DESIGN OF A PRIME-FOCUS DUAL-BAND FEED FOR THE GIANT METRE-WAVE RADIO TELESCOPE IN INDIA

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ABSTRACT
The design of a dual band VHF/UHF prime focus horn for a 45m-diameter antenna is showcased. The design has been made difficult due to the compactness necessary to meet the stringent weight-limits. The paper highlights the engineering challenges and the results obtained after optimization.

INTRODUCTION

We have designed a dual-band VHF/UHF prime focus horn for the 45m-diameter antennas of the Giant Metre-wave Radio Telescope (GMRT). The supply of the design is part of collaboration between CSIRO's Australia Telescope National Facility (ATNF) and ICT Centre (Australia) and the National Centre for Radio Astrophysics (NCRA) (India).

The GMRT [1] is located about 80 km north of Pune (India) and consists of 30 fully steerable prime-focus parabolic reflectors of 45m diameter that are spread over distances of up to 25 km. The antennas have a focal length of 18.54m and a half subtended angle of 62.5°.

The dual-band feed system covers the frequency bands 0.22 to 0.24 GHz and 0.55 to 0.9 GHz. The scope of our work was to design the horn and the associated feed system, and calculate the theoretical performance of the GMRT antennas over these two frequency bands. One of the main constraints in the design was compactness (strongly related to the weight) as the feed support is limited in both strength and length of the feed.

We were asked to aim at designing the full length of the system to be around 1 to 1.2 metre; unfortunately, the final design is slightly longer. It was agreed, from the onset of this project, that CSIRO would only provide a design and that manufacture and testing would be handled by the NCRA.

HORN PERFORMANCE & SIGNAL EXTRACTION

A coaxial horn arrangement was chosen because it leads to a very compact antenna. The 0.55 to 0.9 GHz band is received through the inner waveguide while the 0.22 to 0.24 GHz band is received through the outer coaxial waveguide of the horn (see Fig. 1).

The horn was optimized to cover both bands effectively and provide a suitable illumination to the GMRT reflectors (-12 dB taper at 62.5°) and a good match in both frequency bands. Matching irises were required to provide a good match in the lower frequency band and this was achieved by optimization as well. The radiation patterns of the horn at 0.230 and 0.700 GHz are shown in Fig. 2 where it can be seen that the illumination meets the design specifications.

In addition to the horn design, a means of extracting the signal is required in each frequency band. The 0.22-0.24 GHz band is extracted from the coaxial waveguide using four orthogonal probes and requires a pair of 3dB hybrids and four phased matched cables to combine the ports combiner network (see Fig. 3). This technique has been shown to work well in the past and has been successfully used recently in a similar project [2].

The extraction of the wider-band 0.55-0.9 GHz signal from the inner waveguide is more difficult and requires special attention. As the bandwidth is almost 65%, a wideband transition such as a quad-ridged orthomode transducer (OMT) was considered. However, the conventional design of quad-ridged OMTs uses a very effective but also very long (in terms of wavelength) taper from the input to the output probes. It was estimated that scaling an existing design would lead to a feed-system 3 to 4 m long, which is unacceptable for this application. We decided to try to reduce the length of the transition using a stepped transformer [3] instead of the conventional smooth profile of the OMT fins. A significant effort was then directed towards optimising such a short OMT to cover the required band. The optimized feed-system is shown in Fig. 4 where the overall length is 1490mm. The return loss of the 0.55-0.9 GHz band for both polarizations is shown in Fig. 5 where it can be seen that a nominal 15 dB return loss is achieved over the band.

PERFORMANCE OF THE ANTENNA

The radiation pattern of the antenna was simulated in order to estimate the gain and the associated efficiency. The phase-centre of the feed system is assumed to be 50 mm inside the horn when measured from the aperture (i.e., the focus of the GMRT antenna has to be located 50mm inside the horn along the axis of the horn). The results are summarized in Table 1.

