EVLA Fiber Selection Critical Design Review

December 5, 2001

Fiber Selection CDR

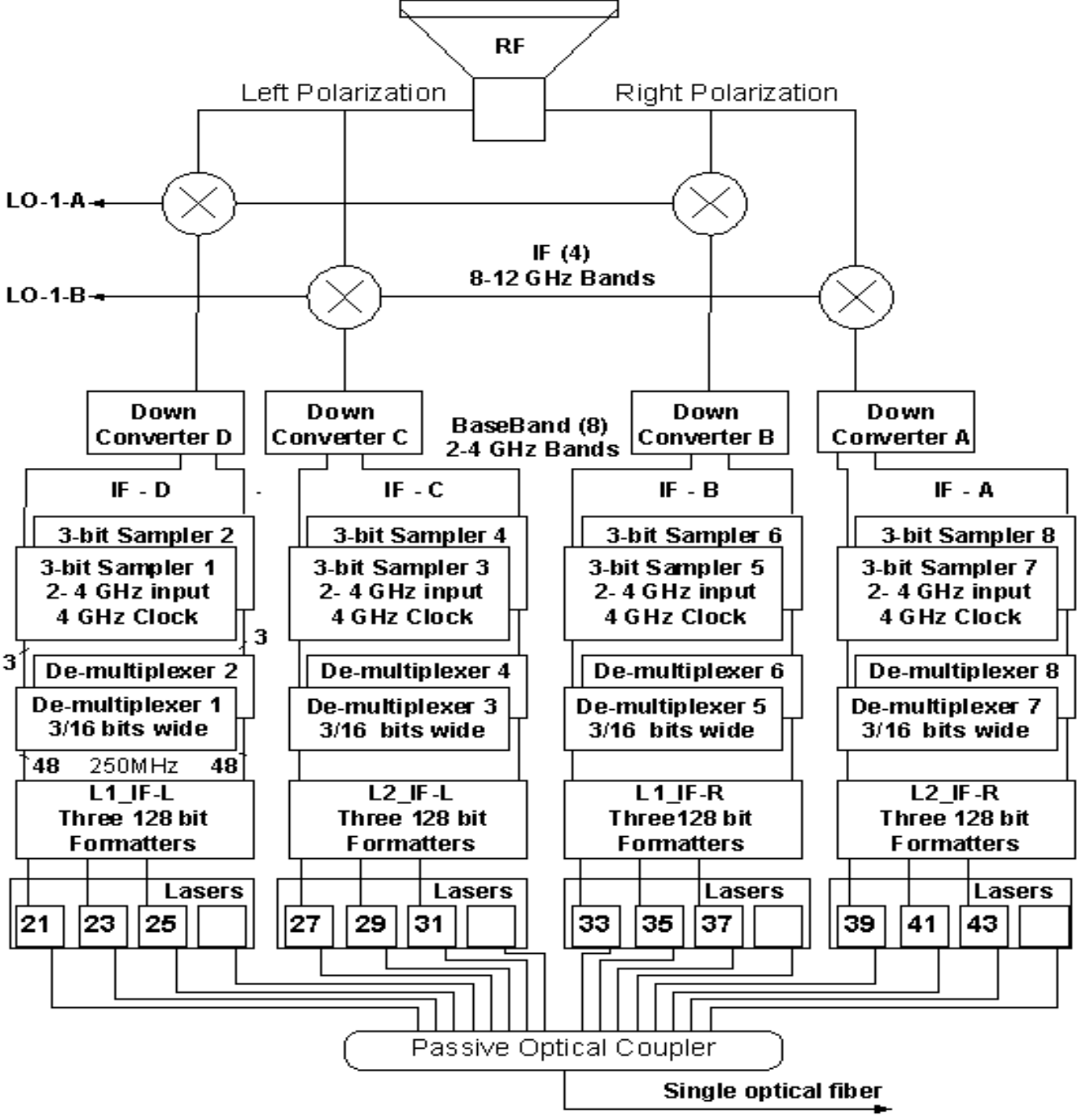
- **Decision about what fiber to install**
  - Select cable — Jan 2002
  - Order cable — Jan 2002
  - Receive cable — May 2002
  - Start installation — June 2002
  - Test Antenna installation — April 2003

