Atacama
Large
Millimeter
Array

APP Optical Fiber Link system design

ALMA-05.11.40.01-0001-A-DSN

Version: A
Status: Draft
2013-04-24

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Approvals:		
TBD		
Release:		
TBD		

Change Record

Version	Date	Affected Section(s)	Change Request #	Reason/Initiation/Remarks
A	2013-04-24	ALL	None	First Issue
B	2014-12-02	4.2	None	Frequency/wavelength table added

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1 Introduction

1.1 Purpose

This document summarizes the design of the Optical Fiber Link system in the APP.

1.2 Reference Documents

[RD 1] ALMA Phasing Project Plan

1.3 Abbreviations and Acronyms

APP	ALMA Phasing Project
AOS	Array Operations Site
DWDM	Dense Wavelength Division Multiplexing
FIT	Failures In Time
ITU	International Telecommunication Union
OFL	Optical Fiber Link
OSF	Operations Support Facility
MTBF	Mean Time Between Failure
NAOJ	National Astronomical Observatory of Japan
PIC	Phasing Interface Card
VLBI	Very Long Baseline Interferometry

2 Specification of the OFL system

2.1 General specifications

The purpose of the OFL system is to transmit the antenna sum data from the AOS to the OSF while using minimal fiber resources [RD01]. The eight 10 GbE data streams are wavelength-division-multiplexed onto one fiber at the AOS. This data is transmitted to the OSF where it is demultiplexed and routed to the appropriate recorder sub-system. The optical fiber link system (a pair of a transmitter and a receiver) is fully symmetric and the two devices are inter-changeable as they are totally in the same design. The device has no packet monitoring capability, so it is a passive participant in the VLBI phasing system.

The part of this subsystem that is installed at the AOS is called the Fiber Multiplexer. The part that is installed at the OSF is called the Fiber Demultiplexer. The Multiplexer and Demultiplexer are identical devices. Both can transmit and receive data. In the APP application, the Multiplexer will transmit to the Demultiplexer, but no transmission is planned in the other direction.

2.2 Specification details

The specifications for the Multiplexer and Demultiplexer are summarized as follows.

General points:
Power supply: AC 100 V / 230 V +/- 10%, 50/60 Hz
Power consumption: less than 150 W
Power supply redundancy: two redundant AC/DC converters
Operation temperature: +5 ~ 40 deg
Storage temperature: -20 ~ +60 deg
Cooling fans: 3 cooling fans with redundancy (2 are enough for cooling at the AOS)
Dimension: 5U of EIA 19-inch rack

Signal transmission:
Local port: nine of 10GBASE-SR ports with LC connector (transceiver type: XFP)
Remote port: one 10GBASE-ZR port with SC connector (transceiver type: XFP)
Mux and Demux: multiplexing/demultiplexing 18 channels for bi-directional transmission.

3 Basic Design

The design of optical fiber link system is fully symmetric and the Multiplexer and Demultiplexer are identical. Signal transmission between the two is by default bi-directional because of the use of 10GbE protocol, although in real operation the data stream is uni-directional from the AOS to the OSF. The Multiplexer (or Demultiplexer) has 9 local ports of 10GBASE-SR including one spare port, and convert signal received at local ports to 10GBASE-ZR and multiplex them so that all the nine streams can be sent through one single-mode optical fiber based on DWDM (Dense Wavelength Division Mupliplexing) technique. Schematic diagram of signal transmission is shown in figure 1. The Multiplexer is to be located at the AOS and Demultiplexer is to be located at the OSF. The connection is made via one single-mode fiber between AOS and OSF (approximately 30 km length) with DWDM at 1550 nm band. Block diagram of the Multiplexer/Demultiplexer is show in Figure 2. Each of nine media converter modules transforms between 10GBASE-SR and 10GBASE-ZR. Note that all the 18 streams in 10GBASE-ZR have different wavelengths defined in accordance with ITU Grids. The information on ITU Grids used in the OFL system is summarized in table 1.

