

ECDA Indirect Inspection Tools – ACVG, Current Attenuation and DCVG

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Mears Group, Inc.

A  QUANTA SERVICES COMPANY

Indirect Inspection

ECDA is a four step process consisting of:

- 1. Pre-Assessment**
- 2. Indirect Inspection**
- 3. Direct Examination**
- 4. Post Assessment**

Indirect Inspection

- Keep it simple and well organized
- Use familiar test methods and available equipment
- Accept that it is time consuming
- Don't cheat on the footage
- Review and evaluate daily
- Work safely

Tool Selection

AUCSC Field Workshop

- **Current Attenuation**
- **Close Interval Survey**
- **Alternating Current Voltage Gradient**
- **Direct Current Voltage Gradient**
- **Other**

ACVG

Alternating Current Voltage Gradient

ACVG

NACE definition

“A method of measuring the change in leakage current in the soil along and around a pipeline to locate coating holidays and characterize corrosion activity.”

ACVG

- **Locate pipeline**
- **Locate coating defects**
- **Locate galvanic anodes**
- **Locate foreign structures (X or //)**
- **Location of bonds**

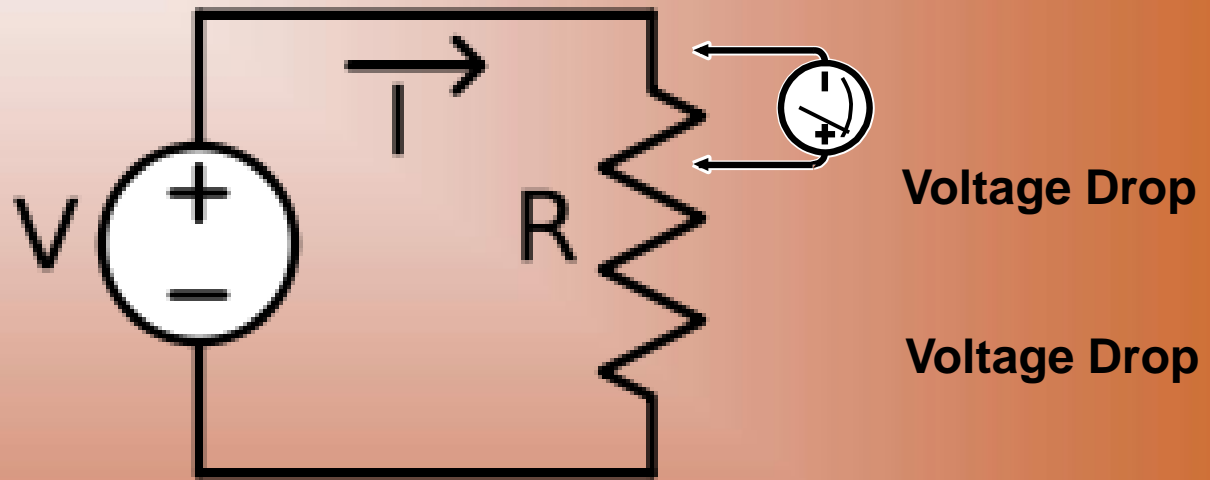
VOLTAGE GRADIENT

**Current flowing through a
RESISTOR will produce a
voltage drop.**

$$V = I \times R$$

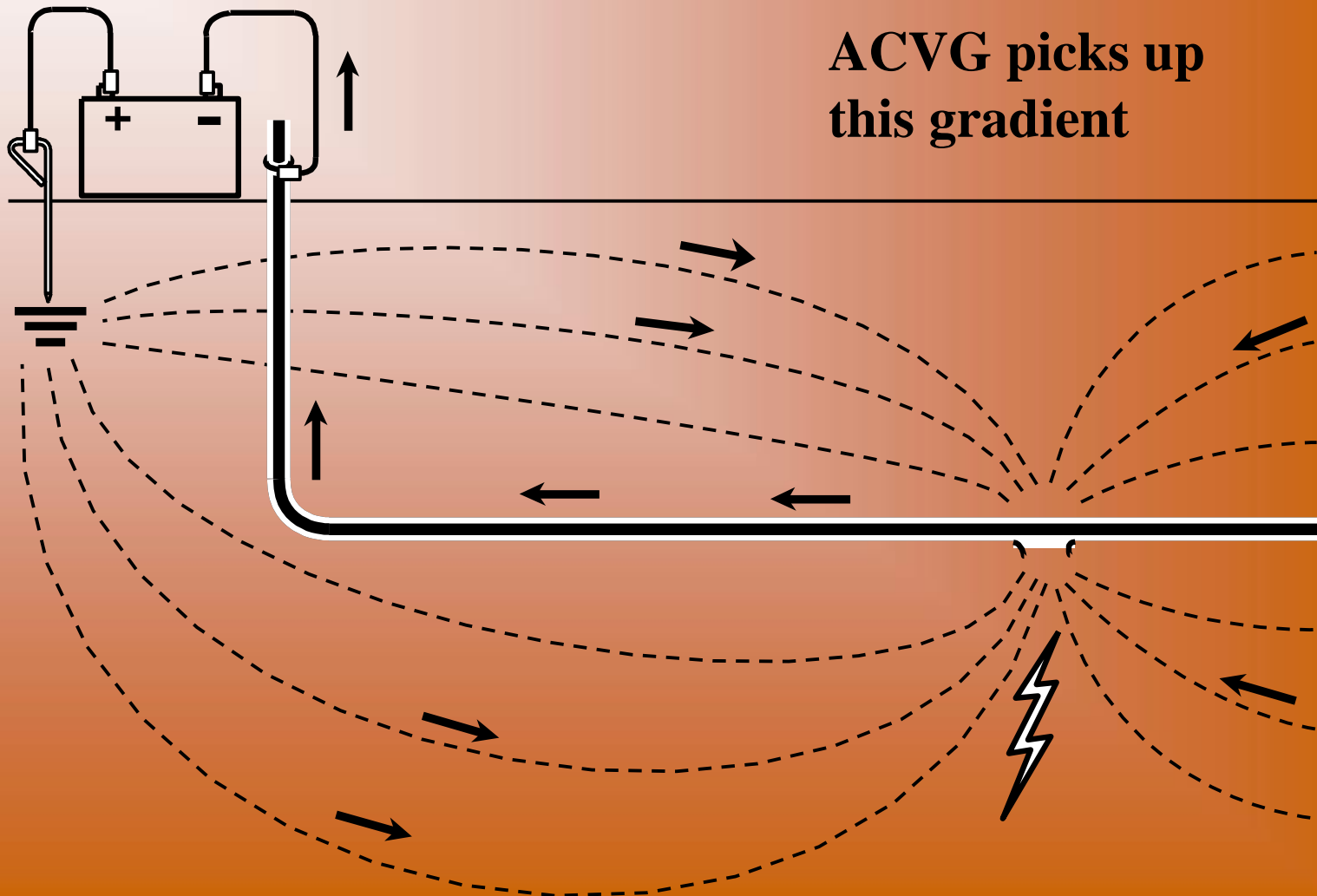
... also called ??

VOLTAGE GRADIENT



$$\text{Gradient} = \Delta V / \Delta d$$

ACVG - Current Flow



ACVG Hardware

1. ACGV Transmitter

- Generates a signal for performing pipeline survey.

2. ACGV Receiver

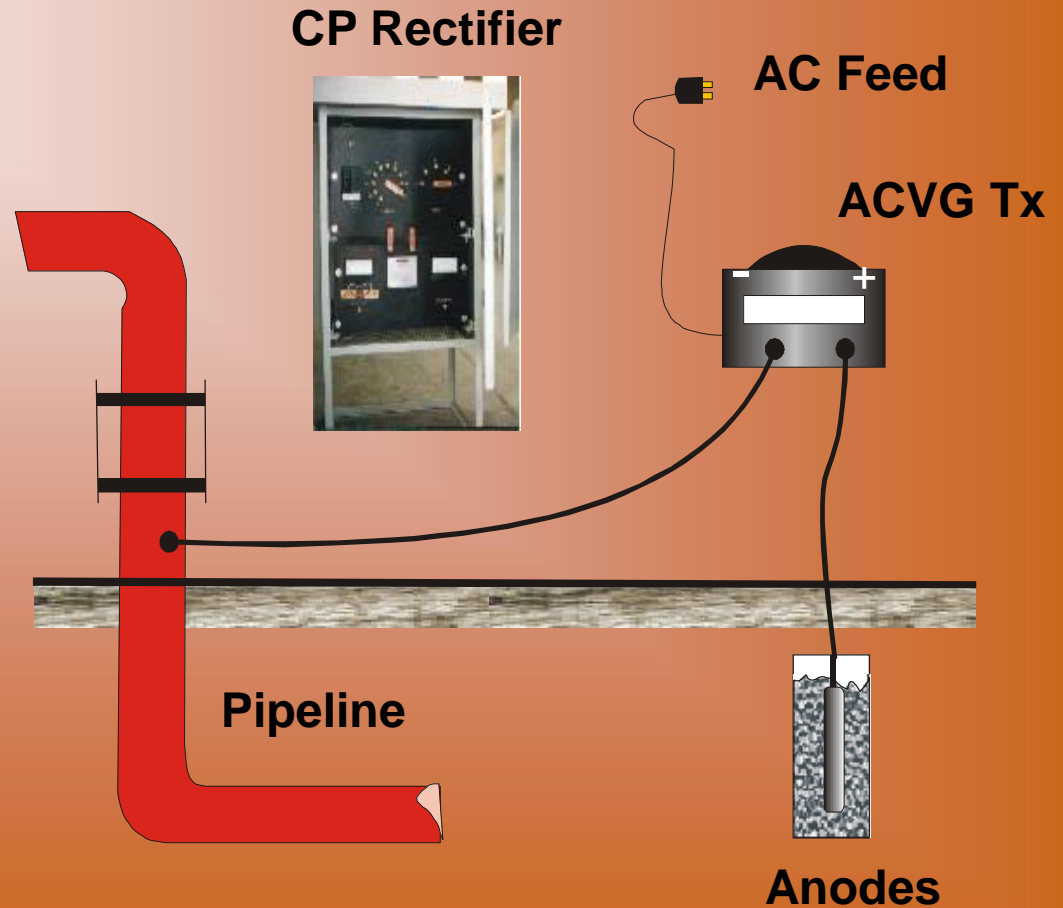
- Processes ACGV signal and displays results.
- Optional data logger and/or GPS.

ACVG Hardware

- Transmitter (Tx)
 - Generates three frequencies:
 1. Locate frequency
 2. 4 Hz for fault finding
 3. 8 Hz for direction to fault
- Receiver (Rx)
 - Locate pipeline
 - Attachment for ACSVG readings
 - Use 4 Hz de measure μV
 - Use 4 + 8 Hz to determine fault direction (phase shift)

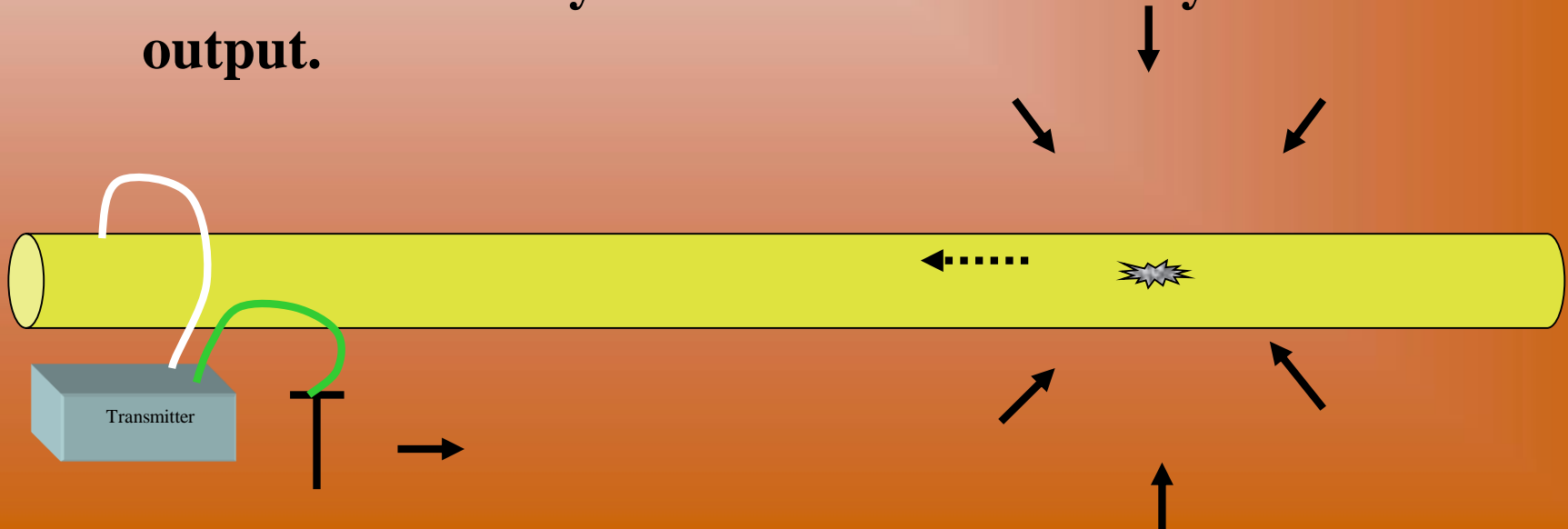
Tx - Connections

- Rectifier
- Test Station
- Metering & Regulating



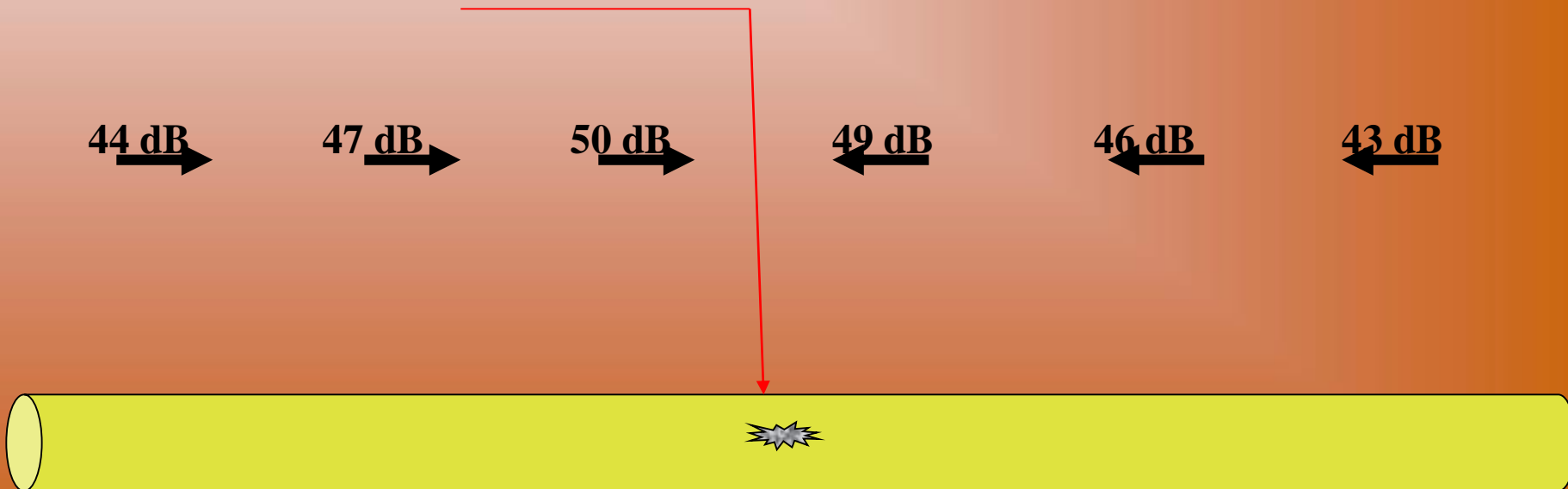
Transmitter

- **Current from the transmitter creates a voltage gradient around coating defects.**
- **Current density greatest at interface between the defect and the surrounding environment.**
- **Current density function of soil resistivity & Tx output.**

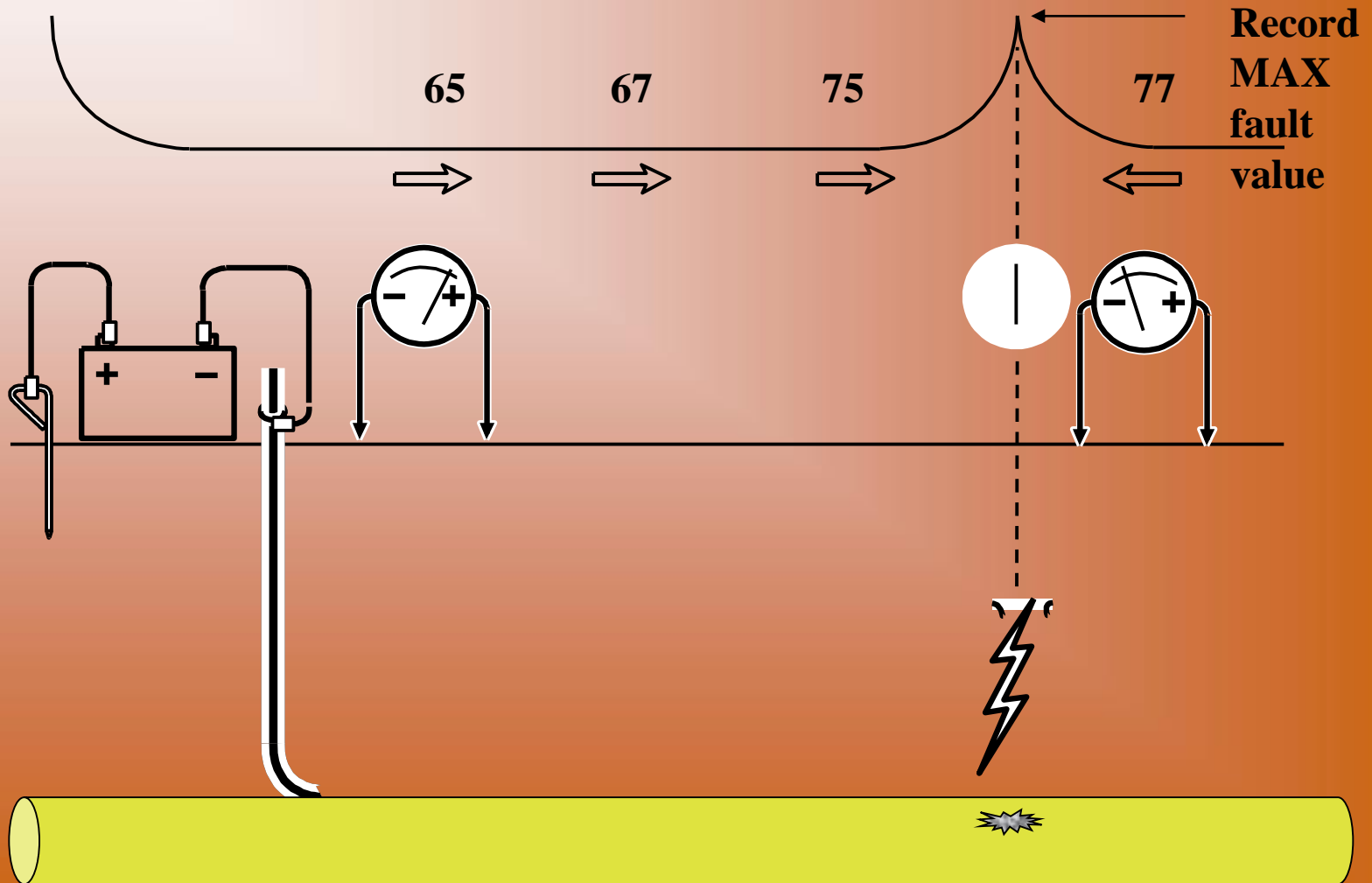


ACVG – Receiver Readings

- An increase in voltage gradient will cause an increase in current density near a given coating defect on the pipeline under test
- Signal Current and Voltage effects viewed on instrument's display
- Signal Current direction is displayed as an arrow
- Voltage is identified as decibels (dB)



