Capacitive Tomography for the Location of Plastic Pipe

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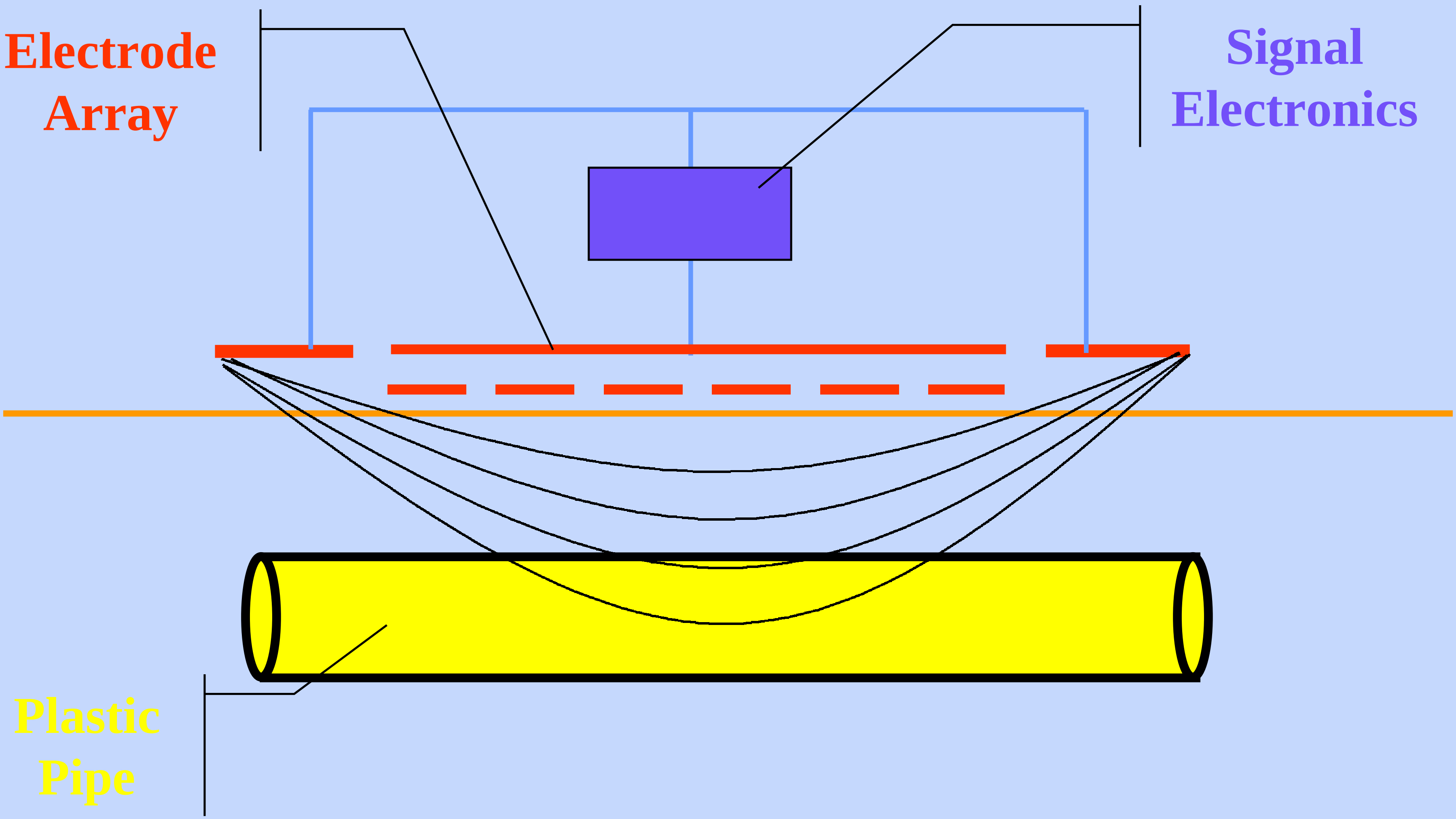
Program Objective

- **Develop a sensing system that can image plastic, ceramic, or metallic piping through common soils**

Key Technical Issues

- Plastics require new methods of subsurface location and imaging
- The installed base of plastic piping is on the increase
- Low-dig installation and repair methods require precise location of facilities

CT Concept



Why Capacitive Sensing?

- Will sense objects with different dielectric properties than soils – not specific to metals.
- Very simple flat plate sensing array.
- One sensor array is operable over a wide range of frequencies.
- Plate spacing, not frequency determines resolution.

Simple CT Has Been Demonstrated

- A two-plate capacitive bridge sensor located plastic pipe in a GTI supervised test.
- The device was about the size of a lawn mower and was moved by the operator to scan the area.
- This device was demonstrated by J. Tuttle of the Aberdeen Proving Ground.
- The basic patent is assigned to the U.S. Government.

