VITESSE

Lucent Technologies
Bell Labs Innovations

10 Gb/s Duobinary Signaling over ATCA PICMC 3.0 Backplanes

(Advanced Telecommunications Computing Architecture)

Measured Results
and Cross-talk Simulations

IEEE 802.3ap Task Force
Ottawa
September 27-29, 2004

Contributors

Lucent

Jeffrey H. Sinsky

Andrew Adamiecki

Marcus Duelk

Mary Mandich

H. Walter

H. –J. Goetz

Chuck Byers

Vitesse

Majid Barazande-Pour

Glen Koziuk

John Khoury

Supporters

- John D'Ambrosia, Tyco

*This contributor supports multi-level signaling standardization for certain applications. His support does not necessarily reflect the support of duobinary over competing technology solutions.

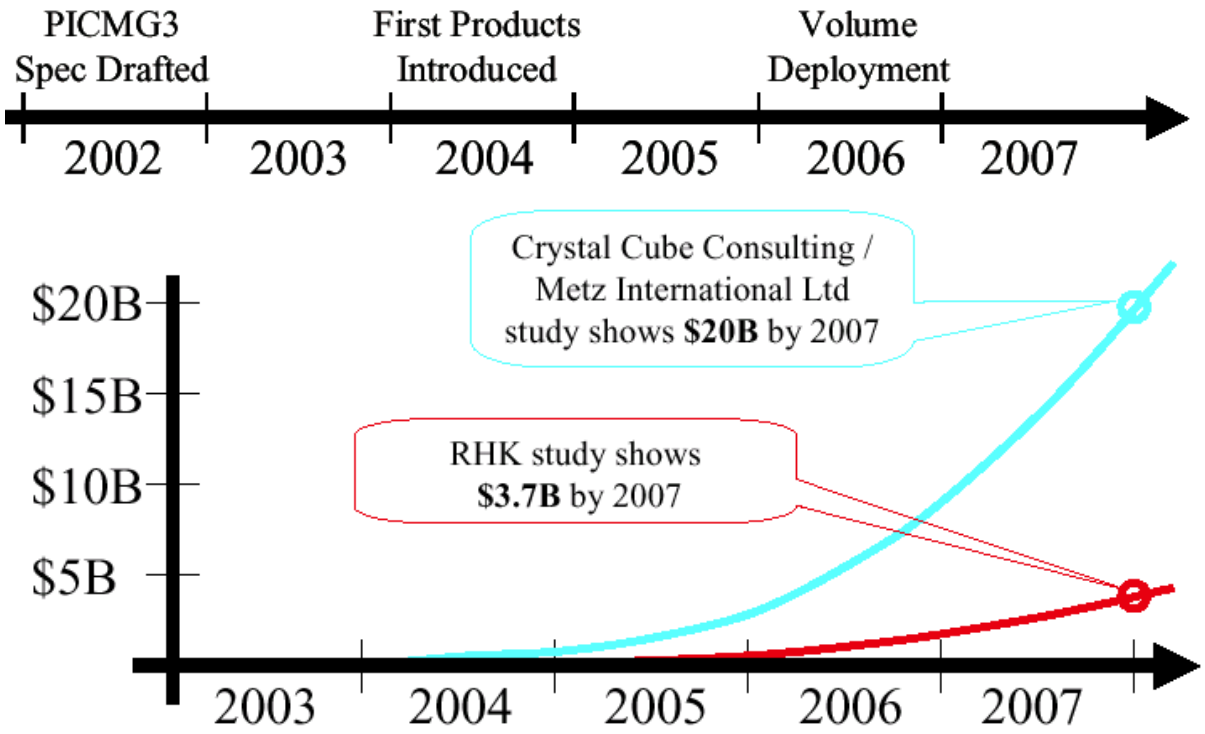
VITESSE
Lucent Technologies
Bell Labs Innovations

Talk Outline

- Motivation – Why ATCA Backplanes?
- Brief Review of Proposed Duobinary Architecture
- Measurement Test Setup
- A Note on NRZ/Duobinary Compatibility
- New Measured Results
  - 10 Gb/s over Tyco ATCA backplanes
  - 10 Gb/s over Kaparel ATCA backplanes
- Cross-talk Simulations
- Conclusion

Motivation - Why ATCA Backplanes?

AdvancedTCA Timeline and Market Uptake

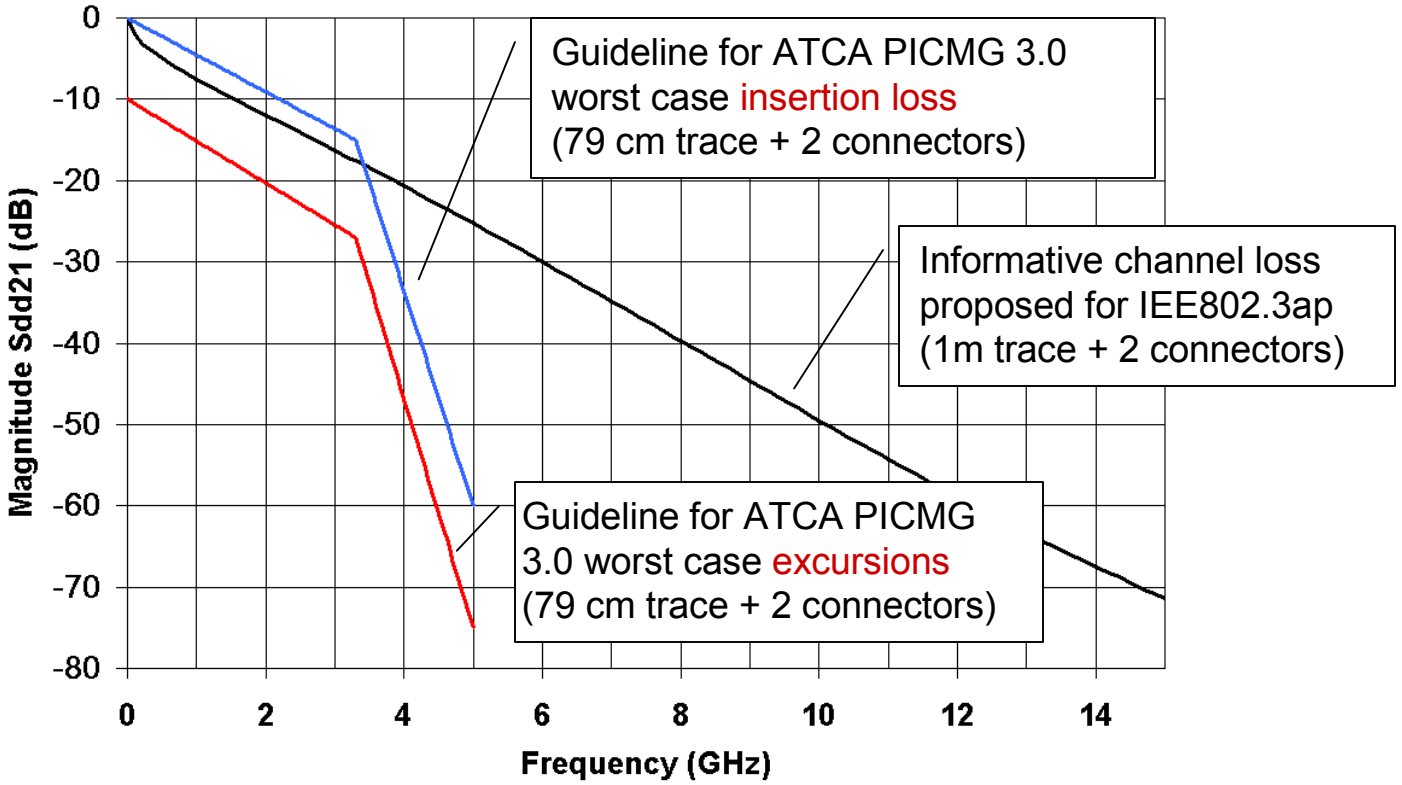


Companies that have publicly announced the use of ATCA platforms.

