A Dual-Band Feed System for the Parkes Radio Telescope

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1. Introduction

In a joint project between the ATNF and CTIP, a dual-band, dual-polarisation, coaxial receiver system for the Parkes radio telescope (Australia, see Fig. 1) covering the 10-cm and 50-cm bands is being designed and constructed. While the primary motivation is to provide a receiver system optimised for pulsar observations, the feed system will also be used for other wide-band continuum observations such as the 3.3 GHz transition of CH and various recombination lines.

Figure 1: The 64-m-diameter Parkes radio telescope (Photograph by S. Juraszek).

2. Design objectives

The main objective is to receive two orthogonal linear polarisations (with > 30 dB isolation) within each band. The low-frequency (LF) band is 0.648-0.712 GHz, and the high-frequency (HF) band 2.6-3.6 GHz. A system temperature, T_{sys}, ≤ 30K+sky is specified for the LF-band and ≤ 25K for the HF-band. On-axis Gain/T_{sys} is optimised with linear calibration at 45°. Another constraint is the available space in the focal cabin of the telescope which calls for a compact design.

The Parkes radio telescope has a diameter of D=64 m and a focal distance of F=26.24 m (F/D=0.41), i.e., the feed edge-illumination angle is 62.75°. Although the best theoretical Gain/T_{sys} is obtained with an edge illumination of around –15 dB, this requirement leads to many design problems (mainly due to pattern asymmetry) and an easier design procedure is readily available for an edge illumination of –12 dB for the outer-coaxial section (LF-Band) [1][2], and the inner-coaxial section [3].

3. Feed horn

CTIP has designed the feed horn and signal extraction components, while the ATNF is designing the two receivers and front-end systems. The feed horn is a coaxial structure where the HF-band is received by the inner circular waveguide (which forms the core of the structure) and the LF-band by the coaxial waveguide itself. To improve the radiation pattern symmetry of the inner waveguide for the HF-band, a choke is located between the two radiating apertures (see Fig. 2). The coaxial waveguide receiving the LF-band has inherently poor return loss and therefore irises are used to improve the match [1]. The return loss of the feed has been optimised to be well above the 15 dB target (see Fig. 3). The theoretical radiation pattern of the feed displays a good degree of pattern symmetry with low cross-polarisation (see Fig. 4). Furthermore, the beamwidth over the frequency bands does not vary appreciably. The Gain/T_{sys} is estimated to be about 36 dB/K for the LF-band and 50 dB for the HF-band system. This was achieved, in part, by realising the specifications on the system temperature. The theoretical radiation pattern of the radio telescope using the new dual-band feed is shown in Fig. 5.

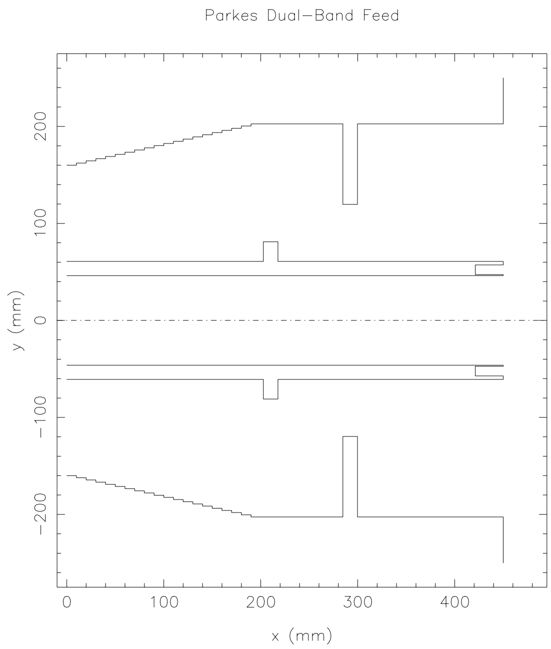


Figure 2: Geometry of the dual-band coaxial feed.

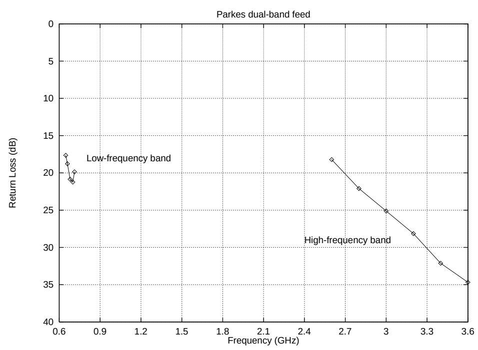
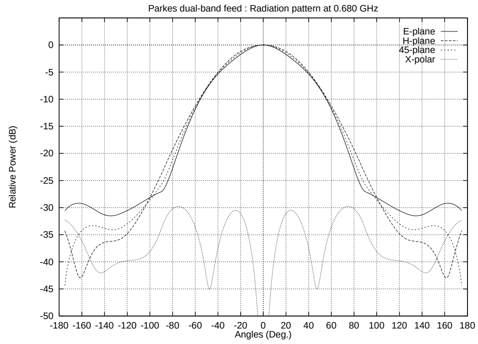


