IMSA® FORUM & EXPO

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Loops 101

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RAE® RENO A&E

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- Circuit design, Tech Support

Why do we use loop detectors?

- **Inductive Loop Detectors - The Most Popular Detection System Since The 1960's – WHY?**
- Precise and Predictable Area can be Defined for the Detection Zone
- Independent of Environment (Weather, Lighting & Sound)
- Most Accurate Technology – Others Always Compared to Loops
- Most Reliable Technology when Installed Properly
- Holds Presence of Stationary Vehicles
- Detects what is Desired - Licensed Vehicles
- No False Calls From Blowing Debris or Animals
- Cost Effective
- Simple Setup for Reliable Detection
- Not as subject to vanalism

There are 2 parts of the loop system

The Detector

The Loop

Part 1
The loop

What is a Loop

Starts with a wire

Wires and Fields

- **When electricity (current) flows in a wire, a field is formed around the wire**
- **Right Hand Rule.**

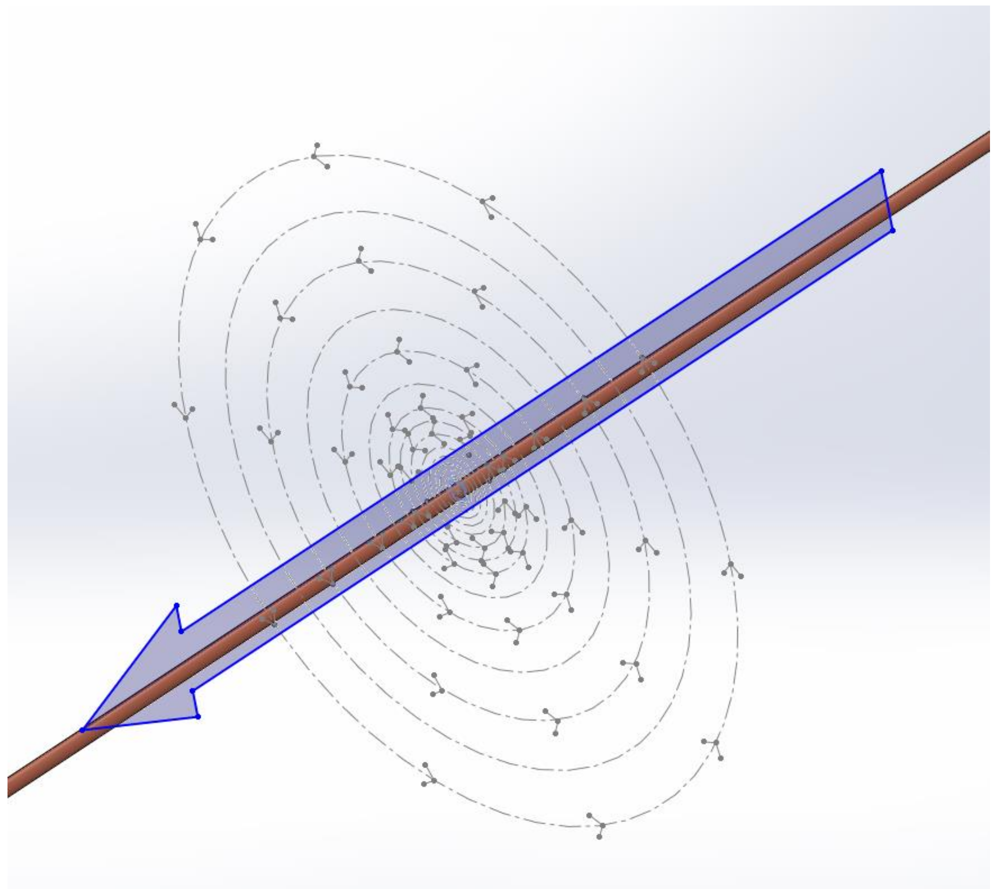
- **Maxwell's Equations**

$$\oint H \cdot dl = I + \varepsilon \frac{d}{dt} \iint E \cdot ds$$

$$\oint E \cdot dl = -\mu \frac{d}{dt} \iint H \cdot ds$$

$$\varepsilon \oiint E \cdot ds = \iiint q_v \, dv$$

$$\mu \oiint H \cdot ds = 0$$



The field interacts with everything in its environment

- **Includes all types of metal both:**
  - **Magnetic (like steel)**
    - » ***Used to make motors and etc.***
  - **Non magnetic (like aluminum and copper)**
    - » ***Typically used for sensors***
- **Other fields like cell phones, power lines, other loops, radio, etc.**

We don’t usually like stray fields

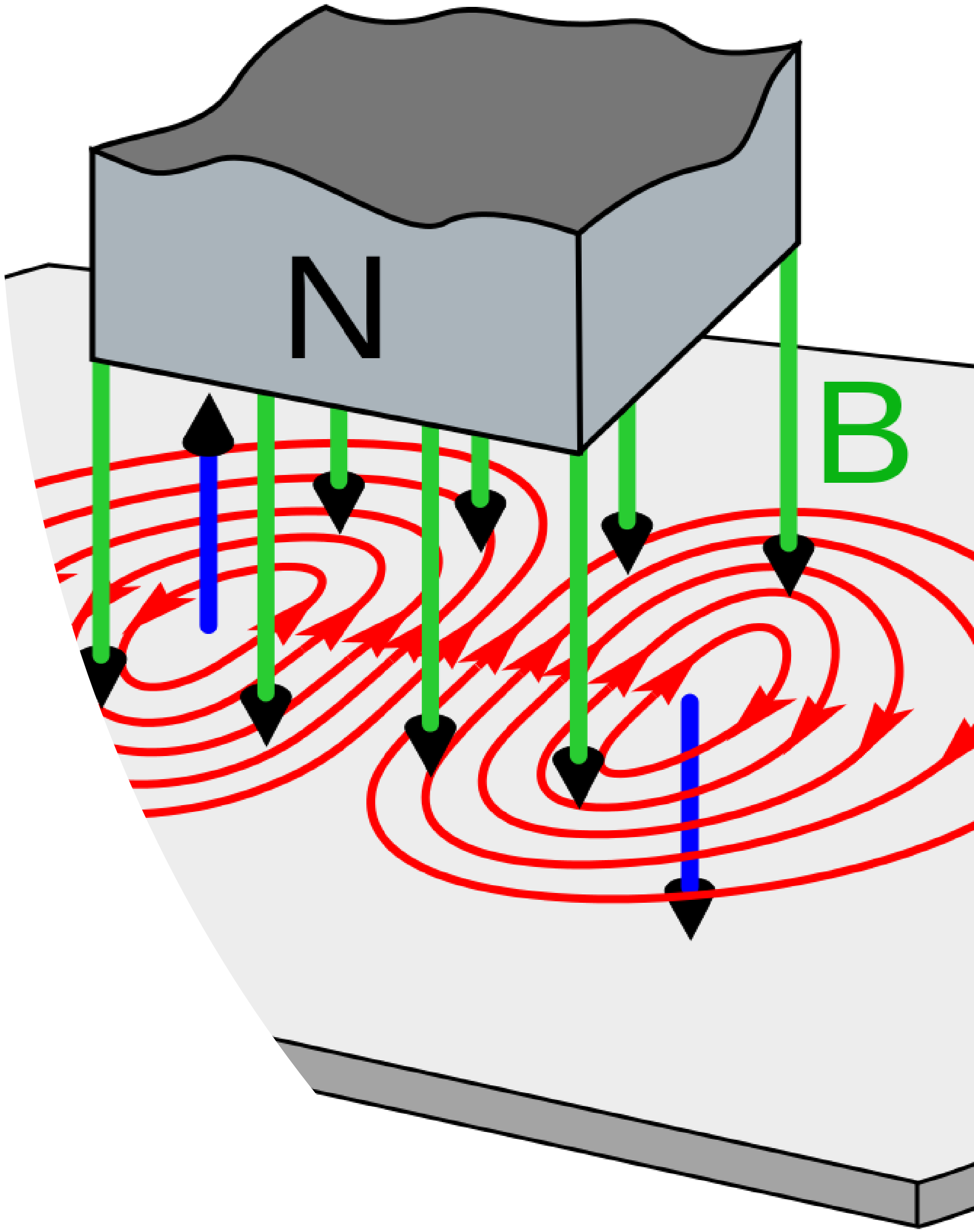
- **Elaborate ways to remove the field**
  - ***Twisting wires***
  - ***Ground wires***
  - ***Cable shields***
  - ***Coax cable***
  - ***Fiber optics***

Loops make convenient use of the field

Since the field interacts with metal, we use it identify vehicles.

Field-metal interaction

- Electricity in a wire generates a field
- A conductor in a field generates electricity
- This is called Eddy Current

