Automotive EMC Workshop

Bench-Top EMC Pre-Compliance Testing

Johnson Controls Automotive Electronics

March 12th, 2008

Automotive Industry Trends

- Increasing complexity of electronics
  - Combining multiple functions on one board
  - New technology such as Bluetooth, GPS, smart keys, and backup cameras
- Unique packaging and mounting conditions (interior/exterior styling trends)
  - Smaller spaces
  - Close proximity to sensitive / noisy modules
- Increased receiver sensitivity
  - Improved performance of RF systems
- Shorter development cycles (<16 months)
  - ‘Get it right the first time’
  - Can no longer iterate the way to compliance

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Example Electronics Content in Vehicles

Mobile Device Gateway

Information Displays

HVAC Heads

HomeLink

Autovision

Compass

eMotion Compass

Blue Connect

Clocks

Overhead Console Electronic

Cluster

PathPoint

Management Contr./Cell Superv.Contr.

Intelligent Power Distribution Module

Tire Pressure Monitoring System

Access Control System

Body and Interior Controller

Immobilizer

Park Distance Indicator

Display Solutions for RSE

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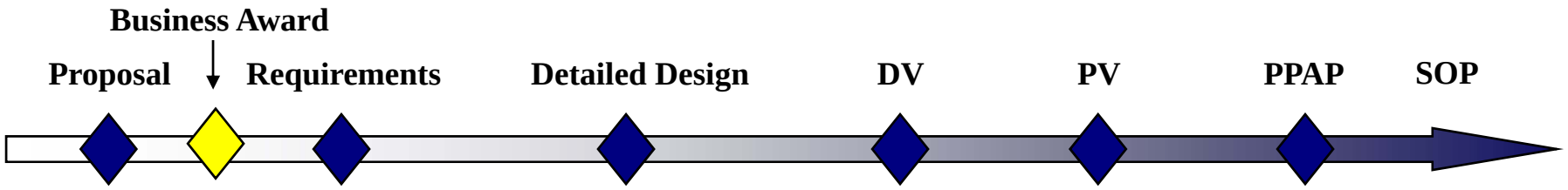
Product Development Trends

- Develop and deliver electronic products on-time
  - Delays impact delivery of new technology and introduction of vehicles
  - Vehicle sales are affected
- Meet all requirements (manage design trade-offs)
  - Product must operate correctly
  - Product must not overheat
  - Product must be compatible with its electromagnetic environment
  - Etc…
- Lowest cost
  - Product cost and engineering development costs
  - Low cost country (LCC) alternative manufacturing and design resources
- End-customer satisfaction…must be high quality
  - JD Power Ratings, etc…

Program Development Timeline



- Proposal → Prospective business quotation
- Business Award → Notification from OEM of awarded contract
- Requirements → Define target requirements for product
- Detailed Design → Develop initial design and prototypes
- DV → Validating the product design
- PV → Validating the process of manufacturing the product
- PPAP → Production part approval process submission to OEM
- SOP → Start of production

EMC Perspective / Point of View

How do we achieve EMC given the industry and product trends?

- Identify potential EMC concerns early
- Derive countermeasures to problems that address the root-cause
- Optimize countermeasures and components for lowest cost
- Evaluate design trade-offs / impact in other areas
  - Adding slewing components can cause thermal issues on switching power supplies
  - Too much series clock termination can add delay to memory BUS and cause timing violations
  - Placing components
- Meet or exceed performance outlined in module/system specification
- Support vehicle level testing and issues

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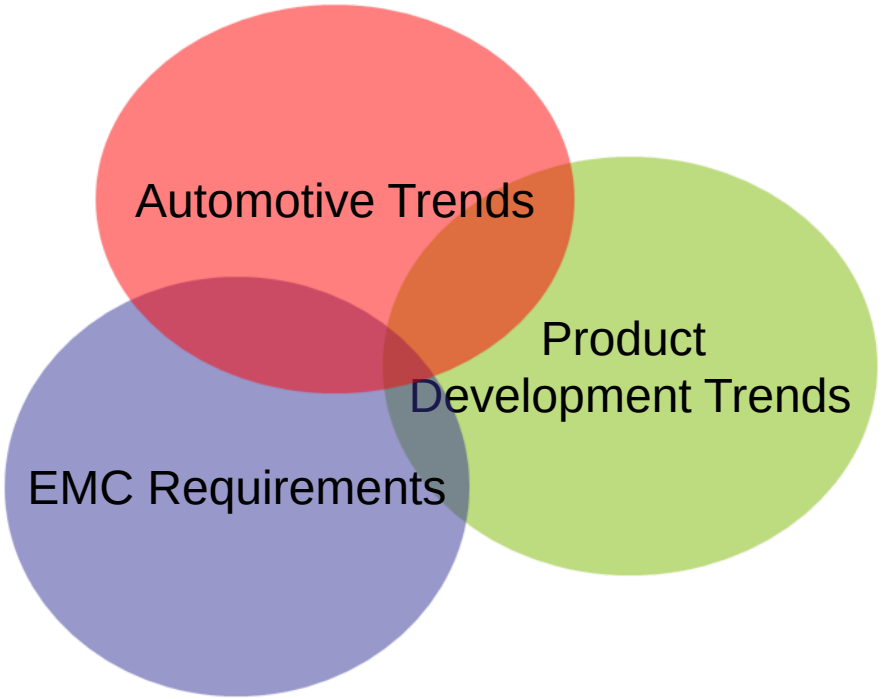
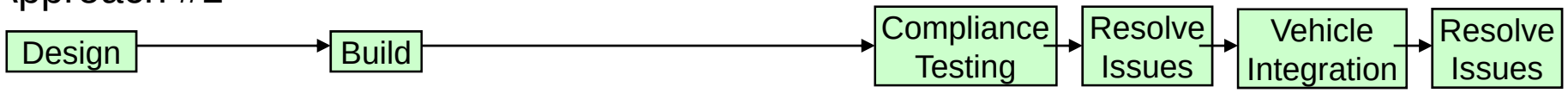
Impact of Trends and Compromise

- Reduced time to do proper simulations/analysis before creating hardware
- Fewer design iterations to improve EMC performance of hardware
- Fewer visits to the compliance laboratories

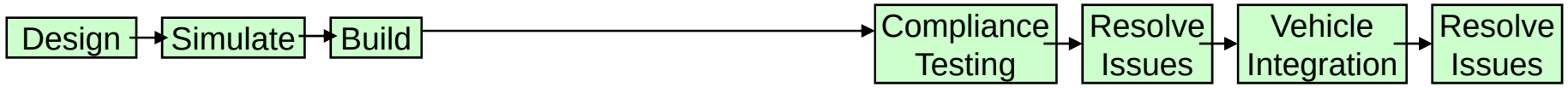


Historical Approaches to EMC Compliance

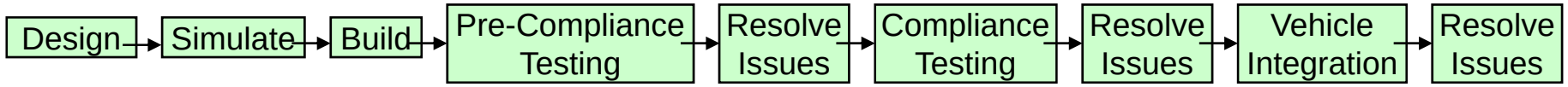
Approach #1



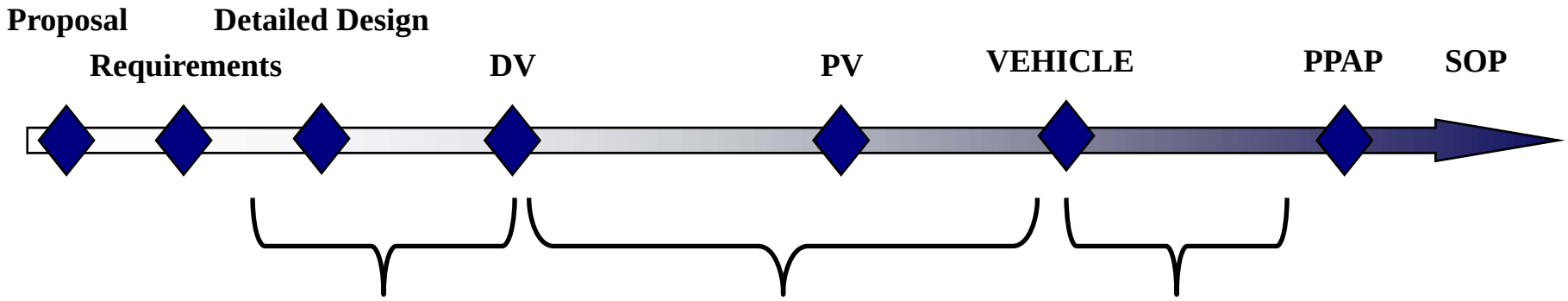
Approach #2



Approach #3



Overview of Testing Opportunities



Pre-Compliance Testing

- Low cost, quick
- Self-directed
- Considered not to be final
- May include system level
- Flexible test methods
- Can 'over test'
- Can correlate to vehicle
- Can address unique config.

Initiated by electronic component supplier

Module Compliance Testing

- Expensive / time consuming
- OEM directed
- Considered not to be final
- Includes system level
- Rigid test methodology
- May not correlate to vehicle

Final internal checks

Vehicle Compliance Testing

- Very expensive / time consuming
- Completed by OEM
- Considered to be final judge
- Includes many systems
- Includes wiring, mounting, etc.
- May not correlate to module
- Results not accessible to Tier 1

OEM assessment

Bench-top Pre-Compliance Methods

- What are pre-compliance tests?
  - Tests that are run prior to formal compliance tests
  - Tests that typically run faster than compliance tests
  - Tests that are cheaper to develop and run than compliance tests

- Why run pre-compliance tests? What is the motivation?
  - Test with methods that emulate the issues found during historical vehicle integration tests
  - Increase confidence in meeting EMC requirements at a lower cost with a more optimal design
  - Allows for troubleshooting and fixing issues during testing
  - Provides quantitative performance levels (not only pass/fail like compliance tests often provide)

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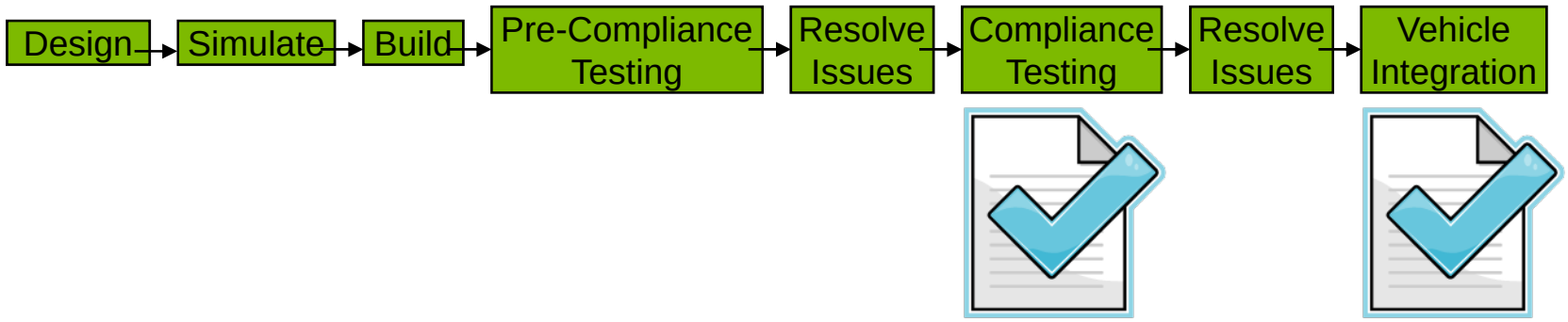
Traditional Implementation of Pre-Compliance Testing

