Evaluating Coaxial Cables for use as Leaky Feeders

*Ordinary low-cost coaxial cable can be used as a leaky feeder for communication along cave passages. **Mike Bedford** reports on tests to compare the performance of two main types of cable, and to determine the optimal operating frequency.*

A leaky feeder is a type of coaxial cable that has a deliberately reduced-coverage shield. Accordingly, although it still acts as a moderately efficient feeder, some of the signal will leak out along its length, and external signals can leak in. This is usually achieved by using a solid shield with periodic slots cut in it. This way, users in the vicinity of the cable are able to communicate. Systems based on this type of cable are used, for example, in subway tunnels to provide mobile phone coverage, and for mine communications. Such systems overcome the high levels of attenuation that very much limit the range of a radio signal in a tunnel environment that is not fitted with a leaky feeder.

Leaky feeders would be suitable for along-passage communication in caves, but there are several drawbacks. Typical leaky feeders are 16mm – 50mm in diameter, they weight 220kg – 1,120kg per kilometre, and they cost thousands of pounds per kilometre.

Fabrizio Marincola (2013) reported that some ordinary coaxial cables will operate as leaky feeders but without the drawbacks of dedicated leaky feeders. He further explained how these cables have been used for cave communication over several hundred metres at VHF.

The work reported here involved comparative tests on a similar cable to the one used by Fabrizio Marincola and one of a different internal structure. The work also involved a comparison of performance on a range of frequencies.

Cable Options

The coaxial cables referred to in (Marincola, 2013) are intended for use with domestic TV antennas and have sufficiently low loss at the frequencies used for satellite TV. They have a diameter of around 6mm or less, and have a shield comprising thin foil plus a very low coverage braid.

An alternative type of cable that is used for domestic TV antennas has a shield that comprises only a low-coverage braid, typically 40%. These cables are suitable only for use with terrestrial TV.

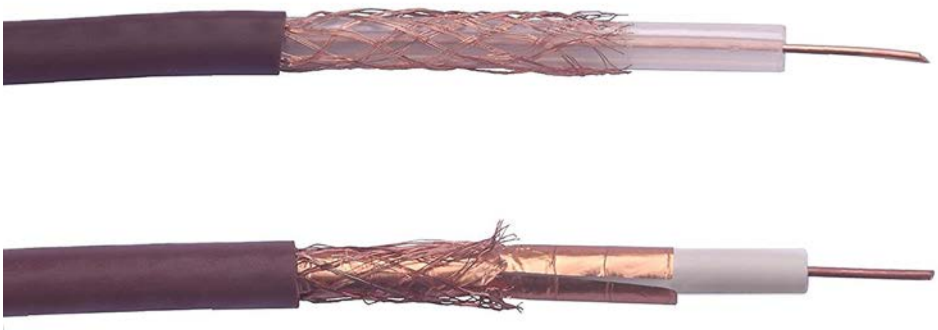
Cables of both these types were used in these tests – the two are contrasted in the photo at the bottom of this page. Both have a diameter of around 6.5mm. For reference, the cables are obtainable from CPC Farnell (**cpc.farnell.com**) with part numbers CB14616 (braid only) and CB19503 (foil plus braid). They both cost just over £10 for a 100m reel. eBay suppliers may be able to offer similar cables although, of course, identical performance cannot be guaranteed. Furthermore, cables with just a low-coverage braid shield are not as widely available.

