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ENERGY, MINES AND RESOURCES
MINES BRANCH
OTTAWA

LOST A DRILL HOLE RECENTLY?

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MINING RESEARCH CENTRE

Reprinted from Canadian Mining Journal, Vol. 95,

No. 3, March 1974, pp. 53, 54 and 58

Reprint Series RS 128

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Information Canada
Ottawa, 1974

Lost a drill hole recently?

By R. TERVO and L. TIRRUL *

Spotting a drill hole and making the necessary calculations for it to hit target is easily enough done but all too often that hole can go astray in the drilling and many expensive, frustrating and sometimes fruitless hours can be spent looking for it.

Until recent years the only way of locating the hole was by listening for the sound of the bit in the target area. At best never a reliable method.

Then an inventive team at Inco perfected an electromagnetic hole finder that depending on strength, can locate holes several hundred feet away.

Requests from various mines for information on the subject have come into the Mines Branch at Ottawa and a team of research scientists, R. Tervo and L. Tirrul were 'assigned to the case'.

The following is a description of their findings on the hole finder and a complete and thorough explanation of its working. A do-it-yourself kind of operation that could prove to be manna from heaven for frustrated drill captains everywhere.

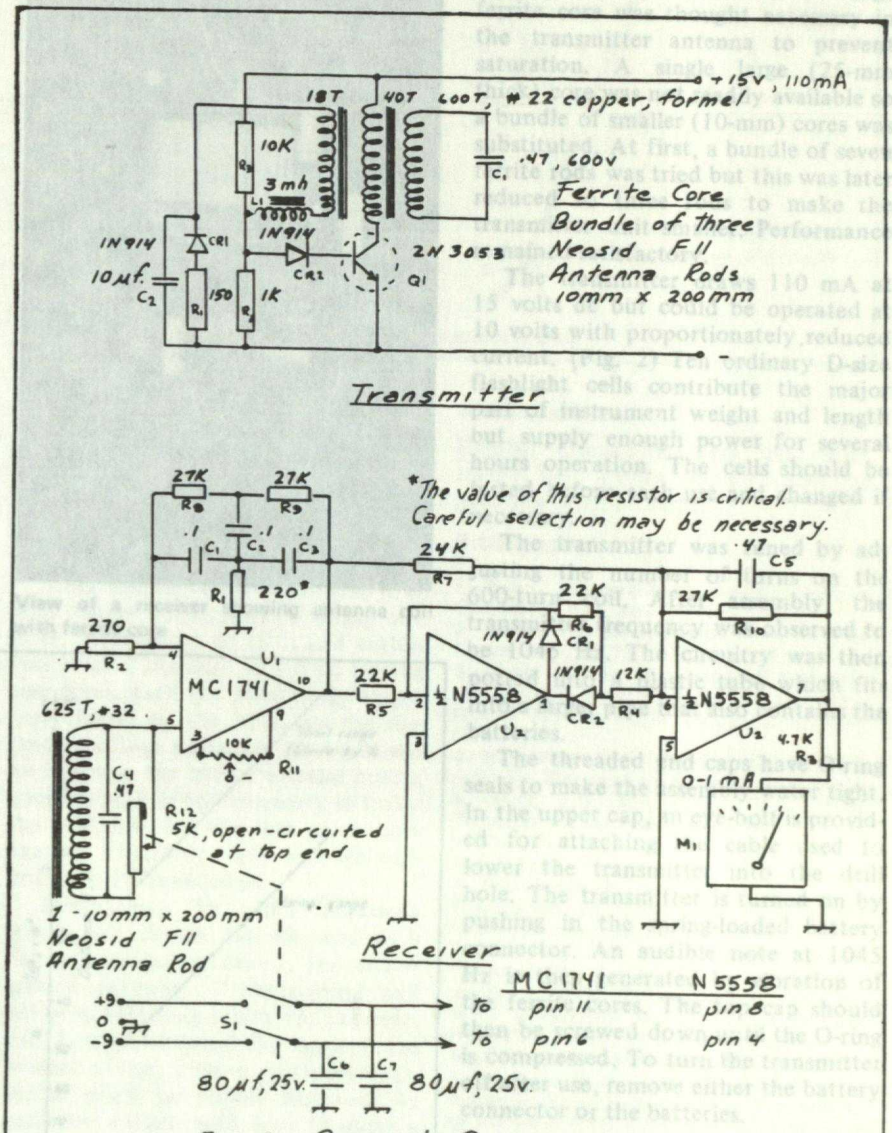


Fig 1: Circuit Diagrams

The technique of transmitting electromagnetic signals through the earth is not a new process, and several references to equipment used for this purpose can be found from various sources.

