



# Technical Feasibility of Sending Common Mode Power on the Signal Pairs

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CISCO SYSTEMS



# Presentation Overview

**Two parts**

**Part 1 - High Level Overview**

**No Questions please**

**Part 2 - Technical Detail**

**250 hrs of investigation**

**90 Slides**

**Questions OK**

# Criteria for Technical feasibility

- 1. Signal Integrity, 10 Mbps**
  - 2. Signal Integrity, 100 Mbps**
  - 3. Effects on Magnetics**
  - 4. Operational characteristics**
- Isolation is important but common to all solutions – will not be addressed here**

# Criteria 1 - details

- **Signal Integrity, 100 Mbit/s**

**Differential Signal 0-Pk**

**Amplitude Symmetry**

**Rise/Fall Time**

**Duty Cycle Distortion**

**Transmit Jitter**

**Overshoot**

**Differential Input Impedance**

**Common Mode Rejection**

# Criteria 2 - details

- **Signal Integrity, 10 Mbit/s**

**Peak Differential Output Voltage on TD(Transmit Data)**

**Harmonic Content, All Ones**

**Output Waveform vs Template**

**Start of TP\_IDL(End of 10Base-T Packet) waveform vs Template**

**Link Test Pulse vs Template**

**TD circuit Differential Output Impedance**

**Transmitter added Jitter**

**TD common mode output voltage**

**TD common mode rejection**

**RD(Received Data) Signal Acceptance**

**Receiver Jitter Acceptance**

**Receiver Added Jitter**

**RD Differential Input Impedance**

**RD Common Mode Rejection**

# Criteria 3 and 4 – details

- **Effects on Magnetics**

  - Return Loss**

  - Common Mode to Differential Mode Conversion**

- **Operational Characteristics**

  - BER Effects**

  - Switching Noise and BER**

# Test methodology

- **All tests conducted with and without power**
- **Test results compared to determine effect**

# Technical Feasibility Conclusion

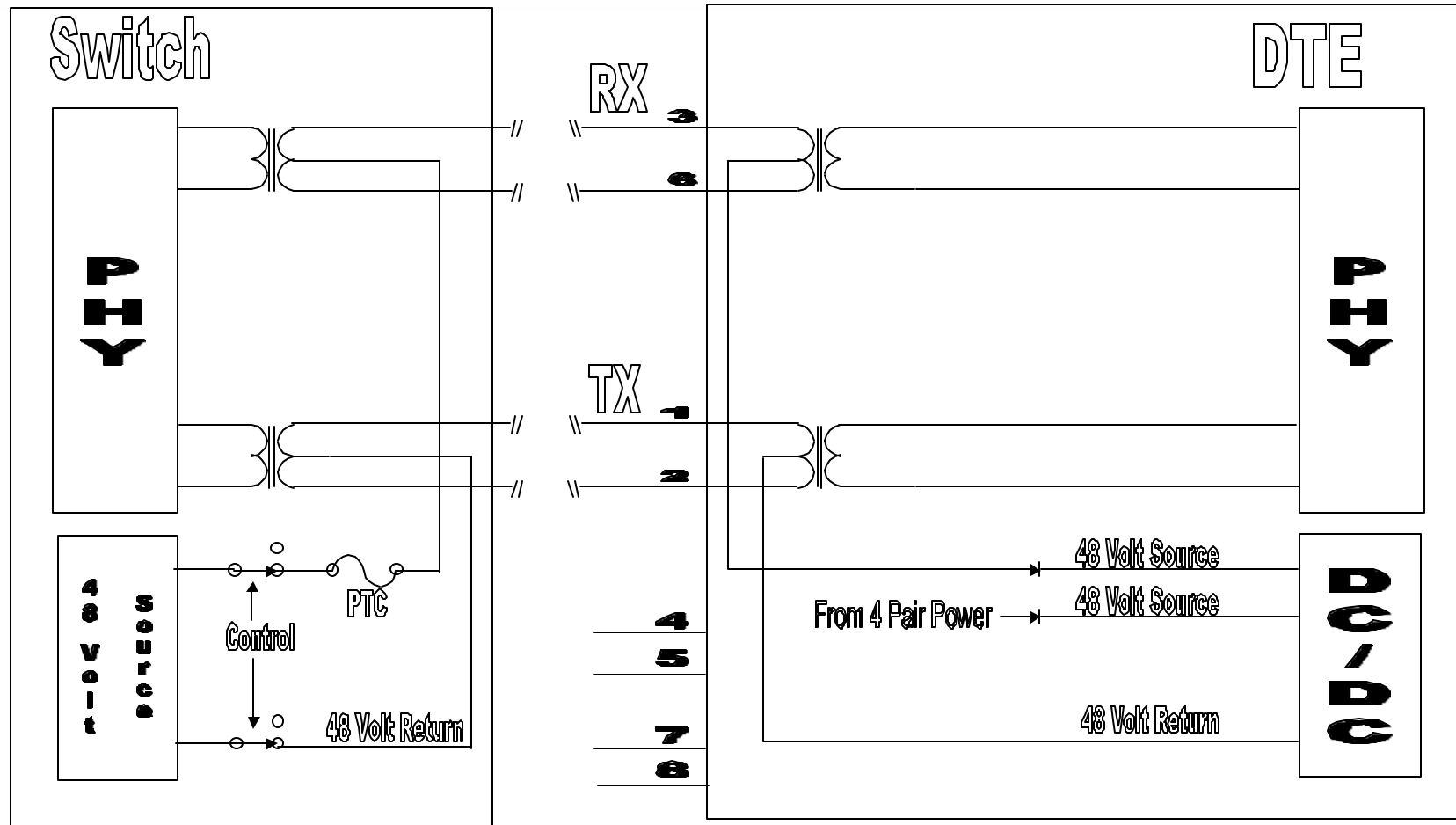
- **Power over Signal Pairs is Technically Feasible**
- **Power noise must be controlled for EMI regardless of which pair set is used for power. Once controlled:**
- **No measurable difference between the Tx or Rx Characteristics with and without power**
- **No link degradation due to power**





# Technical Detail

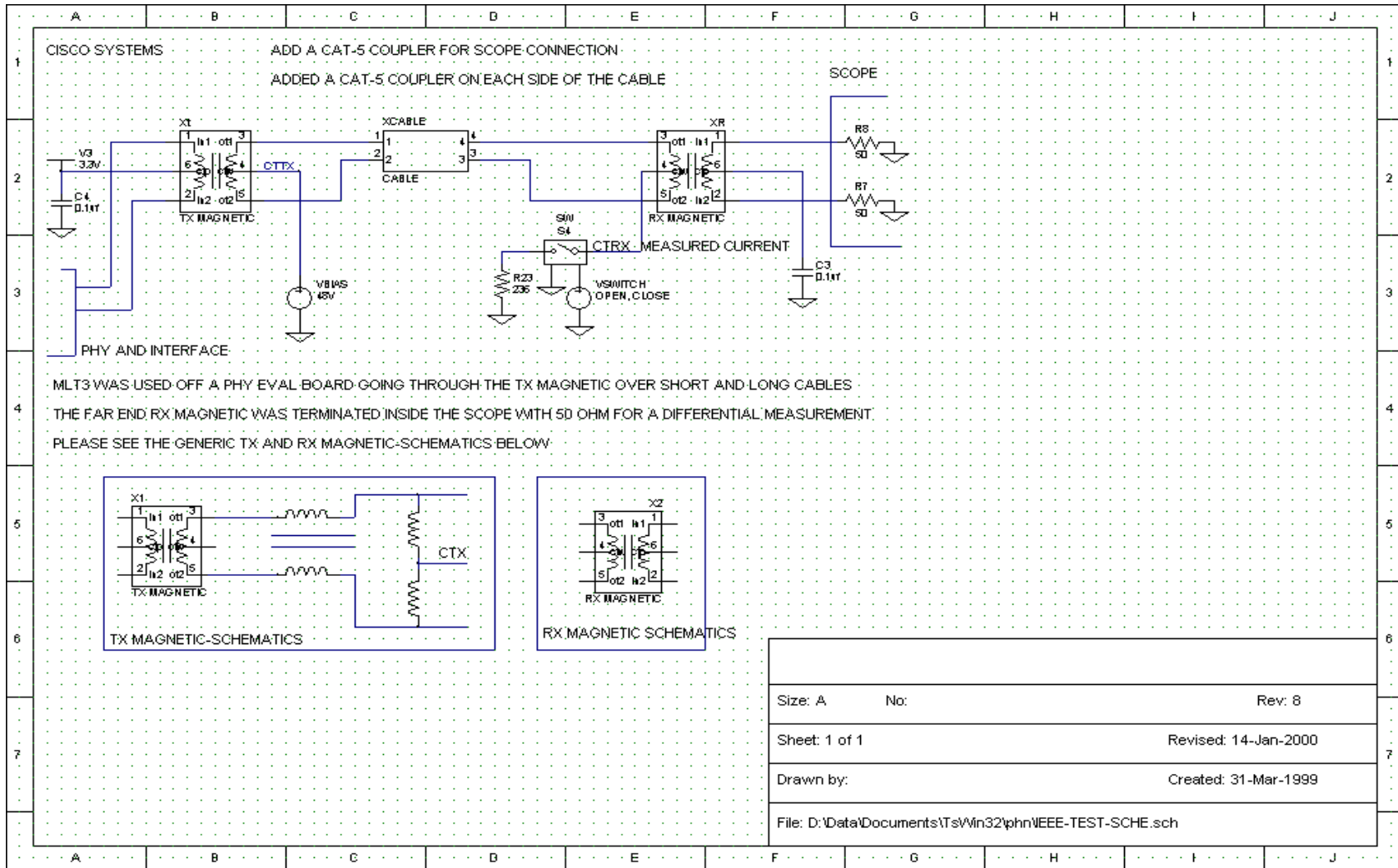
# Power over Signal Pairs Schematic



# Power of Signal Pairs Assumptions

- **SELV DC Power (40-54 Volts DC)**
- **~15 Watts (300mA) over 100 Meters, Cat-5 Cable**
- **Switching Power Supplies at the Source and DTE**

# Signal Quality Measurements 100 Mbit/s

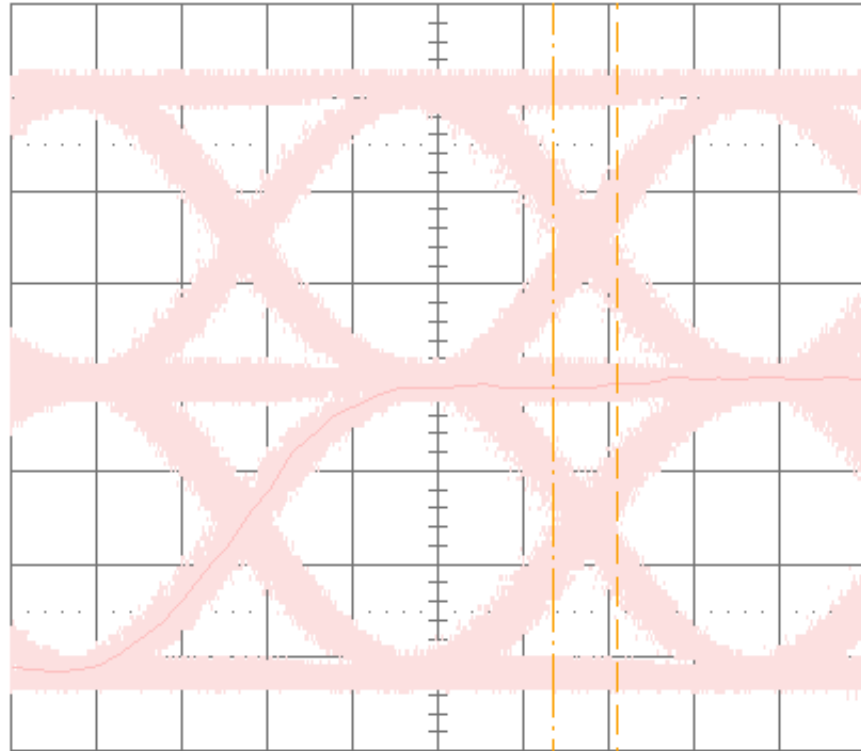


# Signal Quality Measurements 100 Mbit/s

29-Jun-00  
14:40:12

Reading Floppy Disk Drive

0:2-1  
2 ns  
295 mV  
1.50 ns  
10086 swps



20 ns

1	.2	V	50Ω
2	.2	V	50Ω
3	2	mV	50Ω $\times \frac{10}{10}$
4	2	mV	AC $\times \frac{10}{10}$

← 200.000 ps



1 DC 0.072 V

2 GS/s

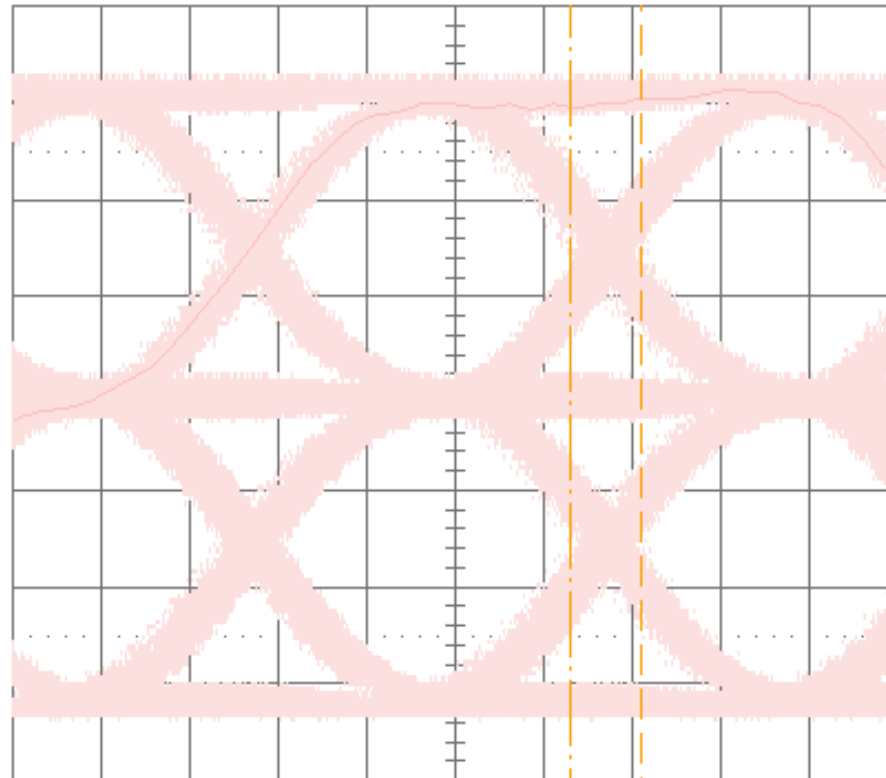
STOPPED

**Tx Eye and Jitter, I = 0**

# Signal Quality Measurements 100 Mbit/s

29-Jun-00  
14:41:38

0:2-1  
2 ns  
295mV  
1.60 ns  
10119 swps



20 ns

← 200.000 μs

1 .2 V 50Ω  
2 .2 V 50Ω  
3 2 mV 50Ω  $\times$   
4 2 mV AC  $\times$

1 DC 0.072 V

2 GS/s

STOPPED

**Tx Eye and Jitter, I = 300 mA**

[www.cisco.com](http://www.cisco.com)

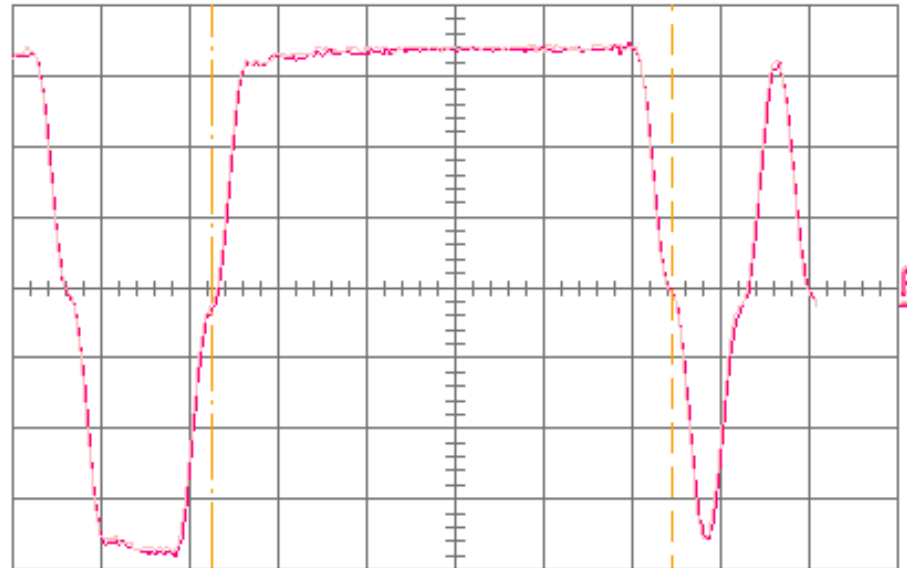
# Signal Quality Measurements 100 Mbit/s

29-Jun-00

17:05:52

**C: 2-1**  
20 ns  
265 mV

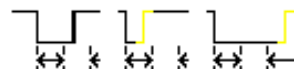
**A: M1**  
20 ns  
265 mV



	2439 sweeps:	average	low	high	sigma
ampl(C)		934mV	911	967	10
Fall(C)		4.98 ns	4.55	5.66	0.15
rise(C)		4.86 ns	4.45	5.33	0.13

20 ns

- 1 .2 V 50Ω
- 2 .2 V 50Ω
- 3 .2 V 50Ω  $\times$   $\frac{10}{10}$
- 4 20 mV AC  $\times$   $\frac{10}{10}$



1 DC -0.028 V  
pw $\leq$  8.0 ns  
OR 99.0 ns $\leq$ pw

2 GS/s

AUTO

**Tx Overshoot, I = 0, 300 mA**

[www.cisco.com](http://www.cisco.com)

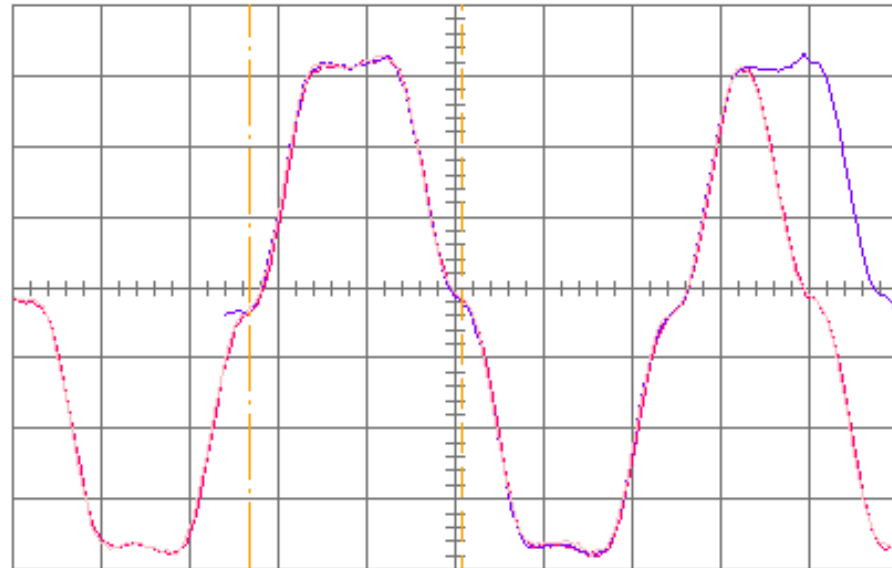
# Signal Quality Measurements 100 Mbit/s

29-Jun-00  
17:10:20

C: 2-1  
10 ns  
265 mV

D: -C  
10 ns  
265 mV

A: M1  
10 ns  
265 mV

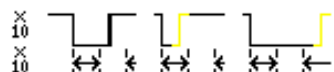


← 3.160 μs

2367 sweeps:				
	average	low	high	sigma
ampl(C)	907 mV	844	943	12
Fall(C)	4.88 ns	4.23	5.79	0.18
rise(C)	4.52 ns	4.10	4.97	0.11
width(C)	15.96 ns	15.57	16.24	0.08

20 ns

- 1 .2 V 50Ω
- 2 .2 V 50Ω
- 3 .2 V 50Ω
- 4 20 mV AC



1 DC -0.028 V  
pw ≤ 8.0 ns  
OR 99.0 ns ≤ pw

2 GS/s

AUTO

**Tx (DCD) Duty Cycle Distortion I = 0, I = 300 mA**

www.cisco.com

**Negate and  
Compare:**

**No Change  
at all**



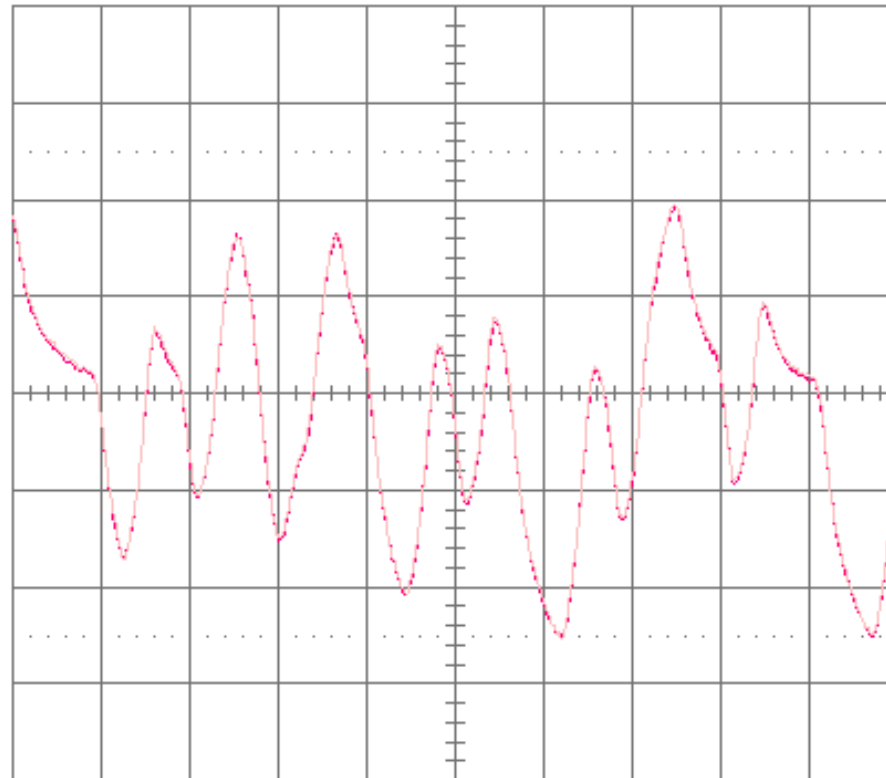
# Signal Quality Measurements 100 Mbit/s

