The upgraded GMRT and prospects for VLBI

Photograph courtesy : Shilkumar Meshram & Divya Oberoi (NCRA)

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VLBI-w-uGMRT meet online from Pune 11th Feb 2021

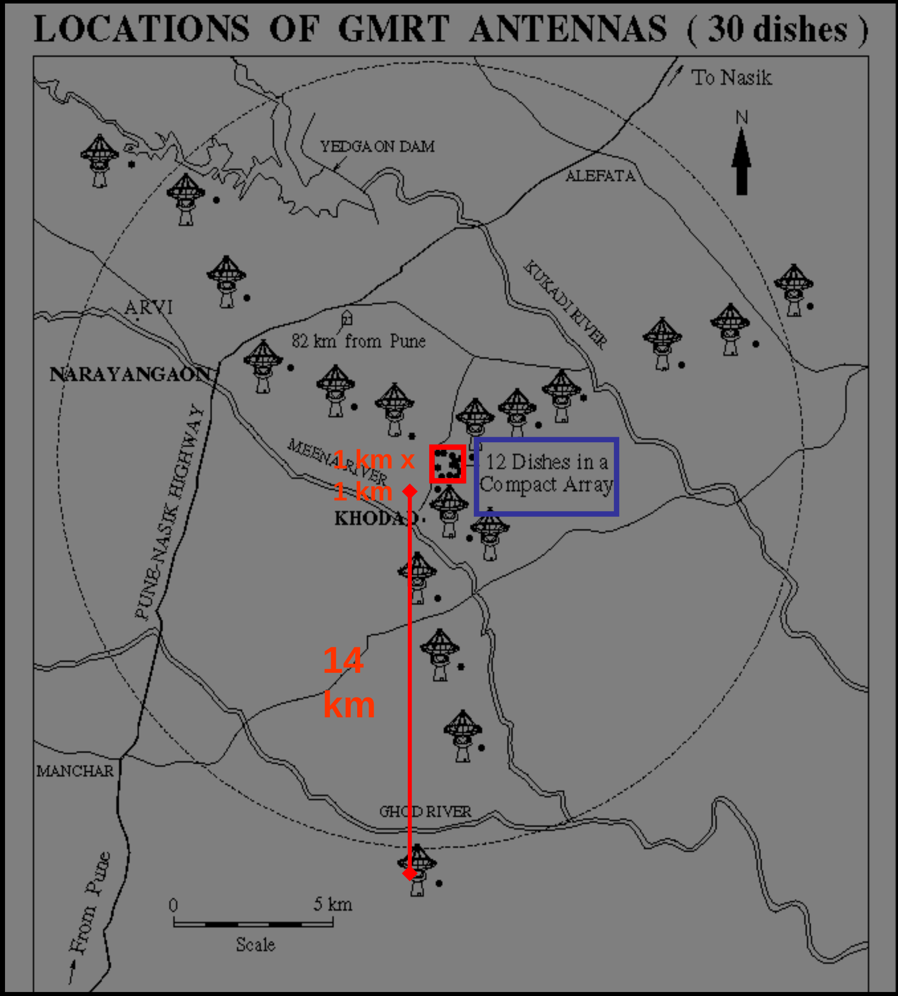
The GMRT : an overview

- The Giant Metre-wave Radio Telescope (GMRT) is a major low frequency facility (~ 100 - 1450 MHz) – one of the largest in the world at these frequencies.
- Array telescope consisting of 30 antennas of 45 m diameter, spread out over an area of 30 km diameter.
- Designed & built during the 1990s; operated since 2002 as international facility.
- Recently (2018) completed a major upgrade : more versatile facility, with increased sensitivity.

Panoramic view of the GMRT

The original (legacy) GMRT

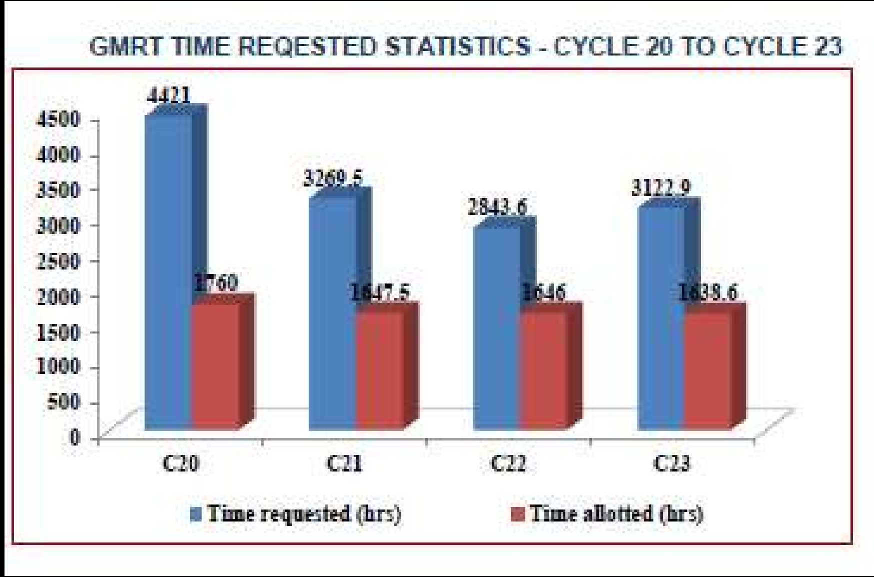
- 30 dishes, 45 m diameter each
  - 12 dishes in a central 1 km x 1 km region (central square)
  - remaining along 3 arms of Y-shaped array
  - baselines : ~ 200 m (shortest);
    ~ 30 km (longest)
- Frequency range (of original, legacy GMRT) :
  - 130-170 MHz
  - 225-245 MHz
  - 300-360 MHz
  - 580-660 MHz
  - 1000-1450 MHz
  - max instantaneous BW = 32 MHz
- Effective collecting area :
  - 30,000 sq m at lower frequencies
  - 20,000 sq m at highest frequencies
- Supports 2 modes of operation :
  - Interferometry, aperture synthesis
  - Beamformer (incoherent & coherent)

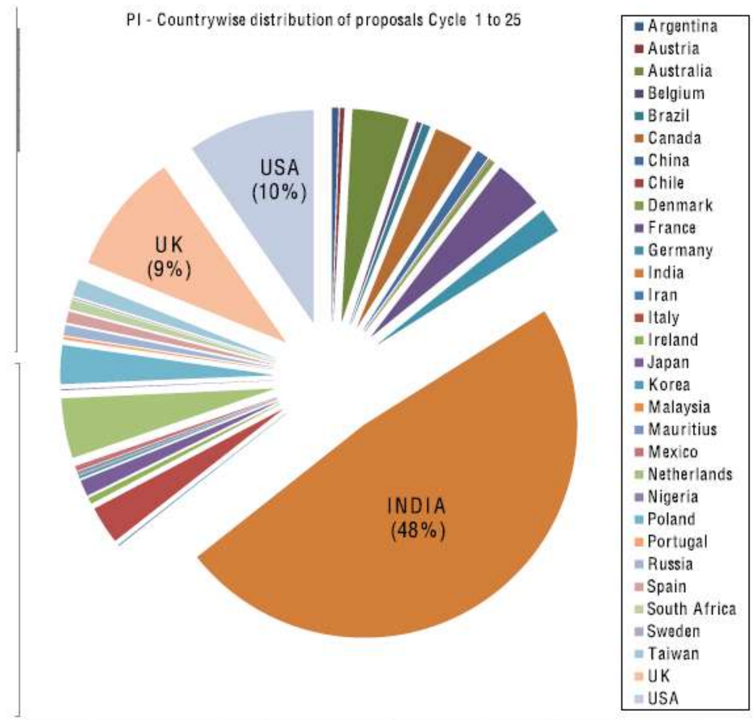


GMRT : Usage Statistics

- GMRT sees users from all over the world : distribution of Indian vs Foreign PIs is close to 50:50

- The GMRT has been typically oversubscribed by a factor of 2 or more





Country	Nos	Country	Nos	Country	Nos	Country	Nos	Country	Nos
Argentina	8	China	14	Iran	1	Mauritius	3	Russia	12
Austria	5	Chile	1	Italy	45	Mexico	6	Spain	13
Australia	67	Denmark	6	Ireland	7	Netherlands	71	South Africa	11
Belgium	6	France	59	Japan	19	Nigeria	1	Sweden	1
Brazil	9	Germany	30	Korea	3	Poland	46	Taiwan	20
Canada	47	India	758	Malaysia	1	Portugal	3	UK	145
								USA	152
Total Proposals Received						1570			

GMRT : Range of Science

The GMRT is a powerful instrument to probe several astrophysical objects and phenomena :

