CABLE MODELS & PROCEDURES

SCSI SSM Meeting

21 Feb 2002

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T10/02-052r1

Participants

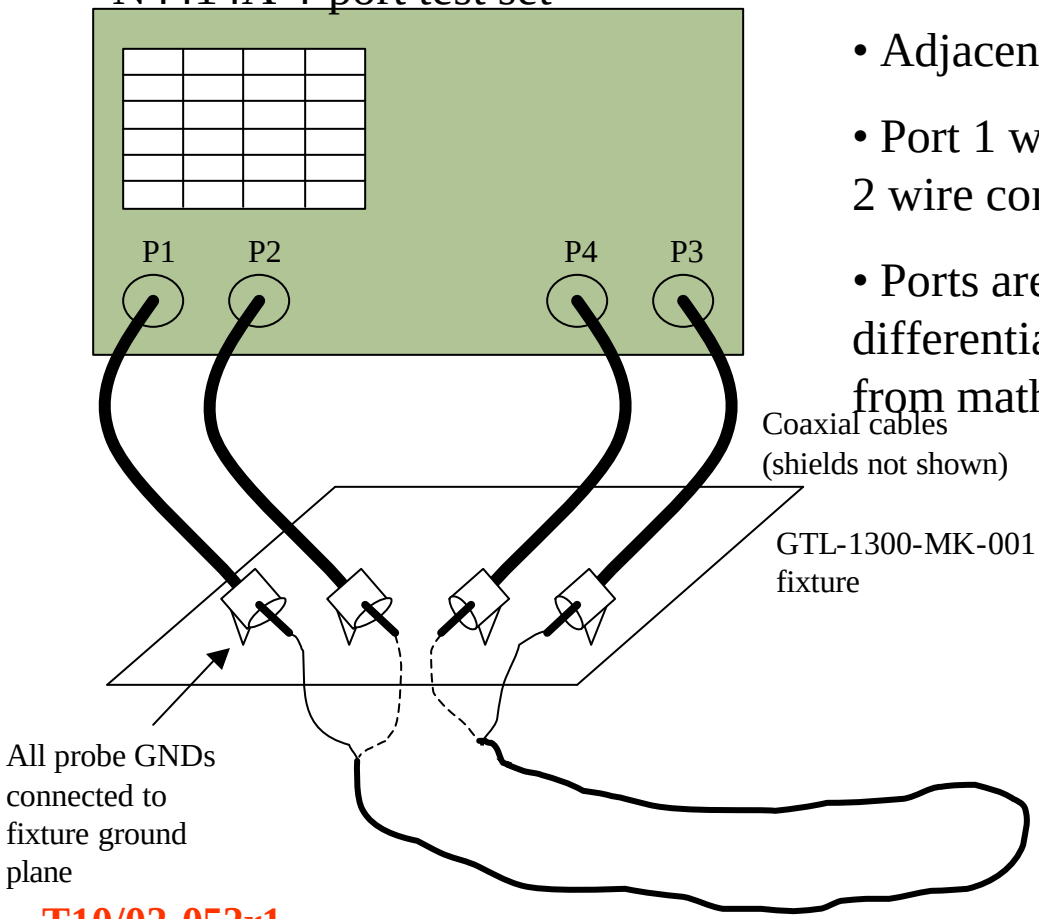
- Supporting Companies
  - JPM, Seagate, Foxconn, LSILogic, Hitachi, Amphenol/SpectraStrip, HP, Tempflex, Adaptec, IBM

Methodology

- Measure cables on 4-port VNA (S-param) and TDR
- Load S-param into ADS and model
- Compare simulation using model to actual – tweak
- Run simulation of attenuation and crosstalk
- Convert to RLGC matrix (for H-Spice)
- Simulate in H-Spice (loss and xtalk) and compare to ADS simulation – tweak
- Publish RLGC model

Gigatest Cable Measurement Test Setup

Agilent 8753ES with
N4414A 4-port test set



Attenuation measurement

- Adjacent wires left unterminated
- Port 1 wire connects to port 3, port 2 wire connects to port 4
- Ports are excited one at a time, then differential response is constructed from mathematical superposition

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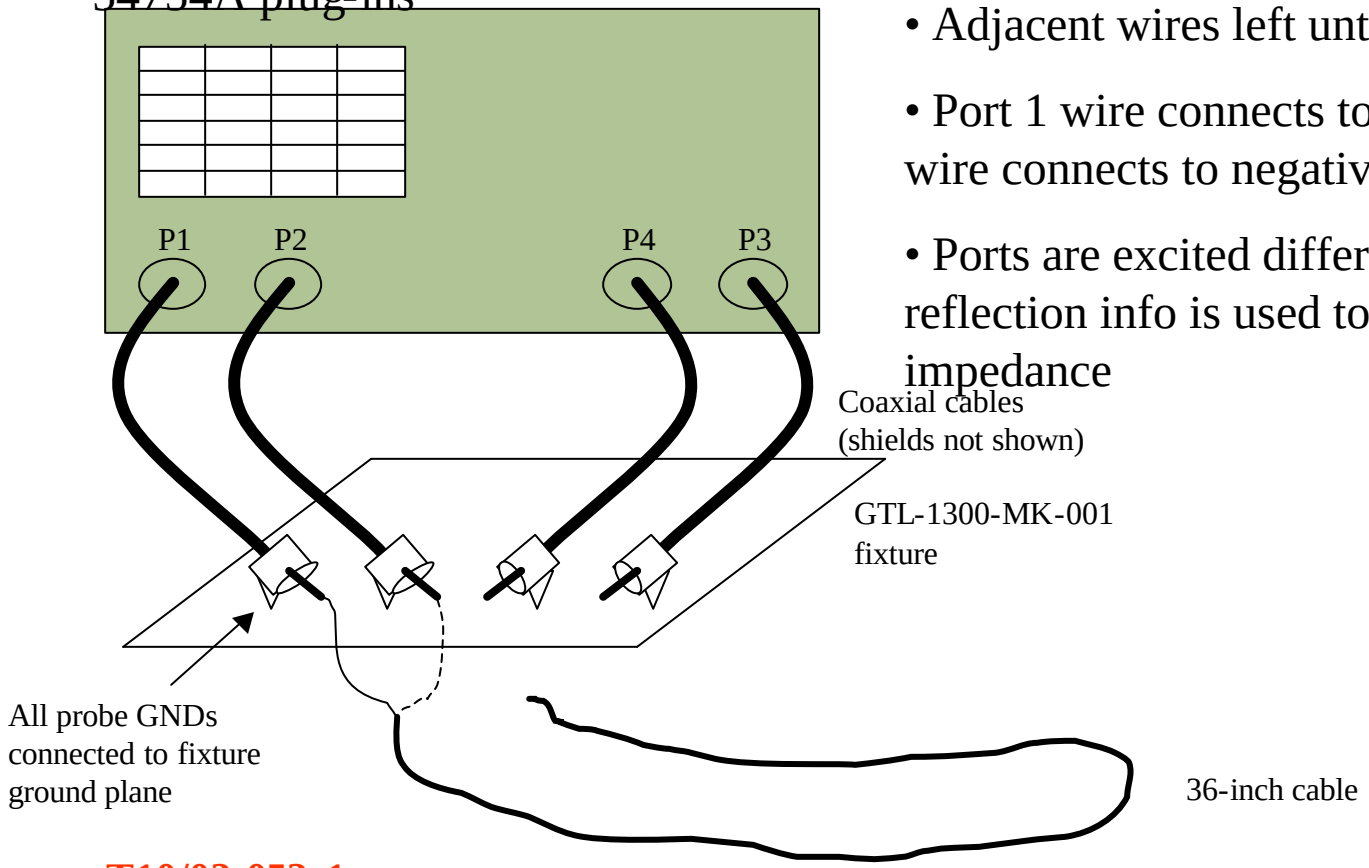
Gigatest Cable Measurement Test Setup

Impedance measurement

Agilent DCA86100 with
54754A plug-ins



- Adjacent wires left unterminated
- Port 1 wire connects to positive, port 2 wire connects to negative
- Ports are excited differentially, TDR reflection info is used to compute impedance

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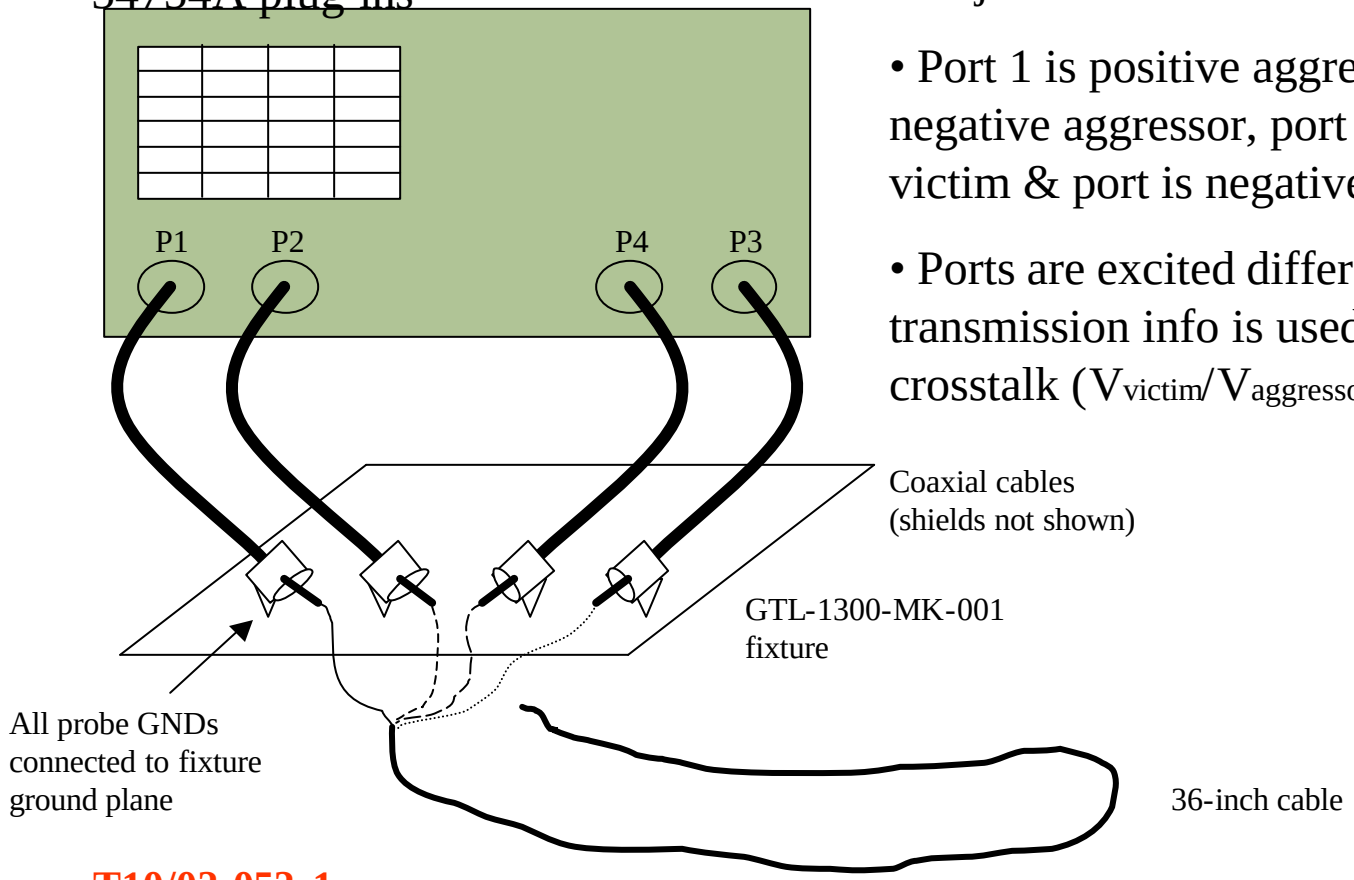
Gigatest Cable Measurement Test Setup

Agilent DCA86100 with
54754A plug-ins



Crosstalk measurement

- Adjacent wires left unterminated
- Port 1 is positive aggressor, port 2 is negative aggressor, port 3 is positive victim & port is negative victim
- Ports are excited differentially, TDT transmission info is used to compute crosstalk ($V_{victim}/V_{aggressor}$)

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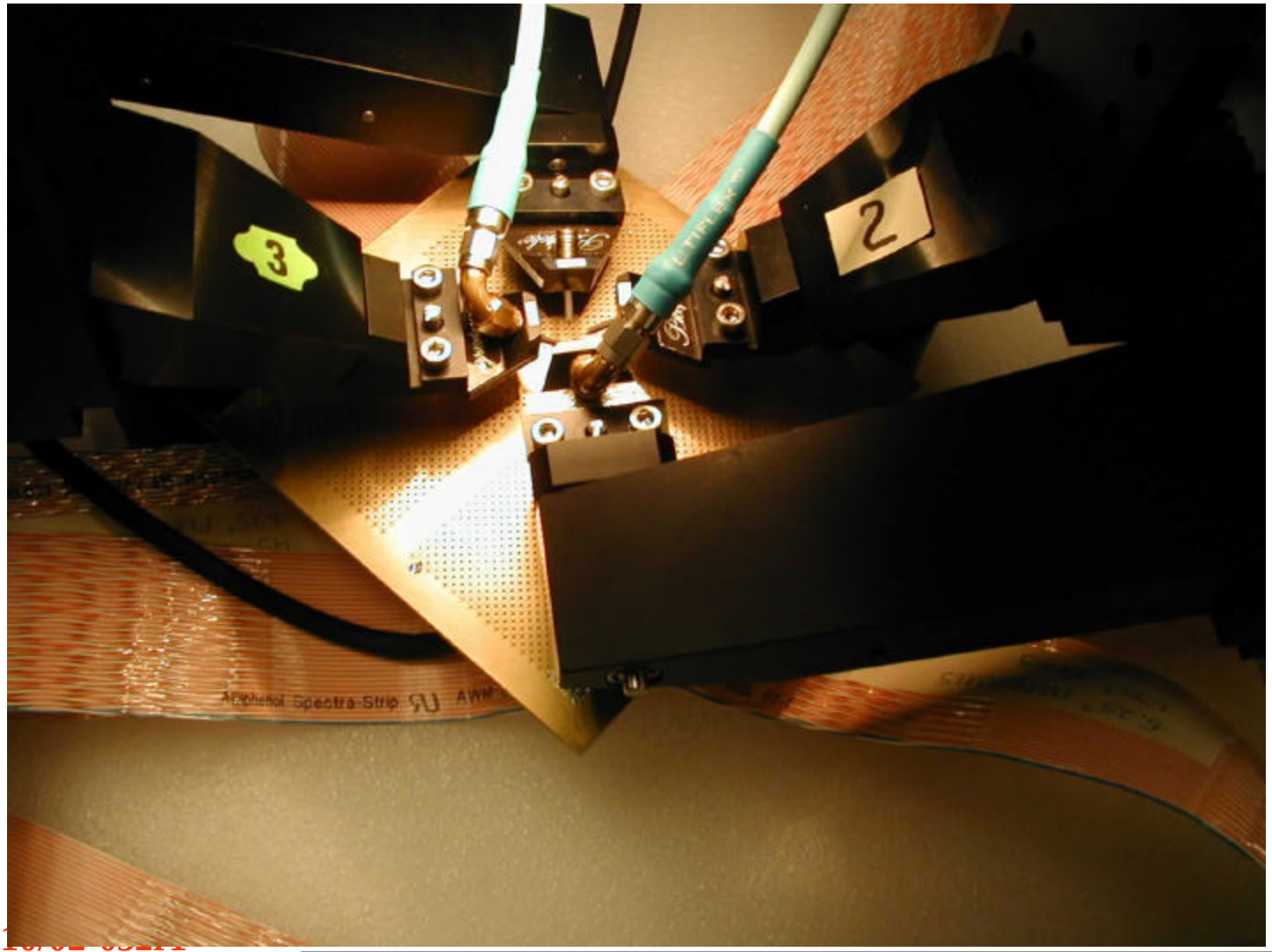
Gigatest Cable Measurement Test Setup

Equipment list:

- Agilent 8753ES w/ N4414A 4-port test set
- Agilent Infiniium DCA 86100A oscilloscope w/ 54754A differential TDR plug-ins
- GigaTest 4060 probe station w/ 4 positioners
- 40 GHz coaxial cables (2.92mm connectors)
- GGB 40A-GS-450-DP and 40A-SG-450-DP probes (two each)
- GGB CS-11 calibration substrate w/ CK11450 calibration kit
- Agilent ADS software (Advanced Design System version 2001)

