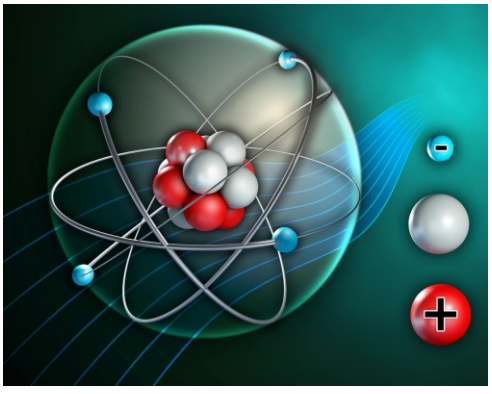
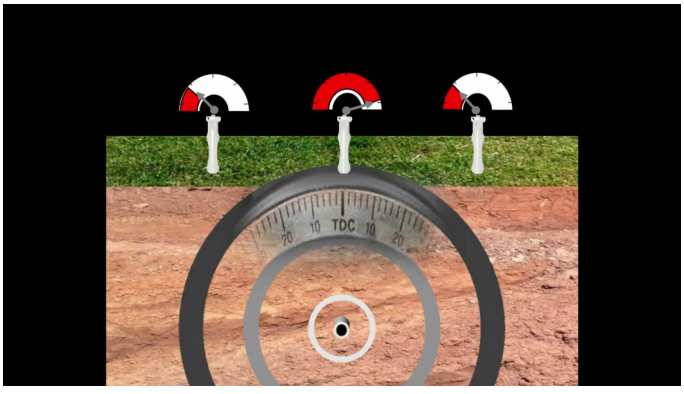
Locating Science and Equipment Operation



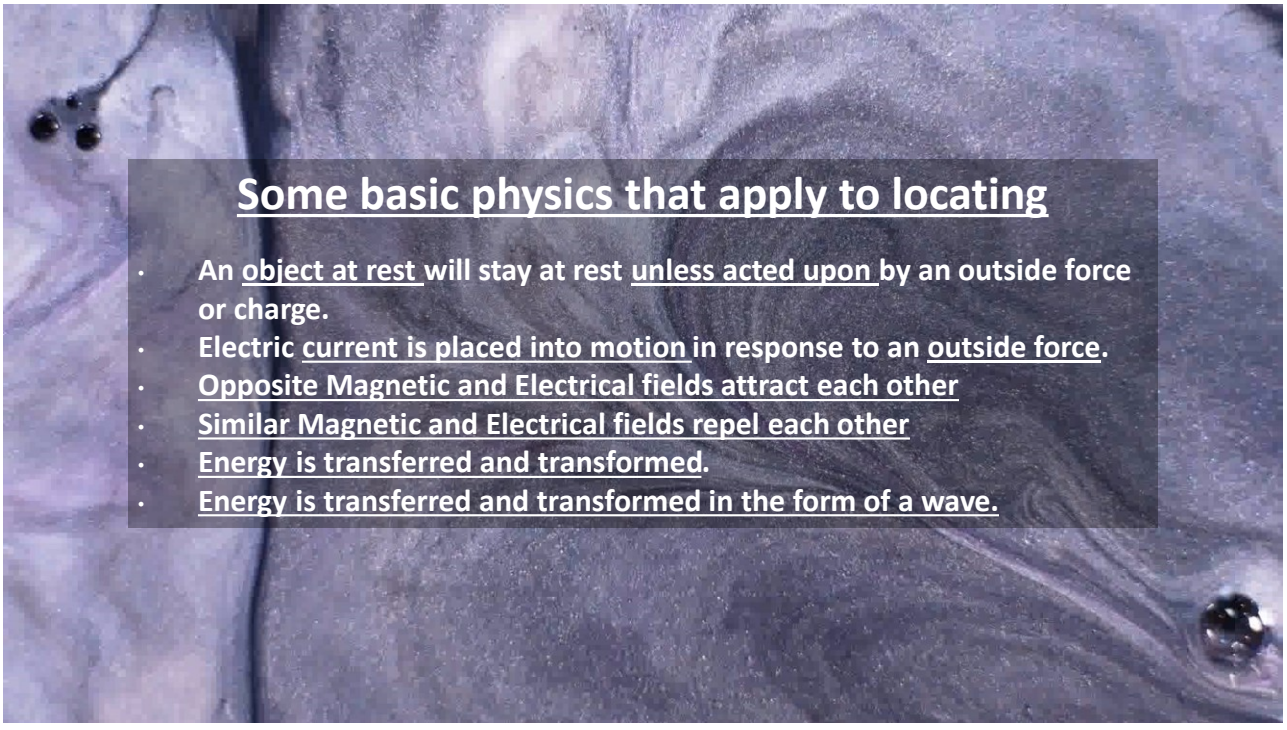


1

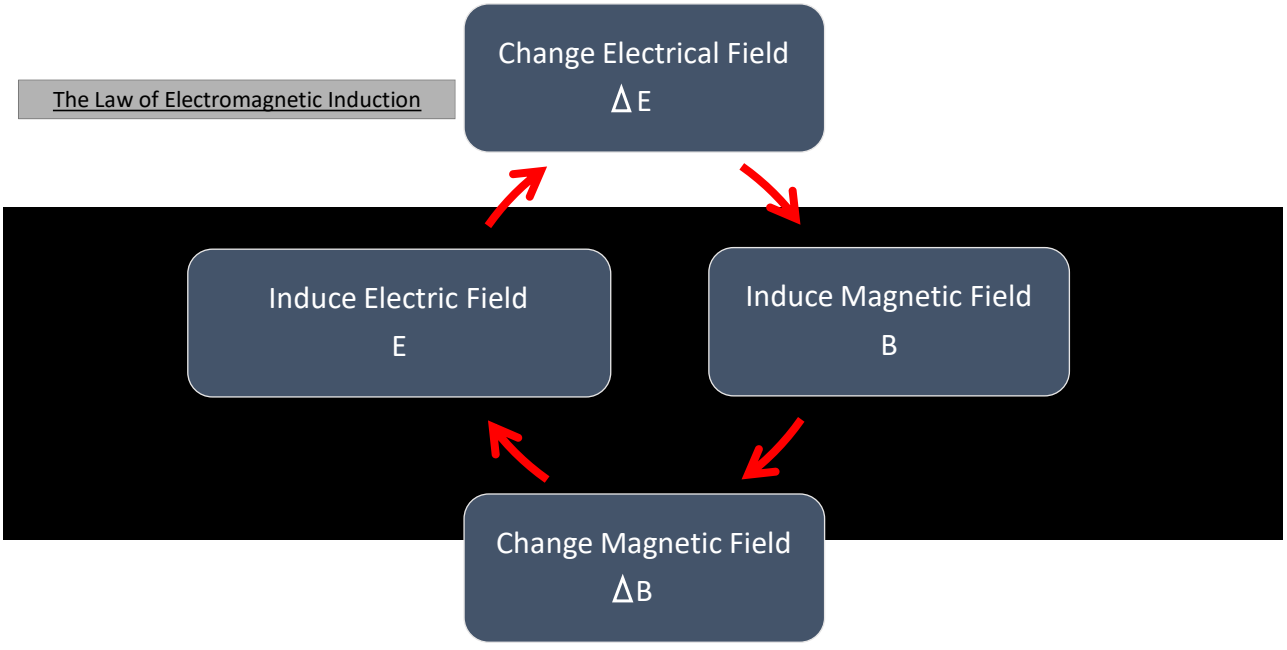
Line locating devices track electromagnetic signals created by the movement of electrical current.

- The signal's current is generated by either a signal transmitter or by other naturally occurring "Passive" forces like commercial radio waves. Many signal receivers have the capability of locating a signal which is actively applied by a signal transmitter or created by outside passive forces.

2


Some basic physics that apply to locating
An object at rest will stay at rest unless acted upon by an outside force or charge.
Electric current is placed into motion in response to an outside force.
Opposite Magnetic and Electrical fields attract each other
Similar Magnetic and Electrical fields repel each other
Energy is transferred and transformed.
Energy is transferred and transformed in the form of a wave.

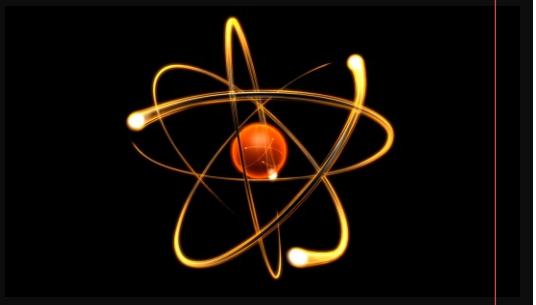
3


The Law of Electromagnetic Induction
Change Electrical Field
ΔE
Induce Magnetic Field
B
Change Magnetic Field
ΔB
Induce Electric Field
E

4

Science of Locating

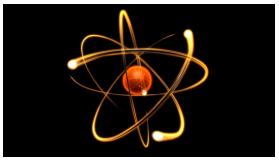
- A locatable signal field is created when current flows back and forth along a conductive circuit at a known frequency
- The signal field takes the shape of the conductor
- For current to flow it needs a source, a conductive pathway to flow and continuity.
- If no current flows on a conductor, no signal radiates
- Locating receivers detect & measure signal fields as they broadcast away from the line
- The signal field is assumed to be perfectly round

