PROCEEDINGS OF ISAP '96, CHIBA, JAPAN

HIGHER ORDER MODE 3-D CORNER REFLECTOR ANTENNA WITH VARIOUS APEX ANGLES

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1. Introduction

A 3-D corner reflector antenna (3D-CRA) is characterized by a very simple structure together with a sharp radiated beam and the possibility of direct feeding with a coaxial cable as shown in Fig.1 [1]. The original structure of the 3D-CRA with apex angle $\alpha = 90°$ and monopole antenna length $\ell = 3/4\ \lambda$ (λ : wavelength) has a gain of 16~17 dB. Recent studies have shown that a 3D-CRA of much higher directivity can be obtained by lengthening a monopole antenna and operated at the higher order modes. The analysis of the radiation pattern based on UTD (Uniform Geometrical Theory of Diffraction) predicted a gain of more than 20dB and side lobe ratio lower than -20 dB for the case of monopole antenna length $\ell = 9/4\ \lambda$ [2].

This paper presents the results of our most recent research on 3D-CRA. First we present the results of investigation of the radiation characteristics of the 3D-CRA with various apex angles, and followed by the precise measurement of the gain which we compare with the theoretically predicted value[3]. Finally, its optimum structure of a 3D-CRA with its directivity, gain and frequency characteristics will be presented.

2. Evaluation by UTD Analysis and Measurement

GO (Geometrical Optics) field of a monopole antenna with a flat plate as its reflector is obtained by method of images, while its first order diffracted field calculated using UTD. The simplicity and extreme preciseness of UTD makes it effective in the far field analysis of 3D-CRA. Higher order diffracted fields, corner and slope diffractions, affects the far field at the intensity levels of -20 dB or less, and are not considered due to excessively high computer calculation time requirements. For numerical analysis of higher order mode 3D-CRA with a long monopole antenna as its primary radiator, it is necessary that a monopole is subdivided into minute segments and the current distribution is analyzed by MM (Moment Method). Evaluation of gain uses the formula(1).

$$G(\theta,\phi) = \frac{4\pi r^2 |E(\theta,\phi)|^2}{Z_0 W} \tag{1}$$

where $E(\theta,\phi)$ is electric field in direction (θ,ϕ), Z_0 is space impedance, and W is input power to the antenna. The parameters $a = 3\ \lambda, b = 7\ \lambda, d = 1/10\ \lambda$ are fixed, and the optimum value of h is determined for varying ℓ. Here, *optimum* means to make the gain higher and make side lobe ratio lower than -20 dB and at the same time keep the reflector size as small as possible. The result for apex angle $\alpha = 60°$ is shown in Table 1. As the monopole antenna length ℓ becomes longer (e.g. $\ell = 9/4\ \lambda$), its gain increases when the gain is calculated with only the GO field, but the gain is the largest for length $\ell = 5/4\ \lambda$ when its calculation includes diffracted fields as shown in Table 1.

Table 1: Result of numerical analysis for the case of $\alpha = 60°$

ℓ	$[n/4\ \lambda]$	3	5	7	9
h	$[\lambda]$	0.90	1.00	1.05	1.15
Beam Width	[°]	24	19	16	12
Side Lobe Ratio	[dB]	-24	-23	-20	-9
Gain	[dB]	20.72	21.16	21.12	20.52

The numerical and measured results of directivity in E-plane for the cases of $\alpha = 90°, 60°, 45°$ are shown in Figs.2 (a), (b), (c). In these figures, field strength is normalized to be 0 dB at the maximum.

3. Frequency Characteristics

The frequency characteristics of the gain is measured in the range 8~12 GHz while keeping the direction fixed at the main beam direction at a design frequency 10 GHz. The numerical and measured results are shown in Figs.3 (a), (b), (c).

4. Conclusion

The merit of adopting higher order modes is most obvious in the case of $\alpha = 90°$. With a side lobe ratio of -23 dB or lower, we are able to obtain a beam width of 13°. In the case of $\alpha = 60°$ and $\alpha = 45°$, the optimum length of the monopole is $\ell = 5/4\ \lambda$ and $\ell = 3/4\ \lambda$, respectively, which give gain greater than 21 dB over wider range of frequency as compared to the case of $\alpha = 90°$. These values of the gain is higher than that of the original 3D-CRA by about 4 dB. Calculated directivity almost coincides with measured value. However, the caluculated gain has an error of 1~2 dB when the monopole antenna is thick and the size of reflector plates is small. It is conjectured that this error is due to the use of MM ignoring the diffracted fields to compute the current distribution. It is expected that we can get more accurate calculated results if MM-GTD is applied. This 3D-CRA is very simple in construction and handling and production are easy, and could therefore be applied for communication in millimeter wave region.

