Coupled Diode Discovery
It works

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AC Coupled Diode Discovery Summary

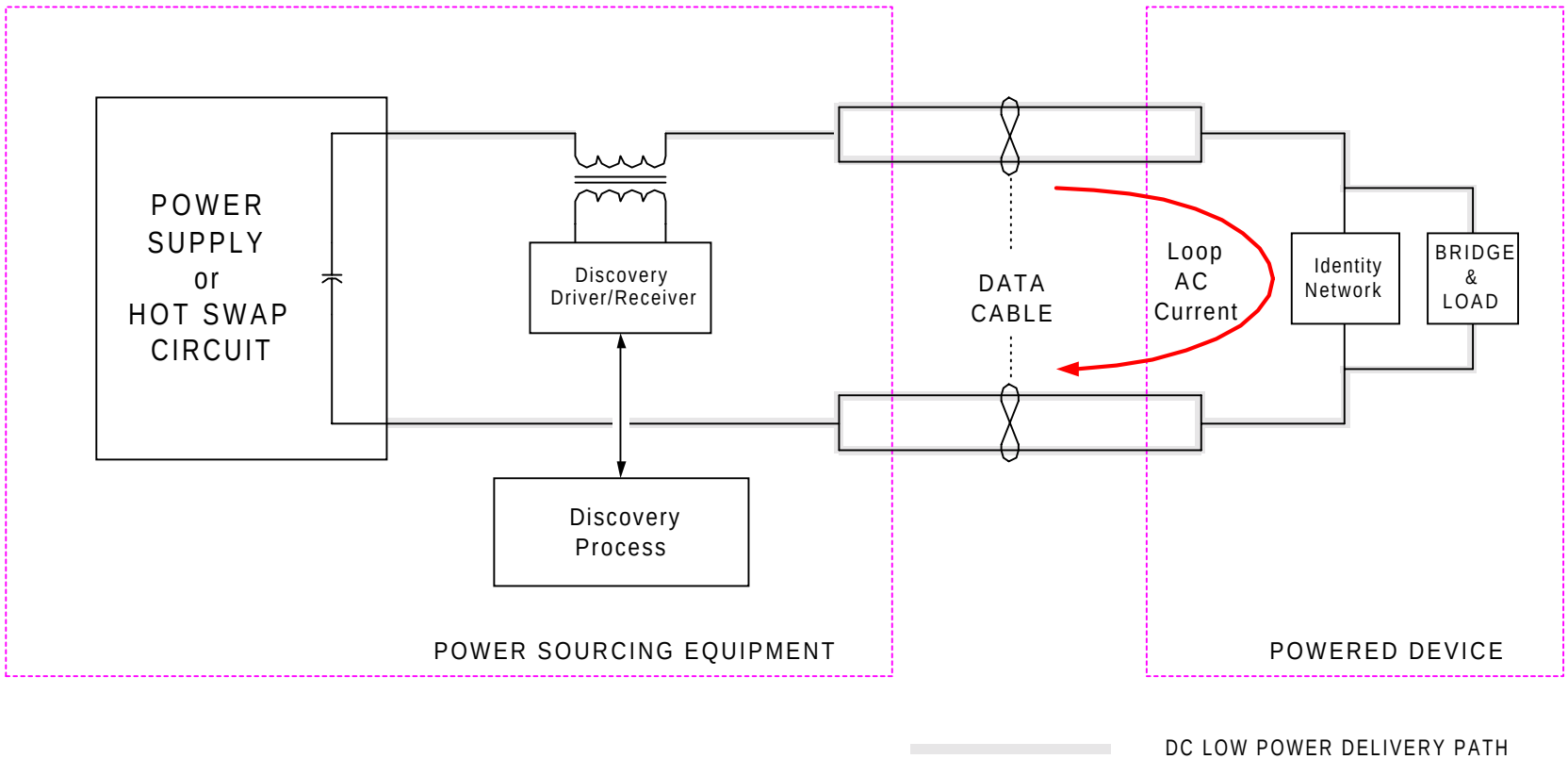
- **For the discovery process, all of the following tests have been passed, including the ones they said wouldn't work**

- **radiated emissions**
- **conducted emissions**
- **radiated susceptibility**
- **conducted immunity**
- **ESD to 15 kV**
- **EFT immunity test**
- **Campbell Clamp immunity test**
- **Cable Discharge, 25 ft. charged to 5 kV**
- **8 simultaneous processes on 25 pair CAT-5**
- **2 simultaneous processes on CAT-3, CAT-5, and CAT-6**
- **discovery and 10/100 data on long/short cables, CAT-3, CAT-5, CAT-6**
- **75 dB of margin to degradation on long 100Base-T link**
- **discovery works on the spare pair, or the signal pair**

- **The biggest issue for all of us is the DTE power supply itself**

Pair to Pair Mode Discovery Block Diagram

- uses an AC coupled diode identity network for polarity sensitive detection
- optional transformer coupled technique provides 2250 VDC isolation
- discovery pulses and synchronous detection are digitally controlled
- pseudo random idle spaces are used: lower radiated emissions, harder to fool
- two stage discovery process eliminates detecting simple diodes
- can also be accomplished on the wire side



Low Frequency TDR

- The features of this method make it a low frequency TDR, where the expected maximum length and velocity of the cable are known in advance. The TDR probes the impedance in both polarities, and the 1 bit data acquisition is made at a delay much longer than 100 meters
- Communications 101; we must know the difference between what is a signal and what is noise
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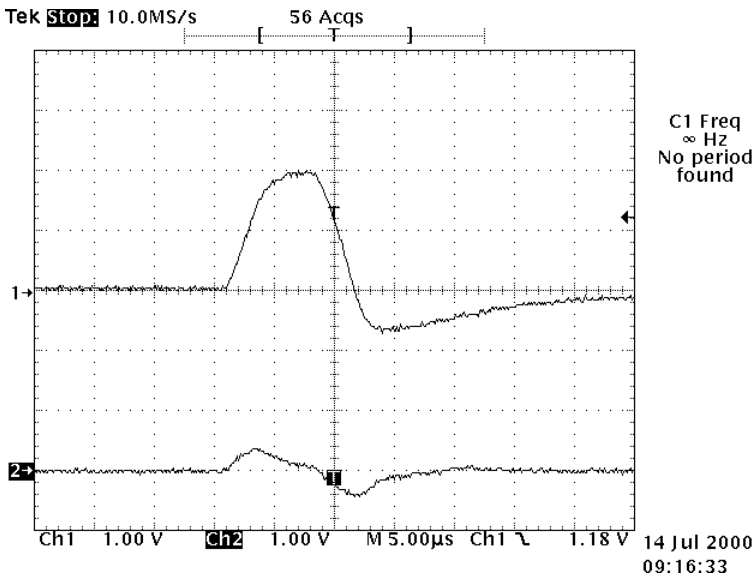
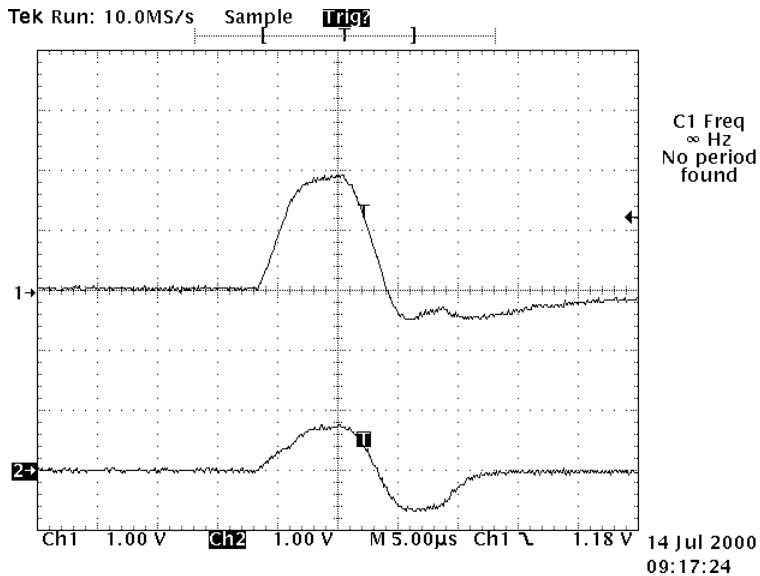


