A study of deployable center-fed reflectarray antenna

Hiromasa Nakajima^{1, a)}, Shin-ichi Yamamoto¹,
Michio Takikawa¹, Syuji Nuimura¹, and Yoshio Inasawa¹

¹ Mitsubishi Electric Corporation,

5–1–1 Ofuna, Kamakura, 247–8501, Japan

a) Nakajima.Hiromasa@dn.MitsubishiElectric.co.jp

Abstract: In this paper a deployable center-fed reflectarray antenna for mobile satellite communication systems is proposed. The proposed antenna consists of a main-substrate, four foldable sub-substrates, and a backfire antenna. This antenna can speedily be installed by attaching the backfire antenna and deploying the folded sub-substrates. The design results show that the antenna can satisfy the target gain by adjusting the deployment angle of the sub-substrates. In addition, the validity of the design is verified by measurements.

Keywords: reflectarray, deployable antenna, backfire, foldable substrate

Classification: Antennas and Propagation

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1 Introduction

Currently parabola antennas are often used in mobile satellite communication systems [1, 2]. These antennas can achieve high gain easily, but they have problems in terms of portable size and installation time because the curved reflector must be divided in order to pack it in a baggage.

This paper proposes a center-fed deployable reflectarray antenna for mobile satellite communication systems [3]. Figure 1(a) shows the structure of the proposed antenna. This antenna consists of a main-substrate, four foldable sub-substrates, and a backfire antenna. Figure 1(b) shows the comparison of the antenna installation process between the conventional and proposed antennas. In order to install the conventional antenna, the antenna parts need to be unboxed, and then the supporting structures must be built. After that, the backfire antenna is attached, and the divided curved reflector is assembled. It is not so easy to install the conventional antenna. On the other hand, the proposed antenna can speedily be installed by attaching the backfire antenna and deploying the substrates. It takes less than five minutes, which is approximately a half of the conventional one. Therefore, this antenna is a good candidate for mobile satellite communication systems as it can achieve high gain using flat substrates that are easy to pack and carry. In this paper, this reflectarray antenna is designed, and its characteristics are analyzed. In addition, the validity of the design is verified by measurements.

Fig. 1. Antenna structures and installation processes.

2 Design

In this section, the proposed antenna is designed and analyzed.

Figures 2(a) and 2(b) show side view images of the antenna, where θ_s shows the deployment angle of sub-substrates. In the case of $\theta_s = 0$ degrees, the path length changes depending on the reflection point. When $\theta_s = 30$ degrees, the path length difference is small. These path length differences cause a narrow bandwidth of the antenna [4, 5]. Therefore, the θ_s is a key parameter in our antenna design.

Figure 2(c) shows the design conditions. An existing backfire antenna is used as the primary feed. Therefore, the characteristics of the primary feed cannot be changed. θ_s is changed from 0 to 60 degrees.

The design and analysis process of the antenna is briefly explained as follows. First, the phase distribution on the substrates from the backfire antenna is calculated. Second, the reflection phase at each element as a function of element size is calculated using a periodic boundary model. Then, each element size is determined so that the sum of the phase shift from the backfire antenna and the reflection phase of the element is uniform across the aperture surface at the design frequency. Finally, the radiation characteristics are calculated.

Figure 2(d) shows the calculated gain of the antenna for several deployment angles. As the deployment angle increases, the path length difference and the spill-over loss decrease, but the antenna aperture size also decreases. As the results, $\theta_s = 30$ degrees (see Fig. 2(e)) is the optimal angle to achieve high gain over the target frequency band.

Figures 2(f) and 2(g) show the radiation patterns in the AZ plane when $\theta_s = 0$ and 30 degrees, respectively. In the case of $\theta_s = 0$ degrees, the side lobe levels are high especially at 100 degrees. It is caused by spill-over. The antenna for satellite communication systems must satisfy the side lobe regulations. In this case, it is difficult to satisfy these regulations. On the other hand, when $\theta_s = 30$ degrees, the side lobe levels are improved.

3 Measurement

Based on the design results in Section 2, a prototype antenna is manufactured and measured to confirm the validity of the design.

Figure 3(a) shows the calculated and measured gain. The measurement results are in good agreement with the calculated results as a whole. The difference between the measured and calculated gain is less than 0.28 dB.

Figures 3(b) and 3(c) show the radiation patterns. In the Co-pol results, the calculated and measured results are in good agreement across the wide angle. On the other hand, in the X-pol results, there is a difference in the front direction ($\theta_s = 0$ degrees). This would be caused by the effect of POL (polarizer)/OMT (orthomode transducer) which is not considered in the design.

4 Conclusion

We have proposed the center-fed deployable reflectarray antenna for mobile satellite communication systems. The proposed antenna consists of a backfire antenna and foldable flat substrates. This antenna is easy to install by attaching the backfire

Frequency band	$0.93f_0 - 1.05f_0$
Polarization	Circular
Deployment angle θ_s	0-60 degrees
Element figure	Rectangular ring patch
Element allocate	Rectangular
Primary feed	Backfire

(c) Design conditions.

(d) Calculated gain in each deployment angle.

(e) Designed reflectarray antenna.

(f) Radiation pattern ($\theta_s = 0$ degrees).

(g) Radiation pattern ($\theta_s = 30$ degrees).

Fig. 2. Configuration and design results.

Fig. 3. Measurement results.

antenna and deploying the substrates. In addition, it can be stored compactly for carrying. It has been shown that the designed antenna can satisfy the target gain by adjusting the deployment angle. In addition, the validity of the design has been verified by measurements.