Scientific Requirements

- **Samplers Dominate the Digital Performance**
  - Input Bandwidth 2-4 GHz
  - Clock Rate 4096 MHz
  - Resolution 3 Bits
  - Aperture Time 50 Ps
  - Clock Jitter 5 Ps
  - Clock Rise Time 25 Ps

IF System Dominates the Digital Transmission System

- Jitter Contribution N/A
- Loss of Synchronization <1% Loss of Data
- Data Bit rate per Polarization 24 GHz
- Data Bit rate per Antenna (12) 96 GHz
- Formatted Bit rate per Antenna 120 GHz
-


RF
Left Polarization
Right Polarization
LO-1-A
LO-1-B
IF (4)
8-12 GHz Bands
Down Converter D
Down Converter C
BaseBand (8)
2-4 GHz Bands
Down Converter B
Down Converter A
IF - D
IF - C
IF - B
IF - A
3-bit Sampler 2
3-bit Sampler 1
2- 4 GHz input
4 GHz Clock
3-bit Sampler 4
3-bit Sampler 3
2- 4 GHz input
4 GHz Clock
3-bit Sampler 6
3-bit Sampler 5
2- 4 GHz input
4 GHz Clock
3-bit Sampler 8
3-bit Sampler 7
2- 4 GHz input
4 GHz Clock
3
3
De-multiplexer 2
De-multiplexer 1
3/16 bits wide
De-multiplexer 4
De-multiplexer 3
3/16 bits wide
De-multiplexer 6
De-multiplexer 5
3/16 bits wide
De-multiplexer 8
De-multiplexer 7
3/16 bits wide
48
250MHz
48
L1_IF-L
Three 128 bit
Formatters
L2_IF-L
Three 128 bit
Formatters
L1_IF-R
Three128 bit
Formatters
L2_IF-R
Three 128 bit
Formatters
Lasers
21
23
25
Lasers
27
29
31
Lasers
33
35
37
Lasers
39
41
43
Passive Optical Coupler
Single optical fiber

