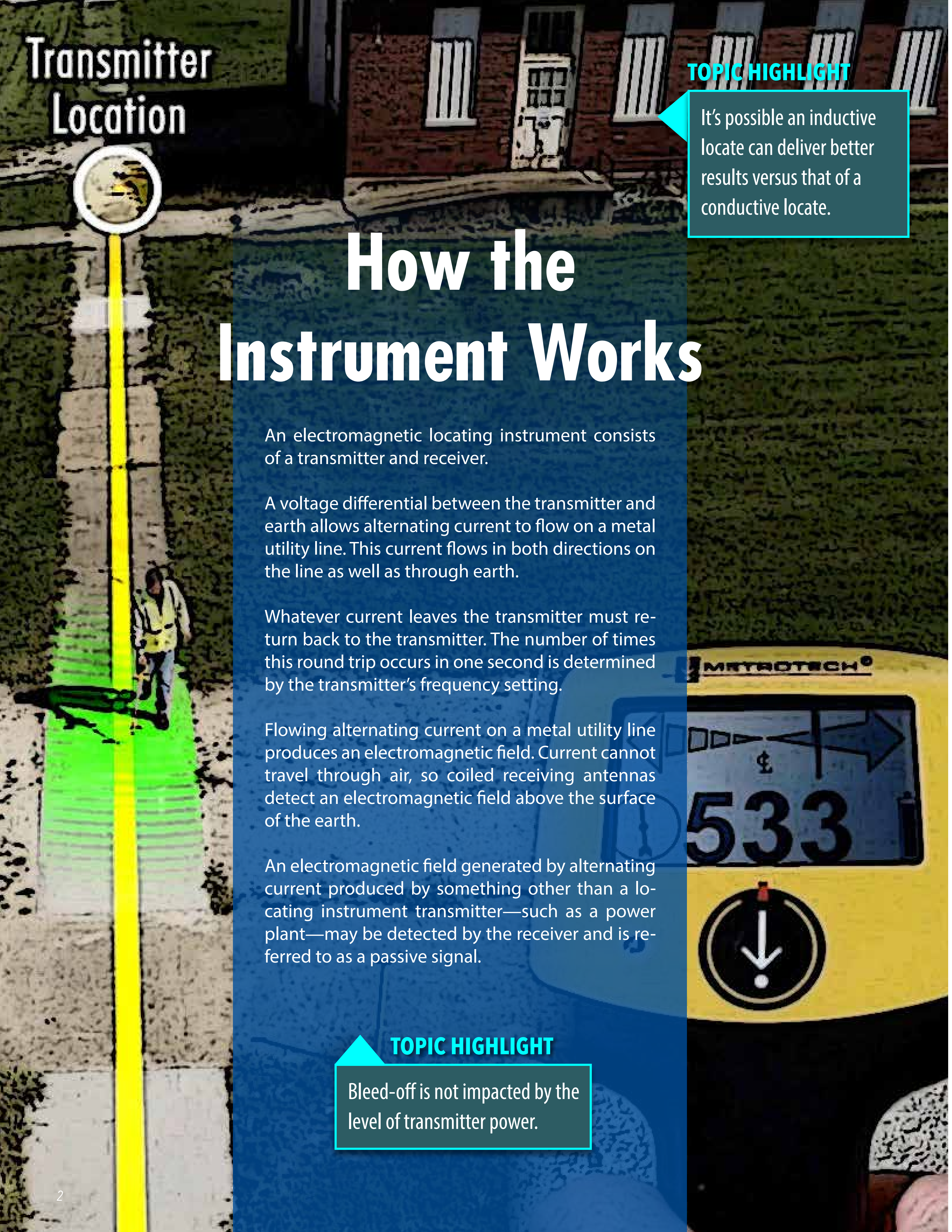
Staking University

The Locating Instrument



TOPIC HIGHLIGHT

It's possible an inductive locate can deliver better results versus that of a conductive locate.

How the Instrument Works

An electromagnetic locating instrument consists of a transmitter and receiver.

A voltage differential between the transmitter and earth allows alternating current to flow on a metal utility line. This current flows in both directions on the line as well as through earth.

Whatever current leaves the transmitter must return back to the transmitter. The number of times this round trip occurs in one second is determined by the transmitter's frequency setting.

Flowing alternating current on a metal utility line produces an electromagnetic field. Current cannot travel through air, so coiled receiving antennas detect an electromagnetic field above the surface of the earth.

An electromagnetic field generated by alternating current produced by something other than a locating instrument transmitter—such as a power plant—may be detected by the receiver and is referred to as a passive signal.

TOPIC HIGHLIGHT

Bleed-off is not impacted by the level of transmitter power.

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SU TRAINING CENTER

How a locating instrument works can be summarized by six statements...

1. There are only two ways to receive: peak and null.

Receiving antennas at different angles provide direction and measurement.

2. There are only two ways to transmit: metal-to-metal and non-metal-to-metal.

There are only two ways to bleed-off: metal-to-metal and non-metal-to-metal.

3. Signal wants to leave equally in all directions.

Due to bleed-off, signal doesn't always leave equally in all directions.

4. Signal always follows the path of least resistance.

The results of any locate–good or not good–are dictated by the route that alternating current (AC) follows.

5. Different frequencies can and sometimes will do certain things.

Sometimes higher frequencies deliver superior results over the results of lower frequencies.

6. You can't change the results of a locate with the receiver.

Any peak reading changes are ratio-metric and do not change the results of a locate.

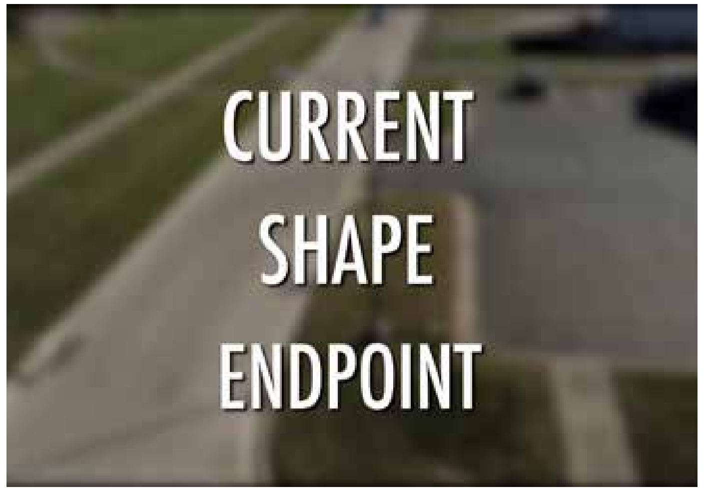
This training material is taken from videos. Most of the filming done for this project took place at Staking University in Manteno, Illinois. The skilled trainers at Staking U are familiar with almost every utility installed on the campus as far back as the 1940s, and this created the perfect setup to demonstrate different locating scenarios and techniques.

Core Concepts

At Staking University, our goal is to teach you two things: how a locating instrument works and how to use that instrument. At its core, locator training comes down to three key concepts: **current, shape** and **endpoint**. This will be a common anchor point for every student undertaking our training program.

The Staking University philosophy is to show the student ways to use a locating instrument to make their locates as smooth and as accurate as possible. The comprehensive body of information provided through this training program is meant to not only teach key concepts, but to demonstrate them as well. Thus, the student will be able to recognize and tackle many different scenarios that require their locating instrument to be used in different ways **(Figure 1)**.

Let's take a look again at the basic core concepts of current, shape and endpoint. Current is produced by the transmitter **(Figure 2)**, and the transmitter is the key part of the electromagnetic locating instrument. The receiver **(Figure 3)** cannot be used to change the results of a locate. Only the transmitter can be utilized in a different way in an attempt to change the results of a locate. Producing current is what the transmitter does.



But there are a few ways a transmitter can transmit current, so it's not as simple as turning an on-switch to the on position and just waiting for the current to flow. As we dive into locate scenarios, you'll see that frequency, utility characteristics, earth and other factors will dictate the current flow produced. You may need to do something different with the transmitter if your initial results are not satisfactory.

TOPIC HIGHLIGHT

Analyzing the information provided by **the receiver** is key to determining the proper utilization of the transmitter.

__Figure 1:__ Staking University training exists because locating instruments are not always used with the best possible method for a given situation.

TOPIC HIGHLIGHT

A **transmitting frequency** of 10 kilohertz and below is a low frequency, while a frequency of 10 kHz is a high frequency.

__Figure 2:__ Current is produced by the transmitter. As current flows on a conductor, an electromagnetic field is produced.

TOPIC HIGHLIGHT

A **conductor** is a material or object that allows the flow of electricity. This includes metal pipes or the metallic component of cables, as well as the earth.

__Figure 3:__ The receiver cannot change the results of a locate. It can only detect an electromagnetic field.

Transmitting Signal

TOPIC HIGHLIGHT

Locating a metallic underground utility is the process of transmitting a signal, receiving the signal, and then following the signal to a visual and logical **endpoint** for that utility.

Figure 4: *Attaching a cable from the transmitter to an electric transformer.*

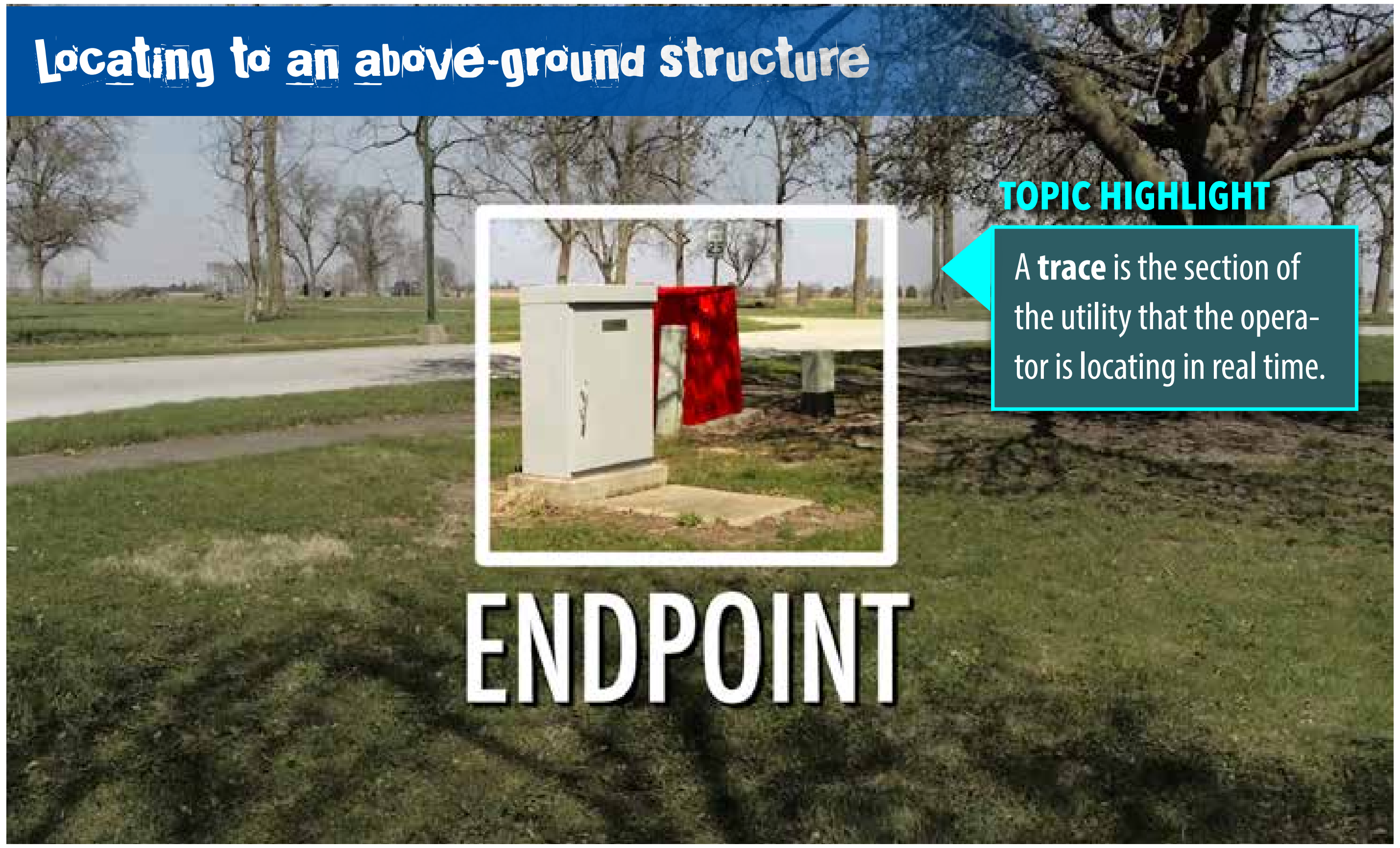
Receiving Signal

Figure 5: *The number 446 is reflective of the amount of current on the underground electric line. This number is known as a peak reading, and the steadiness of this reading determines the level of current flow.*

Receiving Signal

Figure 6: *Arrows provide left-right guidance and this guidance is known as a null reading. Peak and null readings are compared to each other to determine the shape of the electromagnetic field being received.*

Locating to an above-ground structure



TOPIC HIGHLIGHT

A **trace** is the section of the utility that the operator is locating in real time.

Figure 7: *Endpoint is the process of using a locating receiver and following a trace to an above-ground indication for a particular utility. The red highlighted structure is an electric facility.*

Transmitting Methods

The transmitter is the key to the electromagnetic locating instrument. Proper use of the transmitter is what gives us the ability to receive good signal with the receiver. ***The Basics*** video series begins with a lesson on the two ways to energize a line with the transmitter—conductive and inductive. Conductive describes the connection between a metal pipe or cable and earth—the two conductors in every locating circuit.

Inductive, on the other hand, is a nonmetal-to-metal transfer of the transmitter's energy. The signal leaves the transmitter in a pumpkin-shaped field, and some of that field is able to envelop the pipe or cable and creates current flow on the pipe or cable. Once current is flowing on an underground line, the receiver doesn't know whether the signal was applied conductively or inductively **(Figure 8)**.

When you're performing an inductive locate, there's a good chance you're doing it because there may not be an obvious access point above ground that allows you to perform a conductive locate. A useful technique to remember when locating inductively is called a "Two-Man Sweep" **(Figure 9)**. This procedure consists of one operator holding the transmitter slightly above the ground and walking, while another operator holds the receiver and looks for a response.

Another way to transmit is the use of an inductive coupler. Whether using inductive or the inductive coupler, the way signal behaves is different from a conductive locate. The use of an inductive coupler is essentially the use of a remote antenna capable of being placed around specific cables in areas where there are multiple cables. This allows the operator to single out a specific cable that they want to locate and ensures that the signal reading shown on the receiver is as accurate as possible **(Figure 10)**.

All of these different methods of locating are used throughout the entire training course, and it's important to have a basic understanding of each one. This way, it will be easier to see why the operator may elect to use one method over another in any given situation. The goal is to get the best signal possible in order to make the locate easier and for the operator to feel confident that the locate is accurate.

"The transmitter is the key to the electromagnetic locating instrument. Proper use of the transmitter is what gives us the ability to receive good signal with the receiver."

Figure 8 top: *A conductive locate of a steel pipe.*
Figure 8 bottom: *An inductive locate of a three-phase electric line featuring a pumpkin-shaped field.*

Figure 9: *A Two-Man Sweep being performed to locate multiple parallel utilities.*

"Whether using inductive or the inductive coupler, the way signal behaves is different from a conductive locate. With an inductive coupler, you are utilizing a remote inductive antenna capable of being placed around specific cables in areas where there are multiple cables."

Figure 10: *An inductive coupler being used to locate a cable TV feeder.*

Signal

Signal is a very important concept of locating, an idea which should be fully understood before a student dives into the heart of the training program. The best way to do this is to show how signal circles work. Signal circles are created by flowing alternating current on the metallic skin of a pipe or cable. These signal circles want to leave equally in all directions **(Figure 11)**.

We use green arrows to indicate flowing current and green circles to represent the electromagnetic field in an effort to show how the locating instrument works. When the fields build out, current is flowing away from the transmitter. When the fields collapse, current is traveling toward the transmitter. And this is true whether we're utilizing conductive locating, inductive locating or the inductive coupler.

Think of signal circles as what you can see when you throw a rock into a pond. Those waves want to leave equally in all directions, and the waves get weaker as they travel farther from where the rock entered the pond **(Figure 12)**.

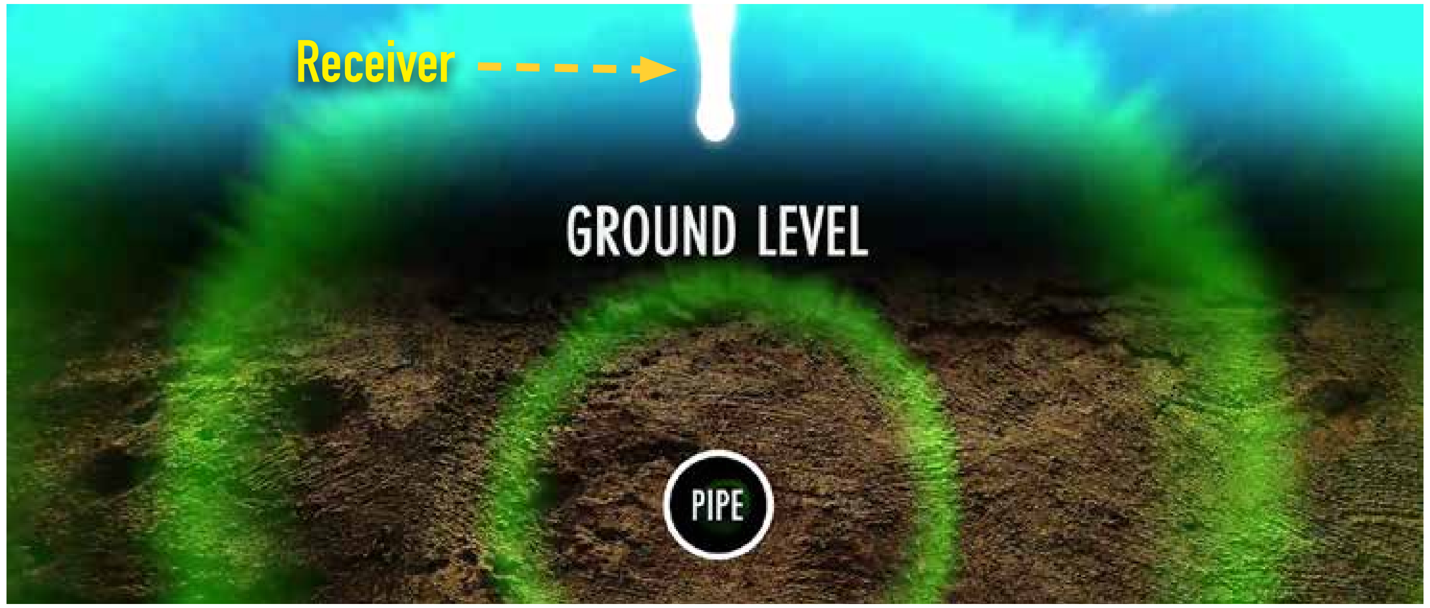


Figure 11: *Signal circles are created by flowing alternating current on the metallic skin of a pipe or cable.*

Figure 12: *Signal circles are created by flowing alternating current on the metallic skin of a pipe or cable like the waves created by a rock tossed into a pond.*

TOPIC HIGHLIGHT

With every locate, current flows on a metallic pipe or cable AND through the earth. **Metal and earth** are the two conductors in a locating circuit.

TOPIC HIGHLIGHT

It is possible that an inductive locate will offer better results than a conductive locate. The results of a locate: **Current. Shape. Endpoint.**

TOPIC HIGHLIGHT

Current flowing on a line produces an electromagnetic field and this field is detected by a receiver. A receiver cannot detect current because current doesn't travel through air.

TOPIC HIGHLIGHT

The term "signal" can refer to the current flowing on a line or the electromagnetic field that the receiver detects.

TOPIC HIGHLIGHT

All changes to a locate will be performed with the transmitter. You can't change **the results of a locate** with the receiver.

Peak and Null

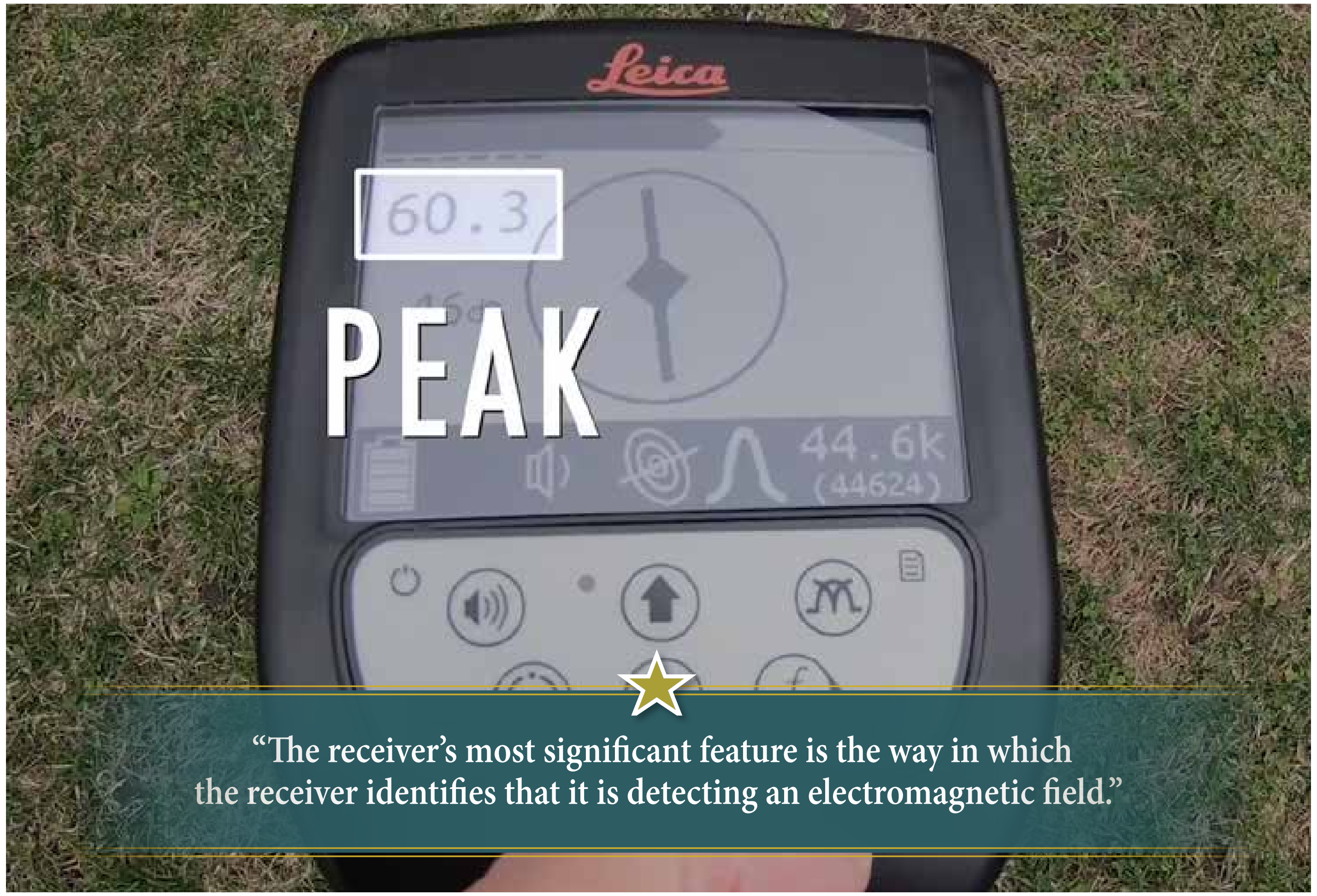
Understanding how a locating receiver works is also a critical component to locator training. There are several features on any given receiver that require significant attention. The receiver's most significant feature is the way in which the receiver identifies that it is detecting an electromagnetic field.

Of course, there are some universal elements that can be understood about every modern receiver. Two of those elements are peak and null. Peak refers to numerals on the receiver **(Figure 13)**, while null **(Figure 14)** refers to left-right directional information. Whether you know locating or you're just now learning locating, it's important to recognize that arrows are guidance. Arrows indicate the direction the receiver needs to move as it is swung over the location of the buried pipe or cable.

Peak is numerical, and it quantifies the strength of the signal being received. A peak response is the receiver location with the highest number. The word "null" refers to a receiver location where an equal amount of signal is received on both sides of an antenna array. With null, when you see both arrows, there is a balance struck. In most cases, a single arrow is an imbalance that indicates the direction the operator should move the receiver toward. When there are two arrows on the machine, the null balance is achieved.

Throughout the course of this training material, peak and null are probably the two most important things to understand regarding the receiver. As stated earlier, any receiver the operator ends up using is going to provide a peak and null reading in some shape or form. Once the student has an understanding of peak and null, they're essentially halfway to a full understanding of the receiver.

All locates are different. It is true that there are things that you can control and things you can't control, but knowing what those things are is what makes a skilled operator. Paying attention to small details during the course of the locate can clue the operator into the probability of an accurate result.



"The receiver's most significant feature is the way in which the receiver identifies that it is detecting an electromagnetic field."

Figure 13: *Peak is numerical and quantifies the strength of the signal being received.*

Figure 14: *Null is typically shown with arrow icons. One visible arrow represents an imbalance that indicates the direction the operator should move the receiver toward. Two visible and opposite arrows represents that a null balance has been achieved.*

As the receiver is lifted off the ground, the peak numbers go down, because the strength of the field that we detect after lifting the instrument above the ground is weaker than the strength of the field at ground level. In this image **(Figure 15)**, there is a difference of 13 signal strength points between the two receiver positions where the receiver was held.

The depth readings indicate the receiver was raised 11 inches resulting in a loss of 13 signal strength points.

Figure 15: *On the left, the strength of the field at ground level is stronger than on the right where the receiver is held higher.*

Energizing

Of the three methods of transmitting a signal, conductive is likely the easiest to understand because there is more to see: the metallic access point, the lead wires, and the grounding device or whatever is used for a connection with earth **(Figures 16-19)**.

Conductively energizing an underground line is the act of creating an electrical circuit. Lead wires typically colored red and black connect the transmitter to a metallic line and to a piece of metal contacting earth. The transmitter creates electricity and places it on both the lead wires.

While the lead wires appear to be two wires, they actually function as one wire while the transmitter is transmitting. The lead connections can be interchanged without changing the results of the locate.

Figure 16: *A connection to a water hydrant and a ground using a hydrant valve box.*

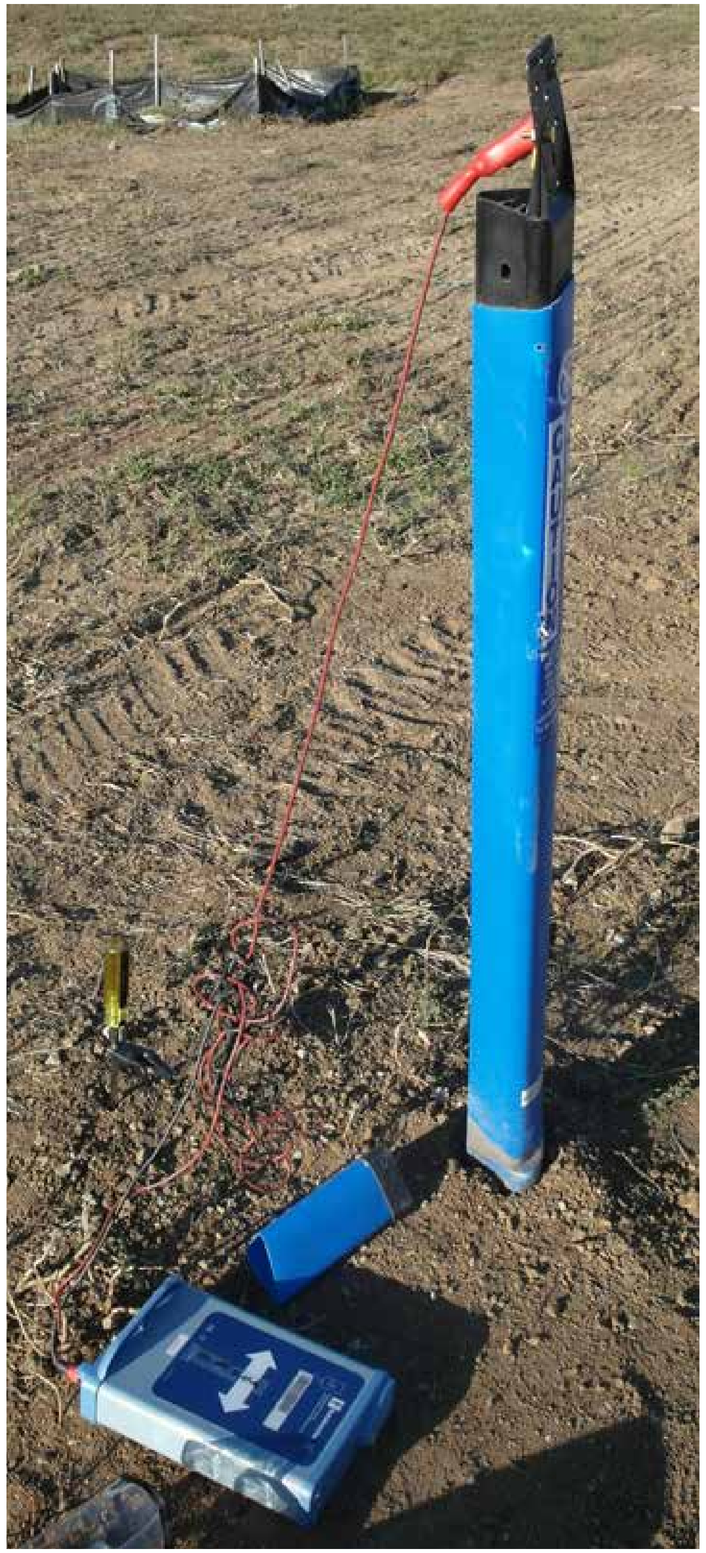


Figure 17: *Connections to a tracer wire for a plastic water main and a screwdriver.*

Figure 18: *A connection to a copper tracer wire on a plastic gas service.*

Of the three transmitting methods, conductive locating almost always initially places more current on the line being located.

TOPIC HIGHLIGHT

Conductive locating is not always more accurate than **inductive** locating.

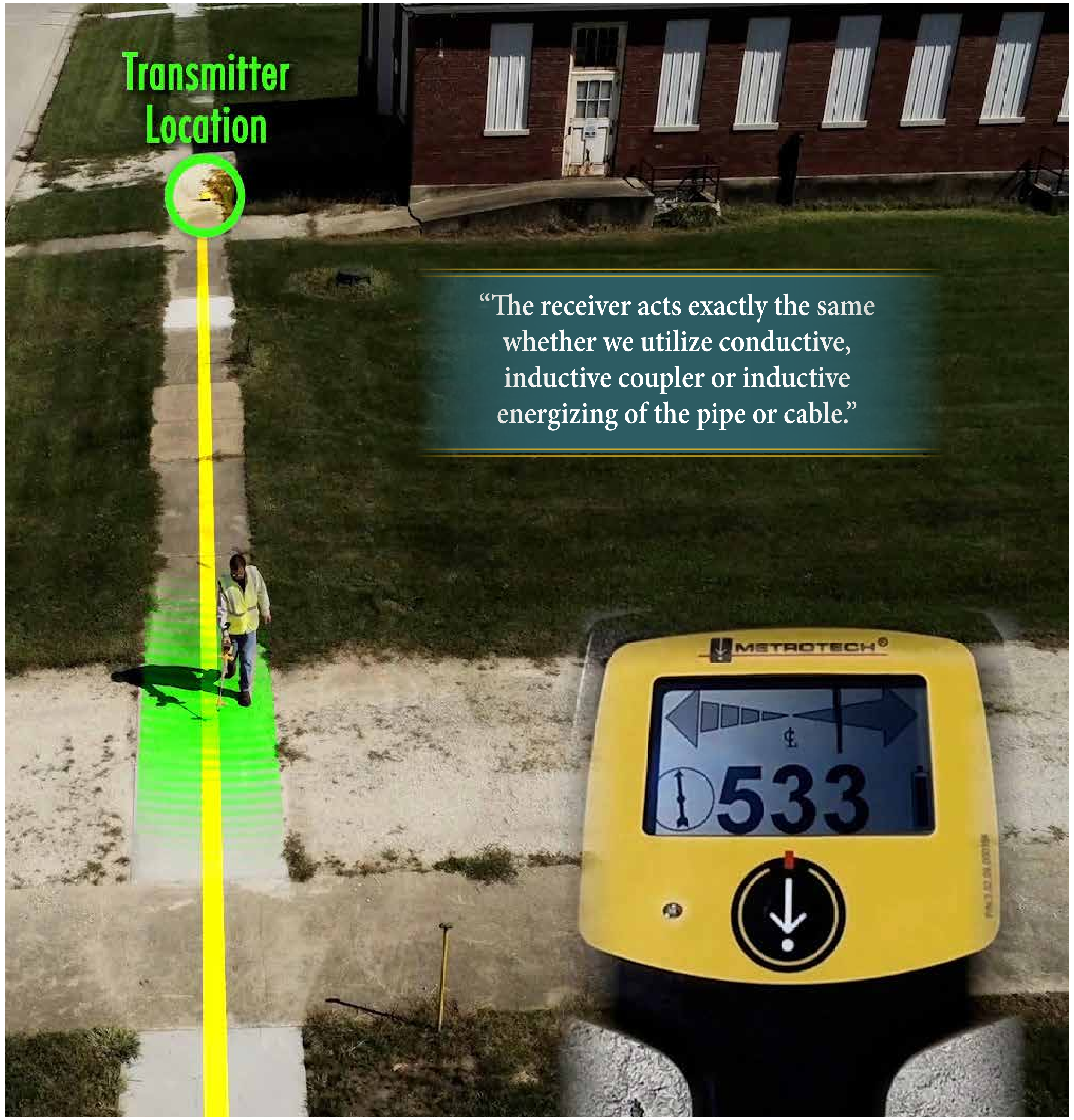
Figure 19: *A connection to the metal shell of a three-phase transformer.*

Energizing

Figure 20: *A conductive connection to a wrench that is seated on a water main valve.*

Figure 21: *The use of the inductive coupler produces current that flows not only on the metal pipe or cable, but also through the earth.*

With the transmitter connected by lead wires to both metal and earth, current flows from the transmitter. The use of an inductive coupler and induction achieve this as well. Even though we're not utilizing a grounding device, the use of the inductive coupler still produces current that flows not only on the metal pipe or cable, but also through the earth **(Figure 21)**. Whatever leaves the transmitter must come back to the transmitter **(Figure 22)**. Induction begins with an electromagnetic field produced by the transmitter, and when that field is able to envelop an underground pipe or cable, current flows on that pipe or cable and also through the earth. The receiver acts exactly the same whether we utilize conductive, inductive coupler or inductive energizing of the pipe or cable.



> "The receiver acts exactly the same whether we utilize conductive, inductive coupler or inductive energizing of the pipe or cable."

Figure 22: *Induction begins with a field produced by the transmitter, and when that field is able to envelop an underground pipe or cable, current flows on that pipe or cable and also through the earth.*

Current Flow

Flowing electrons are known as current, and the current is produced by the transmitter. The type of current that is used in pipe and cable locating is alternating current, which means the energy from the transmitter is going to flow two directions on the pipe or cable we're locating. It will also flow in two directions through the earth. It is helpful to understand the way current travels on a pipe or cable and through earth, as well as the electromagnetic field it produces. Green orbs or green fields are a good visualization of something the human eye cannot see.

With the receiver, we don't actually detect where the pipe or cable is located. We detect where the fields are located that emanate from the pipe or cable. As the current travels away from the transmitter, it builds fields. But since this is alternating current, the energy doesn't always flow away from the transmitter. It will also flow back to the transmitter. And when it does, the fields collapse. Fields build out, and fields collapse. That's the alternating current at work.

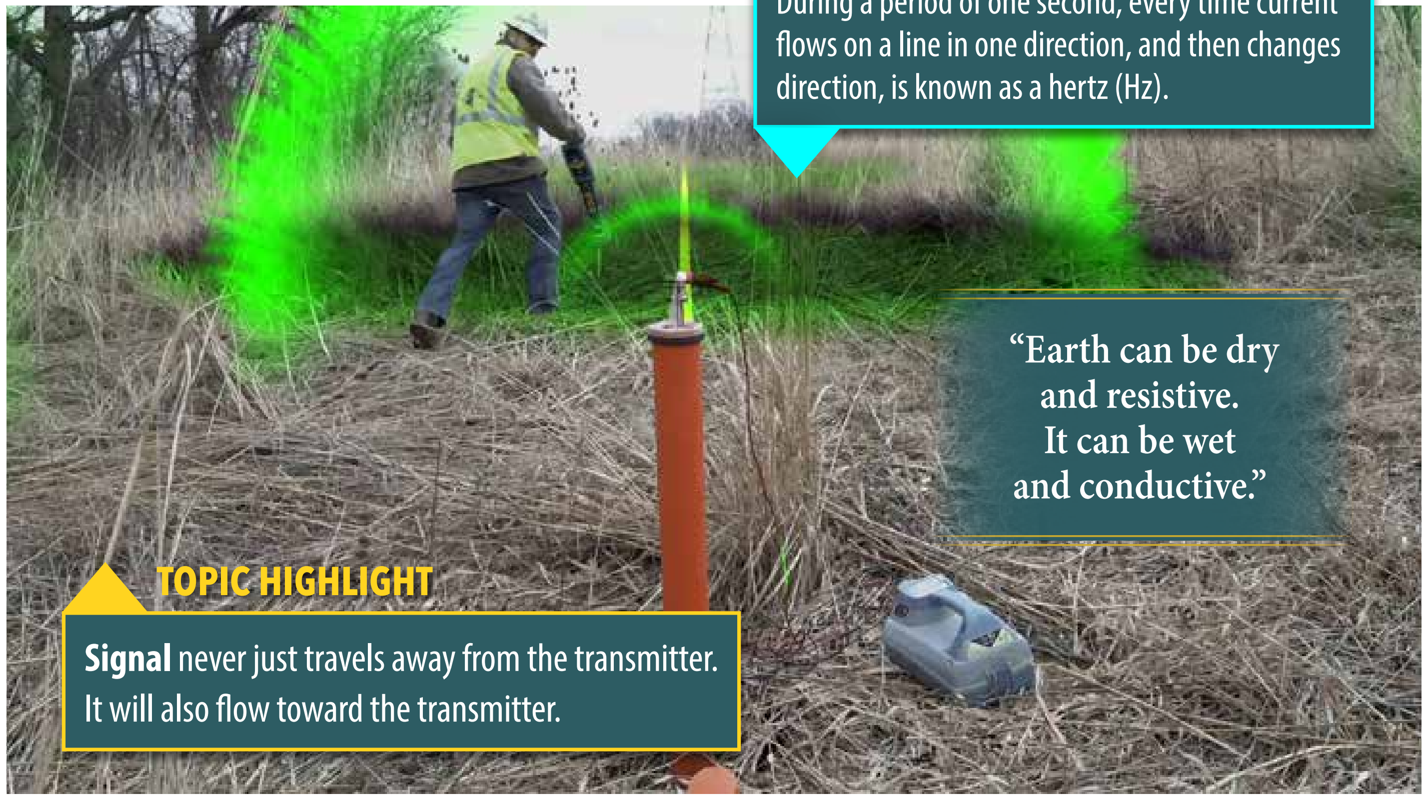
If you could see the current coming out of the transmitter on a conductive lead wire, you'd watch as it flowed to the utility's access point and then onto the metal skin of the utility line. From here, you'd see it traveling down a length of the buried utility and then come back through the earth to the grounding device. From here, you'd watch current travel back to the transmitter on the other conductive lead wire **(Figure 24)**. Alternately, the current travels the same exact path but in reverse **(Figure 25)**. Each time current travels away from the transmitter on the line and then back to the transmitter on the same line is known as a cycle. The number of cycles that occur in one second of time is known as frequency.

There are different characteristics when it comes to both the pipe or cable and the earth. Earth can be dry and resistive. It can be wet and conductive. The utility can be bare to earth or insulated from earth, and if it's insulated from earth, the quality of that insulation is important. Current flows on metal and through earth each time a locate is performed. We're building a circuit, and that circuit involves two conductors: earth and the metallic pipe or cable.

These examples are just a sneak peek at all of the factors that are at play during a locate. This is why it is important to know how conductivity on a metallic line and through earth works. Knowing how to adjust your transmitter properly is critical in producing the most accurate and efficient locate.

TOPIC HIGHLIGHT

During a period of one second, every time current flows on a line in one direction, and then changes direction, is known as a hertz (Hz).

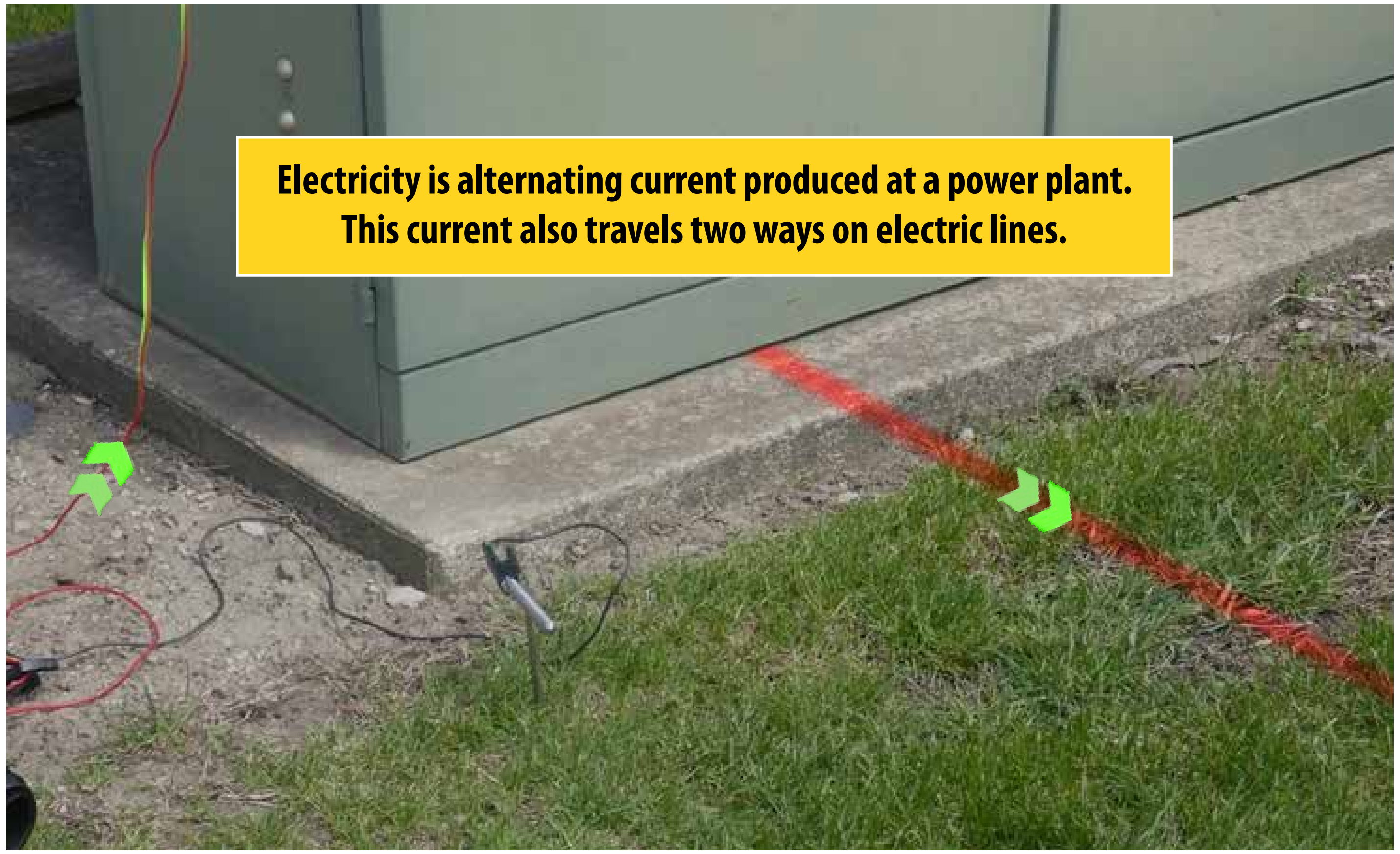


"Earth can be dry and resistive. It can be wet and conductive."

TOPIC HIGHLIGHT

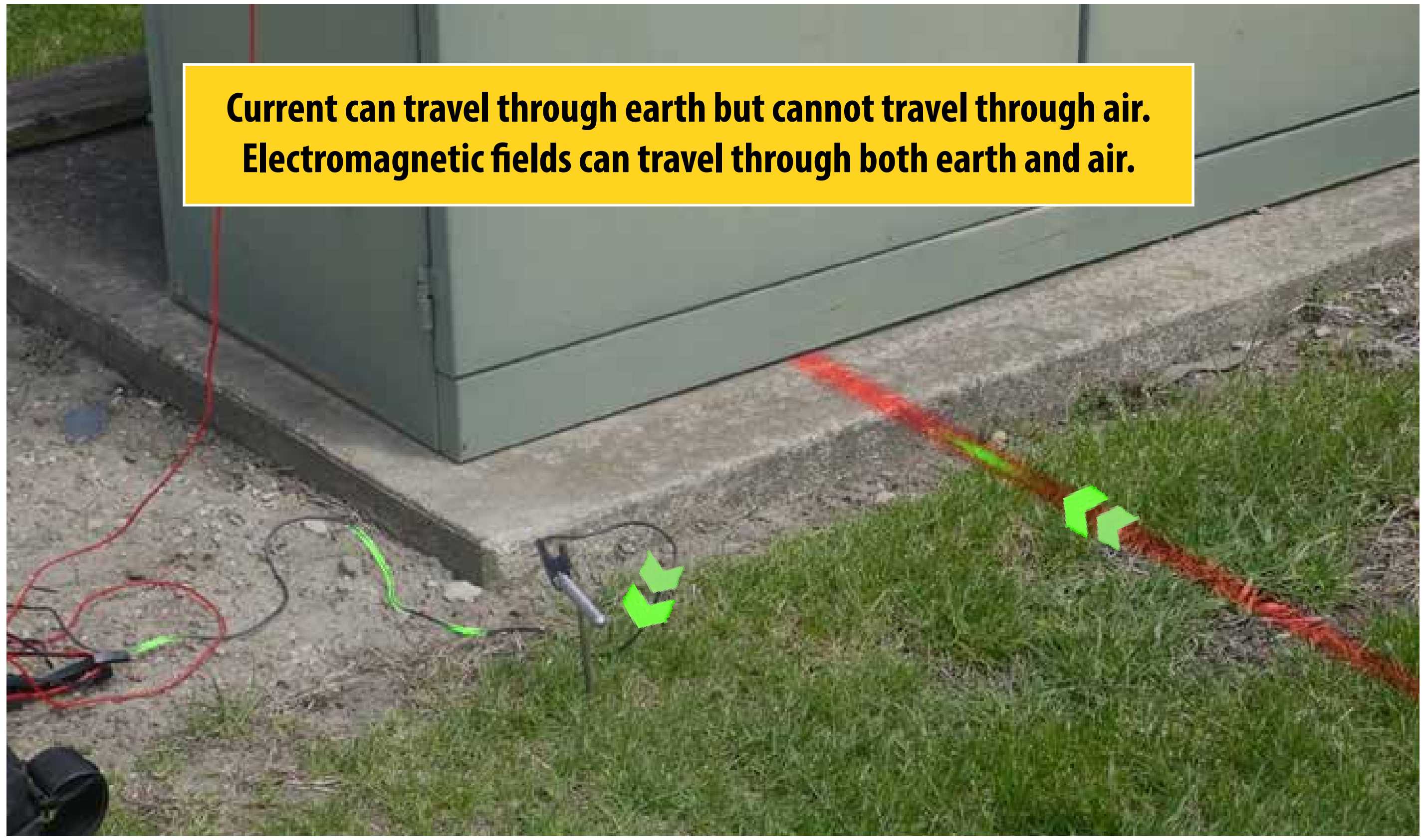
Signal never just travels away from the transmitter. It will also flow toward the transmitter.

Figure 23: *The transmitter produces current and current produces electromagnetic fields.*



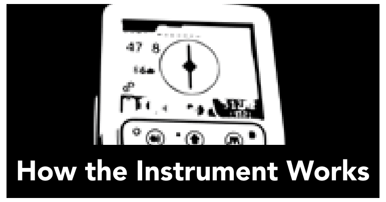
Electricity is alternating current produced at a power plant. This current also travels two ways on electric lines.

Figure 24: *Current flows away from transmitter and out the electric line.*



Current can travel through earth but cannot travel through air. Electromagnetic fields can travel through both earth and air.

Figure 25: *Current flow changes direction on the electric line and flows toward the transmitter.*



Using the Receiver

Now that we've covered the basic idea of how and where current flows from the transmitter, let's talk a little bit about the receiver. Peak readings, peak sounds, null readings and null sounds from the receiver can be utilized simultaneously to see if the pattern indicates a good trace. It's possible that something about the pattern has changed which indicates that the trace is potentially inaccurate.

When we talk about a trace, it's generally the section of the utility that the operator is locating in real time **(Figure 26)**. "The locate" is a term that takes in the entire process of analyzing—verifying the results using "current, shape, endpoint"—as well as changing the deployment of the transmitter in an effort to improve locating results. In this particular example, our operator's trace didn't stay on the target utility, because we veered off a bit to the north over to a non-target line **(Figure 27)**.

In the end, following the trace to a visual endpoint is the best we can do to verify that we're either on our target line, or if we ended up on a non-target line **(Figures 28-29)**. As you'll see moving forward, a target line is the line that we intend to locate and is the main subject of most scenarios we cover. As shown in **Figure 30**, the gas line runs directly parallel to the cable TV line. Non-target lines that run close and parallel to target lines have the potential of becoming energized by the transmitter's signal, a process known as bleed-off.

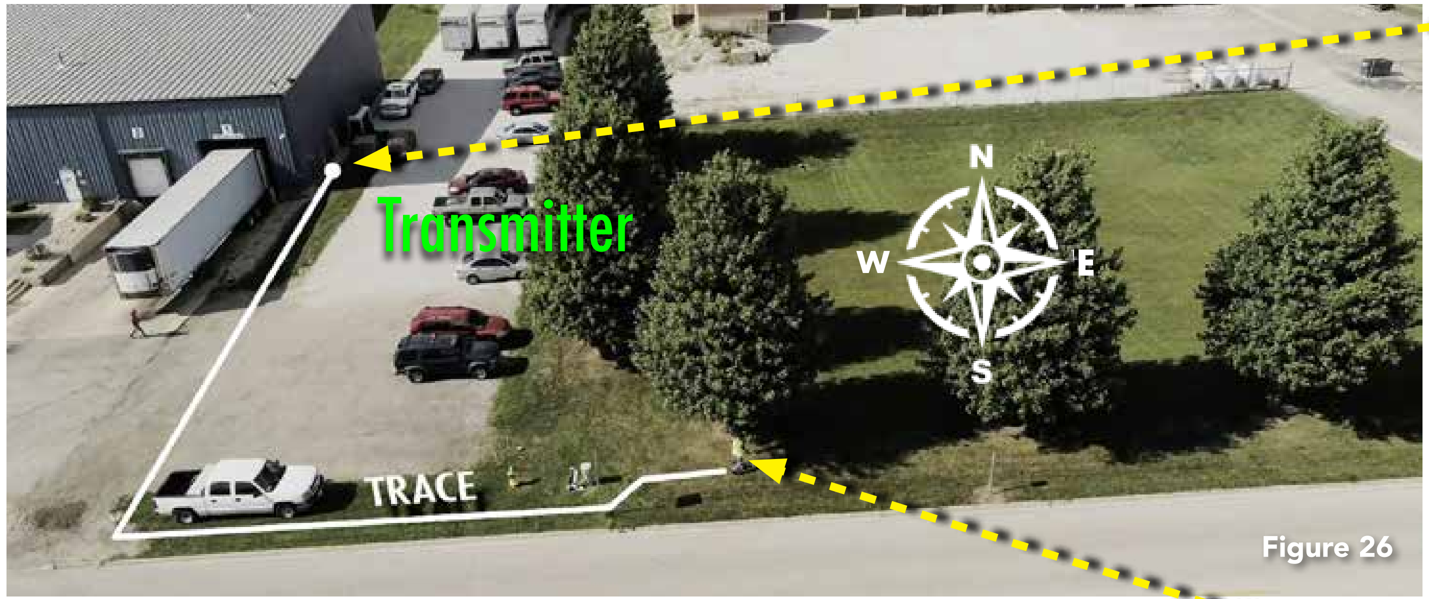


Figure 26

Figure 27

Figure 28

Figure 29

Figure 30

Using the Receiver

To verify the accuracy of a locate, the three things that must be continuously analyzed are current, shape and endpoint. If peak readings are steady when the receiver is held stationary over the trace, this indicates good current. If peak and null readings agree over the trace, this means the shape of the field is round. Finally, if the trace leads to a visual and logical endpoint based on the type of utility being located, there should be a high level of confidence in the accuracy of the locate.

TOPIC HIGHLIGHT

Current, shape and endpoint are the three key things to check to verify the accuracy of a trace.

Figure 31

> "Finally, if the trace leads to a visual and logical endpoint based on the type of utility being located, there should be a high level of confidence in the accuracy of the locate."

Figure 32

If locating a gas line, a valve box is a visual and logical endpoint for the trace.

Figure 33

If locating a water line, a meter box is a visual and logical endpoint for the trace.

Figure 34

If locating an electric line, a transformer is a visual and logical endpoint for the trace.

Figure 35

Sweeping the Line

Every receiving antenna has windings **(Figure 36)**. The orientation of the windings within an electromagnetic field are critical to correctly interpreting the results of a locate. When attempting to find the location of a buried utility line, an analogy that is helpful to think about is a tire in its position to the road **(Figures 37-38)**. Where the operator walks and how the operator holds the instrument are critical elements in locating successfully and it's important to think of buried lines as underground roads.

> "Where the operator walks and how the operator holds the instrument are critical elements in locating successfully."


Figure 36

WINDINGS

The wire in a coil that is wrapped around the core

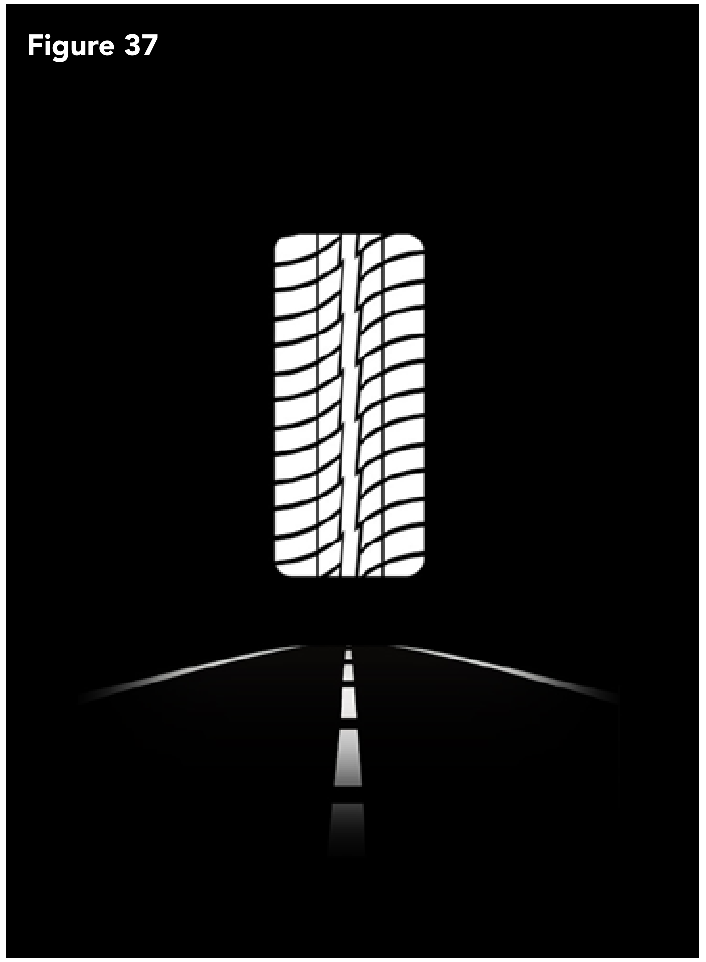
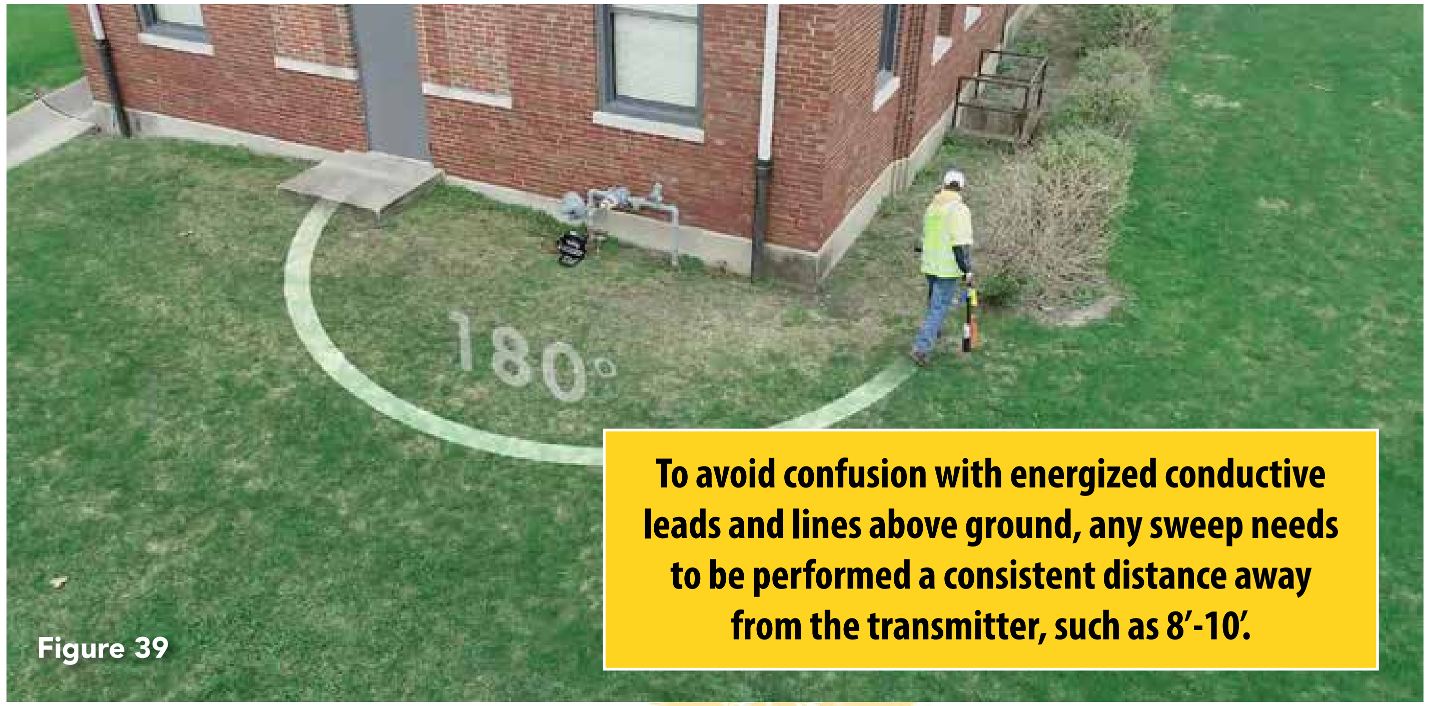


Figure 37


Figure 38

In **Figure 39**, the operator is checking a 180-degree sweep around the access point where the transmitter is energizing a gas service. The instrument is held so that no matter what direction that gas service runs, the receiving coil will always be positioned where a maximum reading will be obtained. In some cases, there may be multiple peaks received. A peak reading with a corresponding null and a logical depth is the starting point for a trace following a sweep **(Figure 40)**.



To avoid confusion with energized conductive leads and lines above ground, any sweep needs to be performed a consistent distance away from the transmitter, such as 8′-10′.

Figure 39

The single peak reading received during a 180-degree sweep

Figure 40

360-Degree Sweep

Other times, access points need to have a full 360-degree sweep. Again, notice how the instrument is being held **(Figures 41-44)**, so that wherever the line or lines that exit this pedestal are, there will be a maximum peak response **(Figure 44)**.

Figure 41: *Starting the 360-degree sweep.*

Focus on identifying peak readings during the 360-degree sweep. Grounding devices should be placed close to the access point to avoid "false peaks" during the sweep.

Figure 42: *The operator adjusts how the receiver is being oriented as he walks around the access point.*

When performing a 360-degree sweep, maintain the same distance from the transmitter for the entire sweep.

Figure 43: *180 degrees around the access point.*

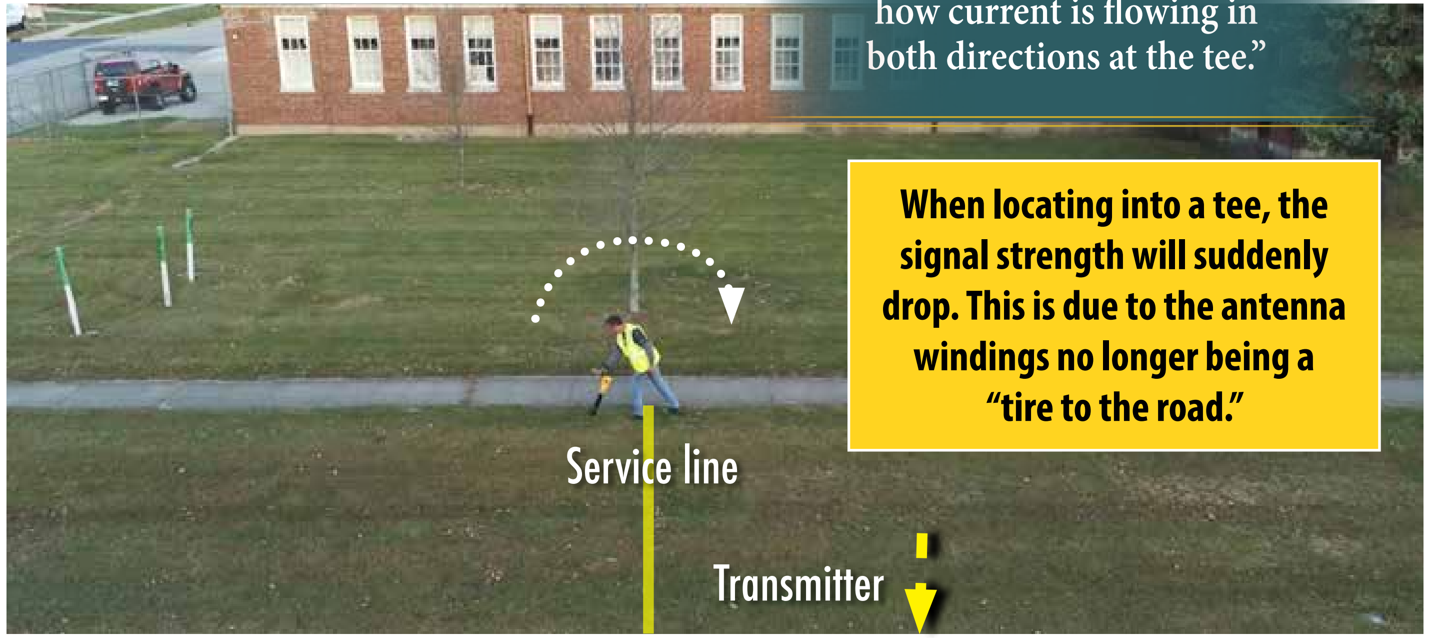
Receiver orientation must change for maximum peak response.

Figure 44: *270 degrees around the access point. The sweep is complete once back to the starting point.*

Sweep at a Tee

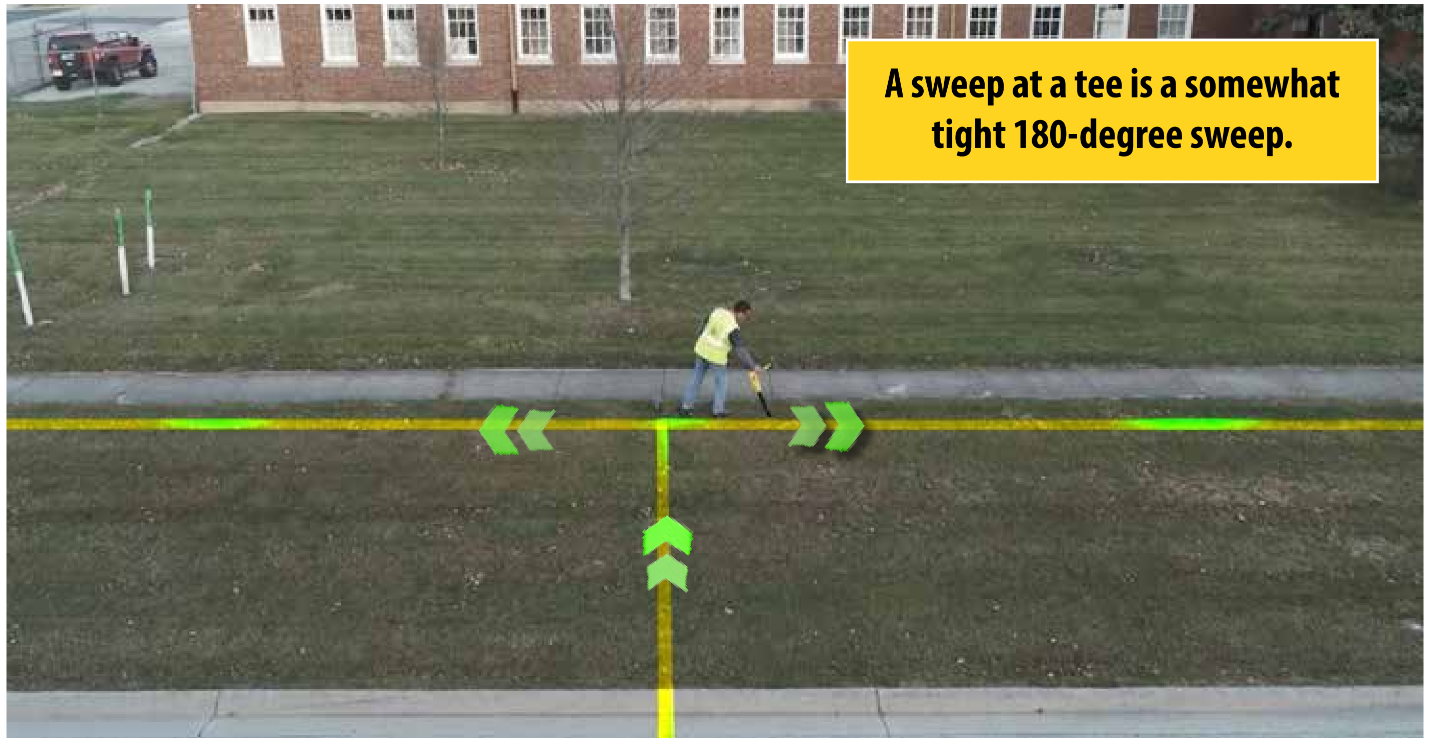
The operator is locating a service line that tees into a main line. This sort of sweep guarantees that the operator can compare the signal strength to his left and to his right **(Figures 45-46)** to get an understanding of how current is flowing in both directions on the main line at the tee. The positioning of the receiver's antenna within a field is going to dictate the response.

> "...the operator can compare the signal strength to his left and to his right to get an understanding of how current is flowing in both directions at the tee."



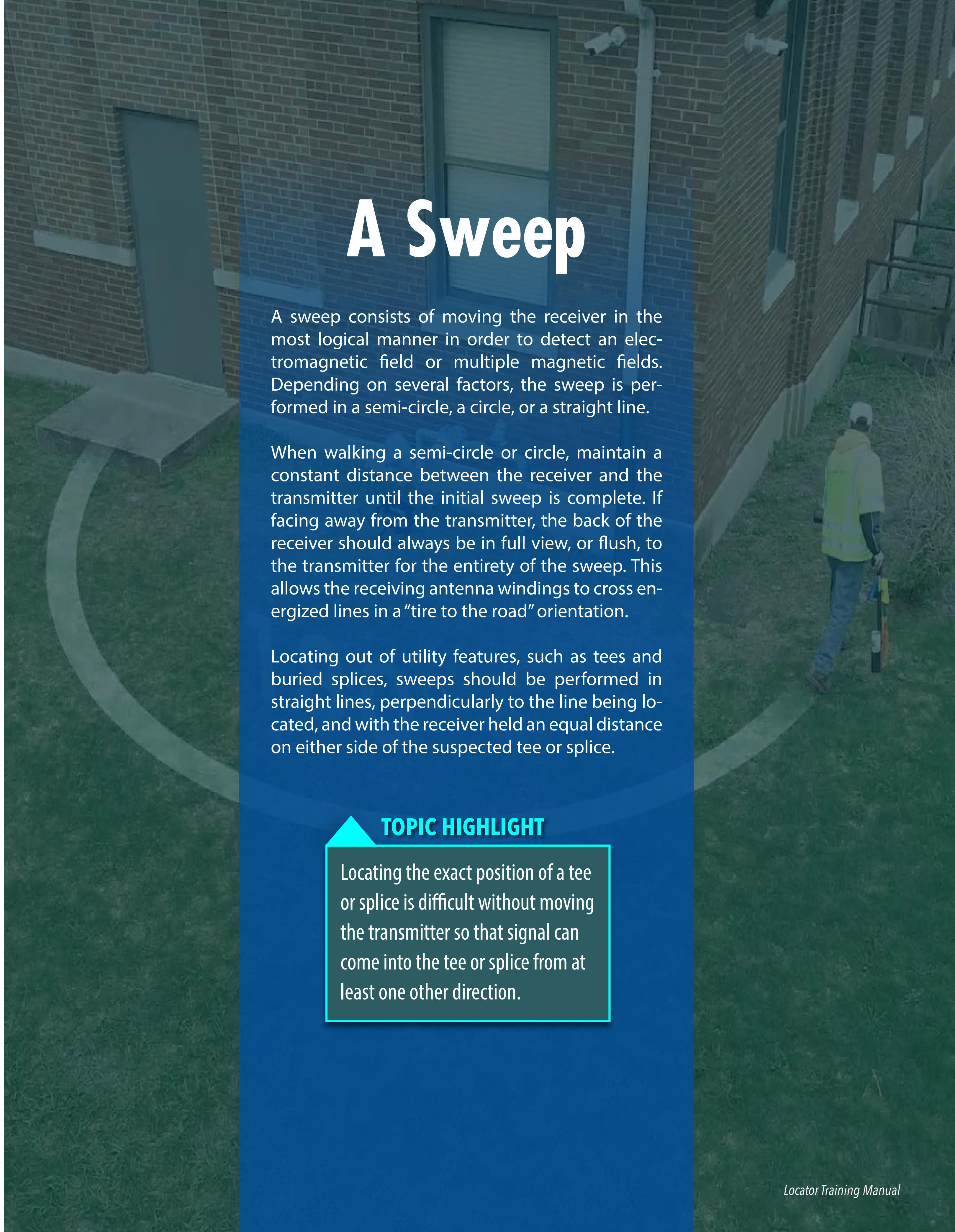
When locating into a tee, the signal strength will suddenly drop. This is due to the antenna windings no longer being a "tire to the road."

Figure 45: *Locating to the left of the tee.*



A sweep at a tee is a somewhat tight 180-degree sweep.

Figure 46: *Locating to the right of the tee. A tee is an opportunity for the signal on the service line to split and travel two ways on the main line.*



A Sweep

A sweep consists of moving the receiver in the most logical manner in order to detect an electromagnetic field or multiple magnetic fields. Depending on several factors, the sweep is performed in a semi-circle, a circle, or a straight line.

When walking a semi-circle or circle, maintain a constant distance between the receiver and the transmitter until the initial sweep is complete. If facing away from the transmitter, the back of the receiver should always be in full view, or flush, to the transmitter for the entirety of the sweep. This allows the receiving antenna windings to cross energized lines in a "tire to the road" orientation.

Locating out of utility features, such as tees and buried splices, sweeps should be performed in straight lines, perpendicularly to the line being located, and with the receiver held an equal distance on either side of the suspected tee or splice.

TOPIC HIGHLIGHT

Locating the exact position of a tee or splice is difficult without moving the transmitter so that signal can come into the tee or splice from at least one other direction.

The Effect of Rotating Antennas

> "Every receiving antenna has windings, and the direction in which they are wound dictates what kind of response the receiver is able to generate."

The antenna or antennas that produce the signal strength number, or the peak number, must have the antenna windings like a tire to the road, the road being the underground pipe or cable **(Figure 47)**.

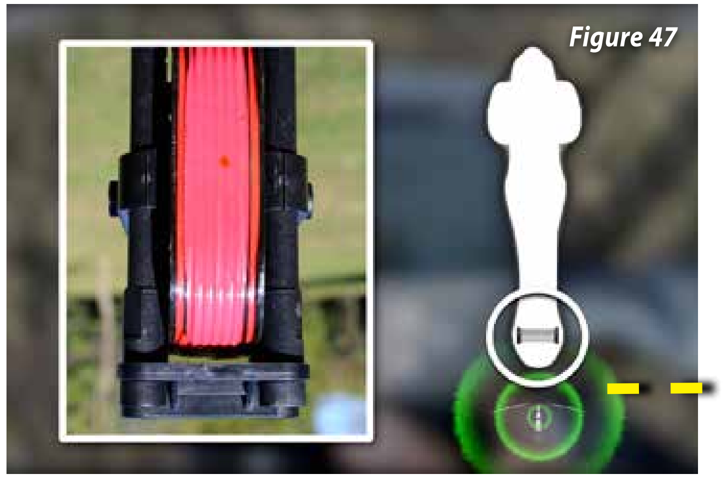


Figure 47

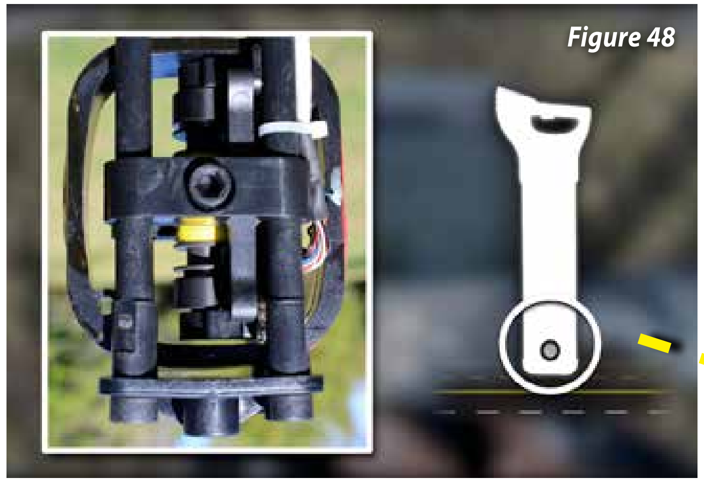
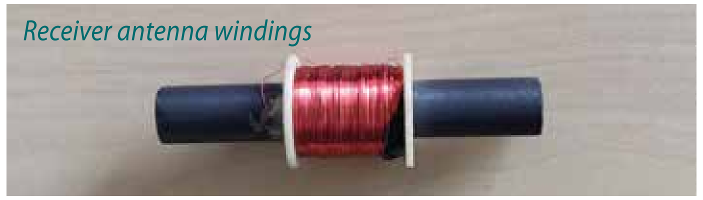


Figure 48

*Windings are copper wires wound in a circular or otherwise symmetric fashion **(Figure 48)** and are often covered with tape.*

Every receiving antenna has windings, and the direction in which they are wound dictates what kind of response the receiver is able to generate. When the receiver is placed on the ground and rotated, the highest peak reading occurs when the windings are in line with the energized underground utility line **(Figure 49)**. When those windings are rotated 90 degrees, no signal strength is detected **(Figure 50)**. How the antenna is oriented within the electromagnetic field dictates the response.



Receiver antenna windings

TOPIC HIGHLIGHT

The highest peak reading occurs when the peak antenna's windings are in line with what is being located.

Figure 49

Figure 50

TOPIC HIGHLIGHT

When the peak antenna's windings are rotated 90 degrees, no signal strength is detected.

TOPIC HIGHLIGHT

When receiver windings are offset 90 degrees to an energized line, the result is a 0.0 reading. In this situation, no signal is transferred from the electromagnetic field to the receiver windings.

Figure 51

To determine the target line's exact orientation, place the receiver on the ground and rotate until the higher peak reading is received.

Antenna Windings

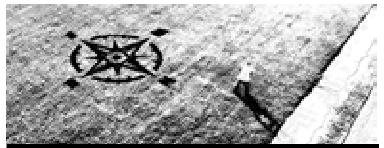
In **Figures 52-53**, the transmitter is being rotated so that its inductive transmitting antenna windings go from being a “tire to the road” to 90 degrees to the road. This transmitter rotation illustrates the 90-degree orientation of antenna windings to buried line orientation. The compass antenna is a peak antenna that is oriented 90-degrees to the regular peak antenna. There is no induction onto the compass antenna when the peak antenna receives maximum induction. When there is maximum induction onto the compass antenna, there is no induction onto the peak antenna **(Figures 54-55)**.

Figure 52: *The transmitter’s windings as a tire to the road.*

Figure 53: *The transmitter’s windings 90 degrees to the road.*

Figure 54: *When the compass antenna receives no signal, the indicator on the display is in line with the line being located.*

Figure 55: *When the compass antenna receives maximum signal, the indicator is horizontal on the display.*



The Target Line

Even when peak and null agree, sometimes we have to walk around objects. We can't always walk right on top of the line. It's a good practice to occasionally do a horizontal sweep across the right-of-way to see that you are still on your target line **(Figures 56-58)**.

It's hard to say there's a right way or a wrong way to hold the instrument, but sometimes excessive swinging of the receiver causes you to miss a change in the target line's direction. You're unlikely to miss a change in direction on the line when you minimize the swing of the receiver.

Figure 56: *Sometimes you have to walk around objects like cars or other obstructions while locating.*

TOPIC HIGHLIGHT

When performing a horizontal sweep, move your feet while letting the receiver hang in your hand.

Figure 57: *It's good practice to occasionally do a horizontal sweep across the right-of-way to make sure you're still on the target line.*

Figure 58: *Excessive swinging of the receiver creates the possibility of missing turns in the target line and instead continuing forward on a non-target line.*

As this diagram **(Figure 59 top)** indicates, both antennas on the swings to the left and to the right are exactly halfway in between producing a peak response and producing a null response.

As the top and bottom diagrams indicate, what are peak response antennas and what are null response antennas change when the receiver swings to a 45-degree angle from the position over the target line.

Comparing the left side of **Figure 59 top** with the left side of **Figure 59 bottom** illustrates how the peak response antenna will become a "null antenna" when the receiver is swung to a 45-angle to the energized buried pipe or cable. Comparing the right sides of the two diagrams shows a null response antenna becoming a "peak antenna."

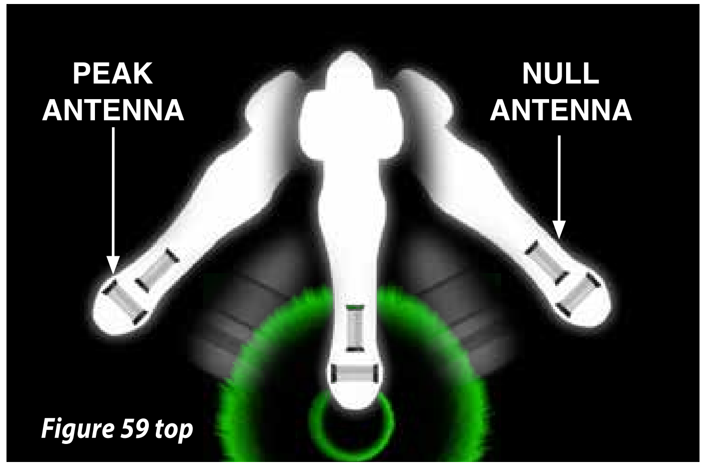


Figure 59 top

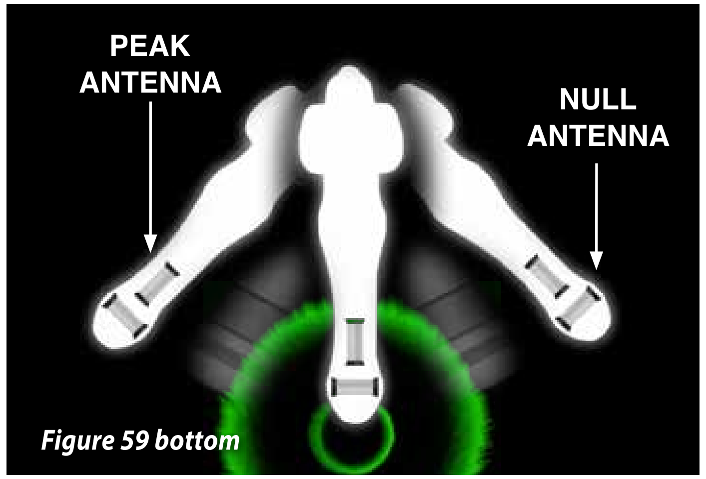


Figure 59 bottom

TOPIC HIGHLIGHT

Minimizing the swing of the receiver to a 20 or 30-degree angle will reduce the chance of misleading information.

> "You're unlikely to miss a change in direction on the line when you minimize the swing of the receiver."

Using the Compass

The target line is a cable TV feeder line that starts out on the west side of a 10-inch cast iron water main **(Figure 60)**. But it will gradually veer over to the east side of the water main **(Figure 61)**. Later, the line will once again shift direction and veer gradually back to the west side of the water main **(Figures 62-64)**.

***Figure 60:** Locating west of the water main. Notice the compass is at an angle.*

Sometimes the change of direction can be a gradual angle, and you can see the change on the receiver's compass indicator. The compass is is an excellent guide for target line direction and may be much easier to use for this purpose than peak or null **(Figure 61)**. The windings on the antenna that provide the compass indicator are offset 90 degrees to the receiver's peak antenna windings. That means the compass windings are offset 90 degrees to the line being located. When the compass antenna receives no signal, the indicator on the display is in line with the line being located. When the compass antenna receives maximum signal, the indicator is horizontal on the display and in line with the line being located.

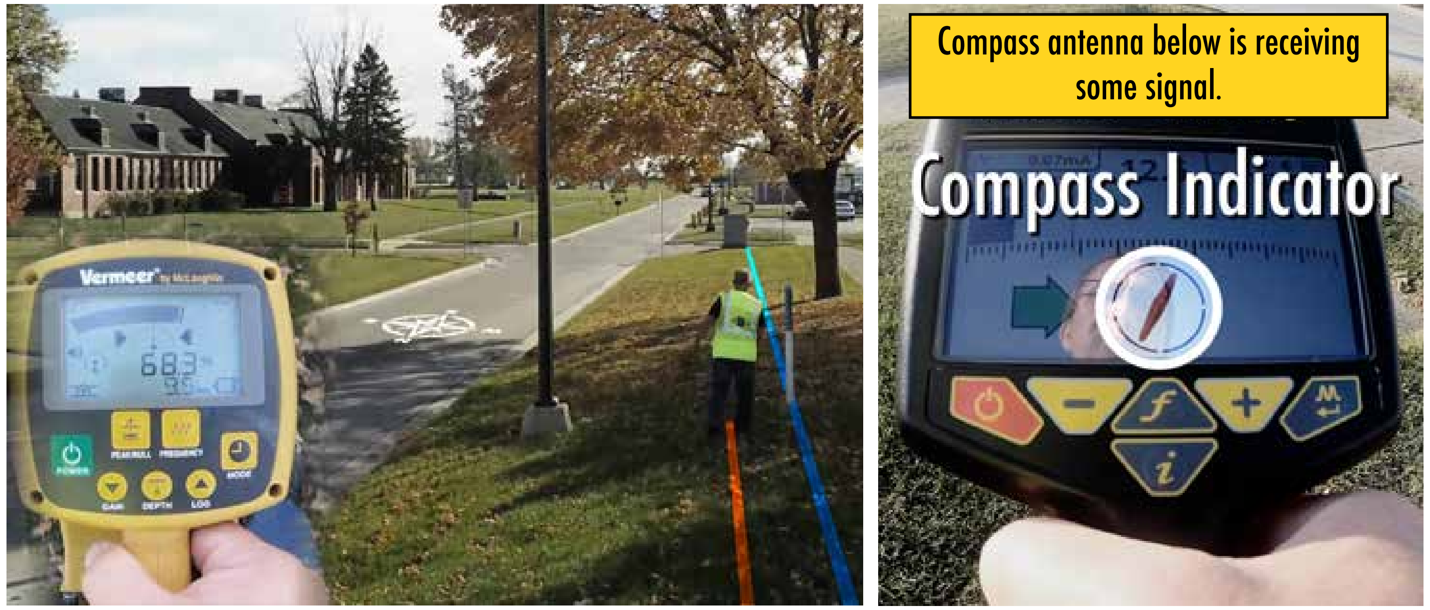


***Figure 61:** Locating east of the water main. The compass indicator on the receiver can show a change in direction of the target line.*

***Figure 62:** The line once again shifts directions and veers gradually back to the west side of the main. Notice the angle of the compass.*

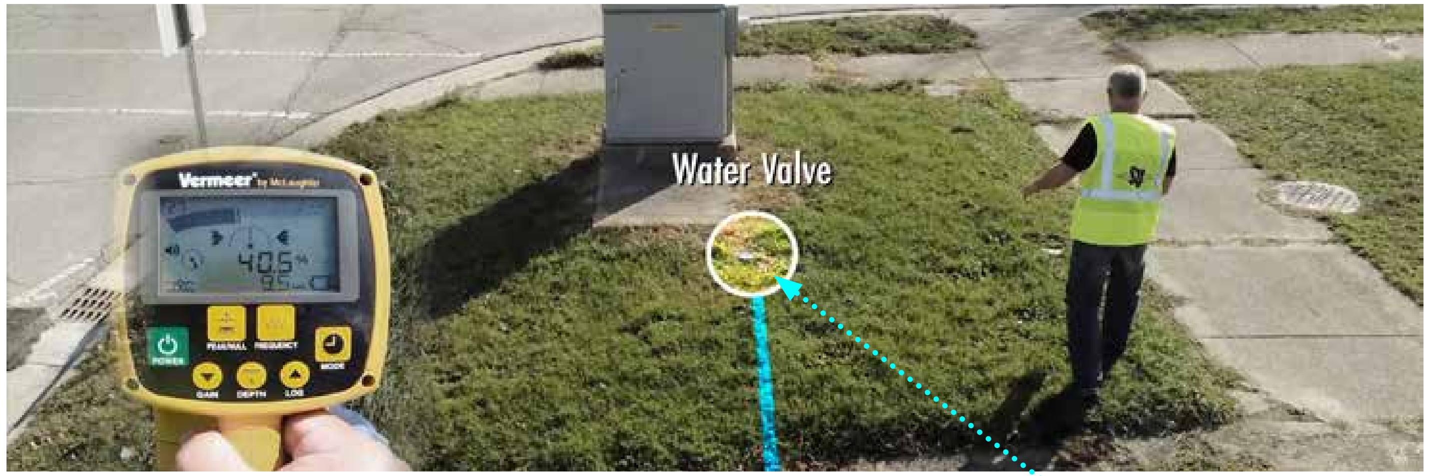


***Figure 63:** Continuing to locate the cable TV feeder line now quite a few feet west of the water main.*

***Figure 64:** The overall path of the water line (blue) and target cable line (orange) can be seen on the map to the right.*

Using the Compass

On this locate, the operator is locating an 8-inch cast iron water main. This main is parallel and on the west side of the 10-inch water main in **Figure 63**. The operator sweeps to find the water main in **Figure 65**. When he's over the water main, the compass is crooked, which doesn't indicate a turn in the water main, but rather the fact that a nearby line, the cable TV line, has some of the transmitter's energy on it **(Figure 66)**. The compass can be a not-round field detector.