- Emulate existing component level EMC standards
  - Emissions
  - Immunity
  - ESD
  - Transients
- Reduce/replace pieces of equipment
- Make the test run faster
- Run testing at higher levels of immunity and lower levels of emissions limits

Overall Improvement Achieved in Addressing EMC

- Adding both simulation and pre-compliance testing has…

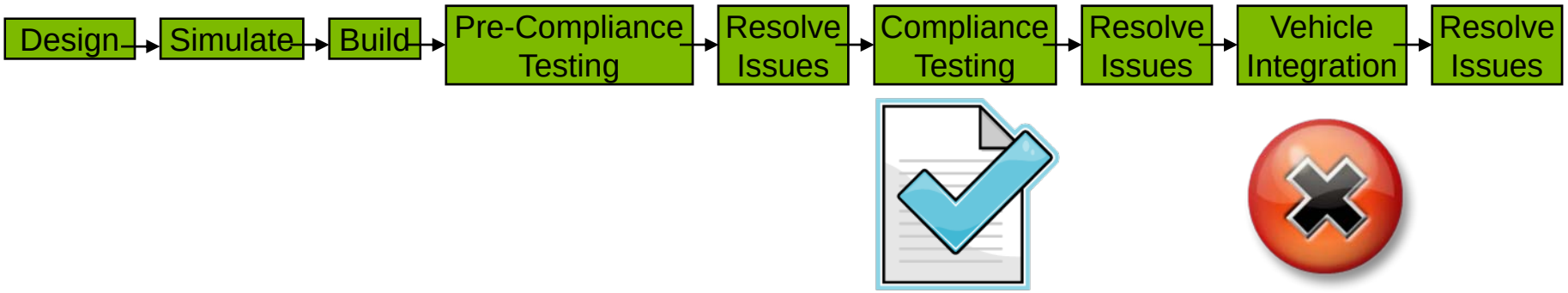


…produced fewer issues in both module and vehicle integration testing

- Costs have been driven down due to a proactive approach
- Product delivery timing has improved

Component Testing → PASS, but Vehicle Testing → FAIL??

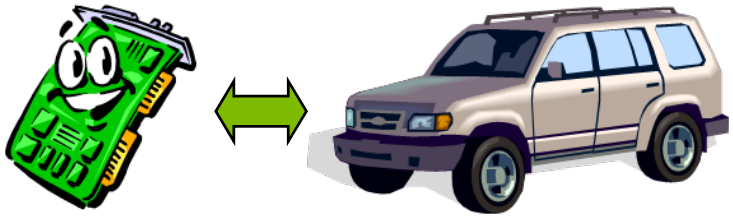
- New product technology and unique vehicle content and packaging
  - More prolific noise source signatures (GSM, CDMA, SMPS, Lighting, BT, etc.)
  - Greater sensitivity in receivers (FM/AM radio, GPS, PKE, USS, etc.)
  - Increased use of consumer electronics devices (USB, Cell phones etc.) in the vehicle



- Traditional test methods may not detect the potential issues
- Module supplier and OEM must work together to resolve vehicle issues

Impact of Identifying EMC Issues During Vehicle Integration

- Poor reliability → unfavorable component choices, or lack of proper prove-out
- Shift the problem → a solution applied to one module can cause problem in another
- Difficult manufacturing → lack of proper time to engineer a manufacturable solution
- Delay program timing → due to a complex and lengthy ‘prove-out’ scheme
- Higher costs → repeat vehicle testing is expensive
- Lack of information → Tier 1 suppliers have little information about the complete system



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Recent Trends in Pre-Compliance Test Methodology

- Existing standards do provide value to the testing process
  - Today's standards were developed for many legitimate reasons
  - They identify real concerns
  - In many cases they are repeatable and use common equipment
- Emulating existing component level standards is not adequate to find issues
  - Standards take time to update
  - Currently the standards do not adequately measure products' performance
  - Configurations that exist in the car are far more complex than the test standards
- Create flexible low cost test methods that emulate 'real' vehicle scenarios
  - Develop methods that are designed to reproduce prior issues at a bench-top level
- Partner with OEMs
  - Suppliers communicate early concerns and develop new ways to test
  - OEMs share information with suppliers about electronic component packaging in the vehicle

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Types of Pre-Compliance Testing

- Emulating component level EMC testing to boost confidence before DV & PV
- Failure analysis testing to identify root-cause of EMC issues
  - Use tools to aid in debugging and countermeasure development
- Testing that emulates scenarios found in the vehicle
  - Often involves two or more modules making a system
  - Measure EMC performance under actual configurations found in the vehicle

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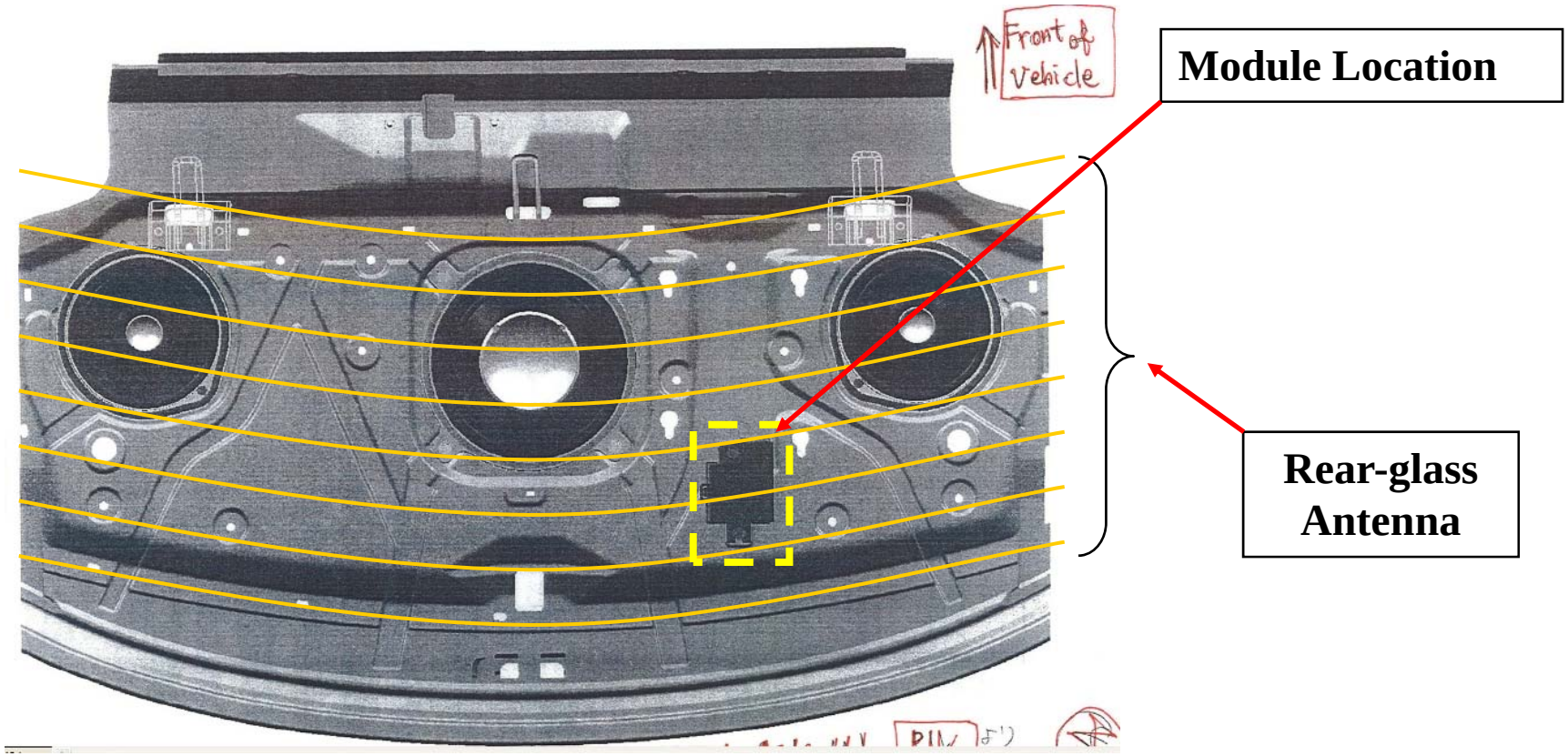
Vehicle Level Issues Discovered → Create New P.C. Test Methods

- RF Emissions
  - FM band interference from compass module
  - AM band interference from compass module
  - Inoperable passive keyless entry and vehicle starting from switching power supply
  - GPS band interference and resulting navigation issues due to digital memory BUS noise
  - FM band noise interference due to harness coupling to nearby digital memory BUS noise
- Noise Immunity
  - Noise in car audio system due to GSM (*Groupe Spécial Mobile*) noise
  - Microcontroller interrupt initiated based upon false input detection
- Voltage Transients
  - LCD display flickering
  - Power supply protection circuit failure

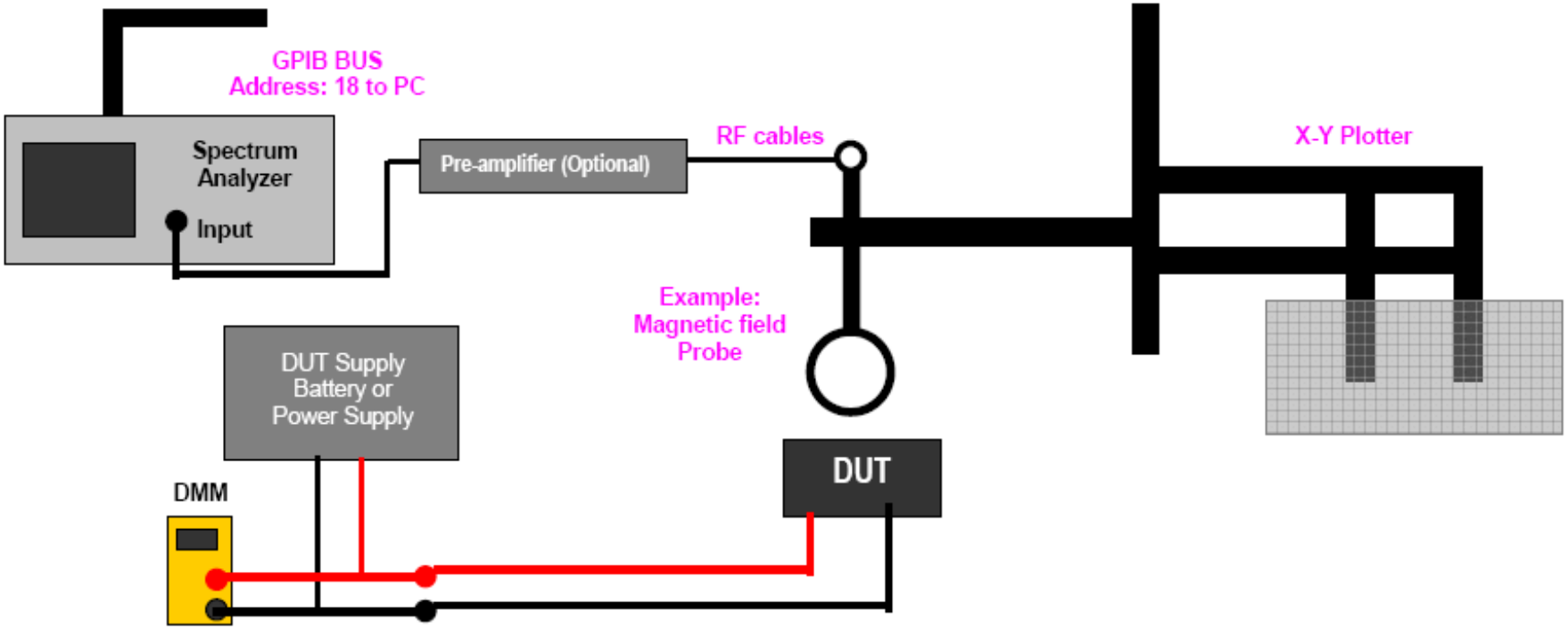
FM Band Interference from Compass Microcontroller