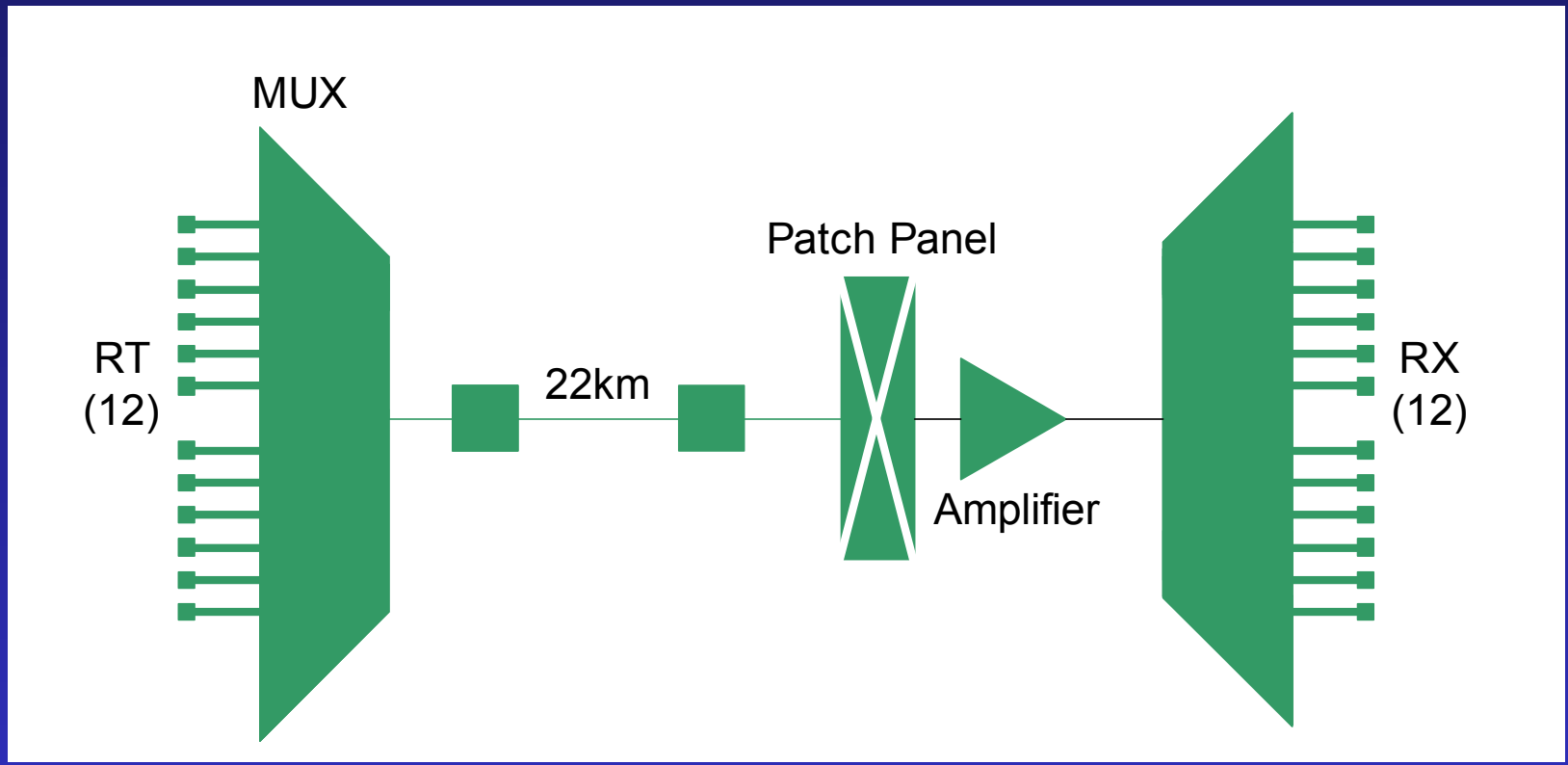
Task at Hand

- **Select a fiber and a Configuration that can transmit the IF data from the antennas to the correlator and support the other fiber systems**
  - — Identify Optical Requirements
  - — Compare Fibers
  - — Select Fiber

