Design of a Traveling Wave Slot Array on Substrate Integrated Waveguide for 24GHz Traffic Monitoring

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***Abstract*—In this paper, a traveling wave slot array on substrate integrated waveguide (SIW) for 24GHz traffic monitoring is designed. The antenna array achieves beam steering through controlling the longitudinal slot spacing. The main beam points at an angle of 20° and has the advantage of miniaturization, easily fabricated and low cost. Simulated result is verified in this design.**

Keywords—traffic monitoring, SIW slot antenna, traveling array antenna, beam steering

I. INTRODUCTION

With the rapid development of economy and the acceleration of urbanization, Intelligent Transportation System (ITS) [1]-[2] plays an increasingly important role in social development. As the front sensor of ITS, traffic monitoring antenna is the key of ITS in the future. The main frequency band used for traffic monitoring is 24GHz. According to the actual situation of the traffic monitoring radar antenna erected on the traffic road, as shown in Fig. 1, a traveling wave slot array antenna is designed on substrate integrated waveguide for 24GHz traffic monitoring. In order to make antenna convenient to work for traffic monitoring, we make the main beam steering replacing the conventional mechanical down dip.

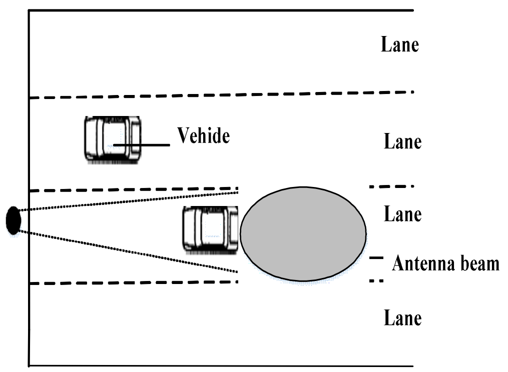

Fig. 1. Traffic monitoring radar antenna

Recently, the substrate integrated waveguide slot array antennas have obtained attention [3]-[5]. The features of SIW slot array antennas make it possess a broad application prospect in the field of microwave millimeter wave. In [3], the designed antenna achieves beamforming with cosecant squared pattern. In [4], a design method based on the Method of Least Squares is presented for the traveling wave SIW slot array antenna. It could extend to nonuniformly spaced slots with good impedance match. In [5], It achieves 10° beam steering that the traveling wave slot array on cylindrical substrate integrated waveguide when frequency swept from 24 to 26GHz. In this paper, a SIW traveling wave slot array antenna is designed for traffic monitoring and simulated (Ansys HFSS) in good agreement.

II. ANTENNA DESIGN AND ANALYSIS

A SIW traveling wave linear array consisting of sixteen elements slots is designed. The geometry of slot element and its dimensions are shown in Fig. 2. The parameters of SIW are as follows: a=6.5mm, p=1.2mm, d= 0.8mm. x is the distance from the center of slot is the distance of the slot. L is the slot length. The geometry of the SIW linear array is shown in Fig. 3.

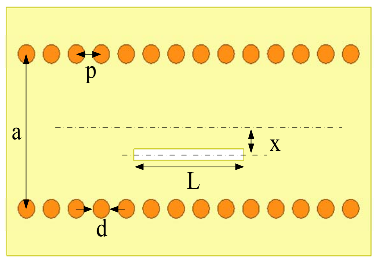

Fig.2.Geometry of slot element

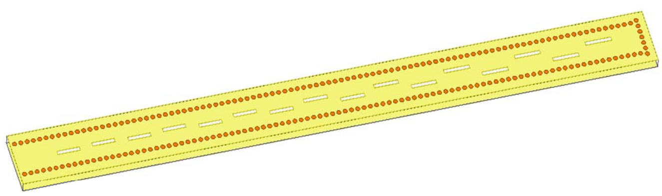

Fig.3. SIW longitudinal slot linear array

The radiating amplitude distribution of 16 cell slots is calculated by Chebyshev distribution. The radiating amplitude from the feed port to the short circuit port are as follows: [0.6123 0.4407 0.5675 0.6919 0.8050 0.8985 0.9652 1 1