polarity 1, diode not conducting

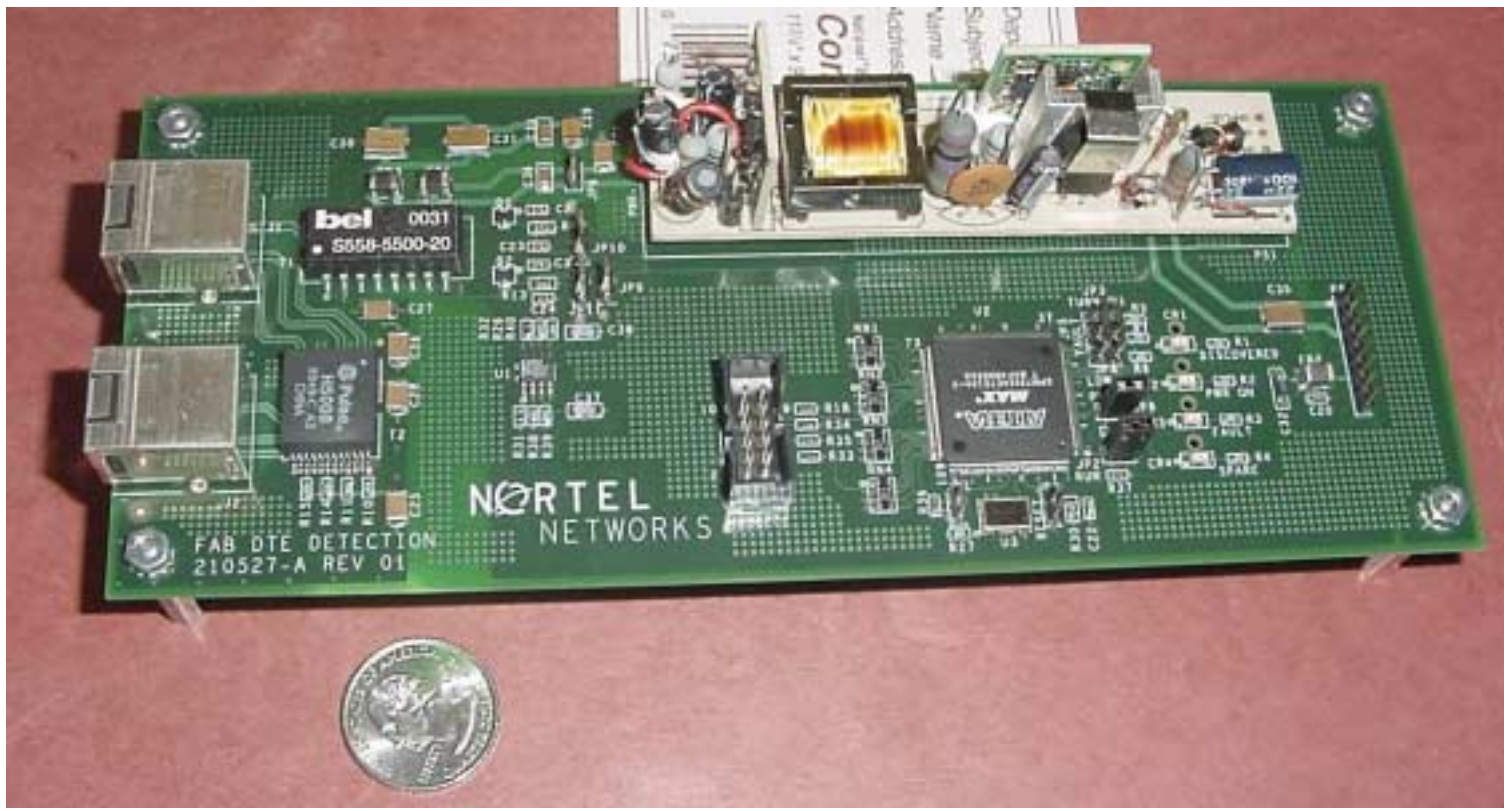


polarity 2, diode conducting

- These are TDR signals that show the impedance as the signal propagates down the cable, these are not noise signals

New Version - Signal Pair Prototype

- **A new AC coupled diode prototype has been built to evaluate sending discovery and power on the signal pairs: 1-2, 3-6**
  - the same two stage discovery process as the “spare pair” prototype
  - now capable of running 1000BASE-T with midspan insertion of power
  - matching PD board allows for midspan removal of power, while passing 10/100/1000 data



Tests that Passed, referring to 802.3af Composite Test Document

- **2.1) Compatibility with legacy 802.3**
  - hazard avoidance and interoperability tests have been completed
- **2.2) Legacy Cabling**
  - standard 4 pair cabling has been tested, along with multiple terminations, short, loop back, etc…
- **2.3) Interaction with other RJ-45 interfaces**
  - most, if not all tests have been completed, see other presentations
- **3) Compatibility with 802.3af system**
  - midspan power over the spare pairs has been successfully demonstrated
  - midspan power over the signal pairs has been successfully demonstrated
  - discovery is independent of the data link
  - discovery is independent of the PD power status for the redundant power case
- **4.1) 100Base-TX requirements**
  - The isolation requirements have been tested, but the results were 1500 VDC and so fail to fully meet the requirement of 2250 VDC (PC board via spacing problem) A proper layout will solve this problem
  - The remaining requirements that pertain to TP-PMD have been demonstrated by showing the margin that exists between the discovery process, and the data path
- **4.2) 10Base-T requirements**
  - The isolation requirements have been tested, but the results were 1500 VDC and so fail to fully meet the requirement of 2250 VDC (PC board via spacing problem) A proper layout will solve this problem

Tests that Passed, referring to 802.3af Composite Test Document, (cont.)

- **5) EMI profile**
  - Radiated emissions results show that discovery does not emit much energy, even without an external box, the PC board demonstrates a 25 dB margin to the class A limit, tested CAT-3 and CAT-5
  - Conducted emissions have been fully characterized, and show a 25 dB margin, for CAT-3, to the 30 dBµA limit, the margin is higher using CAT-5 cable, also tested 25 pair 1m, 10m, 100m CAT-5, 100m and 200m CAT-6
  - The discovery spectrum has been shown to not over lap the spectra of 10Base-T or 100Base-TX on CAT-3, CAT-5, CAT-6 and 25 pair CAT-5 cables
  - the discovery spectrum demonstrates peak amplitudes that are far below that of 10Base-T and 100Base-TX on CAT-3 and CAT-5

- **6) Survivability**
  - ESD tests passed at 15kV, direct contact, horizontal plane, and vertical plane
  - Cable Discharge, the unit survived 20 repetitions of the test. Each test involved statically charging a 25 foot length of CAT-5 cable up to 5 kV on all wires, and then plugging it into the PSE

- **7) Immunity**
  - Passed conducted immunity, 150 kHz to 80 MHz at >3 volt field strength, tested on CAT-5
  - Passed radiated susceptibility, 80 MHz to 1 GHz at >5 volts per meter, tested on CAT-3 and CAT-5
  - Passed standard EFT tests, tested on CAT-5
  - Campbell Clamp test passed at 13 dB above the level specified in 1000BASE-T, tested on CAT-5

Tests that Passed, referring to 802.3af Composite Test Document, (cont.)

