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The GMRT: current status and upgrade plans

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Abstract. The Giant Metrewave Radio Telescope (GMRT) is today a major international radio astronomy facility that has produced several exciting new results since it was commissioned about 10 years ago. The GMRT is presently undergoing a major upgrade that will improve its senstivity by a factor of upto three and make it a much more versatile instrument. Here, we present an overview of the current status of the GMRT, describe the details of the upgrade activity, and outline our future plans.

Keywords : Radio Astronomy – Low Frequency Radio Telescopes – GMRT – upgrade

1. The GMRT : current status

The GMRT (Swarup et al. 1991) is one of the largest low frequency radio telescopes in the world today. With 30 antennas of 45 metres each spread out over a 30 km region, it provides a total collecting area of about 30,000 sq.m. at metre wavelengths, with fairly good angular resolution ($\sim$ arcsec). It also supports a beamformer mode (both incoherent and phased array operations are possible) allowing high quality observations of compact objects like pulsars also to be carried out (Gupta et al. 2000). The present GMRT works in five discrete bands in the frequency range of 150 to 1500 MHz : 130-170 MHz, 225-245 MHz, 300-360 MHz, 580-660 MHz and 1000-1450 MHz. The dual polarisation feeds for these bands are mounted on a rotating turret at the prime focus of the dishes, alongwith the front-end electronics that is based around room temperature, low noise GasFET amplifiers. A heterodyne receiver system converts the dual polarisation RF signals to IF frequencies at the base of the antennas, which are then transmitted over optical fibres to the central receiver building, where they are converted to baseband signals with a maximum instantaneous bandwidth of

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32 MHz. These signals are then processed in a software based digital backend receiver that implements a full polar correlator and beamformer operating in real-time mode (Roy et al. 2010). This backend also supports a mode where raw voltages from both polarisations of all the 30 antennas can be recorded directly to disk, for offline processing for specific, non-standard science goals. Current performance figures of the GMRT are summarised in Table 1.

Since its commissioning in October 2001, the GMRT has been used by astronomers from all over the world for a variety of exciting, new explorations. About 50% of the PIs for GMRT proposals come from India, and the balance from a host of different countries (Fig. 1). The science addressed by the GMRT spans a wide range, from our Sun and nearby stars, to the Epoch of Reionisation, and the observatory is oversubscribed by typically by a factor of 2 or more. There are, on an average, about 40 refereed publications per year reporting results that utilise data from the GMRT.

Table 1. Some performance parameters of the current GMRT system.

	Frequency (MHz)				
	151	235	325	610	1420
Primary Beam (arcmin)	186±6	114±5	81 ± 4	43 ± 3	$(24 \pm 2) * (1400/f)$
Receiver Temperature (T_R)	295†	106†	53	60	45
Typical T_{sky} (off galactic plane)	308	99	40	10	4
Typical T_{ground}	12	32	13	32	24
Total System Temperature (K) ($T_R + T_{sky} + T_{ground}$)	615	237	106	102	73
Antenna Gain (K/Jy/Antenna)	0.33	0.33	0.32	0.32	0.22
Synthesised Beam (arcsec)					
Whole Array	20	13	9	5	2
Central Square	420	270	200	100	40
Largest Detectable Source (arcmin)	68	44	32	17	7
Usable Frequency Range (MHz)	130 to 170	230 to 250	305 to 360	570 to 660	1000 to 1450
Best known rms sensitivity (mJy)	0.7	0.25	0.04	0.02	0.03

† With default solar attenuator (14 dB).
# For spectral observations fudge factor is close to 1.

2. Upgrading the GMRT : key targets

Although the GMRT has done well in its first decade of existence as an international facility, there is a need to upgrade it and keep it competitive in the interntional arena, as other low frequency facilities take shape. Based on the experience of the group gained in building and operating the GMRT, it was thought feasible to make improvements that would add extra capabilities to the existing array, both in terms of frequency coverage and sensitivity, which would result in new windows of astrophysics being opened for its users. The improved frequency coverage would make the instrument much more frequency agile for spectral line observations and this would

