SCOPE
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Physical Layer Requirements For 155 Mb/s Twisted Pair ATM (AF-PHY-0015.000)

3.3.15	Will the IUT achieve the BER of 10^{-10} under the conditions specified at 100 meters with the channel NEXT and attenuation undefined above 100 MHz?	O.6	2.3, 5.1.1, 5.3.1	Yes__No__X__ S__

ATM_Forum / 96-0444

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Outline

- **Discussion of bandwidth requirements for the 155 Mb/s twisted pair interface (96-0444)**
  - **25 to 30 minutes**
- **Overview of the proposed Addendum #2 to the AF-PHY-0015.000 document (96-0527)**
  - **10 to 15 minutes**
- **Overview of the proposed PICS Proforma for AF-PHY-0015.000 interface (96-0445)**
  - **15 to 20 minutes**

SCOPE
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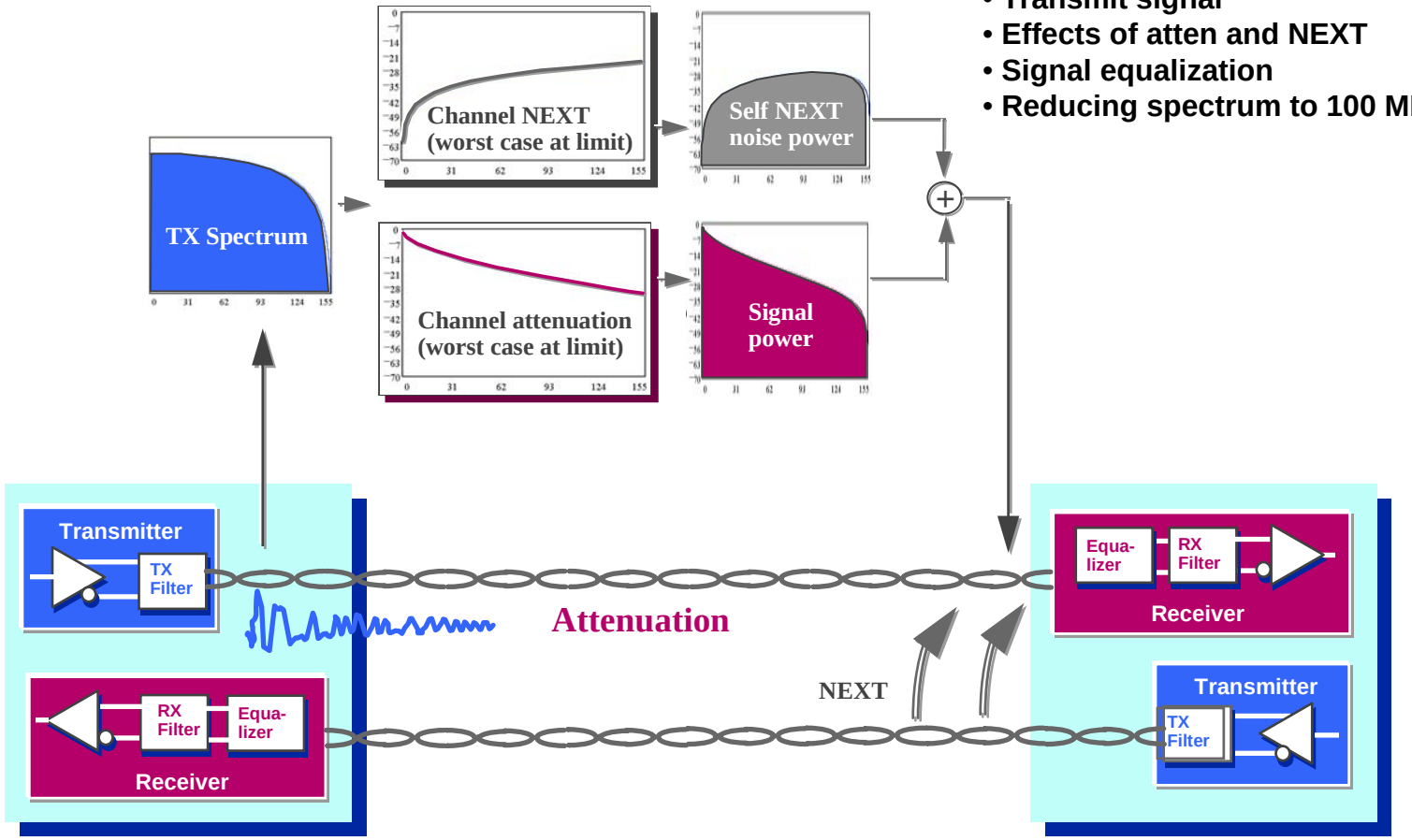
Discussion Overview / The ATM Twisted Pair Channel

- UTP channel overview
- Transmit signal
- Effects of atten and NEXT
- Signal equalization
- Reducing spectrum to 100 MHz



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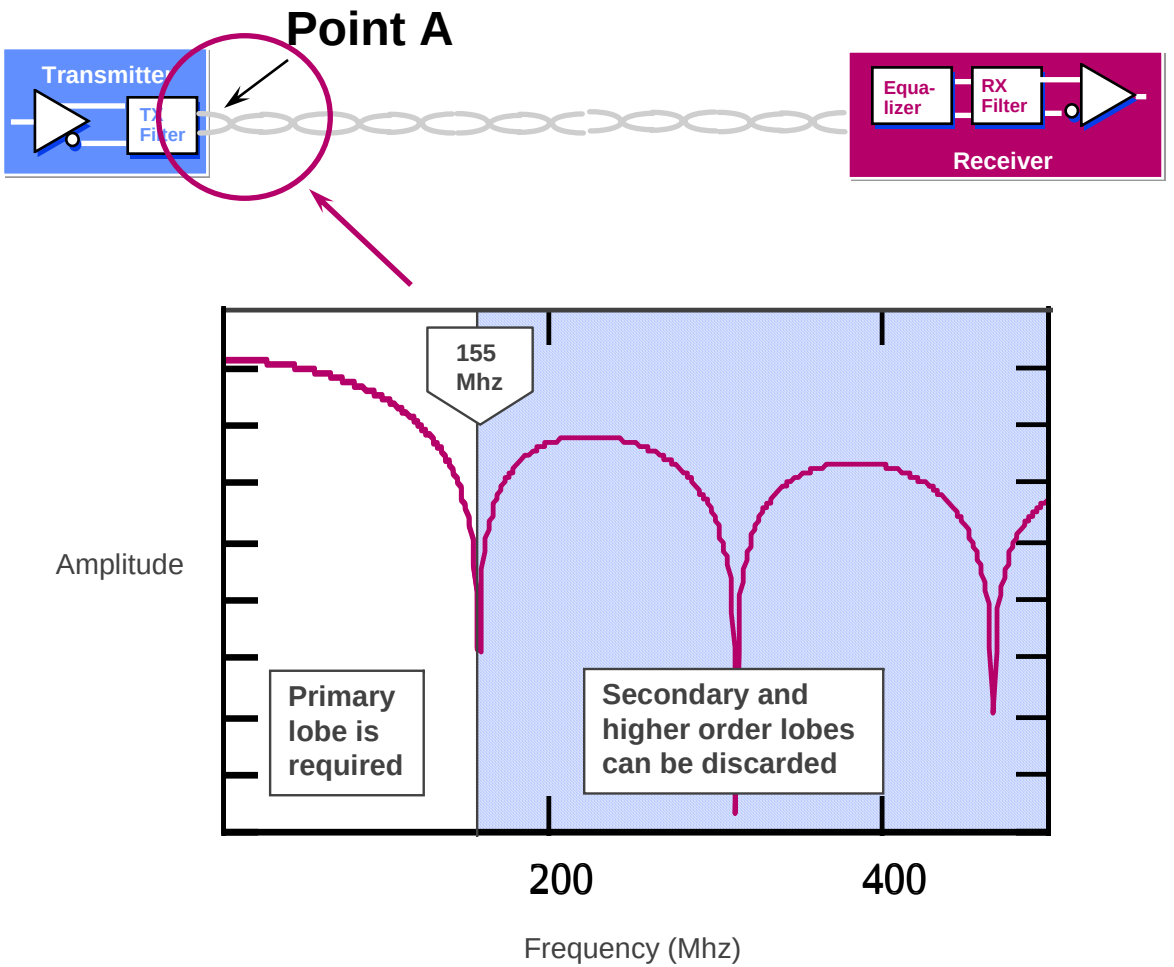
Transmit Data Signal



