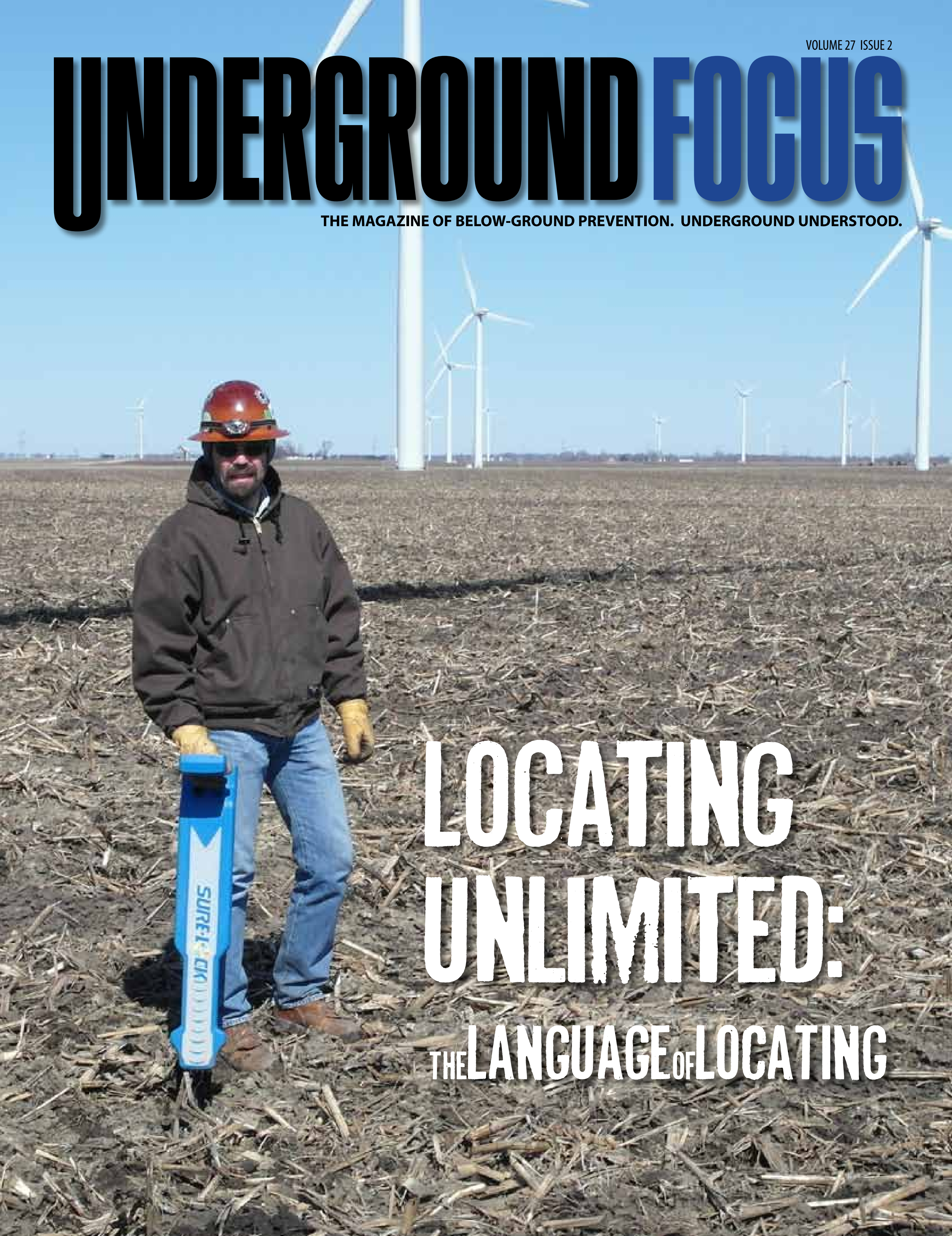
VOLUME 27 ISSUE 2

UNDERGROUND FOCUS

THE MAGAZINE OF BELOW-GROUND PREVENTION. UNDERGROUND UNDERSTOOD.



LOCATING UNLIMITED:

THE LANGUAGE OF LOCATING

VOLUME 27 ISSUE 2

UNDERGROUND FOCUS
Locating Unlimited

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THE LANGUAGE OF LOCATING

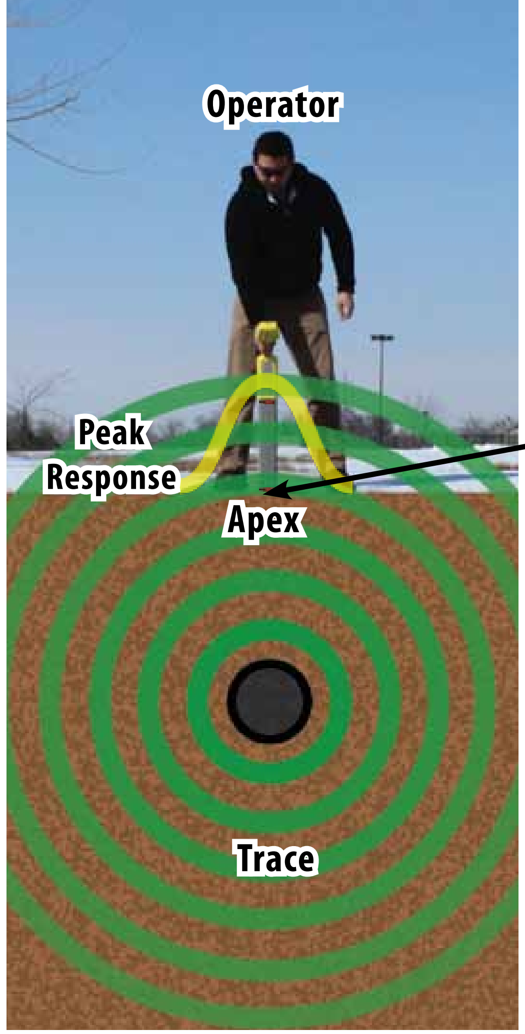
ELECTROMAGNETIC PIPE AND CABLE LOCATING

Locating is not so much a procedure as it is a continuing analysis. Good operators can distinguish between good information and bad information through proper analysis. Despite the difficulty of building a procedure around analysis, that's exactly what this edition of *Locating Unlimited* attempts to do.

The following procedures are intended to be best practices (BEST PRACTICE) and may not be necessary in all locating applications. The following content is not intended to be a substitute for proper training but is designed to supplement Staking University's classroom presentations and Staking University's training material.

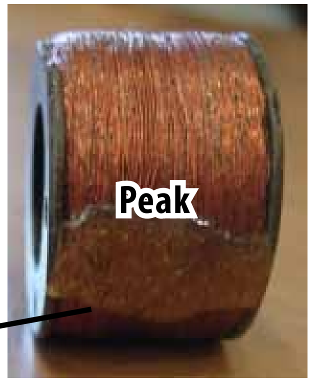
While much of this issue is dedicated to electromagnetic (EM) pipe and cable locating instruments, we do touch on tracer wire, alternate locating methods, and ground penetrating radar (GPR).

Locating Unlimited Training Material and Staking University Locator Training Calendars: **www.locatingunlimited.com**



ELECTROMAGNETIC PIPE AND CABLE LOCATING

Using a transmitter to place electrical current on buried metallic structures and a receiver to analyze current and signal shape, an operator follows the trace to a visual or logical termination point.



Introducing Quick Response (QR) Codes

Our *Underground Focus* magazine content and our library of video training material is connected for the first time through the use of QR codes in *Locating Unlimited*. The QR code above is a video explanation of the term "peak."

Here's how it works: modern smartphones with digital cameras scan a special code, which then links to something. In our case, we've made QR codes that will link to videos to help illustrate concepts even more clearly than we can show in print.

If you have an iPhone, we've tested and like the free QR Reader app. If you have an Android phone, a highly rated app is QR Droid. Once the app is installed, simply open the app and scan the code, almost like you're taking a photo. Your phone or device will automatically link to the correct video page. All you have to do is push play once it loads.

That's it! If you have trouble, a quick Google search for "QR codes help" will yield lots of assistance. We hope this new tool will enhance your use of *Underground Focus*.

TOPSIDE

Topside utility structures are divided into two categories: access points or logical or visual termination points and endpoints.

Peak: a receiver response taken at the apex whereby the coil orientation is vertical, like a tire.

Access point: a bare metal spot on a pipe or cable whereby one end of the conductive transmitting antenna is attached.

Logical or visual termination point: a trace that leads to an above-ground, utility-related structure.

LOCATING VISUALLY AND PASSIVELY

PURPOSE: To gather as much information regarding existing utilities using topside visual cues and transmitters of alternating current.

BEST PRACTICE: The operator will conduct a thorough visual scan of the area to be located paying special attention to topside utility structures, particularly those that may carry electrical current.

A U.S. power plant generates alternating current at a frequency of 60 Hz (power plants in other parts of the world generate 50 Hz).

Current produced at the power plant first flows away from the power plant on a metal conductor. Along the route to the customer, that current finds its way back to the power plant by flowing through earth. On its way back to the power plant, this 60 Hz current may energize metallic utility lines buried in the earth, building a weak magnetic field. This may turn any metallic utility line into a broadcasting antenna.

Although an energized electric cable will likely generate a higher peak response than other lines, any metallic utility line may have 60 Hz current present. In some instances, these other lines may generate a greater 60 Hz response than energized electric lines.

The line's location, depth, size, and grounding configuration will determine the strength of the detected 60 Hz magnetic field. It's possible that not all metallic lines in the vicinity of a passive sweep may be detected using a passive mode.

Current: the flow of the transmitter's energy on a pipe or cable.

Target line: the pipe or cable intended to be detected.

Non-target line: any pipe or cable not intended to be detected.

Magnetic field: the product of alternating current flowing on a pipe or cable.

Alternating current: the type of energy produced both by an electric power plant and the transmitter; energy that flows in two directions.

Energize: to transfer the transmitter's energy to a pipe or cable.

STEP 1 PASSIVE SWEEP AND THE SWEEP TECHNIQUE

PURPOSE: To quickly tell if a metallic utility line may be present in the area.

BEST PRACTICE: Move in a "Mad Dog on a Leash" fashion around an anchor point while keeping the receiver plumb.

Any receiver that detects in passive mode will have 60 hertz (Hz), or 60-cycle passive. In 60 hertz passive, the power plant is the transmitter. The receiver may have more than one passive frequency.

Always begin every new passive locate in peak mode. With the blade of the receiver towards the ground, sweep 360° (if possible) around the topside utility structure while keeping the top of the receiver display pointed at the structure. While sweeping a 360° arc around a structure, focus on the numbers of the peak response. Relative to the receiver's location, higher peak responses represent greater amounts of flowing current. A high peak number can indicate a shallow line or perhaps an energized electric cable. Multiple peak responses may be detected while sweeping the arc.

RADIO PASSIVE

Other generators of alternating current, such as radio communication towers, transmit frequencies other than 60 Hz

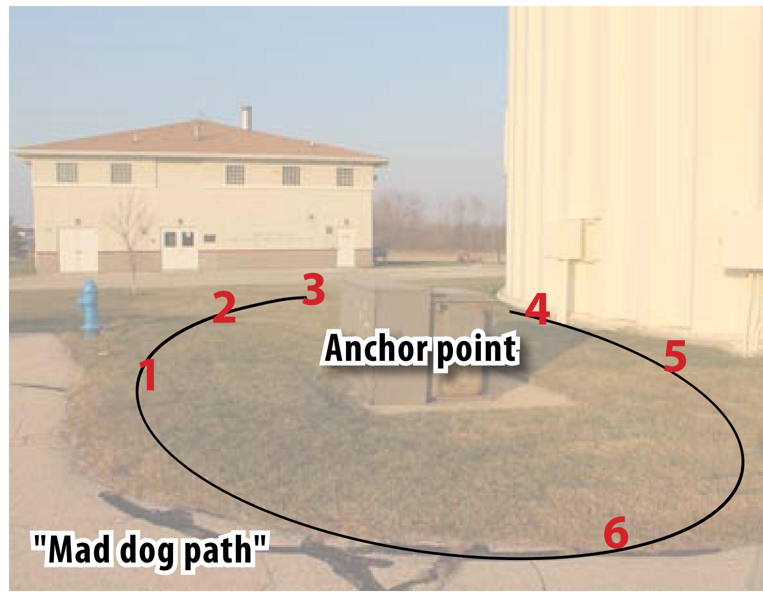
Passive: a receiver response to a magnetic field generated by something other than the transmitter.

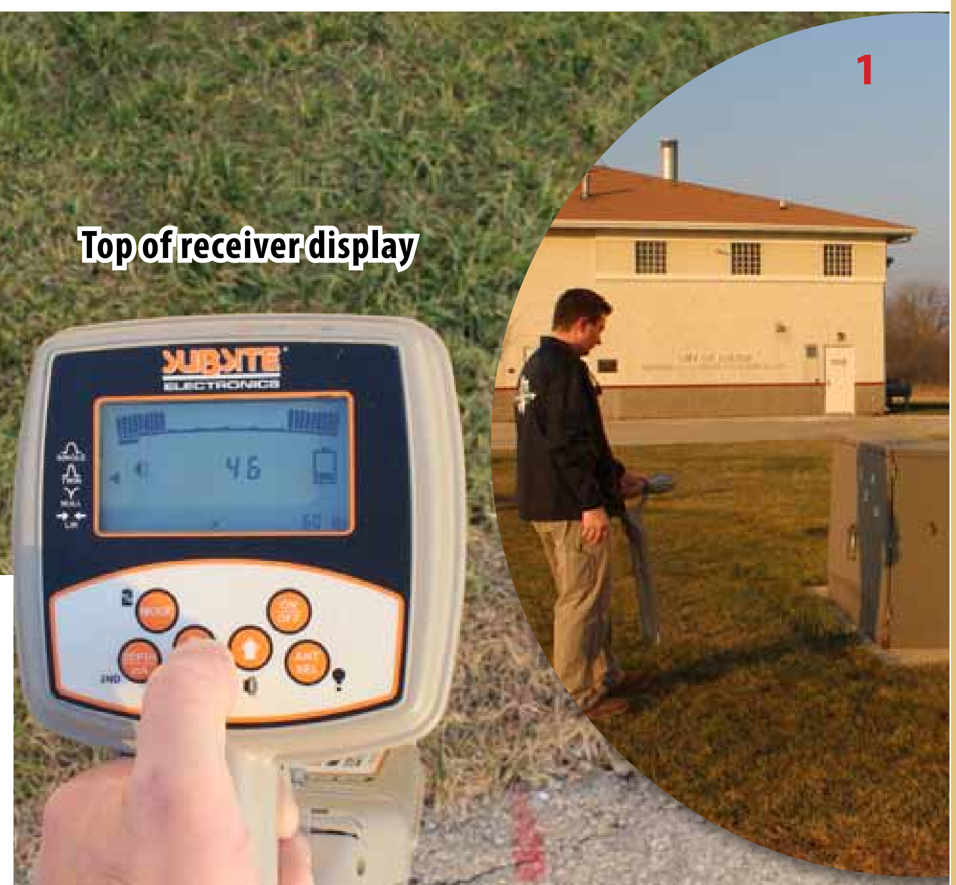
Hertz: the number of times current on a pipe or cable changes directions in one second.

Active: a receiver response to a magnetic field generated by the transmitter.

