INNOVATING NUCLEAR TECHNOLOGY

ANALYSIS AND MEASUREMENT SERVICES CORPORATION

# EMC Troubleshooting in Nuclear Instrumentation Systems

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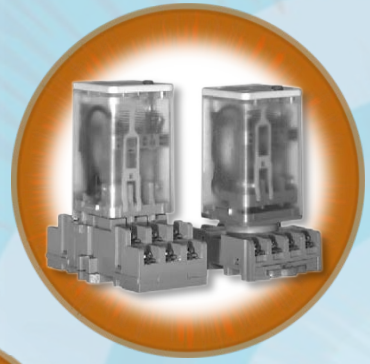
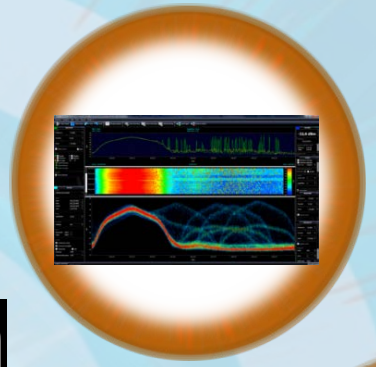
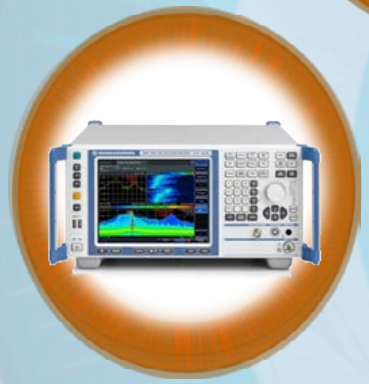
# What is Electromagnetic Compatibility?

