

abc & *xyz*

of locating buried
pipes and cables

for the beginner and
the specialist

Radiodetection

Preface and acknowledgements

This book is intended for everyone taking the responsibility of locating and fault finding buried pipes, cables and buried utility plant. It describes the techniques of successful locating but does not include instructions about the use of any particular instrument or set of equipment: this information should be obtained from the equipment supplier.

The book is for use both as a 'How to do it' book and a reference book.

Even experienced locating specialists may be surprised at the scope and variety of problems that locating instruments can help solve.

The book is divided into 12 parts and an index. Each part is divided into convenient sections and there is a heading on each page with Part and Section number and an indication of the subject.

Anyone using a locator for the first time should focus on the relevant sections of Part 2.

Thanks are due to the many people who have contributed the results of their knowledge and field experience to making up this book. Particular thanks are due to Hubert Brerot, Trevor Fern, Nick Frost, Greg Guy, Alan Haddy, Donald Hore, Bob Lane, Alan Llewellyn, Gerard Varin, Al Wakefoose and Barney Walker.

And thanks are due to Joan Grohmann, Christine James and Dick Knowles for their patience and work with the text and layout.

Improvements, experience and ideas for including in the next edition will be very welcome.

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abc & xyz

of locating buried pipes and cables

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Radiodetection make every effort to ensure that information about locating equipment and its use is correct but do not accept responsibility for damage or problems caused through use of the equipment: priority must always be given to following national and local safety requirements. We are continually developing our products and the design of Radiodetection equipment is subject to change without notice.

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What's all this about locating?

The everyday use of buried pipe and cable locators is recent. Locators existed 20 or 30 years ago but they had little general acceptance and were not used systematically. Little wonder because the response and information they provided was cloudy and very dependent on user interpretation. Things are different now with the introduction of precision locators and many other technical advances.

But technical improvement followed rather than led an increasing realisation that locating provides necessary information. Information that helps control costs, increases efficiency and is necessary for site safety.

* * *

Every civil works enterprise, a multi-million project or just an afternoon's digging requires planning to be economic and successful. Locating buried utility pipes and cables gives the planner information about buried plant that is comparable to topographic information. New utility lines, repairs, buried plant revamps or repairs and changes to road layout can be planned minimizing interference with existing buried utility services and the need for re-routing.

* * *

Replacing iron pipes with plastic pipe, upgrading copper communications cable with fiber, installing cable TV, increasing utility capacity and making repairs all require digging holes or trenches. And each excavation risks damaging valuable existing plant.

The cost of damage to a main fiber cable has become legendary but even the cost of damaging a buried distribution pipe or cable is greater than it first appears. There is the obvious cost of repairing the damage and the cost of the halted excavation. Then there is the loss of revenue from the service failure and the cost of reporting and filing the insurance claims. And each incident of damage reduces the integrity and value of a buried cable or pipe system that costs millions, often hundreds of millions.

Finally, and most important, is the cost to the community. Buried utilities and their services are the veins and lifeblood of the community. Lack of power, water, light or communications affects or even paralyzes a community. And this paralysis can, and all too often does happen if buried lines are not correctly located and staked out before digging.

* * *

Part 1 Section 1. What's all this about locating?

Safety on site is a necessary ingredient of all civil works. Information provided by locating before digging is an essential contribution to safe digging. Spiking a buried power cable or fracturing a pipeline is a cause of serious and dramatic danger that can mutilate or even kill. Knowing their presence and position helps avoid the possibility of damage. Relying on maps, drawings or paint marks on the paving is not enough.

* * *

What's all this about locating? It's about reducing unnecessary costs, about efficient working, about site safety and maintaining essential services to the community.

Importance of accurate information

Information is the end product of locating buried utility pipes and cables.

Positive, accurate and precise information is the only kind of information worth having or worth paying for. Faulty or incomplete information can mislead, it can be the cause of unnecessary costs and it can expose people to danger.

Nothing is black or white until it can be seen; and this isn't possible because pipes and cables are buried and out of sight. Experience, knowledge of the area, using drawings or existing information, together with making intelligent and correct use of a locator can provide information whose shades of grey are almost black or white in their certainty. But sometimes there may be areas where it is not possible to be certain. These areas should always be defined so that further investigation can be made.

Locating buried pipes and cables and providing information is a responsible business: there are no short cuts. The purpose of this book is to provide comprehensive information about the techniques of using a locator so that the user can provide accurate, reliable and valuable information.

Locating buried pipes and cables; the different technologies

There are a number of different techniques or technologies for locating buried pipes and cables

- 1 Existing information** Maps and drawings from the utilities or the city administration contain an enormous quantity of information about the presence and position of buried pipes and cables. Obtaining whatever information is available should always be the first step to locating. The information may be inaccurate or incomplete and should always be confirmed or completed by locating on site. However any information is useful before site work, even if only to know what to expect.
- 2 Ground Probing Radar** Radar techniques have been developed to provide accurate information for navigation and location above ground. Locating buried utility lines, particularly plastic pipes or fiber cables seemed a natural and useful extension of the technology. There is obvious difficulty discriminating between a plastic water pipe and dense soil such as wet clay and ground penetrating radar has not overcome the problem. However, the system can provide a picture of buried pipes and cables in many types of soil. Even in these favourable conditions it is necessary for a built-in computer to provide an image of what lies underground and this image tends to require specialist interpretation. Complexity, high cost, and dependence on favourable conditions put this technique outside the range of usefulness for everyday work. However, it may soon become more useful for mapping buried services.
- 3 Acoustic location** Acoustic techniques are the traditional technology for finding water leaks. A variation of the technology has been developed and has now gained acceptance for tracing buried water pipes, particularly plastic water pipes. For the moment the technology is limited to locating water pipes but development to extend a similar technique for detecting buried plastic gas pipes has already begun.
- 4 Infra red imaging** The temperature of buried pipes or cables is different from the surrounding soil. Detecting temperature differences is a valid method of locating buried utility pipes and cables. However, the technique is not useful for locating buried pipes and cables as outside factors such as sunlight and shade affect results. In fact the technology has specialized applications for finding sewer leaks and voids and for locating fractures in district heating pipes.

5 Dowsing

The oldest technique for locating underground water or buried utility services but hardly a technology. The hazel twig and its variants continue to be used by practitioners of this obscure and interesting art. It is difficult to estimate its usefulness or advantages apart from low cost and ease of handling.

6 Electromagnetic location

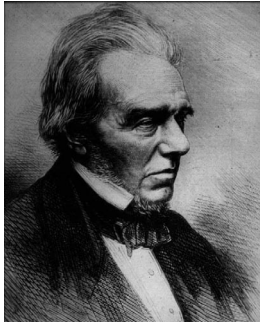
This has become the universal technology for locating and tracing buried utility lines. The technology has the advantage of providing a wide variety of information from underground; an advantage that is not available from any other technology.

- ☐ It can search an area from the surface to locate buried pipes and cables
- ☐ It can trace and identify a target line.
- ☐ It can trace and identify sewers or other non-metallic ducts or pipes to which there is access; it can locate blockages and collapses.
- ☐ It can measure depth from the surface.
- ☐ It can monitor the progress of horizontal boring tools and provide information for steering a guided tool.
- ☐ It can locate many types of cable fault, monitor pipeline coating condition and locate water leaks in plastic pipes.
- ☐ The equipment is portable.
- ☐ The equipment is easily handled and is successfully used by unskilled people.
- ☐ The equipment works in all soil conditions; even underwater.
- ☐ The component parts of the technology are low cost. Sufficiently low cost to be purchased by small contracting companies or issued by regional or national organisations.

The main shortcoming of electromagnetic location is that it cannot locate non-metallic lines such as plastic pipes. However, utilities taking the small amount of trouble to lay tracer wires with plastic pipes are not affected by this shortcoming.

The story of locating buried utilities

Electromagnetic induction is the most widely used technology for locating buried utility pipes and cables.



Michael Faraday
1791 - 1867

The phenomenon of electromagnetic induction was discovered by Michael Faraday. In 1831 he presented a paper to the Royal Institution in London describing the characteristics of the phenomenon and it is evident that he realised at least a part of its potential in the modern world. There is the story that a politician asked him about the usefulness of the discovery; he answered 'At present I do not know, but one day you will be able to put a tax on it.'

The earliest record of using electromagnetic technology to locate buried cables dates from around 1910. The photograph shows a cable locator made from a coil wound round a wooden truss; the coil is just visible at the front of the truss.





More portable locators were made over the next years. The Sharman Main Finder is just one example. The user instructions give a tinge of envy to anyone trying to trace gas pipes '...just clip the generator to a gas bracket in the nearest house or onto a street lamp.'

An American and a German school of design developed over the years leading up to the second World War. Roads in North America were wide, cables were hung on poles and the main requirement for a locator was to locate widely spaced buried pipes. The result was a simple, high frequency, low power and low cost locator. Germany with cables as well as pipes buried under narrow streets, developed elaborate, low frequency and high power locators that required considerable expertise to obtain results.

Dr Gerhard Fisher of California who obtained the first patent ever issued for an aircraft radio direction finder, designed the Metallascope, the first high performance buried pipe and cable locating set. His system made use of the latest scientific developments and his company exists today and produces the M-Scope, an up-to-date descendent of the original Metallascope.

One of the engineering sections of the Bell Laboratories studying the problem of accurate location of their newly buried cables recognised that an antenna with twin sensing aerials would give more positive plan definition and also measure the depth of a target cable. The design, which was called the Depthometer, was engineered and manufactured by the Western Electric Company for use by the Bell Operating companies in 1964.

It was another 12 years before the first commercial twin aerial antenna locator was made by the Electrolocation company in Bristol, England. The company, which later became Radiodetection Ltd, developed the twin aerial system without being aware of the earlier Bell Labs developments.

The twin aerial system was found to have substantial advantages over single aerial locators. Twin sensing aerials combined the seemingly contradictory qualities of discrimination with sensitivity. For the first time it was possible to locate buried cables below an overhead power line and to sort out crowded utility services under a city street intersection. Push button electronic calculation of pipe or cable depth was an obvious advantage and so was a completely new way of locating buried cables as they reradiate VLF radio energy.

The introduction of the twin aerial antenna coupled with miniaturized electronic circuitry coincided with a programme of extending and upgrading utility distribution systems: digging in the street became a national industry in many countries and this led to an increasing need for locating buried pipes and cables. Growing demand and technical progress resulted in a series of advances and new features to make locating more certain and more simple.

Among the more interesting advances: combination of active and passive signal reception to locate a target line and make a quick sweep to check if other utilities are present - Multi-frequency locating sets enabling the user to select the most suitable frequency for each application - Electronic depth measurement - Current measurement along the length of a pipe or cable to detect coating or insulation defects - Current direction recognition to verify the identity of a target line - Permanently installed signal transmitters to apply a signal tone to a telephone cable over distances up to 150km/100 miles - and a range of accessories and equipment to increase the usefulness of the locator and widen its scope.

Today electromagnetic locators are the worldwide standard for locating buried pipes and cables. A number of specialized manufacturers offer a choice of locators ranging from simple equipment to detect the presence of buried cables, to sophisticated instruments for pinpointing, identifying and fault finding buried pipes and cables in the most complex situations.

Glossary

1 Definitions

Certain terms are used in this book. It is important to know their meaning in the context of the book.

Active signal: a signal tone applied to a line with a transmitter.

Cable shield: a conductive layer surrounding the working conductors to provide electrical screening. Usually isolated from ground by a plastic sheath or other insulator. The shield is generally terminated to a ground connection at the end of a cable length.

Clamp: a locator accessory fitting round a pipe or cable either for applying a transmitter signal or as a receiver antenna. Sometimes known as a coupler or 'close induction'.

Coupling: when a signal applied to the target line transfers to other nearby lines.

Line: continuous buried metal pipe or cable or other conductor capable of carrying an electric current.

Meter: a visual display to indicate response when the receiver detects a signal. Some receiver types are fitted with a moving needle meter. On others the meter is shown as part of a liquid crystal display.

Noise: term for spurious and interfering signals.

Pace: unit of measurement approximating to a metre or yard.

Passive signal: a signal that occurs 'naturally' on a buried metal pipe or cable such as 50/60Hz energy or LF/ VLF radio energy.

Pinpoint: using the locator receiver to establish the exact position of a target line.

Precision pinpoint: using different locate modes to confirm the precision of a pinpoint.

Rebars: concrete reinforcing mesh.

Response: the indication on the receiver visual display or loudspeaker or headphones when the receiver detects a signal. The response may be varied for a given signal by adjusting the receiver sensitivity level. Response value is usually indicated as a percentage of full scale deflection.

Search: using the locator to find all buried lines in an area.

Sheath: outer insulating jacket surrounding the shield and/or conductors of a cable.

Sheath fault: damage to the sheath or insulation surrounding a cable shield causing an unintentional conductive path enabling current flow between the shield and ground.

Sheath FaultFind signal: the detectable ground current flowing as a result of connecting a transmitter in its faultfind mode to a cable shield with a fault to ground.

Signal: a flow of alternating electric current on a line resulting in a magnetic field that can be detected with the locator receiver. Sometimes known as a tone.

Sonde: a self-contained waterproof battery powered transmitter whose signal can be located by the receiver. Sondes are commonly used for locating non-metallic drains or ducts or for monitoring boring tool progress.

Sweep: using the receiver to locate cables radiating passive signals. Sweeping an area is usually done in an orderly grid pattern to cover the whole area.

Target: a target line is a selected metal pipe or cable to which the transmitter signal has been applied and which is to be traced and pinpointed with the receiver.

Trace: using the receiver to follow the route of a line.

2 Icons

There is a drawing to illustrate each locating procedure. The receiver shown in the drawings is the precision receiver with its twin horizontal aerials and vertical aerial.



Transmitter



Receiver. Precision receiver with two horizontal aerials and a vertical aerial. Aerials parallel to the line; and at right angles to the line.



Other types of receiver that may be used

Single horizontal aerial

Single vertical aerial

Twin horizontal aerials.



Receiver display. Display can be a moving needle meter or a liquid crystal display indicating receiver response to a signal.

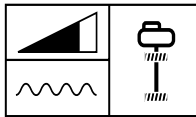


Sonde



A-Frame accessory for cable sheath fault location. The display may be part of the receiver to which the A frame is connected or directly on the A frame.

3 Reference box



There is a reference box beside each application. The box shows other receiver types that can be used for the application and recommends signal frequency and transmitter power.



*Output power** from the transmitter

Low



Mid



High



Very high



*Transmitter and Receiver frequency**

Low <1kHz



Medium <10kHz



High <75kHz



Very high >75kHz

*Transmitter power and frequency are difficult to define for a successful locate as each application and site is different. Suggested values are shown but it may be necessary to change up or down to achieve best results.

4 Symbols

Symbols in the margin refer to safety or to a previous section.



Safety. Safe working is a must, all the time on every site. This symbol against a paragraph emphasises the need for extra precaution for safe working.



Mortarboard refers to the Part and Section of theory relevant to the practical use of the locator on site.



Pointer refers to another section.

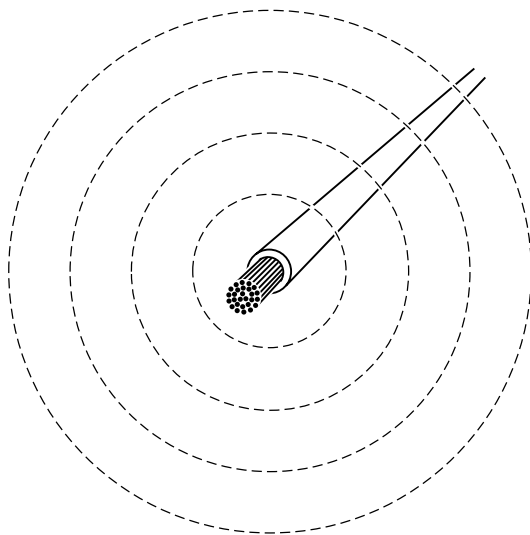
Basic theory

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.

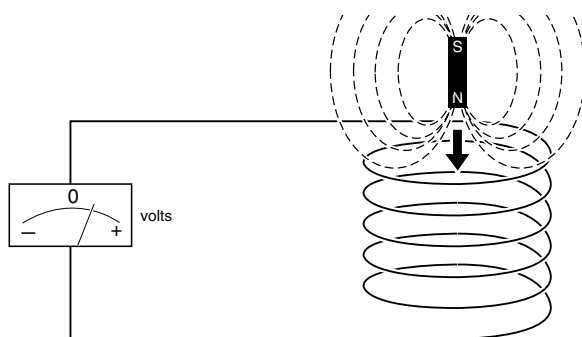
- 1 Electromagnetic induction
- 2 Active and Passive signals
- 3 Applying an active signal
- 4 Passive signals
- 5 Aerials for locating a signal on a line
- 6 Electronic depth estimation
- 7 Locating non metallic lines
- 8 Locating a sonde

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.

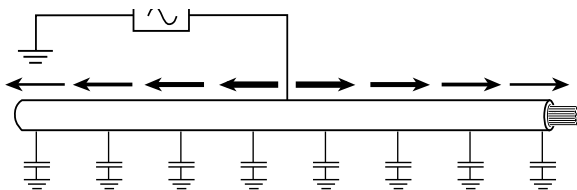
As soon as it stops the instrument reads zero. If the magnet is withdrawn quickly the meter deflection will be in the opposite direction - but only until movement stops. The quicker the movement, the higher the reading.

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.

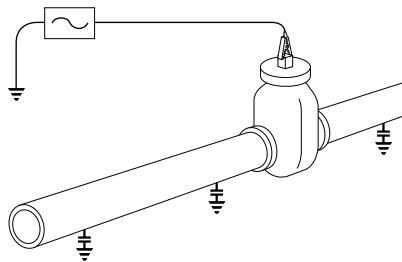
2 Active and passive signals *An Active signal* is produced by a signal transmitter and applied to a line so that it can be located and traced with a receiver. The signal transmitter can also flood an area with signal so that all the lines in the area can be located.

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.

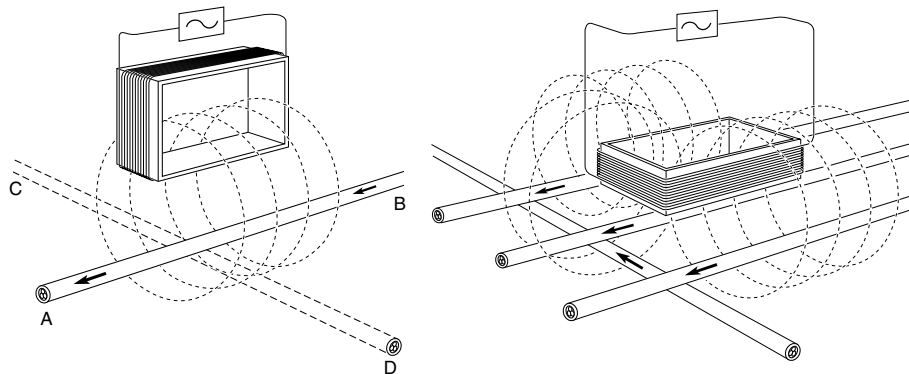
3 Applying an active signal

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



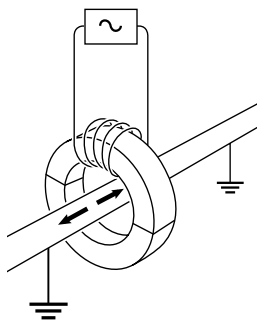
Direct connection: The output ac voltage from the signal transmitter is connected directly to the pipe or cable at an access point such as a valve, meter or end of the conductor, and the circuit is completed by a connection to a stake or other ground connection point.

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.



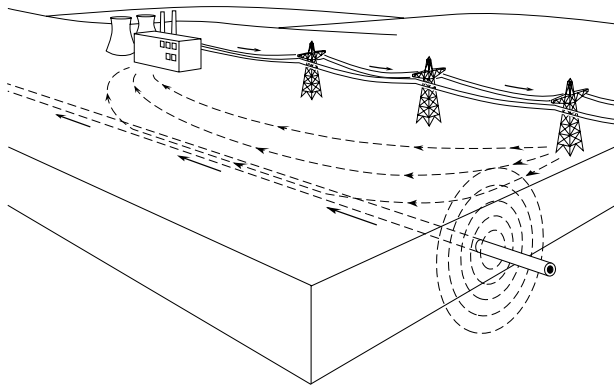
In the first drawing the transmitter aerial lies parallel to line AB and its field links around the line which therefore has a signal induced on it. There is no linkage and no signal induced on line CD at right angles to the aerial.

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.

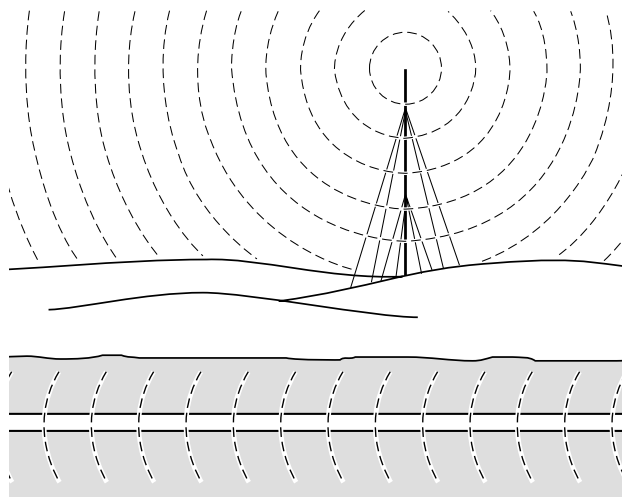


Clamping the signal: Clamping uses the induction principle to give a similar result to direct connection, but without electrical contact to the line. The output from the signal transmitter is applied to a target line by clamping round it with a split toroidal magnetic core, which carries a primary winding 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.

4 Passive signals Passive signals are 'naturally' present on many buried pipes and cables. Obvious examples are power cables which carry currents as part of their normal duty. Less obvious is the fact that the earth is full of power system return currents, which tend to flow along the convenient paths of lower resistance provided by metal pipes and cable sheaths.



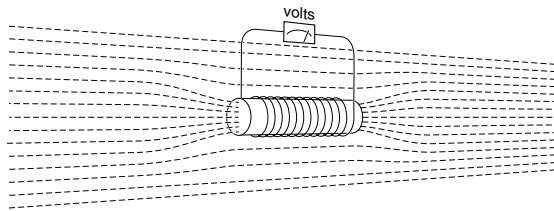
Current flowing in a cable produces a magnetic field or passive signal, but a live cable with no load may not produce a detectable signal and therefore may not be detected. But power transmission systems induce stray currents into the ground and form ground currents and so in practice this enables most, but not all, power cables to be located passively.



Very low frequency long wave radio energy from distant transmitters is present in the atmosphere world-wide. The ground provides return paths for this energy, and buried metallic lines form preferred paths. They then act as aeriels re-radiating these signals. The signals are strong enough to be located in most parts of the country. This can be checked by trial and error before relying on them for location work.

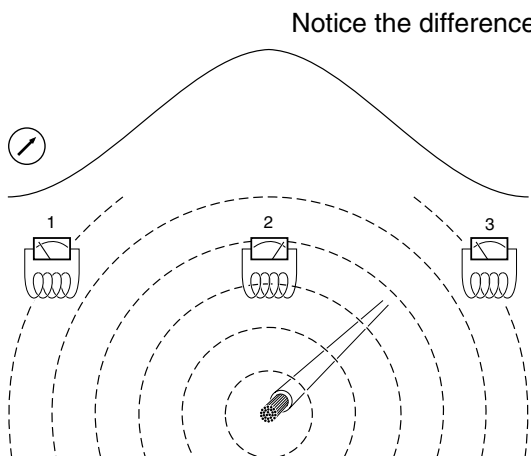
5 Aerials for locating a signal on a line

A coil suspended in a space produces an ac voltage proportional to an ac field or signal passing through it, because of the induction principle.



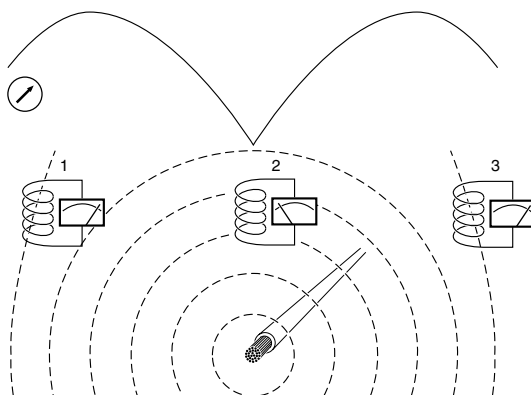
An iron rod through the coil will channel more of the field in the vicinity of the coil through it instead of around it. Receiver aerials generally take this form, using ferrite rods which are more efficient than metallic iron cores, and effectively amplify the tiny signals they receive.

Horizontal aerials. The aerial gives the strongest response when it is as close as possible to the line radiating the signal and in correct alignment at right angles and directly above it.



Notice the difference in response as the receiver traverses across the line through positions 1, 2 and 3. The response at position 2 is greatest, not only because of the proximity of the aerial to the line, but also because of the alignment of the aerial with the field direction, so that it is linked with a higher proportion of the field. Rotating the aerial above the line will therefore indicate the orientation of the line with a maximum response at right angles to the line.

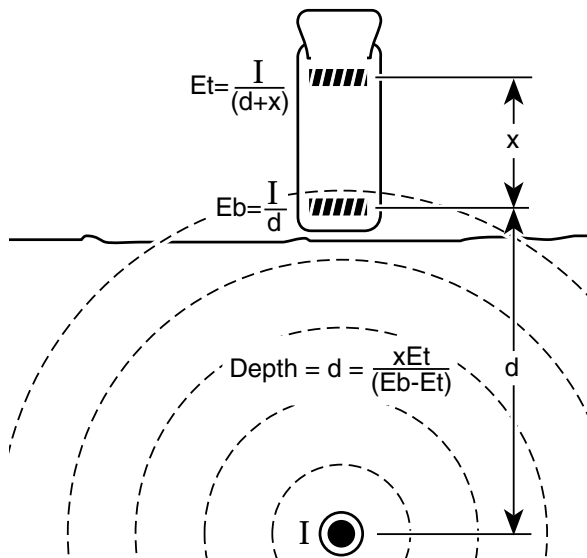
A horizontal aerial provides two separate items of information: line position and line orientation.



Vertical aerial: The vertical aerial gives a null response when it is directly over the line because the field does not flow through the aerial. Move the aerial to either side for the field to flow through the aerial and give a response. The sharp null response of the vertical aerial is easier to use than the flatter peak response of a horizontal antenna. However, it is vulnerable to interference and should not be used for locating except in areas with no interference or as indicated in this book. A vertical aerial indicates line position but not its orientation.

6 Electronic Depth estimation

A receiver with a twin aerial antenna uses the two aerals to measure depth in the same way that two eyes can judge distance.



The signal strength at the bottom aerial is compared to the signal strength at the upper aerial. The receiver circuitry does the arithmetic to provide a depth reading on the receiver display.

7 Locating non metallic lines

All the techniques described so far have been based on the detection of signal currents flowing in a conducting, metallic line. Where plastic or concrete pipes, ducts and drains are concerned, there is clearly no way of detecting and tracing them electromagnetically unless a transmitter can be inserted in them or a tracer wire is laid along the line. This tracer wire can then have a signal applied to it in the same way as to a metal pipe or cable.

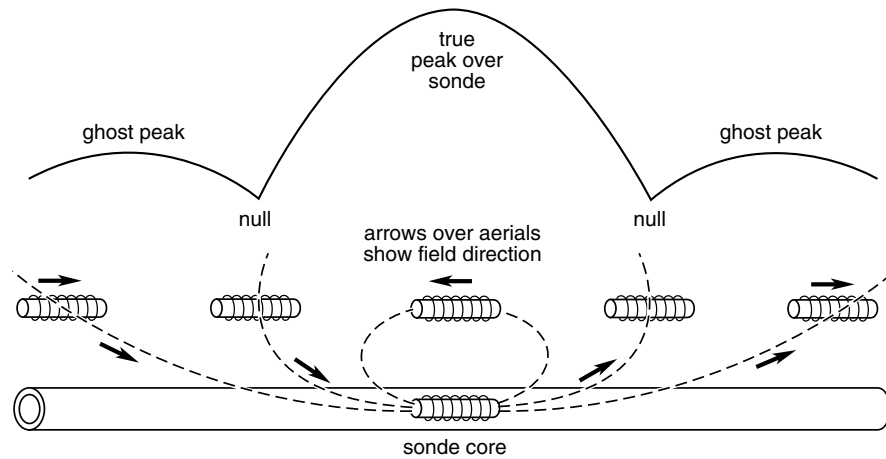


However other technology is available for tracing non metallic water pipes.

8 Locating a Sonde

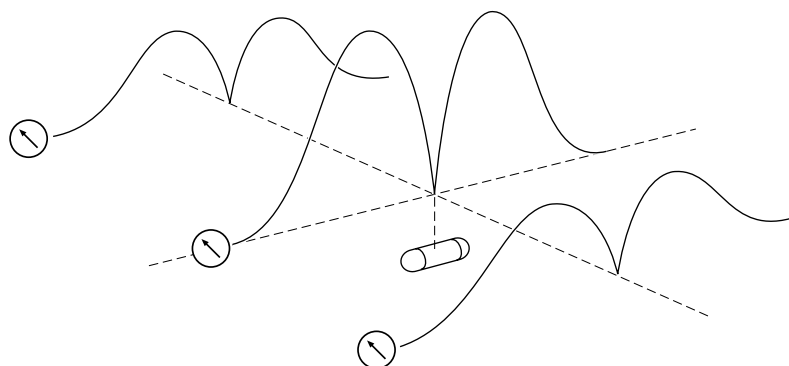
A sonde transmitter is a small self-contained signal transmitter designed for inserting in non metallic ducts, drains or sewers so that it may be located and traced with a receiver.

Although it is an ac signal, the magnetic field or signal produced by a sonde is different to the signal produced by the signal transmitter and described previously in this section.



The sonde produces a field distribution which is not cylindrical as with a line, but is sausage shaped along the orientation of the aerial core. As a sonde is approached with a horizontal aerial, a rising signal will be detected as it comes within range. This will then fall off again to null, giving the impression that the peak signal over the sonde has been passed. But if the traverse is continued, the signal will rise again to a much higher level, the peak of which indicates the actual and exact position of the sonde. It will then fall to null again, followed by a small rise and then fade away. The small ghost peaks either side of the nulls may mislead unless the peak signal is located.

A vertical aerial produces a single null response over the sonde but this null response is present along an axis at right angles to the sonde. For this reason a vertical aerial should not be used to locate a sonde.



Advanced theory

Further theory and explanation of locating and fault finding buried pipes and cables.

The notes in this section are intended for the technician or specialist for whom locating buried pipes and cables is an important part of the day's work.

- 1 Twin aerial antenna
- 2 How far can a transmitter signal be traced
- 3 Accuracy of electromagnetic locators
- 4 Current measurement
- 5 Current direction recognition
- 6 Cable sheath fault finding

1 Twin aerial antenna The detection of a single buried conductor in a green field situation is simple and can easily be made using a single aerial instrument. However, buried pipes and cables are usually adjacent to other lines and may be situated under overhead power lines or other sources of electromagnetic interference. Results from using a single aerial instrument in these situations can become confusing or the interference may render the locating instrument ineffective.

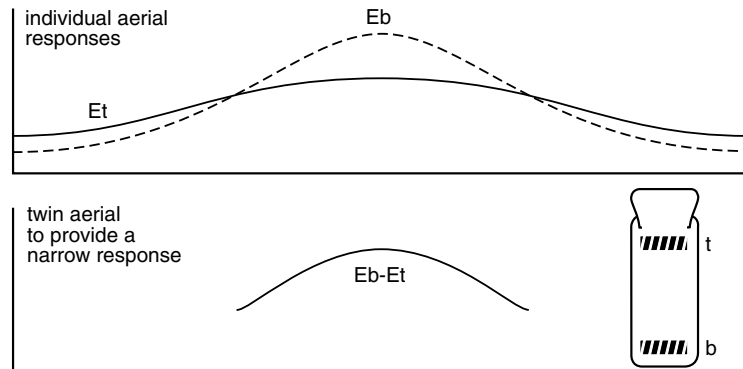
The twin aerial locator has largely superseded the single aerial instrument apart from the most simple low cost instruments. Sensing a signal at two points on a receiver antenna has important advantages:

Interference rejection. A significant advantage of receiving the signal at two aerials is that their outputs can be compared and analysed. By comparing and rejecting all signals other than those which are stronger at the bottom aerial, the twin aerial instrument gives good results in areas where interference makes a single aerial instrument ineffective.

Passive Radio mode operation. The twin aerial system also makes it possible to locate conductors re-radiating a VLF radio signal. This radio energy penetrates the soil and is re-radiated by a buried line acting as an aerial. The twin aerial antenna rejects the atmospheric signal which is received at equal strength at each aerial and only accepts the weaker re-radiated signal which is received at greater strength by the bottom aerial.

Narrow response for accurate location.

Section 1.6.5 described how the aerial picks up the signal. Each of the aerials of a twin aerial antenna receives the same signal but from a different distance, therefore with an appropriately different strength.



In the more simple-to-use locating tools the electronic circuit compares the aerial responses and only allows the amount by which E_b exceeds E_t to produce a response to the user.

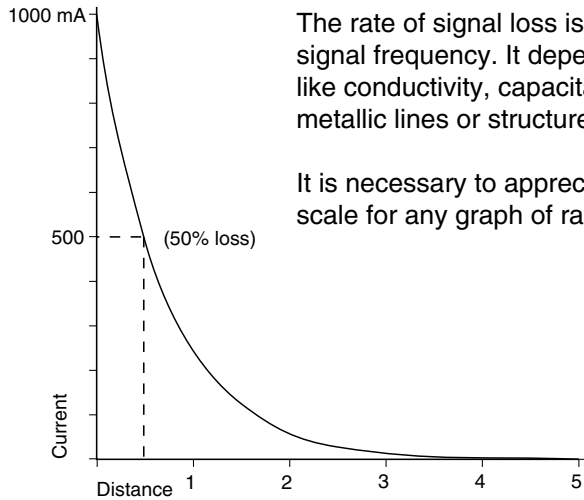
On more sophisticated instruments the slopes to the response as well as its peak are produced for the user. These locators are usually provided with visual indication as well as the audio response of the more simple locating tools.

2 How far can a transmitter signal be traced? This is a question most locator users want to ask, and most manufacturers wish to avoid answering! A more practical question is, 'How can the location distance from a transmitter be increased or maximized?'

2.1. The possibilities for increasing detection distances can be summarized:

- ☐ Reduce the rate of signal loss.
- ☐ Increase the signal current.
- ☐ Increase the receiver sensitivity.

The distance over which a signal starting with a given current strength will effectively reduce to zero will depend upon the rate of signal loss for a line. The most distant point at which this signal will still be detectable will be a function of receiver sensitivity; its ability to detect signal through surrounding noise. The higher the current, the easier it is to detect.



The rate of signal loss is a nominally fixed value for a particular line and signal frequency. It depends upon its fundamental electrical characteristics like conductivity, capacitance and inductance relative to ground and other metallic lines or structures.

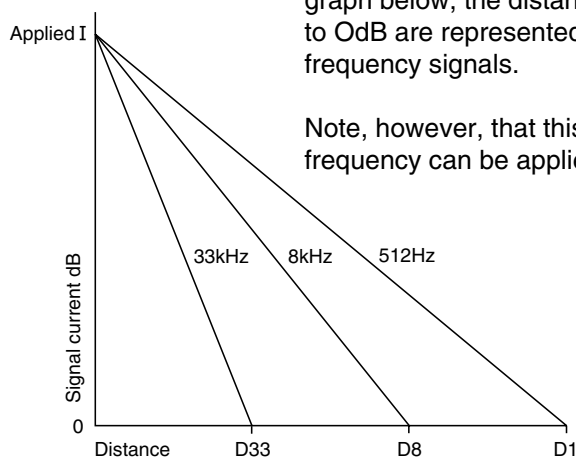
It is necessary to appreciate the necessity of using a logarithmic or decibel scale for any graph of rate of signal loss along a line, if meaningful information is to be conveyed.

The graph illustrates the way a signal current of 1A decays along a given line. It is clear that most of the signal is lost in the line nearest the transmitter, after which there is a more gradual slope down from a low value towards zero.

The gradual slope at low values where small changes in level make significant changes in distance is the critical area, so it is necessary to expand this part of the curve. This is shown by changing the vertical axis to a logarithmic scale, i.e. by substituting its logarithm for the original value. Decibels are simply standard logarithms multiplied by 20 for convenience, and express the ratio between levels. For example, an increase of 6dB represents a doubling, a decrease of 6dB a halving of level. The effect is to change the curve to a straight line and make level comparisons more visually obvious.

2.2. Reducing the rate of signal loss.

It is not possible to alter the characteristic properties of the line itself. However, the transmitter signal can be tailored to give it the best chance of travelling furthest, and this is why choice of signal frequency is important. Generally, a lower frequency travels further than a higher frequency, because the latter leaks away quicker via capacitance to ground. In the graph below, the distances at which the same signal current will have fallen to 0dB are represented by D33, D8 and D1 for 33kHz, 8kHz and 512Hz frequency signals.