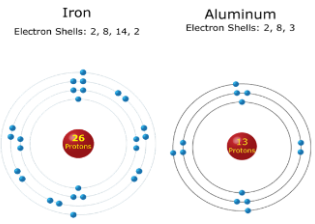


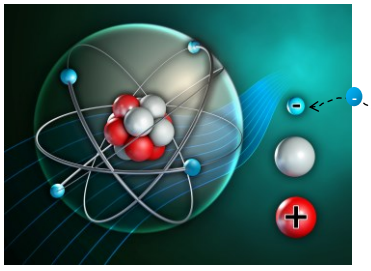
5

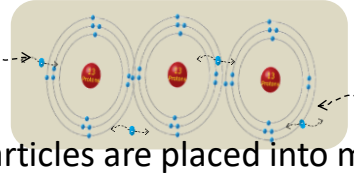
EM Signal Theory

- Electrons revolve around the core or nucleus of an atom at different distances from the .
- The electrons located in the outer shell are called valence electrons or free moving electrons. These electrons travel from atom to atom.
- The further away the free moving electrons are from the center nucleus, the weaker the hold the atom has to the electron.
- Conductive elements like Aluminum and Iron have multiple electrons in their outer shell that are easily transferred from one atom to another.
- The movement of electrons is known as CURRENT and is measured in Amps







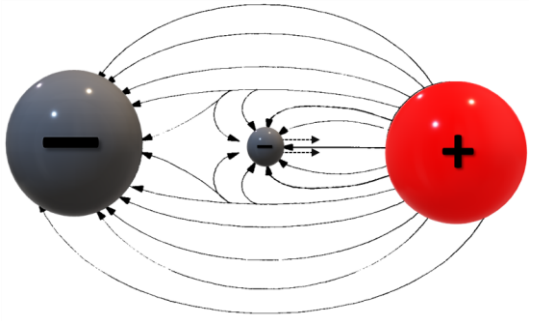


Particles are placed into motion in response to an outside force

6

Opposites Electrical Charges Attract
Similar Electrical Charges Repel

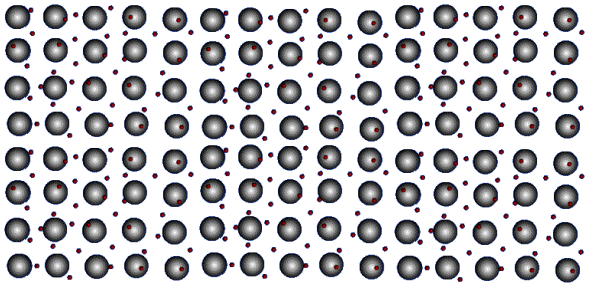
Negative charge point



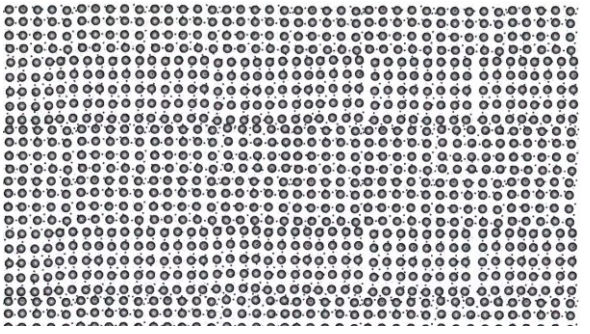
Positive charge point

If an electron is place between a positive charge point and a negative charge point, the electron will be drawn or attracted to the positive charge point. The electron is repelled by the negative charged point that shares a similar charge.

7



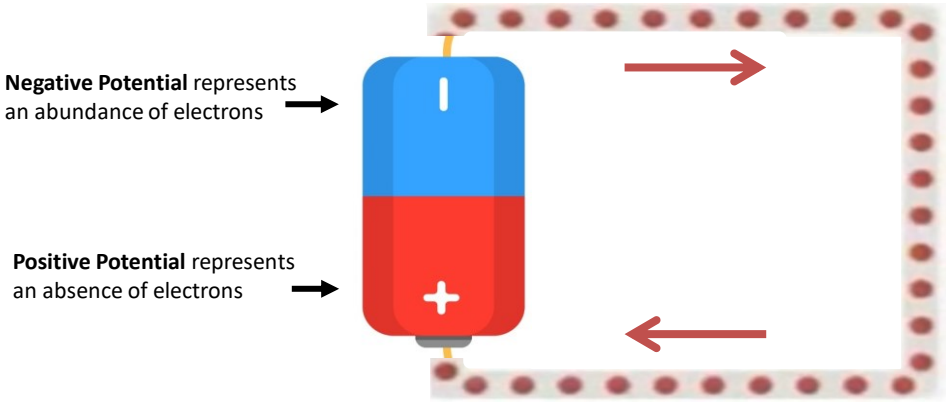
- Conductive Atoms bond together to make material and begin sharing their free moving electrons



- Electrons are placed into motion in response to a positive and negative charge point

8

Electrons/Current flows through a circuit from a negative potential to a positive potential

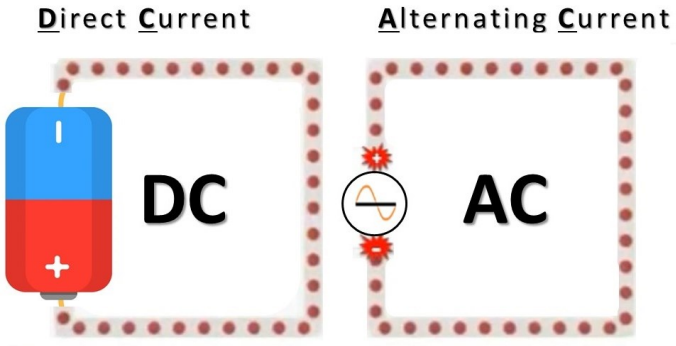


The flow of electrons along an electrical circuit is referred to as **current.** .
Current flow is measured in Amps.
In line locating the current is metered in Milliamps or Thousandth of an amp

9

There are Two Types of Electrical Current

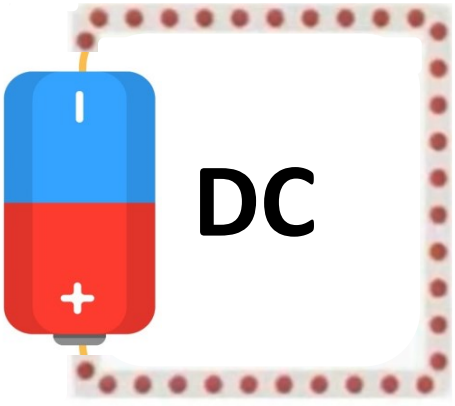
Direct Current or DC and Alternating Current or AC



10

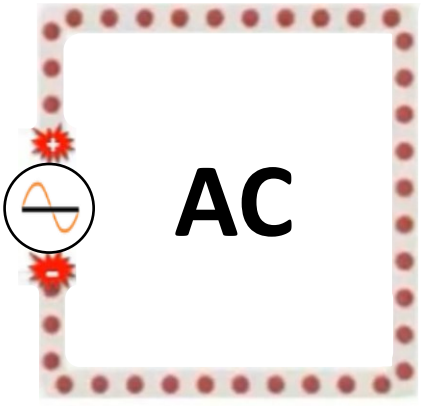
10

Direct **C**urrent



DC flows in one direction through a circuit

Alternating **C**urrent

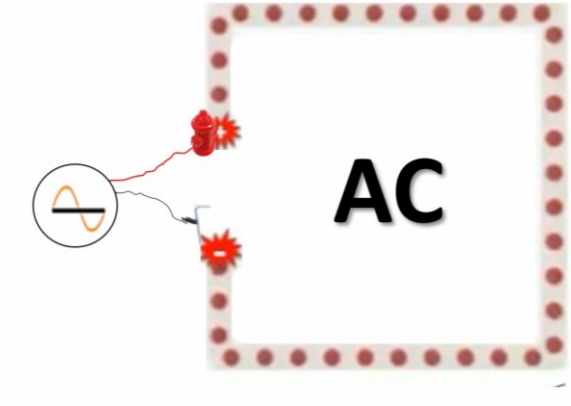


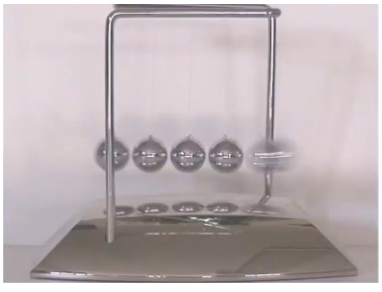
AC is a constant series of reversals in current direction at a set frequency per second through a circuit

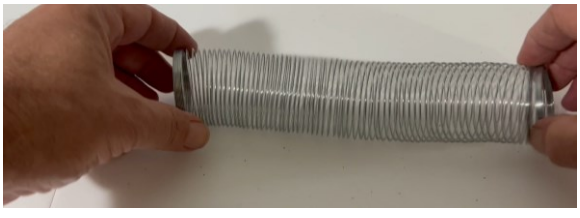
11

Alternating Current (AC) is used for Line Locating

Alternating Current/AC flows the path of least resistance in a circuit.
Energy is transferred in the form of a pressure wave as it travels back and forth between two charge points of an EM Signal Transmitter







