4-6-2 A Folding Parabola Antenna with Flat Facets

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A folding parabola antenna with flat facets designed for portable earth stations of satellite communications systems using the S-band is proposed. High-data-rate satellite communications systems using low power terminals and/or measurement of satellite antenna properties require the use of portable, high-gain antenna. The reflector of this proposed antenna is constructed of flat facets, enabling it to be easily folded and carried. An experimental model of the antenna with a diameter of 68cm has a gain of 21dBi at 2.5 GHz.

Keywords
Folding antenna, Flat facets, Portable earth stations

1 Introduction

The ETS-VIII (Engineering Test Satellite VIII) is equipped with phased array antennas with large deployable reflectors as primary mirrors. It is important to measure and evaluate the characteristics of these antennas as a first step in the mobile satellite communications experiments planned for the ETS-VIII. To evaluate the performance of satellite antennas in orbit, a measurement system with a wide dynamic range is required, and high-gain antennas should be employed. On the other hand, data must be collected from multiple measurement stations in diverse locations for the most efficient evaluation of satellite antenna patterns. These measurement stations must also be portable. For communications at the relatively low frequencies (e.g., S-band frequencies) assigned to mobile satellite communications for the ETS-VIII, the use of high-gain antennas tends to entail the construction of large earth stations, which proves problematic in terms of mobility. We have therefore conducted studies on small, lightweight, high-gain antennas easily carried by a single person. Antennas of this type are also useful for practical applications requiring high-gain antennas (such as high-data-rate communications with low-power earth stations) or for emergency communications in areas of natural disasters such as an earthquake or typhoon.

To achieve the contradictory features of high gain and small dimensions, it makes sense to design a deployable folding structure that is large in use and small in storage. Here we will discuss a detachable folding parabola antenna consisting of small flat facets that form an approximate parabola reflector.

2 Considerations on the folding method

The antenna discussed in this article is designed for high portability without the need for motorized transportation. Particularly in cases of emergency communications in a disaster, maximum flexibility must be provided in transportation through the use of small, lightweight communication structures.

Various forms of deployable folding structures can be used for portable earth stations, including umbrella-shaped, divided, and inflatable structures. The relative characteristics of these types of structures are generally as follows.

Umbrella-shaped: Although it is easy to deploy and fold this type of antenna, reflector accuracy and strength are not ideal. To increase accuracy and strength, it is necessary to increase the number of umbrella spokes, leading to increased weight and greater structural complexity. Further, the pole situated in the center of the aperture leads to problems in the attachment of the feed element.

Divided: Divided antennas are disassembled into multiple parts for storage. The parabola reflector is disassembled and assembled without deforming the parts, leading to relatively high reflector accuracy. However, more segments are required for increased portability. This increase in the number of parts complicates the deployment and folding processes. Further, the curved surface requires added reflector thickness, a drawback in terms of storage. On the other hand, this type of antenna is relatively easy to construct, although connection of reflector parts requires a significant degree of inventiveness.

Inflatable: Inflatable antennas are deployed like balloons, through inflation with a gas such as air, and the resulting curved surface is used as the reflector. This is the simplest of available deployment and folding mechanisms. Use of this parabolic structure may offer enhanced reflector accuracy. The entire structure is quite flexible, which poses problems in attaching the feed system and in the installation of the antenna.

Given these characteristics, the easy-to-construct divided antenna appears most advantageous. The disadvantages of this type of antenna can be overcome through the following countermeasures:

- Connection of the divided parts in a folding structure to simplify assembly and disassembly
- Use of flat reflector elements to facilitate storage and construction, elements that are assembled to form an approximate parabolic reflector.

3 Construction of a prototype

As a result of the considerations set forth in the previous section, we constructed a divided folding parabolic antenna employing a pseudo-parabolic reflector composed of flat facets.

The reflector of this antenna is composed of segments consisting of small flat facets interconnected by hinges; these segments are in turn connected to the center (base) panel. Studies have shown that the maximum dimensions of these facets can be determined based on the applicable focal length and the required reflector accuracy.

The maximum dimension (the length of a side) L of the flat facet is expressed as follows:

$$L = C\sqrt{\delta F}$$

where δ (RMS) is the required reflector accuracy and F is the focal length. Here, C is a constant determined by the shape of the facet: [1]

Hexagon: C = 4.046,

Square: C = 6.160,

Triangle: C = 7.872.

Prototype design values included a gain of 20 dBi or more for the S-band, a diameter of approximately 680 mm, and reflector accuracy of 2 mm or better (RMS). First, a structural model was constructed to confirm the validity of the method of deployment and folding. A patch antenna was used for the feed element, and the focal length of the structural model was determined to be 350 mm based on the radiation properties of the patch antenna. The four segments, each constructed with six facets, were attached to the base plate by hinges. The segments were linked by magnets for easy antenna assembly and deployment. Figs.1 and 2 show the deployed and folded states of the structural model, respectively.

