Basic theory

The elementary science of locating a buried pipe or cable.

The notes in this section are intended to give a layman's understanding of the first principles of electromagnetic location to anyone involved in the day-to-day problems of locating buried pipes and cables.

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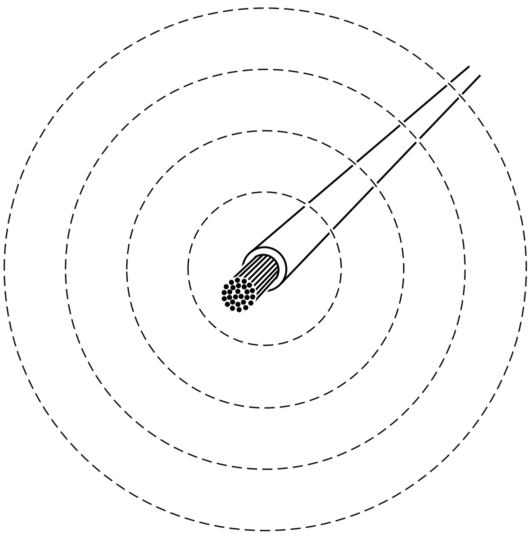
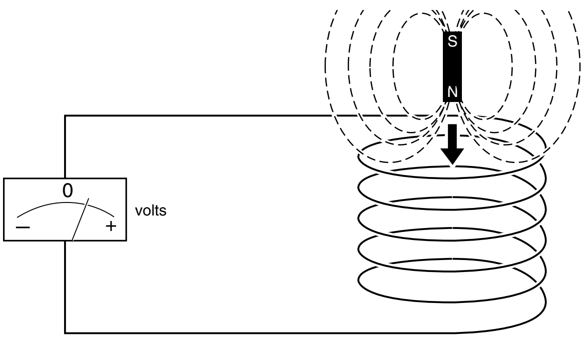
1 Electromagnetic induction

A pipe and cable locator does not locate buried pipes or cables. It detects a magnetic field around the line created by an alternating current - ac - flowing along the line. This magnetic field forms a cylindrical shape around the line and is known as the 'signal'.



While it is possible to insulate against the flow of electricity it is not possible to insulate against a magnetic field, and the shape of the field is not changed by cable insulation or by the presence of different types of soil.

Alternating current creates the detectable magnetic field or signal because it not only provides a field but also an oscillating frequency of reversals, and it is this which makes effective location possible through the principle of electromagnetic induction.



The principal of electromagnetic induction can be illustrated by inserting a bar magnet into a coil of wire. The voltmeter will show a deflection but only while the magnet is moving.

As soon as it stops the instrument reads zero. If the magnet is withdrawn quickly the meter deflection will be in the opposite direction - but only until movement stops. The quicker the movement, the higher the reading.

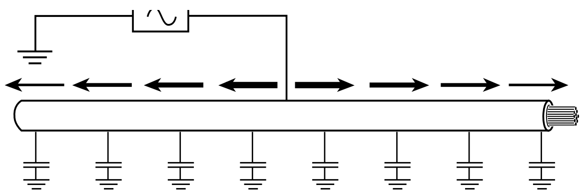
The rate of change of an alternating voltage is its frequency, its number of positive and negative pulsations, cycles per second, and is known internationally as Hertz or Hz. Just as moving the magnet quicker gives a higher reading, alternating a field at a high frequency induces a higher voltage for the same field strength.

Instruments for locating buried pipes and cables use the principles of electromagnetic induction in two ways

- to locate the ac signal on a line with a receiver.

- for the transmitter to remotely apply a detectable ac signal to a line.

An electric circuit has to be completed to allow a current to flow. So how can a low powered signal source at the surface make a detectable current flow in a properly insulated buried conductor? The voltages available are obviously quite incapable of punching through insulation. The answer lies in the effect of capacitance on ac circuits.



Capacitance is the effect by which signals are able to jump across insulation. The mass of the surrounding soil acts as if there is a conducting layer around the conductor.

Signal frequency:

The basic law regarding signal frequency can be summarized:

‘the higher the signal frequency, the greater the ac voltage and signal induced in the conductor and the greater the capacitance current flow.'

It would therefore appear that high frequency signals are more effective than low frequency signals.

However, because a high frequency signal flows to ground via capacitance more easily, it will not carry as far as the same strength of a low frequency signal.