29-Jun-00

17:14:56

**C: 2-1**  
50 ns  
215 mV

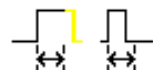
**A: M1**  
50 ns  
215 mV



.1 μs

← 3.16 μs

- 1 .1 V 50Ω
- 2 .1 V 50Ω
- 3 .2 V 50Ω  $\otimes$
- 4 20 mV AC  $\otimes$



1 DC 100 mV  
92.5 ns $\leq$ pw

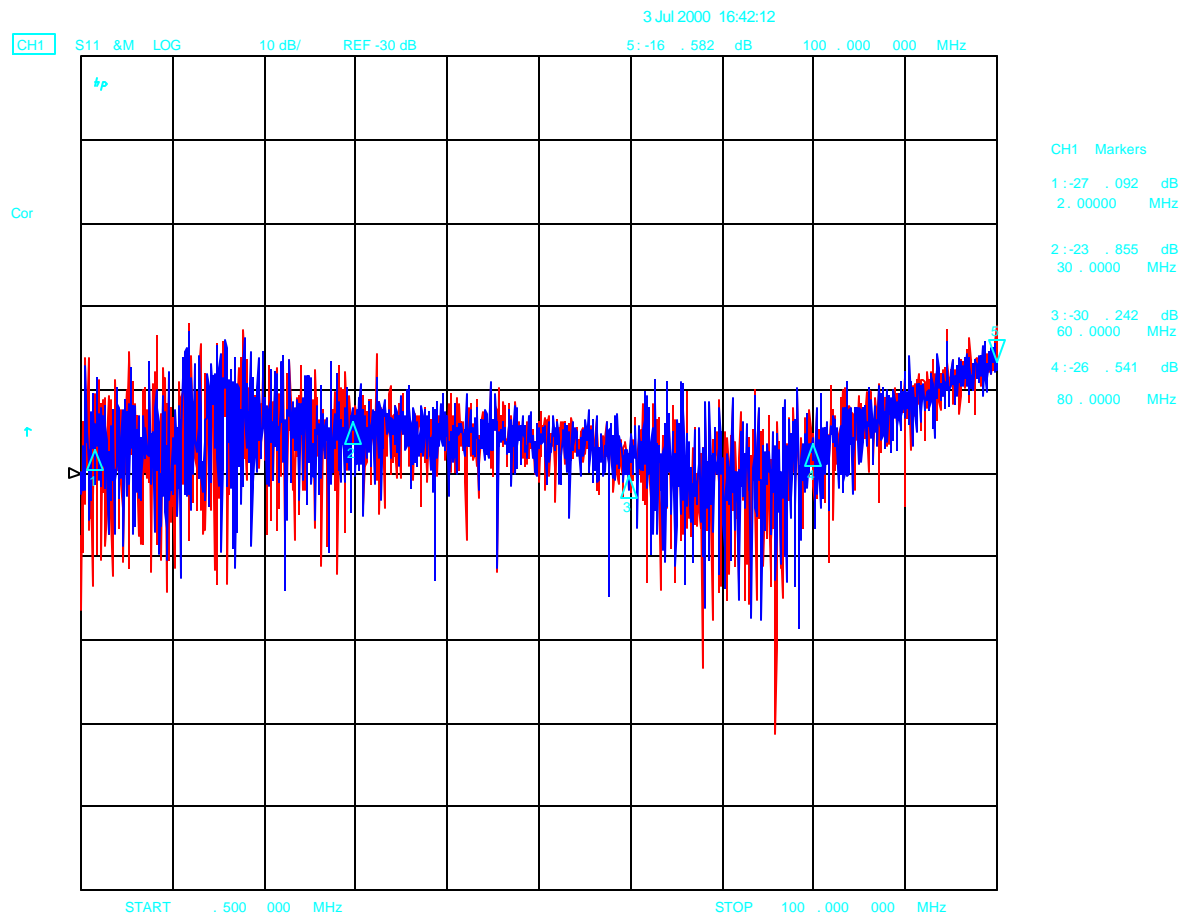
2 GS/s

AUTO

**Tx Waveform at 124 Meters I = 0, I = 300 mA**

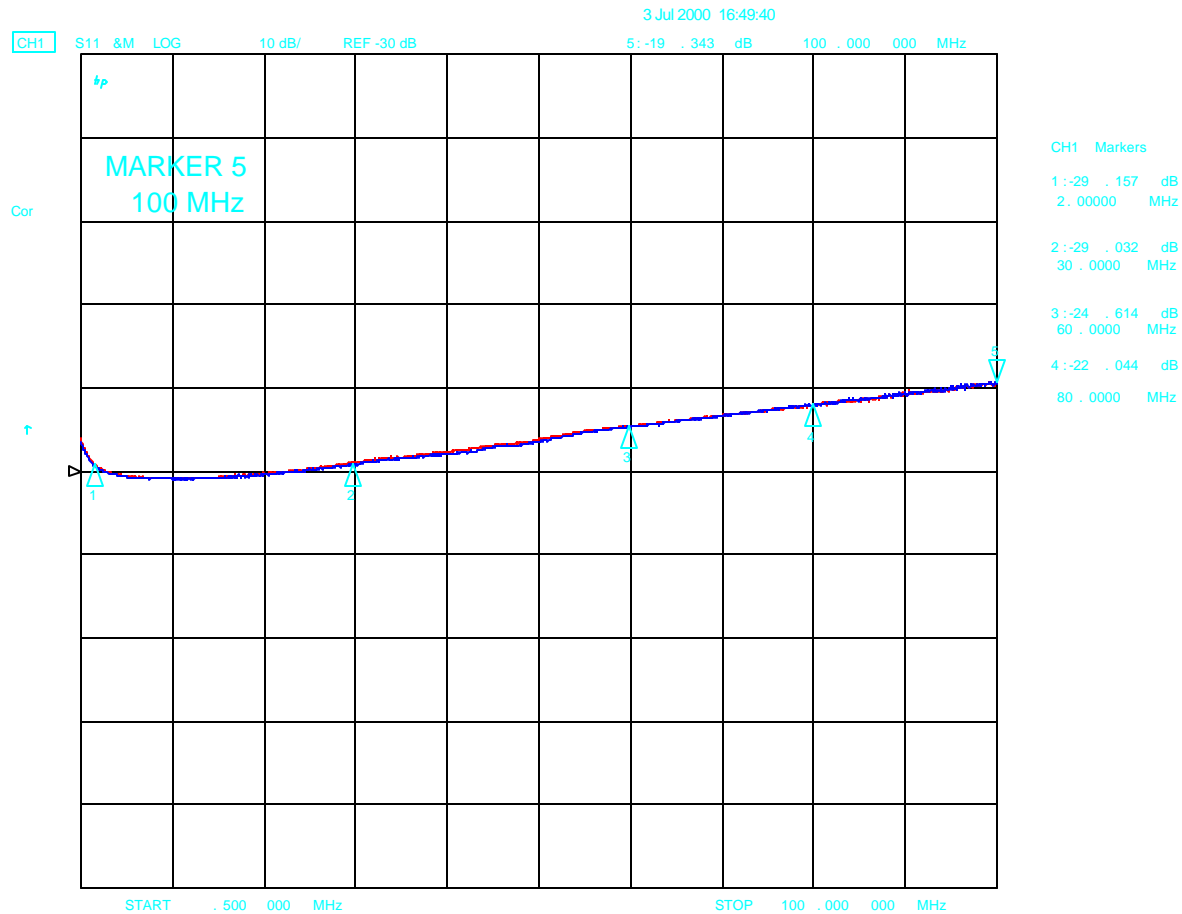
www.cisco.com

# Signal Quality Measurements 100 Mbit/s



**Tx Return Loss I = 0, I = 300 mA**

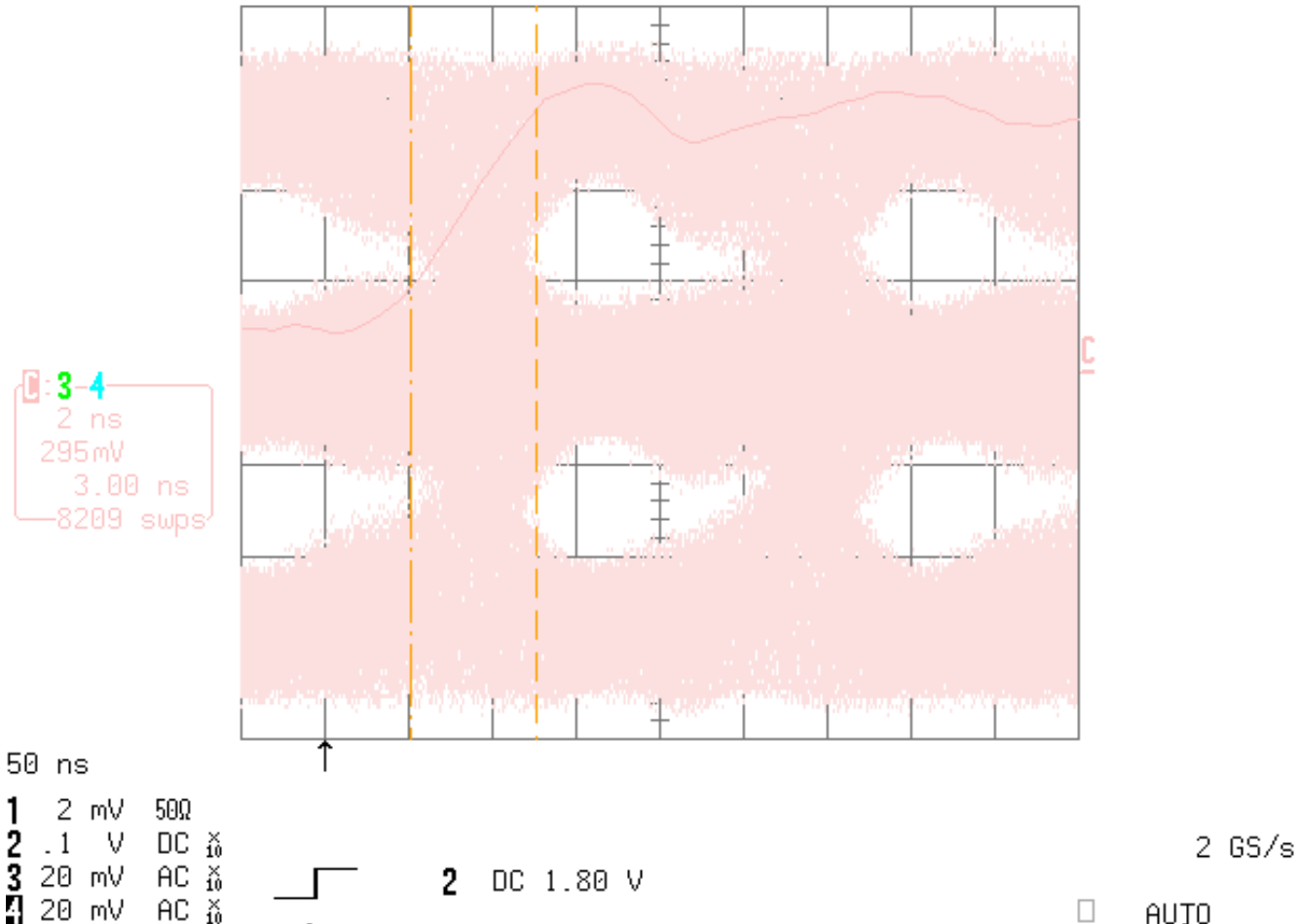
# Signal Quality Measurements 100 Mbit/s



**Rx Return Loss I = 0, I = 300 mA**

# Signal Quality Measurements 100 Mbit/s

4-Jul-00  
12:43:31

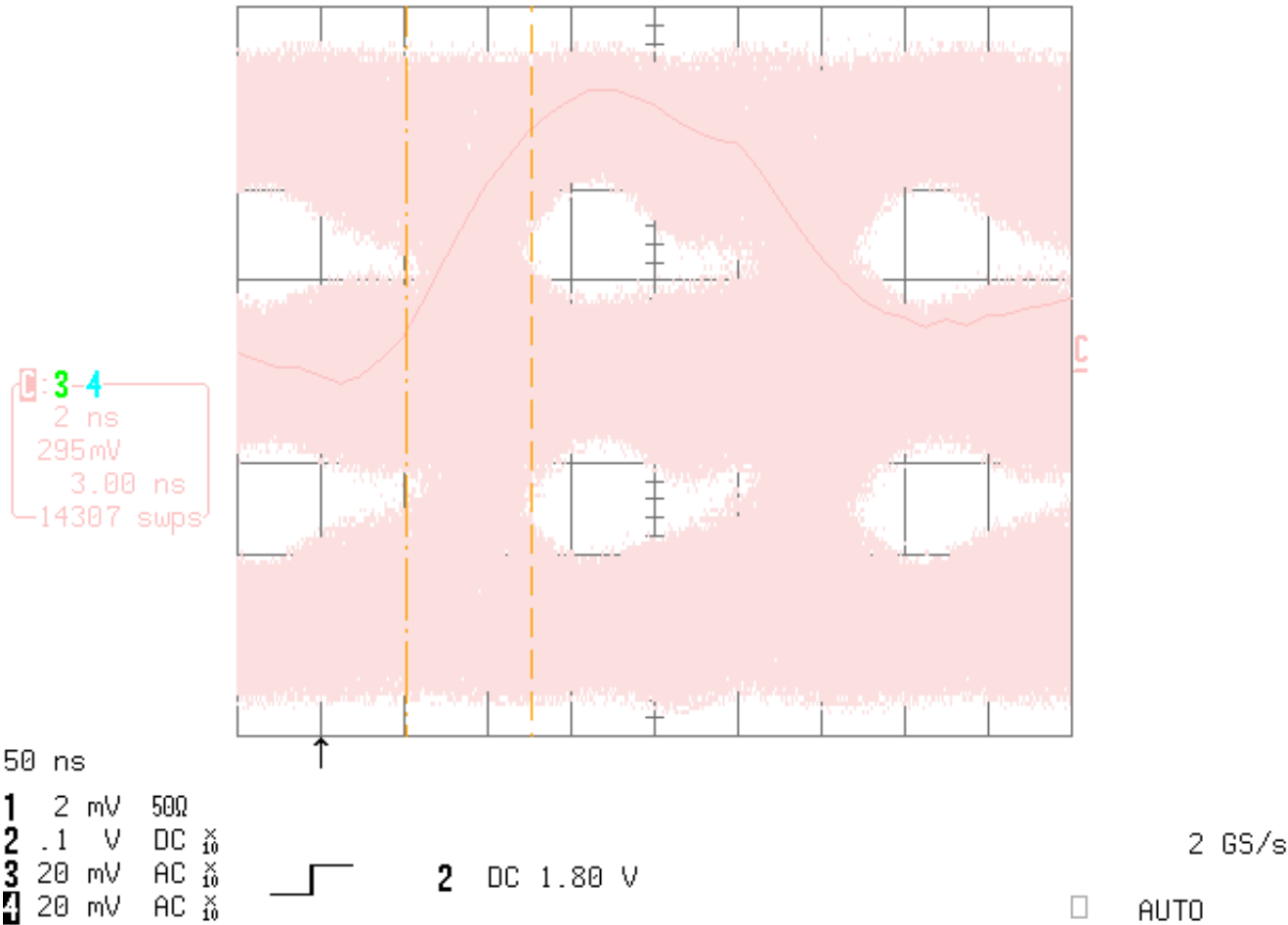


**Rx Jitter and Common Mode Tolerance, I = 0, 1 Error/10M  
Packets @ 30 Meters**

[www.cisco.com](http://www.cisco.com)

# Signal Quality Measurements 100 Mbit/s

4-Jul-00  
12:46:02



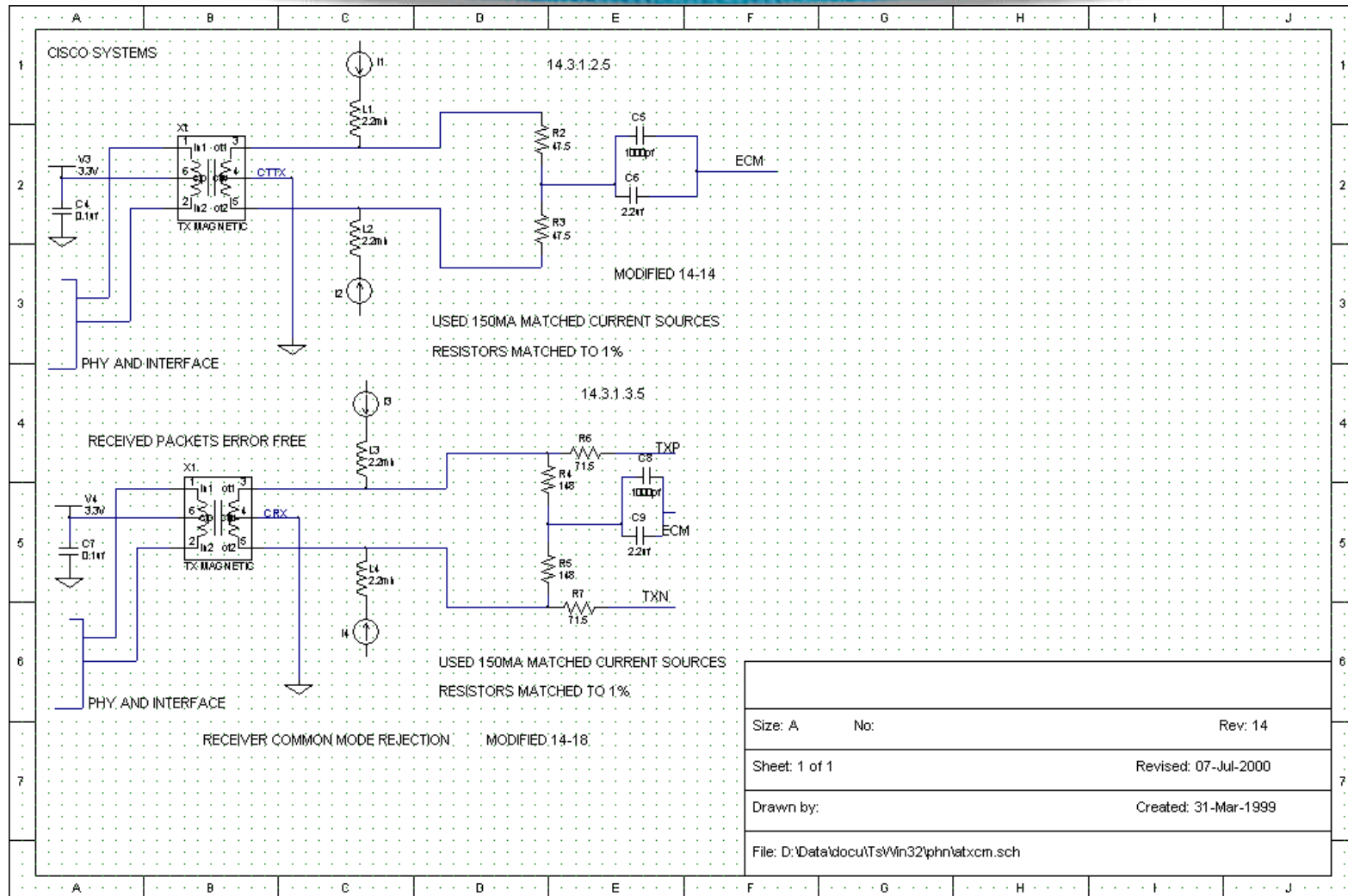
**Rx Jitter and Common Mode Tolerance, I = 300 mA,  
1 Error/30M Packets @ 30 Meters**

[www.cisco.com](http://www.cisco.com)

# 100 Mbit/s, Summary

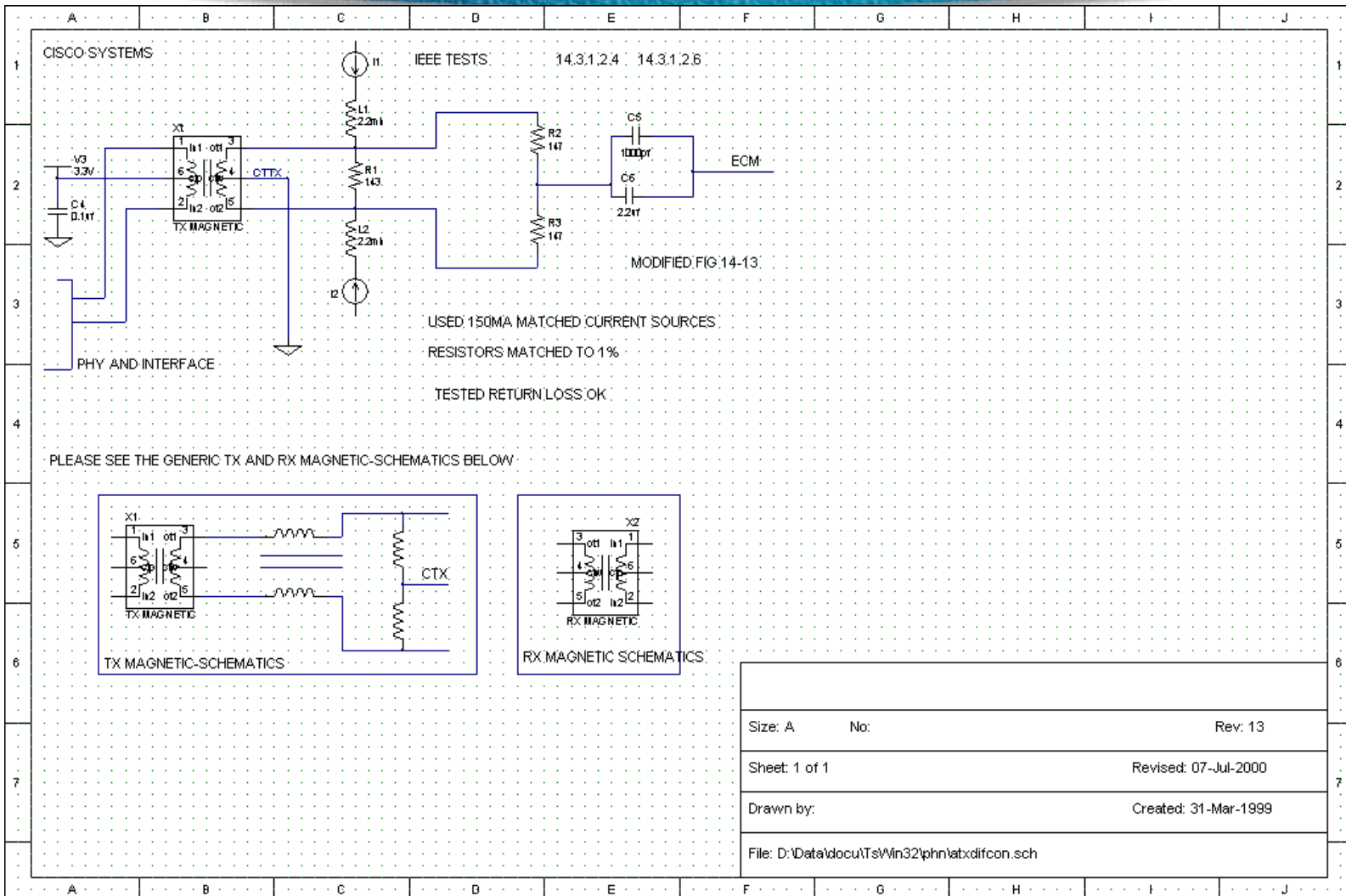
Characteristic	No Power	With Power
Differential Signal 0-PK	934 mV	934 mV
Amplitude Symmetry	1%	1%
Rise/Fall Time	4.98/4.86	4.98/4.86
Duty Cycle Distortion	.04 nSec	.04 nSec
Transmit Jitter (measured triggering on the data)	800 pSec	800 pSec
Overshoot	<3%	<3%
Differential Input Impedance Tx @ 2, 30, 60, 80 Mhz	-27, -24, -30, -27 dB	-27, -24, -30, -27 dB
Differential Input Impedance Rx @ 2, 30, 60, 80 Mhz	-29, -29, -25, -22 dB	-29, -29, -25, -22 dB
Received Jitter Tolerance	See Slides	See Slides
Common Mode Rejection	See Slides	See Slides

# Signal Quality Measurements 10 Mbit/s



Test Schematic for 10MBit/s testing

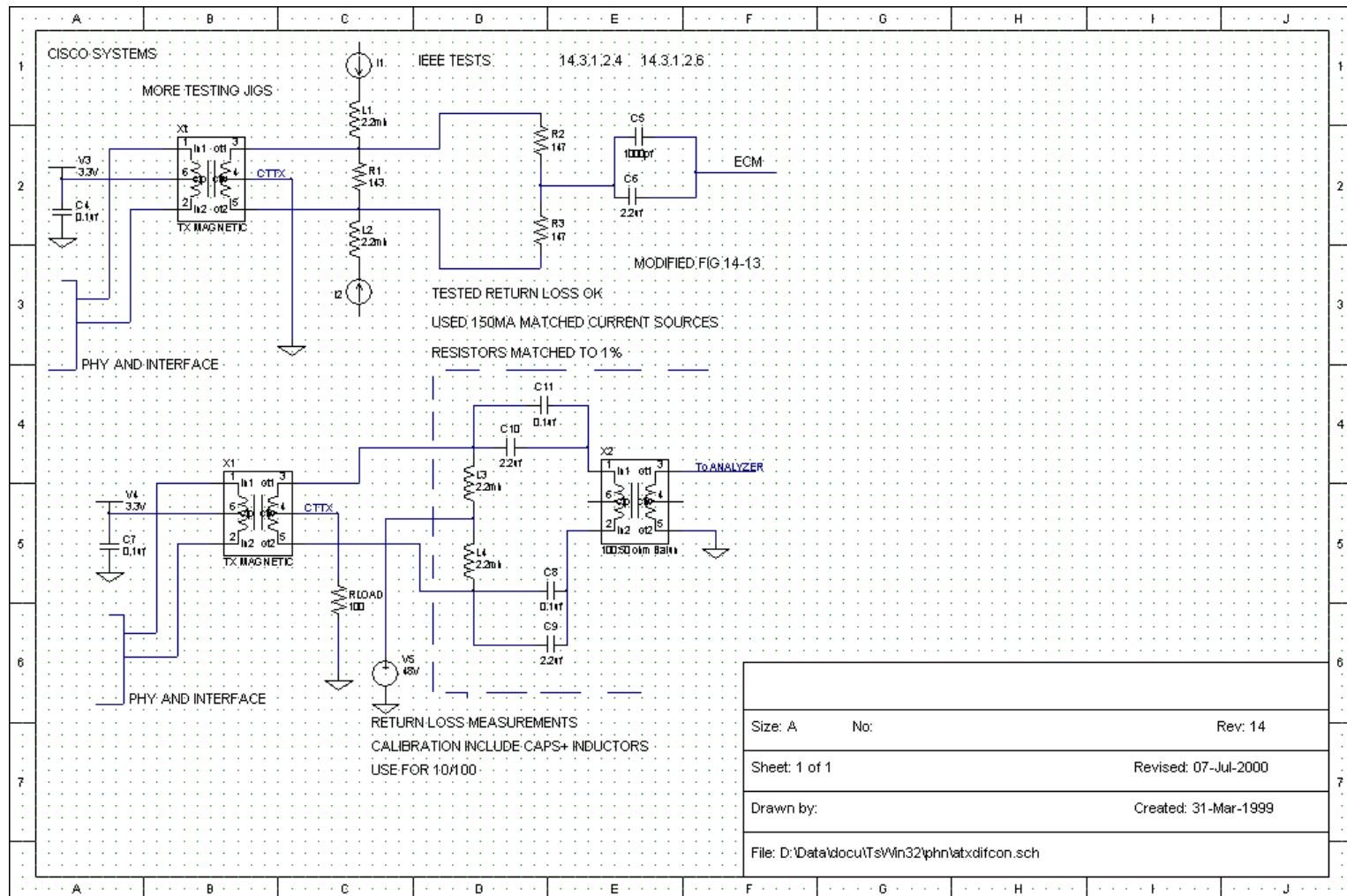
# Signal Quality Measurements 10 Mbit/s



Test Schematic for 10MBit/s testing



# Signal Quality Measurements 10 Mbit/s

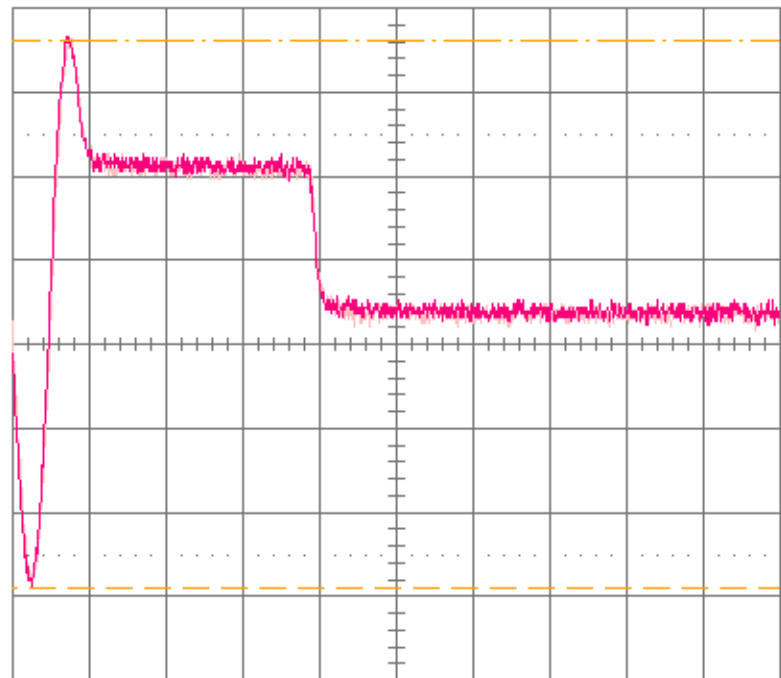


Test Schematic for 10MBit/s testing

# Signal Quality Measurements 10 Mbit/s

16-Jun-00  
13:03:58

A: M1  
.1  $\mu$ s  
0.70 V  
-4.55 V



C: 1-2  
.1  $\mu$ s  
0.71 V  
-4.61 V

.2  $\mu$ s

← 9.16  $\mu$ s

1 1 V 50 $\Omega$   
2 1 V 50 $\Omega$   
3 .1 V AC  $\times$   
4 50 mV AC  $\times$



2 DC 0.00 V

2 GS/s

AUTO

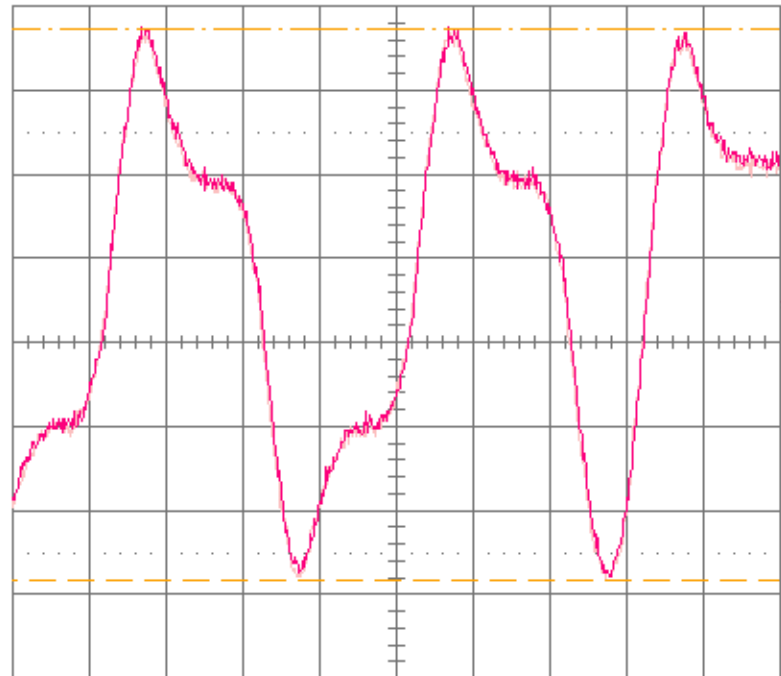
**10 Mbit/s EOP(End of Packet or Start of  
TP\_Idle) I = 0, I = 300 mA**

