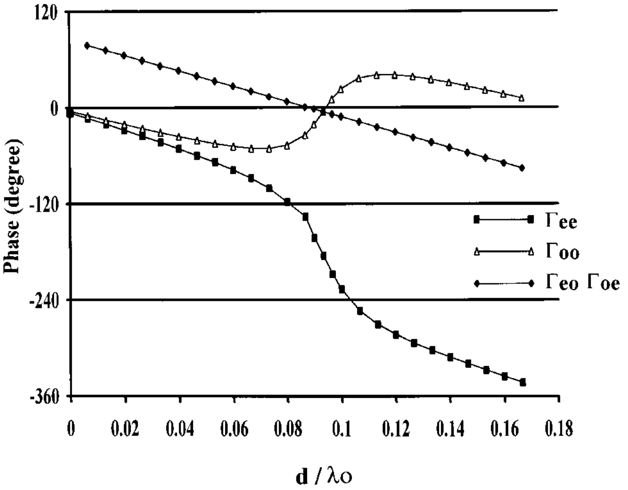

Figure 7 Phase of the reflection coefficients of the asymmetric microstrip coupled line open end shown in Figure 1

mode is found to become significant when the path difference between the two coupled lines is close to a distance which corresponds to the quarter of the waveguide wavelength associated with the loaded microstrip line. Naturally, this critical distance ($d/\lambda g \approx 0.25$) may have been predicted by a qualitative argument according to a quasi-TEM approximation (in this case, one of the two coupled lines is an open end, and the other one is loaded by a short circuit according to the distance d). Nevertheless, quantitative results are given by the matrix pencil method, and the reflection coefficients of the discontinuity, as a function of the parameter $d/\lambda o$, are determined with accuracy. However, these results demonstrate the efficiency of the matrix pencil technique in the study of multiple-mode devices. Associated with a full-wave approach, this posttreatment does not present any restriction regarding the geometry or the frequency as a quasi-TEM approach.

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AN ACTIVE FREQUENCY-TUNED BEAM-SCANNING LEAKY-WAVE ANTENNA

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ABSTRACT: *A frequency-tuned beam-scanning antenna is developed, which integrated a microstrip leaky-wave antenna with a varactor-tuned HEMT VCO as the source. The microstrip leaky-wave antenna is operated in the first higher mode. To excite the first higher mode, the microstrip leaky-wave antenna is fed asymmetrically. The dominant mode excitation has been successfully suppressed by adding a sequence of covered wire in the center of the microstrip leaky-wave antenna. The HEMT oscillator frequency is controlled by tuning the varactor dc bias, and the beam scanning is demonstrated. The measured scanning angle agrees well with the prediction; it is close to 30° as the VCO frequency is tuned from 8.06 to 9 GHz. © 1998 John Wiley & Sons, Inc.* Microwave Opt Technol Lett 17: 43–45, 1998.

Key words: *leaky-wave antenna; frequency scanning; varactor-tuned VCO*

I. INTRODUCTION

Frequency scanning is an effective technique for providing antenna beam steering which has been implemented with microstrip technology in recent years. Frequency scanning can be a cost-effective alternative to phase scanning in certain applications because phase shift elements and their associated drivers are not required to steer the antenna beam. Recently, there has been a growing interest in active antenna integration using the microstrip leaky-wave antenna as a frequency scanning element 1, 2. The microstrip leaky-wave antenna is not a low-loss element. However, it also has the advantages of having a low profile, simple structure, easy fabrication, easy matching, frequency scanning, narrow beam, and it is very suitable for active integrated antenna application. Here, in this letter, the microstrip leaky-wave antenna is fed asymmetrically to excite the first higher mode [3] and leaks in the form of a space wave. In addition, by introducing a sequence of covered wire in the center of the microstrip leaky-wave antenna (see Fig. 1), the excitation of the dominant mode can be successfully suppressed and the radiation efficiency can be improved. The characteristic of the microstrip line antenna is determined by its complex propagation constant. Here, an attempt is made to accomplish an active phase-shifterless frequency-scanning antenna by integrating a varactor-tuned VCO with a microstrip leaky-wave antenna. The radiation main beam depends on its operating frequency, and the frequency is varied by a varactor in the oscillator resonant circuit; the beam direction is controlled by adjusting the varactor dc bias. Therefore, it can be used as a frequency-scanning antenna.