- Noisy modules mounted on the rear tray package near antennas
- Digital integrated circuit (IC) noise couples into radio band antennas



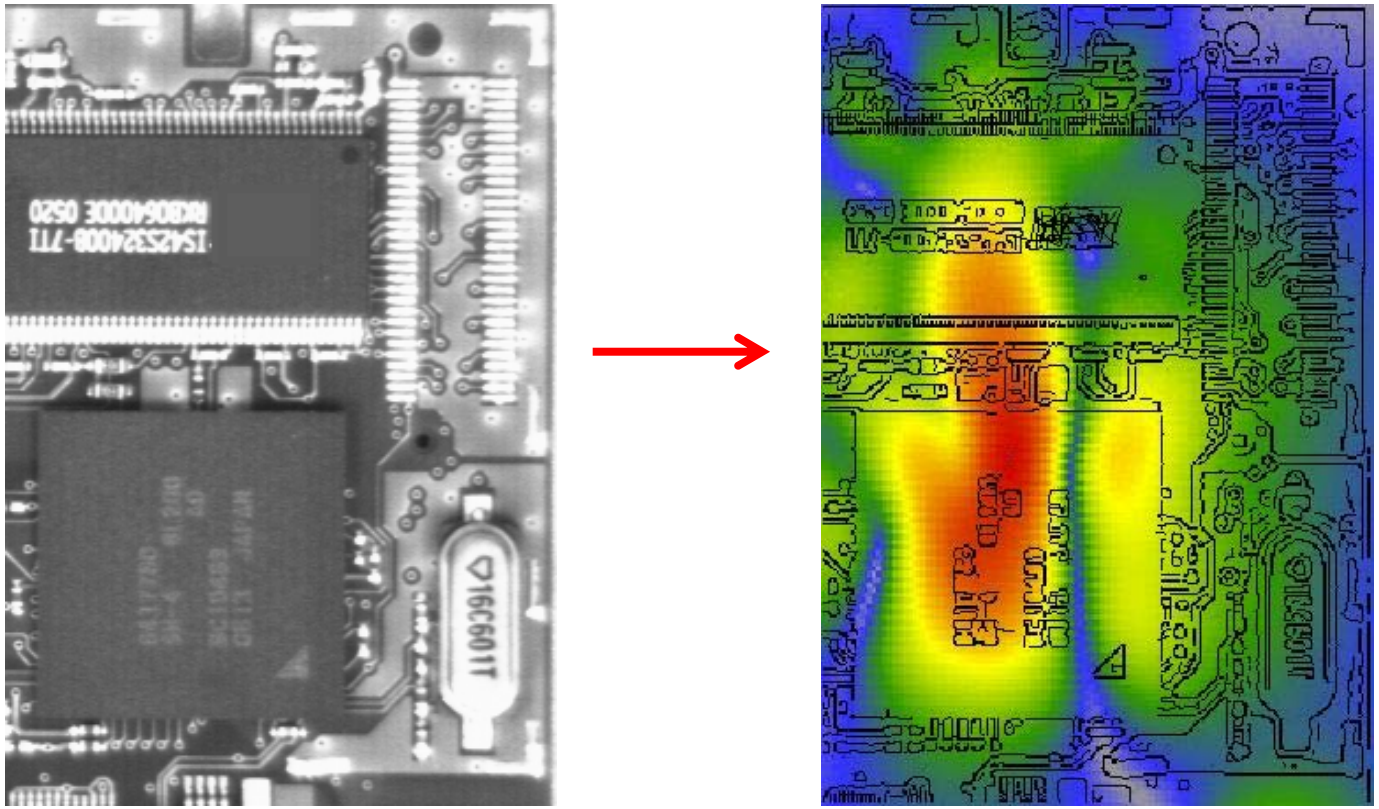
RF Scanning Test Method

- Formalized in the SAE J1752 – 2 by the SAE Integrated circuit/EMC task force
- Intended to measure the electric and magnetic near-fields of integrated circuits



RF Scanning Results

- Results must be interpreted carefully in order to develop countermeasures
- Historical data needs to be tracked to form meaningful limits on radiation



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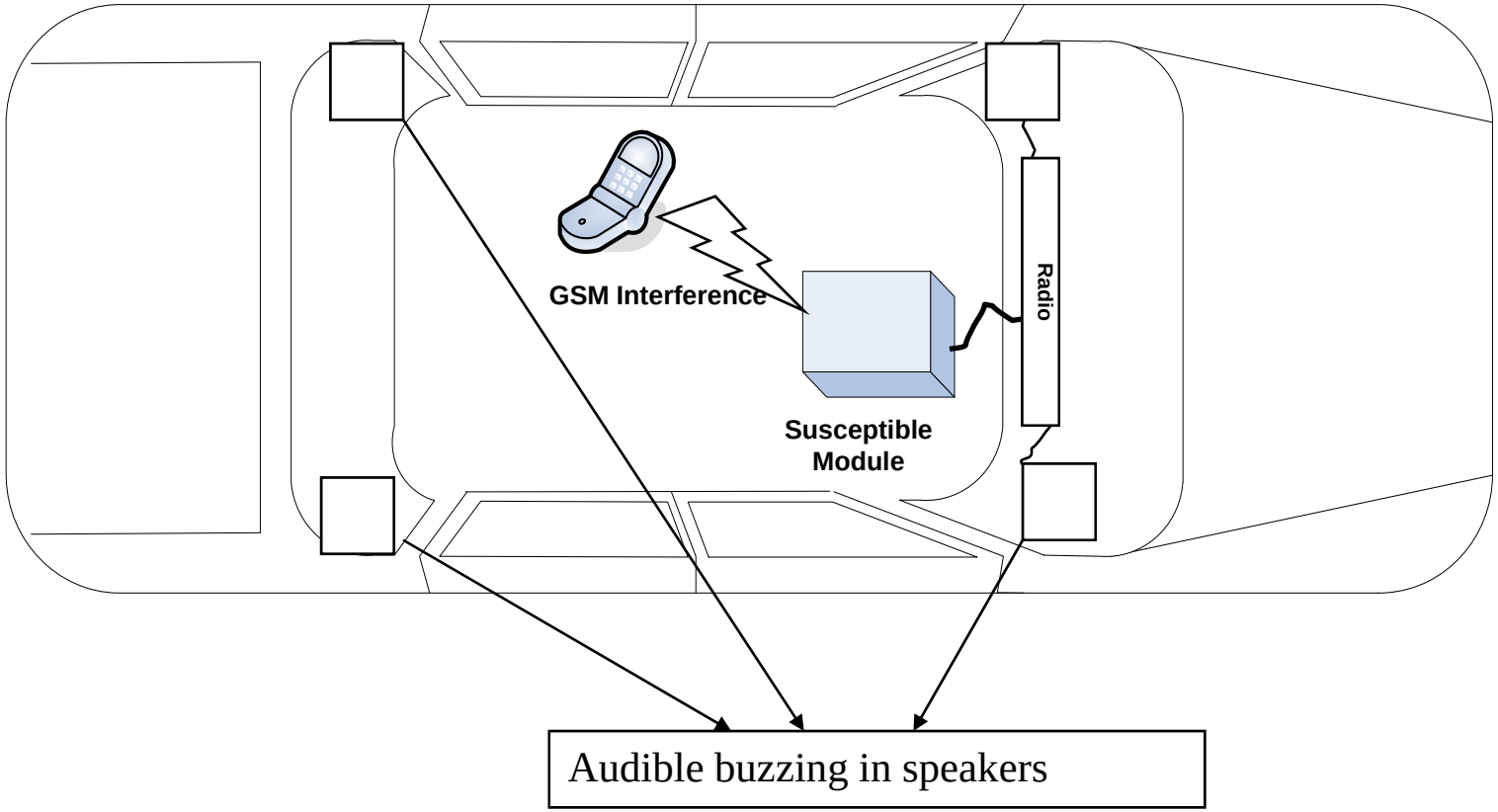
RF Scan Test – Equipment and Approximate Cost

- Equipment
  - Pre-compliant spectrum analyzer → $9,000
  - RF cables → $2,500
  - Pre-amplifier → $1,200
  - Scanning table / machine /controller → $15,000 - $50,000
    - Lower cost to build your own
  - Computer → $1,500
  - Camera → $1,000
  - Automation software → $5,000

- Total Cost Estimate → ~ $50K

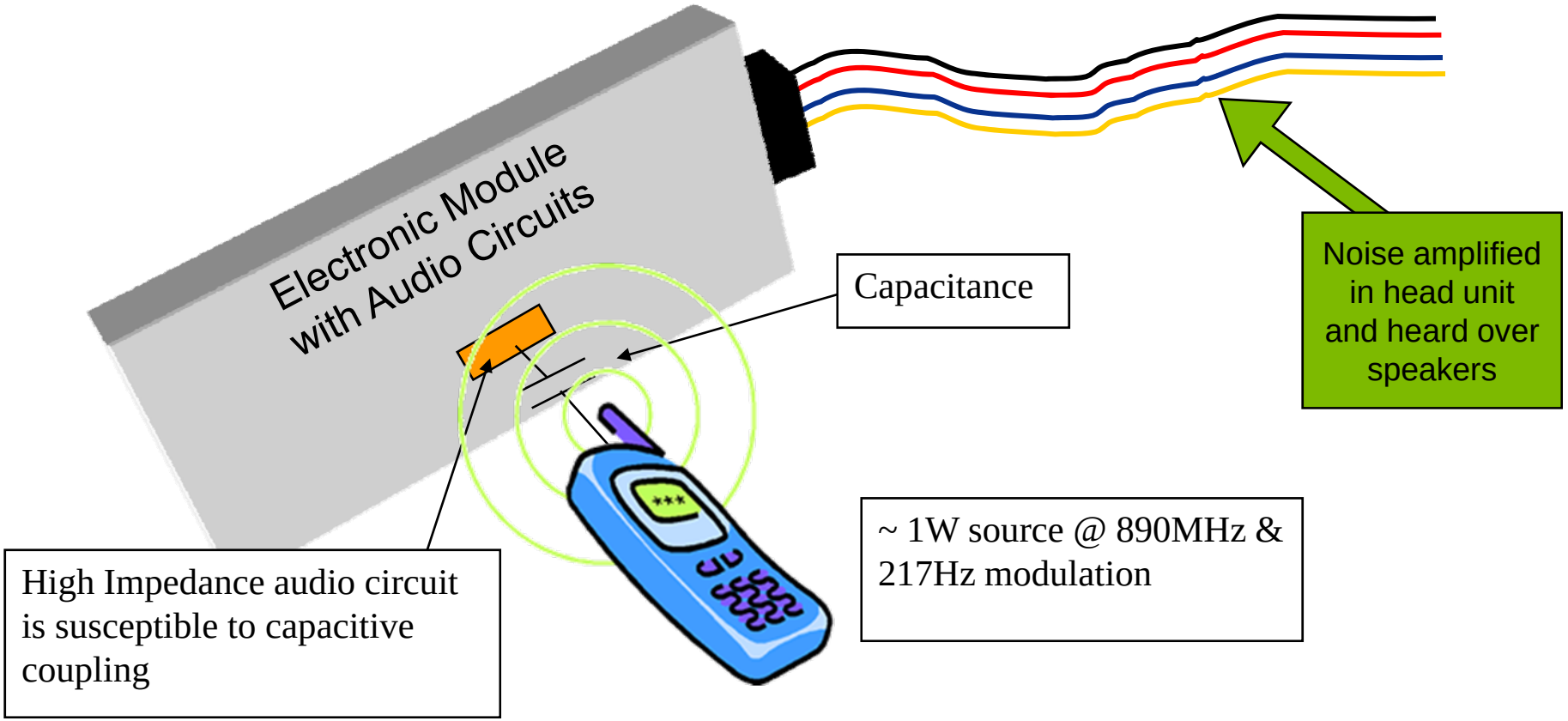
GSM : (*Groupe Spécial Mobile)* Noise Issue

