MD Perspective and Obstacle Detection for HDD

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Mechanical Damage Technical Workshop
Prevention Panel Keynote
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What This Presentation Covers

> Some of the causes of mechanical damage to buried infrastructure

> A brief review of various approaches to MD prevention GTI has pursued

> An in-depth review of Differential Impedance Obstacle Detection (DIOD) for horizontal directional drilling (HDD)

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What are the Sources of Mechanical Damage?

> Third party construction activities

> Impacts during Horizontal Directional Drilling

> Over stress of product pipe during pull-in operation

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Technology Challenges for MD Prevention

- To locate and image the pipe through the intervening soil
- To reliably locate the newer plastic materials
- To locate cement ducts and clay pipes
- Provide the user with easily interpreted, real-time info

MD Prevention Versus Detection

- There are proactive versus reactive approaches to MD
- It is preferable to prevent ANY contact between the pipe and digging equipment
- The use of 24/7 monitoring can detect first contact and alert operators before more serious damage occurs
- Some forms of 24/7 monitor give lead time

Prevention of Damage Is a Major Gas Industry Concern

- 3rd-party damage on HP pipelines can be extremely costly and disruptive
- DOT statistics from 1994-2003 give 252 3rd-party incidents on transmission lines resulting in 9 deaths, 38 injuries, and $91 million in property damage
- One incident cost ~$25 million
- Detection is good; Prevention is better

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GTI Applications for Detection and Prevention

> Detection of activities within the right-of-way

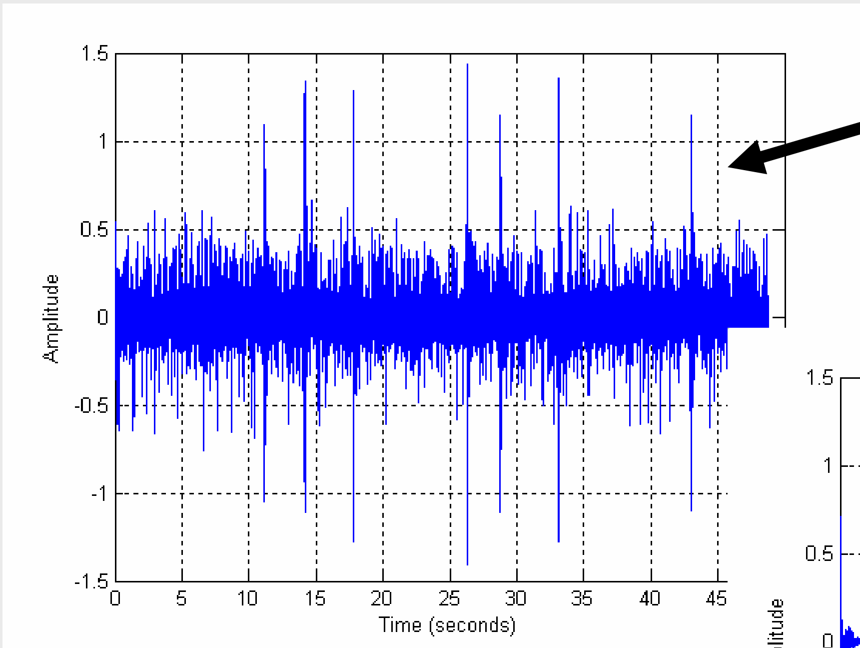
> Monitoring plastic pipe during the installation process

> Detection and imaging of plastic pipe from above ground

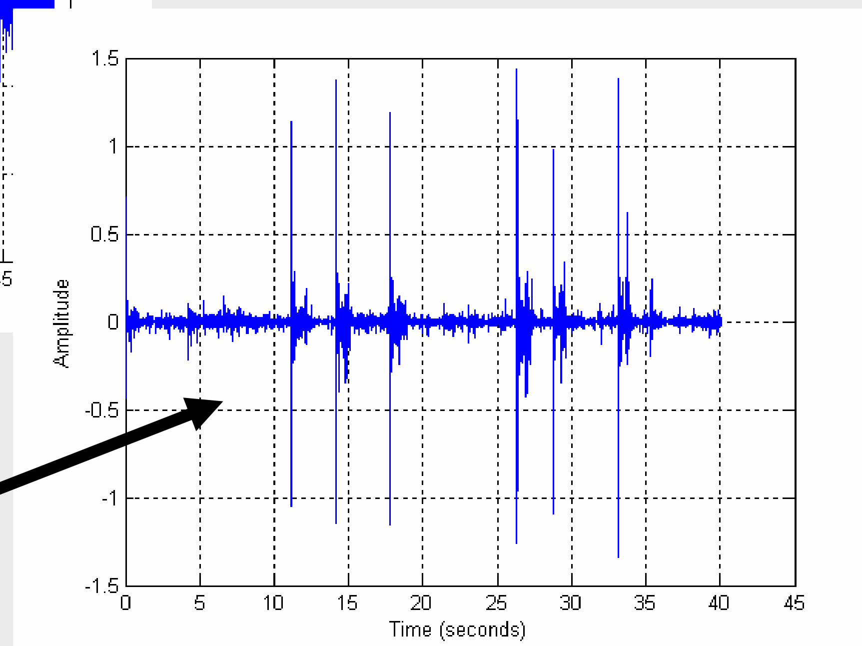
> Detection of obstacles in front of an HDD in time to avoid collisions

Acoustic Sensors Attached to Pipe Wall

Acoustic Systems Must Manage Background Noise



sensor output
before processing



sensor output after
processing

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Optical Fiber Monitoring of ROW

- Basic concept of OTDR using fiber buried above pipeline can detect simultaneous events
- Additional work is required for a practical device
- Large sensitivity improvements over state-of-the-art, but more is needed
- Technique fast enough to discriminate among encroachment types
- Method of installing fiber is critical to performance and cost