CONCLUSIONS

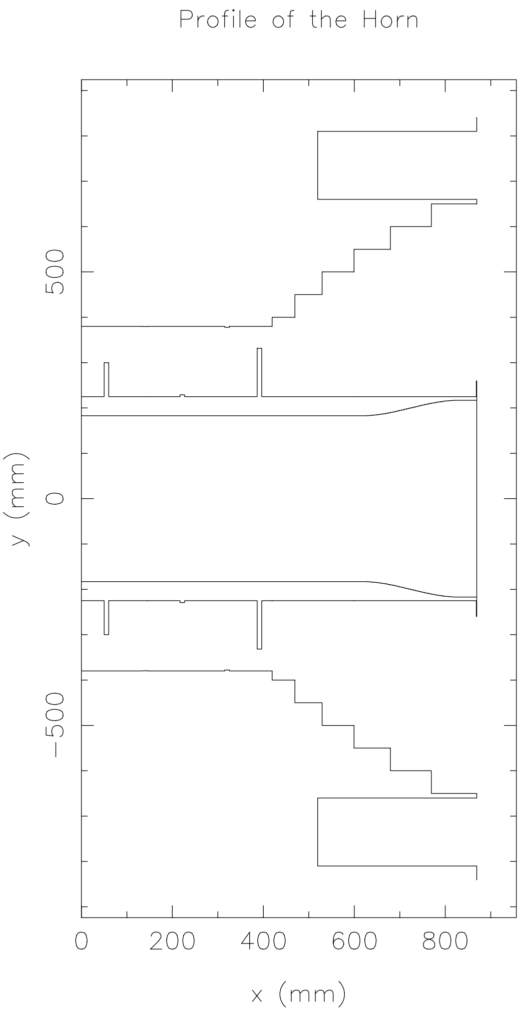
We have described the design of a dual-band feed for the 45m reflectors of the GMRT radio telescope. The feed consists of a coaxial horn with optimised matching irises to reduce the aperture mismatch in the outer coaxial waveguide. The signals in the lower frequency band are extracted from the outer waveguide by means of four orthogonal probes and a combiner network. A stepped quad-ridged transition is used to extract the higher frequency band from the inner waveguide. A nominal edge illumination of –12dB is achieved in both bands and the worst-case return loss is about 15 dB at the edges of the bands.

REFERENCES

[1] http://www.ncra.tifr.res.in/ncra_hpage/gmrt/gmrt.html

[2] C. Granet, H.Z. Zhang, A.R. Forsyth, G.R. Graves, P. Doherty, K.J. Greene, G.L. James, P. Sykes, T.S. Bird, M.W. Sinclair, G. Moorey, R.N. Manchester, "Design, manufacture and test of a dual-band feed system for the Parkes radio telescope", IEEE Antennas & Propagation Magazine, Vol. 47, No 3, June 2005, pp 13-19.

[3] S. Hopfer, "The design of ridged waveguides", IEEE Transactions on Microwave Theory and Techniques, Vol. 3, Issue 5, Oct. 1955, pp. 20-29