Equivalent Circuit from Tuttle Patent

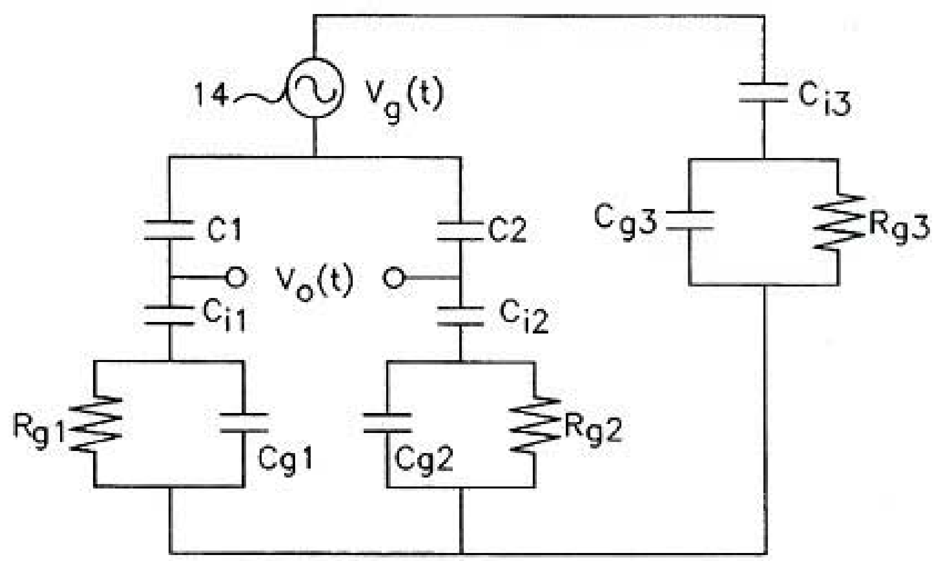


FIG. 4

Scope of Work - Tasks

- 1. Research Management Plan
- 2. Design and Prototype Sensor Array
- 3. Design and Prototype Support Electronics
- 4. Construct Field-Ready Mat Prototype
- 5. Demonstrate Mat Sensor Prototype

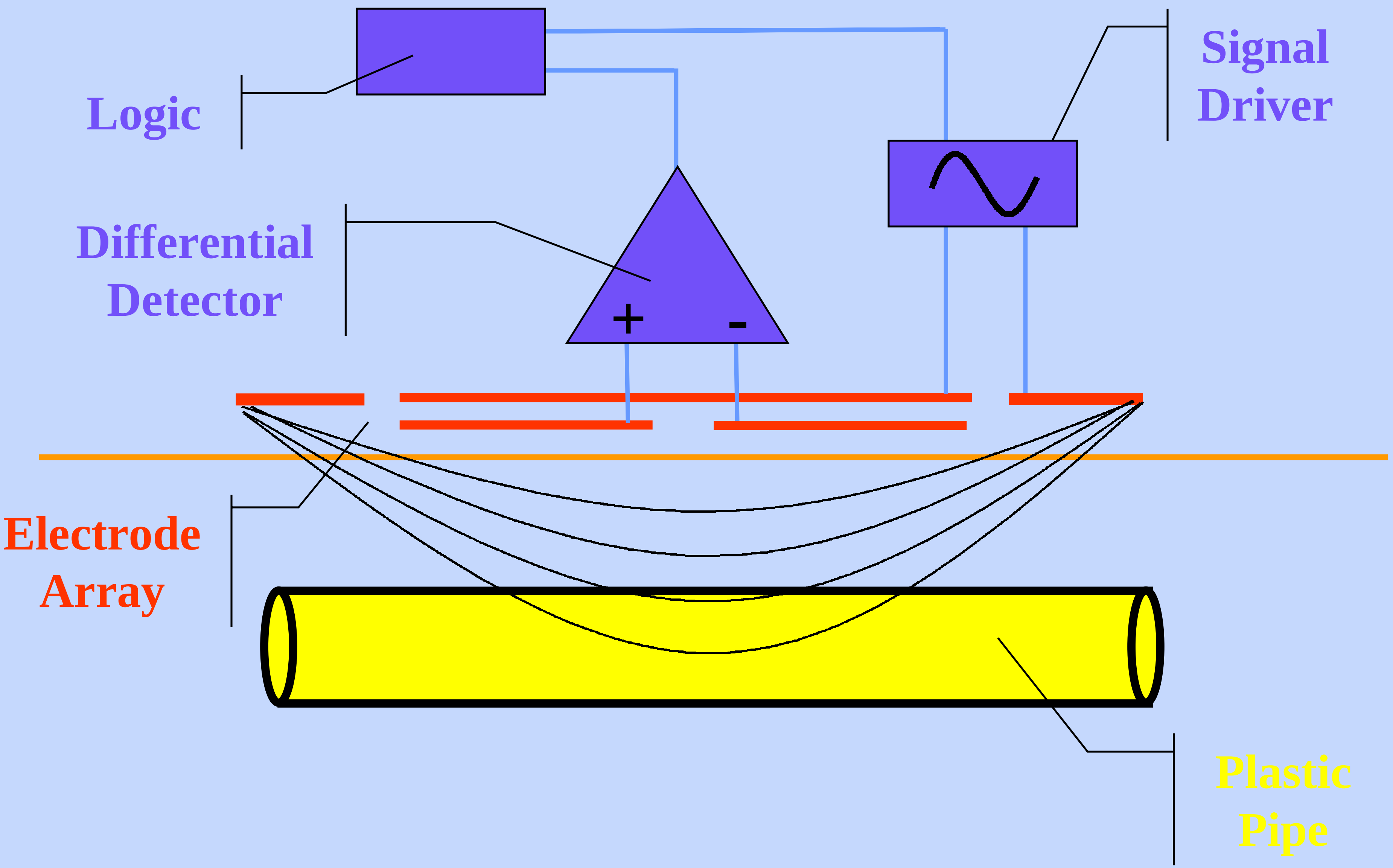
Task 1. Research Management Plan

- Research Management Plan
- Kick-Off Meeting – November 2001
- Technology Assessment
- Three Quarterly Technical Reports
- Three Presentations

Task 2. Design & Prototype Sensor Array

- The initial array was 4 elements for proof of concept.
- Higher order arrays can readily be fabricated using circuit board technology
- GTI is currently working with a 16 element array.
- Flexible circuit board technology will be evaluated for applicability

CT Detail of One Electrode Pair



Task 3. Design & Prototype Support Electronics

- The 4-element array was tested with bench electronics.
- Higher order arrays require multiplexing in order to keep cost & complexity down.
- All signal processing will be at low frequencies, reducing hardware cost & complexity.
- Use LabVIEW front end to keep GUI cost & development time under control.

