A Novel SIW Slot Antenna Array Based on Broadband Power Divider

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***Abstract*- A novel substrate integrated waveguide (SIW) slot antenna array is proposed in this paper. The array, based on SIW scheme, consists of one compact SIW 4-way power divider and 4 radiating SIWs each supporting 4 radiating slots. The 4-way power divider uses the self-compensating phase shift technique, which can make the feeding network operate over a broadband. Comparing with conventional SIW slot antenna arrays, this array has simple structure and broadband bandwidth. The antenna array is fabricated and the measured results are in agreement with the simulated ones. A relative bandwidth over 10% is achieved with return loss below -10 dB.**

I. Introduction

Waveguide longitudinal slot array antennas are widely applied in radar and communication systems featuring high gain, high efficiency, low cross-polarization levels and great capability of accurate control of the radiation patterns.

However, classical rectangular waveguide is costly, heavy, and bulky. In order to eliminate the mentioned drawbacks and make integration with planner circuits possible, substrate integrated waveguide (SIW) as a preferred choice over the classical rectangular waveguide has been proposed and design [1]. Actually, SIW has been proposed to design many high-quality microwave and millimeter wave components because of its advantages of low profile, low insertion loss, low interference and easiness of integrating with planar circuits. Many types of SIW slot antenna arrays have been extremely investigated in recent years [2]-[4]. The feeding networks of SIW slot antenna arrays usually consist of multilevel T-junctions or Y-junctions. As using parallel feeding and multilevel structure, with the increase of output branches, these feeding networks become more and more complex to design. To overcome this drawback and design feeding networks with compact and simple structure is an important issue for SIW slot antenna arrays. In [2], a compact SIW 12-way power divider is used as feeding network for 12 radiating SIWs. This power divider is compact because it is divided into 12 ways directly. However, it only can keep in phase in a narrow bandwidth, so the operation bandwidth of the whole SIW array antennas has been limited. In [5], an alternate phase SIW power divider is proposed. Alternate phase technique and in series structure are used to make the power divider compact. Since SIW is a dispersive guided-wave structure, the effective bandwidth is also narrow.

In this paper, a novel 4-way power divider is proposed. The power divider uses alternate phase technique to make structure compact. Besides, self-compensating phase shift technique is used to make the feeding network operate over a broadband. Based on this broadband feeding network, a 4×4 SIW slot antenna array is design. Comparing with conventional SIW slot antenna arrays, this array has simple structure and broadband bandwidth.

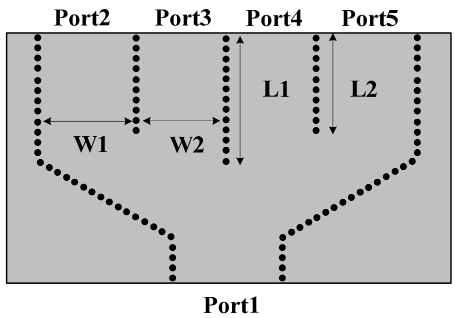


Fig. 1 Geometry of the proposed 4-way power divider.

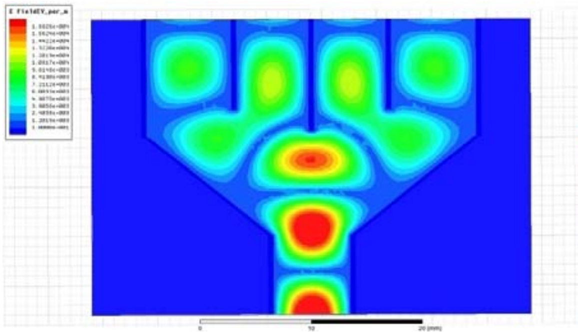


Fig. 2. E-field distribution of the proposed 4-way power divider.

II. Design Of The Antenna

The geometry of the proposed 4-way power divider is shown in Fig. 1. Using tapered transition without multilevel structure, the input port splits into 4-way output ports directly, hence the power divider becomes compact. Besides, this power divider does not need metalized via holes to adjust the magnitude and phase of output ports. Through adjusting the parameters of **L1** and **L2**, power equality can be achieved. The E-field distribution is shown in Fig. 2. The adjacent output ports, port2 and port3 (accordingly, port4 and port5), are spaced by a half guided wavelength, so there exists an alternating-phase of 180^0. Since SIW is a dispersive guided-

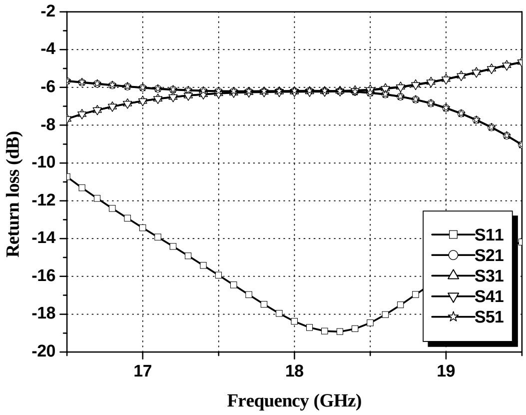


Fig. 3. Simulated S-parameter of the network.