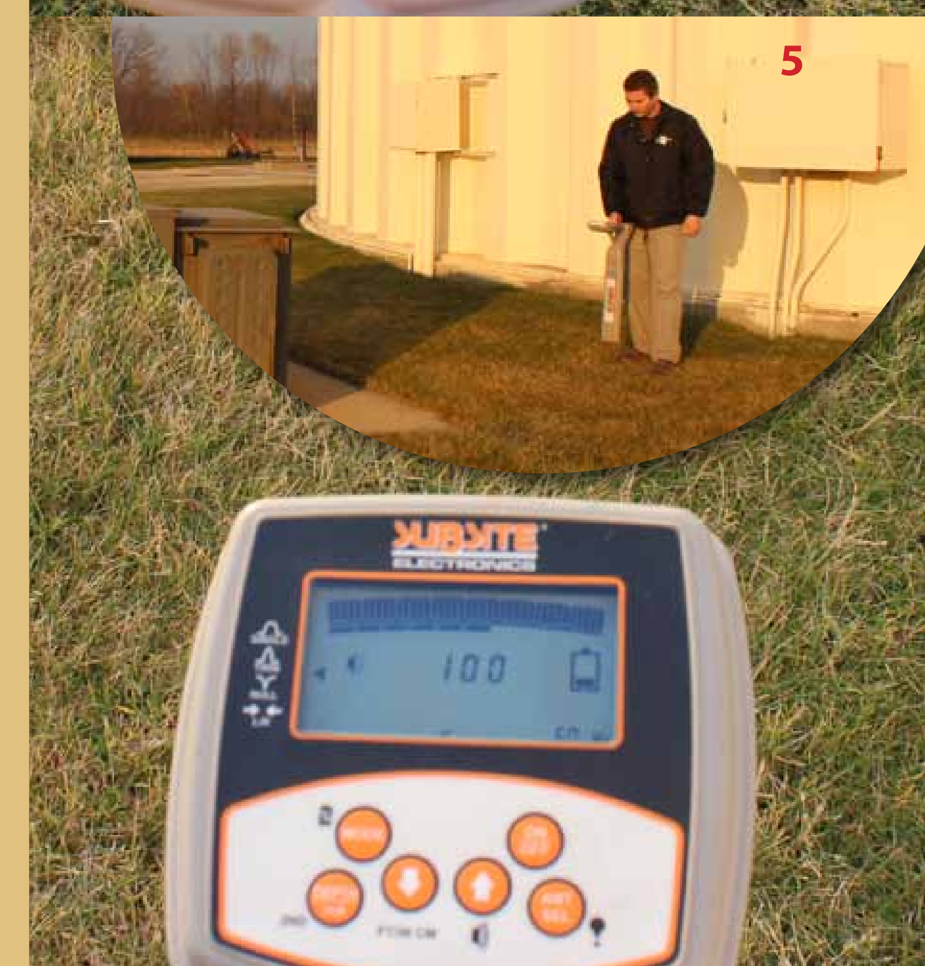
THE MAD DOG ON A LEASH

If a mad dog is tethered to an anchor point in a grass-covered yard, the mad dog will stretch the leash out as far as possible and proceed to run in circles, eventually creating a dirt ring around the anchor point. In terms of locating, the structure to which the signal has been applied is the anchor point and the operator is the mad dog. The top of the receiver display is like the end of the leash.





Once the receiver has been tuned (see page 28), the operator is at the end of the stretched leash. Moving closer to the structure is not an option because the receiving antennas are too sensitive and will most certainly become over-energized, a condition known as air lock. Once tuned, moving farther away from the structure is not an option either. The receiver will no longer be as sensitive, which could cause the operator to miss an energized line. The distance at which the receiver has been tuned is the optimized distance for the operator to conduct a sweep.



SUPPORTING MATERIAL:

THE TROUBLE WITH PASSIVE MODE

The receiver will detect any magnetic field created by the flow of alternating current. Filters in the receiver may be set to "see" particular passively-generated magnetic fields.

The operator is using 60 Hz passive mode to locate a three-phase electric cable. While in 60 Hz (sometimes called "power mode" or "60-cycle") the receiver displays a peak response of 91.0.

60-cycle: alternating current whose frequency is 60 hertz.

Kilohertz: 1000 hertz.

Electronic null: a receiver response whereby two symmetrically and horizontally positioned peak antennas record identical signal strengths.

Peak - 60 Hz Passive **Peak and Electronic Null – 200 kHz**

The operator switches the receiver to see the active frequency of 200 kHz that has been applied by a transmitter. The peak response found with 200 kHz appears to be 3 to 4 feet away from the peak response that was found in passive mode at 60 Hz.

Next, the operator checks to see if both the peak and electonic null responses agree; are the responses at the same location on the ground? In this case, both peak and null responses do in fact agree, a sign of confidence that this is the actual location of the three-phase electric line.

What causes this type of error when using 60 Hz passive? In short, it is the mingling of multiple 60 Hz fields generated from both underground and aerial lines.

Peak – 60 Hz Passive **Peak and Electronic Null – 200 kHz**

STEP 2 A APPLYING ACTIVE SIGNAL BY CONDUCTIVE MEANS

PURPOSE: To place maximum current on the target line.

BEST PRACTICE: Find an access point for the target line and try the conductive method first.

Conductive use of the transmitter involves making a physical metal-to-metal connection to an access point as well as the grounding device. The operator must grind the teeth of the conductive transmitting antenna leads into both the access point and the grounding device.

STRETCHING THE CONDUCTIVE LEADS: A LOCATING PROCEDURE THAT RARELY HELPS AND OFTEN CONFUSES

Any non-target utility may negatively interact with the target utility. This interaction, or "bleed-off," is often aided by the location and size of the grounding device.

A practice without payout: Stretch the conductive leads perpendicular to the expected path of the target line while maximizing the distance between the access point and the grounding device.

What should be done: Place the grounding device close to the access point; do not stretch conductive leads.

Stretching the leads creates additional locating problems and doesn't solve anything. It creates a strong magnetic field that extends well beyond the end of the leads, and creates these issues:

1. The magnetic field created by the leads interacts with the magnetic field created by current flowing on the target line. The result will be a field shape that is not round (see Page 40), a scenario which leads to inaccurate locate results within the immediate area of the access point.

2. There is a significant, albeit short-distanced, area beyond the stretched leads which appears to be an energized line.

3. Non-target lines tend to become more energized than they would if the grounding device were positioned near the access point. The additional current on non-target lines may create inaccurate target line locating or misidentification of the target line.

Conductive transmitting antenna: a wire with two ends which connects the transmitter to 1) the pipe or cable and, 2) the earth.

Grounding device: a piece of metal driven into earth so that the conductive transmitting antenna may be attached.

STEP 2B APPLYING ACTIVE SIGNAL BY INDUCTIVE MEANS

If there is not an access point at the surface, the inductive method must be utilized. The inductive method is also called the nonmetal-to-metal method because there is no physical connection between the transmitter and the target line. Switching from conductive to inductive activates an inductive transmitting antenna inside of the transmitter. This antenna broadcasts a pumpkin-shaped field (see page 18) that radiates an electromagnetic field of significant strength 30 feet in all directions.

The inductive transmitting antenna has windings, or loops of wire. For the maximum energy to be transferred to the pipe or cable, these windings must be oriented in a "tire-to-the-road" fashion. This means the transmitting antenna (the tire) should be centered above and in-line with the target line.

POLE RISERS AND THE VERTICAL ROAD

Here, the "road" travels both up and down the pole as well as from the bottom of the pole to the building. As long as the coils are tire-to-the-road with the vertical road, the buried cable will be energized sufficiently for locating.

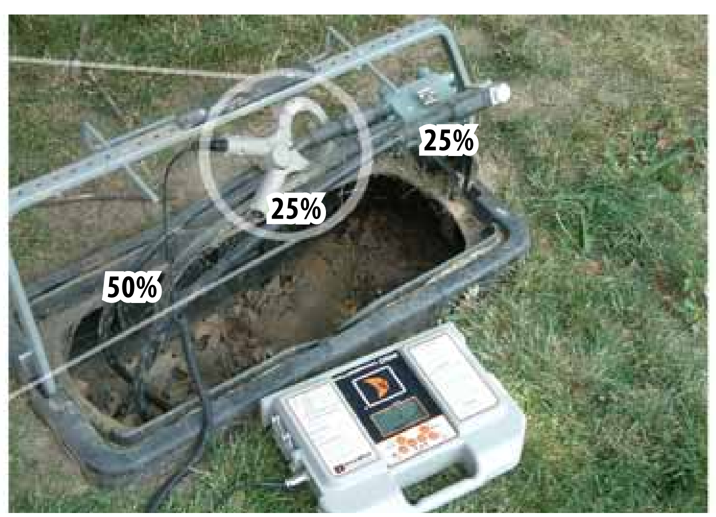
An inductive coupler is a remote inductive transmitting antenna. The windings are energized by the transmitter and the metal plates focus the manipulated pumpkin-shaped field inward.

Inductive transmitting antenna: a coil located in the transmitter whose purpose is to energize the pipe or cable without using a metal-to-metal connection.

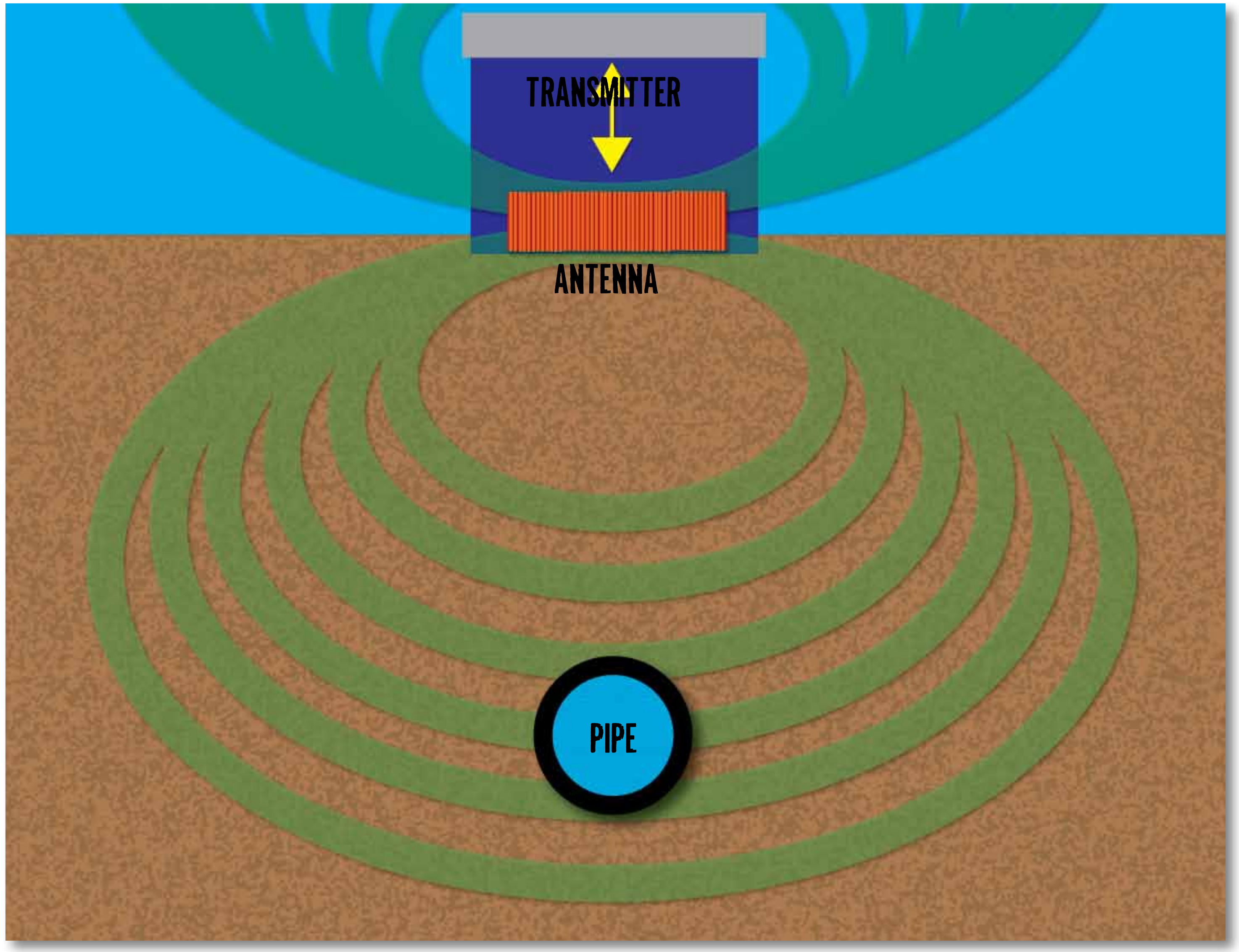
Windings: the wire in a coil that is wrapped around the core.

Nonmetal-to-metal: another term for the use of an inductive transmitting antenna.

From where induction is applied on the target line, 50% of the current leaving the transmitter will travel one direction on the line while the other 50% of the current will travel on the line in the other direction.



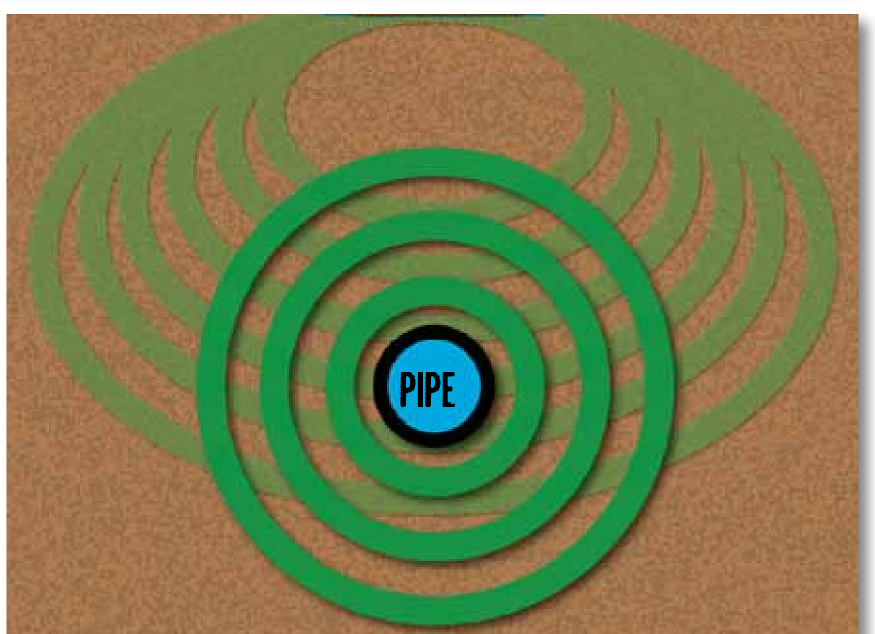
SUPPORTING MATERIAL:
PUMPKIN-SHAPED FIELD



The inductive transmitting antenna broadcasts a pumpkin-shaped field which then energizes the target line below. Once energized the pipe or cable emits a “rock-in-pond field” which is detected by the receiver. A rock-in-pond field is a series of signal circles emanating from the skin of the metal pipe or cable.

Whether energized by conductive or inductive means, the energized pipe or cable itself becomes the final component of the transmitting antenna.

The waves in a rock-in-pond field move outwardly in circular fashion. The shape of the "rock-in-pond" field (see page 37) is either round or not-round depending on whether other nearby metallic objects become energized (not-round) or not (round).



Pumpkin-shaped field: the field that is produced by an inductive transmitting antenna.

STEP 3 CONDUCTIVE CURRENT FLOW READINGS

PURPOSE: When using conductive mode, to make sure that sufficient current is leaving the transmitter to build a magnetic field that the receiver can detect.

BEST PRACTICE: Initial voltage setting of 50% or less for conductive locates.

VOLTAGE IS PRESSURE. CURRENT IS FLOW

Dry soil, no utility line insulation, pipe insulators or unarmored cable splices, and slip-jointed pipe all represent resistance to current flow. Higher voltages settings may be necessary when these utility line conditions are present.

The operator cycles through all available conductive frequencies paying attention to the milliamp (mA) reading. The operator should select the lowest frequency that displays a suitable milliamp reading, such as 25 mA.

The operator always begins each locate with a particular amount of transmitter voltage, or power. Voltage level and the resistance level of the target line will interact to produce a certain amount of current flow.

Most transmitters give the operator a current flow reading. Usually displayed in milliamps (mA), the flow reading serves as a predictor of the strength of the field detected by the receiver. If the current reading is low, deeper lines may be tough to find or shallower lines may not locate as far. Be aware the current flow reading only shows that the transmitter is sending current somewhere. This does not necessarily mean that the current leaving the transmitter is present on the target line.

