A NOVEL ELECTRONICALLY SCANNABLE LOG-PERIODIC LEAKY-WAVE ANTENNA

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ABSTRACT: *An innovative phaseshifterless, wideband, microstrip leaky-wave antenna with an electronically steerable dual-pencil-beam pattern in the H-plane is presented. The log-periodic geometry of the leaky slots of the antenna results in a wide bandwidth of 25.19%. The fan beam can be steered up to 14° over the wide resonating band of the antenna. The beam is also steerable at a fixed frequency. by reactivelty loading the slots and a maximum steering angle of about 14° is observed for different capacitor values with an improved bandwidth of 33.3%. This concept is studied using passive components, but it can be*

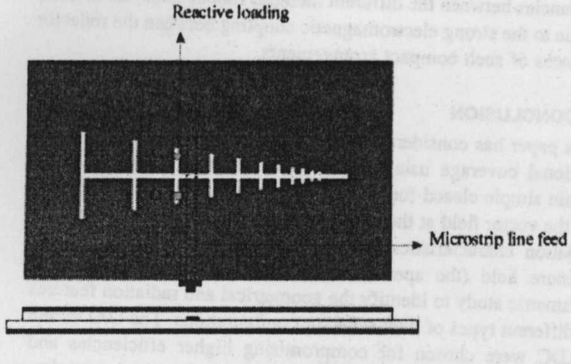

Figure 1 Geometry of the proposed log-periodic leaky-wave antenna (slots are arranged log periodically with design ratio $\tau = 0.8$ and slot width of 1 mm)

extended to varactors. Microwave Opt Technol Lett 45: 163–165, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20757

Key words: *leaky-wave antenna; beam steering; log-periodic leaky slots; wide bandwidth*

1. INTRODUCTION

Simple beam-scanning techniques have found applications in low-cost radar systems, wireless communication, imaging, and side-looking sensors in automotives. Frequency scanning is the cost-effective alternative to phase scanning in the above applications because phase shifters and associated elements are not required to steer the antenna beam [1, 2]. The microstrip leaky-wave antenna has the excellent advantages of wider bandwidth, pencil beam, and frequency-scanning capability [3]. The leaky-wave antenna has a narrow fan beam in the H-plane, with single excitation, which makes it suitable for integrated antenna-array applications. Here we demonstrate a log-periodic slotline microstrip leaky-wave antenna (Fig. 1) with a wide scanning angle of 14° and a −10-dB bandwidth of 33.3%. The log-periodic construction of the leaky slots enables wide bandwidth and hence more frequency scannability. The H-plane pencil beam of the proposed antenna is also scannable at a fixed frequency by varying the capacitance, loaded at the leaky slots. The wide bandwidth of the proposed antenna provides a large steering angle when frequency scanning in the band is required. Moreover, the reactive loading enables beam steering at a fixed frequency by changing the capacitance values loaded at the leaky slot lines. The design has been successfully implemented and proved with passive components, but can be modified with varactors for beam steering by dc bias tuning.

2. DESIGN OF THE LOG PERIODIC LEAKY-WAVE ANTENNA

The geometry of the proposed log-periodic leaky-wave antenna is shown in Figure 1. The log-periodic slot-line structure is etched on a substrate of dielectric constant $\varepsilon_r = 4.7$ and thickness $d = 1.6$ mm. The vertical slot dimension is optimized using Zeland IE3D for a width of 1 mm. The vertical slots are arranged log periodically and optimized for wide bandwidth with design ratio $\tau = 0.8$. The leaky slots of the antenna are loaded with SMD capacitors, which results in beam steering at a fixed frequency. The position of the capacitors along the vertical slot lines are selected so as to enable maximum beam steering at a fixed frequency in the selected band. The antenna is electromagnetically coupled using a 50Ω microstrip feed line.

TABLE 1 Measured Bandwidths for Different Values of Design Ratio τ of the log-periodic Leaky-Wave Antenna

Sl No.	Design Ratio, τ	Resonating Band [GHz]	Bandwidth [MHz]	% Bandwidth
1	0.75	4.74–5.56	825	16.01
2	0.8	**4.797–6.005**	**1209**	**25.19**
3	0.85	4.98–5.45	495	9.47
4	0.9	4.76–5.59	825	16