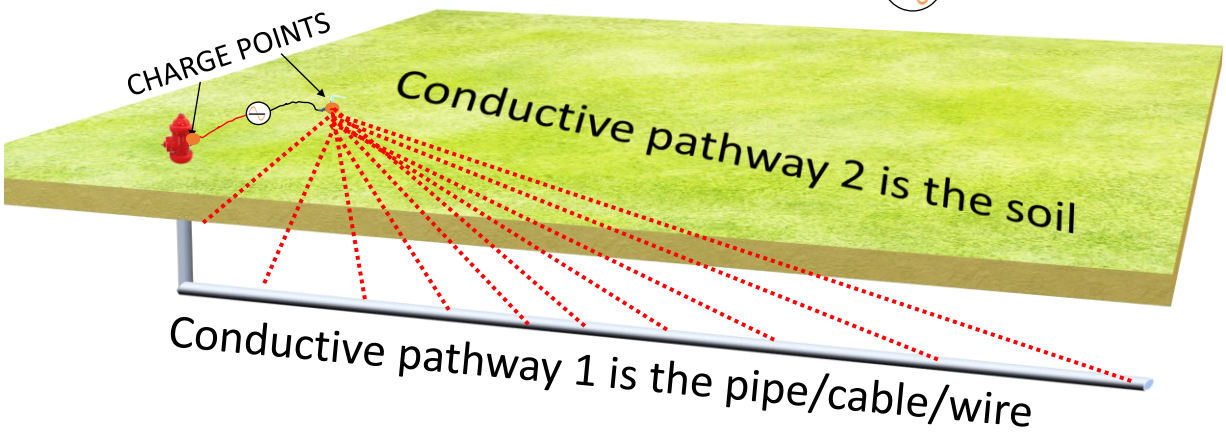
12

Locatable Circuit Loop

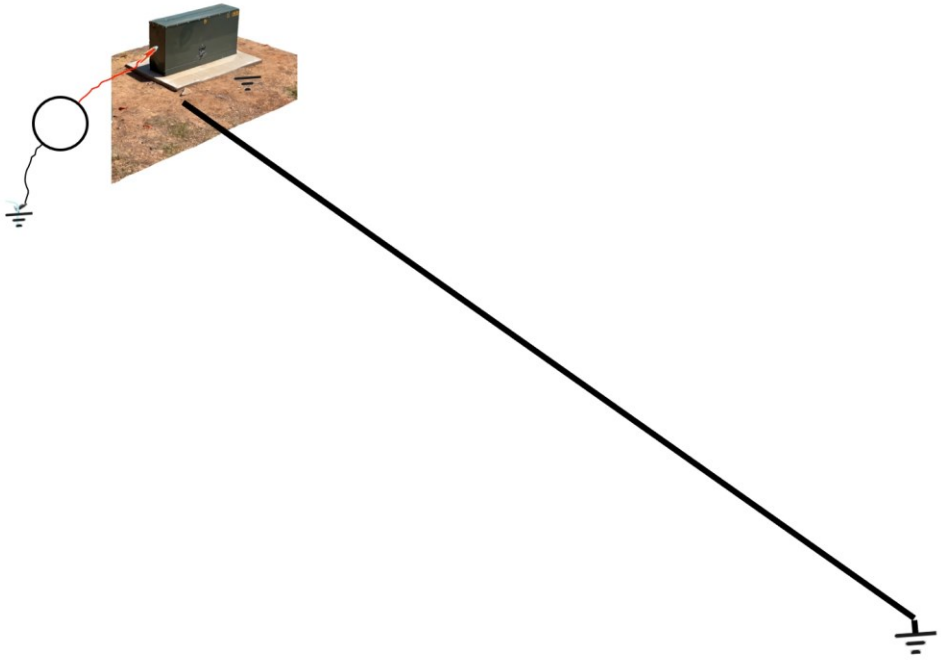
- A good locatable circuit provides a conductive pathway for current to flow with little resistance.
- Current will flow the path of least resistance to and from the signal transmitter
- A locatable circuit must be a conductive loop without breaks in the electrical continuity
- The locatable signal current is alternating in direction at a known frequency.
- We call the current flow back and forth along the conductor the Applied Current is detectable as it spirals around the conductor.
- Signal current flow through the soil is considered Return Current.

13

CURRENT FLOWS THE PATH OF LEAST RESISTANCE. CURRENT FLOWS BACK AND FORTH BETWEEN THE TWO CHARGE POINTS OF THE SIGNAL TRANSMITTER



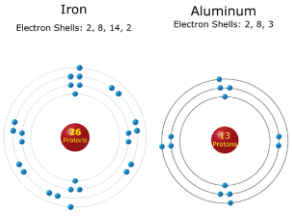
14



15

Good Conductors of Electricity

- Conductive soils high clay moisture content.
- Good conductors of electricity allow current to flow easily due to the number of free moving electrons.
  - Metals
    - Copper (CU)
    - Cast iron (CI)
    - Ductile iron (DI)
    - Aluminum (AL)
    - Steel (STL)
    - Corrugated metal (CMP)
    - The larger the cross section/size of these metals, the greater their capacity to carry current.



  - Good Connection Points
    - All physical connection point represent a certain amount of resistivity to current flow within a circuit
    - Extra time should be taken to ensure a good metal to metal connection is made between the signal transmitter, the underground facility to be located and an independent grounding stake.

16

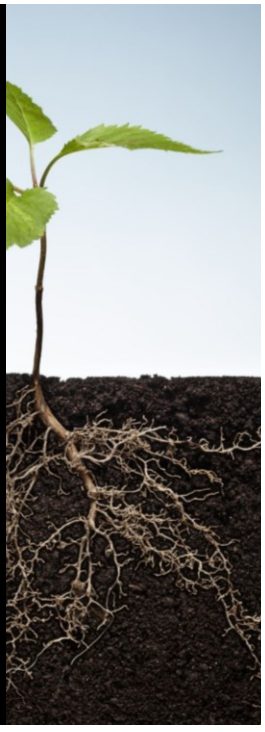
The earth is part of our locatable circuit. The electrical conductivity of soil depends on the blend, compaction and moisture levels and even temperature.

- Organic Materials
- Air
- Water (surface will dry first)
- Mineral Particles - Clay/Sand/Silt/Salt

Note: The earth surface/crust dries first

Dry soil has more air which makes it more resistive to current flow.

Pouring water on ground stake will replace air with more conductive liquid.



17

Bad Conductors of Electricity

- Bad conductors of electricity means current cannot flow easily due to high resistance
  - Rubber, plastics, cement, wood, clay
    - Poly vinyl chloride (PVC)
    - Polyethylene (PE or HDPE)
    - Transite – asbestos / cement (ACP)
    - Cement, mortar, or concrete (CMC)
    - Clay (VCP)
    - Fiberglass
    - Glass/ceramic

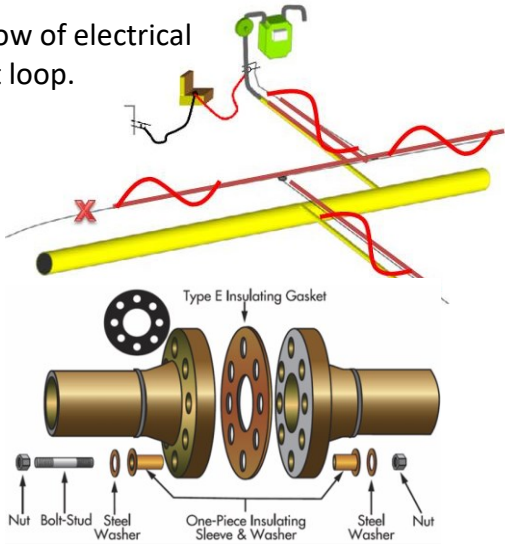
18

Good Conductors with poor continuity

Insulators, gaskets and breaks in continuity stop the flow of electrical current referred to as an open in the circuit loop.

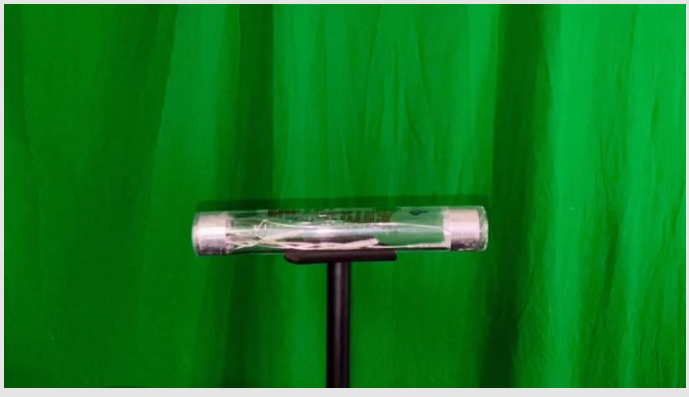
Breaks in locatable circuit:

- Pipe insulators or insulated flanges
- Poor connections points within circuit
- Bad test wire
- Bad connection point to conductor
- Broken connection lead
- Ends of a tracer wire represent on open in the circuit



19

Open Loop and Closed Loop



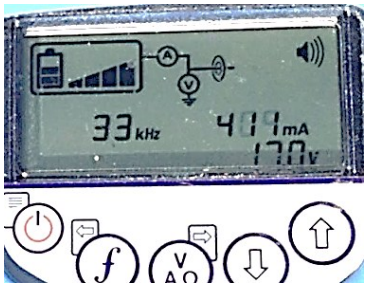
- A circuit loop is a pathway for current to flow to and from the transmitter or source
- A buried conductor and the earth represent the locatable circuit loop
- Current needs a continuous place to flow through the loop. If the loop has an open point, no current will flow beyond.
- EM Force bridges the gap between conductor and earth

20

20

Ohms Law

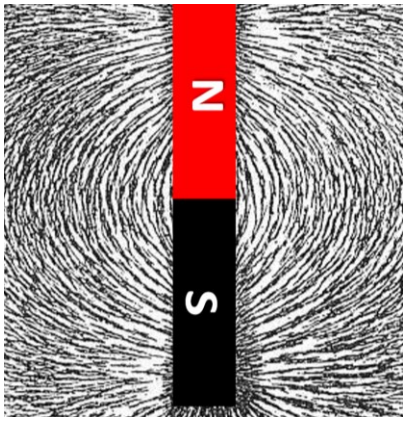
Three fundamental factors in any electrical circuit

