

EM Equipment Operations Guide

Transmitter Signal Application, Receiver Operation,

PART 1: USING AN EM TRANSMITTER

The transmitter is the starting point for every active locate. Its purpose is to place an electrical signal onto a buried conductor so the receiver can detect and measure the electromagnetic field surrounding that conductor. Regardless of the manufacturer or model, every electromagnetic locating transmitter performs the same basic function.

Successful locating begins with establishing the best possible electrical circuit. The quality of that circuit has a direct effect on the quality of the electromagnetic field that the receiver measures. A well-established circuit usually produces a stronger, more controlled locating signal and increases confidence throughout the locate. A poor circuit often results in weak signals, signal transfer onto adjacent conductors, inconsistent receiver responses, and unnecessary troubleshooting.

There are several techniques for applying an active locating signal. The best technique depends on the amount of access available to the target conductor and the conditions at the job site. Whenever practical, choose the technique that provides the greatest control over where the locate current is placed.

This section explains five transmitter techniques that are common to nearly all electromagnetic locating systems.

1. Direct Connection
2. In-Line Connection
3. Closed-Loop Connection
4. Close Induction
5. Broadcast Induction

Each technique has advantages, limitations, and appropriate applications. Learning when and how to use each technique will improve the quality of the locating circuit and increase confidence in the completed locate.

Regardless of which technique is used, the operator should always remember one objective: *Establish the best possible electrical circuit for the locating challenge.*

Every procedure in this section is intended to accomplish that objective.

Technique 1: Direct Connection

What It Is

Direct Connection is the preferred method of applying a transmitter signal because it provides the greatest control over the electrical circuit. One transmitter connection lead is attached directly to the locating conductor, while the second connection lead is connected to a grounding electrode driven into the earth. This creates a complete electrical circuit that allows alternating locate current to leave the transmitter, travel along the target conductor, return through the earth, and flow back to the transmitter.

The objective of Direct Connection is to establish the best possible electrical circuit while placing as much locate current as possible onto the intended facility and minimizing current flow onto adjacent conductors. When a good electrical circuit is established, the transmitter typically produces higher current output, a stronger electromagnetic field, and a more reliable locate.

Before making the connection, identify both the **Access Location** and the **Connection Point**. The Access Location is the physical place where the locating conductor can be reached without excavation. The Connection Point is the actual metallic conductor to which the transmitter connection lead is attached.

For nonconductive piping systems, the locating conductor is typically a tracer wire installed alongside the pipe. Common Access Locations include water and gas meter sets, valve boxes, curb-stop boxes, fire hydrants, cathodic protection test stations, dedicated tracer-wire access boxes, cleanouts, lift stations, valve stations, and other locations where the tracer wire has been intentionally brought to the surface. The Connection Point is the exposed tracer wire or locating terminal.

For conductive piping systems, the pipe itself often serves as the locating conductor when it is electrically continuous. Common Access Locations include exposed piping, meter sets, valve stations, regulator stations, cathodic protection test stations, flange assemblies, pipeline stations, and other accessible portions of the pipeline. The Connection Point is the exposed metallic pipe or another electrically continuous component directly connected to the pipeline.

For cabling systems, the locating conductor is typically the cable shield, concentric neutral, metallic sheath, armor, messenger wire, or another electrically continuous metallic component of the cable. Common Access Locations include pedestals, handholes, pull boxes, splice enclosures, transformer pads, equipment cabinets, meter enclosures, vaults, manholes, and other structures where the cable is terminated, spliced, bonded, or grounded. The Connection Point is the metallic cable component that provides electrical continuity along the cable being located.

Although Access Locations differ between piping systems and cabling systems, the objective remains the same: connect directly to the conductor that provides the most

continuous electrical path along the target facility while minimizing the possibility of transferring locate current onto adjacent utilities.

When to Use

Use Direct Connection whenever an exposed locating conductor is available and a safe metal-to-metal connection can be made. Whenever practical, Direct Connection should be the first choice because it provides the greatest control over the locating circuit, typically produces the highest locate current, and minimizes unwanted signal coupling onto nearby utilities.

The quality of the locate depends less on the transmitter itself than on the quality of the electrical circuit established between the transmitter, the target conductor, and the earth return path.

