A SLOTTED ARRAY ON PARALLEL METAL PLATES WITH PLATE DIELECTRIC LENS FEEDER SYSTEM

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1. INTRODUCTION

Recently, waste of fuel, air pollution and frequent traffic accidents, which are caused by the increased traffic volume and jam, have been serious problems in many urban areas and high ways.

Against these problems, new automobile control systems and traffic management plans are now investigated in many countries, such as IVHS(Intelligent Vehicle Highway System) in USA[1]. In these systems, microwave or millimeterwave technology is regarded as the key technology. As for antennas in these frequencies, thin or small antennas with high gain are strongly requested.

In this paper, a thin high-gain-antenna , that is, a plate antenna with plate dielectric lens feeder system is proposed, and several considerations are presented.

2. STRUCTURE and BEHAVIOR

The structure of antenna suggested is shown in Fig. 1. This antenna is assembled by three parts, a feeder for lens, a dielectric plate lens and an array of long slots whose length is equal to the lens aperture. The feeder system for the slotted array is shown in Fig. 2. The aperture distribution of the sectral horn is assumed so that the TE_{10} mode of the waveguide spreads out analogously, and it is radiated into the space between the parallel plates by the feeder aperture. The radiated wave can be approximated as a cylindrical wave of its center at the phase center that is skillfully designed. In this paper, the power within 10dB beam width of the radiated wave from the feeder aperture is fed into the lens, which transforms the cylindrical wave into a plane wave. Thus the slots array is excited by this plane wave propagating between the parallel plates and a broadside radiation beam can be obtained by an appropriate selection of the slot interval.

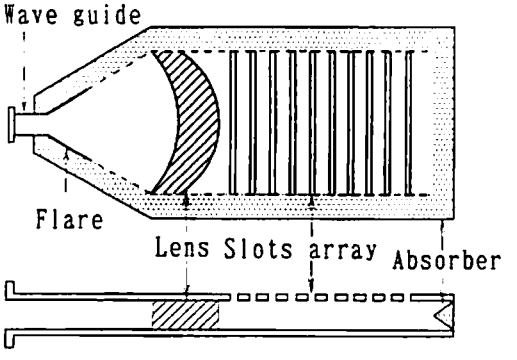

Fig. 1. Structure

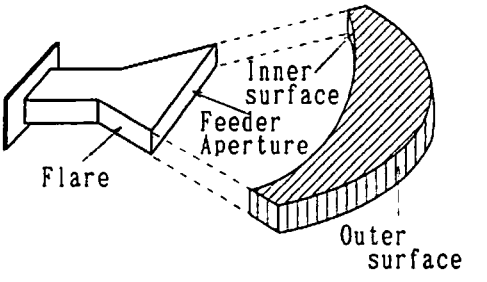

Fig. 2. Feeder system for array

2. PLATE DIELECTRIC LENS

In this antenna system, we use a lens whose inner surface and outer surface are a circle and an oval. The circle is selected to get the minimum reflection from the inner surface , and the oval to get a nearly uniform ray density along y axis. The coordinates system for the lens is shown in Fig. 3, where f, R_0 are the focal distance for the lens, and the position of lens from aperture.

The demerit in the use of the dielectric lens is the useless reflections by two surfaces, and these reflected power makes some antenna gain reduction. Therefore, it is necessary to estimate the lens efficiency, which is shown in Fig. 4 for a Teflon lens ($\varepsilon_r = 2.3$).

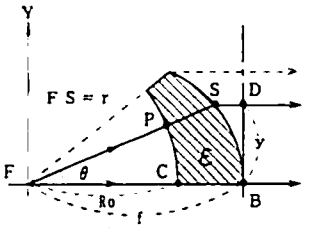

Fig. 3. Coordinates systea

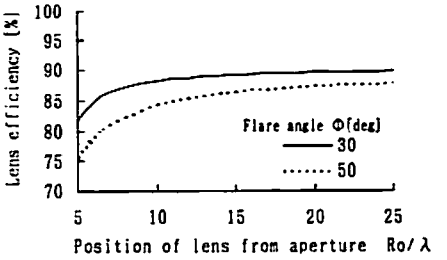

Fig.4. Lens efficiency

3. PHASE CENTER OF FEEDER APERTURE

The dielectric lens is designed on the geometrical optics that requires a point(or a line) source at its focus. However the feeder has an aperture of several wavelengths which is far from a point source. In addition, the lens is set in Fresnel region of the feeder aperture. Therefore, the good approximation method, that is, to find out the phase center of the feeder is necessary in order to make the lens behave on the geometrical optics base.

