A STUDY OF RADIATION CHARACTERISTICS IN AN OPTICALLY CONTROLLED ARRAY ANTENNA

Yoshihiko KONISHI, Wataru CHUJO, Hisao IWASAKI and Koji YASUKAWA
ATR Optical and Radio Communications Reseach Laboratories
Sanpeidani, Inuidani, Seika-cho, Soraku-gun, Kyoto, 619-02, Japan

Introduction An array antenna using optical Fourier transformation investigated so far appears to be possible method for rapid and simple beam formation[1]. From this point of view, the authors have proposed a two laser model[2], in which two lasers phase-locked by a microwave frequency offset are used. The laser output powers in this model, which will be obtained from laser diodes reported in references[3], can be less than those required in the basic model.

In this paper, relations among antenna radiation characteristics such as gain, sidelobe or beamwidth and aperture length of one dimensional image mask are investigated. It is clarified that sidelobe level can be reduced by using tapered distribution in the reference beam without changing gain and beamwidth.

Two laser model The model is shown in Fig.1. An optical beam emitted from the laser diode No.1 (LD1) passes through image mask, which is assumed to be a pinhole here. The beam is Fourier transformed with a FT lens. Output beam of FT lens P_1 has the form of sinc function because the mask has uniform distribution. Another optical beam emitted from the laser diode No.2 (LD2) is used as the reference beam P_2. Mixed beam P_1+P_2 is spatially sampled by an optical fiber array. Heterodyne signals in microwave band are obtained by photo diodes (PDs), and fed to each antenna element.

When antenna is infinite array and mixed beam is sampled ideally by the fiber array, antenna radiation pattern becomes a fan beam. Then, gain G and beamwidth Θ are given as follows;

$$G=\frac{1}{m}\cdot\frac{2F}{D} \tag{1}$$

$$\Theta=2sin^{-1}(m\cdot\frac{D}{2F}) \tag{2}$$

$$m=\frac{d_f/\lambda_o}{d_a/\lambda_m} \tag{3}$$

where, D is aperture length of image mask, F is focal length of FT lens, d_f is element spacing of the fiber array, d_a is element spacing of antenna elements, λ_0 is an optical wavelength and λ_m is an microwave wavelength.

Radiation characteristics The parameters assumed for analysis are shown in Table 1. Beamwidth, gain and sidelobe level are shown in Figs.2-4 as a function of D/F, which is a ratio of mask aperture length to focal length of FT lens. "Peak" and "E.O.C." in Fig.3 denote peak gain and gain at edge of coverage, respectively, and "Ideal" shows the calculated values by equations (1)-(3).

In Fig.2, beamwidths are narrower than the "ideal" in each number of elements N, and become close to the "ideal" with increasing N. On the other hand, gains and sidelobe levels show similar values in each N in Fig.3 and Fig.4. Peak gains are about 1dB higher and E.O.Cs are about 6dB lower than the "ideal" case. Therefore, it is difficult to obtain lower sidelobe level than -27dB, because d_f/λ_0 is about 100 when the commercially available optical fibers are used as the fiber array.

Reduction of sidelobe level To obtain sidelobe level as low as -30dB, it is necessary to reduce the edge level of the array amplitude distribution. In this type of array, reduction of sidelobe level will be possible by using tapered distribution in the reference beam.

Figs. 5-7 show sidelobe level, gain and beamwidth for tapered P_2 distribution which is assumed to be the Gaussian of the edge level EL=0 to -15dB, respectively. The number of antenna elements are fixed at N=11 for calculations. Sidelobe level becomes lower than -40dB at EL=-15dB and D/F>1.4E-3 in Fig.5. Gain and beamwidth for tapered P_2 distribution are kept unchanged compared with those for uniform P_2 distribution, as shown in Fig.6 and Fig.7.

Conclusion From numerical analysis of two laser model of optically controlled array antenna, it is clarified that sidelobe level can be reduced lower than -40dB without changing gain and beamwidth by using tapered distribution in the reference beam. This result can also be applied to the basic model. This type of array will be able to have low sidelobe characteristics as usual array using microwave beam forming network.

The authors would like to thank Dr. Yoji Furuhama, President of the ATR Optical and Radio Communications Research Laboratories, for his encouragement throughout this work.

References

(1) G.A.Koepf; "Optical processor for phased-array antenna beam formation", SPIE, vol. 477, pp. 75-81 (1984).

