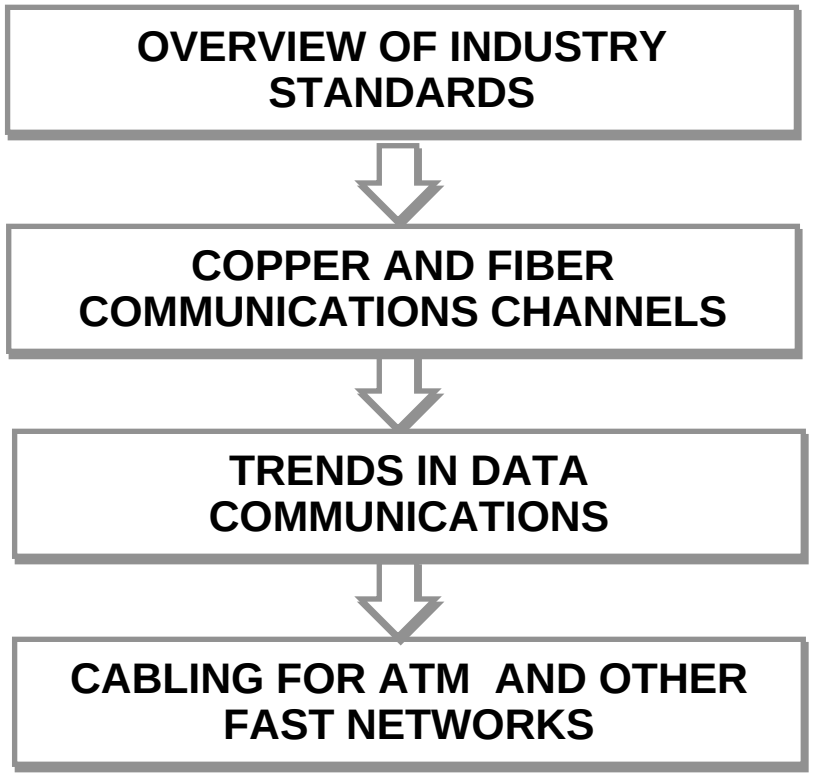
SCOPE
COMMUNICATIONS

Cabling Systems for Next Generation Networking

Fanny Mlinarsky

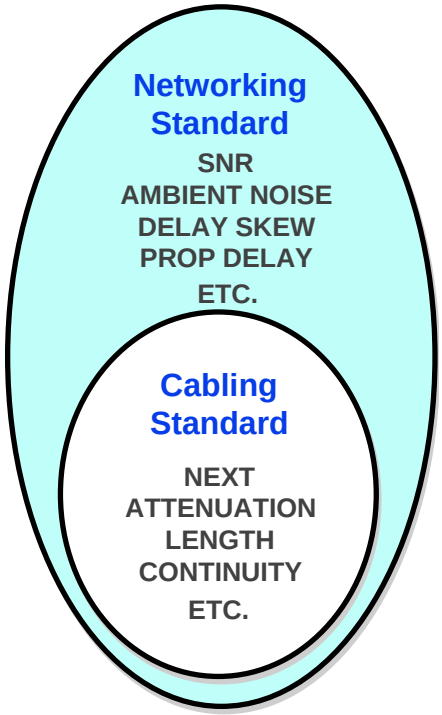
SCOPE
COMMUNICATIONS

Outline



SCOPE
COMMUNICATIONS

Industry Standards



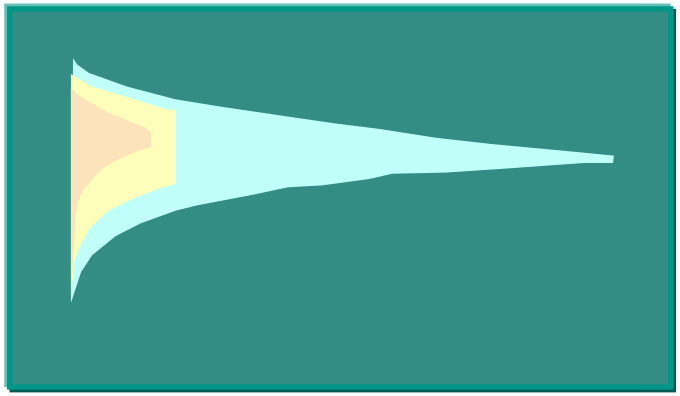
- **Network-specific standards**
  - ATM (12, 25, 51, 155 Mb/s)
  - 100 Mb/s “Fast” Ethernet
  - 100VGAnyLAN
  - 10Base-T, Token Ring
- **Generic cabling standards**
  - ISO 11801
    - » Classes B, C, D
  - TIA 568
    - » Categories 3, 4, 5
    - » TSB-67 Field Testing Standard

SCOPE
COMMUNICATIONS

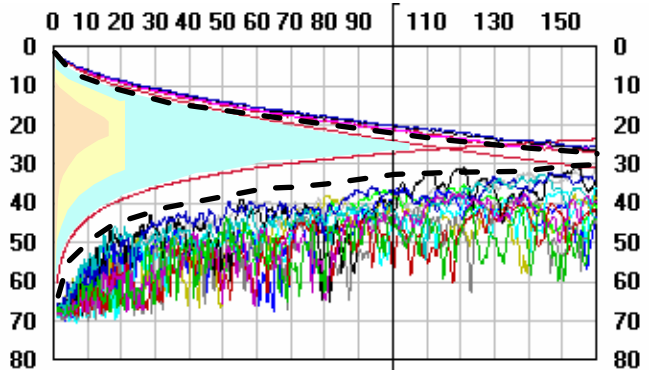
TIA-568-A Categories 3, 4 and 5 NEXT and Attenuation