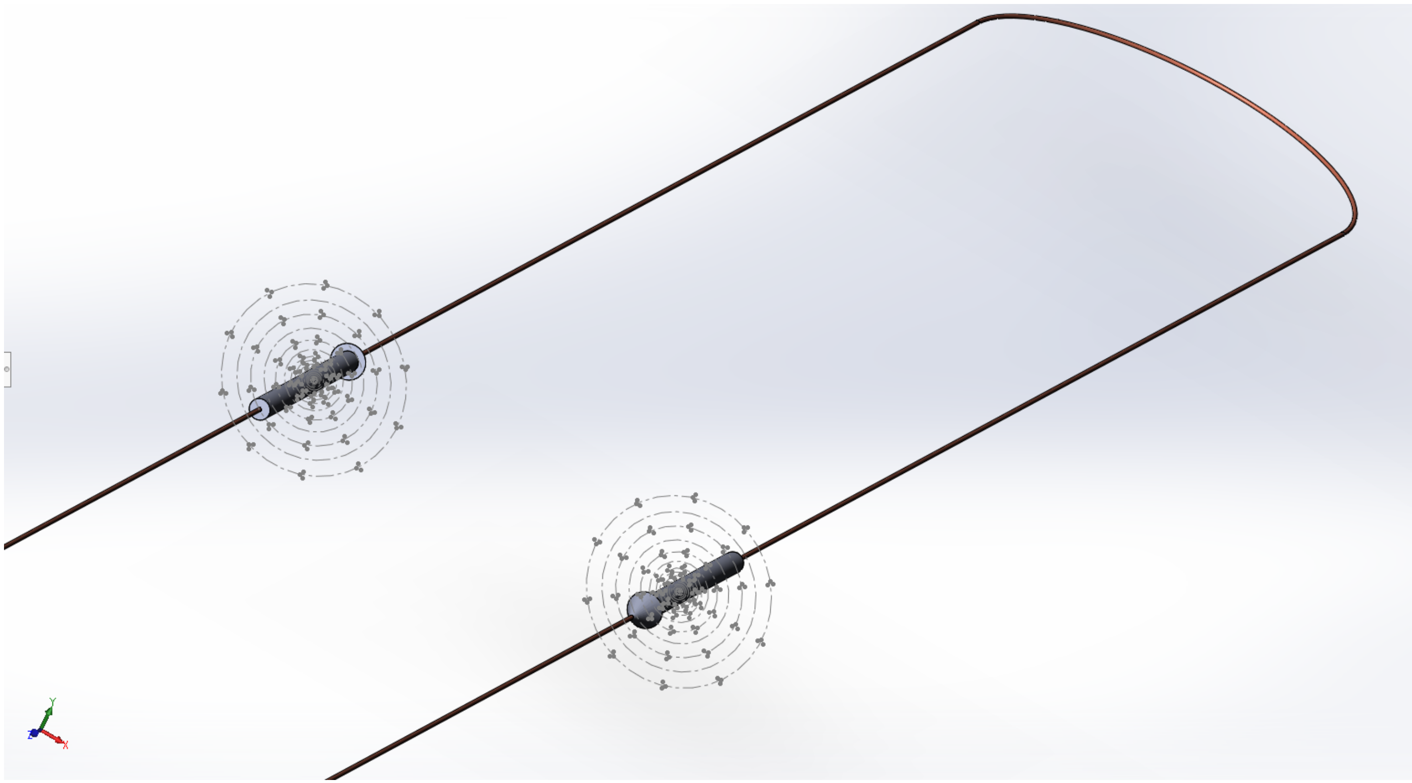


Vehicles over loops affect the field

- When a Vehicle passes over the loop the field generates eddy currents in the metal of the vehicle.
- The field must be large enough to interact with the vehicle.
- The detector recognizes the change and if it meets the right criteria, it creates a detection.
- Any metal will be detected; it does not need to be ferrous (conduct magnetic field like steel or iron)

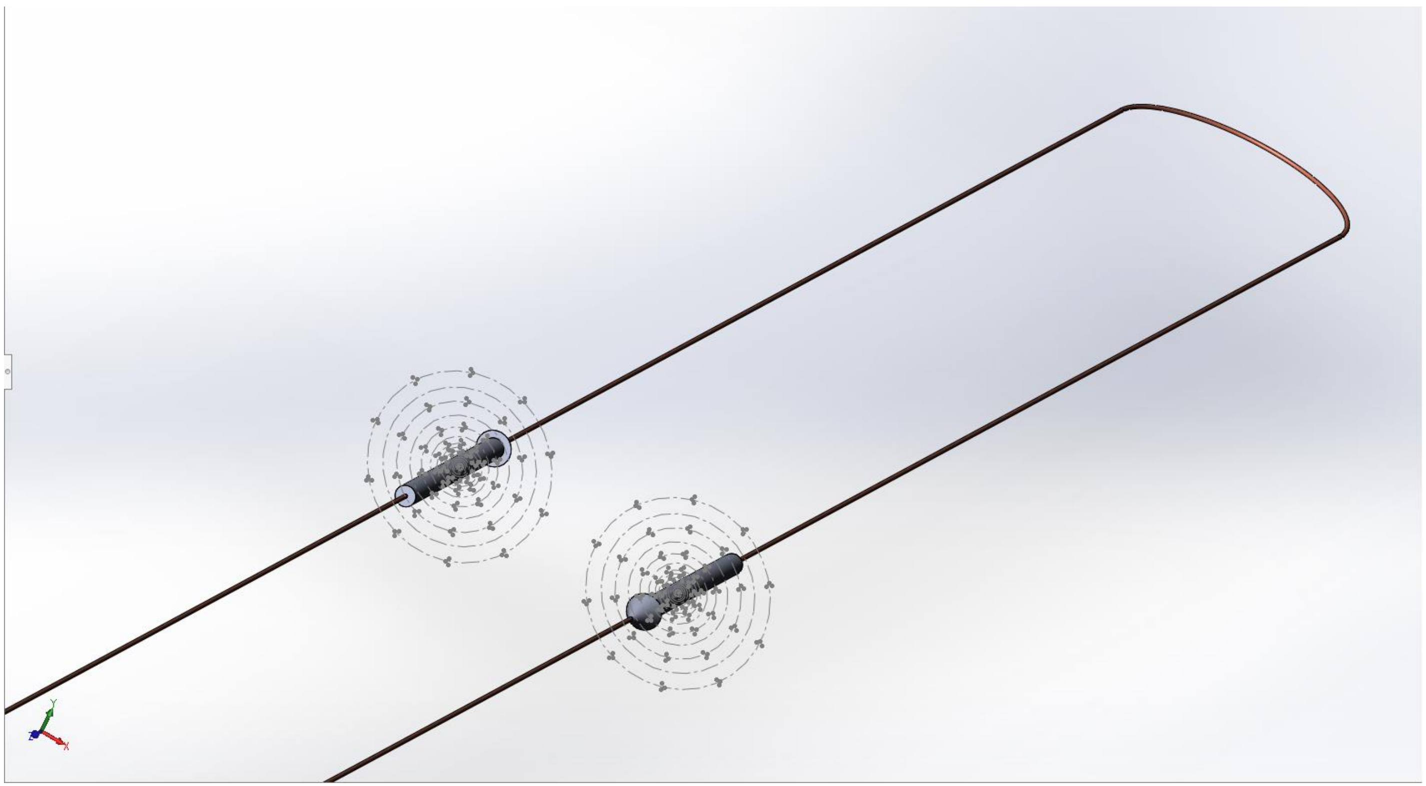
Field self interaction

- Fold the wire in half
- Right Hand rule means that the field is in opposite direction on the two ends of the wire



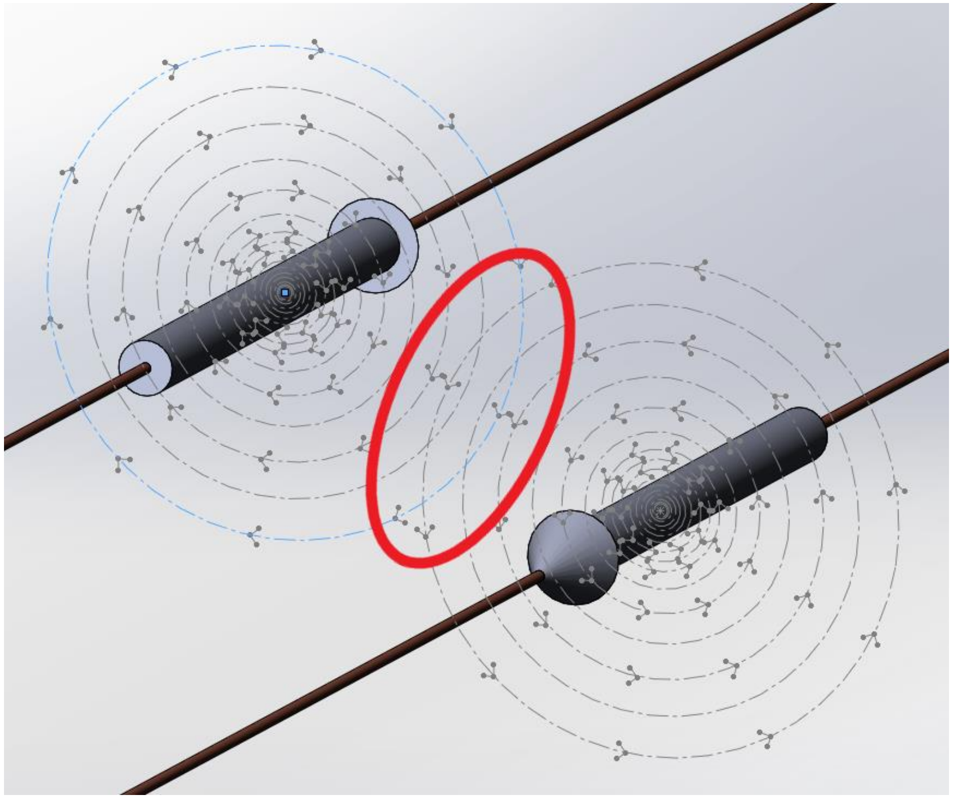
Field self interaction

- As the wires get closer together there is less room for the field to pass through the middle



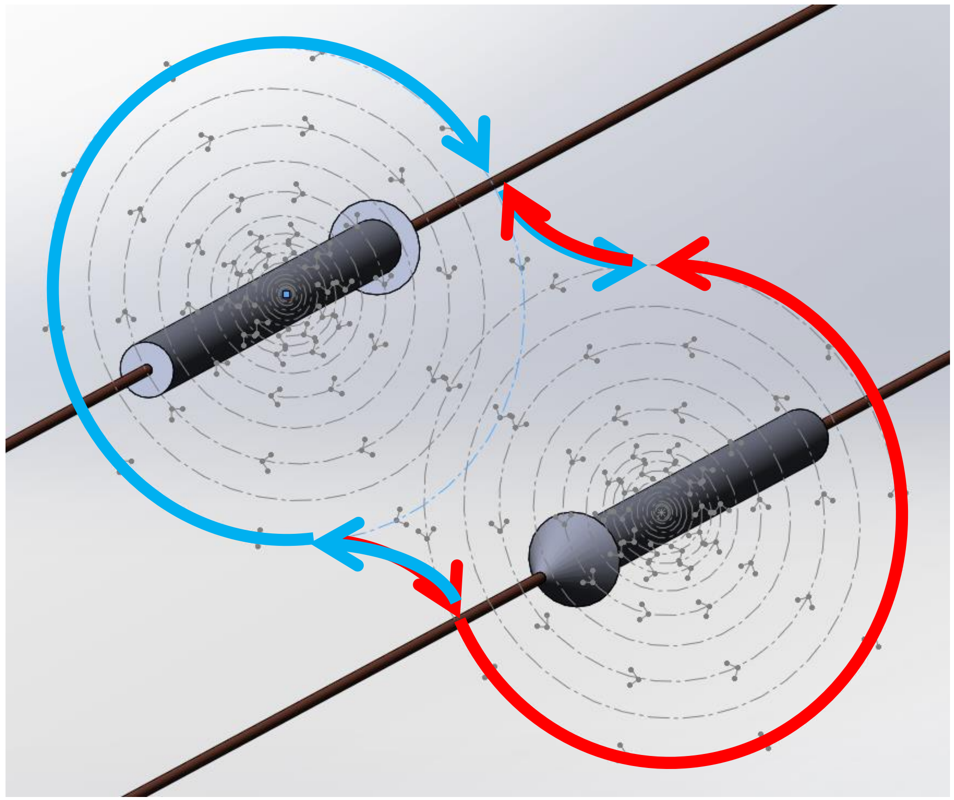
Field self interaction

- When the wire gets close enough together, some of the field from each end of the wire can no longer fit in between



