Frequency-fixed beam steerable microstrip leaky wave antenna using periodic varactor loading

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1. Introduction

Printed leaky wave antennas (LWAs) have been noted for their low profile, high directivity, broad bandwidth, and frequency scanning capability. There has been especially a significant interest in the LWA for beam steering at a fixed frequency [1-2]. However, the antennas have some drawbacks: small beam tilting angle or discrete tilting angle with the requirement of the special feeds to excite the higher order mode and guard against the dominant mode. Recently, dominant mode LWAs are presented in [3-4], but they have no beam steering performance at the fixed frequency and show the bi-directional radiation patterns.

In this paper, we propose a dominant mode LWA which has fast wave (leaky) region by series varactor loading in microstrip line. Since the β of the antenna is varied by changing the loaded capacitance, we can control the main beam's direction by changing the bias voltage of the varactors.

The proposed antenna shows a wide beam steering performance of 56° in E-plane, and also has advantages of simple feeding and uni-directional radiation pattern.

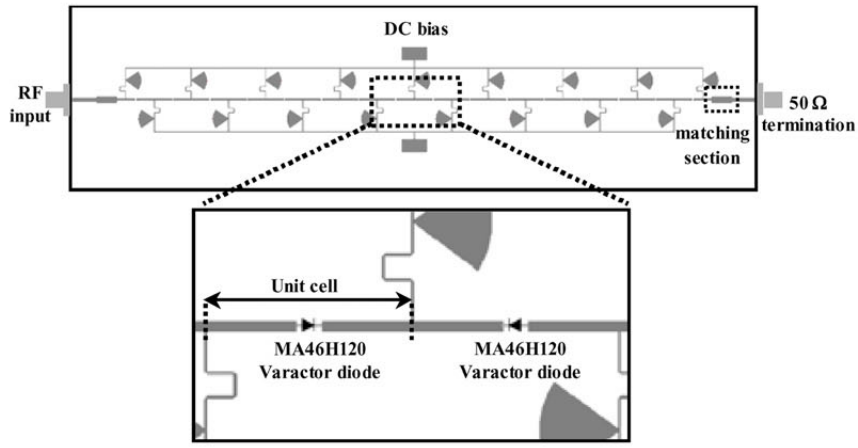

Fig.1 Structure of the proposed Leaky wave antenna

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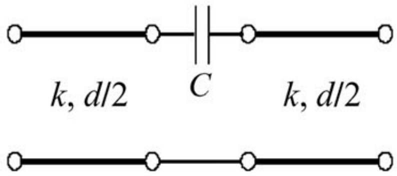


Fig. 2 Equivalent circuit of the unit cell

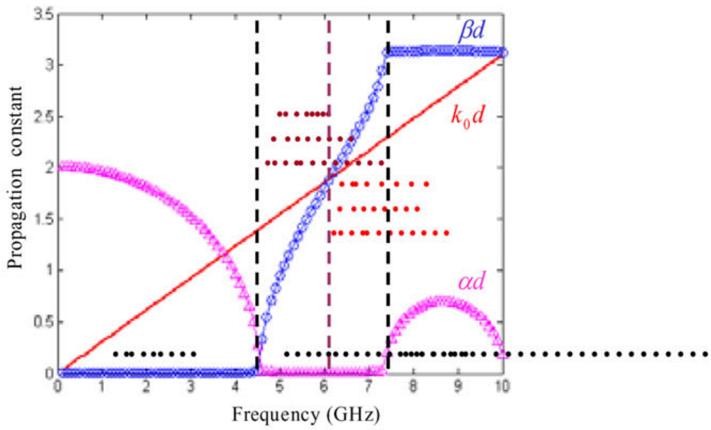


Fig. 3 Dispersion diagram of the unit cell

2. Antenna structure and analysis

The structure of the proposed antenna is depicted in Fig. 1. The antenna is composed of array of 16 unit cells each of which has a varactor with microstrip line and bias circuit of the varactors. It also has impedance matching sections at both ends.

Fig. 2 shows the unit cell consisting of a capacitor in series between two identical sections of transmission line. Since the bias circuit of the varactors has very large impedance in the leaky frequency region, bias lines can be ignored. When unit cell is symmetric, the propagation constant of the periodic structure is estimated either by using ABCD parameters of the unit cell by using (1), or directly calculated from the S-parameters of the unit cell by using (2) [5-6].

$$\begin{aligned}\gamma = \alpha + j\beta &= \frac{1}{d}\cosh^{-1}\left(\frac{A+D}{2}\right) \\ &= \frac{1}{d}\cosh^{-1}\left(\cos(kd) + \frac{1}{2Z_0\omega C}\sin(kd)\right)\end{aligned} \tag{1}$$

$$\gamma = \alpha + j\beta = \frac{1}{d}\cosh^{-1}\left(\frac{1 - S_{11}^2 + S_{21}^2}{2S_{21}}\right) \tag{2}$$

Fig. 3 represents the dispersion diagram of the unit cell calculated from (2). From the dispersion diagram, some properties can be estimated. The first passband exists from 4.4 GHz to 7.4 GHz where attenuation constant (α) is very small. Inside the passband, the leaky region exists from 4.4 GHz to 6.2 GHz where β is lower than k_0.