Connection Technique

1. Identify the target conductor on map or print and locate the best available connection point.
2. Select a connection point that is clean, accessible, and electrically connected to the portion of the utility being located.
3. Turn the transmitter off.
4. Connect the transmitter connection leads to the transmitter.
5. Attach one transmitter connection lead to the target conductor using a clean metal-to-metal connection.
6. Select a suitable location for the ground stake. Whenever practical, position the ground stake approximately perpendicular to the expected direction of the target utility and as far from the transmitter connection as the connection leads will reasonably allow.
7. Push the ground stake firmly into the soil. Greater metal-to-earth contact improves the return path for the applied current. Add water if needed to improve grounding conditions.
8. Attach the second transmitter connection lead securely to the ground stake.
9. Inspect both connections before turning on the transmitter. Make sure the clamps are secure and the connection leads are not stretched, tangled, or creating a trip hazard.
10. Turn on the transmitter.
11. Verify the transmitter battery condition.
12. Select the desired locating frequency.
13. Begin with a moderate output power setting.
14. Observe the transmitter display and verify that locate current is flowing and the transmitter indicates a stable electrical circuit. Locate current is measured in milliamps (mA) and is the primary indicator of how much locate current is flowing on the target conductor.

*Most modern signal transmitters automatically perform impedance matching. At the lower power settings, the transmitter adjusts its output voltage to apply only the voltage necessary to achieve the selected current output based on the resistance and impedance of the locating circuit. As the resistance or impedance of the circuit increases, the transmitter automatically increases voltage to maintain current, up to the limits of the selected power setting. Automatic impedance matching is typically available on the first three power levels of most locating transmitters.

Higher milliamp (mA) readings generally indicate a better electrical circuit because more locate current is flowing on the target conductor. However, current should be interpreted in context, including the utility type, conductor length, selected frequency, and return-path quality. The goal is not simply to achieve the highest reading, but to establish the best electrical circuit for the locating challenge. A stable current reading, paired with a well-designed circuit, increases confidence that the locate signal remains on the intended facility.

15. If locate current is lower than expected, improve the electrical circuit before increasing output power. Check both transmitter connections. Confirm good metal-to-metal contact. Inspect the ground stake placement and move it if necessary.
16. If improvements to the circuit do not produce satisfactory results, consider selecting another connection point or another locating frequency.
17. Once the transmitter is operating normally and producing a stable locating current, proceed to receiver operation.

Things to Remember

- ❖ The objective is to establish the best possible electrical circuit, not simply the highest transmitter output.
- ❖ A clean metal-to-metal connection usually produces better results than increasing transmitter power.
- ❖ The ground stake is part of the electrical circuit. Its location can influence where return current travels.
- ❖ Locate current is an important diagnostic tool. Compare changes in current after improving the circuit rather than relying on a single current value.
- ❖ A high locate current does not guarantee that all current is flowing only on the intended conductor. Current follows every available return path.
- ❖ Direct Connection is generally the first technique to consider because it provides the operator with the greatest control over where locate current enters the electrical circuit.

Before proceeding, confirm signal current is achieved.

Technique 2: In-Line Connection**What It Is**

An In-Line Connection is a Direct Connection technique in which both transmitter connection leads are connected to two accessible points within the same locatable circuit. Instead of using a grounding source, the transmitter becomes part of the electrical circuit by inserting itself in-line with the conductor.

Locate current leaves one transmitter connection lead, travels through the conductor, and returns to the transmitter through the second transmitter connection lead. The conductor may continue beyond either connection point.

An In-Line Connection is particularly effective when the circuit can be isolated so that one conductor leaves each connection point in opposite directions. This encourages the greatest amount of locate current to travel through the intended conductor while minimizing unintended current paths.

When to Use

Use an In-Line Connection whenever two accessible connection points exist within the same locatable circuit.

This technique is particularly effective on tracer wire systems, copper-shielded telecommunications cables, isolated conductors, and other utilities where two accessible connection points are available and the circuit can be isolated as much as practical.

Technique

1. Identify two accessible connection points on the same locatable circuit.
2. Whenever practical, select connection points where only one conductor leaves each connection point in opposite directions. This places the transmitter in-line with the intended circuit and concentrates locate current on the target conductor.
3. Verify that both connection points belong to the same conductor or locatable circuit.
4. Turn the transmitter off.
5. Connect the transmitter connection leads to the transmitter.
6. Connect one transmitter connection lead to the first connection point.
7. Connect the second transmitter connection lead to the second connection point.
8. Verify that both connections provide good metal-to-metal contact.
9. Turn on the transmitter.