GLT-1300-MK001 Fixture



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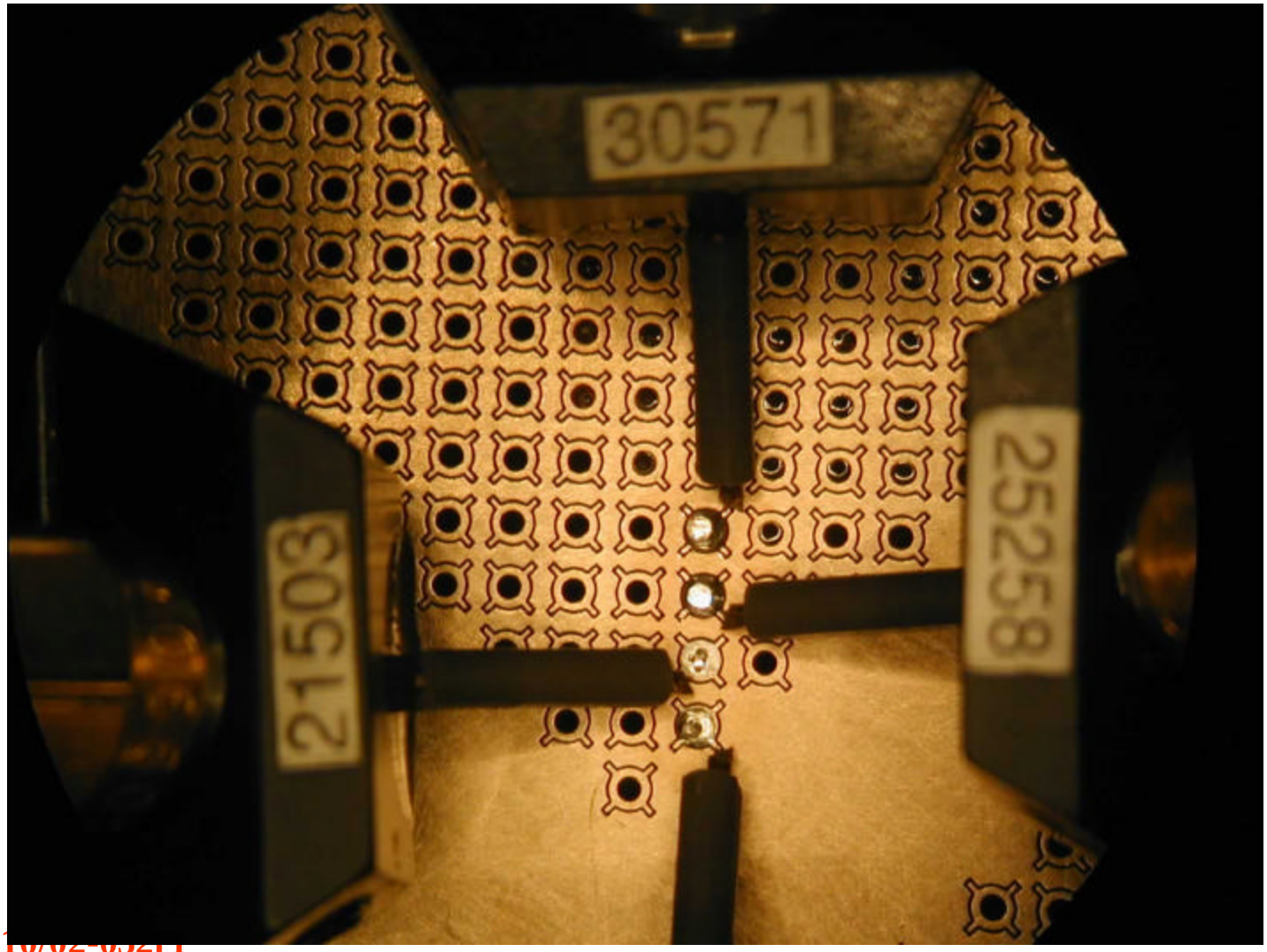
GLT-1300-MK001 Fixture



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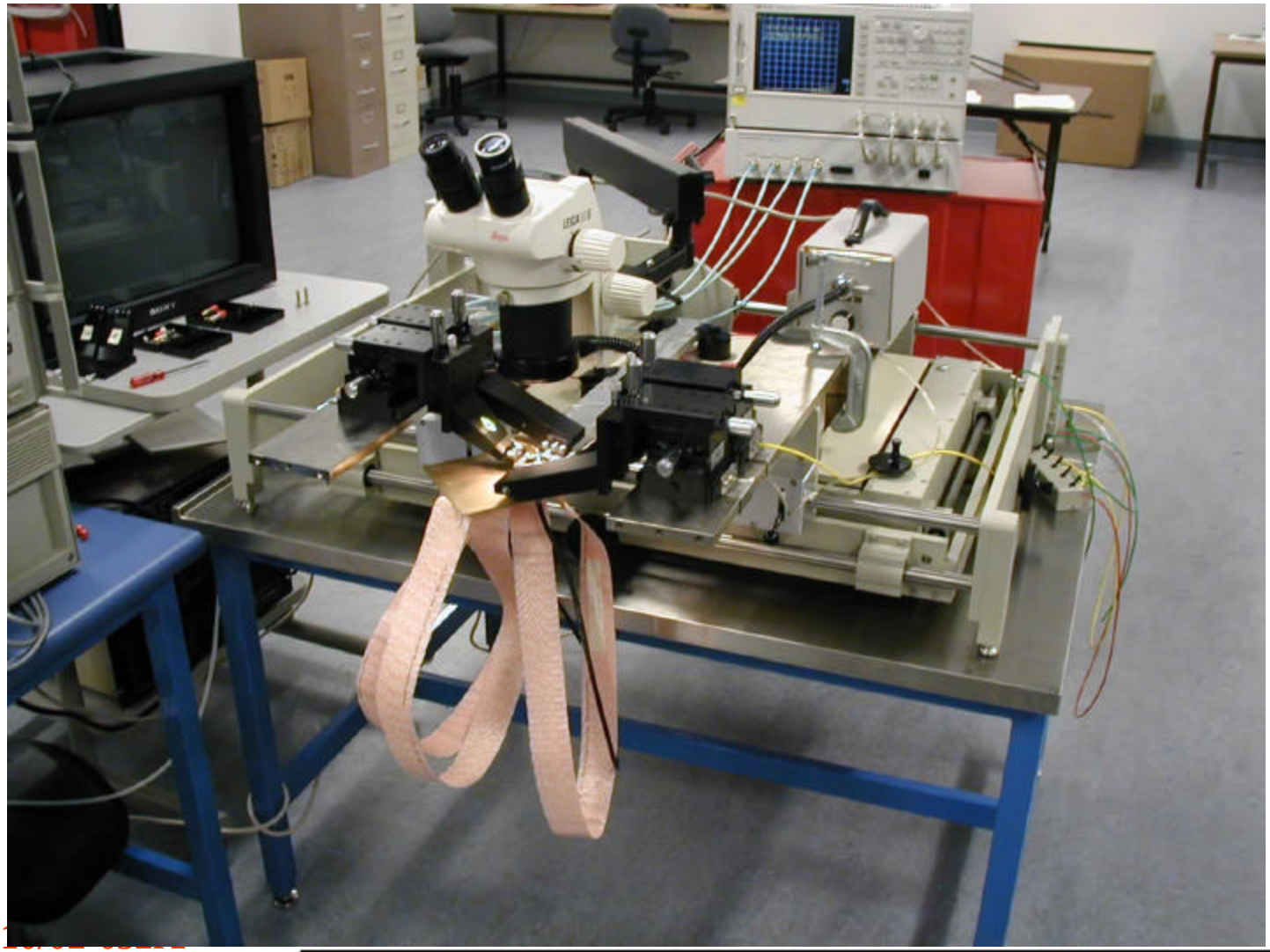
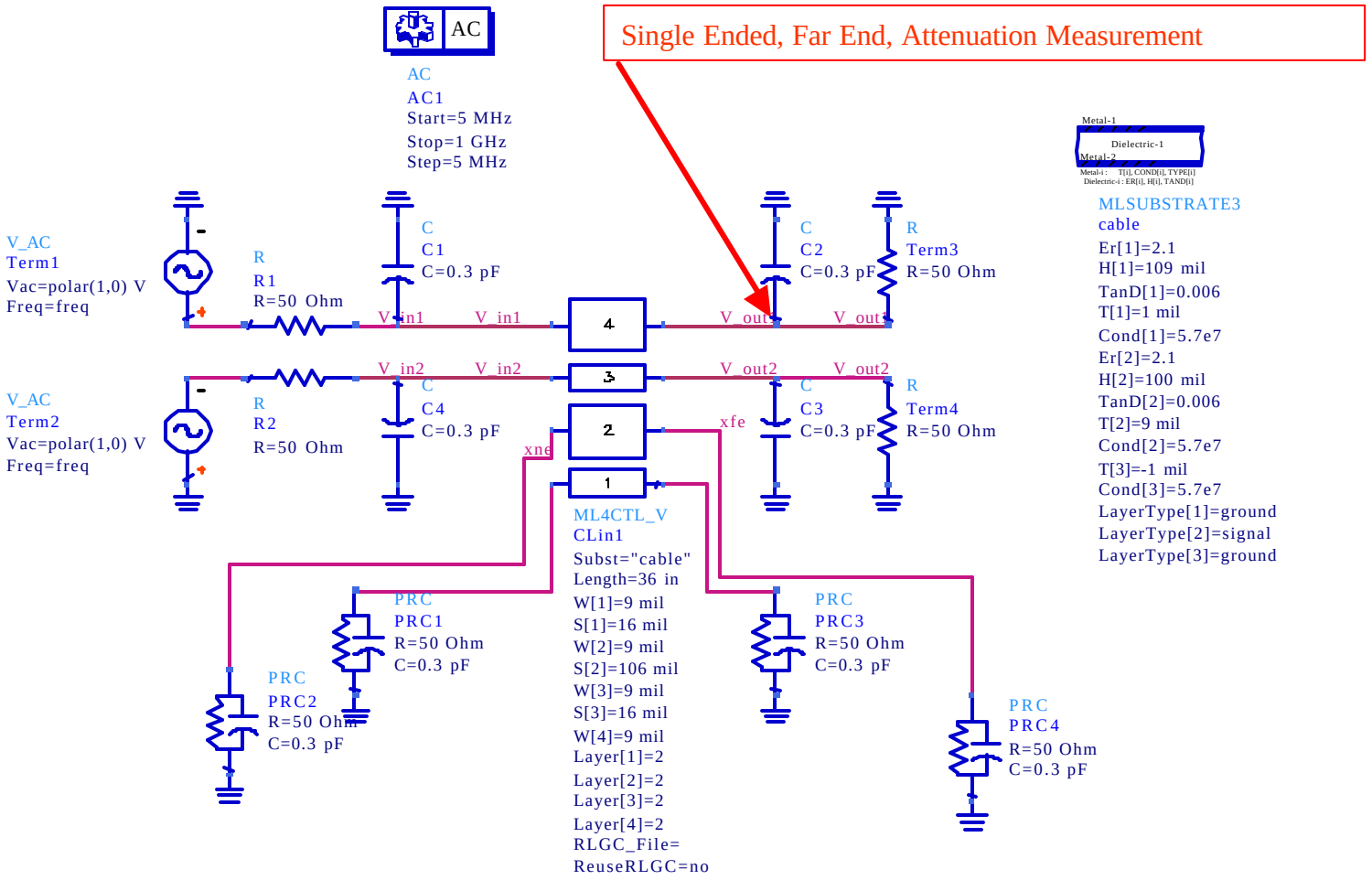
Probe Station with cable under test



Gigatest Cable Measurement – Simulation Model



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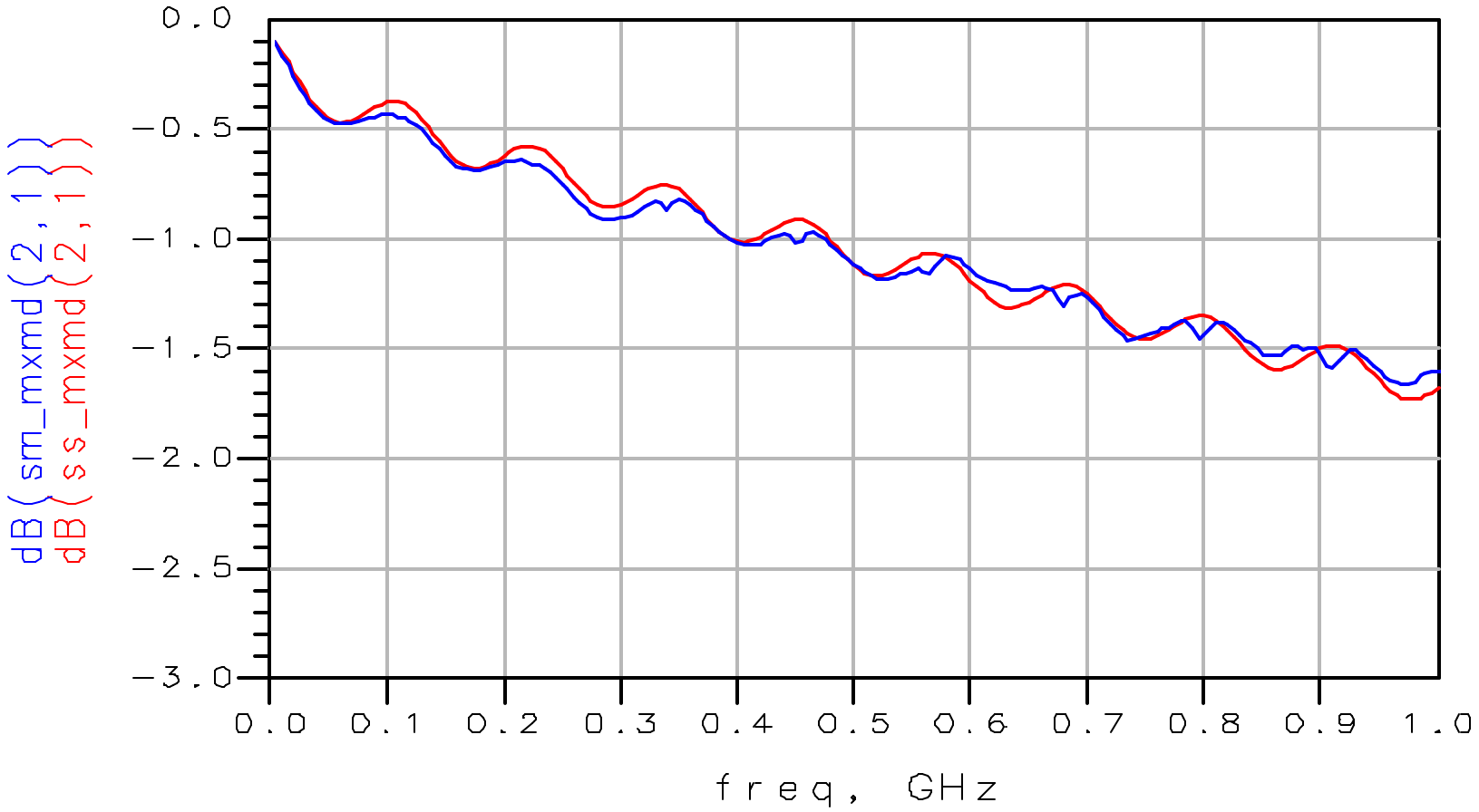
Status

- Four (4) cables measured and modeled
  - Two round – TempFlex and Hitachi
  - Two T'n'F generating model for flat and twisted sections
- All models are RLGC and per meter
- About half way thru the project ($)
- Methodology completed for cables – can make models easily

Round (TempFlex) – Diff. Insertion Loss



TempFlex round cable, differential insertion loss, measured (blue) vs. simulated (red)

