The Giant Metrewave Radio Telescope — An update

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Abstract

The National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research, India has recently fully commissioned a Giant Metrewave Radio Telescope (GMRT), about 110 kms east of Mumbai and 80 kms. north of Pune cities (lat: 19° 6′N; long: 74° 3′E; Alt: 650 m above MSL). GMRT currently operates in the frequency bands 151, 235, 327, 610 and 1000–1400 MHz. There are two OH feeds that can be installed in any two antennas in the place of the L band feeds.

GMRT consists of 30 fully steerable parabolic dishes, each of 45 m. diameter spread over 25 kms in an approximate 'Y' configuration. The antennas have been made using a unique and SMART (Streched Mesh Attached to Rope Truss) design which has resulted in the lightest weight antennas for their size, leading to significant cost savings. Twelve of the 30 antennas are in a central compact random array of 1 km × 1 km in size and the remaining 18 antennas are stretched out along the arms of 'Y', each 14 kms long.

GMRT is a very sensitive aperture synthesis array at low frequencies. The central compact array and the long arm antennas provide good sensitivity for detecting large diffuse objects and for high angular resolution of a few arcsec. needed for small objects respectively. GMRT is currently being used for a variety of astrophysical studies, such as detection of redshifted 21 cm line radiation representing the epoch of galaxy formation, objects such as Pulsars, HII regions and supernova remnants in our Galaxy, diffuse emission from nearby galaxies, giant radio galaxies, distant quasars, damped Lyman-alpha systems as well as our nearest star, the Sun.

In this update, we present the salient features of the GMRT and give some recent results.

Key-words : GMRT, synthesis array, India

1 Introduction

Our basic aim was to build a very sensitive aperture synthesis radio telescope array in the frequency range of 30–1500 MHz, which will be a state-of-the-art instrument in radio astronomy. There are advantages in building such an array in India, since because of the low frequencies, (i) the surface accuracy requirements are not so stringent resulting in lower cost; (ii) low frequency electronics is relatively inexpensive; (iii) high angular resolution is not required, since the interesting science at low frequencies is in diffused extended regions. The disadvantages are that (i) sky background is higher; (ii) ionospheric distortion increases towards lower frequencies and (iii) man made noise is higher.

Although the original proposal envisaged construction of parabolic cylinders along the pattern of the Ooty Radio Telescope, the final design chosen was that of parabolic dishes. This was possible because of a break-through in the design of low-cost dishes (Swarup et al. 1991). This is described in Section 2. 30 parabolic dishes of 45 m diameter each were built, providing a total effective collecting area of nearly 30,000 sq.m for frequncies less than about 600 MHz and 20,000 sq.m for frequencies in the range 1000–1450 MHz. Currently, GMRT operates at five frequency bands at 150, 235, 325, 610 and 1000-1450 MHz. There are also two feeds that can be used at 1665 MHz. The 50 MHz feeds are being proto-typed but have not been installed till now.

2 Array location and its configuration

Figure 1a shows the location and configuration of the array, in which 12 antennas form a random cluster in a central 1 km × 1 km area and the remaining 18 antennas are distributed equally in the 3 arms of a 'Y' configuration with a minimum separation of 105 m and a maximum separation of 25 km.

This configuration gives a good spatial coverage for both high and low declination sources. The highest resolution obtainable, is about 2 arcsec. and 20 arcsec at 1420 and 150 MHz. The design concept used in GMRT (described in more detail in Swarup et al. 1991) is called SMART (Stretched Mesh Attached to Rope