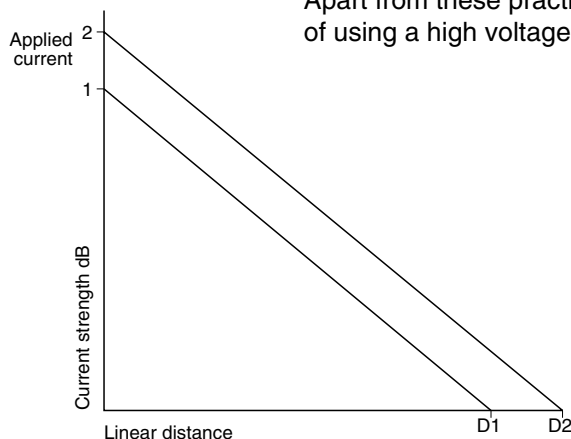
Note, however, that this is by no means the only consideration. Which frequency can be applied most effectively will vary with the method of application; higher frequencies are much easier to apply by induction. The background noise level will also change for different frequencies, particularly within the 50/60Hz power frequency harmonic range, and receiver sensitivities may also be affected. There is likely to be an optimum frequency for any particular line and situation. This choice of frequency is best established by experiment.

2.3. Increasing signal current.

There are three possible ways to increase signal current.

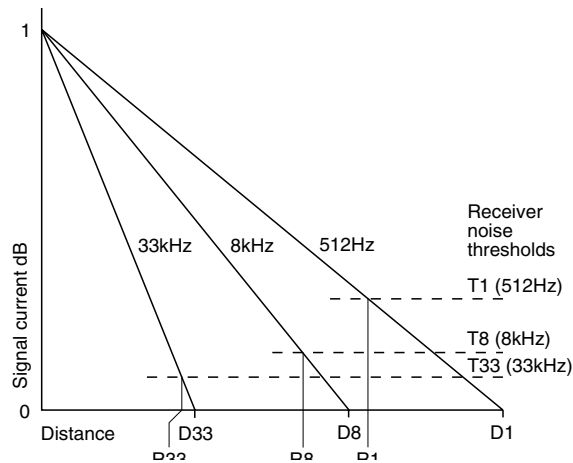
- ☐ Ensure that there is the best possible ground connection for the return of the signal.
- ☐ Impedance matching. Any given line will have a fixed impedance at any particular frequency, but its detection will require a certain signal current flow. The voltage required to drive that current through the line will be the product of that current and line impedance seen from the transmitter. For instance, a line impedance of 10 Ohm would require 10V per amp, while an impedance of 200 Ohm would need 200V per amp. If the transmitter is only capable of delivering its full output at a fixed voltage, say 50V, it could drive 5A through the first line, but only 0.25A through the second. So the power transferred into the second line would be much lower than the first (250VA and 12.5VA respectively) while the low impedance line might overload the transmitter at full output. To optimize the transmitter capability, it is clearly desirable to make its output available at more than one voltage/current combination. It is a parallel to auto gear changing, in that the ideal would be an infinitely variable ratio, but practicalities mean that step changes are more economic. Even having just two choices gives a considerable advantage over a single voltage capability without increasing the power required.
- ☐ Increase the signal power. The third, but impractical and high cost method of increasing current is to increase the transmitter power. A square law applies; four times the power is needed to double the signal current. This not only increases the size, weight and cost of the transmitter elements; it increases the battery drain for portable locators, which then either have a shorter operating time between replacement or recharging, or are larger, heavier, and more costly.

Apart from these practical disadvantages, there is also a safety implication of using a high voltage signal.



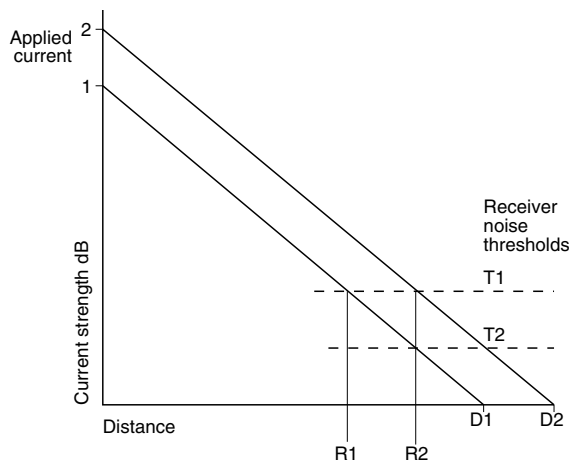
Note that doubling applied current does not double the range

Whatever means is adopted, the effect of increasing signal current with a given line and frequency will be to increase distance. The effect of doubling the transmitter current is typified in the graph below, in which the 0dB current level point distance increases from D1 to D2.



2.4. Increasing receiver sensitivity.

The graphs so far have shown the way signal current falls to virtually zero along a line. But long before this point, the signal current level usually becomes undetectable by the receiver, because it is indistinguishable from background noise and interference levels. It is this noise threshold which is the significant figure to be considered; the graph repeats the comparison of rate of signal loss for different frequencies, but this time shows the effect of different noise thresholds. While the 0dB distance D1 for 512Hz is significantly greater than D8 for 8kHz, the receiver noise threshold T1 at 512Hz is higher than T8 at 8kHz, because it falls within the harmonic frequencies associated with 50 and 60Hz power systems, which are present in strength in most working environments. So the maximum detection distance R1 for 512Hz is not as much further than R8 for 8kHz as the original comparison might suggest. A similar effect is apparent in comparing the 33 and 8kHz detection distances.



It is therefore apparent that receiver sensitivity is an extremely important factor in detection range. Achieving a low noise threshold is a combination of high amplification and high quality filtering to reject signals at frequencies other than the transmitter signal frequency. The graph repeats the comparison of doubling signal current, and shows that the same increase of detection distance from R1 to R2 is achievable by halving the receiver noise threshold from T1 to T2 as by doubling the signal current.

3 Accuracy of electromagnetic locators

Errors of accuracy can arise from two factors:

- ▮ The locator's capability to measure the precise point at which a magnetic field is at a maximum (or minimum) and to correctly measure a field gradient.
- ▮ The cylindrical magnetic field around a line can be deformed or distorted so that the maximum value is no longer directly above the target line and the field gradient is not suitable for making an accurate depth measurement.

3.1. Locator's capability to measure accurately

There are four main types of locator aerial array:

- ☐ Single horizontal aerial.
- ☐ Twin horizontal aerial with one aerial mounted above the other and about 40cm/16in apart.
- ☐ Single vertical aerial.
- ☐ Combination of twin horizontal aerals and a vertical aerial.

The obtainable degree of resolution defines one source of error from the locator. Assuming a long straight isolated target line and a visual output device that can be resolved to within 1% of full scale and vertical alignment of the antenna. A vertical aerial can resolve position to better than $\pm 5\%$ of depth, a single horizontal aerial to $\pm 10\%$ of depth and twin horizontal aerals to $\pm 5\%$ of depth of the line.

Manufacturing tolerances and discrepancies are another possible source of error.

The single horizontal aerial receiver is least affected by mechanical tolerances. A vertical aerial gives twice the error of a horizontal aerial if the aerial is misaligned to the same extent.

3.2. Magnetic field distortion.

Most of the problems of accurate location of buried lines in the highway are due to situations that distort magnetic fields. While there are an almost infinite number of ways that fields may be distorted by other lines at various angles and carrying various signals, a useful analysis of accuracy can be obtained by considering two specific situations:

- ☐ A 90° bend in the line.
- ☐ Two close parallel lines carrying equal signals or currents. Equal signal currents are, of course, an unlikely eventuality but the example serves as a useful reference for comparison.

Error is expressed as a percentage of the depth d of the line. Relevant distances are expressed in units of d . Measurement of two types of error are useful; maximum degree of plan location error and the length of line along which location error exceeds 10% of depth.

The following information is based on a 1m/40in line depth and a 35cm/14in aerial separation on the twin aerial receiver.

Distortion close to a 90° bend: a locator starts giving faulty information as it comes under the influence of the magnetic field of the perpendicular part of the target line.



A null locator traces a path that is outside the actual bend. The only point where the reading is correct is exactly over the point of the right angle bend. Maximum error is at a point 0.7d from the bend and amounts to 33%. 10% error band extends 5d either side of the bend.



The locator traces a path that cuts across the inside of the bend. Maximum error occurs at the point of the bend and is 25%. 10% error band extends only 0.5d from the bend.



Similar to the single horizontal aerial locator, it traces a path to the inside of the bend with a maximum error of 16% and the band of the 10% error is only 0.33d.

Distortion due to parallel lines buried close together: similar strength signals on parallel lines running in the same direction:



Error of less than 10% is only achievable if lines are more than 10d apart. The error will indicate the lines are closer together. If the lines are closer than 2d there will be a single null in the centre of the lines rather than two separate indications.



Locator indicates lines are closer together but separate indication of each line is possible down to separation of 1.2d when error will be up to 60%. Accuracy of better than 10% is possible if separation is twice depth or greater.



Error of 50% at a separation is greater than 1.5d.

Distortion due to parallel lines buried close together: similar strength signals on parallel lines running in opposite directions:



The locator will show two positions outside the actual position of the lines. It will still show two separate responses even if lines are almost touching and error will be 100%. Accuracy better than 10% is only possible if the two lines are nearly 10d apart.



The locator gives response outside the true positions but with maximum error of 60%. Error falls to 10% when lines are 1.7d apart. There is a sharp null response between lines.



Similar response to the single horizontal antenna but a maximum error of 50% reducing to 10% error when separation is 2d.

The previous data indicate several conclusions:



The vertical aerial locator gives responses unacceptably wide from the actual position of lines when more than one line with the same signal is present in a small area.



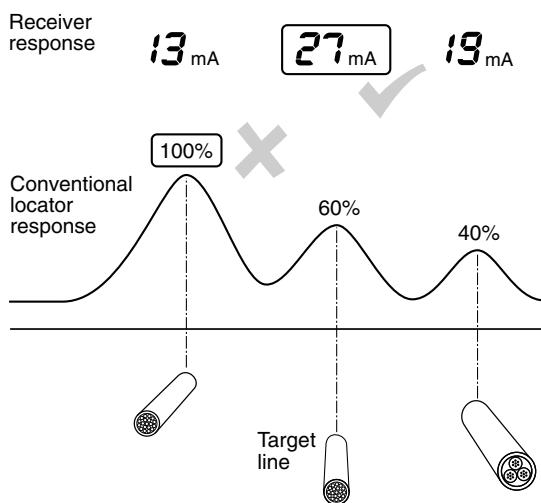
Twin horizontal aerial system provides the best and the most useful response.



Comparison of responses from vertical and horizontal aerals can be used to determine if interference fields are affecting accurate location. Interference is present if the positions providing the responses from the two systems do not coincide. This comparison permits a multi-aerial locator to check if a response is accurate and if the signal is suitable for making an accurate depth measurement. Locators with both horizontal and vertical aerals are known as precision locators or precision receivers.

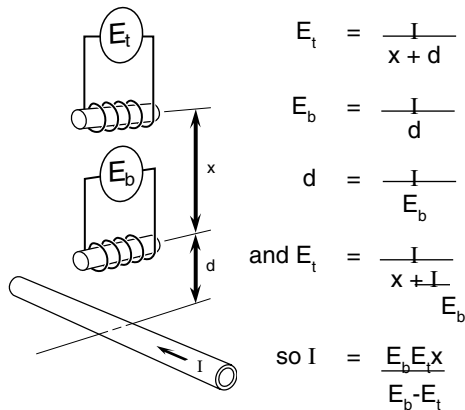
4 Current Measurement The need to confirm target line identity and to measure current loss gradient has led top-of-the range locators to include a current measurement feature. Measuring current on a target line is an aid to verifying line identity. The line with the strongest current, not necessarily the same as the line giving the strongest response, is invariably the target line to which the transmitter signal has been applied.

A receiver gives a response which is dependent on the gain setting and on the line depth. This can lead to errors when tracing signals from several lines at different depths. The errors result from assuming that the line which gives the strongest response is the line carrying the strongest signal. In many cases the deeper line is carrying the strongest signal but does not show the strongest response, as illustrated below.



The drawing also shows the current measurement over the different lines with the reading of 27mA being the target cable to which the transmitter signal has been applied.

Ability to read current measurement on a receiver display greatly increases the certainty of correct line identification, especially in congested areas.



Current measurement is an extension of the principles used for depth measurement. The diagram shows the signals detected by the two aerials and the computation that is performed to derive current value.

5 Current Direction Recognition

Increasing importance is being given to verifying line identify. This is particularly the case with long distance fiber telephone cables which often run parallel to other cables.

Current Direction Recognition is a recent development available as an accessory on top-of-the-range locators. The receiver display indicates a forward or backward pointing arrow indicating the relative direction of current flow and therefore the line to which the transmitter signal has been connected.

However, alternating current does not have a direction. The electrons move backwards and forwards along the conductor and maintain the same average position.

Despite this, many of the diagrams used in this, and other, books, show locator transmitters connected to conductors and use arrows to indicate a direction of current flow. The arrows actually show the direction of current flow at one instant in time; a few thousandths of a second later, the current may flow in the reverse direction.

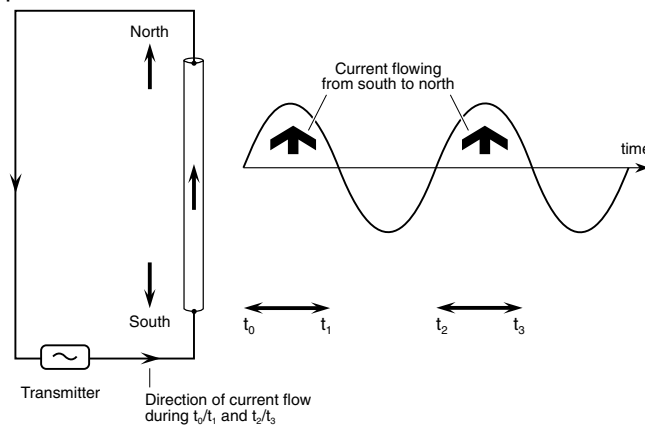
Nevertheless, these current flow direction arrows are useful; they indicate the behaviour of the applied current and allow the use of expressions such as 'the current flows along the pipe and gradually leaks through the ground onto adjacent cable'.

In the diagram the current appears to flow in one direction on the pipe and in the opposite direction on the cable. In practice, both signals are ac and appear identical to a locator receiver.

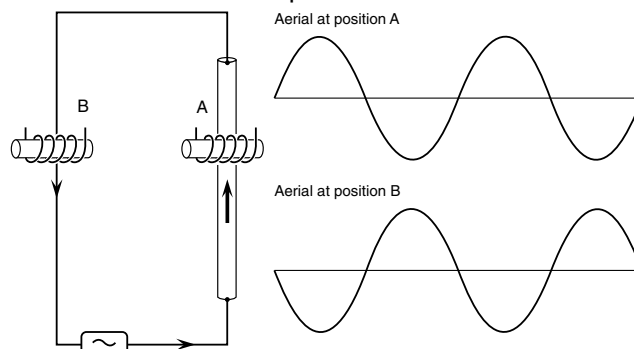
The current direction recognition feature identifies the relative current directions and will discriminate between the pipe and the cable.

The theory of current flow.

Ac signals do not have a direction but have a characteristic known as phase which is similar to direction.



If a signal transmitter is connected to a pipe, it will cause a current to flow initially from South to North, then from North to South and so on. This can be represented on a graph which shows the direction and magnitude of current flow at different points in time.



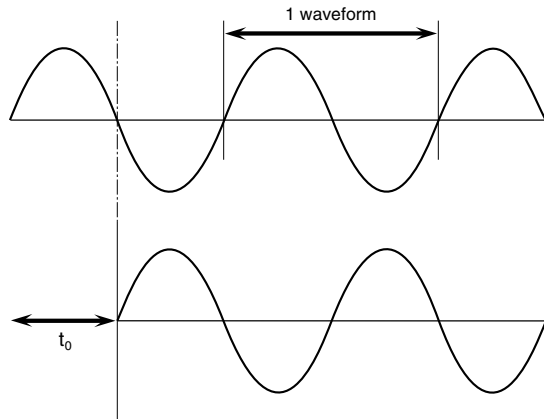
If an aerial is held above the pipe, the induced voltage is proportional to the current flow and can be represented by an almost identical graph.

When the aerial is at position B, the current it detects initially flows from North to South, then from South to North; exactly the opposite of the current

flow detected at position A. It follows that the signal induced in the search aerial is also reversed - at any instant in time, the detected direction of current flow is reversed.

The two graphs show that there is a detectable difference between "Flow" and "Return" ac currents and this is used to determine the relative direction of flow.

Part 1 Section 7. Advanced theory. Current direction recognition



Frequency = 500Hz, $t_0 = 1/1,000$ sec.

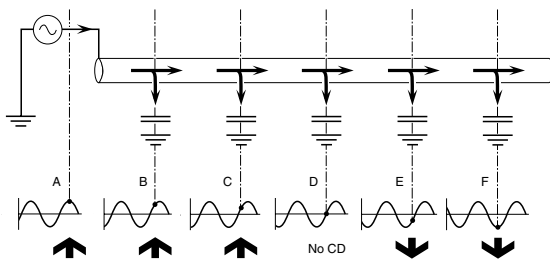
Fail conditions of Current Direction Recognition. The previous section suggests that a reversed ac signal can be considered to be flowing in the opposite direction.

This is true but it can also be considered to be simply time-delayed.

The diagram shows the same two waveforms as before and illustrates that exactly the same current flow pattern is achieved if the signal is simply delayed for a period ' t_0 '. If the frequency is, for instance, 500Hz, the full waveform (positive and negative sections) is repeated 500 times a second.

In this case, a time delay of 1/1000th of a second shifts the waveform forwards and causes it to appear to be upside-down. It therefore appears to be a signal flowing in the opposite direction.

Time delays such as this are normally referred to as phase-shifts. A shift of phase can occur whenever an ac signal is flowing in a system of conductors which have a significant capacitance or inductance.



As signal gradually 'leaks' through a buried line's capacitance, so the phase angle of the signal remaining on the line gradually changes.

This is a diagram of a buried line with significant capacitance to ground. It illustrates the gradual phase-shift which occurs along the line. The diagram shows a reference point on each waveform. At first, the reference point occurs right

on the peak of a positive half cycle (A). It gradually moves towards the zero crossing point (D) and ends up on the peak of a negative half cycle (F).

The direction has shifted from forwards to backwards. At the intermediate point (D) the current flow is indeterminate.

To prevent the CDR feature from giving misleading information, the misleading indication is usually suppressed on the receiver display; CDR indications would be suppressed between points C and E.

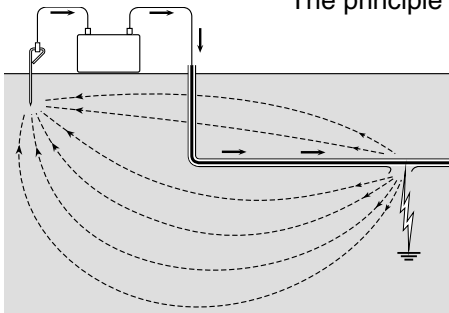
In most cases the intermediate point does not occur until many km/miles from the transmitter. The situation is easily overcome by returning to the last point at which a current direction reading was achieved (C) and resetting the mode. This will have the effect of making the response at C equivalent to that at A.

6 Cable Sheath Fault Finding

The 'A' Frame type fault finder was developed to locate cable sheath faults. It can also be used for locating faults in pipe coating.

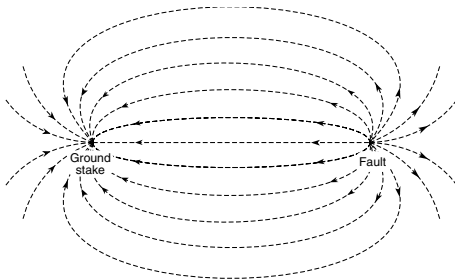
The cable shield is intended to be insulated from ground (except at deliberate terminations) so the locator's function is to find the point where an otherwise insulated conductor is in electrical contact with the ground.

The principle is based on the direction of flow of ground currents.



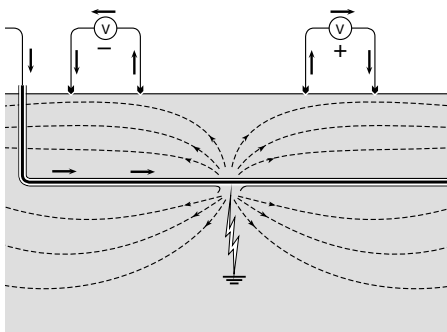
Sheath or coating faults are detected with an 'A' frame accessory for the receiver.

Consider the Fault Find transmitter as a battery connected across a faulty sheath and ground. With all deliberate ground/shield connections removed, the path of the current flow will be along the cable shield to the fault, through the fault to ground and then through the ground back to the other terminal of the battery.



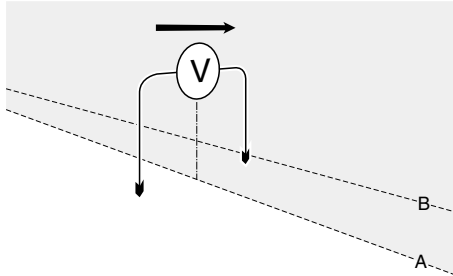
At the sheath fault, the current is 'escaping' to ground and will immediately spread out and return to the battery via many different routes.

The current can be pictured flowing out of the fault in every direction so that in the vicinity of the fault the ground currents on the surface radiate out like the spokes of a wheel.



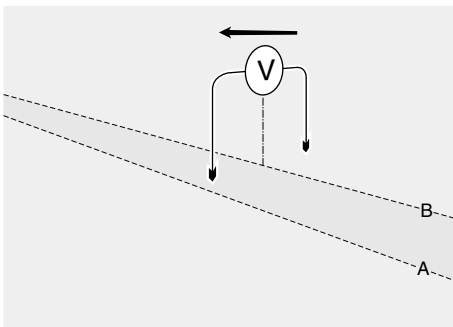
If a voltmeter is connected to the ground at two points, as illustrated, it will display a positive reading or a negative reading, depending on the direction of flow of the local ground currents.

Note that the ground currents are concentrated in the area of the ground stake and the fault, and are very much more spread out in the area between the two; this corresponds to the signal strengths which will be detected - strong when close to the fault and weak or non-detectable when distant from the fault.



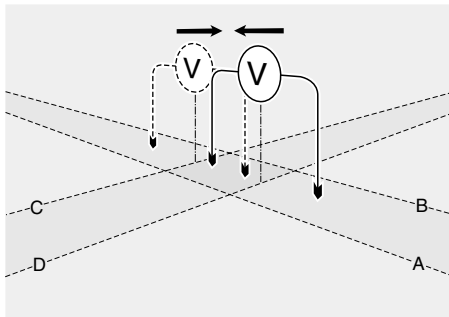
The polarity (negative or positive) of the meter deflection then shows whether the sheath fault is ahead or behind the position of the voltmeter.

Note that the meter does not indicate directly the direction of the fault. Imagine a line drawn through the centre of the meter; the meter deflection indicates which side of the line the fault is.



If the meter is moved along in the direction of the fault, it will eventually flip over and point in the opposite direction. The line of the fault is now known; it must be somewhere in the narrow strip defined by the two overlapping areas.

All that is required to home in on the exact fault location is to turn the meter through 90 degrees and search along the defined narrow strip until the meter again flips. Turn through 90 degrees again to zero-in exactly (thus allowing for the curved path of the ground currents) and soon a point is reached where any movement of the meter in any direction causes the meter indication to flip. The position of the fault is then isolated to within a few square centimetres/inches.



The principle of operation of the 'A' frame is the same as described above except that it does not use a DC battery. In practice, the battery idea does not work because of stray naturally occurring ground currents overpowering the weak fault current. Instead, ac signals are used. The receiver's circuitry decodes the information contained in the signal in order to display the relative direction of flow.

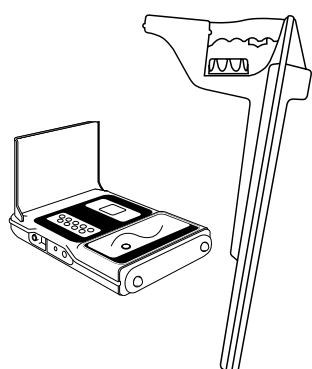
The locating set

The signal transmitter and the receiver are the two building blocks that make up a locating set. The set can vary from a simple unit with limited capability such as locating buried cables, to a sophisticated set with the ability to provide comprehensive information about buried pipes and cables and capable of fault finding and problem solving.

A wide range of accessories is available for both the transmitter and the receiver to increase the usefulness of the locator and extend its scope.

And there is a third building block: the sonde. A transmitting sonde is a small transmitter which can be propelled along non-metallic ducts or sewers so that they can be traced by locating the sonde as it travels along the duct or drain.

1 Transmitter and Receiver



The transmitter creates an identifiable signal and applies it to a target line so that the line can be traced and located with the receiver. It can also flood an area with signal which energises all the lines in the area.

The receiver provides a visual and/or audio response for the user when it detects a signal that has been applied to a line by the transmitter. It can also detect passive signals and signals from a sonde. The receiver is used to trace, pinpoint and identify a target line and to sweep or search an area for unknown lines and to fault find.

2 Locator set features

A number of features should be common to the transmitter and the receiver parts of the locating set.

- ☐ Enclosures and manufacture should be weatherproof to IP54 and NEMA 3S and suitable for use in all weathers and climates; a temperature range of -20°C +50°C/0°F +122°F without performance loss.
- ☐ Construction of the locator and its accessories must be rugged and suitable for daily site use.
- ☐ The shape and weight of the locator set, particularly the receiver, should be convenient, comfortable and suitable for use in all the variety of field situations without unnecessary fatigue.
- ☐ The locating set should come fitted in a portable bag or box to protect the locator and be suitable for storage and carrying on site.

Locator set options

- Signal Frequency. Most locators provide more than one signal frequency so that the user can choose the most suitable frequency for each locate.



Low frequency <1kHz suitable for long distance tracing with minimum coupling. Not suitable for induction.



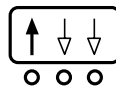
Medium frequency <10kHz suitable for locating utility distribution systems and locating in the street or highway. Not as effective in induction as a higher frequency.



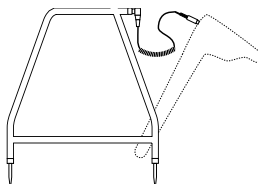
High frequency <75kHz also suitable for locating utility distribution systems and gives effective induction onto lines. Suitable for use with high resistance lines such as small telephone cables or iron pipes with O ring joints. Shorter tracing distance with greater tendency to couple than lower frequencies.



Very high frequency >75kHz useful for locating cable dead ends and other special applications but limited usefulness because of strong tendency to couple and a short tracing distance.



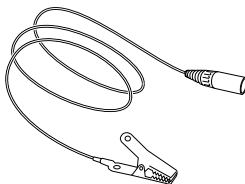
- Current Direction Recognition feature enables the receiver to distinguish a target line to which the transmitter signal has been applied from other nearby lines to which the signal may have coupled. A useful feature for identifying a target line on a long distance trace or when the line crosses a congested area.



- 'A' frame for locating cable sheath faults or line insulation faults. The transmitter applies a specially characterised signal along the line so that sheath faults can be accurately located by the A-frame antenna linked to the receiver. On some models the electronics and display may be built into the A-frame.

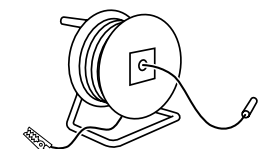
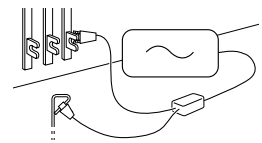
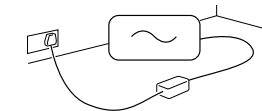
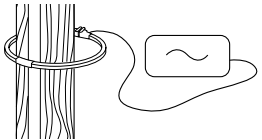
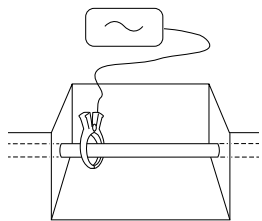
3 Transmitter features The basic specification of the transmitter should include

- Protection. Output circuitry to be protected against inadvertent connection to conductors at up to 250V at 50/60Hz.
- Medium or high frequency continuous sine wave output signal.
- > 0.5 Watt output power.
- < 2m/6ft lead with suitable spring clip for making a direct connection to the line. < 4m/12ft ground lead and stake for making a ground connection. A magnet on the clip is a useful addition.
- Built-in aerial for inducing the signal to a line.
- Indication to warn low battery condition.
- Socket for plugging the direct connection lead or optional accessories such as the clamp.

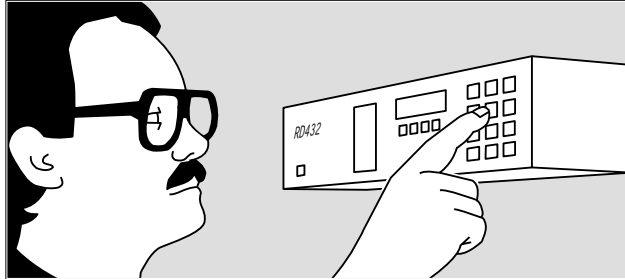


Transmitter options

- ☐ *Increased output power.* 1 Watt is suitable for locating most distribution systems. High power, up to 3 Watts, is often needed to supply sufficient power for long distance traces or to apply a signal to lines with high resistance joints.
- ☐ *Output signal strength control.* Manual control of output signal strength.
- ☐ *Power display.* Visual indication of applied signal strength is useful information when applying a high power signal.
- ☐ *Visual/audio connection indication* to indicate that a direct connect signal has been successfully applied.
- ☐ *Visual indication* of line impedance and manual impedance match control to optimise signal efficiency.
- ☐ *Automatic impedance match.* Transmitter automatically matches line impedance when the signal is direct connected.
- ☐ *Special clips* for the direct connection lead can usually be supplied. For instance, clips with a pierce spike and clamp for a telephone cable or large clips for fastening to a valve stem.
- ☐ *Signal clamp* for applying the signal to a live cable without disconnection. Clamp is usually about $\varnothing 10\text{cm}/4\text{in}$. Smaller clamps are generally available and a large clamp $>\varnothing 40\text{cm}/16\text{in}$ is useful for applying the transmitter signal to cables fastened to poles. Clamp size must be specified. Extension rods for the clamp are useful for clamping to inaccessible cables or cables in a flooded manhole.
- ☐ *Plug connector* applies the transmitter signal to a live domestic socket onto the service cable and the distribution cable in the street. Specify plug type.
- ☐ *Live cable connector* applies the transmitter signal directly to a low voltage live conductor at a junction box or substation. Must conform to a suitable safety standard for supply voltages up to 500V, DC to 65Hz. Should only be used by personnel licensed to work on live cables.
- ☐ *200m/200yd cable* for connecting the transmitter to a remote ground point. Cable should be supplied on a reel or drum.
- ☐ Lead or socket to power the transmitter from an *external 12V supply* such as an auto battery to save battery life particularly on long distance locates and useful in the event of battery failure. Specify if lead is to have a plug suitable for fitting to a cigarette lighter.
- ☐ *Rechargeable batteries and charger.* It should be possible to substitute standard alkaline batteries in the event of failure of rechargeables.
- ☐ *Mains adaptor* to power the transmitter for extended use at high power.



4 Rack mounted high power transmitter sometimes



known as a Line Management System for applying a high power, >35 Watts, signal to very long distance lines such as between fiber cable regeneration stations. It is tailored to the customer's system and engineered to his requirements.



6.2

Features are designed

- ☐ to provide a good quality locating tone for the total length of a fiber optic cable from one regeneration station to the next.
- ☐ to provide electronic identification of the target cable in all situations where locates are possible.
- ☐ to provide a telemetry package that allows remote control of the transmitter by telephone or Order Wire systems to provide the ability to respond immediately to a locate request without needing to visit the transmitter in the regeneration station.
- ☐ to provide cable monitoring capable of indicating an Alarm condition should the transmitted current exceed the set parameters, and with the additional capabilities to confirm that the transmitted tone has been received.
- ☐ to make the system simple to install and operate.

5 Receiver features The basic specification of the receiver should include

- ☐ Aerial and circuitry tuned to receive the transmitter frequency or frequencies.
- ☐ Visual (and/or audio) response to the signal.
- ☐ Manual gain control to adjust receiver response to a signal.
- ☐ Socket for plugging optional accessories.
- ☐ Socket for headphone jack.

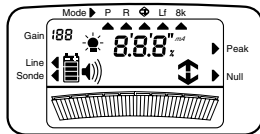


Receiver options

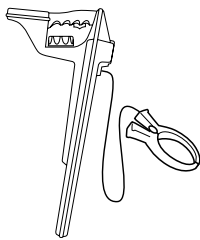
- ☐ *Twin horizontal aerial antenna* for better discrimination and interference rejection.



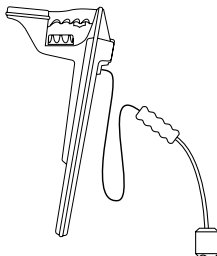
- ☐ *Precision receiver* incorporates a vertical aerial with a twin horizontal aerial antenna to give both a peak and null response. Necessary for precision pinpoint locates.
- ☐ *Passive power locate* mode to detect 50/60Hz energy from power cables and other lines. An important feature for locating power cables before digging.
- ☐ *Passive radio locate* mode to detect VLF radio energy on lines. A useful supplement to the power mode in most areas.
- ☐ *Audio response* to enable the ear and eye to work together to interpret information from the receiver. Can be either a loudspeaker or headphones.
- ☐ *Auto/manual gain control*. Auto gain control responds to the signal and the interference level and avoids the need for adjusting the sensitivity level to keep the meter on scale. Manual override is necessary for some locates and fault finding.
- ☐ *Electronic depth measurement feature*. Depth to the target is indicated on the display.



- ☐ *Liquid crystal display* for indicating digital response combined with bar chart. Necessary for indicating additional receiver information such as current direction or measurement, depth etc. Display should be back-lit for night working.
- ☐ *Current measurement* indication is a useful aid for confirming line identity in congested areas. It can also be used for monitoring cable insulation or pipe coating quality.
- ☐ *Automatic test* feature to confirm the receiver is working correctly at switch on.



- ☐ *Clamp antenna* for plugging into the receiver for locating and identifying cables in a manhole or on a tray.
- ☐ *Stethoscope antenna* for locating and identifying cables in a manhole or on a tray. The concave head can be pressed against each cable in turn to detect a maximum signal if there is not sufficient access to clamp round them.

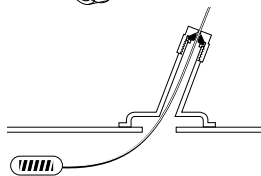
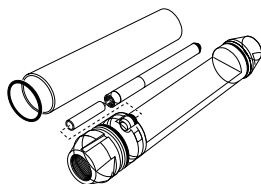
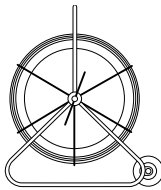
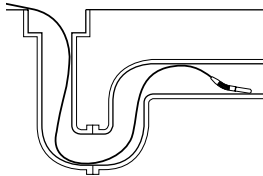


- ☐ *Software updates* for new applications. The receiver should be designed to accept new software as it becomes available.
- ☐ *Submersible antenna* is used for tracing lines and measuring their cover underwater or on seabeds. The submersible antenna is either attached to a boom or used by a diver walking along the seabed.
- ☐ *Rechargeable batteries* and charger. It should be possible to fit standard alkaline batteries in the event of failure of the rechargeables.

6 Sondes

Transmitting sondes are used for tracing and locating non-metallic pipes, ducts, drains and sewers. The sonde is propelled along the pipe and traced by the receiver locating its position at intervals as it progresses along the pipe. The sonde can be used for locating pipe blockages or collapses, detecting water leaks in plastic pipes, monitoring horizontal boring tool progress and finding joints in iron pipes. Sonde housings must be waterproof and rated to withstand the equivalent of 1.5 x pressure at rated detection depth.

- ☐ Features of different size sondes are basically similar and the main variations are in size and depth of location. Sonde signal transmission frequency must correspond to a frequency on the receiver. Sondes range from just over $\varnothing 14\text{mm}/0.5\text{m}$ with a maximum detection depth down to 1.5m/5ft to a sonde that can be located down to 15m/50ft depth.
- ☐ Choice of a suitable sonde is made from a supplier's catalogue as a function of maximum possible sonde diameter, required depth of location, required battery life and a signal frequency corresponding to a frequency available in the receiver.
- ☐ On small sizes the sonde aerial is sometimes incorporated in the head of a flexible rod which incorporates conductors. The batteries and electronics housed on the surface with the user.



Sonde options

- ☐ *Flexible rods* for pushing sondes along pipes or ducts.
- ☐ *Threaded couplings* and flexible couplings for attaching the sonde to drain rods.
- ☐ *Floats* to float the sonde down a drain at the end of a tether.
- ☐ *Sonde Holders* to fit the sonde in the pneumatic hose behind a horizontal boring tool. The progress and position of the tool can be monitored by locating the sonde with the receiver as the bore progresses.
- ☐ *Entry canopy* fitted to a pressurised gas or water pipe provides a safe entry to the pipe for a sonde fitted to a flexible rod. Care must be taken to insure that the canopy is suitable for use on the service type, pressure and pipe size.

7 Horizontal boring

Special sonde/receiver combinations are available for providing information for steering guided horizontal boring tools.



Choosing a suitable locator and accessories

Successful locating begins with having a suitable locator for the job and for the person using it.

1 There are two or three specialist suppliers of buried pipe and cable locating equipment in most countries or areas. Each offers a choice of locator types.

It is advisable - expert or novice, procurement department or engineer - to consider the information that the locator will have to provide before considering a choice of equipment. It is also necessary to consider the knowledge and background of the person who will be using the equipment. It is needless extravagance and confusing to provide a sophisticated locating set to the person working in the trench. However someone facing a complex locating or faultfinding problem needs a suitable set of equipment and accessories.