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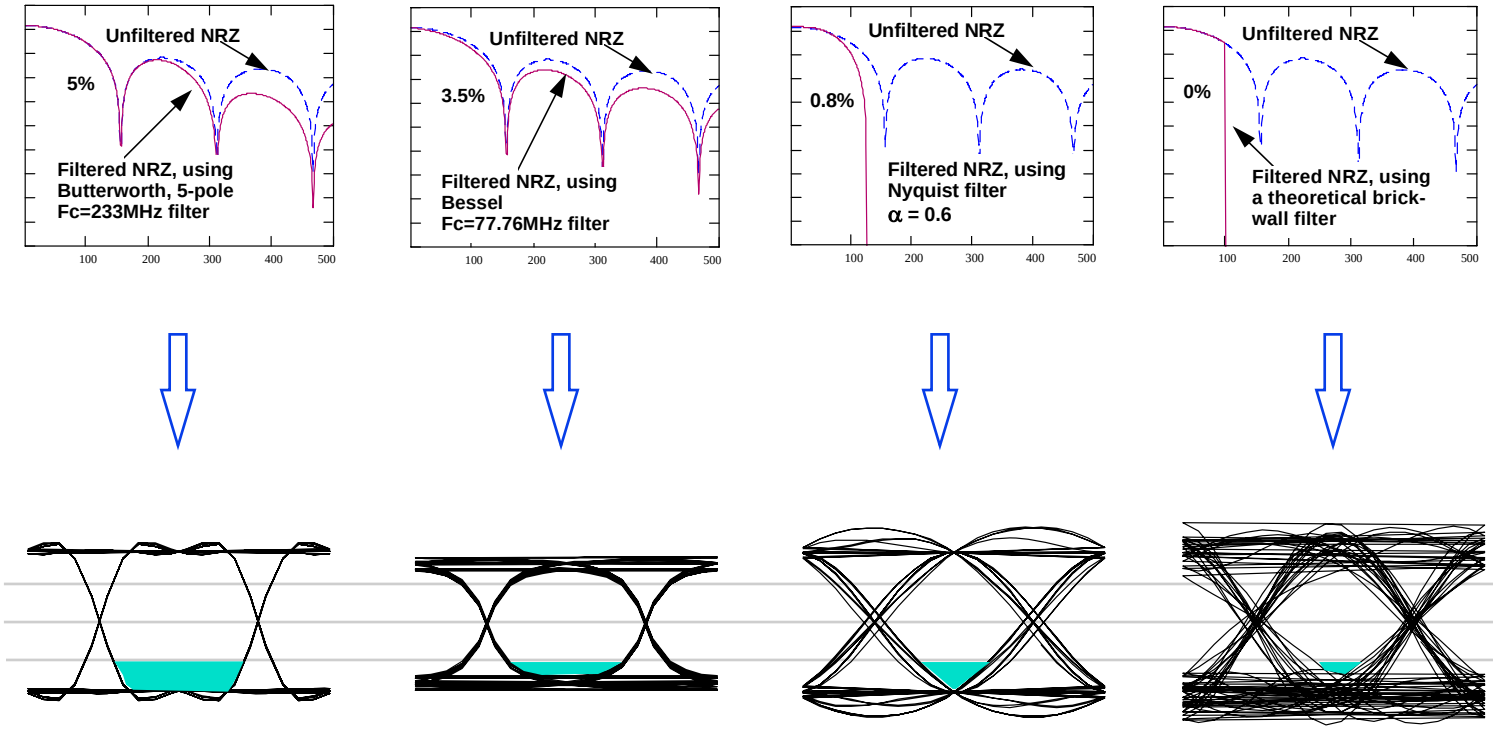
Effect of Filtering on the Data Signal



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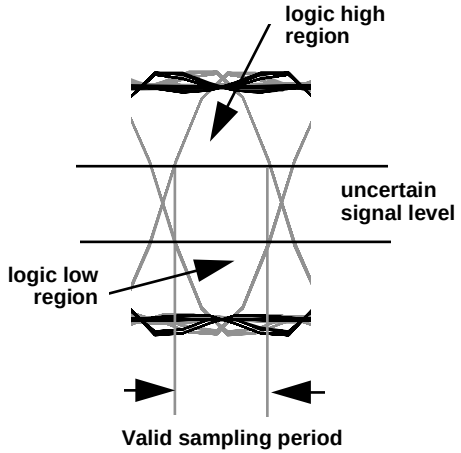
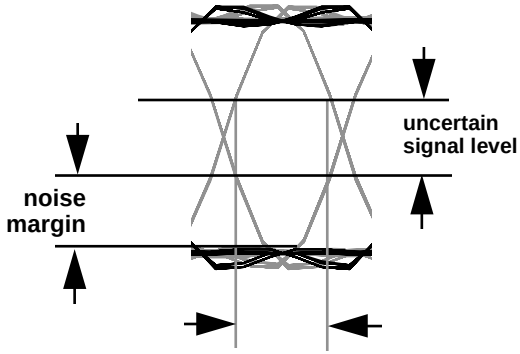
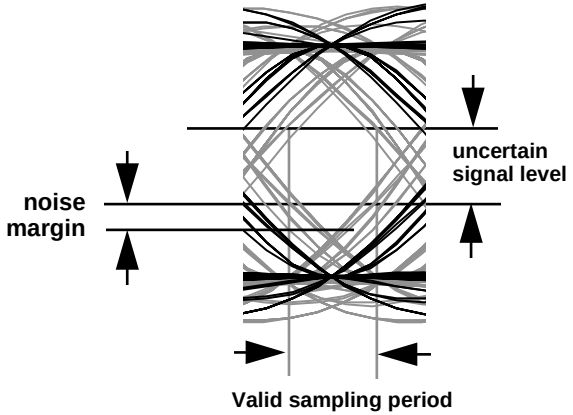
Interpreting the Eye Pattern





- Eye pattern opening determines the noise power needed to cause errors.
- The size of this opening is a good indication of the network robustness.