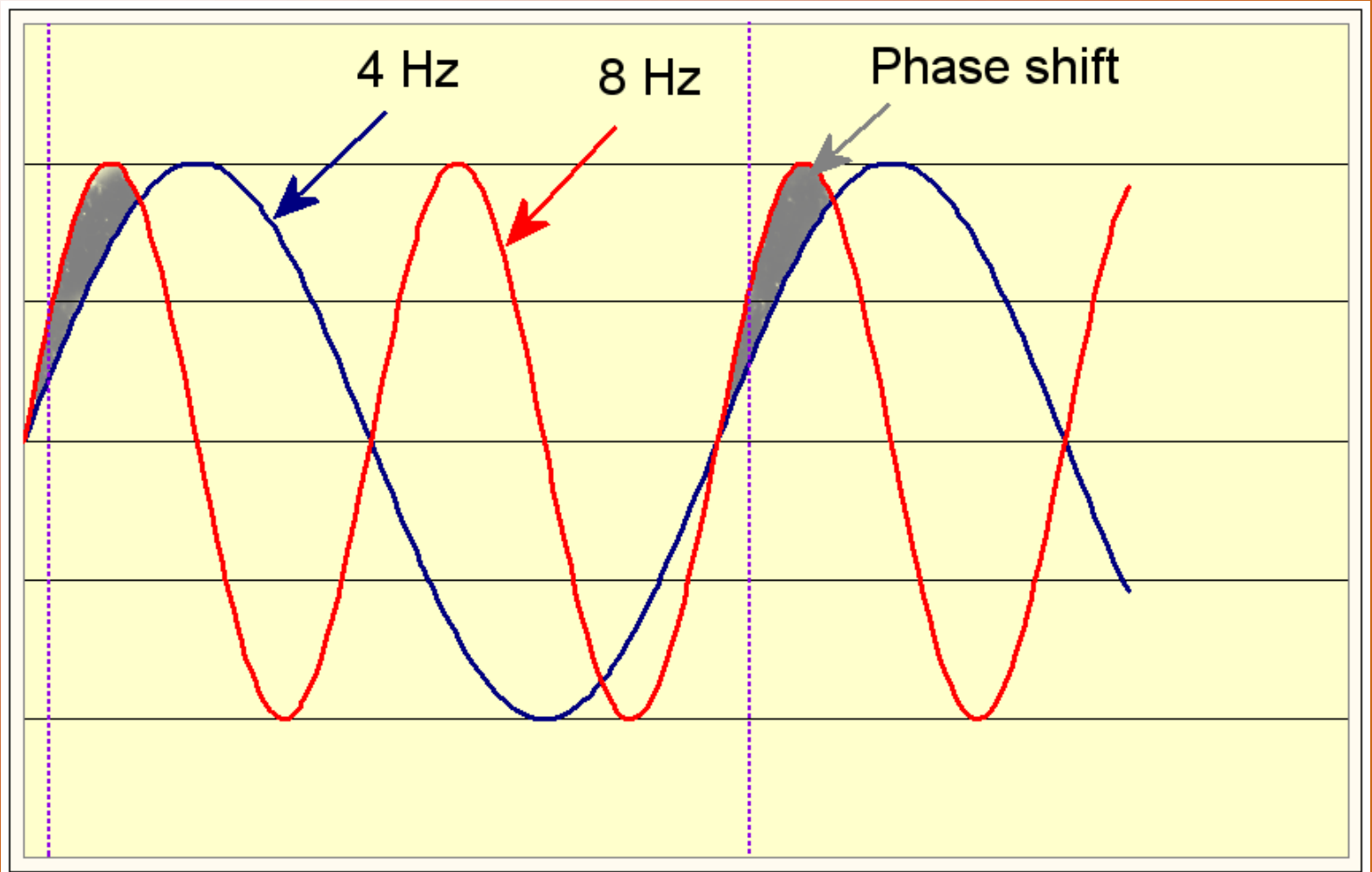
ACVG – Shape of Readings



Rx – Direction to Fault



Rx – Direction to Fault



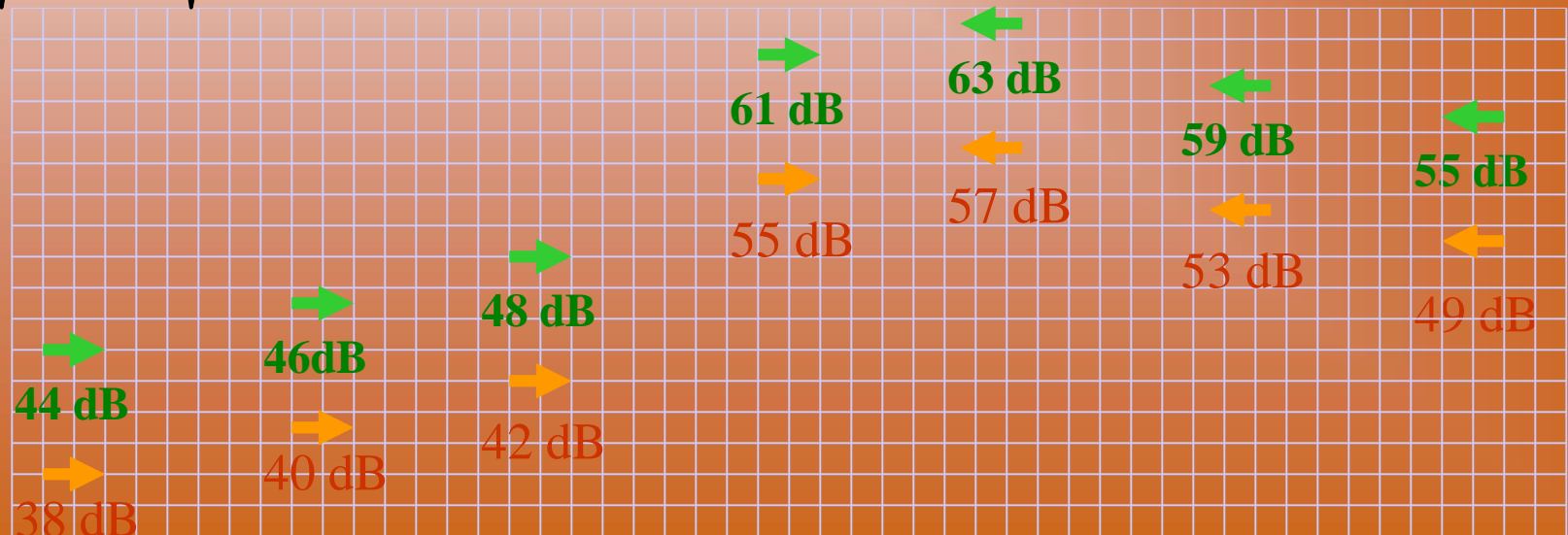
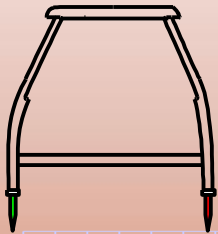
Fault Magnitude – dB (decibel)

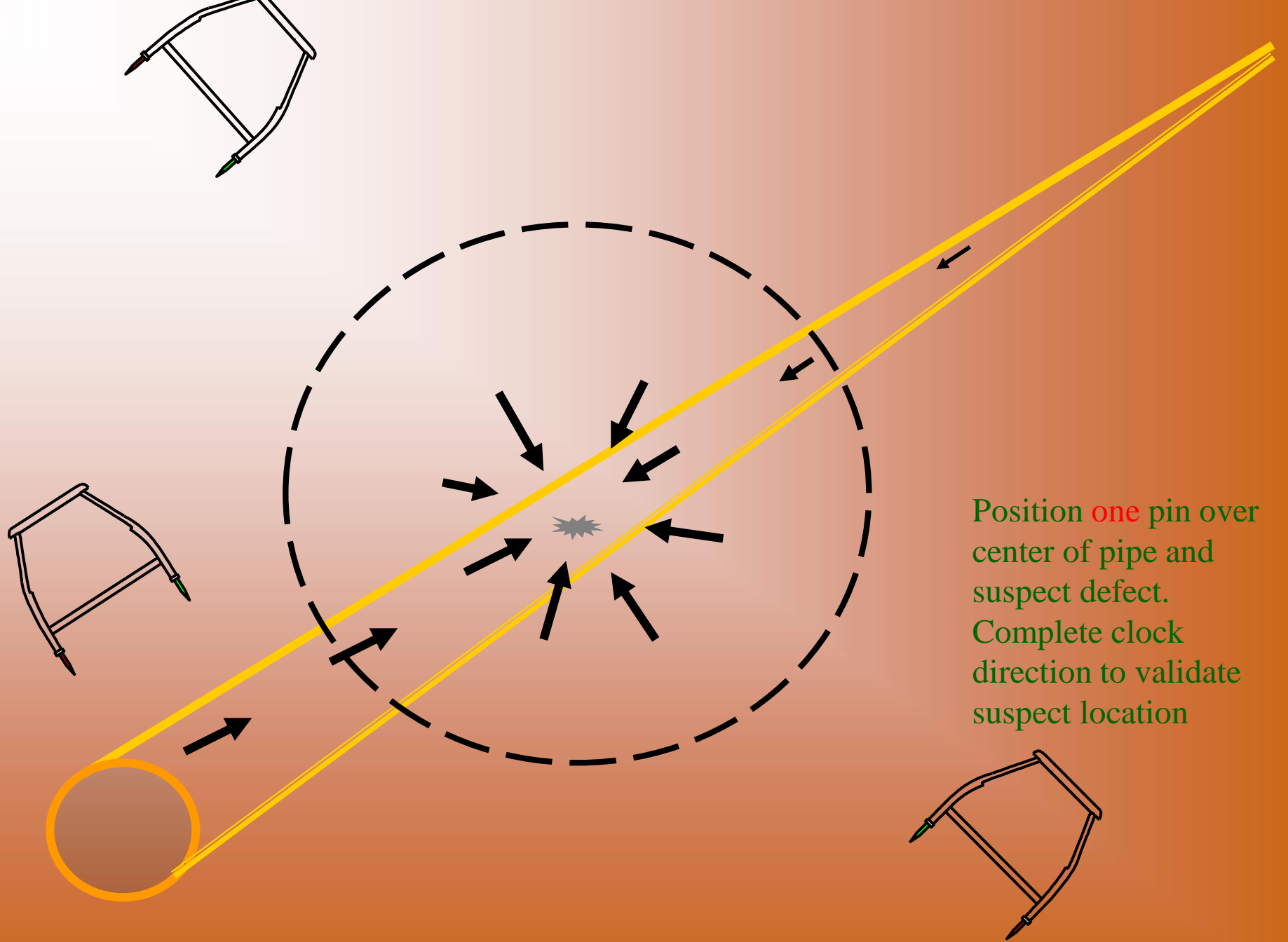
- A decibel is a logarithm of a ratio, multiplied by a constant, or number, usually **10** or **20**.
- If the ratio you are comparing is that of two voltage gradients, then **$dB = 20 \log (\Delta V_2 / \Delta V_1)$**
- Reference Voltage is **$\Delta V_1 = 1 \mu V$**
- Every time you double or half your **voltage**, the level change is **+/-6 dB**

Current Measurement & Decibel levels

600 mA @ 40V

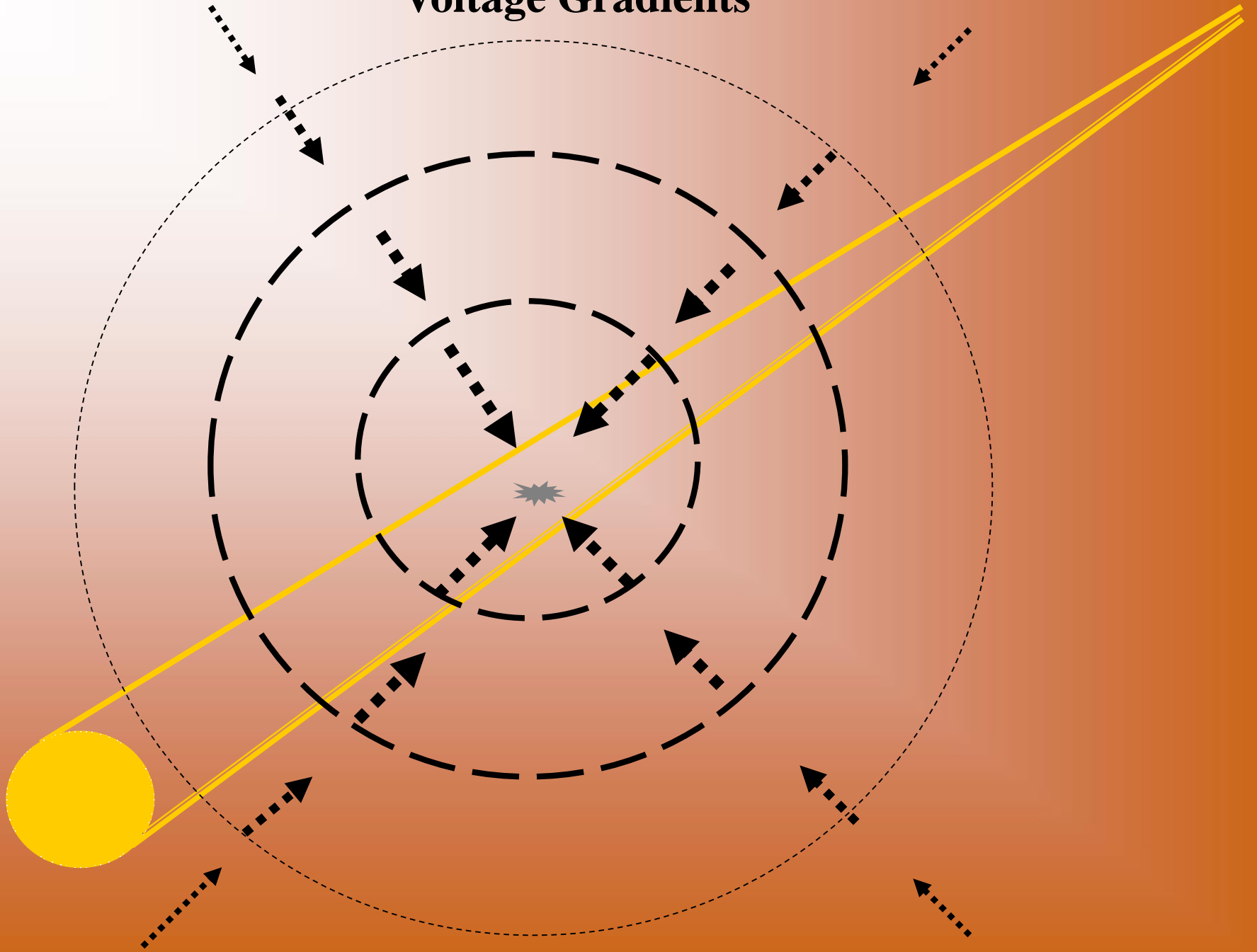
300 mA @ 20V



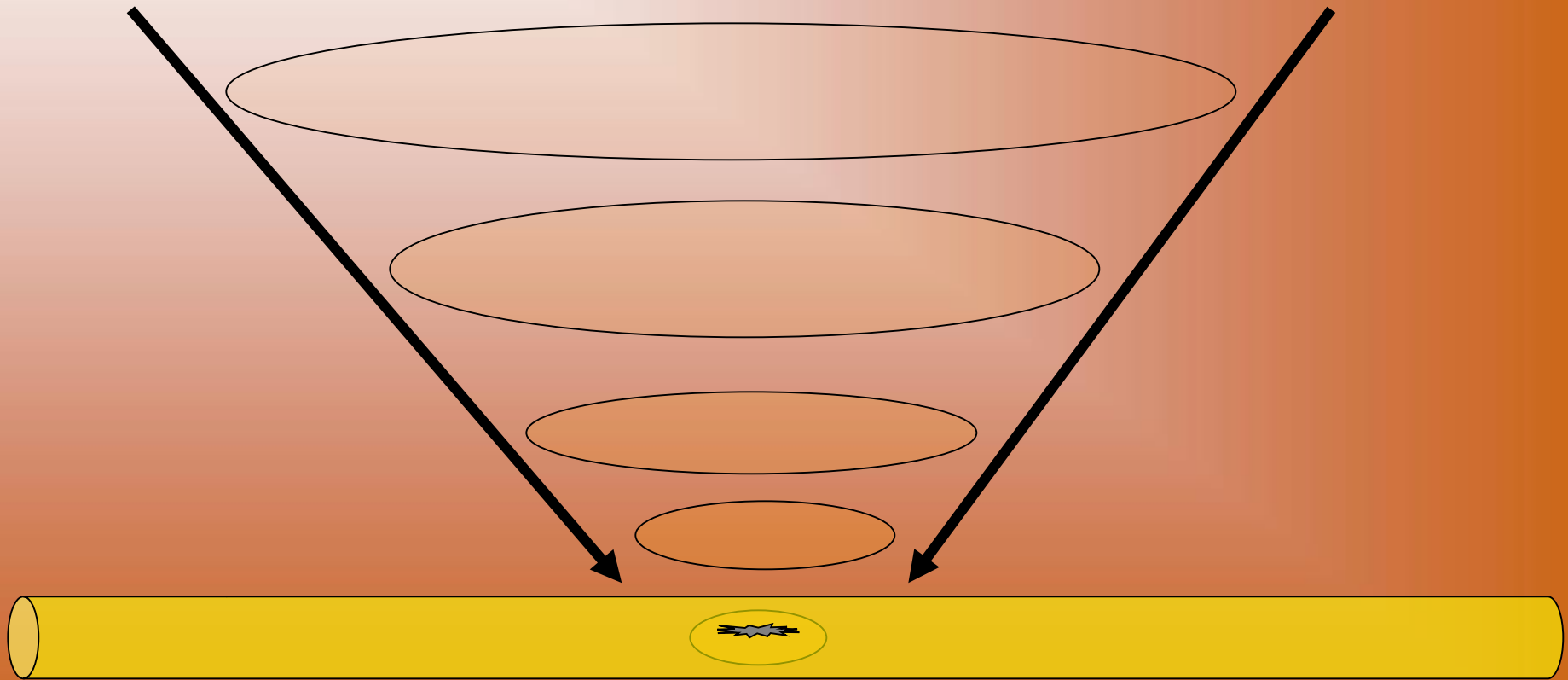


Position **one** pin over center of pipe and suspect defect. Complete clock direction to validate suspect location

