The Pinger

A Simple Underwater Radiolocation System

Ken Smith

CAVE MAPPING

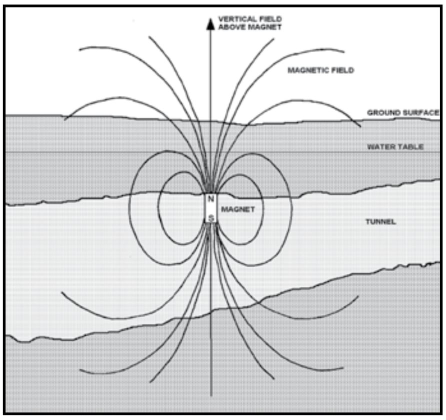
The traditional method of mapping an underwater cave is to take compass bearings and water depth at every point where the guideline changes direction. The length of each section of line is also measured. This allows the position of points in the cave to be determined with respect to the starting point. Unfortunately, in a complex cave, like Tank Cave near Mount Gambier in South Australia, many readings are required to reach the more remote sections of the cave. This can give a significant error in determining the position of the remote sections.

A radiolocation system allows a point in the cave to be found from above ground. Conventional above-ground surveying techniques can then be used to locate the point very accurately. This allows remote sections to be correctly positioned on the map.

Location using a Magnetic Field

Normal radio frequencies cannot penetrate through water and rock. However, a magnetic field can penetrate water and limestone very easily. The diagram shows a simple idea for locating a point in an underwater cave. A bar magnet is hung vertically from the roof of the cave, and an observer on the surface measures the magnetic field until he finds a point where the field is vertical. This point is directly above the bar magnet in the cave, and is called "ground zero".

The observer can also measure the thickness of rock below his feet. He looks for a point on the ground where the magnetic field emerges at 45 degrees to horizontal. By measuring how far this point is from ground zero and multiplying this distance by 1.77, the depth of the bar magnet below the surface can be found.



Magnetic field produced by a bar magnet in a cave passage.

Unfortunately, this method would not work in practice. The magnetic field from the bar magnet will be too weak on the surface and it will be swamped by the earth's magnetic field. The field from a bar magnet is called a "dipole field" and this drops off very rapidly with distance from the magnet. It diminishes in strength as the cube of the distance. In other words, twice the distance means one-eighth of the field strength.

Principle of Radiolocation

Instead of a bar magnet the radiolocation system uses a coil, which is energised with alternating current at an audio frequency. The magnetic field produced by the coil is the same shape as the field of a bar magnet, but it is now an alternating field. This field can be picked up by a second coil, which is connected to an amplifier and headphones. The operator can now "hear" the magnetic field. The earth's magnetic field has no effect, since it is not changing with time and does not generate any sound.

The magnetic field direction is determined by a process of "nulling". The receiver coil is turned until the signal can no longer be heard. This is called the "null" position. At this point the axis of the receiver coil is at right angles to the magnetic field. At ground zero the magnetic field is vertical and the receiver will null when the coil is horizontal. To find ground zero exactly the coil must null horizontally, no matter in which horizontal direction the coil is pointing.

The nulling method can also be used to find the 45º point in order to measure depth.

Design of the Pinger Transmitter

Adrian Richards and I have constructed a simple radiolocation system. We call it "The Pinger" because of the sound it makes.

For underwater use the transmitter needs to be small and easy to handle. Unfortunately, the traditional designs of radiolocation systems use quite large coils, typically 600 mm or more in diameter. The size of the coil can be reduced by winding it on a core of material with a high magnetic permeability. However, a core of laminated iron (like a transformer core) may not be suitable because of excessive losses at the audio frequencies used.

The pinger uses a core of laminated mu-metal with a length of 310 mm and a cross-section of 12 x 10 mm. This allows a long thin coil to be wound with characteristics similar to a much larger "air cored" coil. This coil, together with driver electronics and batteries, fits into a 600 mm length of 50 mm diameter PVC tube. The tube is permanently sealed at one end and has a threaded O-ring cap at the other. The inner workings can be removed via the cap for battery replacement or maintenance.

The pinger is weighted at one end and has a slight positive buoyancy so that it floats upright in the water. At the top end is a central nylon spike which is placed on the roof of the cave. The pinger can be left floating in this position and it will hang exactly vertically to give the correct orientation of the magnetic field.

The pinger is small and simple to use. It is fitted with two plastic rings for clipping to the diver in a similar manner to a stage bottle. Three identical Pingers have been made to this design so far.

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Divers with a pinger prior to diving.

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Pinger attached to a diver in the water.

The driver electronics for the pinger were designed with simplicity in mind. The coil is connected in parallel with a capacitor to form a tuned circuit which resonates at 1.16 kHz. A tuned circuit allows a large alternating current to be generated in the coil, which in turn generates a strong magnetic field.

A simple oscillator provides the 1.16 kHz signal and this is amplified by a single chip audio amplifier and fed to a driver winding on the transmitter coil. Eight alkaline C cells provide the 12 volt power supply required. The current drain when transmitting continuously is about 190 mA. The current consumption was reduced to about 70 mA by adding a circuit to pulse the signal on and off with an on time of about 33%. With this modification the battery life is more than 24 hours.

The pulse rate is different for the three pingers that have been made. This allows each pinger to be uniquely identified by its signal.