CAT 5

CAT 3

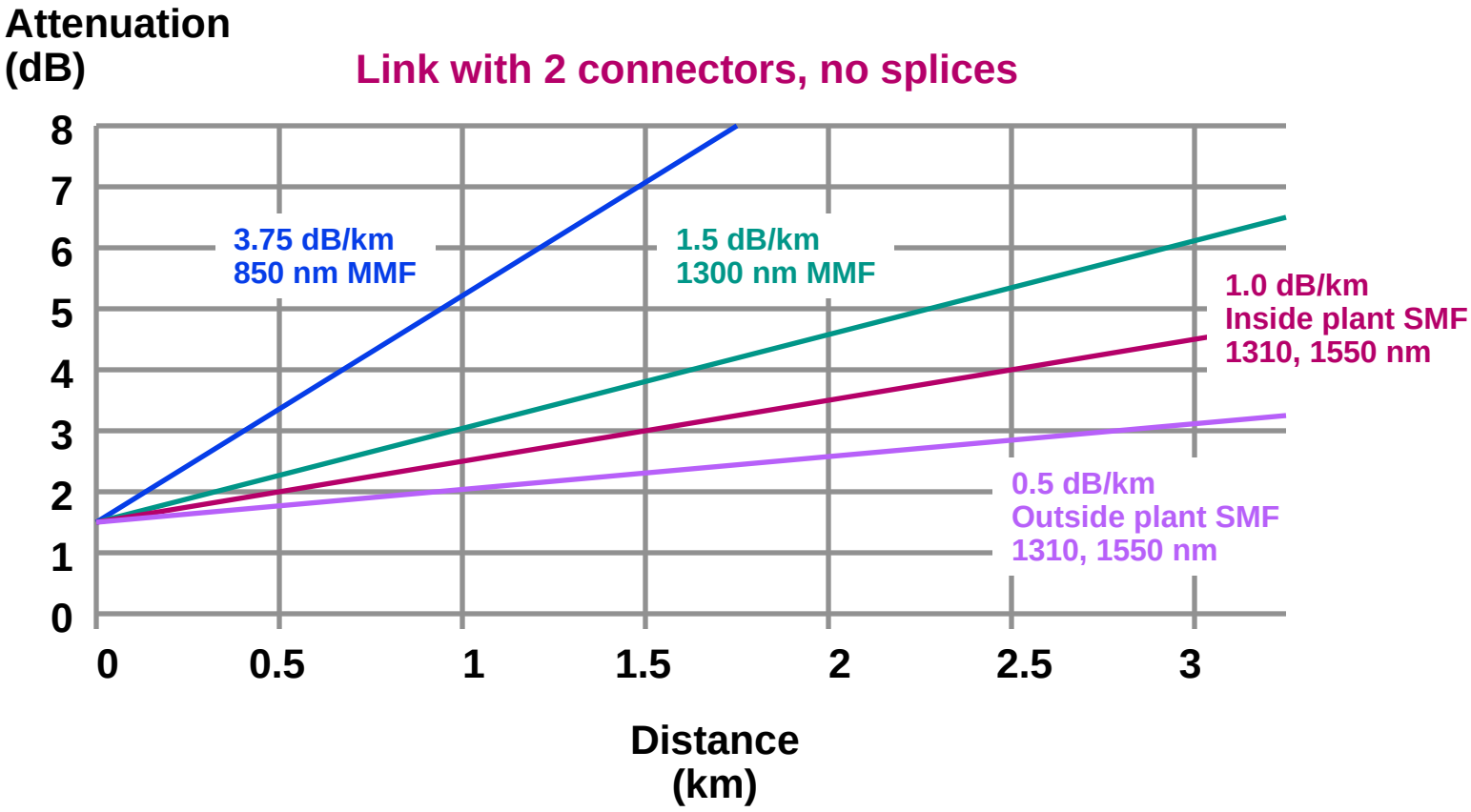


CAT 4



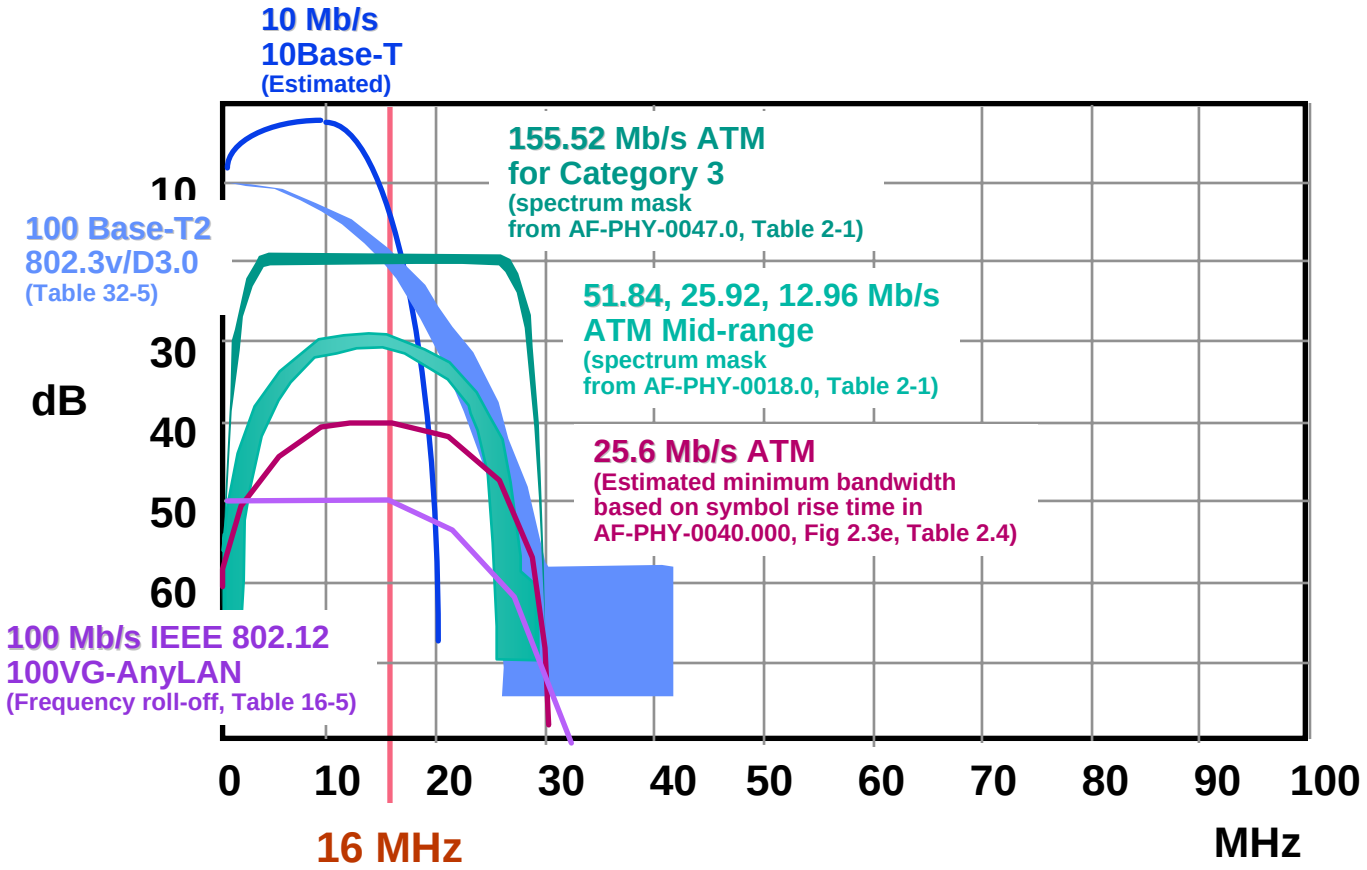
SCOPE
COMMUNICATIONS

TIA-568-A Fiber Optic Link Attenuation



SCOPE
COMMUNICATIONS

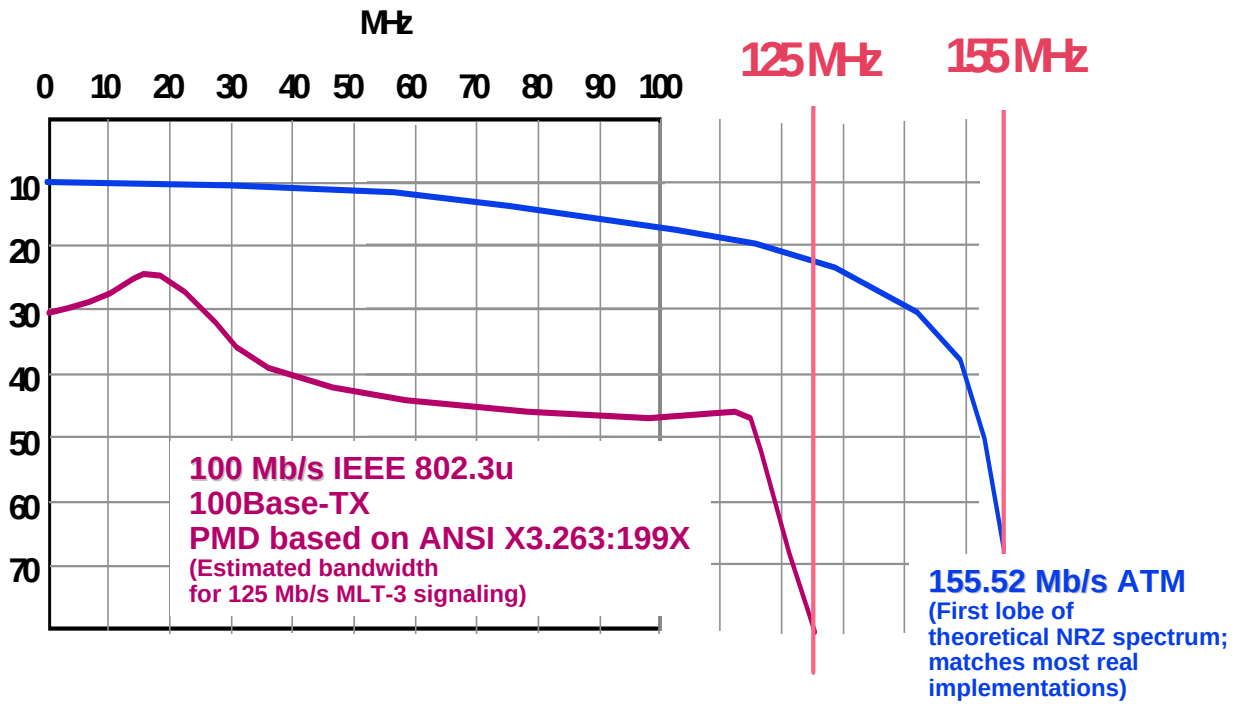
Category 3 Applications



NOTE: All spectra are normalized; drawn at 10 dB offsets for clarity only

SCOPE
COMMUNICATIONS

Category 5 Applications



NOTE: Both spectra are normalized; drawn at 20 dB offset for clarity only

SCOPE
COMMUNICATIONS

100 Mb/s 100Base-T4 Physical Layer Specs not covered by TIA-568-A or ISO 11801

- **100Base-T4, IEEE Std 802.3u-1995**
  - **Section 23.6.1: Category 3 or class C channel**
  - **Section 23.6.2.1: Insertion loss not to exceed 12 dB at 12.5 MHz**
    - **Inconsistent with cat 3 channel attenuation of 12.7 dB at 12 MHz**
  - **Section 23.6.2.3.1: Max NEXT 24.5 dB at 12.5 MHz**
    - **Inconsistent with cat 3 channel NEXT of 21.1 dB at 12.5 MHz**
  - **Section 23.6.2.3.2: Multiple Disturber NEXT (MDNEXT)**
    - **Not specified by TIA-568-A or ISO 11801**
  - **Section 23.6.2.3.3: Equal Level Far-end Crosstalk (ELFEXT)**
    - **Not specified by TIA-568-A or ISO 11801**
  - **Section 23.5.2.4.1: Max link delay 570 ns 2-12.5 MHz**
    - **Specified in TIA Draft 4 "Propagation Delay and Delay Skew Specifications for 100 ohm 4-pair Cabling"**
    - **To be incorporated into the addendum to TIA-568-A**
  - **Section 23.6.2.4.3: Max delay skew 50 ns**
    - **Specified in TIA Draft 4 "Propagation Delay and Delay Skew Specifications for 100 ohm 4-pair Cabling"**
    - **To be incorporated into the addendum to TIA-568-A**

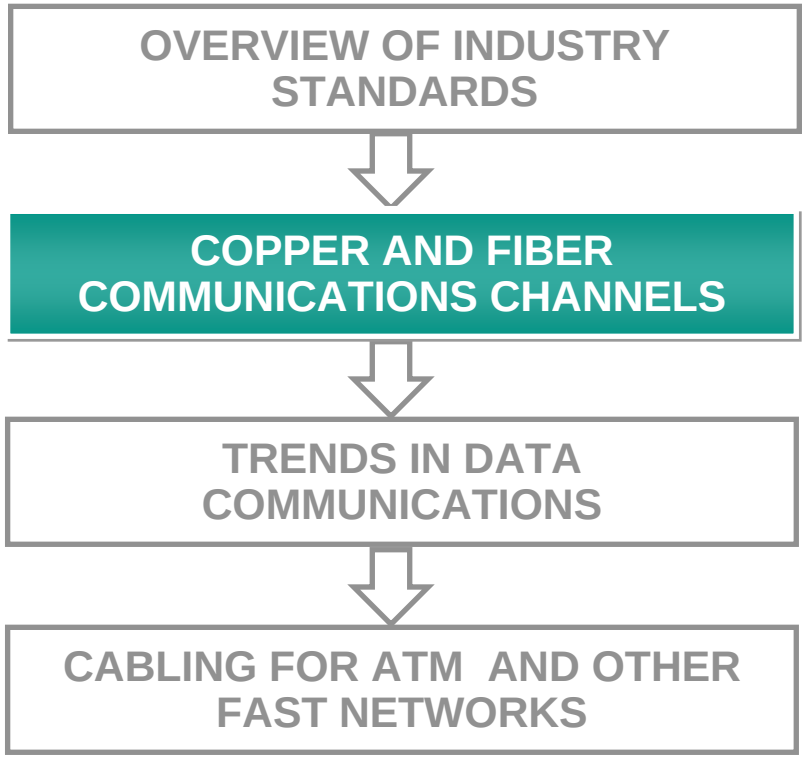
SCOPE
COMMUNICATIONS

100 Mb/s 100VG-AnyLAN Physical Layer Specs not covered by TIA-568-A or ISO 11801

- **100VG-AnyLAN, IEEE Std 802.12-1995**
  - **Section 16.9: Category 3 or class C channel**
  - **Section 16.9.1.1: Insertion loss not to exceed 14 dB at 15 MHz**
    - » **Inconsistent with cat 3 channel attenuation of 14.4 dB at 15 MHz**
  - **Section 16.9.1.3: Max link delay 5.7 ns/m, max 1.2 us total delay**
    - » **Specified in TIA Draft 4 "Propagation Delay and Delay Skew Specifications for 100 ohm 4-pair Cabling"**
    - » **To be incorporated into the addendum to TIA-568-A**
  - **Section 16.9.1.3: Max delay skew 67 ns**
    - » **Specified in TIA Draft 4 "Propagation Delay and Delay Skew Specifications for 100 ohm 4-pair Cabling"**
    - » **To be incorporated into the addendum to TIA-568-A**
  - **Section 16.9.3.1: Impulse noise >264 mV less than 0.2/sec**
    - » **Not specified by TIA-568-A or ISO 11801**

