A cryogenic multi-beam array at one centimetre wavelength

Engineers at Jodrell bank observatory (JBO) are developing an extremely sensitive Ka band multi-beam receiver, operating at a temperature of 20 kelvins. This is being developed for the EC funded FARADAY radio astronomy project. The objective is to produce a ten-beam receiver array to be installed at the focus of a 32-metre diameter radio telescope in Torun, Poland. The receiver, which covers the band 26 – 36 GHz, will be used to produce Ka band radio maps of the sky, acting as a ten-pixel camera.

The system is a non-heterodyne receiver based on the 'Planck Surveyor' satellite radiometer concept; it involves continuously switching the signal between independent receivers and closely spaced pairs of horns. To maximise the sensitivity of the receiver lattice matched indium phosphide HEMT technology has been used, and with the exception of the detector, all the active components have been manufactured on a single wafer process. Use of MMIC technology both facilitates the manufacture of the receiver and ensures that each channel has very similar performance characteristics, giving well balanced radiometer channel pairs.

This paper describes the design of the 26 – 36 GHz cryogenic receiver, including all components, from the cooled feed horns to the ambient temperature back-end detector. The ten-beam receiver is made up of 5 radiometer branches, each with 2 inputs and outputs. The feeds are an exact copy of those used in a prototype MIC based two-beam system, designed and constructed by engineers at JBO, and already installed on the 32-metre dish in Poland. The success of the two-beam design, proven in winter 2003 on the Polish 32-m telescope, has given confidence to use it as the basis of the 10-beam MMIC based receiver. Each of the front-end radiometer branches is made up of MMIC chips and includes a 90° input hybrid coupler, two low noise amplifiers (LNA), two 180° phase switches and a 90° output hybrid coupler. Closed cycle helium refrigeration is used to cool the front-end modules to 20 kelvins.

The back-end of the receiver is at ambient temperature with each radiometer channel consisting of a back-end LNA, a filter and a detector. The back-end LNA is also a MMIC design, part of the same wafer run as the front end MMICs The filter, to define the pass band, is a JBO waveguide design, and the detector uses a schottky diode , also in a waveguide design. With the exception of the detector, the entire receiver including cryostat construction has been designed and is being manufactured at JBO.

Fabrication of the MMICs was very successful and samples of each MMIC design have been tested successfully. Measured results of the various individual MMICs, filters and detectors have given confidence that the integrated receiver will perform very well and exceed the specification.

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