Figure 3: Return loss of the dual-band feed horn over the two frequency bands.



a)

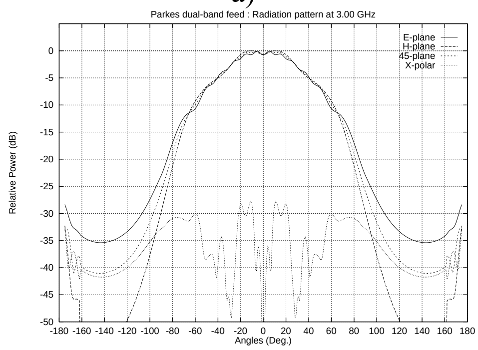


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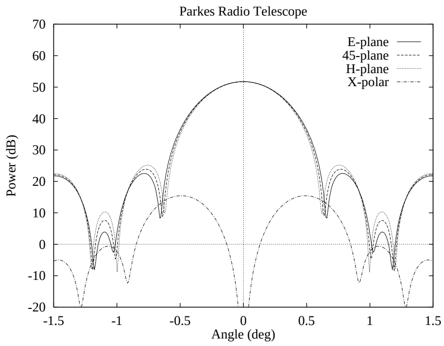
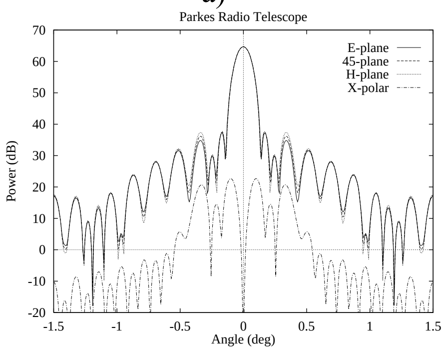
Figure 4: Radiation pattern of the feed horn at a) 0.68 GHz (LF-band) and b) 3.0 GHz (HF-band).



a)



b)

Figure 5: Theoretical radiation pattern of the Parkes radio telescope
with the dual band feed at a) 0.68 GHz and b) 3.0 GHz.

4. Signal extraction

The LF-band is extracted by using a six-port coaxial Orthogonal Mode Junction (OMJ). The incoming signals are coupled from the OMJ to four rectangular waveguides through two matching steps. The signals are then re-combined using two coaxial T-junctions. The coaxial OMJ is designed and analysed using a full-wave method [4][5]. The HF-band is extracted through a conventional OrthoMode Transducer (OMT) whose design is based on previous work [6].

5. Manufacture

The large size of this feed and its component parts has necessitated the use of special design and manufacturing techniques to aid manufacturability and to reduce raw material and manufacturing costs.

The cylindrical components of the LF-band horn and the six-port coaxial OMJ have been designed to be manufactured from smaller parts (see Fig. 6a), machined to near nett shape, then GTAW welded together, and finish machined to final shape and size.

The rectangular ports and the waveguide to co-axial transitions are made from machined sections with flat faces, bolted together to form rectangular waveguides of the correct internal dimensions.

The inner coaxial (HF-band) waveguide is rigidly supported only where it passes through the back-short of the LF-band system, with an intermediate support of low dielectric structural foam near the aperture. To reduce the mass of this waveguide, and to provide a method for attachment of the matching rings on its outer surface, this waveguide is designed to be made from machined thin-walled tubes forming the inner and outer surfaces. Multiple sections are used, with the LF-band matching rings bolted between the sections. The hollow annular space between the walls provides access to circles of attachment bolts used to secure the sections together.

Extensive use has been made of a new high speed CNC machining centre to produce the component parts before welding or bolted assembly (see Fig. 6b). The use of this machine has permitted the design and manufacture of machined components with thin sections for reduced weight. Integral stiffening ribs and webs have been included in the design to maintain flatness and circularity of these lightweight component parts.

a) b)

Figure 6: a) View of the outer-coaxial (LF-band) structure with its 6-ports network before welding, b) Stepped transition of the horn being machined on CSIRO's new CNC Machining Centre.