- **7.1) Crosstalk tests**
  - up to 8 simultaneous discovery processes have been shown to be independent on 100 meter 25 pair CAT-5
  - spectrum of neighbor pair to pair coupling has been shown on: 100 meter 25 pair CAT-5, and on 1m, 10m and 100m CAT-3, CAT-5, and CAT-6
  - two simultaneous discovery processes have been shown to be independent on more than 200 meters of CAT-5
  - two simultaneous discovery processes have been shown to be independent on 100 meters of CAT-3
  - The spectral band used for discovery has been shown to be non-overlapping with 10 Mbps and 100 Mbps traffic on both CAT-3 cables and CAT-5 cables, at lengths of 1m, 10m, and 100m
  - The spectral bands of discovery and DTE power have been demonstrated and show that delivering DTE power is a much bigger potential problem compared with discovery

- **7.2) False Positive**
  - so far, I have not found any false positives

Not Yet Tested, referring to 802.3af Composite Test Document

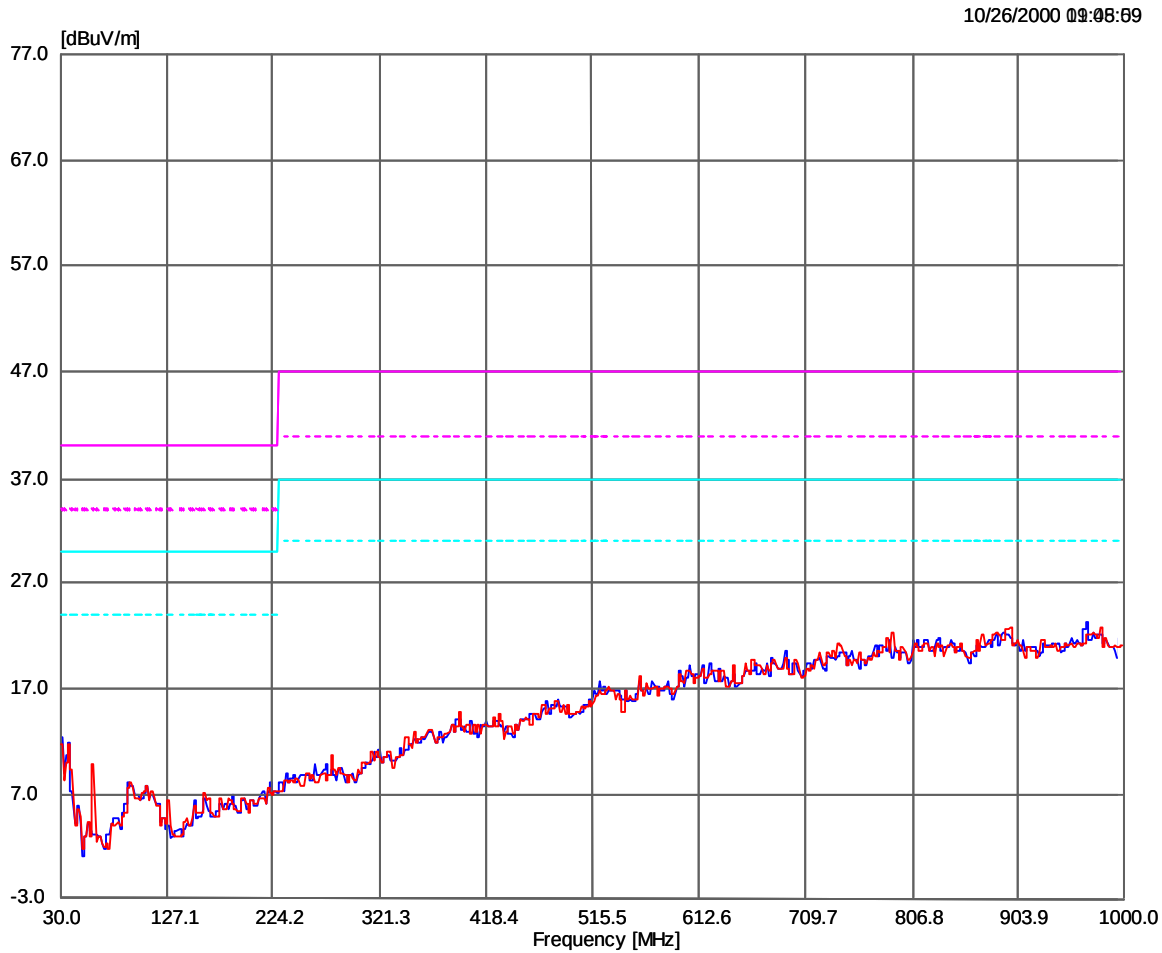
- **2.3) Interaction with other RJ-45 interfaces**
  - there are devices out there, and being developed, that have not been tested, future problems?
- **4.1) 100Base-TX requirements**
  - The TP-PMD, MAU requirements and specifications have not been individually tested as called for in this section
- **4.2) 10Base-T requirements**
  - The TP-PMD, MAU requirements and specifications have not been individually tested as called for in this section
- **5) EMI profile**
  - Radiated emissions have not been shown with all of the combinations shown in this section (42 scans total)
- **7) Immunity**
  - conducted immunity on CAT-3
  - EFT on CAT-3
  - Campbell Clamp test on CAT-3

Tests that failed, referring to 802.3af Composite Test Document

- **the isolation (Hipot) test failed at 1500 VDC, vs. spec of 2250 VDC**
  - due to PC board layout

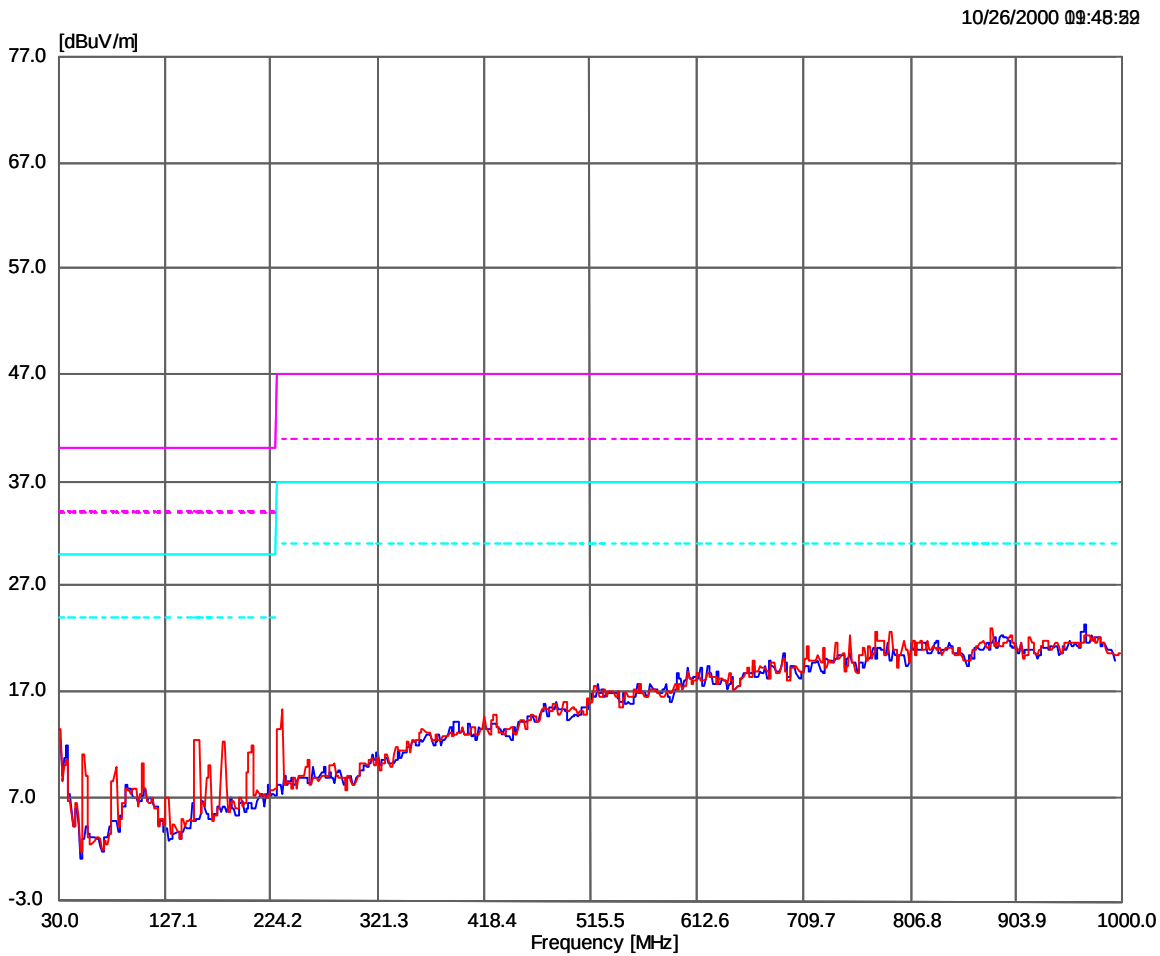
Highlights of Radiated Emissions, 10 meter anechoic chamber