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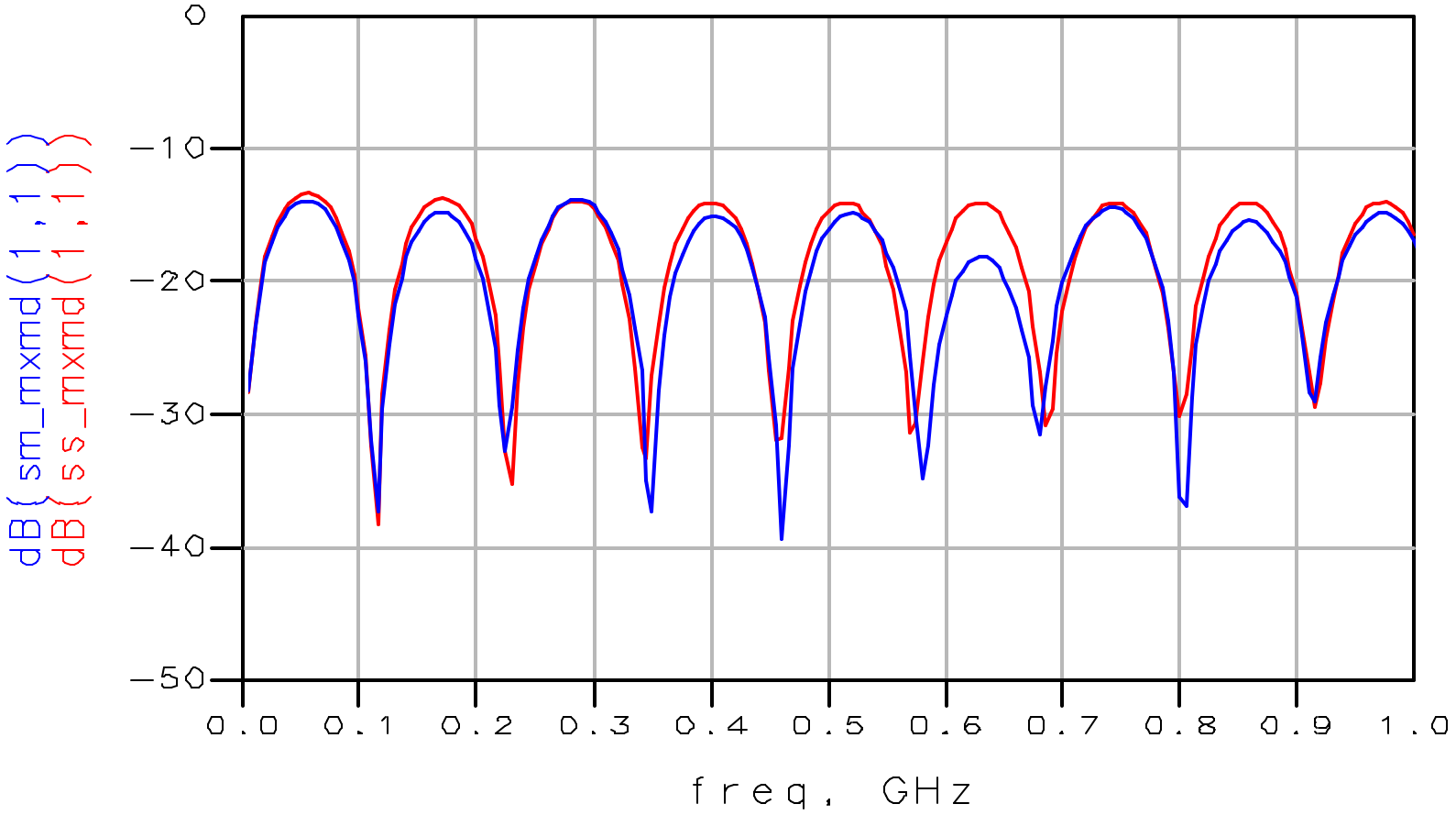
Round (TempFlex) – Differ. Return Loss



T10/02-052r1 **TempFlex round cable, differential return loss, measured (blue) vs. simulated (red)**

tempflex_rlgc.sp

```
* This simulation has been run with Hspice 2000.2.1
.probe
.options post brief accurate
*.option itl4=50
.option reltol=1e-3 abstol=1e-8
*.option gshunt=1e-12 cshunt=1e-12
*.option method=gear

V1 VIN1 0 dc 0 ac=1 0
R1 VIN1 1  50
C1 1 0 .3pf
V3 VIN3 0 dc 0 ac=1 180
R3 VIN3 3 50
C3 3 0 .3pf
R5 5 0 50
C5 5 0 .3pf
R7 7 0 50
C7 7 0 .3pf
.ac lin 1000 5MHZ 1GHZ
WTRACE1 1 3 5 7 0 2 4 6 8 0 N=4 L=0.9144 RLGCMODEL=tempflex
.model tempflex W MODELTYPE=RLGC N=4
+Lo=
+6.3578e-07
+3.3679e-07 6.3565e-7
+4.9635e-8  7.0042e-8 6.3565e-7
+3.5255e-8  4.9635e-8 3.3679e-7 6.3578e-7
+Co=
+51.0958e-12
+-26.9545e-12   51.4327e-12
+-0.8806e-12    -3.0961e-12   51.4327e-12
+-0.2625e-12    -0.8806e-12   -26.9545e-12   51.0958e-12
```

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tempflex_rlgc.sp (contd)

```
+Ro=
+0.3357
+0        0.3357
+0        0        0.3357
+0        0        0        0.3357
+Go=
+0
+0  0
+0  0  0
+0  0  0  0
+Rs=
+6.56176e-4
+2.4472e-5 6.56848e-4
+13.09488e-6 15.64512e-6 6.56848e-4
+10.75136e-6 13.09488e-6 2.4472e-5 6.56176e-4
+Gd=
+1.9398e-15
+-1.0233e-15   1.9526e-15
+-3.34317e-17 -1.1754e-16  1.9526e-15
+-9.9675e-18  -3.3432e-17 -1.0233e-15  1.9398e-15
R2 2 0 50
C2 2 0 .3pf
R4 4 0 50
C4 4 0 .3pf
R6 6 0 50
C6 6 0 .3pf
R8 8 0 50
C8 8 0 .3pf

.probe ac vr(vin1,vin3) vi(vin1,vin3) vr(2,4) vi(2,4)
.end
```

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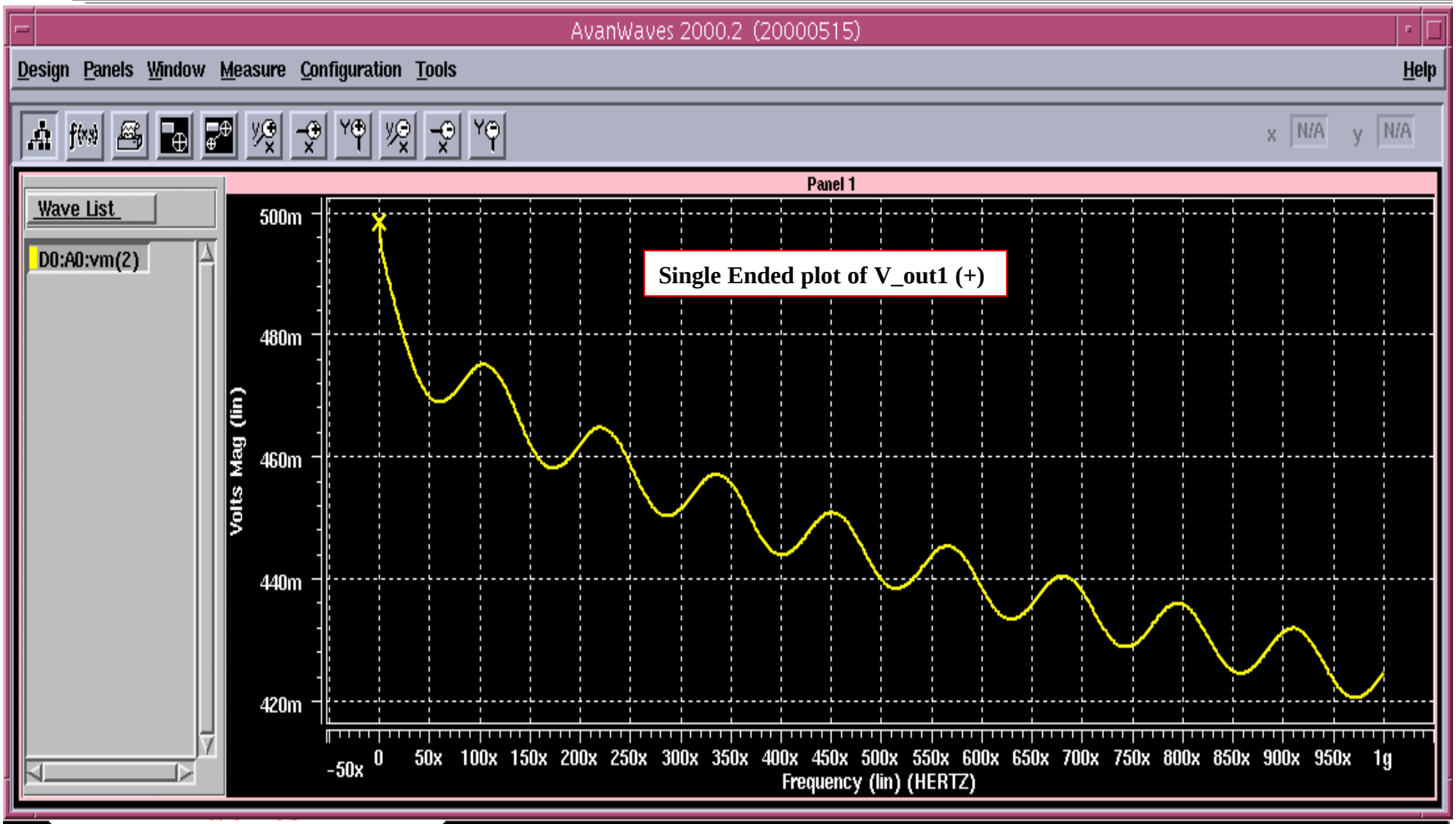
Round (TempFlex) – Diff. Atten. - Hspice



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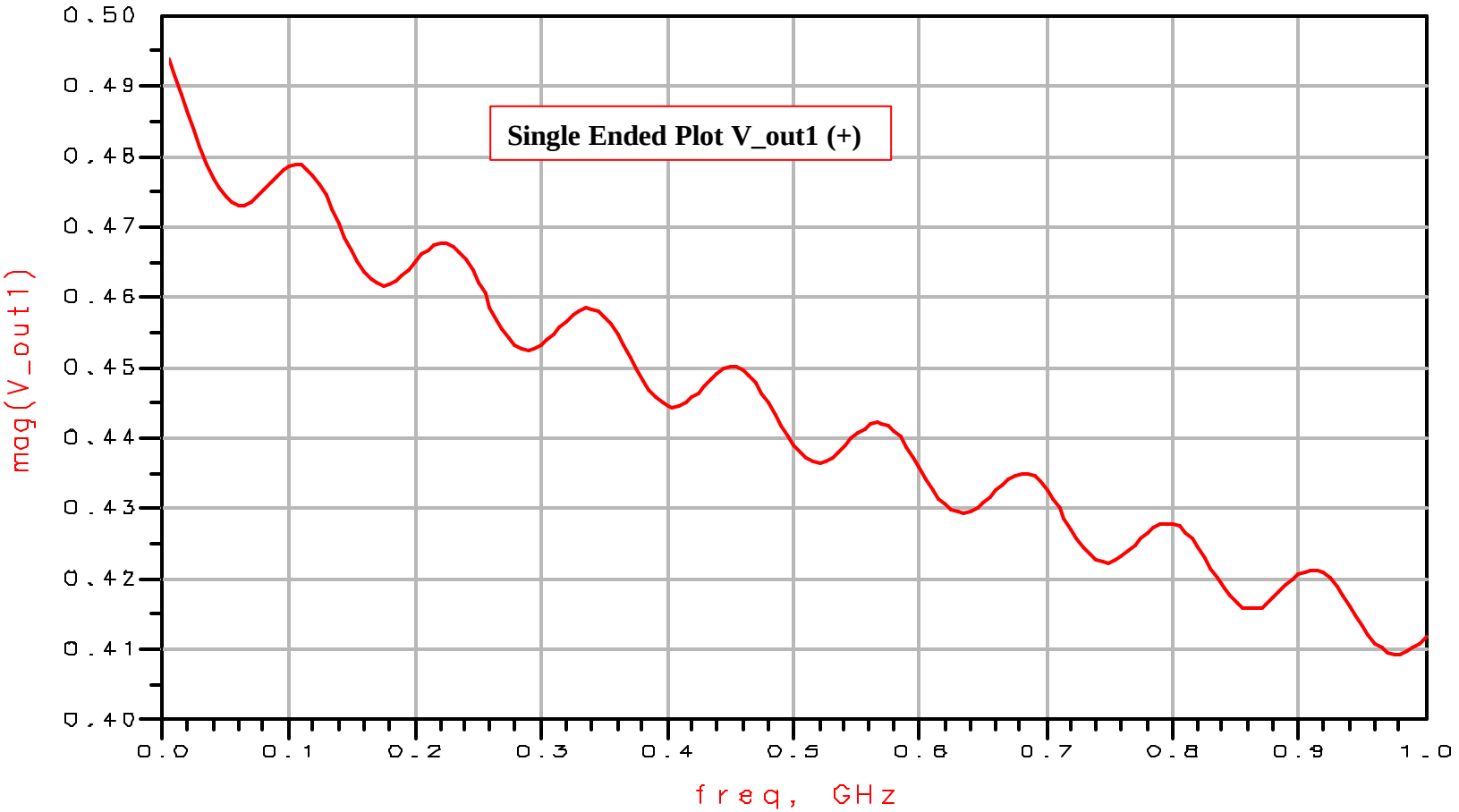
Round (TempFlex) – Diff. Atten.- ADS Converted to HSpice



TempFlex round cable, differential attenuation simulation for correlation with HSPICE results

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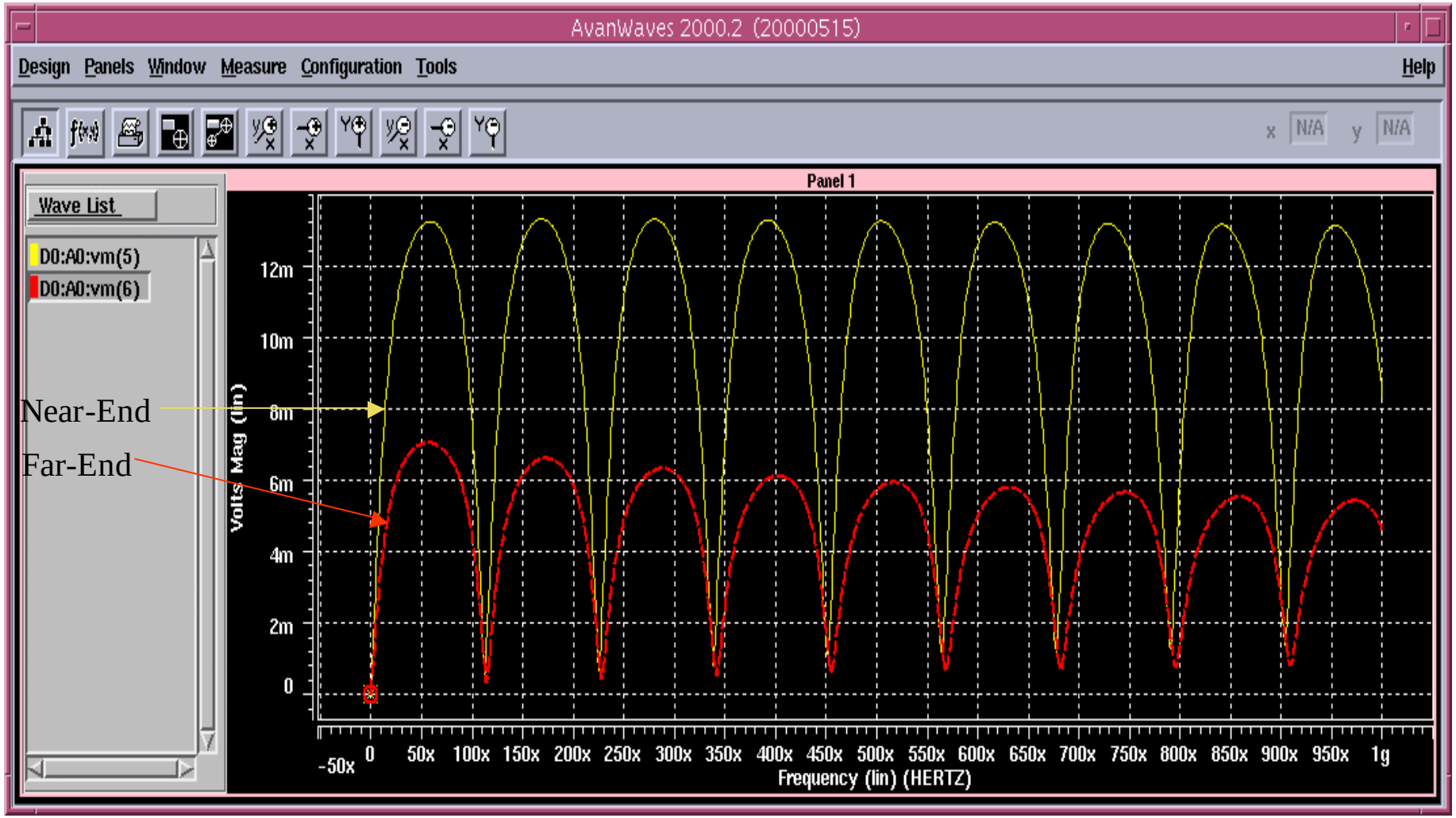
Round (Tempflex) – Crosstalk - Hspice



