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The Giant Metrewave Radio Telescope

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Abstract. The Giant Metrewave Radio Telescope (GMRT), which will be the most sensitive radio telescope facility in the world in the 30–1500 MHz frequency range, is at an advanced stage of construction 80 kms north of the city of Pune in India. GMRT will consist of 30 fully steerable parabolic dishes, of 45 m diameter each. Twelve antennas form a random array in a central 1 km × 1 km area and the remaining 18 are equally distributed along the 3 arms of an approximate 'Y' configuration resulting in a maximum baseline separation of about 25 km. GMRT will initially operate at six frequency bands around 50, 150, 233, 327, 610, and 1420 MHz.

Low noise amplifiers are fitted at the back of each feed near the focus to keep the sensitivity high. Analog wideband optical fibre links connect all the antennas, for distributing local oscillator, intermediate frequency, telemetry and voice communication signals. An 'FX' correlator system will provide a total of 238,080 complex channels including 256 spectral channels for each of the 435 baselines and the self correlation products.

Key words: GMRT—electronics—system parameters.

1. Introduction

The basic aim was to build a very sensitive aperture synthesis radio telescope in the decimeter and metre wavelength range that will be complimentary to both Arecibo and VLA telescopes for investigating many outstanding problems in astrophysics. The advantages in building large antennas at low frequencies are that (i) they can be made at lower cost, due to the lower surface accuracy requirement, (ii) electronics is relatively inexpensive and (iii) moderate resolution is sufficient for many astrophysical problems that are best studied at longer wavelengths because the emission comes from diffuse extended regions. However, there are some disadvantages; (i) sky back ground noise is higher, (ii) man made interference is higher and (iii) the distortion of radiowaves due to the ionosphere increases with wavelength. India has the advantage that man made noise is relatively quite low as yet; the absence of snow in most parts of India also helps in the design of lighter antenna structures as the wind forces can be reduced by using mesh surfaces. Further, the experience of the TIFR group in constructing and operating the Ooty Radio Telescope and the Ooty Synthesis Radio Telescope at 327 MHz during the 1965–1985 period was extremely valuable in the GMRT design. Lastly, the development of self calibration techniques now allows almost complete elimination of ionospheric distortions.

In the original proposal (Swarup 1984), 34 parabolic cylinders, similar in design to the Ooty radio telescope, but with dual polarization, were to be built with a total effective area of 70,000 m^2 for operating upto 600 MHz. Considering the many advantages of parabolic dishes and a break-through in the design of low-cost dishes for metrewavelengths, the proposal was revised in 1985 to replace the cylinders with dishes of 45 m diameter. The 30 dishes enable an effective area of $\sim 30{,}000\,m^2$ to be obtained, which is comparable to that of the Arecibo facility. The reduction in collecting area compared to the original proposal is however compensated for, by the reduced system temperatures and cross polarizations, wider bandwidth, frequency and sky coverage obtainable and by the greater versatility of the facility. In the final design, operation at six frequency bands at 50, 150, 233, 327, 610 and 1420 MHz has been provided for.