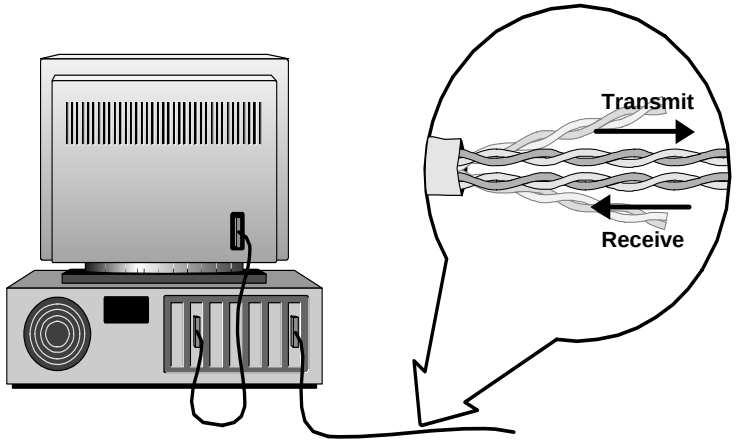
SCOPE
COMMUNICATIONS

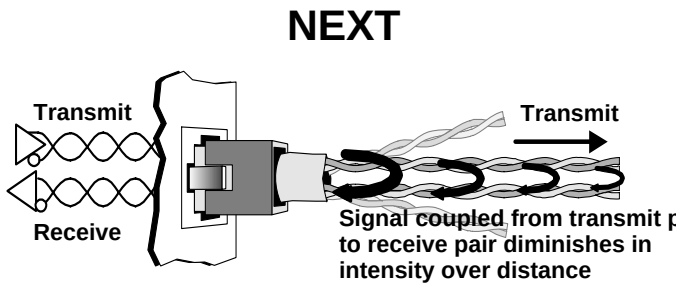
Outline

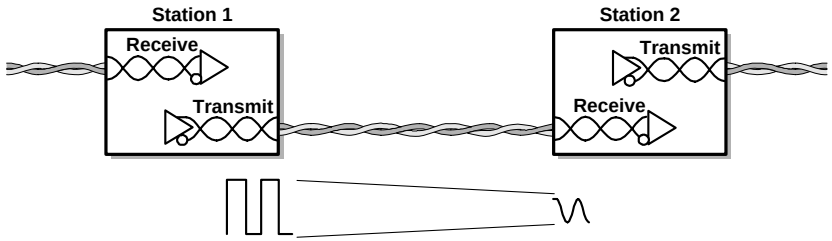


SCOPE
COMMUNICATIONS

Twisted Pair Transmission



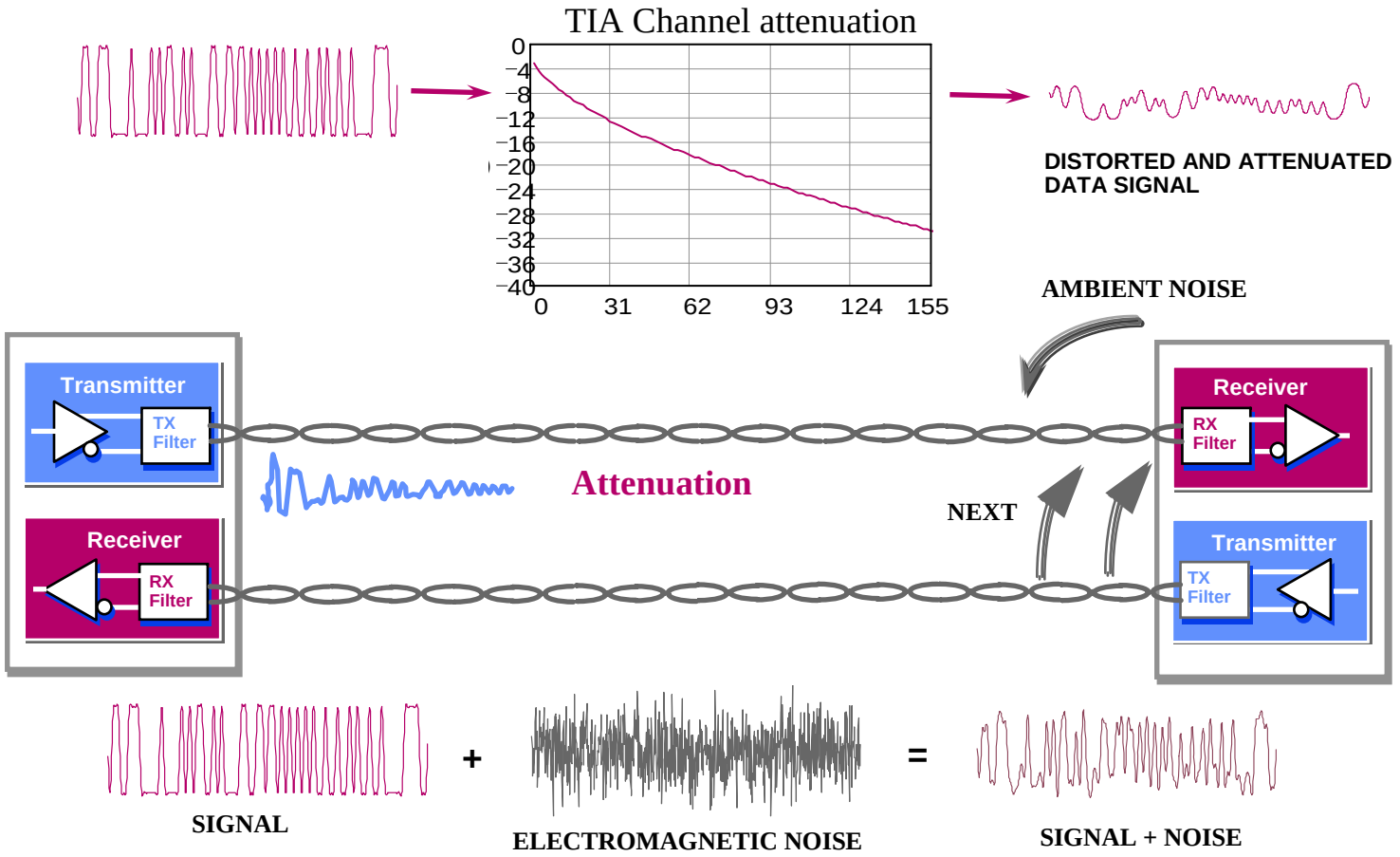




Attenuation

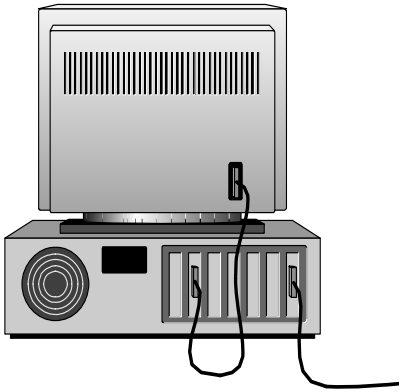
SCOPE
COMMUNICATIONS

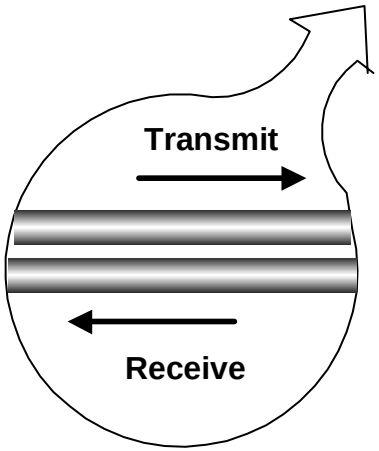
Twisted Pair Channel



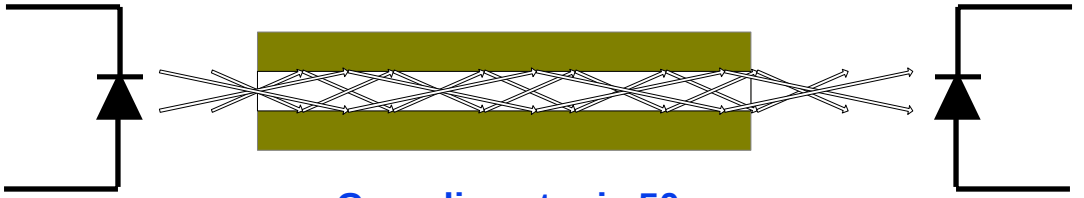
SCOPE
COMMUNICATIONS

Fiber Optic Transmission





TRANSMITTER — **Multi-Mode Fiber** — **DETECTOR**



LED
(850 or 1300 nm)
LASER
(850 or 1300)

Core diameter is 50 or 62.5 um graded index; allows multiple modes

PIN
(P-intrinsic N)
APD
(Avalanche Photodiode)