- The Sun, extrasolar planets
- Pulsars : rapidly rotating neutron stars
- Other Galactic objects like : supernova remnants, microquasars etc
- Other explosive events like Gamma Ray Bursts
- Ionized & neutral Hydrogen gas clouds (our Galaxy & other galaxies)
- Radio properties of different kinds of galaxies; galaxy clusters
- Radio galaxies at large distances in the Universe
- Cosmology and the Epoch of Reionization
- All sky surveys such as the 150 MHz TGSS

…and many interesting new results have been produced in last 18 yrs or so : ~ 50 papers per year based on GMRT data

Next Gen : the upgraded GMRT

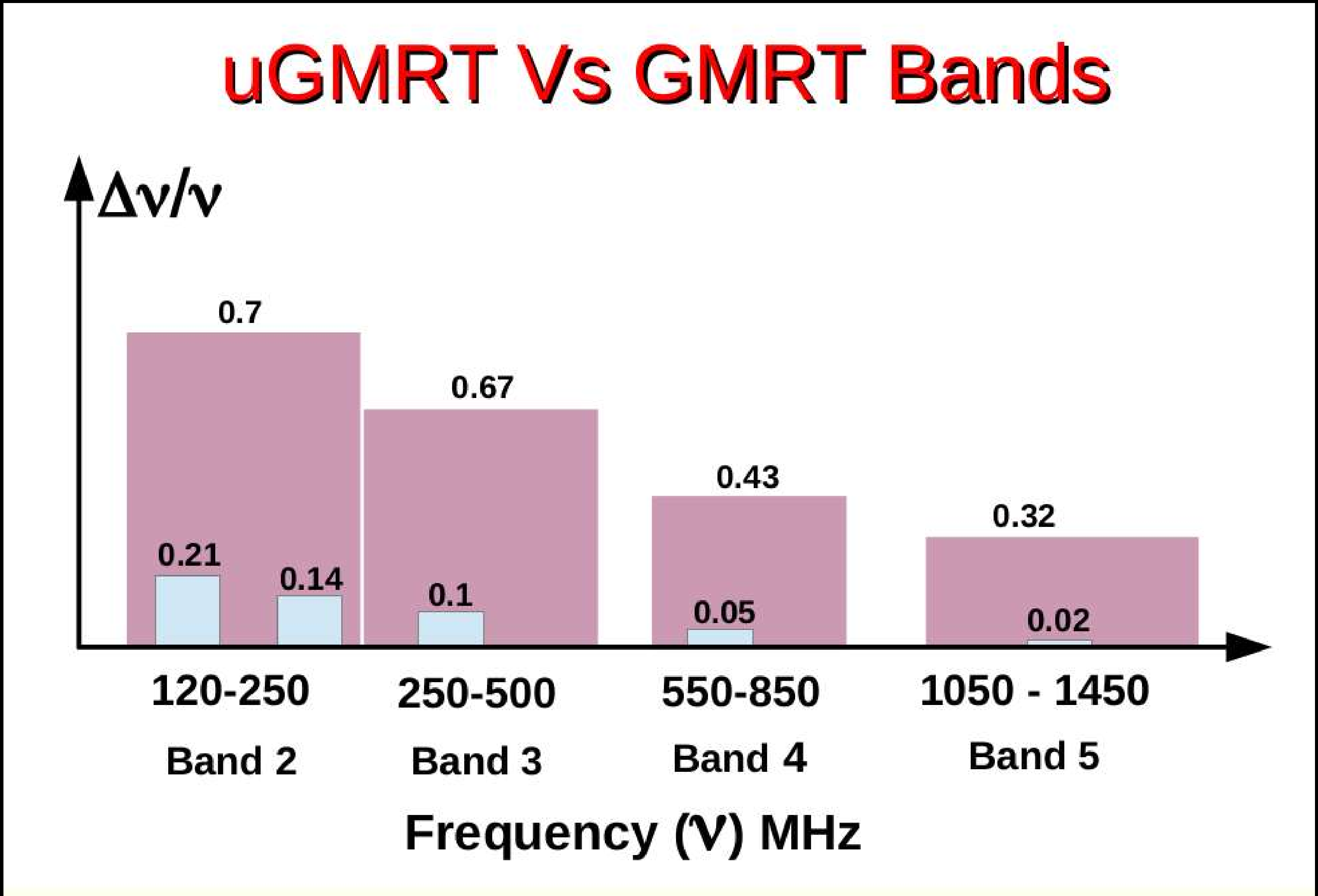
- First concepts proposed : 2007-2008
- Serious work started : c. 2012
- Completed : towards end of 2018 (early partial releases from 2016 onwards)
- Full uGMRT available to users : April 2019 onwards

NextGen : the upgraded GMRT

Main goals for the upgraded GMRT (uGMRT) were identified as :

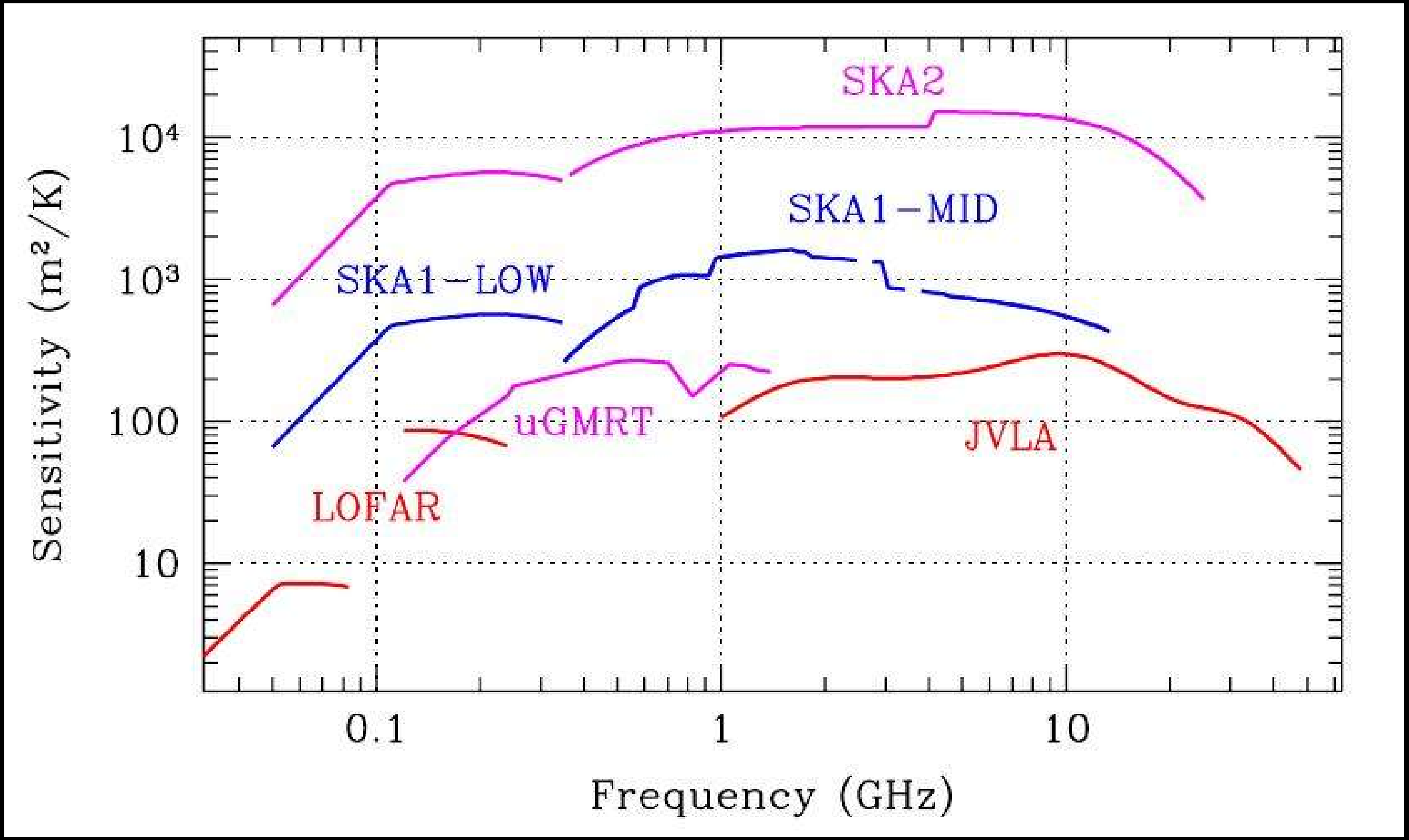
- Seamless frequency coverage : target ~ 50 MHz to 1500 MHz, instead of the limited bands at present ➔ *design of completely new feeds and receiver systems with ~ octave bandwidths*
- Improved dynamic range and G/Tsys ➔ *better technology receivers*
- Increased instantaneous bandwidth of 400 MHz (from the present maximum of 32 MHz) ➔ *new digital back-end receiver*
- Revamped servo system ➔ *brushless drives, new servo computer etc*
- Modern, versatile control & monitor system (synergy : *SKA contribution)*
- Matching improvements in offline computing & archiving facilities
- Improvements in mechanical & electrical systems, infrastructure facilities, commensurate with life of observatory
- To be done without compromising availability of existing GMRT to users

