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OPTICAL POWER MONITORING SCHEME FOR UPGRADED BROADBAND FIBER OPTICS SYSTEM

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Introduction:

The GMRT receiver system is being upgraded to achieve seamless coverage from 50 to 1600 MHz. The upgraded broadband analog fiber optic link to bring in the RF signals directly from the frontend system to central electronics building without down converting it to IF signals. With the new advancement in DWDM technologies, we could combine signals from four LASER transmitters operating at different wavelength on to one single mode fiber using optical multiplexer at antenna base and it is separated into individual channels using optical de-multiplexer at central electronics building. Two optical transmitters are used to carry two polarizations of frontend signal and the third one is used for supporting the existing GMRT fiber optic system to carry the two IF signals, return LO and telemetry signals. The block diagram below explains the detail channel allocation in DWDM multiplexed system.

The forward link between CEB and antenna operates at 1310 nm and it is travelling in the opposite direction to the DWDM link from antenna to the central electronics building. This is done using bi-directional communication scheme by using WDM couplers with DWDM optical multiplexed system. The new upgraded system co-exists with the old fiber optic system of GMRT on one single fiber.

A variable attenuator is placed in the RF gain block unit which is the interface unit between the frontend and optical fiber system. The attenuator is adjusted to ensure linear operation of the new broadband analog fiber optic like at all RF bands. The total power received from the frontend system vary with frequency band and to provide constant input power to the fiber optic system a variable attenuator is included in the RF gain block unit. The RF PIU at remote antenna base has two independent receiver chain carrying both the polarizations from frontend system. The signal from RF PIU is fed to laser transmitter which converts RF signal into optical signal and the optical signal is multiplexed and transmitted on to the single mode fiber from antenna base to CEB.

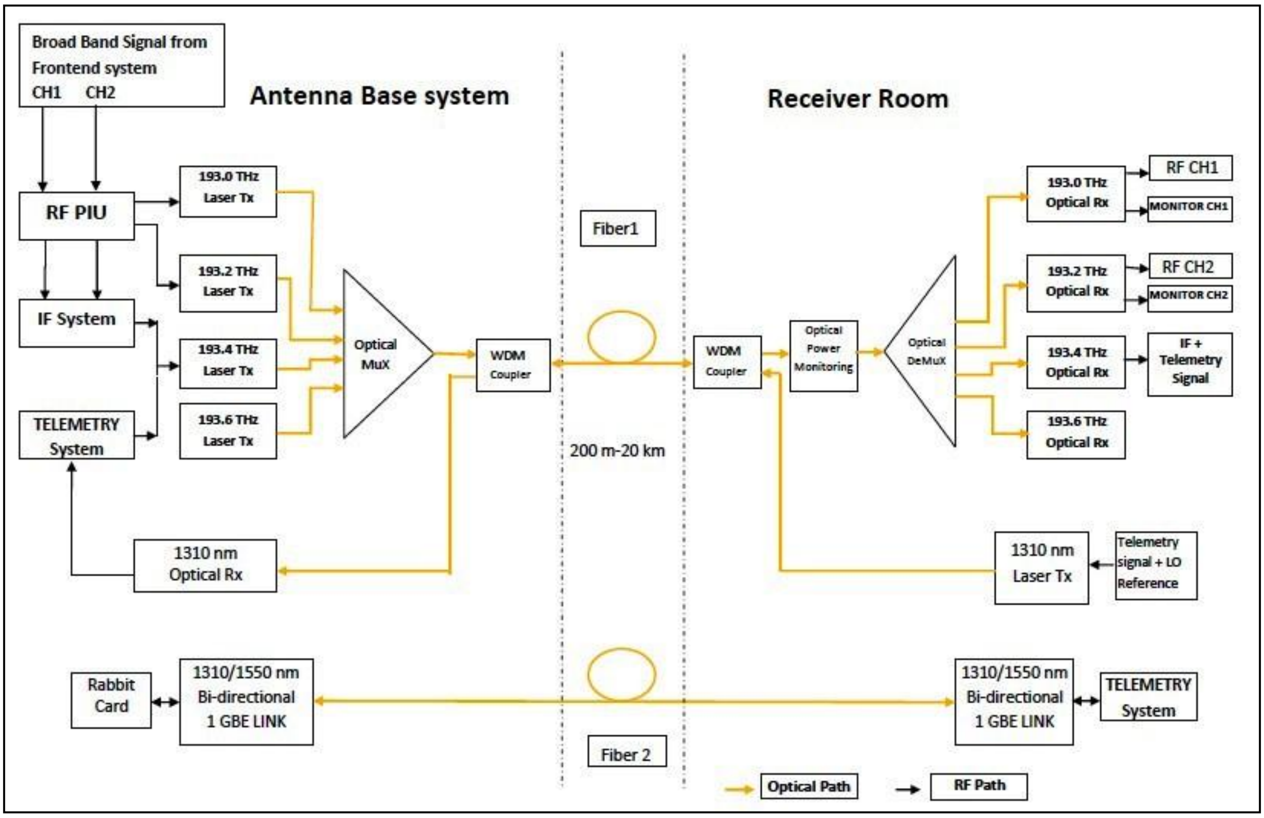

Figure 1. Upgraded DWDM based fiber optics system

Optical Power Monitoring System:-

Power monitors measure the optical power carried by an optical fiber. Unlike power meters, which are terminal devices (i.e. light enters but does not exit), Power Monitors are "in-line" devices, allowing the majority of optical power to pass through to a fiber output. Since the light passes through, Power Monitors can be placed in-line to measure optical power while a fiber optic system is operating. A Power Monitor should ideally have negligible impact on the fiber optic system being monitored, while providing reliable and accurate power measurement over time. Power Monitors are typically used for feedback and control applications, or for dynamic testing of live systems. Here we are using for continuously monitoring power level of the optical fiber system.

