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A Kind of Beam-Scanning Antenna With Amplitude and Phase Control Based on SIW

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***Abstract*—In recent years, the leaky wave antenna belongs to a kind of beam scanning antenna, which has good beam scanning ability and has been fully developed. However, it is difficult to realize fixed-frequency beam scanning in most leaky antennas, and few structures can control the amplitude and phase of electromagnetic wave simultaneously, which reduces the gain of leaky antennas and raises the sidelobe level. In this paper, a novel metasurface structure is designed and combined with SIW to achieve simultaneous amplitude and phase control, and the radiation efficiency of the unit reaches 30% when working between 7.3-7.7GHz, and the S11 is below -14dB. Finally, the genetic algorithm（GA）was selected as the control algorithm of the array factor to optimize the array and carry out simulation verification. The array has more than ±45° beam scanning capability over the operating bandwidth, with stable Y-polarization gain and sidelobe average is less than −10 dB.**

***Keywords*—Leaky-wave antenna, Metasurface, Beam scanning,**

I. INTRODUCTION

Antennas are devices that transmit and receive electromagnetic waves, and are widely used in various radio communication facilities, such as radar, broadcasting, navigation, television, and other use scenarios [1]. In recent years, there has been a growing demand for high-performance beam-scanning antennas for various radar, satellite communications, and unmanned driving technologies [2]. Compared with phased array antennas and transmitted array and reflective arrays， the leaky-wave antenna（LWA）is a traditional traveling wave antenna [3], which has the advantages of low profile, high gain, simple feeding, and easy integration, therefore, the leaky wave antenna is widely used in the design and application of beam scanning antennas [4]. In the past, leaky-wave antennas only had the function of adjusting the phase or the amplitude, and it was rare to realize the adjustment of amplitude and phase at the same time [5].

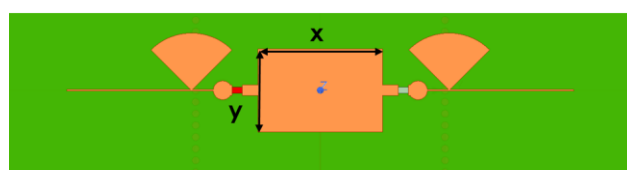
In order to solve the problem of insufficient regulation ability of leaky-wave antenna unit, this paper studies the beam reconfigurable antenna based on switching diode. Firstly, the theory and development of fixed-frequency beam scanning leaky-wave antennas are analyzed, and the types, advantages and disadvantages of beam scanning leaky-wave antennas are analyzed. Secondly, a metasurface unit based on switching diode control was designed, and the metasurface unit was combined with the substrate-integrated waveguide (SIW) to realize the fixed-frequency wave sweeping. Finally, the array has more than ±45° beam scanning capability over the operating bandwidth, with stable Y-polarization gain and sidelobe average is less than −10 dB.

II. DESIGN AND METHODOLOGY

A. Antenna Unit design

The antenna unit designed is shown in Figure 1, where Figure (a) is the top view and Figure (b) is the back view of the unit. The antenna is composed of two layers of plates, the bottom and upper layers are F4BTM300 with a thickness of 0.5mm, the dielectric constant is 3, the loss Angle tangent is 0.0018, and the bonding layer is only 4450F with 0.1 mm.

(a)



(b)

Fig. 1. Antenna unit structure diagram. (a) Front view (b) Back view

As shown in Figure (a), the top layer is the radiation patch, the length x is equal to 10mm, the width y is equal to 8mm, through opening a hole in the bottom waveguide to achieve energy input to the radiation patch, two diodes are around the patch, respectively, to control the two channels. Figure (b) is the bottom metal of SIW. In order to realize the regulation of PIN, a ring gap is dug at the bottom to realize

As shown in Figure (a), two sector bias circuits control two diodes respectively. When one of the two diodes is connected and the other is disconnected, 1bit phase regulation is achieved. When both diodes are disconnected, the state is non-radiation.

Through reasonable optimization, the simulation results of the unit are shown in the figure below. The S-parameter are shown in Figure 2.

(a)

(b)

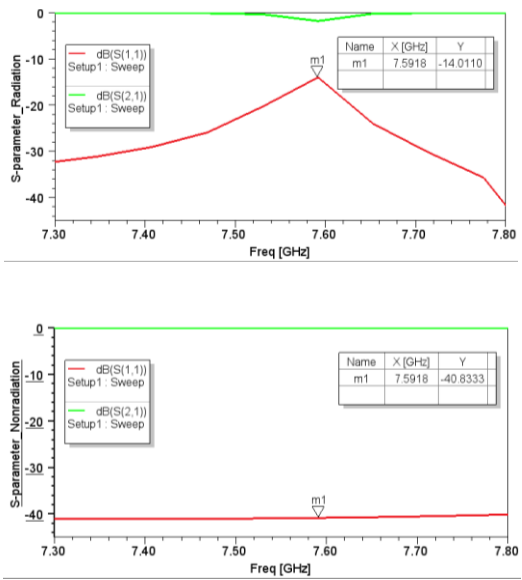


Fig. 2. S-parameter (a) Raditation (b) Non-raditation

According to the S parameter, it can be seen that in the radiation state, the energy S_{21} is cancelled and dented, while in the non-radiation state, all the energy goes through one port into two ports.

