Feeds for the 150-foot radio telescope at the Algonquin Radio Observatory

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Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB), 1973-04

ERB - 876

UNCLASSIFIED

NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

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INTRODUCTION

The purpose of this report is to list the various feeds and feed attachments which have been built for use on the 150-foot radio telescope at the Algonquin Radio Observatory. The following text contains a brief description of each item. Following this, a table is provided for a quick overall view of the feeds available.

22MHz

This feed consists of a pair of cross-polarized two-element Yagis and was built for LBI experiments with the Dominion Radio Astrophysical Observatory (DRAO) at Pentiction, B. C. The two outputs of the Yagis are brought separately into the focus cabin where they are combined in a hybrid to produce right- and left-hand circular outputs. The dipole assembly is mounted in the dish by strapping the dipole supports to the feed legs. This feed has been used twice.

150 MHz

This feed is linearly polarized and consists of two parallel dipoles over a ground plane. A sleeve assembly on the back of the ground plane is provided to mount the device on the end of the feed tube. A hole has been cut in the center of the ground plane to allow simultaneous use of a second feed inside the focus tube.

448 MHz (LINEAR POLARIZATION)

This item was built for an occultation experiment in 1966. Two parallel dipoles over a ground plane mounted on the end of the focus tube make up this feed. Edge illumination in the E-plane was -15 dB; in the H-plane, -14 dB.

448 MHz (CIRCULAR POLARIZATION)

This is similar to the above except that two orthogonal pairs of dipoles are used. Each pair of dipoles is matched separately with a double-stub tuner made of 50-ohm coaxial cable. A quarter wavelength of cable is joined to one of the pairs to produce the 90-degree phase shift required for

circular polarization. The two sets are next joined in parallel and again matched with a double-stub tuner.

This feed was used in early LBI experiments with DRAO and Prince Albert, Saskatchewan.

408 MHz (CIRCULAR POLARIZATION)

A change in LBI frequency led to a new feed identical in design with the 448-MHz feed above. For the first version RG-58 cable was used in the matching and phasing section. Later two new feeds were built with larger cable (RG-213) to reduce losses, and these were used in LBI experiments with Greenbank. One of these feeds was subsequently modified to produce simultaneous right- and left-hand circular outputs for DRAO. A ring circuit made of coaxial cable provided the two outputs. Axial ratio at 408-MHz was 0.92 with a VSWR under 1.2.

408 MHz (LINEAR POLARIZATION)

This is similar to the 448-MHz linear feed previously listed. This feed was required when an LBI experiment with Australia led to an off-center mounting of the regular 408-MHz circularly polarized feed in order to increase the amount of common sky. A hole was provided in the ground plane to allow concurrent use of a feed in the focus tube.

430 MHz (CIRCULAR POLARIZATION)

An LBI experiment with Arecibo called for a new frequency; hence, the new feed. This feed is identical with the 448-MHz and 408-MHz circular polarization feeds.

1420 MHz (LINEAR POLARIZATION)

This is a waveguide horn with a short length of waveguide and a transition to a type-N coaxial cable connector. The flare of the horn has been selected to give approximately equal patterns in two planes, 15 dB edge illumination in the H-plane and $17\frac{1}{2}$ dB in the E-plane. VSWR is less than 1.2 from 1370 MHz to 1460 MHz and 1.025 at the design frequency. This feed has never been used.

9.4 cm TRANSITION

This is a two-section transition from rectangular waveguide to the circular end of the hub horn. VSWR is less than 1.07 from 2.9 GHz to 3.5 GHz. The primary purpose of this transition was to provide a calibrating noise signal for a feed in the focus tube; However, it can of course be used as a feed for Gregorian operation at 9.4 cm.

9.4 cm POLARIZATION ROTATOR

This is a polarization rotator for use at the prime focus. A waveguide horn feeds a length of standard rectangular waveguide which terminates in a loop transition to coaxial transmission line. The entire length of waveguide rotates. Choke joints are located in the coaxial line. Edge illumination is -13 dB in both planes.

9.4 cm POLARIZATION ROTATOR

Essentially similar to the feed above except that it is meant for use in the hub. The coaxial-to-waveguide transition was shortened considerably because of space limitations. A right-angle bend was put into the coaxial portion to facilitate side mounting of the receiver. A tapered section joins the rectangular waveguide to the S-band portion of the hub horn. VSWR is less than or equal to 1.05 from 3.0 to 3.4 GHz.