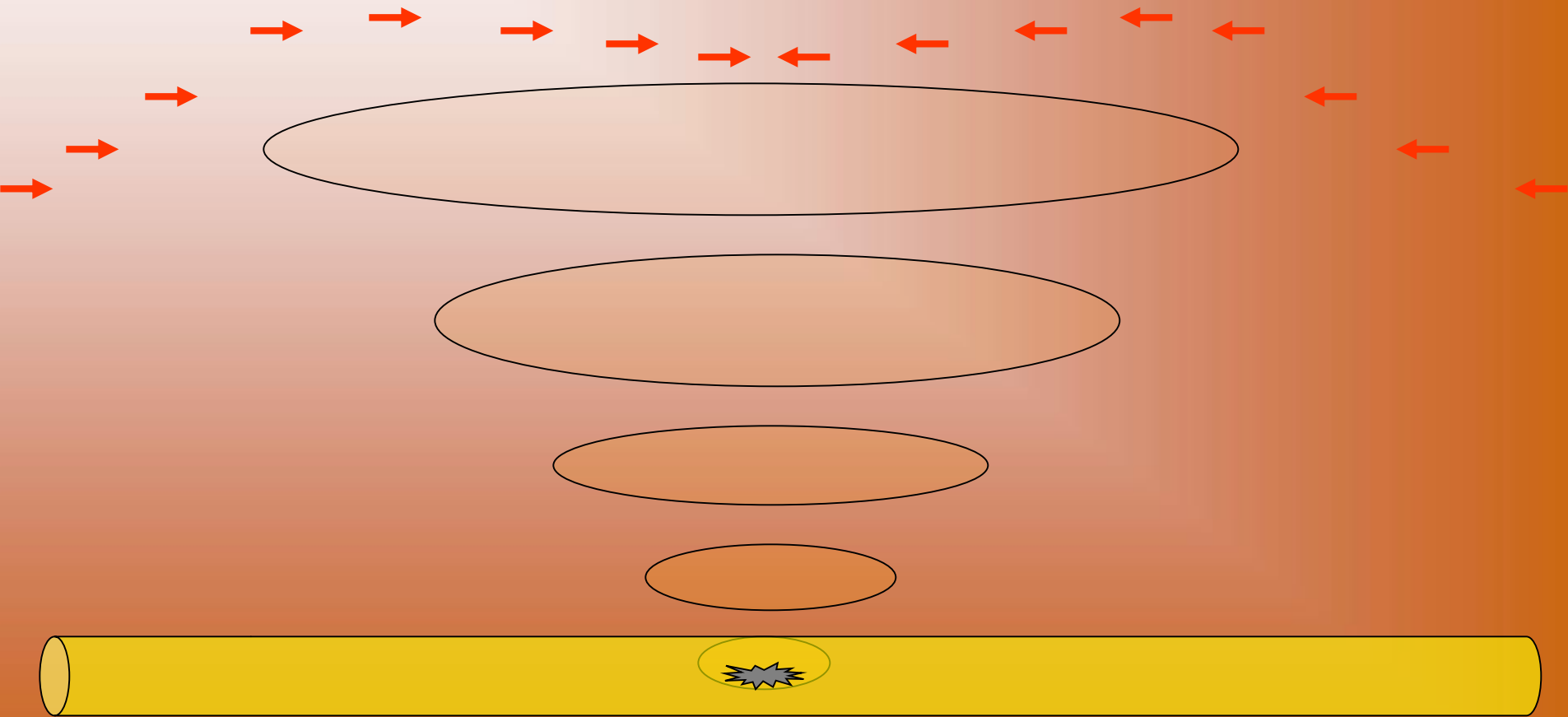
Voltage Gradients



4 Hz Signal Voltage Gradient

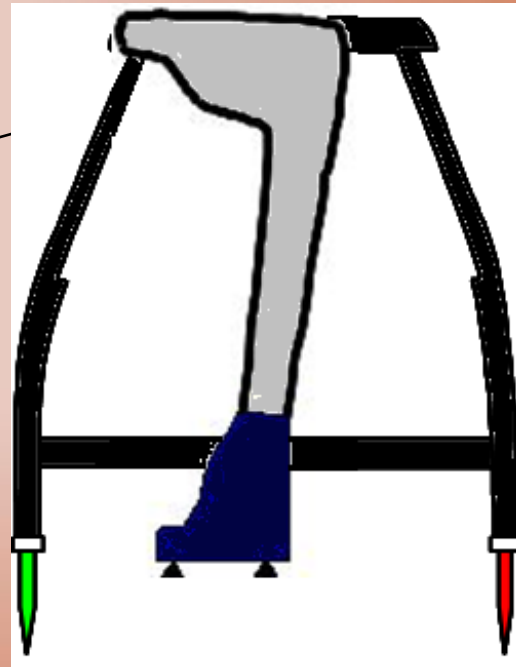


Shape of ACVG response over coating defect



← Directional Display

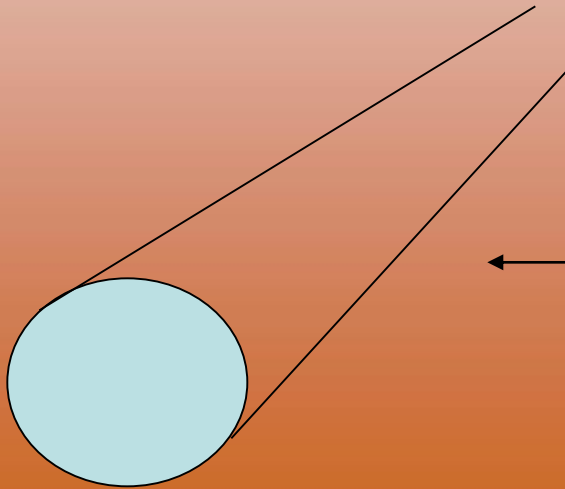
Front of receiver

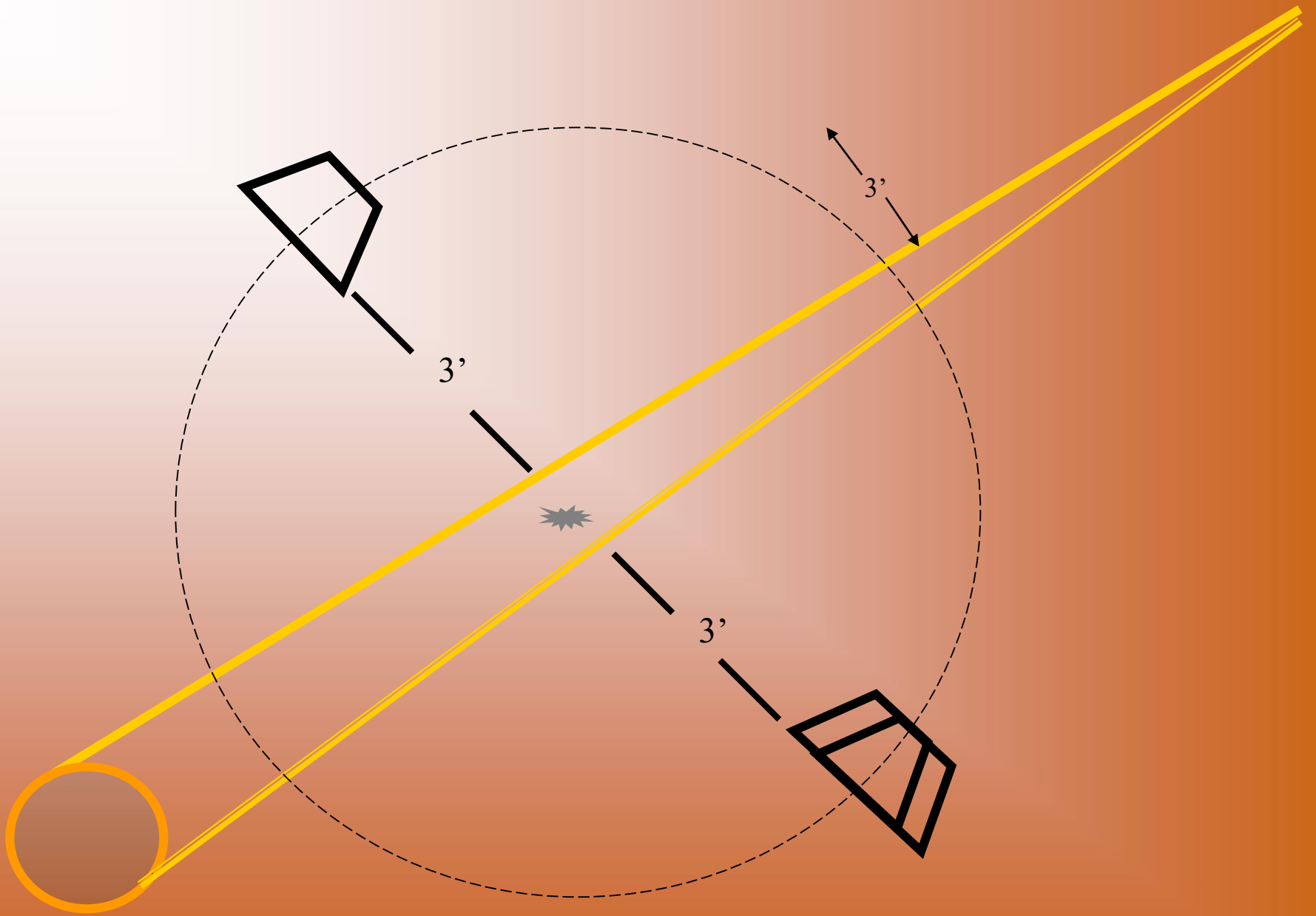


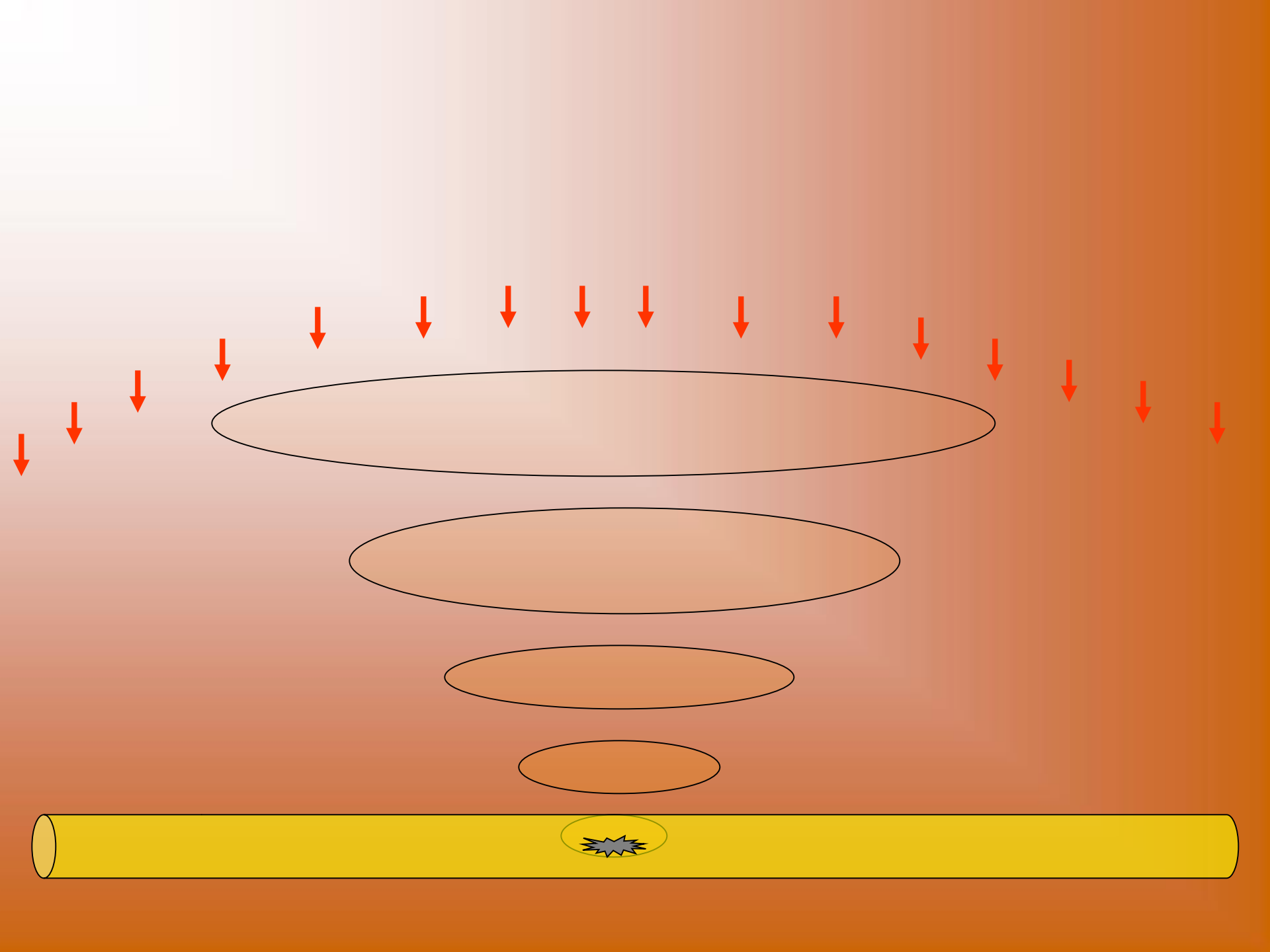
GREEN

RED

← Pipeline





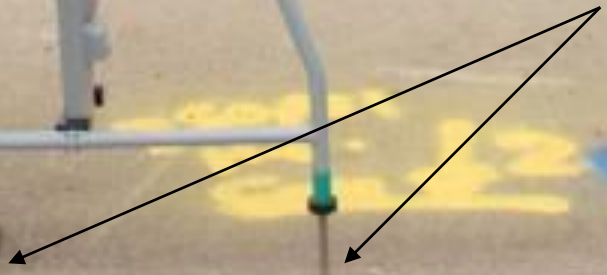




Make sure probes are in good contact with electrolyte



Probe contact in sidewalk seam



ACVG Rx Readings





Pipe 2' to 3' off curb and under macadam road surface

Using guard rail as remote ground for transmitting signal







**Connection to structure at
grade level test box using #8 cu
stranded wire connected to pipe
below grade**



Output On
Over Temperature
Power Load
Voltage Limit

20V 40V 80V 100V
Output Voltage Level

POWER

DC1 Input
Voltage 12V
500 mA

DC2 Input
Voltage 40-50 V
Maximum 1.500-1.800 W
18.00 A 2.000 V

DC1 Input
Voltage 12V
500 mA

DC Power

AC Output
071 mA



**Pipe location below
grade**





ACVG



**Pre-measured
distance for ACVG
data collection**





**Push the A-Frame spikes into the ground to take a reading.
No Rx adjustments.**

ELF LF 8k ⚡ CPS



On/Off



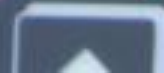
Peak/Null



Depth



Current

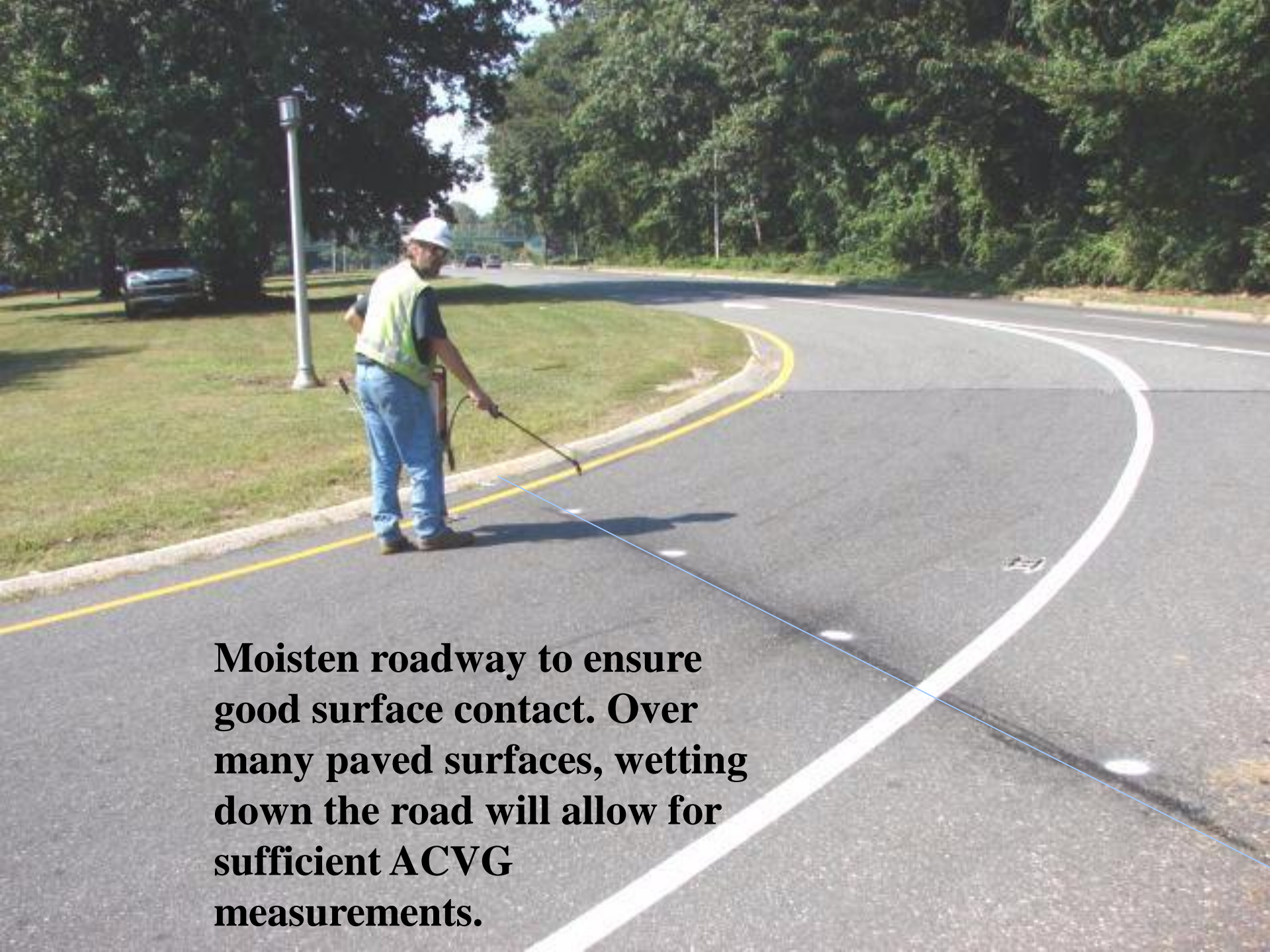


44EN01





Make good electrical contact on ground.



Moisten roadway to ensure good surface contact. Over many paved surfaces, wetting down the road will allow for sufficient ACVG measurements.

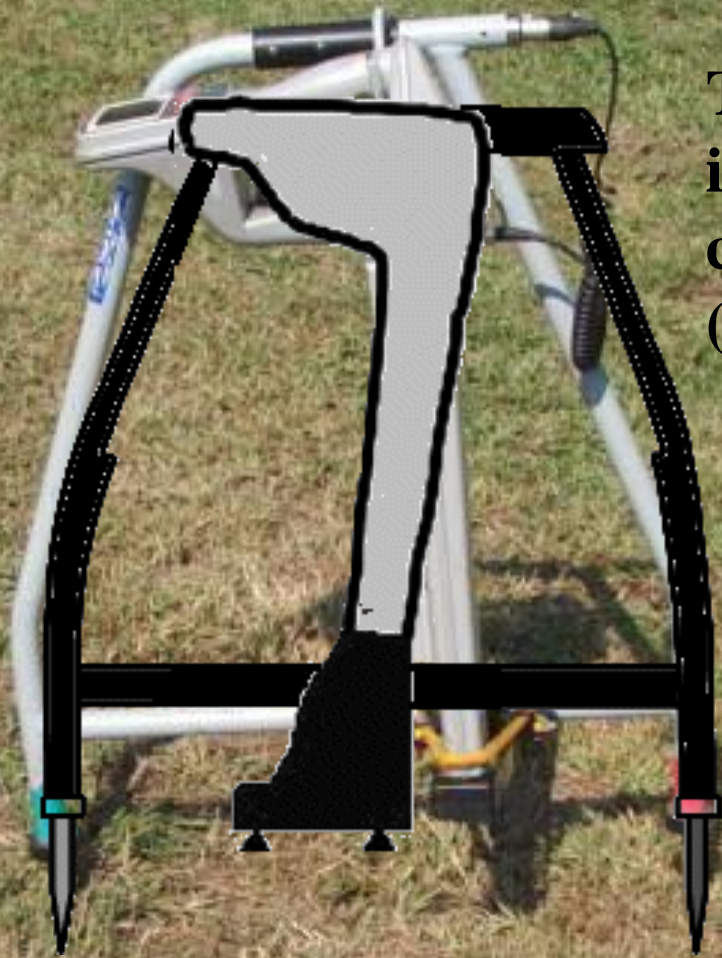
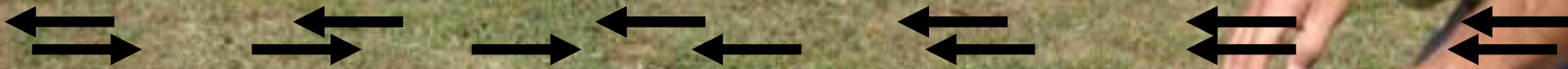












**Typical display
indicating possible
coating defect
(holiday)**



**Coating defects
observed after
excavation of pipeline**

E

D

C





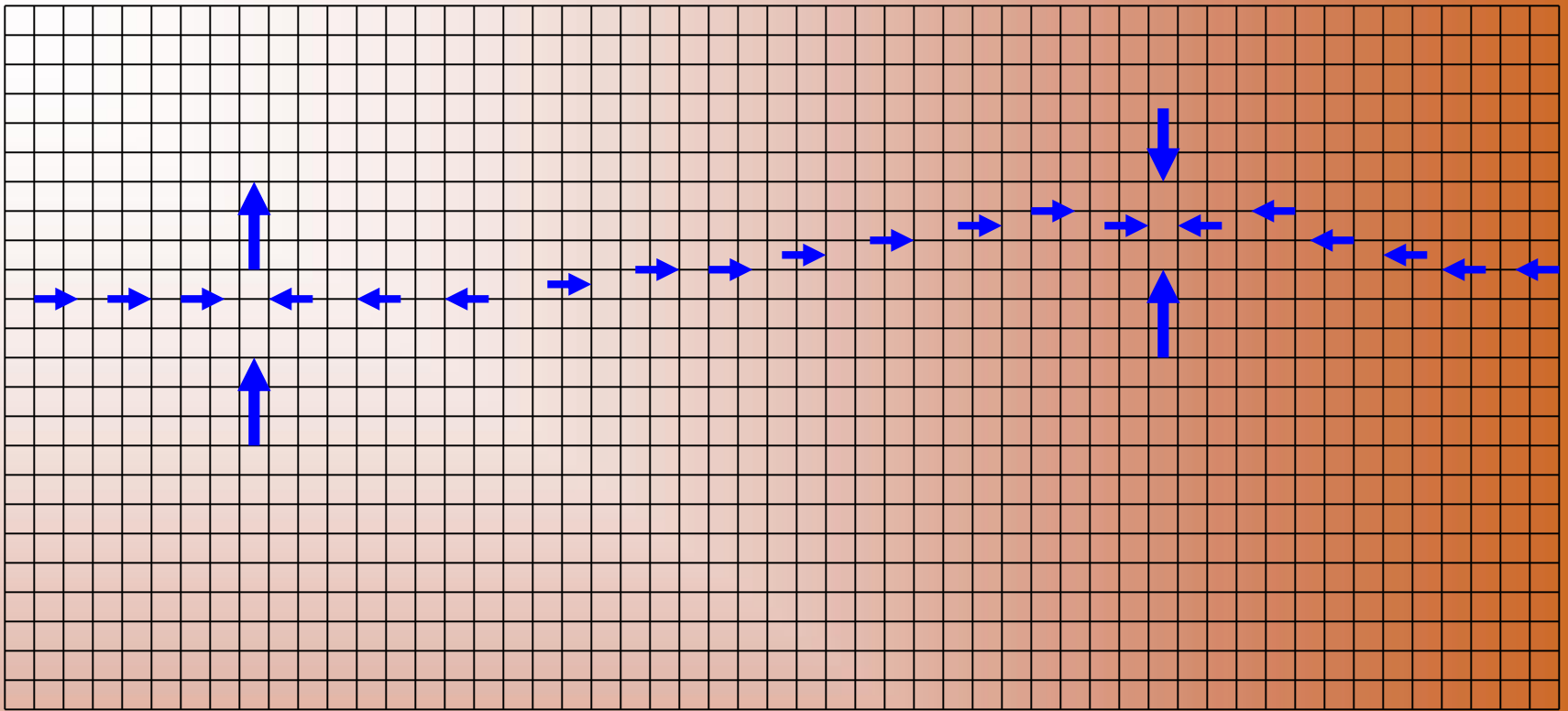
**Section of coating removed
from pipeline after
excavation**