Motorola, NEC, Siemens, Intel, Force Computer (now Motorola)

Motivation – The ATCA Backplane Challenge

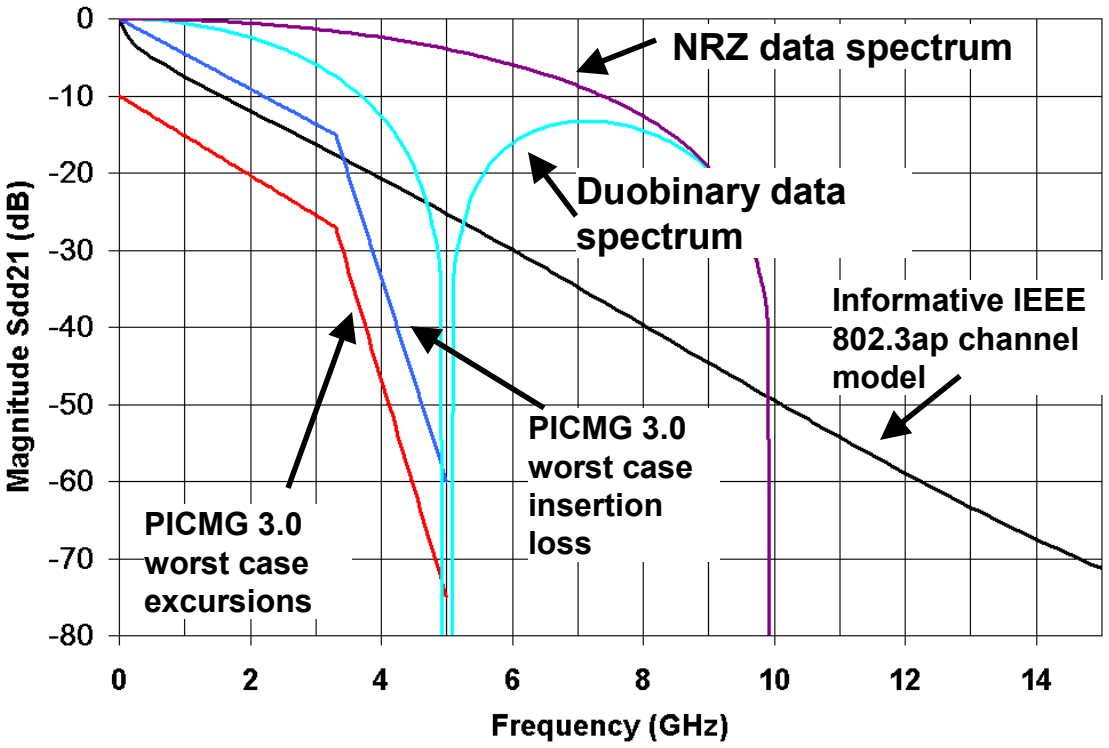
- ATCA PICMG 3.0 backplanes will probably have channels right at the "worst case insertion loss" supported by IEEE 802.3ap guideline
  - **Current ATCA insertion loss guideline parallels the IEEE 802.3ap channel model to 3.3 GHz, BUT actually drops off much faster > 3.3GHz**



VITESSE
Lucent Technologies
Bell Labs Innovations

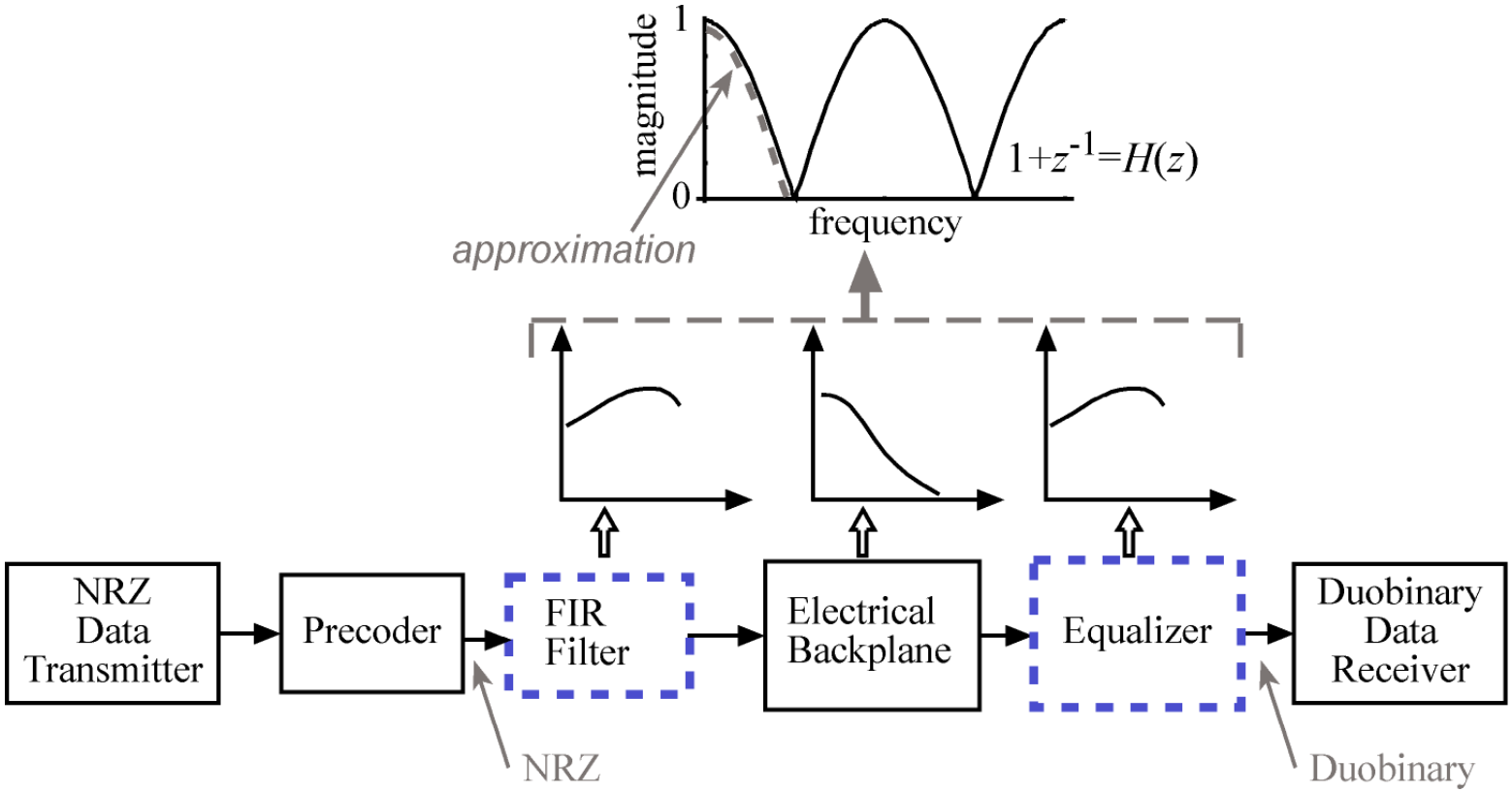
Motivation – The ATCA Backplane Challenge

- The ATCA PICMG 3.0 backplanes will be a challenge for NRZ at 10 Gb/s
- ***Duobinary is a good candidate for this application!!***
  - 3 dB bandwidth is 2.5 GHz for 10 Gb/s transmission
  - Spectral null at 5 GHz



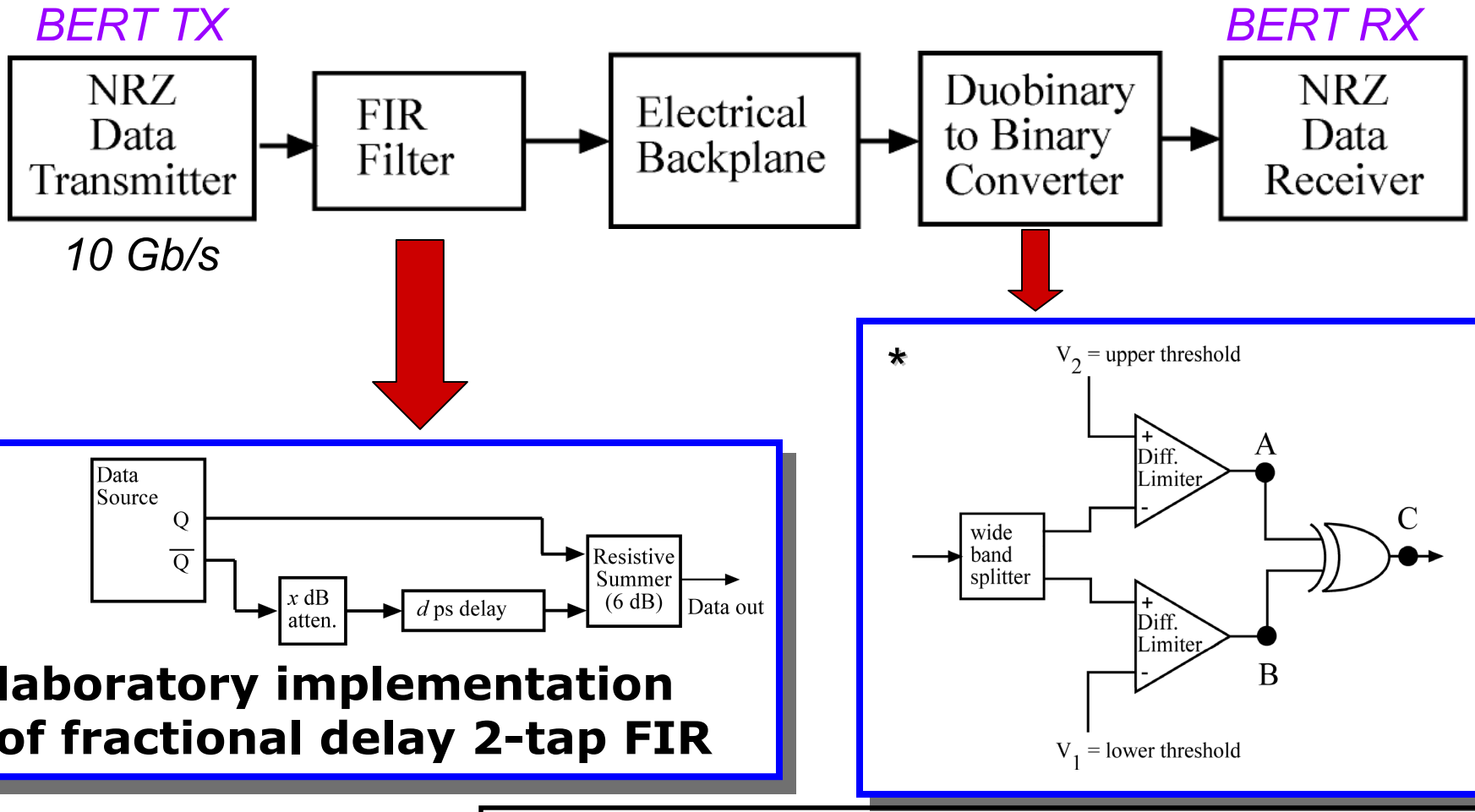
VITESSE
Lucent Technologies
Bell Labs Innovations

