Indeed, circular polarization seems to be better for improving the quality of indoor communication [10].

ACKNOWLEDGMENTS

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A BEAM-FORMING TECHNIQUE FOR LEAKY-WAVE ANTENNAS

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ABSTRACT: *A beam-forming technique for leaky-wave antennas (LWAs) which can switch electronically in three different radiation patterns is developed in this letter. A simple two-terminal feeding microstrip-line LWA works as a radiating element. By varying the phase of the two injection signals from 0 to 180°, the emitting power from the LWA can produce three different radiation modes: the normal mode (one sharp beam), the difference mode (Δ), and the sum mode (Σ). The antenna displays large-bandwidth characteristics, and can be useful near crossroads for collision avoidance or in the radio location of vehicles.* © 2001 John Wiley & Sons, Inc. Microwave Opt Technol Lett 28: 108–110, 2001.

Key words: *leaky-wave antennas; switched-beam antennas; beam steering*

I. INTRODUCTION

Recently, leaky-wave antennas (LWAs) have become popular, and there is a growing interest in various types of leaky-wave antennas used as frequency-scanning elements [1–2]. Leaky-wave antennas possess the advantages of low profile, fabrication simplicity, easy matching, narrow beamwidth, and frequency-scanning capability. As is known, the one-beam scanning LWA [1] and the dual-beam scanning LWA [2] have been studied intensively. However, the above-mentioned research cannot change the beam mode electronically, such as from a one-beam mode jumping into a dual-beam mode. Lin et al. [3] proposed a class of short LWAs with coaxial-to-microstrip transitions on which the differential signals propagate. The sum and difference radiation patterns must be shown by using two different circuit structures, such as the end-fed and center-fed LWAs.

In this study, we present an alternative approach to achieve Δ–Σ radiation patterns using a simple two-terminal feeding microstrip-line leaky-wave antenna design (see Fig. 1). When a short LWA is excited in phase from the two-terminal feeds, a great amount of electromagnetic energy of the leaky mode will survive when it travels down to the other end of the antenna. The remaining power reflects and offsets against the other injection signal, creating the sum pattern. It is a broadside pattern. When the LWA is excited out of phase, the reflected wave will be added into the other injection signal, creating the difference pattern. It is a dual-beam pattern. The advantage of this design is not only that the Δ–Σ patterns can be chosen electronically, not mechanically, but the antenna can also perform as a traditional beam mode by controlling the phase of the input signals.

II. ANTENNA DESIGN

The geometry and coordinate system for this leaky-wave antenna design are shown in Figure 2. Each slot radiates the same field as the magnetic dipole [4], with the equivalent magnetic current density M_{RS} for the right injection and M_{LS} for the left injection. The RT/Duroid substrate used has a

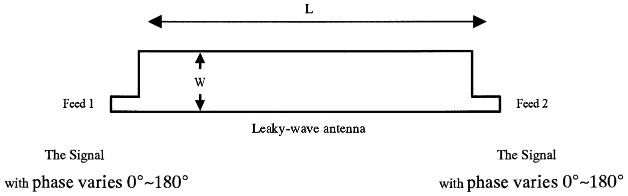

Figure 1 Simple two-feeding microstrip-line leaky-wave antenna

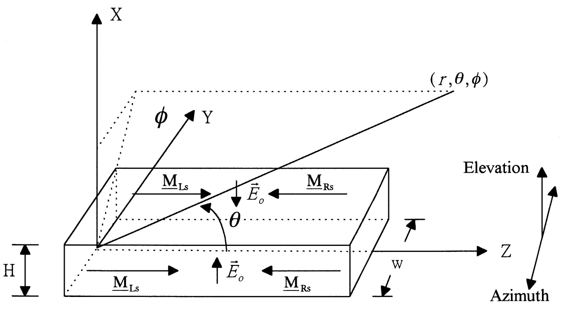

Figure 2 Geometry and coordinate system for the topology of this designed leaky-wave antenna

thickness of 0.635 mm and a dielectric constant of $\varepsilon_r = 2.2$. To excite the first higher order mode within the operating range of frequency, this microstrip leaky-wave antenna is fed asymmetrically, and the width W and length L of the radiating element are empirically chosen to be 0.61 cm (240 mil) and 2.794 cm (1100 mil), respectively.

