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Microwave Time Delays for the X/S-Band Feed System at X-Band

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The X-band time delays for the X/S feed system of the 34-meter high efficiency antenna are required to refine current X-band downlink (8450 ±50 MHz) calibrations and prepare for the Magellan uplink (7190 ±45 MHz). The time delays of elements in the X-band feed system are obtained mostly via computer calculation and partly via measurement. The methods used and results obtained are presented in this article. There is good agreement with theory.

I. Introduction

The X/S feed is a large corrugated horn with extremely deep corrugations that are suitable for both the X-band and S-band (Fig. 1). In order to have the two very similar radiation patterns at X- and S-band, the feed operates in a "beamwidth saturation" mode at X-band. In other words, the beamwidth for this saturated condition depends only on the horn flare angle, and not on the aperture size. As a result, the pattern phase center is moved back into the throat of the horn, instead of its usual position near the horn aperture [1].

II. Time Delay for X/S Feedhorn

The X/S corrugated feedhorn, which is 74.397 inches long with an aperture size of 42.061 inches, is analyzed using a mode matching method [2]. In order to apply the circular waveguide computer program, the feedhorn is broken up into 230 circular waveguides with different radii. The program calculates the modes propagating from each discontinuity between circular sections from the feed throat to the radiating aperture of the X/S feedhorn. Since the aperture is about 30 times the X-band wavelength, many modes are generated at the aperture surface. The radiation pattern of the X/S feedhorn at X-band is calculated using the amplitude and phase of the transmission coefficients for the aperture modes calculated by the circular waveguide program. The phase of the X-band radiation pattern at 0 degree from the center line of the horn changes as the X-band frequency changes. The time delay of the X/S feedhorn was obtained according to the following equation:

$$t_g = \frac{d\phi}{2\pi\, df}$$

where ϕ is the phase of the radiation pattern at 0 degree from the center line of the horn and f is the frequency.

The time delays of the X/S feedhorn from the throat to the aperture are 6.520 nsec at 8.45 GHz and 6.723 nsec at 7.19 GHz. The phase center is in the center of the X/S feed throat and 67.5 inches behind the X/S feed aperture. By using the same method, the time delays from the feed throat to the phase center are found to be 0.769 nsec at 8.45 GHz and 0.869 nsec at 7.19 GHz.

III. Time Delay for Orthomode Junction and Quarter-wave Plate Polarizer

The time delays of the orthomode junction and the quarter-wave plate polarizer were measured with a Hewlett-Packard (HP) 8510 network analyzer. The orthomode junction is a three-way junction with one side connected to circular waveguide WC137, one straight path to rectangular waveguide WR125, and the other orthogonal path to WR125. The time delays of the orthomode junction are 0.947 nsec and 0.961 nsec at 8.45 GHz, and 1.253 nsec and 1.279 nsec at 7.19 GHz for the orthogonal path and straight path, respectively. A quarter-wave plate polarizer is a piece of WC137 waveguide with fins inside. The measured time delay of the quarter-wave plate is 0.457 nsec at 8.45 GHz and 0.525 nsec at 7.19 GHz.

The time delays of the rest of the elements are calculated using the group velocity of straight waveguides [3]. The H-plane bend waveguide and the E-plane bend waveguide, which are 3.5 inches by 3.5 inches by 90 degrees, are considered for this purpose to have an equivalent length (arc length) of 5.498 inches.

IV. Results

The time delays of all of the elements in the X/S feed system at X-band are shown in Table 1. The total time delays from the X/S feedhorn aperture to the ranging coupler are 10.689 nsec at 8.45 GHz and 11.567 nsec at 7.19 GHz. These values are adjusted for the distance to the phase center, which is 67.5 inches behind the feedhorn aperture. The total time delays from the phase center of the X/S feedhorn to the ranging coupler are 4.938 nsec at 8.45 GHz and 5.713 nsec at 7.19 GHz.

A simple experiment was made to measure the total time delay from the X/S feedhorn to the orthomode junction through the straight path using the time-domain feature of an HP 8510 network analyzer. A reflector was put in front of the feedhorn to obtain the round-trip time delay. The measured time delay was about 9.0 nsec at 8.4 GHz, which is close to the calculated value of 8.836 nsec at 8.45 GHz with an error of less than 1.8 percent. Although the experimental technique is not yet mature, good agreement with theory has been obtained in this case.