II. DESIGN OF THE ACTIVE LEAKY-WAVE ANTENNA

Figure 1 shows the microstrip realization of the active leaky-wave antenna structure. The varactor-tuned oscillator was designed using a small-signal iterative procedure utilizing a commercially available CAD tool HP-EEsof Libra. A short-circuited microstrip feedback is used in series with the source to provide the device with negative resistance. The leaky-wave antenna is connected to the drain to compensate the negative resistance under steady-state operation. A varactor with an open microstrip line connected to the gate is used to set the resonance of the oscillator. To excite the first higher order mode, the microstrip leaky-wave antenna is fed asymmetrically. A sequence of covered wire was inserted in the center of the antenna to suppress the propagation of the dominant mode (whereas the longitudinal current would be zero for the first higher mode). In order to understand the radiation properties of such a microstrip leaky-wave antenna, we obtained its complex propagation constants $\beta - j\alpha$ of the first higher microstrip mode in its leaky range, where β is the phase constant and α is the attenuation constant. The complex constants are obtained by employing rigorous (Wiener–Hopf) solutions mentioned in [4]. Figure 2 shows the variations of phase constant β and attenuation α as a function of frequency. The geometry and coordinate system of the structure are shown in Figure 3. In our structure, the microstrip leaky-wave antenna is open at the top. For values of $\beta \le k_0$, power will leak into a space wave in addition to the surface wave. The space wave actually corresponds to radiation at some angle θ; the value of this angle changes

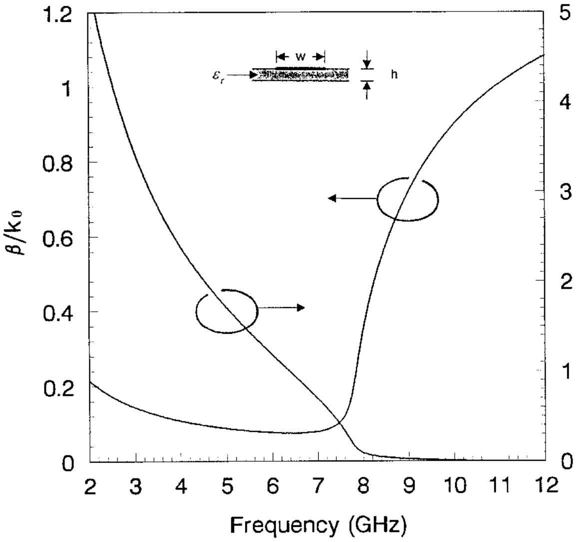

Figure 2 Normalized complex propagation constant of the first higher mode for the particular microstrip leaky-wave antenna. $h = 0.508$ mm, $w = 12$ mm, and $\varepsilon_r = 2.2$. k_0 is the free-space wavenumber

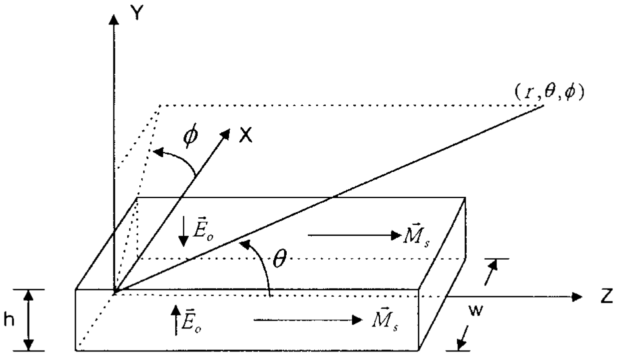

Figure 3 Geometry and coordinate system for the microstrip leaky-wave antenna. The antenna is of width $w = 12$ mm, height $h = 0.508$ mm, and length $L = 100$ mm

