Atacama
Large
Millimeter
Array

APP Optical Fiber Link
Installation and Test report

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1 Introduction

1.1 Purpose

This document reports the installation and on-site test 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 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 at 1550-nm band are wavelength-division-multiplexed onto one fiber at the AOS. The data are transmitted to the OSF where they are 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. Each OFL has nine ports for redundancy. The device has no packet monitoring capability, and 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.

Basic design of the OFL system is summarized in the OFL design report [xxx].

2.2 Brief history before the site installation

The two sets of the OFL system was fabricated by Elecs Engineering in 2012, and handed over to NAOJ in April 2013. Tests of their performance was conducted at NAOJ Mitaka campus. Using 10GbE analyzer, it was confirmed that data transfer between MUX and DeMUX can be successfully done at a rate of 8 x 10 Gbps.

After the test at NAOJ, the OFL system was sent to MIT and then to NRAO, where integration test was done with the control software and Mark6 recorders. After the tests in US, the OFL system was shipped to Chile in May 2014.

3 On-site check

On-site check and installation were done in June 2014, with additional works done till October 2014.

Prior to the site installation, the basic functions of OFLs were confirmed at the Correlator lab at OSF in order to make sure that the system was not damaged by shipping. The on-site check included following items and all were passed without any major problem.

a) Visual inspection of chassis
b) Power on, fan motion and turn-on of LEDs on board
c) Network connection via telnet, and reading status
d) Link establishment between the Multiplexer and De-Multiplexer (both boxes at the lab)
e) Data transmission between the Multiplexer and De-Multiplexer (both boxes at the lab)

After confirming these, we proceeded to the site installation.

4 Site installation

The site installation of the two OLFs was conducted in June 2014. Those who participated in the installation were: Mareki Honma, Kazunori Akiyama, Hikaru Chida (NAOJ), Alejandro Saez, Enrique Garcia, Juan Carlos Gatica (JAO), Jay Blanchard (Univ. Conception). Remote support (network connection and test with recorders) was provided by Geoff Crew (Haystack).

4.1 Multiplexer installation

The Multiplexer was installed in the APP rack in the correlator room at AOS (figure 1). The local-ports (10G BASE-SR) were left open at the time of initial installation, and later connected to the correlator PIC cards through the multi-mode fiber cables. The remote port is connected to the B1 port of the patch panel located at AOS. For this connection, a 30-m-long single-mode fiber was laid in the overhead cable rack. The LAN port was connected to the local network, and the IP address was set to 10.197.49.51.

Figure 1 OFL MUX installed onto the in the correlator room at the AOS.

4.2 De-multiplexer installation

The De-multiplexer is first tentatively installed in the recorder rack in the Correlator lab at OSF, and in late June it was re-installed to the APP rack in the computation room at OSF for the permanent installation (figure 2). The four local-ports (10G BASE-SR) were connected to the Mark6 recorders available in June 2014, with other remaining ports to be connected with the additional two Mark6 recorders to be delivered to the OSF. The remote port was connected to the counterpart port of the patch panel so that the remote ports of both MUX and DeMUX are connected to the same long-distance fiber. The LAN port was connected to the local network, and the IP address was set to 10.197.52.56.

After completion of the installation of the MUX and DeMUX, we confirmed that the link between AOS and OSF were successfully established as the green light for "link" on the front panel of the DeMUX goes on.

Figure 2 OFL DeMUX and Mark 6 recorders installed in the computer room at the OSF.

5 Onsite tests

5.1 Optical power measurement at each 10GbE-ZR port

Optical power at each 10GbE-ZR port (both at AOS and OSF) was measured to check if the OFL system send and receive the optical signal properly. Output power was around 2 dBm for every channel, which is within the expected range between -1 dBm and 4 dBm. Received power is lower with larger scatter due to the loss in the long-distance fiber and scatter in the MUX and DeMUX module (i.e., variation of loss in each channel), but all are well beyond the minimum receiver sensitivity of -25 dBm.