- Cell phone causing interference on car audio system

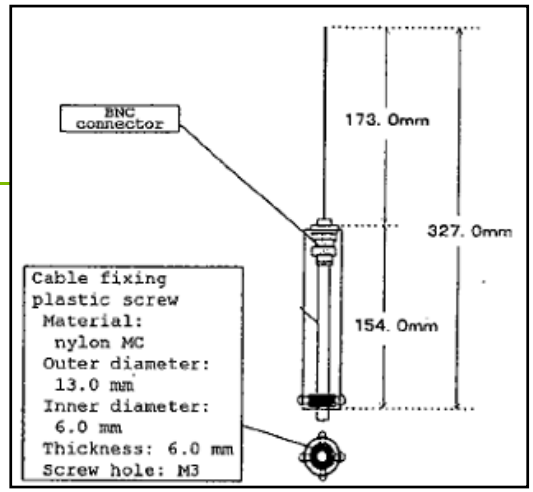


GSM Audio Noise Interference Example

- **GSM** signal is capacitively coupled and demodulated to audio frequencies and passed into the audio system in the vehicle



GSM Test Method Details



- Two suggested methods

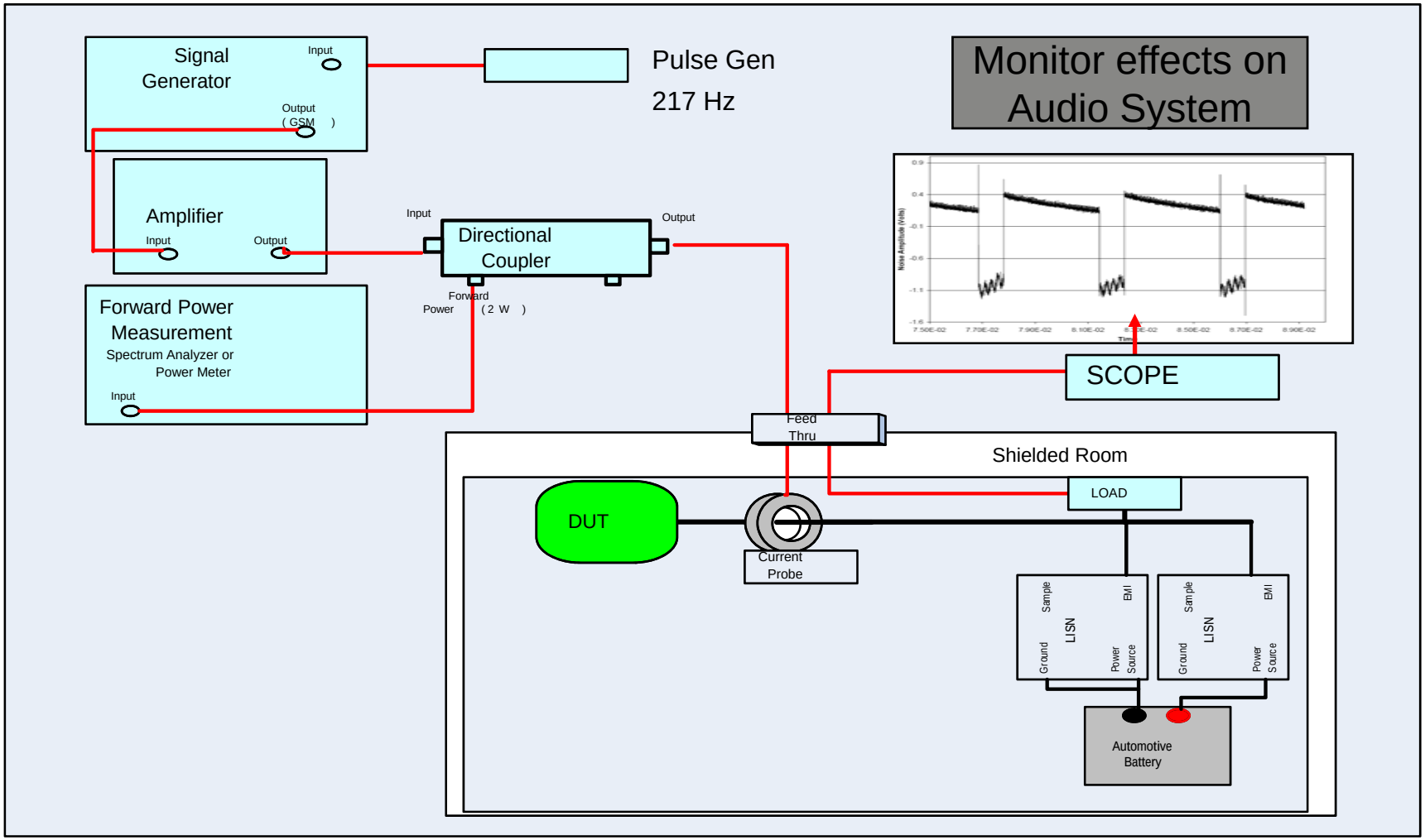
1 – Method according to ISO 11452-9 → using sleeve antennas

- Craig Fanning from Elite Labs (Chicago, IL) presented a paper in IEEE EMC 2007 Titled "**Evaluating Cell Phone and Personal Communications Equipment and their EMC Effects on Automotive Audio and In-Cabin Modules**"
- Found digital transmitters < 0.1 Watts to be a low risk in the vehicle
- Found digital transmitters > 0.7 Watts to cause compatibility issues

2 – Method according to ISO 11452-4 → BCI method

- Used at JCI to reproduce failures found in vehicle
- Testing done with a range of powers (500mW – 2 Watts) to reproduce issues
- Two forms of applied interference → coupling from probe to DUT and injected current in harness

GSM Interference Test Method



GSM Test – Equipment and Approximate Cost

- Equipment
  - RF Signal generator w/ pulse → $12,000
  - RF Cables → $3,500
  - HF RF amplifier → $18,000
  - Directional coupler → $1,500
  - Computer and automation software → $6,500
  - Injection probe → $4,000
  - RF chamber → $18,000
  - Artificial networks and automotive battery → $2,000
  - Monitoring equipment → $2,500

- Total Cost Estimate → ~ $68K

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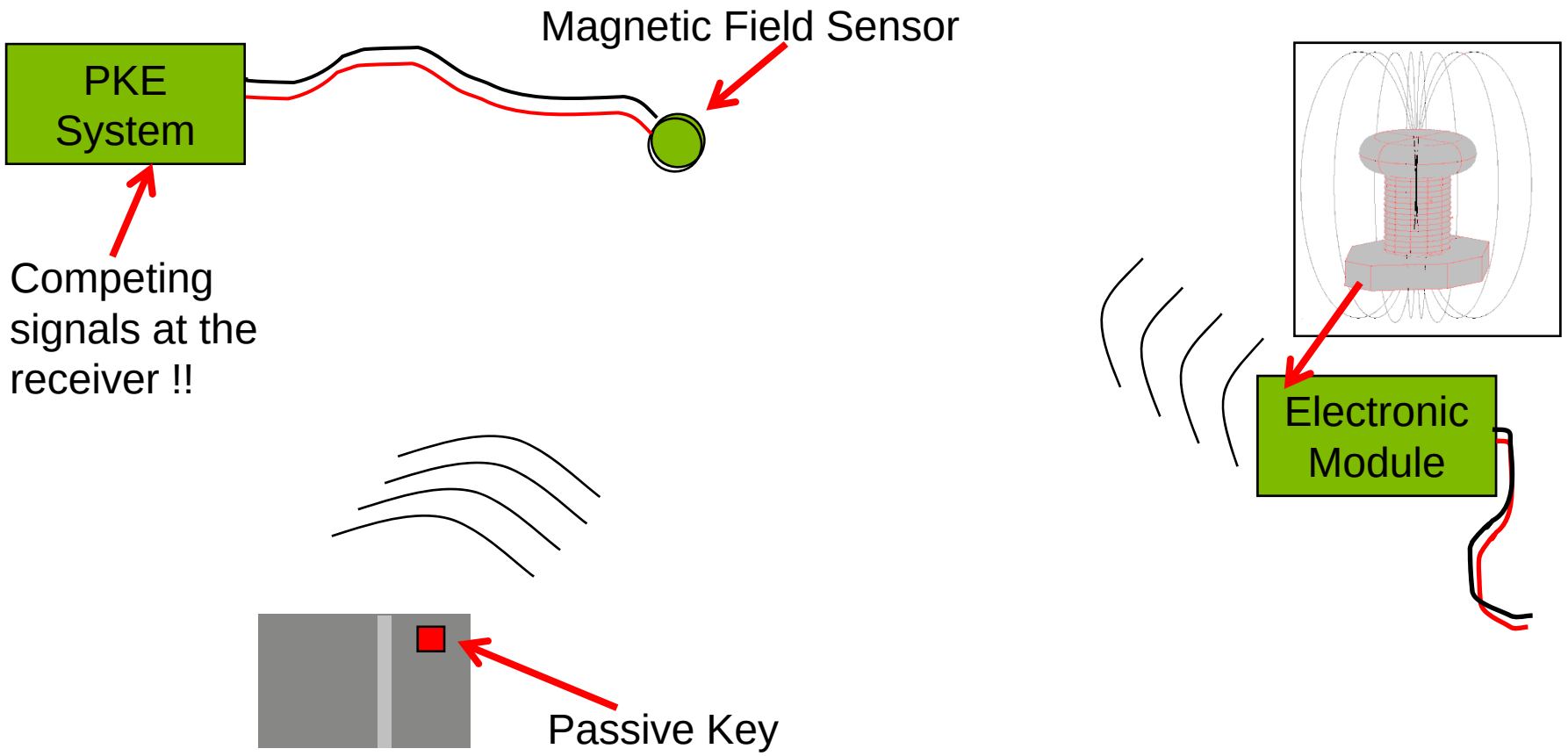
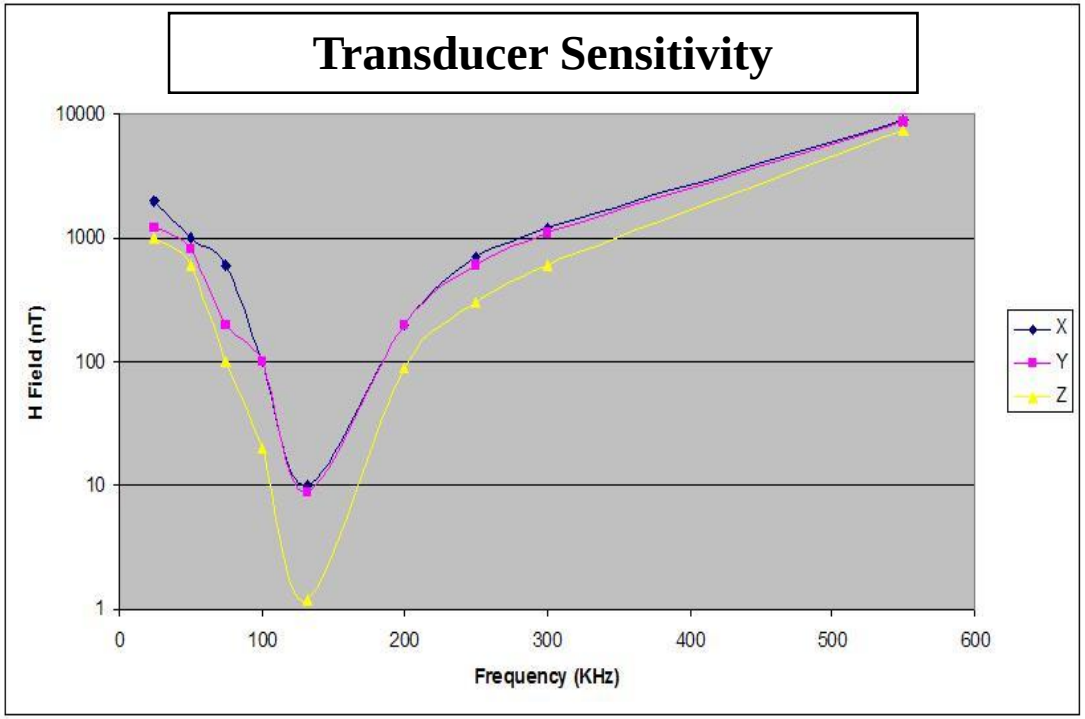
Passive Keyless Entry / Vehicle Starting System