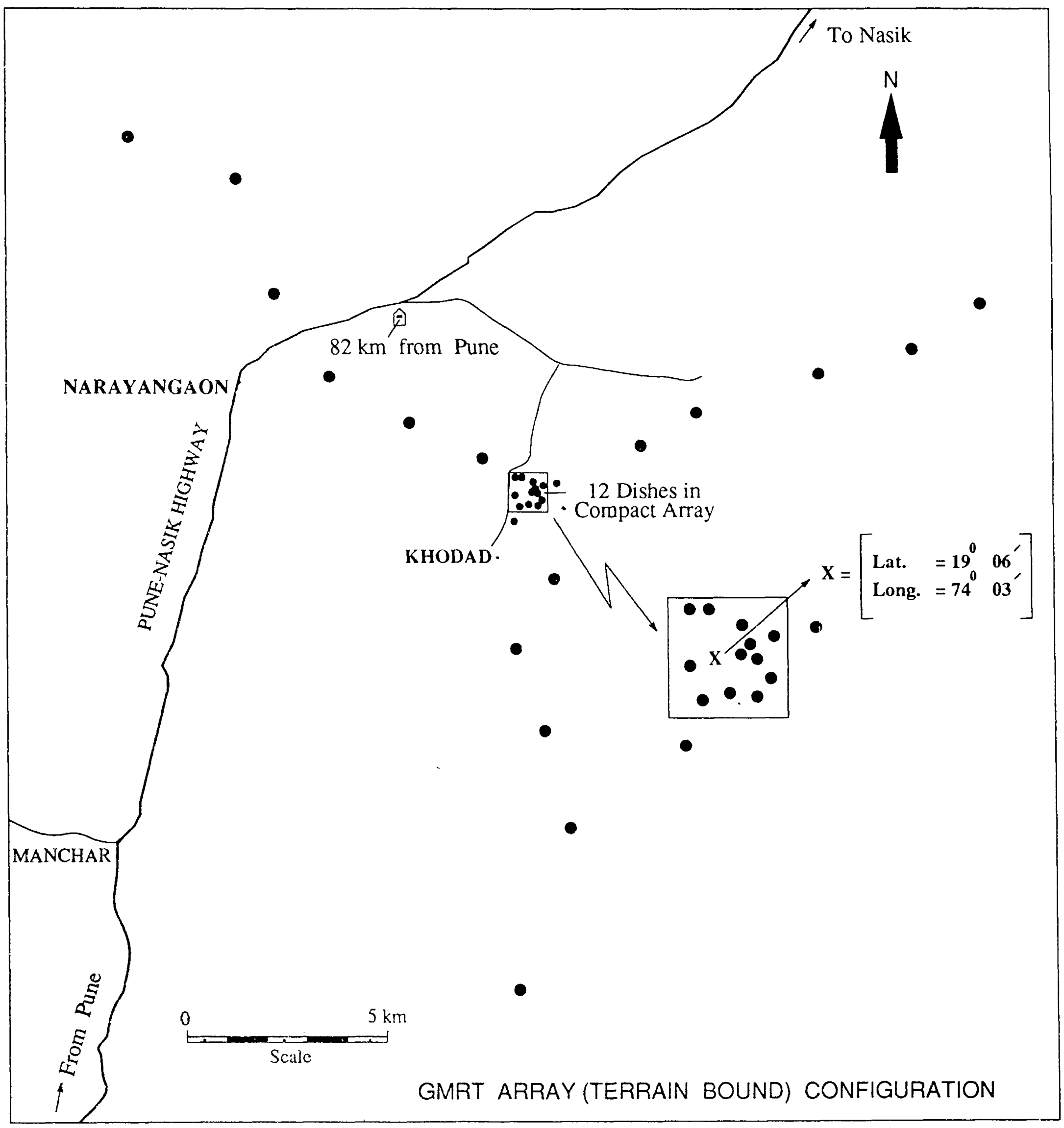

Figure 1. Location and configuration of the GMRT array. The existing rural roads have been advantageously used in placing the antennas.

2. Array configuration and 45 m dishes

Figure 1 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 maximum baseline separation of 25 km. As is well known from the Very Large Array (VLA) experience, the 'Y' configuration gives a good u-v coverage at both high and low declinations. The compact array, which is comparable to the VLA C-D configurations but with larger collecting area, has been designed to provide sensitivity to large extended sources. The 'Y' array antennas provide angular resolutions of about 2 arcsec and 20 arcsec at 1420 and 150 MHz respectively. Thus the hybrid configuration of GMRT gives good u-v coverage and sensitivity for both compact and extended sources (Swarup *et al.* 1991).