Optical power measured at TX and RX ports of 10GbE-ZR channels (MUX at AOS)

MUX@OSF	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8	CH 9
TX	1.8	1.9	1.8	1.8	1.9	1.6	1.9	1.7	1.8
RX	-16.3	-13.4	-15.0	-12.9	-9.5	-15.8	-14.3	-14.1	-13.1

Optical power measured at TX and RX ports of 10GbE-ZR modules (DeMUX at OSF)

DeMUX@OSF	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8	CH 9
TX	1.6	1.8	2.1	2.1	2.1	2.0	2.0	1.2	0.9
RX	-14.2	-11.9	-14.0	-12.9	-9.6	-8.7	-14.4	-12.8	-11.3

All the values are in dBm.

5.2 Optical-spectrum at the DeMUX input port

Optical spectrum received at the DeMUX at the OSF was inspected by the optical spectrum analyzer. The spectrum was taken at the DeMUX input port of the long-distance fiber signal (before splitting the DWDMed data into the 9 channels, see figure 3). The received spectrum shows that the typical power for each channel is around -10 dBm, and they satisfy the required power range of -8 to -20 dBm. Also the 9-channel signals are well above the noise floor, and clearly separated between the channels. Therefore, no contamination/interference between the optical channels is expected.

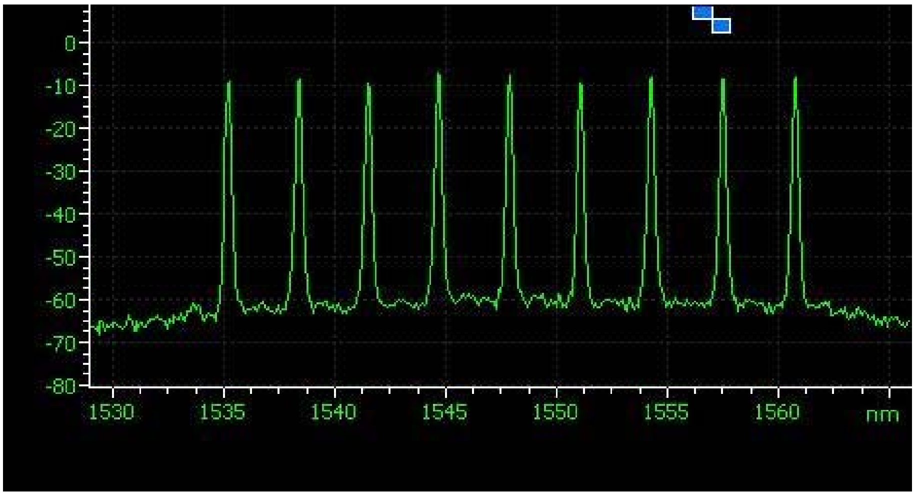

Figure 3 Optical power received at OFL DeMUX remote port (input of DWDMed signal)

5.3 Optical power stability

Optical power stability was also monitored for ~3000 seconds for each channel (note that the power meter and connectors were different from those used in the measurements shown in table 1, resulting in slightly different power results). Channels 4 and 9 show some jitter in optical power with a peak-to-peak amplitude less than 1dB. Although this is in acceptable range of the optical power, we need to keep monitoring and find out possible cause of this. The rest of the channels were found to be stable within 0.1 dB.

