AC Coupled Diode Discovery Technical Feasibility

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Acknowledgments:
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NORTEL NETWORKS

Contents:

Coupled Diode Discovery Evaluation Board Update

There are two evaluation boards in the set

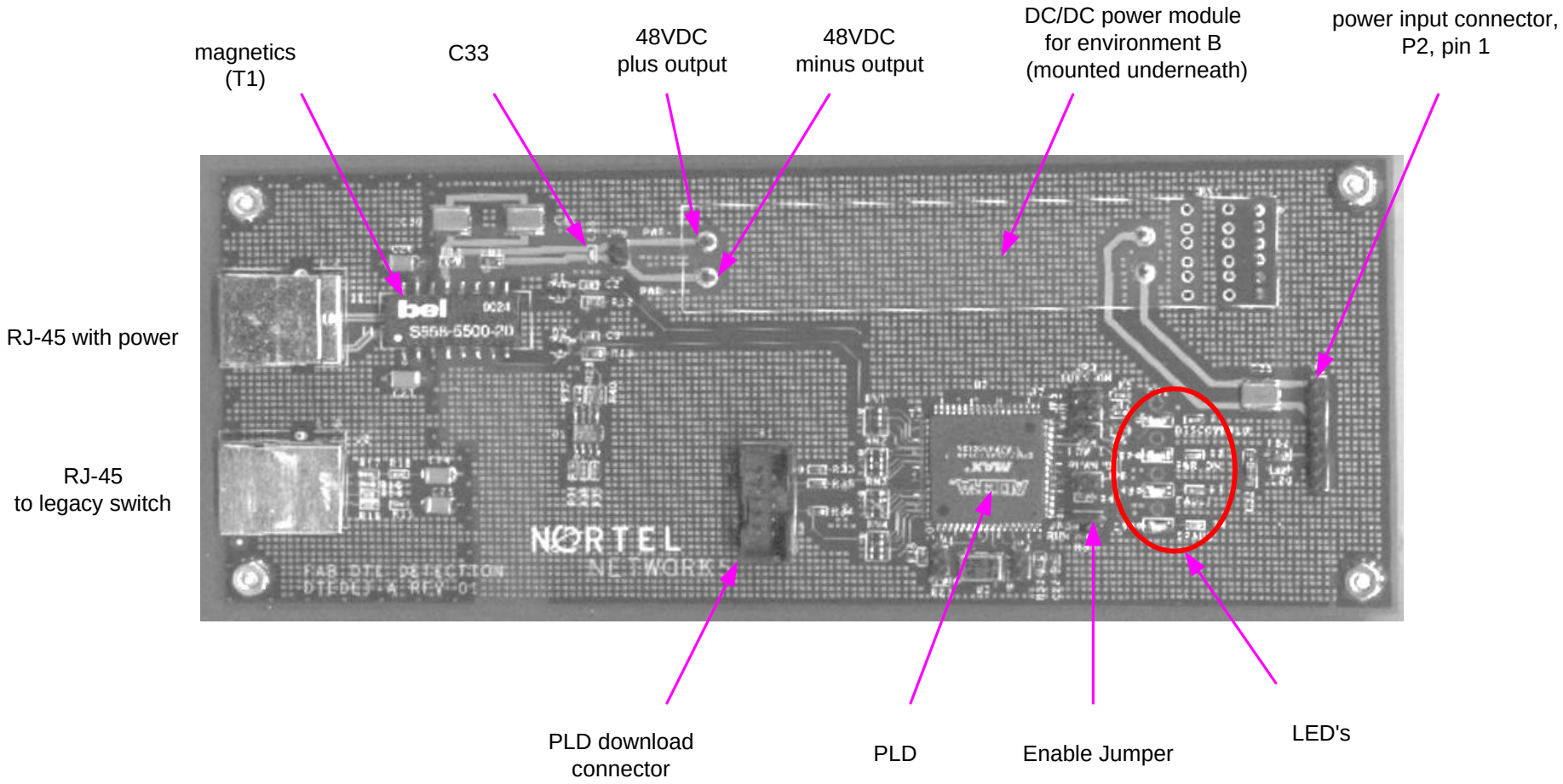
- The Discovery Detector Board (the PSE end)
- The DTE Load Board (the PD end)

There are currently 6 groups independently evaluating these board sets:
(in alphabetical order)

- 3Com (Nick Stapleton, Mike McCormack)
- Broadcom (Kevin Brown)
- Cisco (Roger Karam)
- HP (Dan Dove)
- Level One (Robert Muir)
- PowerDsine (Avinom Levy)

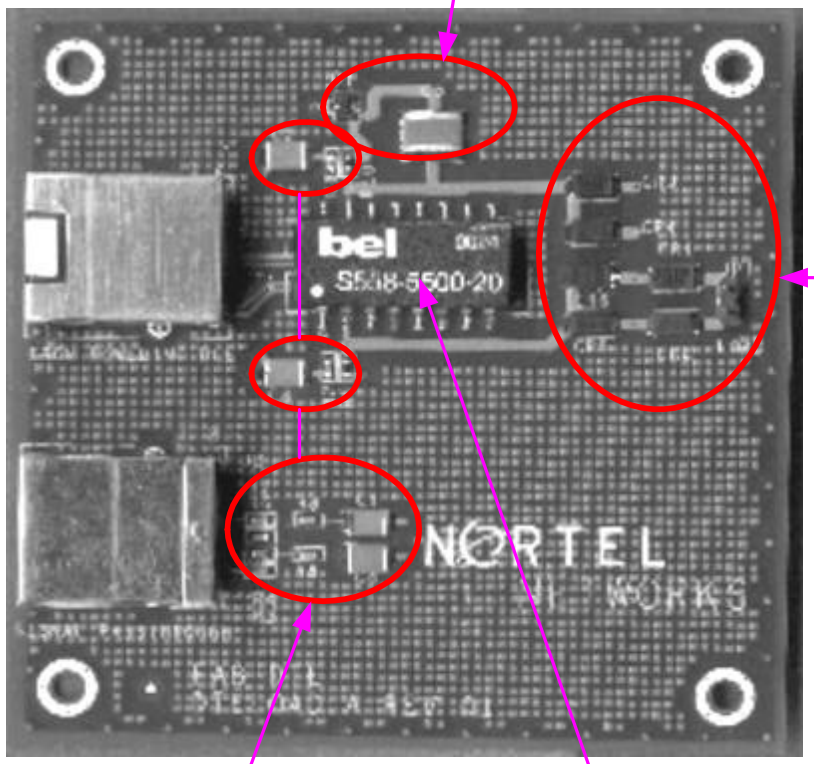
Since many of these groups have not had a great deal of time for evaluation of these prototypes, each group will present their data and opinions in the future when they become available.

DTE Detector Evaluation Board

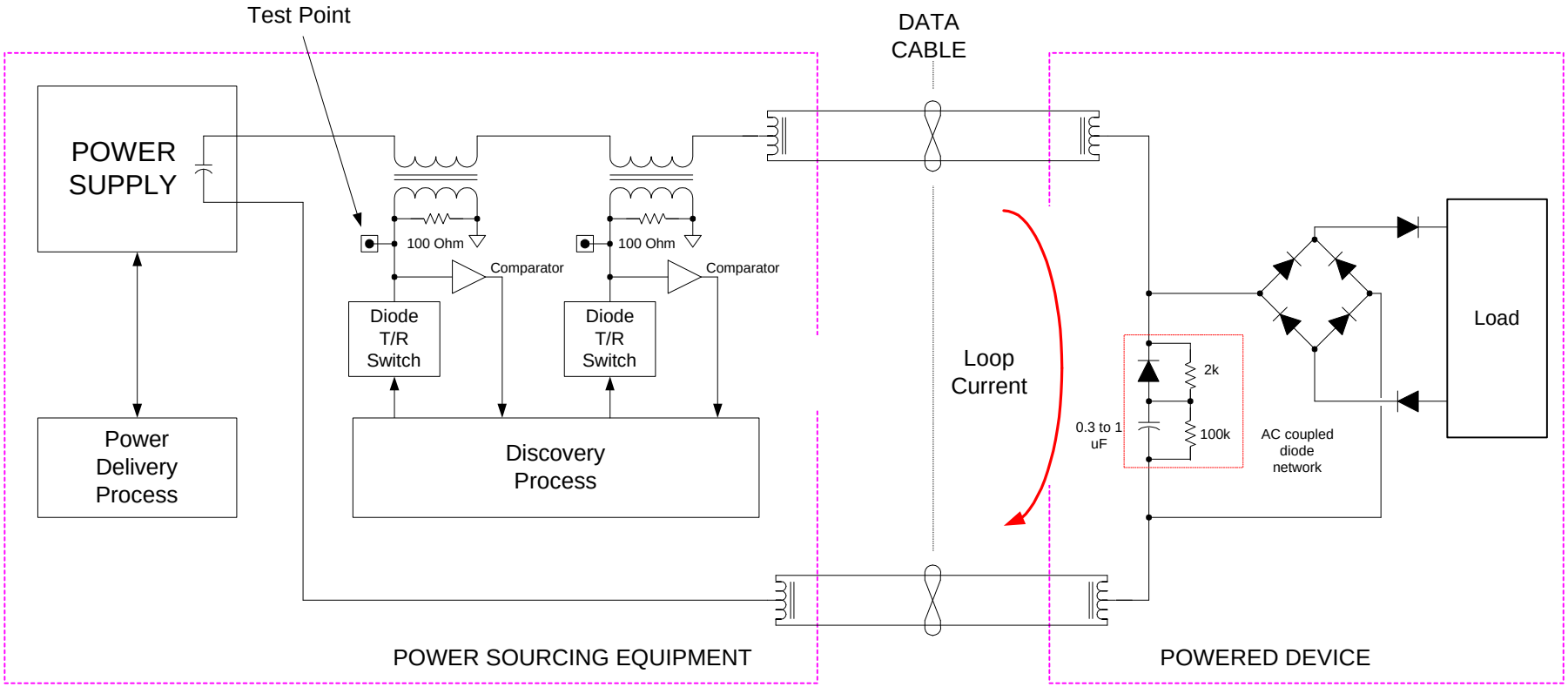


Detector Board Layout

DTE Load Board



DTE Load Board Layout



Diode Discovery Evaluation Boards
Block Diagram

This shows the major components of the system

- The PSE end, with the discovery and power processes
- The discovery transmit/receive test point used for spectrum analysis below
- The PD with the AC coupled diode identity network, and the load isolator (diodes)

AC Coupled Diode Discovery Process Update

A new two stage approach

Discovery Process Update, the two stage approach

We have been talking about the fact that for low duty cycle pulses, the AC coupled diode network behaves essentially like a simple diode. But, when exited by a high duty cycle stream of pulses, it can be made to look like an open circuit. The current Verilog PLD code that is now implemented into the evaluation detector board uses this “two stage” approach. Only after the successful completion of both stages can the DTE power be energized.

- **Discovery Stage 1:**

This is the same as described before. Currently, 256 consecutive successful discovery frames are required for completion. As before, the duty cycle is rather low, and the idle spaces are each an independent pseudo random length of time greater than 40 us. Also, as before, either polarity of the diode characteristic is accepted, to accommodate both straight and crossover cables.

- **Discovery Stage 2:**

Once stage one is completed, the same state machines used to form the discovery pulses start to use a much shorter pseudo random idle time between pulses. The average duty cycle is set to be high enough to charge the diode coupling cap in the identity network. Now the diode characteristic disappears, and the identity network behaves like an open circuit. The requirement here is that 16 consecutive opens be detected in a maximum of 64 discovery frames. When stage 2 is not successful, the discovery process must start at the beginning.

The benefit of this two stage approach is that legacy and unknown RJ-45 devices that contain a simple diode are now excluded from receiving power, and the overall likelihood of a false discovery is reduced. One example of these types of devices are those that contain a reversed biased diode as input protection on a power supply input.

Two Stage Discovery Process: Discovery with “ Distortion”

The data:
The waveforms shown below are for 260 meter CAT-5, and 2 meter CAT-5 cables, as noted.
Note that for the 260 meter cable, 17 2nd stage (distorted) discovery frames are needed. Whereas, for the 2 meter cable, 28 2nd stage (distorted) discovery frames are needed.
This difference is purely the result of signal strength versus cable length

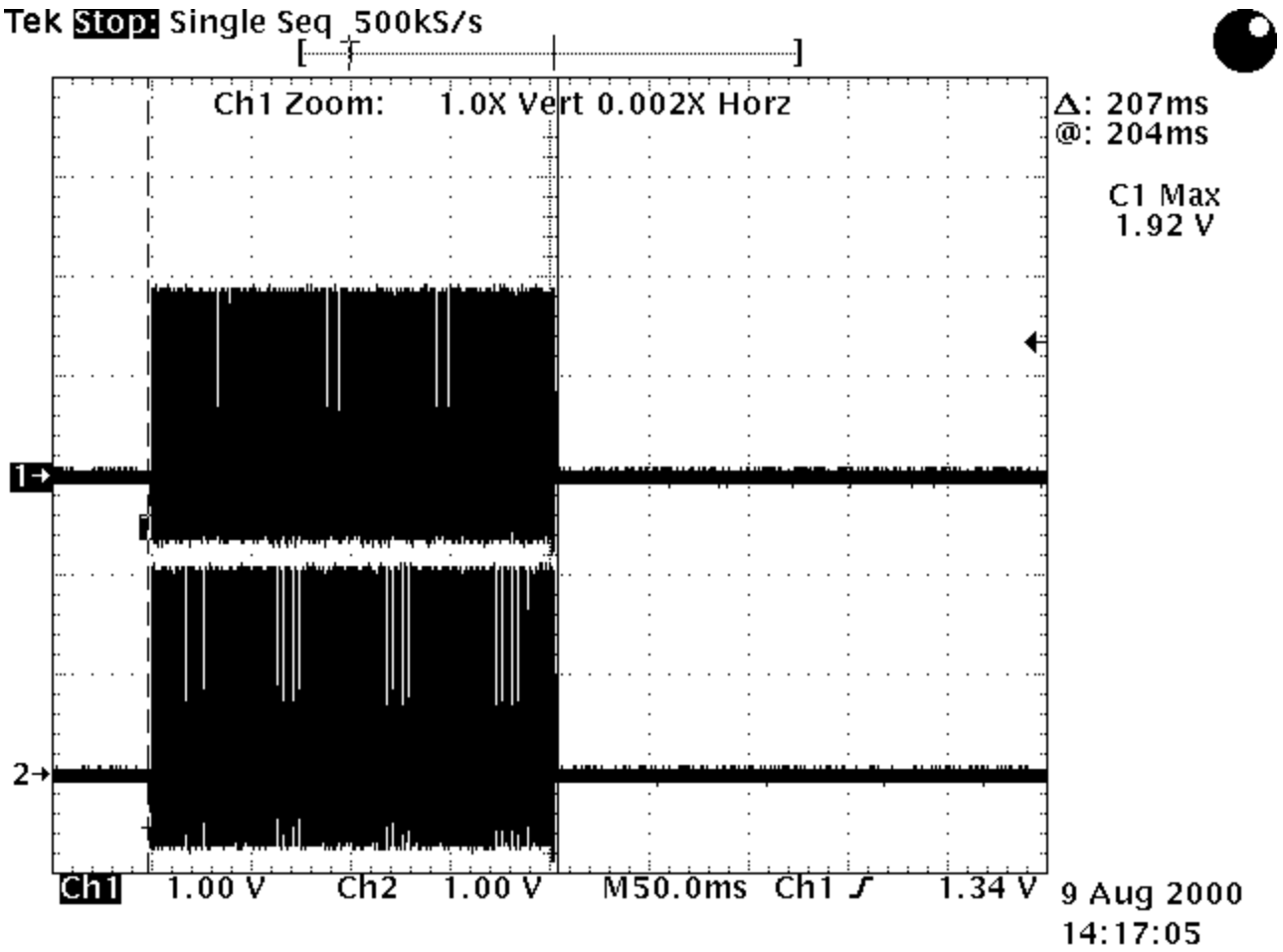
One limitation was noted on one particular detector board at very long cable lengths:
On the unit that I tested, for CAT-5 cables between the lengths of 260 meters and 290 meters, both the AC coupled diode and a normal diode loads were detected.

Above 290 meters, neither the AC coupled diode, nor the normal diode are detected.

Below 260 meters, only the AC coupled diode is detected.

Conclusion:
Cables lengths like these are probably very unlikely, and would not support data communication anyway.

Two Stage Discovery Process (cont.)

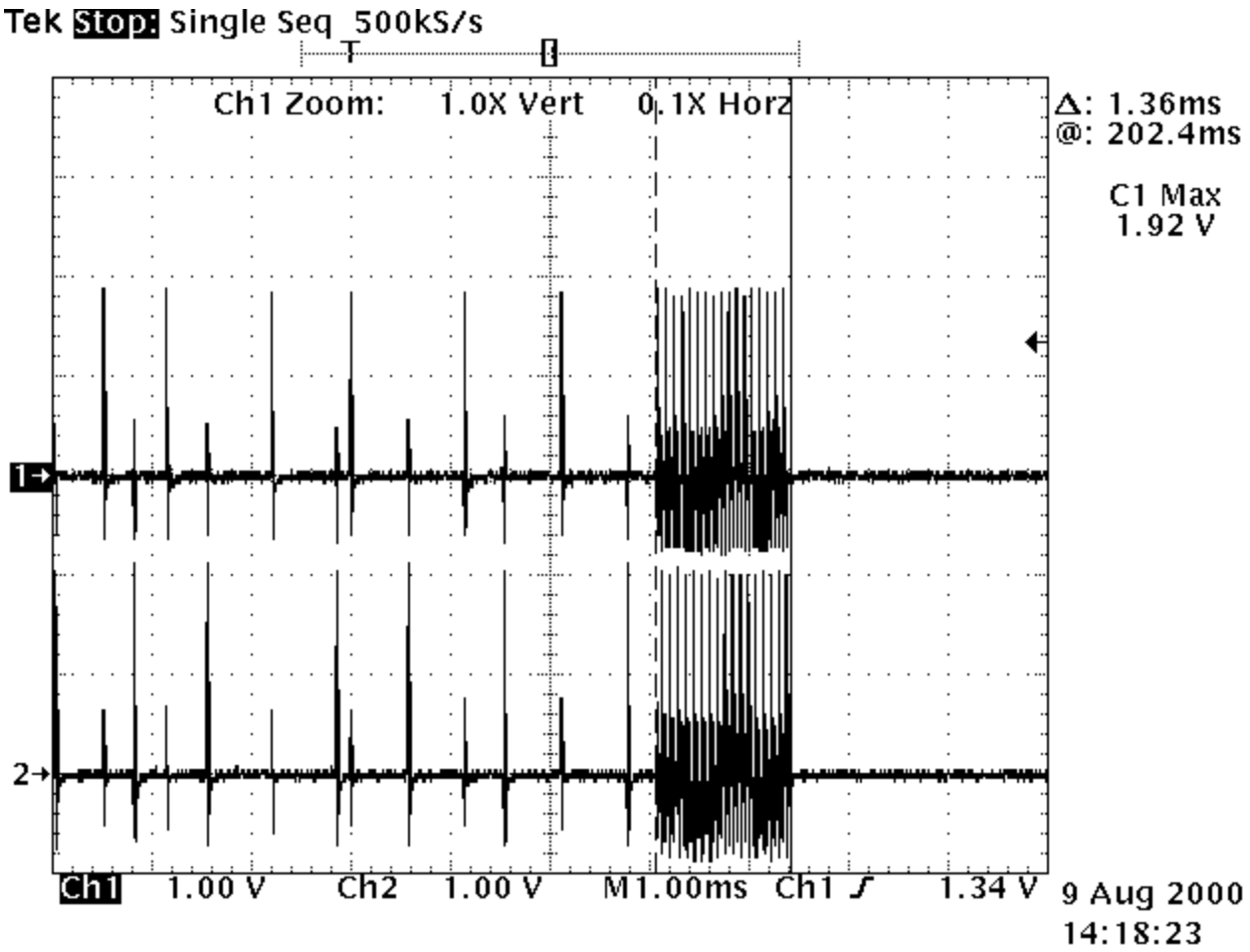


260 meter CAT-5 cable

Voltage across 100 ohm resistors on XFMR's in DTE detector board

One entire discovery sequence is shown: 256 consecutive discovery frames, followed by the 2nd stage discovery sequence (not really visible in this picture), 1 volt/div

Two Stage Discovery Process (cont.)