- **100 meter CAT-3, open load, continuous discovery**
  - prototype in a metal box (red trace), chamber and equipment noise floor (blue trace)
- **There is very little energy emitted onto the cable**



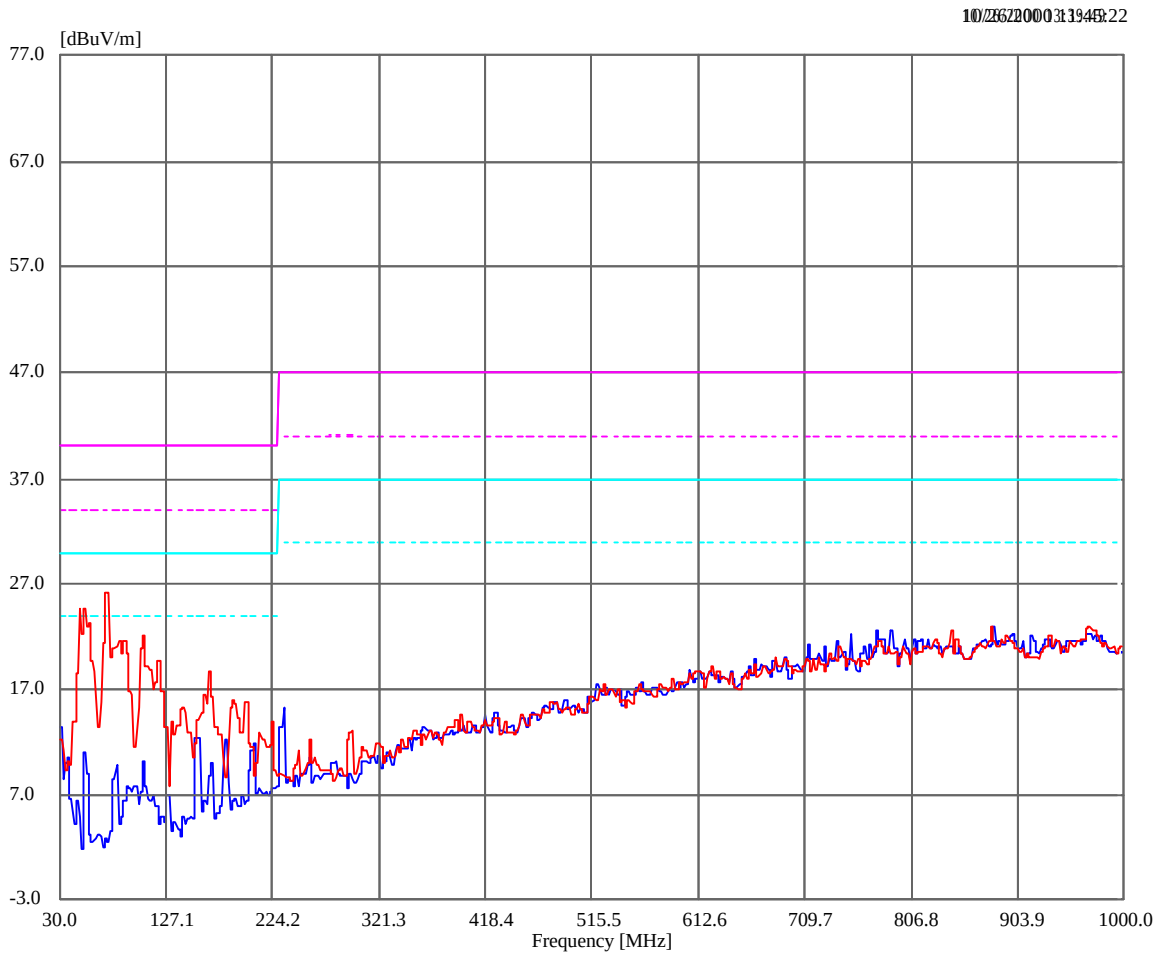
Highlights of Radiated Emissions, 10 meter anechoic chamber

- **100 meter CAT-3, open load, continuous discovery**
  - exposed prototype board, no box box (red trace), chamber and equipment noise floor (blue trace)
- **Even without a box, very little energy is emitted**



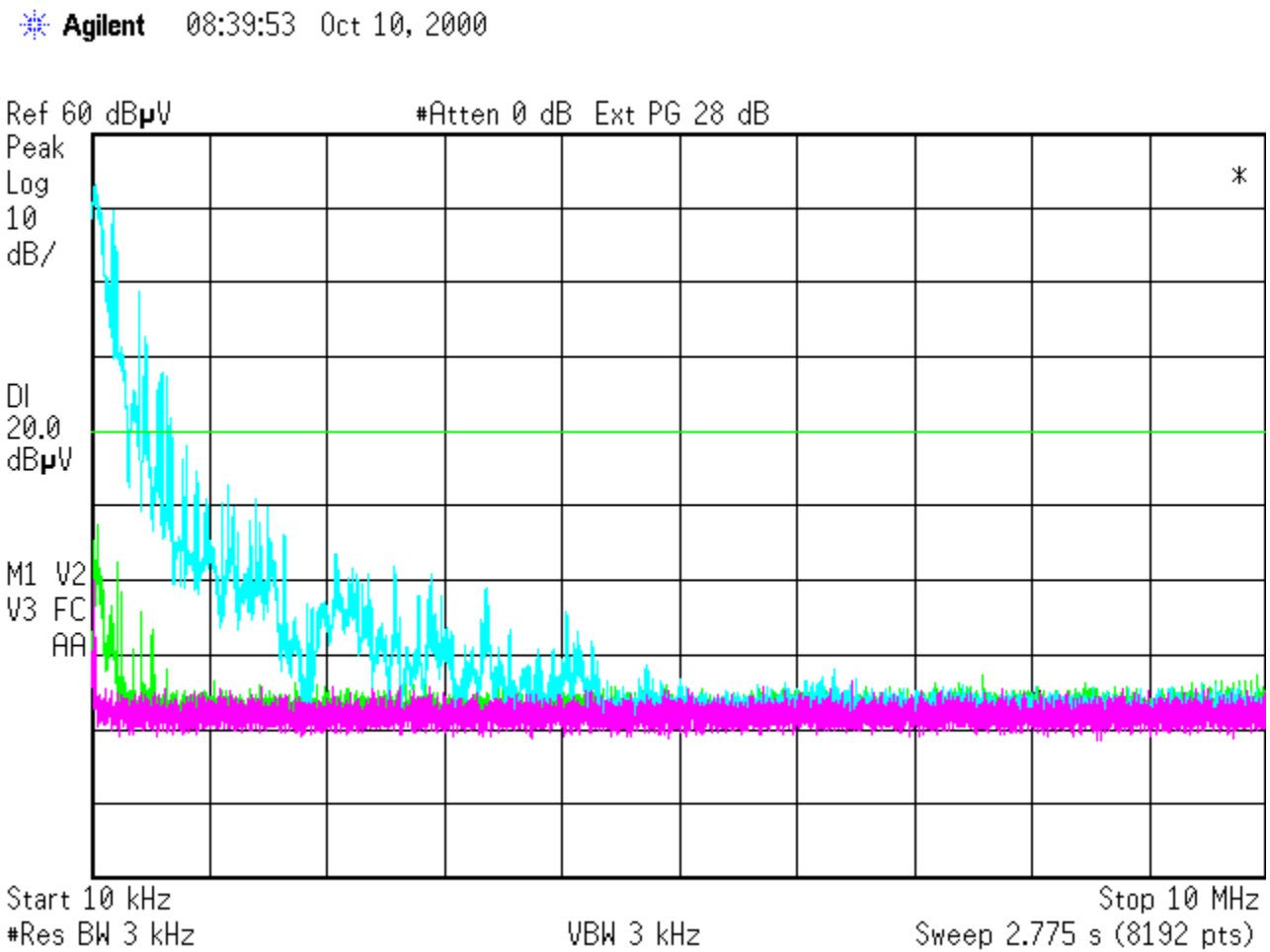
Highlights of Radiated Emissions, 10 meter anechoic chamber

