

What Bandwidth Is Right For 10GBASE-T PHY?

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IEEE802.3-10GBT Interim Meeting
Jan 2003, Vancouver

Overview

- Why Selection of Bandwidth is Important?
- Capacity, Power, and Bandwidth
- Bandwidth vs. Capacity of 100m Cable

- Design Example with PAM
 - Bandwidth vs. PAM Size
 - Bandwidth vs. Required SNR
 - Bandwidth vs. Achievable SNR
 - Bandwidth vs. Required Impediment Cancellation

- Conclusions

Significance of Bandwidth

- Choice of bandwidth decides
 - Constellation density and hence, the required precision for AFE and digital signal processing and receiver SNR
 - Design complexity for both analog and digital
- Not all choices for bandwidth are equal
 - Actually some are just wrong. In other words, not all choices will be able to deliver 10Gbps irrespective of complexity
 - Even within the feasible choices the resulting complexity and achievable system margin are different
- Judicious selection of bandwidth is crucial

Capacity, Power, and Bandwidth

- Capacity of the copper cable depends on
 - Insertion loss of the cable
 - Power: transmit and receiver noise power
 - Bandwidth used for transmission
- Insertion loss needs to be characterized but not much else can be done
- FCC regulations and line driver design put upper limit on transmit power in two ways
 - Total transmit power
 - Transmit power for each frequency, upper limit on PSD

Capacity, Power, Bandwidth (cont.)

- Receiver noise includes
 - Residue ISI and impediments such as NEXT, FEXT, and Echo. The power levels of these impediments depend on the receiver design
 - Background noise @ -140dBm/Hz that cannot be reduced

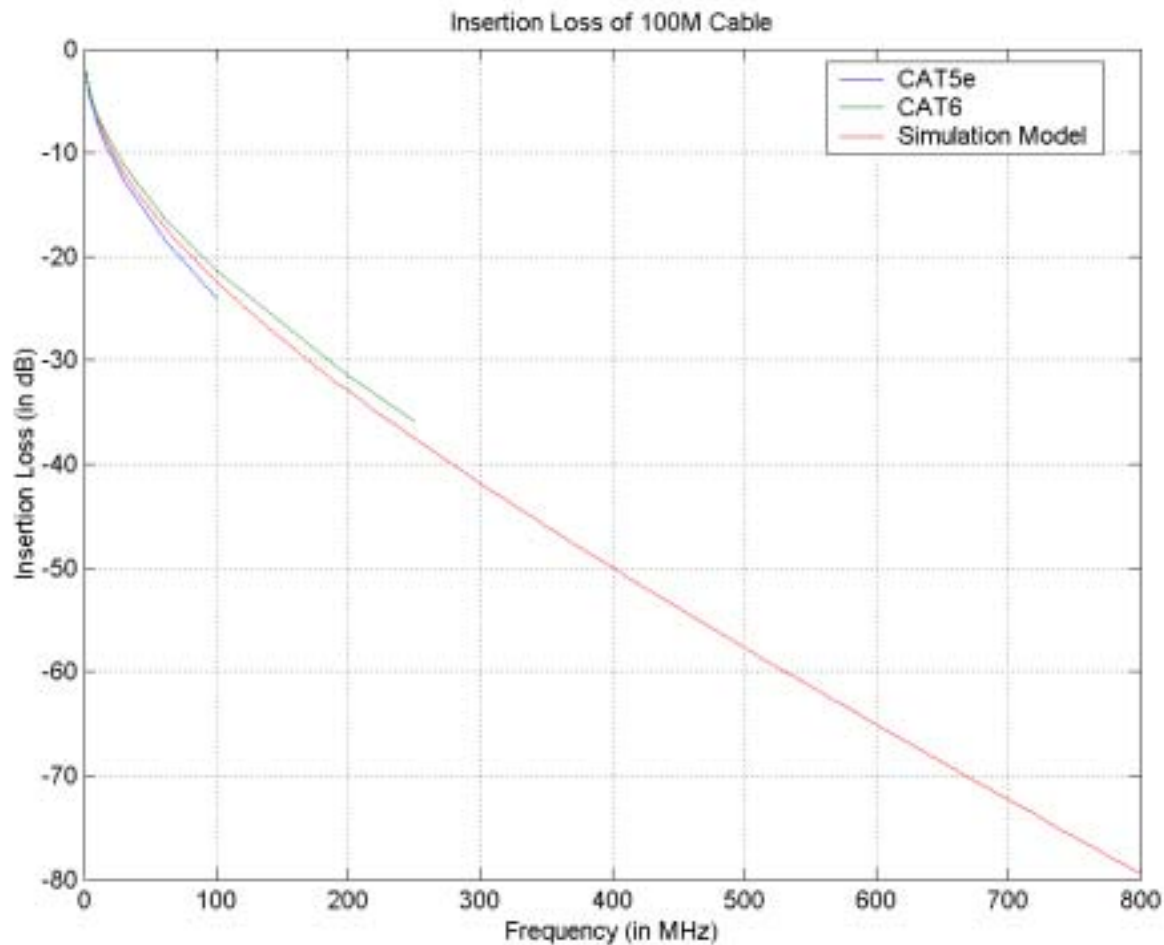
Assumptions:

