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X/X/Ka-Band Prime Focus Feed Antenna for the Mars Observer Beacon Spacecraft

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The results of an X/X/Ka-band feed design concept demonstration are presented in this article. The purpose is to show the feasibility of adding a Ka-band beacon to the Mars Observer spacecraft. Scale model radiation patterns were made and analyzed.

I. Introduction

A concept demonstration of an X/X/Ka-band prime focus feed was made for the Mars Observer spacecraft's 1.5-meter reflector antenna. The purpose was to add a Ka-band capability to the spacecraft for downlink experiments [1]. Radiation pattern models of this feed were constructed and pattern measurements made. A computer analysis of these radiation measurements was performed. The analysis shows that further work is required to complete the design, especially in the areas of impedance matching and packaging.

II. Design

The X/X/Ka-band feed design consists of two types of antennas combined in a multifrequency, prime focus feed as shown in Fig. 1. Examples of similar combined feeds, but with much larger low-frequency apertures, are reported in [2] and [3]. The low-frequency (X-band) radiating element used in this case is an open-ended, circular waveguide with four choke rings as presented in [4] and shown in Fig. 2 (with the Ka-band dielectric rod coaxially mounted in the aperture). This radiator provides a suitable pattern over a bandwidth broad enough to include both the uplink (7.19 GHz) and downlink (8.42 GHz) at X-band. The radiation pattern beamwidth is controlled by the open-ended waveguide aperture diameter.

The high-frequency (Ka-band, 33.7-GHz) element of this design is a dielectric rod surface wave antenna, shown in Fig. 2 (mounted coaxially in the aperture of the X-band antenna) and discussed in [5]. One of the main challenges of this design is to launch a sufficient percentage of the Ka-band power as a surface wave on the dielectric rod. If this is accomplished, the Ka-band radiation pattern is controlled by the characteristics of the dielectric rod and not by the X-band antenna which surrounds it. The launching efficiency of the surface wave is controlled by the profile of the dielectric rod and the flare of the horn at its base (see Fig. 1). The beamwidth of the radiation pattern is controlled mainly by the diameter of the dielectric rod at the antenna aperture.

The combination of the above into a single X/X/Ka-band feed would possibly take the form shown in Fig. 1. The main components of this feed are rectangular-to-circular waveguide transitions, linear-to-circular polarizers, a Ka-band tapered dielectric rod and launching horn, and an X-band aperture radiator with four concentric choke rings.

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III. Results

The results presented here are from measurements of two scale models. The X-band model is full scale and is shown in Fig. 2. The Ka-band model is 4.4:1 scale and is shown in Fig. 3. Figures 4 through 6(a) and (b) display the measured E- and H-plane feed radiation patterns in both magnitude and phase. The X-band uplink and downlink patterns (Figs. 4 through 5[a] and [b]) are well matched in the two planes and result in feed efficiencies of approximately 74 percent, including spillover, illumination, cross polarization, and phase efficiencies. The Ka-band patterns (Fig. 6[a] and [b]) are well matched in the two planes but purposely underilluminate the reflector to lower the antenna pointing accuracy requirement, resulting in a feed efficiency of approximately 42 percent.

Figures 7, 8, and 9 show the co-polarized radiation pattern for the X-band uplink, X-band downlink, and Ka-band downlink, respectively. These co-polarized radiation patterns were calculated by the computer program documented in JPL Publication D-1203.[1] This program used the measured feed patterns (Figs. 4, 5, and 6) and the geometry of the Mars Observer spacecraft's 1.5-meter reflector antenna to predict the co-polarized radiation patterns.

Figures 7 and 8 (X-band uplink and downlink) show low sidelobe levels, which result from a larger than typical edge taper. Figure 9 (Ka-band downlink) shows no distinct sidelobes, which can be attributed to the use of an atypical feed taper.

Table 1 presents the X/X/Ka-band antenna performance in the form of feed efficiency plus overall antenna gain and 3-dB beamwidth. The above analysis assumes an ideal reflector and no aperture blockage.