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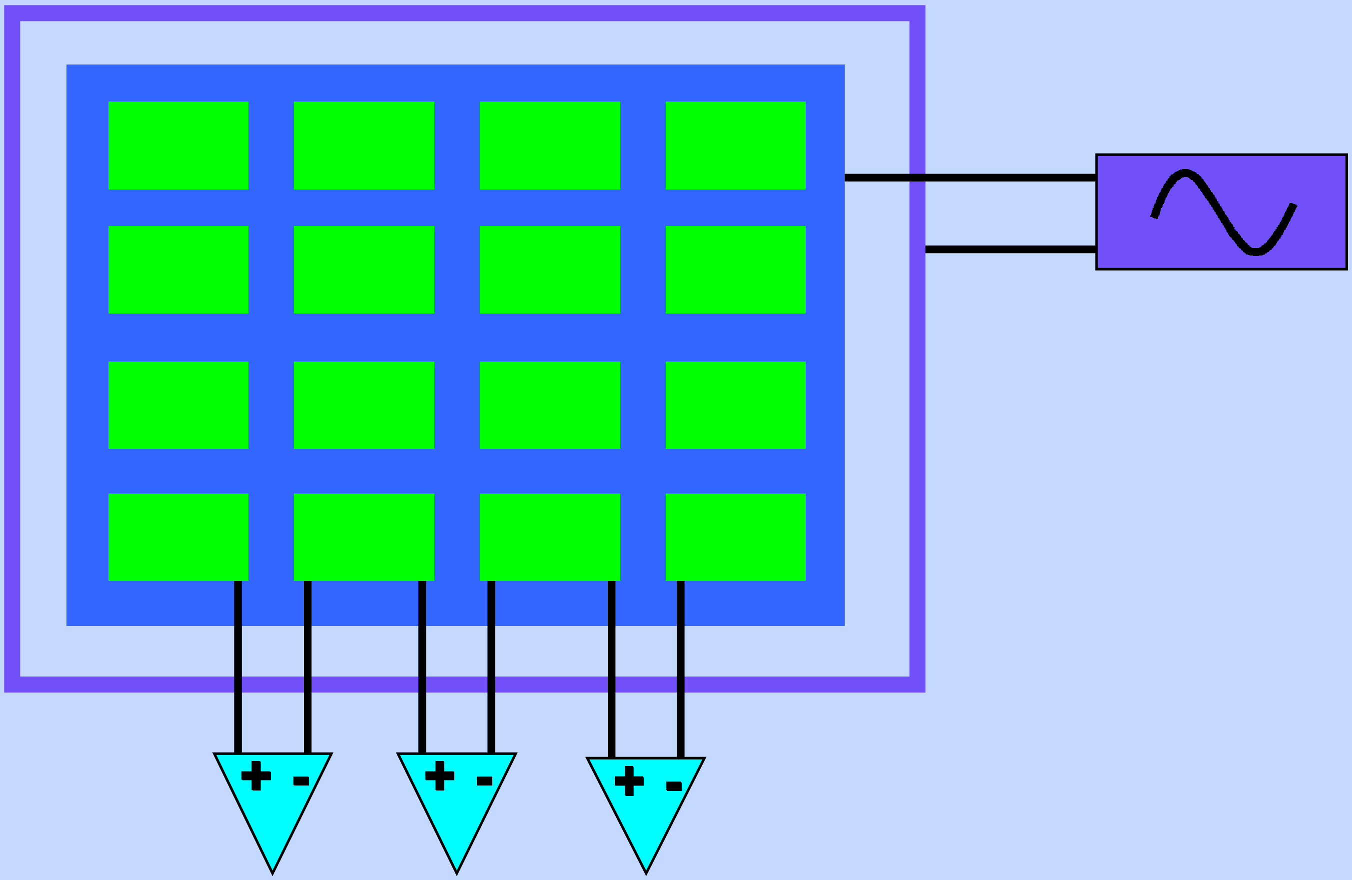
Multi-Element Array



Task 4. Construct Field-Ready Mat Prototype

- The sensor & support electronics must be field-hardened sufficiently for field testing.
- Power consumption must be managed for good battery life.
- Connector systems for field use require special attention.
- In general, the package must make a good impression on the field crews, even at the prototype stage.
- This unit will be tested on GTI pipe farm prior to any public demonstration,

Task 5. Demonstrate Mat Sensor Prototype

- **GTI will schedule and coordinate a field test with a gas distribution utility.**
- **Several of our utility contacts have demonstrated interest in hosting a test.**
- **GTI personnel will transport, set-up, and demonstrate the mat sensor prototype.**
- **GTI will collect and report feedback from the field crews.**

