SIDE-LOOKING CIRCULARLY POLARIZED MICROSTRIP LINE PLANAR ANTENNA

Sadahiko NISHIMURA
Faculty of Engineering Science, Osaka University
Toyonaka, Osaka, 560 JAPAN
Yoshihiko SUGIO and Toshio MAKIMOTO
Faculty of Engineering, Setsunan University
Neyagawa, Osaka, 572 JAPAN

1. Introduction

A circularly polarized microstrip line antenna obtained by periodically bending a strip conductor of a microstrip line has been reported by the authors[1] and Hall[2].

In this report we give the design specification equations for a side-looking microstrip line antenna that radiates circular polarization in any direction of the plane of linear array. Further, we report on experimental results at 12GHz for a side-looking circularly polarized microstrip line planar antenna, where the main beam direction is tilted 30° in respect to broadside.

2. Antenna Configuration

The configuration of the traveling-wave linear array is shown in Figure 1(a). The traveling-wave linear array is formed by crank-type undulation of two strip conductors of a microstrip line with 50Ω line impedance, where the two strip conductors are shifted by half a period in respect to one another. The part encircled by the dotted line constitutes a fundamental element of the traveling-wave linear array.

3. Conditions for the Radiation of Circular Polarization

For calculating the radiated field of a fundamental element shown in Figure 1(b), it is assumed that the strip current of the strip conductor is concentrated along the center line and that there is no transmission loss. The condition equations ensuring that a crank-shaped fundamental element radiates circular polarization in the θ_m direction——taking the effect of the mitered bends into consideration——are as follows.

$$b+(1-\eta\cos\theta_m)2a = 2\delta+\lambda g\left(1\mp\frac{1}{\pi}\mathrm{Tan}^{-1}\Theta\right) \tag{1}$$

$$b+(1-\eta\cos\theta_m)c = 2\delta+\lambda g\left(1\pm\frac{1}{\pi}\mathrm{Tan}^{-1}\Theta\right) \tag{2}$$

$$\Theta = \sin\theta_m \frac{W-\delta}{W(1-\eta\cos\theta_m)-\delta} \times\frac{\sin\frac{\beta}{2}(b-\delta)-\frac{\delta}{W(1-\eta\cos\theta_m)}\sin\frac{\beta}{2}(b+W-W\eta\cos\theta_m-2\delta)}{\sin\frac{\beta}{2}(b-\delta)-\frac{\delta}{W}\sin\frac{\beta}{2}(b-W)} \tag{3}$$

$$\eta = \frac{\lambda g}{\lambda_0}, \qquad \delta = \left(1-\frac{\beta'}{\beta}\right)W. \tag{4}$$

Here a,b and c designate the length of the segments, θ_m the direction of the main beam, η the effective wavelength reduction rate of the straight line, δ the length of the segment rectifyer due to mitered bends, λg the guide wavelength, W the width of the strip conductor, β the phase constant $2\pi/\lambda g$, and β' the effective phase constant of the mitered bend. The upper signs in the above equations give the case of left-hand circular polarization, while the lower signs that of right-hand circular polarization. Given W, λg, η, δ, θ_m and some b, the values of a and c can be determined by equations (1) through (4). The effective phase constant of the mitered bends β' and, thereby, the length of the segment rectifyer length δ has to be determined beforehand in the way described below. (I) The values for the length of the segment a, b and c are obtained from equations (1) to (3) by setting $\delta=0$ and $\theta_m=90°$. The frequency f_m of the main beam in broadside direction is then found experimentally. (II) This frequency f_m together with the design frequency f_d will give δ according to the following formula.

$$\delta = \frac{\eta v}{2}\left(\frac{1}{f_d} - \frac{1}{f_m}\right), \tag{5}$$

where v is the velocity of light. The configuration of the crank-shaped fundamental element, which radiates circular polarization in the θ_m direction, is determined as described above. Though two strip conductors together from one fundamental element, as shown in Figure 1(b), each strip conductor by itself radiates circular polarization in the θ_m direction. The combination of two strip conductors has been taken as fundamental element because the far-field radiation pattern of each strip conductor by itself is mediocre, while that of the two taken together is very good. Moreover, in the case of the side-looking linear array, the array factor has a grating lobe and the radiation field (element factor) of the fundamental element at the angle of grating lobe is always zero, as a result, a single beam linear array is obtained.