A further drawback of high frequencies is the ease with which signals aimed along the target line can couple by mutual induction to other lines in the vicinity. This often makes it more difficult to trace a target pipe or cable in a congested area.

A large pipe or cable diameter increases the line's surface area in contact with soil and therefore the signal leakage to ground. The same signal strength leaks away over a much shorter distance from a large pipe than from a small one.

The ability of the ground to pass current varies locally. Clearly, wet soil is a better conductor than dry sand, and the resulting capacitance effects will vary the apparent conductivity of the conductor. The effect of high ground conductivity is to make it easier to induce current flow and therefore a signal in a buried conductor because of the good return path. At the same time, the easy return means that the signal becomes lost along a short rather than a long length of conductor.

Conversely, low ground conductivity requires more energy to induce signal onto a line, but it will then be detectable along a greater length of the conductor.

There is an optimum frequency for successfully locating and tracing each different type of pipe or cable.

2 Active and passive signals

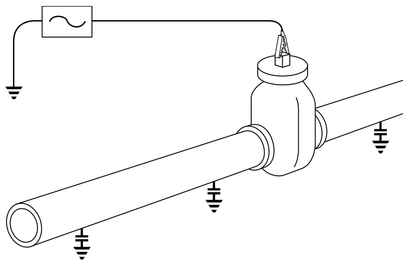
An Active signal is produced by a signal transmitter and applied to a line so that it can be located and traced with a receiver. The signal transmitter can also flood an area with signal so that all the lines in the area can be located.

Passive signals occur 'naturally' on lines as an effect of 50/60Hz electric power energy or VLF radio energy.

Despite the existence of passive signals the best signal to locate and trace a line is an active signal which has been deliberately applied for the purpose of locating and tracing.

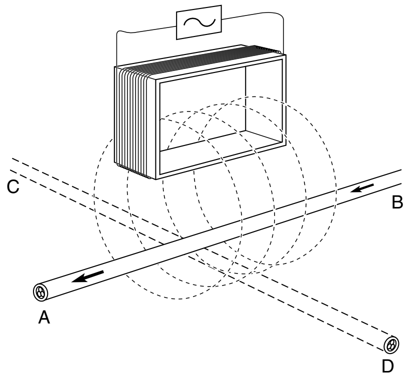
3 Applying an active signal

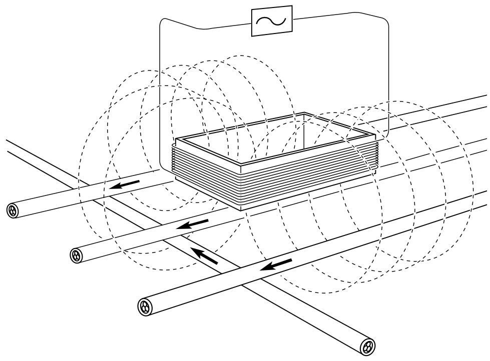
An active signal is applied to a line from a transmitter so that the line can be traced and located with a receiver.



Direct connection: The output ac voltage from the signal transmitter is connected directly to the pipe or cable at an access point such as a valve, meter or end of the conductor, and the circuit is completed by a connection to a stake or other ground connection point.

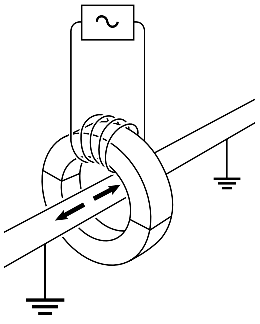
Induction: The aerial in a signal transmitter fed with an ac voltage sets up a magnetic field through the coil returning through the earth below it.





In the first drawing the transmitter aerial lies parallel to line AB and its field links around the line which therefore has a signal induced on it. There is no linkage and no signal induced on line CD at right angles to the aerial.

Laying the coil horizontal produces a much less localized field spread, useful for ‘blanket’ signal application, but the signal is not induced to a line directly below the coil.



Clamping the signal: Clamping uses the induction principle to give a similar result to direct connection, but without electrical contact to the line. The output from the signal transmitter is applied to a target line by clamping round it with a split toroidal magnetic core, which carries a primary winding magnetizing the core with the ac signal. The line becomes the secondary of a transformer, and will carry a strong signal, provided that it is adequately grounded on each side.