As is clear from the figures, the antenna is folded into a box shape; this structure proved unsuitable for storage. The hinges, with no

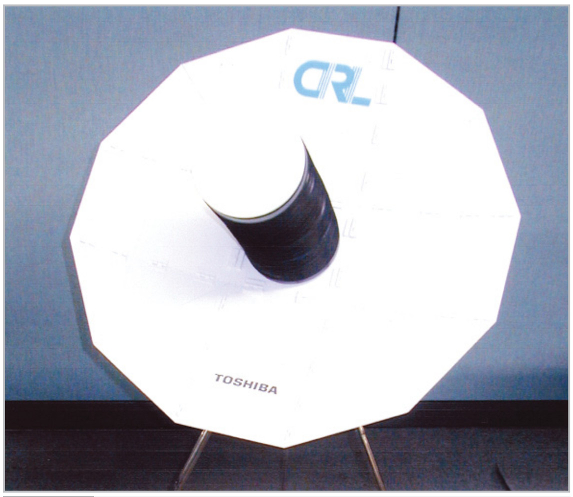

Fig.1 Structural model (deployed)

Fig.2 Structural model (folded)

clamping mechanism, were unstable when deployed and folded, impeding operation. The mechanism of attachment of the feed element also requires further consideration. If a patch antenna is to be used for the feed element, the attachment pole may lead to reduced aperture efficiency. To solve these problems, the following countermeasures were taken.

(1) The segments were separated and smaller facets were used to facilitate storage.

(2) The feed element was directly attached to the base plate.

(3) Notches were introduced to improve the functionality of hinges in deployment and folding.

A prototype was built based on these improvements. A quadrifilar helix antenna was used to attach the feed element directly to the base plate. Fig.3 shows the prepared quadrifilar helix antenna and Fig.4 shows the radiation pattern of the antenna.

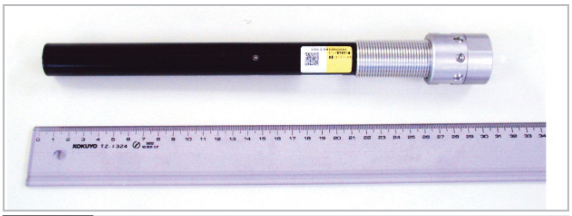

Fig.3 Quadrifilar helix antenna

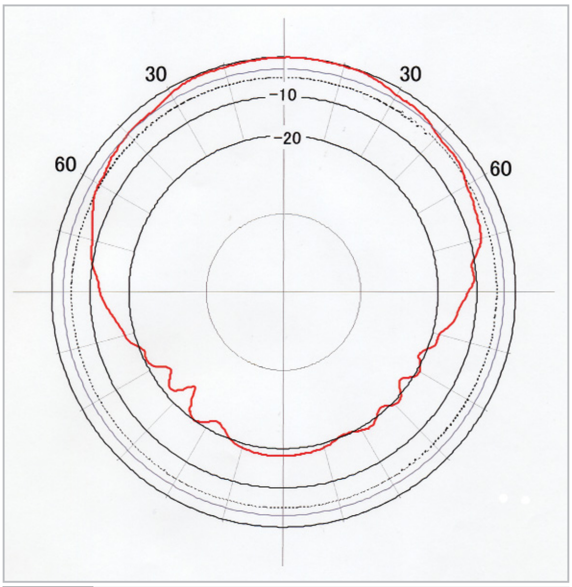

Fig.4 Radiation pattern of the quadrifilar helix antenna

The focal length was set to 220 mm based on the facet dimensions and the radiation pattern of the feed element. Each foldable segment consisted of nine facets, and the reflector was composed of six segments and a base plate. The segments were attached to the base plate through insertion of the hinge section, allowing for the separation of the segments from the base plate. The outermost facets were inserted into the small notches placed on the other facets inside the outermost facets to increase the rigidity of the deployed antenna. The segments were linked by magnets to facilitate assembly and deployment. The feed element was inserted into the central hole through the base panel and fastened in place with plunger pins. The combination of these modifications thus led to a configuration offering greater convenience in assembly and deployment. Fig.5 shows the deployed antenna. Figs.6 and 7 show the partially deployed and folded antenna, respectively.