[1]Y. Rahmat-Samii, "Offset Parabolic Reflector Computer Program for Analysis of Satellite Communications Antennas," JPL Publication D-1203 (internal document), Jet Propulsion Laboratory, Pasadena, California, December 1983.

IV. Conclusions

An X/X/Ka-band prime focus feed for the Mars Observer 1.5-meter reflector antenna seems practical based on the results of the scaled model radiation pattern measurements. The X-band and Ka-band feed patterns can be controlled individually. The present Ka-band design would require an antenna pointing accuracy of 0.26 degree to stay within its 3-dB beamwidth. Further work would be required to optimize these radiation patterns.

Acknowledgment

The authors would like to thank M. Gatti for his help in the use of the offset parabolic reflector computer program.

References

[1] A. L. Riley, D. M. Hansen, A. Mileant, and R. W. Hartop, "A Ka-band (32-GHz) Beacon Link Experiment (Kable) With Mars Observer," *TDA Progress Report 42-88*, vol. October–December 1986, Jet Propulsion Laboratory, Pasadena, California, pp. 66–69, February 15, 1987.

[2] M. S. Narasimhan and M. S. Sheshadri, "Propagation and Radiation Characteristics of Dielectric Loaded Corrugated Dual-Frequency Circular Waveguide Horn Feeds," *IEEE Trans. Antennas Propagation*, vol. AP-27, no. 6, pp. 858–860, November 1979.

[3] J. C. Lee, "A Compact Q/K-Band Dual-Frequency Feed Horn," *IEEE Trans. Antennas Propagation*, vol. AP-32, no. 10, pp. 1108–1111, October 1984.

[4] R. Wohlleben, H. Mattes, and O. Lochner, "Simple Small Primary Feed for Large Opening Angles and High Aperture Efficiency," *Electronics Letters*, vol. 8, pp. 474–476, September 21, 1972.

[5] H. Jasik (ed.), *Antenna Engineering Handbook*, New York: McGraw-Hill, Chapter 16, 1961.

Table 1. X/X/Ka-band antenna performance (1.5-meter antenna)

Frequency, MHz	Feed efficiency	Gain, dB	3-dB beamwidth, deg
7190	0.741	39.8	2.1
8420	0.741	41.2	1.7
33,680	0.419	50.7	0.52

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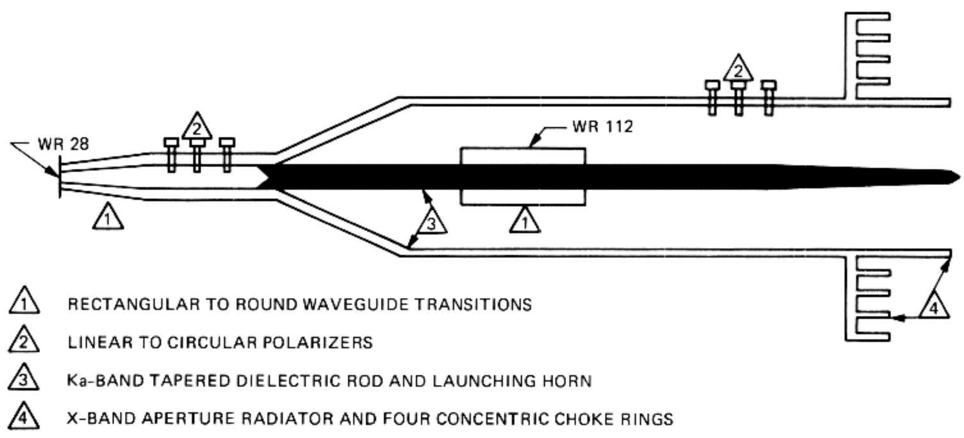