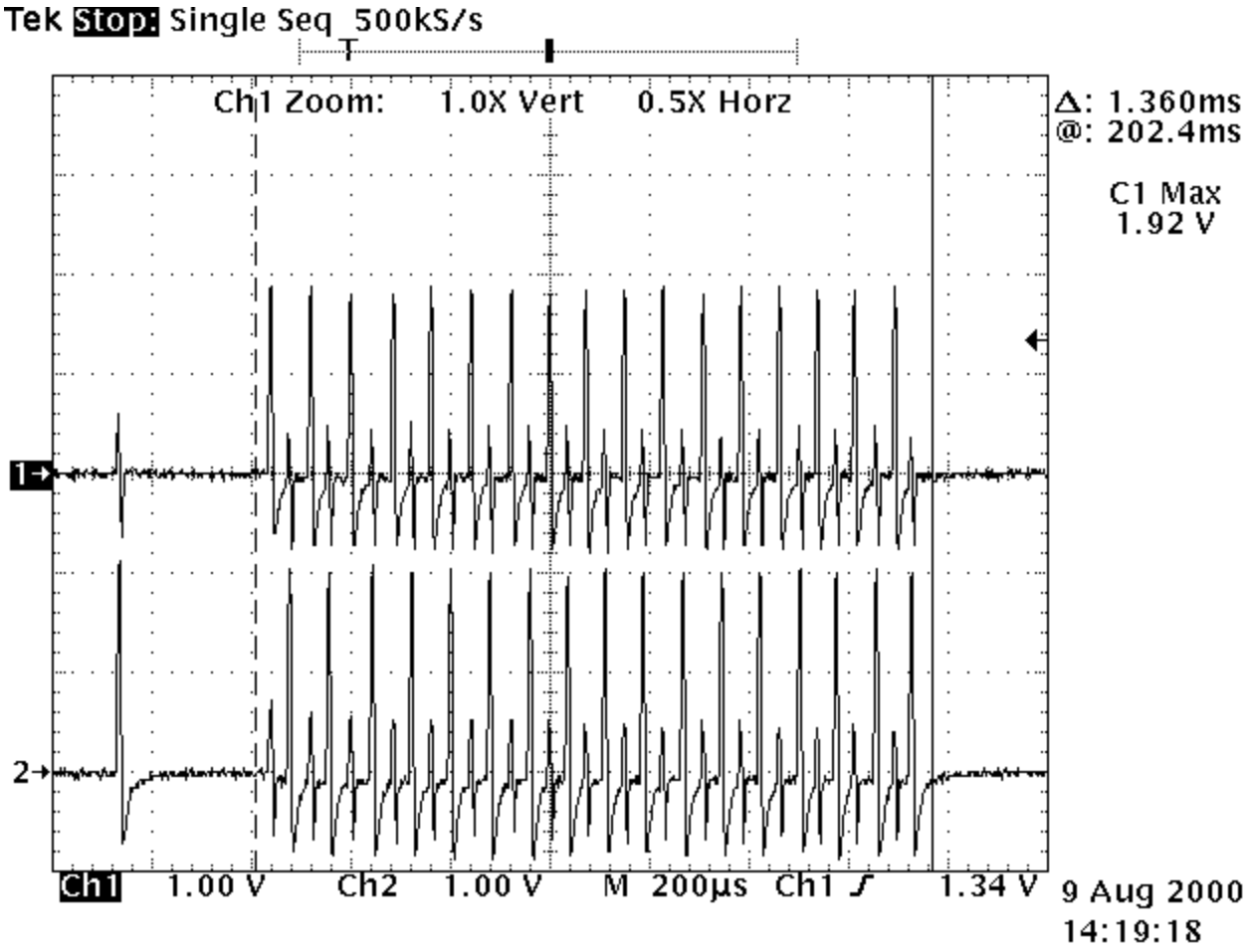


260 meter CAT-5 cable

Voltage across 100 ohm resistors on XFMR's in DTE detector board

The 2nd stage of the discovery sequence is shown following the end of the 1st stage, The 2nd stage has approximately a 1.36 ms duration, 1 volt/div

Two Stage Discovery Process (cont.)

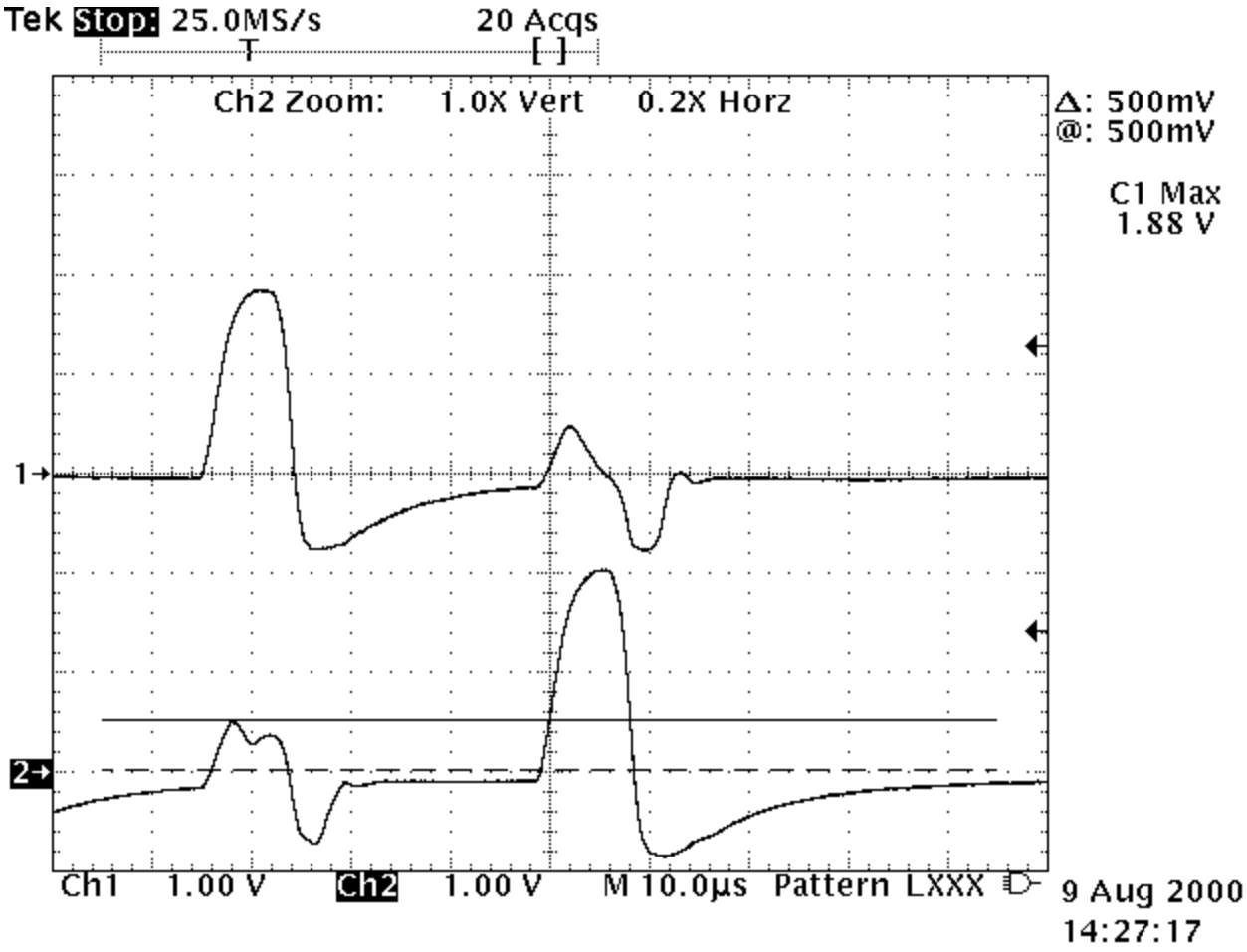


260 meter CAT-5 cable

Voltage across 100 ohm resistors on XFMR's in DTE detector board

The 2nd stage of the discovery sequence is shown again, 1.36 ms duration, 1 volt/div

Two Stage Discovery Process (cont.)

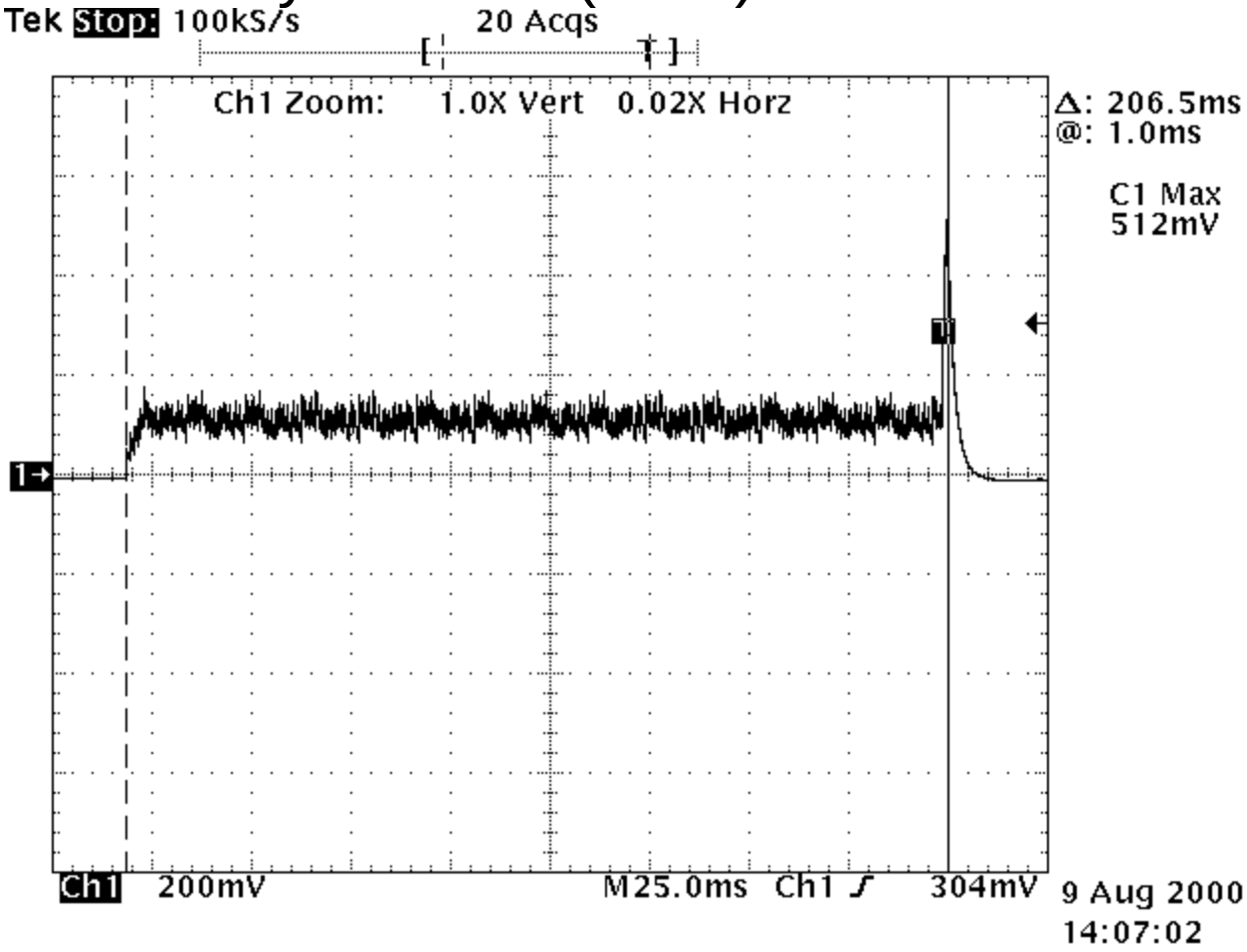


260 meter CAT-5 cable

Voltage across 100 ohm resistors on XFMR's in DTE detector board

The 2nd stage of the discovery sequence is shown again, 1.36 ms duration, 1 volt/div

Two Stage Discovery Process (cont.)



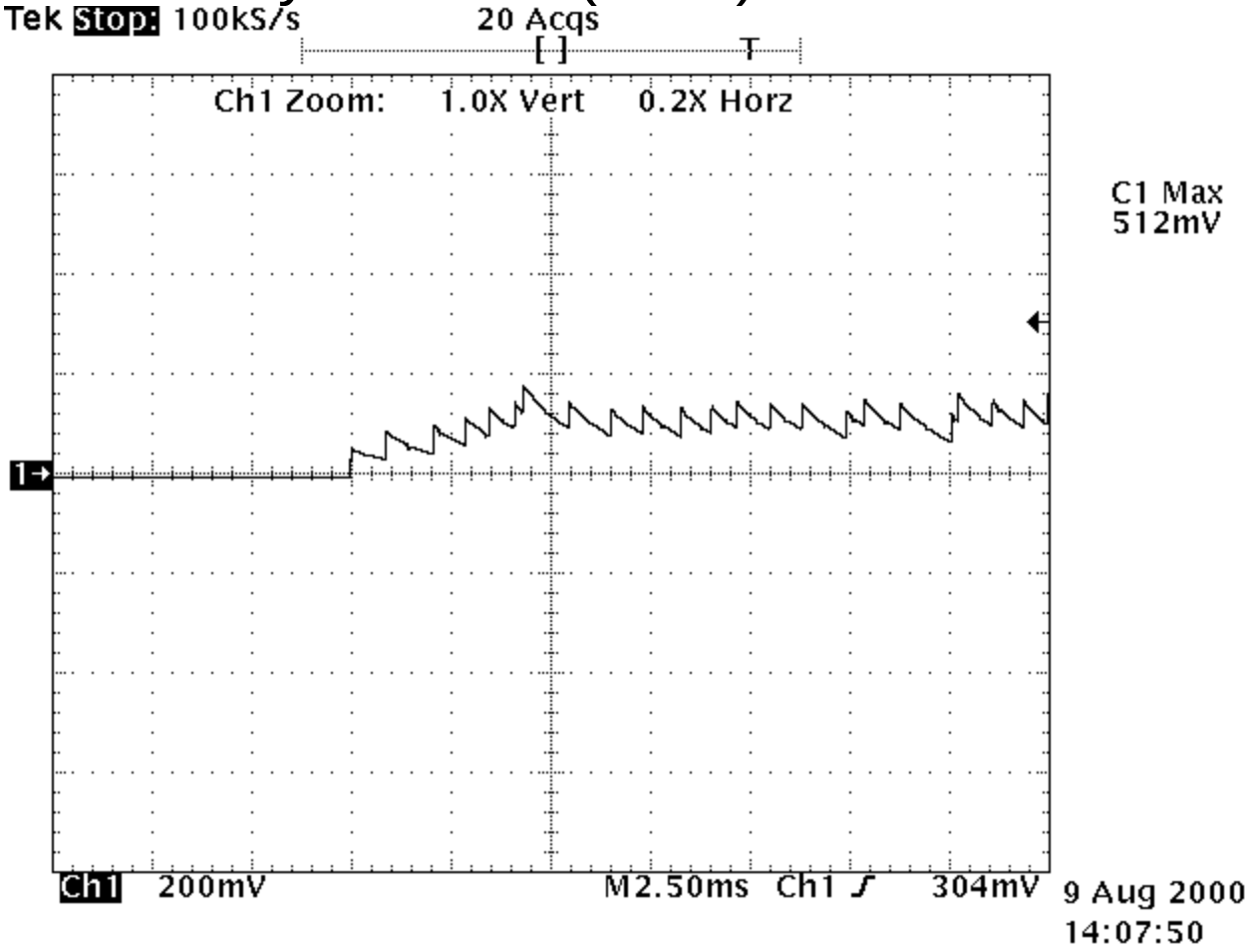
260 meter CAT-5 cable

Voltage across 1 µF coupling capacitor in DTE load board, 200 mV/div

One entire discovery sequence is shown: 1st stage, and 2nd stage

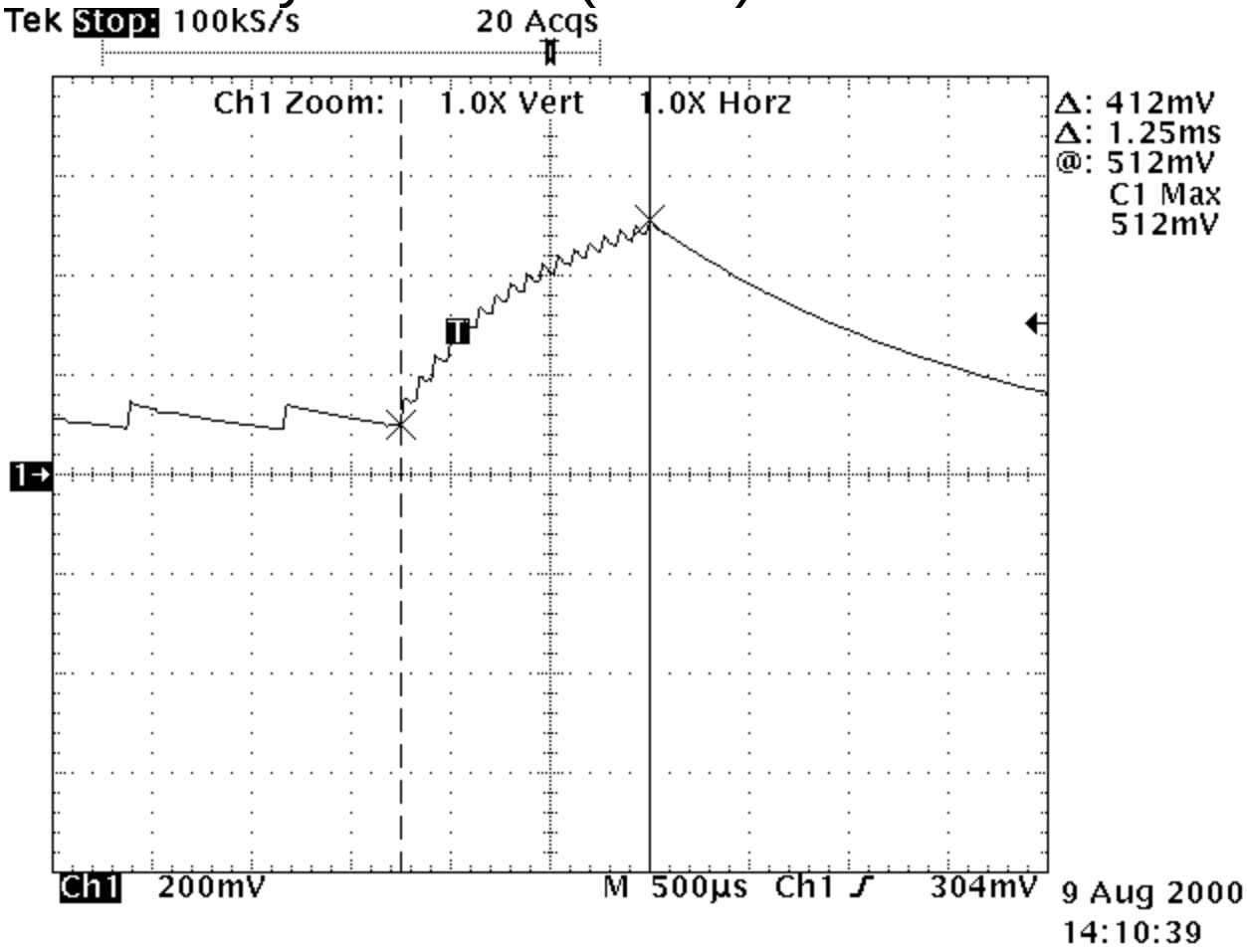
The voltage rise at the end of the sequence is due to 2nd stage: the distortion sequence

Two Stage Discovery Process (cont.)



260 meter CAT-5 cable
Voltage across 1 µF coupling capacitor in DTE load board, 200 mV/div
The start of the discovery sequence, 1st stage, is shown
Note the pseudo random ramp times

Two Stage Discovery Process (cont.)