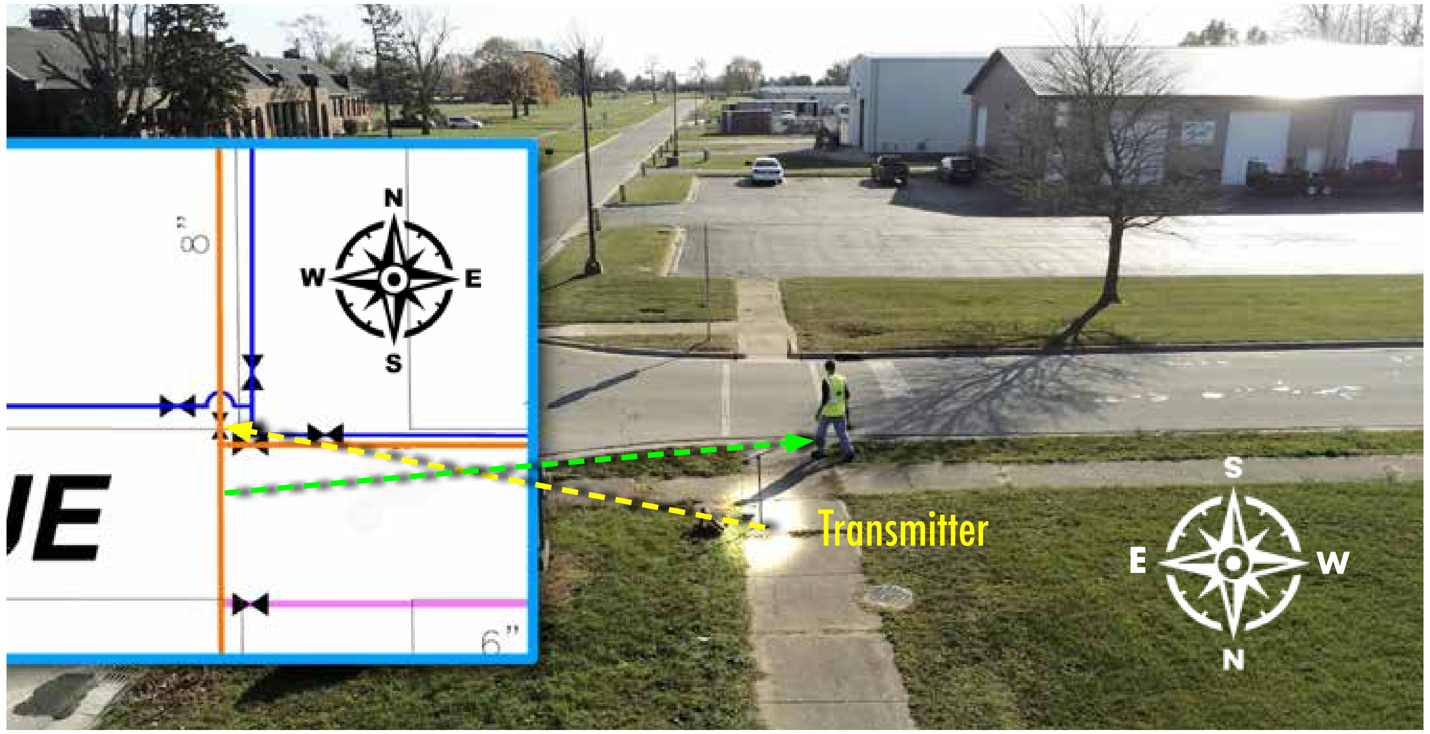


Figure 65: *Sweeping to find the water main, pictured in map on the left.*

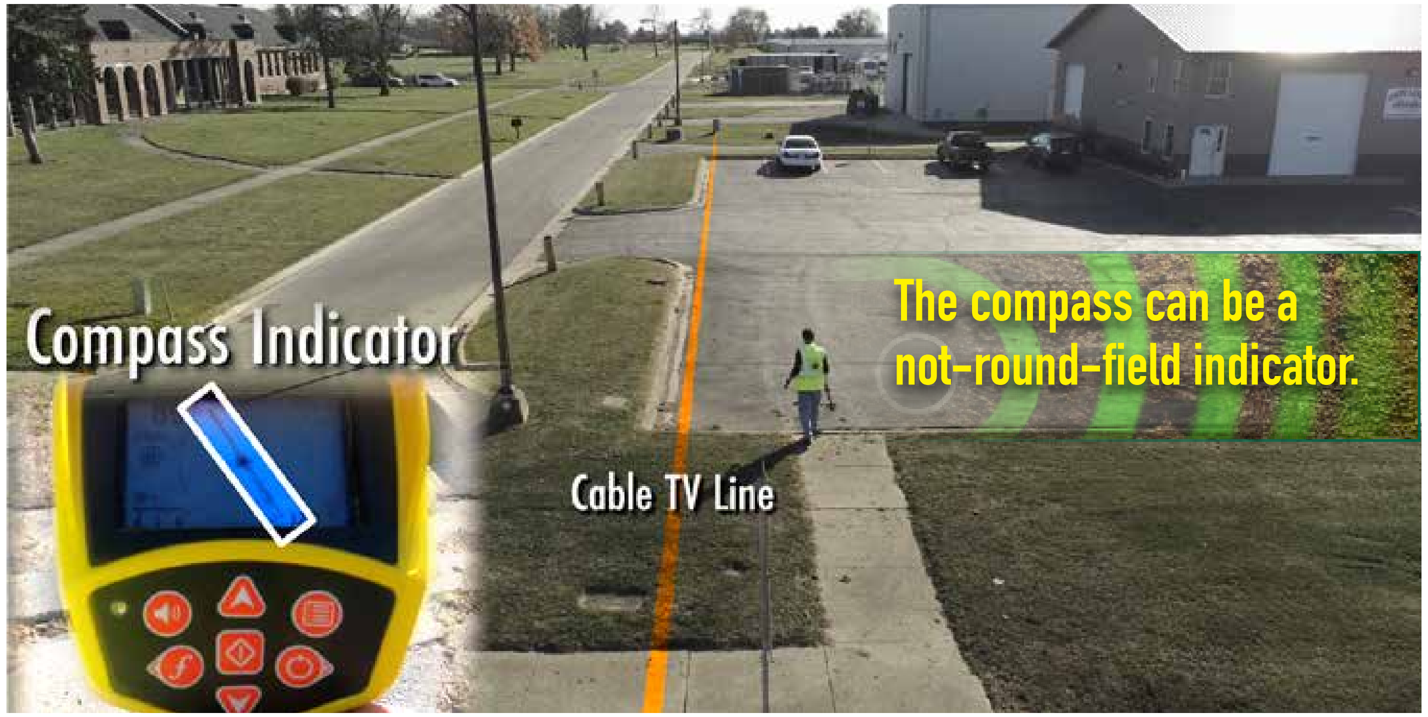


Figure 66: *The energized cable TV line running parallel and to the east of the water main heavily influences the compass indicator while the water main is being located.*

TOPIC HIGHLIGHT

It is important to understand that while the electromagnetic field is three-dimensional, the receiver displays information taken from a single slice of a three-dimensional field.

TOPIC HIGHLIGHT

Determining the orientation of a line by rotating the receiver on the ground is achieved by comparing the peak readings obtained in a series of slices. When the compass indicator alerts the operator to a change in direction, it is a receiver function that mimics a three-dimensional view.

TOPIC HIGHLIGHT

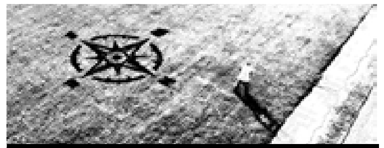
When a sweep is performed, the receiver stays at ground level which reinforces the two-dimensional aspect of locating. Only when the receiver is picked up off the ground and also moved up and down the target line does the trace become three-dimensional in nature.

TOPIC HIGHLIGHT

Two-dimensional locating is a comparison of multiple points along a target line. Two-dimensional locating also includes lifting the receiver from a point on the ground over the target line to a point in the air above the target line.

TOPIC HIGHLIGHT

Obtaining receiver responses to the side and also above the target line creates the ability to label the electromagnetic field's shape as round (circular) or not-round. Not-round fields result when the transmitter's signal energizes multiple metallic objects at once within detection range of the receiver. Checking for a round field is an example of comparing results taken from a series of slices.



Recognizing Bleed-off

The receiver in **Figure 67** shows another change in direction, but this time there's another buried line that causes a problem. We anticipate that the electric line and the gas line run parallel to one another. We start to see that peak and null disagree, and that the compass is indicating a change in direction. The peak appears to be moving in a northward direction, moving closer to the gas line. Our peak reading is 78.1, but the peak reading within our null reading is 66.5, so peak and null do not agree **(Figures 68-69)**. Eventually the trace veered over to the sidewalk. Are we locating the gas line? At the moment, it is impossible to know whether we are locating the gas line or if the electric line has indeed shifted over to the area of the sidewalk.

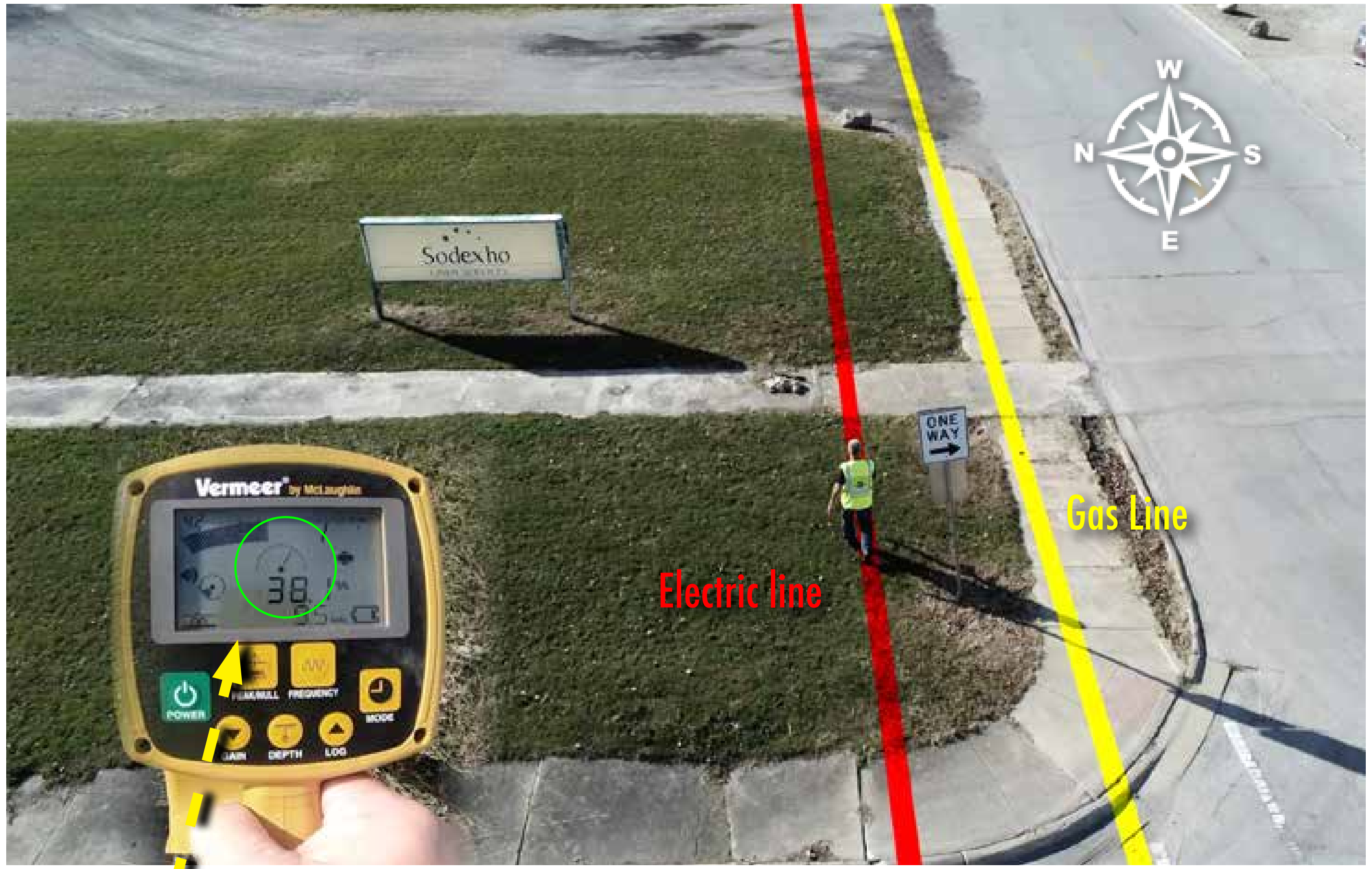
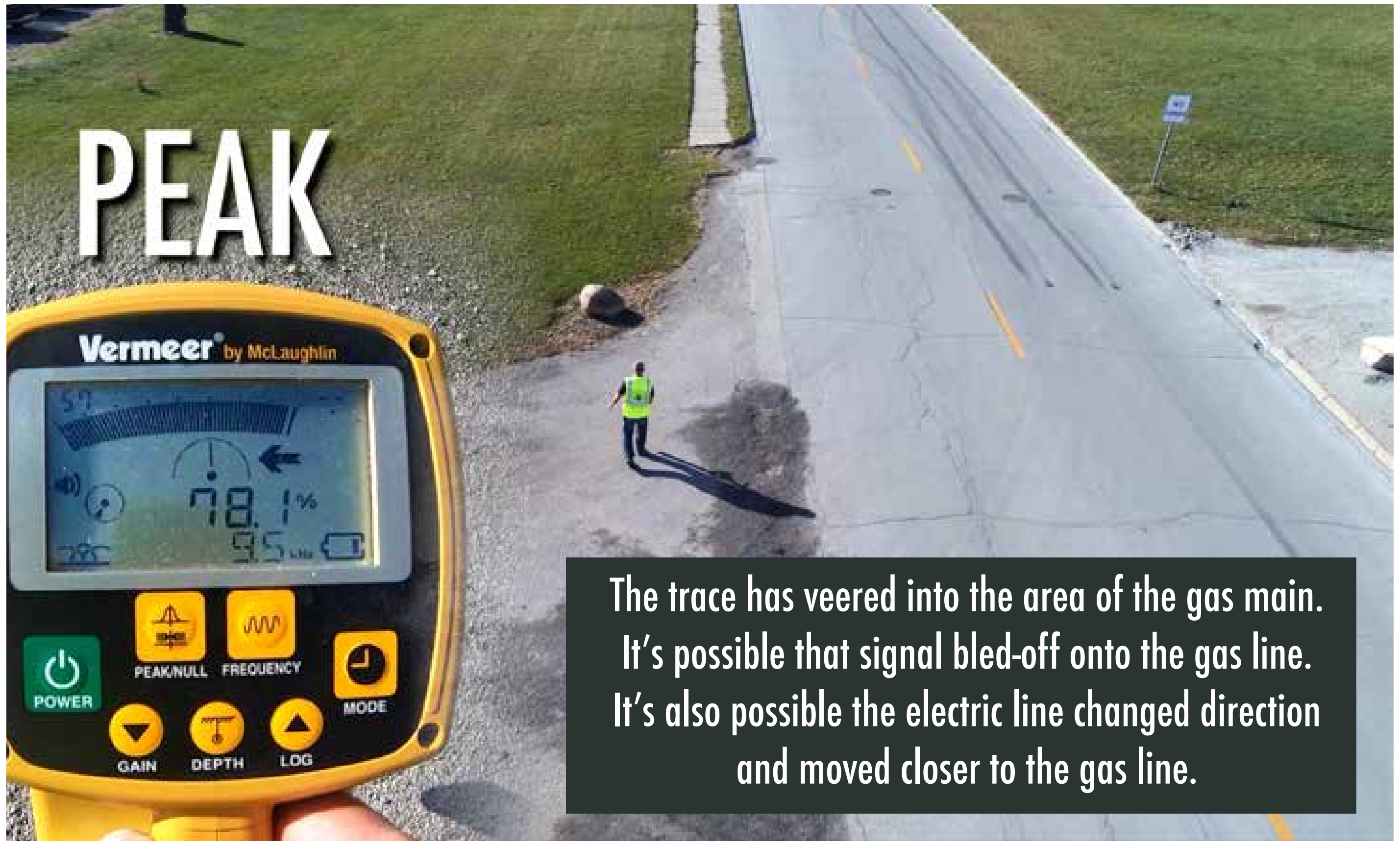


Figure 67: *The receiver in this image shows a change in direction, complicating the locate.*

A crooked compass can indicate bleed-off or a potential change in line direction. Sometimes both bleed-off and a change of line direction are happening at once.

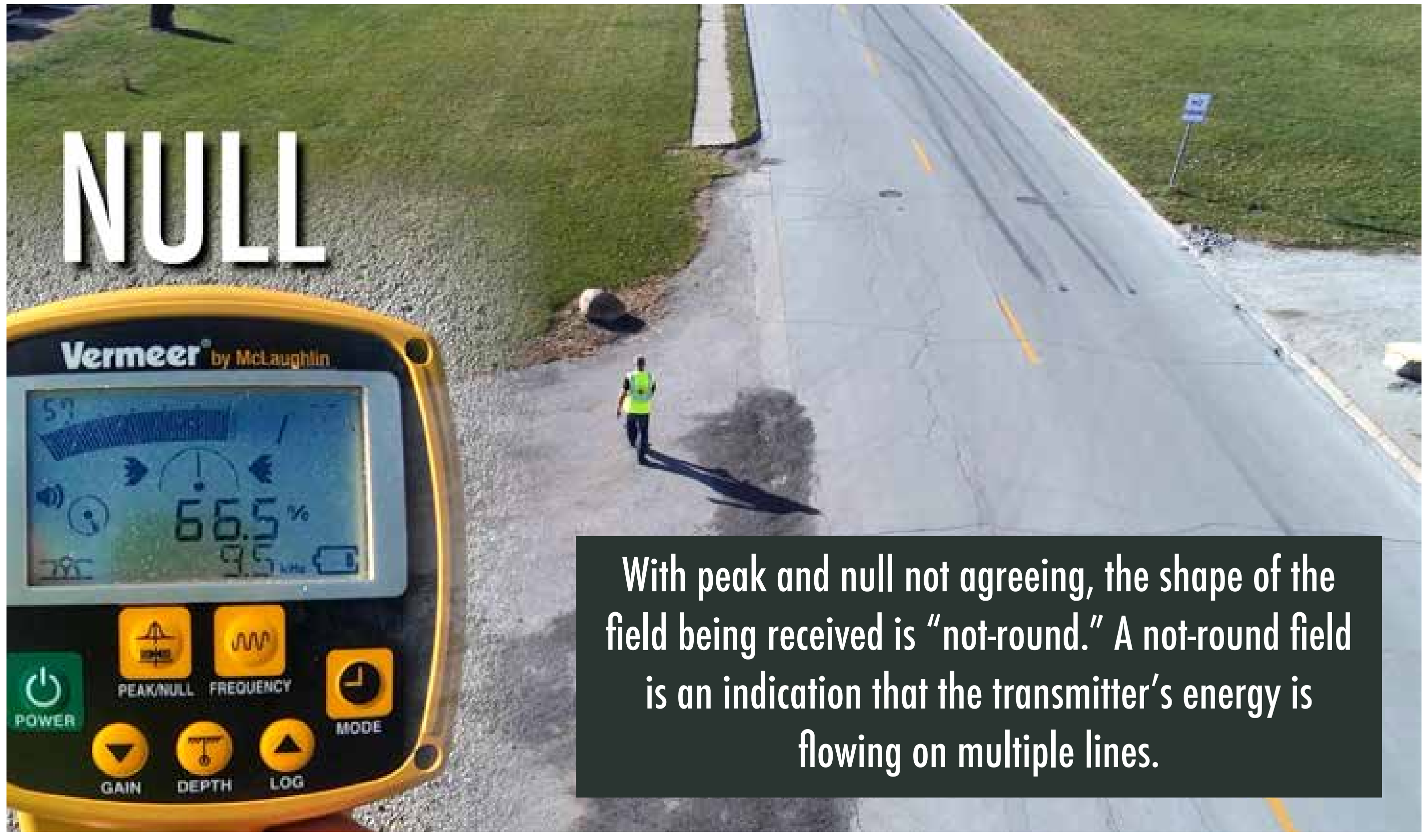
TOPIC HIGHLIGHT

Just as there are two ways to energize a target line, there are two ways that signal can bleed-off: **conductively and inductively**.



The trace has veered into the area of the gas main. It's possible that signal bled-off onto the gas line. It's also possible the electric line changed direction and moved closer to the gas line.

Figure 68: *The peak appears to be moving closer to the gas line under the edge of the sidewalk.*



With peak and null not agreeing, the shape of the field being received is "not-round." A not-round field is an indication that the transmitter's energy is flowing on multiple lines.

Figure 69: *The peak reading within the null is 66.5 and is not the highest peak detected, indicating the electromagnetic field is not-round.*

Recognizing Bleed-Off

And while the trace had us at the edge of the sidewalk, we now seem to be veering back to the south **(Figure 70)**. As we shift farther south, we find peak and null begin to agree again **(Figure 71)**. We're back to the initial separation between the electric line and the gas line. Next, we check to see how many peak readings we receive. We get two, and this seems to line up with the separation we began with between the gas line and electric line. We get one peak reading toward the road and another peak to the south of the sidewalk **(Figure 72)**.

This is bleed-off, and learning to recognize bleed-off is just as important as knowing what to do about it.

> "Learning to recognize bleed-off is just as important as knowing what to do about it." -*The Basics: Part 5*

Figure 70: *Shifting to the south, away from the sidewalk.*

Figure 71: *Peak and null begin to agree again.*

Figure 72: *We have a peak and null over the electric and a high peak reading without a null over the gas.*

TOPIC HIGHLIGHT

Often a **non-target line** is identified as such because there is a peak response but no null response.

Figure 73: *There are only two ways this gas line could have been energized—in a metal-to-metal manner (conductive) or a nonmetal-to-metal manner (inductive).*

Conductive

Lower cost transmitters, or red-light transmitters, do not give a current flow reading. The indication on the transmitter simply says that it's on and what frequency it's transmitting **(Figure 74)**. The bar graph on the receiver is this instrument's sole way of accessing the level of the transmitter's conductive current flow.

Figure 74

This is a direct connection with 82 kHz. This style of instrument must be held this way to the conductor **(Figure 75)**. While rare in the United States, this style of receiver is very popular in other parts of the world, particularly Europe.

Figure 75

TOPIC HIGHLIGHT

Low-high frequencies, such as 82 kHz, are commonly found on single-frequency transmitters.

We have to hold the receiver this way so that the peak coils can be tire-to-the-road with the conductor. There is no digital signal strength, but rather a bar graph that indicates the relative strength of signal received **(Figure 76)**.

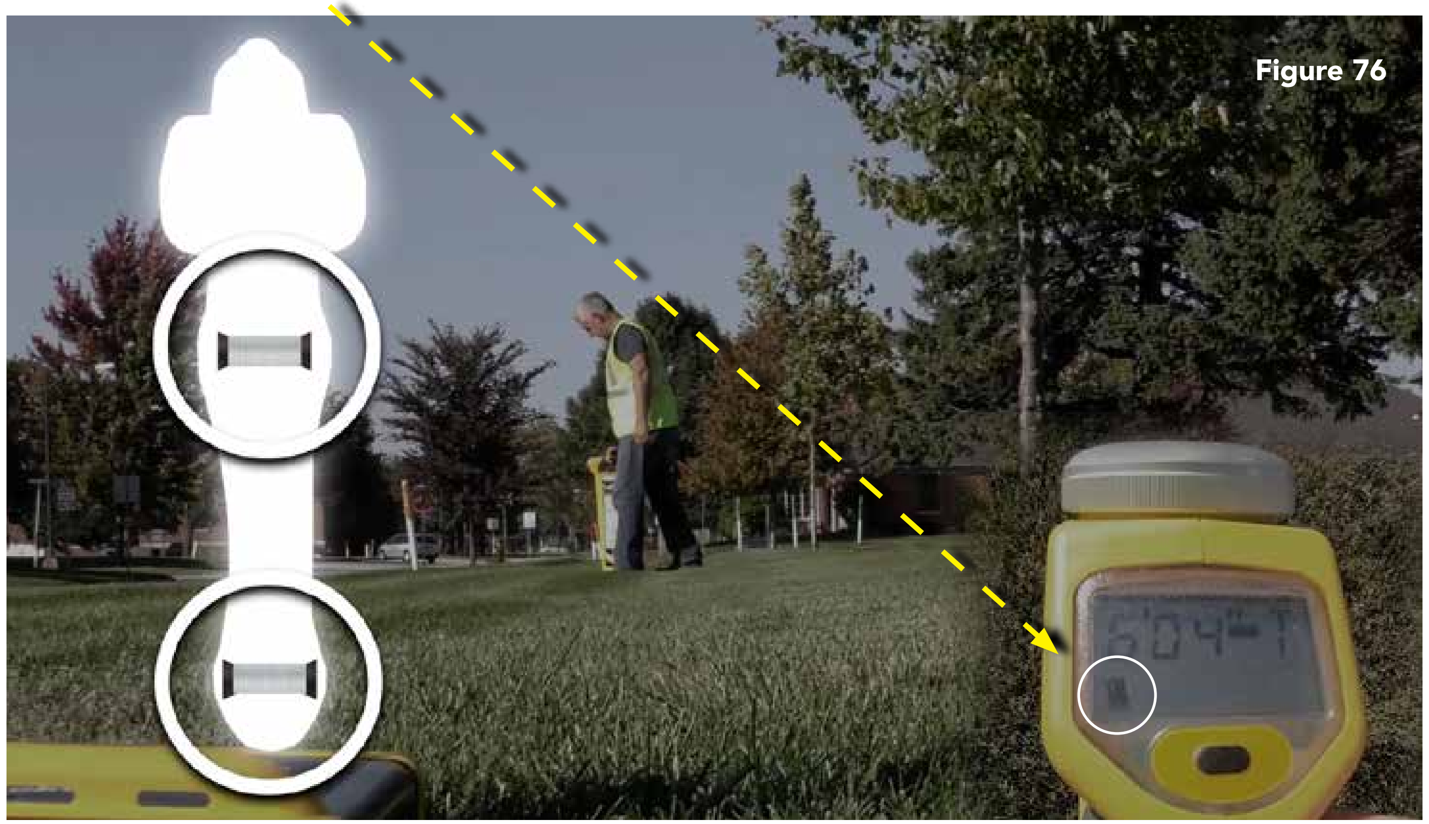


Figure 76

The shallowest depth reading will indicate when we're over the energized line **(Figure 77)**. This receiver's digital depth display only activates after the button under the display is pressed. Obtaining three identical depth readings in a row verifies ample current flow is leaving the transmitter on a conductive locate.

Figure 77

Conductive

On this locate **(Figure 78-80)**, the operator is setting up a conductive transmitting antenna. A conductive transmitting antenna consists of a grounding device **(Figure 79)** and lead wires **(Figure 81)**. Most conductive lead wires are colored red and black but they can also be the same color.


Figure 78

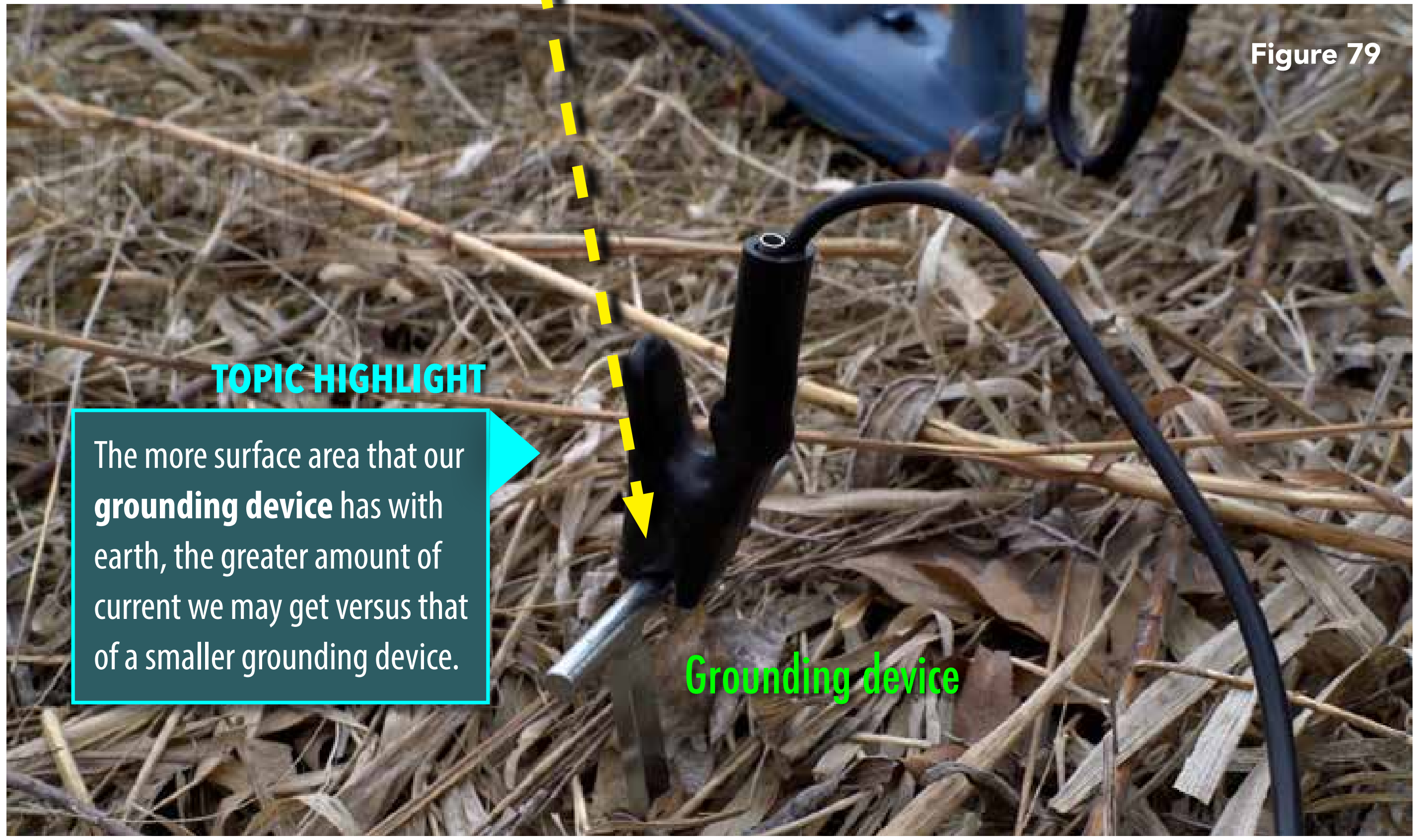


Figure 79

TOPIC HIGHLIGHT

The more surface area that our **grounding device** has with earth, the greater amount of current we may get versus that of a smaller grounding device.


Figure 80

TOPIC HIGHLIGHT

Access points are the origin of a conductive locate.

We're locating at a test station along a 24-inch pipeline. The test wire is welded to the pipeline. One end of the lead is attached to the wire and the other to our grounding device. The transmitter is generating alternating current. Alternating current flows on a conductor, such as this large pipeline, 50% of the time in one direction and the other 50% of the time in the other direction. Flowing one direction on the pipeline is known as a half-cycle, and flowing both directions is known as a cycle.

With the transmitter turned on, the conductive lead wires are actually one wire **(Figure 81)**. Because the leads are often red and black, sometimes they're mistaken for positive and negative. But current travels on the conductive lead wires in two directions, just like on the target line. It is important to understand that the lead wires are energized and when the receiver is close, it will detect the electromagnetic fields coming from the wires as well as the target line.


Figure 81

A conductive locate joins the two conductors in every locate circuit: metal and earth.

Conductive

Sometimes we can hook up to one conductor and ground to another. In this image **(Figure 82)**, you'll see that we've hooked up to both a steel main and a plastic main. It is important to understand that grounding to another utility instead of using a grounding device will energize the other utility, almost always a non-target utility. In this instance, both the steel main and plastic main are target lines, and hooking to both at once results in locating efficiency.

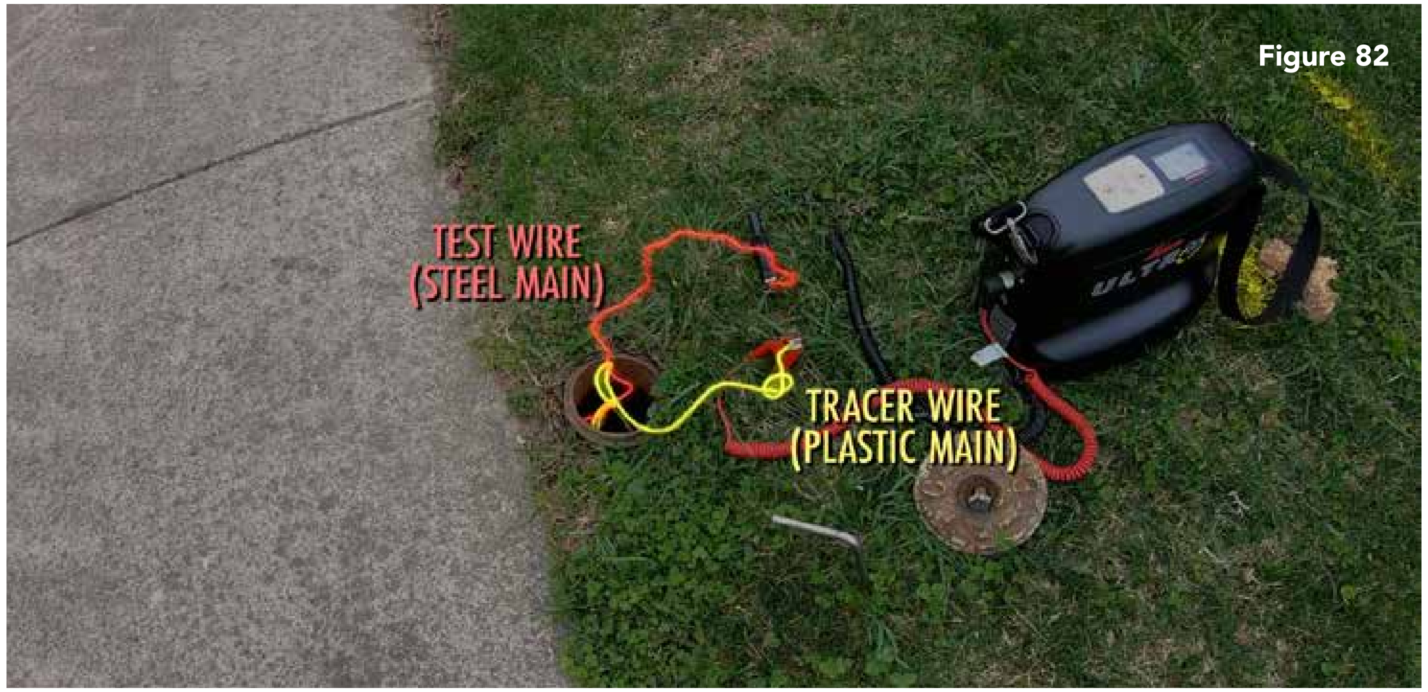


Figure 82

It's possible to energize nearby conductors to a greater extent by putting the grounding device close to their location. In this image below **(Figure 83)**, there is a transformer directly behind our operator, and the electric line can become more energized than it otherwise would have due to the position of the grounding device.

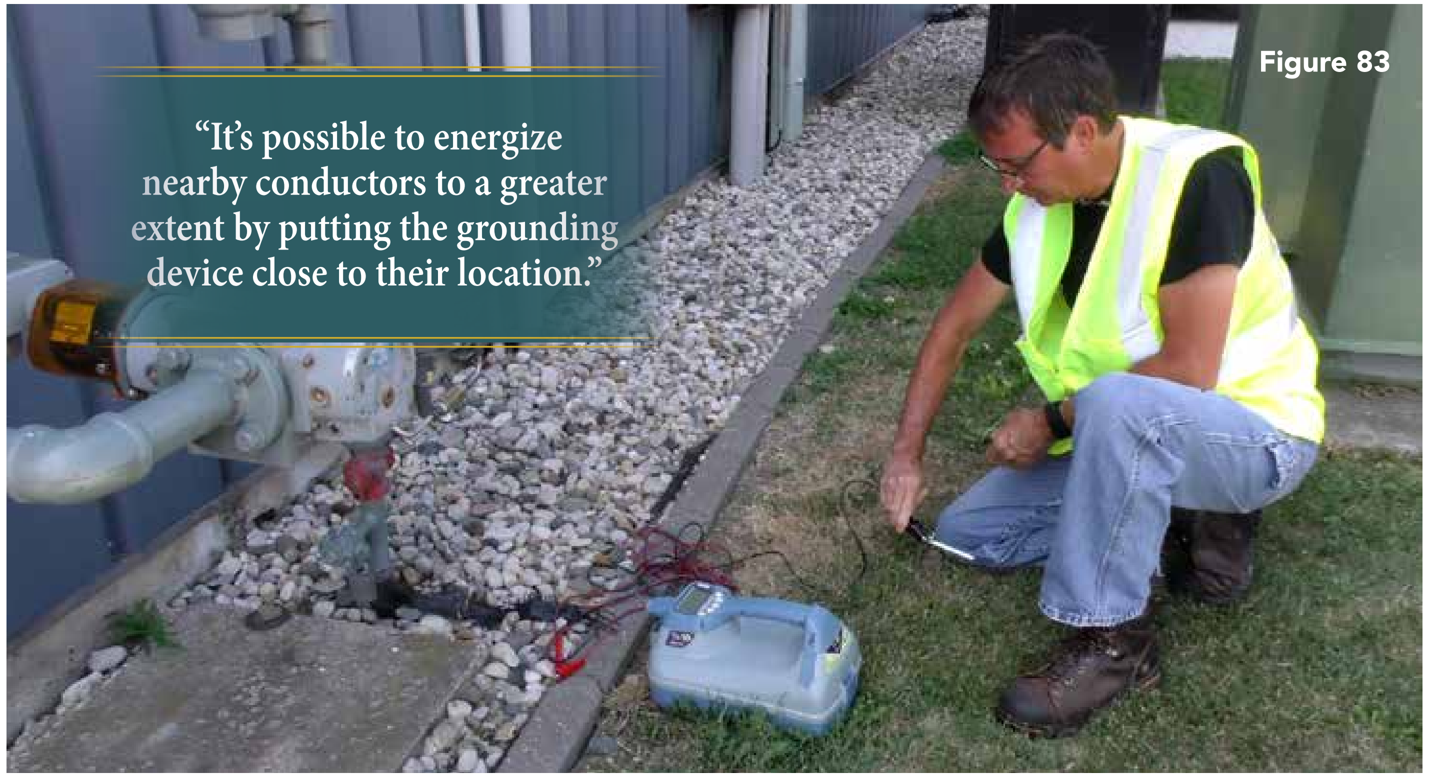


Figure 83

> "It's possible to energize nearby conductors to a greater extent by putting the grounding device close to their location."

This is another test station hookup **(Figure 84)**. There are two wires in this test station. One of these wires is going to be for the casing that protects the pipe going underneath the road, and the other one is going to be for the pipeline itself. Make certain that the conductive connection is to the wire that is welded to the pipe and not the wire that is welded to the protective casing.

Figure 84

Stretching the lead wires to a grounding device placed away from the conductive access point offers no advantage in terms of energizing the line **(Figure 85)**. It is best to ground close to the access point. Lead wires that are stretched atop the ground are fully energized when the transmitter is on and can confuse the early stages of the trace.

Figure 85

Conductive

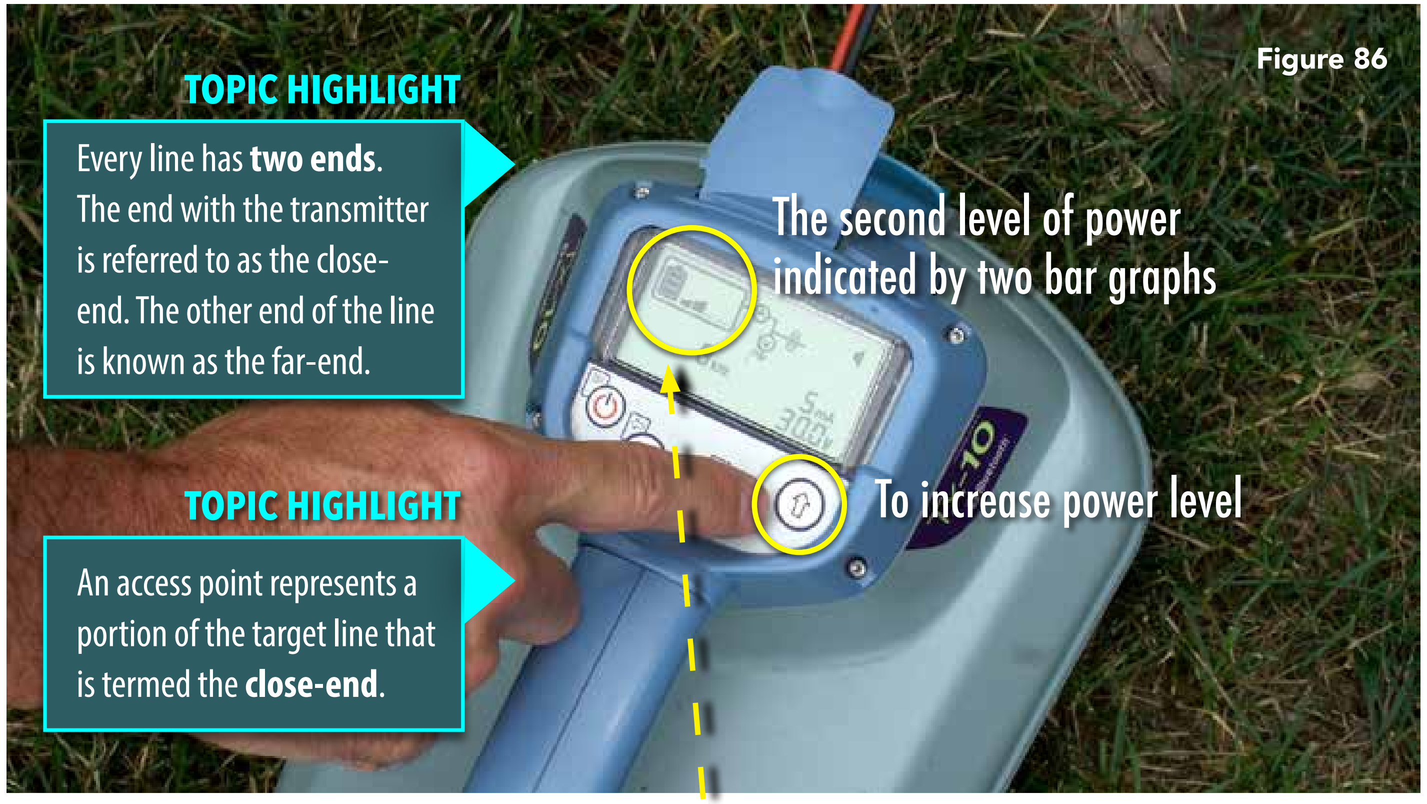


Figure 86

TOPIC HIGHLIGHT

Every line has **two ends**. The end with the transmitter is referred to as the close-end. The other end of the line is known as the far-end.

TOPIC HIGHLIGHT

An access point represents a portion of the target line that is termed the **close-end**.

We're locating an insulated tracer wire on 8 kHz at the second level of power. We only have 5mA of current flow leaving the transmitter **(Figure 86)**. We're going to turn up the transmitter to the third level of power, and we still only have 5 mA **(Figure 87)**.


Figure 87

TOPIC HIGHLIGHT

Voltage is like pressure. A voltage differential between the transmitter and earth allows alternating current to flow on a metallic line. While there is a relationship between voltage and current flow, it's important to note that current builds electromagnetic fields.

We're going to go to the far-end of the tracer wire, which was ungrounded. Using a jumper and a grounding device, we're going to connect the end of the wire to earth **(Figure 88)**. Unlike lead wires, a jumper has no break in metallic continuity.

Now we get 61 mA of current flow out of the transmitter versus 5 mA **(Figure 89)**. This is the value of a far-end ground in terms of building current flow on the target line.


Figure 88

TOPIC HIGHLIGHT

The visual endpoint represents the portion of the target line that is termed the far-end.


Figure 89

TOPIC HIGHLIGHT

There are **only four ways** to change the results of a locate. One of the ways is to change the grounding, which includes not only changing the grounding at the transmitter on conductive but also the ground of the target line.

Conductive

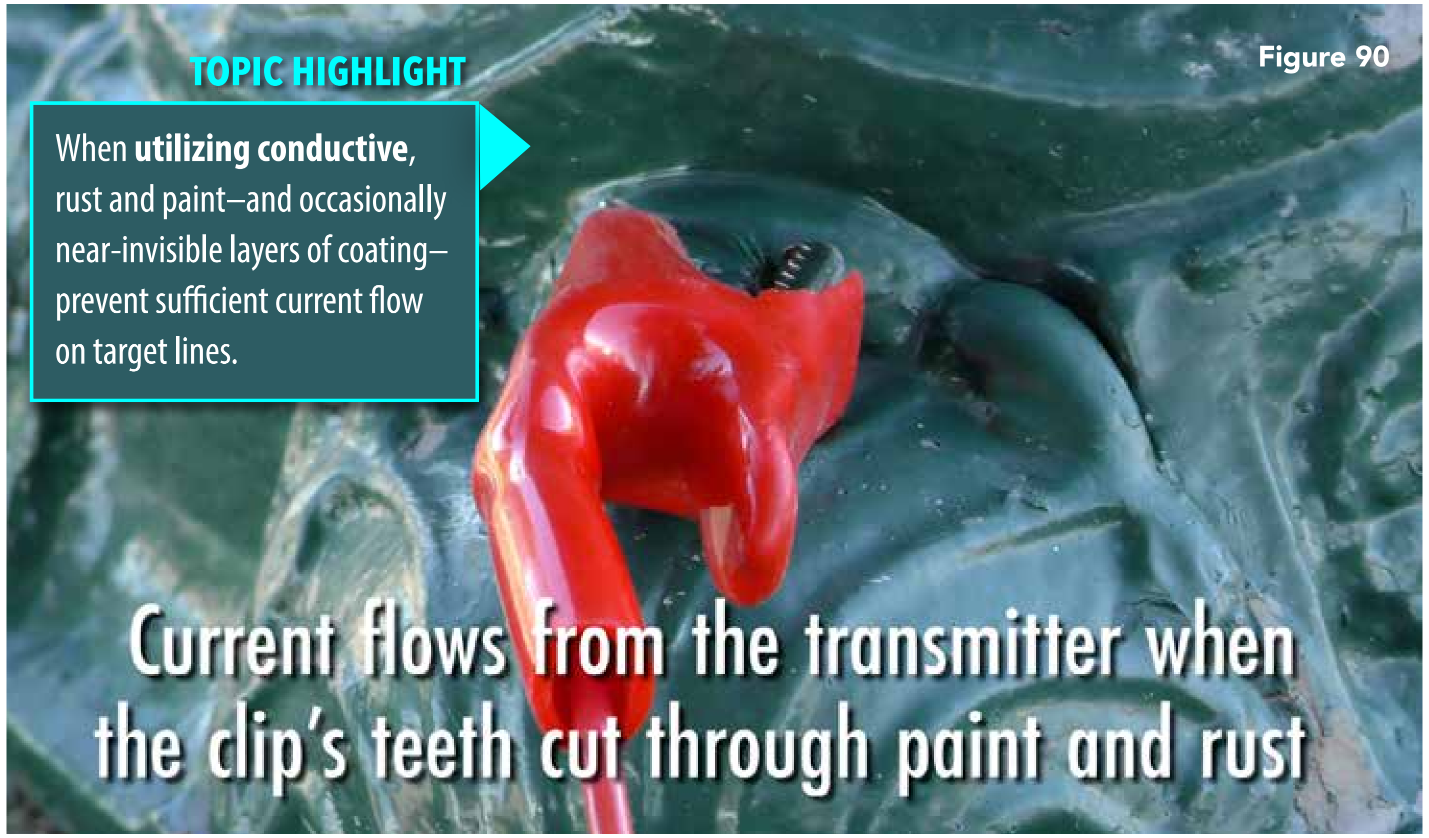


Figure 90

TOPIC HIGHLIGHT

When **utilizing conductive**, rust and paint–and occasionally near-invisible layers of coating–prevent sufficient current flow on target lines.

Current flows from the transmitter when the clip's teeth cut through paint and rust

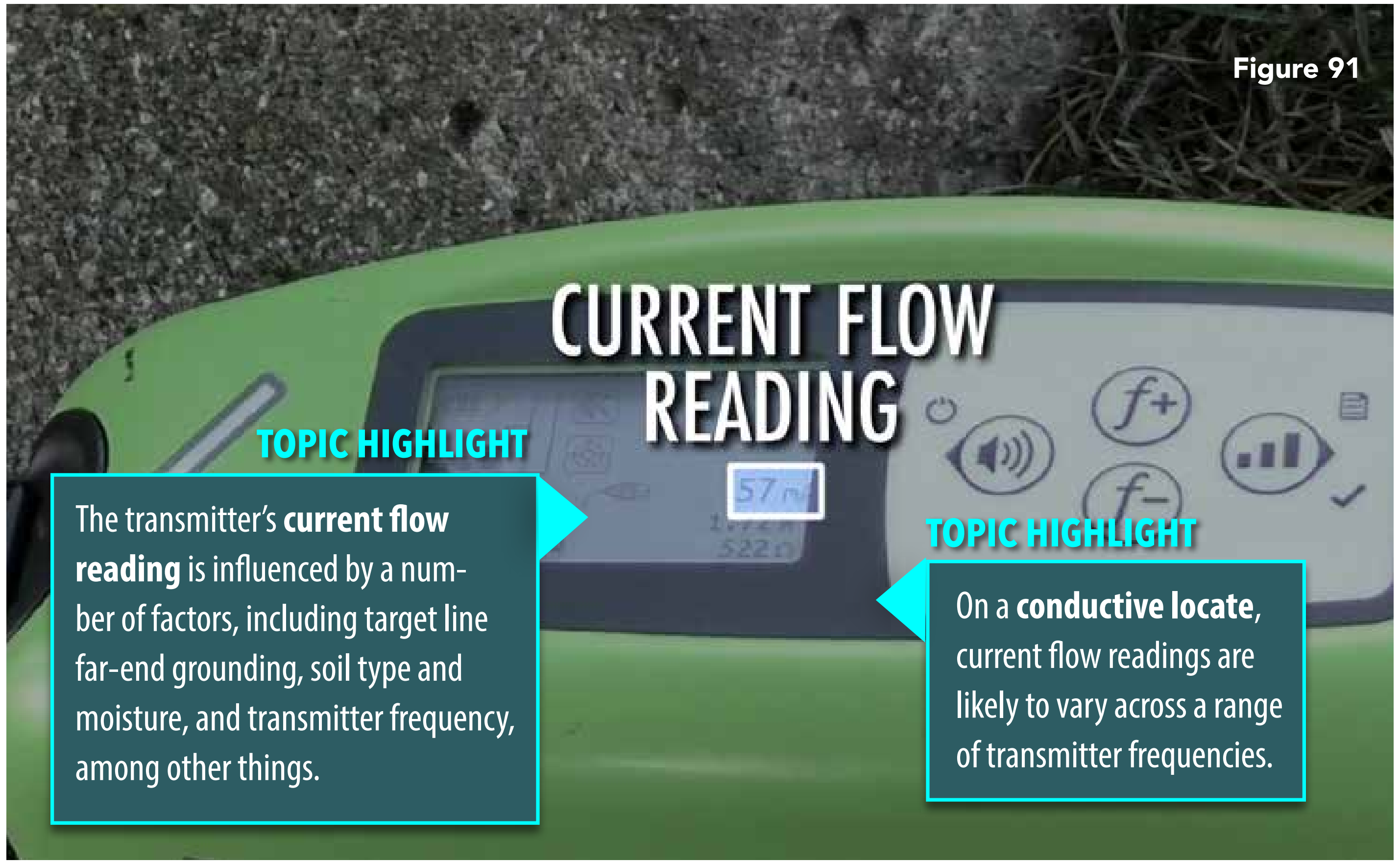


Figure 91

TOPIC HIGHLIGHT

The transmitter's **current flow reading** is influenced by a number of factors, including target line far-end grounding, soil type and moisture, and transmitter frequency, among other things.

TOPIC HIGHLIGHT

On a **conductive locate**, current flow readings are likely to vary across a range of transmitter frequencies.

Set up for this locate allows us to get a conductive locate on a cast iron water main that we otherwise would have no access point on. The operator is getting the valve key seated on the valve on this 8-inch main **(Figure 92)**.

Figure 92

We're on 33 kHz, and we have a current flow reading of 100 mA. Any time that the wrench hits the side of the valve box **(Figure 93)**, we will lose current to the valve box, which means the amount of current on the 8-inch cast iron pipe will be reduced.

Figure 93

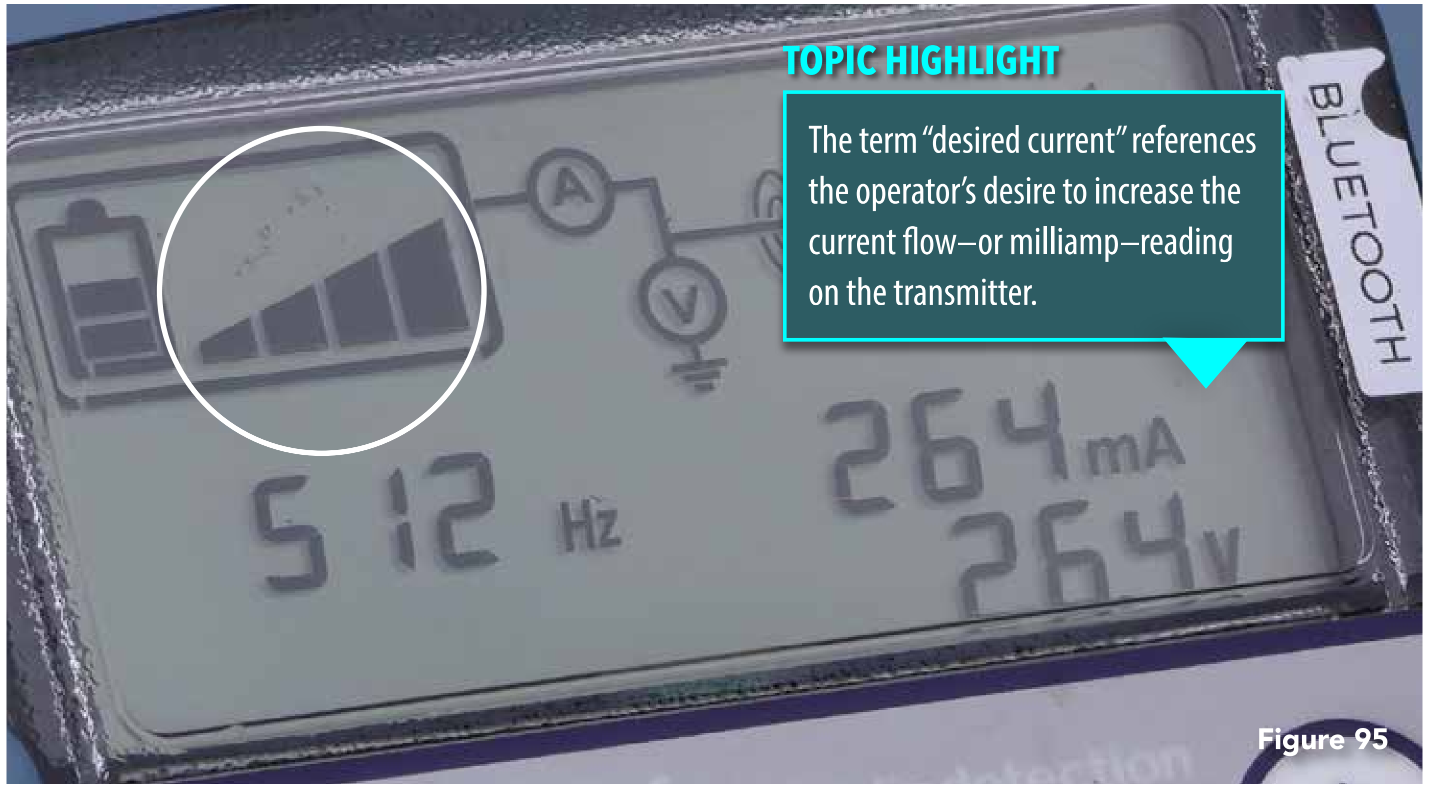
TOPIC HIGHLIGHT

If utilizing a low frequency and the current flow reading is zero, **test the conductive leads** by clipping them together. If still zero, there is a break in the lead wires.

Conductive

We can request more current to leave the transmitter by pushing the power up button, but it's not a guarantee that we're going to get the current flow that we desire. We start at 137 mA, and after increasing the desired current, we're able to increase the current flow to 264 mA **(Figures 94-95)**. These current flow readings do not reach maximum levels.

Figure 94



TOPIC HIGHLIGHT

The term "desired current" references the operator's desire to increase the current flow–or milliamp–reading on the transmitter.

Figure 95

On this transmitter, we're at 25 mA. We can ask it for more, and it goes up to 145 mA **(Figures 96-97)**. The conductive method of transmitter use allows the operator to select how much current they would like to get. The resistance in the earth and the resistance of the conductor—the pipe or cable—can conspire to keep the milliamp readings below the desired level.

Figure 96

At the lowest level of transmitter power, the maximum level of 25 mA of desired current is produced.

Figure 97

At the highest level of transmitter power, the maximum level of desired current is not produced.

Induction

On this image **(Figure 98)**, we have the transmitter set up over a cable TV feeder. Within four feet of the cable TV feeder is a parallel 2-inch steel gas main. We'll be investigating the shape of the received field while locating the cable TV feeder.

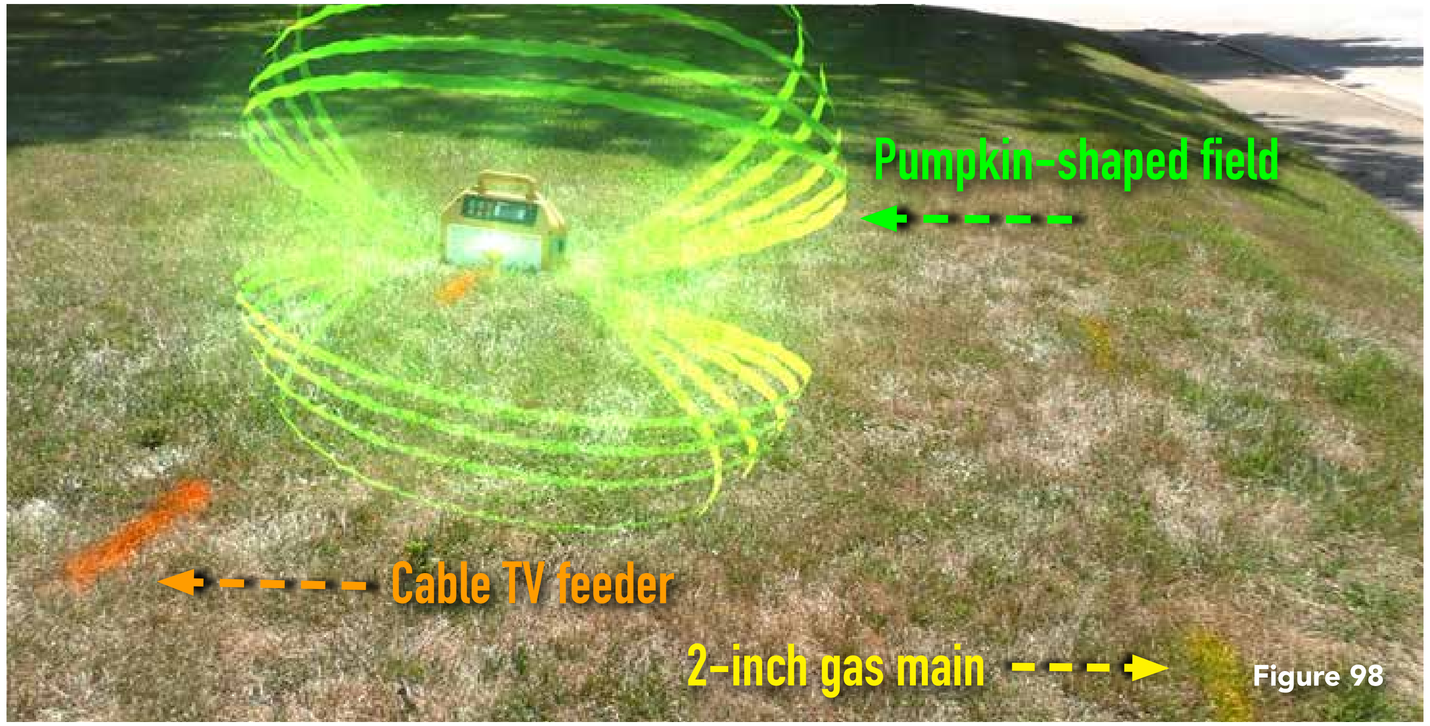


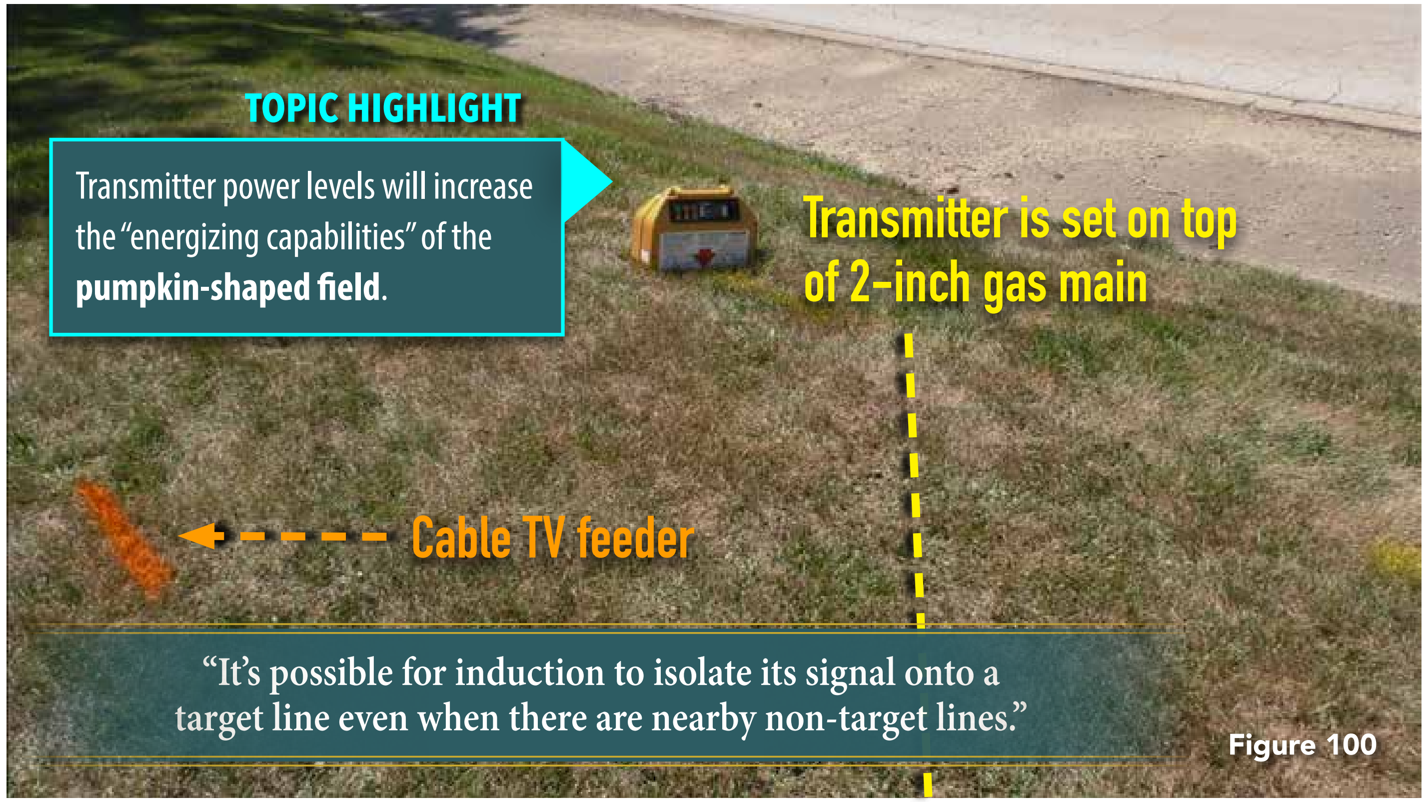
Figure 98

There is virtually no sign of bleed-off when the receiver is positioned in the vicinity of the energized cable TV feeder **(Figure 99)**.

TOPIC HIGHLIGHT

Just because induction is utilized doesn't mean that bleed-off will occur when non-target lines are positioned near the transmitter.

Figure 99



TOPIC HIGHLIGHT

Transmitter power levels will increase the "energizing capabilities" of the **pumpkin-shaped field**.

"It's possible for induction to isolate its signal onto a target line even when there are nearby non-target lines."

Figure 100

Now we'll move the transmitter over the steel gas main. Again, we see great signal over the gas line **(Figures100-101)**, but nothing over the parallel cable TV feeder. Now, every situation can be different from the one that preceded it and the one that follows it. What was demonstrated here, was that by placing the center of the pumpkin-shaped field over the target line, it's possible for induction to isolate its signal onto a target line, even when there are nearby non-target lines.

Figure 101

Induction

When utilizing induction there are two available transmitting antennas. First, there's the antenna in the transmitter: coils of wire that send out the pumpkin-shaped field. The act of inducing is sometimes referred to as "dropping the box" **(Figure 102)**.

Figure 102

But there's also a remote antenna, an inductive coupler **(Figure 103)**, and the inductive coupler has some unique properties. It's able to focus the transmitted signal into the interior of the coupler and can help identify particular conductors situated within gatherings of conductors.

Figure 103

Figure 104

By its nature, induction transmits a pumpkin-shaped field **(Figure 104)**, but the coupler can distort that field so that the energy is located in the interior space of the coupler **(Figure 105)** and not in the exterior space beyond the perimeter of the closed coupler.

Figure 105

Induction

In this diagram **(Figure 106)**, we're locating a secondary cable that exits a streetlight controller box utilizing an inductive coupler on 33 kHz. Both the secondary and a primary are fed out of the transformer in the image below.

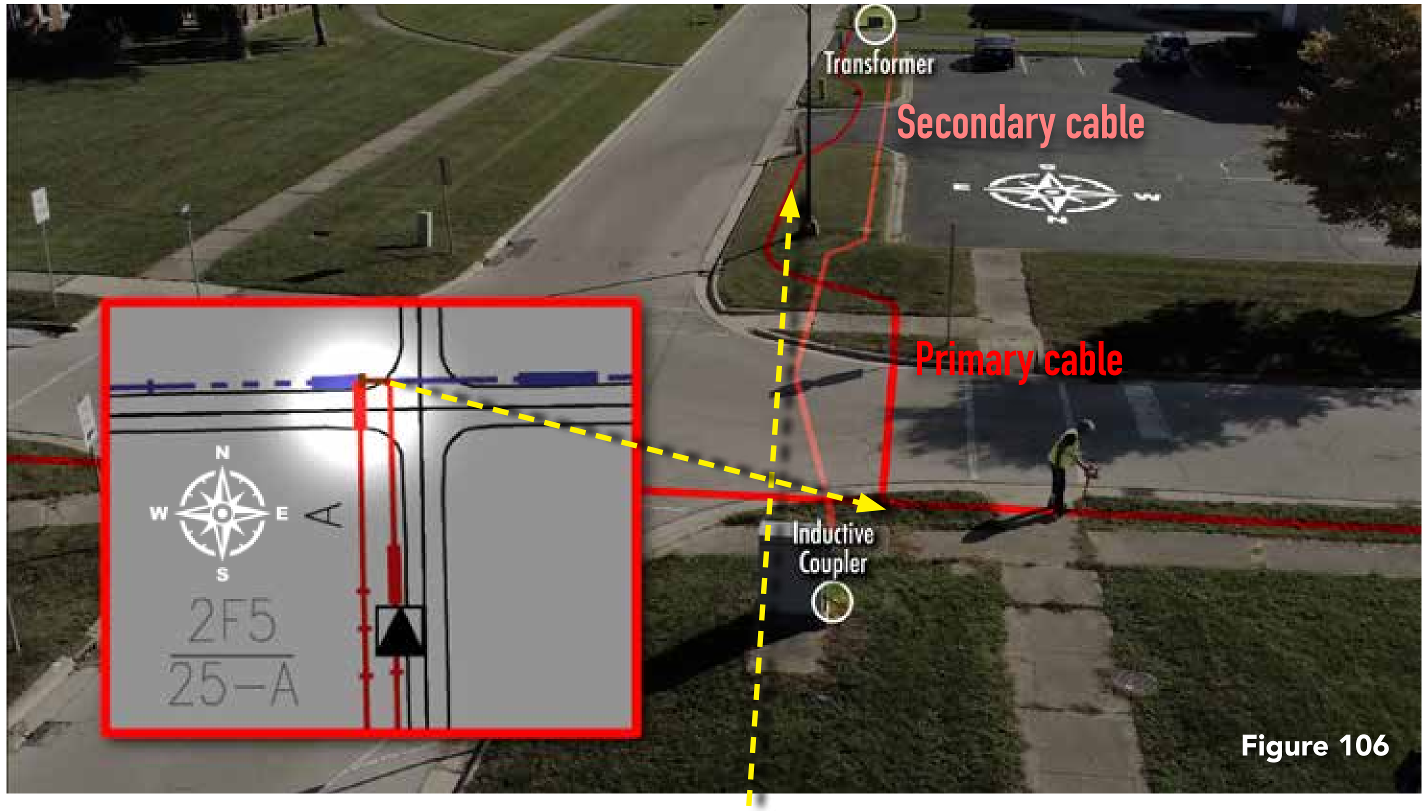


Figure 106

There is a bit of signal on the primary cable, so we're going to drop the box with the frequency set at 200 kHz **(Figure 107)** over the approximate location of the primary. This will allow an exercise where we'll be able to use both forms of induction simultaneously.

Figure 107

Figure 108

When the receiver is set to 33 kHz, we'll be locating the secondary cable. When we switch the receiver to 200 kHz **(Figures 108-109)**, we'll be locating the primary cable.

TOPIC HIGHLIGHT

A receiver only receives **one frequency** at one time.

Figure 109

Induction

In certain situations, such as parallel electric distribution cables fed from the same transformer, an inductive locate can be more accurate than a conductive locate (**Figure 110**).

Figure 110

"An inductive locate can be more accurate than a conductive locate."

The operator is marking a weak, not-round 33 kHz signal to find a place to inductively transmit on 200 kHz.

On the image below (**Figure 111**), we switched the receiver to 200 kHz, and we're having peaks and nulls that agree, telling us that we can have a high level of confidence in the single-phase primary locate. But soon we'll be too close to the transmitter to conduct a proper locate (**Figure 112**).

Figure 111

Forty feet of distance always needs to be the minimum separation of the receiver and the transmitter when dropping the box. Any closer, and the receiving coils can pick up signal from two sources: the signal coming off of the energized conductor below ground, and signal through the air from the pumpkin-shaped field produced by the transmitter (**Figure 113**).

Figure 112

Figure 113

So now we were happy with our locate south of where the transmitter was placed (**Figure 112**). We're going to move the transmitter to a good spot where we felt like our receiver was picking up an accurate locate (**Figure 113**). Why did we feel like it was accurate? Our peaks and nulls agreed. Then we're going to come back through the area where the transmitter was, and we'll see that we had actually placed the transmitter almost, but not precisely, on the primary cable. That red mark that you see on the image (**Figure 114**) was a 33 kHz signal resulting from our inductive coupler trace on the secondary cable exiting the streetlight controller box.

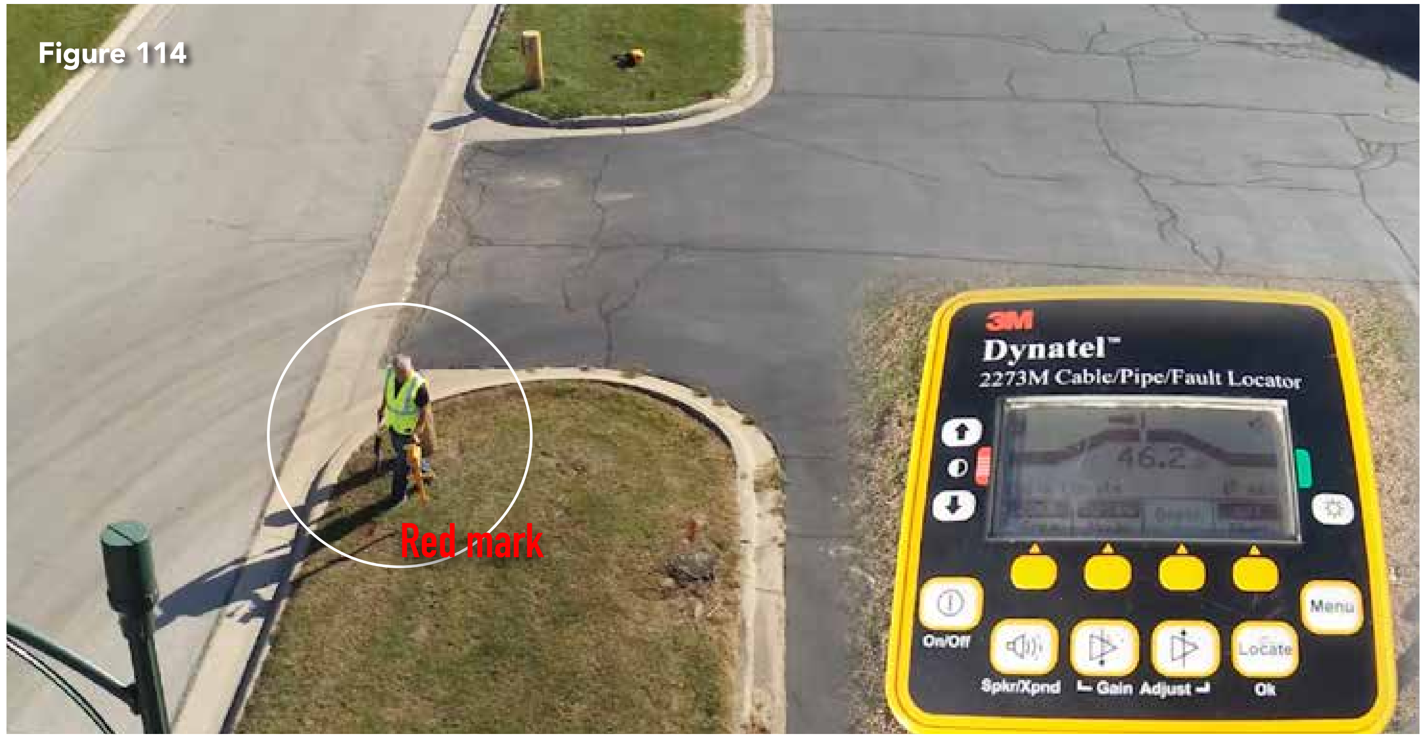


Figure 114

Induction

After moving the transmitter and being more than 40 feet away from it, we once again see peaks and nulls that agree **(Figure 115)**. And we're going to have confidence in this locate, as the primary cable turns and ultimately crosses the energized secondary cable.

But we won't have any problem, because the filters on the receiver are only allowing us to see the 200 kHz right now, not the 33 kHz signal. In **Figure 116**, we're getting ready to complete the locate where the primary crosses the secondary.

TOPIC HIGHLIGHT

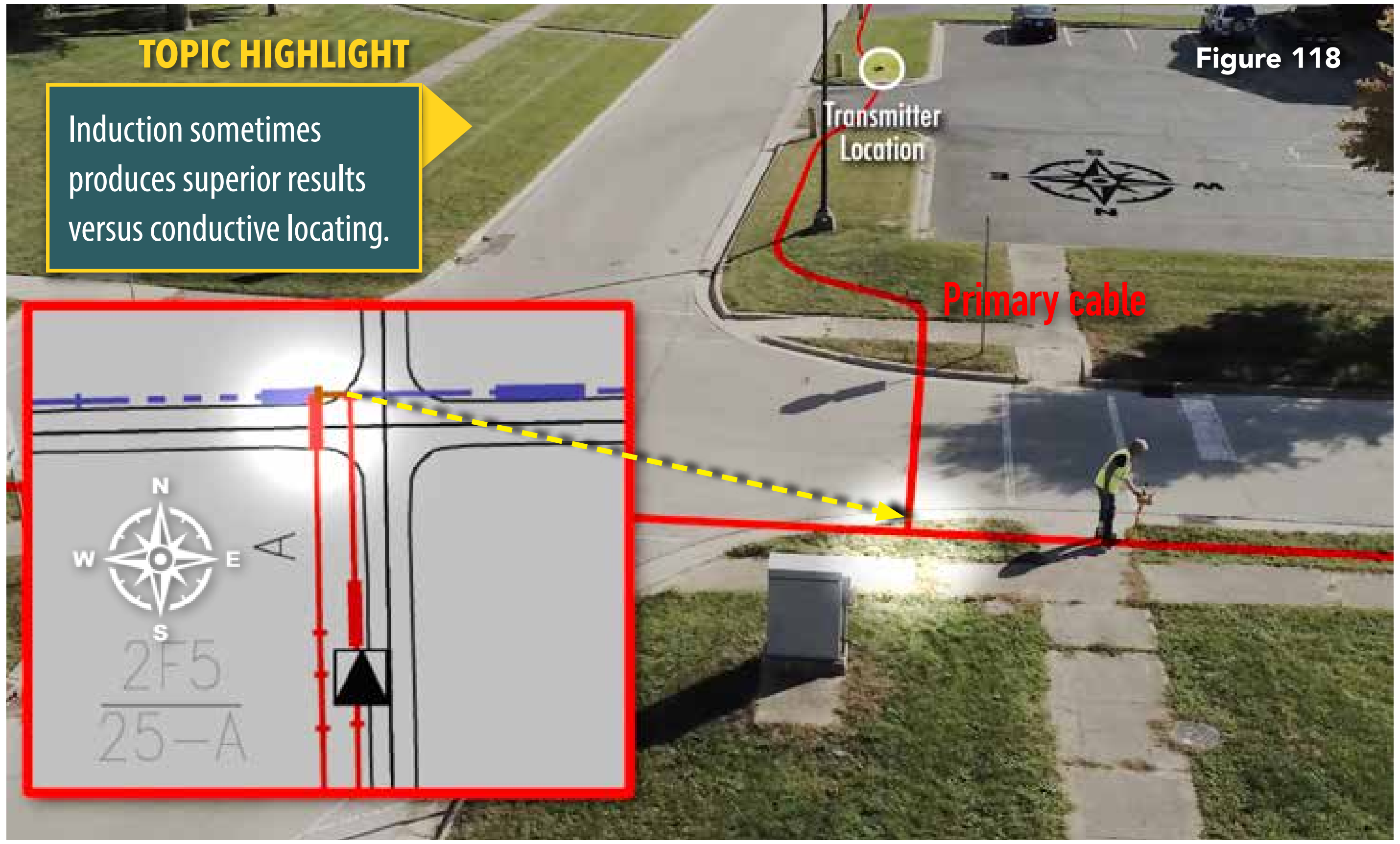
Receiving antennas receive all frequencies at once, but electronics inside the receiver filter all but the frequency selected by the operator.

Figure 115

Figure 116

Figure 117

If we are indeed on the primary, we should be coming up to the end of our northbound signal **(Figure 117)**, because this primary cable is going to be tied into a three-phase cable just south of the sidewalk **(Figure 118)**. To confirm, we locate the three-phase westward.



TOPIC HIGHLIGHT

Induction sometimes produces superior results versus conductive locating.

Figure 118

Bleed-Off

Bleed-off is the transfer of the transmitter's energy from your target line to a non-target line or lines. Your transmitter is energizing not just what you want to locate, but other metallic conductors in the ground as well. Bleed-off can also occur with above-ground metallic objects like chain link fences and guardrails.


Figure 119

> "Bleed-off can also occur with above-ground metallic objects like chain link fences and guardrails."

In this exercise, we're utilizing a low-low frequency of 512 Hz on a tracer wire. Over the tracer wire, we get a peak signal of 79.3 and a current measurement of 5.8 mA. This is our target line **(Figures 119-120)**.


Figure 120

But running parallel to our target line, the tracer wire, is a 6-inch cast iron water main approximately 5-feet deep. Even though low frequencies are generally considered to bleed-off very little, we actually have significant bleed-off in terms of our peak reading over the water line: 79.3 on the tracer wire versus 55.7 over the parallel water main. This is a bleed-off percentage on 512 Hz of approximately 69 percent when we look at only the peak number. The signal from the tracer wire has bled-off onto the water main **(Figure 121)** despite the use of a low transmitter frequency. Different frequencies can and sometimes will do different things.


Figure 121

TOPIC HIGHLIGHT

Low-low frequencies such as 512 Hz can bleed-off through the ground onto non-target lines.

Now we're going to take a look at a much higher frequency of 65 kHz. A commonly held misperception is that the higher the frequency the higher the percentage of bleed-off. With the peak number of 13 over the tracer wire, we're going to compare it to a peak number of just under five on the water line. Whereas we had about 69 percent bleed off with 512 Hz, here, using a much higher frequency, we only have 37 percent bleed-off when looking strictly at the ratio of the two peak numbers **(Figure 122)**.

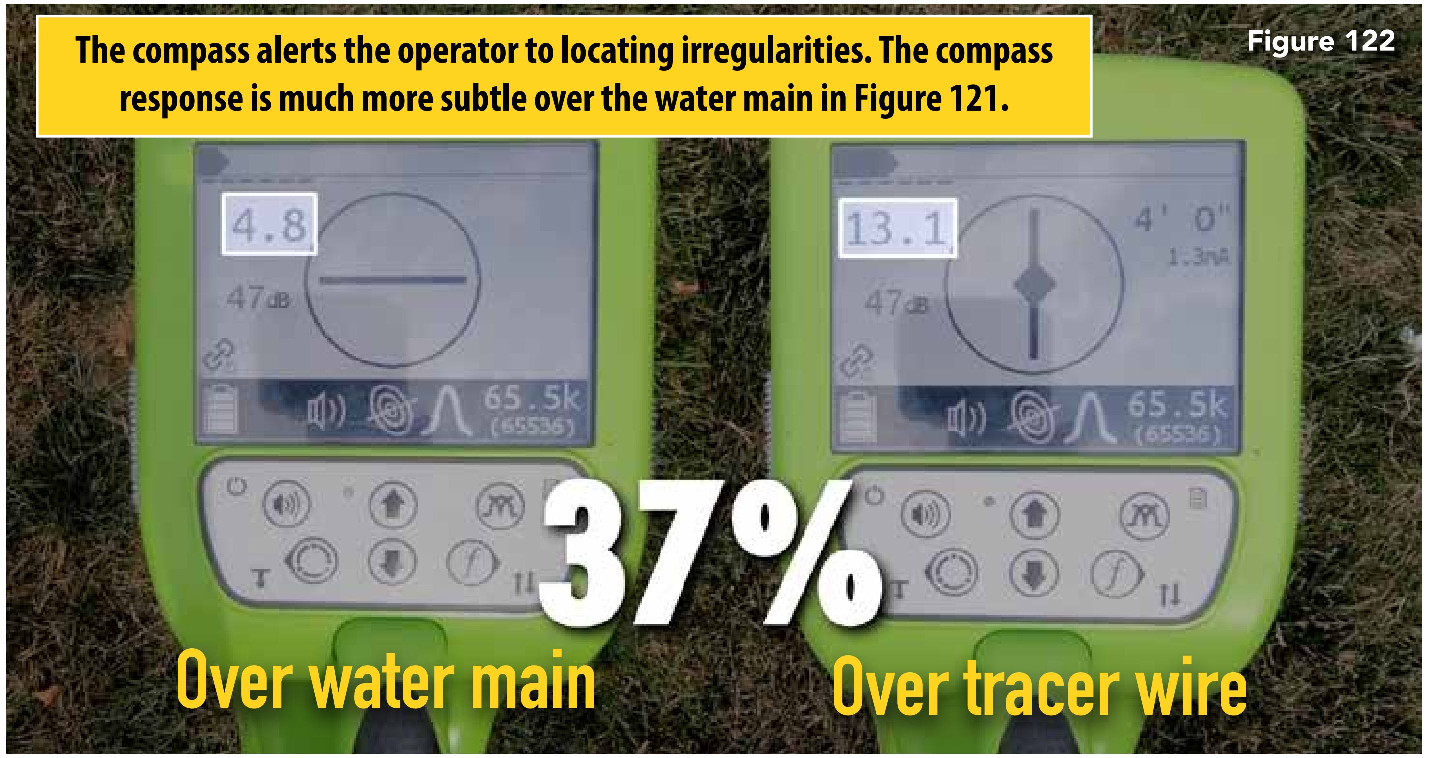


Figure 122

The compass alerts the operator to locating irregularities. The compass response is much more subtle over the water main in Figure 121.

