the desired power pattern, real active impedances and more reasonable R_i^{BL} values can all be achieved together (Table 3).

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Two-dimensional beam-scanning phase-shifterless technique using linear active leaky-wave antenna array

Cheng-Chi Hu, C.F. Jou and Jin-Jei Wu

A novel two-dimensional electronic beam scanning technique using a linear leaky-wave antenna array with coupled oscillators is introduced, eliminating the need for phase shifters. The measured H-plane main beam can be continuously scanned from 70 to 40° as the frequency varies from 7.9 to 9.05GHz. By detuning the free running frequencies of the end elements, the measured E-plane main beam can be continuously scanned from –22 to +26°.

Introduction: The complexity usually associated with the two-dimensional (2D) scanning array offers a special challenge for the planar active phase array design. In 1990, Oliner [1] proposed a 2D scanning array using a one-dimensional (1D) phased array of leaky-wave line-source antennas. A pencil beam can scan in both elevation and azimuth planes, however, phase shifters are required in this design. These phase shifters usually require complicated control circuitry which it may also be difficult to achieve in the limited space. In 1994, Liao and York [2] proposed a new phase-shifterless 1D beam-scanning technique using a patch antenna array with coupled oscillators. By controlling the free running frequencies of the end elements of the array, the main beam can scan in the azimuth plane. In this Letter, we extend the work to encompass the phase control technique [2] and leaky-wave antenna characteristic [1, 3, 4], leading to a novel method for phase-shifterless 2D electronic beam scanning.

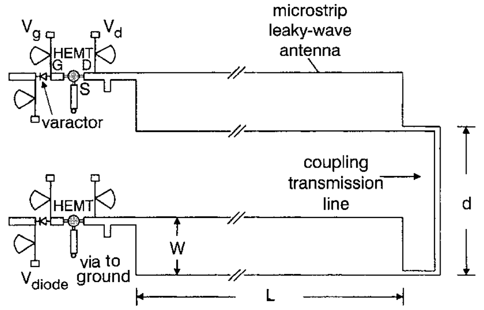

Fig. 1 *Configuration of active microstrip leaky-wave antenna array*
w = 12mm, L = 100mm, $d = 1\ \lambda_g$

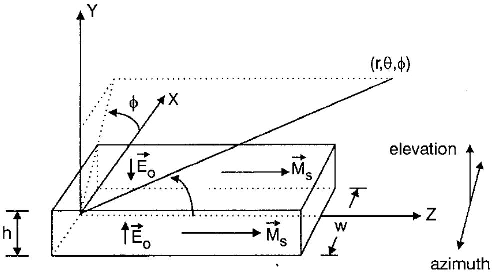

Fig. 2 *Geometry and coordinate system for microstrip leaky-wave antenna*

Design and measurement results: Fig. 1 shows the microstrip realisation of a two-element phase-shifterless active leaky-wave antenna array structure. The varactor-tuned oscillator is based on that we previously designed in [4]. Coupling circuits are designed to provide in-phase coupling, which ensures a stable in-phase mode of operation. The elements within the array are coupled to one another using one wavelength long transmission lines. To excite the first higher order mode, the microstrip leaky-wave antenna is fed asymmetrically [5]. The circuit is designed and fabricated on an RT/Duroid substrate with a dielectric constant of 2.2 and a thickness of 20mils. An NEC NE42484 low noise HEMT is used, and the drain is biased at 2.0V with a drain current of 10mA. The GaAs varactor (M/A-COM MA46410) is used as a tuning varactor, which has a capacitance ratio of 10:1 and a capacitance of 0.5pF at 4V.

Elevation plane scanning: To understand the radiation properties of such a microstrip leaky-wave antenna [1], 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. Such complex propagation constants represent a forward leaky-wave radiating into the space at an angle $\theta_m = \cos^{-1}(\beta/k_0)$, where θ_m is the angle of the beam maximum measured from the z-axis, and k_0 is the free-space wave number. In addition, the scanning angle θ_m can be varied with frequency.

For a tuning voltage of 1.0 to 10V, our active leaky-wave antenna array exhibits a tuning bandwidth of 7.9 to 9.05GHz corresponding to a measured main beam position from 70 to 40°. Fig. 3 shows the experimental results of the radiating patterns scaned in the elevation plane. The maximum effective radiated power (ERP) of this active antenna array is ~ 20dBm ± 2dBm throughout the frequency tuning range. The difference in the power level of the main beam is caused mainly by the varied impedance of the microstrip leaky-wave antenna as function of frequency.

Azimuth plane scanning: Electronic beam-scanning in the azimuth plane requires a constant phase progression along the array [2]. When the adjacent antenna is radiating with a phase difference $\Delta\varphi$, the main beam can be scanned to an angle ϕ, where

$$\phi = \sin^{-1}\left(\frac{\lambda_0 \Delta\varphi}{2\pi d}\right)$$

where λ_0 is the free space wavelength and d is the interspacing between adjacent antennas. In [2], the inter-element phase shift is controlled only by the free-running frequency of the end element. Furthermore, the synchronised frequency is equal to the free-running frequencies of the innermost oscillators. Therefore, by slightly adjusting the varactor's DC bias of the end elements in opposite directions, the radiation pattern can be scanned in the azimuth plane, as shown in Fig. 4.