3.1 A method for decision of phase center

(1) Compute the 10dB beam width ($\pm\Phi$ m) of the radiated field by the feeder.

(2) Compute the phase of the radiated electric field ($P_h(\theta)$) within the 10dB beam width ($\pm\Phi$ m) on the circle whose radius is R_c ($=R_0+x_f$), and its center is C[2] . Then estimate the average value $\overline{P_h}$ over the range: $0 \le \theta \le \Phi_m$.

(3) Change x_f , and search for x_f at which the phase error δ becomes minimum in $0 \leqq \theta \leqq \Phi$ m, where $\delta = \int_0^{\Phi m} \left| P_h(\theta) - \overline{P_h} \right| d\theta$.

We define the point C($-x_f$, 0) that is found out by the above process as the phase center.

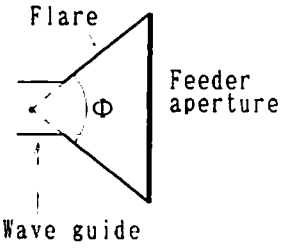

Fig. 5. Flare angle

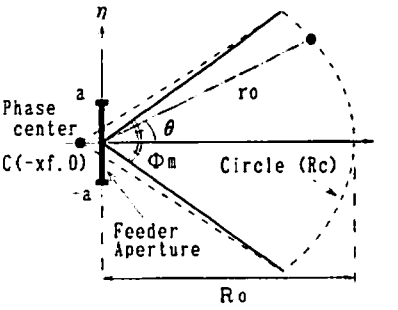

Fig. 6. Conceptual figure

3.2 Example of calculation

The 10dB beam width can be controlled widely by the aperture phase distribution which depends on the flare angle of the feeder. These dependence are shown in Fig. 7. In Fig. 8, a design chart of the phase center is shown for the aperture width of 5 λ.

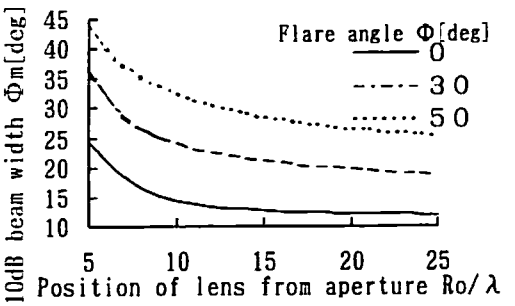

Fig.7. 10dB beam width

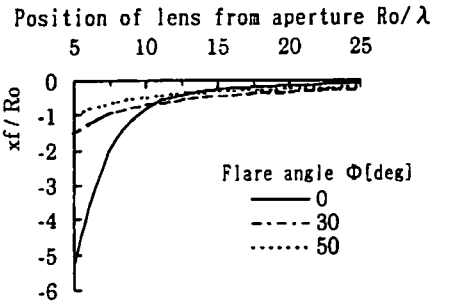

Fig.8. Charts of phase center

In the all cases, the phase center is changed by the flare angle Φ and Ro. The phase center moves to the aperture as Ro approaches to Fraunhofer region (Ro>25 λ), and it moves to the more inside of aperture as Ro approaches to the aperture.

3.4 Phase pattern

To confirm the appropriateness of the phase center defined in the preceding section, the phase pattern of the radiated electric field is computed in Fig. 9, for moving the center of a circle to in front and behind of the phase center.

From these figures, the phase pattern is most uniform when x_f is the phase center. Thus the decision method proposed here is considered as a practical one which determine the phase center for the wide angle region. That is, if the inner surface of the lens is selected a circle with the radius of R_c ($=R_0+x_f$), the lens behaves nearly on the geometrical optics base.