# Signal Quality Measurements 10 Mbit/s

16-Jun-00  
13:05:14

**M1**  
50 ns  
0.71 V  
-4.64 V

**C:1-2**  
50 ns  
0.71 V  
-4.64 V



.2 μs

← 9.16 μs

1 1 V 50Ω  
2 1 V 50Ω  
3 .1 V AC ⓧ  
4 50 mV AC ⓧ



2 DC 0.00 V

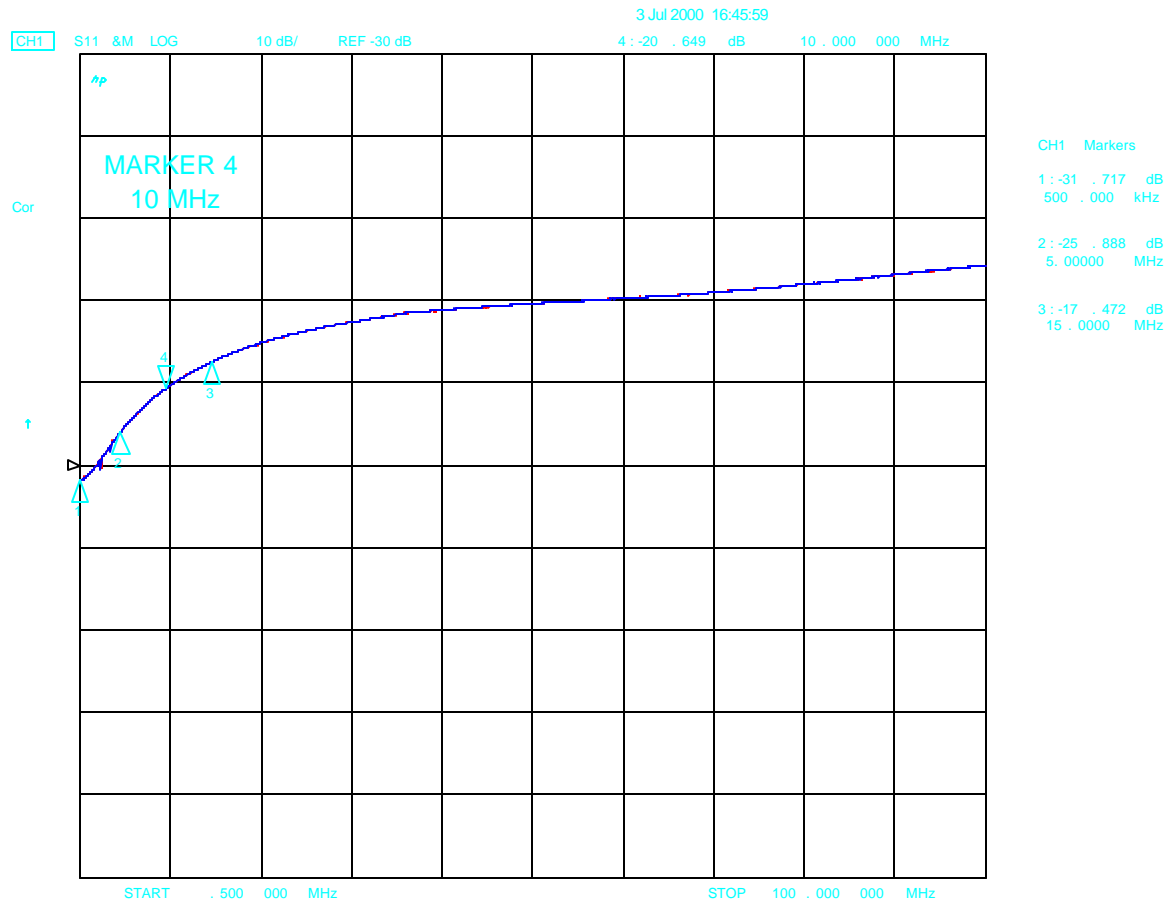
2 GS/s

□ STOPPED

**10 Mbit/s Signal I = 0, I = 300 mA**

# Signal Quality Measurements

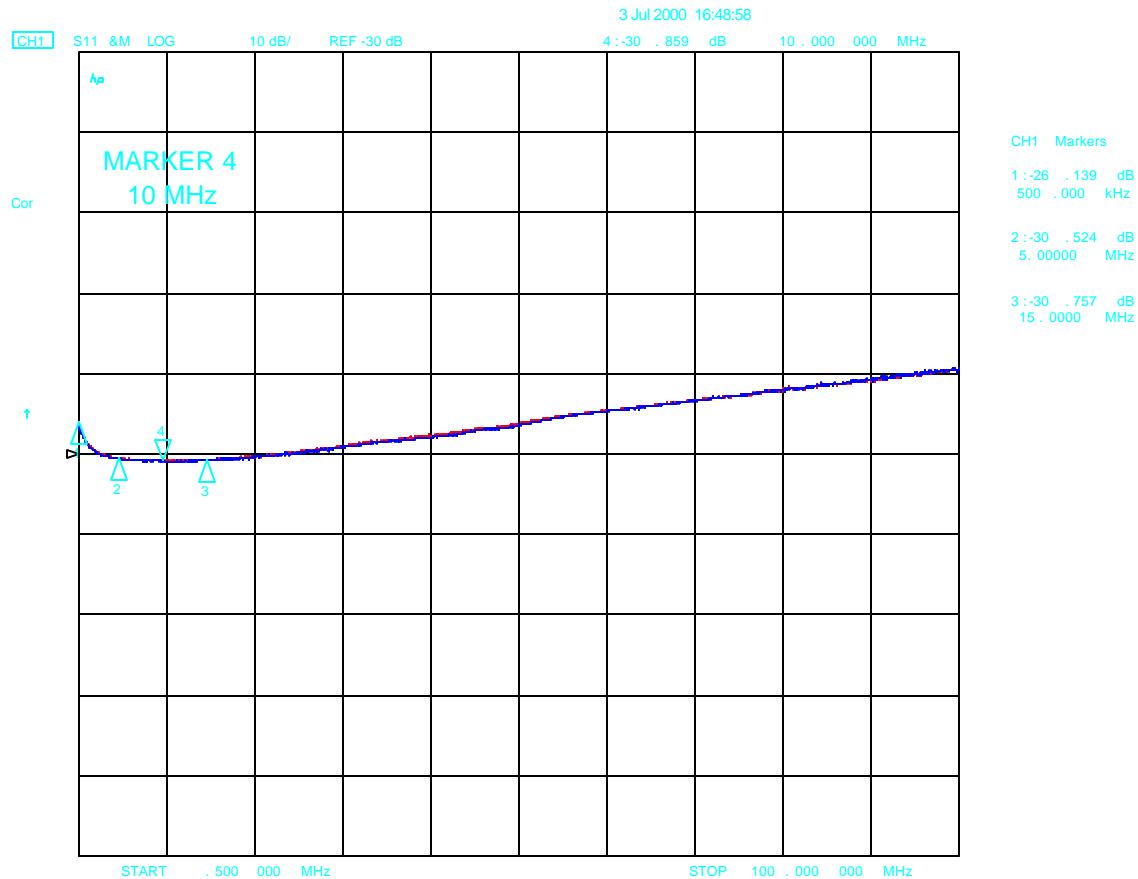
## 10 Mbit/s



**Transmit Return Loss**  
**I = 0, I = 300 mA**

# Signal Quality Measurements

## 10 Mbit/s



**Receive Return Loss**  
**I = 0, I = 300 mA**

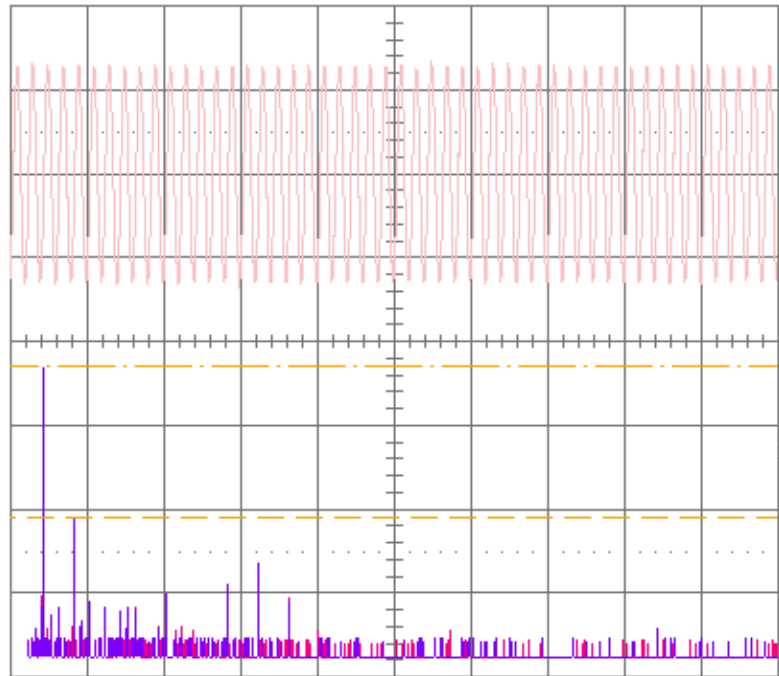
# Signal Quality Measurements 10 Mbit/s

16-Jun-00  
13:20:33

D:PS(FFT(C))  
50 MHz  
18.8 dBm  
-33.9 dB

A:M1  
50 MHz  
20.0 dBm  
-36.0 dB

C:1-2  
.5  $\mu$ s  
1.82 V  
-3.28 V



1  $\mu$ s

1 1 V 50 $\Omega$   
2 1 V 50 $\Omega$   
3 2 mV AC  $\times 10$   
4 2 mV AC  $\times 10$



1 DC 0.14 V

2 GS/s

STOPPED

**10 Mbit/s Harmonics I = 0, I = 300 mA**

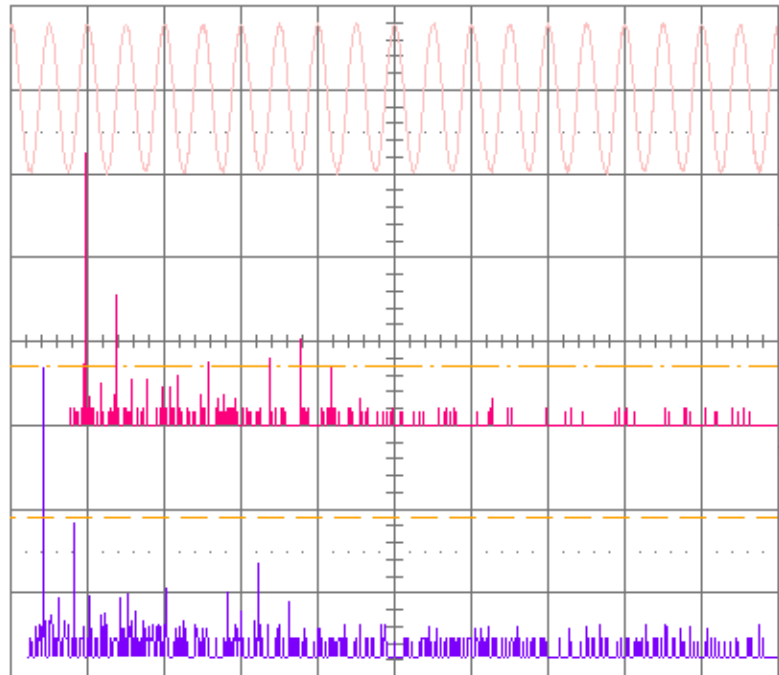
# Signal Quality Measurements 10 Mbit/s

16-Jun-00  
13:22:08

**D:PS(FFT(C))**  
50 MHz  
18.8 dBm  
-33.9 dB

**A:M1**  
50 MHz  
20.0 dBm  
-36.0 dB

**B:1-2**  
.2 ps  
2.65 V  
-4.77 V



1 ps

1 1 V 50Ω  
2 1 V 50Ω  
3 2 mV AC  $\frac{\%}{10}$   
4 2 mV AC  $\frac{\%}{10}$



1 DC 0.14 V

2 GS/s

STOPPED

**10 Mbit/s Harmonics, Clearer Scale I = 0, I = 300 mA**

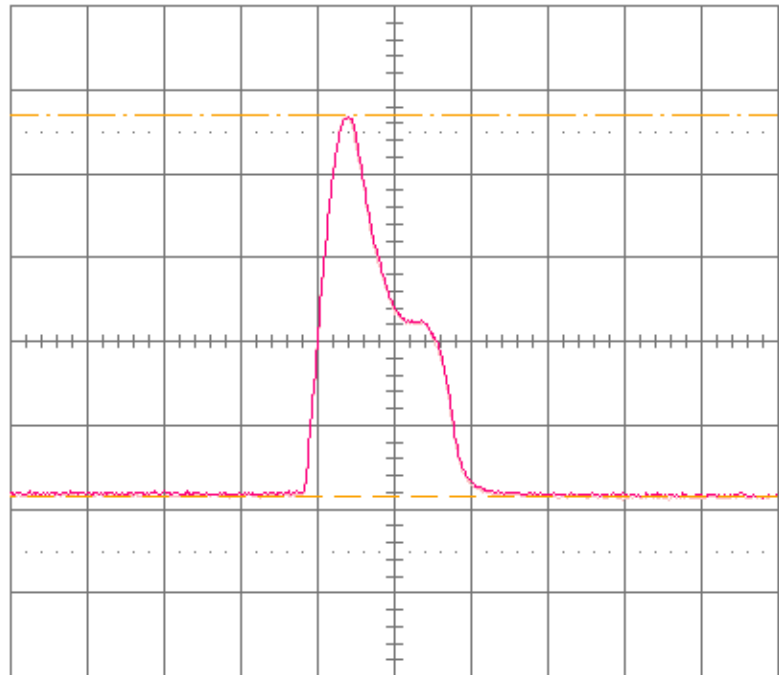
# Signal Quality Measurements 10 Mbit/s

16-Jun-00  
14:49:45

Reading Floppy Disk Drive

M1  
50 ns  
0.50 V  
-2.27 V

C:1-2  
50 ns  
0.50 V  
-2.27 V



50 ns

1 .2 V 50Ω  
2 .2 V 50Ω  
3 2 mV AC  $\times \frac{1}{10}$   
4 2 mV AC  $\times \frac{1}{10}$



1 DC 0.448 V

2 GS/s

AUTO

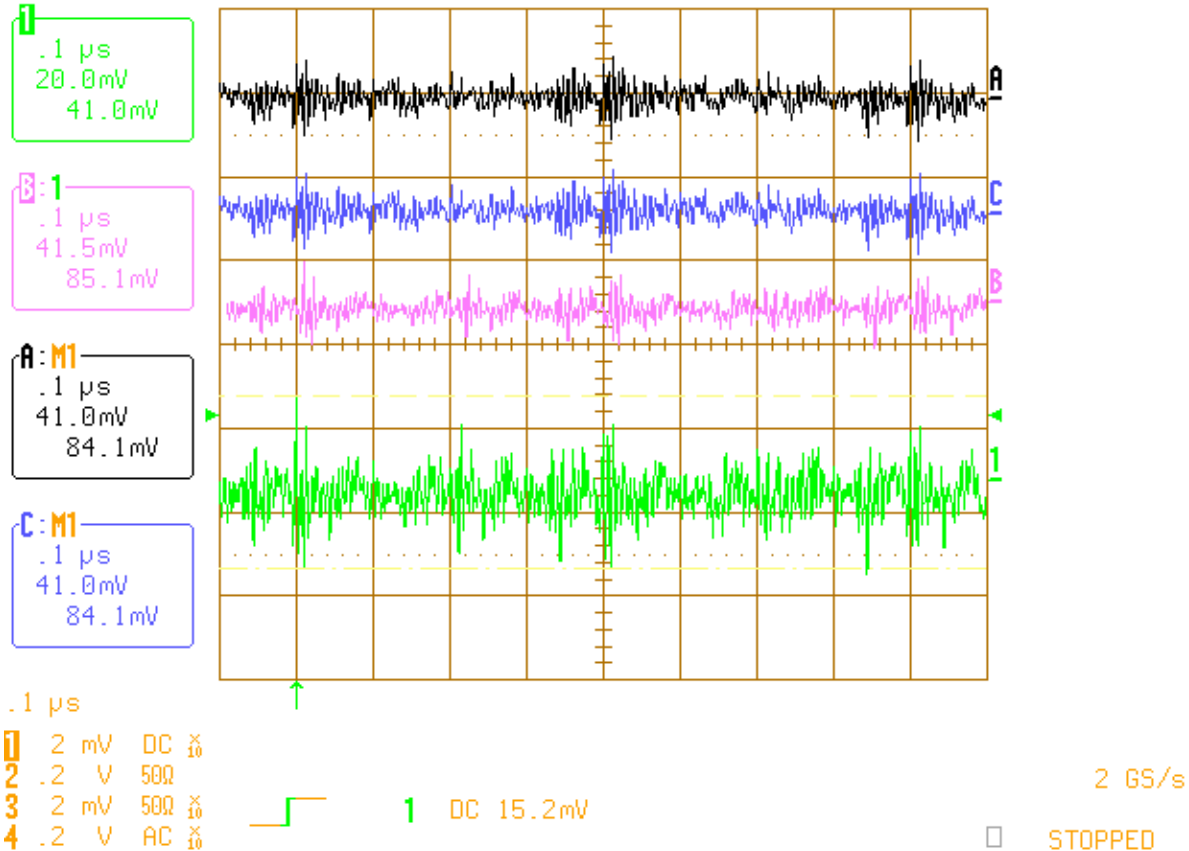
**10 Mbit/s Link Pulses I = 0, I = 300 mA**



# Signal Quality Measurements 10 Mbit/s

22-Jun-00  
21:01:34

Reading Floppy Disk Drive



**10 Mbit/s Common Mode Voltage I = 0, I = 300 mA**

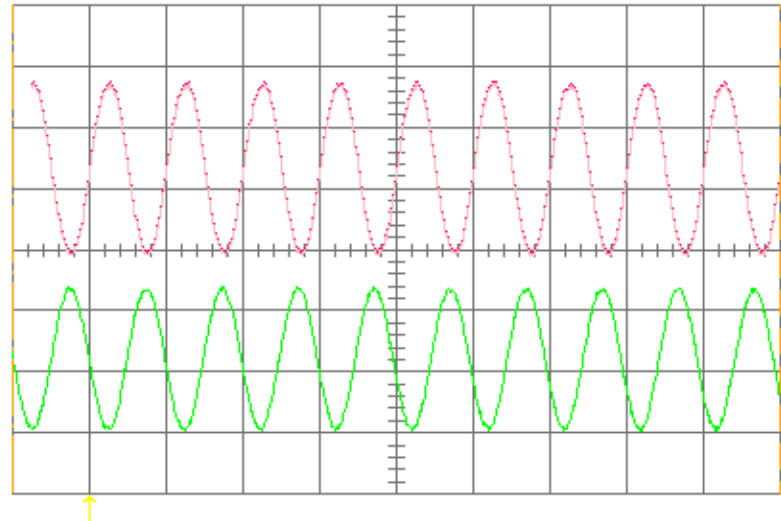
# Signal Quality Measurements 10 Mbit/s

22-Jun-00  
21:57:33

**1-2**  
.1  $\mu$ s  
1.60 V

**3**  
.1  $\mu$ s  
5.0 V

**A:M1**  
.1  $\mu$ s  
1.60 V



21 sweeps: average low high sigma

	average	low	high	sigma
ampl(3)	11.02 V	10.96	11.09	0.04
ampl(C)	4.46 V	4.22	4.64	0.12
Freq(3)	10.1008 MHz	9.9595	10.2302	0.0513

.1  $\mu$ s

1 .1 V DC  $\times \frac{10}{10}$   
2 .1 V DC  $\times \frac{10}{10}$   
3 .5 V AC  $\times \frac{10}{10}$   
4 .2 V AC  $\times \frac{10}{10}$



1 DC 0.06 V  
98.0 ns  $\leq$  pu  $\leq$  98.5 ns

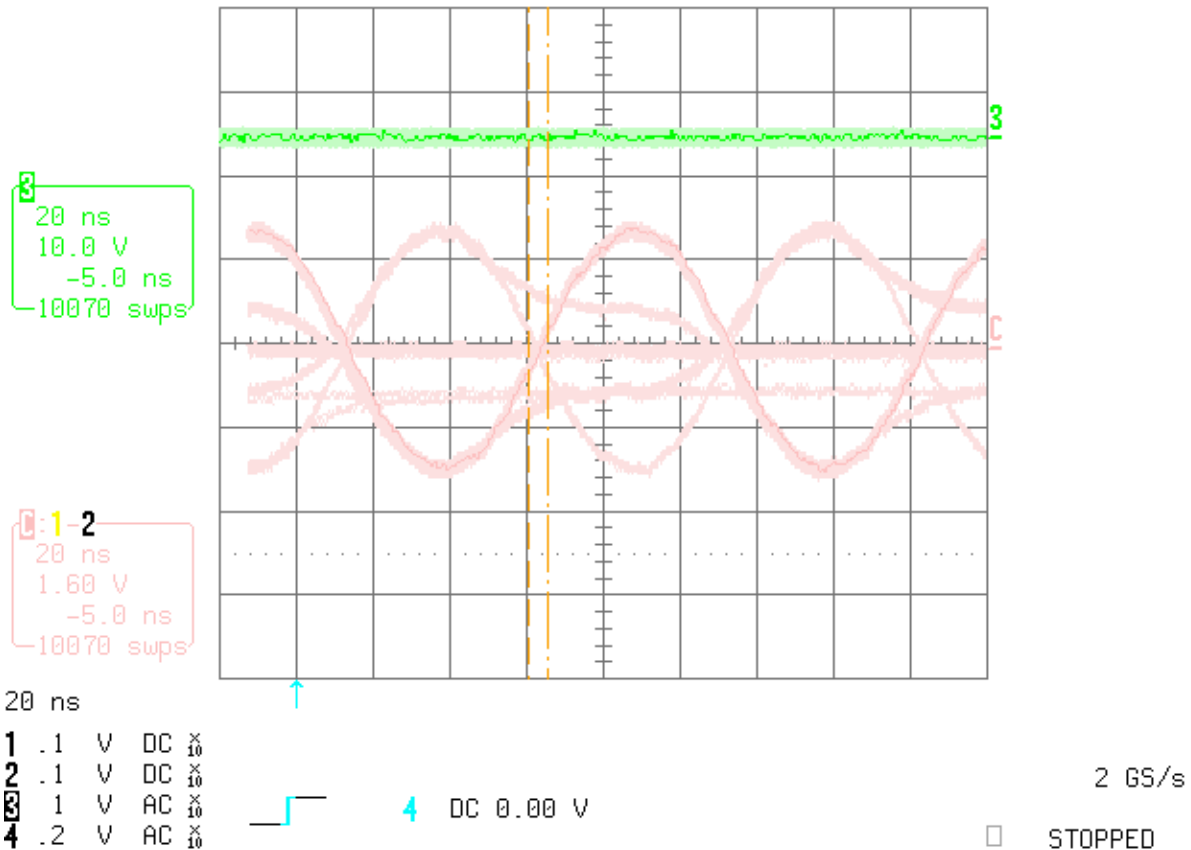
2 GS/s

SINGLE

**10 Mbit/s Common Mode Rejection I = 0, I = 300 mA**

# Signal Quality Measurements 10 Mbit/s

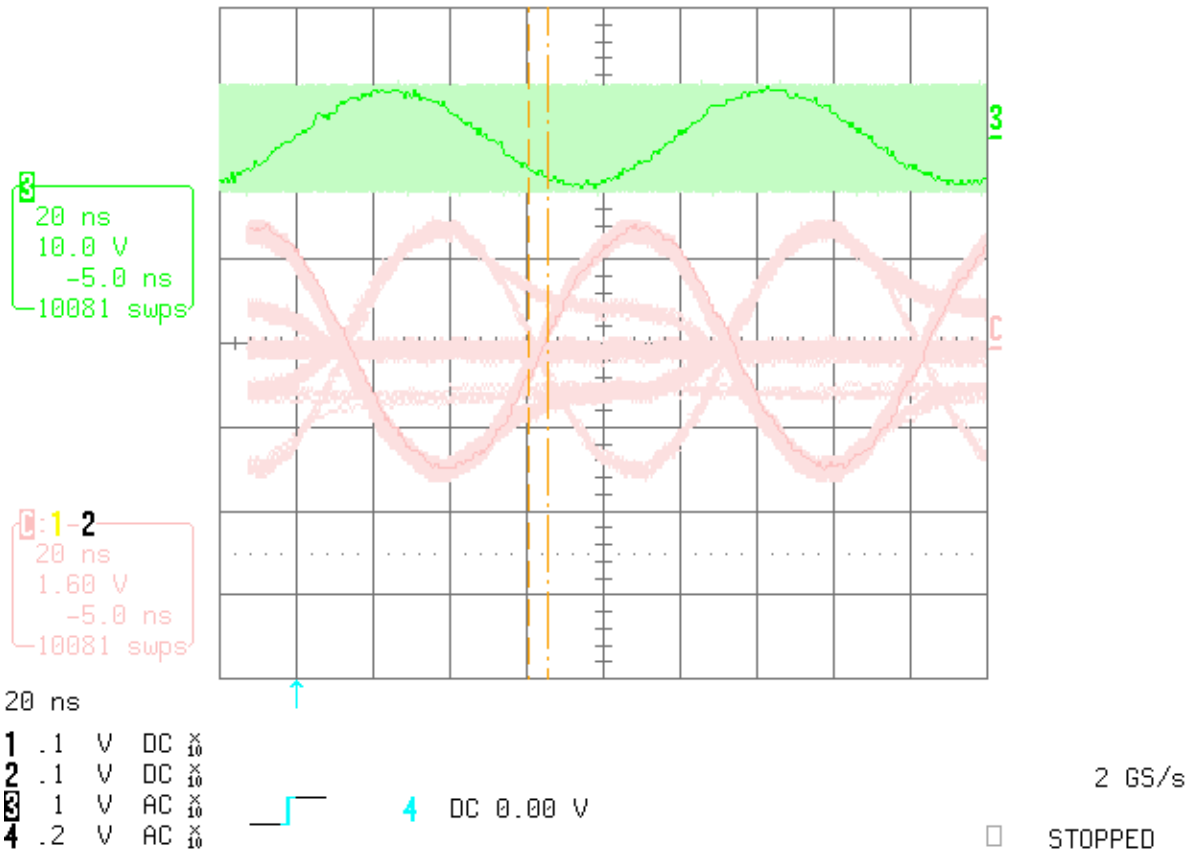
22-Jun-00  
22:15:46



**10.1MHz Sine Wave Injected, No Excess Jitter Present  
I = 300 mA**

# Signal Quality Measurements 10 Mbit/s

22-Jun-00  
22:17:36



**10.1MHz Sine Wave Injected, No Excess Jitter Present**  
**I = 0**

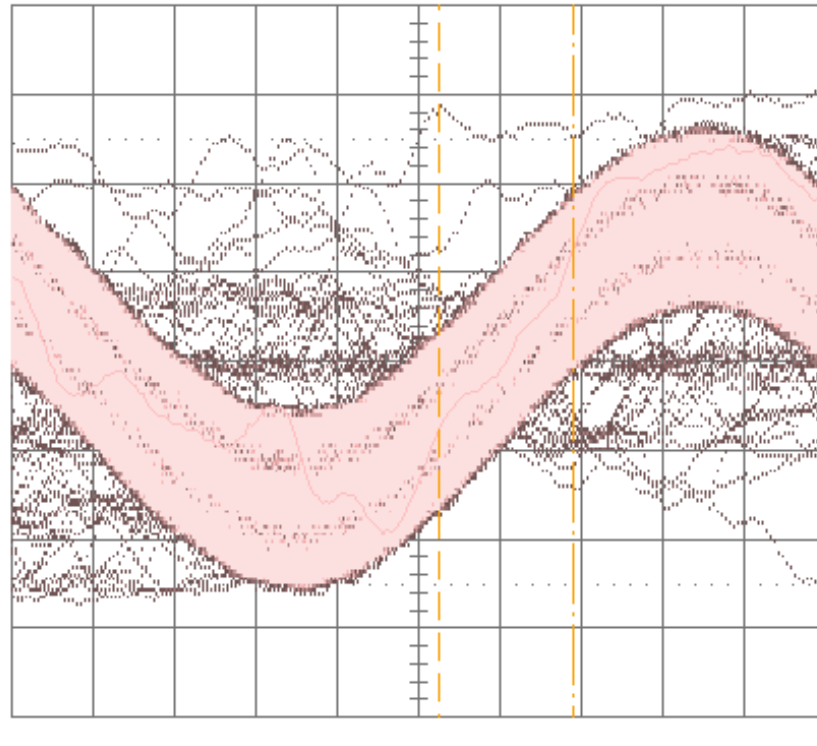
# Signal Quality Measurements 10 Mbit/s

Test 14.3.1.2.4		CISCO SYSTEMS		Common Mode to Differential Conversion				
Freq	TX	calculate			no power	Calculate		20*LOG10(VECM/VDIFF)
MHZ	BALANCE	"29-17*LOG10(FREQ/10)		I=0	20*LOG10(VECM/VDIFF)	Meas		Calculate-I=300ma
			Meas	Meas		I=0	I=300ma	
		SPECIFICATION	VECM	VDIFF		Calculate	VDIFF	Calculate
1.00E+00		4.60E+01	11.1	0.049		47.10254	0.04	48.86526
2.00E+00		4.09E+01	11.1	0.055		46.09921	0.047	47.4645
5.00E+00		3.41E+01	11	0.1		40.82785	0.06	45.26483
1.00E+01		2.90E+01	10.9	0.153		37.0547	0.1	40.74853
1.50E+01		2.60E+01	10.6	0.202		34.39909	0.16	36.42372
2.00E+01		2.39E+01	10.6	0.246		32.68742	0.17	35.89714
WE SEE THE SAME RESULTS WITH CURRENT TURNED ON AT 300MA								
1-	MY GENERATOR CAN'T DO MORE THAN 11.1V							
2-	Freq is in Mhz, so I used 1/10 to calculate the LOG of the 1MHZ data point slight change in balance measurement for the better, you would have hoped that my current source would cause an imbalance if anything.... Looks good.							
Done on #19 - bel								

# Signal Quality Measurements 10 Mbit/s

4-Jul-00  
13:09:33

0:3-4  
10 ns  
375mV  
-16.5 ns  
-2175 swps



20 ns

1 2 mV 50Ω  
2 .1 V DC  $\times 10$   
3 20 mV AC  $\times 10$   
4 20 mV AC  $\times 10$



2 DC 1.90 V

2 GS/s

AUTO

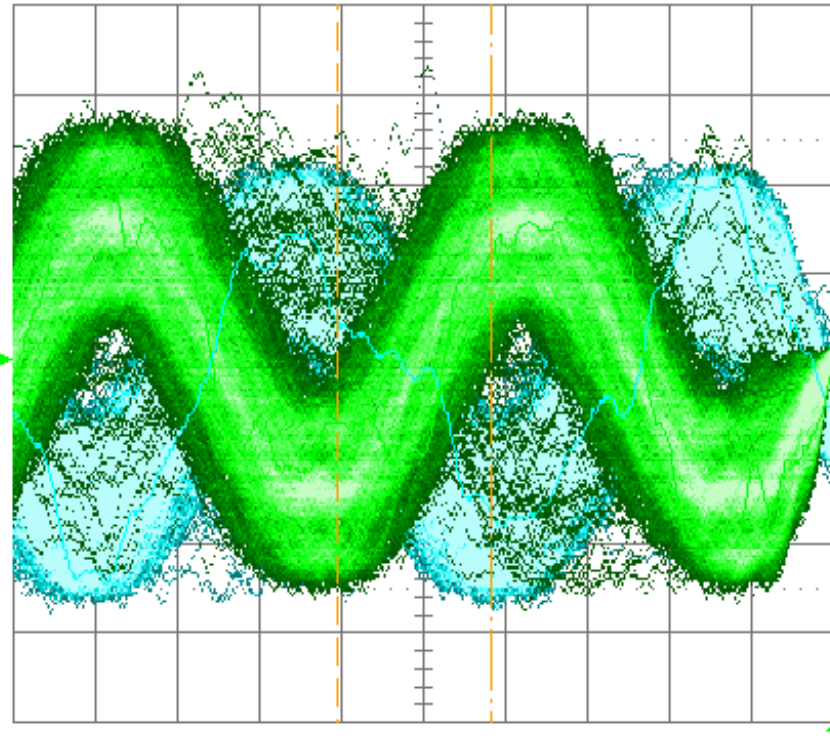
**Receive Jitter and Common Mode Tolerance,  $I = 300$  mA  
at 128 M, Cat-3, Error Free, 5M Packets**