The new design concept used in the GMRT dishes is called SMART – an acronym for Stretched Mesh Attached to Rope Trusses (Fig. 2). The conventional (heavy) backup structure is replaced by a series of 4 mm and 2 mm diameter stainless steel (SS)

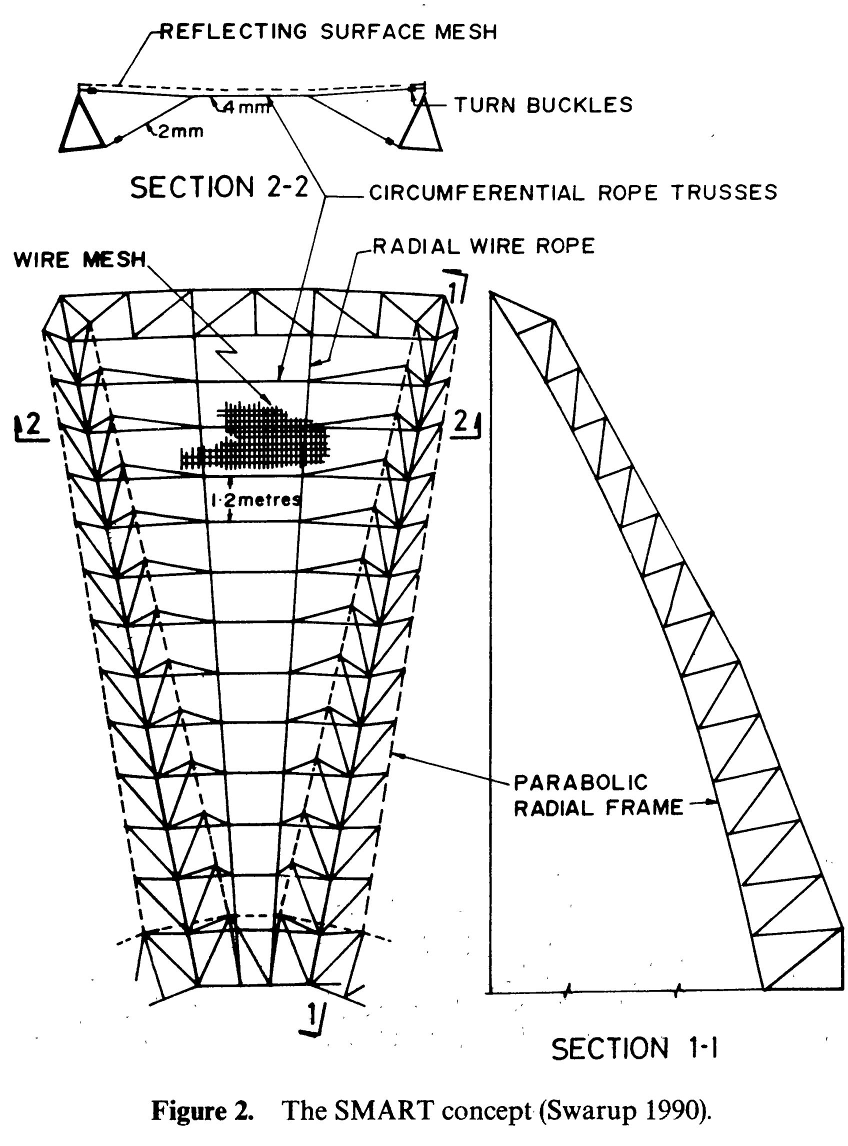

Figure 2. The SMART concept (Swarup 1990).

wire rope trusses stretched between 16 parabolic frames made of tubular steel. The ropes are tensioned to form 360 plain facets over which mesh panels made of 0.55 mm diameter SS wires are stretched. 1200 turnbuckles are used in each dish for tensioning and shaping the facets. The mesh size varies from 10 mm × 10 mm near the central part of the dish to 20 mm × 20 mm near the outer edges.

The low solidity of the mesh surface (~ 7%) greatly reduces the wind forces on the antenna. The total tonnage of the 45 m dish is thus only ~ 80 tonnes, in contrast to ~ 250 tonnes for a conventional 25 m dish. A counter-torque servo system using a pair of 5 KVA DC servo motors connected to azimuth and elevation axes is able to slew the dish at speeds upto 30°/min in azimuth and 20°/min in elevation at wind speeds of upto 80 kmph. The dishes are designed for survival upto 133 kmph. At low winds, the pointing accuracy is better than 1 arcmin rms. More details about the dishes are given in Swarup (1990) and Swarup *et al.* (1991). Some of the erected GMRT antennas are shown in Fig. 3.