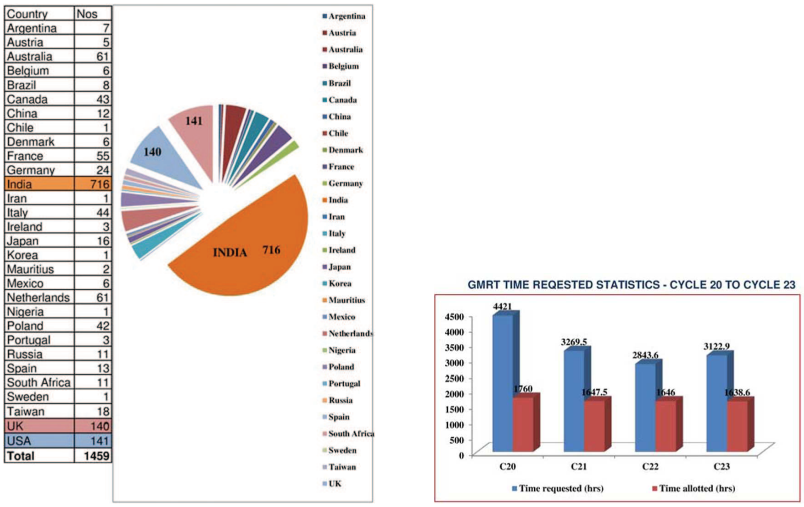

Figure 1. International usage of the GMRT : Left panel shows distribution of proposals from different countries for cycles 1 to 23 (from 2002 to 2013). Right panel shows the statistics of the time request to time allotted for cycles 20 to 23 (2011 to 2013), indicating a typical oversubscription rate of about 2.0.

open up new cabapilities such as exploring the Universe over a much wider range of redshifts than the existing GMRT allows. The increase in sensitivity, obtained by a combination of increased bandwidth and improved technology receivers, would also make the GMRT a more powerful instrument for studies involving continuum observations and those related to pulsar science. Furthermore, some of the original systems of the GMRT needed to be replaced due to obsoloscence related issues. It is with these aspects in mind that the GMRT upgrade was conceived. The main targets for the upgraded GMRT (called uGMRT) are as follows :

1. To provide seamless frequency coverage, as far as possible, from 50 to 1500 MHz, to replace the 5 discrete frequency bands at present;
2. To provide a maximum instantaneous BW of 400 MHz, in place of the current 32 MHz;
3. Improved receiver systems with higher G/Tsys;
4. Versatile digital back-end correlator and pulsar receiver to handle the 400 MHz BW data;
5. A revamped, modern servo system;
6. A sophisticated, next generation monitor and control system;
7. Enhanced computing resources to cater to the larger volumes of data.
8. Matching improvements in mechanical systems, electrical & civil infrastructure;

9. Implementation of the upgrade with minimal disruption to the availability of the existing GMRT for scientific observations.

3. Upgrading the GMRT : implementation details and timelines

Some of the details of the design, expected performance and timelines for the uGMRT are as follows. These are subject to minor refinements with time, based on experience and user feedback.

Wideband receiver systems for the uGMRT : The seamless frequency coverage and wide bandwidth are being achieved by the design of octave wide feeds and front-end electronics with matching frequency coverage (at the antennas), followed by an improved wideband optical fibre transmission scheme and a wide bandwidth analog and digital backend (at the central receiver building). The uGMRT bands currently being implemented are : 130−260 MHz, 250−500 MHz, 550−900 MHz, 1000−1450 MHz (with two gaps left in between where the interference from mobile phone and terrestial TV transmissions is very strong).

For the 1000−1450 MHz system, the existing broadband feed (900 to 1450 MHz) has been coupled with an improved version of the existing front-end system with better dynamic range that results from the use of a better amplifier chain and improved rejection of the strong RFI from the neighbouring mobile phone band. For the other bands, new wideband feeds with matching improved frontend electronics have been designed by the GMRT team. The overall upgraded GMRT receiver chain provides wideband frequency coverage with improved dyanamic range (6-10 dB is expected for most of the bands) and better filtering of adjoining RFI signals. Further details about the new, wideband front end systems, the redesigned optical fibre signal transport system and the wideband backend sytems can be found in the accompanying papers presented in this meeting by the corresponding team leads (Sureshkumar, this volume; Ajithkumar, 2014).

Projected performance, current status : Fig. 2 shows the projected improvements in sensitivity between the existing and upgraded GMRT systems, including a comparison with other existing (and projected) facilities in the world. As can be seen from these, the uGMRT, when completed, will be one of the most sensitive radio facilities in the world in the 250 to 1000 MHz range, till SKA phase-I becomes operational.