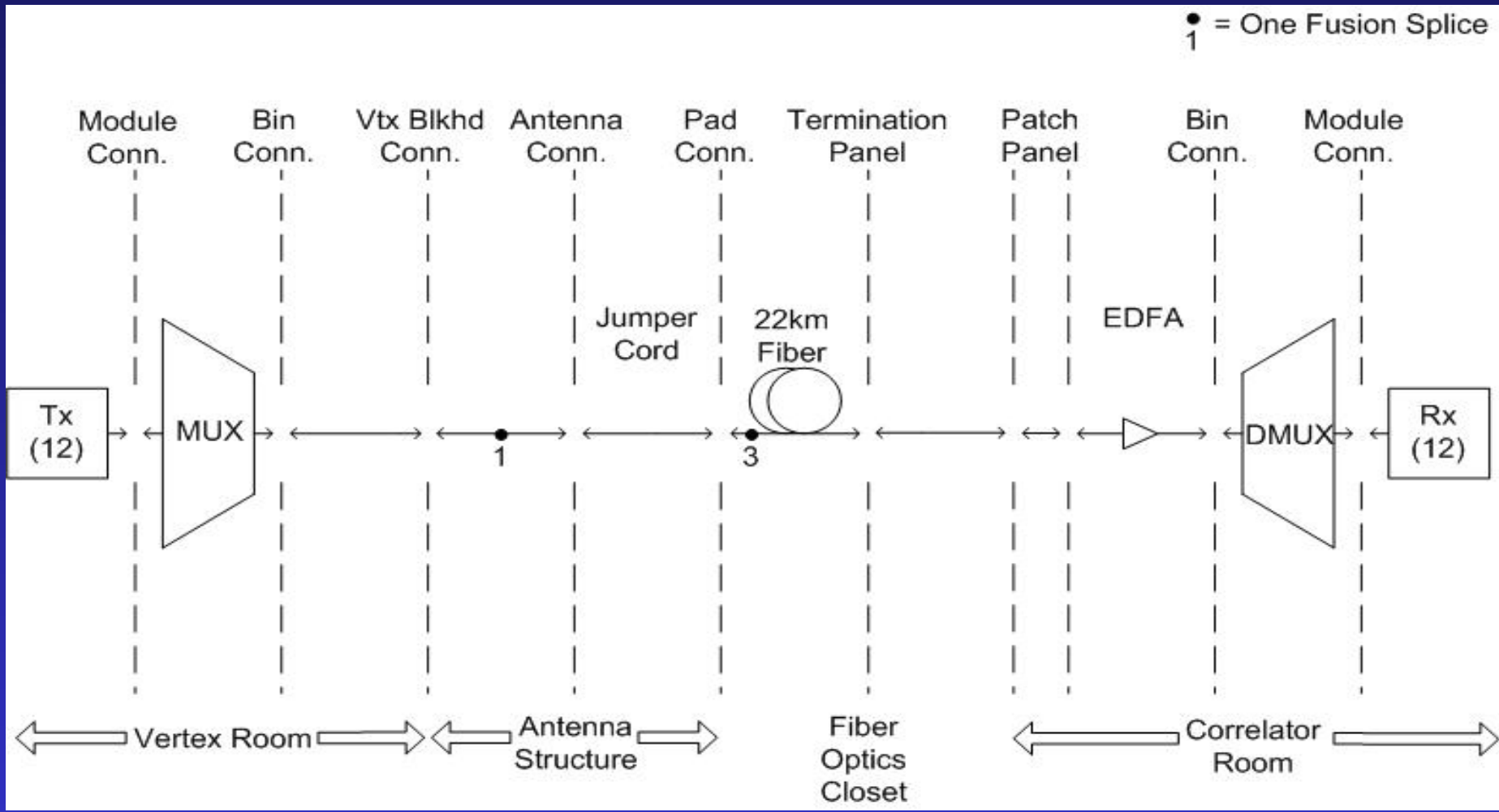
IF Parameters

Bit Rate / Channel	10 Gbits/s
Number WDM Channels	12 Channels
Channel Spacing	200 GHz Spacing
Channel Wavelengths	C-Band
Bit Error Rate	10^{-9} Initial, 10^{-6} Final
Digital RMS SNR (Q)	6 - Initial, 4.7 - Final
Maximum Fiber Length	21.6 km
Minimum Fiber Length	625 m
Operation Temperature	-12 C to 35 C

IF Block Diagram



IF Signal Path



Types of Fiber Analyzed

- **Corning Products**
  - — SMF-28, Standard Single Mode Optical Fiber
  - — MetroCor, Non-Zero Dispersion Shifted Fiber
  - — LEAF, Large Effective Area Fiber

