A Wideband Feed for a Cylindrical Radio Telescope

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Abstract

This thesis investigates the design of a wideband dual polarised, scanning line feed for a cylindrical reflector radio interferometer. Feed elements used in current cylindrical radio telescopes have a narrow bandwidth and operate with a single polarisation. The development of a wideband dual polarised line feed facilitates new scientific capability for cylindrical reflector radio telescopes through polarimetric imaging, increased observing frequency range and improved continuum survey sensitivity.

The new line feed described in this thesis is for the Molonglo Observatory Synthesis Telescope (MOST), which is a cylindrical reflector radio telescope that currently measures continuum radiation with a single polarisation at 843 MHz. The scientific capability of the MOST will be extended through the implementation of the Square Kilometre Array Molonglo Prototype (SKAMP) project. A key technology for SKAMP is the design of a new line feed. From an evaluation of state-of-the-art array element technology, it was determined that a wideband dual polarised dipole suited the performance and engineering requirements at the frequency range of operation (300–1400 MHz). A three-band line feed configuration was proposed to cover the entire frequency range, with each band covering a 1.7:1 bandwidth.

The frequency range selected for the initial design is 700–1100 MHz. The prototype design produces high polarisation purity and symmetric transverse plane radiation as the feed is scanned. One disadvantage is unequal transverse plane patterns for the two polarisations. However, a method of compensation was implemented. A low cost, low loss, integrated wideband matching network/balun and a novel feeding technique were developed to produce dual linear polarisation for the feed element. For telescope operations, an 8-element line feed was prototyped and tested for radiation patterns across the 700–1100 MHz frequency and 0°–45° scan angle range. Measured cross-polar levels in the scan element pattern remained below –22 dB from the main beam for both polarisations across the scan range. A comprehensive analysis of the feed performance was carried out for parameters including the antenna efficiency and spillover temperature. Testing of the feed design will be undertaken at the telescope and implementation on the entire telescope will demonstrate a world first in polarimetric imaging using a cylindrical reflector radio telescope.

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Due to the practical nature of the project, I spent a majority of my time in the first three years at the industry partner, Argus Technologies Australia, to gain experience in antenna design and engineering. As a result, I would like to express my gratitude to staff members who assisted me with various aspects of my project. In particular I would like to thank Peter Liversidge for discussions on feed design and implementation techniques; Martin Owen for assistance with mechanical design issues and for checking my technical drawings; Simon Mackay, Daniel Ryan and Michael Smith for their assistance with antenna testing and discussions on prototyping techniques; Bill Rodgers and Marco Majoniemi for ordering my feed boards and line feed metalwork, and William Chen for skilfully machining parts for my antenna prototypes. A highlight of being at the industry partner was the friendships that I formed in my time there and I would like to sincerely thank Simon Mackay and my carpool team members: Daniel Ryan and Michael Robinson for their honesty, encouragement, humour, support and weird conversations.

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- The School of Physics, ATNF and the Australian Communications Research Network to attend the IEEE Antennas and Propagation International Symposium held in Honolulu, Hawaii USA in June 2007.

Statement of Originality

This thesis describes work carried out between 2003 and 2007 in the School of Physics at the University of Sydney, Argus Technologies Australia and the Australian Telescope National Facility CSIRO. The work presented in this thesis is my own except where acknowledged specifically and no part of the work has been submitted to any other university.

Existing antenna theory and analytical techniques from the literature were used in this thesis and I claim no originality for their development. Instead, I have applied these techniques to the design of a line feed for a cylindrical reflector used specifically for a radio astronomy application. Thus, my contributions are in the feed design methodology and analysis of performance subject to astronomy requirements. Specific contributions from other colleagues are now described.

In Chapter 4, the multiple line feed solution to cover the entire 300–1400 MHz observation frequency range, resulted from discussions with Bevan Jones, Duncan Campbell-Wilson and Andrew Parfitt. In Chapter 5, an existing theoretical modelling approach is used to analyse the combined feed and reflector performance. Programs used to obtain the radiation patterns were provided by Bevan Jones, for this Chapter and Chapter 8. In Chapter 6, the novel in-pairs feeding method for the selected wideband dipole element was conceived in a meeting I had with Bevan Jones. The software, CST Microwave Studio, was used to simulate the line feed array performance. Technical drawings and design of the metalwork for the line feed were carried out by me, in consultation with Martin Owen. The radiation pattern measurements, conducted at the Argus ground reflection test range, were supervised and carried out by me with assistance from Argus Engineering staff.

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