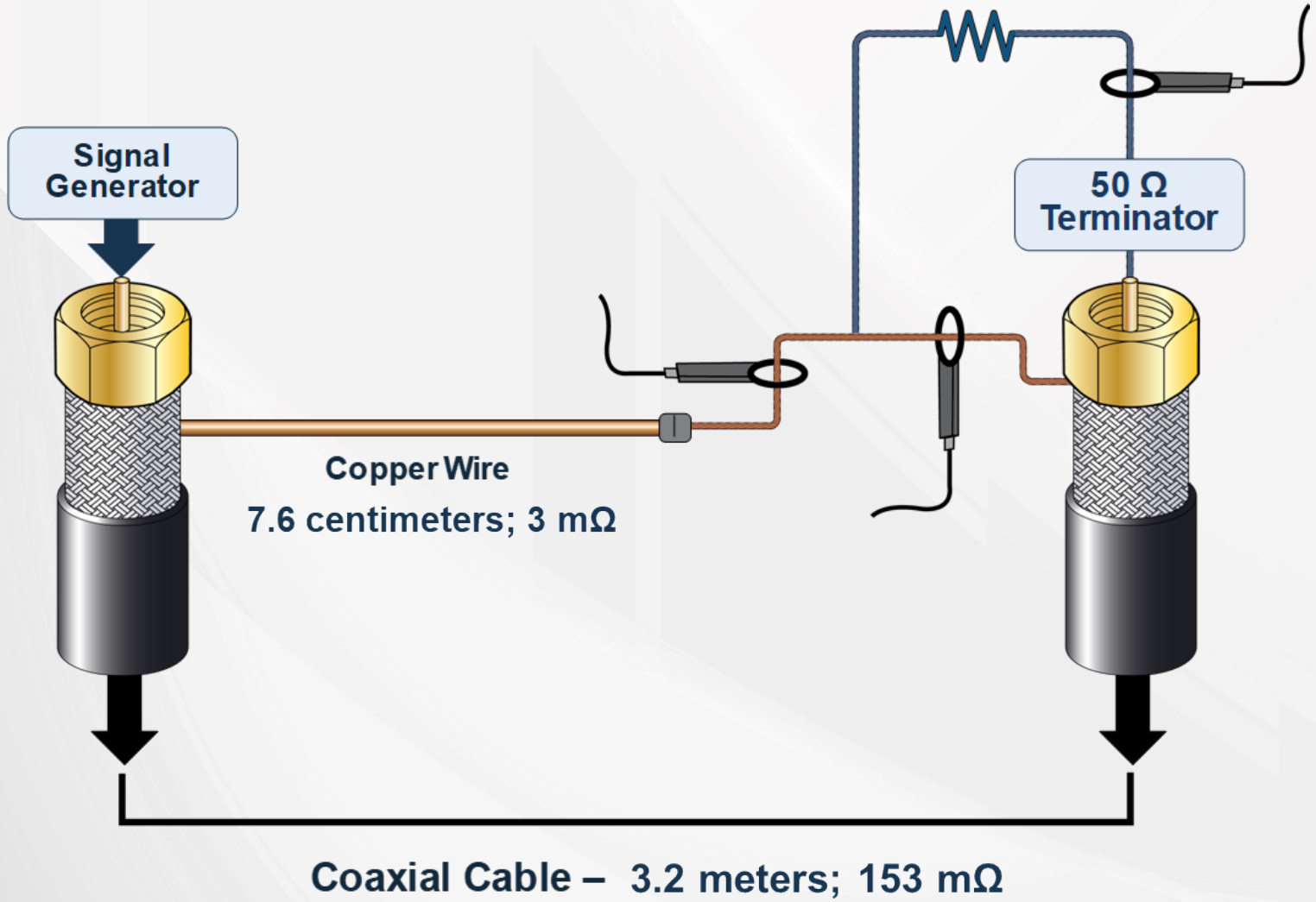




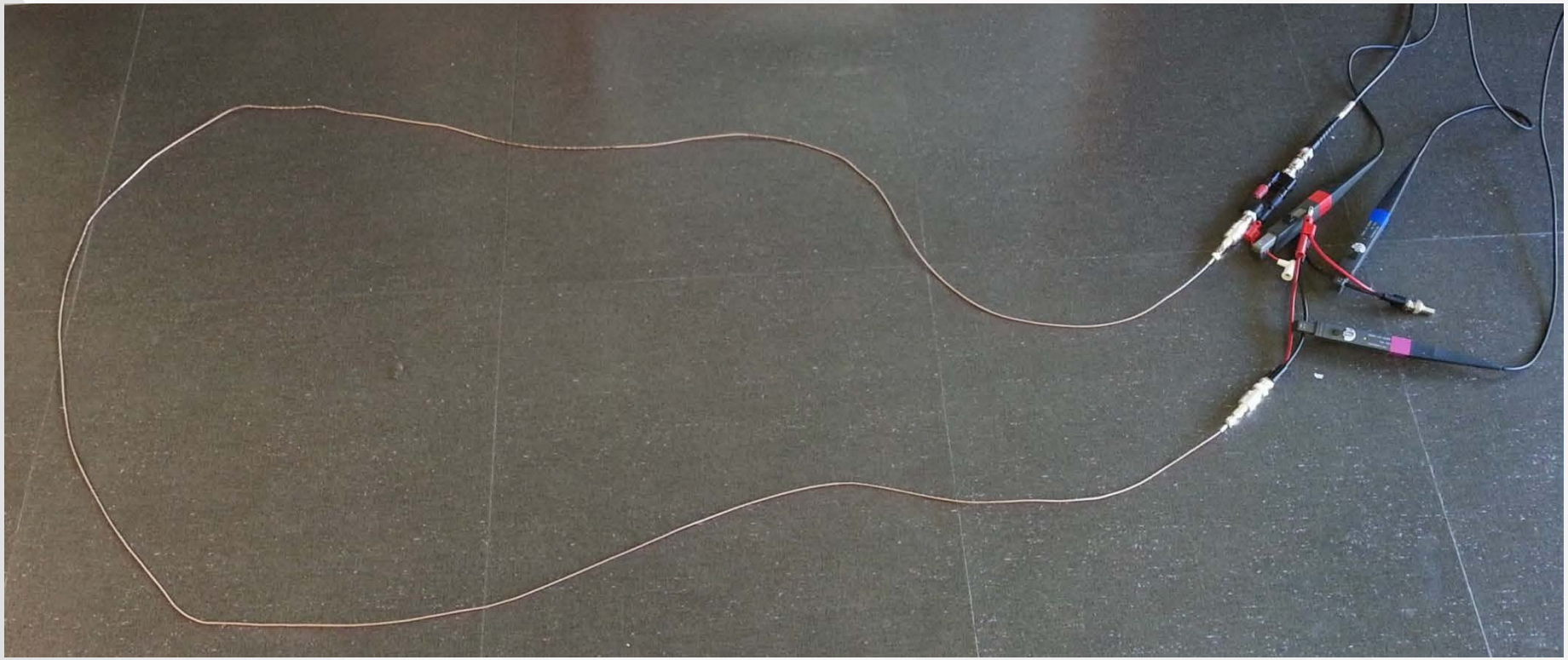


EMC


# Myth: Noise Takes Path of Least Resistance

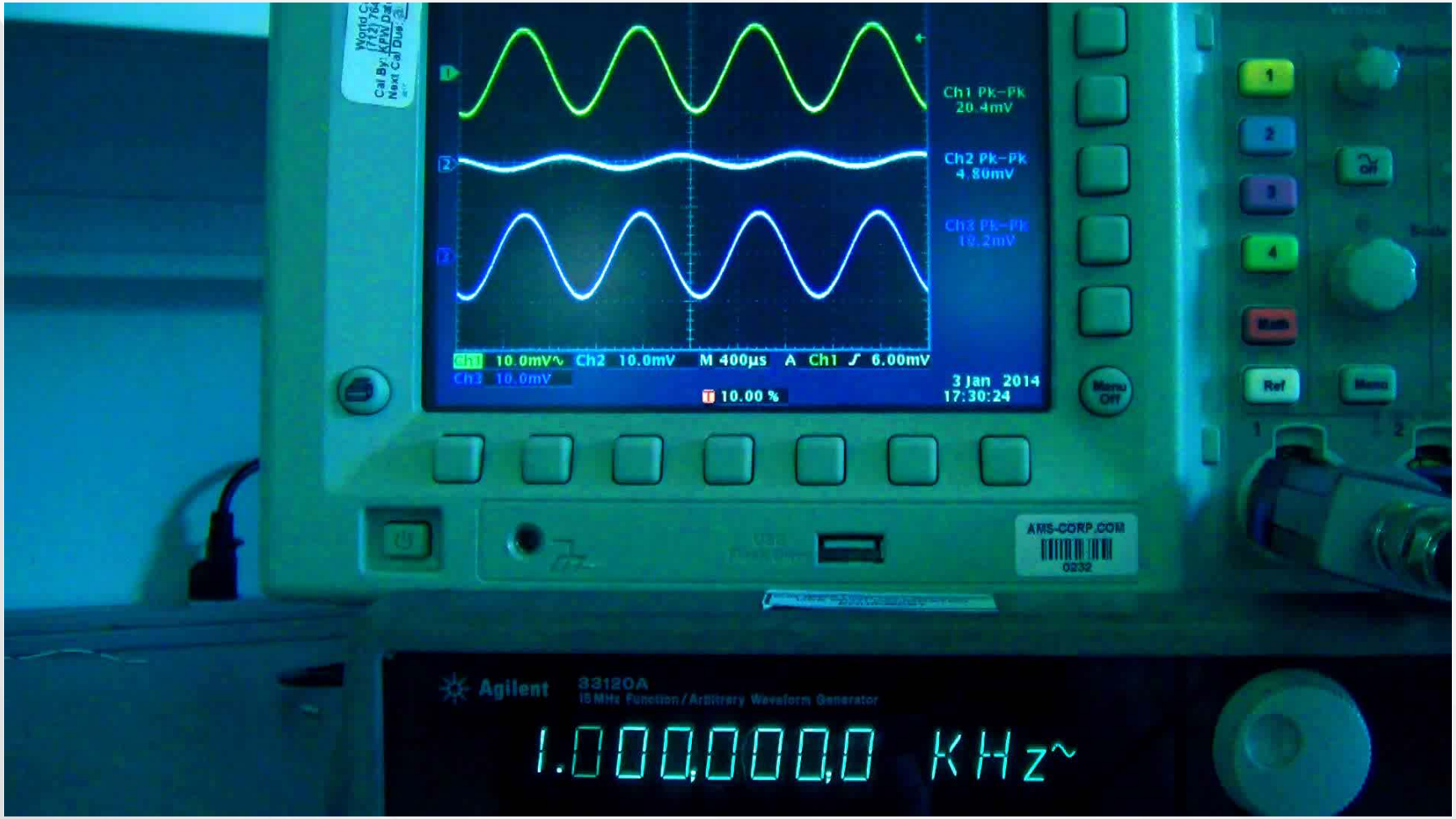


# Where Does Current Flow?



**Cable Length – 10.5 feet; 153 mΩ**
**Short section – 3 inches;  3 mΩ**

# Video: Resistance vs. Impedance



# Standards Used for EMC Qualification

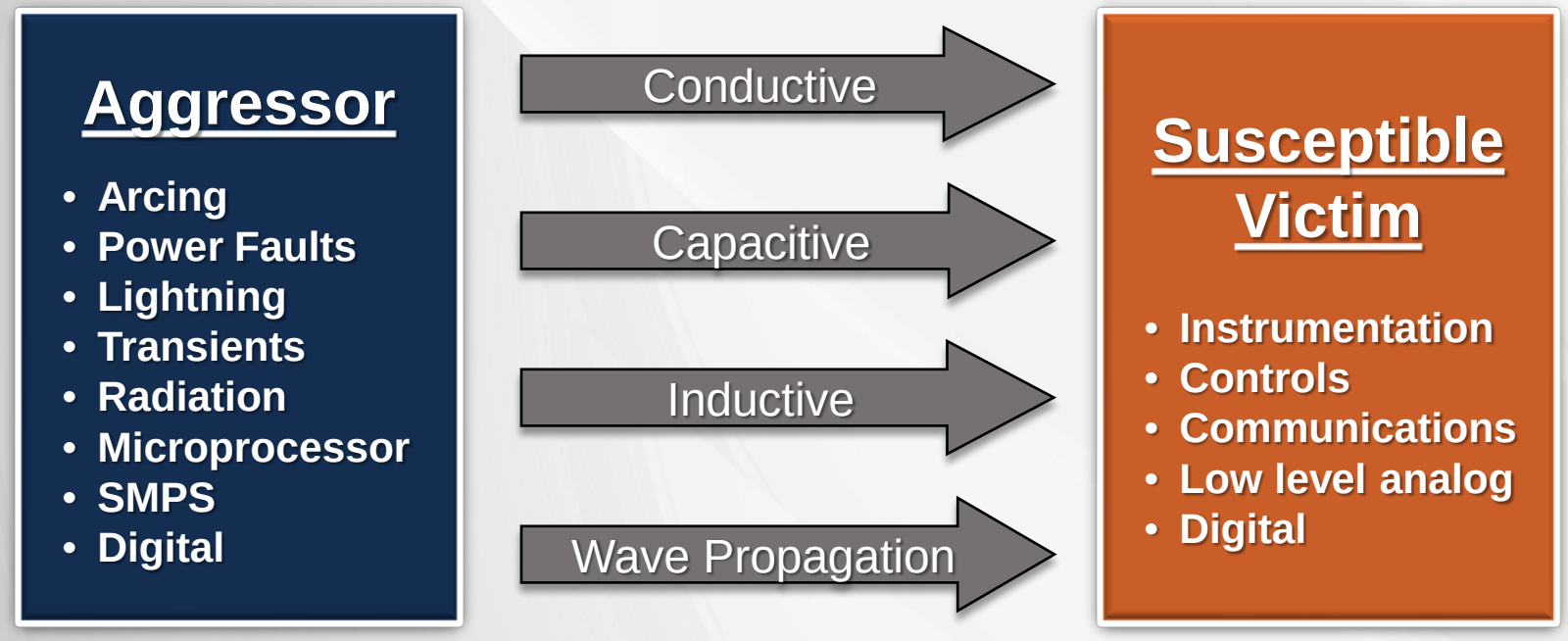
- **Nuclear Regulatory Commission (NRC)**
  - Regulatory Guide 1.180 Rev 0,1,2
- **Electric Power Research Institute (EPRI)**
  - Topical Report TR-102323 Revisions 0,1,2,3,4,5
- **IEC 62003 Revision 1**
- **IEEE P2425 – Under Development**
- **Military Standards**
  - MIL-STD-461 E,F,G
- **International Standards**
  - IEC 61000 and CISPR
  - IEEE

# If It Passes EMC Testing, Then No Issues Will Occur

## WRONG!

- EMC does not test for everything
- EMC tests for one type/frequency of EMI/RFI at a time
- Does it verify EMC for all modes of operation?
- Was it tested for all possible use cases?
- Does the installation match the test setup?
- System components can degrade over time

# What is an EMC issue?




1. System or equipment that is a source (Aggressor) of the Interference
2. System or equipment that is susceptible (Victim) to the Interference
3. Coupling (Path) conducted or radiated

**Must have all three components for EMI to occur**

# Types of Electromagnetic Energy

- Emissions vs Immunity (Susceptibility)
- Transient vs Steady State (Continuous Wave)
- Conducted vs Radiated
- Low Frequency vs High Frequency
- Electric Field vs Magnetic Field
- Destructive vs Non-Destructive??
- Common Mode vs Differential Mode

# EMI Problem Determination

- You probably have an EMI problem if:
  - The circuit checks out functionally before and after the incident
  - Independent circuits actuated simultaneously (a plus if in the same area)
  - Incident is over in milliseconds
  - Circuit has history of sensitivity to position of cables, grounds or people
  - Incident coincides with power off/on action
  - High level EMI can be observed

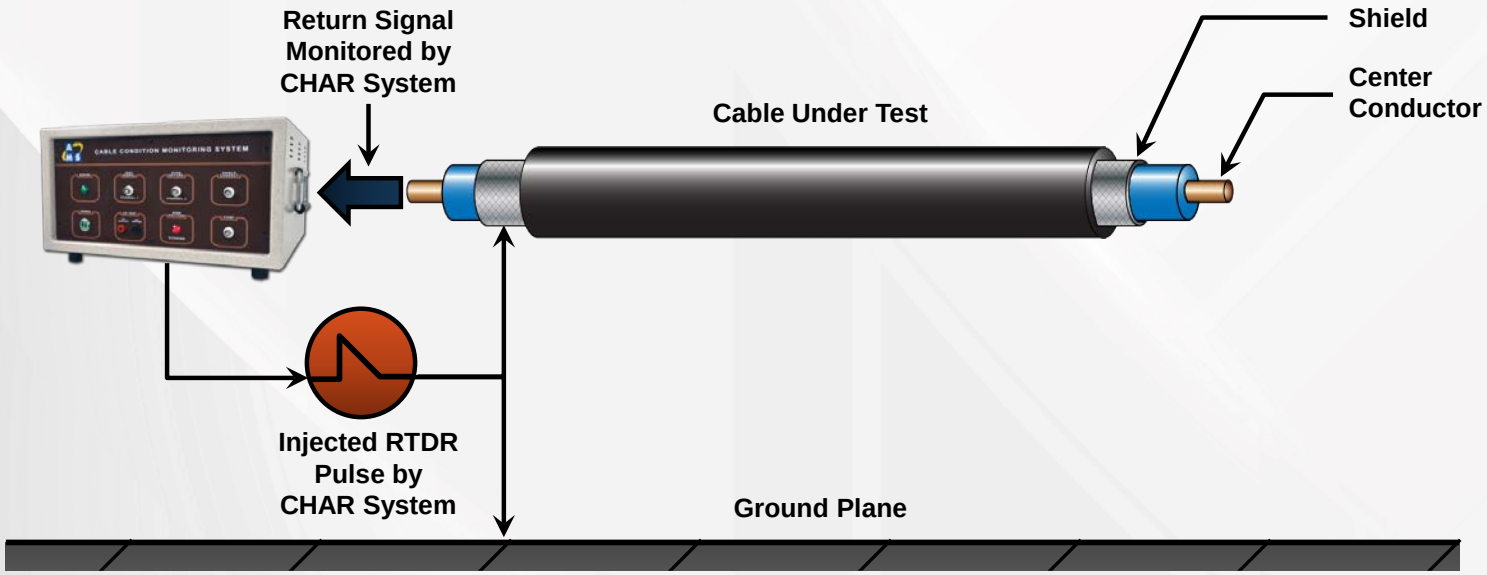
# Systematic Approach to Solving EMI Problems

