FAN RIB TYPE DEPLOYABLE MESH ANTENNA FOR SATELLITE USE

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Introduction The Japanese maritime satellite communication system has been actively studied for the past several years. The proposed system(1) is designed to feature:

(1) A multibeam satellite communication system is used to realize small size, low cost ship terminals.
(2) S band (2.6/ 2.5 GHz) is used for the link between ship terminals and the satellite.
(3) The radiation pattern of the antenna is a multiple beam superimposition of circular beams which cover an area within 200 nautical miles around the Japanese mainland (see Fig. 1).

This paper presents a basic study of a satellite borne S band deployable multibeam antenna as is shown in Fig.2.

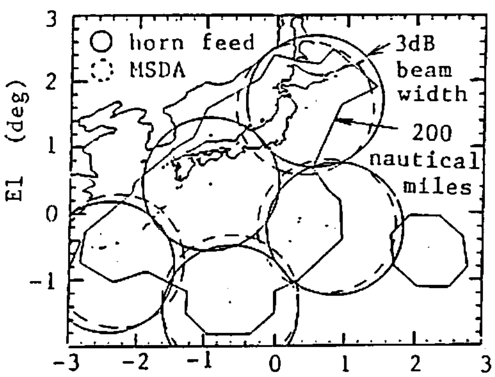

Fig. 1 Radiation pattern

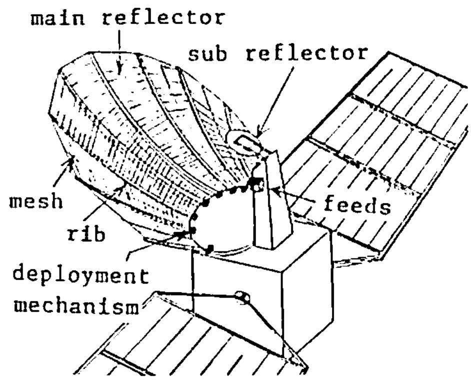

Fig. 2 On-orbit configuration

Basic electrical study

The required antenna specifications are shown in Table 1.

The reflector with 3.5 ~4m aperture diameter is necessary to attain the required gain and beam width. Variations of minimum edge gain with focal length F, plotted for aperture diameter D and a side of rectangular feed horn d as parameters, are shown in Fig.3.

Table 1 Antenna Specification *

Gain in bore sight	G_b	:	>35.5dB
Minimum edge gain **	G_e	:	>31.5dB
Half power beam width	θ_{-3}	:	≃2.0
Beam separation angle ***	θ_a	:	1.7~1.9
Launcher		:	a H-1 vehicle
Stiffness		:	> 30Hz

* Tentative value
** Gain at the center of 3 adjacent beams
*** Angle between centers of adjacent beams

This figure shows that there is an optimal focal length to obtain the highest minimum edge gain for each D and d pair and also shows that antenna with an aperture diameter larger than 3.5m and a focal length longer than 4.8m is necessary to attain the required minimum edge gain and beam separation angle.

Selection of reflector configuration

Compact geometrical arrangement of antenna components, such as the reflector and feeds, in deployed condition is essential to place the deployable satellite antenna into the rocket fairing.

It is difficult to attain a compact arrangement using a single reflector system since this would require arrangement of reflector and feeds with the very same long focal length as is necessary for assuring a proper electrical performance.

With the dual reflector system, a compact arrangement can easily be achieved, since a long equivalent focal length system is made possible by a main reflector with a short focal length, small subreflector near the main reflector focus and feed horns arranged between reflectors.

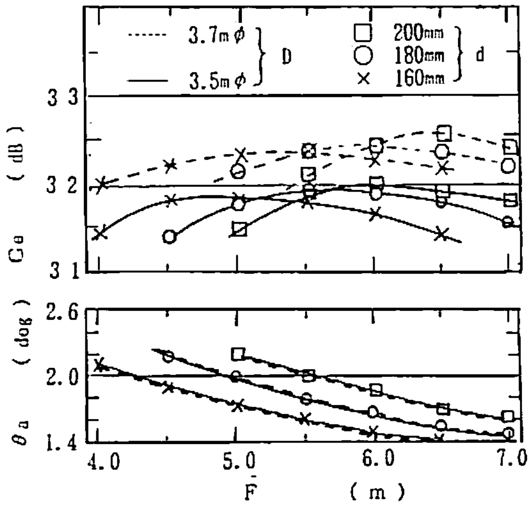

Fig. 3 Characteristics of minimum edge gain and beam separation angle

The offset cassegrain antenna, one of the dual reflector systems, has been selected for the objective of this study.