- Analytical extension of CAT5 model is valid
- Total transmit power: 9dBm
- Receiver noise is white

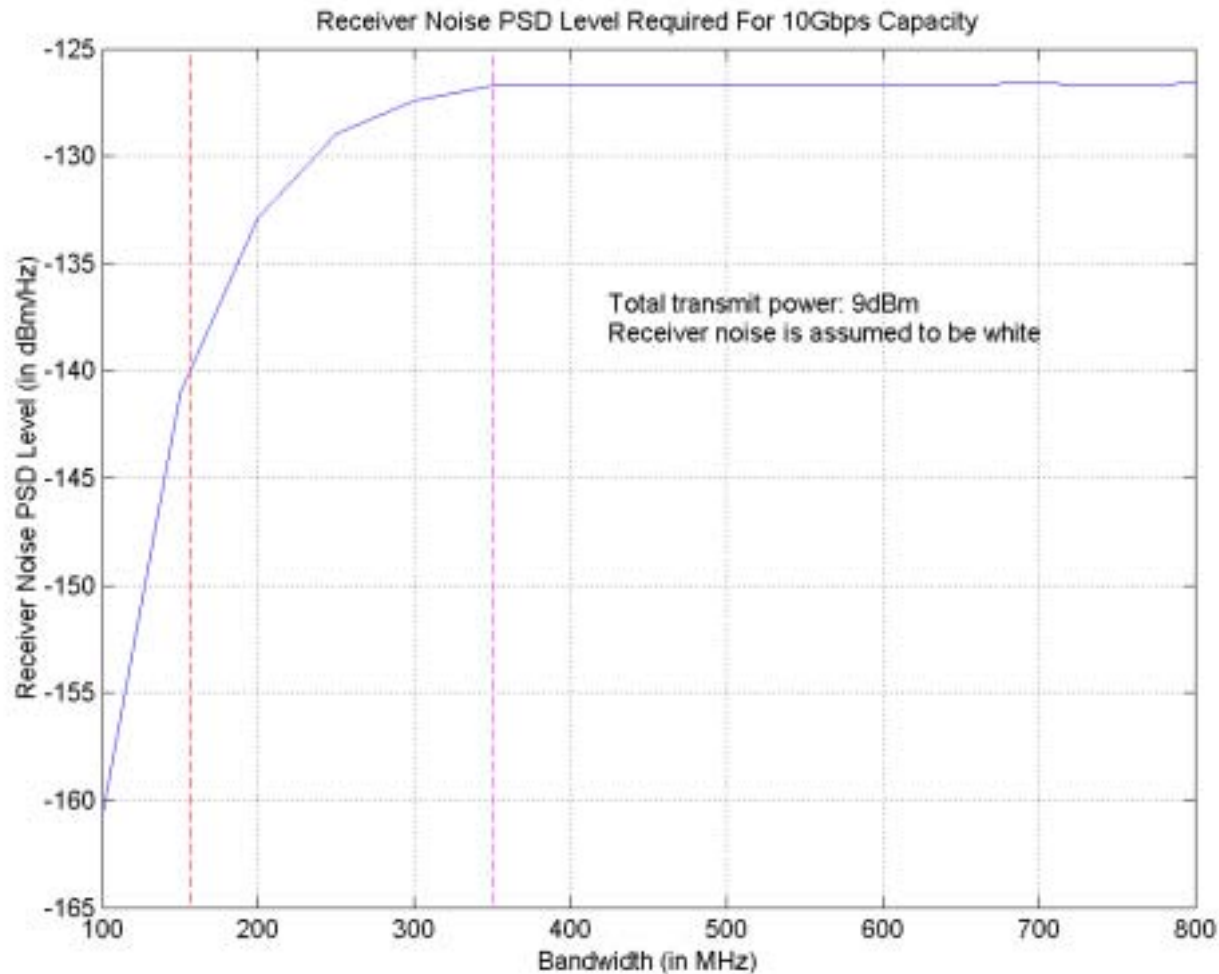
Question:

- What is the required receiver noise floor to achieve capacity of 10Gps for a given bandwidth?