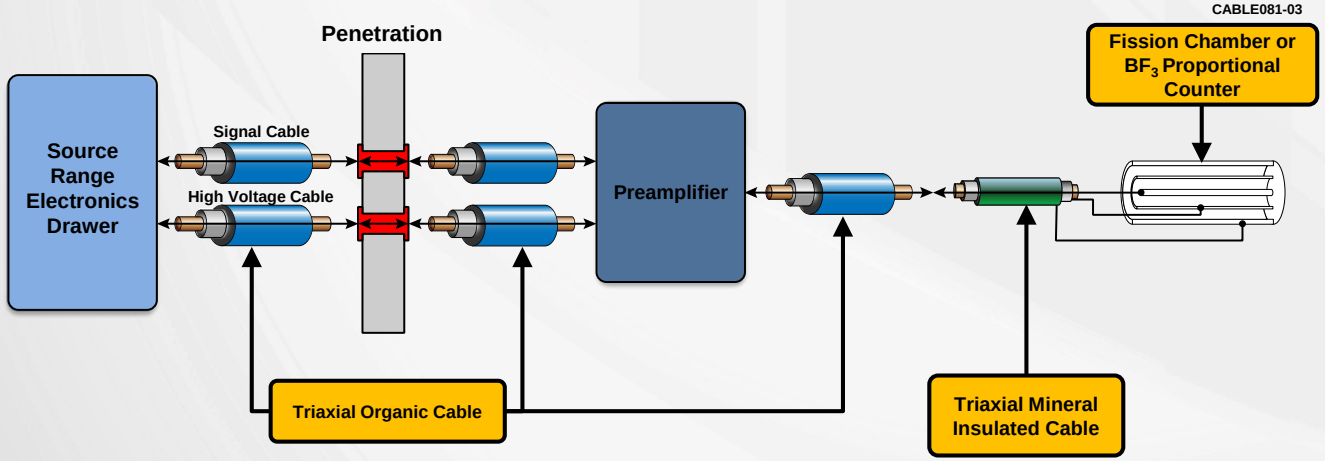
- Define the problem
- Gather information
- Focus on the weak link
- Develop an interference model
- Prepare a test plan and use it to measure EMI levels
- Obtain accurate & reliable test data
- Evaluate test data
- Design and implement fixes

# RTDR is a Powerful Troubleshooting Tool

- **Reverse TDR (RTDR) is a shield integrity test**
- **The RTDR test injects noise on the exterior of a cable and monitors the normal signal path for interference**
- **Degraded cable shield connections allow EMI to enter into a cable**
  - EMI can then be amplified by normal circuitry and interpreted as a valid signal
- **Velocity of propagation and time delays are used to determine the distance to the point of intrusion**
- **Standard TDR signatures are used to determine the location of degraded cable connections**

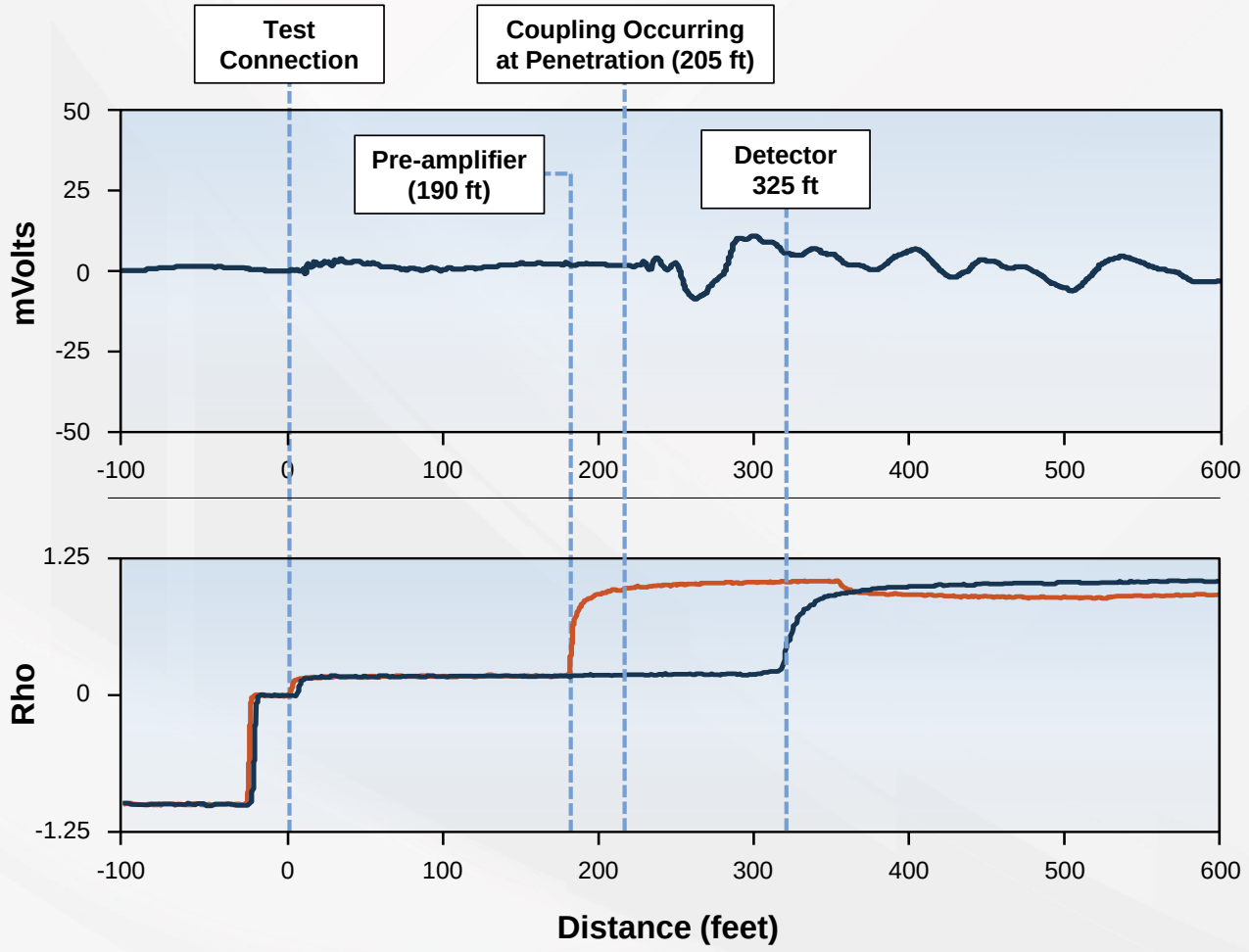
# RTDR Detects EMI / RFI Noise Susceptibility in Shielded Cables



# Analyzing RTDR Data

- **Identify Location of Coupling Point by Comparing Distance to the Normal TDR Signature**