GMRT vs uGMRT : Frequency Coverage



courtesy : Ruta Kale

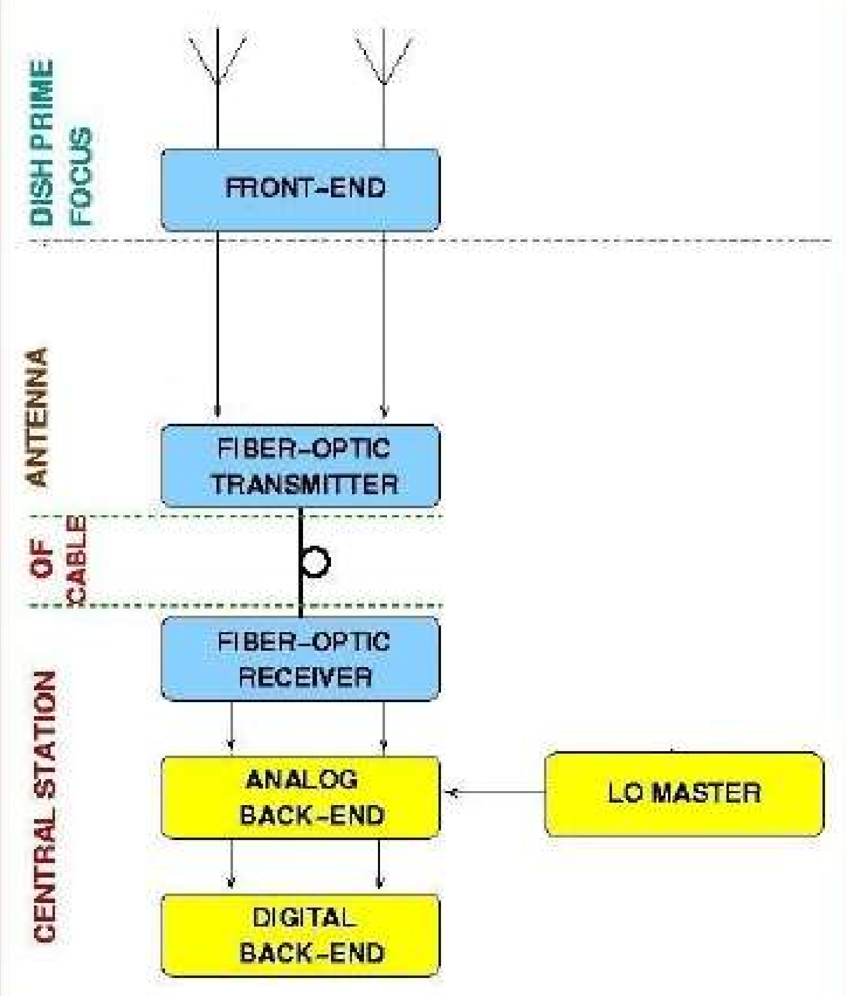
uGMRT : sensitivity comparison



Only SKA-I will do better then uGMRT at centimeter wavelengths

uGMRT Receiver System : Overview

- Broad-band feeds + FE (in octaves) :
  - 1000 – 1450 MHz (updating L-band)
  - 550 – 850 MHz (replacing 610)
  - 250 – 500 MHz (replacing 325)
  - 120 – 250 MHz (replacing 150)
- Modified optical fibre system to cater to wideband (50 to 2000 MHz) dual pol RF signals (while allowing existing IF signals)
- Analog back-end system to translate RF signals to 0 - 400 MHz baseband
- Digital back-end system to process 400 MHz BW for interferometric and beam modes



GMRT RECEIVER BLOCK SCHEMATIC

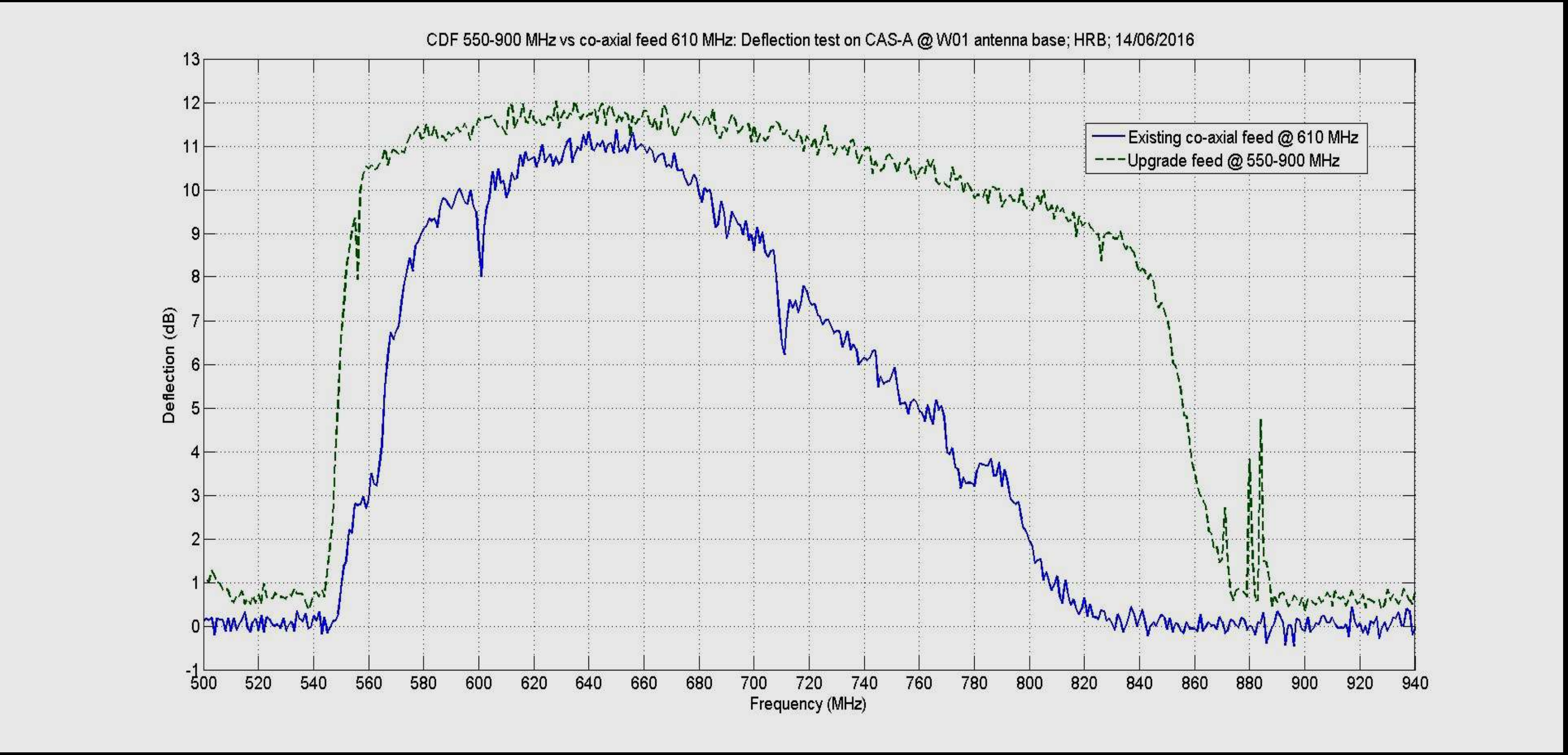
Wideband feeds + FE for uGMRT : 550-850 MHz system – “Band 4”

- Replaces existing 235/610 MHz system
- Front-End system split into two parts :
- Polariser + LNA is right next to feed (to minimize the loss)
- Rest of the FE electronics is in the regular box

Cone Dipole feed (for 550-850) alongwith polarizer and LNA

Wideband feeds + FE for uGMRT : 550-900 MHz system – "Band 4"

- Performs better than existing feed at 610 MHz
- Nice, clean band with negligible RFI