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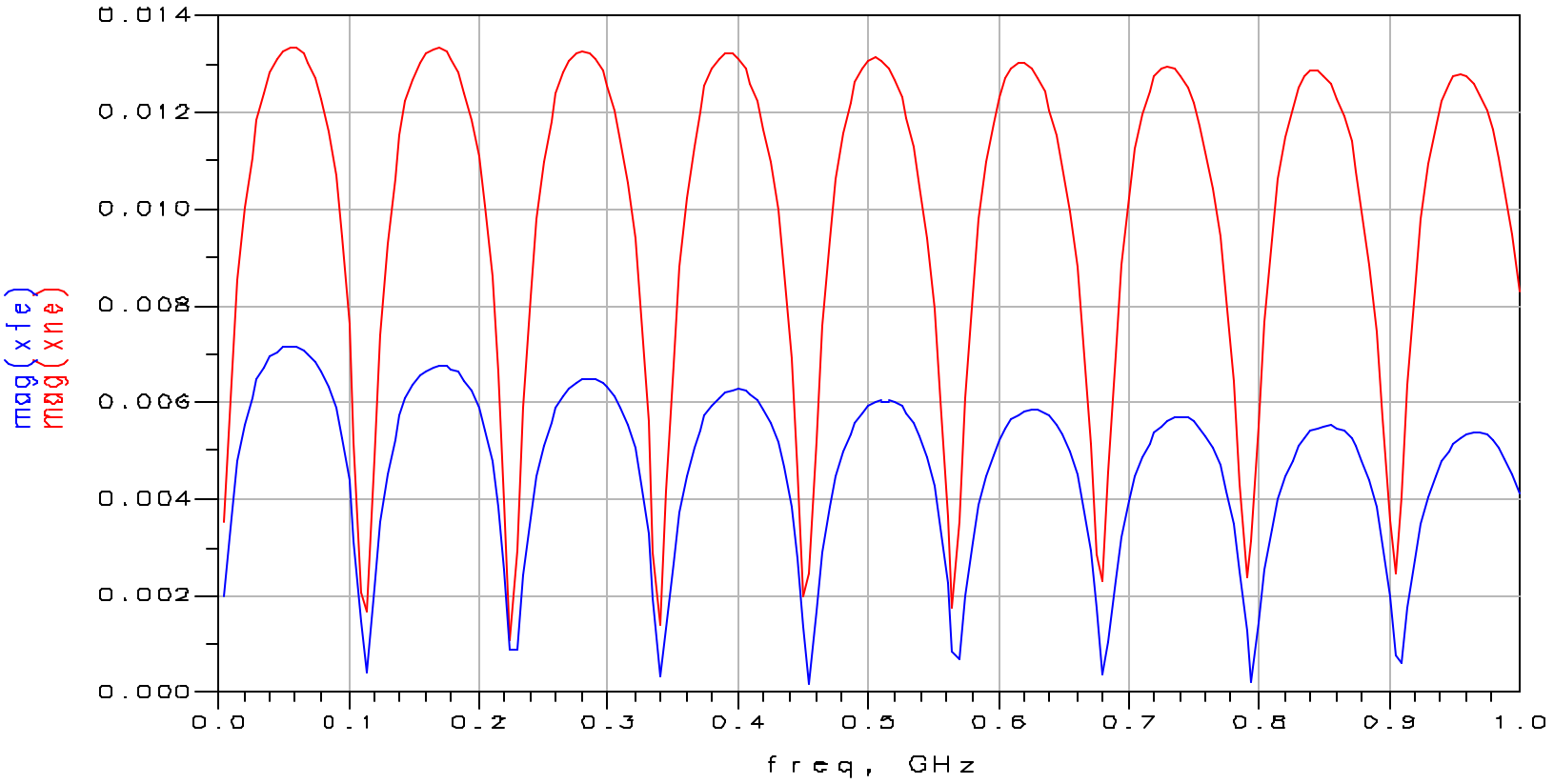
Round (TempFlex) – Xtalk – ADS Converted to HSpice



TempFlex round cable, crosstalk simulation for correlation with HSPICE results (near-end in red, far-end in blue)

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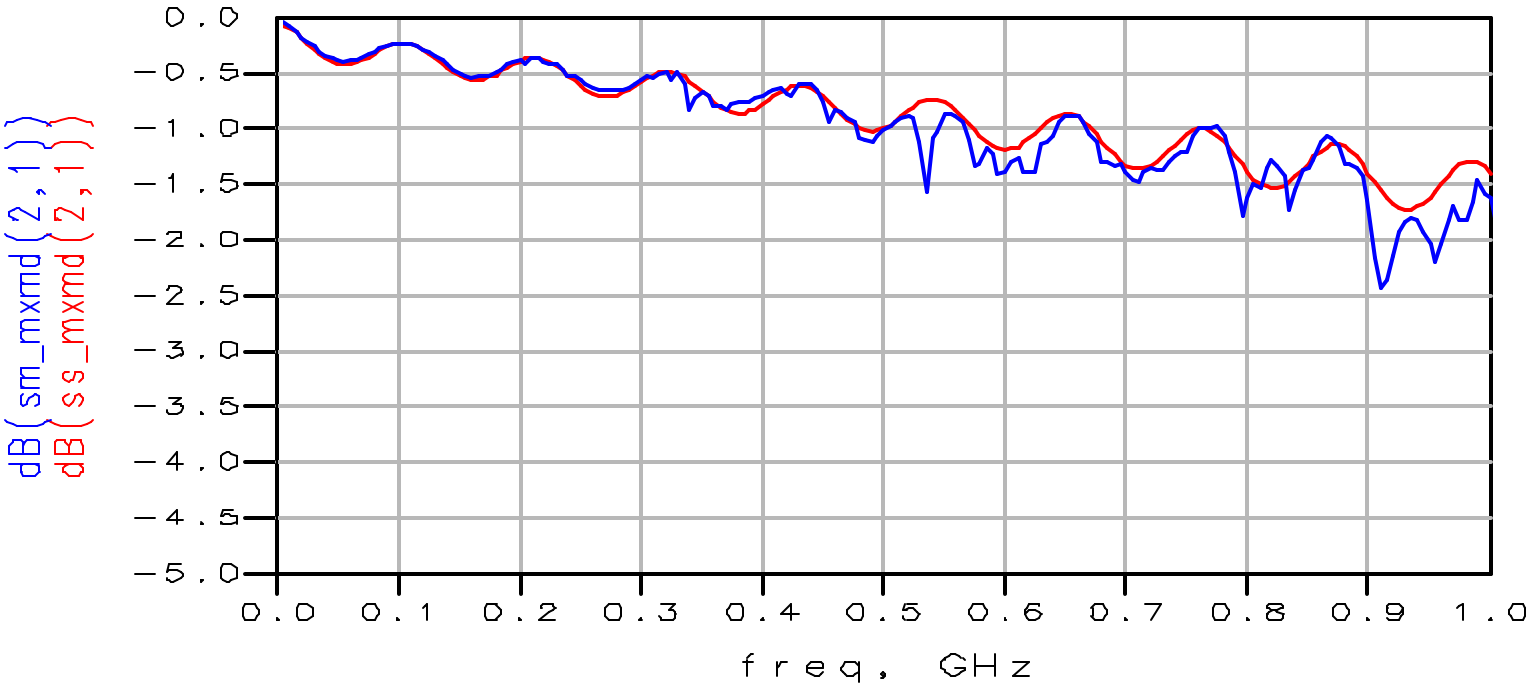
Round (Hitachi) 28 AWG-Diff. Insertion Loss



Hitachi 28 AWG, differential insertion loss, measured (blue) vs. simulated (red)

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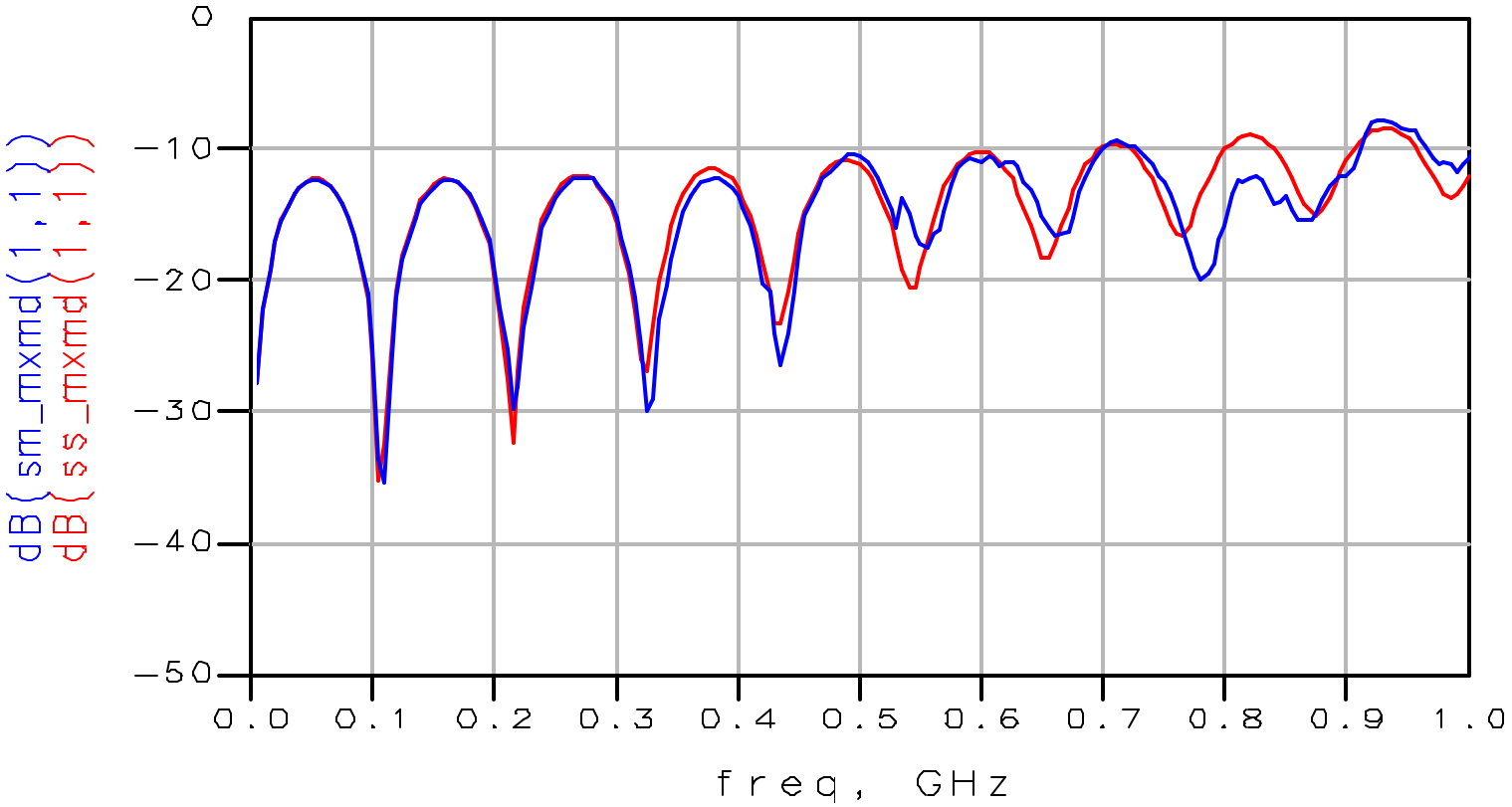
Round (Hitachi) 28 AWG-Diff. Return Loss



Hitachi 28 AWG, differential return loss, measured (blue) vs. simulated (red)

hitachi_awg28_rlgc.sp

```
* This simulation has been run with Hspice 2000.2.1
.probe
.options post brief accurate
*.option itl4=50
.option reltol=1e-3 abstol=1e-8
*.option gshunt=1e-12 cshunt=1e-12
*.option method=gear

V1 VIN1 0 dc 0 ac=1 0
R1 VIN1 1  50
C1 1 0 .3pf
V3 VIN3 0 dc 0 ac=1 180
R3 VIN3 3 50
C3 3 0 .3pf
R5 5 0 50
C5 5 0 .3pf
R7 7 0 50
C7 7 0 .3pf
.ac lin 1000 5MHZ 1GHZ
WTRACE1 1 3 5 7 0 2 4 6 8 0 N=4 L=0.9144 RLGCMODEL=hitachiawg28
.model hitachiawg28 W MODELTYPE=RLGC N=4
+Lo=
+5.41237e-7
+2.29611e-7 5.41162e-7
+1.68389e-8 3.07032e-8 5.41162e-7
+9.2423e-9 1.68389e-8 2.29611e-7 5.41237e-7
+Co=
+5.38788e-11
+-2.28384e-11 5.40102e-11
+-3.55913e-13 -2.20266e-12 5.40102e-11
+-5.85212e-14 -3.55913e-13 -2.28384e-11 5.38788e-11
```

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hitachi_awg28_rlgc.sp (contd)

```
+Ro=
+0.120858
+0        0.120858
+0        0        0.120858
+0        0        0        0.120858
+Go=
+0
+0  0
+0  0  0
+0  0  0  0
+Rs=
+0.000495778
+1.41902e-5 0.00049606
+8.06602e-6 11.98384e-6 0.00049606
+5.2518e-6 8.06602e-6 1.41902e-5 0.000495778
+Gd=
+1.70458e-15
+-7.2255e-16 1.70875e-15
+-1.12602e-17 -6.96864e-17 1.70875e-15
+-1.85146e-18 -1.12602e-17 -7.2255e-16 1.70458e-15
R2 2 0 50
C2 2 0 .3pf
R4 4 0 50
C4 4 0 .3pf
R6 6 0 50
C6 6 0 .3pf
R8 8 0 50
C8 8 0 .3pf

.probe ac vr(vin1,vin3) vi(vin1,vin3) vr(2,4) vi(2,4)
.end
```

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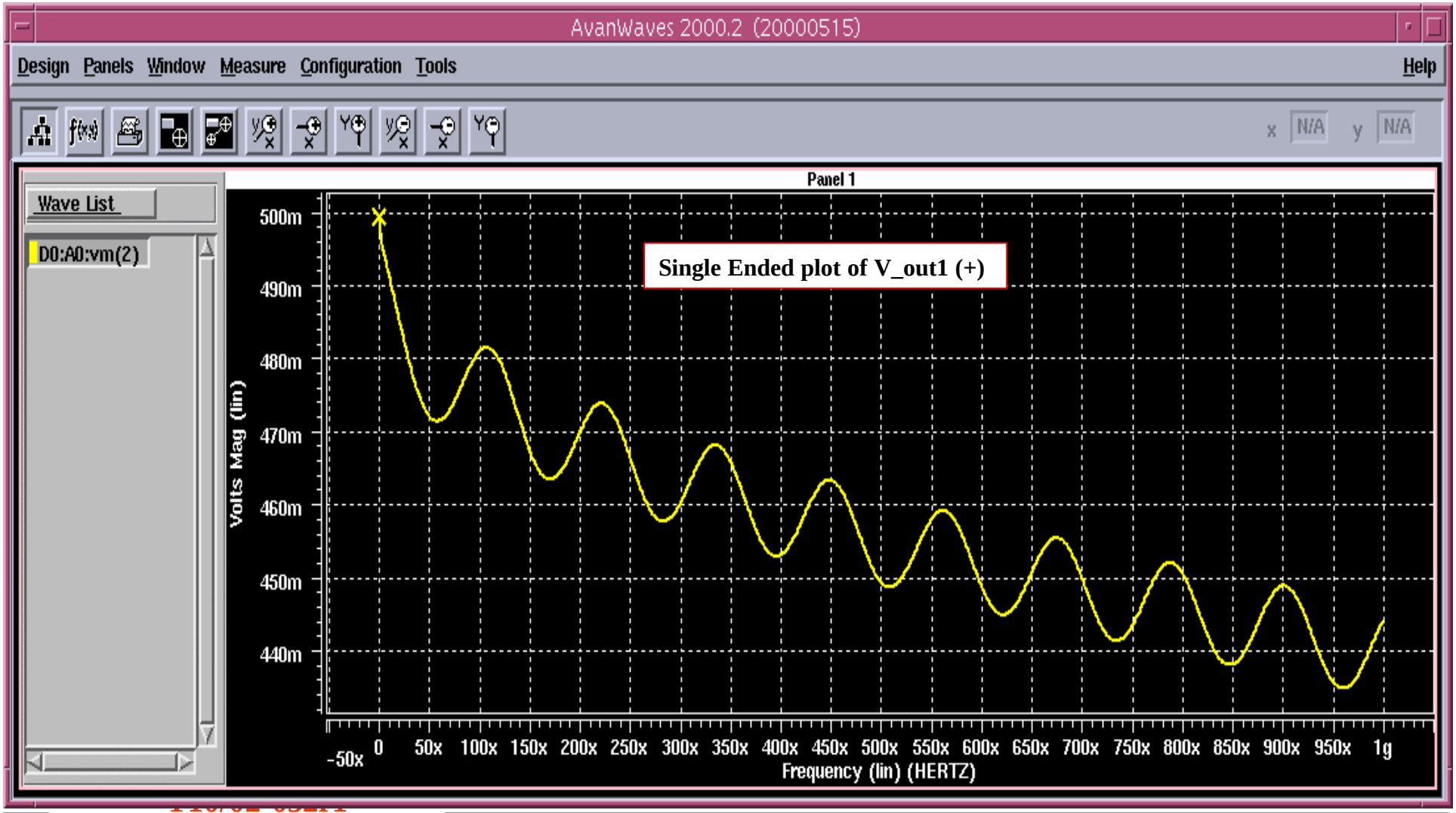
Round (Hitachi) – Diff. Attn. - Hspice