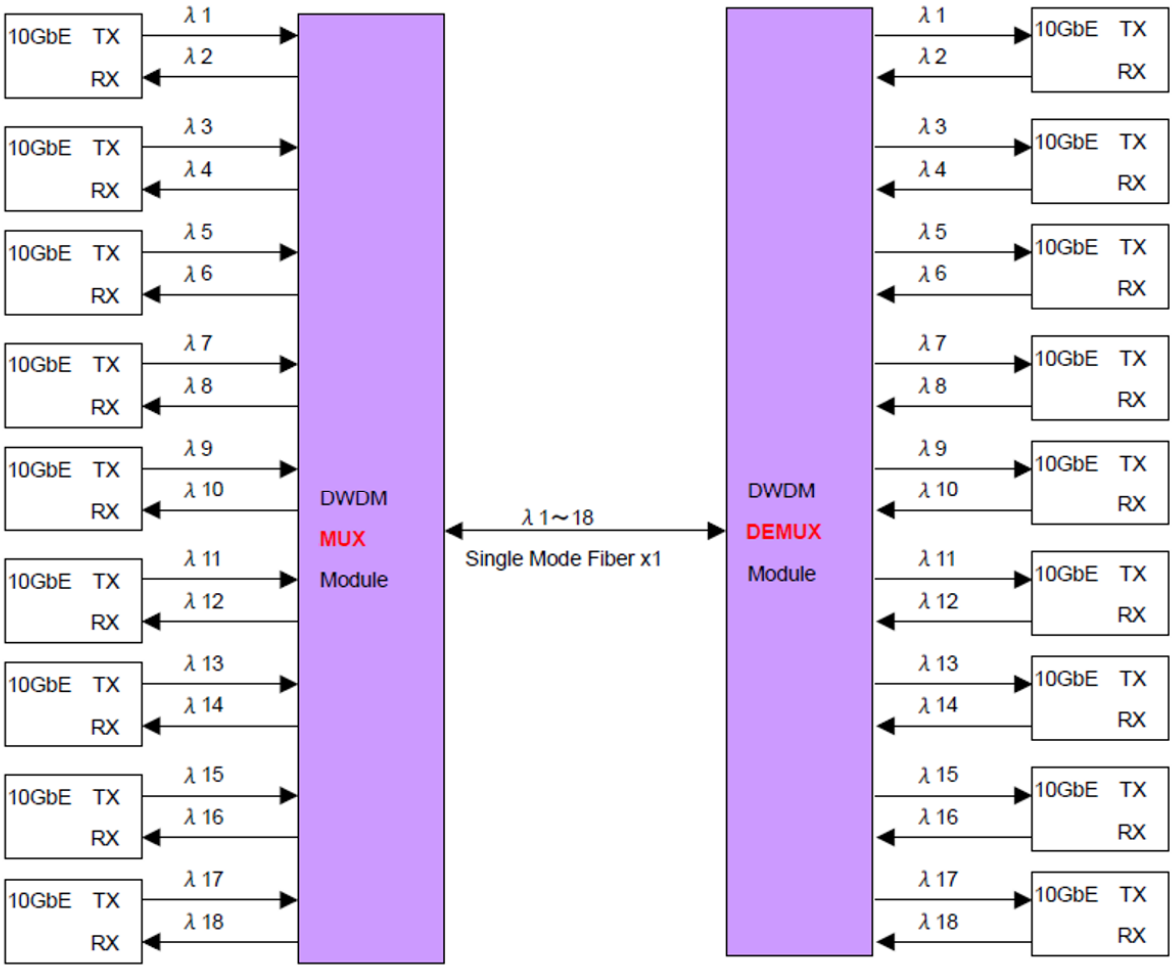

Figure 1: Schematic diagram showing the signal streams in the OFL system

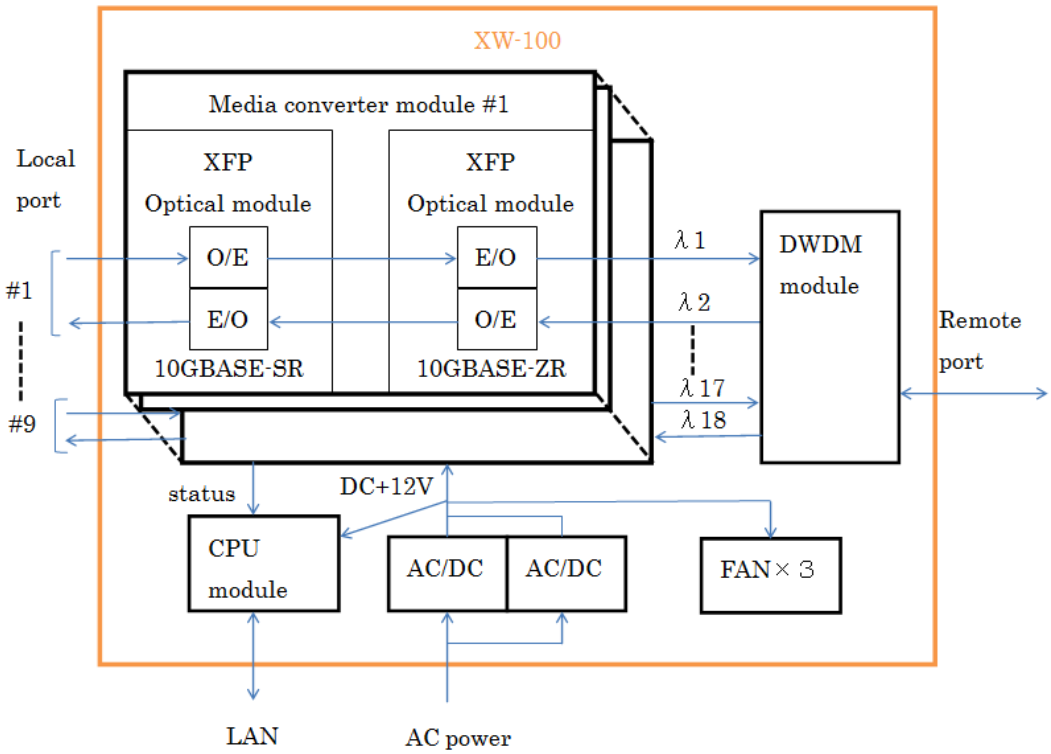

Figure 2: Block diagram of the Multiplexer/Demultiplexer

Front and panel designs are shown below. Nine slots on the front panel are to be attached with 10GBASE-SR XFP modules to constitute nine local ports including one spare port. The DWDM remote port is located at the bottom right corner of the front panel. On the rear panel, three cooling fans are attached. The power on-off switch is located at the bottom left corner on the rear.