Bleed-Off

We're going to look at bleed-off in a practical sense. We are hooked up to a steel gas service line which is tapped into a 2-inch steel gas main. Again, we're going to start with 512 Hz, something that is generally considered a frequency that won't encounter a whole lot of bleed-off.

The steel service locates easily. At the tap, we're going to follow our signal to the east. It's a nice, easygoing locate. But something changes. The peak numbers have really gone up. And now the gas main locates quite a bit farther from the curb than it did before. We don't get anything by the curb, but about seven or eight feet from the curb, we get what appears to be an accurate locate **(Figures 123-124)**.

While it is possible that the gas main has a jog in it, let's take a look at the same trace, but using a higher frequency of 33 kHz. 33 KHz is one of the lowest frequencies in the low-high frequency range. The purpose of redoing this locate is to see if we still encounter the rapid increase in the peak reading as well as a jog in the gas line.


Figure 123


Figure 124

After locating farther down the line, peak readings increased from 33.1 to 46.1.

Our signal is now just a few feet off the curb (yellow line in **Figure 125**), versus the seven to eight feet off the curb with the low frequency (red line). We have a straight compass and a substantial mA reading using both 512 Hz and 33 kHz—just in different locations. We have a good mA reading. Over the course of using two different frequencies, we see that on 512 Hz, our trace on the gas main differed from where it did on 33 kHz by a little over four feet. 512 Hz ended up locating a cable TV feeder. In this particular locate, 33 kHz was a better frequency to use than 512 Hz. 512 Hz bled-off onto the cable TV feeder when we walked past the amplifier pedestal.


Figure 125

Signal always follows the path of least resistance and the path of least resistance can and sometimes will change depending on the frequency selected. It's reasonable to say that when bleed-off occurs it's due to the signal following the path of least resistance.

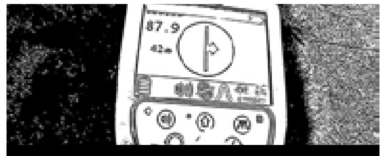
It is impossible to know in advance which frequency is the best to use in a given situation to reduce bleed-off. While low frequencies generally reduce bleed-off through the ground, there are other factors besides frequency that influence bleed-off, such as soil conditions. Plus, there are also metallic connections between utilities—sometimes intentional and sometimes unintentional—which cause low frequencies to easily transfer from one utility to another.

As it did here with the sudden increase in the peak response, the receiver may indicate, through subtle changes over the course of the trace, that bleed-off has likely occurred.

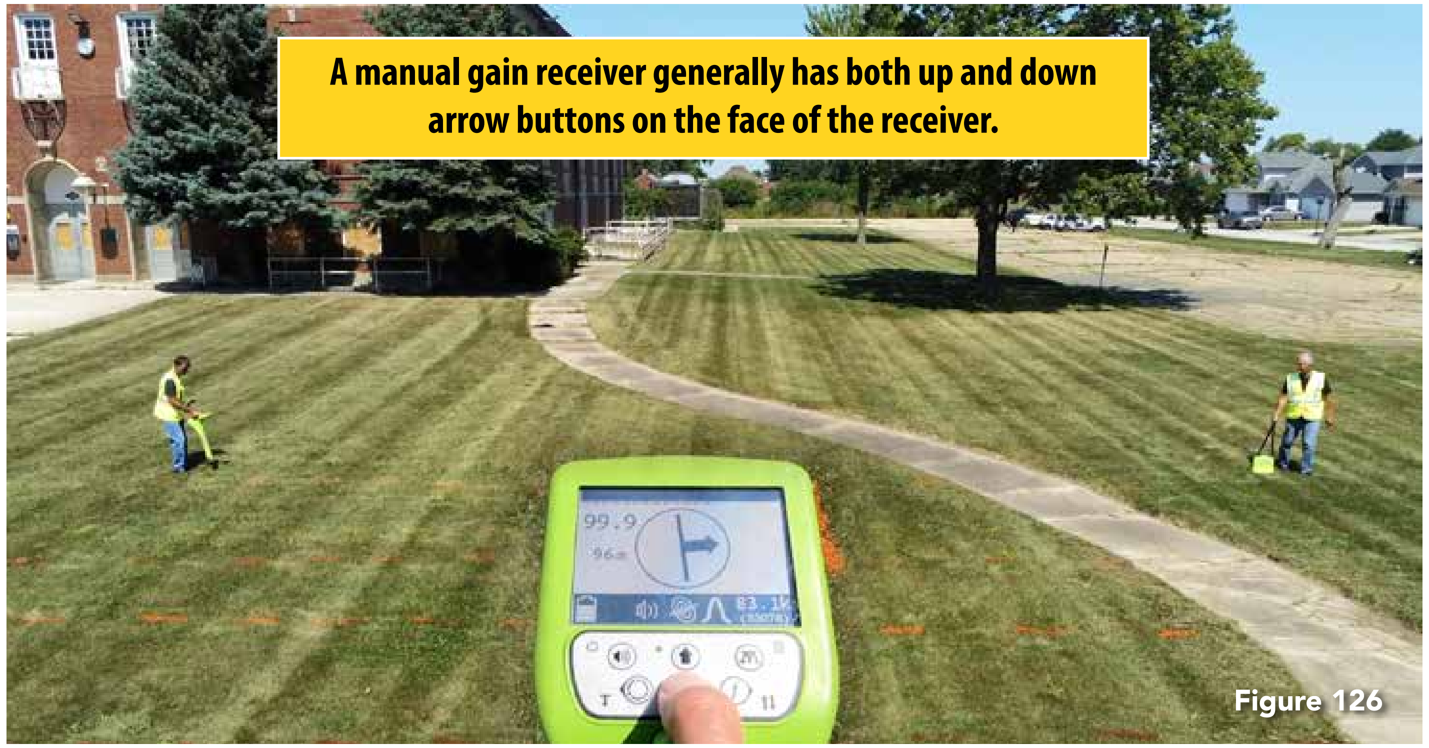
> "Bleed-off is the transfer of the transmitter's energy from your target line to a non-target line or lines. Your transmitter is energizing not just what you want to locate, but other metallic conductors in the ground as well."

TOPIC HIGHLIGHT

There are only **two ways** signal can bleed-off from a target line to a non-target line: metal-to-metal and non-metal to metal.



Gain



A manual gain receiver generally has both up and down arrow buttons on the face of the receiver.

Figure 126

Gain is like a zoom lens. You can zoom in or out. And if that analogy doesn't work for you, let's try another: gain is volume. You can turn the volume up, or you can turn the volume down. But no matter what, it's always the same music that's playing.

We can zoom out, or we can turn the volume down to a mid-range versus a high level. Notice that only the peak number changes with gaining down. Nothing happens to the null response. There are only two instances where we have to use manual gain: when the peak reads full scale **(Figure 126)** or zero. Any time we're in between those two points, we can see peak numbers changing **(Figures 127-128)**. Only the peak number changes when you press gain. Milliamps, depth and null are unaffected by changing the gain **(Figures 127-128)**.

At other times, we'll want to gain up, because we want to see higher numbers changing versus lower numbers. It doesn't mean we can't use the lower numbers. Sometimes it's just easier to see more numerical change, not less, as the receiver is moved across the target line **(Figures 129-130)**.

> "Gain is volume.
> You can turn the volume up,
> or you can turn the volume
> down. But no matter what,
> it's always the same music
> that's playing."

TOPIC HIGHLIGHT

While **gain** will change peak readings, gain does not change null readings.

TOPIC HIGHLIGHT

Most receivers have a maximum peak response of 99.9 or 100. A receiver with no gain control and no maximum numerical response has what is known as **dynamic gain**.

Figure 127

Gain down

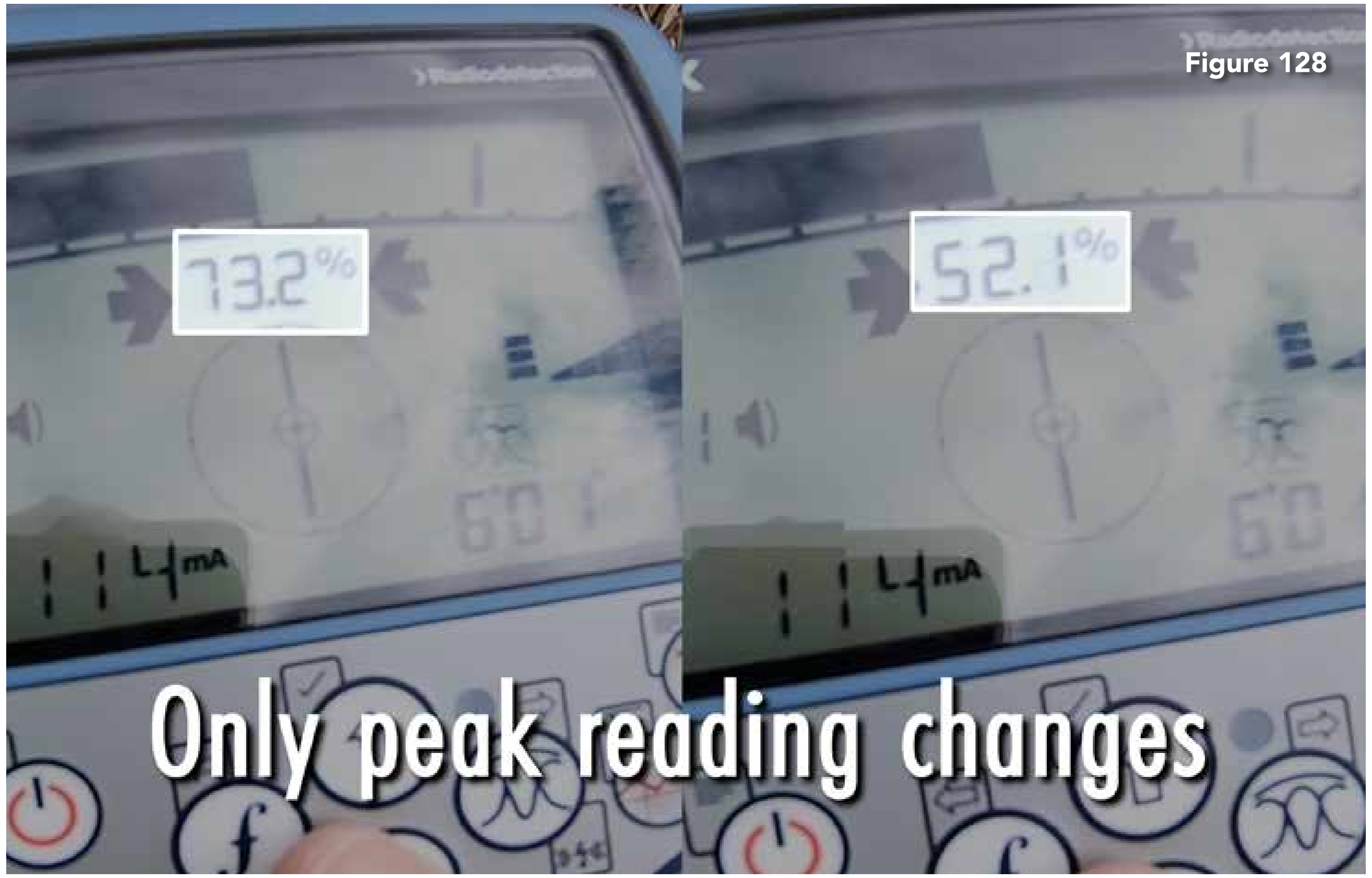


Figure 128

Only peak reading changes

Gain

Many receivers introduce an audible tone only after a certain peak reading has been reached, such as 20% of scale. When peak numbers are less than 20, there is no sound that corresponds with the peak response **(Figure 129)**. Once the receiver has "gained up" over 20, an audible tone begins to correspond with the peak response **(Figure 130)**.

Figure 129

Figure 130

TOPIC HIGHLIGHT

Receivers sometimes have the user option to toggle between manual gain and auto-gain. **Auto-gain** strives to keep the peak response mid-scale.

TOPIC HIGHLIGHT

You can't change the **results of a locate** with the receiver.

TOPIC HIGHLIGHT

Peak readings measure the signal strength of the electromagnetic field. On most receivers, the peak reading can be increased or decreased through the use of the gain setting.

TOPIC HIGHLIGHT

Gain is ratio-metric. When receiving two peak readings on two different lines, a change in gain will change both peak readings the same percentage. If two peak readings are 60 and 30, gaining down to reduce the 60 reading to 30 will result in the 30 reading becoming 15.

TOPIC HIGHLIGHT

An auto-gain feature makes a smaller incremental gain change when a larger amount of signal is present versus a larger incremental gain change when a lower amount of signal is present.

TOPIC HIGHLIGHT

Gain does not change **depth or current** measurement readings.

Gain

When utilizing gain on this particular receiver **(Figure 131)**, the peak number doesn't change, but the length of the bar graph does. The peak audio tone increases as the bar graph gets longer. Some receivers can toggle between a manual gain and an automatic gain. In **Figure 132**, the receiver is set to automatic gain. The results of a locate cannot be changed by the receiver. Only changing something at the transmitter end will change the results of a locate.

Figure 131

Manual gain is often utilized to control the receiver's peak audio response.

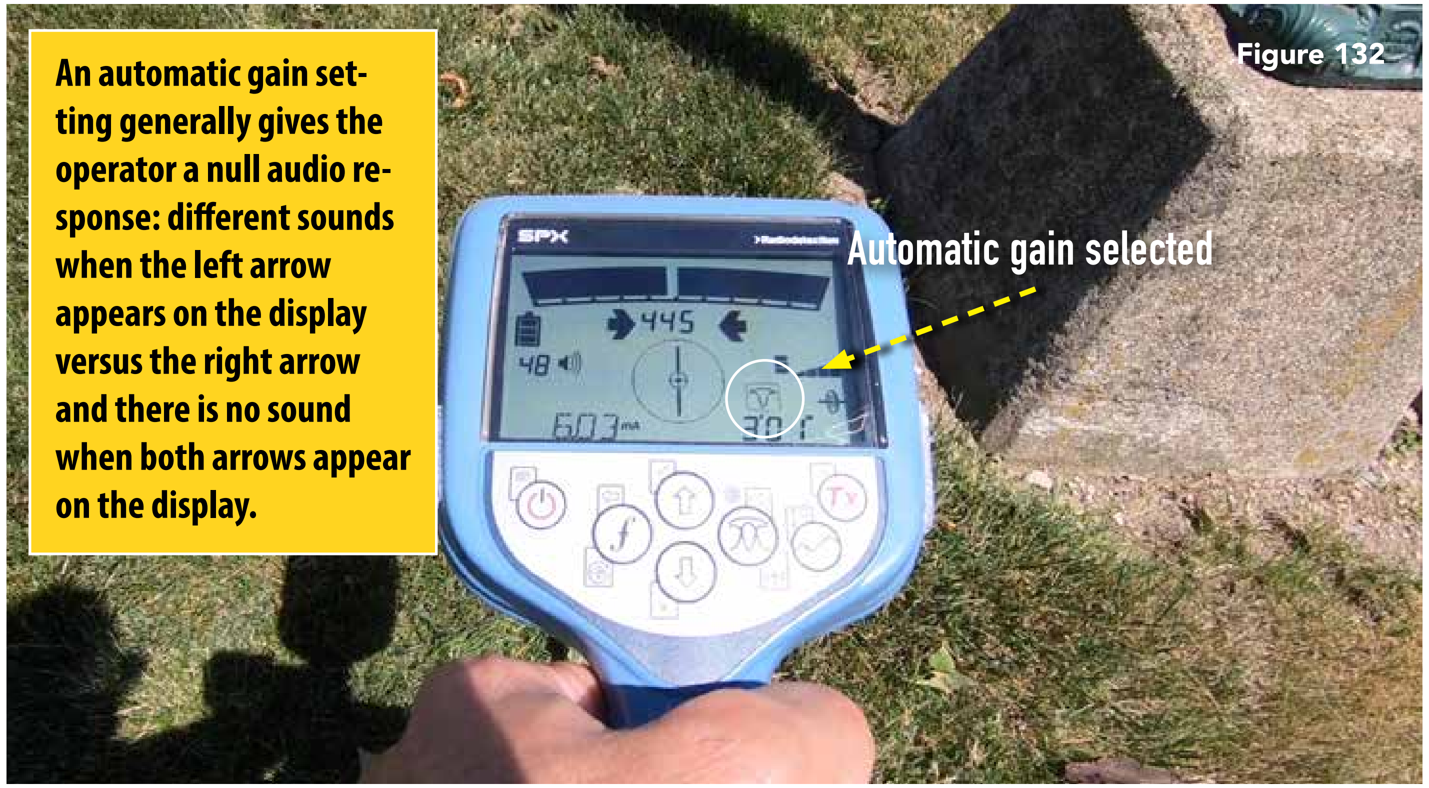


Figure 132

An automatic gain setting generally gives the operator a null audio response: different sounds when the left arrow appears on the display versus the right arrow and there is no sound when both arrows appear on the display.

> "The results of a locate cannot be changed by the receiver. Only changing something at the transmitter end will change the results of a locate"

It's important to underscore that the only two readings on a manual gain machine that cannot be utilized are zero and full-scale. Everything else in between can be used. However, gain does not change the results of a locate. Gain is a convenience tool that allows you to see either a greater number change or a lesser number change while moving the receiver across the target line.

This receiver has neither an automatic gain control nor a manual gain control **(Figure 133)**. It's what's called a dynamic range receiver, which means the low end is zero, but there is not necessarily a high number. We could see 2000. We could see 2100. We could see 2500. We could see 3000. But gain is never manipulated on this receiver, either by the user gaining up or gaining down, or by an automatic gain control.

Figure 133

Gain

So let's prove that gain doesn't change anything about the locate. We get a 79.3 peak reading over the target line, a tracer wire. Over the parallel non-target line, a 6-inch cast iron water main, we receive a peak reading of 55.7. The peak reading of 55.7 over the water line is 69% of the peak reading of 79.3 over the tracer wire **(Figures 134-135)**.

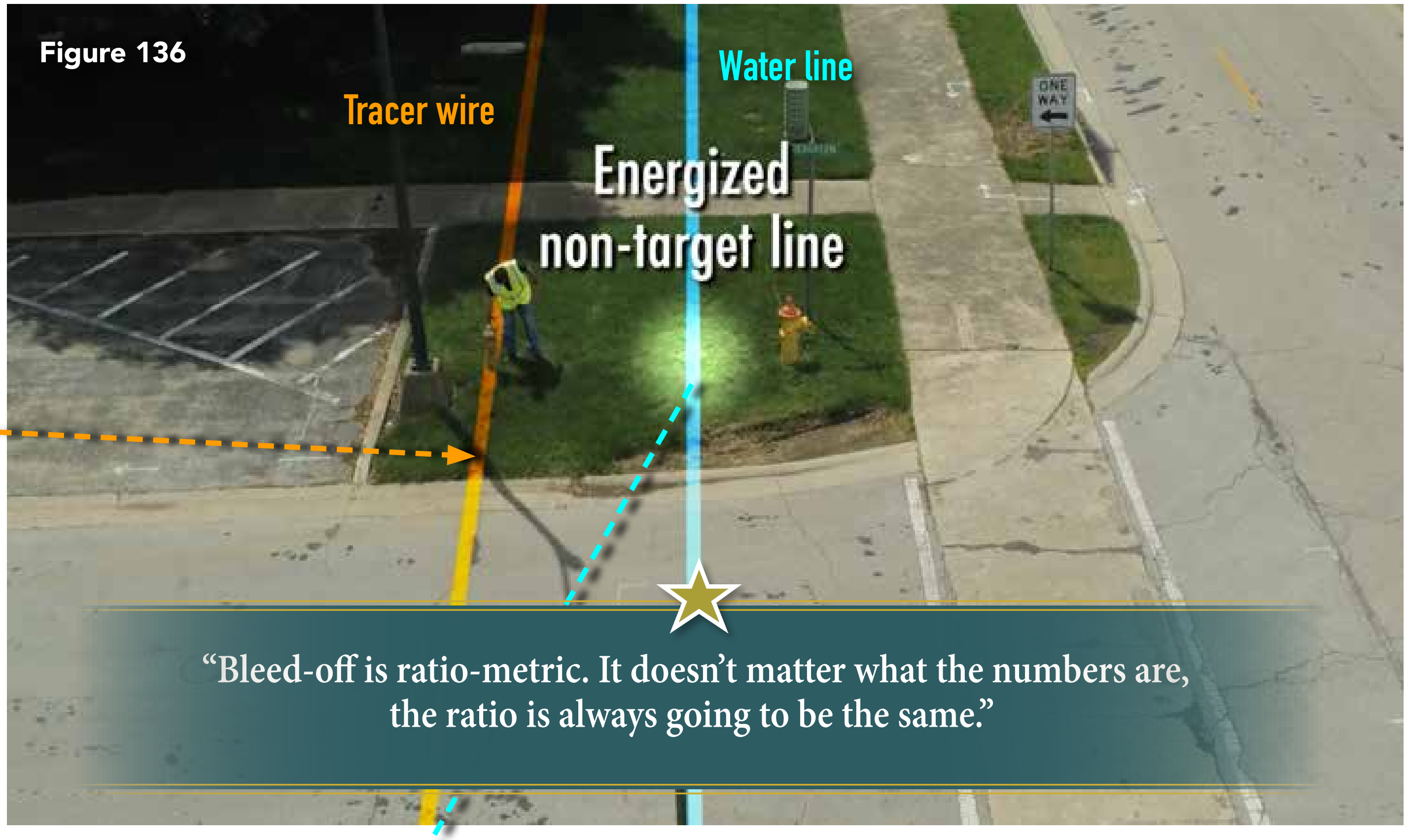
Figure 134

The compass is acting as a not-round field indicator over the water line.

Figure 135

Can we change bleed-off by changing gain? We're going to drop the gain by almost 50 peak numbers. We originally received a 79.3 peak reading over the tracer wire, and after gaining down, we are receiving a 30.1 peak reading **(Figure 136)**. What will be the peak reading over the parallel water line, the non-target? A reading of 24 compared to 30.1 is still 69% of the signal **(Figure 137)**. Nothing changed by lowering the gain. Bleed-off is ratio-metric. It doesn't matter what the numbers are, the ratio is always going to be the same. Changing gain does not change bleed-off or the results of a locate.

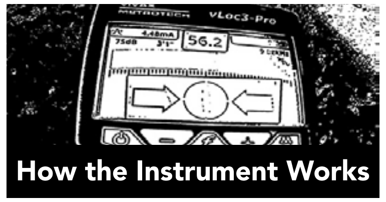
Figure 136



"Bleed-off is ratio-metric. It doesn't matter what the numbers are, the ratio is always going to be the same."

Figure 137

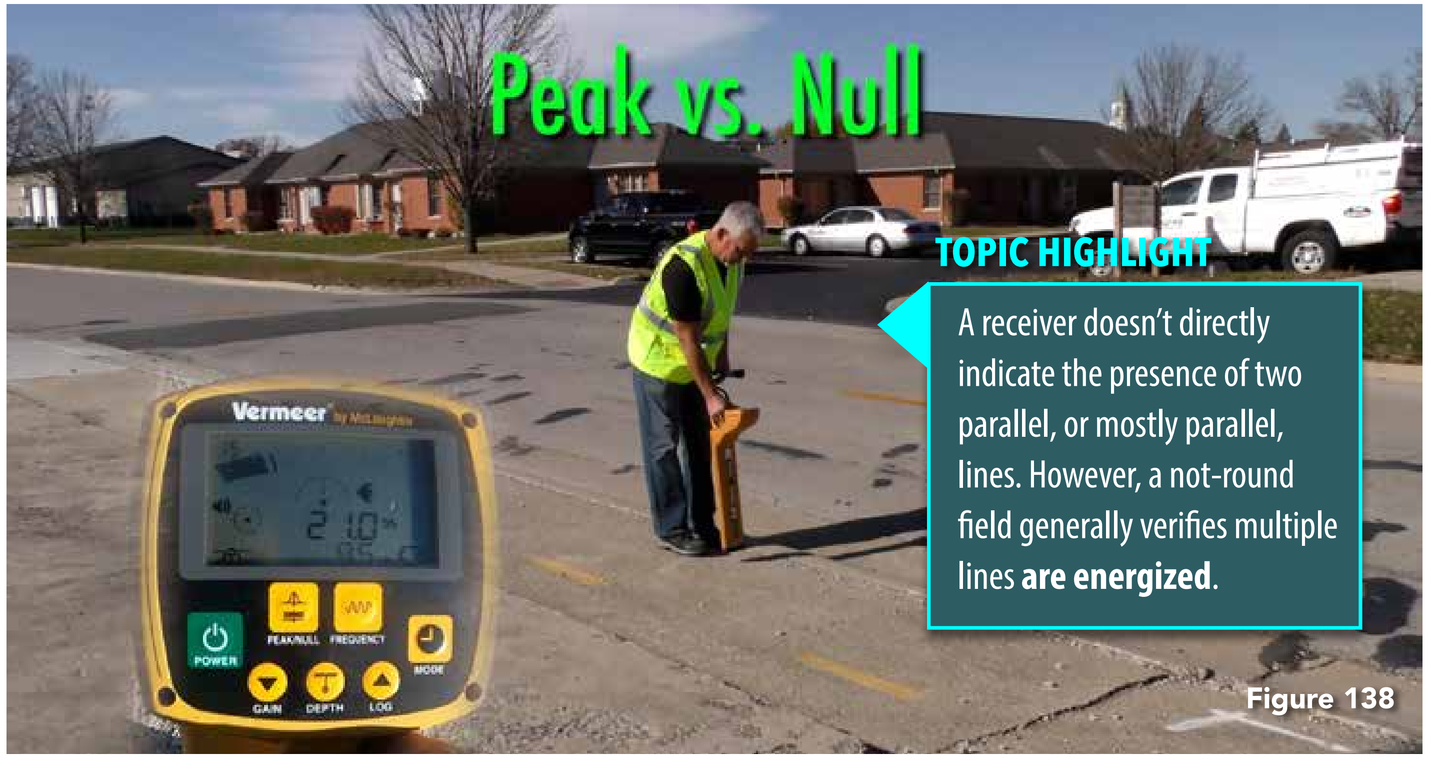
The water line still has 69% of the signal that is on the tracer wire.



How the Instrument Works

The shape of an electromagnetic field may be determined to be "round" or "not-round." A round field indicates there is only one line, or conductor, energized in the immediate area. A not-round field indicates multiple conductors are energized.

Illustrated in these photos are five ways to check the shape of the field: peak versus null, digital depth validation, the straddle test, the lift test, and triangulation **(Figures 138-142)**.



Peak vs. Null

TOPIC HIGHLIGHT

A receiver doesn't directly indicate the presence of two parallel, or mostly parallel, lines. However, a not-round field generally verifies multiple lines **are energized**.

Figure 138

Digital Depth Validation

Figure 139

The Lift Test

TOPIC HIGHLIGHT

The Lift Test uses the null reading to check signal shape and therefore may also be referred to as The Null Test.

Figure 140

The Straddle Test

TOPIC HIGHLIGHT

The Straddle Test uses the peak reading to check signal shape and therefore may also be referred to as The Peak Test.

Figure 141

Triangulation

Figure 142

The level of flow is determined by looking at the peak number. The peak number will either be steady, fluctuating some or fluctuating a lot. Depending on the peak number's fluctuation or lack of it, we term the level of flow as being good, OK or poor current. This is the "Current" in Current, Shape, Endpoint.

There are four factors that dictate what happens to current on a metallic utility line. Is the utility insulated or not? And if it is insulated, what is the condition of that insulation? Is the utility grounded or not? Is it grounded at the close end? Is it grounded at the far end **(Figures 143-144)**?


Figure 143

TOPIC HIGHLIGHT

Bleed-off is not impacted by utility insulation or the lack of it.


Figure 144

TOPIC HIGHLIGHT

The ground wire for electric systems can serve as an **access point**.

TOPIC HIGHLIGHT

Differences between frequencies are differences in the amount of induced current. The amount of induced current is directly related to the path of least resistance and level of flow.

What type of soil do we have **(Figure 145)**, and what is the moisture content of that soil? Remember, earth is a conductor no different than the metal pipe or cable in every locating circuit. The final factor that dictates level of flow is the transmitter's frequency **(Figure 146)**. Frequency is the only factor completely controlled by the operator.

But there are things the operator can do to potentially change the level of flow. In addition to changing the frequency, the operator can move the transmitter, change the grounding of either the transmitter on conductive or, if possible, the grounding of the utility, and lastly change from conductive to inductive **(Figure 147)**.


Figure 145

TOPIC HIGHLIGHT

The accuracy of a trace may be impacted if different soil types are side-by-side near the target line.

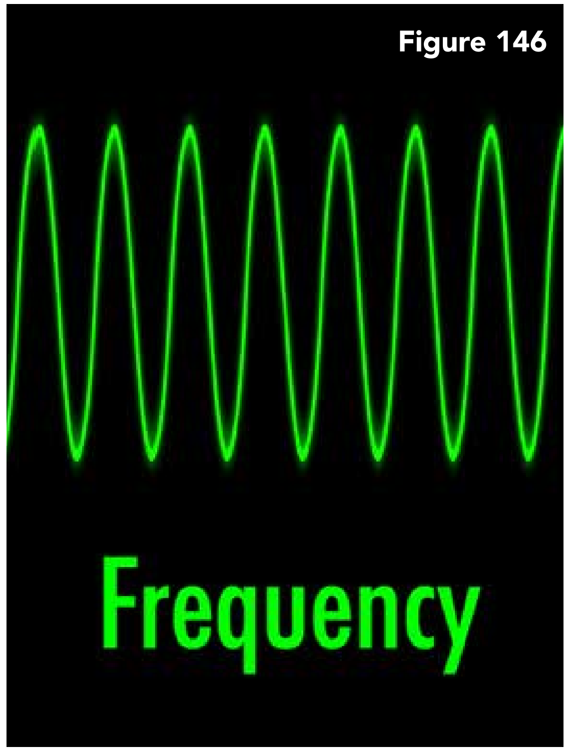
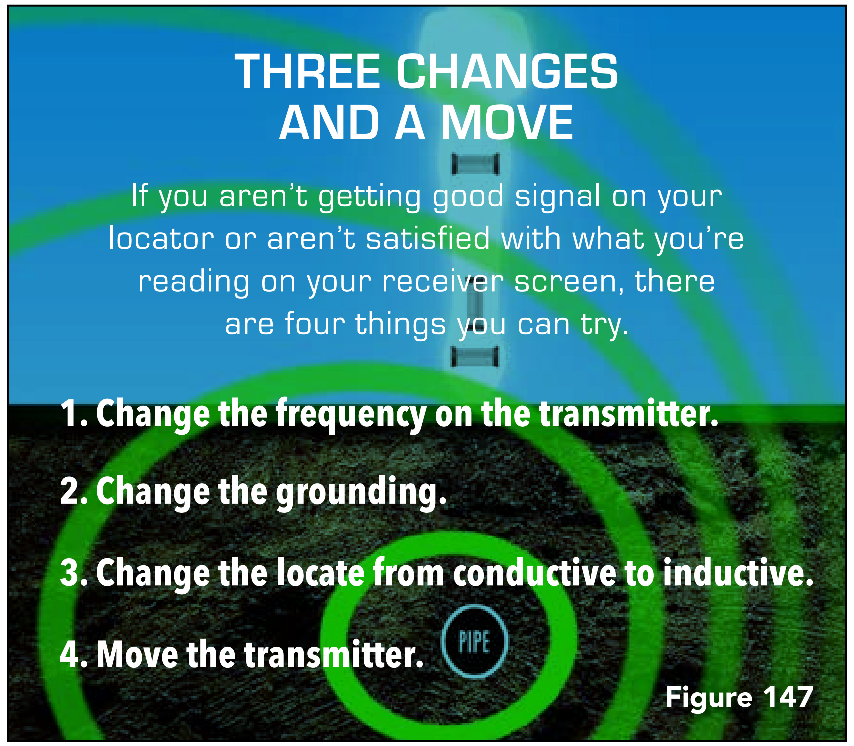


Figure 146


THREE CHANGES AND A MOVE

If you aren't getting good signal on your locator or aren't satisfied with what you're reading on your receiver screen, there are four things you can try.

1. **Change the frequency on the transmitter.**
2. **Change the grounding.**
3. **Change the locate from conductive to inductive.**
4. **Move the transmitter.**

Figure 147

The Transmitted Signal

The key to successful locating is a thorough knowledge of the ways in which the transmitter may be utilized.

The transmitter either conducts current onto a target line or to a coiled transmitting antenna. A coiled transmitting antenna produces an electromagnetic field which in turn produces current onto a target line.

Whether used conductively or inductively, the purpose of the transmitter is to turn a buried metallic pipe or cable into the last leg of a transmitting antenna. The impact of the path of least resistance on a particular locate may vary when utilizing the transmitter inductively versus conductively.

Differences in transmitter frequencies create differences in the production of induced current. Different levels of induced current is why different transmitter frequencies may do different things.

Transmitter frequencies set near multiples of 50 or 60 are avoided to enable the receiver to filter unwanted electromagnetic fields produced by the alternating current of electricity grid cables. For example, 512 Hz is not close to 500 or 550 Hz nor is it close to 480 Hz or 540 Hz.

Table of Contents

**A multiple-page section used to break down a video featuring a lengthy locating exercise.*

Different Frequencies Do Different Things

The *Creating the Circuit* video series begins with a lesson illustrating the change in locating results when using different transmitter frequencies. We're hooked to a test wire that is attached to the end of a steel main **(Figure 1).** We're utilizing a transmitter frequency of 512 Hz. Initially, the main only travels westward, but then it's going to turn northward **(Figure 2)**.


Figure 1

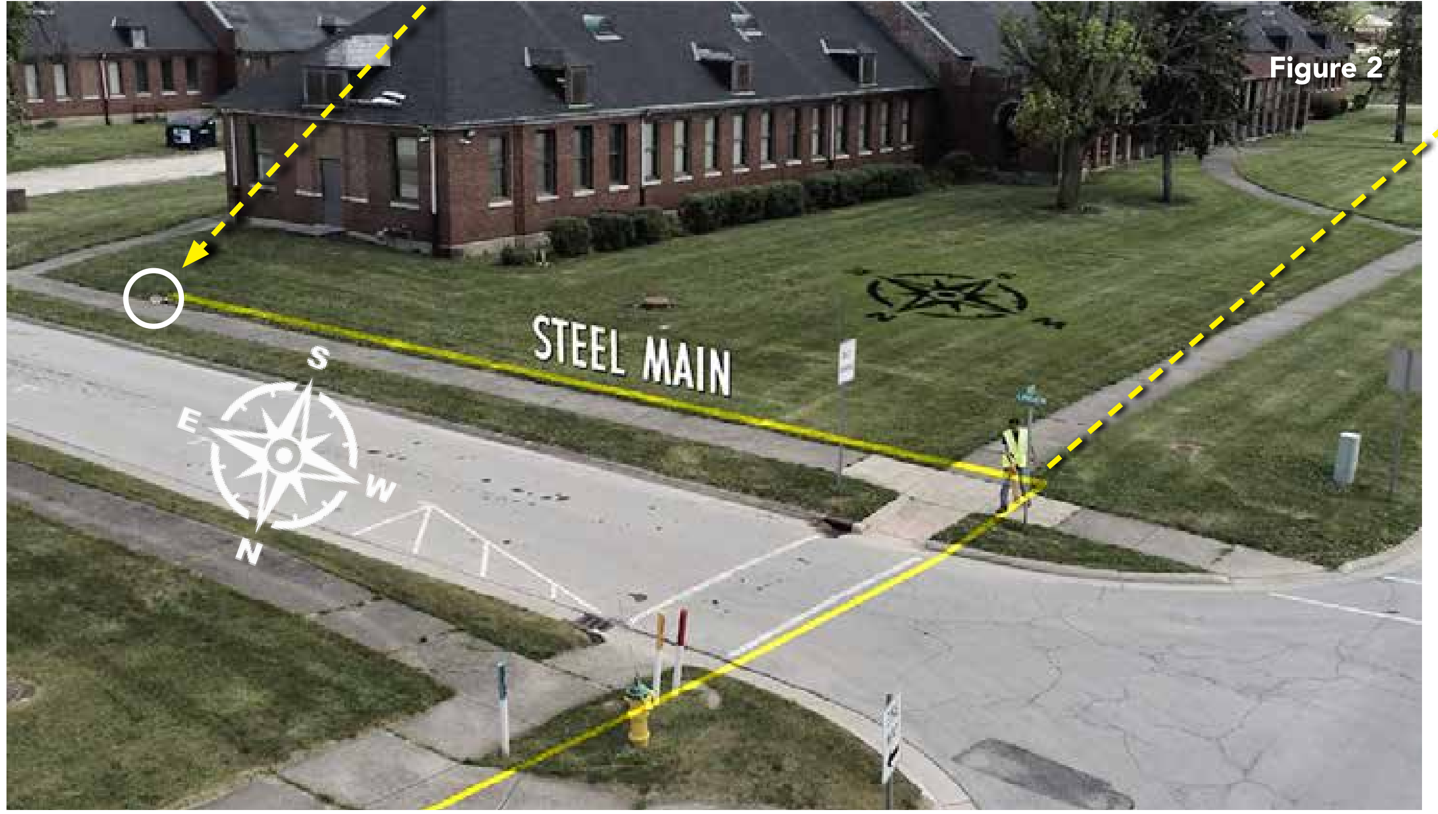


Figure 2

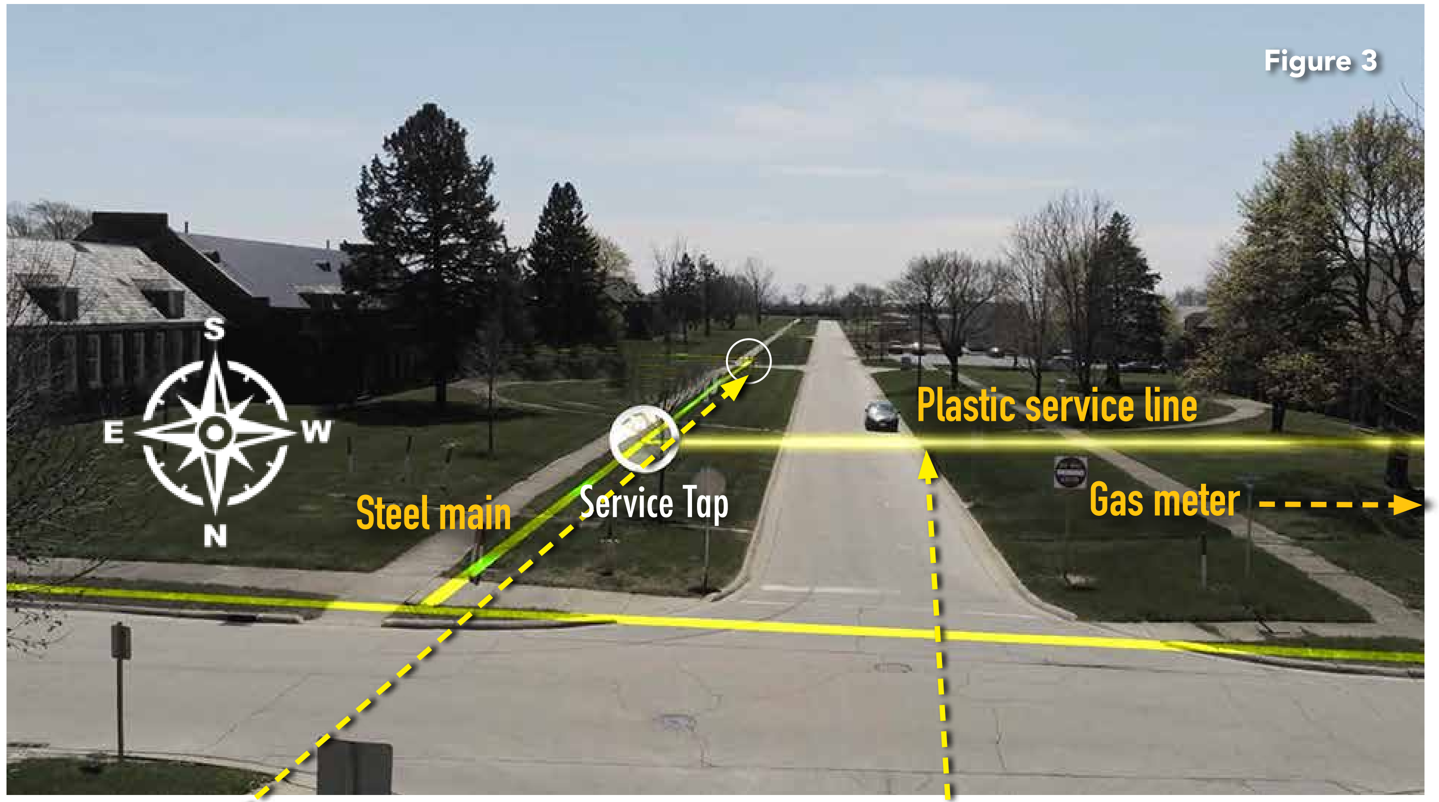


Figure 3

As we locate on 512 Hz, we're going to come across a plastic service that is attached to the steel main. The plastic service has a tracer wire and at the service tap, it is welded to the steel main. The 512 Hz does not want to travel up the tracer wire towards the gas meter, where the far-end of the tracer wire is not grounded to earth **(Figure 3)**. Because the path of least resistance for this low frequency is to stay on the steel main, the receiver does not detect a peak signal over the service line, as there is no current on the tracer wire **(Figure 4)**.


Figure 4

Different Frequencies Do Different Things

We're going to come back and do this exact same locate, but this time with 83 kHz. Eighty-three kHz is what we would call a low-high frequency. Although nothing has changed about where the signal is applied, with 83 kHz, we can now send a signal up the tracer wire toward the ungrounded far-end of the tracer which is wrapped around the riser at the gas meter. So this illustrates that different frequencies can and sometimes will do different things.

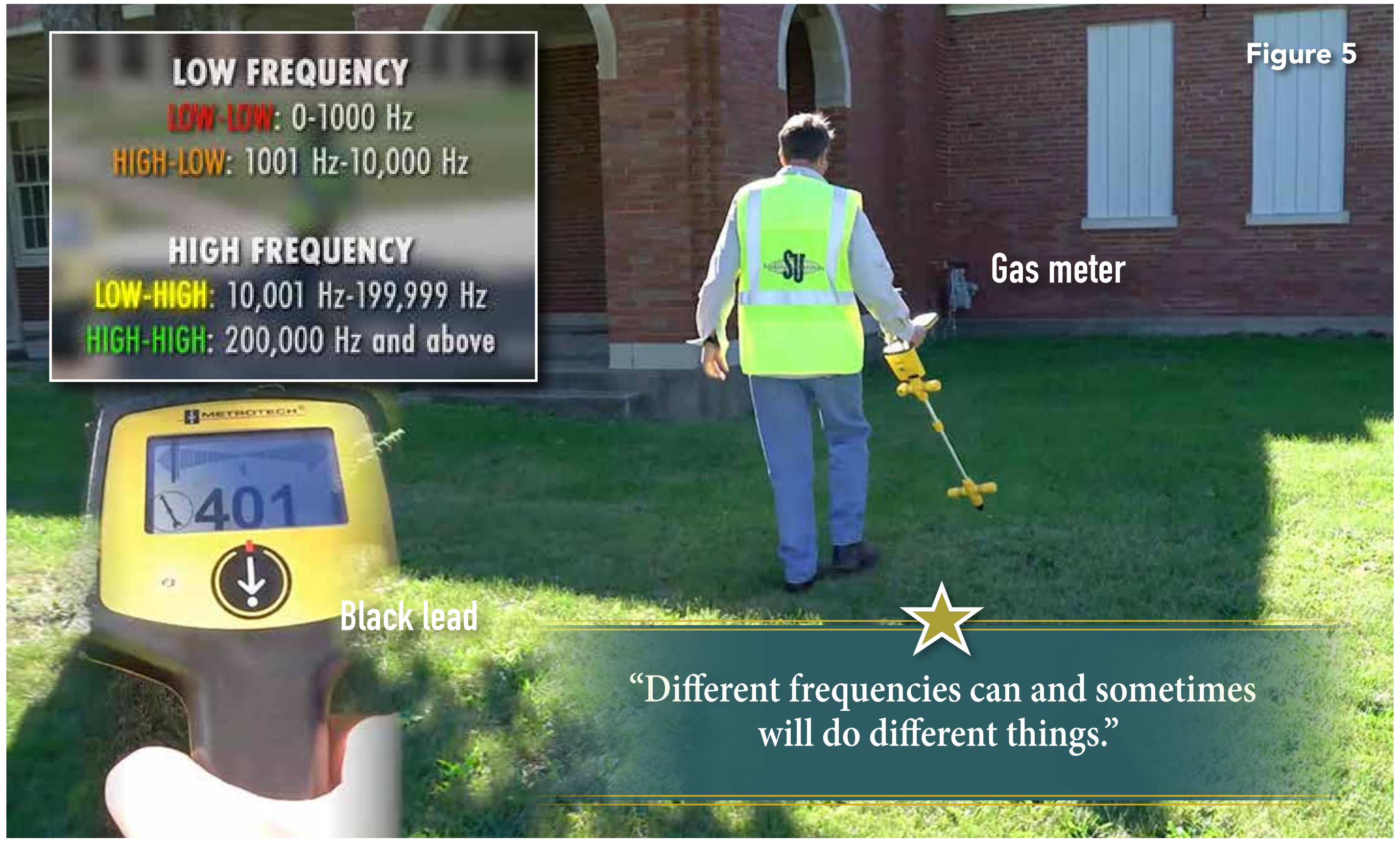


Figure 5

> "Different frequencies can and sometimes will do different things."

The service tap represents a signal split opportunity. As the signal travels north, it can go either west up the tracer wire or north along the steel main. 512 Hz only went north on the steel main, where 83 kHz made the turn and went up the tracer wire **(Figure 6)**.

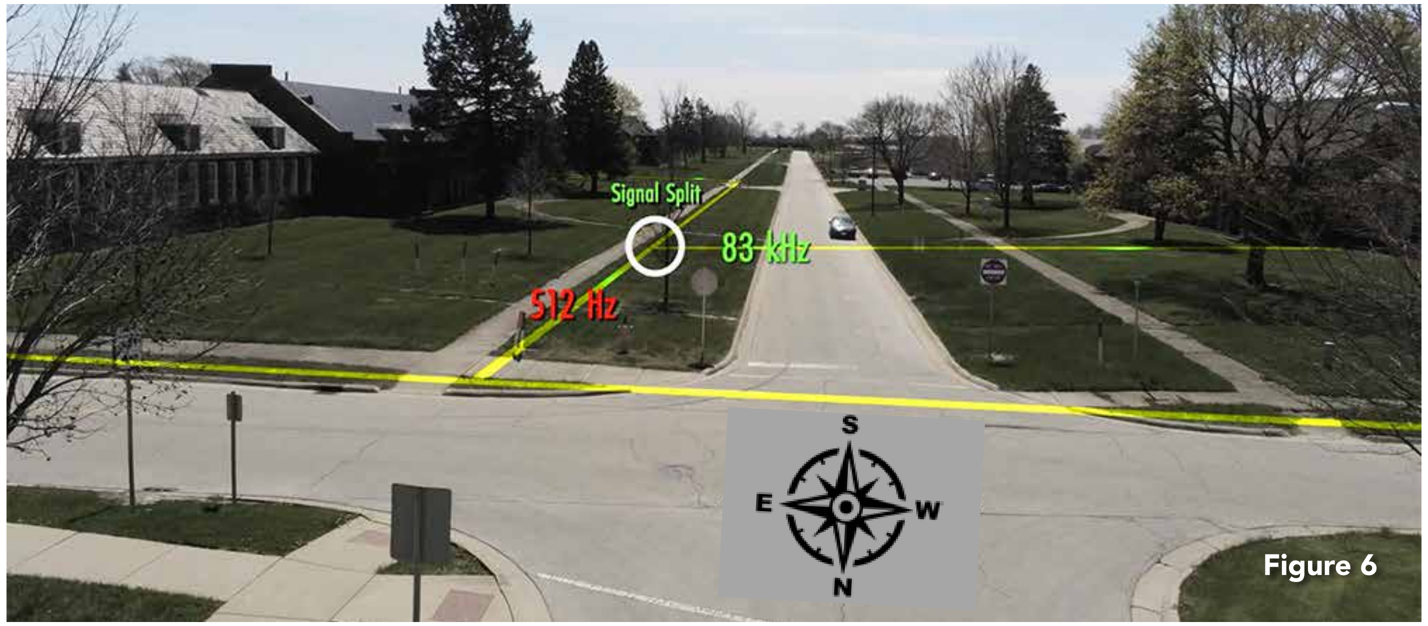


Figure 6

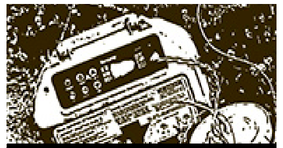
So for the same reason that 83 kHz went up the tracer wire as well as also going north on the main, we can utilize 65 kHz, a low-high frequency, without placing the grounding device. This range of frequencies has a certain set of characteristics that make it different than low frequencies. We're going to take off the lead that was on the grounding device **(Figure 7)**. On the westbound cable that crosses the road, we get signal **(Figure 8)** that provides good current and a peak and null that agree.

TOPIC HIGHLIGHT

The use of a grounding device is not necessary when employing direct connection utilizing a **low-high frequency** such as 65 kHz.

Figure 7

Figure 8



Milliamps and Power: Part 1

What is good current? It's a peak number that is stable, and we use the peak number to determine our level of current flow. This is despite the fact that the receiver has a current measurement indication. Current measurement is performed with two stacked-peak antennas, as is digital depth **(Figure 9)**. Both readings are estimates based on measuring the strength of concentric signal circles: one that intersects the bottom peak antenna and another, weaker signal circle that intersects the top peak antenna.

> "Current measurement is performed with two stacked-peak antennas, as is digital depth."

Figure 9

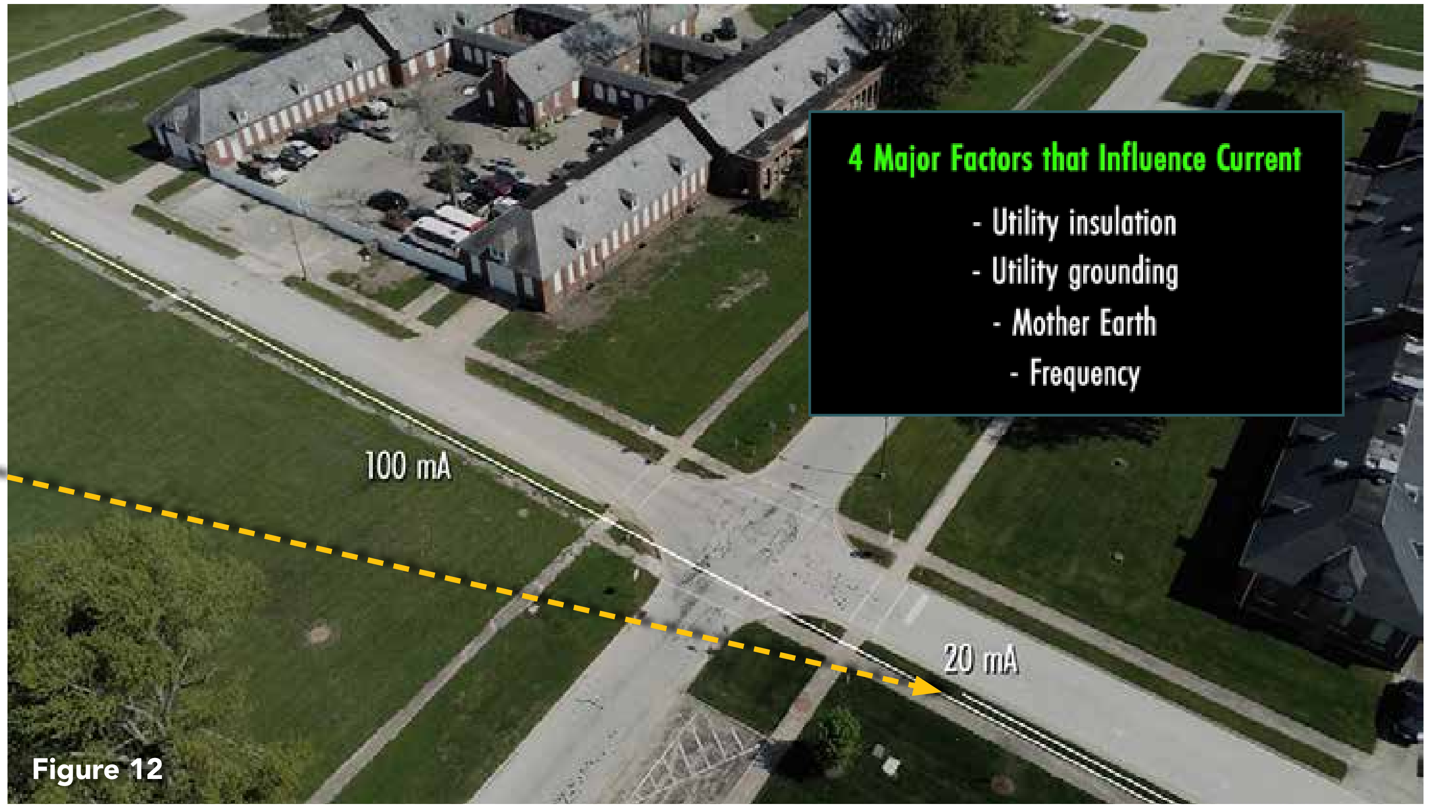
This locate was performed in the spring and the clay soil was full of moisture. Employed conductively at a transformer, the transmitter's signal is flowing on the neutral of a 3-phase cable. There is no insulation on the cable so the neutral is in continuous contact with the moist soil **(Figure 10)**.

Figure 10

The transmitter is utilizing 512 Hz, and the power level on the transmitter is set to a low level. The transmitter current flow reading is 20 mA. This is a real flow reading, unlike the current measurement reading on the receiver which is an estimate. Given the low-low frequency, moist soil and non-insulated conductor, the peak number begins to fluctuate wildly within 150' of the transmitter. Wild fluctuation of the peak number is known as poor current, the result of current returning to the transmitter and no longer traveling down the line.

Without changing the frequency and still using conductive, an option to change poor current to good current is to increase the power level of the transmitter, raising the current flow reading from 20 mA to 100 mA. Picking up on the trace where poor current initially appeared with the lower transmitter power level, the peak numbers are now steady. The receiver's current measurement reading is also now higher **(Figure 11)**. The trace is now able to be conducted for an additional 200' using the higher level of transmitter power **(Figure 12)**.

Figure 11



4 Major Factors that Influence Current

- Utility insulation
- Utility grounding
- Mother Earth
- Frequency

Figure 12

Creating the Circuit

Moving the Transmitter

We're locating the tracer wire for a plastic service line to its tap with a steel main. But there is a section of the steel main we cannot locate **(Figure 13)**. To be able to locate the eastward leg of the steel main, we're going to have to move the transmitter, because no matter what frequency we utilize on the tracer wire, we're always going to turn west at the tap.

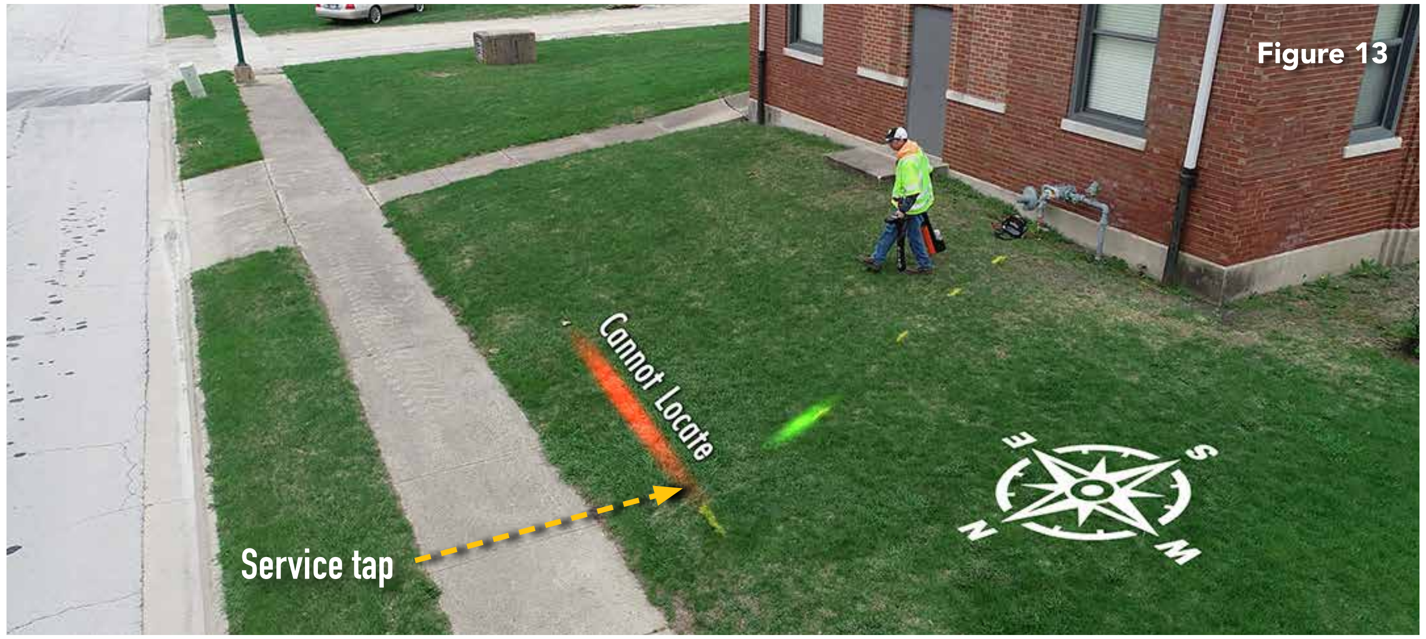
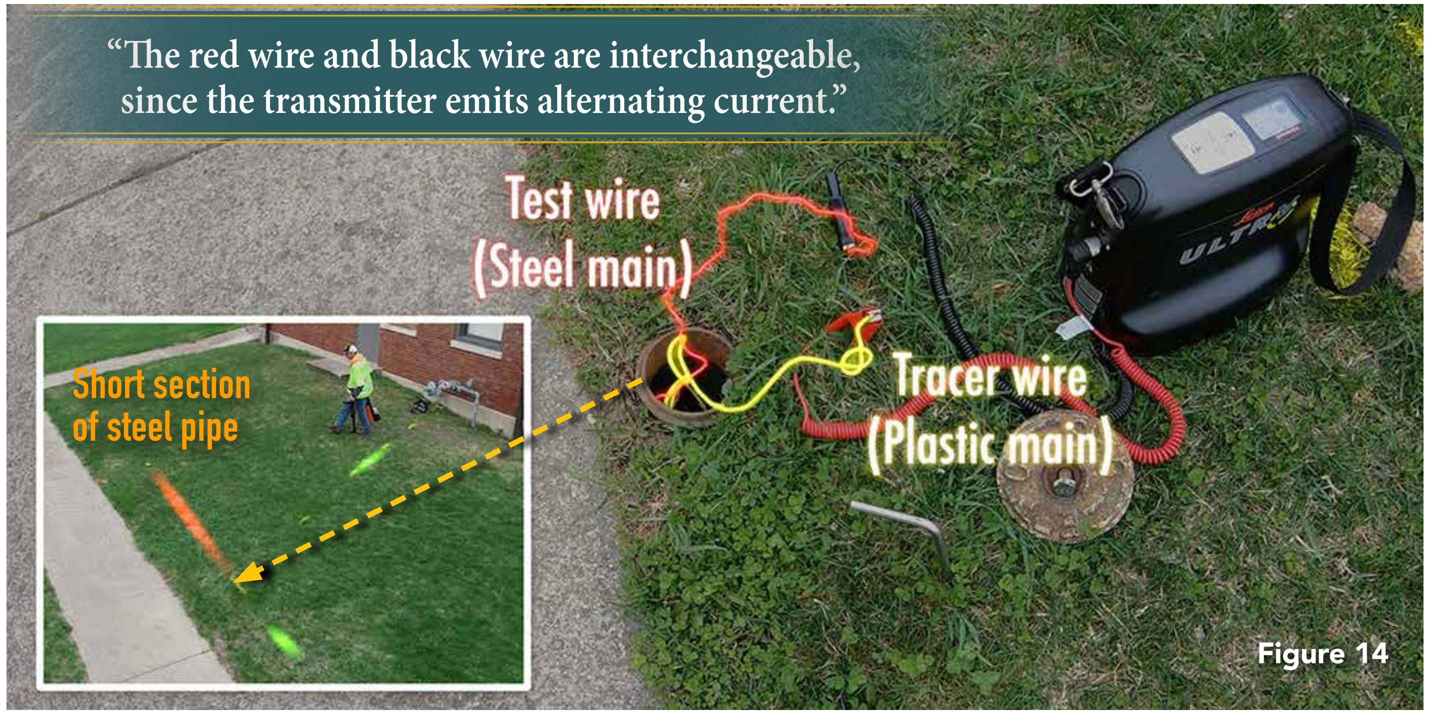


Figure 13

The reason is, there's not a whole lot of length of the steel main going east before it transfers to a plastic main. At this hook-up **(Figure 14)**, we're able to hook to the red wire which is connected to the steel gas main. We're also able to "ground" to the yellow wire, which is the tracer wire for the plastic main. This access point allows both mains to be located simultaneously. The red wire and black wire are interchangeable, since the transmitter emits alternating current. Fifty percent of the time, current leaves the transmitter on the red wire, and 50 percent of the time, current leaves the transmitter on the black wire.



"The red wire and black wire are interchangeable, since the transmitter emits alternating current."

Figure 14

The plastic main with tracer wire is shown in yellow, and the steel main is shown in red **(Figure 15)**. This red section is what could not be located when we conductively energized the tracer wire at the gas riser, transmitter location 1. Two transmitter locations are used to complete this locate. The tee represents a signal split, but our signal, no matter what frequency, is always wanting to go to the west, not to the east at the tee when transmitter location 1 is utilized **(Figure 16)**.

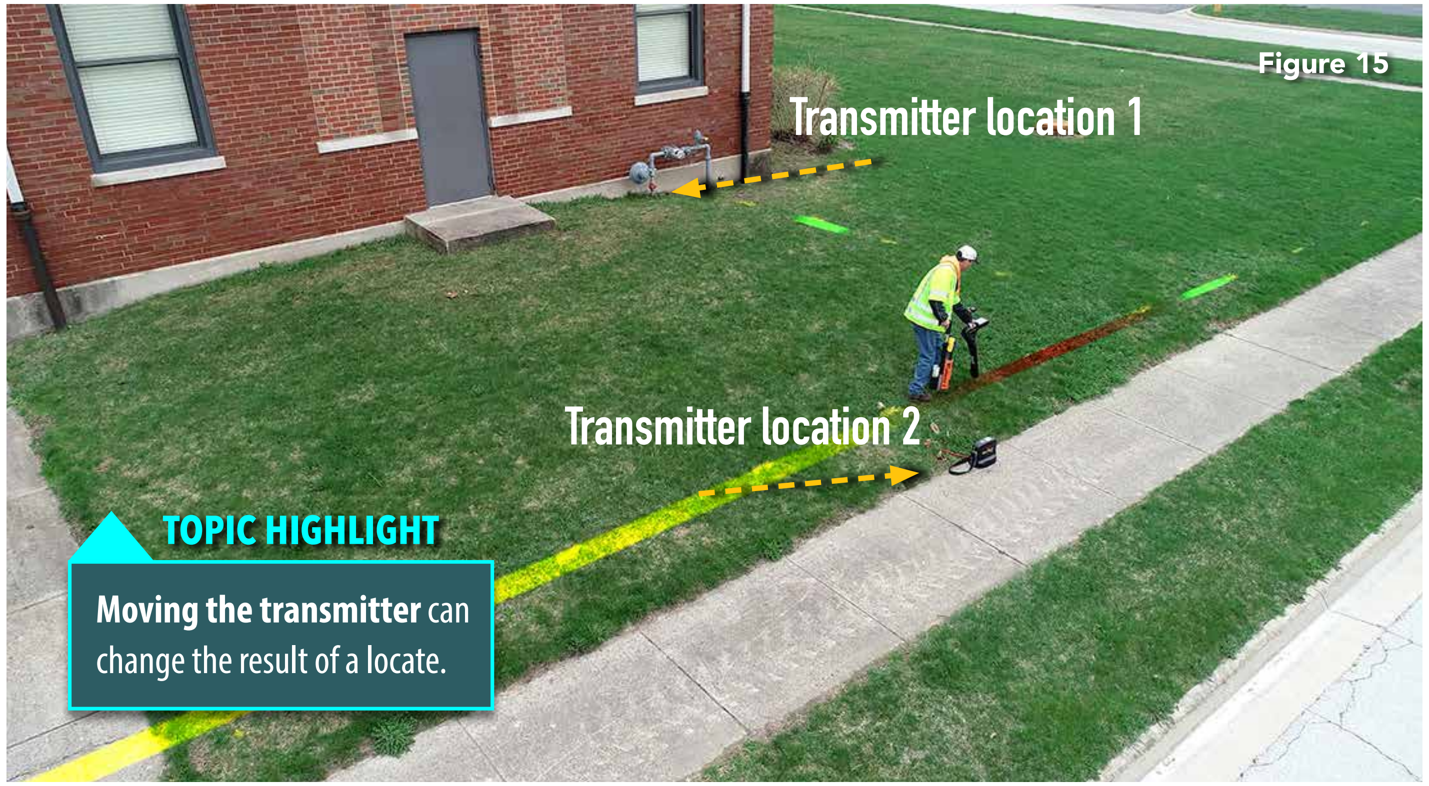


Figure 15

TOPIC HIGHLIGHT

Moving the transmitter can change the result of a locate.

Figure 16

TOPIC HIGHLIGHT

In addition to poorly installed metallic connectors on tracer wire, the small amount of metal **on one side of a tee** can result in signal following only the opposite direction at the tee.

Moving the Transmitter

The inductive coupler utilizing 65 kHz is placed around a fiber cable in a hand hole (**Figure 17**). When searching for the cable by performing a 360-degree sweep around the hand hole, the receiver only detects erratic peak readings (**Figure 18**).

Next, the coupler is moved to a ground cable in the hand hole (**Figure 19**). After sweeping the hand hole, peak, null, and depth readings are obtained (**Figure 20**). The fiber cable did not have a metallic component so the transmitter was moved to the ground cable, which serves as a tracer wire for the fiber conduit.

Performing this locate, which only involved a single cable in a hand hole, is not nearly as complex as locating multiple cables in a manhole (**Figure 21**). However, the technique of moving the transmitter and then analyzing the results with the receiver is exactly the same—it is done one cable at a time.

Figure 17

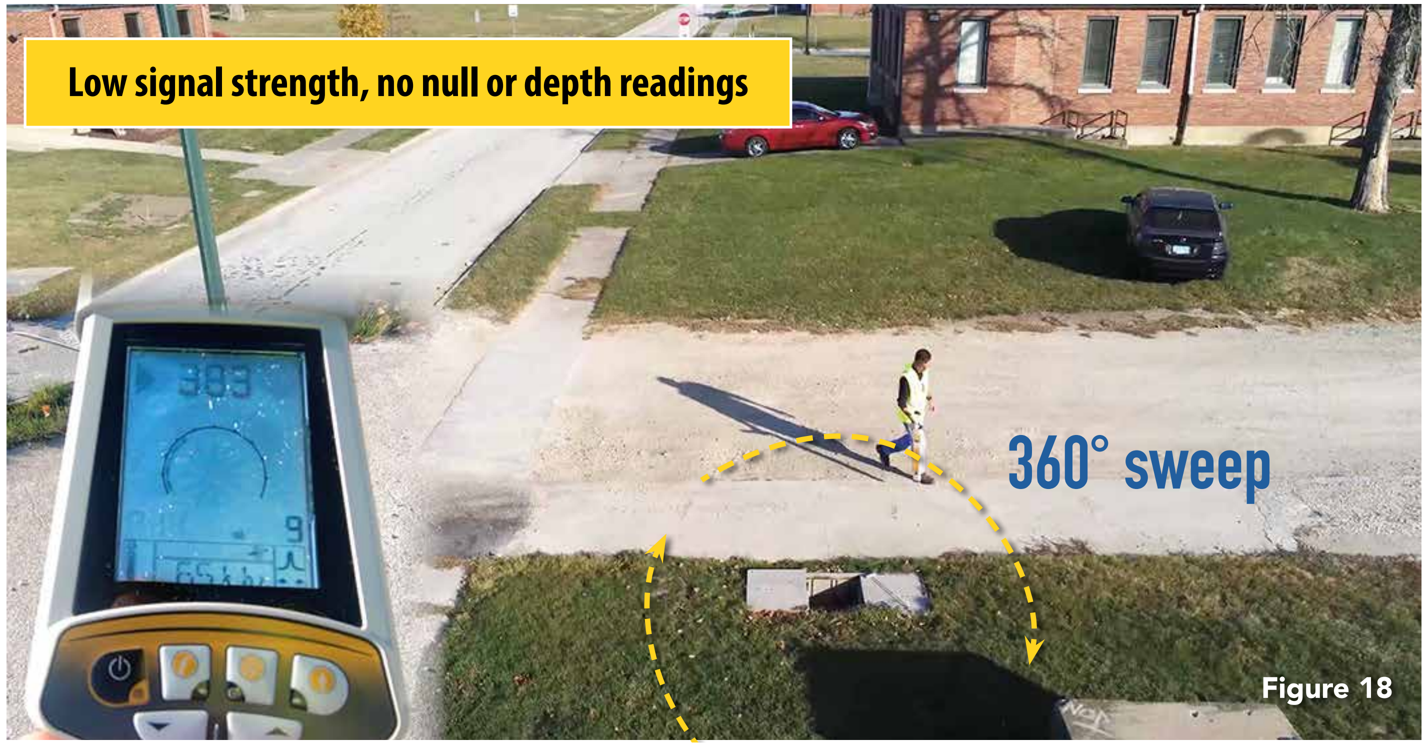
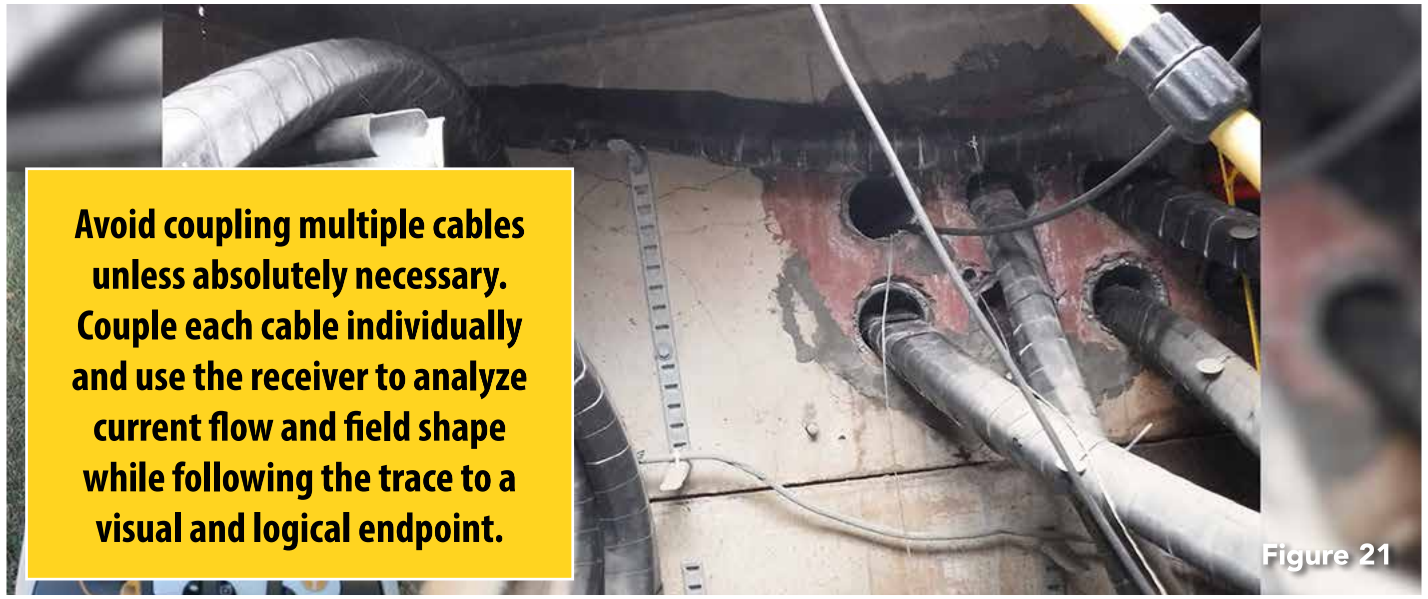


Figure 18

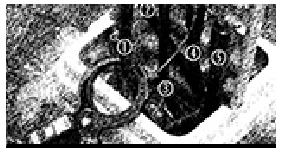
Figure 19

Figure 20



Avoid coupling multiple cables unless absolutely necessary. Couple each cable individually and use the receiver to analyze current flow and field shape while following the trace to a visual and logical endpoint.

Figure 21



The Advantage of the Inductive Coupler

We're going to do a conductive locate at a cable TV amplifier **(Figure 22)** using 33 kHz and locating in a southerly direction **(Figure 23)**. The signal is going to follow the path of least resistance, but that path of least resistance doesn't always take the transmitter's signal where we want it to. Using conductive, the operator cannot control the path of least resistance when the cables must remain metallically connected in order to provide service **(Figure 24)**.

Figure 22

Figure 23

Three of the cables exit the amplifier pedestal to the south.

Figure 24

With this conductive locate, the signal can go to earth through the ground rod, and it can choose to go down any or all of the five cables that leave this amplifier pedestal **(Figure 25)**. Three cables go south, but none of them located particularly well. There were only two peaks, not three. Nulls did not agree with the peaks and digital depth readings were illogical and inconsistent.

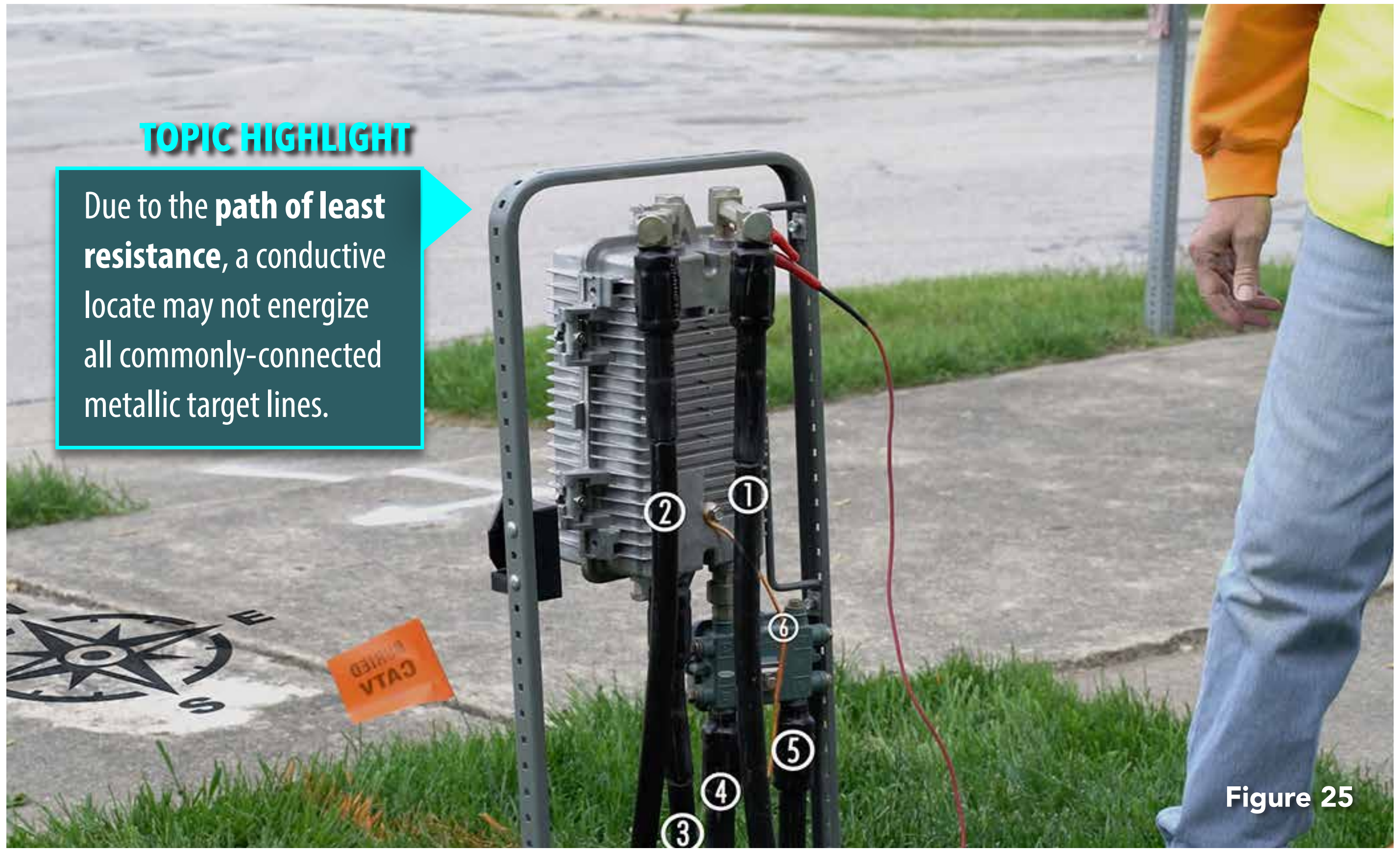


Figure 25

TOPIC HIGHLIGHT

Due to the **path of least resistance**, a conductive locate may not energize all commonly-connected metallic target lines.

The Advantage of the Inductive Coupler

The use of an inductive coupler gives us an advantage over conductive locating in certain situations. Here, there are five cables as well as a ground rod **(Figure 26)**. A conductive locate may or may not energize conductors going in six different directions.


Figure 26

> "The use of the inductive coupler gives us an advantage over conductive locating in certain situations."

Making sense of a situation such as this when using a conductive locate may prove extremely difficult. With the signal potentially ignoring one, two, or even three of the six paths due to the path of least resistance, it can be impossible to account for all five of the cables. The path of least resistance does not ensure that signal will energize metallically-connected cables equally.

When we use an inductive coupler, we anticipate that half the signal goes one way, and half the signal goes the other. In this case, we can anticipate that half the signal flows on the cable down into the ground, while the other half of the signal is going to flow up into the metallic amplifier.

Once at the amplifier **(Figure 27)**, the signal can be split five other ways—the other four lines and earth. This means we should have a lot more signal strength on the one cable that we've coupled versus any of the other five paths—the four cables and the pathway to earth.

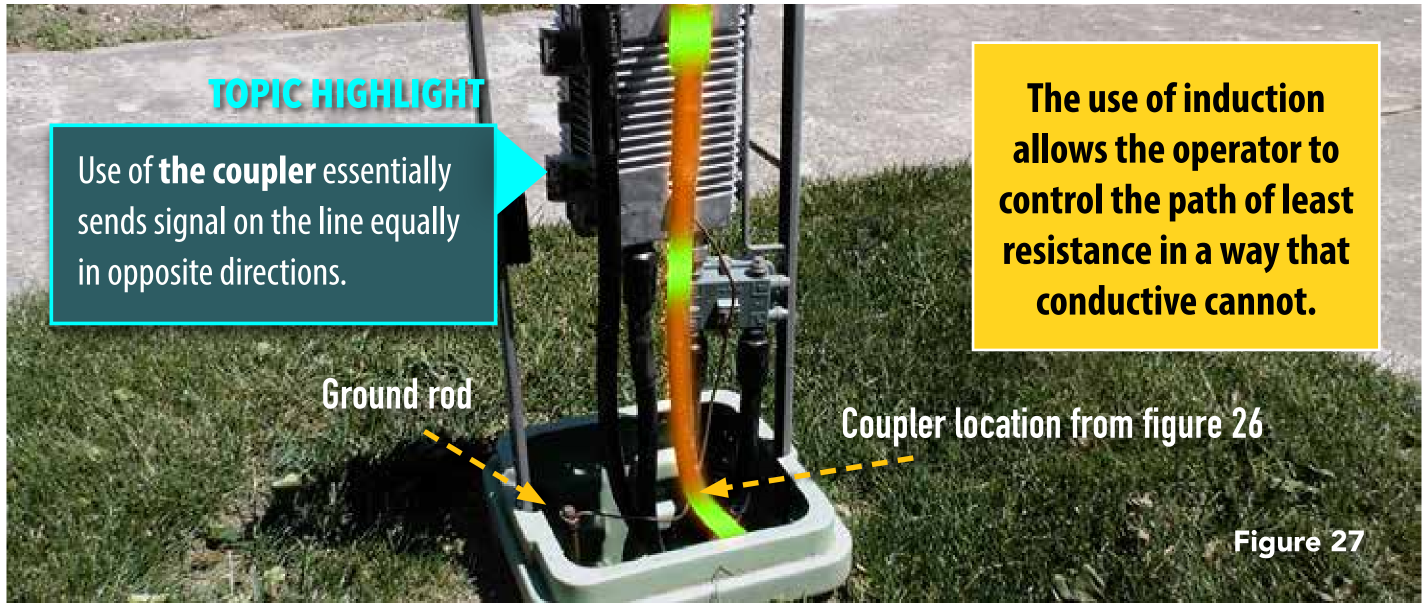


Figure 27

TOPIC HIGHLIGHT

Use of **the coupler** essentially sends signal on the line equally in opposite directions.

The use of induction allows the operator to control the path of least resistance in a way that conductive cannot.

As we search for this one particular cable that we've coupled, we expect peak and null to agree and the depth reading to be logical. Although there are three cables that are parallel to one another, we have a high signal strength that agrees with the null locate only in one spot **(Figure 28)**. What do we do about the other two cables? Well, we couple them one at a time, and now the target cable becomes the one that will have approximately 50 percent of the transmitter's energy on it, while the other 50 percent is split five directions **(Figure 30)**. High peak, logical depth, a null that agrees **(Figure 29)**—this is how an inductive coupler can help you isolate a single cable from others that travel in the same direction.


Figure 28

The operator continues his sweep looking for other potential peak readings.