This system mainly consist these four parts following:

a) In-line power monitor
b) LabJack card
c) Data acquisition card
d) Monitor Screen

Figure 2. Optical Fibre system in receiver room

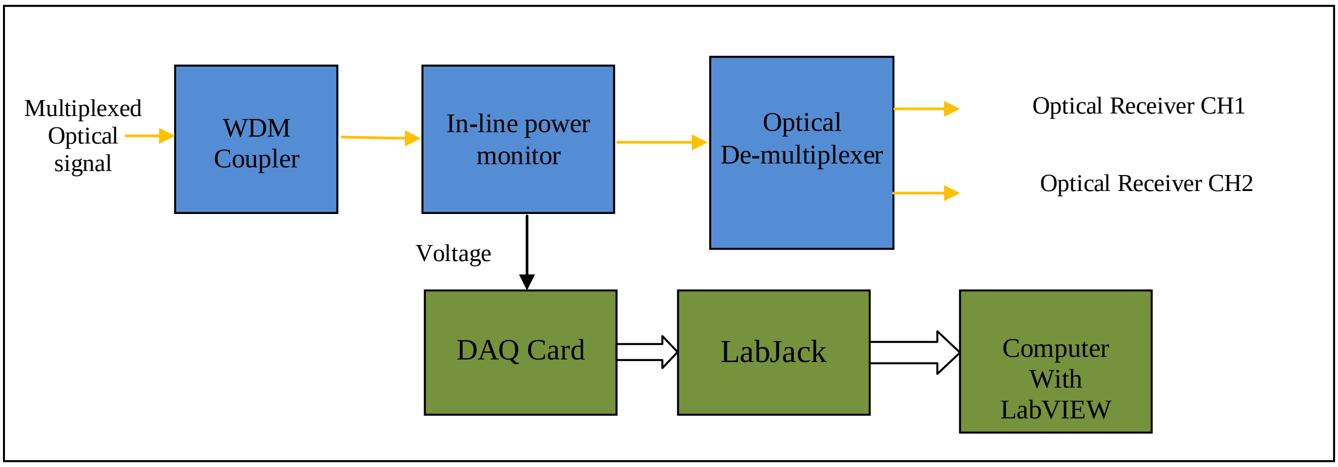

Figure 3. Block diagram of optical power monitoring system

In-line power monitor:-

In-line Power Monitors include at least two elements:

1. An optical tap for extracting a small amount of light from the fiber core.
2. A photo detector for converting the light tapped out of the fiber core into an electrical current.

Power monitoring in light wave systems was done using a discrete fused fiber optic tap in which the tapped optical power was carried by separate optical fiber to a discrete optical detector. In this approach, both the fused-fiber tap and detector were separately packaged devices. Now optical tap and detector are integrated into a single package.

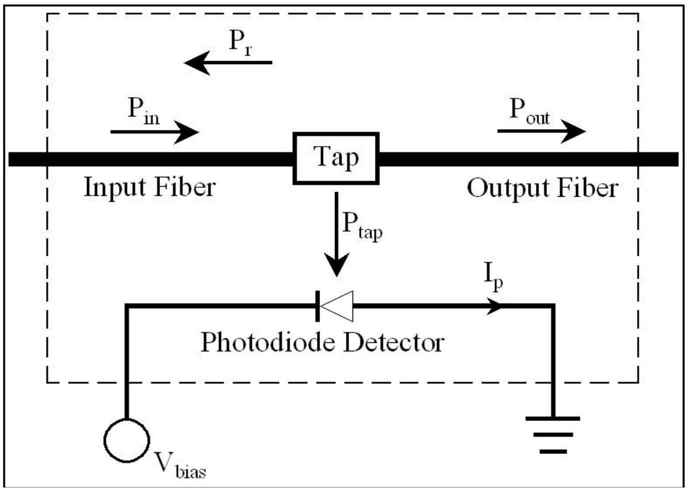

Figure 4. Functional diagram of In-line Power monitor

A variety of technologies like In-fiber tap, lens based design are used to integrate optical taps and detectors for power monitor applications. In-fiber tap, light is scattered out of the fiber core onto the surface of a detector.