(2) Y.Konishi, W.Chujo, H.Iwasaki and K.Yasukawa ; "A study of laser radiated power in optically controlled array antenna", Natl. Conv. Rec. IEICE Japan (Mar. 1989).

(3) T.Matsuoka, et al. ; "Design and performance of high-power 1.5μm DFB lasers", Tech. Dig. OEC'86, p.200 (1986).

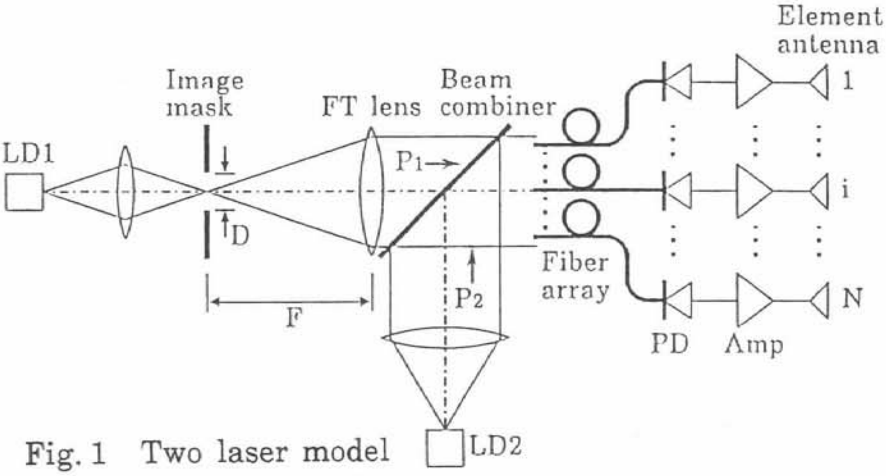

Fig. 1 Two laser model

Table 1 Parameters for analysis

Mask diameter / Focal length	D/F = 0 to 5E-3
Optical wavelength	$\lambda_o = 1.3$ µm
Fiber element spacing	$d_f = 125$ µm
Antenna element spacing	$d_a = 0.5\ \lambda_m$
Amplitude distribution on the mask aperture	Uniform
Amplitude distribution in the reference beam	Uniform and Tapered
Antenna element type	Isotropic
Number of antenna elements	N = 11, 21 and 31