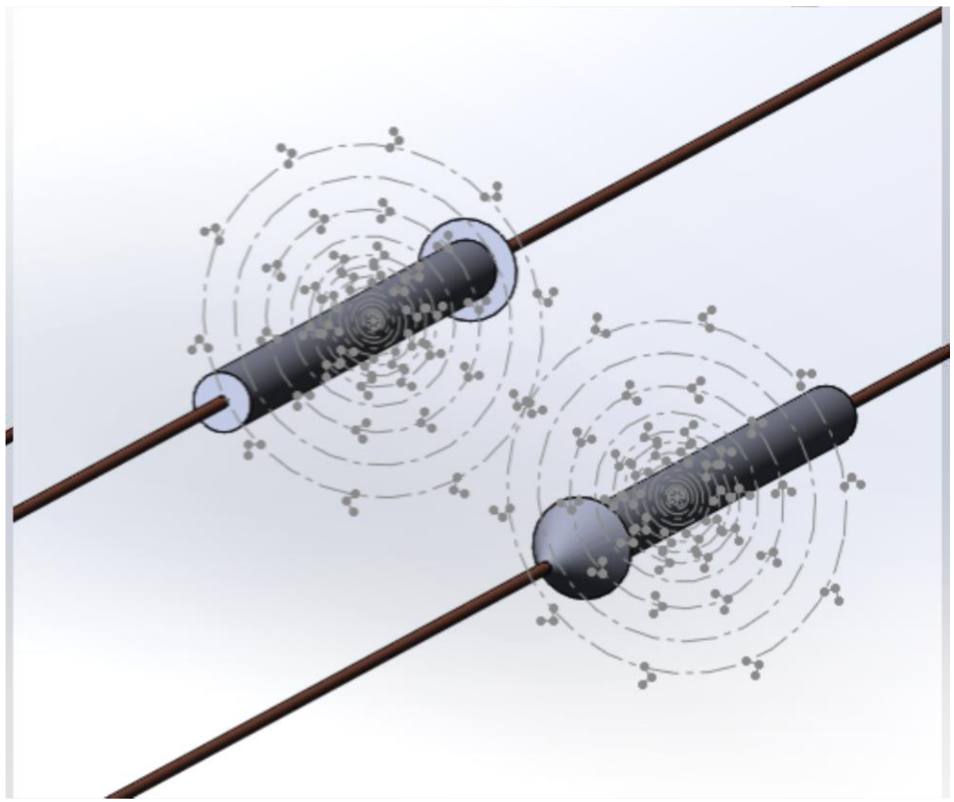
Field self interaction

- It is forced to go around the outside of the whole pair.
- These two portions combine together.
- Since they are equal and opposite when they add together they nullify each other



Field self interaction

- The result is that the field shrinks in size.

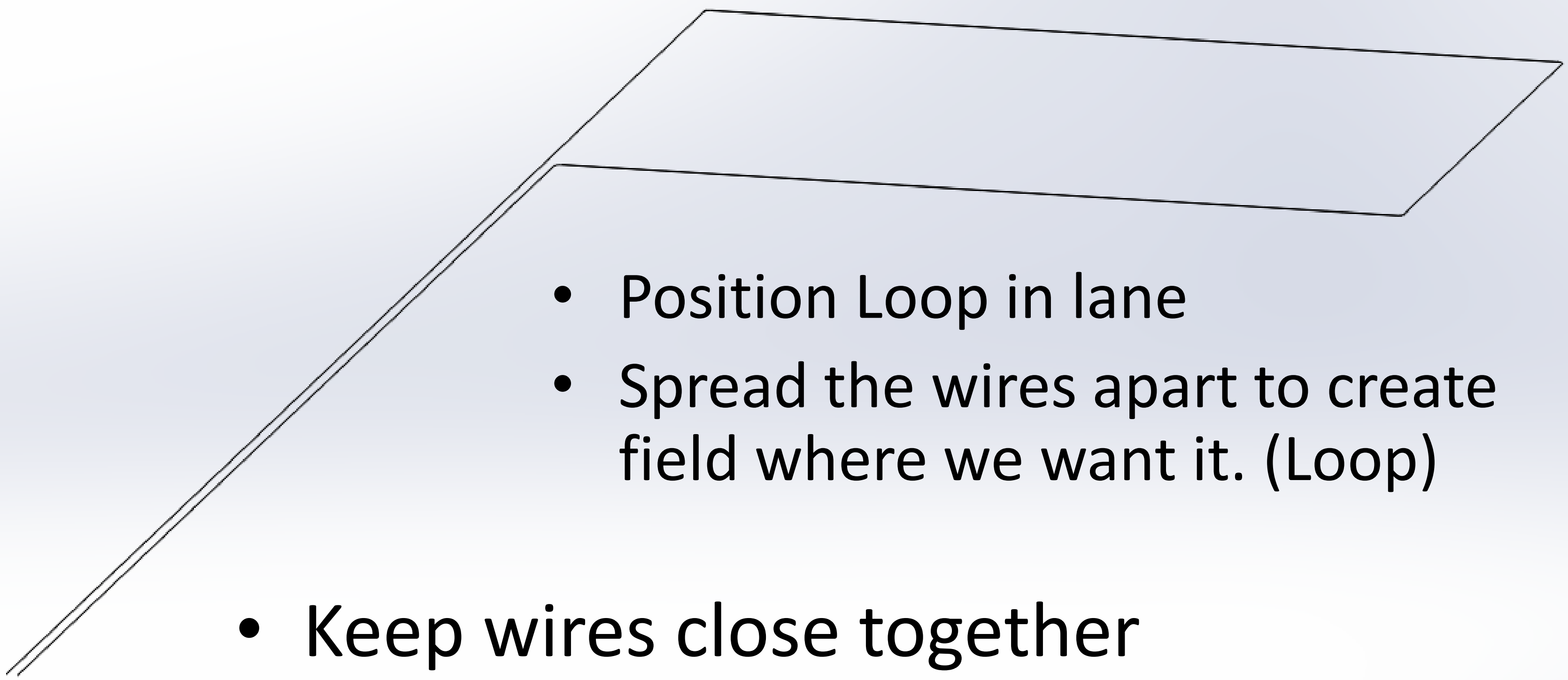


Field self interaction

- If the wires are touching the fields cancel completely

- **Notes**
  - The field isn't in the wire; it is in the surrounding material
  - So wire gauge doesn't matter to create the field (current does)
  - Effective Field can be canceled but the effort to try to create field still exists.

Loops: Field only where you want it



- Position Loop in lane
- Spread the wires apart to create field where we want it. (Loop)

- Keep wires close together where we don't (Lead-In)

Loop Size

- Size the loop to create the field needed for the application
- Size affects not only length and width but also height.
  - The wire spacing is still in effect so height is limited by the closest wires (short leg)

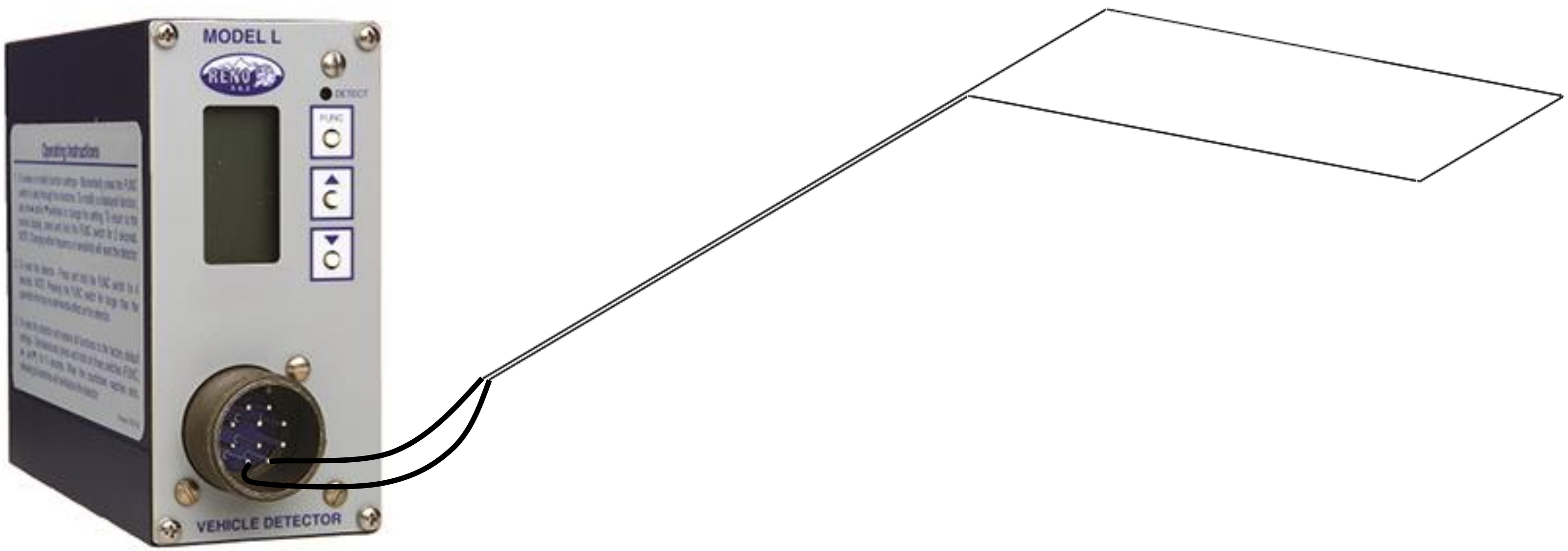
- **<u>Detection Height = 2/3 the shortest leg</u>**
- For example a 6’x20’ short leg is 6 * 2/3 = 4’ detection height

Loop items not yet covered

- Inductance
- Resistance
- Twisting leads
- Turns
- Shapes
- Quadrapoles
- Power heads
- Ground wires
- Multiple loops
- Etc.
- Talk about after we discuss a little about detectors

Part 2
The detector

Connect loop to the detector



Loops in a perfect world

- Measure the amount of field that the vehicle is affecting
- Ignore all of the lead-in and just look at the Loop
- Loops would all be identical in shape and amount of lead-in
- Never interact with other external fields.