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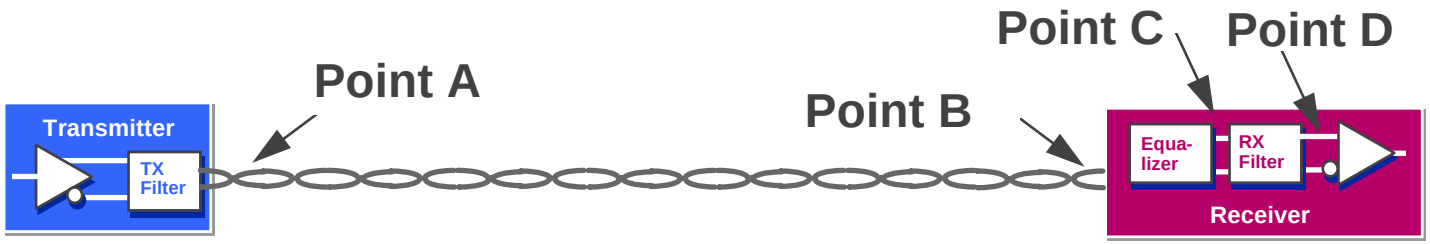
Transmit Data Signal



- **Band limiting the data signal**
  - **Reduces NEXT**
  - **Lobes above 155 MHz can be eliminated**
- **Band limiting the first spectral lobe**
  - **Impacts signal quality**
  - **Should be done either at the transmitter or at the receiver**
  - **Could impair inter-operability if location of filter (i.e. transmitter or receiver) is inconsistent from vendor to vendor**

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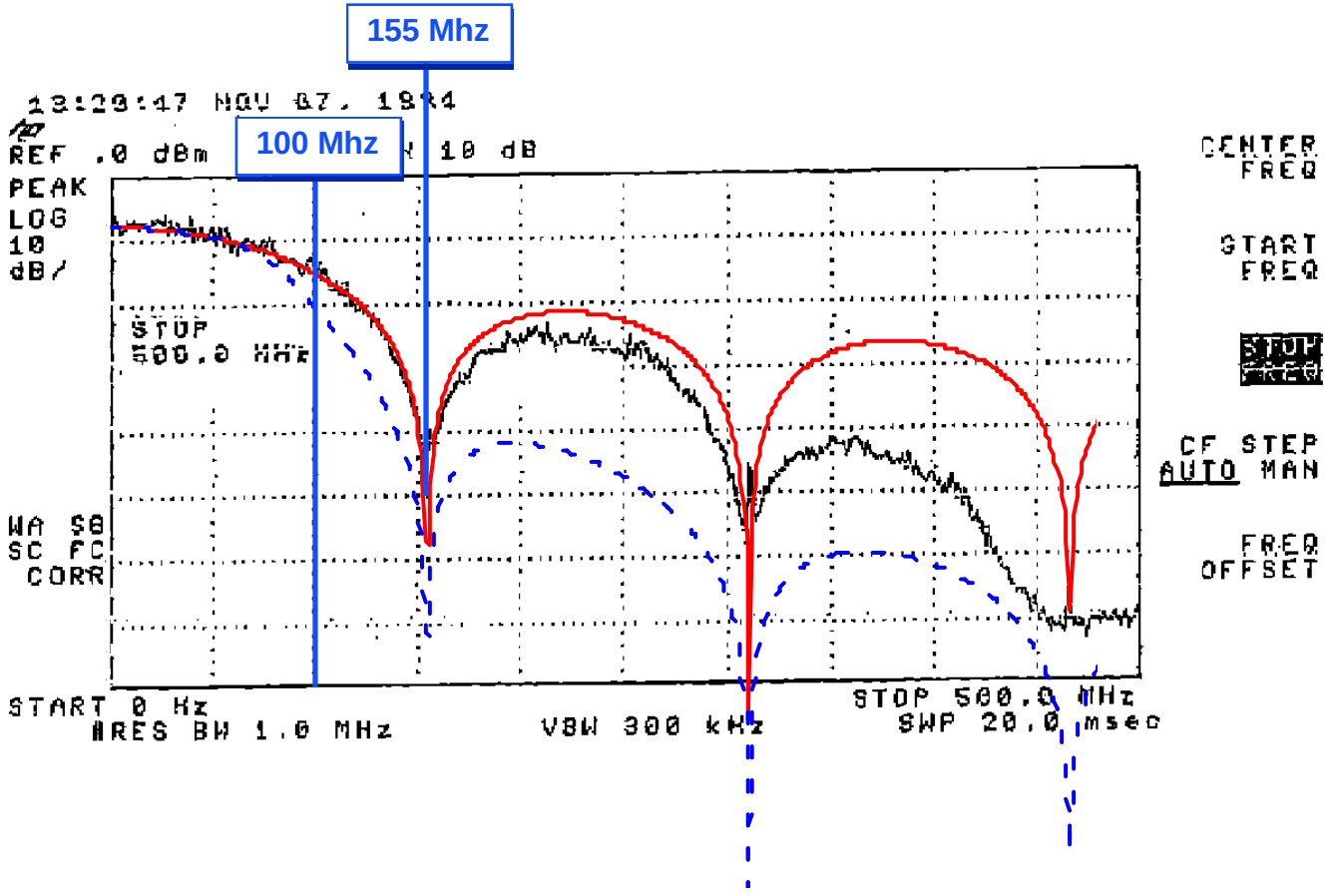
Transmit Spectrum, Vendor A



