Novel Hybrid Antenna Design having A Shaped Reflector for Mobile Satellite Communication Applications

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Introduction

This paper presents novel hybrid antenna (HA) design based on shaped reflector for mobile satellite communications. HA is composed of a shaped reflector and the feeder having a 1×8 linear phased array, and reflector shaping method is applied for the performance optimization with minimum aperture size. And, in the feeder design, HA has another merit to minimize the manufacturing cost by optimizing the number of element. Proposed HA is designed at Ka-band and can electrically control a beam pattern within ±3° in the basic angle of +45° in elevation. This antenna is designed to meet the international regulations for very small aperture terminals (VSAT) including ITU-R S.465-5 for beam pattern including side-lobe level.

Proposed Antenna Design

The interest of antenna engineers to hybrid antennas has a strong reason. If it is needed for rapid beam steering in respectively small angle sector, we can utilize the hybrid composition of antenna such as ‘reflector + phased array’, which is named as HA. The hybrid antenna comprises the merits of both the mechanical and the electrical antennas using them. A sufficiently large aperture of reflector can provide a high gain being typical for reflector antennas, and a compound feed provides an rapid electrical beam scanning capacity in a narrow angle sector. Thus, in a certain sense, the HA is the reasonable compromise between the reflector antennas which has high-efficiency but not to control antenna beam and the electrical antennas having a compound and expensive phase array providing electrical scanning capacity.

In order to clarify the principle of hybrid antenna design it is effective to use the ray-path method for description of antenna radiation field. As is well known, the analysis on a base of ray-path or geometrical optics (GO) method gives a good approach in the case when a size of antenna system is much greater than a wavelength. At the same time, the ray-path analysis enables a clear understanding of physical sense and permits to recognize the restrictions and the limiting possibilities at the first stage of HA development [1-3].

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Successive steps of the synthesis of HA, based on focuser principle, can be briefly described as follows.

First step is GO synthesis. It involves a choice of the focuser surface parameters, determination of the focal line length, mutual arrangement of the surface and focal line. Next an antenna aperture should be chosen by ray coordinates on a reflector surface. Third step involves to discrete the reflector surface obtained from GO synthesis. This means a division of the reflector into triangles, simple grid 3×3 nodes. Following step is involves a choice of the feed array structure, such as number of elements, element type and so on. Sixth step involves a reflector shaping. This is done using Physical Optic (PO) approximation for higher frequency. Then, last antenna performance is simulated for all frequency bands.

The proposed antenna is shown in Fig. 1 schematically. Antenna consists of the shaped reflector-focuser, linear feed array and support construction. The linear feed array is designed of linear phased array having 8 elements. Each element has a square horn radiator fed by a stacked patch exciter. The exciter has the shape of the corner truncated square patch generating left-handed circular polarization (LHCP). The main specifications of the proposed HA are summarized in Table 1.

Table 1. Main **s**pecifications of proposed HA

Item	Specification	Note
Operating Frequency	30.085~30.885 GHz	800MHz
Antenna Gain	35 dBi Min.	
Polarization	LHCP	
Beam scanning range	Elevation: $\pm$ 3°	
Size	$60 \times 50 \times 50$	$L \times W \times H$

Fig. 2 shows the simulation results of the shaped reflector. As shown in these figures, because signal power is not illuminated in the edge area of the reflector, we could reduce the reflector size by eliminating the edge area of it maintaining the antenna performance. Thus the final reflector shape was similar to a shield, and we could reduce the aperture size by about 25%. In these figures, the feed array symbolized as a line above the reflector and the structure of it is the same above explained.

The prototype antenna was fabricated with aluminum using computerized mechanical process. Using the prototype, we tested the antenna performances in anechoic chamber of *Orbit/FR* Inc. The HA has the gain of minimum 37.6 dBi in the required scanning range of $\pm$ 3° in elevation. The axial-ratio performance is about 1.3 dB in LHCP. The radiation patterns results are shown in Fig. 3. The results were measured in the center frequency 30.485 GHz, and as shown in the figures, the result satisfies the international VSAT regulations including Intelsat and ITU which especially regulate the side-lobe characteristic to prevent mutual interference between communication-satellite systems and between earth stations of such systems and stations of other services sharing the same frequency band

[4]. Fig. 4 shows the fabricated HA with test environment of the anechoic chamber.

Conclusions

In this paper, the novel HA having a shaped reflector for mobile satellite communications is introduced. The shaped reflector was designed to have optimum antenna performance, especially gain and radiation pattern, and whole antenna design was performed using GO and PO in 30.085 ~ 30.885 GHz. The feed array is composed of linearly alligned 8 elements, and the each of them is controlled by active channel including amplifiers and phase shifters. The fabricated HA has the minimum gain of 37.6 dBi with about 1.3 dB axial-ratio performance, and the radiation patterns satisfied various international regulations for VSAT.

Finally, it is confirmed that we can reduced the antenna size with opitimum performance and this approach is very useful in the design of mobile satellite communication applications .