Detectors

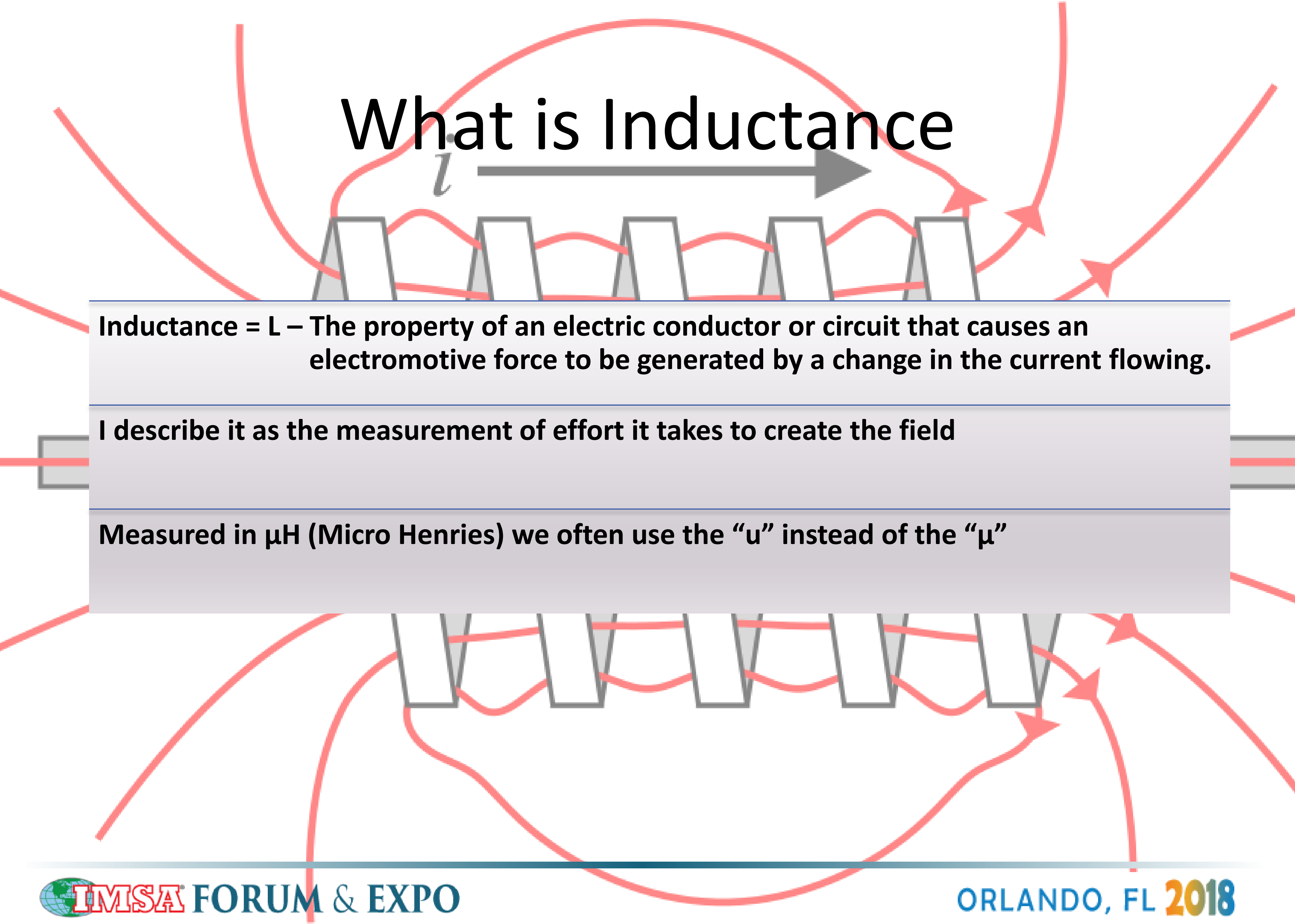
Can't measure the field directly

Can measure the inductance of the loop/Lead-in system

Inductance is directly related to the Field

Can't tell the difference between lead-in inductance and Loop inductance

What is Inductance



Inductance = L – The property of an electric conductor or circuit that causes an electromotive force to be generated by a change in the current flowing.

I describe it as the measurement of effort it takes to create the field

Measured in µH (Micro Henries) we often use the "u" instead of the "µ"

Inductance per Foot

- Most loops are in Pavement (Concrete or Asphalt) and very close to the surface (Air)
- Pavement looks like air when forming a field.
- Wire in air has 11uH (Micro Henries) of inductance per 100ft (Foot)
- 1ft of lead-in has 2 feet of wire so:
- <u>**100ft of Lead-In = 22uH of inductance**</u>

Detectors and Inductance

Detectors have a wide range of inductances where they will work.

- Not enough inductance = Short Circuit
- Too much inductance = Open Loop

Common Operating Range

- 50-1000uH
- Some work over extended ranges like 20-2500uH

Detectors actually measure the change of inductance

- The detector keeps track of what the current inductance is but only uses it as a reference
- Change of inductance is what determines a call.

ΔL/L

- ΔL/L = Change of inductance/Actual inductance
- The loop and its surroundings don't move (it is buried in the street) so it always has a constant inductance.
- The only thing that can cause a change is a vehicle driving over the loop. (Careful with this—we will talk about it later)

Inductance
Loop vs Lead-in

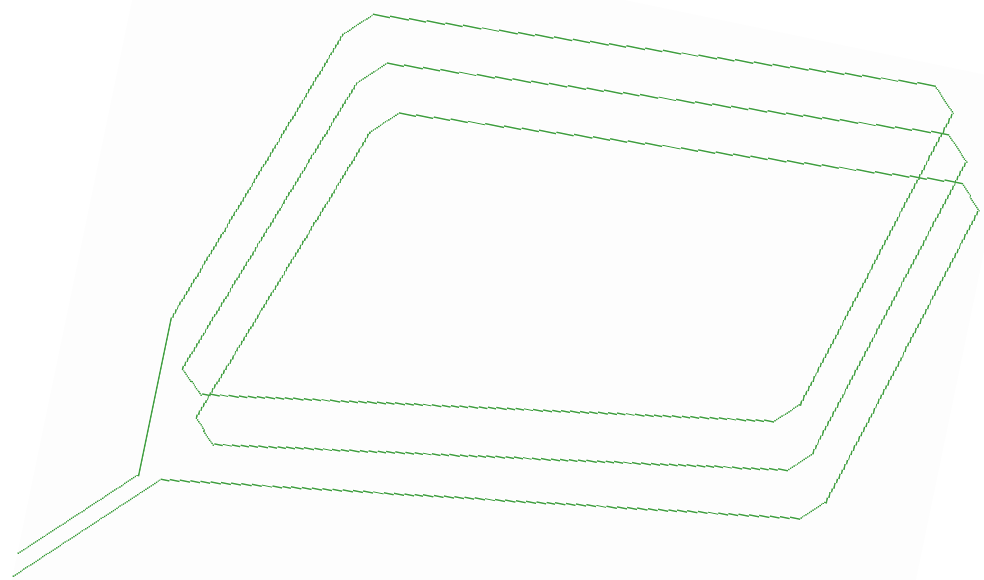
- The detector can't tell the difference between the Loop inductance and the Lead-in inductance
- Just sees them added together.
- We want to have most of the inductance in the Loop not in the Lead-In (**loop inductance > Lead-In Inductance**)
- Have a name for this figure called:
- **Loop Efficiency = Loop Inductance/Total inductance * 100%**

Turns

We add or remove turns to adjust the inductance of the loop system

What are Turns

- Each turn winds the wire around the loop one more time (3 turns are shown)
- If we don't have enough Inductance we can add turns to increase the inductance
- If we have more inductance in the Lead-In than in the loop, we can add turns to increase the inductance in the Loop.



How do we use Turns (Part 1)

Easier to explain with an example.

Given:

6x20 loop with 200 feet of lead-in.

We know that we need the loop/lead-in to total between 50 and 1000uH

We know that we want at minimum half of the inductance to be in the loop.

How do we use Turns (Part 2)

1

2

3

4

1) Use the estimation calculation for the loop:

- Loop Inductance = (Turns^2 + Turns) x (Perimeter) / 4

Check to make sure there is more inductance in the loop than in the lead-in.

- Lead-in Inductance = Lead-In Length * 0.22

Check to make sure that we are in range of the total inductance

- 1000 > Loop + Lead-In > 50uH

If we don't meet these requirements then adjust the number of turns.