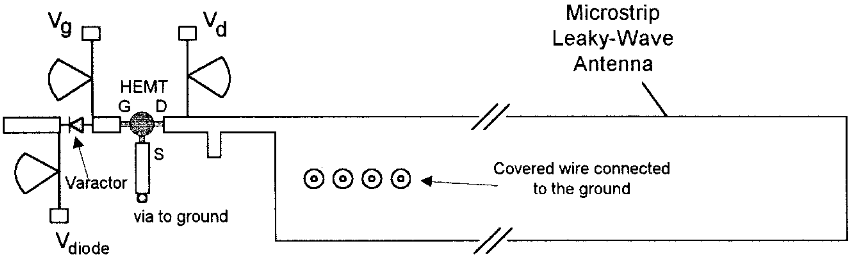

Figure 1 Configuration of the active microstrip leaky-wave antenna

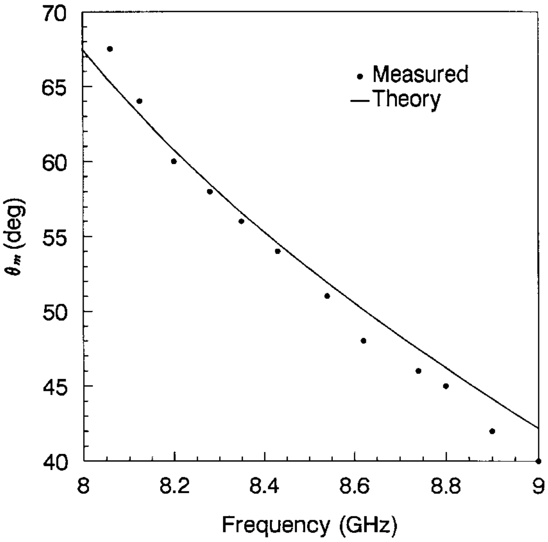

Figure 4 Beam position angel θ_m versus operating frequency of the active microstrip leaky-wave antenna

with frequency. By using the approximate relationship $\theta_m = \cos^{-1}(\beta/k_0)$, where θ_m is the angle of the beam maximum measured from the z-axis, we can predict the main beam position.

III. EXPERIMENTAL RESULTS

The circuit is designed and fabricated on RT/Duroid substrate with a dielectric constant of 2.2 and a thickness of 20 mil. An NEC NE32484 low-noise HEMT is used, and the drain is biased at 2.0 V with a drain current of 10 mA. A GaAs beam lead varactor (M/A-COM MA46585) is used as a tuning varactor, which has a capacitance ratio of 10:1 and a capacitor of 0.5 pF at 4 V. For a tuning voltage of 1.0–10 V, the active leaky-wave antenna exhibits a tuning bandwidth of 8.06–9GHz. The variation of scanning angle as a function of frequency is shown in Figure 4, where the beam-scanning angle is close to 30°. Figure 5 shows the experimental results of the H-plane patterns for operating frequencies at 8.06 and 9 GHz. We see from Figure 5 that as the operating frequency is lower, the beam swings up from the z-axis. Referring to Figure 2, the attenuation constant α decreases as the operating frequency increases, resulting in the observed narrower beamwidth in Figure 5. The effective radiated power (ERP) of this active antenna is about 18 dBm ± 2 dBm throughout the frequency-tuning range. The difference in power level of the main beam is caused mainly by the varied impedance of the microstrip leaky-wave antenna.

IV. CONCLUSION

The present work demonstrated the operation principle for electronic beam control where as phase shifters do not enter into the concept. Instead, we utilize the frequency-scanning antenna, the microstrip leaky-wave antenna, as the beam-scanning active antenna. In this letter, an active microstrip leaky-wave antenna capable of frequency scanning has been demonstrated. By tuning the varactor dc bias, beam-scanning control of close to 30° is achieved. The measured beam-scanning angle agrees with the predicted data. The circuit offers a small, simple, lightweight, low-cost tunable source for many microwave applications. And since it is planar, therefore it is suitable for monolithic circuit integration.

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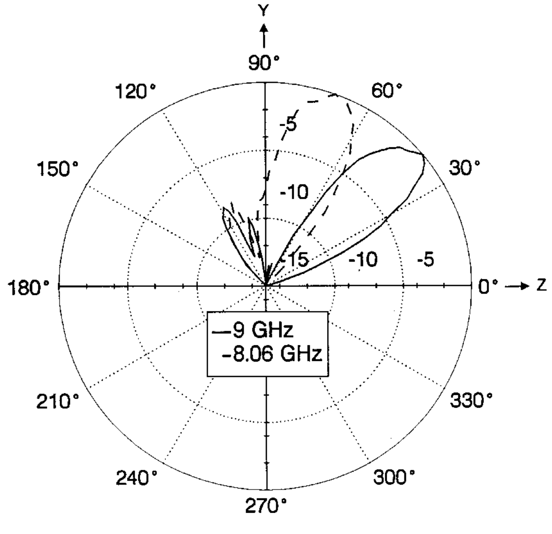

Figure 5 H-plane (y–z plane) frequency-scanned radiation patterns

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GREEN'S DYADICS FOR BI-ANISOTROPIC MEDIA WITH SIMILAR MEDIUM DYADICS

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ABSTRACT: *The Green's dyadics are constructed for a bi-anisotropic medium in which the four medium dyadics are proportional to the same dyadic. Since this dyadic is not symmetric, it is not possible to derive the Green's dyadics from the Green's dyadics for a bi-isotropic medium by an affine transformation. If one scalar material condition is satisfied it is possible to derive the Green's dyadics in closed form; otherwise, a one-dimensional integral representation is obtained. © 1998 John Wiley & Sons, Inc.* Microwave Opt Technol Lett 17: 45–47, 1998.