Experimental Work

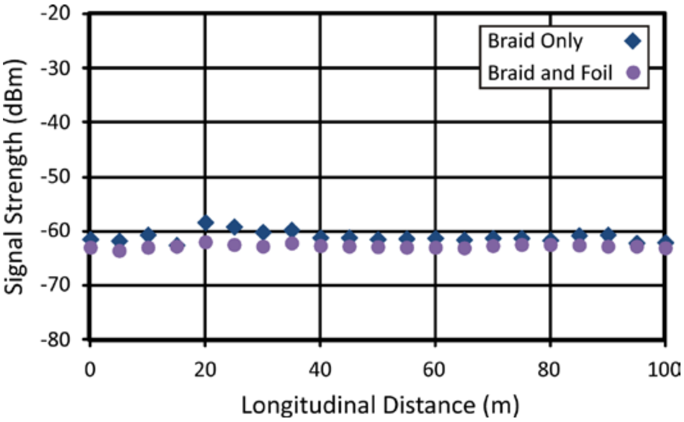
The majority of today's leaky feeder systems operate at UHF or SHF because they are designed to carry mobile phone or wi-fi traffic. For a caving system that is intended primarily for analogue voice communication, or perhaps low-speed text and data, the same frequency constraints do not apply. It's pertinent to point out, therefore, that the manufacturers' quoted attenuation figures for the low-cost coaxial cables chosen for evaluation have relatively high attenuation at microwave frequencies. For this reason, it was decided to characterise the performance of these cables for use as leaky feeders, at a range of frequencies in the HF and VHF portions of the radio spectrum. In particular, frequencies close to 3.5MHz, 7.0MHz, 14.0MHz, 28MHz, 50MHz and 144MHz were used, this decision being made because of the availability of amateur radio equipment which operates in these frequency bands.

Prior to testing, the cable was connected to the transmitter and laid out along the surface of the ground, which would be the normal situation for caving applications. The test procedure involved measuring the signal strength at 5m intervals along a 100m length of cable using a handheld receiver and compact antenna, which was at a separation of 2m from the line. This process was carried out for each of the frequencies identified above. In addition, using the optimal frequency identified from the above tests, signal strength measurements were made at a distance of 50m from the transmitter, at various separations from the cable, ranging from 0 to 12m.

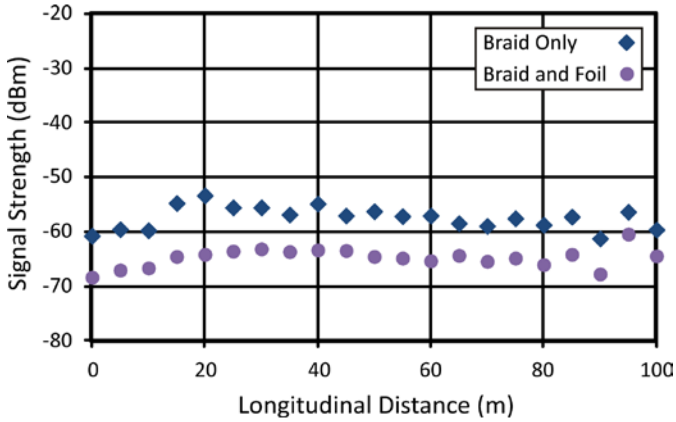
The transmitter was a Yaesu FT-857D amateur radio transceiver. It was configured to transmit a CW (continuous) signal with an output power of 5W. The cable was wired directly to the transmitter and the end of the cable distant from the transmitter was terminated with a 75Ω dummy load resistor, this being the characteristic impedance of both cables. This is normal practice for leaky feeders, and is necessary to provide an acceptable match between the transmitter and the cable. The receiver was an Aeroflex 9103 spectrum analyser which was used with a 1.5m whip antenna in a vertical configuration. This is approximately a quarter wave on 50MHz, which would probably result in higher signal strength



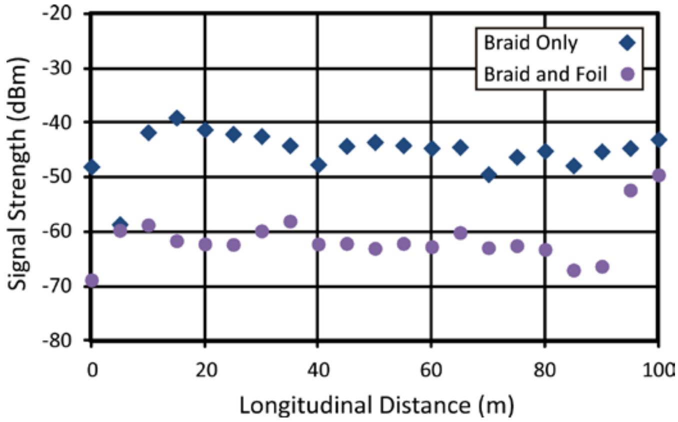
Two types of low-cost coaxial cables were tested: one with a shield comprising only a 40% coverage braid shield (top), and one with a shield comprising a foil plus braid (bottom).



