Chapter 18

An Overview of the GMRT

Jayaram N. Chengalur

18.1 Introduction

The Giant Metrewave Radio Telescope (GMRT) consists of an array of 30 antennas. Each antenna is 45 m in diameter, and has been designed to operate at a range of frequencies from 50 MHz to 1450 MHz. The antennas have been constructed using a novel technique (nicknamed SMART) and their reflecting surface consists of panels of wire mesh. These panels are attached to rope trusses, and by appropriate tensioning of the wires used for attachment the desired parabolic shape is achieved. This design has very low wind loading, as well as a very low total weight for each antenna. Consequently it was possible to build the entire array very economically. In this chapter I give a very brief overview of the GMRT. Subsequent chapters discuss in detail each of the major subsystems of the GMRT.

18.2 Array Configuration

The GMRT has a hybrid configuration, (see Figure 18.1) with 14 of its antennas randomly distributed in a central region (~ 1 km across), called the central square. The distribution of antennas in the central square was deliberately "randomized" to avoid grating lobes. The antennas in the central square are labeled as Cnn, with nn going from 00 to 14 (i.e. C00, C01,....C14)[1]. The remaining antennas are distributed in a roughly Y shaped configuration, with the length of each arm of the Y being ~ 14 km. The maximum baseline length between the extreme arm antennas is ~ 25 km. The arms are called the "East" "West" and "South" arms and the antennas in these arms are labeled E01..E06, W01..W06 and S01..S06 for the east, west and south arm respectively.

The central square antennas provide a large number of relatively short baselines. This is very useful for imaging large extended sources, whose visibilities are concentrated near the origin of the UV plane. The arm antennas on the other hand are useful in imaging small sources, where high angular resolution is essential. A single GMRT observation hence yields information on a variety of angular scales.

[1]The array was originally meant to have 34 antennas, but because of escalating costs, was finally constructed with 30. Consequently some antenna stations do not actually have any antennas in them, resulting in "missing" numbers (C07, E01, S05) in the numbering sequence.

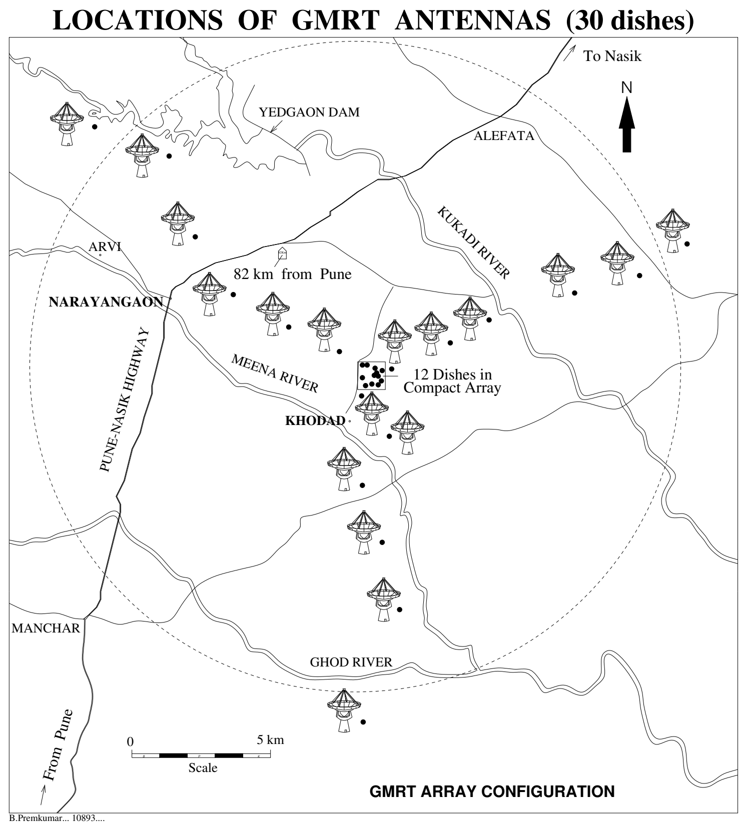

Figure 18.1: GMRT array configuration.

18.3 Receiver System

The GMRT currently operates at 5 different frequencies ranging from 150 MHz to 1420 MHz. Some antennas have been equipped with receivers which work up to 1750 MHz. Above this frequency range however, the antenna performance degrades rapidly both because the reflectivity of the mesh falls and also because of the rapidly increasing aperture phase errors because of the deviations of the plane mesh facets from a true parabola. A 50 MHz receiver system is also planned. Table 18.1 gives the relevant system parameters at the nominal center frequency of the different operating frequencies of the GMRT.

The GMRT feeds, (except for the 1420 feed), are circularly polarized. The circular polarization is achieved by means of a polarization hybrid inserted between the feeds and the RF amplifiers. No polarization hybrid was inserted for the 1420 MHz feed, in order to keep the system temperature low. None of the receivers are cooled, i.e. they all operate at the ambient temperature. The feeds are mounted on four faces of a feed turret placed at the focus of the antenna. The feed turret can be rotated to make any given feed point to the vertex of the antenna. The feed on one face of the turret is a dual frequency feed, i.e. it works at both 233 MHz as well as 610 MHz.