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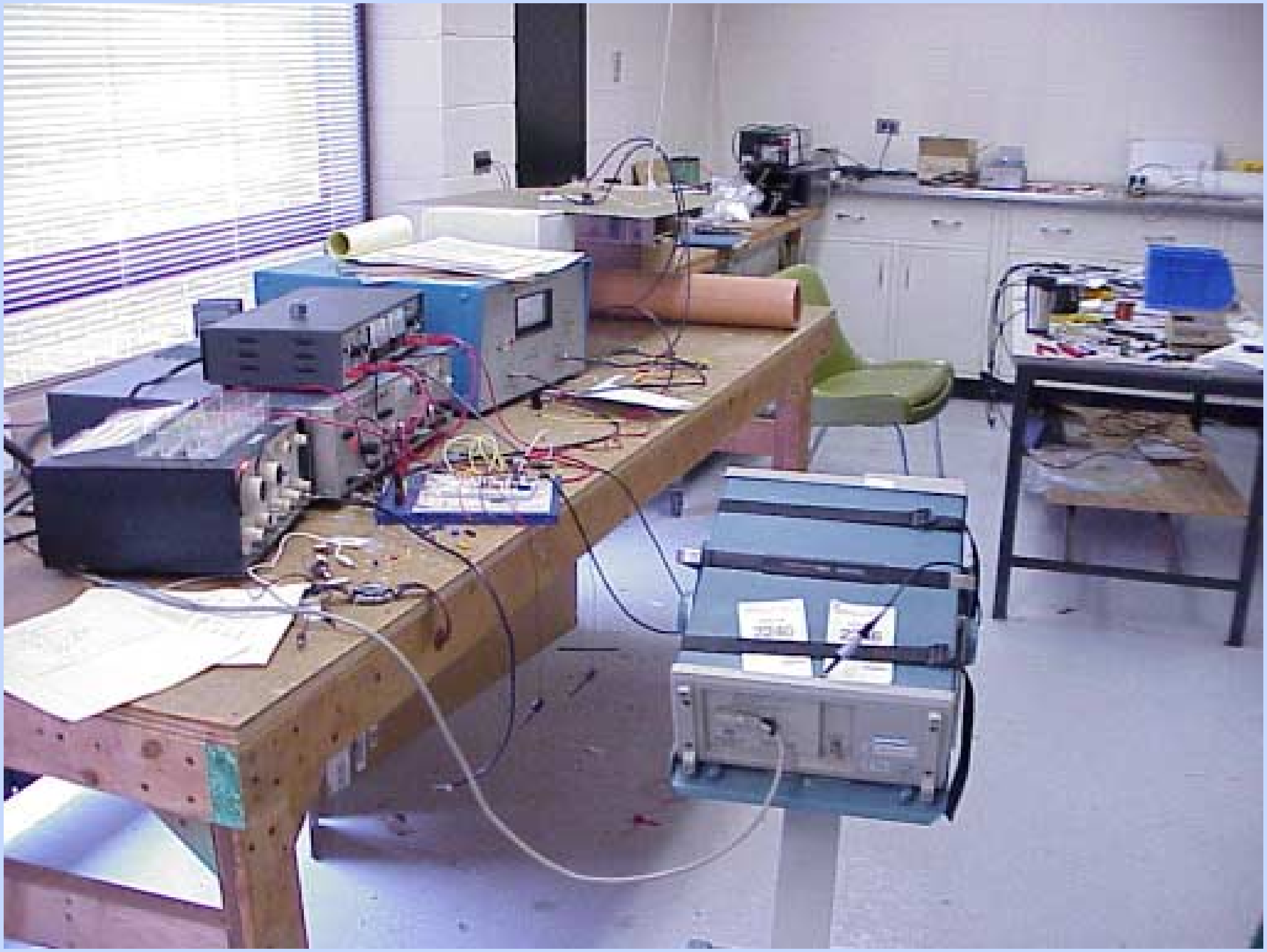
Task 2 Progress with 4-Element Array

- **Several 4 element arrays have been fabricated.**
- **The instrumentation to evaluate these arrays was primarily analog.**
- **The array demonstrated sensitivity to PE in the lab.**
- **As predicted, the sensitivity was even greater with PE in the indoor soil box.**