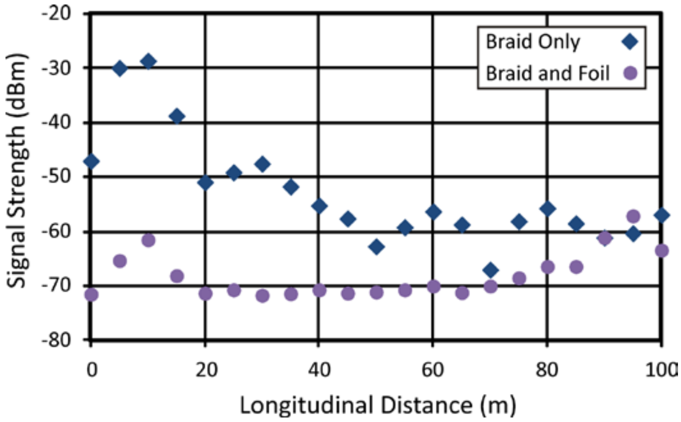
Signal strength along the cable at 7MHz.



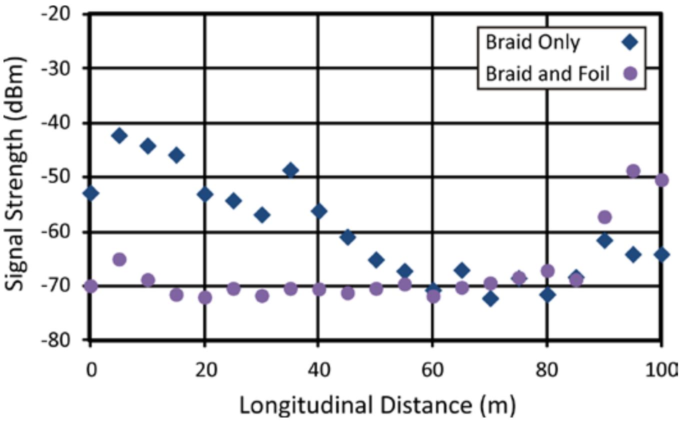
Signal strength along the cable at 14MHz.



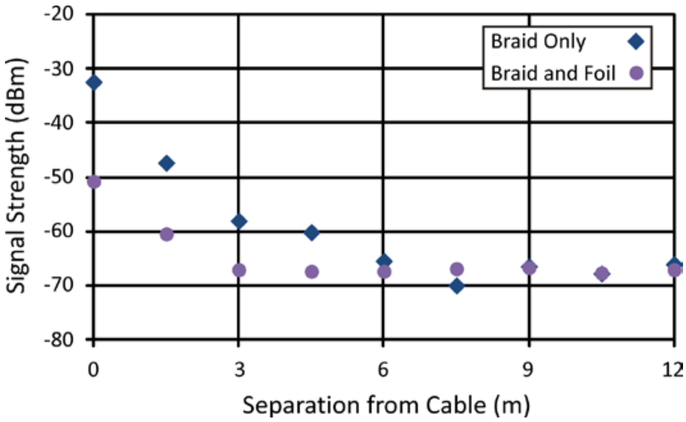
Signal strength along the cable at 28MHz.



Signal strength along the cable at 50MHz.



Signal strength along the cable at 144MHz.



Signal strength at various distances the cable at 28MHz.

readings on that frequency. However, since it would be totally impractical in most cave environments to use an antenna approaching a quarter wave on test frequencies below 50MHz, the test rationale is appropriate since it reflects likely caving equipment.