Review of Proposed Duobinary Signaling Concept for Backplane Transmission



We reshape the NRZ data spectrum from the transmitter using pre-emphasis and/or equalization such that the resulting waveform available at the receiver *after* traveling through the backplane is a *duobinary* signal.

Measurement Test Setup



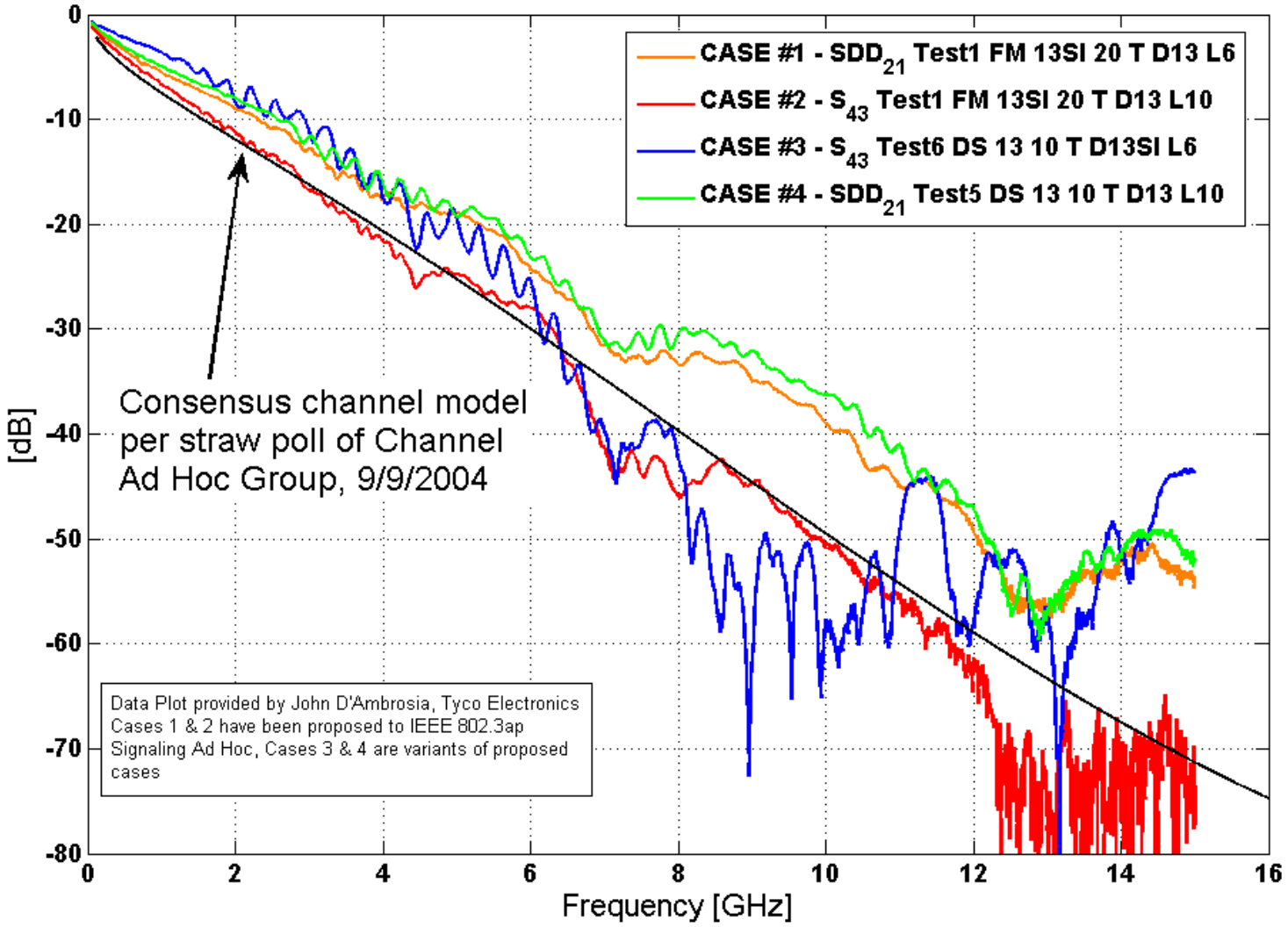
*** For more details on the decoder architecture, see IEEE IMS-2004 article entitled, "10-Gb/s Electrical Backplane Transmission using Duobinary Signaling," by Sinsky, Adamiecki, and Duelk – *Lucent Technologies*.**

VITESSE
Lucent Technologies
Bell Labs Innovations

Measurement Notes

- All tests are for a data rate of 10 Gb/s
- A PRBS sequence length of 2^{31}-1 is used in all cases
- Two-tap pre-emphasis was used in all cases
  - Passive microwave components were used
- Cases #1 and #4 were measured differentially
- Cases #2 and #3 were measured single-ended
  - Tough Channels – Needed to reduce reflections resulting from our differential distributed circuit FIR implementation -- not an issue for real IC implementation
- The amplitude of the signal driving the backplane was between 590 mV – 760 mV single-ended (*dependent on FIR taps*)
- Limited time and availability of the ATCA backplanes did not allow us to measure BER better than 10^{-14}

ATCA Backplane Channels



VITESSE

Lucent Technologies
Bell Labs Innovations

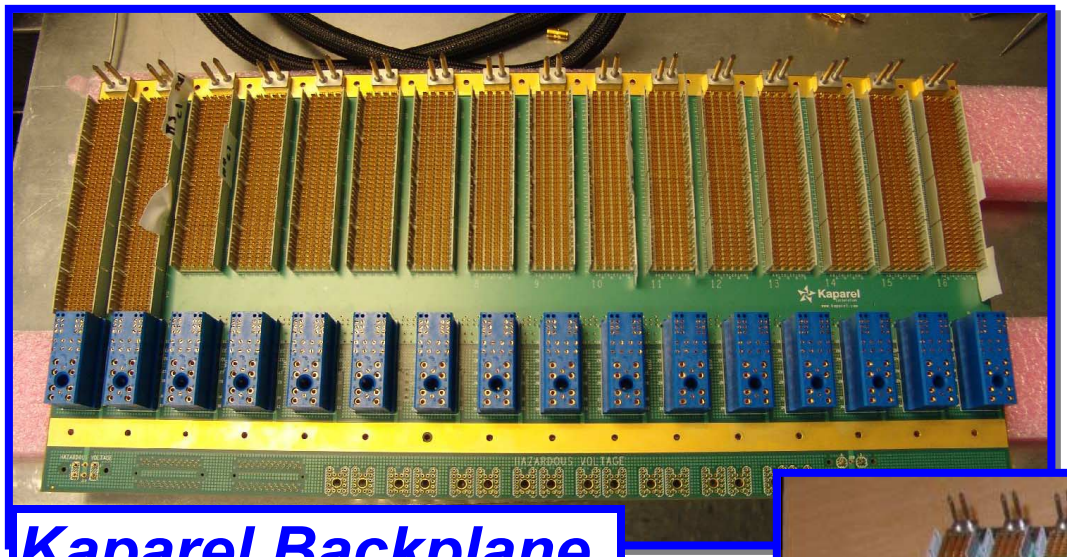
Measured Backplane Trace Descriptions

Case # (per slide 11)	Backplane		Line Card		Total Length	Manufacturer/ Configuration	D'Ambrosia designation**	Measurement Approach
	Length	Material	Length	Material				
1	20"	Nelco 4000-13 SI	6"	Nelco 4000-13	32"	Kaparel Full Mesh	Test Case 4	Differential
2	20"	Nelco 4000-13 SI	10"	Nelco 4000-13	40"	Kaparel Full Mesh	Test Case 2	Single-ended
3	10"	Nelco 4000-13	6"	Nelco 4000-13 SI	22"	Tyco Dual Star	Variant	Single-ended
4	10"	Nelco 4000-13	10"	Nelco 4000-13 SI	30"	Tyco Dual Star	Variant	Differential