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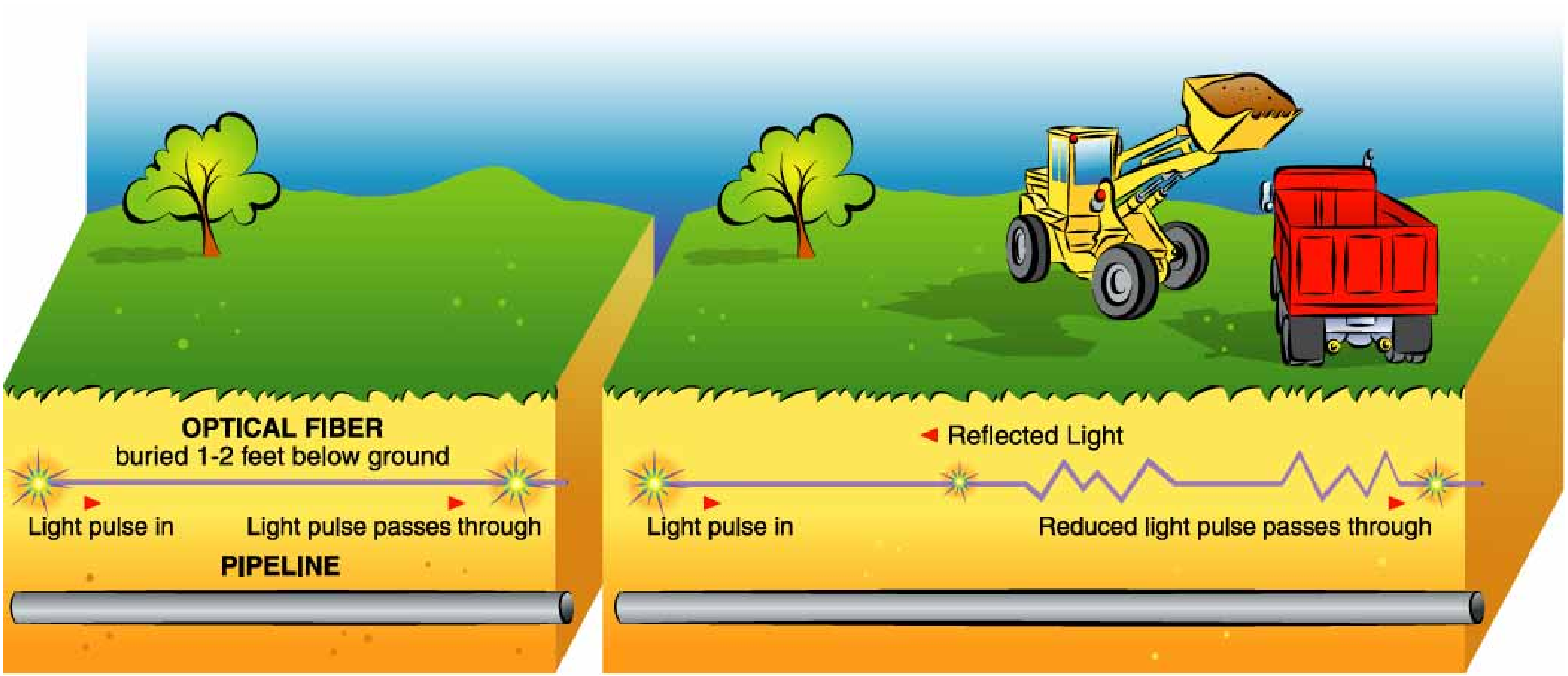
OTDR Technique Can Discriminate Simultaneously Occurring Events

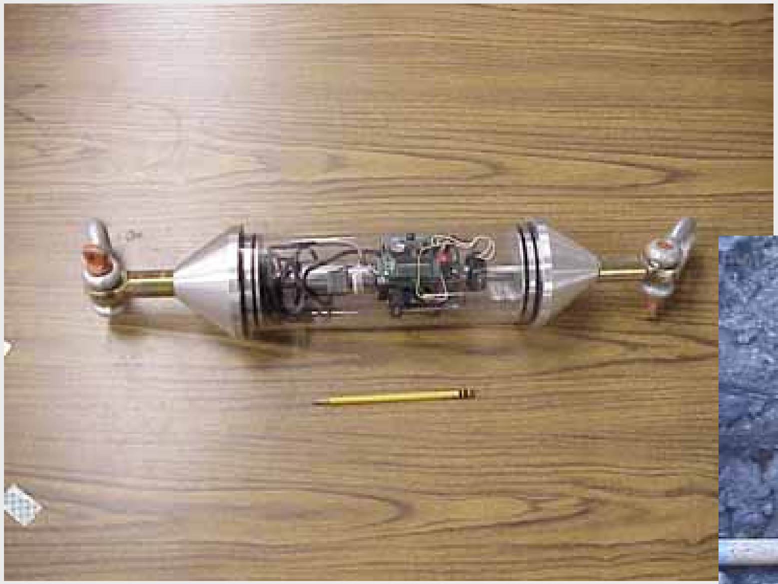


Round trip travel time of a light pulse locates encroachment.

Variations in amplitude identify type of encroachment.