4 Element Array Fabricated on PC Board

Laboratory Set-Up to Evaluate 4-Element Array



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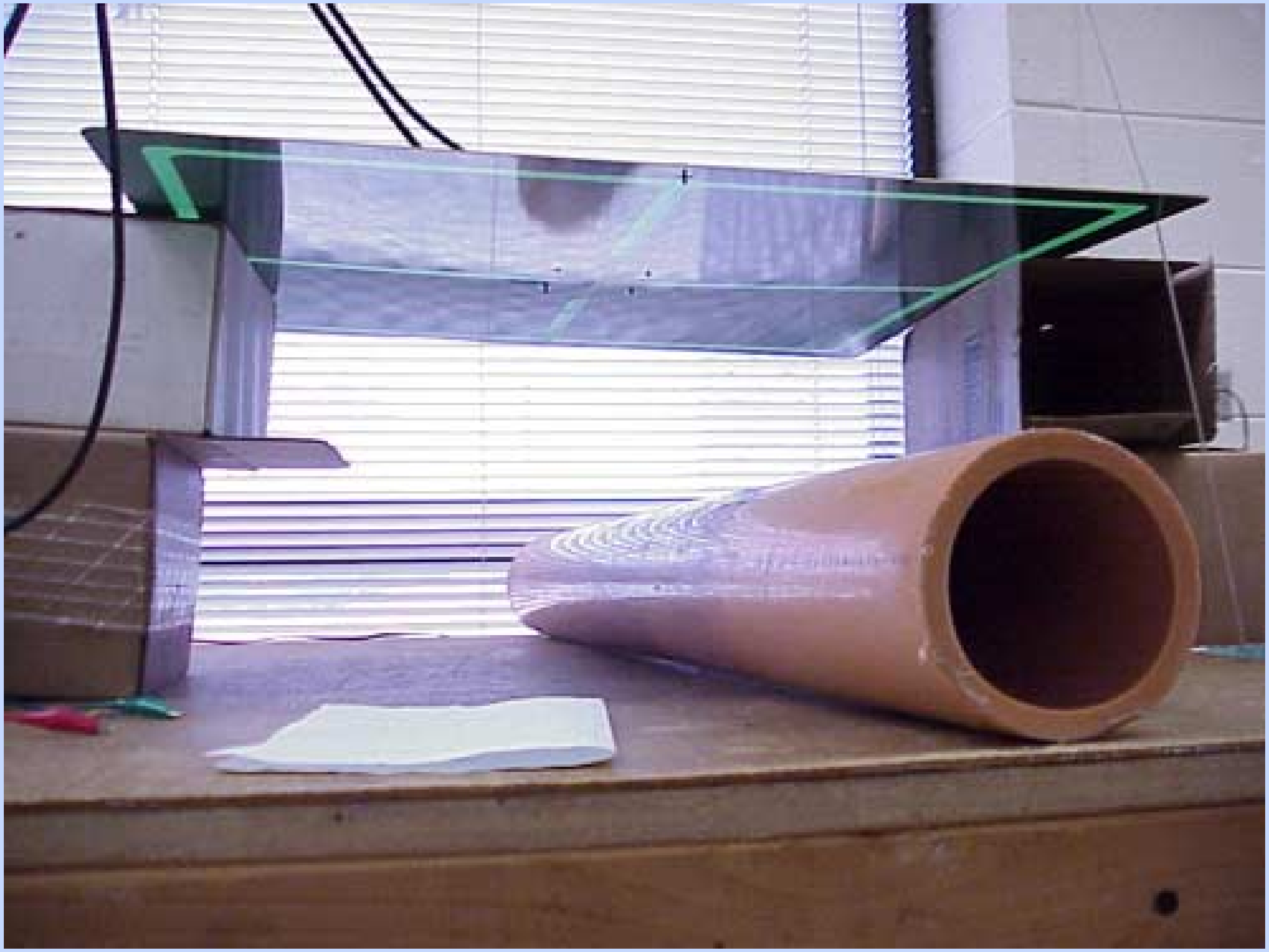
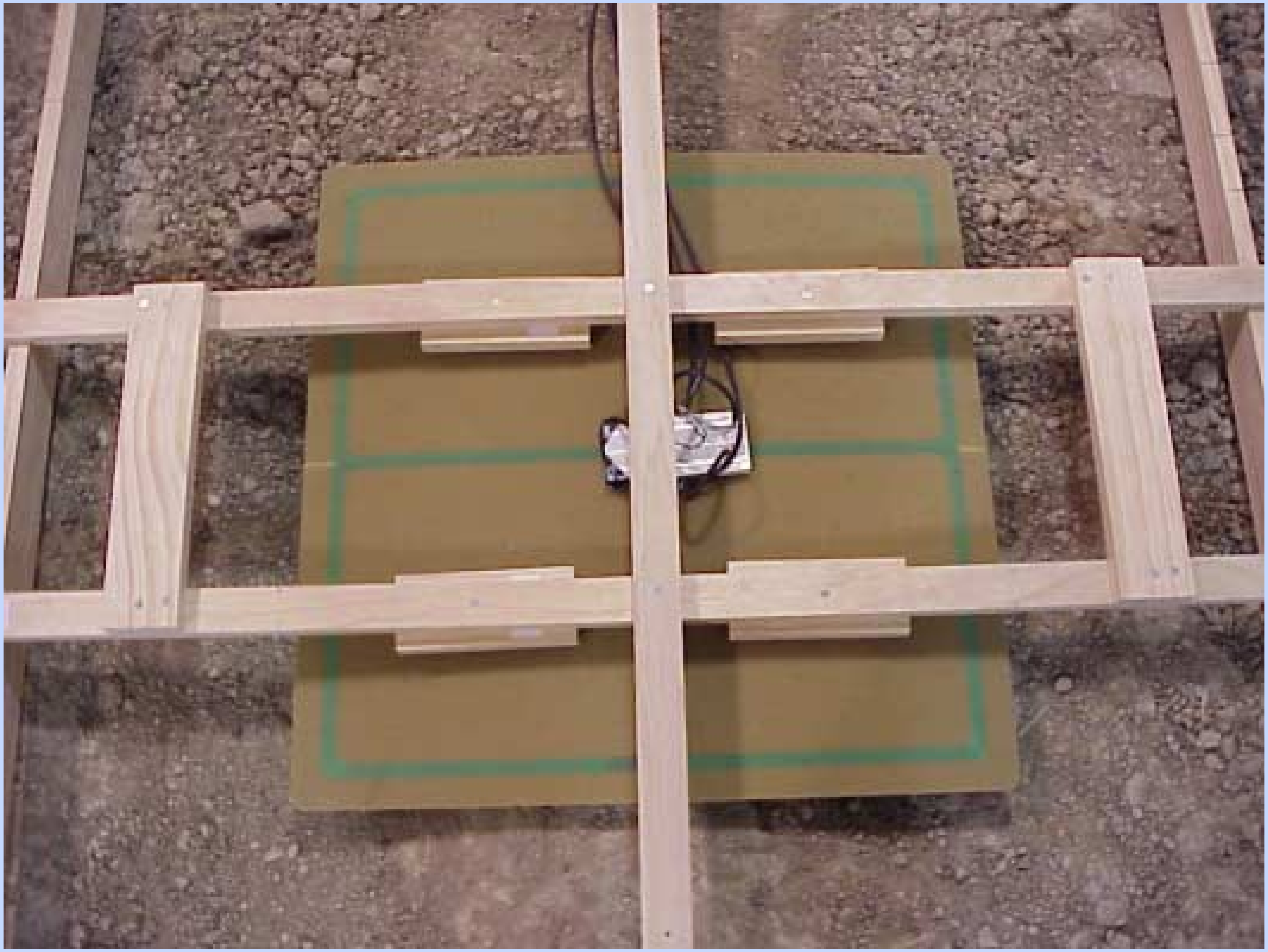
PE Pipe Beneath Array