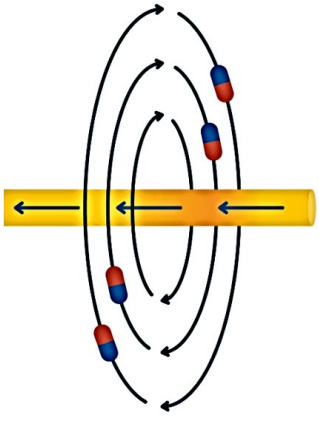


- Voltage **(V) Potential/Force/Pressure**
  - *Potential - Acts as electrical pressure forcing current to move within loop
  - Measured in Volts (**V**)
- Current **(I) Movement/Current Flow**
  - Is relative to the amount of voltage applied into the set resistance
  - Measured in amps and milliamps (**mA**)
- Resistance **(R) Resistance to Current Flow**
  - Molecular force that resists or impedes current flow within an electrical circuit
  - Measured in ohms (**Ω**)

Ohm's law states that the amount of current (i) in a circuit is directly related to the potential difference (V) and inversely related to the resistance (r) in the circuit. In other words, i = V/r. What Ohm's law says is that an increase in potential difference or a decrease in resistance produces an increase in current flow. Conversely, a decrease in potential difference or an increase in resistance produces a decrease in current flow

21

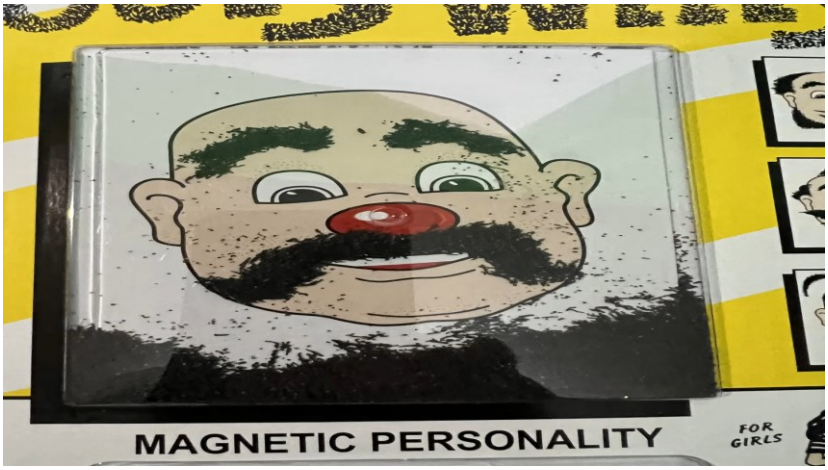




Magnetics and Electromagnetics

22

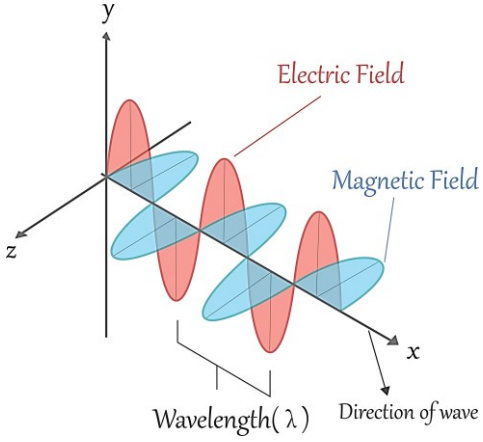
Magnetics and Electromagnetics

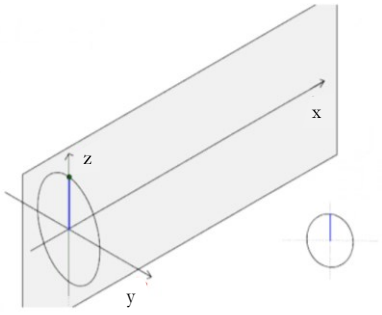


23

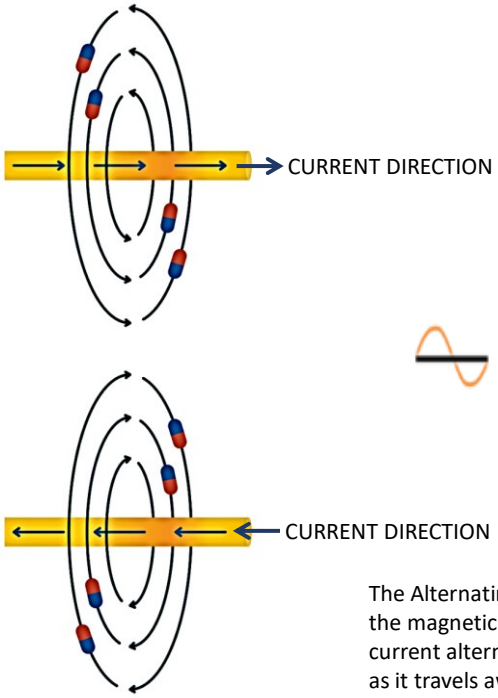
The Basic Law of Electromagnetic Induction

Current flowing along a conductor will induce a moving magnetic field
Current flows in a spiral fashion around the surface of the conductor, the magnetic field of force also spirals as it radiates away.

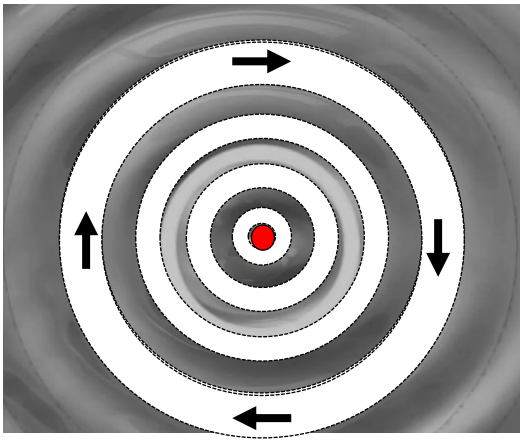




24



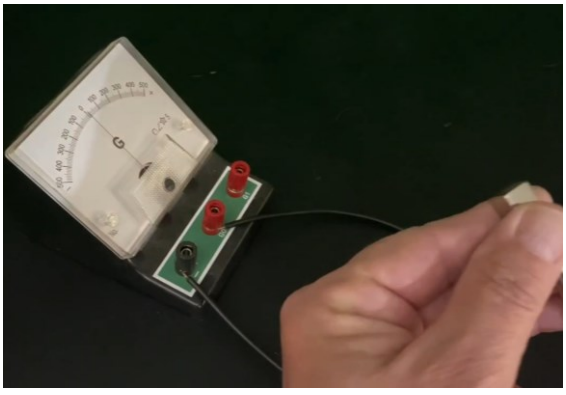
Current moving along a conductor creates a moving magnetic field we call signal.

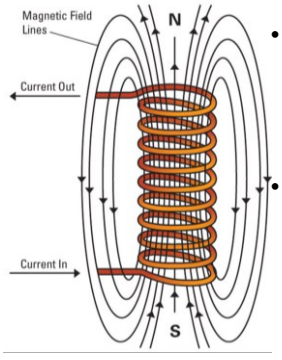


The Alternating Current moving along an underground conductor causes the magnetic field that alternates direction at the same frequency of the current alternates back and forth. The force of the signal field weakens as it travels away from the conductor.

25

Electromagnetic Induction

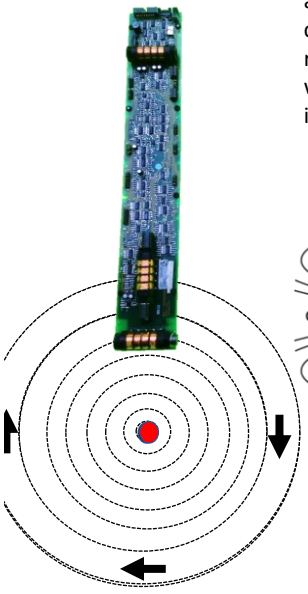




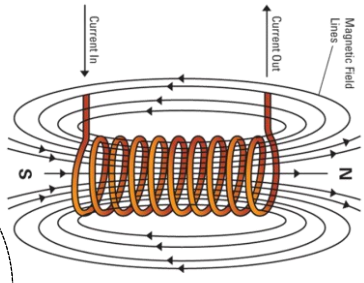
- The movement of a magnetic field through a coiled loop of copper wire, will induce current to the wire.
- The direction of current moving on the coil loop depends on the direction of the magnetic force plain copper coil.

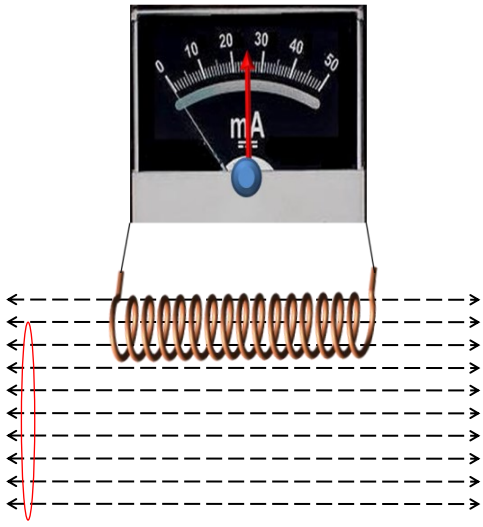
26

Signal Receiver



Coils of copper act as receiving antennas and are place in difference configurations within a signal receiver. These antennas charge when the signal field travels through its center.

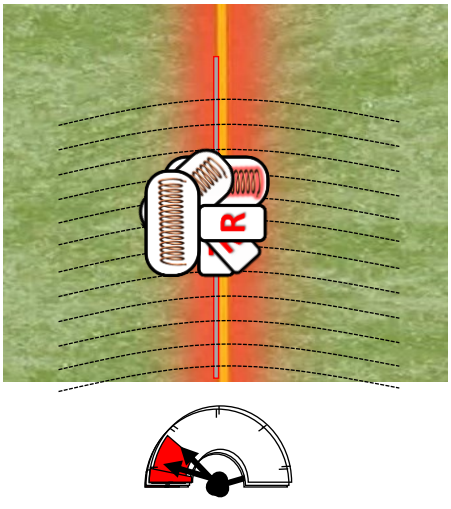




When a magnetic field breaks the plane of loop of copper wire, electrical current and resulting charge is induced into motion on the copper wire.