10. Verify battery condition.
11. Select the desired locating frequency.
12. Begin with a moderate output power setting.
13. Observe the transmitter display and verify that locate current is flowing.
14. If locate current is lower than expected, inspect both connection points and determine whether additional conductors or bonds are allowing current to leave the intended circuit.
15. If practical, improve circuit isolation by selecting different connection points that better concentrate current onto the intended conductor.
16. Once a stable locating current has been established, begin receiver operations.

Things to Remember

The transmitter becomes part of the electrical circuit.

An In-Line Connection does not require a grounding source because the transmitter connection leads complete the circuit through the conductor.

The best In-Line Connection is usually achieved when one conductor leaves each connection point in opposite directions.

This technique is especially effective on tracer wires and copper-shielded telecommunications cables because the circuit can often be isolated, allowing most of the locate current to remain on the intended conductor.

The objective is not simply to complete the circuit. The objective is to concentrate as much locate current as possible onto the conductor being located while minimizing current flow onto adjacent conductors.

Technique 3: Closed-Loop Connection**What It Is**

A Closed-Loop Connection is a Direct Connection technique that uses two accessible connection points on the same continuous utility system to complete the electrical circuit. Instead of using a ground stake, one transmitter connection lead is connected to one point on the utility system and the second transmitter connection lead is connected to another point on the same utility system. Locate current leaves the transmitter through one connection, travels through the buried utility system, and returns to the transmitter through the second connection.

Unlike an In-Line Connection, which normally uses two ends of the same isolated conductor, a Closed-Loop Connection is commonly used on operating utility distribution systems where multiple interconnected paths exist between the two connection points.

When to Use

Use a Closed-Loop Connection when two accessible connection points exist on the same utility system and using a ground stake is either impractical or may reduce the quality of the locating circuit.

This technique is commonly used on natural gas distribution systems, water distribution systems with tracer wire, interconnected electrical systems, and other continuous utility networks.

Technique

1. Identify two accessible connection points that are part of the same utility system.
2. Verify that both connection points belong to the utility you intend to locate.
3. Whenever practical, select connection points that will encourage locate current to travel through the portion of the utility you intend to trace.
4. Turn the transmitter off.
5. Connect the transmitter connection leads to the transmitter.
6. Attach one transmitter connection lead to the first connection point.
7. Using the second transmitter connection lead, or an extension lead if necessary, connect to the second connection point on the same utility system.
8. Verify that both connections are clean, secure, and making good metal-to-metal contact.
9. Arrange the connection leads to avoid traffic, pedestrian walkways, and equipment movement.
10. Turn on the transmitter.
11. Verify the transmitter battery condition.
12. Select the desired locating frequency.
13. Begin with a moderate output power setting.
14. Observe the transmitter display and verify that locate current is flowing.
15. If locate current is lower than expected, inspect both connection points and verify that both are electrically connected to the same utility system.
16. Begin tracing the utility between the two connection points while continuously observing the electromagnetic field, locate current, and field behavior.
17. If the utility branches between the connection points, expect locate current to divide among the available paths. Continue evaluating the field to determine which branch is being followed.
18. Once the desired utility has been identified and confirmed, continue tracing and marking the utility.

Things to Remember

A Closed-Loop Connection does not require a ground stake because the electrical circuit is completed through the utility system.

This technique often performs well in paved or congested areas where placing a ground stake is difficult or where a ground stake could unintentionally place return current onto nearby buried conductors.

Locate current may divide at tees, branches, and interconnected portions of the utility system. Current levels should be observed as one tool for understanding how the electrical circuit is behaving.

When using a Closed-Loop Connection on a distribution system, think about where you want the current to travel before selecting the two connection points. The location of each transmitter connection influences the path the locate current will follow.

A Closed-Loop Connection is often one of the most effective techniques for locating utilities in commercial developments, shopping centers, industrial facilities, and other areas where multiple service connections are available and installing a ground stake is difficult or undesirable.

Before selecting another connection technique, ask yourself one question:

“Can I create a better electrical circuit by using two connection points on the same utility system instead of using a ground stake?”

If the answer is yes, a Closed-Loop Connection will often produce a cleaner, more controlled locating circuit while reducing the possibility of unintentionally energizing adjacent buried utilities.

Technique 4: Close Induction

What It Is

Close Induction is a transmitter technique that transfers locate current onto a target conductor without making a direct metal-to-metal connection. A Close Induction accessory is placed around an accessible conductor, and the transmitter induces current onto that conductor through a magnetic field. Since there is no direct electrical connection, this technique is commonly used when Direct Connection is not practical, not permitted, or could create a safety concern.