View of Array on Indoor Soil Box

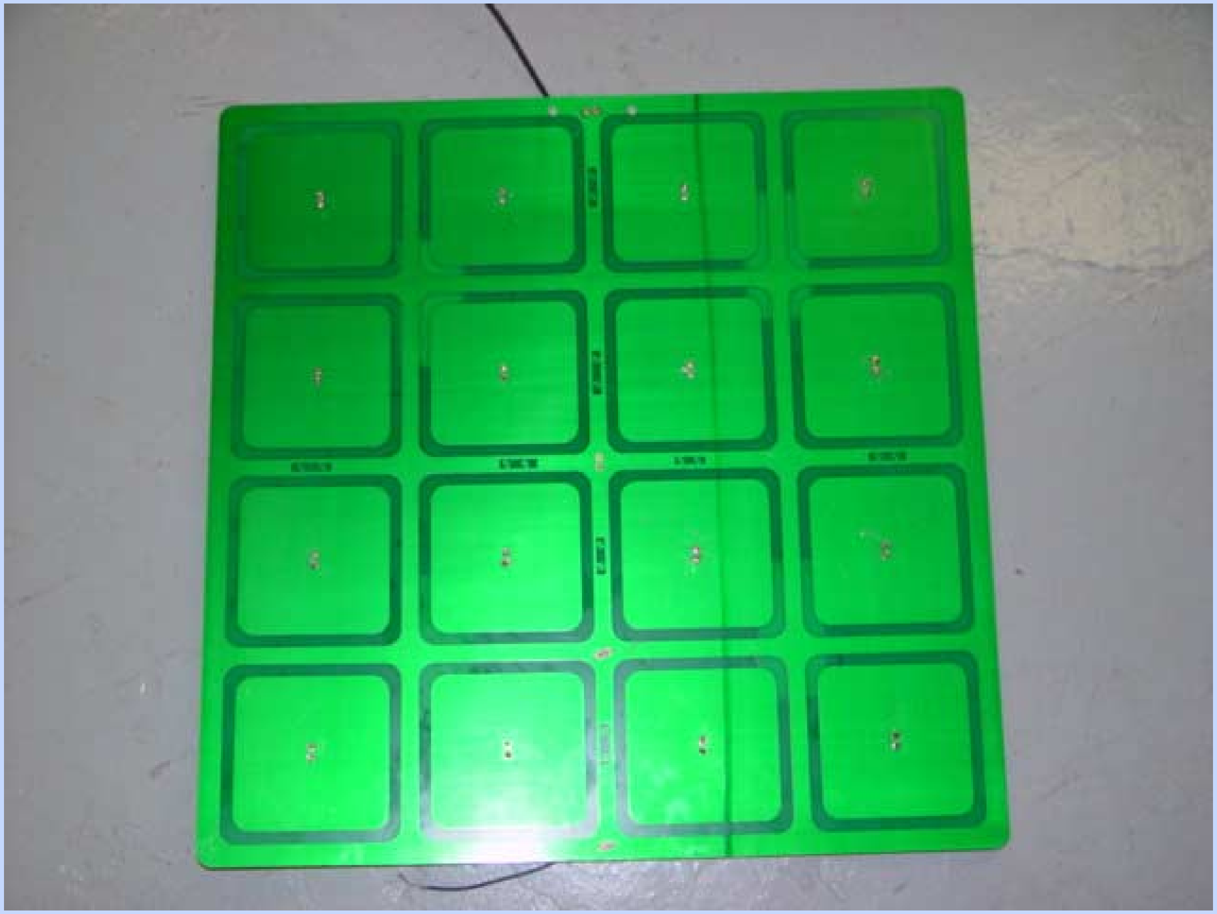
Close-up View of Array on Slider



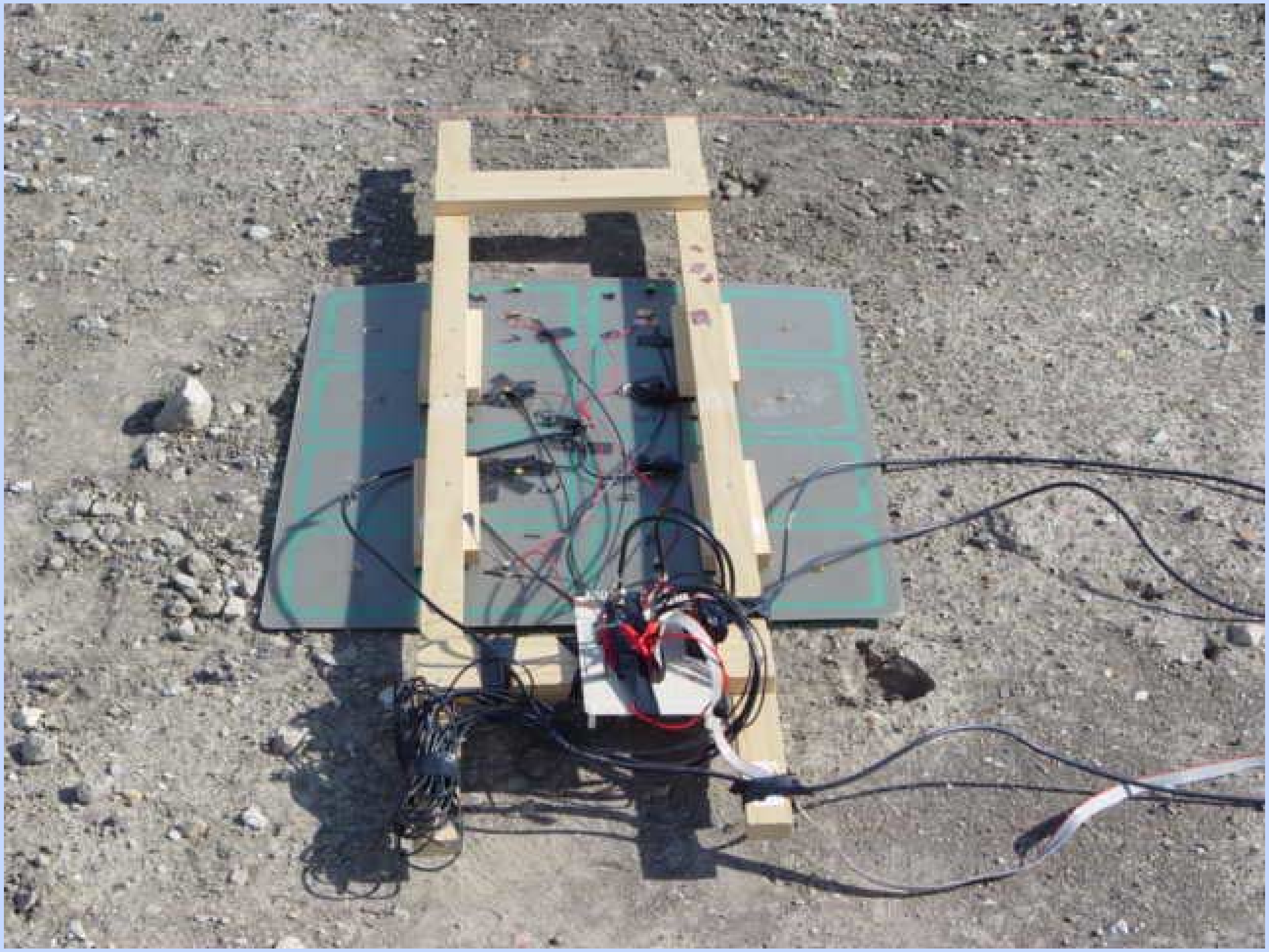
Task 2 Progress with 16-Element Array

- **Several 16 element arrays have been fabricated**
- **The instrumentation to evaluate these arrays is primarily PC based due to the need for multiplexing**
- **The sensitivity to plastic pipe is still very good with the smaller size of individual elements**