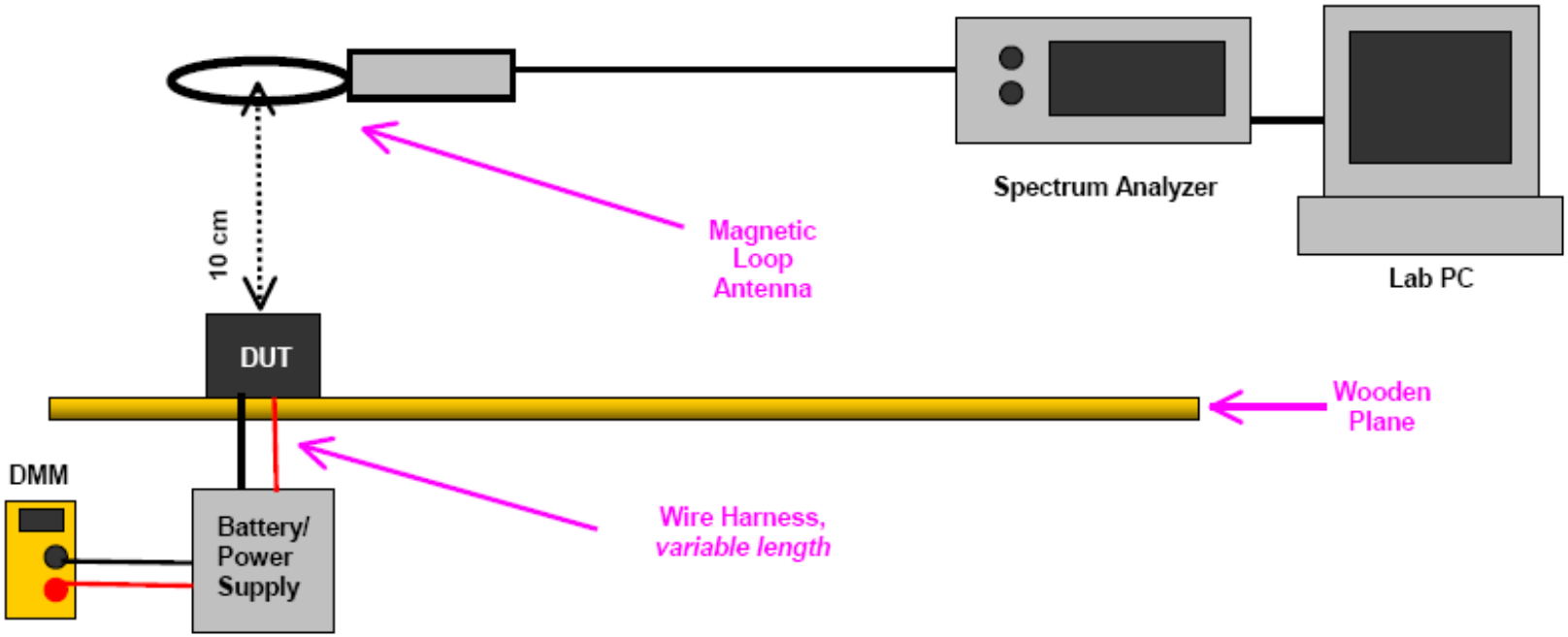
Switch-mode Power Supply Interfering with Passive Key System

- The source:
  - 12 Volt → 3.3V buck (step-down) power converter
  - Switching inductor generates powerful magnetic field
  - Field strength range → 4 – 25nT at distance of 10cm
- The victim:
  - Passive keyless and vehicle start system
  - Magnetic transducers located in the vehicle at various locations
  - Sensitivity range → 1 – 10nT at distance of 10cm

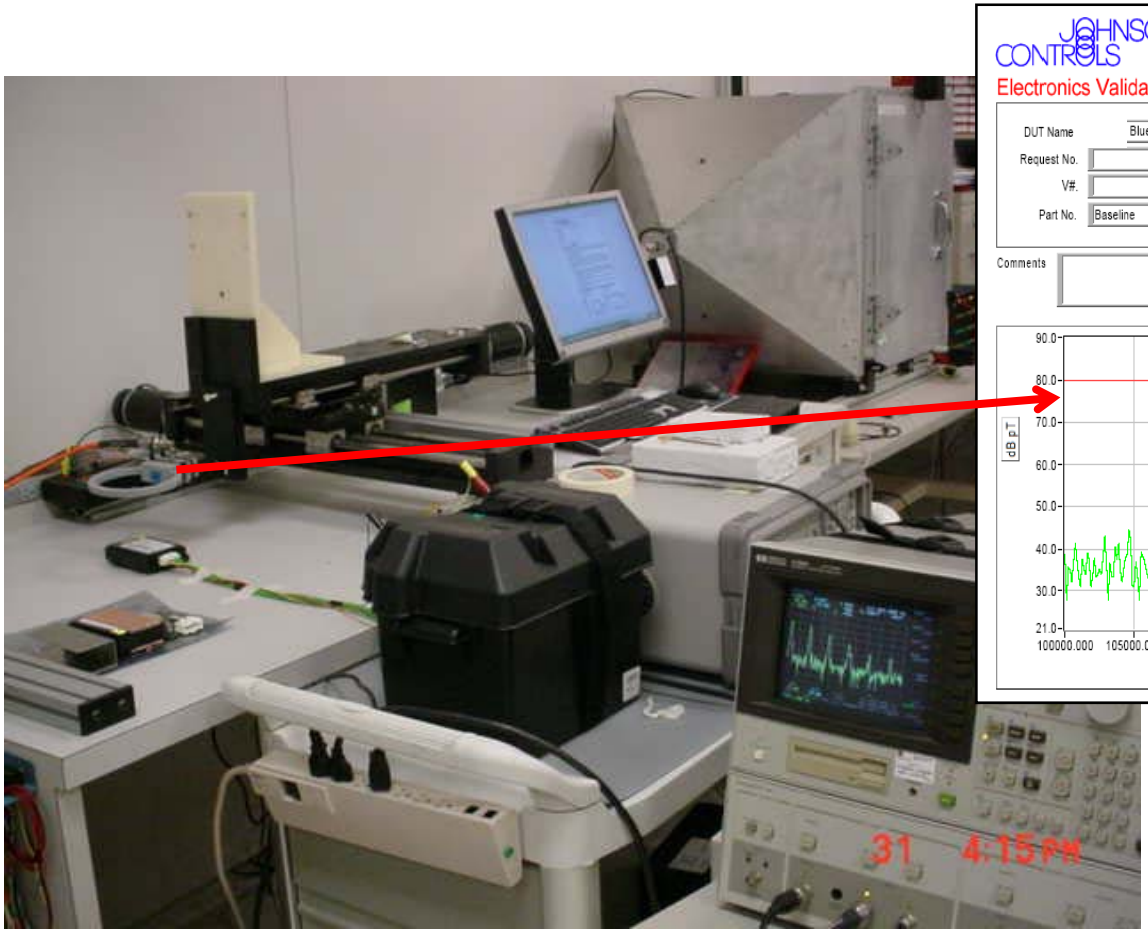


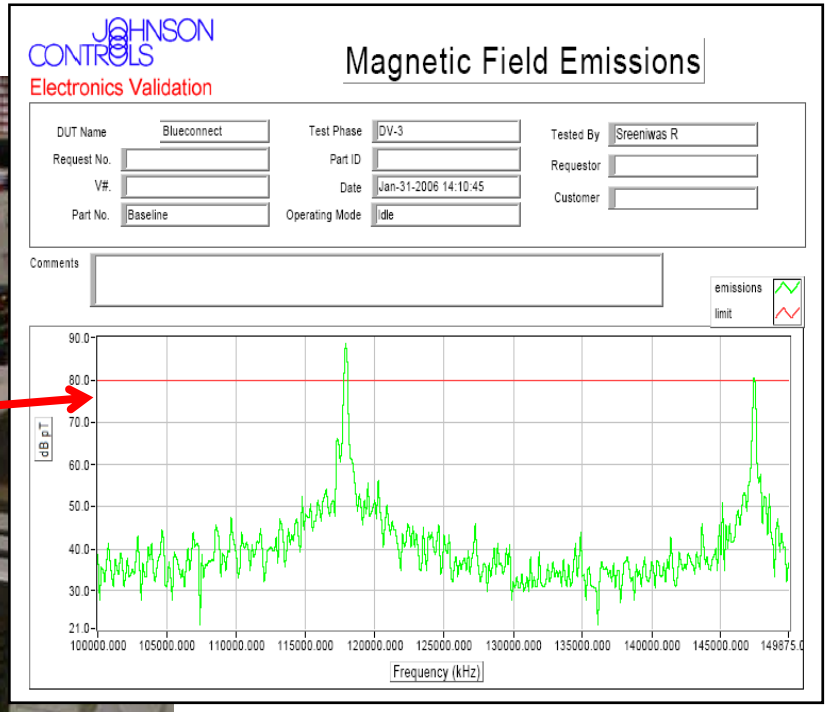
Passive Keyless Entry Magnetic Field Test

