically, when they did start to fail, this contributed to difficulties in maintenance.

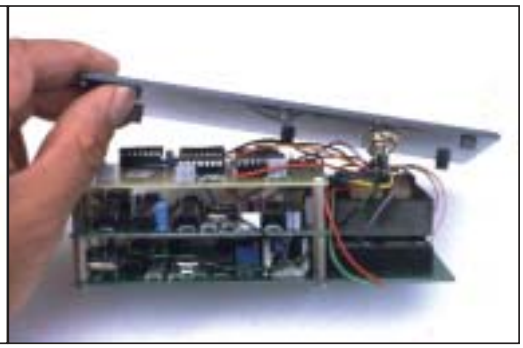
A different approach was taken in the design of the HeyPhone. The three pcbs are cushioned by neoprene sheeting and housed in a sealed plastic 'main box' but no attempt was made to pot them. The user controls, connectors and indicators are fitted into a separate 'top box' which is sealed to the main box, the two being attached via D-type connectors. The rationale is that the components which are most likely to fail (due to mechanical damage, mud and water) are the ones in the top box. So people with only basic constructional skills can carry out the most common maintenance tasks without the risk that they'll disturb the more delicate components.

But the HeyPhone wasn't just an updated Molefone; it operates in a fundamentally different way as John Hey explains: "Loops had been the traditional antenna for cave radio and much work had been done to improve their performance. Even so, a maximum range of not much more than 120m could be achieved even when the two loops were mutually aligned. It was known as early as World War 1 that audio signals fed into earth electrodes could be picked up by similar electrodes some distance away. So we decided to experiment with earth arrays for the HeyPhone. We added a transformer to lift the transmitter output voltage and impedance to the much higher value of an earth array. At our first test, a 35dB improvement was noted. With earth electrodes also at the receiver, a further 30dB was achieved. Trial end error at our experimental meetings have shown radio contact to more than 800m is possible,

The HeyPhone was designed by Cave Radio and Electronics Group member John Hey. Hey then undertook the electronic construction of 66 units for the British rescue teams by hand.

innovation





Above: The design features a two part box. The main tranceiver box contains the main electronics and the 'top box' contains all the panel mounted components.

John Hey hasn't patented the HeyPhone in the belief that it will only serve its purpose of saving cavers lives if the design is placed in the public domain. This ensures that maintenance and replacement is easier.

subject to certain geological conditions."

The most important consequence of a greater range is that it's very much easier for a surface rescue controller to remain in contact with the team underground. When operating with the Molefone at maximum depth, contact was only maintained by the surface party tracking the cavers along the surface. Quite apart from the additional burden it placed on a surface radio operator, this required an intimate knowledge of how underground locations related to features on the surface. With the range of the HeyPhone now hundreds of metres it's possible, in many cave systems, to set up a single surface station which will be able to communicate with the underground team anywhere in the cave. What's more, it might even be possible to establish the surface station from the comfort of a vehicle – a far cry from an exposed area of moorland in the pouring rain.

The way ahead

It's now three years since the rescue teams took delivery of their HeyPhones and today they're as familiar with these as they had been with the Molefone for the previous 15 years. And communication is proving possible over paths which hadn't previously been achievable. One high profile rescue involving use of the HeyPhone was at Otter Hole near Chepstow last year. As a tidal cave on the Severn estuary, this particular cave is a proverbial quagmire and a graphic illustration of the conditions the HeyPhone has to be able to withstand. At the end of the rescue, the radios emerged dripping and encased in brown mud, but still working perfectly.

So does the HeyPhone represent the ultimate in cave radio development or are there new challenges to be overcome? Hey comments: "Because of their success, no great improvements have been made to the basic design. However because of an annoying interference from LORAN, a navigation aid, other frequencies are being investigated and a pair of radios working at 38.4kHz (the original sets worked on 87kHz for compatibility with the Molefone) are now being evaluated."

Hey foresees that the only commercial application of the HeyPhone would be in the mining industry. He recounts that although most mines have leaky feeder and telephone systems for communication, there are indeed applications for a through rock system should the fixed installation be taken out by a catastrophe such as a fire. And although the HeyPhone cannot be used in coalmines with their explosive atmospheres, Hey has demonstrated the HeyPhone to British Gypsum in one of its mines. He does not, however, expect to build a business providing through-rock communication systems. "No, I'm now beyond retirement age and I'm certainly not about to enter a further business venture". And to further emphasise the point that his interests are technical and altruistic rather than commercial, John has refused to patent the HeyPhone in the belief that it will only fully serve its purpose of saving cavers' lives if the design is placed in the public domain.

The schematics and a host of other technical information are available at **www.heyphone.org**.

Further information on cave-related electronics can also be found at **www.bcra.org.uk/creg**. NE

Sub surface comms

Conventional radio at hf, vhf and uhf can be used for short range communications along tunnels, although this is often limited to little more than line of sight working. Leaky feeder systems are used to extend the working range in permanent installations, but are very expensive. Therefore, despite the disadvantage of having to lay a cable, telephones continue to be used for cave and mine rescue operations because they are simple and robust.

The single wire telephone, known also as an earth return telephone, uses the conductivity of the ground to provide a return path for the current. Like 19th Century electric telegraphs, the obvious advantage is that only half the weight of cable has to be laid. The high impedance devices used by cavers will often operate without any specific earthing other than through the operator's body.

For true 'through rock' operations, we have to turn to 'wireless' communications. The challenge is that electromagnetic fields are attenuated as they penetrate a conducting medium and low frequencies are attenuated less than high frequencies – hence, the HeyPhone and previous cave rescue radio, the Molephone, operate at around 87kHz. For more on sub surface communications, see Dr David Gibson's cave radio website:
http://caves.org.uk/radio/comms_in_caves