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Scattering by Circular Polarizer Composed of Double Screens of Photoetched Dipole Array

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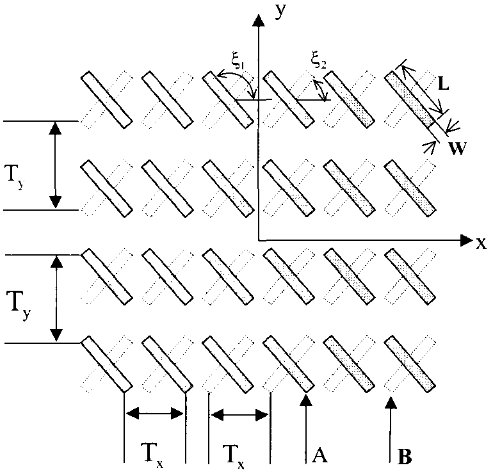
Abstract

A circular polarizer structure of a reflection type, which consists of two sheets of photoetched diople array, is investigated theoretically and experimentally.

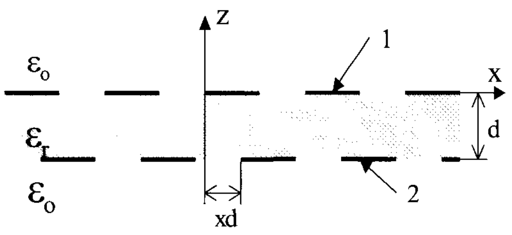
Key words : FSS, Polarizer

Ⅰ. Introduction

Conversion of electromagnectic wave from linear to circular polarization may be effected by either transmission or reflection. There have been various research works on such circular polarizer structures of both transmission[1]~[3] and reflection[4] types.



(a) top view



(b) side view

Fig. 1. Circular polarizer composed of double screen.

We investigate a new configuration which can be used as a circular polarizer of a reflection type. The present circular polarizer comprises two planar printed dipole array structures spaced about one eighth wavelength apart, the element orientations of the two sheets being roughly perpendicular to each other as shown in Fig. 1. This structure is similar to that of the novel frequency-selective twist polarizer proposed by Zhang[5] except the inserted dielectric thickness between two sheets with printed dipole arrays. But we are to focus our attention on examining the scattering characteristics of the present structure from the viewpoint of circular polarization converter.

Ⅱ. Theoretical Analysis

The operating principle of the polarizer is as follows: for the TE polarization case where the incident electric field is parallel to y-axis(restricting the incident plane only to x-z plane), the plane wave component parallel to the dipole axis of the upper sheet will be reflected directly from this sheet, while the perpendicularly polarized wave after transmitting through the upper sheet will be reflected by the lower sheet and through the upper sheet again, which results in a 90°-differential phase delay corresponding to twice the distance between two sheets.

So for the above TE case where the incident wave is polarized at about 45° to the direction of the dipole element as roughly sketched in Fig. 1, the linear polarization of incident wave is converted to the right handed circular polarization (RHCP) after reflection. Note that ζ_1=132° and ζ_2=44° in the geometrical parameters of Fig. 3. Similarly also for the TM-polarized case where the incident magnetic field is parallel to the y-axis, the linear pol-arization is converted to the circular polarization but to left handed circular polarization(LHCP).

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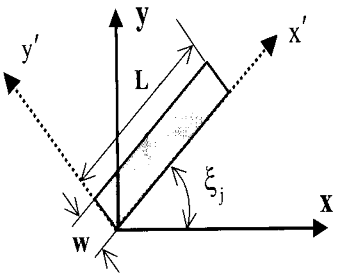

Fig. 2. Coordinate transform; j=1 and 2 respectively corresponding to upper and lower sheet.

