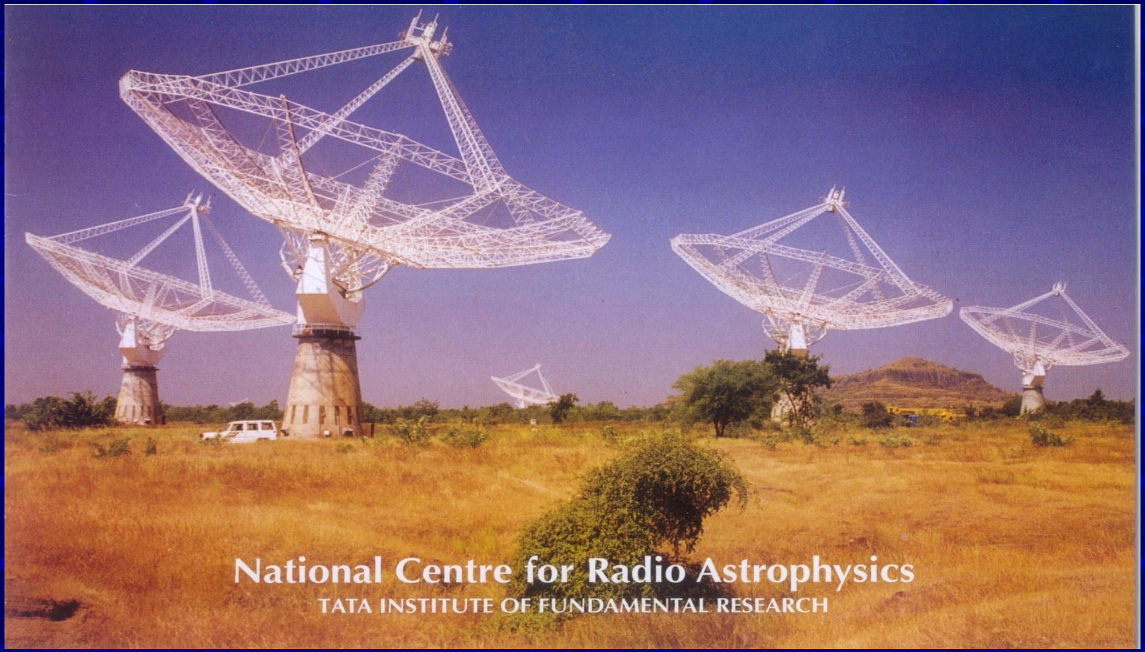
Giant Metrewave Radio Telescope

Introduction,

Current System Details & Future Upgrade Plans



Ajith Kumar. B

Group Co-ordinator, GMRT Backend Systems

Aug 24, 2013

Introducing the GMRT

- The Giant Metrewave Radio Telescope - GMRT is a world class instrument for studying astrophysical phenomena at low radio frequencies (50 to 1450 MHz)

- Located 80 km north of Pune, 160 km east of Mumbai

- Array telescope consisting of 30 antennas of 45 metres diameter, operating at metre wavelengths -- the largest in the world at these frequencies

GMRT : Quick Overview

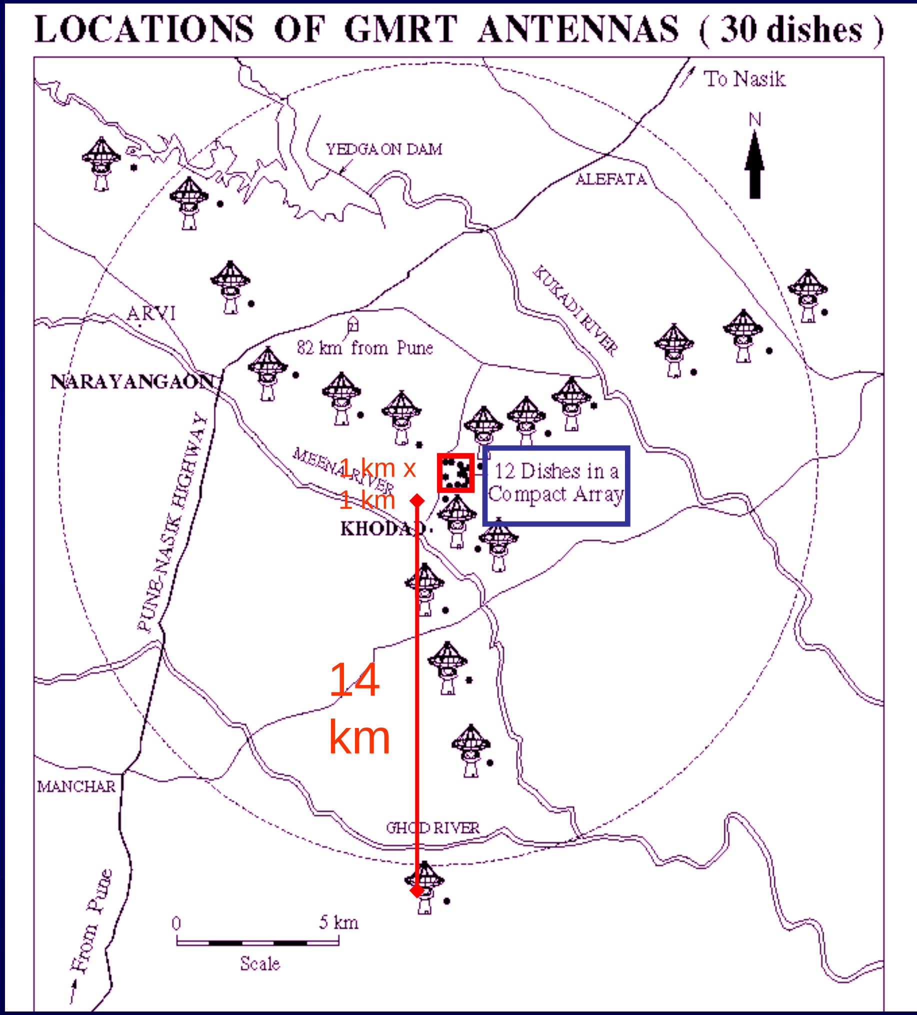
- 30 dishes, 45 m dia each
  - 12 in a central 1 km x 1 km region
  - 18 along 3 arms of Y-shaped array

  baselines : ~ 200 m to 30 km.

- Frequency range :
  - 130-170 MHz
  - 225-245 MHz
  - 300-360 MHz
  - 580-660 MHz
  - 1000-1450 MHz
  - max instantaneous BW = 32 MHz

- Effective collecting area (2-3% of SKA) :
  - 30,000 sq m at lower frequencies
  - 20,000 sq m at highest frequencies

- Supports 2 modes of operation :
  - Interferometry, aperture synthesis
  - Array mode (incoherent & coherent)



GMRT : Modes of Operation

The GMRT supports two modes of operation :

1. The Earth Rotation Aperture Synthesis Mode
2. The Phased Array Mode

The Synthesis Mode

- Useful for making maps of extended radio sources
- Each antenna pair used as an interferometer that measures one Fourier component of the radio image $\Rightarrow$ (30*29)/2 = 435 instantaneous Fourier components
- Rotation of the Earth is used to get more Fourier components (UV plane)
- Array configuration optimized to give maximum, uniform coverage in the Fourier domain
- Final image obtained by 2-D inverse Fourier Transform of recorded data $\Rightarrow$ advanced signal processing needed

The Array Mode

- Useful for studying compact objects e.g. Pulsars
- Signals from all antennas are added together to make it look like a large dish $\Rightarrow$ proper phasing is required
- Incoherent and Coherent addition are both available
- Incoherent addition is useful for large scale search / survey work ; coherent mode is meant for study of known objects
- Maximum array sensitivity : 30 x single dish sensitivity
- Will be used for VLBI observations also

The Giant Metrewave Radio Telescope

A closer view of Central Square Antennas

The Giant Metrewave Radio Telescope
The central closely spaced antennas

Construction of a GMRT antenna

Sub-systems of GMRT

- Mechanical sub-system
- Electrical sub-system
- Servo sub-system
- Antenna feeds & feed positioning
- Receiver chain -- analog
- Optical fiber sub-system
- Receiver chain -- digital
- Telemetry sub-system
- Control and Monitor sub-system
- Off-line data processing chain(s)

GMRT Engineering Team

Dean, GMRT : Prof Y Gupta

Mechanical : H.S. Kale
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Servo, FPS : Suresh Sabhapathy
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Feed, FE : S. Suresh Kumar
Optical Fiber G. Shankar
Anil Raut

Backend : B. Ajith Kumar
S. Choudhari
KD. Buch

Telemetry : S. Nayak
Sentinel

Electrical : R.V. Swami

RFI, GCC : Shubendu Joardar

Mechanical, Servo & Feed Position Systems

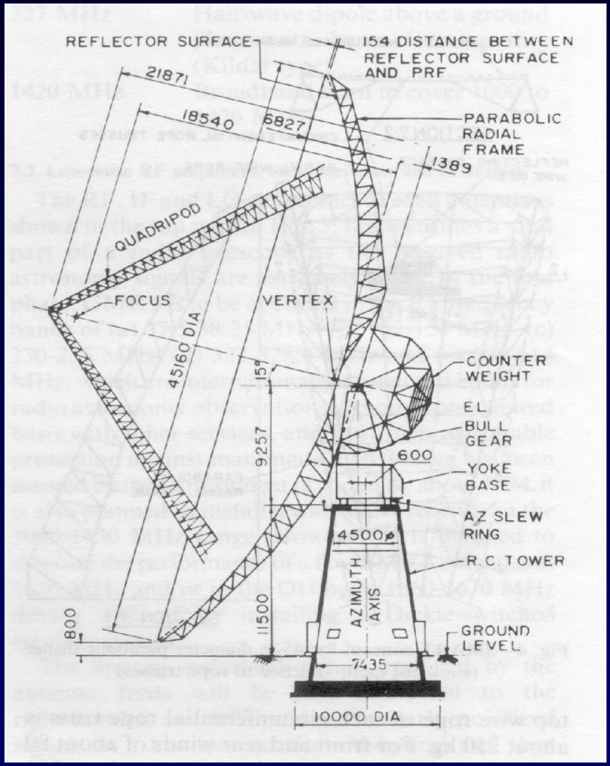
A quick overview

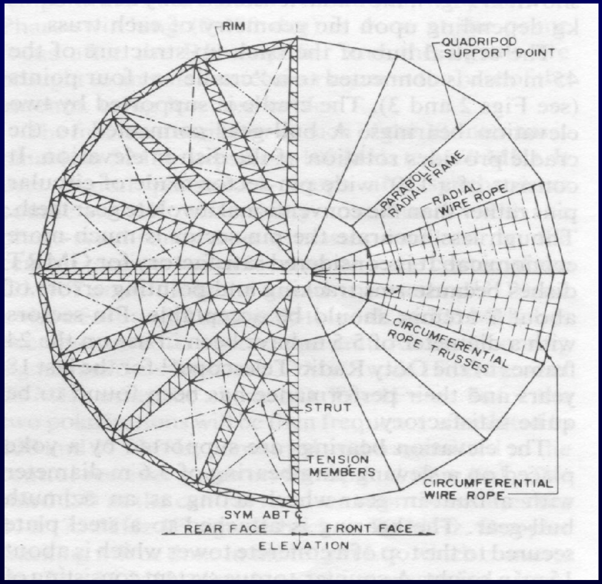
Main parameters of the 45-m GMRT Dish

Focal Length	18.54 m
Physical Aperture	1590 m^2
Mounting	Altitude – Azimuth
Elevation Limits	15^o to 110^o
Azimuth Range	± 270^o
Slew Rates	Alt – 20^o / Min Az – 30^o / Min
Weight of moving structure	82 tons+Counter weight of 34 tons
Survival wind speed	133 km/hour
RMS Surface Error	< 10mm
Tracking and pointing error	< 1' arc

The Antenna - Specifications

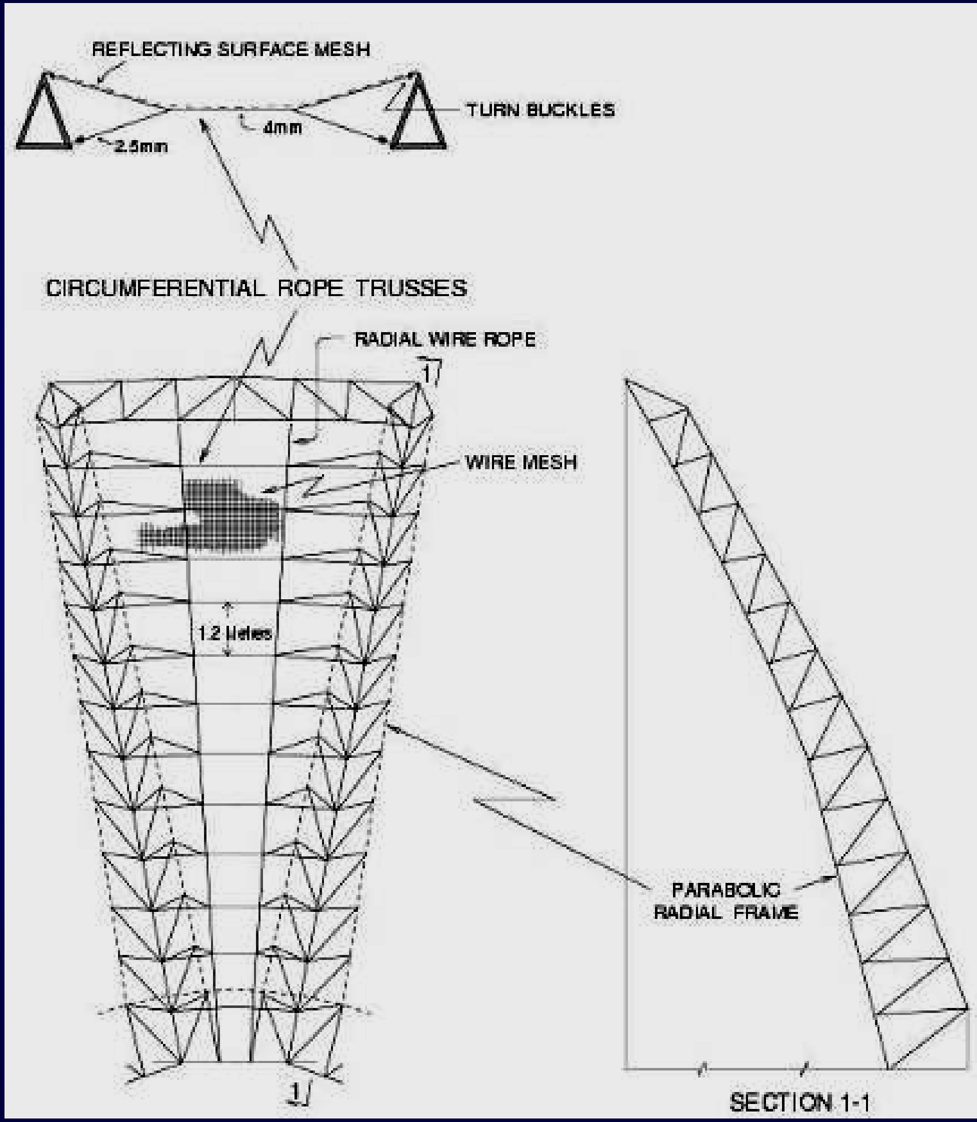
- f/D ratio: 0.412
- 85 tonnes weight
- Alt-Azimuth mount with a 3.5m dia azimuth bearing
- 7% solidity with 0.38 mm dia ss wires spot-welded at junction point to form a surface with 10x10 / 15x15/ 20x20 mm wire-grid
- Mesh panel supported by ss rope trusses attached to tubular parabolic frame: SMART concept to form the parabola
- RMS surface error at 40 kmph winds: 10 mm
- Survival Wind Speed – 135 Kmph





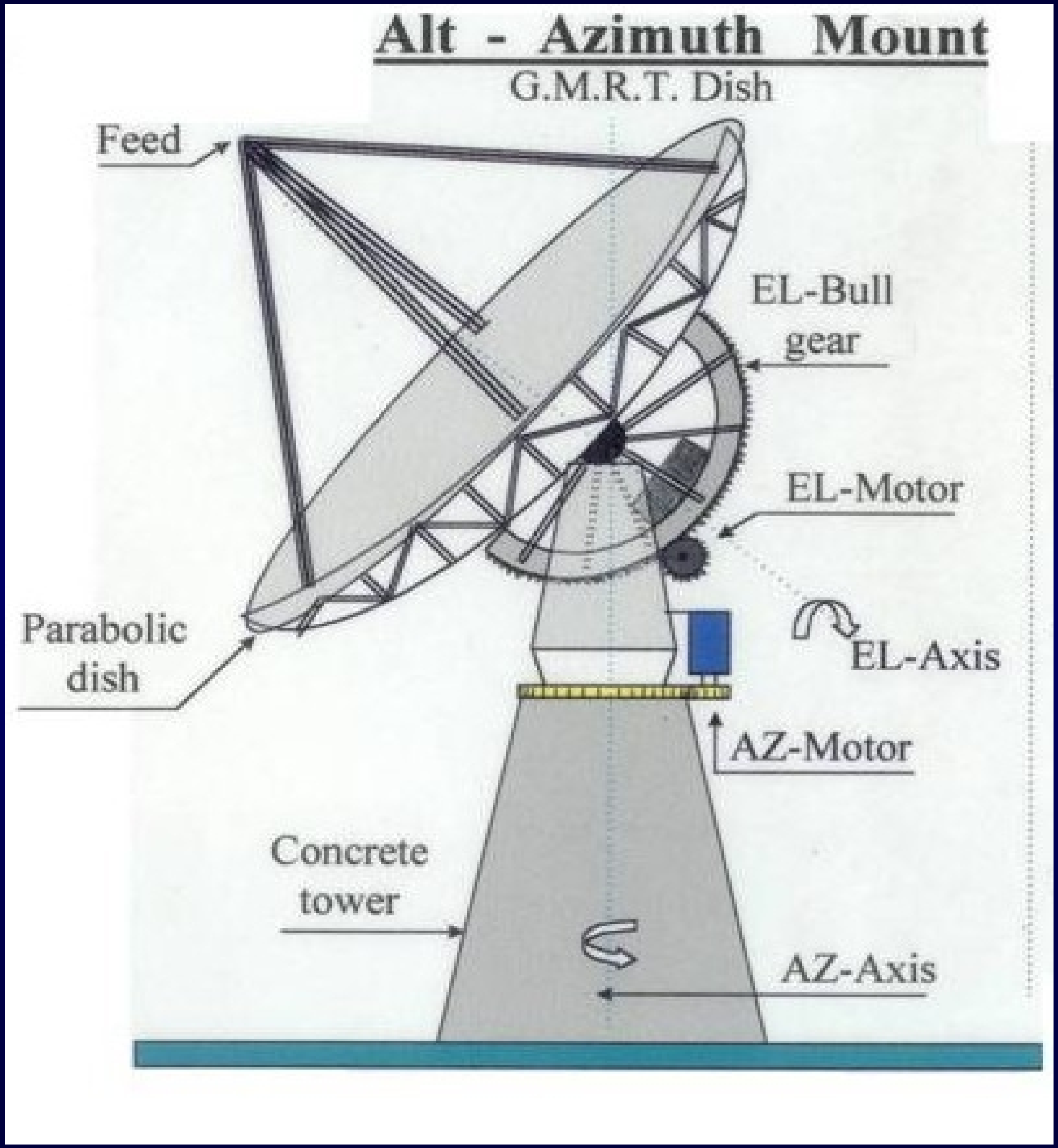
GMRT Antennas : The ‘SMART’ Concept

- The dish has 16 parabolic frames which give the basic shape
- The reflecting surface consists of a “Stretched Mesh Attached to Rope Trusses”
- The wire mesh size is matched to the large wavelengths of operation