The purpose of purchasing a locator is to locate buried utility services and other buried plant successfully; that is to say accurately and economically. To purchase the ability to locate rather than just buying a locating instrument.

2 Matching locator features and optional accessories to the job

	Locating before digging	Locating power distribution	Locating local telecom	Locating long distance telecom	Locating metal distribution pipes	Locating pipelines	Locating underwater	Locating industrial site services	Locating cable sheath faults	Locating cable conductor faults	Line identification	Site survey for buried drains and ducts	New line acceptance	Current gradient survey	Short distance boring	Ground potential survey
Locating set options																
Low frequency	▲	■	▲	■	■	■	▲	■	■	■	■	■	■			▲
Medium frequency	■	■	■	■	■	■	■	■	■	■	■	■	■			■
High frequency	■	■	■	■	■	■	■	■	■	■	■	■	■			
Very high frequency	■	■	■	■	■	■	■	■	■	■	■	■	■			
Current direction recognition		▲	▲	■	■	▲	■		■	▲	▲					
'A' frame fault find							▲	■								
Transmitter options																
Medium power >1 Watt	▲	■	■	■	■	■	■	■	■	■	■	■	■			■
High power > 3 Watt		●	▲	■	▲	■	▲	■	▲	▲	▲	▲	■			▲
Rack mounted transmitter				■	■	■	■									
Output control	■	■	■	■	■	■	■	■	■	■	■	■	■			■
Power display	●	▲	▲	■	▲	▲	▲	▲	▲	▲	▲	▲	▲			
Impedance match and display	●	▲	▲	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		
Auto impedance match	▲	▲	▲	■	▲	▲	▲	▲	▲	▲	▲	▲	▲			
Connection indication	▲	▲	▲	■	▲	▲	■	▲	▲	■	▲	▲	■			■
Special connection clips			■	■			■					▲				
Signal clamp	■	■	■	■	■		■			■	■	■				
Plug connector	▲	■	■				■				▲					
Live cable connector		▲					▲									
Long ground cable				▲	■	■	■			▲	■					
Socket for external 12V supply		▲	▲	▲	▲		■	▲		▲						■
Rechargeable batteries	●	●	●	●	●	●	●	●	●	●	●	●	●			●
Sonde(s)	■		■	▲			■		■		■			■		
Receiver options																
Twin aerials	■	■	■		■				■					■		
Precision antenna	▲	▲	▲	■	▲	■	■	■	■	■	■	■	■	▲		
Power mode	■	■	▲	▲	■	■	■	■	■	■	■	■	■			
Radio mode	▲	▲	▲	▲	▲	▲	■	■	■	■	■	■	■			
Audio response	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Auto/manual gain control	▲	▲	▲	▲	▲	▲	▲	■	▲	▲	▲	▲	▲	▲	▲	
Electronic depth measurement	▲	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
LCD display	●	▲	▲	■	●	■	■	■	●	■	■	■	■	■	■	▲
Current measurement		▲	●	■	●	■	■	■	■	■	■	■	■	■	■	
Auto test	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Clamp antenna		■	■	▲	▲		■			■	■	▲				
Stethoscope antenna		▲	▲		▲		■	■		■	■	▲				
Submersible antenna				●		●	■									
Software update	●	▲	▲	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	
Rechargeable batteries	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

■ Necessary

▲ Desirable

● Optional

3 Field support and training The capability of the supplier is as important as the quality and features of the locator.

- ☐ Does the supplier have a good reputation with the local utility companies?
- ☐ Are the user instructions comprehensive and easy to understand and follow?
- ☐ Is a repair and calibration service available and is it dependable?
- ☐ Does the supplier organise training courses?
- ☐ Does the supplier organise periodic technical seminars?
- ☐ Is expert field advice available to advise methods of solving particular locating problems?

4 Locator cost Locator cost varies with the sophistication of the instrument and the first stage of procuring a suitable locator is to establish the required features and capability.

The cost of ownership of the instrument must be considered at the same time as the cost of purchase. The depreciation on the value of the locating set is the lowest constituent cost of making a site locate; much lower than the cost of the user's time and transportation to and from the site.

Clearly the user should have the best possible locating set to provide accurate information in as many site callouts as possible. The difference in cost between a first class locating set suitable for the job and a second best is very much less than the cost of only a few site visits that result in faulty information or a failure to locate.

5 Radio transmitter regulations The locator transmitter is a radio transmitter and most countries have regulations defining permissible transmitter frequency, power and wave form. Check with the supplier that the locator conforms to all relevant norms or regulations.

6 Demonstration Most locator suppliers are prepared to make a presentation to demonstrate the capability of their equipment. A purchaser should take advantage of the opportunity to use the equipment to solve typical daily locating problems. It is an opportunity to assess equipment quality, ease of use and technical capability.

Part 2. Successful locating: the basics

Successful locating buried pipes and cables is a combination of using a small number of simple procedures.

These must be understood before doing field work or before attempting any more elaborate procedures.

Part 2: Section 1. Safety

Safety



Safe working on site is always the first priority and must never be neglected.

Any electrical apparatus has its potential dangers and locators are no exception. The locators must only be used with strict observance of standard safety procedures.

The locator signal transmitter must always be switched off while making a connection.

Always follow company regulations and procedures when opening a man-hole or making access to any other plant to apply a transmitter signal to a pipe or cable.

Specialised procedures such as applying a transmitter signal directly to a live power cable conductor or inserting sondes into pressurised pipes must only be undertaken by licensed or qualified personnel.

Always make sure that the locating set is working correctly before locating. Test receiver passive locate modes over a known cable and check that the receiver is giving a good response to an active signal from the transmitter.

Locators are often used in the highway where there are dangers of passing traffic: be prudent and look and listen for traffic.

Safety first, safety last, safety always.

Successful locating

There are no secrets about successful locating. As with anything else getting field experience takes time, effort and persistence. Then follows the success of the professional.

- 1 Locating buried pipes, cables and drains begins by looking for visible clues.

Look for valve box covers, manhole covers, pedestals, splice or junction boxes, overhead wires, poles with downward cables; look for any sign that gives an indication of what may lie underground.

It is also important, mandatory in many countries, to obtain and consult maps and drawings from the utility companies and from owners of buried plant.

The cumulative information from site observation and maps provides useful information on what to expect and where to start locating.

- 2 Become familiar with the use and 'feel' of the locator and set up a trial site.

- ☐ Use the receiver to detect the passive 'power' signal on a buried power cable. Experiment with the sensitivity control to obtain a satisfactory peak signal with the receiver aerials at right angles across the line.
- ☐ Direct connect the transmitter signal to a buried metal pipe and connect the ground lead to a ground point 2 or 3 paces away. Notice the change in transmitter response when the signal is being applied to the line.
- ☐ Cross the pipe with the receiver aerial at right angles to it and adjust sensitivity to keep the meter on scale over the line. Make a rapid pass over the line noting the meter rise and fall.

Repeat, but this time inching the receiver slowly across while observing the meter. Determine the speed of response that gives the most positive indication of line position.

Hold the receiver directly over the line and slowly rotate it as if it is a pivot. Keeping the meter on scale, note its reading when the aerial is parallel to the line and at right angles to the line.

- ☐ Usually positive and brisk receiver movement over the line gives the best and easiest contrast to determine the position and orientation of the line. The technique of using the receiver to get the best 'feel' from the signal on a line is a matter of personal preference and comes after familiarisation and practice.

- ☐ Disconnect the transmitter ground lead and reconnect to a ground point 25 paces away. Use the receiver to locate the line and notice any difference in response. Reduce transmitter power by half and then locate the line. Reduce transmitter power by another half and again locate. Determine what transmitter power gives the cleanest signal for the receiver to locate.
 - ☐ Work through the Trace, Pinpoint and Sweep and Search sections (4, 5 and 7) of this part of the book.
 - ☐ Become familiar with the use of the controls of the locator so that the instructions can be followed without difficulty.
- 3 Always be sure to take the elementary precautions:
- ☐ Test receiver and transmitter batteries before use. Replace when necessary.
 - ☐ Take spare batteries on each job. Replace batteries when necessary to maintain best locator performance.
 - ☐ Follow safety procedures in all respects, especially when switching on the transmitter.
 - ☐ Check that transmitter and receiver are switched to the same frequency.
 - ☐ Always switch off equipment after use.
 - ☐ Check that equipment is clean and dry after use.
- 4 Precision locators, receivers that incorporate two horizontal aerals and a vertical aerial are becoming standard equipment for all but the most simple locating tasks. Always use them in the horizontal aerial mode giving a peak response over a target. Only use the vertical aerial giving a null response when instructed.
- The null gives a sharp, easily recognised response in contrast to the wider peak response over a target, but the null mode is more subject to interference and error. Null gives an easily recognised response....but not necessarily over the target line.
- 5 Using a locator with success is not only a matter of following hard and fast rules. Parts 2 and 3 of this book show the wide variety of ways of using the transmitter/receiver combination. The most obvious procedure may not always provide the information and it will be necessary to use another procedure or procedures to get results.
- 6 Three different techniques; Trace, Pinpoint and Sweep and Search make up the procedure for locating buried utility pipes and cables. But first the transmitter must be used to apply an identifiable signal to the line and this is detailed in Section 3.

Applying the transmitter signal

The transmitter is used to apply an easily identified signal to a target line for it to be traced, identified and pinpointed using the receiver. A number of different application techniques are available for use in different site situations and the user must choose the technique that applies the best signal with minimum coupling. Field experience or the trial and error of working through the application techniques determines the best method of applying the transmitter signal.

1 Setting the transmitter controls

- If more than one frequency is available choose a frequency that is suitable for the job; high frequency for a high resistance line or a small telecom line; medium for power cables and continuous metal pipes or for applying the signal by induction; and a low frequency signal for long distance tracing with minimum coupling.

Check that receiver is switched to the same frequency as the transmitter.

- Successful location uses as low power a signal as possible. A high power signal couples to unwanted lines and spreads over the line. It is much easier to trace a low power clean signal along a line. Once the signal has been applied to the line, trace it for 20 paces and locate. Reduce signal strength if there is a needlessly strong response on the receiver. Experience will help determine the most suitable power setting for each locate.

2 Direct Connecting the transmitter signal *Advantages:* target



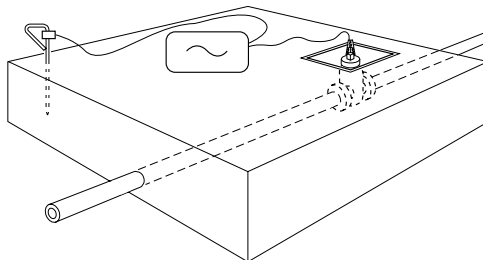
1.6.3



3.5

line is positively identified at application point. Suitable for use on tracer wires, metal water and gas pipe distribution systems, on a telecom pair or on a power cable sheath (only to be applied by qualified personnel) or to a pipeline at a suitable access point.

Disadvantages: None: however, sometimes difficult to apply to corroded valves or lines and cannot be applied to live conductors of an electrical cable.



Procedure: Plug the connection lead into the transmitter output socket and connect to the target line. If necessary, clean off paint, rust or scale to make a good electrical contact.

Clip the ground lead to an independent ground point 4 or 5 paces away from the transmitter and preferably at right angles to the probable route of the target line. Do not attach the ground lead to a water pipe or other buried line which would then carry the transmitter signal. Use the receiver passive mode to check that there are no lines buried between the ground point and the transmitter; they could pick up the signal and confuse the locate.

Switch on the transmitter only after the direct connection and ground connection have been established.

Change in loudspeaker tone or display indicates that a circuit has been completed from the transmitter along the target line and back through the ground return. Check change in tone or display by switching on the transmitter with clip connected and disconnected.

When there is no change in tone or display: check electrical contact to the target line and check ground contact. If necessary change position of ground point or pour water over ground contact in dry soil or sand.

A tone or display change on the transmitter indicates a good connection and that a strong signal has been applied to the target line. However, the receiver can often detect a signal on the target line over short distances which is not strong enough to make a change in transmitter tone or display.

3 Clamping the transmitter signal

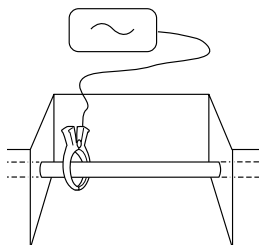
Clamping is a convenient method of applying the signal to a pipe or cable. The clamp is a standard or optional accessory with most locating sets.



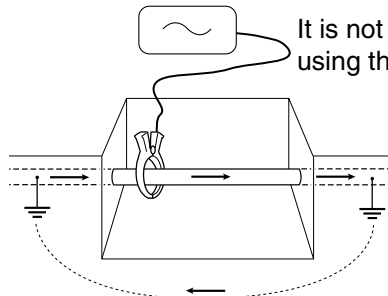
Advantages: the clamp safely applies a signal to a live cable without interrupting the supply. It applies a very discriminating signal to a target line with reduced coupling. It is very simple to apply.

Disadvantages: clamp signal may not travel as far as a connected signal. The target line needs to be grounded at each end.

Procedure: Plug the clamp to the transmitter output socket. Close the clamp around the pipe or cable, making sure the jaws are closed and switch on the transmitter.



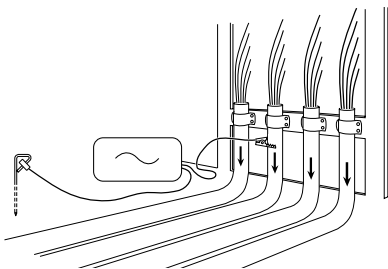
The clamp may buzz or vibrate if around a power cable with significant net current flow. This is normal and does not harm the equipment. Do not touch the exposed pins of the plug when the clamp is around a power cable.



It is not necessary to make a ground connection from the transmitter when using the clamp.

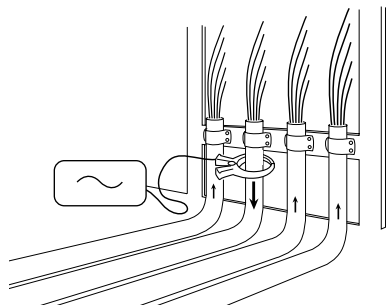
The line should be grounded on each side of the clamp for the signal to transfer to the line. It may be necessary to make a ground connection from the line.

An insulated cable may be traced even if it has no actual ground connection providing a reasonable length is buried either side of the clamp to provide enough capacitive coupling to ground to draw the signal.



The clamp can be a more selective method of applying the signal than direct connection in many situations because it works as if the line has been cut and the transmitter connected between the cut ends.

When direct connecting to mutually bonded lines, the signal will flow on whichever line presents the easiest path; not necessarily the one to which the clip is applied.

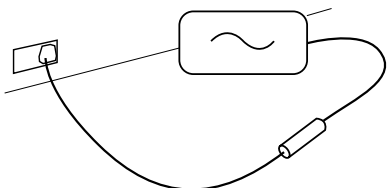


Using the signal clamp, the target line must carry the strongest signal - the other lines carry the weaker return signal.

Note that if the system comprises only two conductors they may carry equal signals.

4 Applying the transmitter signal with the plug connector

The plug connector is an optional accessory to apply the transmitter signal to a live domestic power socket through the domestic wiring system onto the service cable and the supply cable in the street. The signal should be detectable on the supply system a few hundred paces each side of the point of application.

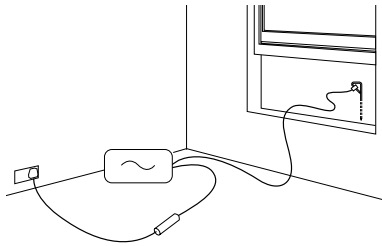


Advantages: applies a very selective signal to a power cable. The most certain method of locating a power distribution system in the street.

Disadvantages: entry to domestic or other premises is necessary to apply the plug connector.

Procedure: Insert the plug connector to the transmitter output socket and fit the plug to a domestic power socket. Switch on socket. Socket must be live for signal application.

The plug connector incorporates a protection unit which includes a filter, isolating transformer and fuse to protect the user and the transmitter from mains voltage up to 250V.



The signal is applied between the live and ground conductors on a 3-pin plug and between live and neutral on a 2-pin plug.

Connecting the ground lead to a remote ground point will increase tracing distance when a 2-pin plug connector is used.

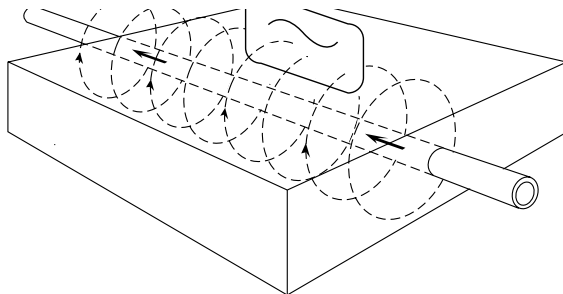
Using a 3-pin plug gives better result for maximum tracing distance and reduced coupling.

On two-wire Protective Multiple Earth (PME) systems, with no local domestic connection, the plug connector signal may not be detectable. Make a remote ground connection for locating these cables.

5 Induction

1.6.3

A transmitter includes an aerial that will induce a signal to a line directly below the transmitter. It's efficiency is poor on deep targets; induction is only useful at depths down to 2m/6ft.



Advantages: signal can be applied without access to the line. Very simple and quick.

Disadvantages: the signal can induce onto nearby lines as well as the target. Substantial part of the signal strength is lost in surrounding soil. Receiver cannot be used within a minimum of 10 paces from transmitter, and often much further if high power is being used from the transmitter. Induction should not be used to apply a signal to a line below a metal cover or reinforced concrete; the signal is intercepted by the metal shield and the reinforcing mesh.

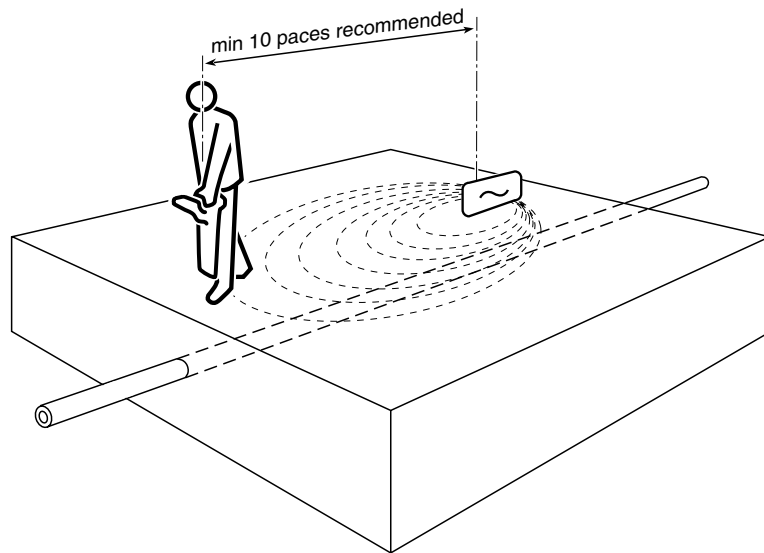
Induction will not apply a signal to a well insulated line unless the line is effectively grounded at each end.

Procedure: Switch on the transmitter and place it with the aerial directly above and in line with the buried pipe or cable.

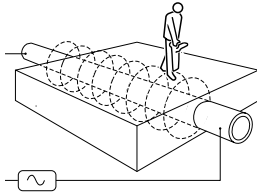
Turn down sensitivity of the receiver to minimum and start locating the line at least 10 paces distant from the transmitter.

Part 2 Section 3. Applying the transmitter signal

Precautions: The transmitter radiates a signal into the atmosphere as well as onto the line and the receiver may locate this signal rather than the signal radiated by the line. Check by moving the transmitter two paces to one side. If the line appears to move too it indicates that the receiver is too close to the transmitter. Another method is to point the receiver directly at the transmitter. If the response is the same or increases it indicates that the receiver is picking up airborne signals. In this case transmitter power should be reduced and receiver sensitivity reduced. It may be necessary to move the receiver as much as 25 or 30 paces from the transmitter.

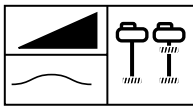


Trace



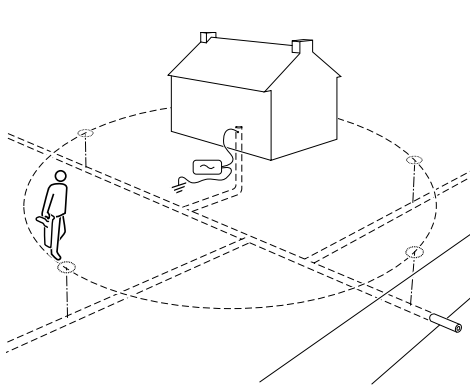
The receiver is used to trace a target line once a transmitter signal has been successfully applied to it. Passive signals present on a target line are almost certainly present on other nearby lines. A transmitter signal on the target line is necessary for reliable tracing.

1 Tracing



Precision receivers with peak and null response should always be switched to peak unless otherwise noted.

First, locate the line that is to be traced. Walk at least 6 paces from the transmitter if the signal is connected or clamped to the target line and at least 10 paces from the transmitter if it is inducing its signal to the line.

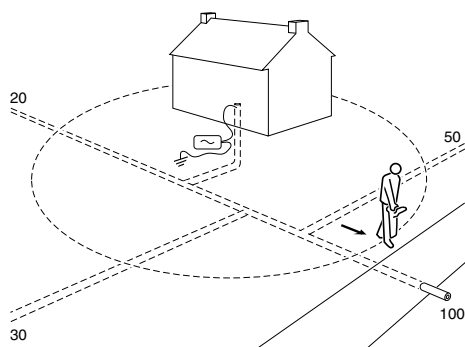


Hold the receiver at comfortable arm's length, turn sensitivity to maximum.

With the aerials on the antenna facing the transmitter, walk in an arc around the transmitter. Reduce sensitivity as necessary to keep the meter on scale.

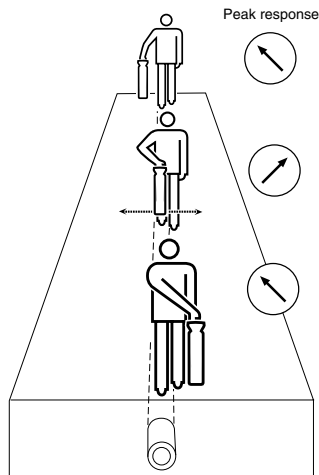
Stop at a point where the meter registers a peak response. Move the receiver from side to side to get a peak response to establish the exact position of the line. Place the end of the antenna on the ground, again adjusting the sensitivity control to keep the meter on scale.

Mark the spot and note the meter reading.



Still with the antenna aerials facing the transmitter, continue the arc round the transmitter without changing the sensitivity setting. Stop each time there is a response, determine the position of the line, mark it and note the meter reading.

If the receiver locates more than one signal, compare the meter reading of each signal. The strongest signal will almost certainly be the target line to which the transmitter signal has been applied.



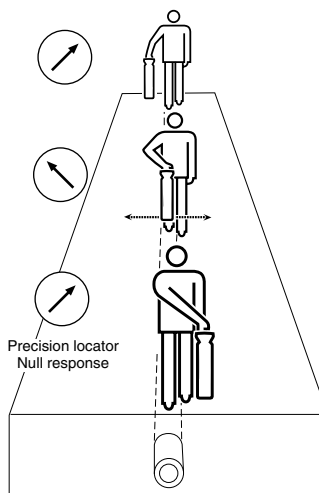
Hold the receiver over the target line. With the aerial at right angles over the line and holding the receiver comfortably, adjust the sensitivity to give a meter reading of between 50% and 90%.

Walk away from the transmitter moving the receiver firmly left and right with each pace. Peak response with a reduced response to each side indicates the position of the line. It should be possible to trace the line at a brisk walk.

Stop every 10 or 20 paces and carefully check the exact position of the peak response and then continue tracing.

Check an area several paces either side of the target line to be sure that there are no other lines carrying the transmitter signal.

2 Tracing with a Precision Locator



Line tracing can be speeded up by switching to the null response. The receiver can be held in any orientation as its null response is not dependent on line direction. Move the receiver left and right while walking along the path of the line to observe the null directly over the line and a peak response to each side of the line.

Periodically switch back to peak response to make a locate to verify the exact position of the target line.

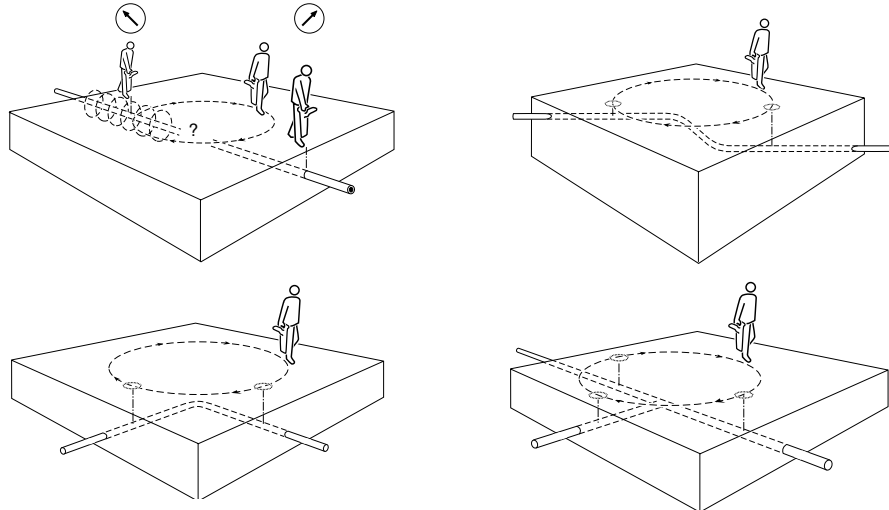
3 Tracing problems

3.1. Stop if there is a sharp drop in meter response. Re-trace to a position over the line at which meter response is lost. Turn up sensitivity and make an arc about 2 paces radius around the point where the response reduced.

Part 2 Section 4. Trace

The line may have become deeper. Increase sensitivity to see if it is possible to continue tracing.

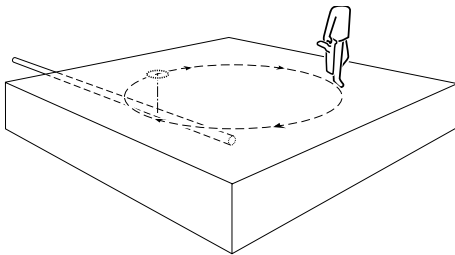
The line may have altered direction or there may be a tee. Check if more



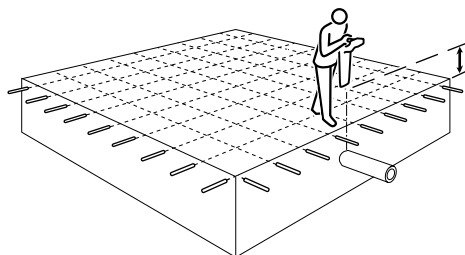
than one line with the signal leaves the arc. If there is more than one line measure the response from each line 4 or 5 paces away from the junction. It is probable that the higher response will be the main line, and a lower response on the tee. This is because the signal 'sees' a better ground return from the longer or larger line.

It may be advisable to trace both the line and the tee.

3.2. Complete loss of signal. The line may have ended or a metal pipe changed to plastic. The line may run under a metal cover in which case pick up the path of the line on the far side and continue tracing.

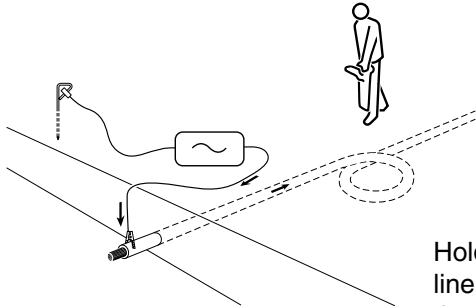


3.3. Gradual reduction of response to signal. Turn up the sensitivity and continue tracing. In time the line may run out of signal. If this is the case bring up the transmitter to apply a signal to the last point at which the line was positively identified.



3.4. Signal loses clarity and spreads over a wide area. The line may be passing under rebar which pick up and re-radiate the signal. Raise the receiver 0.5m/20in, reduce sensitivity to the minimum that still gives a response over the signal and continue tracing with the raised receiver.

3.5. A slack loop in a buried cable will sometimes cause a fall in response over the path of the cable which should be investigated.



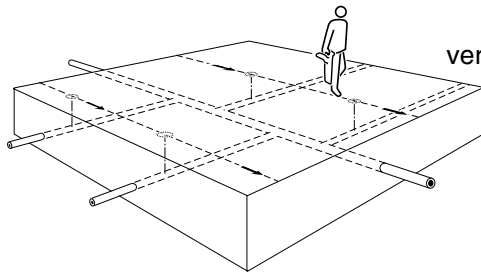
Hold the receiver with aerials parallel to the route of the line. Two peak responses, one after the other, confirm the presence of a loop.

4 Line identification

If it is necessary to verify the identity of a target line after tracing, place the transmitter and apply its signal at the opposite end of the line and trace the line back to the position of the original transmitter signal.

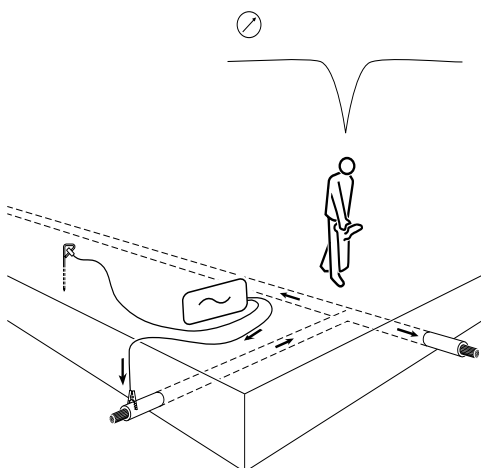
5 Locating tees

Once the path of a line has been traced and marked, and with the transmitter signal still applied carry the receiver along the line again, about one pace to the side and with the blade parallel to the line. No signal (or



very little) will be picked up from the main, but branch connections will show up with clear responses.

The most reliable method of pinpointing a tee is to apply the transmitter signal to the end of the drop or service. The signal will flow to the main and then along in each direction.

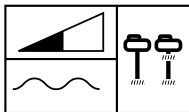


Tracing the signal back to the main with the blade at right angles over the service connection will result in a null over the tee.

Pinpoint

Pinpointing a target line defines the exact position of a target line after it has been traced and its position approximately known.

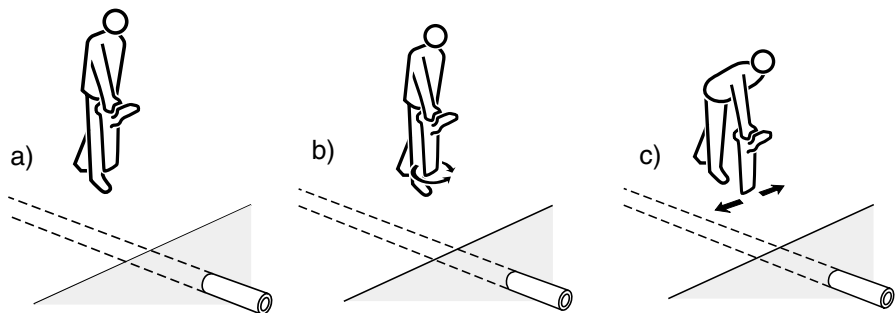
1 Procedure



Set the receiver sensitivity to half scale; it may be necessary to adjust the sensitivity level throughout pinpointing to keep the meter on scale.

- With the antenna aerial at right angles to the line, make traverses across the line. Define the point of maximum response.
- Without moving the receiver turn it round as if on a pivot. Stop at the point of maximum response.
- Hold the antenna vertical only just above the ground and move the receiver from side to side across the line. Stop at the point of maximum response.
- Still with the end of the antenna close to the ground repeat (b).
- Finally repeat (c). The target line lies directly below the antenna and runs at right angles to it.
- Mark the position and direction of the line.

Repeating the steps of this procedure increases pinpoint accuracy.



- ### 2 Pinpointing precautions
- If lines are close together, a part of the transmitter signal may have coupled and be present on a nearby line and affect the accuracy of the pinpoint. Check by increasing receiver sensitivity and move the receiver 3 paces to each side of the target line. No response other than a single peak response over the target line with symmetrical decay each side confirm the accuracy of the pinpoint.

If signal is present on another nearby line or if the response decay either side of the peak is asymmetrical, it will be necessary to pinpoint the target further along the line where interference is not present. If this is not possible it is almost certain that the position of the line indicated by the receiver is displaced toward the source of interference and an exact pinpoint is not possible.

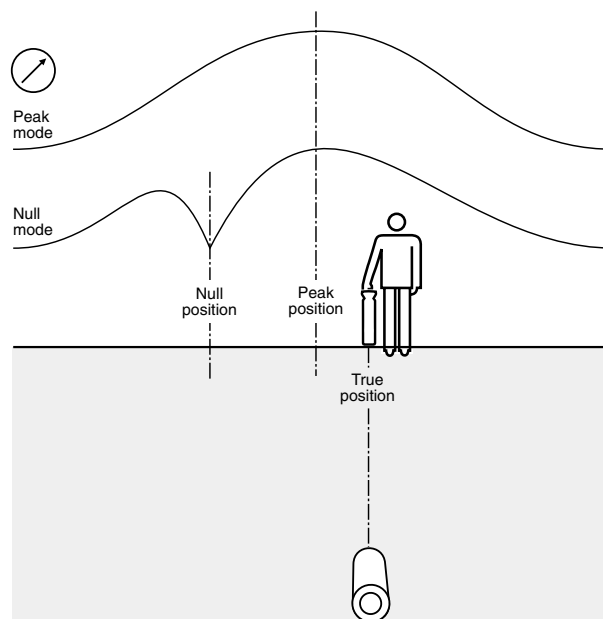
3 Pinpointing with a Precision Locator

Follow the procedure for pinpointing with a peak response and mark.

Switch to null response mode and move the receiver to find the position of the null response.

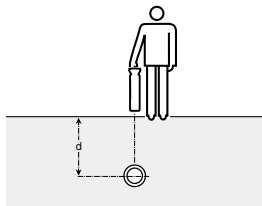
If the position of the peak and the null pinpoints correspond, it can be assumed that the pinpoint is precise.

The pinpoint is not precise if the marks do not correspond; both marks will show an error to the same side. True line position will be close to peak position.



An approximation of the position of the line can be made with the two-thirds plus one-third rule. The line lies half as far to the side of the peak position as the distance between the peak and the null positions.

Electronic depth measurement



Electronic depth measurement to a line is possible down to depths of 3m/10ft when the line has been energised with the transmitter signal.

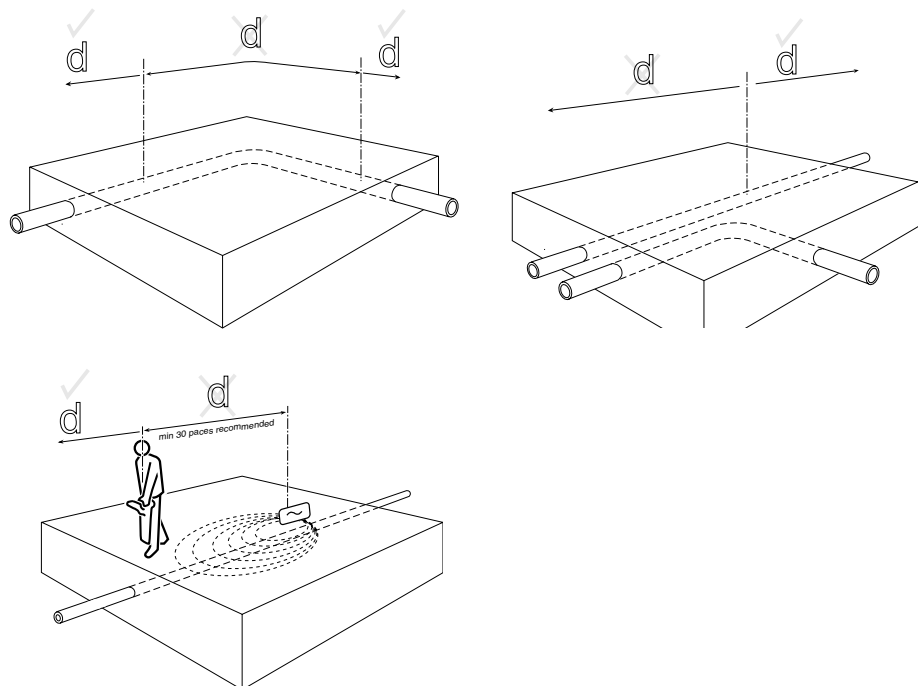
Passive signals on lines are not suitable for measuring depth because accuracy is questionable.

Measurement is to the center of the pipe or cable. Depth of cover is necessarily less than the reading, possibly critically on large diameter pipes.

1 Precautions:

Do not make depth measurements near bends or tees in the line. Go at least 5 paces from a bend for best accuracy.

Depth measurement will not be accurate if there is audible interference or if part of the transmitter signal has coupled to a nearby line.



Avoid applying the signal by induction. If there is no choice, the transmitter must be at least 30 paces from the point of any depth measurement.



Confirming the position a peak pinpoint with a null pinpoint indicates that the position is suitable for making a depth measurement.

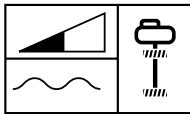
2 Procedure for electronic depth measurement

Pinpoint the target

line accurately with the receiver.



2.5.1



Check the receiver is directly over the line, the aerials at right angles to it and vertical. Adjust sensitivity level to bring the meter indication on scale. Press the depth measurement button and read the depth from the receiver display.