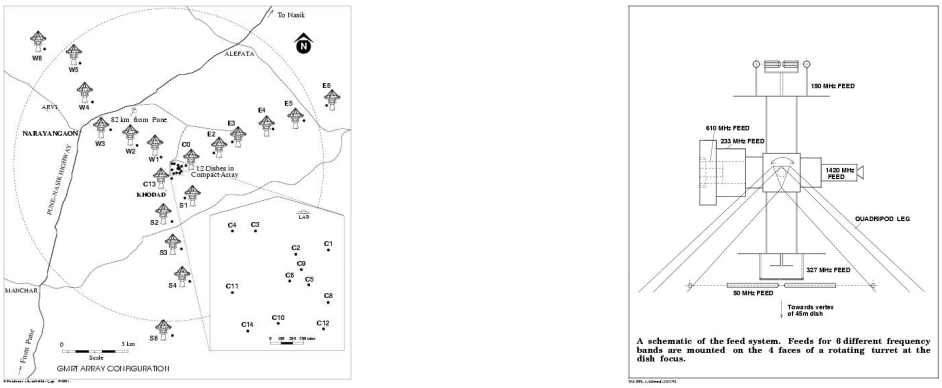

Figure 1: *(a)* Antenna location. *(b)* A schematic of the feed system

Truss) and involves replacing conventional back-up structure by a series of 4 mm and 2 mm diameter stainless steelwire (SS) rope trusses stretched between parabolic frames made of tubular steel. The ropes are tensioned to form 360 plain facets over which panels made of 0.55 mm dia. SS welded mesh is spread and tied to the back-up SS ropes. 1200 turn buckles are used for tensioning and shaping the facets. The mesh size varies from 10 × 10 mm in the central one third of the dish, 15 × 15 mm over the next third and 20 × 20 mm over the last outer third. Such transparency of the dish reduces the wind forces significantly and the dish is designed to withstand wind speeds of about 135 kmph. Due to the SMART design the weight of the moving portion of the 45 m dish is only 80 tons in contrast to about 200 tons for a conventional 25 m dish. A counter-torque system using a pair of 6 hp DC servo motors connected to azimuth and elevation axes is able to slew the dishes at speeds upto 30 deg./min. in azimuth and 20 deg./min. in elevation. When the winds are low the pointing accuracy of the dishes is less than 1 arcmin. The reader is referred to www.ncra.tifr.res.in for pictures and other details of GMRT.

3 Brief description of GMRT receiver system

The dual polarised feeds of the GMRT for the various frequency bands are located at the prime focus (Fig 1b), which has a rotating turret controlled by the central computer. While the L-band feed has two linear polarisations, the other feeds are circularly polarised. This was done to minimse losses due to polarisers at the higher frequency. Feeds are connected to low noise receivers and brought via low loss cables to the antenna base.

A simplified schematic diagram of the receiver system is shown in Figure 2.

Dual polarized RF signals are down converted to two IF bands of +/- 16 MHz width at the bottom of each antenna and sent to the reciver room on optical fibre links. The back end consists of LSB/USB baseband coversion and providing video filters that go from 62.5 KHz to 16 MHz in binary steps. Video bands are followed by an FX type correlator that uses high speed FFT/mutiplier chips. The 256 channel cross correlator for the 30 antennas has (30x31/2)x256x2 pol.=238,080 correlated outputs including self correlation products. Each of the outputs can be averaged over integration times selectable from 64 msec to 16 secs. The special purpose hardware of GMRT includes an incoherent as well as coherent array mode for pulsar observations. The antennas can be used for simultaneous observations at 235 and 610 MHz by using the 'two frequencies, one polarization' mode. The GMRT can also be at present used for a single output VLBI observation at frequencies up to 1665 MHz.

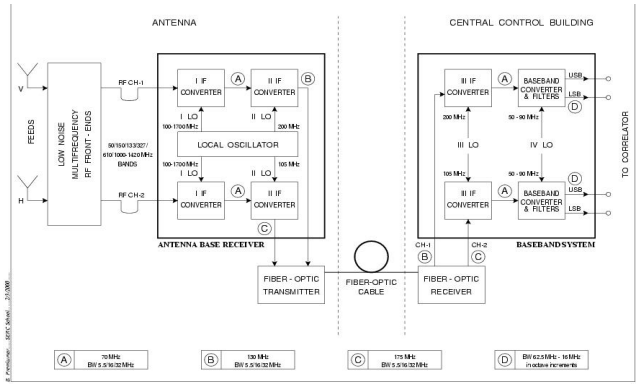

Figure 2: Simplified schematic of the receiver system.