- Measures magnetic field emissions from a given module or system
- Quantified field (dBpT or nT) at a given distance
- Developed due to magnetic field interference not detected by module level testing
- Performed correlation in-vehicle measurements (developed a magnetic field limit)



Passive Keyless Entry Test Results





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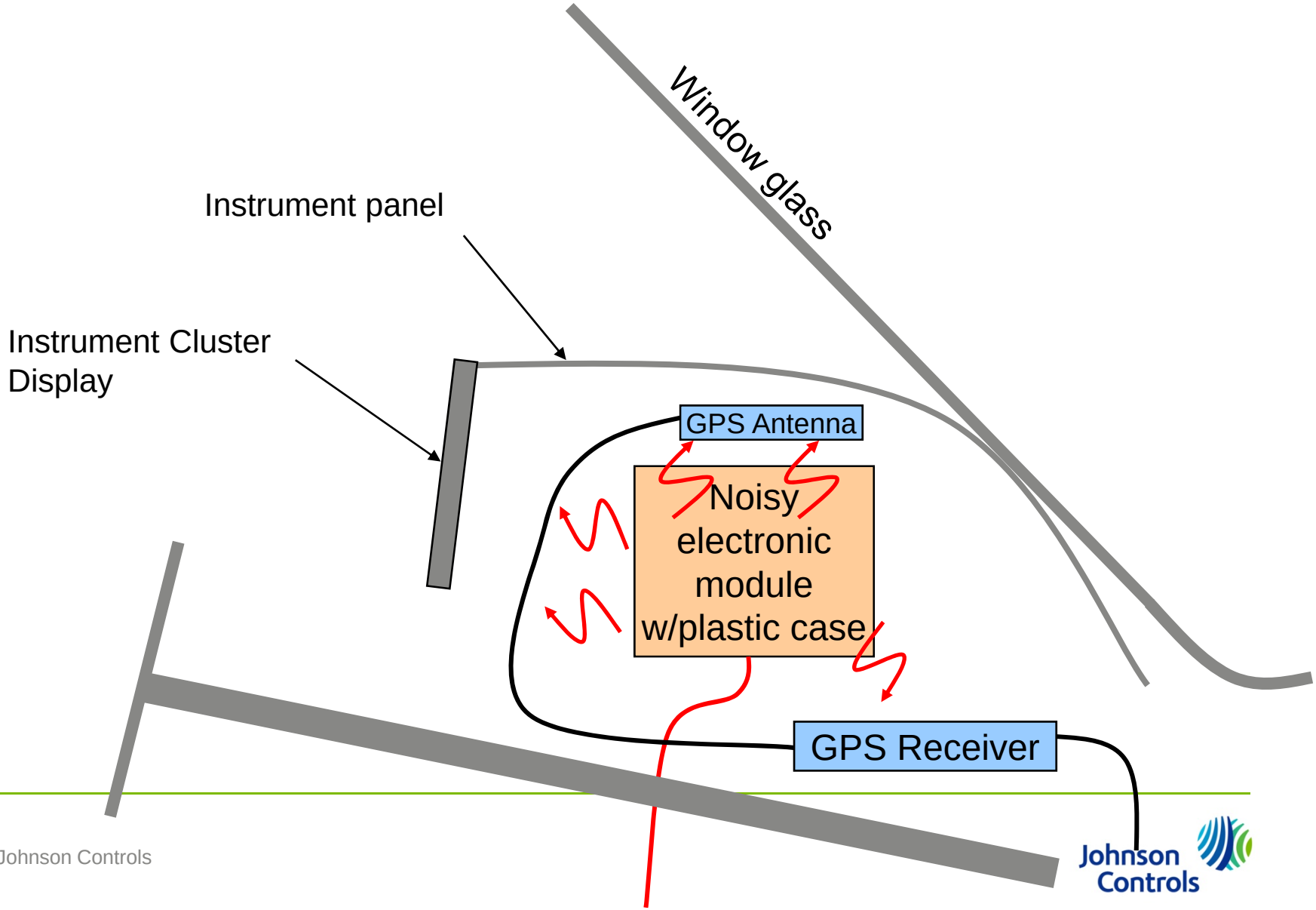
Passive Keyless Entry Magnetic Field Test – Equipment and Approximate Cost

- Equipment
  - Pre-compliant spectrum analyzer → $9,000
  - RF cables and low dielectric table → $3,500
  - Magnetic Loop → $3,500
  - Computer and automation software → $2,800

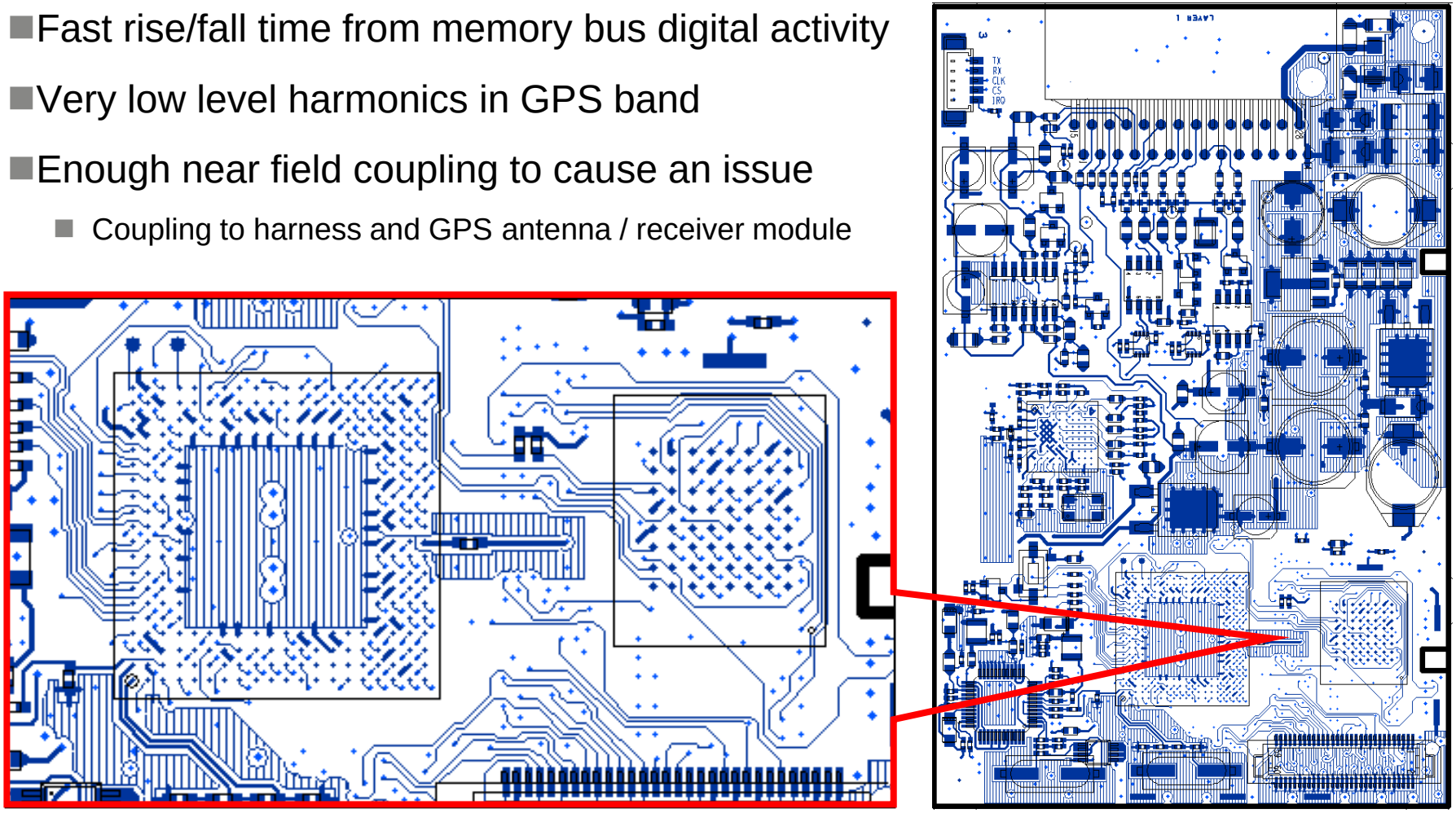
- Total Cost Estimate → ~ $20K

GPS Noise Interference In Vehicle Example (Side view of car)



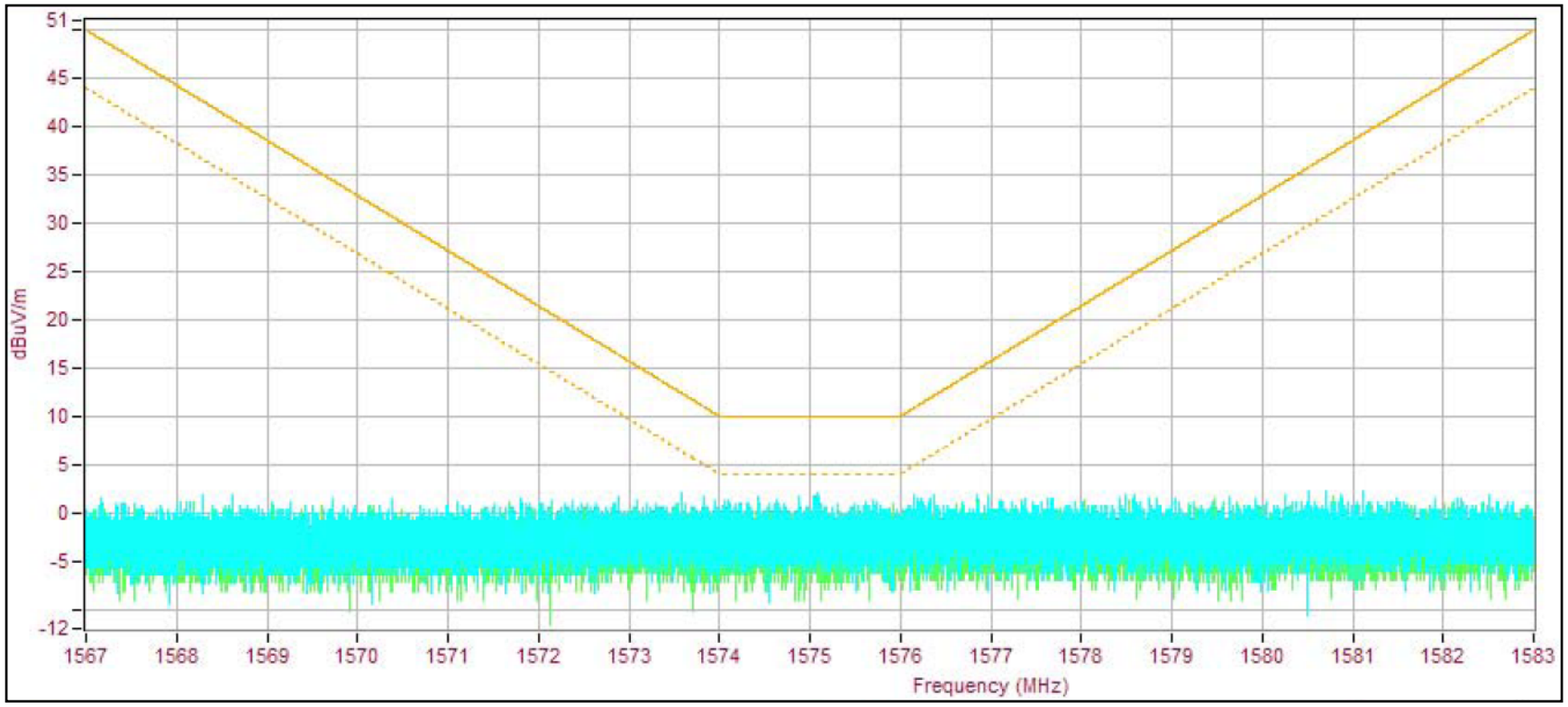
Inside The Noisy Product – Noise Source Details