Insertion Loss Model (100m)



Bandwidth vs. Receiver Noise Level



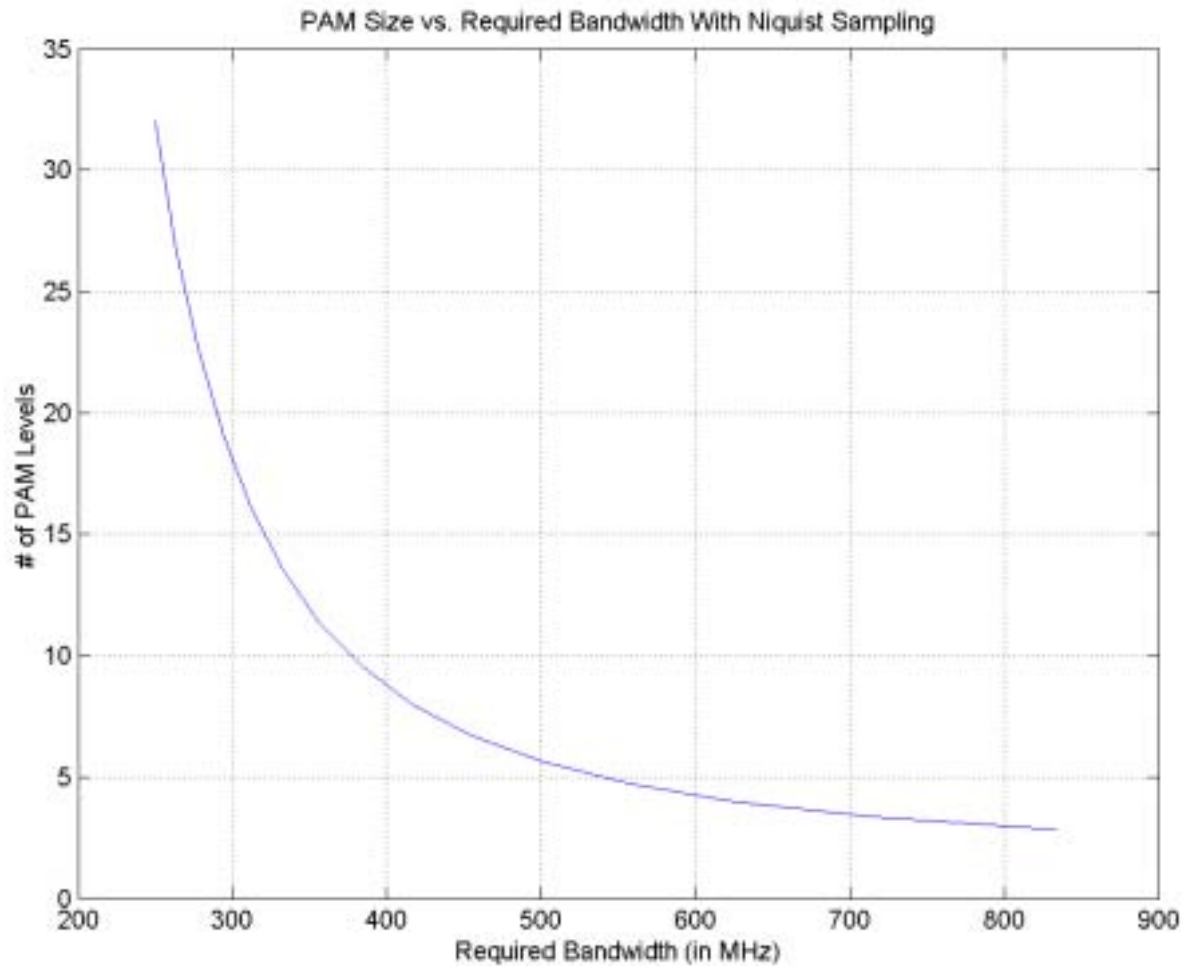
Capacity & Bandwidth: Remarks

- There is a minimum bandwidth that is needed to achieve 10Gbps capacity
- With increased bandwidth there is a saturating effect
- The design margin is tight