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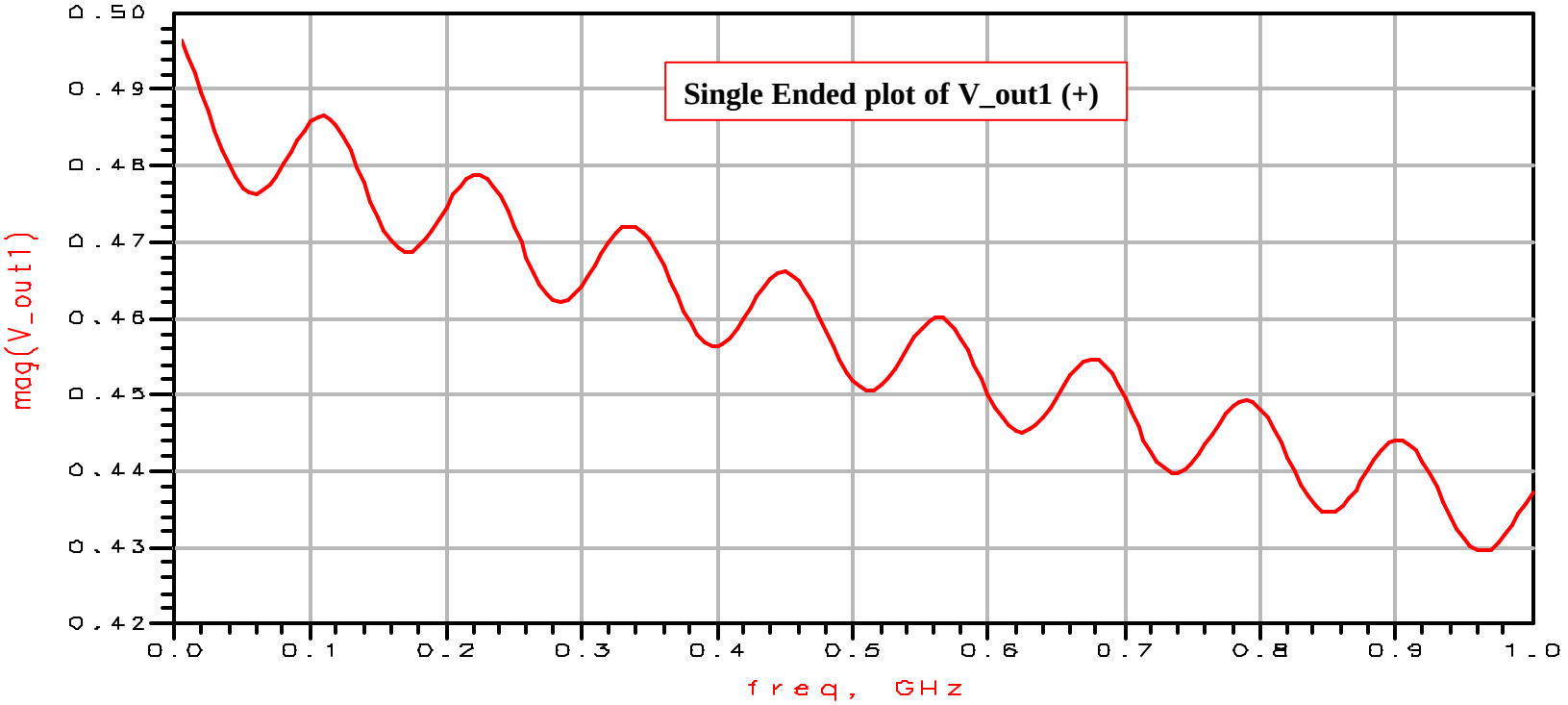
Round (Hitachi) - Diff. Attn. – ADS Converted to HSpice



Hitachi 28 AWG, differential attenuation simulation for correlation with HSPICE results

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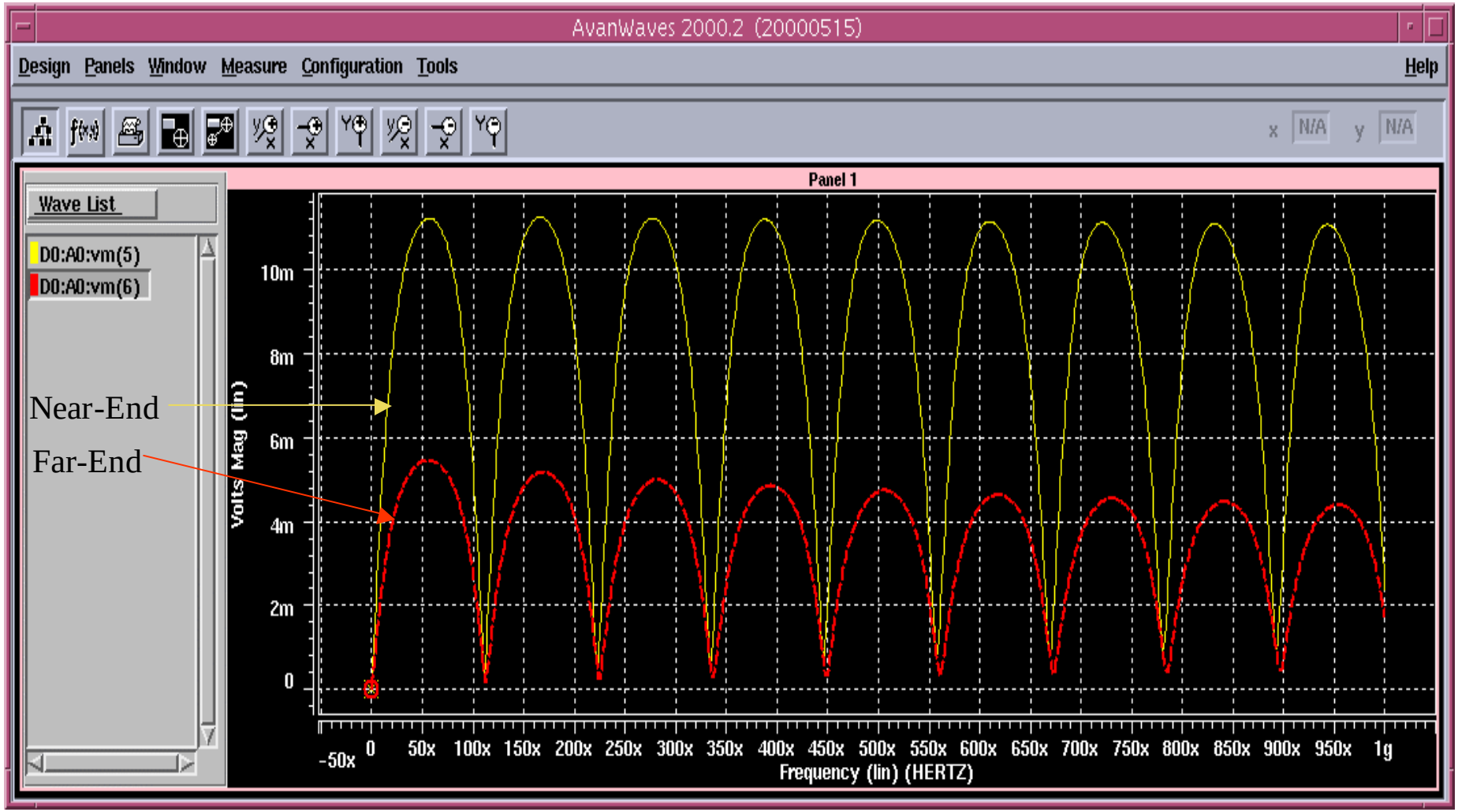
Round (Hitachi) - Crosstalk - Hspice



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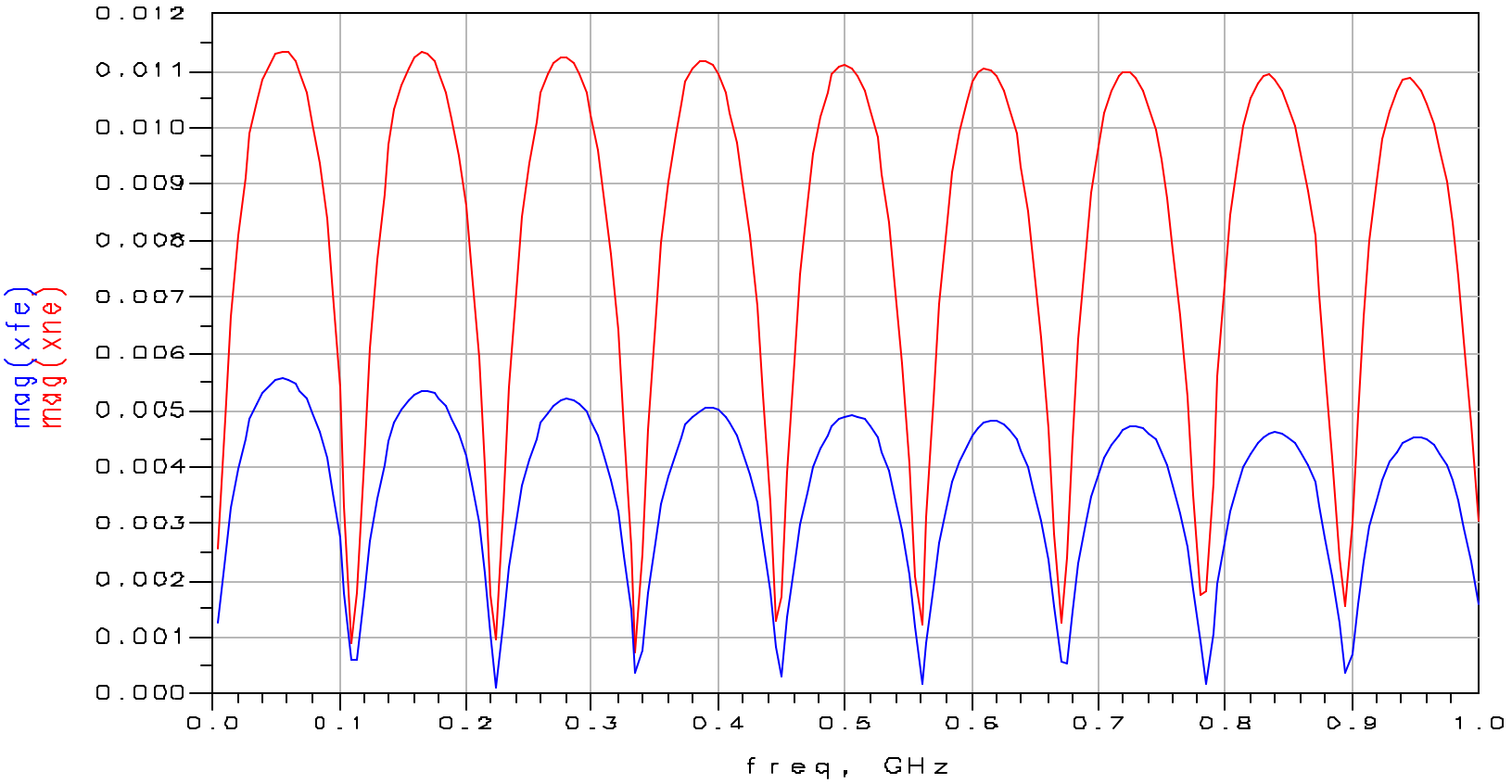
Round (Hitachi) – Xtalk – ADS Converted to HSpice



Hitachi 28 AWG, crosstalk simulation for correlation with HSPICE results (near-end in red, far-end in blue)

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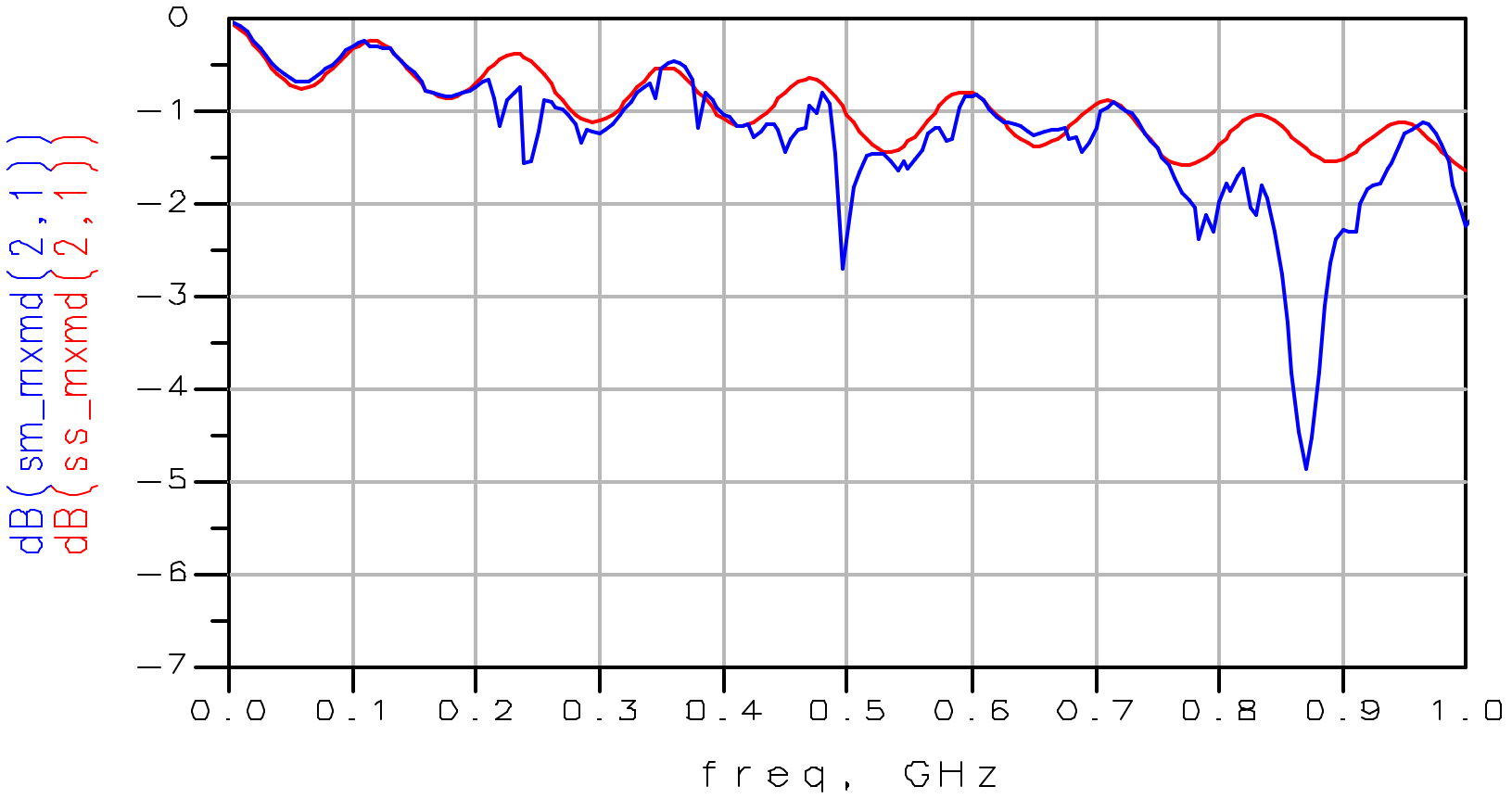
T'n'F (16") Spectra – Diff. Insert. Loss