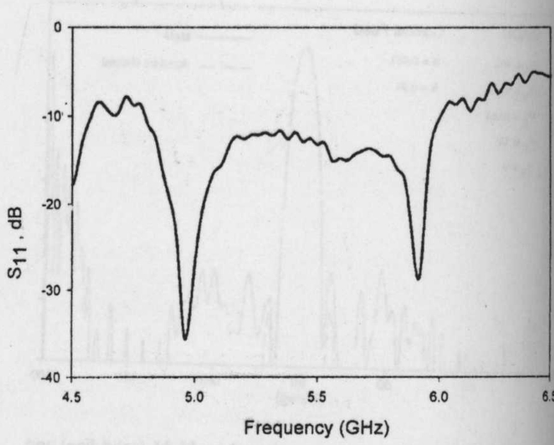

Figure 2 Measured return-loss characteristics of the leaky-wave antenna for optimized log-periodic structure with design ratio $\tau = 0.8$, obtaining a −10-dB band width of 25.19%

3. EXPERIMENTAL RESULTS

The log-periodic leaky-wave antenna is designed and studied experimentally. The design ratio τ of the leaky slot line varies from 0.75 to 0.9 and is optimized for maximum bandwidth. The variation of the bandwidth with the design ratio τ is shown in Table 1. A maximum bandwidth of 25.19% is obtained in the frequency band of 4.797 to 6.005 GHz for the design ratio $\tau = 0.8$. The measured return-loss characteristics of the log-periodic leaky-wave microstrip antenna are shown in Figure 2. The measured H-plane radiation pattern shows a dual pencil beam, scannable in the entire frequency band, as shown in the Figure 3.

The reactive loading in the vertical slot lines resulted beam scanning at a fixed frequency. The position of the capacitors in the slot lines are determined experimentally. The antenna shows an

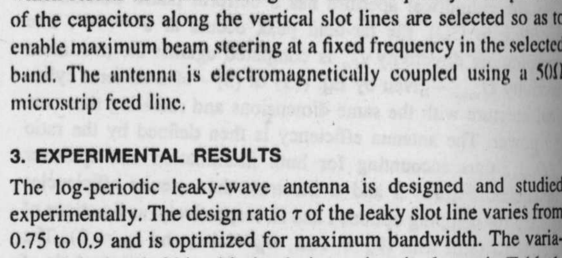

Figure 3 Frequency-scanned H-plane patterns of the log-periodic leaky-wave antenna. The beam is scanned for an angle of about 14° when frequency is varied from 4.93 to 5.81 GHz (—: 4.93 GHz; ----: 5.81 GHz)

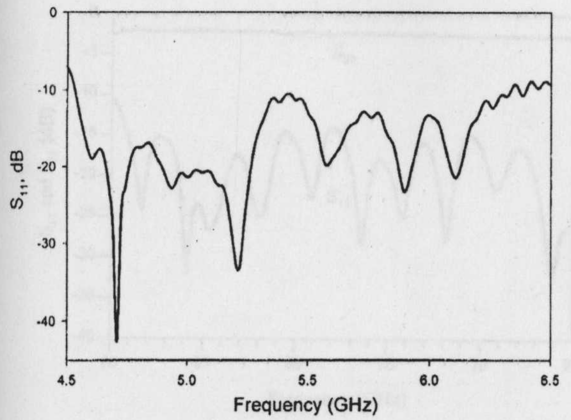

Figure 4 Measured return-loss characteristics of the reactively loaded log-periodic leaky-wave antenna with design ratio $\tau = 0.8$ and $C = 2$ pF, obtaining an improved -10-dB band width of 33.3%

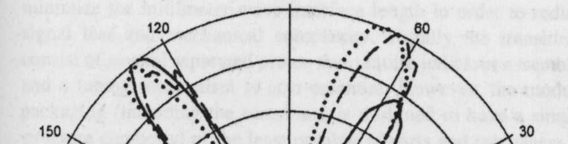

Figure 5 Measured H-plane patterns for different values of reactive loads of the log-periodic leaky-wave antenna. By changing the capacitor values from 2 to 33 pF, a maximum steering angle of 13.3° is obtained (—: 2 pF; ----: 5.6 pF; ....: 33 pF

improvement in bandwidth of 33.3% after the reactive loading. The measured reflection coefficient for a capacitance value of 2 pF is shown in Figure 4. The radiation patterns measured in the H-plane at a fixed frequency of 5 GHz, by changing the values of the loaded capacitors, are displayed in Figure 5, which illustrates that the H-plane dual-pencil beam with a half-power beam width of less than 20° can be steerable up to 14° by increasing the capacitor values from 2 to 33 pF.

4. CONCLUSION

The work reported in this paper has presented a wideband beam-steering microstrip leaky-wave antenna without a phase shifter. The main beam can be steerable either by reactive loading over the leaky slots of the antenna at a fixed frequency or by changing the operating frequency in the entire bandwidth. Varactors or switching diodes can be used as reactive loads and can find applications in side-looking radars for automotive sensors or similar low-cost tracking.

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