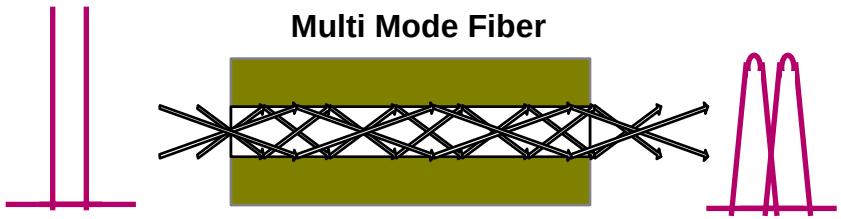
TRANSMITTER — **Single-Mode Fiber** — **DETECTOR**

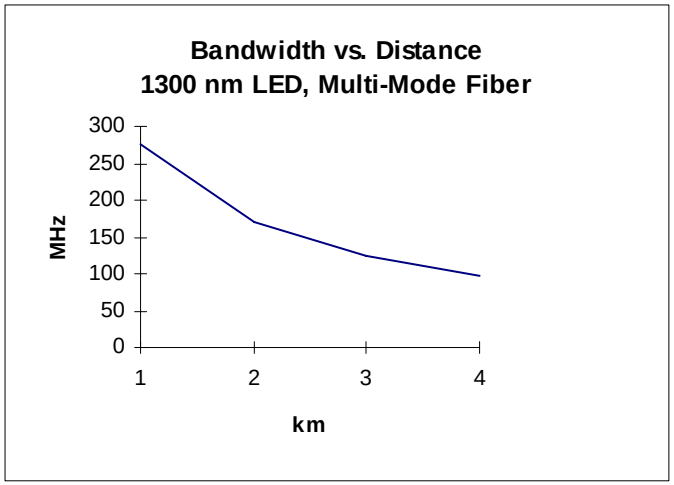
LASER
(1310 or 1550 nm)

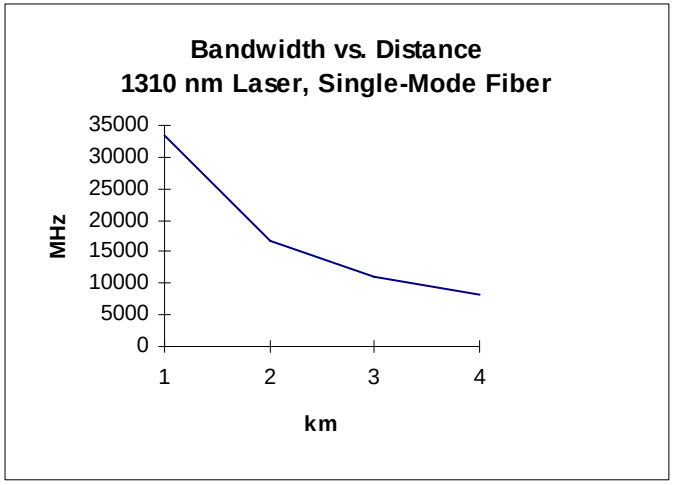
Core diameter is < 10 um; allows only a single mode

