“Resistive” Signature and Detection Protocol Summary and Overall Feasibility

IEEE 802.3af DTE Power via MDI Interim Meeting
November 2000

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Contents

- Updated protocol
- Prototype Evaluations
  - Non-Interfering
    - Non-interfering with 10/100 Ethernet via cross-talk
    - CISPR 22 radiated emissions
    - CISPR 24 conducted emissions
  - Detection Robustness and Flexibility
    - Avoids "false positive" detections
      - CISPR 22 radiated environment
      - CISPR 24 EFT environment
      - CISPR 24 conducted environment
      - Hazard Matrix
    - Reliably detects valid PDs
      - Line Build out test
      - CISPR 24 radiated susceptibility
      - CISPR 24 EFT susceptibility
      - CISPR 24 conducted susceptibility
    - Low risk of equipment damage IF power is ever inappropriately provided

Contents (Continued)

- Prototype Evaluations (continued)
  - Ability to survive ESD
  - Cost (High points from Sept. presentation)
    - Leverage the necessary function of precisely monitoring current levels, to inexpensively perform detection
    - Cost projections
    - Compact, allowing high density implementations
- Summary

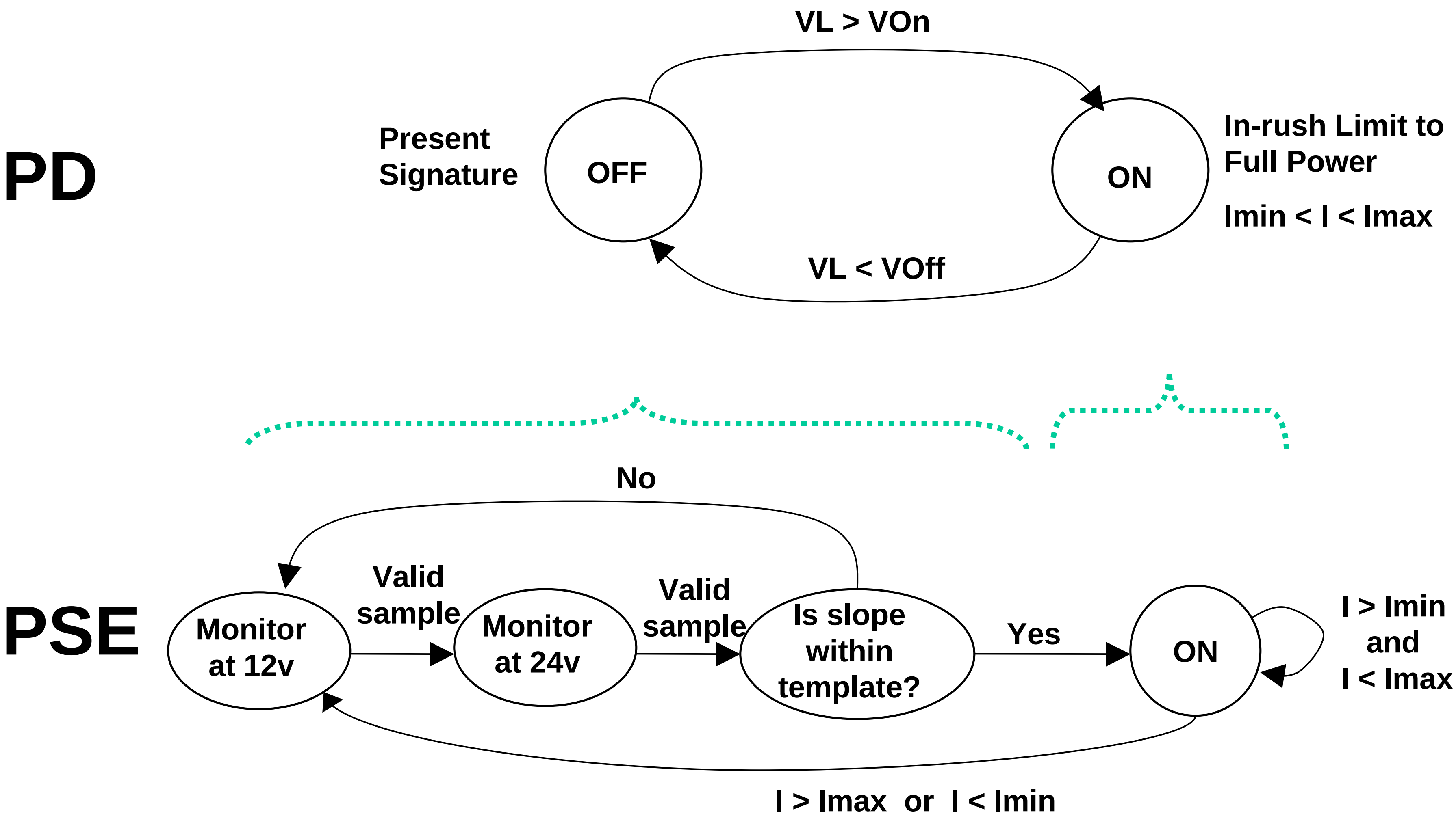
Protocol Update

- September Proposal and Prototypes
  - PD was to look like 25K ohm resistor plus two diode voltage drops
  - PSE was to take advantage of “unique” 25K ohm resistance and use diode offsets to discriminate against pure resistances
- November protocol update
  - PD exhibits slope of 25K ohm resistor
  - PSE detects 25K ohm slope
    - Slope is insensitive to temperature, highly controllable
    - Insensitive to diode offset (over components and temperature)
    - Insensitive to constant leakage paths
  - Does not discriminate against linear resistances falling within tolerance window (propose something like +/- 10% to +/- 20%)

Detection Protocol Overview

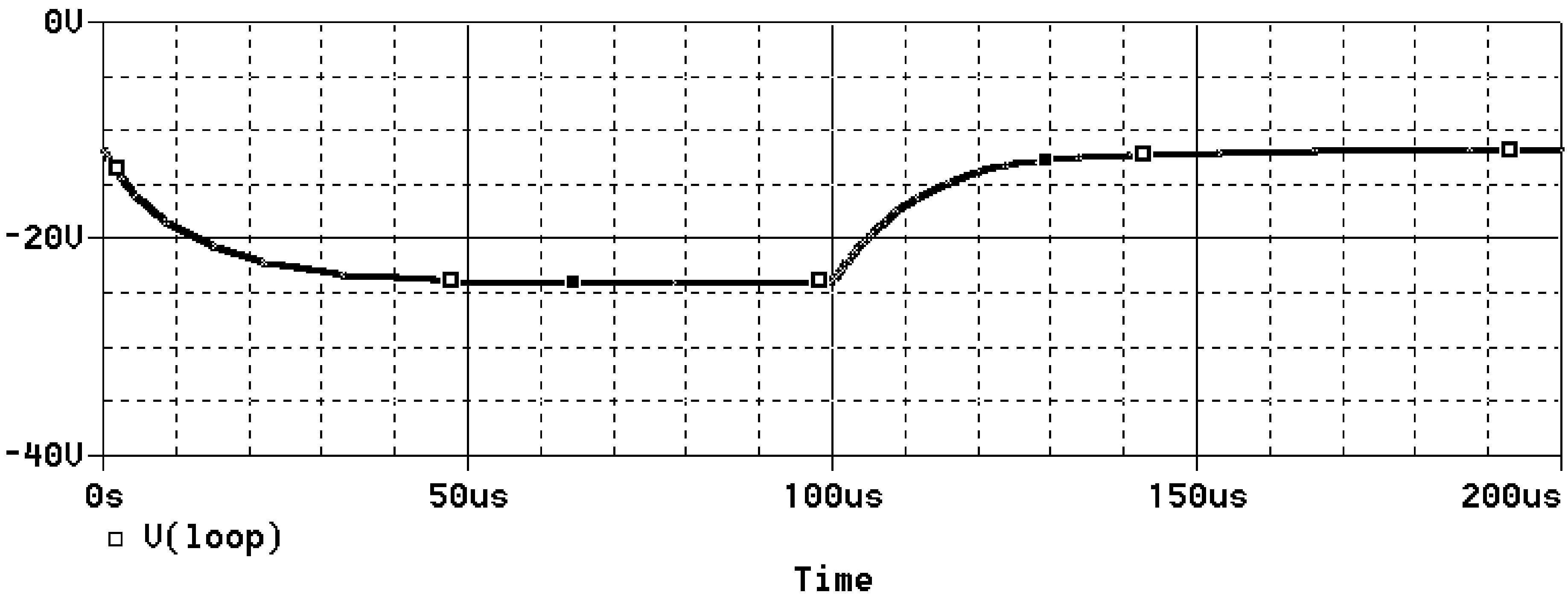
- PD:
  - Displays 25k ohm “slope” characteristic in off condition
    - Presence or absence of polarity guard diodes is immaterial
  - Accept power at load resistance when full voltage is offered
  - Control in-rush current
  - Maintain appropriate current
- PSE:
  - Observes the delta voltage and delta current between two test voltages (~24v and ~12v at source)
    - Verifies expected resistance slope
    - Measures at high impedance, multiple measures at each voltage
  - Applies full voltage (low resistance) after signature is detected
  - Removes voltage when current becomes too high or too low

Protocol at DTE and Source



Note: Repetitively switches between DC levels in “off” state

Open Circuit Loop Voltage (Simulated)