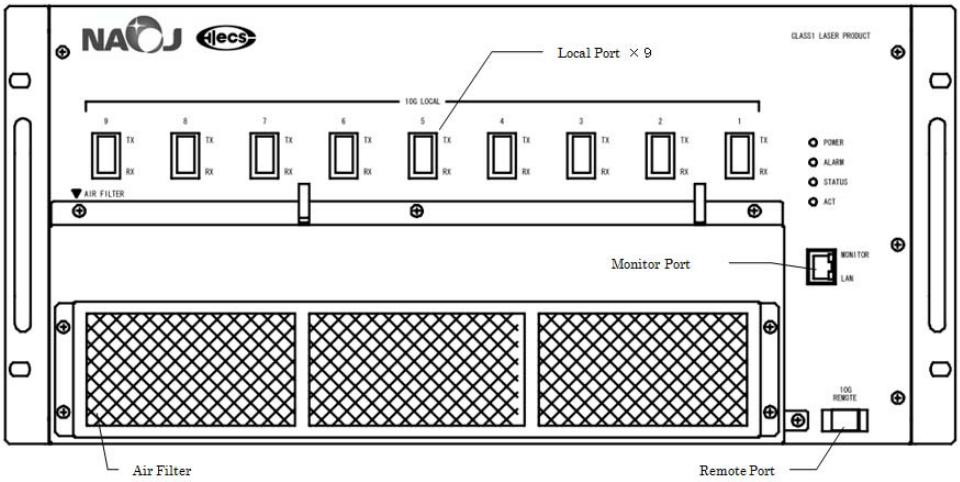

Figure 3: Front panel design

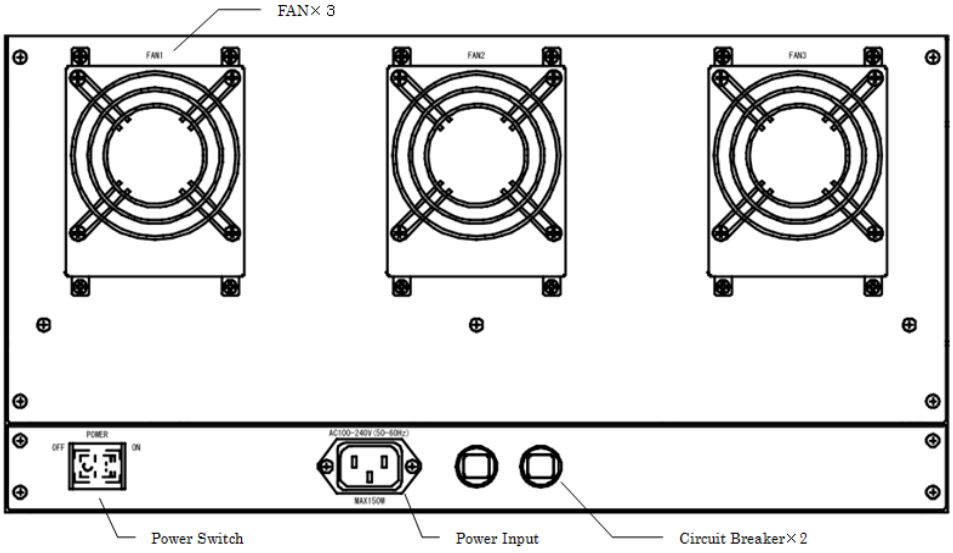

Figure 4: Rear panel design

4 Part details

Below are details of the parts to be used in the OFL system.

4.1 10GBASE-SR XFP transceiver

Model number: Sumitomo Elec. SXP3100SX

This module is attached to the local ports of the Multiplexer and Demultiplexer to optically link them with the correlator PIC cards and Mark6 recorders at 850 nm band. The number of this part required per the Multiplexer is nine, and all the 9 transceivers are identical to each other including operating wavelengths.

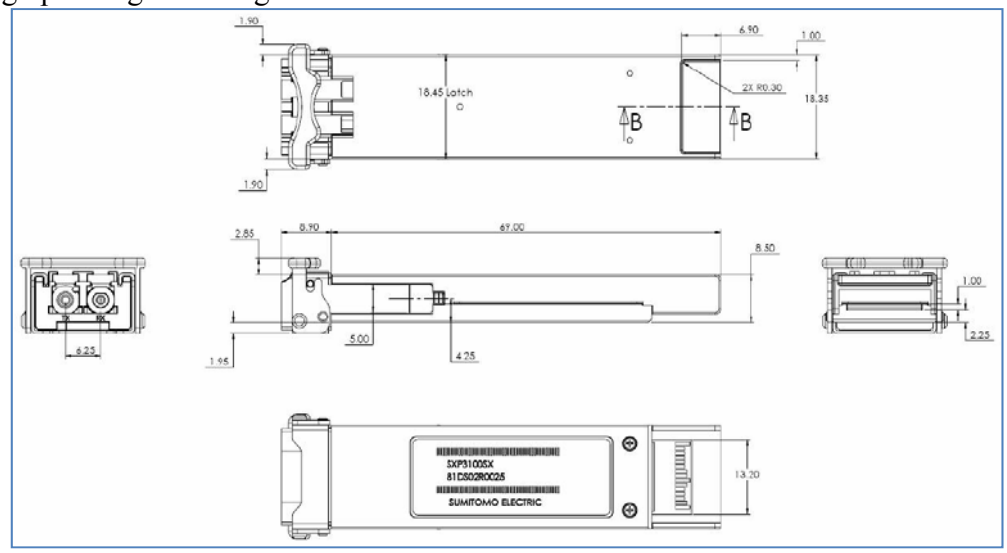

Figure 5: Part drawing for Sumitomo SXP3100SX

Figure 6: Picture of XFP transceiver

4.2 10GBASE-ZR XFP transceiver

Model number: Sumitomo Elec. SXP3102DA-Fxxx

This module is attached to the remote ports of the Multiplexer and Demultiplexer to optically send the DWDMed optical signal between AOS and OSF. The module just looks like the 10GBASE-SR XFP transceiver shown in figure 8 except the model number. The number of this part required per the Multiplexer is nine, and all the parts have their own operating wavelengths which are assigned according to the ITU Grid with 100 GHz spacing. The ITU grid table for all the nine ports are summarized below. Note that operating channels are alternately located with out-of-service channels in order to minimize possible interference between channels in operation.