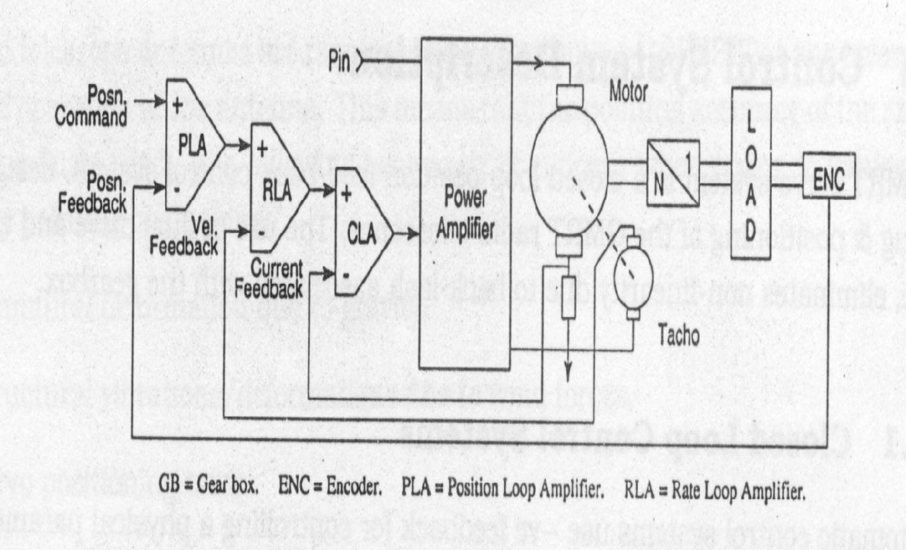
The “Invisible” Reflecting Surface

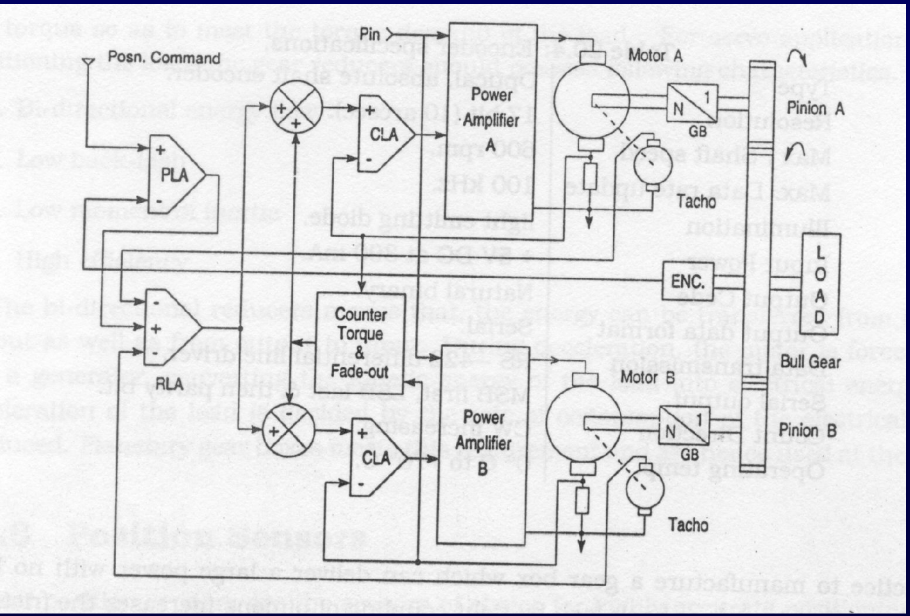
The GMRT Servo System

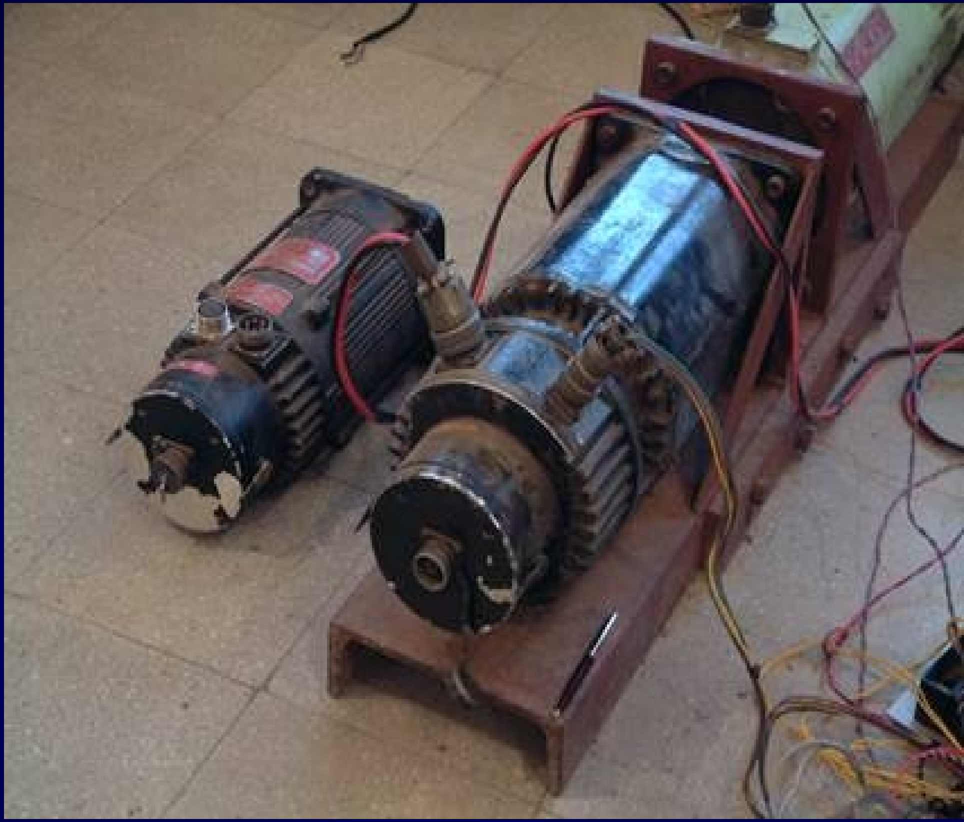


- Points the antennas to any part of the sky and tracks a source
- 17-bit absolute encoder
- ± 270° movement around Az axis and 15 to 110° above horizon about elevation axis
- Slew speed of 30°/ min in Az axis and 20°/ min in El axis
- RMS tracking and Pointing accuracy: 1 arcmin at 20 kmph winds

Servo System







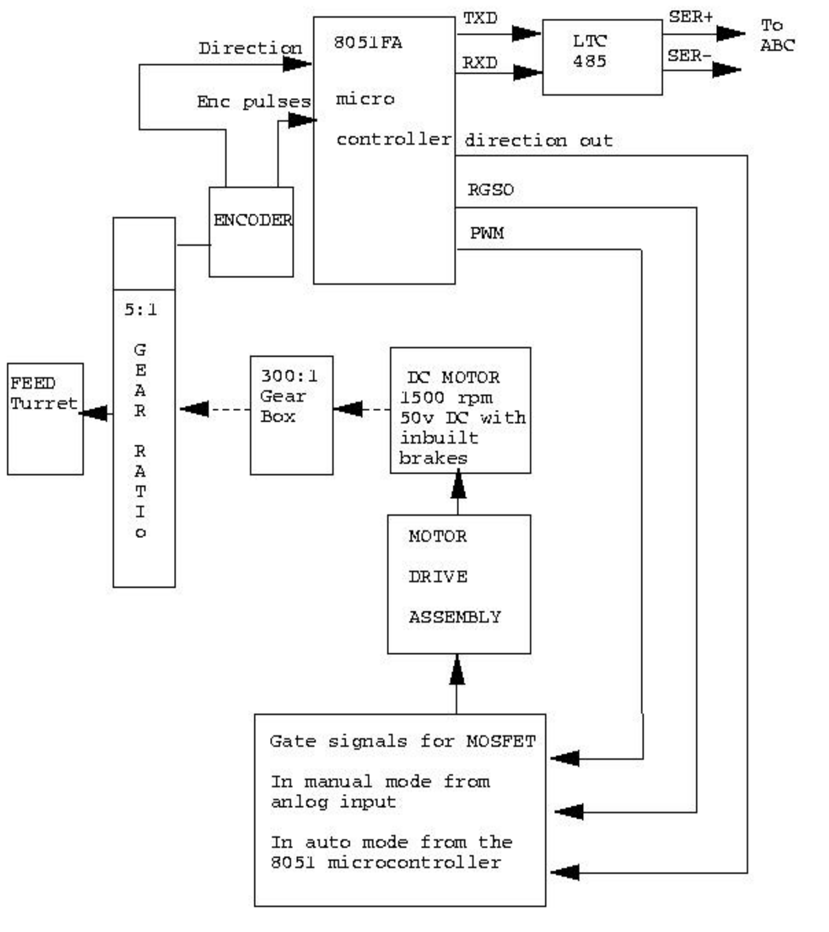
Pair of 6 HP DC servo motors in a counter-torque system for Azimuth and Elevation axes

The Feed Position System

- Position Loop Control system with Incremental encoder for position feedback
- 8051 Microcontroller based system
- 0.5 hp DC servomotor
- Positioning Accuracy of 6’ and Resolution of 1.05’

FPS System - Details

Operating RF Frequency band of GMRT can be changed in about ONE MINUTE



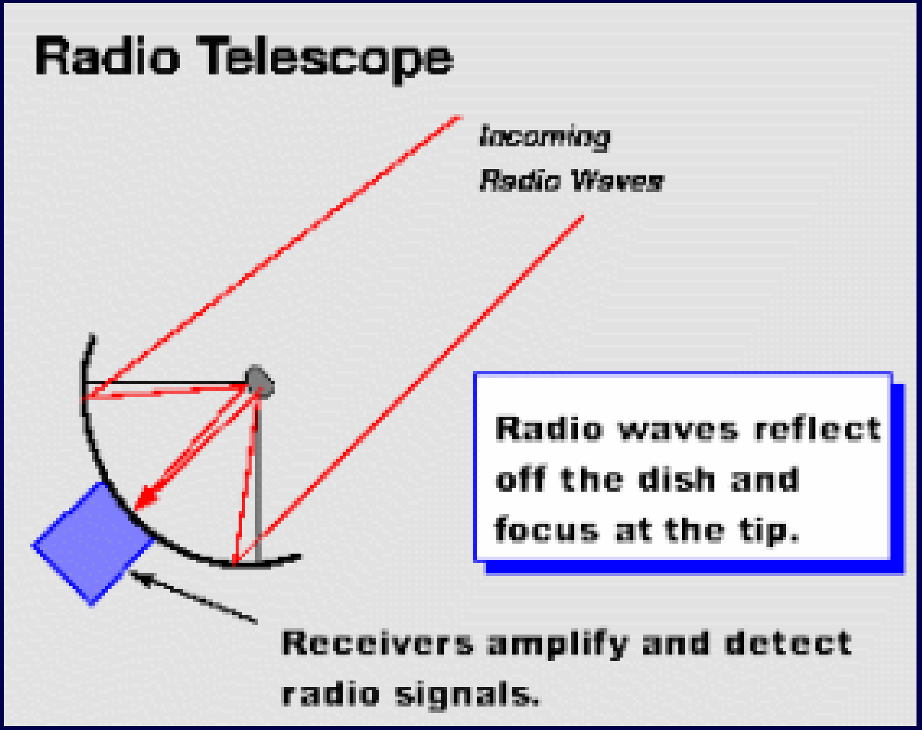
General Block Diagram Of FPS

Radio Telescope Receiver

An Introduction

A Single Dish Radio Telescope

- Collects radio waves from the celestial sky over an effective aperture area and converts the signal to an electrical voltage, in 2 orthogonal polarisations.
- A Highly sensitive Receiver with Low Noise Amplifiers provide a total Gain (approx) 100 dB.
- Power detectors are used to measure the power in the amplified signal and it is integrated to achieve the desired signal-to-noise ratio.
- Final sensitivity depends on Collecting Area, Bandwidth, Integration Time & Receiver Noise Temperature.



A Single Dish Radio Telescope

- For High Sensitivity & Signal-to-Noise Ratio : Collecting Area – HIGH,
  Bandwidth - LARGE,
  Integration Time- LARGE,
  Receiver Noise - LOW.

- Map of the Source Structure is made by multiple pointings over different parts of the source.

- Celestial Radio signals are VERY weak ; unit of flux used is :
  1 Jansky = 10^{-26} W / m^2 / Hz
- Input radio power into a typical telescope is ~ -100 dBm !
  (would take 1000 years of continuous operation to collect 1 milliJoule of energy !!)

Single Dish & Array Telescopes

- Resolution and sensitivity depend on the physical size (aperture) of the radio telescope.

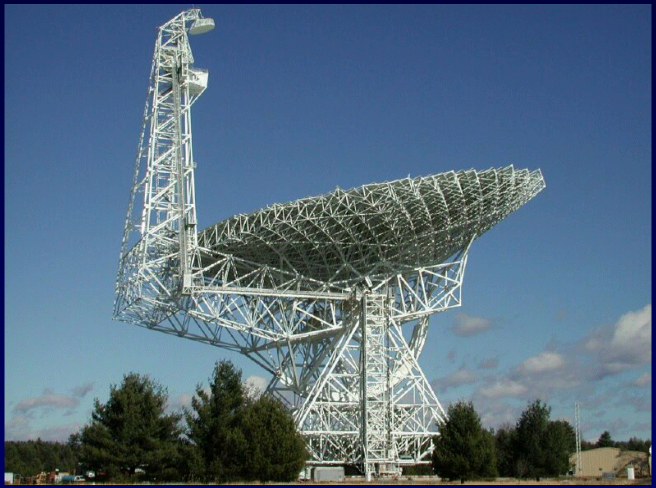
- Due to practical limits, fully steerable single dishes of more than ~ 100 m diameter are very difficult to build.

  $\Rightarrow$ resolution (λ / D) ~ 0.5 degree at 1 metre (very poor compared to optical telescopes).

- To synthesize Telescopes of larger size, many individual dishes spread out over a large area on the Earth are used.

- Signals from such array telescopes are combined and processed in a particular fashion to generate a map of the source structure : EARTH ROTATION APERTURE SYNTHESIS

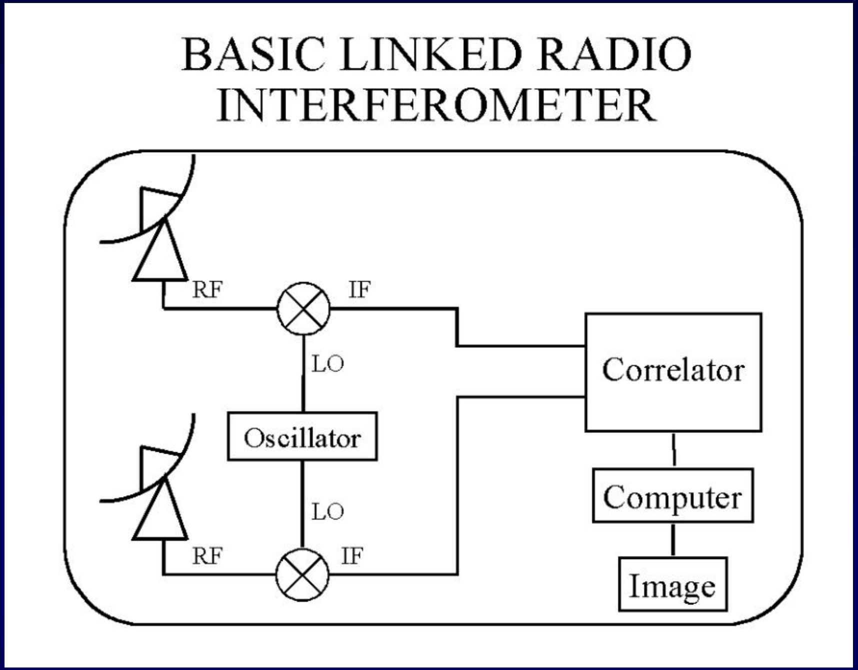
  $\Rightarrow$ resolution = λ / D_s , D_s = largest separation.



New 100-m Greenbank Telescope

The Very Large Array

Radio Interferometry & Aperture Synthesis



- Signals from a pair of antennas are cross-correlated (cross-spectrum is obtained).
- This functions like a Young's double slit, measures one Fourier component of the image in the U,V Plane.

- From measurements using different pairs of antennas, several Fourier components of the image are obtained.
- Inverse Fourier transform of the combined "visibilities" gives a reconstruction of the original image ➔ aperture synthesis.

The Receiver Specifications

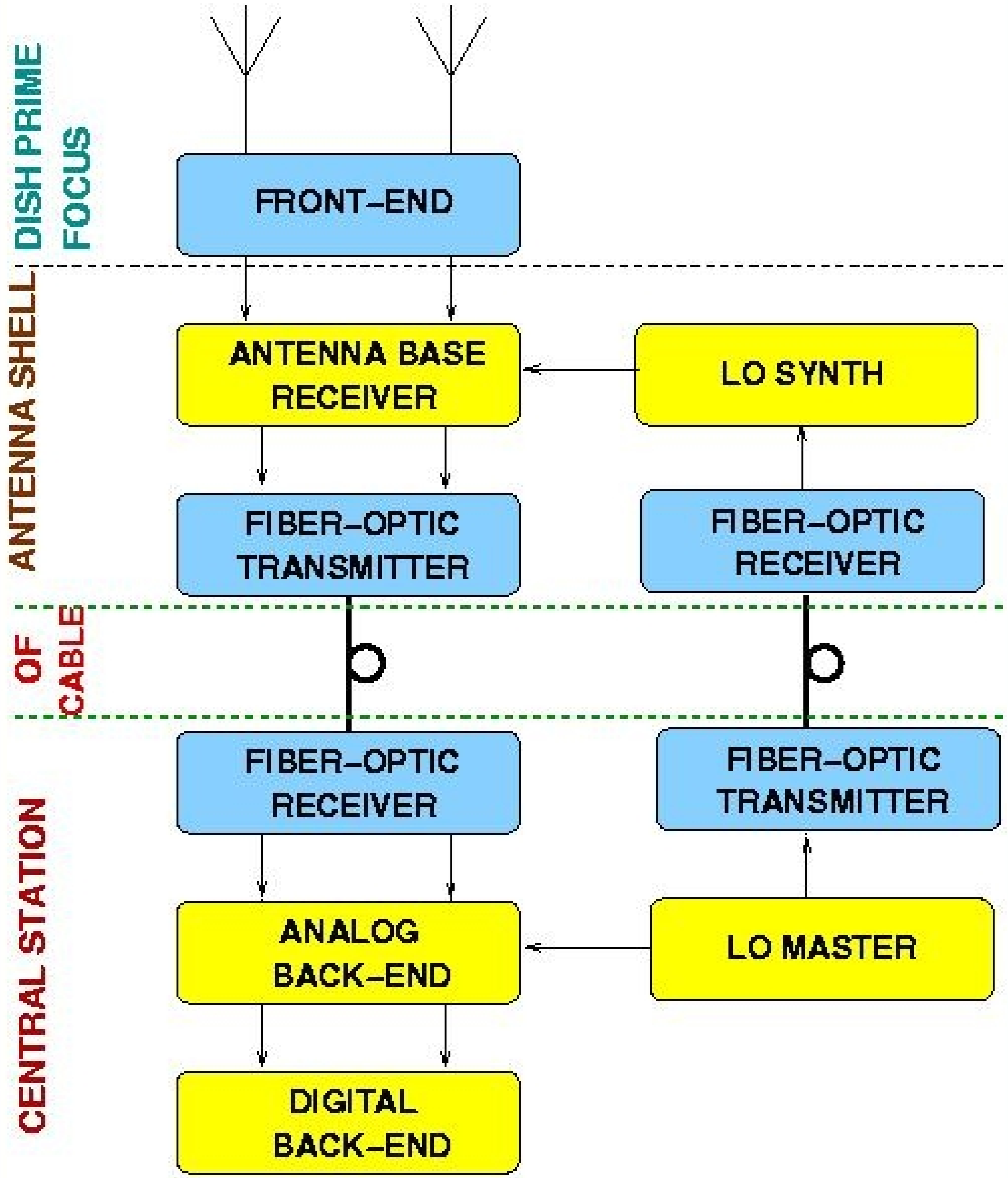
- *IDEAL Radio Telescope Receiver*: INFINITE bandwidth and ZERO noise

- *PRACTICAL Radio Telescope*:
  - Parabolic Reflector Surface acts like a Low-Pass Filter due to surface errors and reflector dimensions (~ 2 GHz for GMRT)
  - Internationally protected frequency bands
    - For Spectral line observations
    - For Continuum Observations

- The input to the receiver (=kTB, ~ -100 dBm) must be amplified to around 0 dBm (=220 mv rms) for processing in the Digital back-end. Thus, a gain of around 100 dB is involved.