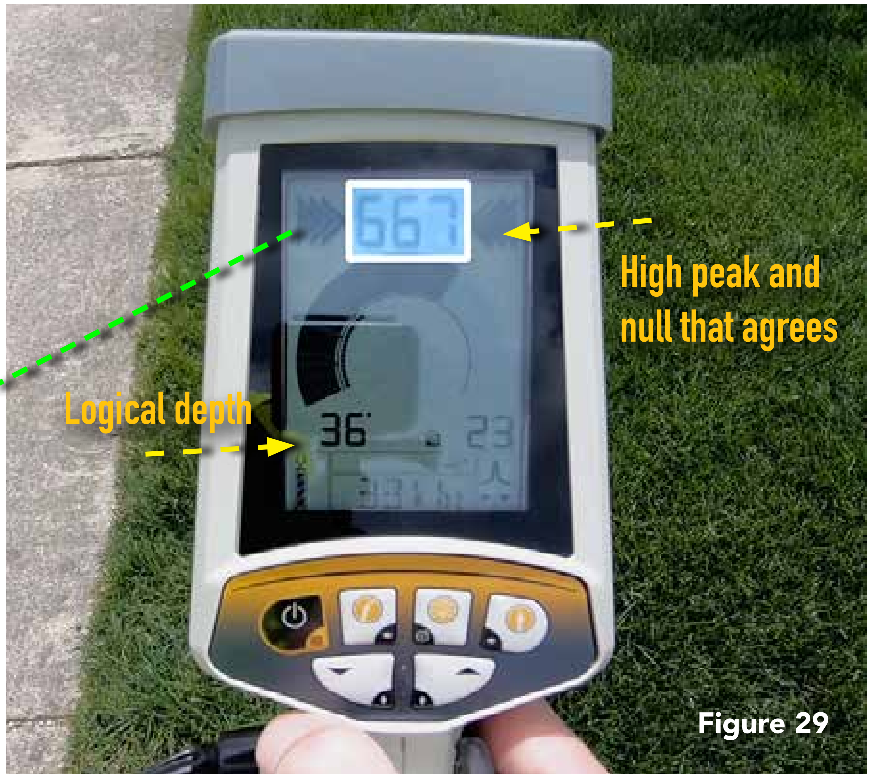


Figure 29

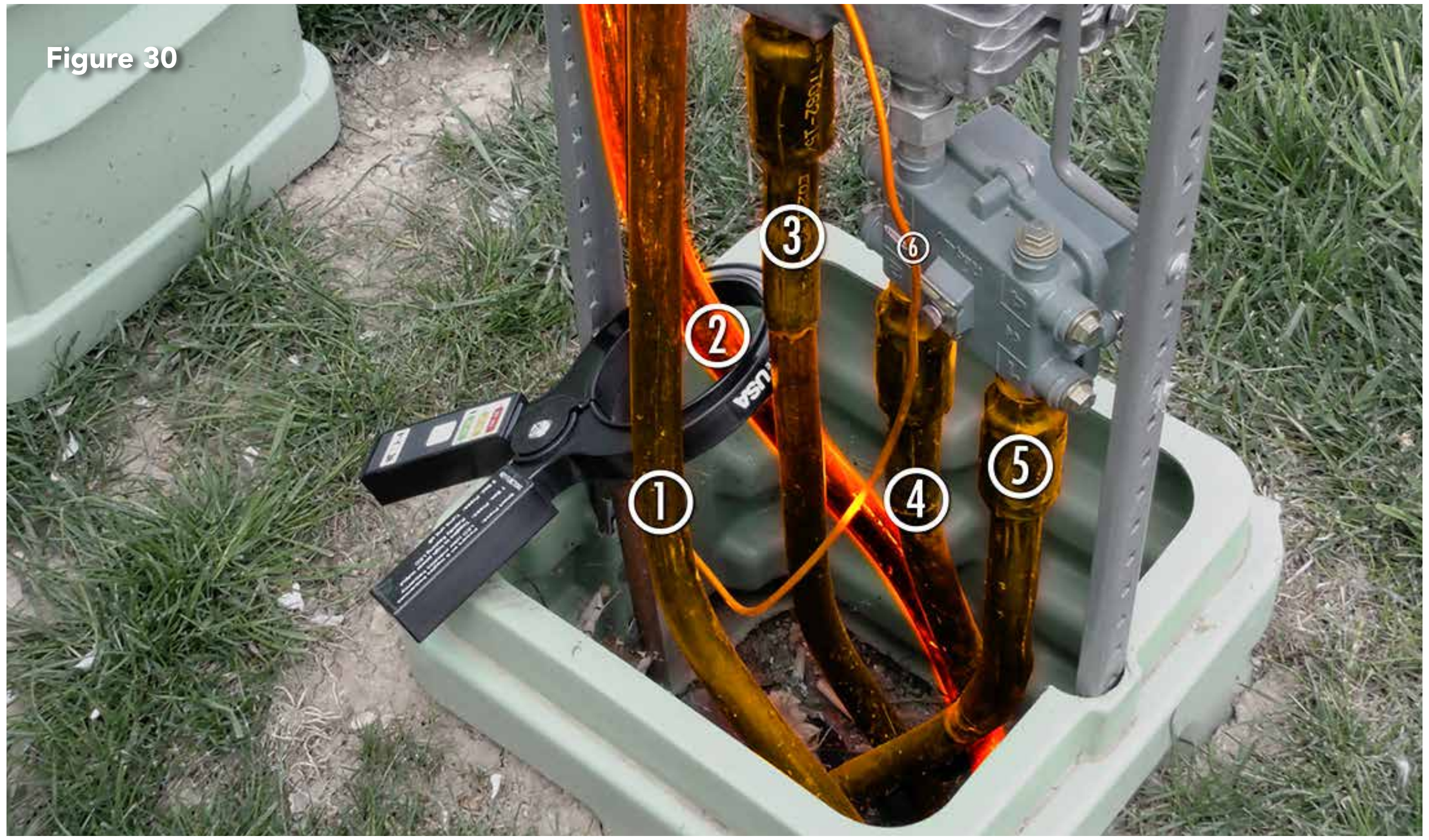


Figure 30

The Advantage of the Inductive Coupler

There's one more cable to do **(Figure 31)**. Again, we're looking to see if peaks and nulls agree and if depths are logical. The highest peak reading comes at the same time we get two arrows, so peak and null agree **(Figure 32)**. We've successfully located all three cables that leave the amplifier pedestal in a southerly direction **(Figure 33)**.


Figure 31


Figure 32

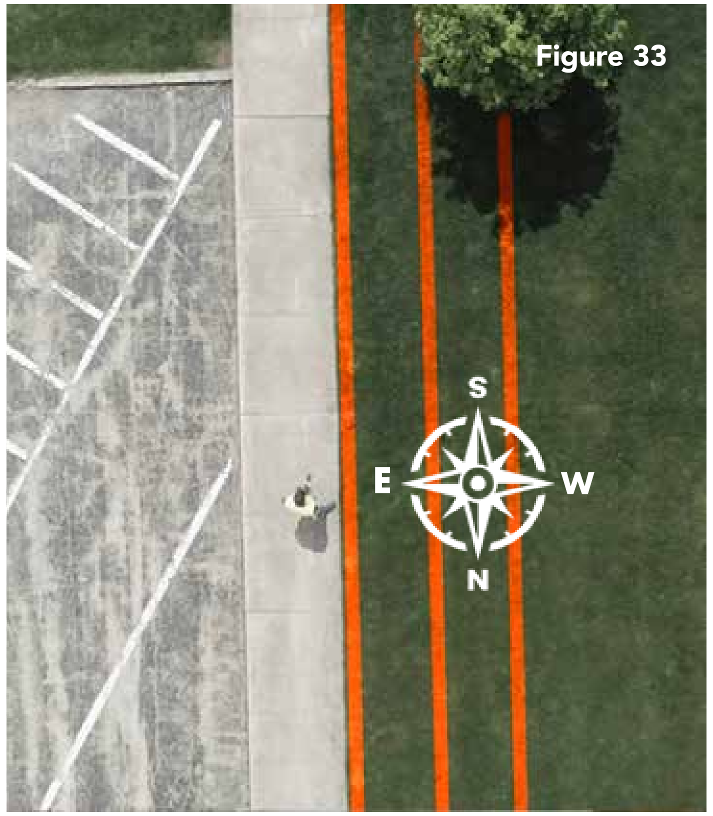


Figure 33

In the photo below featuring a conductive locate **(Figure 34)**, signal can potentially travel in five directions: four ground cables (for four streetlight cables) and the green ground wire connecting to a ground rod.

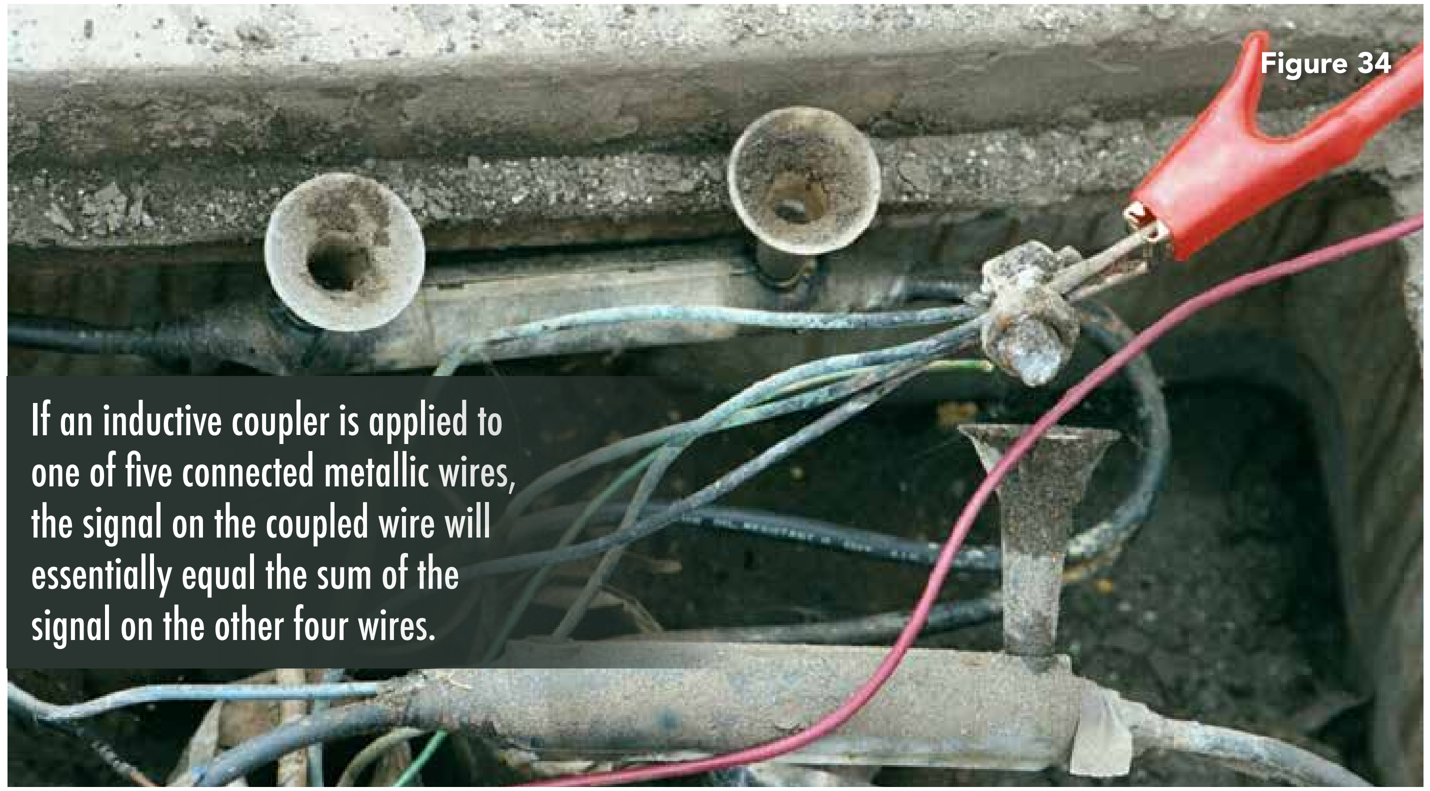


Figure 34

If an inductive coupler is applied to one of five connected metallic wires, the signal on the coupled wire will essentially equal the sum of the signal on the other four wires.

In **(Figure 35)** below, the use of the coupler would place 50% of the transmitter's signal on a single streetlight cable ground, while the other four directions would split the other 50% of the transmitter's signal. In this scenario, the three other cable grounds and the green ground cable would not each be guaranteed to have the same amount of the transmitter's signal. That's why the coupler would next be placed around the remaining three ground cables to achieve the best possible locate.

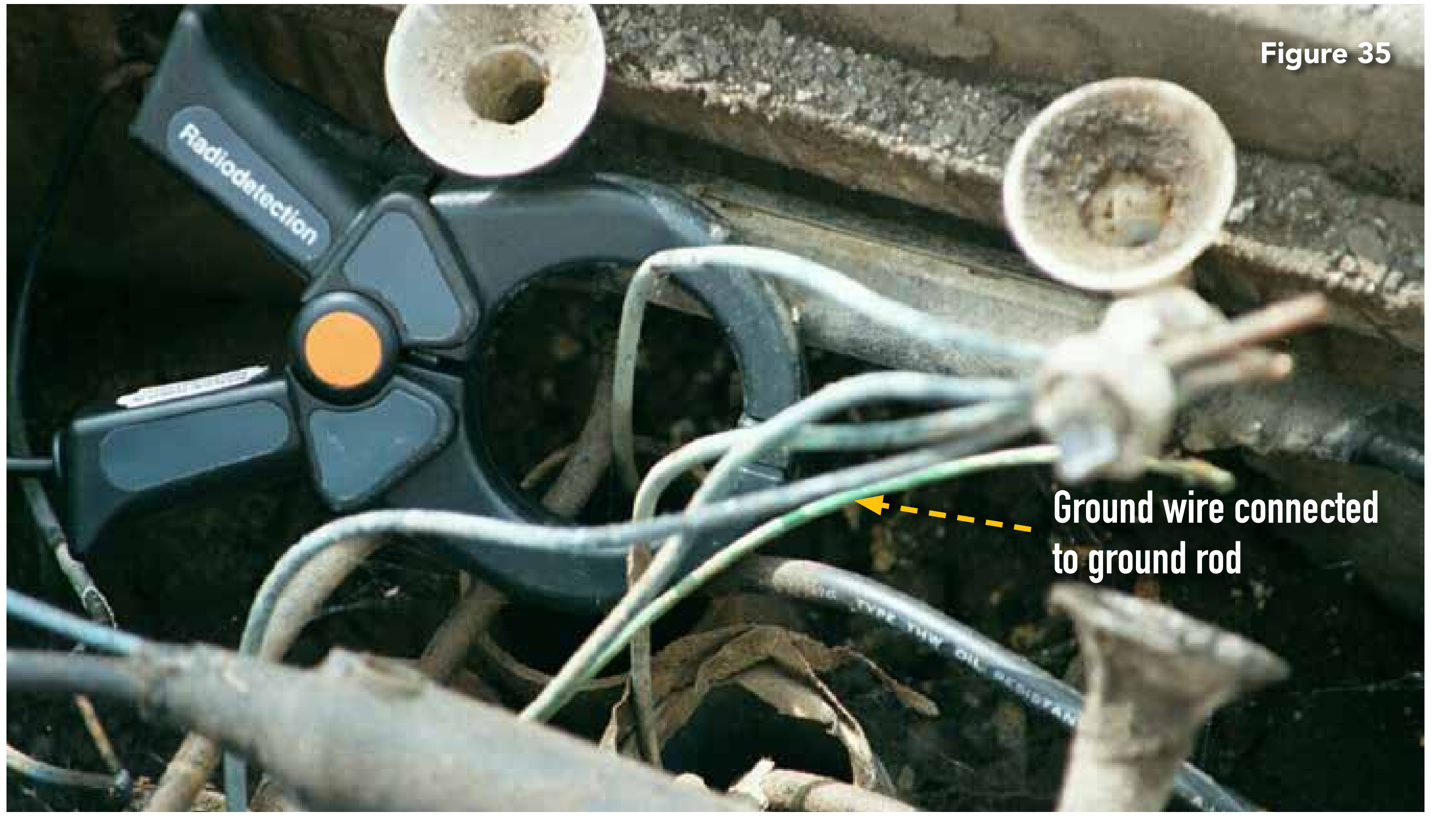


Figure 35

Signal's Path at Signal Splits

Our next locate is going to be on a three-phase transformer. We're going to be on 8 kHz, and we've asked for a desired current of 20 mA **(Figure 36)**. While we locate the three-phase electric cable, we will encounter two underground splices.

Figure 36

As we proceed with the locate, something's going to change in front of us. Our signal is going to have the chance to go in multiple directions. We call this location a signal split. This signal split occurs at an underground cable splice on the three-phase cable. **(Figure 37)**.

The receiver indicates "zero" signal strength which is an indication something has changed with the locate.

Figure 37

Although we'd like to continue south on the cable, the path of least resistance is going to take our signal to the west **(Figure 38)**.

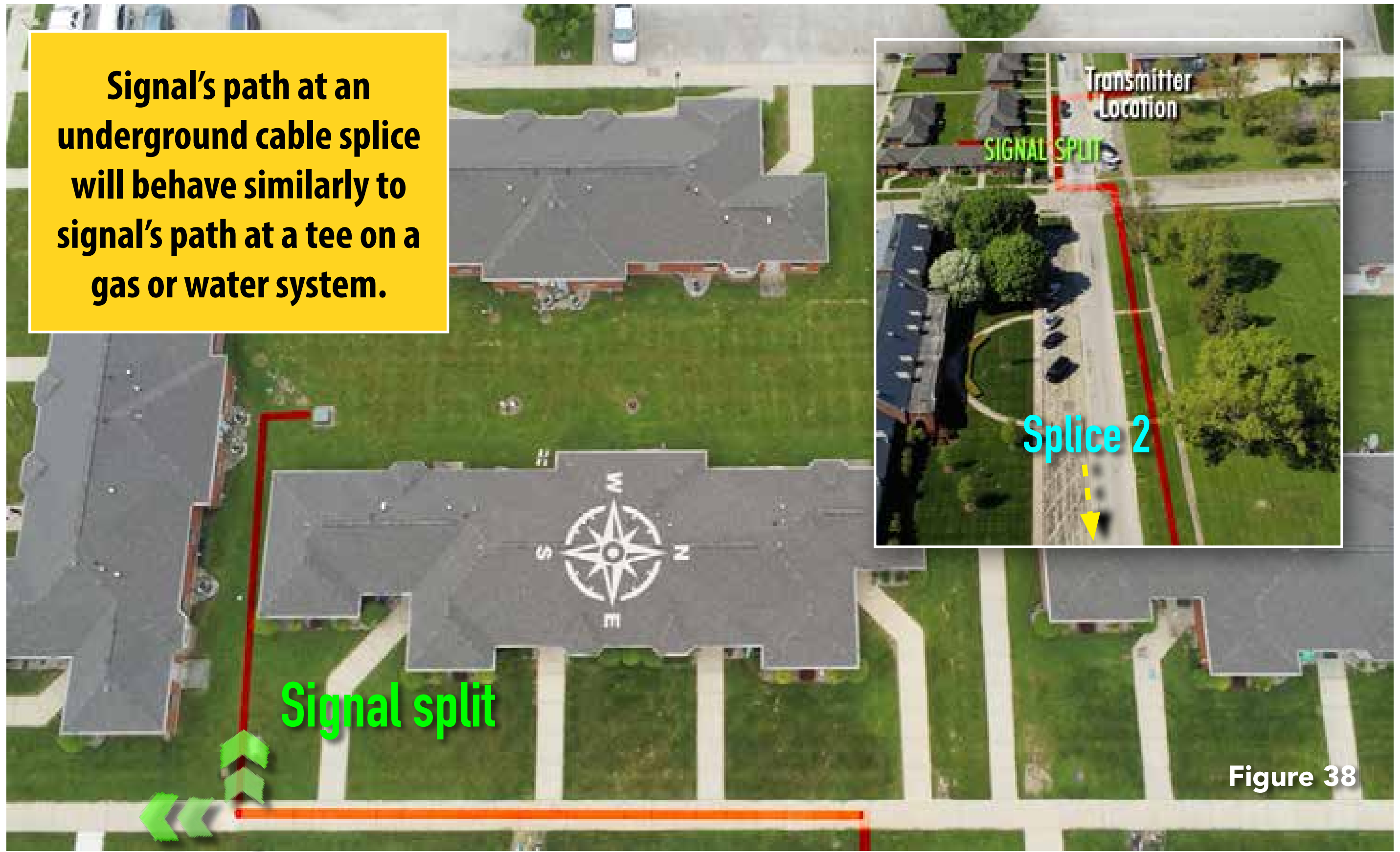

Signal's path at an underground cable splice will behave similarly to signal's path at a tee on a gas or water system.

Figure 38

Walking past the signal split, we're able to continue our locate of the three-phase cable in a southward direction, but with a reduced current flow **(Figure 39)**.

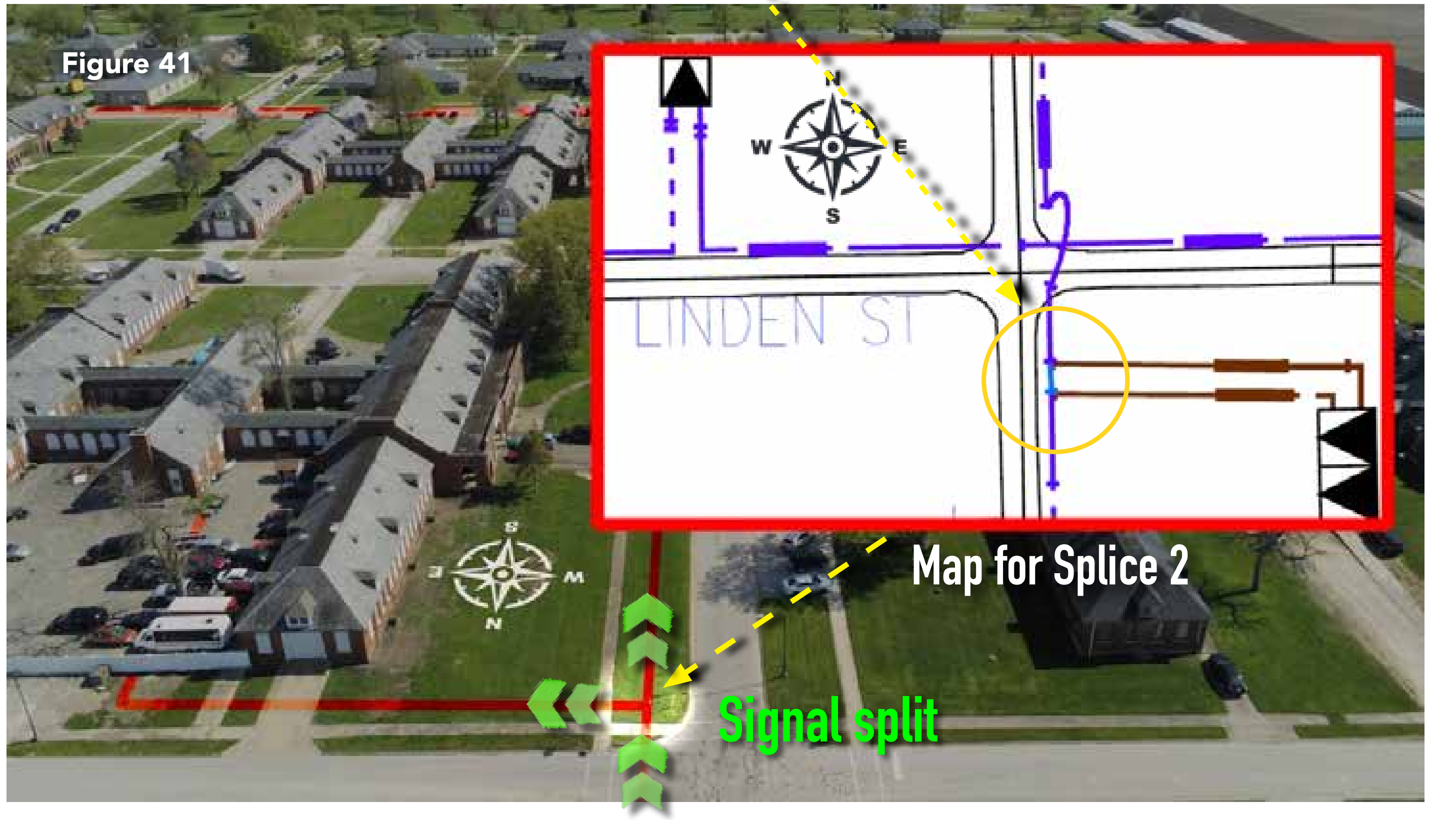
Before signal split, current measurement reading of 1.49 mA

After signal split, current measurement reading of 1.08 mA

Figure 39

Signal's Path at Signal Splits

Continuing to trace the three-phase cable, we once again run into the same problem that we did at Splice 1—our signal wants to go in the direction that we don't necessarily want to go (**Figure 40**). Unlike Splice 1, where signal ultimately continued past the signal split, here at Splice 2 we cannot continue along "the path we want" (**Figure 40**). All our signal has turned east. **Figure 41** shows how we were hoping the signal would split at Splice 2.



Changing the power level of the transmitter will not change the path of least resistance. However, higher frequencies are more likely than lower frequencies to travel in multiple directions at signal splits. Changing the transmitter frequency at the transformer, we are now receiving 33 kHz (**Figure 42**).

TOPIC HIGHLIGHT

Splices and tees encountered during the locate can create a situation where higher frequencies travel longer distances in the direction we want to locate.

Different frequencies can and sometimes will do different things. In this case, 33 kHz locates well beyond Splice 2 (**Figure 43**). When considering the distance that a particular frequency may travel on a target line, it is important to remember that the presence of splices and tees enter into the equation of distance.

If this was a long run of cable without a splice, 33 kHz might not have gone farther but it went in the direction we wanted at the signal split.

Different frequencies can and sometimes will do different things.

Milliamps and Power: Part 2

We're going to locate an insulated tracer wire along the south side of the street. On the tracer wire, we're going to utilize 33 kHz **(Figure 44)**, and 200 milliamps is going to be our transmitter output, or current flow reading.

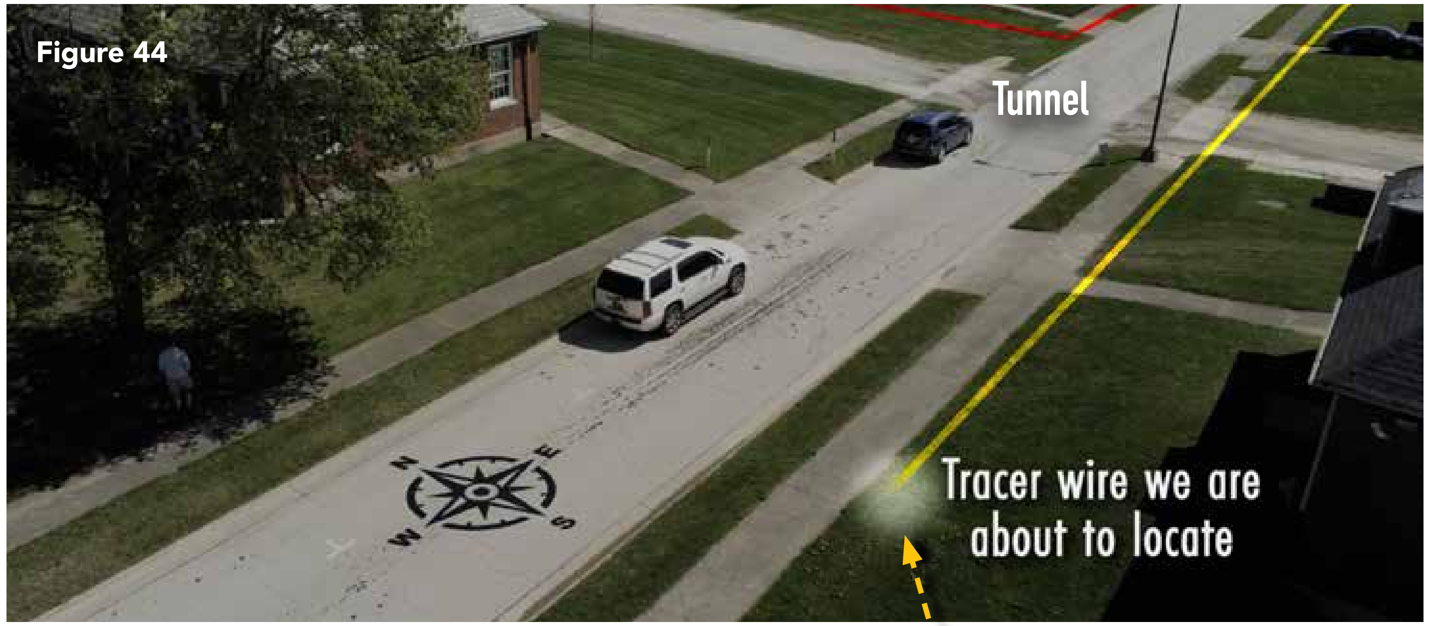


Figure 44


Figure 45

It's important to look at signal strength, peak and null, digital depth, and to some degree, the current measurement indication. On this receiver **(Figure 45)**, the current measurement indication is in the upper right-hand corner. As we begin this locate, we have a current measurement reading of 57 mA, a digital depth of 3-feet, 8-inches, and a signal strength of 2903**.**

The compass line on the receiver's display does not go between the two directional arrowheads. This indicates the presence of a not-round field **(Figure 46)**. A not-round field is the result of the transmitter's energy flowing on more than one underground line. To the operator's right, a streetlight wire is running parallel and to the south of the tracer wire, which is over 7′ deep under the tunnel.

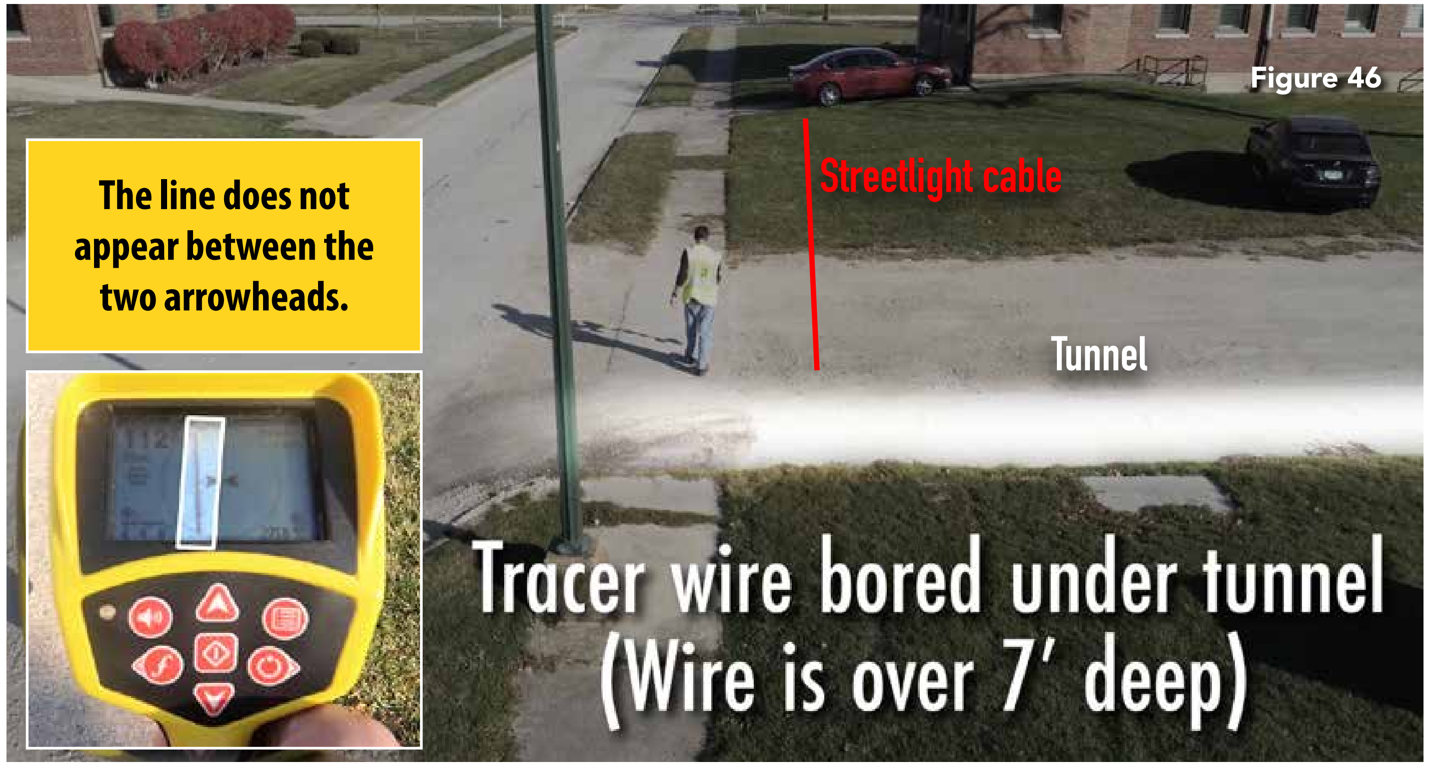


Figure 46

After crossing the tunnel, the tracer wire angles to the south and is now positioned closer to the streetlight wire. The line on the receiver's display splits the arrowheads but is crooked, another sign of a not-round field **(Figure 47)**. The change in the compass line on the receiver is due to the change in the tracer wire's depth over the course of the trace.


Figure 47

	Before tunnel	Past tunnel
Signal strength	2903	3070
Depth	3′8″	2′7″
Milliamps	57	78

Milliamps and Power: Part 2

Figure 48

Signal strength and milliamps are higher, because the wire is shallower now than when the receiver was closer to the transmitter.

Once the receiver is moved past the tunnel, signal strength increases so that we have more signal strength now than what we had closer to the transmitter. Our signal strength over the target line is 3070 **(Figure 48)**, and we also have a higher milliamp reading—we're at 78 mA, where before the tunnel the milliamp reading was 57 mA.

Figure 49 shows two 4-foot depth readings. Less than 100 feet from the transmitter and before we reach the tunnel, the receiver display to the left is indicating a signal strength of 2718. In the image to the right, we're past the tunnel and about 125 feet from the transmitter with a signal strength of 3019. The signal strength will go higher as the receiver is moved to the operator's right. And when it does, the depth will become shallower.

The main factors that impact signal strength are distance from the transmitter and depth of the target line.

Before tunnel

Past tunnel

Figure 49

Current measurement (mA) is raw signal strength factored by depth. If depth is identical at two locations over the target line, then signal strength and mA will move in unison.

We are locating an insulated copper tracer wire that is not grounded on the end. Because higher frequencies have more induced current than lower frequencies, we chose 33 kHz hoping the signal would get to the end of the tracer wire. Recall that we had a milliamp reading on the transmitter of 200 mA **(Figure 50)**. Now, the highest current measurement reading that you've seen on the receiver is 77 mA.

There's not a direct comparison between the current flow number on a transmitter and a current measurement number on a receiver. We're still showing around a three-foot nine-inch depth as we begin to cross the road, and that's without the receiver right on the ground. But remember, we're looking at a constant depth, trying to see if we can get any information about the locate from that constant depth.

Figure 50

"There's not a direct comparison between the current flow number on a transmitter and a current measurement number on a receiver."

The null line is in the middle of the arrowheads **(Figures 50-51)**. But as the trace advances past the red line marker, there will be a three-phase electric primary to the operator's left **(Figure 52)**. After the operator walks beyond the red marker post, bleed-off may cause the angle of the null line to change, or possibly move outside of the arrowheads.

Figure 51

Figure 52

Milliamps and Power: Part 2

Figure 53

Figure 54

At this location, about 300 feet from the transmitter, the compass is somewhat crooked. We still have over 3000 signal strength points **(Figure 53).** Next, the signal strength drops, and the null line starts to jump around **(Figure 54)**. If we back up, we can regain some signal strength. What happened? We walked past the end of the tracer wire at the end of the gas main **(Figure 55)**. There's still current on the line, but it's on the service line that goes up to the gas meter.

This locate started with a transmitter current flow of 200 mA. An attempt to boost the current flow to 400 mA failed because the far-end of the tracer wire was not grounded (See photos on the opposite page).

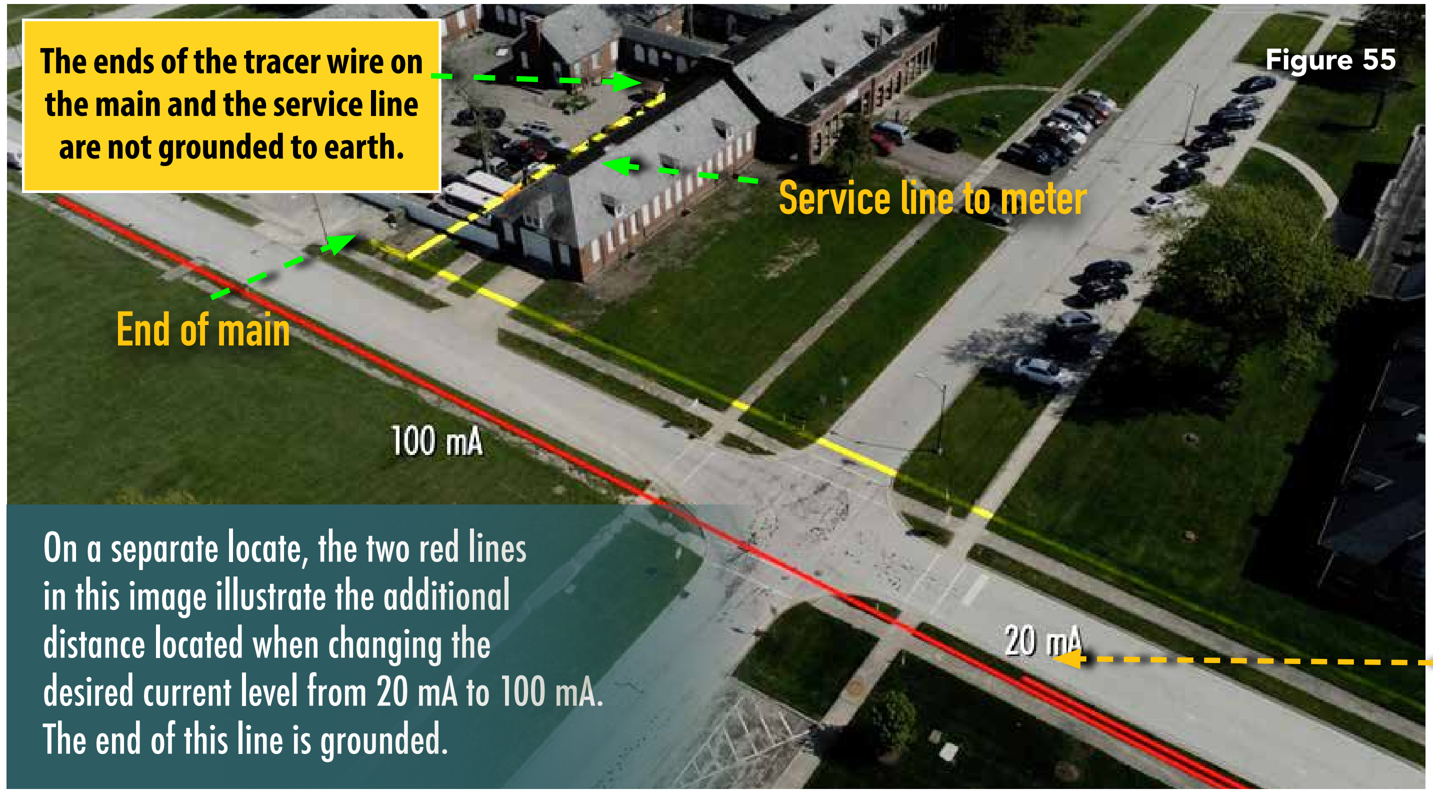


Figure 55

The ends of the tracer wire on the main and the service line are not grounded to earth.

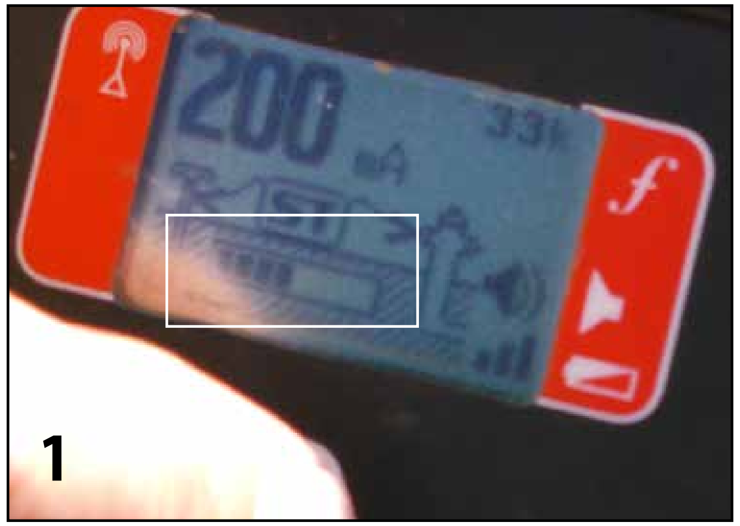
On a separate locate, the two red lines in this image illustrate the additional distance located when changing the desired current level from 20 mA to 100 mA. The end of this line is grounded.

Desired Current

What happens when you increase the transmitter power level when locating conductively:

1. The path of least resistance will not change.
2. The current flow reading (the mA reading on the transmitter) may increase.
3. Bleed-off onto non-target lines will not increase. Transmitter signal bleed-off is ratio-metric. Peak readings may increase but if you didn't have bleed-off before increasing transmitter power, you won't have it afterwards.
4. If the current flow reading increases, you may locate longer distances and you may be able to locate deeper pipes or cables.

By increasing the transmitter power (1), we "desired" to increase the current flow reading from 200 mA to 400 mA (2). However, due to the resistance of the line or the earth (or both), we were not able to increase the current flow leaving the transmitter from 200 mA to 400 mA (3).



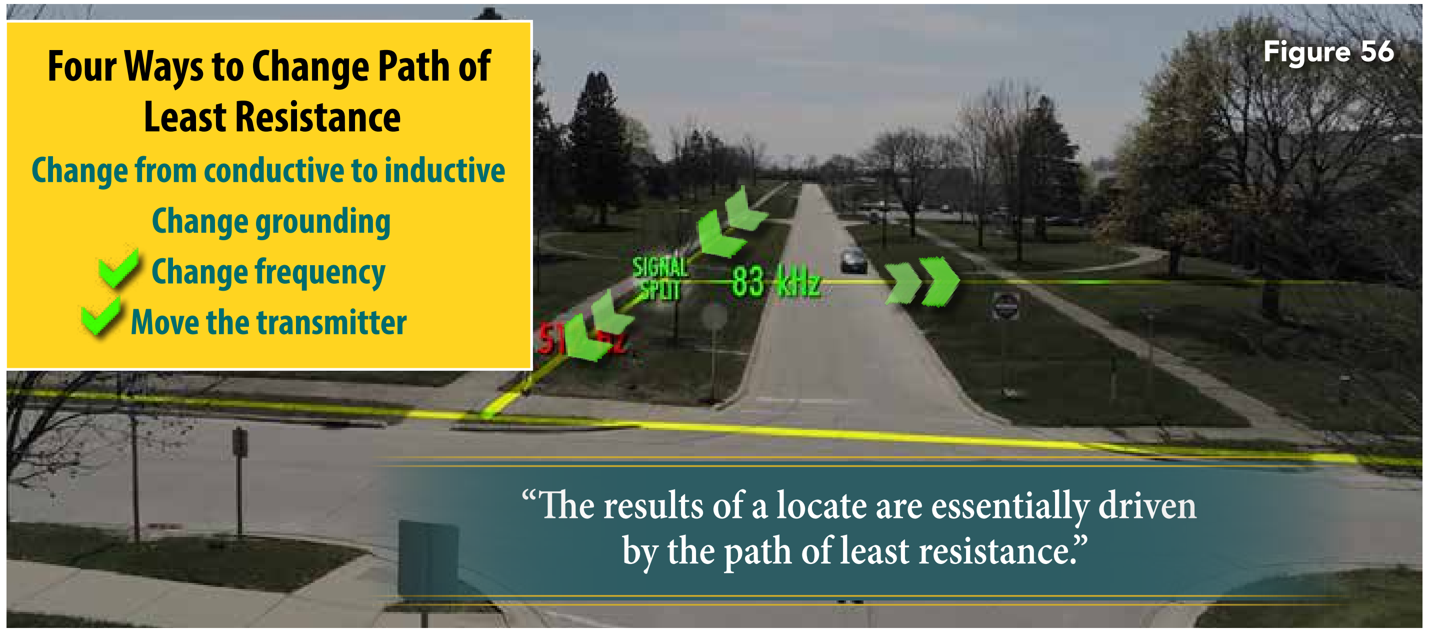
1

2

3

Path of Least Resistance

The results of a locate are essentially driven by the path of least resistance. There are four ways to potentially change locate results by attempting to change the path of least resistance. Since utility grounding and signal splits greatly impact the direction current will flow on the target line, changing frequency or moving the transmitter are the most effective tools for changing the path of least resistance. Low frequencies tend to travel one direction when given a chance to travel multiple directions at a signal split. A higher frequency such as 83 kHz will tend to travel all directions at a signal split **(Figure 56)**.



Four Ways to Change Path of Least Resistance

- Change from conductive to inductive
- Change grounding
- ✓ Change frequency
- ✓ Move the transmitter

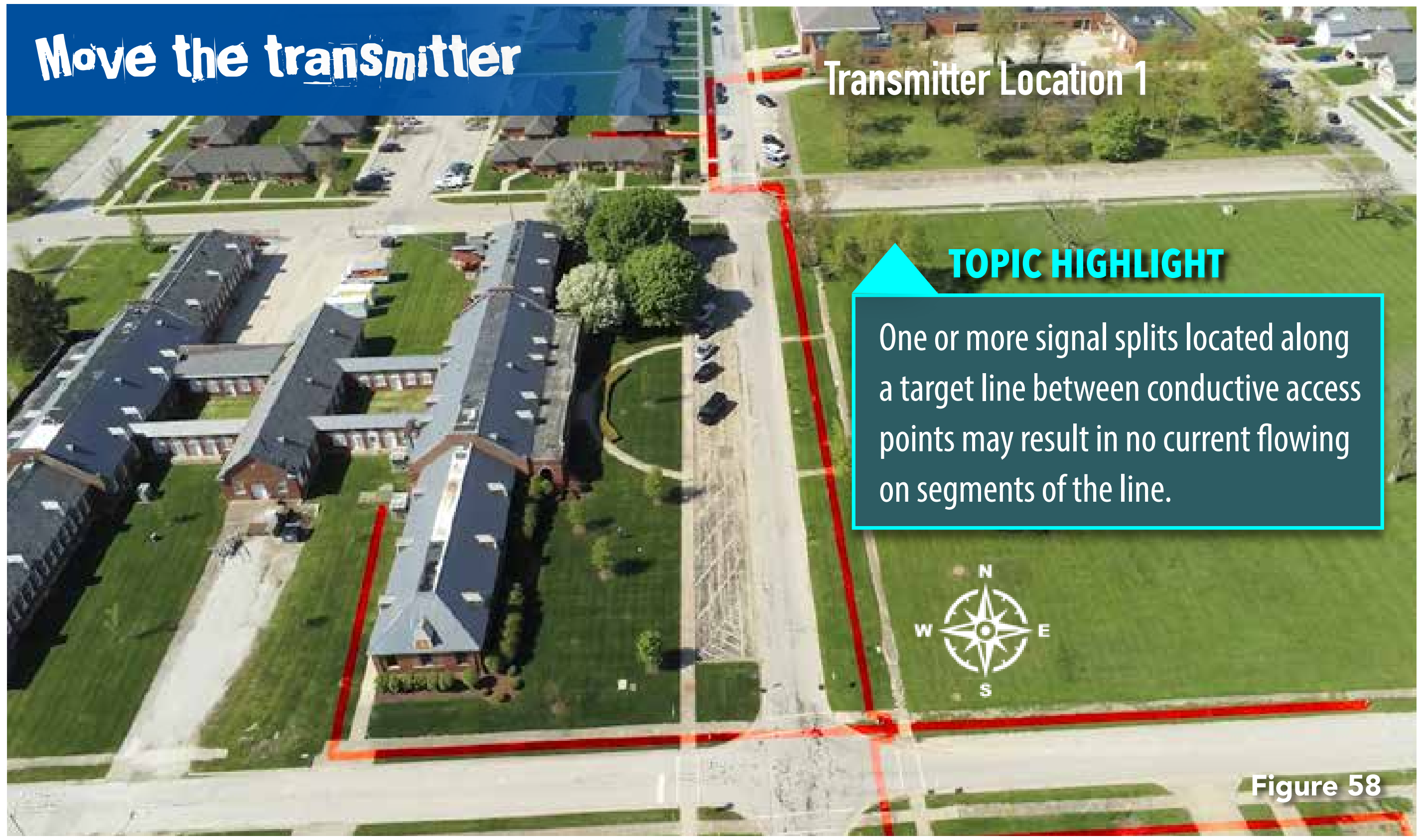
Figure 56

> "The results of a locate are essentially driven by the path of least resistance."

Figure 57

You can't say that one frequency is better than another. Depending on the situation, a high frequency may outperform a low frequency. The differences in utility composition, insulation, and grounding, as well as the proximity of utilities to one another dictate what's going to happen with a particular transmitter frequency at signal splits and transmitter locations **(Figure 57)**.

Move the transmitter



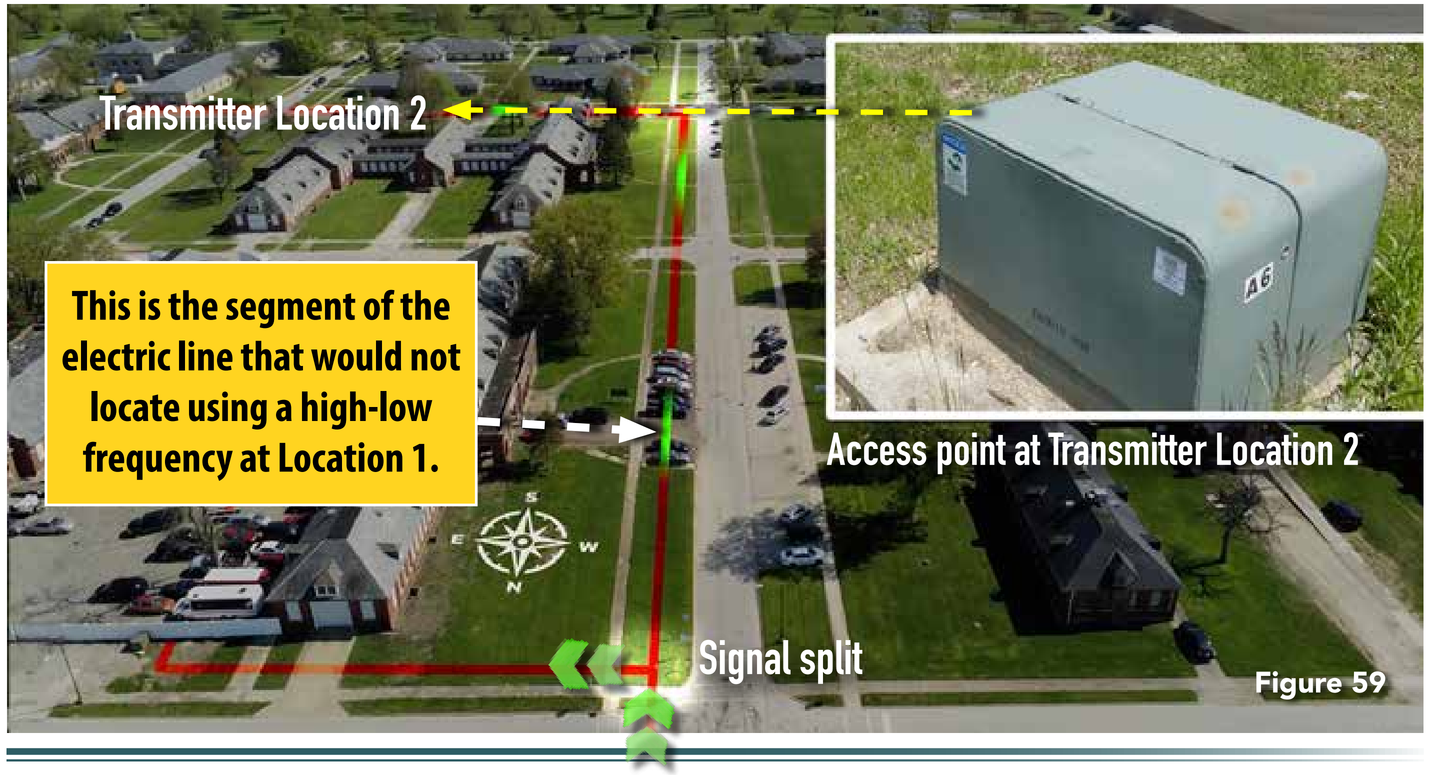
TOPIC HIGHLIGHT

One or more signal splits located along a target line between conductive access points may result in no current flowing on segments of the line.

Figure 58

Low-high frequencies in the 8-10 kHz range are generally useful for locating electric lines. This frequency range offers enhanced distance and reduced bleed-off through the ground versus higher frequencies. And often these frequencies offer better conductive results than low-low frequencies (1-1000 kHz) due to the grounding of the electric system, which results in the great loss of current to earth at the transmitter.

Using 9.5 kHz at Transmitter Location 1 **(Figure 58)**, current travels into the signal split and follows the path of least resistance to the east. At the next signal split over a block away, the segment of the cable traveling south does not become energized. To conductively locate this segment of cable and still use 9.5 kHz, the transmitter must be moved to the next access point at Transmitter Location 2 **(Figure 59)**.



This is the segment of the electric line that would not locate using a high-low frequency at Location 1.

Access point at Transmitter Location 2

Figure 59

Path of Least Resistance

Using 9.5 kHz after moving the transmitter to Location 2, the cable segment that would not locate is now easily located **(Figure 60)**. At Location 2, the transmitter is set to both 9.5 kHz and 38 kHz which will allow for an easy comparison between a high-low frequency and a low-high frequency **(Figure 61)**.

Figure 60

"Moving the transmitter is probably the most effective way to change the path of least resistance."

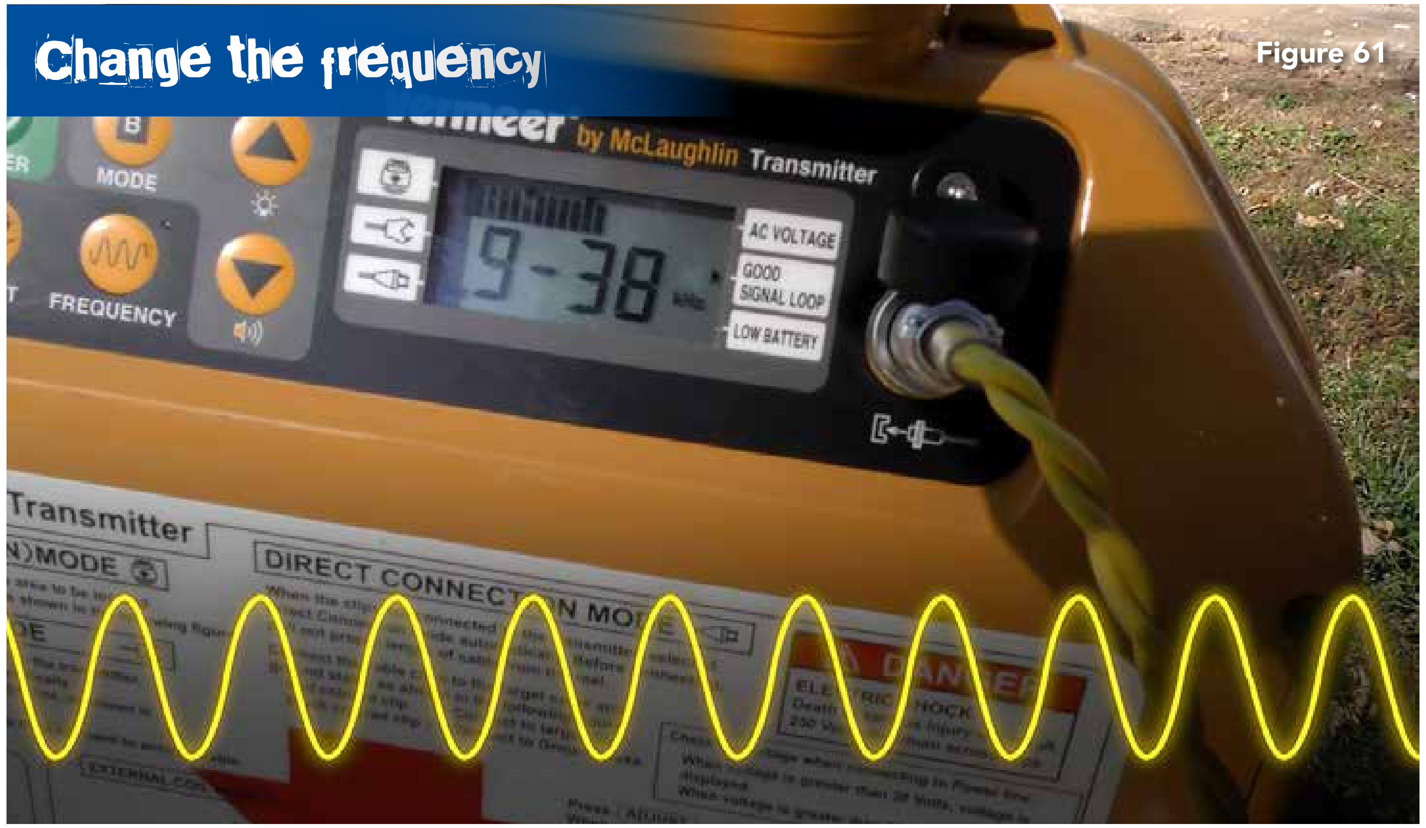


Figure 61

Figure 62

16.8 Peak Reading North of Signal Split

Unlike the results when using Transmitter Location 1, 9.5 kHz travels through the signal split and continues north **(Figure 62)**. The path of least resistance at the signal split—a cable splice—is different when using Transmitter Location 2. Signal also travels east where the strength is higher than to the north **(Figure 63)**.

Figure 63

25.3 Peak Reading East of Signal Split

Path of Least Resistance

An incremental change in transmitter frequency—such as 512 Hz to 960 Hz, or 8 kHz to 9.5 kHz—will not change the path of least resistance in a perceptible way. However, change of frequency group—such as from a high-low frequency to a low-high frequency—is much more likely to create a change in the path of least resistance. Remember, different frequencies can and sometimes will do different things. **Figures 64 and 65** show what happens when using 38 kHz. More signal goes north than east of the splice, which is opposite of 9.5 kHz **(Figure 66)**.

21.0 Peak Reading North of Signal Split

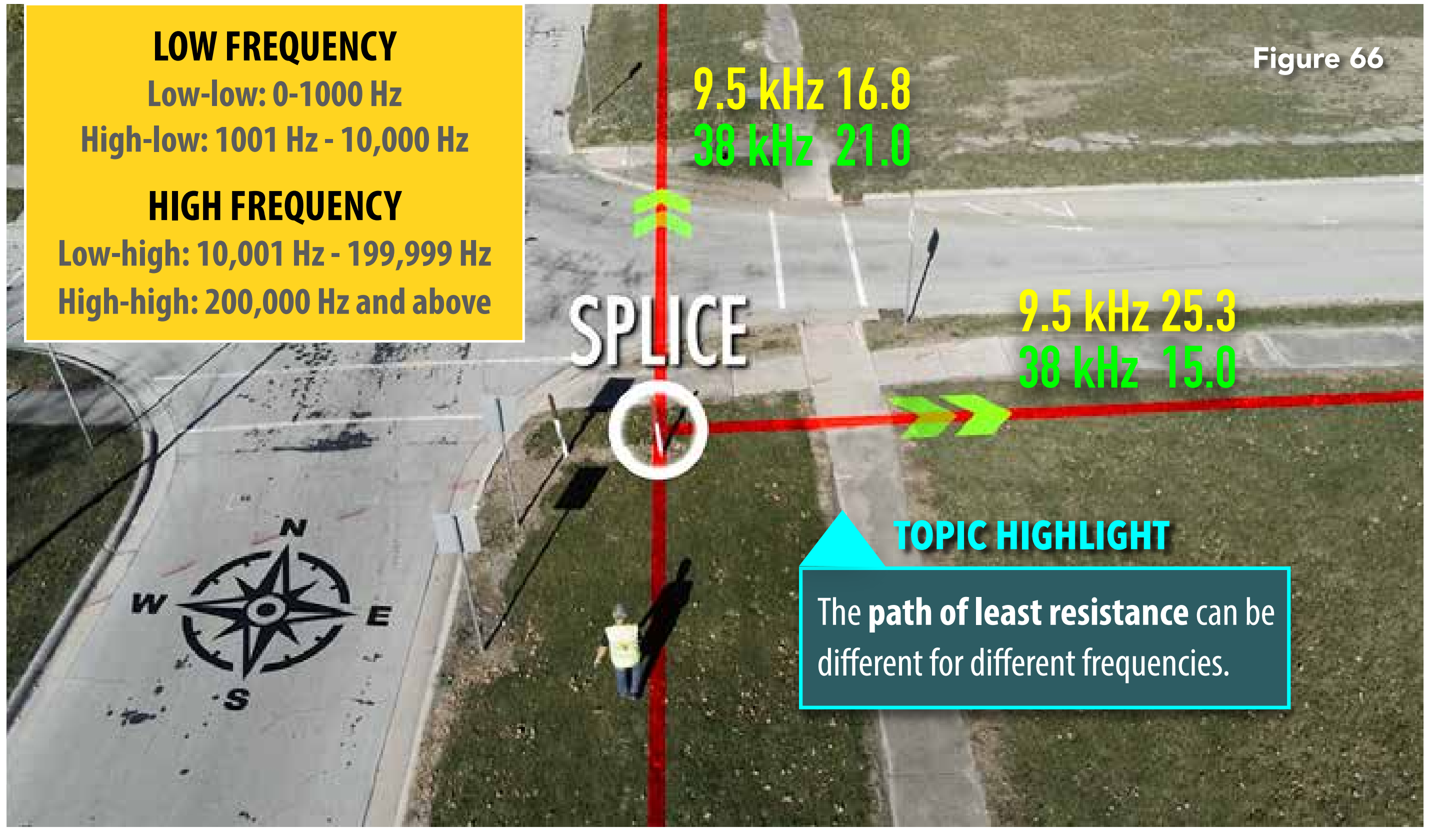
Figure 64

TOPIC HIGHLIGHT

Utilizing a **higher transmitter frequency** can change the results of a locate at a signal split.

15.0 Peak Reading East of Signal Split

Figure 65



LOW FREQUENCY
Low-low: 0-1000 Hz
High-low: 1001 Hz - 10,000 Hz

HIGH FREQUENCY
Low-high: 10,001 Hz - 199,999 Hz
High-high: 200,000 Hz and above

TOPIC HIGHLIGHT

The **path of least resistance** can be different for different frequencies.

Figure 66

When comparing signal strengths on two line segments downstream of a signal split, line depths must be very close to the same on both segments for a true comparison **(Figure 67)**. If the line depths differ significantly, the current measurement reading is a better indicator for determining the path of least resistance for signal entering a signal split.

TOPIC HIGHLIGHT

Determining the **path of least resistance** can sometimes tell you something about the utility system, such as its grounding or lack of grounding, the quality of its insulation, or the presence of features that cannot be seen above the ground.

Figure 67

Isolation and Bonding

One of the things that can be done to change the results of a locate is to change the grounding of the target utility. Here, we are going to separate the grounds of three copper telephone lines, and while doing so, we're also going to remove those lines from the grounded pedestal. We're going to conductively locate on 8 kHz, and we'll select the desired current of 20 mA **(Figure 68)**.

While doing a 360-degree sweep around the pedestal, we pick up a lot of signal on what appears to be a southbound telephone cable segment **(Figure 69)**.


Figure 68


Figure 69

TOPIC HIGHLIGHT

Bonding is the joining of metallic cables together with the purpose of ultimately connecting the metallic cables to earth.

We also pick up a lot of signal and a much higher current measurement reading on another cable segment **(Figure 70)**. We follow the trace north and then east. Ahead, we can see a visual and logical endpoint, another pedestal **(Figure 71)**.


Figure 70

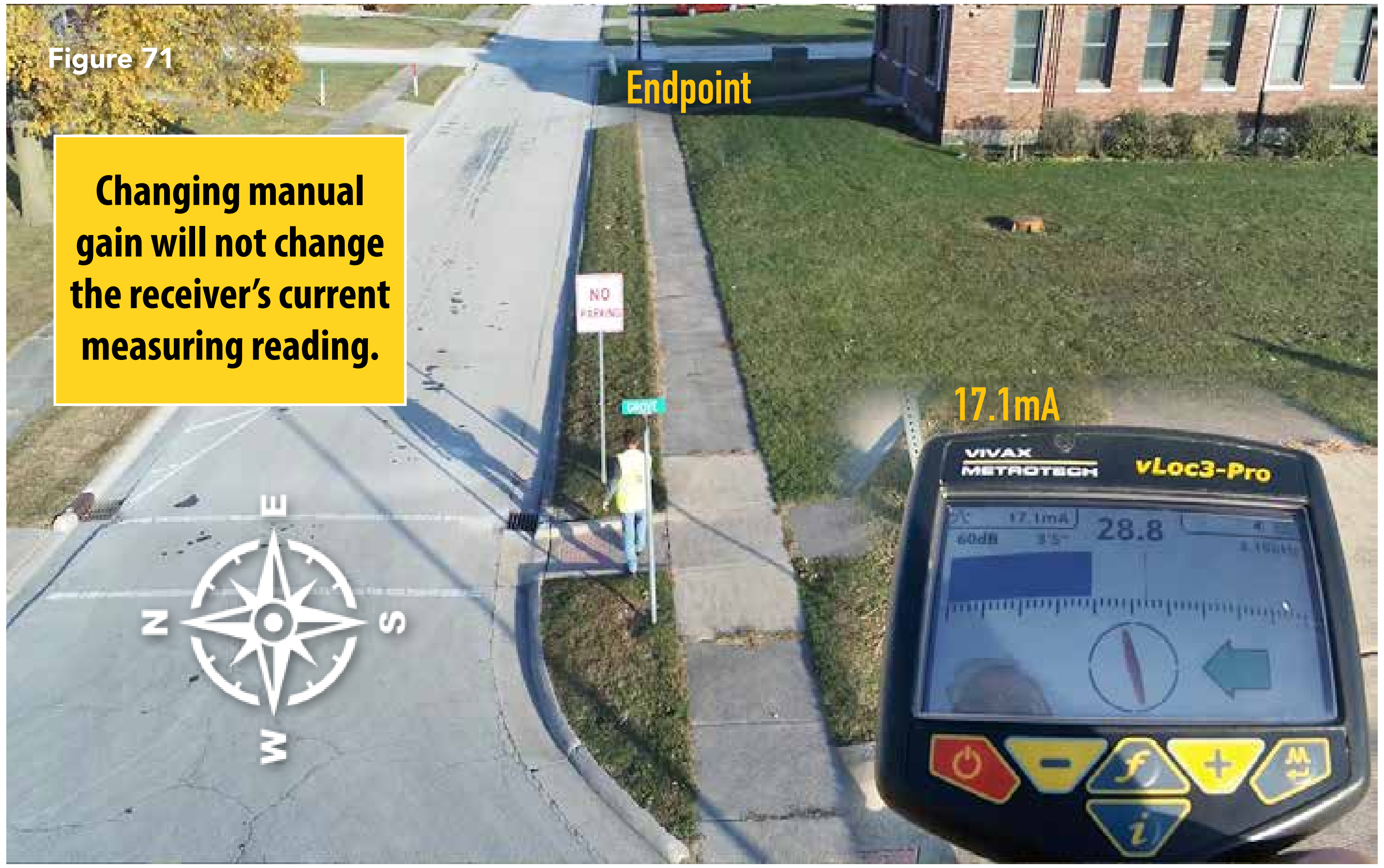


Figure 71

Changing manual gain will not change the receiver's current measuring reading.

Isolation and Bonding

On to our next ground **(Figure 72)**. With a high signal strength and a current measurement reading of 28.6, we have isolated and located the southbound cable **(Figure 73)**. We've identified and located two of the three cables coming out of this telephone pedestal.

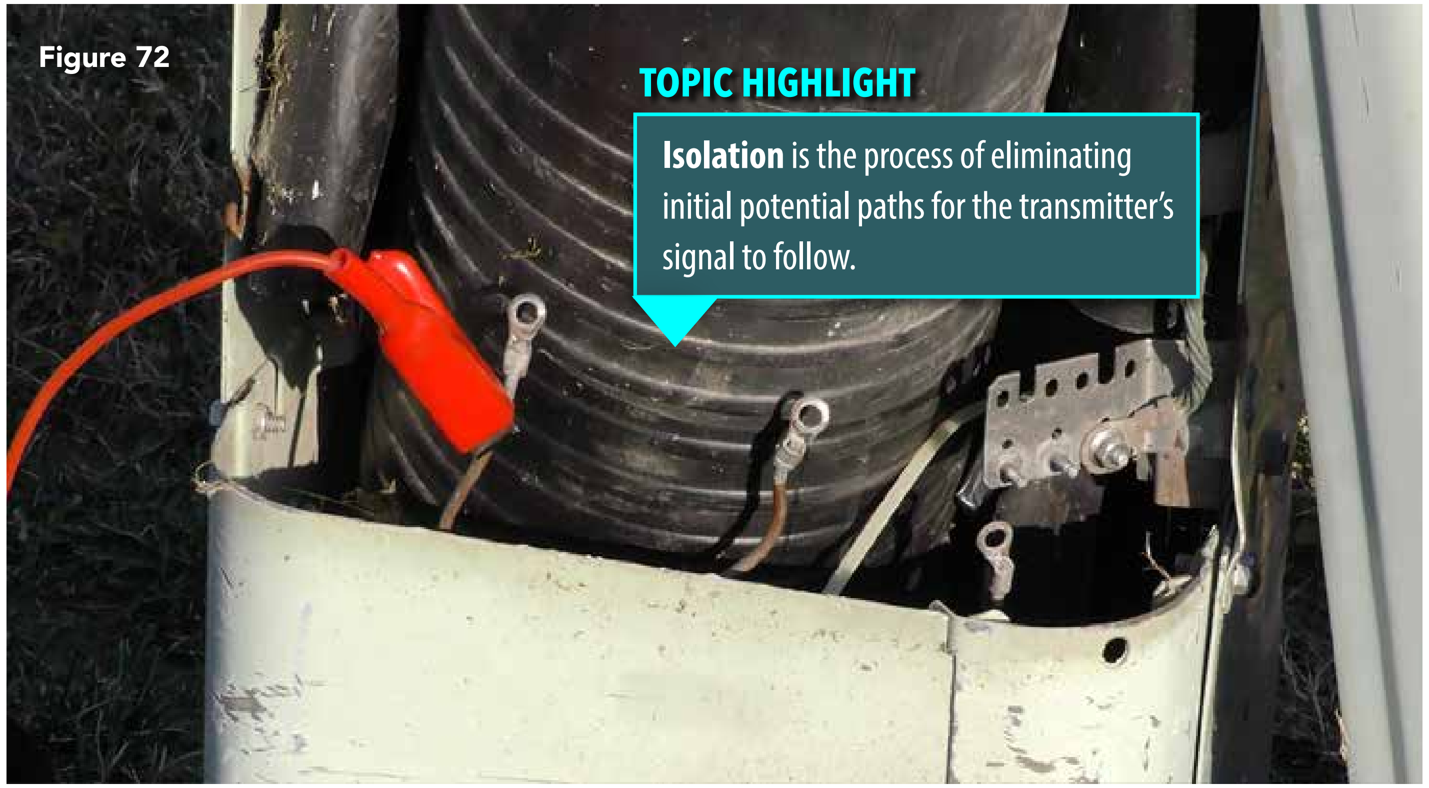


Figure 72

TOPIC HIGHLIGHT

Isolation is the process of eliminating initial potential paths for the transmitter's signal to follow.


Figure 73

On to the third ground that's connected to the sheath of the third cable **(Figure 74)**. The trace exits the pedestal at a bit of a diagonal to the west **(Figure 75)**.

We've now accounted for all three cables in the pedestal. The process of eliminating initial potential metallic paths for the transmitter's signal to follow is known as isolation.

The 20 mA reading on the transmitter is real **(Figure 76)**. While sometimes useful, the mA readings on the receiver are estimates.

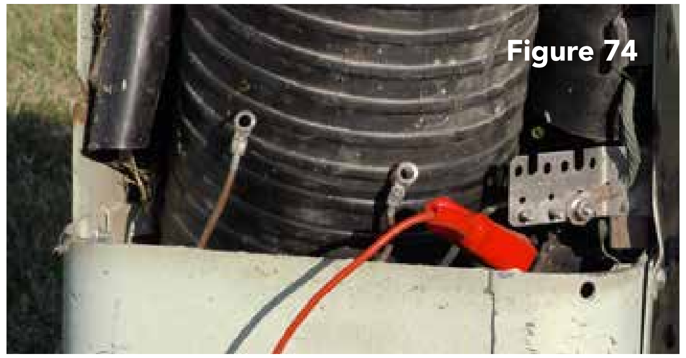


Figure 74

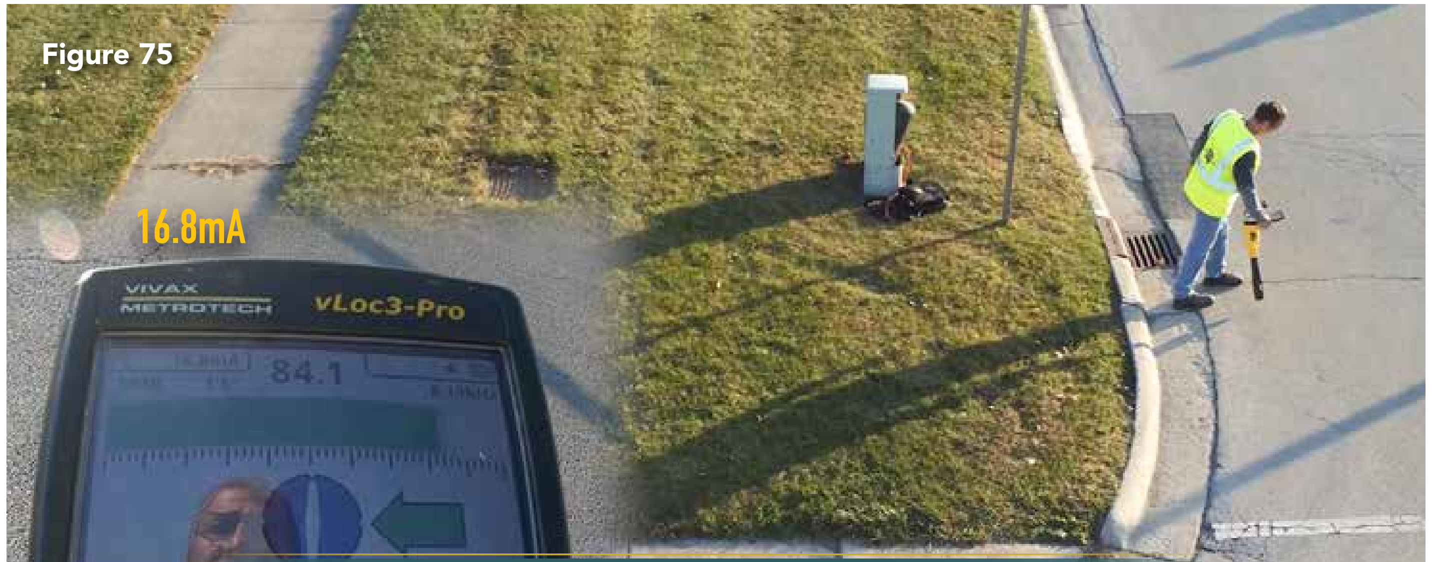


Figure 75

> "While sometimes useful, the mA readings on the receiver are estimates."


Figure 76

Isolation and Bonding

We're going to locate a copper telephone line on 4 kHz **(Figure 77)**, and we're going to energize the copper telephone line by hooking up to the outside of a telephone pedestal. There are two other cables that are in this pedestal. The signal can choose to go on all three cables, two cables, one cable or zero cables. We're only concerned with the cable that travels in a westerly direction **(Figure 78)**. But keep in mind, the signal can travel in more directions than simply going west. As we look inside the pedestal, you can see all three ground wires.


Figure 77


Figure 78


Figure 79

As we approach the next pedestal, we're going to see that the signal strength drops from the east side of the pedestal **(Figure 79)** to the west side of the pedestal **(Figure 80)**. This pedestal is a splice cabinet. There are no other cables other than the one coming into it from the east and leaving it to the west. But the signal strength degrades as we lose some of the current to earth, because both legs of the cable are grounded to earth.

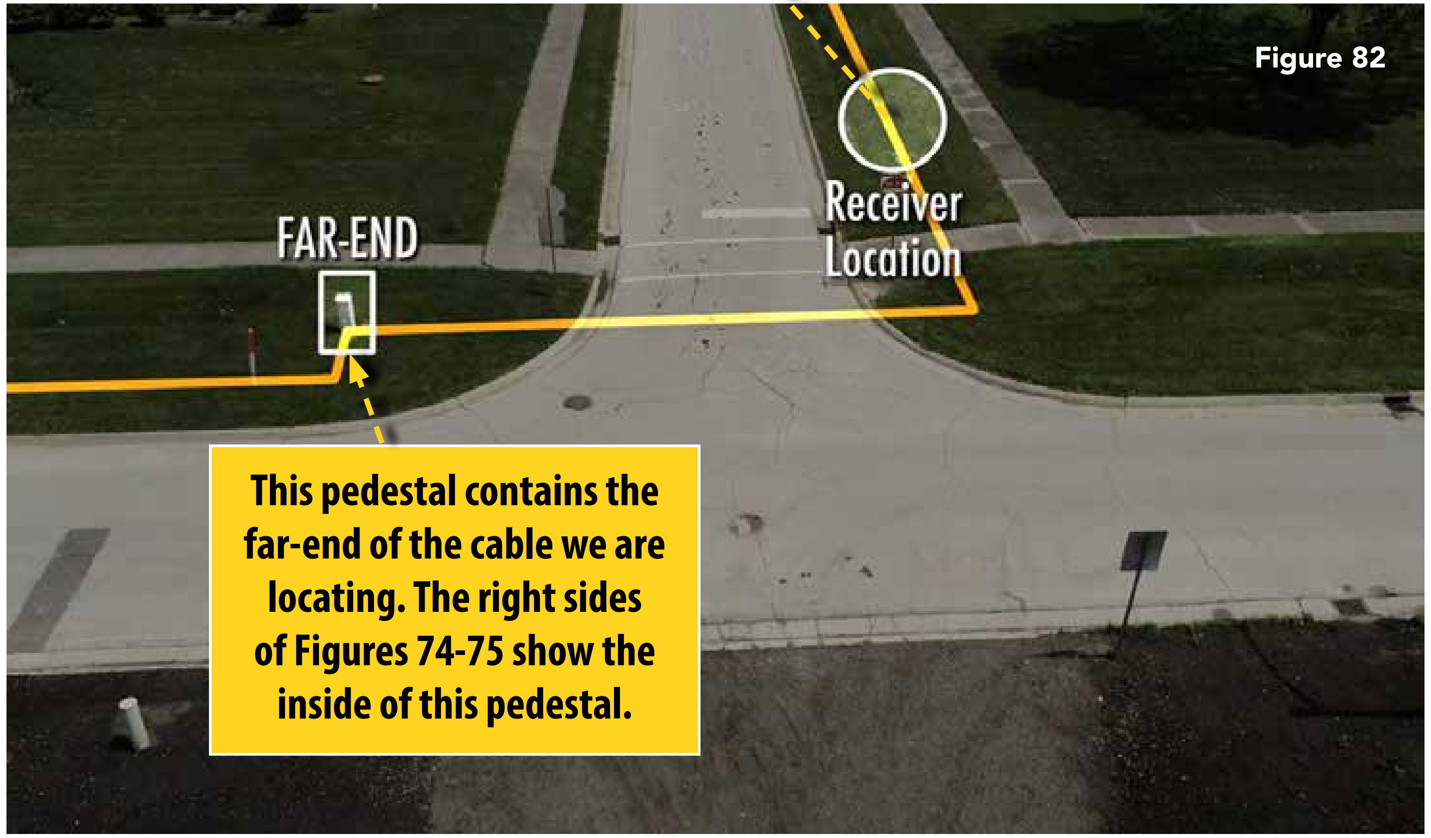

Figure 80

Isolation and Bonding

Figure 81

The transmitter is located at the close-end where multiple cables were bonded together. Cables were also bonded at the splice cabinet.

Figure 82



This pedestal contains the far-end of the cable we are locating. The right sides of Figures 74-75 show the inside of this pedestal.

Figure 83

Cable is grounded to earth

Watch our signal strength at the far-end as we take the ground off of this cable, so that it will no longer send signal to earth **(Figure 83)**. There is a significant drop in signal strength **(Figure 84),** because now the far-end is not grounded.

Figure 84

Cable is not grounded to earth

Telecom Drop Problems

The locate begins with a direct hook-up on the cable TV drop wire. The cable TV drop is grounded to the electric ground rod **(Figure 85)**. The access point is a metallic connector attached to the building **(Figure 86)**.

Figure 85

Figure 86

With the cable TV grounded to the electric, multiple underground lines are energized. At the start of the trace, the compass is not straight **(Figure 87)**. As the trace moves toward the street, the compass straightens out **(Figure 88)**, the result of only one nearby underground line being energized.

Figure 87

Figure 88

Telecom Drop Problems


Figure 89

Since the trace ends at the electric transformer **(Figure 89)**, it is clear that the cable TV drop has not been located. Sweeping around the cable TV pedestal–the visual endpoint for the target line–yields no signal **(Figure 90)**. The electric line took virtually all of the transmitter's energy.


Figure 90

Rotating the receiver during the sweep around the cable TV pedestal produces a higher peak reading than peak readings during the sweep **(Figures 91-92)**. Following the trace leads to the electric meter for the building south of where the transmitter is located **(Figure 93)**. It is now clear the transformer feeds electric to two buildings.


Figure 91


Figure 92


Figure 93

Telecom Drop Problems

There are four things that can be done differently with the transmitter to possibly change the results of a locate. One of the four things is to change the grounding system. Here, the black ground wire that runs from the cable TV connector to the electric ground rod is removed **(Figure 94)**. This will give the transmitter's energy one less metallic path to the underground electric line **(Figure 95 inset photo)**.

Even though the ground wire was removed from the cable TV drop wire, there is a lot of signal on the electric line **(Figure 95)**.

Figure 94

The crooked compass indicates more than one line is energized.

Figure 95

Figure 96

TOPIC HIGHLIGHT

There are two ways a **non-target line can become energized**: by metal-to-metal means (conductively) or by nonmetal-to-metal means (inductively).

Removing the ground wire from the cable TV connector did not change the results of this locate. The electric line is most likely energized through another metallic pathway **(Figure 96)**. This trace is a virtual replica of the trace with the ground wire still connected to the electric ground rod. The shape of the field is round once the trace moves toward the street **(Figure 97)**.

Figure 97

Telecom Drop Problems


Figure 98

This is the location of the cable TV drop wire that is not yet successfully located **(Figure 98)**. The only signal that is received near the visual endpoint for the cable TV drop is coming from the neighboring building's electric line. This electric line is also fed from the same electric transformer that feeds the building where the transmitter is located **(Figure 99)**.


Figure 99

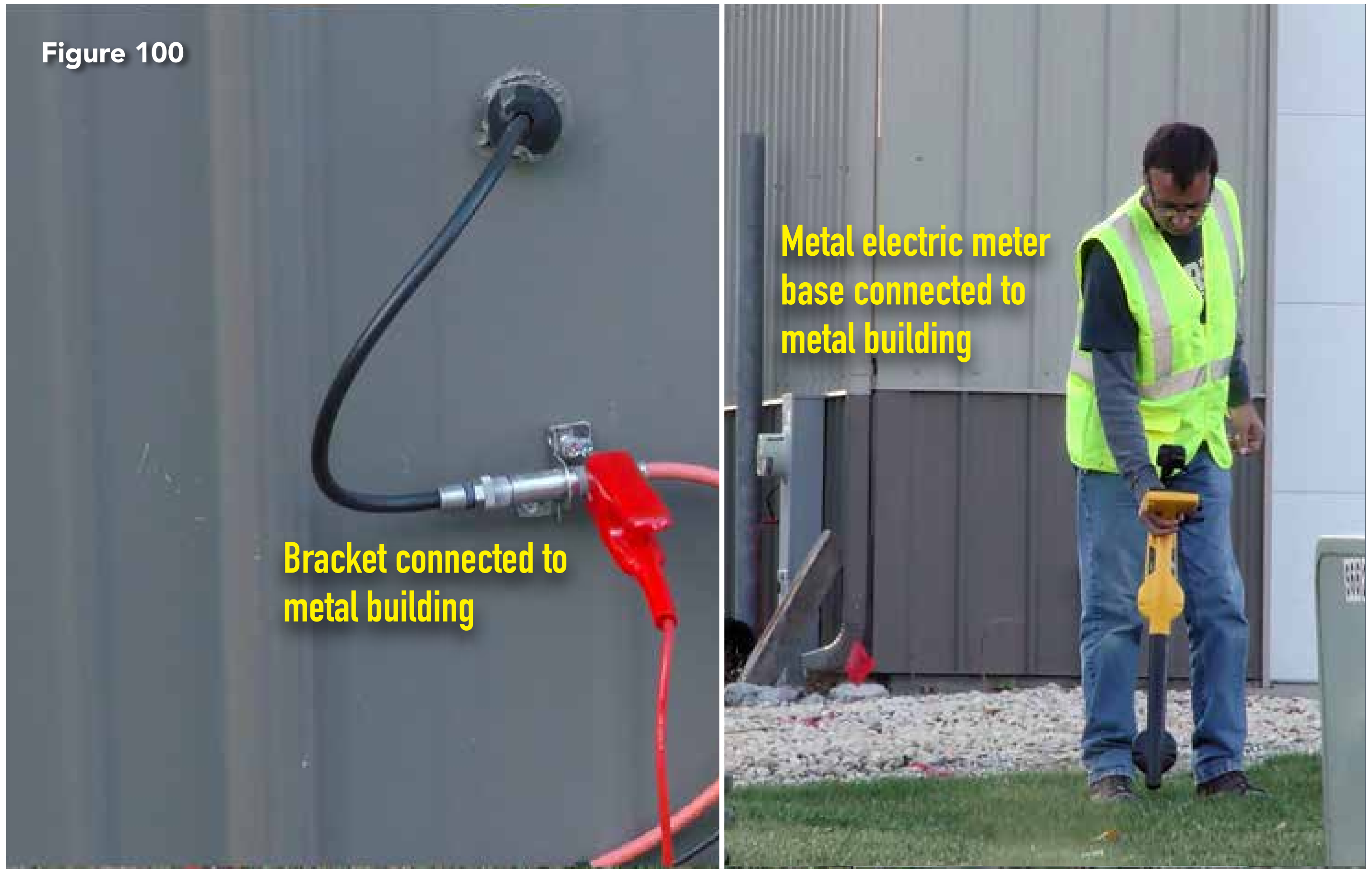


Figure 100

The issue that prevents the cable TV from being successfully located is related to the cable TV connector bracket, which is affixed to the metal building. Also affixed to the metal building is the electric meter **(Figure 100)**. This means that unless the bracket is removed from the metal building, the electric line is always going to be energized better than the cable TV drop. The solution is to move the transmitter and energize the cable TV drop wire from the pedestal **(Figure 101)**.


Figure 101

TOPIC HIGHLIGHT

Of the four things you can do to change a locate, **moving the transmitter** changes results more often than the other three.

Telecom Drop Problems

After moving the transmitter, the cable TV successfully locates with the receiver not impacted by signal on the adjacent electric line. The signal received is "round" **(Figure 102)**. The trace continues to the building where the visual endpoint is the cable TV drop wire and not the electric meter **(Figure 103)**. In this scenario, the highest signal strength is not at the base of the electric meter.

Figure 102

Figure 103

TOPIC HIGHLIGHT

When electric and communications cables are commonly-grounded, there is no distinction between these utilities from a **path of least resistance** perspective.