Design of the Receiver

The receiver uses a coil identical to the transmitter coil. It is also tuned to resonate at 1.16 kHz. Use of a tuned receiver minimises interference from other signals, such as power lines and electric fences. The signal from the receiver coil is amplified by a single chip audio amplifier and fed to the headphones. The electronics are housed in a small die cast box, which can be mounted on a waist belt.

The receiver coil is mounted in a PVC tube. This is carried in one hand when searching for the pinger. The tube is fitted with two spirit levels. One indicates when the coil is horizontal, for ground zero determination. The other indicates when the coil axis is at 45°, for depth measurement.

At Tank Cave there is almost no electrical interference and the distinctive “beep beep” of a pinger can be heard at up to 90 metres from the transmitter. The pulsing of the signal assists in finding the pinger. It seems to be easier to hear a weak pulsing signal than a weak continuous signal. Plenty of signal strength was available for measurements at Tank Cave, since the pingers were rarely more than 20 metres below the ground surface.

Using the Pingers

Placing of the pingers is usually done by volunteer divers. As the diver is preparing to enter the water, the pinger is switched on and the end cap screwed on. The pinger can

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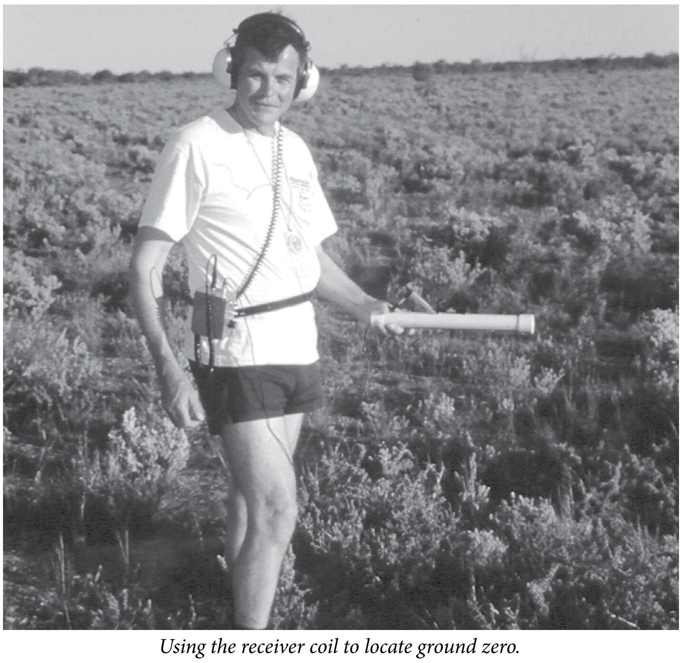
Locating the 45° point for depth measurement.



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Using the receiver coil to locate ground zero.

be clipped to the diver's vest. One or more pingers can be easily carried without any interference in the enjoyment of the dive.

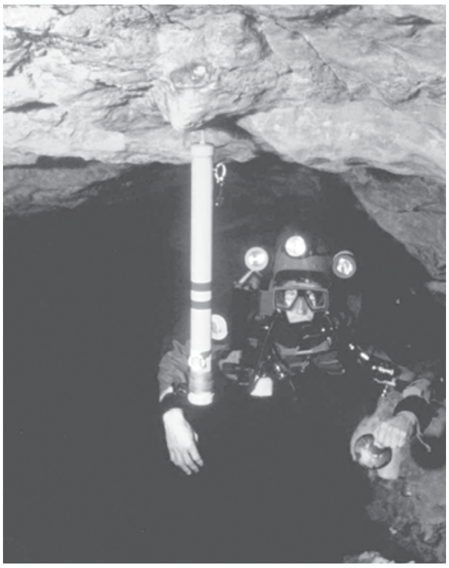
The diver is asked to place the pinger on the roof of the cave above a specified survey point and also to measure the roof and floor depths at this point. Metal clips must not be left on the on the pinger. They can cause the pinger to sink, or not hang vertically. Clips are normally left on the guideline nearby for use when the pinger is collected.

On the surface we can estimate when the pinger will be placed and we have a reasonable idea of where to find it. The pinger can easily be heard within 50 metres of ground zero.

With a bit of experience the orientation of the magnetic field can be used to find ground zero quite quickly. Within five minutes the position and depth have been recorded and we can go looking for another pinger.

Later in the day the pingers can either be moved to new survey points or brought out of the cave.

Bringing them out at the end of the day is preferred because the batteries can then be turned off and saved for more pinging on the next day.


TIM FOSTER

A pinger in place underwater

Recent Developments

The range of the pingers has now been extended to about 150 metres.

They have recently been used to track divers swimming in the third sump in Cocklebiddy Cave. A diver carrying a pinger can easily be located based on signal strength even though the diver is over 100 metres below the ground surface. When the diver places the pinger on the roof of the cave the pinger can then be precisely by using field angle.

Unfortunately two of the three pinger transmitters were lost in a car fire when returning from the Nullarbor in August 2008. Construction of some new smaller transmitters is currently under way.

Thanks and Acknowledgments

Thanks are due to:

Adrian Richards for the construction of the receiver and other useful help and advice.

Tony Carlisle, whose Nullarbor cave radio, first used in 1991, gave inspiration for this project.

Brian Pease, whose informative web site gave me much needed technical information. Doing a web search for "Brian Pease" is probably the best way to find out about radiolocation.

See http://radiolocation.tripod.com/

All of those who have helped by carrying pingers underwater and making surface measurements.

Landowner Rob Dycer, for allowing us to have so much fun in, and underneath, his paddock.