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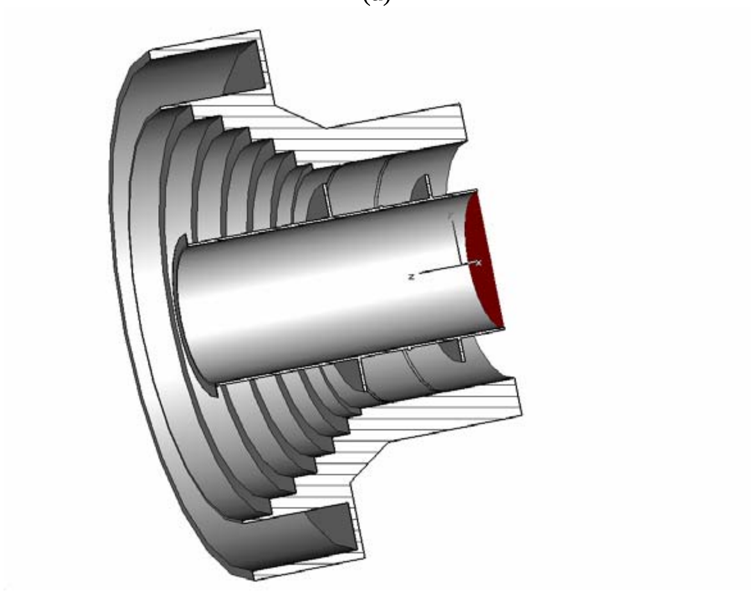
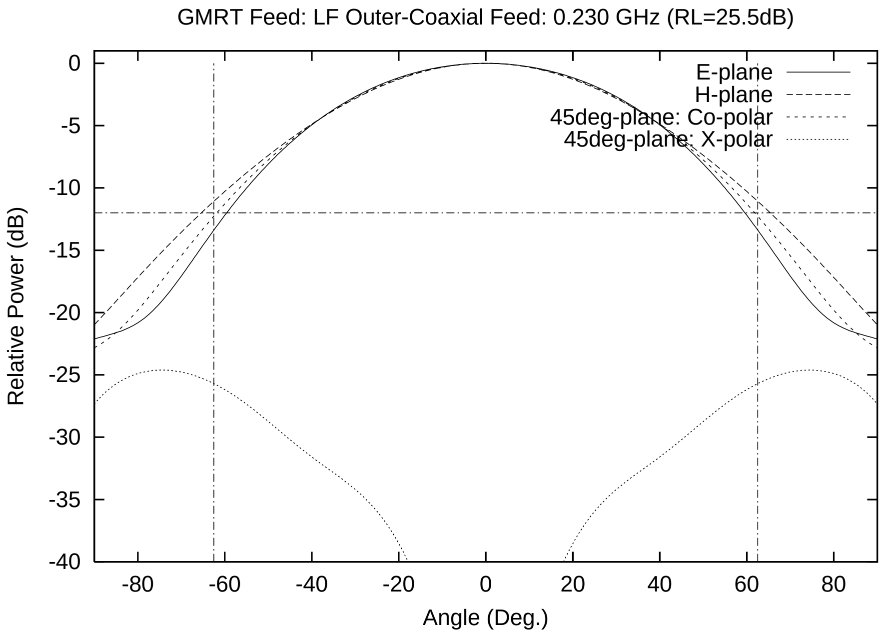
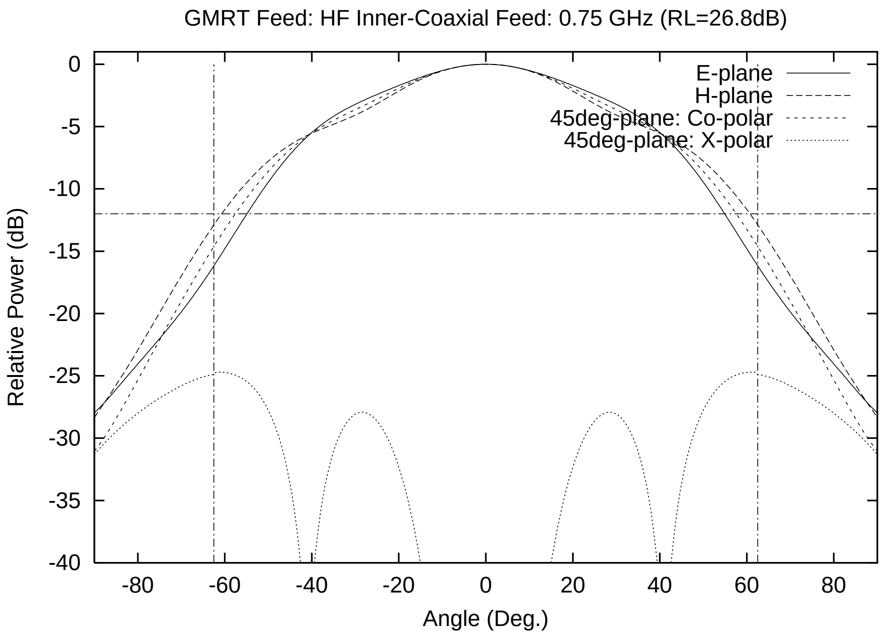


(b)

Figure 1: Cut-away view of the dual-band coaxial horn with the matching irises for the 0.22-0.24 GHz band: (a) detailed drawing and (b) cut-away of the 3D model.