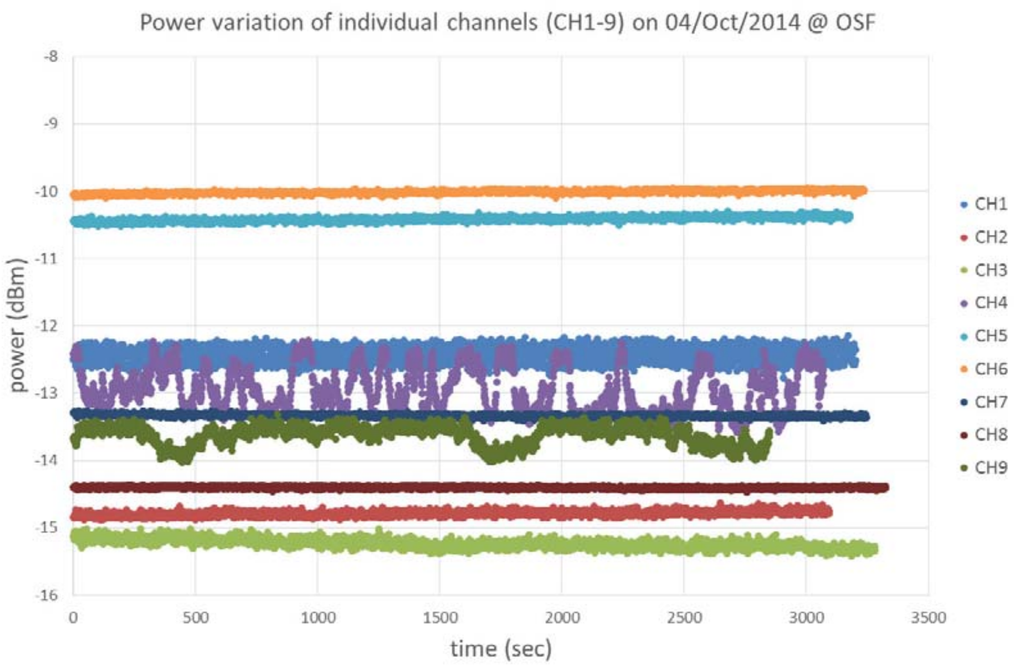

Figure 4 Stability of Optical power received at OFL DeMUX for ~3000 sec

5.4 Long-term monitoring of total power

To test the long-term power stability, total power of 9 channels received with DeMUX was monitored for ~10 hours. Data were recorded every second. The result shows that the power was stable for ~10 hours without any jump (for instance, if one channel were missed, there should have been a jump of ~1 dB). The result indicates that all the 9 channels were stable for the period.

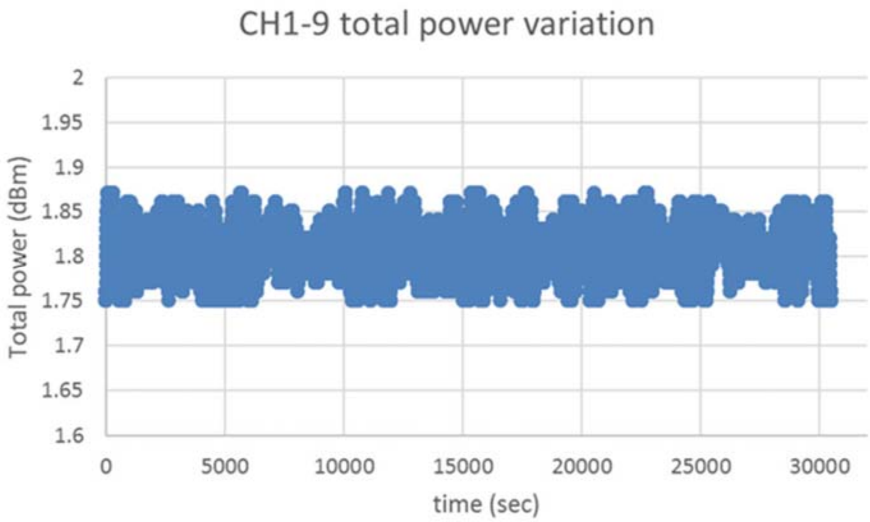

Figure 5 Long-term stability of total power received at OFL DeMUX (CH 1 to 9)

Considering all the results presented above (power level and its stability, spectrum and SNR), we judge that the Optical Fiber Link System should be working properly both at the OSF and AOS.

5.5 Packet counting and data transmission test

During the phase-up software test in October 2014, data transfer tests were done by combining correlator PICs, OFLs and Mark 6 recorders.