Telephone Drop

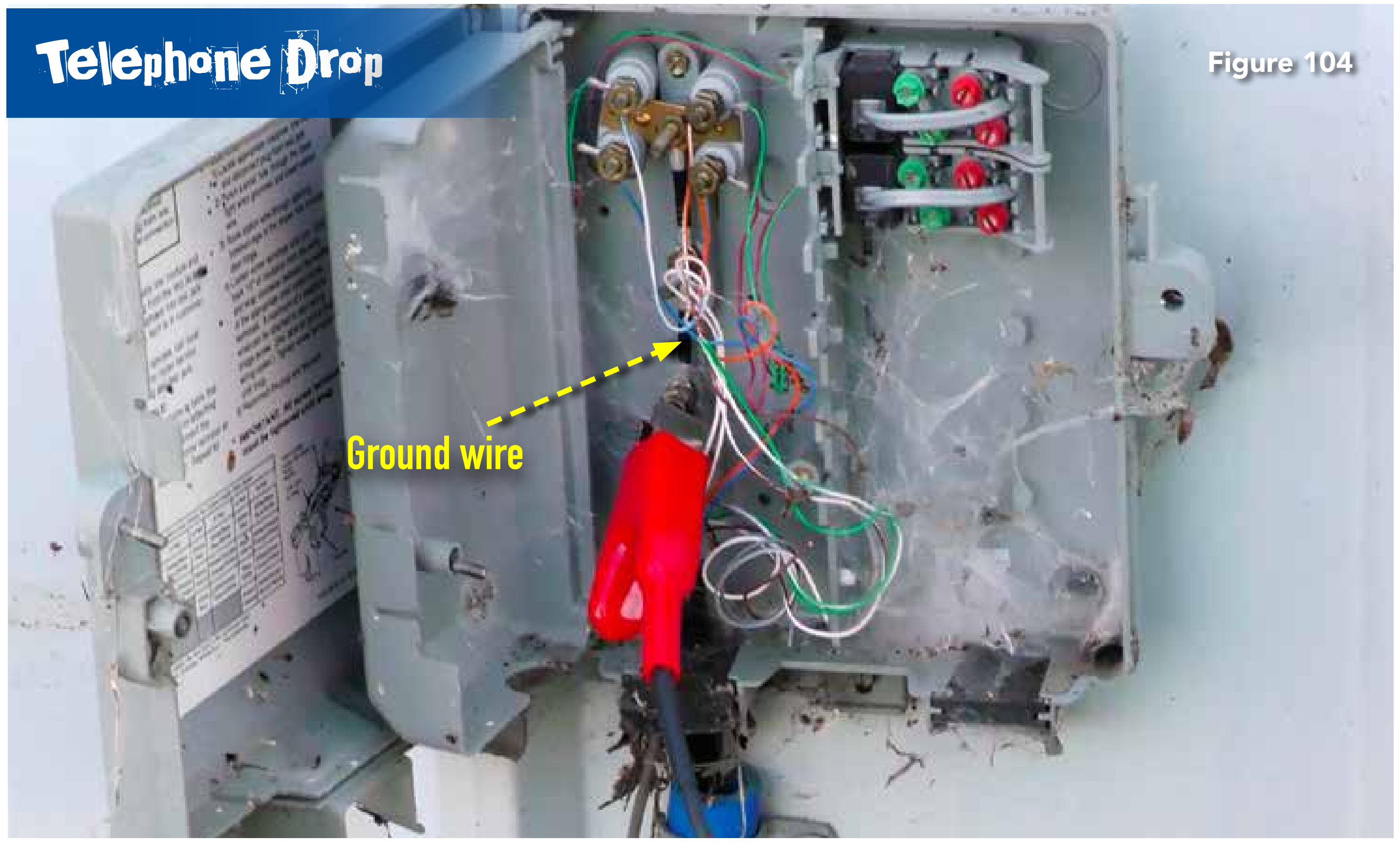


Figure 104

The next exercise is an attempt to locate the neighboring building's telephone drop from the building to the telephone pedestal near the street. A direct connection is made with the telephone ground wire inside the telephone box at the building **(Figure 104)**. The transmitter is utilizing a low-low frequency of 815 Hz, and the grounding device is placed in the soil at a right angle to the building **(Figure 105)**.

Figure 105

Telecom Drop Problems

The trace begins with good current, a peak and null that agree, and a direction pointed toward the telephone pedestal **(Figure 106)**. However, the trace bypasses the telephone pedestal and ends up at the electric transformer **(Figures 107-108)**. To solve this problem something different must be done at the transmitter location.


Figure 106


Figure 107


Figure 108

The telephone ground is disconnected from inside the box with the hope that this isolation attempt will keep a lot of signal off the metal building and therefore off the electric line **(Figure 109)**.

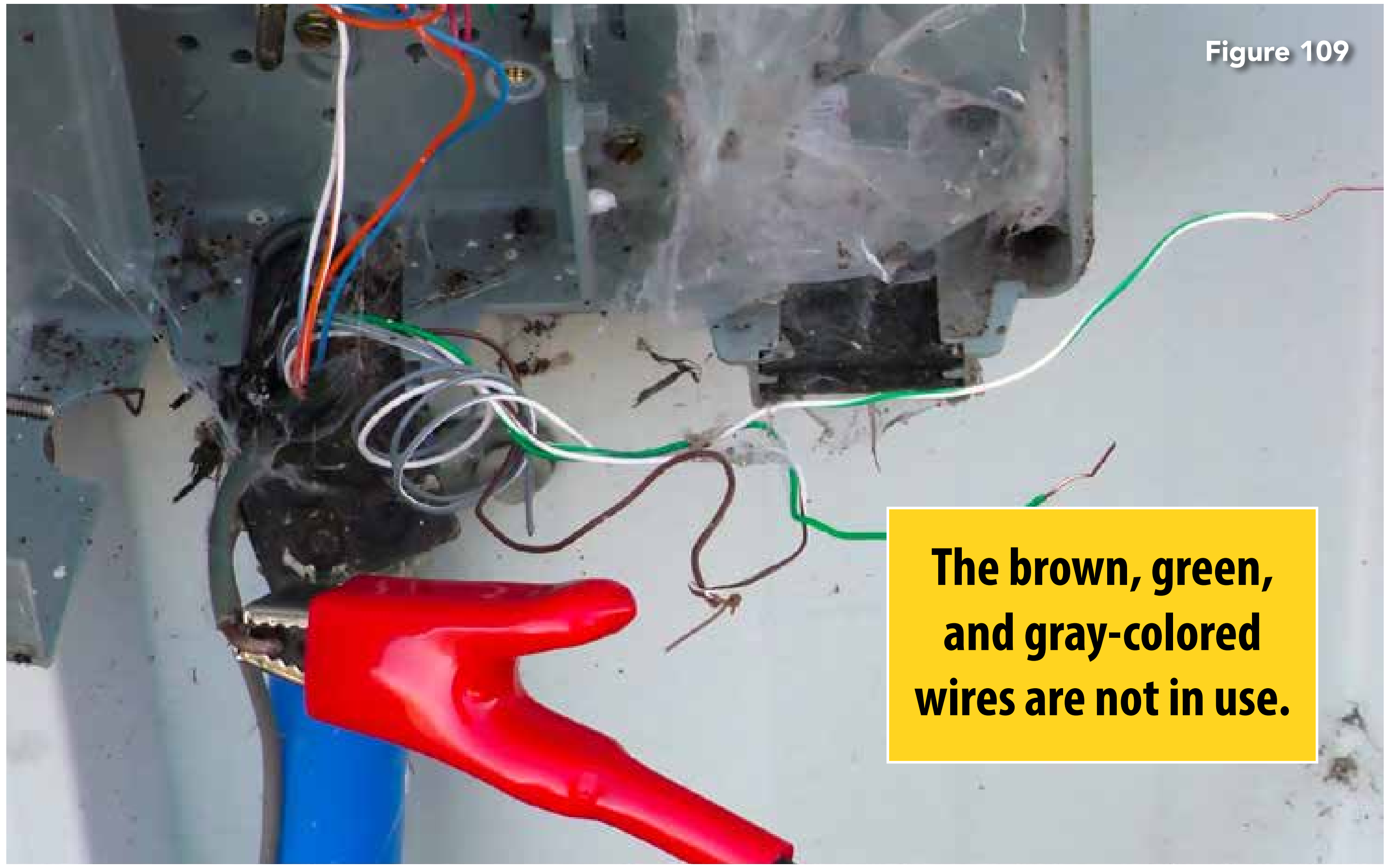


Figure 109

The brown, green, and gray-colored wires are not in use.

Telecom Drop Problems

The trace still bypasses the telephone pedestal and goes to the electric transformer **(Figure 110)**. Taking the ground wire off inside the telephone box did not change the results of the locate. Opening the telephone pedestal reveals that the telephone drop wire does not have a metallic sheath **(Figure 111)**. While the unsheathed phone drop could have been identified at the telephone box at the building, sometimes things are overlooked during the locate process.

Figure 110

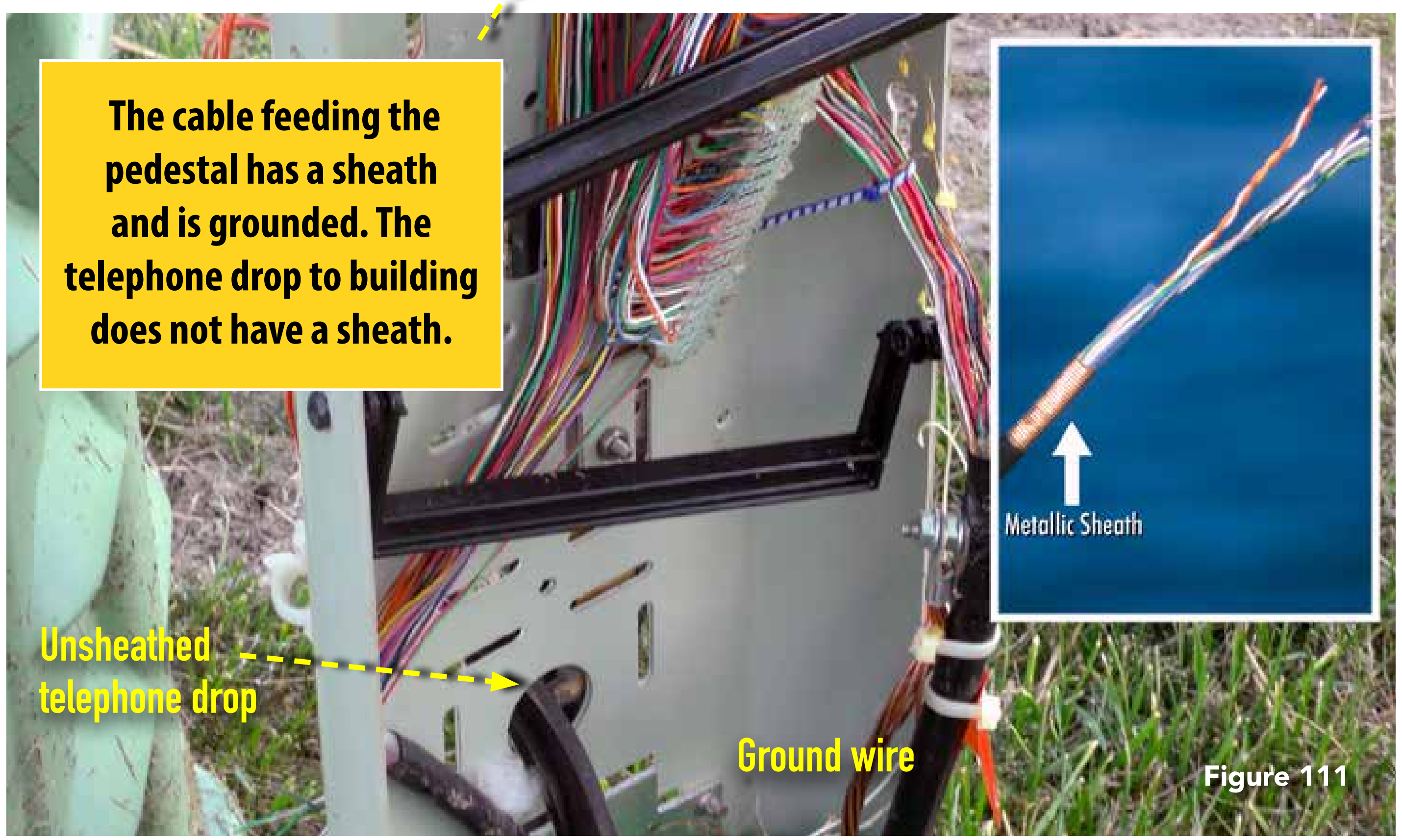

The cable feeding the pedestal has a sheath and is grounded. The telephone drop to building does not have a sheath.

Figure 111


Figure 112

Inside the pedestal, these are the other ends of the wires, known as pairs, that were not in use inside the telephone box at the building **(Figure 112)**. Back at the building, unused wires become the access point **(Figure 113)**. Because the ends of these wires are not grounded at the pedestal, a frequency higher than 815 Hz will be used.


Figure 113

Telecom Drop Problems


Figure 114

Using the transmitter frequency 82 kHz, the connection to the unused pairs leads directly the logical and visual endpoint—the telephone pedestal **(Figure 114)**. With the receiver beyond the pedestal and over the electric line, there is no null response **(Figure 115)**. A "peak but no null response" is the result of a very low amount of signal on the electric line.


Figure 115

TOPIC HIGHLIGHT

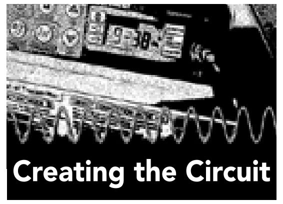
A peak reading without a corresponding null reading is an indication of low current flow on a line.

Looking at the red paint on the ground and performing a trace back to the starting point reveals the signal is not on the electric line **(Figures 116-117)**. A turn in the phone drop is indicated once the peak reading decreases significantly **(Figure 117)**. Upon turning, the trace is directed toward the telephone box **(Figure 118)**.


Figure 116

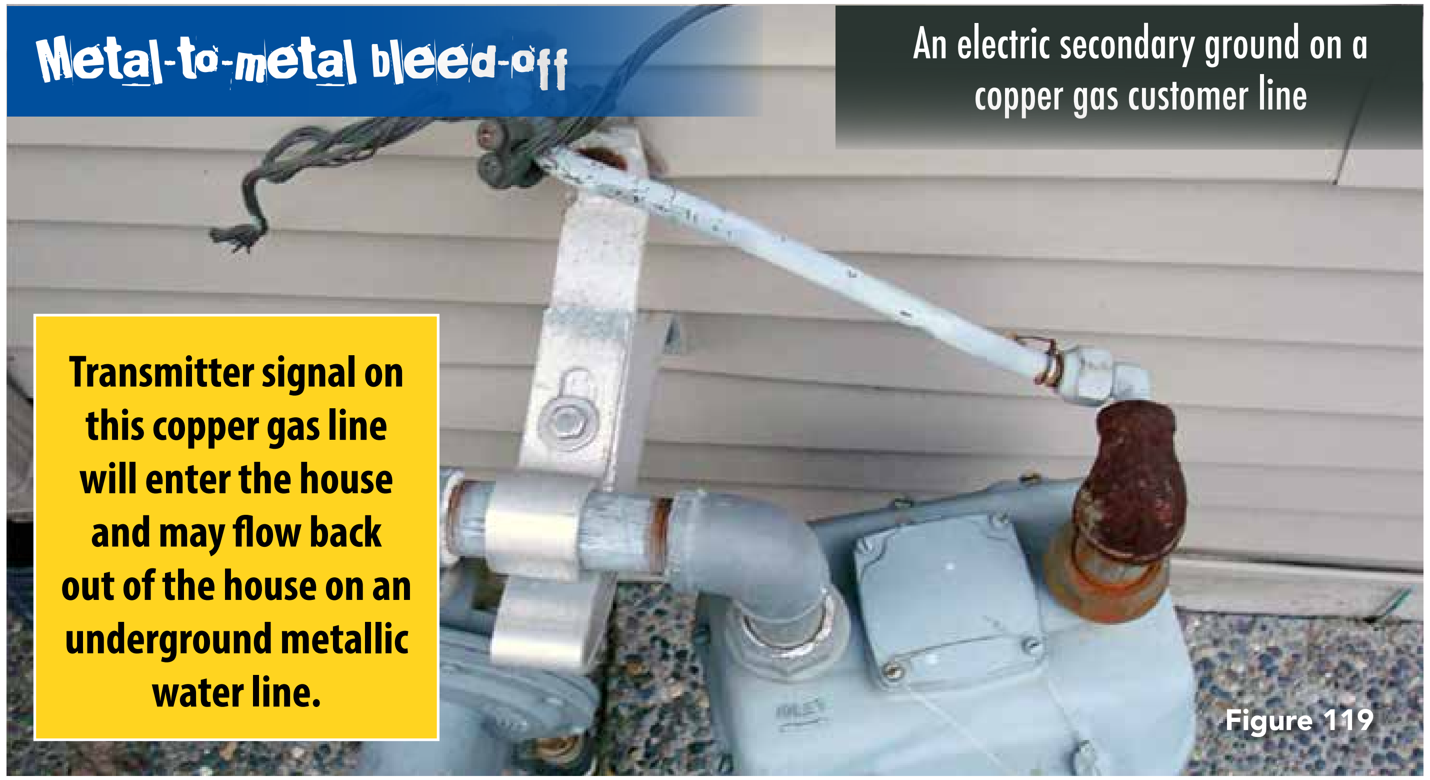

Figure 117


Figure 118



There is No Best Frequency

Utilities are grounded to each other to divert lightning or faulted electric current safely to earth. When utilities are grounded to each other, no transmitter frequency will only energize the target line and not energize non-target lines. Changing the transmitter frequency may have some effect on the desired results but metal-to-metal bleed-off will always occur in these situations.

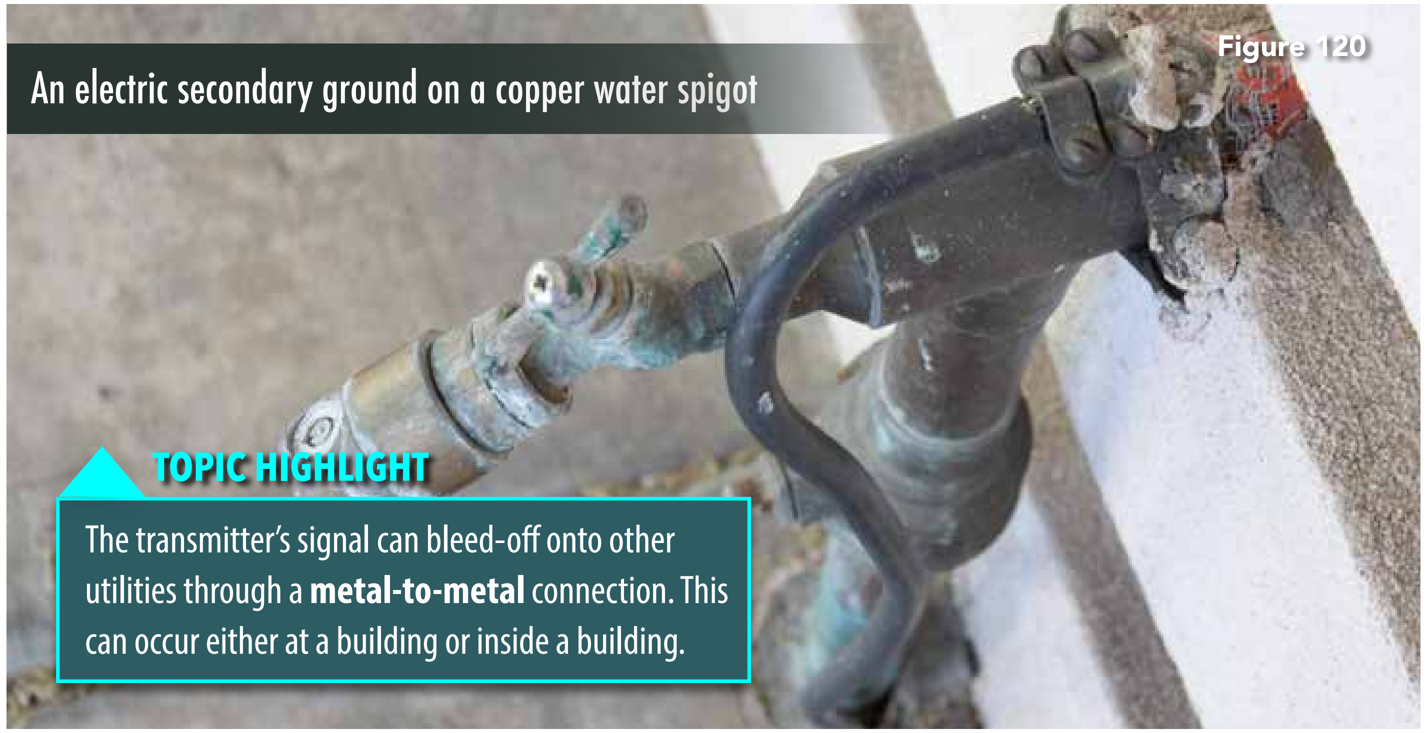


Metal-to-metal bleed-off

An electric secondary ground on a copper gas customer line

Transmitter signal on this copper gas line will enter the house and may flow back out of the house on an underground metallic water line.

Figure 119



An electric secondary ground on a copper water spigot

Figure 120

TOPIC HIGHLIGHT

The transmitter's signal can bleed-off onto other utilities through a **metal-to-metal** connection. This can occur either at a building or inside a building.

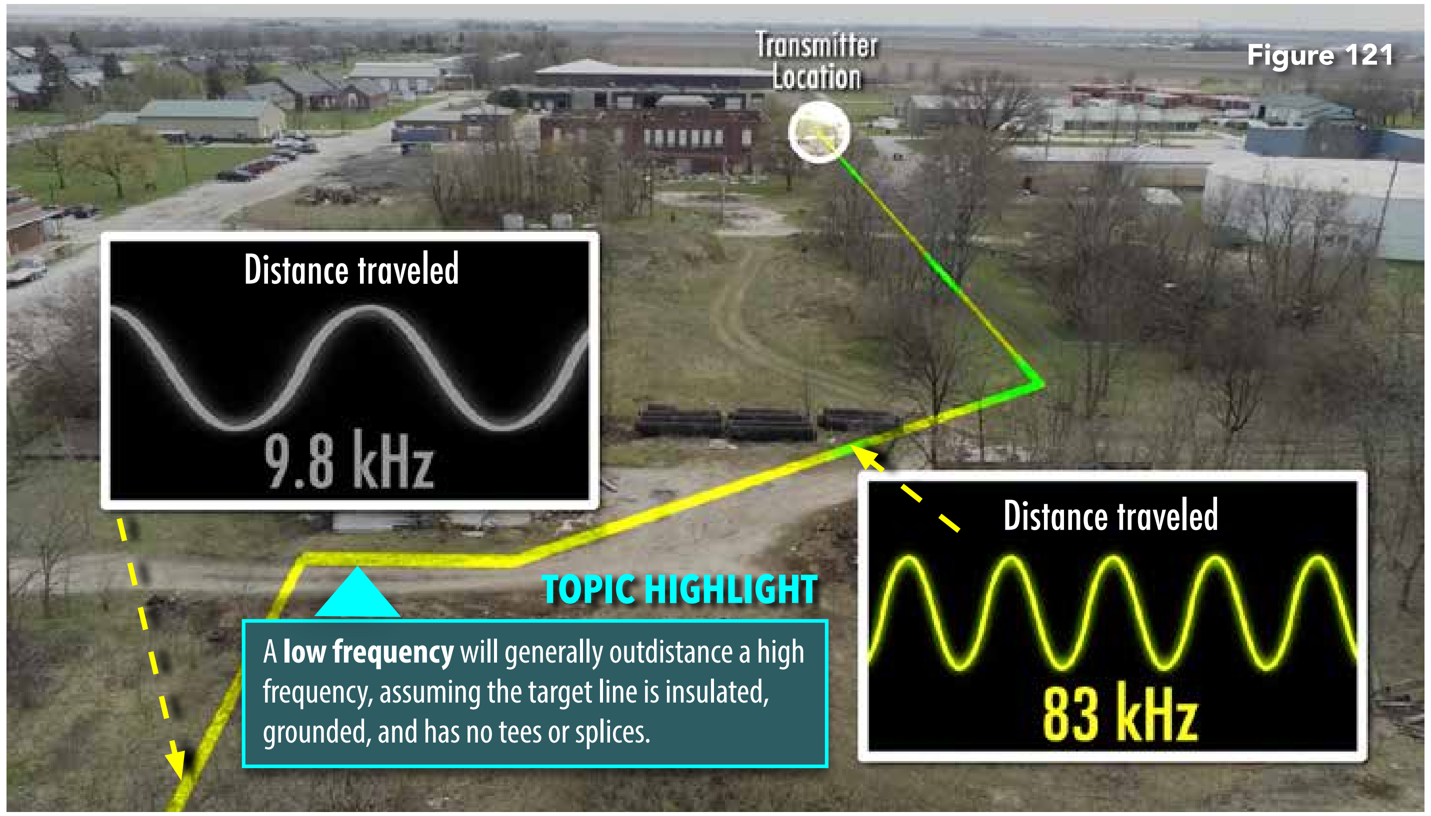


Figure 121

TOPIC HIGHLIGHT

A **low frequency** will generally outdistance a high frequency, assuming the target line is insulated, grounded, and has no tees or splices.

Low frequencies tend to travel greater distances than high frequencies. In a head-to-head comparison on a straight conductor with no laterals or tees, a low frequency is going to outdistance a high frequency, assuming good insulation of the utility and a grounded far-end **(Figure 121)**. Low frequencies also have higher maximum outputs in terms of milliamps than do higher frequencies **(Figure 122)**. However, given the level of induced current embedded in higher frequencies, higher transmitter outputs are not necessarily advantageous for locating purposes.

"Low frequencies have higher maximum outputs in terms of milliamps than do higher frequencies."

Figure 122

There is No Best Frequency

The unintended consequence of locating buried electric lines is that the transmitter's energy will travel into a building on the service line as well as away from building toward the street or utility easement. Here, 8 kHz travels into the building **(Figure 123)** and out the other side on a cable TV feeder **(Figure 124)**. The signal received on cable TV has good current and a round field.

Figure 123

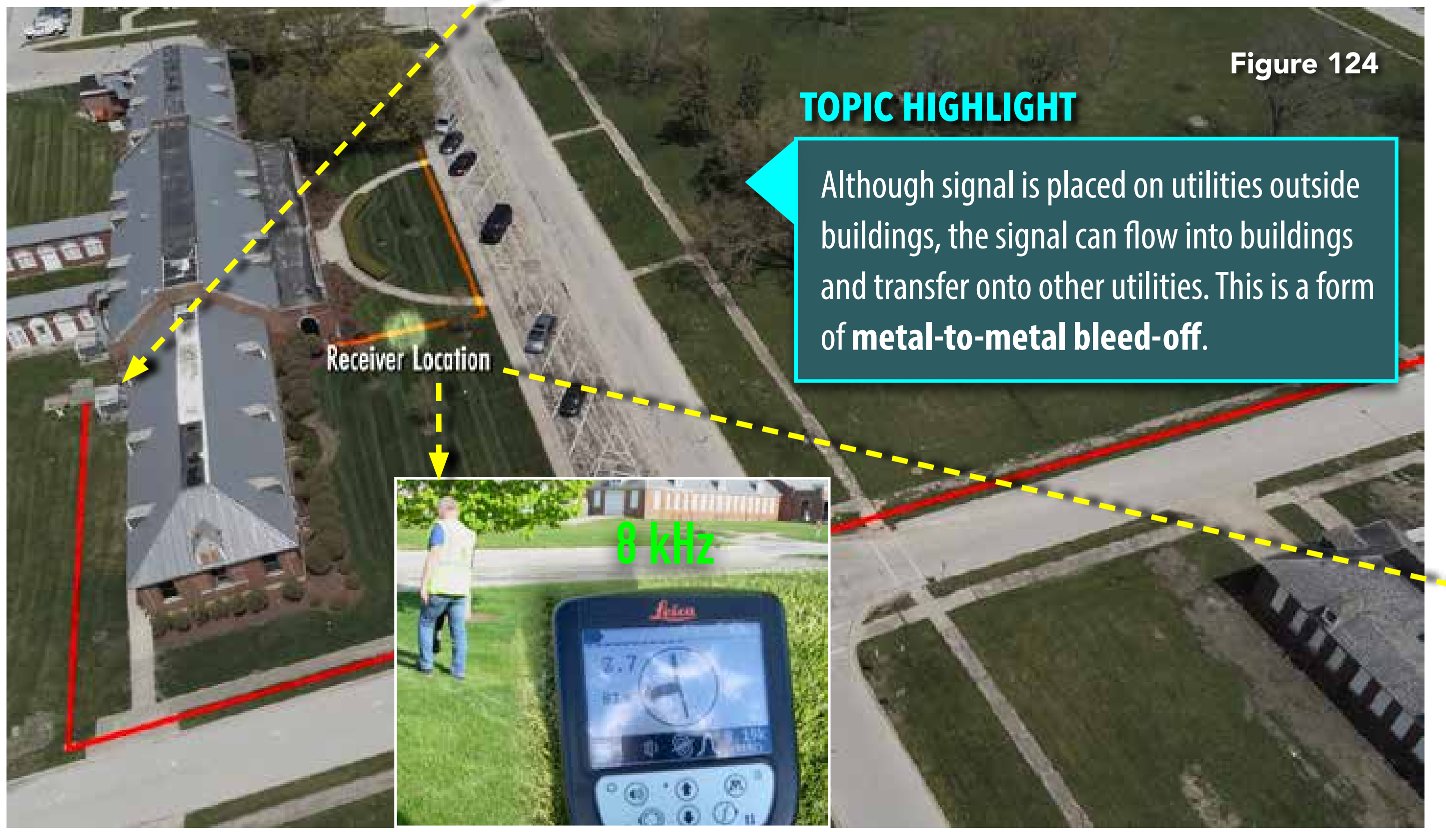


Figure 124

TOPIC HIGHLIGHT

Although signal is placed on utilities outside buildings, the signal can flow into buildings and transfer onto other utilities. This is a form of **metal-to-metal bleed-off**.

Figure 125

TOPIC HIGHLIGHT

With lower frequencies, we can expect more **metal-to-metal bleed-off** inside buildings.

Although there's still signal on the cable TV line using 44 kHz **(Figure 125)**, the peak number fluctuates (OK current). Using the higher 83 kHz, not only does the peak fluctuate more than 44 kHz, there is no null response; the arrow does not change direction **(Figure 126)**. As we locate with lower frequencies, we can expect more metal-to-metal bleed-off. As we get into the higher frequencies, the signal dissipates within the building and therefore does not as successfully energize the other utilities.

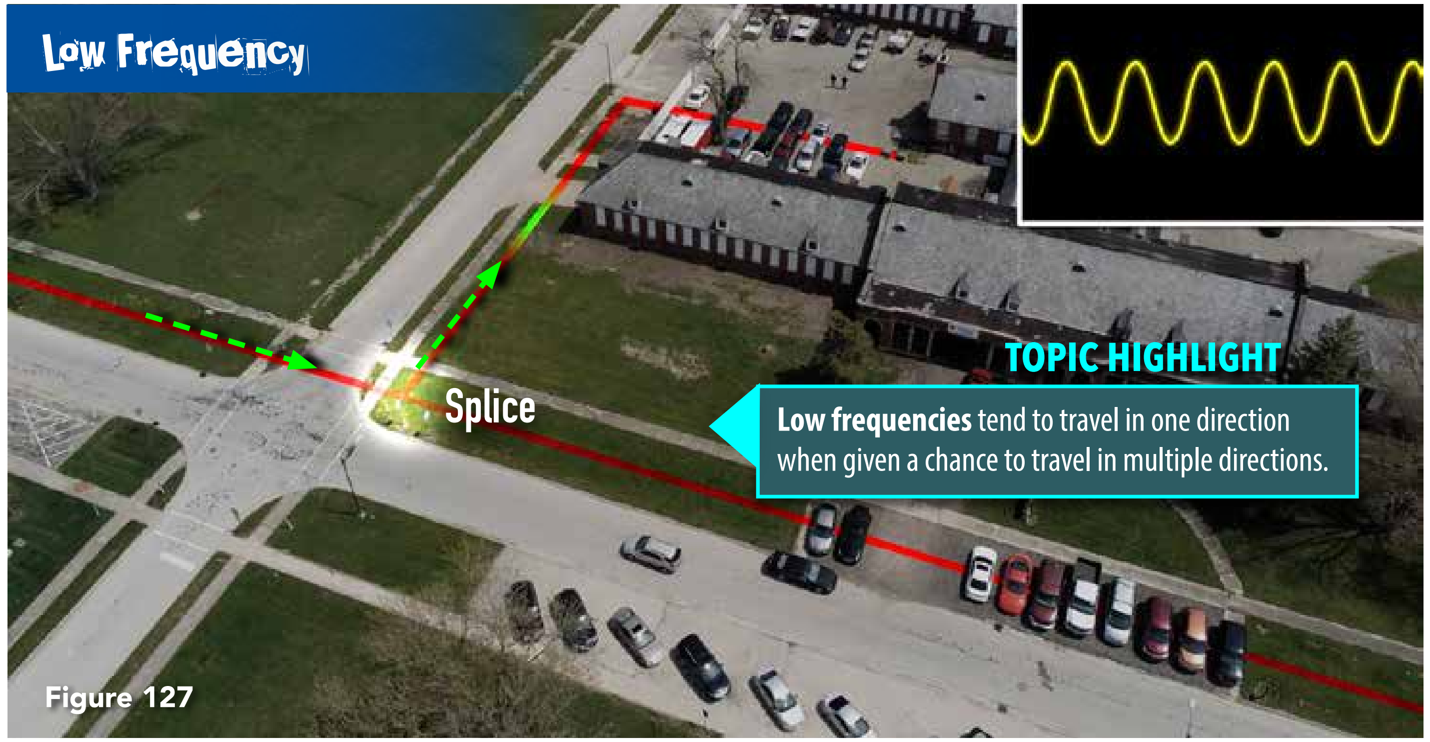
Figure 126

TOPIC HIGHLIGHT

As we get into the **higher frequencies**, the signal dissipates within the building and does not energize non-target utilities as easily as lower frequencies.

There is No Best Frequency

Low frequencies, particularly low-low frequencies, when approaching a junction or a signal split area where they can travel multiple directions, tend to want to go only one direction much more than higher frequencies **(Figure 127)**. Higher frequencies, when entering into a signal split area, tend to go in all available directions **(Figure 128)**. And the higher you go in frequency, the more likely you will go in all directions at a signal split opportunity.



TOPIC HIGHLIGHT

Low frequencies tend to travel in one direction when given a chance to travel in multiple directions.

Figure 127

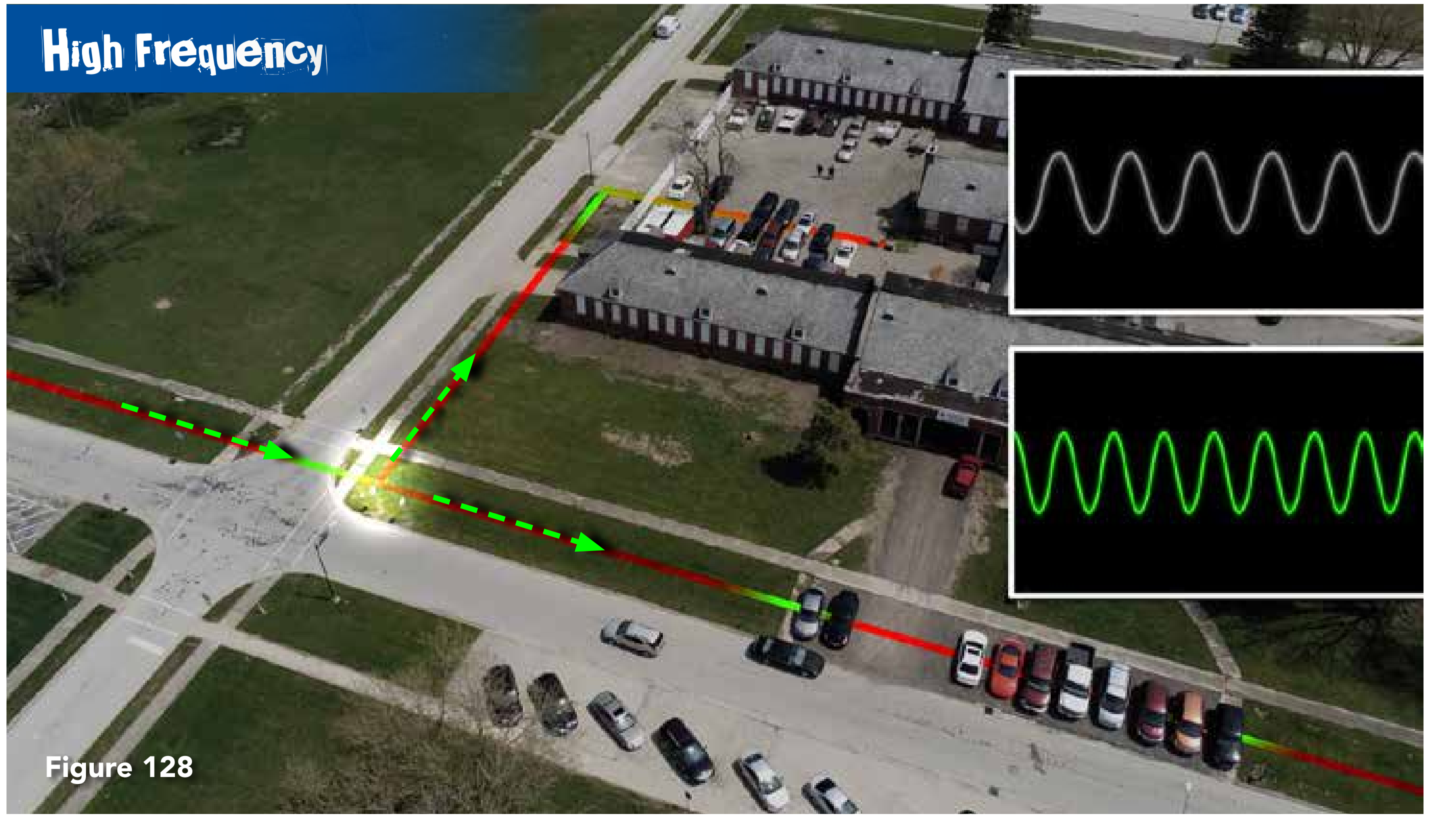
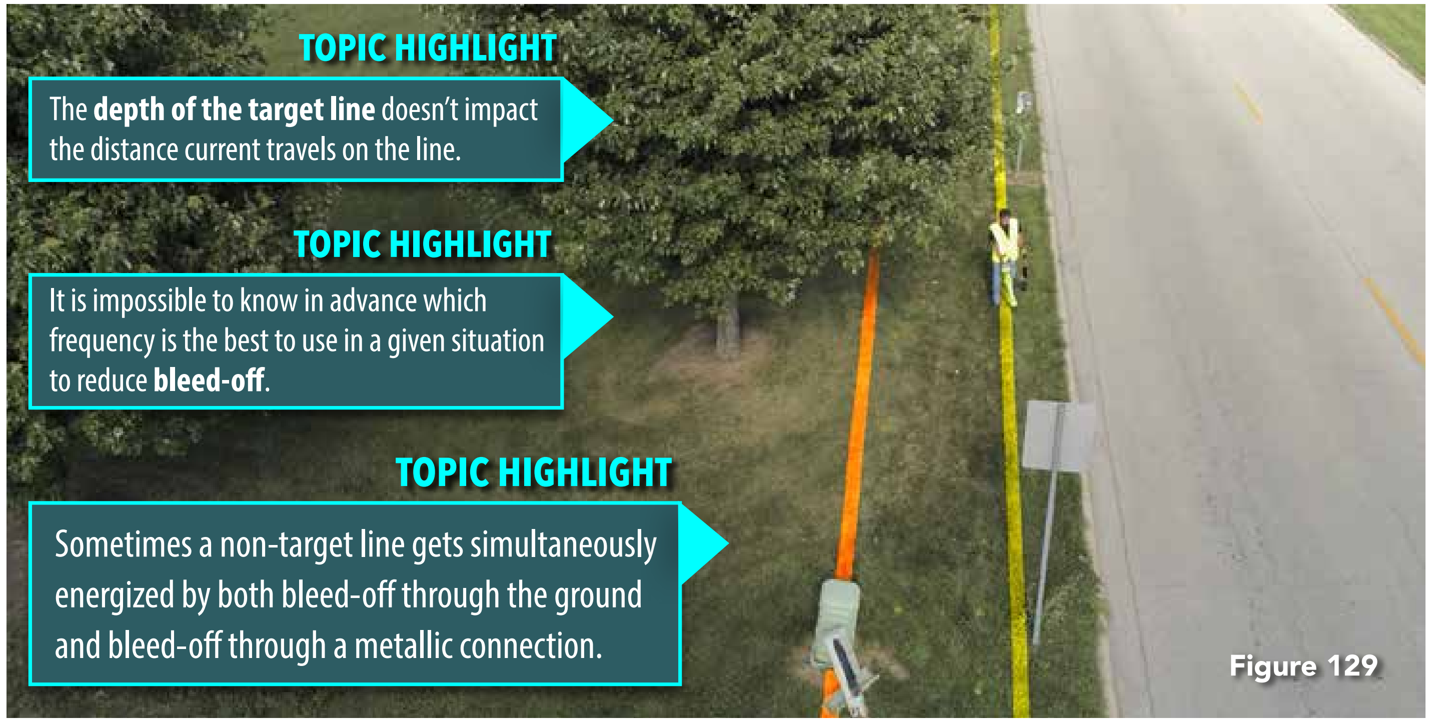


Figure 128



TOPIC HIGHLIGHT

The **depth of the target line** doesn't impact the distance current travels on the line.

TOPIC HIGHLIGHT

It is impossible to know in advance which frequency is the best to use in a given situation to reduce **bleed-off**.

TOPIC HIGHLIGHT

Sometimes a non-target line gets simultaneously energized by both bleed-off through the ground and bleed-off through a metallic connection.

Figure 129

There are some generalizations about low frequencies that are true a lot of the time, such as: there are lower levels of bleed-off through the soil and longer tracing distances. But soil and utility characteristics have a lot to do with bleed-off.

Simply put, there is no best frequency. Conductors are great conductors when they have metallic continuity, are insulated from earth, and are well-grounded. If a nearby parallel utility is a great conductor, bleed-off occurs no matter how low a frequency is transmitted **(Figure 129)**. Conductors become good conductors through connections with earth. Again, there is no best frequency.

It's not a bad strategy to start with your lowest transmitter frequency and go to higher frequencies as you need to. But starting at 8 kHz, 9.8 kHz, 25 kHz or 33 kHz allows plenty of opportunity to drop into the lower frequency range, while still having many higher frequencies that are available to use.

In the end, no frequency is always going to be a better frequency to choose than another. It depends on what results you get when you check the level of current flow, shape of the field, and where you are led as you seek to follow your trace to a visual endpoint **(Figure 130)**.

Figure 130

The Received Signal

The receiver determines if a change in transmitter deployment is necessary.

A receiving antenna positioned within an electromagnetic field results in current flowing on the coils of the antenna. The amount of current is directly proportional to the strength of the received field and is expressed as a peak reading.

Equivalent to a volume setting, a manual gain control merely increases or decreases the numeric value of the peak reading as well as any audio or visual indicator associated with the peak reading. The level of current flow on receiving antenna coils is a result of transmitter deployment, the path of least resistance, the distance above the electromagnetic field and the distance between the transmitter and receiver.

The receiver analyzes information through the use of multiple coiled antennas within the electromagnetic field. Utility line depth and current measurement readings, or milliamp readings, are estimated values determined by stacked-peak receiving antennas.

Known as constructive or destructive interference, commingled electromagnetic fields result in an increased or decreased relative strength of the received fields. Accessing the impact of interference is critical to establishing the accuracy of locate results.

Table of Contents

**A multiple-page section used to break down a video featuring a lengthy locating exercise.*

Digital Depth

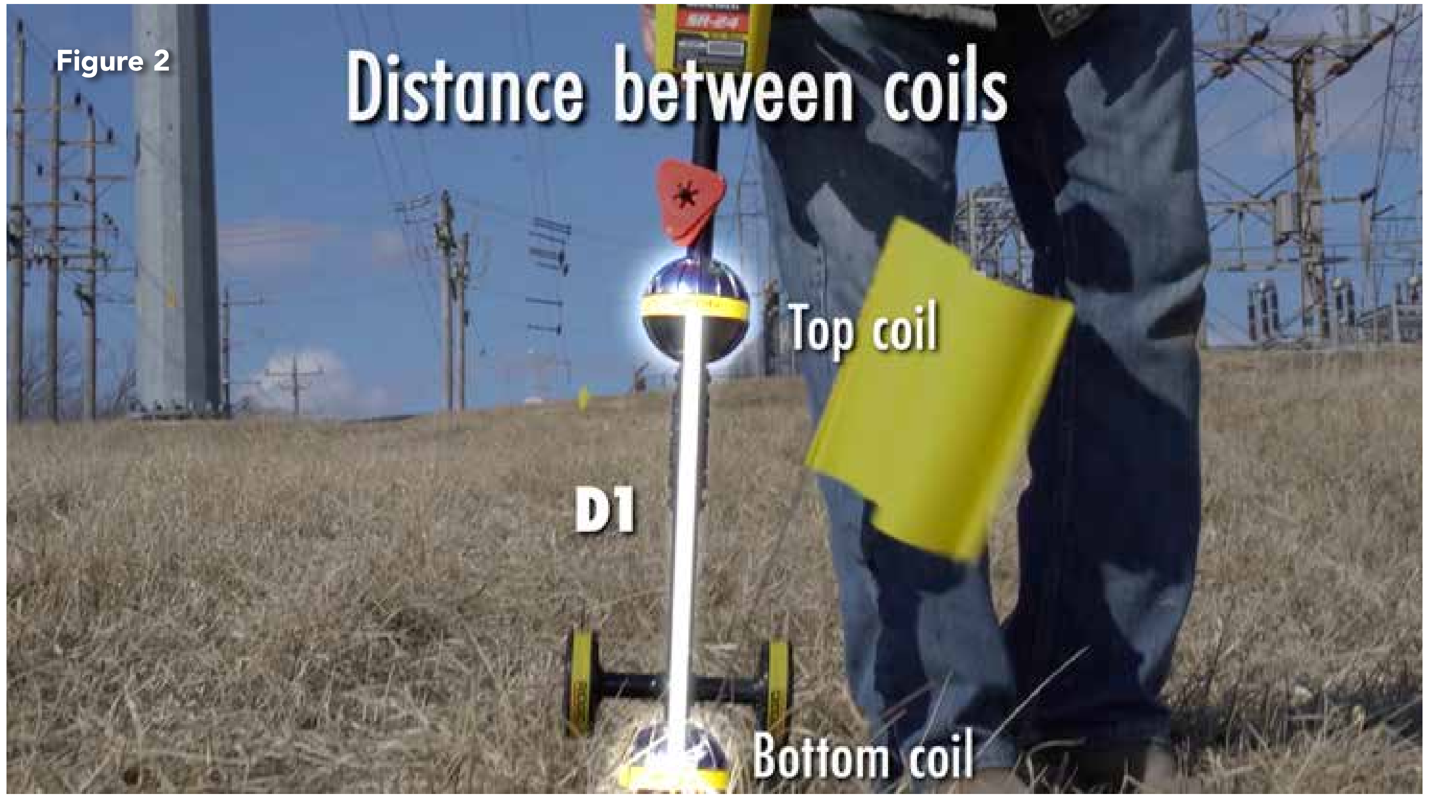
The *Analyze* video series begins with an explanation of how digital depth readings are produced by the receiver. Digital depth readings are produced by stacked-peak antennas with both the bottom and top antennas positioned over the energized line **(Figure 1)**. The distance between the antennas, or coils, is part of the formula used to produce depth readings. This distance is shown below as D1 **(Figure 2)**.

Figure 1

TOPIC HIGHLIGHT

Depth readings are determined by comparing signal strength on two stacked antennas above the ground. A receiver cannot see signal below the ground.

Figure 2



A digital depth reading is a calculation that begins with measuring the signal strength of two different signal circles, what are shown below as Circle 1 and Circle 2 **(Figure 3)**. Circle 1 intersects the bottom coil and Circle 2 intersects the top coil.

Then, based on the signal strengths received, the receiver calculates the distance from the bottom coil to the center of the two signal circles, shown below as D? **(Figure 4)**.

Figure 3

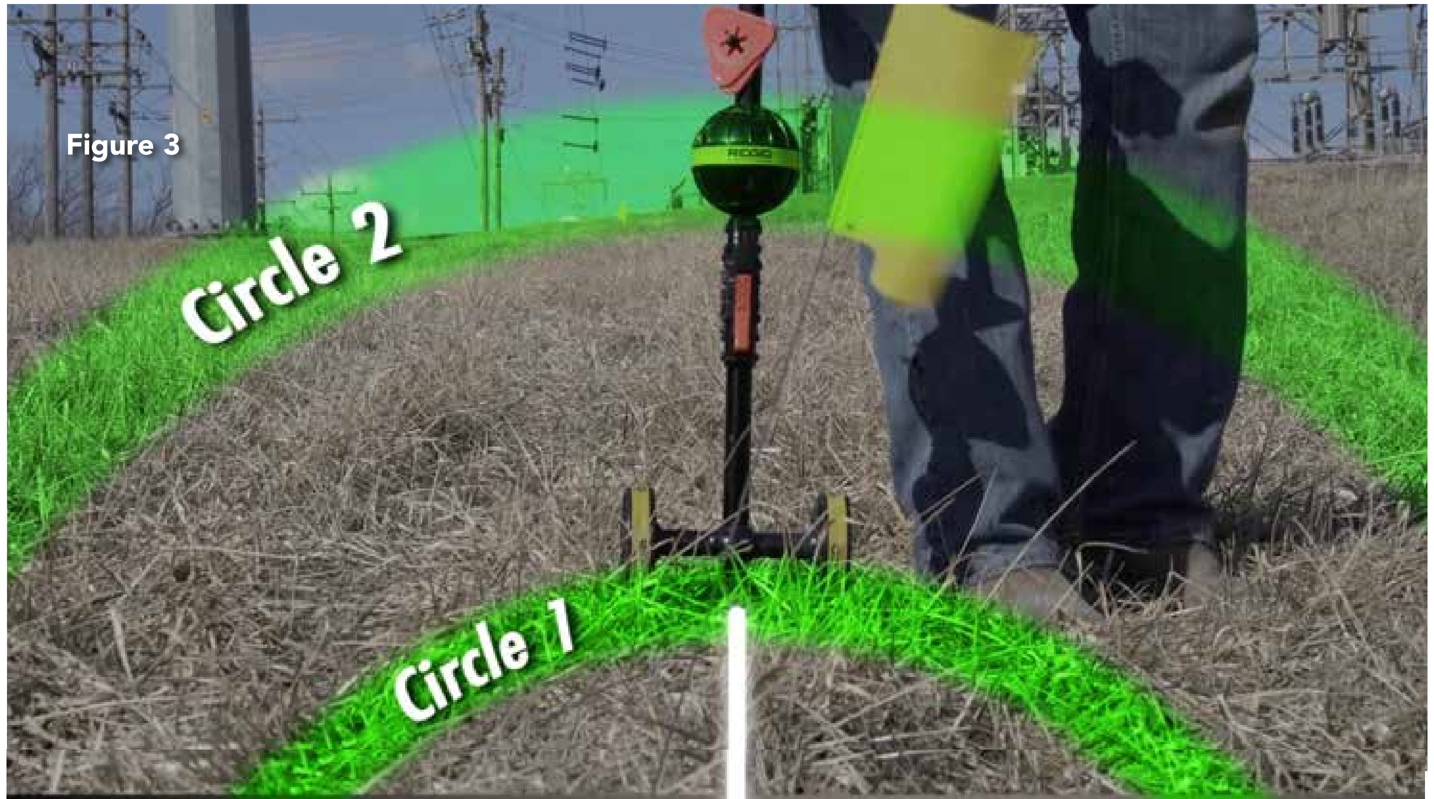
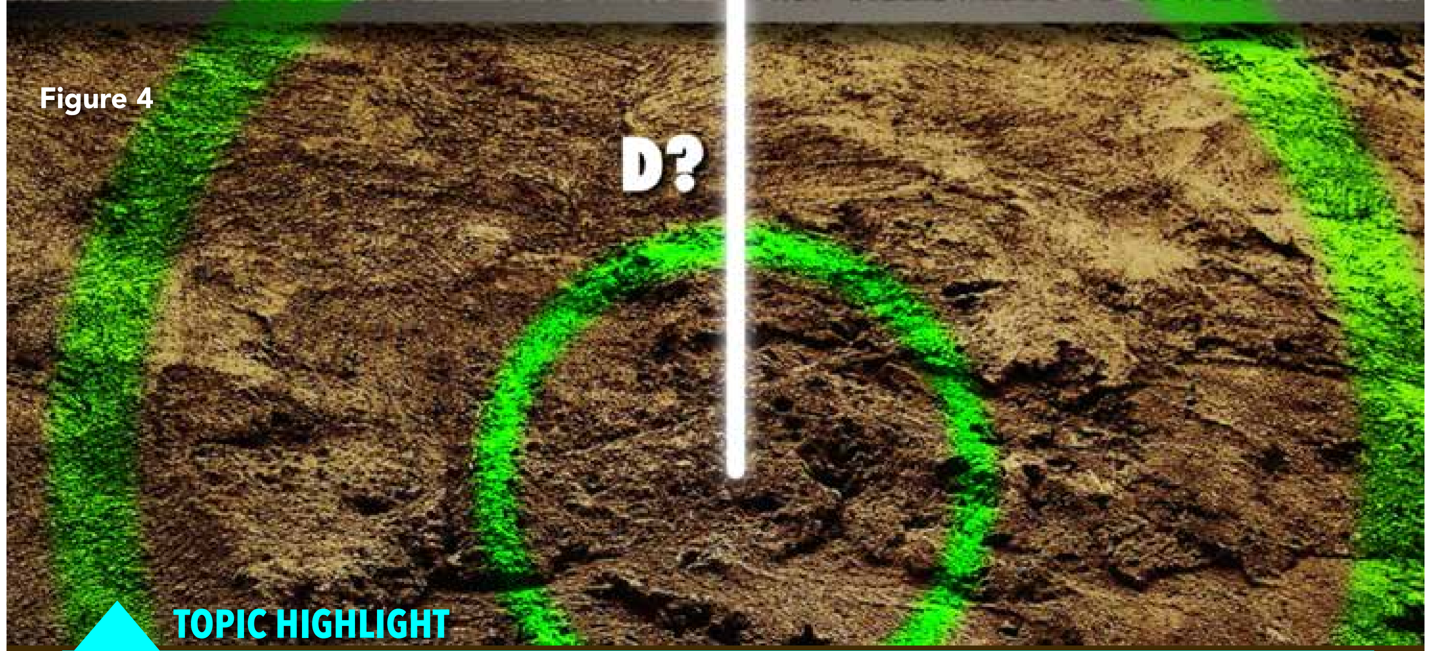


Figure 4



TOPIC HIGHLIGHT

This illustrates why a **receiver cannot determine the diameter of a pipe**. Whether the pipe is 6" or 18" in diameter, there will still be two signal circles that intersect the two coils above the ground. Depth calculates the distance from the bottom coil to the center of the two signal circles. Since the distance from the top of the pipe to the bottom coil cannot be determined, neither can the diameter be determined.

Digital Depth

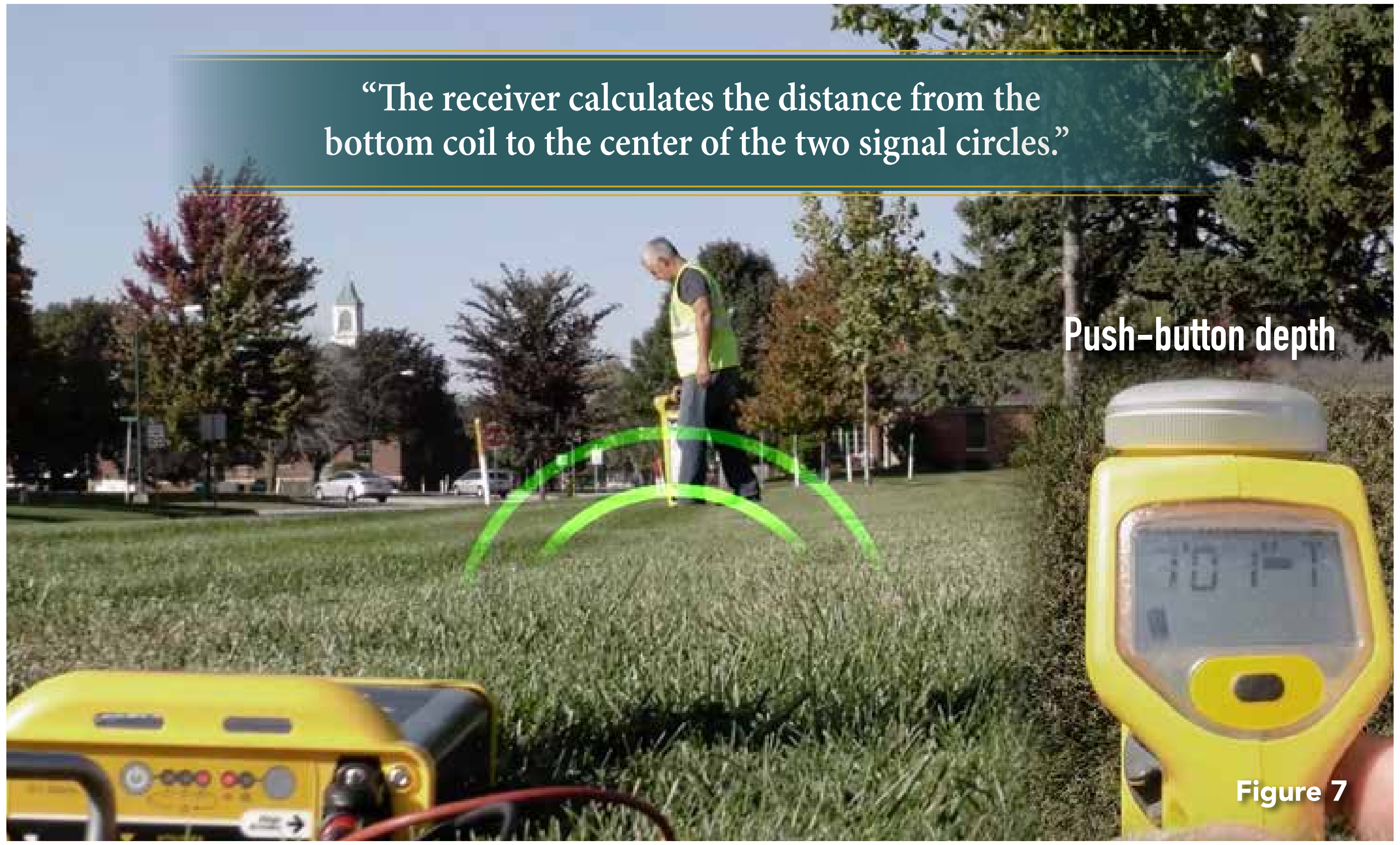
In **Figure 5** below, 5'4" is the depth to the center of Circle 1 and Circle 2. To obtain an accurate depth reading, the field must be round. Although the depth reading may be presented only when the receiver is within the field, most receivers display a constant digital depth reading. The receiver in **Figure 6** displays depth when the "tilted square" indicating a null response appears. Less expensive or older receivers may require the push of a button to display digital depth.


Figure 5

"To obtain an accurate depth reading, the field must be round."


Figure 6

Digital depth takes a look at two concentric circles: the circle that intersects the bottom antenna and the weaker circle that intersects the top antenna **(Figure 7)**.


"The receiver calculates the distance from the bottom coil to the center of the two signal circles."

Push-button depth

Figure 7

The bottom antenna housing and upper antenna housing are circled below. The coil windings must be tire-to-the-road **(Figure 8)**. Only when the field is round can depth readings be accurate. If peak and null responses agree, digital depth is more likely to be accurate. The more peak and null disagree, the more inaccurate the depth reading is.


Figure 8

Digital Depth

Does the transmitted frequency matter when it comes to getting a digital depth reading? Yes, because a particular frequency's ability to energize nearby lines will impact the accuracy of digital depth readings. Here, with identical circumstances, there is a two-inch difference between 512 Hz and 8 kHz, which is a 6% difference in depth readings **(Figures 9-10)**.

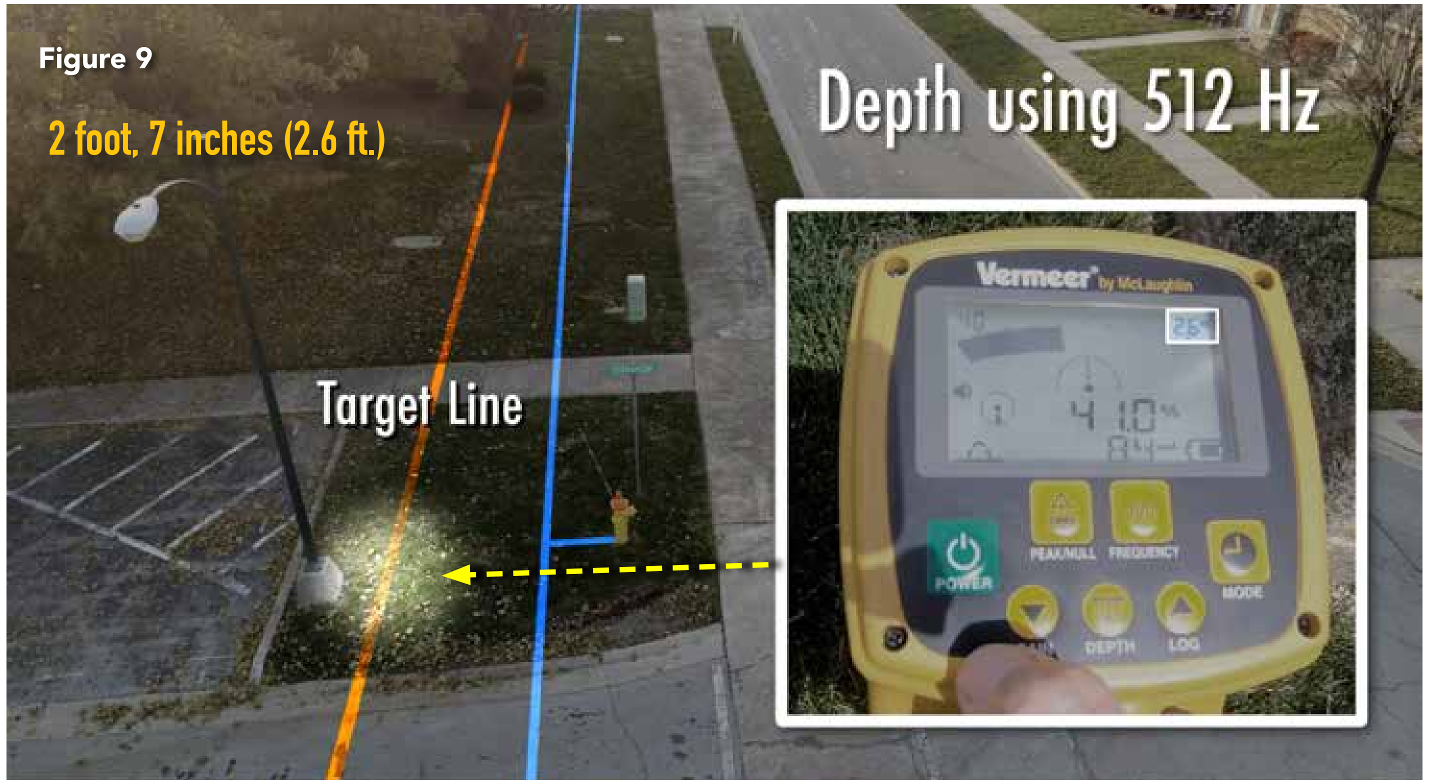


Figure 9

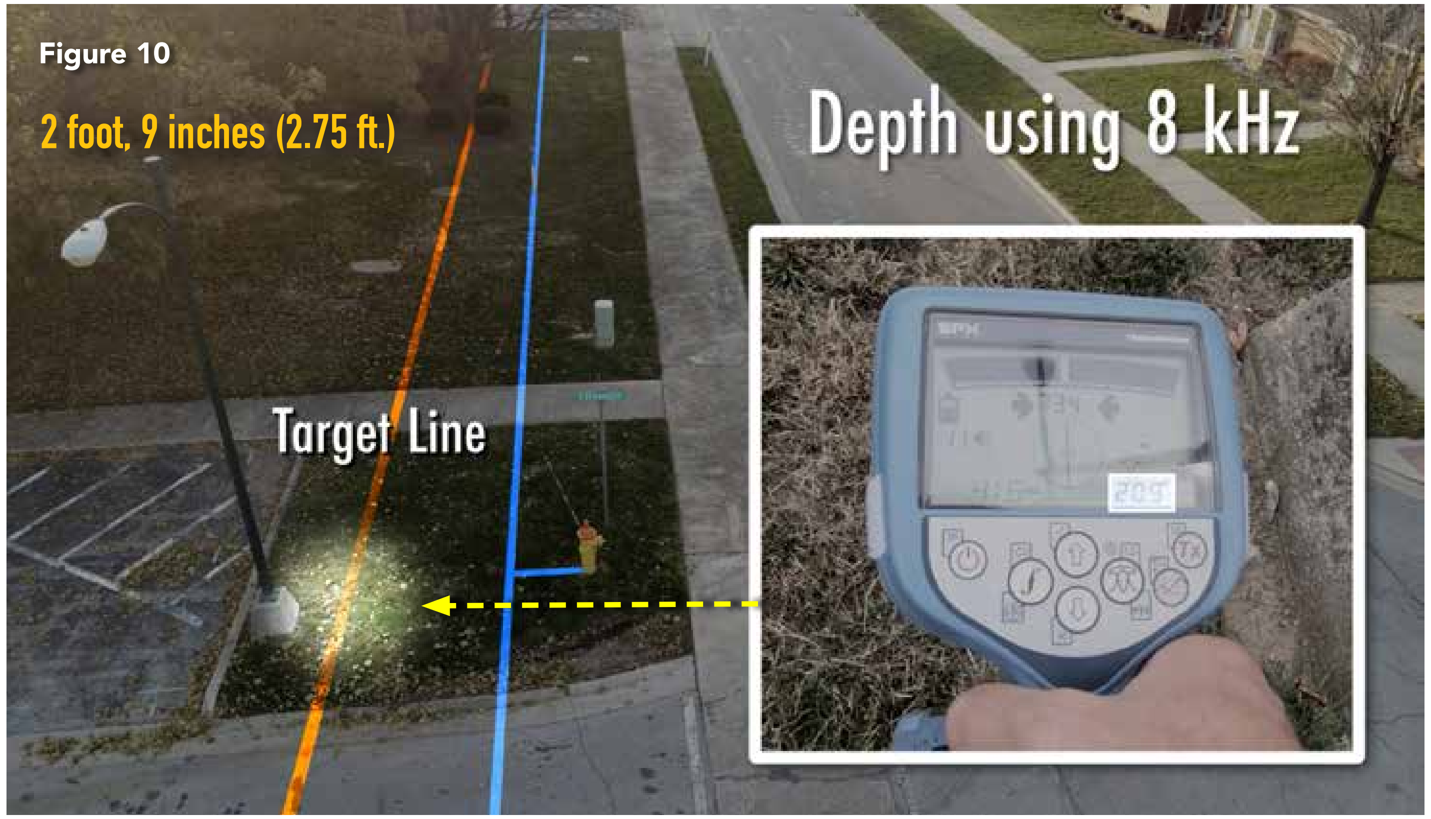


Figure 10

In the case of an energized three-phase electric line, there are actually three fields coming from three cables that intersect at the stacked-peak antennas. It is more difficult to get an accurate depth on a three-phase cable than a single conductor **(Figure 11)**.


Figure 11

A measurement to the top of the pipe is not what the digital depth is giving you **(Figure 12)**. It is giving you the center of two circles: the circle that intersects the bottom antenna and the weaker circle that intersects the top antenna. These circles are parts of the electromagnetic field which gets weaker as the distance becomes greater from the energized conductor.

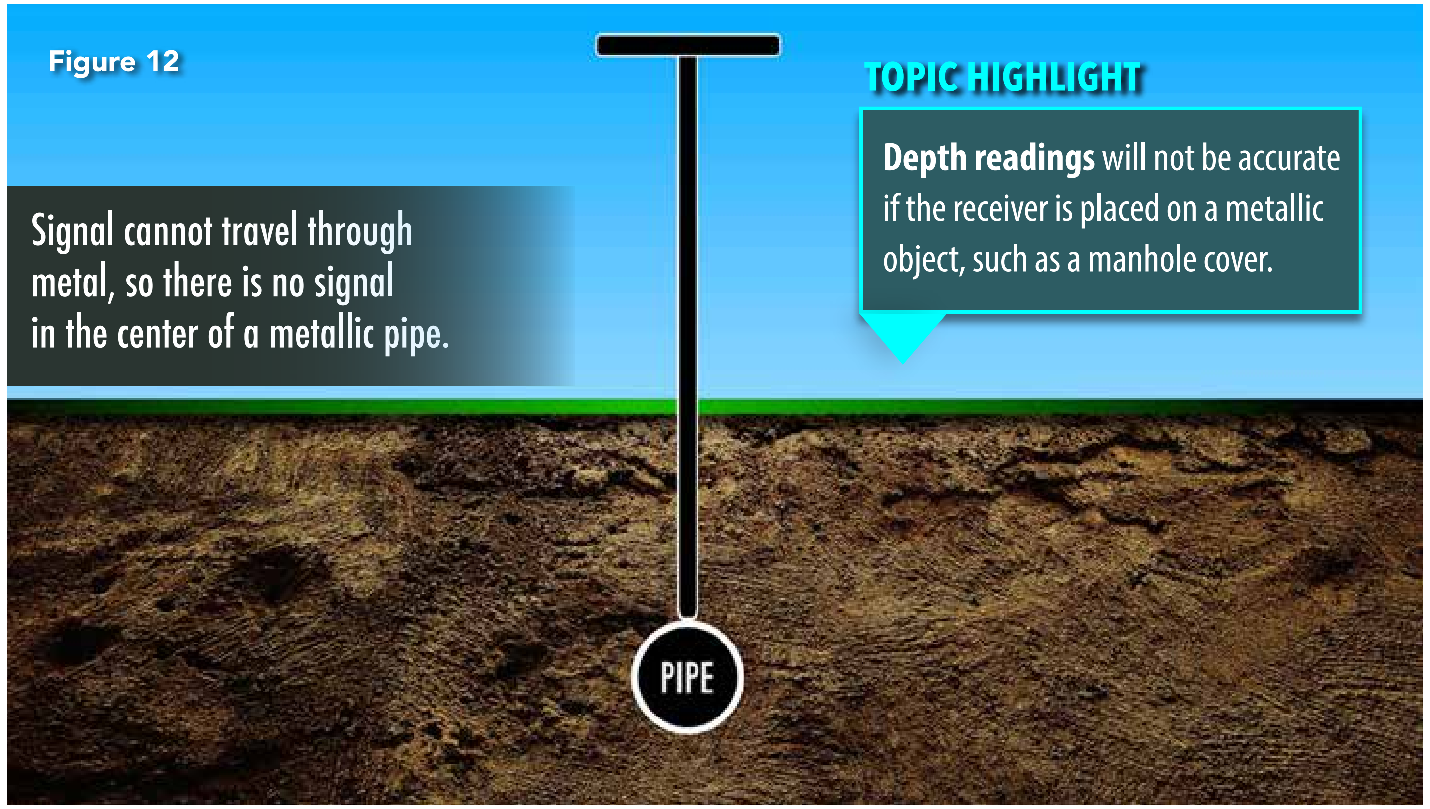


Figure 12

TOPIC HIGHLIGHT

Depth readings will not be accurate if the receiver is placed on a metallic object, such as a manhole cover.

Digital Depth

Notice how the digital depth becomes shallower as the receiver is moved toward the target line (**Figures 13-14**). When you are situated away from the target line with the receiver, you'll see an exaggerated, deeper than actual depth reading.

But as you approach your energized target line, your depth readings are the shallowest when you're on top of your line and will become exaggerated once more as you move away from the target line in the opposite direction.


Figure 13


Figure 14

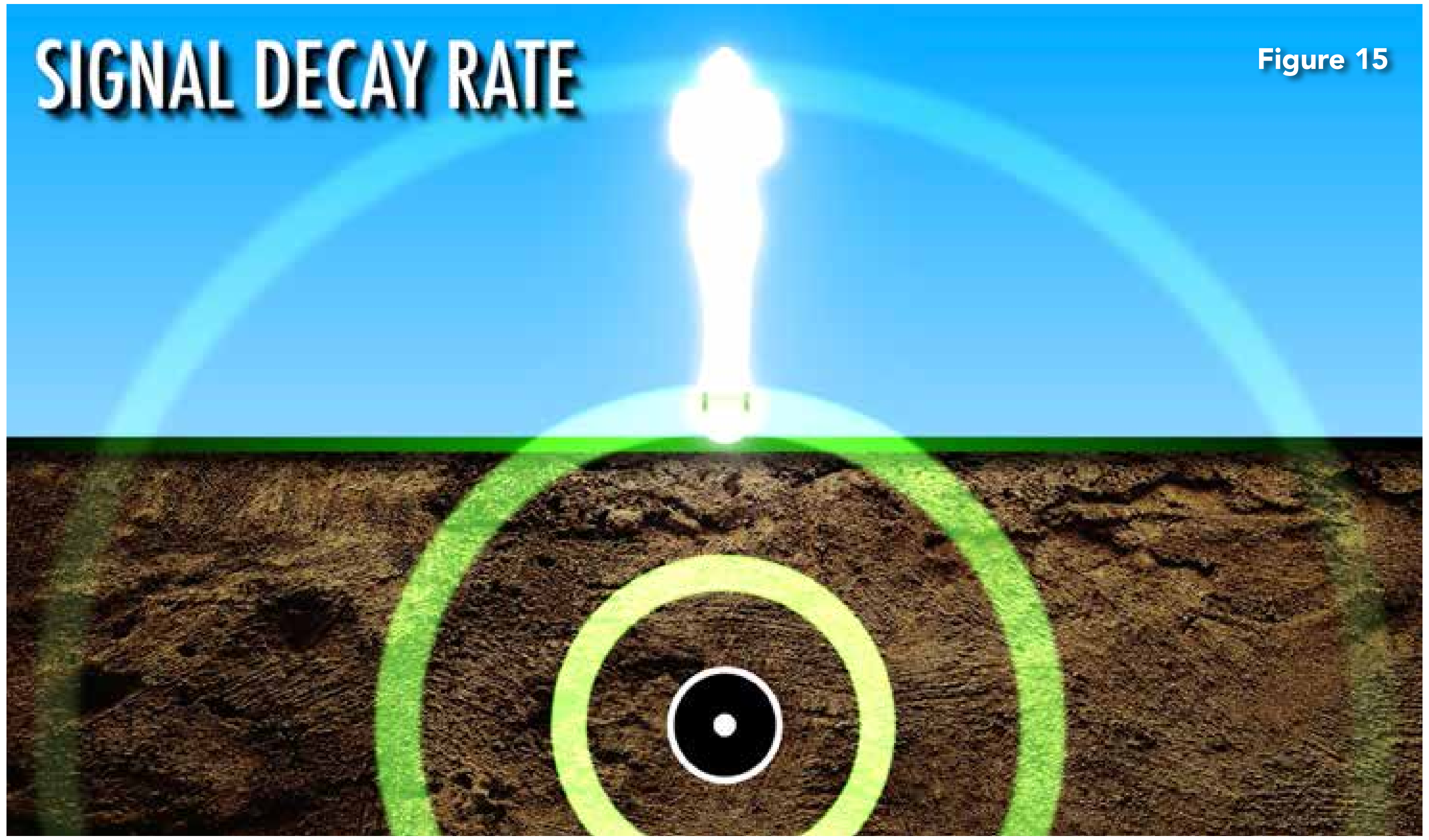


Figure 15

At a particular distance above an energized target line, the receiver's antenna receives a certain signal strength. If the antenna was raised into the air to a height that would double the original distance above the energized utility, the strength of the received field at this new height would be 25% of the original strength of the received field. This is known as an inverse square rule (**Figures 15-16**). And it doesn't matter what the frequency is, all radio waves will do this: double the distance, and you receive one-fourth of the original signal strength.

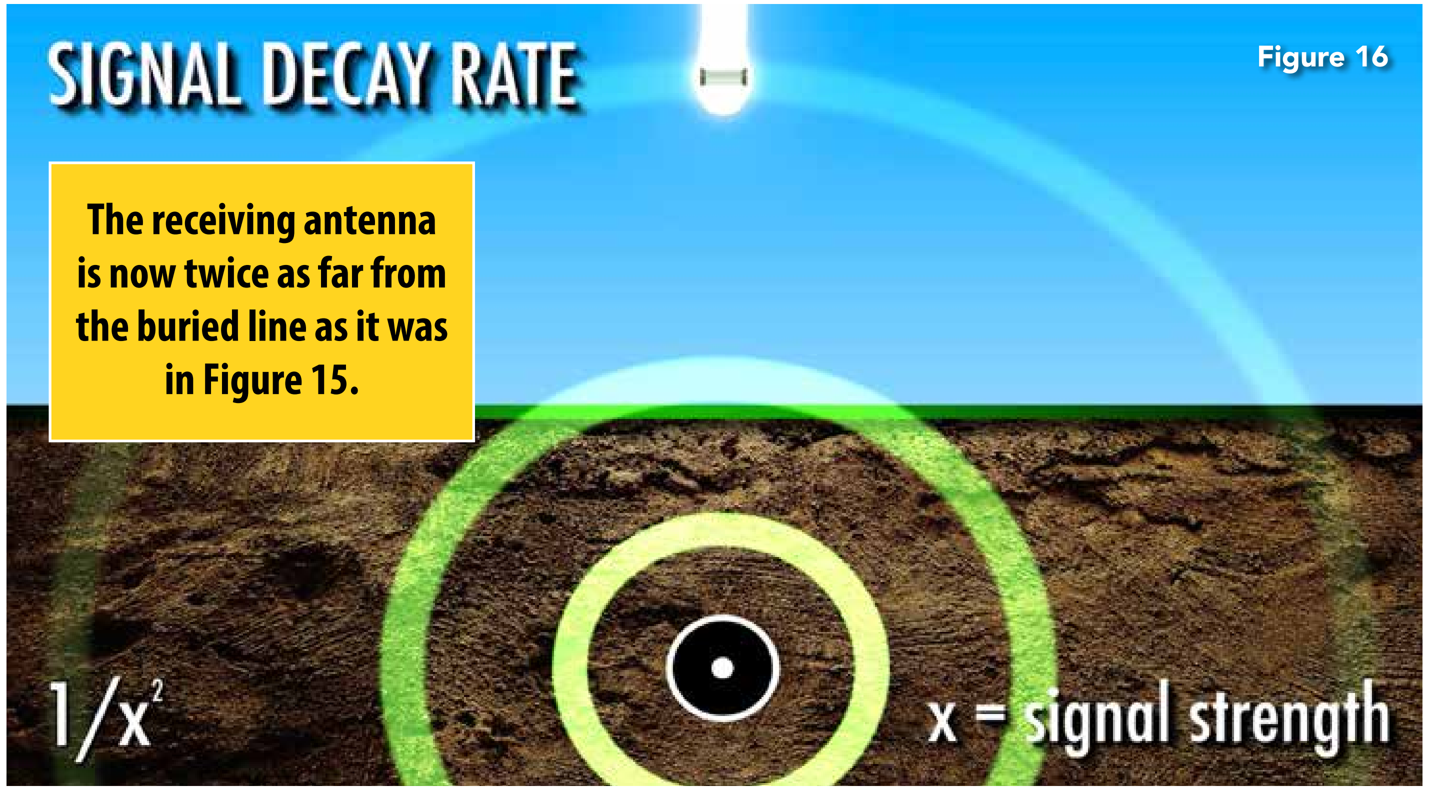


Figure 16

The receiving antenna is now twice as far from the buried line as it was in Figure 15.

Digital Depth

A digital depth reading takes into account four quantifiable knowns: (1) the signal strength on the bottom coil, (2) the signal strength on the top coil, (3) the distance between the coils (D1), and (4) the rate of decay **(Figures 17-18)**.

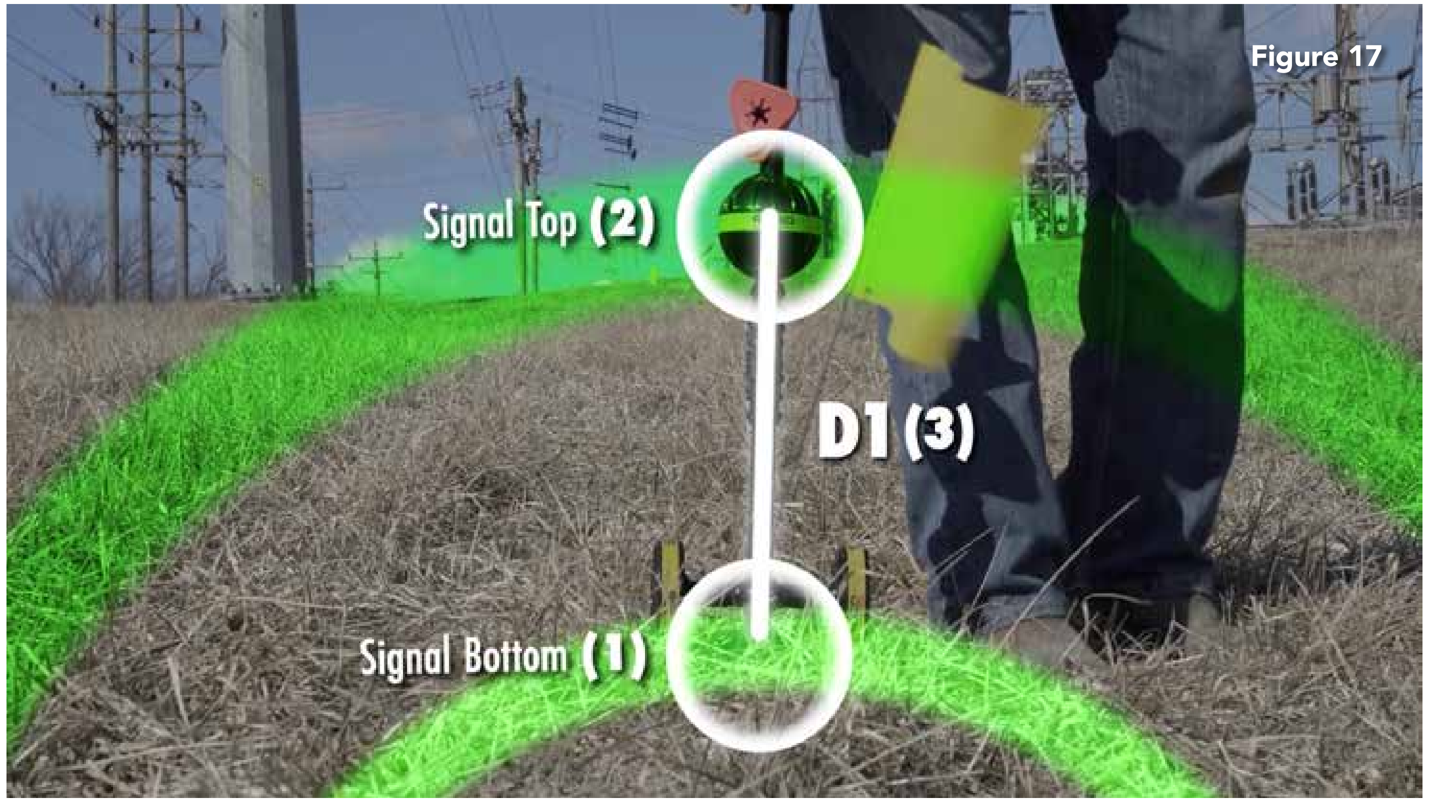


Figure 17

Figure 18

With these four knowns, we're able to calculate the one unknown we're after, which is the distance from the bottom antenna to the center of two circles—D2, the digital depth **(Figure 19)**.

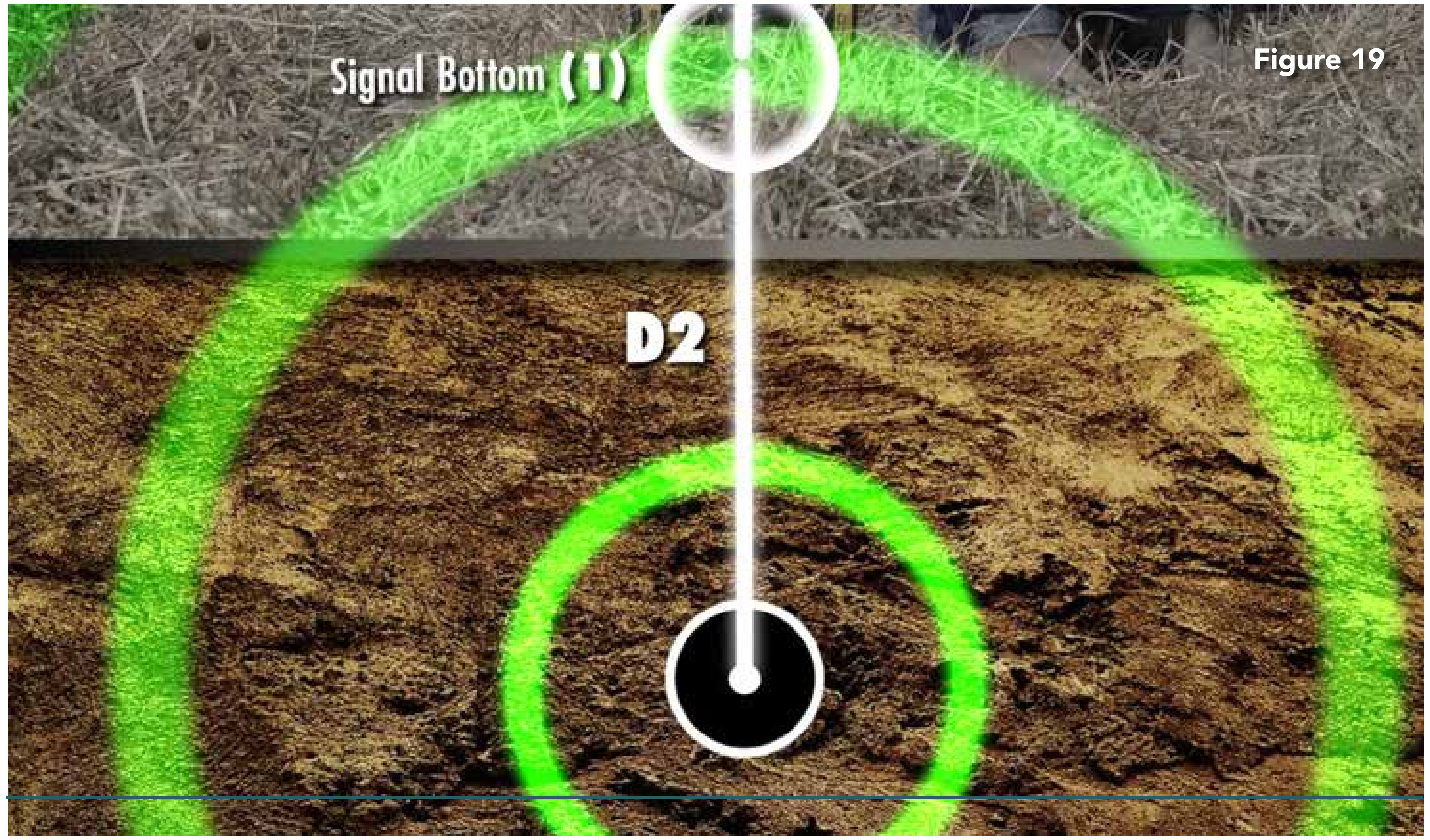


Figure 19

TOPIC HIGHLIGHT

A **depth reading** results from "stacked" signal strength readings taken from stacked-peak antennas. Current measurement readings, or receiver milliamp readings, are determined by comparing signal strength to depth.