(a)



(b)

Figure 2: Radiation pattern of the dual-band horn at (a) 0.230 GHz and (b) 0.700 GHz.

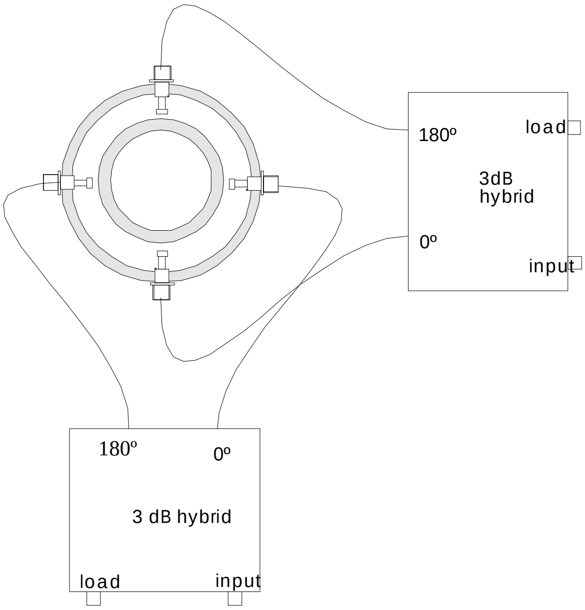


Figure 3: Coaxial junction and coaxial network.