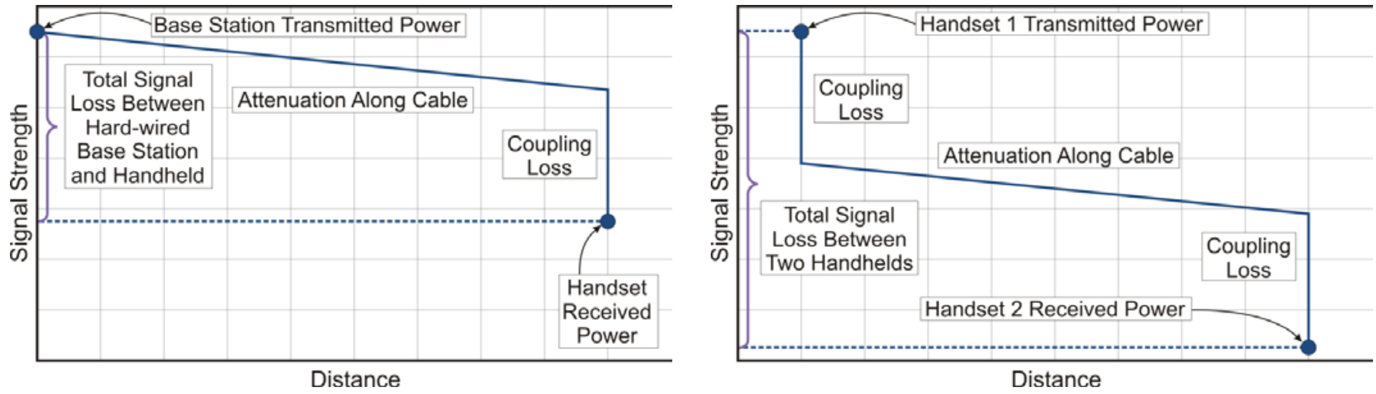
Results

Graphs of signal strength against distance along the cable at various frequencies, and against separation from the cable at the optimal frequency, are presented above. Graphs have not been presented for 3.5MHz because no appreciable signal could be detected on this frequency with either cable. It should be borne in mind that the plotted values of signal strength are not absolute values because they do not take into account the gain of the receiving antenna which, as already discussed, will vary with frequency.

Analysis

A few unexpected effects were observed in the experimental results. First, on several frequencies, the signal strength very close to the transmitter was lower than at greater distances, even though it then reduced gradually with distance as expected. Because there is no reason for using a leaky feeder system over such a short range, these anomalous results were ignored in the analysis process. Also, on 144MHz and 50MHz, and on 28MHz with the foil plus braid shield cable, the signal strength increased towards the end of the cable. It is thought that this was due to radiation from the 75Ω dummy load. It is consistent with this theory that the effect is greater on the higher frequencies at which the dimensions of the dummy load are closer to the wavelength, thereby causing the dummy load to be a more efficient radiator. Because this effect only affects the last few readings, and is not noticeable at all on some frequencies, again these anomalous readings were ignored in the analysis process.

With both cables, the overall degree of leakage, and hence also the received signal strength, increased with frequency. The other obvious trend, which is probably a result of the first trend, at least in part, is that the reduction in leaked signal as a



Losses associated with communication between a hard-wired base station and a handheld (left), and two handhelds (right).