- **Lucent Prototype and Nortel Prototype, 100 meter CAT-3, open load, continuous discovery**
  - Lucent prototype with “clean” DC power supply (red trace), exposed Nortel prototype, no box box (blue trace)
- **When given “clean” DC power, the Lucent prototype has more noise, data cable? power cable?**



Highlights of Conducted Emissions

- **100 meter CAT-5, on/off repeating discovery**
  - common mode current (green trace), pair to pair mode current (blue trace), baseline (magenta trace)
- **Note the green trace, the common mode emissions of discovery, low frequency and energy**



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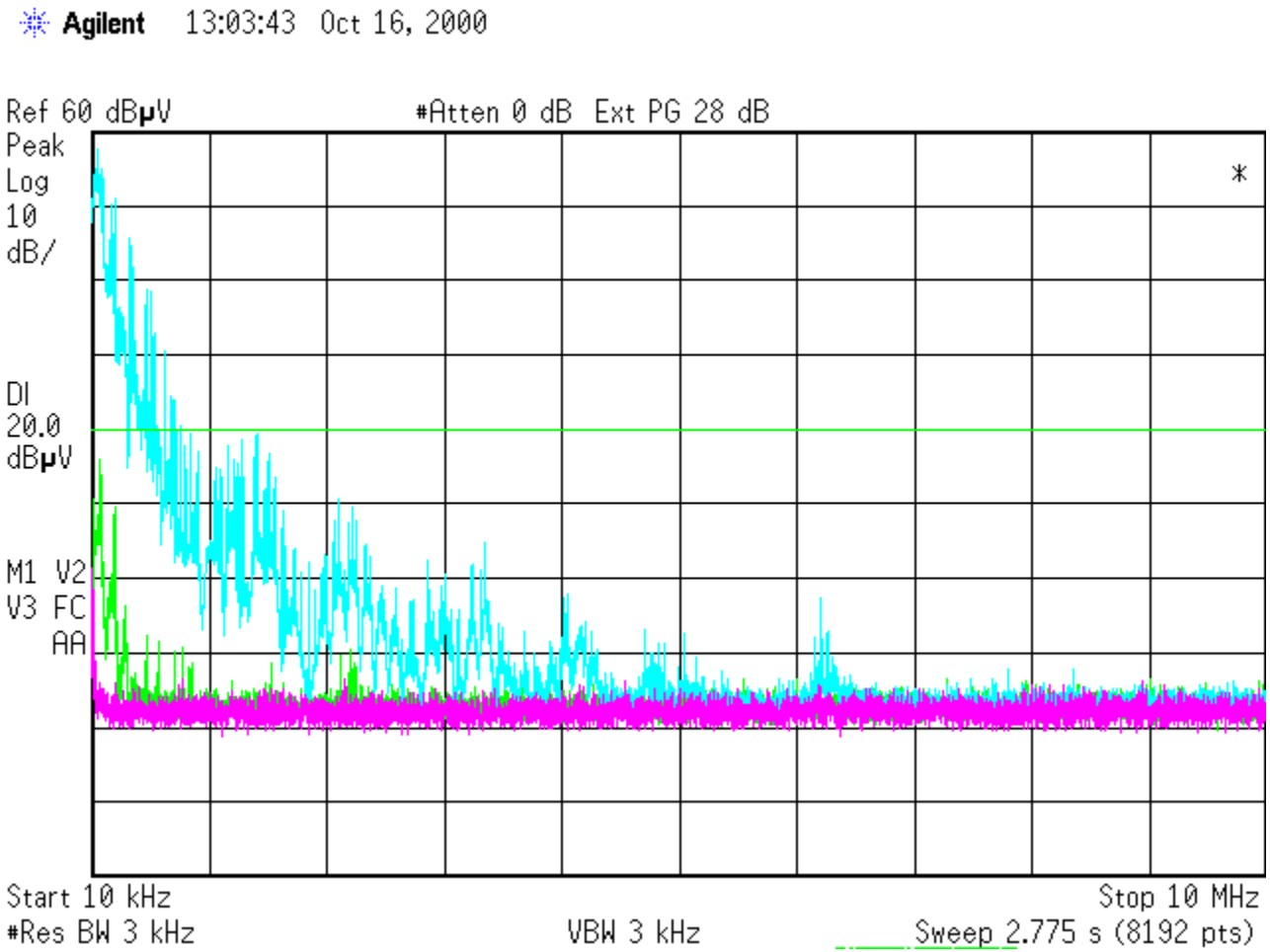
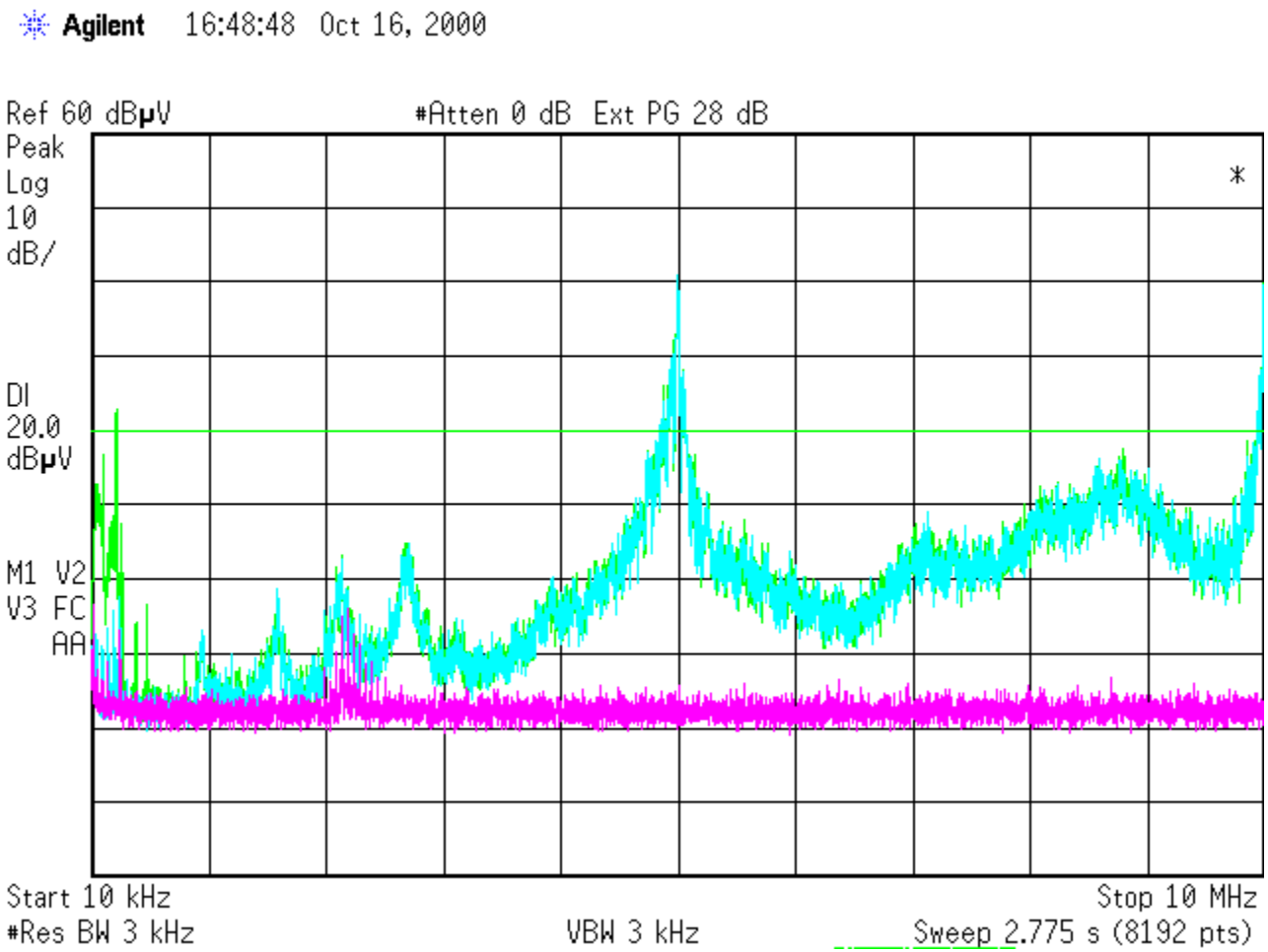