Acknowledgment

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References

[1] W. F. Williams, "A Prototype DSN X/S-Band Feed: DSS 13 First Application Status," *DSN Progress Report 42-44*, vol. January and February 1978, Jet Propulsion Laboratory, Pasadena, California, pp. 98-103, April 15, 1978.

[2] D. Hoppe, "Modal Analysis Applied to Circular, Rectangular, and Coaxial Waveguides," *TDA Progress Report 42-95*, vol. July-September 1988, Jet Propulsion Laboratory, Pasadena, California, pp. 89-96, November 15, 1988.

[3] J. Chen, "Microwave Time Delays for the Dual L-C-Band Feed System," *TDA Progress Report 42-96*, vol. October-December 1988, Jet Propulsion Laboratory, Pasadena, California, pp. 126-131, February 15, 1989.

Table 1. Time delay of each element in the X/S feed system from feedhorn aperture (or the phase center) to the ranging coupler at 8.45 GHz and 7.19 GHz

Element	t_g, ns	
	Downlink, 8.45 GHz	Uplink, 7.19 GHz
Feedhorn (from aperture)	6.51977	6.72339
(from phase center)	0.76855	0.86898
Bethe hole coupler (4.500 in.)	0.47567	0.53591
Rotary joint (2.000 in.) × 2	0.21141 × 2	0.23818 × 2
Quarter-wave plate polarizer	0.45661	0.52526
Orthomode junction	0.9475	1.25335
Spacer (0.280 in.)	0.02860	0.03145
H-plane bend (3.500 in. × 3.500 in. × 90 degrees)	0.56163	0.61760
E-plane bend (3.500 in. × 3.500 in. × 90 degrees)	0.56163	0.61760
54-dB ranging coupler (7.000 in.)	0.71510	0.78635
Total time delay		
(from aperture)	10.689	11.567
(from phase center)	4.938	5.713

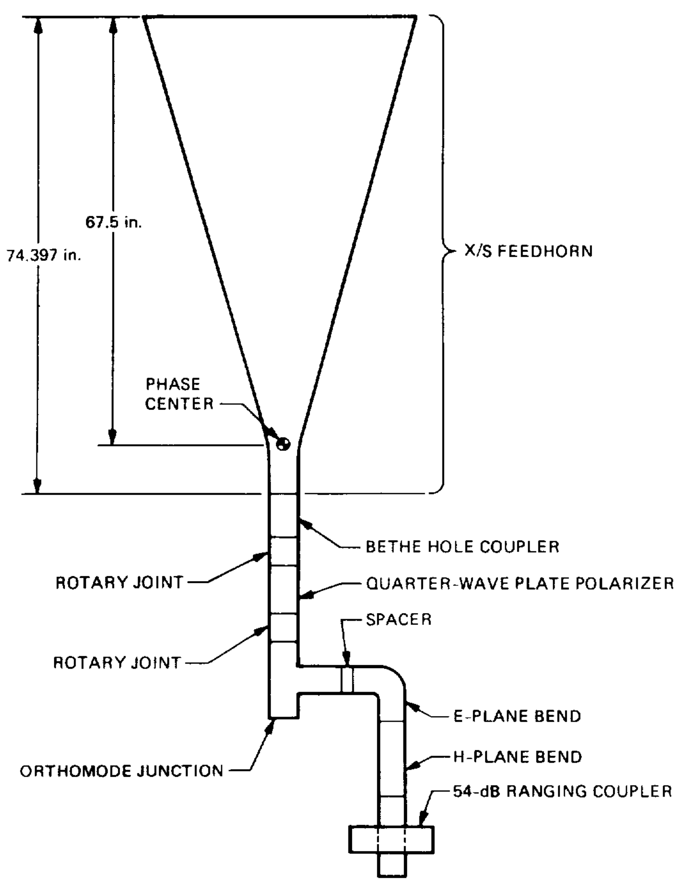

Fig. 1. X/S feed system of 34-meter high-efficiency antenna.