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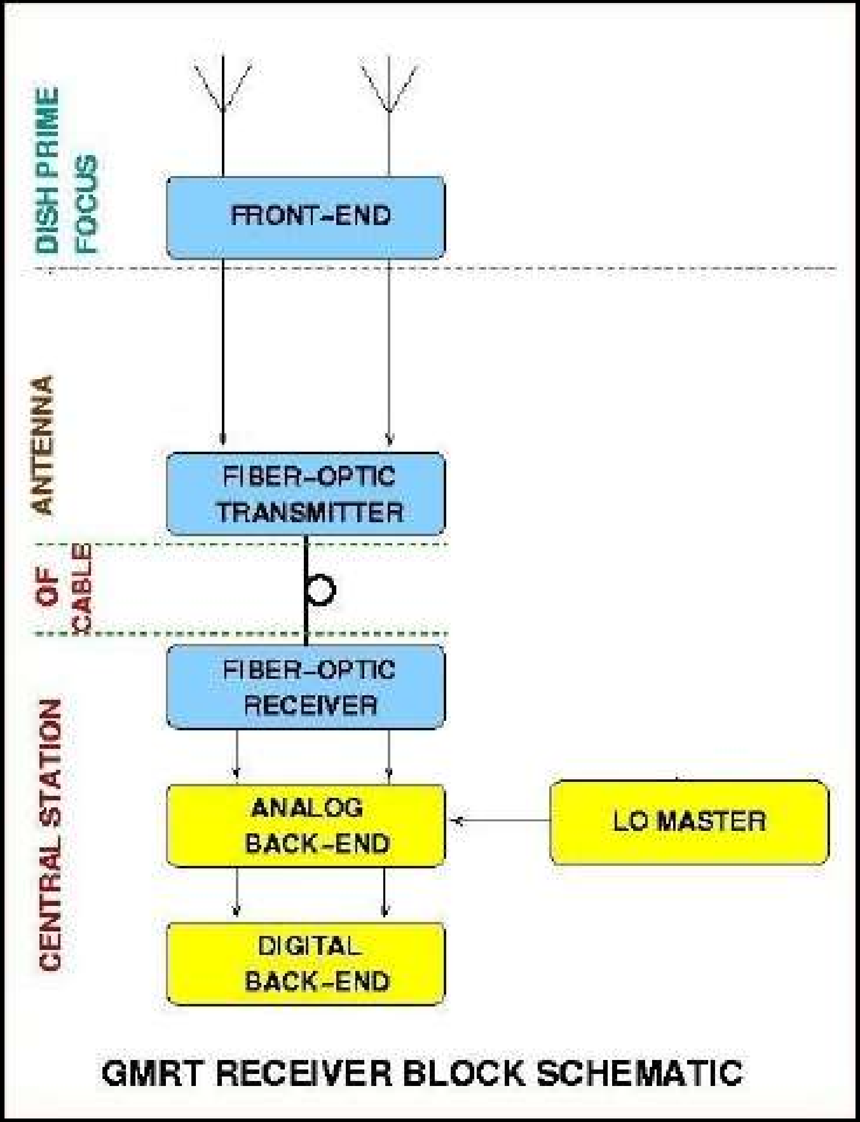
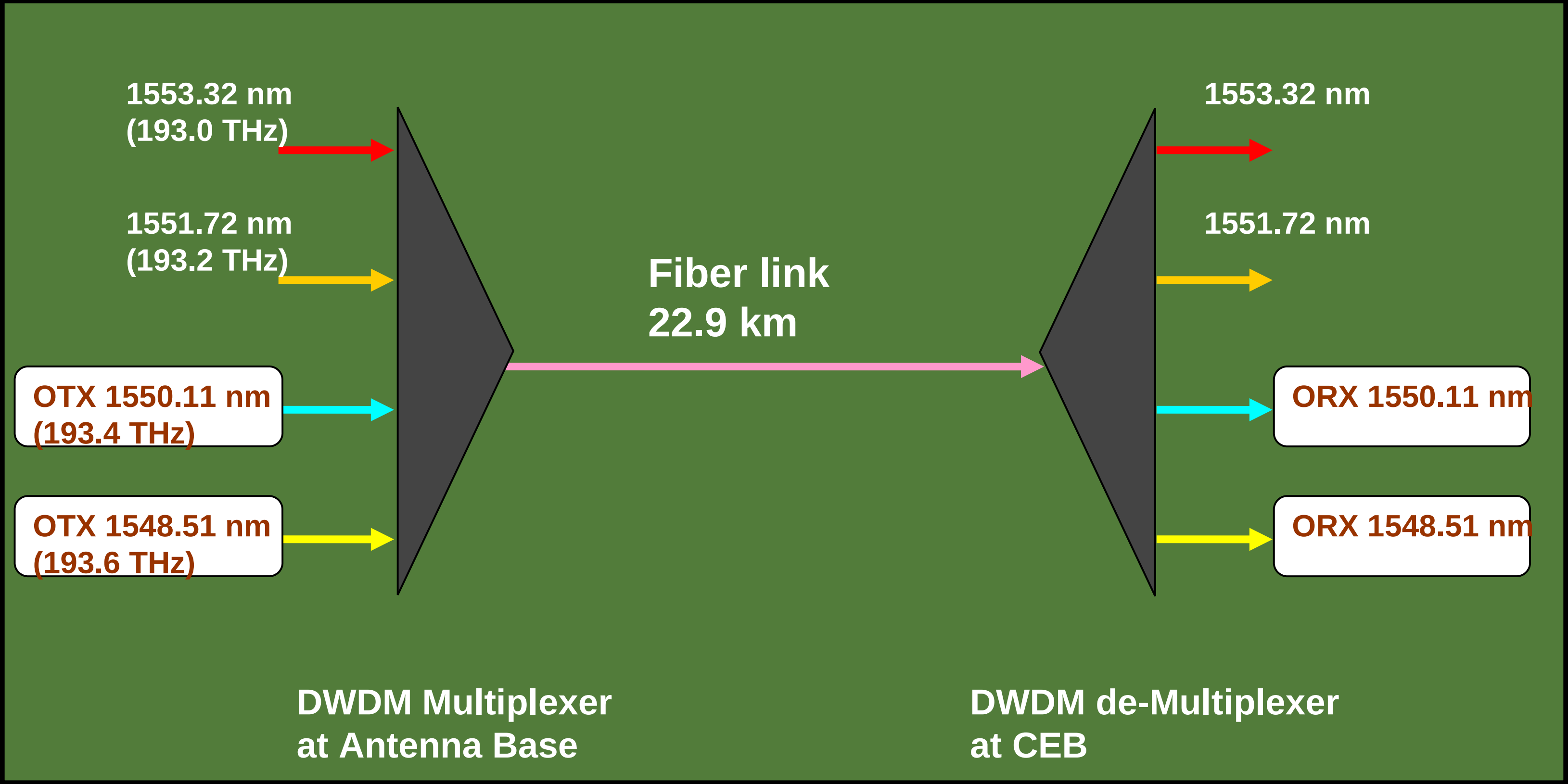


uGMRT : Optical Fibre System

- DWDM based, broad-band (2.5 GHz), analog optical fibre transmission scheme; features : 20 dB S/N; 40 dB dynamic range
- Brings back 2 broad-band RF channels + existing IF channels ; also supports new and existing control and monitoring schemes