7. Cryogenic receiver

The cryogenic receiver system consists of the wide-band HF dual-polarisation OMT, a pair of 1 GHz-bandwidth HF low-noise amplifiers (LNA's) and a pair of LF-LNA's. All these components are mounted inside a large stainless steel vacuum chamber attached to the top of the feed horn structure. These components are mounted on a thermally isolating structure inside the dewar and cooled to a physical temperature of 15 K by a closed-cycle Helium refrigerator with a 10 W thermal load capacity. The HF-signals from the feed horn are coupled to the interior of the dewar through a microwave vacuum window and then to the quadridged OMT via a set of waveguide thermal isolation gaps. The LF-signals will be coupled into the vacuum dewar and thence to the cooled LNA's via low-loss coaxial lines and hermetic connectors. After amplification of ≥ 30 dB both these signals are then connected via coaxial lines and hermetic connectors to external RF signal processing electronics.

6. Conclusions

A full overview of a new dual-band feed system for the Parkes radio telescope, including the design, manufacturing processes and the engineering challenge in installing it into the focal cabin (see Fig. 7), has been presented. Manufacture has already started and the system is expected to be fully operational by the end of the year.

7. References

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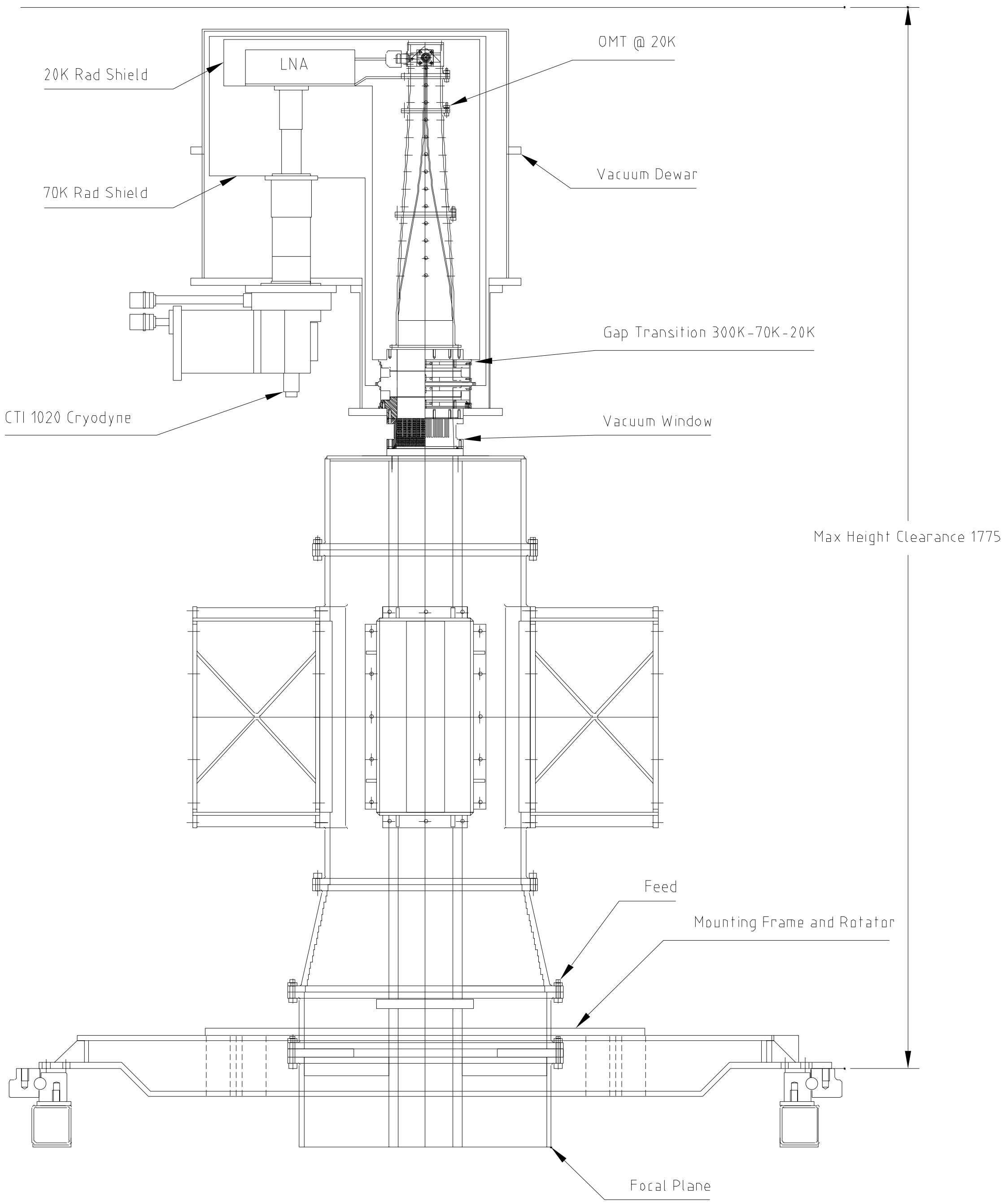

Figure 7: General arrangement of feed horn structure and cryogenic receiver dewar on the Parkes radio telescope mounting interface.