References

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[3] H.Sugiura, N.Kikuma, N.Inagaki : "Higher order mode 3-D Corner Reflector Antenna", IEE of Japan, Vol.116-C, No.1, pp.16-21, Jan. 1996.

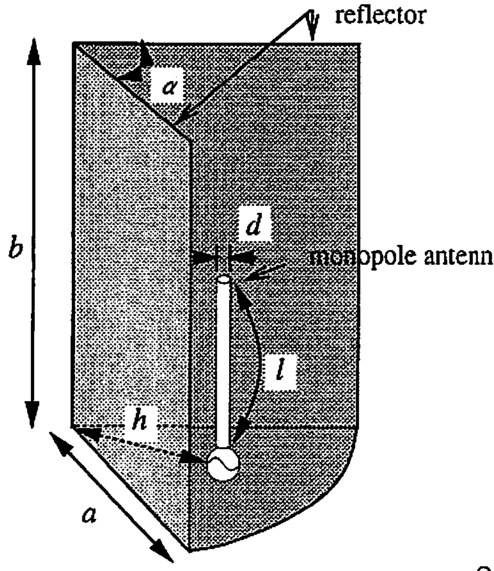
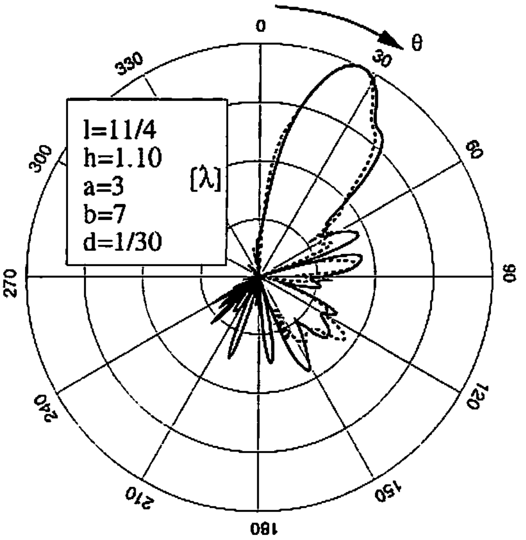
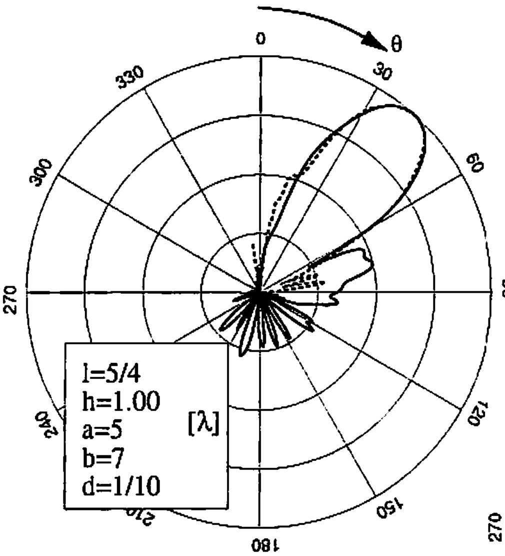