Figure 20

Horizontal Inspection of Field

A single target line is energized at an access point **(Figure 21)** and signal travels northbound to the next above-ground structure **(Figure 22)**. At this structure, the target line is connected to a number of other lines. One of these lines travels south back toward the access point. At the receiver's location, the transmitter's signal is flowing in opposite directions.

Although alternating current flows in two directions on energized lines, it doesn't flow in two directions at once. Taking a hypothetical snapshot in time, the direction which current flows on two energized lines can be identified. In this case, current flows in opposite directions **(Figure 23)**. The snapshot in time is looking at current flow in the "half-cycle."

This image **(Figure 24)** shows a lot more current on the northbound cable (90) than the southbound cable (10). This is because the signal splits in multiple directions on multiple cables at the structure seen in Figure 22.

In all of these images, the operator is holding the receiver at a forty-five degree angle to the sides of the target line **(Figures 21, 23, 25)**. This process is horizontal inspection of the electromagnetic field and checking the field in this manner can provide important information, such as depth estimates and identification of other energized buried lines in the nearby vicinity of the receiver.

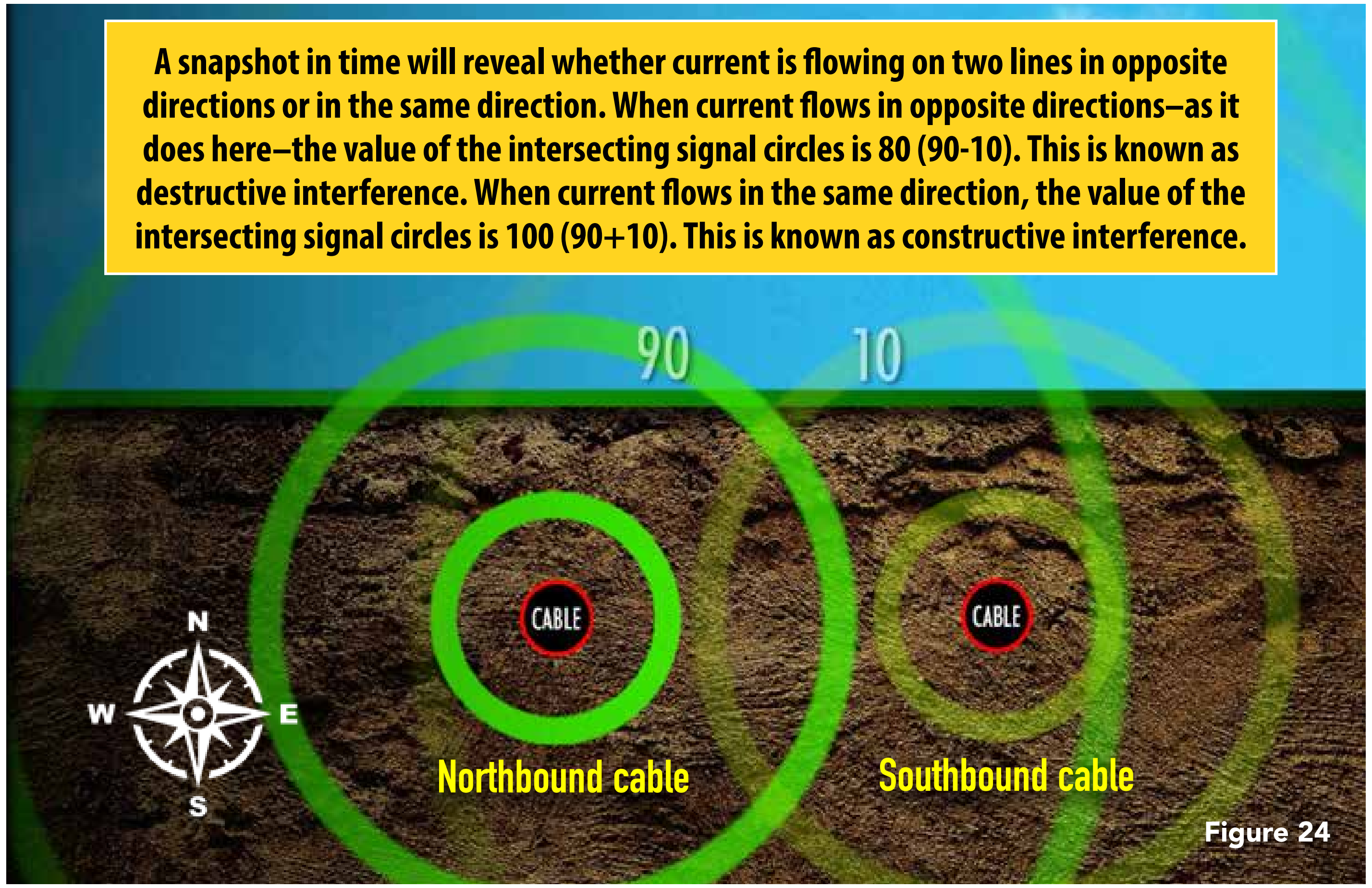
TOPIC HIGHLIGHT

There are two ways signal can energize a non-target line: 1) through a metallic connection between lines and 2) through the earth.

Figure 21

Figure 22

Figure 23



A snapshot in time will reveal whether current is flowing on two lines in opposite directions or in the same direction. When current flows in opposite directions–as it does here–the value of the intersecting signal circles is 80 (90-10). This is known as destructive interference. When current flows in the same direction, the value of the intersecting signal circles is 100 (90+10). This is known as constructive interference.

Figure 24

The operator is moving the receiver away from the target line, performing half the method known as "triangulation" to determine field shape.

Figure 25

Horizontal Inspection of Field

With the bottom of the receiver still positioned at the initial null reading **(Figure 26)**, the receiver is tilted at a 45-degree angle, eliminating the null response. The receiver is then dragged perpendicularly to the target line until a second null occurs **(Figure 27)**.

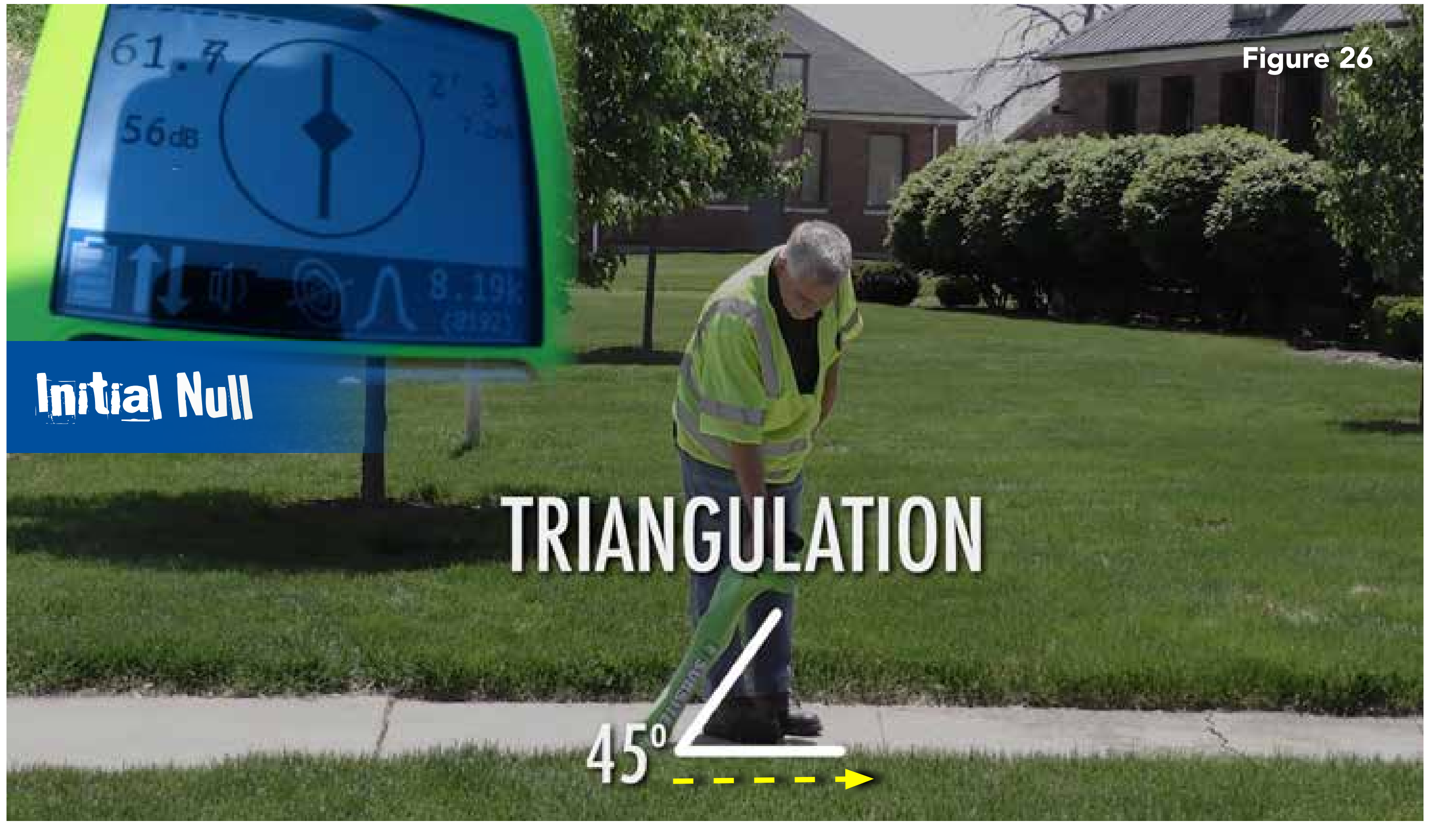
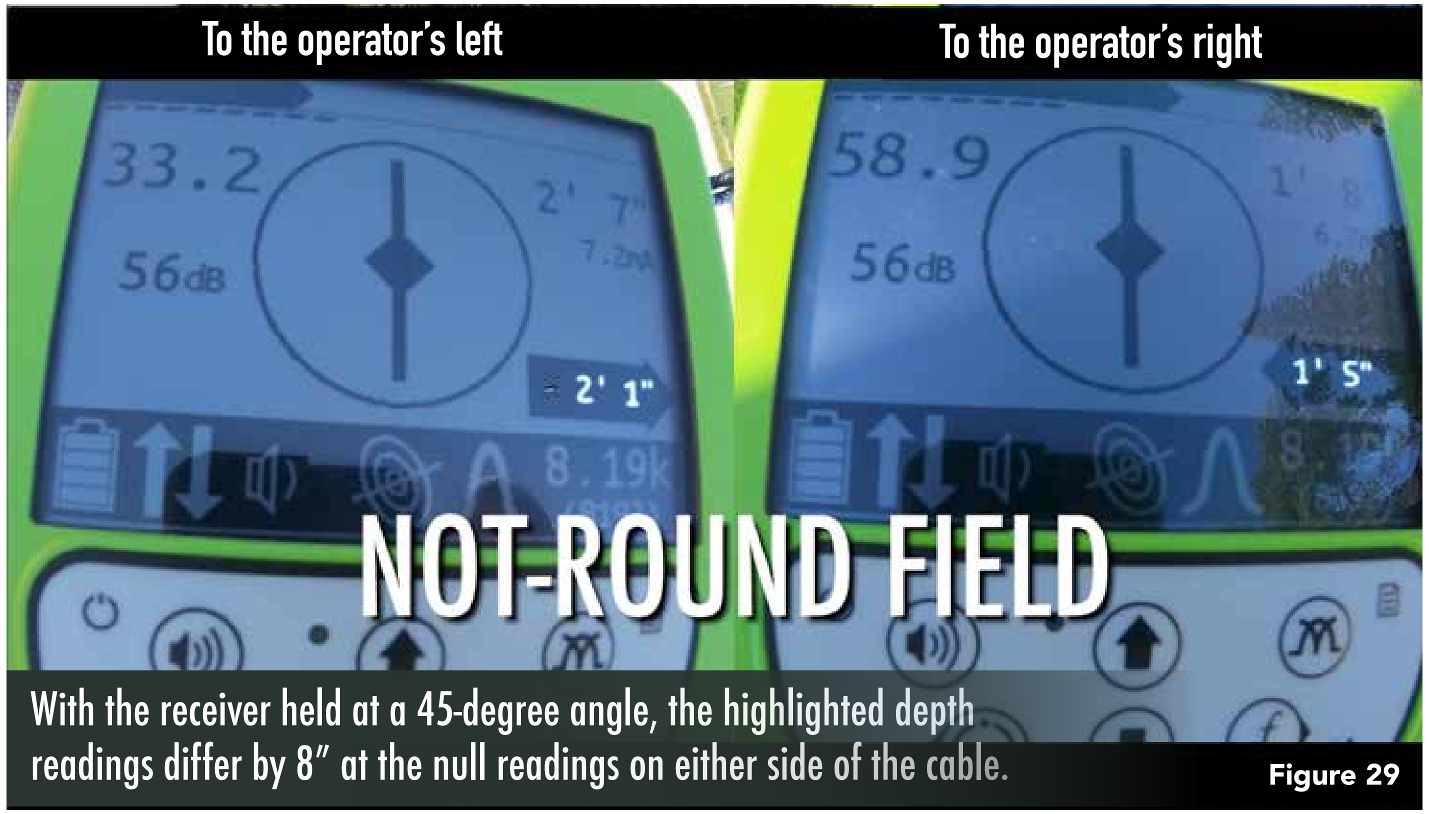


Figure 26

Figure 27

Figure 28

Next, the tilting and dragging of the receiver is done on the other side of the cable. If our signal is round, we'll see that the distance we drag our receiver away from the original locate is the same on both sides. In this case, we do not get the same distance, so by utilizing triangulation, we've determined that our field is not-round **(Figure 28)**. And if there are no metallic conductors above the ground, that means for sure there are other metallic conductors below the ground. When current is flowing in opposite directions on two parallel lines, the shorter distance indicates the direction to the interfering line.



With the receiver held at a 45-degree angle, the highlighted depth readings differ by 8" at the null readings on either side of the cable.

Figure 29

Horizontal Inspection of Field

We're locating a cable TV feeder line, and we're going to see if our field received is round or not-round. We'll start with triangulation. Using our null locate to begin with, we place the instrument at a 45-degree angle and drag in a perpendicular fashion away from our null locate (**Figure 30**). We mark that spot, and then we go back to our original null locate, repeating the process but in the opposite direction, with the receiver again held at a 45-degree angle.

Triangulation

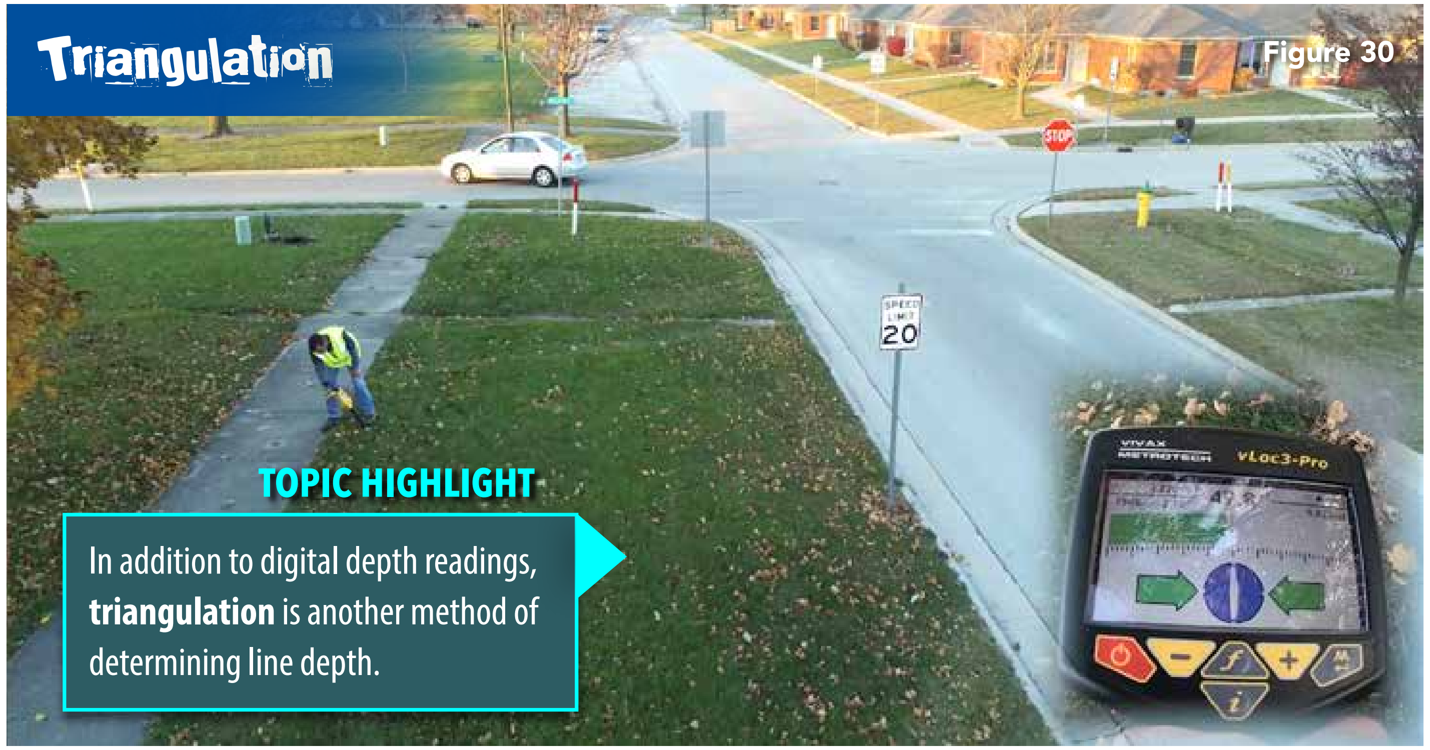


Figure 30

TOPIC HIGHLIGHT

In addition to digital depth readings, **triangulation** is another method of determining line depth.

"The formula for triangulation assumes the ground is flat and that the receiver is always held at a 45-degree angle."

Figure 31

Next, we mark the second null **(Figure 31),** and then we compare the two distances on each side of the null locate. If they are the same, the field is round. Triangulation results cannot provide a depth estimate unless the instrument is held at a 45-degree angle. However, as long as the angle is the same on both sides, any angle can be used for checking field shape. But only a receiver held at a 45-degree angle on flat ground provides a depth estimate **(Figure 32)**.

Figure 32

The formula for triangulation assumes the ground is flat and that the receiver is always held at a 45-degree angle. Triangulation involves all three angles of a triangle **(Figure 33)**: 1) The original null on flat ground creates a 90-degree angle, 2) tilting the receiver creates a 45-degree angle, and 3) the remaining angle must then be 45-degrees since the interior angles of a triangle equal 180 degrees. These angles represent what is called a right triangle, where both legs of the triangle are the same distance.

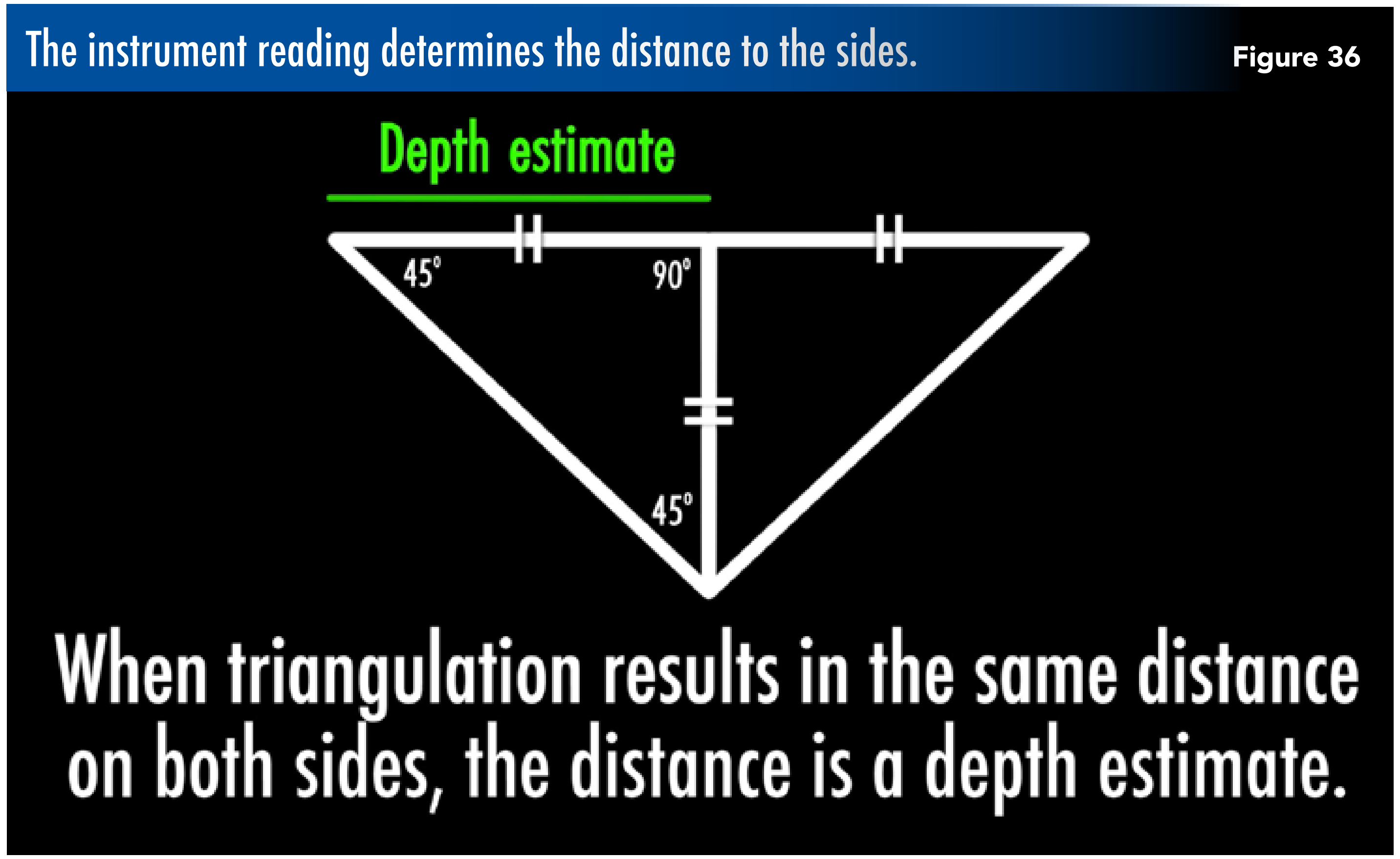
Figure 33

Horizontal Inspection of Field

The straddle test is the second method of horizontally checking the shape of the electromagnetic field. Signal flowing on a non-target line on either side of the target line will create a difference in peak readings when checking either side of the line. Here, a 36.1 peak reading **(Figure 34)** on one side of the target line and a 22.1 peak reading **(Figure 35)** on the other indicates a not-round field. Unlike triangulation **(Figure 36)**, the straddle test is not capable of providing a depth estimate.

Figure 34

Figure 35



The instrument reading determines the distance to the sides.

Figure 36

When triangulation results in the same distance on both sides, the distance is a depth estimate.

The operator determines the distance to the sides.

Figure 37

Unlike triangulation, where the instrument is used to determine distances, the straddle test is performed by putting our feet on either side of our locate the same distance away and then checking the peak readings at our toes **(Figure 37)**. We're keeping the distance the same and then seeing if we have the same or different peak readings at our toes. If the peak readings are different, the field is not-round. The larger the difference between the peak readings the greater the degree of bleed-off.

Horizontal Inspection of Field

The use of induction doesn't necessarily result in significant bleed-off. Bleed-off, the transfer of signal from one line to another, is dependent on soil type and soil moisture as well as a host of other factors. Here, the transmitter is placed over a cable TV feeder using a frequency of 38 kHz **(Figure 38)**. Parallel and four feet away from the cable TV line is a 2″ steel gas main **(Figure 39)**.

Figure 38

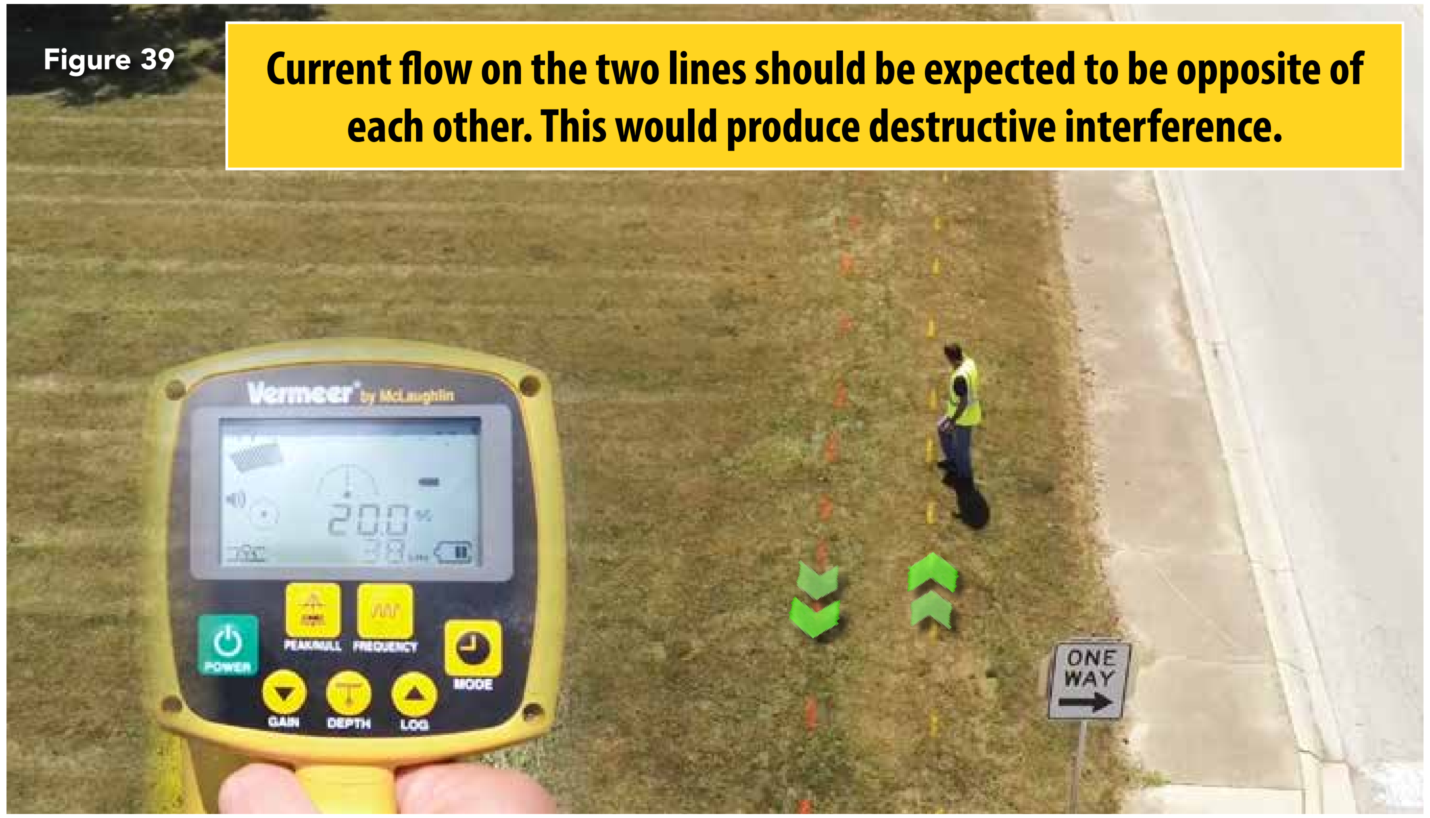


Figure 39

Current flow on the two lines should be expected to be opposite of each other. This would produce destructive interference.

Peak and null agree

Figure 40

The gas main doesn't have enough signal flowing on it to prevent peak and null from agreeing over the cable TV line **(Figure 40)**. But a straddle test indicates the presence of another buried line due to the side peak reading differences **(Figure 41)**. However, just because we have a nearby line doesn't necessarily mean that the straddle test is going to indicate that we have a nearby line. It depends on whether the nearby line has current flowing on it or not.

Straddle test

Figure 41

The 66.6 peak reading is the result of destructive interference.

Analyze

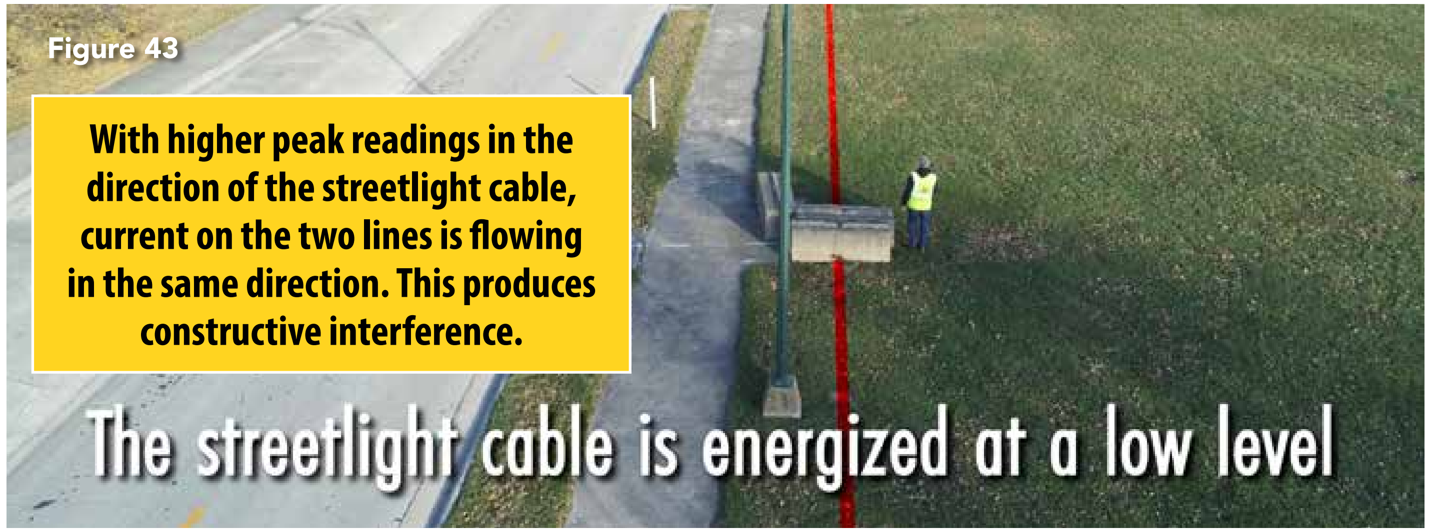
Horizontal Inspection of Field

The straddle test can be performed while moving, as long as the instrument is swung the same distance to both sides. To the operator's left, the peak readings are in the high 20s and low 30s. To the operator's right, the peak readings are in the teens **(Figures 42-44)**. An audible peak tone can alert the operator to an imbalance of peak readings without the need to look at the receiver display while walking and locating.

Figure 42

The operator is locating a water line on 512 Hz.

Figure 43



With higher peak readings in the direction of the streetlight cable, current on the two lines is flowing in the same direction. This produces constructive interference.

The streetlight cable is energized at a low level

Figure 44

Vertical inspection of the electromagnetic field can show round, while horizontal inspection of the same field can show not-round. The locate can be accurate AND you can learn there is a nearby line.

The water line locate is accurate

Vertical Inspection of Field

TOPIC HIGHLIGHT

A round field is indicated when the highest number (peak) occurs at the same location on the ground as two inward pointing arrows (null).

TOPIC HIGHLIGHT

A **not-round field** is indicated when the highest number (peak) occurs at a different location on the ground as two inward pointing arrows (null).

TOPIC HIGHLIGHT

A round field is indicated when the receiver is lifted straight up a certain distance above the line, such as 8", and the resulting depth reading adds 8" to what the reading was when the receiver was on the ground.

TOPIC HIGHLIGHT

A not-round field is indicated when the receiver is lifted straight up a certain distance above the line, such as 8", and the resulting depth reading does not add 8" to what the reading was when the receiver was on the ground.

TOPIC HIGHLIGHT

If the vertical inspection of field indicates "round," the target line location is extremely likely to be accurate. This includes times when vertical inspection indicates "round" but horizontal inspection indicates "not-round."

Analyze

Current Measurement vs. Current Flow

This is a conductive locate using 4 kHz with a transmitter output of 35 mA. The mA reading on the transmitter—the current flow reading—is a real measurement of current flow leaving the transmitter **(Figure 45)**. The current measurement reading on the receiver **(Figure 46)** is an estimate of current on the target line. Current cannot travel though air.

Figure 45

Figure 46

We're going to take the far-end ground off of the cable that we're locating. Observe what happens to the 93.2 peak reading and the 4.94 mA current measurement reading **(Figure 47)**. Both are significantly reduced by removing the cable's far-end ground, but the digital depth does not change **(Figure 48)**.

Figure 47

Figure 48

Changing the grounding of the target line is one of the ways to change the level of current flow on the line. This exercise allows us to estimate that the far-end ground of the cable is responsible for about 1.72 mA of current using a 4 kHz signal (4.94-3.22).

Analyze

Current Measurement vs. Current Flow

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Current measurement (mA) is raw signal strength factored by depth. On most receivers, the operator will not see raw signal strength on the display. Raw signal strength cannot be adjusted by manual or automatic gain. The signal strength number on nearly all receivers can be adjusted by gain.

If raw signal strength does not drop, the current measurement reading does not drop. This is what we see in **Figure 49**. When gain was used to reduce the displayed signal strength from 73.2 to 52.1, the 114 mA current measurement reading did not change.


Figure 49

Utilizing the same gain setting (27), this receiver is held over two different lines on opposite sides of a street. Both fields are round and the line that is deeper has a higher peak reading.

Figure 50

Depth and current measurement readings are calculated using the same stacked-peak antennas in the receiver. The purpose of current measurement readings is to help distinguish between peak readings on target lines versus peak readings on non-target lines (**Figure 51**). But it's important to understand that just like depth readings, current measurement readings can range from good estimates to really poor estimates.

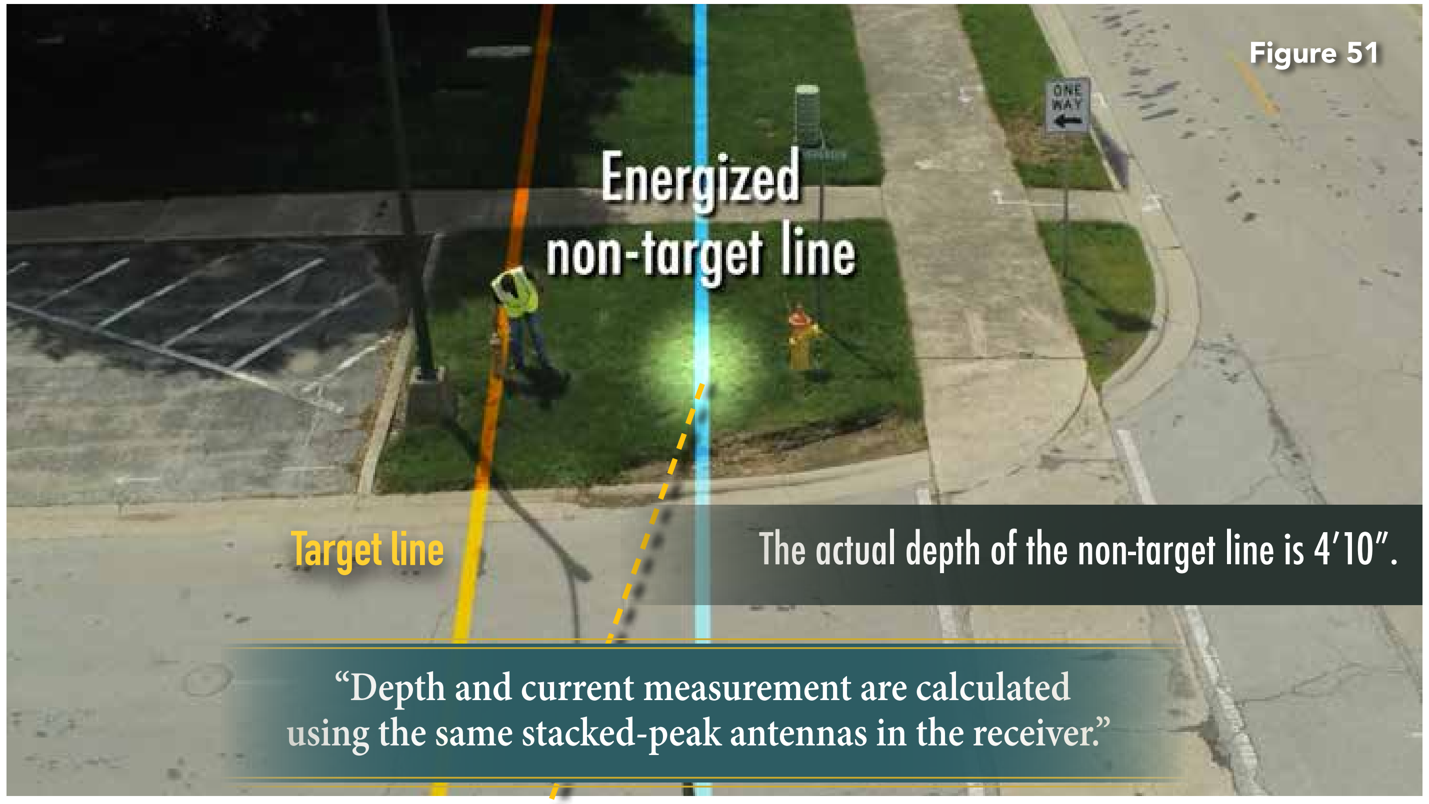


Figure 51

The actual depth of the non-target line is 4′10″.

"Depth and current measurement are calculated using the same stacked-peak antennas in the receiver."

In **Figure 52**, the gain setting is the same (40) over both the target line and the non-target line. The current measurement reading over the target line is over eight times greater than over the non-target line. However, the depth reading .5 feet (6") over the non-target line is wildly inaccurate when compared to the actual depth of 4′10". This means that the current measurement reading of 1 mA is also wildly inaccurate.

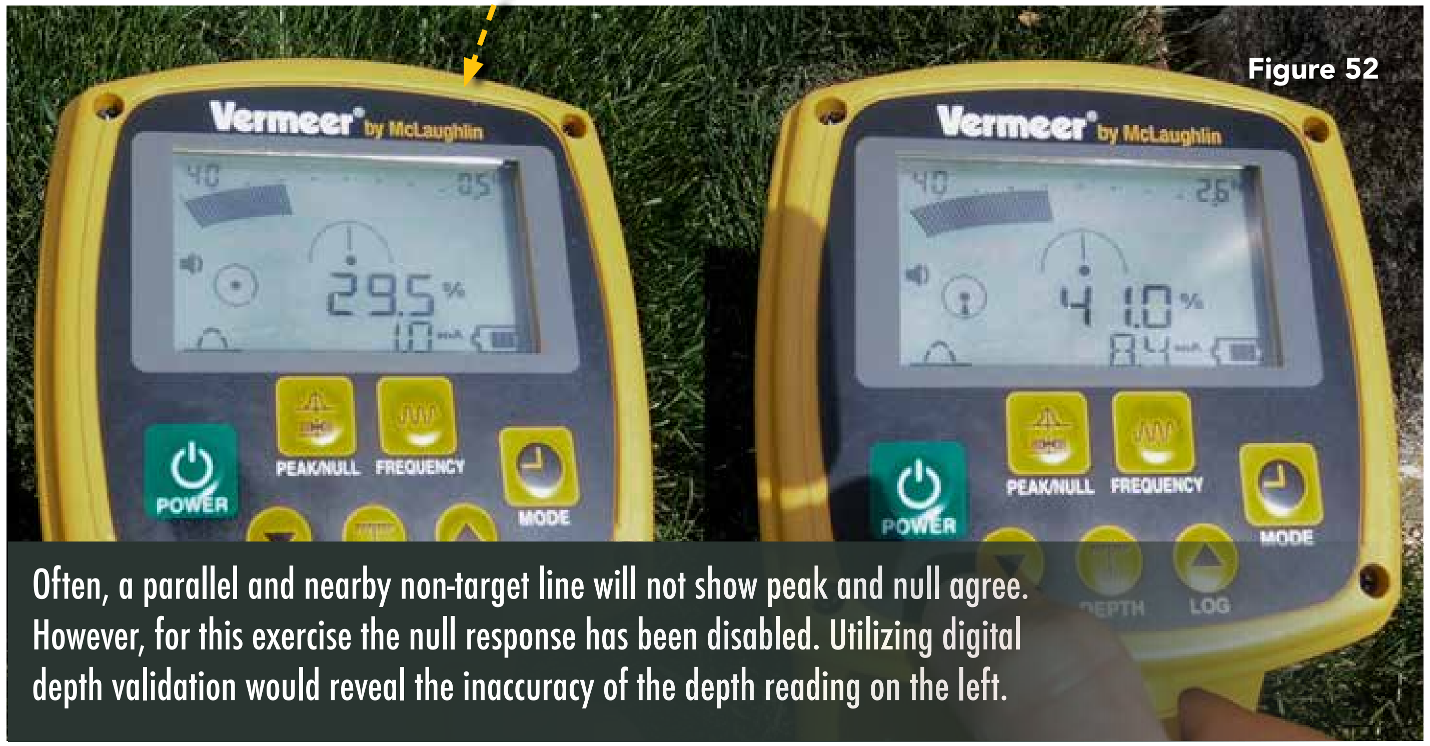


Figure 52

Often, a parallel and nearby non-target line will not show peak and null agree. However, for this exercise the null response has been disabled. Utilizing digital depth validation would reveal the inaccuracy of the depth reading on the left.

Current Measurement vs. Current Flow

Figure 53

In **Figure 53**, the receiver is held over two different buried lines. The gain is set at a level of 27 over both lines. The photo on left indicates a signal strength of 57. 5 over a line 3.6′ deep. The photo on the right shows a signal strength of 46.8 over a line 2.9′ deep.

When you factor in the depth of the line, it's clear that there's more transmitter energy on the line with the higher signal strength. In **Figure 54**, the milliamp readings over the two lines are highlighted with the 7.5 mA reading over the target line and the 3.7 reading over a non-target line.

Figure 54

The milliamp readings...

...over the lines in Figure 54 are no surprise—the deeper line had a higher signal strength and a milliamp reading that was double the milliamp reading of the shallower line. Even without the milliamp reading it's clear which line was likely the target line. But it's important to note the signal strength displayed over the target line was only 23% higher (57.5) than the signal strength over the non-target line (46.8).

In this scenario, the gain setting of 27 is the same over both lines. Imagine what the signal strength difference would have been if the receiver over the non-target line was raised a distance of .7′ off the ground, matching the height over the target line (3.6′). This helps explain the information current measurement (mA) provides on the receiver—raw signal strength factored by depth.

The current measurement reading on a receiver does not directly measure current flow on an energized buried pipe or cable because current cannot travel through air. However, the reading is able to provide an estimate of the impact of depth on signal strength.

While milliamp readings can be useful, they should be utilized in unison with vertical and horizontal inspections of field shape.

Current Measurement vs. Current Flow


Figure 55

Current measurement, or the milliamp reading, is an estimate. It is signal strength factored by depth, whereas the current flow reading is a factual number, real milliamps, leaving the transmitter on a conductive locate. Hooked up to a test wire to a steel main **(Figure 55)**, the transmitter reads a current flow of 116 mA **(Figure 56)**. While current flow (mA) builds the fields we detect with the receiver, pipes and wires offer resistance to current flow. The resistance of this steel pipe is measured at 385 ohms.


Figure 56


Figure 57

If there is a relationship between the estimated current measurement reading and the real current flow reading, why is the milliamp reading on the receiver so much lower than what's on the transmitter **(Figure 57)**? The reason is that the steel gas main going to the west ties into two other mains that run for blocks and blocks. However, the steel main going east ends after traveling only 127 feet **(See map, Figure 65)**. Much less current will flow the 127 feet to the east than flows west toward much more steel pipe (**Figure 58**).

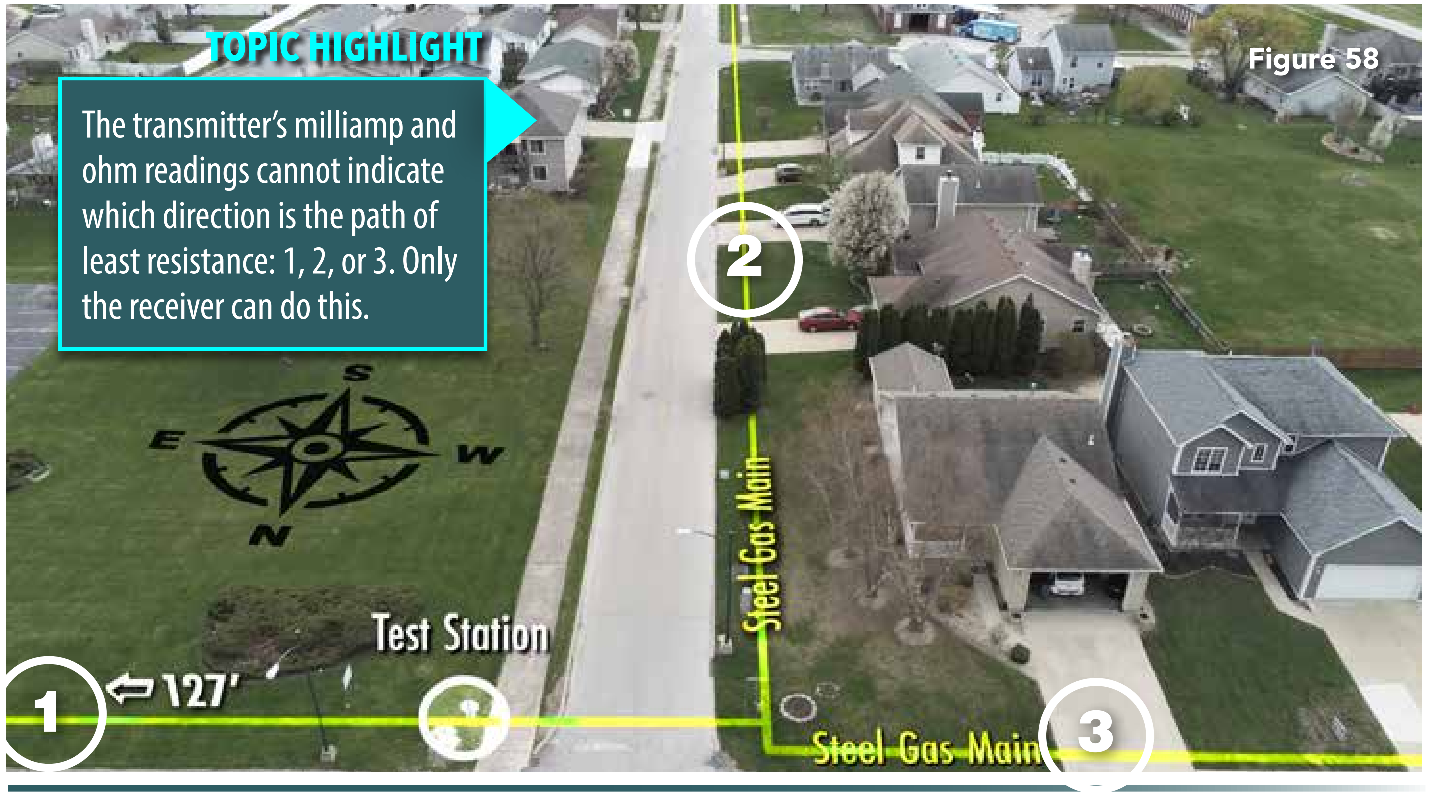


Figure 58

TOPIC HIGHLIGHT

The transmitter's milliamp and ohm readings cannot indicate which direction is the path of least resistance: 1, 2, or 3. Only the receiver can do this.

Analyze

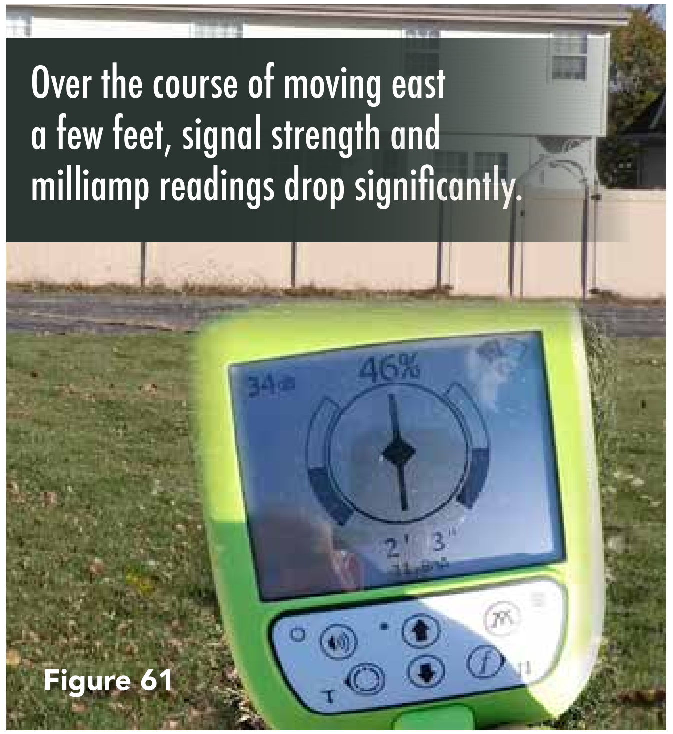
Current Measurement vs. Current Flow

Let's take a look at the milliamp readings as we move away from the transmitter. We have 18.2 mA with the signal strength at 72 (**Figure 59**). Farther east, we have a signal strength of 63 and 14.9 mA (**Figure 60**). We're approaching the end of the steel main. It's also a good idea to take a look at the depth, because the depth readings will alert us when we're past the end of the steel main (**Figure 61**).

As we locate eastward, depth readings are consistent as current measurement and signal strength readings gradually drift lower. Another few steps eastward, and depth gets deeper while signal strength and milliamps go lower (**Figure 62**). And now, we start to get a much deeper depth, along with continued lower milliamps and lower signal strength (**Figure 63**).

Figure 59

Figure 60



Over the course of moving east a few feet, signal strength and milliamp readings drop significantly.

Figure 61

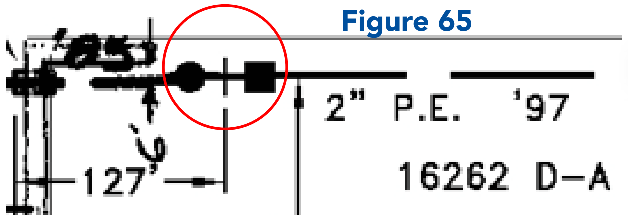
Figure 62

Figure 63

Let's back it up. Maybe we could find the exact end of the steel pipe. First, we're looking for an end to consistent depth readings. Secondly, we're looking for a spot where depth readings increase while signal strength and milliamp readings decrease. It's going to be hard to tell, because receiving antennas detect the field in an area that extends beyond the receiver, but this location is our estimate of where the end of the pipe is using all the information given to us (**Figure 64**).

Figure 64

Figure 65



TOPIC HIGHLIGHT

The exact ends of **metal pipes** are difficult to pinpoint because signal continues through earth beyond the end of the pipe.

Current Measurement vs. Current Flow

Although resistance on the target line is a factor, signal strength is always proportional to distance from the transmitter and the depth of the target line being located **(Figure 66)**. If we keep our eye on both the depth and the signal strength, we can then extract the same information that the milliamp reading is giving us, as long as the manual gain is not adjusted.

Figure 66

This is a 300-foot long tracer wire, and we're using a scaled down receiver, one that doesn't give us a digital signal strength reading **(Figure 67).** Instead, it gives us bar graphs, but we can still get depths in feet and inches up to 10'.

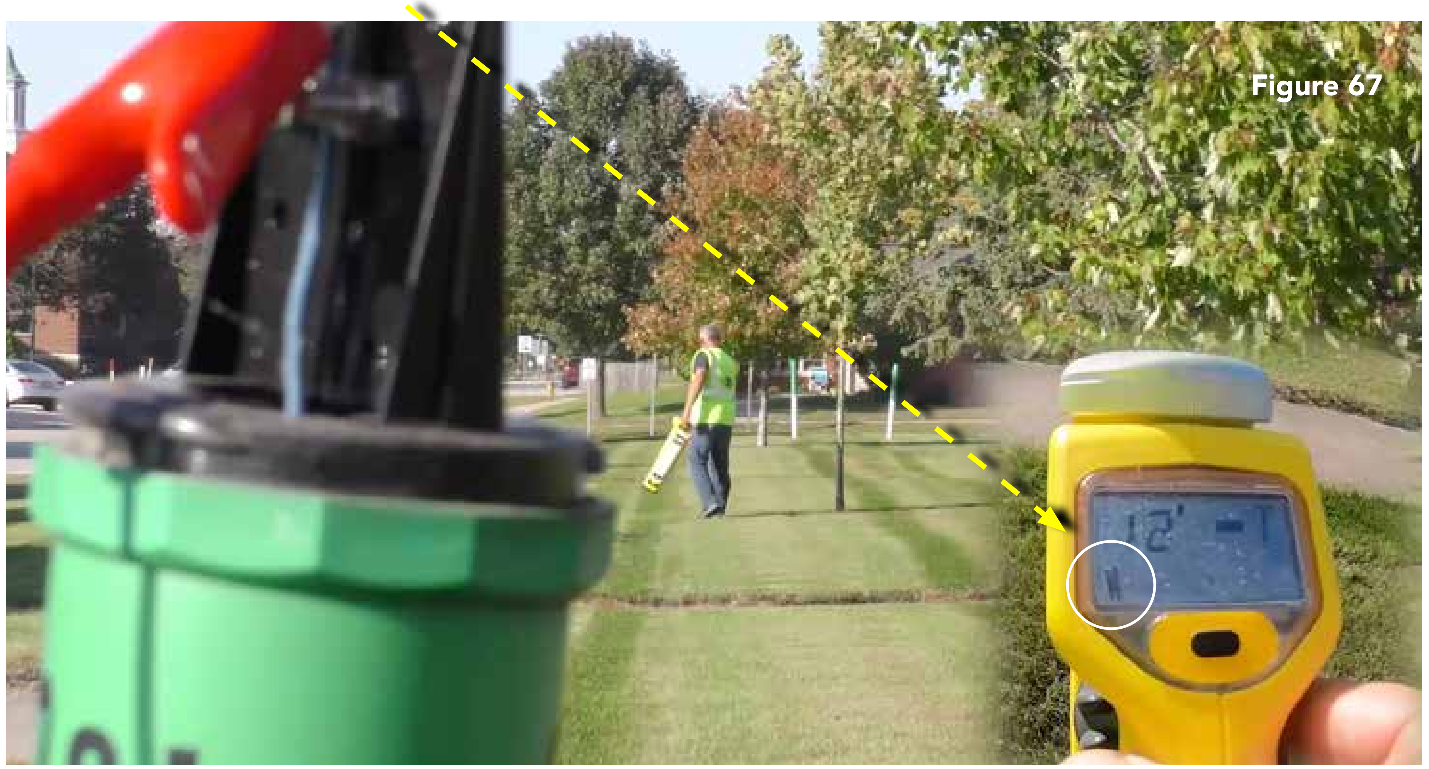
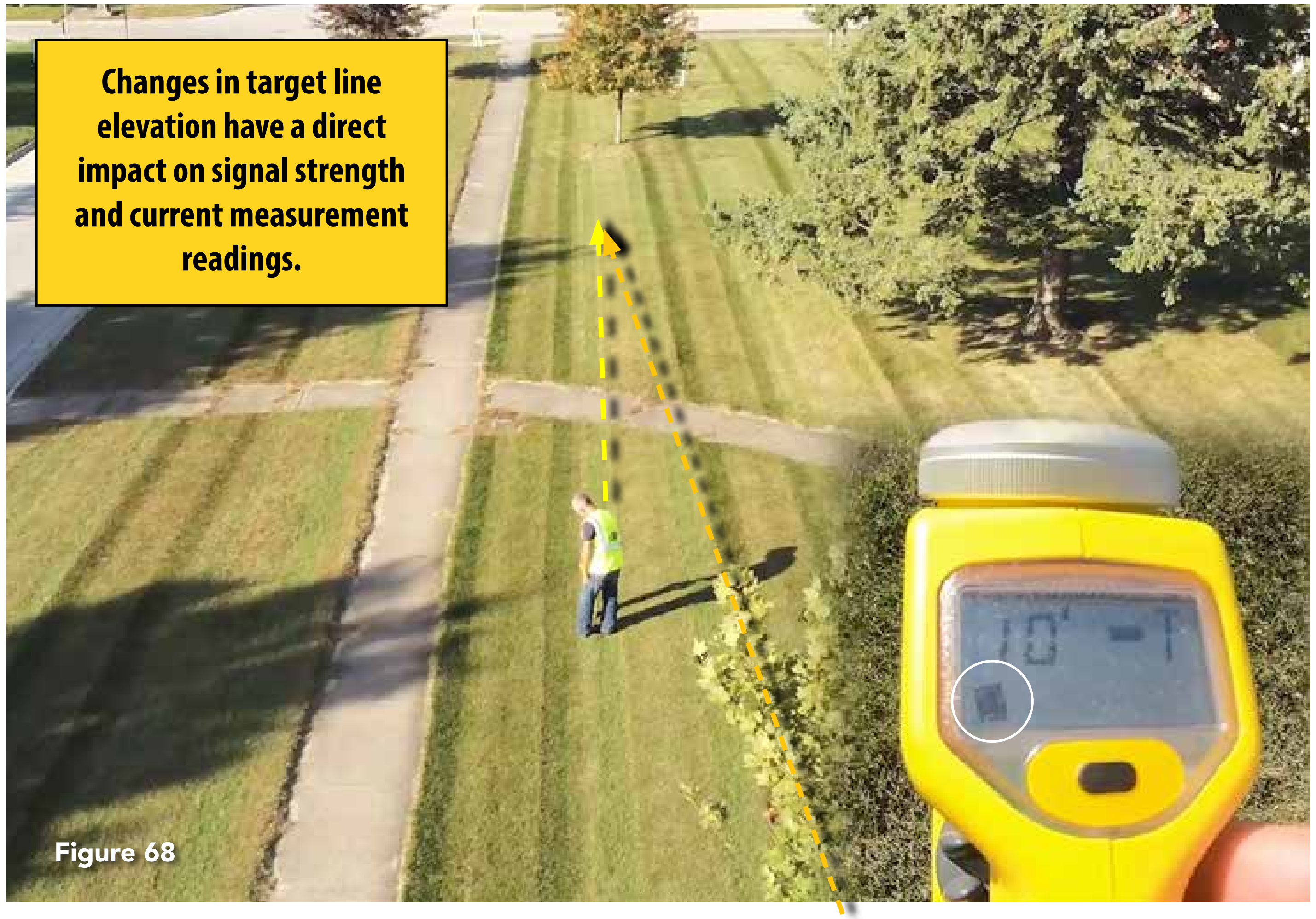


Figure 67



Changes in target line elevation have a direct impact on signal strength and current measurement readings.

Figure 68

About halfway between the transmitter and the end of the tracer wire, we get a 10-foot depth **(Figure 68)**. There's not going to be milliamps on this receiver, but you need to watch the relationship of the depth and the bar graphs.

As the operator moves down the wire, the bar graphs are coming farther to the right, meaning more signal strength as we move away from the transmitter. But the wire isn't buried as deep here, 10' versus 5'2" **(Figure 69)**. The shallower depth of the wire results in receiving a higher signal strength.

TOPIC HIGHLIGHT

If the **impact of depth** on signal strength is to be measured, it must be measured on raw signal strength, not on signal strength that can be manipulated by gain settings.

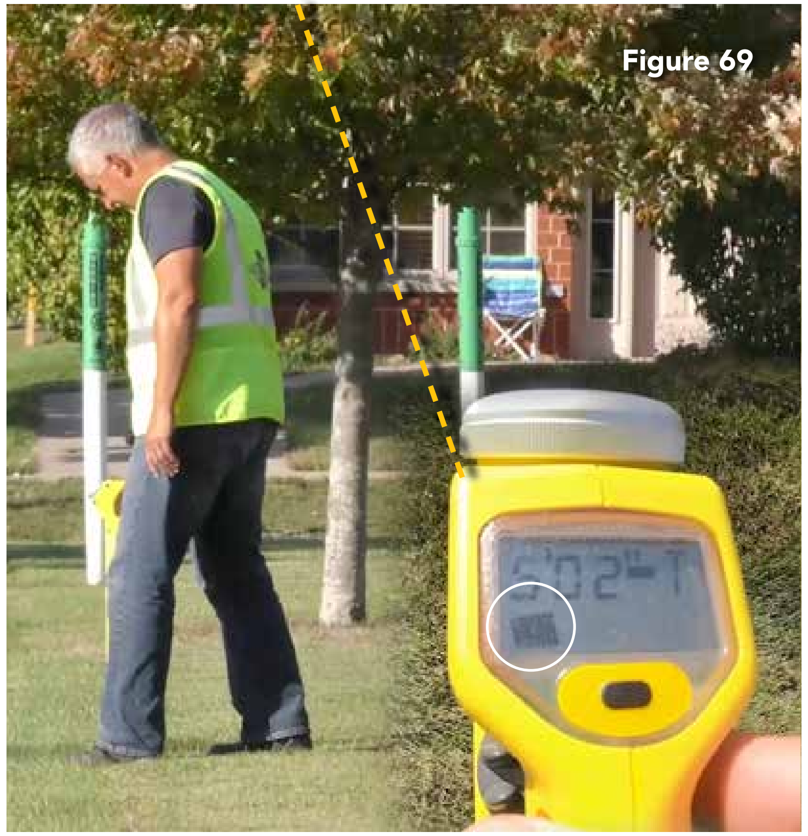
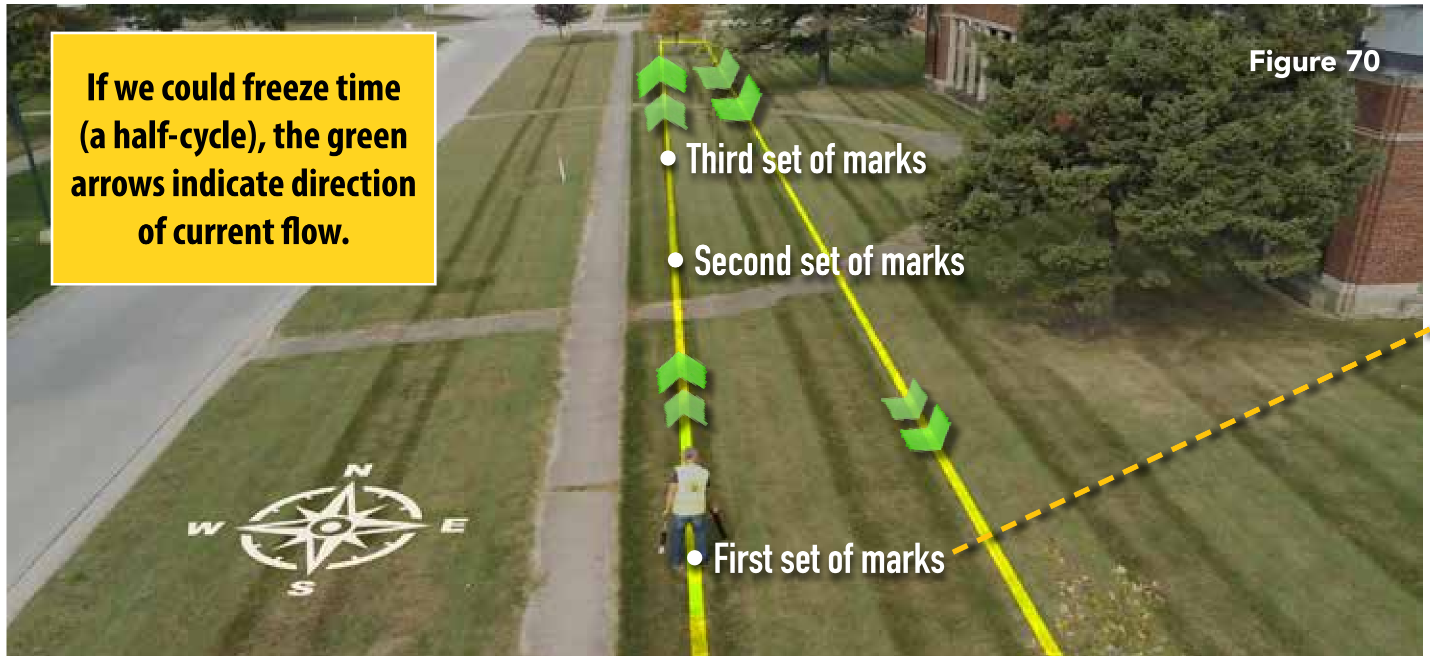


Figure 69

Receiving Antennas for Left-Right Guidance

For this locate, we've constructed a loop of wire. From the access point, we travel 300 feet north and then right back down to the south. So, we have about 600 feet of wire. This is a test scenario so that we can take a look at not-round fields. And depending on the instrument, we'll see different results **(Figure 70)**. We begin transmitting on 9.8 kHz and we're going to look at the different ways that two antennas can give the operator left-right guidance. Depending on the manufacturer, it's done one of three ways. One way is using a peak and null antenna working together **(Figure 71)**.



If we could freeze time (a half-cycle), the green arrows indicate direction of current flow.

Figure 70

Peak and null antenna

Figure 71

Figure 72

In this exercise, we want to determine whether there is a difference between the left-right guidance and the highest peak number **(Figure 72)**. We're also going to keep our eye on depth. Notice at the first set of marks, the depth at the highest peak reading location is 4'9" **(Figure 73)**. The depth reading at the null is 5'6", nine inches deeper than at the peak.

Depth reading 4'9"

Figure 73

Analyze

Receiving Antennas for Left-Right Guidance

The distance between the peak and null readings at the first set of marks is approximately 12" and the null is to the west of the peak **(Figure 74)**. It's as if the null reading is being "pushed" to the west.

TOPIC HIGHLIGHT

When **peak and null** readings disagree, peak is almost always closer to being accurate than null.

The distance between the peak and null responses at the second set of marks is only slightly wider than at the first set of marks. The depth reading at the highest peak reading location at the second set of marks is 5′0″ versus 4′9″ at the first set of marks **(Figure 75)**.

At the third set of marks, the test wire is deeper than the first two sets of marks. The distance between peak and null responses is approximately 3′, about triple the distance versus the separation at the first set of marks **(Figure 76)**.

The wire is actually 10′ deep. Notice the difference between the depth reading at the null location versus the depth reading at the peak location **(Figure 77)**. The difference in depth between null and peak responses is almost 3′.

Analyze

Receiving Antennas for Left-Right Guidance

It's not possible to say how deep a locating instrument can receive signal because of the impact of varying soil conditions. Despite the destructive interference encountered here, 9.8 kHz clearly can energize this wire at, or greater than, 10′ deep **(Figure 78)**.

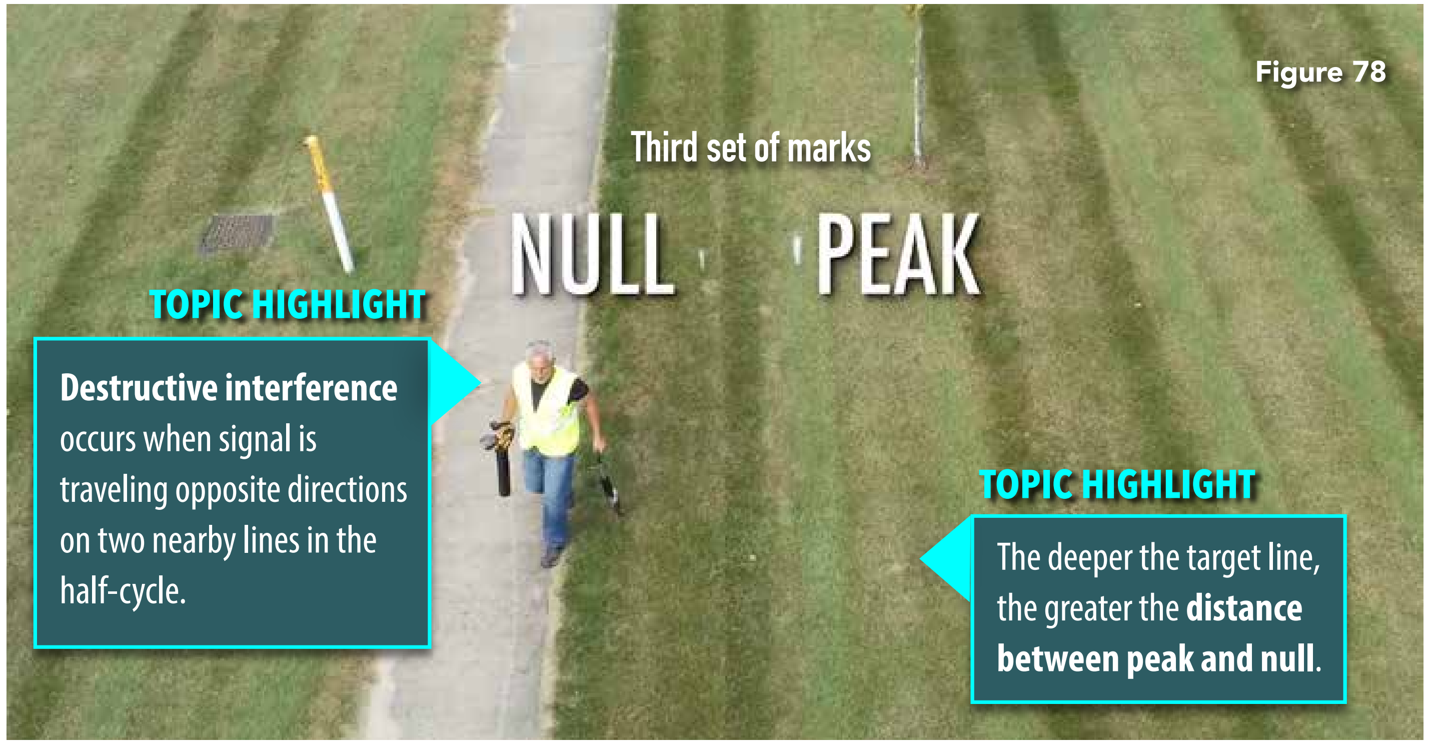


Figure 78

Third set of marks

TOPIC HIGHLIGHT

Destructive interference occurs when signal is traveling opposite directions on two nearby lines in the half-cycle.

TOPIC HIGHLIGHT

The deeper the target line, the greater the **distance between peak and null**.

Using the same transmitter, this instrument is utilizing the second way to do left-right guidance: two horizontally-positioned peak antennas, which produce an electronic null response **(Figure 79)**. Back at our first set of marks, peak and null agree on what was originally the peak mark. **Figure 82** shows two more receivers that use horizontally-positioned antennas.


Figure 79

Peak and null agree

First set of marks

Horizontally positioned peak antennas

We're now at our second set of marks, and once again peak and null agree on what was originally the peak mark **(Figure 80)**.


Figure 80

Peak and null agree

This is an auto-gain receiver

Second set of marks

But watch what happens when we get back to our 10′ depth at the third set of marks. Peak and null do not agree. The high peak reading of 691 is situated between the original receiver's peak and null reading. At these target line depths, it is not totally unexpected to see some deviation between peak and electronic null positions **(Figure 81)**.


Figure 81

Peak and null do not agree

Third set of marks

Receiving Antennas for Left-Right Guidance

As in the previous trace, these receivers use horizontally-positioned peak antennas to give the operator left-right guidance **(Figure 82)**. The response these antennas present to the operator is what is known as an "electronic null."

Figure 82

The next locating results you'll see will be performed with the transmitter set to 8 kHz, which will behave almost identically to the previously used 9.8 kHz. This receiver uses two separate antenna configurations to give us two different null responses: null and electronic null **(Figure 83)**. Below is a 2027 peak reading at the original peak mark.

Figure 83

At the first set of marks, the receiver gets a null response over the original null white paint marks **(Figure 84)**. The null response is where the digital line intersects the crosshairs. There is only an inch difference in depth and a difference of 4 signal strength numbers between the original null and the original peak white paint marks **(Figure 83)**.

Figure 84

At the second set of marks, the distance between the original white paint marks for the peak and null locations are a bit farther apart than at the first set of marks. Here, the difference between peak and null is 5 inches in depth and 51 in signal strength numbers **(Figure 85)**.

Figure 85

Analyze

Receiving Antennas for Left-Right Guidance

Back at the 3rd set of marks where the wire is 10′ deep, the line on the receiver's display is in the crosshairs. This line represents the null response, and it is located at the original null marked in white paint **(Figure 86)**. Observe the peak response increases as the receiver is moved away from the null response and in the direction of the arrow on the display **(Figure 87)**.

Figure 86

Figure 87

Continuing in the direction of the arrow, the receiver moves farther away from the original peak location marked by the white paint **(Figure 88)**. Once the receiver is moved well beyond the null response, the milliamp reading changes to the number of degrees the receiver is held from the null reading. This feature allows the operator to perform triangulation without tipping the instrument at a 45-degree angle. Instead, the receiver is held normally until the angle number reaches 45.

Figure 88

Although the peak number was 6 points higher in **Figure 87's** right-side image, the receiver in **Figures 88-89** has been moved until the electric null response is displayed (two arrows pointing inward). This is the only time during this exercise that a receiver correctly identifies the general location of the target line. The digital depth reads 9′8″ which is about 4″ off the actual depth.

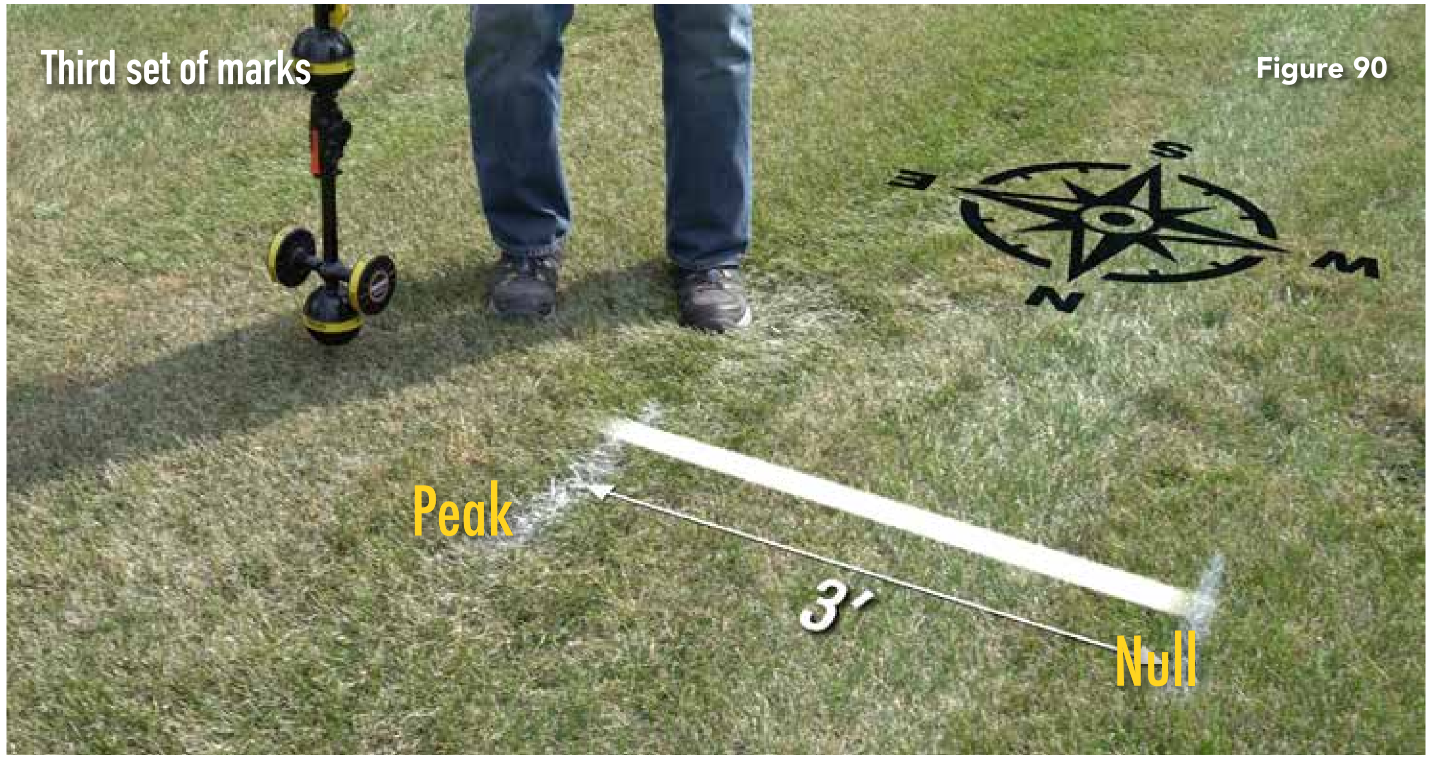
Figure 89

TOPIC HIGHLIGHT

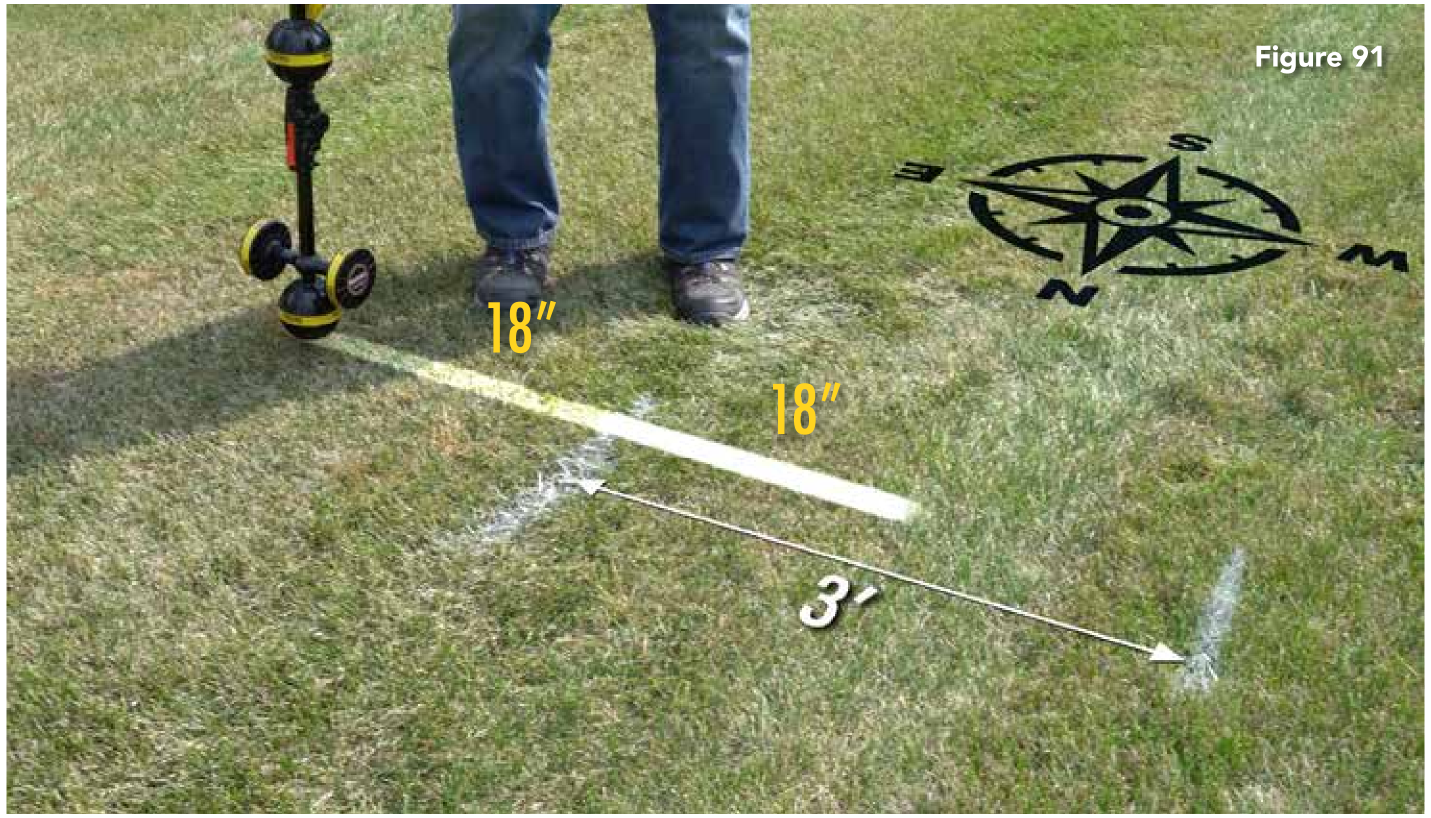
Left-right locating accuracy typically degrades proportionally with depth as target lines reach 10′ deep or deeper.

Receiving Antennas for Left-Right Guidance

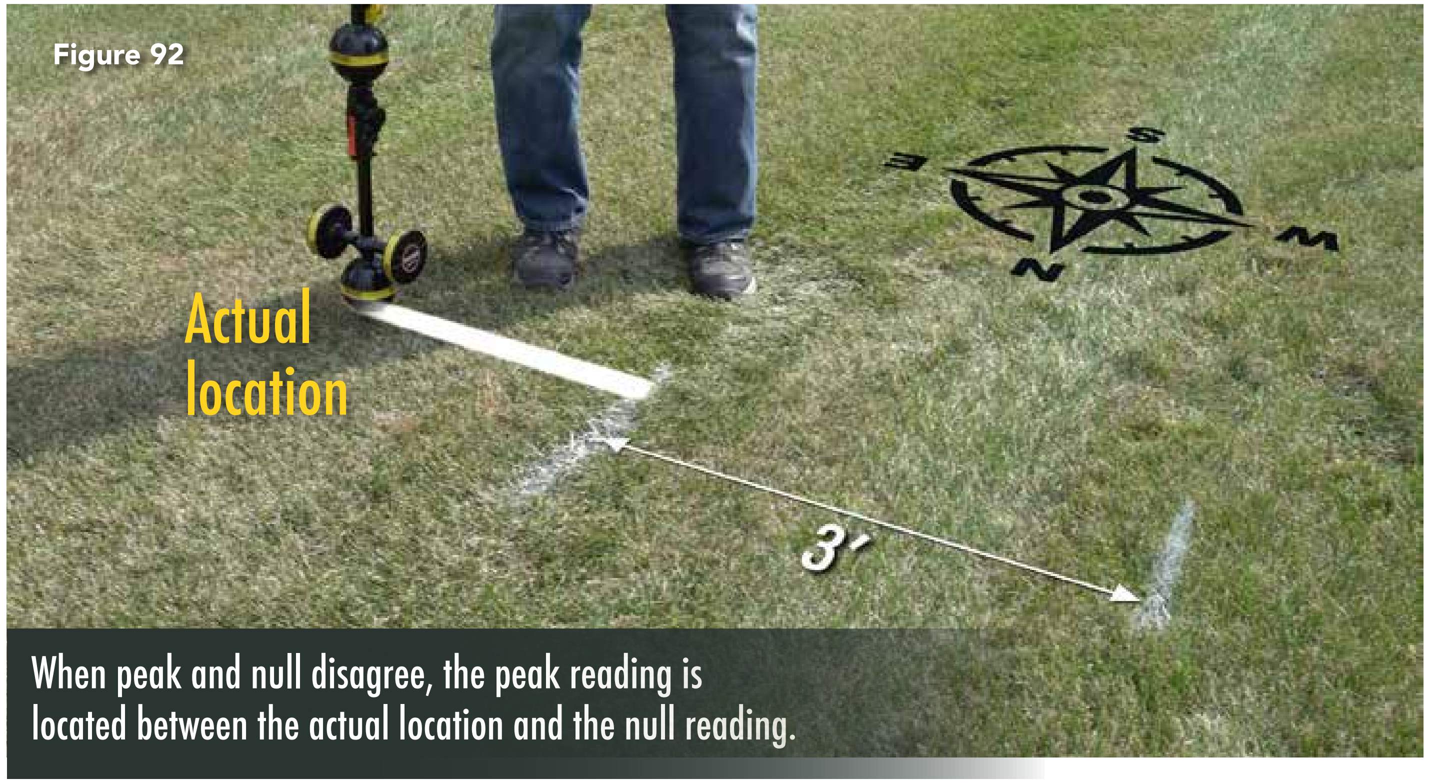
The distance between the null and the peak—the white marks—is three feet **(Figure 90)**, however, this instrument's electronic null is reading about 18″ to the east of the peak mark, or 50% of three feet **(Figure 91)**.