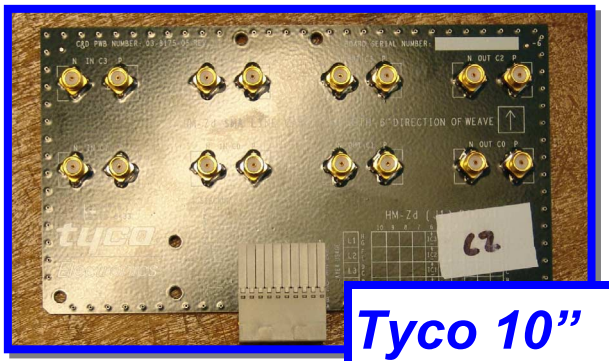
** This test case designation is per the proposal to the IEEE 802.3ap Signaling Ad Hoc group entitled, "Channels for Consideration by the Signaling Ad Hoc," John D'Ambrosia, Tyco Electronics, Sept. 17, 2004, page 6.

VITESSE
Lucent Technologies
Bell Labs Innovations

ATCA Backplanes and 10” Line Card



Kaparel Backplane
Full Mesh



Tyco 10”
Line Card

Tyco Backplane
Dual Star

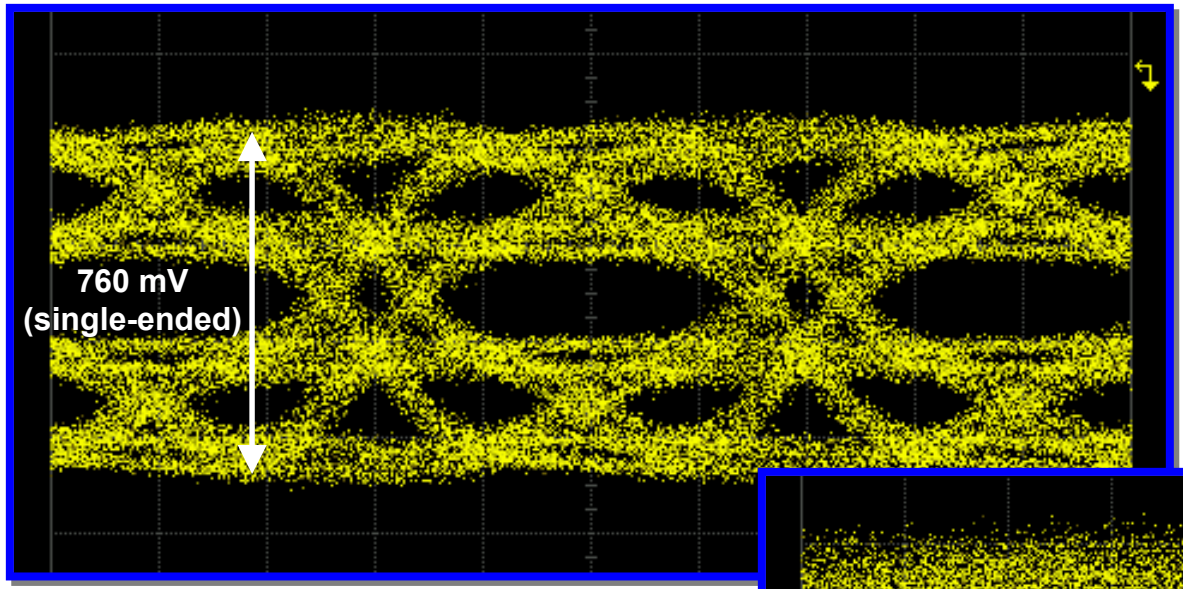
VITESSE
Lucent Technologies
Bell Labs Innovations

Case #1

Duobinary over ATCA Test1 FM 13SI 20 T D13 L6

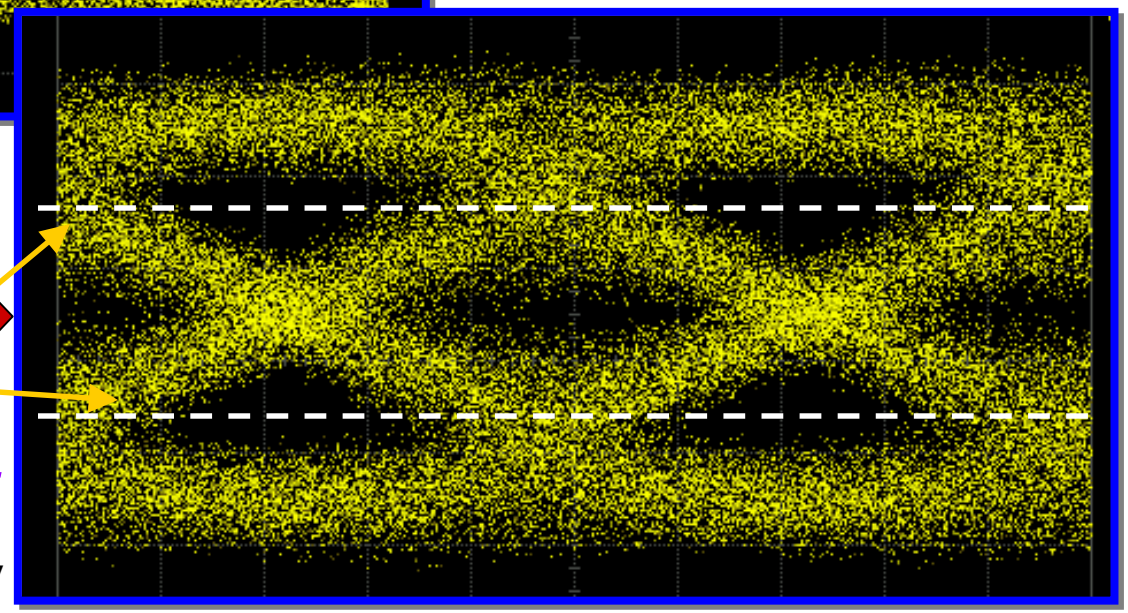
Kaparel – 32" Trace – 6" Line Card

- FIR Settings
  - 5 dB Attenuation
  - 150 ps delay
- Performance at 10 Gb/s
  - BER $<10^{-13}$ (time limited measurement)