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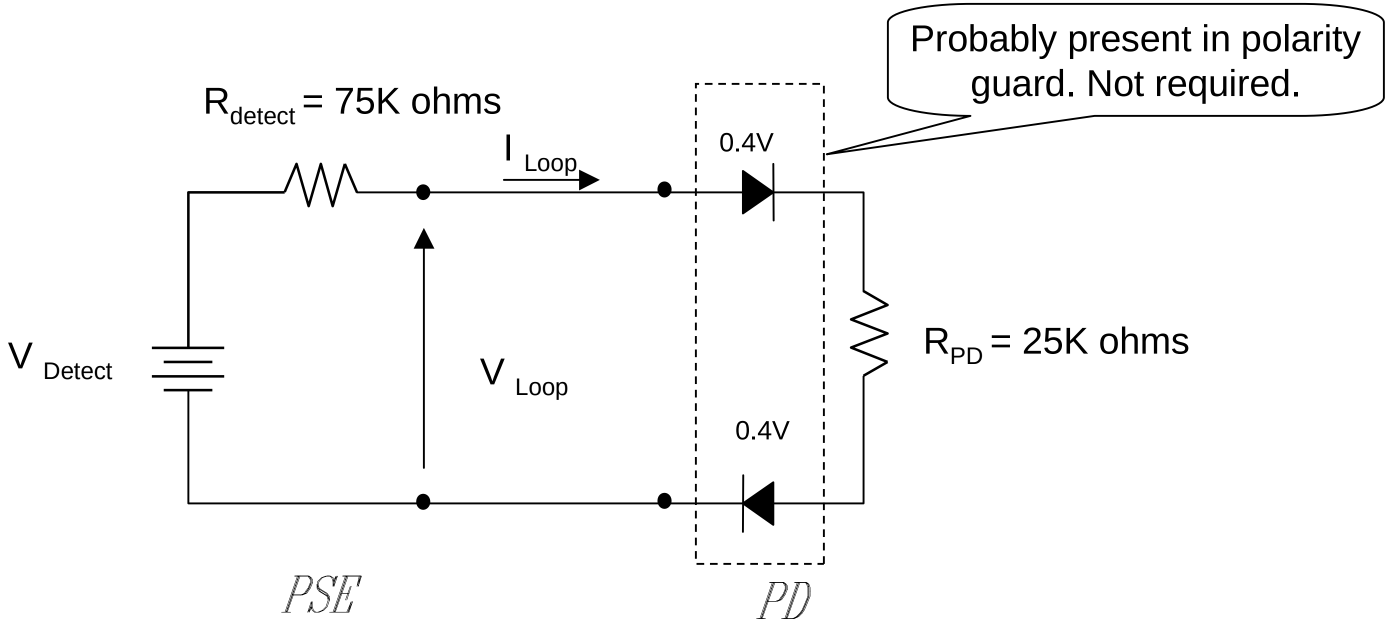
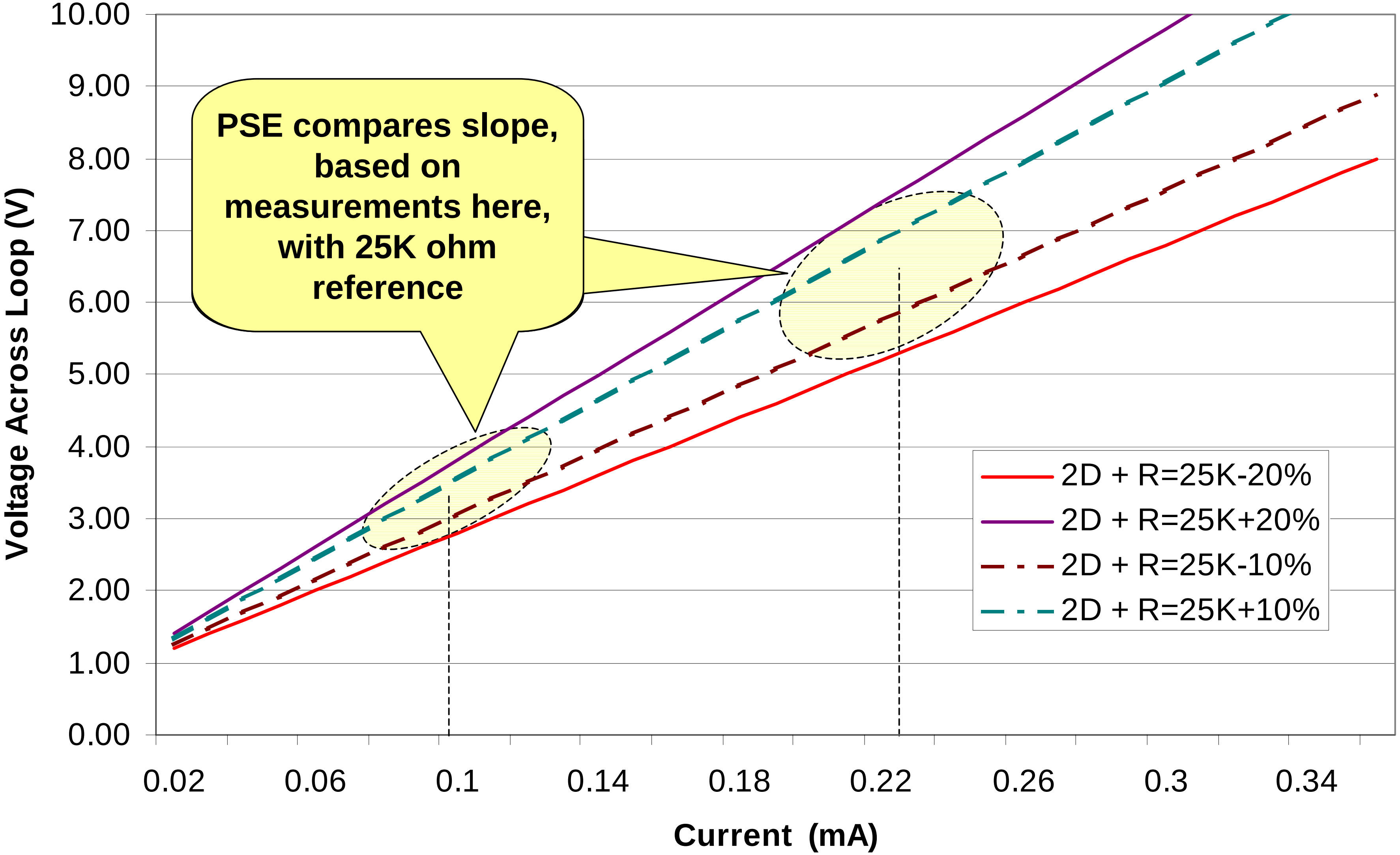
Approximate Detection Current-Voltages



Use two Detection Voltages

			Power (mW)	Power (mW)
V-Detect (V)	I-Loop (mA)	V-Loop(V)	Source	PD
24	0.232	6.6	5.6	1.5
12	0.112	3.6	1.3	0.4

V-I Characteristic: Resistance Plus Two Diodes



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Evaluation of September Prototype

Non-Interfering

Non-Interfering with 10/100 Ethernet - Via Cross Talk

A Line Build out Experiment was performed using September Mid-span insertion prototype:

1) Prototype PSE was inserted 5m away from a 100BaseTX node.

2) Cable was added to the link until errors just started occurring (144m).

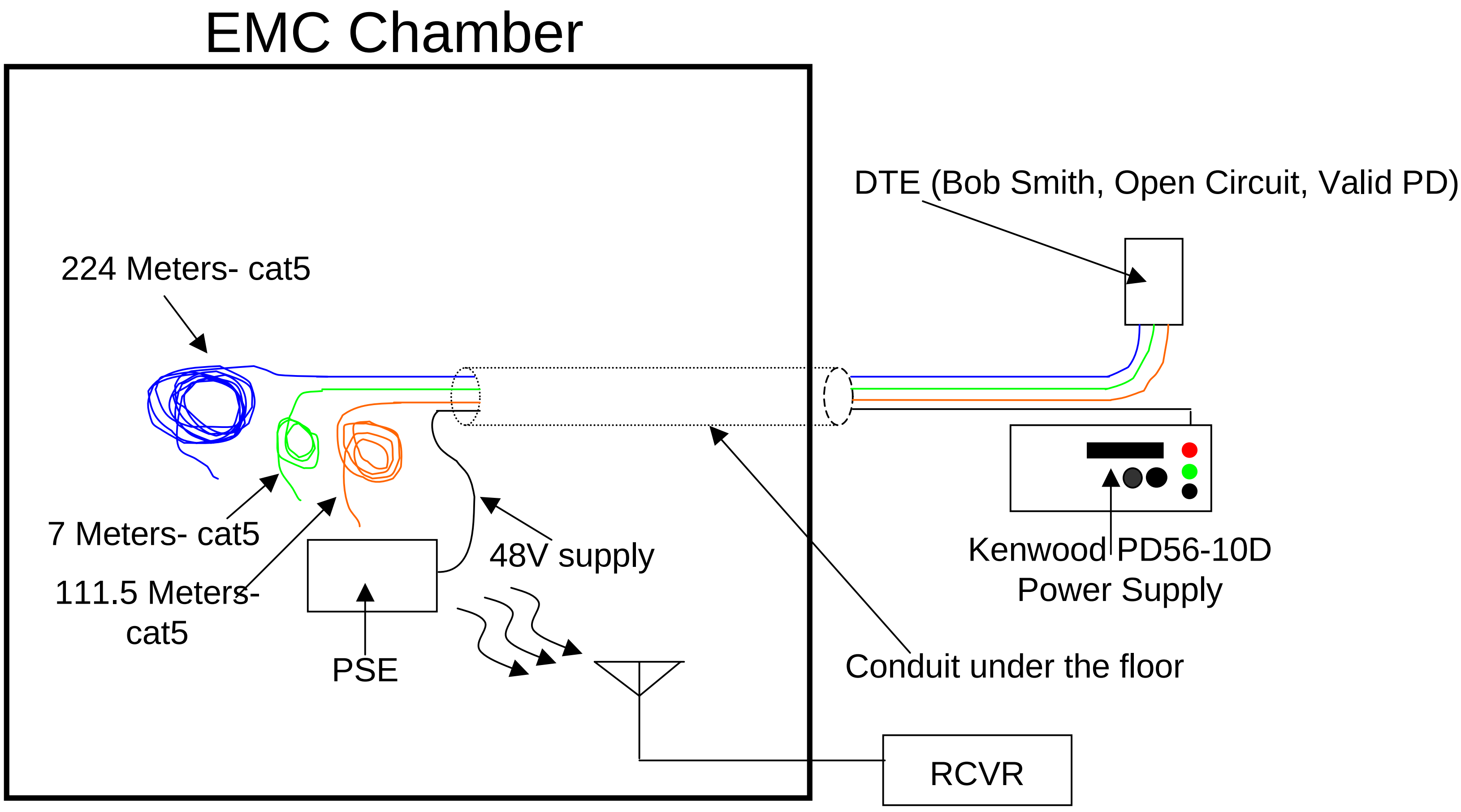
3) Prototype PSE was continually measuring for a PD since the signature intentionally wasn't presented in this configuration.