Close Induction generally provides better control over signal placement than Broadcast Induction because the transmitted energy is applied directly to the selected conductor.

When to Use

Use Close Induction when the target conductor is accessible but a Direct Connection cannot be safely or practically made.

This technique is commonly used on energized electrical cables, insulated conductors, grounding conductors, cable shields, and other accessible conductors where opening the system or making metal-to-metal contact is not permitted.

Technique

1. Locate an exposed section of the target conductor that can be completely enclosed by the Close Induction accessory.
2. Verify that only the intended conductor will pass through the accessory. If multiple conductors are enclosed together, locate current may be transferred to all of them.
3. Turn the transmitter off.
4. Connect the Close Induction accessory to the transmitter.
5. Open the accessory and place it completely around the target conductor.
6. Close the accessory completely. Verify that the mating surfaces are fully closed and securely latched.
7. Make certain the accessory is not being held open by dirt, insulation, cable ties, or other obstructions.
8. Turn on the transmitter.
9. Verify the transmitter battery condition.
10. Select the desired locating frequency.
11. Begin with a moderate output power setting.
12. Observe the transmitter display. If the transmitter displays locate current, verify that current is being transferred onto the conductor.
13. Move approximately ten feet from the transmitter before beginning receiver operations.
14. Confirm that the receiver detects a stable electromagnetic field on the intended conductor.
15. If the signal is weak or unstable, return to the transmitter and inspect the setup. Verify that the accessory is completely closed, properly connected, and surrounding only the intended conductor.
16. If necessary, select another accessible location on the same conductor or another suitable locating frequency.
17. Once a stable locating signal has been established, proceed with tracing and marking the utility.

Things to Remember

Close Induction does not require a direct metal-to-metal connection.

The Close Induction accessory must completely surround the target conductor and close properly to transfer energy efficiently.

The target conductor must still provide a complete electrical circuit for locate current to flow.

Nearby bonded conductors may also carry locate current. Continue evaluating the electromagnetic field throughout the trace to confirm that the intended conductor is being followed.

Close Induction generally provides greater control than Broadcast Induction because the signal is transferred directly onto the selected conductor rather than being broadcast into the surrounding area.

Before selecting another connection technique, ask yourself one question:

“Can I improve the locating circuit by moving the Close Induction accessory to another location on the same conductor?”

Often, a different location on the conductor will produce a better electrical circuit and a more reliable locate without changing equipment or increasing transmitter power.

Technique 5: Broadcast Induction

What It Is

Broadcast Induction is a transmitter technique that applies a locating signal without making a physical connection to the target conductor. The transmitter uses its internal broadcast coil to generate an electromagnetic field that induces locate current onto nearby conductive utilities. Since the transmitter is not connected directly to the target conductor, the operator has less control over which conductors receive the transmitted signal.

Broadcast Induction should generally be considered the last choice when the target conductor cannot be accessed for Direct Connection, In-Line Connection, Closed-Loop Connection, or Close Induction.

When to Use

Use Broadcast Induction when there is no accessible point for making a direct electrical connection and no opportunity to use a Close Induction accessory.

This technique is commonly used when searching for unknown utilities, locating conductors beneath pavement or

concrete, or beginning a locate before an accessible connection point has been found.

Technique

1. Review available maps, utility records, existing utility markings, and visible surface features to estimate the route of the target utility.
2. Position the transmitter directly over the expected path of the utility.
3. Align the transmitter parallel with the expected direction of the utility. Proper alignment increases the amount of energy coupled onto the conductor.
4. Disconnect the transmitter connection leads and Close Induction accessory if required for Broadcast Induction operation.
5. Turn on the transmitter.
6. Verify the transmitter battery condition.
7. Select a Broadcast Induction frequency supported by the transmitter.
8. Begin with a moderate output power setting.
9. Leave the transmitter undisturbed throughout the locate. Moving the transmitter changes the broadcast field and may energize different conductors.
10. Move approximately thirty feet away before beginning receiver operations. This reduces the possibility of detecting the transmitter's direct airborne field instead of the electromagnetic field surrounding the buried conductor.
11. Set the receiver to the same active frequency as the transmitter.
12. Search across the expected utility corridor until a repeatable field is located.
13. Establish the peak response and begin tracing the conductor.
14. Continue tracing away from the transmitter. As distance from the transmitter increases, the receiver becomes less influenced by the transmitter's broadcast field and more dependent upon the field surrounding the buried conductor.
15. If multiple conductors are detected, evaluate each conductor carefully before deciding which one is the intended target.
16. If an accessible connection point is discovered during the locate, stop and consider changing to Direct Connection, In-Line Connection, Closed-Loop Connection, or Close Induction. Those techniques usually provide greater control over the locating circuit.