While the practice of beginning a conductive locate with lower voltages is somewhat arbitrary, higher voltages will emit magnetic fields of higher strengths from the conductive leads which may produce air lock. In addition, when the transmitter's voltage is set to higher levels, the transmitter's batteries drain faster.

Bleed-off, the transfer of energy from the target line to a non-target line, increases little when using higher voltages. Unless dealing with commonly-grounded utilities, bleed-off is primarily a function of transmitter frequency. Higher frequencies produce more bleed-off than lower frequencies.

Higher voltage settings are particularly helpful, however, when attempting to establish current on highly resistive utilities, such as slip-jointed ductile iron pipe or bare steel pipe.

SUPPORTING MATERIAL:

FOUR MAJOR FACTORS THAT MAKE A TARGET LINE CONDUCTIVE OR RESISTIVE:

No matter whether the line is energized by conductive or inductive means, signal wants to leave the pipe or cable equally in all directions. Like a rock tossed into a pond, concentric signal circles emanate outward from the skin of the metallic line.

As the signal travels away from the transmitter, it is constantly peeling back to return to the transmitter. Think of a particular signal circle whose apex intersects ground level with a received strength of 500 units. This signal circle is located 100 feet from the transmitter. At a distance 200 feet from the transmitter, the 500 unit signal circle is located below ground level. The signal circle that intersects ground level 200 feet from the transmitter may be received as 450 units.

Assuming the line is buried at a constant depth, as signal travels away from the transmitter its received strength is constantly getting smaller at ground level.

FREQUENCY
INSULATION
MOTHER EARTH
FAR-END GROUNDS

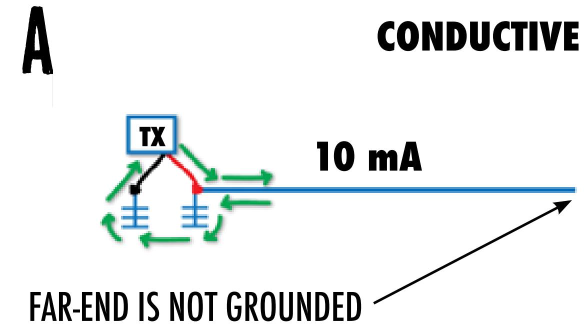
Like a giant cone laid on its side, the widest part of the cone is located closest to the transmitter and the narrowest part of the cone is located farthest from the transmitter.

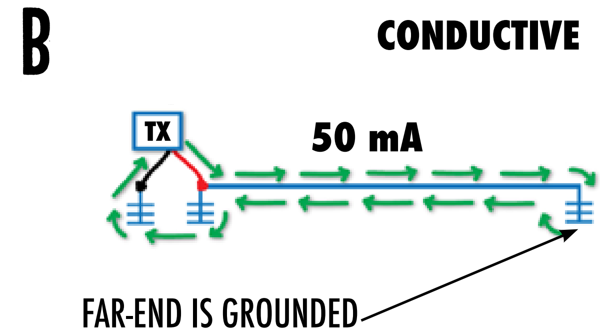
There will be points along the line where the receiver needs to be zoomed-in (see page 28) to detect the field because the receiver is no longer sensitive enough to see the field at its present gain level. As the operator continues to trace the line away from the transmitter, there may come a point where the peak response changes from steady numbers to fluctuating numbers as the receiver is held motionless over the target line.(See page 32)

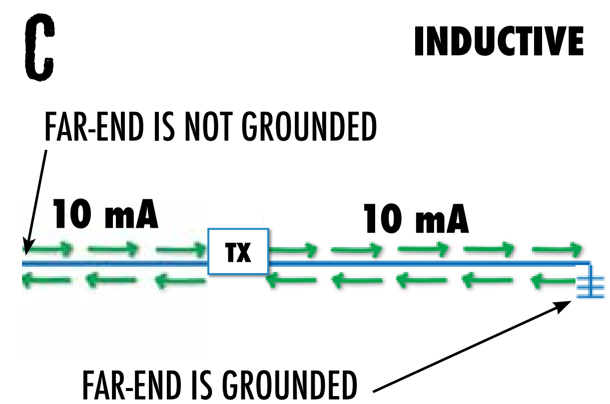
Current on a target line is always influenced by four factors: the transmitter frequency, the far-end grounding of the target line, the quality of the insulation (or lack of insulation) on the target line, and the type of soil along with the moisture content of the soil.

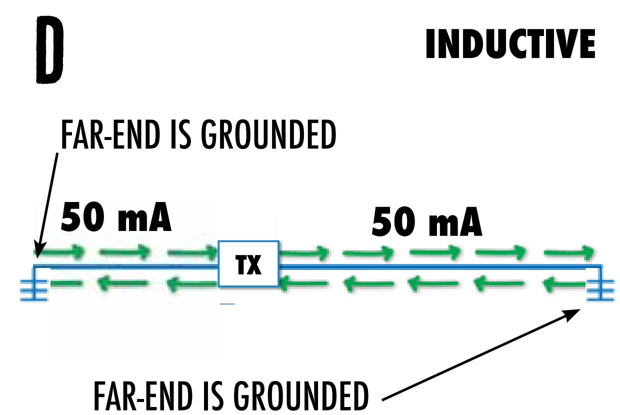
Far-end: the end of a line leg opposite of the transmitter location.

CURRENT THAT LEAVES MUST COME BACK: THE FIFTY/FIFTY RULE









The transmitted signal is bound by laws of electricity that cannot be changed, similar to the law of gravity. One such law says that signal will always follow the path of least resistance. Another law, modified for locating, says that all of the signal that leaves the transmitter must return to the transmitter. While this is true for both conductive and inductive, it is important to understand that there can be a significant difference between the two transmitting modes in how signal travels on a utility system.

Conductively attached to a target line (Figure A) with no tees, splices, or laterals and with the line ungrounded at the far-end, the transmitter's current flow reading may read 10 mA. But with the far-end grounded (Figure B), the current flow reading may read 50 mA. In both scenarios, all the signal that left the transmitter returned to the transmitter. The only difference between the two scenarios is the amount of current leaving and returning to the transmitter.

All locates produce current flow on the skin of the metallic target line and also produce current flow through the earth. Earth encompasses the type of soil and moisture content of the soil. If earth is resistive, less current will flow on the target line. If earth is conductive, more current will flow on the target line.

(Figure C) Inductively, 50% of the current exits one side of the transmitter onto the target line in one direction while the other 50% of the current exits the other side of the transmitter onto the target line in the other direction. If one far-end of the line is ungrounded and the other far-end of the line is grounded, the same amount of current will leave both sides of the transmitter.

(Figure D) If both far-ends of the target line are grounded, more current will leave the transmitter in both directions as compared to only one target line far-end being grounded.

INTRODUCTION TO TUNING THE RECEIVER: PREVENTING LOCATING ERROR DUE TO AIR LOCK

Gain, also known as "sensitivity," is like a zoom lens on a camera. A zoom lens allows a photographer to frame the subject of a photo. If the subject is too far away, the photographer "zooms-in." If the subject is too large in the frame, the photographer "zooms-out."

Just as changing the zoom setting on a camera doesn't change the location of the object being photographed, changing the gain on a receiver does not change the locate results.

An autogain receiver, such as the orange one shown on the opposite page, self-adjusts the peak response by zooming-in or zooming-out as necessary. The operator controls the zoom function with a manual gain receiver.

STEP 4 TUNE THE RECEIVER

PURPOSE: To ensure optimum sensitivity of receiver while avoiding air lock.

BEST PRACTICE: Always tune the receiver no matter if transmitting by inductive means or conductive means.

Tuning the receiver sets the receiver sensitivity to an optimum level for locating in the area closest the transmitter.

With the blade of the receiver towards the ground, sweep 360° around the structure (whenever possible) while keeping the top of the receiver display pointed at the structure. If the receiver sensitivity is set too low, the operator may walk right over an energized line. If the receiver sensitivity is set too high, it is possible for the operator to "locate the transmitter."

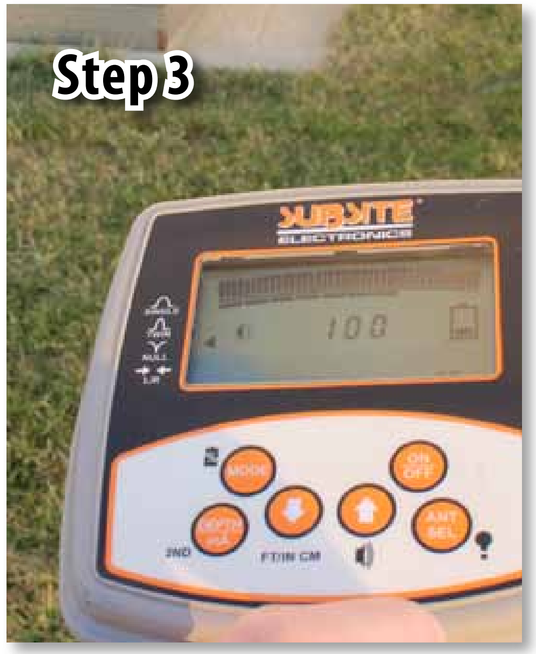
As the operator walks away from the transmitter with a manual gain receiver, the gain will need to be zoomed-in on occasion. A notable exception occurs if the target line becomes shallower as the operator moves away from the transmitter. Once the receiver is tuned, locating toward the transmitter is not recommended as air lock may occur.

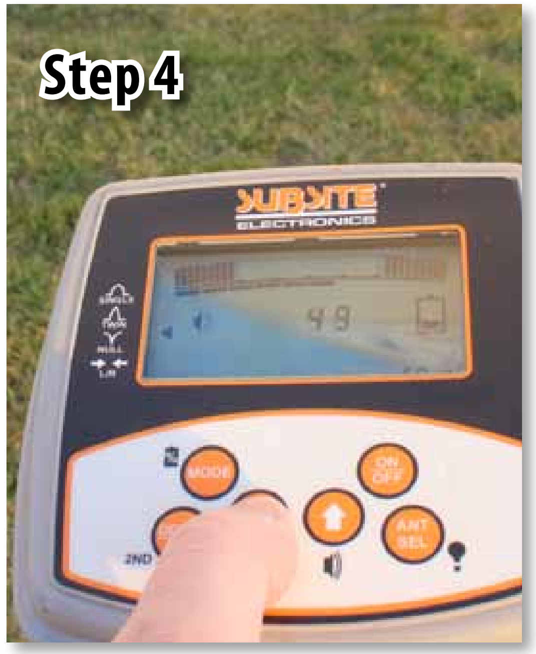
Autogain receivers zoom-in and zoom-out as needed. Air lock may occur if the operator locates while walking towards the transmitter after the receiver is tuned.

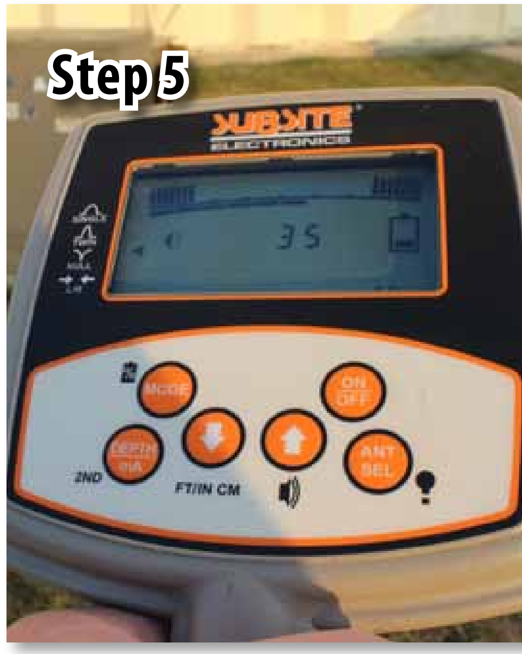
Air lock: any receiver reading created by the transmitter's energy leaving the transmitting antenna and not the pipe or cable.

AIR LOCK

If the peak response is higher when the blade of the receiver is pointed at the transmitter than when the blade is pointed at the ground, the receiver is air locked. The operator must take several steps away from the transmitter and repeat.







TUNING THE RECEIVER

FOR MANUAL GAIN RECEIVERS:

Step 1: Point the blade of the receiver directly at the transmitter. Zoom-in so that the receiver reads maximum peak signal strength (100% or 99.9, for example). This is your baseline reading.

Step 2: Most modern receivers reset maximum peak signal strength readings to a level of 40-70% signal strength with a single tap of the zoom-out control. The signal strength now displayed should be strong enough to see an energized line but not be overly influenced by conductive or inductive air lock.

Step 3: Lower the blade of the receiver to point towards the ground. If the peak response increases or maxes out, the receiver is likely detecting the signal from an energized buried utility line.

Step 4: With the blade still pointed towards the ground, tap the down arrow (zoom-out) button one time. If the peak response was maxed out, this should automatically reset the receiver response to 40-70% signal strength. If not maxed out, the signal strength will simply be lowered.

Step 5: Raise the receiver straight into the air. The signal strength should decrease, meaning that the receiver has been moved farther away from the source of the signal on an energized buried utility line. If upon raising the receiver straight into the air the signal strength stays the same or increases, the receiver is air locked. Move away from the transmitter.

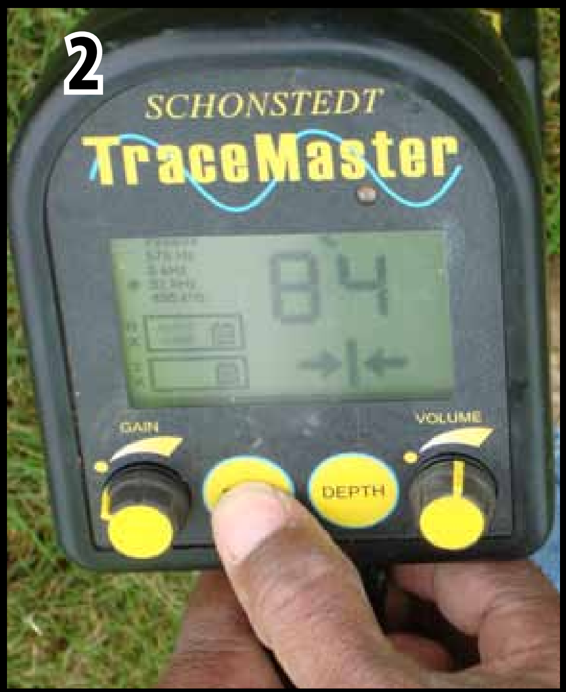
Step 6: To verify that the receiver is not in air lock, point the blade of the receiver directly at the transmitter. If the signal strength decreases, the operator is not air locked and has successfully tuned the receiver.

DIFFERENT METHODS FOR GAIN

Instrument #1: The manual gain controls the sound and the graphics but never changes the numeric peak response.

Instrument #2: The operator can chose between manual gain and autogain.

Instrument #3: There is only one gain button and when pushed, the gain adjusts to 70% of peak scale.



STEP 5 ASSESSING CURRENT WITH THE RECEIVER

PURPOSE: To determine if a sufficient level of current is present at a particular spot over the target line in order to produce a series of receiver readings.

BEST PRACTICE: The operator assesses the current along the target line at the location where the highest peak response is found.

The operator assesses the current as “good current” if the peak numbers are steady (no fluctuation) while the receiver is held motionless over the target line.

A slight fluctuation of the peak numbers is known as “OK current.” OK current is acceptable as long as good current cannot be attained. It should be noted that some receiver functions are compromised with an OK current level, such as digital depth validation (see page 42).

