Low Sidelobe Compact Reflector Antenna Using Backfire Primary Radiator for Ku-Band Mobile Satellite Communication System on Board Vessel

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Abstract- **We developed low side lobe compact reflector antennas of aperture diameter of 60cm and 120cm. They are corresponding to 30 and 60 wavelength. These antennas are axial symmetry antennas using a backfire primary radiator. They are used in Ku-band mobile satellite communication. The requirements of antennas are low side lobes and low cross polarization. The antennas have satisfied ITU-R recommendation S.580-6. This paper introduces the structures and the radiation patterns of the antennas.**

I. INTRODUCTION

Recent years have seen a growing need for broadband communications services for aircraft, ships, automobiles and other vehicles. Purposes include providing Internet service to passengers, traffic control, and the transmission of high definition video from the sight of disasters and incidents. Introduction of the earth stations on board vessels (ESVs) system using the Ku-band satellite communications systems has been started [1-3]. We propose the two size antennas for the system. They are a 120cm antenna (high gain type) corresponding to global use, and a 60cm antenna (compact type) suitable for a small vessel. It is necessary to conform to international and regional standards and regulations all around the world. For this purpose, antenna needs to be designed to achieve low side lobe with keeping high antenna efficiency. We designed the antenna with which it is satisfied of ITU-R: International Telecommunication Union Radio communications Sector, recommendation S.580-6 radiation pattern mask. In addition, in order to use them at Ku-band, they are operated with linear polarization, and a low cross polarization characteristic is required. In this paper, we report the design and measured results of the compact reflector antennas for the Ku-band satellite communications system on board vessel.

II. ANTENNA STRUCTURE

In mobile satellite communication, mechanical-drive compact reflector antenna is an attractive candidate. It could achieve the required function and performance in a reasonable cost.

The antenna is scanned to the direction corresponding to the relative location of a satellite and a current position. The antennas are used in radome. In order to make radome size small, it is necessary to make swept volume small. The offset reflector antenna realizes high performance, since there is no blockage, but the swept volume is rather large. The center feed antenna is effective to realize compact reflector antennas.

Dual-reflector antennas have the advantage to optimize aperture distribution by using reflector surface shaping technique. The diameter of the subreflector is several wavelengths at least, in order to achieve the function as a reflector and to realize optimum aperture distribution.

In the single-reflector antenna, making the primary radiator smaller is important in order to reduce blocking, and a backfire primary radiator is effective. A backfire primary radiator is self-supporting structure, so it has the advantage of avoiding the blocking caused by a support structure. However, primary radiation patterns cannot be finely controlled with backfire primary radiators, so there are limits on how far the aperture distribution can be optimized.

Figure 1 shows the antenna structure, which has self-supported backfire primary radiator [4-5] in the centre of a main reflector. A backfire primary radiator consists of a circular feed waveguide and a hat structure supported by a dielectric spacer.

There are three key points of the antenna design for low side lobe level and low cross polarization. They are a backfire primary radiator with a small diameter (small blockage area), the suppression structure of a surface current on the feed

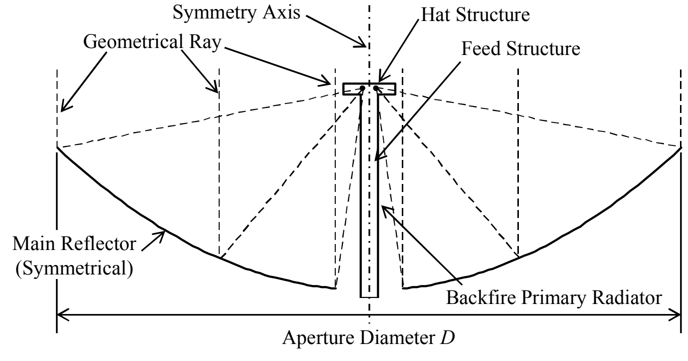


Figure1. Antenna Structure

waveguide, and the hat structure which produces rotational symmetry electromagnetic fields.

For high antenna aperture efficiency, a sharp primary radiation pattern with shallow reflector or a wide primary radiation pattern with deep reflector are chosen in order to suppress the spill-over power from the main reflector. However, for the sharp primary radiation pattern, blockage area by the primary radiator or the subreflector becomes large and side lobe level at the near axis becomes high. We adopt a small backfire primary radiator with a deep reflector.