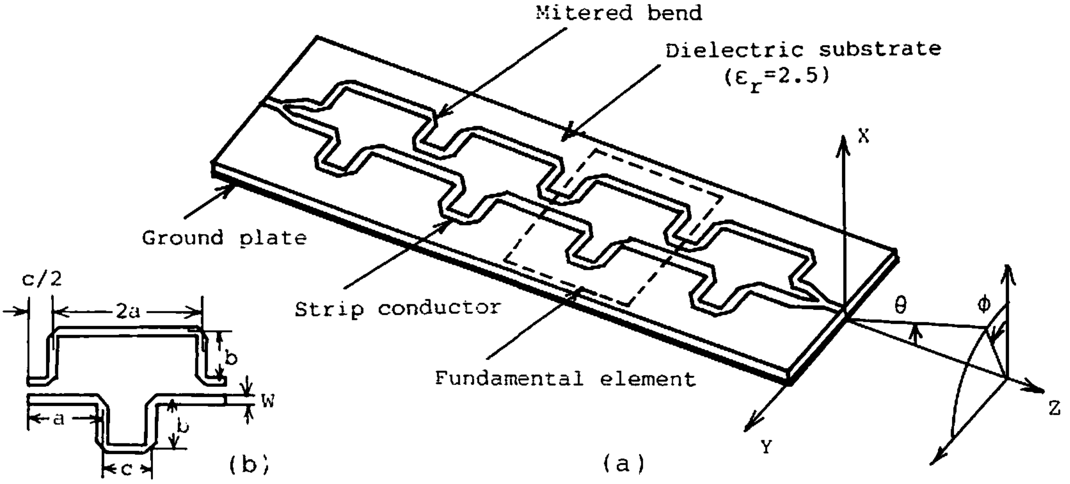


Figure 1. Antenna Configuration

4. Microstrip Line Planar Antenna

A planar antenna, made by arranging a number of circularly polarized microstrip line antennas on a single substrate, was tested. Figure 2 is a photograph of such an arrangement. A cross-linked polyethylene glass-fiber board (ε_r=2.5, 0.8mm thick) was used as printed board. The planar array antenna is composed of 16 parallely aligned linear arrays, each consisting of 12 fundamental elements. At both ends of the linear arrays, parallel feeding circuits enabling in phase and equal amplitude feeding are incorporated on the printed board. When power is supplied from the lower feeding port, the planar array radiates right-hand circular polarization at an angle of elevation of approximately 30°. The area of the antenna part is 366(Z direction) × 351(Y direction) mm^2.

Figure 3 shows the measured ZX-plane and X'Y-plane radiation patterns. The test results for the relation between the gain and frequency, where the angle of observation is in respect to the design direction, are given in Figure 4. The result obtained for a design frequency of 11.95 GHz listed in Table 1, shows very good values of 29.8 dBi for the gain and 0.8 dB for the axial ratio.

5. Conclusion

The design specification equations for the side-looking circularly polarized microstrip line antenna are given and their usefulness confirmed by experiment.

The proposed planar antenna can serve as receiving antenna for satellite broadcasting by doubling or quadrupling the aperture surface.

Finally, we would like to gratefully acknowledge the cooperation extended by the members of the Kansai Electronic Industry Development Center, Microwave System Research Group in the fabrication of the planar antenna.