III. THEORETICAL AND EXPERIMENTAL RESULTS

The microstrip leaky-wave antenna is operated at 15.5 GHz. Figure 3 shows a comparison between the measured and theoretical H-plane patterns of a broadside sum pattern, as the two feeds have in-phase current excitation (the phase difference is 0°) with a maximum directivity of 8.3 dBi. Figure 4 shows the pattern of a difference pattern, as the two feeds have out-of-phase current excitation (the phase difference is 180°) with a maximum directivity of 8.5 dBi. Note that the main beam positions of the out-of-phase mode are at $\theta = \pm 26°$. Figure 5 shows a comparison between the measured and theoretical prediction of the traditional one-beam radiation pattern. The antenna radiates a pencil beam for a phase difference of 90° between the two injection signals. It can be observed that reasonable agreement between the simulation and experimental results is obtained. The measured results prove that this beam-forming technique allows one to choose the sum pattern, the difference pattern, or the traditional one-beam radiation pattern electronically. The radiation pattern of this antenna design depends on the phase difference of the two injection signals, instead of different circuit structures. Figure 6 shows a comparison of the measured and theoretical S-parameters of this designed antenna, and the results show that the bandwidth is at least 2 GHz.

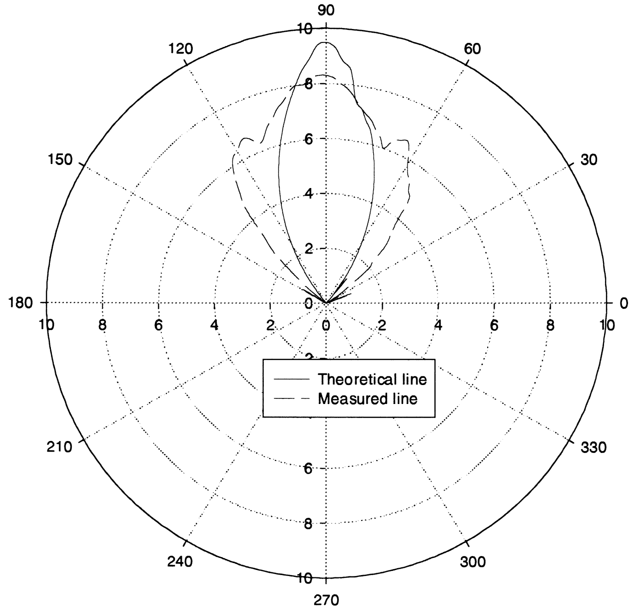

Figure 3 Measured and theoretical broadside sum pattern as the excited injection signals are in phase

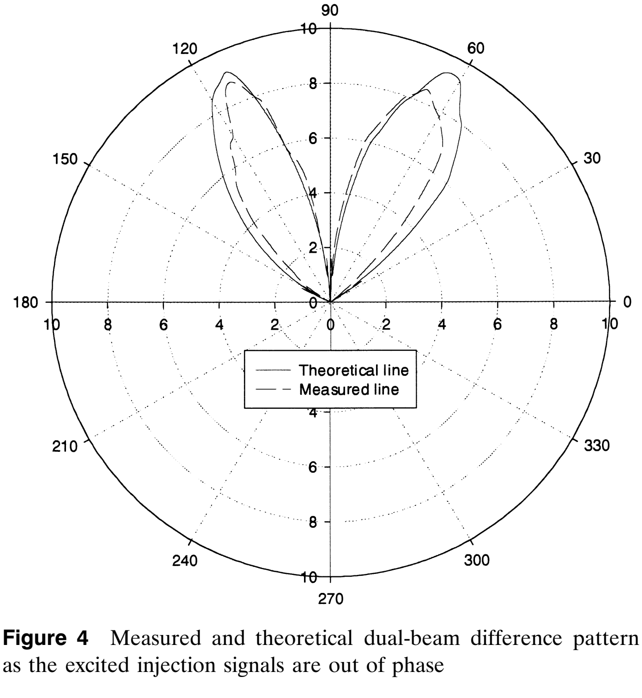

Figure 4 Measured and theoretical dual-beam difference pattern as the excited injection signals are out of phase