9.4 cm (DUAL CIRCULAR POLARIZATION)

A square waveguide is used. Pins are used on the edge of the horn to equalize the E- and H-plane patterns. A Teflon quarter-wave plate in the waveguide converts the two circularly polarized signals into two orthogonal linearly polarized waves which are picked up by two probes feeding coaxial lines. In operation, a diode switch is used to switch alternately between the two probes. Average axial ratio is better than 0.99. VSWR is of the order of 1.05 and isolation between probes is 46 dB. All of the above figures are for the band 3.1 to 3.4 GHz.

9.4 cm (VARIABLE POLARIZATION)

This feed was intended for use with a maser in the vertex. A coaxial line feeds a rotatable half-dipole in the end of a circular waveguide. This automatically produces a rotating linear polarization. If either of the circular polarizations is required, a length of elliptical waveguide is inserted between the dipole and the vertex horn. The elliptical waveguide has a 90-degree differential phase shift which, when combined with the appropriate setting of the dipole, produces the required circular polarization. VSWR is under 1.09 over a 40-MHz band centered on 3.2 GHz, axial ratio at midband is better than 0.99. Further details are given in ERB-834.

4.97 cm (VARIABLE POLARIZATION)

The design is identical with that of the 9.4-cm feed above. VSWR is under 1.07 over a 50-MHz band centered on 6.035 GHz. In the circular mode, axial ratio at midband is better than 0.99 with an average of 0.97 over the band. Further details can be found in ERB-834.

4.61 cm POLARIZATION ROTATOR

This feed was designed to be used at either the prime focus or in the hub. Considering the device as a transmitter, the signal from a rectangular waveguide is fed into a circular waveguide through a long tapered section. A fixed quarter-wave plate made from a Teflon vane converts the linear signal to a circularly polarized one. The signal next passes through a rotatable quarter-wave plate where it is converted back to linear polarization but with an orientation that is a function of the quarter-wave plate position. At this stage the signal passes either into the hub horn for Gregorian operation or into a small horn for prime focus use. VSWR is under 1.06 from 6.35 to 6.65 GHz for all settings of the rotatable section. At midband, 6.5 GHz, the worst cross-polarization is less than -40 dB. Total loss through the polarizer is 0.07 dB. Full details can be found in ERB-774. A rectangular waveguide with a suitable horn was later added to this feed for beamswitching.

2.8 cm TRANSITION

This is a very short transition (about an inch long) which matches standard rectangular waveguide to the X-band end of the hub horn. Two quarter-wave transformers are used which, combined with a single tuning screw, produce a VSWR better than 1.05 from 10.3 to 11.1 GHz. This item was meant for use with the line receiver.

2.8 cm (CIRCULAR POLARIZATION)

For LBI work in the Gregorian mode, a circularly polarized feed was required. This was achieved by using a transition as outlined above followed by a quarter-wave plate made from a squeezed section of circular waveguide. Locating pins and holes have been included so that either of the circular polarizations can be used. The axial ratio is 0.97. VSWR is under 1.05 from 10.2 to 11.1 GHz.

2.8 cm POLARIZATION ROTATOR

The design is similar to that of the 4.61-cm polarization rotator listed earlier. The 2.8-cm device was, however, designed to be used solely at the prime focus. Four different horns were supplied to provide a choice of dish illumination. Effective aperture efficiencies ranging from 0.419 to 0.450 were calculated. Average VSWR is better than 1.04 for all horns over the band 10.2 to 11.2 GHz. Further details are given in ERB-735.

As before, a rectangular waveguide and horn were later added for beamswitching.

2.8 cm (DUAL BEAM VARIABLE POLARIZATION)

This feed consists of two identical channels of over-size circular waveguides for reduced losses. A quarter-wave plate in each channel permits the choice of either two orthogonal linear polarizations or two circular polarizations of opposite sense. The quarter-wave plates are geared to a single motor which is operable from the control room. The loss in each channel is estimated to be about 0.2 dB. VSWR is less than 1.05 from 10.4 to 10.9 GHz. The axial ratio in the circular mode is 0.98 at 10.68 GHz.