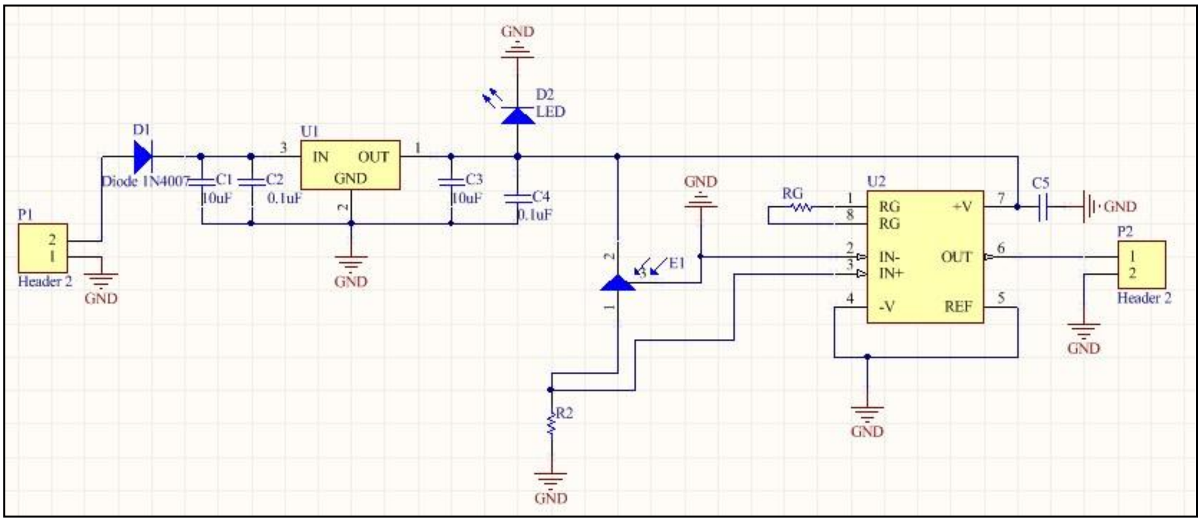

Figure 6. Schematic diagram of optical power detector circuit

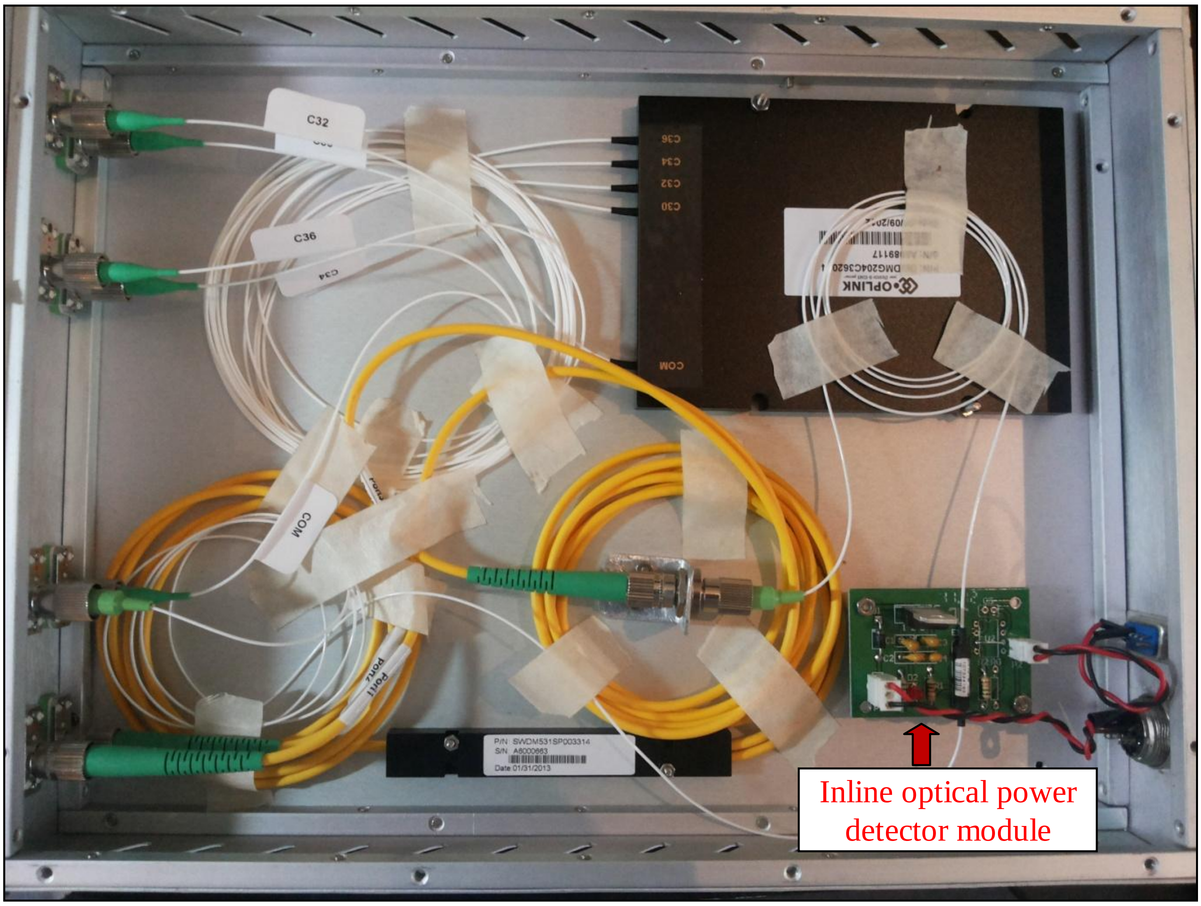

Figure 7. Optical De-Multiplexer with optical power detector unit

Methods for scattering light out of the fiber include:

1. Laser induced index changes in the core.
2. Micro bending of the fiber.
3. Laser induced ablation of the fiber cladding to create a reflecting surface.
4. Removal of fiber cladding to produce evanescent coupling of light out of the core.
5. A lens and partial reflector that reflect majority of power back and partially transmitted, is used in lens based design.