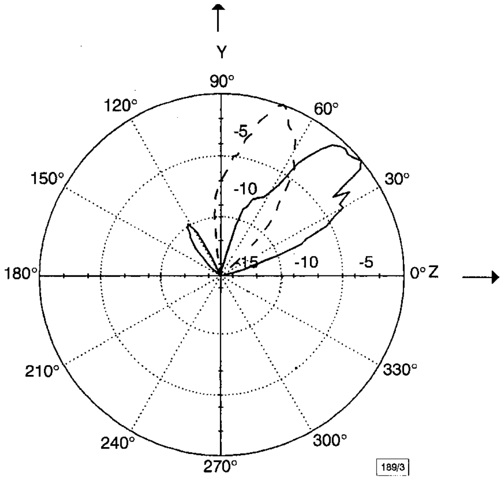

Fig. 3 *Comparison of measured radiation patterns of active leaky-wave antenna array in elevation plane (H-plane)*

Main beam can be scanned from 70 to 40° as frequency varies from 7.9 to 9.05GHz

——— 9.05GHz

- - - - 7.9GHz

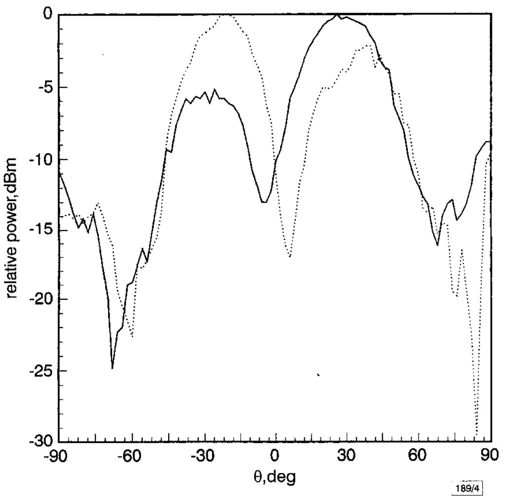

Fig. 4 *Comparison of measured radiation patterns of active leaky-wave antenna array in azimuth plane (E-plane)*

Continuous beam scanning was possible from –22 to +26° measured at ~ 9GHz

Conclusion: This Letter has presented a novel 2D beam-scanning technique using an active linear microstrip leaky-wave antenna array. We demonstrated that the main beam of a two-element active antenna array can be continuously scanned in both the azimuth and elevation directions by tuning the varactor's DC bias. The initial results show the good potential of this circuit for use with compact and low cost transmitters, active arrays, spatial power combiners and radar applications.

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Two-dimensional cylindrical dielectric resonator antenna array

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A square 2 × 2 subarray and infinite phased array of aperture-coupled cylindrical dielectric resonator antennas is investigated experimentally. The return loss, radiation pattern, and antenna gain are studied and compared with those of the single element antenna, and the waveguide simulator is used to measure the return loss of the element in an infinite array environment

Introduction: Since the work reported by Long *et al.* [1], the dielectric resonator antenna (DRA) has attracted a number of researchers [2 – 7], owing to its inherent merits of small size, light weight, low cost, and high efficiency. The single-element DRA has been well studied, but its antenna gain is limited to ~ 5dBi. In some applications a higher antenna gain is required. Recently, more effort has been devoted to DRA array design [4 – 7] to increase the antenna gain. In this Letter, we extend the previous work of a 1 × 2 linear cylindrical DRA array [5] to its two-dimensional version, which has not been reported in the literature. The aperture-coupled source is used to excite the DRA elements, which are operated at the broadside TM_{110} mode [1]. First a 2 × 2 square subarray is studied in which all elements are fed in phase. The measured return loss, radiation pattern, and antenna gain are presented, and the results are compared with those of the single element. Next, a preliminary study of an infinite DRA phased array

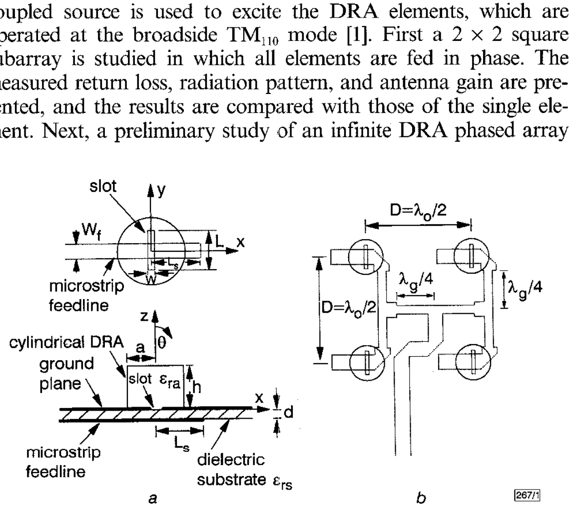

Fig. 1 *Geometry of configurations*

a Single element

b 2 × 2 subarray