Here, the 3′ distance white line graphic from **Figure 90** has been moved so that the west end of the line is placed in the center of the original peak and null responses **(Figure 91)**. The east end of the white line graphic aligns with the location of the receiver.



There is a useful formula that says if you take 50% of the distance between peak and null and apply it to the opposite side of the peak that the null is on **(Figure 92)**, you can determine the actual location of a conductor when peak and null disagree. While that's a nice formula, it doesn't always turn out to work as advertised, because we don't know how many conductors are in the ground and what their relative depths are. But the more antennas a receiver utilizes, the more information the operator has to make a determination of locating accuracy.

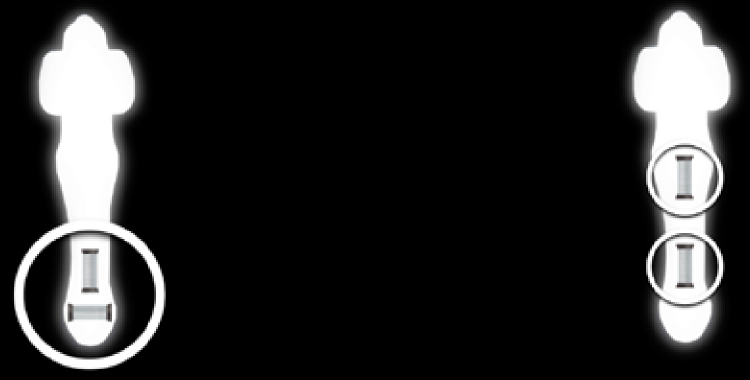


When peak and null disagree, the peak reading is located between the actual location and the null reading.

Figure 93 illustrates the last last two receiver antenna configurations to be used in this exercise.

Figure 93

The next two instruments look the same.
We will differentiate by using these icons:



Receiving Antennas for Left-Right Guidance

Let's go back to our first set of marks. This instrument **(Figure 94)** does left-right guidance with a peak and a null antenna, just like the first receiver **(Figure 95)** we used to locate the target line. The locate results are identical—peak and null disagree by 12".


Figure 94


Figure 95

This instrument uses the third way to use two receiving antennas to achieve left-right guidance **(Figure 96)**. It uses stacked-null antennas, and you can see that peak and null agree on the painted peak mark at the first set of marks.


Figure 96

Figure 97 shows a side view of an outer peak antenna with a smaller null antenna inside (yellow-wrapped coil). This is the receiver's only null antenna. **Figure 98** shows an a null antenna inside of a larger peak antenna on both the bottom and top of the receiver.

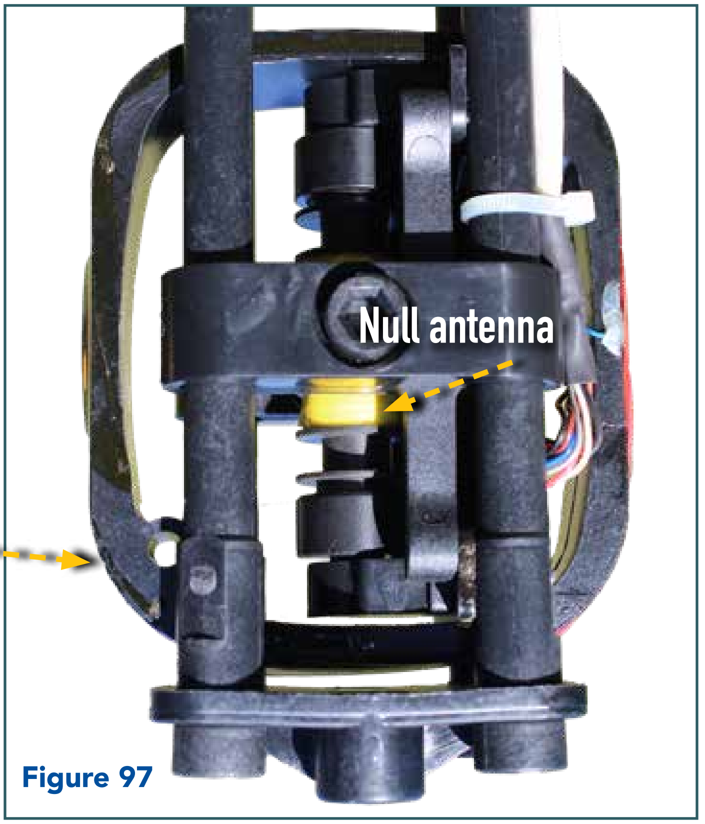


Figure 97


Figure 98

Receiving Antennas for Left-Right Guidance

At the second set of marks, the "peak-null antenna" receiver is positioned over the original peak mark**.** The arrow on the display points to the west toward the original null mark **(Figure 99)**. Although these receivers look the same, compare the antenna configuration of **Figure 100** to that of **Figure 101**.

Figure 99

Figure 100

Figure 101

As the receiver is guided to the null response, there is a 7.85 mA reading and 5'07" depth **(Figure 101)**. Using the "stacked-null" antenna receiver, both the peak and the null responses agree at the location of the original peak mark **(Figure 102)**. Notice the lower mA reading and shallower depth versus those seen in **Figure 101**.

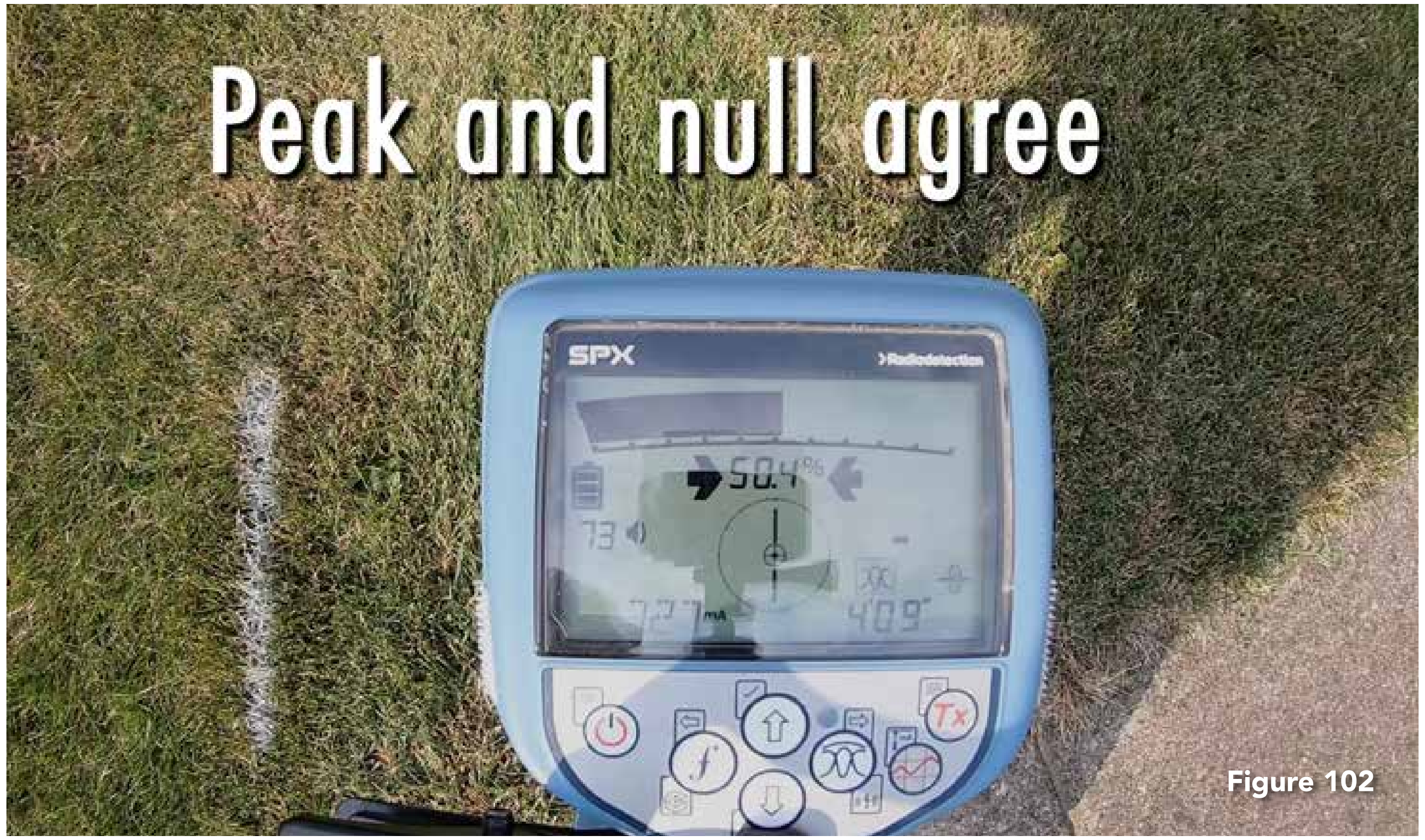


Figure 102

Receiving Antennas for Left-Right Guidance

At the third set of marks, the "peak-null" antenna configuration guides us to the original null paint mark **(Figure 103)**. Notice the depth reading approaching the null response versus that of approaching the peak response **(Figure 104)**.


Figure 103

Once this peak-null receiver is moved a bit to the west and becomes positioned directly over the peak mark, the depth reading will be 7'11", which is exactly what the stacked-null receiver reads in **Figure 105**.

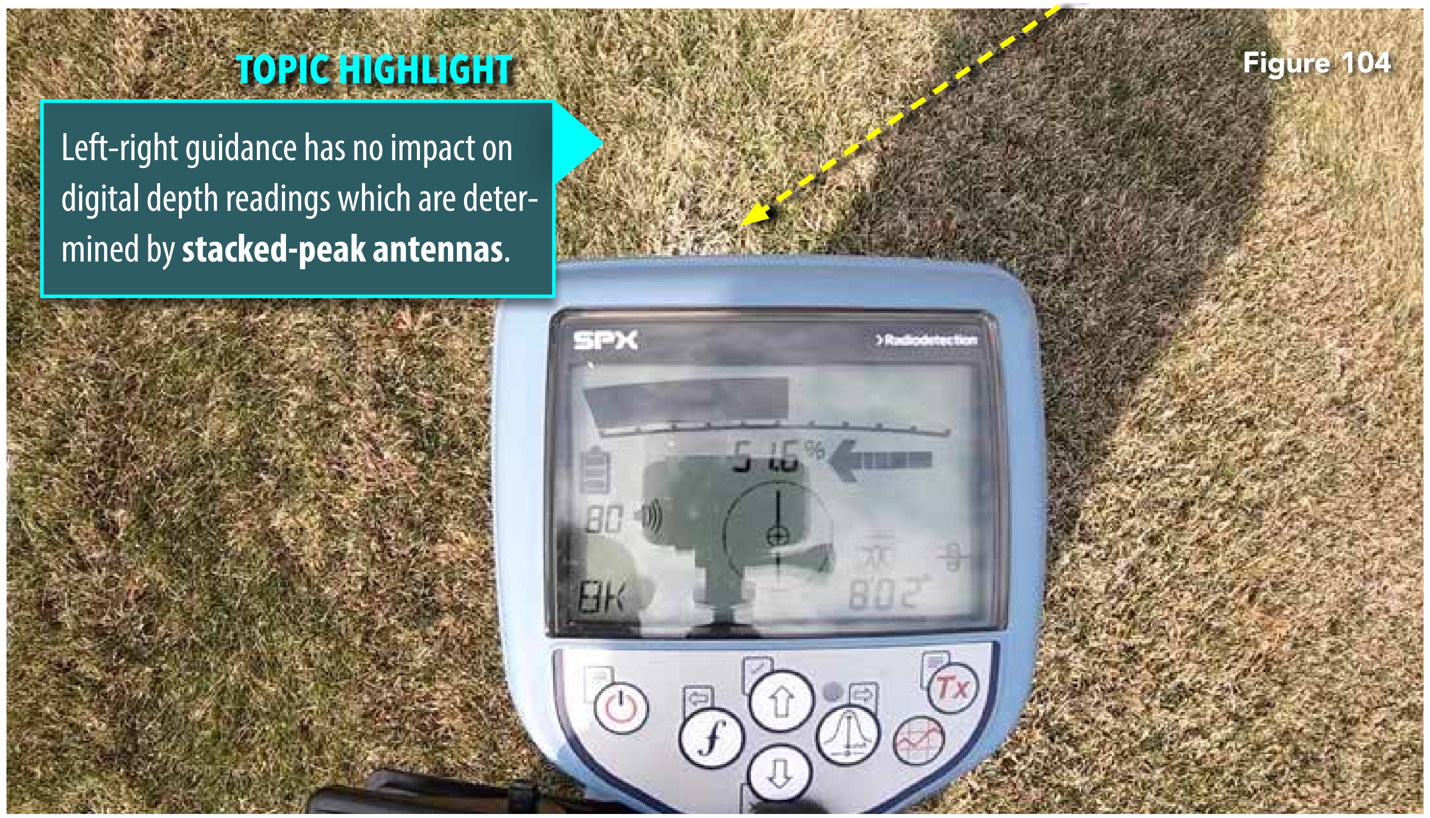


Figure 104

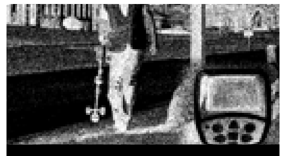
TOPIC HIGHLIGHT

Left-right guidance has no impact on digital depth readings which are determined by **stacked-peak antennas**.

Using the stacked-null antennas for left-right guidance, the peak and null readings agree on the peak mark **(Figure 105)**. The destructive interference at the third set of marks has produced an inaccurate trace that is virtually impossible to spot because peak and null agree. Additionally, the lowest depth reading corresponds with the location where peak and null agree. The actual wire location is 18" to the east as indicated by the electronic null reading in **Figure 106**.


Figure 105


Figure 106



Different Antennas Different Results

The locate begins with coupling an electric secondary cable on 33 kHz. This secondary cable is fed from a transformer that can be seen in the distance **(Figure 107)**. The electric primary cable that feeds the transformer runs parallel to the secondary cable. The location of these cables is illustrated in **Figure 108**.


Figure 107

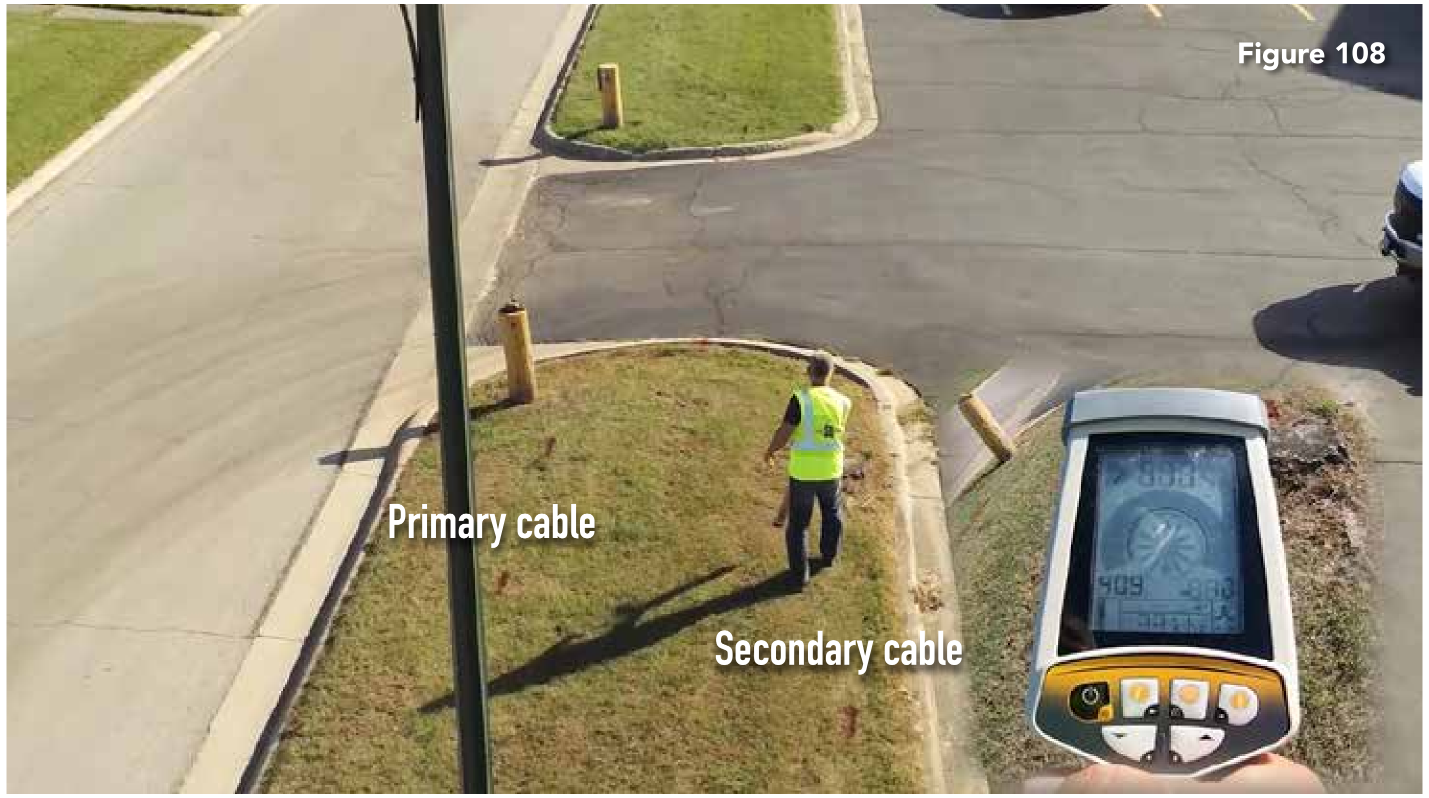


Figure 108

Although there are a number of other underground lines present besides the secondary and primary cables, the shape of the field over the secondary is round. But a quick check of the field shape over the primary shows not-round and the depth reading at the peak location indicates 23", a shallow depth for a primary cable **(Figure 109)**. The initial attempt at a trace on the primary, as indicated by the red graphic line, appears to place the cable under the wooden post **(Figure 110)**.


This receiver uses the peak-null antenna configuration for left-right guidance.

Figure 109

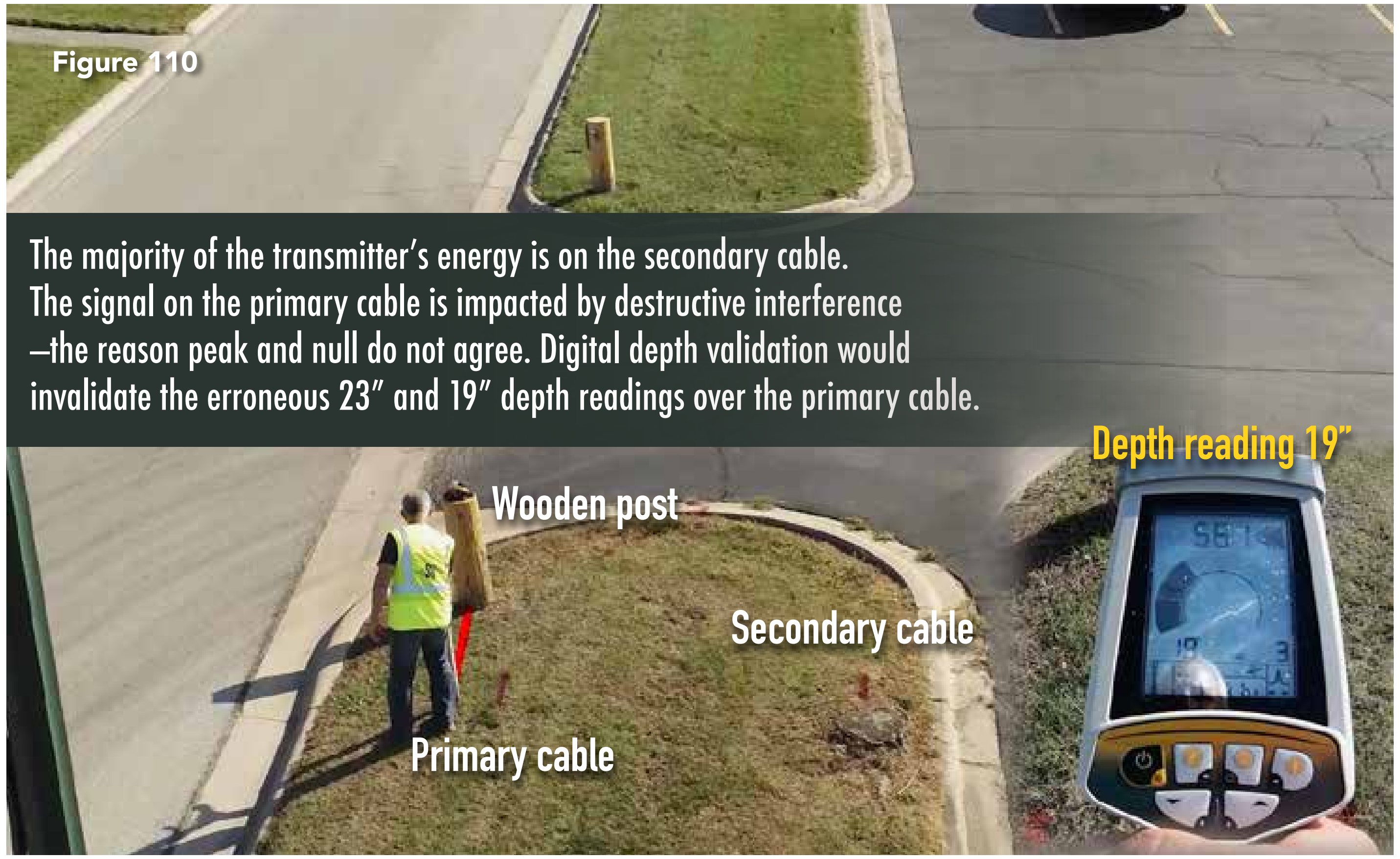


Figure 110

The majority of the transmitter's energy is on the secondary cable. The signal on the primary cable is impacted by destructive interference –the reason peak and null do not agree. Digital depth validation would invalidate the erroneous 23" and 19" depth readings over the primary cable.

Different Antennas Different Results

Tracing the secondary cable leads to a logical and visual end-point: a single-phase, pad-mounted transformer **(Figure 111)**. One thing to keep in mind when locating electric is that as we get close to a transformer, we're going to see signal coming off of the cables inside the transformer, as well as the energized metallic shell of the transformer **(Figure 112).** Generally, it's safe to say that when you get within two or two and a half feet of a transformer, your field is likely to be significantly not-round due to the congestion of energized cables in, as well as exiting, the transformer.

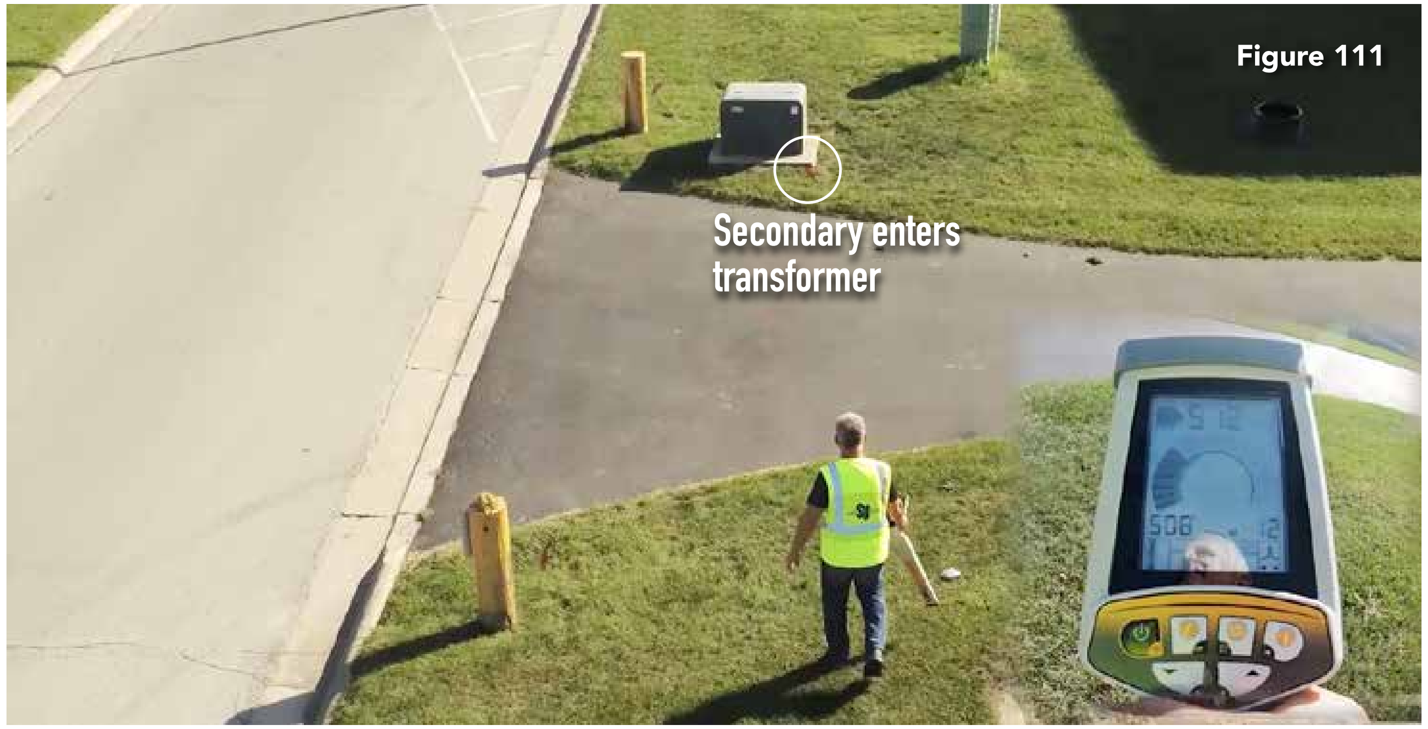


Figure 111

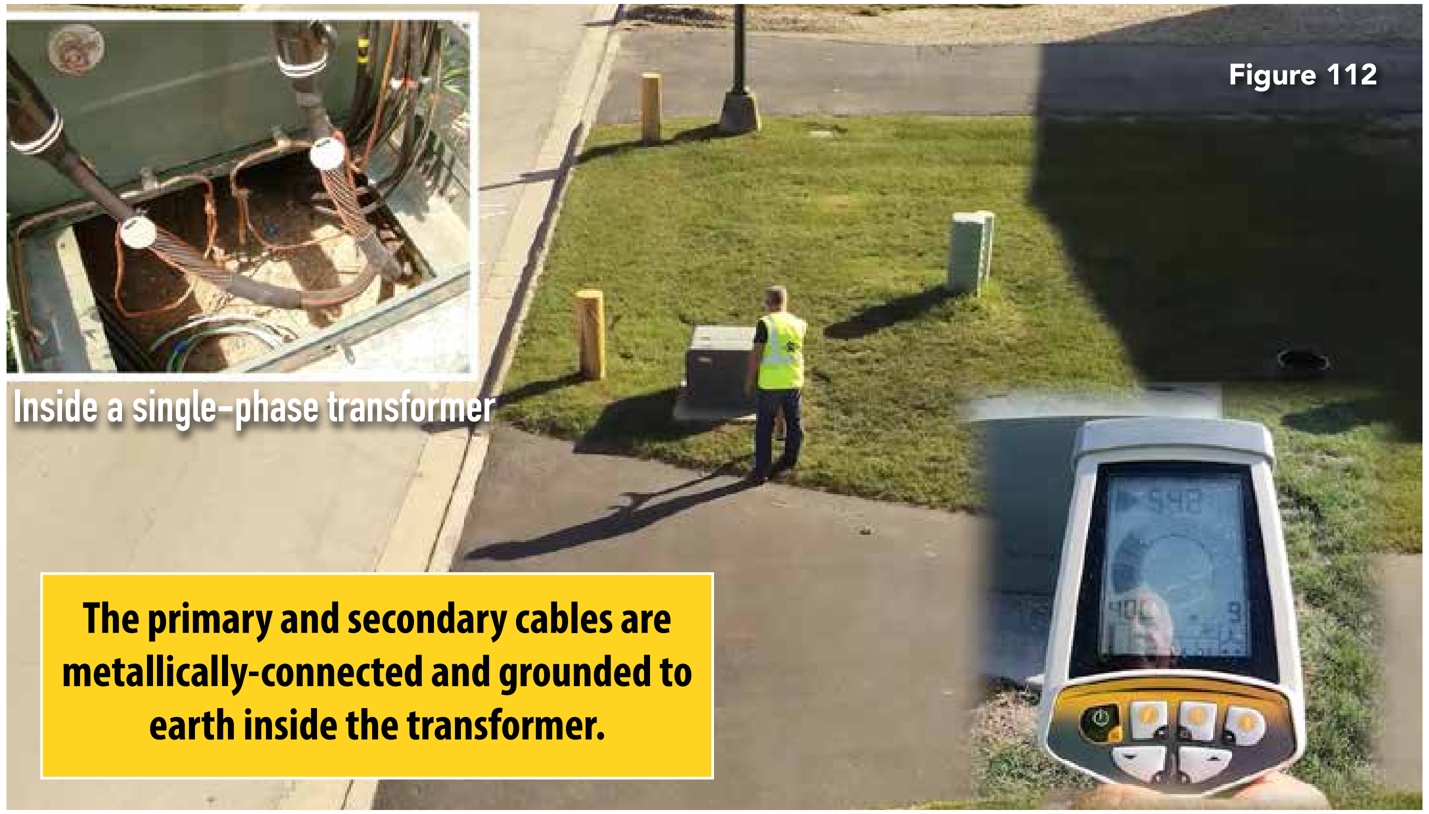


Figure 112

The primary and secondary cables are metallically-connected and grounded to earth inside the transformer.


Figure 113

Signal from the transmitter leaves the transformer and energizes the primary cable exiting the transformer.

We're now searching for the primary. The primary cable enters and exits from the east side of the transformer **(Figure 113)**. Going south beyond the transformer, the primary does not locate particularly well **(Figure 114)**. Peak and null do not agree, and there's been a substantial loss of signal at the transformer grounding system.

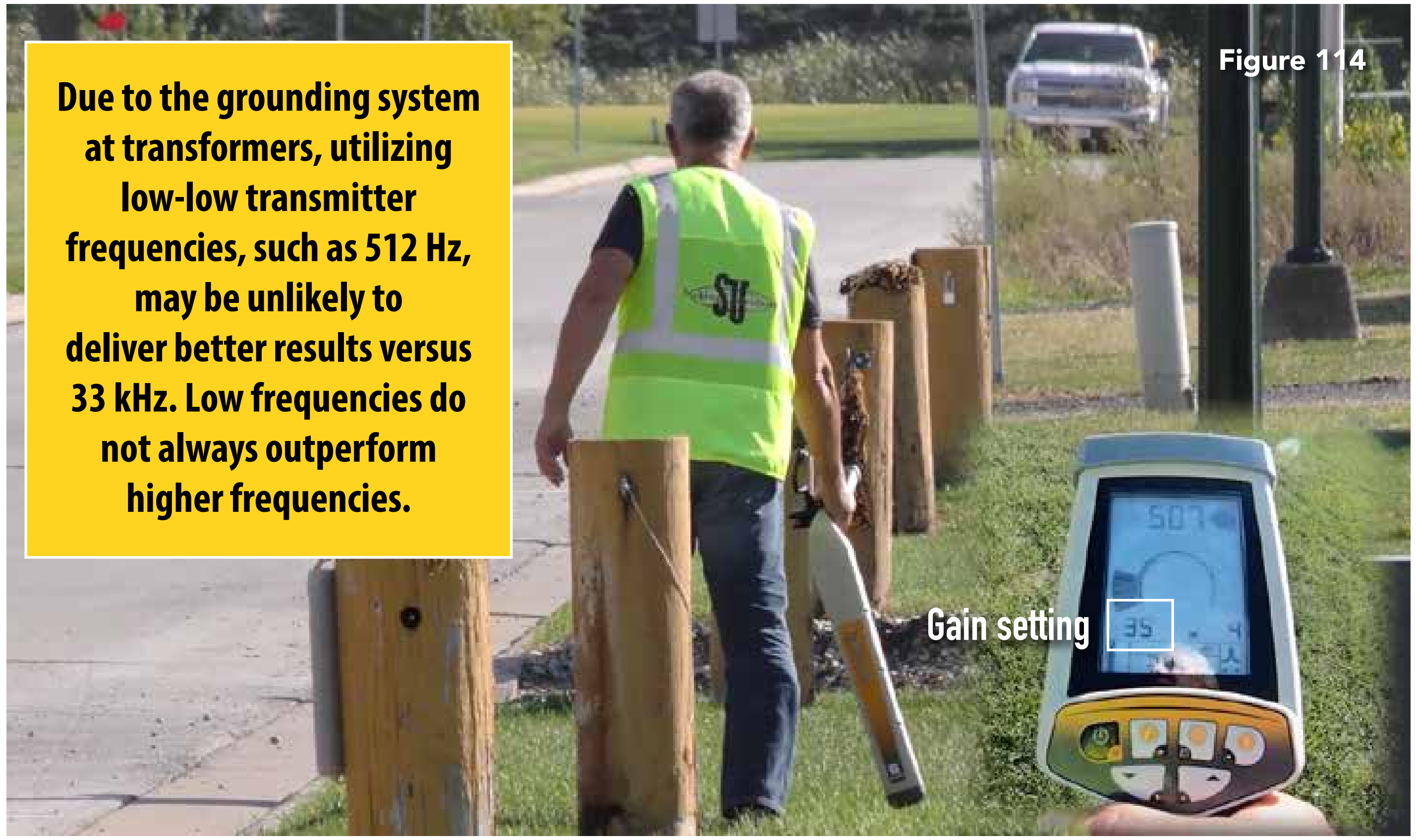


Figure 114

Due to the grounding system at transformers, utilizing low-low transmitter frequencies, such as 512 Hz, may be unlikely to deliver better results versus 33 kHz. Low frequencies do not always outperform higher frequencies.

Different Antennas Different Results

Signal Splits

> “Using the coupler where it was placed represents the best transmitter usage for placing signal on the secondary coming into the transformer.”

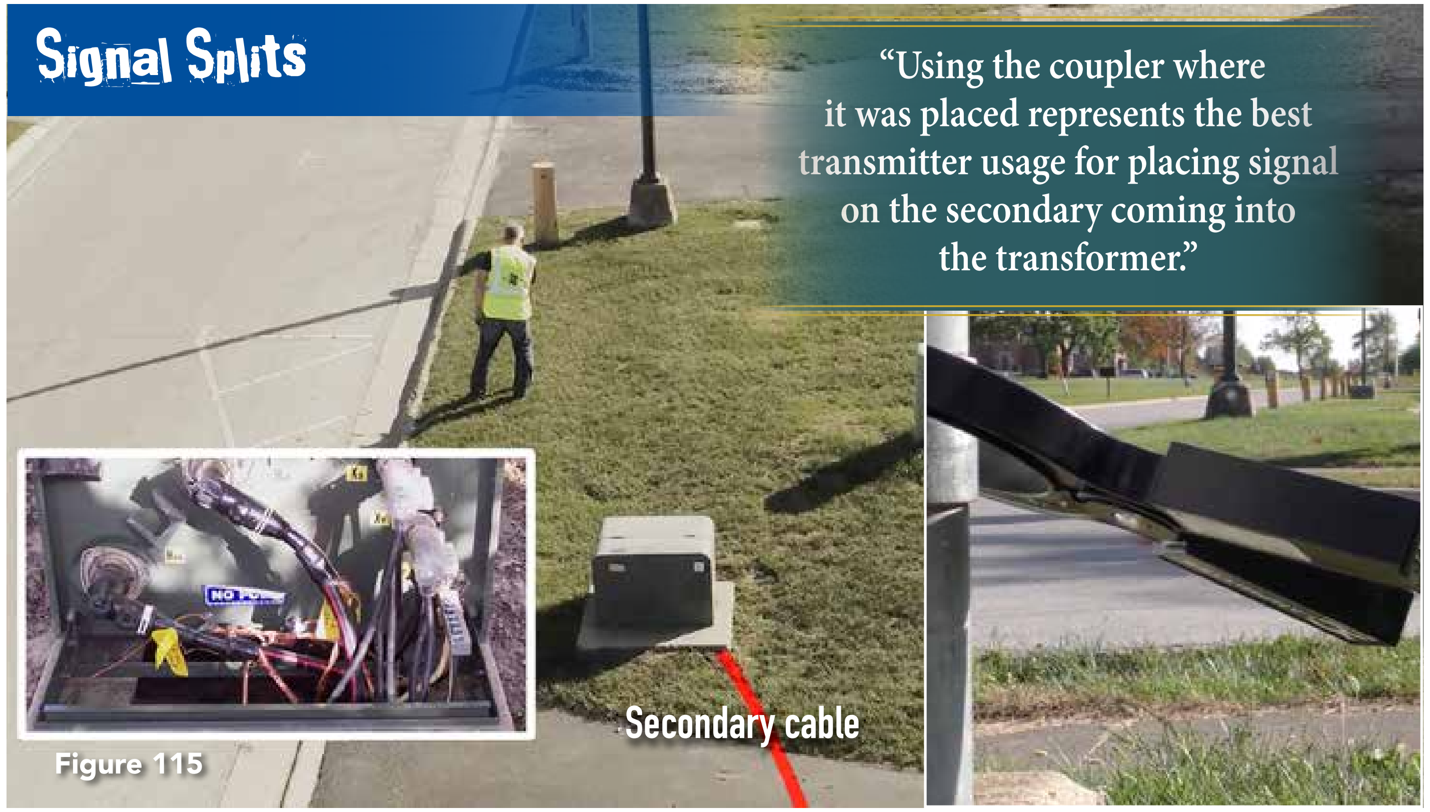


Figure 115

Using the coupler where it was placed represents the best transmitter usage for placing signal on the secondary coming into the transformer **(Figure 115)**. If the goal was to locate the secondary by hooking-up conductively at the transformer, the signal would split in a number of directions, including two additional secondaries feeding two nearby buildings **(Figure 116)**.

Figure 116

This locate exercise is designed to compare two different kinds of receiving antenna configurations. To do this, the transmitter was not moved during the course of this exercise.

Figure 117

Arguably one method to energize the primary in a northerly direction from the transformer would be a conductive locate at the transformer. It’s important to note that the signal will also energize the primary leaving the transformer to the south **(Figure 117)**. In addition, the three secondaries would become energized as well **(Figure 118)**. Although signal would be lost to the grounding system and secondary cables, getting a good trace on primary cables often consists of using transformers as access points.

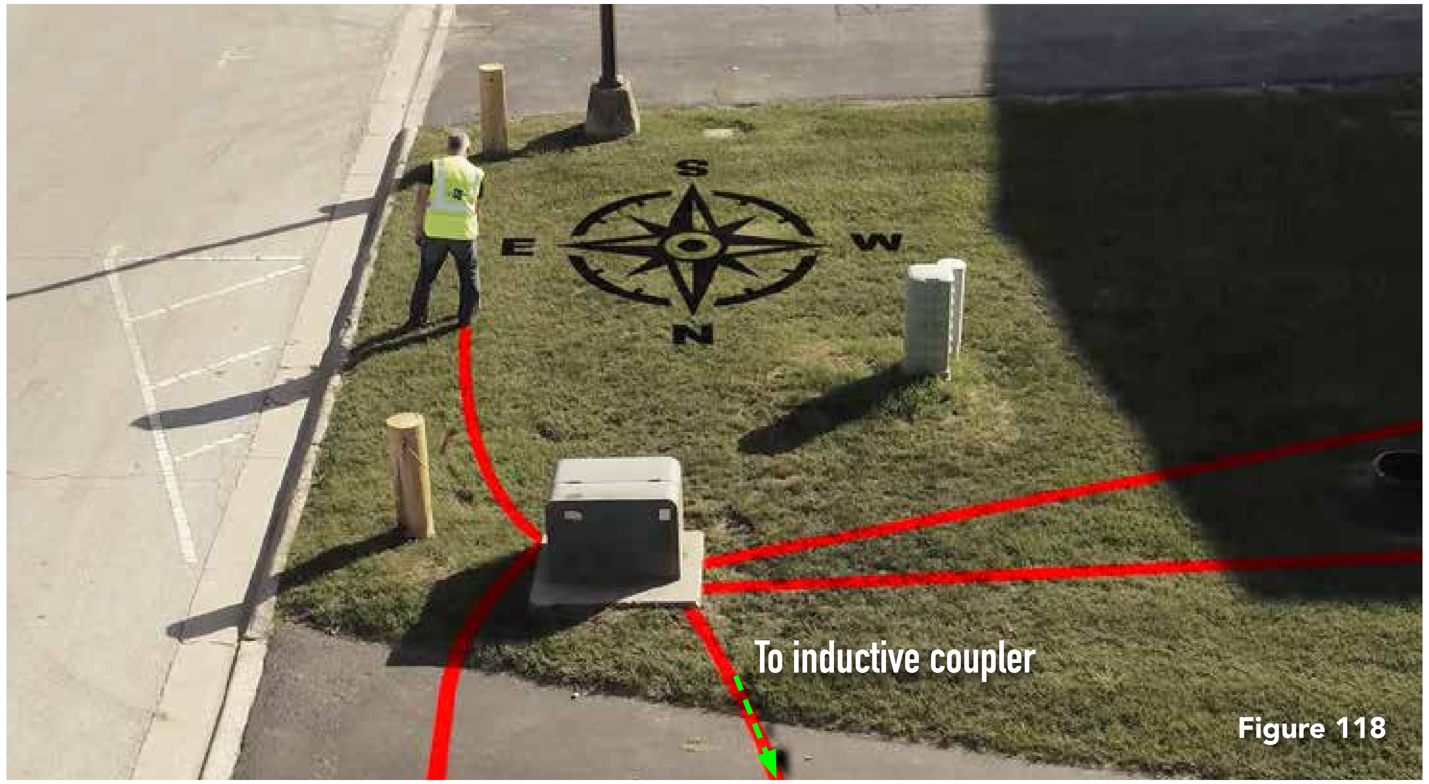


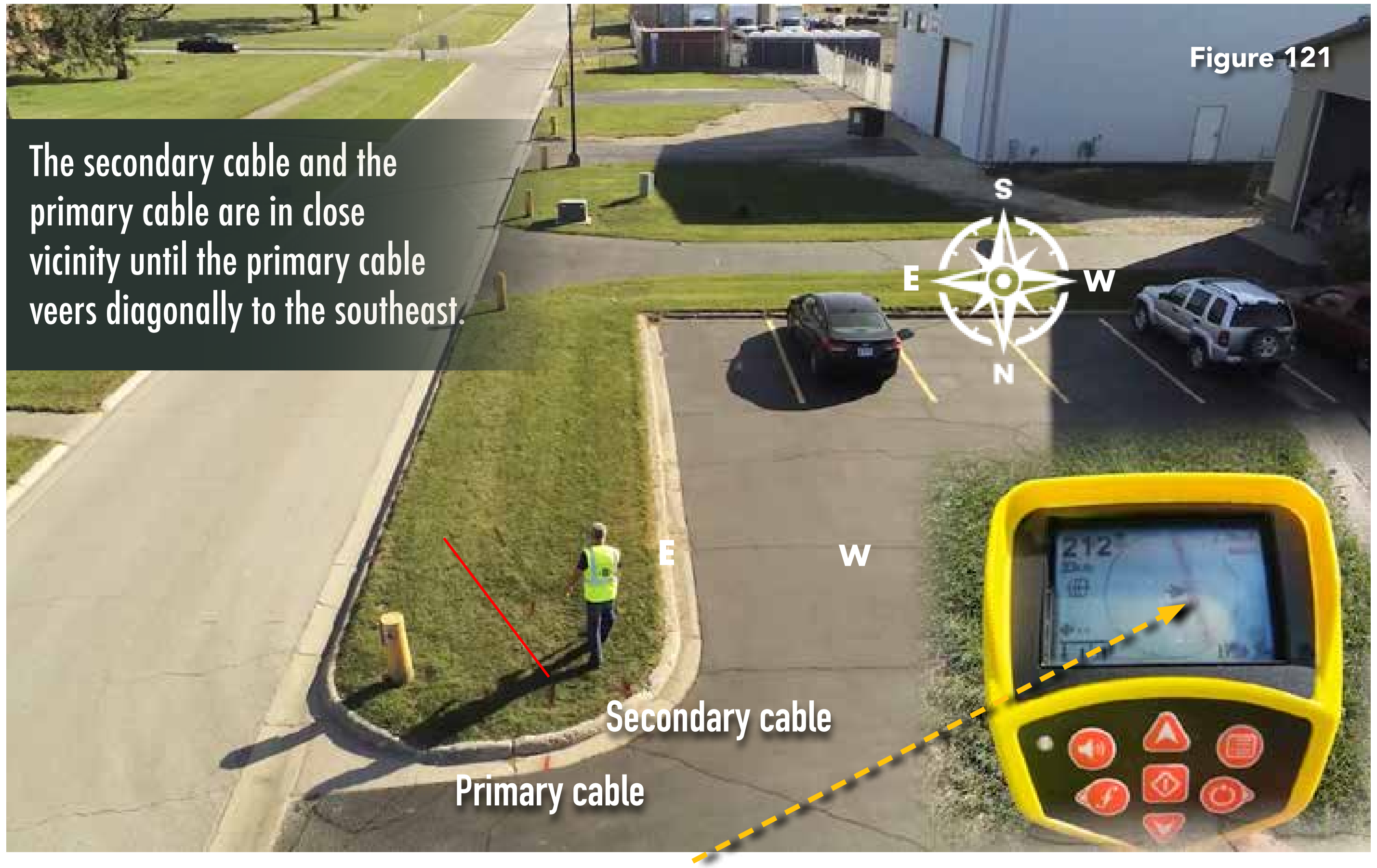
Figure 118

Different Antennas Different Results

Although this exercise continues with the same inductive coupler using 33 kHz, the receiver has changed. The main difference between the previous receiver and this receiver is the addition of more receiving antennas, namely the addition of horizontally-positioned peak antennas that produce left-right guidance **(Figure 119)**. If Antenna A sees more signal than Antenna B, then an arrow points to Antenna A. When both A and B see the same signal, both arrows appear **(Figure 120)**.

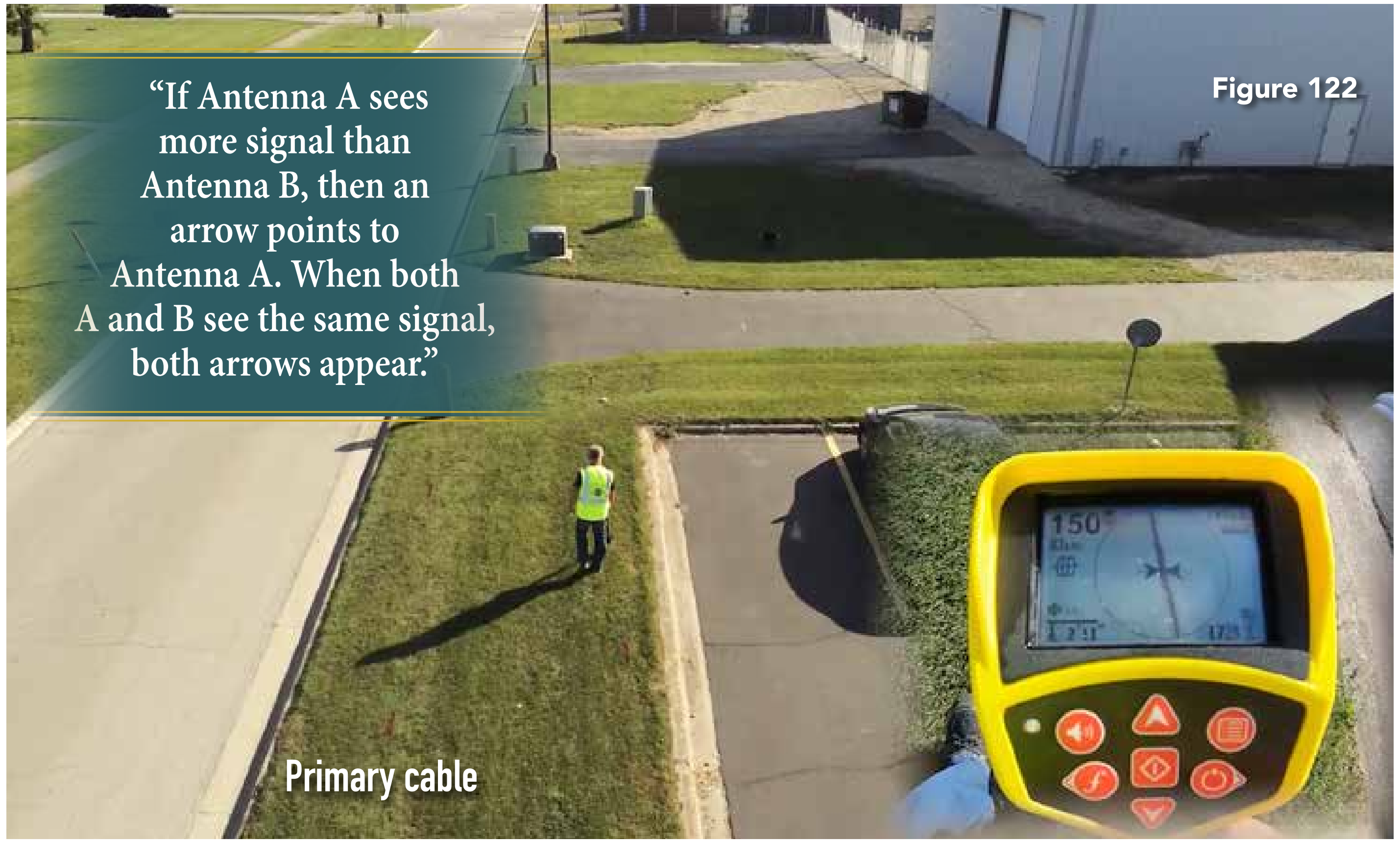
From the location of the inductive coupler, the initial path of the secondary cable is to the east of the primary cable.

The location of the null (two arrows) on the previously-used receiver is indicated on the new receiver by the digital line aligning in the crosshairs (crosshairs visible in Figure 124).



The secondary cable and the primary cable are in close vicinity until the primary cable veers diagonally to the southeast.

As the trace continues south on the secondary cable, the crooked line indicates the transmitter's energy is also on something else **(Figure 121)**. However, with the digital line dissecting the arrowheads, the accuracy of the trace is confirmed **(Figure 122)**.



"If Antenna A sees more signal than an Antenna B, then an arrow points to Antenna A. When both A and B see the same signal, both arrows appear."

Different Antennas Different Results

Any results locating the primary cable will be greatly influenced by a low level of current flow. While the left-right guidance appears, the digital line is virtually nonexistent **(Figure 123)**. As the primary cable begins to veer toward the secondary cable, the digital line completely disappears **(Figure 124)**.

Momentarily shifting over to the secondary reveals the digital line dissecting the arrowheads **(Figure 125)**, indicating a round field. The secondary's electromagnetic field is only slightly impacted by the primary's electromagnetic field, visible on the receiver by the slightly crooked, pixelated line.

But, moving back to the primary shows the primary's electromagnetic field is significantly impacted by the secondary's electromagnetic field **(Figure 126)**. Only when the primary veers away from the secondary do the arrows reappear **(Figure 127)**.


Figure 123


Figure 124

There is no digital line over the primary.

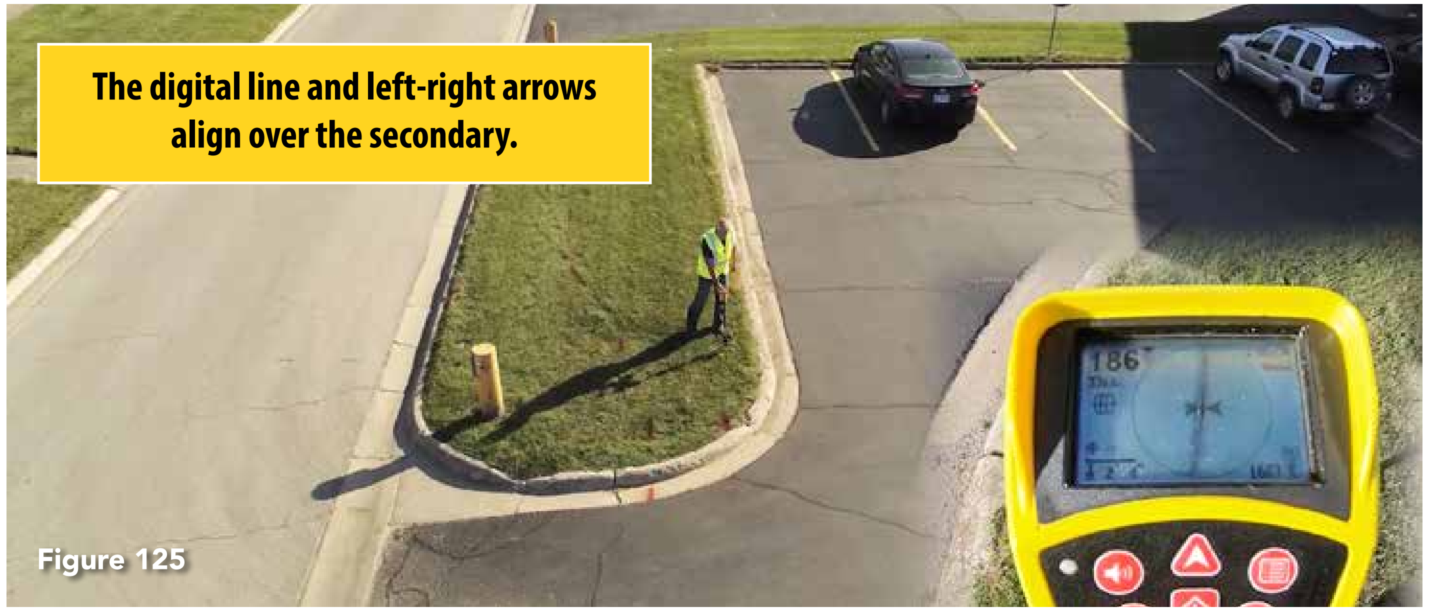

The digital line and left-right arrows align over the secondary.

Figure 125


The left-right arrows disappear over the primary.

Figure 126


The left-right arrows reappear over the primary.

Figure 127

Analyze

Different Antennas Different Results

Approaching the location where the primary crosses over the secondary, the line on the receiver's display snaps onto the secondary's orientation **(Figure 128)**. Rotating to locate the secondary at the crossing, the line practically disappears **(Figure 129)**. Locating the primary beyond the crossing, the line is missing but the left-right arrows locate the primary **(Figure 130)**.

Figure 128

Figure 129

Figure 130

Due to the crossing, there is no signal on the primary, and there is no digital line on the receiver display. But the horizontally-positioned antennas are close enough to the ground to do left-right guidance.

This is a tough locate, with so much more signal on the secondary. Due to the signal splitting once it gets to the transformer, only a fraction of it comes northward on the primary. All this makes the area of the crossing **(Figure 131)** almost impossible to locate the primary. In an attempt to locate the primary at the crossing, induction must be used. This is the only way to guarantee that the primary has substantially more signal on it versus the secondary. Hooking up at the transformer would not guarantee a positive result, because it's possible the secondary may still become more energized than the primary.

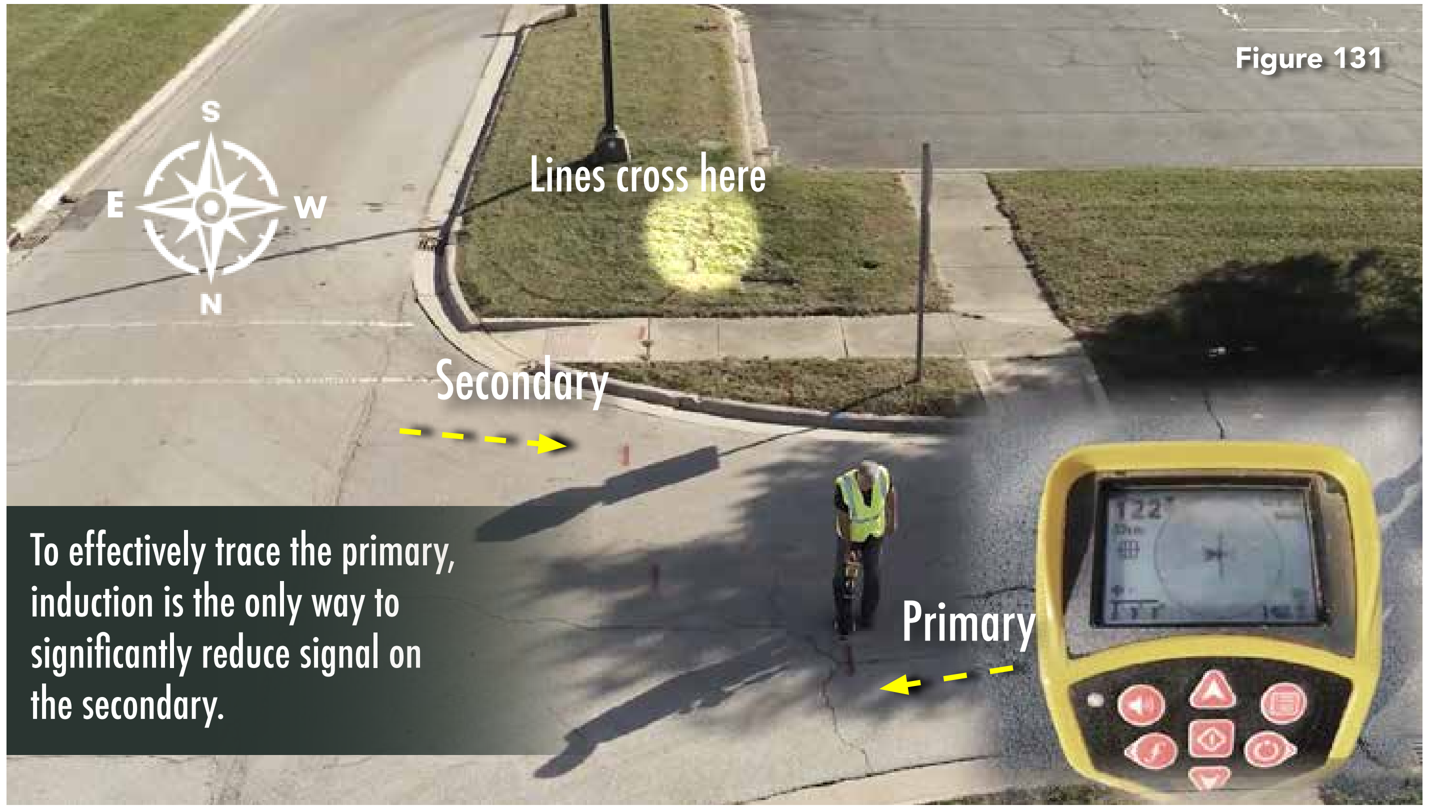


Figure 131

To effectively trace the primary, induction is the only way to significantly reduce signal on the secondary.

Pipeline Depth and Guidance

At the highlighted area over a 30″ pipeline **(Figure 132)**, the operator uses a probe to make contact with the top of the pipeline **(Figure 133)**. Once on the pipe, the ground level will be marked on the probe before it is pulled out of the ground. A measurement is taken from the tip of the probe to the ground level mark **(Figure 134)**.

TOPIC HIGHLIGHT

Both a small energized pipe and a large energized pipe emit **concentric signal circles**. It is not possible for the receiver to determine pipe diameter based on the signal it receives above the ground.

Figure 132

Multiple probes are necessary to find the exact top of large diameter pipelines

Figure 133

A digital depth **(Figure 134)** is only capable of telling you where the center of two signal circles is located **(Figure 135)**. The probe measured 67″ to the top of the pipeline, but the digital depth reading of 6′10″, or 82″, will take into account half the diameter of the 30″ pipe, or 15″ **(Figure 136)**.

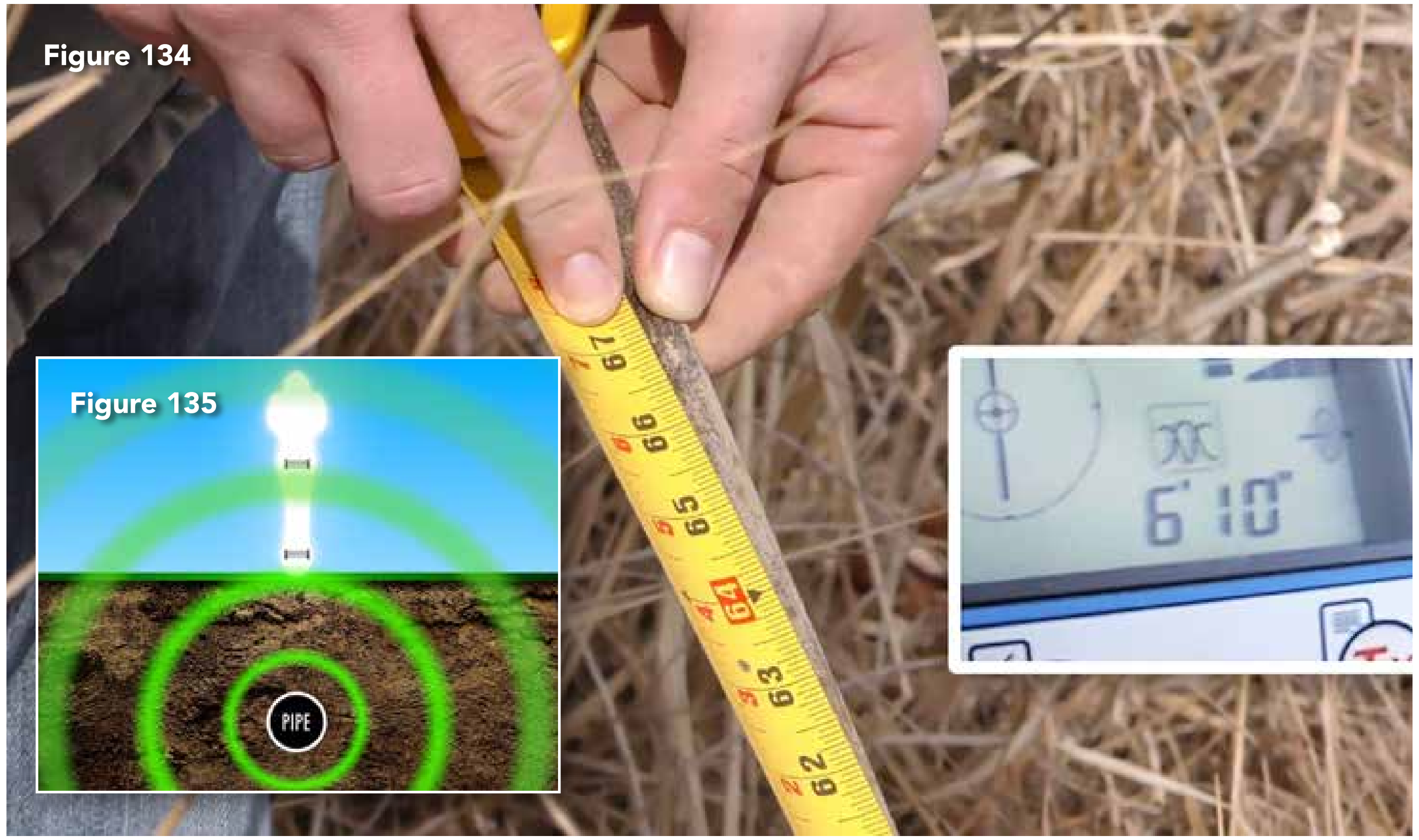


Figure 134

Figure 135

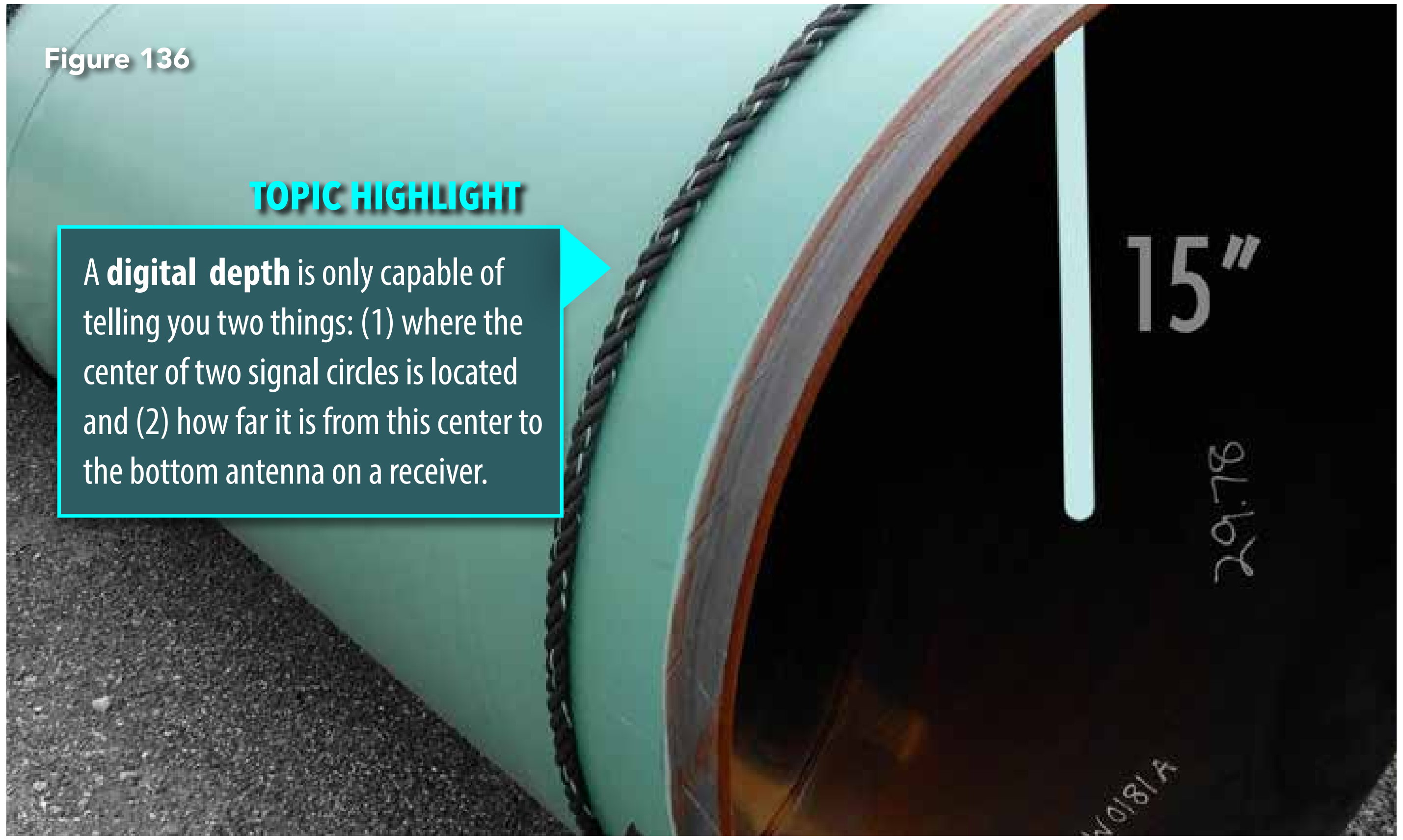


Figure 136

TOPIC HIGHLIGHT

A **digital depth** is only capable of telling you two things: (1) where the center of two signal circles is located and (2) how far it is from this center to the bottom antenna on a receiver.

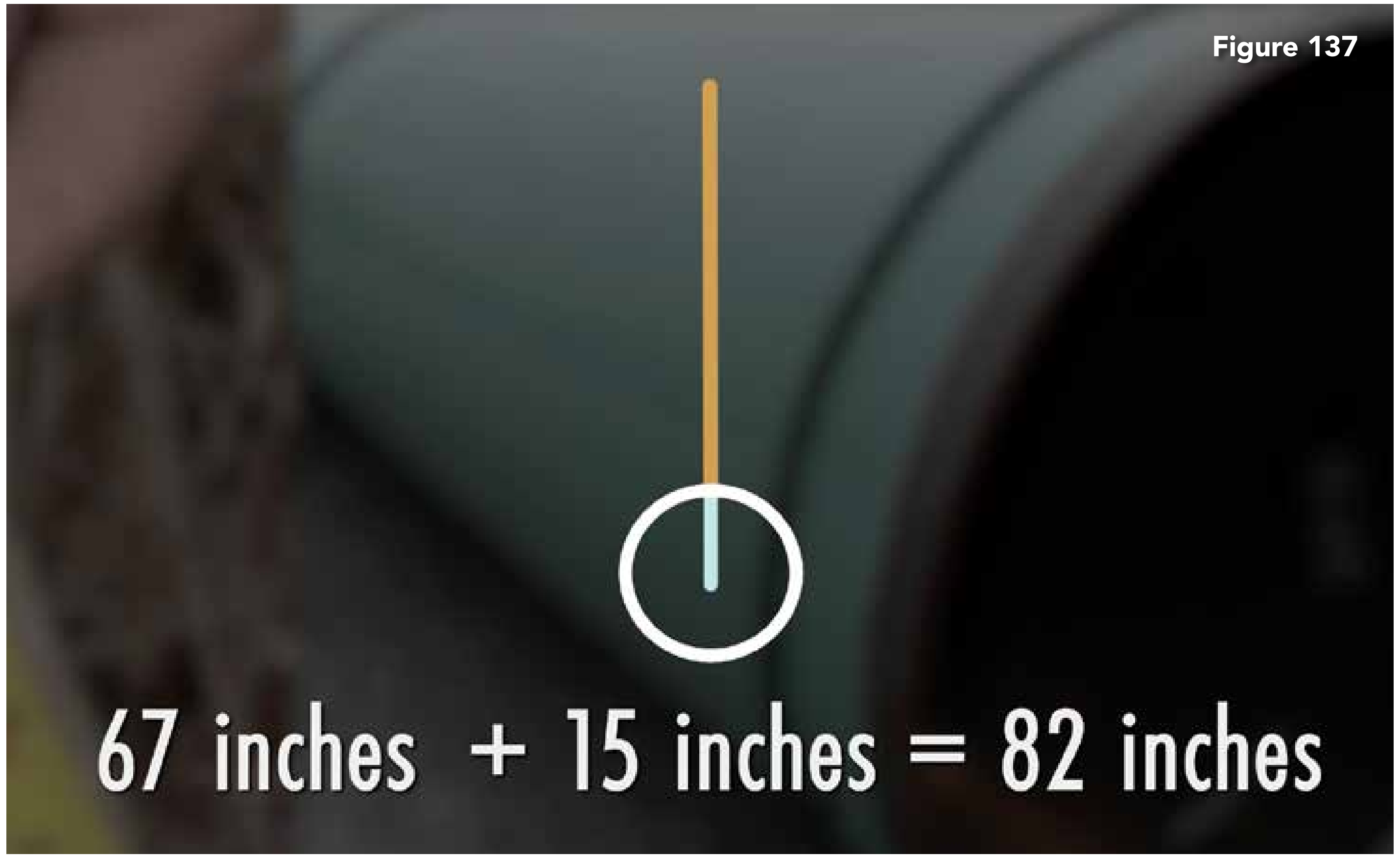


Figure 137

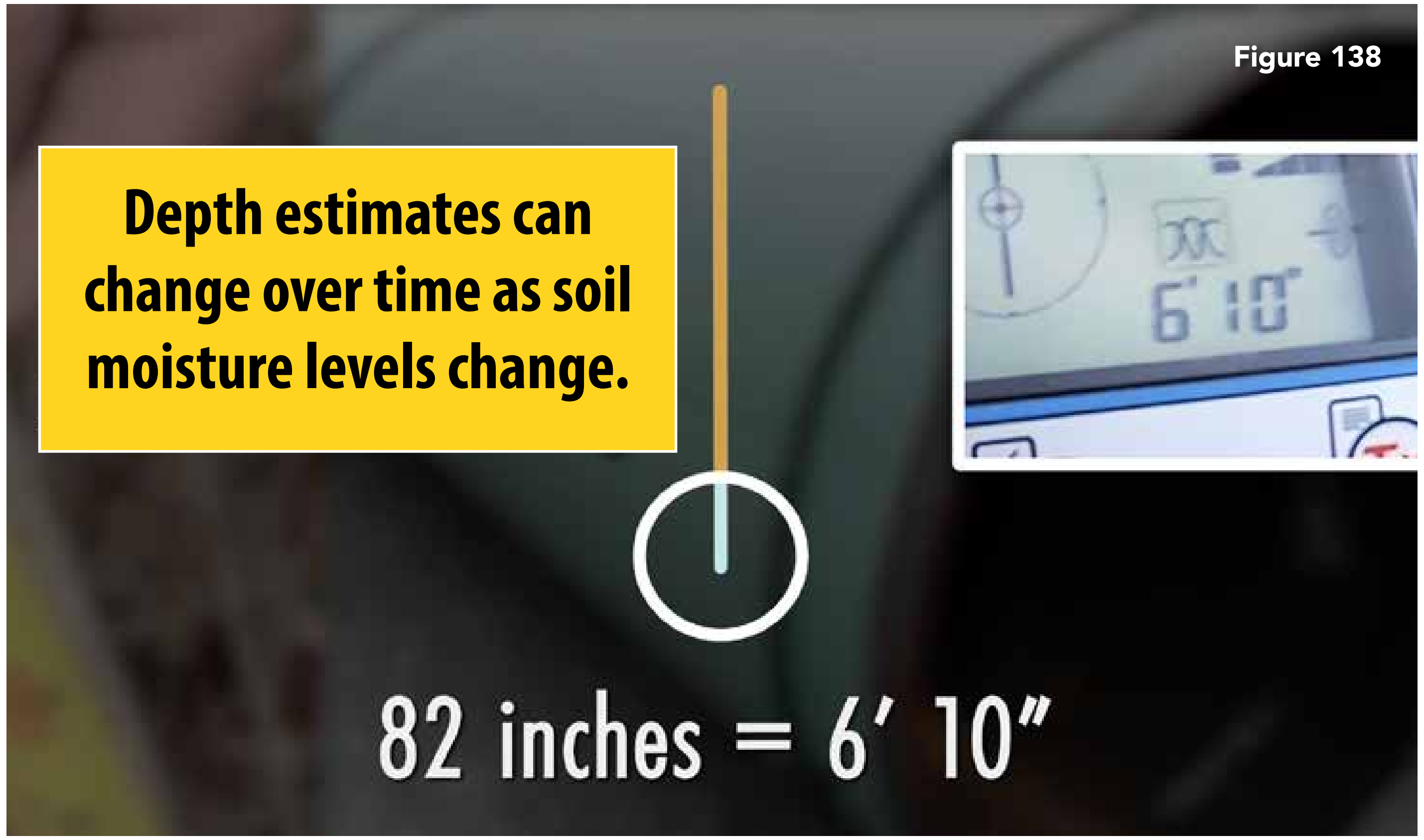


Figure 138

Depth estimates can change over time as soil moisture levels change.

TOPIC HIGHLIGHT

The transmitter's signal travels on the thin outer layer, or skin, of metallic pipes and cables. Since pipes and cables are round, the signal which is emitted is round.

TOPIC HIGHLIGHT

The transmitter's signal cannot travel through metallic objects, such as steel casings that protect gas and oil pipelines under roads and railroads. The transmitter's signal on the pipe will energize the skin of the interior wall of the steel casing but cannot penetrate the casing itself.

TOPIC HIGHLIGHT

While a metallic manhole lid may become energized from signal flowing on a cable below, it's not because signal penetrates the lid. Rather, the signal travels through the soil around the manhole and then energizes the surface side of the lid.

TOPIC HIGHLIGHT

As with a manhole lid, the **exterior of a steel pipe casing** can become energized by current flowing through the soil. This permits the pipe/casing to be located even though the signal doesn't penetrate the steel casing.

While a single depth reading doesn't provide much information, a series of depth readings can. The best way to ensure accurate locating results is to pay constant attention to depth readings over the course of a trace. The actual depth is not nearly as important as looking for a change to an otherwise consistent pattern.

For example, consider this series of depth readings:

1) 36″—35″—35″—36″—37″—37″—77″—90″— 85″—36″—35″—35″

Now consider this series of depth readings:

2) 36″—35″—35″—36″—37″—37″—77″—18″— 18″—19″—19″—19″

Finally, consider this series of depth readings:

3) 36″—35″—35″—36″—37″—37″—77″—36″— 35″—36″—35″—35″

All three of these locates has a pattern change. Only #2 indicates likely bleed-off onto a non-target line. #1 may be the result of locating a pipeline in a casing and #3 may be the result of locating past a buried valve box lid.

Pipeline Depth and Guidance

We're going to take a look at the digital death readings and the milliamp readings as the operator walks away from the transmitter and toward a pipeline station while locating a 24″ steel pipe **(Figures 139-141)**. At the pipeline station, the transmitter's signal will be split in a number of directions. These signal splits will complicate the locate near the pipeline station.

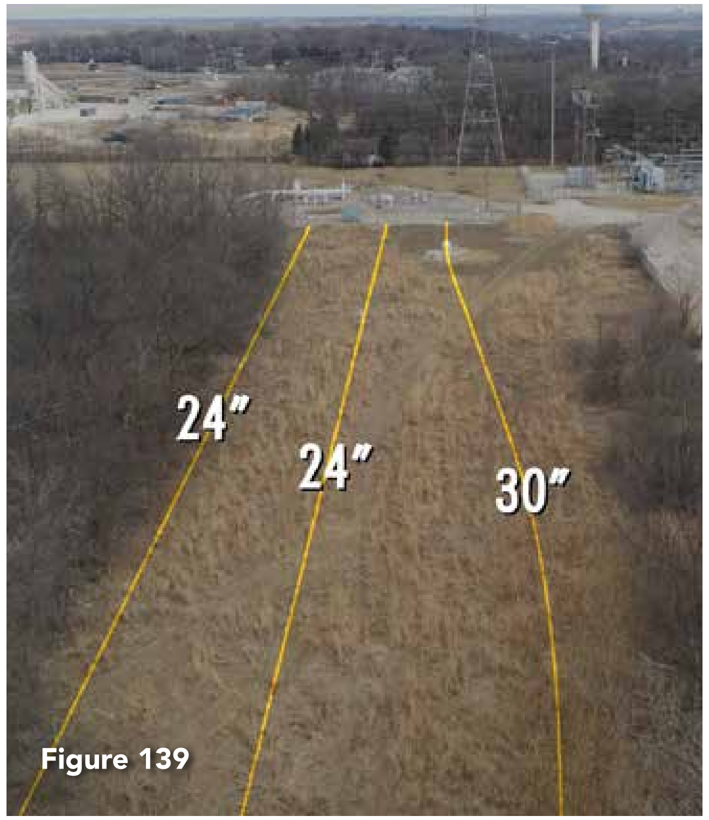


Figure 139

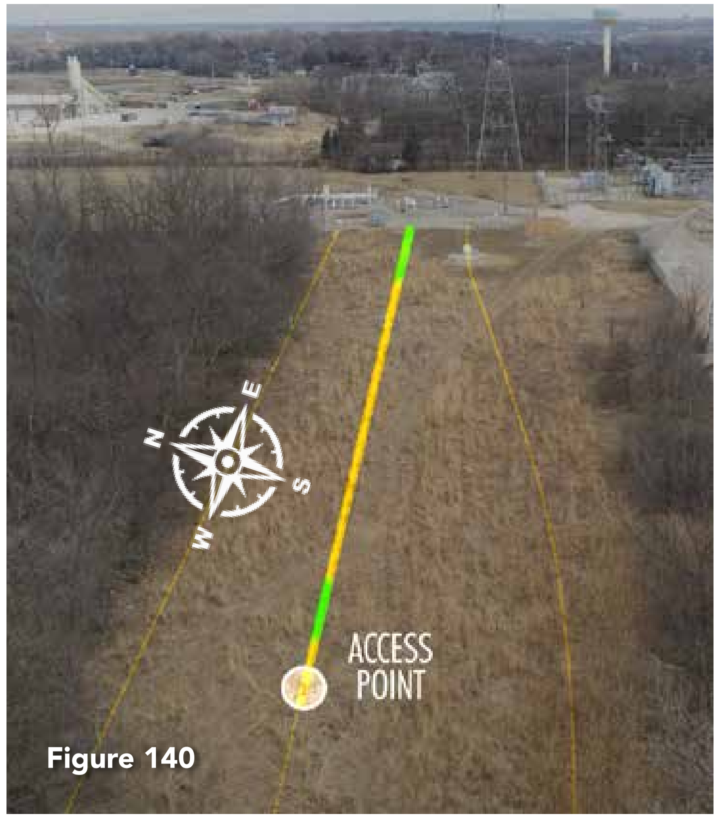


Figure 140


TOPIC HIGHLIGHT

Depth and current measurement readings are the result of utilizing **stacked-peak antennas.**

Figure 141

In general, milliamps would decrease over distance, assuming the depth of the pipe is the same. When the depth of the pipe changes over the course of the locate, the current measurement, or milliamp reading, will be impacted as well **(Figures 142-143)**.

When the operator moves the receiver laterally across the location of the pipe, the depth reading is going to be the shallowest (6′09″) when we're directly on top of the pipe. The milliamp reading will be the lowest number (119) when directly on top of the pipe.

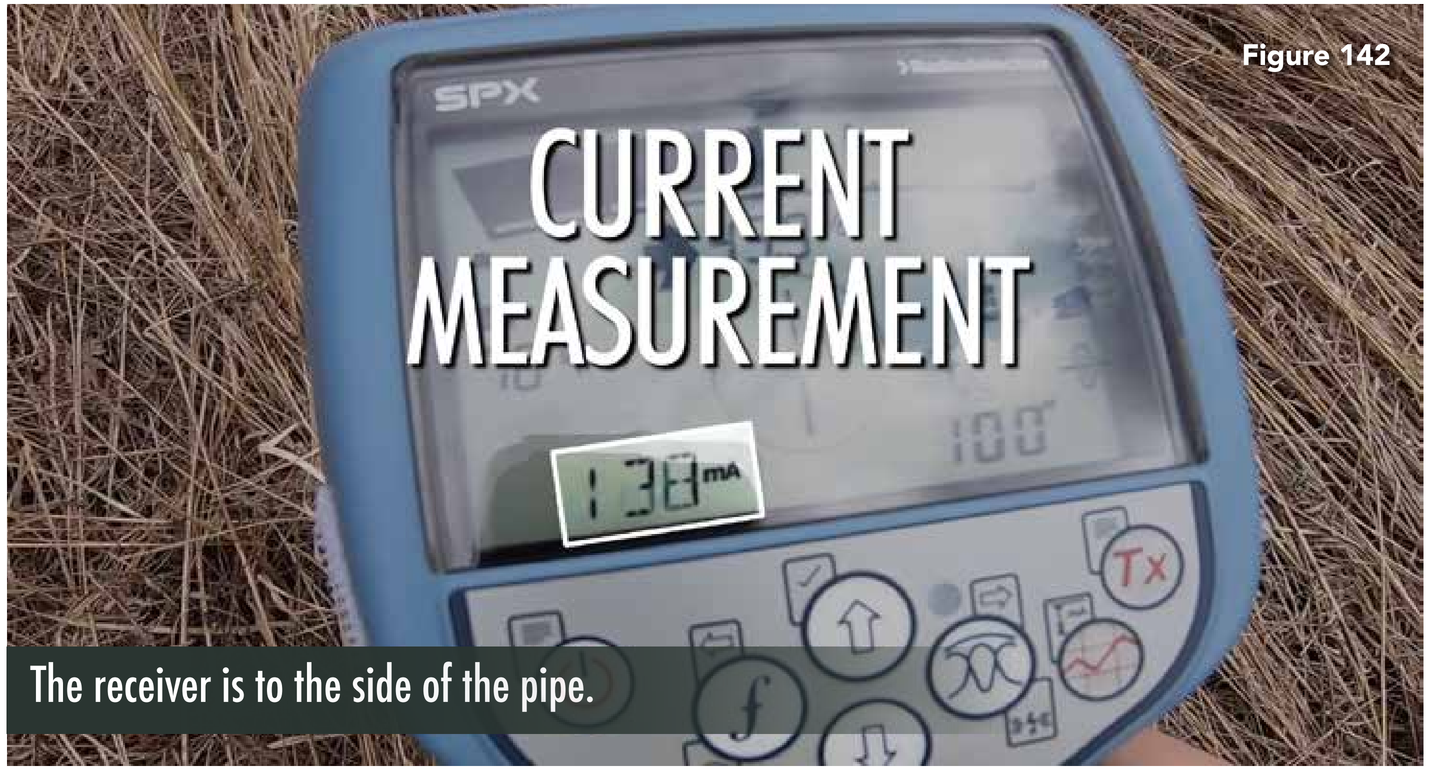


Figure 142

The receiver is to the side of the pipe.