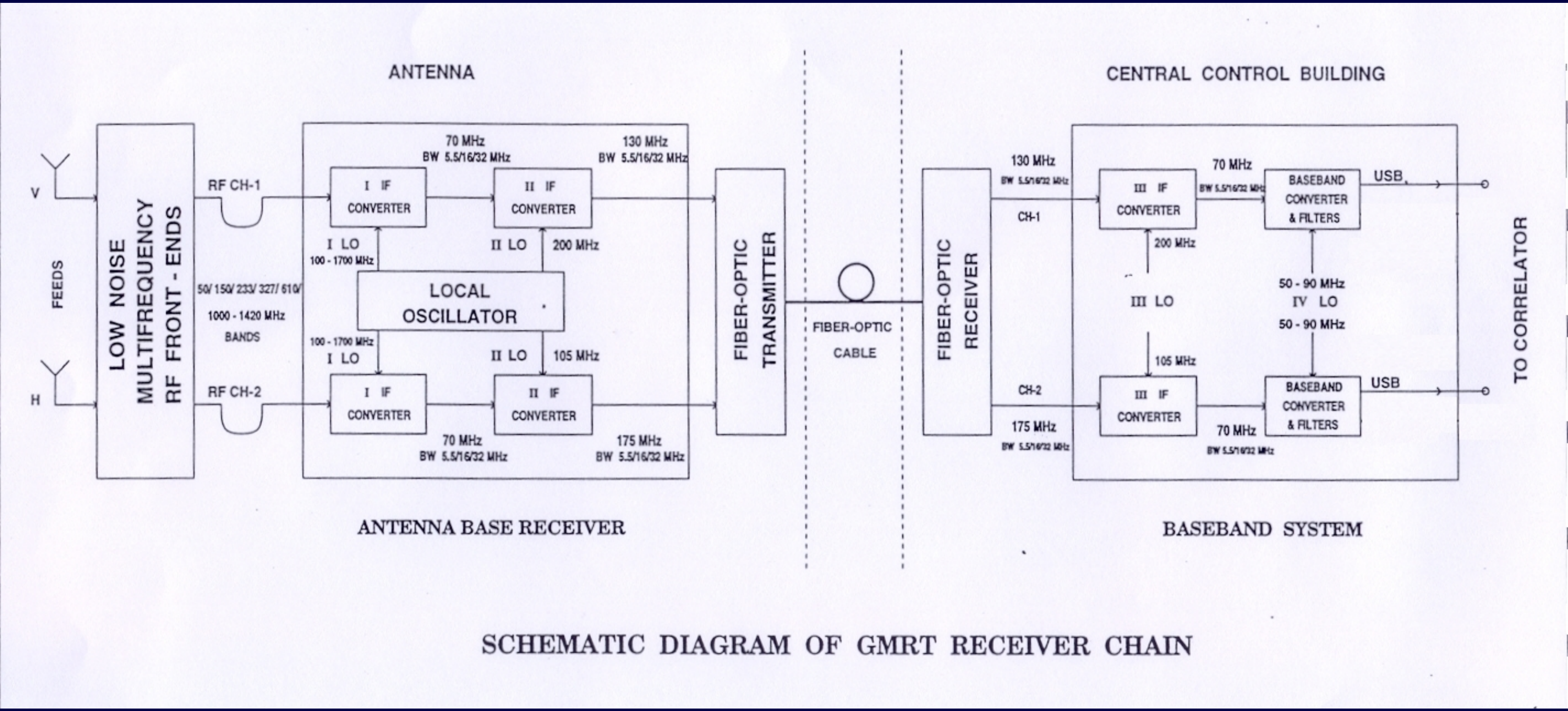
- The above gain must be distributed among various sub-systems with a good matching between
  - Noise Figure
  - Linear Dynamic Range
  - Spurious Free Dynamic Range
  - *Ensure NO bottleneck is created by any Receiver stage !*

GMRT Receiver System



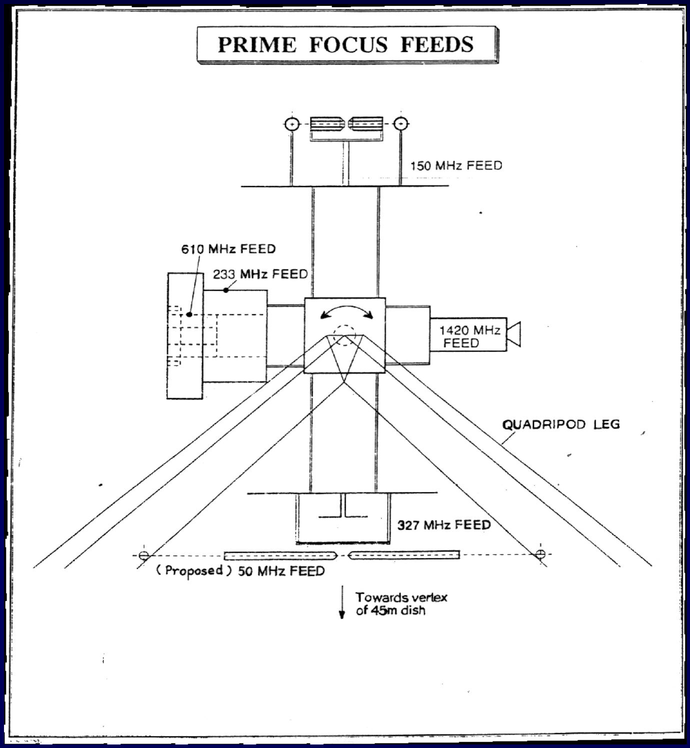
GMRT RECEIVER BLOCK SCHEMATIC

The "Simplified" Schematic Diagram



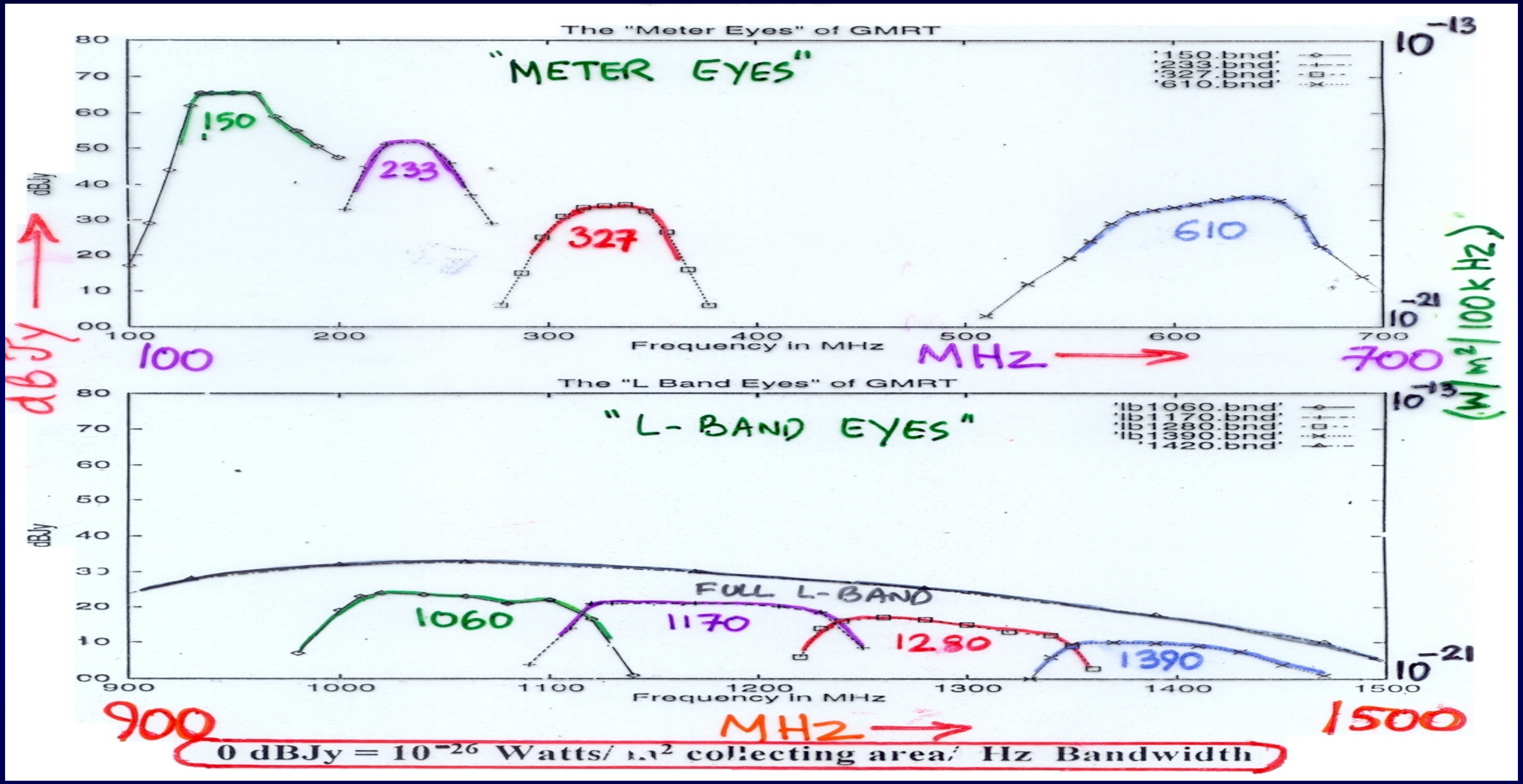
The Forward Broadcast link sets the parameters and transfers LO Reference

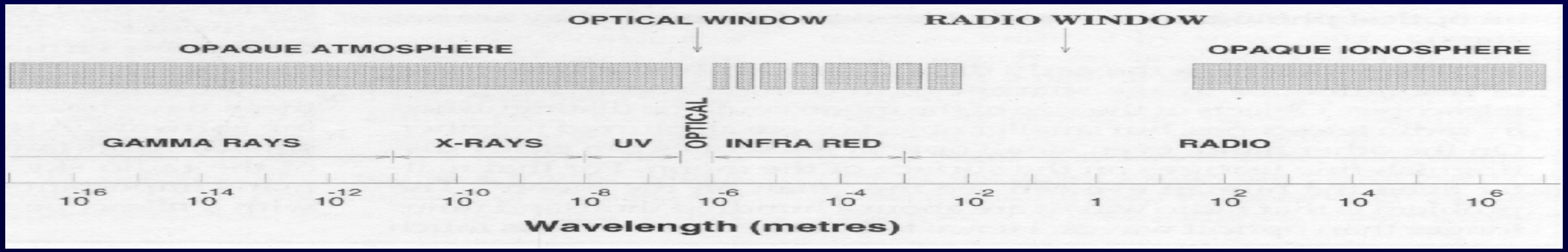
The Feeds of GMRT



- Dual Polarised Prime-focus feeds to cover the six bands of operation of GMRT
- Dual Frequency operation in 233 and 610 MHz bands
- Matched E and H plane patterns with ~10 dB edge-taper and ~20% bandwidth
- Mounted on a rotating turret – Band of operation changed in about a minute

Current “Eyes” of GMRT





Operating Frequencies of the GMRT

★ 40 – 60 MHz	300 – 360 MHz
120 – 180 MHz	580 – 650 MHz
225 – 245 MHz	1000 – 1430 MHz

Antenna primary feeds are placed on **a rotating turret** near the focus of the dish

Summary of GMRT Feed Performance

	150 MHz	***233 MHz***	***325 MHz***	***610 MHz***	***L-Band***
BandWidth (SWR< 2)	130 MHz	12 MHz	138 MHz	127 MHz	580 MHz
BeamWidth (3dB)	2° 53’	1° 51’	1° 21’	0° 43’	0° 19’
Side-lobe level	-22 dB	-15 dB	-22 dB	-17 dB	-20 dB
X-polar peak	-17 dB	- 24 dB	-28 dB	-23 dB	-24 dB
Taper	-9 dB	-9 dB	-12 dB	-10 dB	-19 dB
Aper. Eff.	65 %	65 %	66 %	61 %	42 %

The Front-End System of GMRT

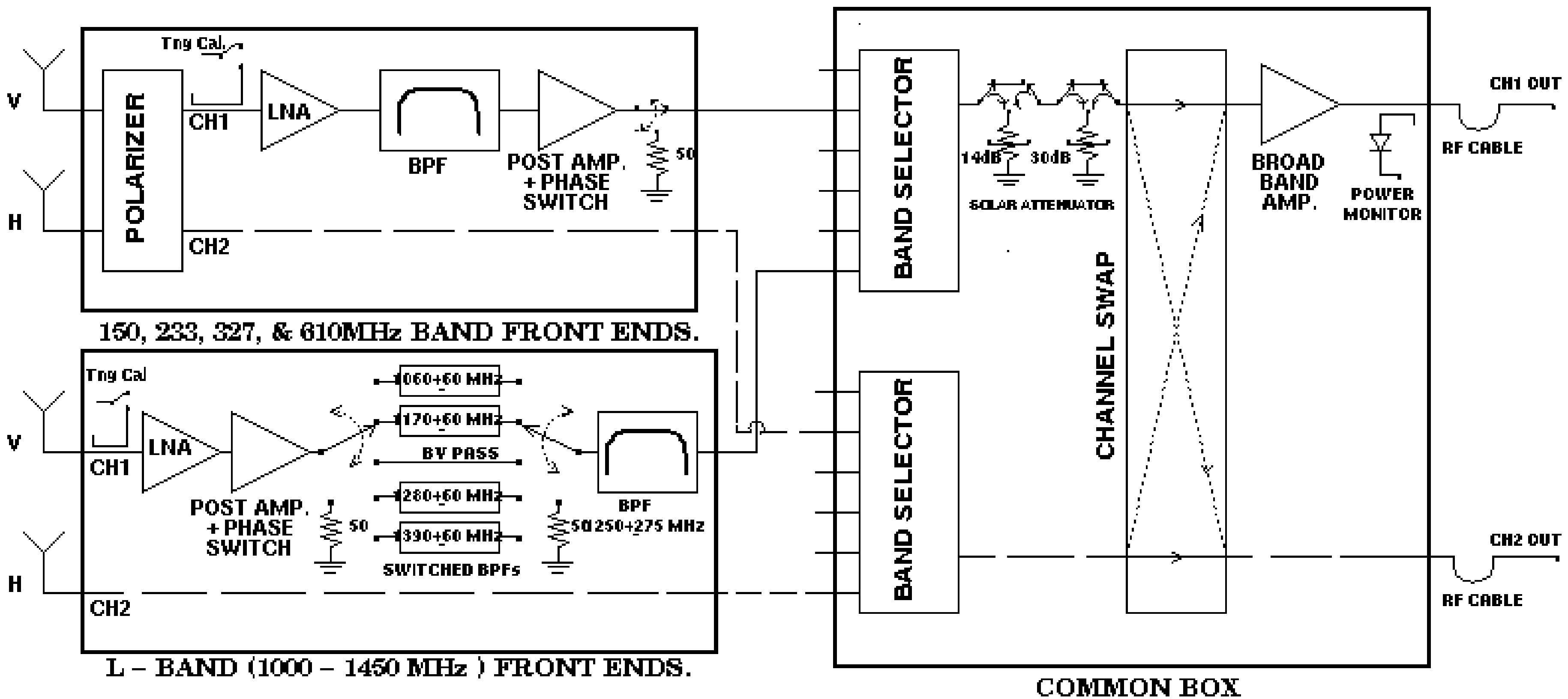


Fig : MULTIFREQUENCY RF FRONT – ENDS FOR GMRT.

Performance of Feed and FE System

SYSTEM TEMPERATURES

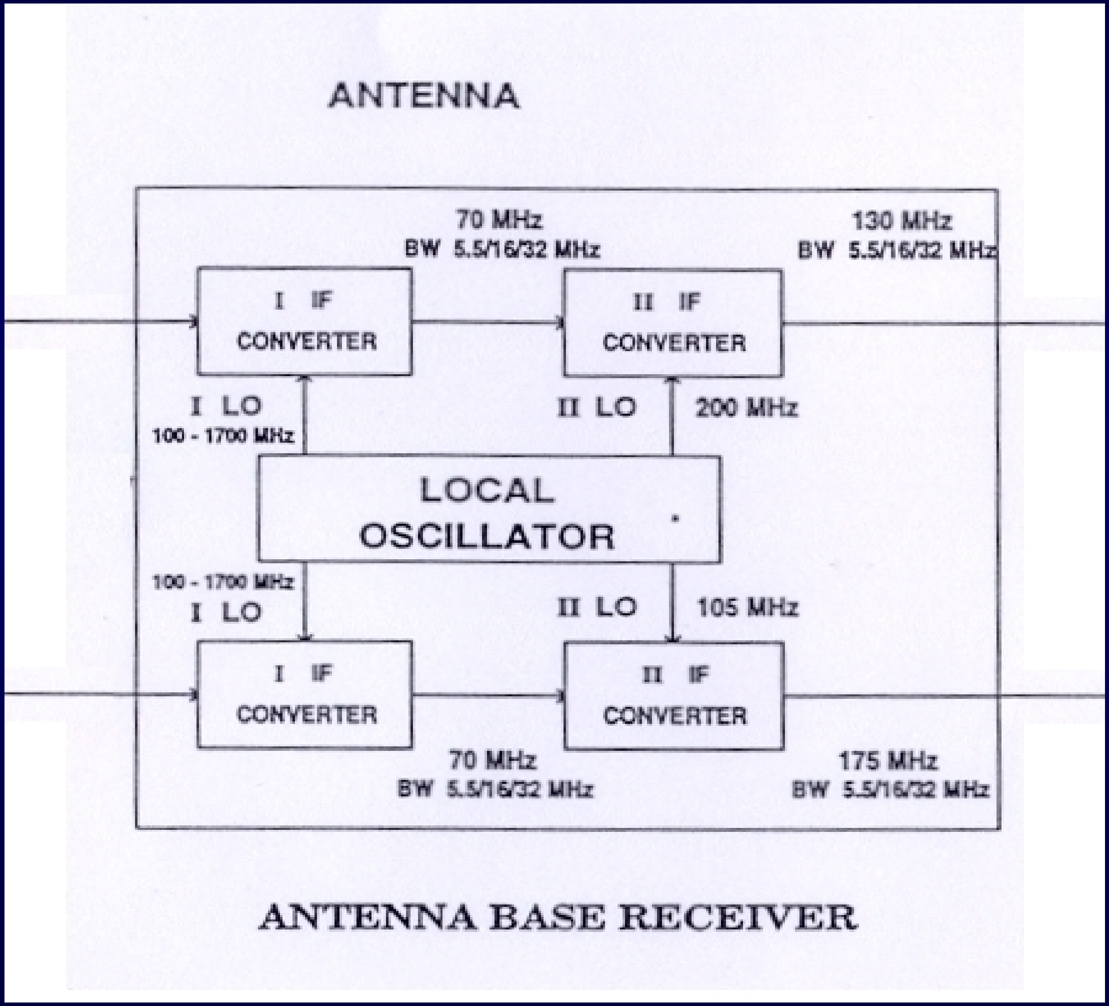
Frequency Band [MHz]	Input Cable Loss L' [dB]	Polarizer Loss L [K]	LNA Temp. T_{LNA} [K]	Receiver Temp. (Includes cable losses) T_R [K]	Ground Temp. T_{Gnd} [K]	Sky Temp. T_{Sky} [K]	System Temp. T_{Sys} [K]	Bandwidth [MHz]
150	0.2	0.75[1]	150	260	12	308	**580**	40
235	0.55[2]	0.25	35	103	32	99	**234**	40
327	0.13	0.18	30	55	13	40	**108**	40
610	0.22[3]	0.15	30	59	32	10	**101**	60
1060	0.22[4]	--	35	53	25	5	**83**	120
1170	0.22[4]	--	32	49	24	4	**77**	120
1280	0.22[4]	--	30	47	23	4	**74**	120
1390	0.22[4]	--	28	45	23	4	**72**	120

1. Includes 2-1 combiner insertion loss.
2. Insertion loss of Balun & associated cables.
3. Insertion loss of Balun & 20 cm 0.141" semirigid cable from Balun to Probe.
4. Contains loss of OMT & OMT to LNA input cable.