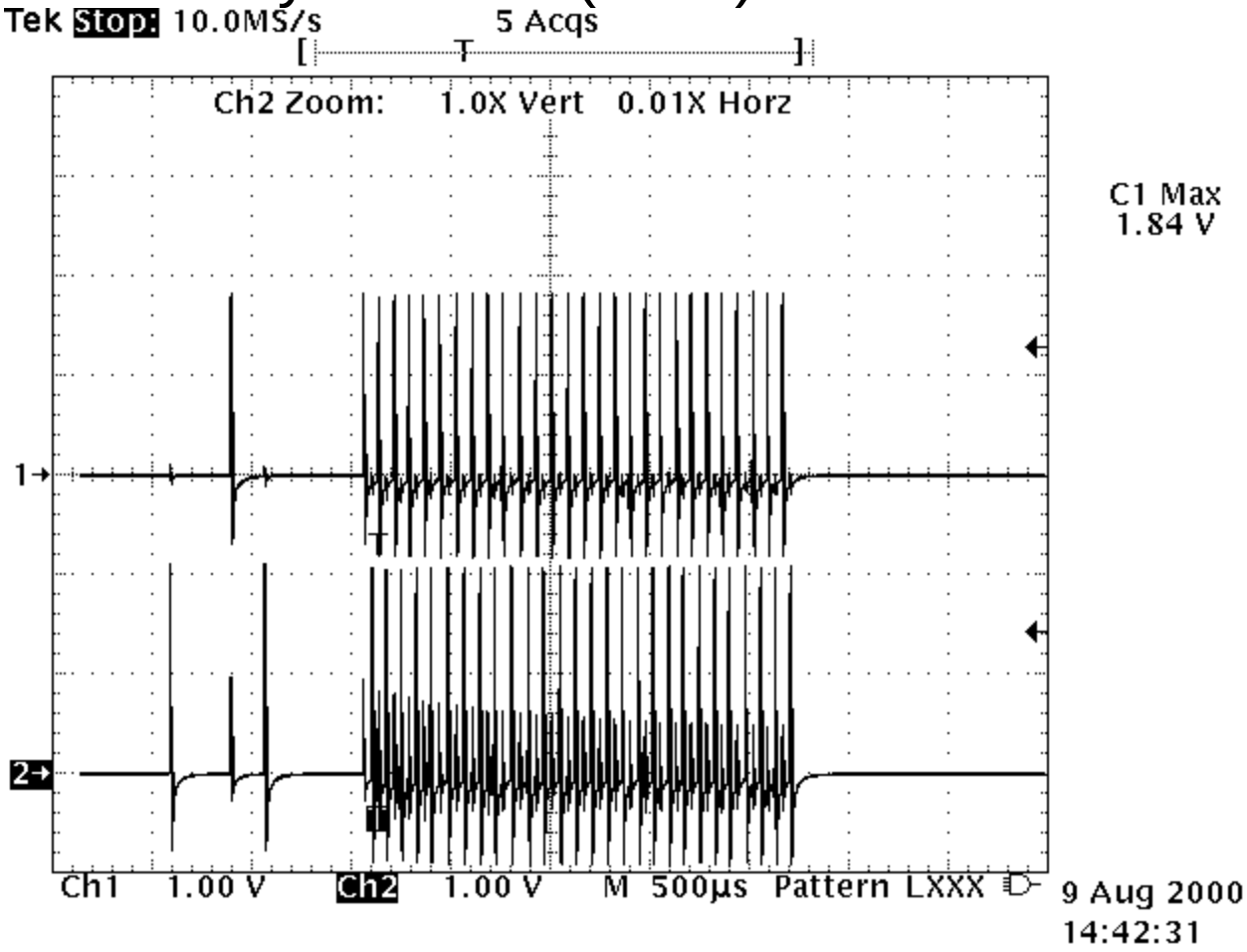


260 meter CAT-5 cable

Voltage across 1 µF coupling capacitor in DTE load board, 200 mV/div

The 2nd stage of the discovery sequence is shown, the distortion sequence measures approximately 1.25 ms. This shows how the higher duty cycle used during the stage 2 sequence causes the capacitor voltage to ratchet up. The effect is to increase the impedance in series with the diode.

Two Stage Discovery Process (cont.)



2 meter CAT-5 cable

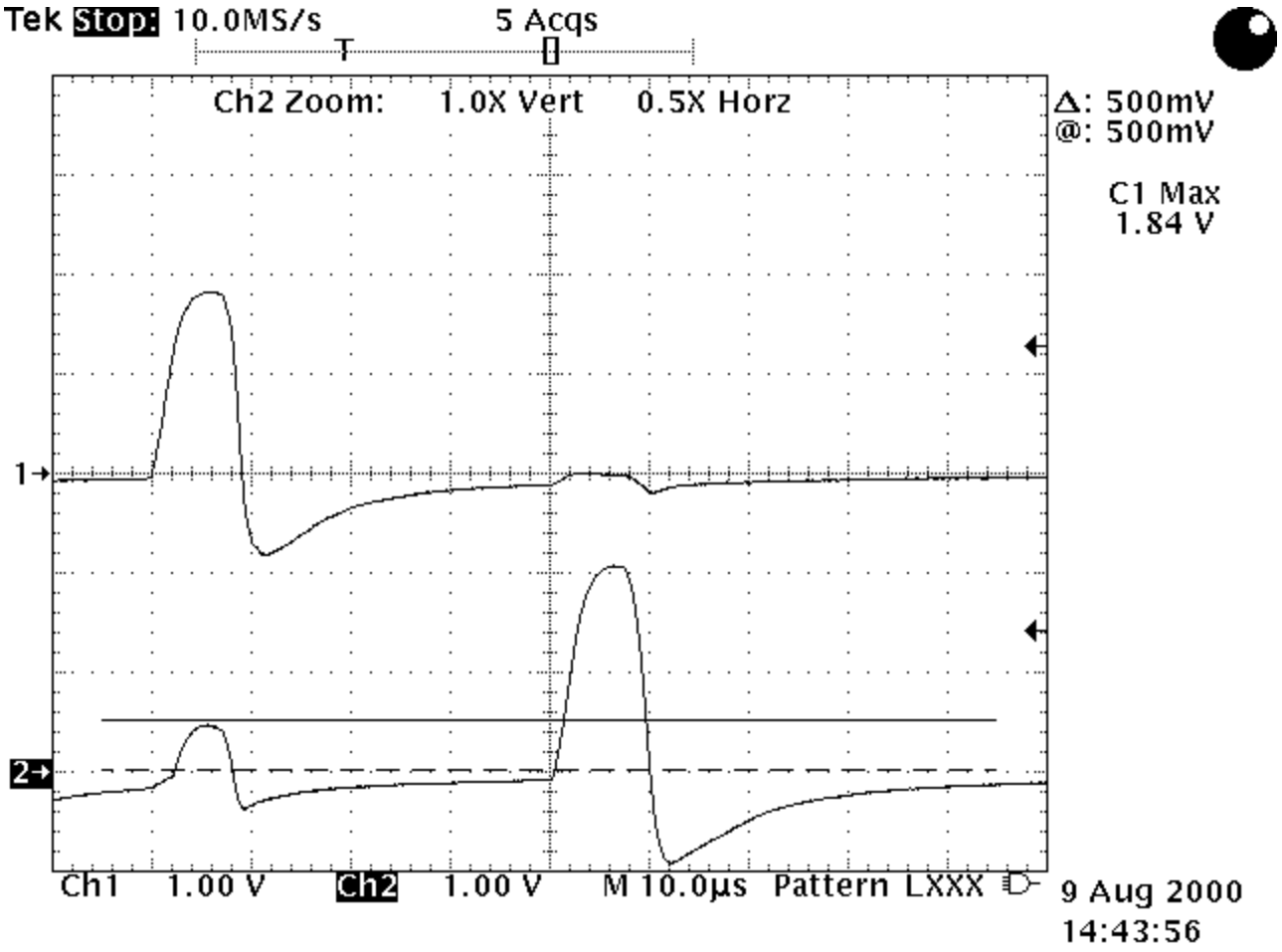
Voltage across 100 ohm resistors on XFMR's in DTE detector board, 1 volt/div

The 2nd stage of the discovery sequence is shown

The last 16 2nd stage, or "distorted" discovery frames detect an open circuit

(note that there are 28 2nd stage discovery frames in this case)

Two Stage Discovery Process (cont.)

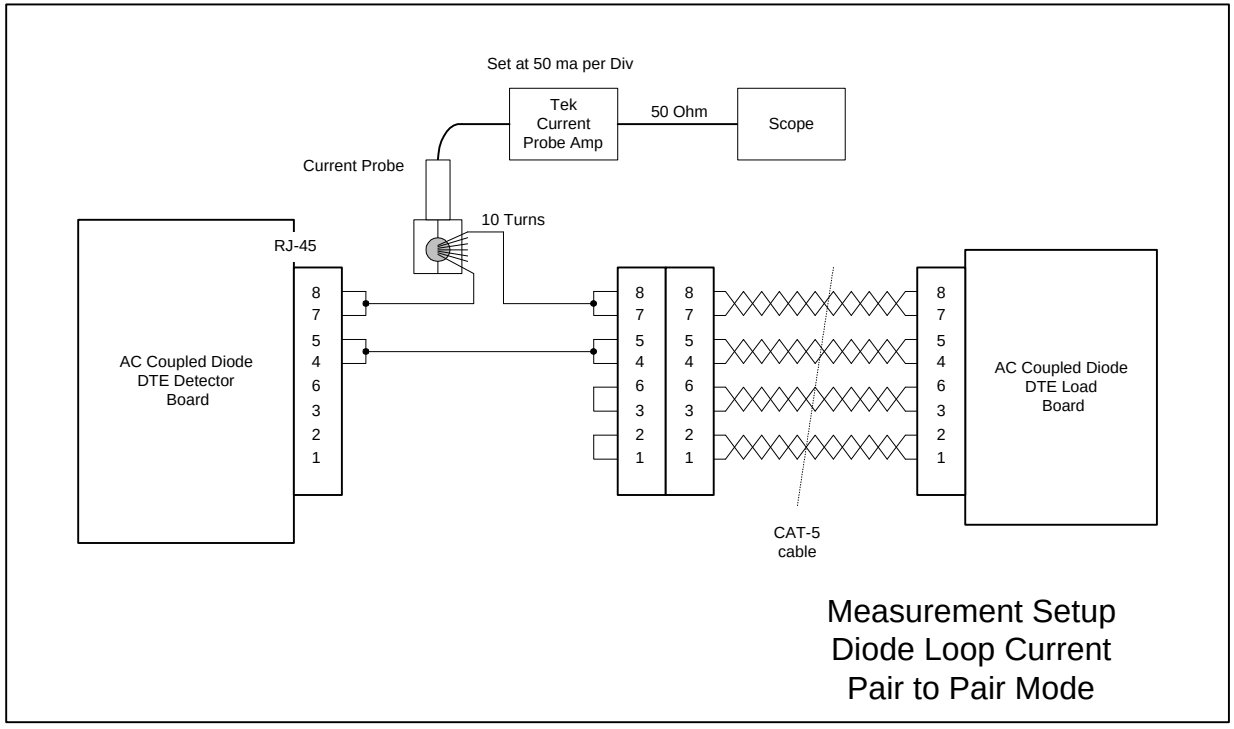


2 meter CAT-5 cable
Voltage across 100 ohm resistors on XFMR's in DTE detector board, 1 volt/div
The end of the 2nd stage discovery sequence is shown

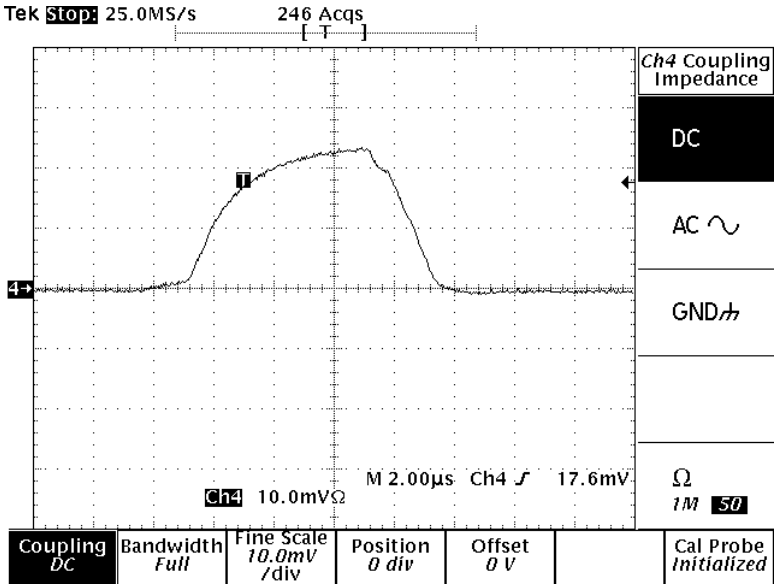
Discovery Loop Current Waveforms

AC Coupled Diode Discovery Loop Current Test

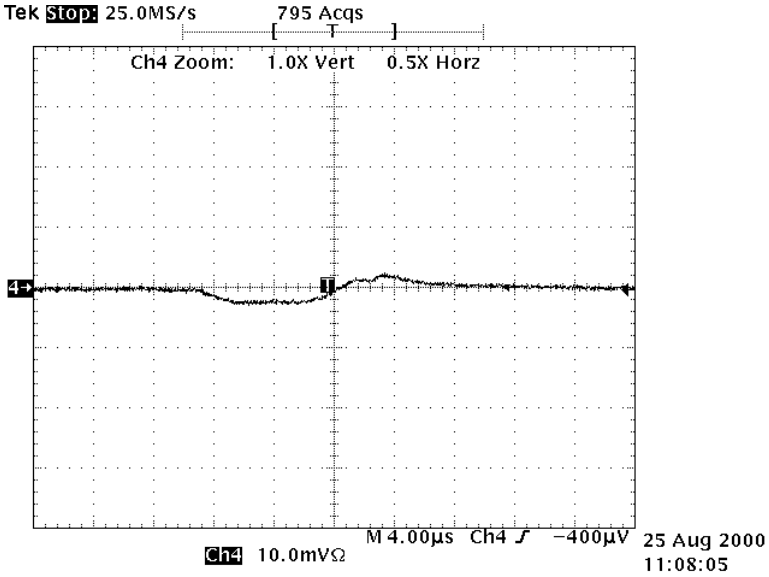
Coupled Diode Identity Network Current Waveforms have been measured using the test setup shown below. In order to get enough resolution on the scope, 10 turns were wound through the Tek current probe. Then the sensitivity was set on the probe amplifier to be 50mV per div. The net result is that the waveforms have a vertical resolution of 5 mV per Div.
The peak current through the identity diode is about 12.5 ma for short UTP cables, and just above 10 ma for the 145 meter cable.



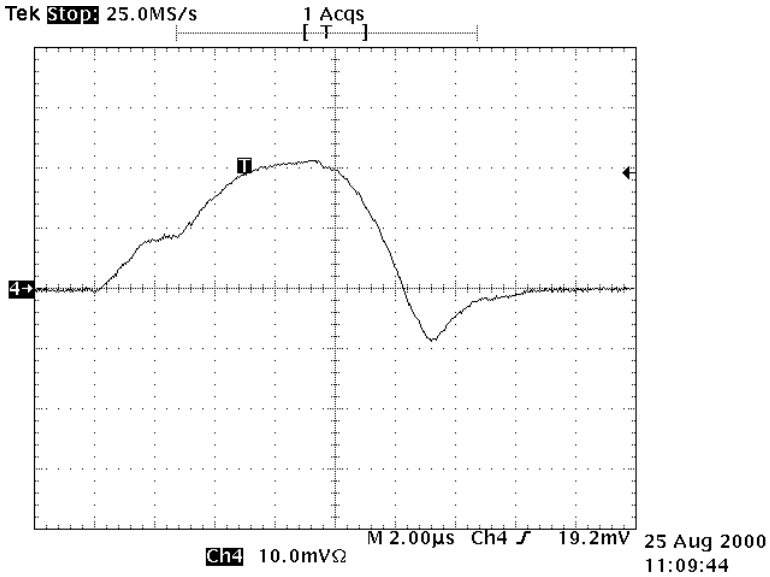
Discovery Pulse Loop Current Test Setup



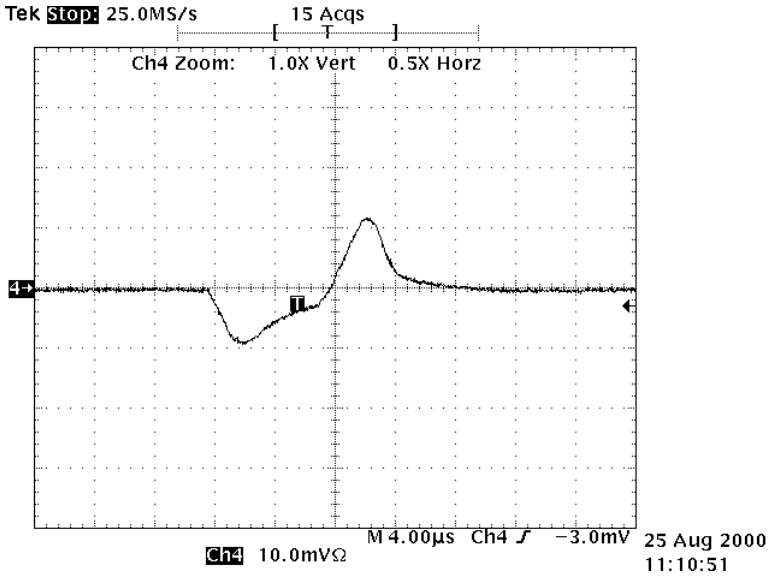
AC Coupled Diode Discovery Evaluation Board, Loop Current, Pair to Pair Mode
2 meter CAT-5 Cable, Diode Conducting Direction, 5 ma per div



AC Coupled Diode Discovery Evaluation Board, Loop Current, Pair to Pair Mode
2 meter CAT-5 Cable, Diode Non-conducting Direction, 5 ma per div



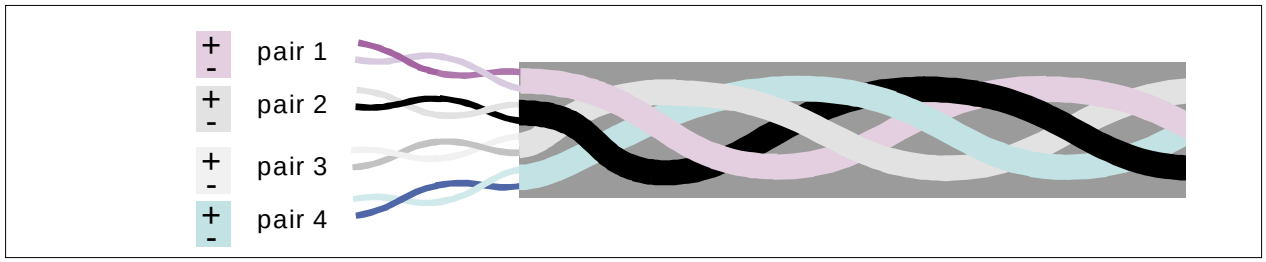
AC Coupled Diode Discovery Evaluation Board, Loop Current, Pair to Pair Mode
145 meter CAT-5 Cable, Diode Conducting Direction, 5 ma per div



AC Coupled Diode Discovery Evaluation Board, Loop Current, Pair to Pair Mode
145 meter CAT-5 Cable, Diode Non-conducting Direction, 5 ma per div

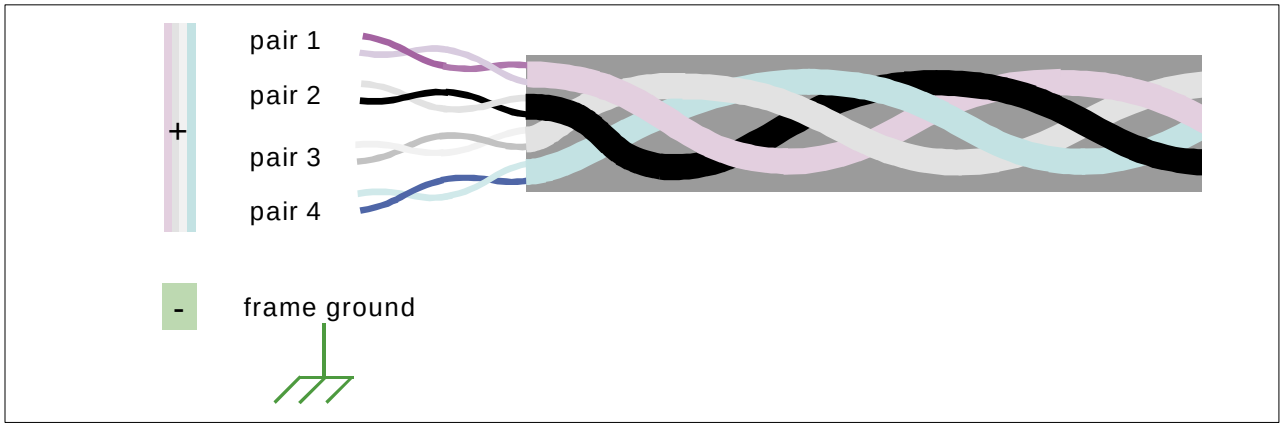
UTP Cable Propagation Mode

UTP Cable Propagation Mode Definition



Differential Pair Mode

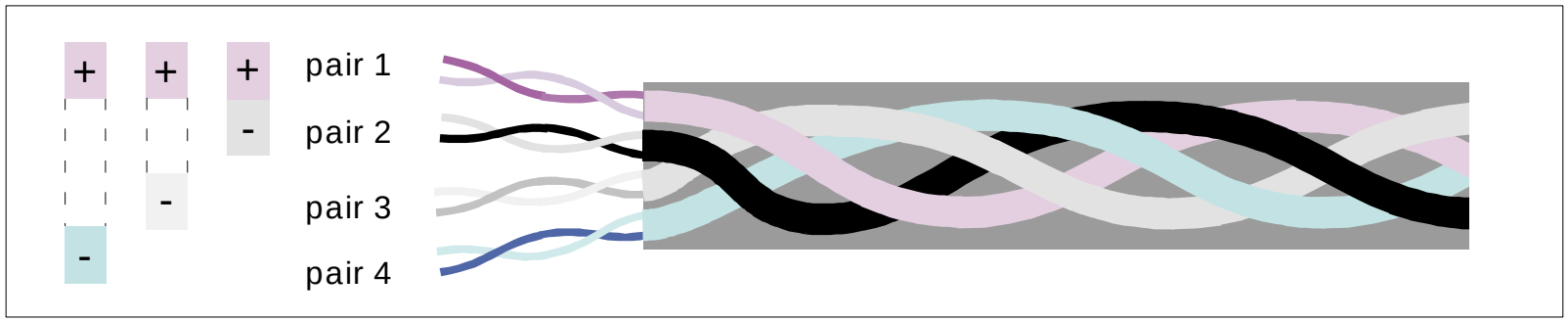
This is obviously the 10/100/1000 signaling mode, each pair contains it's own differential signal. At low frequencies each of the four differential signals is independent from other differential signals to a first order.



