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AN OFFSET REFLECTOR ANTENNA WITH A FREQUENCY SELECTIVE SURFACE OPERATING IN MULTI-FREQUENCY BANDS

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Introduction

It is advantageous for antennas covering multi-frequency bands simultaneously to be used for communication satellites. Recently, frequency selective surfaces (FSS) are often used for multi-frequency operation [1] , [2] . In this paper, the offset reflector antenna operating in 4, 6, 20 and 30 GHz bands is proposed. The present antenna, using a simple square metallic mesh as an FSS, can be constructed compact by modifying the feed assembly. By theoretical and experimental analyses, transmission characteristics of the mesh and radiation characteristics of the antenna are examined.

Antenna Configuration

The geometry of the antenna is shown in Fig. 1. The metallic mesh in this figure is reflective at lower bands (4 and 6 GHz), and transparent at higher bands (20 and 30 GHz). This antenna operates as an offset paraboloidal reflector antenna in lower bands and as an offset Cassegrain antenna in higher bands. Compared to conventional offset configurations, the subreflector and the feed horn are simultaneously rotated about 53° around the offset axis of the main reflector in higher bands, and the metallic mesh and the other feed horn are rotated about 42° around the same axis in lower bands. By modifying the feed assembly as mentioned above, this antenna configuration becomes compact and flexibility for designing it is increased.

The antenna dimensions are chosen as follow ; aperture diameter Dm is 1 meter, focal length F is 84.5 cm and offset angle θ_0 is 50°. Angle between the normal direction to the plane of the metallic mesh and the offset axis of the main reflector is 41.6°.

Metallic mesh design

Transmission characteristics of meshes have been investigated theoretically

[3] and experimentally [4] , but they are restricted mainly for a $< \lambda/2$ (a is period of the mesh and λ is wavelength). For this restriction, the use of meshes have been limited in a simple application. In this section, characteristics of the mesh for a $> \lambda/2$ are investigated experimentally.

The geometry of the metallic mesh is illustrated in Fig. 2, and the dimensions are as follow ; period a = 10 mm, thickness t = 0.2 mm, width w = 0.25 mm and 0.75 mm. Each mesh was made from a sheet of copper by using conventional photoetching techniques. The properties of meshes illuminated by a plane wave were measured in 8 ~ 40 GHz bands for 0°~ 60° incident angle.

Measured transmission characteristics versus normalized frequency $\omega = a/\lambda$ for 40° incidence are shown in Fig. 3, where the electric field is parallel to the plane of incidence (e-mode). This figure indicates that normalized frequency, ω_n (n = 1, 2, ...), at which the transmitted power becomes maximum, appears periodically. The subscript n is the sequential number from lower frequency. ω_n depends on w/a, incident angle and incident wave polarization, and ω_{n+1}/ω_n mainly on the polarization. It can be shown from this figure that ω_2/ω_1 is about 1.5 for e-mode. On the other hand, it was obtained that ω_2/ω_1 is about 2 for h-mode.

Since both 20 and 30 GHz bands are required to be transmitted, the mesh should be used at e-mode, where ω_1 and ω_2 correspond respectively to 20 and 30 GHz. In 4 and 6 GHz bands, it should be used at h-mode, for the reflected power is larger at h-mode than at e-mode. From above discussions, mesh dimensions for the proposed antenna are determined as follow ; a = 6.9 mm and w = 0.17 mm.

Fabricated antenna characteristics

Figure 4 shows measured insertion losses of the mesh in the fabricated antenna. Losses are about 0.5 dB in 4, 20 and 30 GHz bands and are about 1.2 dB in the 6 GHz band. On the other hand, gain reductions due to the modification of the feed assembly are calculated to be about 0.07 dB in 20 and 30 GHz bands.

In Fig. 5, azimuth radiation patterns for the overall antenna with and without the mesh are shown in 6 and 30 GHz bands. Similar radiation patterns are also obtained in 4 and 20 GHz bands. From these results, it is seen that radiation pattern degradations due to the mesh are negligibly small.

The measured gain for the overall antenna is shown in Table 1. Aperture efficiency is more than 57 % at 4, 20 and 30 GHz bands and is about 46 % at the 6 GHz band.

Conclusion

A compact antenna with a metallic mesh operating in four frequency bands was proposed and analyzed. From the above investigation, this antenna indicates relatively high aperture efficiency in each frequency band. It was confirmed that this antenna can be applicable for satellite use.

References

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[2] T.W.Leonard and L.R.Young, "Frequency Selective Surfaces," Int. AP-S Symp., Stanford, Calif., June 1977.

[3] D.A.Hill and J.R.Wait, "Electromagnetic Scattering of an Arbitrary Plane Wave by a Wire Mesh with Bonded Junctions," Can. J. Phys., 54, p. 353, 1976.

[4] R.Ulrich, "Far-Infrared Properties of Metallic Mesh and its Complementary Structure," Infrared Physics, 7, 1, p. 37, March 1967.