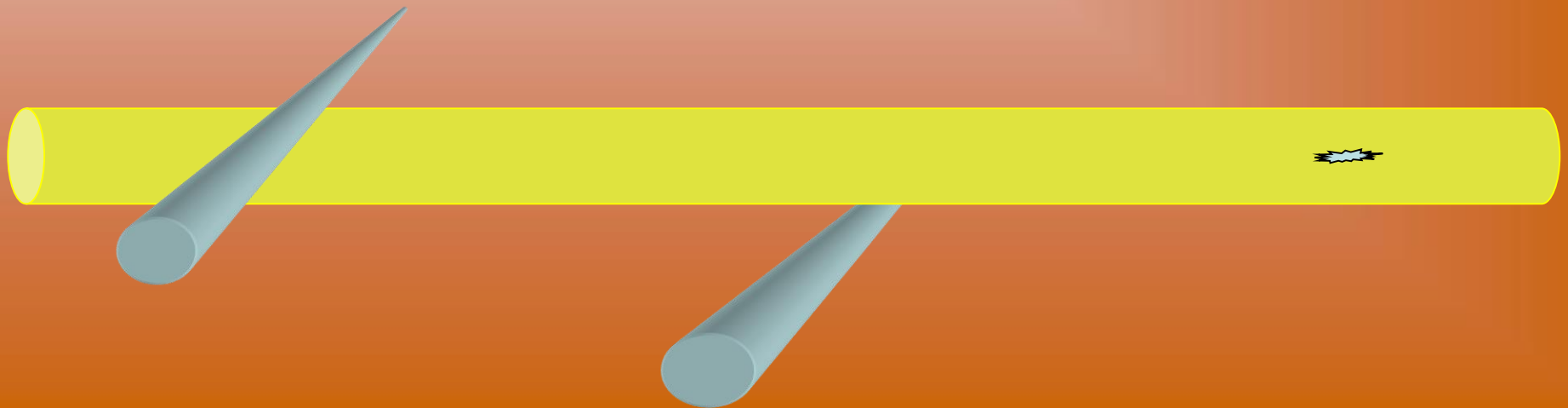
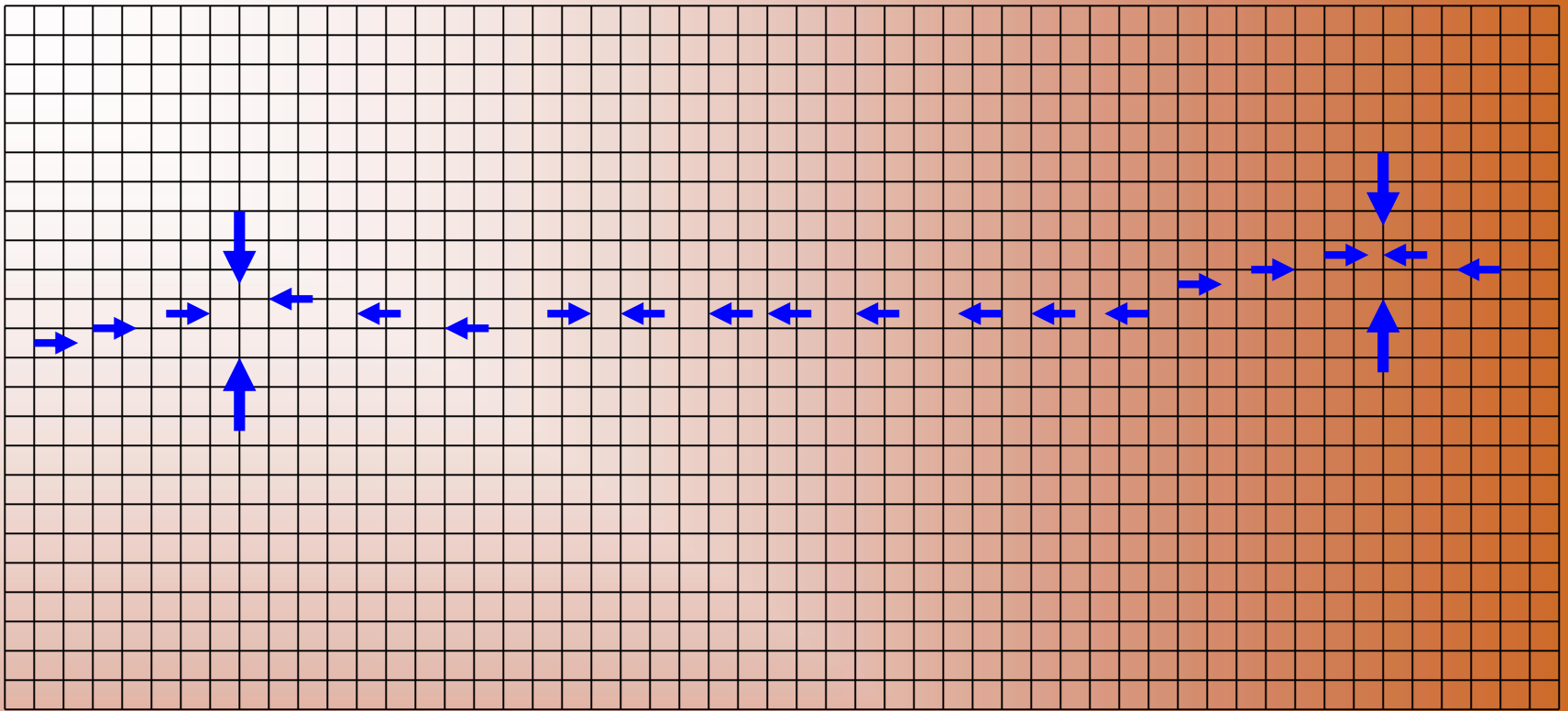
**Damage observed
after coating
removed**

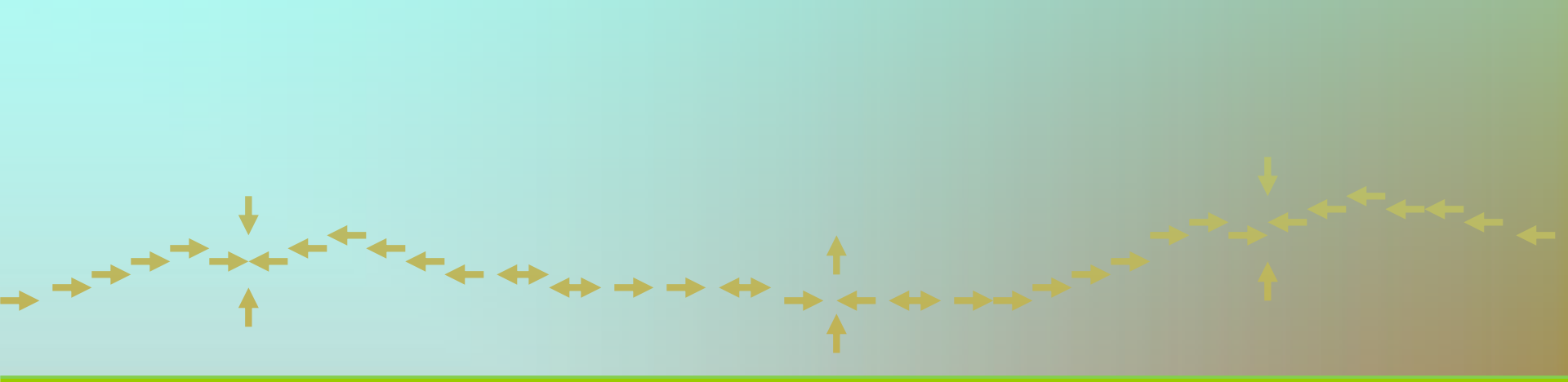












Data logging w/GPS



Interpreting Results

- No direct correlation between dB and size of fault
- dB indicates severity of current loss
- Factors affecting dB readings
 1. Tx output
 2. Current available at fault
 3. Quality of contact to ground:
 - Concrete
 - Sand
 - Railroad ballast
 4. Conductivity of path fault-to-ground (electrolyte, rain)

Interpreting Results

- Normally Faults are CATEGORIZED
 1. Manufacturer's recommendations
 2. Own internal documentation
 3. Recommended industry best practices
- Note that Transmitter output will affect dB readings because of the amount of current at the holiday. Apply correction to normalize the readings are utilized.

Interpreting Results

- Example:
 1. Severe – 80-100 dB
 2. Moderate – 65-80 dB
 3. Minor – 50 - 65 dB
 4. Note – 0-50 dB

Interpreting Results

- Can use 1A or othe current amount as a “standard” output, and refer all readings to it.

- Conversion

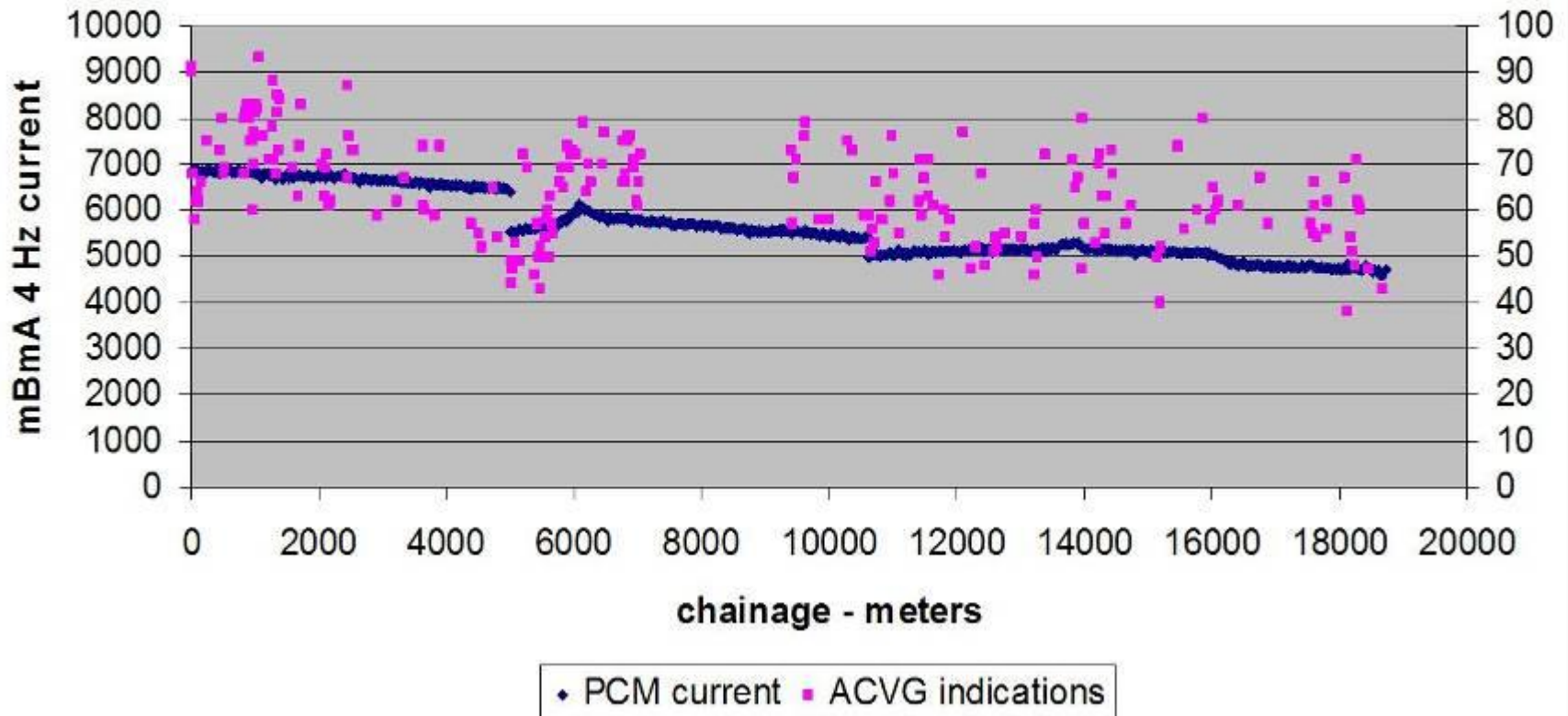
| | |
|--------|---------------|
| 100 mA | +20 dB |
| 300 mA | +10 dB |
| 600 mA | + 4 dB |
| 1 A | no correction |
| 2 A | - 6 dB |
| 3 A | -10 dB |

What can ACVG data tell us?

- It is a micro tool that pinpoints coating defects and can find:
 - Large coating defects
 - Small Coating defects
 - Severity of the coating defect
 - Possible interference areas
 - Shorted casings
 - CP cable breaks
 - Position of Anodes

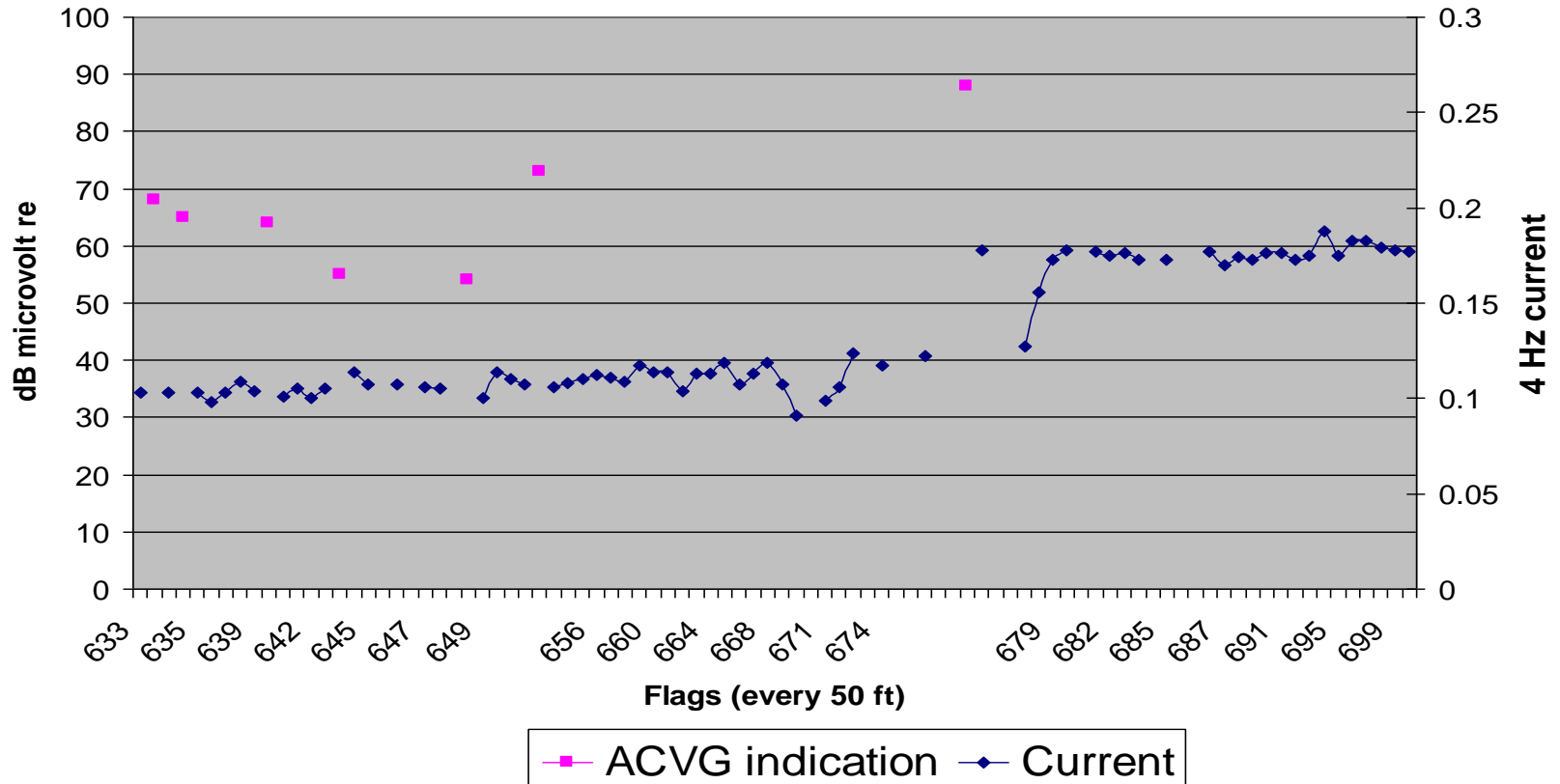
ACVG with Current Attenuation

16 inch PCM and ACGV



ACVG data

20in PCM and ACVG 03302006 AM 134



External Corrosion Direct Assessment:

Four step process consisting of:

One of these tool
requires the use of two
choices can be

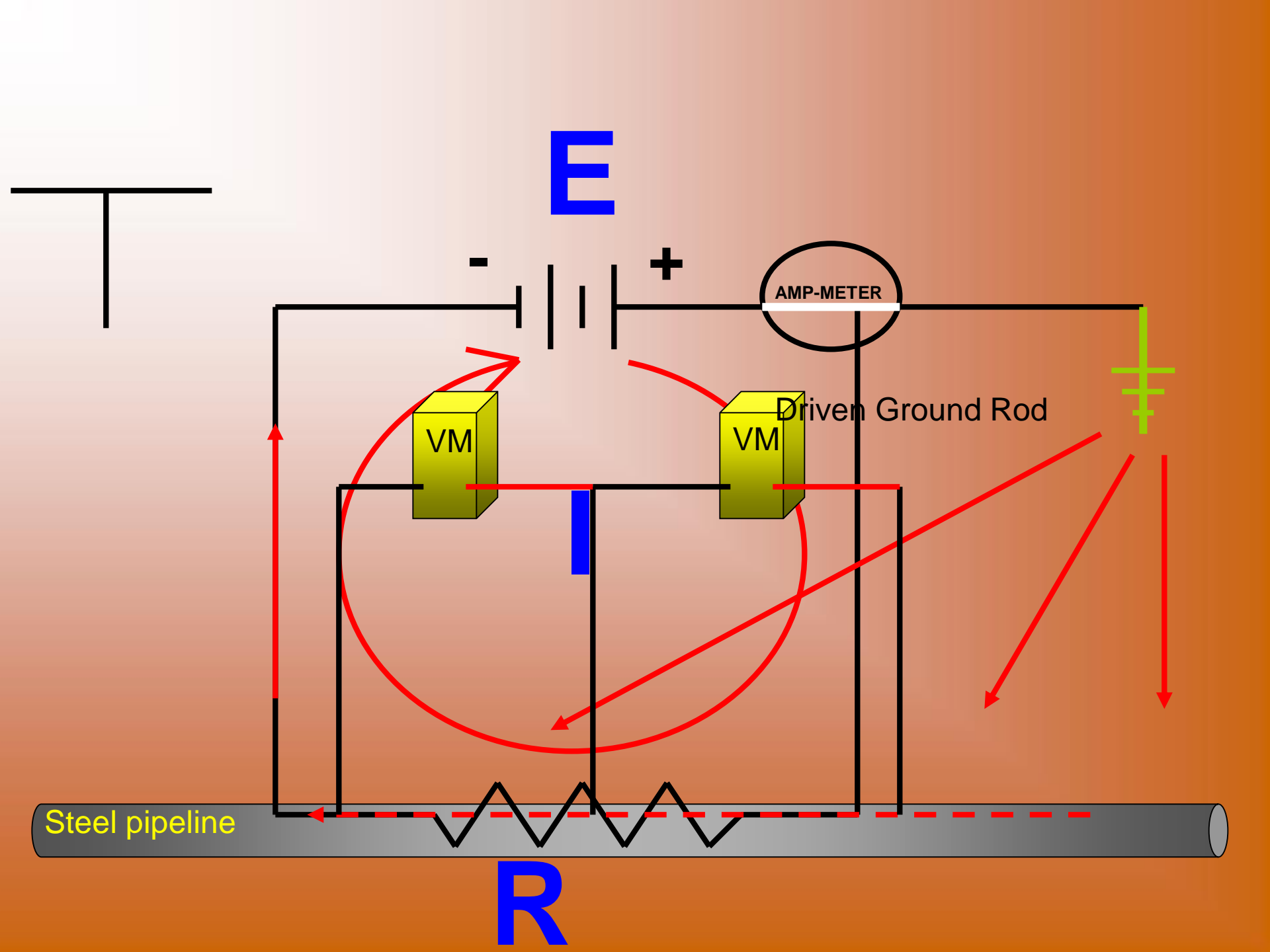
complementary tools
ACVG

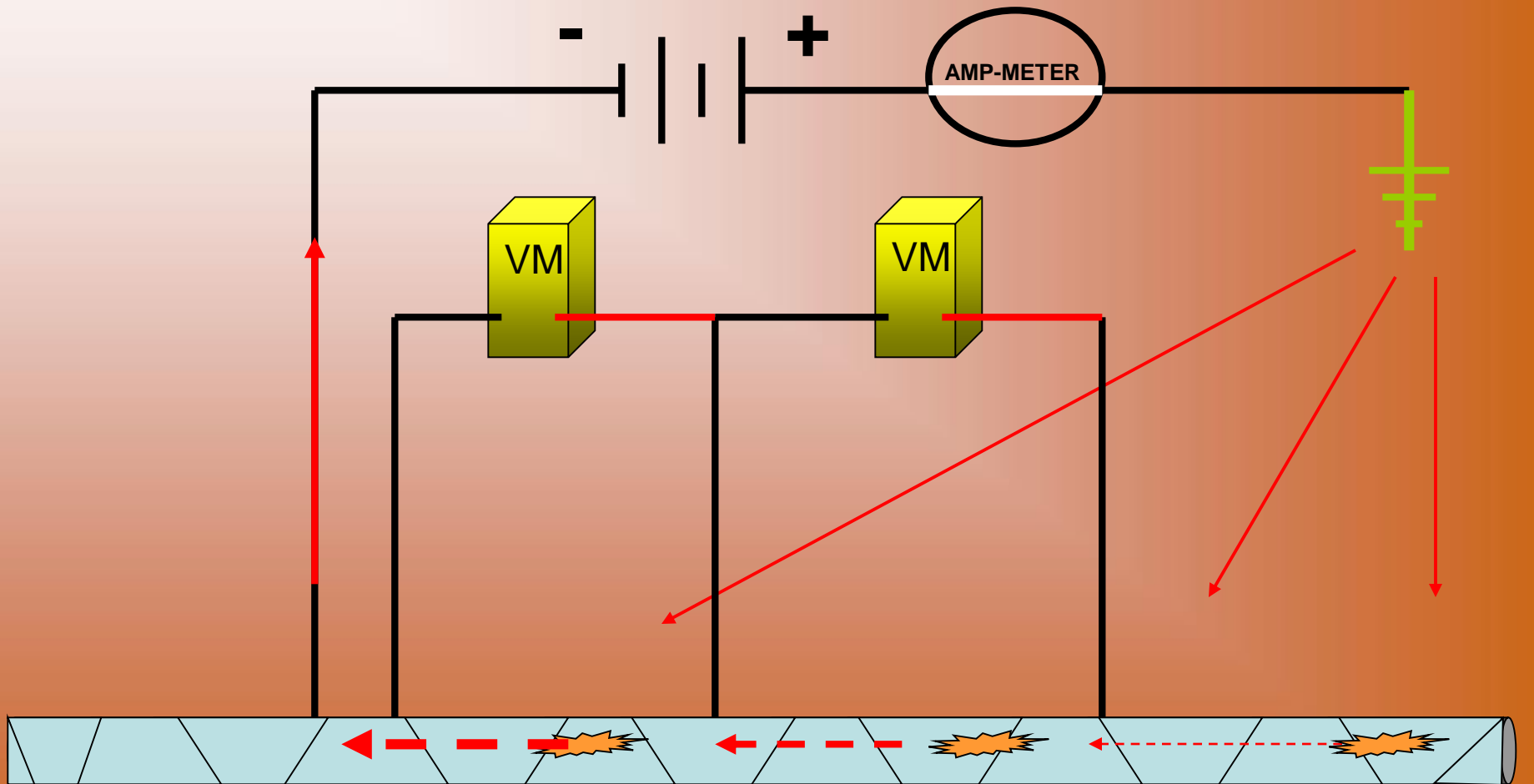
4. Post assessment

AC Current Attenuation

Introduction to Basic Concepts

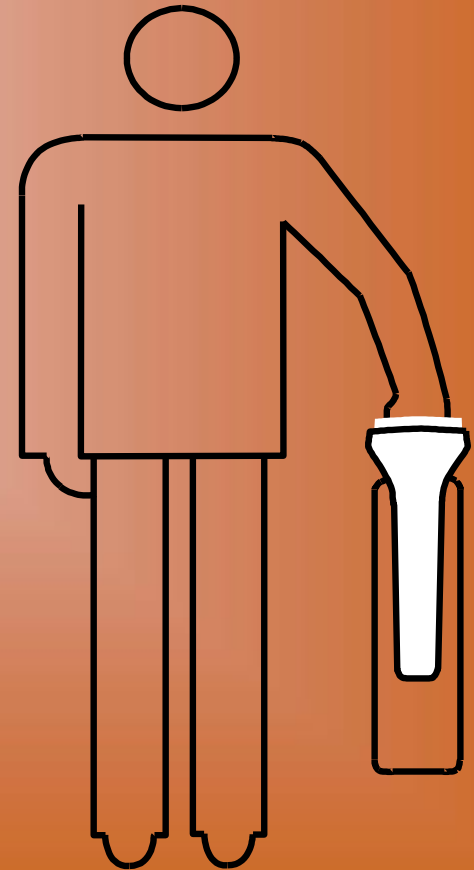
Need to understand behavior of AC current on a pipeline.