The phase curve of the radiation state is shown in the figure 3 below, and it can be seen that a 1bit phase can be introduced through the switching change of the diode. In this figure, the red line and the green line are respectively the far-field electromagnetic wave phases generated by the two radiation states.

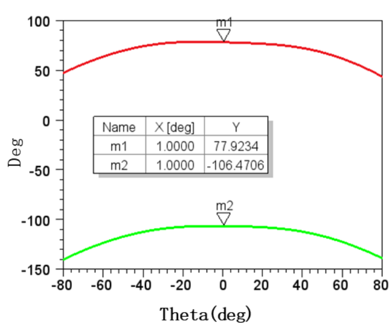


Fig. 3. Phase of two radiation states

B. Array analysis

In this section, the constraint adjustment of the spacing of leaky antenna elements is given. Suppose the unit has only three states, namely an electromagnetic wave with a radiation phase of 0 degrees and an electromagnetic wave with a radiation phase of 180 degrees, and a non-radiation state. The array factor of a leaky wave antenna can be expressed as the following equation (1).

$$AF(\theta)=\left|\sum_{n=0}^{N-1}\mathrm{M}_n e^{-j(k_s-k_0\sin\theta)np}\right| \tag{1}$$

Where M is 0, 1, and -1 respectively correspond to the above three radiation states. n is the number of cells and the maximum number is N. p is the cell spacing, and k_s is the wave number of waveguides. We assume that the following functions exist such as the (2) formula.

$$AF(\mathrm{X})=\left|\sum_{n=0}^{N-1}\mathrm{M}_n \mathrm{e}^{jXn}\right| \tag{2}$$

Formula (2) has the following two properties, such as formula (3) and (4).

$$AF(\mathrm{X})=AF(-\mathrm{X}) \tag{3}$$

$$AF(\mathrm{X}+2\mathrm{n}\pi)=AF(\mathrm{X}) \tag{4}$$

Using equations (3) and (4), it can be deduced that function (2) has an axis of symmetry as follows which are X=nπ. Comparing formula (1) with formula (2) shows that by formula (5) gives us formula (1) from formula (2).

$$\mathrm{X}=-\left(k_s-k_0\sin\theta\right)p \tag{5}$$

The range of X is ($-k_sp-k_0p$, $-k_sp+k_0p$), and the X value range cannot include the axis of symmetry. The leak wave antenna must meet the condition $k_s > k_0$, otherwise it cannot realize the single beam scanning of the antenna. In addition, the symmetry analysis can be obtained that the following formula (6) must be met to realize the single beam scanning.

$$p\le\frac{\pi}{k_0+k_s} \tag{6}$$

C. Antenna Array design

The designed array is composed of 36 units with a spacing of 9mm. Genetic algorithm is used to optimize the state of the antenna unit. The antenna array diagram is shown in Figure 4(a)., and the simulation results are shown in Figure 4(b). The simulation frequency is 7.5GHz.

(a) (b)

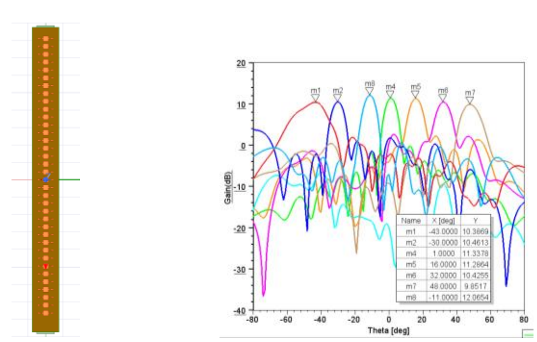


Fig. 4. Array Antenna (a) Antenna structure (b) Simulation result

According to Figure 4 (b), it can be seen that the leakage wave antenna can achieve ±45° wave sweep, the sidelobe level is below -10dB, and the gain is above 10 dB

III. RESULTS AND DISCUSION

. In this paper, we design a novel and simple leak-wave antenna with amplitude-modulation and phase-modulation characteristics, and give the constraints on the spacing of the design elements of the array. Through simulation, it can be seen that the designed antenna has good performance.

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