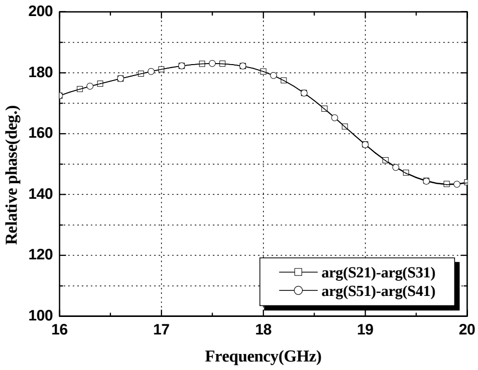


Fig. 4. Simulated phase difference of the network.

wave structure, the phase difference can only keep 180^0 in narrow bandwidth.

In order to broaden the bandwidth of the feeding network, self-compensating phase shift technique is used. In [6], a concept and mechanism of phase compensation combining delay line and equal-length unequal-width phaser is proposed, which can make the phase shift almost constant over a very wide band. As shown in Fig. 1, the length and width of SIW output branches is different. Though tuning the parameters of **L1**, **L2**, **W1**, **W2**, the phase difference between port2 and port3 (accordingly, port4 and port5) can keep 180^0 in a wide bandwidth.

Fig. 3 depicts the characteristic of S parameters after optimization. The power equality for S_{n1} (n=2, 3, 4, 5) is -6 dB ±0.5 dB in 17.1-18.9 GHz. The return loss is better than -10 dB over the frequency band from 16 to 20 GHz. The results of phase difference between port2 and port3 (accordingly, port4 and port5) are shown in Fig 4. The phase difference is 178^0 $\pm 5^0$ from 16.1 to 18.4 GHz covering a 12% relative bandwidth.

Based on this broadband feeding network, a 4×4 SIW slot antenna array is design. The geometry of the proposed antenna array is shown in Fig. 5. The feed consists of a 50 Ω microstrip line with a tapered transition to provide impedance

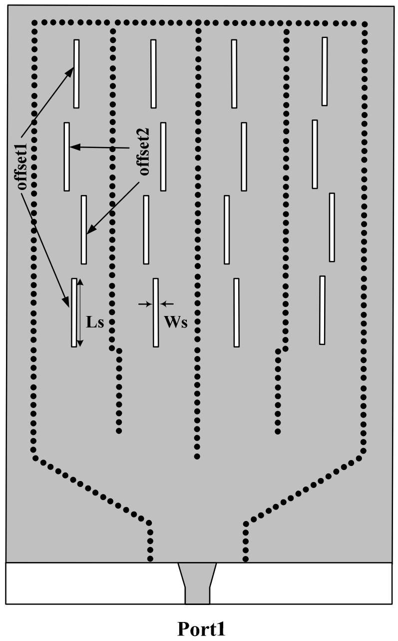


Fig. 5 Geometry of the antenna array.

TABLE I
PARAMETERS OF THE STRUCTURE

L1	L2	W1	W2
11.4mm	8.5mm	8mm	7mm
Ls	Ws	offset1	offset2
7.2mm	0.22mm	0.13mm	0.4mm

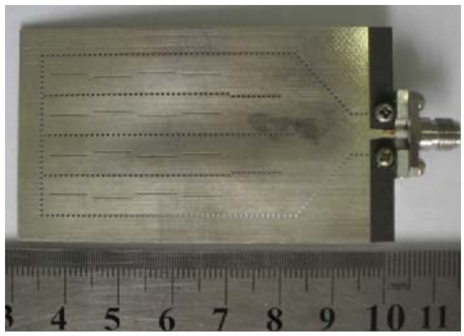


Fig. 6. Photograph of the antenna array.