Slot	ITU Grid 1550nm 帯	XW-100-M XW-100-D Direction
1	21	TX → RX
	23	RX ← TX
2	25	TX → RX
	27	RX ← TX
3	29	TX → RX
	31	RX ← TX
4	33	TX → RX
	35	RX ← TX
5	37	TX → RX
	39	RX ← TX
6	41	TX → RX
	43	RX ← TX
7	45	TX → RX
	47	RX ← TX
8	49	TX → RX
	51	RX ← TX
9	53	TX → RX
	55	RX ← TX

Table 1: The list of the ITU Grids used in the OFL system

Note that the appearance of the ZR XFP module is identical to that shown in figure 8.

Below is the table summarizing the frequency and wavelength of ITU Grids with 100 GHz spacing. For instance, the ITU Grid 21 (the one for the port #1 from MUX to DeMUX) has frequency of 192,100 GHz and wavelength of 1560.61 nm.

Channel	Frequency (GHz)	Wavelength (nm)	Channel	Frequency (GHz)	Wavelength (nm)
1	190,100	1577.03	38	193,800	1546.92
2	190,200	1576.20	39	193,900	1546.12
3	190,300	1575.37	40	194,000	1545.32
4	190,400	1574.54	41	194,100	1544.53
5	190,500	1573.71	42	194,200	1543.73
6	190,600	1572.89	43	194,300	1542.94
7	190,700	1572.06	44	194,400	1542.14
8	190,800	1571.24	45	194,500	1541.35
9	190,900	1570.42	46	194,600	1540.56
10	191,000	1569.59	47	194,700	1539.77
11	191,100	1568.77	48	194,800	1538.98
12	191,200	1567.95	49	194,900	1538.19
13	191,300	1567.13	50	195,000	1537.40
14	191,400	1566.31	51	195,100	1536.61
15	191,500	1565.50	52	195,200	1535.82
16	191,600	1564.68	53	195,300	1535.04
17	191,700	1563.86	54	195,400	1534.25
18	191,800	1563.05	55	195,500	1533.47
19	191,900	1562.23	56	195,600	1532.68
20	192,000	1561.42	57	195,700	1531.90
21	192,100	1560.61	58	195,800	1531.12
22	192,200	1559.79	59	195,900	1530.33
23	192,300	1558.98	60	196,000	1529.55
24	192,400	1558.17	61	196,100	1528.77
25	192,500	1557.36	62	196,200	1527.99
26	192,600	1556.55	63	196,300	1527.22
27	192,700	1555.75	64	196,400	1526.44
28	192,800	1554.94	65	196,500	1525.66
29	192,900	1554.13	66	196,600	1524.89
30	193,000	1553.33	67	196,700	1524.11
31	193,100	1552.52	68	196,800	1523.34
32	193,200	1551.72	69	196,900	1522.56
33	193,300	1550.92	70	197,000	1521.79
34	193,400	1550.12	71	197,100	1521.02
35	193,500	1549.32	72	197,200	1520.25
36	193,600	1548.51	73	197,300	1519.48
37	193,700	1547.72			

4.3 DWDM module

Model number: X-one Technologies Co. WDMM-M(D)-18-1-21-5-9-S
This module accepts nine inputs and nine outputs of 10GBASE-ZR optical signals and multiplexes them into one single channel for Multiplexer or vice versa for Demultiplexer. All the 18 input/output signals must be exactly tuned to the optical wavelengths defined in accordance with the ITU Grids listed in table 1.