Amphenol ribbon cable (16" pitch), differential return loss, measured (blue) vs. simulated (red)

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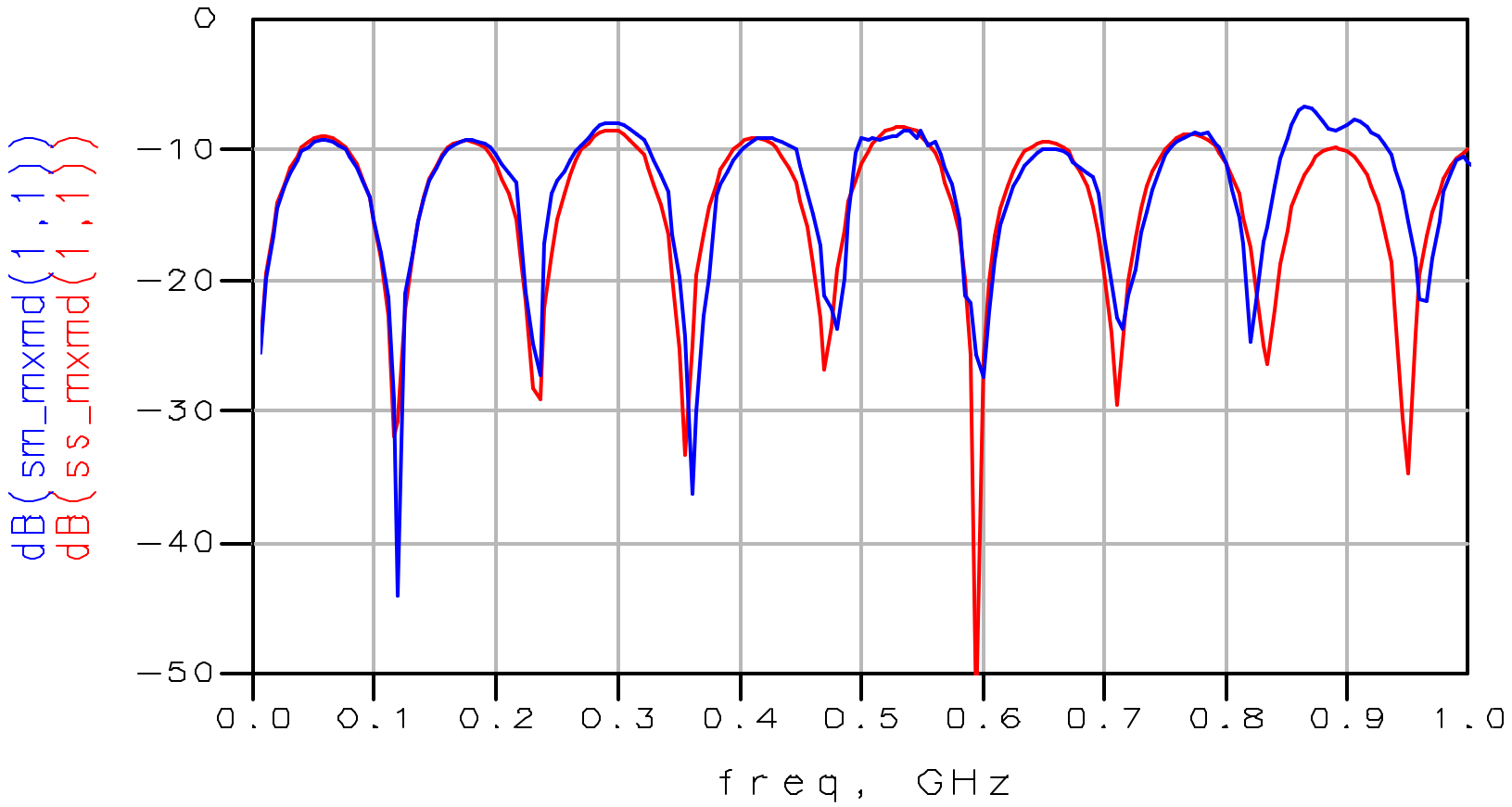
Seagate
Information the way you want it

T'n'F (16") Spectra – Diff. Return Loss



Amphenol ribbon cable (16" pitch), differential return loss, measured (blue) vs. simulated (red)

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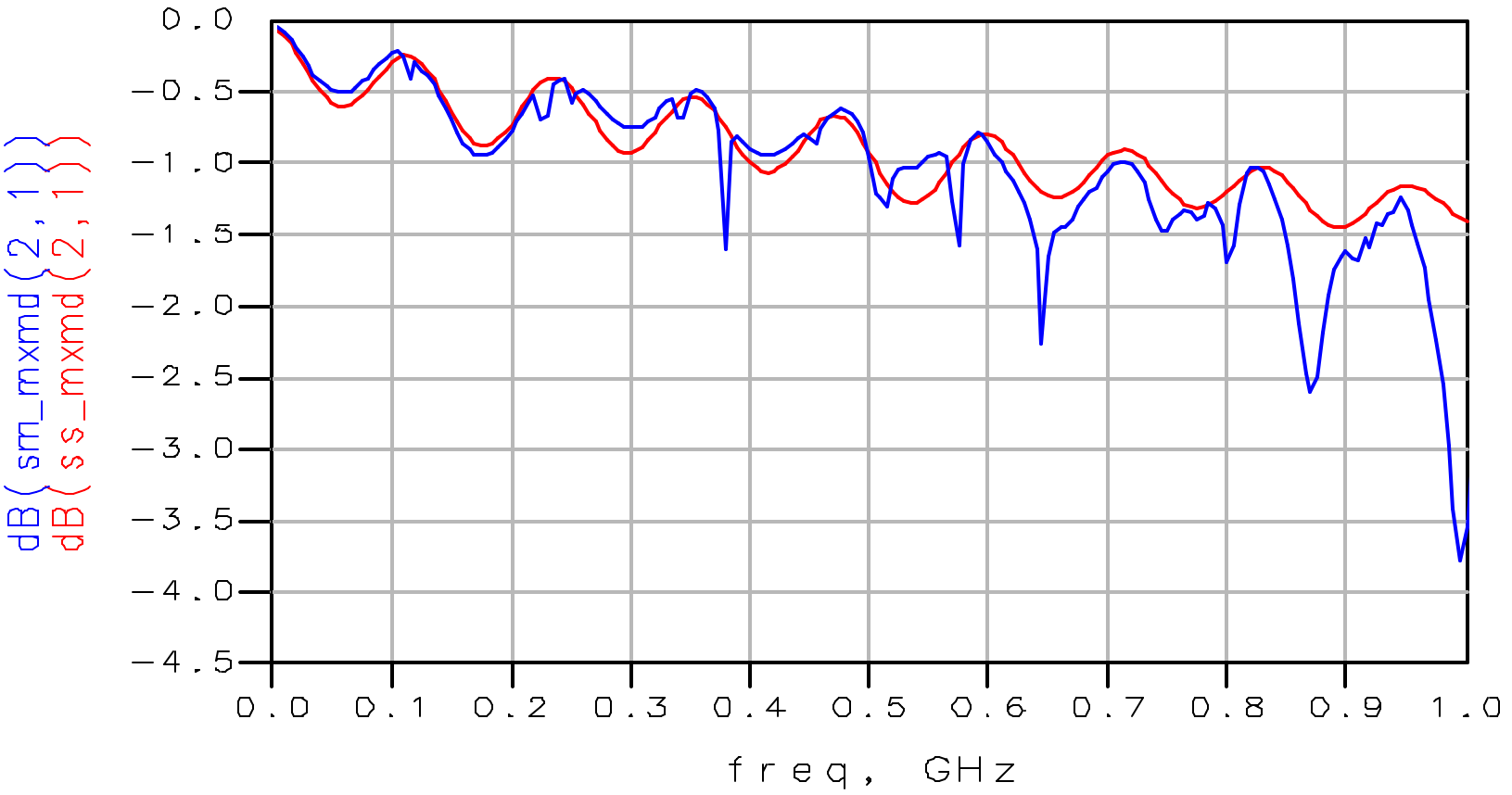
T'n'F (45") Spectra – Diff. Insert. Loss



Amphenol ribbon cable (45" pitch), differential insertion loss, measured (blue) vs. simulated (red)

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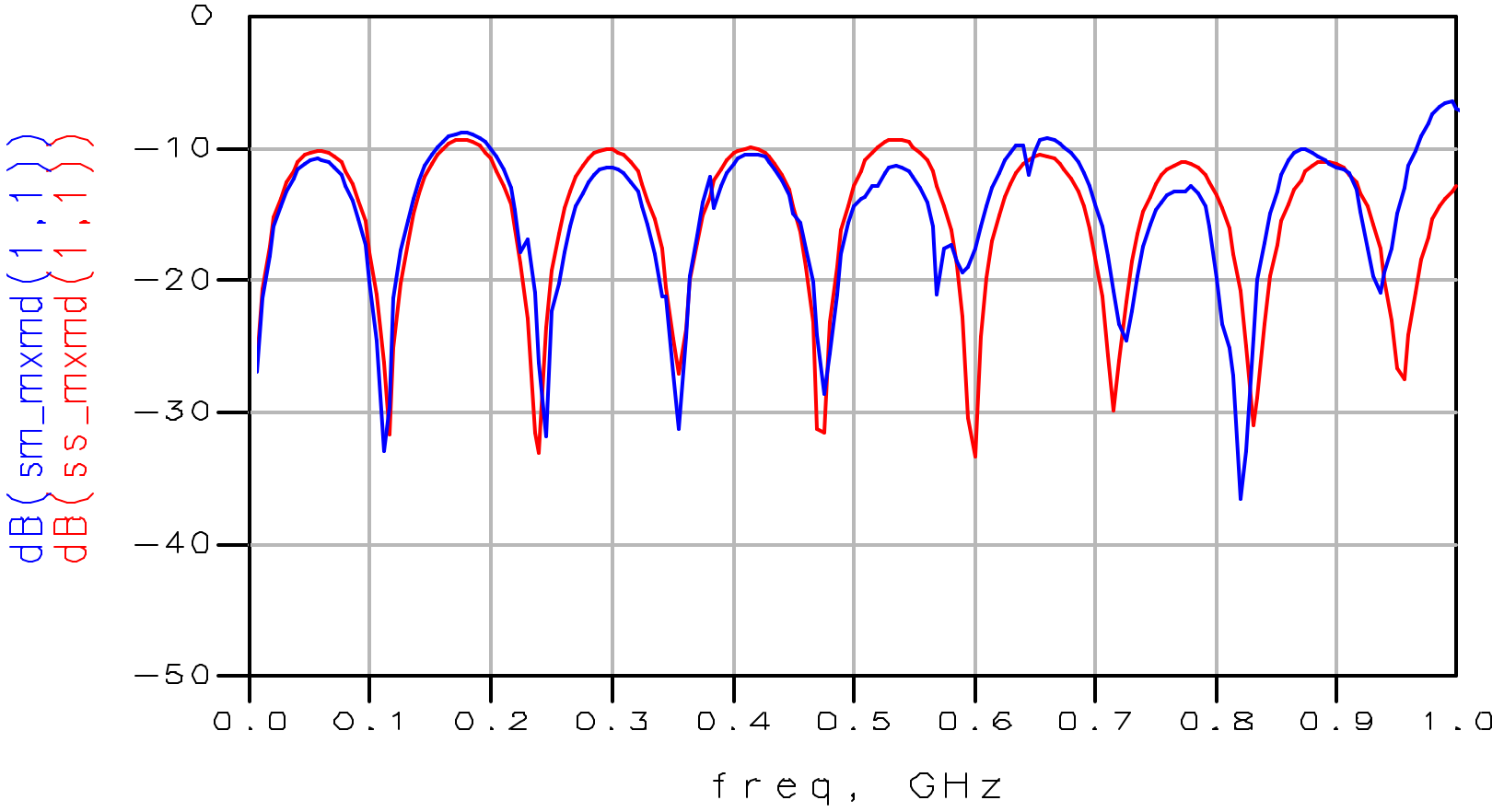
T'n'F (45") Spectra – Diff. Return Loss



Amphenol ribbon cable (45" pitch), differential return loss, measured (blue) vs. simulated (red)

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amphenol_ribbon_straight_rlgc.sp

```
* This simulation has been run with Hspice 2000.2.1
.probe
.options post brief accurate
*.option itl4=50
.option reltol=1e-3 abstol=1e-8
*.option gshunt=1e-12 cshunt=1e-12
*.option method=gear

V1 VIN1 0 dc 0 ac=1 0
R1 VIN1 1  50
C1 1 0 .3pf
V3 VIN3 0 dc 0 ac=1 180
R3 VIN3 3 50
C3 3 0 .3pf
R5 5 0 50
C5 5 0 .3pf
R7 7 0 50
C7 7 0 .3pf
.ac lin 1000 5MHZ 1GHZ
WTRACE1 1 3 5 7 0 2 4 6 8 0 N=4 L=0.9144 RLGCMODEL=ribbonstraightrlgc
.model ribbonstraightrlgc W MODELTYPE=RLGC N=4
+Lo=
+5.4256e-7
+1.9356e-7 5.37335e-7
+9.43629e-8 2.10055e-7 5.37335e-7
+4.42192e-8 9.43629e-8 1.9356e-7 5.42567e-7
+Co=
+4.47637e-11
+-1.53915e-11 5.17857e-11
+-1.71469e-12 -1.69234e-11 5.17857e-11
+-3.59647e-13 -1.71469e-12 -1.53915e-11 4.47637e-11
```

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amphenol_ribbon_straight_rlgc.sp (contd)

```
+Ro=
+0.120858
+0        0.120858
+0        0        0.120858
+0        0        0        0.120858
+Go=
+0
+0  0
+0  0  0
+0  0  0  0
+Rs=
+0.000490464
+2.71948e-5 0.000512566
+2.15324e-5 2.75818e-5 0.000512566
+14.74238e-6 1.07662e-5 2.71948e-5 0.000490464
+Gd=
+1.69945e-15
+-5.84336e-16 1.96603e-15
+-6.50979e-17 -6.42495e-16 1.96603e-15
+-1.3654e-17 -6.50979e-17 -5.84336e-16 1.69945e-15
R2 2 0 50
C2 2 0 .3pf
R4 4 0 50
C4 4 0 .3pf
R6 6 0 50
C6 6 0 .3pf
R8 8 0 50
C8 8 0 .3pf

.probe ac vr(vin1,vin3) vi(vin1,vin3) vr(2,4) vi(2,4)
.end
```