EVLA Memo 32

Fiber Comparison

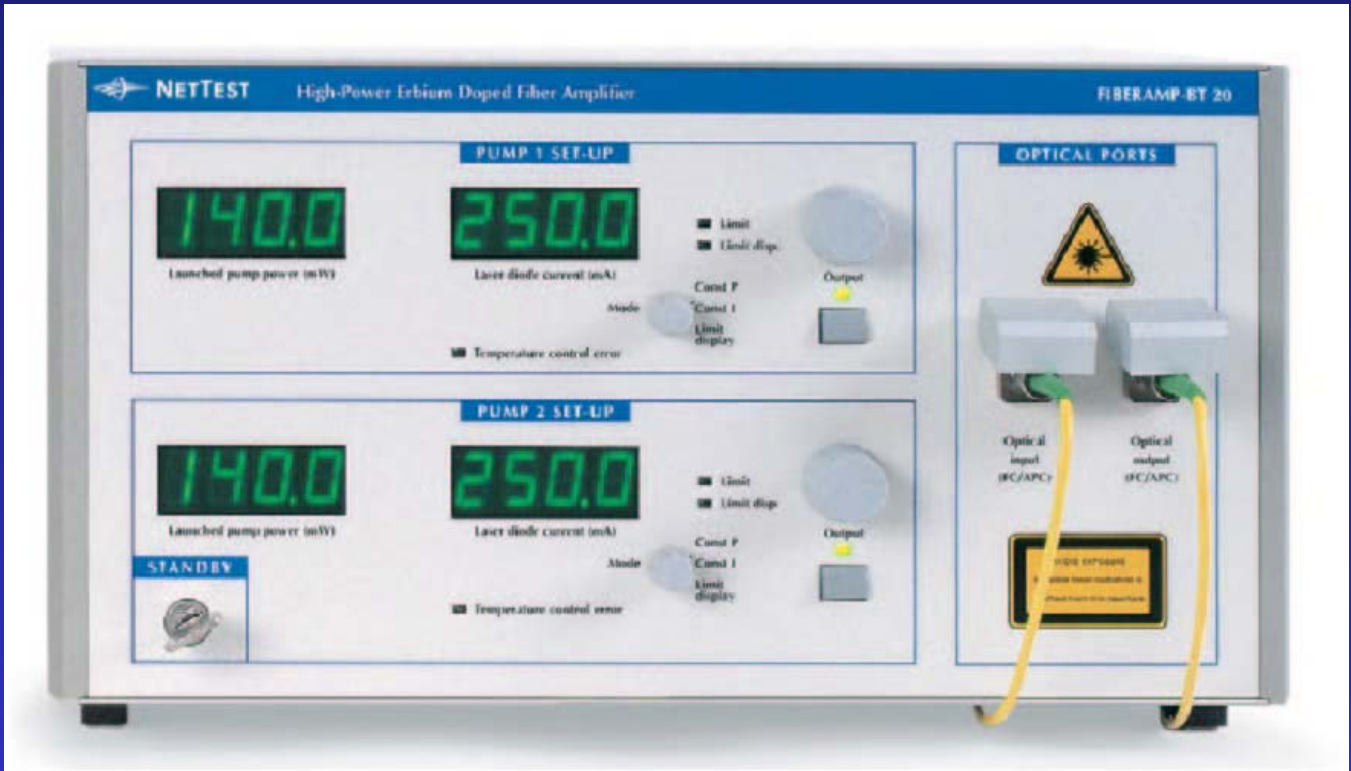
Parameter	SMF-28	MetroCor	LEAF
Attenuation (22 km)	6.6 dB	5.5 dB	5.5 dB
Maximum Bit Rate w/o Penalty	8.2 Gbits/s	20.8 Gbits/s	16.4 Gbits/s
Dispersion Power Penalty (22 km)	2 dB	0.3 dB	0.5 dB
Max. Launch Power	4.3 dBm	2.5 dBm	3.8 dBm

IF Rack to Vertex Room Bulkhead				
	Launch Power in dBm			0.00
	16ch WDM MUX	1	-6.00	-6.00
	Connector	3	-0.30	-0.90
	Fiber (km)	0.004	-0.30	0.00
Vertex Room Bulkhead to Antenna Pad			$P_{vtx\ bulkhead}$ =	-6.90
	Connector	1	-0.30	-0.30
	Fiber (km)	0.02	-0.30	-0.01
Farthest Antenna Pad to CB Termination Panel			$P_{last\ antenna\ pad}$ =	-7.21
	MIL Connector	2	-0.50	-1.00
	Connector	1	-0.30	-0.30
	Fiber (km)	0.7	-0.30	-0.21
	Splice	2	-0.10	-0.20
	Bends	18	-0.10	-1.80
CB Termination Panel to Patch Panel			$P_{termination\ panel}$ =	-10.72
	Connector	3	-0.30	-0.90
	Fiber (km)	22	-0.30	-6.60
	EDFA Gain	1		12.00
Correlator Patch Panel to Correlator Receiver			$P_{IF\ patch\ panel}$ =	-6.22
	Fiber (km)	0.004	-0.30	0.00
	Connector	3	-0.30	-0.90
	16ch WDM DMUX	1	-6.50	-6.50
Received Power				-13.62
Commercially Available Receiver Sensitivity				-20.00
Margin				6.38