APD or PIN

Fiber Optic Channel Properties -- Attenuation and Dispersion

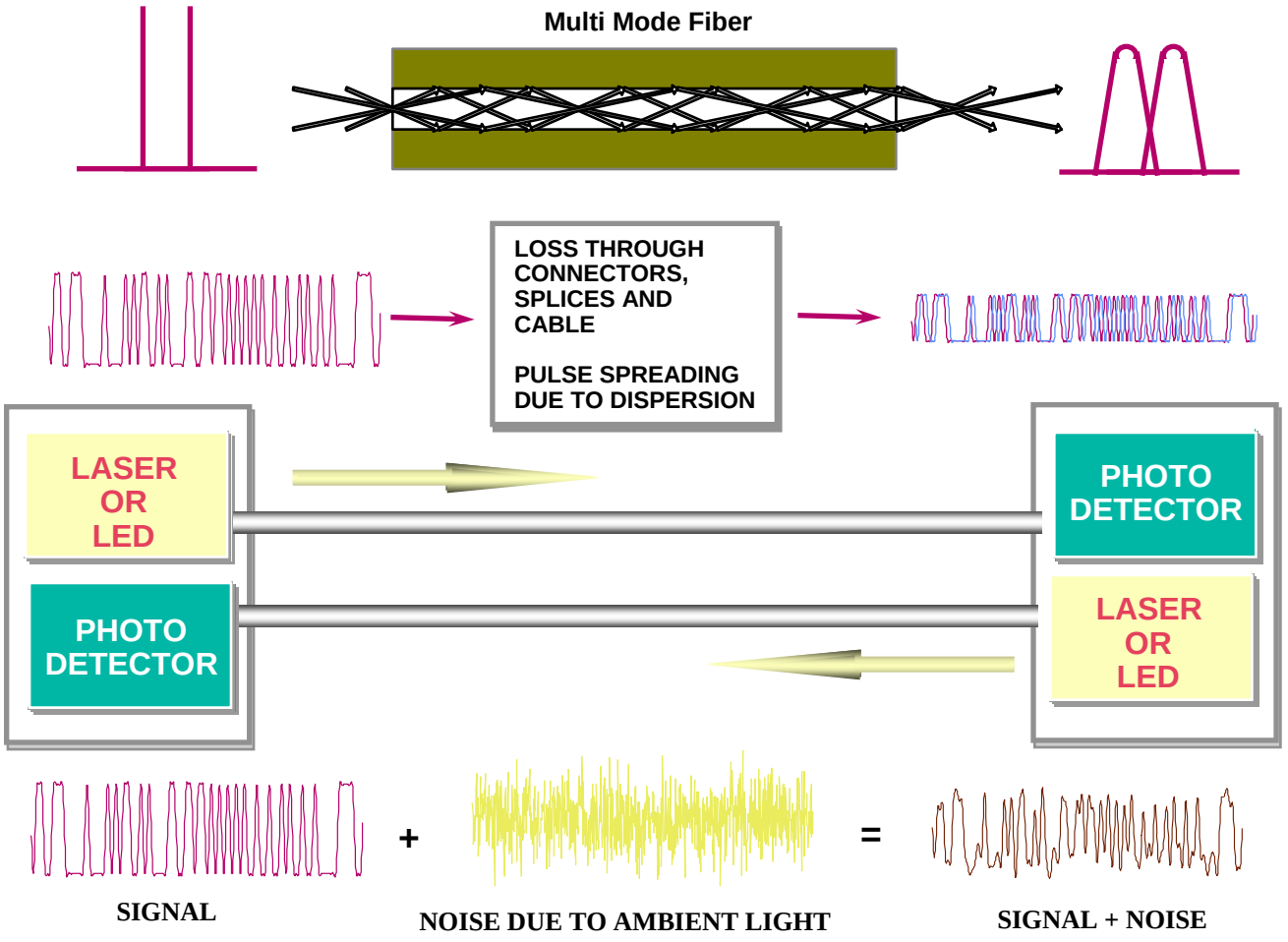






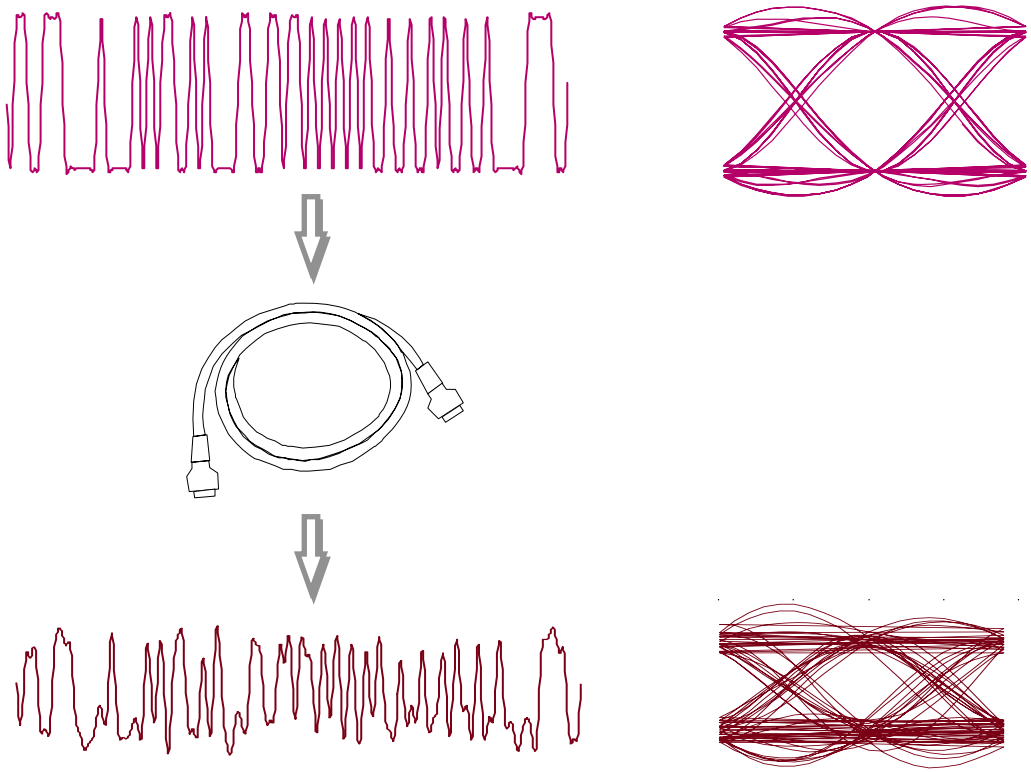
SCOPE
COMMUNICATIONS

Fiber Optic Channel



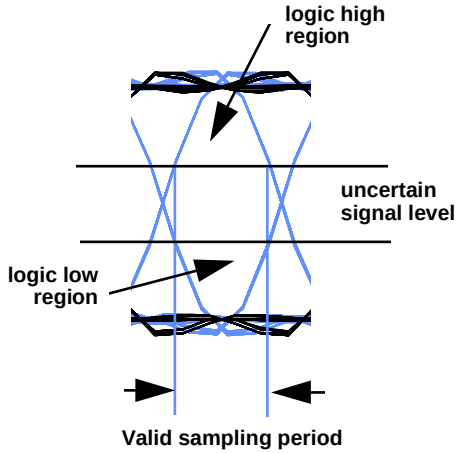
SCOPE
COMMUNICATIONS

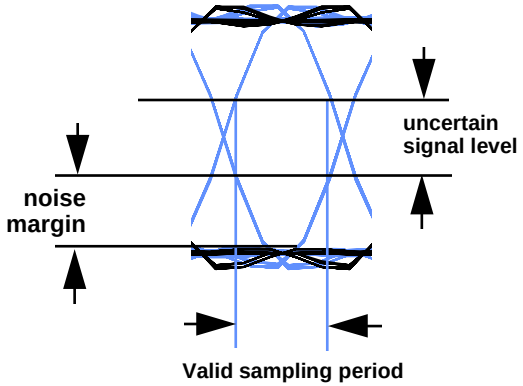
Bit Errors



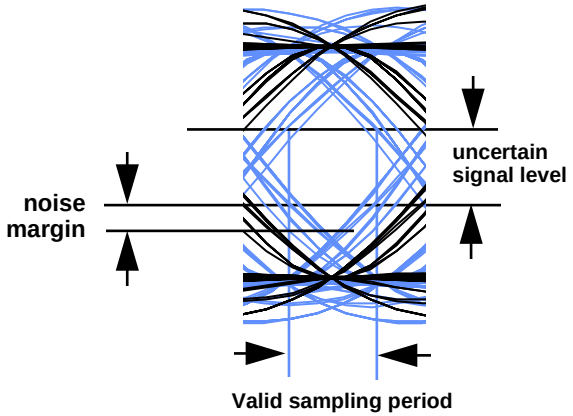
SCOPE
COMMUNICATIONS

Bit Errors



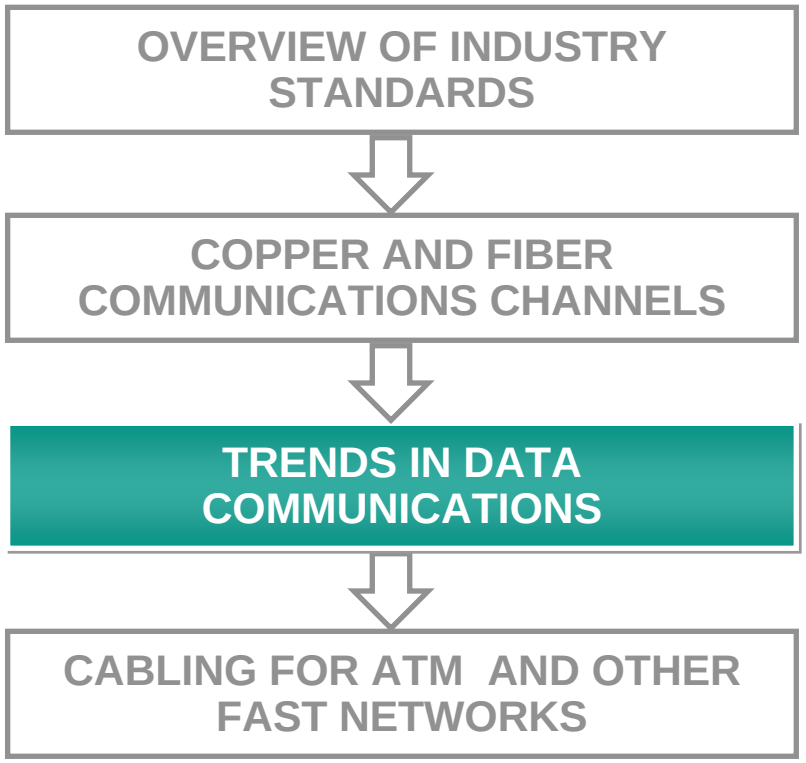


- Eye pattern opening determines the noise power needed to cause errors.
- The size of this opening is a good indication of the network robustness.



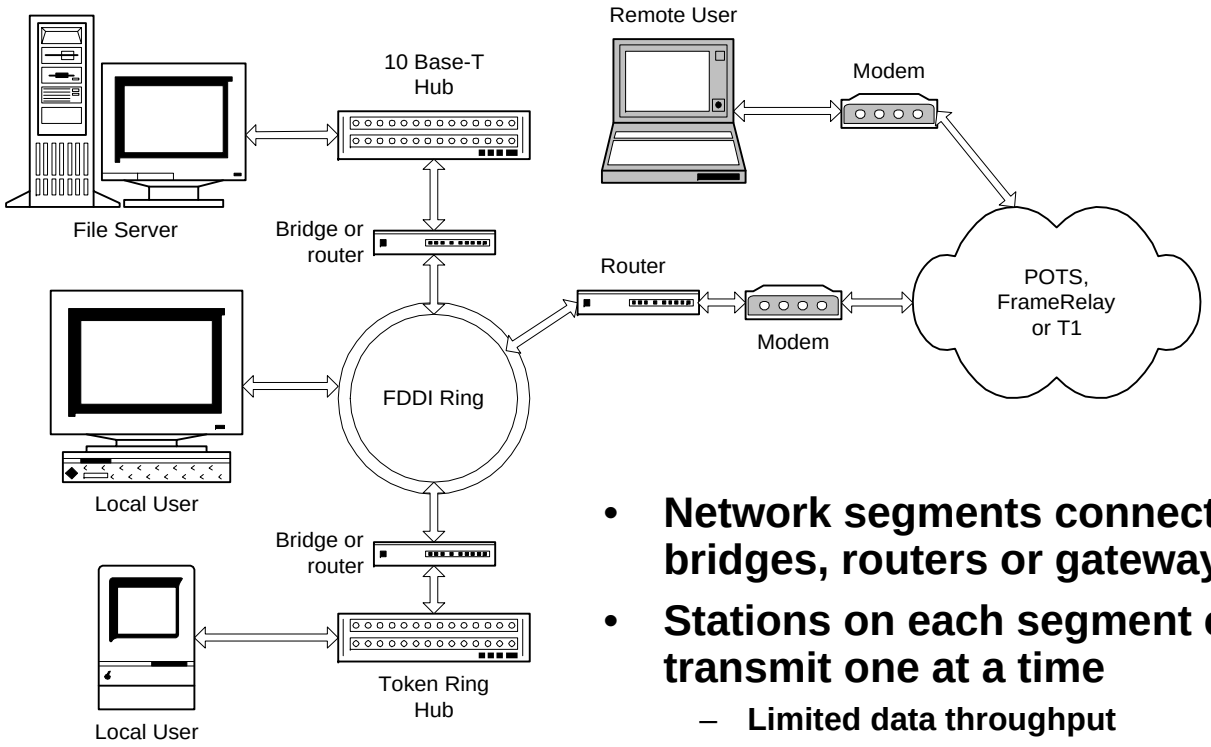
SCOPE
COMMUNICATIONS

Outline



SCOPE
COMMUNICATIONS

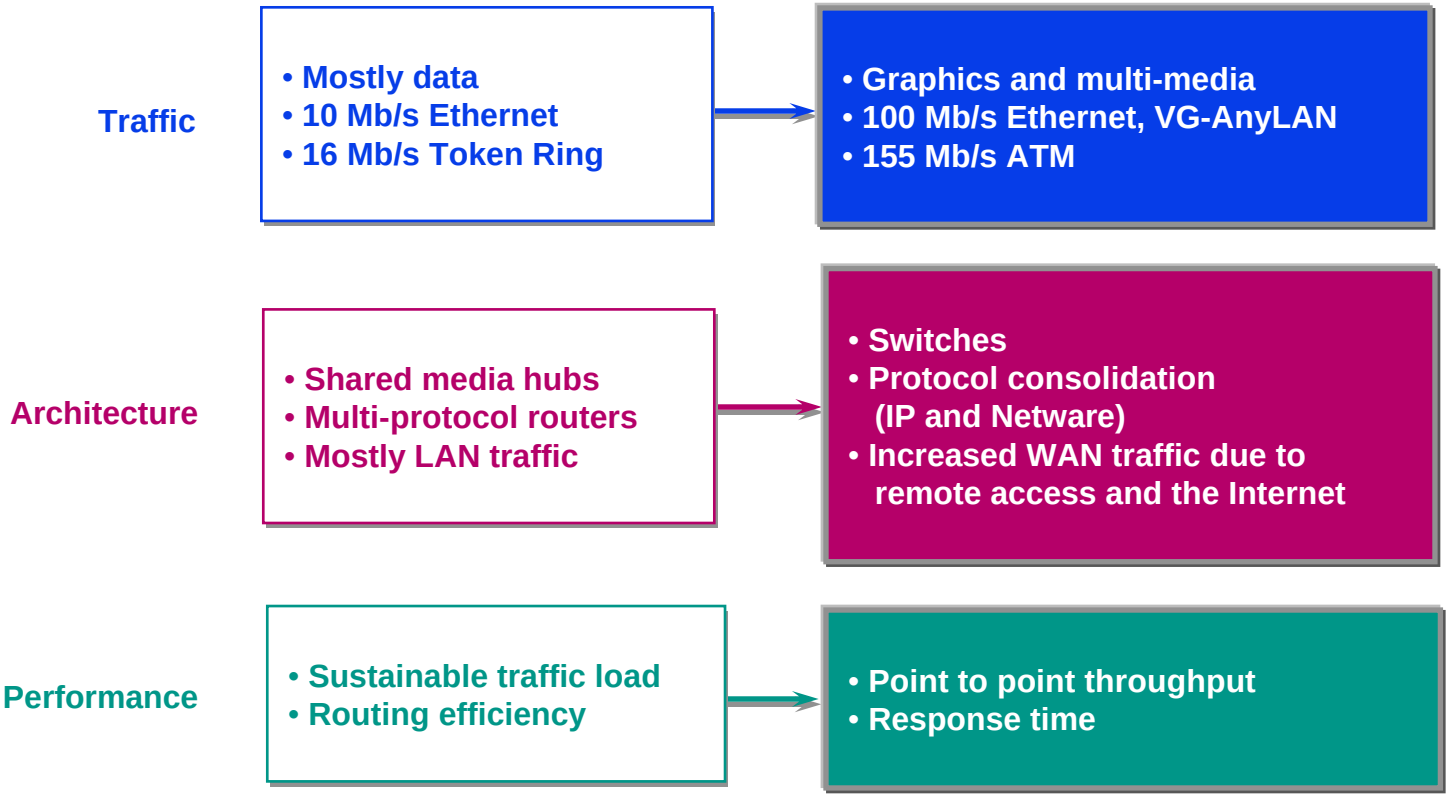
Today's Local Area Networks



- **Network segments connected by bridges, routers or gateways**
- **Stations on each segment can only transmit one at a time**
  - **Limited data throughput**
- **Modem connection to remote sites**