IV. CONCLUSIONS

It is demonstrated that the sum, the difference, and the traditional one-beam radiation patterns can be chosen elec-

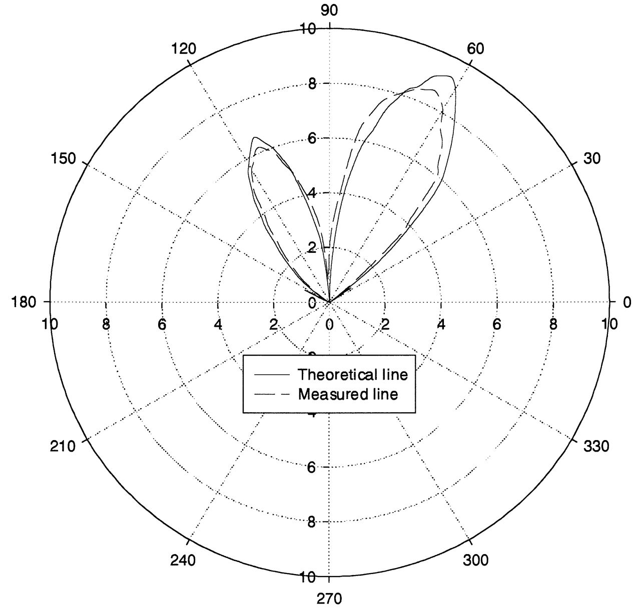

Figure 5 Measured and theoretical one-beam traditional pattern as the excited injection signals have a phase difference of 90°

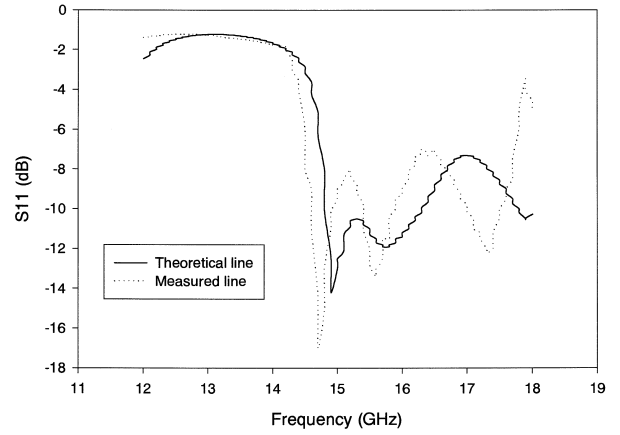

Figure 6 Comparison of the measured and theoretical S-parameters of this designed antenna

tronically by using a simple two-terminal feeding leaky-wave antenna structure. This beam-forming technique for leaky-wave antennas exhibits the properties of flexible beam switching and large bandwidth, and will be a suitable candidate for applications such as mobile communication and satellite communication.

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MODELING OF A TWIN-RIB NONRECIPROCAL PHASE SHIFTER BY THE SPECTRAL-INDEX METHOD

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ABSTRACT: *The design of a phase shifter with minimum device length that could be easily integrated into the isolator is investigated in this work. A twin-rib-waveguide nonreciprocal phase shifter having composite magnetic garnet film is characterized here using the spectral-index method. The proposed phase shifter has a device length of 22.54 mm at 1.3 μm wavelength, which is the length of the entire isolator.* © 2001 John Wiley & Sons, Inc. Microwave Opt Technol Lett 28: 110–113, 2001.

