Front-end Electronics for the upgraded GMRT

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Abstract: This paper first describes briefly the existing front-end receiver in use at the GMRT observatory and then details the ongoing development of next generation receiver systems for the upgraded GMRT. It covers the design of the new, two stage, room temperature, low noise amplifiers with better noise performance and matching, and improved dynamic range that are being implemented for the 130-260 MHz, 250-500 MHz and 550-900 MHz bands of the upgraded GMRT front-end systems.

1. Introduction

The GMRT is an aperture synthesis array of 30 fully steerable, 45 metre diameter antennas, spread out over a 30 km region near Pune in western India [1]. It is designed to operate at a range of frequencies from 50 MHz to 1420 MHz, in five distinct frequency bands. All the front end electronics for these bands is located along with the feeds at the prime focus of the dishes, on a rotating turret [2]. Currently the GMRT is going through an upgrade to provide seamless frequency coverage from 50 to 1500 MHz, with a maximum instantaneous bandwidth of 400 MHz for increasing the sensitivity of the telescope. As a part of this upgrade, the existing front end receivers are being modified to have wide band low noise amplifiers (LNAs), octave-band polarizers with low insertion loss, wide band filters and high dynamic range broadband post-amplifiers. The L-band front end receiver has already been reconfigured and modified for better dynamic range, using a high dynamic range two stage wideband post amplifier, and band reject filter for rejecting CDMA and GSM mobile interference signals. New LNAs are being designed for the other broadband systems that are part of the upgraded GMRT.

2. The existing GMRT front end receiver system

Existing GMRT front-end systems operate at five frequency bands centered at 150 MHz, 233 MHz, 327 MHz, 610 MHz and L-band extending from 1000 to 1420 MHz [2]. The L-band is split into four sub-bands centered at 1060 MHz, 1170 MHz, 1280 MHz and 1390 MHz, each with a bandwidth of 120 MHz (see figure 1). The 150 MHz, 233 MHz and 327 MHz bands have about 40 MHz bandwidth, and the 610 MHz band has about 60 MHz bandwidth. All these low noise front-end receivers operate at ambient temperature. They are designed for dual polarization signals, with the lower frequency bands from 150 to 610 MHz having dual circular polarization channels and the higher frequency L-band having dual linear polarization channels. The front end system has flexibility to be configured for either dual polarization observation at single frequency band or a single polarization observation at

Figure 1. Block diagram of existing GMRT Front End Receiver
two different frequency bands. The polarization channels can be swapped whenever required. For observing strong radio sources like the Sun, selectable solar attenuators of 14 dB, 30 dB or 44 dB are provided. The front-end also has a RF termination facility. Any band of the receiver can be switched OFF whenever not in use, with the RF ON/OFF facility provided in the front end. The receiver can be calibrated by injecting four levels of calibrated noise, named Low cal, Medium cal, High cal and Extra-high cal, depending on the specific needs. To minimize cross coupling between channels, a phase switching facility using Walsh function modulation has been provided.

3. Front End Receiver for the upgraded GMRT

As a part of the ongoing upgrade to wideband the GMRT observatory, the front end receiver system is being modified to include wide band, high dynamic range LNAs, wide band filters and octave band polarizers with low insertion loss, amongst other improvements.

At present, new LNAs have been designed for the 130-260 MHz, 250-500 MHz and 550-900 MHz bands of the upgraded GMRT. For radio astronomy requirements, the LNA should be able to amplify extremely low level signals with minimal noise contribution, should have good input impedance match and must be unconditionally stable. Though cryogenically cooled LNAs provide the best performance, they are a costly solution and also increase the complexity of the front end receiver. For metre wavelength radio telescopes like the GMRT, where sky and background noise contributions are substantial, it is possible to obtain optimal system noise temperature performance using the latest devices at room temperatures. Requirements for higher dynamic range, characterized by high OIP3 values which are attained by higher currents in the amplifier leading to elevated noise figure, also need to be balanced with low noise temperature requirements [3].

It is found that E-pHEMT technology provides a combination of high gain, low noise and high dynamic range in high linearity LNA applications [4]. Therefore all these low noise amplifiers are designed using Avago Technologies make E-pHEMT, ATF 54143 device. The designs are simulated using Applied Microwave Research (AWR) make Microwave Office software. Two stage amplifiers are designed with single ended +5 V supply and current consumption of less than 120 mA. All these LNAs have been tested thoroughly on the bench as well as on GMRT antennas and give unconditionally stable performance. They are all in the phase of mass production at present.

3.1. 130-630 MHz Low Noise Amplifier

This LNA is designed for the upgraded 130-260 MHz front end, using some of the ideas given in [5].