Tow Tension Monitor

Prevents over stress to plastic pipe during pull-in operations



Capacitive Tomography for Imaging Plastic Pipe

Look before you dig – multiple materials

Obstacle Detection for HDD

> With reduced installation costs and increased use of HDD comes crowded utility easements

> In the last few years, there have been a few extreme incidents of damage resulting from drill collisions with buried facilities

> Thousands of other utility strikes on gas, electric, telecommunications, water and sewer lines occur annually

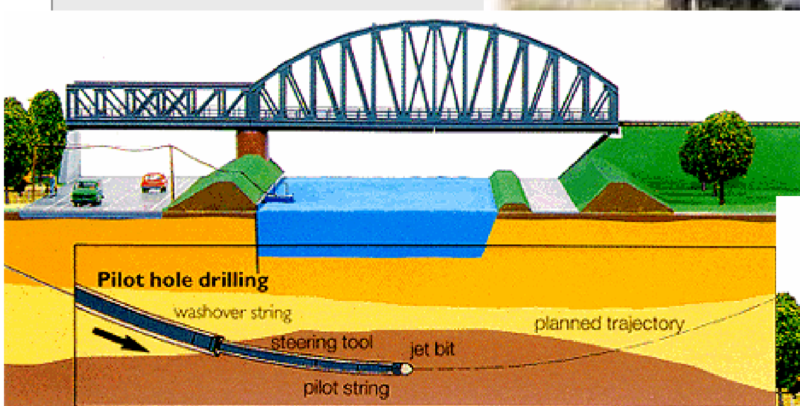
Do We Need Obstacle Detection?

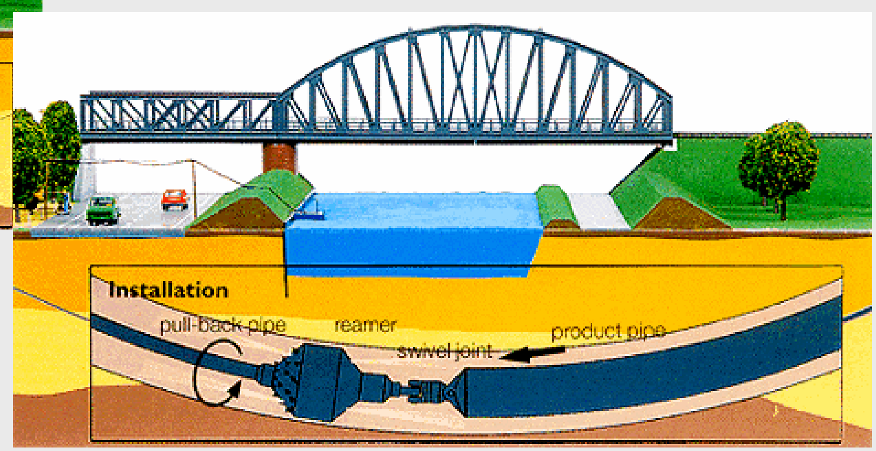
Damage to lead sewer pipe from HDD tool

Horizontal Directional Drilling (HDD)

> Trenchless Method to Install Pipe
> Reduces Costs of Installation
> Two Small Holes vs. One Long Trench
> Drill Rig Pre-bores Hole Underground
> Pipe is Attached and Pulled Back

What Is HDD?





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Objectives of DIOD

- Design a prototype sensor system for detecting obstacles during HDD pre-bore. The sensor should:
  - Work
    - Be sensitive to metallic, plastic and ceramic obstacles embedded in the soil
  - Be Better than Others
    - Address negative issues associated with other technologies like GPR
  - Be simple to use
    - Cannot complicate work for the crew

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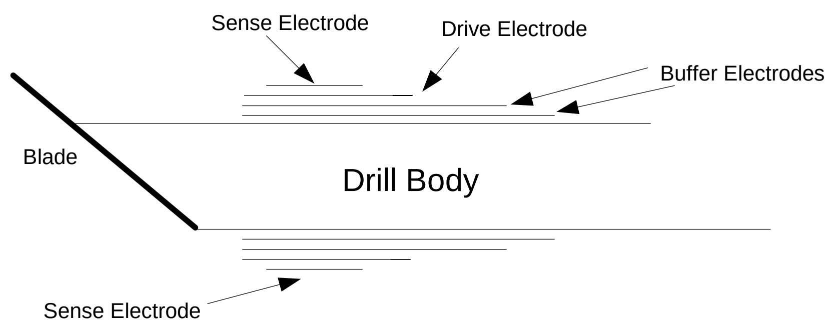
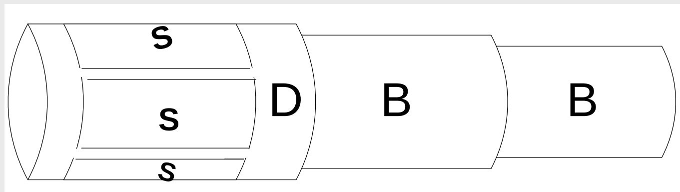
Initial DIOD Approach