25 ps/div

Pre-emphasized data



decision thresholds

Backplane Output

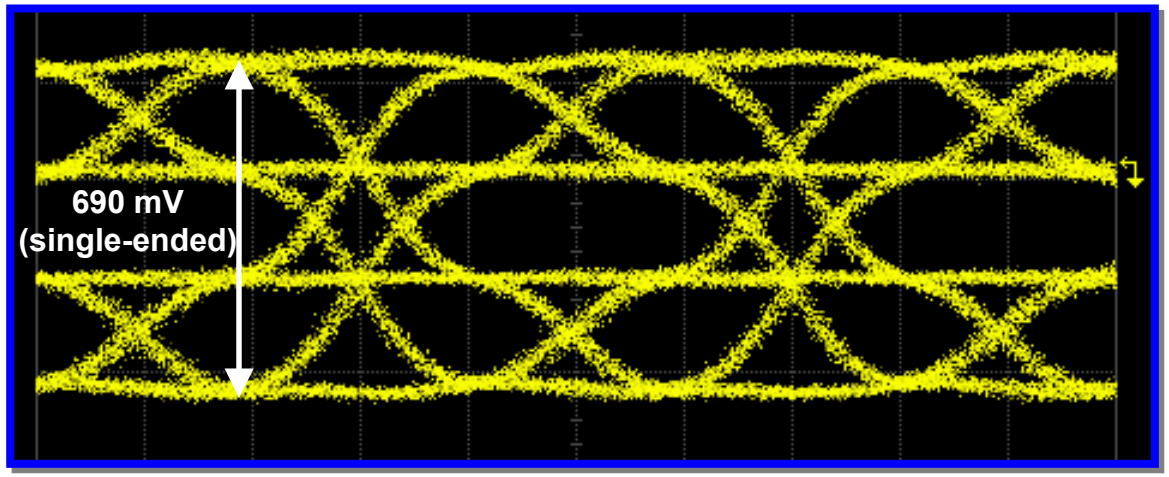
20 ps/div

VITESSE
Lucent Technologies
Bell Labs Innovations

Case #2

Duobinary over ATCA Test1 FM 13SI 20 T D13 L10

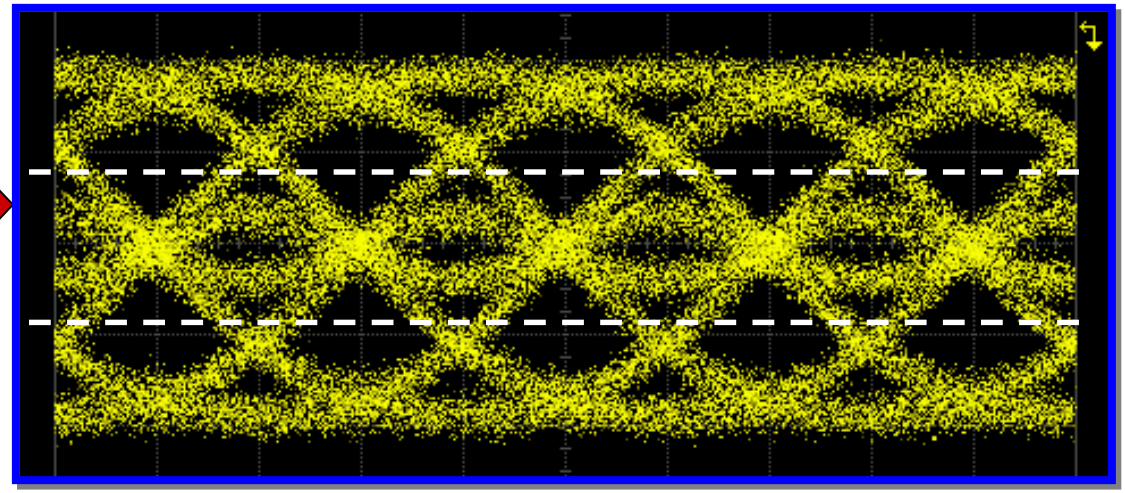
Kaparel – 40” Trace – 10” Line Card



- FIR Settings
  - 6 dB Attenuation
  - 150 ps delay
- Performance at 10 Gb/s
  - BER <10^{-14} (time limited measurement)

Pre-emphasized data

25 ps/div



Backplane Output

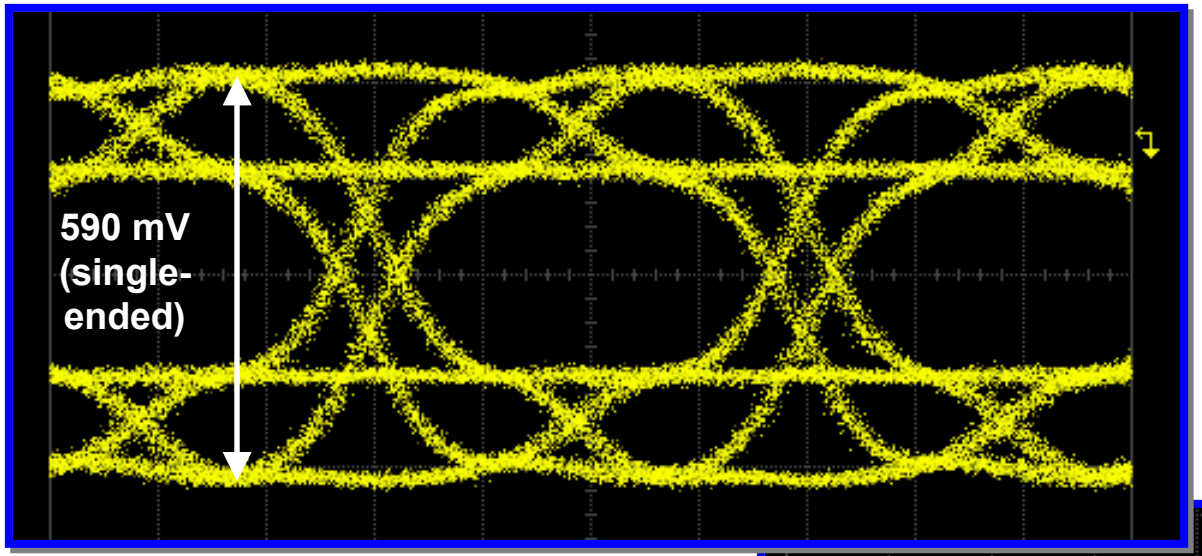
50 ps/div

VITESSE
Lucent Technologies
Bell Labs Innovations

Case #3

Duobinary over ATCA Test6 DS 13 10 T D13 L6

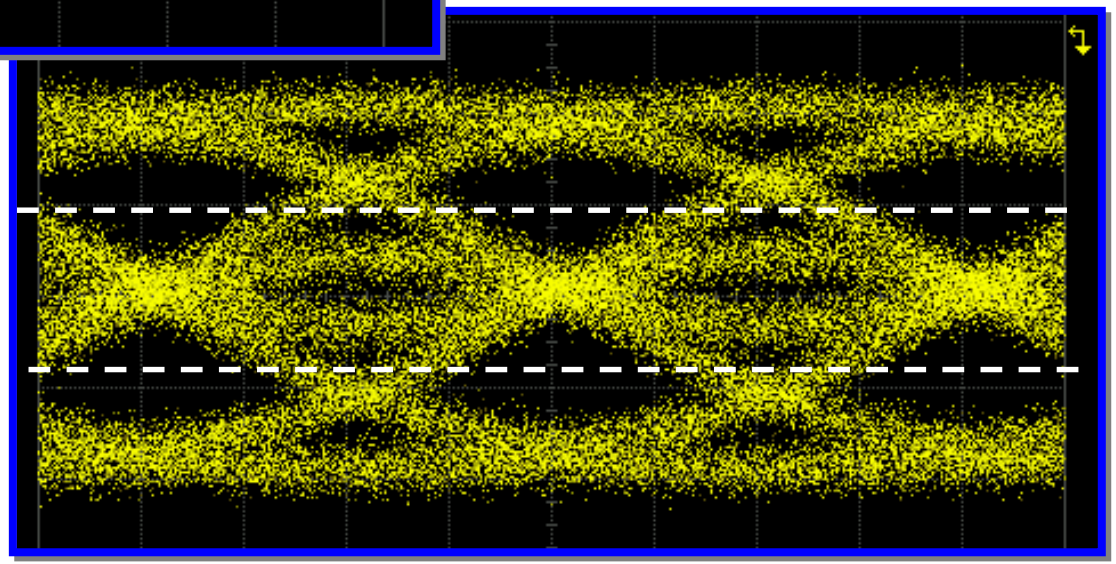
Tyco – 32" Trace – 6" Line Card



- FIR Settings
  - 10 dB Attenuation
  - 145 ps delay
- Performance at 10 Gb/s
  - BER $<10^{-14}$ (time limited measurement)