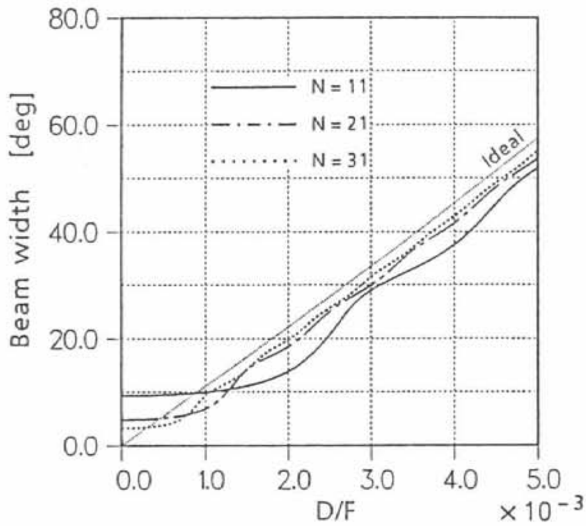

Fig. 2 Beamwidth vs. D/F for uniform P_2 distribution

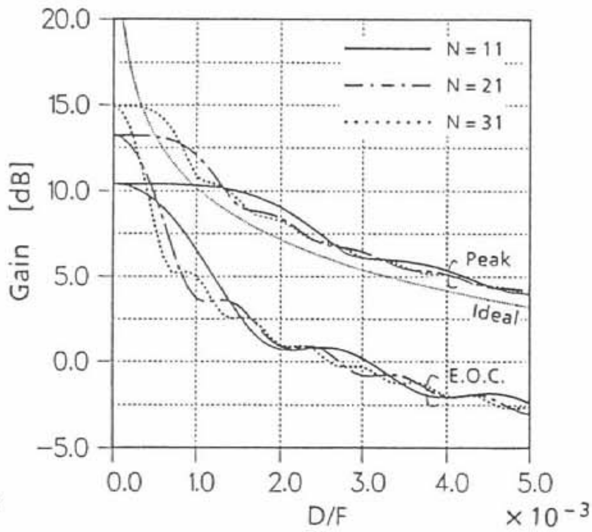

Fig. 3 Gain vs. D/F for uniform P_2 distribution

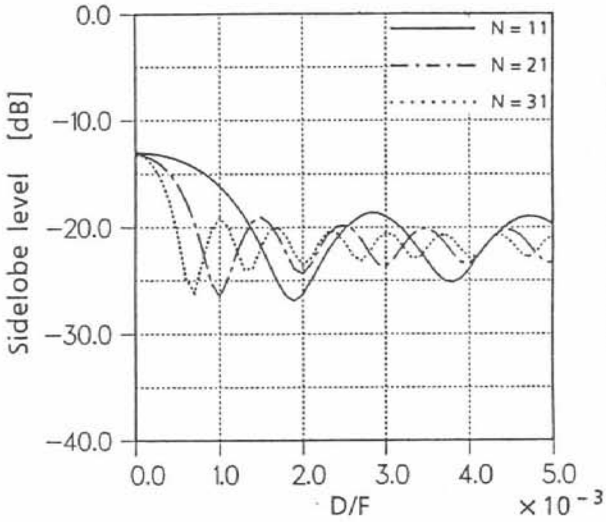

Fig. 4 Sidelobe level vs. D/F
for uniform P_2 distribution

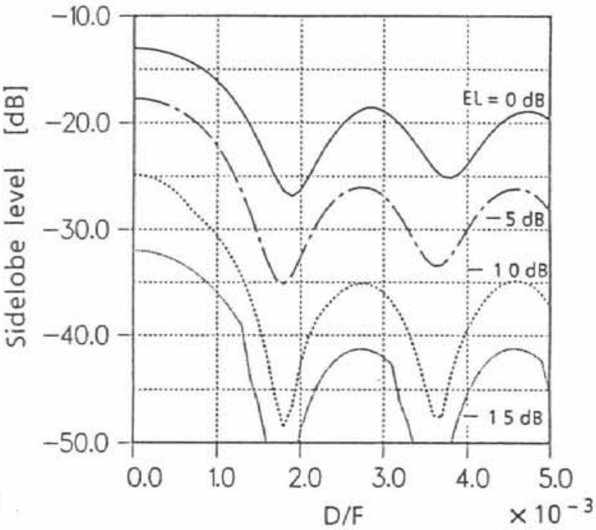

Fig. 5 Sidelobe level vs. D/F
for tapered P_2 distribution

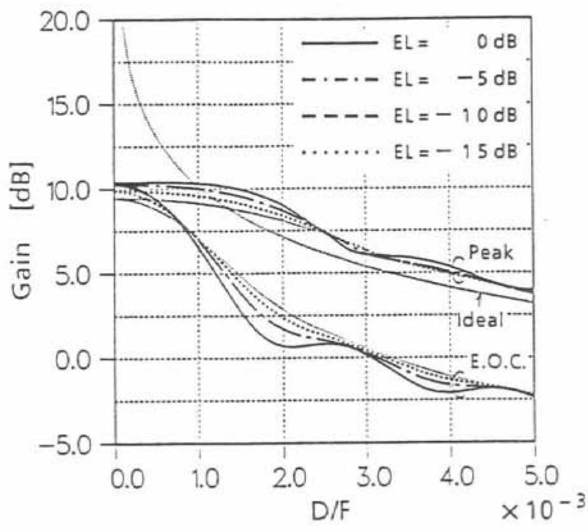

Fig. 6 Gain vs. D/F
for tapered P_2 distribution

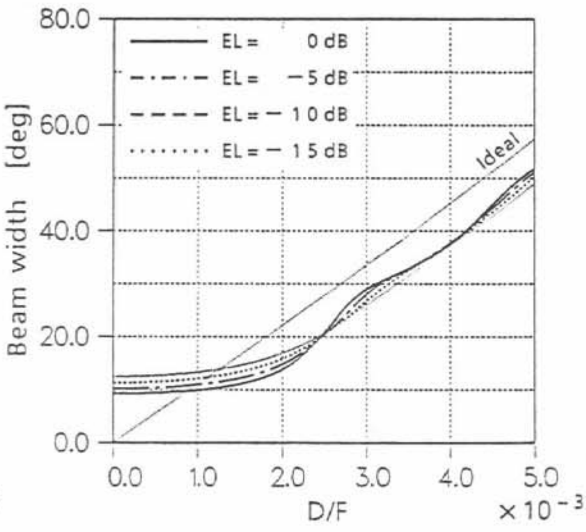

Fig. 7 Beamwidth vs. D/F
for tapered P_2 distribution