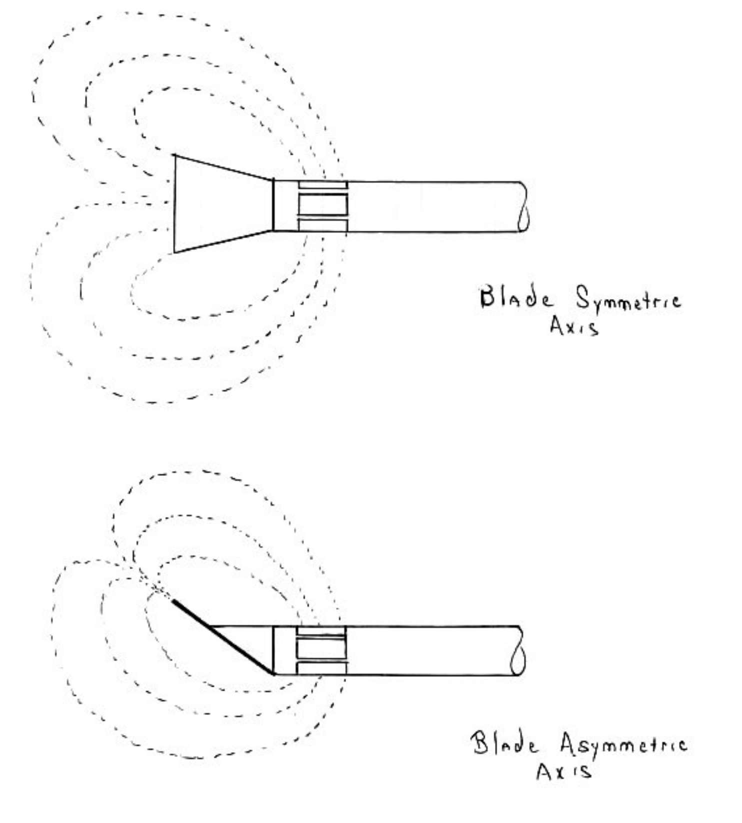
> Proposal Concept to DOE and FERC



Cross Section



Initial DIOD Approach

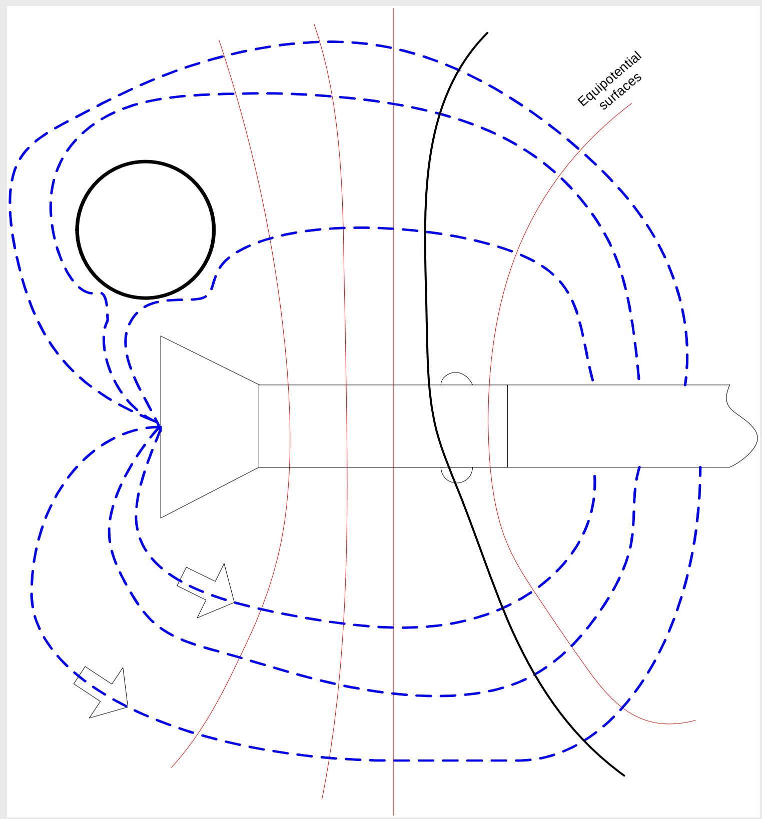


DIOD Technical Advantages

- The use of drill head to carry signal minimizes modifications to drill
- The use of drill head also eliminates any blind spot dead ahead
- The low frequency of operation gives better penetration than GPR
- The system is self-contained, requiring no sensors on the surface

Differential Impedance Sensing

- **Obstacles in the soil cause changes in the soil impedance**

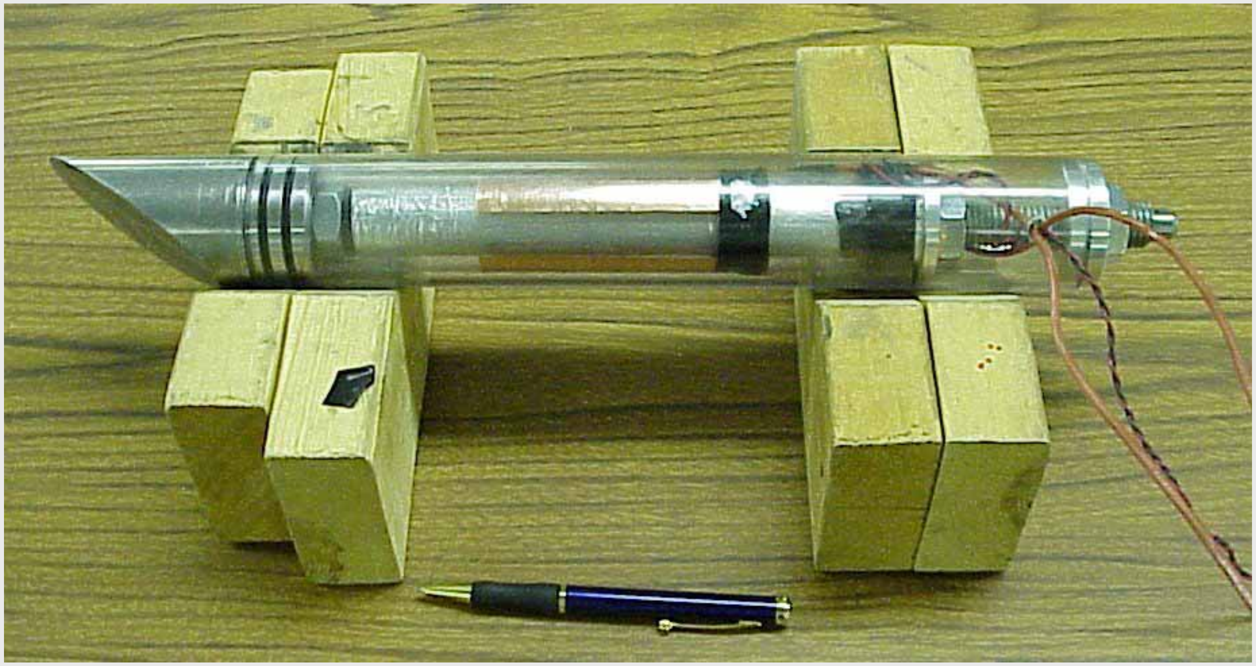


DIOD Disadvantages

- Poor image resolution compared to GPR
  - Have to be more creative at accounting for false positives like dry voids in soil