How do we use Turns (Part 3)

- Example a 6'x20' loop with 200' of lead-in
- Start with a guess of 2 turns
- 1) Loop Inductance = $(T^2 + T) \times (P) / 4$

  $= (2^2 + 2) \times (6+6+20+20)/4$

  $= (4 + 2) \times (52)/4$

  $= (6) \times 13$

  = 78uH
- 2) Lead-In Inductance = 200 x 0.22

  = 44uH – The Loop has more Inductance
- 3) Total Inductance = 78uH + 44uH = 122uH – the Loop/Lead-In has a sufficient inductance.
- If we had tried to use 1 turn the loop inductance would only have been 26uH not enough compared to the 44uH of the Lead-In
- If we had tried to use 3 turns, the loop inductance would have been 156uH and the total would have been 200uH which would also be fine, but we would need to use more wire

Sensitivity

Level	ΔL/L % Change
1	0.64%
2	0.32%
3	0.16%
4	0.08%
5	0.04%
6	0.02%
7	0.01%
8	0.005%
9	0.0025%

Percentage of change necessary to detect a vehicle

Actual change seen = %Change x Loop Efficiency/(100*number of loops)

Reduce Sensitivity to reduce crosstalk

Sensitivity 2

- LCD detectors can be used to show the %Change
- Utilize the Deflectometer or Bargraph on LCD detectors

Vehicle Type	Typical Change on 6'x6' loop (No Lead-In)
Car	1.0%
Pick-up Truck	0.5%
Semi Cab	0.5%
Semi Trailer	0.125%
Motorcycle	0.008%
Bicycle	0.003% (in center of the loop)

Crosstalk

- The current that is flowing in the loop is actually an AC current which has a frequency.
- Loop Frequencies are usually in the range of 20-100kHz
- Loops that are positioned close to each other and that are running at the same frequency can interact with each other (cause noise, false calls, drops, etc.)
- Called Crosstalk.
- Usually is seen as random detections when there is no vehicle present

Frequency

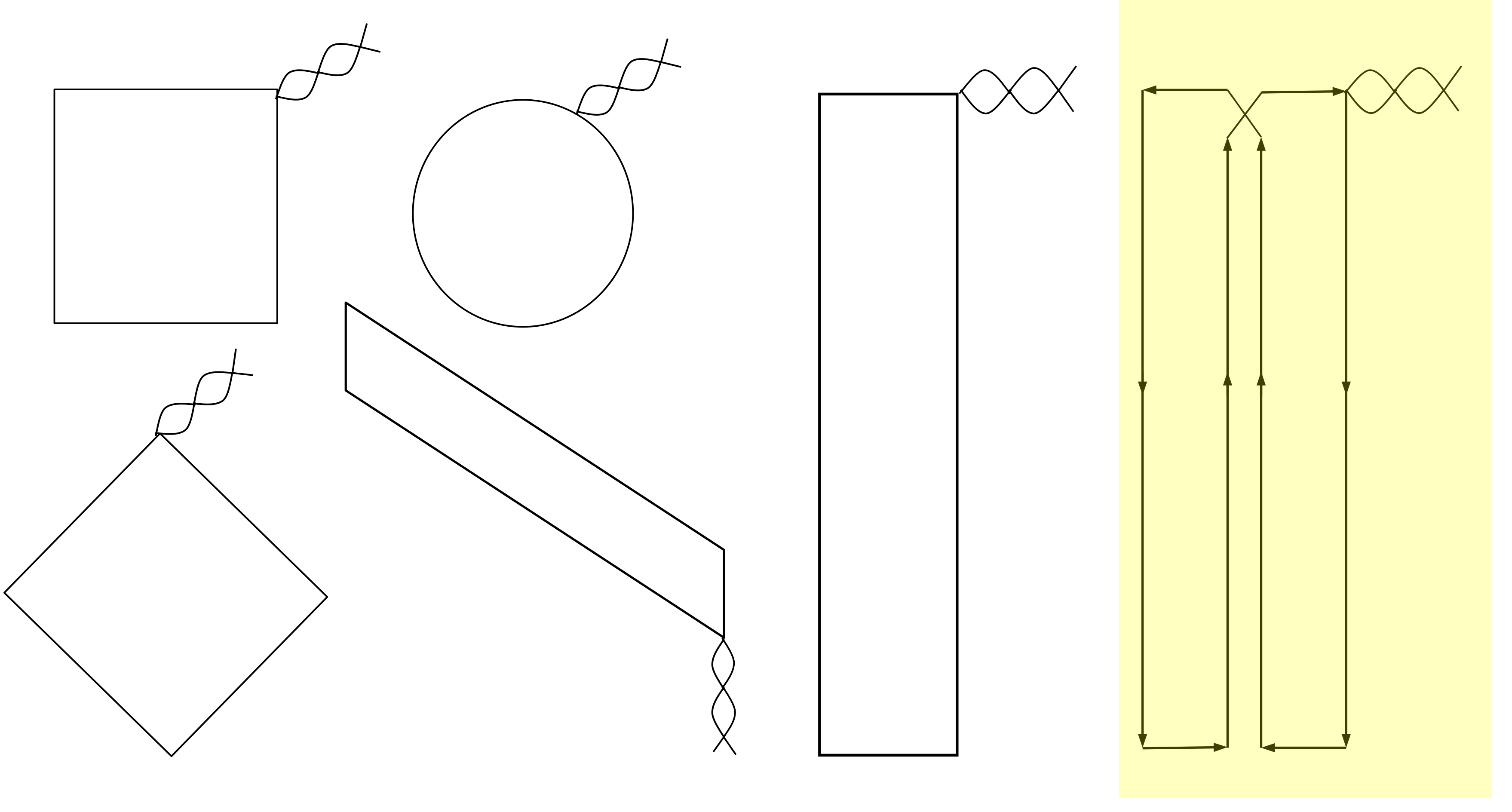
- Detectors have the ability to change frequency for each channel.
- Adjust the frequency to be different between adjacent loops and you know you will never crosstalk.

Scanning

- Many detector operate in scanning mode
- They have 2 or 4 channels of detection but they cycle through each channel individually with the other channels off.
- Done very quickly but the more channels used, the longer the response time.
  - Usually not an issue at intersections, but could be for Speed measurement loops.
- This means that the adjacent channel is not running so it can't crosstalk.

Part 3 Additional Loop Design

Loop Designs

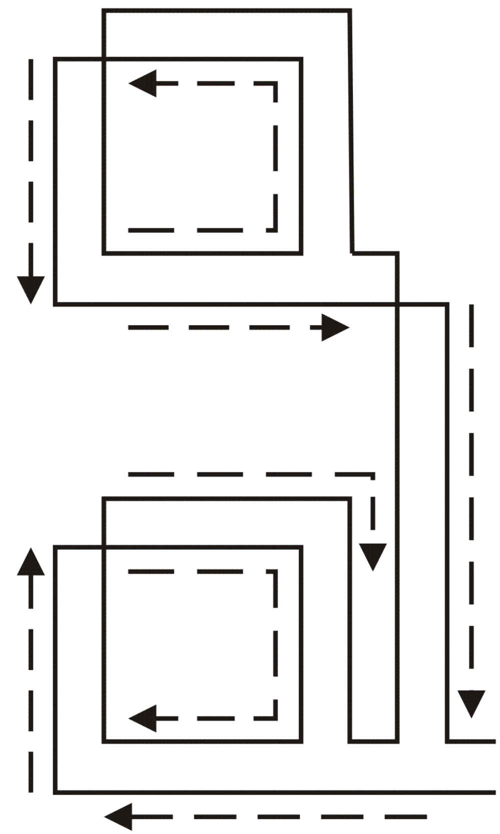


Loop types by usage

- Traffic Control Common Types:
  - ***Stop bar***
  - ***Count/advance loop***
  - ***Left turn***
  - ***Right turn***
  - ***Directional logic***
  - ***Speed Pair***
  - ***Classification***

Multiple loops on one channel

- Depending on the type of loop chosen, a single loop may not cover a given detection area. Multiple loops can then be installed.
- Should always be wired in Series
  - Parallel can cause odd sensitivity issues
- Bring Lead-In to Cabinet
- Recommend at least 1 channel per Lane



Splices

What not to do

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What to do

- Proper Splice technique
- Strip the wire back
- Solder connections
- Heat shrink over all solder joints
- Insulate and waterproof with
    - Mastic tape
    - 3M splice kit
    - Etc.

Lead-In

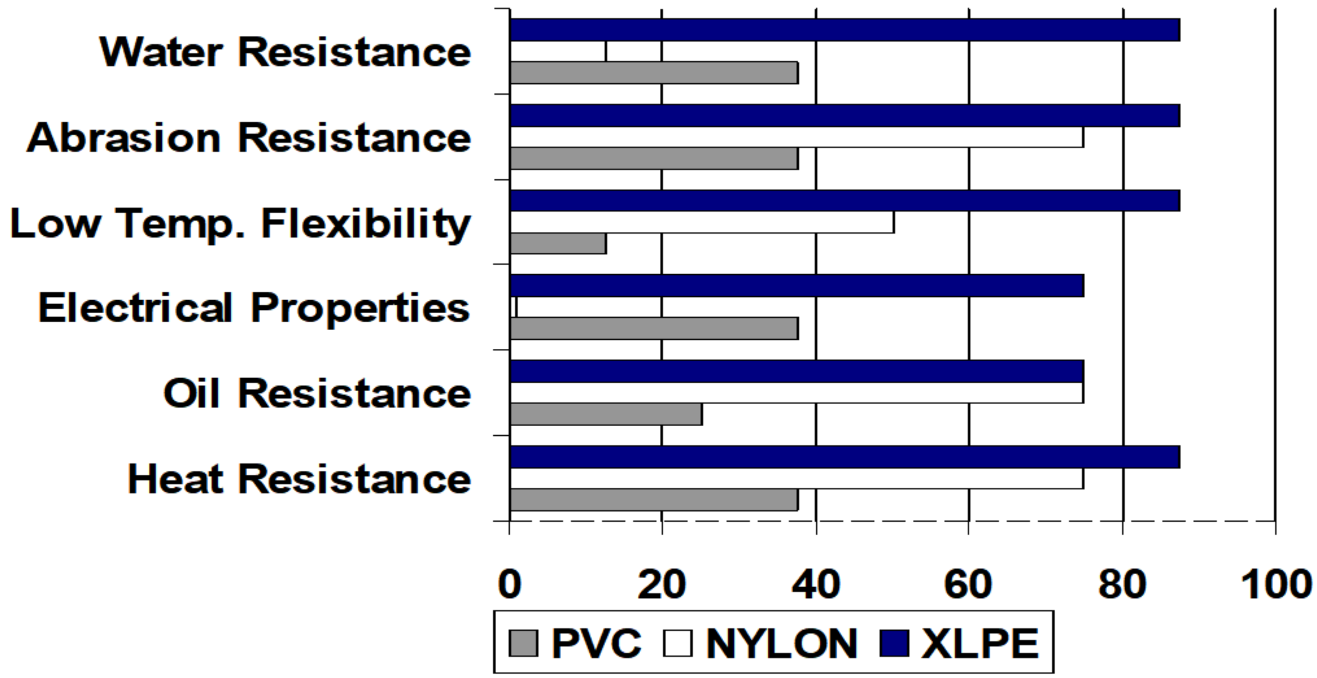
- Lead-in should be tightly coupled together.
- Twisting Lead-In is usually the easiest way to ensure tight coupling
- Twisting has added benefit of better rejection of unwanted external fields
- Ground/Shield wire is not desirable.
  - The nature of loops and their fields mean that there is no value in the ground.
  - Ground leads, if tied together with another loop, will induce crosstalk as a capacitive coupled signal.