Several configuration for deployable mesh reflectors has been proposed, and some of these have been developed.(2)(3)(4)(5)(6) In view of the required reflector diameter, deployment reliance, lightness and ease of fabrication, a fan rib type deployable reflector with simplest mechanical configuration and the least number of movable joints, has been selected for further detailed study.

Design of offset cassegrain antenna

A side view of launch and on-orbit configuration of the antenna is shown in Fig.4. Antenna diameter is limited to less than 3.6m of the payload useful area limitation. The minimum edge gain increases with increase of the diameter as shown in Fig.3. Thus the main reflector diameter d is determined to be 3.6m. The side of the feed horn is determined to be 195mm, in consideration of blocking caused by feeds. The equivalent focal length F of the offset cassegrain antenna is determined to be 5.8m, obtaining a highest minimum edge gain for the determined D and d pair.

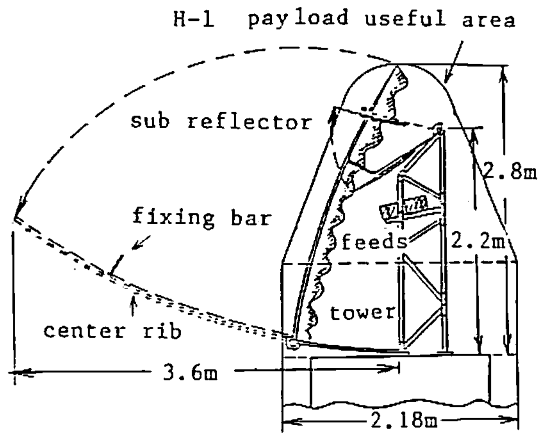

Fig. 4 Side view of stowed and on orbit configuration

Effect of sub reflector edge diffraction is calculated to determine the subreflector size using a current distribution method; the results are shown in Fig.5. The half of the subreflector angular apperture determined through geometrical optics (G.O.) is 17°, while apperture determined through a current distribution method (C.D.M.) is 24°. Fig.5 shows that the angular apperture of the subreflector should be enlarged about 40% more than the size determined by geometrical optics, regardless of the feed horn diameter; directive gain of 36.2dB is obtained.

Gain degradation is primarily due to the surface roughness, reflection loss of the mesh and ohmic loss at the feed circuit. The estimated gain degradation is 0.7dB. These results show that there is no gain margin for the horn fed antenna.

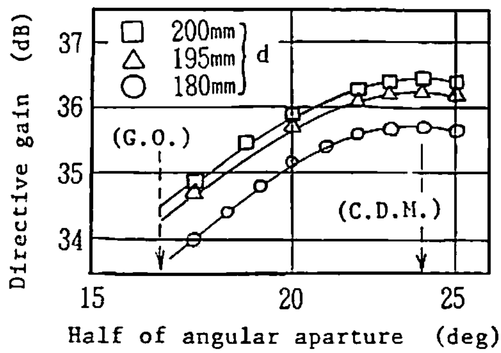

Fig. 5 Gain variation due to sub reflector angular aparture

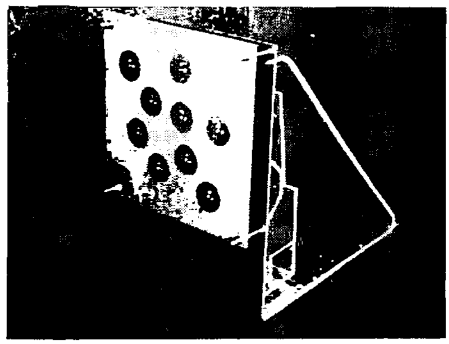
Fig. 6 Fablicated MSDA feed.