APK/GSS/TBA/ 25/11/99. tsys.fig

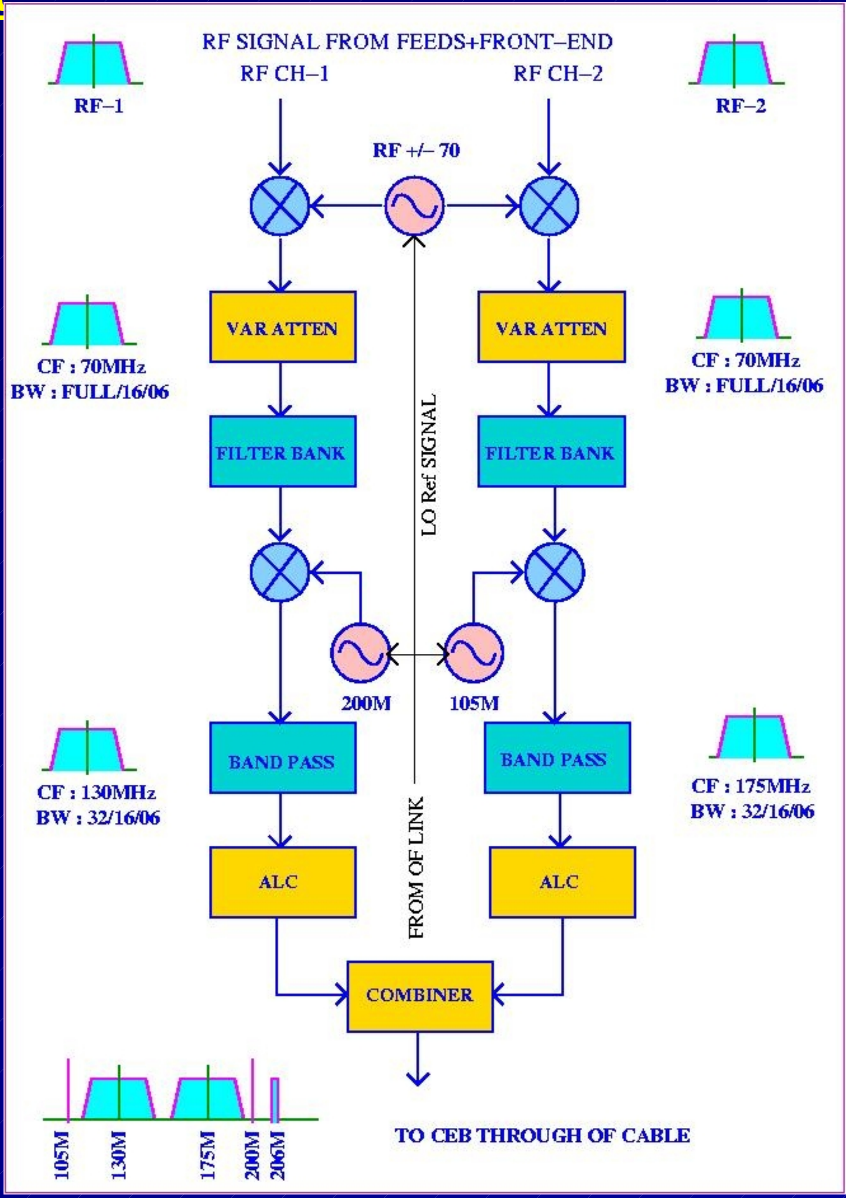
"Operation Cherry Picker"

The Signal Processing in IF systems



Analog Receiver at Antenna

- The Analog Receiver systems at the antenna converts the RF signal in both polarisations to a common IF Frequency of 70 MHz.
- SAW (Surface Acoustic Wave) Filters are used at 70 MHz for Band shaping of the signals.
- The IF signals are then upconverted to 130 and 175 MHz for transportation to CEB through Optical Fiber.
- High dynamic range ALC circuits are used before the signal is given to OF Transmitter to maintain a constant power.



Analog Receiver at Antenna

Main Features

- Choice of three IF bandwidths – 6, 16, 32 MHz. Bandwidth compensation circuits to provide constant power irrespective of selected bandwidth.

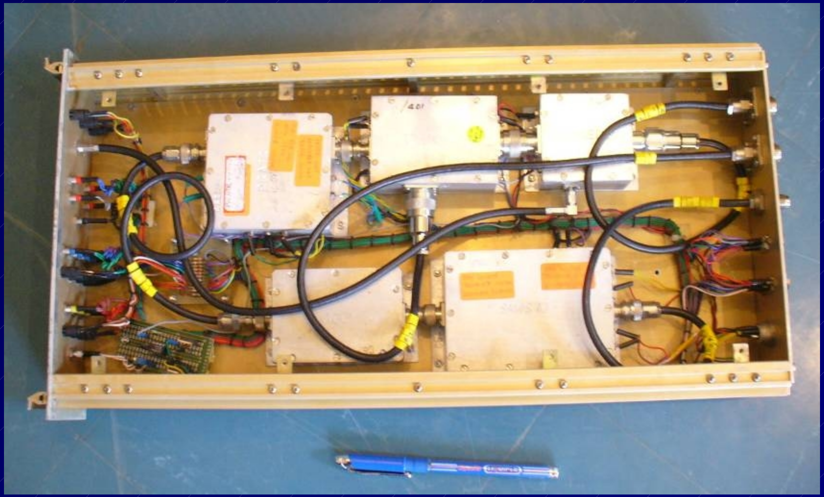
- Variable pre-attenuator values in the range 0 to 30 dB in 2 dB steps.
  Variable post-amplifier values in range 0 to 30 dB in 0.5 dB steps.

- Automatic Level Control (ALC) circuits with dynamic range 30 dB and 1.0 sec time constant with facility to switch off for specific observations.

- Overall gain of 60 dB (approx) in IF chain with linearity upto –5 dBm at output (in ALC off mode).

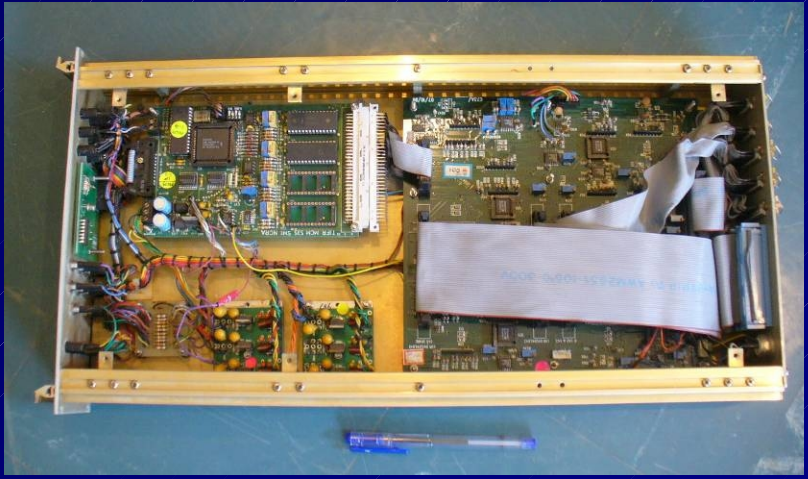
Analog Receiver at Antenna - *Main Plug in Units*

RF to 70 MHz Converter



70 to 130/175 MHz Converter

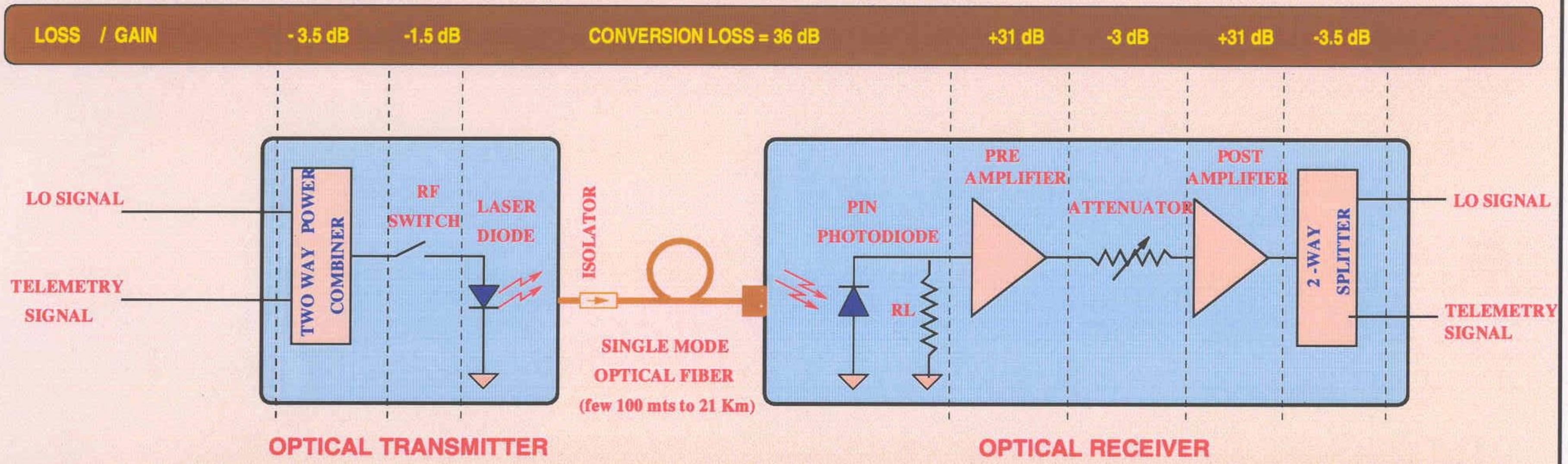
Control Unit



Monitor Unit

Forward Fiber Link of GMRT

FORWARD LINK FOR GMRT OPTICAL FIBRE SYSTEM



SPECIFICATIONS OF RECEIVER

RF PARAMETERS

MODULATION BANDWIDTH : 7MHz- 870MHz
FREQUENCY RESPONCE : +/- 2 dB
OUTPUT IMPEDENCE : 50 Ohm

OPTICAL PARAMETERS

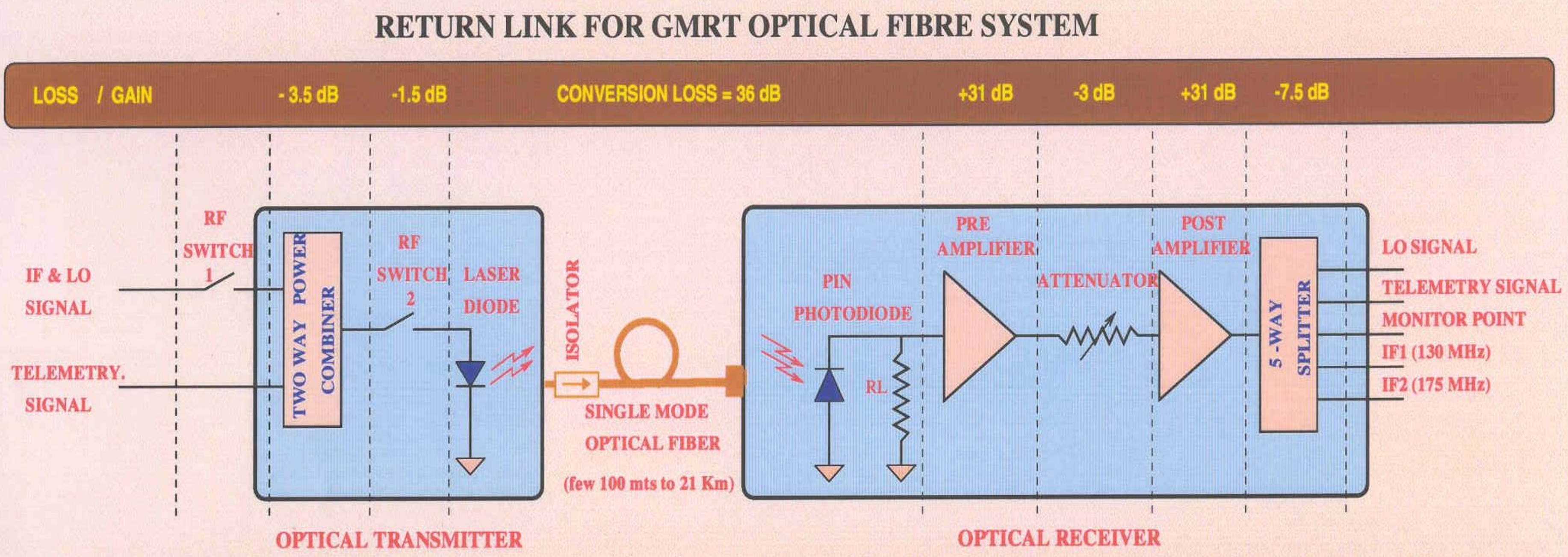
RESPONSIVITY : 0.8 mA/mW
OPERATING WAVELENGTH : 1100 - 1600 nm
OPTICAL RETURN LOSS : -45 dB

SPECIFICATIONS OF FIBER

TYPE : SINGLE MODE FIBER
DISPERSION : 3.5 ps/(Km-nm)
ATTENUATION : 0.4 dB/Km
FIBER SIZE : 9/125/250 um
CABLE TYPE : UNARMED, JELLY FILLED

Drawn by : DSP/ BAV

Return Fiber Link of GMRT



SPECIFICATIONS OF TRANSMITTER

RF PARAMETERS

MODULATION BANDWIDTH	: 60 KHz - 1GHz
FREQUENCY RESPONCE	: +/- 2dB
INPUT IMPEDENCE	: 50 Ohm
INPUT 1 dB COMPRESSION POINT	: > +10 dBm
INPUT 3 rd ORDER INTERCEPT POINT	: > +18dBm
EQUIVALENT INPUT NOISE	: <-135dBm/Hz

OPTICAL PARAMETERS

SLOPE EFFICIENCY	: 0.04mW/mA
OPTICAL OUTPUT POWER	: 1mW
PEAK OPTICAL WAVELENGTH	: 1310 +/- 10 nm
SPECTRAL WIDTH (rms)	: < 1.5 nm
FIBER DISPERSION	: 3.5 ps/(Km-nm)

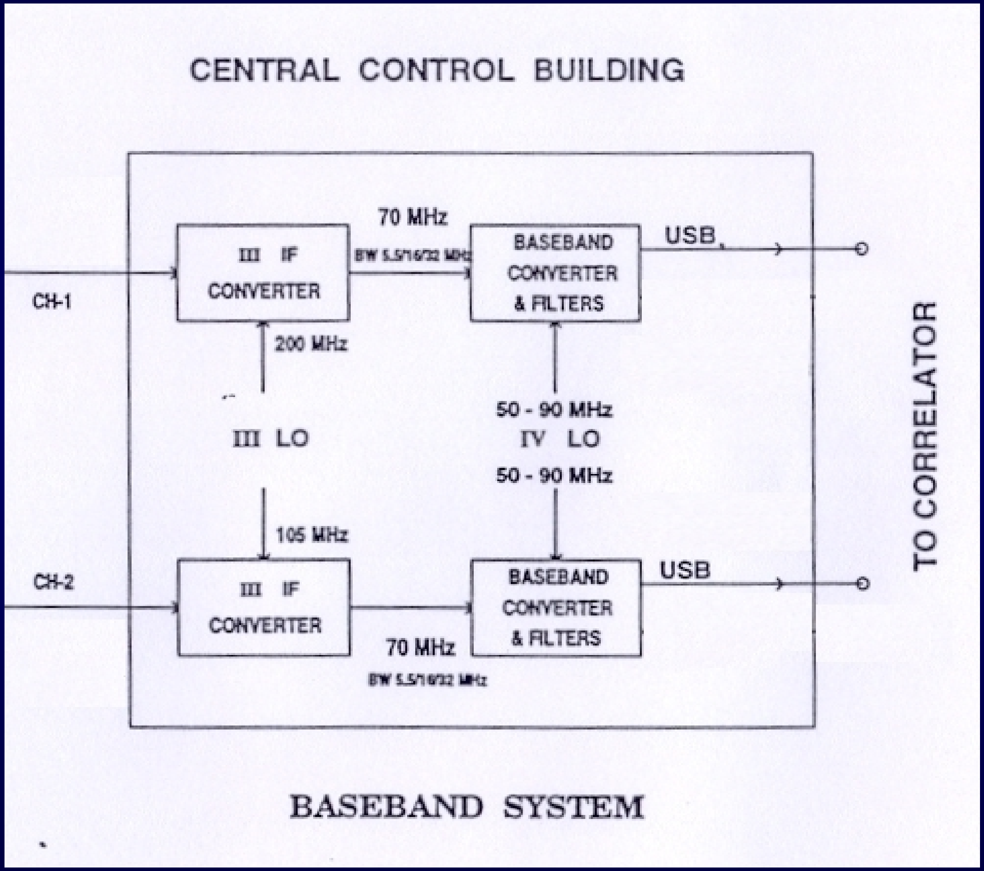
TYPICAL OPTICAL LOSSES

CONNECTOR LOSS	: 0.2 dB/connector
ISOLATOR	: 0.35 dB
SPLICES	: 0.05 dB/splice
FIBER ATTENUATION	: 0.4 dB/Km
CONNECTOR RETURN LOSS	: -80 dB