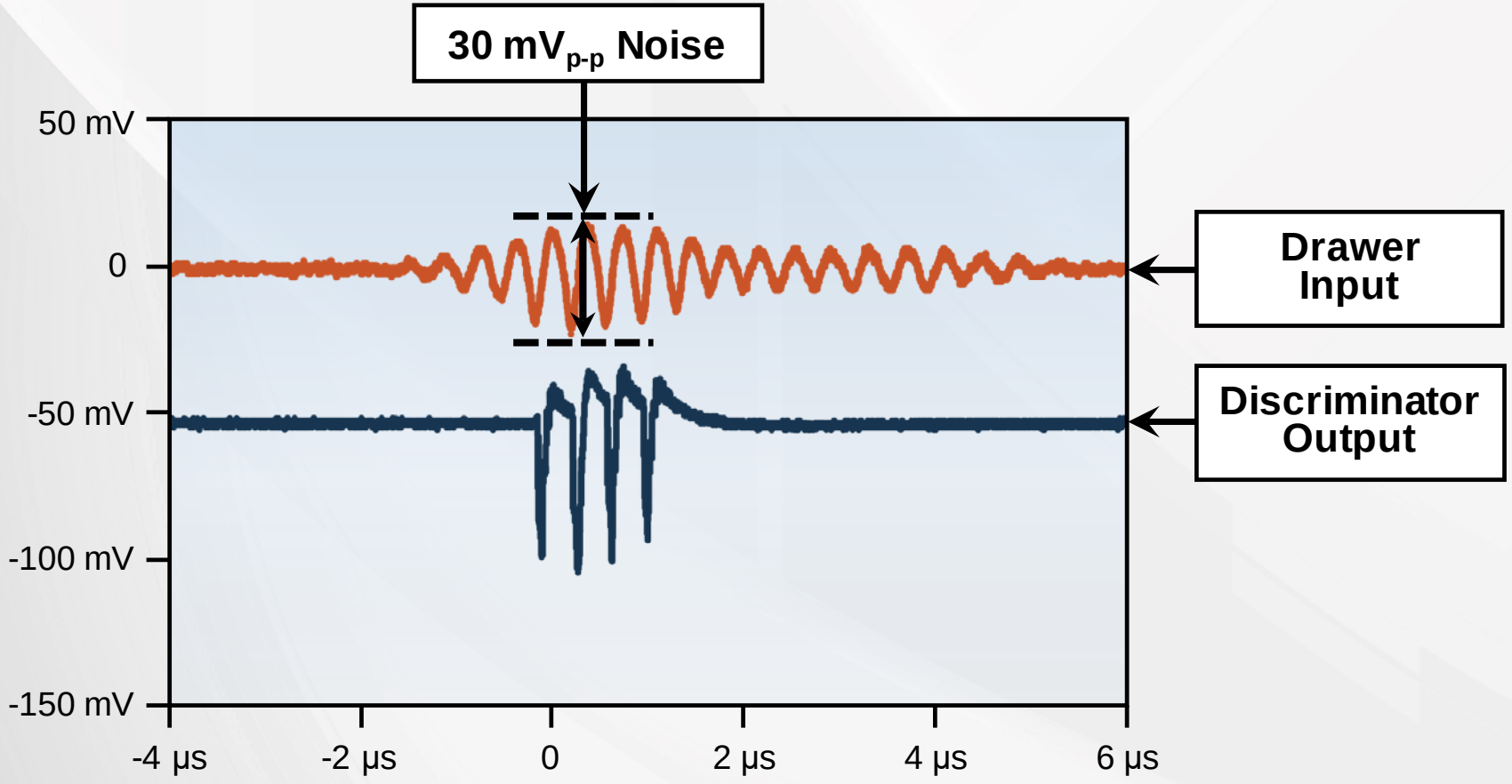
# PWR NIS Problem

- N32 was experiencing indication of up to 60 counts per second (cps) with the HV off while at 100% power – Should be zero

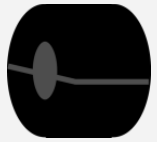
- Cable and EMI tests on the N32 source range detector were performed in the control room and at the preamplifier location while the plant was at 100% power.

- The purpose of this testing was to examine the cables, connections, and electronics associated with N32 to identify any anomalies contributing to unexpected counts.