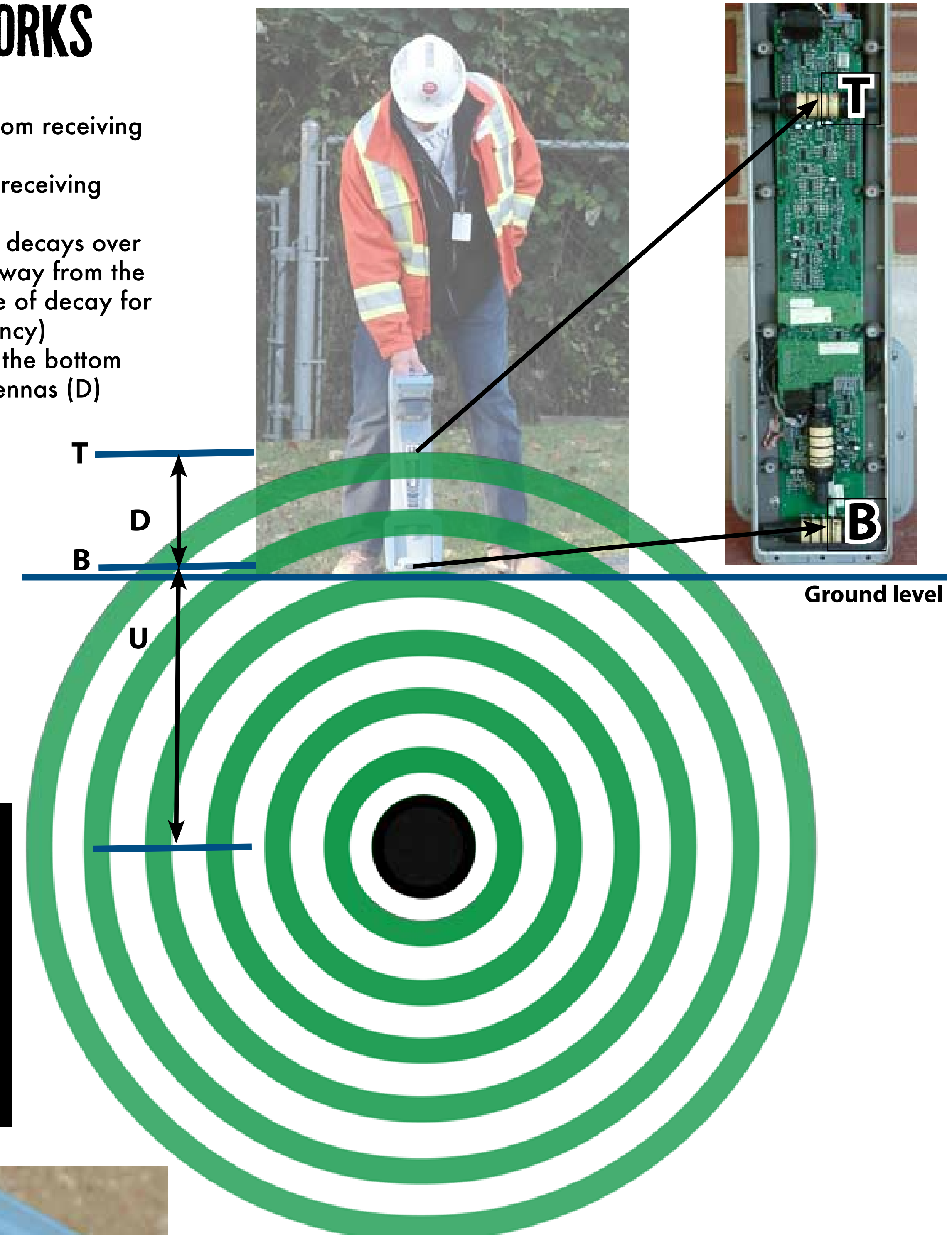
“Poor current” is defined as wildly fluctuating peak numbers. It will not be possible for the operator to perform locating with poor current. Only a change in the deployment of the transmitter can upgrade poor current to either good current or OK current. (See "Three Changes and a Move" on page 48).

SUPPORTING MATERIAL:
HOW DEPTH WORKS

Known:

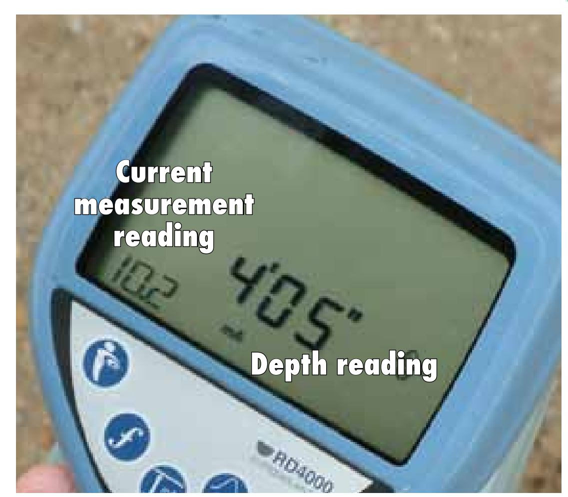
- Signal strength at bottom receiving antenna (B)
- Signal strength at top receiving antenna (T)
- The amount the signal decays over distance as it moves away from the line (it is the same rate of decay for any transmitter frequency)
- The distance between the bottom and top receiving antennas (D)

Unknown:
The distance from the bottom receiving antenna to the center of the two concentric signal circles which intersect the two receiving antennas. (U)



HOW CURRENT MEASUREMENT WORKS

While the mathematical calculation varies from that of digital depth, current measurement readings use the same antennas that determine depth readings.



Stacked-peak antennas: two coils—a bottom receiving antenna and a top receiving antenna—which are both situated at the apex of two concentric signal circles.

Current measurement: a receiver reading, usually displayed in milliamps, that is produced by stacked-peak antennas and estimates how much of the transmitter’s energy is located at the point of the reading.

Signal decay rate: the diminishing strength of the magnetic field as the field travels away from the pipe or cable.

Concentric signal circles: the transmitter’s energy that orbits the pipe or cable at all distances from the pipe or cable.

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SUPPORTING MATERIAL:
PEAK

Like an inductive transmitting antenna, a receiving antenna has windings. These windings are generally made of copper and wound around a core, like a spool of thread. There are two main types of cores used for receiving antennas: air-core and ferrite-core. An air-core antenna is hollow; the coils are essentially wound around nothing but air. With a ferrite-core, the coils are wound around a ceramic compound that is magnetic but not conductive.

In addition to different cores, the number of antenna windings varies from one manufacturer to another. Any receiving antenna will receive certain ranges of transmitted frequencies well, other ranges adequately, and some ranges poorly.

PEAK QUANTIFIES SIGNAL STRENGTH

When a receiving antenna is positioned like a tire-to-the road (the antenna is the tire, the target line is the road), the antenna will receive the maximum signal strength possible. The windings of the peak antenna are directly in-line, or parallel, with the target line. If the tire antenna is rotated while still positioned over the target line, the peak numbers go down.

Most modern receivers display peak information in three ways simultaneously: a number, an audible tone and a graphical response.

THE RISE AND FALL

In peak mode as the receiver is positioned away from the target line, the receiver sees less signal strength than when positioned over the target line. As the receiver is held plumb and moved perpendicularly towards the target line, the peak number will increase. This is known as "the rise." The operator never knows where the highest peak reading is located until the receiver travels past the apex. As the receiver is held plumb and allowed to swing past the apex, the peak response decreases. This is known as "the fall."

If the signal above the ground was visible to the eye it would look like an arc or a rainbow. If the field is round, the target line would be positioned directly below the highest portion of the arc. But the signal is not always round (see page 43).

PINPOINTING

Pinpointing uses the peak antenna to find line direction. Where the highest peak response is found, the receiver is placed on the ground. The operator rotates the receiver to the left and then back to the original position. Next, the receiver is rotated to the right side until the peak response diminishes. Wherever the highest peak response is found is the direction the target line is positioned underground, in-line with the handle of the receiver.

The waves created by a rock tossed into a pond serve as a visual analogy for a round field.

REVIEW

The operator tunes the receiver and sweeps a 360° radius around the target structure, looking for the highest peak response. In order for the assessment of shape to be as accurate as possible, the target line must be pinpointed to find line direction.

Signal shape analysis requires the operator to position the receiver parallel to the target line while holding the receiver plumb. The operator holds the receiver's handle loosely and letting the receiver hang allowing gravity to do the rest. Any time the receiver is moved to the side of the target line, it should be done so in a 90° angle to the line, or perfectly perpendicular. Any time the receiver is raised, it should always be positioned perfectly above the target line.

Concentric signal circles: the transmitter's energy that orbits the pipe or cable at all distances from the pipe or cable.

Coil orientation: the positioning of coil windings within a magnetic field.

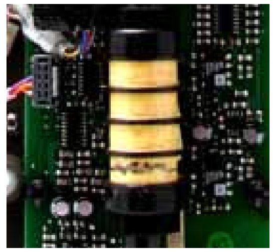
Round field: a magnetic field that is not an attracting or repelling field.

Signal strength: measurement of the magnetic field with a tire coil orientation.

PEAK GIVES THE MOST INFORMATION

Peak is the most important piece of information that the receiver can display. Peak is the only way the operator can assess the level of current, determine direction of the target line, and operate a 360° sweep. Plus, peak is equally used with null to determine signal shape.

SUPPORTING MATERIAL:
TWO KINDS OF NULL



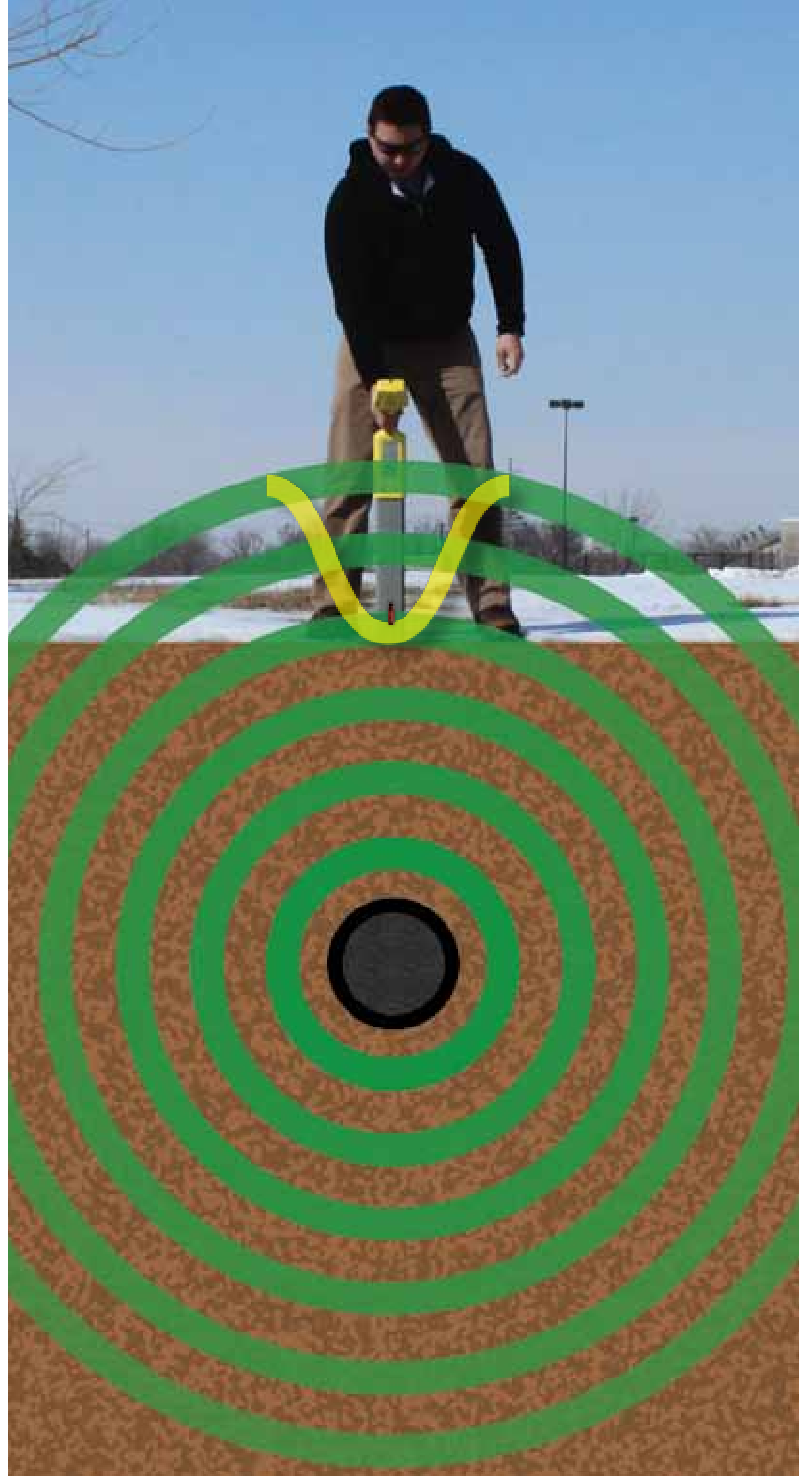
Generally, a receiving antenna is oriented like either a tire or a tornado to the target line. The manner in which the operator gets information depends on the antenna's orientation. When a receiving antenna is positioned tire-to-the-road, it quantifies signal strength; a peak response. When the same antenna's axis is rotated so that the coils are wound like a tornado, it gives the operator "balance/imbalance" information; a null response.

BALANCE/IMBALANCE, LEFT/RIGHT

With a tornado orientation, the windings are perpendicular to the target line. When the windings are immersed in the apex of a signal circle, the tornado windings see the same amount of signal on both of its sides.

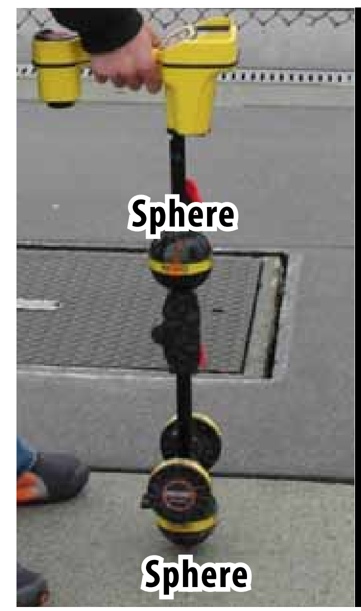
Picture a hula hoop placed on the ground and centered directly over an underground line. An arc of signal leaving the underground line will simultaneously intersect both sides of the hula hoop. Electronic cancellation occurs when the antenna sees the same amount of signal on both sides, creating a "nothing (null)" response or a "balanced". An "imbalanced" response occurs when the hula hoop is moved to one side of the underground line. The two sides of the hula hoop are intersected by two different signal arcs of signal strength.

A single null antenna cannot provide left/right guidance; it can only present either a balanced indication or an imbalanced indication. Stacking a tornado antenna above a tire antenna and using both simultaneously will give the operator left/right guidance, usually in the form of arrows which appear to point the operator into the direction of the target line. If the receiver is on the left side of the line, the arrows will point to the right. If the receiver is on the right side of the line, the arrows will point to the left. When the receiver is positioned directly above the line, both arrows appear and point towards each other.



TORNADO ORIENTATION

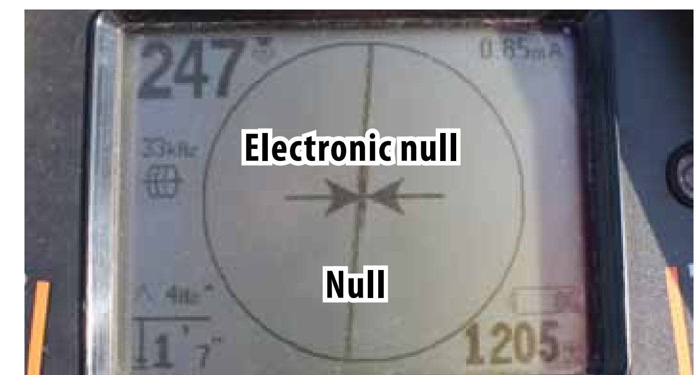
No matter how the receiver is rotated, the tornado windings are always tornado windings.



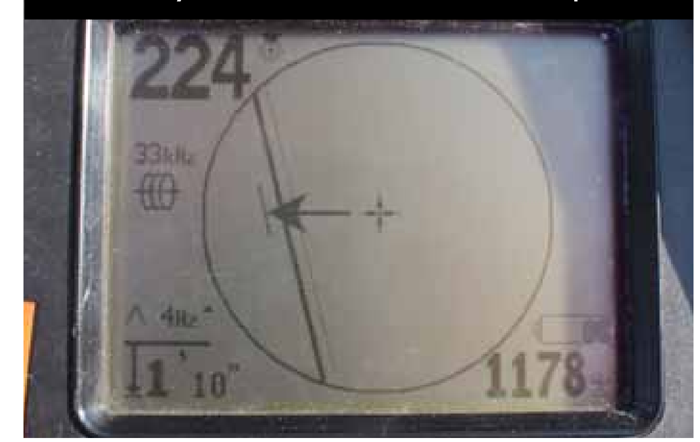
Horizontally-positioned peak antennas at the bottom of this instrument produce an electronic null reading. An imbalance of the horizontally-positioned peak antennas presents a single arrow. The single arrow points to the peak antenna that receives more signal strength than the other peak antenna. Both arrows appear when both antennas see the same signal strength.