Initial DIOD Prototype

- Inner silver tube is capacitive drive
- Copper elements are capacitive sensors

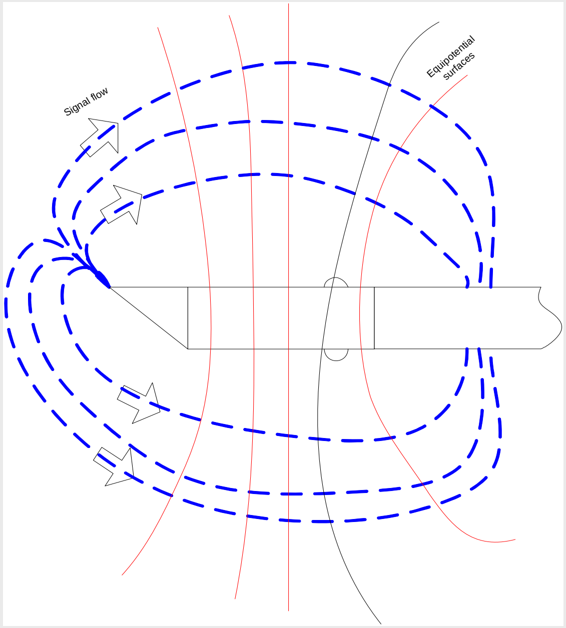


Results Of DIOD 1.0

- Sensitivity lower than expected
- Concerns with effects of adding several hundred feet of drill pipe aft of the sensor
  - Current flow also likely be from drill pipe
  - Wish to focus the sensing current ahead of drill through the tip

DIOD Approach 2.0

> Use metallic body of drill to inject a low frequency signal into the soil
> Current flow from tip to drill pipe
> Metallic contact for sense elements



DIOD Version 2.0

- Used screws as sense elements
- V2.1 used larger square sense elements
- Long steel portion to simulate drill stem

Results of Version 2

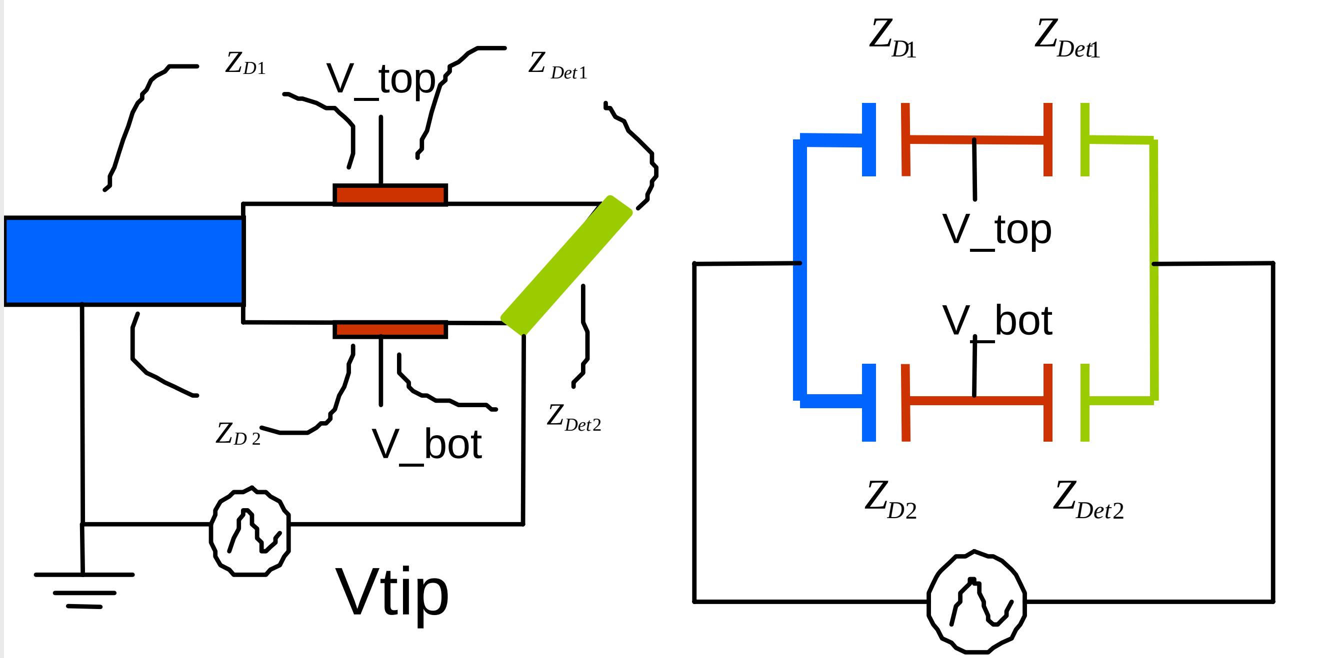
- Difficulty in balancing symmetric axis in homogenous soil condition
- Contact potential is larger than signal
  - Electrochemical contact potentials vary greatly even when all elements have good contact
  - Even differential sensing could not remove this

DIOD Version 3.0

> Hybrid using the best of earlier versions
  - Metallic coupling for signal injection
  - Capacitive coupling of sense elements
  - Improved construction of sense elements and their shielding