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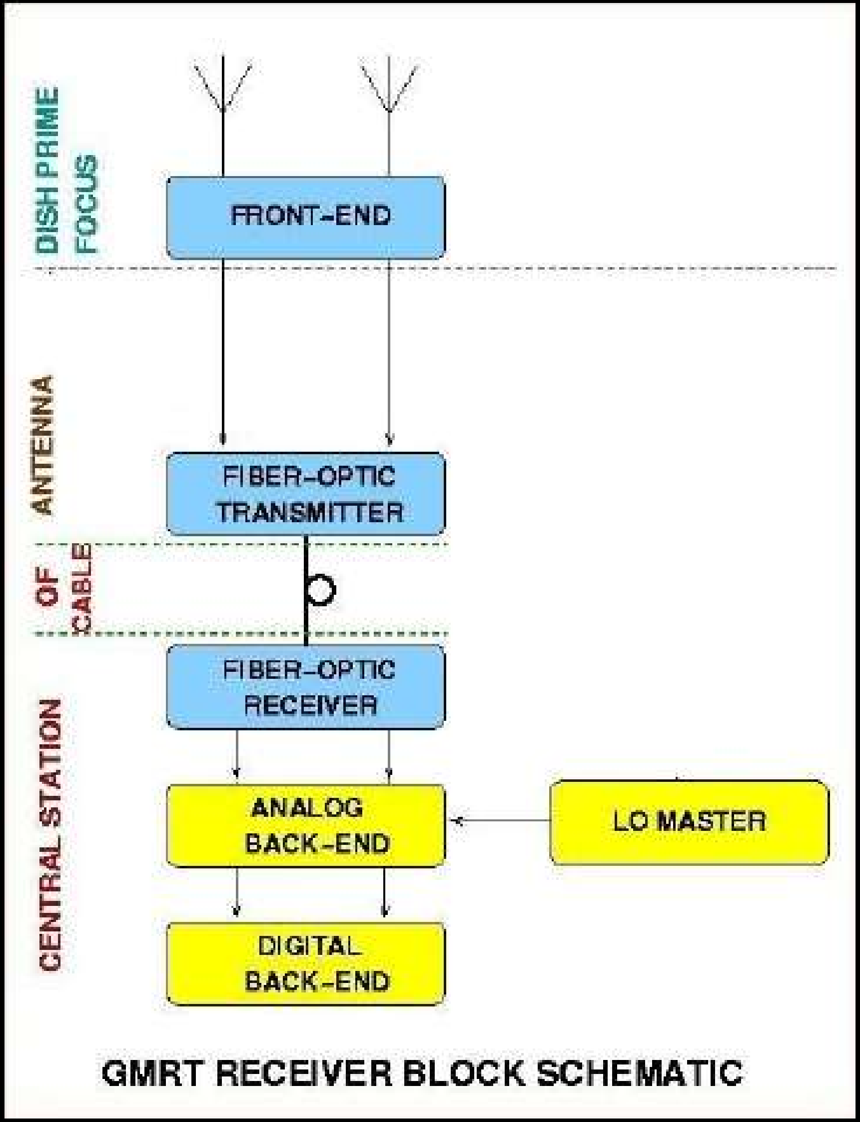
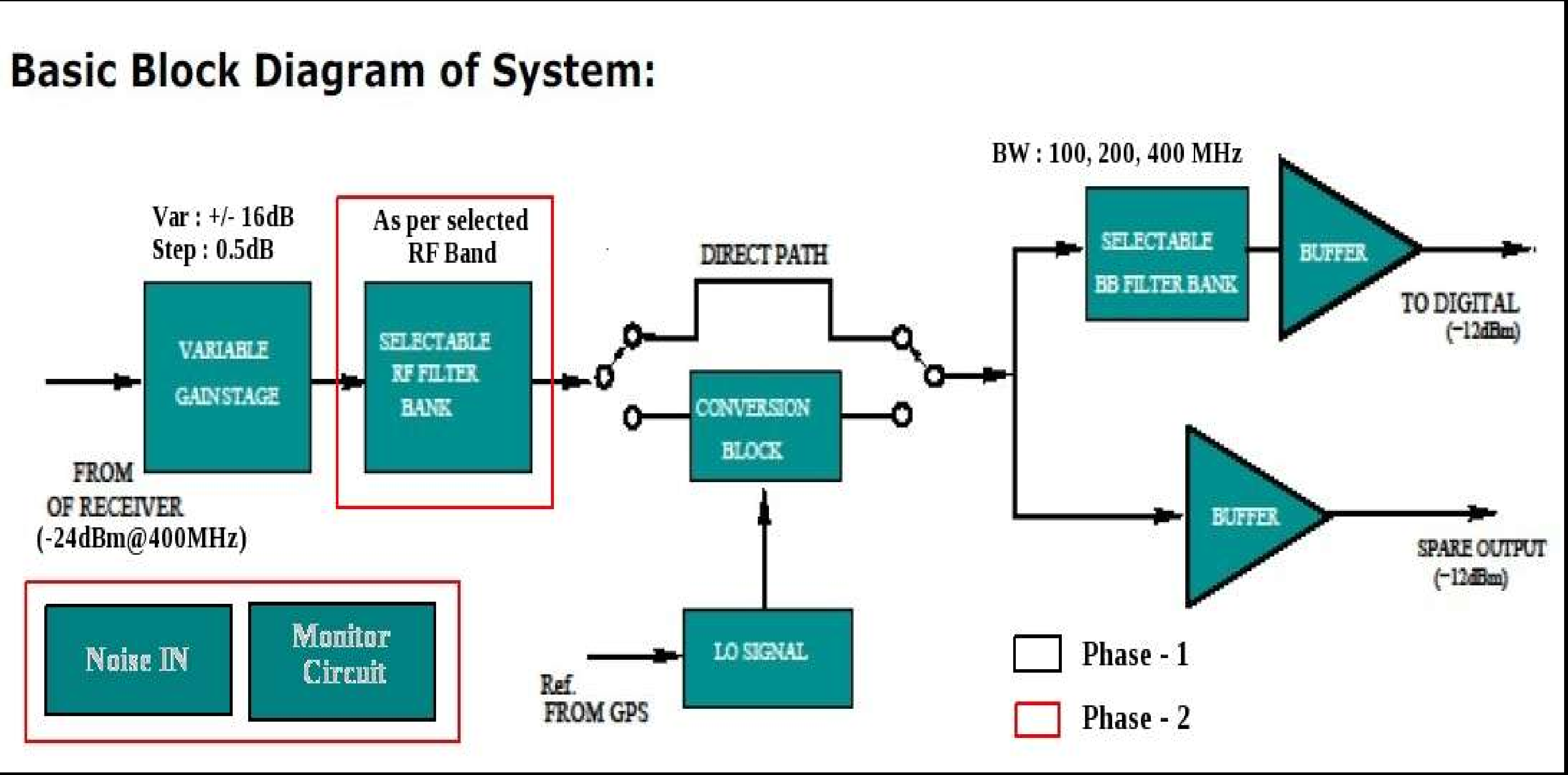


uGMRT : Analog Backend

- Receives wideband RF signals from OF system output
- Converts to baseband signals of 100, 200, 400 MHz BW after appropriate signal conditioning (amplification, filtering etc)



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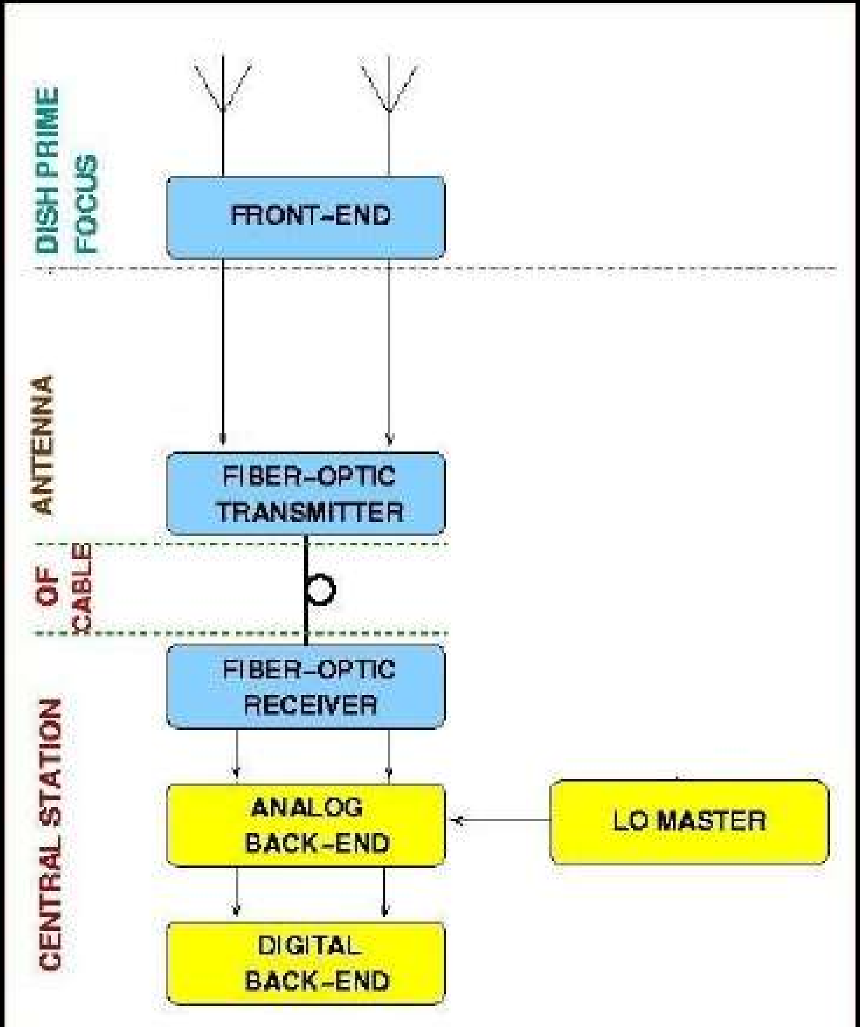
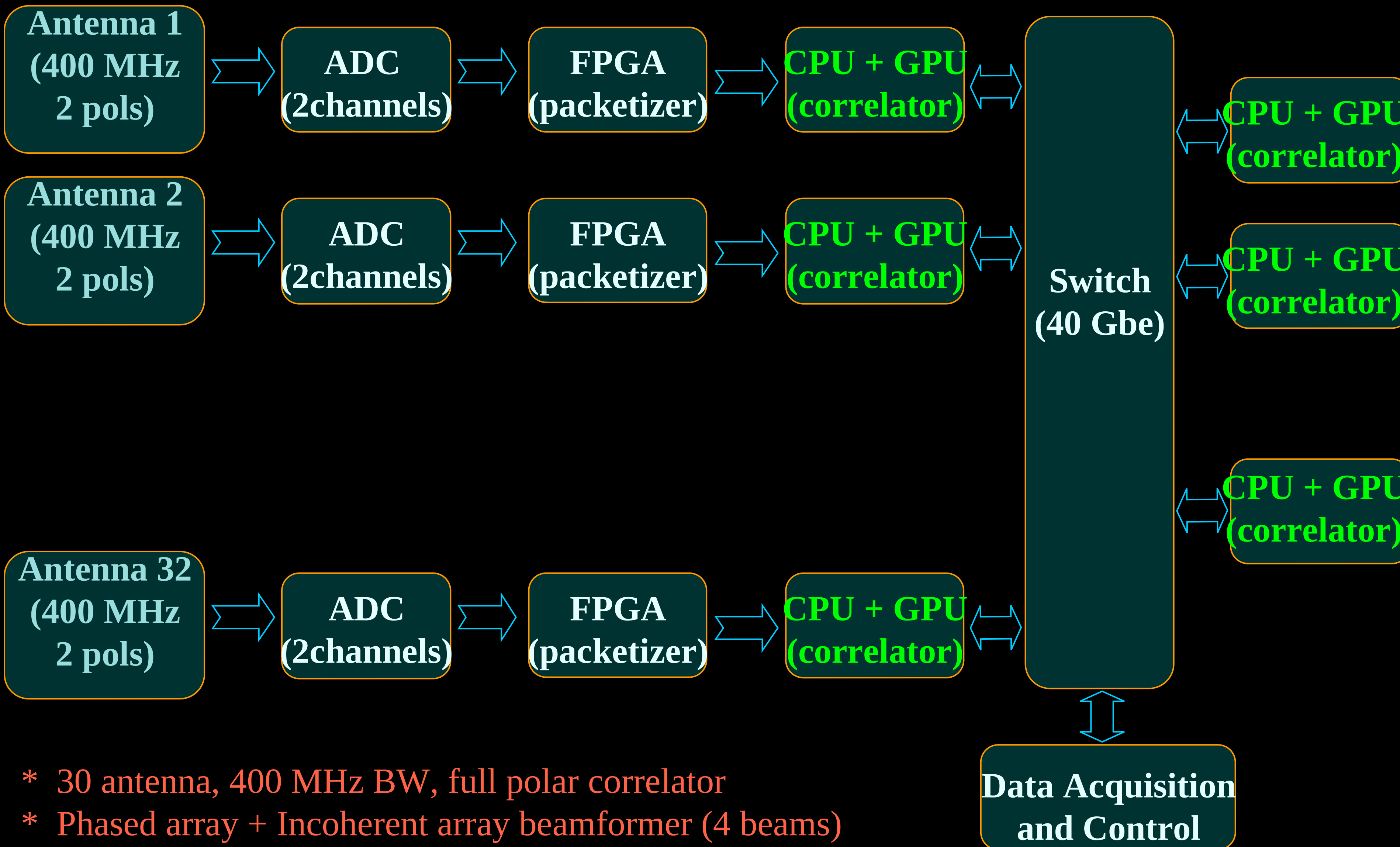