Common Mode

This is true "common mode", in the sense that each wire carries a common signal with respect to earth, or frame ground, i.e. the same signal as all other wires and pairs. This mode can generally cause EMI problems.

UTP Cable Propagation Mode Definition



Pair to Pair Mode

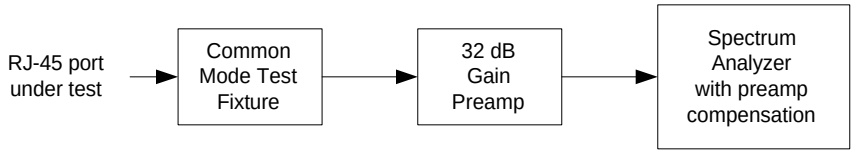
“ Pair to Pair” mode is the mode that IEEE802.3af has chosen for DTE power and discovery, one pair carries the DC send current, and another pair carries the DC return current.

This mode has been referred to in the IEEE802.3af working group as “ common mode” , but that is not really correct. Actual common mode is with respect to earth ground. However, what is true for the pair to pair mode, that each wire in a given pair carries a common signal.

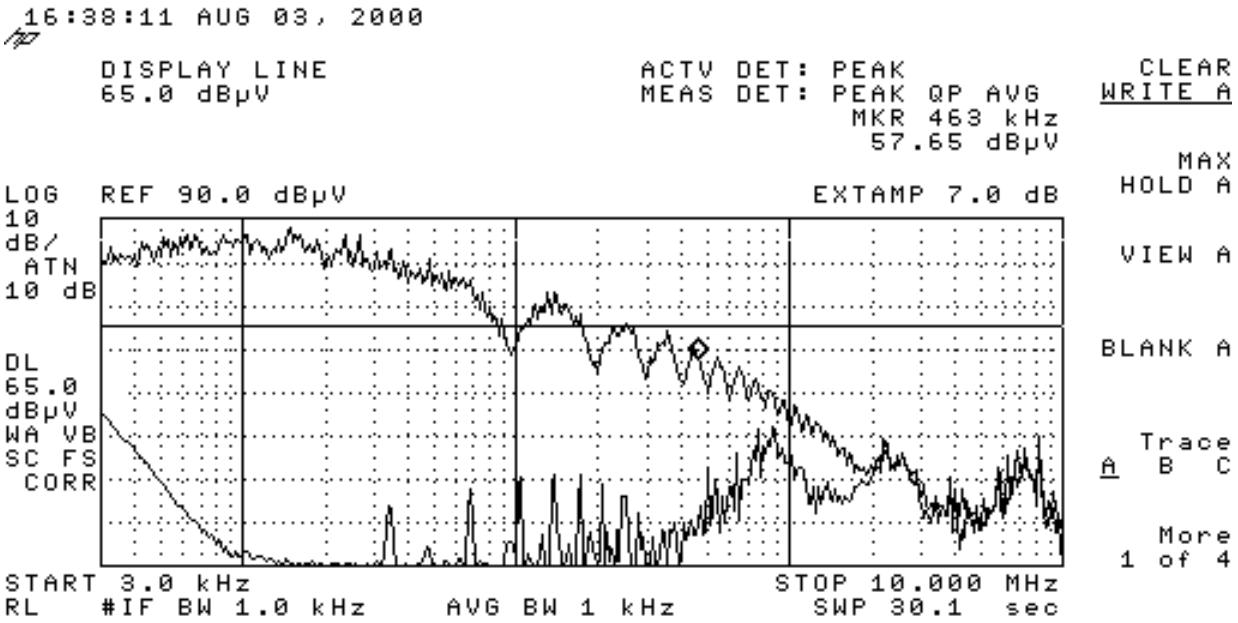
There are 6 examples of this mode: (pair-pair) 1-2, 1-3, 1-4, 2-3, 2-4, and 3-4.
The four pair sets are all twisted around each other in CAT-3, CAT-5, etc… in a way that is not necessarily well controlled.
However, based on my measurements, all four pairs are coupled to each other, as would be expected from the cable construction.

AC Coupled Diode Discovery Spectrum

AC Coupled Diode Discovery Spectrum

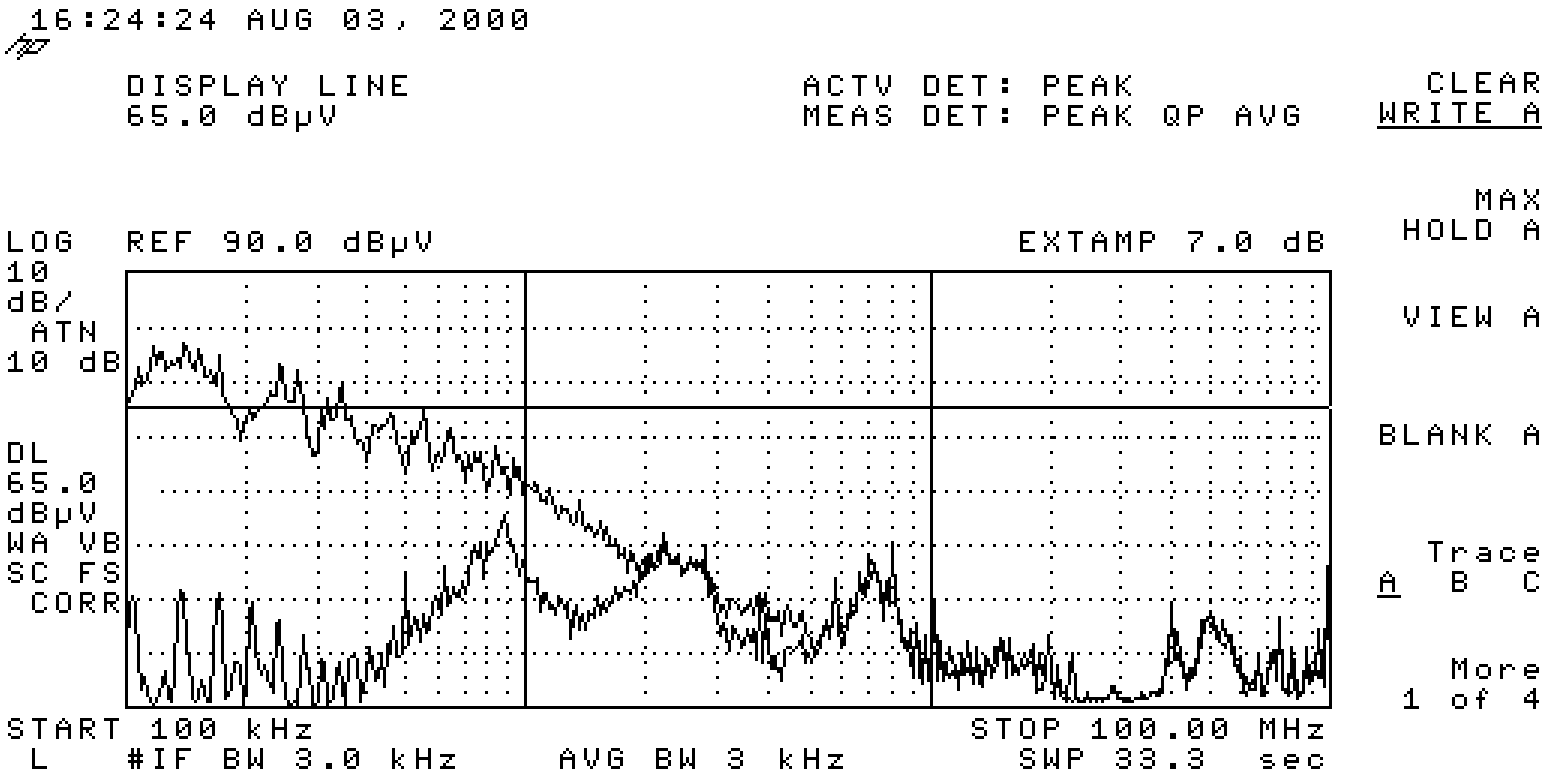


Test Setup



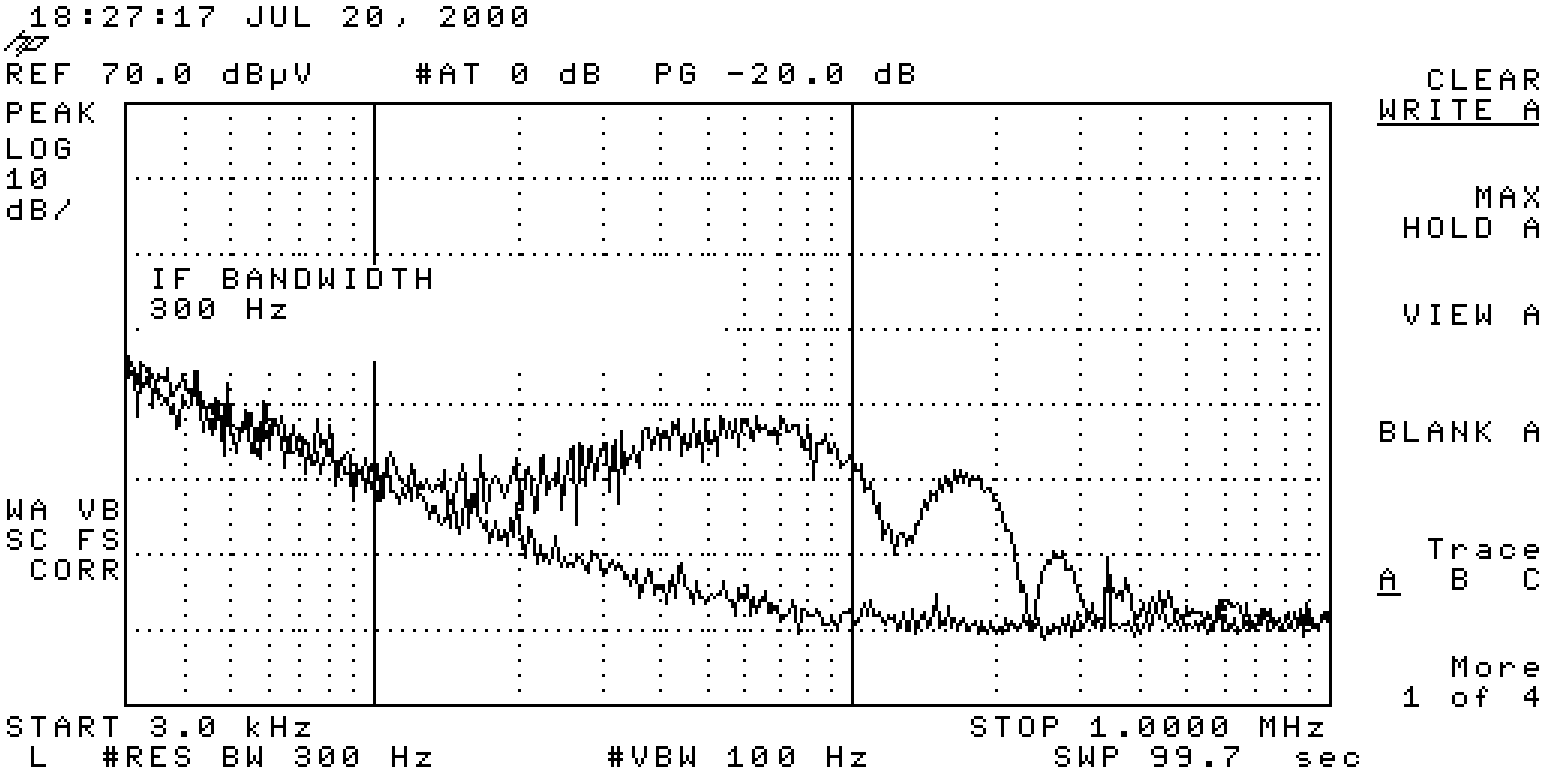
Common Mode Voltage on PSE Detector Board RJ-45 pins 4 and 5 (top trace)
Noise Floor (bottom trace)
Measured with a common mode test fixture for the RJ-45, as shown above, the Spectrum Analyzer had a 7 dB compensation for the preamp and fixture.
The line at 65 dBuV represents a marker for radiated emissions above 30 MHz
The reference line at the top of the graph is 90 dBuV

AC Coupled Diode Discovery Spectrum



Common Mode Voltage on PSE Detector Board RJ-45 pins 4 and 5 (top trace)
Noise Floor (bottom trace)
Measured as above, except showing from 100 KHz to 100 MHz
The line at 65 dBuV represents a marker for radiated emissions above 30 MHz
The reference line at the top of the graph is 90 dBuV

AC Coupled Diode Discovery Spectrum

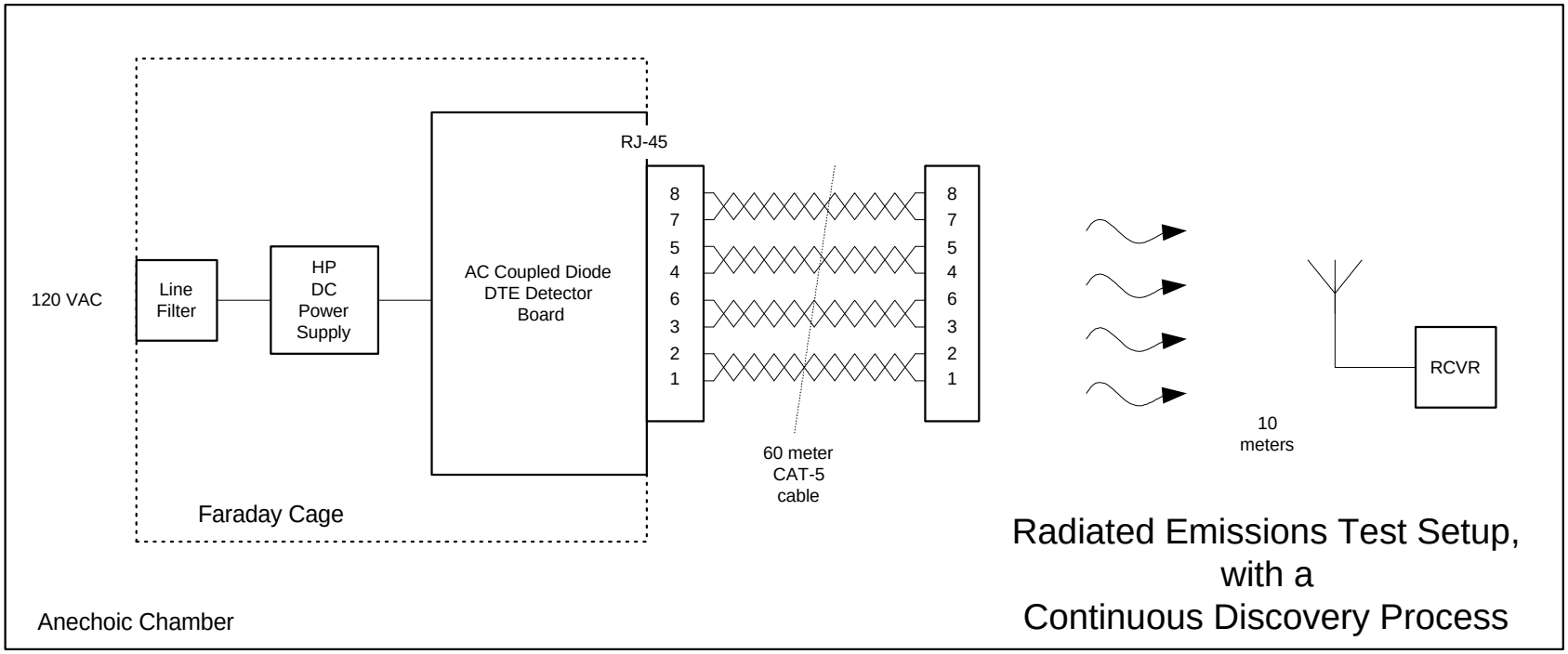


Spectrum at the 100 ohm and transformer test point
Input voltage to 48V/48V Power Supply is off, Discovery Circuit running on 3.3 VDC
Measured at the “ test point” , the discovery T/R transformer and the 100 ohm resistor
120 meter CAT-5 cable, far end of cable is open
The reference line at the top of the graph is 70 dBuV
The probe is a x10, 500 MHz scope probe, therefore a –20 dB preamp compensation was used

EMC Tests

Radiated Emissions and Susceptibility Testing of the Diode Discovery Prototype Board Set

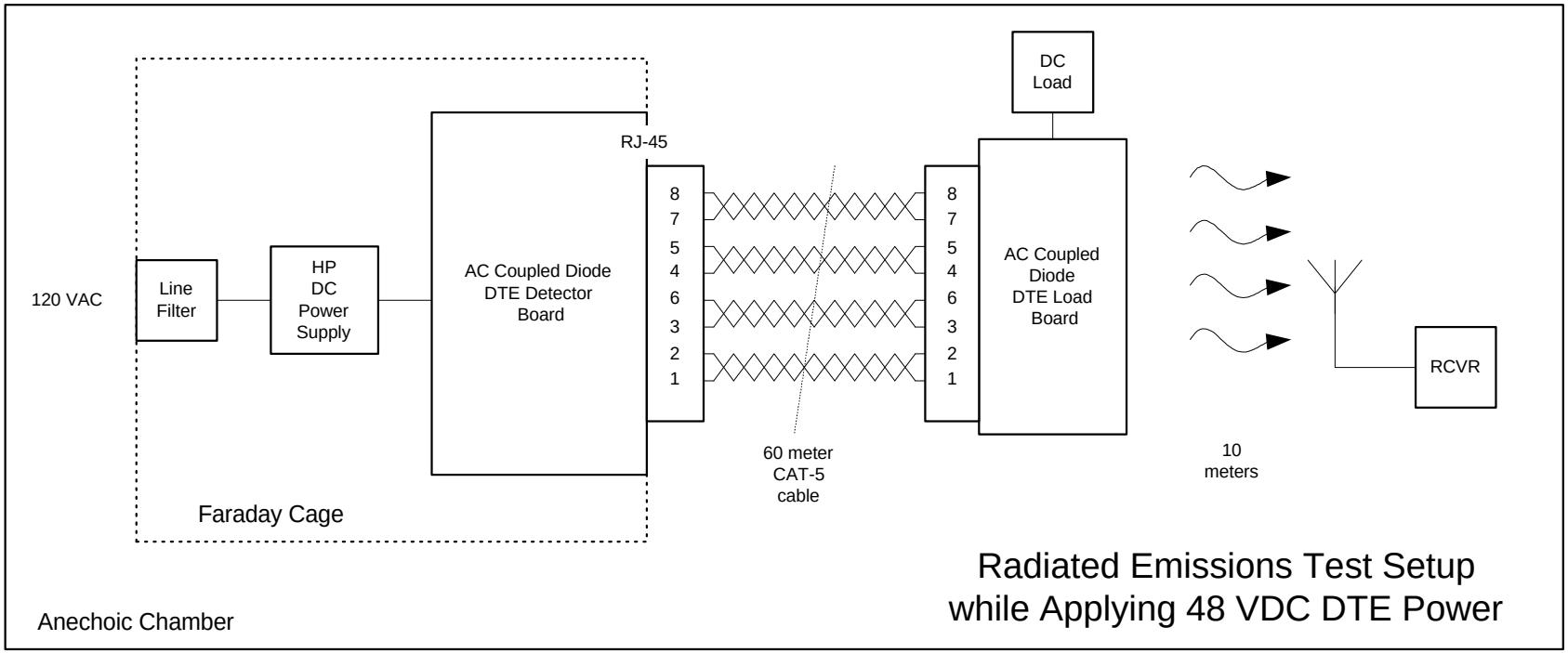
Radiated Emissions Test Setups:



Radiated Emissions Test Setup for Continuous Discovery Mode

In the "continuous" discovery mode, the far end of the CAT-5 cable is open, therefore the discovery process continues to run. This mode is the best to see how much RF energy is radiated due to this process.