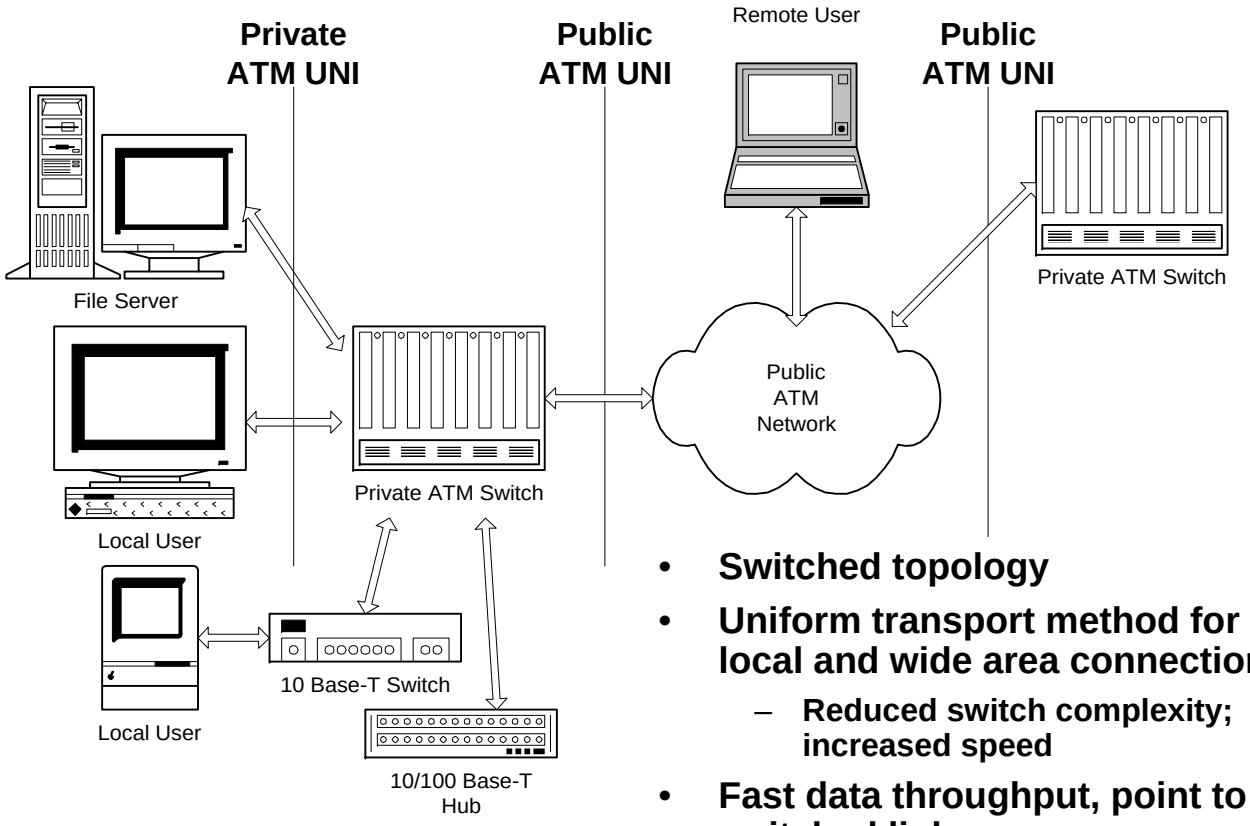
SCOPE
COMMUNICATIONS

Trends in Data Communications



SCOPE
COMMUNICATIONS

Next Generation Networks



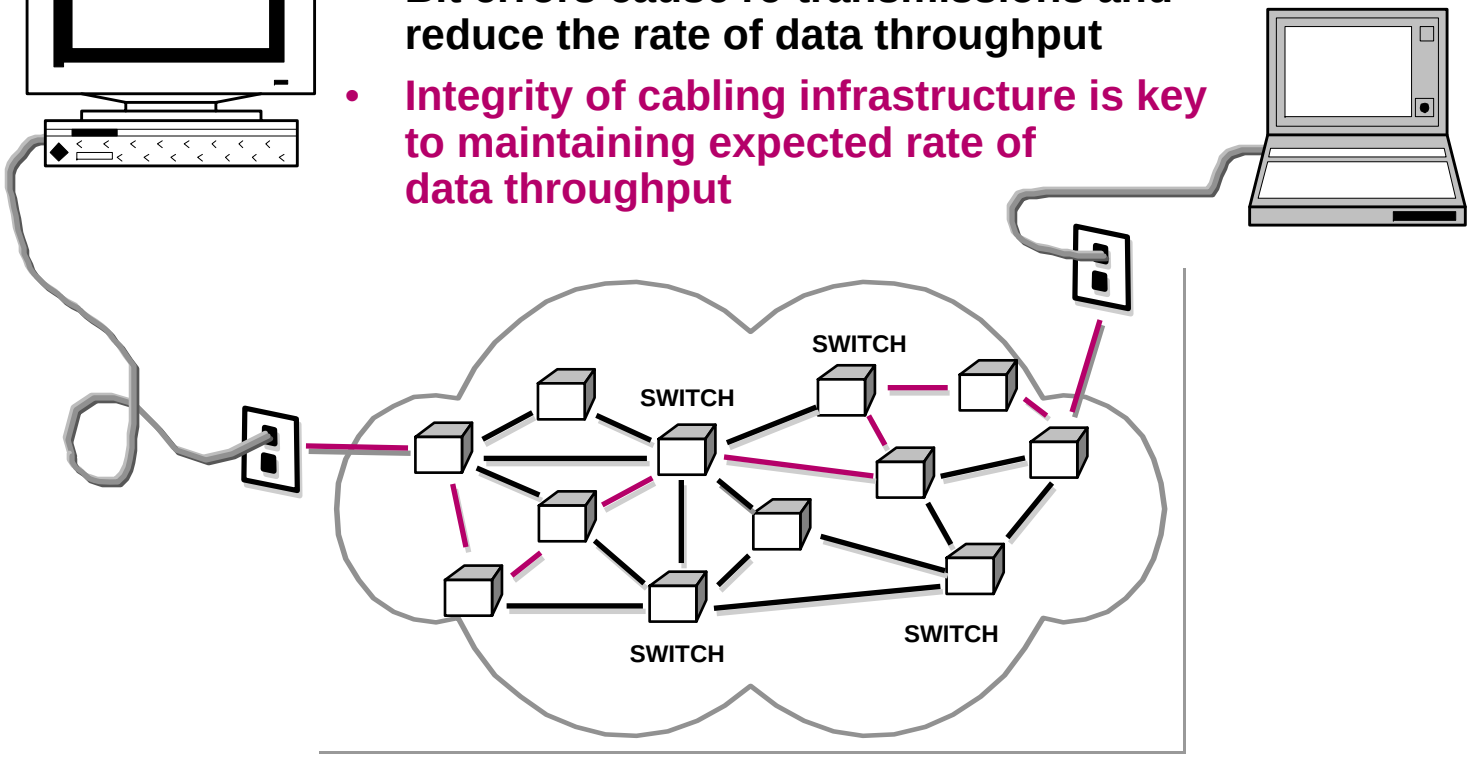
- **Switched topology**
- **Uniform transport method for both local and wide area connections**
  - **Reduced switch complexity; increased speed**
- **Fast data throughput, point to point switched links**

Note: UNI = User-to-Network Interface

SCOPE
COMMUNICATIONS

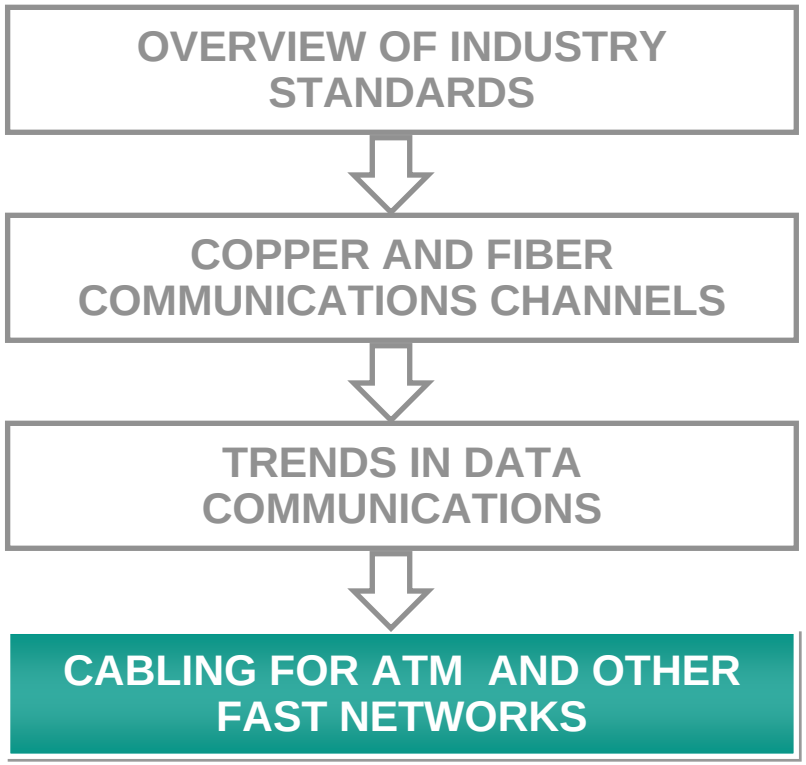
Performance Metrics for Next Generation Networks