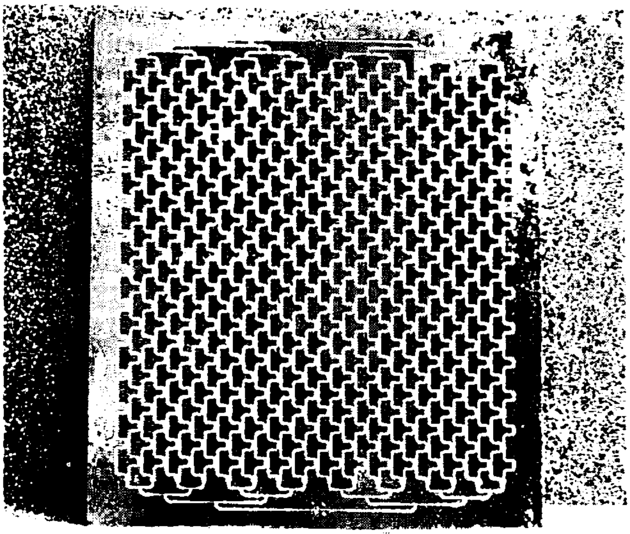
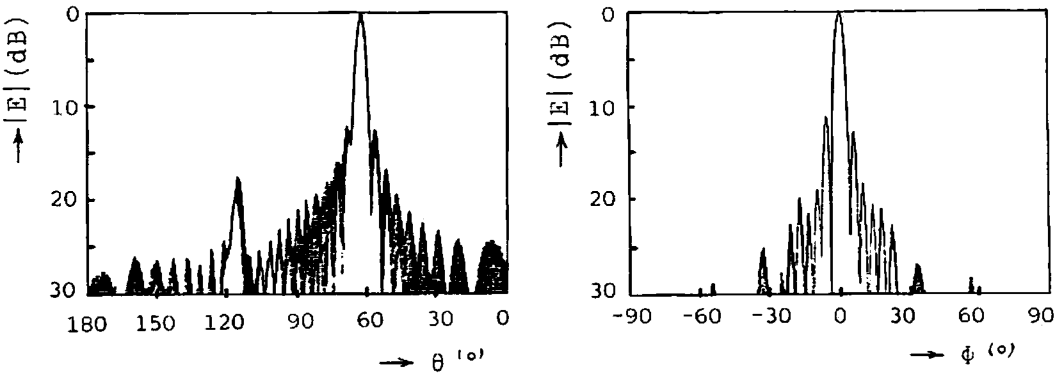
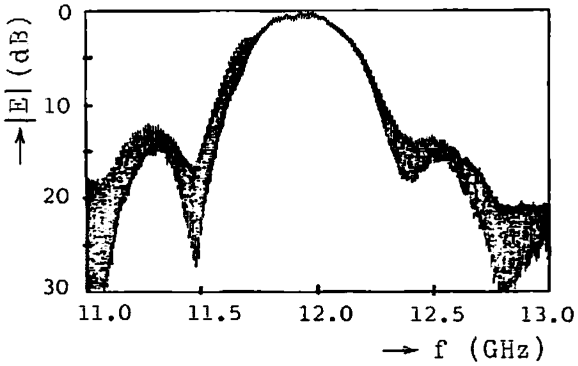


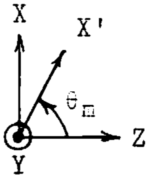
Figure 2. Side-Looking Planar Array



(a) ZX-plane (φ=0°) (b) X'Y-plane (θ_m=62°)

Figure 3. Radiation Pattern (f=11.95GHz)





(c)

Figure 4. Frequency Characteristics (θ=62°, φ=0°)

Table 1. Characteristics of Side-Looking Planar Array

Number of elements	192 (12 × 16)
Mainbeam direction	θ=62°, φ=0°
Frequency	11.95 GHz
Gain	29.8 dBi
Axial ratio	0.8 dB
Beamwidth	4.0° (ZX-plane) 4.0° (X'Y-plane)
Bandwidth	410 MHz
Efficiency	42.2 %
Size of substrate	400 × 450 mm^2

References

[1] S. NISHIMURA, Y. SUGIO and T. MAKIMOTO, "Crank-Type Circularly Polarized Microstrip Line Antenna" 1983 IEEE Int. Sym. Digest-AP, Vol.1.

[2] P. S. Hall, "Microstrip Linear Array with Polarization Control" IEE PROC., Vol.130, Pt.H, No.3, APRIL 1983