Things to Remember

Broadcast Induction provides the least control over where locate current is placed.

Nearby metallic utilities may also receive the transmitted signal.

The strongest receiver response is not always the intended utility.

As the receiver moves farther from the transmitter, confidence generally increases because the influence of the transmitter's airborne field decreases.

Continue evaluating the electromagnetic field throughout the trace. Observe field shape, utility orientation, locate current when available, estimated depth, and the overall behavior of the field. All of these observations should support the conclusion that the intended conductor is being traced.

Broadcast Induction is often the technique that allows a locate to begin, but it does not have to be the technique used to finish it. As soon as a better connection opportunity becomes available, consider changing to one of the direct application techniques to improve the electrical circuit and increase confidence in the locate.

Before selecting another connection technique, ask yourself one question:

"Have I found a way to place the locating signal directly onto the target conductor?"

If the answer is yes, changing from Broadcast Induction to a direct signal application technique will usually improve signal control and produce a more reliable locate.

Evaluating the Transmitter Circuit

Applying a signal is only the first step in active locating. Before beginning receiver operations, evaluate the information provided by the transmitter. A few seconds spent confirming the quality of the electrical circuit can save considerable time in the field and improve confidence throughout the locate.

The transmitter provides information about the electrical circuit. Although the information displayed varies by manufacturer, most transmitters provide one or more indicators that help the operator evaluate circuit performance.

Locate Current

Locate current is one of the most useful indicators available during active locating. It represents the amount of transmitter current flowing through the completed electrical circuit.

A measurable locate current confirms that the transmitter has established a circuit. As the electrical circuit improves, locate current will often increase. If locate current decreases

after making a change, the change may have reduced the quality of the circuit.

Locate current should be observed throughout the locate, not just at the transmitter. Consistent current measurements often increase confidence that the receiver is following the same conductor. Sudden changes may indicate a branch, bonded conductor, damaged tracer wire, parallel utility, or current leaving the intended conductor.

Locate current should always be considered together with field behavior, utility direction, estimated depth, and other receiver observations.

Output Power

- Output power is the amount of energy the transmitter is attempting to deliver into the electrical circuit.
- Higher output power does not necessarily produce a better locate.
- If the electrical circuit is poor, increasing transmitter power may simply place more energy onto unintended conductors instead of improving the intended circuit.
- Whenever practical, improve the electrical circuit before increasing transmitter output.

Frequency Selection

- Frequency influences how locate current travels through the electrical circuit.
- Lower frequencies generally remain on the intended conductor more effectively and are less likely to transfer onto adjacent utilities.
- Higher frequencies are often helpful when locating conductors with higher circuit resistance, poor continuity, mechanical joints, insulating gaps, or short buried lengths.
- Frequency should be selected to establish the best possible electrical circuit, not simply to produce the strongest receiver response.

Circuit Information

Many transmitters display additional information such as impedance, resistance, voltage, connection quality, or circuit status.

These values help the operator evaluate changes made to the electrical circuit.

Rather than concentrating on one number, observe how the information changes after improving a connection, relocating the ground stake, changing frequencies, or selecting another connection technique.

Improving the Circuit

If transmitter performance is not satisfactory, improve the electrical circuit before changing receiver settings.

Inspect the transmitter connections to Verify clean metal-to-metal contact.

Inspect the ground stake location when one is being used.

Consider another connection point.

Consider another broadcasting technique.

Each improvement should be made one step at a time so the operator can observe its effect on the electrical circuit.

Things to Remember

The transmitter establishes the electrical circuit. The receiver measures the electromagnetic field produced by that circuit. A better electrical circuit is usually more valuable than additional transmitter power.

PART 2: USING THE RECEIVER

The receiver detects and measures the electromagnetic field around a buried conductor. Unlike the transmitter, it does not place energy onto the utility. Instead, it helps the operator estimate the conductor's horizontal position, direction, depth, and continuity.

Successful receiver operation depends on one principle: the receiver does not locate pipes or cables directly. It measures the electromagnetic field around the conductor carrying locate current, and the operator interprets that field to estimate the utility's position.