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0.9652 0.8985 0.8050 0.6950 0.5675 0.4407 0.6123]. The conductance distribution of each element is calculated [6] as

$$C_n = \frac{f_n^{\,2}}{f_{n+1}^2 + f_{n+2}^2 + \ldots + f_N^2} \tag{1}$$

where f_n is the radiating amplitude of the nth element. The conductance distribution of each slot is as follows: [0.0410 0.0217 0.0374 0.0588 0.0864 0.1207 0.1618 0.2102 0.2662 0.3298 0.4001 0.4730 0. 5371 0.5660 0.5180]. In order to make the traveling wave energy radiate as much as possible in the last slot, the last slot is regarded as the radiation slot [6] to achieve traveling wave in the SIW array antenna. The width of these slots is 0.2mm. The distance D of adjacent element slots can be calculated by

$$\theta = \arcsin(\lambda / \lambda_g - \lambda / 2D) \tag{2}$$

where the working wavelength λ of SIW is 12.5mm and the waveguide wavelength λ_g is 10.13mm. In order to make the main beam steering $\theta = 20°$, the distance of elements slots D is 6.77mm. The parameters of slot element are optimized. In Fig. 2, the slot x (unit mm) are as follows: [0.217 0.119 0.179 0.246 0.317 0.391 0.469 0.550 0.636 0.729 0.830 0.938 1.038 1.074 0.970 0.950]. The slot length L (unit mm) are as follows: [4.322 4.304 4.313 4.331 4.358 4.395 4.443 4.500 4.568 4.646 4.734 4.823 4.896 4.848 4.919 4.950]. The antenna is designed on a F4B substrate with dielectric constant of 2.65 and thickness of 1.5 mm.

A 1×4 T-shaped power divider is designed according to the reference [7]. The linear array is fed and connect with the designed power divider. The overall structure of the 4×16 SIW slot traveling wave array antenna is shown in Fig. 4.