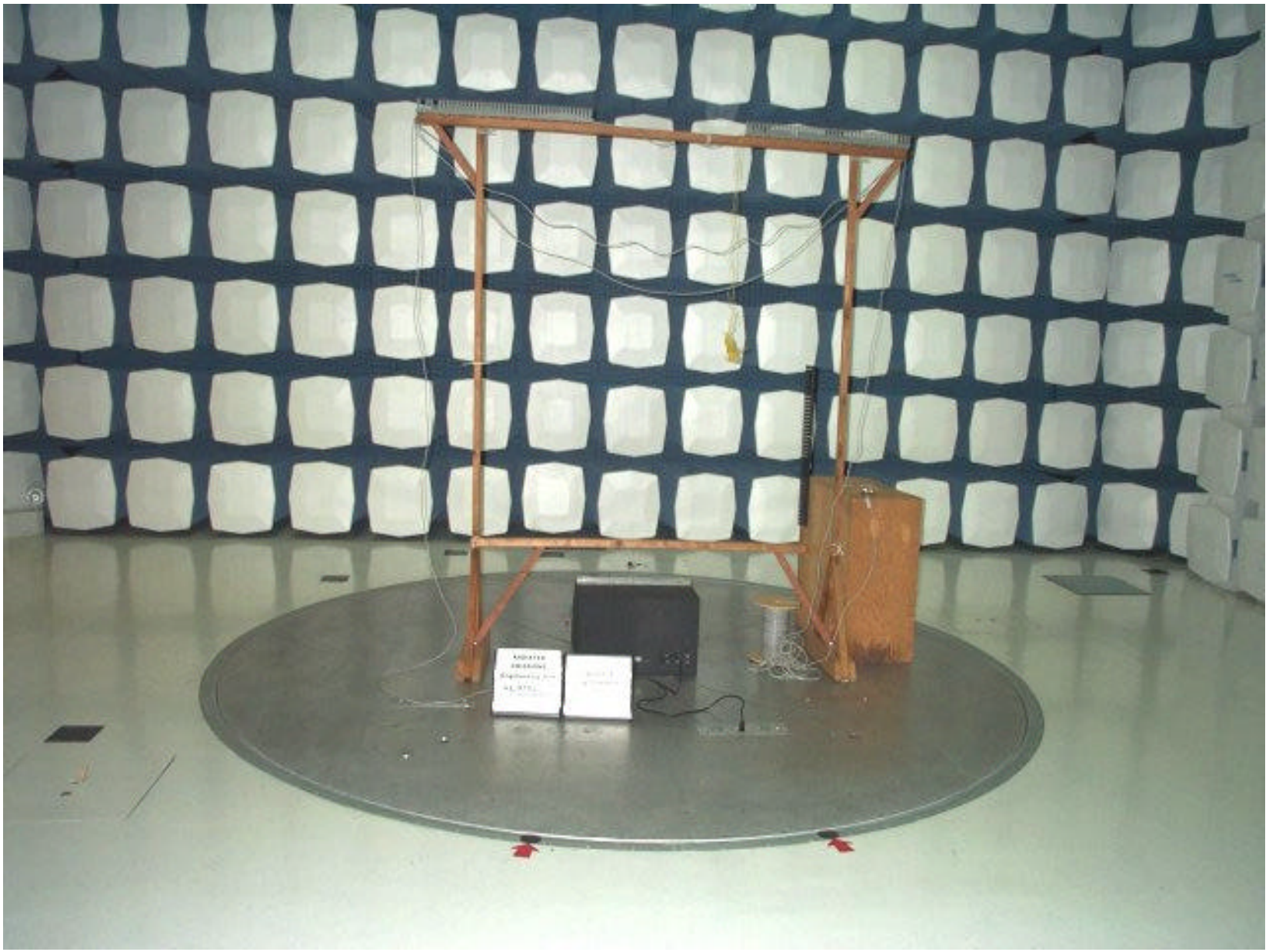
Radiated Emissions Test Setups (cont):

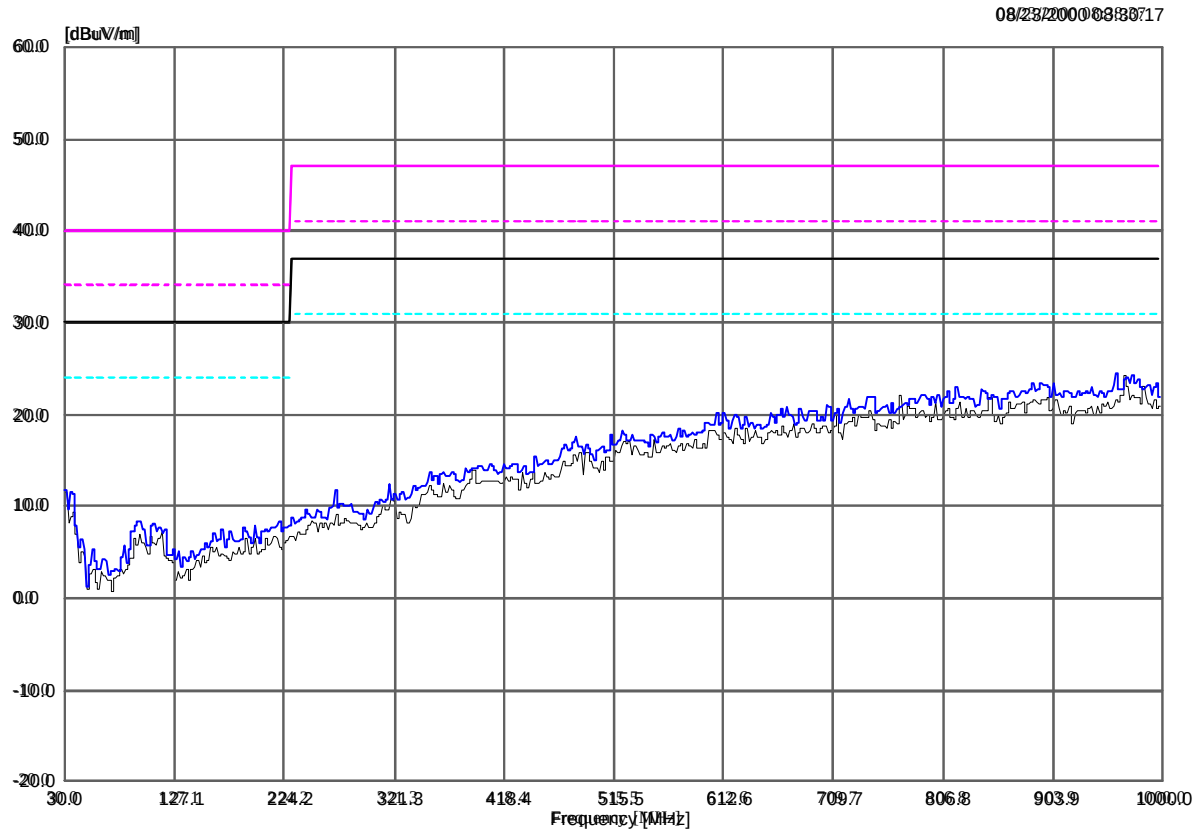


Radiated Emissions Test Setup for DTE Power Delivery Mode

Following the discovery process, DTE power is delivered continuously into the load, in this case the load receives 7.87 watts, whereas the PSE (detector board) delivers 8.69 watts.

Radiated Emissions Test Setup, 10 meter Anechoic Chamber

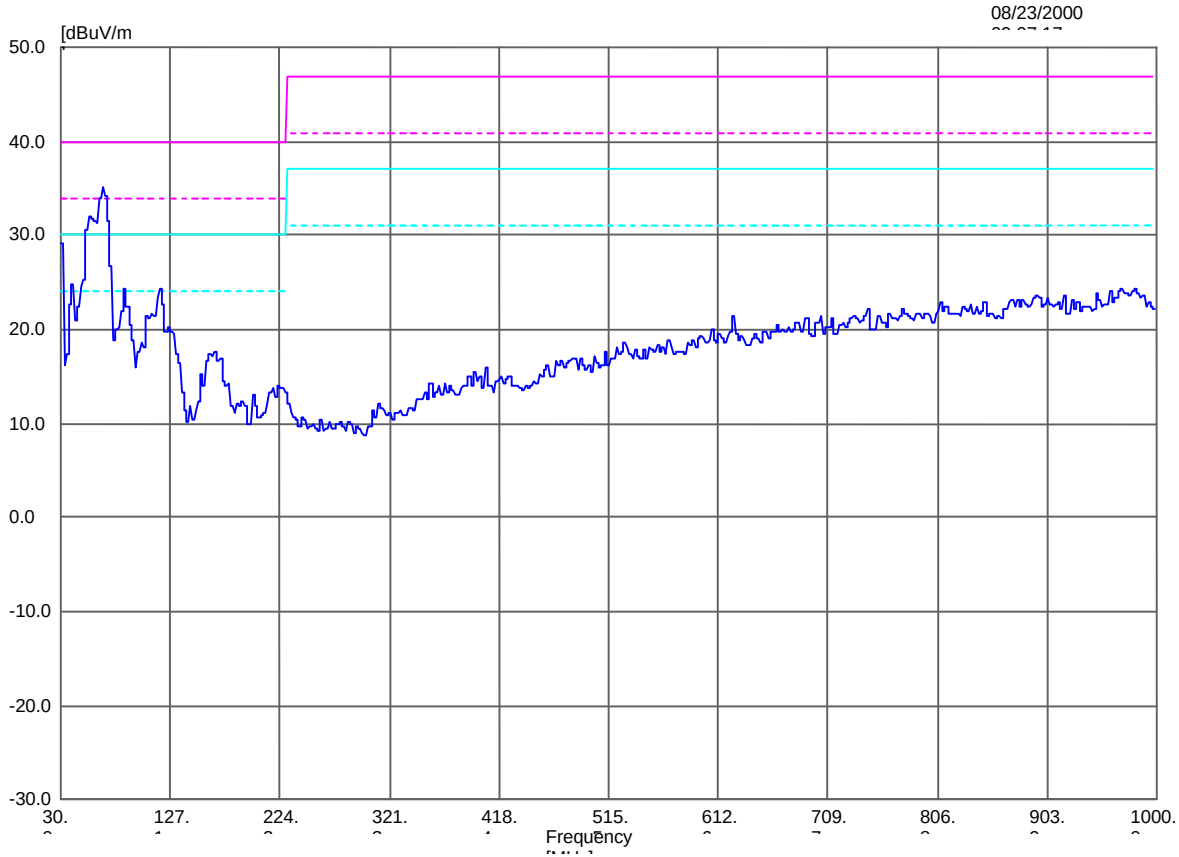




Radiated Emissions with Continuous Coupled Diode Discovery Running

Legend:

Class A Limit	solid violet line
6dB margin to Class A Limit	dotted violet line
Class B Limit	solid black line
6dB margin to Class B Limit	dotted light blue line
Continuous Diode Discovery	solid dark blue trace
Noise Floor of chamber and receiver	solid black trace



Radiated Emissions with 48 VDC DTE Power Applied

Legend:

Class A Limit	solid violet line
6dB margin to Class A Limit	dotted violet line
Class B Limit	solid light blue line
6dB margin to Class B Limit	dotted light blue line
DTE Load Power at 8.7 watts	upper solid dark blue trace
Noise Floor of chamber and receiver	lower solid dark blue trace

Radiated Emissions Results

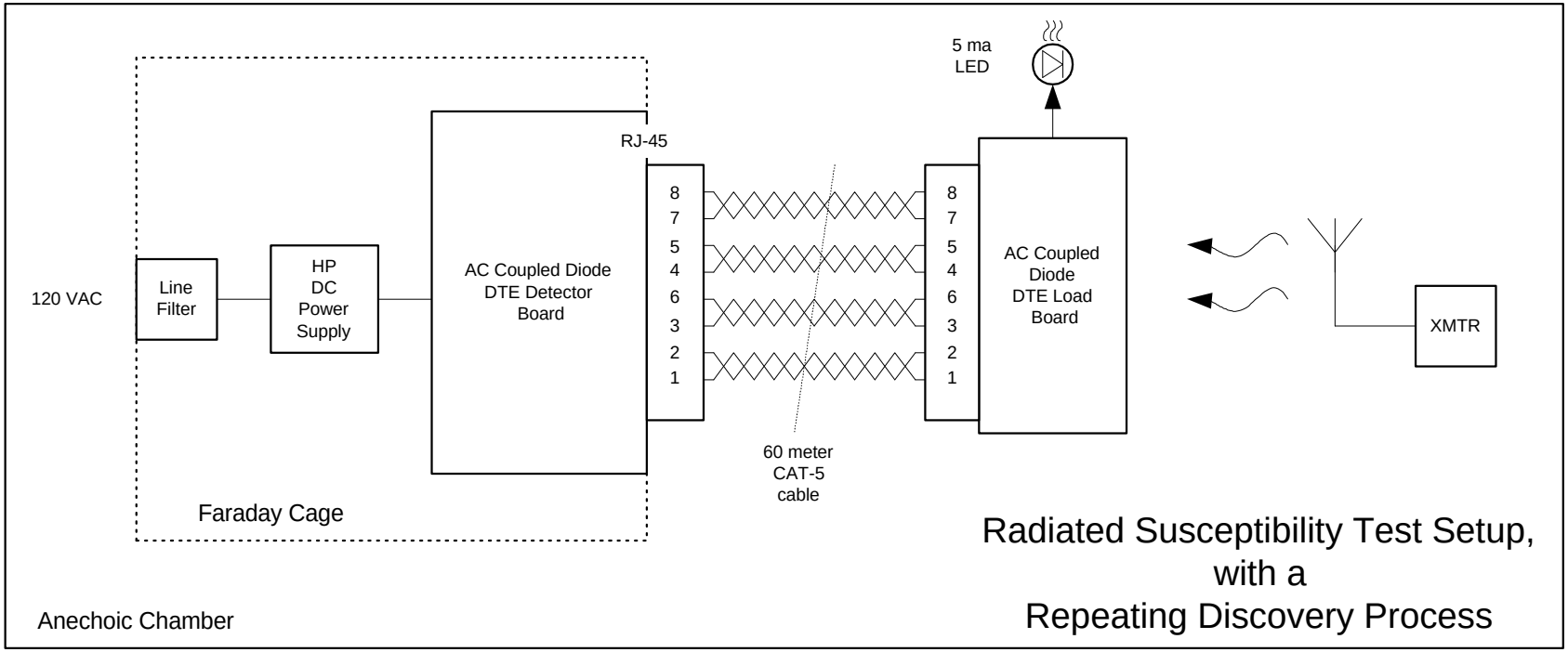
Continuous Discovery Running, no DTE Power
The results obtained show that very little energy is radiated from the CAT-5 cable.

The emissions risk due to this method running on a Cat-5 cable is extremely low. Given the energy spectrum of the discovery signal, the conclusion is that this method will work on any relevant transmission line system.

DTE Power Energized:
Here the radiated emissions spectrum shows a fair amount of energy in the 30 MHz to 65 MHz range. This is due to switching noise in the DC/DC converter itself.
All implementations will face this problem. Real world DC power supplies actually emit AC noise. The key is to limit and filter it, so that it is not a problem.

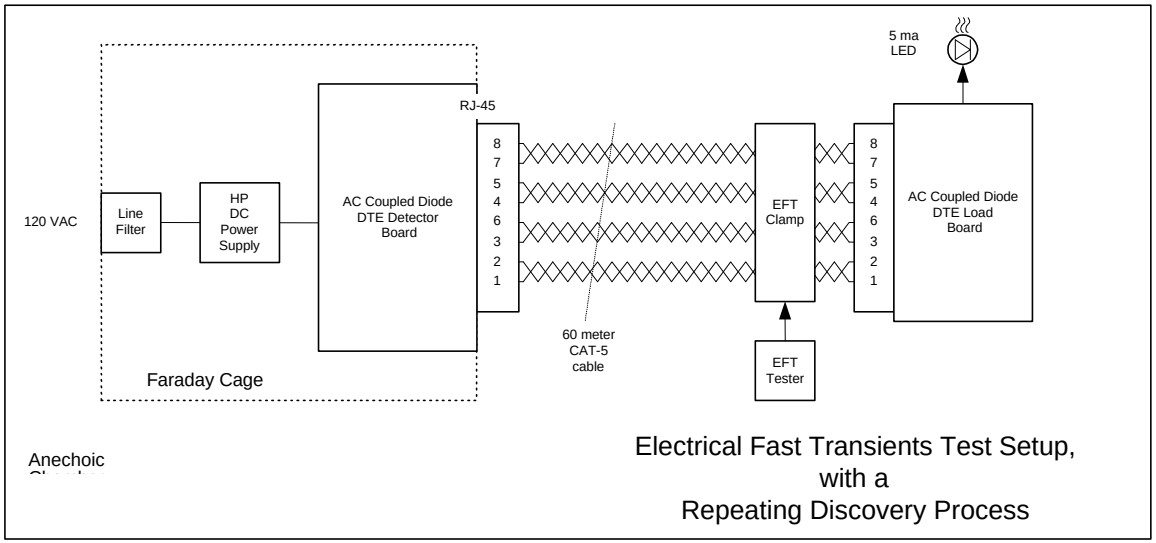
What we need is pure DC!
The key here is getting a DC power supply, generally a switching power supply, to be sufficiently quiet. That will generally cost extra. The important question is, how quiet does it have to be?

Radiated Susceptibility, EFT, and Conducted Immunity Test Setups:

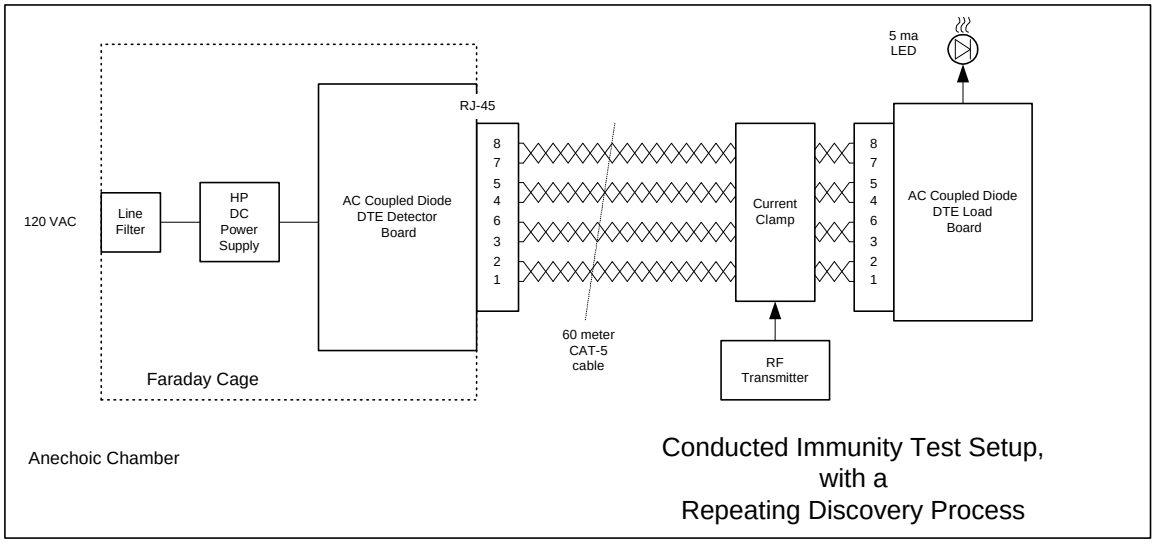


Radiated Susceptibility Test Setup for Repeated Discovery and Power Mode

In the "repeated" discovery and power mode, the DTE Load board is connected to a small LED, which is under the minimum load for the power supply, therefore the discovery process starts again followed by power on. In this way, the small LED turns on and off at a rate of about 0.5 to 0.8 Hz. By watching this small LED load with a camera, the effect of the controlled 5 volt per meter field can be assessed during the various tests.