A surface current on the feed waveguide degrades side lobe patterns especially in near axis of the E-plane. The surface current is suppressed by the corrugation loading in the whole feed waveguide surface and chokes around the aperture of the feed waveguide.

The hat has $\lambda/4$ grooves in order to improve the rotational symmetry of the electromagnetic field. The combination of the vertical (parallel to the waveguide axis) and horizontal (normal to the waveguide axis) grooves is effective in stopping the spill-over power from the hat and the main reflector, even if the hat diameter is small. Since reflective conditions differ between E- and H-plane, rotational symmetry is degraded and the cross polarization level is increased. The slope and vertical grooves, instead of the horizontal groove, are suppressed the spill-over, with rotational symmetry maintained.

Figure 2 and 3 show photographs of fabricated antennas for the Ku-band satellite communications system on board vessel. Figure 2 shows 120cm antenna (high gain type antenna). Aperture diameter of the main reflector is 60λ. Figure 2 shows 60cm antenna (compact type antenna). Aperture diameter of the main reflector is 30λ.

Figure 2. 120cm antenna (high gain type).

III. RADIATION PATTERN

Figure 3. 60cm antenna (compact type).

An analytical model for the radiation pattern of the antenna is a combined method of electromagnetic analysis and high frequency approximation (physical optics, PO). The electromagnetic fields around the backfire primary radiator are calculated by the finite element method (FEM). Ansoft HFSS is used for the FEM simulation. The currents at the reflector surface are calculated from the electromagnetic fields, and a radiation pattern is calculated by integrating them. This calculation procedure can obtain accurate radiation patterns compared with the conventional calculation method using near or far field radiation patterns of the primary radiator. The ideal reflector surface is used in calculation and the influence of a reflector fabrication error is not include in calculated values. Although the antenna is measured and used with a radome, affects of the radome are not included in calculated values.

Figure 4 shows antenna measurement equipment. These antennas are measured with a compact range measurement system. An inclined fixer is used in order to point the antenna in the direction of 30degree which is the typical elevation angle of satellite station in mid-latitude region.

Figures 5 to 8 show measured and calculated results at transmission frequency band in E-plane (horizontal

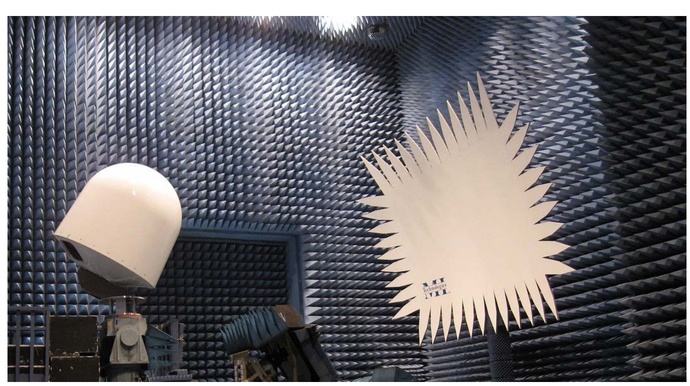
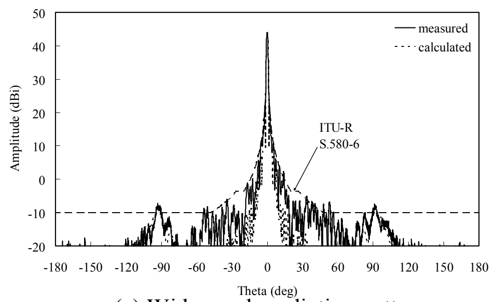
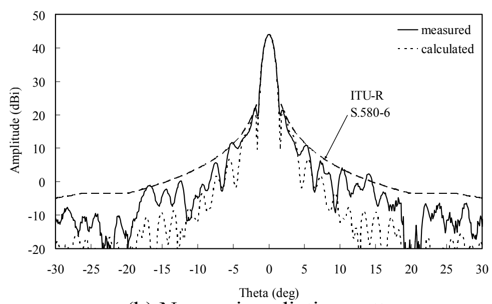


Figure 4. Antenna measurement equipment.

polarization) and H-plane (vertical polarization), respectively. Since the influence of radome and the influence of a reflector surface error are not taken into calculation, differences are seen between calculated values and measured values. These figures include ITU-R S.580-6 radiation pattern mask. The low side lobe characteristic is achieved over the wide angle range. The radiation patterns are satisfied with the mask.