NULL VS. ELECTRONIC NULL

There are two multiple antenna configurations that provide the operator left/right guidance: 1) The simultaneous use of a tornado and a tire antenna and 2) two horizontally-positioned peak antennas working in tandem. Two horizontally-positioned peak antennas provide what is known as an electronic null response. Electronic null receivers often have a "cross" on the lower part of the receiver that house peak antennas on opposite sides of the blade.



The line represents the null reading and is generated by the antennas located in the spheres.



STEP 6 A ASSESSING SHAPE WITH THE RECEIVER

PEAK VS. NULL

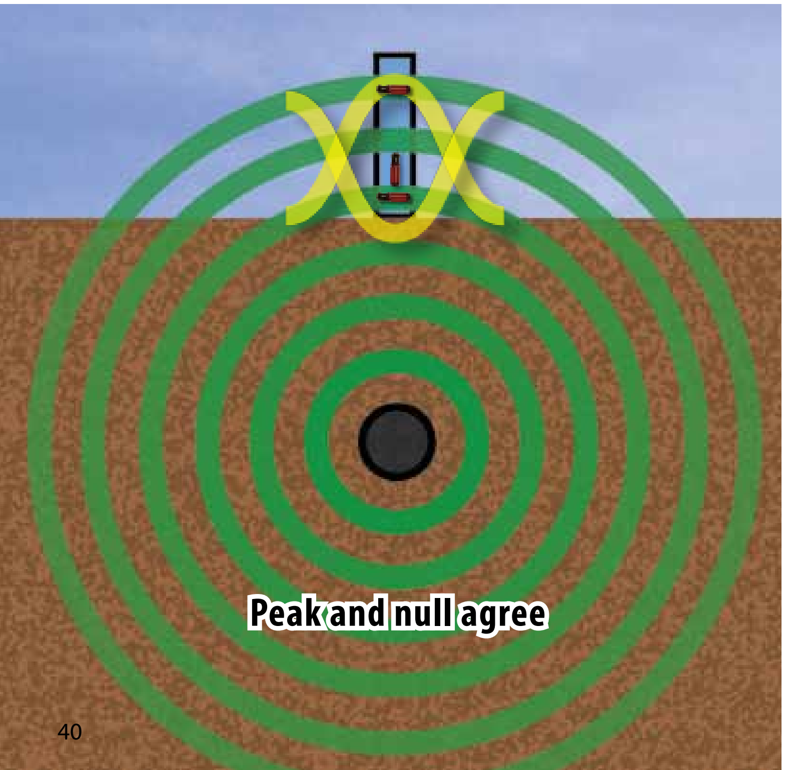
PURPOSE: To assess the accuracy of a locate result by comparing the location of peak readings to null readings.

BEST PRACTICE: Always use peak responses as well as null responses.

Round signal shape is a leading indicator of an accurate locate. Likewise, a not-round field is an indicator of an inaccurate locate. If a peak reading and a null reading agree at the same location on the ground, the locate result is likely accurate. If a peak reading and a null reading disagree, the locate result is likely inaccurate.

Peak vs. null is the primary tool for assessing the shape of the magnetic field. The term "round" is somewhat misleading; the magnetic field is three dimensional, surrounding the target line like a tube. A two-dimensional slice of the tubular field will reveal either a round field or a not-round field.

A not-round field is created when the transmitter energizes other nearby metallic objects, such as non-target lines. The more peak and null disagree, the more the transmitter has energized other nearby objects. Because there are so many factors at work at once, it is impossible to say how much distance between peak and null readings is of no concern relative to accurate locating. When peak vs. null indicates a not-round field, consideration must be given to changing the utilization of the transmitter.



STEP 6B ASSESSING SHAPE WITH THE RECEIVER

DIGITAL DEPTH VALIDATION

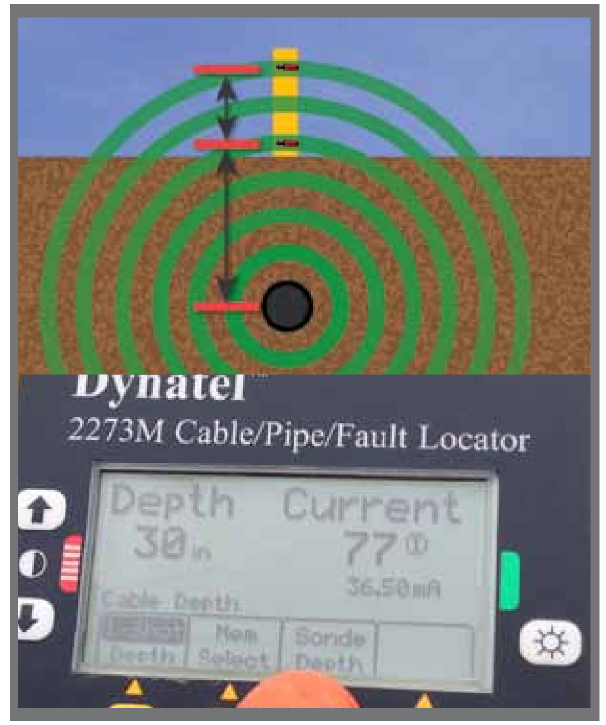
PURPOSE: To assess the accuracy of a locate result by first taking two digital depth readings over the target line, the second reading taken directly above the first reading.

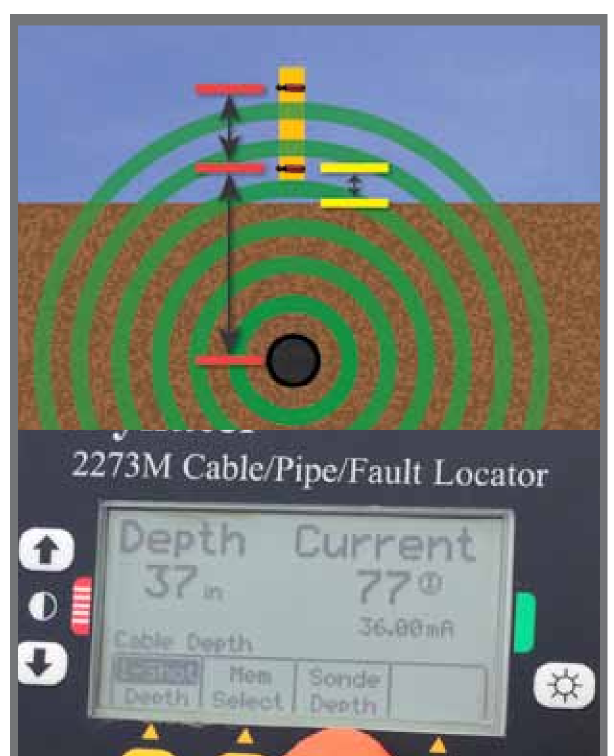
BEST PRACTICE: When using digital depth validation, know exactly how high the receiver is raised before obtaining the second depth reading.

Vertical inspections of the field are used to determine locating accuracy. Along with peak vs. null, digital depth validation is a vertical inspection of the magnetic field. Vertical inspections take place at the apex, or in-line with the apex above the ground.

Digital depth validation ranks as the second and last primary method of assessing the shape of the magnetic field. If peak and null agree and digital depth validates, the locating of the target line is not impacted by other energized metallic objects. If digital depth validates yet peak and null readings minimally disagree, the locating results may be considered accurate.

It is important to note that peak and null readings can agree and digital depths validate when locating a non-target line. That's why following the trace to a logical and visual termination point is critical to accurate locating.





NULL METHOD

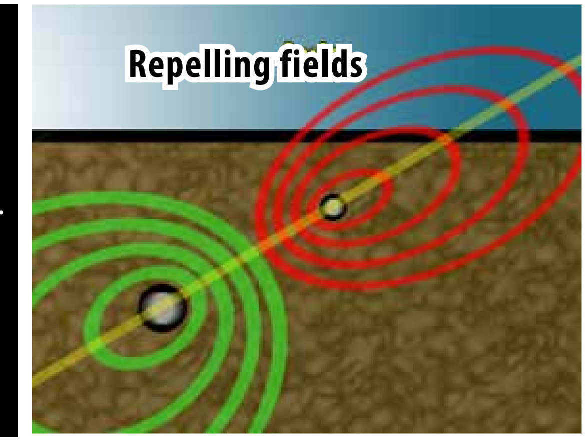
PURPOSE: To vertically assess the accuracy of a locate by first determining the null response at ground level and then lifting the receiver several feet straight into the air.

BEST PRACTICE: When using the null method, the operator should lift the receiver display to a chest-high level.

ROUND VS. NOT-ROUND

When the fields of two equally energized lines converge, they will either produce a "zero" peak reading or a "double" peak reading. These electromagnetic convergences are known as destructive interference (zero) or constructive interference (double).

Diagramed to allow for visual comprehension, interference appears as either repelling fields (destructive interference) or attracting fields (constructive interference). Both of these field shapes are not-round. When no interference occurs, fields are round.



Vertical inspection of field: receiver readings that are obtained on top of the pipe or cable location.

STEP 6C ASSESSING SHAPE WITH THE RECEIVER — PEAK METHOD

PURPOSE: To determine if other nearby energized metallic objects exist, particularly when the vertical methods of inspections indicate a round field.

BEST PRACTICE: By using the peak audio response, the peak method can be used to assess signal shape while tracing the line.

Once the target line is pinpointed, the operator stands directly over the line. With the instrument plumb, the operator's feet are placed equal distance apart from the target line location, a bit past shoulder width.

1. The operator takes a peak reading on the ground at the position of the right foot.

2. Next, the operator takes a peak reading on the ground at the left foot.

3. Lastly, the operator compares the peak results from each foot. If the peak readings at each foot are the same, the field is round. If the readings are different, the field is not-round.

WALKING AND ACCESSING

Of the five ways to assess signal shape, only the peak method can be performed while tracing the line, so long as the receiver's audio response is a peak-generated, variable pitch response. While walking directly over the peak response, the operator must swing the receiver an equal distance on either side of the trace. If the audio response is identical on either side of the receiver's swing, the field is round.

Trace: the entire section of a pipe or cable being located.

Horizontal inspection of field: receiver readings that are obtained perpendicular to the pipe or cable location.

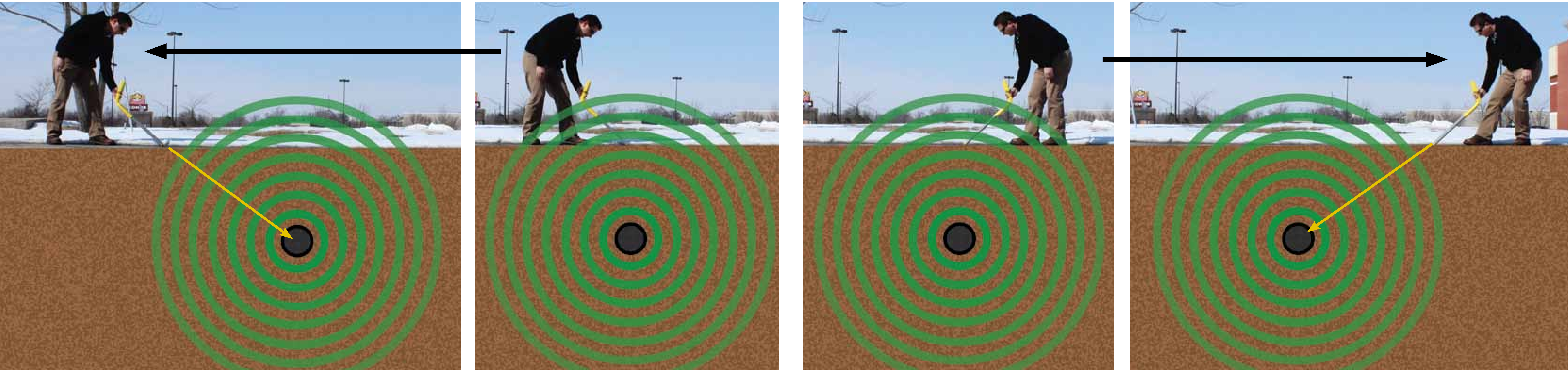
STEP 6 D

ASSESSING SHAPE WITH THE RECEIVER

TRIANGULATION

PURPOSE: To determine if other energized metallic objects exist, particularly when the vertical methods of inspections indicate a round field.

BEST PRACTICE: Triangulation estimates target line depths only if the receiver is held at a 45° angle.



Triangulation begins by obtaining a null response. Next, the operator lowers the receiver to a 45° angle. Dragging the receiver in a perpendicular direction away from the target line, the operator stops dragging the receiver after obtaining another null response. This process is repeated on the other side of the target line.

If the measurements from the original null to the two outer nulls are the same, the field shape is regarded as round; if the measurements are different, the field shape is regarded as not-round.

REVIEW: ASSESSING SHAPE WITH THE RECEIVER

While the primary purpose of using the five methods to determine field shape is to insure accurate locating results, these methods can provide other useful conclusions about what is beneath the ground. One such conclusion occurs when the vertical inspection of field indicates round but the horizontal inspection of field indicates not-round. The conclusion is that the locating results are accurate but some other piece of metal—typically another underground line—has become energized by the transmitter.

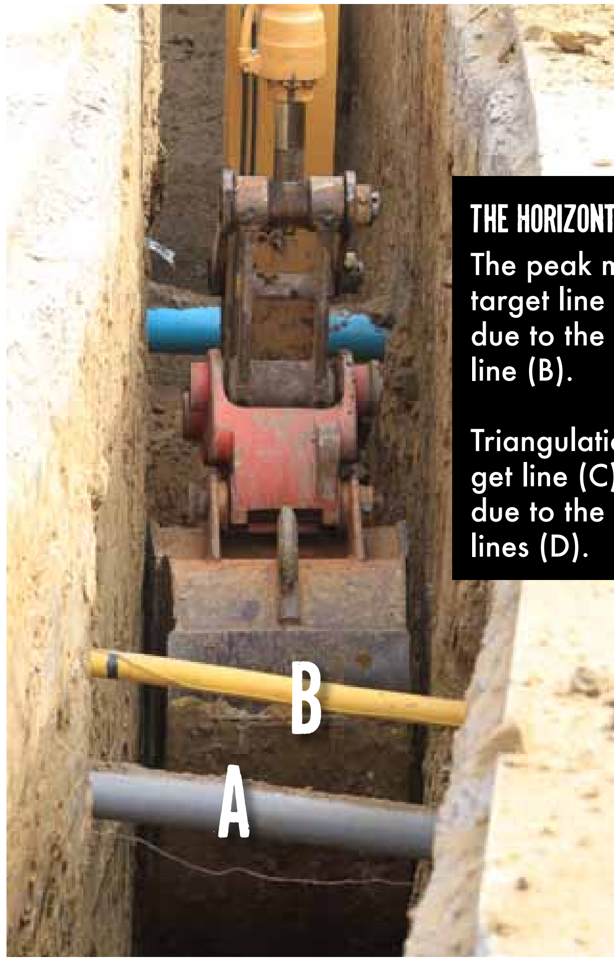
Vertical inspection cannot see the non-target line because there's not enough of the transmitter's current on the line to build a field strong enough to affect the target line's field. But when there is some current on a non-target line, peak method or triangulation readings obtained when moving the receiver toward the non-target will differ from readings obtained when moving the receiver away from the non-target.