In South Africa (1), a 10-watt low-frequency (300-kHz) transmitter has been developed for rescue work; it can transmit signals through 3000 ft of rock. Westinghouse (2) has a high-power 200 to 3000-Hz communication system that can signal through 2500 ft of rock. Lee Engineering Division of Cosolidation Coal Co. (3) used a 200-watt transmitter, connected to two electrodes spaced as far as half a mile apart, for through-the-earth transmission to underground receivers equipped with a loop or dipole antenna.

Roeschlin (4) described a low-frequency magnetic-induction-field direction finder for mapping caves magnetically. The transmitter operated at 2 kHz with a 5-watt output into a tuned loop antenna with a range of up to 400 ft through rock. By calibrating the system on surface, depth as well as direction could be determined. Both the transmitter and receiver antenna were in the form of 19-in. diameter coils containing 400 turns of #28 copper wire. In use, the receiver remained on surface and the transmitter was taken underground.

Parris and Taylor (5) explain how to find a pilot hole that has gone off course. The procedure was described as follows: "If a breakthrough does not occur, the pilot hole is drilled 2-3 rods (8-12 ft) beyond layout hole depth. The drill string is then removed and an electronic probe is lowered to the bottom. This emits a signal picked up by the receiver in the zone adjacent to the target area. At the point of maximum reading, the distance from the receiver to the probe is estimated by signal strength and a drift or raise round driven to intersect the hole. The hole finder was designed and built by Inco electronic personnel."

Finkelstein and Erdem (6) have analysed the phenomenon of transmission of electromagnetic signals through rock. It would be difficult to consider all inhomogeneities in a rock strata so that only a simple homogeneous medium of known electrical property is considered. The problem becomes that of determining the voltage induced in a receiving antenna by a current in the transmitter antenna separated from it by the rock.

Consider two loop antennas in the same plane. When distance between

* Research scientists at EMR, Elliot Lake, Ont.

them is large compared with the dimensions of the antennas, Finkelstein and Erdem showed that the voltage induced in the receiving antenna should vary directly as the inverse cube of the separation distance.

Aldridge and Cannon (7) developed a power transfer equation from which it is concluded that maximum power transfer for co-planar antennas is inversely related to the 10th power of the distance between them at optimum frequency.

For a practical system they presented design criteria for a through-the-earth transmitter and receiver. Ten watts was decided upon for a transmitter with a range of 600 meters at 870 Hz, because at 100 watts, the range would increase to only 750 meters due to the high rate of attenuation with distance as predicted by their equation.

The proposed transmitter antenna, 2 meters in diameter would consist of 100 turns of 15 gauge wire, while the receiver antenna would be 29 turns at a diameter of 0.8 meters.

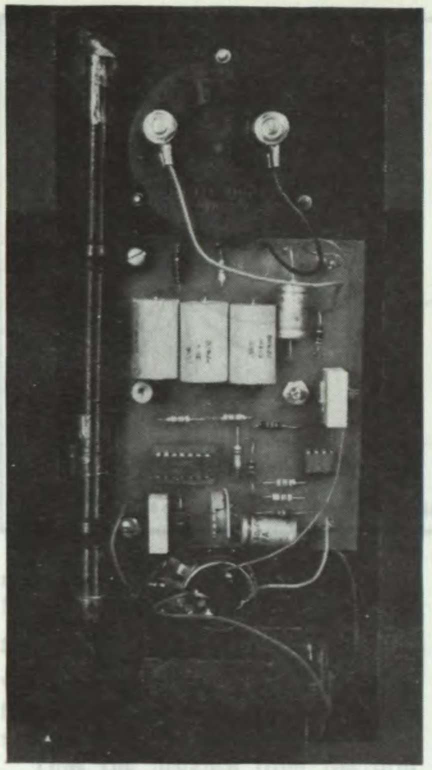
The preceding discussion also provides some design guidelines for constructing a short-range transmitter for locating drill holes that have not intersected their target.