Fig. 1. X/X/Ka-band prime focus feed

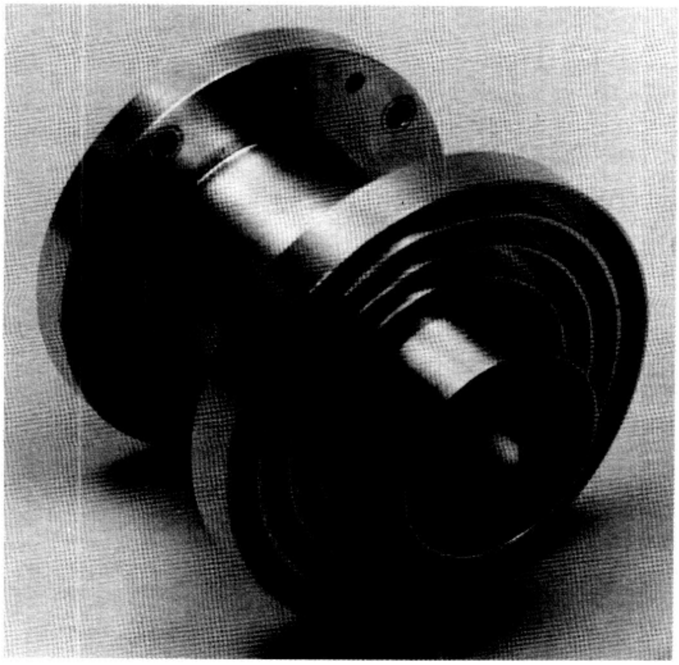

Fig. 2. X-band feed model

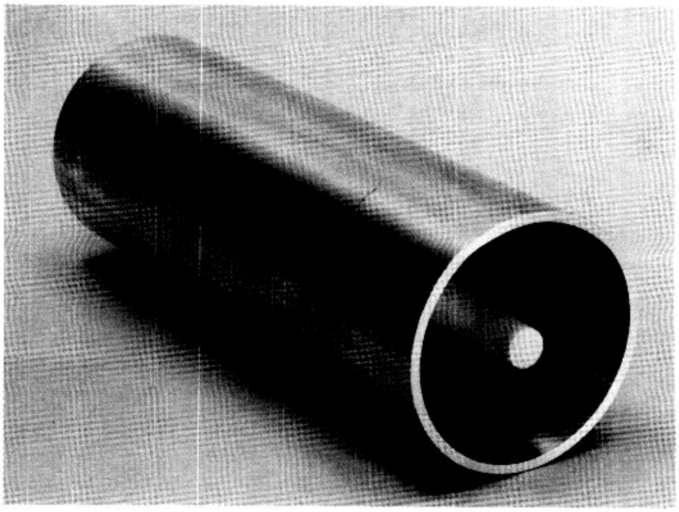

Fig. 3. Ka-band feed model

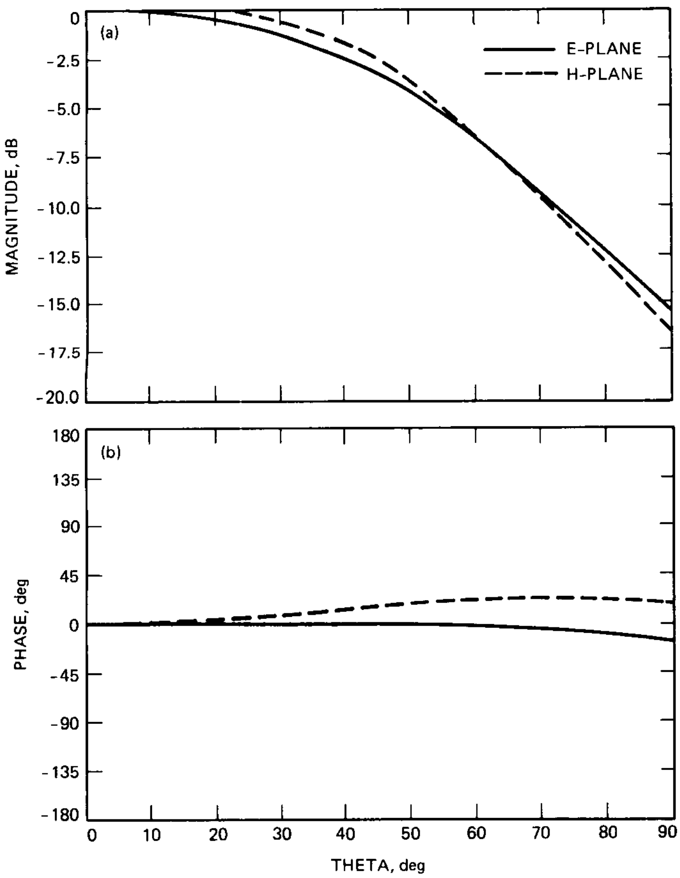