If the ground appears to radiate a strong field, perhaps near a radio station, check depth by holding the bottom of the antenna 5cm/2in above the ground and deduct this from indicated depth.

3 Verifying a depth measurement

A suspect or critical depth measurement can be checked by lifting the receiver 0.5m/18in above the ground and repeating the measurement. If the measured depth increases by the same amount it is a good indication that the depth measurement is correct.

Depth measurement should be accurate to 5% if conditions are suitable. However, the user may not always know if the conditions are suitable so the following techniques should be used to check critical readings:

- ☐ Check that the line's route is straight for at least five paces to either side of the measurement point.
- ☐ Check that the signal response is reasonably constant over the ten paces length and make depth measurements to either side of the original point.
- ☐ Check that there are no adjacent lines carrying a significant signal within three or four paces of the target line. This is the most common source of error of depth measurements; a strong signal coupled to an adjacent line can often introduce +/- 50% error.
- ☐ Make several depth measurements at points slightly displaced from the line's apparent position. The most shallow indication will be the most accurate and will also indicate the line's position most accurately.

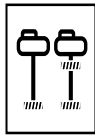
Sweep and search

There are a number of techniques available for locating unknown lines in an area. Use of these techniques are particularly important before digging in order to avoid damage to buried lines.

1 Passive Sweep

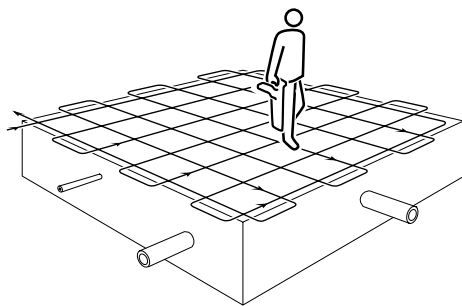


1.6.4



Most locators have a 'passive' locate mode. Some more sophisticated locators have a passive, 'radio' search mode to detect lines reradiating VLF radio energy as well as the more conventional 'power' search mode to detect 50/60Hz energy on buried power cables and other nearby lines.

Switch to Power mode.



Adjust sensitivity to maximum; reduce to keep meter on scale when there is a response.

Traverse the area in a grid search, at a steady walk holding the receiver comfortably with the aerial in line with the direction of movement and at right angles to any lines that may be crossed.

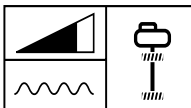
Stop when the receiver response rises to indicate the presence of a line. Pinpoint the line and mark its position. Trace the line out of the area being searched. Resume grid search in the area.

In some areas there may be a confusing amount of 50/60Hz power signals. Lift the receiver 5cm/2in from the ground and continue the sweep.

Switch the receiver to 'Radio' if the locator has a Radio detect mode. Increase sensitivity to maximum and repeat the above grid search procedure over the area, pinpointing, marking and tracing out any lines that are located.

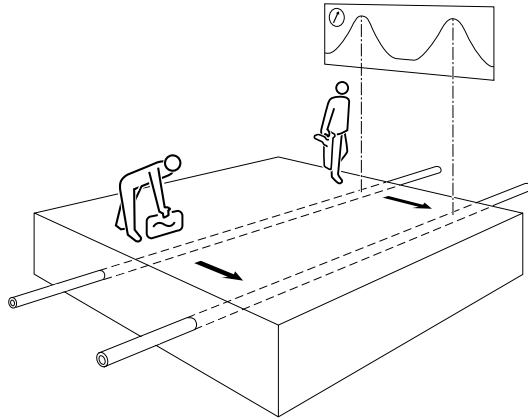
In most, but not all areas, the Radio mode will locate lines that do not radiate Power signals and a grid search should be made in both the Power and the Radio modes.

2 Active search



An inductive search procedure is the most certain technique for locating unknown lines. Unlike the sweep it requires the use of the transmitter and two people.

Define the area of search and the probable direction of lines crossing the area.



The first person holds the transmitter and the other the receiver. The transmitter induces a signal onto lines as it passes over them and the lines are then detected with the receiver 20 paces upstream or downstream.

The second holds the receiver at the start of the area and with the aerials at right angles to the probable direction of the buried lines. Set receiver sensitivity level as high as possible without picking up any airborne signal directly from the transmitter.

The second operator is 20 paces or so either upstream or downstream along the probable path of the lines and holds the transmitter with its length aligned with the assumed direction of any lines.

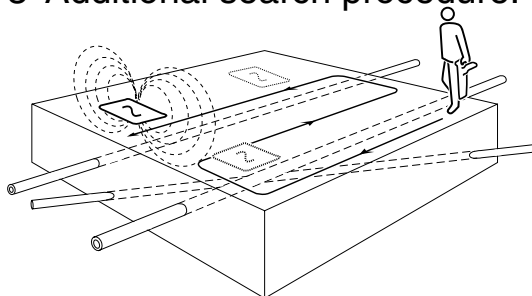
When the transmitter is in line with the receiver, both operators start to move slowly forward in parallel. The operator with the receiver also moves it backwards and forwards as he proceeds in parallel with the transmitter.

The transmitter applies its signal to lines directly below, which are then located with the receiver.

Mark the ground at the point of each peak signal detected with the receiver. Repeat the search along any other possible paths of lines.

Once the positions of any lines have been marked, reverse positions and place the transmitter over and along each in turn and trace each out of the area being searched.

3 Additional search procedure:



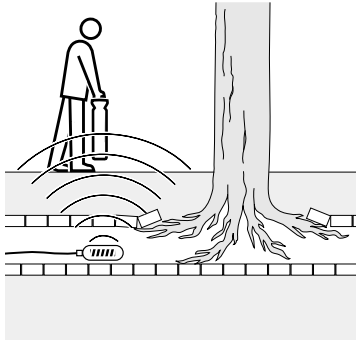
A technique that is not as thorough as the previous procedure and should only be used if one person is available or if there is not sufficient space for the previous search procedure.

Lay the transmitter on its side. The transmitter signal will energise all the lines to either side but not the lines running directly below the transmitter.

Sweep the area with the receiver at least 10 paces around the transmitter. Pinpoint and mark any lines that are located.

Reposition the transmitter at 5 pace intervals around the site, sweeping the area each time with the receiver 10 paces from the transmitter. Stop when there is a response. Pinpoint and mark any lines. Trace the lines out of the area.

Locating sondes: tracing non metallic ducts, drains and sewers



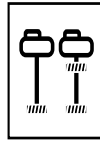
A transmitting sonda is a small waterproof self-contained transmitter radiating a signal that is located by the receiver.

Sondes enable non-metallic ducts, drains or sewers to be located and traced with the receiver.

The technique for locating a sonda is the same, regardless of the type of duct or drain, provided there is access for inserting the sonda and a means of propelling it. The sonda signal cannot be located under metal covers or plates.

1 Choosing a suitable sonda

Locator manufacturers usually offer a range of sondes. The larger the size of the sonda, the greater the possible depth of location.



Check that the sonda has sufficient depth range for the application and is dimensionally small enough to fit in and go round the bends in the duct or drain.

Check that the frequency of the sonda corresponds with the receiver frequency; the receiver will not locate the sonda unless the frequency is the same. Sondes are usually marked with their transmitting frequency.

Ensure that the means for propelling the sonda are available together with the correct fittings or couplings.

2 Propelling the sonda

A variety of different means are available for propelling the sonda. Adaptors are available for screwing the sonda to the end of a set of drain rods or a flexible nylon rod.

It is usually advisable to fit a spring coupling between the end of the rod and the sonda to avoid damaging the sonda in bends in the drain.

The sonda can be strapped with clips to the hose behind the head of a high pressure cleaning jet.

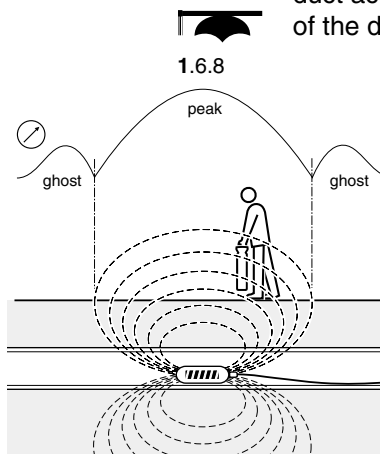
It can also be floated along a sewer at the end of a tether.

Very small sonda systems for tracing small size drains down to depths of 0.8m/30in usually have the transmitting aerial incorporated in the head of a flexible rod with the electronics and batteries attached to the rod reel on the surface. The rod can usually be fed into the pipe at a gully or trap.

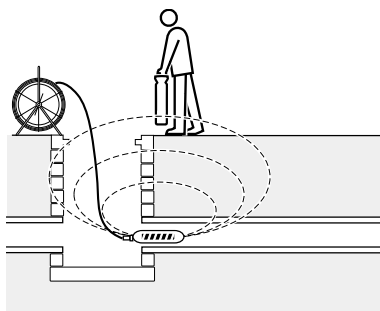
- 3 Before inserting the sonde** Insert a new battery in the sonde. A new battery or a freshly recharged battery should be used at the beginning of each day and preferably at the start of each new job.

Check that the sonde and receiver are the same frequency and working correctly. Position the sonde on the ground at a distance equal to its rated depth range from the receiver. Point the receiver at the sonde with the aerial in line with the sonde (the opposite of using the receiver to locate a line) and check that the meter reading exceeds 50% at maximum sensitivity.

- 4 Setting receiver sensitivity level** Insert the sonde in the drain or duct access point and locate it while it is still just in view at the entrance of the drain or duct.



Hold the receiver vertical directly over the sonde with the aerial in line with the sonde. Adjust the receiver sensitivity so the meter reads between 60% and 80%. The sonde radiates a peak field from the centre of its axis with a ghost signal at each end of the peak. Move the receiver a little way behind and then in front of the axis of the sonde to detect the ghost signals. Finding the two ghost signals positively confirms the locate. Reduce the receiver sensitivity to lose the ghost signals but still indicate a clear peak response directly over the sonde. Receiver sensitivity is now set for tracing the duct or drain unless the distance between sonde and receiver changes.



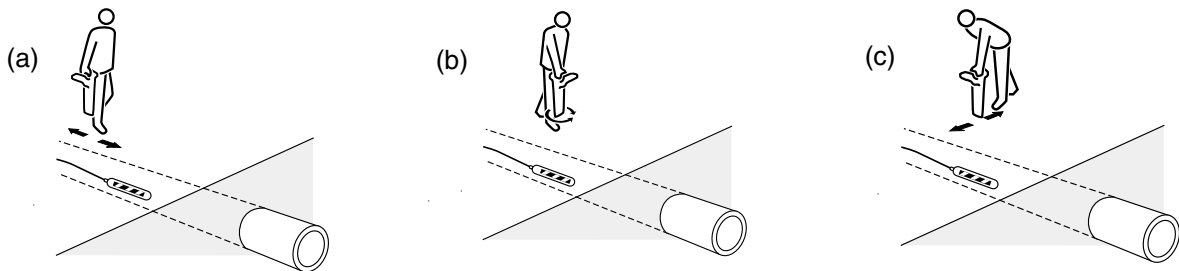
5 Locating and tracing Propel the sonde three paces along the drain or duct and stop. Place the receiver over the supposed position of the sonde. Do not adjust sensitivity level.

(a) move the receiver backwards and forwards with the blade in line with sonde and stop when the meter indicates a peak.

(b) rotate the receiver as if the blade is a pivot. Stop when the meter indicates a peak.

(c) move the receiver from side to side until the meter indicates a peak.

(d) repeat (a), (b) and (c) procedure with the antenna vertical and resting on or just above the ground. The receiver should then be directly above the sonde with the aerial in line with it; mark the position of the sonde and its direction.



Propel the sonde a further three or four paces and pinpoint and mark. Repeat this pinpoint procedure at similar intervals along the line of the drain or duct.

6 Measuring depth to a sonde Calibration for electronic depth measurement to a sonde is different to the calibration needed to give a depth measurement to a line. Check that the receiver can be switched to a suitable scale before attempting to make an electronic pushbutton depth measurement.

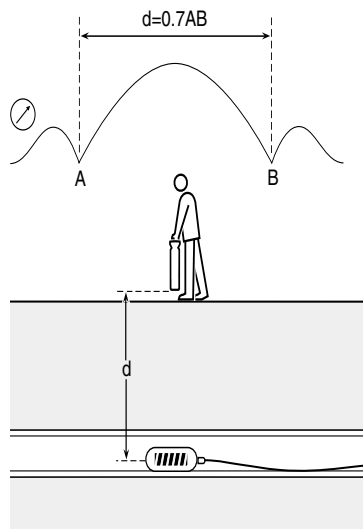


- ☐ Electronic depth measurement. Pinpoint the sonde following procedure (a) thru (d) detailed in the previous paragraph. Adjust sensitivity to bring meter indication on scale. Switch the receiver to sonde depth indication. Depress the depth measurement button and read the depth on the display.

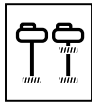


- ☐ Calculation method to measure sonde depth. Pinpoint the sonde. Move the receiver in front of the sonde and still with the aerial in line with it, increasing sensitivity to find the peak of the ghost signal.

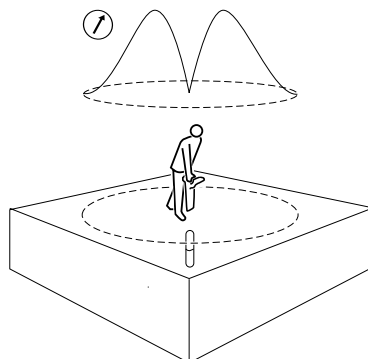
Move the receiver to behind the sonde always with the blade in line with the sonde. Then find the null positions A and B. Measure the distance between them and multiply by 0.7 to give an approximate depth measurement.



7 Special techniques for locating deep sondes The axial position of a sonde is easier to locate more accurately than its lateral position and it may be possible to position the sonde across the sewer as well as in line along the sewer. This technique is generally used in walk-through sewers or culverts. First, the sonde is located in its lengthways position, then turned 90 degrees to be across the sewer route.



Another method is to position the sonde vertically. The locator on the surface will pick up a pool of signal with a null point in the centre, directly over the sonde. This is a very accurate method, but depends on the sonde being absolutely vertical.



Locating lost metal covers

Finding covers lost under new black top or grass verges is a frequent locating requirement. Generally electromagnetic pipe and cable locators are not fitted with an aerial suitable for locating covers unless an additional aerial and circuitry has been fitted in the receiver or transmitter. A dedicated metal cover locator is almost always required.

1 Cover locator types

Cover locators are simple to use and are calibrated by the manufacturer to ignore small metal trash, such as bottle tops, near the surface.

Cover locators transmit a continuous magnetic field and respond to variations or differentials in the field below the aerial.

There are two main types of cover locator: a simple unit with a horizontal aerial which typically locates 10cm/4in iron valve box covers at depths down to 30cm/12in and a 60cm/24in square iron cover down to a depth of 75cm/30in.

A cover locator with a vertical aerial locates covers 25-30% deeper and has the advantage of defining the outline of the lost cover so that rectangular or circular or square covers can be distinguished and identified.

2 Sweeping to find lost covers

Finding lost covers requires sweeping the area with the locator. Locating is speeded up if there is information to indicate the approximate position of the cover so that search can be focused over that area.

An approximate position of covers is indicated by a loss of signal and response when tracing a line or locating a sonde. Suspect areas should be marked and then swept with a cover locator to define the position of the cover. Tracing a known line to a cover helps establish the identity of the cover.

Always sweep an area following a grid pattern. Spacing of the grid should be tight when searching for a small cover and looser when looking for a big cover.

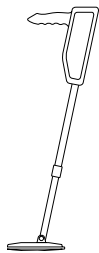
3 Locating lost covers

Find an exposed cover similar to the one to be located. Hold the receiver directly over the cover at a height approximating to the distance of the probable depth of the lost cover. Set the sensitivity at a level that gives

a clear response defining the position of the cover. Reset the sensitivity if the locator has auto sensitivity control and be sure of obtaining a clear response from the visible cover.

4 Locating with a horizontal aerial locator

A horizontal aerial locator can easily be identified by the flat aerial about ø20cm/8in at the end of the antenna.

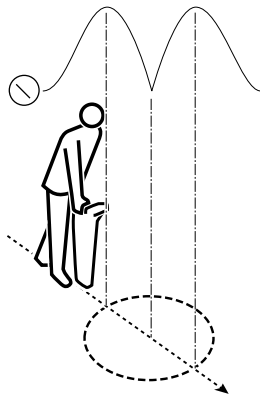


This type of locator usually has auto sensitivity adjustment and it is only necessary to sweep the suspect area with the aerial close above the ground.

If the locator has manual sensitivity control it should not be adjusted unless there is a possibility that the lost cover is deeper than the exposed cover used to set the sensitivity level. A locator with auto sensitivity control may need re-setting to align sensitivity to the environment.

5 Locating with a vertical aerial cover locator

Most manufacturers recommend a procedure for setting up sensitivity level. This procedure should be verified by obtaining a suitable response over an exposed cover.



Sweep the suspect area in an orderly grid pattern.

Stop when the locator gives a response over a lost cover.

Peak responses occur at the edges of a cover and a null response occurs at the centre. Reduce sensitivity to obtain narrow, sharp peak responses over the two edges of the cover as the locator is moved backwards and forwards along the same axis.

Approach the target from different directions, defining the peak-null-peak. Always cross the target area in a straight line and do not change direction while traversing the area.

Mark the edges of the cover with each pass over it.

Depth of the lost cover can be estimated by comparing the locator's response at the buried cover with a response over a similar cover that is visible. Adjust sensitivity until the buried cover can only just be found.

Without altering sensitivity level use the locator over a similarly sized visible cover and lift the receiver to achieve the same response. The height of the locator above the visible cover will be approximately equal to the depth of the buried cover.

7 Interference

Locating range is reduced when a metal cover locator is used close to a metal fence or a parked auto.

Locating buried markers

Markers are used to indicate the position of buried plant; particularly features such as a valve box, cable splice box or a tee and have been in use since utility plant first started to be buried. Traditionally these markers have been aluminium, iron or plastic plates fastened to a wall or a concrete stand. They provide information about the identity of the buried plant, its distance from the marker and its depth.

Over the years these visible marker plates have been found to be unsatisfactory. They are often defaced by vandals, destroyed by careless auto drivers, commonly damaged by mowing, hedge trimming or care of the verges, and often lost under vegetation.

As a result different types of buried markers have been developed.

1 Applications for Buried Markers Buried markers may be used wherever the precise position of a specific piece of plant needs to be known at the surface. Buried markers are commonly used to indicate the position of service drops, splices, duct stubs, valve boxes, anodes and plastic pipe tees.

In each case the approximate location of the feature is known and marked on relevant maps or drawings and the search to locate the marker is confined to a relatively small area.

Markers may also be used for marking the route of a plastic pipe or fiber cable. This is not a suitable application because the locator user has to make a time consuming search to find each marker and there is the often mistaken assumption that the route of the line between the markers is straight. Burying tracer wires with the pipe or cable and using standard tracing and locating procedures is the preferable method for finding the position and tracing the route of any non metallic pipe or cable.

2 Types of Buried Markers

- ☐ Permanent Magnet Markers
- ☐ Induction Coil Type Markers

3 Permanent magnet markers Permanent magnets are simple and low cost markers. They can be located by searching with a standard Magnetometer, typically used for locating buried property markers.

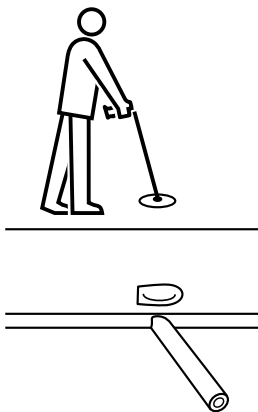
A stack of up to eight permanent magnets are used for marking features to a depth down to 1.5m/5ft. The magnets must be buried in the correct orientation with the stack vertical over the feature they are marking. Plastic holders are available for housing the magnet stack and protecting it from soil chemical attack.

Some manufacturers of plastic tees incorporate a slot in the moulding to accept a magnet stack.

The magnetometer is used to search for the marker over the area following a tight grid pattern. There is an audio or audio/visual response when the magnetometer is over the marker. The marker position can be precisely defined by reducing magnetometer sensitivity to a just distinguishable minimum.

The effectiveness of a magnetometer is reduced when it is used close to a metal feature, parked auto or other metal mass.

4 Induction Coil Type Markers A tuned coil marker in a sealed protective envelope is buried over the feature to be marked and is then located by being energised by a Marker Locator with a similarly tuned coil on its antenna.



A variety of markers are available with coil diameter corresponding to maximum location depth. A $\varnothing 375\text{mm}/15\text{in}$ marker can be located down 2.4m/8ft and a 200mm/4in marker can be located down to 1.2m/4ft.

A range of specially tuned markers and Marker Locators is available for marking the different types of utility feature. The markers are usually supplied in an appropriately coloured protective envelope: red for power, blue for water etc.

The markers have to be laid flat or horizontal in the trench so that the coil position exactly corresponds to the search coil of the Marker Locator on the surface.

One supplier floats the smaller marker coils in a spherical container. The marker can be dropped in the trench and the coil always remains in the correct orientation for location.

Part 2 Section 10. Locating buried markers

The markers are located by searching the area with a Marker Locator. The locator gives a sharp audio and visual indication when it is directly above a similarly tuned marker.

The Marker Locator is an instrument dedicated to locating the marker to which it is tuned. A locator tuned to find a red power line marker does not register over a blue water pipe marker.

Induction coil markers are an effective way of locating and identifying a feature of buried plant.

Conventional electromagnetic type locators cannot be used to locate induction coil type markers and these markers are not suitable for use to warn third parties of the presence of buried plant. Their primary use is to indicate the position of a feature to the owner of the buried plant.

Marking the line

Locating the line is the first step to providing information about its position to others who need to make use of the information. It is necessary to communicate the information in such a way that it cannot be misunderstood.

- 1 Assembling marking materials before setting out on the locate is as important as ensuring the locating set is complete and in working order.
- 2 Decisions must be made in advance about marking; marks to indicate the position and identity of the target line and other marks to indicate the presence and position of other nearby cables must be agreed with everyone needing to make use of the information. Arrows, crosses, dashes or different color marks are all valid but they have to be known and agreed before locating. Marks for tees and other buried features should also be agreed.

It is necessary to have an adequate supply of color coded pegs if the survey or the locate is going to be in the countryside or on grass verges.

- 3 The line must be marked after each pinpoint or locate. Marking it retrospectively can lead to error or confusion in an area congested with different pipes and cables.

Marking each locate as it is made makes it possible to look back over the route of the line to check that it appears logical. Any locate in an improbable or illogical position along the route can be investigated. The reasons for any mistaken locate should be investigated so that faulty procedure is not repeated.

- 4 Any uncertainty about the accuracy of the position of a locate or pinpoint must be highlighted so that further investigation, location by a specialist or trial holes can be undertaken.
- 5 Do not mark maps or drawings with locate positions without first marking the ground.

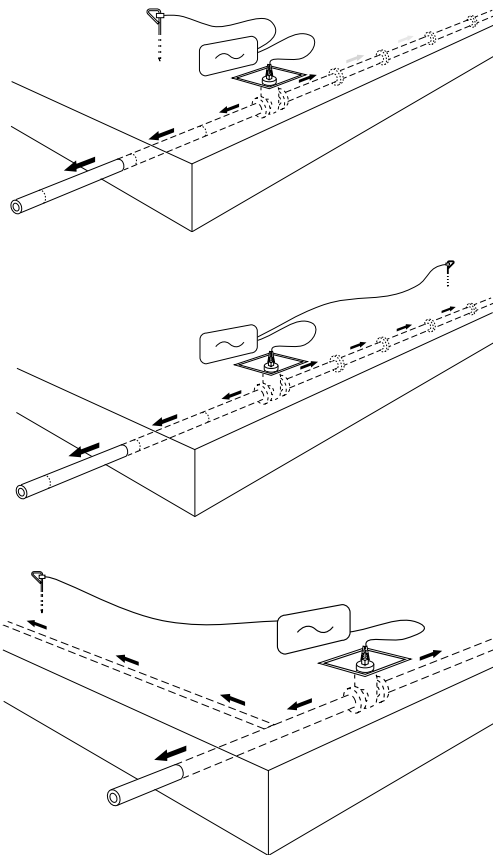
Each organisation has its own procedures for marking up drawings and maps. These procedures should be followed in a way that is clear and not open to misinterpretation. Any uncertainty about the accuracy of locates, depth or line identity must be shown clearly on all paperwork.

Part 3. Successful locating: additional locating and tracing techniques

There are a number of techniques for obtaining information about buried cables in addition to those described in Part 2. There are also a number of additional ways of applying the transmitter signal that are useful in difficult locate situations.

Part 3 Section 1. Direct connection

Direct connection: overcoming problems

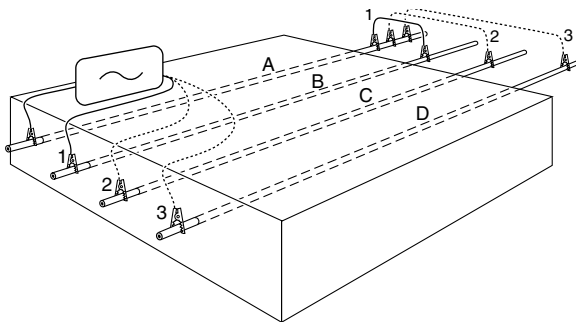


1 Sometimes when making a single ended connection to a service, the majority of signal does not travel along the section to be located, but in the opposite direction. The cause could be mechanical joints on the leg to be located and welded joints in the opposite direction. If the mechanical joints offer some electrical resistance, the signal takes the easiest path along the welded section.

The situation can often be improved by moving the ground return to a position which encourages the signal to flow in the desired direction. This usually means positioning the ground stake in the general direction of the section to be located. Normally this is achieved using the standard ground return lead, but in a more difficult situation it may be necessary to position the ground stake 200 paces away in the approximate vicinity of the conductor and as far as possible from the transmitter.

This technique can be used to encourage the signal to take a required path from a tee or junction. The double ended connection would be used in preference when possible.

2 When using a single ended connection ground return signals can often cause confusion by returning to the transmitter along other lines. The problem sometimes occurs when return signals appear stronger than on the target line usually because the target line is deeper than the line carrying the return signal or the return path may be a better electrical conductor than the target line.



An adjacent parallel line can be used to advantage - especially for long distance location. By making one transmitter connection to the target line, the other connection to an adjacent line, and bonding the two lines together at a distant point - effectively a double ended connection - the signal will travel along the target line and back down the adjacent line, giving two definite locations. The use of visual clues and depth

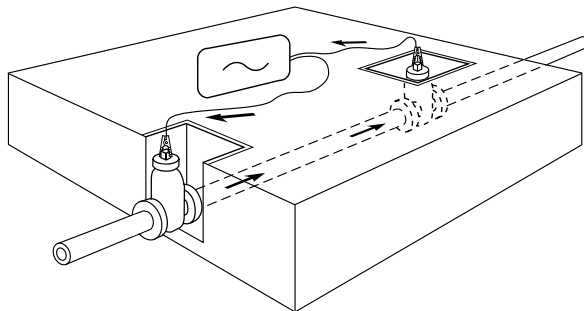
measurements should enable the user to identify the two lines.



3.7 & 8

The problem of identifying a target line can best be solved by using a locator with modes to measure current and recognize current direction.

Where there are many parallel lines the task of identification becomes easier because by systematically using other lines as return paths, the location position over the target line remains constant. The target line can be identified by a process of elimination .



3 Applying a double ended transmitter connection is a useful technique for positively tracing and identifying a target line in a situation such as a heavily congested industrial site, provided there are access points at each end of the line.

Connect the transmitter to an access point on the target line. The transmitter ground is connected with a long cable to another access point further along the line. A complete circuit is achieved without using ground as a current return path. The long cable should be kept as far away as possible from the expected route of the line.

This method of applying the transmitter signal is ideal for positive identification of a target line. When a connection has been made to two points on the same line, the same level of current should be detectable all round the circuit. The receiver display should remain constant if the depth of the line does not change.

Transmitter controls

1 *Impedance matching.* All but very low power transmitters have an impedance match facility to make the most efficient use of the available power. Where possible use a low impedance setting to conserve power. Increase impedance setting if more signal is required to trace the line.

Some transmitter types incorporate an automatic impedance match feature.

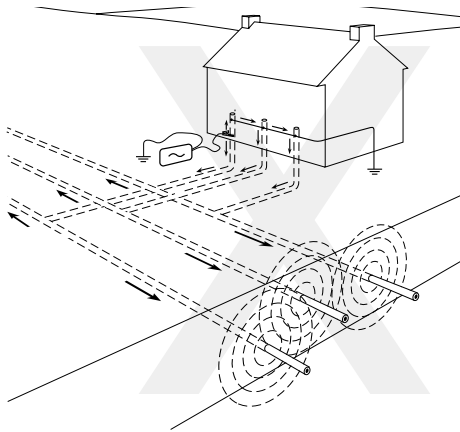
2 *Frequency choice.* It is often difficult to determine the most suitable frequency to apply in a particular situation. A recommendation is made with each drawing of an application. Past experience and trial and error are the only ways of determining if the recommendation is the most suitable for a particular locate.

Top of the range transmitters usually include the ability to apply two or more signals of different frequency to a line at the same time. It is then possible to use the receiver to make locates on the line at each frequency in turn. It should be evident which frequency is the most suitable for locating the target line.

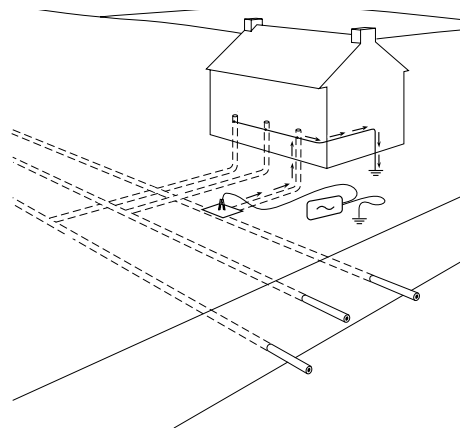
The transmitter must then be switched out of its multi-frequency mode to the chosen frequency to get the benefit of full power.

Unwanted signal coupling

Unwanted coupling of the signal from the target line to another nearby line is one of the commonest location problems. It leads either to an error in the marked position and depth of the target line or to marking the wrong line. A certain degree of coupling is unavoidable in many situations but there are ways in which a careful user can reduce coupling and increase location reliability.



- ☐ Avoid applying the signal by induction. The signal may be coupling to more than one line directly from the transmitter. Use the signal clamp where possible.
- ☐ Identify points where lines may be bonded or in close proximity. Work toward these points rather than away from them. For example if gas and water are bonded within a building, apply the signal at the valves or access points in the road rather than in the building.
- ☐ Reduce coupling to a parallel line by using a low signal frequency where available.
- ☐ Return signal flowing on another line. Use a double-ended connection to by-pass the ground return if possible.

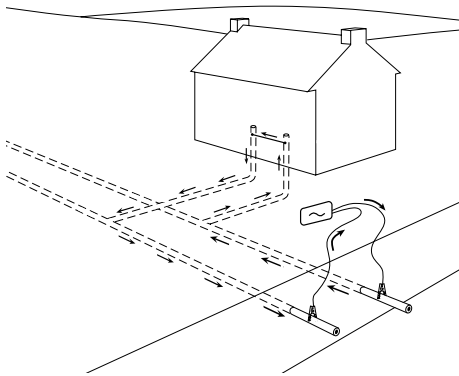


- ☐ Choose a signal application point where the line is furthest from other lines; not a congested area.
- ☐ When using single-ended connection, site the ground stake as far from the target line as possible and away from other buried lines.
- ☐ Avoid using existing structures for ground connections; other buried lines may be bonded to them.
- ☐ A bad ground connection or just laying the ground lead on the surface at right angles to the line may result in less coupling than a good ground provided long distance tracing is not required

Applying the transmitter signal for maximum tracing distance



Several factors influence the distance that a line can be traced. The aim of any current flowing on the line is to get off the line and return to the transmitter ground. This results in the familiar gradual decay of the signal strength with increasing distance from the transmitter. It is therefore necessary to apply the signal in the most effective manner.



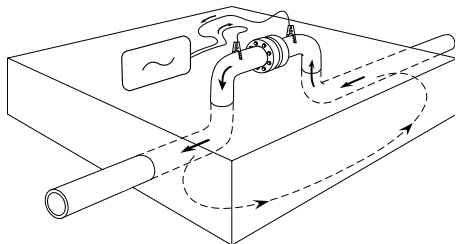
1 Double ended connection where the transmitter cables are connected to both ends of a line is an effective way of applying a signal because the ground is effectively bypassed.

The other advantage of double-ended connection is that the signal is being applied to what amounts to a short-circuit so that the transmitter output is at maximum.

Sometimes an effective double-ended connection can be achieved over very long distances by applying the two transmitter leads to two converging lines. For example, if two lines, say water and gas, follow roughly parallel paths to a distant building where it is known they will have a common bond.

A connection to both lines should insure a strong signal over a long distance. Caution must be taken when tracing to avoid confusing the two lines.

2 Improving the quality of the ground connection can increase the applied current and therefore the tracing range. The ground quality can be improved by careful positioning of the ground stake in damp soil, by hammering a long copper rod into the ground or by connecting to an existing metallic earthed structure, provided no other pipes or cables are bonded to it.



3 The best possible ground connection in any given situation will be the line itself. The only situation when it can be used is where the line has an insulated section effectively splitting it into two conductors. For example a long distance pipeline which has an insulation flange; applying the transmitter clips to either side of the joint will apply the best possible signal.

Part 3 Section 4. Applying the transmitter signal

4 A single-ended connection signal will apply current in both directions of a line if connected to the middle rather than one end. The signal can be doubled if it is possible to disconnect the line in the unwanted direction.

5 Induction should be avoided. It is an inefficient signal application technique because most of the transmitter energy is wasted in the ground.

Applying the transmitter signal to a live power cable



Check that the transmitter and the user are protected against voltages of 500V AC RMS up to 60Hz before using a live cable connector on low voltage systems. Observe safety procedures and regulations.

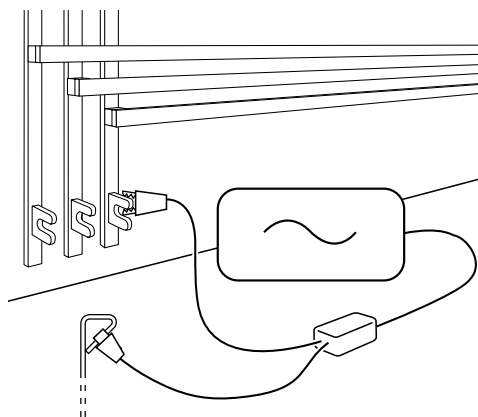
The live cable connector is an optional accessory to apply the transmitter signal to a live cable. It is for use only by personnel licensed or permitted to work on live cables.

The live cable connector is plugged into the transmitter. The red clip is connected to the live conductor and black clip connected to neutral or ground as appropriate. The transmitter indicates by change in tone or on the display when a satisfactory connection has been made.

Positive cable tracing and identification in a domestic house: connect the red clip to a terminal box connection. Remove fuse if necessary. Connect the black clip to an independent ground point outside.

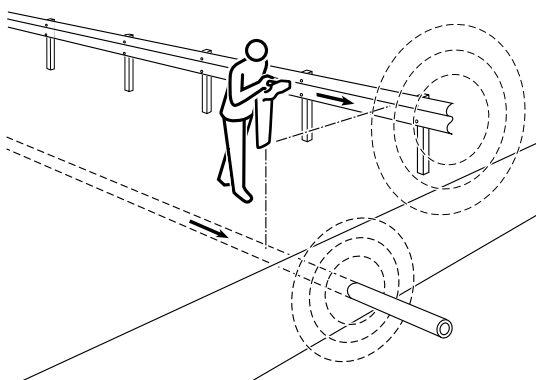
Street light cable tracing: connect red clip to the incoming live cable. Connect black clip to the lighting column if metal or to an independent ground point.

The live cable connector can be used in a similar way to apply a signal directly to cables through live LV isolators, fuse boxes etc in industrial sites.



Accurate locating along a motorway or turnpike

Many main roads have metal crash barriers or guard rails with buried lines laid below. Accurate location is often a problem because the guard rail radiates a stronger signal than the target line; the return current which normally flows back through ground flows along the guard rail with its lower resistance. The proximity of the energised guard rail to the locator often causes serious mislocates.



A single horizontal aerial receiver needs to be lifted directly above the line so that the aerial is at the same height as the guard rail.

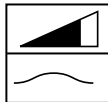


A twin aerial receiver may need lifting higher to null out the coupling from the guard rail. Suitable height can only be established by trial; try losing the signal from the guard rail by experimenting on its far side away from the line.

Measuring current on a target line



1.7.4



Measuring current value on a line helps confirm the identity of the line and provides information about the condition of cable insulation or pipe coating.

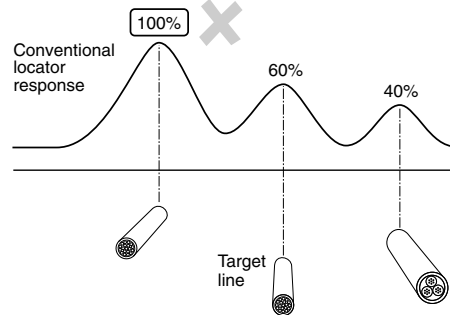
Current Measurement feature is included as standard on some types of locators and is an option on others.