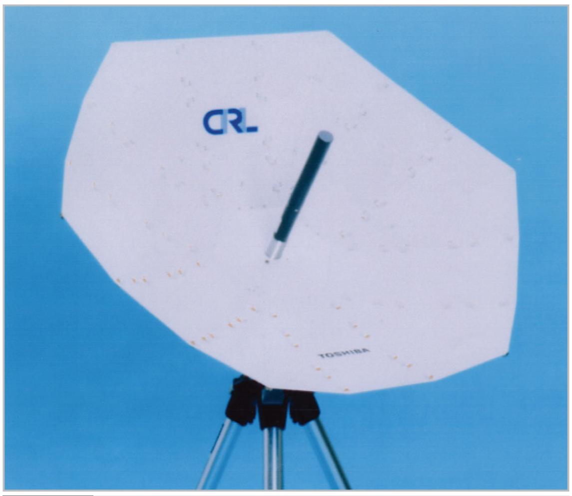

Fig.5 *Deployed prototype*

Fig.6 *Partially deployed prototype*

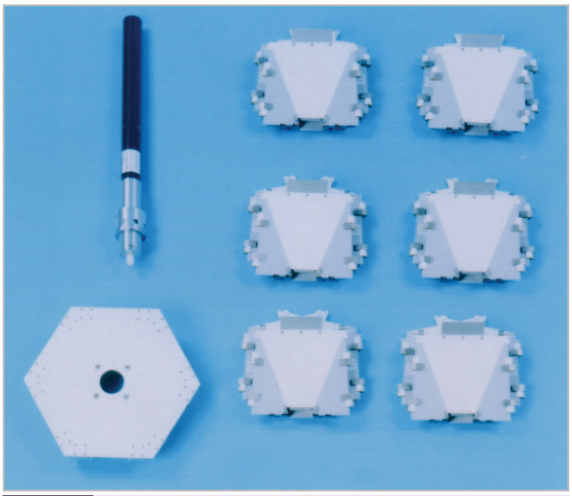
Fig.7 *Folded prototype*

The reflector is 667 mm × 732 mm and weighs 2.2 kg. The folded segment is 130 mm × 144 mm × 28 mm (including protrusions). Except for its thickness (28 mm), the reflector is approximately the size of a CD case, allowing for convenient storage.

4 Measured electrical characteristics

To evaluate the electrical characteristics of the prototype, measurements were made of gain values, radiation pattern, and reflector accuracy. Fig.8 shows the measured radiation pattern values.

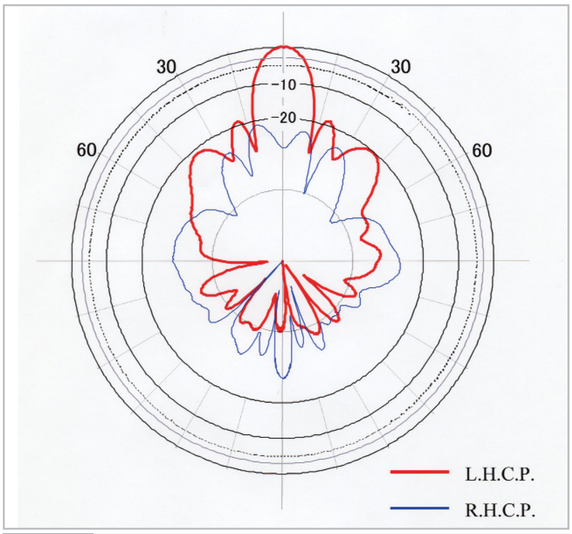

Fig.8 *Prototype radiation pattern*

Accuracy was measured at 3 mm (RMS) for the entire reflector (including the protrusions at the hinges), which is slightly less accurate than the design value. In particular, the apexes around the reflector limbs and one part of the base panel showed increased reflector errors. However, the radiation pattern indicated no abnormality. Peak gains were 21.6 dBi and 22.4 dBi for the frequencies of 2.50 GHz and 2.65 GHz, respectively. The beam angle (−3 dB width) was approximately 11 degrees and aperture efficiency was approximately 50%. These electrical results were roughly in accordance with the design values and are sufficient for practical purposes.

5 Summary

We proposed a folding parabola antenna offering superior portability, confirming that an approximately parabolic antenna composed of flat facets will prove satisfactory for practical use in the S-band. Durability and wind resistance must be verified next through further experiments.

The flat facets of parabolic reflectors incorporating these design elements must be very small due to the requirements governing reflector accuracy. It is also necessary to evaluate the adaptability of this structure to additional frequency bands.

The antenna presented in this study will be used in various communications experiments, including ETS-VIII antenna pattern measurements.

References

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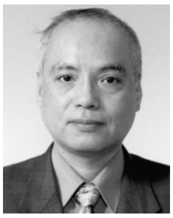

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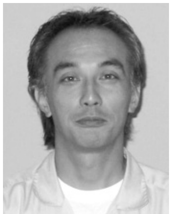

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