4) BER performance of the network was compared with the PSE ON and OFF to get a sense of the impact of running the unit.

Test #	CRC/M Packets (OFF)	CRC/M Packets (ON)
1	52	144
2	125	147
3	142	54

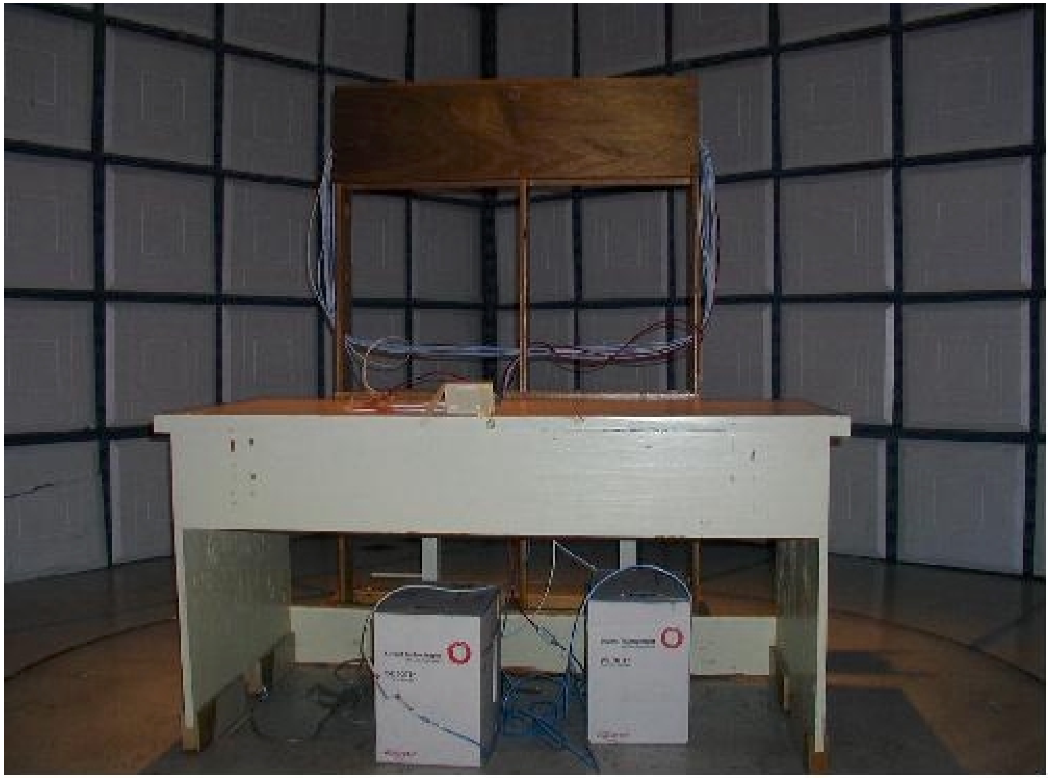
5) Similar ON/OFF results show no averse behavior resulted.

Lab Configuration - CISPR 22 Radiation Tests



Three cables ran into the chamber allowing all possible combinations to be tested with minimal disturbances.