SCOPE
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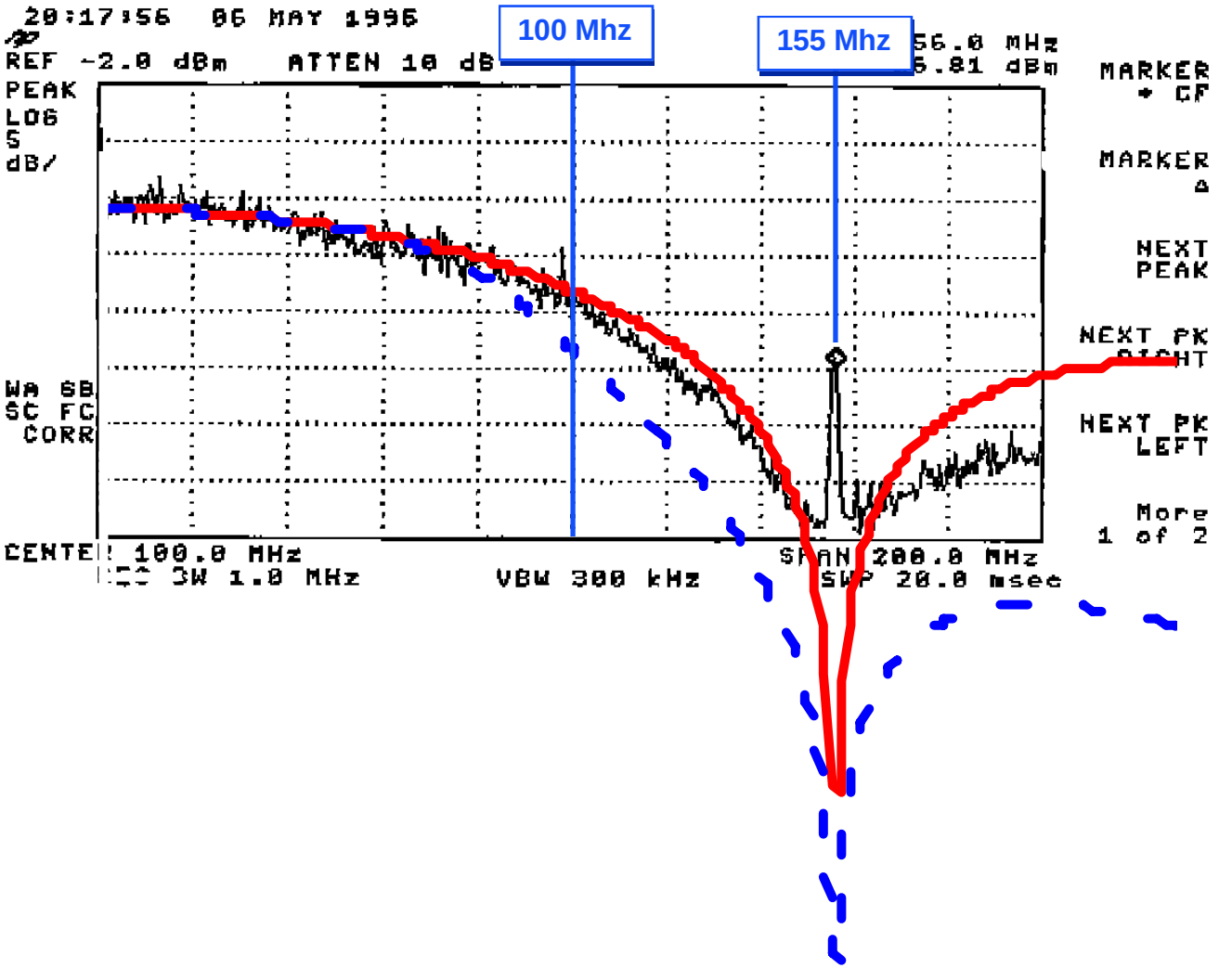
Transmit Spectrum, Vendor B



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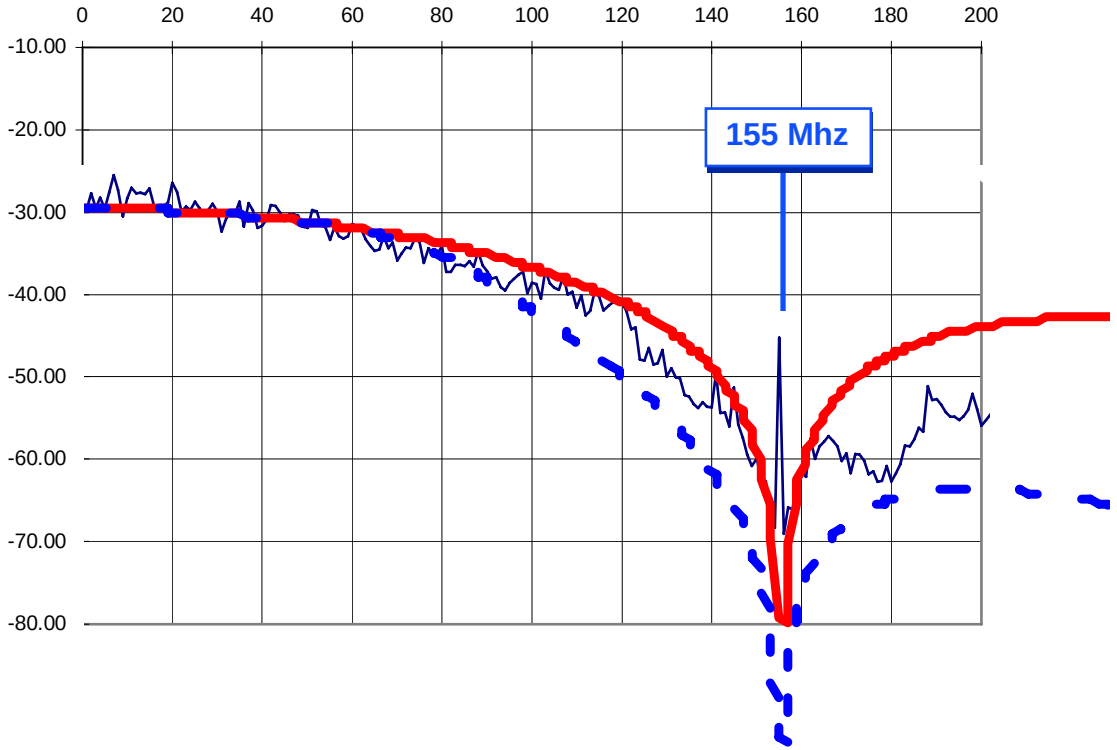
Transmit Spectrum, Vendor C