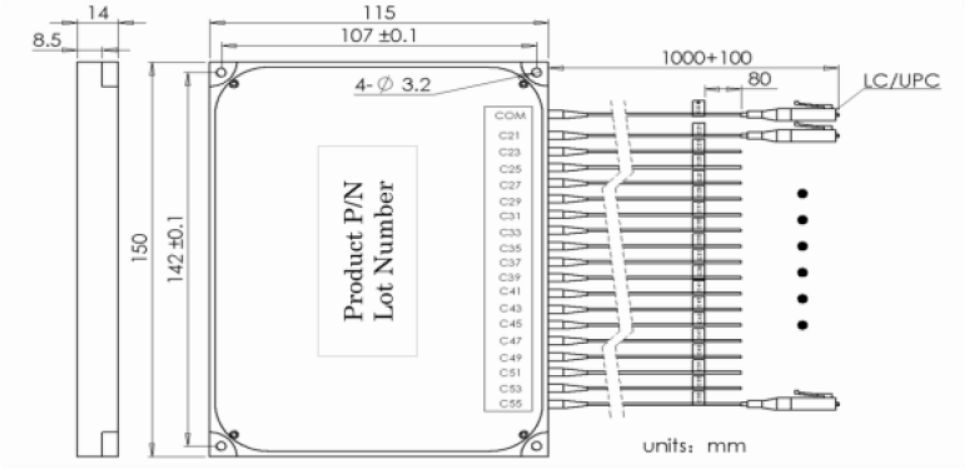

Figure 7: Drawing of DWDM module

4.4 Cooling fan

Model number: Sanyo Electric. San Ace 80, 109R0812G401(4011)
This fan has a typical rotation speed of 4,500 rpm and maximum air flow of 1.5 cubic meter per min. Two fans are required for cooling at the AOS, and both Multiplexer and Demultiplexer have three fans for redundancy.

Figure 8: Picture of cooling fan San Ace 80

4.5 Power supply

Model number: Cosel PBA150F-12
This power supply provides electricity for the OFL system with maximum power of 150 W. Typical power required for regular operation of Multiplexer and Demultiplexer is around 68 W. The input is AC 100 - 250 V and the output is DC 12V. Both of Multiplexer and Demultiplexer have two power supplies for redundancy.

5 Part Reliability

Following is a list of components per one TX or RX. For the whole OFL system (TX at AOC and RX at OSF), all the numbers should be doubled. Number of spare parts will be fixed after detailed operation plan of ALMA phase-up mode is determined.

Item	Model number	#	FIT (MTBF)	System Redundancy	Needed spares on shelf
10GB-ZR opt module	Sumitomo Elec. SXP3102DA-Fxxx	9	9.0 (12700 yr)	Eight for full operation. One is for spare.	0
10GB-SR opt module	Sumitomo Elec. SXP3100SX	9	7.1 (16080 yr)	Eight for full operation. One is for spare.	0
DWDM module	X-one technologies DWDMM-x-18-1-21-5-9-s	1	85 (1343 yr)	No redundancy	0
Cooling fan	Sanyo denki 109R0812G401	3	25,000 (4.6 yr)	Two fans are minimum for cooling at high site.	17 (TBD) (3*30/4.6 - 3)
AC/DC power supply	Cosel PBA10F	2	2,506 (46 yr)	One is in use and the other for backup.	1 (TBD)

Note on FIT (Failures In Time) and MBTF (Mean Time Between Failure)

FIT means a failure rate per 10^9 hours operation.

MBTF: 1/FIT * 10^9 / (365 * 24) year

6 Interfaces

6.1 Multiplexer

Physical location: AOS, Correlator Room, Communications Rack

Rack space requirments:

8U of 19" rack mounted. (The equipment is only 5U, but additional space is required for cooling at the AOS.)

Power requirement:

100/230 V, 50/60 Hz. Interface point is an AC connector on the power strip in the communications rack.

Cable tray space:

- Eight multi-mode optical fibers are required from the PICs in the correlator to the fiber mux in the Communications Rack in the Correlator Room. These fibers will be supplied by the Phasing Project.
- One single-mode optical fiber is required from the AOS Correlator Communications Rack to the AOS Computing Room Fiber Rack. The fiber (approximately 30 meters in length) will be supplied by the Phasing Project. The interface point is the type SC connector in the Computing Room Fiber Rack which completes the connection to the Fiber Demux at the OSF.

Cooling: Air intake from front of chassis; air exhaust from rear of chassis.

Connection to Ethernet required: 10BASE-T / 100BASE-TX with telnet / VSI-S protocol.

6.2 Demultiplexer

Physical location: OSF, Archive Room

Rack space requirments:

5U of 19" rack mounted.

Power requirement:

120 or 230 V, 50/60 Hz. Interface point is a connector located in the power strip in the rack where the Fiber Demultiplexer will be mounted

Cable tray space:

- One single-mode optical fiber from the rack in which the fibers from the AOS terminate. The interface point is SC connector in the patch panel that completes the connection to the Fiber Mux at the AOS.
- Eight multi-mode optical fibers from the fiber demux to the recorders at the OSF in the Server Room. These fibers will be supplied by the Phasing Project.

Cooling: Air intake from front of chassis; air exhaust from rear of chassis.

Connection to Ethernet required: 10BASE-T / 100BASE-TX with telnet / VSI-S protocol.