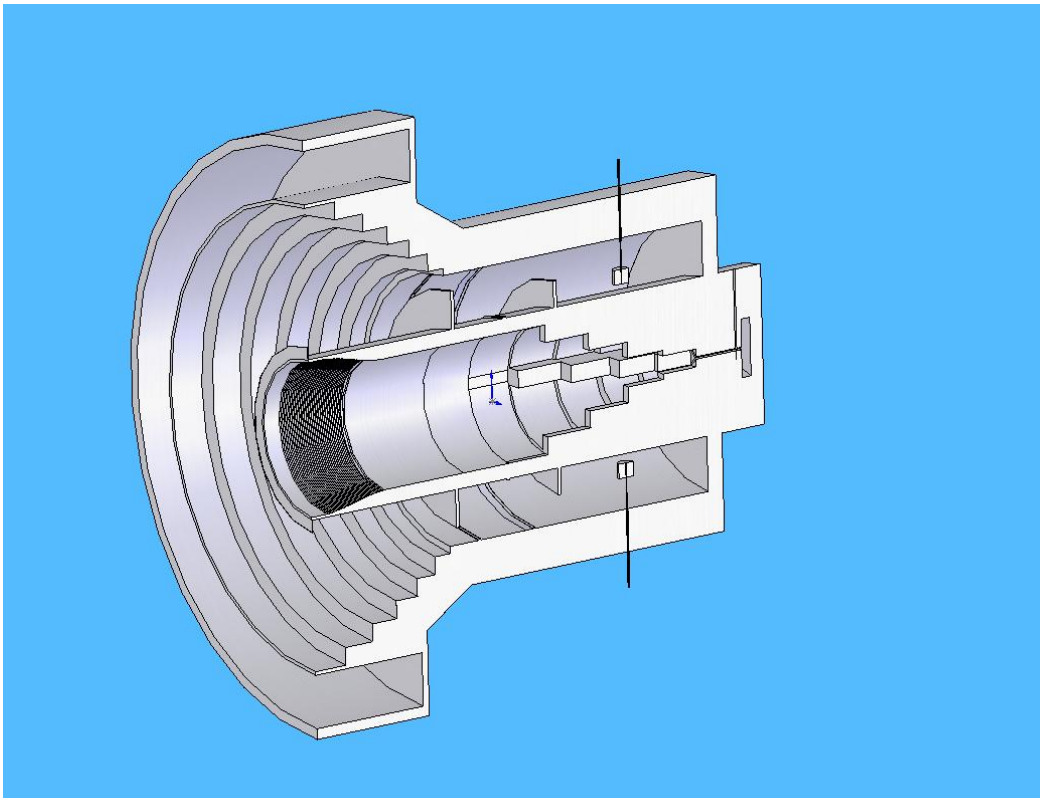


Figure 4: Cut-out view of the complete feed-system.

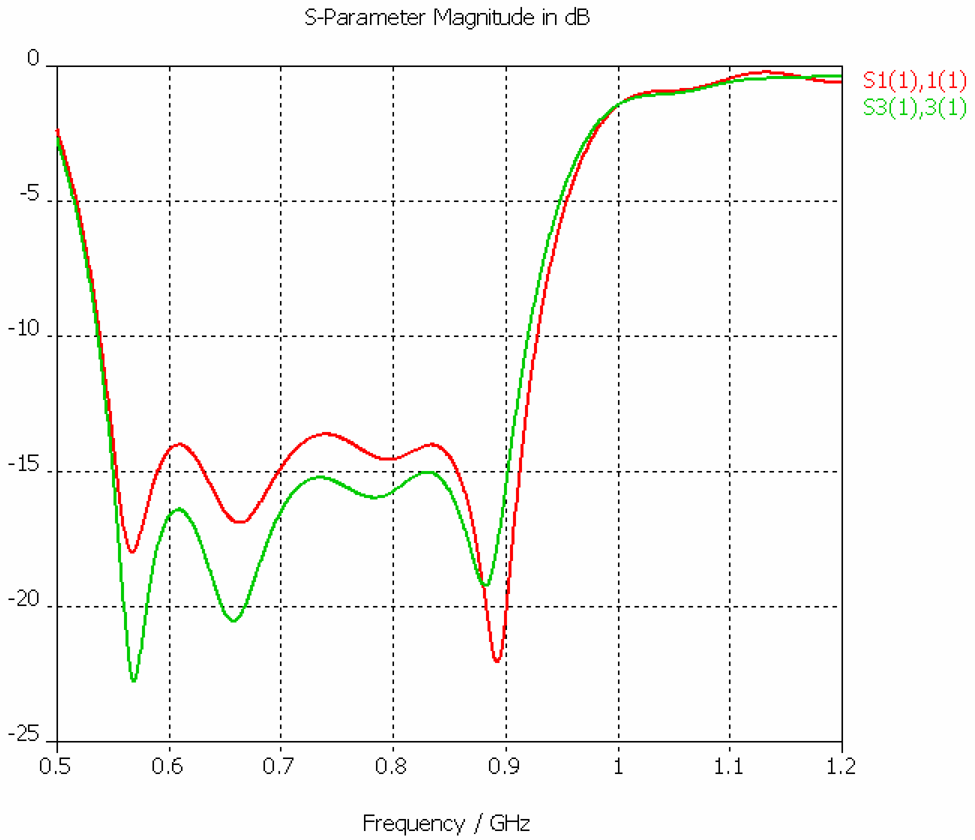


Figure 5: Return loss of front-probe (red) and rear-probe (green) of the 0.55 to 0.9 GHz OMT. (S11: Rear-probe, S33: Front-probe).

Table 1: Simulated performance of the GMRT 45m-diameter antenna with the dual-band horn.

Frequency (GHz)	Gain (dBi)	Efficiency (%)
0.22	38.6	**67.8**
0.23	39.0	**68.1**
0.24	39.1	**64.0**
0.55	46.7	**70.1**
0.60	47.6	**72.5**
0.65	48.3	**72.5**
0.70	49.0	**73.5**
0.75	49.5	**71.8**
0.80	49.7	**65.6**
0.85	49.7	**59.0**
0.90	49.5	**49.9**