Drawn by DSP/ BAV

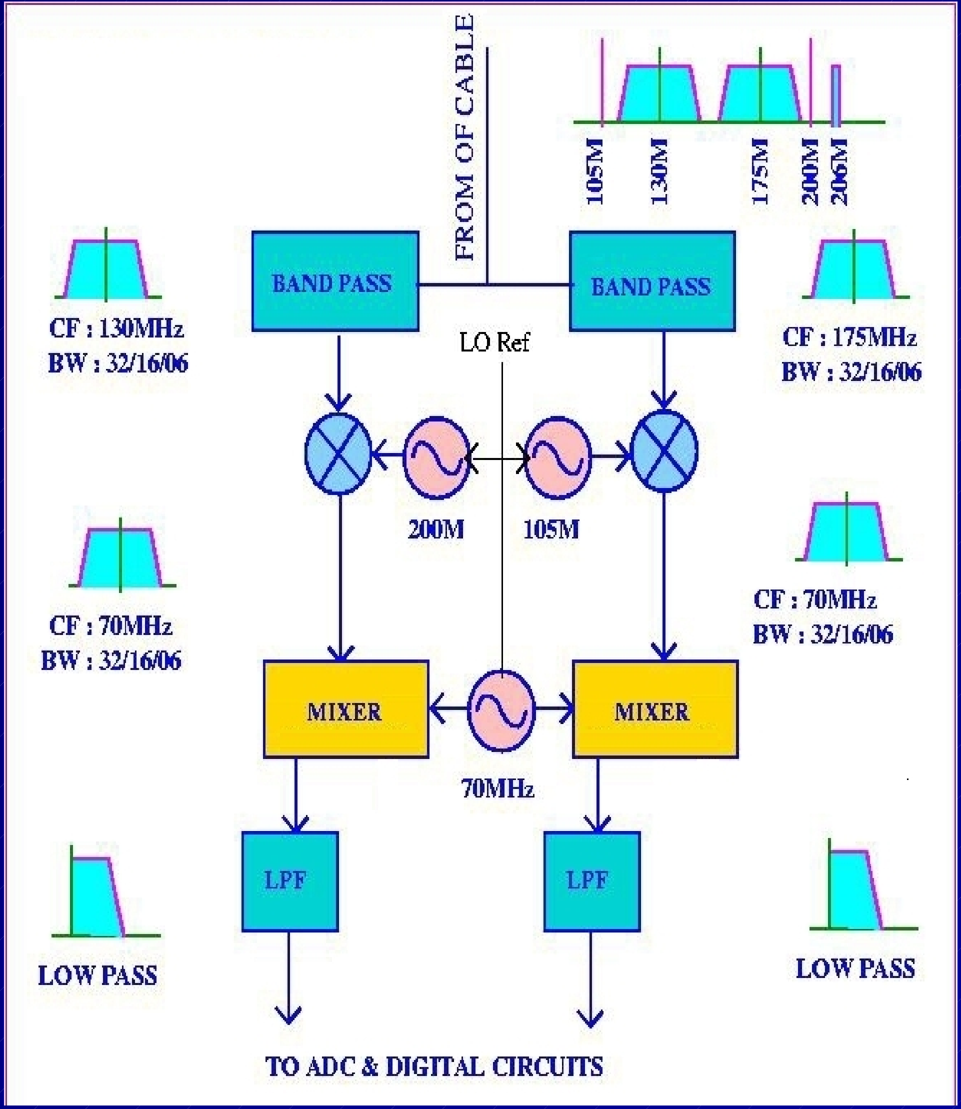
Transreceiver unit built for GMRT

Signal Processing in Baseband system



Baseband Receiver at CEB

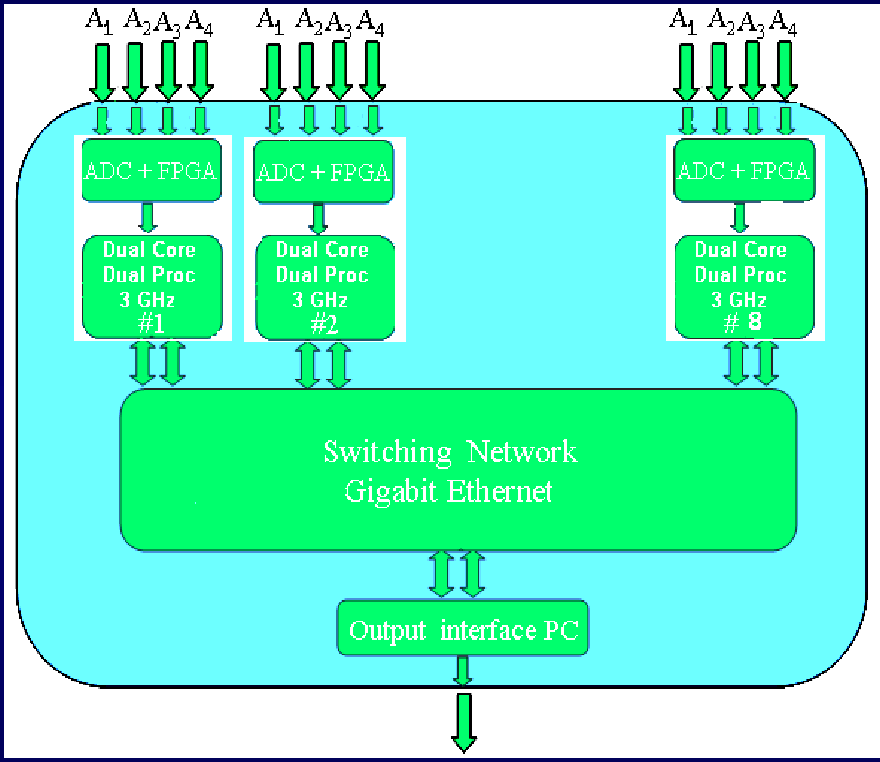
- Converts IF Frequency signals to baseband frequency of 32 MHz.
- Facility to choose different observaion bands in the two IF channels.
- Facility for noise injection at input for system level tests.
- 30 to 1 monitoring at Central station for “live” checking of quality of signal from antennas.



The GMRT Software Back-end (GSB)

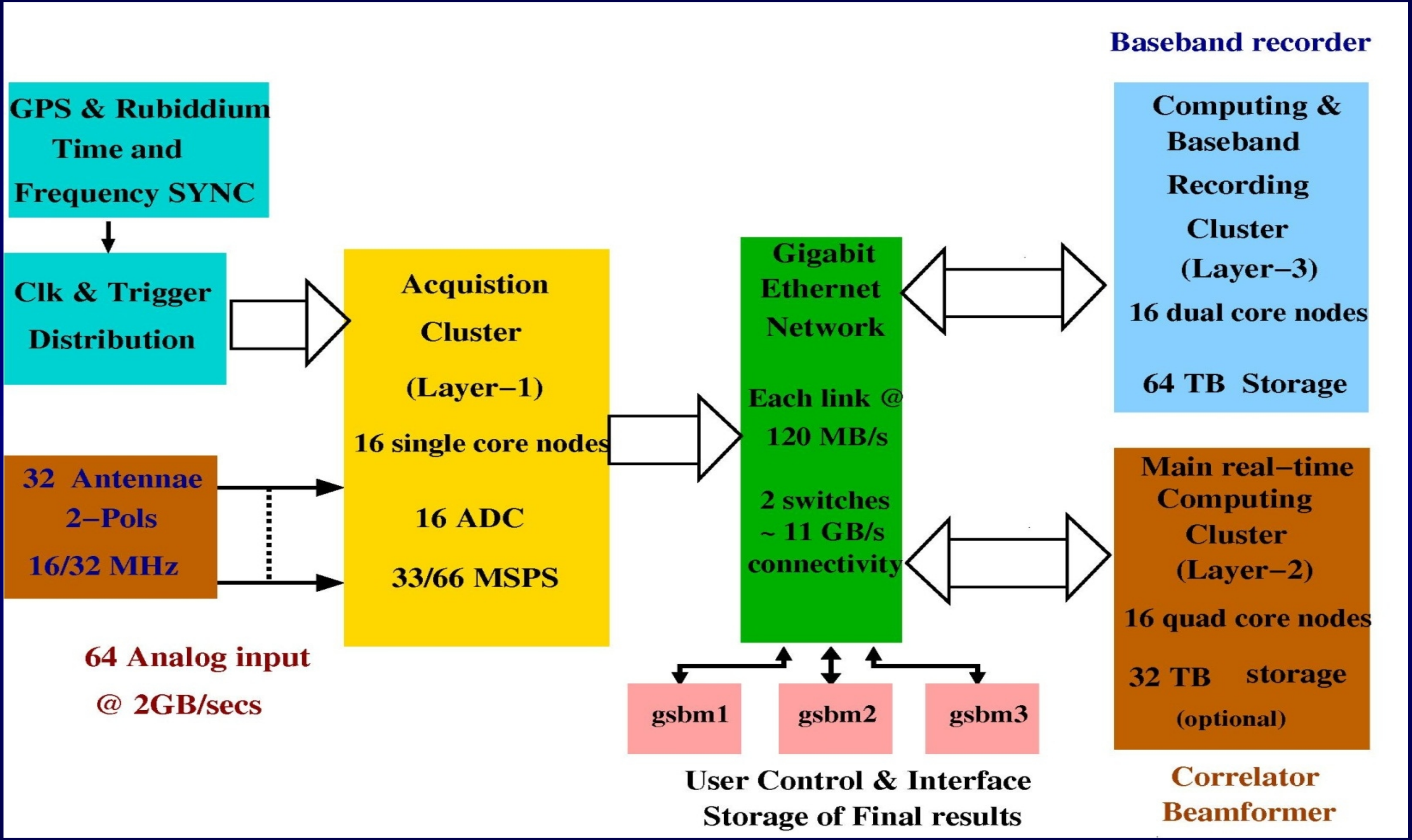
- Software based back-ends :
  - Few made to order hardware components ; mostly off-the-shelf items
  - Easier to program ; more flexible

- The GMRT Software Back-end (GSB) :
  - 32 antennas
  - 32 MHz bandwidth, dual pol
  - Net input data rate : 2 Gsamples/sec
  - FX correlator + beam former + pulsar receiver
  - Uses off-the-shelf ADC cards, CPUs & switches to implement a *fully real-time back-end*
  - Raw voltage mode : record raw data to disks, for all antennas; off-line read back & analysis



Jayanta Roy et al (2010)

The GMRT Software Backend : Block diagram



Roy et al (2010)

New capabilities : raw voltage mode

- The GSB also supports a *raw dump* mode : can record raw voltages from 32 stations (dual poln.) for ~ 12 hrs (sustained)

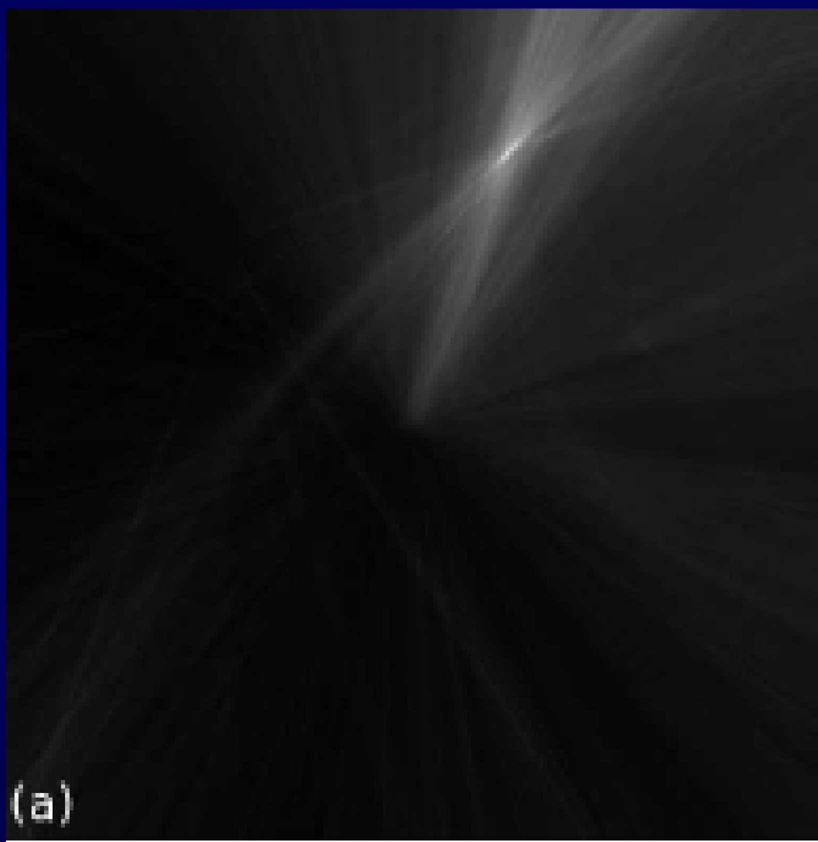
- Data is transferred from the 16 acquisition nodes to 16 recording nodes. Each node records data for 4 antennas (1 polarisation) as 4 raw data files.

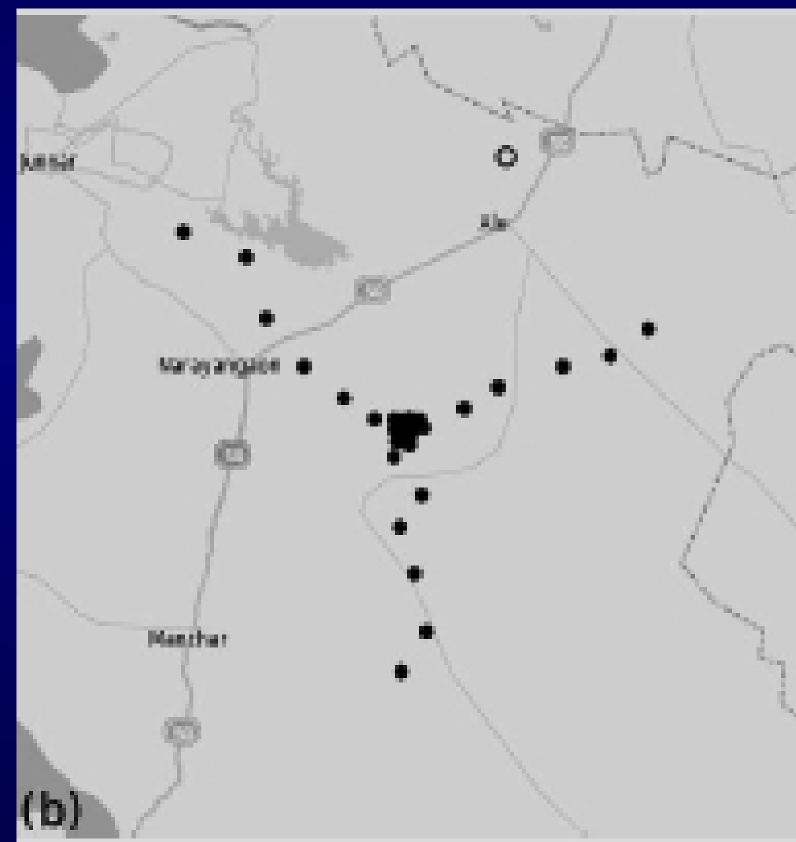
- Offline analysis code for producing visibility data

For VLBI : Data conversion to LBA format and subsequent analysis in DiFX (courtesy : colleagues from Curtin)

New capabilities : finding RFI sources

Imaging RFI sources on the ground -- work done by the GMRT EoR group (Ue-Li Pen et al)





Paciga et al, 2011

GMRT Performance Figures

	Frequency (MHz)				
	150	**235**	**327**	**610**	**1420**
Primary Beam (deg)	3.2	2.0	1.4	0.8	0.4
Synthesized Beam (arcsec)	20	13	9	5	2
Effective Area (m^2)	30,000				18,000
System Temp (^{o}K)	450	180	110	100	70
Usable Band (MHz)	150 - 156	232 -244	310 -350	590 -650	1000 -1450
Best known RMS sensitivity (μJy)	700	250	40	20	30
Typical Dynamic Range achieved	> 1500	> 1500	> 1500	> 2000	> 5000

Performance Figures for array mode

- Effective Area : 30,000 sq. m. for 610 MHz and below
  20,000 sq. m. for 900-1400 MHz
- Maximum Bandwidth : 32 MHz
- Sampling time : > 16 microsec for incoherent dedispersion
  < 1 microsec for coherent dedispersion
- Polarization : All 4 Stokes parameters for coherent phased array
  Total intensity for incoherent array
- Sensitivity :
  - For pulsar search mode (using incoherent array mode) :

    $S_{av} = 1$ mJy

    [f = 325 MHz; all 30 dishes added; 2 polarisations; 100 microsec sampling; 10 minute scans]
  - For single pulse mode (using phased array mode) :

    $S_{av} = 35$ mJy

    [f = 325 MHz; all 30 dishes added; 2 polarisations; 500 microsec sampling]

Telemetry System

<u>A quick overview</u>

The Telemetry System

- The systems described till now have many controllable parameters for
  - Antenna and Feed position settings
  - Local Oscillator Frequency settings
  - Front-end selection
  - Bandwidth setting in IF and Baseband systems
  - Signal level control in IF and Baseband systems
    - ***THESE FUNCTIONS ARE ACHIEVED BY ISSUING COMMANDS FROM CONTROL ROOM THROUGH ONLINE SYSTEM***

- To confirm successful operation of the above AS WELL AS to get feedback on parameters like wind, temperature etc from each antenna, a comprehensive Monitor system is being used

- Non-coherent FSK techniques for data transmission over the OF link.

  Bit interleaved techniques are used for multiplexing telecommand data, voice communication with dial-up and sync pulse.

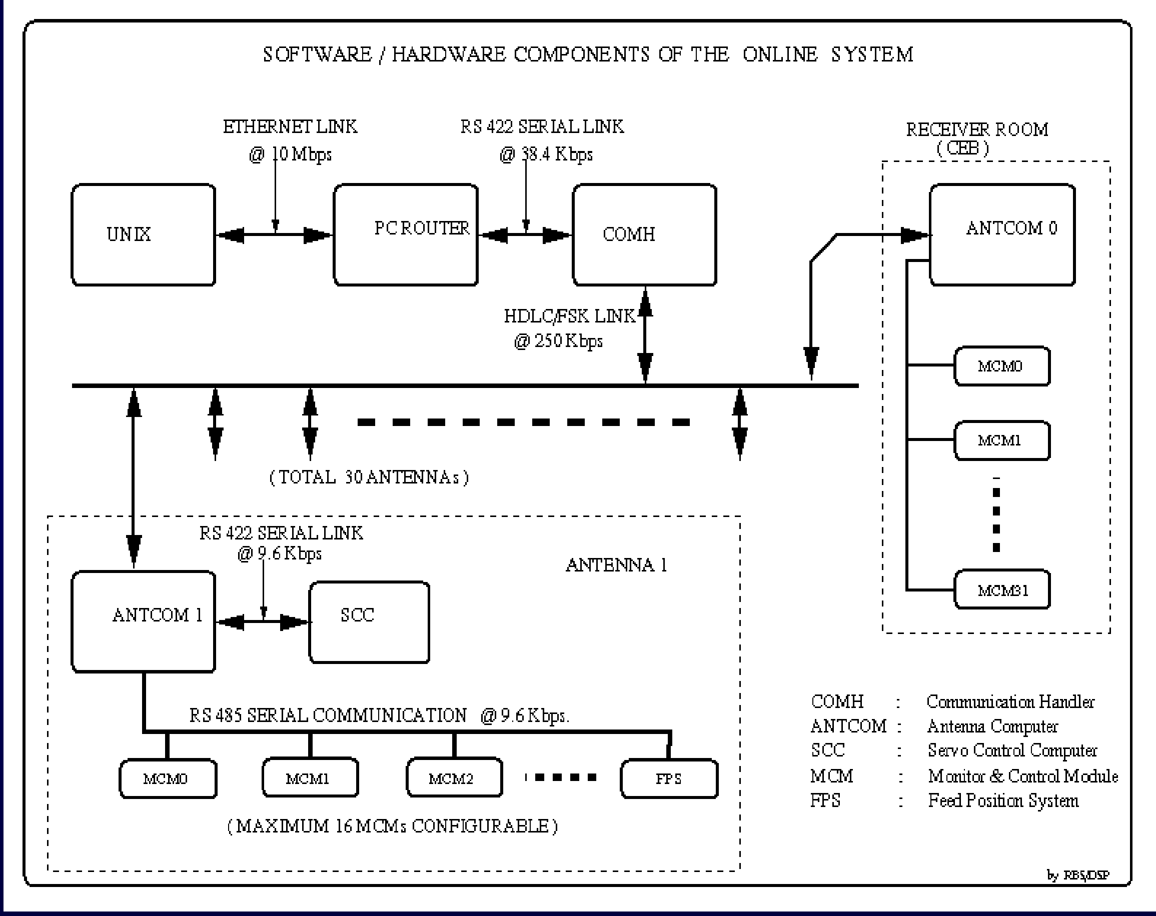
  CRC and Checksum error detection results in a BER probability of 10^{-10}.