Receiver operation is continuous. As the utility is traced, the operator evaluates peak response, field shape, utility direction, locate current, estimated depth, and other receiver information. Together, these observations build confidence that the intended conductor is being followed.

No single receiver indication should determine the utility location. Confidence increases when several independent observations support the same conclusion. The peak response, field symmetry, utility direction, locate current, estimated depth, and the overall behavior of the electromagnetic field should all describe the same conductor.

Good locating is a process of collecting evidence. Each receiver observation either increases confidence or indicates that additional investigation is needed before continuing.

The following techniques explain how to acquire the electromagnetic field, establish the utility position, trace and

mark the utility, interpret receiver information, and complete the locate with confidence.

Technique 1: Preparing the Receiver

What It Is

Preparing the receiver is the process of verifying that the instrument is ready to detect the transmitted signal before beginning the locate. Proper receiver setup allows the operator to begin with consistent operating conditions and reduces unnecessary adjustments while tracing.

When to Use

Prepare the receiver before every active or passive locate.

Technique

1. Inspect the receiver for visible damage.
2. Verify that the battery has sufficient charge to complete the locate.
3. Turn the receiver on and allow it to complete its normal startup sequence.
4. Observe the display for battery warnings, fault messages, or other indications that require attention.
5. Select the appropriate locating mode for the operation to be performed.
6. For active locating, select the same frequency currently being transmitted by the transmitter.
7. Verify that both the transmitter and receiver are operating on the same frequency before beginning the locate.
8. Adjust the receiver sensitivity to a moderate starting level.
9. Hold the receiver in its normal operating position as recommended by the manufacturer.
10. Begin receiver operations approximately ten feet from the transmitter when using Direct Connection, In-Line Connection, Closed-Loop Connection, or Close Induction.
11. Begin approximately thirty feet from the transmitter when using Broadcast Induction to reduce the influence of the transmitter's direct airborne field.
12. Pause for a moment and observe the receiver. Become familiar with the display, audible response, and sensitivity before beginning the search.

Things to Remember

- ❖ The receiver detects the electromagnetic field. It does not create or strengthen the field.
- ❖ Receiver sensitivity changes how the receiver responds to the existing electromagnetic field. It does not

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increase or decrease the strength of the electromagnetic field itself.

- ❖ The receiver and transmitter must be operating on the same active frequency before an active locate can begin.
- ❖ Avoid unnecessary sensitivity adjustments. A properly adjusted receiver usually requires only occasional changes as locating conditions change.
- ❖ Begin every locate with a stable transmitter circuit. The receiver cannot compensate for a poor electrical circuit established by the transmitter.

Technique 2: Finding Location the Signal

What It Is

Acquiring the signal is the process of locating the electromagnetic field produced by the transmitter and identifying the first repeatable response from the target conductor. The objective is not simply to find a signal. The objective is to identify the correct signal and establish the first confirmed locating point.

When to Use

Use this technique after the transmitter has established a stable electrical circuit and the receiver has been prepared for operation.

Technique

1. Move to the recommended starting distance from the transmitter.
2. Hold the receiver in its normal operating position and maintain a consistent height above the ground.
3. Face the expected direction of the buried utility whenever it is known.
4. Begin walking across the expected path of the utility using slow, controlled movements.
5. Observe both the receiver display and audible response while moving.
6. Continue crossing the expected utility corridor until the receiver responds to an electromagnetic field.
7. Do not stop at the first indication. Continue moving until the receiver response increases to a maximum and then begins to decrease.
8. Turn around and repeat the crossing from the opposite direction.
9. Confirm that the receiver identifies the same field during each crossing.
10. If the field cannot be repeated, continue searching rather than assuming the first response represents the target conductor.
11. Once a repeatable field has been found, reduce the width of each crossing.
12. Keep the receiver moving only far enough to observe the increase and decrease of the receiver

response. Avoid wide sweeping motions that may allow the receiver to respond to adjacent conductors.

13. Glide the receiver smoothly back and forth across the field while maintaining a constant receiver height.
14. Do not swing the receiver in an arc. Swinging changes both the receiver position and its orientation, making the field more difficult to interpret.
15. Continue shortening each crossing until the receiver repeatedly identifies the same point of maximum response.
16. Establish the first confirmed locating point.
17. Before moving forward, repeat the crossing several more times. Confidence is established by obtaining the same result repeatedly.

