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Beam-switchable scanning leaky-wave antenna

Chien-Jen Wang, Ying-Chou Shih and C.F. Jou

A beam-switchable scanning leaky-wave antenna (LWA) has been developed. This LWA with a two-terminal feeding microstrip line structure is integrated with a single port double throw (SPDT) switch as a control circuit. In dual-beam mode, the scanning angle is steered over a range of 36–64° for the right-hand beam and 144–116° for the left-hand beam. In one-beam mode, the scanning angle is measured over 20° for the right-hand beam. The measured result shows that we can change from the one-beam mode to the dual-beam mode electronically by controlling the on/off status of an SPDT switch, in contrast to the case for traditional leaky-wave antennas.

Introduction: Leaky-wave antennas (LWAs) have recently attracted a significant degree of interest, and the use of various types of leaky-wave antenna as frequency-scanning elements is increasing [1 – 4]. Leaky-wave antennas possess the advantages of having a low profile, being simple to fabricate, ease of matching, having a narrow beamwidth and frequency-scanning capability. They are also highly suitable for use as active integrated millimetre-wave antennas.

One-beam scanning leaky-wave antennas [1, 2] and dual-beam scanning leaky-wave antennas [3, 4] have been widely studied. Unfortunately, no method has yet been proposed which can enable the beam mode, such as the one-beam scanning or dual-beam scanning mode, to be changed.

In this Letter, we present a one-beam/dual-beam scanning leaky-wave antenna (see Fig. 1) design. A two-terminal feeding LWA is integrated with a single port double throw (SPDT) control circuit, shown in Fig. 2. The radiation pattern can be switched between one-beam mode and dual-beam mode by changing the DC bias voltage of the switch. An advantage of our design is that the beam mode can be chosen electronically, not mechanically.

Design of LWA and SPDT circuit: As shown schematically in Fig. 1, the unit consists of an SPDT control circuit, a matching circuit and a microstrip two-terminal feeding leaky-wave antenna. The RT/Duriod substrate used has a thickness of 0.508 mm and a dielectric constant of ε_r = 2.2. Two SPST switches, forming an SPDT switch, were designed by using a commercially available CAD tool HP-EEsof Libra. We used an M/A COM MA4GP030 GaAs *pin* diode as the solid-state device in an SPDT switch to obtain low insertion loss, high isolation level, fast switching speed, and high power capacity.

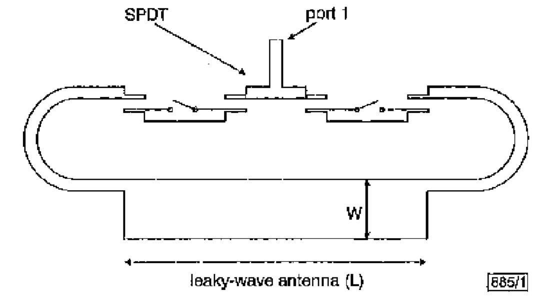

Fig. 1 *Configuration of one-beam/dual-beam scanning leaky-wave antenna*

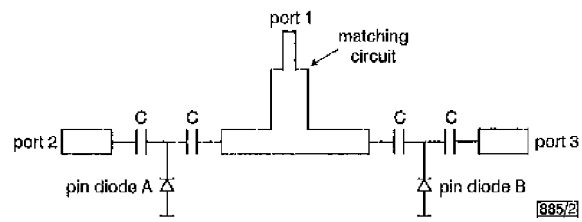

Fig. 2 *SPDT control circuit*

To excite the first higher order mode within the operating frequency range, the microstrip leaky-wave antenna is fed asymmetrically, and the width W and length L of the antenna are empirically chosen to be 1.06cm and 12cm, respectively. A rigorous (Wiener-Hopf) solution [5] is employed to find the normalised complex propagation constant $\beta/k_0 - j\alpha/k_0$ of the first higher order mode, where β/k_0 is the normalised phase constant and α/k_0 is the normalised attenuation constant. The variations in β/k_0 and α/k_0 with frequency are plotted in Fig. 3. The normalised phase constant β/k_0 is less than 1, and most of the radiating energy leaks in the form of the space wave.

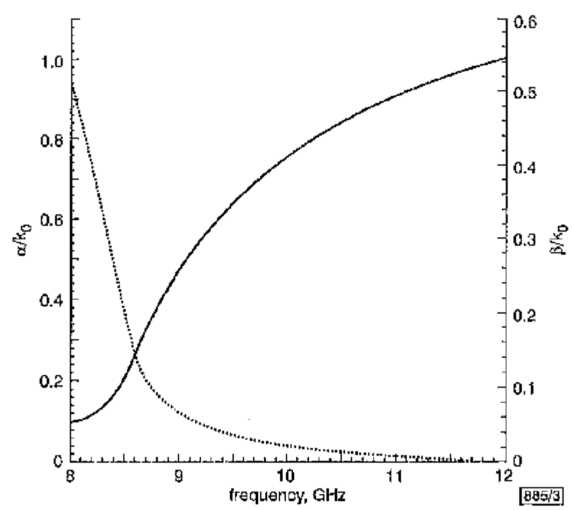

Fig. 3 *Normalised complex propagation constants of first higher mode for particular microstrip leaky-wave antenna*

H = 0.508mm, W = 11mm, and ε_r = 2.2; k_0 is free-space wave number

- - - β/k_0

–·–·– α/k_0

Theoretical and experimental results: The SPDT element has three ports and works in four operating modes, the left-hand beam mode, the right-hand beam mode, the dual-beam mode and the beam-off mode. When diode A is ON (forward-biased) and diode B is OFF (no bias), no signal passes through port 2 and all of the input power will appear at port 3. This is referred to as the one-beam mode. When diode A is ON and diode B is ON, the input signal will be returned at port 1 (beam-off mode). When diode A and diode B are both OFF, the SPDT works as a power divider and the input power is split in half (dual-beam mode).