GMRT RECEIVER BLOCK SCHEMATIC

uGMRT Digital Backend : Hybrid Correlator Design



- 30 antenna, 400 MHz BW, full polar correlator
- Phased array + Incoherent array beamformer (4 beams)

VLBI with the GMRT

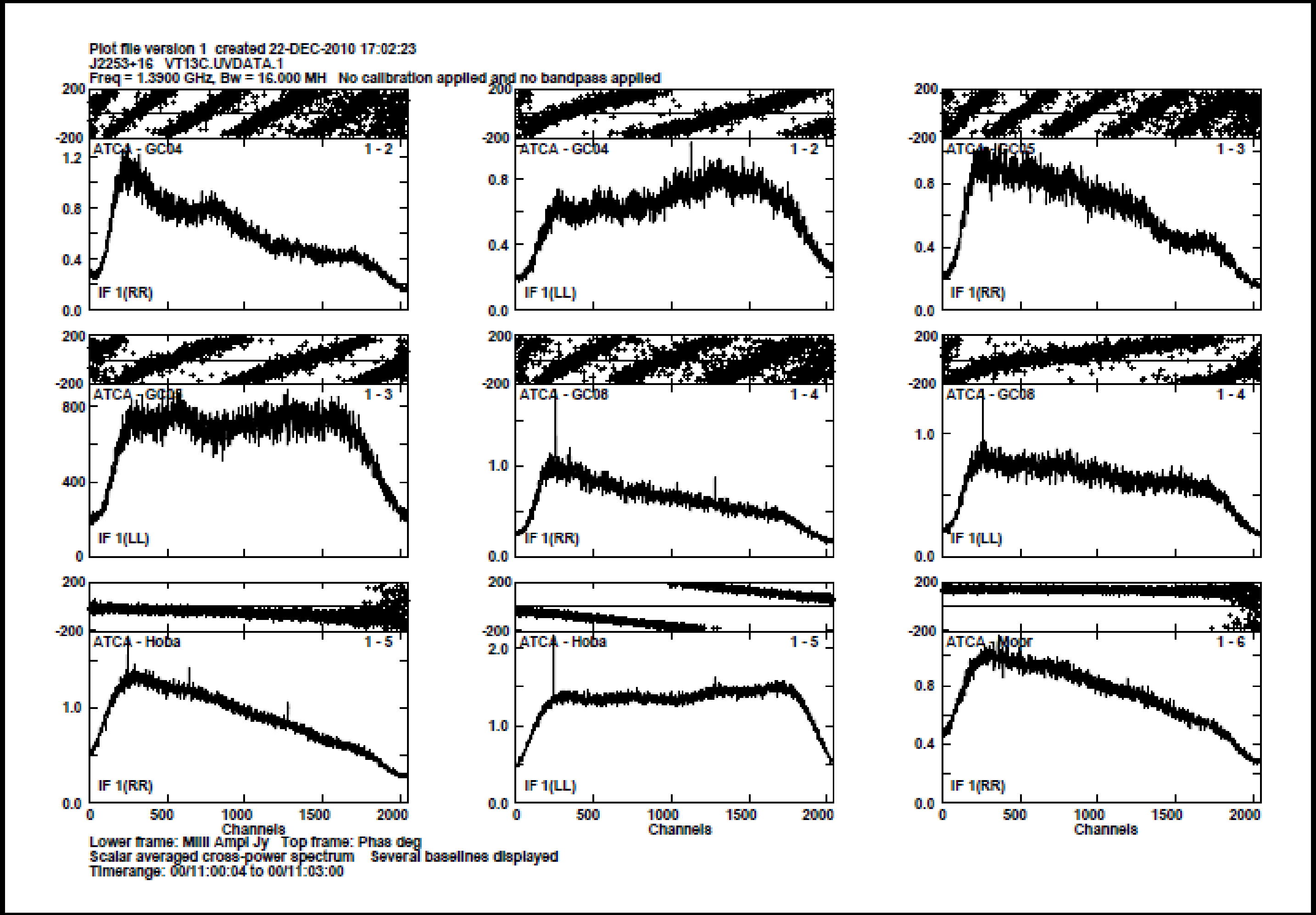
- First experiments were done c. 2010-11 with Australian telescopes using legacy GMRT system at L-band
- VLBI at L-band with 16 MHz BW using legacy system
- Moderately successful
- Should be able to do much better with the uGMRT