# Signal Quality Measurements 10 Mbit/s

4-Jul-00  
13:11:32

3  
20 ns  
200mV  
-37.5 ns  
1791 swps

4  
20 ns  
200mV  
-37.5 ns  
999 swps



20 ns

- 1 2 mV 50Ω
- 2 .1 V DC  $\times 10$
- 3 20 mV AC  $\times 10$
- 4 20 mV AC  $\times 10$



3 DC -0.008 V

2 GS/s

STOPPED

**Receive Jitter and Common Mode Tolerance, I = 300 mA  
at 128 M, Cat-3, Error Free, 5M Packets, Single Ended**

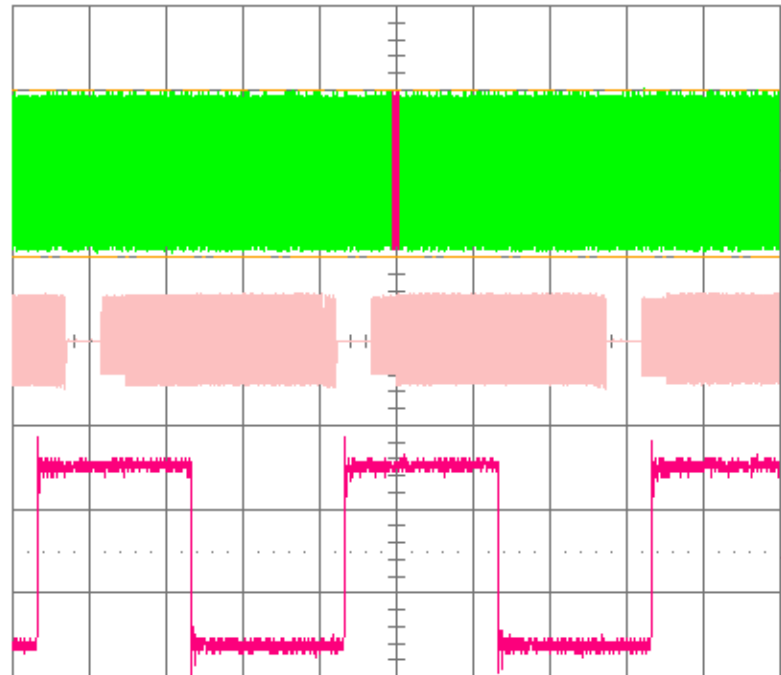
# Signal Quality Measurements 10 Mbit/s

23-Jun-00  
16:34:52

**C-2-1**  
20  $\mu$ s  
5.5 V  
10.9 V

**3**  
.2 ms  
5.0 V  
9.9 V

**1-3**  
.5  $\mu$ s  
3.20 V  
6.35 V



.2 ms

1	.1	V	DC	$\times 10$
2	.1	V	DC	$\times 10$
3	.5	V	AC	$\times 10$
4	.5	V	AC	$\times 10$

1 DC -0.02 V

2 GS/s

AUTO

**10 Mbit/s 500 KHz, 25V Square Wave Common Mode  
Rejection of the RX I = 300 mA**

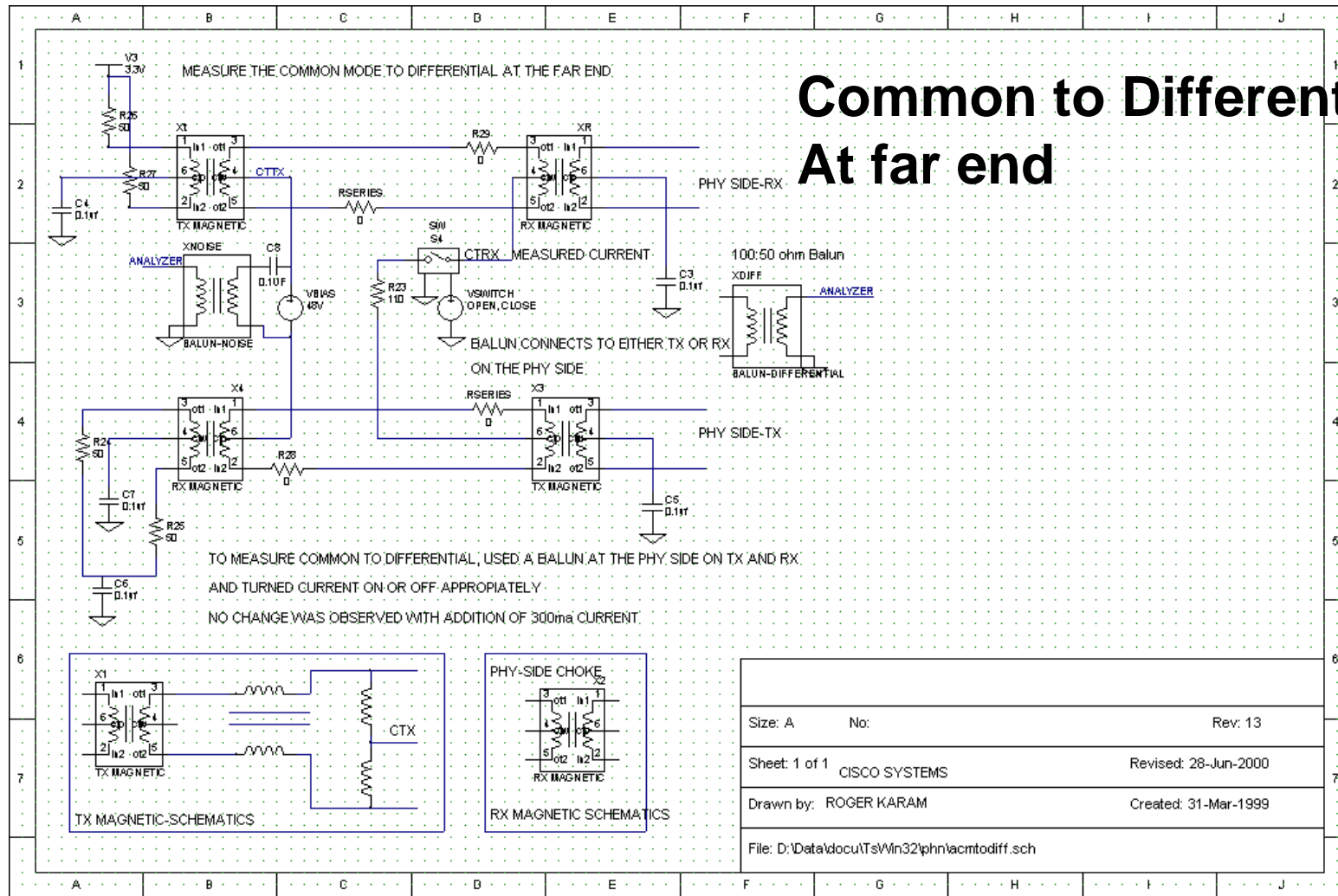


# 10 Mbit/s, Summary

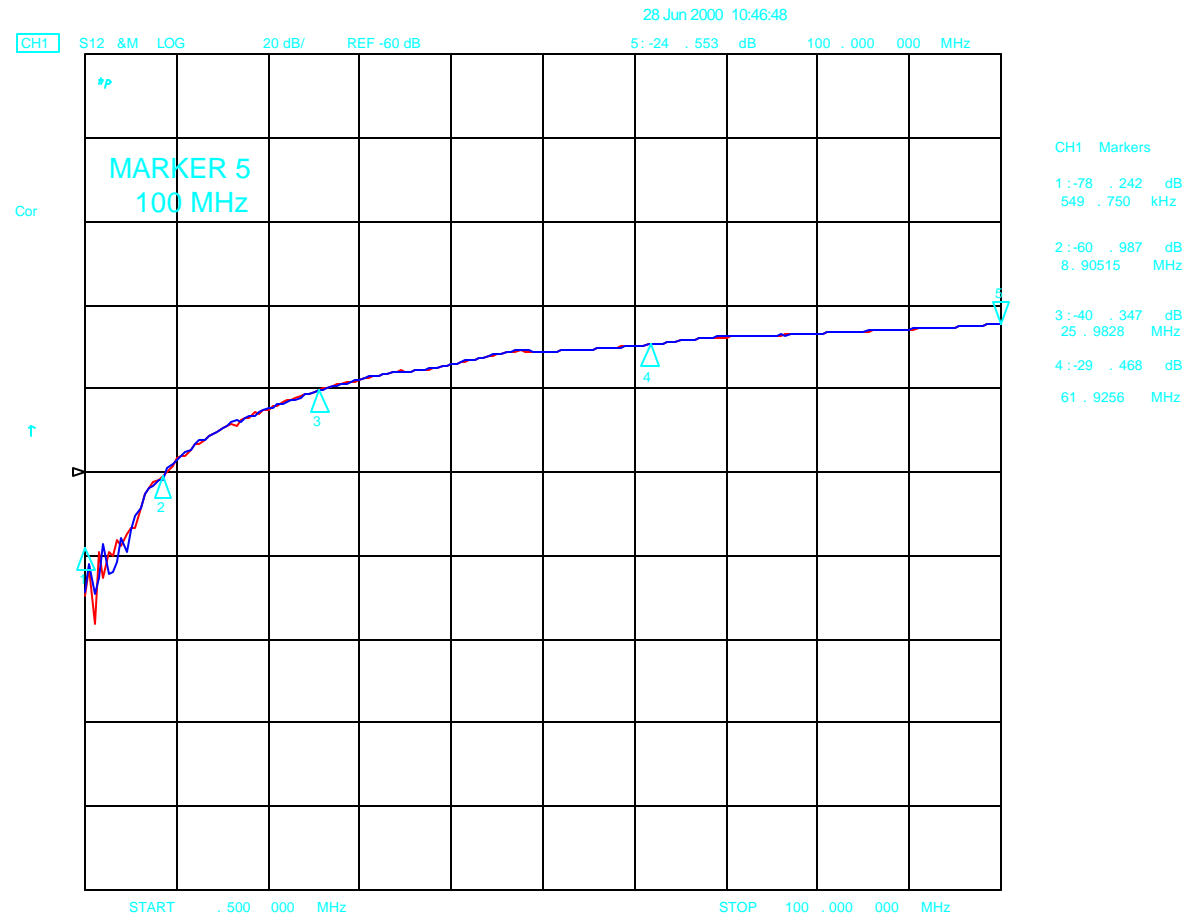
Characteristic	No Power	With Power
Peak Differential Output Voltage on TD	4.64/4.64	4.64/4.64
TD circuit Differential Output Tx Impedance @ 5, 10Mhz	-26, -18 dB	-26, -18 dB
TD circuit Differential Output Rx Impedance @ 5, 10Mhz	-31, -31 dB	-31, -31 dB
TD common mode output voltage	< 40 mV	< 40 mV
TD common mode rejection(See Slides 24-26)	Pass	Pass
RD Signal Acceptance	690 mV	730 mV
Receiver Jitter Acceptance (See Slides)	>13 nSec	> 13 nSec
Receiver Added Jitter	< 1 nSec	< 1 nSec
Common Mode to Differential Mode Conversion	Pass	Pass
RD Common Mode Rejection (See Slide 27)	Pass	Pass

# Signal Quality Measurements Magnetics

## Common to Differential At far end

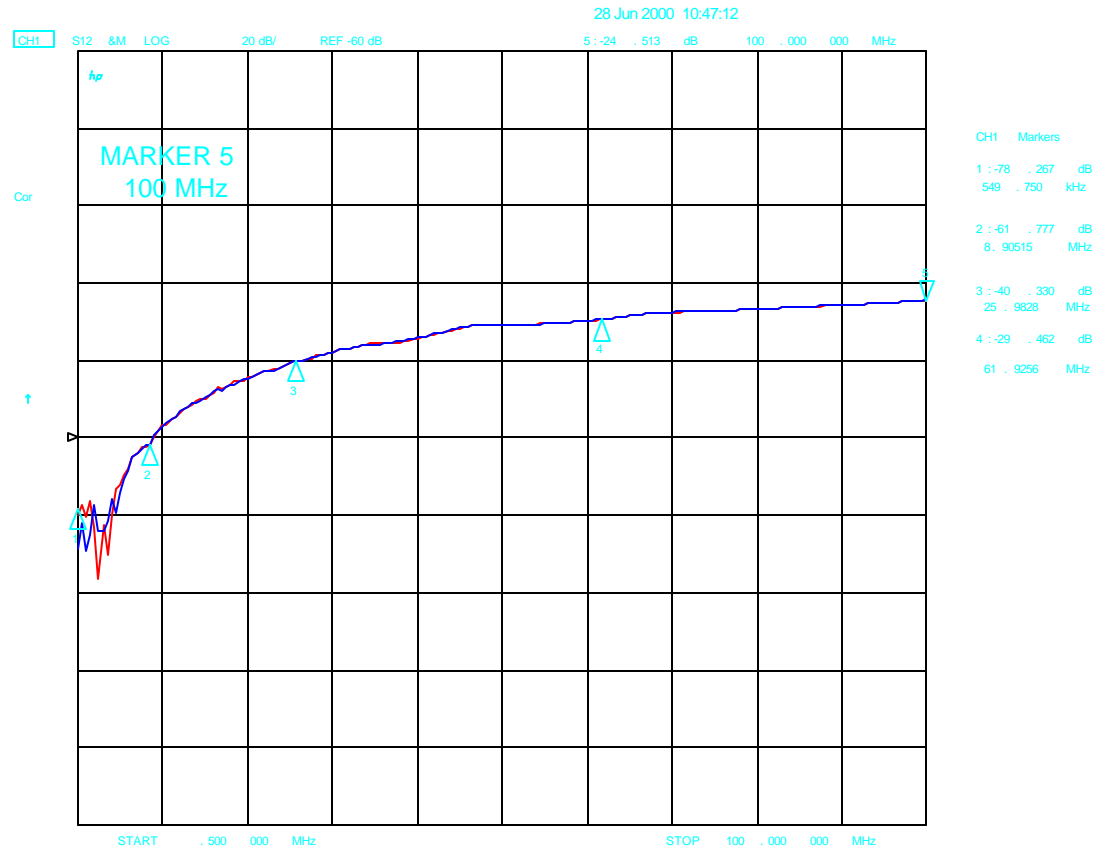


# Signal Quality Measurements Magnetics



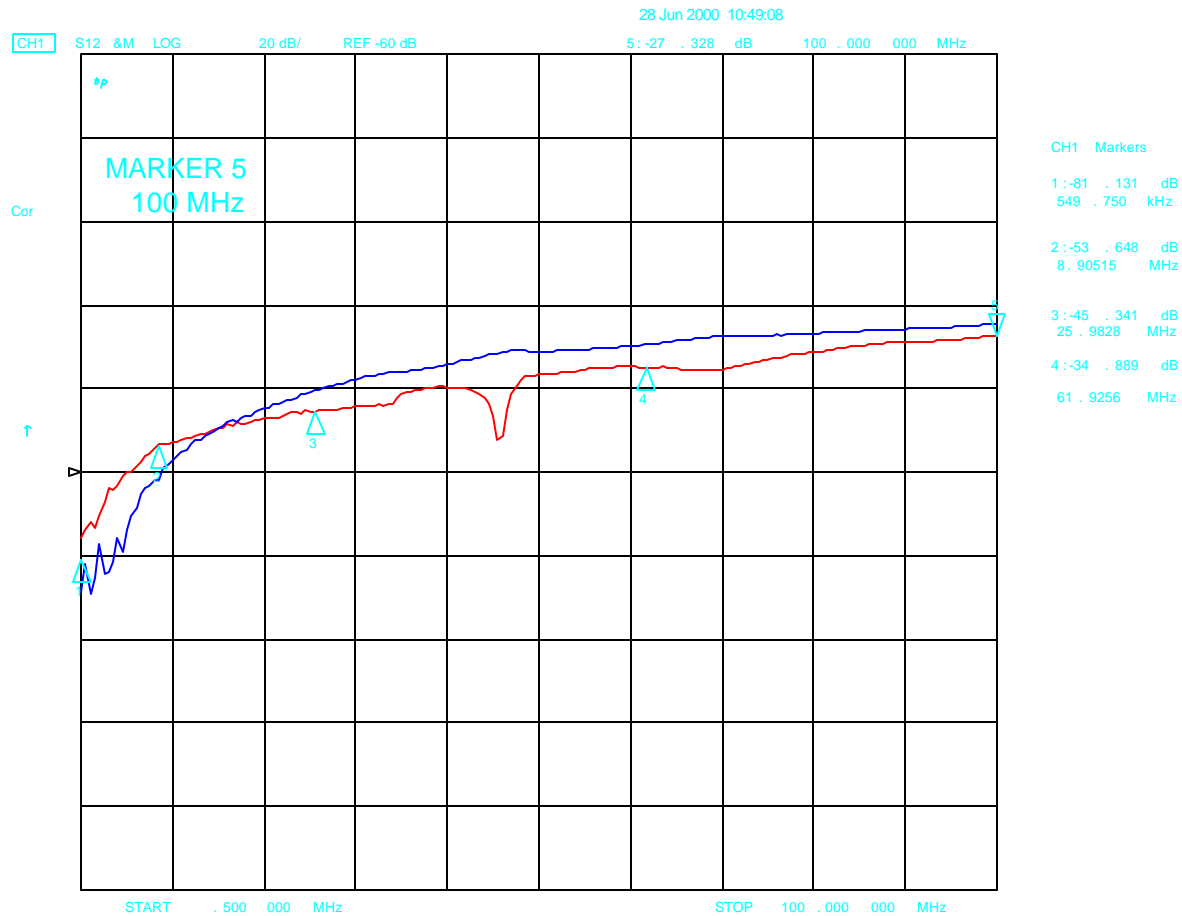
**Common Mode to Differential Conversion, Drove Supply Side, Measure at  
PHY on the RL Side**

# Signal Quality Measurements Magnetics



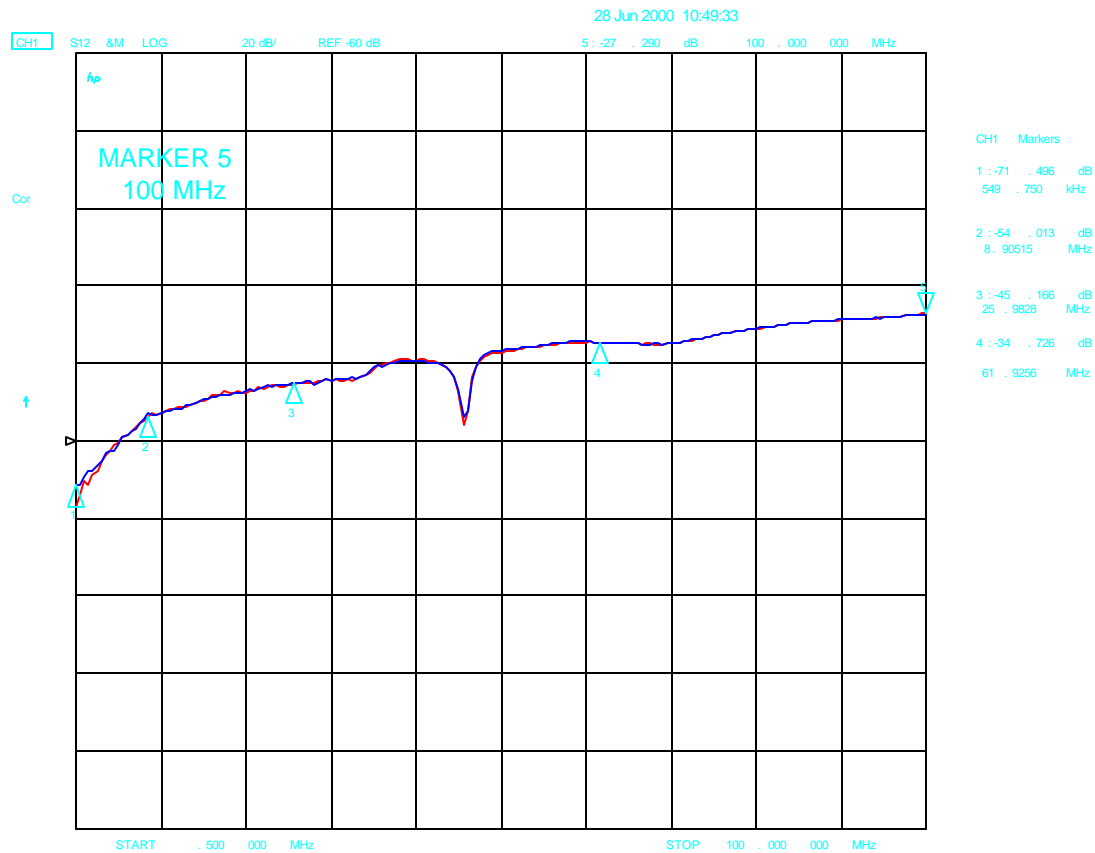
**Common Mode to Differential Conversion, Drove Supply Side, Measure at  
PHY on the RL Side, I = 0, I = 300 mA**