Fiber Amplifiers

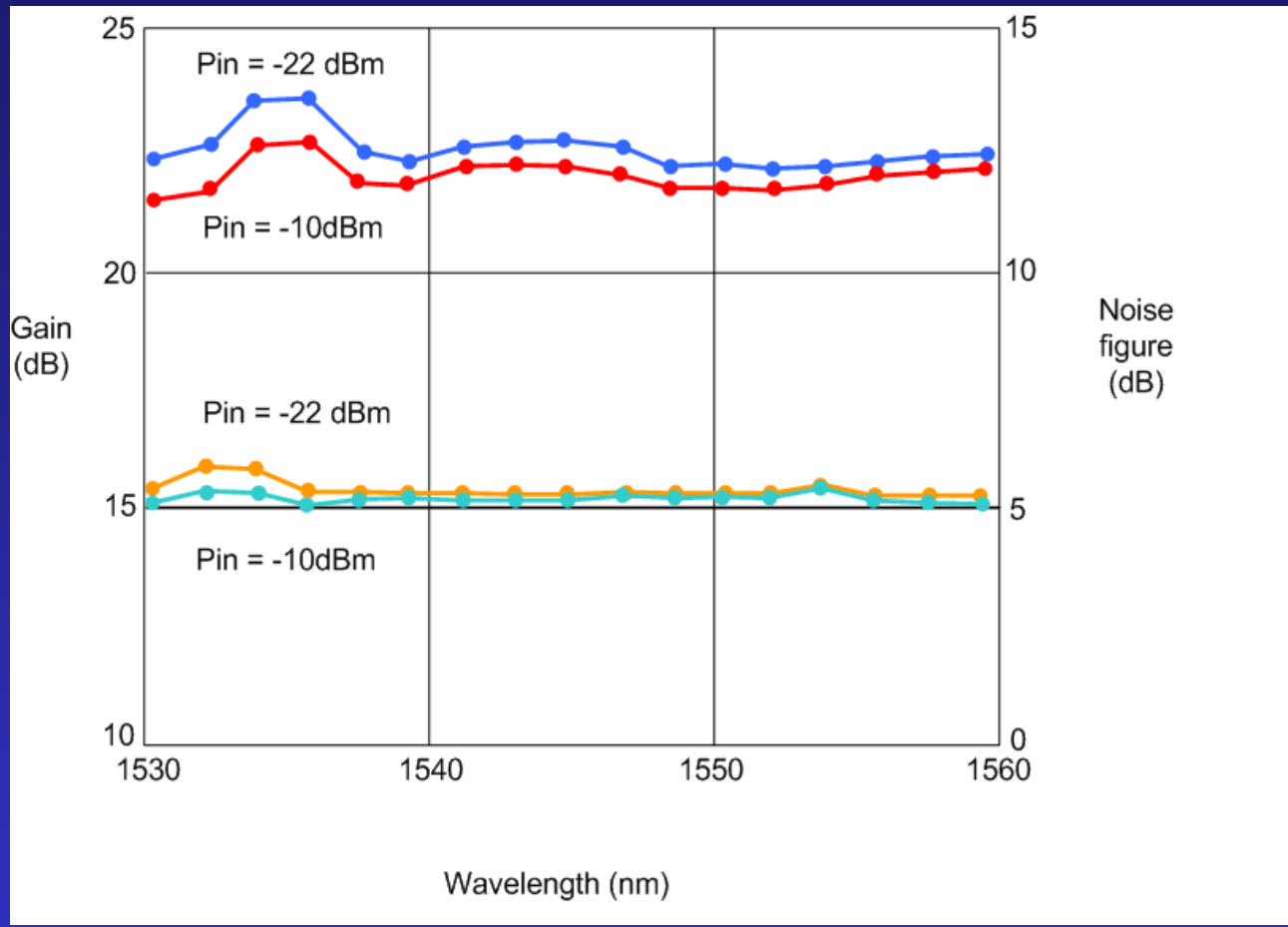
- Erbium Doped Fiber Amplifier
- Flat Operation from 1520 – 1570 nm
- Maximum Output power ~ 17 dBm
- Small Signal Gain > 25 dB
- PMD < 0.2 ps
- Noise Figure < 6 dB