3. Electronics system

A simplified block diagram of the receiver system is shown in Fig. 4. All the six frequencies have dual polarized feeds (Sankar *et al.* 1995, this issue) at the prime focus of the antenna mounted on a rotating turret (Fig. 5) which is controlled by a D.C servo

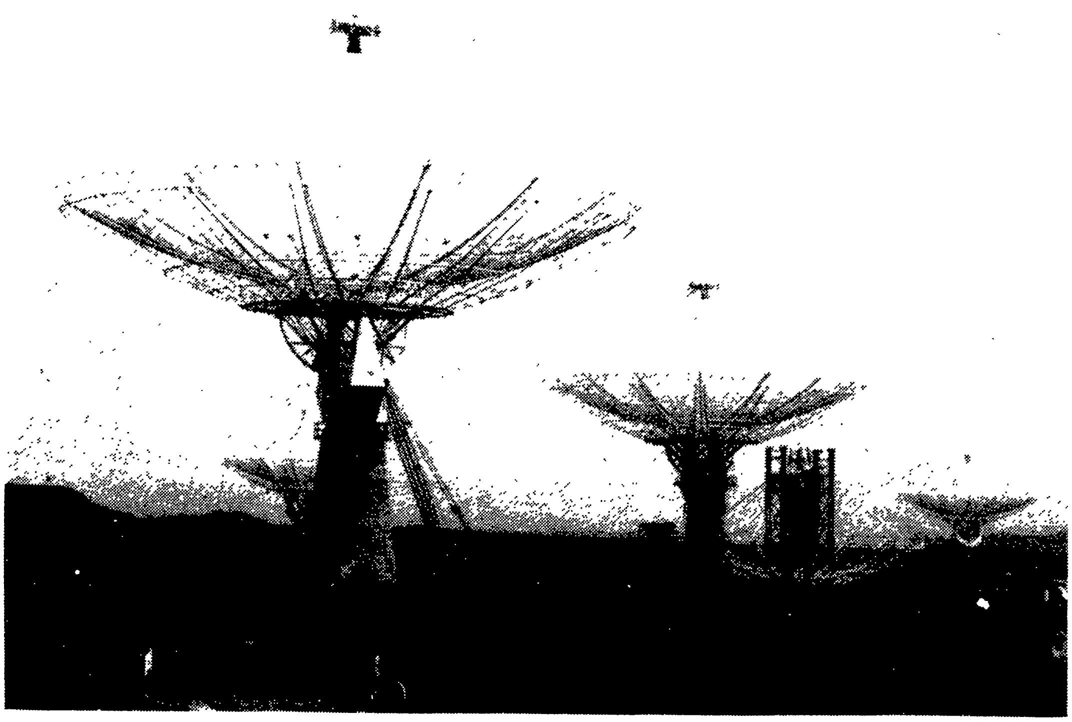

Figure 3. GMRT dishes in the 'central square' at Khodad.