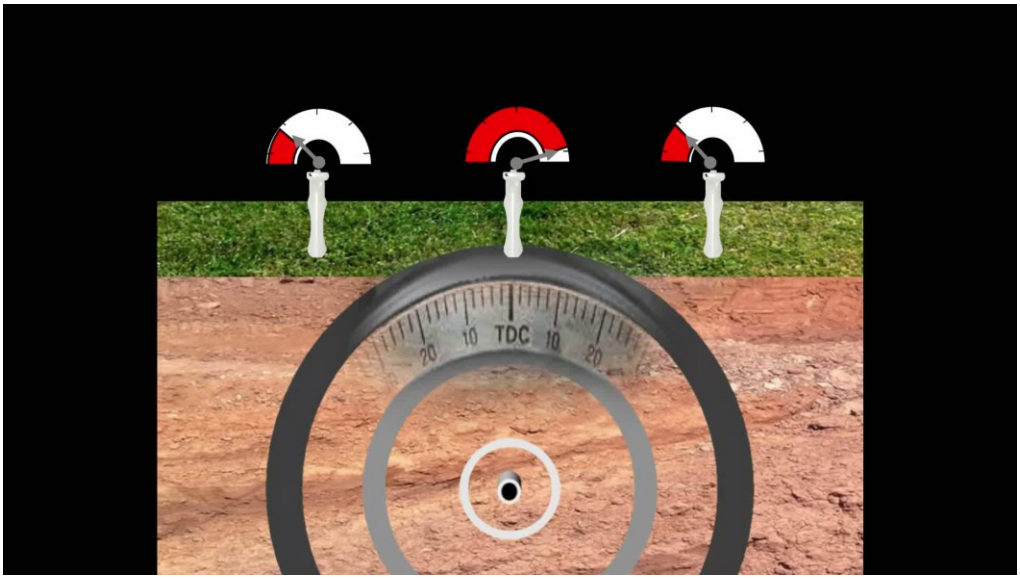
27

Determine Orientation with a few turns of your handle

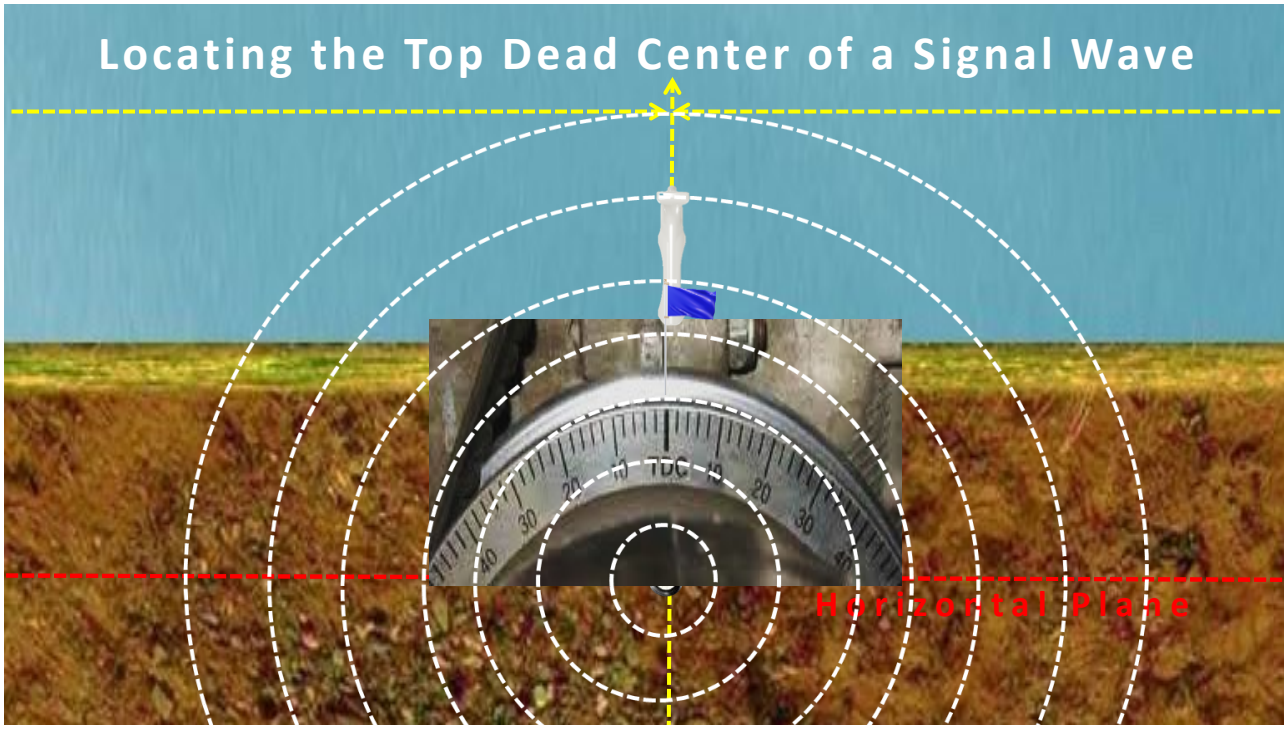


28

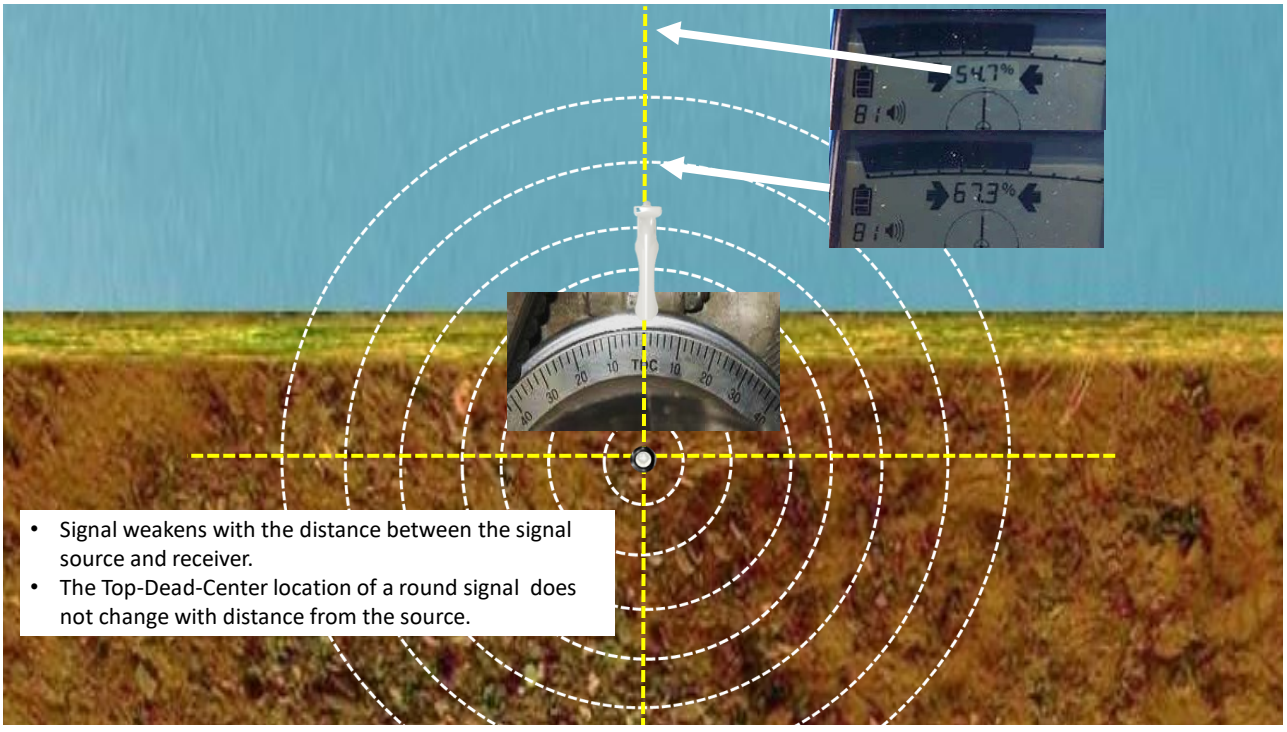
EM Signal receivers are designed to sweep, pinpoint and trace the top dead center (TDC) location of a round signal wave.