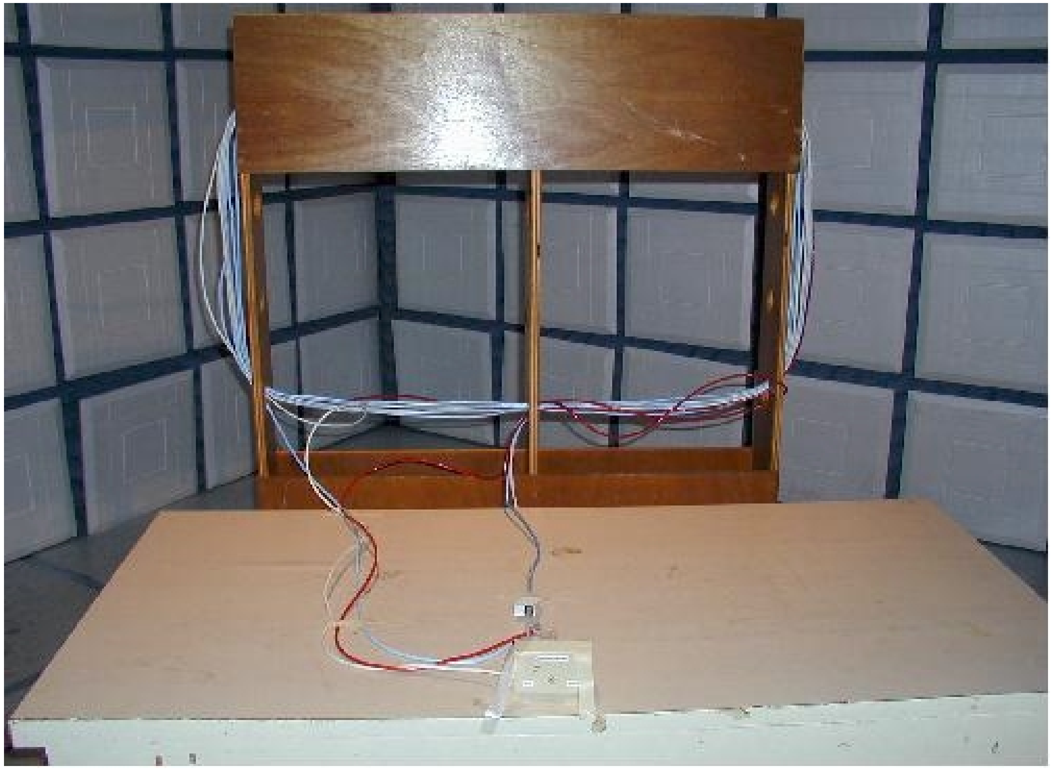
CISPR 22 Lab Configuration



Radiated Emissions Lab Setup. 3 Meter Anechoic Chamber

All cables in place

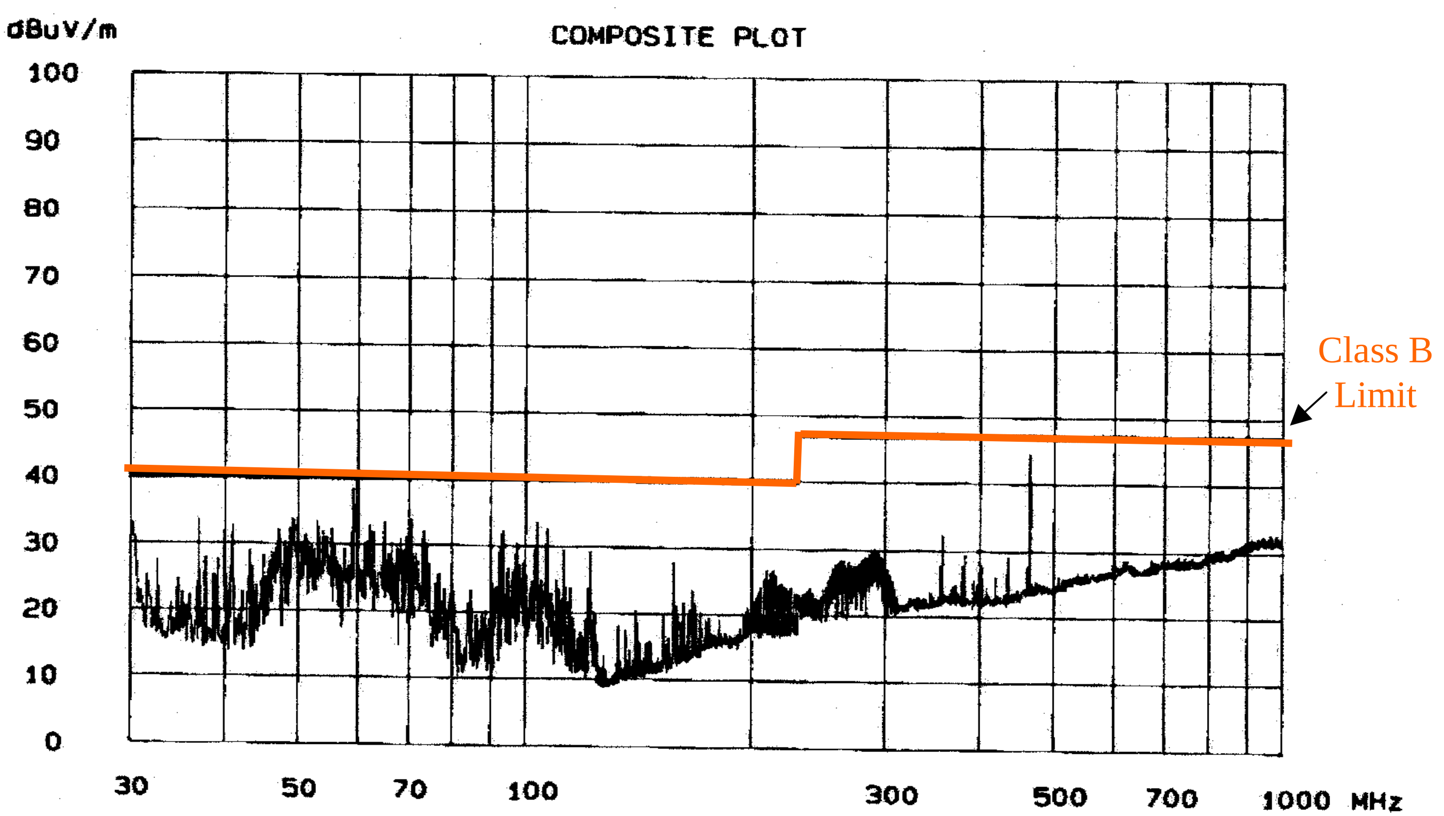
CISPR 22 Lab Configuration



10 meters of all three cables (224 m, 111.5 m, and 7 m) wrapped on the rack

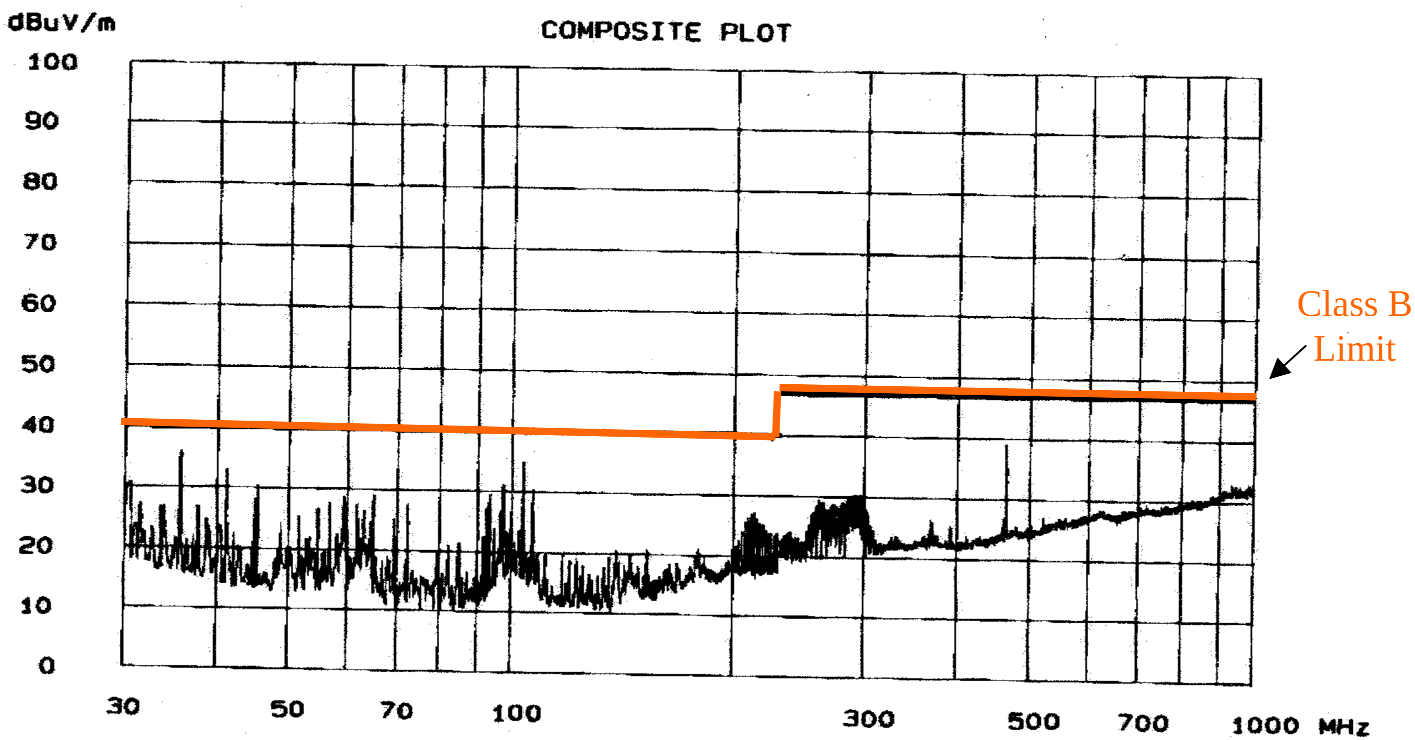
PSE in the center

Radiated Emissions (CISPR 22, Class B)



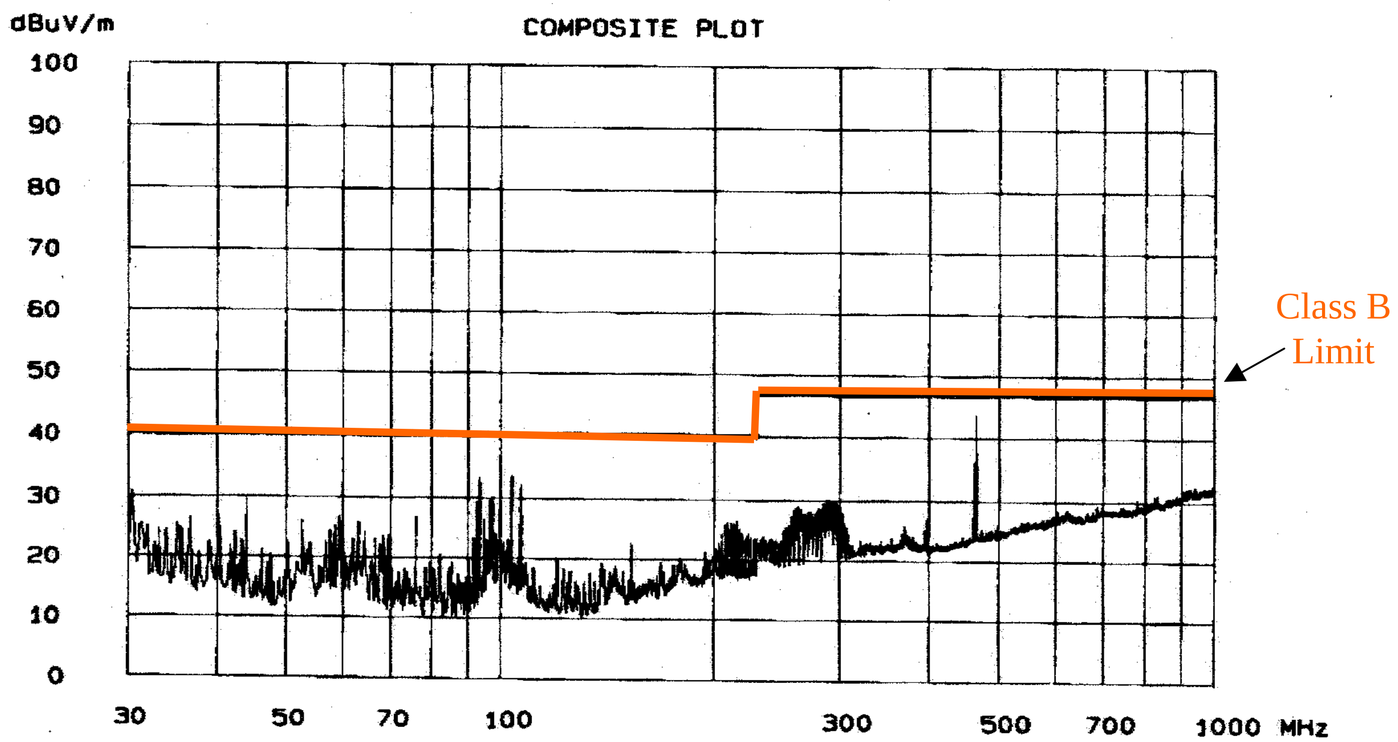
Ambient chamber- all cables and PSE in place (power off)

Radiated Emissions (CISPR 22, Class B)



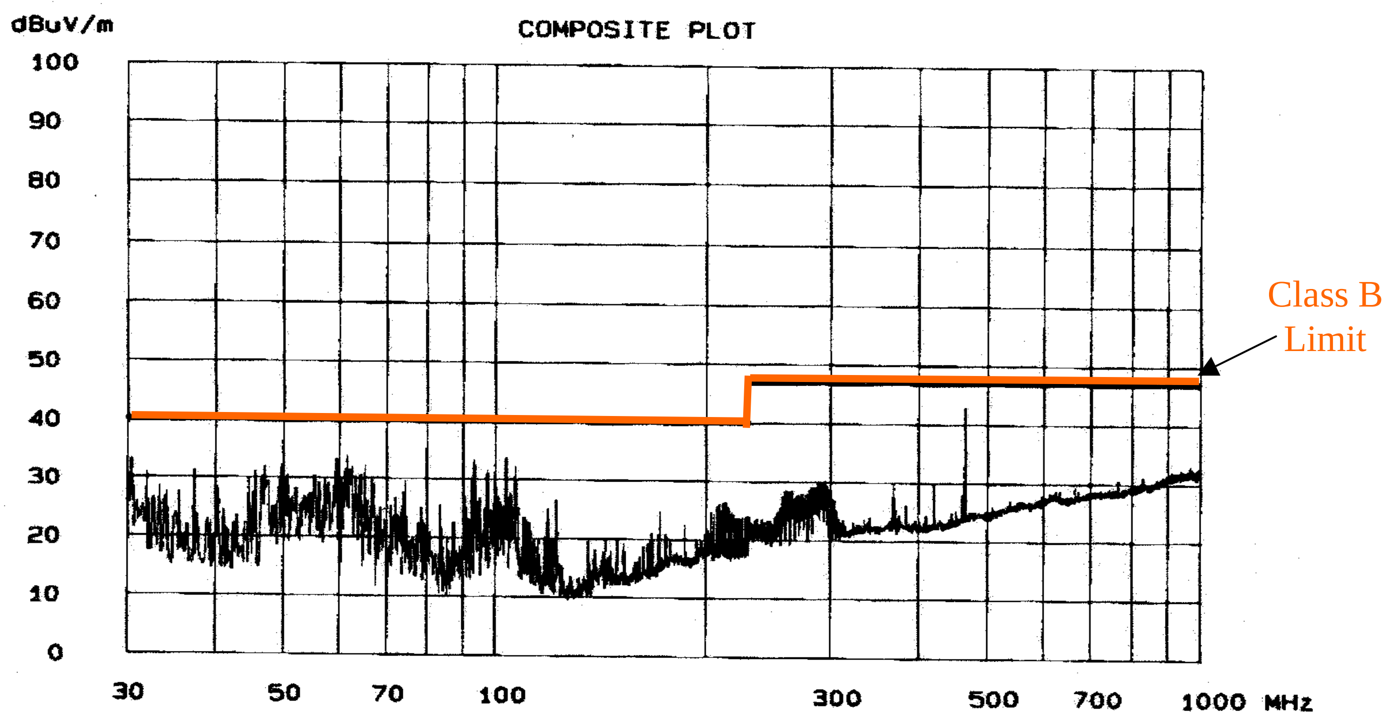
PSE Monitoring an Open Circuit Termination with 7 meters of cat 5 cable

Radiated Emissions (CISPR 22, Class B)



PSE Monitoring a Bob Smith Termination with 7 meters of cat 5 cable

Radiated Emissions (CISPR 22, Class B)