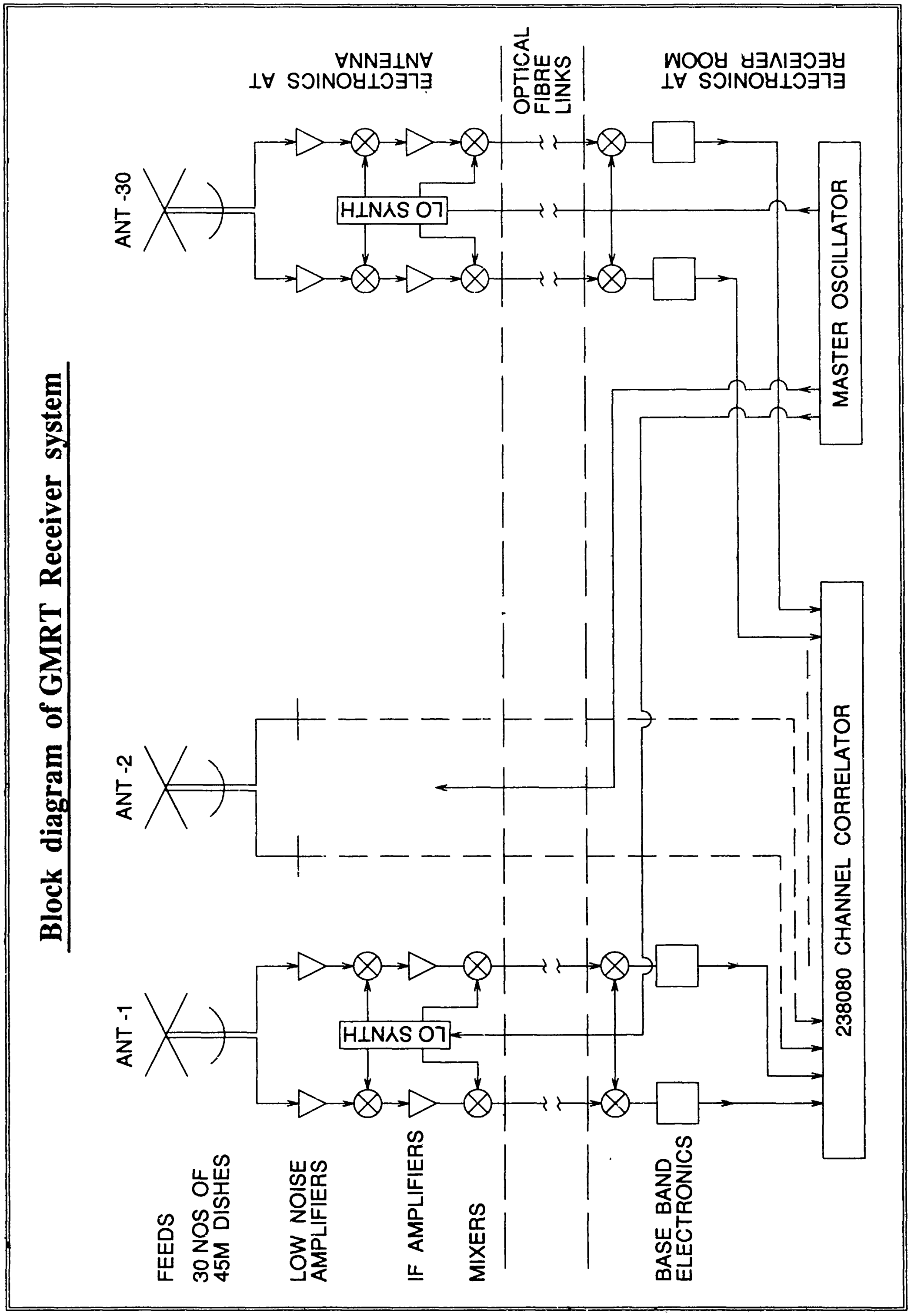

Figure 4. Block diagram of the GMRT receiver system.