![Figure 2. 130-630 MHz Low Noise Amplifier with performance curves](image)
The LNA has a measured noise temperature \( T_{\text{eff}} \) of 45 \(^\circ\)K, Gain \( G \) of 37 dB and return loss of -10 dB (figure 2). These LNAs are integrated with the feed and rest of the receiver electronics and successfully tested on GMRT antennas. Inclusion of this LNA in the system has reduced the system noise temperature \( T_{\text{sys}} \) to 407 \(^\circ\)K for 130 MHz bandwidth at ambient temperature (see table 1).

3.2. 200 – 500 MHz Low Noise Amplifier

This LNA is designed for the upgraded 250-500 MHz front end receiver, using ideas described in [5]. It has a measured noise temperature \( T_{\text{eff}} \) of 20 \(^\circ\)K, Gain \( G \) of 35 dB and return loss of -10 dB (see Figure 3). The measured OIP3 of this amplifier was found to be +18dBm. These LNAs have been integrated with the 250-500 MHz Cone Dipole Feed and rest of the receiver electronics and tested successfully on few GMRT antennas. Inclusion of this LNA in the system has reduced the system noise temperature \( T_{\text{sys}} \) to 88 \(^\circ\)K for 250 MHz bandwidth at ambient temperature (see table 1).

3.3. 550 – 900 MHz Low Noise Amplifier

Figure 3. 200-500 MHz Low Noise Amplifier with performance curves

Figure 4. 550-900 MHz Low Noise Amplifier with performance curves
This LNA is designed for the upgraded 550-900 MHz front end receiver, using some of the ideas in [6]. It has measured noise temperature (Teff) of 20 °K, Gain (G) of 30 dB and return loss of -10 dB. The measured OIP3 of the amplifier was found to be +18dBm. These LNAs are integrated with 550-900 MHz Circular Waveguide Feed designed by CSIRO, Australia and rest of the receiver electronics and tested successfully on GMRT antennas. Inclusion of this LNA in the system has reduced the system noise temperature (Tsys) to 58 °K for 350 MHz bandwidth at ambient temperature (table 1).

Table 1. Tsys values for various frequency bands of existing and upgraded GMRT

| Sr. No | Frequency Band [MHz] | Input cable loss L1[dB] | Polarizer Loss L2[dB] | LNA Temp T_LNA [K] | Receiver Temp a T_R [K] | Ground Temp T_ground[K] | Sky Temp T_Sky[K] | System Temp T_sys[K] | Bandwidth [MHz] | System Temp (Existing FES) T_sys[K] |
|--------|----------------------|------------------------|----------------------|-------------------|-------------------------|-------------------------|-----------------|---------------------|----------------|-----------------------------|
| 1      | 150                  | 0.1                    | 0.4                  | 45                | 87                      | 12                      | 308             | 407                 | 130            | 580 (40 MHz)                |
| 2      | 235                  | 0.1                    | 0.4                  | 45                | 87                      | 12                      | 99              | 198                 | 130            | 234 (40 MHz)                |
| 3      | 327                  | 0.1                    | 0.1                  | 20                | 35                      | 13                      | 40              | 88                  | 250            | 108 (40 MHz)                |
| 4      | 610                  | 0.1                    | 0.1                  | 20                | 35                      | 13                      | 10              | 58                  | 350            | 101 (40 MHz)                |
| 5      | 1060                 | 0.22                   | -                    | 35                | 53                      | 25                      | 5               | 83                  | 120            | 83 (120 MHz)                |
| 6      | 1170                 | 0.22                   | -                    | 32                | 49                      | 24                      | 4               | 77                  | 120            | 77 (120 MHz)                |
| 7      | 1280                 | 0.22                   | -                    | 30                | 47                      | 23                      | 4               | 74                  | 120            | 74 (120 MHz)                |
| 8      | 1390                 | 0.22                   | -                    | 28                | 45                      | 23                      | 4               | 72                  | 120            | 72 (120 MHz)                |

a Includes Input cable losses

4. Summary
New wideband, high dynamic range, room temperature LNAs have been successfully designed for 3 of the wideband configurations of the upgraded GMRT. They have been integrated with the feed and front-end electronics systems and have passed the initial acceptance tests and are in mass production phase. There is scope of improvement in the gain slope of 550-900 MHz LNA by incorporating a negative feedback network in the second stage, and possibility of reducing the Teff for 130-260 MHz LNA. Successful completion of these will improve the sensitivity and versatility of the GMRT by a large amount, keeping it at the forefront of low frequency radio astronomy at the global level.

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