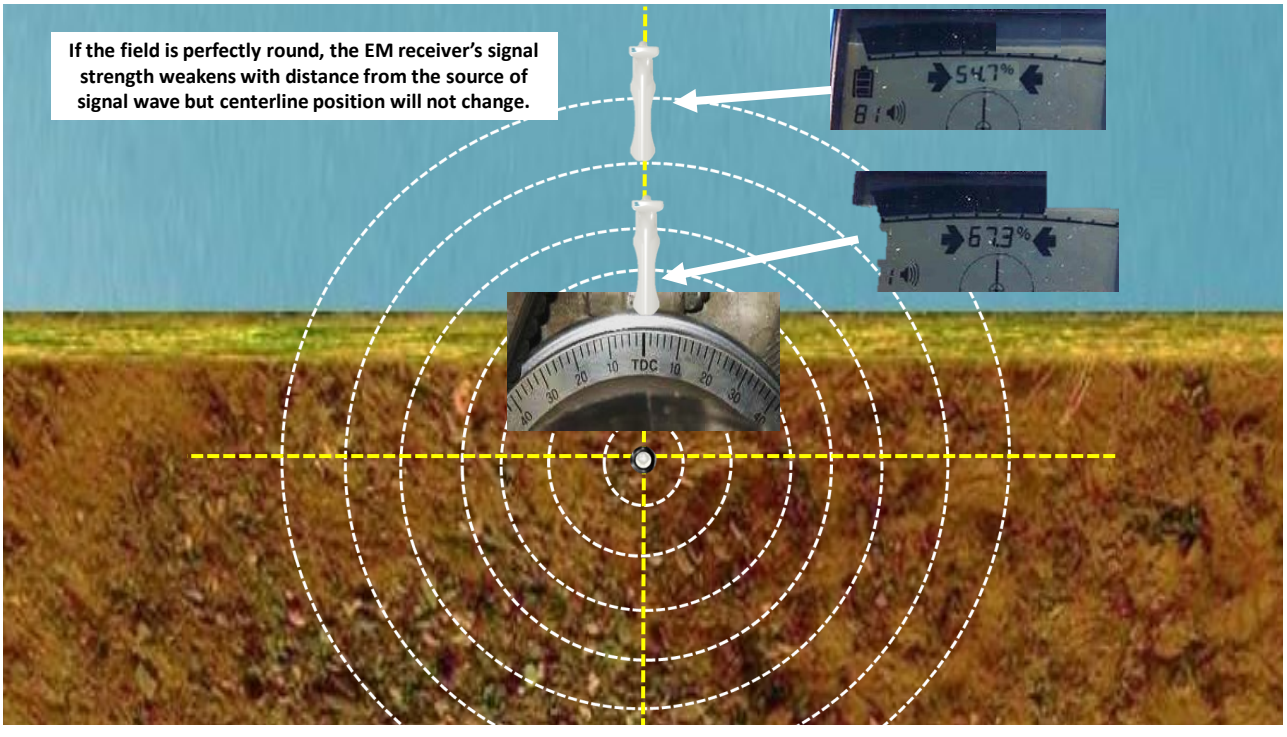
29



30


54.7%
67.3%
TDC
• Signal weakens with the distance between the signal source and receiver.
• The Top-Dead-Center location of a round signal does not change with distance from the source.

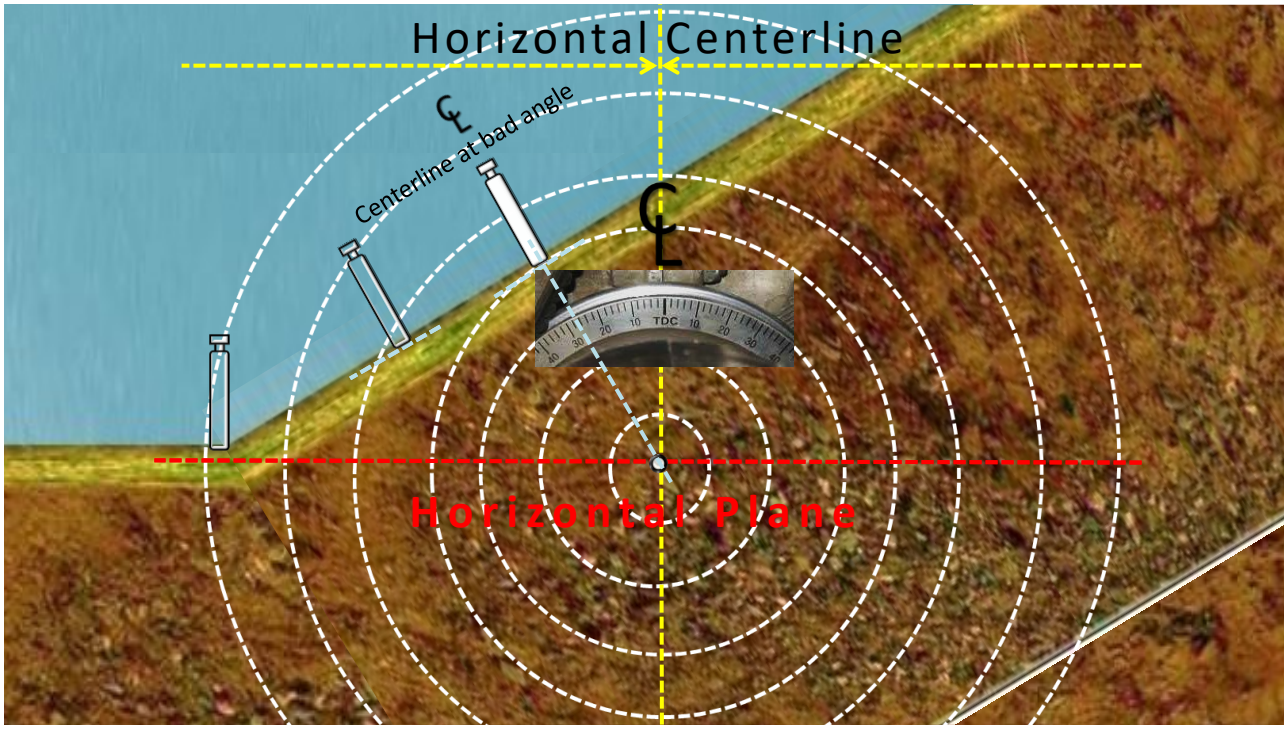
31


If the field is perfectly round, the EM receiver's signal strength weakens with distance from the source of signal wave but centerline position will not change.
54.7%
67.3%
TDC

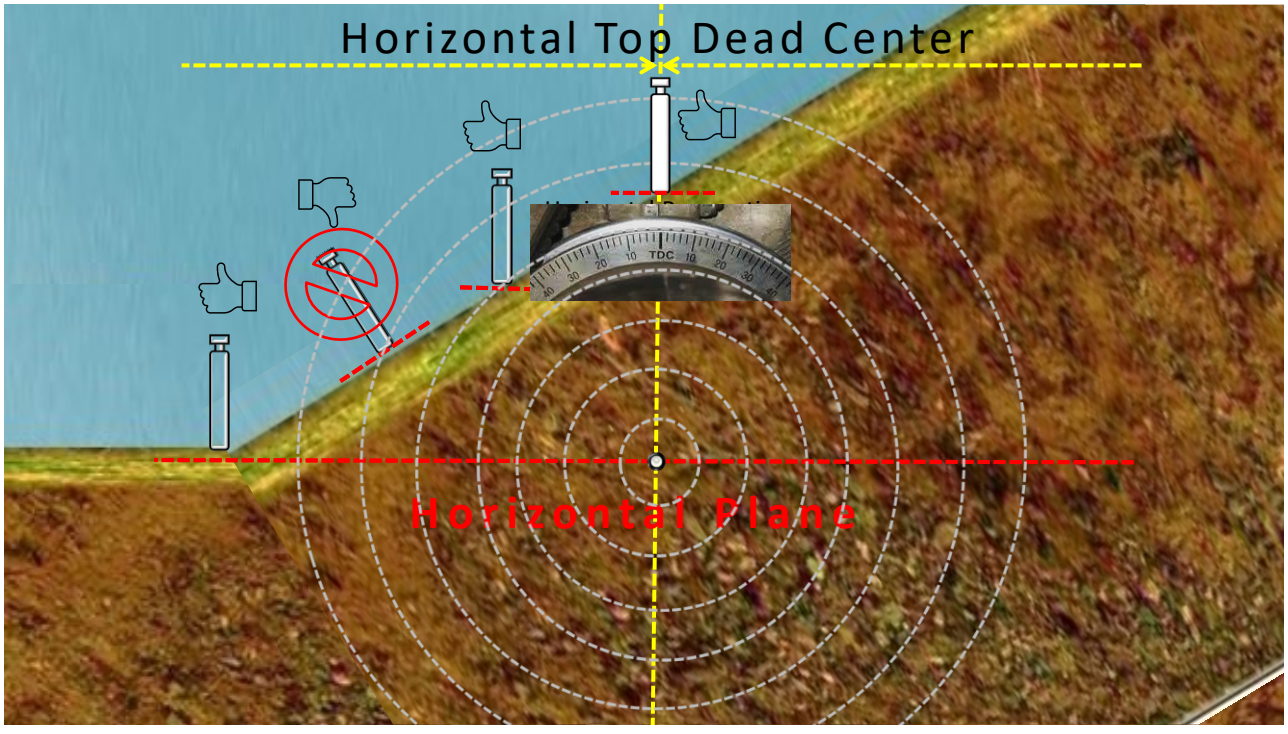
32


Locating Along A Slope

33


Horizontal Centerline
℄
Centerline at bad angle
℄
TDC
Horizontal Plane

34



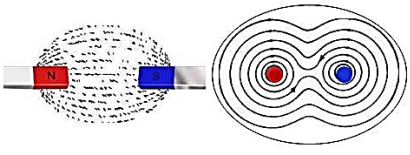
35

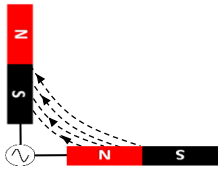
Electromagnetic Fields are Magnetic Fields

EM Signal fields are moving magnetic fields created by current and able to create electrical current on adjacent conductors.

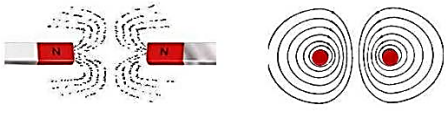
The EM Signal field respond the same as stationary magnets when close to a metal object or other magnetic fields.