DIOD V3 Equivalent Circuit

> **Resembles a 3-plate capacitor**



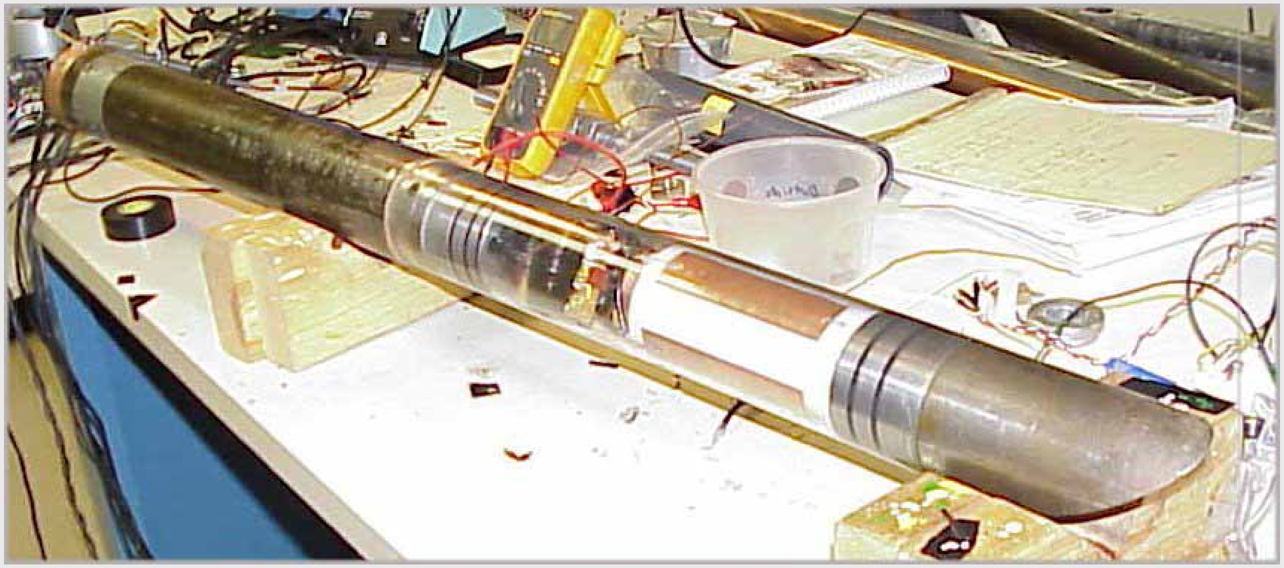
$$Vtop = V_{tip}\left(\frac{Z_{D1}}{Z_{D1} + Z_{Det1}}\right)$$

$$Z_{Det1} = \frac{1}{j\omega C_{Det1}}$$

$$Z_{D1} = \frac{1}{j\omega C_{D1}}$$

DIOD V3.0 Results

- Slightly better, but still had balance issues
- Moved the first amplifier closer to sense elements
- Improved electronic shielding



DIOD V3.1 Results

- Able to achieve balanced condition by adjusting excitation signal phase with respect to reference signal
- In bench tests, medium is air
- Equal sizes of copper and plastic tubes placed near symmetric axis elements
- Copper caused larger imbalance, as expected in air

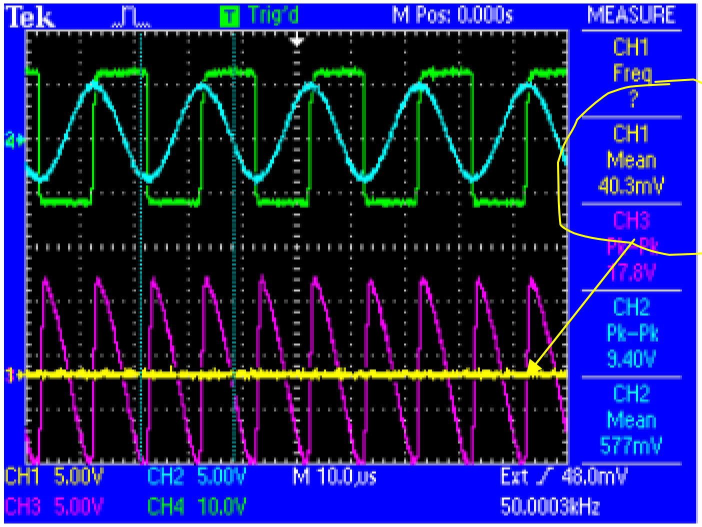
DIOD V3.1 Bench Test

> 50 kHz/20 Vpp excite, obstacle~3” away from each element

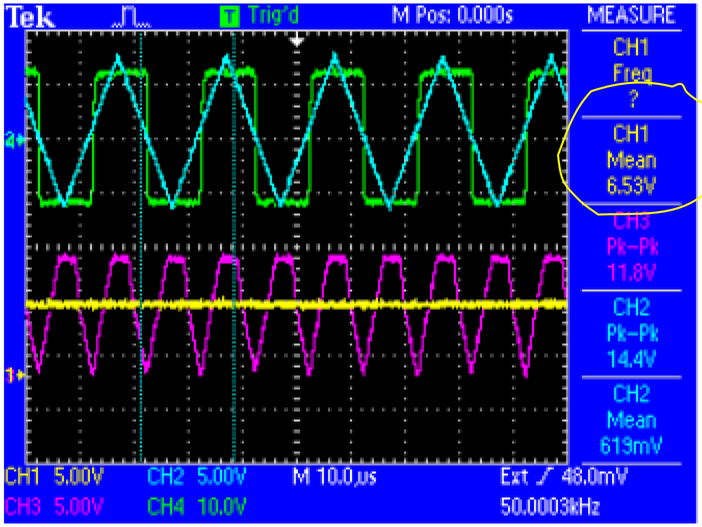
	Copper Mean out	Plastic Mean out
Balanced/No Obstacle	40.3 mV	35.1 mV
S- Imbalance	6.53 V	2.74 V
S+ Imbalance	-5.32 V	-2.82 V