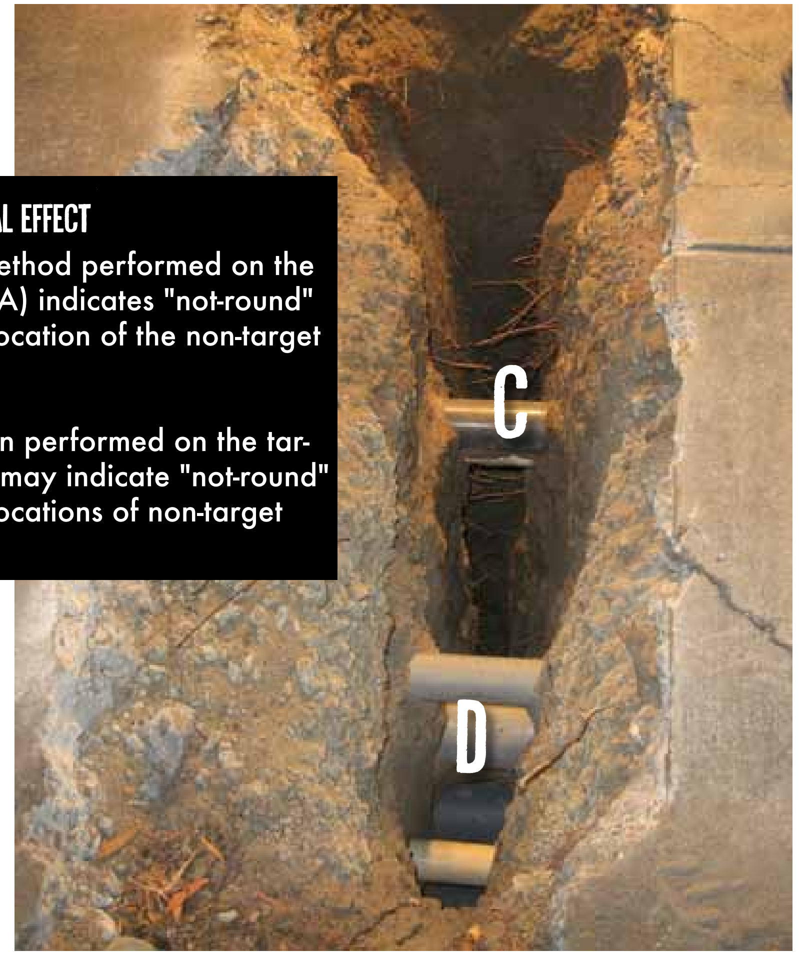
If there was enough current to build a stronger non-target line field, the null method may indicate not-round. If this non-target field is even stronger, digital depth will not validate over the target line. When non-targets are energized to a significant degree, peak and null readings will not agree.

When peak and null agree, digital depth validates, the null method indicates round, the peak method indicates round and triangulation indicates round, the conclusion is no non-target lines in the immediate area are energized by the transmitter.

ABOVE GROUND METALLIC OBJECTS

Metallic objects such as chain link fences, guardrails, dumpsters, vehicles and the like are easily energized by the transmitter. If energized, these objects help create not-round fields.





THE HORIZONTAL EFFECT

The peak method performed on the target line (A) indicates "not-round" due to the location of the non-target line (B).

Triangulation performed on the target line (C) may indicate "not-round" due to the locations of non-target lines (D).

THREE CHANGES AND A MOVE...

Receivers only provide the operator with two results: the level of current and the shape of the field. While good current and a round field are always the desired receiver results, good or poor current and a not-round field often occur. There are only four changes in the deployment of the transmitter that may be able to change the locating results of the receiver.

1. Change the frequency
2. Change the grounding system
3. Change the transmitter mode
4. Move the transmitter

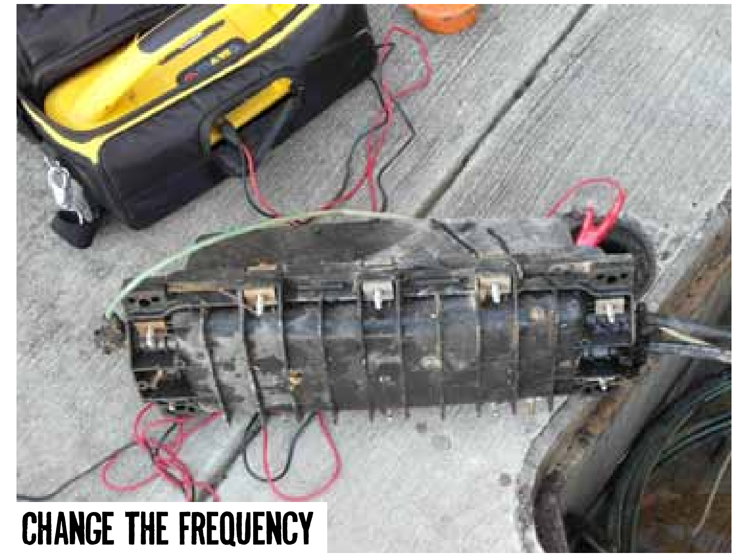
Changing the transmitter frequency changes the amount of induced current on the pipe or cable in the earth. This change in the amount of induced current may change the path of least resistance which in turn may change locating results.

Changing the grounding system includes changing the grounding of the transmitter when using conductive mode or changing the grounding of the utility system being located. While changing how the transmitter is grounded will likely change the amount of current leaving the transmitter, it is infrequent that the path of least resistance is changed. Changing the grounding system of the utility, however, often changes the path of least resistance which may in turn change locating results.

Changing the transmitter mode from conductive to inductive (or vice versa) may change the path of least resistance which in turn may change locating results. (Please reference the 50/50 Rule on page 25.)

Moving the transmitter often changes the path of least resistance which in turn may change locating results. Moving the location of the transmitter whether in conductive mode or inductive mode heavily influences locating results.

...CAN CHANGE THE PATH OF LEAST RESISTANCE



CHANGE THE FREQUENCY

CHANGE THE GROUNDING SYSTEM OF THE TRANSMITTER ON CONDUCTIVE

CHANGE TRANSMITTER MODE

CONDUCTIVE...

...TO INDUCTIVE

CHANGE THE GROUNDING SYSTEM OF THE UTILITY

MOVE THE TRANSMITTER

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The classic Metrotech 810 locator has become the new VM-810. The VM-810 incorporates all the classic 810 features into the new digital age allowing even better performance than before. The vLocPro2 is the updated version of the vLocPro receiver. Its new features include over 4 times the battery life in a smaller lighter package.
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www.vivax-metrotech.com

Contractor Bets on a *SHORE THING*

Kinsel Industries, now a part of Insitu-Form, can't take any chances when it comes to the project constructed in Jacksonville, Florida. The contract with the city utility authority, J.E.A., is a five – year, $160 million contract that initially required the bursting and replacement of sewer pipeline at a rate of over 45,000 lf. PER WEEK. This includes the tie-in of utilities to the community.

A great deal of the work is done in tight conditions and back yards.

Kinsel Industries has a long history of putting safety to work, hand in hand with productivity.

The project required constant monitoring for hazardous atmospheres and protection of workers in the excavation.

The initial use of hydraulic shores proved to be too time consuming, slowing productivity and increasing costs. The decision was made to use the latest technology in aluminum trench shoring, **ultraSHORE ™** trench boxes manufactured in Denver, Colorado. The trench depths are less than 12 ft. deep and **ultraSHORE™** is well suited to the Florida sands. A variety of Mini-Excavators are used to handle the excavation and boxes, even though most **ultraSHORE™** shields are light enough for two men to handle.

The local rental dealer for **ultraSHORE™, Trench Shoring Services**, (TSS) was able to supply a wide selection of inventory to match the variety of applications that were encountered. **Carlos Zambrano** was one of the many foremen on this vast project. Carlos appreciated the fast and dependable service provided by Trench Shoring Services to meet the ever-changing ground conditions.

The Jacksonville TSS facility also provides steel trench boxes and road plates to the region. CPT training is available in English and Spanish to meet the needs of the growing workforce.

..most ultraSHORE™ shields are light enough for two men to handle

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The sound of: you making fewer trips to the truck.
PSSSSSHH HHHHHHH
The sound of: spraying a solid 2-inch mark in one pass.
PSSH
The sound of: no clogging.
PSSH
WOOHOO!
The sound of: you maintaining the rhythm of your job thanks to the best marking paint.
RATTLE RATTLE RATTLE
The sound of: fewer shakes of the can.
Dinngg
The sound of: colors that don't fade.
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Krylon Industrial knows that locators like you have a unique rhythm to your job - from the moment you arrive, 'til the last mark is made. And we've designed our products to make sure you keep your rhythm all day long... without missing a beat!
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HARD TO TRACE TRACER

EM locating can't detect nonmetallic pipes or cables, such as polyethylene pipe or fiber optic cable. Metallic tracing mechanisms installed years ago are not detectable today due to poor design, broken or deteriorated wires, poor splicing or grounding techniques, low-grade wire insulation resulting in corrosion issues, or a host of other factors.

Even tracing mechanisms installed as recent as a decade ago have failed, or are about to fail, due to harsh conditions brought about by boring and other construction means that comprise the integrity of the tracing product.

Often, only very high transmitter frequencies have a chance to locate these poor conducting tracer wires. These frequencies are those over 400 kHz and are only found on a select few manufacturers' instruments

TRACER WIRE BLUES

Deteriorated wire above the ground signals the likely condition of the wire placed underground.

THE LANGUAGE OF LOCATING TRACER WIRE

TRACER WIRE FOR HDD APPLICATIONS

By: Maureen Droessler
Program Administrator
Operations Technology Development, NFP
Contact: 847/768-0608

Extensive research and testing has culminated in the release of a new report that provides valuable information on tracer-wire products for use in horizontal directional drilling (HDD) operations.

PROJECT DESCRIPTION

For more than 20 years, the installation of solid copper tracer wire – buried alongside polyethylene (PE) pipes – has been the standard practice used to help utilities locate underground plastic piping. Copper wire is readily available, highly conductive, and relatively easy to handle. However, the increased use of more demanding operations – such as horizontal directional drilling (HDD) operations – creates challenges and can cause breaks in tracer wire during installation.

Utility practices vary during HDD pipe installations. Some utilities pull multiple wires, while others may rely on a single large-gauge wire. The desire for a stronger tracer wire has led some utilities to turn to copper-clad steel (CCS) wire.

Other options for tracing plastic pipe have been brought to market with mixed levels of satisfaction.

These systems primarily lack the needed tensile strength necessary for HDD operations.

To address these challenging installation issues (rocky, long pulls, etc.), researchers under the sponsor- ship of Operations Technology Development (OTD) investigated the properties and performance of currently used tracer wire products as well as new, potentially stronger, tougher-to-cut, and more "HDD friendly" products.

There are many tracer wire variables for operators to consider with different properties, such as: conductor type, gauge size, hardness, insulation thickness, and material type. New tracer wire options for locating plastic pipe primarily attempt to address a lack of tensile strength of traditional tracer wire. One such product, Polymer Fiber Reinforced Solid Copper, differs from traditional tracer wire products in that it employs a layer of insulation placed over the conductive metallic core. Such woven-strip configurations have a very high strength-to-weight ratio and are commonly used in industrial lifting and towing applications at very high levels of loading. In theory, the woven fabric in this wire would contribute to the bulk of the product's tensile strength and provide additional abrasion resistance, both protecting the wire from damage and reducing the chance of breakage.

Given the number of tracer wire configurations available, along with new products such as Polymer Fiber Reinforced Solid Copper, the industry supported a comparative evaluation to allow operators to select a cost-effective tracer wire that can withstand the stresses of installation techniques in various environmental and soil conditions

BENEFITS

Data developed through this project can be used by the gas industry and its contractors to enhance the efficiency and success of installing and locating plastic piping systems used to transport natural gas.

Wire #	Co.	Tracer Wires	Overall Performance Rating*							
			Tensile Break Load		Insulation Jacket		Corrosion Performance		Wire Flexibility	
			No Kink	Kinked	Abrasion	Scrape	Continuity	Break Load	Rigidity	Spring-back
1	A	Solid Copper (12 AWG)	NT	NT	NT	NT	YES	NT	NT	NT
2	B	Solid Copper (12 AWG)	12	12	51	34	YES	NT	73	26
3	B	Solid Copper (10 AWG)	18	NT	51[a]	NT	NT	NT	NT	NT
4	B	Hard Drawn Solid Copper (10 AWG)	26	25	51[a]	34[a]	NT	NT	29	35
5	C	Solid Copper (14 AWG)	8	8	65	18	YES	NT	100	100
6	C	Solid Copper (12 AWG)	12	12	65[a]	18[a]	YES	100	67	29
7	A	Fully Annealed CCS (12 AWG)	16	16	76[a]	9	YES	NT	57	40
8	A	Stress Relieved CCS (12 AWG)	32	24	76[a]	45[a]	NT	NT	28	18
9	A	HDD CCS (12 AWG)	61	28	76	45	YES	NT	21	13
10	D	Super Flex CCS (14 AWG)	11	11	53[a]	10	YES	NT	100	29
11	D	Super Flex CCS (12 AWG)	17	17	53[a]	10[a]	NT	88	50	30
12	D	High Strength CSS (12 AWG)	23	23	53[a]	10[a]	NT	NT	50	24
13	D	Extra High Strength CSS (12 AWG)	63	25	53	44	YES	NT	23	13
14	B	Dead Soft Annealed CCS (12 AWG)	16	16	51[a]	34[a]	NT	NT	57	35
15	B	Stress Relieved CCS (12 AWG)	30	29	51[a]	NT	NT	NT	NT	NT
16	E	High Flex CCS (12 AWG)	19	19	100[a]	56[a]	YES	NT	57	33
17	E	HDD CCS (12 AWG)	61	45	100	56	NO	63	16	15
18	F	Fiber and Copper (19 AWG)	100	100	62	100	YES	NT	100	12

***The overall performance rating** NT = Not Tested

- *Rating of tensile break load (with and without a kink) was calculated using the laboratory tensile test results by the ratio of the break load of the evaluated wire to that of the best performed wire (#18 having the highest tensile break load with and without kink).*
- *The rating of abrasion resistance was calculated using the laboratory abrasion resistance test results by the ratio of the insulation thickness loss of the best-performed wire (#17 having the lowest number of thickness loss) to the evaluated wires.*
- *The rating of scrape resistance was calculated using the laboratory scrape resistance test results by the ratio of the scrape-through cycles of the evaluated wire to that of the best performed wire (#18 having the highest cycles that the insulation was scrape through).*
- *The rating of the wire tensile performance at exposure to corrosion environment was calculated by the ratio of the break load measured after corrosion test to the break load measured on the as received specimens made from the same wire product.*

a: This wire was not tested in this project. The rating is referred to the other product having the same insulation material from the same manufacturer.

A more effective tracer wire that is readily locatable, strong, and easy to handle would improve the gas operations by:

- Preventing wire breaks which result in unlocatable plastic pipes (therefore, reducing the risk of third party damage and potential incidents)
- Reducing cost by allowing for the use of a single wire for a directional-bore pullback instead of using multiple tracer wires
- Providing faster installations by reducing the time required to address breakage of the tracer wire during challenging HDD pipe installations.

TECHNICAL CONCEPT & APPROACH

This project included the following tasks:

- Product Review and Test Protocol Development
- Laboratory Testing
- Field Testing
- Development of Recommendations.

Products tested in this program are manufactured by: Agave Wire, Ltd.; Copperhead Industries, LLC; Kris-Tech Wire; NEPTCO, Inc.; Paige Electric Company, LLP; and Pro-Line Safety Products Company.
Note: In the chart, companies are coded.

LABORATORY TEST RESULTS

The traditional, soft-drawn solid copper tracer wires have relatively low tensile break load; however they exhibit greater elongation in the plastic deformation range before the ultimate tensile loads (tensile break load) were reached.

The extra-high-strength copper-clad steel wires are made with a high-carbon steel core, which significantly improves the wire tensile strength (>1,000 lb for 12 AWG wires). However, this type of wire is more brittle and breaks without significant plastic deformation in the tensile test. Therefore, the tensile break load is significantly reduced when the wire is kinked.

The high-flex copper-clad steel wires are made of low-carbon steel by a special annealing process to make these CCS wires more flexible. They have a slightly higher ultimate tensile load than the traditional soft-drawn copper wire and also exhibit similar elongation properties as traditional, soft-drawn copper wire.