EFT Test Setup for Repeated Discovery and Power Mode



Conducted Immunity Test Setup for Repeated Discovery and Power Mode

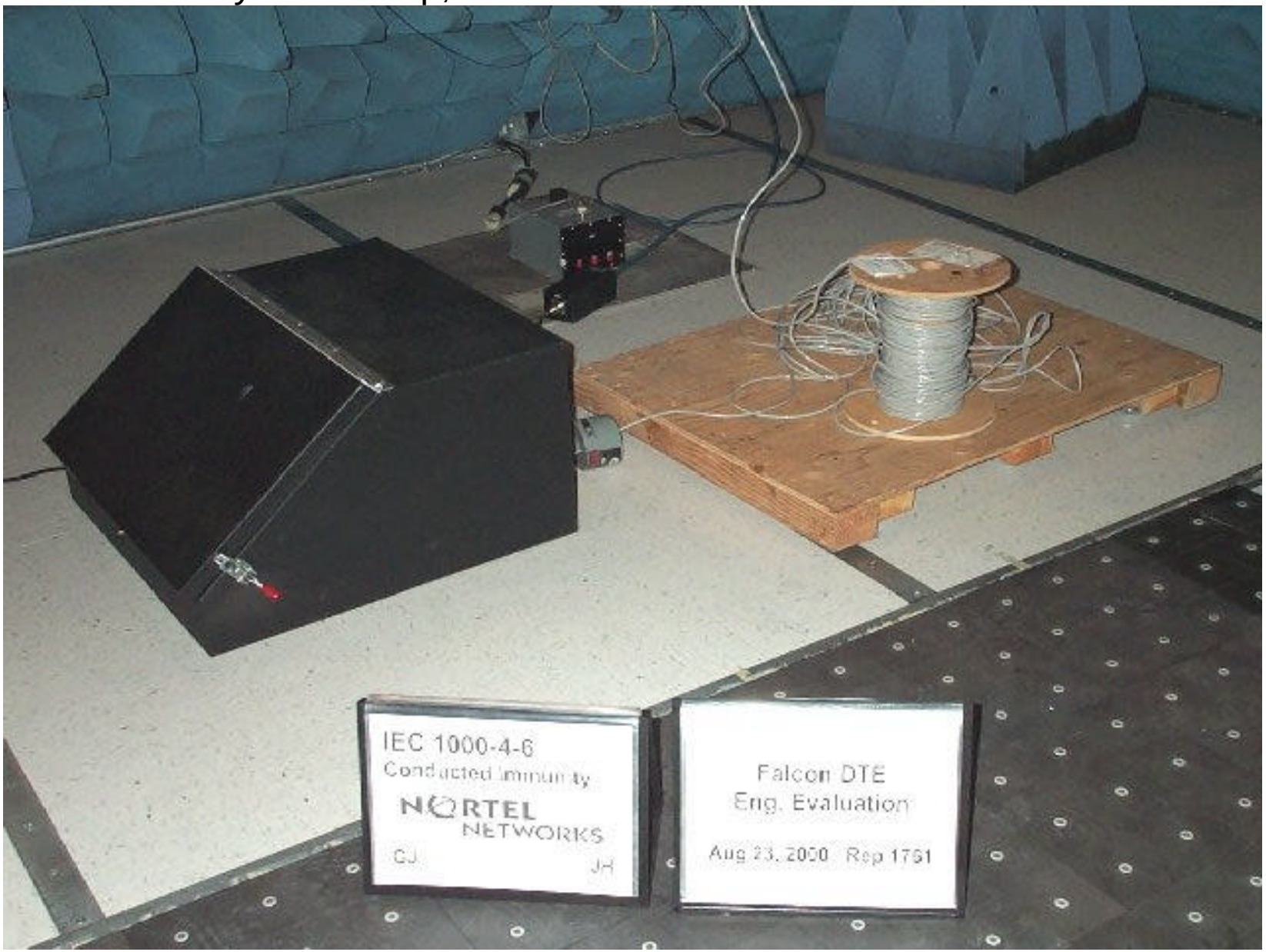
Radiated Susceptibility Test Setup, 10 meter Anechoic Chamber

Radiated Susceptibility Test

DTE Load Board with LED load below the minimum load

Electrical Fast Transients Test Setup, 10 meter Anechoic Chamber

Conducted Immunity Test Setup, 3 meter Anechoic Chamber



EMC Susceptibility and Immunity Results:

Radiated Susceptibility:

Tested from 80 MHz to 1 GHz at 5 volts per meter — **Test Passed**, no effect seen on discovery/power cycle

Electrical Fast Transients:

Tested using 500V pulses and the capacitive clamp fixture to the CAT-5 cable — **Test Passed**, no effect seen on discovery/power cycle

Conducted Immunity:

Tested from 150 KHz to 80 MHz at 3 volts field strength — **Test Passed**, no effect seen on discovery/power cycle

Summary:

Discovery Process:

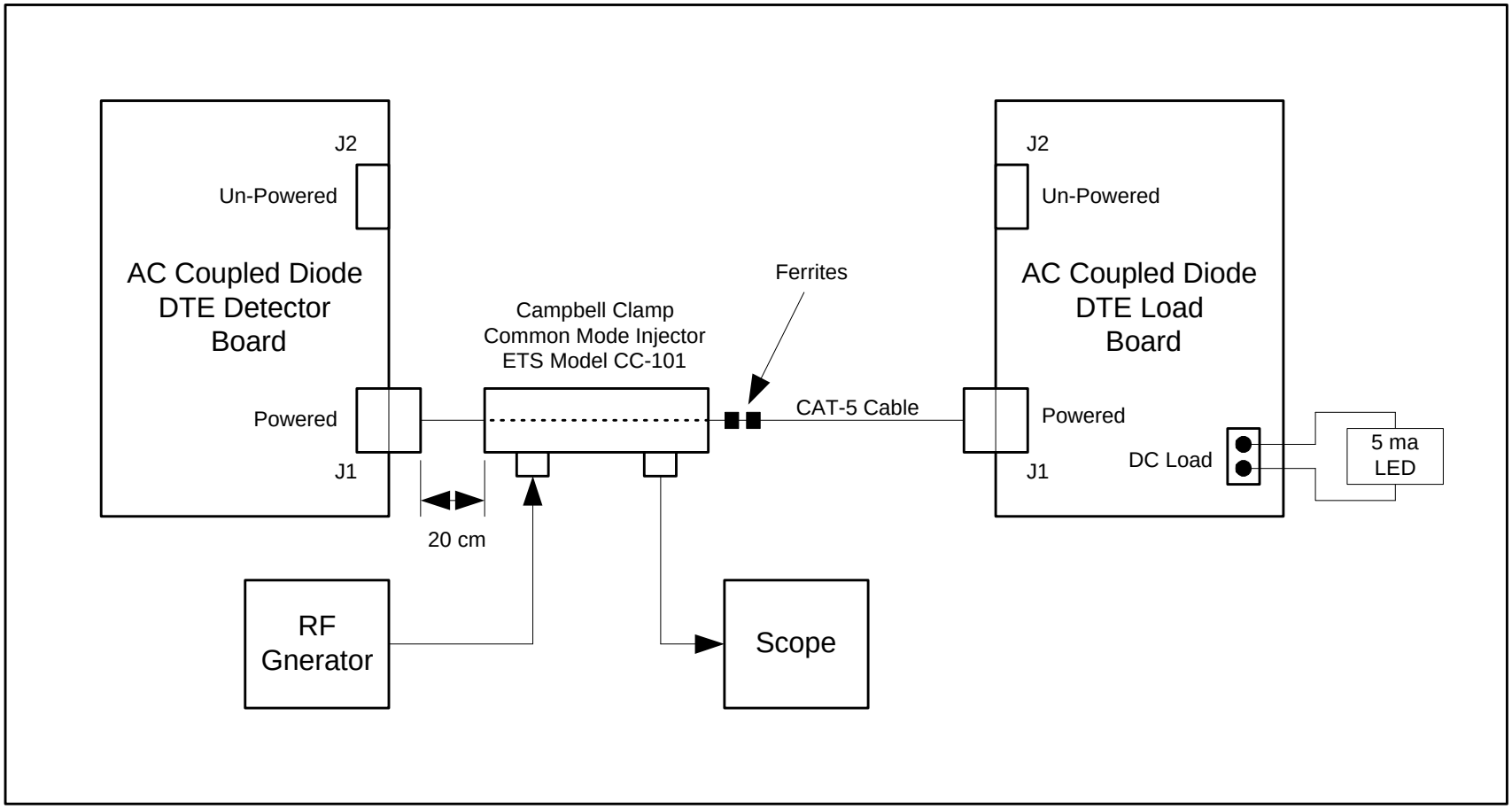
The discovery process tested on the prototype board has an extremely small level of radiated emissions.
All of the immunity and susceptibility tests passed, although further testing is needed to find the margin to these tests.

Power Delivery:

The DTE power supply does have some output noise that creates radiated emissions, although this prototype passes Class A, it does not pass Class B. The output switching noise of the power supply must be specified, and represents an area of risk.
All of the immunity and susceptibility tests passed, although further testing is needed to find the margin to these tests. Of particular interest will be sending power and data at the same time.

Common Mode Noise Rejection Test

Common Mode Noise Rejection Test



Common Mode Noise Injection Test

This test and fixture are outlined in 802.3 (1999), part 40.6.1.3.3, and Annex 40B
I'm looking for any signs of inhibited discovery.

Common Mode Noise Rejection Test (cont.)

The tested frequency range was:
1 MHz to 100 MHz in 1 MHz steps, and 100 MHz to 300 MHz in 2 MHz steps.

Frequency Range	measured voltage without affecting discovery
1 MHz to 44 MHz	7.87 volts peak (15 dB above the 1000BASE-T test) this is as high as the generator would go
45 MHz to 51 MHz	6.39 volts peak (13.1 dB above the 1000BASE-T test) above this voltage, the discovery did not make progress
52 MHz	6.88 volts peak (13.7 dB above the 1000BASE-T test) above this voltage, the discovery did not make progress
53 MHz to 300 MHz	1.3 volts peak, to 1.5 volts peak, the same as for 1000BASE-T this is as high as the generator would go

Note that 1.414 volts peak is called out for testing 1000BASE-T receivers in part 40.6.1.3.3.

Common Mode Noise Rejection Test (cont.)

The setup was similar to the one used in the radiated susceptibility tests, above. Namely that that small (5 ma) LED load, below the minimum load, was used to monitor whether or not discovery and power were successful. Also, the "spare" LED on the detector board was visually monitored for any influence upon any single discovery frame. This LED is turned after any discovery frame where either an open circuit or a short circuit is detected. A further note is that for this test, unlike the EMC tests, the detector board was sitting on a bench, not in a faraday cage.

Result:

There was no noticeable effect upon the ability to perform discovery or to power up at or below the voltage levels listed above.

Only at frequencies between 45 MHz and 52 MHz, did I have an RF generator that could output enough power to cause discovery to fail.

At frequencies that I could cause discovery to fail, the voltage required was at least 13 dB higher than is called out for 1000BASE-T tests in IEEE802.3, part 40.6.1.3.3.

Category 3 Cable Tests

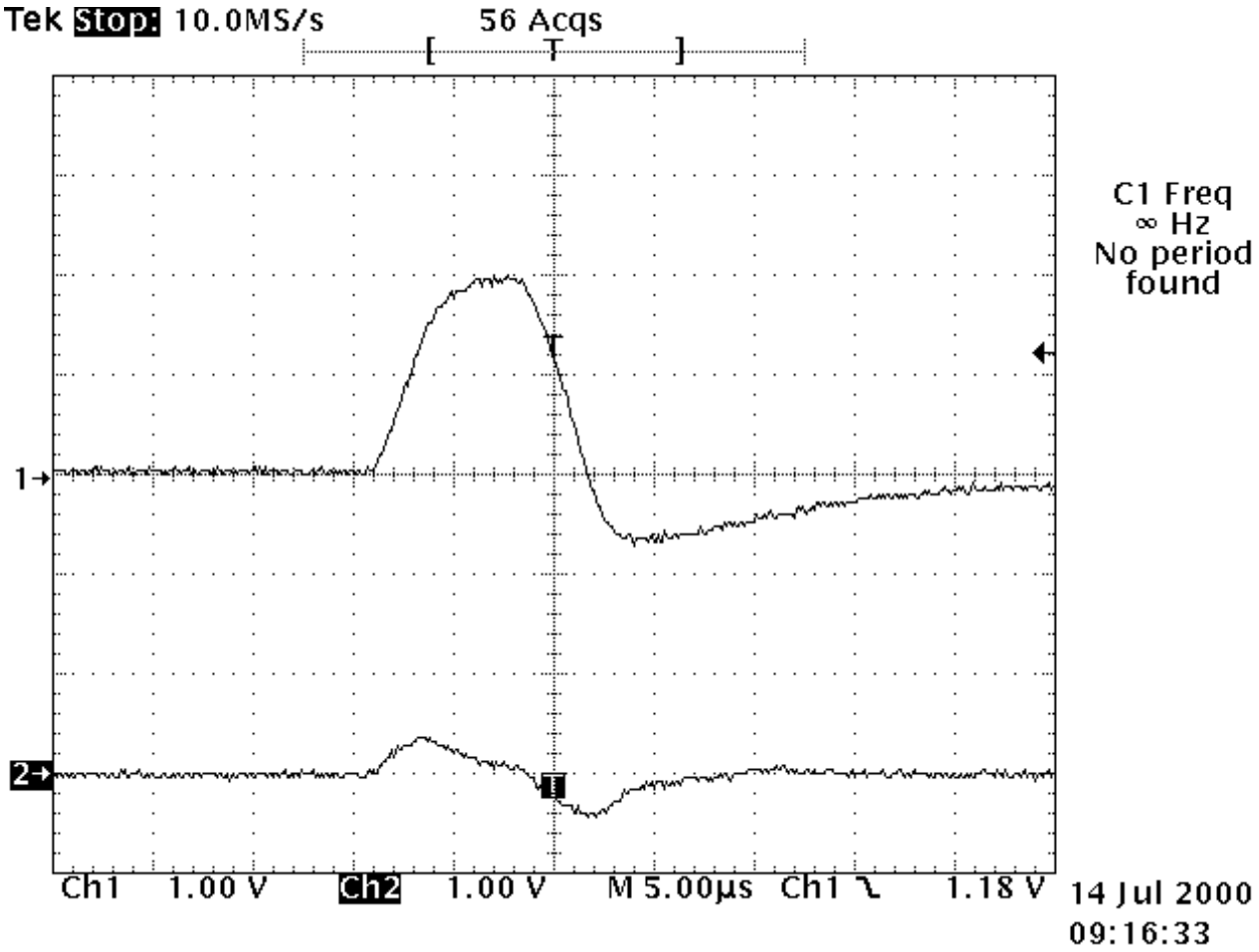
Category 3 Cable Tests

Below are the results of discovery using the AC coupled Diode method that I described in May 2000 and July 2000 using Cat 3 cable, and running on the evaluation prototype boards.
The results are shown for 98 meters, and 304 meters of CAT-3 cable.
In both cases the discovery worked properly for the 10 times that I tried it.
In addition, there were 15 inch clip leads on each end to patch into the wire.

Summary:

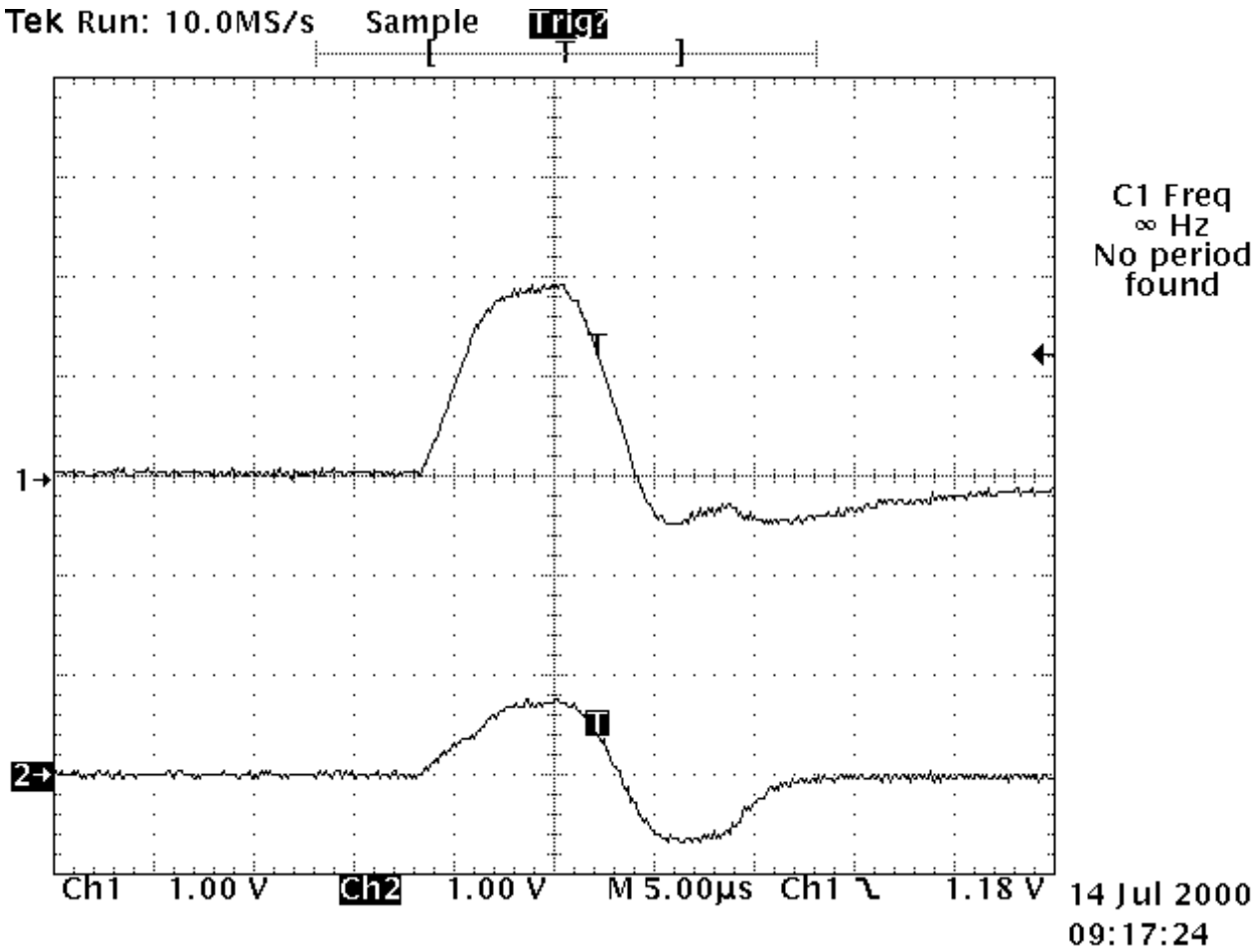
I think this data shows that the diode method will work for Cat 3 cable, and that the results are very similar to that of Cat 5 cable. Due to the limited bandwidth required by the shaped pulses, the discovery process is not that particular as to the transmission medium.

CAT-3 Cable Tests



AC Coupled Diode Discovery, Non-conducting Direction
CAT 3 Cable at 98 meters, plus two 15” clip leads at each end of the cable
Top trace: drive signal, 1 volt/div
Bottom trace: receive signal, 1 volt/div

CAT-3 Cable Tests



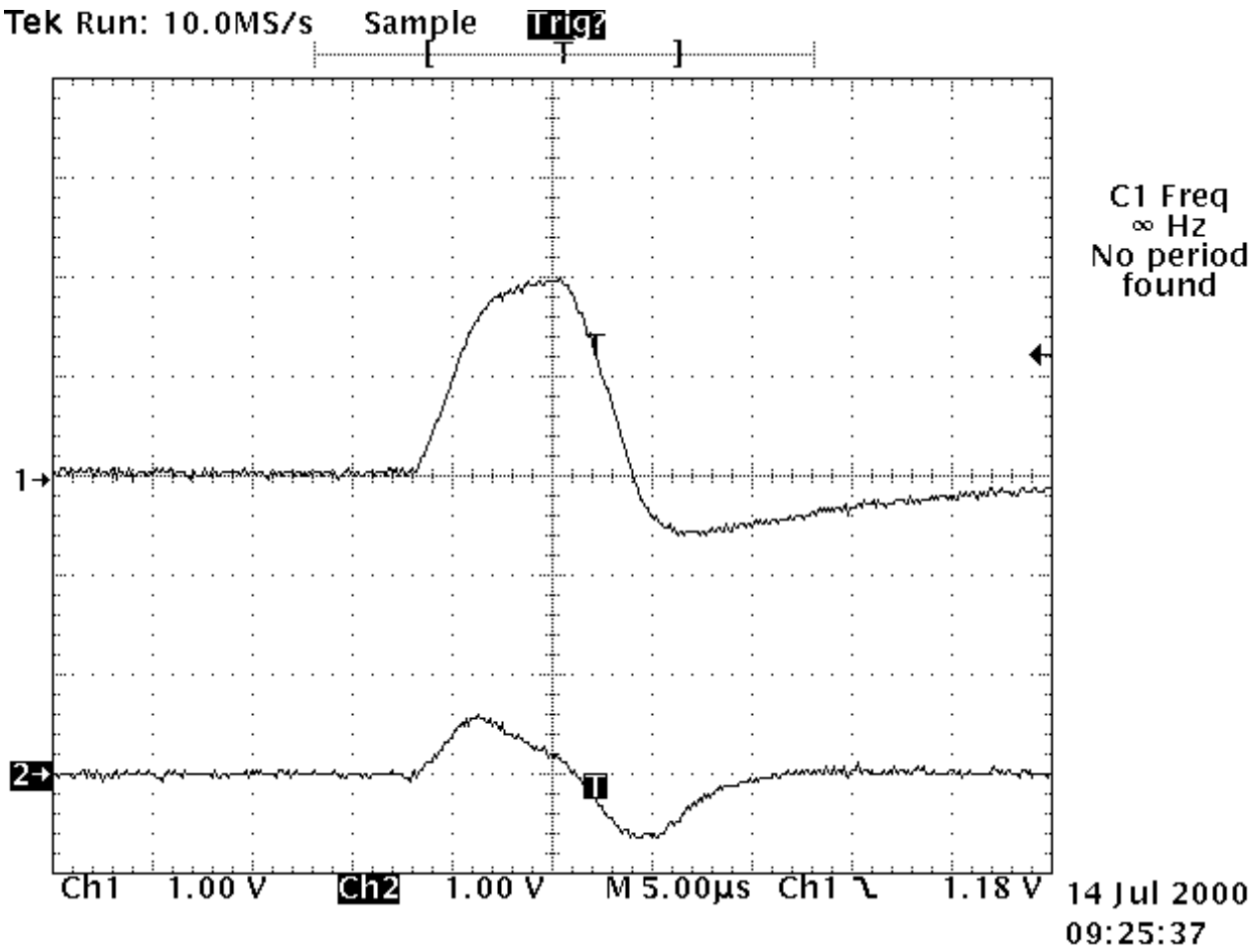
AC Coupled Diode Discovery, Conducting Direction