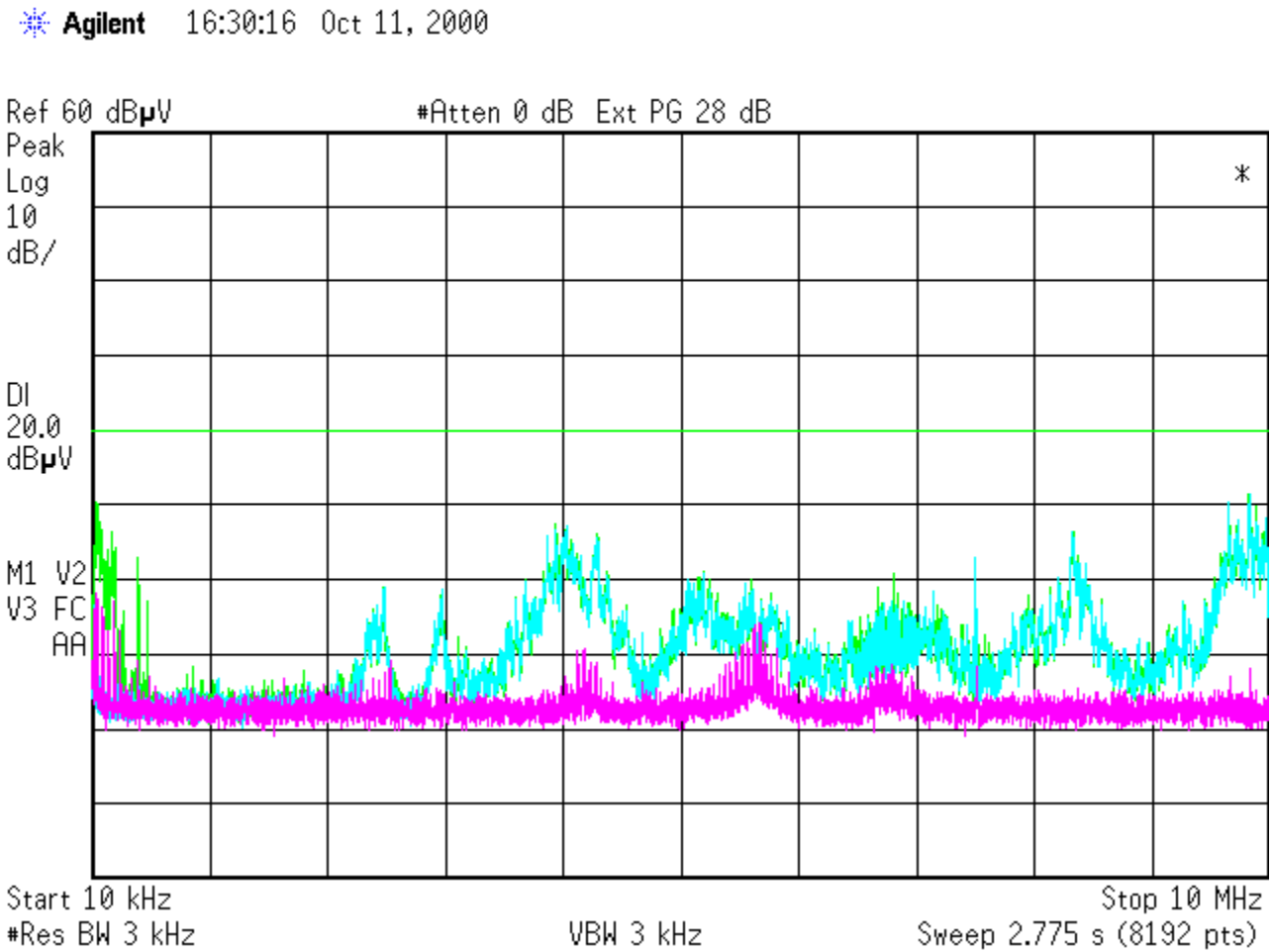
Highlights of Conducted Emissions

- **100 meter CAT-3, on/off repeating discovery and 10Base-T**
  - both discovery and 10Base-T (green trace), 10Base-T only (blue trace), baseline (magenta trace)
- **Note the green trace, the common mode emissions of discovery, low frequency and energy**



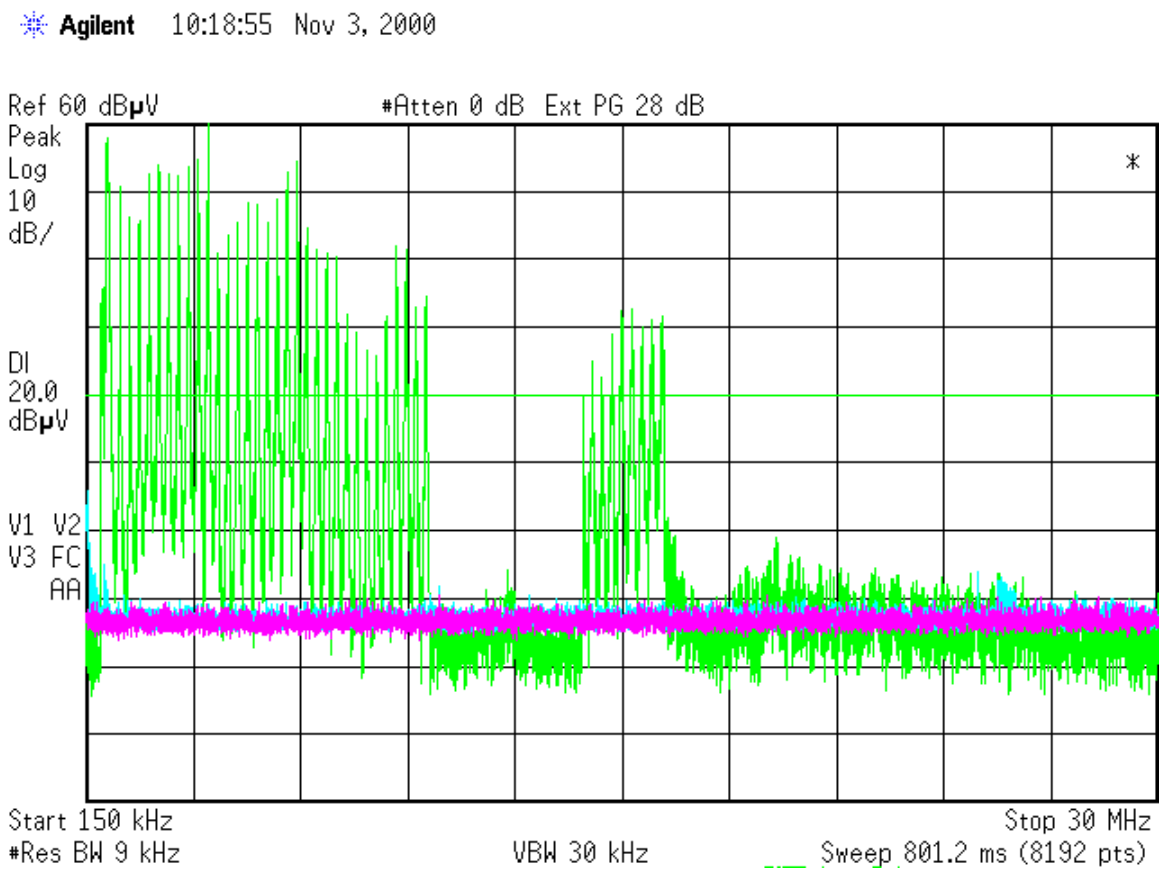
Highlights of Conducted Emissions

- **100 meter CAT-5, on/off repeating discovery and 100Base-TX**
  - — both discovery and 100Base-T (green trace), 100Base-TX only (blue trace), baseline (magenta trace)
- **Note the green trace, the common mode emissions of discovery, low frequency and energy**