RD432PDL
receiver
response

13 mA

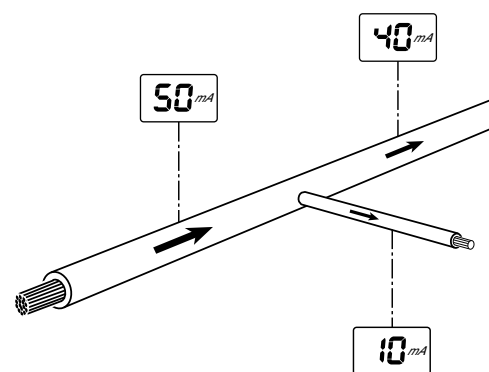
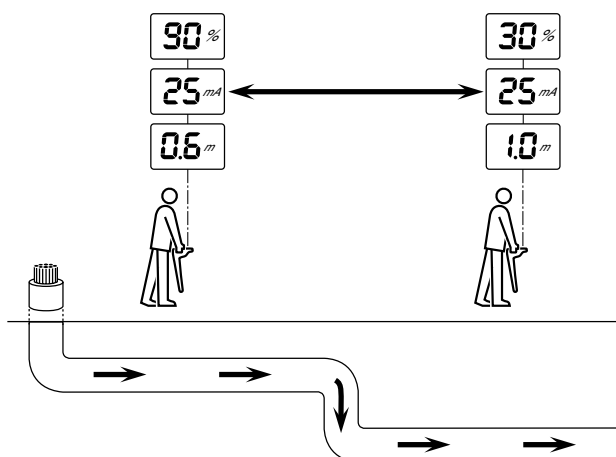
27 mA

19 mA

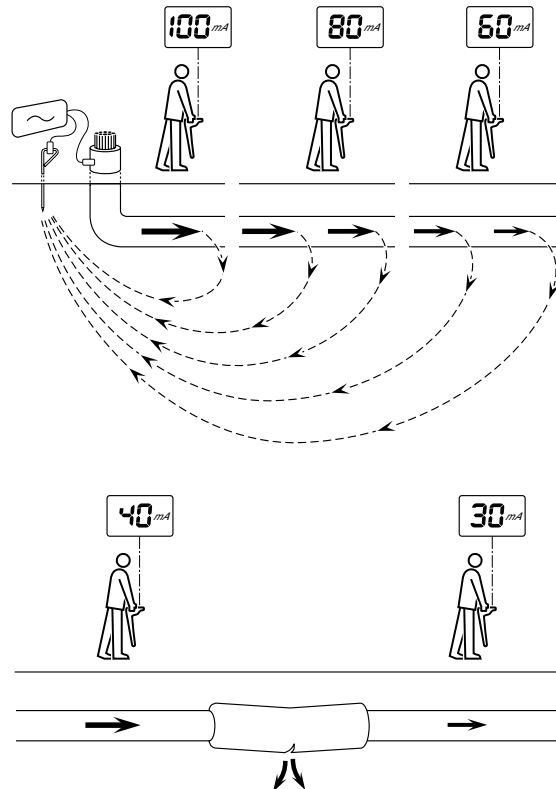


Measuring current on a target line helps to confirm the identity of the line. In congested areas a locator may sometimes detect a stronger signal from an adjacent line to which the signal has coupled because it is nearer the surface. The line with the highest current measurement rather than the line giving the strongest response is the target line to which the transmitter signal has been applied.

Measuring current provides useful information about the position of tees. Measuring current after a tee will indicate the main line which pulls more current along its greater length.



2 The principle



The transmitter applies a signal or current onto a target line and this current reduces in strength as the distance from the transmitter increases. This rate of reduction or attenuation depends on the type of line and on soil conditions. Regardless of the type of line, the rate of attenuation should be regular with no sudden drops or changes. Any sudden or abrupt current change indicates that the line or its condition has changed.

3 Applying the transmitter signal

The transmitter signal can be connected, clamped or induced to the target line in the same ways as applying the signal for line tracing.

4 Measuring current

Pinpoint the line and confirm the accuracy of the peak pinpoint with a null pinpoint. Check the receiver is directly over the line, the aerials at right angles to it and vertical.



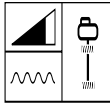
2.5.3

Switch the receiver to its Current Measurement Mode and a value in mA will be displayed.

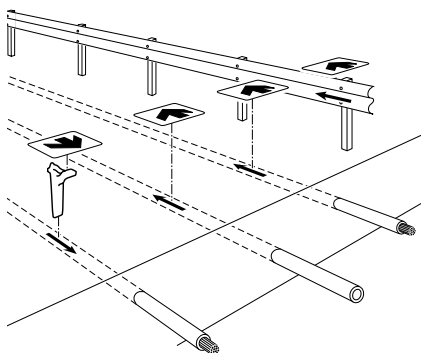
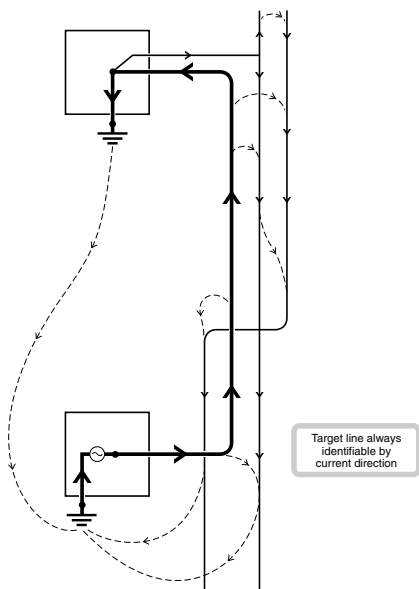
Signal coupled to a nearby line may distort the accuracy of the measurement. If the reading is suspect sweep the area to check if other nearby lines are radiating the signal. If other signals cause interference it may be necessary to make the current measurement at another point along the line.

Both antenna aerials are needed to make a Current Measurement and accessory antennas such as a clamp or stethoscope can not be used.

Current direction recognition



Current direction recognition is a feature that helps resolve the problem of providing the user with a positive means of line identification even at points distant from the application of the signal.



1 Current Direction Recognition (CDR) is a standard or an optional feature on top-of-the-range locators. It is a desirable, even necessary feature for positive identification of long distance lines. These lines can be traced and positively identified through congested areas or when running parallel to other lines.

2 The CDR signal has a specially engineered characteristic imposed on the standard type signal. It is therefore necessary for both the transmitter and receiver to be fitted with this optional accessory. (Possibly a standard on some locators.)

3 The CDR feature on the receiver indicates the direction of the flow of current on a line. Identity of the target line is established if the receiver display indicates that the current is flowing forward and away from the point of application of the transmitter signal.

Signal that has coupled onto adjacent lines finds a return path back to the point of the original signal application and is indicated by the receiver display arrow pointing backwards toward the transmitter. This is in contrast to the forward pointing arrow indicating the target line.

4 The CDR signal from the transmitter must be direct connected to the target line and with a remote ground connection. It cannot be applied by clamp or induction.

- It is necessary to set (or reset) the receiver with a CDR reference before using the CDR feature. After connecting the transmitter signal, trace the target cable about 15 paces away from the transmitter.
- Pinpoint the line. With the receiver pinpointing the line reset the CDR reference in the receiver. Check that the receiver display indicates a forward pointing arrow after the reset.
- Reset the receiver CDR reference each time the transmitter is turned off or the signal disconnected.

- ☐ It is also recommended to reset the CDR reference at intervals of several kilometres/miles tracing distance.
- ☐ This reset procedure can be carried out at a joint or splice box where the identity of the target line is certain.
- ☐ However, it may be difficult to determine the direction (to define if the transmitter is ahead or behind) of a line for resetting the receiver when locating midway along a long line. Find a nearby conductor with a visible identity to which the signal has coupled. A railway line, a continuous metal fence or highway crash barrier are suitable.
- ☐ Make a CDR locate on the visible line. The arrow should point back toward the transmitter. Then pinpoint the target line to check that there is a forward pointing arrow on the display.
- ☐ Reset the CDR reference after pinpointing the target line.
- ☐ If a nearby line also radiates a transmitter signal, pinpoint it and activate the CDR feature to establish the current direction. The arrow will point back toward the transmitter if the signal has coupled to it from the target line.

5 CDR is only effective on multiple cable installations as far as the following splice box as the cable shields are bonded and the outward CDR signal travels over the bond.

Positive line identification

Locating buried lines has ceased to be a problem except in the most complex or congested areas. However, positive line identification can often be a problem, particularly on lines in congested areas or on long distance lines when signal application with the transmitter is remote from the point of location and identification.

Successive techniques should be used to provide positive line identification.



2.5.3

1 Precision pinpoint and mark the target line position.



3.7

2 Search the area to check if the signal has coupled to any nearby lines within a radius of ten paces.



3.8

3 Measure the current on the target line and on any other lines located within the ten pace radius. Check that the mA current value is higher on the target line than on any other nearby lines.

4 Check current direction on the target line and on other nearby lines. The current direction of the target line should be pointing forward away from the transmitter. CDR signal on other lines should point back to the transmitter.

5 The target line will have been correctly identified if

- ☐ the pinpoint with horizontal aerials corresponds to the pinpoint position with the vertical aerial.
- ☐ the current measurement is higher than on any other nearby line.
- ☐ the current direction recognition feature indicates a forward response away from the transmitter.

If there is a discrepancy between any of these indications it will be necessary to repeat the verification procedure a few paces upstream and downstream.

6 A target cable can be identified in a chamber, on a tray or other access point by fitting a clamp or stethoscope antenna to the receiver and examining each cable in turn. Signal strength response shown on the receiver display should be noted for each cable. The cable giving the strongest response is almost certainly the target cable to which the transmitter signal has been applied.

Target line identity should be confirmed by reversing the positions of the transmitter and receiver and checking that the strongest response is still received from the target cable by the receiver in its new position.

Calculating line depth



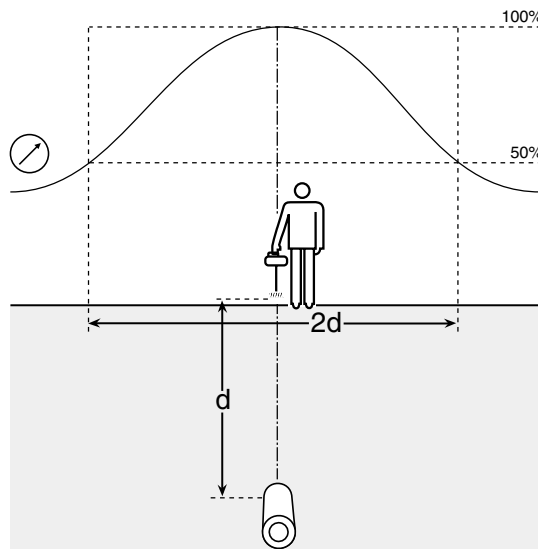
Depth to a line can be calculated if the receiver is a single horizontal aerial instrument.

only It is necessary to calculate depth to the line at a position where the signal is not subject to distortion from coupling or change of line direction.

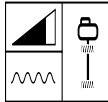
The calculation involves measuring the signal at different points and is an effective check of accuracy because it is unlikely that a signal will suffer the same error distortion in each direction.

Pinpoint the target line. Set the meter to 100% when directly above the line; with receiver vertical and close to the ground, move to both left and right until the meter drops to 50%. Mark these points and measure the distance between them.

Do not attempt to measure depth with the 45° method, a technique that is often advocated; it is prone to erroneous readings due to signal distortions.



Locating under water



Tracing buried pipes and cables across waterways and estuaries is a frequent and critical locating application. Less frequent but equally important is tracing and locating lines between the mainland and offshore islands.

In most cases it is necessary to measure the depth of cover to insure the line is protected from dragging anchors or other underwater hazards.

1 The receiver sensing aerials should be as close as possible to the target line so it is not practical to locate lines buried under the waterway floor from the surface. Locator suppliers offer a submersible antenna as an optional accessory. Generally it is usually pressure tested to the requirements of IP68 for depths down to 100m/325ft. The antenna usually has more widely spaced aerials to give greater depth measurement accuracy.

2 The transmitter applies its signal at an access point on the shore to the target line. The lead of the submersible antenna for tracing the line under water is plugged into the receiver which is on board a boat directly over the line.

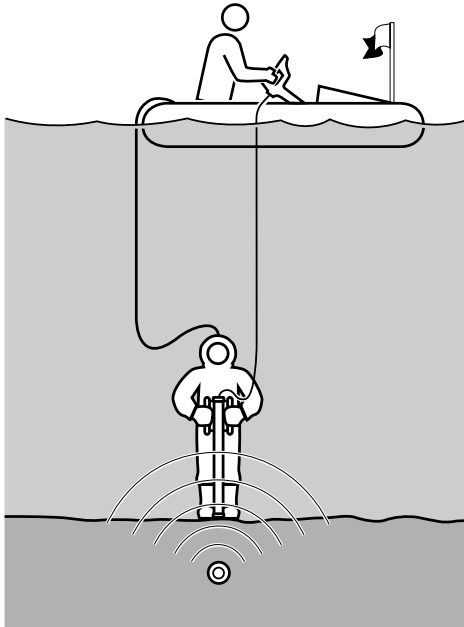
Care should be taken applying the transmitter signal to the line by direct connection with the strongest possible signal at low frequency, <1kHz. Make a high quality independent ground connection about 100 paces from the transmitter application. Quality of the signal on the target line should be verified before locating on the water.

3 It is preferable to attach the submersible antenna to the bottom of a vertical wood boom supported on the side of the boat if the waterway or sea floor is shallow, <6m/20ft and provided there is a means of accurately positioning the boat, possibly by cables from the shore.

The receiver controls and display are used normally as if integral with the antenna and boat manoeuvred to follow the route of the target line.

With the boat stationary and the boom lowered to the river floor there should be no difficulty in making a depth measurement to define the depth of cover over the line. The depth reading on the display will need to be doubled if the aerial spacing is double the spacing on the receiver antenna.

4 A diver is necessary to do traces, locates and depth measurements in deeper water. A good communication system is essential between the diver with the antenna on the seabed and the user in the boat with the receiver controls and display.



5 The user in the boat should be a specialist or have considerable experience using a locator so that he can give concise instructions to the diver and avoid needless waste of expensive time in trial and error.

It is prudent for the pair to learn working together with a trial on dry land. The diver should use the antenna and locate and trace a known line blindfold receiving his directions from the user with the receiver out of sight of the line and the diver.

6 There may be problems applying a suitable signal for tracing a large diameter pipe because of rapid signal loss due to a combination of large surface area and very conductive soil. It may be necessary to use a high power, around 100 Watts, tracing signal at very low frequency, below 50Hz.

7 It is necessary to define a method to record target line position/depth before starting work in the boat or on the seabed.

Using the 'A' frame to locate cable sheath faults



The 'A' frame sheath fault finder is a simple tool to locate faults up to 2 Megohm on power and telecom cables.

Most commonly the 'A' frame accessory is an antenna that plugs into the receiver. However, some manufacturers fit the signal processing unit and display directly to the 'A' frame.

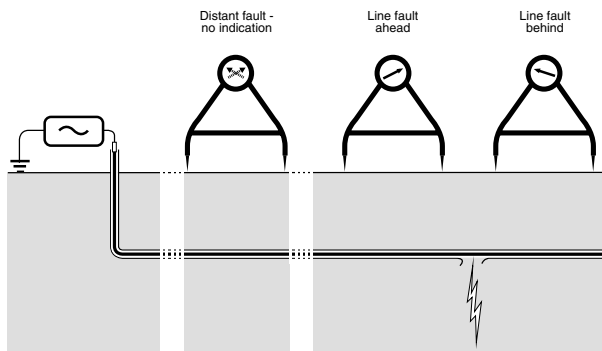
A characterized signal is required and the signal transmitter has to include a feature to provide a suitable signal for the 'A' frame.

The 'A' frame locates sheath faults on direct buried cables in permanent contact with soil. It will not detect faults on cables in ducts, lead cables or armoured cables.

1 Locate and trace the suspect length of cable using an ordinary locator. Mark the route of the cable every two or three paces.

2 Disconnect the ground bonds at each end of the suspect cable. The cable is then isolated and the only place for the signal to go to ground is through the fault.

Direct connect the transmitter signal to the cable sheath with a remote ground point.



3 Follow the route of the cable with the 'A' frame connected to the receiver. Push the 'A' frame spikes into the ground every 2 or 3 paces. The display will either indicate forward or back or it will fluctuate.

Fluctuating display indicates that the needle is searching backwards and forwards for the fault and that the 'A' frame is not within range of the fault. It is necessary to continue following the line pushing in the spikes every 2 or 3 paces until the display shows a positive back or forwards indication.

The 'A' frame is within range of the fault when it points either forward or backward. Move the 'A' frame in the direction indicated by the display: either forward or back with the 'A' frame over and parallel to the cable. Push the spikes into the ground at every pace until the indicator changes direction.

4 Go back one pace along the cable from the point where the indicator changes direction and place the 'A' frame across the cable and inch it along the line.

When the 'A' frame is directly over the fault the display will flip and point in the opposite direction.

5 Check the fault location by pushing one spike of the 'A' frame in the ground directly over the fault. Move the other leg of the 'A' frame round in a circle pushing in the spike every 60° and noting the indicator which should always point to the leg over the fault.

6 It should be possible to locate a series of faults along a line depending on the resistance of the faults. However, it may be necessary to expose and clean or repair any low resistance fault before continuing to locate other faults.

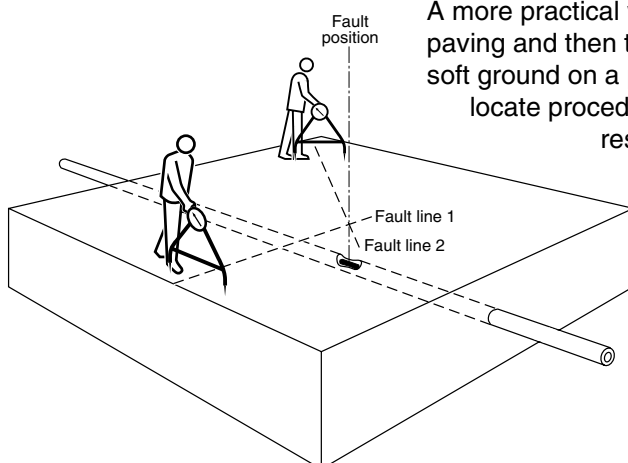
Continue along the path of the cable pushing in the spikes at intervals of no more than 2 paces. The indicator will fluctuate as soon as it leaves the area of the first fault and will then point to the next fault as it gets close to it.

It is often possible to gauge the relative importance of faults. Repeat the 'A' frame search on a path parallel to the cable but 2-5 paces away. Indication of middle and high resistance faults will be lost as a function of distance away from the cable.

7 Check the cable with the 'A' frame after the faults have been repaired: it may be possible to locate other faults whose presence was masked by the low resistance faults that have been repaired.

8 If the cable is buried under paving or concrete it may be possible to use the 'A' frame by pouring water on the road or fastening damp sponges to the 'A' frame spikes.

A more practical way is to locate and mark the line under the paving and then to use the 'A' frame in the verge or other soft ground on a path parallel to the cable. The 'A' frame fault locate procedure should be followed and all but the highest resistance faults will be located.



Alternatively, use the receiver to take bearings to the fault. Get as close as possible to the fault and then rotate the receiver and note the meter responses until the receiver is aligned so that a slight further rotation causes the meter to flip. A line drawn through the middle of the two spikes will lead directly to the fault.

Repeat at one or two positions and the fault is at the point where the lines meet.

Locating sondes in iron pipes

Sondes were originally introduced to trace non metallic pipes and drains. Their signal frequency was designed to combine a small and robust device with maximum locating range and battery life. This frequency is too high to penetrate a metal barrier which acts as a shield.

Recently manufacturers have introduced a low frequency signal sonde and receiver for tracing iron pipes.

- ☐ Successful location of a sonde in metal pipe depends on the composition of the pipe, wall thickness and pipe diameter.

Experience has shown that a 10ft locating range can be obtained from a small sized sonde (about 10cm/4in long and $\varnothing$ 4cm/12in) from a typical $\varnothing$ 15cm/6in cast iron pipe.

Range increases from a larger sonde with a more powerful signal.

Locating range can vary depending on pipe diameter and the distance of the sonde from the pipe wall.

Locating range reduces substantially from a sonde in a ductile iron pipe and even more from a sonde in a steel pipe.

- ☐ Check that the receiver has the same frequency as the sonde.

Check the locating range of the sonde and receiver combination by locating the sonde in a sample length of the pipe before tracing the buried pipe.

Note that battery life is greatly reduced in a low frequency sonde. Check that battery life is sufficient for completing the tracing job.

Locating procedure is similar to tracing a sonde in a non metallic duct or drain.



2.8

Part 4. Recording locate information

Traditionally locate information is recorded manually immediately after each pinpoint, locate or depth measurement. It is not only laborious to transfer written information to a map or computerised record but it is also open to human error.

Software is now available for a hand held computer which is fitted to the receiver for recording the required information.

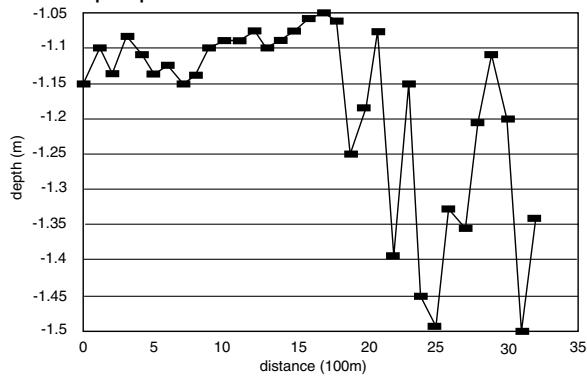
Part 4: Recording locate information

- 1 Software has been developed for two main locator applications:
 - ☐ Recording information about depth and/or current loss along a buried cable or pipe.
 - ☐ Recording complete information, including spatial information, about buried utilities in a sub-surface survey.
- 2 Recording line depth or current loss along a pipe or cable has become a common requirement, especially as part of the acceptance procedure for a new line. Software known as LineLog has been devised for the Psion Organiser hand held computer to enable information from the receiver to be stored, tabulated and displayed graphically.
 - ☐ The receiver may need special software to transfer information into the computer or it may be a standard part of the receiver specification.
 - ☐ A datapak with LineLog software is fitted to the computer which is connected to the receiver.
 - ☐ All the information available on the receiver display is transferred into the computer. This includes aerial mode, frequency etc., as well as the required current measurement or depth information.

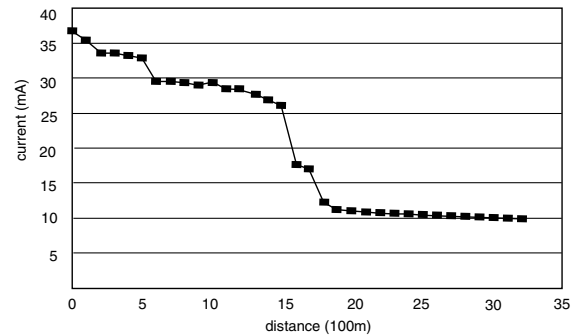
Part 4 Recording locate information

Example. A cathodically protected steel water pipe running under pasture for the first 1600m and then under cultivated land.

Line depth profile



Current loss gradient



- ☐ At the end of the survey the information is dumped in a PC and converted into a linear data listing with a LineLog floppy disc. The information can then be displayed or recorded as a gradient or a profile using a standard graphing programme.
- 3 Surveyors making a complete site survey of all buried utilities need to record spatial and line direction information in addition to the information displayed on the receiver.

The receiver can be fitted with a rod mounted prism and is then used in conjunction with a Total Station.

A development from LineLog software is available for both the receiver and the Total Station. No special instructions are needed for using the receiver to locate but the complete system is mainly suitable for use by qualified surveyors.

Part 5. Locating before digging

National or local administrations in most parts of the world recognise the dangers that may result from damaging a buried power cable and the effects of a utility failure. They have legislated or issued ordinances on the precautions to be taken before digging.

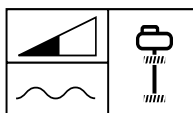
These ordinances require the digging company to obtain the relevant plans or for the utilities to mark out the position of their buried plant.

Whatever the information or whatever its source it should be on site verified before digging.

Part 5: Locating before digging

1 Plans from utility companies should be treated with caution. The information may be out of date or it may be incomplete. At the very least it gives information on what to expect. At best the information will just need confirmation.

2 Paint marks over the excavation site to indicate the presence and position of buried utility plant will have been put there by employees of the utility company or by a specialised contract location company. They usually have information about buried pipes and cables in the area and should have confirmed this information using a locator on site.



However, the position of the buried utilities should be verified before digging. Contact the utility or the locating contractor if any additions or variations to the marks are found. Digging before agreeing the exact position of a buried utility may involve contractual and legal liability.

3 There may be situations where no information is available before digging and a thorough search of the area is needed.



2.2.1

- ☐ Examine the area for indications of buried pipes or cables. Apply a transmitter signal to any visible access point such as a down cable in a pole, at a manhole or valve box and trace the line across and out of the area.



2.7.1



2.7.2

- ☐ Make a passive sweep across the area to detect any buried cables.
- ☐ If there is any possibility of any other pipes and cables being present, make an active search of the area. It may be necessary to make the search north/south as well as east/west.

Part 5: Locating before digging

4 Clearly mark the presence and position of all the buried lines in the area.

If an excavation is over or around a critical or dangerous line it may be necessary to stay on site during digging to ensure that its precise position is known as the trench gets deeper.

Part 6. Buried telephone cables: locating and fault finding

Locators are very effective locating all types of telephone cables. The locator and its accessories can also be used to fault find and solve problems on buried telephone cables.

- Section 1 Locating distribution cables
- 2 Locating long distance fiber cables
 - 3 Cable fault finding
 - 4 Check cable sheath continuity and grounding at splices
 - 5 Cable sheath fault finding
 - 6 Duct tracing
 - 7 Finding lost manholes
 - 8 Acceptance procedures for new lines

Always observe Telephone Company Safety Rules and Work Practices, especially relating to underground chambers.

Part 6 Section 1. Locating distribution cables

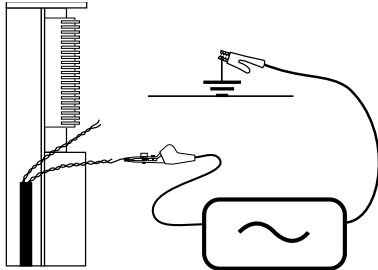
Locating distribution cables

Conventional methods of applying the transmitter signal, tracing and pin-pointing are effective for locating telephone cables.

1 Direct connection to a cable pair



- ☐ Direct connection to a cable pair gives maximum tracing distance through splices and pedestals without signal loss past ground points. Connect to the tip or first side of the cable pair. If connection is to a non working pair they must be grounded beyond the area where they are to be located. There is minimum coupling to adjacent lines.
- ☐ Access to a cable pair can be made at a telephone pedestal, cross box, cabinet, splice or join, central office or exchange or at a domestic socket (modular outlet) or a protector.

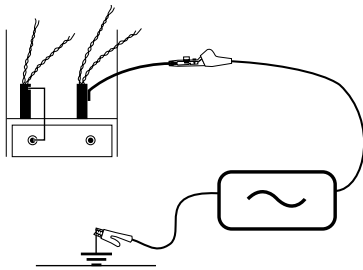


- ☐ Connect the transmitter to the tip or first side of a working pair.

Connect the ground to an independent ground point.

Caution. Do not use a fence, power downguy, ground wire or pedestal ground.

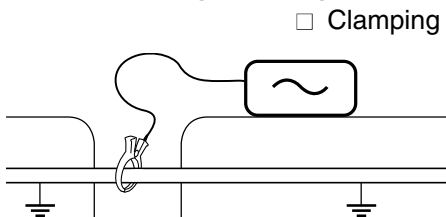
2 Direct connection to the cable shield



- ☐ Direct connection to the cable shield provides an accurate method of applying the transmitter signal with minimum coupling. Tracing distance is reduced by periodic or standard grounding of the shield.
- ☐ Access to the cable shield can be made at a telephone pedestal, cross box, cabinet, splice, protector or exchange or central office.
- ☐ Disconnect the ground strap from the grounding bar and make a direct connection to the ground strap. Remember to reconnect the ground strap when the locate has been completed.

Connect the ground to an independent ground point. **Caution. Do not use a fence, power downguy, ground wire or pedestal ground.**

3 Clamping the signal to the cable



- ☐ Clamping the signal to the cable is a quick and simple method of applying the transmitter signal to a cable. Tracing distance is not as great as a direct connection but is usually sufficient to trace a cable to the next manhole.

- ☐ The clamp can be used to apply its signal to a cable in a manhole. It can be fitted to an extension rod if the manhole is flooded.
- ☐ Cable shields should be grounded at each end.
- ☐ The clamp can be used to apply a signal to a riser on a pole. Do not use a large diameter clamp around the pole if there is a power company groundwire running down the pole.

4 Applying the transmitter signal in the exchange or a central office

There may be problems of coupling to other cables if the transmitter signal is applied in or near to the exchange. Always try to locate cables running to the exchange rather than from the exchange.

If there is no alternative to applying the signal in the exchange, make a direct connection to a cable pair which must be grounded at their ends beyond the area of the locate. The transmitter should be grounded to an independent ground point at least five paces outside the building.

5 Inducing the signal to a target cable

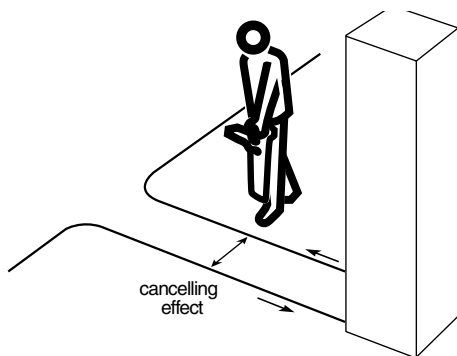
Inducing the signal to a cable is a last resort because of its inefficiency and because the signal may be induced onto other nearby lines. Induction should only be used if there is no access to the cable.

However, induction can often be the only way of tracing a lead cable if it is not possible to connect directly to a pair. Use the receiver passive modes to check there are no other cables nearby before placing the transmitter over the cable. Signal leaks off a lead cable after a short distance and it will be necessary to re-position the transmitter over the line before the tracing signal runs out and then leapfrog along the line. This process demands extreme care. Ideally locate from a known point on the line to another known point to check that the target cable is being located throughout.

6 Tracing and pinpointing

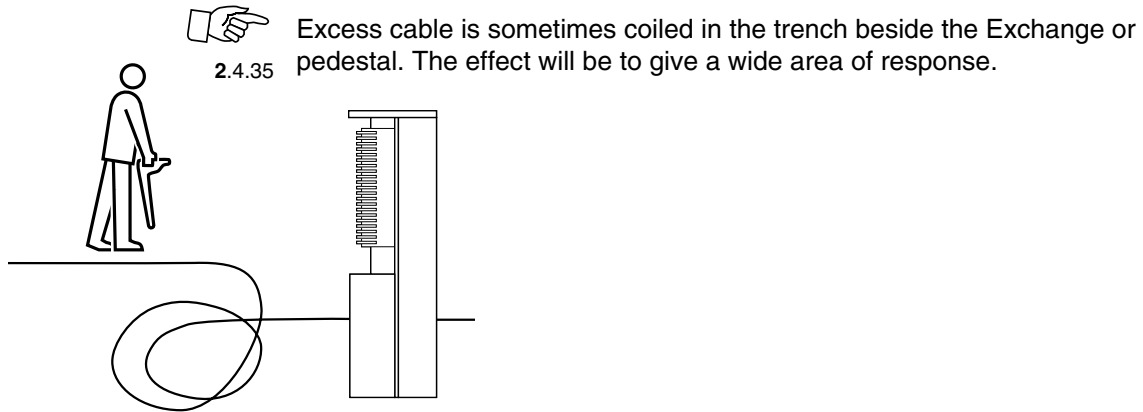


Always walk a complete circle round the pedestal or signal application to check if more than one cable is energised by the transmitter.



Trace the first 10 or 15 paces with great care. Then make a precision pinpoint to confirm the exact position of the cable. Then continue to trace the line.

Some pedestals or other points of signal application may be offset from the route of the cable resulting in 2 cables running in the same trench with a signal cancelling effect. Isolate the grounding points and trace each cable independently.

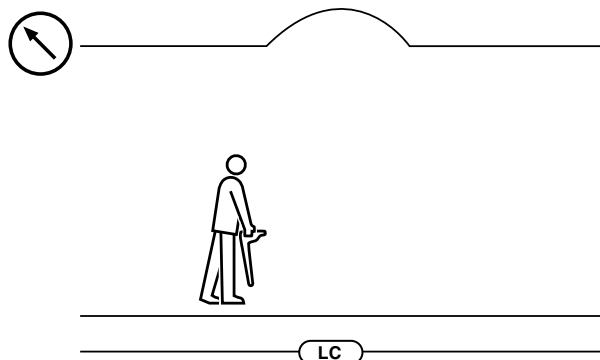


7 Locating the position of load coils

Connect signal from the transmitter to the tip or first side of a cable pair. Connect the transmitter ground lead to an independent ground point.

Trace the cable away from the transmitter with the response set at 50%. Continue the trace until response rises, possibly to 70% along a distance of 2 or 3 paces. The response will then fall back to its previous level.

The increase in response is over the load coil.



Locating long distance fiber cables

Accurate location and correct identification of a long distance fibre cable is very critical because of the high cost of repairing the cable and because of the high value traffic it carries.

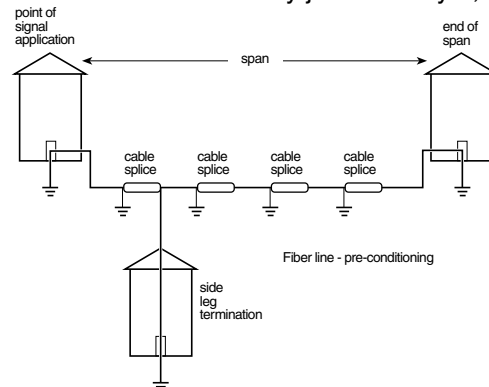
Most long distance fiber cables include a metallic sheath which makes it possible to locate these cables with an electromagnetic locator.

However, with improving technology the repeater stations have become more widely spaced, sometimes as far as 130km/90 miles apart and this has led to new problems for successful locating. Portable transmitters are not sufficiently powerful to transmit a signal over such distances, especially as the sheath is grounded at splices. Even if the signal travelled the distance, the time taken to make a locate midway between regeneration stations would be excessive by the time the transmitter signal had been applied at a regeneration station. A development in locating technology was necessary for these long lines to be accurately located and correctly identified throughout their length.

1 Bay mounted transmitter The solution for locating long lines is to install a high power, about 30 Watts, bay mounted transmitter in each regeneration station drawing power from the 48V supply in the station. The transmitter applies its signal either to the incoming or outgoing cable from the station and is activated remotely by phone or an order wire system.

Cable identification as well as location is critical even though there may be excessive signal coupling to other cables running parallel or when the cable runs through a congested area. The transmitter signal is therefore characterised for CDR so that the receiver can recognise current direction on the target cable and on any lines to which the signal has coupled.

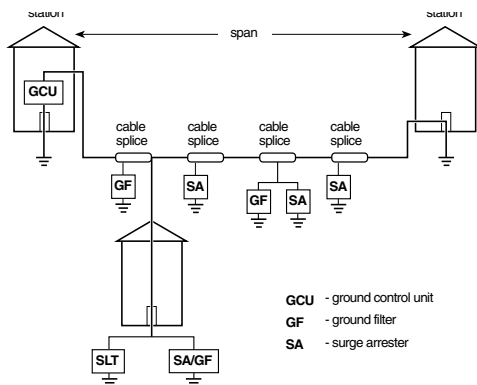
2 Ground points Fiber cables are usually joined every 1,800m/6,000ft with a cable splice and the sheath bonded to ground. In order to achieve the necessary tracing distance to the next station the signal has to by-pass the many grounding points at joins and at spurs known as side legs.



Part 6 Section 2. Locating long distance fiber cables

A number of devices are available to permit the passage of the transmitter signal while providing the same margins of operating safety provided by the sheath-ground bonds.

- ☐ Ground Control Unit/Signal Protection relay fitted to the cable sheath at the entry and exit of the cable from the regeneration station connects the cable sheath to the transmitter when it is activated and returns it to ground when the transmitter is switched off.



- ☐ On some systems company practice requires that a ground filter is buried at each splice and fitted in series between the cable sheath and ground to isolate all frequencies from passing to ground except a specified frequency, usually 50 or 60Hz.

- ☐ A surge arrester is buried at each splice to maintain the locating signal on the sheath and pass any electrical surge that exceeds a pre-defined voltage to ground.

- ☐ A side leg termination unit is fitted between the end of a tee or side leg and ground to prevent the side leg having a lower resistance to ground than the main cable at the next regeneration station. The resistance value can be set on the unit to suit the installation. The unit is connected in parallel to the ground filter and the surge arrester.

3 Pre installation survey

The distance between each regeneration station or span has to be surveyed before installation to design the transmitter system so that the signal with its CDR component travels the complete distance of the span and is easily located along its length.

Information must be available so that individual engineering consideration can be given to each span.

- ☐ On new or recently installed lines it is usually sufficient to test shield continuity from splice point to splice point, and locate and repair any sheath faults.
- ☐ A more detailed preinstallation survey may be necessary for installations that have been installed for a longer period.

The cable shield is disconnected from ground (at the first regeneration station) and the portable transmitter output lead is connected to the shield. The transmitter ground return should be made at an independent ground point.