Bench-top EDFA



EDFA Performance

- All channels will fall in the linear region
- Input power Range
  –40 to 10 dBm



Result #1

- **All Three Fibers, with an optical amplifiers, will have adequate optical power.**

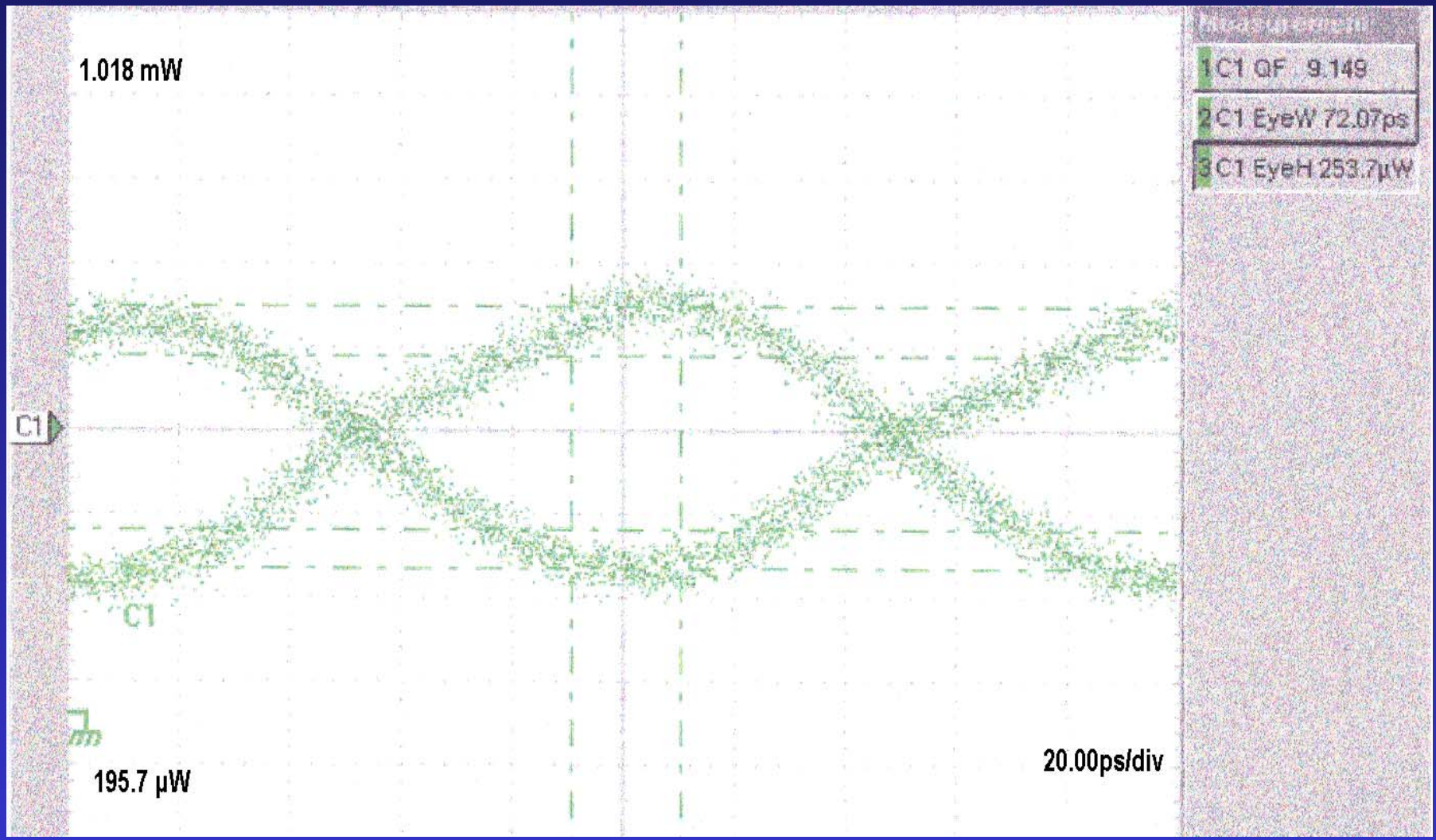
- **But what about Q ?**

Digital SNR (Q)

- Q is the ratio of signal current to noise current.

- $Q = (I_1 - I_0) / (i_1 + i_0)$
- $(I_1 - I_0)$ is the excess electric signal available for distinguishing between a 1 and a 0.
- $(i_1 + i_0)$ is the RMS electric current induced by noise during a transition.

Eye Pattern


1.018 mW
1 C1 QF 9.149
2 C1 EyeW 72.07ps
3 C1 EyeH 253.7µW
C1
C1
195.7 µW
20.00ps/div

Q Penalty Budget

	SMF	Metro	LEAF
Required Received Q (6)	15.56	15.56	15.56
Extinction Ratio	1.86	1.86	1.86
Crosstalk	2.00	2.00	2.00
Chromatic Disp.	2.00	0.30	0.50
Polarization Mode Dispersion	0.04	0.04	0.04
Nonlinearities	0.00	0.00	0.00
Polarization Dependant Loss	2.12	2.12	2.12
Optical Amplifier Noise	2.50	2.50	2.50
Component Aging	1.00	1.00	1.00
Margin	3.00	3.00	3.00
Required Transmitter Q (dB)	30.08	28.38	28.58