V3.1 Bench Test With Copper

> The Yellow trace is the filtered output

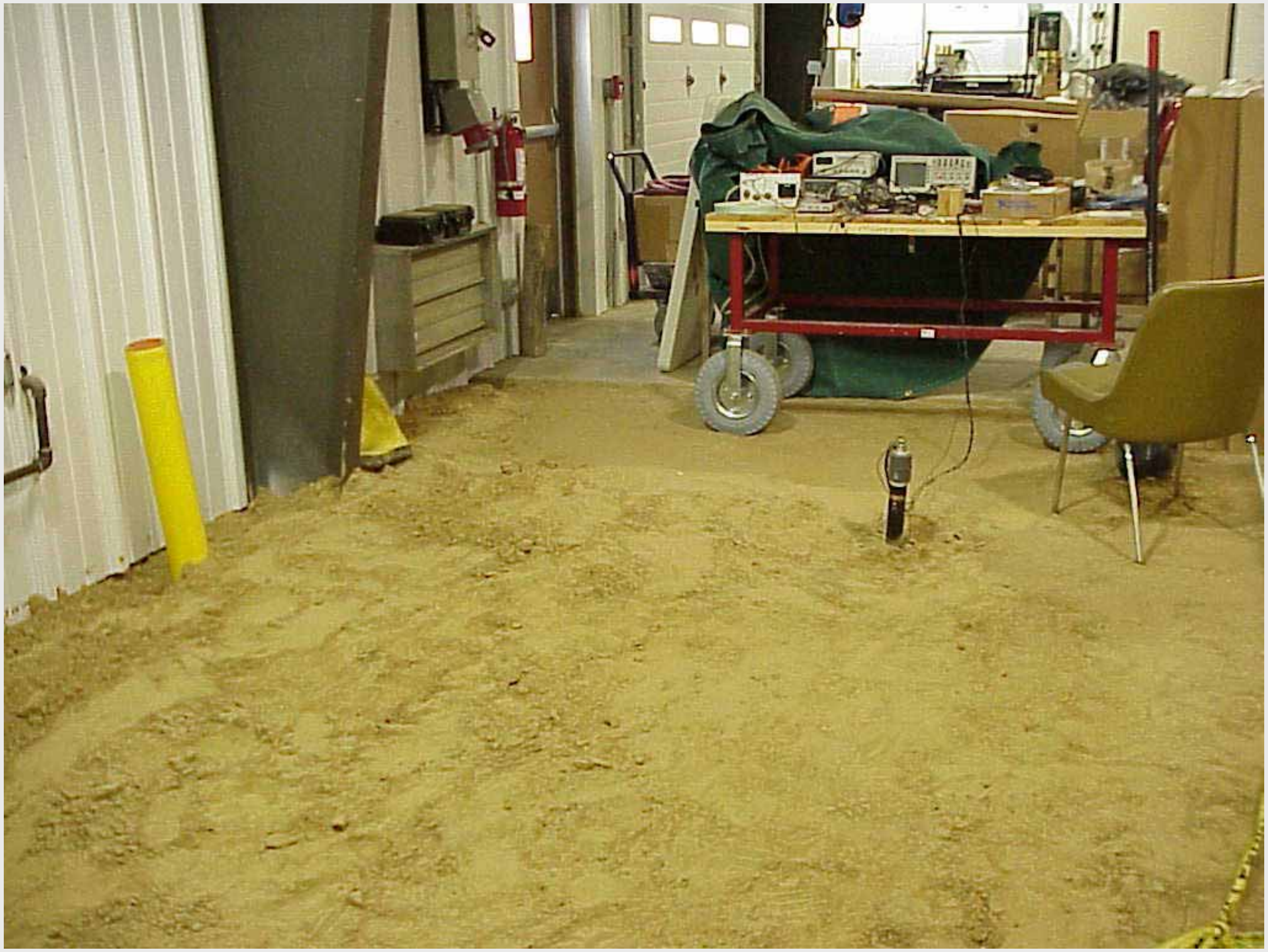


9/3/04 - "balanced" condition



9/3/04 - copper tube by S-

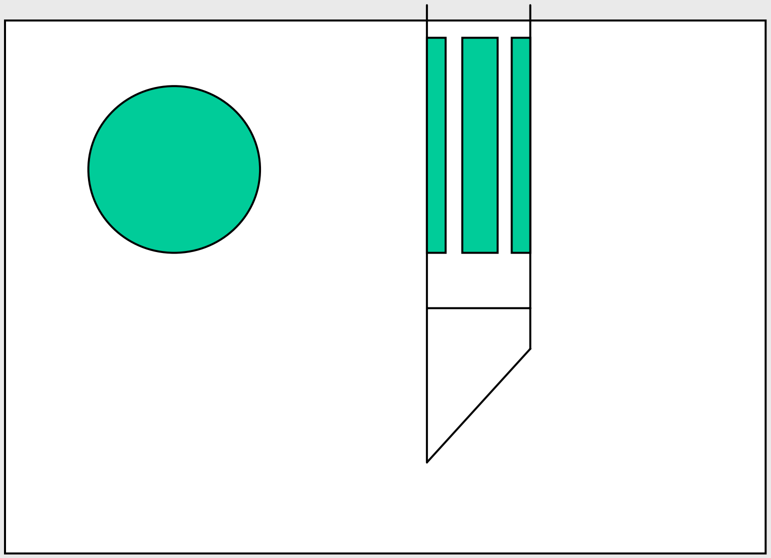
The GTI Pit Lab



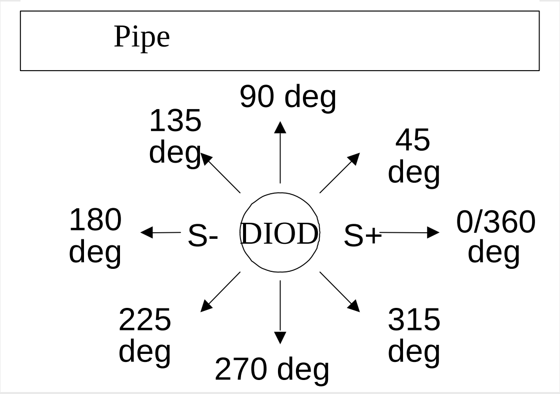
Tests in Loam Soil

> 25 kHz excitation, 4” PE pipe ~3’ deep and 6” from sensor

Side View



Top View



Results From Loam Test

Degrees	Output
0	873 mV
45	-4.68 V
90 (S+ toward pipe)	-4.28 V
135	-4.40 V
180	325 mV
225	4.34 V
270 (S- toward pipe)	5.06 V
315	2.99 V
360	-632 mV