A 16-Element Array Fabricated on PC Board



16-Element Array and Multiplexer Under Test



Task 3. Progress – Support Electronics

- **Analog support electronics was used for initial tests of 4-element array.**
- **LabVIEW is being used to test signal processing and develop graphical user interface.**
- **A multiplexer was constructed to interface the 16-element array to the PC.**

Data Acquisition Station running LabVIEW

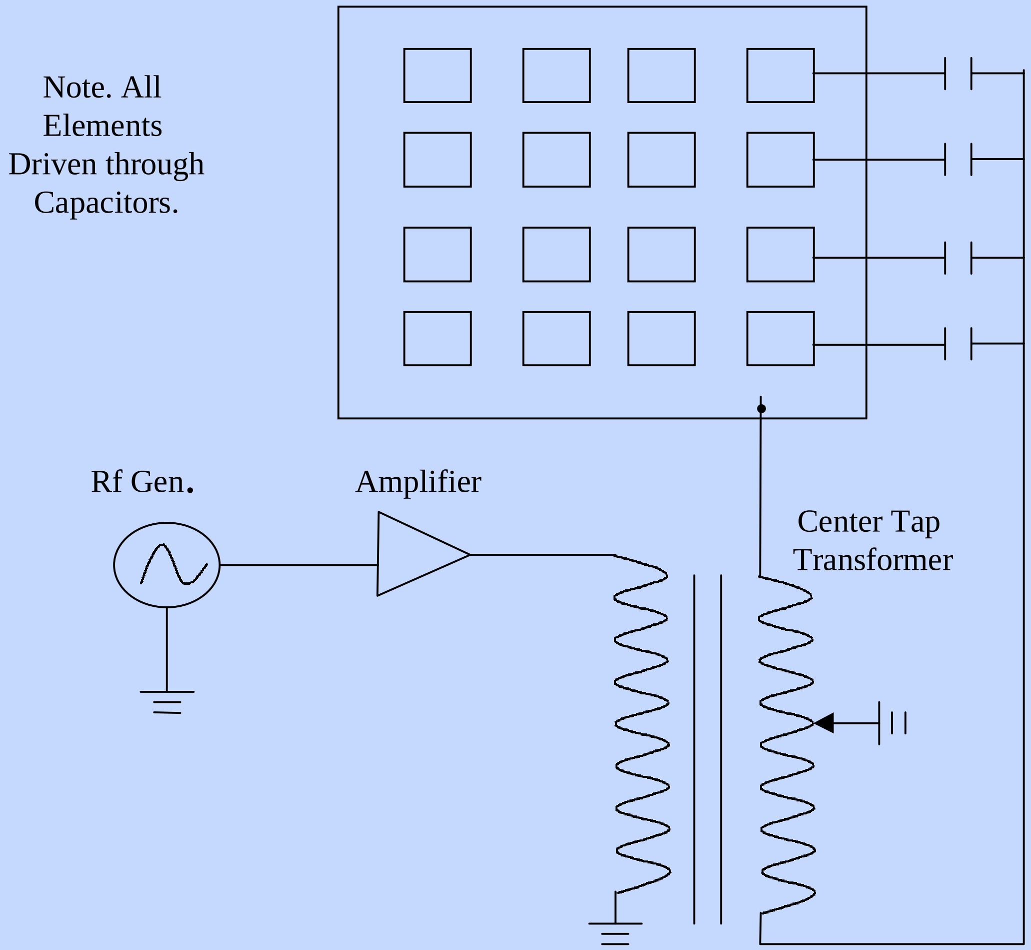
Sensor Array & Multiplexer tested on Pipe Farm