One company's product exhibited a significantly high tensile load (~1,800 lb), attributed to the polymer fibers which provide the strength. This wire also exhibited the similar high tensile load when it was tested with a kink.

Abrasion and Scrape Resistance Test Results

The abrasion and scrape resistance of the tracer wire jackets varied based on the type of PE material and also the manufacturer of the wire. In general, high-density polyethylene (HDPE) insulation jackets have a higher scrape resistance than low density polyethylene (LDPE) insulation jackets with the same coating thickness. The increased thickness of the insulation jacket from 30 mils to 45 mils significantly increases the scrape resistance of the wires.

The abrasion resistance of the HDPE jackets from two companies outperformed the other tested PE jackets (LDPE and HDPE).

The scrape resistance of one company's insulation (containing polymer fiber and HDPE coating) was significantly higher than the traditional HDPE and LDPE coating.

Corrosion Evaluation

One company's CCS wires for HDD application were severely corroded at the locations where the insulation jacket was damaged during the laboratory scrape test or through field installations. The wire completely lost continuity or resulted in a reduced tensile break load at the damaged insulation due to corrosion.

FIELD TEST RESULTS

Several tracer wire products were selected for field evaluations based on laboratory test results. The two test sites selected were contained in rocky soils and represented a difficult scenario for HDD pipe installation. Although none of the wires broke during pull in, many of the wires that experienced flaws on their insulation jackets and kinks after they were pulled through the bore hole.

The field test results suggested that the users and wire should take into account the selection of high-performance insulation materials that have higher abrasion and scrape resistance in order to prevent wire insulation damage during HDD installations. In one case, corrosion of a CCS wire at the damaged insulation jacket reduced the wire tensile break load and may result in a complete loss of wire continuity during the service life of the wire.

The overall performance of the tracer wire products investigated in this project were rated using the laboratory test results on tensile break loads (with and without kink), flexibility and springback of the wires, abrasion resistance, and scrape resistance together with the corrosion performance post-field installation.

In all, one company's wire outperformed the other wires based on its rating for the various performance properties evaluated. This wire was also tested in the two field test trials by HDD installation and did not show significant damage on the wire insulation. Furthermore, the continuity of this wire conductor was not affected after a 2,000-hour corrosion test.

The high-strength CCS wires designed for HDD installation had improved tensile break load compared to the traditional solid copper wire; however, some of the CCS wires' tensile break loads were significantly reduced when the wires were kinked and then tensile tested. These wires with the reduced tensile properties when the wire was kinked are the CCS wires with less flexibility and a higher springback. In addition, the abrasion and scrape resistance of the wires needs to be improved in order to prevent insulation damage during HDD installation (to prevent corrosion of the exposed wire).

WITHOUT WIRE, TRACING NONMETALLIC LINES

LOCATING OBSTACLES

Compared to EM, utilizing instruments to detect nonmetallic lines is a more time-consuming process. In addition, the results of detecting nonmetallic lines are often delivered with less confidence as compared to EM locating of metallic lines. The major obstacles to effective EM locating:

- congested utility environments
- lack of metallic continuity

The major obstacles to effective nonmetallic line locating:

- Lack of access for insertion of tracable push rods
- Operator time and experience necessary to interpret results effectively

THE LANGUAGE OF LOCATING
ALTERNATE LOCATING METHODS

A traceable push rod allows the operator to locate non-metallic pipes, conduit and duct banks. The operator must be able to access the pipe through an opening such as a manhole or hand-hole. Any EM pipe and cable locating equipment will work to energize a traceable push rod.

The metal rod on the spool is encased with a nylon sleeve which prevents corrosion when the push rod encounters liquids. The end of the push rod is threaded to accept a variety of tips designed to aid in the travel of the push rod through a duct or pipe.

The rod is first inserted into the pipe or conduit and pushed the desired distance to be located. The operator then applies signal to the push rod by attaching one end of the transmitter's conductive leads to the locate clip on the reel. Current travels on the metallic push rod, enabling the operator to find the rod using the receiver.

Since the end of the rod is not a grounded far-end, higher transmitter frequencies may work better than low frequencies in certain situations.

An acoustic locating instrument provides an alternative and supplemental method of locating buried pipes, particularly nonmetallic pipes, ducts, or conduits. Sometimes called "thumping," an acoustic instrument transmits and receives sound waves. An acoustic instrument detects voids in the ground created by a pipe or other utility structures, by using a process known as impedance mismatch.

Located near the front of the instrument's chassis, an actuator sends a series of sound waves, or "pings," into the ground. To the rear of the chassis, the accelerometer receives the sound waves once they have been reflected off of a buried pipe.

A single ping is known as a slice and series of slices is known as a scan. To allow internal software to calculate the location of a buried pipe, a scan must consist of at least 5 slices. This information is presented to the operator in the form of a pipe map on the display.

To conduct a scan using an acoustic instrument, the operator sets up a tape measure on the ground to track slice intervals perpendicular to the believed path of a target line. The closer the slice intervals are taken, the higher the resolution of a scan. Slices should be taken in a series of multiple rows that are spaced six to ten feet apart.

To scan for pipes that may run perpendicular to the first set of rows, a grid scan must be utilized. To conduct a grid scan, a series of rows will be scanned in a perpendicular orientation the first set of rows.

ACOUSTIC LOCATOR AND SCANNING GLOSSARY

Actuator: Sends acoustic waves into the ground.

Accelerometer: Receives acoustic waves reflected from a buried pipe.

Pipe map: A calculation made using software to estimate the location of a void in the ground created by a buried pipe using scan data.

Acoustic Wave: A sound pressure wave.

Void: The absence of material within the ground created by the presence of a pipe.

Row: The position of a scan in succession, within an axis.

Grid: A series of scans conducted perpendicular to one another on an X and Y axis.

Axis: The alignment of a scan, such as north-to-south or east-to-west or any reference line in a Cartesian Grid (X or Y).

Origin point: A location in which two axes intersect or in a Cartesian Grid, where the X and Y axis meet. (0 and 0).

Scan: A data collection method.

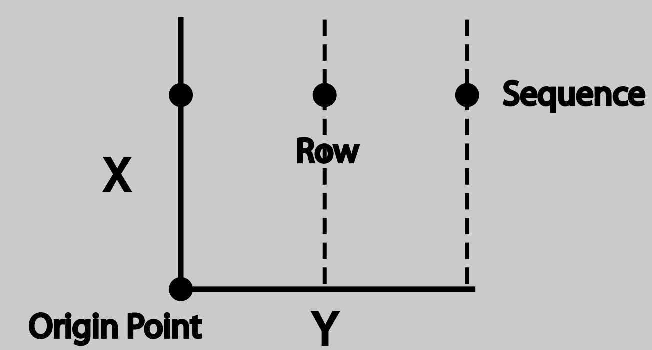
Slice: A vertical or horizontal sectional view of the scan.

Cartesian Grid: A coordinate system based on an origin point. These grids can be used to create 3D images when using GPR.

Survey: Data collection method using multiple scans.

Perpendicular: The optimal orientation of the sensor head to a target object.

Sequence: A consistent pattern of objects in a series of line scans.



THE LANGUAGE OF LOCATING
GROUND PENETRATING RADAR

Ground penetrating radar (GPR), functions in the same manner as radar used to see airplanes in the sky, but the GPR signal is simply applied underground. The data displayed to the operator is similar to that of a fish finder. GPR is capable of allowing the operator to locate metallic and non-metallic objects.

A GPR cart houses all of the components needed to conduct a real-time scan. The GPR cart allows the operator the ability to push or tow the cart to conduct a scan.

Sensor head: Contains send and receive antennas.

Sled: An attachment on the GPR cart that allows freedom of movement for the sensor head. Sometimes used to describe the sensor head.

Cart: A small wheeled vehicle that houses GPR components in a single unit.

Odometer: Tracks distance traveled, necessary for locating and marking objects.

Display: Provides graphical GPR scan data in real-time.

CPU: Computer that processes GPR scan data.

HOW IT WORKS:

An antenna inside of the sensor head sends and receives the GPR signal. If it were visible to the naked eye, the shape of the signal leaving the sensor head would look like a cone. When the sensor head's energy encounters an object, the energy reflects back from the object and returns to the sensor head.

Scan data is then processed in the CPU and displayed to the operator. An odometer tracks the distance traveled and can be used to set markers or notes within the scan data, or to physically mark the location of found objects with paint or flags.

Substrate: Any material beneath the surface of the earth.

Dielectric Constant: A non-conductive medium or substrate that supports the creation of a magnetic field.

Medium: The composition of a section of substrate that is scanned using GPR.

Signal: Energy produced by an antenna.

Resistivity: A measure of how much a substrate or medium resists the GPR signal.

Object: Any material underground that has a different dielectric constant than the substrate or medium.

Reflection: Data from a scan resulting from signal leaving the sensor head and returning to the sensor head.

Nanosecond: One billionth of a second. The measurement of time used to estimate depth to target using reflection.

Slap-back: Signal reflection that may cause ghosting.

Target: An object identified by a parabolic arch.

Marker: A note that may be saved within GPR scan data to reference a point of interest at a later time.

THREE MAJOR FACTORS THAT IMPACT GPR SIGNAL:

- Frequency
- Water Content
- Soil Type

LINE LOCATING USING GPR

The operator begins a line scan at a distance of about 3 feet away from the suspected target area, perpendicular to the believed path of the target line. The operator then pushes the GPR cart in a smooth and fluid manner, making sure that the odometer doesn't skip and cause a distortion in the scan data.

Line Scan: A GPR scan taken in a linear fashion.

Grid Scan: A GPR scan that can be used to create three-dimensional data.

Centerline: The apex of a parabolic arch, sometimes denoted on a GPR cart with arrow markings.

When the operator pushes the GPR cart, the data populates on the display from right to left. As the cart approaches an object, the first tail of a parabola will become visible on the screen.

Marker: A note that may be saved within GPR scan data to reference a point of interest.

Tails: Created when the GPR signal encounters an object. Two tails create a parabola when the sensor head completely pass over an object.

Parabola: A curved shape that is formed when the GPR signal contacts an object.

Parabolic Arch: Indicates a possible target when viewed on the display or DVL.

Apex: The highest point of a parabolic arch.

The complete parabolic arch will only become visible after the sensor head has completely passed an object and has created the second tail of the parabolic arch. To ensure that no objects are missed, the operator pushes the cart at least 3 feet beyond the limits of the area to be scanned.

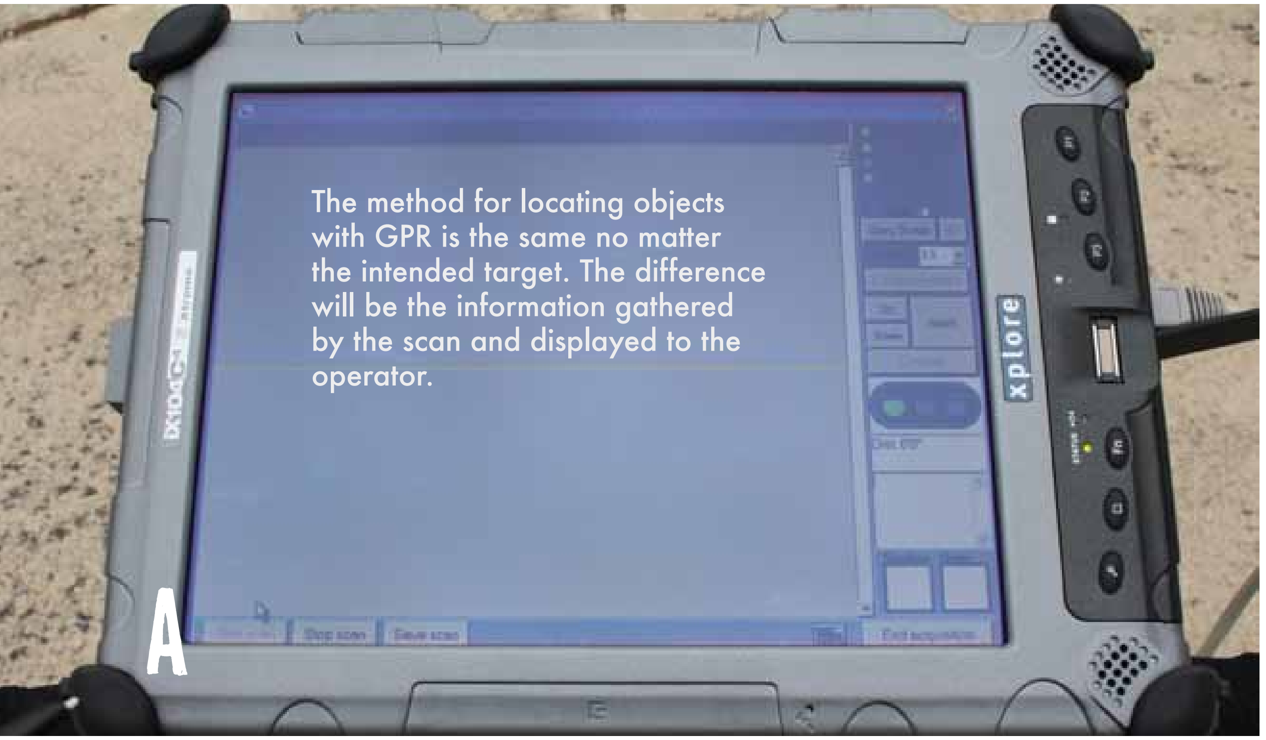
The operator then walks backwards, pulling the GPR cart in a smooth, fluid motion, paying attention to the reference marker. The tracking line of the reference marker will move, but the scan data will remain stationary on the display.

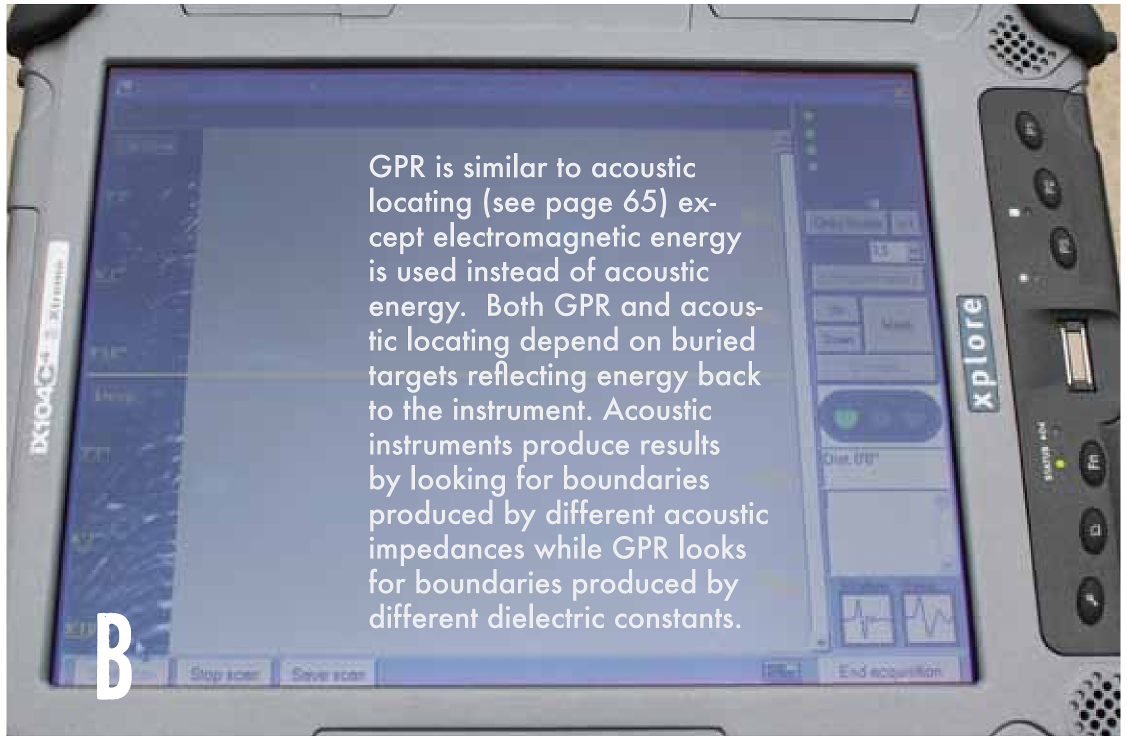
Wherever the tracking line is positioned on the screen indicates the center of the sensor head. Arrows placed on the sides of the sensor head sometimes indicate the center as well. When the tracking line is positioned on the center of a parabolic arch at the apex, the sensor head will be centered on an object.