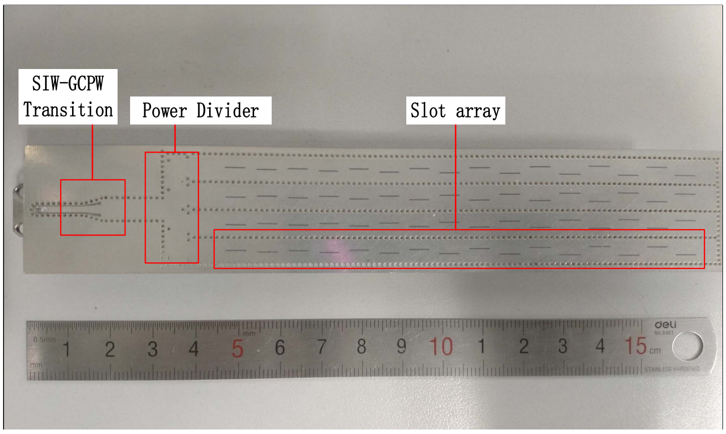


Fig.4. 4× 16 SIW slot array

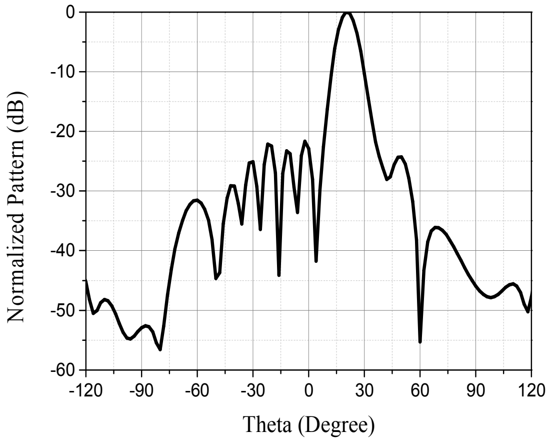
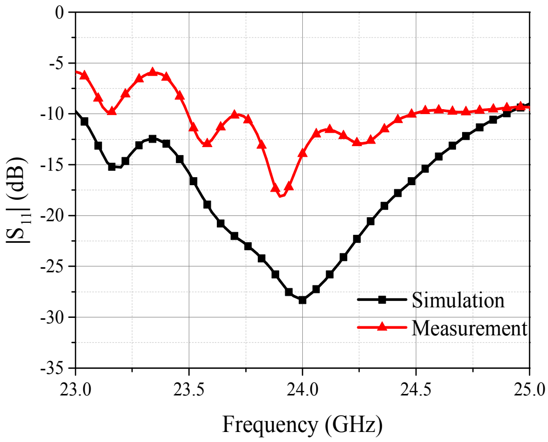
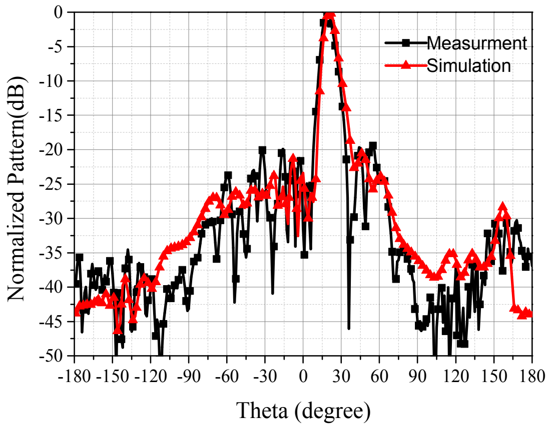


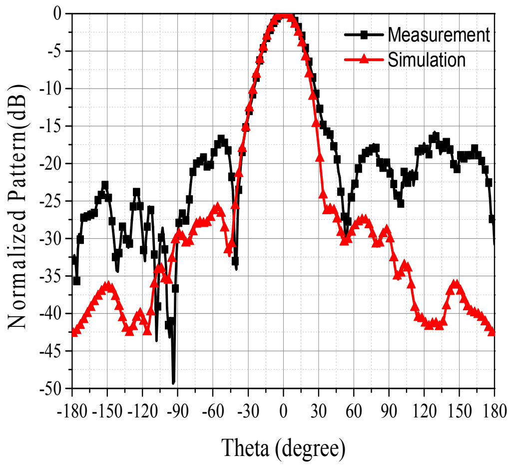
Fig.5. SIW linear array radiation pattern



(a)



(b)



(c)

Fig.6. 4×16 SIW slot array simulation and measurement results (a) S11 (b) pitch plane radiation pattern (c) horizontal plane radiation pattern

III. RESULTS AND DISCUSSIONS

Fig. 5 shows the SIW linear array radiation pattern. It can be clearly seen that 3dB beam width of the designed 16 elements SIW slot linear array is 7 ° and side lobe level (SLL) is -21dB. The main beam points at an angle of 20°.

In Fig. 6, the measurement results of 4×16 SIW slot traveling wave array shows that the impedance bandwidth of S11 is 23.5GHz~24.5 GHz. The 3dB beam width of the pitch plane is 8.5 ° and the side lobe level is -19dB. The maximum gain is 17.5dBi at 24GHz. The measurement result shows that the main beam points at an angle of 21°. The 3dB beam width of the horizontal plane is 30° and the SLL is -17dB. The results of measurement fit with the simulation. The antenna results achieve the design requirements and have sufficient impedance bandwidth, which is suitable for traffic monitoring in intelligent transportation system.

IV. CONCLUSION

A 4×16 SIW traveling wave slot array is presented for traffic monitoring. The SIW slot array antenna is designed to operate in the 24GHz. Through above description, we know the designed antenna achieve 20° beam steering and could be well work for traffic monitoring.

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