A Low-cost Leaky Feeder System for Cave Communication

*Radio amateur **Fabrizio Marincola**, I0HCJ, describes a leaky feeder system using ordinary low-cost coaxial cable. Practical details are provided allowing others to duplicate the system underground.*

Introducing CSR

This article describes an underground radio communication system named CSR – Communications Speleological Radio-transmitted, an acronym coined by the Club Speleologico Romano and developed during the exploration of the Gnomo Gnomo cave in the Ernici mountains of Italy. This simple underground communications system operating at VHF frequencies (specifically, the Italian 160MHz civil band, although it could be adapted for use at other frequencies) immediately showed its peculiarities (and also its deficiencies) but has, nevertheless, facilitated the success of the cave's exploration.

This system has also been used on several occasions by cavers in Cani Sciolti and Buca della Giana, a resurgence located on the southern Moune Acuto, in the Mount Catria mountain range. It has proved to be essential in coordinating cavers during the emptying of sumps and also as a security measure, given the high concentration of carbon dioxide that had accumulated in several points in the cave. Recently, it was exploited for the very basic but essential purpose of communicating between the two ends of the final sump of the Viva le Donne cave.

Compared to LF through-the-rock radios such as the HeyPhone and the System Nicola, the advantage of this system is that communication can readily be achieved from any point within the cave. By way of contrast, because of the weight of the equipment and particularly the size of the antennas, LF cave radios tend to be used for point-to-point links.

Leaky Feeder Systems

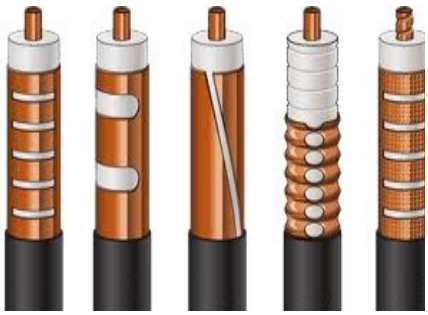
You may have noticed that it is commonly possible to use mobile phones in railway and road tunnels, urban underpasses, underground car parks in major shopping complexes, in terminals at airports, and in other large reinforced concrete buildings. These are all places where we wouldn't expect good radio communication because of the severe attenuation caused by passage through the ground and reinforced concrete structures.

When communication is possible, it's often because the telephone network operators have installed radiating cables that are connected to the mobile phone networks. By use of repeaters connected to similar radiating cables, such systems are also used by police and emergency services in areas devoid of normal radio coverage, by staff working in the holds of ships, in the vaults of banks, and in mines. Mention of the use of radiating cables in mines suggests that it might also find application in caves.

These systems use so-called 'leaky feeders', which are coaxial cables that are designed to be partially radiating. Their operation is comparable, therefore, to a very long antenna in which radiation is achieved by incorporating gaps into the copper screen. Various types of slotted coaxial cables are illustrated in the diagram to the left.

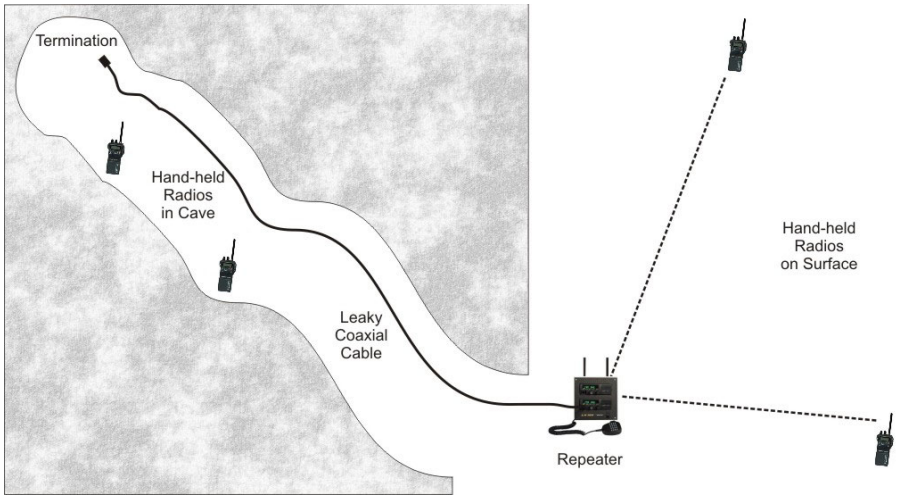
A Solution for Caving

Although a leaky feeder system would, potentially, be suitable for cave communications, there is a problem. There are several types of leaky feeder cable on the market but all have drawbacks. First, the diameter ranges from 6mm upwards, the weight is considerable, and bends must be of a wide radius to avoid causing damage to the cable. Second and most importantly, the price is considerably more than most cavers would want to pay. So what alternative solution can we find? Several options were considered.



