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THEORETICAL AND EXPERIMENTAL STUDY OF CONFORMAL ARRAY ANTENNAS FOR MOBILE SATELLITE COMMUNICATIONS

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1. Introduction

In mobile satellite communications, antennas with electrical beam scanning capability in a wide angle scan region are required, especially for land-mobile vehicles. A conformal array antena has a particular advantage in terms of the wide angle scan region. In addition, the conformal array is preferable from the standpoint of vehicle aerodynamics and ready adaptability to a curved surface. This paper makes use of computer simulations to examine radiation characteristics of conformal array suitable for mobile satellite communications. Mechanical and electrical performances of conformal array fabricated by the round-faced compression method are presented. First, the calculation of 16-element conformal array using icosahedron arrangement demonstrates that radiation characteristics of the conformal array can be improved by adjusting the radius of the curvature, and that optimum radius of the curvature with maximum gain exists. Second, in order to test the feasibility of producing such an antenna, the array is fabricated using the round-faced compression method. The round-faced compression method provides excellent electrical characteristics for the antenna element and excellent beam scanning characteristics for the array antenna, these are considered to be optimal for mobile satellite communications.

2. Analysis

The configuration of the conformal array is shown in Fig.1. An icosahedron inscribed in a sphere was hypothesized. The equilateral triangles of which the icosahedron is composed are further divided into smaller equilateral triangles. The number of divisions in a given side of the icosahedron is N. Each antenna element is arranged at the position where each vertex of the small equilateral triangle is projected on the sphere surface. The total number of the elements is assumed to be 16 here. In this configuration, the curvature radius of the conformal array increases as the number of divisions increases. Therefore, when the diameter of the base is constant, the hight of the conformal array decreases as the number of divisions increases. In order to compare the conformal array with the more conventional 19-element planar array, the base is assumed to be 475mm ($2.5\lambda_0$ at $f_0 = 1.54$ GHz). Given this, a low profile conforml array with a hight of 60 mm can be realized when $N = 5$. Variation of minimum directive gain in the scan region of ± 60° with the number of divisions N are shown in Fig.2, where ε_e is the effective permittivity. In comparison, directive gain of the 19-element planar array is also shown in this figure. It is obvious that the conformal array is effective as the effective permittivity ε_e decreases and the element spacing increases. Directive gain in the scan region of ± 60° can be improved by adjusting the curvature of the surface.

3. Experimental results

We have already evaluated the mechanical performance of a spherical array fabricated by a vacuum forming technique [1]. This technique can easily be applied to any curved surface. However, with the vacuum forming technique, the printed accuracy of the element antenna is inadequate, since the antenna is made on the curved surface after forming the substrate. Considering the large radius of the curvature of the substrate, we felt that a round-faced compression method could be introdued to improve the printed accuracy of the element antenna. The flow chart for the fabrication procedure is shown in Fig. 3. First, thin planar substrates with a $130\mu m$ thickness for the element antenna and ground plane use are fabricated. To improve the printed acuracy of the element antenna, each antenna is etched on the thin planar substrate. In this way, the same printed accuracy as that of a planar array can be obtained. Second, to adjust the substrate thickness, 24 sheets of thin prepreg are combined with the antenna substrate and ground plane substrate. Third, these sheets are cut into the correct shape before press forming. Finally, the sheets are combined and pressed using metal molds. A fabricated conformal array antenna with visible joints and the holes for fixing the element locations can be seen in Fig. 4. The performance of the fabricated array is summarized in Table 1. This table shows that the mean bandwidth of VSWR less than 2 is nearly 2% and the tolerance of each resonant frequency is within the bandwidth. A comparison of the measured return losses of the elements on the conformal array and the plane substrate is shown in Fig. 5. Beam scanning characteristics of the 16-element conformal array are shown in Fig. 6, where the scan angles are 0°, 30° and 60° and the array is excited to attain maximum gain. In comparison, beam scanning characteristics of the 19-element planar array are also shown in this figure. The difference between the gain of the conformal and the planar array is estimated to be about 0.7 dB at a scan angle of 60°, which is almost the same as the theoretical difference 0.3 dB shown in Fig. 6.

4. Conclusion

In this paper, the performance of a conformal array suitable for mobile satellite communications has been presented. It has been demonstrated that radiation characteristics can be improved by adjusting the curvature of the conformal array. Furthermore, the mechanical and electrical performance of a 16-element conformal array fabricated by the round-faced compression method has been investigated. The obtained mean resonant frequency is 1.528 GHz and the standard deviation is 5.8 MHz when compared to the design frequency of 1.538 GHz. The obtained bandwidth of VSWR less than 2 and the mutual coupling are almost the same as those of the patches fabricated on a planar substrate. Furthermore, the beam scanning characteristics of the 16-element phased array are also the same as the theoretical one. The results of the experiments show the validity of the conformal array for mobile satellite communications and the effectiveness of the round-faced compression method.