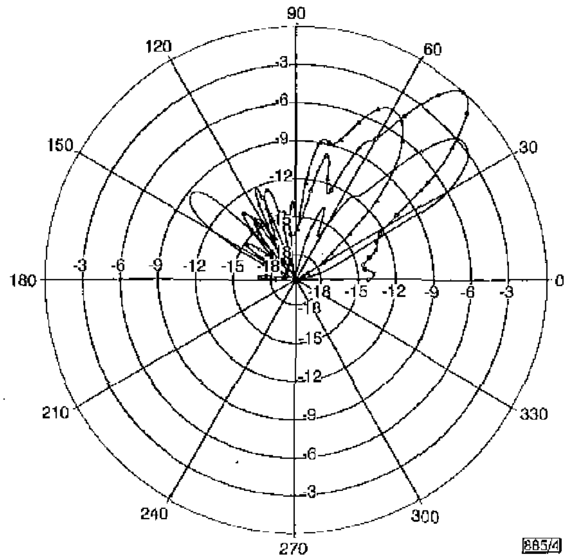

Fig. 4 *Measured one-beam scanning radiation patterns for proposed antenna at 9.3, 9.8 and 10.4GHz*

—— 10.4GHz
—O— 9.8GHz
—Δ— 9.3GHz

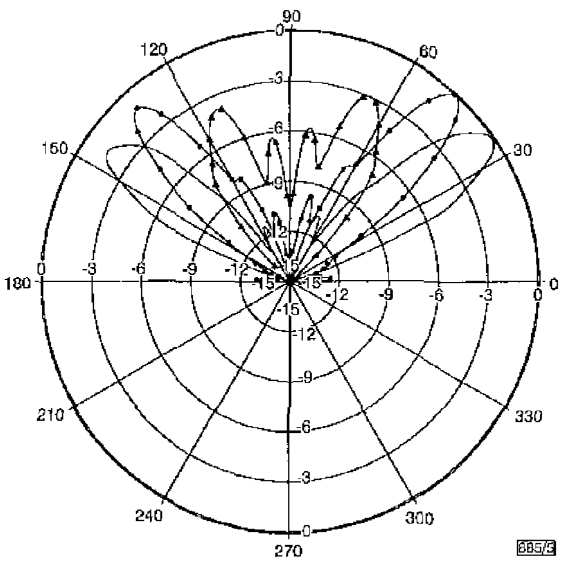

Fig. 5 *Measured dual-beam scanning radiation patterns for proposed antenna at 9.2, 9.8 and 10.6GHz*

- - 10.6GHz
—●— 9.8 GHz
- ▲ 9.2GHz

Fig. 4 shows the measured one-beam scanning radiation patterns for this antenna at 9.3, 9.8 and 10.4GHz. The main beams swing up from the end-fire direction (the Z-axis), which is characteristic of an LWA. For the one-beam mode, the measured angles of the main beam are ~61, 50 and 41°. Fig. 5 shows the measured dual-beam scanning radiation patterns at 9.2, 9.8 and 10.6GHz. Note that the measured scanning angles for the right-hand beam are 65, 49 and 38°; meanwhile, the measured angles for the left-hand beam are 115, 131 and 142°, respectively.

Conclusion: We have successfully employed a two-terminal feeding topology to create a dual-beam radiation pattern and an SPDT switch to electronically select a one-beam or dual-beam radiation pattern. This designed antenna has a large bandwidth and flexible beam-switching mechanism, and will be a suitable candidate for mobile and satellite communications applications. The circuit can be easily implemented in a monolithic array module.

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Broadband microstrip patch antennas for MMICs

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A broadband microstrip patch antenna well suited for monolithic microwave integrated circuits (MMICs) is presented. The antenna exhibits a measured bandwidth of 35%, low surface wave loss, a high front-to-back ratio, and is fabricated directly on the MMIC substrate material. The predicted and measured input impedances are given along with the measured radiation performance.

Introduction: Antennas suitable for integration with monolithic microwave integrated circuits (MMICs) and optoelectronic integrated circuits (OEICs) have found numerous applications, such as fibre-based antenna remoting, phased arrays, and quasi-optical power combining systems [1]. The integration of the antenna with microwave and/or optical components generates a compact, low-profile, lightweight and low-cost architecture.

To be integrated, the antenna must be fabricated on the high dielectric constant material used for the MMICs. This makes the antenna susceptible to surface wave excitation. A few attempts have been made to design an antenna to meet the requirements for integration [2, 3]. However, most efforts reveal a narrow impedance bandwidth (< 6%), and/or a reduced gain antenna due to surface wave loss.

Recently, two MMIC-compatible printed antenna structures have been reported with low surface wave loss and a wide bandwidth: the hi-lo stacked patch [4]; and the coplanar waveguide (CPW) fed aperture stacked patch (ASP) [5]. The CPW fed ASP, however, suffers from a relatively low front-to-back ratio of ~11dB, which complicates the packaging of the integrated MMIC/antenna. The hi-lo stacked patch has a much higher front-to-back ratio of ~22dB on a similar sized ground plane as the CPW fed ASP, yet has a smaller impedance bandwidth (~25% compared to 40%).

In this Letter, the hi-lo stacked patch configuration is extended to enhance the bandwidth. An extra parasitic patch is added to the hi-lo structure on a slab of low dielectric foam. The measured results for this new hi-lo-lo geometry will be presented, and the