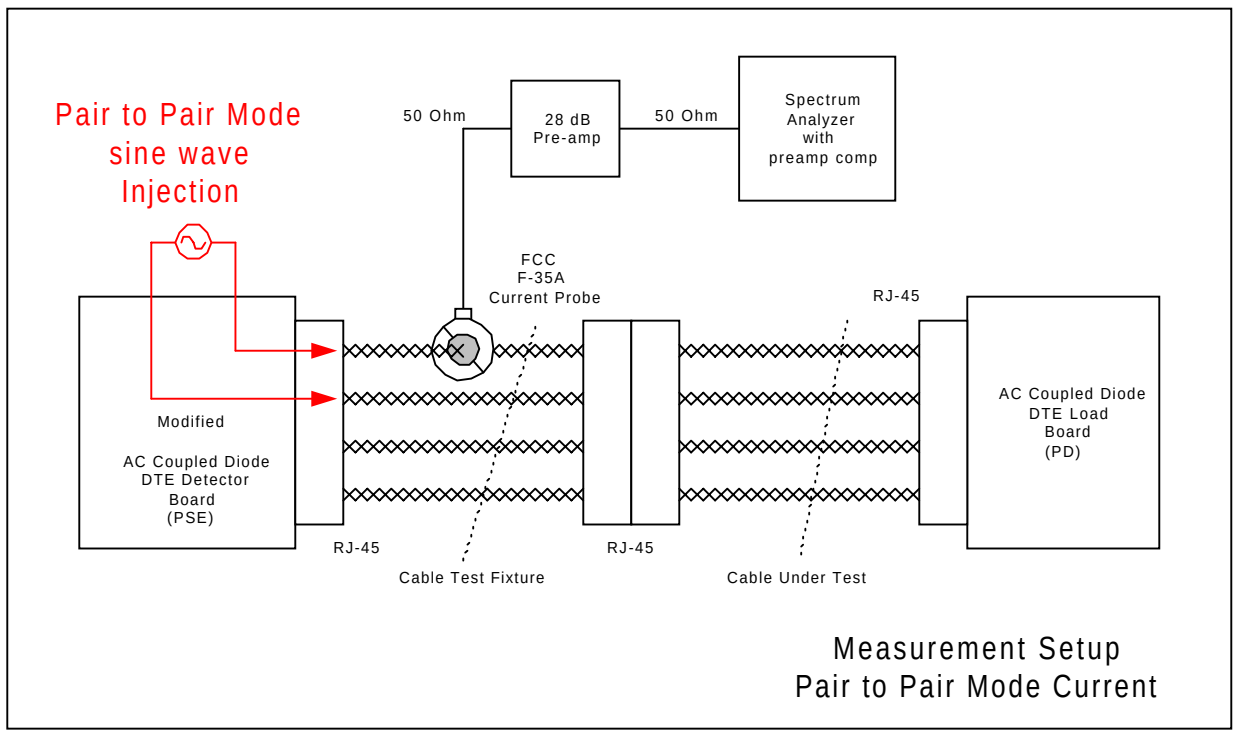
Discovery is not the Problem, the Power Supply is the Problem

- **48 VDC Power Supply Noise is a problem, repeating on/off discovery and PSE power**
  - baseline, max hold, (magenta trace)
  - Nortel prototype on/off discovery only, no 48 VDC input, max hold (light blue trace)
  - Nortel prototype on/off discovery and 48 VDC input, no max hold (green trace),15W switcher is turning on and off
- **Note the light blue trace, which is discovery only (no power): low frequency and low energy**



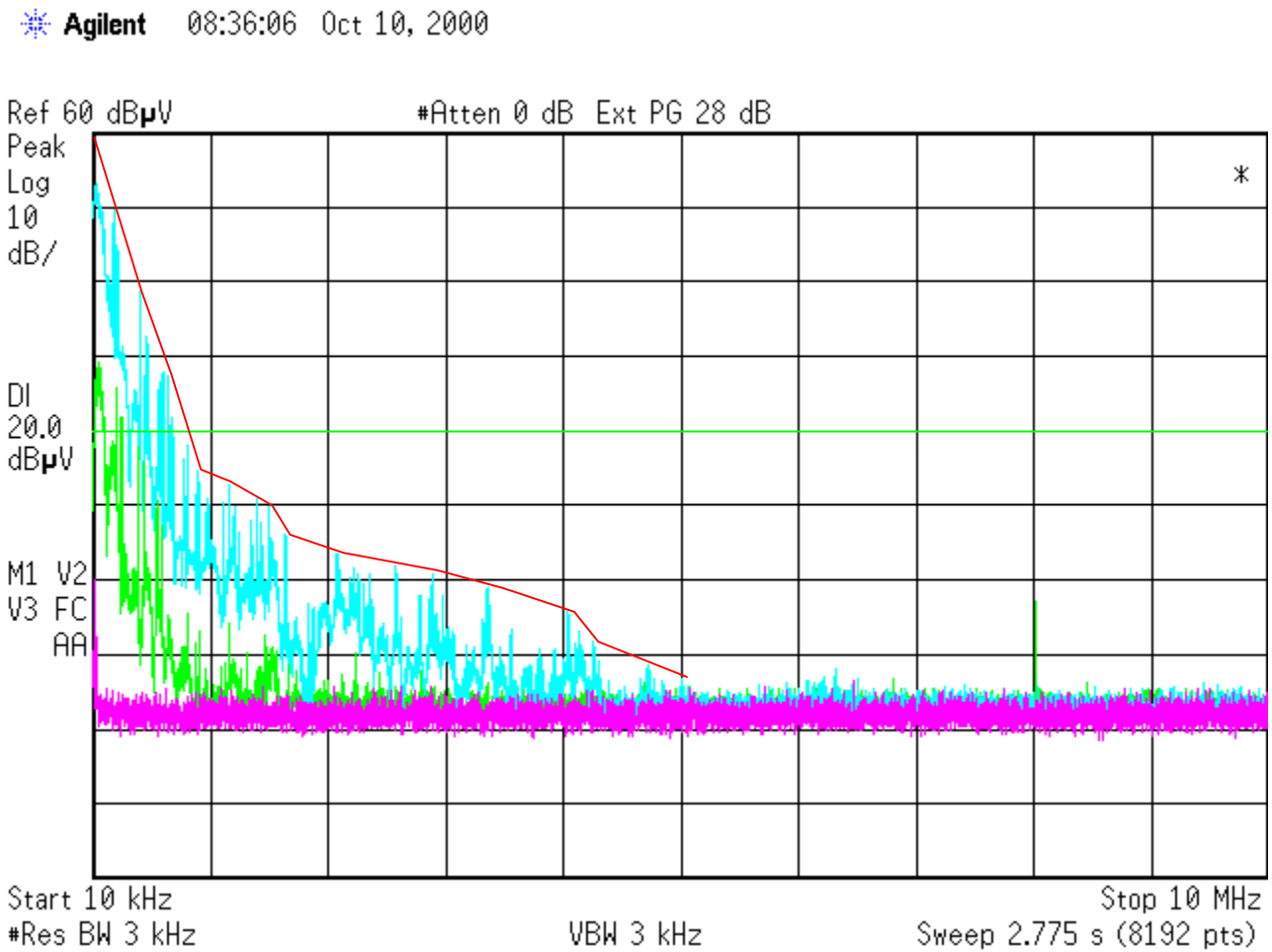
Determining the Margin of Coupled Diode Discovery to 100Base-T

- **The margin determination process**
  - inject a sine wave into the pair to pair mode on a long (130m - 140m) CAT-5 cable
  - measure the pair to pair mode voltage and current
  - determine the degradation threshold for the marginal 100 Mbps link
  - plot the degradation current level (dBµA) vs. frequency
  - plot the highest peaks of the discovery current level (dBµA) vs. frequency
  - the approximate margin is the difference between these two curves