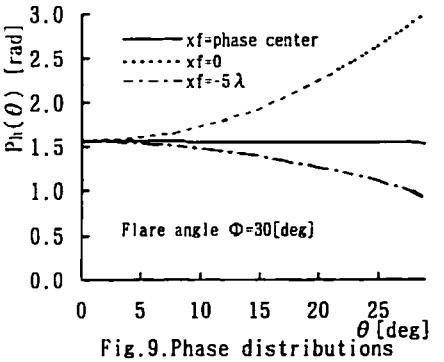

Fig.9.Phase distributions

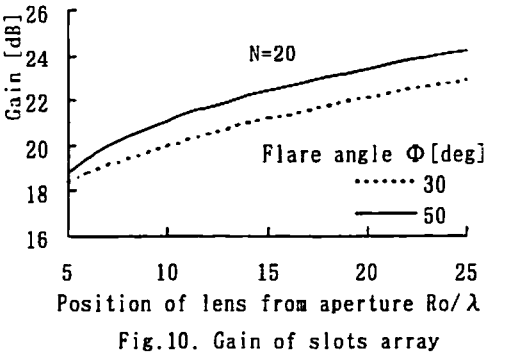

Fig.10. Gain of slots array

4. GAIN and RADIATION PATTERN

The gain and radiation pattern of this antenna are computed for 20 slots array and the results are shown in Fig. 10, Fig11, and Fig12.

The condition of these computations are (1) the substance between the parallel plates is a foamed polystyrene whose specific dielectric constant: ε_s=1.15, (2) the attenuation constant in the substance: α=0.5[Nep/m], (3) the interval of slots=0.95 λ, (4) the absorbed power at terminating load=16[%] of input power for slots array, (5) every slot has the same amplitude and (6) the couplings among slots are negligible.

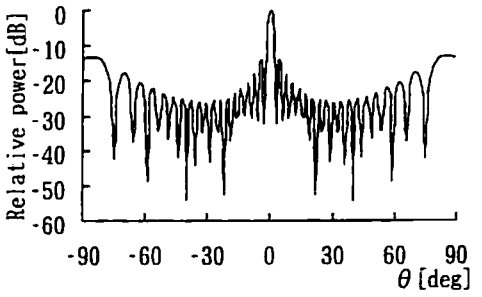

Fig.11. E-plane radiation pattern

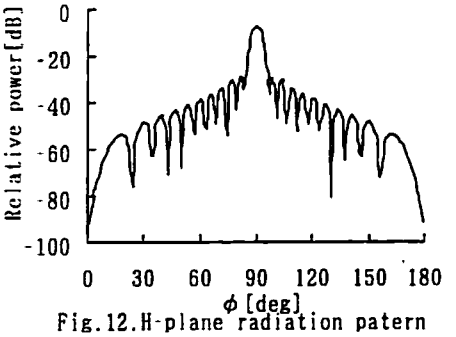

Fig.12.H-plane radiation patern

From these results, we find that this antenna proposed has a potential to be a thin type high gain antenna with a broadside beam.

5. CONCLUSION

A thin antenna with high gain is proposed, and several considerations to put the antenna into practice are presented. Main results are the followings.

(1) By setting the focus point of the lens on the phase center proposed in this paper, the lens behaves nearly on the geometrical optics base.

(2) The efficiency of the lens is more than 75[%] at least.

(3) The 10dB beam width of the feeder can be controlled widely by changing the flare angle.

(4) This antenna proposed has a potential to be a thin type high gain antenna with a broadside beam.

A total design problem and some applications are being researched now.

6. REFERENCES

[1] T.Rose, "Intelligent Vehicle Highway Systems:Going Places Fast", Microwave Journal, May, 1993, pp. 172-178.

[2]S. Silver, "Microwave antenna theory and design", McGraw-Hill, 1949, pp. 341-347.

7. BIOGRAPHICAL NOTES

Kenichi Sato graduated from Tohoku Institute of Technology in 1995. He is now in the master's course of Tohoku Institute of Technology, where he engage in the research on microwave antenna.

Hiroshi Ujiie was born in Tokyo, on SEP 17, 1938. He received Ph.D. degree in Electrical Communications Engineering from Tohoku University in 1975. He is now a professor of Tohoku Institute of Technology and a member of IECE Japan. His current research interests are in wave absorber and microwave antenna.