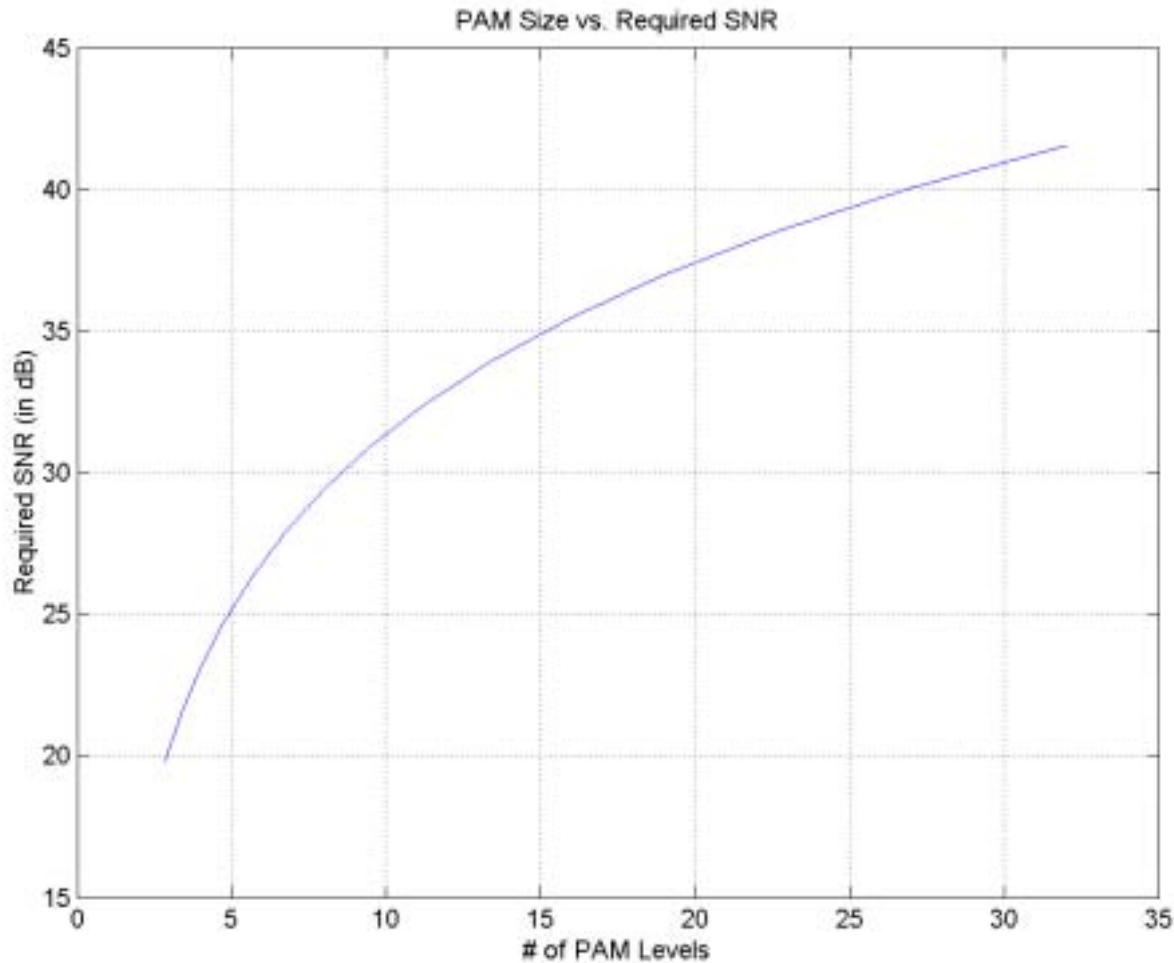
Design Example with PAM

- We will consider system with Nyquist sampling, i.e., no excess bandwidth
- We will analyze:
 - Bandwidth vs. Required Number of PAM levels
 - **Control signals are not included**
 - Number of PAM levels vs. Required SNR
 - **For BER of 10^{-10} ; Without coding gain or system margin**
 - Bandwidth vs. Required SNR
 - Bandwidth vs. Achievable SNR
 - **With -140dBm/Hz receiver background noise level**
 - **Salz's limit**
 - Required suppression level for impediment