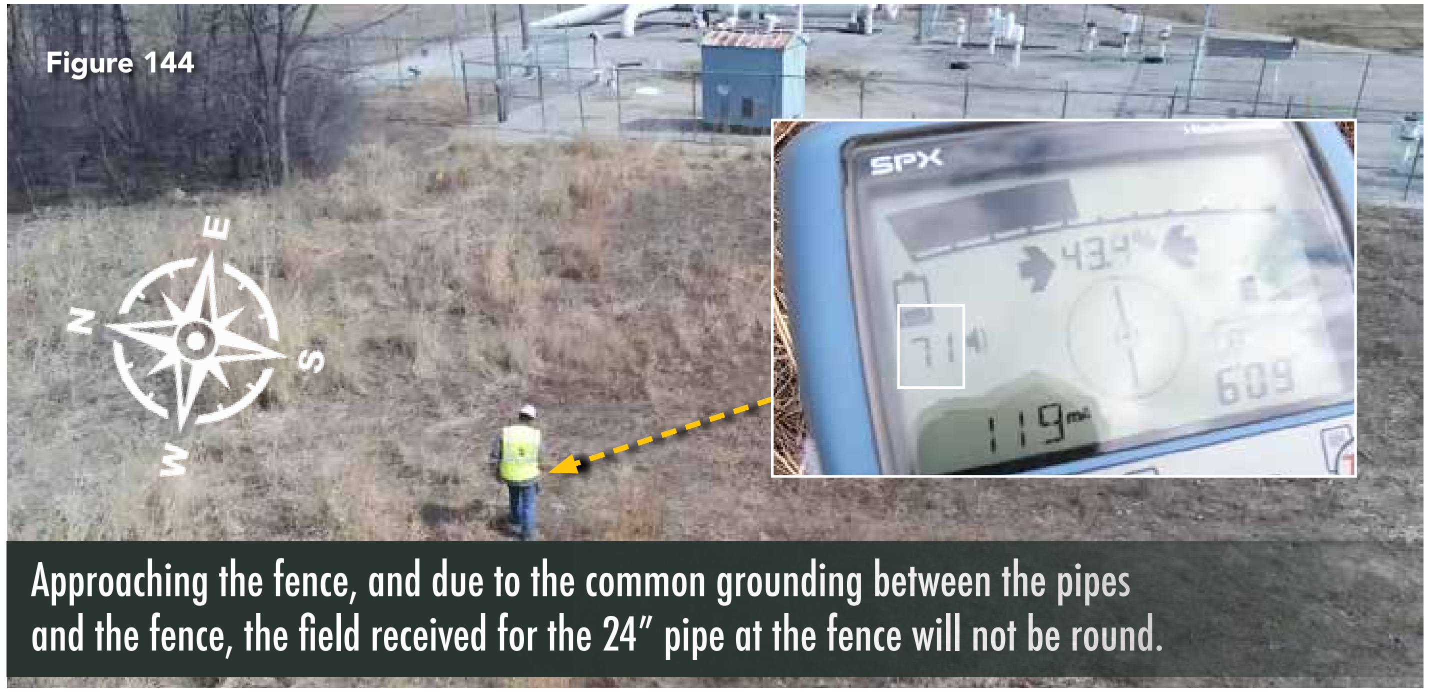
Figure 143

The receiver is over the top of the pipe.

Pipeline Depth and Guidance

In **Figure 144**, the depth is 6'09" and the mA is 119. At the peak reading along the pipeline station fence, the depth still reads 6'9" but the mA has dropped to 109 (Figure 146). The drop in mA is due to the increased distance from the transmitter. Signal strength in **Figure 146** is higher because the gain setting is 73 versus 71.

Figure 144



Approaching the fence, and due to the common grounding between the pipes and the fence, the field received for the 24" pipe at the fence will not be round.

The operator gets a null reading at the fence. The corresponding peak reading is 46.0 and the compass is crooked **(Figure 145)**. As the receiver is moved to the south along the fence, the peak reading reaches a maximum of 49.5 and the compass is straight **(Figures 146-147)**. There is a 7" difference in depth between the null reading and the peak reading **(Figure 148)**.

Figure 145

Figure 146

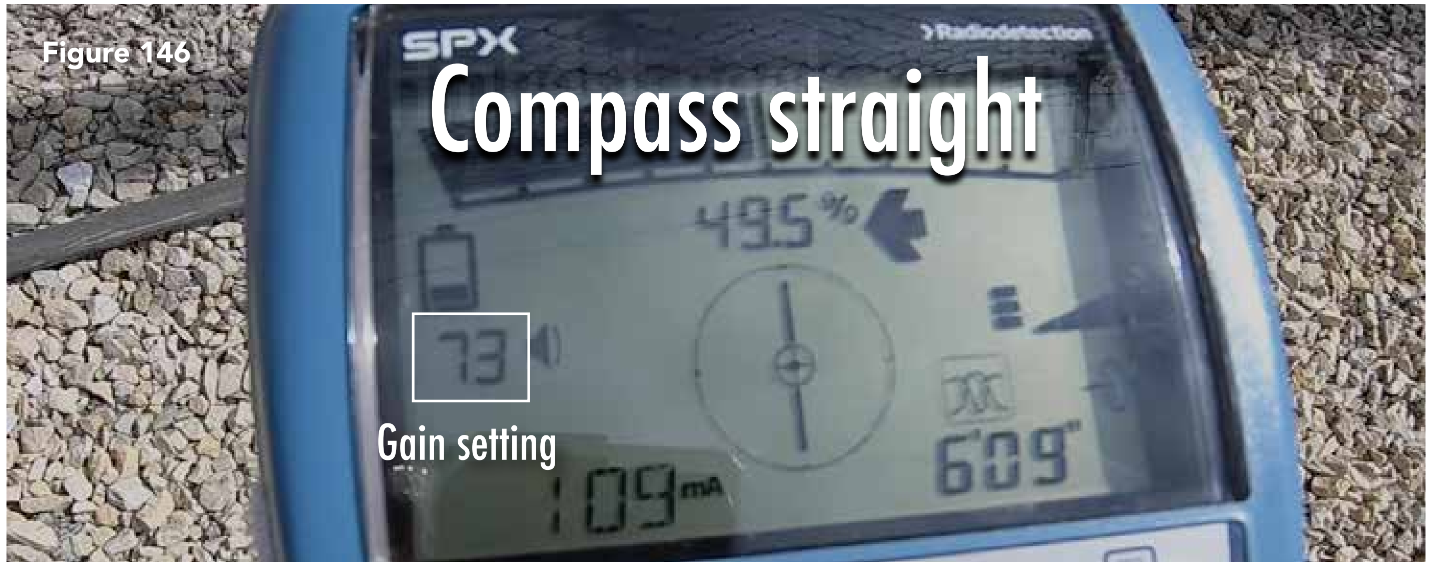


Figure 147

The 24" pipe's location will be closest to the highest peak reading, the shallowest depth, and the straight compass.

Figure 148

Difference in digital depth readings = 7"

Pipeline Depth and Guidance

Next up is locating the 30″ line on 8 kHz from an access point west of the pipeline station. As the trace progresses, the operator will check three locations along the pipe. We're going to be looking at the milliamp reading as well as the peak reading as we travel westward away from the access point **(Figure 149)**.

When the receiver is placed on the ground at location #1, the peak number is steady, resulting in what is termed "good current."

This designation of good current is completely independent of the milliamp reading **(Figure 149)**. The highest peak reading (32.0) does not align with the peak reading within the null (31.0). The 32.0 peak reading has the shallower depth and the lower milliamp number **(Figure 150)**.

It's possible that peak and null do not agree due to the proximity of the previously located 24″ pipeline **(Figure 139)**.

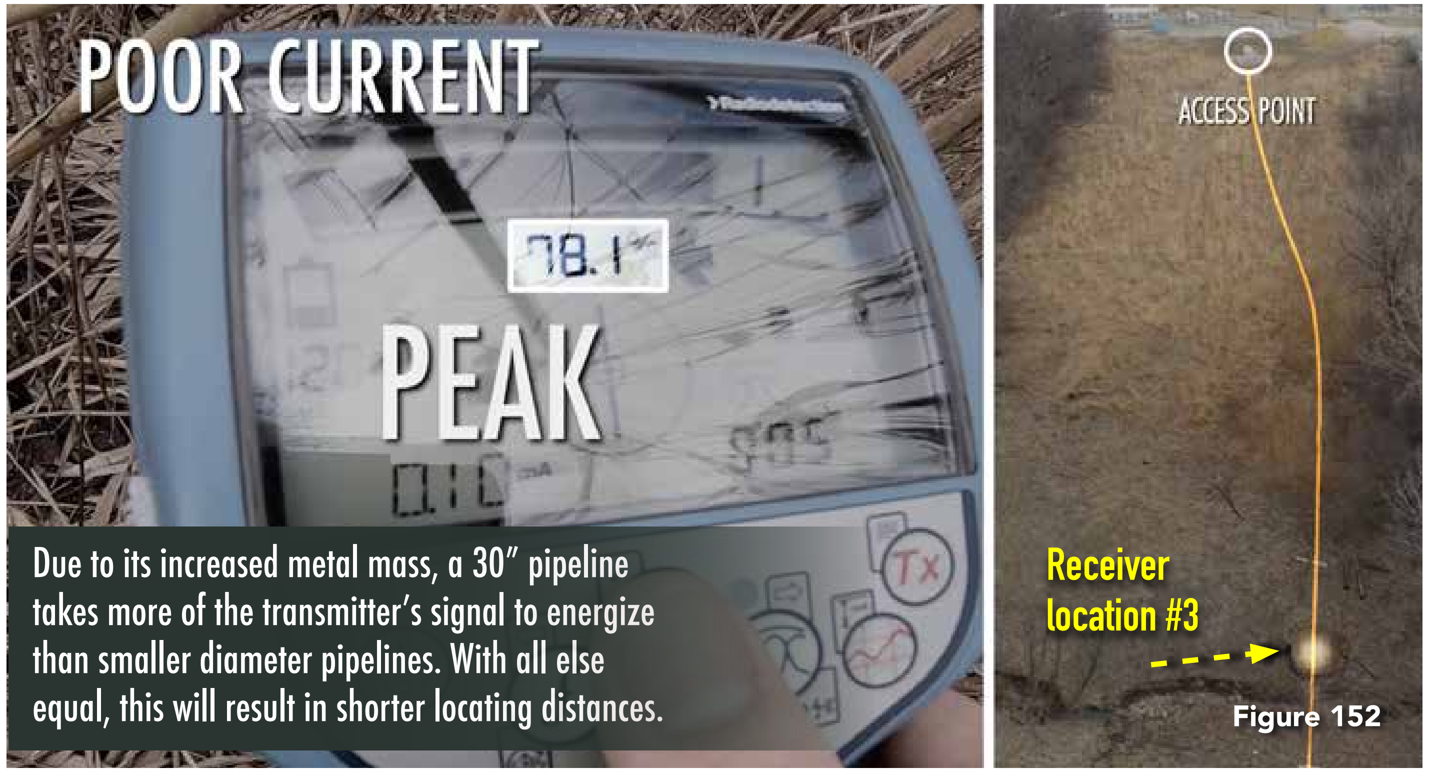
Figure 149

Figure 150

Figure 151

There is less current on the pipeline at receiver location #2 as validated by a fluctuating peak number **(Figure 151)**. With a fluctuating peak number, depth readings may fluctuate, too. As long as these numbers fluctuate in a small range, the current flow on the target line is classified as "OK current."

Reasons for a change from good current to OK current include a longer distance from the transmitter and a deeper depth at receiver location #2 versus receiver location #1. The combination of distance from the transmitter and depth of the line also contribute to a lower mA reading. With "poor current" and its wide-ranging fluctuation of peak and depth readings, the trace cannot continue past receiver location #3 **(Figure 152)**. The .10 mA reading is reflective of the same factors which produce the poor current designation.



Due to its increased metal mass, a 30″ pipeline takes more of the transmitter's signal to energize than smaller diameter pipelines. With all else equal, this will result in shorter locating distances.

Figure 152

Analyze

Something Else is Near

We're hooking up to a three-phase transformer on 8 kHz. We have a current flow reading of 100 mA **(Figures 153-154)**. The transmitter's signal will split between the cables leaving the transformer in all directions—including the lines entering the building—as well as the transformer's grounding system. There are two target lines to trace, and it's possible one will have more signal than the other.

Figure 153

Figure 154

Figure 155

TOPIC HIGHLIGHT

The access point sets up constructive interference.

There's a three-phase line that enters the transformer **(Figure 155)**, and there's another three-phase line that leaves the transformer. Both the entrance cable and the exit cable are in the same trench until they separate following a change in direction, as indicated by the map below **(Figure 156)**. These cables run parallel and are about six feet apart.

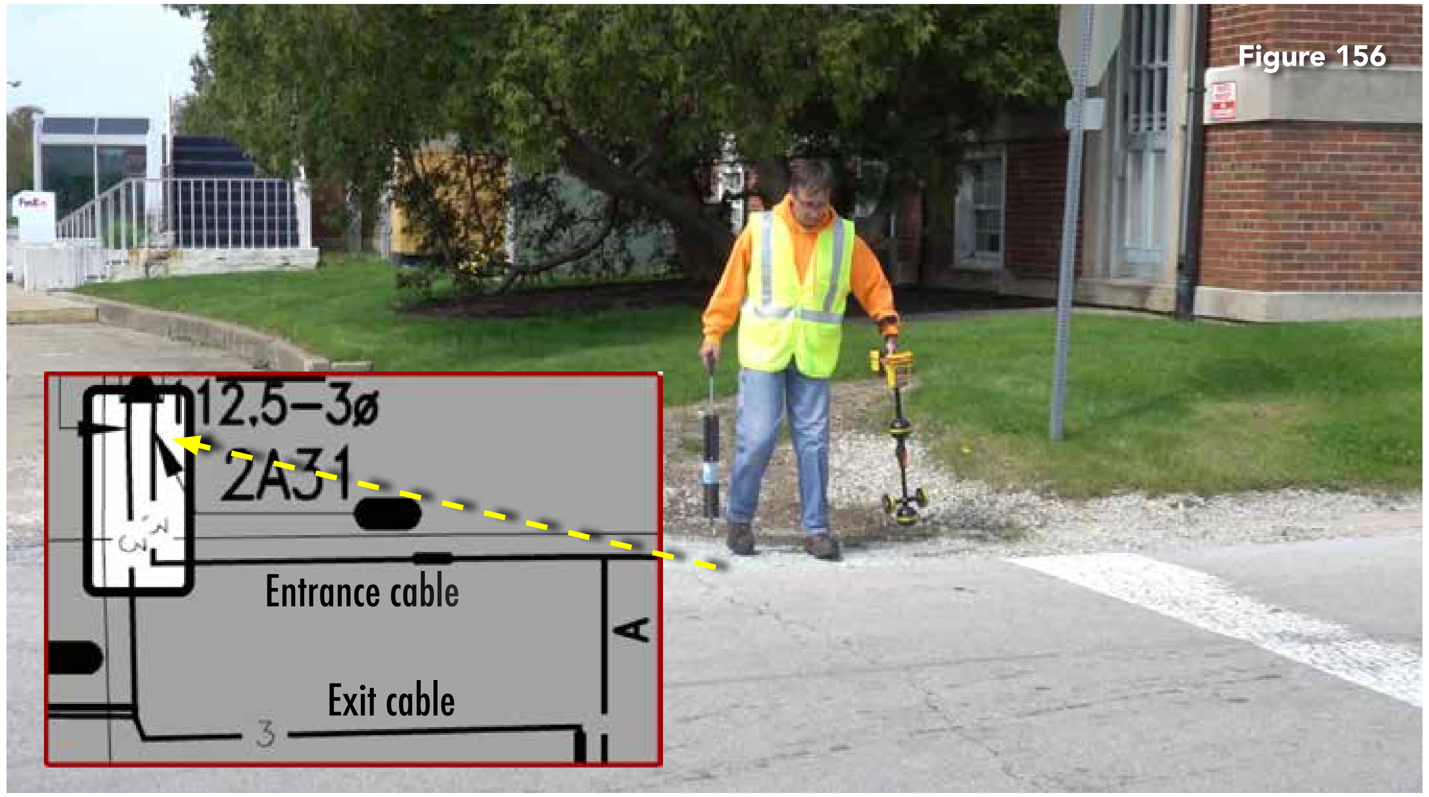


Figure 156

Something Else is Near

It is impossible to identify the number of lines in a trench when the lines are laid side-by-side or atop each other because the receiver cannot distinguish between multiple signal circles positioned so close together. This is particularly true when all of the cables are energized at a single access point. Since these are three-phase cables, there are a total of six cables that carry the transmitter's signal **(Figures 157-158)**.


Figure 157


Figure 158


Figure 159

The compass at a diagonal indicates that a line is turning **(Figure 159)**. Originally going south, the trace is about to turn to the east where the entrance cable and exit cables are approximately six feet apart. The map in **Figure 160** indicates that the exit cable is spliced into by a couple of single-phase cables. This likely results in the entrance cable having more of the transmitter's energy on it than the exit cable as the trace moves east.

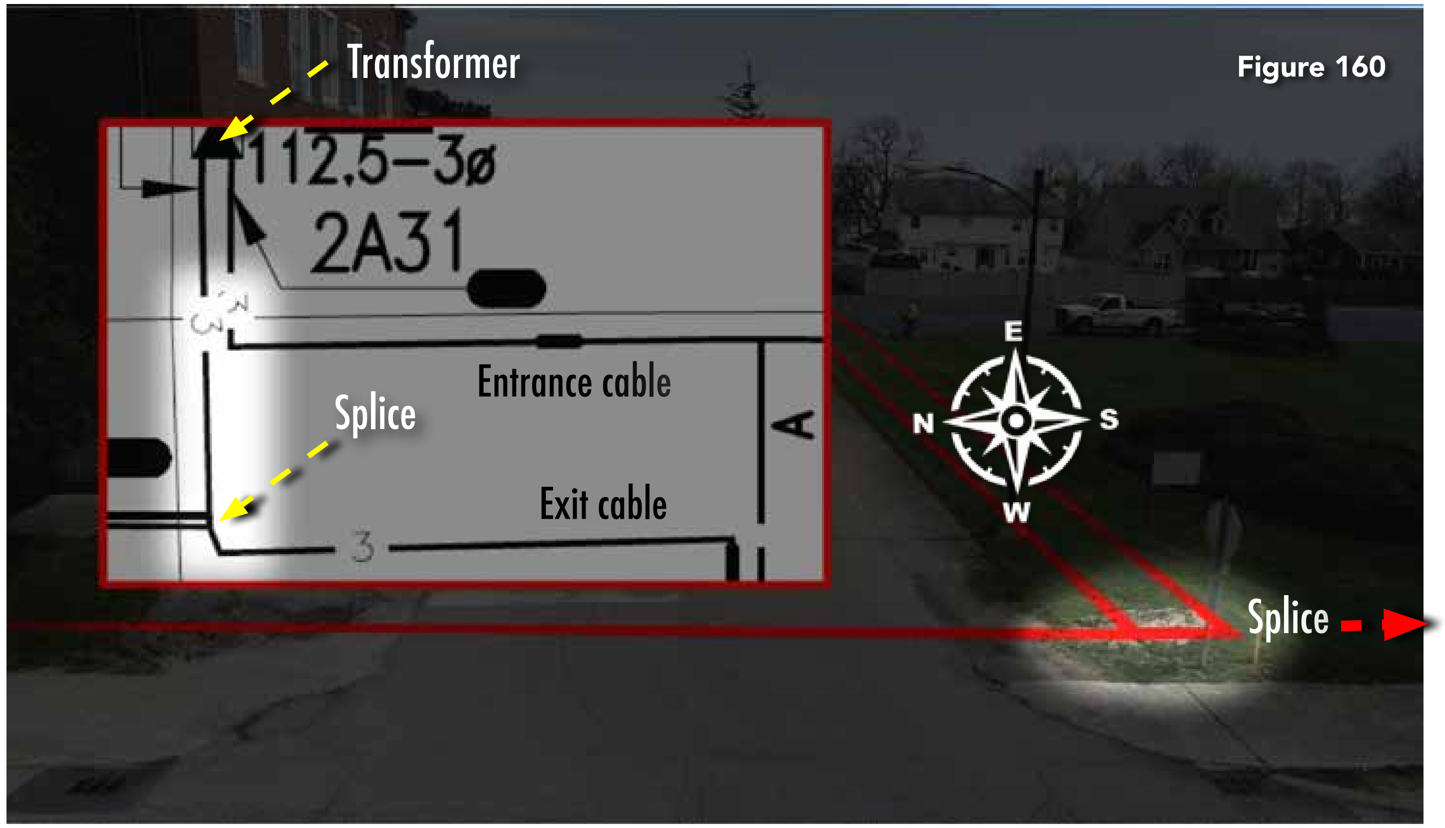


Figure 160

Something Else is Near


Figure 161

We are locating the entrance cable which is located just south of the south edge of the sidewalk **(Figure 161)**. Our left-right arrows and our peak numbers agree, but the null line is outside of the crosshairs as if the line is being attracted, or pulled, toward the exit cable **(Figure 162)**.


Figure 162

During the trace on the entrance cable, the null line is seemingly being pulled toward the exit cable. However, an attempt to locate the exit cable fails **(Figure 163)**. There is no peak, null, or electronic null reading until the receiver is in the vicinity of the entrance cable.

Doing something different to locate the exit cable, the transmitter at the transformer is changed to 33 kHz. The current flow reading remains at 100 mA. However, this attempt also fails **(Figure 164)**. Again, there is no peak, null, or electronic null reading until in the receiver is in the vicinity of the entrance cable.

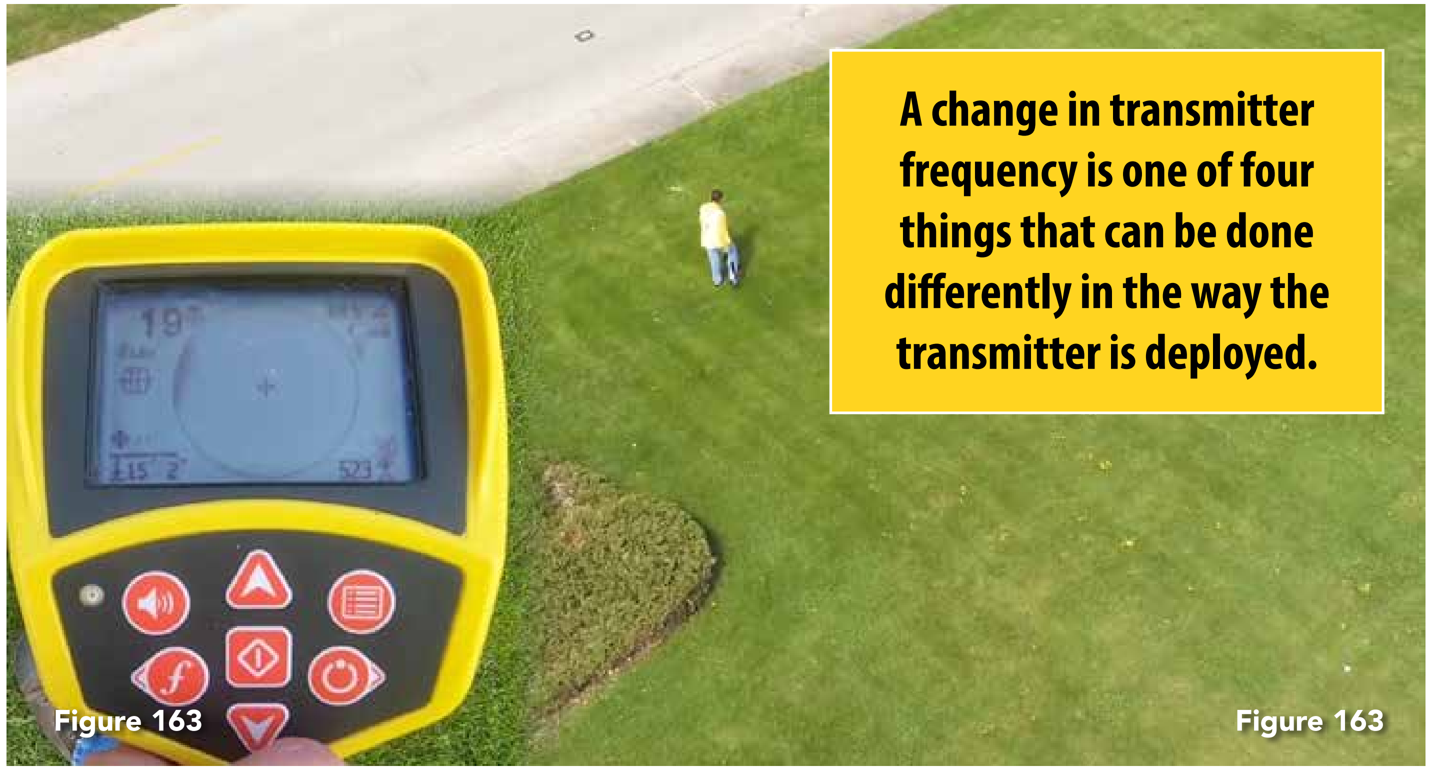


Figure 163

A change in transmitter frequency is one of four things that can be done differently in the way the transmitter is deployed.


Figure 164

Since the exit cable cannot be traced on 8 kHz or 33 kHz, is it possible both the entrance cable and the exit cable are buried in the same trench?

Something Else is Near

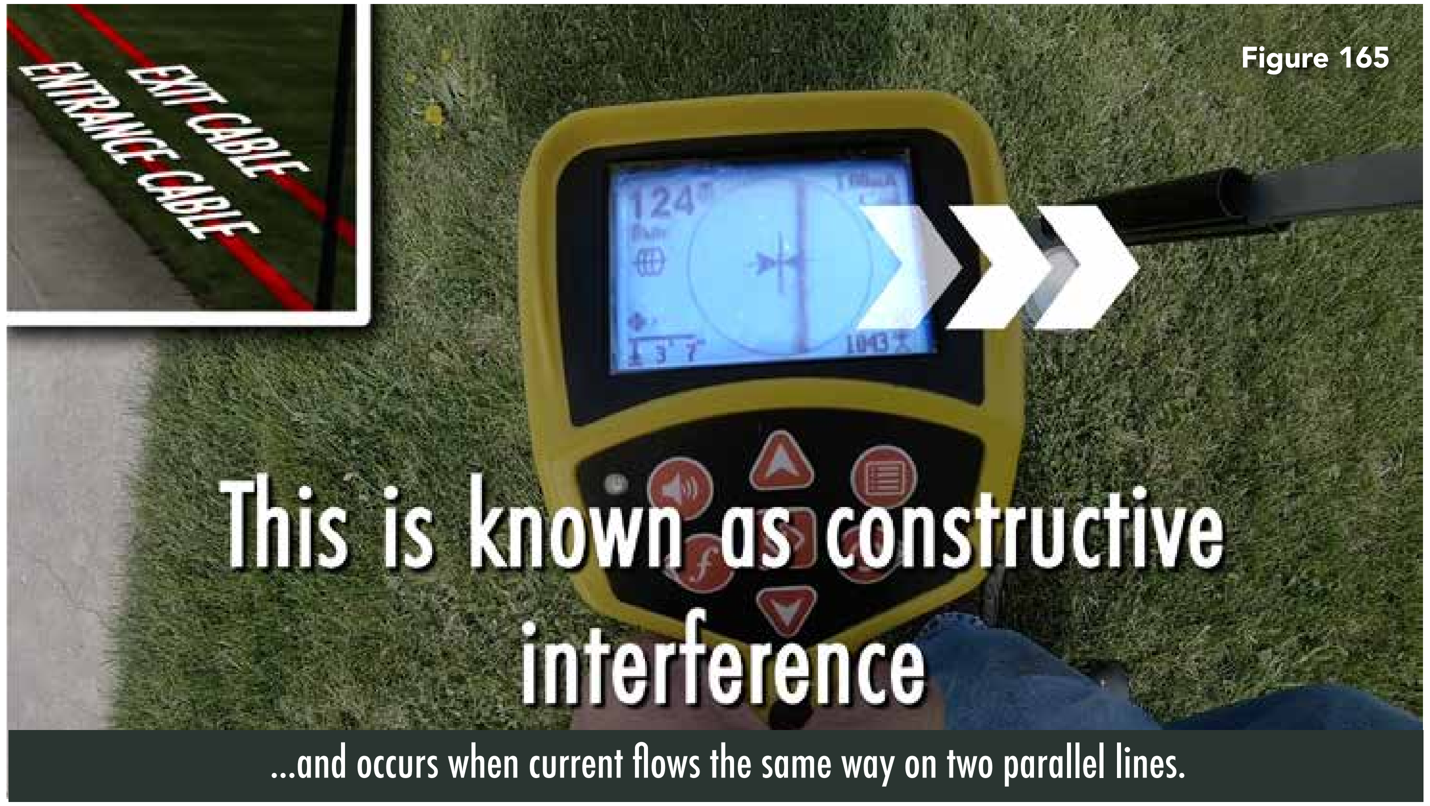


Figure 165

This is known as constructive interference

...and occurs when current flows the same way on two parallel lines.

Energizing two lines at the same time at the transformer creates the set-up for constructive interference. Constructive interference is somewhat like two magnets whose fields are attracting one another **(Figures 165-166)**.

Figure 166

Current flows the same way because both lines are energized here

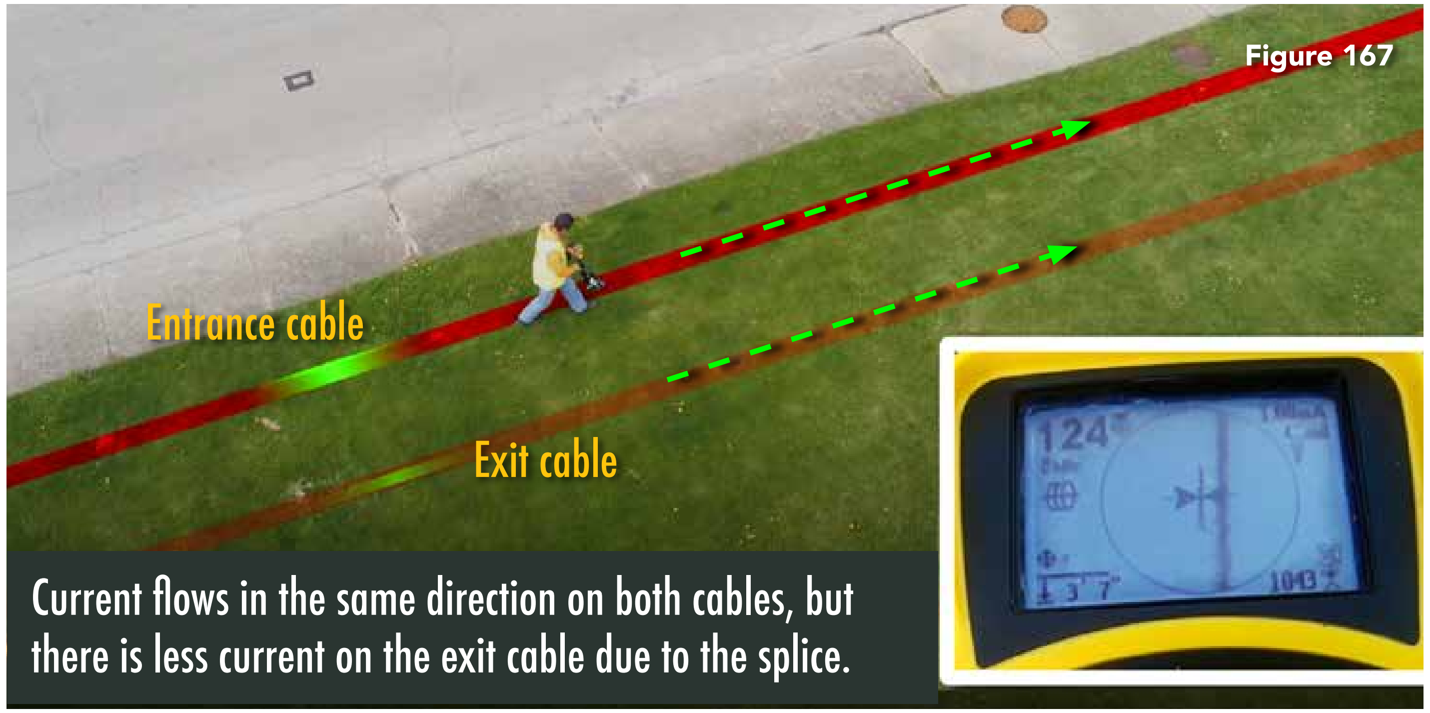


Figure 167

Current flows in the same direction on both cables, but there is less current on the exit cable due to the splice.

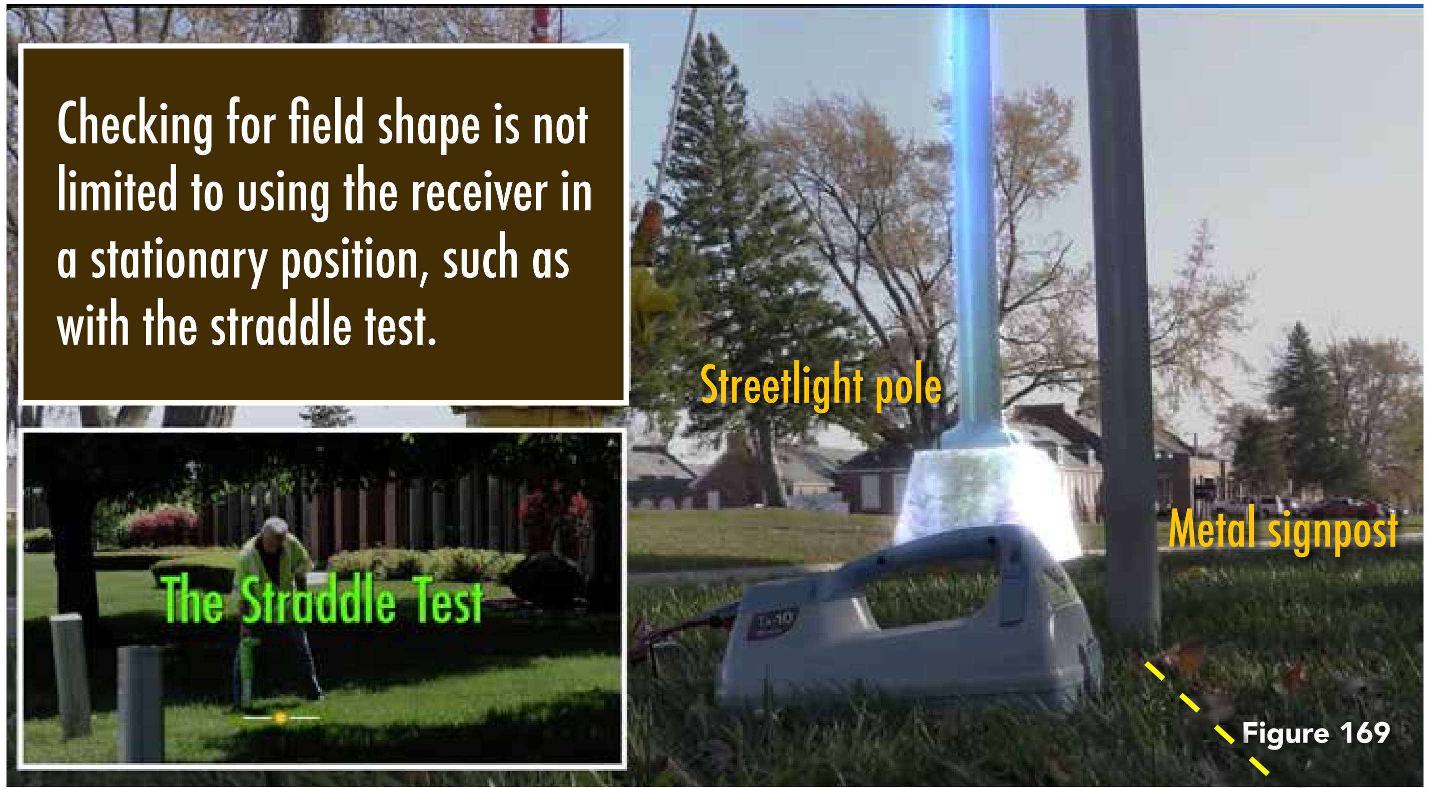
Locating in 8 kHz tells the operator that something else is near and energized even though the exit cable could not be found **(Figure 167)**. Locating in 33 kHz may have led the operator to believe that both the entrance and exit cables were in the same trench, which they are not.

Figure 168

Different transmitter frequencies can and sometimes will do different things. In this situation, a decision to locate the lines using 33 kHz at the access point may have resulted in missing the exit cable **(Figure 168)**. However, 8 kHz resulted in alerting the operator that something else was near. It's also worth pointing out that following the trace to logical and visual endpoints would have virtually eliminated the possibility of missing the exit cable.

SHAPE

Due to the nature of alternating current, half the time the transmitted signal is sent to earth at the grounding device. Due to the grounding device's proximity, the metal signpost becomes energized **(Figure 170)**. Once the signpost is energized, the buried streetlight cable located within a foot of the signpost becomes energized as well.



Checking for field shape is not limited to using the receiver in a stationary position, such as with the straddle test.

Figure 169

Figure 170

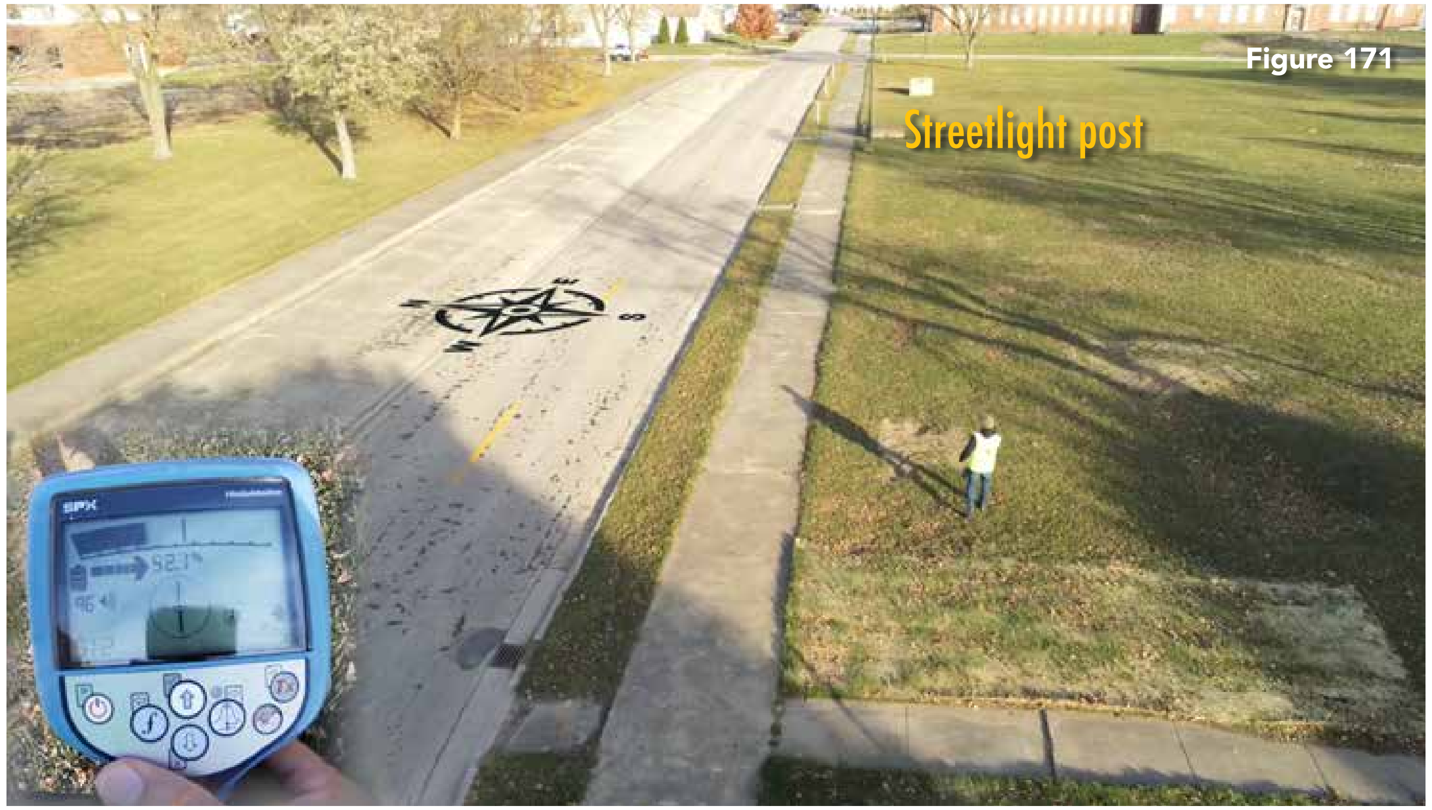


Figure 171

Horizontal inspection of the field will oftentimes tell you whether there are other energized lines within the area of your target line **(Figure 169)**. When the instrument is swung to the north **(Figure 171)**, the peak numbers are higher than when the instrument is swung to the south **(Figure 172)**.

With the receiver being swung to the sides an equal distance, the "straddle test" is performed while walking. Differing audio levels tied to the peak response alert the operator to different peak readings on either side of the trace while walking and locating.

Figure 172

Shape

Assuming that this is a symmetrical swing of the receiver, the reason why the numbers are higher to the north is that a streetlight cable has some of the transmitter's energy on it. It's not enough to make peak and null disagree, but you can see it on the outer edges of the swing. This is a horizontal inspection of the field, and what we're seeing is known as constructive interference. Current is traveling in the same direction on both the line we're locating—a water main—as well as the streetlight cable **(Figure 173)**. With constructive interference, signal circle values are added **(Figure 175-176)**.

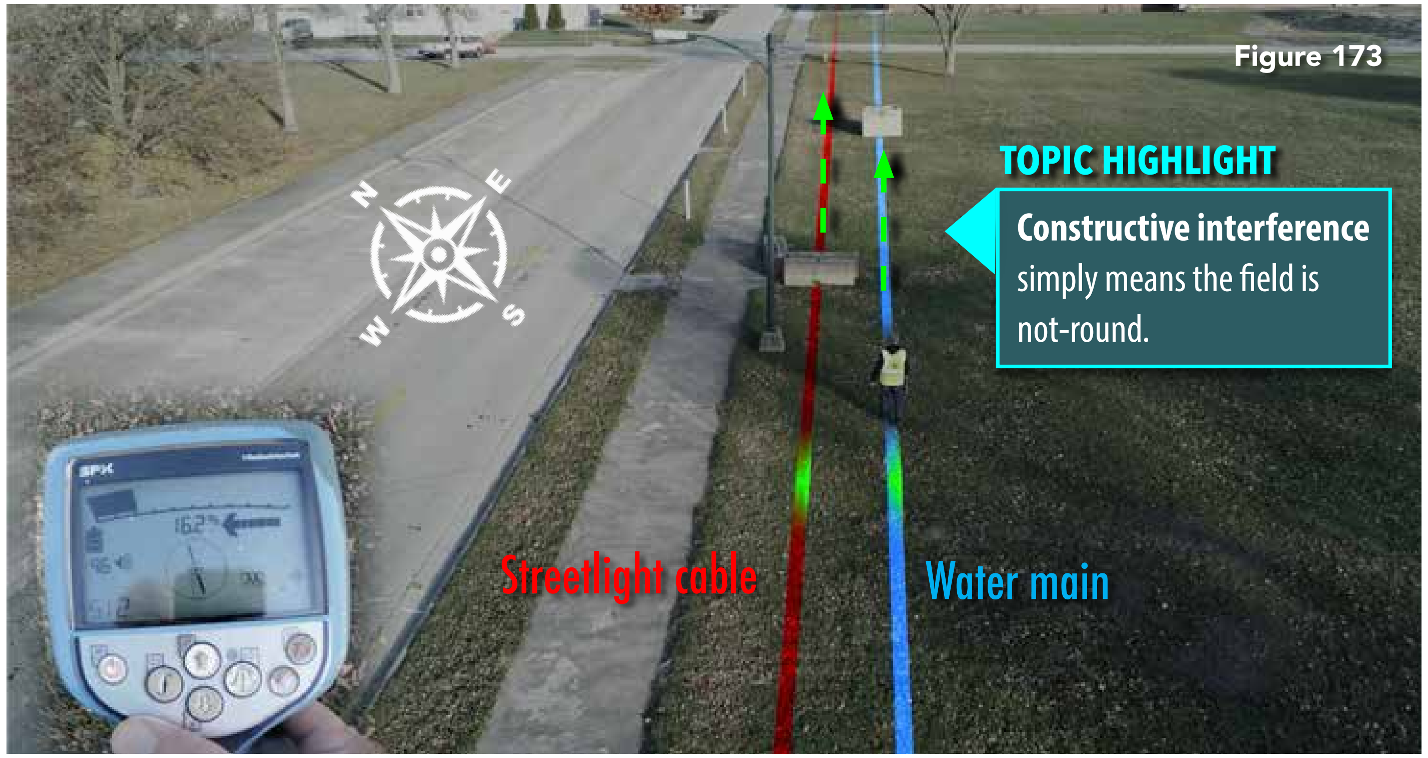


Figure 173

TOPIC HIGHLIGHT

Constructive interference simply means the field is not-round.

With the signpost energized, it re-radiates signal to the adjacent streetlight cable **(Figure 174)**.

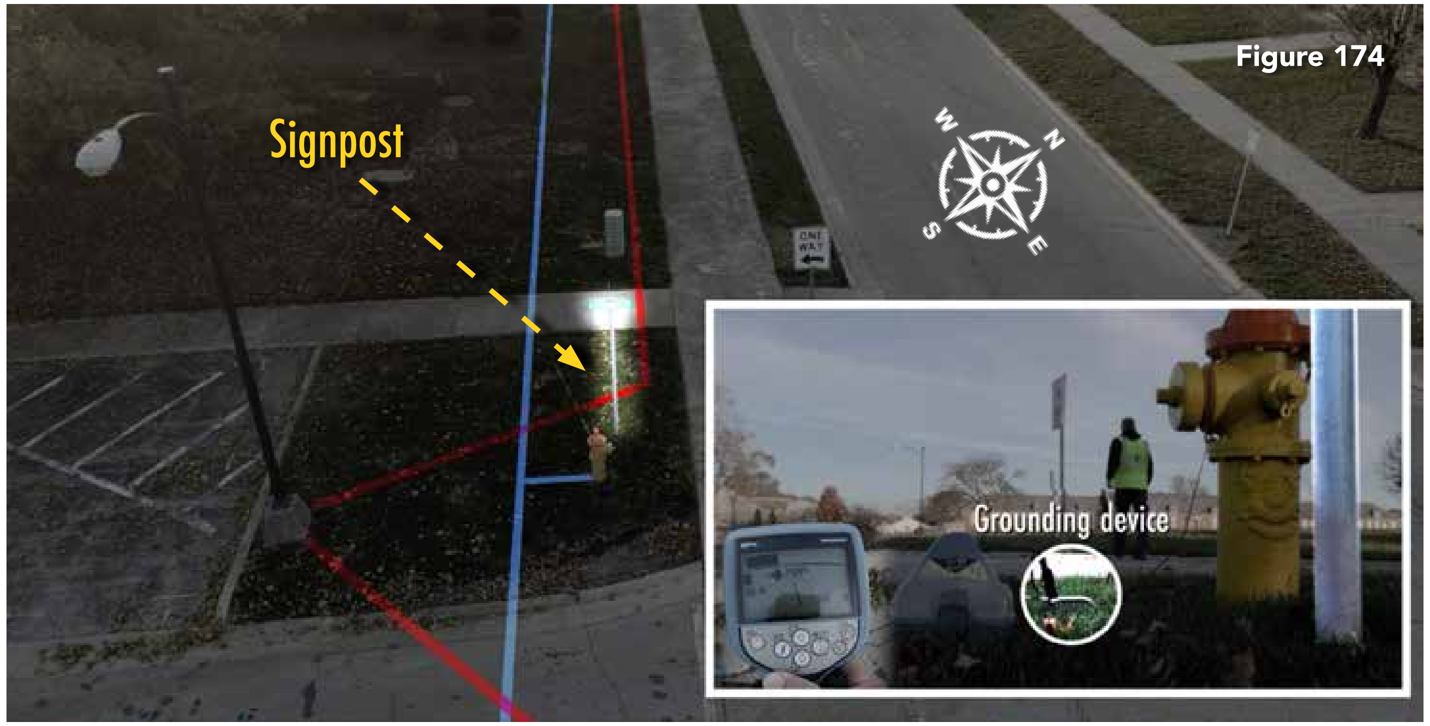


Figure 174

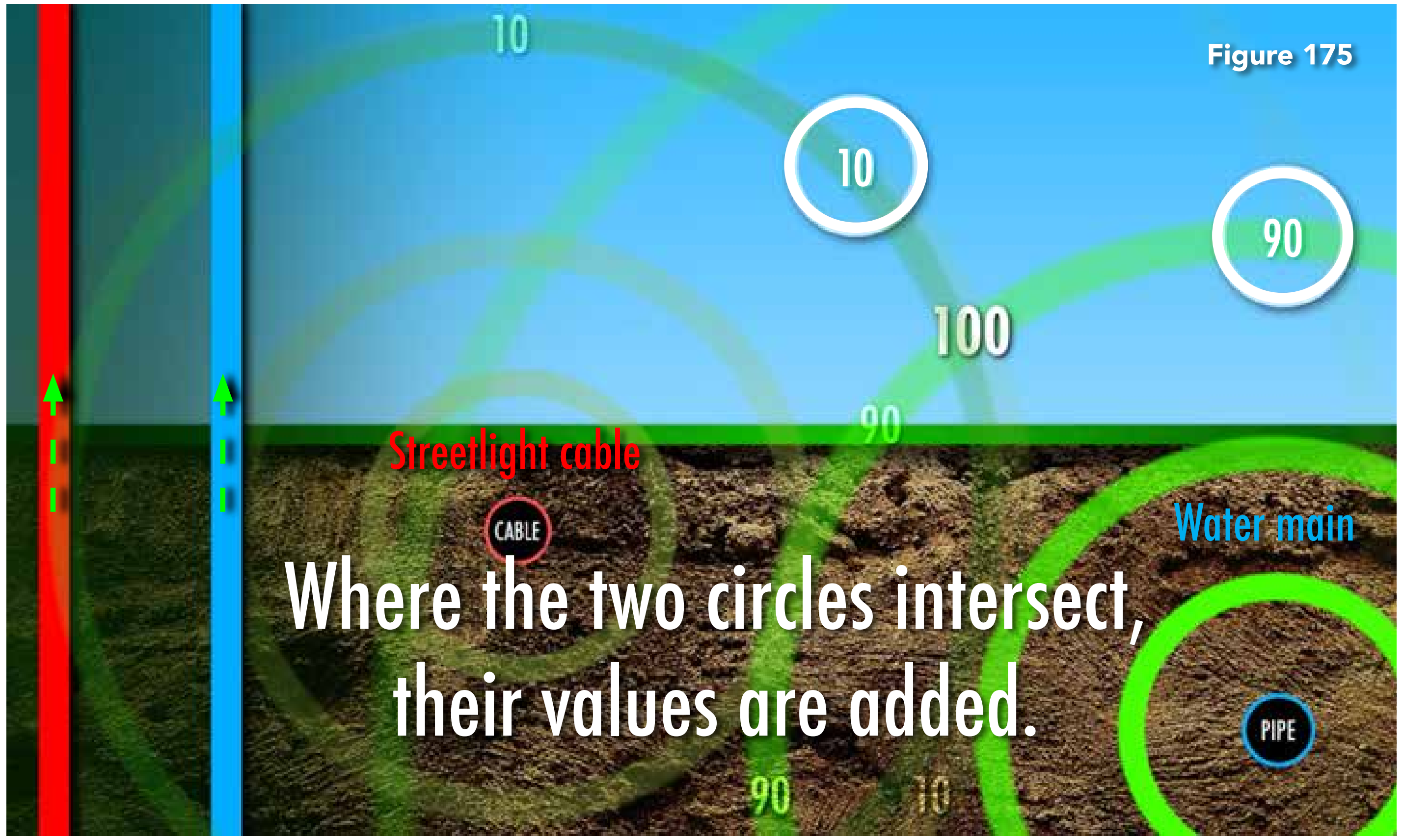


Figure 175

Where the two circles intersect, their values are added.

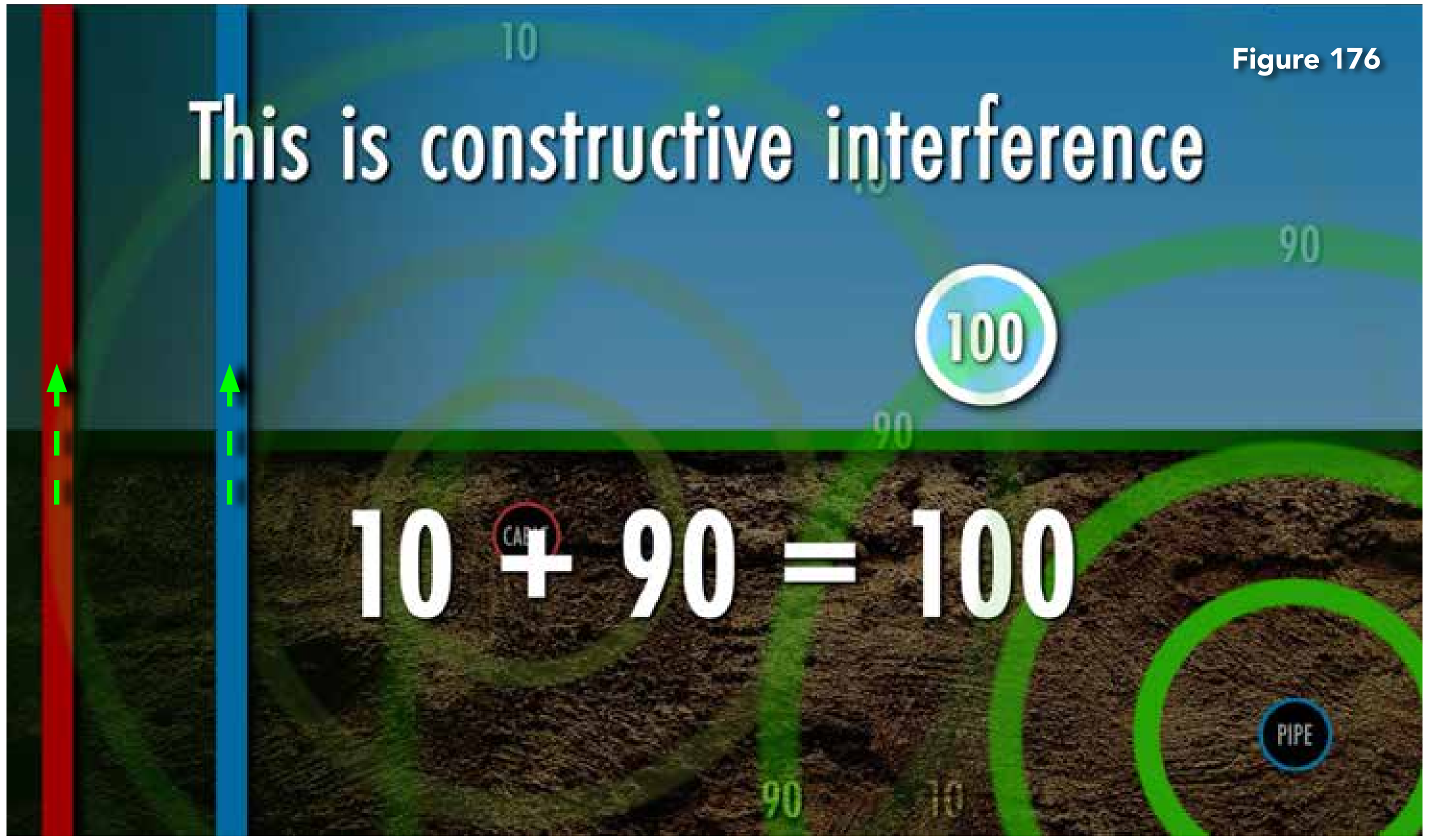


Figure 176

This is constructive interference

10 + 90 = 100

> "With constructive interference, signal circle values are added."

Shape

We're hooked to a steel gas service that's connected to a steel gas main **(Figure 177)**. Our transmitted frequency is 38 kHz. Once we're locating the steel main to the west, a cable TV feeder will be located to our south **(Figure 178)**.

Figure 177

Figure 178

Figure 179

When the instrument is swung to the south **(Figure 179)**, the peak reading numbers are lower than when the instrument is swung to the north **(Figure 180)**. Assuming a symmetrical swing of the receiver, the reason the peak readings are lower to the south is due to destructive interference.

Figure 180

Shape

There's some energy from the transmitter on the cable TV line **(Figure 181)**. The current on the cable TV line is running in an opposite direction to that on the steel gas main, the target utility. With destructive interference, the lower signal circle value is subtracted from the higher signal circle value **(Figures 182-183)**.

Figure 181

TOPIC HIGHLIGHT

Destructive interference simply means the field is not-round.

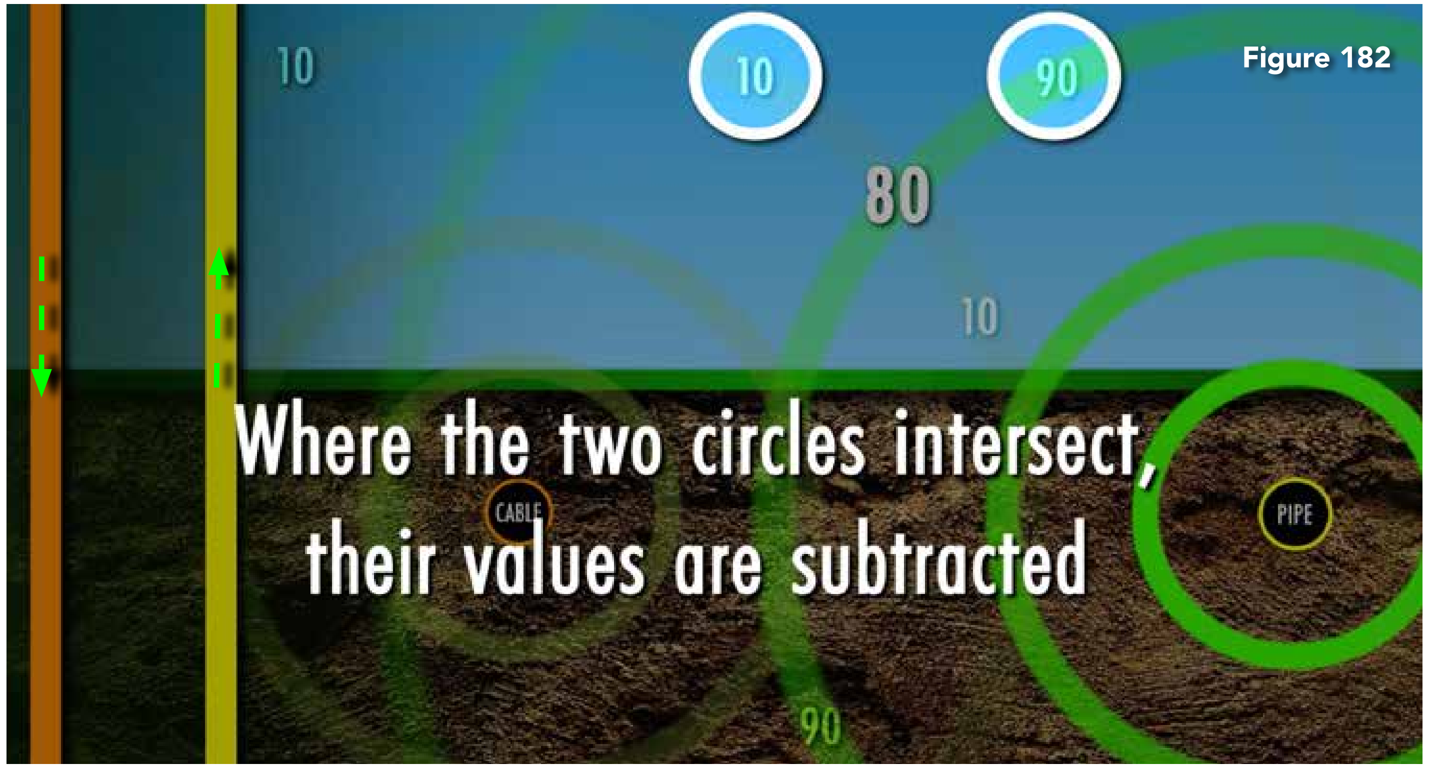


Figure 182

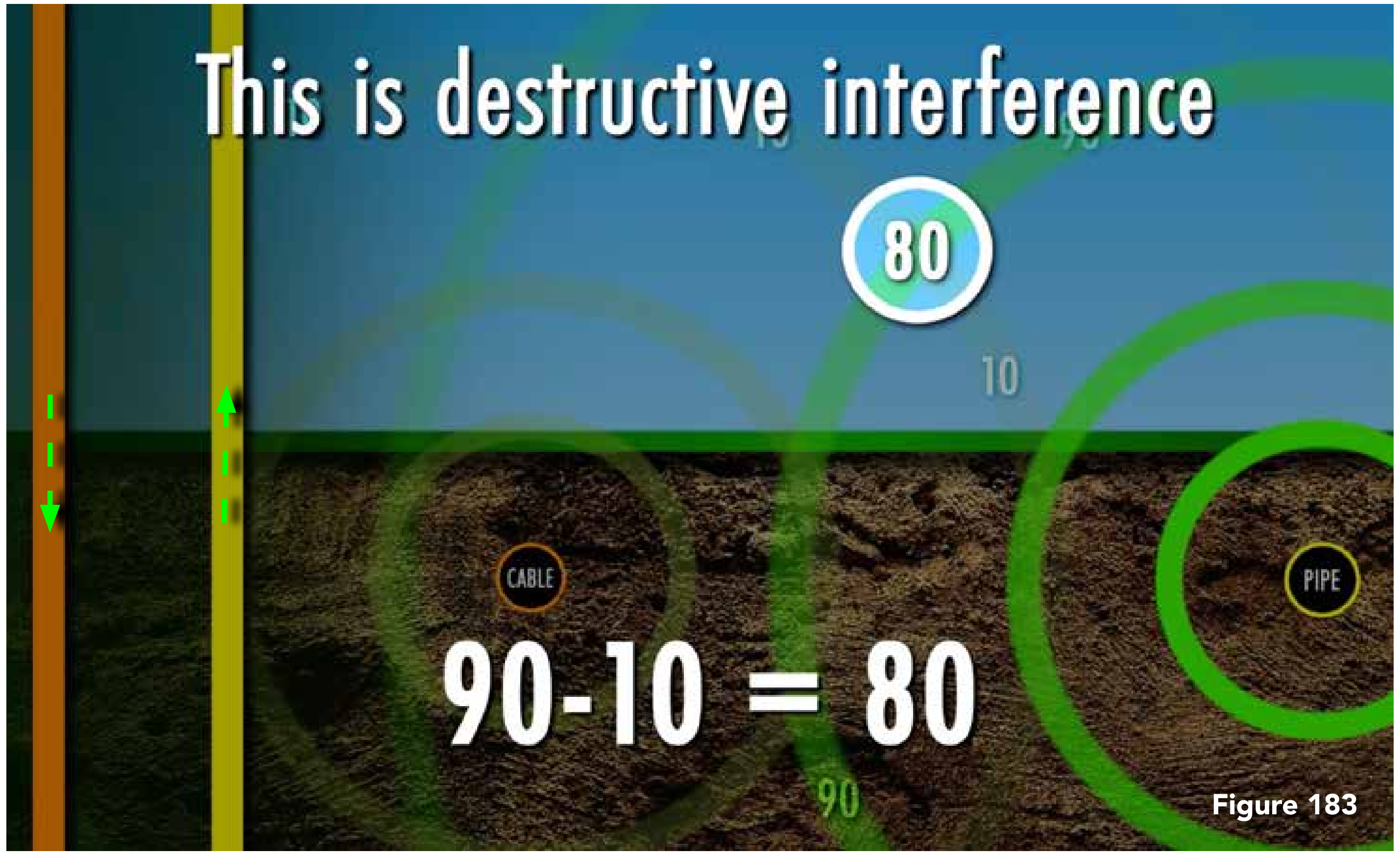


Figure 183

The current on the cable TV line is running in an opposite direction to that on the steel gas main, the target utility **(Figure 184)**.

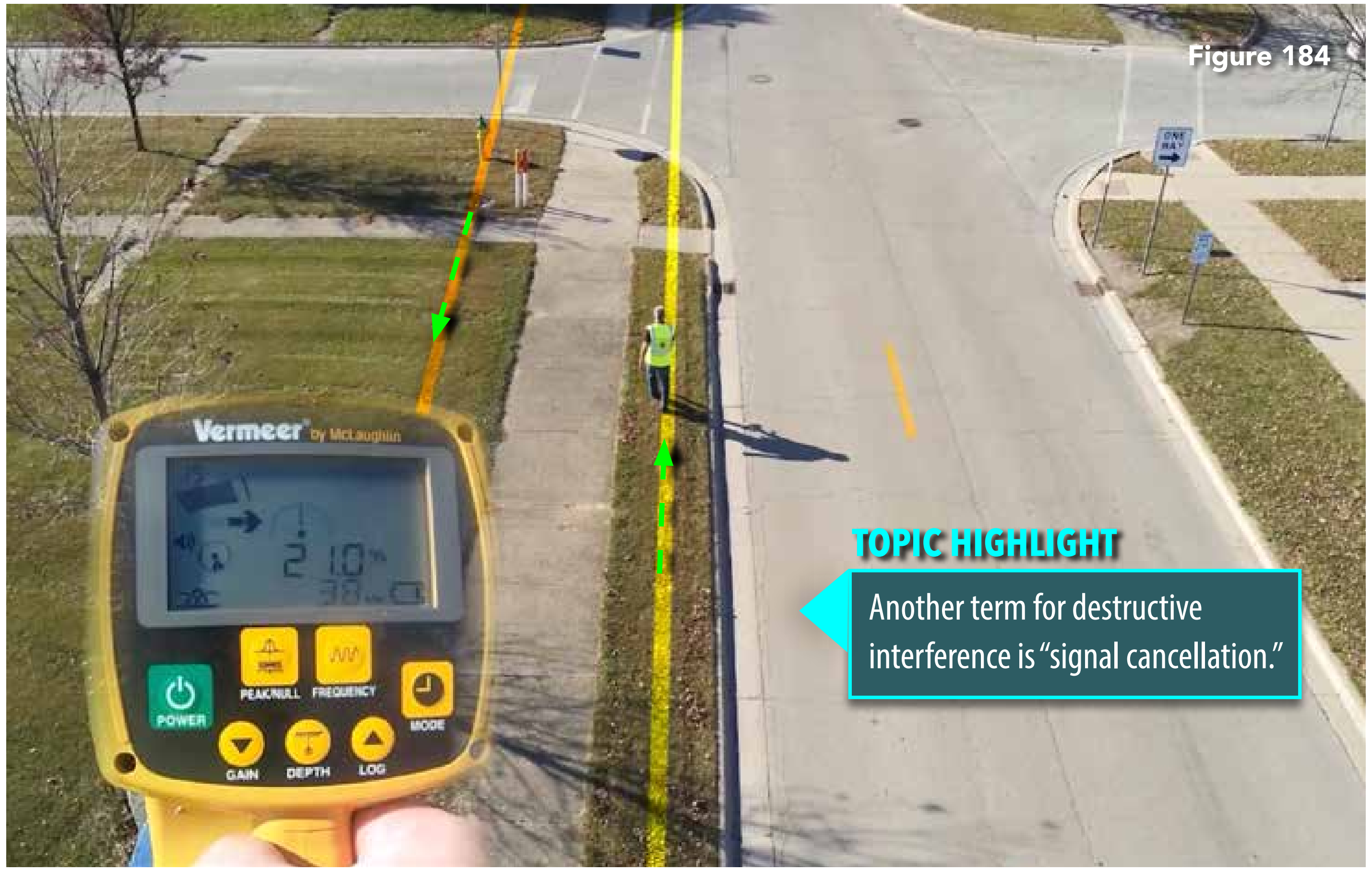


Figure 184

TOPIC HIGHLIGHT

Another term for destructive interference is "signal cancellation."

Shape

Vertical inspection of the field is utilized to determine the accuracy of your trace. There are three ways in which you can check for the shape of your field in a vertical perspective: peak vs. null, depth validation, and the lift test. The easiest and most efficient method of determining field shape is to compare the peak location to the null location. If they agree, the signal is round. If they disagree, the signal is not-round. If peak and null disagree **(Figure 185)**, it is very unlikely that depth validation or the lift test will indicate that the field received is round.

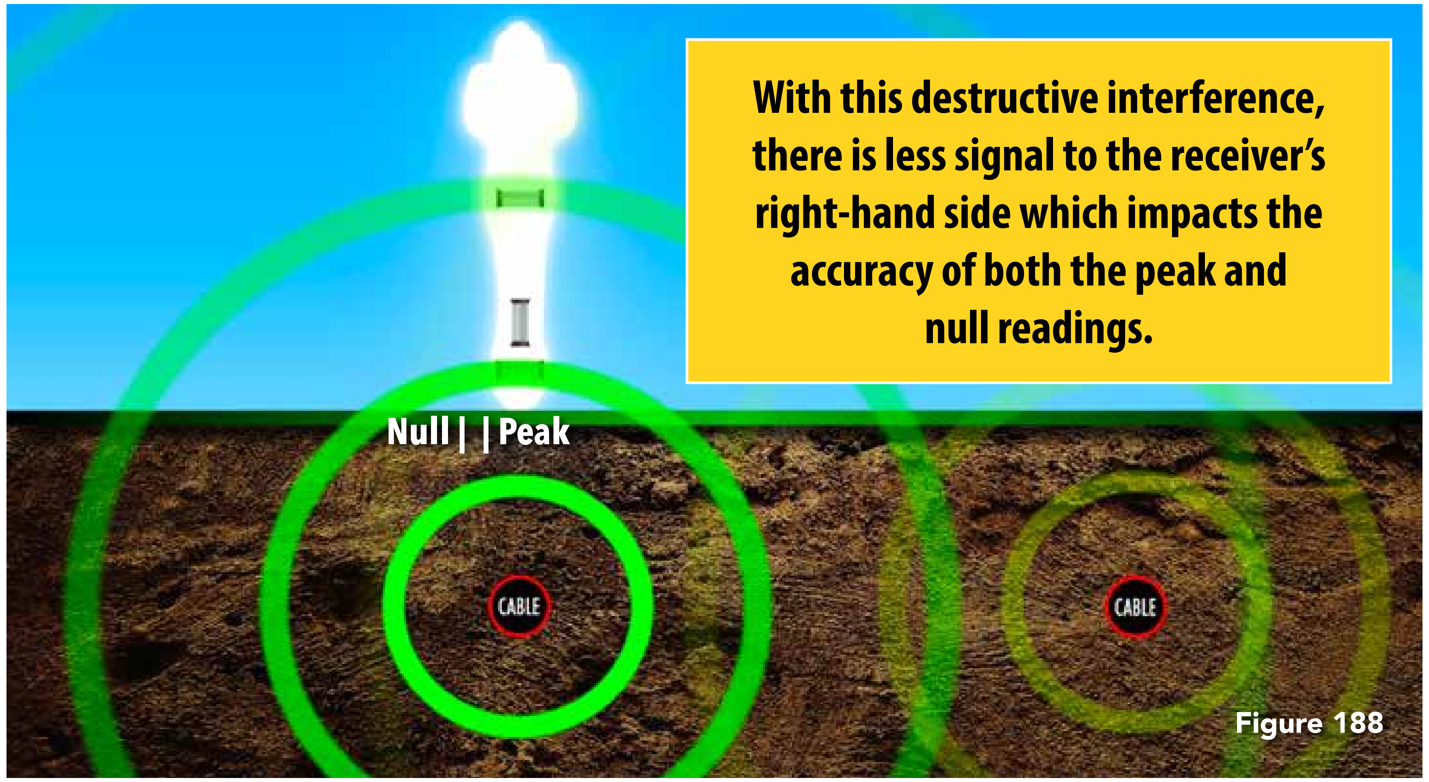
Figure 185

Below, the null is to the west of the peak **(Figure 186)**. Peak and null do not agree, indicating the shape of the field is not-round. The greater the distance between peak and null locations, the greater the degree of destructive interference. Destructive interference may show a single null between two peaks. The null is west of the peak with the instrument in **Figure 187** as well.

Figure 186

Figure 187

What causes a not-round field? It's the presence of the transmitter's energy on more than just the target line **(Figure 188)**. Comparing peak to null (or peak versus null) is a vertical inspection of the field. Conversely, when peak and null locations agree, it's because no other nearby metallic object is sufficiently energized to affect the accuracy of the trace. However, it's possible that destructive interference may show that peak and null agree, while depth validation will show a significant error.



With this destructive interference, there is less signal to the receiver's right-hand side which impacts the accuracy of both the peak and null readings.

Figure 188

Shape

Another method that checks the vertical nature of the field is depth validation. The receiver is raised a known distance, and the new depth reading will either agree with that raised distance or disagree. If it agrees, the field is round. If it disagrees, the field is not-round **(Figures 189-190)**.

Depth validation may indicate not-round even though peak and null agree. One potential reason for this scenario would be the presence of two energized conductors atop each other with a foot of separation between the conductors.

Figure 189

TOPIC HIGHLIGHT

When **depth readings** validate, it's because no other nearby metallic objects are sufficiently energized to result in receiving a not-round field. If peak and null disagree, it is unlikely digital depth will validate.

Figure 190

TOPIC HIGHLIGHT

When the receiver is lifted a known amount of distance, the resulting new depth may be:

1. Deeper (possible validation)
2. The same (not-round)
3. Shallower (very not-round)

The field is round

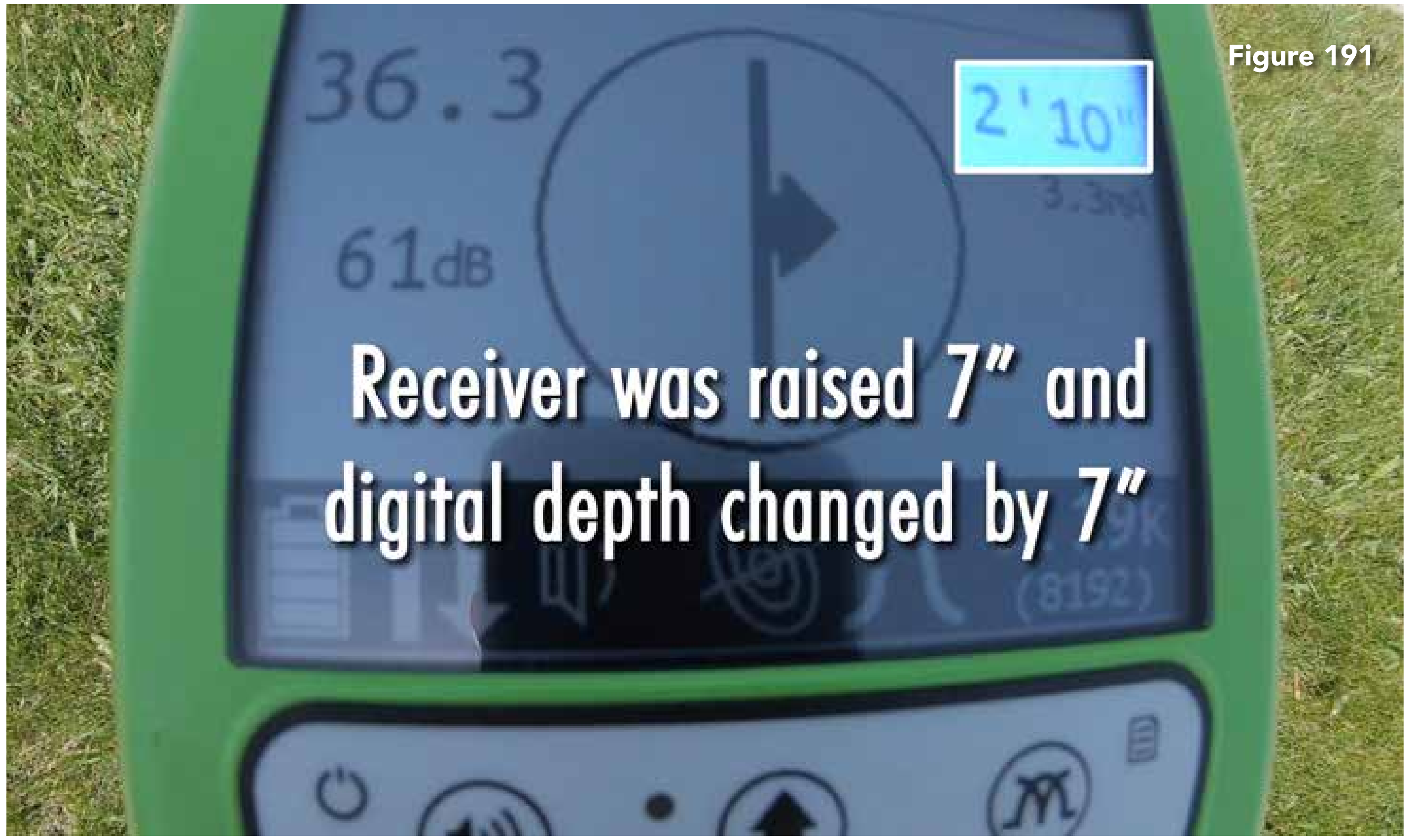


Figure 191

Receiver was raised 7" and digital depth changed by 7"

When the receiver is stationary with its bottom on the ground, the rest of the receiver needs to be held straight and perpendicular with flat ground for the truest depth reading. In **Figure 191**, the null arrow begins to appear as the receiver is dipped slightly to its right.

The receiver should be held precisely perpendicular to ground when obtaining depth readings. With a depth of 2'10", the receiver was raised 7" and the new depth is 3'5" **(Figure 192)**. The field is round.

Figure 192

Receiver raised 7" and depth changed 7"

Shape

The receiver on the ground indicates a 4′06″ reading **(Figure 193)**, and when lifted 7″ off the ground gives a reading of 5′01″. This is a round field. During depth validation, the peak reading and the mA reading should diminish as the receiver is raised.

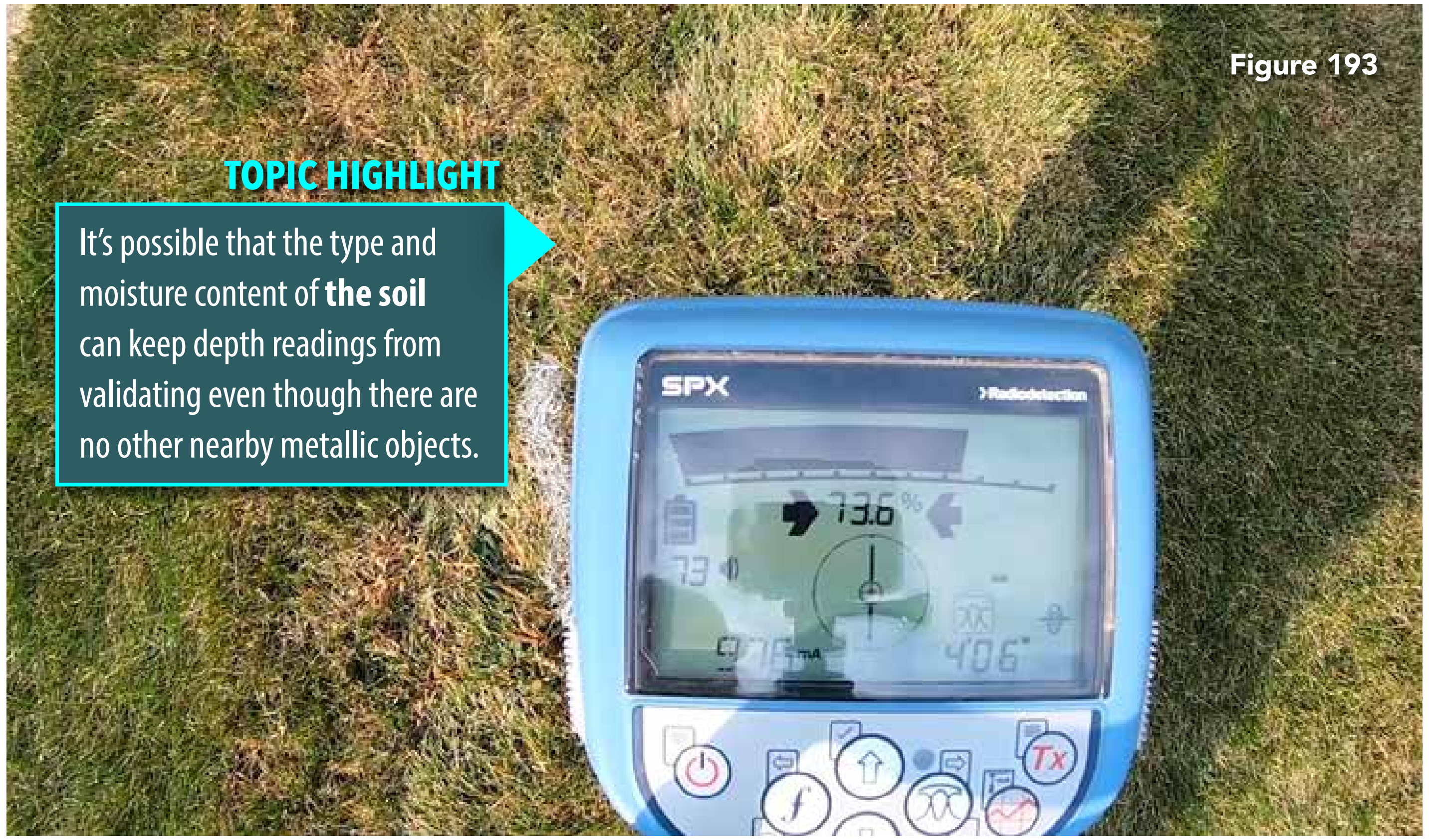


Figure 193

TOPIC HIGHLIGHT

It's possible that the type and moisture content of **the soil** can keep depth readings from validating even though there are no other nearby metallic objects.

Figure 194

With a not-round field, it's possible that the mA reading will increase when the receiver is raised.

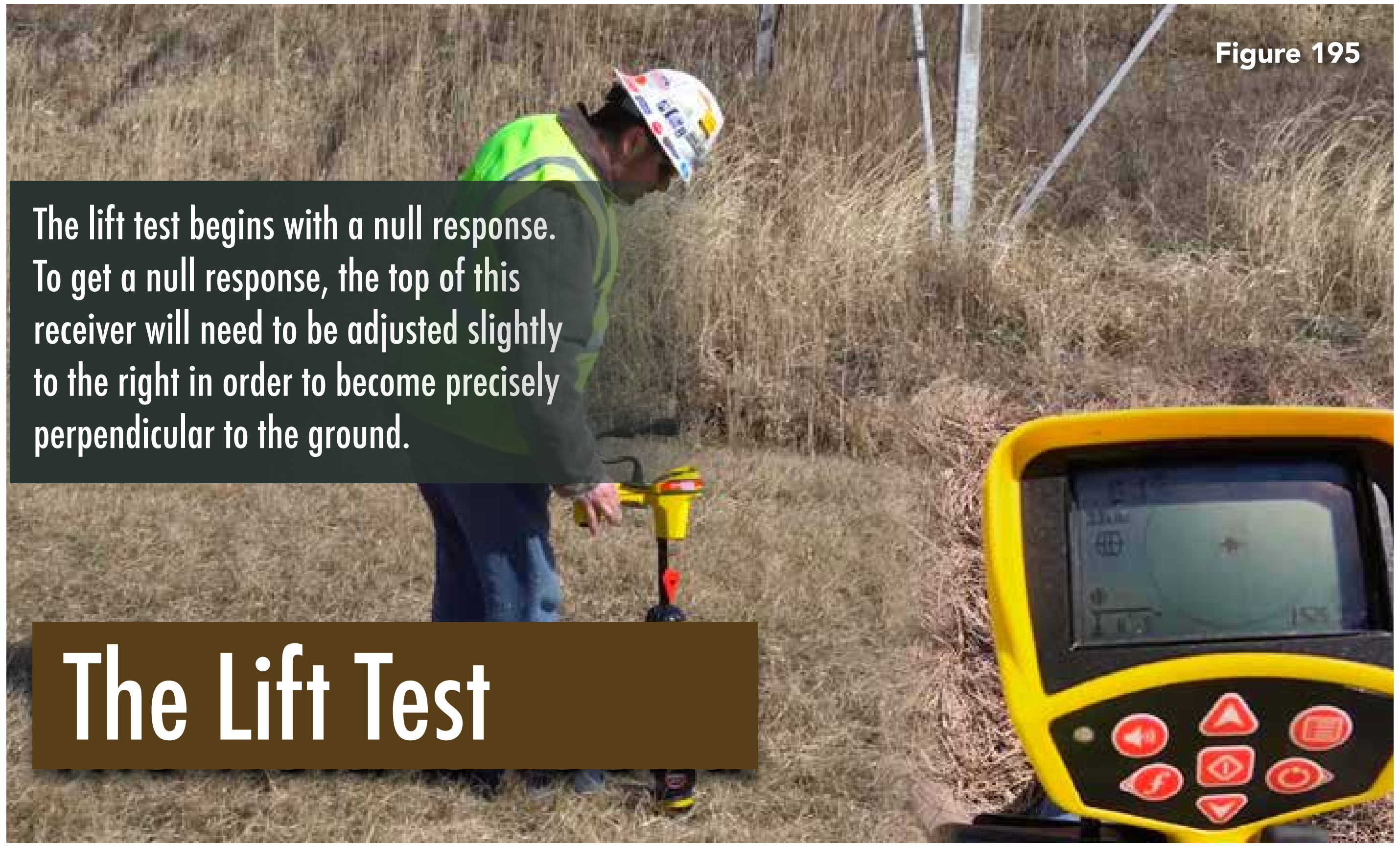


Figure 195

The lift test begins with a null response. To get a null response, the top of this receiver will need to be adjusted slightly to the right in order to become precisely perpendicular to the ground.

The Lift Test

The third and last method of inspecting the field from a vertical perspective involves getting a null reading at the ground and lifting the receiver chest-high to see if there's still a null reading **(Figure 195)**. If there is, the field is round **(Figure 196)**. If there isn't, the field is not-round.

Figure 196

TOPIC HIGHLIGHT

The **lift test** is not impacted by the type of soil or the moisture content of the soil.

The Field is Round

Figure 197

The lift test is a vertical inspection of the field. Using our null reading (1), we lift the instrument into the air (2). We don't have a null reading here, so the field is not-round **(Figure 197)**. We'll do a lift test on another line. The instrument should be lifted chest-high, but still permitting the display to be read. Here **(Figure 198)**, we had a null on the ground, the starting point for the lift test, and we had a null when we lifted it chest high. This indicates a round field.

Figure 198

Figure 199

Checking the shape of the field is all about checking the accuracy of the trace. For example, if digital depth validation is way off, there's a chance the line being located is not the target line. The same is true if there's a good deal of separation between peak and null, or if the null moves a lot when the receiver is lifted chest high.

When vertical inspection of the field produces small differences in locations at the ground, or between depths or nulls, a nearby metallic object—often another utility line—has a small amount of the transmitter's signal flowing on it. Changing this result means there must be a change at the transmitter.

However, there is a fundamental difference between vertical inspection of the field and horizontal inspection of the field **(Figure 199)**. Determining that a trace is accurate does not require that all five methods of checking field shape need to agree. Vertical inspections and following the trace to a visual and logical endpoint determine target line accuracy.

Horizontal inspections are much more valuable as a means to determine if other buried utilities may be in the ground in addition to the target line **(Figure 200)**.

Figure 200

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