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References

(1) Chujo W., Konishi Y., Ohtaki Y. and Yasukawa K.: "Performance of a spherical array antenna fabricated by vacuum forming technique", Proc. 20th European Microwave Conf., Budapest, Hungary (Sept. 1990).

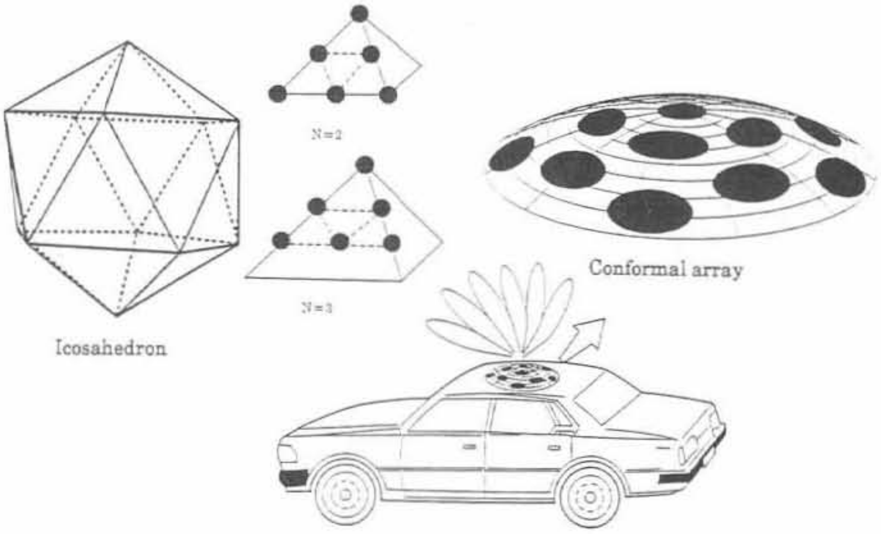
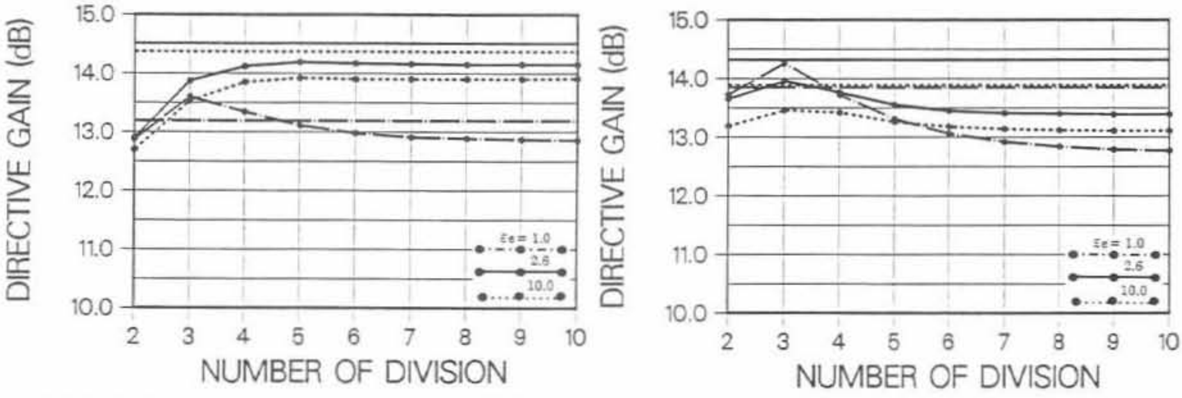


Fig.1. Configuration of a conformal array for mobile satelite communications.



(a) Minimum element spacing 0.5λ (b) Minimum element spacing 0.6λ

Fig.2. Directive gain versus number of division (minimum value within ±60°).

Table 1 Performances of a fabricated conformal array.

	Mean value	Standard deviation	Element on planar substrate
Center frequency	1.528GHz	5.8MHz	1.538GHz
Bandwidth(VSWR≤2)	1.85%(28.1MHz)	0.19%	1.30%
Substrate thickness	3.17mm	0.037mm	3.2mm