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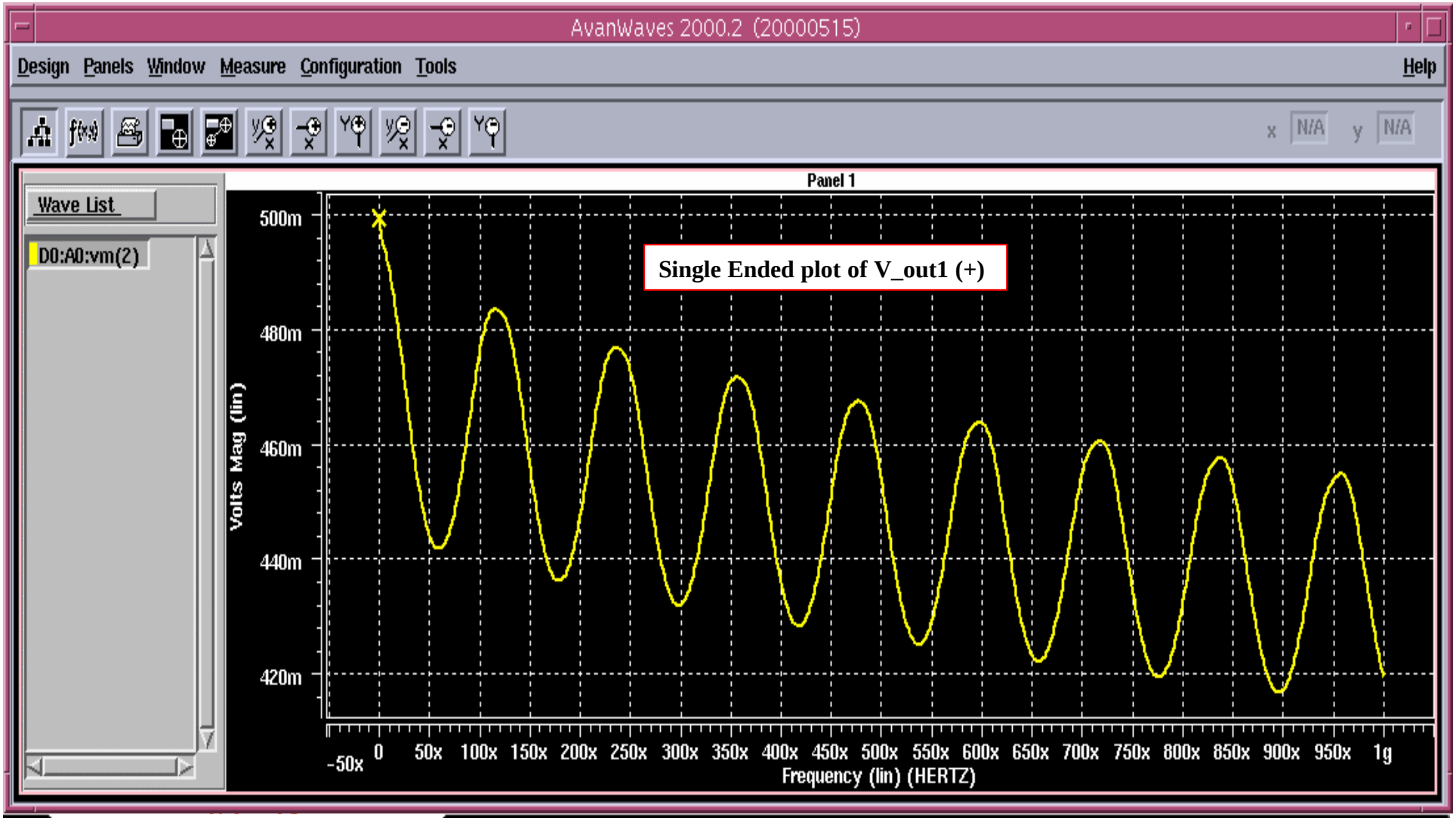
T'n'F Flat (Straight) Section – Diff. Attn. _ Hspice



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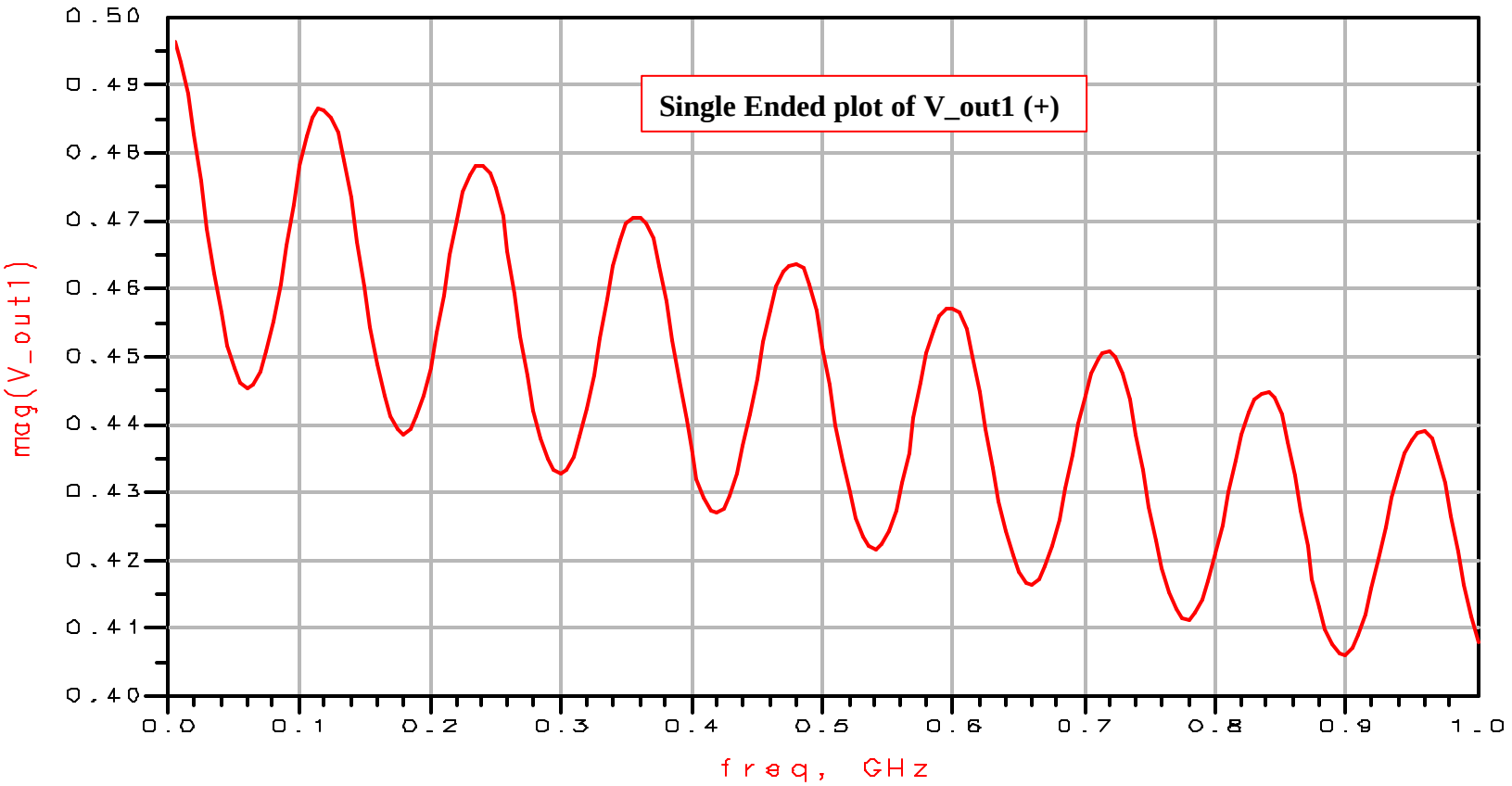
T'n'F Flat (Straight) Section – Diff. Attn. – ADS Converted to Hspice



Amphenol straight-section of ribbon cable, differential attenuation simulation for correlation with HSPICE results

T10/02-052r1

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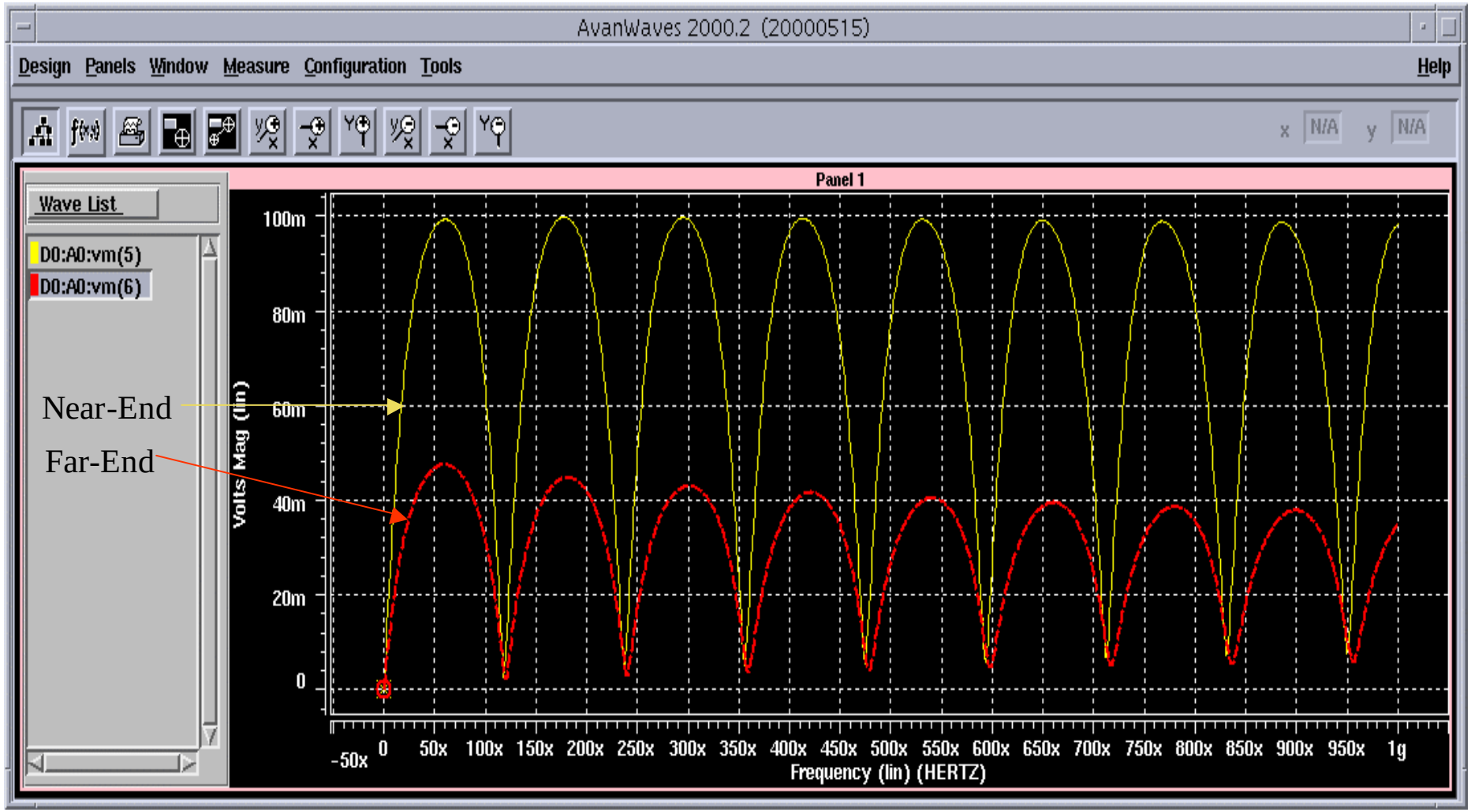
Information the way you want it

T'n'F Flat (Straight) Section – Cross Talk - Hspice



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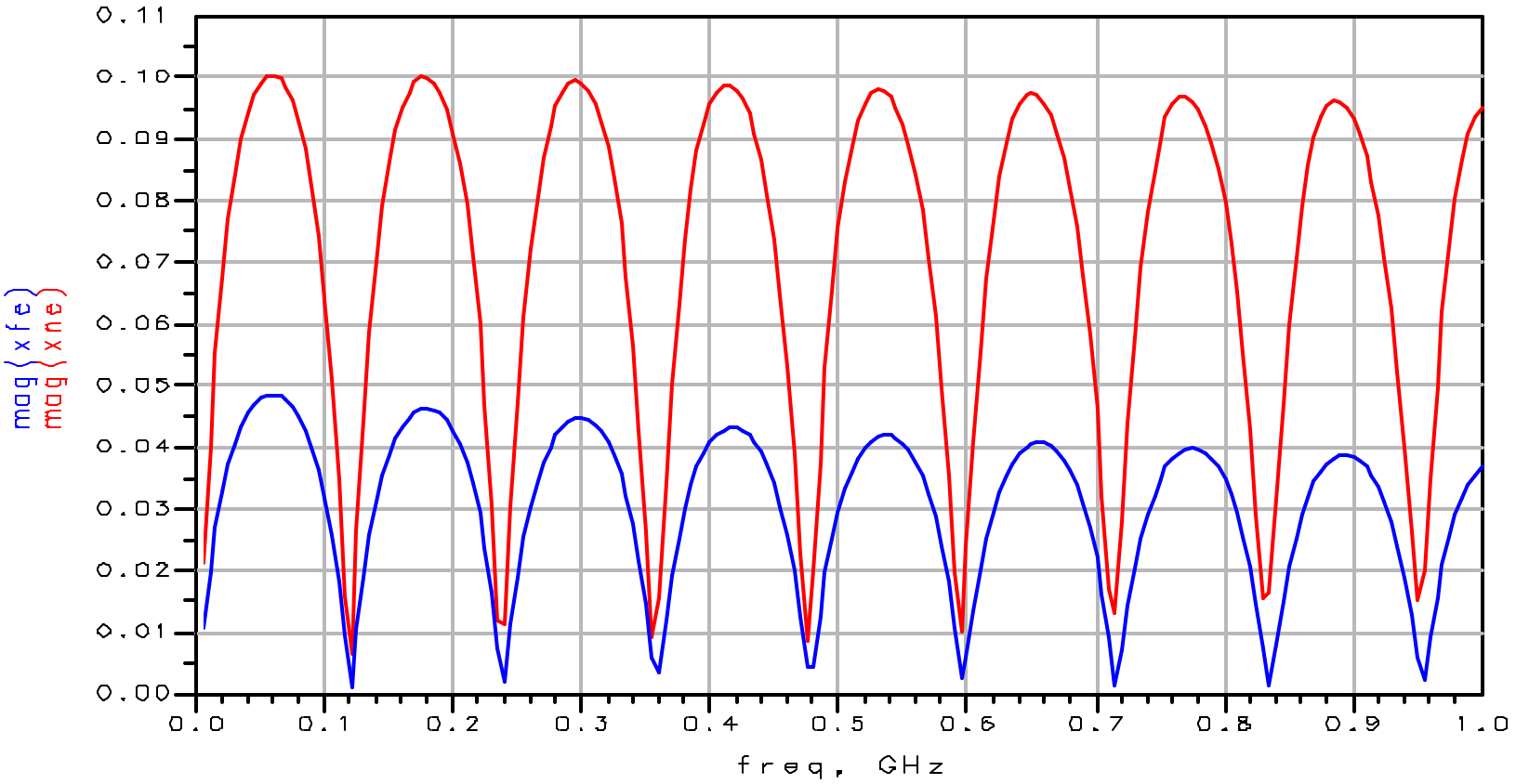
Seagate
Information the way you want it

T'n'F Flat (Straight) Section – Xtalk – ADS Converted to Hspice



Amphenol straight-section of ribbon cable, crosstalk simulation for correlation with HSPICE results (near-end in red, far-end in blue)

T10/02-052r1

Seagate
Information the way you want it

amphenol_ribbon_twisted_rlgc.sp

```
* This simulation has been run with Hspice 2000.2.1
.probe
.options post brief accurate
*.option itl4=50
.option reltol=1e-3 abstol=1e-8
*.option gshunt=1e-12 cshunt=1e-12
*.option method=gear

V1 VIN1 0 dc 0 ac=1 0
R1 VIN1 1  50
C1 1 0 .3pf
V3 VIN3 0 dc 0 ac=1 180
R3 VIN3 3 50
C3 3 0 .3pf
R5 5 0 50
C5 5 0 .3pf
R7 7 0 50
C7 7 0 .3pf
.ac lin 1000 5MHZ 1GHZ
WTRACE1 1 3 5 7 0 2 4 6 8 0 N=4 L=0.9144 RLGCMODEL=ribbontwistedrlgc
.model ribbontwistedrlgc W MODELTYPE=RLGC N=4
+Lo=
+5.42101e-7
+2.08812e-7 5.39897e-7
+7.37553e-8 1.4977e-7  5.39897e-7
+3.70765e-8 7.37553e-8 2.08812e-7 5.42101e-7
+Co=
+4.58537e-11
+-1.7322e-11   4.8991e-11
+-1.35993e-12 -1.0698e-11   4.8991e-11
+-2.55497e-13      -1.35993e-12      -1.73224e-11     4.58537e-11
```