Wire Type

- IMSA specifies several types of wire

HTTP://WWW.IMSASAFETY.ORG/CABLESPECS.HTM

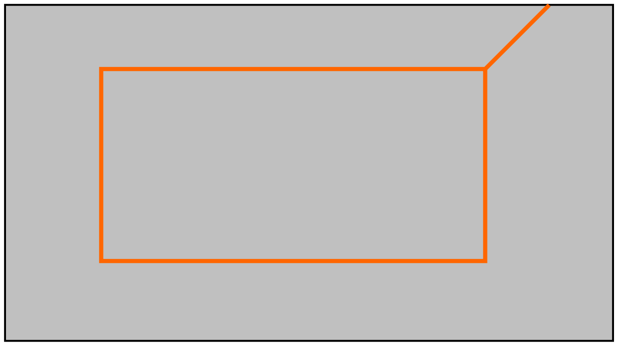
50-2		Polyethylene insulated, polyethylene jacketed, loop detector lead-in cable
51-1		Polyvinyl chloride insulated, nylon jacketed loop detector wire
51-3		Cross linked polyethylene insulated loop detector wire
51-5		Polyvinyl chloride insulated, nylon jacketed, loosely encased in a polyvinyl chloride or a polyethylene tube loop detector wire
51-7		Cross linked polyethylene insulated loosely encased in a polyvinyl chloride or a polyethylene tube loop detector wire



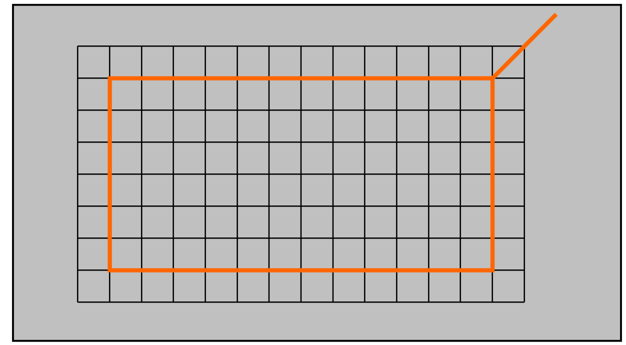
Reno A&E recommends a narrow subset of that list.

In fact we only recommend 1 material: XLPE (cross-linked polyethylene).

Rebar

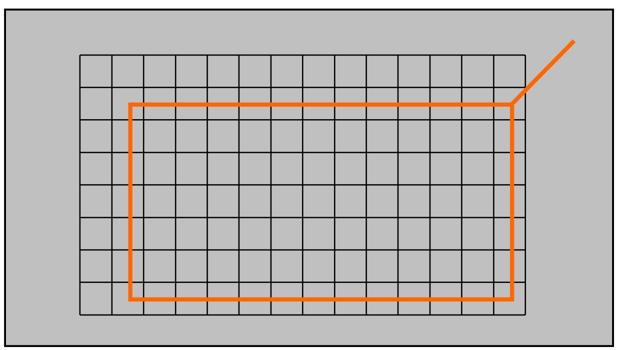


No mesh -4.5% ΔL/L



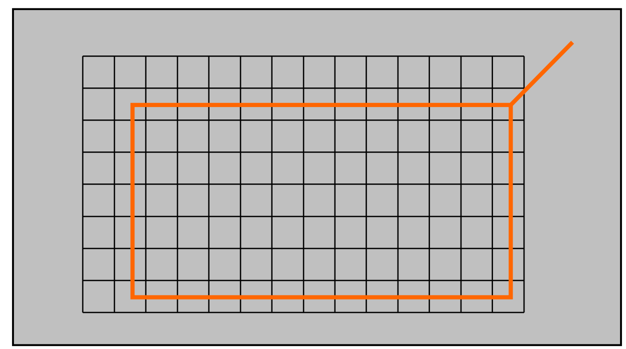
Loop tied to the grid -0.90% ΔL/L

Signal loss 80%



Loop mounted 2” above the mesh

-2.30% ΔL/L Signal loss 48%



Loop tied between the grid

-1.50% ΔL/L Signal loss 66%

Part 4
Loop Installation

Loop Types

Saw Cut

- Most common installation approach
- Locate and mark where you want the loop to be placed in the completed pavement
- Using a pavement cutting saw, cut a slot in the pavement to accept the wire
- Wrap the loop in the cut
- Seal the cut with sealant

Pave Over

- Newer option
- Prior to the final paving of a roadway, locate the loop in the roadbed (usually a preformed loop)
- Pave over the loop
- Loop is permanently installed in the roadway
- The loop must be able to withstand the paving process

Rules to follow for a good install

1) The installed loop must not move
2) Metal near the loop must not move
3) Protect the loop from water
   – Keep the loop in bottom of the saw slot
   – Use good sealant
4) Protect the loop from sharp points
   – Includes the pavement and tools
5) Don't splice the wire
6) Keep lead-in tightly coupled

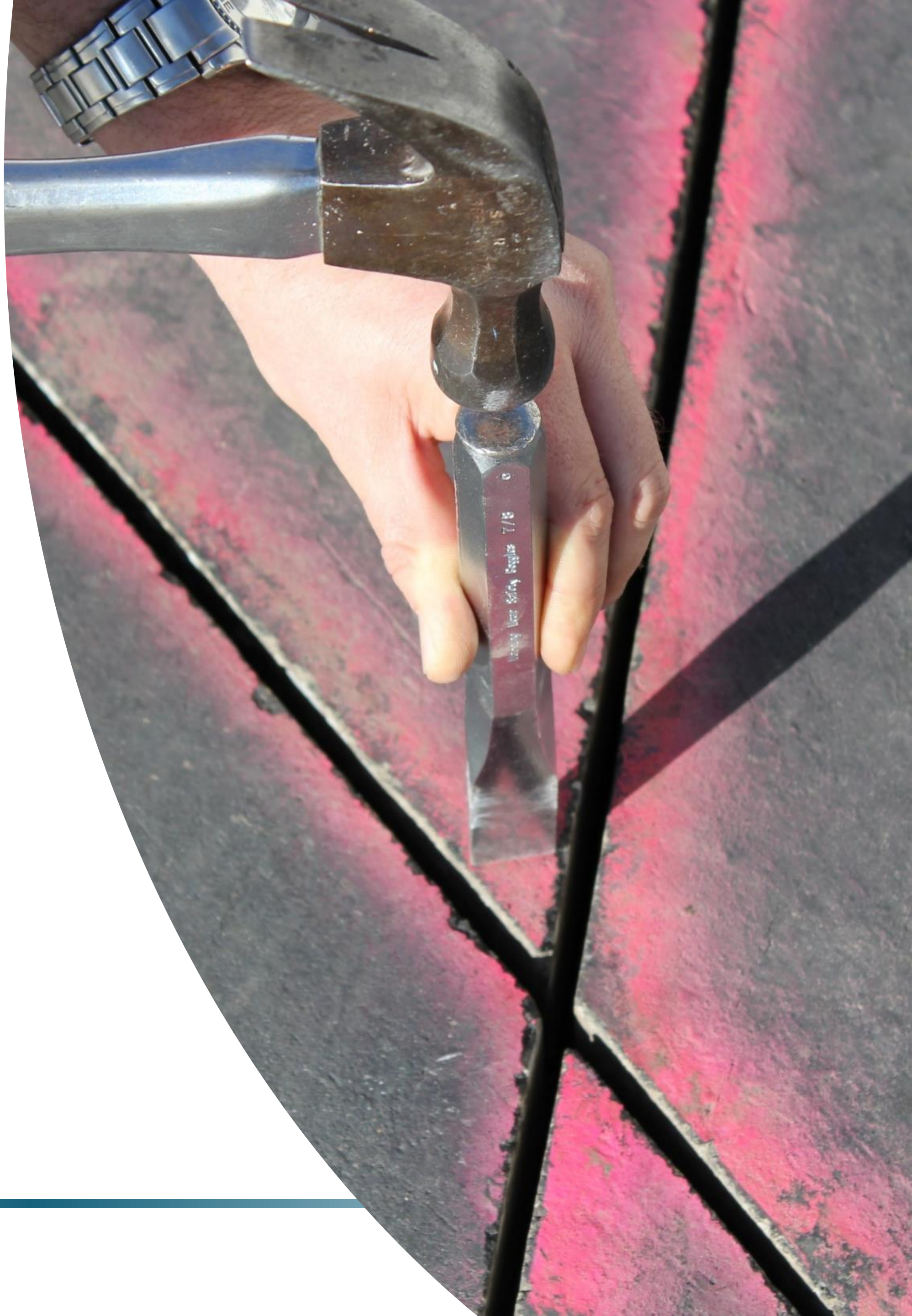
Step 1: Mark Loop install location

Sawcut loop install

Cut the pavement

Chamfer the corners

- This is for a prefabricated loop. Usually the saw is used to cut a 45 degree angle across any sharp corners
- The second (and in some cases 3rd) layer of insulation on prefabricated loops allows less ideal installations without damage to the loop.