After the first RF amplifier, the signals from all the feeds are fed to a common second stage amplifier (this amplifier has an input select switch allowing the user to choose which RF amplifier's signal is to be selected), and then converted to IF. Each polarization is converted to a different IF frequency, and then fed to a laser-diode. The optical sig-

System Properties	in MHz 50	153	233	327	610	1420
Primary beam (degree)		3.8	2.5	1.8	0.9	0.4×(1400/f)
Synthesized beam						
Full array (arcsec)		20	13	09	05	02
Central array (arcmin)		7.0	4.5	3.2	1.7	0.7
System temperature (K)						
(1) $T_{\rm receiver}$		144	55	50	60	40
(including cable losses)						
(2) $T_{\rm ground} = T_{\rm mesh} + T_{\rm spillover}$		30	23	18	22	32
(3) $T_{\rm sky}$		308	99	40	10	4
Total $T_{\rm sys}$		482	177	108	92	76
$= T_{\rm sky} + T_{\rm receiver} + T_{\rm ground}$						
Gain of an antenna (K/Jy)		0.33	0.33	0.32	0.32	0.22
RMS noise in image* (μJy)		46	17	10	09	13

*For assumed bandwidth of 16 MHz, integration of 10 hours and natural weighting (theoretical).

Table 18.1: System parameters of the GMRT

nals generated by the laser-diode are transmitted to a central electronics building (CEB) by fiber optic cables. At the central electronic building, they are converted back into electrical signals by a photo-diode, converted to baseband frequency by another set of mixers, and then fed into a suitable digital backend. Control and telemetry signals are also transported to and from the antenna by on the fiber-optic communication system. Each antenna has two separate fibers for the uplink and downlink.

18.4 Digital Backends

There are a variety of digital backends available at the GMRT. The principle backend used for interferometric observations is a 32 MHz wide FX correlator. The FX correlator produces a maximum of 256 spectral channels for each of two polarizations for each baseline. The integration time can be as short as 128 ms, although in practice 2 sec is generally the shortest integration time that is used. The FX correlator itself consists of two 16 MHz wide blocks, which are run in parallel to provide a total instantaneous observing bandwidth of 32 MHz. For spectral line observations, where fine resolution may be necessary, the total bandwidth can be selected to be less than 32 MHz. The available bandwidths range from 32 MHz to 64 kHz in steps of 2. The maximum number of spectral channels however remains fixed at 256, regardless of the total observing bandwidth. The GMRT correlator can measure all four Stokes parameters, however this mode has not yet been enabled. In the full polar mode, the maximum number of spectral channels available is 128. Dual frequency observations are also possible at 233 and 610 MHz, however in this case, only one polarization can be measured at each frequency. The array can be split into sub-arrays, each of which can have its own frequency settings and target source. The correlator is controlled using a distributed control system, and the data acquisition is also distributed. The correlator output, i.e. the raw visibilities are recorded in a GMRT specific format, called the "LTA" format. Programmes are available for the inspection, display and calibration of LTA files, as well as for the conversion of

LTA files to FITS.

The first block of the GMRT pulsar receiver is the GMRT Array Combiner (GAC) which can combine the signals from the user-selected antennas (up to a maximum of 30) for both incoherent and coherent array operations. The input signals to the GAC are the outputs of the Fourier Transform stage of the GMRT correlator, consisting of 256 spectral channels across the bandwidth being used, for each of the two polarization from each antenna. The GAC gives independent outputs for the incoherent and coherent array summed signals, for each of two polarizations. For nominal, full bandwidth mode of operation, the sampling interval at the output of the GAC is 16μsec.

Different back-end systems are attached to the GAC for processing the incoherent and coherent array outputs. The incoherent array DSP processor takes the corresponding GAC output signals and can integrate the data to a desired sampling rate (in powers of 2 times 16 microsec). It gives the option of acquiring either one of the polarizations or the sum of both. It can also collapse adjacent frequency channels, giving a slower net data rate at the cost of reduced spectral resolution. The data is recorded on the disk of the main computer system.

The coherent array DSP processor takes the dual polarization, coherent (voltage sum) output of the GAC and can produce an output which gives 4 terms – the intensities for each polarization and the real and imaginary parts of the cross product – from which the complete Stokes parameters can be reconstructed. This hardware can be programmed to give a sub-set of the total intensity terms for each polarization or the sum of these two. The minimum sampling interval for this data is 32 microsec, as two adjacent time samples are added in the hardware. Further preintegration (in powers of 2) can be programmed for this receiver. The final data is recorded on the disk of the main computer system.

There is another independent full polarimetric back-end system that is attached to the GAC. This receiver produces the final Stokes parameters, I,Q,U & V. However, due to a limitation of the final output data rate from this system, it it can not dump full spectral resolution data at fast sampling rates. Hence, for pulsar mode observations the user needs to opt for online dedispersion or gating or folding before recording the data (there is also a online spectral averaging facility for non-pulsar mode observations).

In addition, there is a search preprocessor back-end attached to the incoherent array output of the GAC. This unit gives 1-bit data, after subtracting the running mean, for each of the 256 spectral channels. Either one of the polarizations or the sum of both can be obtained.

Most sub-systems of the pulsar receiver can be configured and controlled with an easy to use graphical user interface that runs on the main computer system. For pulsar observations, since it is advisable to switch off the automatic level controllers at the IF and baseband systems, the power levels from each antenna are individually adjusted to ensure proper operating levels at the input to the correlator. The format for the binary output data is peculiar to the GMRT pulsar receiver. Simple programs to read the data files and display the raw data - including facilities for dedispersion and folding - are available at the observatory and can be used for first order data quality checks, both for the incoherent mode and coherent mode systems.