Table 1 The measured gain of the overall antenna

Frequency (GHz)	3.95	6.175	19.5	29.5
Gain (dB)	29.9	32.9	43.9	47.7

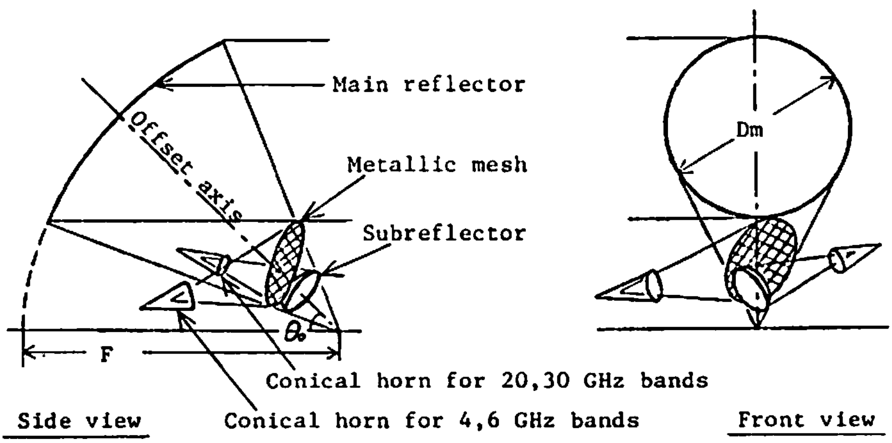


Fig. 1 Proposed antenna geometry

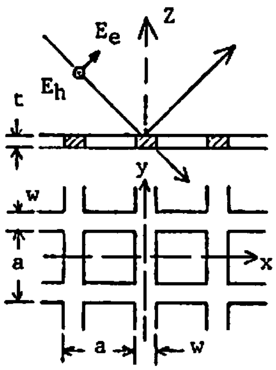


Fig.2 Metallic mesh geometry
E_e : Field vector for e-mode
E_h : Field vector for h-mode

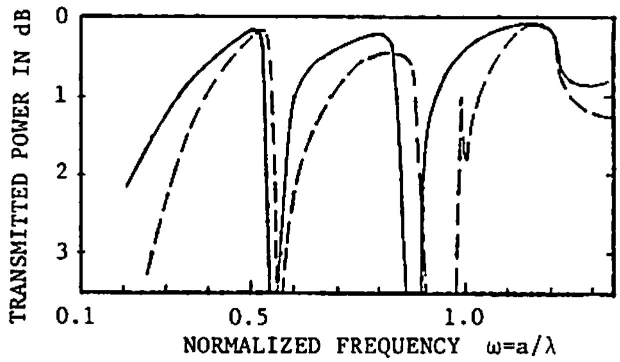


Fig.3 Frequency response of metallic meshes for e-mode and incident angle 40°
——— w/a=0.025 , – – – w/a=0.075

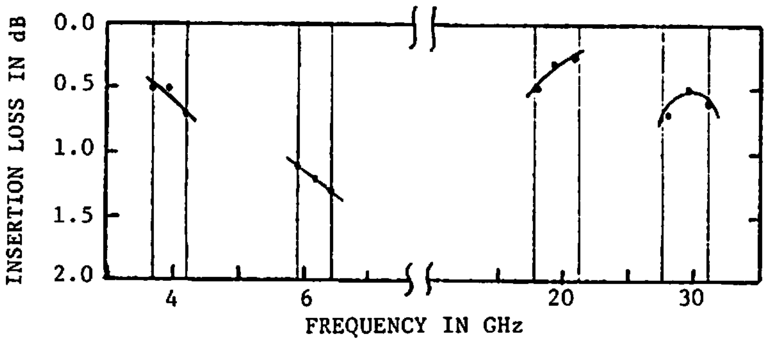
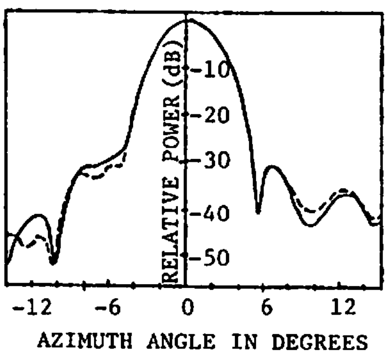
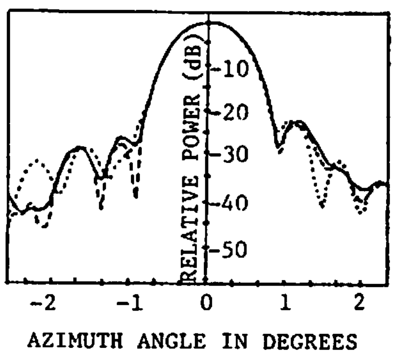


Fig.4 Measured insertion losses of the mesh with dimensions ; a=6.9mm, w=0.17mm, t=0.15mm



(a) 6.175GHz



(b) 29.5GHz

Fig.5 Radiation patterns of the azimuth plane
——— measured with the mesh
– – – { measured with a metallic plate in (a) / measured without the mesh in (b)
. . . predicted without the mesh in (b)