Power tapped from the optical fiber needs to be converted into electrical signal so that it can be processed and data that is carried can extracted. The component that is used for this purpose is Photodiode. A photodiode is a p-n junction or PIN structure. When a photon of sufficient energy strikes the diode, it excites an electron, thereby creating a free electron (and a positively charged electron hole).

In our Optical monitoring system, we are using SR101B-1-15 In-line optical power monitor. The Tap Power Monitor's small, hermetic package houses a stable optical tap and PIN photodiode. This provides exceptional performance, including the lowest insertion losses among competing technology, virtually no back-reflection, and directionality to >30 dB.

Specification of SR101B-1-15 Optical monitor:

Parameter	**Unit**
Wavelength	1280-1580nm
Responsivity	25-50mA/W
Insertion loss	<0.4dB
Return loss	>70dB
Polarization dependence loss	<0.01dB
Polarization stability	<0.15dB
Directivity	>30dB
Max. optical power	+16dBm
Fiber type	SMF28e
Dark current @-5V, 23 degree Celsius	<1nA
3 dB bandwidth @ -5V	200MHz
Capacitance	<10pF
Max. Forward Current	10mA
Max. Reverse Current	5mA
Max. Reverse voltage	10V

DAQ and LabJack card :-

LabJack card are USB/Ethernet based measurement and automation devices which provide analog inputs/outputs, digital inputs/outputs, and more. It is a multipurpose card which having 16 analog I/P channel, 23 Digital I/O channels and 2 DAC ports. Communication to LabJack card can be done by USB and Ethernet. The main function of LabJack card is to read the output of sensors which measure voltage, current, power, temperature, humidity and many more. A LabJack brings this data into a PC where it can be stored and processed as desired. In our application it read the output voltage of photodiode detector through the DAQ card. Here we are using UE9 PRO LabJack card.

DAQ(Data acquisition) card is control and monitoring card which is design to enhance the capability of LabJack unit. The 14 user accessible analog I/P i.e. Analog channel are increased to112channels by using 8 channel analog multiplexer. The bit selection of multiplexer are controlled by 3 digital bit (MIO0-MIO2). Out of 112 analog channels, 16 channels are having instrumentation amplifier at its input to acquired the weak signal and 16 channels are having Op-amp to acquire the differential voltage.

The remaining Digital I/O channels are used to control the filter selection bits in receiver to continuously monitor the broad band RF signals.

Analog Inputs:

The LabJack UE9 has 14 external analog inputs (AIN0-AIN13). AIN0-AIN3 are available on screw terminals and also on the DB37 connector. All 14 analog inputs are available on the DB37 connector.

Each analog input can be configured individually as unipolar (four ranges from 0-5 volts to 0-0.625 volts) or bipolar (±5 volts). Analog input resolution is 12-bits at max speed (12 us conversion time), increasing up to 16-bits at slower speeds (2.7 ms conversion time).

Command/response (software timed) analog input reads typically take 1.5+ ms depending on number of channels and communication configuration. Hardware timed input streaming has a maximum rate that varies with resolution from 250 samples/s at 16-bits to 50+ K samples/s at 12-bits.

Analog Outputs:

The LabJack UE9 has 2 analog outputs (DAC0 and DAC1) that are available both on screw terminals and the DB37 connector. Each analog output can be set to a voltage between 0 and 4.9 volts with 12-bits of resolution. The analog outputs are based on a true voltage reference. The analog outputs are updated in command/response mode, with a typical update time of 1.5-4.0 ms depending on communication configuration.

Digital I/O:

The LabJack UE9 has 23 digital I/O channels which can be individually configured as input, output-high, or output-low. 8 of these lines are called flexible digital I/O (FIO) and can be software configured as up to 6 timers and 2 counters.

The first 4 FIO are available on screw terminals and the DB37 connector. All 8 FIO and 3 MIO are available on the DB37 connector, and 8 EIO and 4 CIO are available on the DB15 connector. Command/response (software timed) reads/writes typically take 1.5-4.0 ms depending on communication configuration. The digital inputs can also be read in a hardware timed input stream where up to 16 inputs count as a single stream channel.

Photo detector based optical power monitoring system:

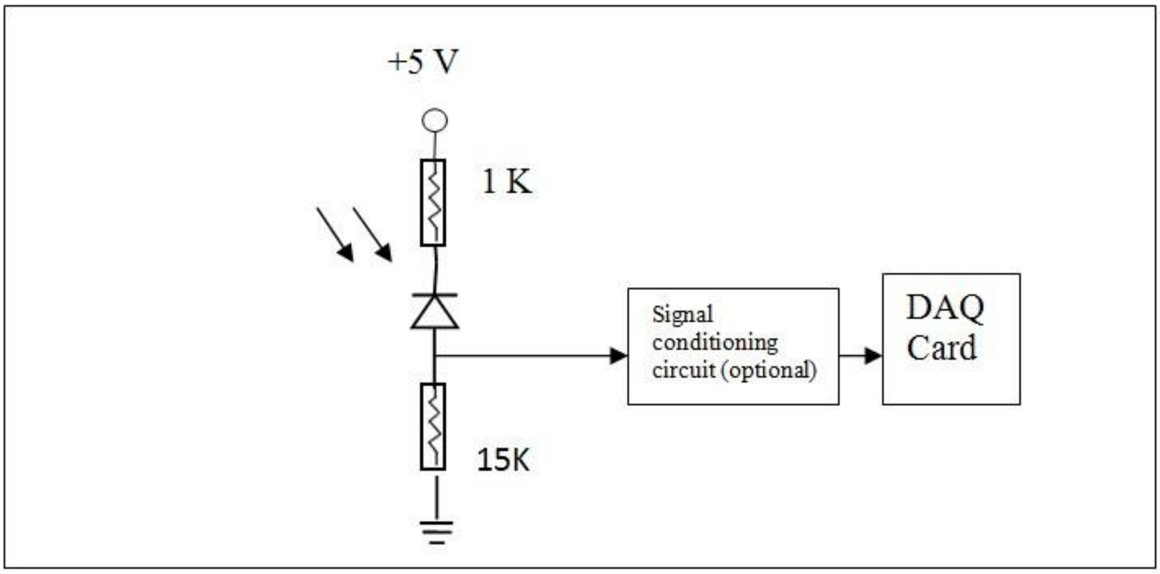

Figure 5. Photodiode detector circuit diagram

Above figure shows the photo detector circuit diagram. The photodiode having high responsivity is used in reverse bias condition, to enhance its response characteristics. Signal conditioning circuit is optional that we not used in our monitoring circuit.

Responsivity of monitoring photodiode=26.66 mA/watt.
So current produce due to 0dBm optical power i.e. 1mW of optical power

I=(26.66 mA/W)*1mW
=26.66 µA.

The Voltage drop across 15K Ohm resistor
$=26.66*10^{-6}*15*10^{3}$
=0.399 Volts.

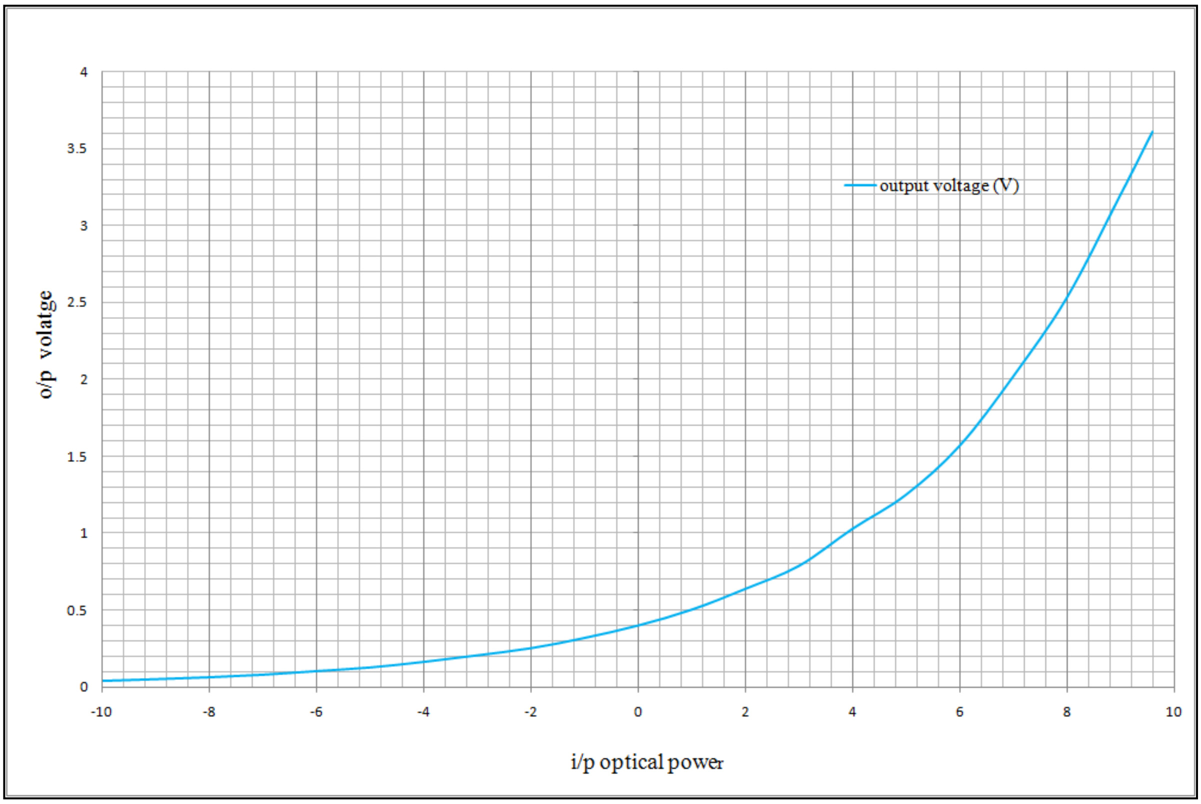

Figure 8. Photo diode characteristics plot for optical power monitor

Above plot shows the response of photodiode detector that we have used in optical power monitoring system. In this measurement we have vary optical power from -10 to 10 dBm and corresponding voltage is measured.