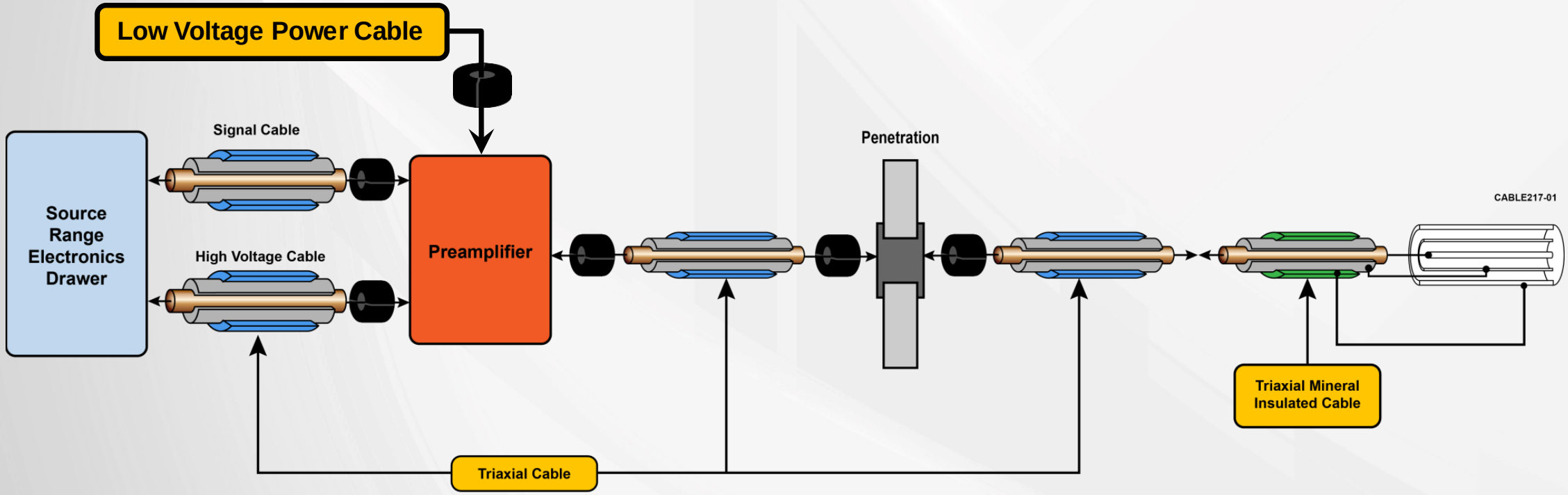
# EMI/RFI Causing False Counts



# NIS Source Range Channel

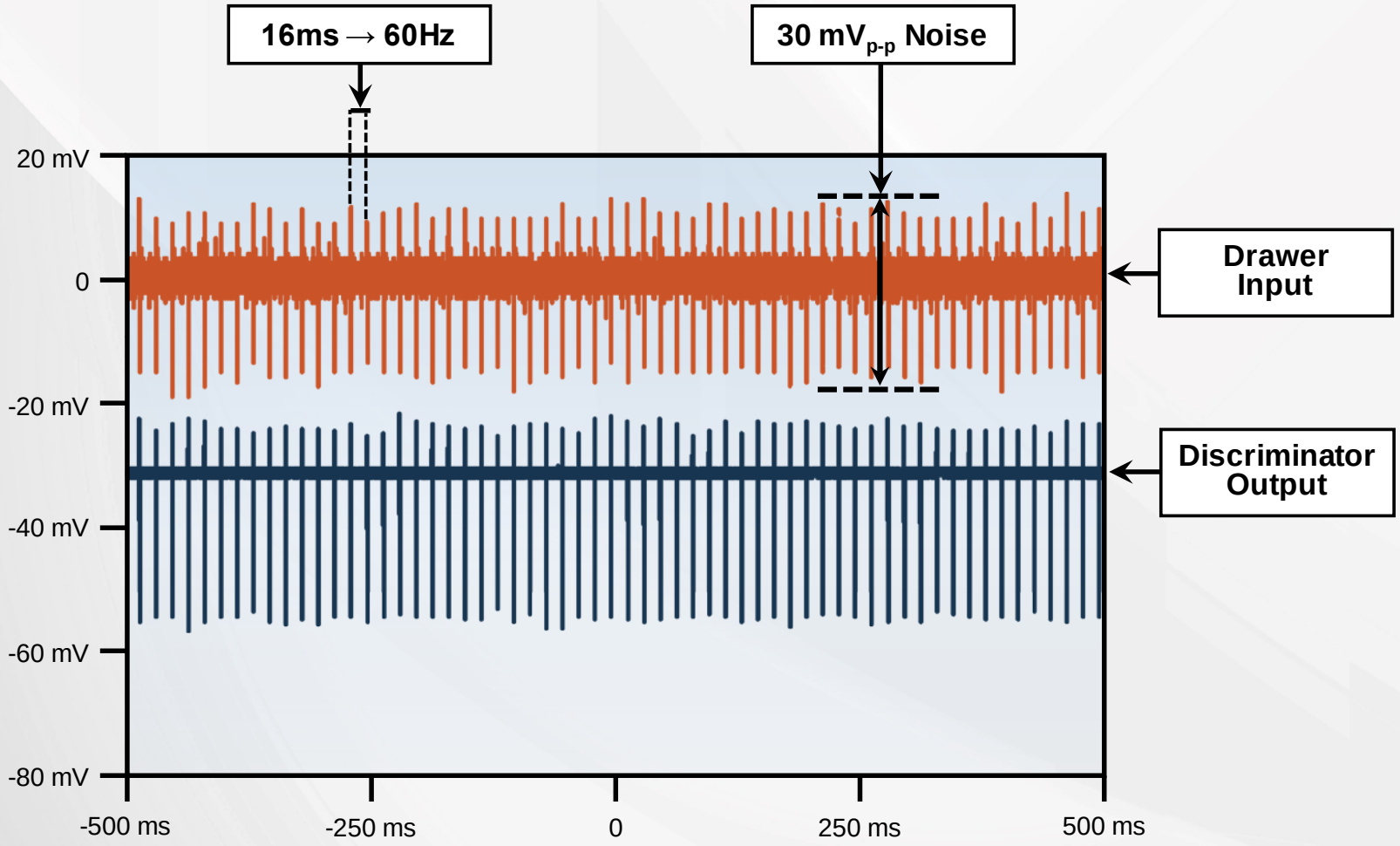


*Ferrite Placement*




NIS Source Range

# High Frequency Noise Coupling



# Interference Theory

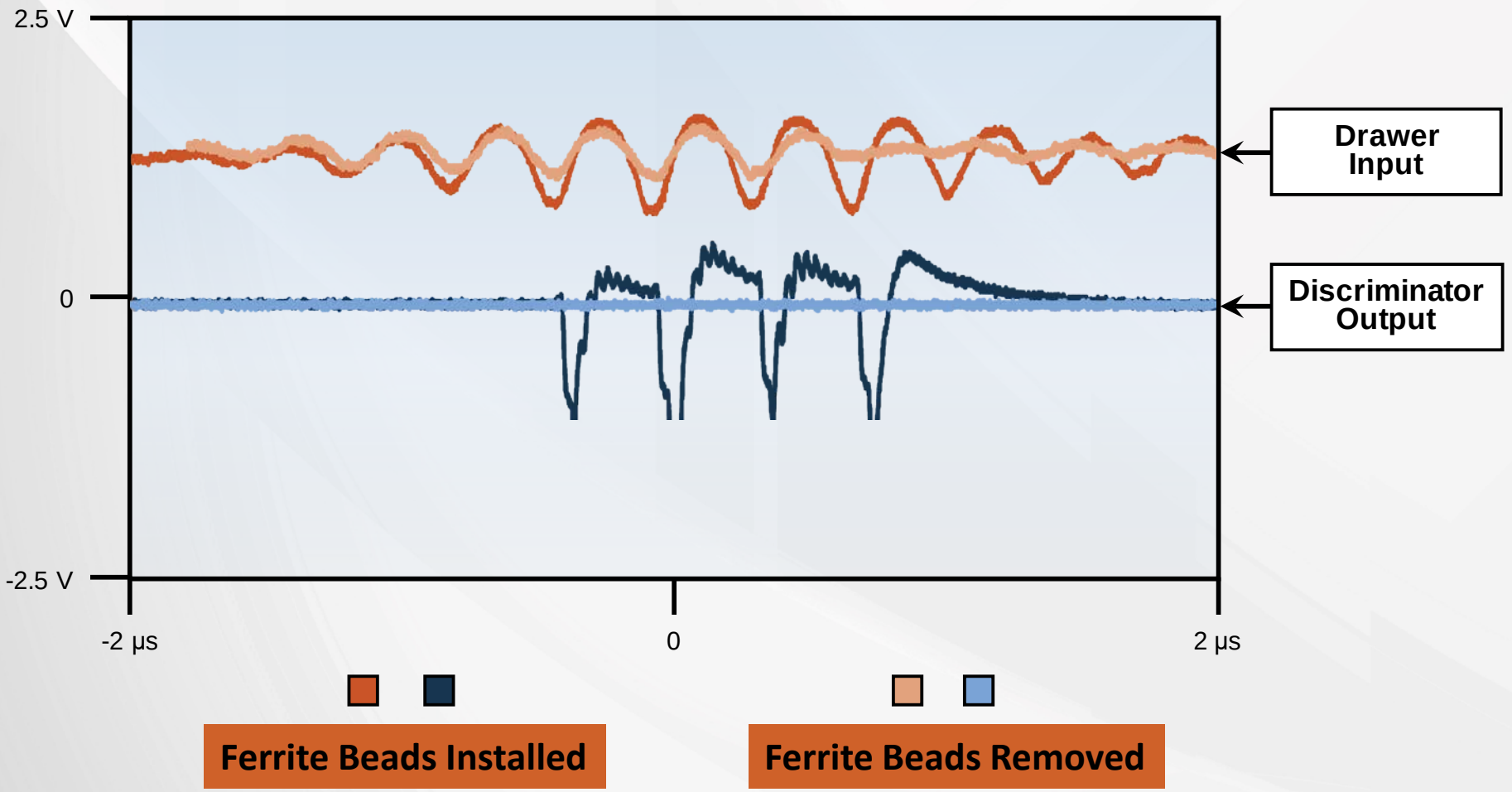
- Noise was conducted on the power to the preamplifier
- Ferrite beads installed at the preamplifier and containment penetration were containing the noise to the preamplifier
- Increased coupling to signal cable center conductor
- Noise exceeded discriminator level

# Mitigation Strategy

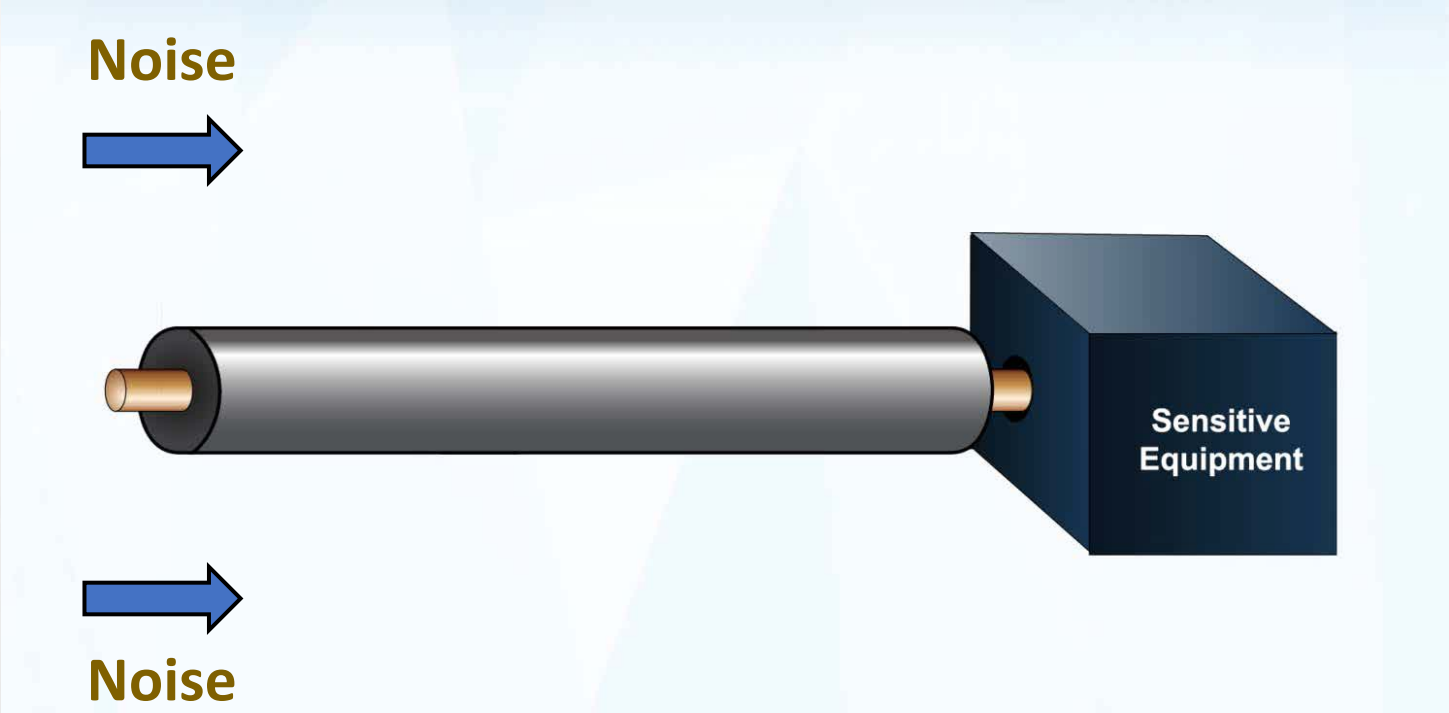
- **Recommendation**
  - **Remove the ferrite beads at the preamplifier and the penetration**
  - **Maintain the grounding strap at the preamp**

- **Result**
  - **Removal of ferrite beads allow the noise to spread out on the cables exiting the preamplifier**
  - **Noise was reduced to a level below the N32 discriminator setting**
  - **Eliminated false counts**