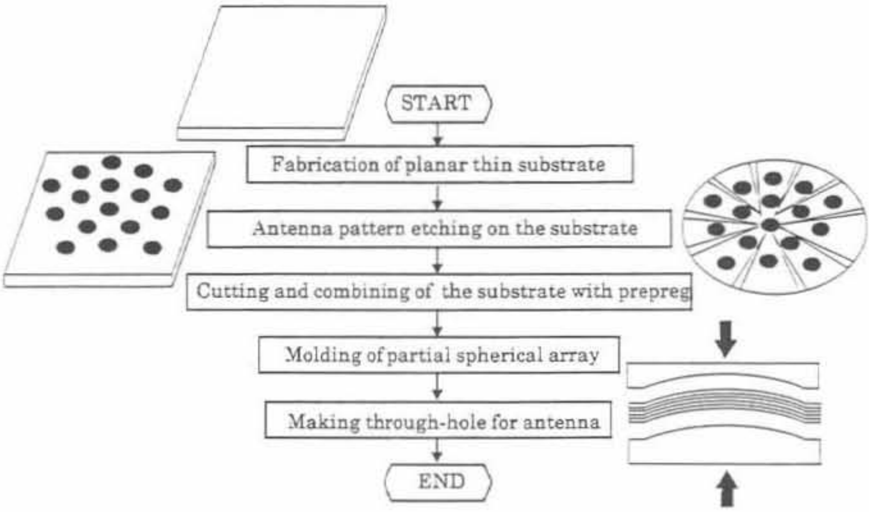
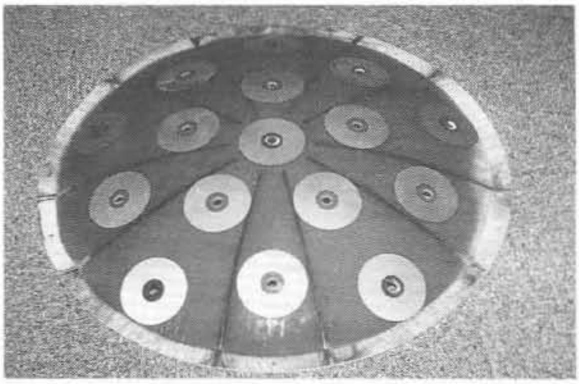


Fig.3. Fabrication techniques using the round-faced compression method.



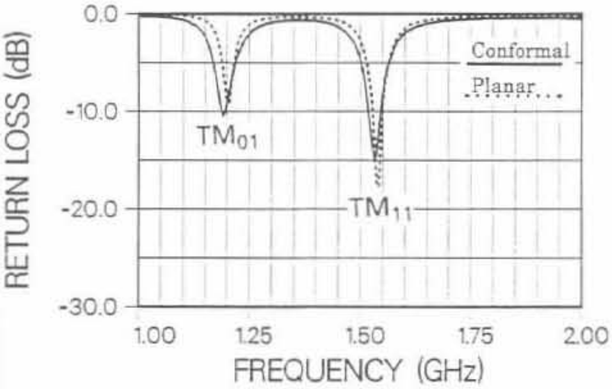
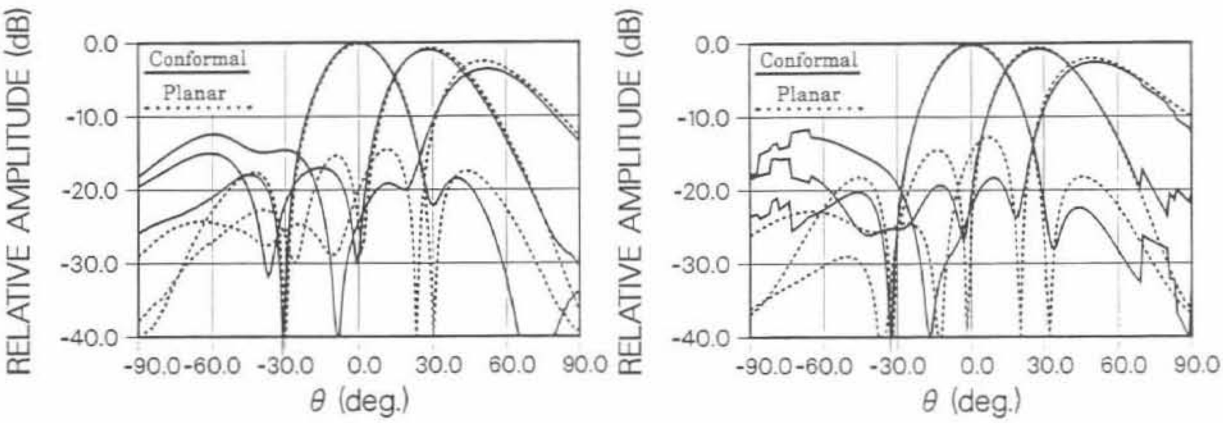


Fig.4. A fabricated conformal array. Fig.5. Measured return loss characteristics.



(a) Patterns evaluated from measured element patterns.

(b) Calculated patterns.

Fig.6. Circularly-polarized radiation patterns ($\phi = 0°$, f=1.53GHz).