CAT 3 Cable at 98 meters, plus two 15" clip leads at each end of the cable

Top trace: drive signal, 1 volt/div

Bottom trace: receive signal, 1 volt/div

CAT-3 Cable Tests



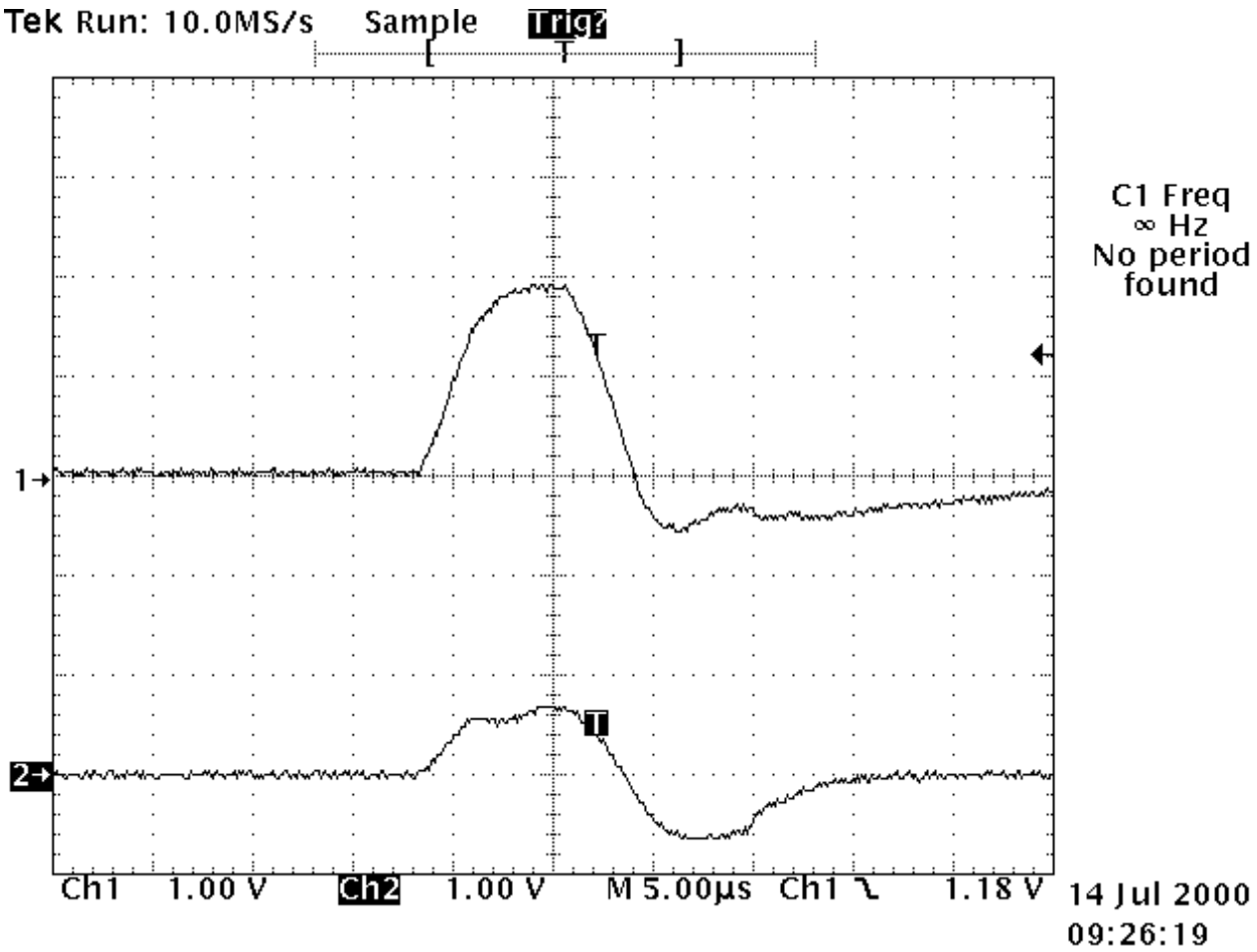
AC Coupled Diode Discovery, Non-conducting Direction

CAT 3 Cable, 304 meters, plus two 15" clip leads at each end of the cable

Top trace: drive signal, 1 volt/div

Bottom trace: receive signal, 1 volt/div

CAT-3 Cable Tests



AC Coupled Diode Discovery, Conducting Direction

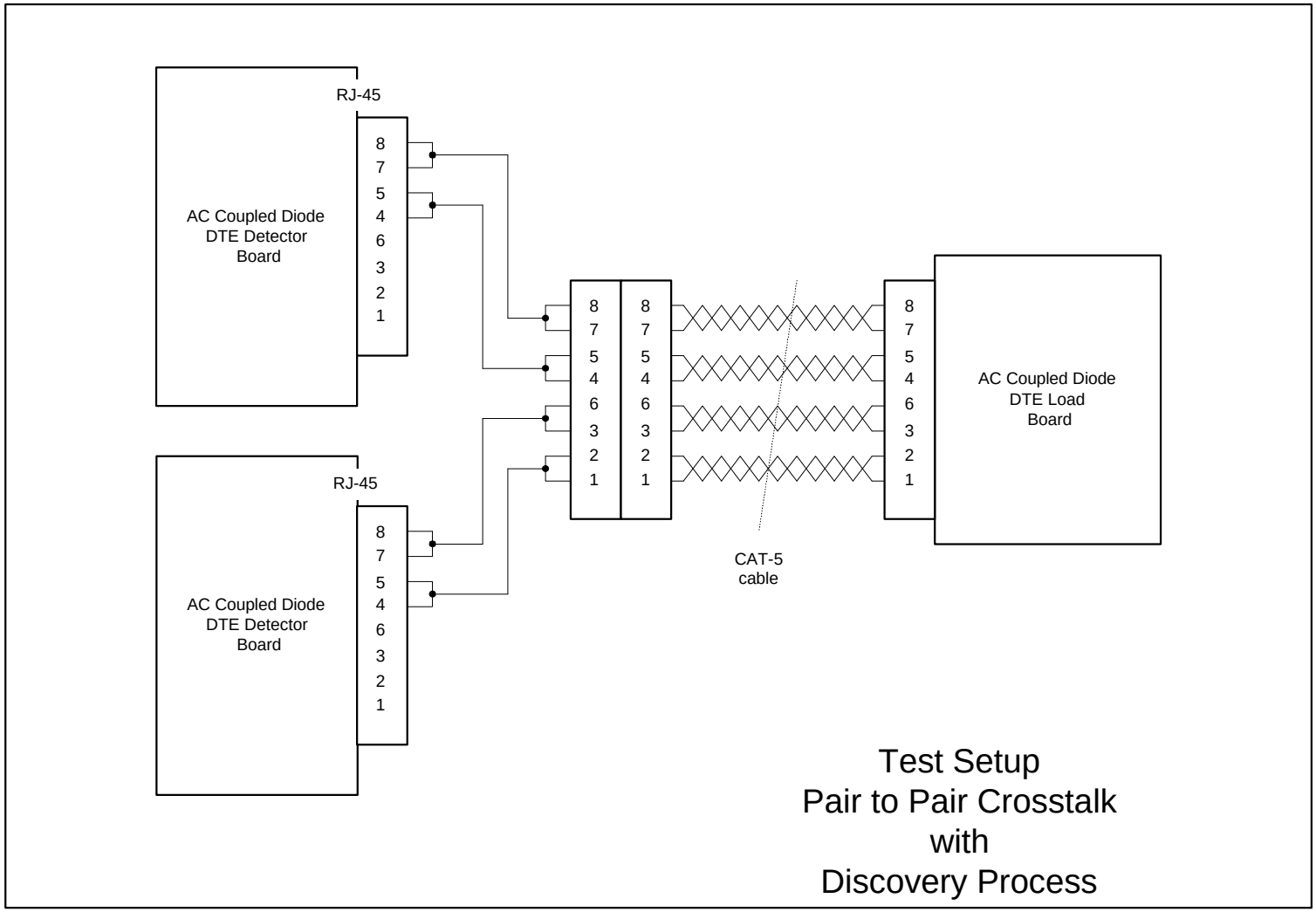
CAT 3 Cable, 304 meters, plus two 15" clip leads at each end of the cable

Top trace: drive signal, 1 volt/div

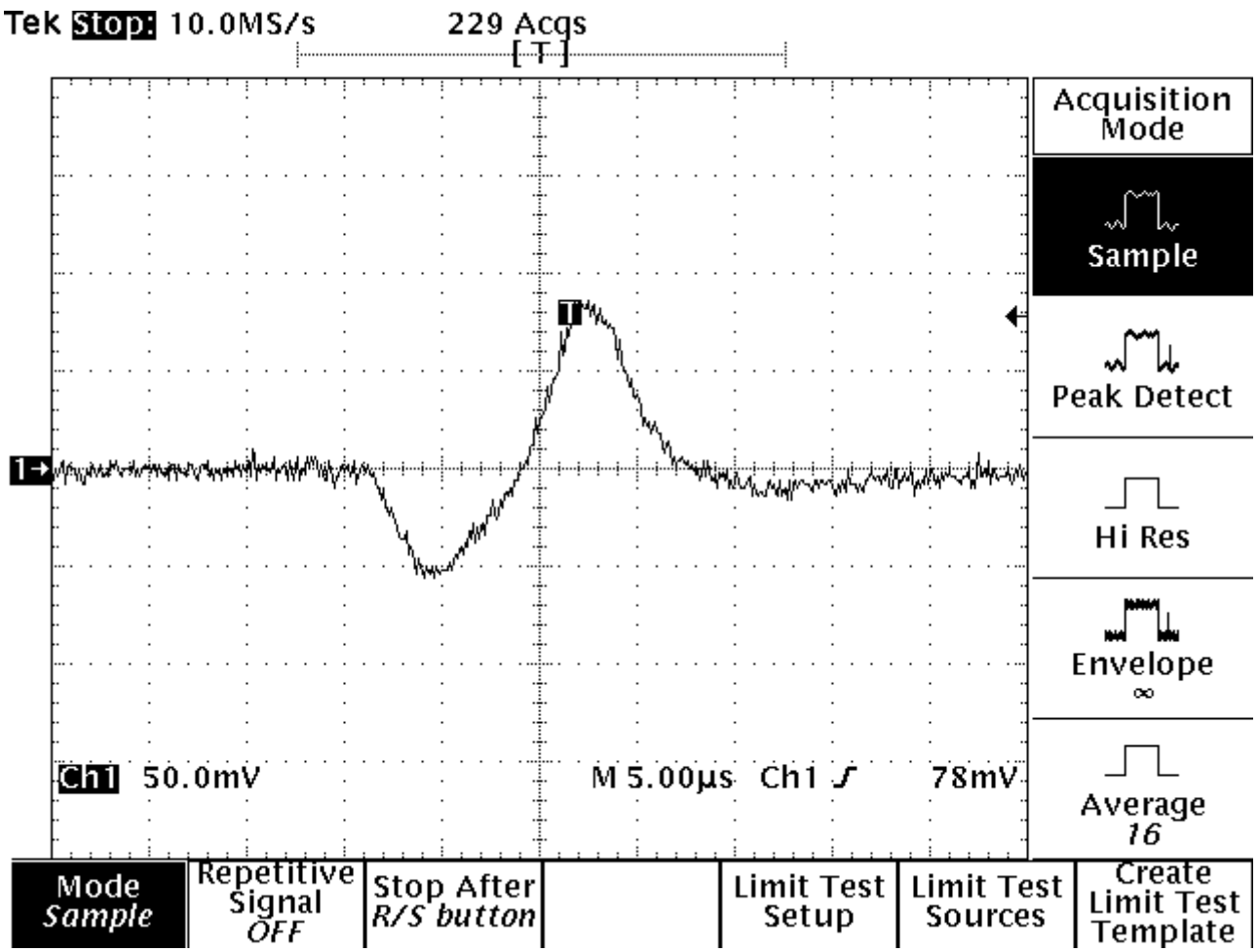
Bottom trace: receive signal, 1 volt/div

AC Coupled Diode Discovery Crosstalk

Two Simultaneous Discovery Process on One CAT-5 cable



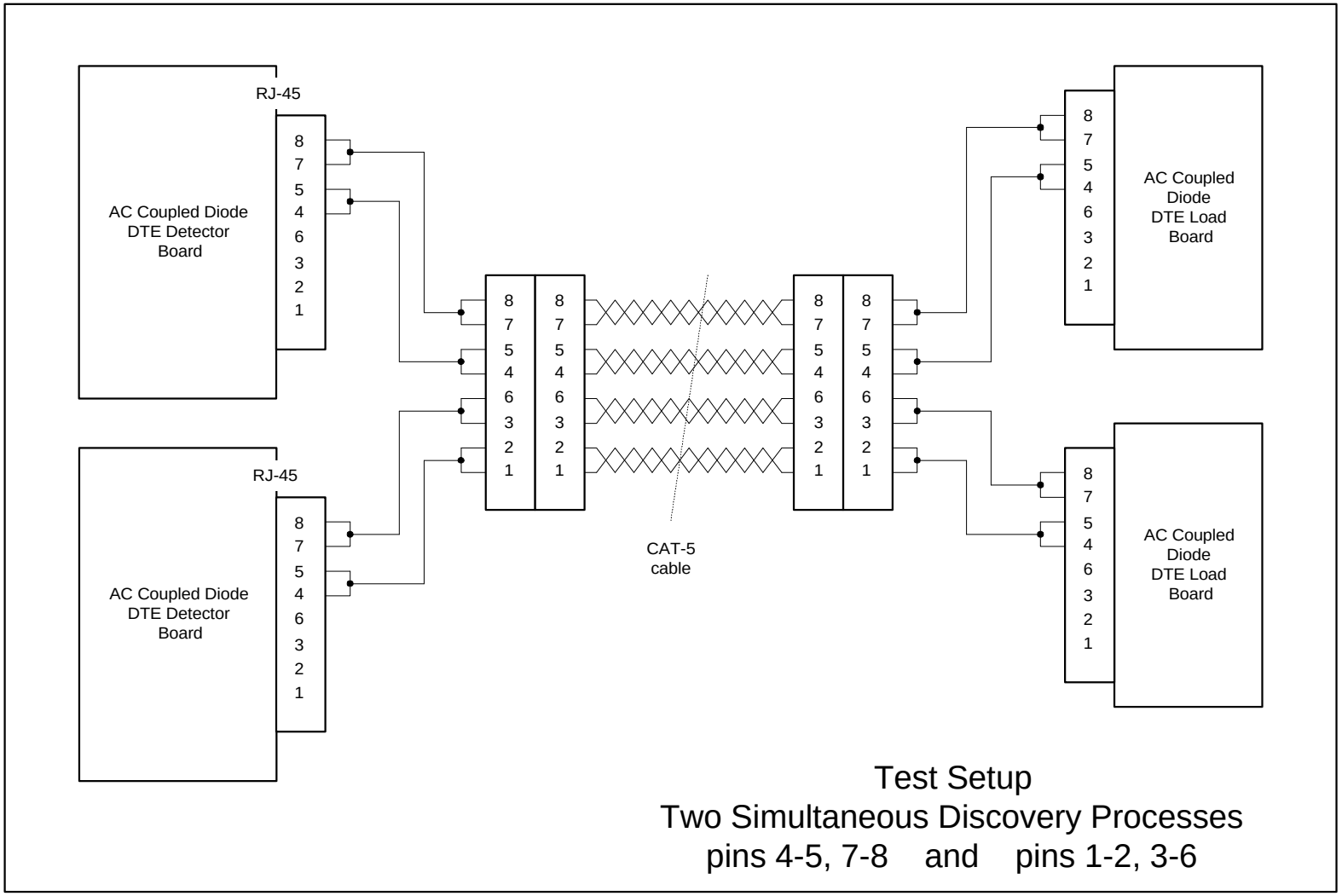
Pair to Pair Crosstalk Test Setup



AC Coupled Diode Discovery Evaluation Board
Loop Crosstalk, Pair to Pair Mode

145 meter CAT-5 Cable, 50 mV per Div
measured at the 100 ohm resistor Test Point on a 2nd Detector board with it's own discovery process disabled.
The peak crosstalk is about 80 mV.

Two Simultaneous Discovery Process on One CAT-5 cable



Two Simultaneous Discovery Processes
Test Setup

Two Simultaneous Discovery Process on One CAT-5 cable

This test helps to demonstrate that two separate and independent discovery processes can take place on two different pair sets on a CAT-5 cable with very little crosstalk.

Task: determine the max cable length under the following conditions with the criteria of 20 successful power on cycles without an interruption or noticeable delay:

Results:

Discovery Process Running on 1st Detector Board Only
Maximum CAT-5 cable is 140m + 130m + 120m + 50m (including 6 RJ-45 mated pairs) =
440 meters

Discovery Process Running on 2nd Detector Board Only
Maximum CAT-5 cable is 140m + 90m + 30m + 5m (including 6 RJ-45 mated pairs) =
265 meters

Discovery Process Running Simultaneously on both 1st and 2nd Detector Boards
1st Detector maximum cable is 140m + 130m + 100m + 5m (including 6 RJ-45 mated pairs) =
375 meters a 14.8% reduction in workable cable length

2nd Detector maximum cable is 140m + 90m + 30m + 5m (including 6 RJ-45 mated pairs) =
265 meters no reduction in workable cable length

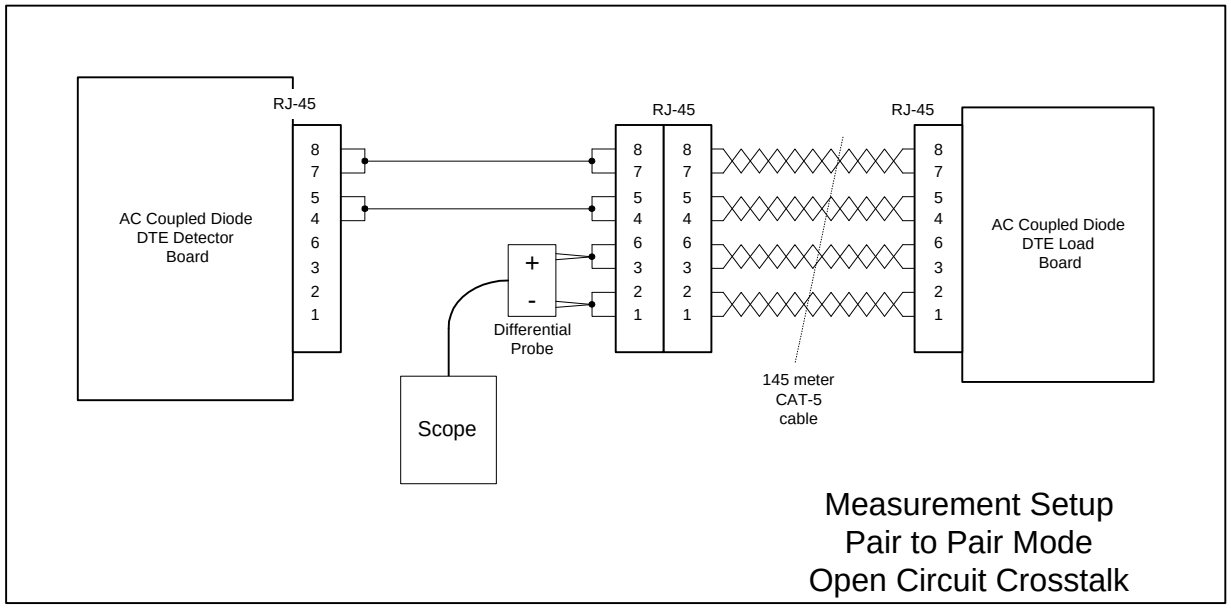
Considering the cable length, this is not much effect

AC Coupled Diode Discovery,
Pair to Pair Mode Open Circuit Crosstalk

Pair to pair open circuit crosstalk has been measured using the test setup shown below.

