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Multi Frequency, Wideband, Low Noise Front-end Receiver Systems for the uGMRT

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The Giant Metrewave Radio Telescope (GMRT) is one of the largest and most sensitive fully operational low frequency radio telescopes in the world. The aperture synthesis array configuration of fully steerable 30 antennas (each of 45 m diameter) spanning over 25 km, provides a total collecting area of about 30,000 sq. m at meter wavelengths [1, 2]. To keep the GMRT competitive in the global arena in the future, a major upgrade of the observatory is nearing completion that will increase its sensitivity significantly and make it a more powerful and versatile facility [5]. The main objective of the GMRT upgrade was to add an extra capability to the existing GMRT array in terms of frequency coverage and sensitivity. The improved frequency coverage is achieved by broad-banding the receiver systems and the increased sensitivity is achieved by designing the new receiver systems with wider bandwidth and incorporating the new Low Noise Amplifiers (LNA's) with very low noise figures at room temperature.

To achieve the objectives stated above, the GMRT was upgraded (uGMRT) to provide seamless frequency coverage from 50 to 1500 MHz, with a maximum instantaneous bandwidth of 400 MHz as against the 32 MHz final instantaneous bandwidth of the existing GMRT bands centered at 150 MHz, 233 MHz, 327 MHz, 610 MHz and L-band extending from 1000 to 1450 MHz. The final choice of bands for the uGMRT was 120–250 MHz (band2), 250–500 MHz (band-3), 550–850 MHz (band-4), 1050–1450 MHz (band-5). The seamless frequency coverage was achieved by the design of feeds and frontend electronics in octave ranges of frequency [4]. As a part of this upgrade, the existing front-end receiver electronics was modified by introducing wideband low noise amplifiers, octave-band polarizers with low insertion loss, low loss wideband directional couplers for noise injection, wideband filters and high dynamic range broadband post-amplifiers. Provision for switching the filters in any given band was made for offering the flexibility of sub-band selection to the user. Band reject filters were provided in each of the bands to reject some of the strong commercial radio signals to mitigate the radio frequency interference. The improved receiver system has better dynamic range.

The room temperature low noise amplifiers with improved noise performance, wider bandwidth, better matching and high dynamic range have been designed for 120-250 MHz, 250-500 MHz, 550-850 MHz and 1050-1450 MHz band of the upgraded GMRT [3]. The newly designed LNAs offer less than 0.5 dB noise figure at room temperature for all the uGMRT bands. All these LNAs have more than 30dB flat gain and better input & output matching over the band.

The low noise front-end receiver system of the GMRT has been designed to process dual polarization signals for all the bands. For observing strong radio sources like the Sun, selectable solar attenuators of 14 dB, 30dB or 44 dB can be used. The receiver can be calibrated by injecting four levels of calibrated noise, ranging from a small fraction to a few times of the system noise temperature for the particular band [2]. These features of the existing GMRT front end receiver are preserved while upgrading the system.

The 1050-1450 MHz front-end receiver was reconfigured and modified for better dynamic range using a high dynamic range post amplifier. A new band pass filter and switched filter bank with sharp cut-off for better rejection of the out of band signal were incorporated. A band reject filter was added to the system for rejecting the CDMA and GSM mobile interference signal.

A two stage broadband, high dynamic range post amplifier was designed to offer flat gain to all the frequency bands supported by GMRT. Temperature, RF power and Voltage monitoring facilities are provided to monitor the health of the system and to study the stability of front- end receiver system. The monitoring of physical temperature of the enclosure helps in studying the performance of the front-end system with the variation in ambient temperature. The Rabbit based MCM card (Monitoring and Control module) with very high processing speed is incorporated for control and monitoring operation along with an additional facility to have ethernet interface over the optical fibre in order to improve the reliability.

The upgrade of the feed and front-end systems with improved capabilities was successfully completed over the past few years in a phased manner and the systems have been populated on all GMRT antennae, except for a small portion of control and monitoring of front-end receiver which is in the final stages of implementation. The uGMRT have been released for use by the global community in phased manner and the initial test results have been encouraging. This paper presents some of the main aspects of the design of these upgraded front-end systems and characterizes their performance. The improved sensitivity and versatility of the uGMRT will keep the observatory at the forefront of low frequency radio astronomy at the global level.

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