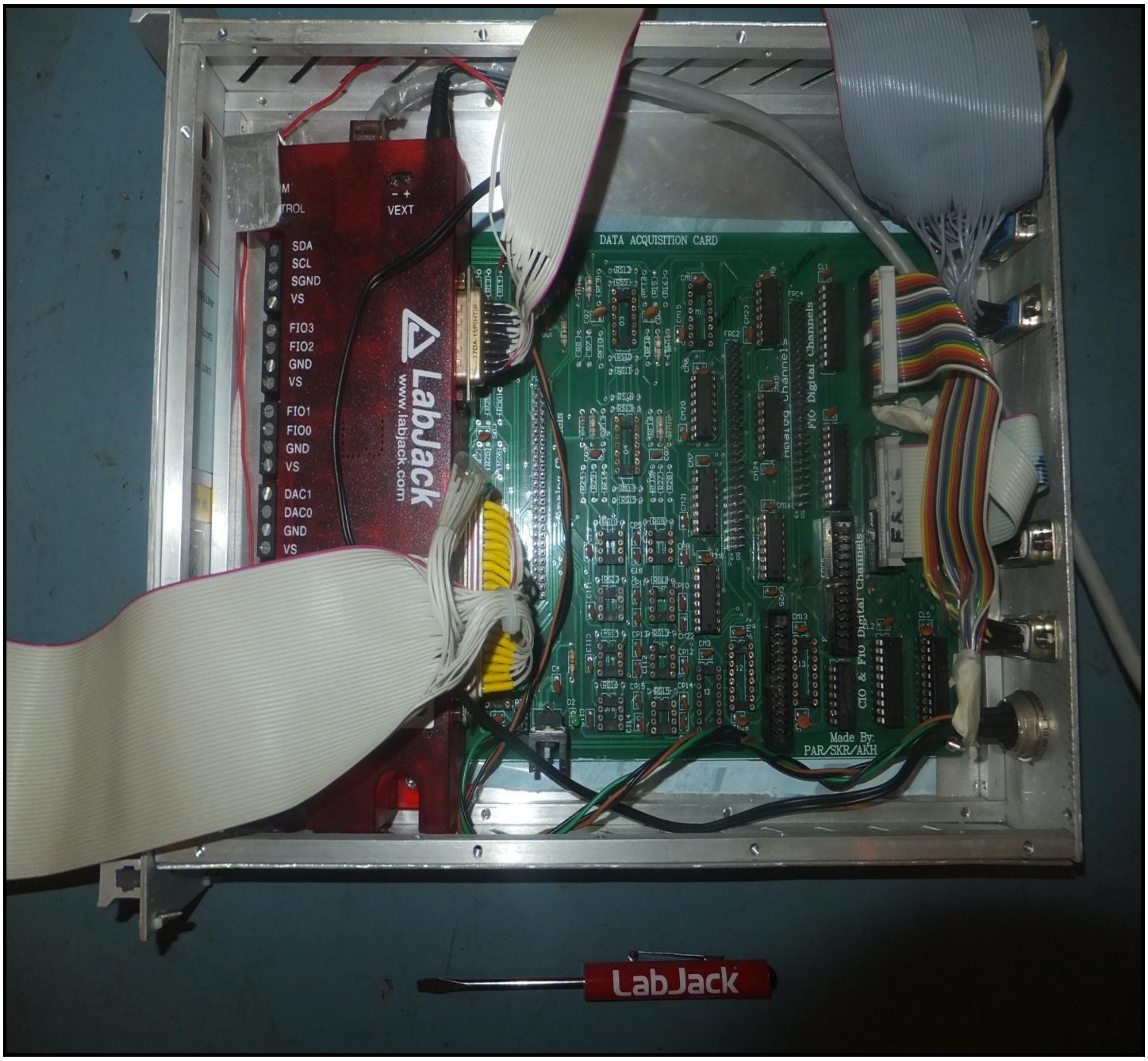

Figure 9. LabJack and DAQ card

This LabJack card is interfaced with computer system through LABVIEW program which will record corresponding voltage for optical power continuously.