A series of line scans must be conducted parallel to one another, yet still perpendicular to the target line. A sequence, or consistent pattern of objects, indicates the possible location of a utility line. This can only be verified visually, however, via potholing.

Sequence: A consistent pattern of objects in a series of line scans.

LOCATING BURIED TANKS WITH GPR



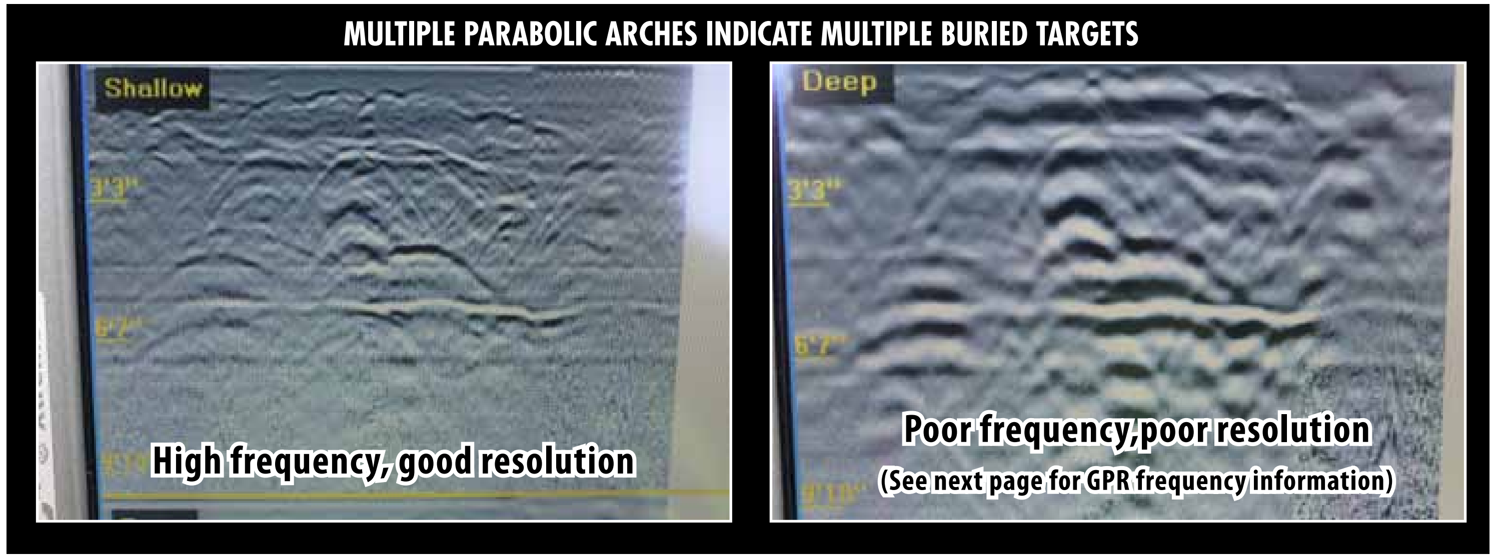


The operator begins the scan about 3 feet before the area to be scanned. As the cart approaches an object, a tail will begin to be visible on the display. When the sensor head is directly over an object only half of the parabola is visible.

A buried tank has a large diameter and therefore the parabola will be broad. As the cart is pushed beyond the limits of the object, the full parabolic arch will become visible to the operator. The larger the diameter of an object, the broader the parabolic arch will be.

The center of the object is always indicated by the center of the parabolic arch, at the apex. The operator extends the scan at least 3 feet beyond the scan area to ensure that any objects within the scan area are registered.

To mark the center of an object, the operator walks backwards, ensuring that the wheel with the odometer has good contact with the earth and doesn't skip. When the tracking line is centered with a parabolic arch, the sensor head will be centered on an object. Unless the actual diameter of an object is known, the exact limits of a buried object can only be speculative at best.



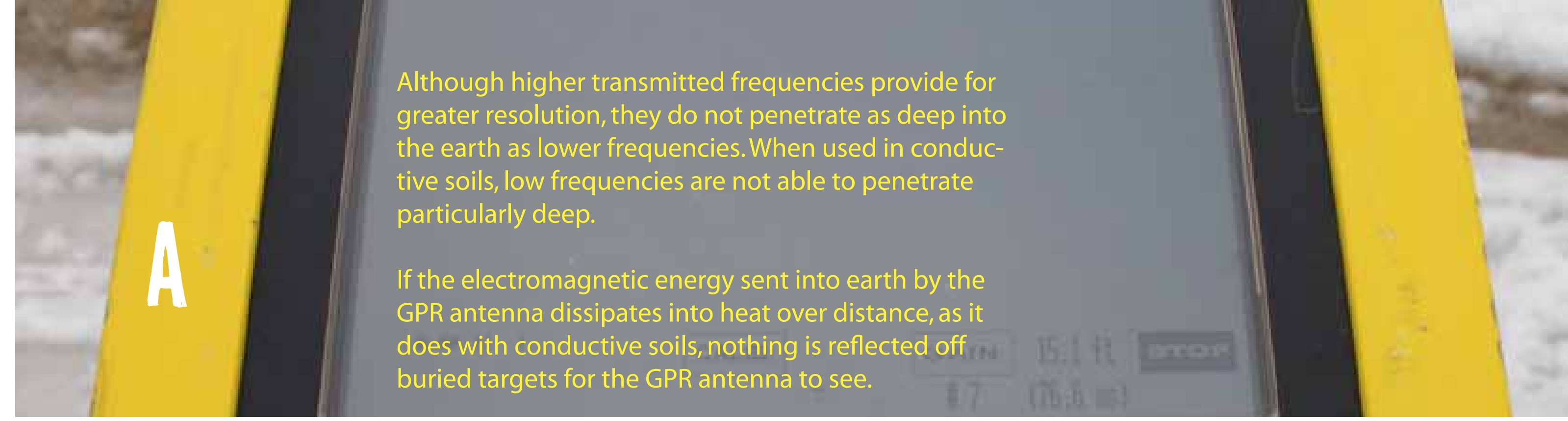
LOCATING VOIDS WITH GPR

When scanning an area for voids, the operator begins the scan about 3 feet before the scan area. The operator pushes the GPR cart in a smooth and steady motion, ensuring the odometer wheel doesn't hop or skip. Any hop in the odometer wheel will translate to a gap in data acquired during the scan.

As the operator approaches a void, an anomaly may become visible on the far right-hand side of the display as data populates. When the sensor head is centered on a void area, an anomaly will be apparent as a visual difference in scan data on the display. Once the GPR cart completely passes a void, an anomaly may be made fully visible to the operator as a definite change in scan data. The void location will extend from the beginning of an anomaly all the way to where the anomaly ends.

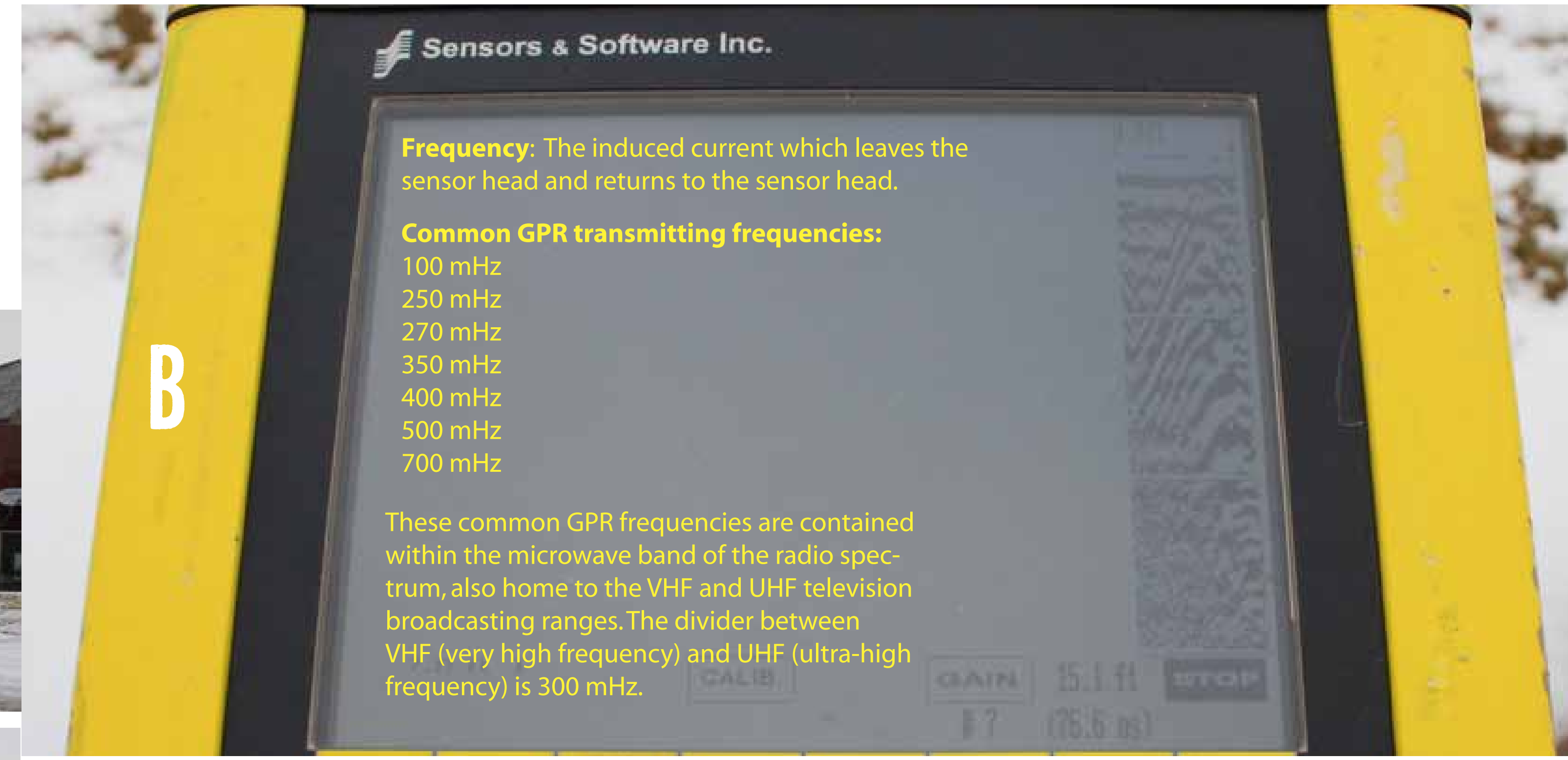
Void: The absence of medium within a substrate; a hollow area beneath the surface.

Arrows: Markers sometimes placed on the sensor head to denote the location of target.



Although higher transmitted frequencies provide for greater resolution, they do not penetrate as deep into the earth as lower frequencies. When used in conductive soils, low frequencies are not able to penetrate particularly deep.

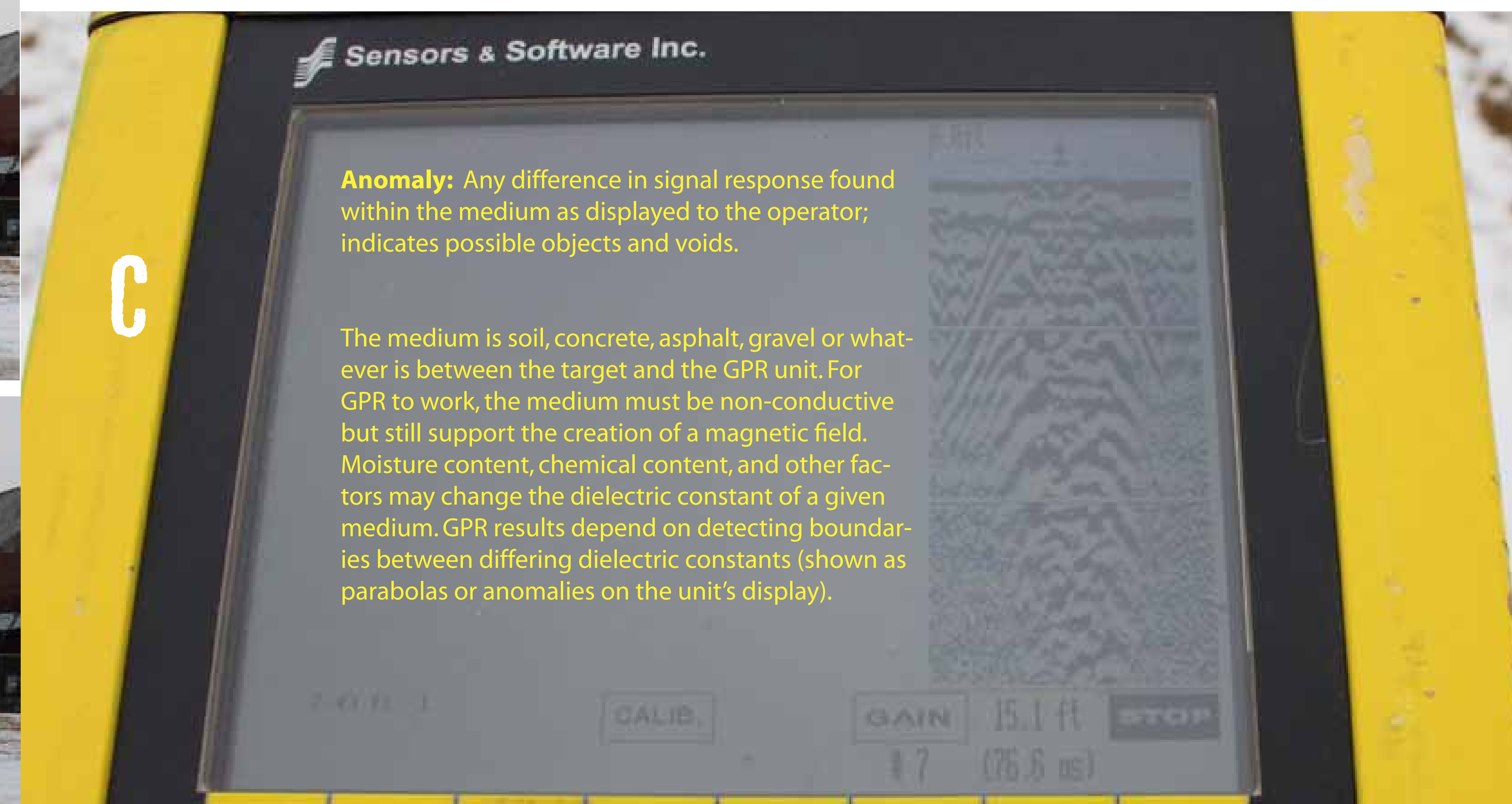
If the electromagnetic energy sent into earth by the GPR antenna dissipates into heat over distance, as it does with conductive soils, nothing is reflected off buried targets for the GPR antenna to see.



Frequency: The induced current which leaves the sensor head and returns to the sensor head.

Common GPR transmitting frequencies:
100 mHz
250 mHz
270 mHz
350 mHz
400 mHz
500 mHz
700 mHz

These common GPR frequencies are contained within the microwave band of the radio spectrum, also home to the VHF and UHF television broadcasting ranges. The divider between VHF (very high frequency) and UHF (ultra-high frequency) is 300 mHz.



Anomaly: Any difference in signal response found within the medium as displayed to the operator; indicates possible objects and voids.

The medium is soil, concrete, asphalt, gravel or whatever is between the target and the GPR unit. For GPR to work, the medium must be non-conductive but still support the creation of a magnetic field. Moisture content, chemical content, and other factors may change the dielectric constant of a given medium. GPR results depend on detecting boundaries between differing dielectric constants (shown as parabolas or anomalies on the unit's display).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