# Signal Quality Measurements Magnetics



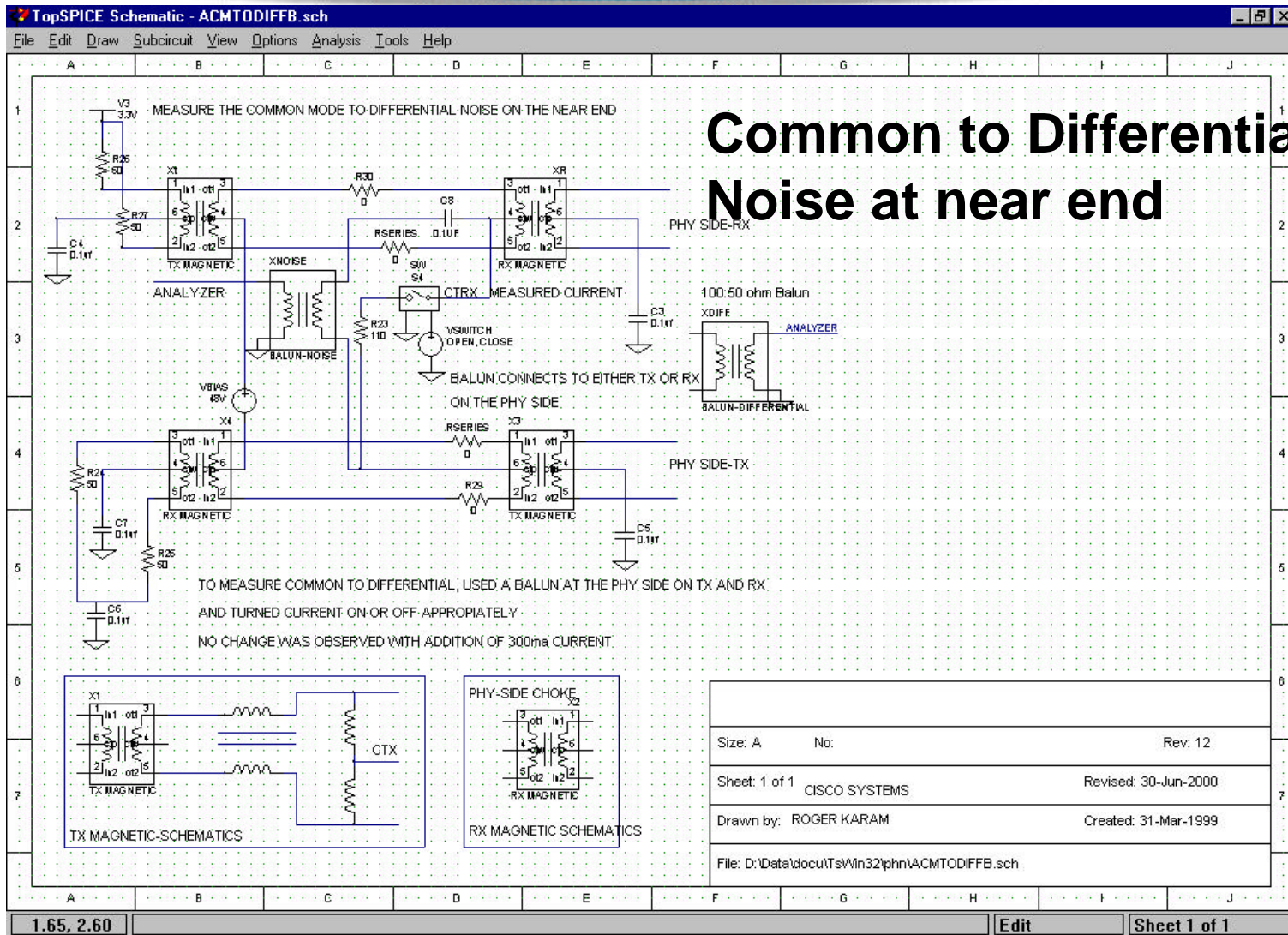
**Compare Tx to Rx, I = 0**

# Signal Quality Measurements Magnetics

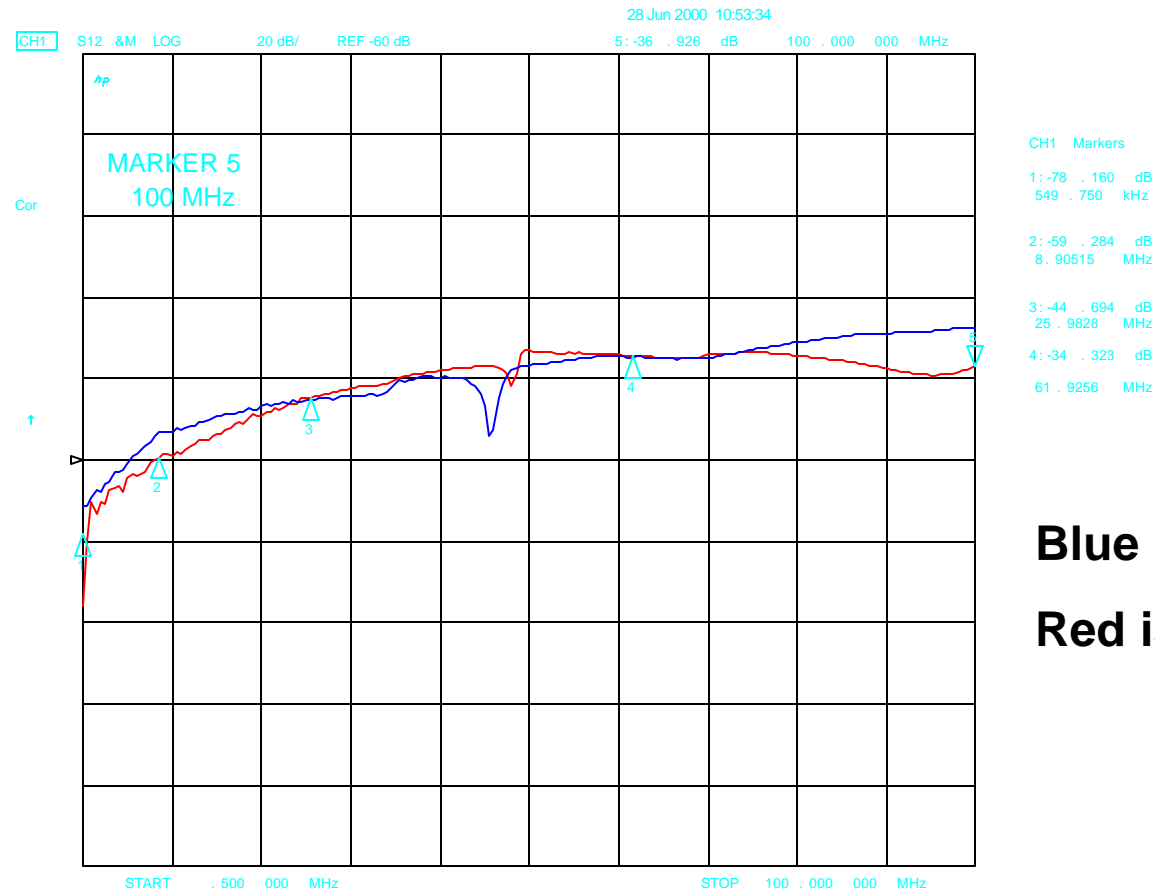


**Tx I = 0, I = 300 mA**

# Signal Quality Measurements Magnetics



# Signal Quality Measurements Magnetics

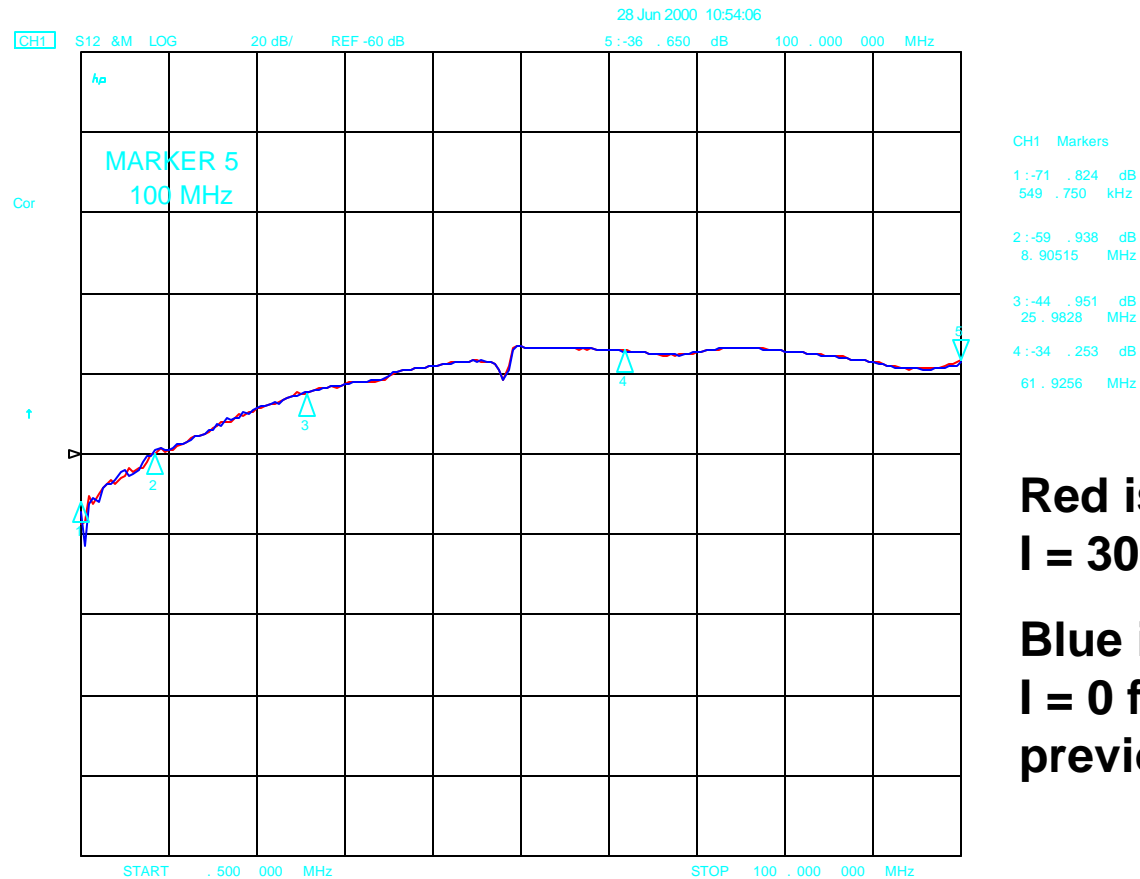


**Blue is PHY Side**  
**Red is Wire Side**

**Rx Common Mode to Differential, Drove the Rx side of the RL and  
measured on the wire side I = 0**



# Signal Quality Measurements Magnetics

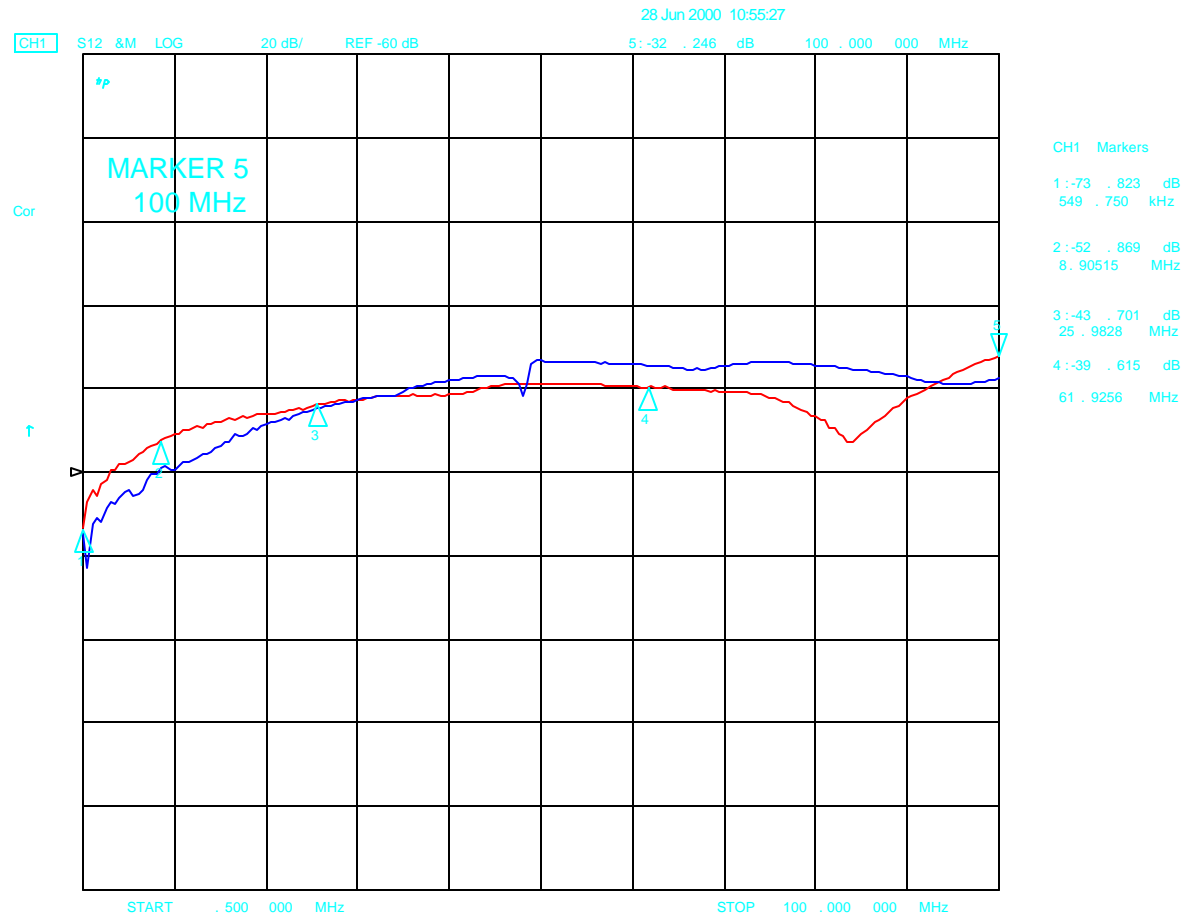


**Red is Wire Side,  
I = 300 mA**

**Blue is Wire Side,  
I = 0 from  
previous slide**

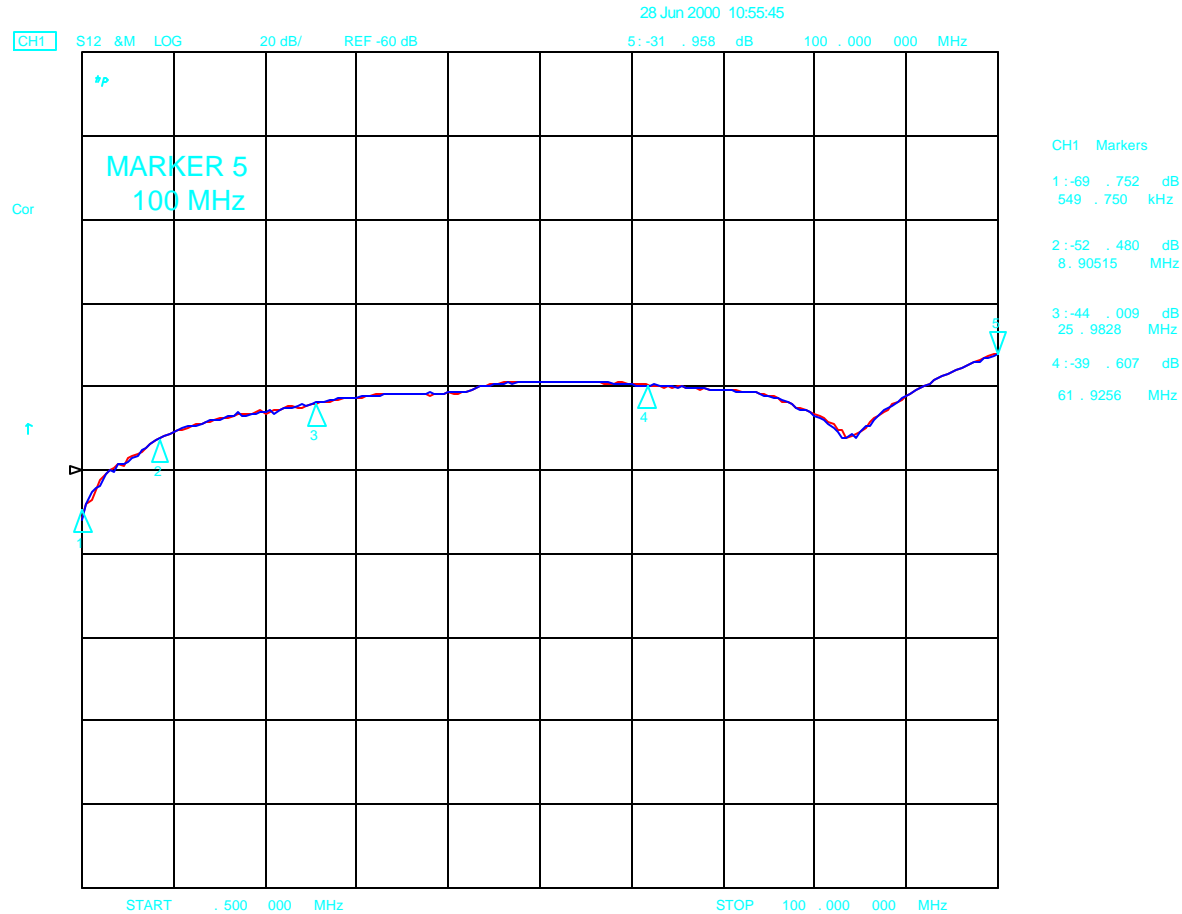
**Rx Common Mode to Differential, Drove the Rx side of the RL and  
measured on the wire side I = 0, I = 300 mA**

# Signal Quality Measurements Magnetics



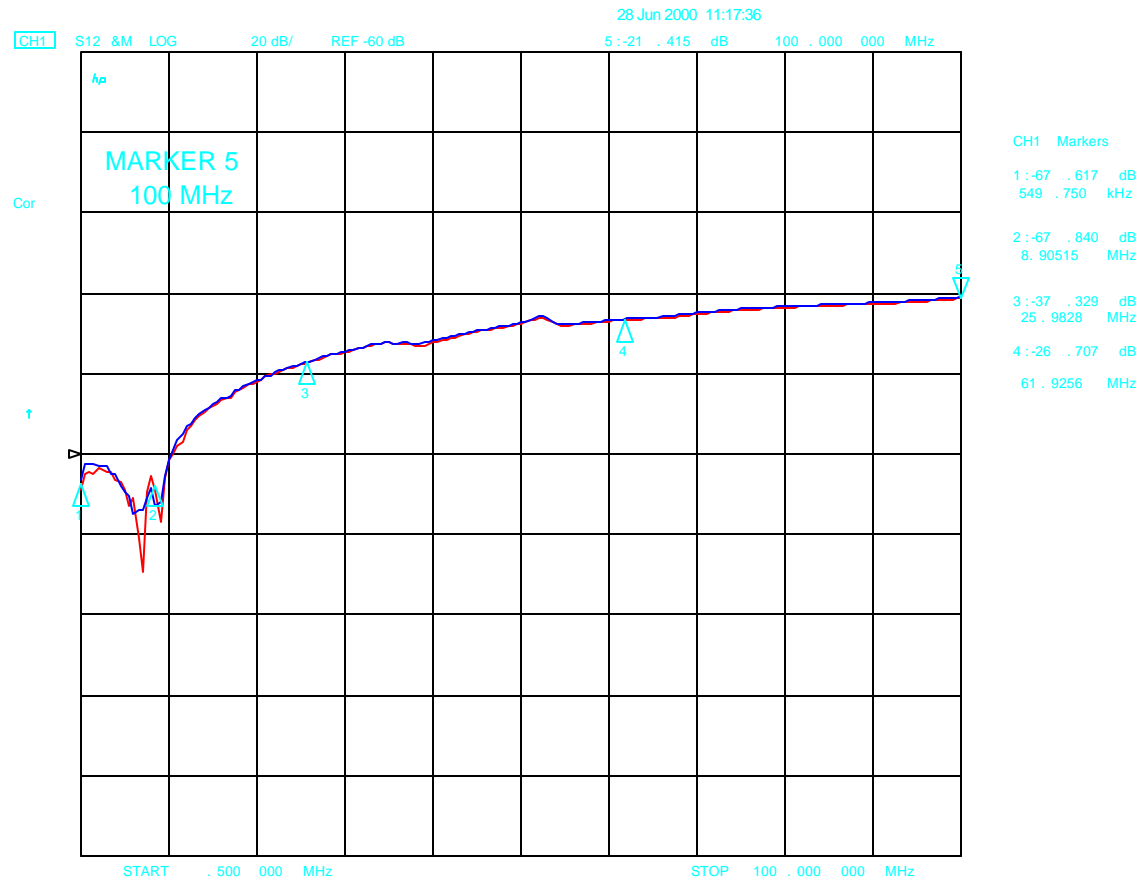
**Compare Tx to Rx, Wire Side, I = 0 mA**

# Signal Quality Measurements Magnetics



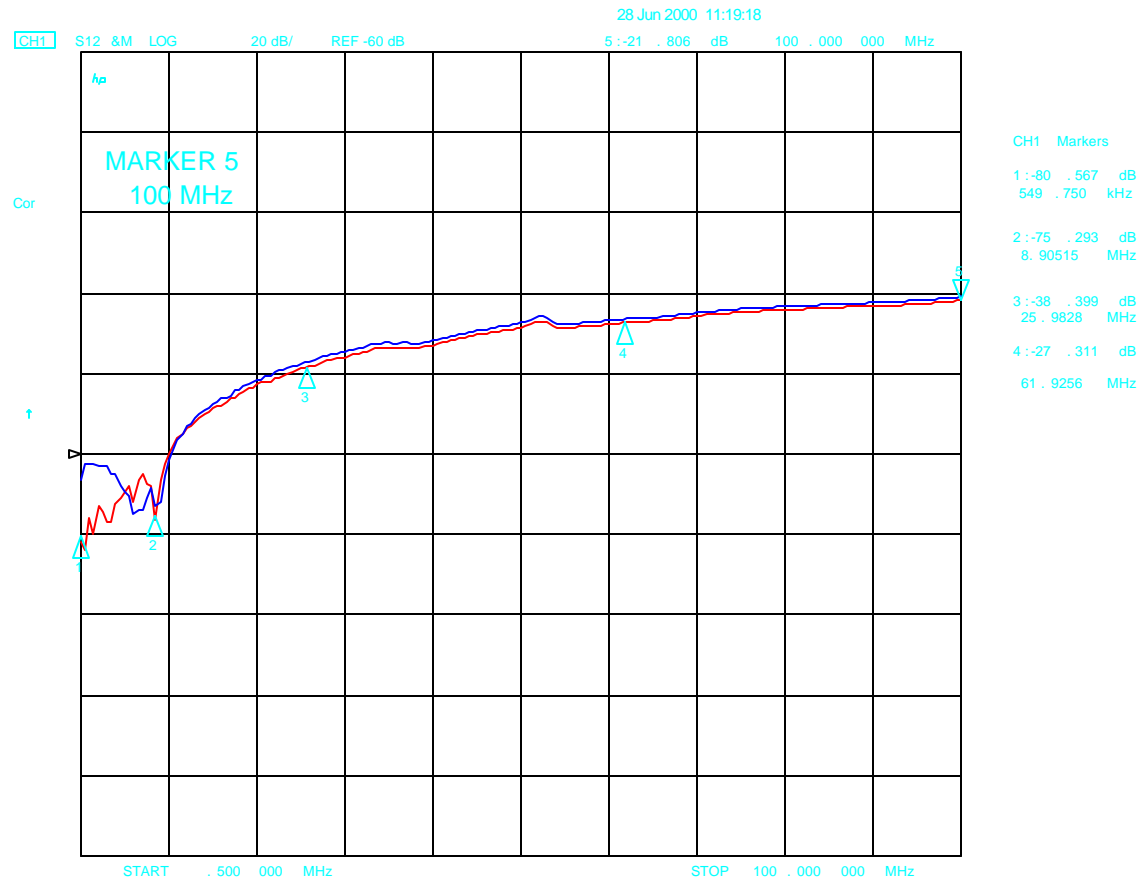
**Tx Common Mode to Differential, Wire Side I = 0, I = 300 mA**

# Signal Quality Measurements Magnetics



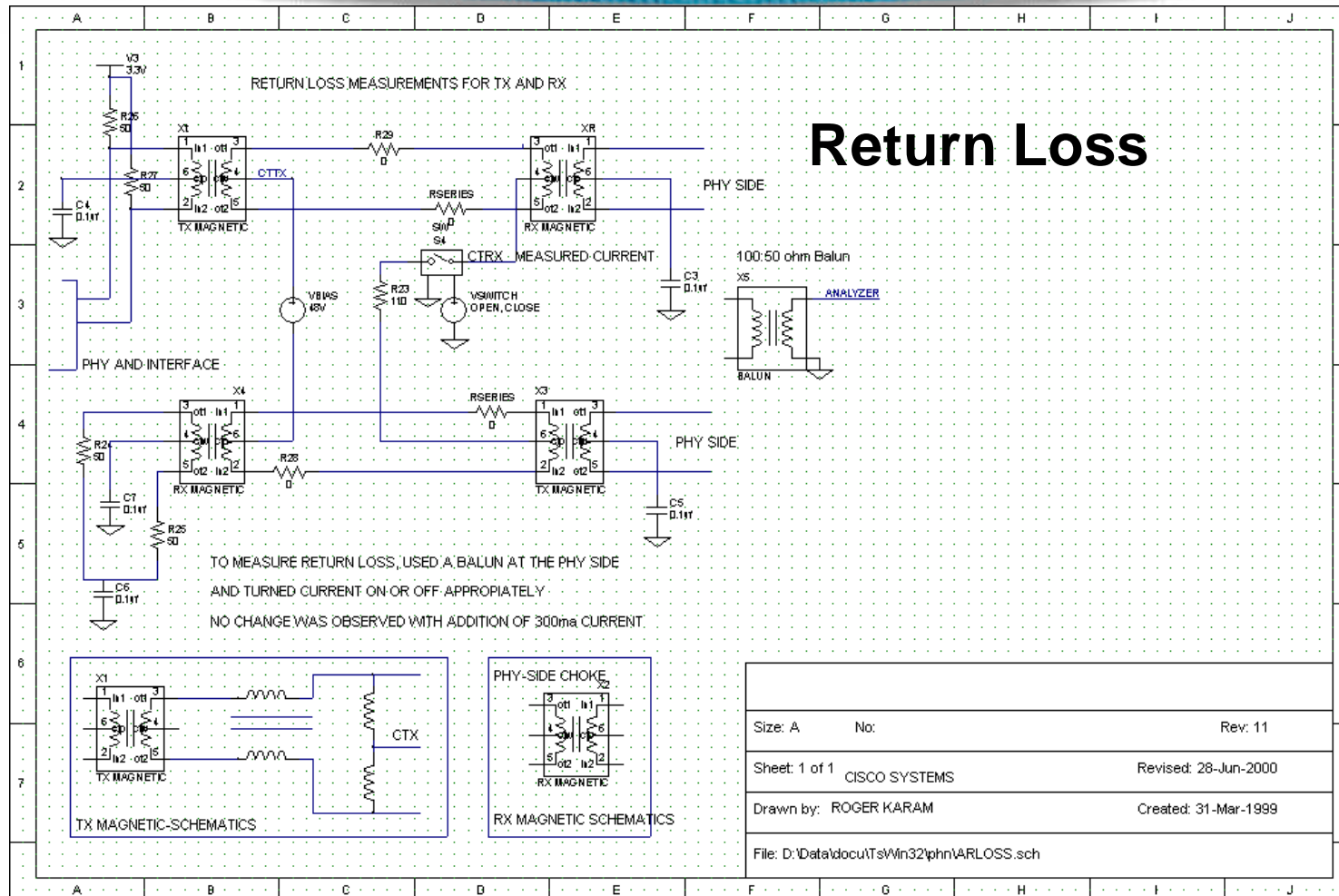
**Tx Common Mode to Differential Conversion, Wire Side,  
R = 0, R = 2.5 Ohms in series with Rx**