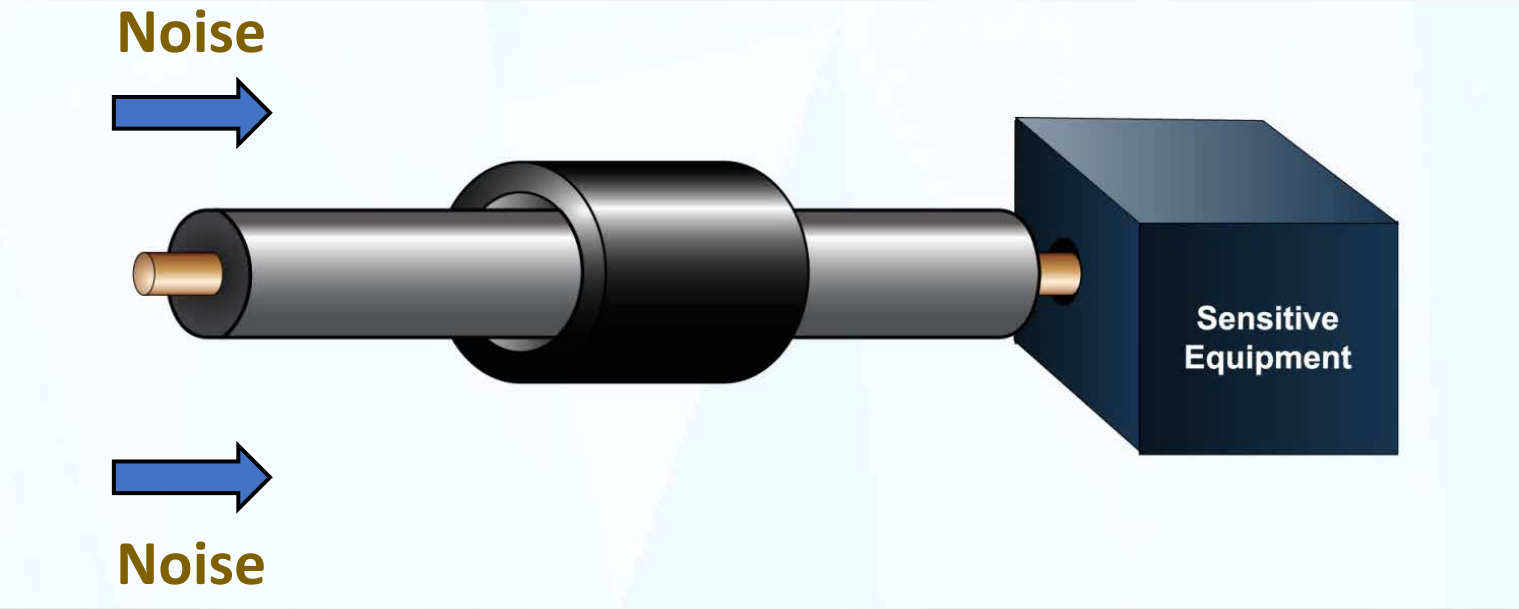
# Comparison of Voltage Waveforms



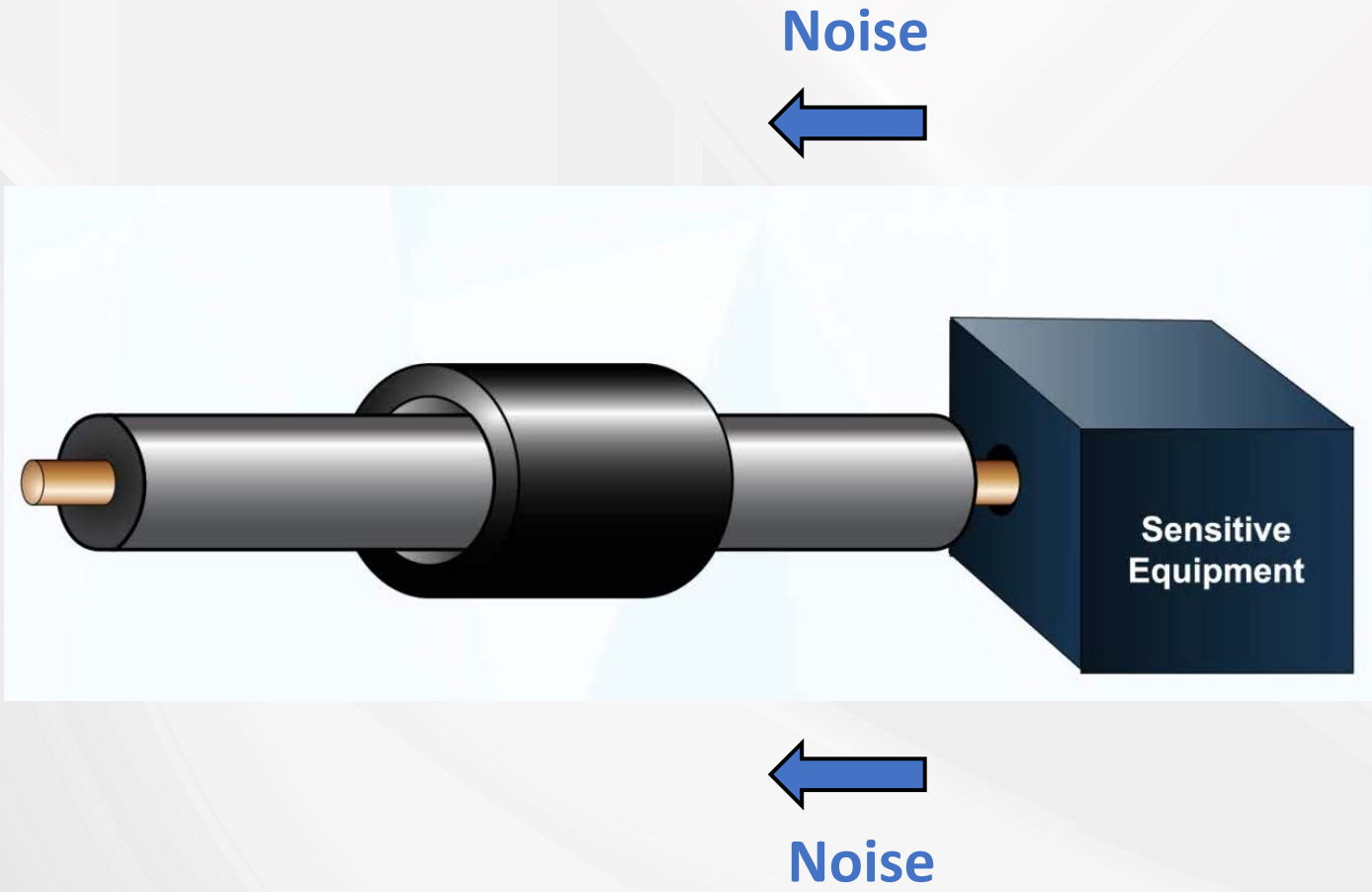
# Noise Propagation to Sensitive Equipment



# Ferrite Bead Protecting Sensitive Equipment

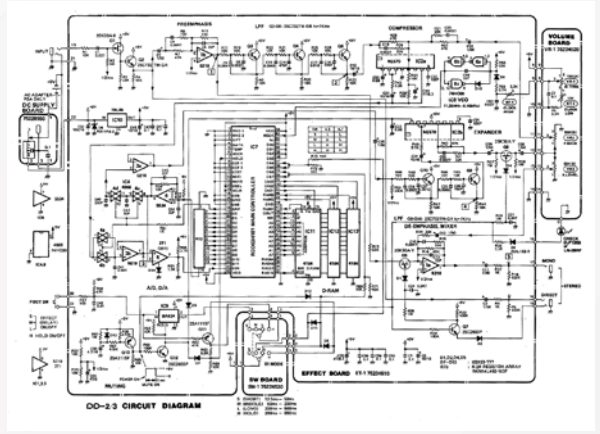


# Ferrite Bead Containing Noise to Sensitive Equipment



# Applications of Ferrite Beads

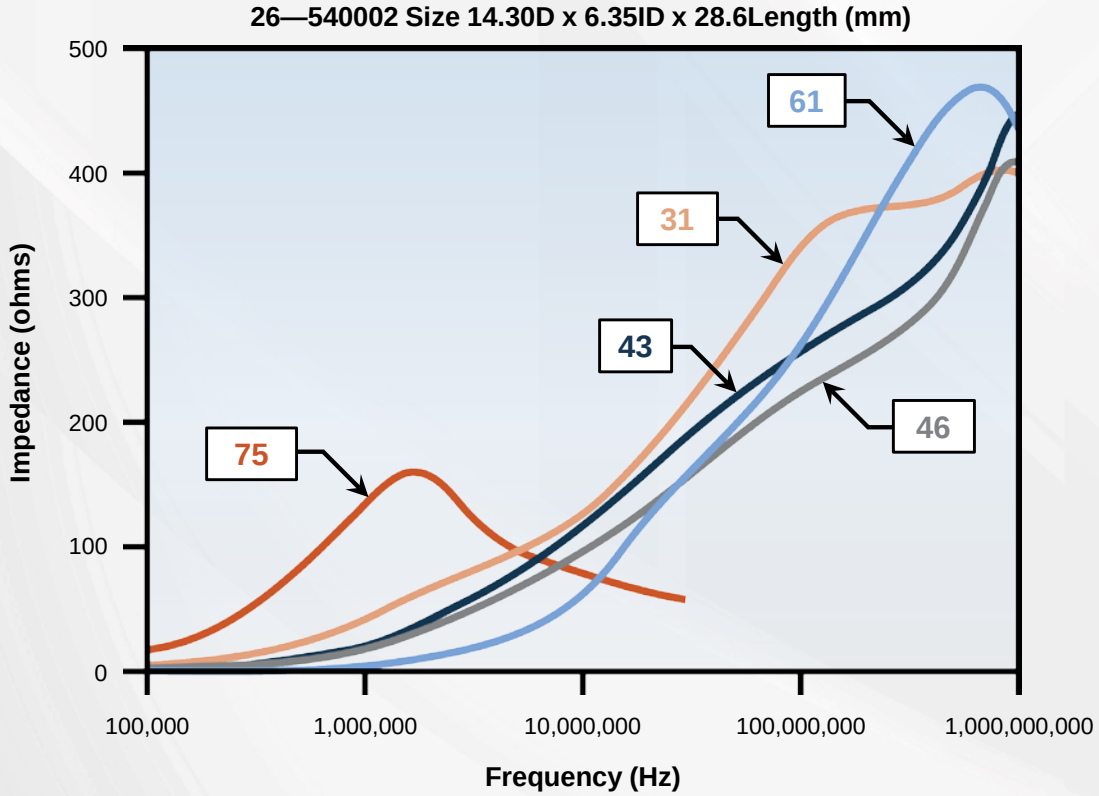
- **Electromagnetic Compatibility**
  - Product Design
  - Minimize Emissions
  - Improve Susceptibility



- **Troubleshooting**
  - Protect poor connectors
  - A ferrite is used as a “band-aid”
  - Rework/replace connectors