The current status of the widebanding of the reciever systems is as follows : the upgrade of the 1000−1450 MHz frontend system is completed for all the 30 antennas; the 550−900 MHz frontend system is in final stages of evaluation of two potential designs for the feed, with prototypes of the matching LNAs available; the 250−500 MHz frontend system has cleared the prototyping stage and is in mass production, with the version-1 now installed in 10 antennas; the 130−260 MHz system is in the stage of testing and final acceptance of the prototype unit that has been installed on

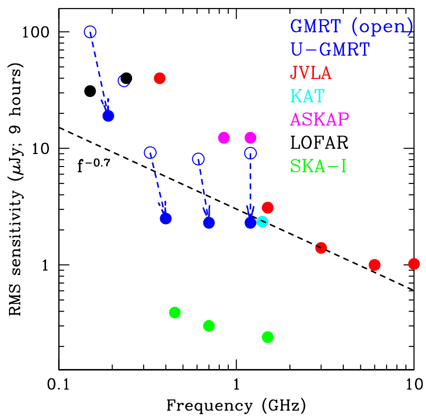

Figure 2. Expected sensitivity improvement for the upgraded GMRT : the open circles indicate the RMS sensitivity of the existing GMRT for a best caes 9 hour synthesis imaging observation; the filled circles show the same for the uGMRT with the targeted bandwidths; known and projected sensitivities of the major radio observatories in the world, including those for the SKA Phase-I, are also indicated (Courtesy : N. Kanekar, NCRA).

2 antennas; the upgrade of the optical fibre transport system is well into the mass production phase, with more than 10 antennas outfitted with the new system; for the backend systems, the analog part of the wideband receiver has completed the design and prototyping phase and units for 8 antennas have been installed; for the digital backend processor, the design and prototyping phase has been completed with the installation of 8-antenna prototype which has been released for user trials.

In the light of the above progress, earlier this year, a 8-antenna phase-I system of the uGMRT was released for internal use and shakedown tests on September 15, which also marks the celebration of Engineer's Day in India.

Other upgrades and improvements : In addition to the widebanding of the receiver chain, there are other important parts of the uGMRT, as outlined in section 2 above. Some of the details of these are as follows.

For the servo system upgrades, the main thrust has been to replace old systems with modern versions to (a) reduce problems and breakdowns (b) counter obsolesence and (c) facilitate possible improvements in performance. The scope of works (Bagde, 2014) has included development and installation of new solid-state interlock system (completed in all 30 antennas), a PC104 based next generation servo control computer (in installation and commissioning phase) and replacement of the existing permanent magnet DC servo motors and drives with an advanced brushless motors and drive system (also in installation and commissioning phase).

For the monitor and control (M&C) system, there are two aspects being pursued: (i) replacement of the existing M&C hardware controller cards and network with modern micro-controllers connected to the main control computer via ethernet links to each antenna; (ii) change over of the existing high level M&C software to next generation software that follows modern architectural principles. At present, after successful completion of the design and validation via a prototype, the hardware for the new micro-controller cards has been procured and these are in mass production phase. Work on the high level software has been initiated (Nayak, 2014). The installation and commissioning of the hardware and the switch-over to the new software will happen in a single concerted effort, wherein the entire existing M&C system will get replaced by the new M&C system, in one go.

Mechanical systems at the GMRT antennas pose their own issues in terms of maintenance and improvements (Nandi, 2014). The main works being carried out as part of the upgrade are related to improved designs for the corroded items, refurbishing of the antenna reflector surface, improved painting schemes, procurement of new gearboxes, improvements in the feed turret drive system, procurement of 2 new high lift platforms with improved capabilities etc. Similarly, there are improvement works for the electrical systems at the antennas and the central electronics building, that are part of the upgrade activities.

One of the significant issues facing the existing and upgraded GMRT is the threat from RFI, and special measures are being taken as part of the upgrade for (a) better identification of sources of RFI (b) improved shielding practices for all the next generation electronics being developed for uGMRT and (c) improved RFI detection and mitigation schemes – for both broadband, impulsive RFI and narrowband spectral line RFI – some of which will work fully in real-time.

4. Summary

The GMRT is today a front-line international facility for low frequency radio astronomy and, in over a decade of operations, it has produced many new and interesting results. The ongoing upgrade will deliver the uGMRT as an even more versatile and sensitive instrument, and keep it in the forefront of global facilities till the era of the SKA.

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