PSE delivering power to a Valid PD with 7 meters of cat 5 cable

CISPR 22 Radiated Emissions Summary

Considerations

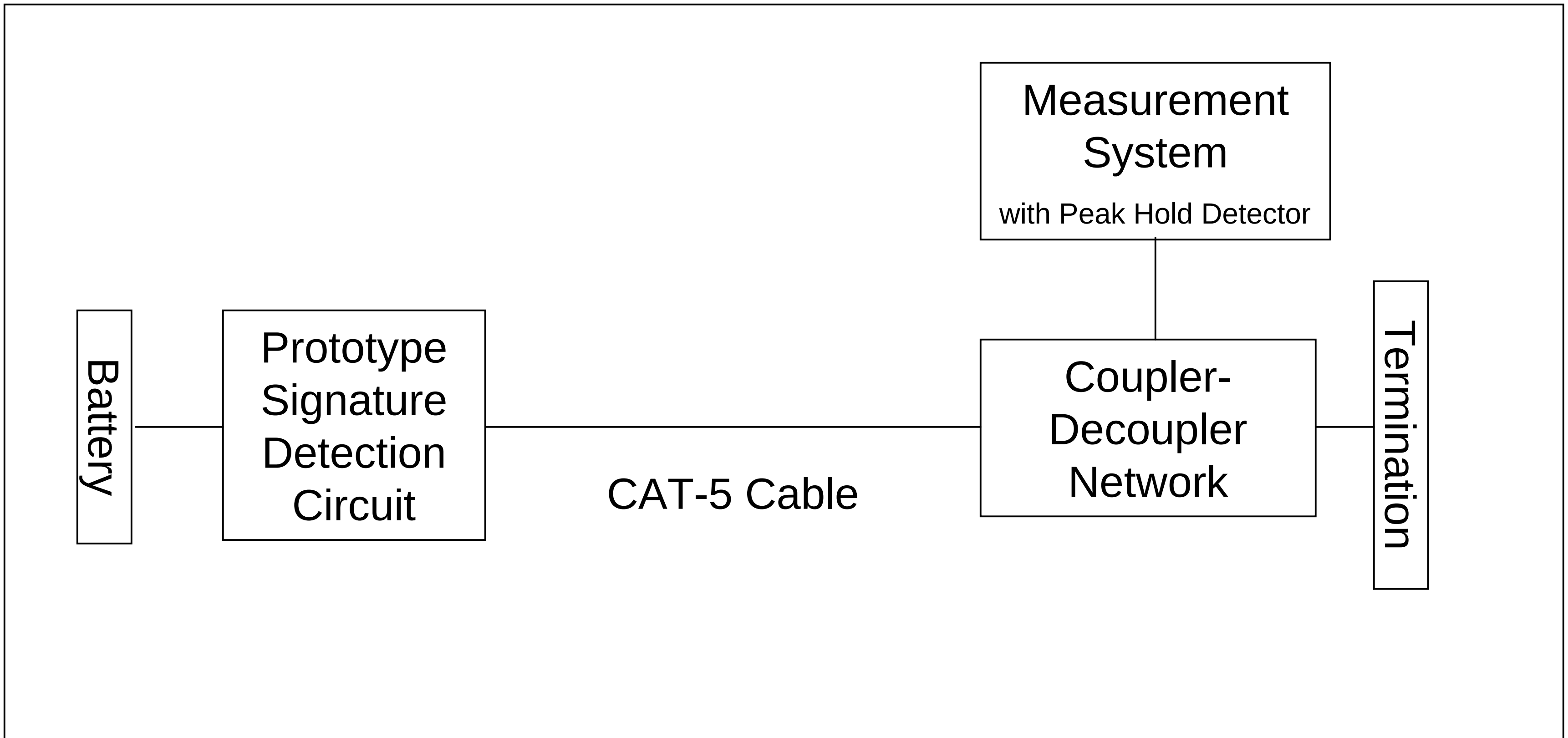
- The ambient chamber was noisy due to radio frequency (FM radio 464 MHz) energy transmitted into the chamber through the three lengths of test cable
- The unit under test is the PSE and cable. The DTE was outside of the chamber

Radiated Emissions Results

- Comparing each termination test result to the ambient chamber shows that the PSE, ***with no special shielding***, radiates very little energy in the 30 to 1000 MHz spectrum.

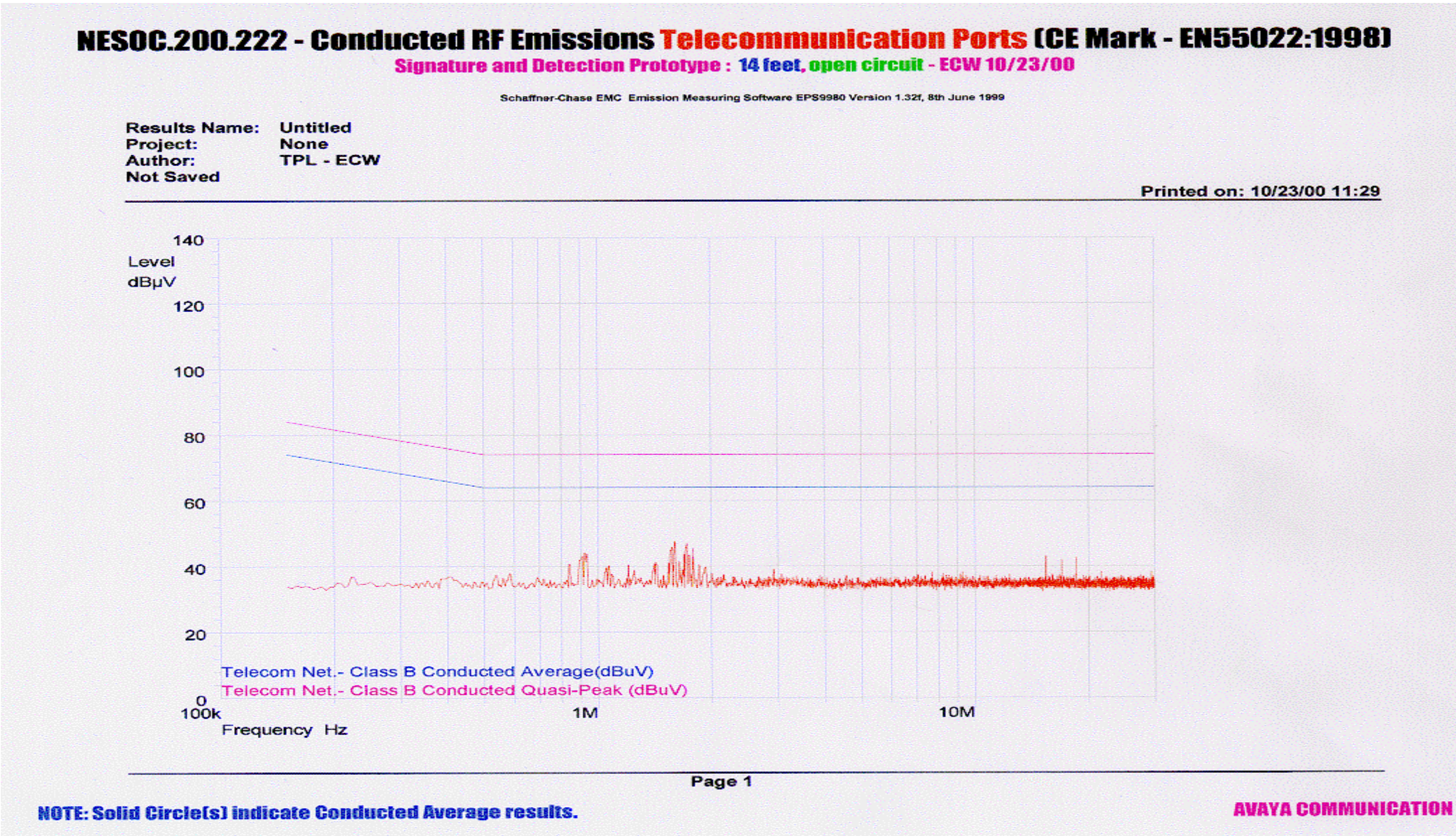
Conducted Emissions - CISPR 22

Test Setup for Conducted Emissions Testing



Conducted Emissions - CISPR 22

Typical CISPR Conducted Spectrum - 160 kHz to 30 MHz



Conducted Emissions, CISPR 22, Class B - Summary of Test Results

Conducted Emissions - Resistance + 2 diodes Prototype					
CISPR 22, Class B Limits					
	Open Ckt	Bob Smith	Valid PD (Prototype)	Power OFF, ambient with cable in place	
Cable Lengths	14 ft or 328 ft	14 ft or 328 ft	14 ft or 328 ft	14 ft or 328 ft	
Min Margin (dB)	16	16	16	16	

Conclusion: With or without the valid powered endpoint, the measured emissions were virtually the same as the unpowered background measurement.

These results, ***based on a prototype with no filtering***, show that the detection process itself would not be a significant contributor to CISPR22 conducted emissions.

