Development of an On-boad Antenna for a Mars Spacecraft

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1. Introduction

The 18-th scientific satellite PLANET-B is sheduled to be launched in 1998 by ISAS. The diameter of the reflector should be as big as 1.6m as the communication distance extends 3.8×10^{8}km between Earth and Mars. This paper describes the design and characteristic of the antenna.

A new reflector matelial called Tri-axial Woven Fabric (TWF) is adopted to achieve the required mass reduction and high reflector accuracy. A primary radiator of stacked microstrip antennas has been developed to be used in S/X-bands in common. Owing to this technique, the configuration is simplified and the mass has been further reduced.

2. Antenna Configuration

The block diagram of the antenna subsystem is shown in Fig.1. The reflector of 1.6 m diameter is fed by a primary feed at the prime focus. The primary feed, two hybrid circuits and high power amplifier are covered by a feedom to avoid the solar heat.

3. Primary feed design

The primary feed is stacked microstrip antennas as shown in Fig.2. The smaller element of the stacked microstrip antennas is for X-band, and is placed closer to the reflector than the larger element for S-band to avoid blockage. The S- and X-band antennas are circular microstrip antennas fed through an annular slot and a coaxial line , respectively.

The dimensions and the spacing are determined by the way of cut-and-try to optimise the VSWR characteristics and radiation patterns. The realised VSWR is shown in the fig.3 . The frequency bandwidths of 200 MHz is sufficient for both of S- and X-bands.

4. Reflector Design

The Tri-axial Woven Fabric (TWF) is chosen to achieve both of the mass reduction and high reflector accuracy. This reflector consists of a sheet of TWF of approximately 0.2mm thickness and a back support structure made of CFRP.

The total mass of the TWF reflector including the back support structure is about 2.0 kg., which is about half of a conventional reflector mede of honycomb core and CFRP skins.

A strip-aperture model is adopted to express the TWF. This model analysis gives good approximation for the periodic structure.

We define the incident electric field along Es and Ep by I and $\bar{I}$,respectively. And also we define the transmission electric field along Es and Ep by T and $\bar{T}$, respectively. Then,the relation between I, $\bar{I}$, T and $\bar{T}$ can be written in the following equation.

$$\begin{bmatrix} T \\ \bar{T} \end{bmatrix} = \begin{bmatrix} T11 & T12 \\ T21 & T22 \end{bmatrix} \begin{bmatrix} I \\ \bar{I} \end{bmatrix}$$

where

T11, T12, T21, T22 : element of coefficient matrix
a :distance between elements along X axis
b :distance between elements along Y axis
Ω1:inclination angle of these cells
c , d :aperture size
Ω2:inclination angle of the aperture.
T11,T12,T21 and T22 can be expressed by a,b,c,Ω1 and Ω2 using the equation (8) and (51)-(56) of the paper [1] .

According to Fig.5. of the paper [1] ,the following parameters are chosen: a=3.1mm, b=3.4mm, c=1.5mm, d=2.25mm, Ω1=65.5° , Ω2=0.0° . The computed and measured results are shown in Fig.5. The Ep polarized wave is subject to larger reflection loss than the Es polarized wave. But the difference between two polarizations is small because the incident angle is less than 34.6 degrees.

5.Antenna characteristics estimation

The radiation patterns are calculated on the basis of the primary feed data in Fig.4 by the ray tracing and the aperture integration method. The results are shown in Fig.6.

We get the loss budget and antenna gain shown in Table 1. Antenna gain is estimated to be 26 and 38 dBi in S- and X-bands ,respectively.

6.Conclusion

This antenna satisfies the mass and electrical requirements. The final Mass is estimated to be 6.33kg.

The proto model shown in Fig.7 is now under testing. The vibration test is already done. The thermal vacuum test and electrical performance test are sheduled.