The present structure is analyzed by use of the standard spectral domain immittance method in [6]. Only difference is that here the unknown induced current distributions on the dipole surface of upper and lower sheets are expanded as $j^j_{x'} = \sum_{m,n} A^j_{x',mn} \sin(m\pi x'/L)\cos(n\pi xy'/W)$ and $j^j_{y'} = \sum_{m,n} A^j_{y',mn} \cos(m\pi x'/L)\sin(n\pi xy'/W)$ in the transformed coordinate in Fig. 2.

In these expressions, the superscript j can take the value of 1 or 2 corresponding to upper and lower sheet. Next we are to express Green's functions and forcing function in the transformed coordinate (x', y') corresponding to the Green's functions(i.e., $\widetilde{G}^{ij}_{xx}$, $\widetilde{G}^{ij}_{xy}$, $\widetilde{G}^{ij}_{yx}$, and $\widetilde{G}^{ij}_{yy}$ of eq. (2.89) in [6, p.51]) and the incident electric field in (x, y) coordinate. Then employing the Galerkin's scheme leads to the algebraic linear equation[7]. The scattering characteristics of the present circular polarizer are calculated from knowledge of the unknown coefficients, $A^j_{x',mn}$ and $A^j_{y',mn}$, for the current distribution on the dipole.

Based on the analysis method, a circular polarizer has been designed and fabricated using RT/duroid 5880 substrate. Fig. 3 shows theoretical results for axial ratio and the normalized reflected power for the case that the geometrical parameters are $T_x = T_y = 7$ mm, $L = 6.18$ mm, W=1 mm, $\zeta_1 = 132°$, $\zeta_2 = 44°$, $\varepsilon_r = 2.2$, $d = 1.5748$ mm, $\theta_i = 30°$, and $\phi_i = 0°$, which have been chosen so that best performance may be achieved from the viewpoint of the axial ratio(AR) and the bandwidth for AR<2 dB (corresponding to ±1.26 in the right side scale of Fig. 3) for the given incident angle θ_i. The data have been obtained for both TE and TM cases.

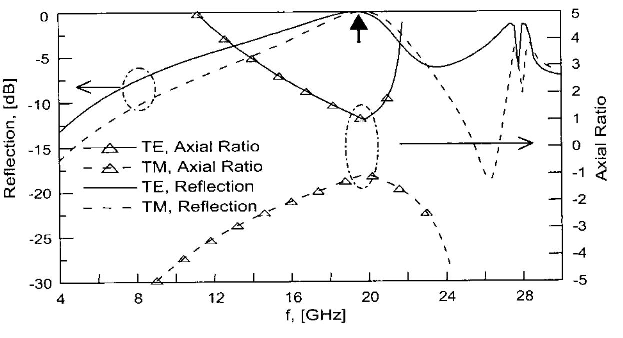

Fig. 3. Frequency response for axial ratio and normalized reflected power. (T_x=T_y=7 mm, L=6.18 mm, W=1 mm, ζ_1=132°, ζ_2=44°, ε=2.2, d=1.5748 mm, θ_i =30°, ϕ_i= 0°)

From Fig. 3 the reflection resonances are observed to occur at 19.4 GHz and 19.8 GHz, respectively, for TE and TM cases. It is also seen that for the TE incidence case the reflected wave is RHCP, whereas the reflected wave for TM case is LHCP. The frequency bandwidth for AR<2 dB is 1.0 GHz (i.e., 19.1~20.1 GHz) for TE case and the corresponding bandwidth for TM case is 1.8 GHz(19.0~20.8 GHz). It is noted that the bandwidth for TM case is broader than that for TE case approximately by 0.8 GHz.