Evaluation of September Prototype

Detection Robustness and Flexibility

IEC 1000-4-3 Lab Configuration - CISPR 24 Radiated Susceptibility Testing

Transmitting antenna

Monitoring antenna

Radiated Susceptibility Test Configuration

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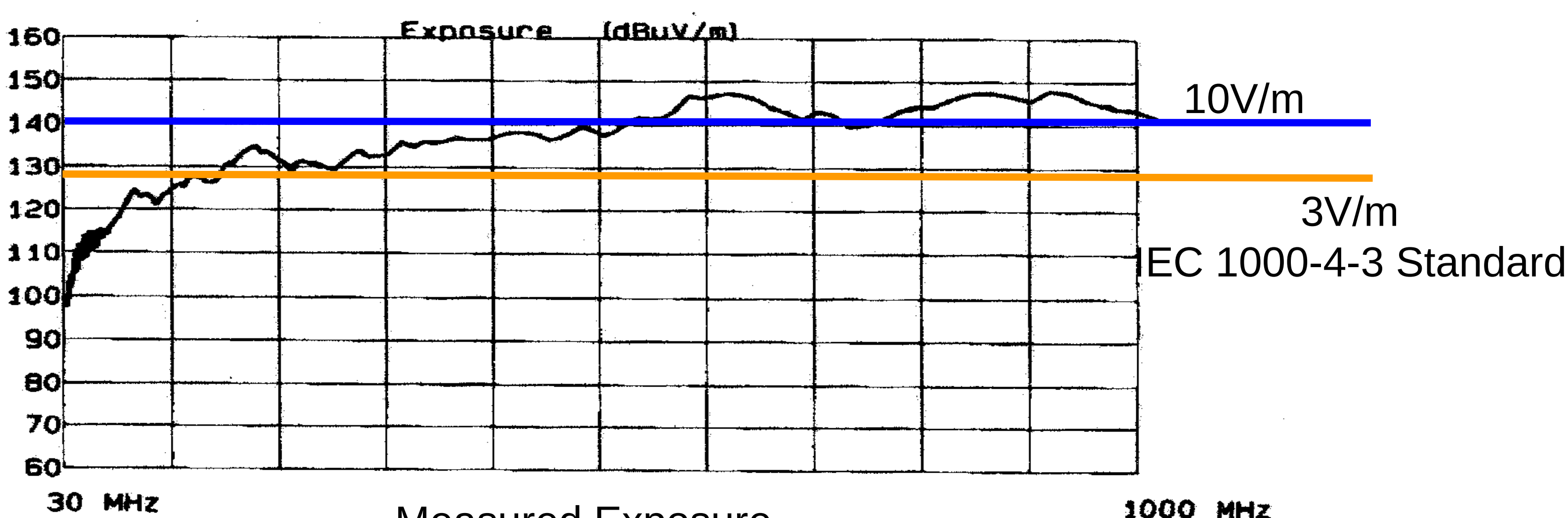
Radiated Susceptibility - 10V/m

Avoids False Positive Detection

CISPR 24 Radiated Susceptibility Test Results

Cable / antenna / Termination	25 feet or 7m		366 Feet or 111.5m		738 Feet or 224m	
	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.
Open Circuit			Pass	Pass		
Bob Smith			Pass	Pass		
Worst Case Sig 32K			Pass	Pass		
Parallel PD’s			Pass	Pass		



Measured Exposure

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Radiated Susceptibility - 10V/m

Avoids False Positive Detection

Considerations:

- The CISPR requirement is 3V/m
- We tested the PSE and the cables to 10V/m

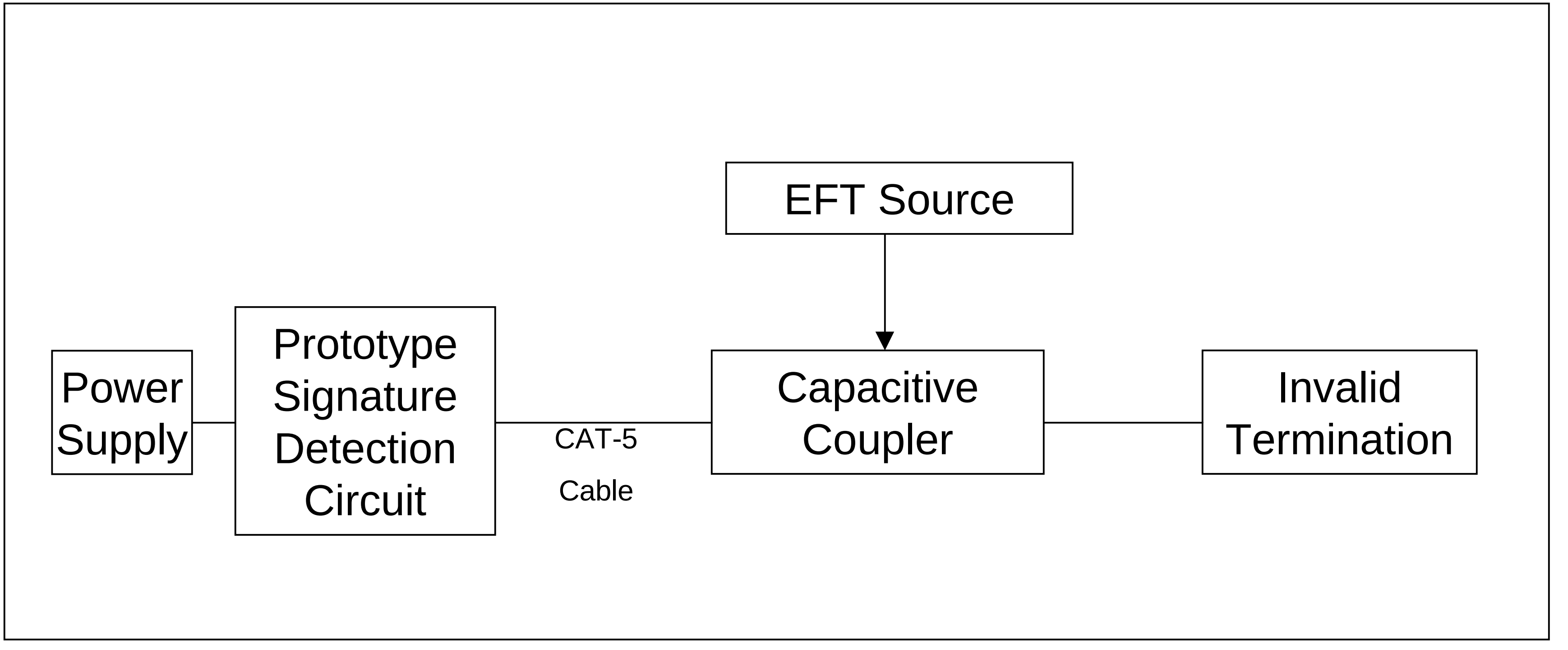
Summary:

- All tests passed demonstrating a very robust design, without adding special radiation shielding for the PSE.

EFT Environment

Avoids False Positive Detection

Test Setup for EFT Susceptibility Testing



EFT Environment
Avoids False Positive Detection

Summary of Test Results

CISPR 24:

Basic Standard: IEC 61000-4-4

Test Specification: 500 V peak, 5/50 ns Tr/Th, 5 kHz repetition rate

Test Passed (at 14 ft and at 328 ft)

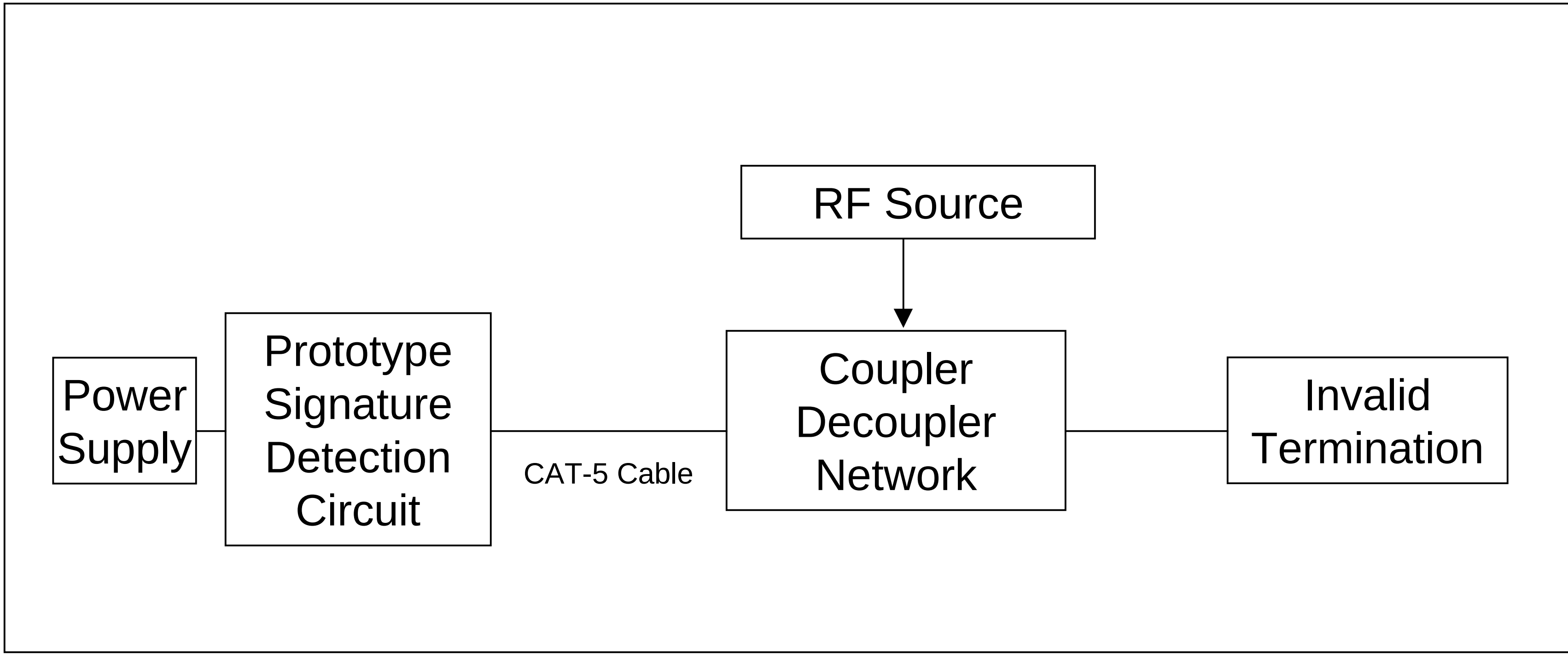
No false positive detections for the following terminations

- Open Circuit
- Bob Smith Termination
- 34 K resistor (“almost valid signature”)
- ***<u>Two parallel valid PDs</u>***

Conducted RF Environment

Avoids False Positive Detection

Test Setup for Conducted RF Susceptibility Testing



Conducted RF Environment
Avoids False Positive Detection

Summary of Test Results

CISPR 24:

Basic Standard: IEC 61000-4-6

Test Specification: 0.15 - 80 MHz, 3 V, 80% AM modulated (1kHz)

Test Passed (at 14 ft and at 328 ft)

No false positive detections for the following terminations

- Open Circuit
- Bob Smith Termination
- 34 K resistor (“almost valid signature”)
- ***<u>Two parallel valid PDs</u>***

Line Build Out
Reliably Detects Valid PD

- Mid-span Prototype was tested for various cable lengths
- Cat 5 cable 1m – 1,200m inserted between PSE and PD
- Cable was inserted 3X and LED was observed to see if power was applied or not
- For each cable length tested power was applied to the PD

Cat 5 Cable Length	DTE Load Power Applied
Meters	
1	Y
20	Y
40	Y
60	Y
80	Y
100	Y
140	Y
200	Y
400	Y
500	Y
1,200	Y

EFT and Conducted RF Environments

Reliably Detects Valid PD

Test Setups and conditions:

Same as in False Positive Tests, except that terminations are:

1. Valid PD
2. Valid signature, but no load (repetitive discovery)

Results: Reliable detection with the following observations

1. EFT at 14 ft may cause overload protection sensing to prematurely release the load
2. RF may cause slight delay in detection

- In all cases prototype recovers.
- Software fixes in progress to eliminate these effects.
  - Prototype reacted to a single event; new code would go back to verify.