# Signal Quality Measurements Magnetics

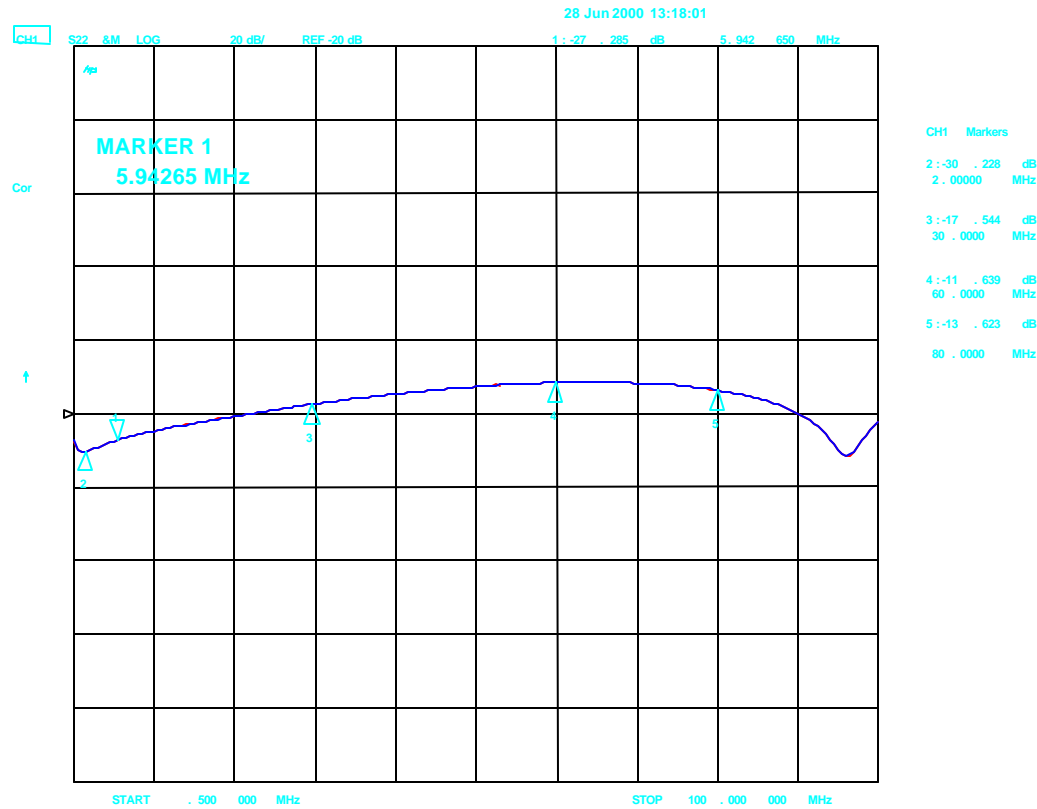


**Tx Common Mode to Differential Conversion, Wire Side,  
R = 2.5 Ohms in series with Rx, I = 0, I = 300 mA**

# Signal Quality Measurements Magnetics



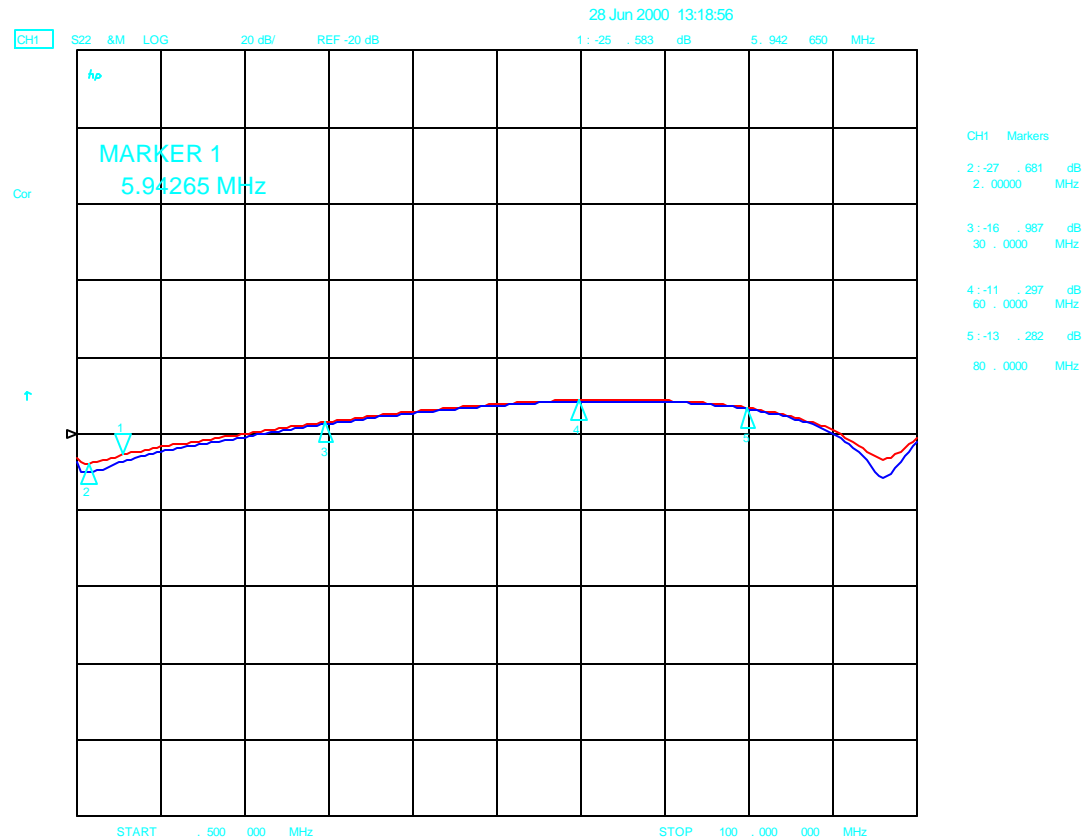
# Signal Quality Measurements Magnetics



**Return Loss, Rx, Wire Side**

**I = 0, I = 300 mA**

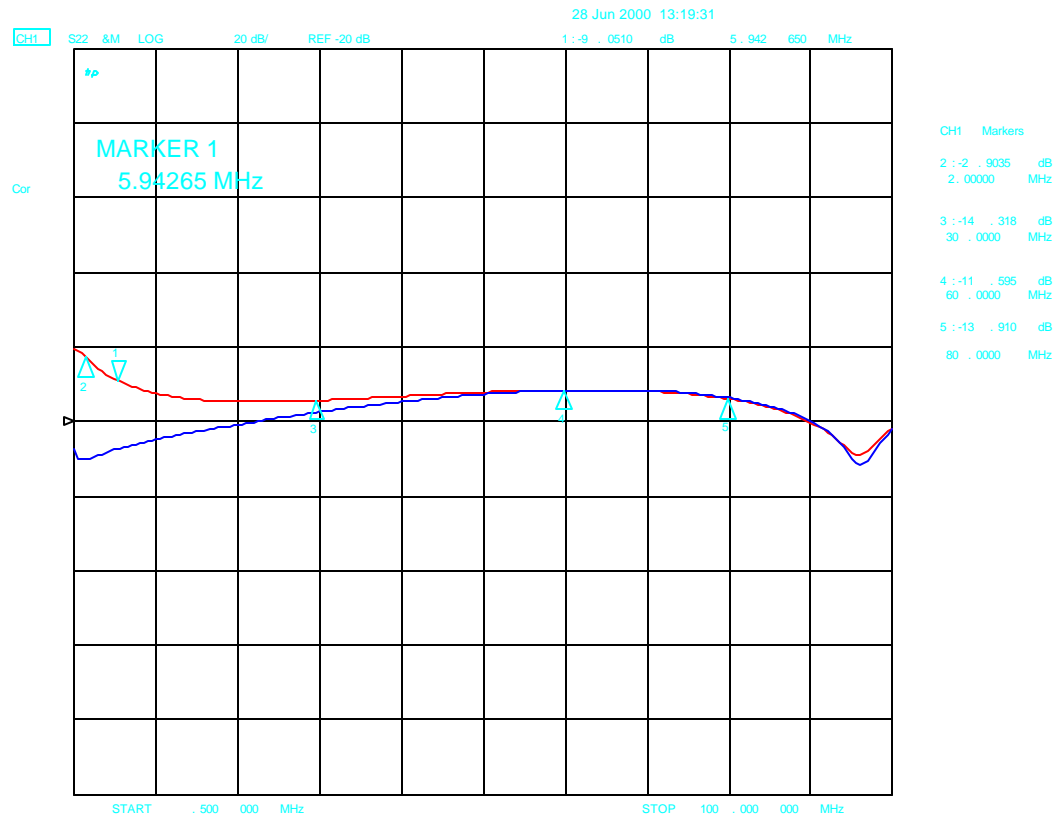
# Signal Quality Measurements Magnetics



**Return Loss, R = 0, R = 2.5 Ohms Series on RX Wire Side I = 0**

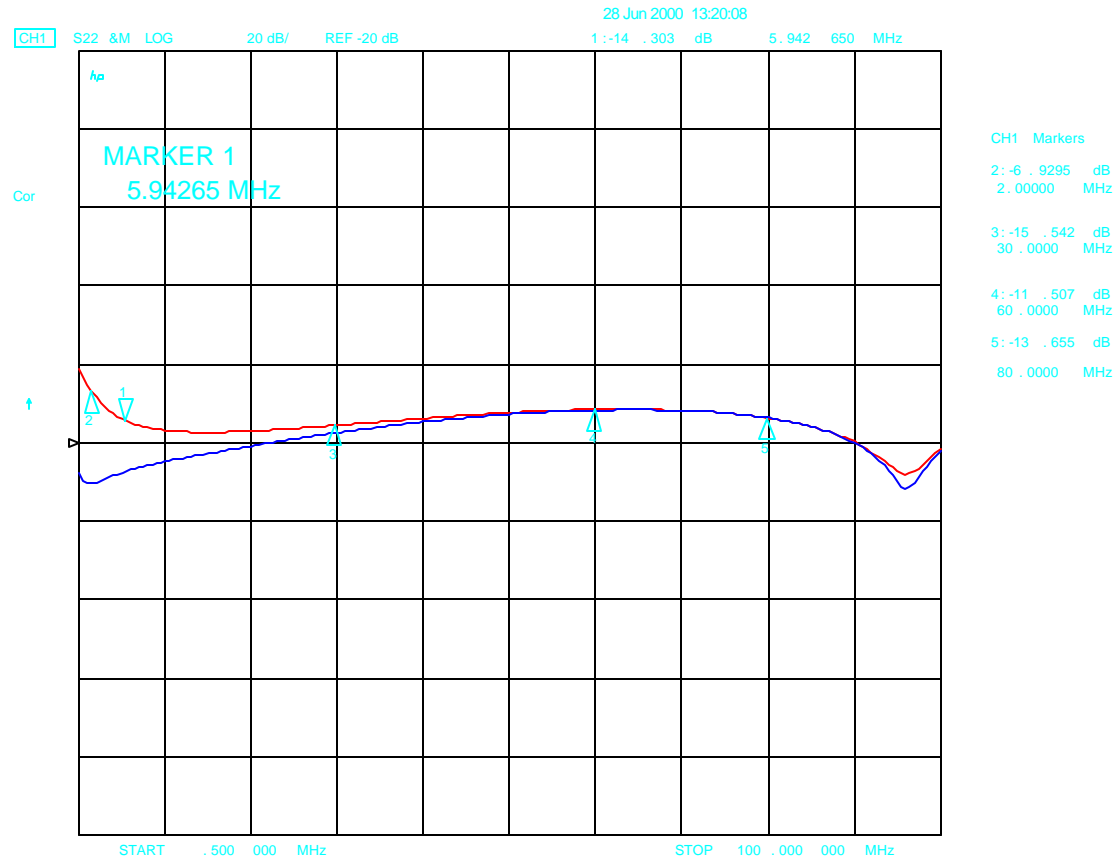


# Signal Quality Measurements Magnetics



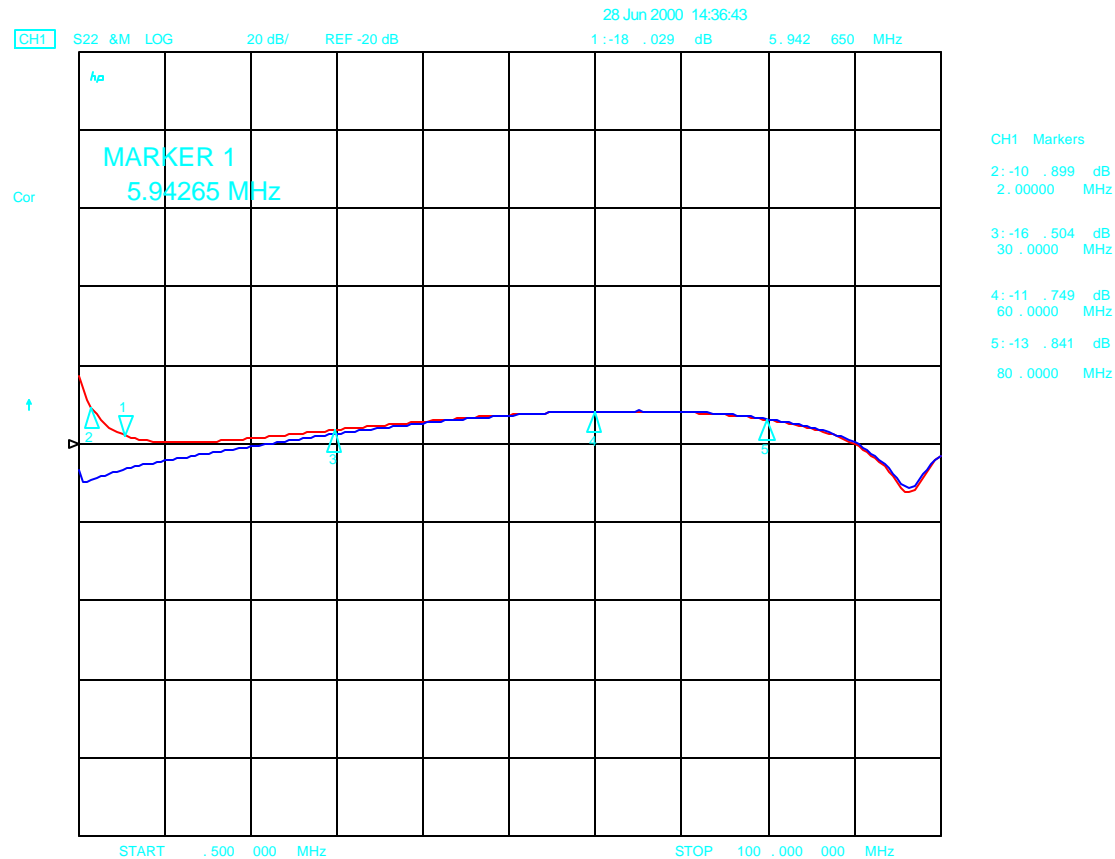
**Return Loss, R = 2.5 Ohm Series on RX Wire Side**  
**I = 0, I = 300 mA**

# Signal Quality Measurements Magnetics



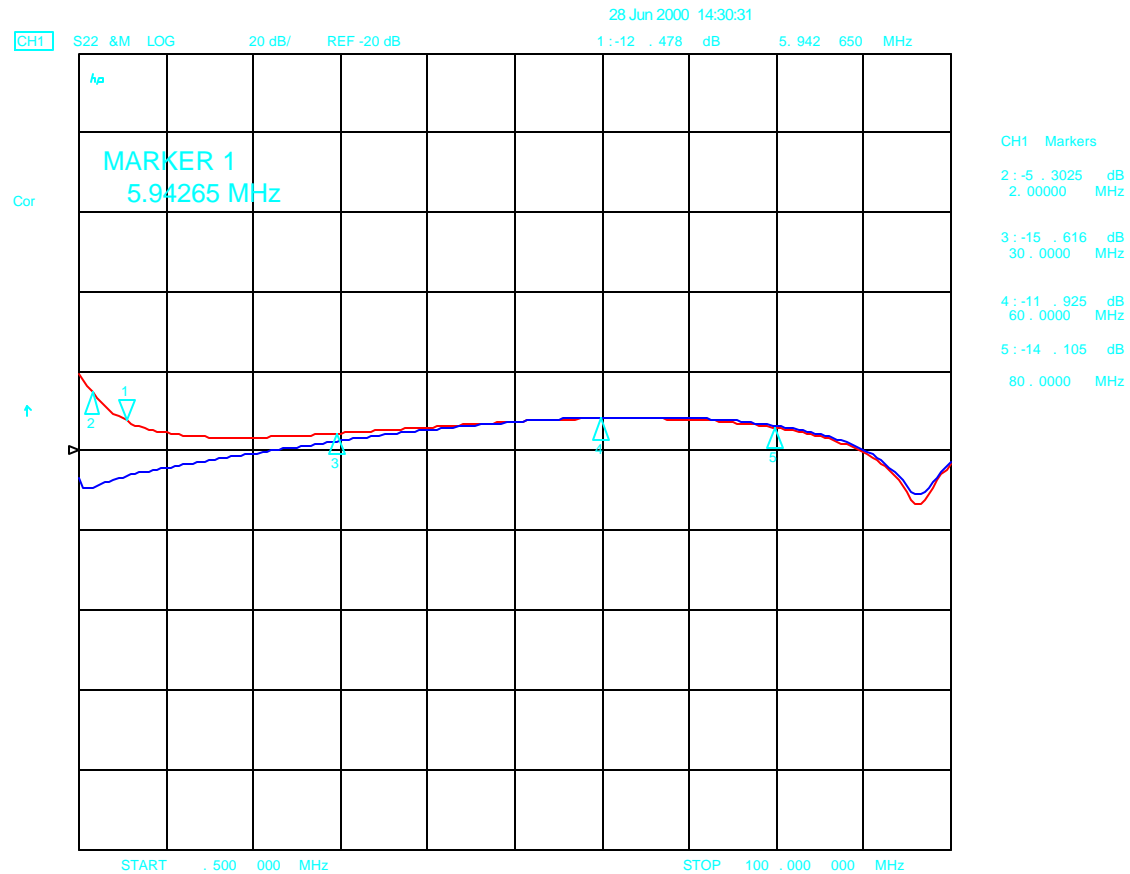
**Return Loss, R = 2.5 Ohms Series on RX Wire Side**  
**I = 0, I = 200 mA**

# Signal Quality Measurements Magnetics



**Return Loss,  $R = 1.25$  Ohms Series on RX Wire Side**  
 **$I = 0, I = 200$  mA**

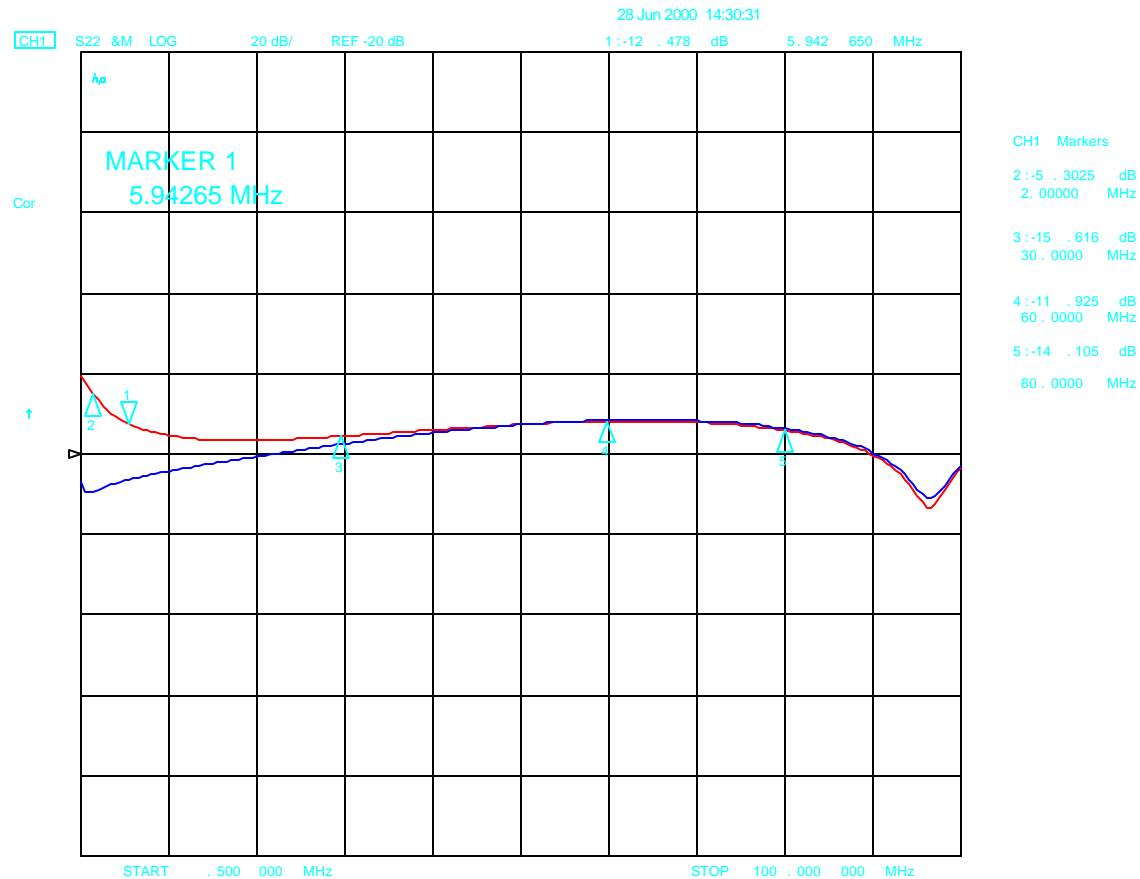
# Signal Quality Measurements Magnetics



**Return Loss, R = 1.25 Ohms Series on RX Wire Side**  
**I = 0, I = 300 mA**

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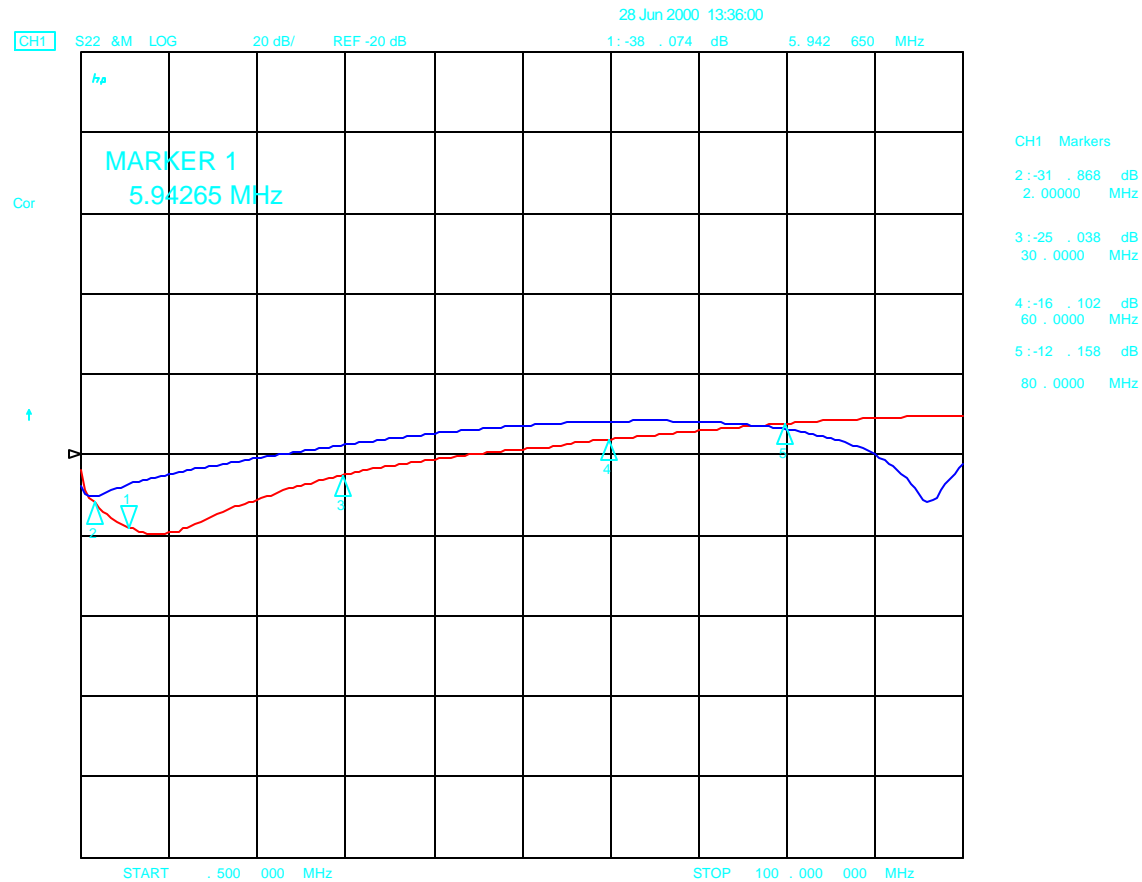
# Signal Quality Measurements Magnetics



**Return Loss,  $R = 1.25$  Ohms Series on RX Wire Side**  
 **$I = 0, I = 300$  mA**

[www.cisco.com](http://www.cisco.com)

# Signal Quality Measurements Magnetics

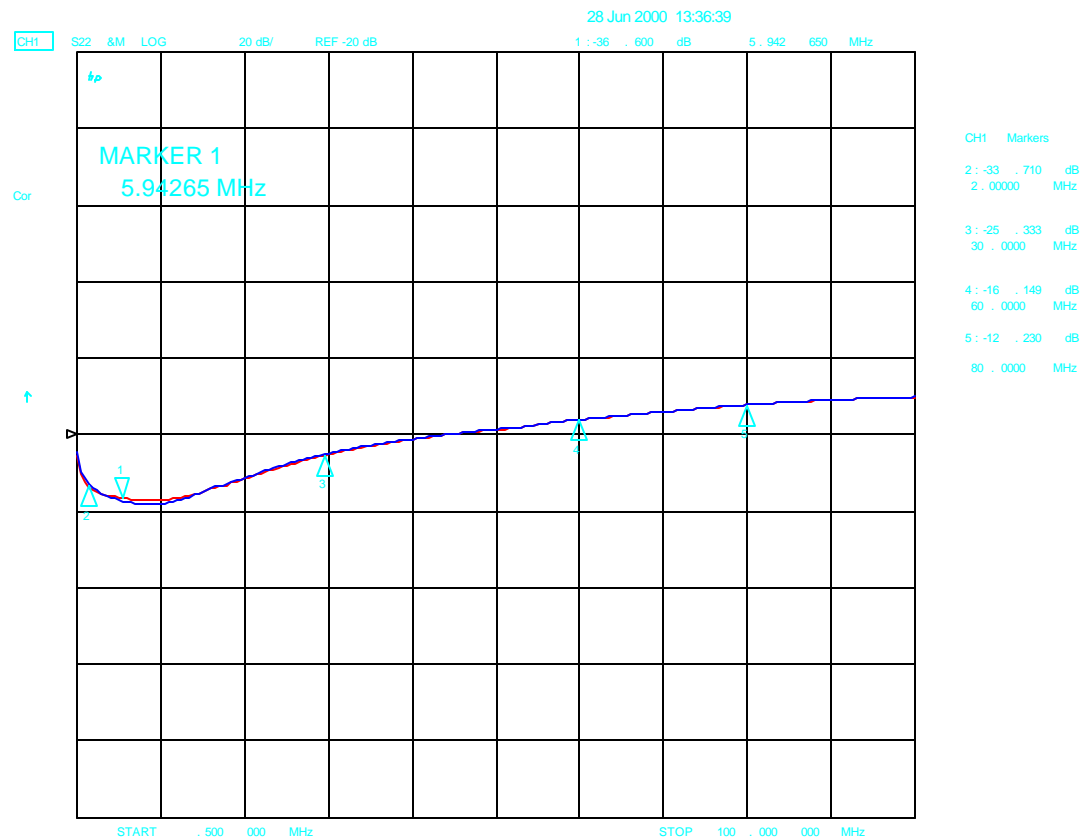


**Return Loss Compare TX Wire Side to RX Wire Side**

**I = 0**

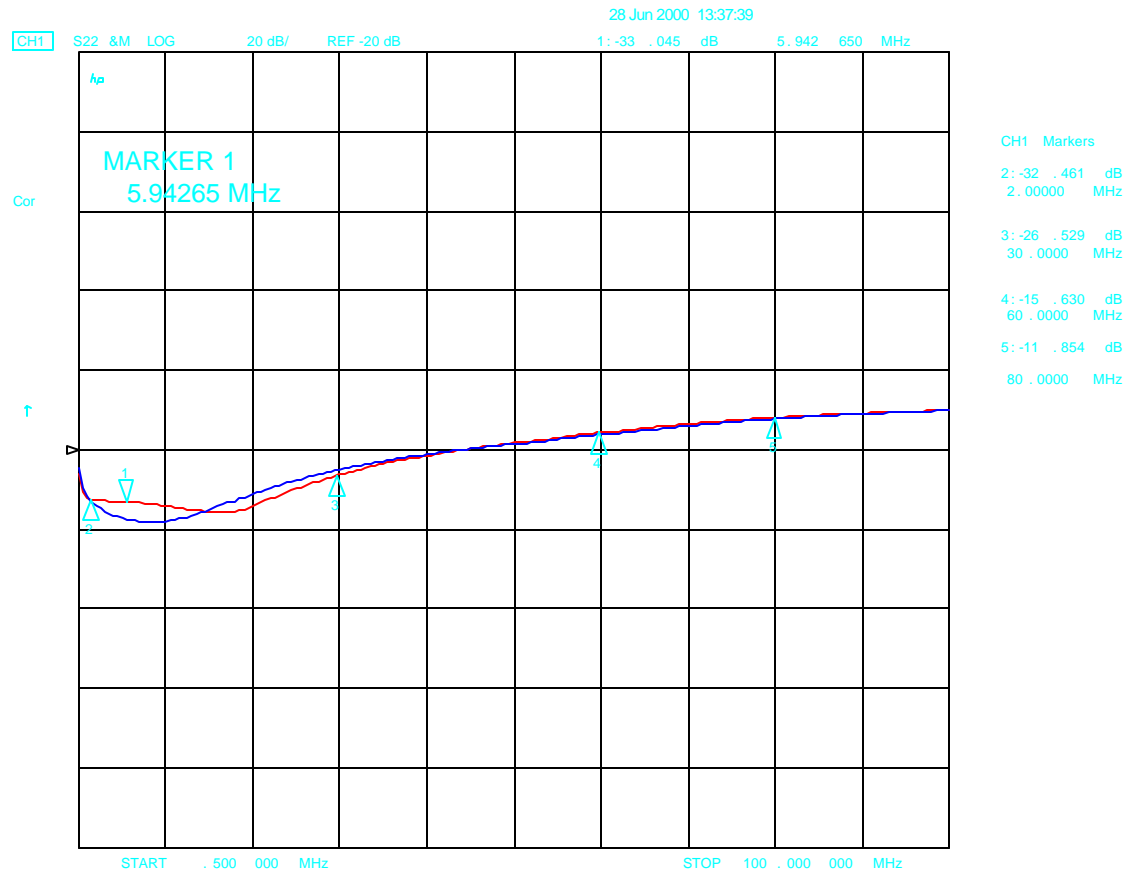
[www.cisco.com](http://www.cisco.com)

# Signal Quality Measurements Magnetics



**Return Loss, TX Wire Side, R = 0, I = 0, I = 300 mA**

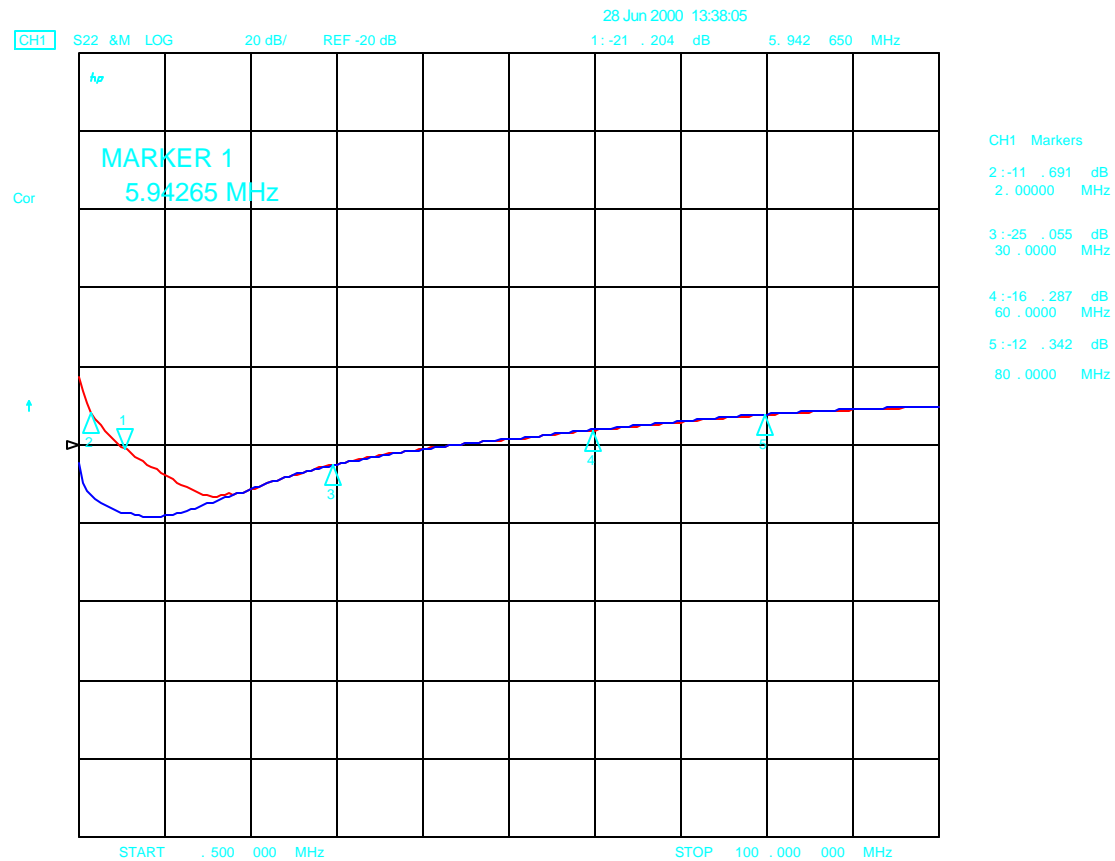
# Signal Quality Measurements Magnetics



**Return Loss, R = 0, R = 1.25 Ohm Series TX Wire Side  
I = 0**



# Signal Quality Measurements Magnetics



**Return Loss,  $R = 1.25$  Ohm Series TX Wire Side**  
 **$I = 0, I = 300$  mA**

# Summary of Common mode to differential conversion

Freq (MHz)	Rxwire (dB)	Txwire (dB)	Freq (MHz)	Pair-Pair (dB)	Pair Common-Mode (dB)	Freq (Mhz)
1	-78	-71	1	-74	-31	29
8	-60	-54	16	-54	-32	37
25	-40	-45	40	-53	-30	64
63	-29	-34	70	-47	-29	72
100	-25	-27	100	-43	-39	86

**Having a 2.5 Ohm R series with the Magnetics at 300mA degrades Conversion by 20dB at low frequency. Not an issue at -78dB**

**Pair to Pair Isolation is superior to the Common Mode to Differential conversion of the magnetic**

**Binding the 2 wires in the pair together causes isolation to approach the common mode to differential conversion of the magnetic (proved in following slides)**

# Summary of Return Loss

Freq (MHz)	RX (dB)			Tx (dB)	
	Rseries=0	Rseries=2.5	Rseries=1.25	Rseries=1.25	Rseries=0
2	-30	-3	-5	-33	-12
5	-27	-9	-13	-36	-21
30	-18	-14	-16	-25	-25
60	-12	-12	-12	-16	-16
80	-13	-14	-14	-12	-12