Task 4. Progress on Field-Ready Prototype

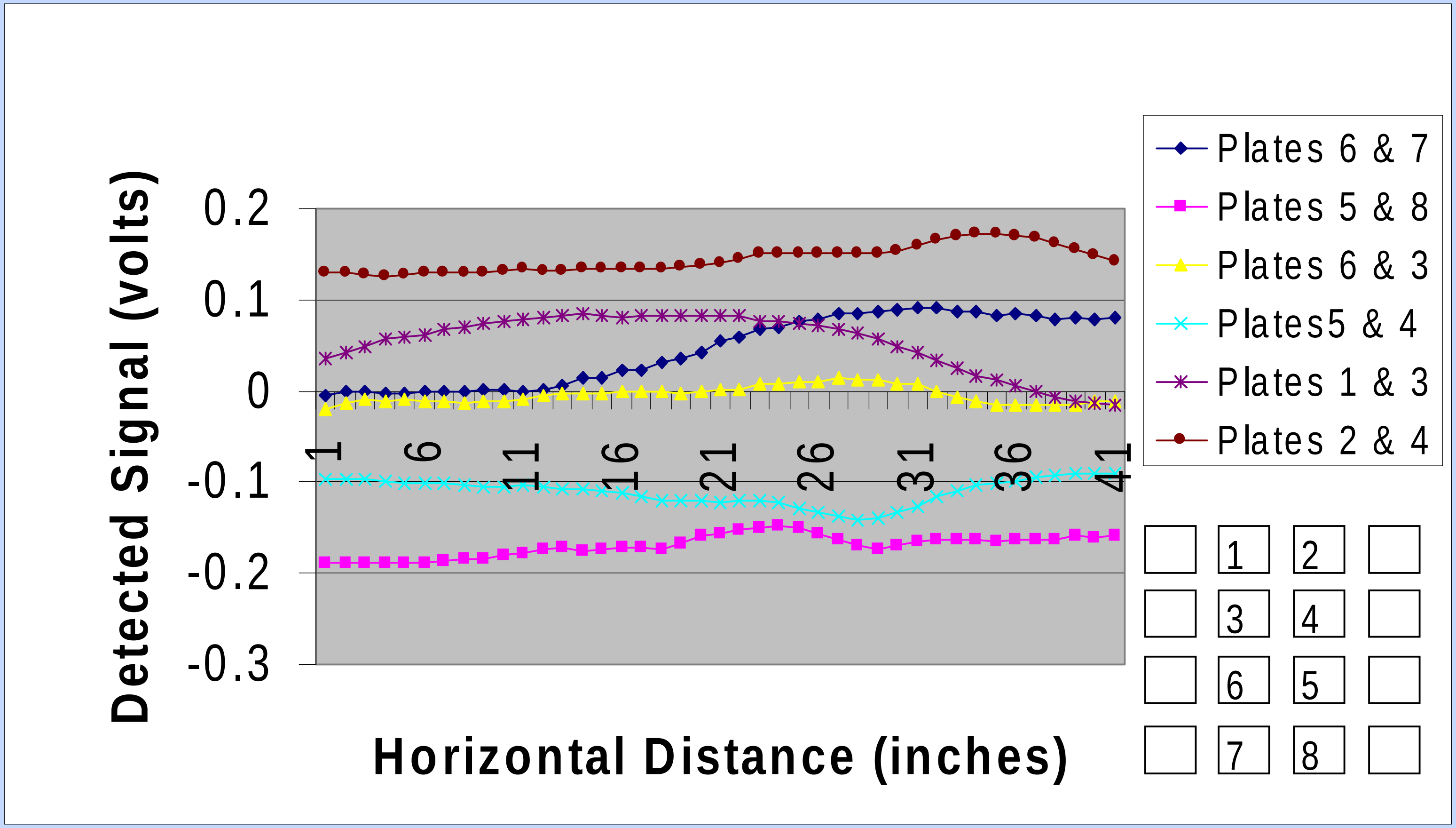
- **An area of the GTI Pipe Farm has been set aside for this project.**
  - Three, 100’ runs of PE pipe were installed.
  - The PE pipes are 2”, 4”, and 6” in diameter.
  - Burial depth varies from 5’ to 0’ over the length
- **The excitation drive circuitry has been modified to minimize the size and power consumption.**

Installation of PE Pipe for CT Experiments

Detail of Drive Circuitry



Detected Pipe Signal Levels



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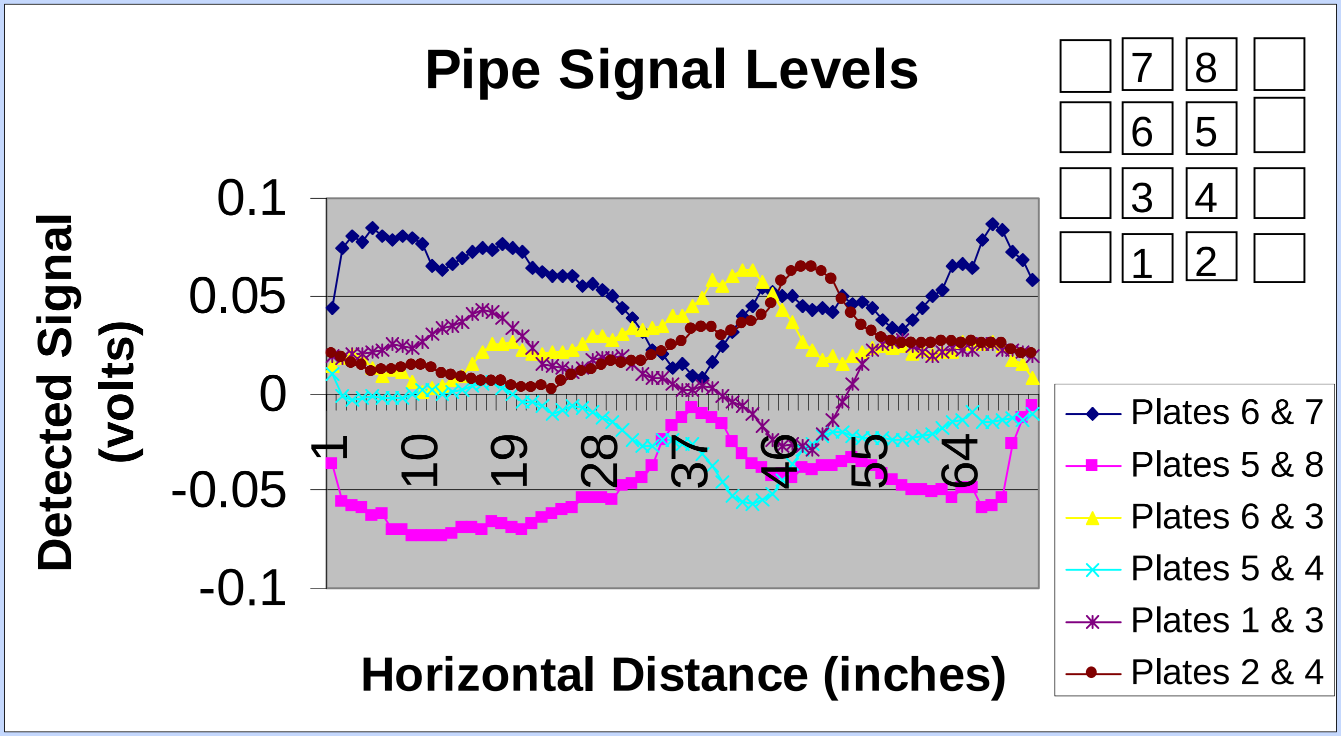
SIX INCH PLASTIC PIPE AT DEPTH OF 4 FT.



Summary

- CT can detect plastic pipe in wet soils.
- Resolution is limited by electrode size, not wavelength, unlike GPR.
- The sensor was successfully transitioned from 4 to 16 elements.
- The signal to noise ratio is sufficient to make the elements smaller still.

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