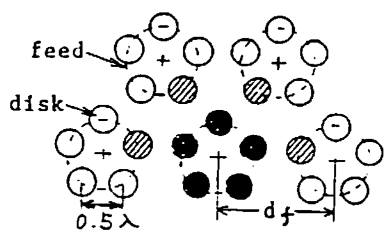

Fig. 7 Arrangement of feeds and disks

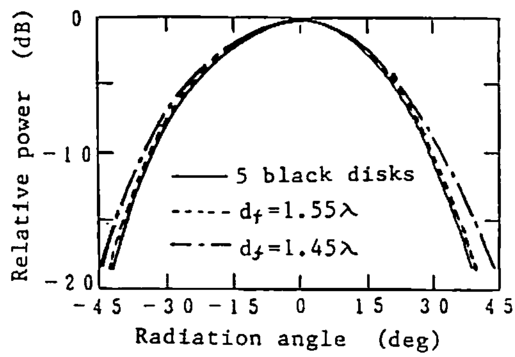

Fig. 8 Effect of mutual couplings

Feeds using micro strip disk antenna

The distance d_f between centers of adjacent feeds should be shortened to decrease the beam separation angle and to increase the minimum edge gain. However, it is impossible for the feed horn to decrease the distance less than its aperture size because of physical limitations.

A micro strip disk antenna (MSDA) feed has a possibility to decrease the distance less than its equivalent aperture size since it has a larger equivalent aperture than its physical size.

The arrangement of the disks to minimize the distance between adjacent feeds and the effect of mutual coupling between disks are examined to determine minimum distance between MSDA feeds. The experimental study has been conducted for the MSDA feed. A fabricated MSDA feed for studying mutual couplings is shown in Fig.6. The arrangement of the disks and experimental results are shown in Figs. 7 and 8, respectively. The effect of mutual couplings are apparent when the distance between feeds is shorter than 1.45λ. When the distance between feeds is longer than 1.55λ, the effect of mutual couplings are negligible. Thus, a minimum distance of 1.55λ is possible for MSDA feeds without serious degradation in electrical performance of the feed. The radiation pattern of the antenna fed by MSDA feeds with a 1.55λ distance is indicated by dotted circles in Fig.1 . About 1dB increase in minimum edge gain is accomplished using MSDA feeds instead of horn feeds and an adequate margin for required minimum edge gain is obtained.

The mechanical configuration   The major mechanical requirement for determining the configuration are the surface roughness of the deployed reflector and the stiffness of the rib in its stowed condition.

A 1/5 scale model of the mesh reflector, which is shown in Fig.9, has been made to examine the property of the mesh surface. Examination of the reflector clarifies that the surface roughness within 2mm r.m.s is feasible by supporting the mesh surface with ribs and/or quartz cords in radial direction at intervals of 3~3.5°.

The main reflector is composed of 9 ribs of different lengths. The ribs with cross sections of larger diameter and thinner skin are employed to obtain a reflector with lighter weight and more stiffness. The ribs are usually fixed at the top with fixing bars, and at the bottom with deployment mechanisms in the stowed condition. To raise the lowest natural frequency the point attaching the fixing bars is changed to a point 1/3 of full length from the top. This change provides an increase in the lowest natural frequency with thinner skin. The loss is antenna gain loss (less than 0.1dB) caused by the fixing bar blockings.

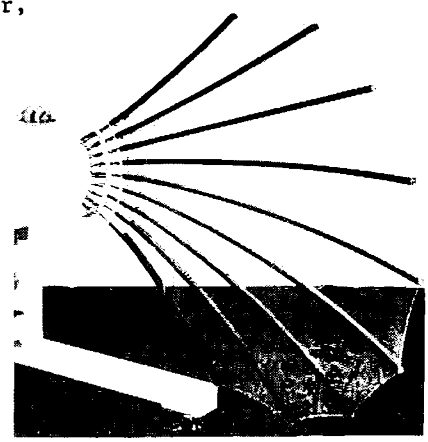

Fig. 9   Scale model of mesh antenna

Thus the main reflector with lowest natural frequency of 30Hz in stowed condition is obtained. Total weight of the antenna is 20kg, including the weight of the subreflector and the feeds.

Conclusion   It is verified that the fan rib type deployable mesh antenna which satisfies the all required antenna specifications is feasible, in consideration of the pay load useful area limitation of H-1 rocket.

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