SCOPE
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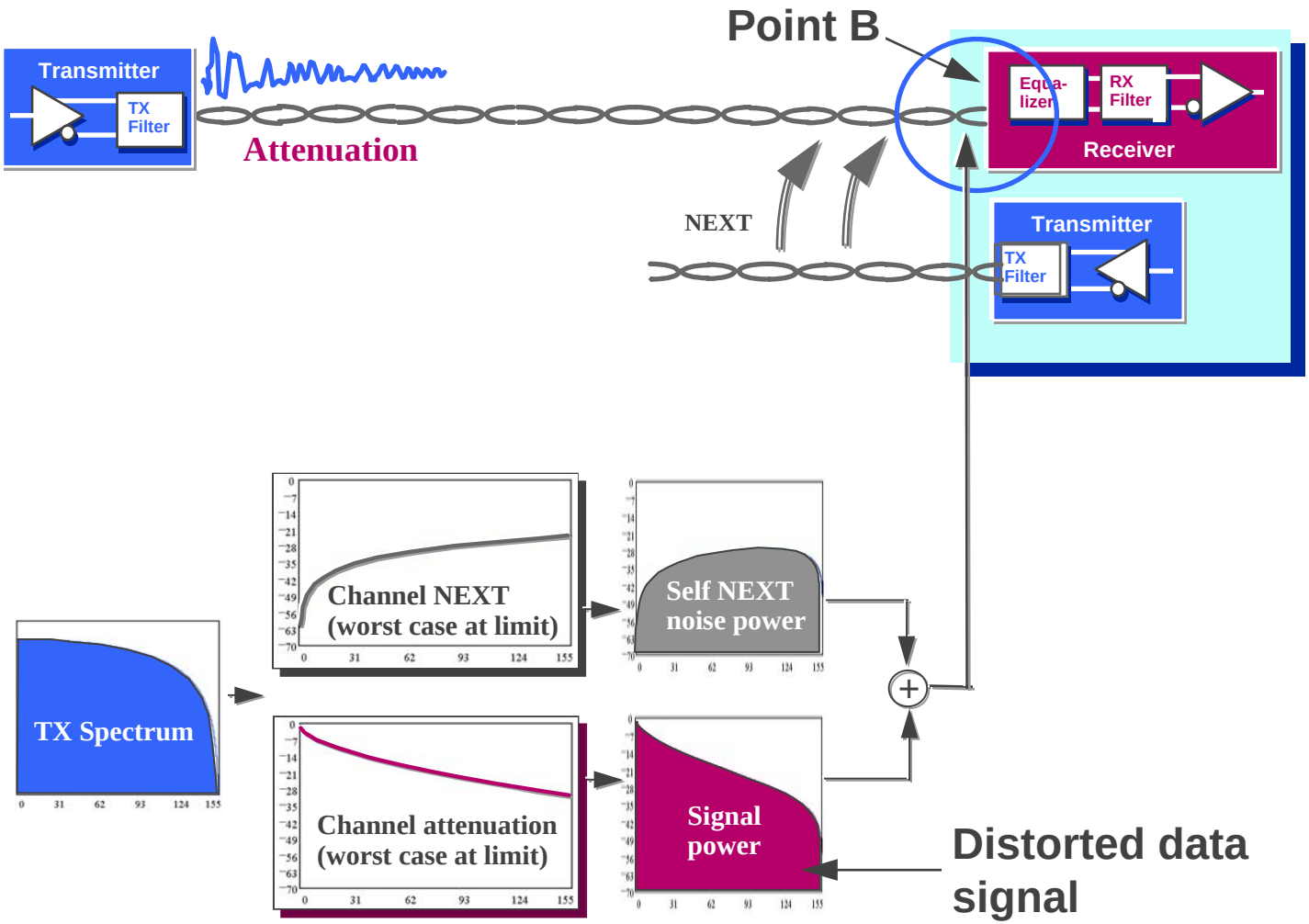
Signal at the End of the Worst Case TSB-67 Channel



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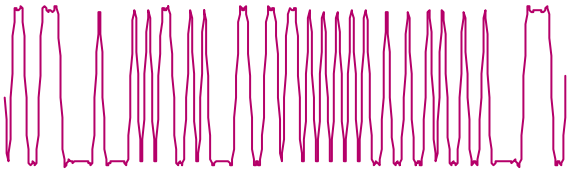
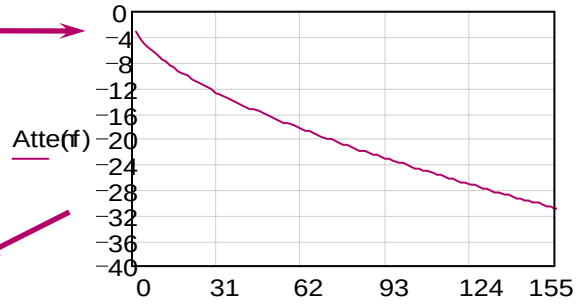
Effect of Attenuation

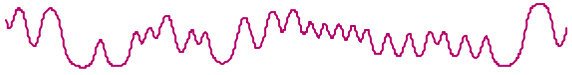
Transmitted data signal

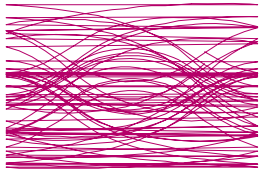


TIA Channel attenuation



Same signal attenuated by worst case TIA channel response





Eye pattern

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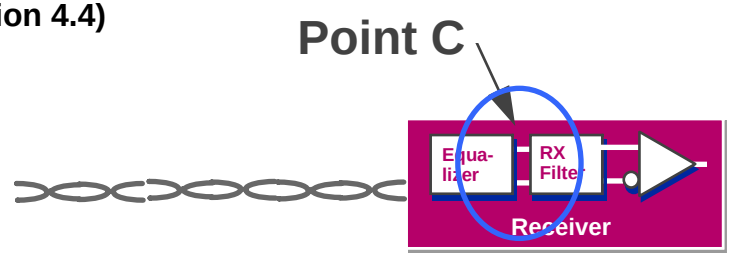
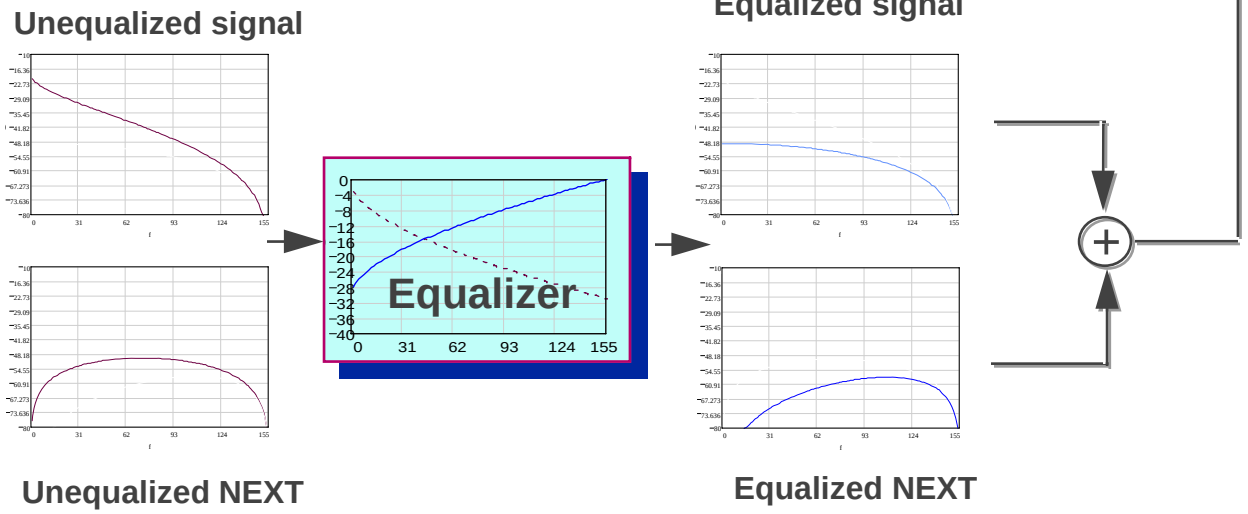
Receiver Equalizer