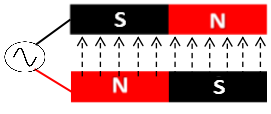
- Opposite fields attract





- Similar fields repel





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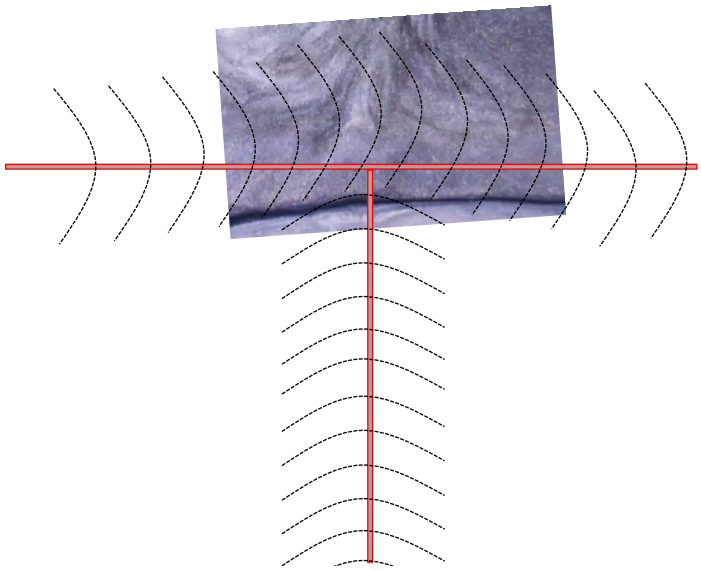
Signal Fields Collide but do not overlap at points of intersect or inflection like a turn or a splice. The shape of the signal field can be impacted within 5’-10’ from the point of intersect. This can impact the accuracy of the signal receiver.



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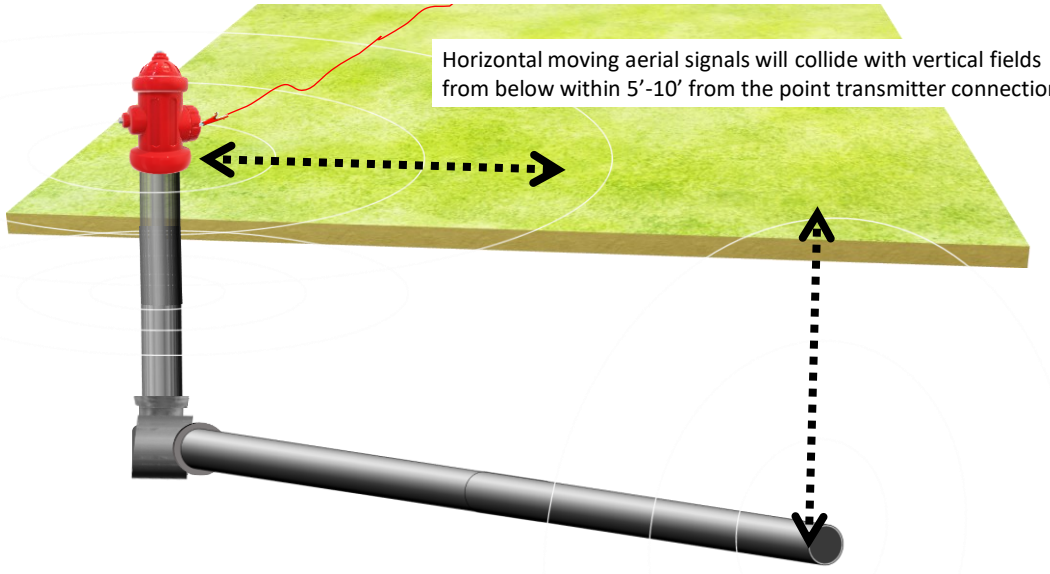

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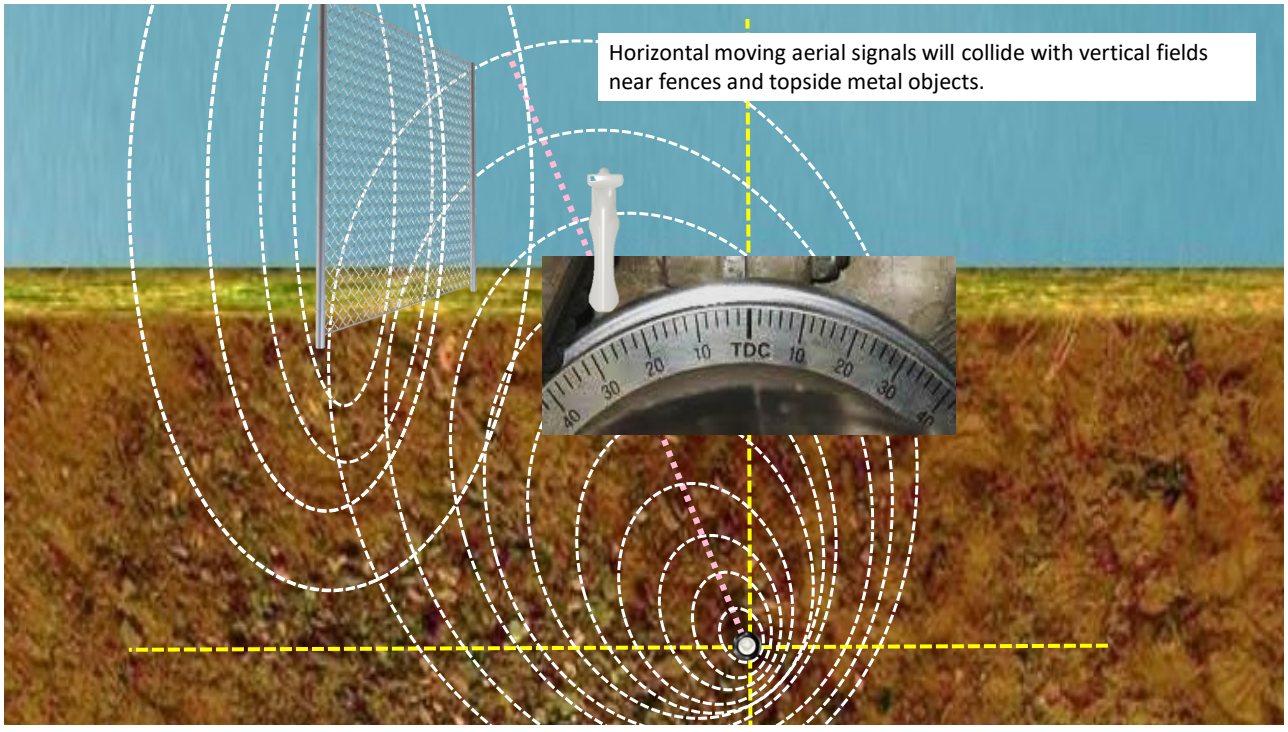
Horizontal moving aerial signals will collide with vertical fields near fences and topside metal objects.
TDC

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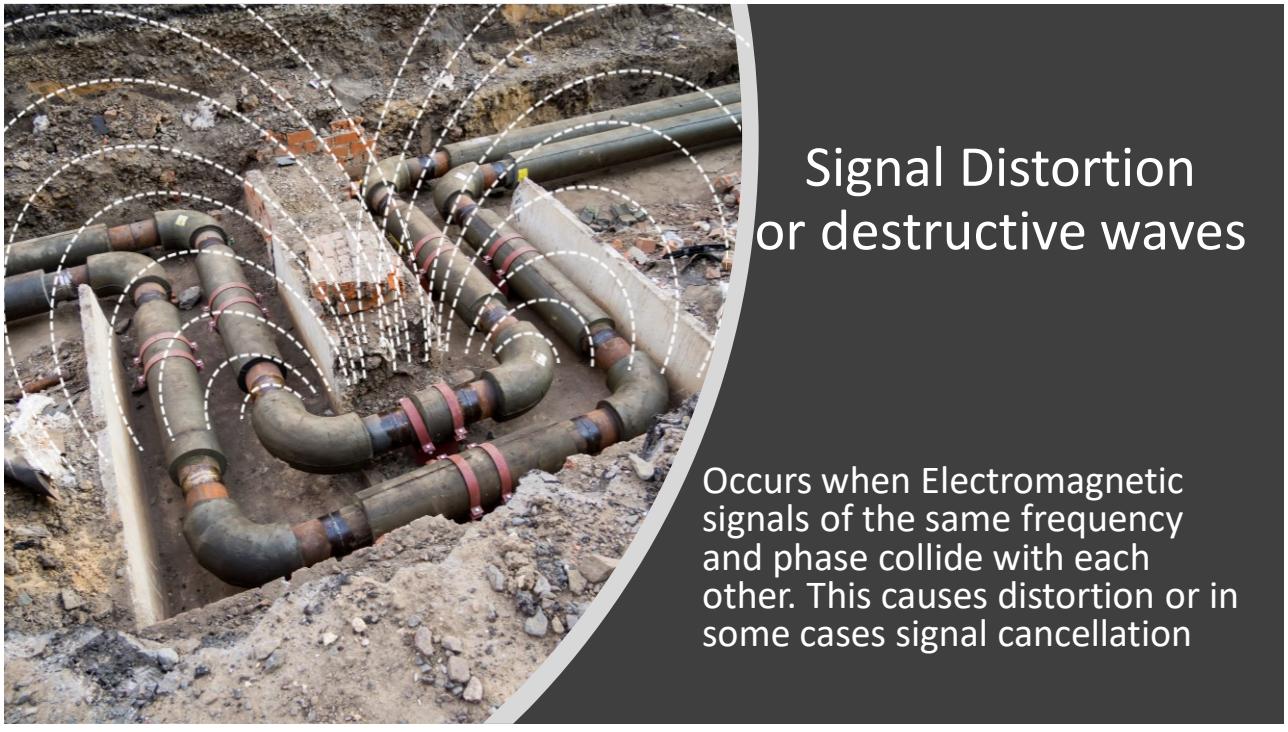
Signal Distortion or destructive waves
Occurs when Electromagnetic signals of the same frequency and phase collide with each other. This causes distortion or in some cases signal cancellation

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Signal Frequencies

ONE COMPLETE A/C CYCLE CONSIST OF
A POSITIVE PHASE AND A NEGATIVE PHASE

TIMELINE

1 AC CYCLE is 1(Hz) Hertz

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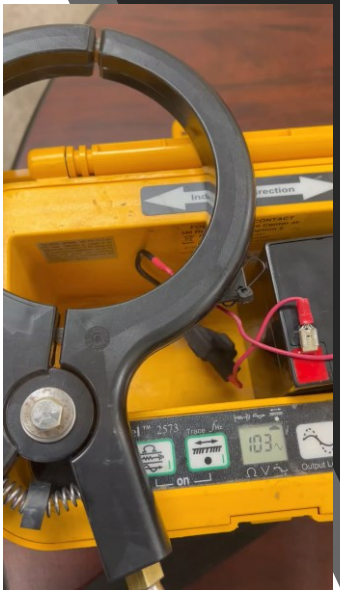

Audio and Radio Waves

- Audio Signal Range 0-20 kHz
- Radio Signal Range for locating 20kHz - 480kHz
- AM Commercial Radio Broadcast 530 kHz to 1600 kHz
- 60 Hz Audio created by power plants in North America and is commonly present on buried cables and pipes.