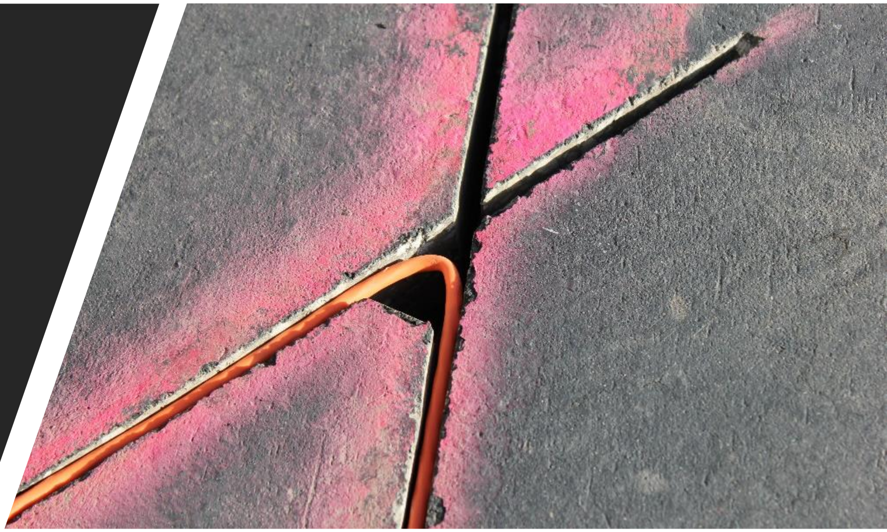
Make sure you remove any debris that could rub and damage the Loop

It is a good idea to blow out the slot with compressed air just prior to installing the loop

Clean out the slot

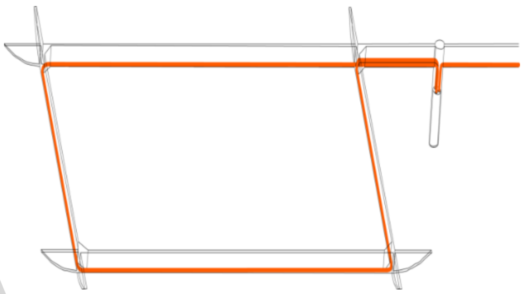
Install the loop

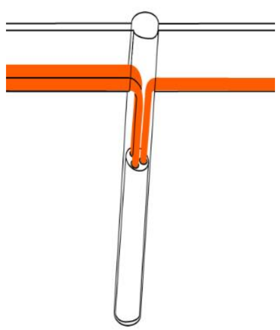
- The loop is placed into the saw cut and held down with ~ 1" pieces of backer rod to keep it in the bottom of the saw slot.
- IMPORTANT: Use a rounded tool to press the loop into the slot. Never use a sharp instrument on a loop.
- Twist the Lead-In Wires where they exit the Saw Slot all the way back to the detector

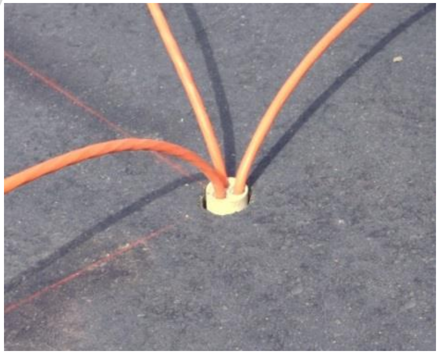


Prefabricated Loop Block

- Locate block location
- Drill or cut hole for block

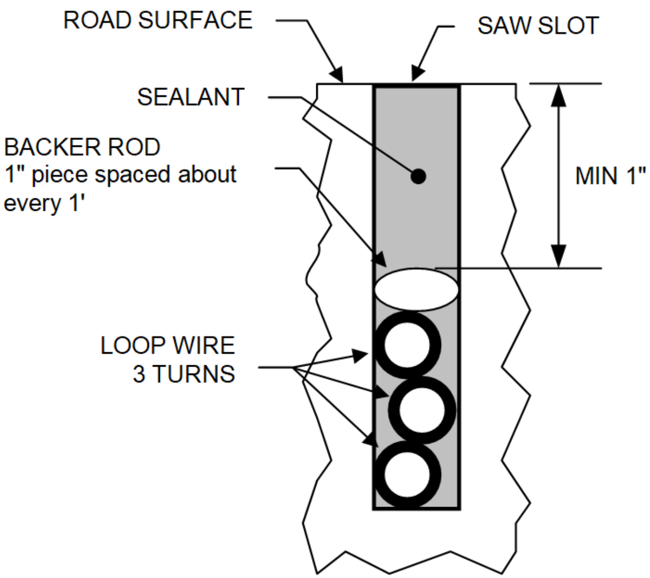






Seal the loop

- Make multiple passes if necessary to ensure that the sealant completely fills the gap
  - Any gap remaining will be subject to freeze thaw cycles, and water intrusion

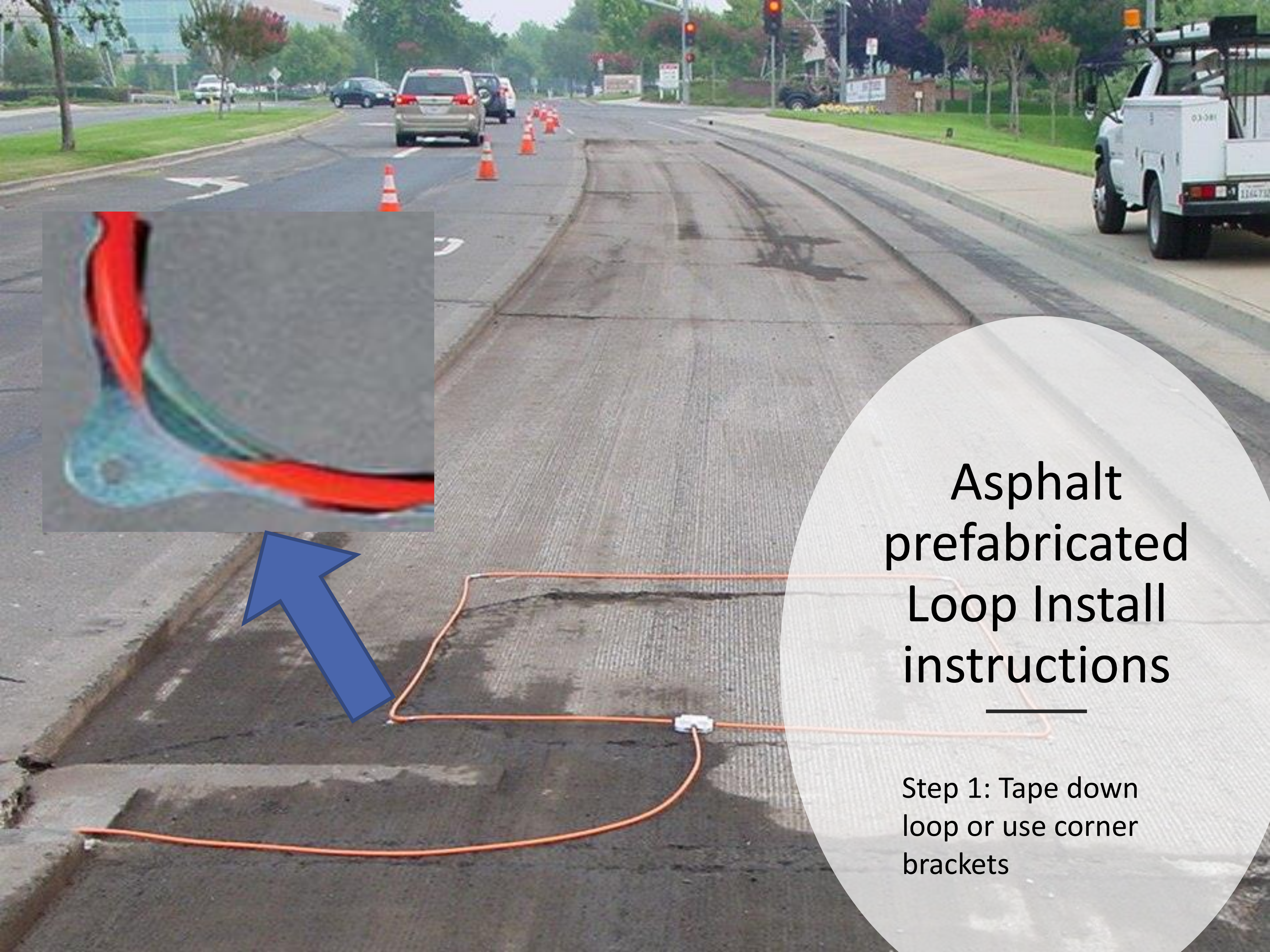


Case for Prefabricated loops

- A prefabricated Loop is Stronger than a Standard Loop
  - Multiple layers of insulation
- Can use a shallower sawcut
- High temperature materials allow for better sealants
- Cost Effective
- Easy to handle, ship, and install
- Comes with the correct number of turns for the size of the loop
- Sized so that it can be installed in imperfect loop slots
- More inductance in the loop due to tight coupling