References

[1] Y.R.Samii and S.W.Lee:"Vector diffraction analysis of reflector antennas with mesh surface"IEEE Trans. Antennas & propag.,AP-33,1,pp76-90(1988-01)

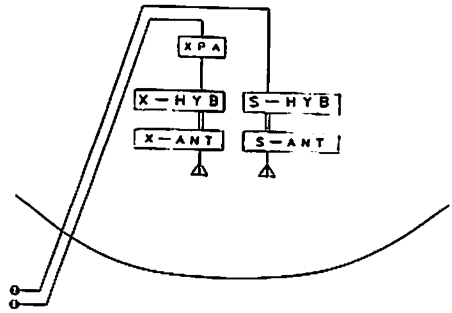


Fig. 1 Block diagram of the antenna

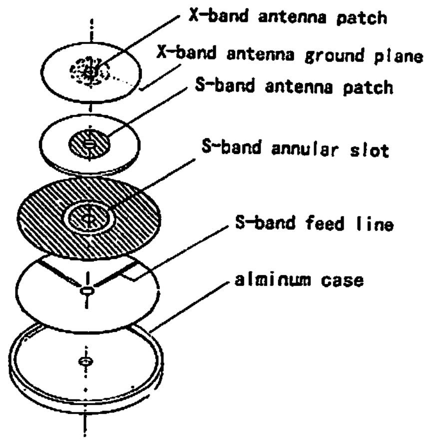
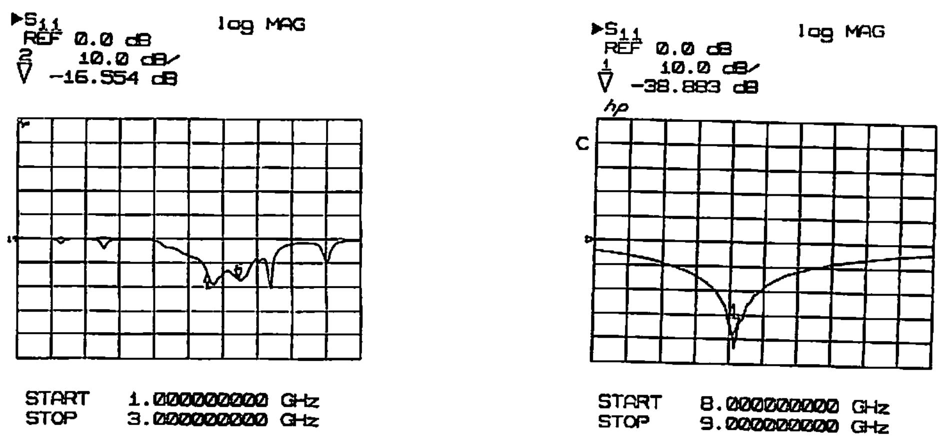


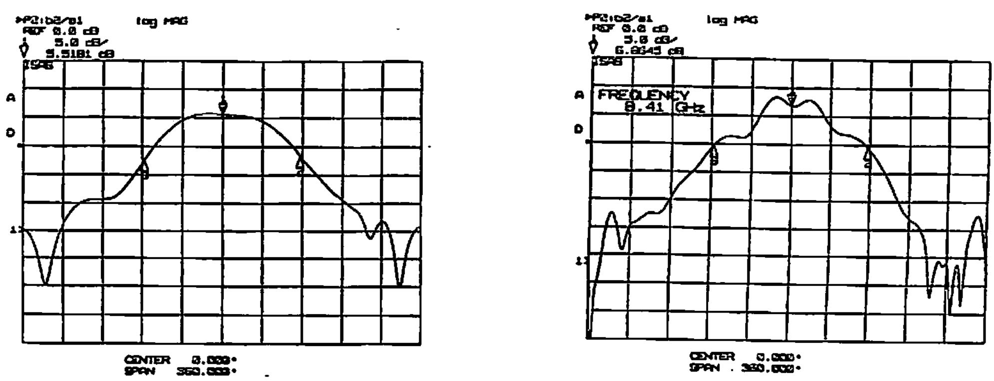
Fig. 2 Detailed structure of a primary feed