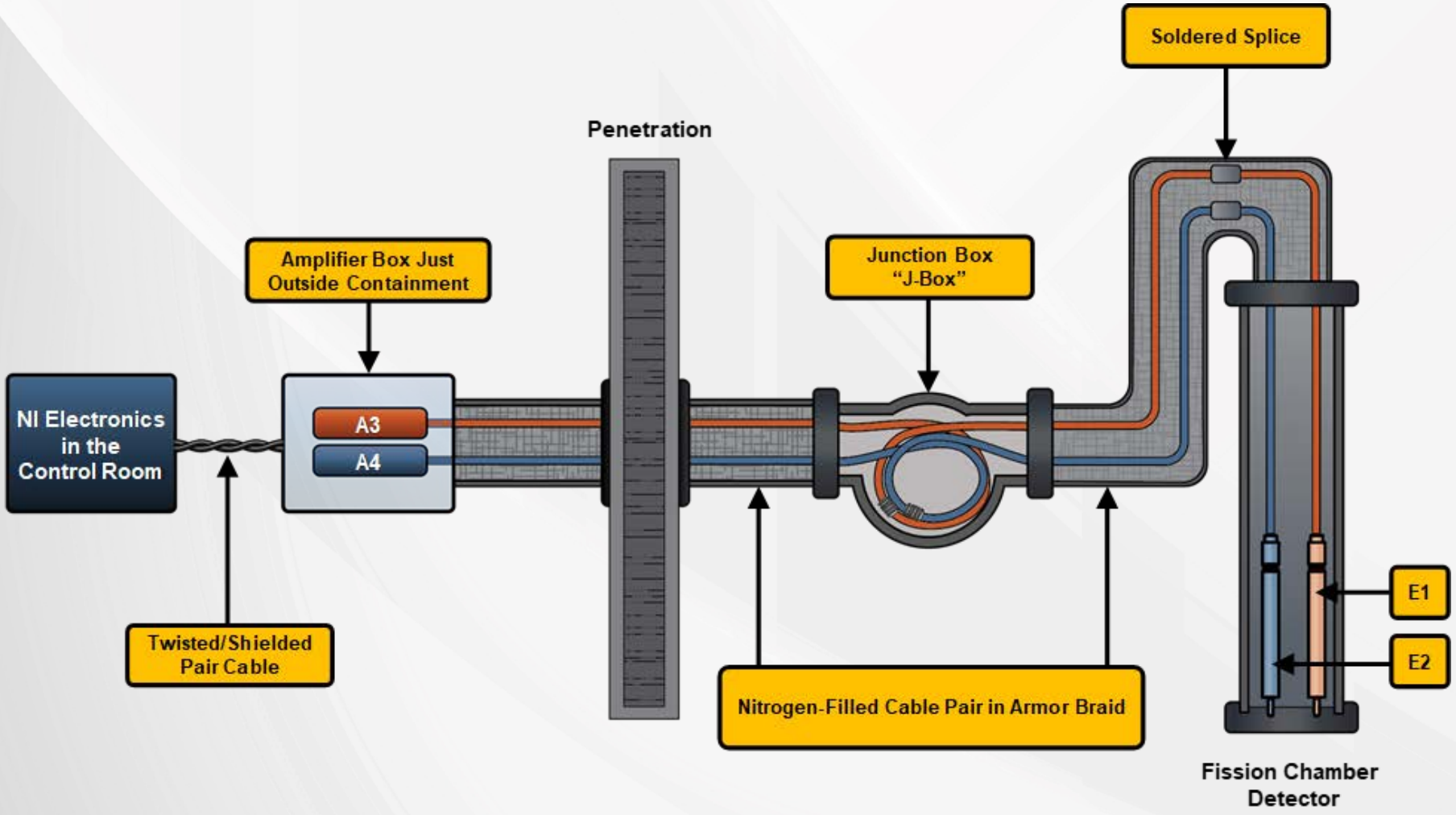
# Ferrite Bead Selection

**Ferrite beads are especially helpful in reducing the flow of higher frequency EMI on cables and conductors. They should be selected on the basis of impedance vs. EMI frequency.**