- Ideal equalizer restores the signal to original shape
- Real equalizer leaves up to 1.5 ns of jitter (Section 4.4)
- Total receive jitter is :
  2 ns of transmit jitter (Section 3.7)
  + 1.5 ns of equalizer jitter
  = 3.5 ns of jitter at data recovery circuit
  => 55% of total horizontal eye opening





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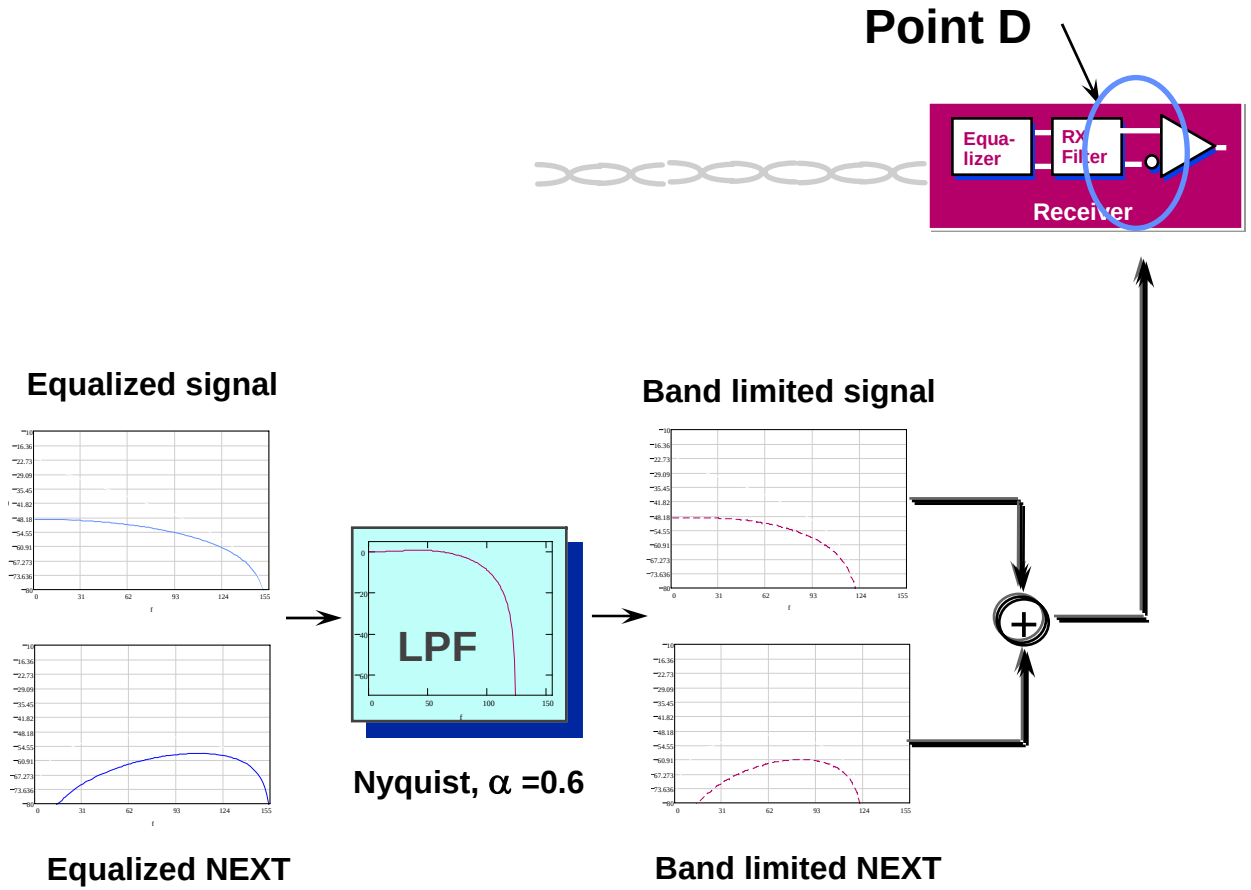
Band Limiting the First Spectral Lobe to 100 MHz



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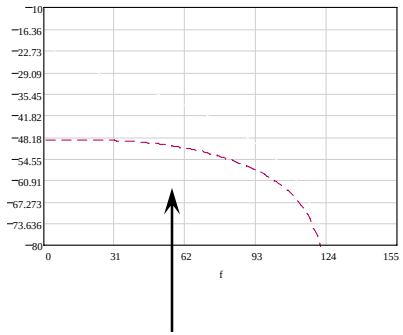
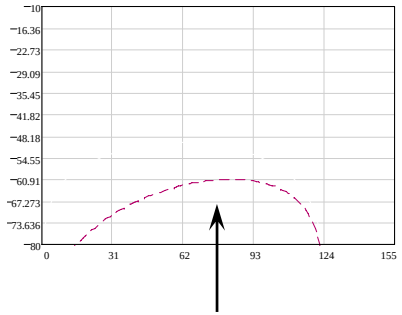
Receive Signal and Noise Power

SNR inside the receiver is the ratio of the integrals of the signal and noise spectra

SNR = 10 * Log (Signal Power / Noise Power)



Signal Power



Noise Power

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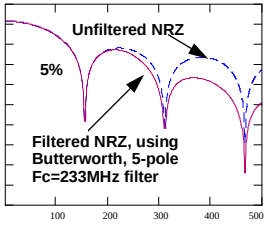
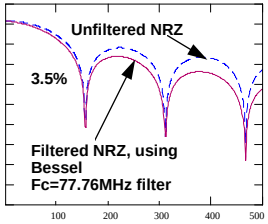
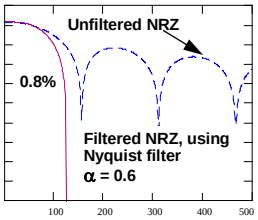
Apparent Improvement in SNR due to Band Limiting the First Spectral Lobe







	Filter A (5% of power, 100-155 MHz)	Filter B (3.5% of power, 100-155 MHz)	Filter C (0.8% of power, 100-155 MHz)
SNR computed by integrating signal and noise power spectra	9.3 dB	10.4 dB	13.0 dB
Apparent improvement in SNR due to filtering the first lobe of the spectrum	0 dB	1.1 dB	3.7 dB
Degradation in SNR due to distortion caused by filtering	?	?	?
Net effect of filtering on SNR	?	?	?