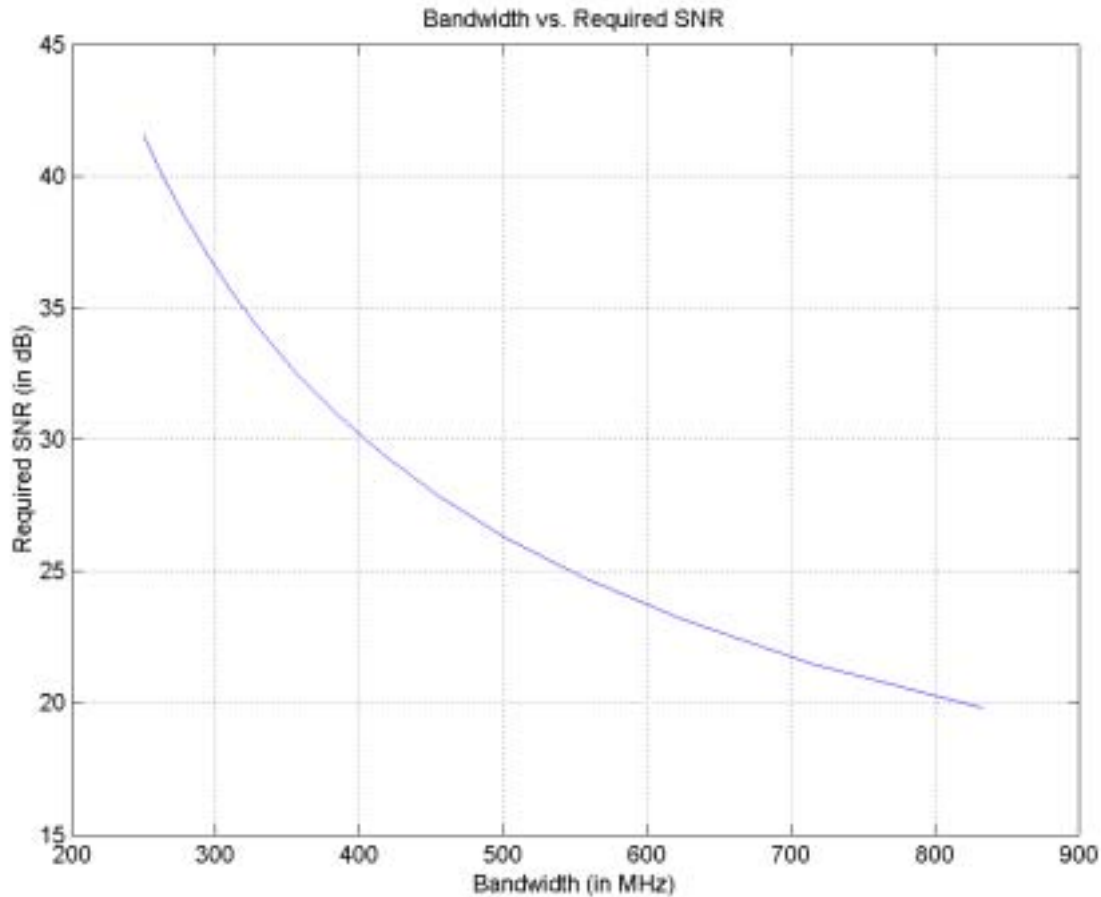
Bandwidth vs. PAM Size



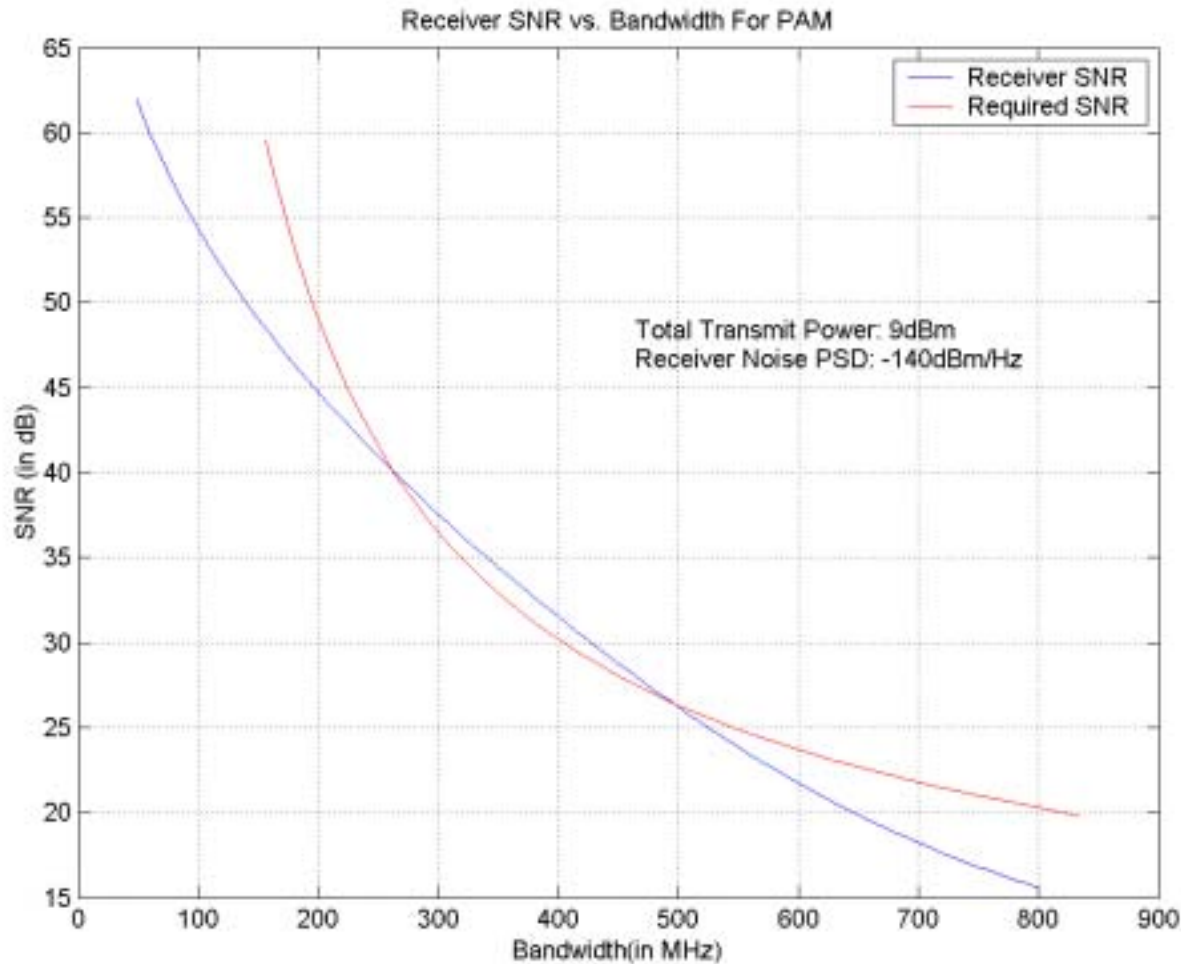
Required SNR for BER 10^{-10}