The Telemetry sub-system

For control & monitoring of :

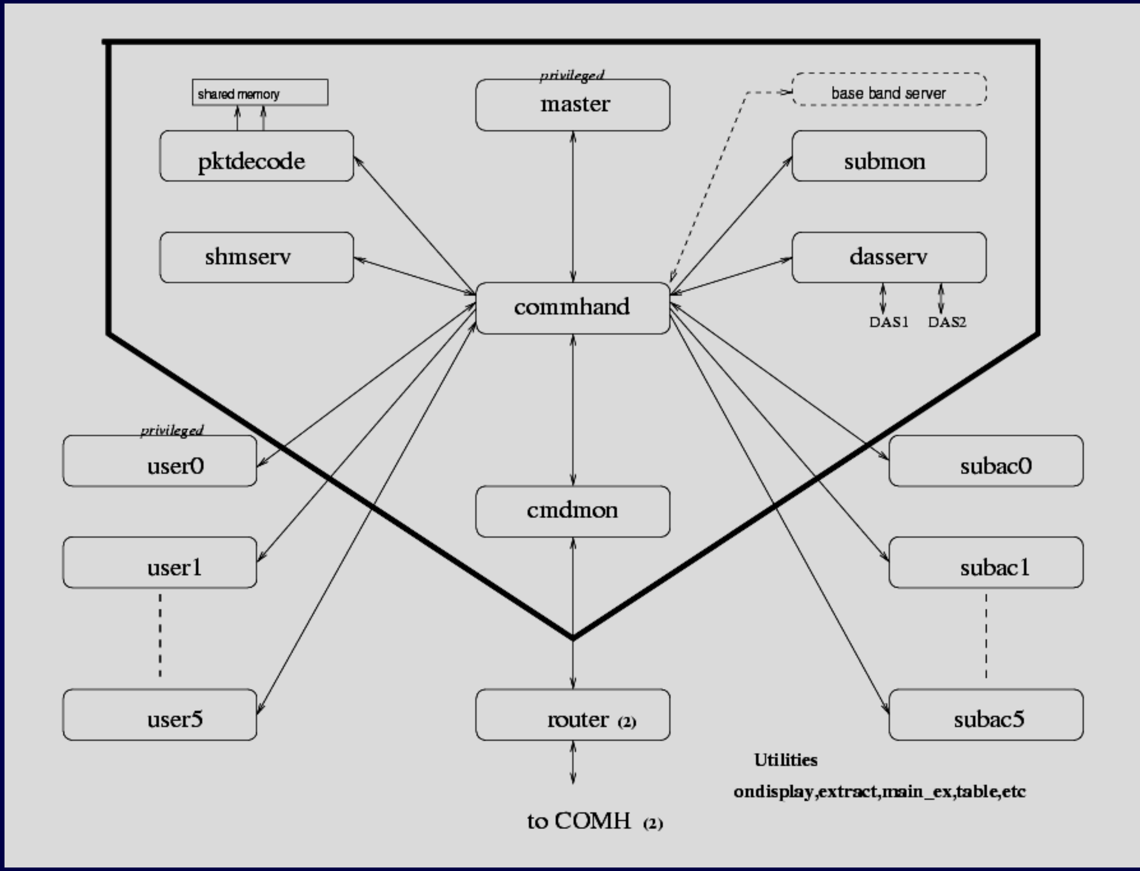
- Antenna positioning and movement
- Feed positioning control
- Configuration of entire analog receiver chain
- Safety parameters like supply voltage, temperature, wind speed etc.

Also provides a voice link between each antenna and central control room



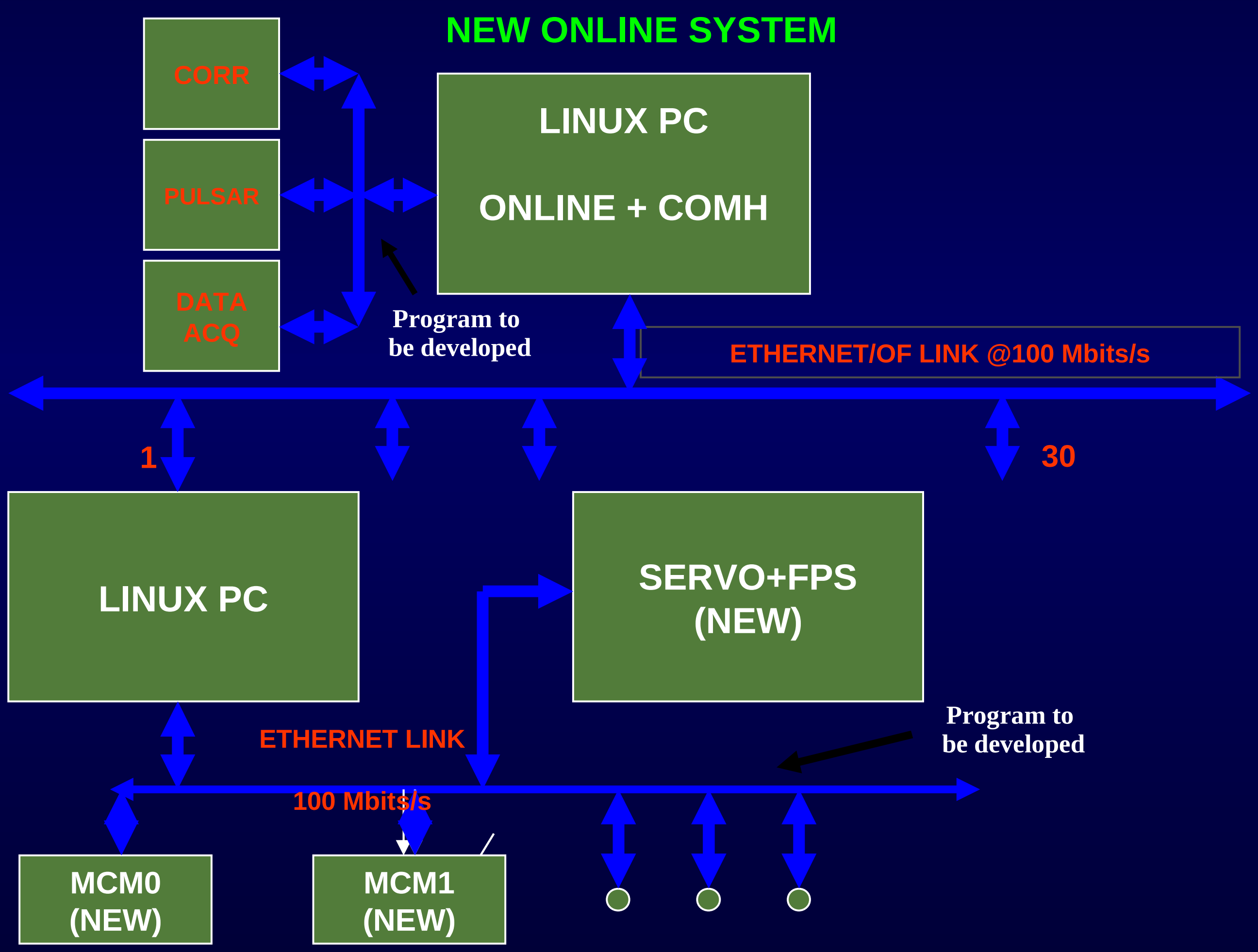
ONLINE Control Software

- Main control software on UNIX workstation that provides the user interface for the control & monitor telemetry sub-system
- 6 different subarrays can be controlled independently by different users, for different jobs.
- Can control the final data acquisition (start/stop) from the digital back-ends (correlator & pulsar receiver).



GMRT Upgrade Details

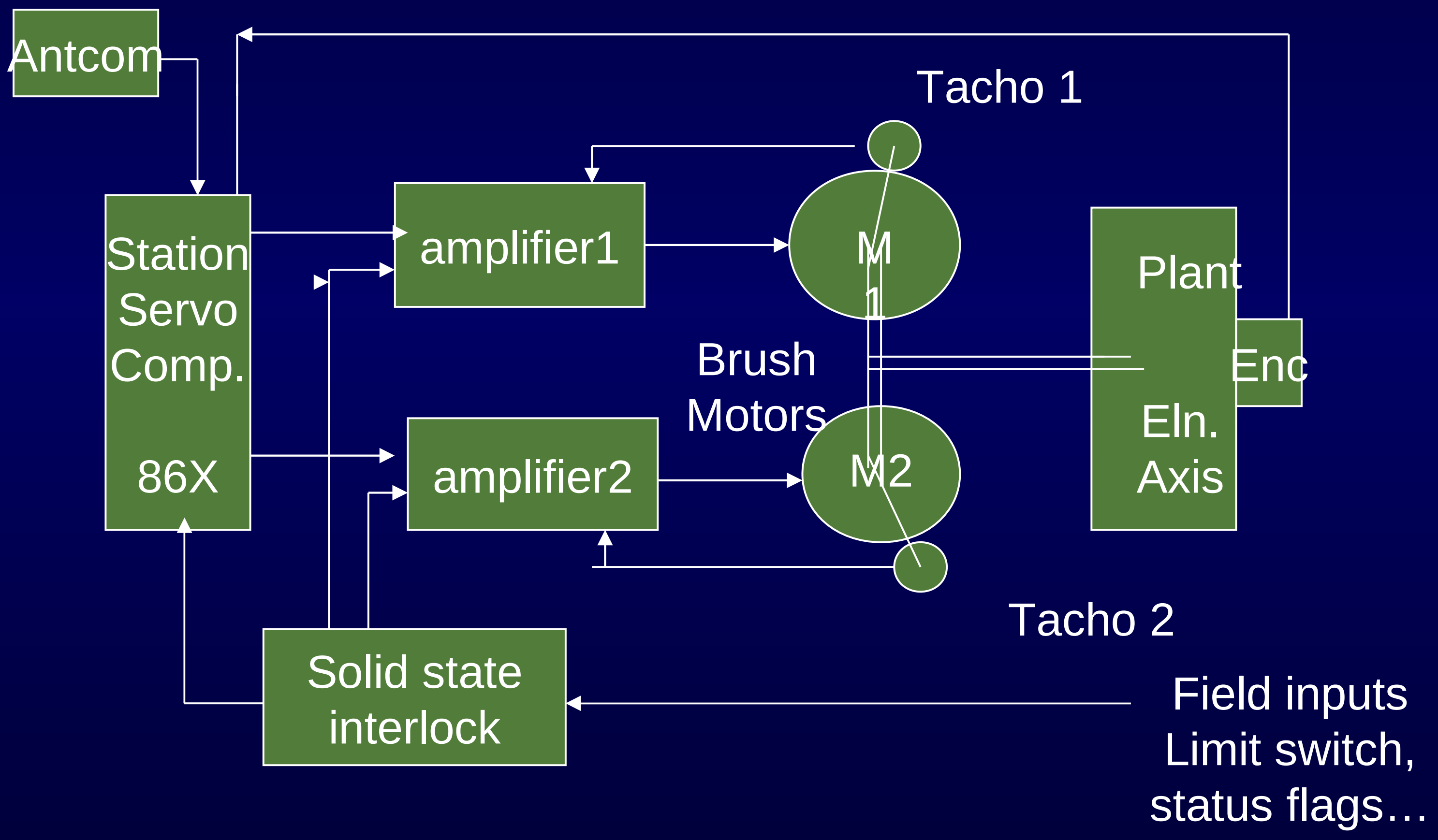
- New station control computer
- Ethernet link from central station to each antenna, via the optical fiber
- New generation monitor and control modules using modern microcontroller
- Improved control room software running on Linux platform



GMRT Upgrade : Control, Telemetry & Operations

GMRT Upgrade : Servo Systems

- Brushless DC motor drive system to replace existing motors
- New station servo control computer, based on PC-104 architecture
- Solid state interlock system

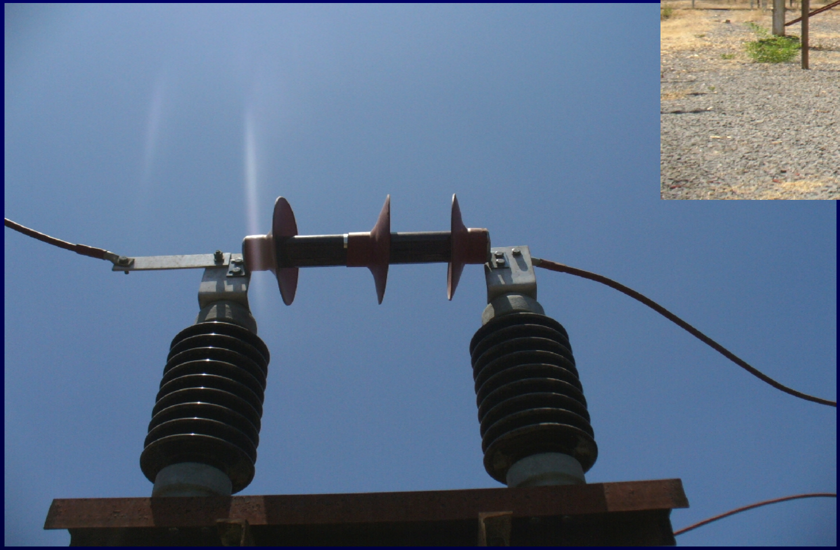


GMRT Upgrade : Mechanical Systems

- New high lift platform; improvements to existing ones
- Determination of antenna surface accuracy – repairs of the same
- New test jigs and fixtures for the new servo system

GMRT Upgrade : Electrical Systems

- Power back-up (UPS and DG sets) to cover ALL the antennas
- Finding and eliminating sources of power-line interference
- Improved reliability of electrical sub-systems



Looking ahead : The upgraded GMRT

- Seamless frequency coverage from ~ 30 MHz to 1500 MHz, ⇒ *design of completely new feeds & receiver system.*
- Improved G/Tsys by reduced system temperature ⇒ *better technology receivers*
- Increased instantaneous bandwidth of 400 MHz (from the present maximum of 32 MHz) ⇒ *modern new digital back-end receiver*
- Revamped servo system for the antennas
- Modern and versatile control and monitor system
- Matching improvements in offline computing facilities and other infrastructure
- Improvements in mechanical systems and infrastructure facilities

Features : Comparison with Current System

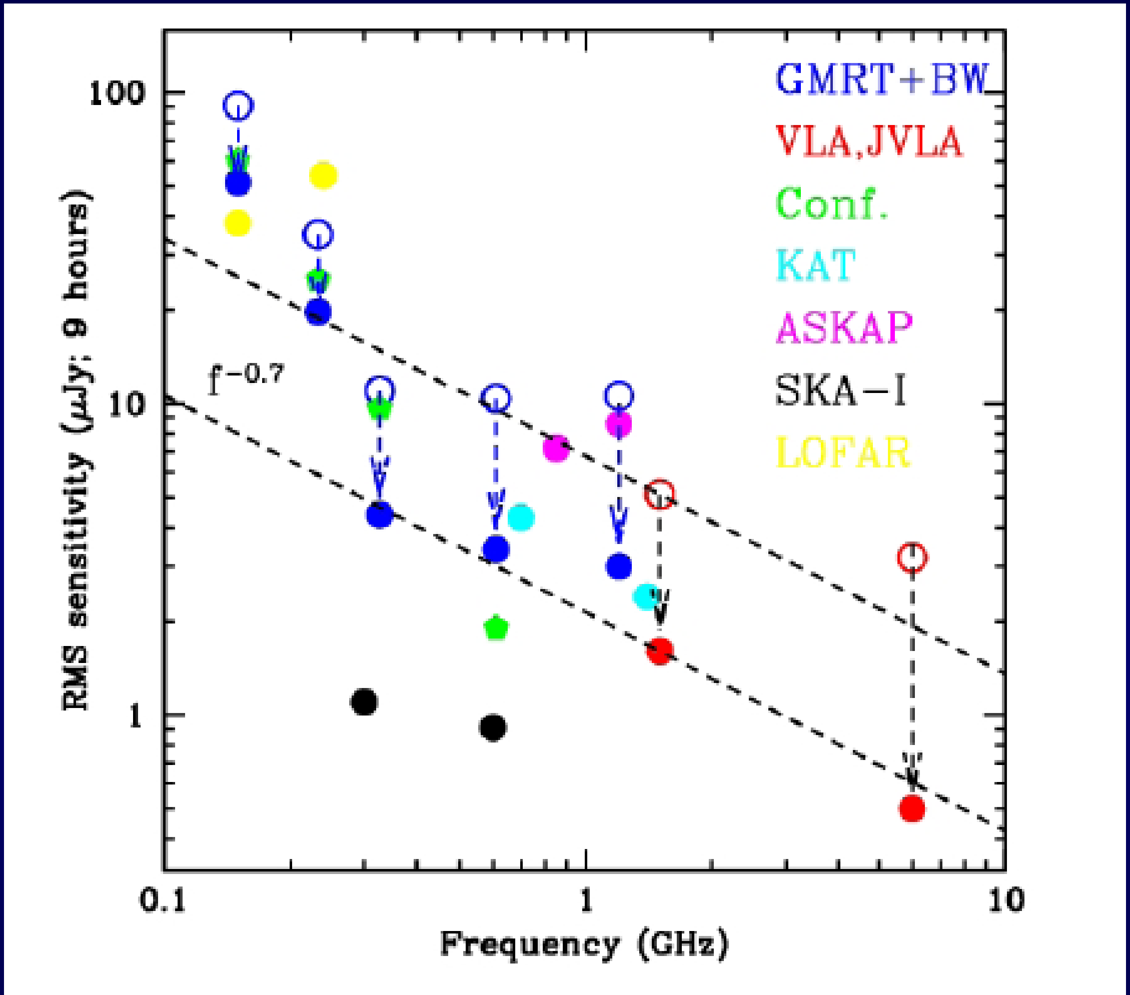
Current system

- Supports observation at specific frequency bands in 50 to 1500 Mhz.
- Instantaneous Bandwidth of 32 MHz in each polarisation.
- Facility for dual frequency observations with 32 Mhz in each band.
- Low dynamic range & RFI rejection capabilities.
- Power Level monitoring available at few stages in Receiver chain.

Upgraded System

- Seamless Coverage from 30 to 1500 MHz.
- Supports instantaneous Bandwidth of 400 MHz in each polarisation.
- Possible only if the frequency bands are within same feed bandwidth.
- Improved dynamic range and in-built RFI cancellation scheme.
- Integrated Power Level Monitoring Circuits for easy trouble shooting.