Fig.1 Construction of 3D-CRA



(a) Apex angle $\alpha = 90^\circ$



(b) Apex angle $\alpha = 60^\circ$

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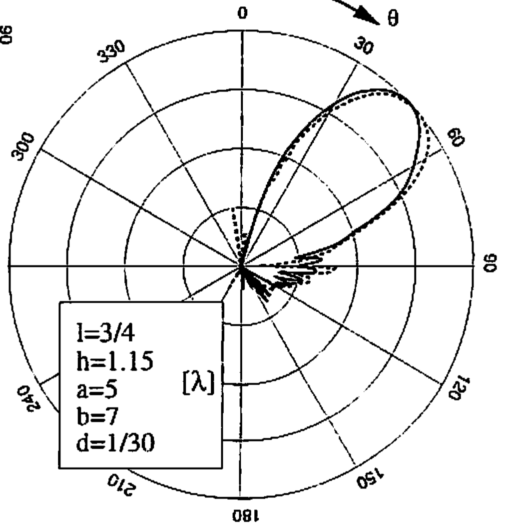
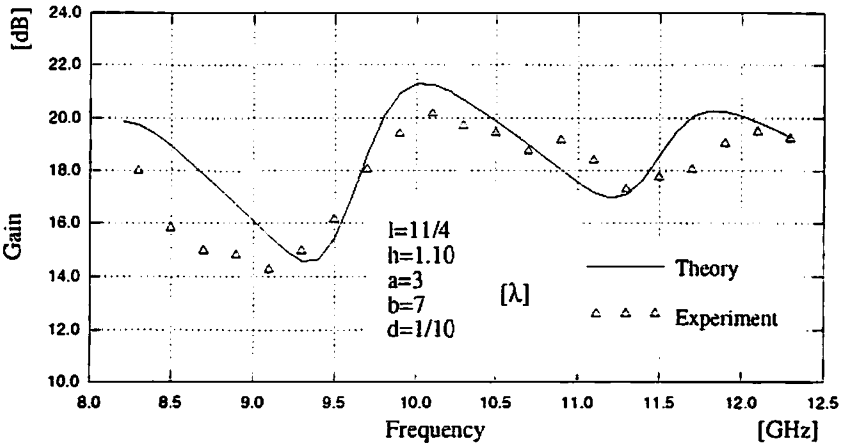
——— Experiment

10 dB/div

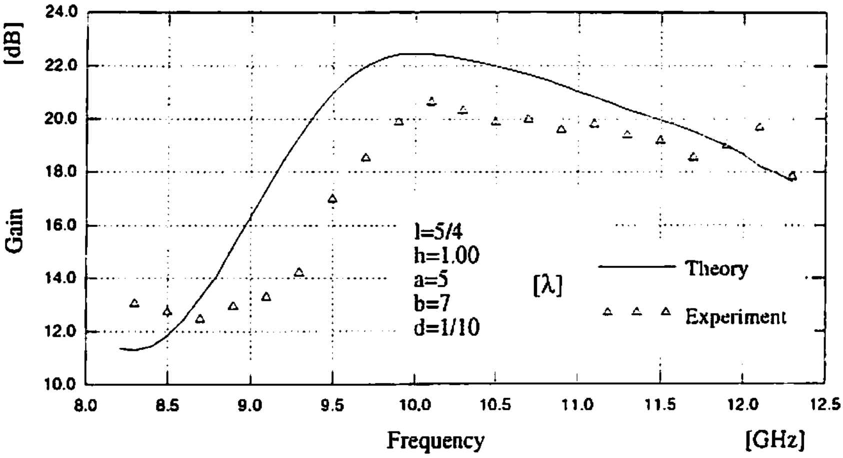


(c) Apex angle $\alpha = 45^\circ$

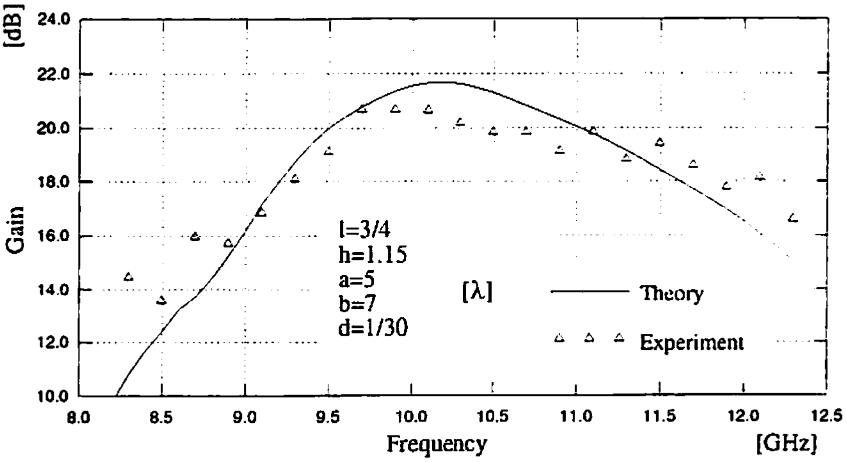
Fig.2 Directional patterns



(a) Apex angle $\alpha = 90^\circ$



(b) Apex angle $\alpha = 60^\circ$



(c) Apex angle $\alpha = 45^\circ$

Fig.3 Frequency characteristics