Test packets were sent from the correlator PICs via OFLs and being counted by the NICs of Mark 6.The log of the packet counting attached below. Packet creation rate is 125000 packets/sec, and the received packed by Mark6 NICs matches with this at a level of 10^-6.

```
oper@Mark6-4005:~/test$ head -3 out-oct-mission-4005/byte-rate-Oct21.txt
#unix-time     dt    eth3       eth5
1413899099.073 0.003 2227414796 2227483440
1413899100.076 0.003 2227540212 2227608849

oper@Mark6-4005:~/test$ tail -3 !$ tail -3 out-oct-mission-4005/byte-rate-
Oct21.txt
1413906127.022 0.003 3105909235 3105977842
1413906128.025 0.003 3106034635 3106103264
1413906129.028 0.003 3106160080 3106228689

gbclapdog:hopswork gbc$ bc -lq
( 3106160080 - 2227414796 ) / ( 1413906129.028 - 1413899099.073 )
125000.12930381488928449755
( 3106228689 - 2227483440 ) / (1413906129.028 - 1413899099.073 )
125000.12432512014657277322

oper@Mark6-4006:~/test$ head -3 out-oct-mission-4006/byte-rate-Oct21.txt
#unix-time     dt    eth3       eth5
1413899113.410 0.003 2225140961 2225215433
1413899114.414 0.003 2225266475 2225340936

oper@Mark6-4006:~/test$ tail -3 out-oct-mission-4006/byte-rate-Oct21.txt
1413906127.173 0.003 3101862259 3101936698
1413906128.177 0.003 3101987715 3102062152
1413906129.180 0.002 3102113161 3102187591

gbclapdog:hopswork gbc$ bc -lq
( 3102113161 - 2225140961 ) / ( 1413906129.180 - 1413899113.410 )
125000.13540922806762479385
( 3102187591 - 2225215433 ) / ( 1413906129.180 - 1413899113.410 )
125000.12942271482674032928
```

```
oper@Mark6-4007:~/test$ head -3 out-oct-mission-4007/byte-rate-Oct21.txt
#unix-time     dt    eth3       eth5
1413899138.000 0.003 2225284160 2225343377
1413899139.004 0.003 2225409672 2225468899 ...
1413902221.374 0.002 2610705912 2610765102
1413902222.376 0.002 2610831247 2610890442
(reset)
1413902307.611 0.002 2611216165 2611274894
1413902308.615 0.002 2611341610 2611400344 ...
1413906127.492 0.003 3088701543 3088760277
1413906128.495 0.003 3088826990 3088885771
1413906129.499 0.003 3088952502 3089011234

gbclapdog:hopswork gbc$ bc -lq
( 2610831247 - 2225284160 ) / ( 1413902222.376 - 1413899138.000 )
125000.02820667778506900585
( 2610890442 - 2225343377 ) / ( 1413902222.376 - 1413899138.000 )
125000.02107395466700557908
( 3088952502 - 2611216165 ) / ( 1413906129.499 - 1413902307.611 )
125000.08817631495219116834
( 3089011234 - 2611274894 ) / ( 1413906129.499 - 1413902307.611 )
125000.08896126731081601553

oper@Mark6-4008:~/test$ head -3 out-oct-mission-4008/byte-rate-Oct21.txt
#unix-time     dt    eth3       eth5
1413899126.546 0.003 2216593486 2216532805
1413899127.549 0.003 2216718925 2216658224

oper@Mark6-4008:~/test$ tail -3 !$ tail -3 out-oct-mission-4008/byte-rate-
Oct21.txt
1413906128.118 0.003 3091790304 3091729602
1413906129.121 0.002 3091915695 3091854976
1413906130.124 0.002 3092041137 3091980419

( 3092041137 - 2216593486 ) / ( 1413906130.124 - 1413899126.546 )
125000.05725644806126240044
( 3091980419 - 2216532805 ) / ( 1413906130.124 - 1413899126.546 )
125000.05197343415037285227
```

Also data transmission was done during the session in October 2015, and a preliminary analysis shows that the packet missing rate is around 10^-5 to 10^-6.

6 Known issues

While the data transmission can be readily done at an acceptable level of packet loss and/or error rates, the OFL system quite frequently issues “operation fault” alarm at some channels, which indicates that the link between AOS and OSF is occasionally lost. The duration of such link loss is not clear at this moment, but judging from the 1-sec stability of the power shown in figures 4 and 5, and also from the small packet loss rate, the connection losses are likely to occur at a time scale much shorter than 1 sec. At this moment it is not clear whether the connection loss is caused by internally (problem in OFLs) or externally (environmental effect such as power instability or any stress on optical fiber), and this should be investigated further in depth.