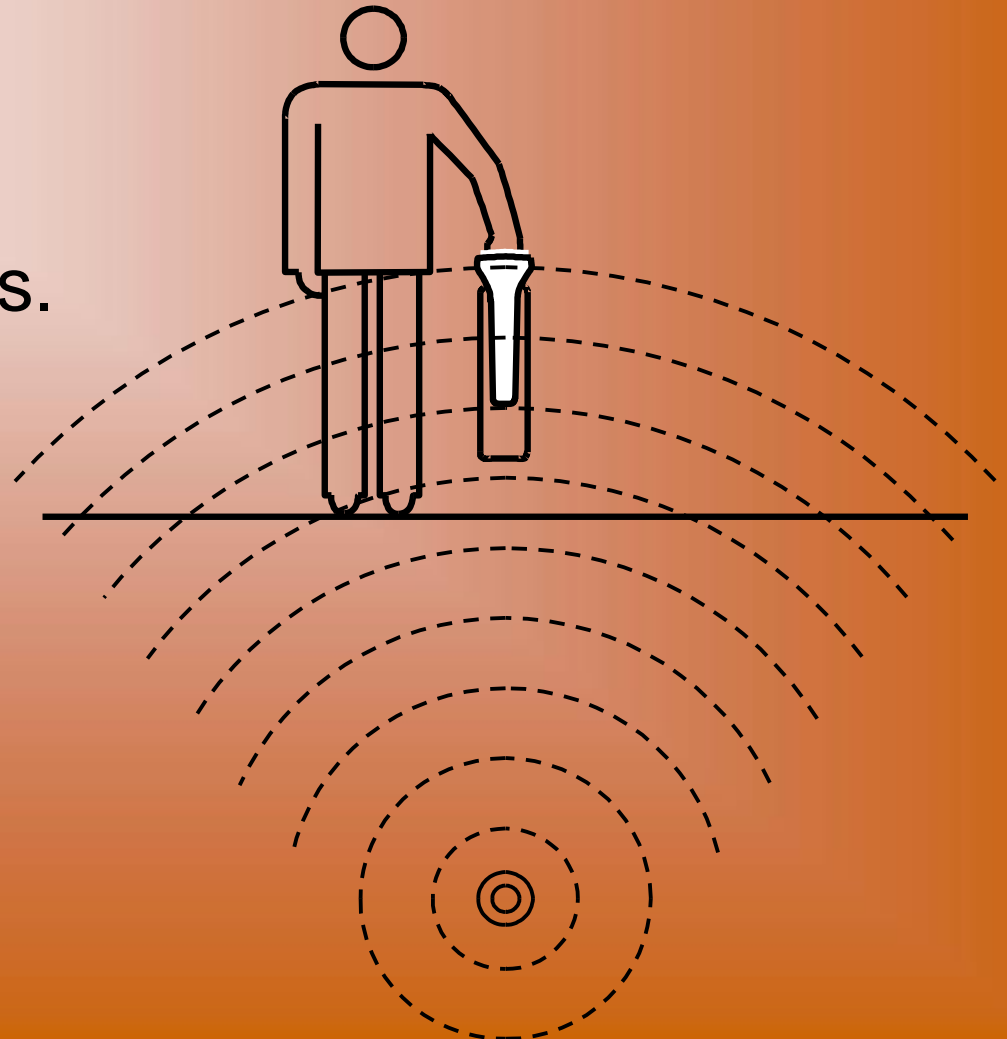
AC Current Attenuation

Pipe and Cable locators do not find pipelines (or header cables.....)



AC Current Attenuation

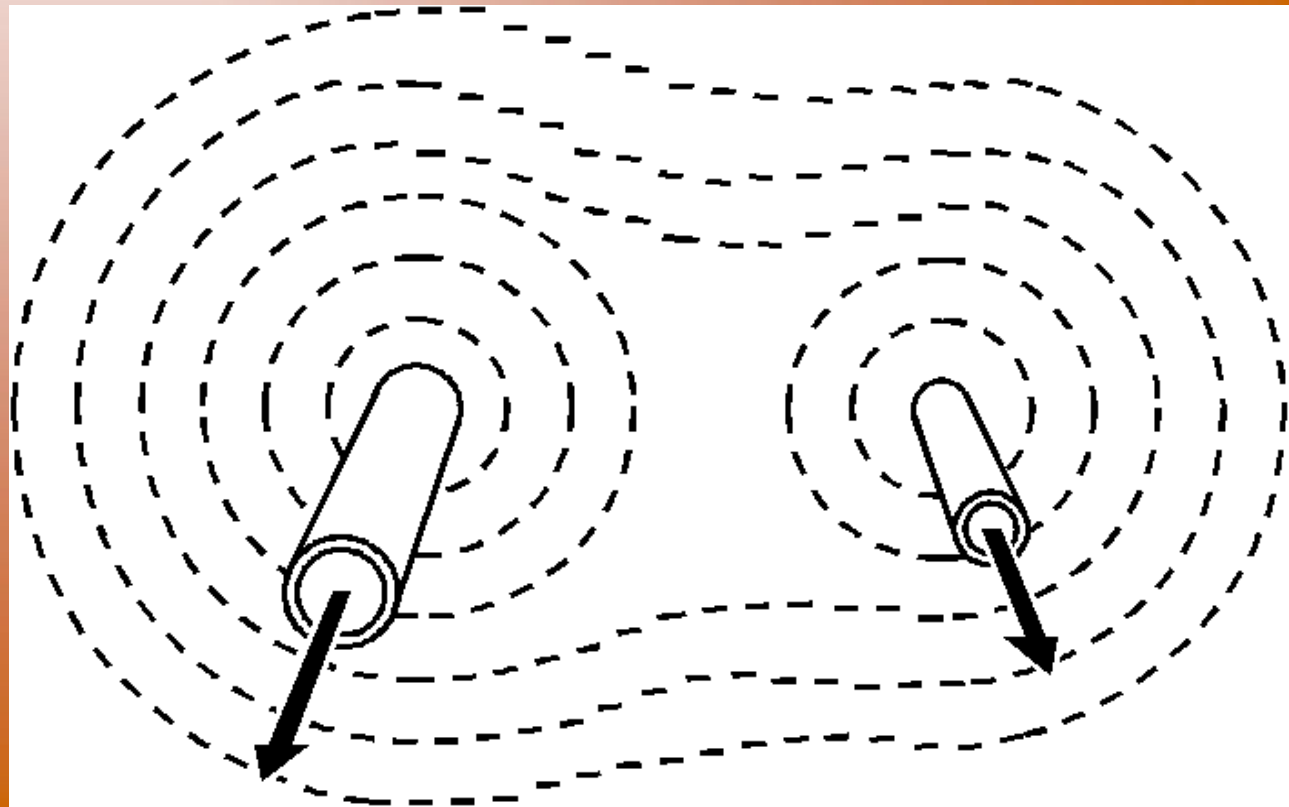
....they find magnetic fields.



AC Current Attenuation

WHY DOES IT MATTER ?