Leaky feeders can employ several methods of radiating a signal but are expensive.

By way of contrast, ordinary TV coaxial cable is cheap and will actually radiate.



The CSR system allows users with handheld radios within range of the repeater on the surface to communicate with cavers underground, also using handheld radios.

Installing the System: Step-by-Step Guide

Installation is not particularly complicated. Two cavers, even if not expert in telecommunications, can do it very easily. The instructions here provide practical guidance on how to install a CSR system.

1. As preparatory work before going into the cave, unpack the rolls of coaxial cable and solder F-type connectors to both ends. Wind it onto a spool to make it easier to roll it out in the cave.

2. Install the repeater outside or just inside the entrance of the cave. Alternatively (but with reduced functionality as discussed in this article) use an ordinary VHF radio so long as it has an antenna socket.

3. If you're using a repeater, ideally install a solar panel for recharging the batteries. Try to find a suitable south-facing place in the sun, avoiding the shadows of branches and the inevitable very narrow gorge.

4. One drum at a time (a 100m drum being the most you'll want to carry in a cave), run the coaxial cable throughout the cave passage. Where possible, fix it securely to the ceiling or walls where nobody is likely to tread on it. Remember that cavers are not renowned for their delicacy and will undoubtedly damage the cable unless installed carefully.

5. At the end of each 100m drum, connect it to the next drum using an F-type back-to-back connector. Take care not to get any mud or water into the joint and protect the connection with a good measure of self-amalgamating tape.

6. At the end of the cable run, to simulate an antenna, connect a dummy load (terminator) made from a non-inductive 75Ω, 2W resistor mounted in a waterproof box.

7. Plug the cable into the repeater or base station at the cave entrance and all cavers equipped with radio will be able to talk to users on the surface.

First, at the suggestion of Daniele Reggianini, telecommunications engineer at Latel-COM in Rome, many tests were conducted, both in the laboratory using test equipment and practically, with the old flat 300Ω TV antenna cable.

However, the standard cheap types of coaxial cable that is usually installed in homes for digital terrestrial and satellite TV reception were found to offer a better solution. By exploiting its inherent characteristics of radiating a radio signal involuntarily, it can be used as a sort of 'poor man's slotted cable'. The performance is not remotely comparable to professional leaky feeder cables but it works and it's affordable. On eBay you can buy 6 rolls (600m in total) of medium quality cable for the modest sum of a little over €60.

Performance

The system as used to date includes a repeater at the cave entrance so that anyone with a handheld radio who is within range of the repeater can talk to cavers in the cave. This is shown in the diagram on the previous page. However, if you are happy to provide communication only between the cave and the cave entrance, any compatible VHF radio with an antenna socket can be used instead of the repeater.

The CSR system has been used to a range of 400 – 500m into a cave using 4W radios. However, at this range the signal was still strong which suggests that the maximum range is probably in excess of 500m. If the handheld radios used in the cave have the same transmitter power as the repeater or base station at the cave entrance, the range is the same in both directions.

So far the system has only been used in caves that did not have very wide passages so I can't say how far the handheld radios can be from the cable. However, if the radio signal passing through the coaxial cable is strong, I have not noticed any difference if the handheld radio is near or far from the cable.

The performance of the system is closely related to the power of the radio link and the quality of the cable used. The range referred to above was achieved using a medium quality 6mm TV cable and a VHF radio repeater with a 4W output. 5mm cable has also been tried and, while it is lighter and much more manageable, it has greater attenuation which limits the range, albeit only slightly. However, it is possible that really good quality cable might be less effective because of its reduced stray radiation.

It should be noted that the leaky feeder has no beneficial effect on communication

between two cavers in the cave. In this case, the cavers can talk to each other only if they are in line of sight, with no major obstacles, in just the same way that VHF handheld radios would work in a cave that doesn't have a cable installed. Accordingly, the maximum range depends on the cave geomorphology and is often little more than a few meters. Sometimes the waves bounce off the rock, slightly increasing the range but this is apparently random, never totally reliable and certainly not repeatable in the same way.