Part 6 Section 2. Locating long distance fiber cables

The cable should be located approximately 10m/30ft from the station and a current measurement reading taken and noted (IA). Then travel to a point 5-8km/3-5 miles away and repeat the locate and make a Current Measurement (IB). By using the following formula the signal loss rate in mA per km/mile can be established.

$$\frac{IA - IB}{(\text{distance located})} = \text{Signal Loss Rate (mA per km/mile)}$$

This number is the current loss over the section travelled. By using the following formula it is possible to establish the distance that the Signal should remain locatable;

$$\frac{IA - 50}{\text{Signal Loss Rate}} = \text{Remaining Locatable Distance}$$

(Where 50 serves as a safety factor - general minimum locating signal required is 20 mA)

By repeating the above calculations at different points along the span of the cable (using the latest current reading, in comparison with the previous) the signal loss rate can be established for each section, and remaining distance for the signal to travel can be calculated.

Check the signal loss across a splice by comparing Current Measurements approximately 6m/20ft each side of the splice.

All recorded splice loss measurements should be comparable to each other.

Knowing the signal loss xxx (in mA per km/mile plus average splice loss) it is a simple calculation to establish the anticipated signal trace capability. The signal present at the end of the span should be approximately 40mA and not less than 20mA.

The current loss over the length of the span may be too great for the signal to travel to the next regeneration station. The transmitter in this regeneration station can apply its signal back along the incoming cable so that the length of a span can be double the tracing distance from a single transmitter.

If the transmitter signal effectively covers a span its presence and quality can be monitored with a toroidal clamp connected to an alarm at the distant regeneration station.

4 Installation Follow the manufacturer's instructions for installing and connecting the transmitter.

5 Post installation survey This survey is made with the receiver when the bay mounted transmitter has been fitted and connected in the regeneration station and the filters, surge protectors and ground control units have been fitted to the ground points and tees. Its purpose is to verify that the cable can be satisfactorily located along the length of the span and that the Current Direction Recognition feature provides dependable information.

6 Locating and tracing Locating is simple once the transmitter system has been installed and proved.

The technician doing the locate activates the transmitter at the appropriate regeneration station and receives confirmation that the signal has been applied successfully while driving to make the locate .



2.5, 3.7, 3.8

The receiver is used to locate the line at the desired point and if there are any nearby lines its identity can be confirmed by making a current measurement and making a CDR reading to confirm the outward direction of the current on the target cable.

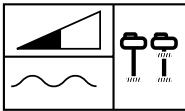
7 Duct problems Long distance cables frequently run in multi-way ducts in city or congested areas. The long distance cable is often at the bottom of the duct with local city copper cables lying above but it may change position in the duct. Three problems arise from locating the long distance cable in a crowded duct.

- ☐ The signal from the transmitter couples onto adjacent cables creating a return current resulting in two signals out of phase with each other that tend to cancel out.
- ☐ The other cables shield the magnetic field and signal from the long distance cable.
- ☐ The second problem is caused by severe interference from 50/60Hz hum caused by the large number of cables and their proximity to the target line. The problem increases if the shield of the target line has some high resistance splices along its length.

The most simple solution is to apply a second signal at the same frequency to the target cable at an access point as close as possible to the problem. Direct connect to the shield and to a high quality remote ground, possibly a long copper rod hammered in the ground. The shielding effect is broken up and it is possible to trace the cable.

If the target cable continues in the same duct, the duct run can be easily traced by clamping a signal round the top cable in the duct.

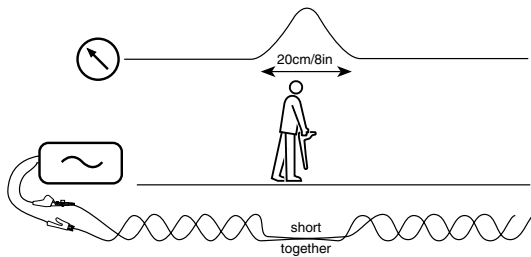
Cable fault finding



Successful cable fault finding often involves the use of a number of techniques such as TDR's, bridges etc., which provide information about the distance to a fault or its general whereabouts. Electromagnetic location takes over where they leave off and defines the precise position of the fault saving time and avoiding wasted digging.

1 Shorted conductors

This procedure locates the position of shorts between conductors but not between the conductors and the sheath.



Trace and mark the cable through the suspect area.

Remove central office or exchange battery connection from the faulty cable pair.

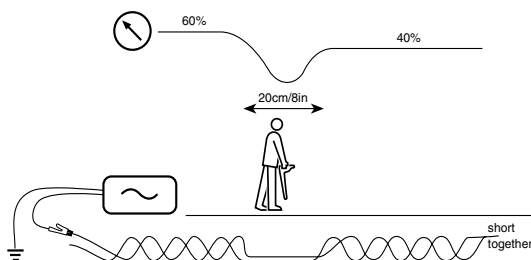
Connect the transmitter signal to the tip or first side of the pair and a ground lead to the other side of the pair.

Increase the gain to maximum while still keeping the meter on scale.

Walk over the cable. Reduce sensitivity to lose any low level response. A short and sharp response over a distance of 20cm/8in indicates the position of the short.

2 Open conductor, one side

If one conductor of a cable pair is open, the point that the open occurs can be pinpointed. Connect the transmitter direct connection lead to the 'Good' side of the pair, and connect the ground lead to an independent ground.

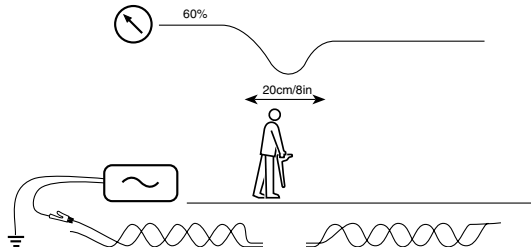


Go to the next access point, and short together the two conductors of the faulty pair.

The transmitter tone will travel along the single working conductor to the far end, and back on the faulty conductor to the point of the fault. There may be some cancelling effect as it returns from the far end to the point of the fault.

Trace the cable away from the transmitter with the gain at 60%. Continue tracing the cable until the response dips and then resumes at a level of 40%. The dip indicates the position of the cable fault.

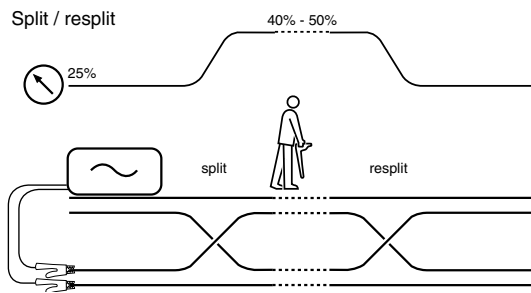
3 Open conductor, both sides



Connect the transmitter to one side of the pair and to ground. Trace the cable with 60% response. There will be a significant reduction in response over the break.

4 Split - resplit

A split is the point where two pairs of conductors have been wrongly connected.

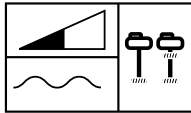


The response from a signal on a cable pair is low because of the cancelling effect of the signal. Level of response increases when a conductor is no longer twisted with its partner.

Connect the transmitter to the suspect pair of conductors:
Connect one lead to one side and the ground lead to the otherside of the pair.

Trace the cable away from the transmitter with gain set as near as possible to 25%. Gain will increase substantially at the point of the split. Do not adjust gain if a re-split is suspected and continue tracing until response reduces indicating the position of the re-split.

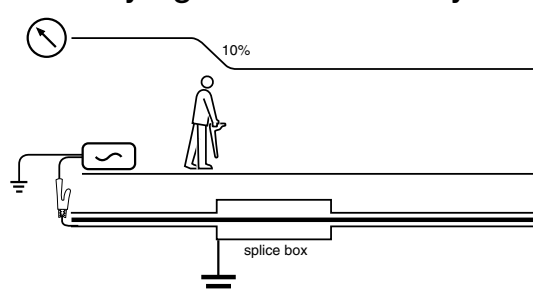
Checking cable continuity and grounding at splices or joints



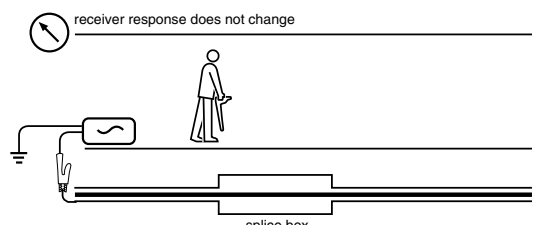
Maintaining shield continuity with grounding at splices or joints is important to insure the telephone cable integrity.

The locator can be used to check a number of fault conditions from the surface.

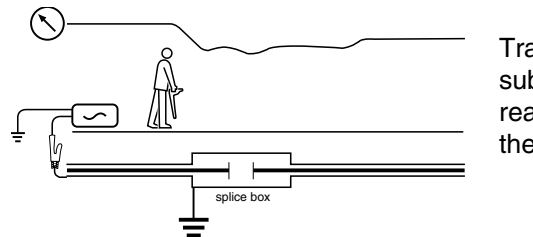
- 1 Verifying shield continuity and splice grounding** Connect the transmitter signal to the cable shield and an independent ground.



Trace the cable with gain set at about 60%. Assuming the bond to be about 25 Ohms to ground, the response should reduce over the grounding point and continue at that level.
- 2 Shield Continuity across splice but no grounding** Connect the transmitter signal to the cable sheath and an independent ground.

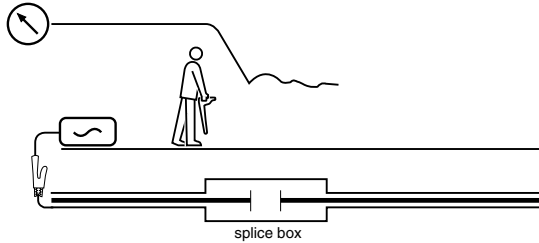


Trace the cable with gain set at 60%. At the splice/bond point there will be no change in the receiver response.
- 3 Shield grounded but no continuity across the splice** Connect the transmitter signal to the cable shield and an independent ground.



Trace the cable with gain set at 60%. The response will substantially reduce or even disappear at the splice but reappear, or even increase 3-5 paces past the splice and then reduce.

4 No shield continuity and no ground Connect the transmitter signal to the cable sheath and an independent ground.



Trace the cable with gain set at 60%. The response will reduce sharply or disappear over the splice.

Cable sheath fault finding

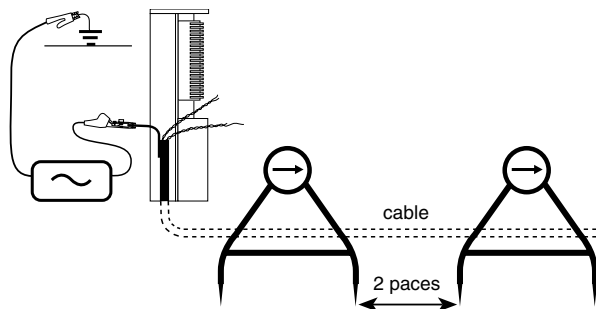
The importance of locating sheath faults. The outer insulating jacket prevents water or moisture from getting into the cable. A fault in the sheath allows moisture to enter the cable where it can permeate the conductor insulation. This causes a high resistance ground which provokes noise and together with current flow causes conductor oxidization.

The actual fault caused by water in a cable may be found by any of several techniques such as impedance bridge measurements or Pulse/Echo (TDR) techniques. These will find the faulty conductors and enable repair of the service but may not necessarily find the sheath fault which may be some distance away.

Finding and repairing sheath faults is important preventative maintenance to reduce recurring cable failures.

- 1 The 'A' frame locates sheath faults on cables buried in soil. It does not find faults on cables in ducts or on lead and armoured cables.
- 2 In good conditions it finds high resistance faults up to 2 Megohms.
- 3 Trace and mark the route of the line using an electromagnetic locator.
- 4 Remove bonds on near and far ends of faulty cable connection.
- 5 Follow the procedure of using the 'A' frame to locate the sheath fault or faults.
- 6 Repeat the 'A' frame survey once any low resistance faults have been

3.12

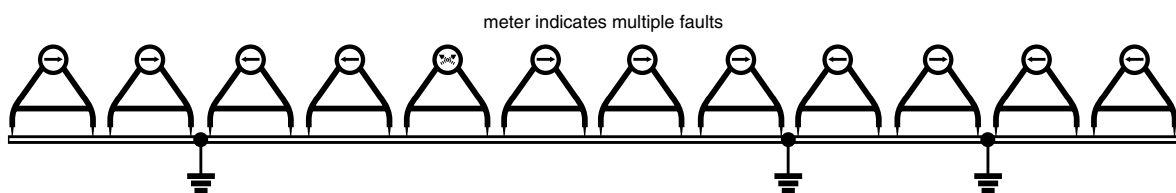


Part 6 Section 5. Telephone cable sheath fault finding

repaired to check if there are other higher resistance sheath faults on the line.

7 Replace the bonds between the sheath and ground at each end of the line once the fault finding survey has been completed.

Faultfinding - over cable

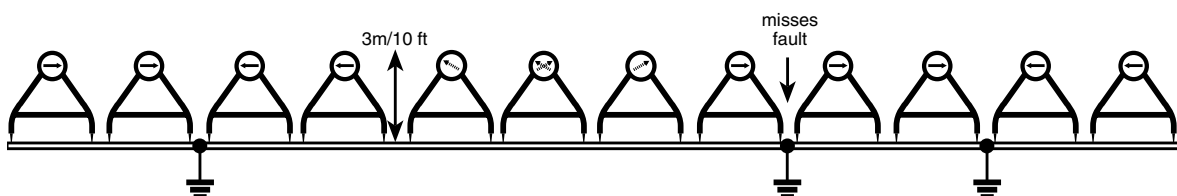


8 Searching with the 'A' frame over the cable will detect high resistance faults.

Searching with the 'A' frame on a path parallel to the cable, perhaps 3m/10ft away, will find only the low resistance faults.

A parallel search may be necessary because the cable is buried below a paved surface or because the intention is to locate just the more important faults

Faultfinding - offset from cable



Tracing ducts

Propelling a sonde along an empty cable duct is a simple and reliable way of tracing the duct and locating any blockage or collapse.



2.8

1 Follow the instructions for locating and tracing the sonde. Ensure that rods or other equipment for propelling the sonde are available on site together with the means for attaching the sonde.

2 A blockage or collapse is located when the sonde jams in the duct and cannot be pushed in any further. It may be advisable to insert the sonde from the other end to measure the extent of the blockage.

3 Inserting a new cable in a duct can sometimes jam. A sonde can be fitted in the drawsock so that the position of the end of the cable can be located if it jams in the duct.

Finding lost manholes

Manholes are often lost under a layer of blacktop in the road or hidden under vegetation beside the road.



2.9

1 It can take a long time to locate a lost cover if its approximate position is not known. The quickest way to find a cover is to apply the transmitter signal to the cable at a convenient access point and trace the line along through to the area with the suspect cover. A loss of response along a small distance usually indicates the presence of a cover.

The route can then be checked with a cover locator to confirm the position of the cover.

If there is little or no loss of signal at any point along the length of the line it indicates that the cover is a concrete lid in a metal frame. Sweep the suspect section of the path of cable with a cover locator to detect the position of the lost cover.



2.8

2 If the manhole cover is on a duct run, propel and trace the sonde along the duct. The signal will be lost under a cover whose position can be confirmed with the cover locator.

3 A vertical coil cover locator has the advantage of defining the outline of the cover. It is particularly effective at identifying rectangular telephone covers with three lids in a metal frame. There is a sharp response on the edge of each lid.

Acceptance procedures for new lines

Using a locator as part of the new cable acceptance procedure helps confirm that the installation conforms to specification.

1 Cable depth can be checked at intervals and profiles of depth of cover made at ditches or road crossings.



2 The electrical continuity of the shield can be confirmed with a simple trace.



3 A profile of the current gradient can be made over the length of the line. Any anomalies or loss of the outer cable insulation will be indicated.

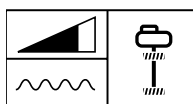
Part 7. Buried power cables: Locating and Fault finding

Locating buried power cables with their attendant dangers is one of the main functions of the electromagnetic locator.

Recently locators have been obtaining acceptance as an aid for locating a wide variety of cable faults.

Part 7: Section 1. Locating cables

Locating cables

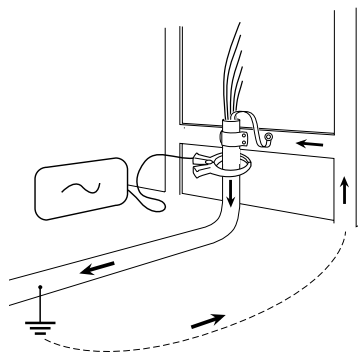


Although buried electric cables usually radiate a strong power 50/60Hz signal, this detectable signal is not consistent in every situation and it is always necessary to apply the transmitter signal to trace or locate a target cable.

- 1 Locating a cable from a house into the street** Applying the transmitter signal to a live domestic power socket is the most positive way of tracing and locating a service connection running into the street distribution cable.

The signal can be clamped to the cable if the cable is accessible at the meter outside the house and the building has its own grounding.

- 2 Locating cables leaving a sub-station** Apply the transmitter signal with the clamp onto an outgoing cable.



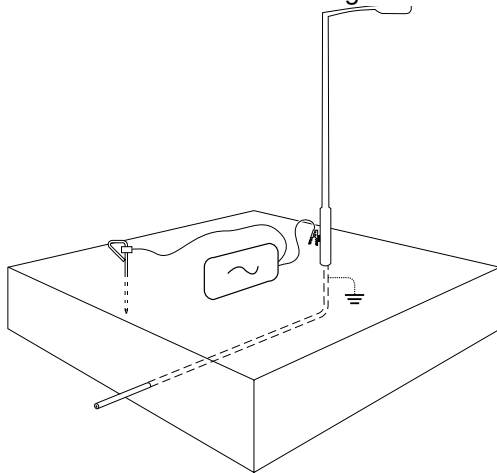
Do not assume the transmitter signal is only on the target line. Always take the precaution of walking a circle of about 5 paces around the transmitter and note all signals crossing the circle. The target signal should be the signal giving the strongest response.

Using the live cable connector is an alternative way of applying a very selective signal for long distance tracing. This should only be done by personnel licensed to work on live conductors.

The live cable connector should always be used to apply a signal to conductors even if the cable has been isolated from the supply.

3 Locating street lighting cables

Street lighting cables may be fed from a dedicated supply system or from the power distribution cable running along the street.



Direct connecting to a metal street lamp column is almost as effective as connecting to the cable sheath itself. Normally the cable sheath is bonded to the metal column, therefore a simple connection onto the column enables the user to locate the street lighting cable quickly and safely without having to call out the lighting department.

Concrete columns. Make the transmitter connection to the cable sheath unless the cable is earthed to the inspection door frame. Connection to the cable sheath applies the transmitter signal for a considerable distance enabling the receiver to trace cables feeding illuminated street furniture as well as other street lights.



3.5

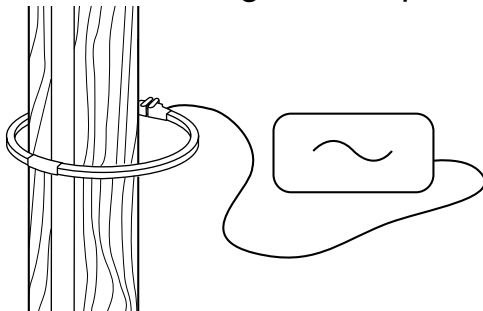


When the cable is not grounded at the column, open the inspection door and use the live cable connector to the live or neutral conductor.

The use of a street light column as a means of applying a signal to other power cables is a possibility. The signal may be weak using this method because it may have travelled some distance back to the sub-station and out again on the other system, but with the receiver used on a high sensitivity setting it is often possible to locate a cable which would otherwise have been difficult or inconvenient to energise.

4 Cable running down a pole

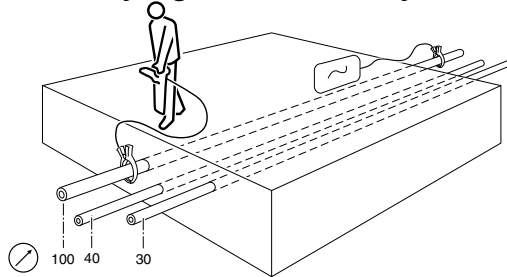
Cables running down a wood or concrete pole or lighting column can be energized by applying the transmitter signal with a big clamp round the pole and cable. They can also be energized by standing the transmitter in its induction mode at right angles to the ground against the pole.



Cables running down a wood or concrete pole or lighting column can be energized by applying the transmitter signal with a big clamp round the pole and cable. They can also be energized by standing the transmitter in its induction mode at right angles to the ground against the pole.

Check if there is a groundwire running down the pole. Part of the signal will flow on this wire which should then be traced away to insure there is no confusion with the target cable.

5 Verifying cable identity



Two methods are available for confirming cable identity which are useful if the locator does not include current measurement or current direction recognition features.

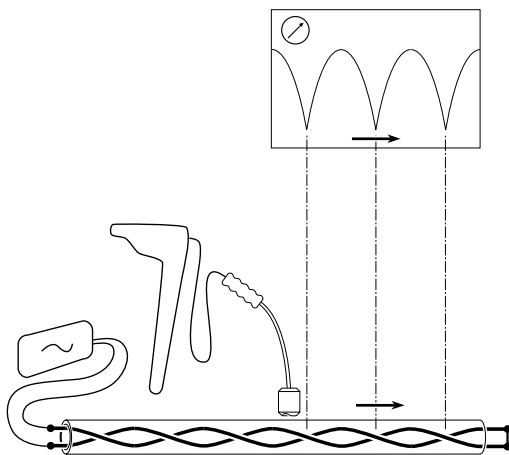
Trace the cable to the access point where the cable identity can be established.

Fit the clamp antenna round each cable in turn, noting the meter response. Compare the strength of responses from each cable. The cable with a substantially stronger response than the others will be the cable to which the transmitter signal has been applied.

It may not be possible to put the clamp around the cables because of congestion or because of inaccessibility. A stethoscope antenna should be used in the place of the clamp. Press the concave detector head against each cable and note the response from each cable.

To be sure that the cable has been correctly identified reverse the position of the transmitter and the receiver and repeat the identification routine.

An alternative method of identification uses the effect of cable twist to provide a precise 'signature'. This method should only be used by personnel licensed to work on live cables.



This technique cannot be used on live cables because it is necessary to make a short circuit at the far end.

Always use the Live Cable Connector to energize power cables, even when they are supposed to be isolated.

The twisted cores cause a 'corkscrew' signal. A stethoscope antenna (not clamp antenna - it cannot detect this corkscrew signal) moved along the cable displays a distinctive rise-and-fall response.

Other adjacent cables will not show the same effect and therefore this is a positive method of cable identification.

Locating cable faults

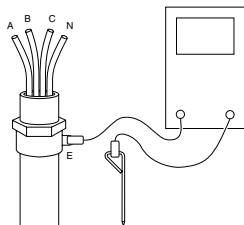
- 1 Procedure for fault finding Determine the type of fault.
Evaluate the suitable fault finding procedure.
Locate where the fault is on the cable route.

2 Determine the type of fault



Safety: Before carrying out any procedures make certain the cable is dead or isolated at each end.

Carry out the following procedures using a multimeter/insulation tester:

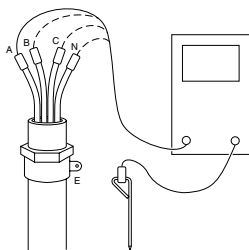


☒ **Sheath fault**

Find a low resistance external independent earth point or drive the ground stake into the ground. Use water around ground stake if ground is dry.

Make sure that any ground bonds on the faulty cable are disconnected for sheath fault location.

Shield-ground fault can be located with the 'A' frame if resistance is below $2M\Omega$. Connect multimeter as shown.

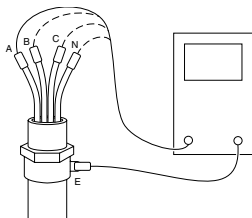


☐ **Core-ground fault**

Find a low resistance external independent earth point or drive the ground stake into the ground. Use water around ground stake if ground is dry.

Readings of less than 200Ω are low resistance faults. Up to $1M\Omega$ is a high resistance fault.

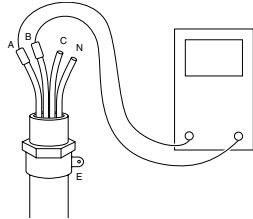
Core-ground fault can be located with the A frame providing core does not contact shield. The A frame can also be used on cables without sheath.



☐ **Core-shield and shield-neutral fault**

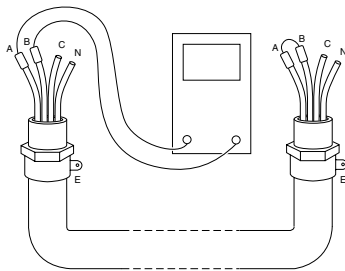
FFL cannot be used on this type of fault. Readings of less than 200Ω indicate faults that can be found using a standard type electromagnetic locator.

Part 7: Section 2. Locating power cable faults



Core-core and core-neutral fault

A frame cannot be used unless there is ground contact between the faulty conductor and ground. Readings of less than 500Ω indicate faults that can be found.



Open circuit fault

There is an open circuit fault if all previous test method show very high resistance both between cores and ground, and sheath to ground.

Pulse Echo/TDR equipment generally easiest to use and best for open circuit faults.

The A frame can be used if there is some ground contact on any conductor.

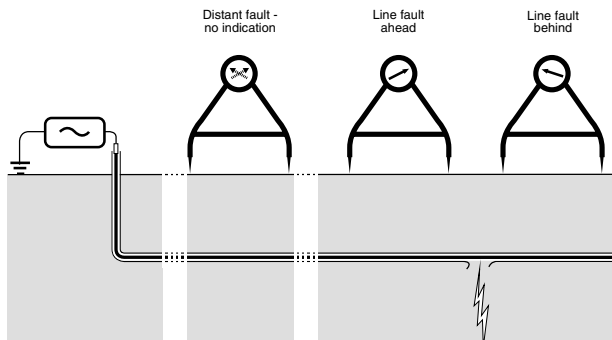
3 Determine a suitable locating procedure Determine the type of fault and cable to decide on the suitable fault finding procedure.

Fault type	Cable type						
Shield/ground		a		a	a	a	a
Core/ground	b, c	b, c	b, c	b, c	b, c	b, c	b, c
Core/shield		e	d	d	d, f	d	e, f
Core/core			g	g	g	g	g
Core/shield/ground		d		d, h, j	d, h, j	d, h, j	d, h, j
Shield/neutral		d, e		d, e	d, e	d, e	
Low insulation/ground	c, l	c	a, k, l				
Loss of insulation oil						a	a
Open circuit	h, j	h, j	h, j	h, j	h, j	h, j	h, j

The letter references refer to the procedures in the following paragraphs.

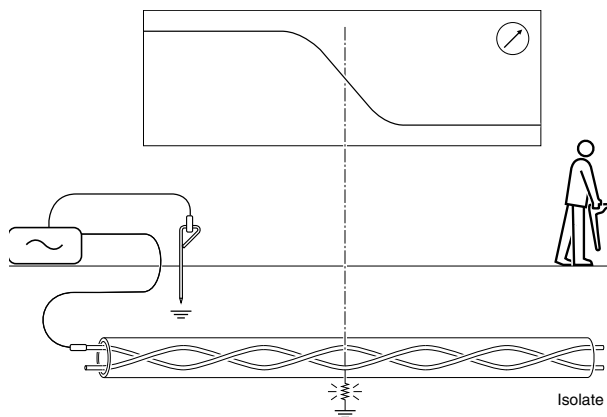
4 Fault finding procedures

a *Shield-ground fault*



Disconnect ground links and isolate cable from ground.

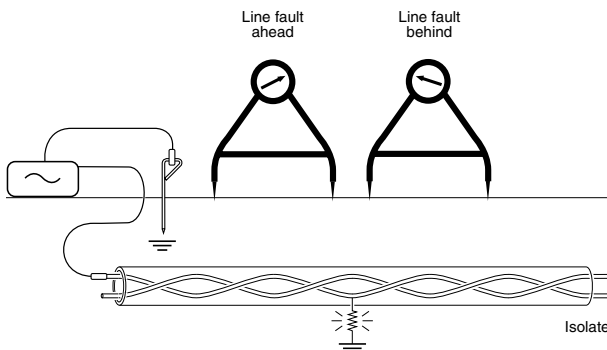
b *Low resistance core-ground fault*



Connect to a single core - or if whole cable is damaged and in contact to ground connect to more than 1 core.

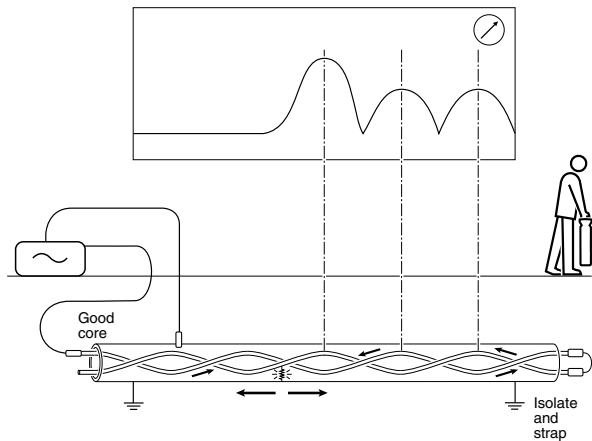
Isolate cable from ground.

c *High resistance core-ground fault*



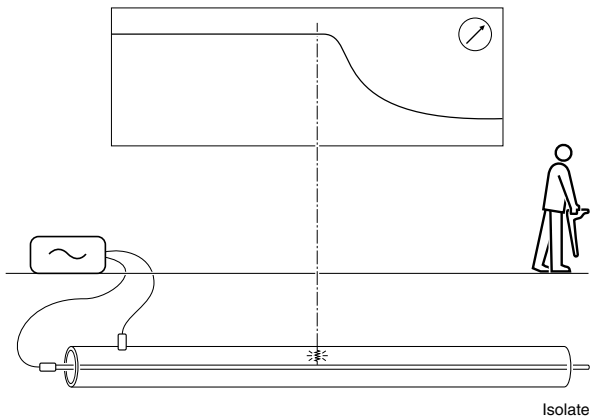
Providing cable cores, neutrals, shields and grounds are isolated and provided the cable has a plastic insulating layer this type of fault can be located with the A frame and is direct buried on plastic sheathed cables.

d *Core-shield fault, Core/shield/ground, shield/neutral*



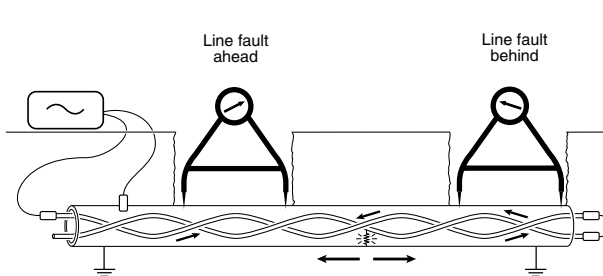
Isolate shield from ground. Hold receiver blade parallel to cable.

e *Core-shield fault, Shield-neutral*



Isolate shield from ground.

f *Core-shield fault*



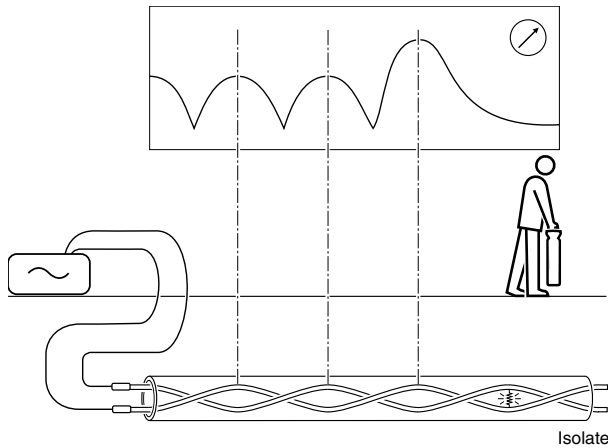
Fault on armoured (tape or steel wire armoured) cables may be core to armour/shield due to failure of internal insulation.

The cable is often effectively grounded along its length if there is inadequate insulation around the armouring.

The 'A' frame receiver used on the surface will not detect the direction of the ground current.

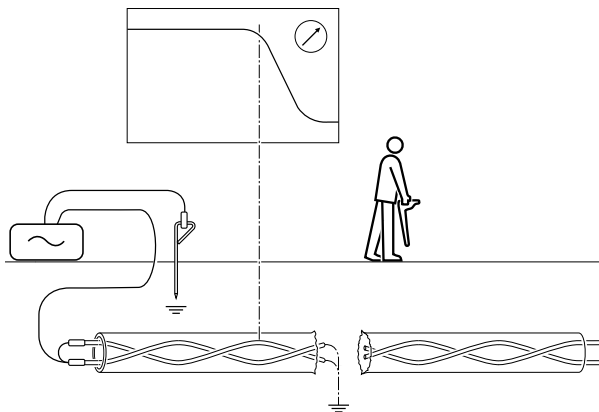
However, the 'A' frame can provide information if the cable is exposed and identified - when the spikes contact the armouring the 'A' frame will indicate direction to the fault. This may save unnecessary cutting and testing.

g *Core-core fault*



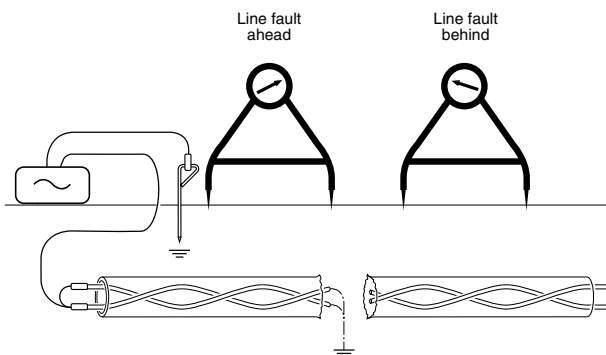
Isolate cable and connect transmitter across faulty conductors.

h *Open circuit fault*



A standard locator can be used to locate a low resistance fault provided it is grounded.

j *Open circuit fault, Core/sheield/ground fault*



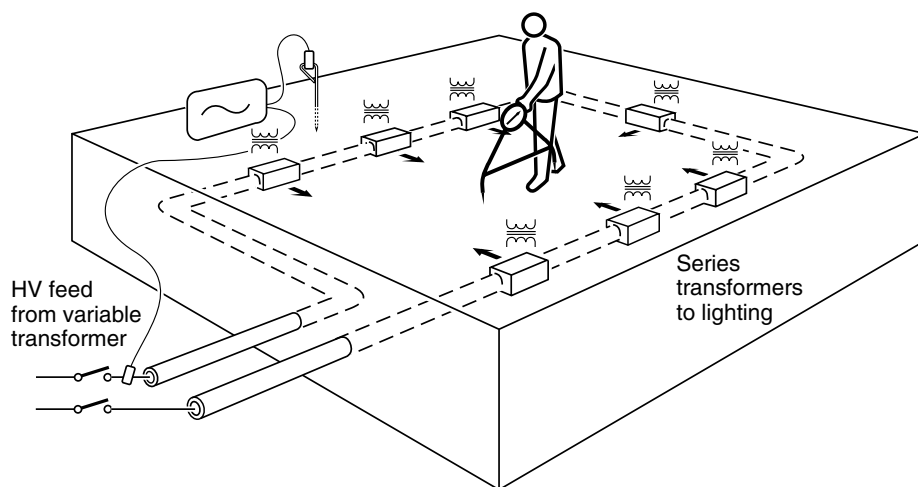
The 'A' frame can be used to locate high resistance faults providing they are grounded.

Part 7: Section 2. Locating power cable faults

k *Low insulation fault - 'A' frame*

The 'A' frame can be used to find low insulation faults. Applicable to single core and 3 core cables with no shield. Disconnect any ground bonds, connect either to core or shield and use as if searching for shield fault operation as a or c.

l *Low insulation/ground fault on direct buried airport runway lighting systems*



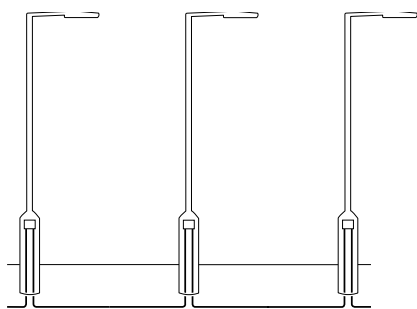
Airport lighting systems usually use single core HV cable feeding series transformers and these power the runway lights. Many lights/transformers are fed from the same single cable loop.

HV loops can be disconnected from HV feed/return by removing links. Connect the transmitter to feed or return. Leave other side open. Choose independent ground outside building: do not use building ground point. Use the 'A' frame receiver in the usual way.

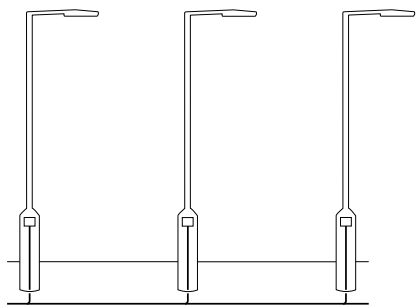
5 Street light cable fault finding

It is necessary to determine the type of cabling to the street lights before deciding on a suitable fault finding procedure.

Street lights are normally supplied by 'loop-in' or 'tee'd off' feeds. The loop-in has more than one cable terminated in the column and the tee'd off system has a single cable in the column. There may be some columns which have a combination because of previous cable failure and replacement.