Bandwidth vs. Required SNR



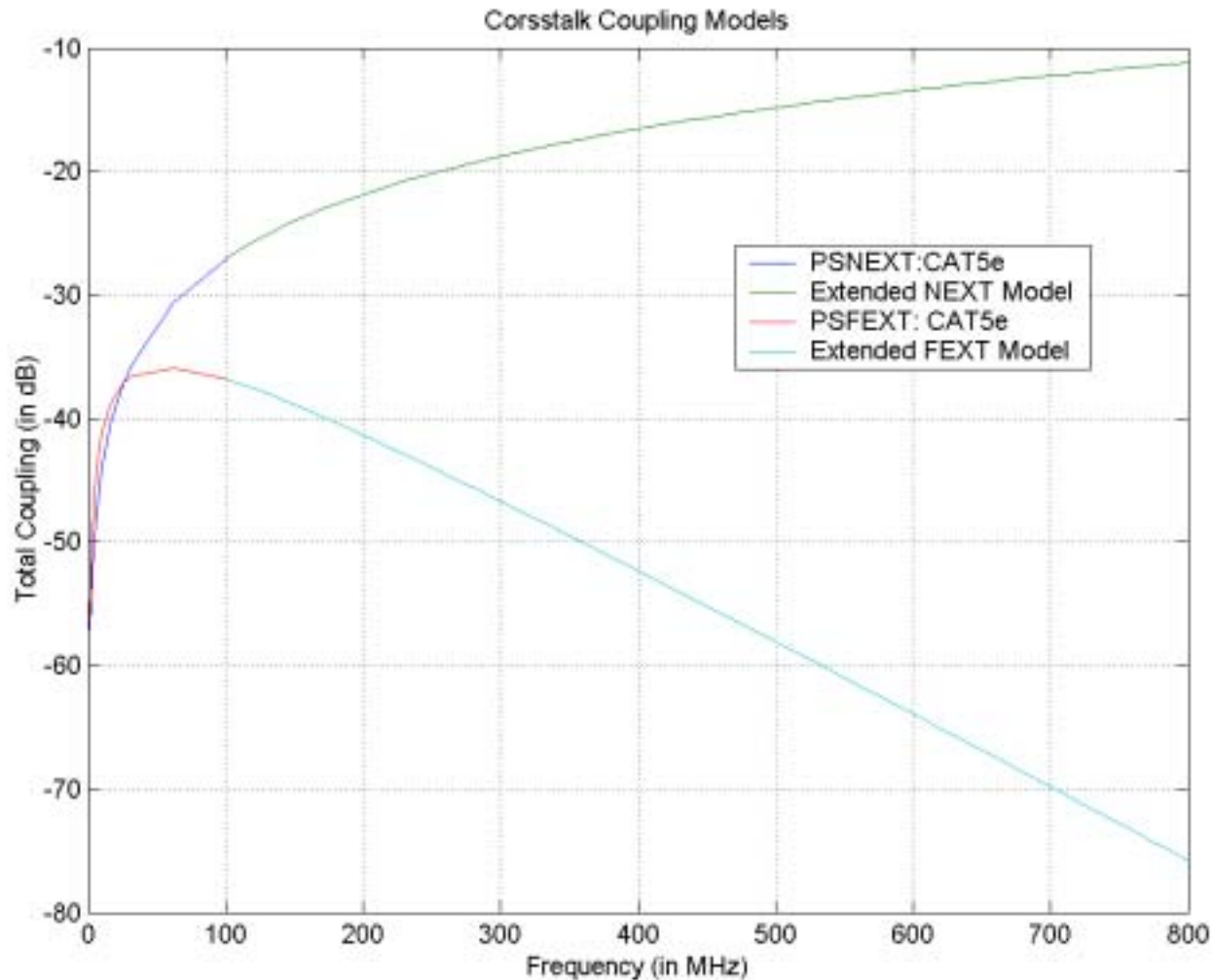
Achievable Receiver SNR With -140dBm/Hz White Noise