Advantages

To summarise, all cavers who are equipped with a radio can talk to a user at the cave entrance.

So long as a repeater is used at the cave entrance, the range can be extended to a few kilometres on the surface, depending on the topology of the area.

As an alternative to the microphone in the handset, cavers can use a clip-on microphone or a throat microphone for hands-free operation.

Using some very simple radio frequency filters, the coaxial cable lying in the cave can be used for other purposes simultaneously to providing the radio link. For example, it could be used as a telephone wire or to provide power for any low power electronic apparatus underground.

Disadvantages

As the longitudinal range increases, the more the signal decreases. Under these conditions, I assume that cavers will be forced to stay closer to the cable although I cannot yet quantify this.

Some types of Petzl headlamps exhibit an increase in the light output due to a malfunction of the circuit caused by RF interference when the lamp is close to the radio antenna.

The visual impact of installing a cable in a cave is not good, especially if it's left in place permanently. It is a bit of a 'punch in the eye' to see the white cable sandwiched between stalactites and other formations.

Alternate Frequencies

The system as implemented in Italy uses licensed VHF radios which are intended for civil use. Similar VHF allocations are available in other countries for PMR (Private Mobile Radio) and emergency use. However, the former usually requires a commercial licence and the payment of a fee (with the exception of PMR446 which is licence-free in several countries but at low-power UHF rather than VHF) and the latter is only available to the emergency services which might include cave rescue organisations but not general cavers. It is appropriate, therefore, to consider what alternative types of radio might be suitable but without the difficulty of licensing.

Licence-free Options

Italy is unusual in having a licence-free allocation at 43MHz but several other countries have similar VHF allocations although often with a very low power limit, for example the UK's 49MHz allocation.

More universally is the 27MHz CB allocation which allows low-cost handheld radios to be used with a power output of a few watts. Strictly speaking, this isn't VHF (30 – 300MHz) but it is close enough. The size of CB handheld devices isn't exactly small but it's bearable. The antennas are also much larger than those which are used with 160MHz VHF radios.

CB equipment might be suitable but field trials would be needed to assess the performance.

It might also be possible to use licence-free UHF equipment such as the PMR446 radios (446MHz) that are available in many countries, mostly in Europe.

Because an external antenna often can't be attached to this type of equipment, and because the power is low, they might only be suitable for this purpose after several modifications. Of course, any changes should be made only in an 'experimental' and reversible way so as not to invalidate the approval of the devices.

So far only laboratory tests have been conducted. In theory, the attenuation of the cable should be reduced at lower frequencies. However, the cable might radiate differently and we await tests in the field.

Also, for technical reasons, it is almost impossible to obtain radio repeaters that operate on these frequencies. In addition, if they were available, it is likely that they couldn't be used legally. For this reason, a base station at the cave entrance would have to be used instead.

144MHz Amateur Band

Although not licence-free, the band that would provide the most comparable performance to 160MHz, and which is available in most countries worldwide, is the 144MHz (2m) amateur band. Handheld radios with a power output of up to 5W are widely available and cheap (albeit not as cheap as licence-free radios) and some are rugged and waterproof.

Strictly speaking these can only be used by radio amateurs but so long as they're only used in a cave (and the radio at the cave entrance is connected only to a leaky feeder – i.e. not a real antenna) no interference will be caused to amateur radio operators. These amateur handheld radios must be simple, though, without the sophisticated features that are often found on amateur rigs. Remember that they have to be used by cavers, not by experienced amateurs, so it's important that they have the keypad lock.

A short article about amateur handheld VHF and UHF radios, which are also potentially useful for in-cave line-of-sight communication without a leaky feeder, will be published in the next issue.

Conclusions

The CSR system doesn't really represent a new invention. Instead, it's simply an adaptation allowing a professional underground communications system to be used by cavers in an economical way. As such it's an important tool for safety and an aid to cave exploration.

The system is open source and has absolutely not been produced for profit. In addition it's always being improved, or at least that's our aim. Any radio amateur or caver can easily build a cheap but efficient CSR system. Reports, advice, criticism and goodies will be greatly appreciated.

Further Information

This article is based on information on Fabrizio Marincola's website at **digilander.libero.it/i0hcj**. Although these pages are solely in Italian, readers may be interested in the video, on the second page, that shows the system being installed in a cave and used for the first time.

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