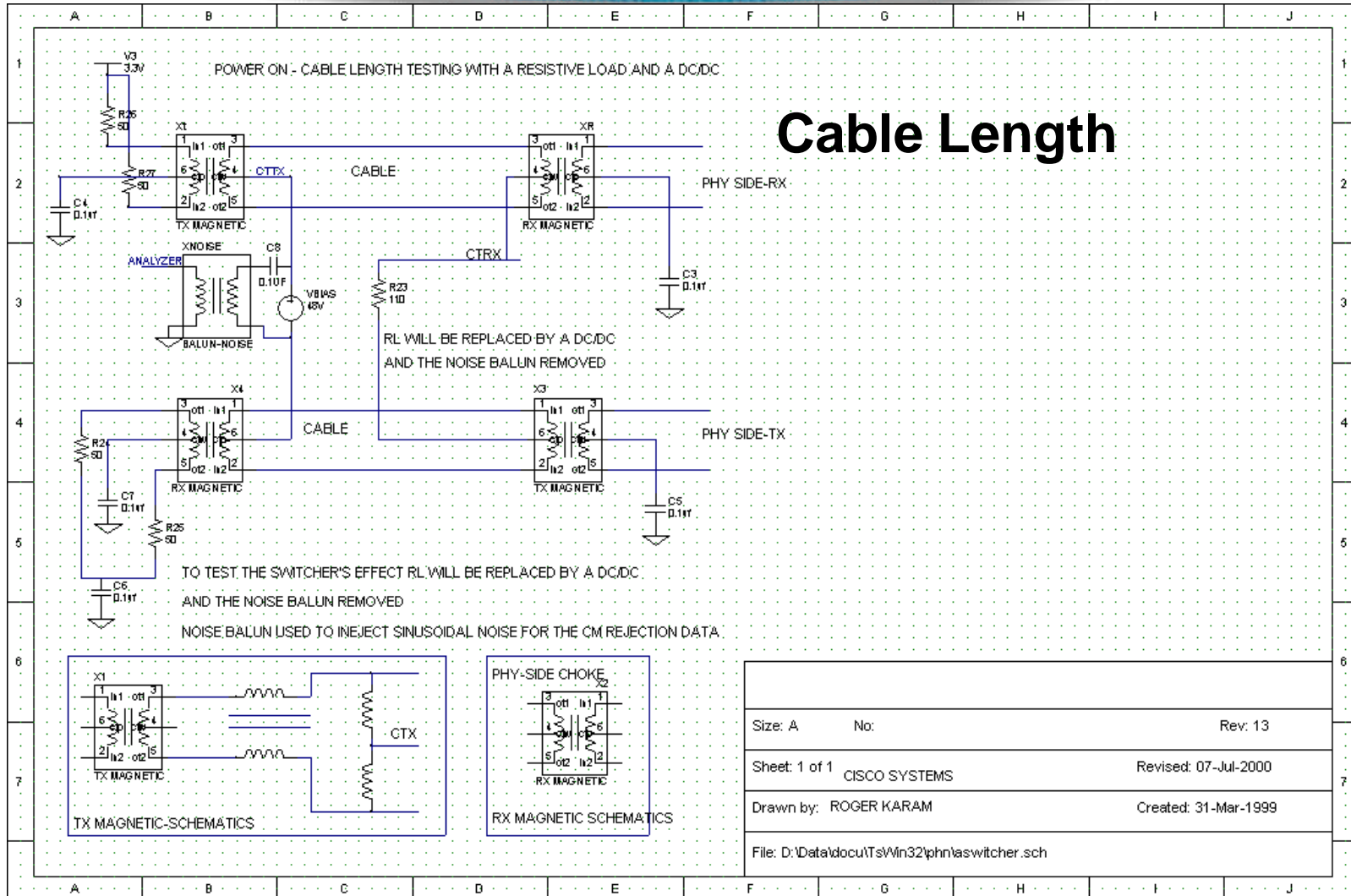
**Question raised “What happens if there is an imbalance in the cable”**

**Findings:**

- **At 1.25 Ohms, 300 mA no errors after 8m length**
- **At 1.25 Ohms, 240 mA no errors after 1m length**
- **For 8m cable 1.25 Ohms is a 50% imbalance**

# Operational Characteristics BER and Switching Noise

## Cable Length



# Operational Characteristics

## BER and Switching Noise

- **10 Million Packets per Test**
- **Covered 2 PHY/ 2 Magnetic Vendors**
- **10 and 100 Mbit/s Testing**
- **Random Data Random Length Packets**
- **Switching Power Supplies**
  - 6 Watt Production 48 V to 3.3/1.8 V Supply
  - 50W 1/2 a Brick 48 V to 5 V Supply
- **Testing With and Without Switcher Filtering and EMI results**

# Operational Characteristics, Results

Condition	Cable Length	Errors, Source	Errors, Load
PHY One / Magnetic One			
Power OFF, RL=110 ohms see <b>schematic</b> max cable reach=163M	163M	0	0
Power ON 300 mA , RL=110 ohms	163M	0	0
Power ON, RL = 110ohm	167M	318	0
Power OFF, RL = 110ohm	167M	315	
Power OFF, 6 Watt DC/DC replaces RL	167M	322	0
Note that no Filter exist at the input of the DC/DC in all my testing unless I say.			
Power OFF, 6 Watt DC/DC Rerun	167M	323	0
Power ON 6 Watt DC/DC	167M	295	0
Power ON 6 Watt DC/DC- Rerun test	167M	308	0

**Conclusion: 6 Watt Switcher has no effect with or without Power, without Filter**

# Operational Characteristics, Results

Condition	Cable Length	Errors, Source	Errors, Load
PHY One/Magnetic One			
No Power, No Load	163M	0	0
Power Off, 50 Watt Switcher Load Connected (Test 1/Test 2= a repeat)	167M	344 / 334	0 / 0
50 Watt Switcher (No Input Filter) with 300 mA Load (Test 1/Test 2)	167M	2599 / 1417	<b>108243 / 115988</b>
50 Watt Switcher (No Input Filter) with 300 mA Load (Test 1/Test 2)	156M	0 / 1	106 / 126
50 Watt Switcher (No Input Filter) with 300 mA Load (Test 1/Test 2)	140M	0 / 0	7 / 5
50 Watt Switcher (No Input Filter) with 300 mA Load (Test 1/Test 2)	135M	0 / 0	0 / 0
So We Lost 28M Due to this Switcher			

**Conclusion: 50 Watt Switcher has no effect without Power, Needs Filtering With Power On**

# Operational Characteristics, Results

Condition	Cable Length	Errors, Source	Errors, Load
Phy One, Mag One			
No Power, No Load	163M	0	0
Power Off, 50 Watt Switcher Load Connected (Test 1/Test 2)	167M	344 / 334	0 / 0
50 Watt Switcher (With Input Filter) with 300 mA Load (Test 1/Test 2/Test 3)	167M	100/10 / 0 / 385	0 / 0 / 0
50 Watt Switcher (With Input Filter) with 300 mA Load (Test 1/Test 2/Test 3)	163M	0 / 0 / 0	0 / 0 / 0

**Conclusion: 50 Watt Switcher With Filtering To Pass FCC Causes No Operational Effects on BER at Long Cable Lengths (28 Meter Loss Restored)**



# Operational Characteristics, Results

Condition	Cable Length	Errors, Source	Errors, Load
PHY Two Magnetic Two			
Power OFF, RL=110 ohms see schematic max cable reach=148m	148M	0/0/0	0/0/0
Power ON 300 mA , RL=110 ohms	148M	1/0/0	0/0/2
Power OFF, RL = 110ohms	156M	0/0/0	0/5/0
Power OFF, RL = 110 ohms	163M	0/0/0	<b>60/34/15</b>
Power OFF, 6 Watt DC/DC replaces RL Note that no Filter exist at the input of the DC/DC in all my testing unless I say.	148M	0/0/0	0/0/0
Power ON 6 Watt DC/DC	148M	0/0/0	1/0/0
Ran 100 Million packets Power OFF/ON	148M	0/0	0/2
Power ON 6 Watt DC/DC- Rerun test	163M	0/0/0	32/34
10BT 5 Million Packets of CAT-3	128M	0	0
10BT Ran 5 million packets CAT-5	148M	0	0

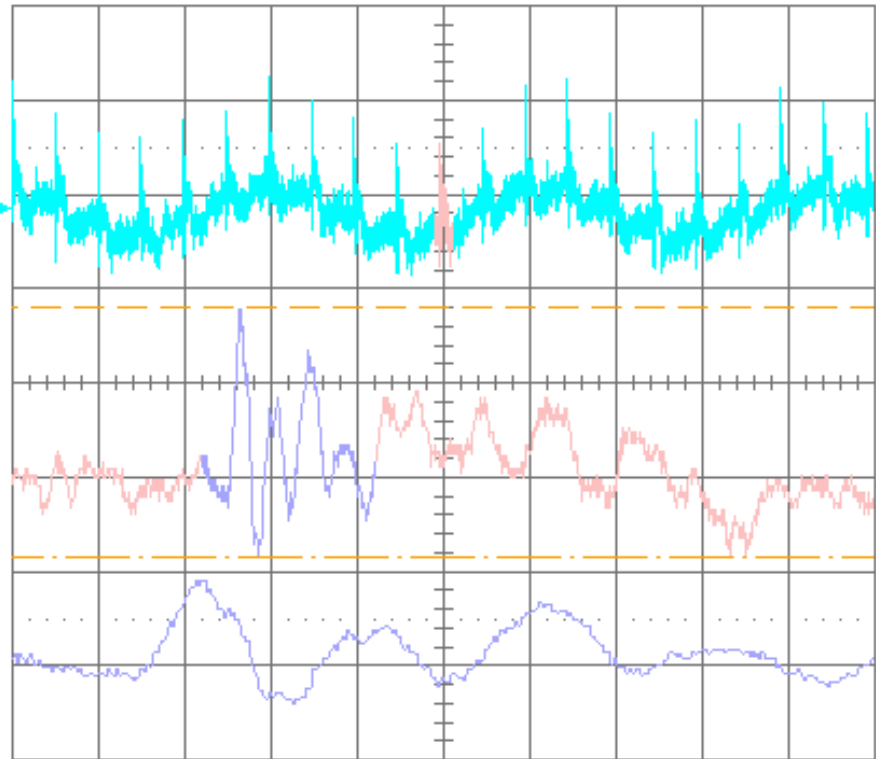
# Signal Quality Measurements BER and Switching Noise

1-Jul-00  
10:27:41

**C:4**  
.1  $\mu$ s  
100mV  
264mV

**4**  
5  $\mu$ s  
200mV  
529mV

**B:C**  
20 ns  
200mV  
529mV



5  $\mu$ s  
**1** .5 V 50 $\Omega$   
**2** .5 V 50 $\Omega$   
**3** 10 mV AC  $\times$   
**4** 20 mV AC  $\times$



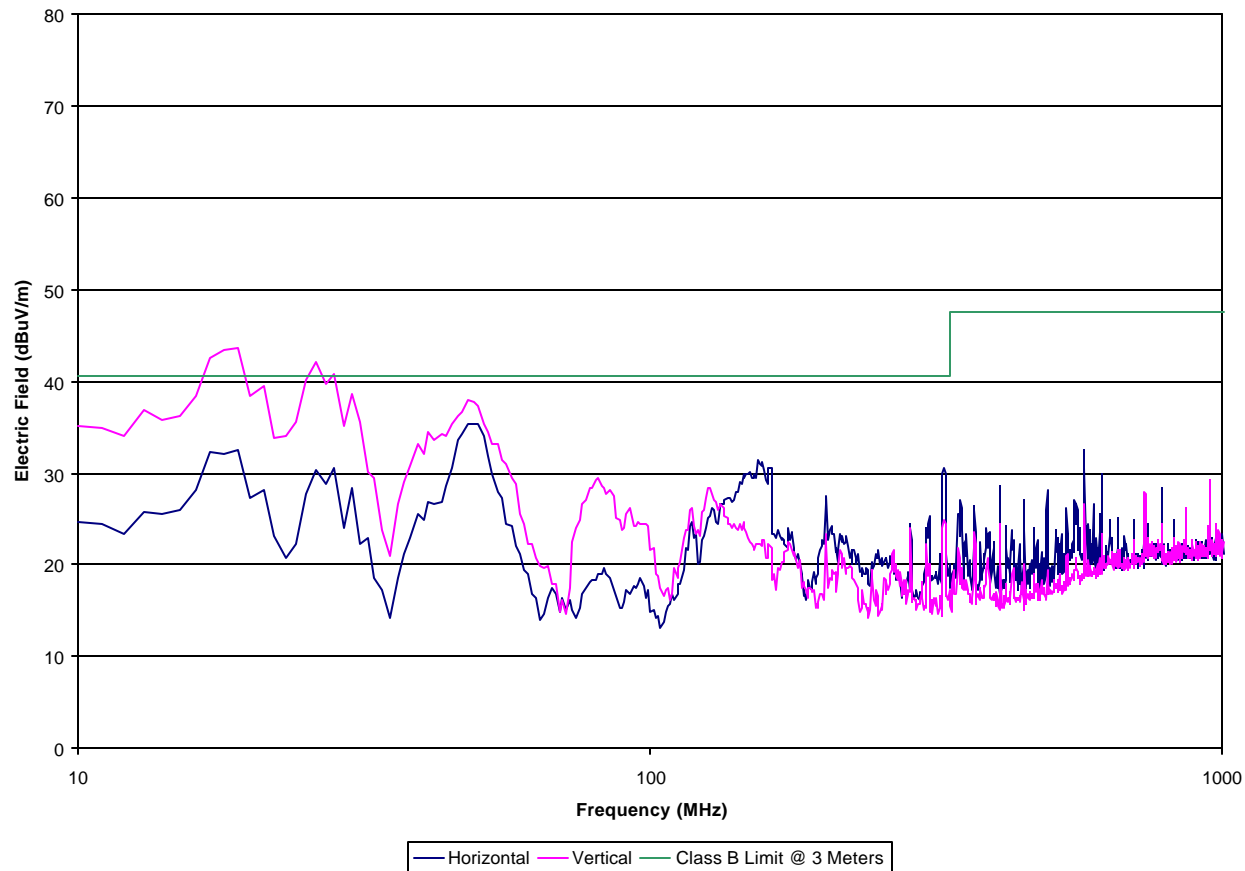
**4** DC 0.048 V

2 GS/s  
SLOW TRIGGER  
 NORMAL

**6 Watt Switching Noise (Unfiltered) at Tx Center Tap**

# Signal Quality Measurements BER and Switching Noise

Cable Attached



**6 Watt Switching Noise FCC Scan, Fails Class B, with  
Unchanged BER at Cable Length**

# Operational Characteristics, Results

Condition	Cable Length	Errors, Source	Errors, Load
Phy Two/Magnetic Two			
No Power, No Load	148M	0	0
Power Off, 50 Watt Switcher Load Connected(Test 1/Test 2= a repeat)	148M	0 / 0	0 / 0
50 Watt Switcher(No Input Filter) with 300 mA Load (Test 1/Test 2/test3)	148M	0/0/0	<b>136/29/40</b>
50 Watt Switcher(No Input Filter) with 200 mA Load (Test 1/Test 2)	148M	2/0	<b>3423/3245</b>
50 Watt Switcher(No Input Filter) with 200 mA Load (Test 1/Test 2)	124M	11/2	0/0
50 Watt Switcher(No Input Filter) with 200 mA Load (Test 1/Test 2 /Test 3)	103M	0/00	1/0/0
50 Watt Switcher(No Input Filter) with 200 mA Load (Test 1/Test 2 /Test 3)	100M	1/0/0	0/0/0
50 Watt Switcher(No Input Filter) with 200 mA Load (Test 1/Test 2)	92M	0 / 0	0 / 0
Decided to Stick with Wcase Noise 200ma load here- we lost a good 48M			

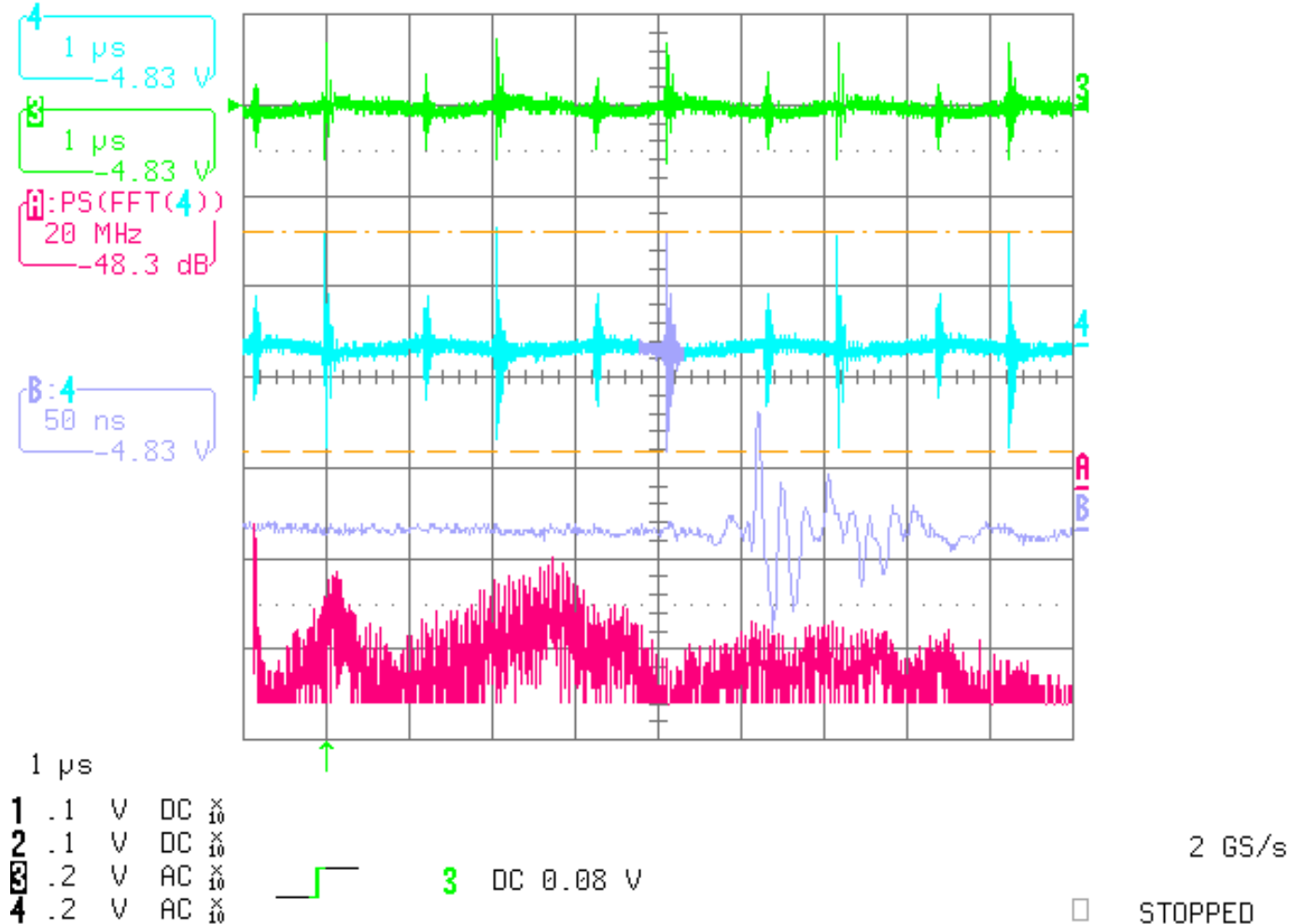
# Operational Characteristics, Results

Condition	Cable Length	Errors, Source	Errors, Load
Phy Two, Mag Two			
No Power, No Load	148M	0	0
Power Off, 50 Watt Switcher Load Connected(Test 1/Test 2)	148M	0/0	0 / 0
50 Watt Switcher(With Input Filter on one center tap) with 200 mA Load (Test 1/Test 2) Stuck to 200mA- Wcast noise!	148M	202/172	0 / 0
50 Watt Switcher (With Input Filter on Both Center taps) with 200 mA Load (Test 1/Test 2)	148M	0 / 0 / 0	0/0/1
100 Million Packets at 200ma w/ Filter on both Center taps next to DC/DC	148M	0	0
100 Million Packets at 300ma w/ Filter on both Center taps next to DC/DC	148M	0	1

**Conclusion: A Filter on the Switcher Input Restores Link Integrity**

# 50 W Switching Noise, Reference

23-Jun-00  
20:56:12

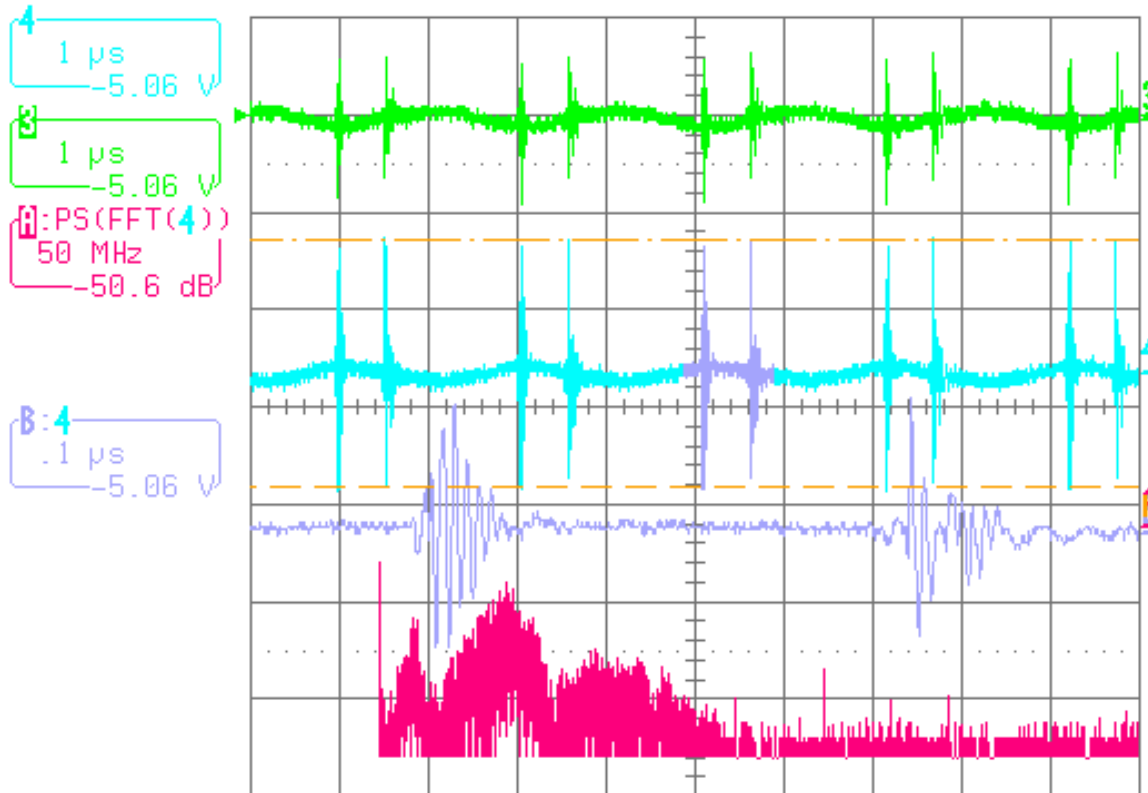


**50 Watt Switching Noise (Unfiltered) at 300 mA**

# 50 W Switching Noise, Reference

23-Jun-00  
21:00:55

Reading Floppy Disk Drive



1 µs

1	.1	V	DC	$\times 10$
2	.1	V	DC	$\times 10$
3	.2	V	AC	$\times 10$
4	.2	V	AC	$\times 10$



3 DC 0.08 V

2 GS/s

STOPPED

**50 Watt Switching Noise (Unfiltered) at 200 mA (There's More Noise)**

www.cisco.com

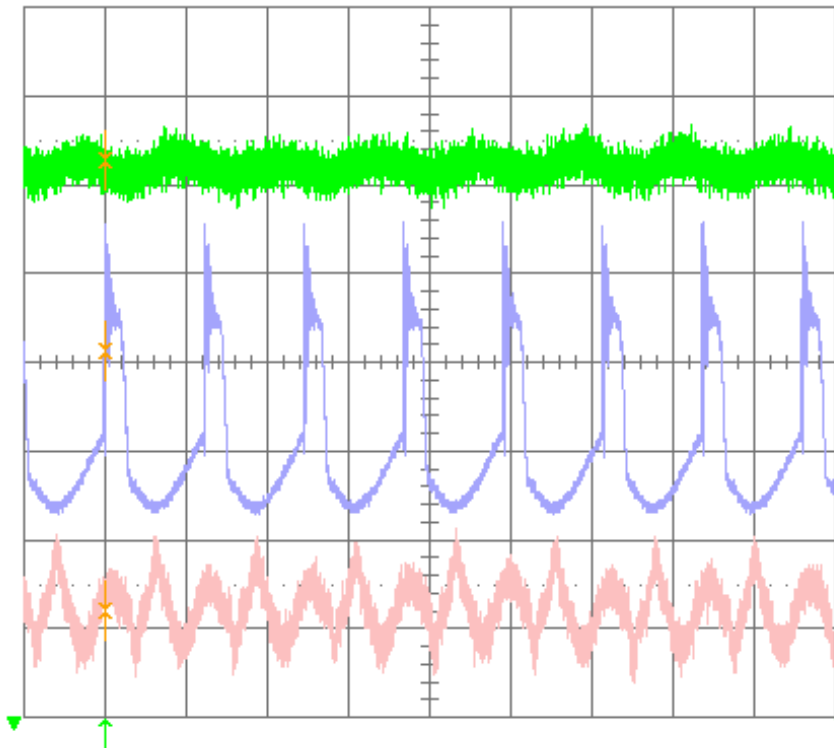
# Switching Noise: What's DC?

6-Jul-00  
18:35:33

3  
2  $\mu$ s  
20.0mV  
0.0mV

B: M2  
2  $\mu$ s  
0.50 V  
0mV

C: M3  
2  $\mu$ s  
20.0mV  
0.0mV



**Green: Choke, Cap,  
Ferrite Cap**

**Blue: Unfiltered**

**Red: Choke, Cap**

2  $\mu$ s

1 2 mV 50 $\Omega$   
2 .1 V DC  $\times$   
3 2 mV AC  $\times$   
4 .5 V AC  $\times$

$\Delta t$  0.0 ns  $\frac{1}{\Delta t}$   $\infty$

3 DC -146.0mV

2 GS/s

STOPPED

**Switching Power Supply Noise. Red is the likely best case**



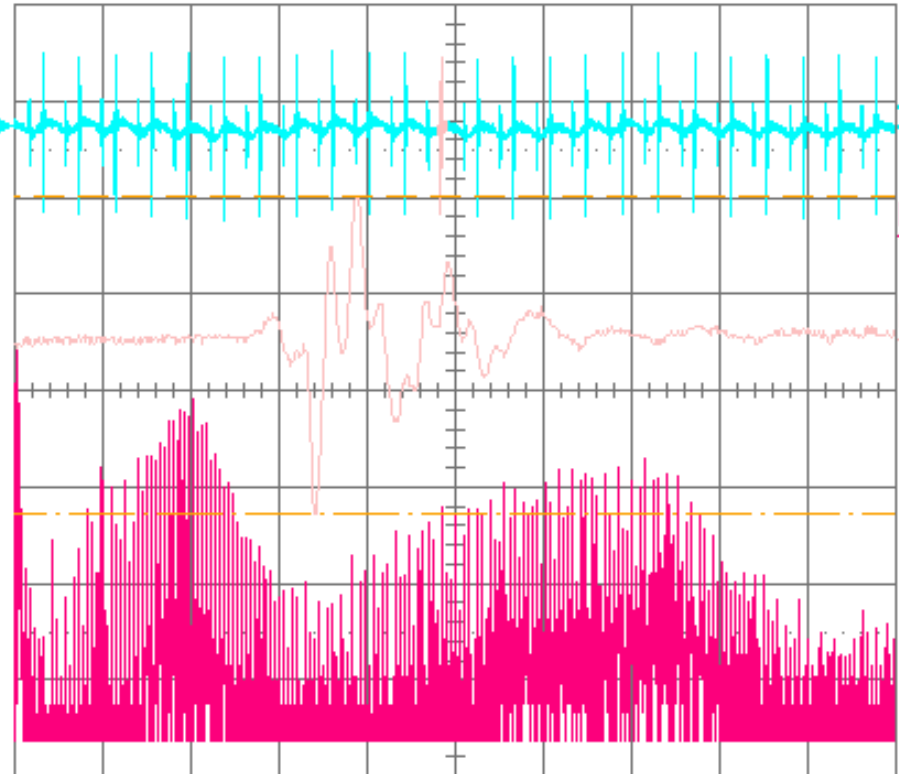
# Signal Quality Measurements BER and Switching Noise

1-Jul-00  
11:09:00

**C:4**  
50 ns  
1.00 V  
3.28 V

**A**  
5  $\mu$ s  
2.00 V  
6.56 V

**Q:PS(FFT(4))**  
10 MHz  
10.2 dBm  
33.5 dB



5  $\mu$ s

**1** .5 V 50 $\Omega$   
**2** .5 V 50 $\Omega$   
**3** 10 mV AC  $\times \frac{10}{10}$   
**4** .2 V AC  $\times \frac{10}{10}$



**4** DC 0.04 V

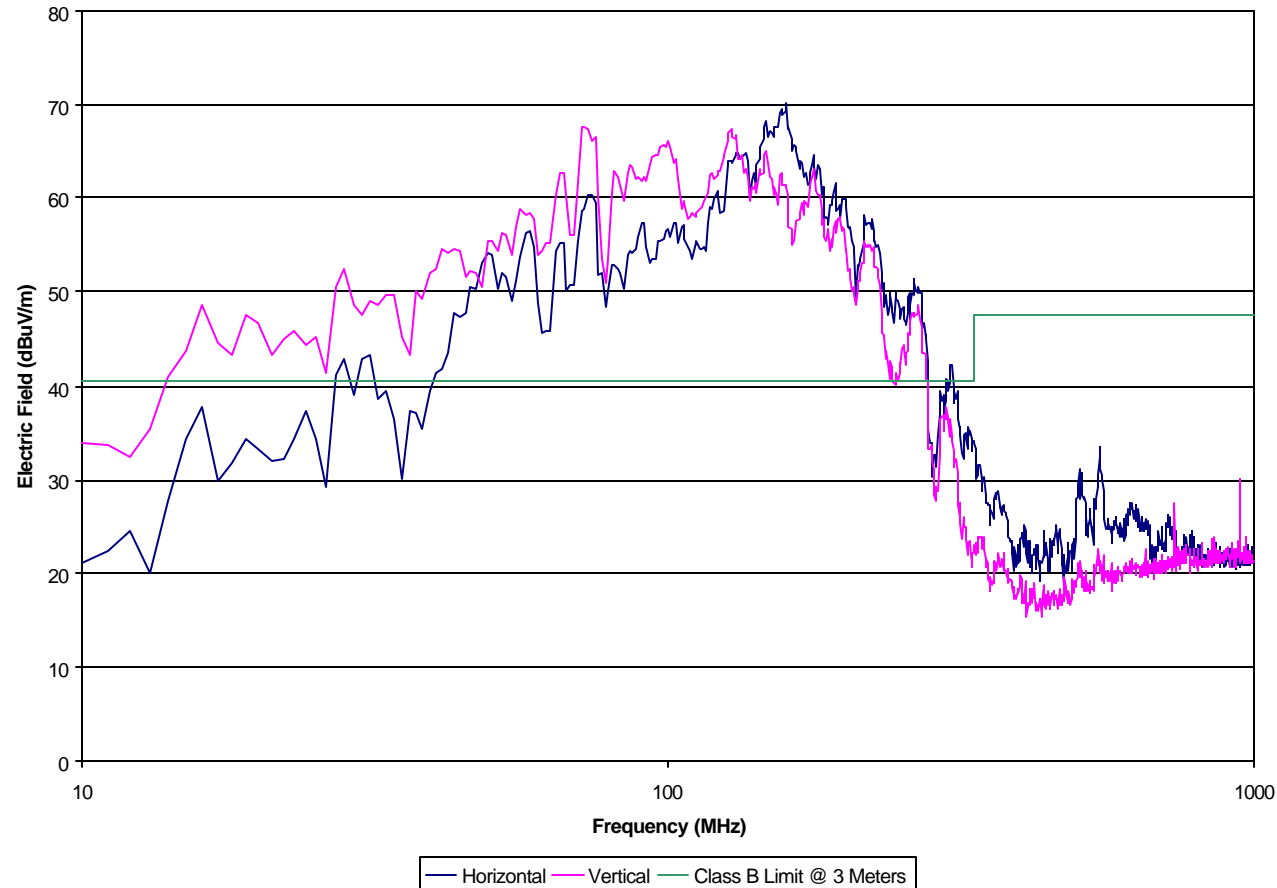
2 GS/s

STOPPED

**50 Watt Switching Noise (Unfiltered) at Tx Center Tap**

# Signal Quality Measurements BER and Switching Noise

Supply Powering DC/DC Convertor.