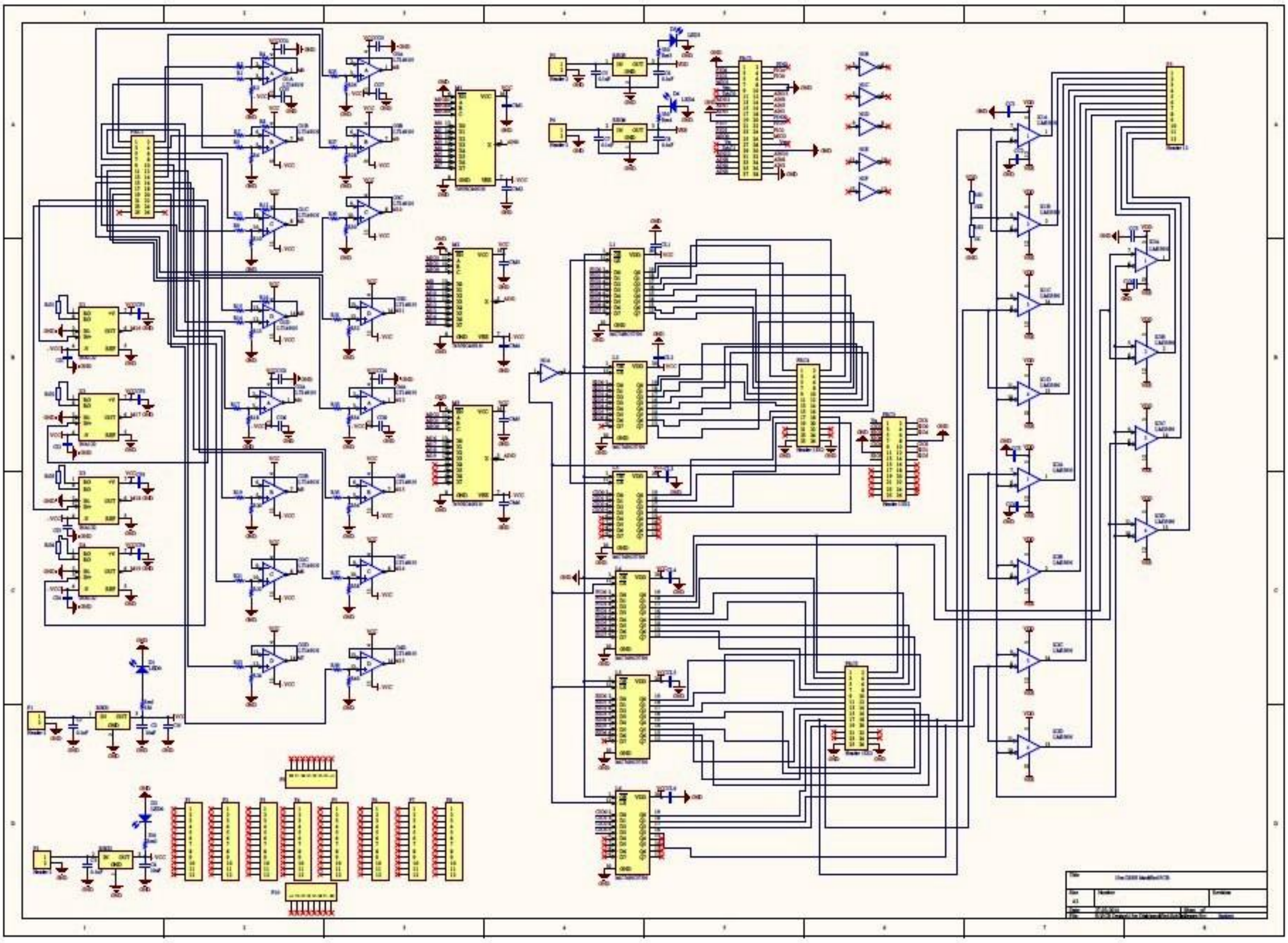

Figure 09. Schematics for DAQ PCB

This is the DAQ card which will interface with LabJack card to increase its analog channel. We have used 8:1 analog multiplexer, to enhance LabJack card capability. From 114 analog channels we have used 30 channels for optical detector voltage recording.