25 ps/div

Pre-emphasized data



Backplane Output

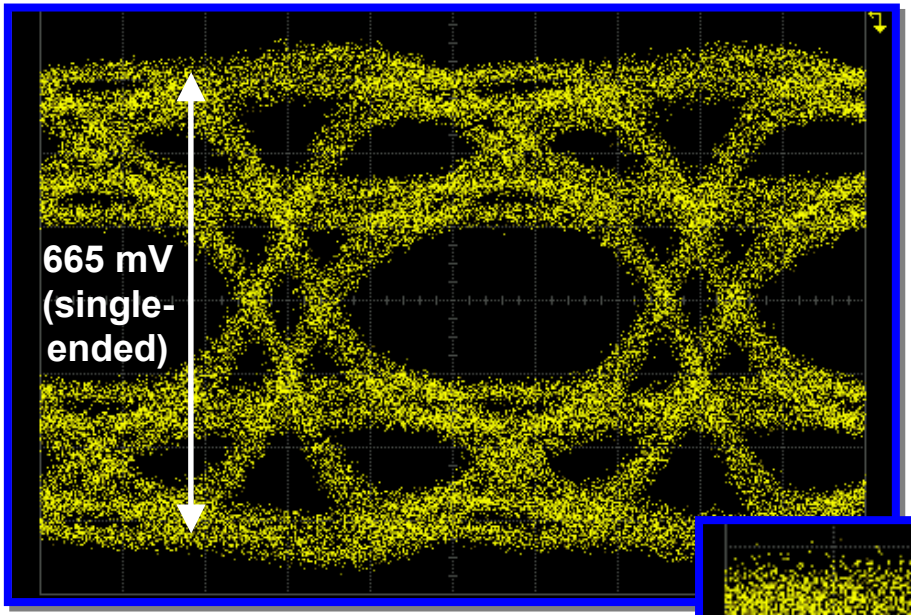
25 ps/div

VITESSE
Lucent Technologies
Bell Labs Innovations

Case #4

Duobinary over ATCA Test5 DS 13 10 T D13SI L10

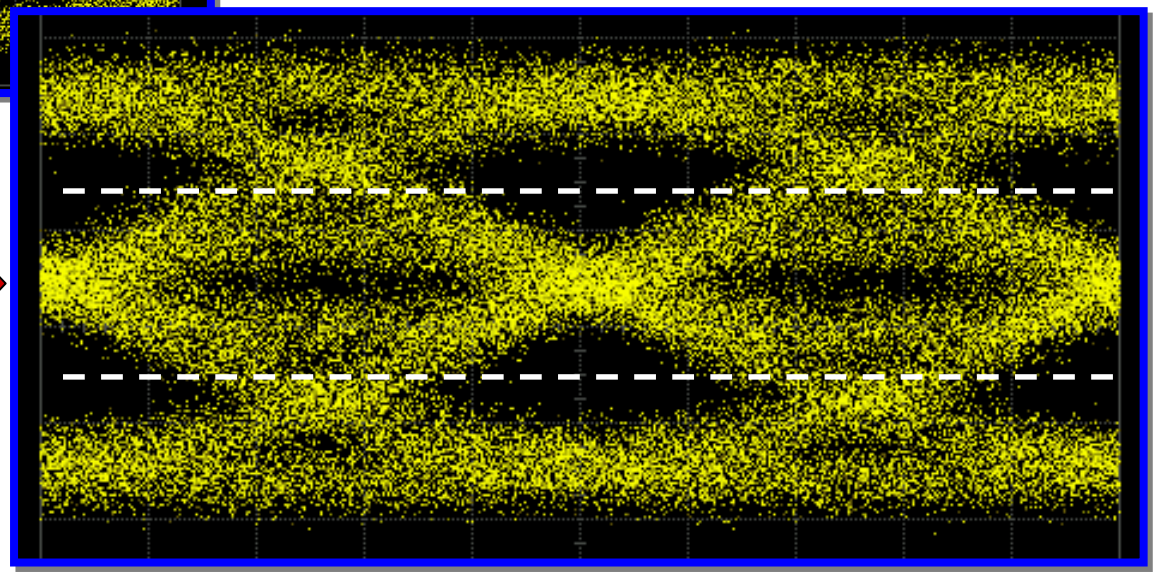
Tyco – 30” Trace – 10” Line Card



- FIR Settings
  - 10 dB Attenuation
  - 150 ps delay
- Performance at 10 Gb/s
  - BER $<10^{-13}$ (time limited measurement)

Pre-emphasized data

20 ps/div

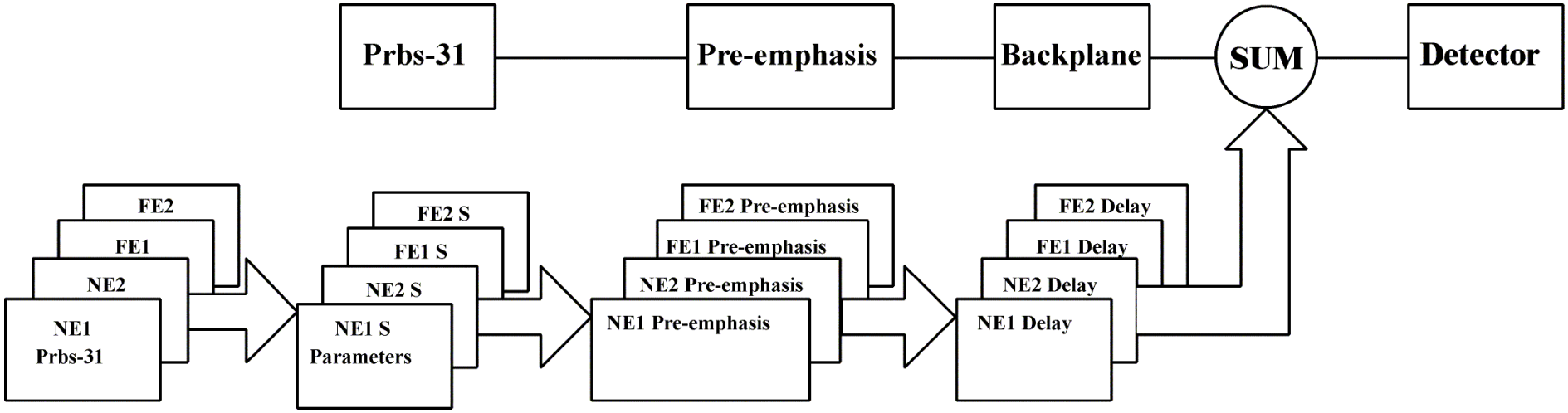


Backplane Output

20 ps/div

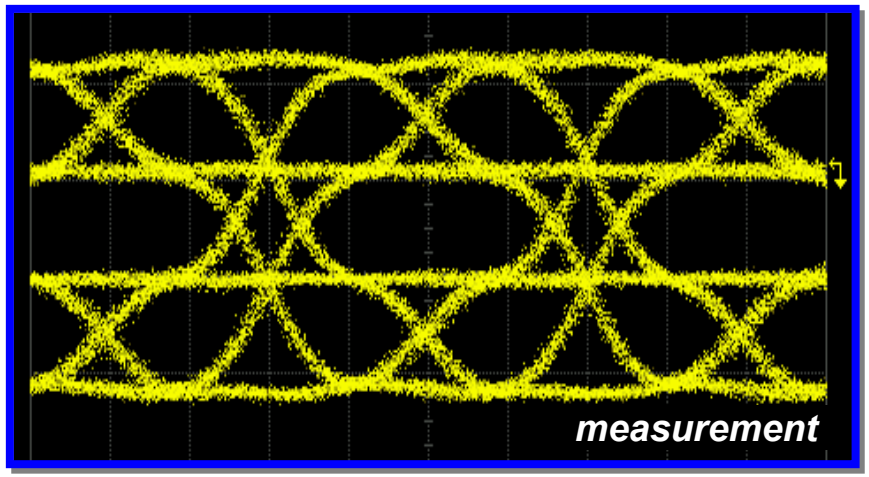
VITESSE
Lucent Technologies
Bell Labs Innovations

Topology for Transmission and Cross-talk Simulations

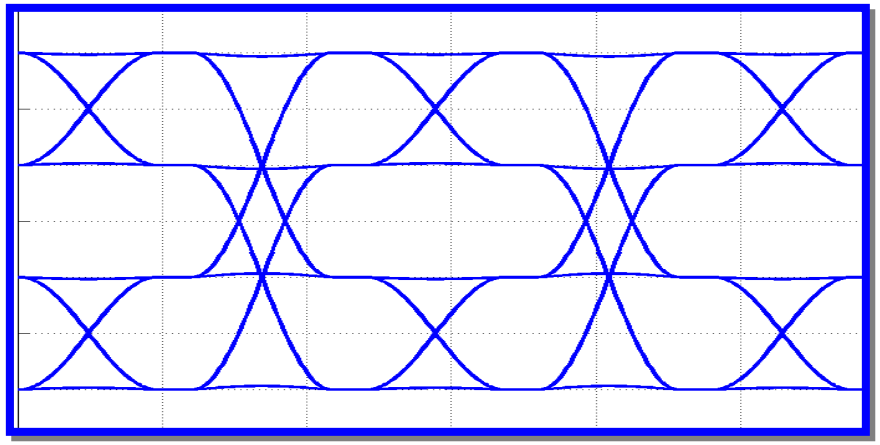


- Four cross-talk aggressors are assumed
  - NE1 = Near end 1, NE2 = Near end 2
  - FE1 = Far End 1, FE2 = Far End 2
- 1200 bits of a PRBS31 sequence are used
- Measured 4-port S-Parameters are used to represent transmission and cross-talk characteristics
- Cross-talk data streams are delayed in such a way as to provide a worst case scenario and have the same pre-emphasis as the primary data stream
- Simulations were done in Matlab by Majid Barazande-Pour, of Vitesse