Things to Remember

- ❖ The objective is not to find the strongest signal. The objective is to find the correct signal.
- ❖ Once a repeatable field has been acquired, remain focused on that field. Do not continue making wide search patterns unless the field has been lost.
- ❖ The receiver should glide smoothly across the peak rather than swinging from side to side.
- ❖ The first confirmed locating point becomes the foundation for the remainder of the locate.
- ❖ A repeatable response is always more valuable than a single response.
- ❖ Once the first locating point has been established, the locate changes from searching for a signal to tracing a conductor. From this point forward, the objective is to remain locked onto the same electromagnetic field while continuously building confidence that the intended utility is being followed.

Technique 3: Trace and Mark the Utility

What It Is

Tracing is the process of following the electromagnetic field from one confirmed locating point to the next while continuously confirming that the receiver is responding to the same conductor. Marking is the process of identifying each confirmed locating point on the ground. A completed locate is built from a series of confirmed points, not from one continuous receiver sweep.

When to Use

Begin tracing after the first locating point has been established and the receiver has acquired a stable, repeatable electromagnetic field.

Technique

1. Begin at the first confirmed locating point.
2. Position the receiver directly over the established peak response.
3. Glide the receiver slowly left and right across the peak. Keep the receiver movement within approximately one to two feet of the established peak response. Do not return to wide search patterns unless the field has been lost.
4. Confirm the center of the field before moving forward.
5. Advance one or two steps in the expected direction of the utility while keeping the receiver centered over the field.
6. Stop and glide across the field again.
7. Confirm that the peak has moved in the expected direction.
8. Place a temporary mark at the new confirmed locating point.
9. Repeat the process by advancing one or two steps at a time, always confirming the new peak before placing the next mark.
10. As you trace, continuously observe the shape of the electromagnetic field. A smooth, repeatable field generally increases confidence that the intended conductor is being followed.
11. Observe the left and right receiver response. Under favorable conditions, the field should respond similarly on both sides of the established peak.
12. Compare Peak and Null whenever appropriate. Both locating modes should support approximately the same horizontal position. If they disagree, determine why before continuing.
13. Observe the compass or directional indicator when available. The indicated direction should agree with the path being traced.
14. Monitor locate current throughout the trace. Current should change gradually under normal conditions. Significant changes may indicate a branch, bonded conductor, damaged conductor, or current transferring to another utility.
15. Observe estimated depth whenever additional confirmation is needed. Depth measurements should support the established trace and should remain reasonably consistent unless construction conditions indicate otherwise.
16. Compare all available receiver information together. The peak response, field shape, utility direction, locate current, estimated depth, and overall behavior of the field should all support the conclusion that the same conductor is being followed.
17. Slow down whenever approaching utility crossings, parallel utilities, service connections, valves, manholes, transformers, pedestals, reinforced concrete, vehicles, fences, or other metallic objects that may influence the electromagnetic field.
18. Reduce the distance between locating points whenever locating conditions become more

complex. More frequent confirmation increases confidence.

19. If any receiver observation disagrees with the others, stop tracing and determine the reason before placing additional marks.
20. Continue tracing and marking until the required portion of the utility has been completely located.

Things to Remember

- ❖ The receiver should remain locked onto the established electromagnetic field. Avoid allowing the receiver to wander into adjacent fields.
- ❖ The quality of the locate depends on the quality of each confirmed locating point.
- ❖ Do not allow the paint marks to determine where the next mark will be placed. Let the electromagnetic field determine every locating point.
- ❖ Locate current, estimated depth, field shape, utility direction, and Peak-to-Null agreement are continuously evaluated while tracing. They are not separate operations.
- ❖ The operator should never become so focused on one receiver indication that the remaining information is ignored. Confidence is built when multiple independent observations agree.
- ❖ The most experienced locators are not necessarily the fastest. They are the most consistent. Every locating point is confirmed before moving to the next, producing a completed locate that can be defended with confidence.

Technique 4: Passive Locating

What It Is

Passive locating is the process of detecting electromagnetic fields that already exist on buried conductors. Unlike active locating, the operator does not use a transmitter to apply a signal. Instead, the receiver detects naturally occurring or externally generated electromagnetic energy present on the conductor.

Passive locating is an effective search technique, but passive signals cannot be controlled by the operator. For that reason, passive locating should be used to supplement active locating whenever possible.

When to Use

Use passive locating during the initial site assessment, when searching for unknown utilities, when comparing active locate results, or when no direct access to the utility is available.