Campbell Clamp Test

Reliably Detects Valid PD

1000Base-T (Clause 40.6.1.3.3) Common-mode noise rejection

- 100m cat 5 cable was inserted between mid-span Prototype PSE and PD
- Cable Clamp inserted 20cm from PD
- 2 Chokes installed on cat 5 cable 2 cm from clamp (on Transmitter side)
- Common copper ground plane under cable clamp and PD
- 1Vrms sine wave applied to cable clamp from 1Mhz to 250Mhz (Larger amplitudes were used when the equipment allowed it)
- Cat 5 cable was inserted into PD 5 times for each frequency tested
- For each insertion at each frequency the Green LED was illuminated
- No blinking was observed, each insertion produced a solid green indication

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Campbell Clamp Test Results

Reliably Detects Valid PD

DTE POWER DETECTION CIRCUIT CMNR TEST

Freq		Amp RMS		Amp p-p		PASS	FAIL
MHz		Volts		Volts		5X insertions	5X insertions
1		1.4		3.7		YES	No
2		1.3		3.5		YES	No
5		1.3		3.5		YES	No
10		1.2		3.3		YES	No
20		1.1		3		YES	No
30		1.1		3		YES	No
40		1.1		3		YES	No
50		1.1		3		YES	No
60		1.1		3		YES	No
70		1.1		3		YES	No
80		1.1		3		YES	No
90		1.1		3		YES	No
100		1.1		3		YES	No
110		1.1		3		YES	No
120		1.1		3		YES	No
130		1.1		3		YES	No
140		1.1		3		YES	No
150		1		2.9		YES	No
160		0.9		2.6		YES	No
170		1		3		YES	No
180		1		3		YES	No
190		1		3		YES	No
200		1		3		YES	No
210		1		3		YES	No
220		1		3		YES	No
230		1		3		YES	No
240		1		3		YES	No
250		1		3		YES	No

Hazard Matrix Experiment, Part I.

Supporting data behind this chart was presented at July and September meetings.

An approximate 24.2V power supply with a 75K Ohm Series Resistor was applied to wires 4,5 and 7,8 and the resulting voltage across the pairs was measured and recorded. This was also done for wires 1,2 and 3,6. The following Hazard Matrix Table shows how the resulting margins under a variety of conditions compare to the margins illustrated in the previous Signature Margin Table. Most equipment clustered around the expected "Open" or "Short" circuit regions as expected.

Hazard Matrix, Part II.

This chart was used at September meeting. We do not expect new protocol to affect hazard results

A prototype module that replicates and automates the previous experiment was fabricated. With this, a second voltage measurement criteria was added to the algorithm that must *also* be satisfied in order for power to be applied. This 12V measurement, when coupled with the previous 24V measurement, ensures that purely resistive and highly non-linear loads will not match the signature. The 8410D phone, and a number of new units were tested and found not to promote power application.

Make/Model	Status	Power?
Lucent 8410D Phone	OFF	No
Lucent 4624	ON	No
IP phone	OFF	No
Cajun P220FE	ON	No
(Gigabit Switch)	OFF	No
Cabletron Systems	ON	No
Smart Switch 2200	OFF	No
Cisco 1600	ON	No
(Router)	OFF	No

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Low Risk of Damage *IF* Power is Ever Inappropriately Applied

- Suppose a mistake is made
- Worst case assumption: a 25K -20% = 20K ohm linear resistance is mistaken as valid PD
  - This is a worst case for ***November Protocol***
- Then full 48 volts is applied
- Power is delivered momentarily: $P = E^2/R = 48^2/20K = 115$ mW
- Current delivered will be under I_{min}: $I = E/R = 48/20K = 2.4$ mA
- Will revert back to monitoring
  - PSE can be made smart enough to avoid oscillating (12v-24v-48v-12v-24v….)

Evaluation of September Prototype

Surviving ESD

Surviving ESD - Concept Employed in Prototype

- Energy = Voltage * Current * Time
- Want at least one term to be equal to zero
  - Can't block high voltage.
    - Current is not equal to zero.
    - Use high Impedance to limit circuit current.
  - Make Voltage low – provide easy path
    - MOSFET = Surge Rated Power Zener.
    - Surge current is passed to Power supply or PD

Surviving ESD - Mid-span Prototype Cable Discharge Tolerance Test

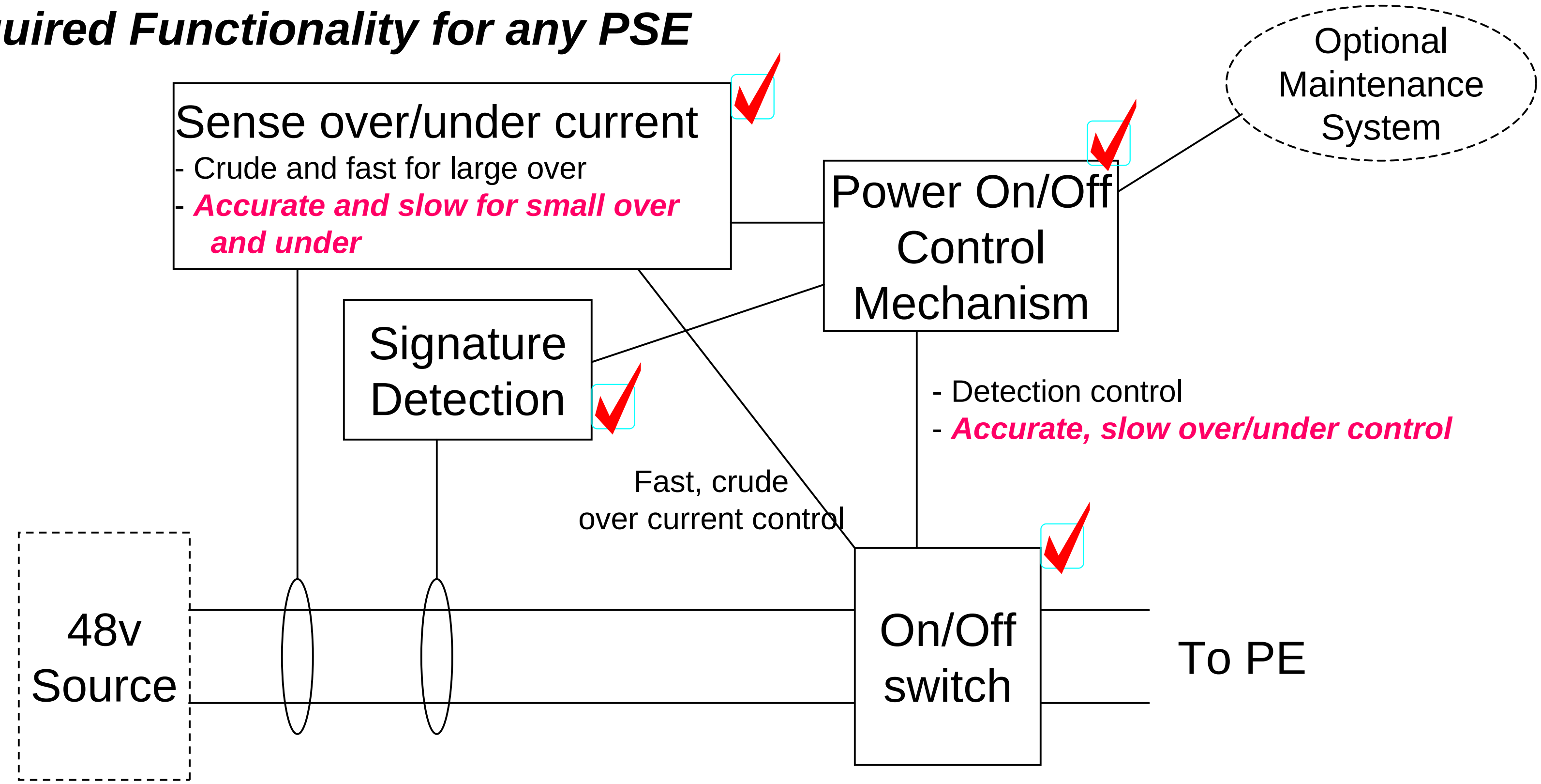
- Schaffner NSG 435 ESD simulator gun used on one prototype
- Contact discharge mode used, 150pf, 330 Ohms
- 10 discharges @ 2kV, 3kV, 4kv and 5kV
- Each discharge applied to pairs 4,5 and 7,8 in each polarity with and without power applied to Controller (40 zaps total for each voltage)
- All of these passed with no damage to Power Controller
- 1 Discharge at 9kV was applied, with and without power applied. With power applied 9kV produced latch up of the Power Controller that was restored by reconnecting the PD. Code was verified to be correct after these tests.
- Similar contact and air discharge results were performed on the PD.