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Combined Effects of Receive Jitter and Filtering

Filter A
Butterworth
5 pole
Fc=233 MHz

5%

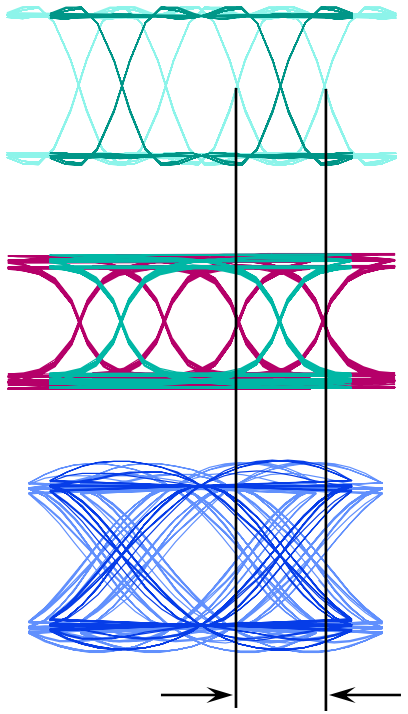
Filter B
Bessel
Fc=77.76 MHz

3.5%

Filter C
Nyquist
α =0.6

0.8%

% of spectral power between 100 and 155 MHz



3.5 ns jitter

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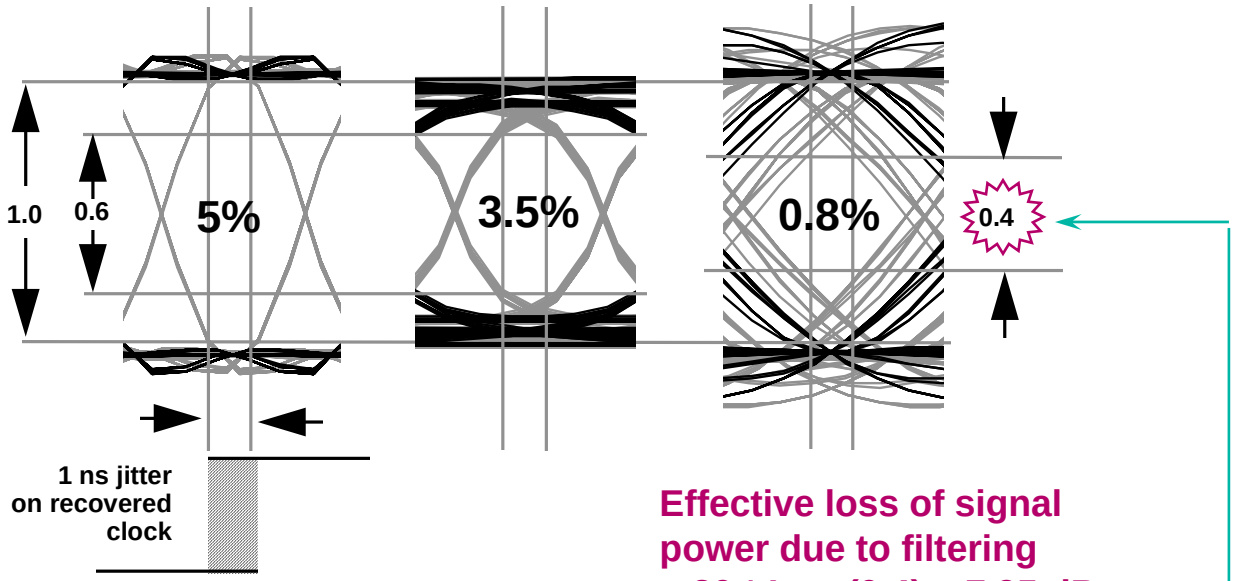
SNR Degradation Caused by Jitter and Filtering



Effective loss of signal power due to filtering = 20 * Log (0.4) = 7.95 dB

Translates into a 7.95 dB degradation in SNR

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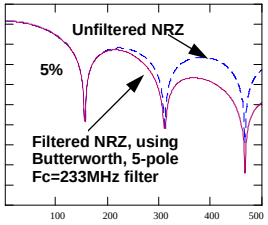
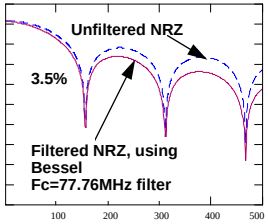
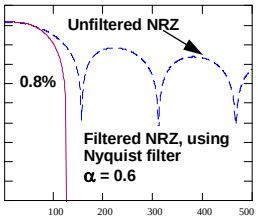
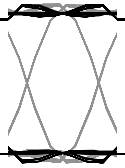
Net Effect of Filtering on SNR

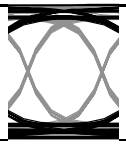






	Filter A (5% of power, 100-155 MHz)	Filter B (3.5% of power, 100-155 MHz)	Filter C (0.8% of power, 100-155 MHz)
SNR computed by integrating signal and noise power spectra	9.3 dB	10.4 dB	13.0 dB
Apparent improvement in SNR due to filtering the first lobe of the spectrum	0 dB	1.1 dB	3.7 dB
Degradation in SNR due to distortion caused by filtering	0 dB	-4.4 dB	-8.0 dB
Net effect of filtering on SNR	**0 dB**	**-3.3 dB (degradation)**	**-4.3 dB (degradation)**





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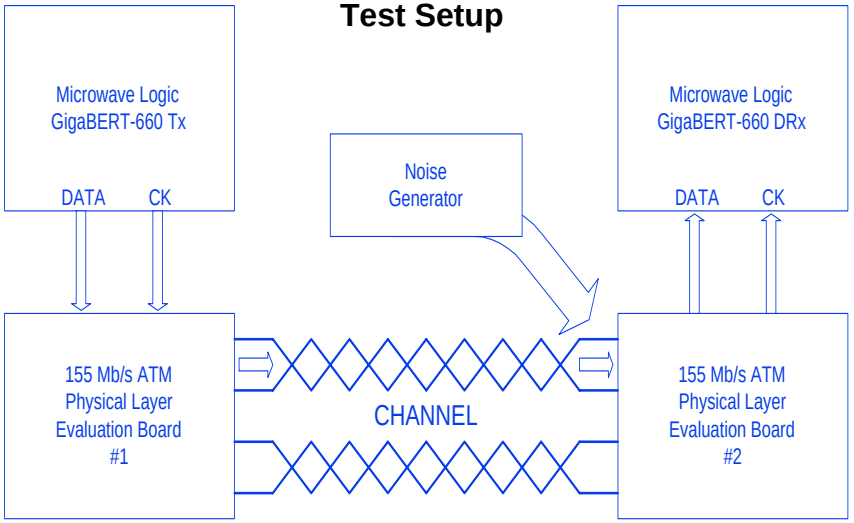
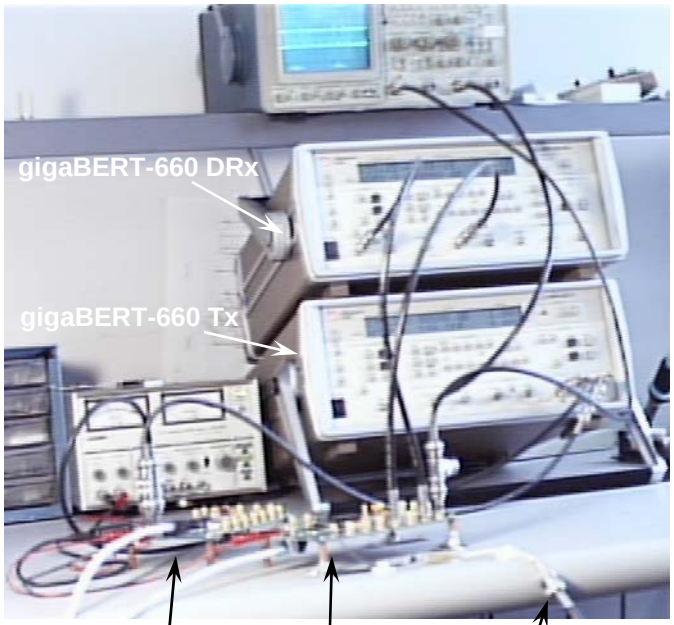
Importance of Energy Above 100 MHz to 155 Mb/s ATM Operation -- Example