- **Emphasis on high rate of point to point data throughput**
  - **High frequency data signal**
    - » **Vulnerable to physical layer imperfections**
- **Bit errors cause re-transmissions and reduce the rate of data throughput**
- **Integrity of cabling infrastructure is key to maintaining expected rate of data throughput**



SCOPE
COMMUNICATIONS

Outline



SCOPE
COMMUNICATIONS

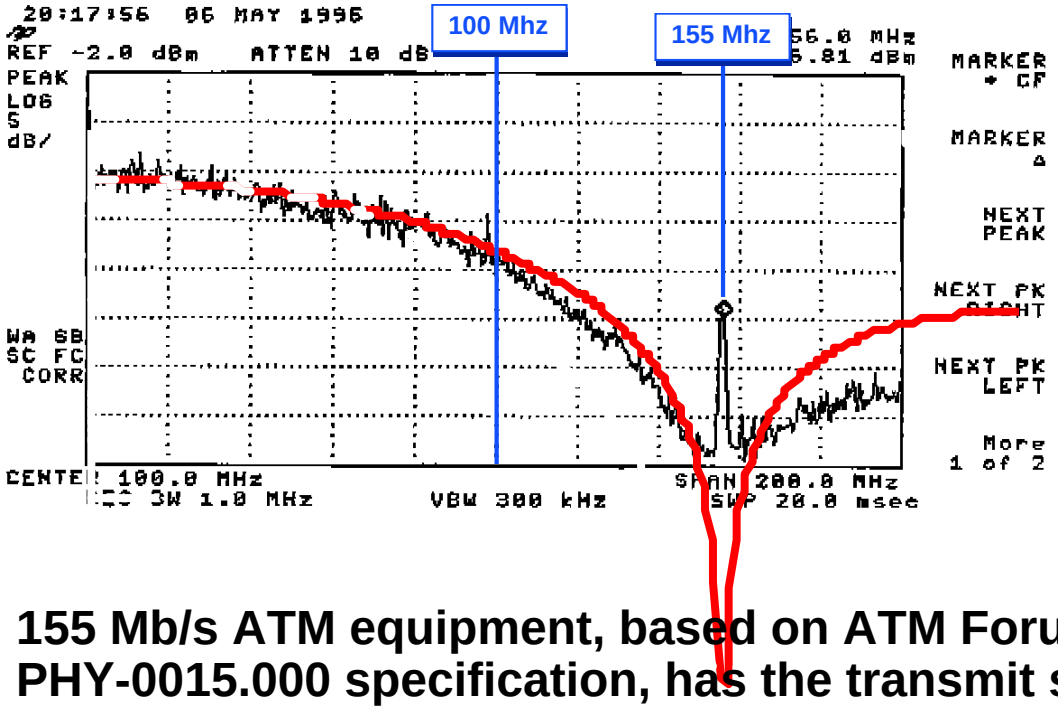
ATM Physical Layer Interfaces

INTERFACE	DATA RATE (Mb/s)	LINE RATE (Mbaud)	PHYSICAL LAYER	STANDARD
622.08 Mb/s (SONET STS-12c based)	622.08	622.08	SMF, 1300nm, 2 or 15 km MMF, 1300nm LED, 500 m MMF, SW Laser, 300 m	AF-PHY-0046.000
155.52 Mb/s (SONET, STS-3c based)	155.52	155.52	MMF, 1300 nm SMF, 1300 nm	AF-BICI-0013.003, TR-NWT-000253
DS3	44.736	44.736	75 Ohm Coax	AF-PHY-0054.000 (Ballot)
DS1	1.544	1.544	100 Ohm UTP	AF-PHY-0016.000
E4	139.264	139.264		UNI v3.1, ITU-T G.703
E3	34.368	34.368	75 Ohm Coax	UNI v3.1, ITU-T G.703
E1	2.048	2.048	120 Ohm STP, 75 Ohm Coax	AF-PHY/94-0422R7 (straw vote)
100 Mb/s FDDI-PMD	100	125	SMF, MMF, 1300 nm	UNI v3.1, ISO/IEC 9314-3
155.52 Mb/s (8B/10B) (Fiber Channel based)	155.52	194.4	MMF, 1300 nm, 2 km 150 ohm STP, 100 m	UNI v3.1
155.52 Mb/s POF/HPCF *	155.52, 50	155.52, 50	MMF, 650 nm, 50 / 100 m	Proposal
155.52 Mb/s SW Laser	155.52	155.52	MMF, 850 nm, 1 km, TIA-568	AF-PHY-0062.000 (Ballot)
155.52 Mb/s Cat 5 UTP	155.52	155.52	Cat 5 UTP, TIA-568 Channel	AF-PHY-0015.000
155.52 Mb/s Cat 3 UTP	155.52	25.92	Cat 3 UTP, TIA-568 Channel	AF-PHY-0047.000
Mid-range Phy, Cat 3 UTP	51.84, 25.92 12.96	12.96	Cat 3 UTP, TIA-568 Channel	AF-PHY-0018.000
25.6 Mb/s, Cat 3	25.6	32	Cat 3 UTP, TIA-568 Channel	AF-PHY-0040.000

* Plastic Optical Fiber / Hard Polymer Clad Silica Fiber

SCOPE
COMMUNICATIONS

155.52 Mb/s Category 5 ATM Physical Layer

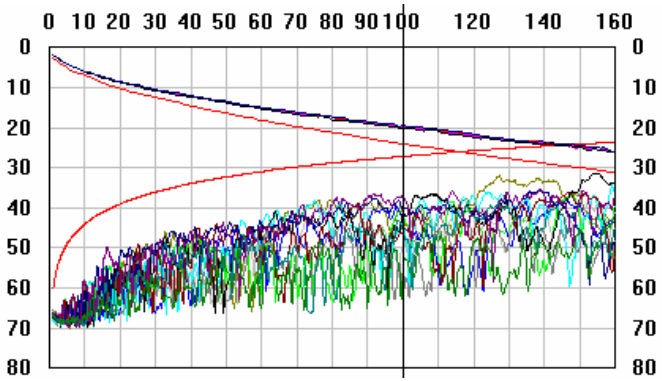


- **155 Mb/s ATM equipment, based on ATM Forum AF-PHY-0015.000 specification, has the transmit spectrum extending to 155 MHz**
- **It is a good idea to characterize channels expected to carry 155 Mb/s ATM to 155 MHz**

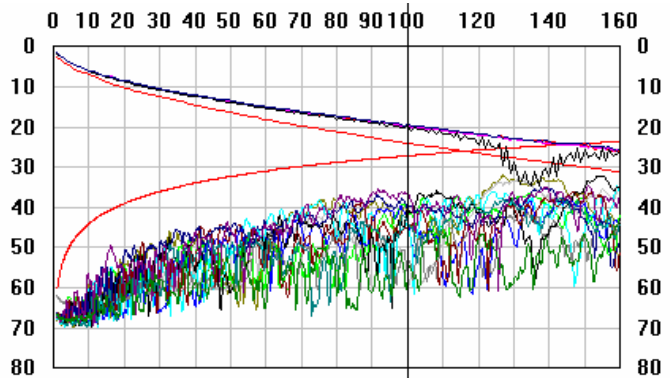
SCOPE
COMMUNICATIONS

155 Mb/s BER TEST
Channel Certification Results

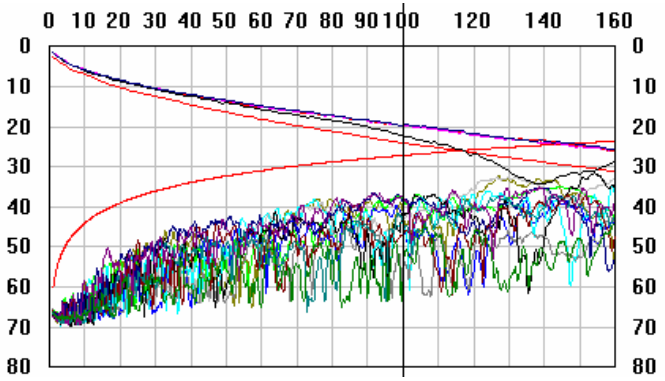
Channel NEXT and attenuation; no filtering
BER:
2.1×10^{-11}
3.9×10^{-11}



Channel NEXT and attenuation; with a notch
BER:
6.1×10^{-10}
7.8×10^{-10}



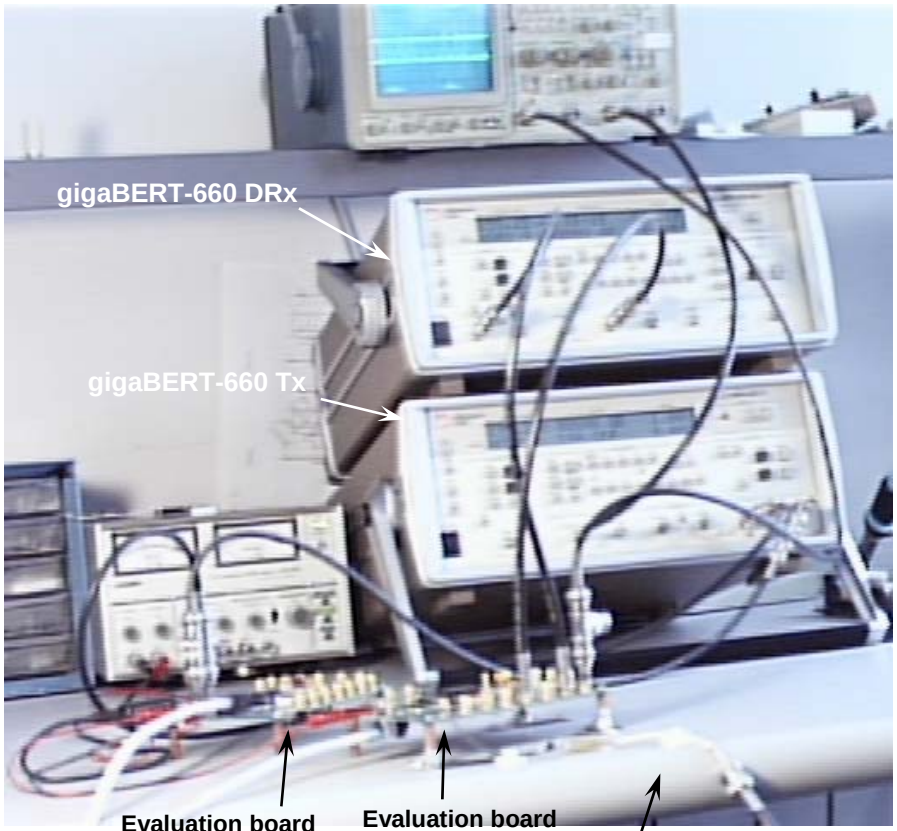
Channel NEXT and attenuation; With a stub
BER:
1.2×10^{-8}