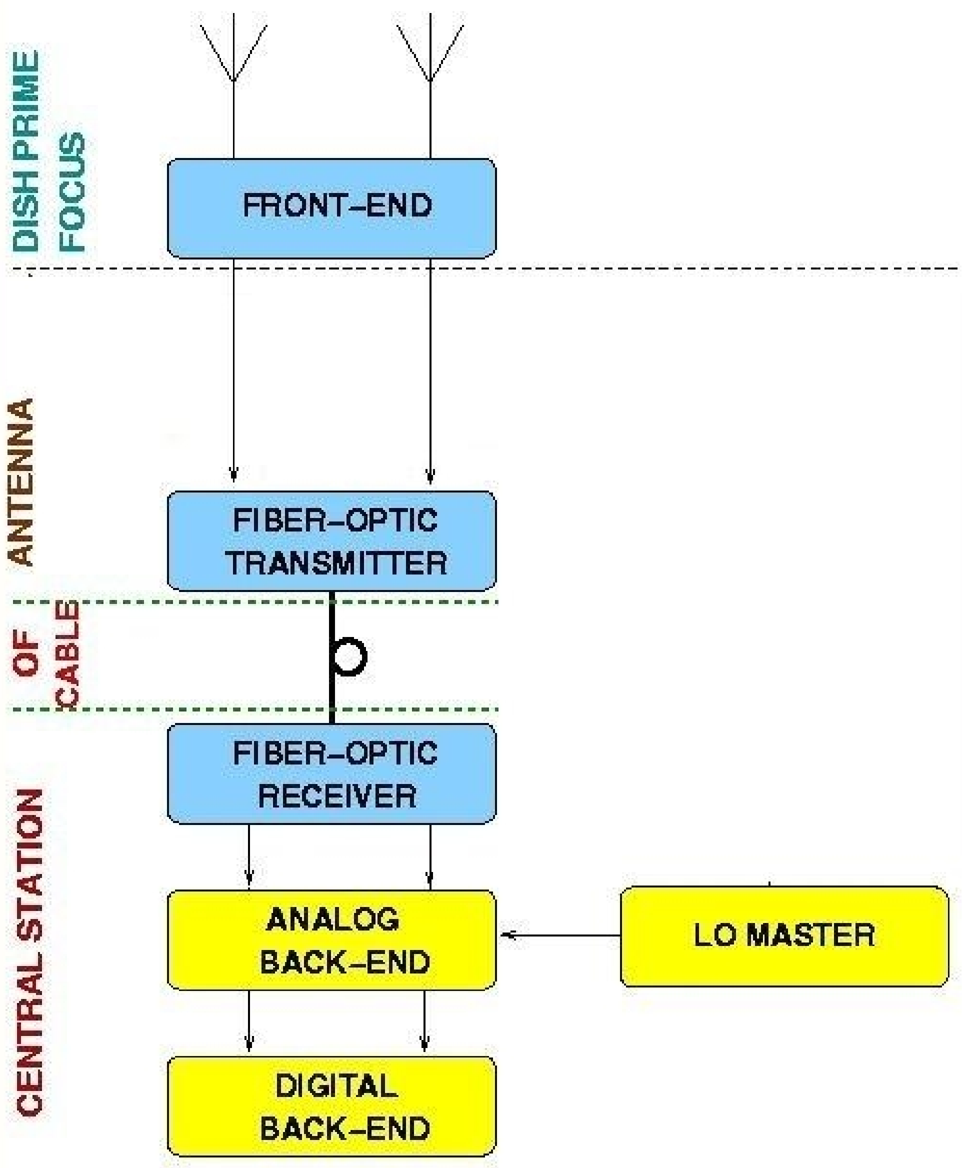
Upgraded GMRT : Expected Performance



Expected performance of the upgraded GMRT compared to other major facilities in the world, present and projected (courtesy : Nissim Kanekar, NCRA)

Expected Performance Figures : Array mode

	Frequency Band (MHz)			
	125-250	250-500	550-900	1000-1450
Max Bandwidth (MHz)	125	250	350	400
Incoherent Array Beam FoV (deg)	3.2	1.4	0.8	0.4
Incoherent Array search sensitivity for 10 min (uJy)	2500	350	250	200
Phased Array Beam FoV (arcsec)	20	9	5	2
Phased Array search sensitivity for 10 min (uJy)	400	60	40	35



GMRT RECEIVER BLOCK SCHEMATIC

Upgraded Receiver Block Schematic

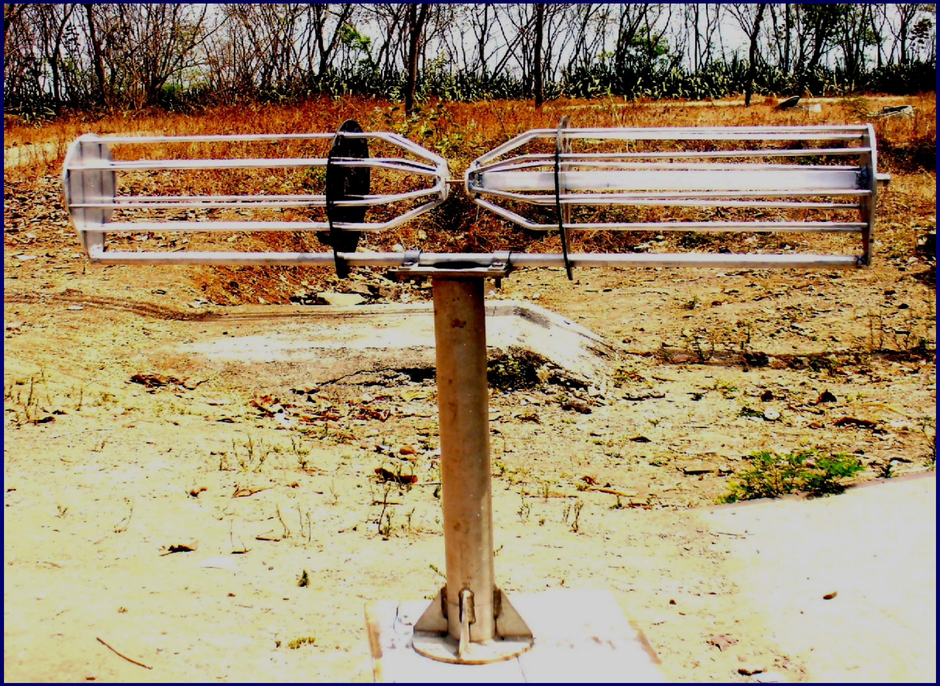
1. New feeds with wider frequency coverage allowing observations at 30 to 1500 MHz band
2. Improved Front-end electronics with low noise and increased dynamic range
3. RF signal is directly transported to Central station using a Broadband analog fiber
4. Reduced electronics at antenna sites

Feeds Upgrade : 30 – 80 Mhz

- 30 – 80 MHz : prototype system (in collaboration with RRI, Bangalore) installed & tested on 4 antennas; awaiting decision for mass production

30 – 80 MHz Feed

Feed Upgrade : 125 – 250 MHz



Improved 150 MHz feed
(130 to 280 MHz)

Feed Upgrade : 250 – 500 MHz

- 250 – 500 MHz : prototype feed + receiver tested & now in mass production

250 – 500 MHz feed

Feed Upgrade : 550 – 900 MHz

- 550 – 900 MHz : prototype feed + receiver tested on 2 antennas; getting ready for mass production

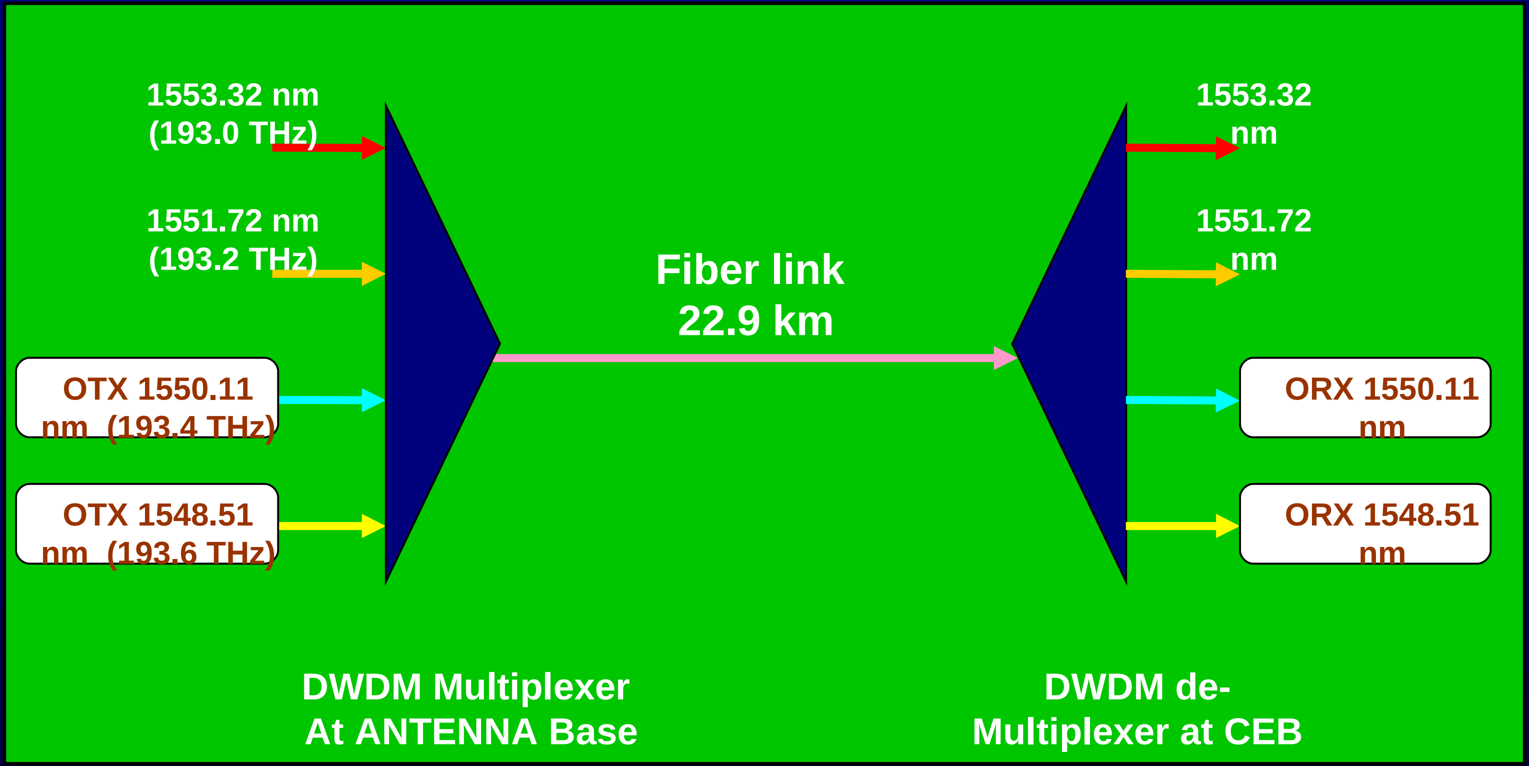
550 – 900 MHz feed

Feed Upgrade : 900 – 1500 MHz

- Corrugated Horn
- Quad-Ridged Orthomode Transducer
- 880-1500 MHz Band Coverage

GMRT Upgrade : Optical Fiber Systems

- DWDM based, broad-band (2.5 GHz), analog optical fibre transmission scheme; features : 20 dB S/N; 40 dB dynamic range ; < $ 2000 per Tx -- Rx set !
- Will bring back 2 broad-band RF channels + existing IF channels ; will also support new and existing control and monitoring schemes
- Prototype tested and installed on 12 antennas ; in mass production phase

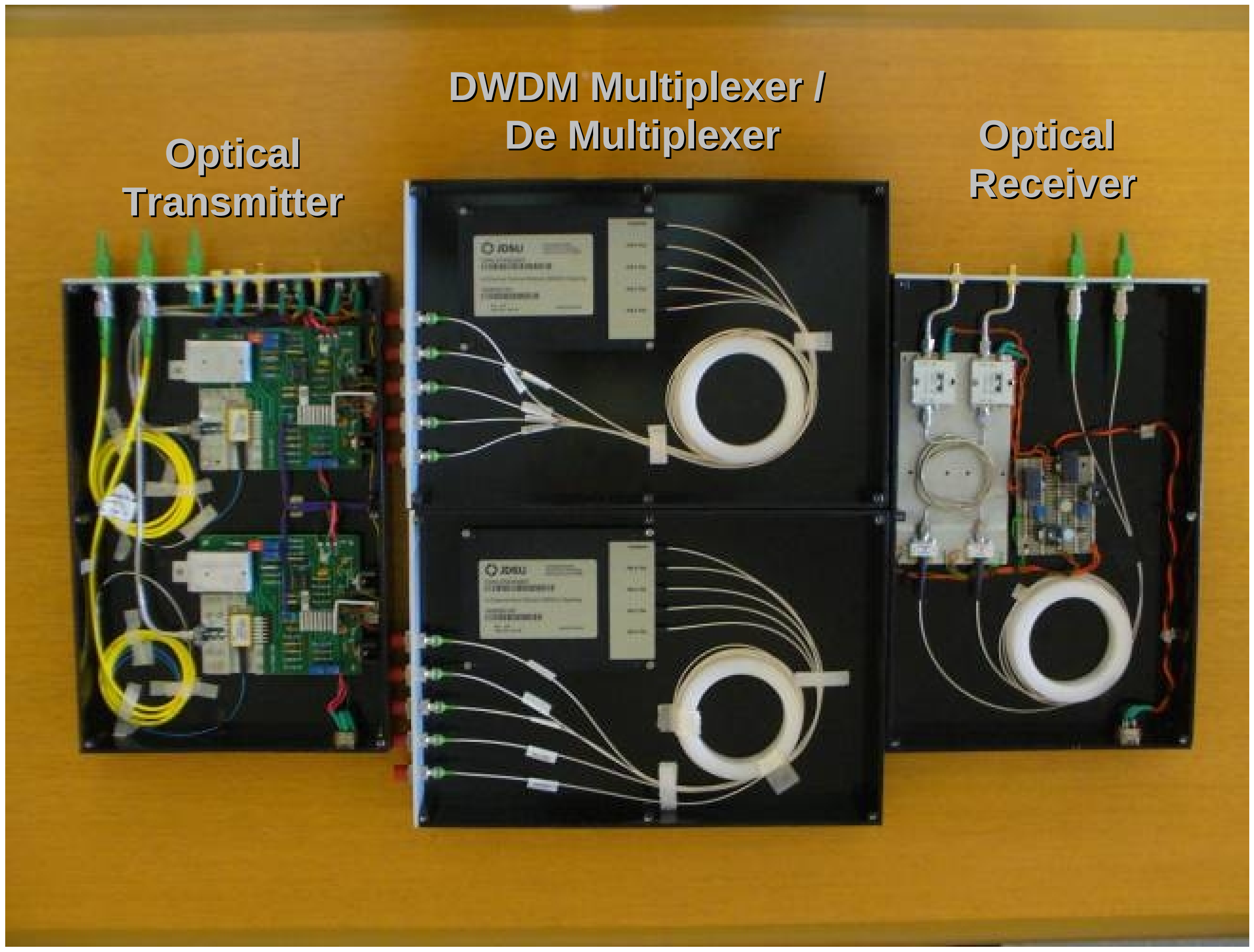


GMRT Upgrade : Optical Fiber Systems

Overall System Specifications

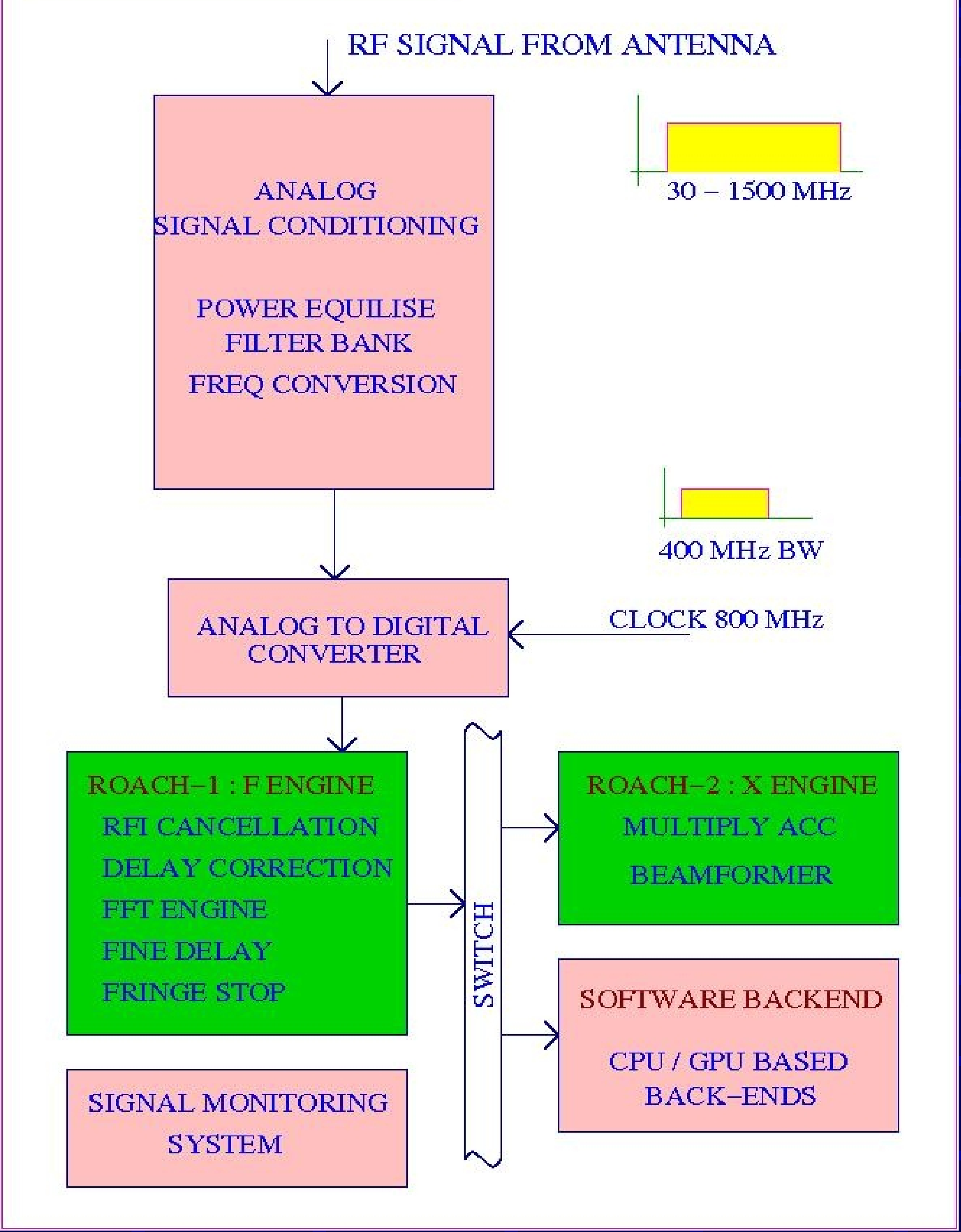
- Analog bandwidth : 0.300 MHz – 2.5 GHz
- Gain flatness over full band : + / - 1 dB
- Return loss over full band : < - 18 dB
- 1 dB compression point : + 23 dBm
- 3rd order intercept point : + 34 dBm
- Spurious Free Dynamic Range : 136 $dB/Hz^{2/3}$
- DWDM adjacent channel RF isolation : 65 dB