- Fast rise/fall time from memory bus digital activity
- Very low level harmonics in GPS band
- Enough near field coupling to cause an issue
  - Coupling to harness and GPS antenna / receiver module



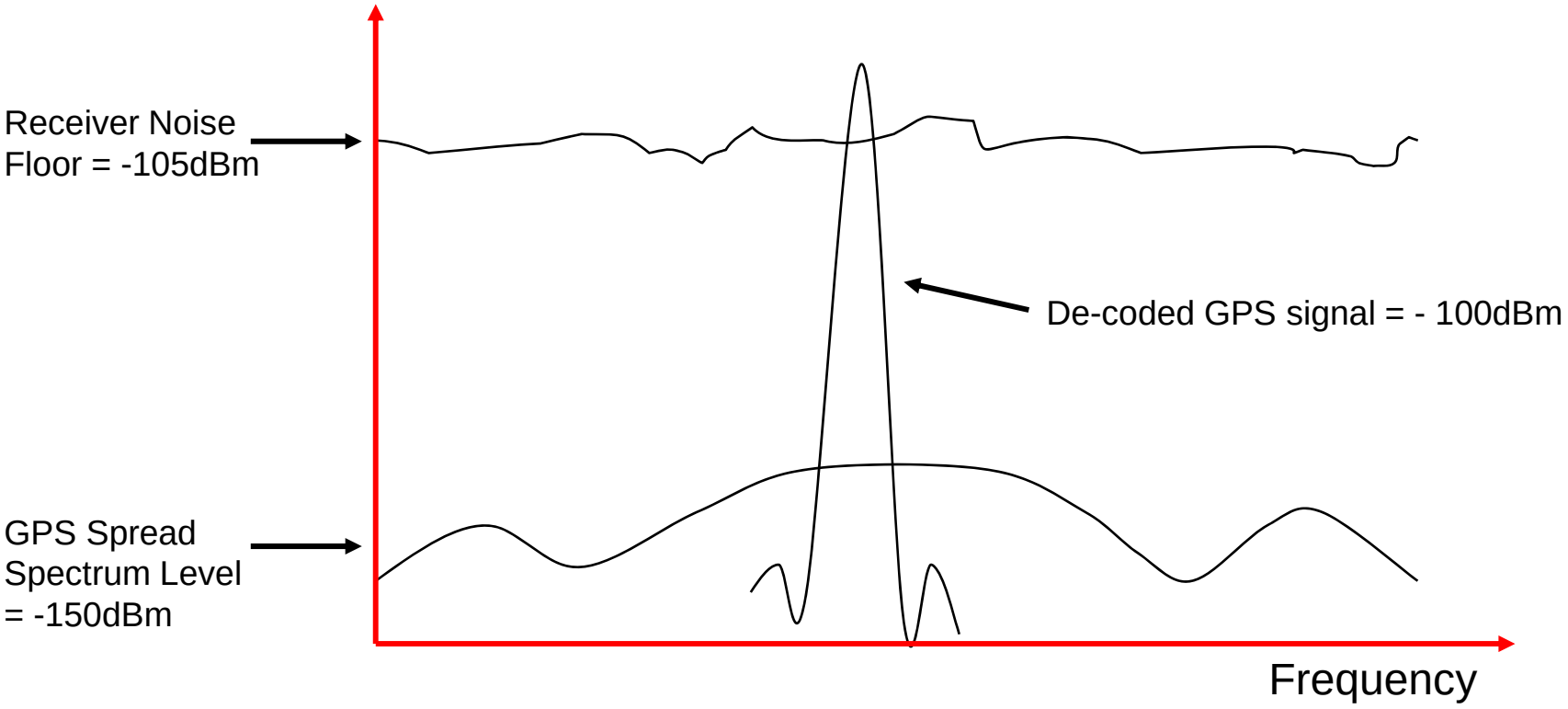
CISPR25 1 Meter GPS Test Not Sufficient To Detect Vehicle Issues

- Dynamic range of CISPR25 test is ~ 0 dBuV/M
- Typical signals that cause interference can be much lower in amplitude



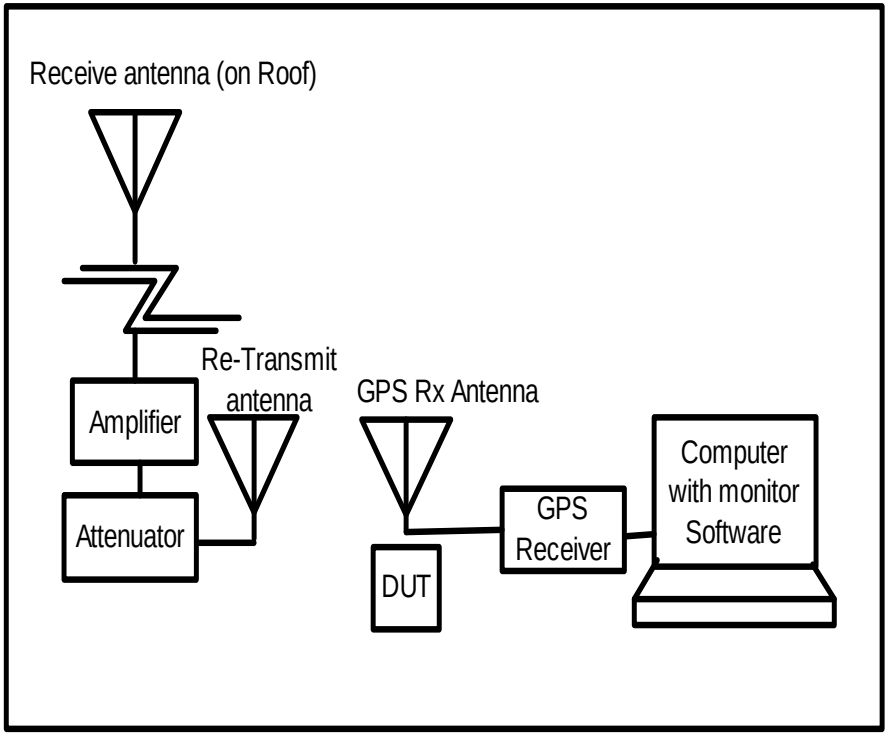
GPS Signal Amplitudes

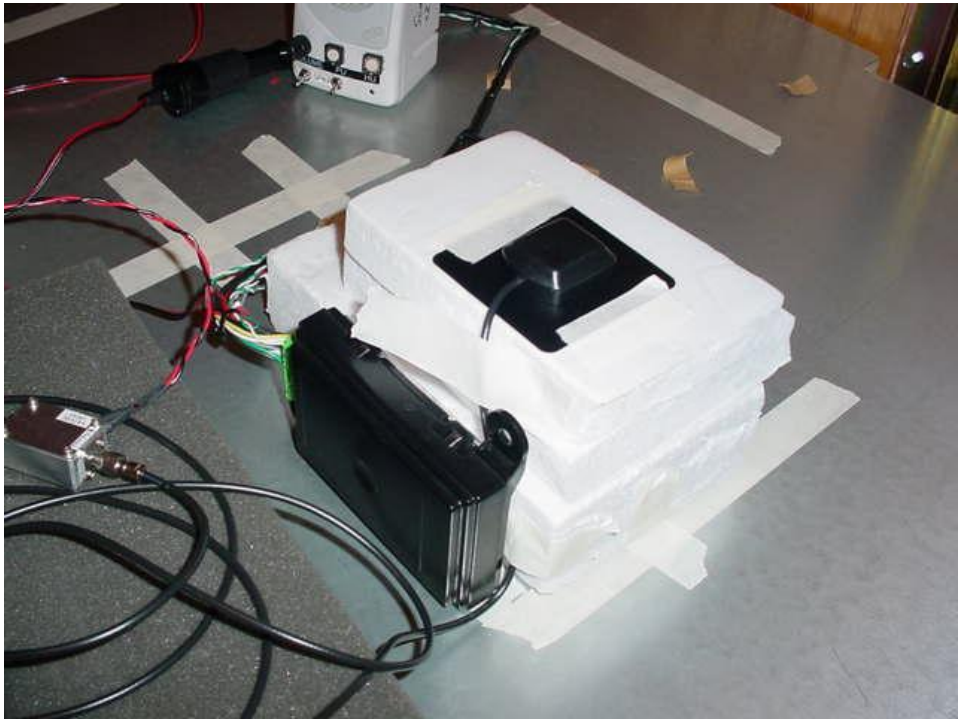
- Pseudo random modulation code is required to restore GPS signal to full amplitude (-100dBm)
- The signal can then be measured by a receiver



GPS Noise Evaluation Test Method

- Test narrow & broad band emissions from product that may interfere with GPS
- Tested with GPS Antenna, bias and pre-amplifier
- Measure satellite reception and RSSI (received signal strength input)





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GPS Noise Test – Equipment and Approximate Cost

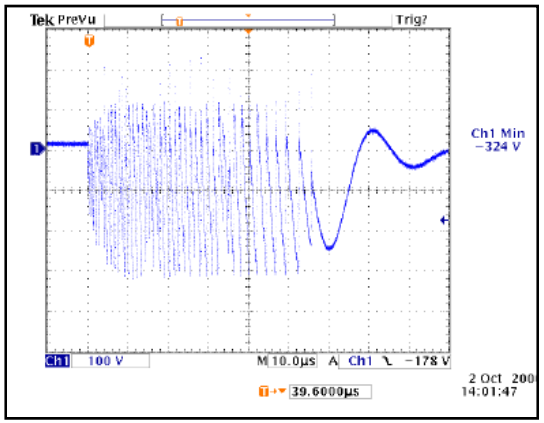
- Equipment
  - GPS receiver with RS-232 output → $2,500
  - GPS patch antenna and RF cables → $5,500
  - Attenuator and retransmit antenna → $2,000
  - Non-metallic bench → $1,000
  - Computer and automation software → $3,200