Key words: *optical isolator; nonreciprocal phase shift; gyrotopic; twin rib; spectral index*

INTRODUCTION

The nonreciprocal phase shifter is an important component of optical isolators that protect semiconductor lasers from reflected light. Concepts of integrated optical isolators are based on either nonreciprocal TE–TM mode conversion or nonreciprocal phase shifts of TM modes. The nonreciprocal phase shift of TM modes refers to the difference $\Delta\beta = |\beta_{fw} - \beta_{bw}|$ between the forward and backward propagation constants β_{fw} and β_{bw}, respectively. Nonreciprocal effects in passive linear materials are caused by the contributions of ε of odd order in the external, quasi-static magnetic field or for ferromagnetic or antiferromagnetic substances in magnetization. Typically, magnetic garnets such as yttrium iridium garnet (YIG) are used in the near infrared region between the 1.3 and 1.55 μm wavelength where optical communication applications are being developed. The magnetic garnets are grown by liquid phase or sputter epitaxy on paramagnetic substances like gadolinium gallium garnet (GGG). Each magneto-optic medium with an external dc magnetic field applied in the transverse plane along the y-axis has the permittivity tensor

$$\tilde{\varepsilon} = \begin{pmatrix} \varepsilon_{xx} & 0 & j\delta \\ 0 & \varepsilon_{yy} & 0 \\ j\delta & 0 & \varepsilon_{zz} \end{pmatrix}. \tag{1}$$

The gyrotopy δ represents the magneto-optic effect due to the applied magnetic field, and affects only TM modes. The gyrotopy parameter changes its sign if the magnetization is reversed, and is related to Faraday rotation Θ_F by

$$\delta \approx \frac{2n\Theta_F}{k_0} \tag{2}$$

where n is the refractive index and k_0 is the free-space propagation constant.

THEORY

The optical isolator in Figure 1 comprises two nonreciprocal phase shifters and two symmetric Y-branch couplers configured in the form of a Mach–Zehnder interferometer [1]. It functions as an isolator that routes forward- and backward-propagating signals differently. The isolator relies on the nonreciprocal phase shift between counterpropagating TM modes in a magneto-optic waveguide. An enhancement of the nonreciprocal effect is necessary to minimize the device length. At present, magnetic garnets are the only materials that have been studied for nonreciprocal devices in the infrared region. Because of their high Faraday rotation, magnetic garnet films are suitable for realizing integrated optical isolators [1].

The nonreciprocal phase shifters in Figure 1 employing single-rib magneto-optic waveguides have been analyzed using the effective-index method [2], as well as the more accurate spectral-index method [3]. It was found that, by loading a high-refractive-index material on the surface of the magneto-optic film, the nonreciprocal effect was enhanced. The thickness of this high-index cover can be adjusted in order to concentrate the field on the top side of the magneto-optic

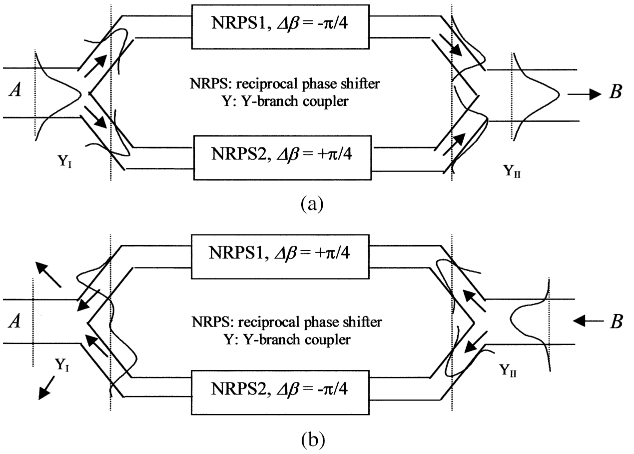

Figure 1 Mach–Zehnder nonreciprocal phase shifter with twin-rib configuration. (a) Forward propagation. (b) Backward propagation