Fig. 4. X-band uplink (7190-MHz) feed: theta versus (a) magnitude and (b) phase

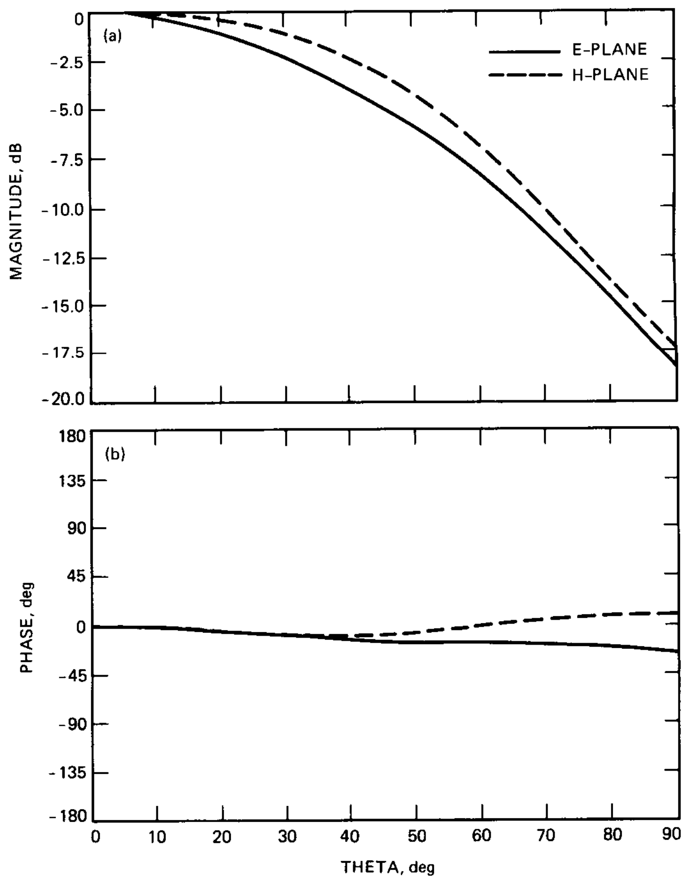

Fig. 5. X-band downlink (8420-MHz) feed: theta versus (a) magnitude and (b) phase