2.22 cm POLARIZATION ROTATOR

The design of this feed is similar to that of the 4.61-cm polarization rotator except that elliptical waveguides are used for quarter-wave plates instead of Teflon vanes. The feed may be used either on the Ku band conical section horn in the hub room or, with a small horn, in the focus tube. Average cross-polarization over a 350-MHz band centered on 13.5 GHz was -31.9 dB. VSWR was under 1.05 for all settings of the rotatable section over the frequency range 13.3 to 13.7 GHz. Additional details may be found in ERB-774.

An oversize circular waveguide (1 inch I. D.) has since been added for beamswitching. VSWR of this component is under 1.04 from 13.3 to 13.7 GHz.

2.2 cm

This feed is quite different from any of the previous ones. A short rectangular-to-circular waveguide transition is followed by a single rotatable quarter-wave plate (elliptical waveguide). On transmit, this feed will produce a field which goes from linear through elliptical to circular then back to linear as the plate is rotated. Order is made out of chaos by sampling the received signal at several angular positions of the quarter-wave plate and then processing the results with a computer to provide the four Stokes parameters. As before, a second fixed oversize circular waveguide has been included for beamswitching.

SUMMARY

The feeds and modifications outlined above were produced in the period from 1966 to 1972. During this time feeds were also produced for other antennas but these are not listed here. The largest share of these were for DRAO in the form of nine different horns - both linearly and circularly polarized and ranging from 1 GHz to 4 GHz.

TABLE

SUMMARY OF FEEDS

WAVELENGTH OR FREQUENCY	POLARIZATION	BRIEF DESCRIPTION	USED IN HUB	USED IN PRIME FOCUS	REMARKS
22 MHz	Two orthogonal linear	Crossed two-element yagis		X	LBI-DRAO (Costain)
150 MHz	Linear	Two parallel dipoles over a ground plane		X	
448 MHz	Linear	Two parallel dipoles over a ground plane		X	Occultation 1966
448 MHz	Left circular	Two orthogonal pairs of dipoles over a ground plane		X	LBI-DRAO, Parl
408 MHz	Left circular	Two orthogonal pairs of dipoles over a ground plane		X	LBI-Greenbank et al
408 MHz	Linear	Two parallel dipoles over a ground plane		X	
430 MHz	Left circular	Two orthogonal pairs of dipoles over a ground plane		X	LBI-Arecibo
1420 MHz	Linear	Coax to waveguide Transition plus horn		X	Koehler - U. of S.
9.4 cm	Linear	Rectangular to circular waveguide transition - two matching sections	X		Noise injection (Seaquist)
9.4 cm	Rotating linear	coax to waveguide transition; rotating waveguide & horn		X	
9.4 cm	Rotating linear	Coax to waveguide transition; rotating waveguide	X		
9.4 cm (1	Right and left circular	Square waveguide; two independent coax outputs		X	Polarization switching (Seaquist)
9.4 cm (1	Rotating linear or right or left circular	Rotating half-dipole with or without 1/4λ section	X		Maser
4.97 cm (1	Rotating linear or right or left circular	Rotating half-dipole with or without 1/4λ section	X		Maser
4.61 cm (1 (2	Rotating Linear	Rotating 1/4λ plate (Teflon vane)	X	X	

Cont'd.....2

WAVELENGTH OR FREQUENCY	POLARIZATION	BRIEF DESCRIPTION	USED IN HUB	USED IN PRIME FOCUS	REMARKS
2.8 cm	Linear	Rectangular to circular waveguide transition; two matching sections	X		Line Receiver in Hub
2.8 cm	Right or left circular	Transition as above plus 1/4λ plate - squeezed circular waveguide	X		LBI from Hub
2.8 cm (1 (2	Rotating linear	Rotating 1/4λ plate (Teflon vane); Four different horns provided		X	
2.8 cm	Two orthogonal linear or right and left circular	Two identical channels with switchable 1/4λ plates		X	LBI etc from prime focus, reduced loss
2.2 cm (1 (2	Rotating linear	Rotating 1/4λ plate (squeezed waveguide)	X	X	
2.2 cm	Variable	Rotating 1/4λ plate in main channel; fixed linear polarization in reference channel		X	Output computer processed for Stokes parameters

1) Designed by R.W. Breithaupt.
2) Reference channel added later for beamswitching.