VLBI with GMRT : December 2010

- VLBI run with :
  - Mopra
  - ATCA
  - GMRT

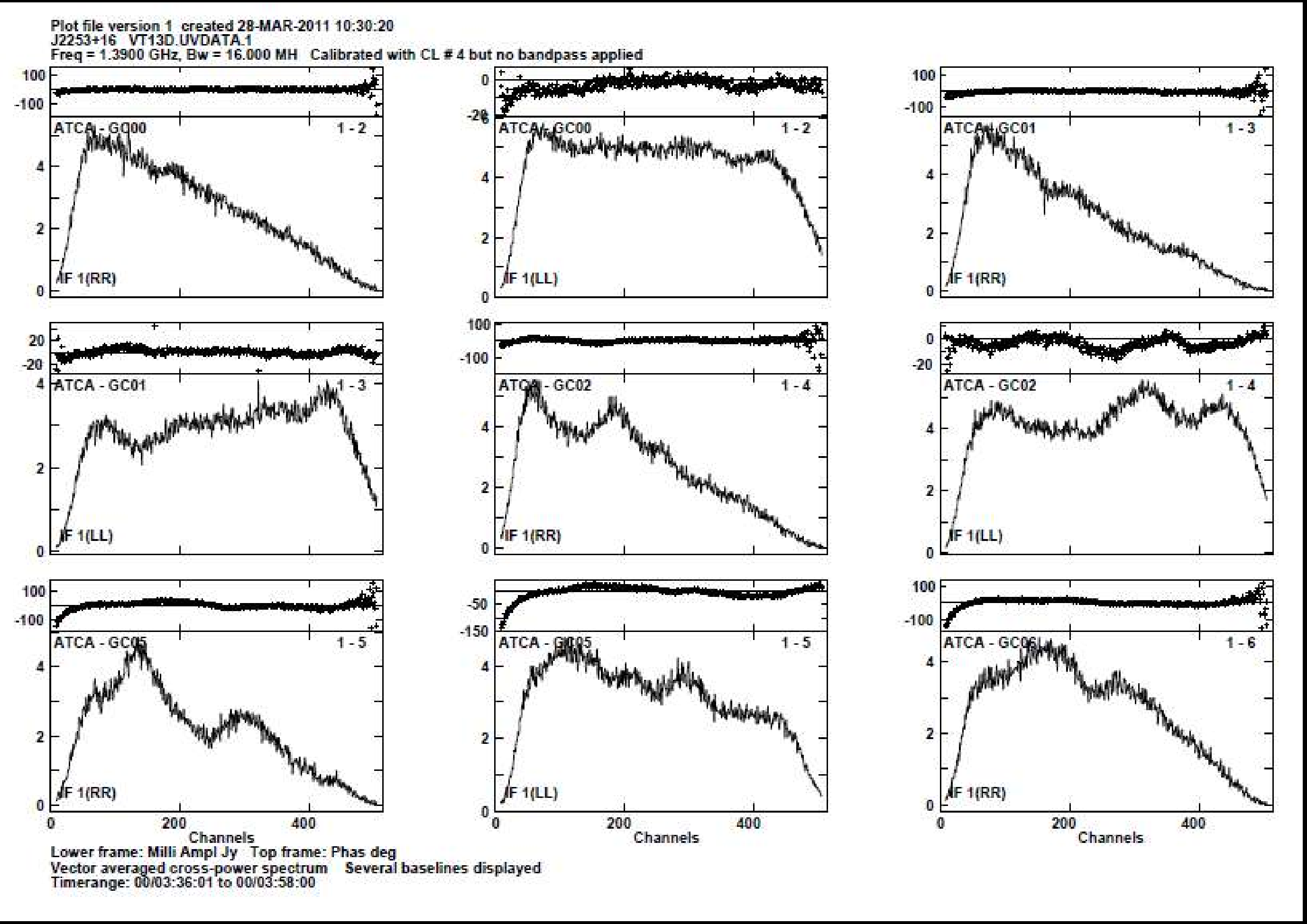
December 2010 : first fringes !

- VLBI run of 15 Dec 2010 : GMRT (4) + Mopra + ATCA
- 1390 MHz ; 16 MHz BW ; J2253+1608 (3C454.3) (5 Jy at S-band)



Confirmation : February 2011

- Confirmation VLBI run : 18 Feb 2011 : GMRT (4) + Mopra + ATCA
- 1390 MHz ; 16 MHz BW ; J2253+1608 (3C454.3) (5 Jy at S-band)



Unresolved issues from 2010-11

- Basic results looked OK, but some aspects remained to be understood :
  - Stability of delay & fringe rate solutions from GMRT was not very good – instrumental effects? ionosphere?
  - Phase variations after calibration : ionosphere? Rb?
  - Linear vs circular polarisations
- Phase referencing studies : could not understand finer details of analysis and results

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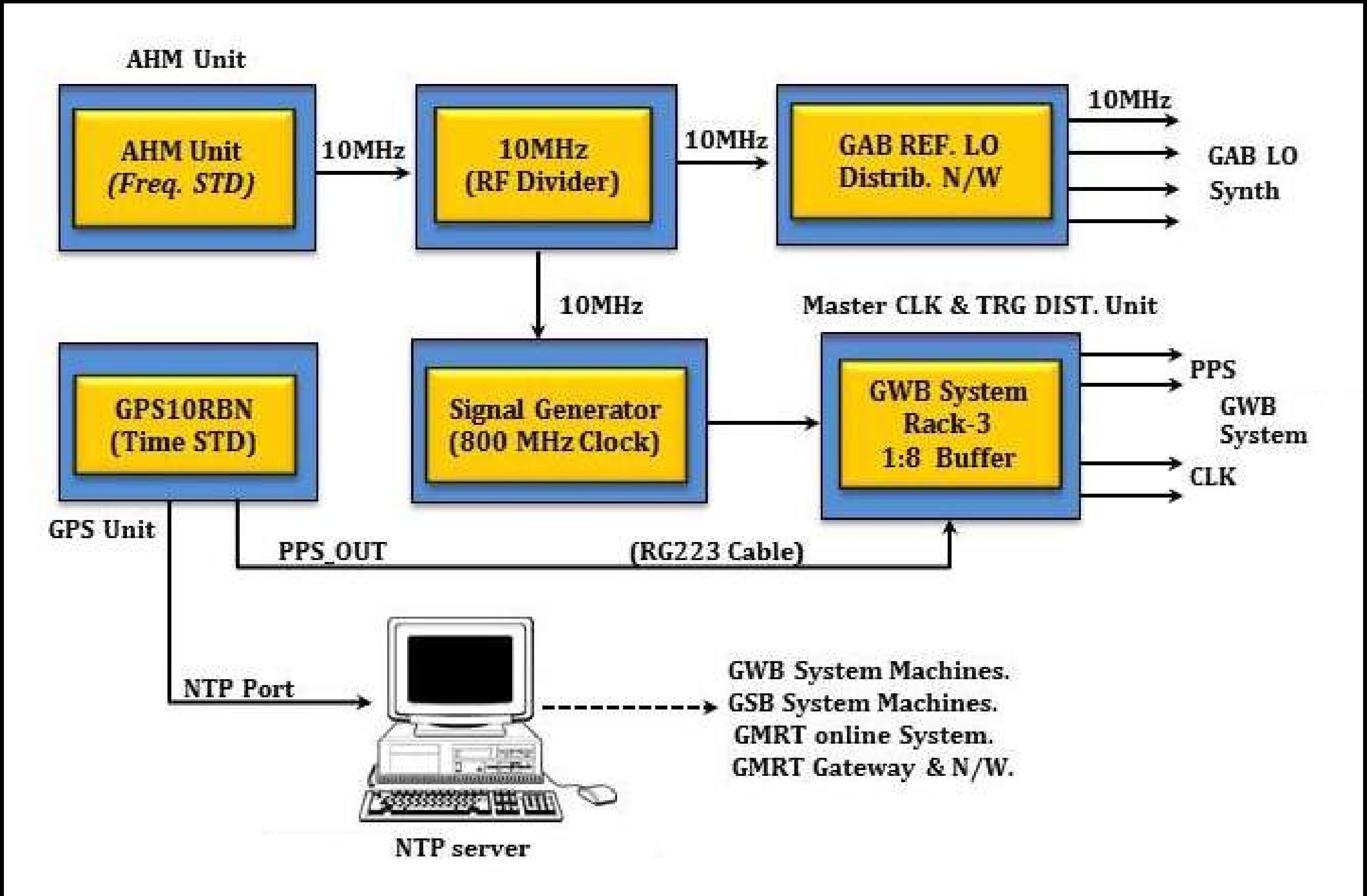
  - Phase variations after calibration : ionosphere? Rb?
  - Linear vs circular polarisations
- Phase referencing studies : could not understand finer details of analysis and results
- Is the Rb standard at GMRT good enough ?

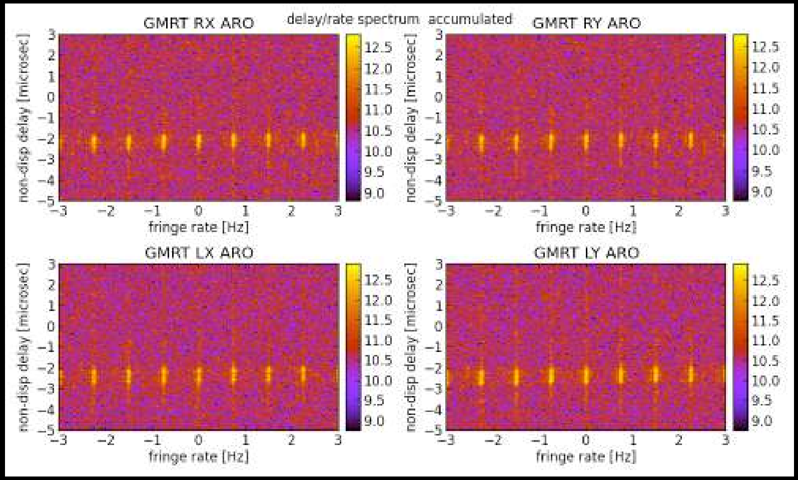
uGMRT : now with H-Maser

- As part of the upgrade, GMRT now has active Hydrogen Maser based frequency standard – operational for the last one year