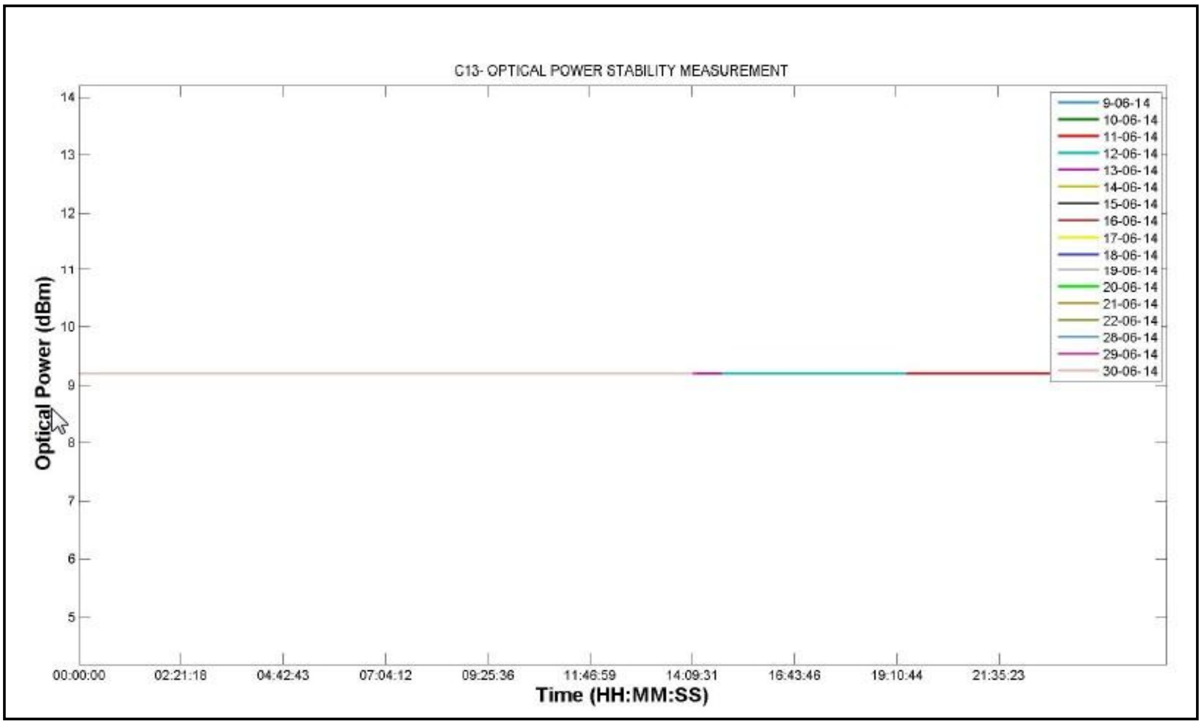

Figure 10. C13 optical power stability plot

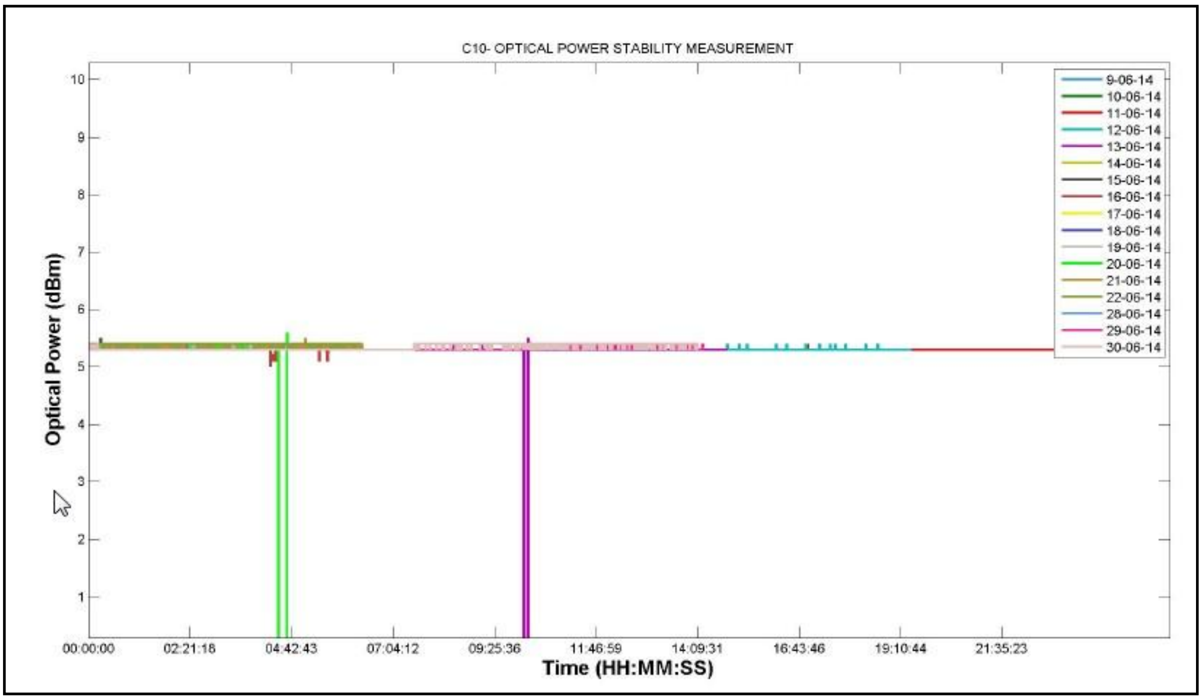

Figure 11. C10 optical power stability plot

Above two figure shows the plot of optical power vs. time recorded for 17 days, C13 antenna show very stable optical power and C10 is also stable with less than +/- 0.1 dB variation, the possible reasons for optical power fluctuation is

1. Temperature variation in antenna shell.
2. If TEC controller is not able properly control and maintain the set temperature.
3. The large drops in optical power measurement plots is due to electrical power shutdown.

Sr. No	Antenna	Optical Power Level (dBm)	Optical power variation (dB)
1	C04	6	± 0.25
2	C06	8.2	± 0.2
3	C08	6.5	± 0.3
4	C09	9	± 0.1
5	C10	5.5	± 0.1
6	C12	9	± 0.1
7	C13	9.4	± 0.05
8	C14	9	± 0.05
9	E02	9.3	± 0.1
10	E06	3.1	± 0.2
11	S02	2.4	± 0.15
12	S04	4.9	± 0.2
13	S06	3.3	± 0.2
14	W01	9.2	± 0.05
15	W06	0.9	± 0.3

Table1: Antenna optical power level and its variation over 17 Days

Conclusion:

Now we have 27 antennas with Broadband optical fiber system and optical power monitoring facility, it is stand alone system which will run independently for 24 X 7 and record the data. The system is designed such that it will work linearly from -10dBm to +12dBm optical power range. The LabVIEW based monitoring window has facility which will give warning message when optical power of antenna falls below the set limit. This system can be used to regularly, to monitor optical power stability.

Future Scope:

In future we are trying to develop a web based application, now computer system having LabVIEW based program is simulating the DAQ card and store the data in hard disk. This web-based application will continuously plot the total optical power of each antenna with time and develop a daily report of optical power stability from the stored data. Along with this system, the laser current and bias voltage measurement to be done with Rabbit card definitely will prove a useful tool for debugging the fiber optics system problems.