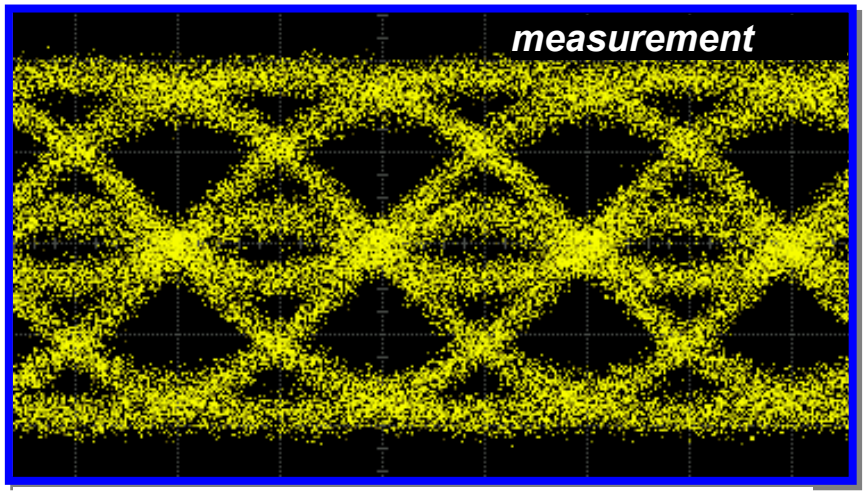
Comparison of Measurement and Simulation (Case #2)



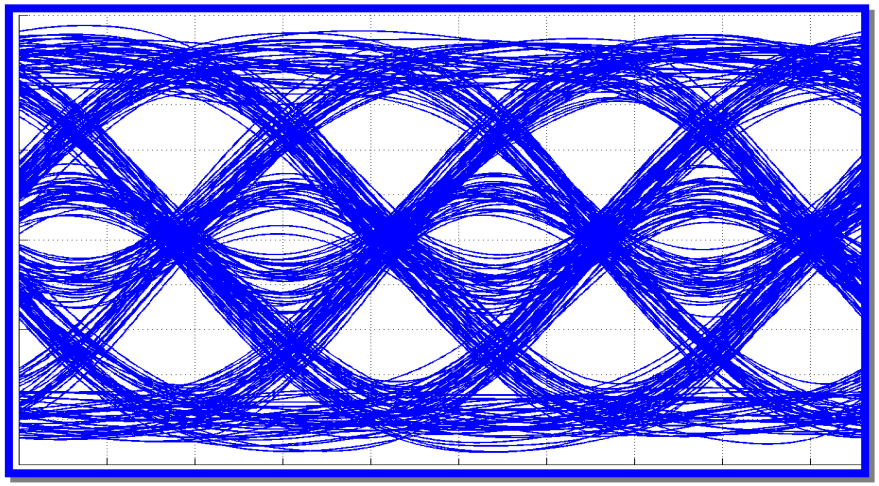
pre-emphasized NRZ eye



simulation



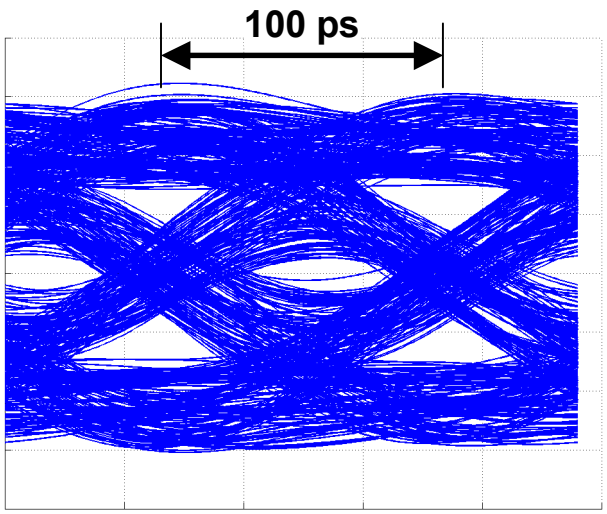
Duobinary output from the channel



simulation

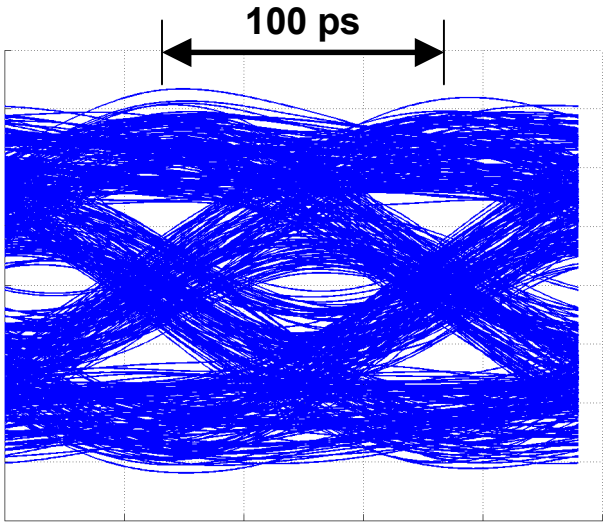
VITESSE
Lucent Technologies
Bell Labs Innovations

Cross-Talk Simulations

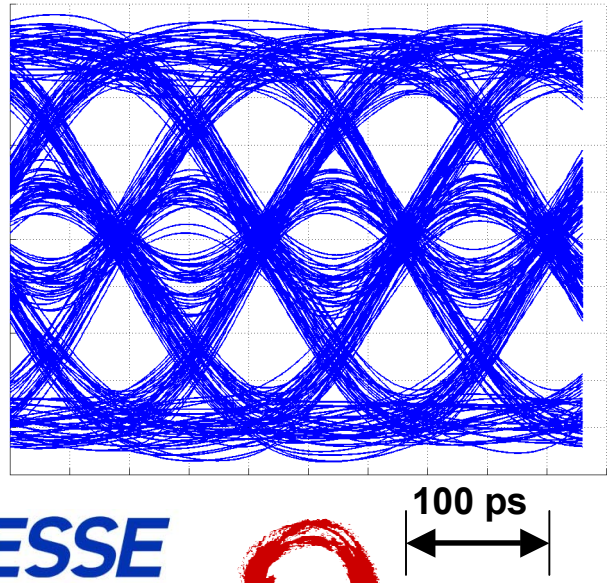


no cross-talk

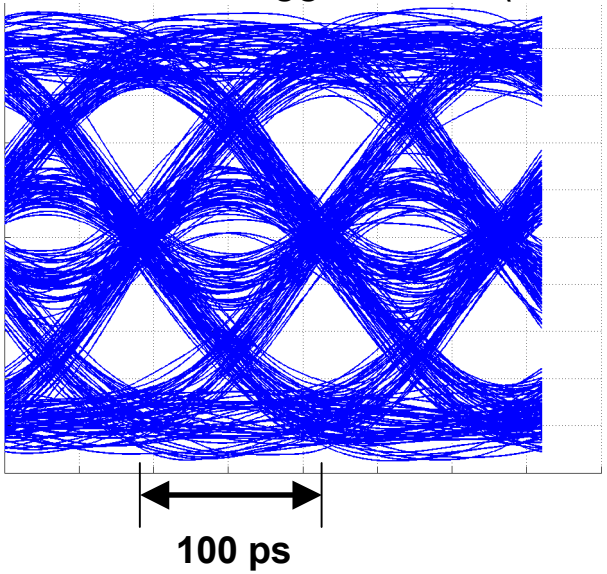
Case #1



cross-talk: 4 aggressors - (2 NE, 2 FE)