T10/02-052r1

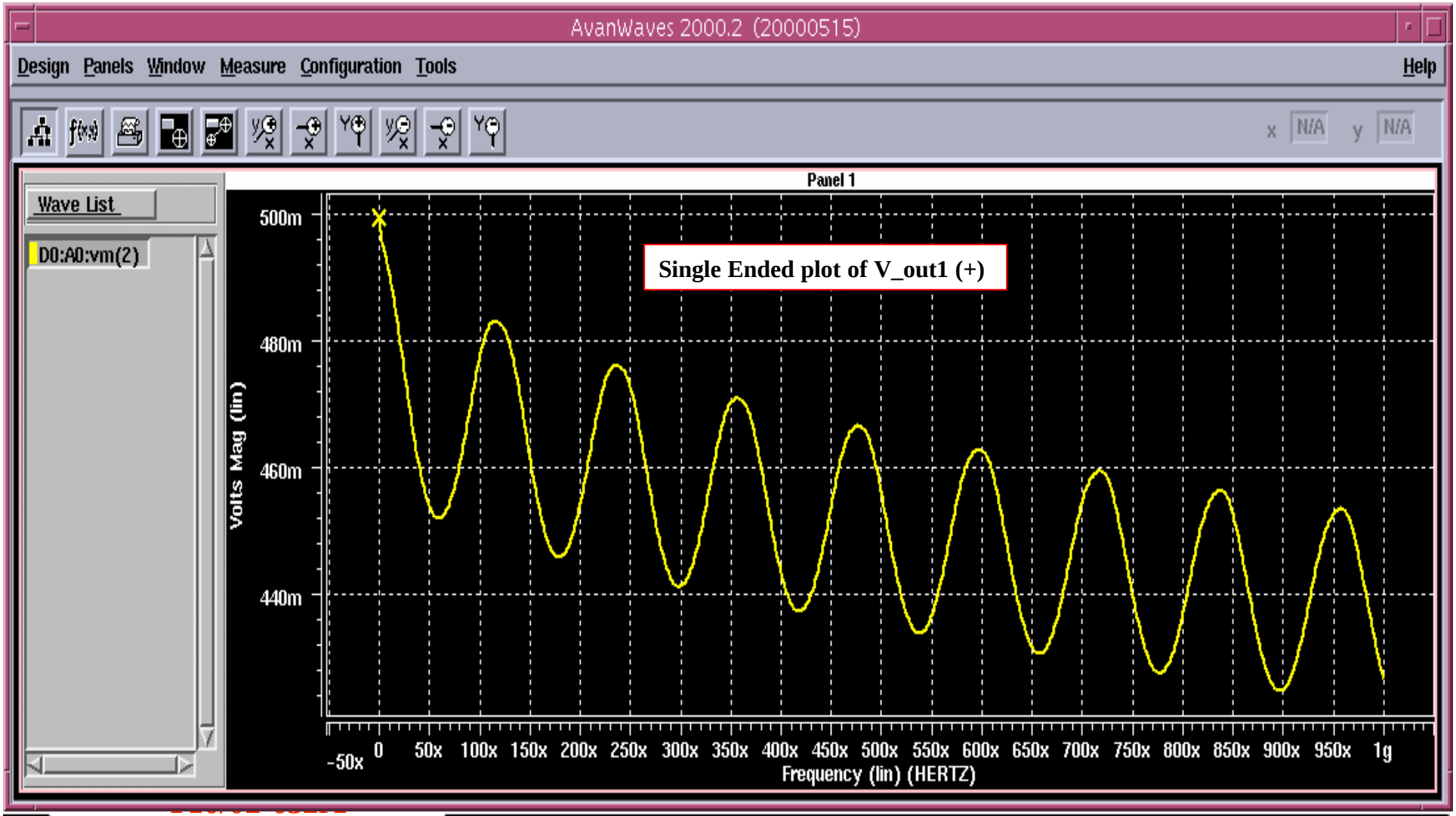
amphenol_ribbon_twisted_rlgc.sp (contd)

```
+Ro=
+0.120858
+0        0.120858
+0        0        0.120858
+0        0        0        0.120858
+Go=
+0
+0  0
+0  0  0
+0  0  0  0
+Rs=
+0.0004922
+2.76878e-5 0.000501374
+19.31134e-6 2.54108e-5 0.000501374
+13.32314e-6 19.31134e-6 2.76878e-5 0.0004922
+Gd=
+1.74083e-15
+-6.57643e-16 1.85994e-15
+-5.16295e-17 -4.06149e-16 1.85994e-15
+-9.69989e-18 -5.16295e-17 -6.57643e-16 1.74083e-15
R2 2 0 50
C2 2 0 .3pf
R4 4 0 50
C4 4 0 .3pf
R6 6 0 50
C6 6 0 .3pf
R8 8 0 50
C8 8 0 .3pf

.probe ac vr(vin1,vin3) vi(vin1,vin3) vr(2,4) vi(2,4)
.end
```

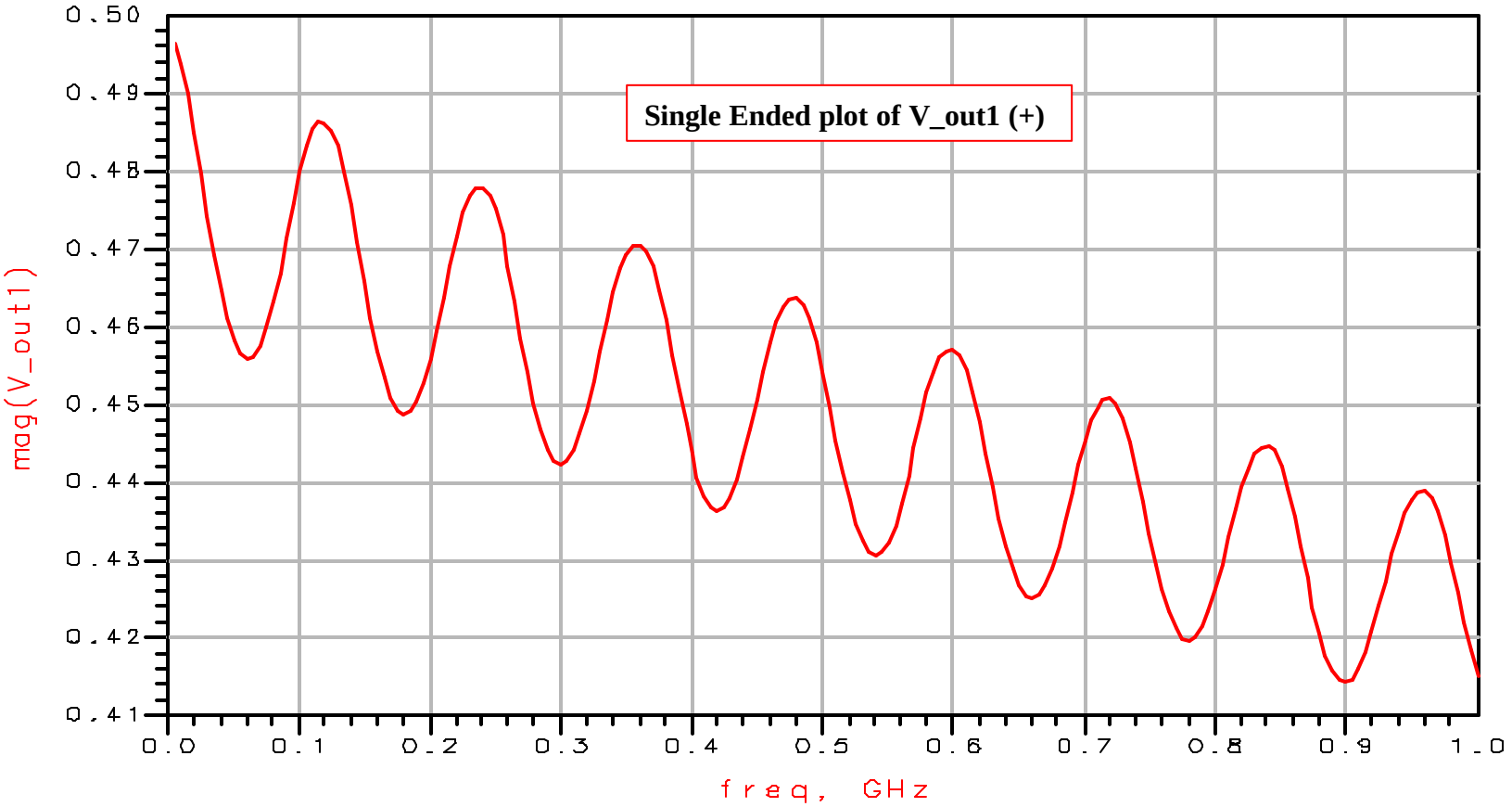
T10/02-052r1

T'n'F Twisted Section – Diff. Attn. - Hspice



Seagate
Information the way you want it

T'n'F Twisted Section – Diff. Attn. – ADS Converted to Hspice

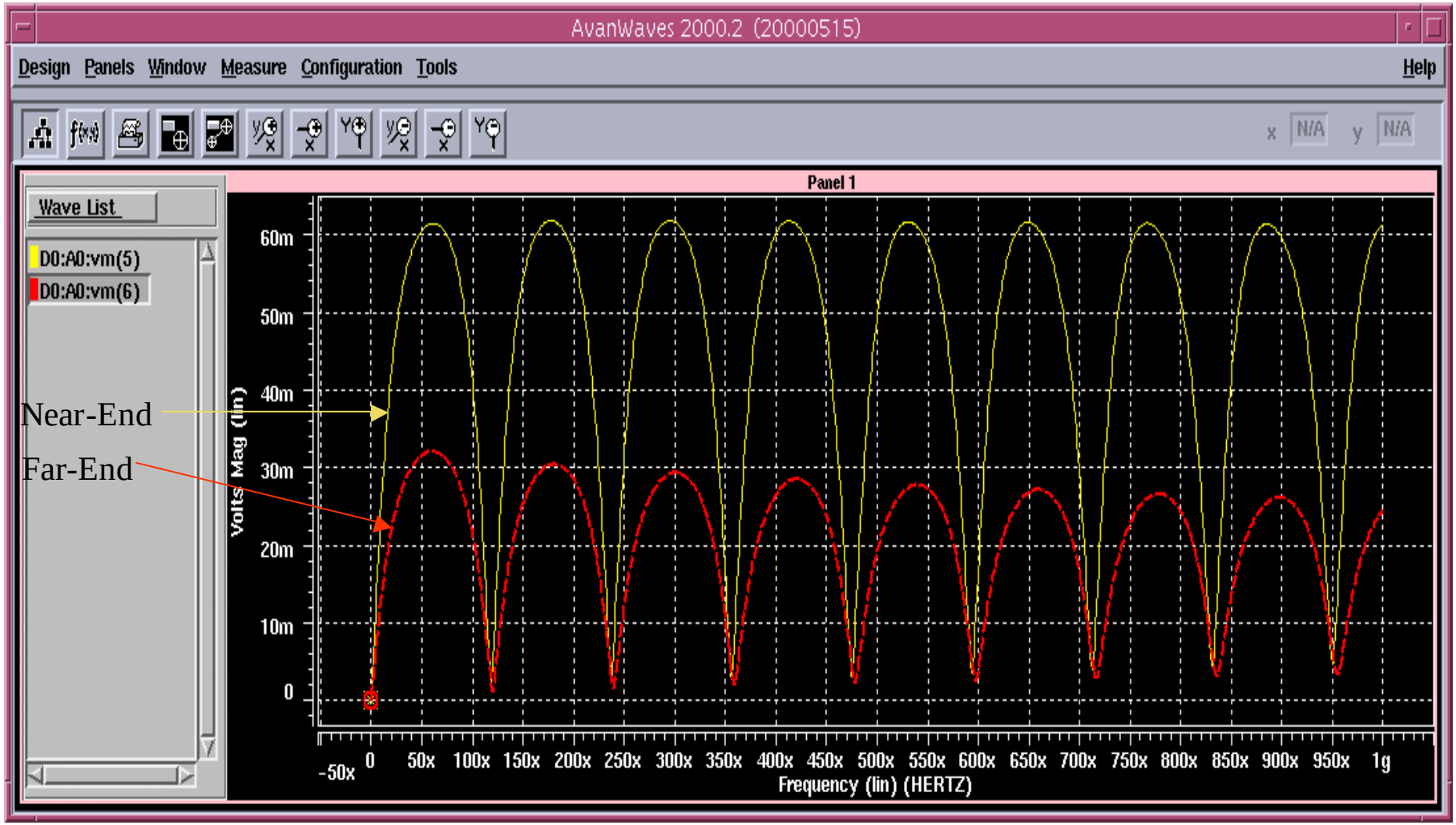


Amphenol twisted-section of ribbon cable, differential attenuation simulation for correlation with HSPICE results

T10/02-052r1

Seagate
Information the way you want it

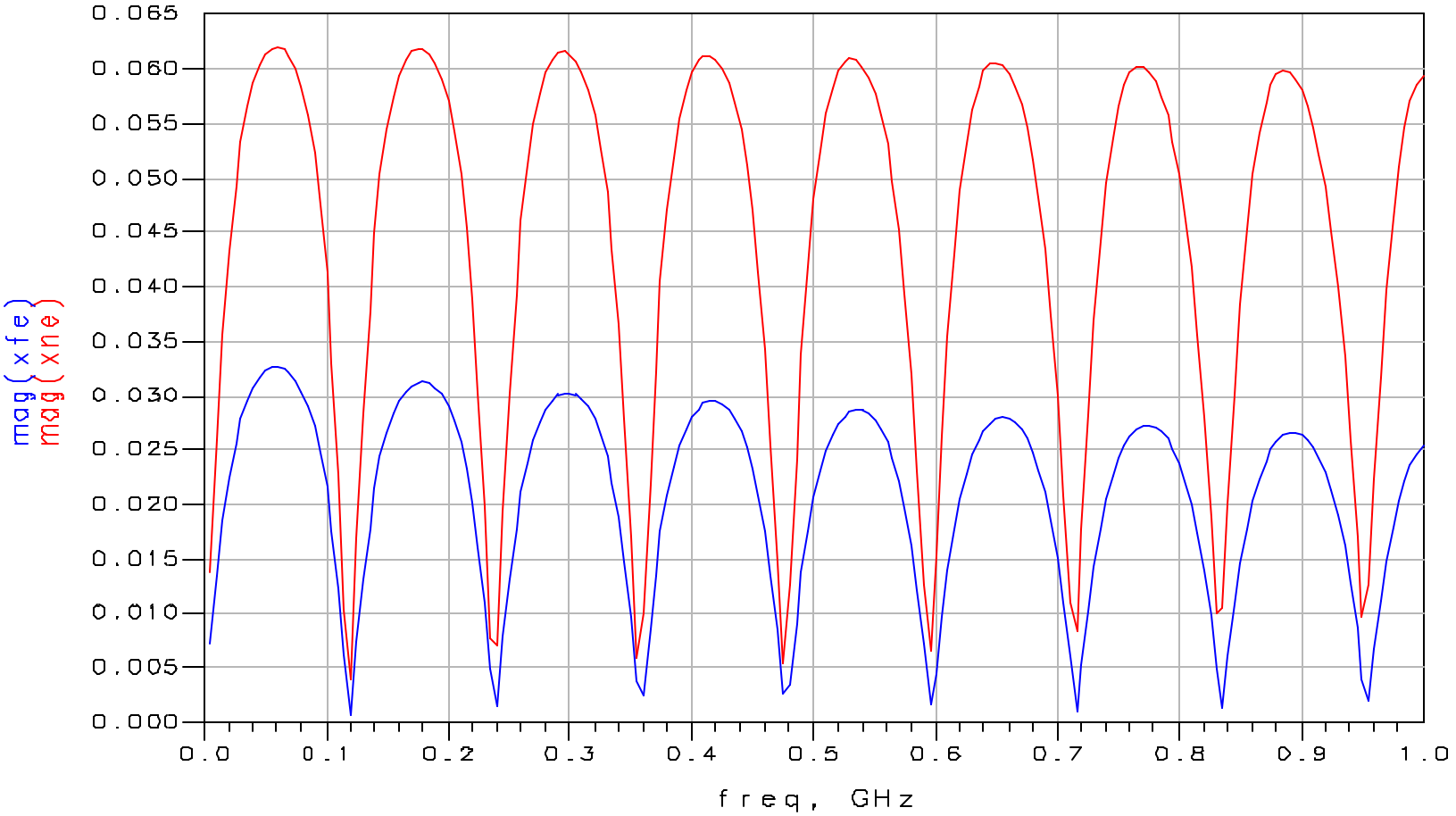
T'n'F Twisted Section – Cross Talk - Hspice



T10/02-052r1

Seagate
Information the way you want it

T'n'F Twisted Section – Xtalk – ADS Converted to Hspice



Amphenol twisted-section of ribbon cable, crosstalk simulation for correlation with HSPICE results (near-end in red, far-end in blue)

T10/02-052r1

Seagate
Information the way you want it

Summary of what was heard

- Model is simplified version of actual DUT (sample)
  - Dramatically reduces the amount of data required
  - Reduces the amount of time for simulation(s)
  - Can be used for lengths different than the test sample
- The model generated creates a baseline against which a difference function can be calculated
  - The difference function can be evaluated to determine if it is caused by noise or by features of the sample not included in the model
- Ability to project in other configurations (needs to be proven)

T10/02-052r1

What's next

- Measure and model 3-4 more cables
- Predict using model and verify using measurement
- Model Assy. – JPM cable with connector pair
  - Measure bulk cable piece, install connector pair in the middle, re-measure
  - Generate connector pair and fan-out model as difference
- Make preliminary model of 2 backplanes and verify predictability