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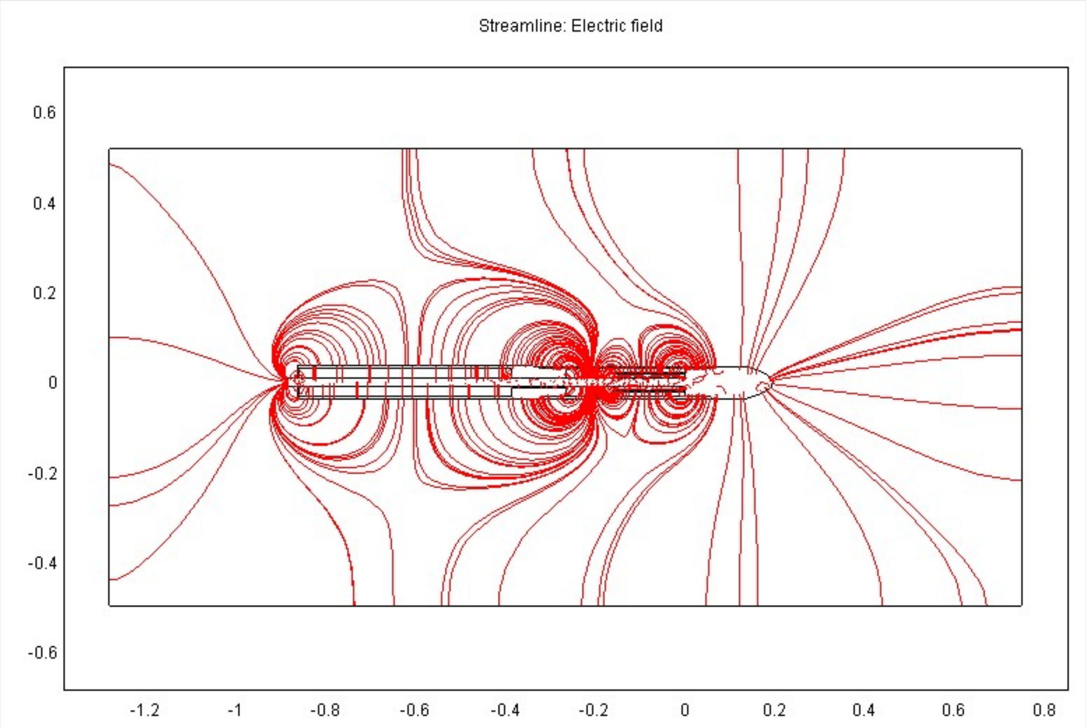
DIOD Phase 1 Lessons

- Contact/repeatability issues between tests in soil
- Sensitivity to objects ahead of sensor tip lower than desired
- Effects of soil characteristics on field lines greater than originally anticipated!!!
- End of Phase 1

DIOD Phase 2

- Currently funded by American Water Works Research Foundation (AWWARF)
- Under consideration for DOT co-funding



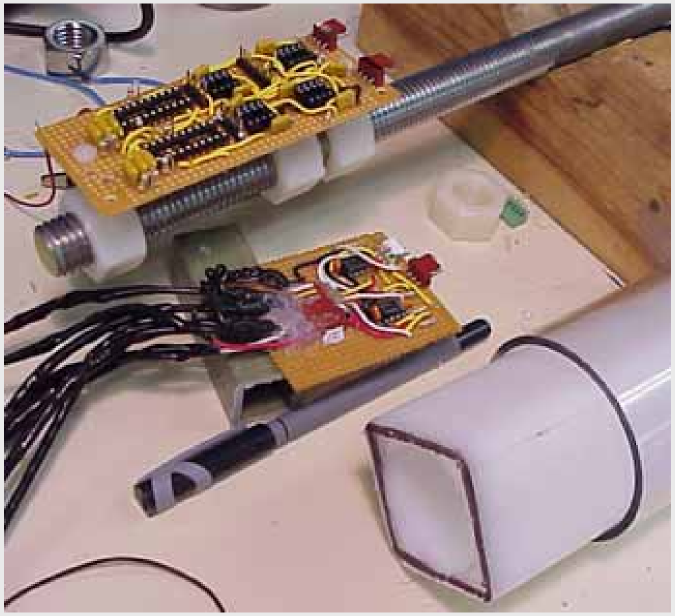
DIOD Phase 2

- Finite element modeling & experiment
  - Model first before cutting metal
  - The TTC at LA Tech may assist GTI in the modeling effort
- Need improvement to forward sensitivity
  - Guard electrode around tip did not help
  - Increasing excitation voltage helped some
  - Current drive versus voltage drive may help

DIOD Phase 2 Near Term

> Replace external circuitry with components that can fit inside pod

> This will reduce cable capacitance and noise pick up



DIOD Conclusions

- Some advantages to DIOD, some negatives
- Combining differential impedance with soils characteristics and the harsh HDD environment is challenging
- There are some modifications to the sense elements yet to be tried

2006 No-Dig Show

- **March 27 in Nashville TN**
- **Max Kieba will be presenting the DIOD in greater depth.**
- **Thank You!**