- Promotes longer Roadway life
  - No Saw cuts
  - No Sealant to fail

Prefabricated Pave over loop



Asphalt prefabricated Loop Install instructions

Step 1: Tape down loop or use corner brackets

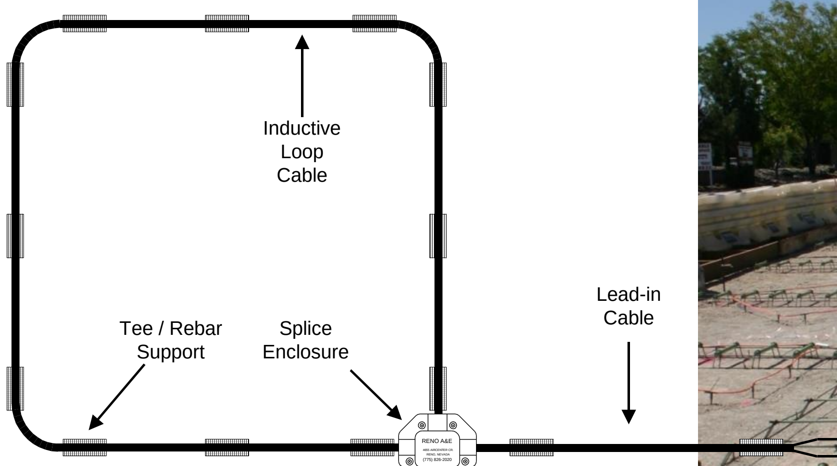

Step 2: Cover loop to protect it from the paver


8500
CAUTION
PRECAUCION
ATTENTION
Step 3: Pave over loop.
Compress as usual.

No Saw Cuts

Step 2 cover loop to protect from paver

Preformed Loop Concrete install



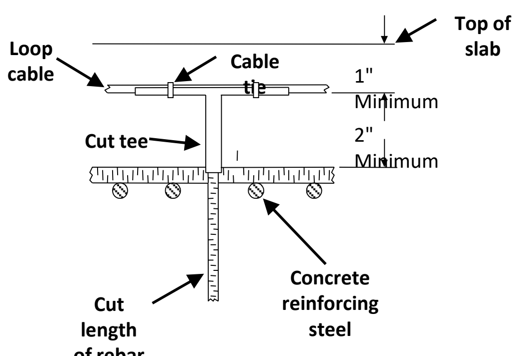


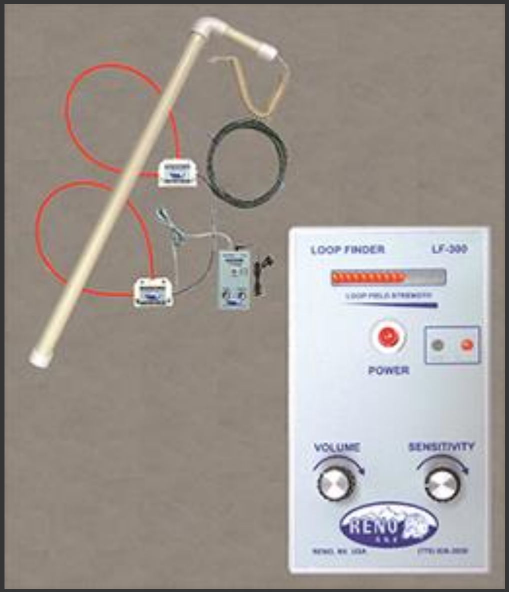
Figure 2


Raise loop into
the pour

Part 5 Loop Diagnostics

Testing Tools

- Meter
- LCD detector
  - Buzzer
  - Inductance
  - ΔL/L
  - Fault type
  - Fault History (count)
- Meg-Ohm Meter
- Loop Finder



Measurements

- Install records
  - Loop Location
  - Loop Resistance
    - Detector will work with <10 Ohms but high resistance could indicate questionable joints/wire
  - Loop Inductance
  - Loop Meg-Ohm reading
    - Loops will work with a single point fault to EGND. But bad insulation is an indication of other potential damage
    - Prefabricated loops have been tested for >10Gig Ohms of insulation resistance
    - Loop should have minimum 50Meg Ohms of resistance to EGND

Troubleshooting Loop Failure

1) Is the issue in the detector or the loop

- Detector Fault information
- Swap detectors does the issue follow loop or detector

2) If in the loop – Check:

- Are the loop joints bad
- Is the pavement in good condition
- Is the Lead-In tightly coupled

3) Disconnect loops in series or parallel, Check each individually

- Does the loop work on the detector
- What is the inductance
- What is the resistance
- What is the Meg-Ohm Reading

Troubleshooting Crosstalk

1) Crosstalk usually comes in pairs identify the loops with the issue

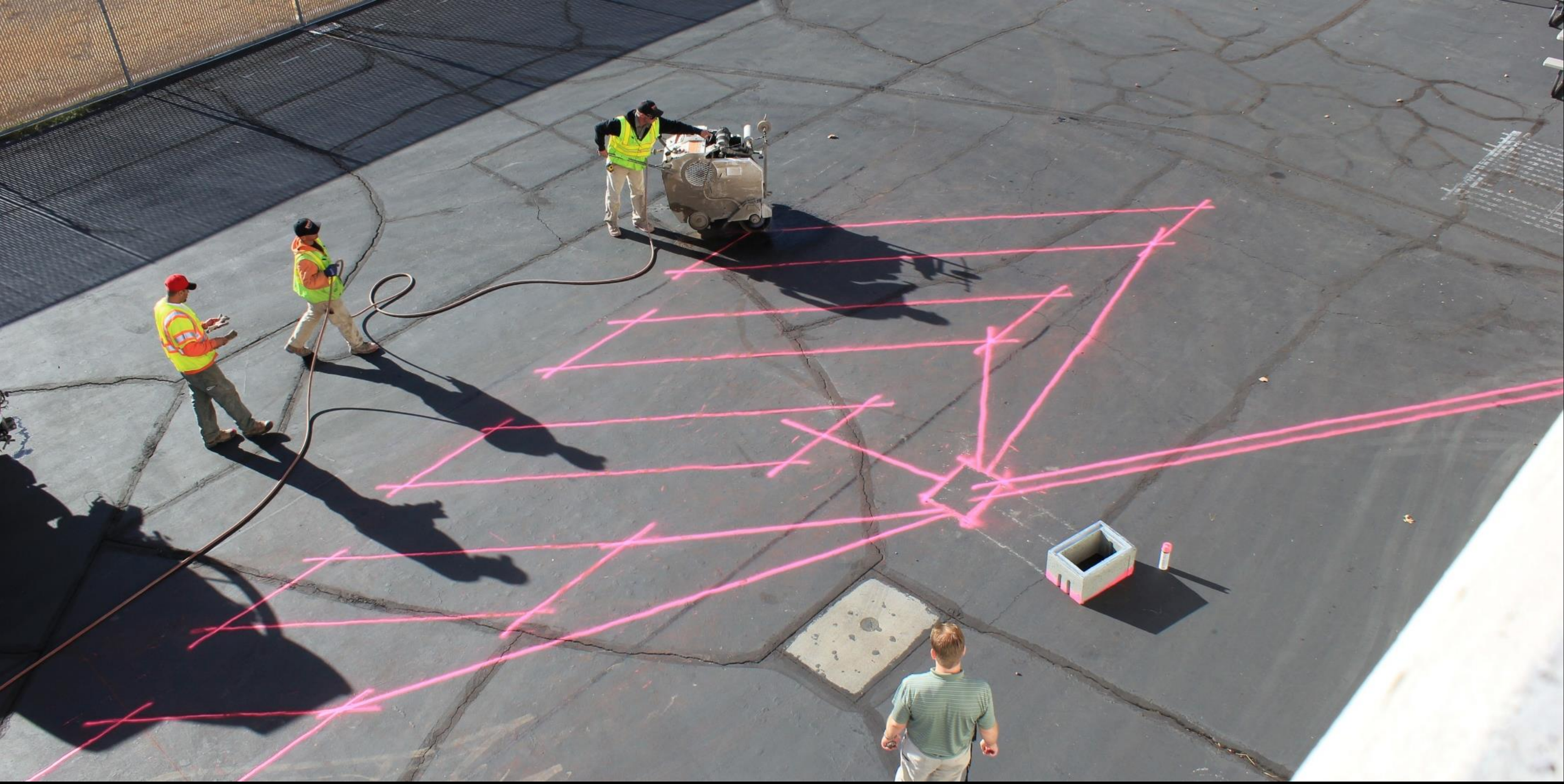
- If possible physically locate the loop
- Crosstalk could be in lead-in not in loops
- Pair may be hidden with one loop of lower sensitivity or in a different cabinet

2) Adjust the frequency of crosstalking loops

- Be careful that the issue doesn't jump to other adjacent loops

3) If issues persist try an alternative solution

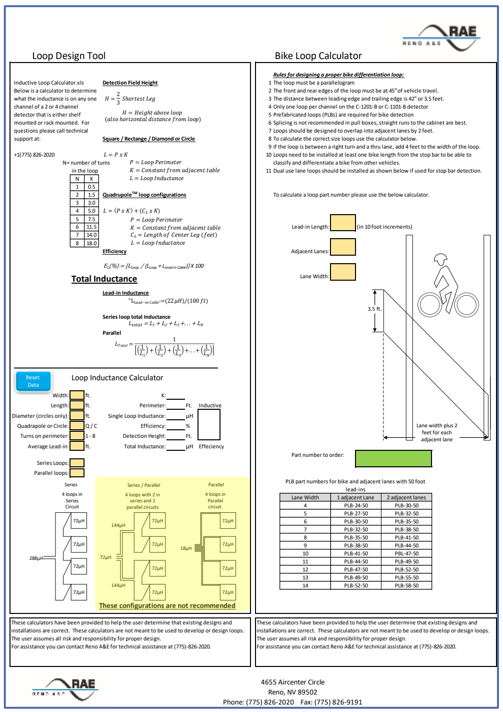
- Connect both loops to single scanning detector
- Reduce the sensitivity to reduce the issue



Covered a lot, Loops are actually very simple

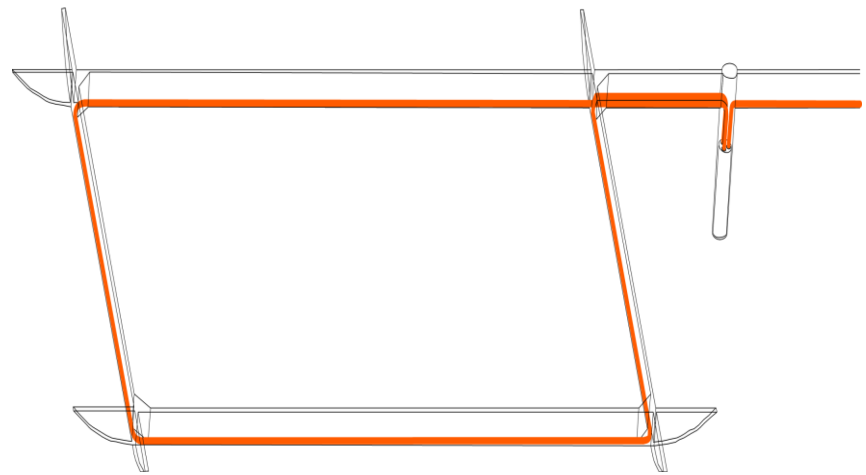
Ways to Simplify

1 Use a Loop calculator tool



Available on our Website www.renoae.com

2 Let us do the Math for you



Use a Prefabricated loop and we will make all of the best choices for you. Materials, size, turns, and testing will already have been done. Plus you get a 10 year warranty.

Things to Remember

- Detection Height = 2/3 shortest leg
- Depth of loop subtracts from Detection Height
- Lead-in cable 22uH/100ft
- Typical detector Range 50-1000uH inductance
- Loop Efficiency = Loop inductance/total inductance *100%
- <u>Loop Inductance</u> = (Turns^2 + Turns) x (Perimeter) / 4
- <u>Lead-in Inductance</u> = Lead-In Length * 0.22

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