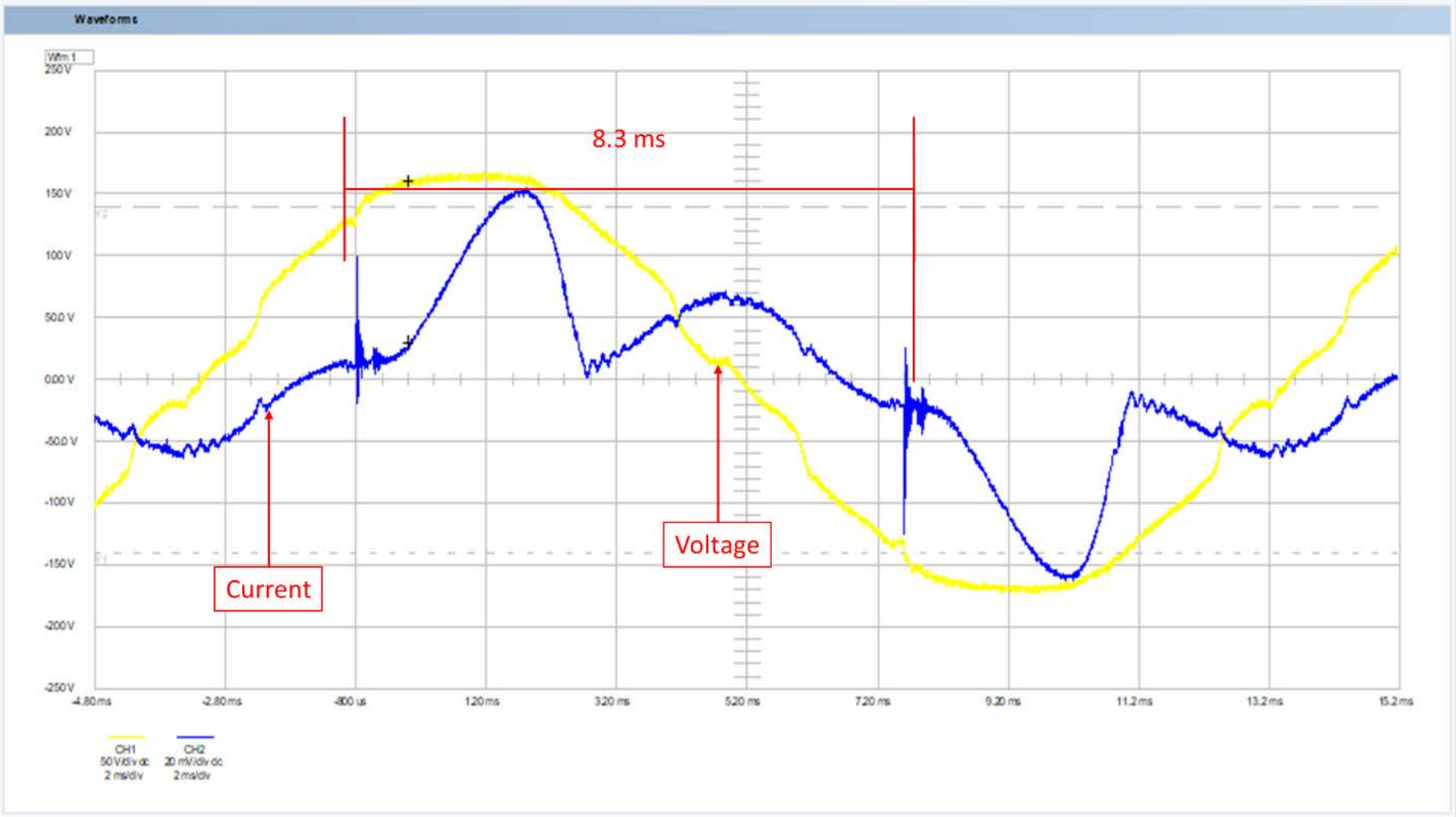

**(REF: Fair-Rite Products Corp. Technical Information)**

# Gamma-Metrics Detector System – Troubleshooting Example

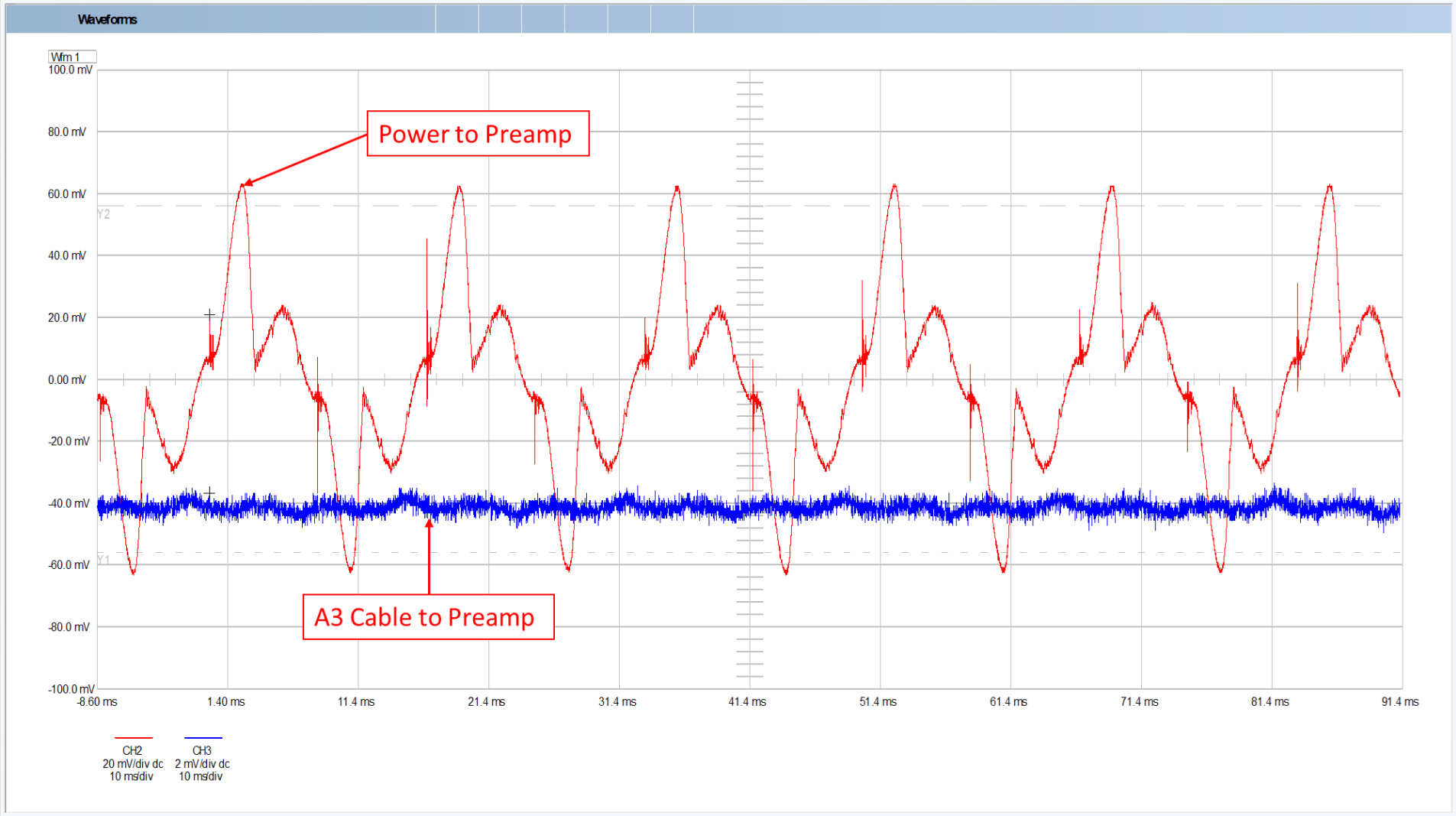



Typical Gamma-Metrics Detector Block Diagram

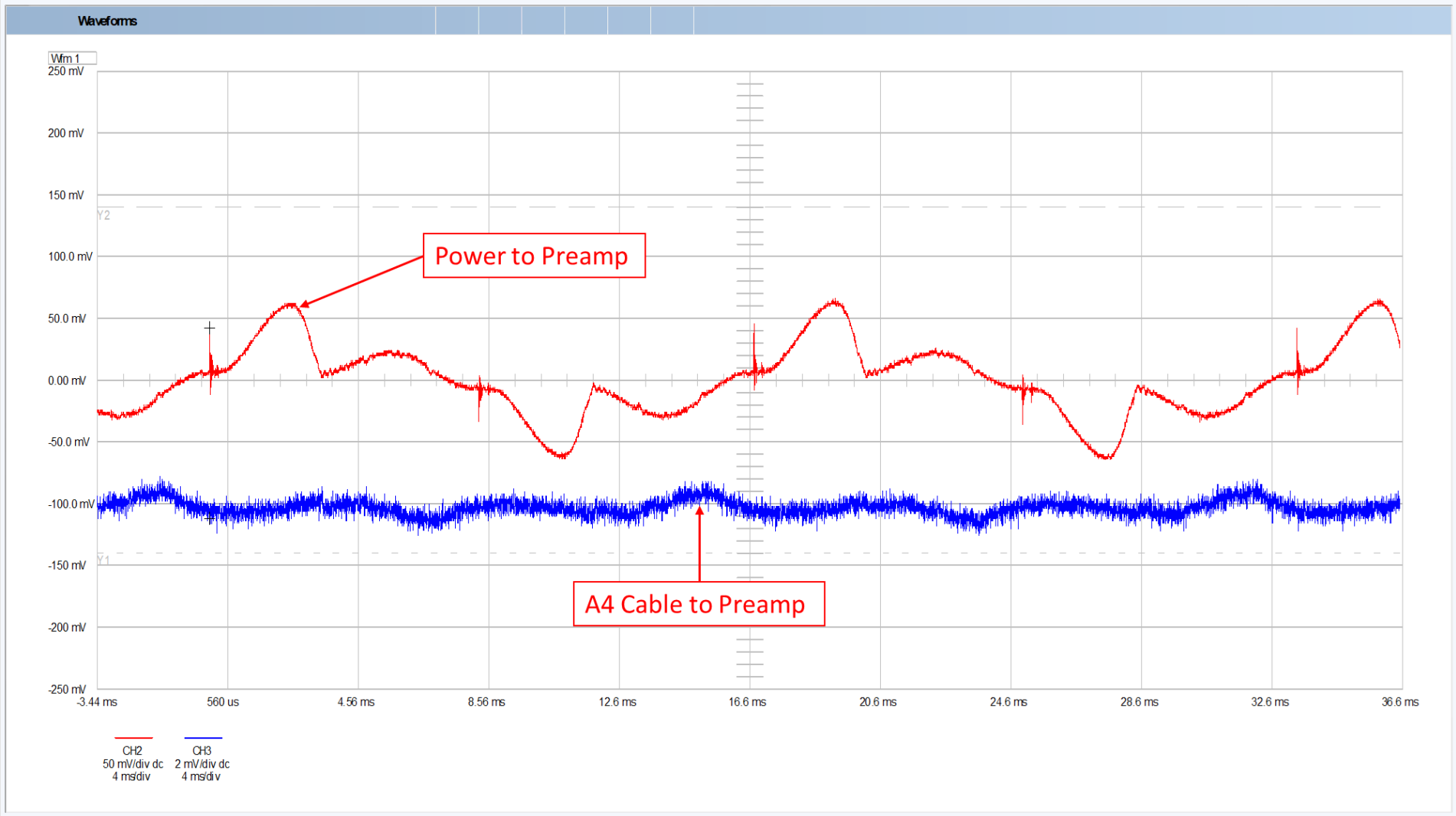
# Transients Identified on the Current from Invertor to Preamplifier but not on the Voltage



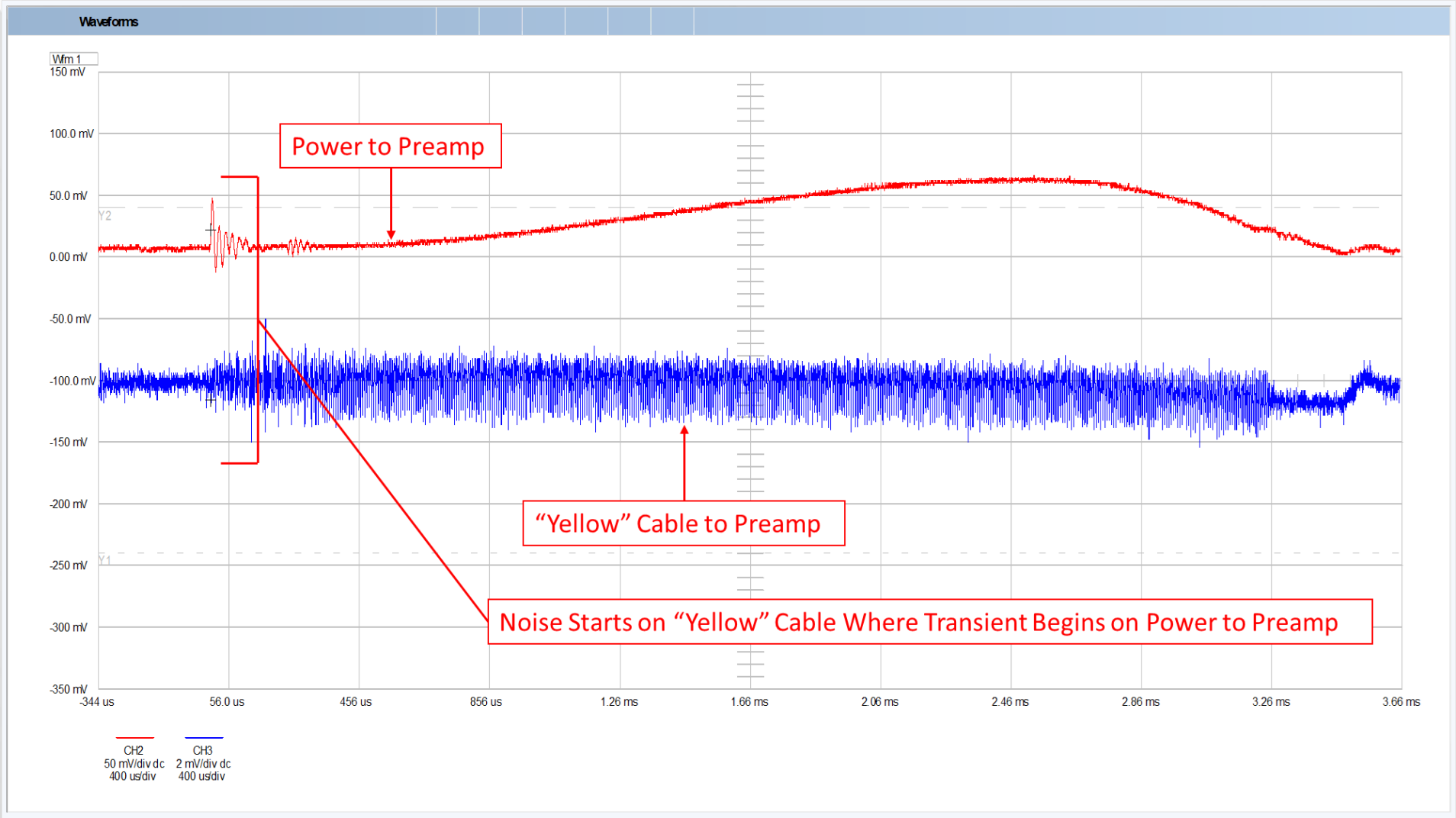
# Noise Measurements from A3 Detector Cable at Preamplifier – No Noise Coupling from Power



# Noise Measurements from A4 Detector Cable at Preamplifier – No Noise Coupling from Power



# Noise Measurements from Signal Cable Connecting Preamplifier to Processor Panel



# Degraded Processor Card in Electronics Cabinet

- 120 Hz noise is typical inverter noise
- Likely a failed or degraded component on the A3 PCB card
- Noise causes oscillations that couple to N46 indication within the processor panel and cause false counts
- Suppress the noise from reaching the card by adding a ferrite bead on the shield of the signal cable between the preamplifier and the processor
- Noise eliminated by replacing the A3 PCB card in the processor panel

# Summary

- **Addressing EMC requires a wholistic approach**
  - Appropriate design
  - Proper EMC Qualification Testing
  - EMC Best Practices during Installation
- **When issues occur**
  - Verify healthly cabling, especially connectors
    - Cable Testing (TDR, IR, etc.)
    - RTDR to identify degraded shielding
  - Measure EMI/RFI levels
    - Oscilloscope with voltage and current probes
    - Determine optimal EMI/RFI mitigation strategies (ferrite beads, capacitors, shielding, grounding,…)

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# Thank You

***Questions?***

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