(a) S-band

(b) X-band

Fig. 3 VSWR of the primary feeds



(a) S-band

(b) X-band

Fig. 4 Radiation pattern of the primary feed

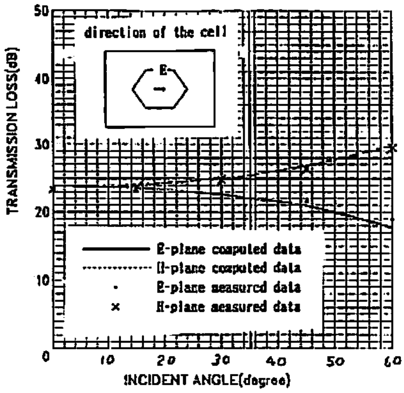
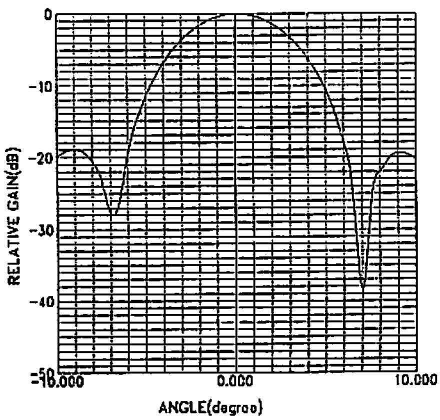


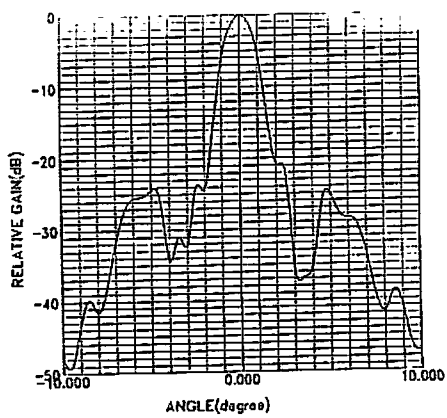
Fig. 5 Transmission loss of TWF

Table.1 Antenna Performances

Mechanical Characteristics		Electrical Characteristics			
		Item	S-band Rx	S-Band Tx	X-Band Tx
Antenna Type	Parabola	Frequency (GHz)	2. 112	2. 293	8. 410
Feed Type	Stacked Microstrip Antenna	Directivy (dBi)	27. 30 (42. 83%)	29. 33 (51. 98%)	40. 27 (53. 56%)
		Blocking Loss(dB)	0. 52	0. 57	0. 69
Weight	6. 33 kg	Reflector Tolerance (dB)	0. 04	0. 04	0. 54
		Reflection and Trans-mission Loss(dB)	00. 4	0. 04	0. 22
		Feed Line Loss(dB)	0. 50	0. 50	0. 30
		Total Loss (dB)	1. 05	1. 22	1. 94
		Gain(dBi)	26. 15	28. 11	38. 34



(a) S-band



(b) X-band

Fig. 6 Radiation pattern of the antenna

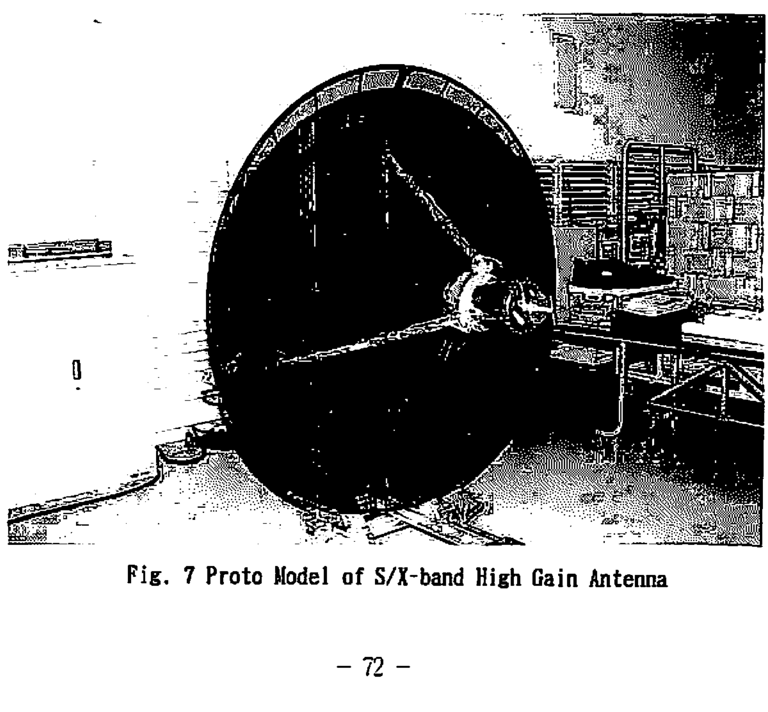


Fig. 7 Proto Model of S/X-band High Gain Antenna