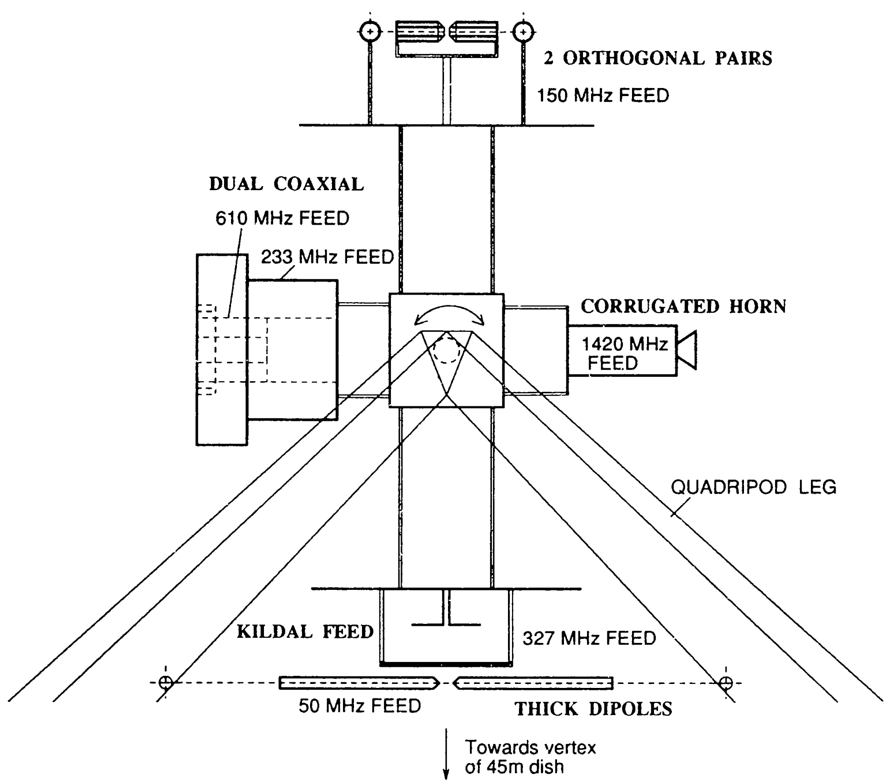

Figure 5. Configuration of feeds on the rotating turret at prime focus.

motor and encoder for precise positioning of the feeds. While the five lower frequency feeds and front-ends are being made by NCRA at Pune, the 1420 MHz system is being built by the Raman Research Institute at Bangalore.
Features of the receiver system include:

- Simultaneous observation at two frequencies (i.e., 2 frequency, 1 polarization or vice-versa).
- Low-noise uncooled RF amplifiers (A. Praveen Kumar *et al.* 1994, this issue).
- Phase switching using Walsh functions to minimize coupling between antenna electronics.
- A flexible Local Oscillator System (Venkatasubramani *et al.* 1994, this issue).
- Low-loss analog fibre optic link between the Central Electronics Building and the antennas (Sivaraj *et al.* 1994, this issue).

- Maximum IF bandwidth of 32 MHz.
- SAW filters at 70 MHz IF for good rejection of out-of-band interference signals.
- The 32 MHz IF signals down converted to two baseband signals of 16 MHz each.
- Video filters from 62.5 KHz to 16 MHz in binary steps.
- Frequency and time referencing using crystal oscillators, GPS and Rubidium standards.

The control and monitor system positions the 30 antennas with full steerability over $\pm 270°$ in azimuth and $+15°$ to $+110°$ in elevation; sets the various receiver parameters such as frequency, bandwidth and noise calibration steps and monitors the health of the systems. It further provides voice communication between the central computer and the antennas (Balasubramanian *et al.* 1994, this issue).

The receiver backend includes:

- An Fx type correlator that uses 1650 high speed FFT/multiplier chips developed by National Radio Astronomy Observatory (NRAO), USA for the Very Long Baseline Array (VLBA).
- A 256 spectral channel cross correlator for the 30 antennas giving $(30 \times 31/2) \times 256 \times 2$ pol. = 2,38,080 correlated outputs including self correlation products. Each of the complex outputs can be averaged over integration times selectable from 0.04s to 10s (Subrahmanya *et al.* 1994, this issue). The special purpose hardware for GMRT includes a phased array mode for Pulsars, VLBI, IPS and Lunar Occultation observations. A pulsar search machine is being designed in collaboration with the Raman Research Institute. An S2 recorder system, specially developed for the space antenna Radioastron by the Canadian scientists, will be used for both VLBI and Pulsar observations.

4. Scientific studies

GMRT will be a very versatile instrument capable of investigating a variety of astrophysical objects and phenomena. These include:

- Continuum studies of the Solar System, HII regions, planetary nebulae, SNRs, Radio stars, Pulsars, metre wavelength variability, mapping of extragalactic radio sources and cosmological investigations.
- Spectral line studies involving neutral hydrogen surveys, search for protoclusters, deuterium line and recombination lines.
- VLBI observations with Ooty and other radio telescopes for pulsar parallaxes and other high resolution studies.