Table 1: Measured System Parameters of GMRT

	Frequency (MHz)				
	151	235	325	610	1420
Primary Beam (Degrees)	3.8	2.5	1.8	0.9	0.4
System Temperature (K)	450	180	100	90	70
Antenna Temp (K/ Jy/ Antenna)	0.35	0.3	0.35	0.3	0.25
Synthesised Beam (arcsec)					
Whole Array	20	12	9	5	2
Central Square	420	270	200	100	40
Largest detectable source (arcmin)	68	44	32	17	7
Sensitivity (rms image noise mJy/ MHz/ min)					
Whole Array	5.2	3.9	1.2	1.2	1.2
Central Square	10.4	7.8	2.4	2.4	2.4
Usable frequency range (MHz)					
Reliable	—	232–238	315–335	590–630	1000–1450
With some luck	146–158	230–240	305–360	580–640	850–1450

4 Scientific Results

During the past 2 years GMRT has been used for a variety of astrophysical objects such as Sun, Pulsars, HII regions, Supernova remnants in our galaxy, Damped lyman alpha systems, HI associated absorption systems, Giant radio galaxies, Nearby galaxies and distant quasars. Some of these are described below.

Radio detection of Damped Lyman Alpha systems have been extensively studied with the GMRT. The radio detection of such systems give information of the spin temperature of the hydrogen atom and the temperature varies with the age of the universe. (Kanekar and Chenglur (2001) and references therein)

Of the twenty odd radio detections of such systems, more than ten have have been from the GMRT. A number of related projects to detect hydrogen in absorption against a variety of extragalactic objects are being carried out since the GMRT, with its large collecting are is probably the most powerful instrument in the world, today.

The GMRT has also been used to map a variety of galactic and extragalactic objects, ranging from QSOs down to the Sun. Clusters of Galaxies are being systematically studied to detect and study steep spectrum relic sources. Nearby galaxies are being studied to look for halos and other evidence of outward diffusion of high energy electrons. A systematic study of a number of possible Supernovae Candidates has been carried out and a number of them confirmed (Bhatnagar, 2000). A number of new candidates have also been proposed from

GMRT data (Roy & Rao (MNRAS, 2002 in press). Two images produced using GMRT are shown in Fig.3.

The GMRT has also been used to study or put limits on the low frequency flux of a number of variable sources like GRB sources, X-ray flare source (1915+10, CygX3), radio flare stars etc. (Sagar et.al., 2001).

The pulsar backend of the GMRT has been used for multifrequency and single pulse studies of pulsar . A project to probe the ISM by studying the Inter Stellar Scintillation of pulsars is also going on. Using the multifrquency capabilities of the GMRT it is possible to make precise measurements of the dispersion measure of pulsars and its variability which give information on the large scale density fluctuations in the density of the interstellar plasma. (Gangadhara & Gupta, 2002).

5 Conclusions

The GMRT provides high resolution, high sensitivity, wide sky coverage and polarisation capability in the frequency range 100-1450 MHz. It can be used also at 1665 MHz, albeit for limited VLBI observations at present using one or two antennas. It is beginning to be used by a large number of astronomers from India and abroad for a variety of astrophycial objectives.

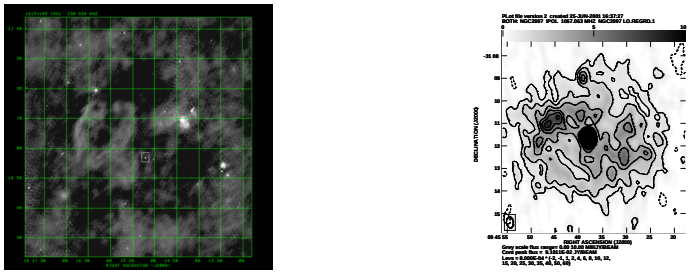

Figure 3: *(a)* Field of galactic microquasar 1915+105 at 330 MHz showing interesting SNR and HII regions. *(b)* Image of nearby galaxy NGC2997 at 1060 MHz.

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