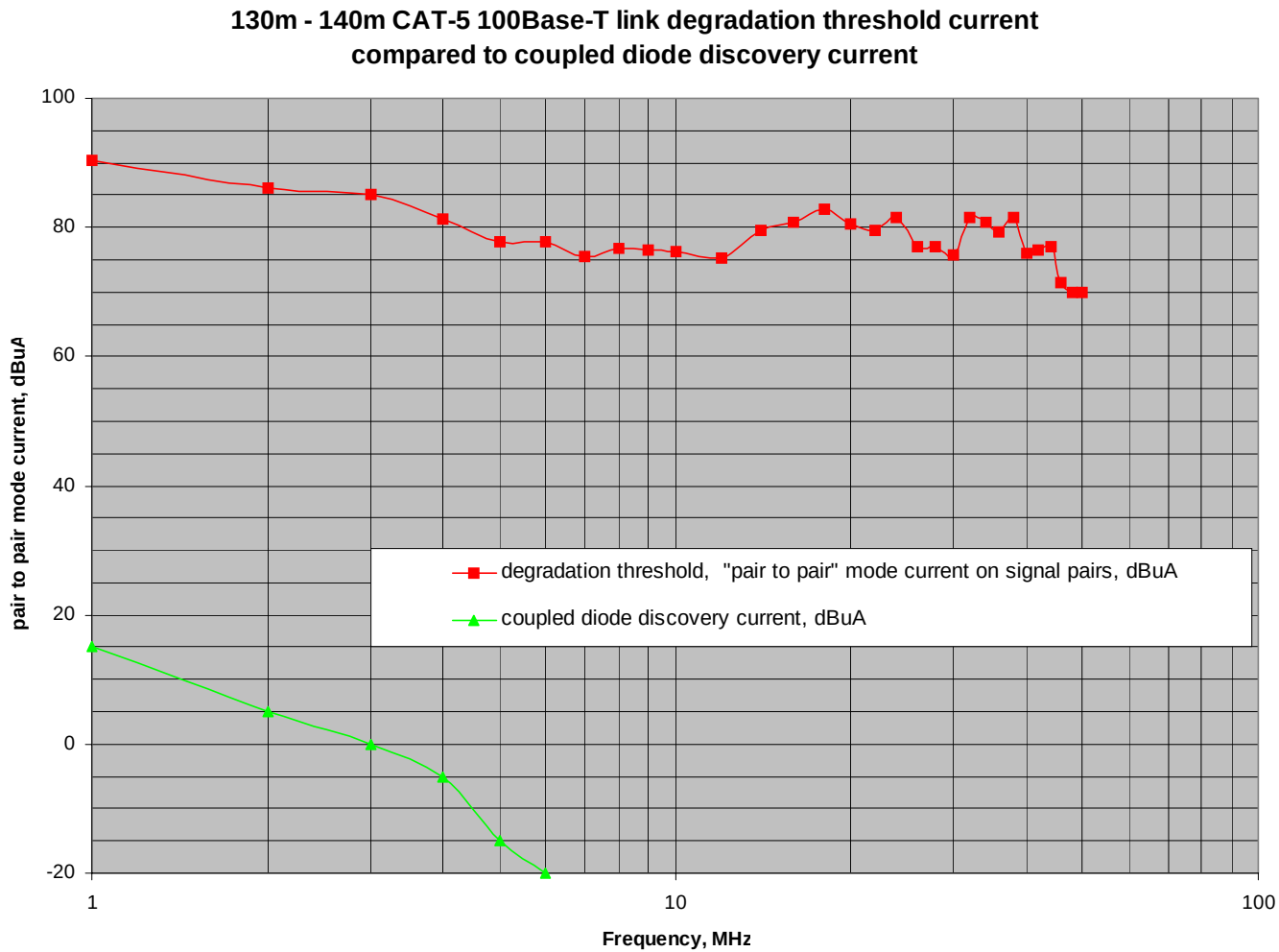
Determining the Margin of Coupled Diode Discovery to 100Base-T

- **Determining the maximum height for discovery pair to pair mode current (the red line)**



Non-Interfering Margin: Discovery to 100Base-TX link on the “signal” pairs

- **demonstrates more than 75 dB of margin between discovery and the 100Base-TX degradation**



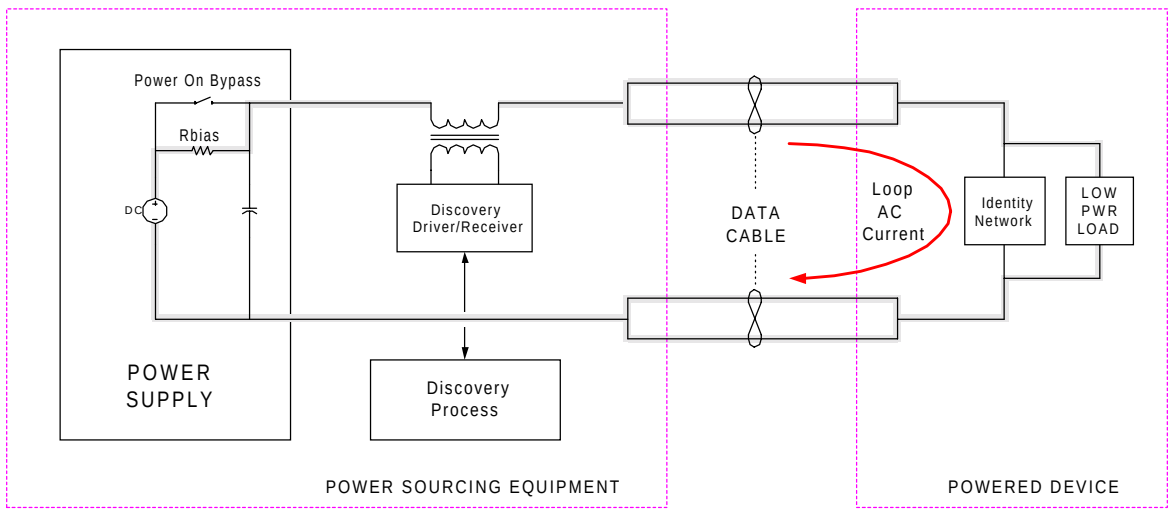
Parallel Loads, Identity Capacitor Value

- **The prototype was tested with a valid PD signature connected with a 1 meter cable, and in parallel with that, a second cable and load which is not a valid powerable load**
  - The results show that with a 400 meter open ended cable connected in parallel, the discovery process fails
  - If the parallel load is a 0.1 µF cap, instead of a long cable, the discovery process also fails
  - a parallel load that is an open circuit below a few volts will not be detected
    - Do we care?
    - What can happen?
    - Is there an example of this?

- **A value of 0.1 µF has been found to work in place of the 1 µF cap in the identity network, at the expense of cable length:**
  - On the prototype that was tested the maximum cable length was measured as:
    - 236 meters with a 1 µF cap
    - 186 meters with a 0.1 µF cap
  - no algorithm changes were needed to accommodate the value change
  - the algorithm can be optimized to provide more or less sensitivity to component values by changing the characteristics of the 2nd stage of discovery

Future Possibilities

- **Discovery Flavors for expected power demand**
  - can be accommodated by using different resistor and capacitor values in the identity network
  - the 2nd stage of discovery can test for which identity network is present
    - starts by testing for the fastest time constant, then tests for the next fastest time constant
    - by process of elimination, the shortest valid time constant is discovered
- **Micro-power Applications**
  - a minimum load of 10 ma implies a minimum power of 0.48 watts at 48 VDC
  - what if there is an application that uses less power than that?
    - LED indication of power available on the RJ-45 - advertising DTE power
    - micro power devices
  - the AC coupled diode method can accommodate these cases, since the AC (TDR) pulses are independent of the DC load current, up to about 5ma as tested on the prototype



Summary, AC Coupled Diode Discovery

- **The discovery method works, it is the power supply that is and will be a bigger problem**
- **The “spare” pair prototype demonstrates that the coupled diode discovery mechanism is technically feasible**
- **The “signal” pair prototype demonstrates that the coupled diode discovery mechanism is technically feasible**
- **This method uses AC pulses of limited spectral width, it is mostly independent of the DC path, so future low DC power applications are possible**
- **acknowledgements:**
  - Larry Miller, Paul Moore, Geoff Thompson, Tom Gilheany, Richard Patchet,
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