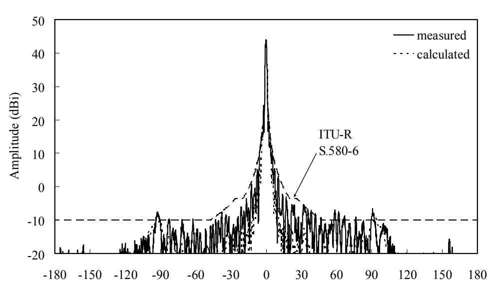


(a) Wide angle radiation pattern

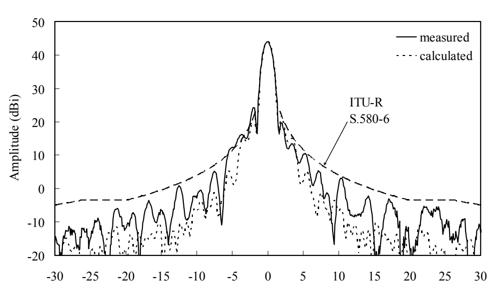


(b) Near axis radiation pattern

Figure 5. 120cm antenna radiation pattern (E-plane)

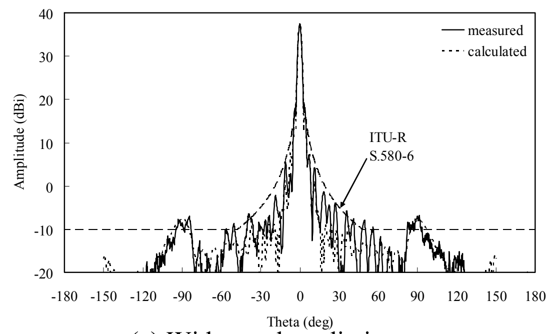


(a) Wide angle radiation pattern

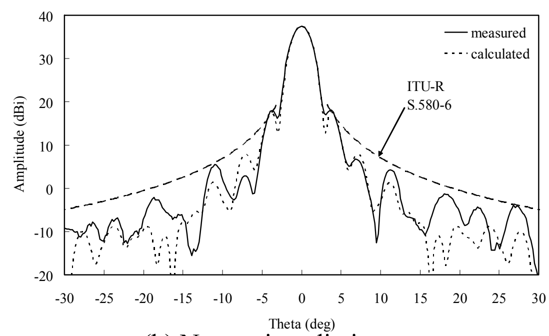


(b) Near axis radiation pattern

Figure 6. 120cm antenna radiation pattern (H-plane)

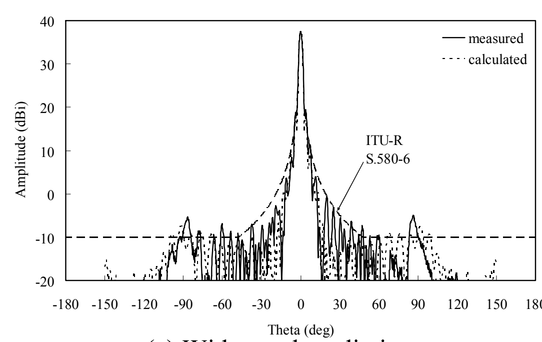


(a) Wide angle radiation pattern

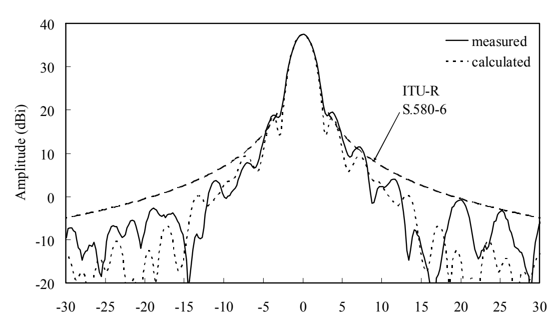


(b) Near axis radiation pattern

Figure 7. 60cm antenna radiation pattern (E-plane)



(a) Wide angle radiation pattern



(b) Near axis radiation pattern

Figure 8. 60cm antenna radiation pattern (H-plane)

IV. CONCLUSION

We reported the design and measurement results of the compact reflector antennas for the Ku-band satellite communications system on board vessel. The backfire primary radiator, the suppression structure of the surface currents on feed waveguide, and the hat structure with rotational symmetry electromagnetic field are applied to the antenna design. The low side lobe characteristic is achieved over the wide angle range.

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