Theoretical and experimental results for the normalized transmitted power and reflected power are illustrated, only for TE incidence case, in Fig. 4 and Fig. 5 respectively. For brevity,

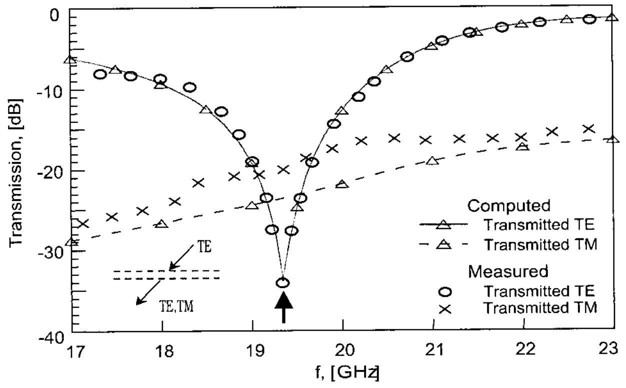

Fig. 4. Experimental and theoretical results for transmission. (All the geometrical parameters are the same as those used in Fig. 3)

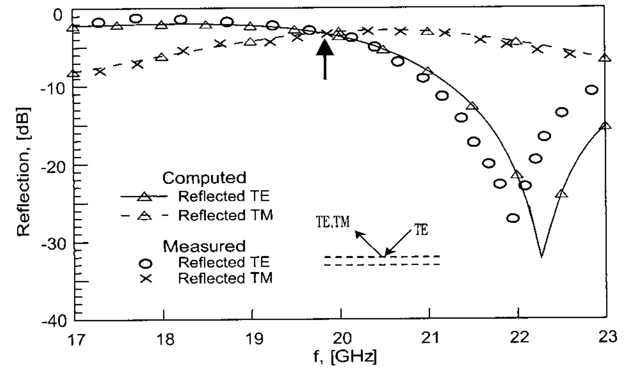

Fig. 5. Experimental and theoretical results for reflection. (All the geometrical parameters are the same as those used in Fig. 3)

corresponding data for TM case have not been included. All the geometrical parameters in Fig. 4 and Fig. 5 are the same as those in Fig. 3.

The practical size of the fabricated circular polarizer structure is 30[cm] × 45[cm]. In Fig. 4, comparison shows good agreement between theory and experiment except some difference for TM transmitted power. The sharp minimum at 19.4 GHz(marked with an arrow) of the TE transmitted power in Fig. 4 corresponds to the reflection resonance point(also marked with an arrow) in Fig. 3. From Fig. 5, two curves for normalized TE and TM reflected power are observed to intersect at almost -3 dB level at 19.4 GHz. So the two TE and TM reflected powers are summed to be almost zero dB at 19.4 GHz as shown in Fig. 3.

Also for the case that dielectric thickness d becomes $(2n+1)\lambda_g/8$ (n = integer, λ_g ; wavelength in the dielectric medium of dielectric constant $\varepsilon_0 \varepsilon_r$), circular polarization conversion can be achieved. But the bandwidth for AR<2 dB tends to decreases as *d* increases.

Ⅲ. Conclusion

A simple circular polarizer has been considered and implemented: this structure can be good candidate for the subreflector[4] circular polarizer in the offset reflector system.

References

[1] A. J. Lait, "Broadband circular polrizer", *The Marconi Review, Second Quarter*, pp. 159-184, 1969.

[2] K. A. J. Warren, "A planar antenna circular polarization converter utilizing printed circuit technology", *The Marconi Review Third Quarter*, pp. 176-184, 1980.

[3] B. A. Munk, *Frequency Selective Surface, Theory and design*, Wiely Interscience, Chap. 1, pp. 20, 2000.

[4] E. V. Jull, "Reflection circular polarizer", *Electron Lett.*, 15, (14), pp. 423-424, 1979.

[5] W. M. Shi, W. X. Zhang and M. G. Zhao, "Novel frequency-selective twist polarizer", *Electron Lett.*, vol. 27, no. 23, pp. 2110-2111, 1991.

[6] T. K. Wu, *Frequency Selective Surface and Grid array*, Wiely Interscience, Chap. 2, pp. 51, 1995.

[7] J. W. Ko, "Analysis and Application of Electromagnetic Scattering by a Two-dimensional Periodic Array", *Ph.D. dissertation*, Department of Electronic Engineering, Kyungpook National University, 1997.

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