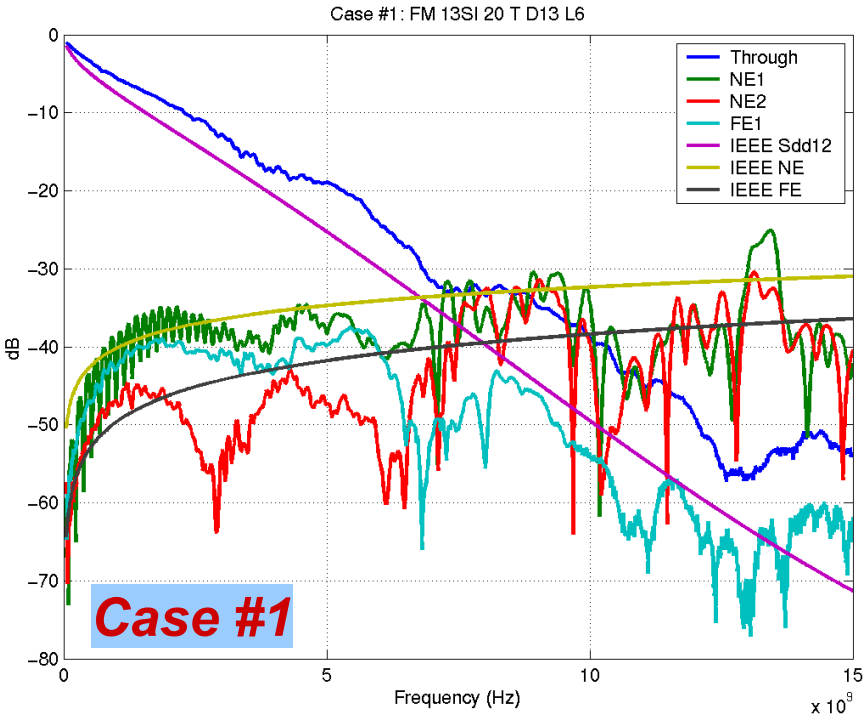


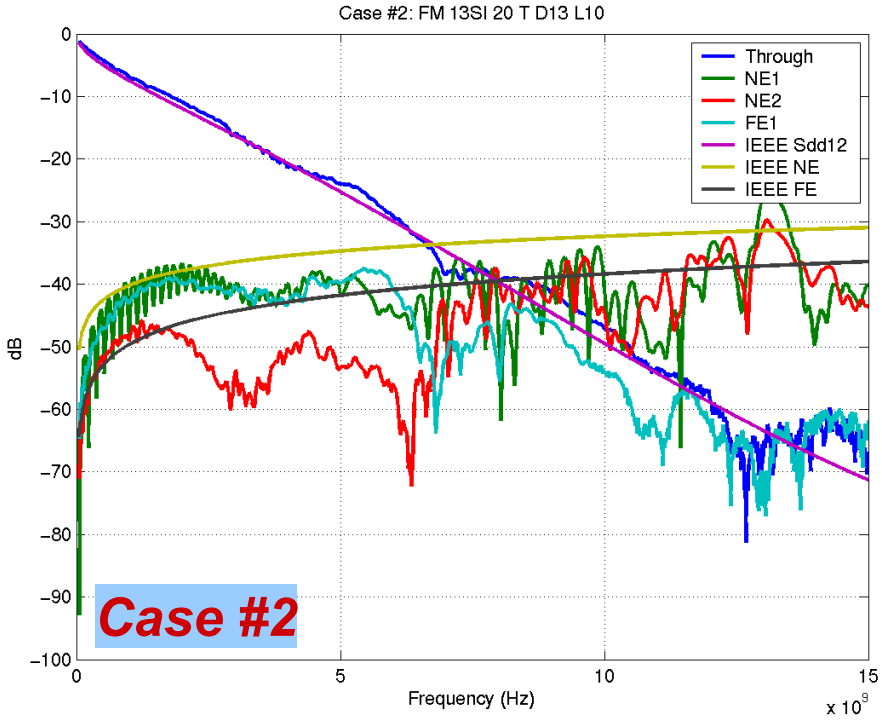
Case #2



VITESSE
Lucent Technologies
Bell Labs Innovations

Frequency Domain View of Cross-Talk



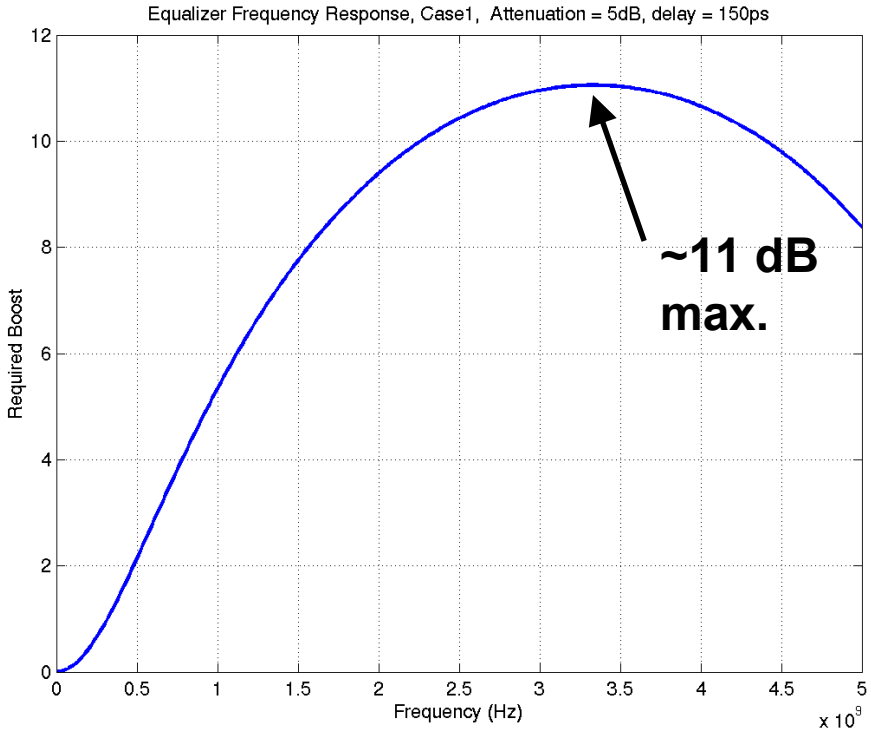


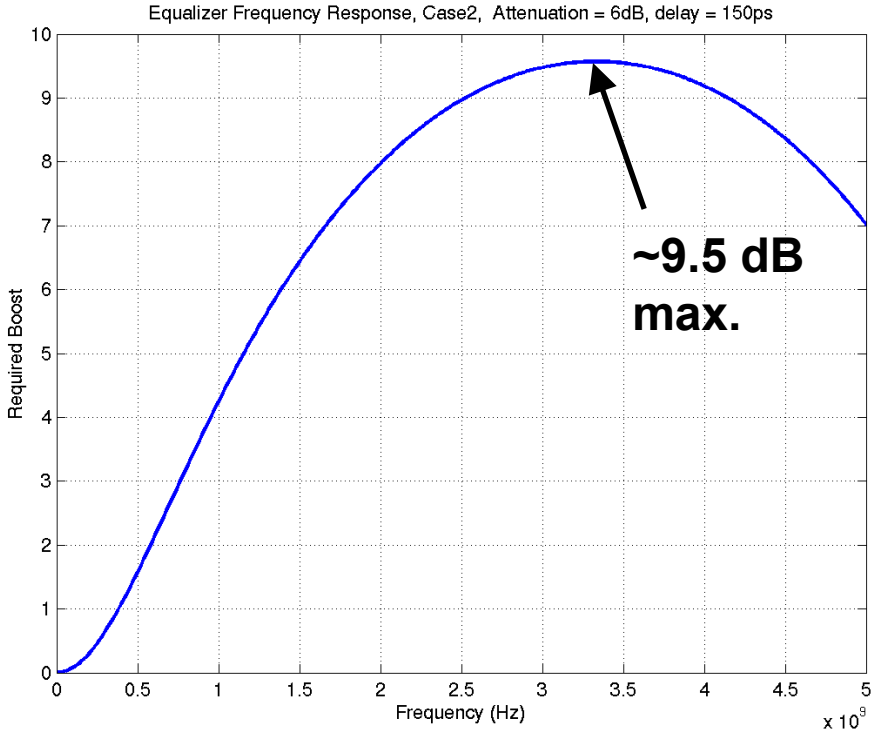
Legend Key

NE1= near end interferer #1
NE2 = near end interferer #2
FE1= far end interferer #1 and #2
IEEE Sdd12= IEEE 802.3ap channel model
IEEE NE=IEEE 802.3ap near end cross talk bound
IEEE FE = IEEE 802.3pa far end cross talk bound

VITESSE
Lucent Technologies
Bell Labs Innovations

Required Signal Boost





*Simulations show that a **reasonable** amount of boost is required to achieve good performance*

Conclusion

- **We have successfully *measured* 10 Gb/s data transmission through four representative ATCA backplane traces with BER <10^{-13} (time limited) in all cases**
  - For two cases, we extended the test time and achieved ***BER <10^{-14}***
  - PRBS sequences of 2^{31}-1 were used in all cases
  - These results are real measurements, NOT SIMULATIONS!
  - Both Kaparel and Tyco backplanes were used
- **We have shown through *simulation* that even with 4 interferers, cross-talk does not have a significant impact on the duobinary eye for two test cases.**
- We have shown that Duobinary signaling provides a simple and attractive approach for dealing with challenging backplane channels.
- We are willing to work with other parties interested in 10 Gb/s duobinary transmission over ATCA.