Design of lost drill hole finder

First, one must decide on the frequency and power required in the transmitter. Roeschlin (4) used 5 watts at 2 kHz into a 19-in.-diameter loop, to transmit through 400 ft of rock. The bore hole locator must fit into holes as small as 2 in. in diameter and must have a range of only about 50 ft, so a one-watt transmitter is a reasonable starting point. Higher power would result in a heavy drain on the enclosed batteries.

Lower power would make the receiver more subject to interference from harmonics of the 60-HZ power used throughout mines. Other than that the choice of frequency is not critical. However, the lower the frequency the bulkier the coils required in the tuned circuits, more important the lower-order harmonics are potential sources of interference.

Bensema (8) made low-frequency (40 Hz to 10 kHz) electromagnetic noise measurements in mines. He found noise sources to be air compressors, electric locomotives, dc motors, etc. He suggested operating through-the-earth transmitting equipment at frequencies between the 60-Hz harmonic peaks; we aimed at 1050 Hz to stay between 1020 and 1080 Hz. The bandpass filter in the receiver should have a bandwidth less than 30 Hz to minimize the interference from these harmonics. If interference is not a



View of a receiver showing antenna coil with ferrite core

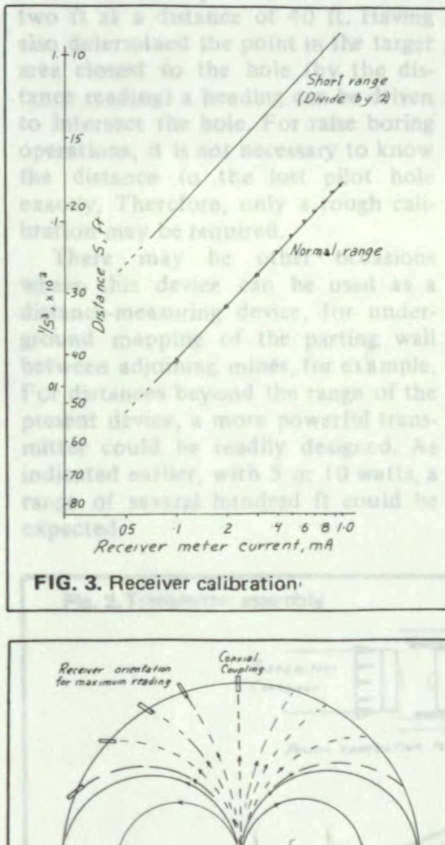


FIG. 3. Receiver calibration

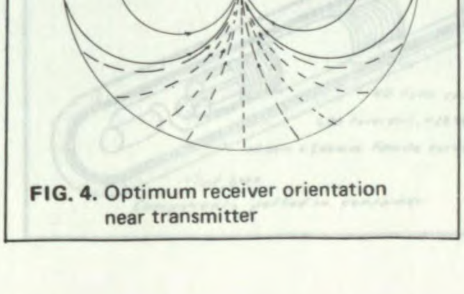


FIG. 4. Optimum receiver orientation near transmitter

problem, the circuit may be simplified by dispensing with the bandpass filter.

Figure 1 shows the circuits used in the transmitter and receiver. Ferrite antenna rods were used in the coils to improve the performance. A large ferrite core was thought necessary in the transmitter antenna to prevent saturation. A single large (25-mm thick) core was not readily available so a bundle of smaller (10-mm) cores was substituted. At first, a bundle of seven ferrite rods was tried but this was later reduced to three rods to make the transmitter unit smaller. Performance remained satisfactory.

The transmitter draws 110 mA at 15 volts dc but could be operated at 10 volts with proportionately reduced current. (Fig. 2) Ten ordinary D-size flashlight cells contribute the major part of instrument weight and length but supply enough power for several hours operation. The cells should be tested before each use and changed if necessary.