In the leaky region, the radiation angle of the antenna is obtained by (3), and β is varied by changing the loaded capacitance as shown in (1). Therefore, the radiation angle of the antenna can be controlled by changing the bias voltage of the varactors.

$$\cos\theta = \frac{\beta}{k_0} \tag{3}$$

For the impedance matching to 50 Ω, Bloch impedance of the periodic structures can be calculated as (4), and the calculated Bloch impedance changes from 20 Ω to 28 Ω in the leaky region. The impedance matching is easily accomplished by using quarter wavelength impedance transformer.

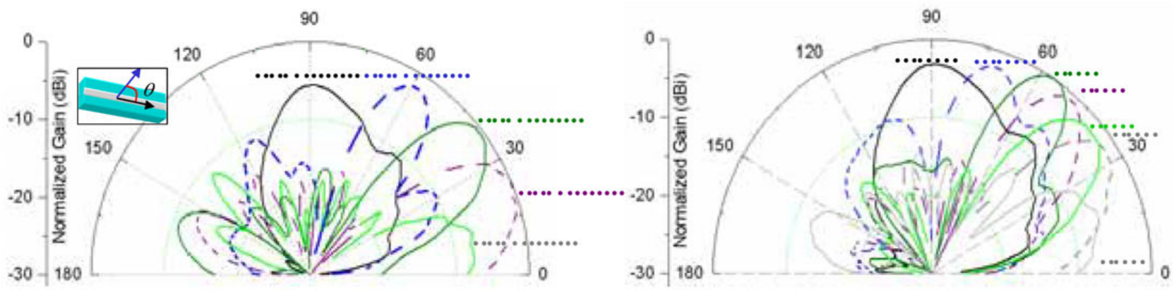
$$Z_B = Z_0 \frac{V_{n+1}}{I_{n+1}} = \frac{-BZ_0}{A - e^{\gamma d}} = \frac{\pm BZ_0}{\sqrt{A^2 - 1}} \tag{4}$$

3. Experimental results

A substrate with the dielectric constant of 2.52, the thickness of 0.564 mm, and the varactors of MA46H120 were used in the design. The length of a unit cell (d) is 14.8 mm, and the width of microstrip line (w) is 0.8 mm. To verify the performances of the antenna, the radiation patterns of the antenna were measured in an anechoic chamber.

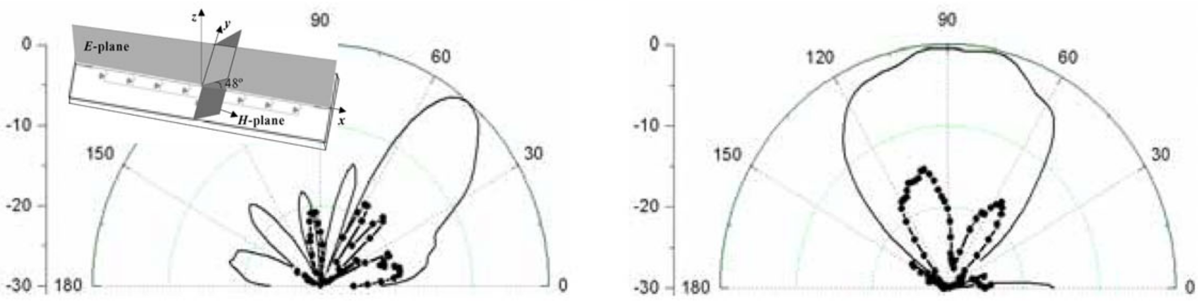
Fig. 4(a) shows the measured E-plane radiation patterns at the fixed bias voltage of 12 V. As expected, the radiation angle of the antenna was varied with the change of frequency from broadside toward the direction of propagation. The measured E-plane radiation patterns at the fixed frequency of 4.2 GHz is shown in Fig. 4(b). The radiation angle was changed from 90° to 34° when the bias voltage was changed from 12 V to 5 V.

Fig. 5 shows the measured cross polarization properties of antennas at each plane. The maximum cross polarizations are reasonably low at approximately –19 dBc in the E-plane and –15 dBc in the H-plane.



a. at fixed bias voltage of 12V b. at fixed frequency of 4.2GHz

Fig. 4 Measured E-plane Radiation patterns of the LWA



a. E-plane b. H-plane

co-polarization cross- polarization

Fig. 5 Measured radiation patterns at fixed bias voltage of 7V and frequency of 4.2GHz

4. Conclusion

A new beam steerable microstrip LWA is proposed. Since the antenna use the dominant microstrip mode, the antenna has a simple feed and uni-directional radiation pattern. Most of all, the antenna has a wide beam steering performance of 56° in the *E*-plane. The proposed antenna can be applied to use as vehicle DBS (Direct Broadcasting system) reception antenna or low cost tracking Radar.

5. Acknowledgement

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