Testing audited by

SCOPE
COMMUNICATIONS

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



SCOPE
COMMUNICATIONS

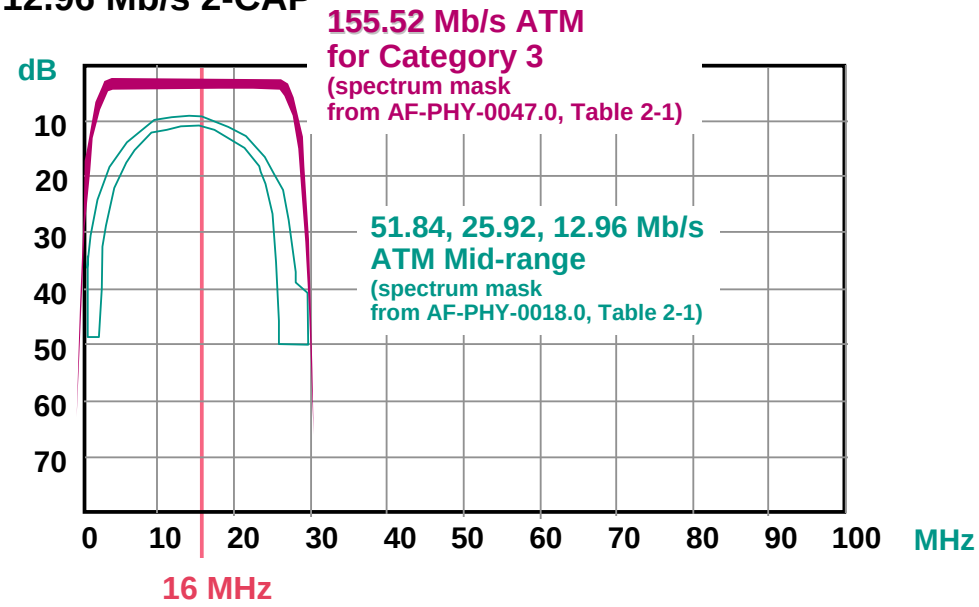
155 Mb/s ATM Physical Layer Requirements

- **The 155 Mb/s ATM interface (AF-PHY-0015.000) uses the twisted pair channel beyond the frequency range specified by TIA-568-A and ISO-11801 and relies on the extended frequency response of the channel for maintaining the required BER performance of 10^{-10}.**
- **This service works only because most category 5 installations behave predictably above 100 MHz.**
- **Using components beyond their frequency specification is a poor design practice -- it leaves the system vulnerable to new products which might employ emission suppressing filtering and to installation flaws which might be outside the specified frequency range.**

SCOPE
COMMUNICATIONS

Mid-range Twisted Pair ATM Physical Layer

- ATM Forum AF-PHY-0018.000, 9/94; AF-PHY-0047.000
- Spectral width and line rate of 12.96 Mbaud are the same for all data rates
  - 155.52 Mb/s 64-CAP (Carrierless AM / PM)
  - 51.84 Mb/s 16-CAP
  - 25.92 Mb/s 4-CAP
  - 12.96 Mb/s 2-CAP



SCOPE
COMMUNICATIONS

Mid-range Twisted Pair ATM Physical Layer

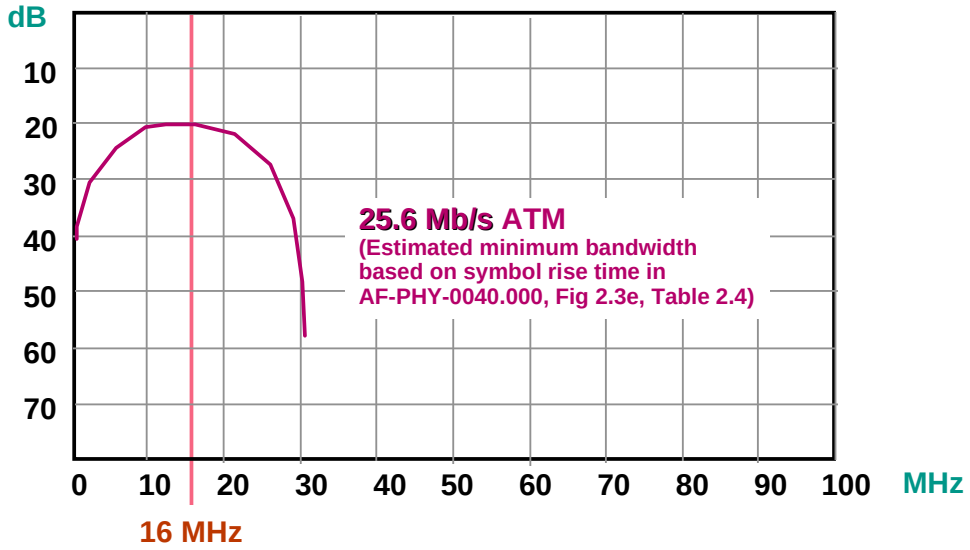
- Template for the power spectrum of a Mid-range ATM device is specified in AF-PHY-0018.000 Figure 2-8 and Table 2-1
  - Spectrum centers around 12.96 MHz and has 100% excess bandwidth, extending to 25.92 MHz
- Template for the spectrum of 155.52 Mb/s service specified in AF-PHY-0067.000 Figure 2-6 and Table 2-1
  - Spectrum centers around 25.92 MHz and has 15% excess bandwidth, extending to 29.8 MHz
- Transmitter and receiver return loss for both services is specified in the frequency range 1-30 MHz to be >15 dB
- If it is important to maintain return loss of 15 dB at the device, then the cable needs to behave consistently in the range of 1-30 MHz as well
  - Inconsistent with the 16 MHz range of category 3 specification

➧ Good idea to verify channel NEXT and attenuation beyond the category 3 range of 16 MHz
  - Field test range should extend to 26 MHz minimum

SCOPE
COMMUNICATIONS

25.6 Mb/s Twisted Pair ATM Physical Layer

- ATM Forum document AF-PHY-0040.000, 11/95
- Line rate is 32 Mbaud after 4B5B encoding (Section 2.1.1)
- Spectrum is not specified directly but can be estimated from the rise time of a One Symbol Element template in Figure 2.3e and Table 2.4



SCOPE
COMMUNICATIONS

25.6 Mb/s Twisted Pair ATM Physical Layer

- **Sections 2.2.4 and 2.3.2 specify transmitter and receiver return loss in the frequency band of 1-25 MHz**
  - **Transmitter 1-6 MHz 14 dB, 6-17 MHz 12 dB, 17-25 MHz 8 dB**
  - **Receiver 1-17 MHz 15 db, 17-25 MHz 8 dB**
- **If it is important to bound return loss at the device up to 25 MHz, then the cable should be characterized up to 25 MHz as well**
  - **Inconsistent with the 16 MHz range of category 3 specification**

➧ **Good idea to verify channel NEXT and attenuation beyond the category 3 range of 16 MHz**

  - **Field test range should extend to 25 MHz minimum**

SCOPE
COMMUNICATIONS

10/100 Base-TX Physical Layer

- IEEE Std 802.3u-1995, Chapter 25, refers to TP-PMD standard, ANSI X3.263, 3/95, for category 5 UTP and 150 ohm STP interfaces
- TP-PMD standard specifies
  - 100 Mb/s using 4B/5B encoding to produce 125 Mb/s data stream
  - Multi-Level Transmission-3 (MLT-3) modulation
    - » 3 voltage levels with the spectral peak at around 30 MHz
    - » Return loss of transmitter and receiver is specified (Sections 9.1.5 and 9.2.2) up to 80 MHz
      - Ranging from 16 to 10 dB as frequency increases
  - Insertion loss deviation (Sections 11.1.5) 0.35 dB max
    - » This specification ensures consistent attenuation slope over frequency and ensures integrity of Structural Return Loss (SRL)
- Maximum medium propagation delay, IEEE Std 802.3u-1995 Table 29-1
  - Twisted pair link 1140 ns

➧ Category 5 certification with additional measurement of propagation delay is sufficient field verification

SCOPE
COMMUNICATIONS

155.52 Mb/s Short Wavelength Laser ATM Physical Layer

- ATM Forum AF-PHY-0062.000, Letter Ballot, 5/96
- TIA-568-A or ISO 11801 compliant Multi-Mode Fiber installation
- Cable plant attenuation
  - < 7.2 dB for 62.5 um
- Distance
  - 1 km
- Line code
  - Optical NRZ, 152.52 MBaud
- Laser wavelength
  - 770 to 860 nm
- Full Width Half-Maximum (FWHM) spectral width
  - 9 nm

↓ Field verification of attenuation budget at 850 nm is sufficient

SCOPE
COMMUNICATIONS

10/100 Base-FX Physical Layer

- IEEE Std 802.3u-1995, Chapter 26 refers to the FDDI PMD, ISO 9314-3 for the fiber physical layer specification
- ISO 9314-3 specifies the following fiber interfaces
  - Single-Mode Fiber
  - Multi-Mode Fiber, 2 km
  - MMF, 500 m Low Cost Fiber (LCF-PMD)
- Wavelength 1300 nm
- Symbol rate 125 Mbaud
- Maximum propagation delay, 802.3u-1995, Table 29-1
  - Fiber link 4120 ns

⇓ Field test should include verification of

- Attenuation
- Propagation delay

SCOPE
COMMUNICATIONS

Outline