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Low Frequency (HZ Range)

- Very Low Frequency > 1K or lower (Hz-Range) Long Waves!
  - Creates very little signal bleed off compared to higher frequency
  - good for long distance and will continue travel to the next available grounding point on jacketed cables and insulated tracer wires.
  - needs a very good near end and far end ground connection to maximize current levels and distance
  - Great for target shooting one line at a time in a congested area
  - not likely to leave main target and travel up short laterals
  - Influenced by background noise created by electrical activity
  - Results in higher level of current shared to any directly bonded cable

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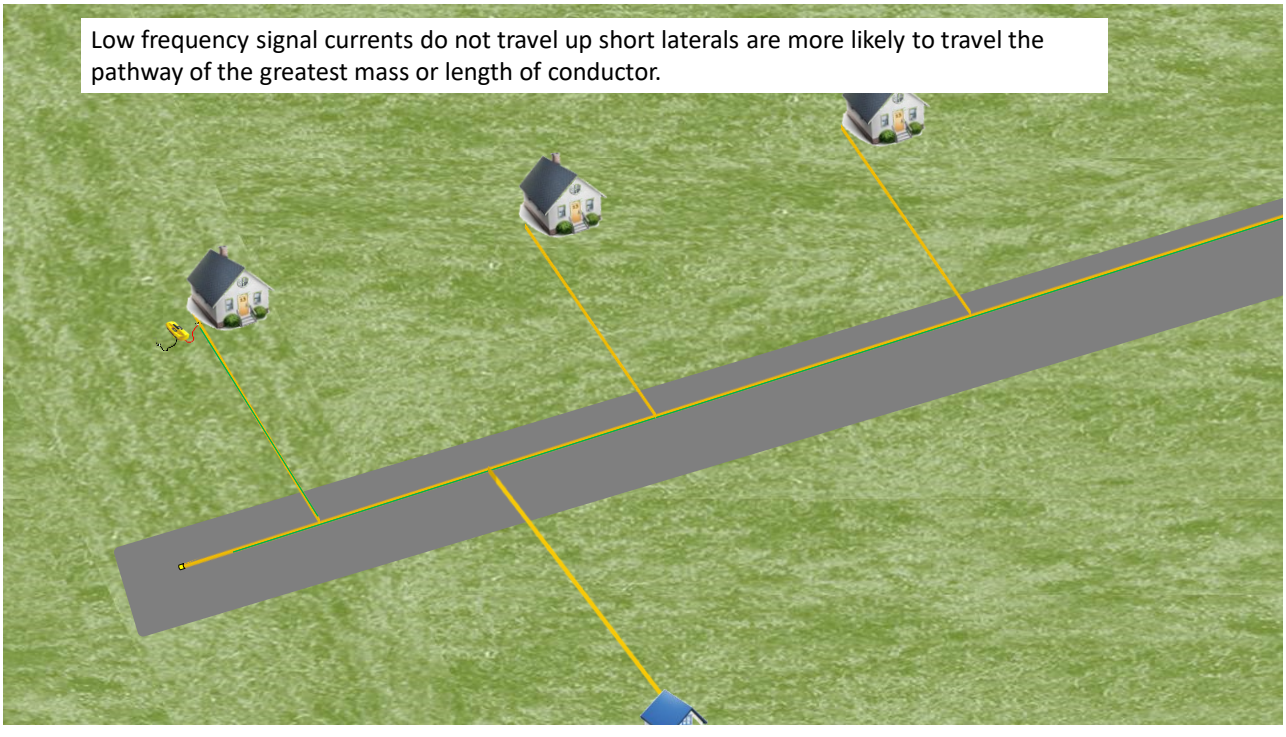

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Mid Range Frequency

- Mid-Range Frequencies 1-kHz to 45kHz
  - Better suited to higher resistance circuit loop (poor conductor and dry soils)
  - Increased chances of signal bleed off to other utilities increases with frequency
  - tends to travel on both main target and lateral lines with the amount signal shared with laterals increases with frequency.
  - Better suited for locating dead end of conductor
  - maximum power available on transmitter from Hz up to 45kHz (*all EM Transmitters are limited to 1 watt when broadcasting over 45kHz)
  - mid range frequencies are often better suited for inductive broadcast

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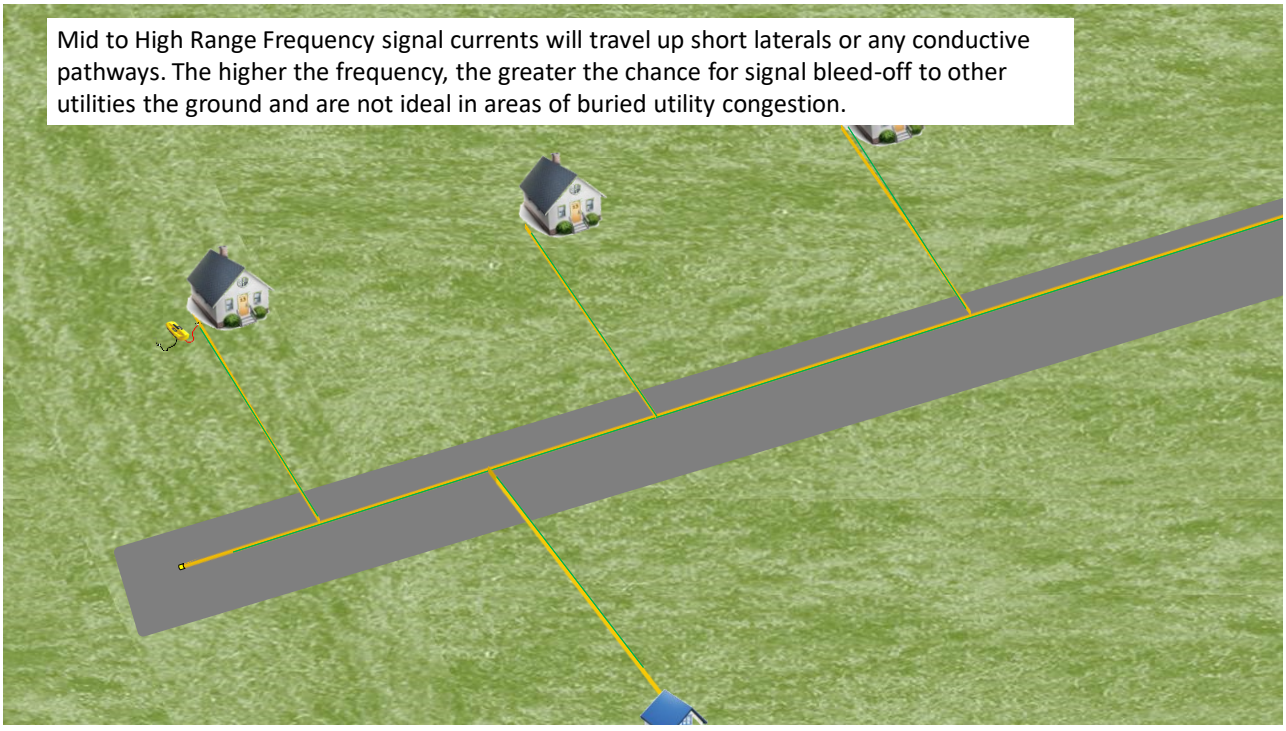

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High Range Frequency

- High Frequencies 45 kHz-480 kHz
  - higher frequencies couple to ground more easily causing them to lose their energy quicker
  - not good for target shooting one line at a time in congested areas
  - very little energy loss at cable grounding points
  - **chances of signal bleed off (coupling to other utilities) increases with frequency choice**
  - can help overcome resistance caused by bad soils or poor conductor
  - tends to travel main target and lateral lines as well as crossing conductors. The percentage of signal lost to laterals and crossing conductors increase with frequency
  - maximum power output from EM Transmitters are limited to only 1 watt of power broadcasting over 45K)
  - good for inductive search for unknown conductors

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Tips for frequency choice

- Use lowest possible power and frequency settings to achieve a clean traceable signal throughout the entire area you need to locate. Low Hz range frequencies are great for locating lines buried in congested areas
- Increase power output before increasing frequency. The higher the **k**Hz frequency the greater chance you have for bleed-off onto other nearby conductors in the ground.
- Very high frequencies should be used as last resort to overcome resistance or if performing signal induction
- Start with mid to high range frequency for signal induction

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ANY QUESTIONS ?

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