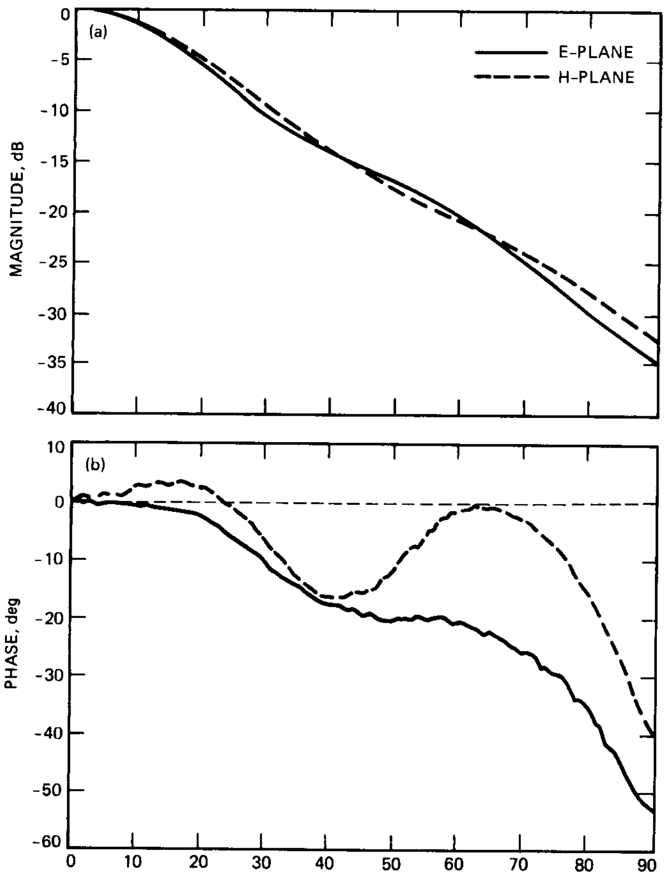

Fig. 6. Ka-band feed: theta versus (a) magnitude and (b) phase

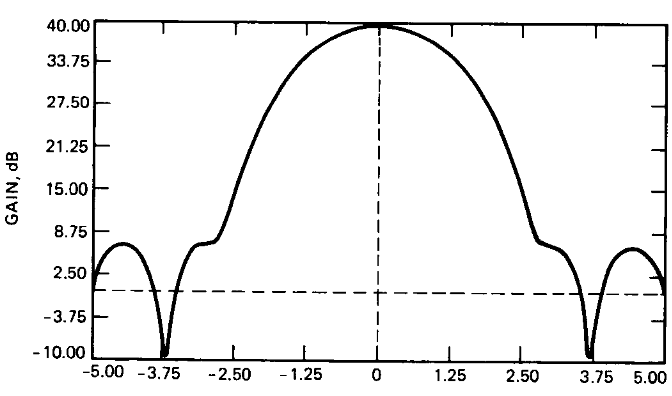

Fig. 7. X-band (7190-MHz) uplink: theta versus gain

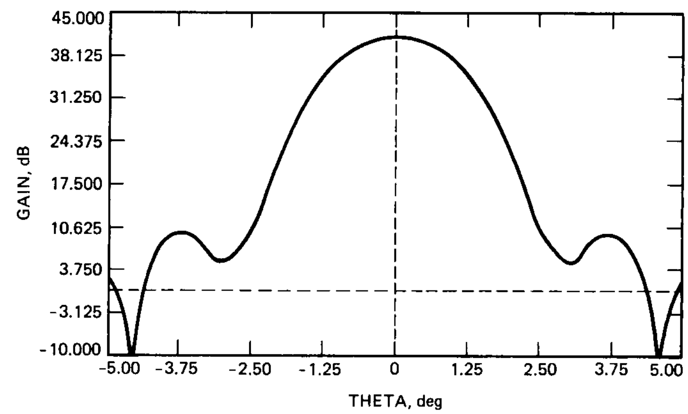

Fig. 8. X-band (8420-MHz) downlink: theta versus gain

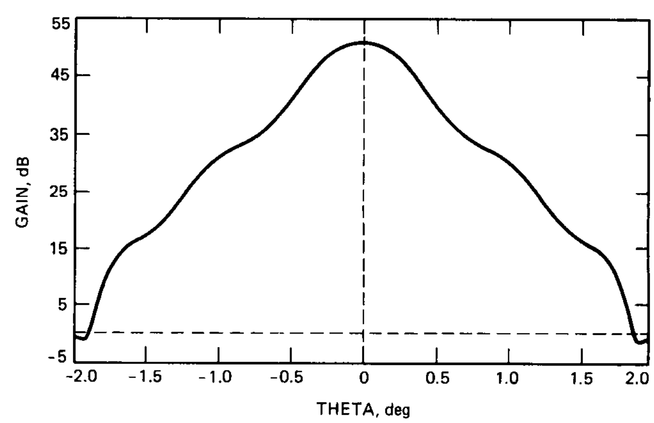

Fig. 9. Ka-band downlink: theta versus gain