Test Setup



Test Pattern

Noise: 19 mV ptp, swept sine wave, 10 MHz to 50 MHz



Evaluation board transmitting the test pattern

Evaluation board receiving the test pattern

Noise source

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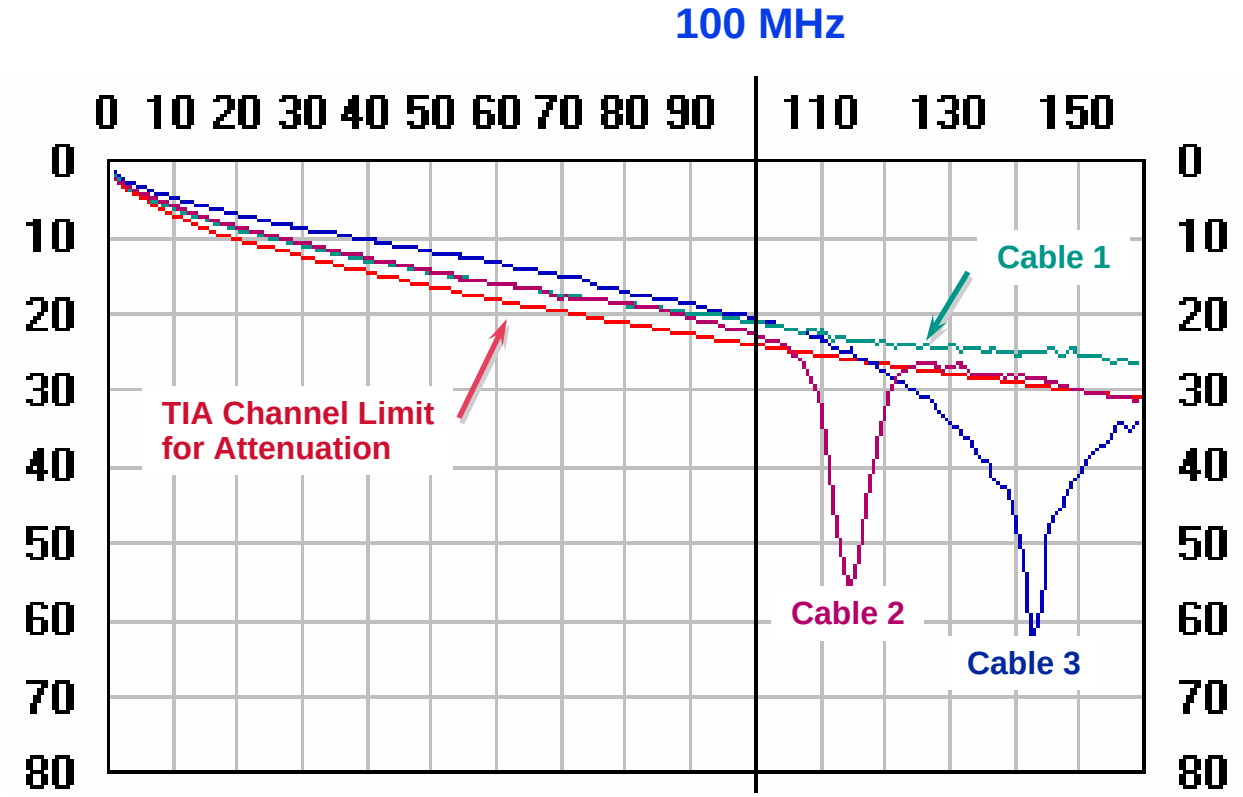
Importance of Energy Above 100 MHz to 155 Mb/s ATM Operation -- Example



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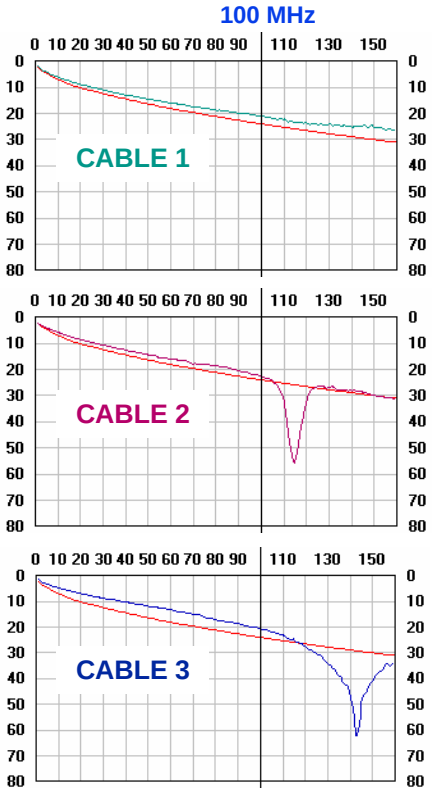
Bit Error Rate (BER) Measurements on Cables 1, 2 and 3



TEST #	CABLE	START	STOP	RUN TIME	ERRORS	BER
1	CABLE 2	4/1 8:00 am	4/1 6:10 pm	10 hours 10 min	38,525	6.8×10^{-9}
2	CABLE 1	4/1 6:15 pm	4/2 7:15 am	13 hours 0 min	460	6.3×10^{-11}
3	CABLE 3	4/2 7:15 am	4/3 6:20 am	23 hours 5 min	329,500	2.5×10^{-8}
4	CABLE 1	4/3 6:20 pm	4/4 6:30 am	12 hours 10 min	393	5.8×10^{-11}
5	CABLE 2	4/4 6:35 am	4/5 5:55 am	23 hours 20 min	71,592	5.4×10^{-9}
6	CABLE 3	4/5 6:00 am	4/5 6:00 pm	12 hours 0 min	158,100	2.3×10^{-8}
7	CABLE 1	4/5 6:00 pm	4/8 8:30 am*	61 hours * 30 min	691	2.0×10^{-11}
8	CABLE 3	4/8 9:15 am	4/8 7:40 pm	10 hours 25 min	129,410	2.2×10^{-8}
9	CABLE 2	4/8 7:40 pm	4/10 6:30 pm	46 hours 50 min	76,380	2.9×10^{-9}

*Time shift 1 hour ahead