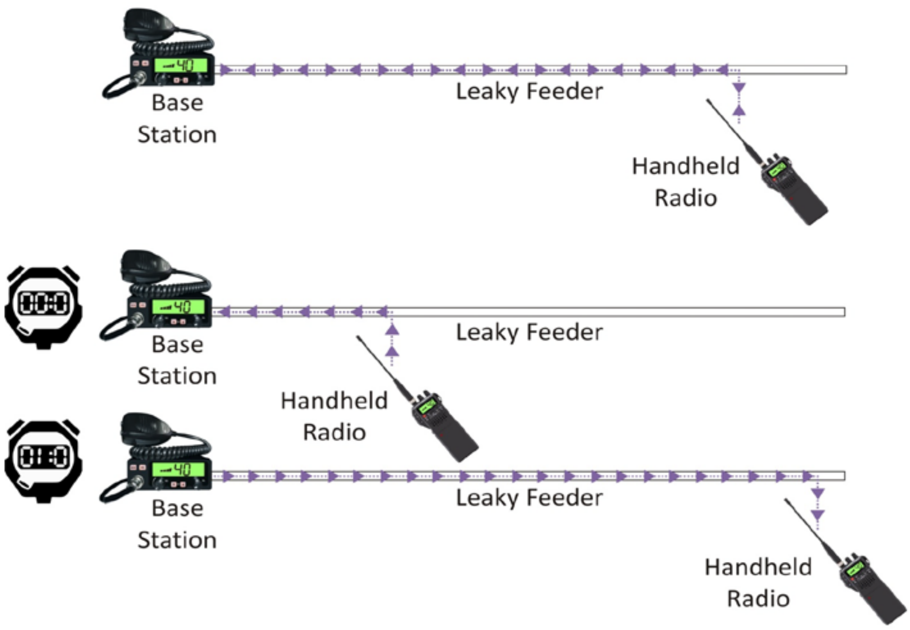
function of distance decreases with frequency. The implication of this is that there's an optimal frequency which provides an acceptable level of overall signal strength while also having an acceptably low reduction in signal strength along the length of the cable. The optimum depends, to a degree, on the range required of the system. However, it is clear that while the signal strength continues to increase with frequency at all frequencies tested, the reduction in signal strength as a function of distance plateaus as the frequency is reduced. For this reason, it is fairly simple to determine an optimal frequency by eye, and that will apply to most scenarios. For both cables, that frequency is 28MHz.

Turning to a comparison between the two cables, it is obvious that the cable with the braid only shield radiates more signal than the cable with foil plus braid shield on all frequencies. This is particularly noticeable on the optimal frequency of 28MHz, where the signal strength along the length of the cable was about 20dB higher, for the same transmitter power. Despite this, the rate of attenuation along the cable does not appear to be substantially different. For this reason, the coaxial cable with a sheild comprising only a low-coverage braid is recommended.

From the experimental results presented so far, it is anticipated that the maximum range will be several hundreds of metres to over a kilometre, although the exact distance will depend on the specification of the radio equipment that is used as part of the system. However, it is pertinent to point out that this assumes a distance of 2m between the mobile handset and the cable. Although a benefit of a leaky feeder compared to an LF guidewire system is that it provides much more freedom of movement by not requiring the handheld to be almost touching the line, if the user is prepared to stand within 500mm of the leaky feeder, the signal could be boosted by approximately 20dB. This is not considered to be onerous, yet it could improve the range by several hundred metres.

It is important to recognise that the experimental setup of a transmitter directly connected to the cable and a mobile receiver at some distance from the cable parallels the operational scenario of a hard-wired base station and mobile handsets. However, it is also necessary to consider communication between two handsets. There is an appreciable coupling loss between a handset and the leaky feeder but, in the case of a wired base station, there is only such loss in the complete transmission path. In the case of communication between two mobile handsets, however, there will be two coupling losses and, therefore, a very much higher end-to-end attenuation. Graphs summarising these two scenarios are presented above.

Accordingly, with two handsets, either communication will not be possible or, at the very best, the range will be very much reduced and/or it would be necessary to stand much closer to the cable, or perhaps to hold the handset almost touching the cable. An alternative method, that is recommended to allow two handhelds to communicate, is to incorporate a store-and-forward facility into the base station. This would allow the base station to record and retransmit any message transmitted by a mobile station for reception by another mobile station. Normal communication between the base station and a handheld radio is contrasted with communication between two handhelds via a store-and-forward equipped base station in the diagram to the left.



Base station to handheld communication (top) vs communication between two handhelds via a store-and-forward equipped base station (middle and bottom).

References

Marincola, Fabrizio (2013) *A Low-cost Leaky Feeder System for Cave Communication*, CREGJ **81**, pp. 4-6.

Rattray, Fred (2020) *Store-and-Forward Functionality for Simplex Repeaters*, CREGJ **110**, p17.