**50 Watt Switching Noise FCC Scan, Fails Class B, with No Input Filter, Affects BER, Reduces Cable Length**

# Signal Quality Measurements BER and Switching Noise

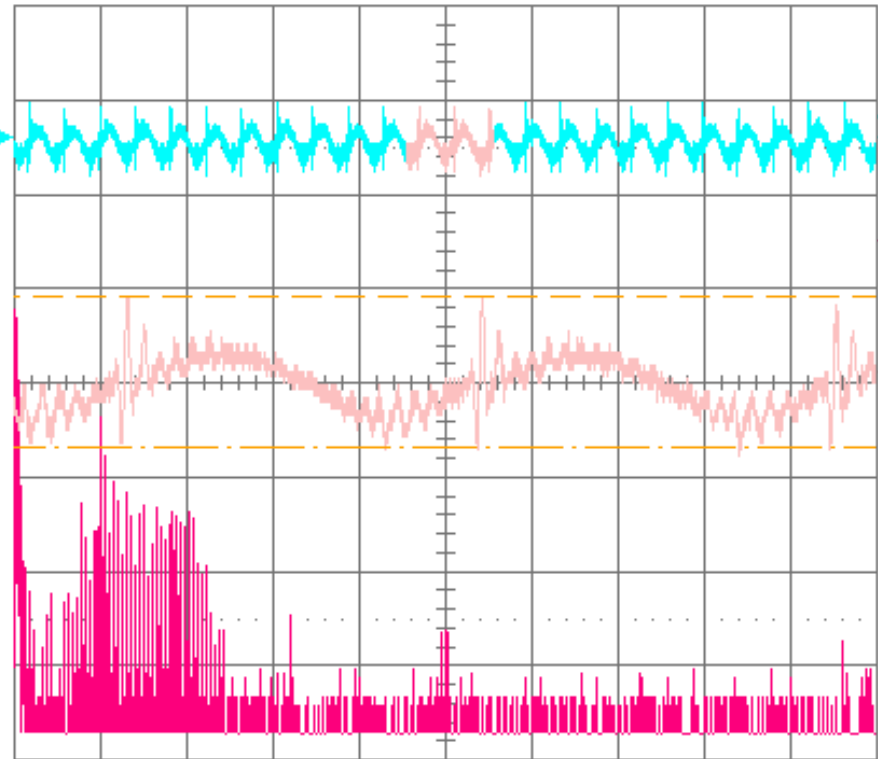
1-Jul-00  
12:30:34

Reading Floppy Disk Drive

0:4  
.5  $\mu$ s  
445mV  
0.71 V

4  
5  $\mu$ s  
1.00 V  
1.60 V

A:PS(FFT(4))  
10 MHz  
10.2 dBm  
16.3 dB



5  $\mu$ s  
1 .5 V 50 $\Omega$   
2 .5 V 50 $\Omega$   
3 10 mV AC  $\times$   
4 .1 V AC  $\times$



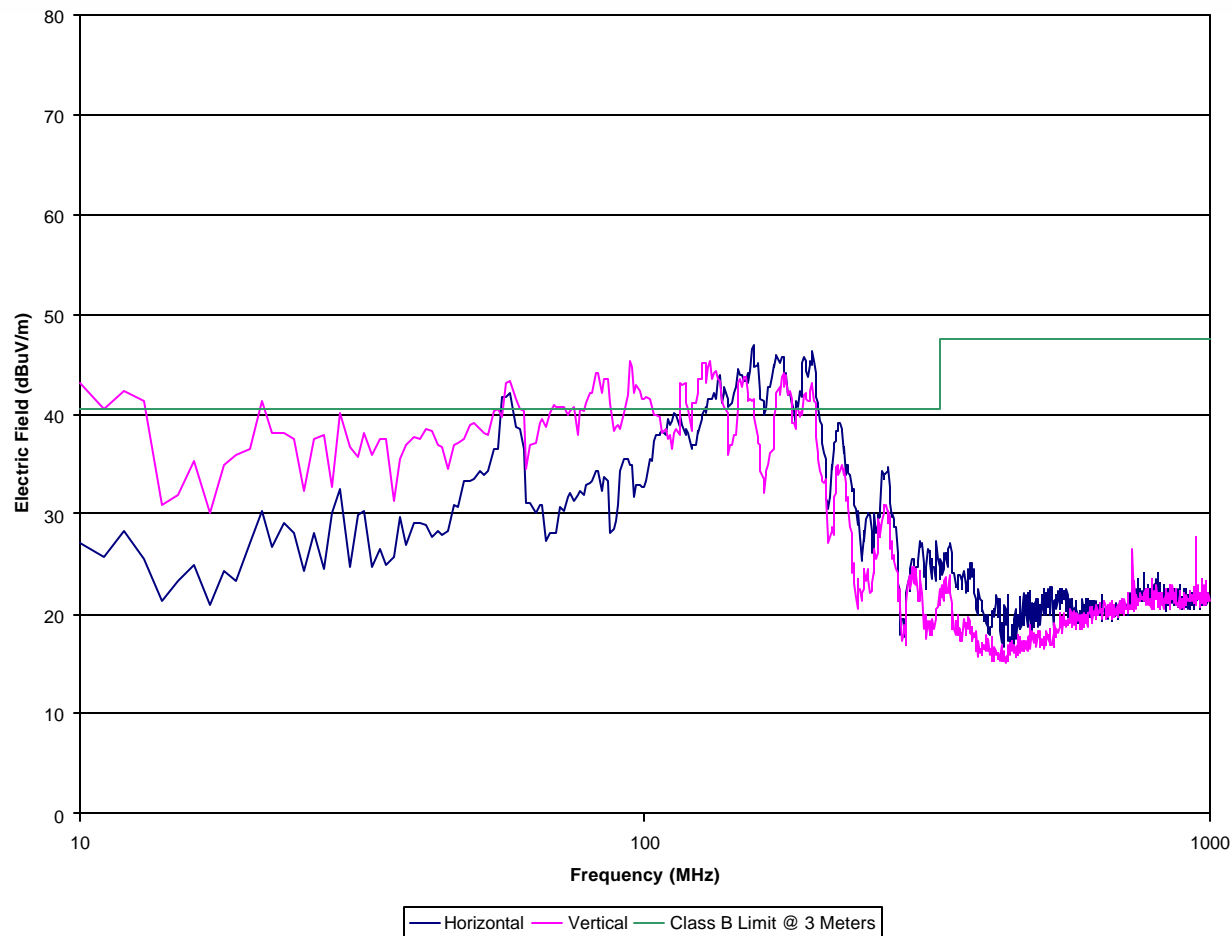
4 DC 0.02 V

2 GS/s

STOPPED

**50 Watt Switching Noise (Filtered) at Tx Center Tap**

# Signal Quality Measurements BER and Switching Noise



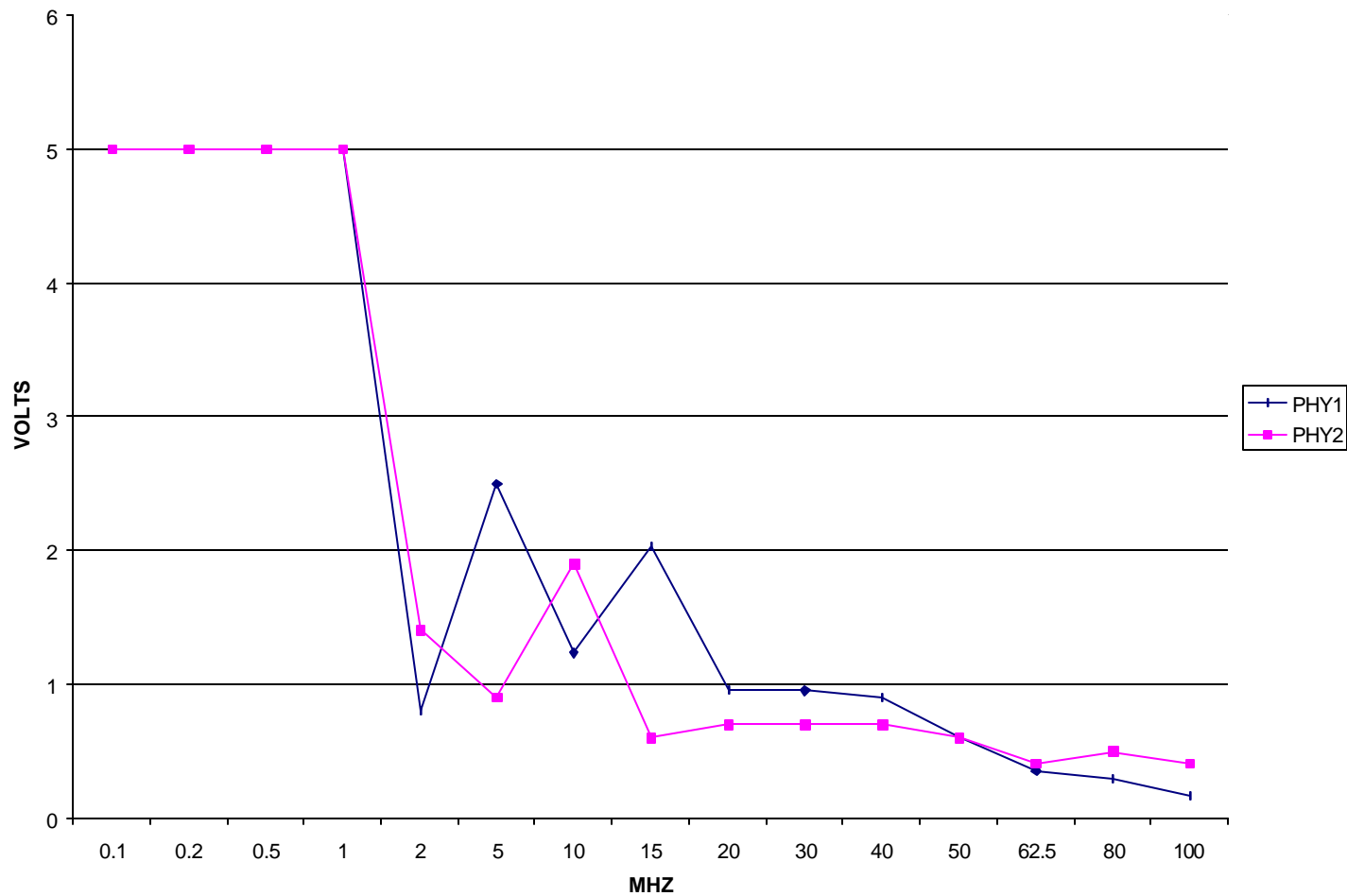
**50 Watt Switching Noise FCC Scan, Fails Class B, with Input Filter, Restore BER Performance at Maximum Cable Length**

# Signal Quality Measurements BER and Switching Noise

- **Controlled Noise Injection Study**
- **Characterize the Frequency Envelope For Common Mode Noise Immunity**

# Signal Quality Measurements BER and Switching Noise

Injected Sine Wave Amplitude At Zero Error  
Vs Freq

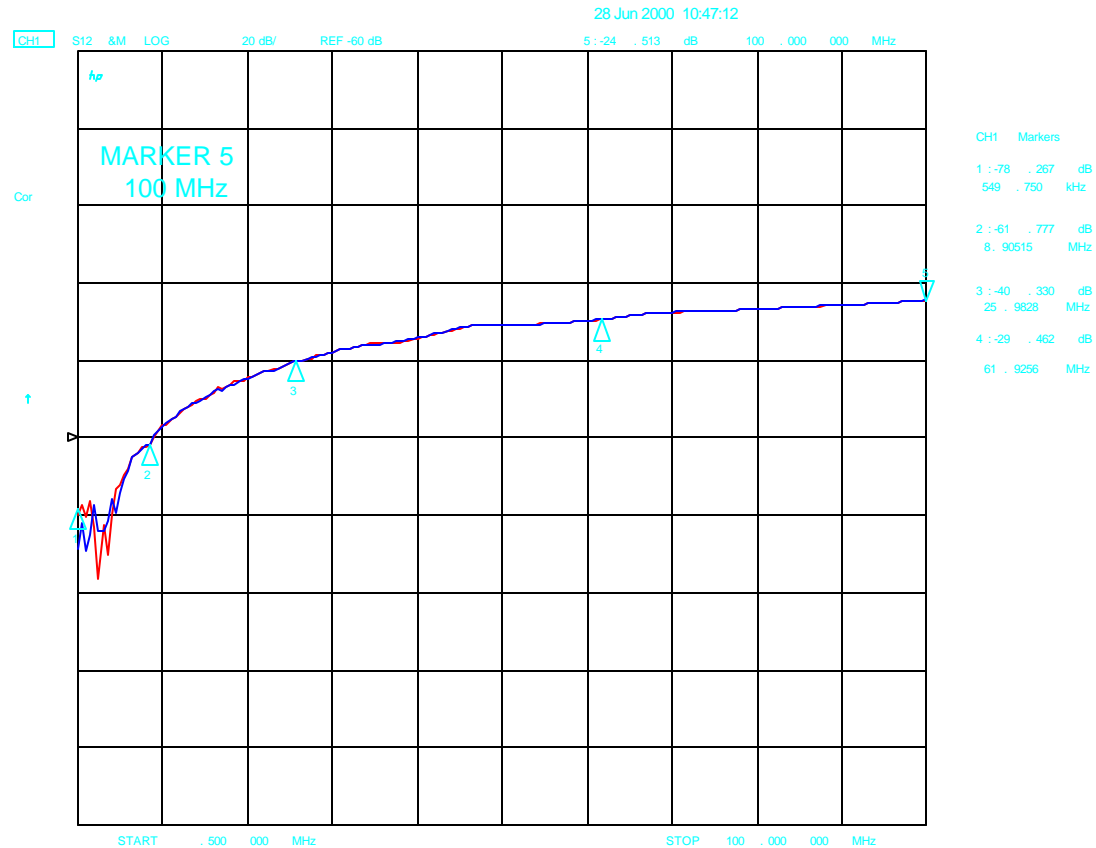


# Signal Quality Measurements

## BER and Switching Noise

- **Conclusion: With Switching Power Supply Noise on the center tap of the used pairs, the system is EMI limited, not BER or cable reach limited.**
- **Same EMI limitations with power over unused pairs (next slide)**

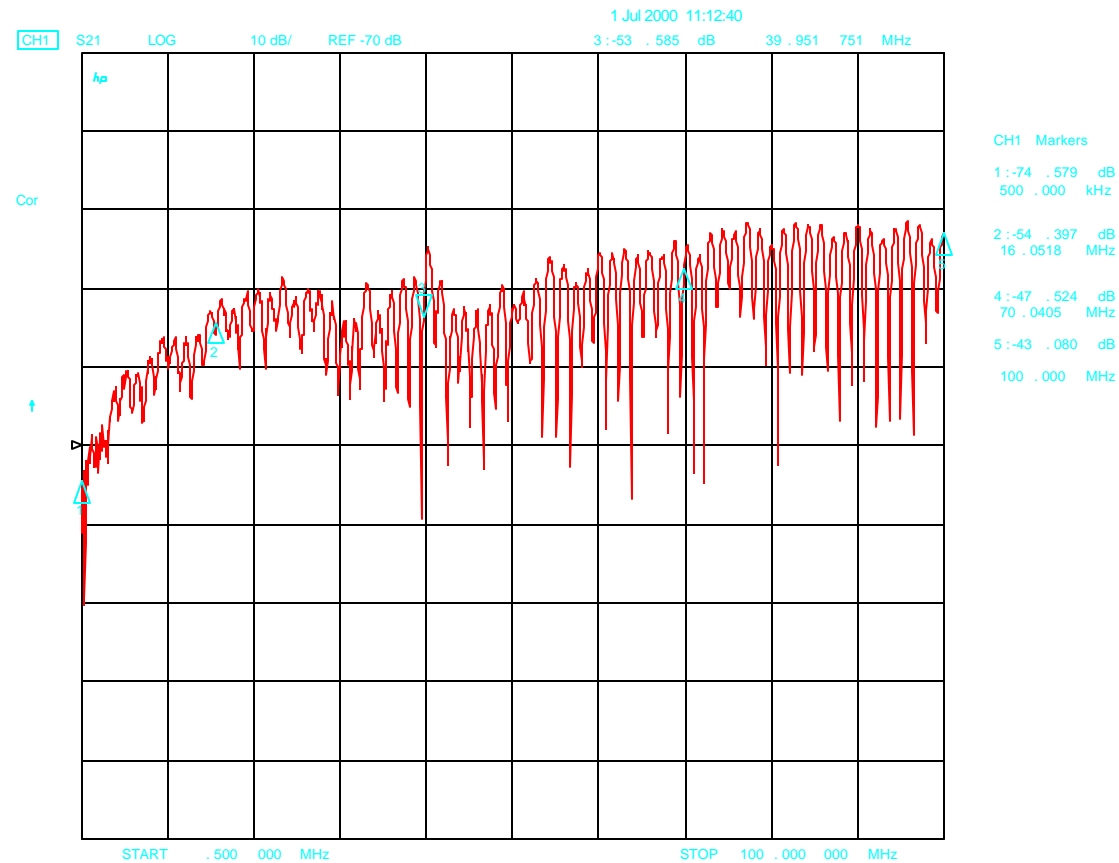
# Signal Quality Measurements Magnetics



**Common Mode to Differential Conversion, Drove Supply Side, Measure at  
PHY on the RL Side, I = 0, I = 300 mA**

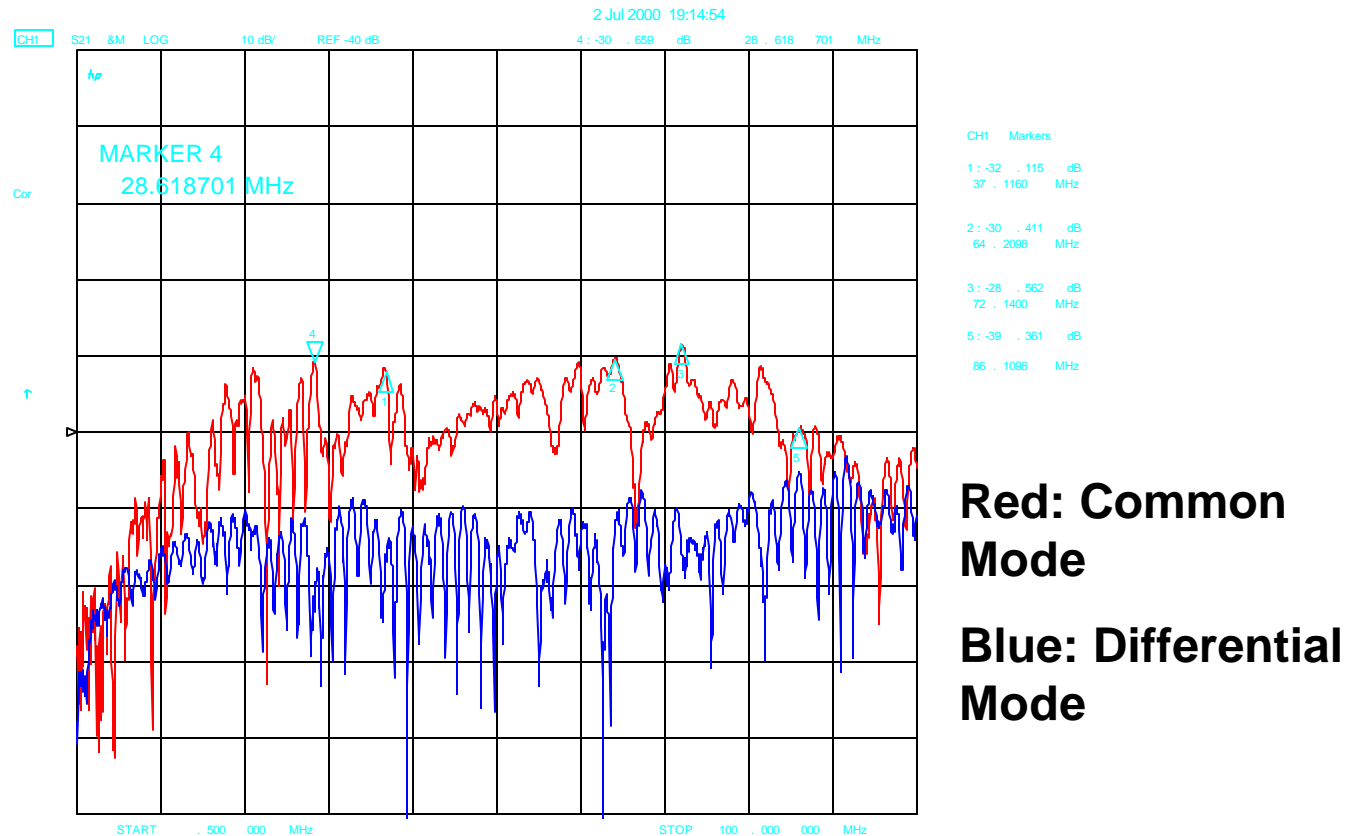


# BER and Switching Noise Effects on the “Unused” Pairs



Isolation of Differential Pairs

# BER and Switching Noise Effects on the “Unused” Pairs

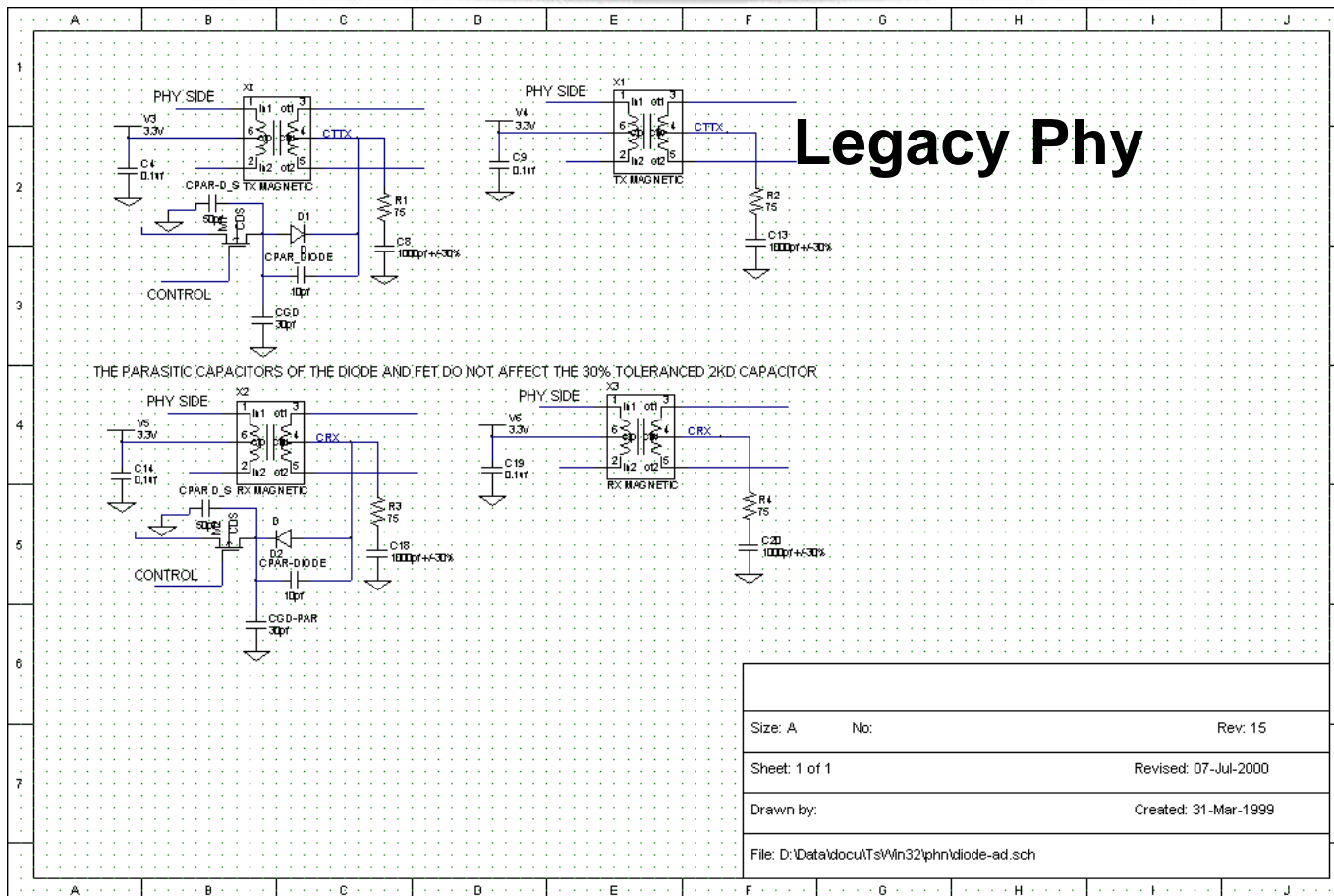


**Isolation of Differential vs Common Mode Signals on the “Unused Pair”**

# BER and Switching Noise Effects on the “Unused” Pairs

Condition	Cable Length	Errors, Source	Errors, Load
Phy Two/Magnetic Two, 50 W DC/DC			
No Power to DC/DC on the Unused Pairs on This Slide.	148M	0	0
Power Off, 50 Watt Switcher Load Connected(Test 1/Test 2)	148M	0 / 0	0 / 0
50 Watt Switcher(With No Input Filter) with 300 mA Load (Test 1/Test 2) Stuck to 300mA- NOT Wcast noise that was at 200ma...	148M	12861/ 13920	136/29/40
50 Watt Switcher(With No Input Filter) with 300 mA Load (Test 1/Test 2/Test 3)	124M	3/19/7	0/0/0
50 Watt Switcher(With No Input Filter) with 300 mA Load (Test 1/Test 2/Test 3)	100M	5/0/0	0/0/0
Go Back to 200ma and 148M All Hell Broke Loose, So much for the “Unused Pairs”	148M	0/0	842186/ 852436

# Operation of Legacy PHYs: Analysis(No Power Applied)



**Conclusion: Power over Signal Pairs does not impact link operation and hence legacy PHYs.**

# Power over the Signal Pair

- **Technically Feasible**