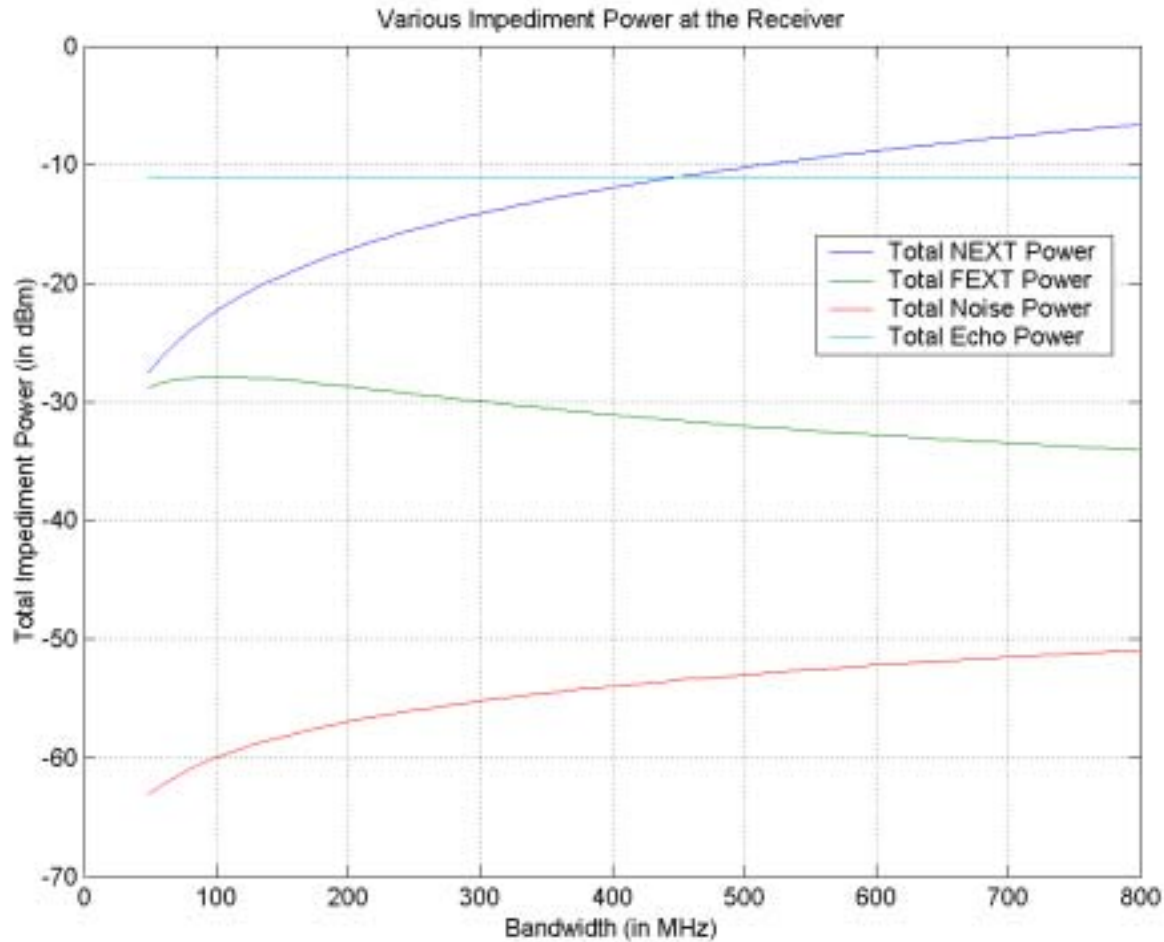
Impediments

- Echo: for 9dBm transmit power and 20dB Hybrid rejection the echo power is -11dBm. Assumed to be independent of bandwidth selection
- Self Next: extended CAT5e model (ISO/IEC 11801 '02)
- FEXT: extended CAT5e model (ISO/IEC 11801 '02)
- Background Noise: -140dBm/Hz
- Inter Symbol Interference, alien NEXT, and other source of Impediments are not included