5. System parameters

The aperture efficiency of GMRT dishes would be about 65% at frequencies between 150 and 610 MHz and about 40–45% at 50 and 1420 MHz. Table 1 gives the estimated values of total system temperatures at various frequencies and the resulting rms thermal noise in μJy (1 Jy = 10^{-26} Wm^{-2} Hz^{-1}).

Table 1. GMRT system parameters (30 nos. 45m dishes).

Frequency (MHz)	Primary beam (Deg)	Synthesised beam (Arcsec)	T_{sys} (°K)	S^*_{min} (μJy)
50	9.0	60	8170	4300
150	3.0	20	578	300
233	2.0	13	234	120
327	1.4	9	108	56
611	0.7	5	102	53
1420	0.3	2	98	67

*5 RMS over 10 hrs integration.

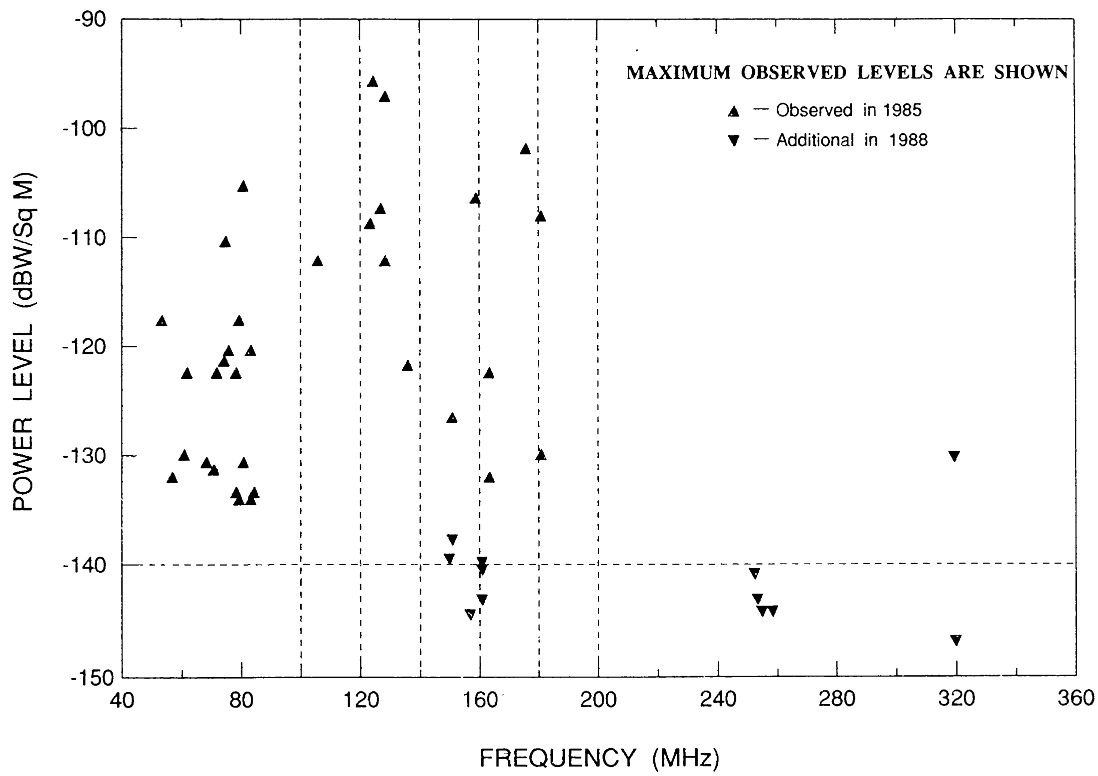

Figure 6. RFI survey at the GMRT site (Swarup & Venkatasubramani 1991).

A comparison of the effective areas and resolutions provided by VLA, Arecibo and GMRT facilities shows that GMRT should provide as high a sensitivity as the partially steerable Arecibo dish in the 150–600 MHz range of frequencies, while it has angular resolution comparable to the fully steerable VLA in its mid frequency range. The radio interference levels at the GMRT site are however expected to be $\sim 10^5$ times lower than at VLA in the metre wavelength range (Fig. 6). This should make GMRT an outstanding radio astronomical facility at metre wavelengths.

Acknowledgements

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