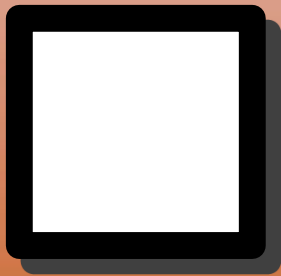
Distortion



AC-Current Attenuation

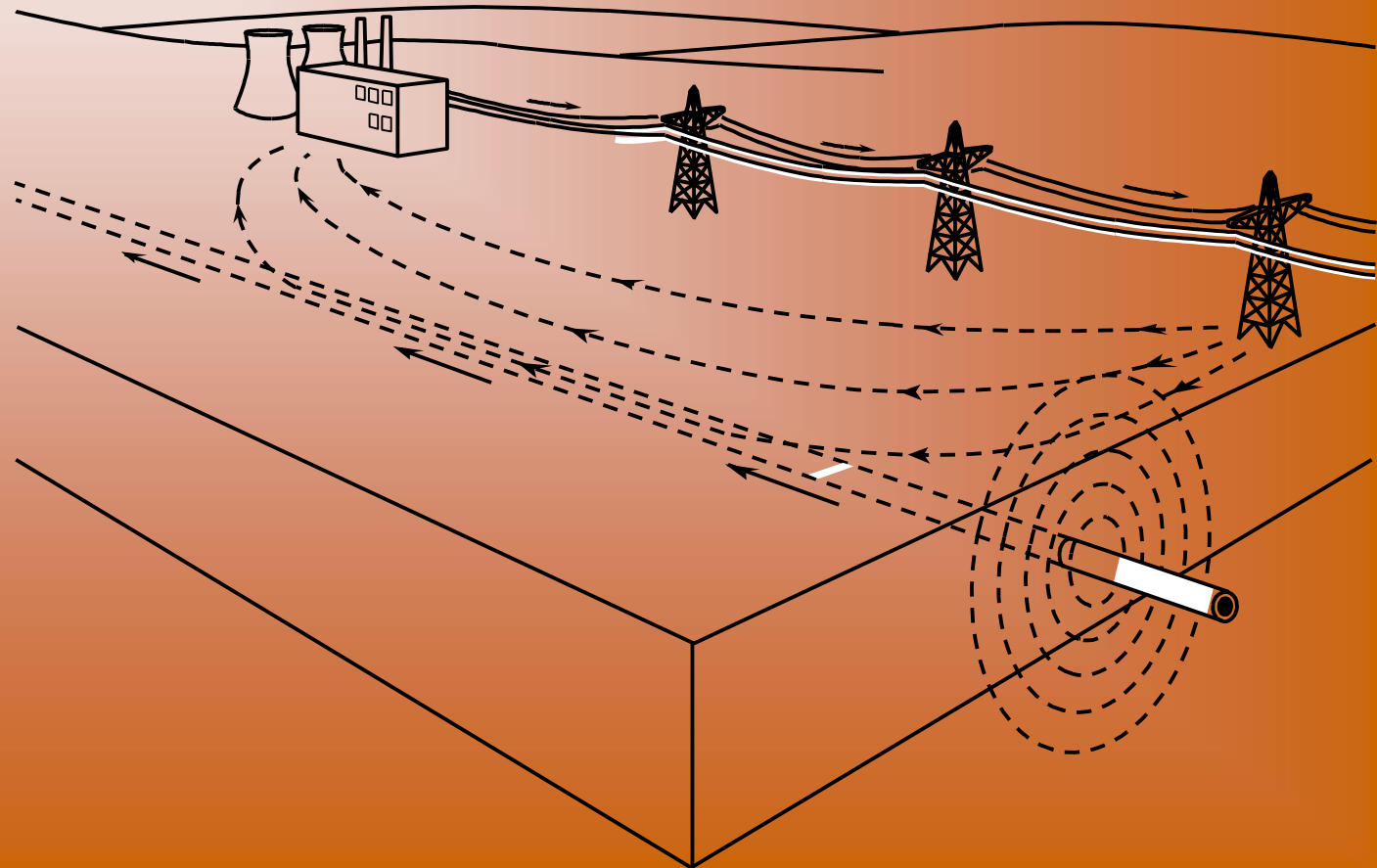


Passive

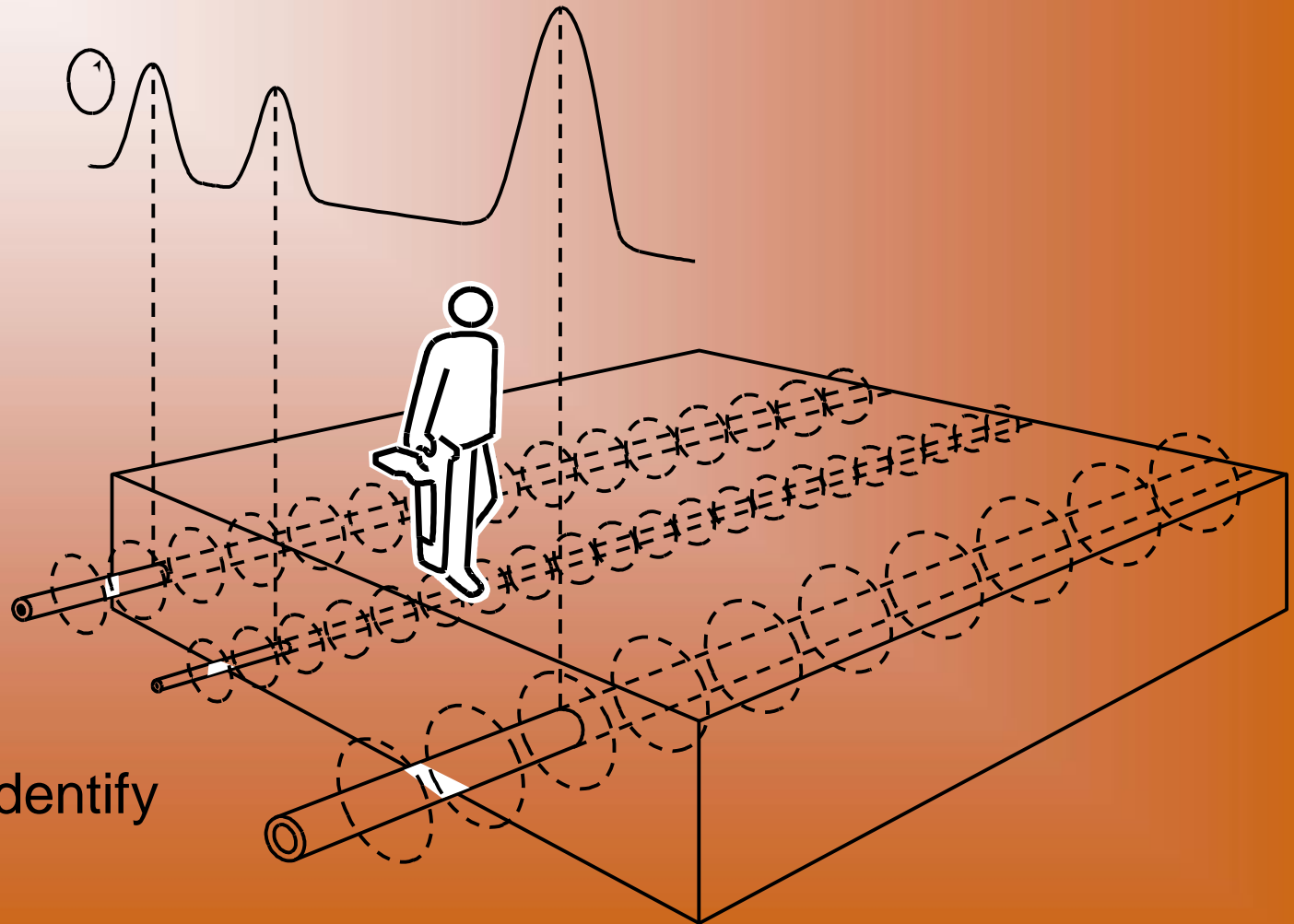


Active

AC Current Attenuation



AC Current Attenuation



- Fast
- Easy
- Does not identify

AC Current Attenuation

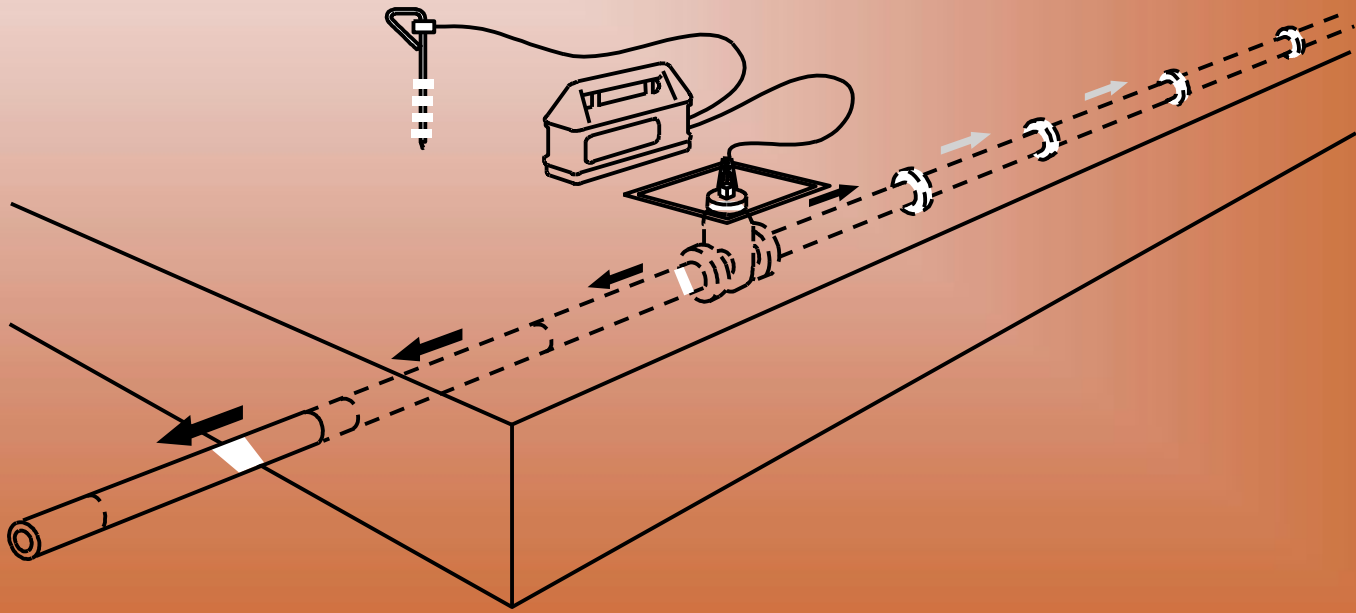


Passive



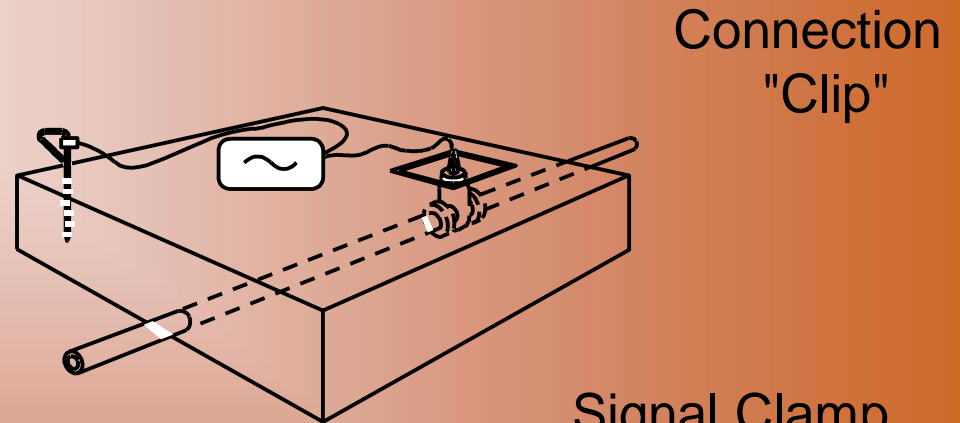
Active

AC Current Attenuation

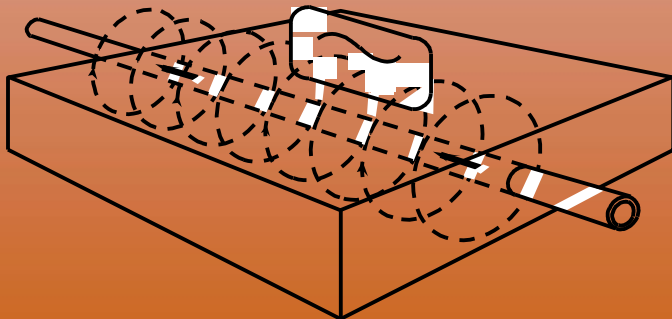


AC Current Attenuation

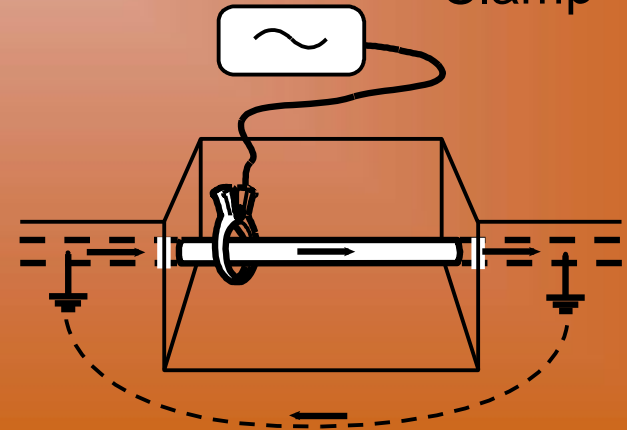
Applying a Signal



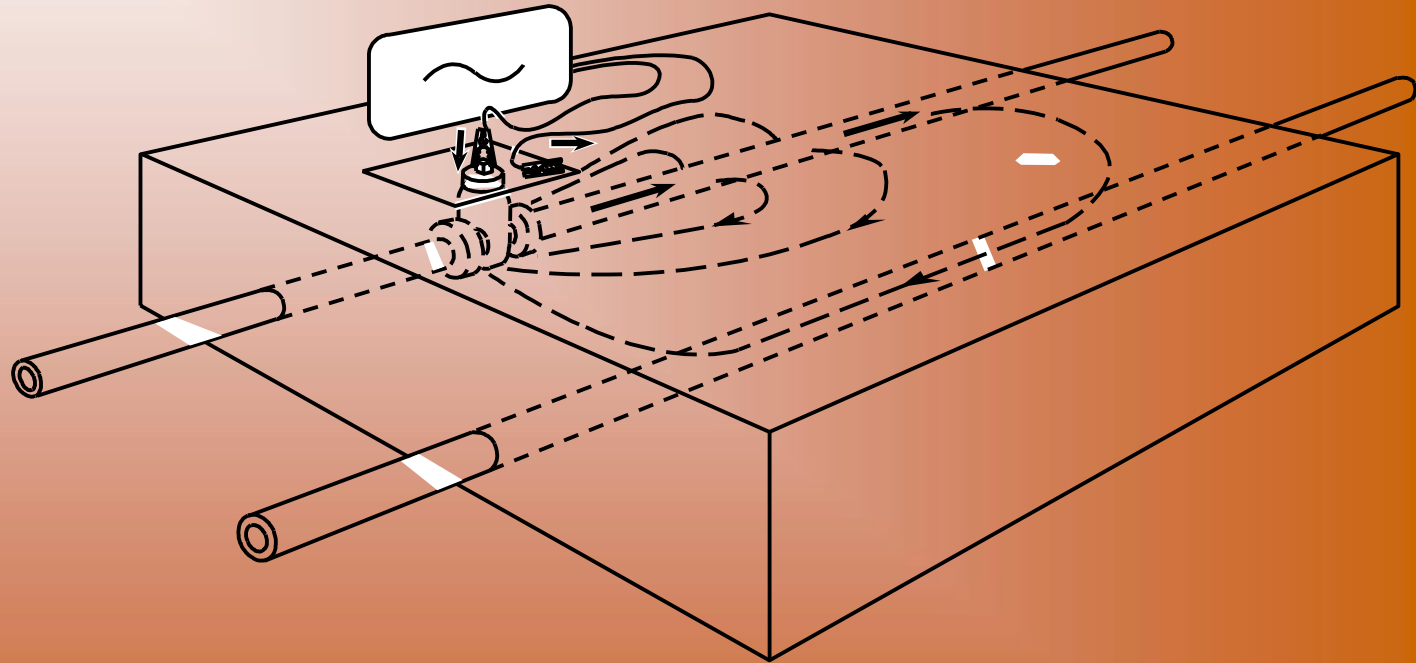
Induction "Spill"



Signal Clamp
"Clamp"

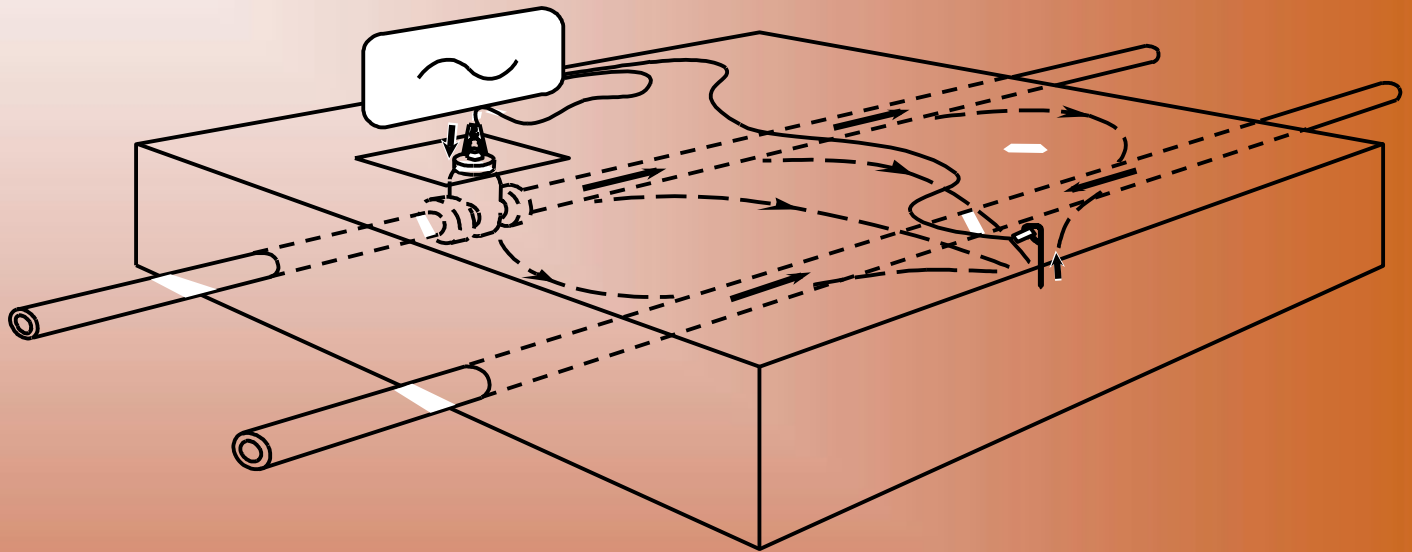


AC Current Attenuation



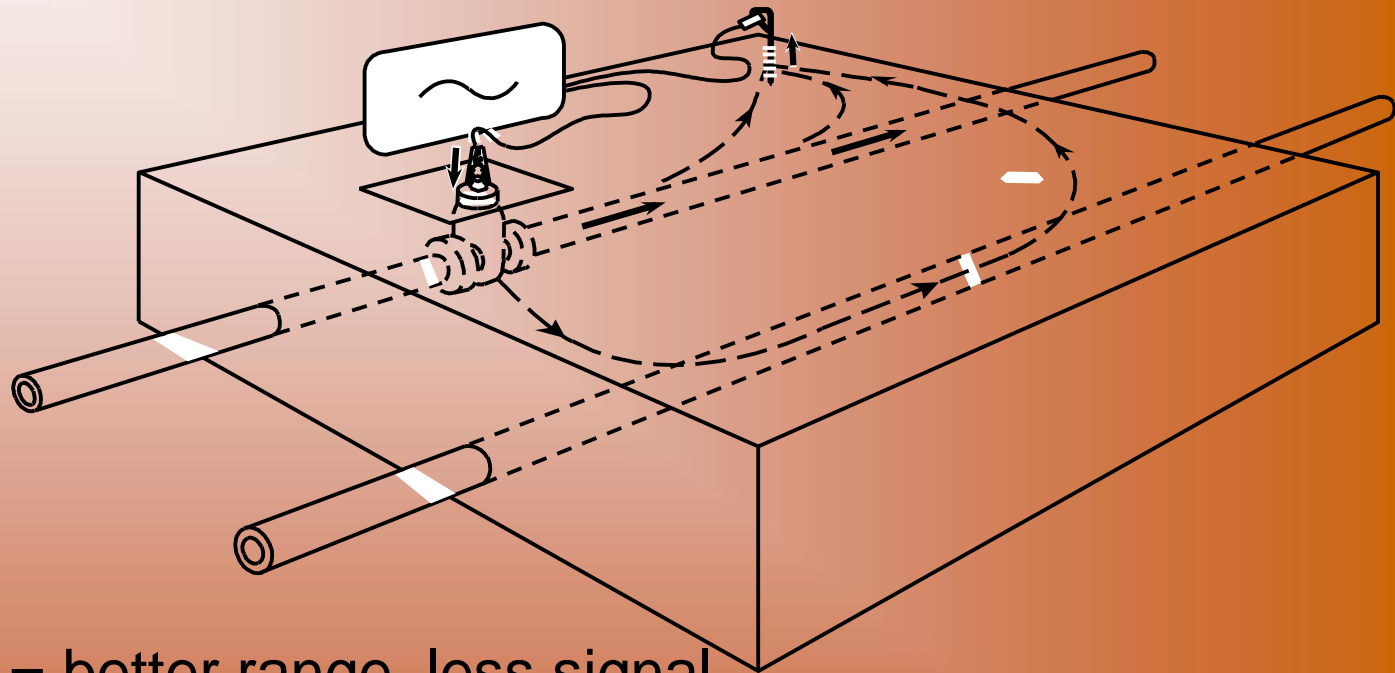
Ground stake too close to target conductor:
Less range, some signal transfer.

AC Current Attenuation



Bad ground choice causes more bleed off.
Place ground rod away from known adjacent
pipes/utilities which may act as return paths.

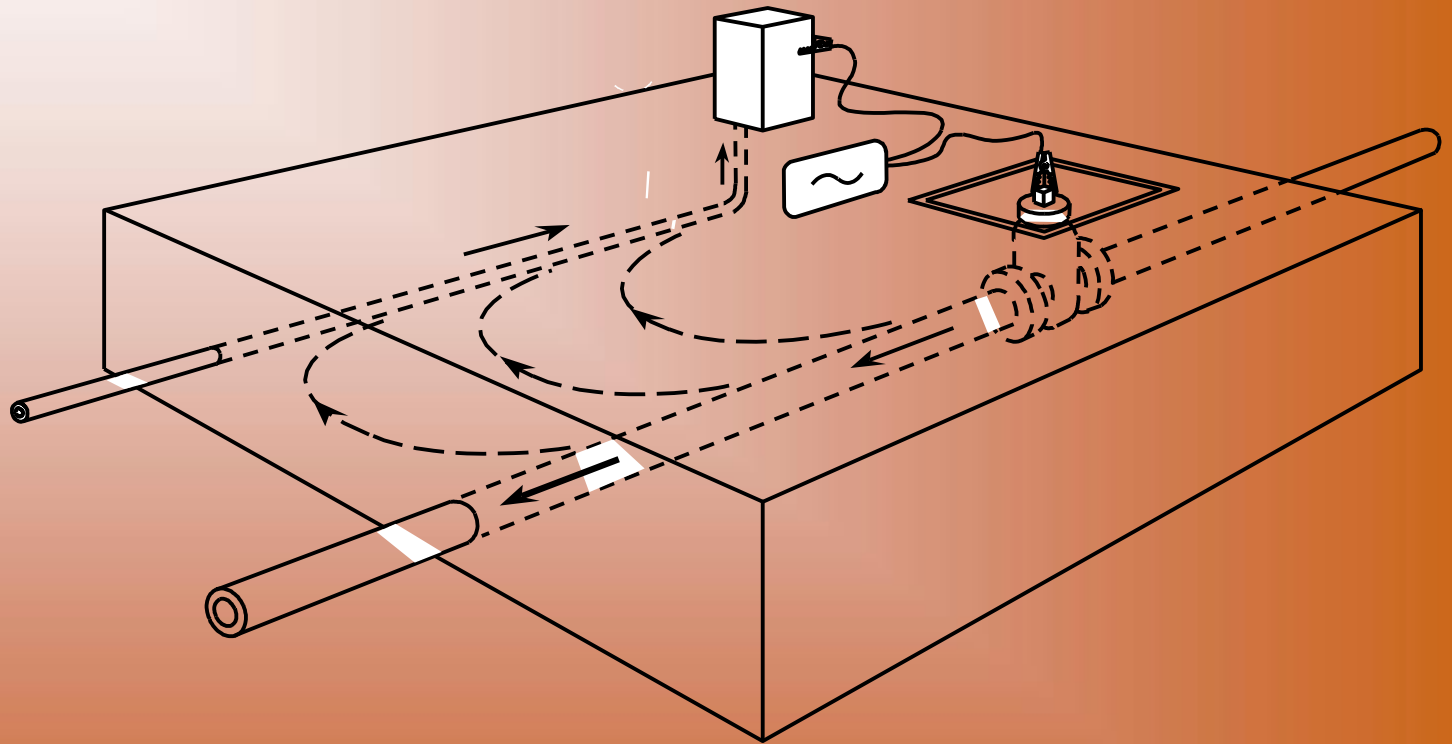
AC Current Attenuation



Remote ground = better range, less signal transfer.

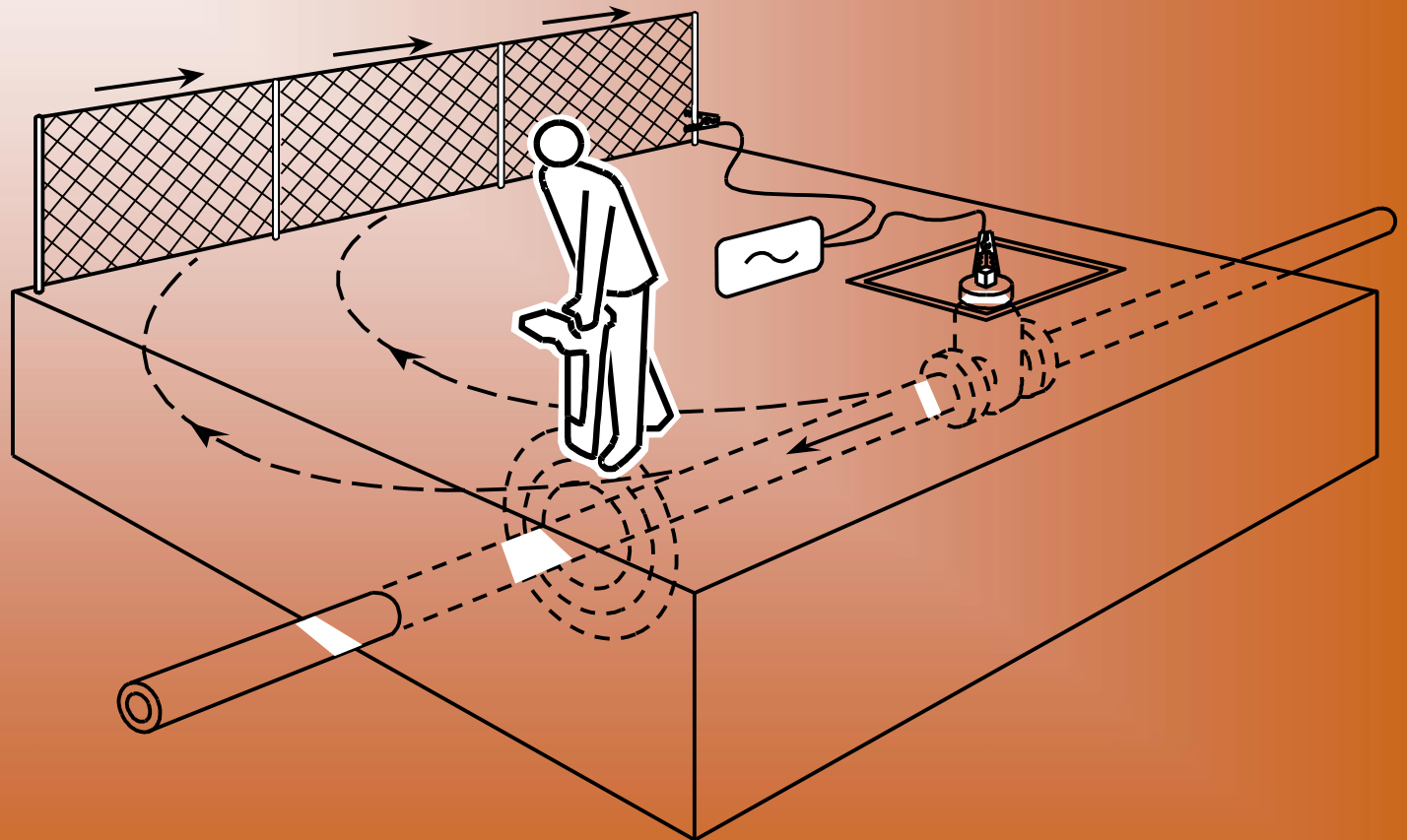
GENERAL RULE: position ground point at right angles to pipe.

AC Current Attenuation



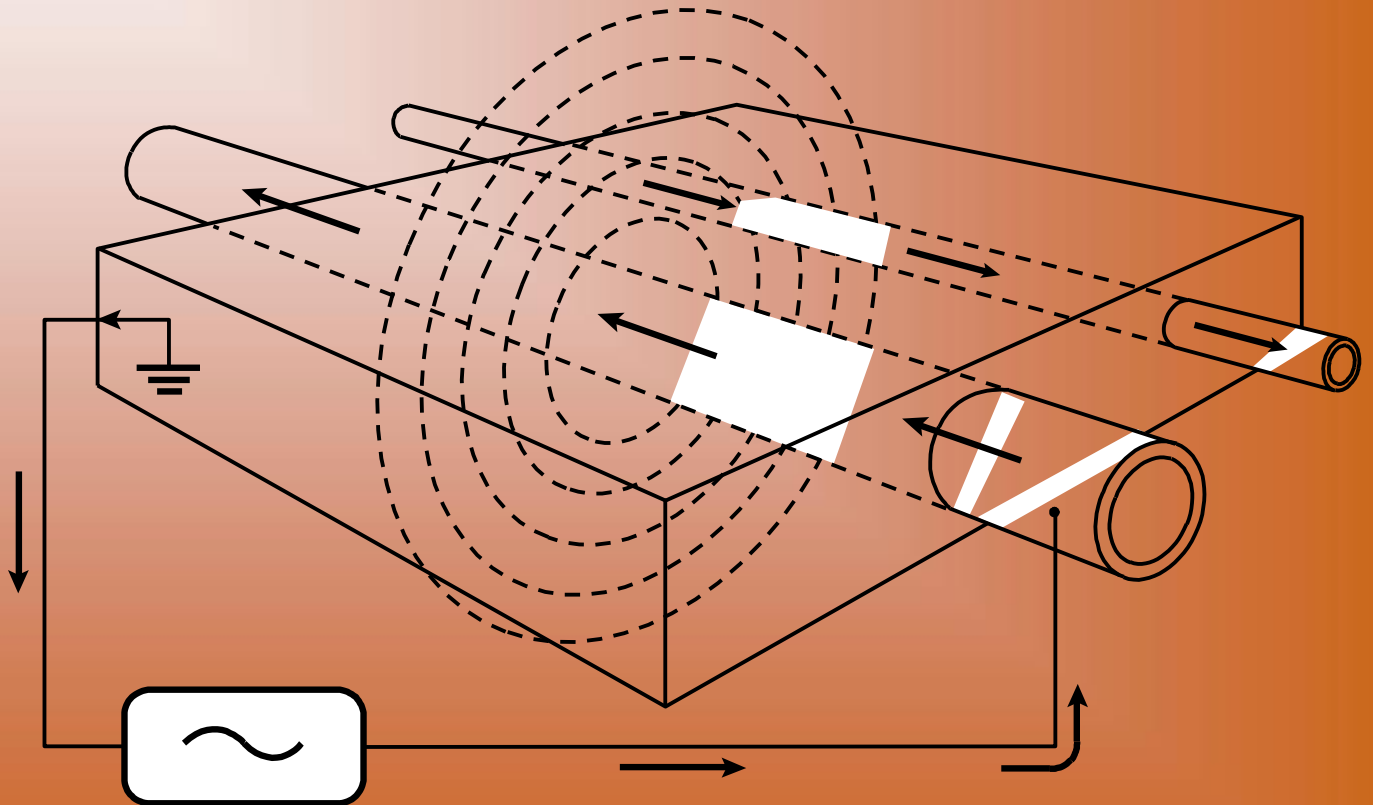
Grounding to a structure which is also grounded can produce multiple signals.