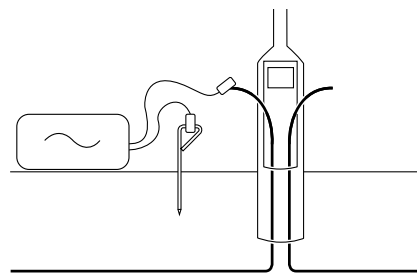
'Loop-in'



'Tee'd off'

Procedure

- ☐ Use a locator to locate and mark the system.
- ☐ Disconnect and test the system to determine which section of cable is faulty.
- ☐ Isolate the cable at both ends on a 'loop-in' system and isolate everything connected to the cable on a 'tee'd off' system. Disconnect the ground of the faulty cable at both ends and also any other cable connected at the same point, so there is no chance of backfeed from the transmitter.
- ☐ Test the cable to check that there are core to ground or sheath to ground faults which can be found with the 'A' frame.
- ☐ Connect the transmitter signal to one end of cable and locate the fault with the 'A' frame. Double check from other end of cable; there could be more than one fault.



Part 8. Gas distribution. Locating and problem solving

Gas distribution pipes and systems represent a declining application for electromagnetic locators because of the increasing use of polyethylene pipe to replace iron or steel pipe.

Even metal distribution systems present a challenge to the locator user unless there are external meters; there are many fewer valves or other access points as compared to a water distribution system.

- 1 Tracing metal gas pipes
- 2 Tracing plastic gas pipes

Part 8: Section 1. Tracing metal gas pipes

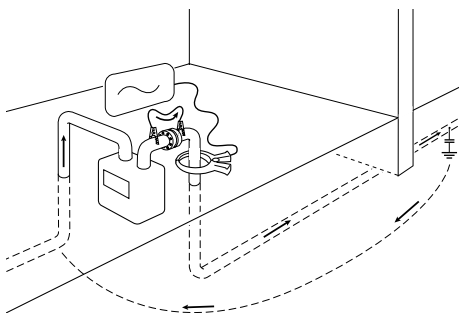
Electromagnetic locators can be used to trace steel pipes and most ductile or cast iron pipes.



2

Standard line locating and tracing techniques are suitable for locating steel pipes.

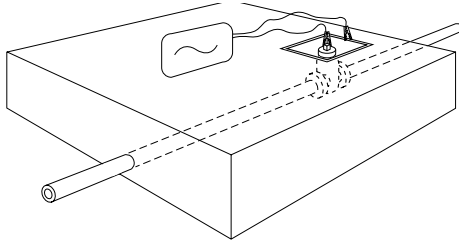
- ☐ Some steel pipes may be fitted with an insulated joint to prevent stray signals travelling along the pipe. The joint will also stop the transmitter signal.
- ☐ Where possible apply the transmitter at the consumer's meter and trace into the main.



Clamp the transmitter signal at the meter. Make sure any insulating gasket is bypassed with a jumper wire so that the gas pipe into the house provides an effective ground return.

- ☐ Some gas distribution systems have very few access points or access points cannot be found. Determine the approximate position of the distribution main from any existing plan or from local knowhow and induce a signal to it with the transmitter over and in line with the supposed position of the pipe. Trace the signal to a point where the line can be identified at a valve or other access point and then connect or clamp the transmitter signal to the valve.

Part 8: Section 1. Tracing metal gas pipes



- If the pipe has to be located under or beside the highway make a single ended transmitter connection to a valve with the ground lead connected to the metal frame of the valve box.

Check that the clip is making good electrical connection. It may be necessary to brush off paint or scale to make a successful connection.

Iron pipes may present problems for tracing and locating. Insulated flanges or bell joints will reduce or even stop the transmitter signal. A high proportion of the ferrous content of an old pipe may have corroded and the pipe present a high resistance path to the transmitter signal.



2

- Try locating and tracing the pipe using the techniques for locating a steel pipe.

- New iron pipes may not transmit any signal for more than 2 or 3 lengths of pipe or perhaps just a single length of pipe. Trace the pipe with an induced transmitter signal and move the transmitter up to the last point where the signal was detected.



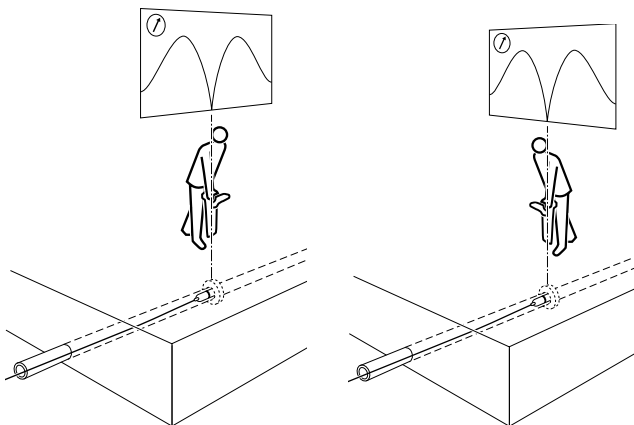
2.7

- The pipe may have sufficient power or radio signal to allow it to be traced with the receiver in its passive mode.



3.13

- If available, use a low frequency sonde/receiver to trace the pipe. Check that the sonde is sufficiently small diameter to fit in the pipe.



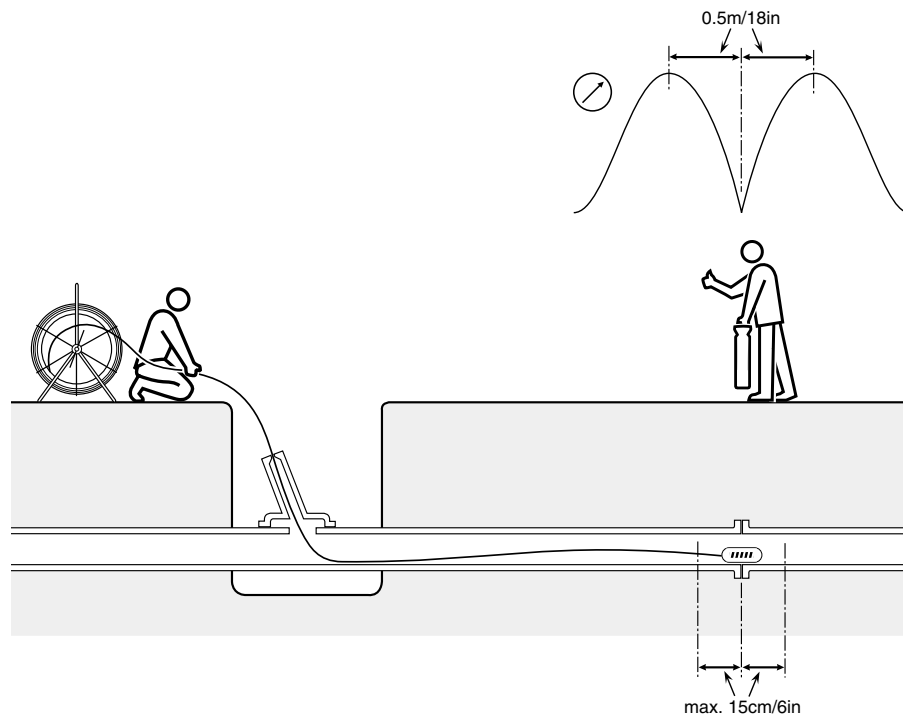
- An iron pipe with insulated joints can be traced by inserting a >5kHz frequency sonde. The signal will not be located through the pipe wall but when the sonde is 15cm/6in either side of the pipe joint it will transmit a signal that gives a peak response either side of the joint and a null response directly over the joint.

Turn the receiver at 90° to the line of the pipe and locate a second null response. The pipe joint is directly below the point where the two null responses intersect.

Knowing the length of the pipes it is possible to propel the sonde in similar increments and make a series of successive pinpoints to define the path of the pipe.

Part 8: Section 1. Tracing metal gas pipes

- The technique of pinpointing the joints is suitable and sufficiently precise to enable a small bore hole to be made to the joint for injecting anaerobic sealant.



Tracing plastic gas pipes

- ☐ There has been considerable effort and investment to devise a system to locate buried plastic gas pipes from the surface. In particular there has been effort in a number of different countries to develop ground probing radar to locate buried plastic gas pipe. There has been some success and equipment is available suitable for use by specialists. The equipment can provide adequate location information in some but not all soil conditions.

Use of the equipment is costly; probably more costly than digging trial holes. However, its cost can probably be justified if information about buried pipes is required over a large area.

- ☐ Propelling a sonde inside the pipe and locating it as it progresses along the pipe is the only practical method of tracing a plastic gas pipe.

Insertion canopies are available to fit most sizes of plastic pipe and it should be possible to trace at least 100m/375ft in each direction from an insertion point.

Part 9. Pipelines: Locating and coating survey

Pipelines may be defined as long or medium distance pipes that are welded and are coated to prevent corrosion.

The locating or problem solving techniques are the same regardless of whether it is a gas, crude, product, chemical or water pipeline.

- 1 Locating
- 2 Problem solving cathodic protection systems
- 3 Monitoring and investigating pipeline coating condition
- 4 Current gradient survey
- 5 Ground potential or Pearson survey

Part 9 Section 1. Locating pipelines

Locating pipelines

Successful and accurate locating depends on knowledge of the pipeline: its layout, access points, cathodic protection system if installed and the position of any insulating joints or flanges.

1 Safety

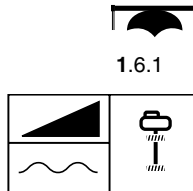


Pump or compressor stations are hazardous areas. Always follow company regulations and request official authorization to use a locator in any area classified as hazardous or where flammable gases may be present.

Most locator types are neither explosion proof nor intrinsically safe. Any equipment suitable for use in a hazardous area will have a label with a certificate number and the name of the issuing organization prominently displayed.

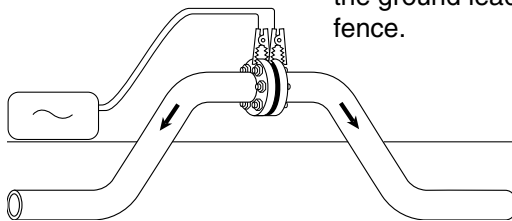
Always obtain authorization from the pipeline company before using the transmitter to apply a signal or before locating.

2 Applying the transmitter signal



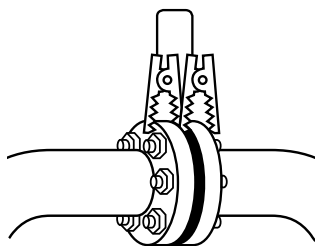
- ☐ The large surface area of the pipe means that the transmitter signal leaks to ground over a shorter distance than from a cable. The same signal leaks away over a much shorter distance from a large pipe than from a small one. It is therefore important to make a very effective connection of the transmitter signal.
- ☐ The transmitter signal can be applied to a cathodic protection test point used for measuring CP potential.

It is necessary for the transmitter to have a good ground in order to apply as much signal as possible to the pipe. Where possible connect the ground lead to the ground wire or stay wire on a pole or to a metal fence.



- ☐ The signal can be applied across an insulating flange/joint. The transmitter ground lead can then be connected to the far side of the insulating flange/joint and should provide a good quality ground return.
- ☐ The signal can be connected to the dc output of a CP transformer rectifier with the ground lead connected to the positive cable of the transformer rectifier. Isolate the ac supply when the transmitter is connected to the CP installation.
- ☐ Sometimes there is difficulty getting the signal to travel in the desired direction along the pipeline. Connecting a distant CP test point to ground will draw the signal in the required direction.

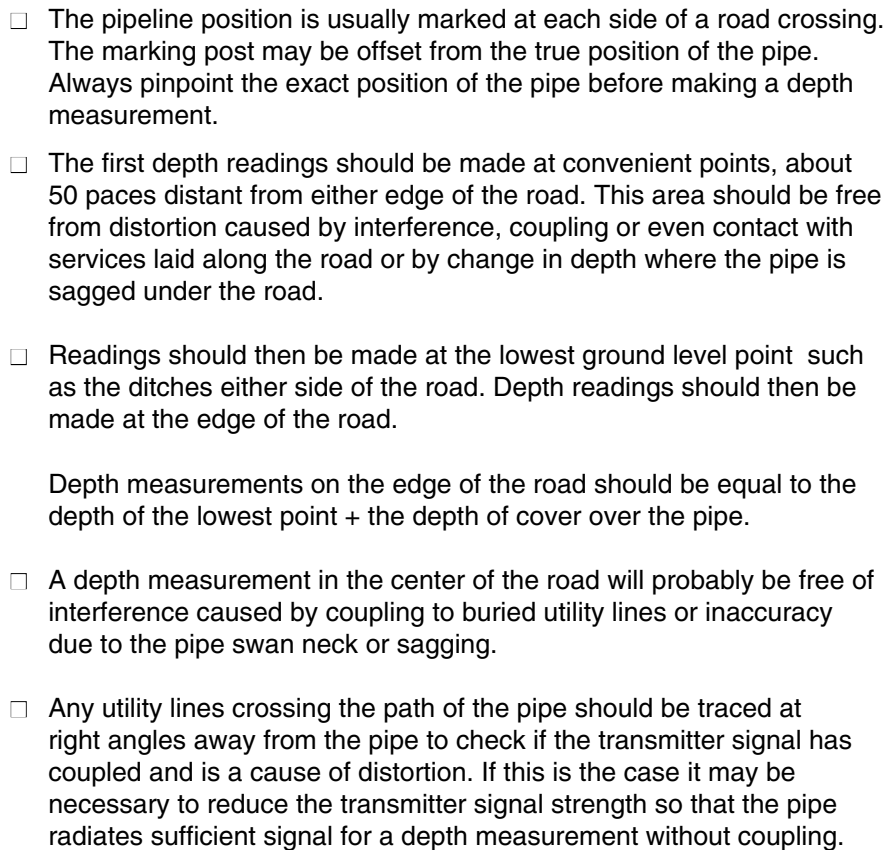
3 Tracing the Pipeline



- ☐ It is not possible to define the maximum tracing distance along a pipeline. Maximum distance is dependent on pipe size, coating condition and soil resistivity. Typically a 4 Watt transmitter signal can be traced for up to 20 kms/12 miles on a well wrapped 16in pipe.
- ☐ It is important to know of the presence and position of any insulating joints or flanges so that they can be bypassed with a jumper lead.
- ☐ Meter stations, or other plant can be bypassed with a long lead to provide maximum tracing distance from a single transmitter application.
- ☐ A pipeline transporting hot product has thick insulation to reduce heat loss. The thickness of the insulation and the lack of bonded coating reduces the signal strength along the line and underlines the need for very effective transmitter signal and ground connection.

4 Road crossings

Confirming depth of cover at road crossings is a common requirement



- ☐ The pipeline may run through a sleeve under the road crossing. The sleeve may cause a loss of response along its length. The response should return a few paces from the far side of the sleeve, provided there is no contact or coating defect within the sleeve.

Depth measurement will probably be inaccurate over a sleeve.

- ☐ The sleeve may be in contact with the pipe either because of faulty installation or because of ground movement. This will be indicated by a sharp and permanent drop in response.



- ☐ Make a current measurement on the pipe 50 paces away from each side of the road crossing.
- ☐ Any change other than an extension of the normal rate of signal attenuation may require investigation.

5 River crossings

Small river crossings present less of a problem for locating or depth measurement because there are seldom any utility lines running along the river.

The procedure for road crossings may be used for pinpointing the pipe and measuring depth at 50 paces from each side of the crossing and then at the edge of the river bank.

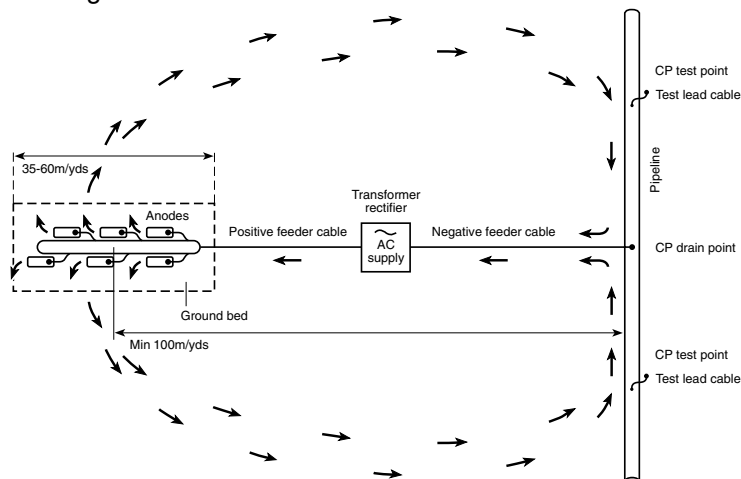
Problem solving cathodic protection systems

Cathodic protection systems are an almost universal solution for protecting pipelines from corrosion. Electromagnetic locators can solve numerous problems that affect cathodic protection systems.

1 Tracing and faultfinding the feeder cables from the transformer rectifier



A higher voltage and lower current reading at the transformer rectifier indicates a problem with either of the feeder cables or with the anodes in the ground bed.



- ☐ Isolate the ac supply to the transformer rectifier when locating and fault finding.
- ☐ *Locating the positive feeder cable.* Direct connect the transmitter to the positive feeder cable at the transformer rectifier and the ground lead to the transformer rectifier ground or the negative feeder cable provided there is no parallel run.

Trace the cable from the transformer rectifier to the ground bed.

A sharp loss of response indicates a broken cable or ground bed connection point.

- ☐ There may be a *faulty link to one or more anodes* in the ground bed. It is simple to use the locator to locate the problem if there is access to the connection between the positive feeder cable and the anodes.

Make a direct connection to the anode test post after disconnecting it from the feeder cable. Make a ground connection with a stake in the ground bed.

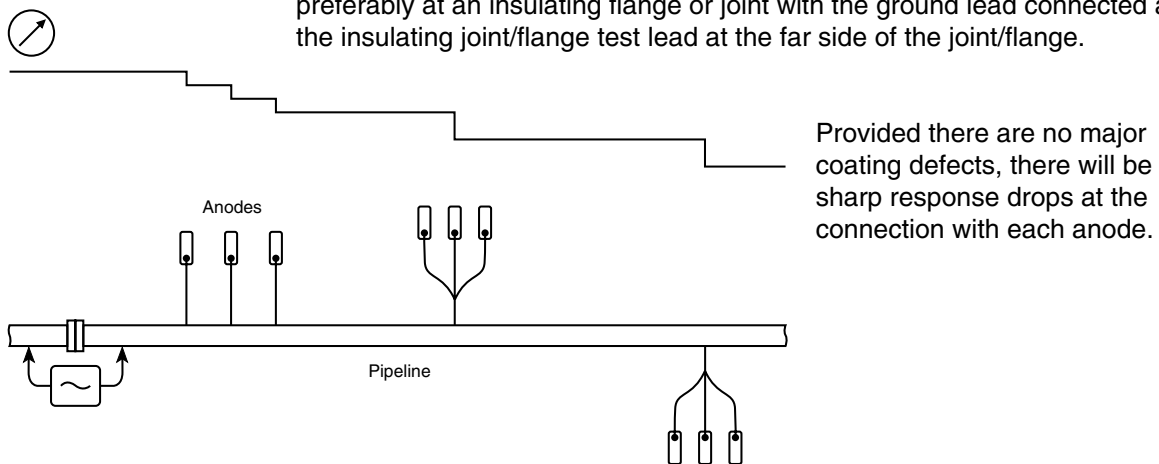
Use the receiver to check the signal on each anode lead in turn. Each lead should provide an approximately equal response. A lead with a significantly lower response indicates an anode which may have expired.

- ☐ Tracing and fault finding the negative feeder cable. Direct connect the transmitter signal to the negative feeder cable at the transformer rectifier and the ground lead to the transformer rectifier ground point or to the positive feeder cable provided there is no parallel run. Trace the signal on the feeder cable to the CP drain point and in either direction along the pipe.

A sharp drop in response indicates a cable break or fault or change in depth.

2 Locating sacrificial anodes along the pipeline

Connections from the pipeline to sacrificial anodes can be located by applying a signal to the pipe preferably at an insulating flange or joint with the ground lead connected at the insulating joint/flange test lead at the far side of the joint/flange.



3 Measuring ac current on the pipeline

Tracing the pipe in the Power passive locate mode will give an indication of the amount of 50/60Hz stray current on the pipeline. Some locator types may provide an mA reading. This reading is unlikely to be precise because of the fluctuating 50/60Hz energy but may be used as a basis of comparison.

4 Testing integrity of an insulating flange

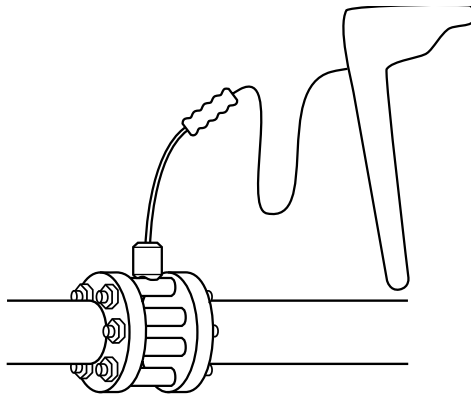
Connect the transmitter signal to the insulating flange test lead and make an independent remote ground connection.

First connect a jumper lead across the insulating flange and trace the pipe on the unprotected side away from the flange. Mark the path of the pipeline. Then remove the jumper lead and transmitter.

Reconnect the transmitter to the protected side of the pipeline, at least 50 paces from the insulating flange; a cathodic protection test point would be suitable. Trace along the path of the unprotected side of the pipeline with maximum gain. Any response will indicate that the insulating flange is faulty and passing current.

A faulty bolt on an insulating flange may be found by connecting the transmitter to a cathodic protection test point at least 50 paces from the insulating flange on the protected side of the pipeline. The faulty bolt conducting current can be found by applying the stethoscope antenna to the threaded shank of the bolt between the two halves of the insulating flange.

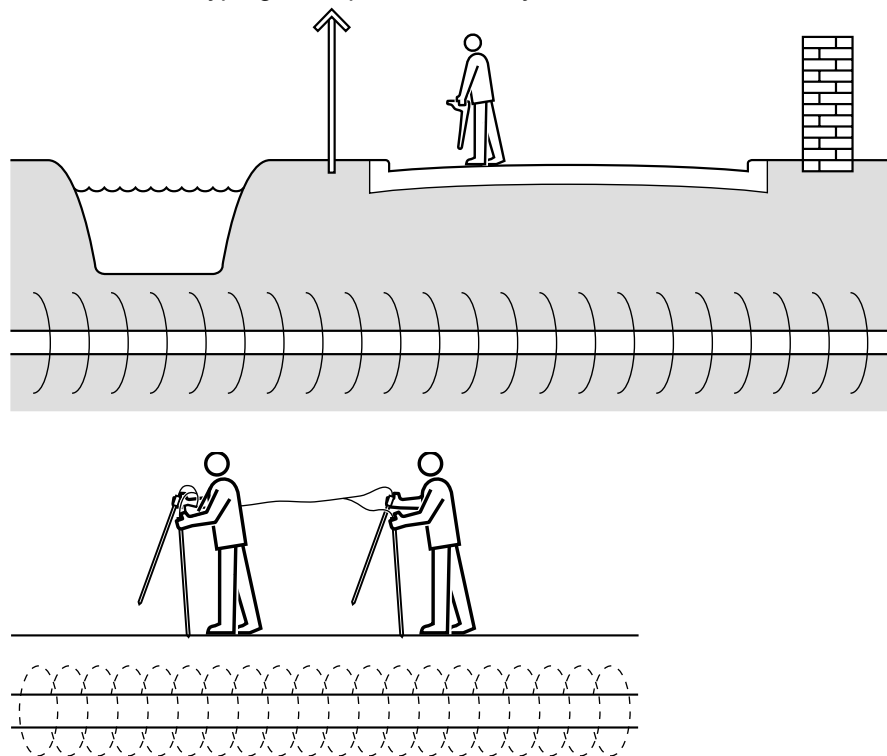
Examine each bolt in turn to find which gives a response and is therefore faulty.



Monitoring and investigating pipeline coating condition

The corrosion engineer needs as much information as possible about the condition of the coating of the pipeline.

There are two techniques for monitoring the condition of pipeline coating and locating holidays or coating faults: a current gradient survey and the classic Pearson type ground potential survey.

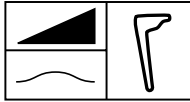


- ☐ Either or both sets of results should be used in conjunction with any cathodic protection potential survey information to confirm the severity of any coating defects. The cathodic protection potential survey results may be obtained from the periodical potential surveys or a full close interval potential survey (CIPS).
- ☐ Active corrosion on the pipeline corresponds to a low resistance fault and consequent high current loss; the greater the amount of corrosion and electrochemical reaction the greater the loss of current. The current gradient system therefore gives a direct indication of the comparative importance of coating defects on the pipeline.

- ☐ A current gradient survey indicates current loss over a particular section. A ground potential or Pearson type survey indicates voltage loss only at the point where it occurs.
- ☐ A 50km/30 mile length of pipe can generally be surveyed by one man in one day using the current gradient technique. No more further survey work may be needed if it is found that there is no serious loss of current.
- ☐ The current gradient system takes readings at intervals and indicates that there is a loss of current between two points A and B. A and B may be 50 metres/yards apart or up to 5km/miles apart.
- ☐ The current gradient system can be used to draw a profile of current loss for a complete pipeline from readings taken at points of around 3 or 4km/miles apart. Readings taken at intervals of, say a year, will indicate any increase in the deterioration of the coating.
- ☐ A section shown to have a high current loss after taking current readings at intervals of several kms/miles can be monitored in detail with a ground potential or Pearson type survey and defects in the pipe coating located to within a few metres/yards. The larger the fault, the more precise the location.
- ☐ Current gradient readings may be taken through all types of soil or on all types of surfaces such as roads or through crushed rock. Readings can even be taken from a boat on a river or shallow lake. Ground potential or Pearson type survey is only effective when the survey poles make an effective electrical ground contact.
- ☐ The ground potential or Pearson type survey gives similar readings for high or low resistance defects and so does not give information about the comparative importance of corrosion areas. However, it is a more sensitive system and can indicate high resistance faults in the coating where corrosion is not occurring or not established.
- ☐ A useful feature of a current gradient survey is that during survey work the data from a reading may be evaluated against information obtained from a previous reading. If required intermediate or additional readings may be made before moving on with the survey. Alternately a ground potential survey may be conducted using the same signal application from the transmitter.

Both types of survey contribute important information. Making a current gradient survey along a pipeline indicates if any sections, and if so which, need more detailed investigation. This may be done by making a ground potential Pearson type survey or a more detailed current gradient survey along the suspect length of pipeline.

Current gradient survey



A receiver measuring signal in decibels is needed for conducting a current gradient survey. mA current readings can be converted to decibels if the receiver does not include a feature to provide decibel readings: $\text{dB} = 20 \log_{10} \text{mA}$.

Apply the signal to the pipeline with a direct connection to an insulating joint lead and use the far side of the insulating joint for the ground connection. Alternatively connect to a CP test point with a good remote ground connection.

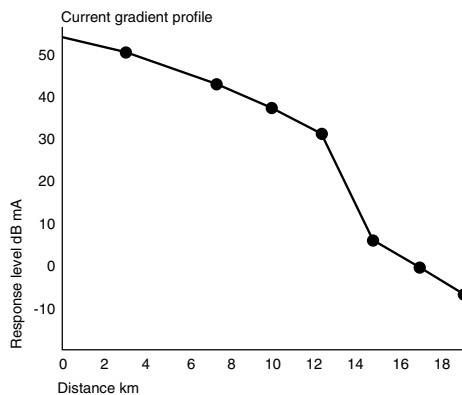
Pinpoint the position of the pipe and make a decibel reading.

Proceed to the next convenient access point and repeat the pinpoint and decibel reading.

Continue taking readings at convenient access points to the pipeline. The example shows readings taken at 3, 7, 10 etc kms from the transmitter application.



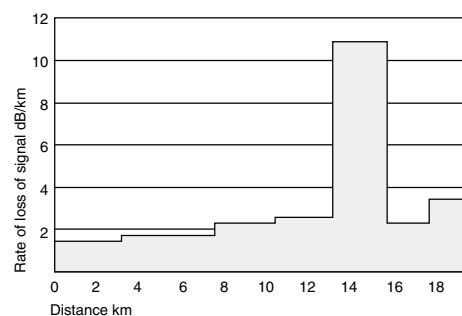
4



Record the distance and the dB reading manually or in a data logger.

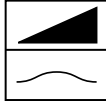
Draw a profile of the pipeline current gradient.

It may be useful to make a second graph to highlight sections with a high rate of current loss.

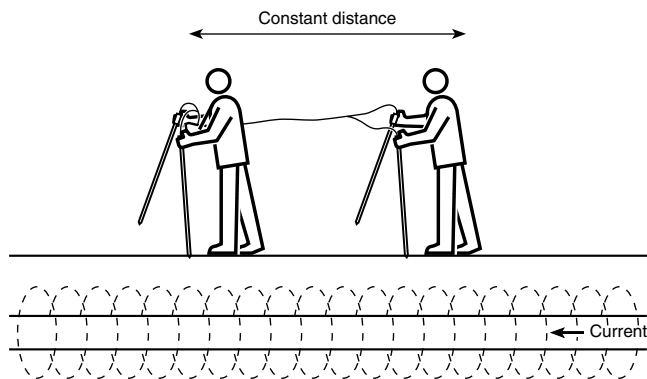


A more detailed current gradient survey can be made over suspect lengths of line by walking the line and making current measurements at convenient intervals, perhaps 100 paces. The fault can then be located by repeating the current measurements at 1m/yard intervals within a suspect 100 paces area.

Ground potential Pearson type survey



Ground probes can be used with the receiver to make a ground potential survey similar to a conventional Pearson type survey over a length of suspect pipeline.



The ground potential is detected by four ground probes connected to the receiver. A steady decay of voltage is observed by making ground contacts at two points above the buried line and keeping their separation constant as they are moved along the line.

Any defect in the insulation of the buried service which permits a current flow directly between pipe and ground results in a high ground potential. This is observed as a high reading at the receiver as each of the ground probes passes the fault point.

Procedure

Apply a transmitter signal with a good ground connection.

- 9.1.2 The two operators position themselves directly above the pipe, with the signal wires connected to the ground contact probes and the wire reasonably taut between them; this defines the separation distance.

The lead operator usually holds the receiver. It may be necessary to locate and pinpoint the line at intervals if it has not already been marked.

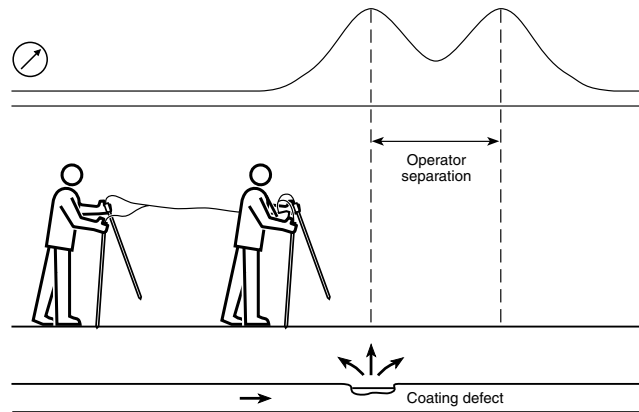
With both poles making good ground contact, the receiver sensitivity is set to give a reading of approximately 25% of full scale.

The operators proceed along the pipe, one behind the other, each maintaining at least one ground contact at all times.

The receiver gives a continuous response as the survey progresses which gradually decreases so that occasional re-setting of the sensitivity level may be required.

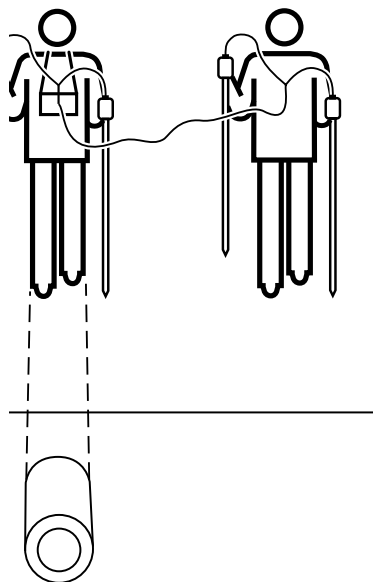
Part 9 Section 5. Ground potential Pearson type survey

A defect in the pipe insulation is indicated by an increase in response which peaks as each operator crosses it and a null response when the operators are to either side of the fault.



The fault is pinpointed by moving the probes a short distance at a time to obtain the highest possible reading.

Pinpointing a fault may be easier if the operators change orientation so that the lead operator is above the pipe and the other is to the side.



Part 10. Locating metal and plastic water pipes

Locating buried metal water pipes has always been one of the principal applications for electromagnetic locators. Successful pipe location is not only important for providing information to avoid third party damage but also to help pinpoint the position of leaks.

Recently PVC and polyethylene have become a near standard for small and medium size pipe for water distribution, for sprinklers and for irrigation. This plastic pipe cannot be located with electromagnetic locators and a new locating technology has been devised to locate buried plastic water pipes.

- Section*
- 1 Locating metal water pipes*
 - 2 Locating tracer wires buried with plastic pipe*
 - 3 Locating plastic water pipes*
 - 4 Locating leaks in plastic pipes*
 - 5 Locating lost valve boxes*
 - 6 Locating the water in water pipes*

Part 10 Section 1. Locating metal water pipes

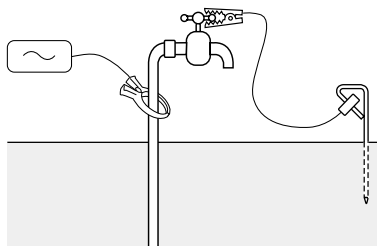
Locating metal water pipes



2

All the basic locating techniques are useful for locating buried metal pipes.

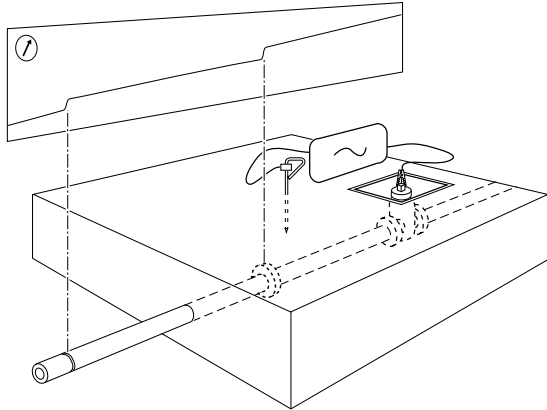
Water distribution systems usually have stop taps or valves at tees and property boundaries. This frequency of access points makes applying a direct connection signal simple and effective.



Care should must be taken to check if the signal has coupled to buried cables through bonds in a nearby building. Check that the water pipe and not the power cable is being traced.

Clamping the signal to a metal water pipe is an effective method of applying a signal. Ensure that the pipe is grounded either side of the clamp.

There is often difficulty tracing high resistance iron pipes with bell joints and elastomer seals. The difficulty increases if the pipe is new with an anti-corrosion coating or if it has been in the ground a long time with a large part of its ferrous content corroded away.



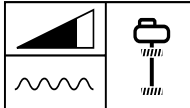
If a high frequency transmitter signal does not travel further than 2 or 3 lengths of pipe it may be necessary to use a high power and very high frequency signal, in excess of 100kHz, to get a detectable signal to travel a reasonable distance up to two or three hundred paces. Beware of identification problems caused by coupling to nearby lines. Be aware if the signal has coupled to an adjacent line and trace both lines. Check line identity by visual clues such as valve box covers.

The problem of successful signal application is exacerbated if a cable runs parallel to the iron pipe. The majority of the signal will find a preferred path along the cable and it will not be possible to detect any signal on the pipe. Leapfrogging an induction signal is not effective and a double ended signal application may be the only method of applying a satisfactory signal to trace the water pipe.



Sometimes using the alternative induction method of laying the transmitter on its side so that the axis of the transmitting aerial is vertical, will enable the offending cable to be eliminated and the pipe to be located.

Locating tracer wires buried along plastic pipe



Burying a tracer wire with a plastic pipe has become common practice. However no standard or code has been established to ensure that the tracer wire is an effective means of locating the pipe.

Look for a tracer wire end, tag or loop at the meter, valve, hydrant or pipe end. Make a direct transmitter connection to the wire and trace the wire and pipe. Technique for tracing and locating will be similar to tracing a metal pipe. Beware when digging because the tracer wire may not be directly above the pipe.

In many cases the tracer wire is just thrown in the trench and not terminated above the ground. The only way to apply a transmitter signal is by induction with a very high frequency signal well in excess of 100kHz, possibly as high as 500kHz. Such a high frequency signal will not only energise the tracer wire but will also couple onto any nearby line and any reinforcement mesh or bars in the ground. Use great caution tracing this signal. Be sure that the receiver is not picking up the signal directly from the transmitter; it may be necessary to go as far away as 30 or 40 paces. Search the area for signal which has coupled to other lines and trace all energised lines away from the transmitter before deciding on the identity of the tracer wire over the target pipe.

Locating plastic water pipes

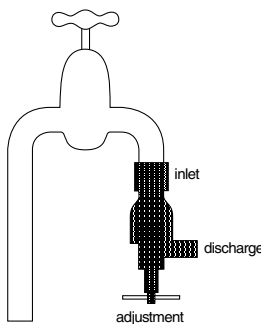
There have been a number of attempts at solving the problem of locating plastic water pipes. The best known was a technique of vibrating the column of water at a relatively high frequency and then using a tuned audio sensor to locate the signal. The high rate of signal attenuation combined with the high cost of this sophisticated technology has recently led it to be overtaken by a more simple and more effective technique of using a pressure wave for the signal.