The transmitter was tuned by adjusting the number of turns on the 600-turn coil. After assembly, the transmitter frequency was observed to be 1045 Hz. The circuitry was then potted into a plastic tube which fits into a larger pipe that also contains the batteries.

The threaded end caps have O-ring seals to make the assembly water tight. In the upper cap, an eye-bolt is provided for attaching the cable used to lower the transmitter into the drill hole. The transmitter is turned on by pushing in the spring-loaded battery connector. An audible note at 1045 Hz is then generated by vibration of the ferrite cores. The top cap should then be screwed down until the O-ring is compressed. To turn the transmitter off after use, remove either the battery connector or the batteries.

The receiver circuit is shown in Fig. 1, housed in a 2 x 4 x 9-in. box. The receiver antenna consists of 600 turns of #32 copper wound on a high permeability ferrite antenna rod, of a composition suitable for use at low frequencies. The receiver was tuned to the transmitter frequency of 1045 Hz by adjusting the number of turns on the 625-turn coil. The bandpass filter consists of capacitors C1, C2, C3 and resistors R1, R8 and R9.

Using a Hewlett-Packard #650A signal generator as a variable frequency source, it was observed that the meter current dropped from full scale to half scale within less than 10 Hz either side of the peak. The bandwidth is thus between 10 and 20 Hz and could not be determined more accurately from the coarse dial of the signal generator. The receiver selectivity is important in reducing pick-up from electrical noise sources within 100 ft of the receiver at them is large compared with the dimensions of the antennas, Finkelstein and Erdem showed that the voltage induced in the receiving antenna should vary directly as the inverse cube of the separation distance.

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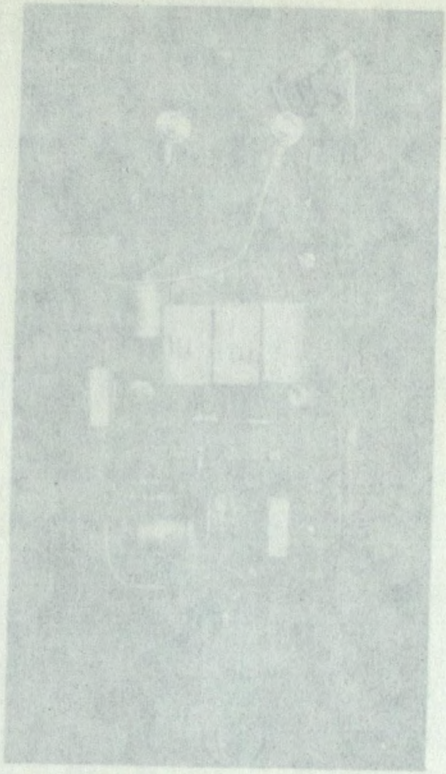

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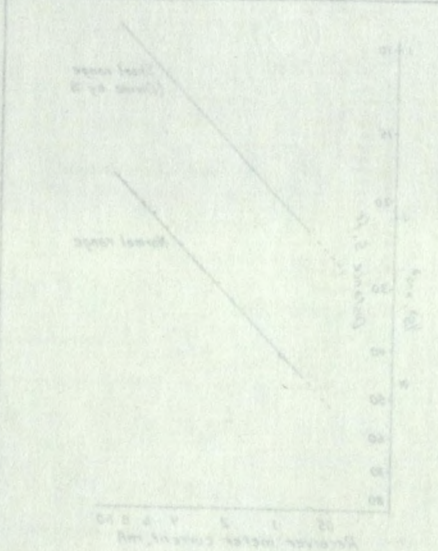

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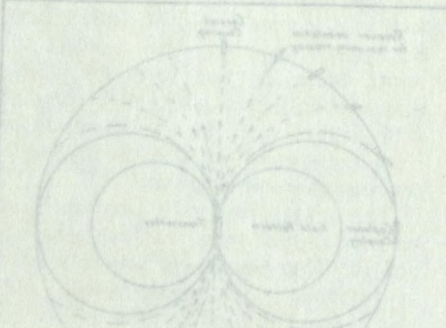

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Calibration

Calibration was performed above ground by setting the receiver to maximum sensitivity and recording the receiver output current (0 to 1mA) as a function of distance. The transmitter was held vertically, and the receiver antenna coil was parallel (co-planar) to the transmitter antenna coil.

