Meander-Line Polarizer for Arbitrary Rotation of Linear Polarization

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Abstract—**A versatile meander-line polarizer is described and demonstrated for arbitrary rotation of linear polarization. This polarizer consists of eight-layer meander-line grids with rigid foam spacers between any two layers. It is shown that the field polarization rotation angle through this meander-line polarizer is twice the angle between the incident polarization and the polarizer grating lines. Hence, any polarization rotation can be accomplished by a simple mechanical rotation of this low-mass polarizer instead of rotating or modifying the much heavier antenna and its complex feed components.**

I. INTRODUCTION

ALTERATION of signal polarization is usually accomplished by inserting a half-wave phase shifter in the signal's transmission path [1], [2] or simply imposing an external polarizer [3]–[8] in front of the antenna's radiating aperture, as depicted in Fig. 1. Typically, the external polarizer consists of one or multiple sheets of printed parallel meander-lines etched on thin dielectric substrate. Among many different polarizers, the meander-line polarizer has the advantages of broadband, low insertion loss, and ease of manufacturing. In the past, meander-line polarizers have been used to effect linear-to-circular polarization conversion [3]–[6] and to cause a 90° rotation of a linearly polarized signal [7]–[8]. However, the latter can only rotate the polarization to angle at 90° and the polarizer grids line orientation must be fixed at 45° with respect to the incident polarization.

In advanced radar and communication systems, it is still necessary to have an antenna with polarization diversity. For example, the NASA Advanced Communication Technology Satellite (ACTS) Mobile Terminal (AMT) Project requires this polarization-varying antenna, since ACTS changes its polarization from vertical to horizontal or vice versa as the mobile terminal moves from city to city or across the continental United States (CONUS) [9], [10].In another case, it is also desirable that the signal polarization can be changed without any rotation or modification of the original antenna and its components. This is particularly true in the case of a large, complex, heavy phased array radar system.

Toward that end, a versatile and low-mass meander-line polarizer will be described and demonstrated in this letter for any arbitrary rotation of linear polarization. This polarizer consists of eight layers of parallel meander-line grids etched on 0.05-mm-thick Kapton sheets. The rigidity of the polarizer and the accurate spacing between the sheets are achieved by bonding the thin sheets on low loss, low mass foam or honeycomb spacers [11]. In the following sections, the principle of operation, the design, and a demonstration of this versatile polarizer will be descibed in detail.

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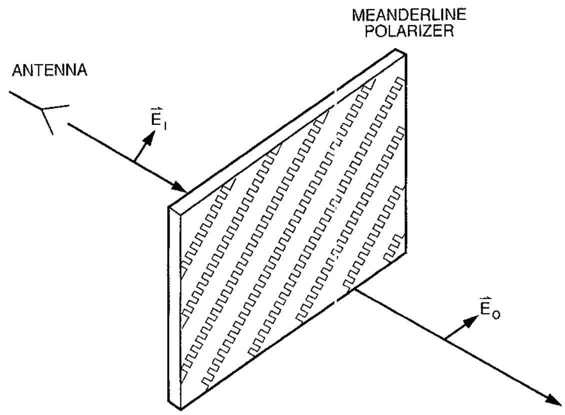

Fig. 1. A meander-line polarizer for antenna's polarization rotation.

II. THEORETICAL BACKGROUND

It was shown previously in [3], [4] that a wide-band circular polarizer can be made with four sheets of parallel meander-line grids. This circular polarizer provides a differential phase shift of 90° between two orthogonal components of the incident electric field, since the field component parallel to the meander-line is delayed by the inductive character of the grids and the perpendicular component is advanced by the capacitive character of the grids. To devise a versatile polarizer providing arbitrary rotation of a linearly polarized field, a 180° differential phase shift is required.

The principle of operation is very similar to the theory of a circular polarizer [3]–[5]. Consider an external polarizer illuminated by an incident plane wave with the electric field polarized at an angle Θ with respect to the meander-line orientation, as illustrated in Fig. 2. The incident field is resolved into two in-phase orthogonal components parallel and perpendicular to the grating line. The polarizer introduces a 180° phase shift between the two emerging orthogonal components, so that the resultant polarization is rotated an angle 2Θ with respect to the incident polarization. For example, if the desired polarization rotation of the antenna is $2\Theta = 45°$, then the polarizer's line orientation should be rotated to $\Theta = 22.5°$ with respect to the incident field polarization.