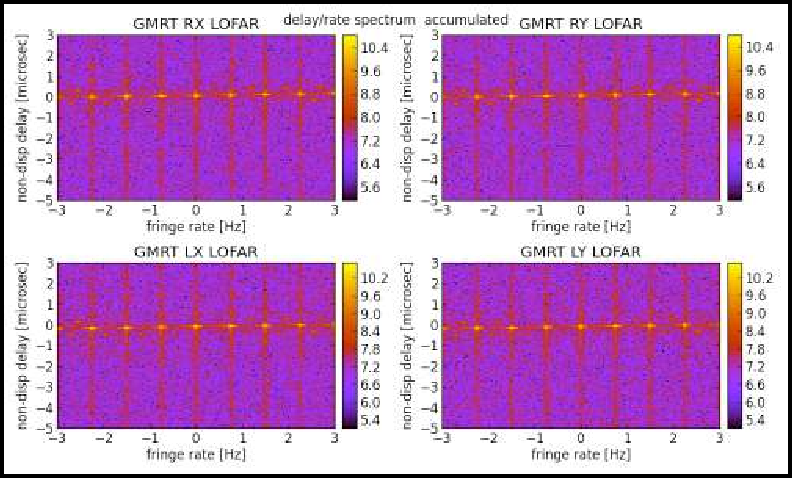


Time & Frequency set-up for the upgraded GMRT

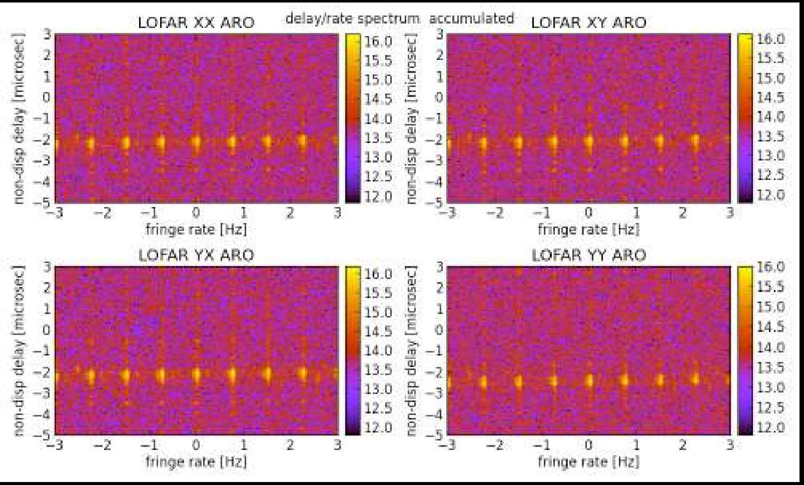
VLBI : pulsar "scintellometry"



GMRT -- ARO



GMRT -- LOFAR



c. December 2013

courtesy : Olaf Wucknitz

LOFAR – ARO

VLBI with uGMRT : potential

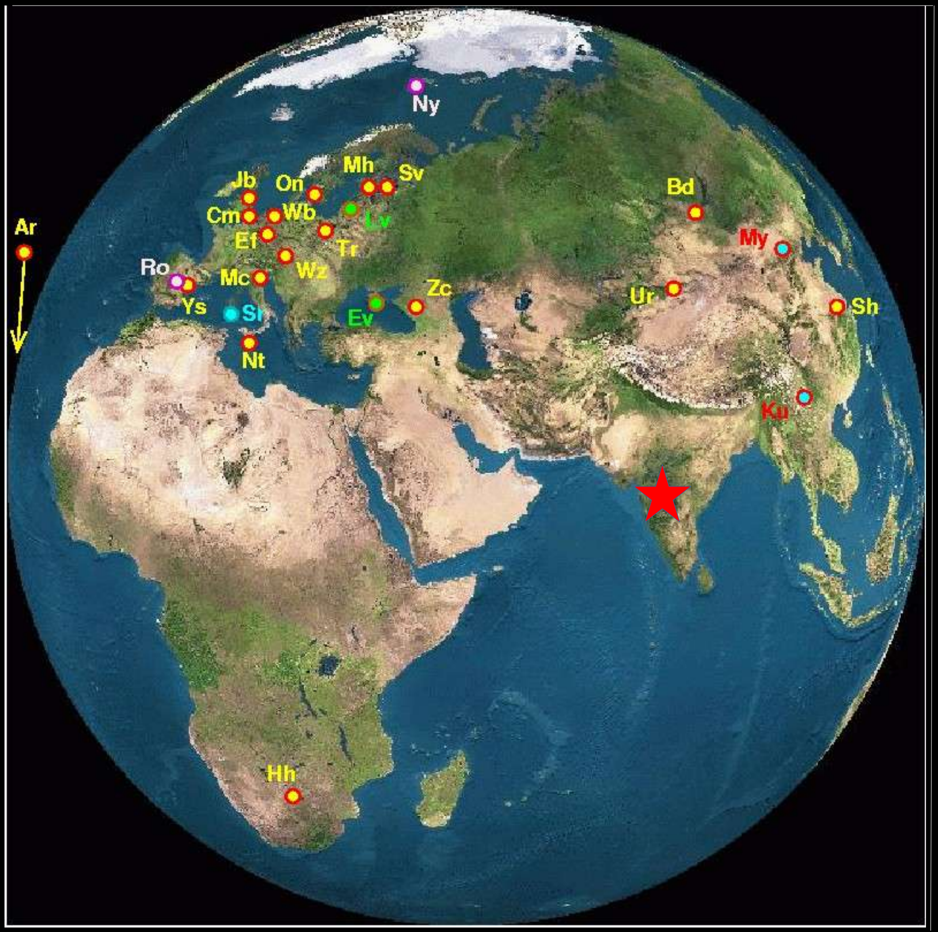
- GMRT has unique geographical location – bridges many other VLBI networks :

  European VLBI n/w, East-Asian VLBI n/w, MeerKAT/SKA-Mid, Australian n/w + SKA-Low

- Frequency coverage of uGMRT can support VLBI with all of the above n/w

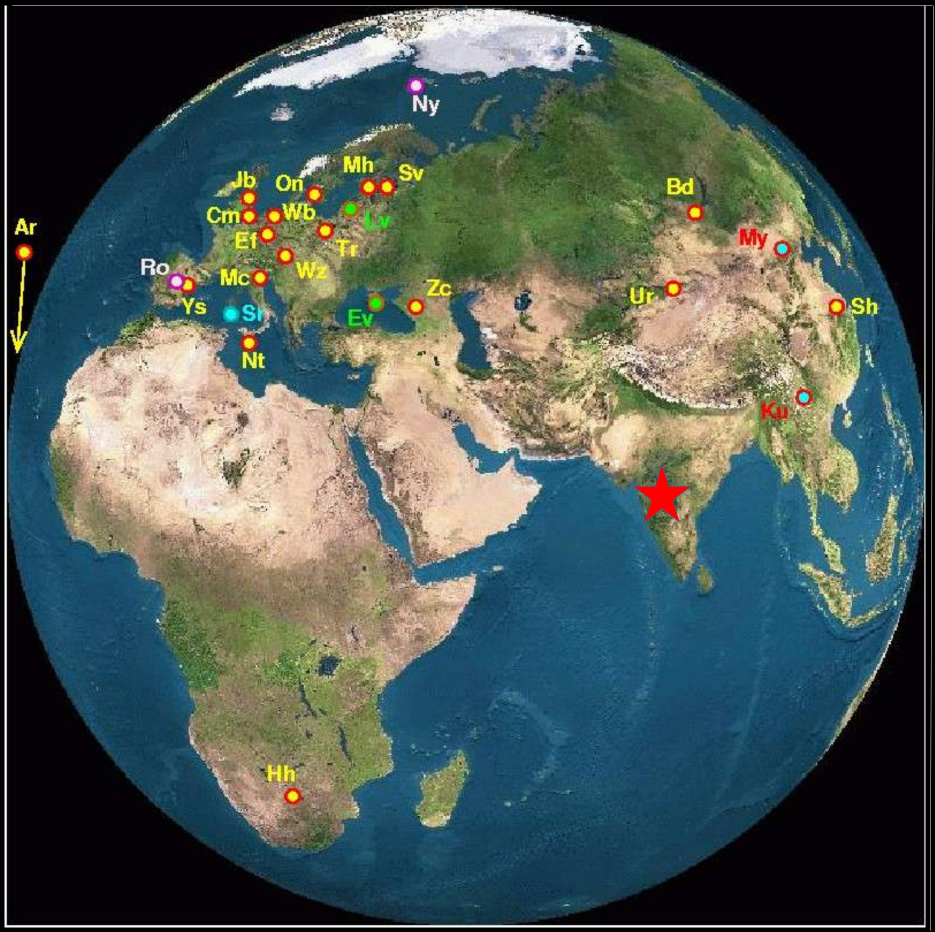
- Sensitivity of uGMRT phased array mode offers significant gain to all the VLBI n/ws

- Overall : tremendous science potential – hear about in this meeting



VLBI with uGMRT : plans

- First trial observations done (with our Australian friends) late last year – awaiting results…
- Ready to plan some more tests with others
- Initial tests using legacy GMRT backend – restricted bandwidth
- Prototype set-up for recording 100 / 200 MHz BW with uGMRT phased array output getting ready
- Working on standard set-up for format conversion of GMRT data to VLBI standards
- Looking forward to being regular member of VLBI networks !



Thank you ！

Many new science results… already discussed yesterday…