In Fig. 3, the receiver meter current is plotted against the inverse cube of the separation distance in air. The resulting graph is linear and at 45°, confirming the inverse cube relationship predicted by the theory. The calibration may not be exact for transmission through rock because rock properties can be different than those of air.

On normal range, a full-scale reading of 1 mA will show the receiver when it is 18 ft from the transmitter and in the co-planar position. In the co-axial position (Fig. 4), the signal is stronger and indicates about 10% shorter distance.

To reduce sensitivity, the gain control on the panel can be turned to Position 2, which halves the reading and gives full-scale deflection at 9 ft. Similarly, Position 4 quarters the receiver sensitivity and gives a full-scale reading at 4.5 ft. The receiver should be held parellel to the transmitter, or turned to give maximum reading. This will be at the same angle as the drill hole if the transmitter has been lowered exactly to the target depth.

If the drill hole is too short or too long, the transmitter will be above or below the receiver. Unless one considers the field about the transmitting coil, the optimum receiver orientation may appear unusual, but the maximum reading will be observed with the receiver antenna coil parallel to the flux of the transmitter coil as shown in Fig. 4. If difficulty is experienced in finding the lost drill hole as shown in Fig. 5, the transmitter may have to be raised or lowered to a position opposite the target area after which it should be easy to determine on which side of the target area the transmitter is located.

With the transmitter below the target area, the receiver output would remain fairly constant as the receiver was taken from one side of the target area to the other. However, lowering the receiver towards the transmitter would result in a higher reading and it should be easy to establish that the transmitter is below the target. It would be a problem to say in which direction the drill hole was, but on raising the transmitter, it is easy to find.

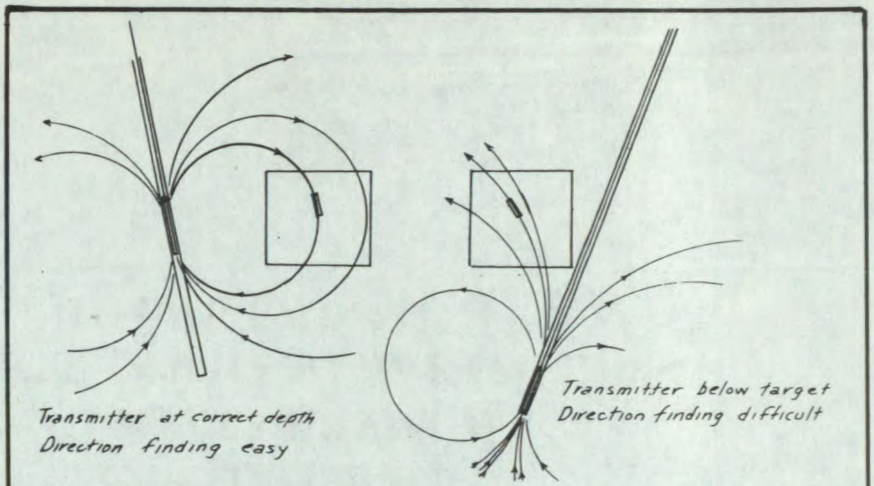

FIG. 5. Effect of transmitter position on direction finding

Sensitivity

With the receiver reading full scale (18 ft), moving it a few inches produces a noticeable change in meter reading.

Thus the distance from the drill hole can be determined to within one ft at distances up to 10 ft and within two ft at a distance of 40 ft. Having also determined the point in the target area closest to the hole (by the distance reading) a heading can be driven to intersect the hole. For raise boring operations, it is not necessary to know the distance to the lost pilot hole exactly. Therefore, only a rough calibration may be required.

There may be other occasions where this device can be used as a distance-measuring device, for underground mapping of the parting wall between adjoining mines, for example. For distances beyond the range of the present device, a more powerful transmitter could be readily designed. As indicated earlier, with 5 or 10 watts, a range of several hundred ft could be expected.

Acknowledgment

Helpful discussions were held with Inco's W.J. Taylor, C. Cyr and the geophysics department.

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Fig. 2. Transmitter assembly