Launch Q (linear)	31.9	26.2	26.9

Transmission Quality

- Typical Transmitters
  - Launch at 0 dBm @ Q > 32
- Typical Receivers Provide
  - a BER of at least 10^{-9} @ –20 dBm

Result #2

- All Three fibers can Support a BER of 10^{-9}
  - Launch Requirements
    - 10 Gbits/s @ 0 dBm and a Q > 32
  - Receiver
    - Sensitivity of –20 dBm (10^{-9})

Fiber Allocations

IF 120 Gbps WDM	1
LO - 2.048GHz, 512 MHz, 128 MHz	2
MCB Ethernet	2
Battery Back-up Communication	1
Telephone Digital System	2
Total Lit Fibers per Antenna	8
12 Fibers Installed per Pad, 4 spares	

Cable Cross Section

Corning Cost Comparison
(Quoted prices)

24 Fiber Cable - Single Steel Armor		
SMF 28	$0.75 /ft	100%
MetroCor	$1.25 /ft	167%
LEAF	$1.70 /ft	227%
120 Fiber Cable - Single Steel Armor		
SMF 28	$2.88 /ft	100%
MetroCor	$5.38 /ft	187%
LEAF	$7.32 /ft	254%

System Budget

Double Armor Cable, SMF-28	$636,000
EDF Amplifier (27)	$300,000
Total	$936,000

CDR Recommendation

- **Single Mode Fiber, SMF**
- **Twelve fibers per pad**
- **Fourteen connectors**
- **Erbium doped fiber amplifiers (27)**
- **Bench Prototype before purchase**