Technique

1. Turn on the receiver.
2. Select the desired passive locating mode.
3. Begin with a moderate receiver sensitivity.
4. Walk slowly through the work area while observing both the receiver display and audible response.
5. Sweep the receiver across the expected utility corridor using slow, controlled movements.
6. When a passive signal is detected, repeat the crossing to verify that the response is repeatable.
7. Establish the approximate horizontal position using the same tracing techniques used during active locating.
8. Continue tracing the conductor while observing the behavior of the electromagnetic field.
9. If additional passive signals are detected, evaluate each one independently before assuming they belong to the same conductor.
10. Compare passive responses with available maps, visible utility appurtenances, existing utility markings, and known utility routes.
11. Whenever practical, confirm passive locate results by applying an active locating signal and repeating the locate using one of the transmitter techniques described earlier.
12. Continue tracing only after confidence has been established that the receiver is following the intended conductor.

Things to Remember

Passive locating does not place energy onto a conductor. It only detects electromagnetic fields that already exist.

The absence of a passive signal does not prove that a utility is not present.

Not every buried utility carries a passive signal.

A passive signal may transfer from one conductor to another through bonding, induction, shared grounding systems, or nearby parallel utilities.

More than one utility may produce the same passive response. Always compare passive receiver observations with other available information before reaching a conclusion.

Passive locating is an excellent search tool, but active locating generally provides greater control over the electrical circuit and greater confidence in the completed locate.

Whenever practical, confirm passive locating results using an active locating technique.

The objective of passive locating is not simply to detect energy. The objective is to identify which conductor is producing that energy and determine whether it is the intended utility.

Technique 5: Completing the Locate

What It Is

Completing the locate is the final step of the locating process. Before leaving the job site, the operator should confirm that the utility has been located as requested, that the markings accurately represent the estimated horizontal position of the buried facility, and that any conditions affecting the quality or limitations of the locate have been identified and communicated.

The completed locate should reflect the information gathered throughout the tracing process. Every mark should represent a confirmed receiver observation supported by the electromagnetic field.

When to Use

Complete this procedure after the requested portion of the utility has been traced and marked.

Technique

1. Walk the completed locate from beginning to end.
2. Verify that the marked route follows a logical path between visible utility features such as valves, meters, test stations, pedestals, transformers, manholes, pull boxes, and other above-ground appurtenances.
3. Review the locate for consistency. Areas where the utility changes direction, crosses another facility, branches, or enters a structure should be supported by confirmed receiver observations.
4. Recheck any section where the electromagnetic field behaved unusually or where confidence was reduced during the locate.
5. Confirm that each marking represents the estimated horizontal position established by the receiver.
6. Apply paint, flags, stakes, whiskers, or other temporary markings in accordance with the facility owner's requirements, applicable regulations, or the APWA Uniform Color Code.
7. Clearly identify changes in direction, utility crossings, offsets, and other features required by company procedures or the facility owner.
8. Continue marking until the requested locate is complete.
9. When practical and permitted by the facility owner or company procedures, place one or more

additional confirmed locating marks beyond the excavation limits. If markings within the work area are destroyed during excavation or following a utility damage, these additional reference marks can assist in re-establishing the utility's estimated horizontal position. Every additional mark should be based on a confirmed receiver observation.

10. If any portion of the utility could not be located with confidence, communicate those limitations before excavation begins.
11. Record any information required by company procedures, including unusual field conditions, abandoned facilities, unknown utilities, damaged tracer wires, signal distortion, inaccessible areas, or other observations that may benefit future locating activities.
12. Turn off the receiver and transmitter.
13. Remove the transmitter connection leads, Close Induction accessory, ground stake, extension leads, and any other equipment used during the locate.
14. Inspect the equipment for damage, clean it if necessary, and return it to its carrying case.

Things to Remember

- ✓ Every locating mark should represent a confirmed receiver observation.
- ✓ A completed locate is built one confirmed locating point at a time.
- ✓ The quality of the completed locate depends on the confidence developed throughout the tracing process.
- ✓ Additional confirmed marks beyond the excavation limits may provide valuable reference points if markings within the work area are destroyed during construction.
- ✓ When locating conditions reduce confidence, communicate those limitations clearly before excavation begins.
- ✓ The objective is not simply to leave paint or flags on the ground. The objective is to provide the excavator with the best possible estimate of the buried utility's horizontal position based on the information available at the time of the locate.