AC Current Attenuation



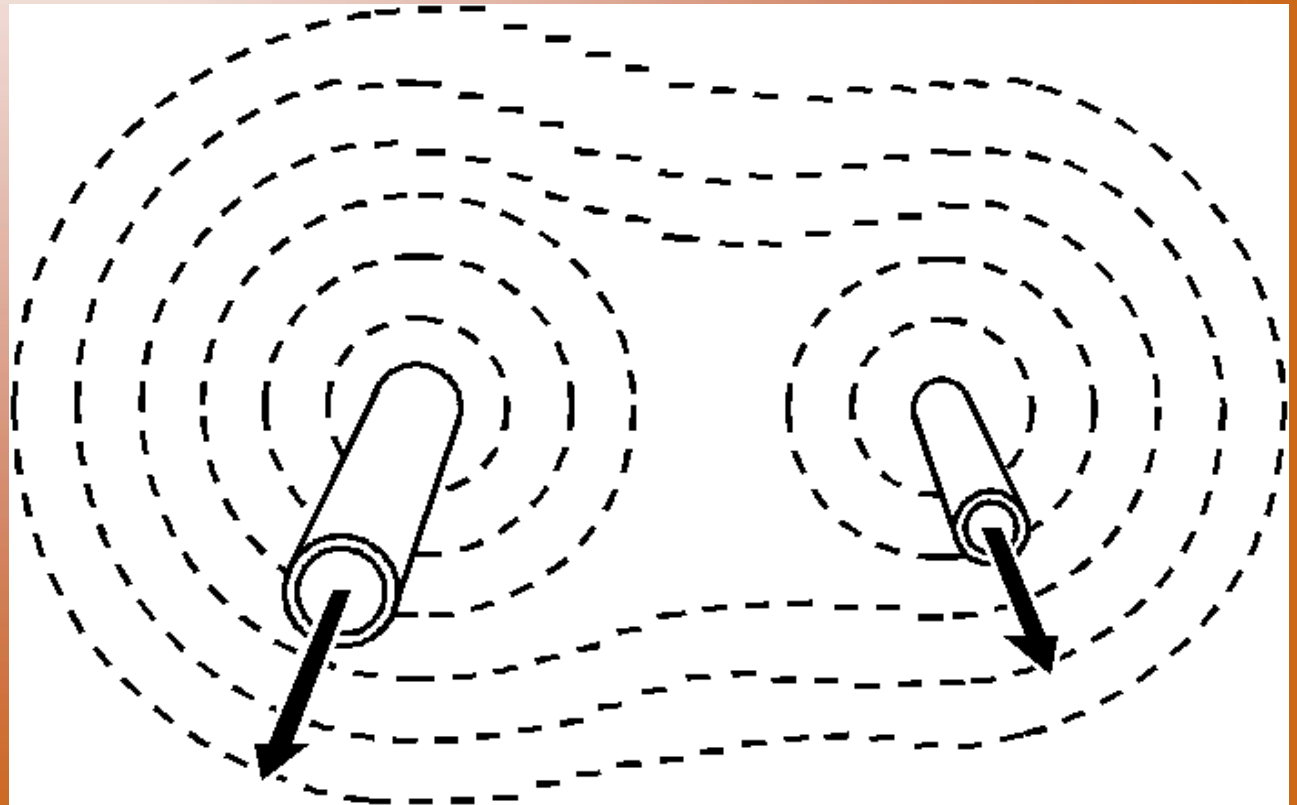
AC Current Attenuation

Distortion

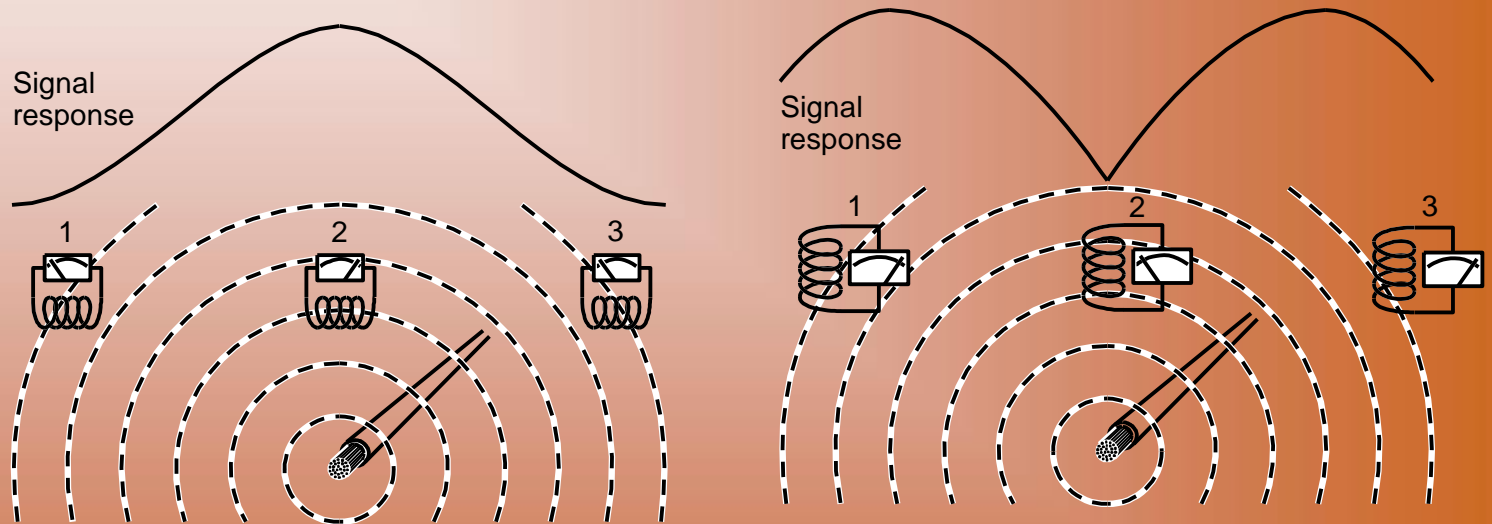


AC Current Attenuation

Distortion



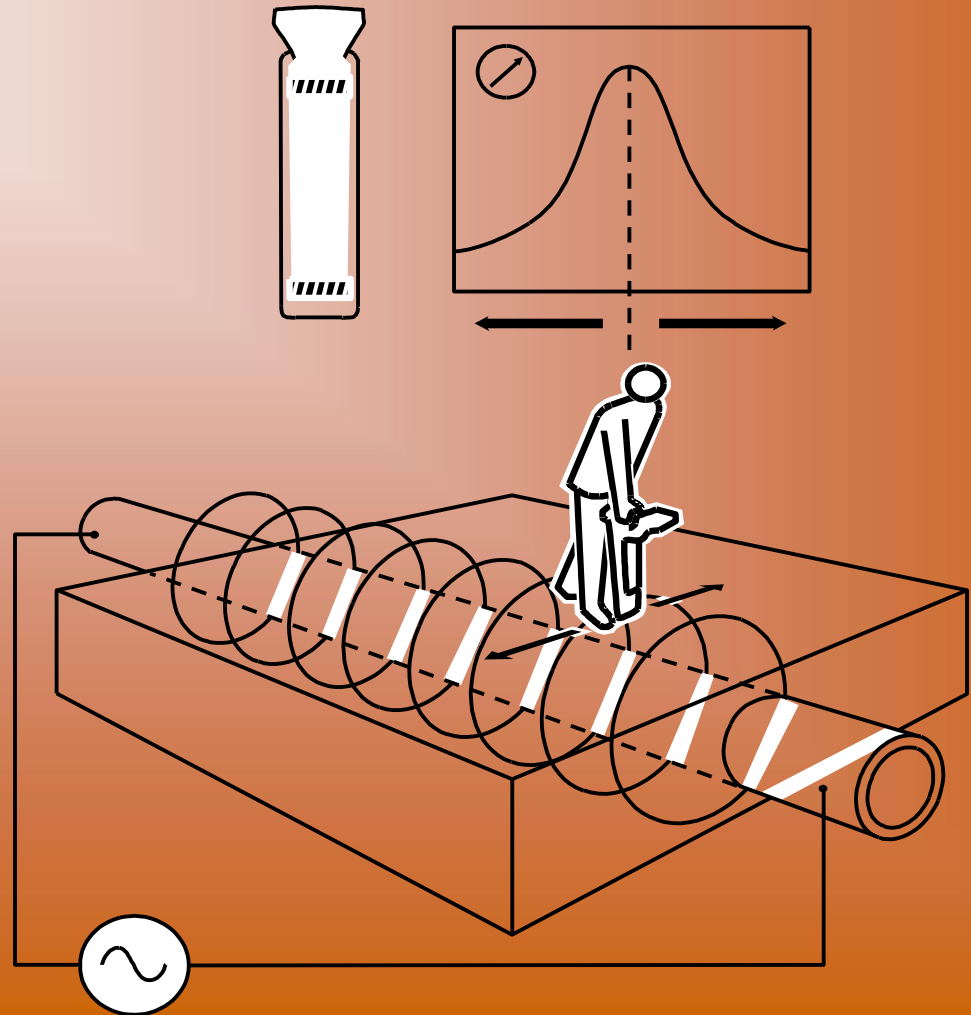
AC Current Attenuation



Aerial Responses

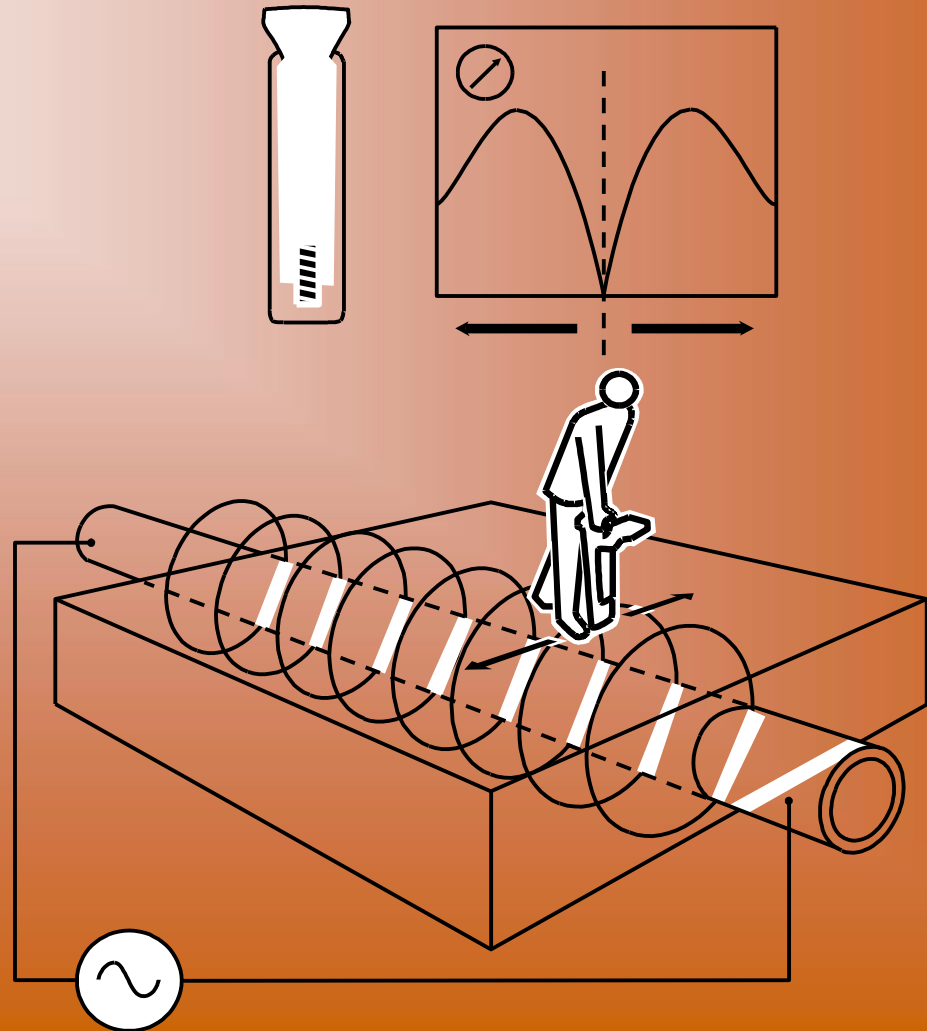
AC Current Attenuation

PEAK Response

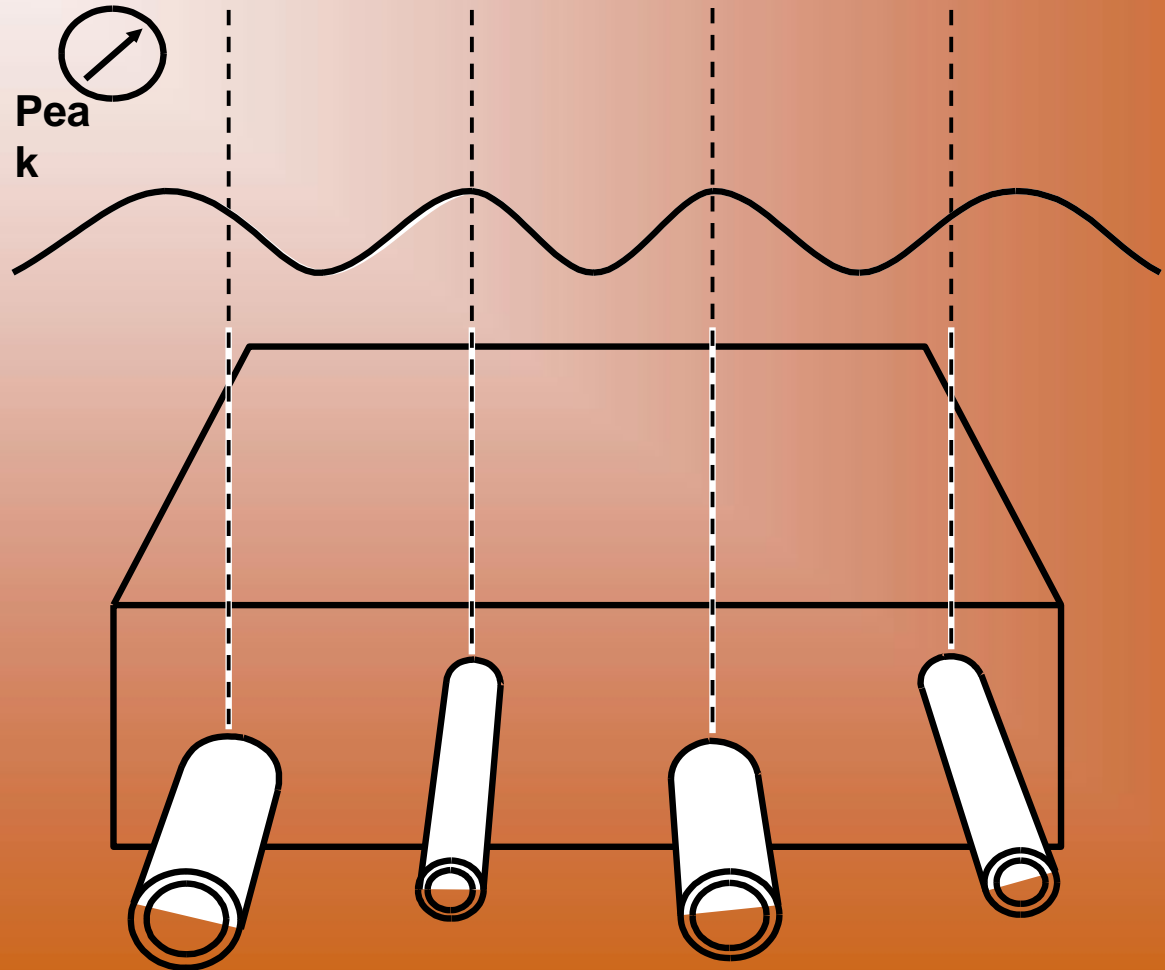


AC Current Attenuation

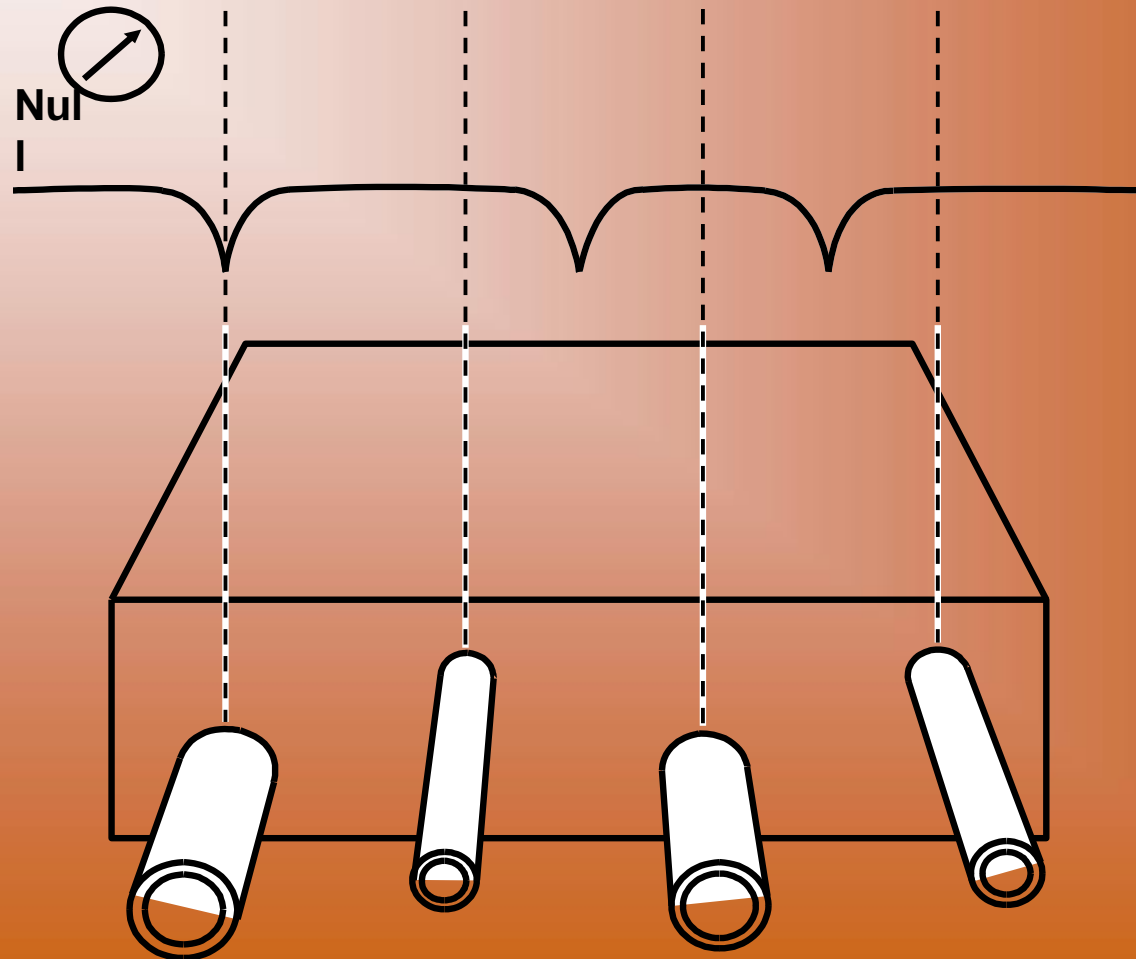
NULL Response



AC Current Attenuation

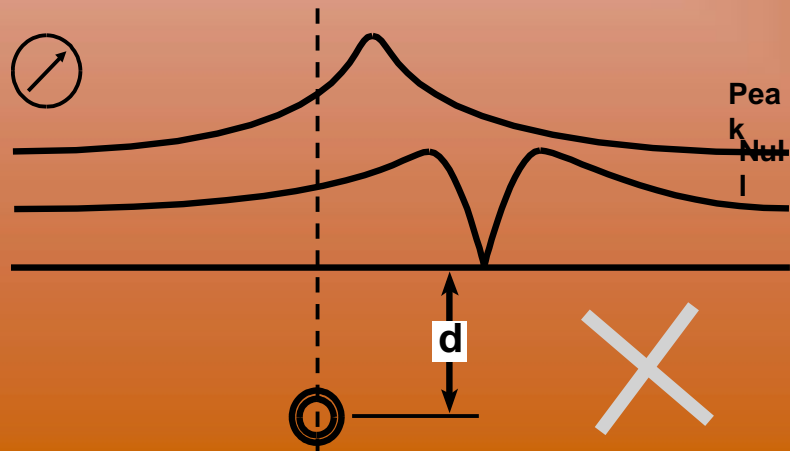
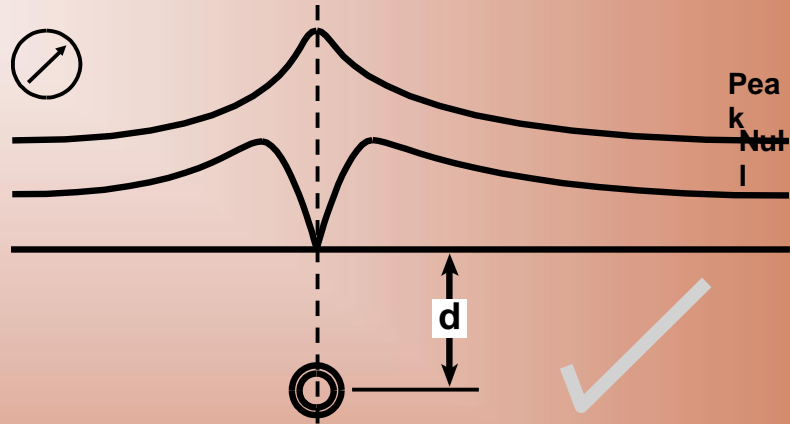


AC Current Attenuation



AC Current Attenuation

Peak response will **ALWAYS** be more accurate.



Current Attenuation Tools

PCM

Vivax-PDM
The Pipeline
Defect Mapper

C-SCAN
2000 SERIES



Current Attenuation Continued

What can CA data tell us?

- It is a macro tool that highlights the bigger problems in a coated pipeline system including:
 - Shorts to other structures
 - Grounding to electric neutral
 - Bad insulators
 - Large coating defects
 - Shorted casings
 - Other current distribution problems
 - Depth of cover at the same time (possible TPI)
- Any or all may affect the ability of the other tools to perform in a consistent and reliable manner.

Things to remember when conducting Current Attenuation Surveys

- 1) Always direct connect
- 2) Always use an independent ground
 - a) Anode Bed
 - b) Ground Stake
 - c) Across an insulator?
- 3) Always have a map of the facility
- 4) Never use another utility as the ground return.
- 5) Never assume anything.
- 6) Shorts
 - a) First signal loss may not be the short.
 - b) There may be more than one short.
 - c) There may be an unknown source.
- 7) Coating defects
 - a) Take readings at the same intervals.
 - b) Make sure unit and boot are perpendicular to the pipe.
 - c) Hold unit steady and upright when reading current.
- 8) You do not always have to connect closest to the suspected short or coating defect.
- 9) More is not always better.

FACTS TO REMEMBER

- 1) Lower frequencies couple less.
- 2) Locators with a digital depth readout, current measurement and current direction provide more information and lead to more answers.
- 3) Verify with peak and null locates.
- 4) Log readings manually or digitally.
- 5) Take readings at every split or at equal distance.