To determine the inductive and capacitive susceptance of each grid, a quasi-static approximation has been used by

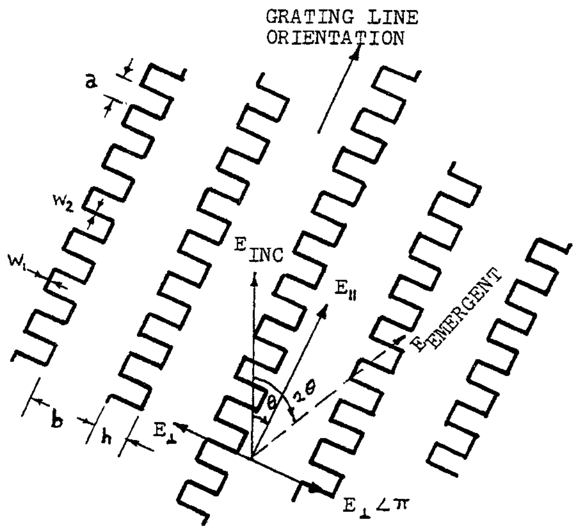

Fig. 2. Meander-line polarizer operation principle.

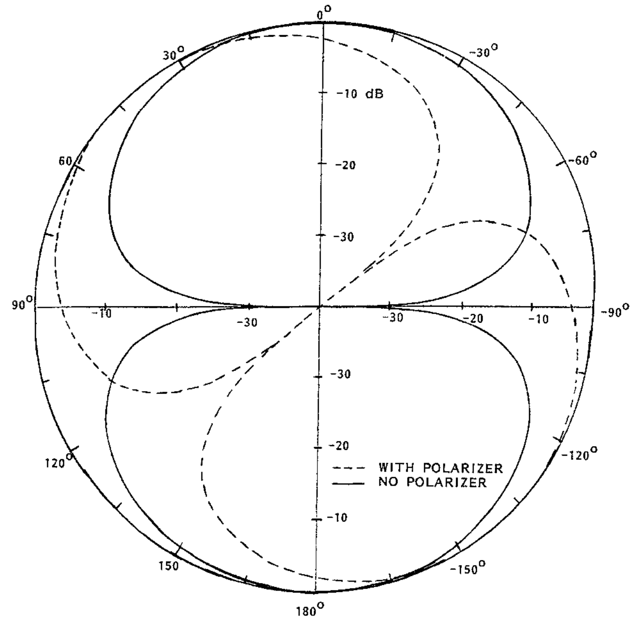

Fig. 3. Measured antenna polarization pattern with/without the polarizer.

TABLE I
GEOMETRICAL DIMENSIONS (IN cm) OF AN EIGHT-LAYERED MEANDER-LINE POLARIZER

Layer number	a	b	h	w_1	w_2
1,4,5,8	.399	1.87	.513	.1	.044
2,3,6,7	.574	1.87	.805	.147	.19

[4], [5], [7] to get the equivalent circuit parameters with respect to the E-field polarization, meander-line geometry and dimensions, dielectric substrate, and the operating frequency. A more rigorous computation of these susceptances has also been described in [6] via the integral equation formulation and the moment method. In this letter, the equivalent circuit parameters are computed from the above mentioned quasi-static approximation. Once they are determined, the performance of the multi-layered meander-line polarizer is readily predicted through the same transmission-line model as in [4], [5], [7].

III. Design and Demonstration

This versatile polarizer consists of eight-layered meander-line grids etched on 0.05-mm-thick Kapton sheets to provide the required 180° differential phase shift between the E-field's two orthogonal components. The top four sheets (with a 0.4-cm-thick Rohacell foam spacer between any two sheets) are exactly same as the bottom four and are separated by a 1.27-cm-thick Rohacell foam spacer. The meander-line geometrical dimensions for each layer are listed in Table I. Note that the Kapton substrate and uniform density Rohacell foam spacer are used here to devise a low-mass and rigid polarizer that can be easily rotated.

Next, the fabricated polarizer was mounted in front of a linearly polarized antenna and tested in a far-field range. Fig. 3 shows a representative measured polarization pattern of the antenna with/without the polarizer. Without the polarizer, the pattern shows maximum strength (or the co-polarized fields) at $\Theta = 0°$ and 180° directions, and the cross-polarized fields are at least 30 dB lower at $\Theta = \pm 90°$. In the presence of the polarizer and setting the polarizer's line orientation at $\Theta = 22.5°$, Fig. 3 also illustrates that the antenna's co-polarized field is at $\Theta = 45°$, which is two times the polarizer's line orientation angle, 22.5°. Hence the objective of this eight-layered meander-line polarizer is achieved.

IV. Conclusion

A versatile meander-line polarizer is described and demonstrated for arbitrary rotation of linear polarization. It is shown that the field polarization rotation angle through this meander-line polarizer is twice the angle between the incident polarization and the polarizer grating lines. Like most meander-line polarizers, the polarizer described here is inexpensive to fabricate with the printed circuit technology and operates well over a broad frequency band. It may be placed in front of either a transmitting or receiving antenna system. Its particular feature is that in association with a large complex antenna and feed system, the polarization rotation is accomplished by a simple rotation of the polarizer without moving or modifying the rest of the system. It should find myriad applications in both commercial and military systems.

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