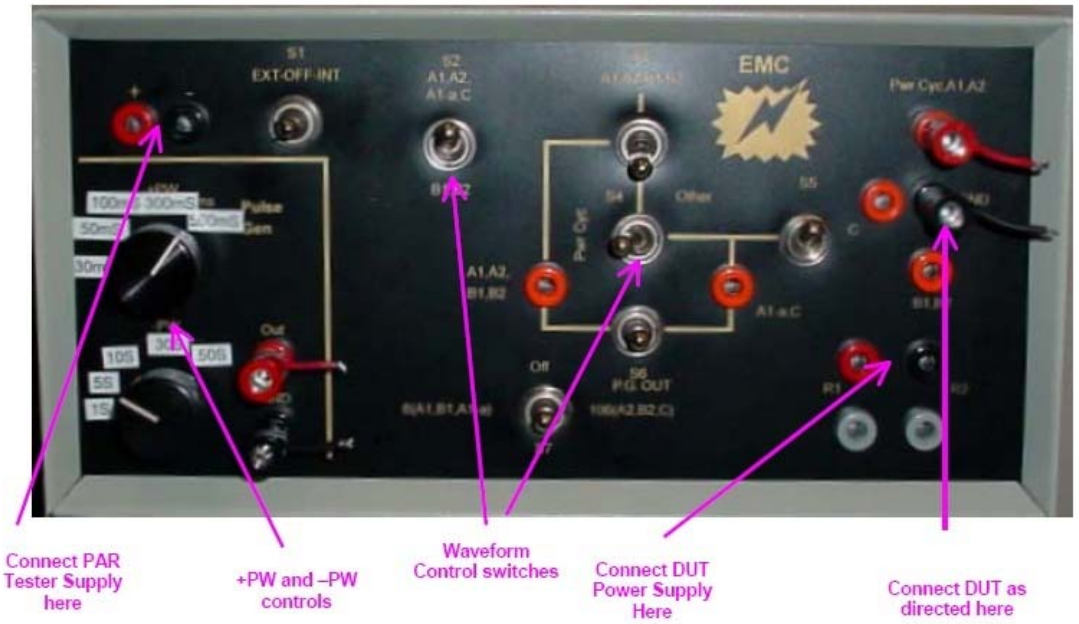
- Total Cost Estimate → ~ $15K

Transient Test Box

- Product Assurance Robustness (PAR) Tester
  - Development is credited to Arnold Nielson (retired from Visteon)
  - PAR tester design and test philosophy is formalized in the SAE J2628
  - Low cost solution to simulate vehicle transient events
  - Designed to produce random voltage transient events in a systematic way

JCI Version





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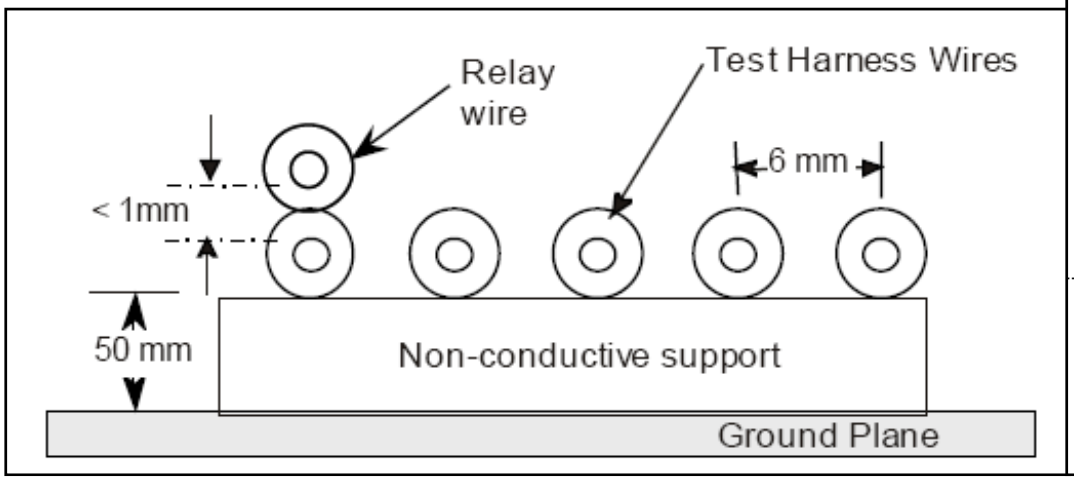
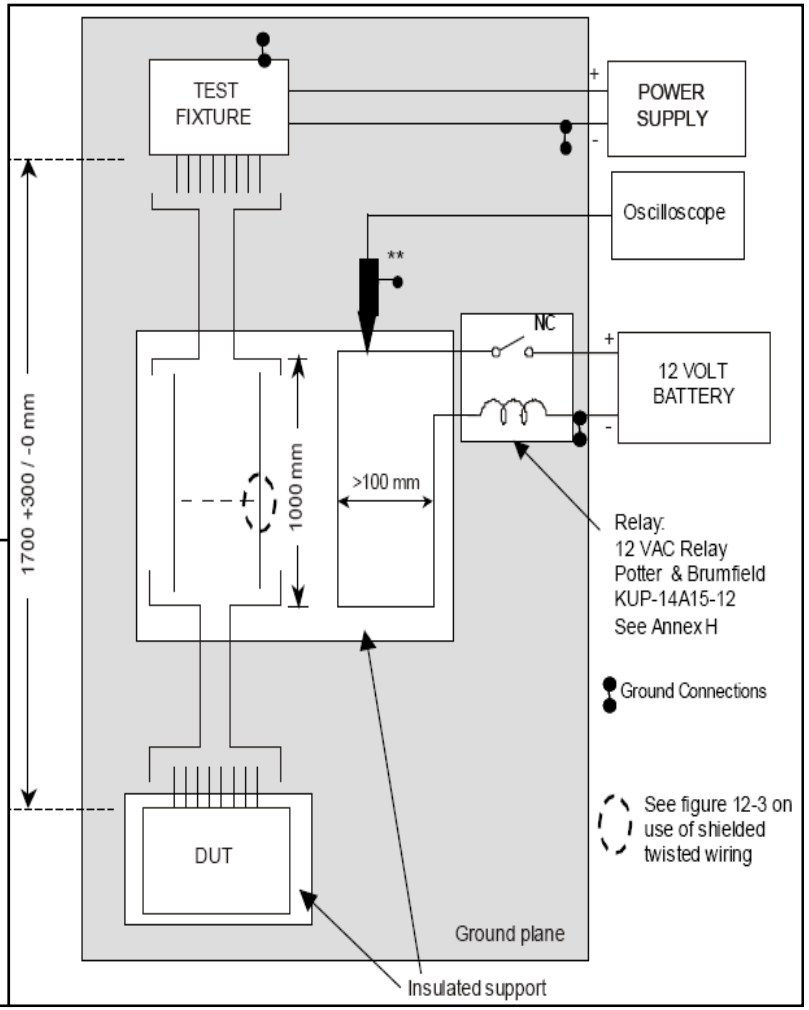
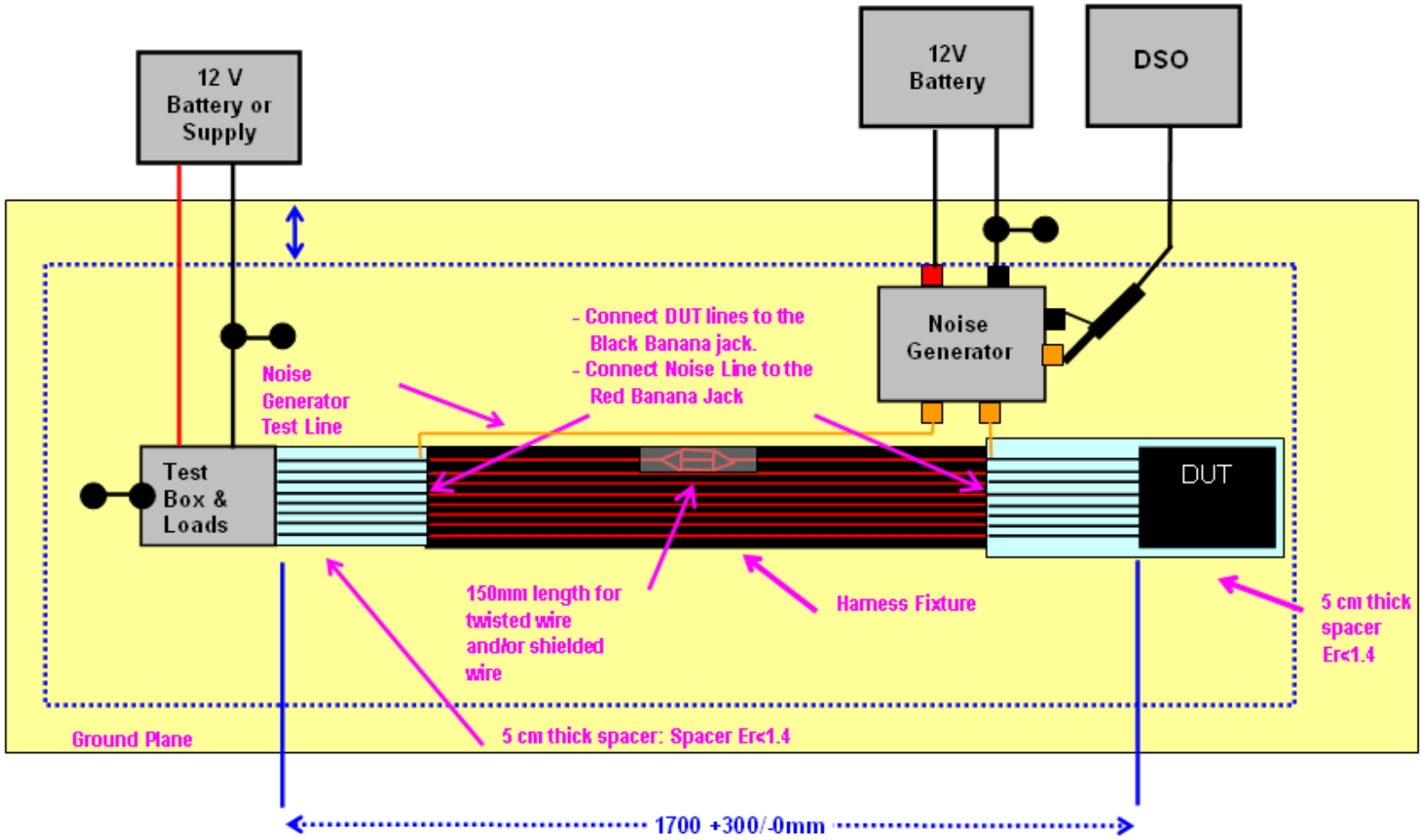
Parallel Miscellaneous Noise Tester – From FORD EMC RI130/RI150

- Couple inductive and charging system transients to product wiring
- Expose each wire in harness
- Observe product functionality during exposure





Parallel Miscellaneous Noise Fixture + PAR Tester



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Parallel Misc. Noise + PAR Test – Equipment and Approx. Costs

- Equipment
  - Digital storage oscilloscope → $15,000
  - Probes and cables → $1,500
  - PAR Tester → $5,500 - $15,000
    - Lower cost to build your own according to SAEJ2628
  - Miscellaneous Noise Fixture → $2,500
  - Relays, table, automotive batteries → $1,500

- Total Cost Estimate → ~ $30K

Conclusions

- Component level compliance tests are performed according to standards
  - Not updated frequently; requires agreement from many parties
  - May not represent unique vehicle scenarios, rather the more traditional EMC issues

- Pre-Compliance tests are performed according to the need
  - Methods are updated frequently
  - More flexible and can adapt to the scenario in the vehicle
  - Allow for root-cause and countermeasure development while testing
  - Allow for testing to collect quantitative data rather than attribute (PASS/FAIL)
  - Tests are low cost to develop and maintain
  - In partnership with OEMs correlation to vehicle level has been established

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Thank you for your attention

Questions?