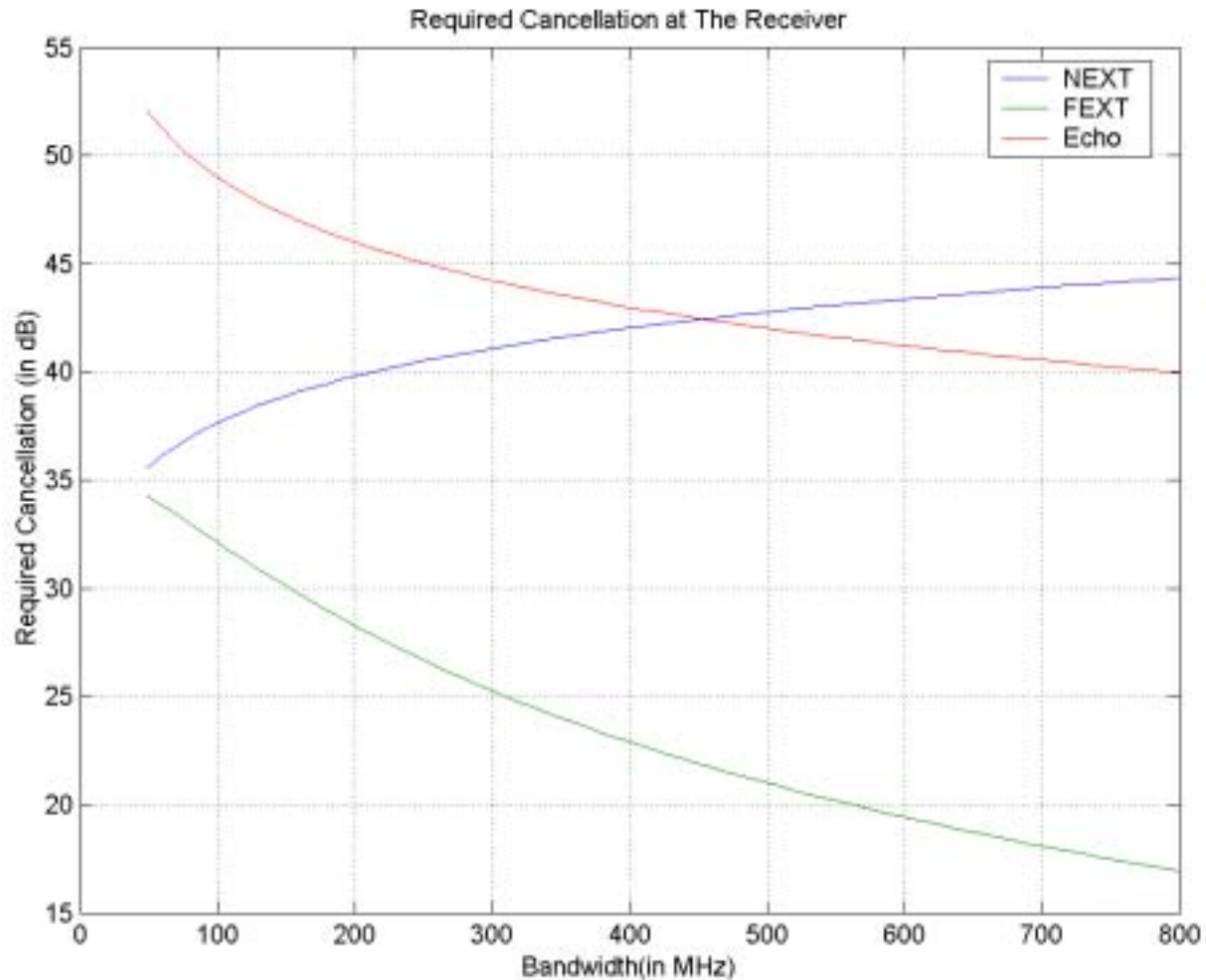
Crosstalk Models



Total Crosstalk At The Receiver



Required Cancellation



Conclusions

- We need a minimum bandwidth to achieve 10Gbps capacity
- More bandwidth is better but let us not forget the rate of diminishing return
- For system with PAM there is also an upper limit
- Hence, for PAM the range of feasible bandwidth is limited
- Significant reduction of impediments is required
- The choice of bandwidth should be made based on
 - Feasibility
 - Complexity
 - Achievable system margin