GMRT Upgrade : Optical Fiber Systems



DWDM Based Broadband Analog Fiber Optic System

New Backend Block Schematic

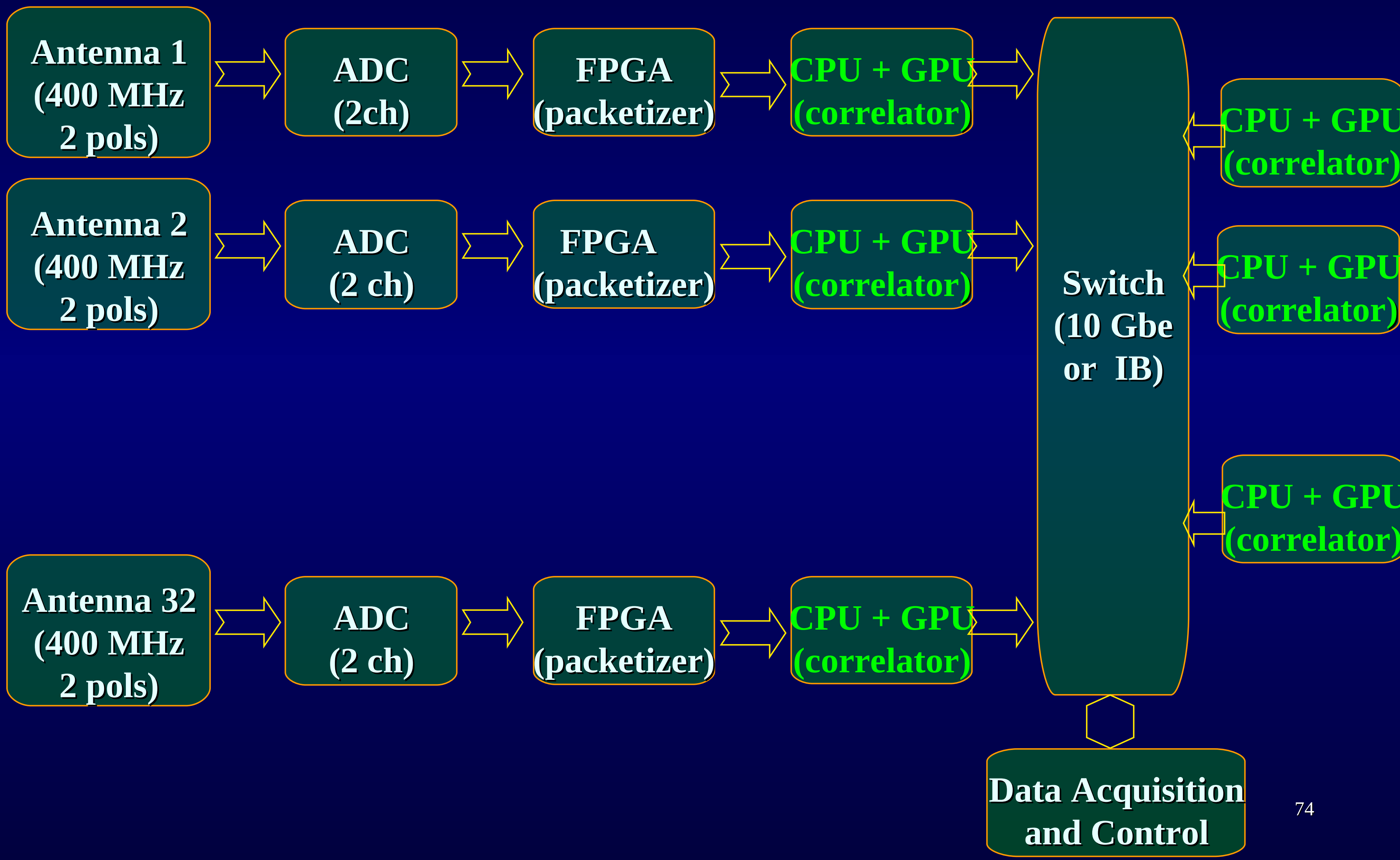


Signal Processing by Backend Electronics at the Central Station :

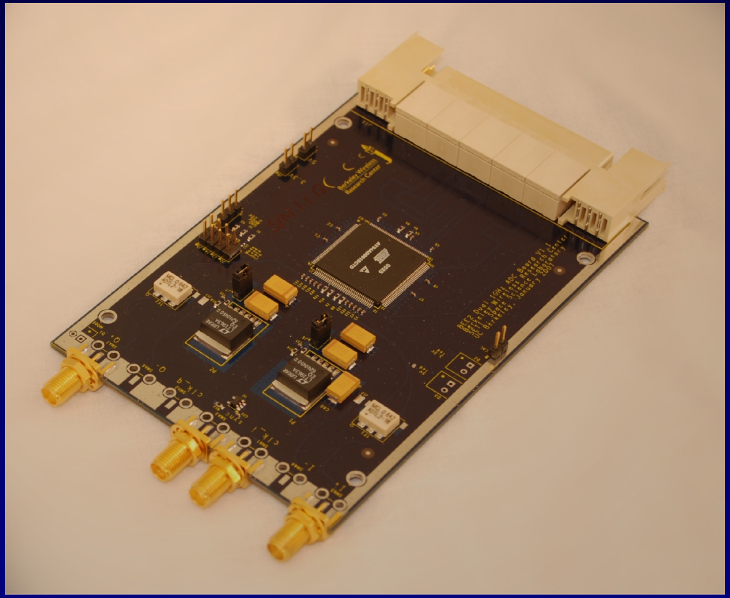
- Analog Processing
- Digitisation
- Digital Processing
- RFI Excision
- Signal Monitoring

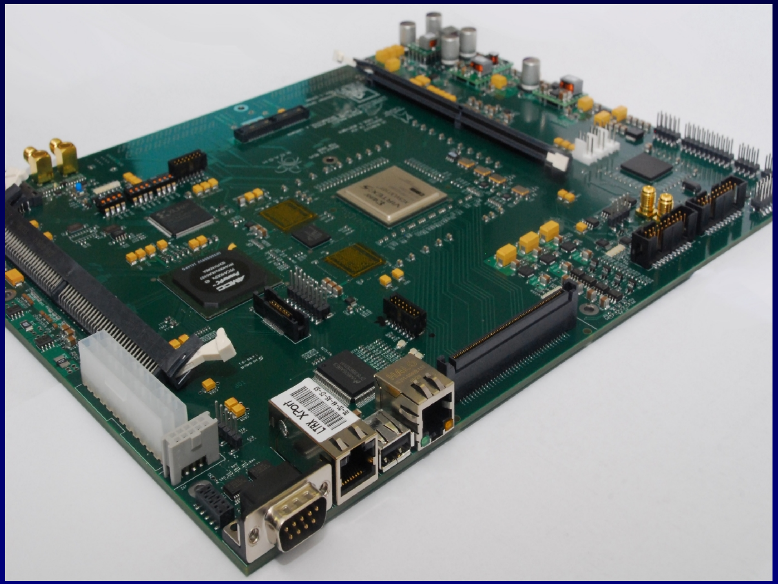
Hybrid Correlator Design

(collaboration with NVIDIA, India & Swinburne Univ)



Upgraded Digital Back-end development

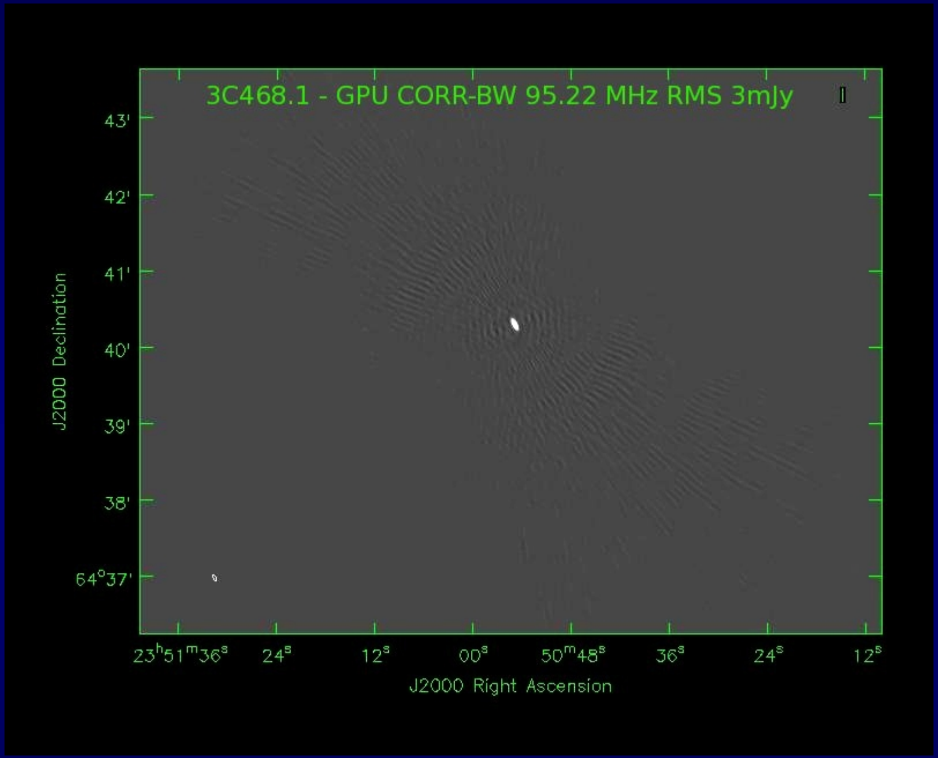


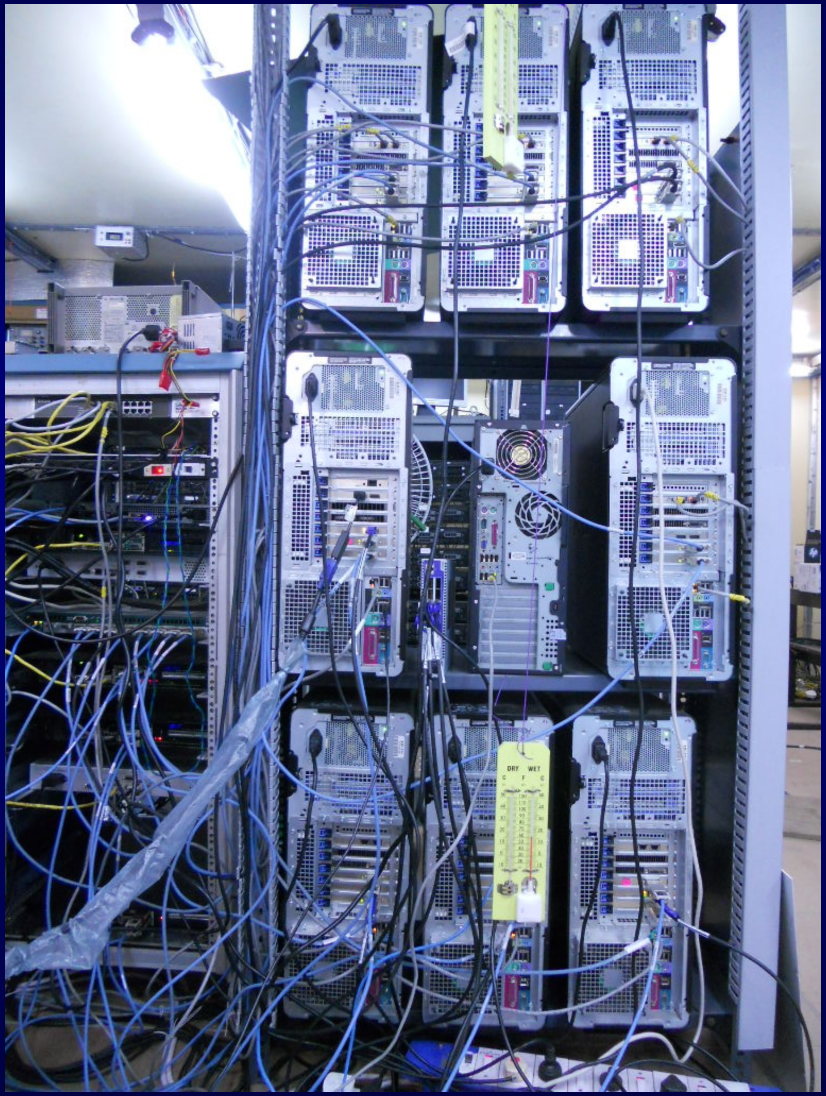


- Xilinx virtex-5 FPGA boards with ADC cards connected
- CPU hosts : DELL T7500; Myricom 10GbE NICs; Infiniband interconnect using 8-port Mellanox Switch
- GPU cards : Tesla C2050 and K20

Upgraded Digital Back-end development

Prototype 8 antenna system

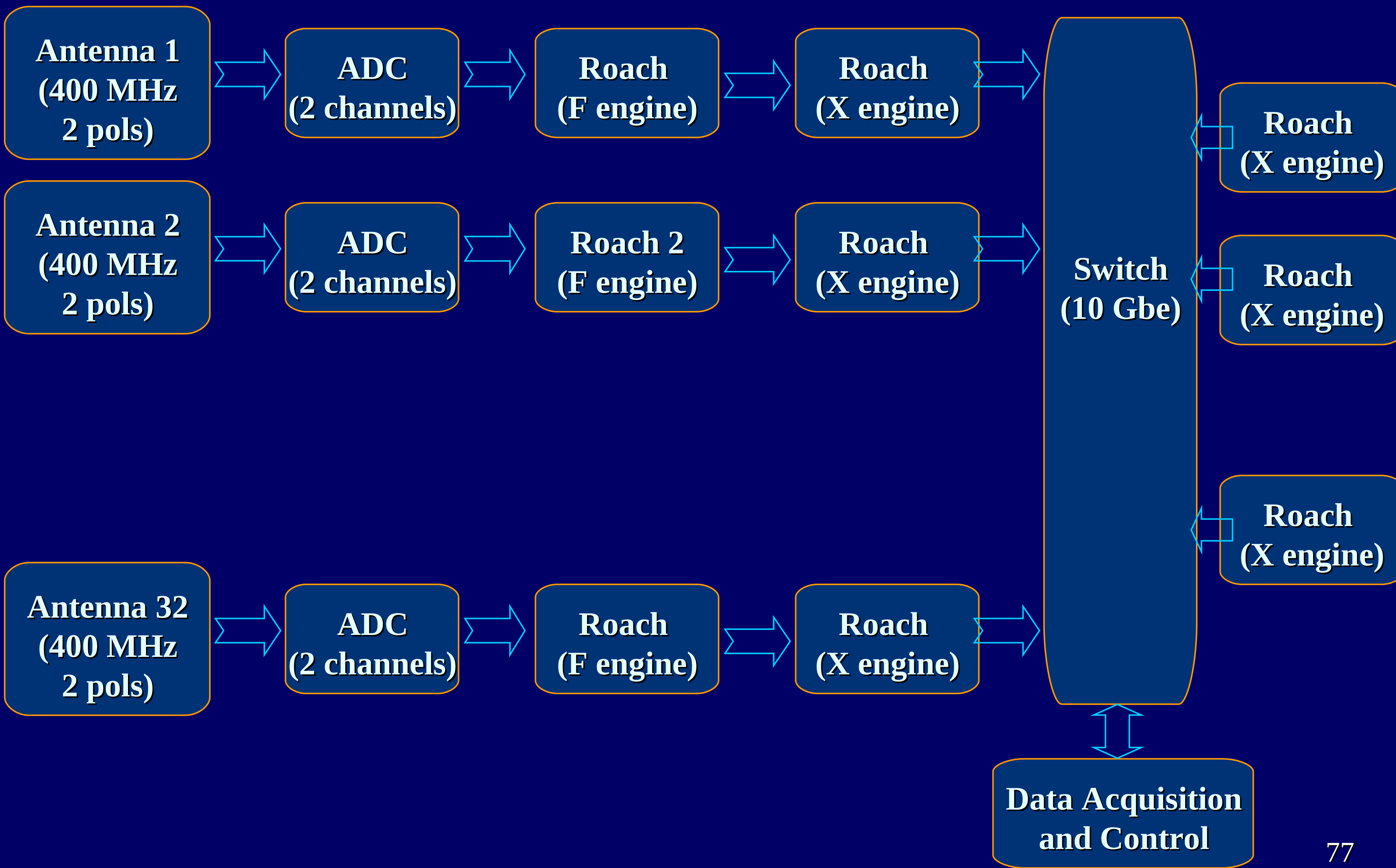




- First GMRT image using 100 MHz RF BW at L-band
- RMS noise : 3 mJy

Packetised Correlator Design

(collaboration with SKA-SA + CASPER)

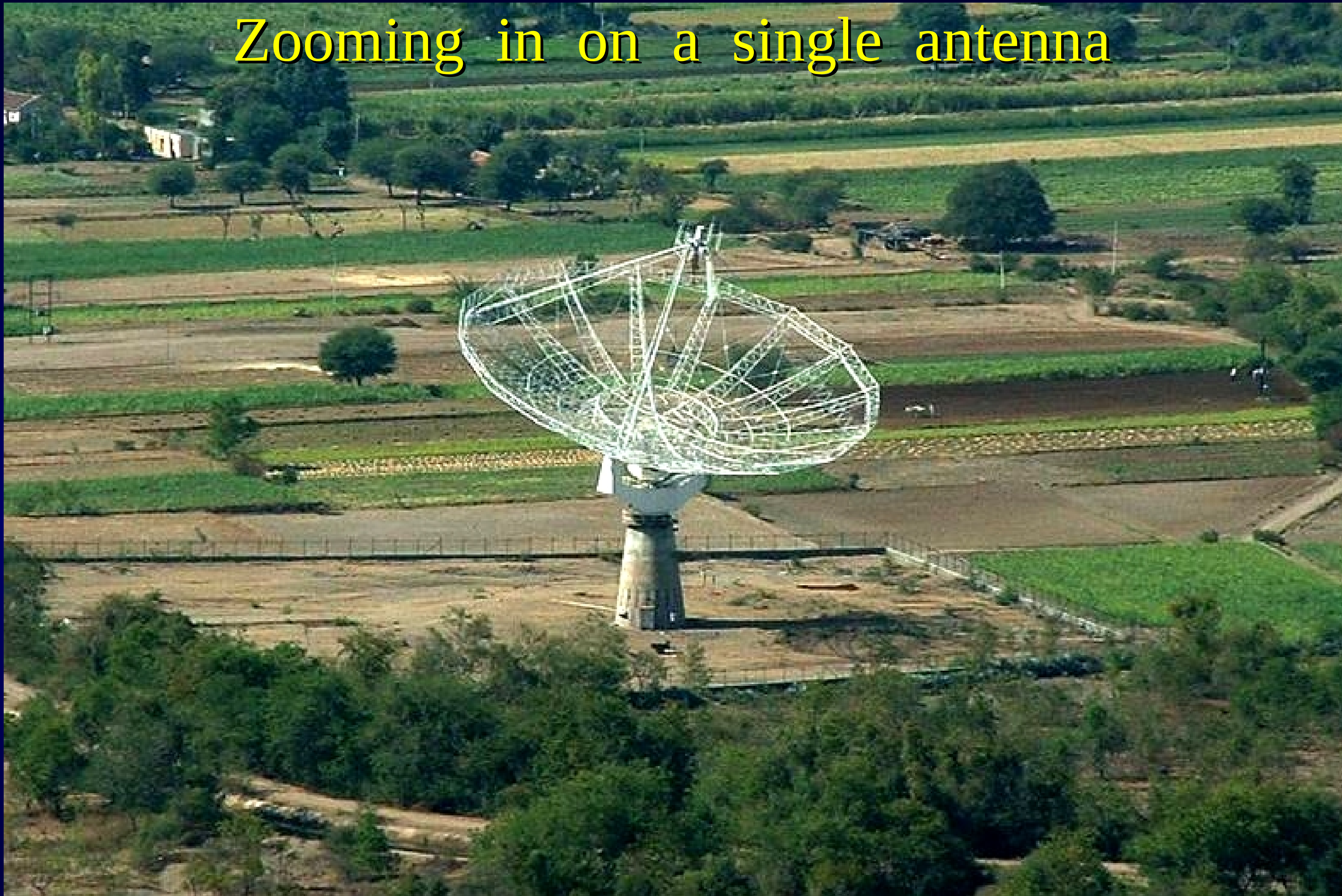


GMRT antennas – more pictures

Panoramic View of Central Array

A view of GMRT Observatory

Zooming in on a single antenna



In the evening …

… at sunset

Thank You