Evaluation of September Prototype

System Cost

Facilitates Delivering Maximum Power to PD

Required Functionality for any PSE



✓ Included in single port prototype, Bill of Materials, Costs

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These were all addressed in September Presentation

System Costs

- Prototype Schematics
- Prototype Bill of Materials
- Cost Extrapolation
- Space
- Suitable Configurations

Cost Summary (Based on Bill of Materials Parts)

From September Presentation

	Per Port Solution	Per Port Solution	Share over 8 ports	Share over 8 ports	Share over 24 ports	Share over24 ports
	Low Volume - 2000	***Est*** High Vol, Integration, 2001	Low Volume - 2000	***Est*** High Vol, Integration, 2001	Low Volume - 2000	***Est*** High Vol, Integration, 2001
Environment A						
Per Port						
Power Switch & Current Sense	0.35	0.25	0.35	0.25	0.35	0.25
Signature Detect	0.09	0.07	0.09	0.07	0.09	0.07
Common						
Control	1.10	0.50	0.50	0.25	0.25	0.15
Reference Signature	0.10	0.08	0.01	0.01	0.01	0.01
5 volts supply	0.35	0.10	0.15	0.10	0.10	0.05
Total (Per Port)	**1.99**	**1.00**	**1.10**	**0.68**	**0.80**	**0.53**
Environment B (additional)						
Per Port Isolation						
DC-DC converter	20.00	10.00	20.00	10.00	20.00	10.00
Total (per port)	**21.99**	**11.00**	**21.99**	**11.00**	**21.99**	**11.00**
Optional Isolation for Mgmt Interface						
Opto isolator-dual (per port)	0.60	0.50	0.60	0.50	0.60	0.50

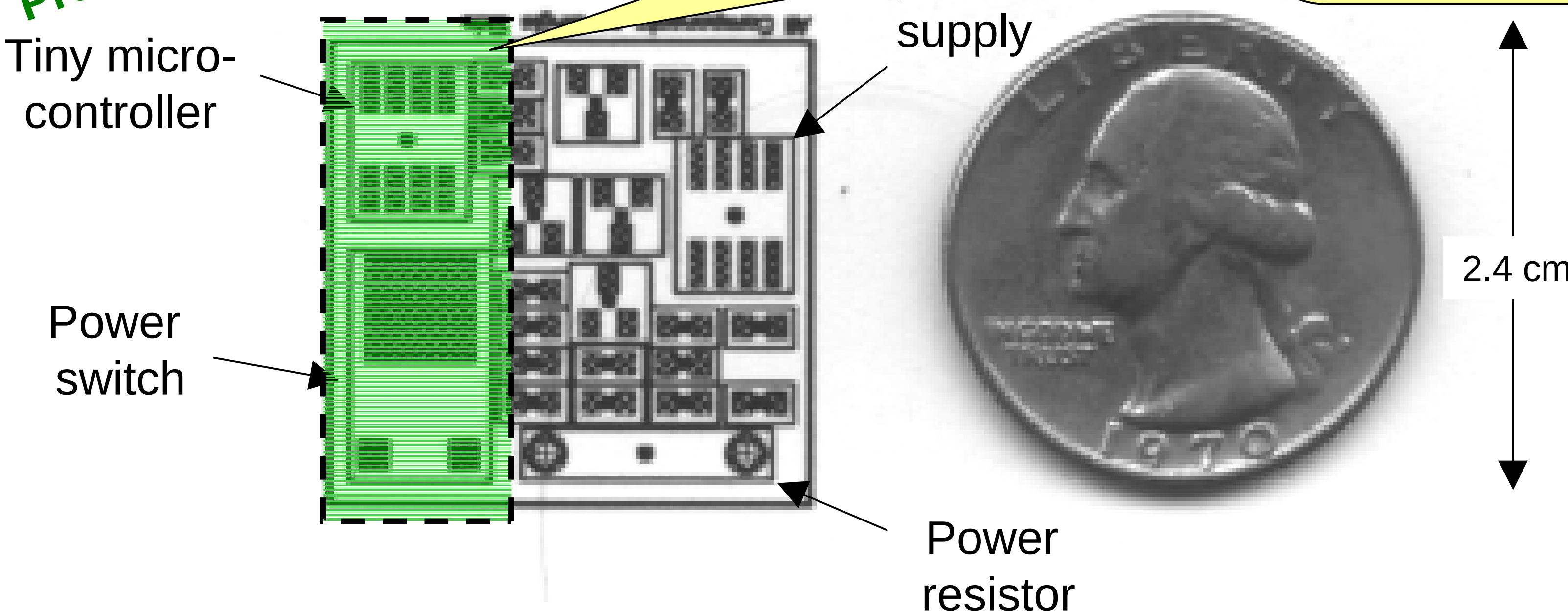
No "sharing" advantage for Env B

Layout of Detect and Power Control Circuit for PSE (Single Port)

- Layout shown is for an individual port
- Space and cost can be further reduced by sharing over m
- Area can be reduced by placing resistors on back plus us instead of shunt regulator (so8)

There is opportunity to integrate all but the MOSFET and a cap or two into a custom IC, reducing per port board space to about this area

From September Presentation



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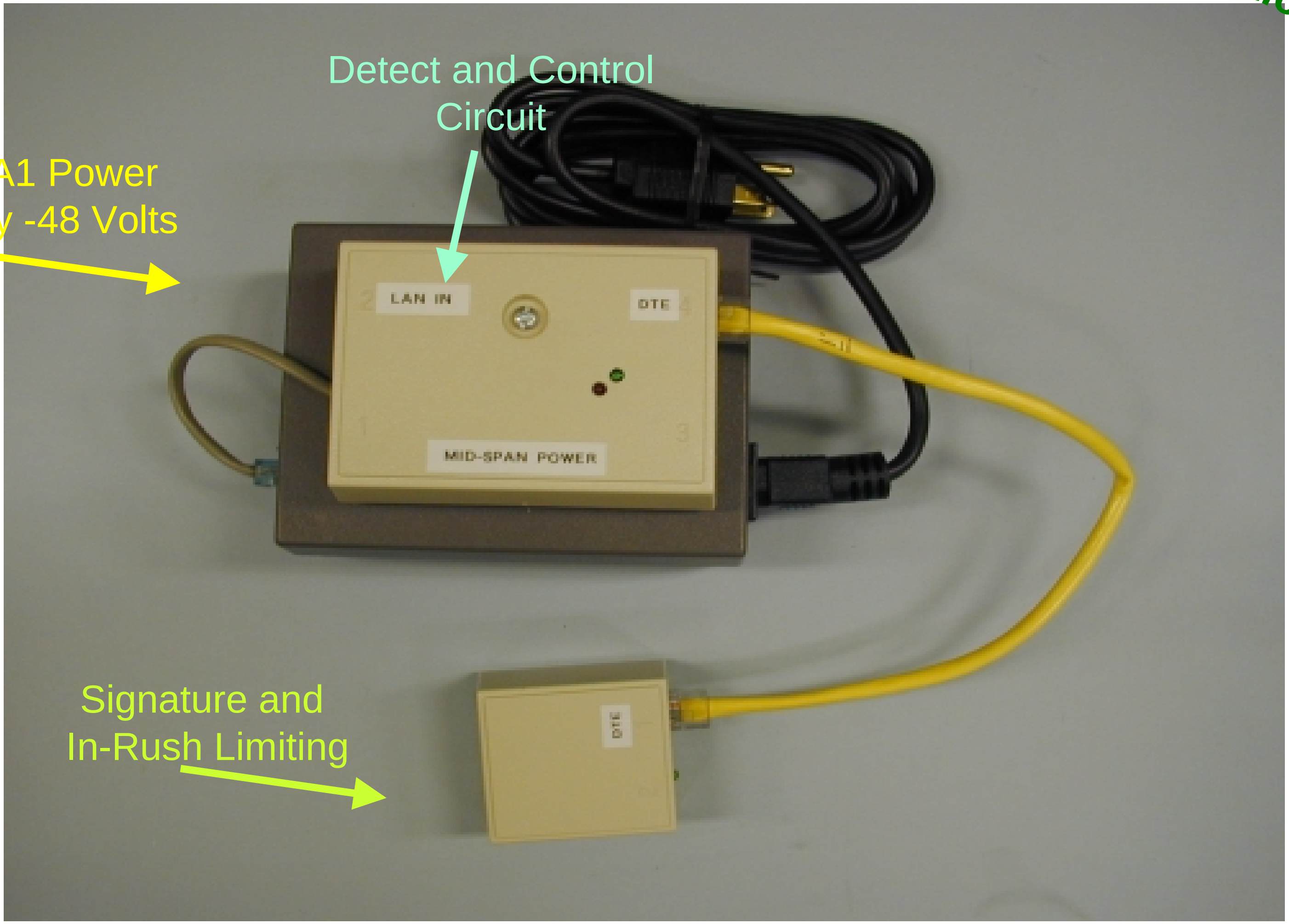
Evaluation Prototypes

- Four “resistive” prototypes were provided for evaluation to,
  - Roger Karam - Cisco
  - Dan Dove - HP
  - Rick Brooks - Nortel
  - Mike McCormack - 3COM
- Our limited access to a coupled diode prototype and its reliability hindered side-by-side tests

Prototype PSE and Signature and In-Rush Limiting PD

From September Presentation



Summary

- Updated detection protocol and signature
  - To minimize concerns about component tolerances, temperature, and leakage current, no longer take advantage of diode drops typically provided by polarity guards
  - Utilize the slope of a 25K ohm resistance
- Strengths of this approach
  - Ensures lowest additional noise for Ethernet and future applications, since DC based
  - Robust in delivering power: Operational range not an issue
  - Robust against false detection
    - Fully expect revised protocol to pass same hazard matrix tests passed by the first protocols
    - Expect to pass all noisy “false detect” tests of second protocol, except will temporarily power proper linear resistances

Summary (Continued)

- Strengths of this approach (continued)
  - Inherent safeguard against misapplication of significant power due to signature resistance (25K ohms)
    - ***If*** a mistake were ever made, current/power delivered would be small (115 mW, corresponding to 20K ohms and 48v)
  - Expect to be simple to specify, document, implement, integrate, troubleshoot, train, ….
  - Prototype's micro-controller approach easily supports rich management (e.g., monitor current/power levels ***per port***)
  - Amenable to mid-span and LAN switch implementations
    - Small space - even per port design small enough for LAN switch
    - Low cost: Can be integrated, Can be shared across Ports
  - Maintains maximum power to PD, power efficiency
    - Signature requires no diode drops
    - Prototype easily supports precise control of power shut off for excessive continuous current; preserves maximum power to PD