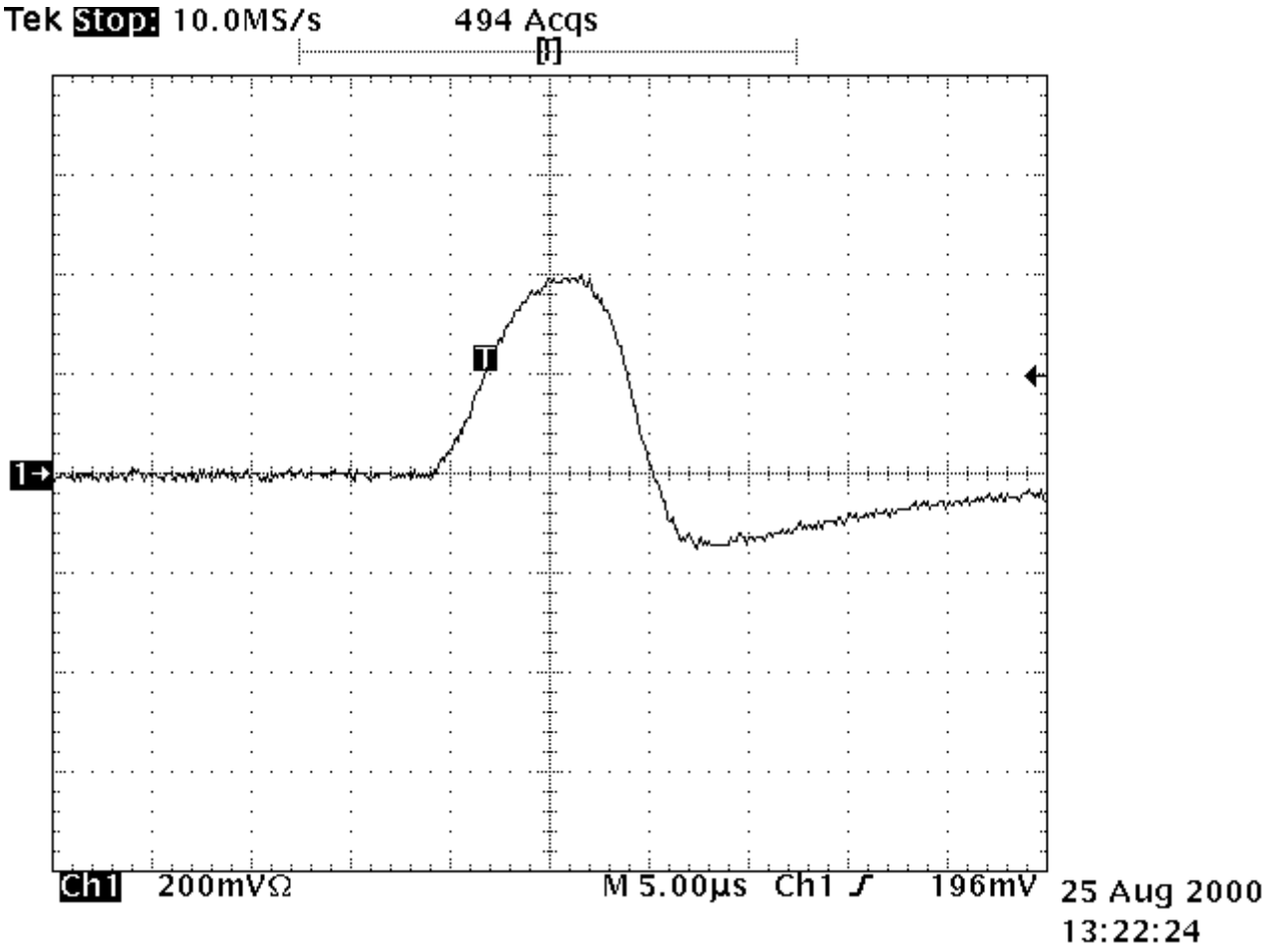
The DTE discovery prototype board was running the continuous discovery process on pins 4-5 and 7-8. The pair to pair crosstalk was then measured with 1-2 shorted, and 3-6 shorted as shown. Pins 1-2 and 3-6 were otherwise not connected, as shown below.

A differential probe was used to measure at 1-2 to 3-6, as shown below, the waveform shows a peak voltage of about 400 mV on a cable length of 145 meters.



Pair to Pair Mode Open Circuit Crosstalk Test Setup

AC Coupled Diode Discovery,
Pair to Pair Mode Open Circuit Crosstalk

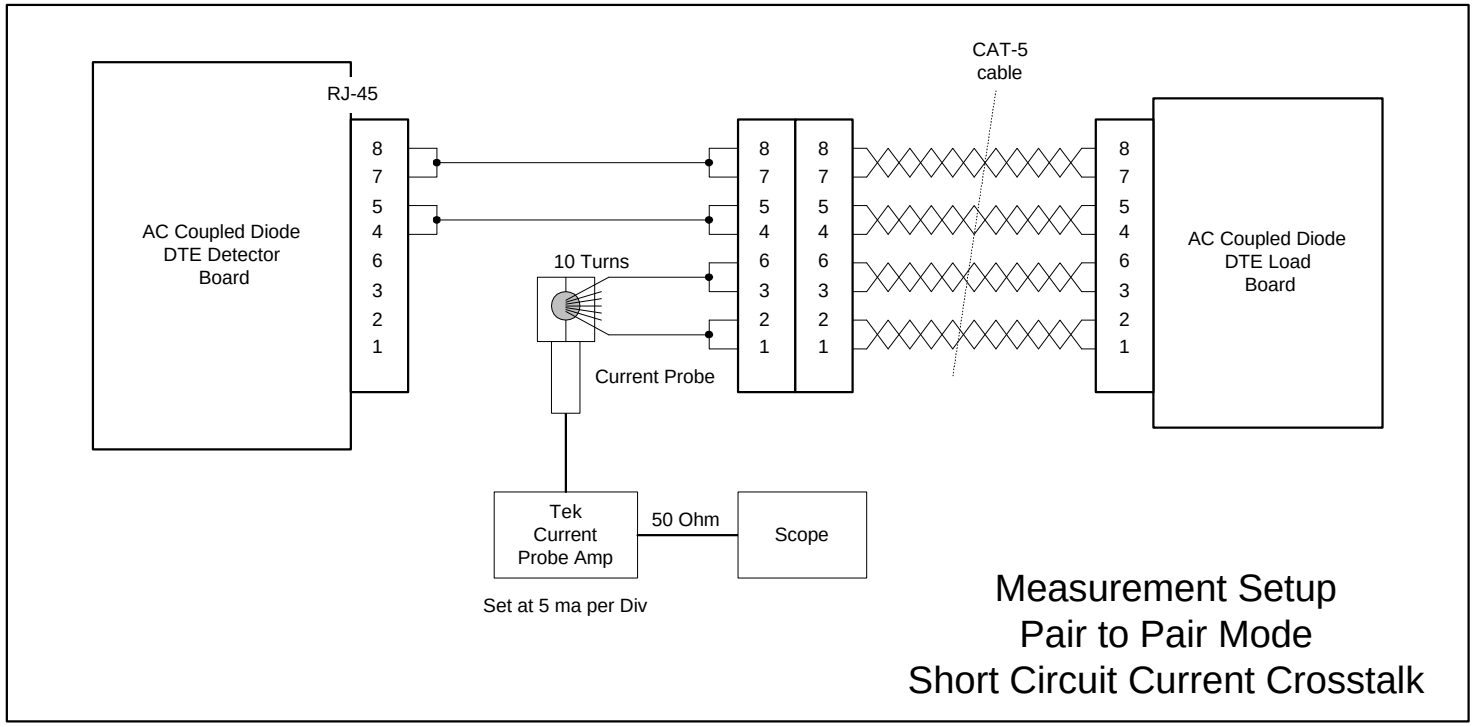


AC Coupled Diode Discovery Evaluation Board
Pair to Pair Mode, Open Circuit Crosstalk
145 meter CAT-5 Cable, Diode Conducting Direction
measured 400 mV peak of open circuit crosstalk, 200 mV/div

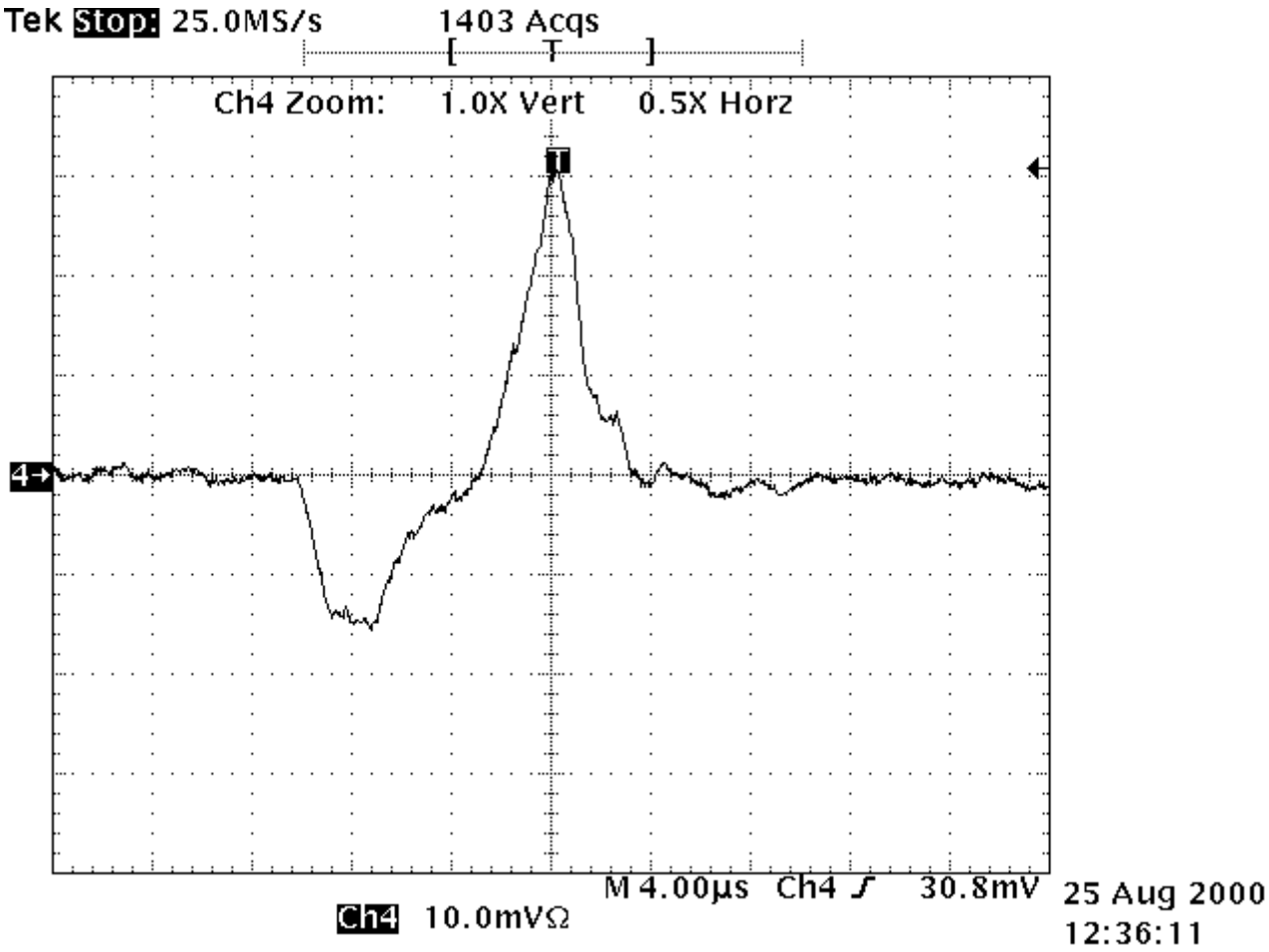
AC Coupled Diode Discovery, Short Circuit Crosstalk Test

In this test the discovery process runs continuously on pins 4-5 and 7-8. The pair to pair mode crosstalk is measured while the 1-2 and 3-6 set of pairs is shorted at the near end of the cable, as shown below.

The current probe amplifier is set for a sensitivity of 5 ma per div, so the net result is that 0.5 ma per div is displayed on the scope.



AC Coupled Diode Discovery, Short Circuit Crosstalk Test

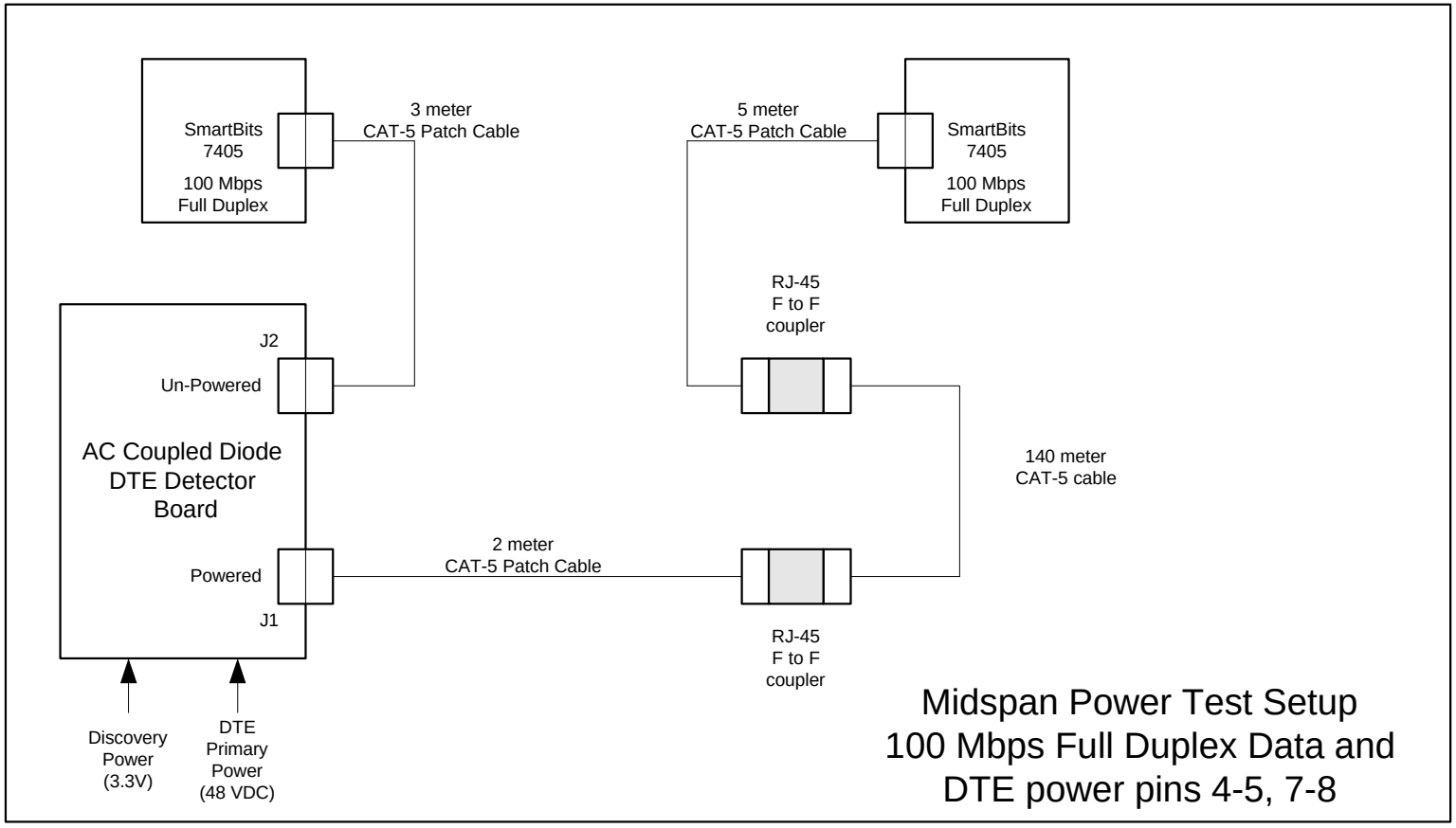


AC Coupled Diode Discovery Evaluation Board
Loop Current Crosstalk, Pair to Pair Mode
145 meter CAT-5 Cable
0.5 ma per div, The peak crosstalk current is about 1.5 ma.

Discovery Impact on Data Integrity

Discovery Impact on 100 Mbps Data Integrity

In this test a 100 Mbps link cable length is increased until a fair number of CRC errors are seen. Then, through a repetition of the same experiment, a comparison is made between the 100 Mbps link without discovery running, and with discovery running. In this case the cable length is 150 meters with 8 RJ-45 connector pairs



Discovery Impact on Data Setup

Discovery Impact on 100 Mbps Data Integrity

Experiment: send approximately 1 million packets, record the number of CRC's

No Discovery, all Prototype power off:

1st test:	1863 errors out of 1035280 frames:	1.7995 E-3 errors per frame
2nd test:	1665 errors out of 1017255 frames:	1.6368 E-3 errors per frame
3rd test:	3195 errors out of 1839308 frames:	1.7371 E-3 errors per frame
4th test:	1640 errors out of 1021734 frames:	1.6051 E-3 errors per frame
5th test:	1630 errors out of 1009676 frames:	1.6144 E-3 errors per frame

errors per frame:
mean: 1.67858 E-3 standard deviation: 7.6564 E-5

Continuous Discovery, Prototype 3.3V power on:

1st test:	1661 errors out of 1031436 frames:	1.6104 E-3 errors per frame
2nd test:	2156 errors out of 1341906 frames:	1.6067 E-3 errors per frame
3rd test:	1498 errors out of 1015143 frames:	1.4756 E-3 errors per frame
4th test:	1601 errors out of 1022798 frames:	1.5653 E-3 errors per frame
5th test:	1723 errors out of 1137458 frames:	1.5148 E-3 errors per frame

errors per frame:
mean: 1.55456 E-3 standard deviation: 5.2474 E-5

This test shows very little statistical difference between no discovery and discovery

Hazard Matrix Testing

Hazard Matrix Testing

I tested about 300 to 400 separate ports on the boxes, and boards listed below without ever seeing a single false detection.

Cisco:

Cat 5500	WS-X5530	WS-X5234
ATM Switch Processor	7200 Series VXR	WS-X5225R
Cat 3500 series XL	1750	MC3810
3660-MB-2FE	WS-X5248 RJ45	WS-X6K SUP1A-2GE
Cat 2900	Cat 4000	WS-X4232
Light Stream 1010	Cat 8500 (16 port blade)	Cat 5000 (12 port blade)
Cat 5000 (8 port blade)	Cat 5505 (24 port)	WS-X5225R
Cat 2926 (24 port blade)	Cat 2926 (mgmt module)	7140-2T3
AS5800 Channelized T1, Dial Shelf Controller		2984G-L3
WS-PWR-Panel Inline Power Panel		

Nortel:

BS350	BS450	Business Policy Switch
Enterprise Edge 1000, digital trunk interface, NIC cards		Accelar 8010
development IP phones	BS151 10Base-T	100Base-T Hub
Baystack Advanced Remote Node		Backbone Node Chassis
NT Magellan Passport, (100Base-T, & CP)	NT 5000CVM/2/8 (10Base-T, mgmt port)	

Hazard Matrix Testing (cont.)

Nortel (cont):

Development boards 10/100/1000…
Netgear 10/100 Switches
Netgear 10/100 NIC card

3Com:

NBX 100, 3C10116
Digital Line Card
10Base-T Hub card
Superstack II Switch 9300
Link Builder MSH/11 (12 port blade, mgmt blade)
Superstack II Switch 3000 (12 ports)
Core Builder 3500 (6 port blades, mgmt port, main blade)
Cellplex 7000 Switch 16x16, mgmt port
Linkswitch 1000 3C16900 (24 ports)
Linkswitch 2700 (10 ports)
FMS TP Hub (12 ports)
FMS II (12 port and 24 port)
Superstack II, 24 ports
Link Switch 3000 (8 ports)
Superstack II Netbuilder (3 ports)
Pathbuilder S500 (2 ports)
Superstack II Switch 3900 (36 ports)
Switch 3000 (12 ports)

Cabletron:

Switch 2200 (24 port)
Switch 6000 (24 port blade)

Hazard Matrix Testing (cont.)

Lucent:
Cajun P550

Extreme:
Summit 4 (16 copper ports)

Xylan:
Omniswitch ESM blade Omniswitch TSM blade Omniswitch LLM blade

AT&T:
8410B phone

IXIA:
LM-100TX

Netcom:
several 10/100 modules tested, 7410 etc…

So far, no false detections.

Implementation Notes

The AC coupled diode discovery method has been demonstrated by this set of evaluation boards running the referenced Verilog code. All of these elements are just examples of one possible implementation, obviously not the only one. It is also quite possible to implement this form of discovery into the DTE power circuit.

The IEEE802.3af DTE power spec should not specify:

- how to implement a design
- to use a coupling transformer
- to use a PHY
- to use a power supply
- to use any specific type of component or topology

In almost all cases, these are really just implementation details.
This demonstration is meant to show how practical this approach is.

The IEEE802.3af DTE power spec should specify:

- the behavior for the PSE
- what the acceptance template is for the PSE
- the behavior for the PD
- what the acceptance template is for the PD
- the required elements to get all compliant PSE's and PD's to inter-operate

Future Tests

- CAT-6 cable
- 25 pair cable
- Shielded UTP
- Campbell clamp common mode test at higher power
- Discovery process running simultaneously with data on the same wires
- More hazard matrix testing
- Further tests on the pair to pair mode coupling
- 1000BASE-T
- Immunity and susceptibility tests at higher levels

AC Coupled Diode Discovery Conclusions

Robust

- I have not been able to fool it into false discovery yet
- Passes radiated susceptibility 5 volts per meter
- Passes Electrical Fast Transients
- Passes Conducted Immunity tests, treating the CAT-5 cable as a power line
- Passes the Common Mode Noise Test for 1000BASE-T
- Two simultaneous discovery processes can co-exist on a single CAT-5 cable
- Works virtually identically on CAT-3
- It works on most reasonable transmission lines, but it will not work on series lumped elements, for instance a series 1000 µH element. This behavior will tend to reject misconnected lumped loads

Quiet

- passes radiated emissions per EN55022
- the discovery spectrum is limited due to the pulse shaping used
- one discovery process on one pair set does not interfere with discovery on the other pair set
- discovery can co-exist with 100 Mbps data with little or no effect on the data
- Discovery and DTE power share the same transmission mode – Pair to Pair mode. This is different than true common mode, although like differential mode, Pair to Pair mode does couple into common mode to some extent

Reference Documents

- Schematics (DTE detector board sheet 1, DTE load board sheet 2)
http://www.ieee802.org/3/af/public/jul00/brooks_3_0700.pdf

- Verilog Code, Two Stage Discovery and Power Processes
http://www.ieee802.org/3/af/public/sep00/brooks_5_0900.pdf

- AC Coupled Diode Discovery White Paper
http://www.ieee802.org/3/af/public/sep00/brooks_4_0900.pdf

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