This technique, devised by the Heitman Laboratories, Allen, Texas is based on producing a pressure wave along the pipe and detecting it from the surface with a receiver fitted with a seismic sensor.

In favourable conditions it should be possible for the user to define the pipe position to an accuracy of $\pm 30\text{cm}/12''$ along distances of up to 200 paces.

- 1 The transmitter
- 2 The receiver
- 3 Using the locator
- 4 Applying the transmitter signal
- 5 Tracing with the receiver
- 6 Applications

1 The transmitter The transmitter is a spring loaded oscillator in a special housing and is fitted to the end of a water pipe or to a hydrant. There is an adjustment to control the pulse rate of a continuous series of pressure waves along the water in the pipe at frequencies ranging between 5 and 50Hz.



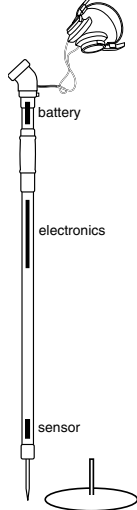
The pressure wave generated by the oscillating transmitter does not exceed the rated pressure of most water supply systems. To avoid the risk of damage it should not be used for extended periods or used on old substandard plumbing installations or a system with lead piping.

The transmitters are designed to operate with water pressures ranging between 1.5 - 11 bar/20-160psi.

The transmitter has to be sized correctly to fit the pipe diameter and water velocity (combination of water volume and pressure). Manufacturers offer a range of transmitters suitable for fitting to pipes ranging from sprinklers and service lines to medium sized water mains.

Each transmitter comes with a range of adapters to fit taps, fittings, faucets or hydrants. Choice of transmitters to suit an application is made from the manufacturer's sizing table.

2 The receiver



The receiver's function is to detect and locate the position of the pressure wave signal generated by the transmitter.

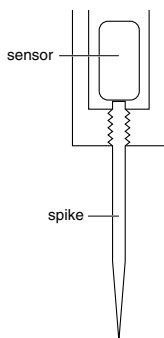
The hand held receiver comprises a seismic sensor connected to a spike, electronic circuitry to process the signal from the sensor, a visual display and a loudspeaker or headphone to indicate the response. The response to the signal can be controlled by adjusting the receiver sensitivity level. The receiver is powered by a battery and includes a display to indicate battery state.

The spike has to be pressed on or into the ground and make good ground contact to obtain a response from the transmitter signal.

The locating set usually includes a ground plate when the receiver is used over a paved surface. The plate replaces the spike at the bottom of the receiver and is pressed on the ground to transmit signal to the receiver sensor.

3 Using the locator

There are obvious parallels with an electromagnetic locator: a transmitter to apply the signal to a target pipe and a receiver to locate the signal and trace the pipe.



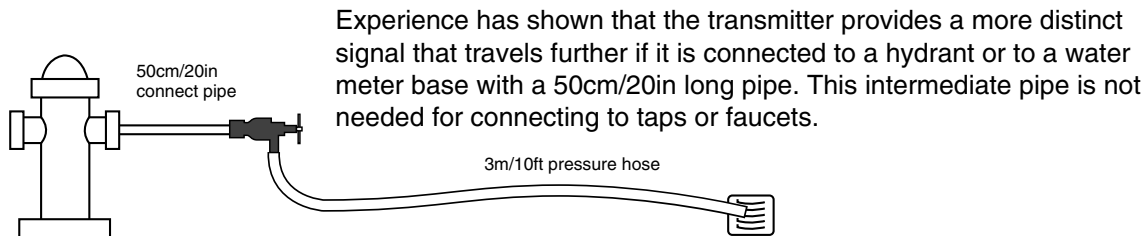
However, there are important differences:

- ☐ The electromagnetic signal transmitter is completely self-contained with its own power source as well as its signal processing. The transmitter of the plastic water pipe locator depends on an outside power source; a combination of water pressure and flow. And this external power source can vary as a result even of flushing a nearby wc. Lack of consistency of the power source often means adjusting the transmitter setting to get the continuous pulse necessary for locating.

Pipe tracing is speeded up if there is a second person by the transmitter making setting adjustment in response to variations in water supply velocity.

Manufacturers' user instructions indicate that a steady, slow pulse from the transmitter gives the best tracing signal. This is often the case but the most suitable pulse rate can only be determined by trial and error; by detecting the signal 5 or 10 paces from the transmitter,

adjusting the transmitter through its range and then deciding which pulse rate is most effective and positive for tracing the pipe.



- ☐ Transmitter performance is improved by connecting a 3m/10ft high pressure hose to the transmitter discharge. The length of the hose creates a back pressure that often makes the difference between a failed and a successful signal application. A garden hose with its flexible walls is not suitable. The hose also has the advantage of channelling the waste water to a convenient container or drain.
- ☐ A clear pulse from the transmitter is dependent on the oscillator making a tight seal with each pulse. Dirt on the seat causes the seal to leak and renders the transmitter ineffective. And any reduction in water flow also makes the transmitter ineffective. It is therefore essential to check that water is clear of grit or scale and the filter is clean before fitting the transmitter. A clogged filter is the most likely cause of transmitter failure during a trace. It is advisable to have replacements available in case of damage to the filter.
- ☐ Changes in ground conditions, a grass verge or paving for instance, do not affect locating an electromagnetic signal on a line. But ground conditions can seriously affect reception of the pressure wave signal from the pipe. Good judgment of the reliability of the response on each locate only comes with experience. Tracing and marking the line for 10 paces both east and west of the area where the locate is to be made will help establish the path of the pipe to confirm the actual position of the pipe in the target area.

The character of the receiver response is different to the response from an electromagnetic receiver. The user must put his electromagnetic locating background to one side and learn to understand and use the response from a seismic sensor.

- ☐ Passing traffic, heavy movement or even wind are sources of interference and may cause the meter to indicate a reading. Listening to the audio response in the headphones and making the ear work together with the eye is critical for locating success. The ear can distinguish the transmitter pulse through almost all interference and qualify the response on the display. Ear and eye work together.

Part 10 Section 3. Locating plastic water pipes

The easiest and quickest technique for searching for the transmitter signal is to make a large number of quick locates about 60cm/24in apart rather than slow deliberate locates 15cm/6in apart. A quick locate will pick up the pulse signal and widely spaced locates provide a greater and more easily recognised contrast than locates that are close to each other.

A comparison
Electromagnetic and plastic pipe location

Similarities

- Time spent carefully applying the signal is crucial to the locate.
- Apply a signal from a service connection to the main
- Trace pipe away from the transmitter
- Use the receiver to get contrasting responses to locate the line or pipe.

Differences

- Unlike an electromagnetic transmitter the plastic pipe transmitter may need adjustment during a trace because of changes in water velocity
- Pressure wave signal does not couple to other services. Coupling can be a serious problem with electromagnetic locating.
- Flat response from a pressure wave signal perhaps up to 60cm/24" wide over a target compared to the narrow electromagnetic peak or null response
- Ground conditions affect response to a pressure wave signal, less precise under paving.

Electromagnetic locator response hardly affected by paving or ground conditions.

The diagram consists of two parts. The top part shows a person standing on a paved surface, holding a seismic sensor. A wide, flat, rounded response curve is shown above the sensor, indicating a broad area of detection. Below this, a circle represents the plastic water pipe. The bottom part shows a person standing on a paved surface, holding an electromagnetic receiver. A narrow, sharp, peaked response curve is shown above the receiver, indicating a precise location. Below this, a circle represents the metal water pipe.

Seismic sensor pressure wave response over a plastic water pipe

Electromagnetic response from a signal on a metal water pipe

- ☐ In good conditions there will be a sharp response about 30cm/12in wide over the pipe. In less suitable conditions such as under concrete or heavy paving the response may stretch over a 3m/10ft band. Attempting to define a peak signal in the band may be frustrating and may not be possible. If this is the case locate and mark the edges of the response area. It is probable that the pipe runs midway between the two edges. If possible locate the pipe before it enters the problem area and after it leaves it and check that the path of the pipe leads into the middle of the response band.
- ☐ Locating sets usually include a ground plate to be used in the place of the spike on a paved road. Opinion is divided as to whether the plate is more effective than a spike on a clean paved surface. Maintaining ground contact with the whole surface of the plate requires more time and care than pressing the spike on the road surface and is not effective if there is grit or gravel on the surface. Trial is necessary to make the best choice.

The above points may appear to make locating a plastic water pipe to be uncertain and complicated. This is not the case. Field experience will generate a "feel" for both setting the transmitter and tracing with the receiver. Technicians in the water industry accustomed to using audio devices for leak locating have little difficulty getting good results with a plastic water pipe locator apart from the complications of fitting the transmitter to the water source. Users of electromagnetic locators will have more difficulty because there is less logic and more feel to get a satisfactory pulsing signal and because more feel and judgment are necessary to interpret the receiver responses.

After only a little practice it should be possible to make satisfactory locates in the great majority of applications. And digging is the only alternative to a successful locate.

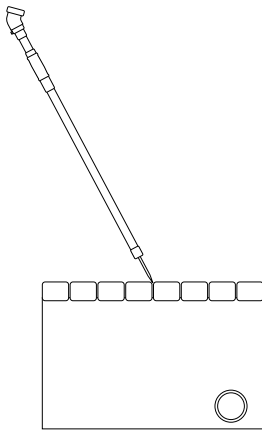
4 Applying the transmitter signal Choose a suitable point for fitting the transmitter to the pipe which is to be traced. A hydrant, water meter base, garden stand pipe or sprinkler head are all suitable. Beware of fitting the transmitter to a domestic tap or faucet. Vibration from the transmitter's mechanical action may damage the internal pipework unless the access point is well supported.

- ☐ Select the suitable transmitter for the application. The manufacturer's user information will include a table to match the transmitter and adaptors to the pipe and to the access point.
- ☐ Fit a connection 50cm/20in connection pipe if the transmitter is being fitted to a hydrant or a water meter base.
- ☐ Flush out rust, sealing compound, plastic shavings or silt from the tap or application point. Continue to flush until the water is clear.
- ☐ Check water pressure to ensure it is adequate for the locate and that the transmitter is correctly sized.
- ☐ The transmitter incorporates a washer filter. Check the filter is clean and replace if necessary.
- ☐ Attach the transmitter and adaptor to the access point. Hand tighten the transmitter. Over tightening may damage the washer filter
- ☐ Attaching a 3m/10ft hose to the transmitter discharge helps apply a clear and effective signal. The hose also channels the waste into a suitable container or drain.
- ☐ Turn on the water and fully open the valve or tap.
- ☐ Adjust the transmitter control to apply 2-6 pulses/second. Lock in the adjustment setting to prevent vibration creep. Generally the slower the pulse rate the further distance and the more distinct the signal. However, a faster pulse rate may be more suitable for some applications. Trace the pipe for 5 or 10 paces and then adjust the transmitter pulse rate through its range to determine which pulse rate is the most effective and positive.

It may be necessary to adjust the transmitter control to maintain a suitable pulse rate if there is any change in water pressure or flow.

5 Tracing with the Receiver Check the spike is firmly screwed in the bottom of the receiver and in contact with the sensor.

- ☐ Locate the position of the pipe three or four paces distant from the transmitter. Sweep to detect the signal and locate the pipe by pressing the receiver spike into or onto the ground at 60cm/24in intervals until there is a positive response.



- ☐ Use the visual display to gauge the strength of the response and the audio response to recognise the pulse signal through any interference. Adjust sensitivity as necessary to keep the meter on scale.
- ☐ Trace the pipe away from the transmitter at intervals of about two paces. Make several locates at each stop to verify the position of the peak response. If there is difficulty determining a peak response locate each side away from the path of the pipe to a point where no response is found. It is probable that the position of the pipe is in the center of the response band.
- ☐ After 5 paces adjust transmitter control through its range to give the most effective tracing signal.
- ☐ Slanting the receiver at 45° with the spike firmly in or on the ground may help pulse recognition. Slanting the receiver increases the surface area of the spike contact with the ground.
- ☐ Fitting the ground plate in the place of the spike may give improved response on a paved surface. Press the plate hard and evenly on the ground for the best result.
- ☐ Continue tracing until the signal runs out and there is no more response from the receiver. Audio response will usually be present for some distance after the disappearance of any visual response. It may be possible to increase the tracing distance from the transmitter by adjusting the transmitter pulse rate.

6 Applications

Tracing long distance water mains can be speeded up by fitting two transmitters and applying their pulse signals at the same time.

In typical suburban areas hydrants are spaced about 200 paces from each other which about corresponds to distance of signal travel on a water main. Fitting a transmitter to the first hydrant, then missing out a hydrant and fitting a second transmitter to the next hydrant will provide a signal along 800 paces. The effect of two pulse signals on the pipe between the transmitters appears to amplify the signal and result in an improved response.

An electronic listening stick for detecting water leaks can be used for locating the pulsing transmitter signal.

In some areas it may provide a more positive response and be easier to use. However, a seismic type receiver usually provides a response for tracing longer distances than a leak locator.

Some procedures for successful locating with electromagnetic locators are relevant, such as applying a signal from a service connection into a main rather than the reverse.

Locating water leaks in plastic pipes

Conventional acoustic leak location methods are often ineffective finding leaks in plastic pipes, especially if the pipe is buried in soft soil or sand with their qualities of absorbing sound, or the leak is large, makes little noise due to saturated ground and does not show on the surface.

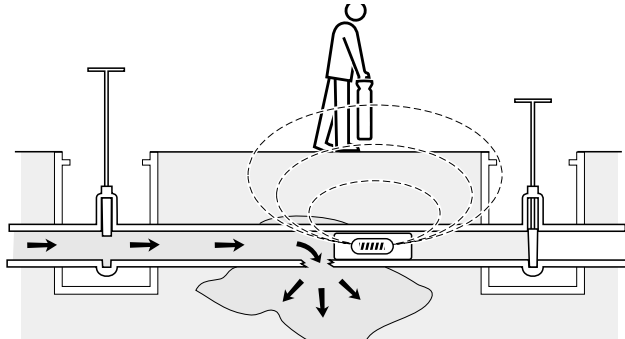
Leaks can be found by inserting a sonde as a piston in the pipe, and monitoring its progress from the surface.

Select a sonde with a suitable range and a suitable size to fit in the pipe.

Check the sonde is clean; suitable for inserting in a water service. Wrap it round with plastic foam to give a tight interference fit in the pipe. Check that the swab and sonde move freely in a sample length of pipe and also act as a piston.

Cut into the pipe and insert the detectable foam swab which becomes a piston in the pipe.

Close the downstream valve and open the upstream valve. The detectable piston will move along the pipe and come to a stop at the point of the leak.



Keep the receiver directly over the sonde as it moves down along the pipe by maintaining the peak response. It may be necessary to crack open the downstream valve to get the piston on the move. If sonde progress is too rapid it may be necessary to throttle the upstream valve to reduce flow.

The piston will halt its progress along the pipe just beyond the leak position. Or it may continue its progress at a much slower rate if the leak is small; it should be simple to monitor the point at which the speed changes.

Correct setting of the valves is made easier if a flow meter is inserted close to the upstream valve.

Determine the flow rate required to achieve a comfortable speed for monitoring sonde progress and adjust the valve as necessary. The flow rate should increase when the sonde passes the leak. This provides a means to confirm that the piston has stopped because of the leak and is not jammed at an obstruction.

It may be possible to insert a small size sonde in a swab into the pipe by pumping it down a fire hydrant or by removing a valve bonnet.

Locating lost valve boxes

Valve boxes easily become lost under a layer of new blacktop or in vegetation in the verge. It is important to locate these boxes to gain access to the valve in order to isolate or control sections of the distribution system.

There are two recognised methods of locating lost valve boxes.

- ☐ A cover locator to detect the position of a valve box cover.
- ☐ A magnetometer to locate the valve stem in the box.



2.9

A metal cover locator will find a 10cm/4in square valve box cover at depths down to 30cm/12in. Plastic valve box covers usually have a thin steel backing plate which can be detected to 70% of the depth of a traditional iron cover.

A standard magnetometer designed for locating property boundaries is very effective for locating an iron valve stem under a cover. It will detect a Ø20mm/3/4in stem at depths down to 50cm/20in.

Locating a lost cover is simplified and more speedy if the path of pipe can be traced so that sweeping with the cover locator or magnetometer is focused over a small area along the pipe.

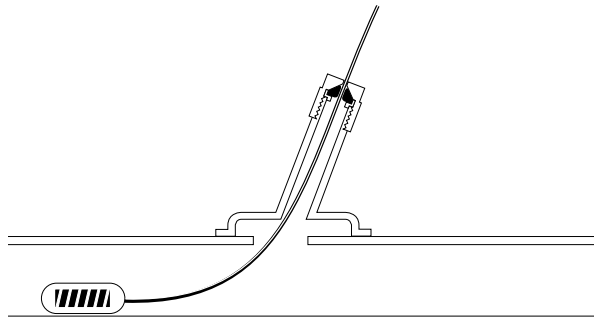
Tracing the water in a plastic pipe

The impurities in water make it slightly conductive and there are often claims of success in tracing plastic water pipe after applying a high power signal to the water by induction or with a clamp.

There is little doubt that a small minority of these claims are genuine but in most cases the transmitter signal coupled to a cable close to the water pipe and running parallel to it.

Attempting to apply a transmitter signal to a column of water in a water pipe should not be attempted as chances of success are negligible.

If a seismic type locator is not available the only way to trace the pipe is to insert a sonde and locate from the surface as it is pushed along the pipe on the end of a flexible rod.



Part 11. Locating and tracing sewers and drains

Most drains and sewers are made from plastic, brick or asbestos cement. They have frequent access points from manholes and are therefore suitable for tracing with a receiver and sonde.

Steel or metal sewers should be considered as large pipes and be located conventionally by applying a transmitter signal at an access point and tracing with a receiver.

Part 11 Section 1. Tracing sewers and drains

Tracing sewers and drains

Sondes were originally designed for tracing sewers and drains. Over the years a range of sondes have become available offering combinations of size, range and battery life. The smallest sonde attached to the end of flexible rod is only $\varnothing 8\text{mm}/0.32\text{in}$ for tracing $\varnothing 25\text{mm}/1\text{in}$ pipes and drains at depths down to $\varnothing 1.5\text{m}/5\text{ft}$. At the other extreme large sondes $\varnothing 64\text{mm}/2.5\text{in}$ can be located in deep sewers at depths down to $15\text{m}/50\text{ft}$.

There is a suitable sonde available for almost every tracing application in drains or sewers.

- ☐ Sondes provide an adequate signal even from asbestos cement or concrete pipes with a tight metal reinforcing mesh. Location range may be reduced and it is advisable to check that there is sufficient signal from a particular pipe to be traced at the required depth.

A sonde will not transmit its signal through a steel plate or manhole lid.



2.8.2

- ☐ There are a variety of methods for propelling the sonde.



2.8.3.
3.5

- ☐ Follow the standard procedures for tracing the sonde. Remember that the sonde may not be in the center of the sewer when it is being pinpointed.

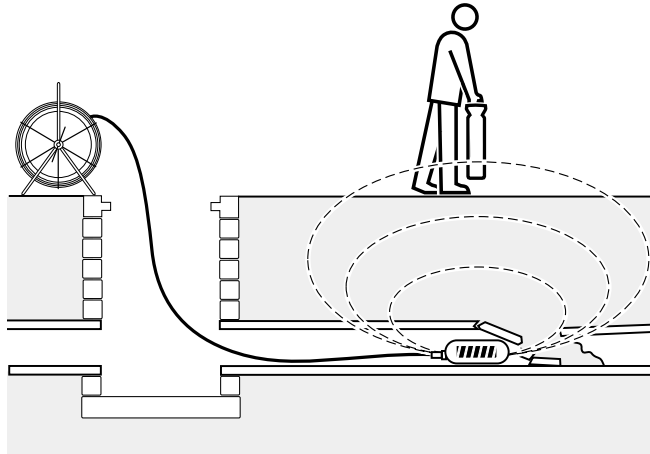


2.8.6

- ☐ Follow the standard procedure for measuring depth to the sonde. Depth to the top of the sewer will be less than the distance to the sonde which may be floating or lying on the bottom of the sewer.

Part 11 Section 1. Tracing sewers and drains

- ☐ Sewer blockages and collapses can be pinpointed from the surface. The progress of the sonde along the drain is stopped by the obstruction.



Locating manhole covers and lids

Manhole covers are often lost under a coating or successive coatings of black top. It's important to find them to gain access to the sewer.



2.9

Use a cover locator to find lost manholes. Searching time is reduced if the approximate location of the cover is known. Tracing a sonde along the sewer defines the area to be searched. The cover is probably where the sonde signal is lost under the metal shield of the cover.

Locating inspection cameras

The purpose of an inspection camera is to provide information. Knowing the position of the camera from the surface enhances the value of the information.

The ground can be marked directly over situations requiring remedial action or the position of the camera can be pinpointed in the event of it becoming stuck.

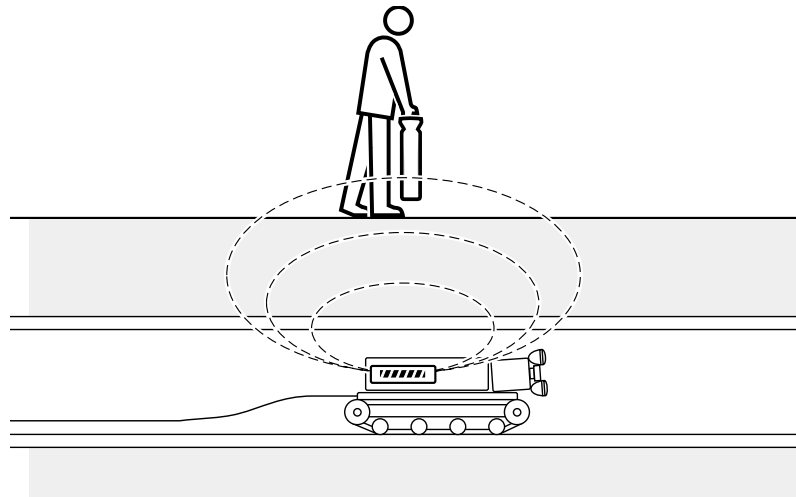
Some manufacturers of camera systems incorporate the sonde element inside the camera housing and feed it from the existing power supply.

A sonde element can be fitted inside a large camera or a sonde with its independent battery supply can be attached to the outside housing of the camera.

Sonde location range may be reduced if the sonde is fitted inside the camera. Check location range with the camera supplier to check that it is suitable for the application.



In each case, the routine of monitoring the progress of the camera and pinpointing its position is the same as locating and tracing a sonde.



Part 12. Information for successful horizontal boring

Horizontal boring is increasingly replacing trenching for laying new utility services. A successful bore may be defined as 'Reaching a defined termination point as directly and efficiently as possible without damaging existing utility services'. Accurate and reliable information is necessary for successful boring.

Section 1 Locating before boring

2 Monitoring a short bore

3 Information for steering guided boring tools

4 Information for deep bores

5 Recording bore information

Part 12 Section 1. Locating before boring

Locating before boring

It is probable that a bore in a town or in almost any built up area will run past or beside existing buried utility lines. A path and depth for the bore must be chosen to avoid the possibility of damage to these lines.

The start and termination points of the bore are defined at the outset and the depth of the bore will be determined by the type of service to be installed in the bore, the soil type and the road classification.

It is necessary to detect the presence of any buried utility lines, locate their position and measure their depth. It should then be possible to plan the bore to avoid damage.

- ☐ Obtain drawings, plans or available information from local owners of buried plant. Check if any of their lines cross the path of the bore or run close to it.



- ☐ Locate the lines indicated to be in the proximity of the bore path. Apply the signal at convenient access points on either side of the bore and trace the lines across the bore path.

- ☐ Pinpoint any line in the bore path and measure its depth.



- ☐ Make a passive sweep along the path of the bore to check if there are any unknown cables. Trace them from the area of the bore to a convenient access point for applying the transmitter signal. Trace back across the bore, pinpoint and make a depth measurement.



2.7.2

- ☐ Make an active sweep if there is any possibility of undetected lines remaining in the area of the bore.
- ☐ Some utilities, particularly iron pipe, may be damaged by soil compaction from the bore. The bore must be planned to allow sufficient distance from these pipes or cables.

Complete information about the position and depth of existing utilities will contribute to planning the route and depth of the bore.

Monitoring a short bore

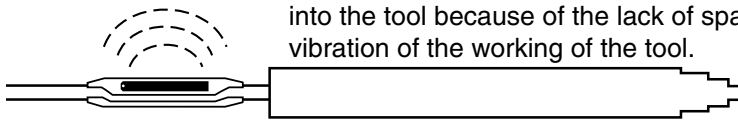
Most short bores are made with a ground displacement or percussive boring tool from a launch pit and aimed to a retrieval point.

1 Although short bore ground displacement tools cannot be steered it is important to monitor the position and depth of the tool as the bore progresses.

- ☐ The bore can be aborted and restarted if it has been deflected beyond an acceptable tolerance. The deviation can be detected early in the bore and wasted boring time reduced.
- ☐ The depth of the tool can be measured and boring halted if there is a danger of damaging an existing utility line.
- ☐ If desired and if the tool is on course the bore can be continued for a longer than planned distance. The extended bore can be halted if the tool deviates off its course.
- ☐ A tool boring through sand or soft soil may dive and be irretrievable. Information about its position and depth will enable the user to decide if it is economic to dig to the tool.

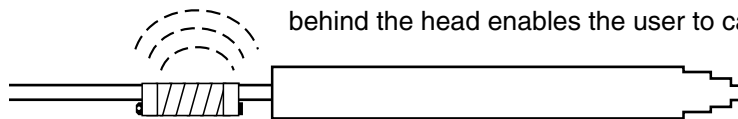
2 The most simple method of locating the boring tool is to attach a sonde immediately behind the tool. A standard receiver can then be used to locate the position of the sonde and measure its depth.

It is not practical to attach the sonde directly to the tool or to incorporate it into the tool because of the lack of space and because of the shock and vibration of the working of the tool.



The sonde can be attached to the hose immediately behind the tool

where it is not affected by the tool's vibration and shock. This position is not ideal as the sonde follows the tool. However, recognising its distance behind the head enables the user to calculate the position of the head.

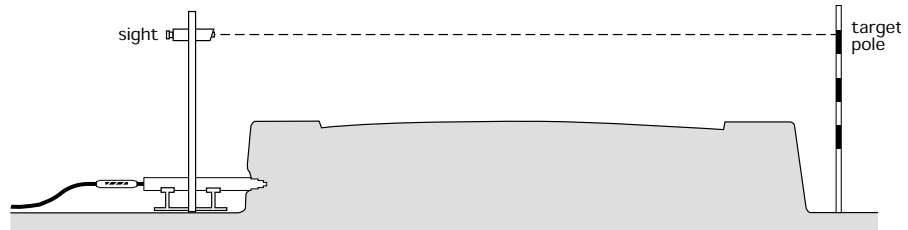


The sonde can be attached to the hose with clips or duct tape. Care must be taken to insure that the

size of the sonde attached to the hose is less than the diameter of the boring tool. Care must be taken when withdrawing the tool from the bore to prevent the sonde from snagging in the bore and being detached from the hose.

Recently manufacturers have designed a housing for the sonde that fits into the hose. The housing has a female thread at each end to fit a standard male hose fitting. Airflow equivalent to the full bore of the hose is maintained through the housing and past the sonde.

Part 12 Section 2. Monitoring a short bore



3 Procedure for monitoring the bore.

After determining the launch and retrieval positions aim the tool at the sighting pole in the retrieve pit. This defines the desired path for the bore. The tool may be deflected by a buried obstruction. Determine the amount of deflection that is acceptable and draw the width of the acceptable area for the bore on either side of the chosen path.

Determine a suitable depth of the bore that avoids damage to any pipes or cables in the path of the bore.

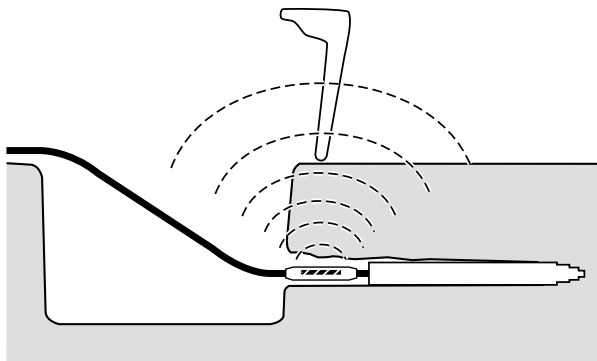
Insert a new battery in the sonde and attach the sonde to the hose or place it in the sonde holder. Measure the distance of the sonde from the head of the tool.



2.8

Follow the procedure for locating a sonde in order to monitor the progress of the bore.

Drive the tool into the bore. Stop with the sonde about 50cm/20in into the bore. Pinpoint the sonde position. Adjust sensitivity to a level that clearly indicates the peak response and eliminates any response to the ghost signals.



Proximity of the metal tool or the sonde holder may affect accuracy of a depth measurement. Make an electronic depth measurement and check the measurement with a tape. Any variation between electronic measurement and the actual depth will remain constant during the bore. Note the variant and use it as a factor to get a true depth measurement with each electronic depth reading.

Continue boring and stop to make a pinpoint to the sonde every one or two paces. Mark the position of the sonde and estimate the position of the tool head.

Note that the sonde does not give a positive indication of the position of the tool head. It indicates the position and depth of where the tool has passed. Marking successive pinpoints rather than making a single pinpoint during the bore will indicate the path of the tool and its depth.

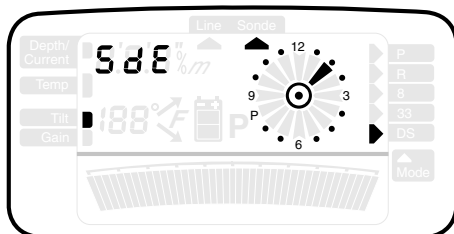
Information for steering guided boring tools

Comprehensive information is required at the tool controls throughout the bore in order to adjust the steering mechanism to guide the tool to its destination.

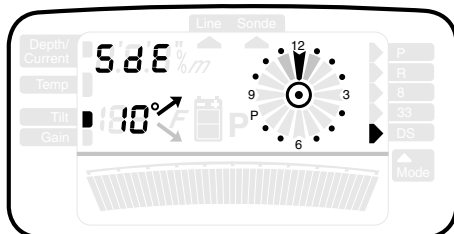
A special three part set of locating equipment is necessary; a sonde to provide position and depth information plus the information needed for making steering adjustments to the tool; a receiver to indicate the position and depth of the sonde and to obtain the information needed for steering. The receiver transmits this information to a display console situated at the machine controls at the launch point of the bore.

1 The sonde is fitted in the tool head or just behind it. The tool manufacturer is responsible for the design of the housing to allow the sonde signal to project through to the ground surface; slots are usually cut in the body as outlets for the signal. The tool manufacturer should provide information about the maximum depth of locating the tool and obtaining data transmission.

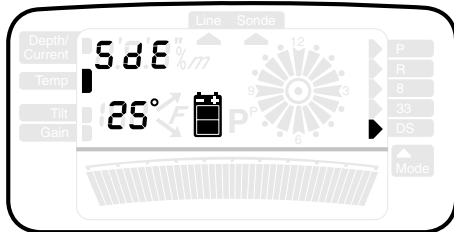
2 In addition to being a signal source for location and depth measurement, the sonde is fitted with sensors to transmit the following information to the receiver on the surface above the sonde in the boring tool.



Roll angle. The steering mechanism is used to change the direction of the bore. It is therefore necessary to know the roll angle so that the steering can be activated with the tool in the correct orientation.



Tilt angle. The tool steering mechanism also controls the inclination of the tool as well as its direction. Reading the tilt angle enables the operator to make steering decisions. It is mainly used to keep the bore at a constant inclination, usually 0°, but can also be used to run the bore parallel to the ground surface.



Sonde Temperature. In some circumstances the tool head can become very hot, sufficiently hot to affect the chemistry of the battery or even burn the electronic components in the sonde. Knowing sonde temperature enables the operator to stop boring when the sonde reaches 80°C (or other temperature defined by the manufacturer) and allow the tool to cool.

Battery life. Battery life may be reduced from its nominal rating by heat, vibration and shock. It is therefore important for the operator to know the battery state.

Some types of sondes extend battery life by incorporating a device to turn off the sonde until a reading is required or during a part of every tool revolution.

3 Sondes are primarily designed for use in pushing and hydraulic boring tools. Fitting a sonde in a percussive tool reduces its working life.

The sonde's working life is affected by the tool type and boring conditions. Tool manufacturers can advise the expected sonde life and it is prudent to send the sonde back to the manufacturer for revision and inspection at regular intervals to avoid sonde failure during a bore.

4 Sonde-receiver performance such as depth measurement range, location accuracy and data transmission is reduced when the sonde is fitted in the boring tool and it varies in different types of tool. It is important to use performance data from the tool supplier rather than from the sonde manufacturer when considering the suitability of a tool type for boring.

It is advisable to verify performance when acquiring a new tool by checking with the sonde fitted in the tool.

5 Procedure

Define the path the bore is going to take. The tool may be deflected by a buried obstruction. Determine the amount of deflection that is acceptable and draw the width of the acceptable area for the bore on either side of the chosen path.

Check that the sonde is fitted with a new battery recommended by the manufacturer.

Test the sonde - receiver - display console combination before starting the bore. Take the sonde and receiver to a point away from the display console that corresponds to the length of the bore. Put the sonde on the ground (in the tool head) and stand back from it with the receiver at a distance approximating to the depth of the bore. Twist and tilt the sonde to simulate its movement underground.

Point the receiver at the sonde and check that correct information is shown on the display and transmitted to the display console. It may be necessary to position the console aerial higher or in a different position to get good reception from the receiver.



2.8

The technique for locating a sonde in a boring tool is the same as locating a standard type sonde.

Use the receiver to interrogate the sonde at each locate to obtain roll and tilt information and information about sonde temperature and battery state.

It is usually necessary to halt the boring tool to make an accurate pinpoint and depth measurement and obtain information about the sonde. This can be done conveniently every time the bore is halted to add another section to the drill string.

It may also be possible to obtain data with the tool on the move.

Locates should be done at intervals of not more than 3m/10ft.

It may be desirable for the bore to be parallel with the ground surface even if the land is on a steep gradient. The angle of the land surface can be learned by laying the sonde on the surface and using the receiver to measure tilt angle.

Greater accuracy and therefore greater care is needed for locating the sonde in a boring tool than is customary for locating buried utility lines. It is important to pick up and correct deviations from the chosen bore path and depth as early as possible. It is easier to make steering corrections when the trend starts to become evident rather than when there is a substantial deviation. It is also easier to pull the pipe or cable through a bore made with minimal steering corrections.

Information for deep bores

Accuracy and usefulness of traditional electromagnetic location techniques are limited to depths down to about 8m/25ft. Below this depth it becomes difficult to locate the peak of the signal from the sonde and the tolerance on depth measurement is unacceptable.

However, some bores need to be deeper than 8m/25ft and may be as deep as 12m/40ft at river or canal crossings to allow a margin below the bottom of steel side piling.

An elaborate sonde/receiver combination has recently been designed to provide a locate, depth measurement and the required steering information. The receiver has a special aerial array and a computer to analyse the field from the sonde.

The system has been designed for use on larger steerable boring machines. The sonde, including battery pack, sensors and all electronics, is designed to be an integral part of the bore head.

Transmitting and receiving signals at distances over 8m/25ft requires extremely sensitive aerals and electronic processing. Any strong interference at the transmit frequency prejudices the system and it becomes unworkable.

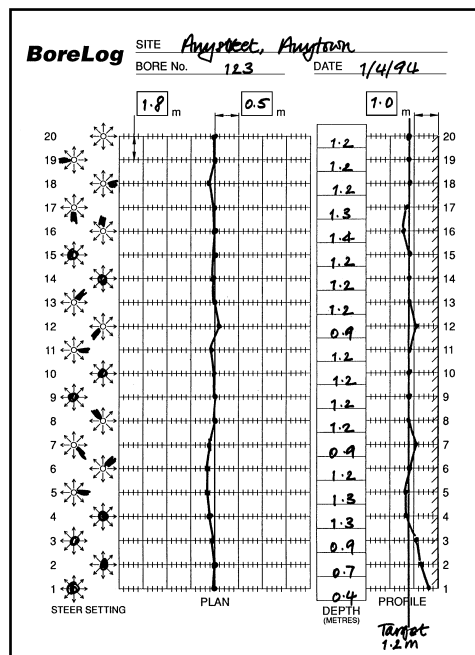
As a result the sonde/receiver can operate on a number of different low frequency signals. Before the bore is begun the receiver is used to search out and identify the frequency of any interference in the area of the bore.

The receiver then switches to an interference free frequency for use during the bore.

The procedure for monitoring progress of the bore is similar to the more simple sonde/receiver/display console information systems fitted to conventional boring tools.

Recording bore information

A permanent record of the bore path and depth should be compiled. The record is important first because it may be important evidence in the event of damage to existing utilities or the paved road surface being affected by the bore. Second, it is needed by the owner of the pipe or cable to form part of the records of his buried plant.



Pre-printed forms such as the DataBore form are an ideal format for recording details of the bore.



4

Alternately the information from the receiver monitoring the bore may be entered in a data logger, which can then be used to make a graphic image of the plan and section of the bore. The position of the bore will need to be shown as a measurement from the planned bore path.

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