Current Measurement and Current Direction

- 1) Current measurement is depth compensated.
- 2) If depth readings are erroneous, so is current.
- 3) PCM uses 98Hz for depth & 4 Hz for current.
- 4) PCM Current Direction is displayed in relation to Cathodic Protection current (from the anode to the pipe and back to the rectifier).
- 5) CD gives us the final determination many times before we dig a short. CD normally does not help in determining coating defects alone.
- 6) Electromagnetic receivers can obtain readings over various soil conditions including asphalt, concrete and water and still will obtain accurate readings.
- 7) Unit does not have to touch the ground but must be steady.

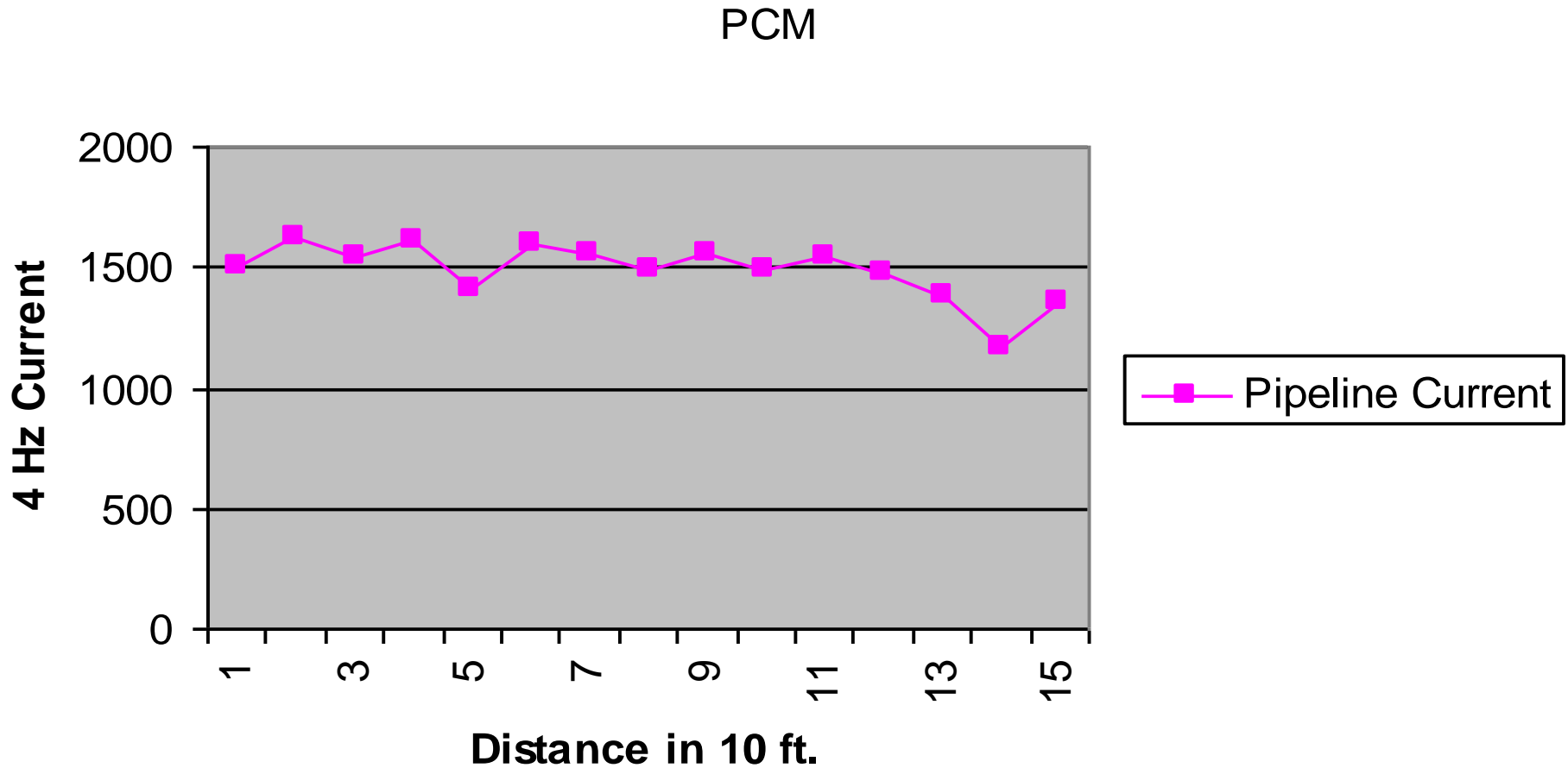
Other Applications with Current Attenuation

- 1) Looking for hot spots.
- 2) Determining the best location for a permanent ground bed.
- 3) Determining the effectiveness and life of a ground bed.
- 4) Pinpointing coating damage with an A-frame.
- 5) Yearly analysis of coating conditions.

Methodology using PCM for Current Surveys

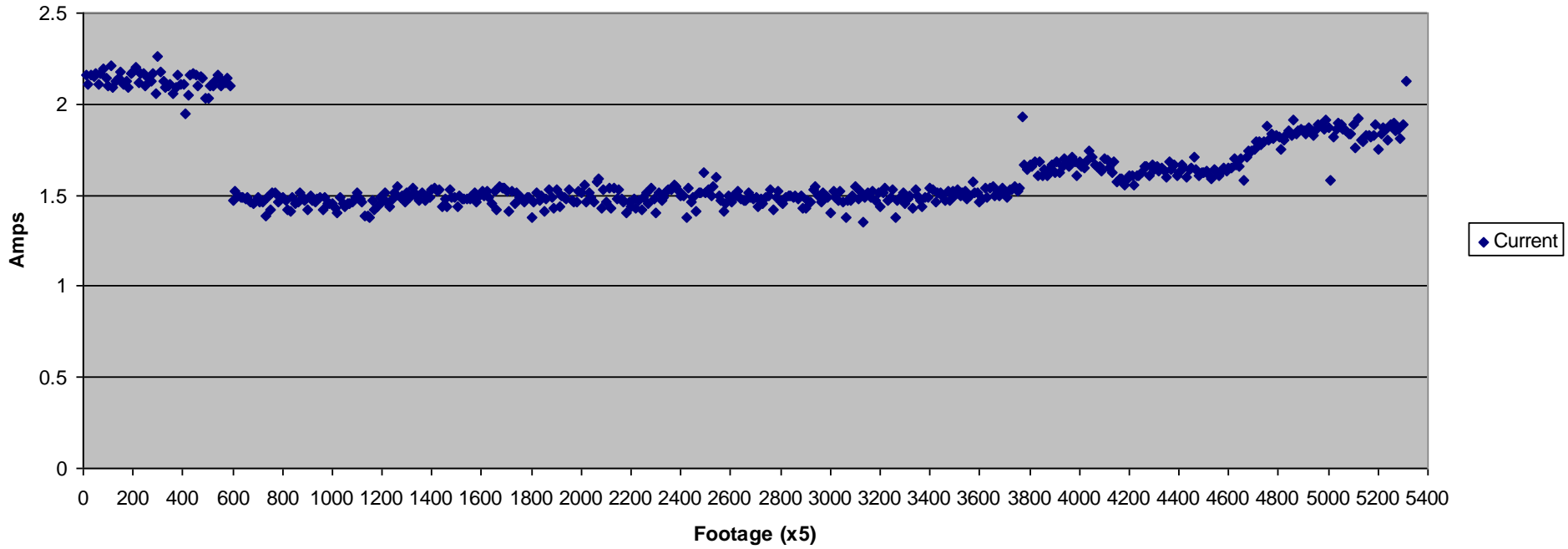
- Use an independent ground and try to mimic your CP circuit when possible
- Make sure rectifiers are not influencing the signal (turn off AND disconnect if necessary)
- Isolate your circuit whenever possible (disconnect bonds for better surveys)
- Take readings at equal distances and record your distances
- Every 50 feet is a good standard(others can be used dependant on location)
- Use it as a macro tool and depth of cover tool (use A-frame for micro)
- Look for anomalies with more than a 5% change normally
- Make sure unit is upright and perpendicular to the pipe
- Stay on peak and check peak and null readings and verify depth when readings are suspect.
- Take multiple readings in one location if you are suspect of the accuracy.
- Know what is in the area of your pipe and what it is connected to it

Graphed data



CA Data

Current



DCVG

Direct Current Voltage Gradient

Principles of DCVG

DCVG uses the differences between two reference electrodes.

These differences can assist in pinpointing holidays and corrosion cells on a pipeline. DCVG, because it uses DC current, can also determine if the holiday is cathodic (protected) or anodic (corroding).

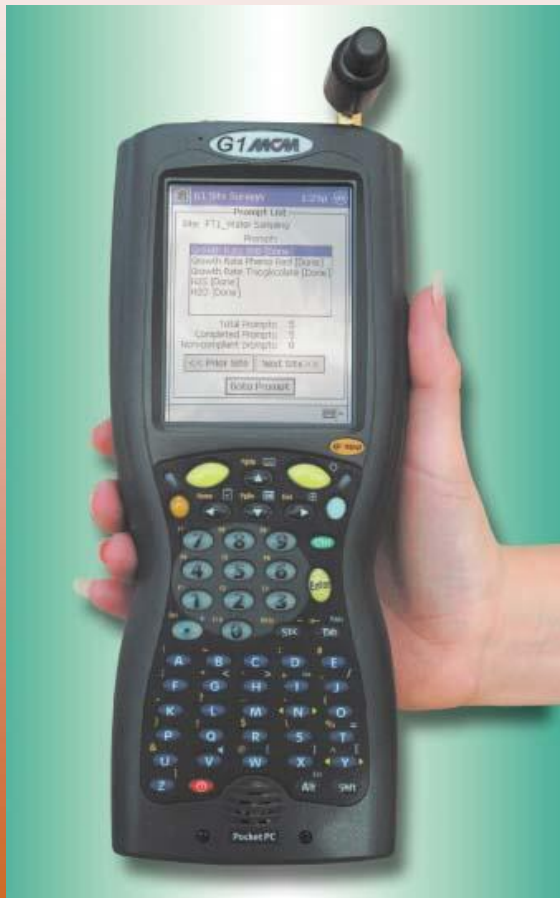
- Asynchronous interruption (0.3sec on, 0.7sec off) is required
- Accurately ($\pm 4''$) locates coating anomalies
- Differentiate between isolated (discrete) and continuous anomalies
- Predict relative importance/severity of anomaly
- Examine the direction of the current flow (anodic vs. cathodic)

What can DCVG data tell us?

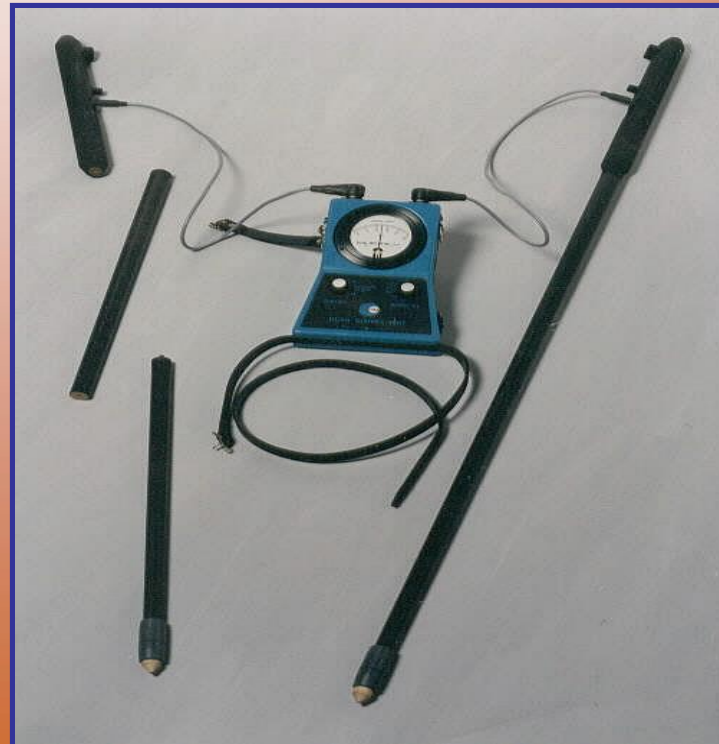
- It is a micro tool that pinpoints coating defects and in some instances can give us a relative state of the cathodic protection at that indication and can find:
 - Large coating defects
 - Small Coating defects
 - Severity of the coating defect
 - Possible interference areas
 - Shorted casings
 - CP cable breaks
 - Position of Anodes
 - Cathodic/Anodic condition at the time

DCVG tools

G1



PCS-2000



DCVG meter



Similarities to ACVG

- Both require sufficient ground contact.
- Both require sufficient current flow on the pipeline to provide sufficient voltage gradient fields at holidays.
- Both can accurately detect and pinpoint positions of holidays, shorts, anodes, cable breaks and other areas of metal to dirt contact.
- Both can be used in water.
- Both do not require trailing wires.
- Both can detect the severity of the indication.
- Both can indicate if it is a single anomaly or a continuous anomaly.
- Both are affected by large indications overpowering nearby small indications.
- Both ACVG and DCVG can be less sensitive in high contact resistance areas (i.e. paved surfaces, very high resistant soils or rocky surfaces).

Differences from ACVG

- DCVG uses interrupted CP source or sources. ACVG uses either low frequency AC or interrupted DC (mimicking an AC signal).
- DCVG uses two poles with half cell type of contact probes. ACVG uses two metal probes.
- DCVG probe space varies. ACVG probe space is fixed.
- DCVG can be interfered with from existing or stray DC sources. ACVG normally is not.
- DCVG normally requires 400 – 500 mv shift which cannot be obtained in all pipeline conditions. ACVG requires a minimum amount of low frequency applied current.
- DCVG can be less sensitive under paved surfaces than ACVG.
- ACVG performs very well in high AC corridors.
- ACVG requires less operator interpretation because of the fixed spacing, unique applied signal and directional indication.
- Digital DCVG meters have a fixed directional indication like ACVG.
- DCVG can provide a relative cathodic/anodic condition of CP at an indication at that moment in time.

DCVG in-line technique

In carrying out a survey, the surveyor walks the pipeline route testing at regular intervals with the probes in a position of one in front of the other, separated by 3' to 6' above the pipeline. As a fault is approached, the surveyor will see the volt meter start to respond to the ON/OFF pulsed current, which is either a coating fault or interference from another structure. When the fault is passed, the needle deflection completely reverses and slowly decreases as the surveyor moves away from the fault. The surveyor then back up along the pipeline and where the needle or arrow indication reverses again, the fault is sited.

This procedure is repeated at right angles to the first set of observations and where the two midway positions cross is the epicenter of the voltage gradient. This is directly above the coating fault.

DCVG side by side technique

In carrying out a survey, the surveyor walks the pipeline route testing at regular intervals with the probes side by side to each other with one probe over the pipe and one off to the side 3' to 6'. As a fault is approached, the surveyor will see the volt meter start to respond to the ON/OFF pulsed current and give a higher voltage measurement and or greater needle or arrow deflection. When the fault is passed, the voltage measurement decreases. The surveyor now moves the probes in-line with the pipe and continues in the same manner as an in-line survey. The surveyor then back up along the pipeline and where the needle or arrow indication reverses again, the fault is sited.

This procedure is repeated at right angles to the first set of observations and where the two midway positions cross is the epicenter of the voltage gradient. This is directly above the coating fault.

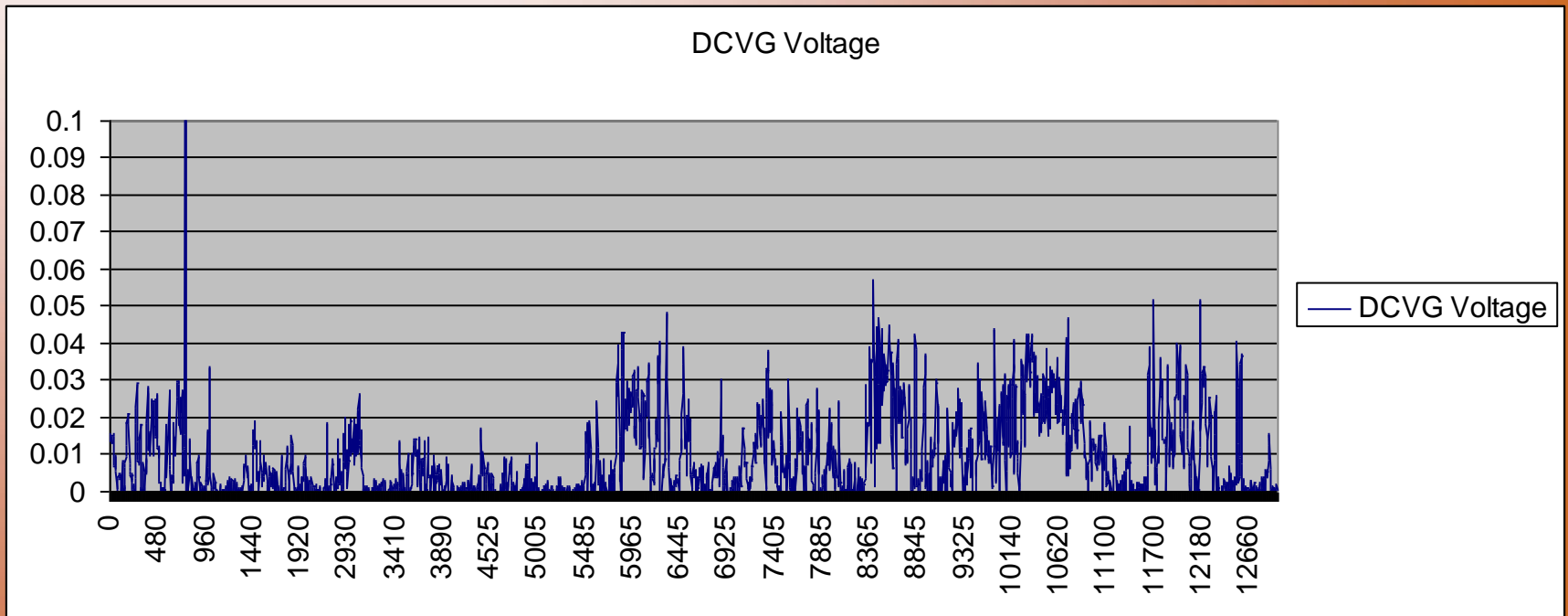
DCVG side drain and % IR

- Once an indication is found, the surveyor now must take a side drain measurement. This is completed by taking measurements over the pipe and at continuous distances to the side of the pipe until remote earth is reached. This total voltage value will be the total side drain voltage.
- This voltage is then used in conjunction with voltage measurements taken at pipe access points and the indication distance from those points to calculate a % IR. Digital meters can calculate this automatically while analogue meters will require manual calculation.
- DCVG indications are normally categorized as 1- 15% IR – very minor, 16% - 35% IR - minor, 36% - 60% IR – moderate, 61% - 100% IR - severe.

Problems/Solutions to DCVG surveys

- P - DC noise level too high for proper interpretation of field indications due to interfering DC sources. S - Add current with portable rectifiers to raise the amount of current change and voltage gradient near the indications.
- P - Fluctuating voltages due to interfering DC sources. S- Conduct survey at less interfering times (i.e. nighttime).
- P - Inability to find indications due to AC grounding for AC mitigation. S - Use filter(s) in CP system that discharges AC current but blocks DC current from earth where grounding is necessary for safety.
- P – Paved surfaces. S- wet down pavement or drill holes for lower contact resistance. May also have to raise the amount of current on the pipe.

DCVG graph results



DCVG Cathodic/Anodic results

| | | | | | |
|-------|-------------------------------|----------|----------|----------|-------------------|
| 36500 | Custom 8 | 0 | 0 | 0 | FLAG 730 |
| 36730 | DCVG Anomaly: DCVG Max/Total | 0.014264 | 0.014264 | 3.648994 | |
| 36730 | DCVG Anomaly: DCVG Max On/Off | 0.004001 | -0.01026 | 0 | Cathodic/Anodic |
| 36755 | DCVG Anomaly: DCVG Max/Total | 0.024353 | 0.052707 | 13.48348 | |
| 36755 | DCVG Anomaly: DCVG Max On/Off | 0.018961 | -0.00539 | 0 | Cathodic/Anodic |
| 37000 | Custom 8 | 0 | 0 | 0 | FLAG 740 |
| 37205 | DCVG Anomaly: DCVG Max/Total | 0.027136 | 0.085584 | 21.89396 | |
| 37205 | DCVG Anomaly: DCVG Max On/Off | 0.025049 | -0.00209 | 0 | Cathodic/Anodic |
| 37500 | Custom 8 | 0 | 0 | 0 | FLAG 750 |
| 37540 | DCVG Anomaly: DCVG Max/Total | 0.011829 | 0.038965 | 9.967984 | |
| 37540 | DCVG Anomaly: DCVG Max On/Off | 0.039487 | 0.027658 | 0 | Cathodic/Cathodic |

What data is most important?

- IT DEPENDS!
 - What is the history of the line?
 - Leaks, Stray Current, TPI, dis-bondment, soils, CP, etc.
 - Are there shorts or bonds in the system?
 - Is there new coating followed by old coating?
 - Are there paved or very rocky areas?
 - How many rectifiers are in the system to be surveyed?
 - How many foreign crossings are there?
 - And the list goes on...

What data is most important?

(cont.)

Multiple applicable tools are key to having a good ECDA indirect inspection survey.

While the rule only requires two inspection techniques it is almost always required at some locations to have a minimum of three.

Knowing where your holidays are AND the cathodic protection state are key in making informed decisions about External Corrosion.

Soils can also be of added value where the tools need supplemental data for support.

Of course any and all Pre-Assessment data is crucial to success.

Summary

- Combining data and tools are crucial to proper identification of possible external corrosion.
- Other items in the indirect inspections such as depth of cover and foreign crossings should be included in the analysis at indications to look for Third Party Damage.
- If one tool shows an indication and the others do not, it should be verified as to why this occurred and not ignored.
- Coating is not perfect. Therefore if you find nothing you need to find out why the tools didn't work, resolve the issues and resurvey where necessary.
- All local conditions must be considered before deciding what indications are monitored, scheduled and immediate.

QUESTIONS?

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