References:

[1] C.H.Tang, R.S.Chu, "Hybrid antenna configurations for limited electronic scanning," *NEREM-74, Rec*. Newton, Mass., pp 184-188,1975

[2] R.J.Mailloux, et al., *The Hand book of Antenna Design*, Peter Peregrinus Ltd., London, UK, 1982

[3] L.I.Alimova, et al., "Possibility of wide angle scanning in hybrid antennas," Radio-engineering & Electronics, Vol. 26, No. 12, pp 2500-2510, 1981

[4] Recommendation ITU-R S.465-5, *Reference Earth-station Radiation Pattern for Use in Coordiation and Interference Assessment in The Frequency Range from 2 to About 30 GHz*

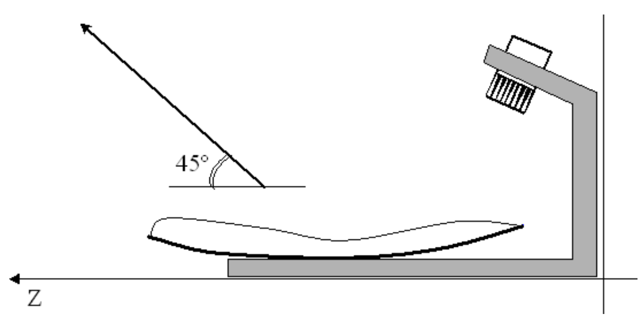
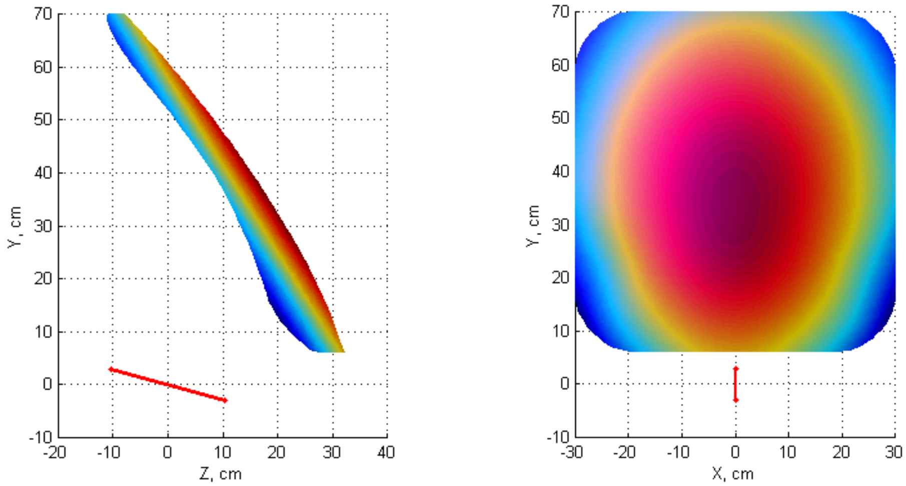
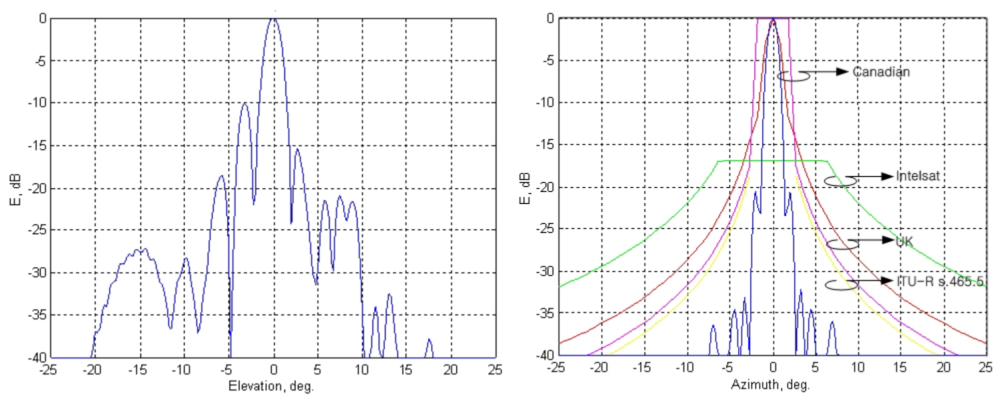


Fig.1. Proposed antenna structure



(a) Side-view (b) Top-view

Fig.2. Reflector simulation results at tilt angle = 0°



(a) Elevation cut (b) Azimuth cut

Fig.3. Test results of the proposed HA tilt angle = 0°

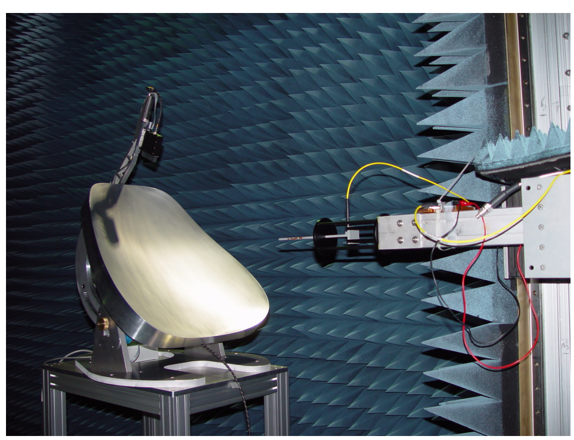


Fig.4. Fabricated HA in anechoic chamber