matching between the microstrip and SIW. The 4-way SIW power divider is to feed 4 linear SIW slot arrays, and each of them carries 4 radiation slots etched on the broad wall of SIW. The SIW structure is terminated with a short-circuit quarter guided wavelength beyond the centre of the last radiation slot. In order to allocate the slots at the standing wave peaks and excite all the slots with the phase condition, the slots in a linear array are placed half a guided wavelength at the required centre frequency and the adjacent slots have the opposite offset with respect to the SIW centre line. The slots lengths are half a wavelength in the free space to ensure good radiation. The width of radiation slot should be much smaller

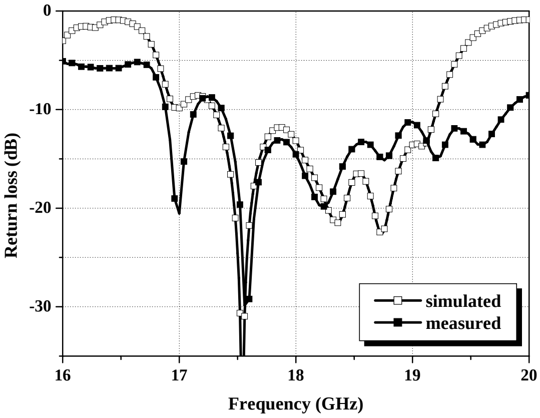


Fig. 7. The simulated and measured return loss of the antenna array.

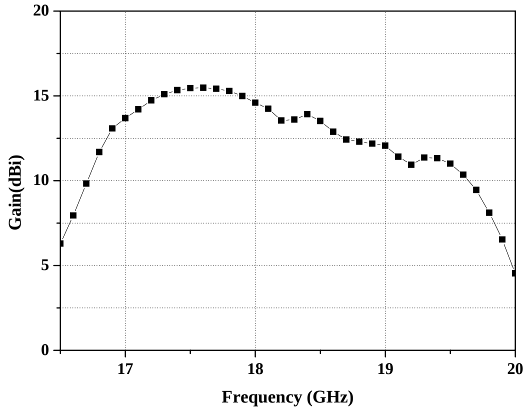


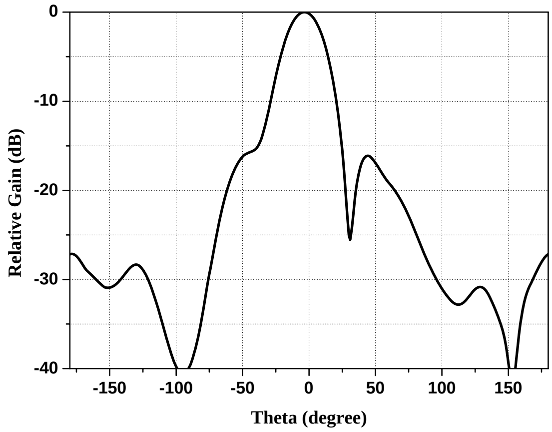
Fig. 8. The simulated gain of the antenna array.

than the slot length, usually between one tenth and one twentieth of the slot length. Because the radiating SIWs are excited with alternating-phase of 180^0, in order to keep 4 linear SIW slot antenna arrays in phase, the offset of slots following port2 and port3 (accordingly, port4 and port5) need to be set opposite.

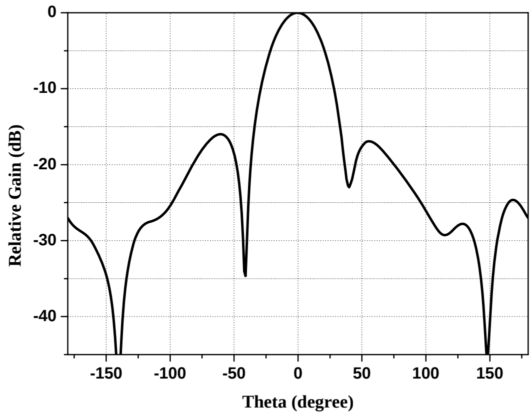
Simulated and Experiment Results

After optimization with Ansoft HFSS, the geometry parameters for the array are listed in Table I. A Rogers-Duroid 5880 high-frequency substrate with thickness h=0.5mm, ε_r =2.2, tan δ =0.0009 is used in our experiments. According to the optimized simulation parameters, we fabricate and measure the antenna array. Fig. 6 shows photograph of our proposed array.

Fig. 7 depicts simulated and measured return loss of the antenna array. The measured results follow the trend of the simulated ones well. The simulated return loss below -10 dB is from 17.3 GHz to 19.2 GHz, while the measured result is from 17.4 GHz to 19.8 GHz. The measured impedance



a. E-plane



b. H-plane

Fig. 9 The simulated normalized radiation patterns of the array at 17.5 GHz

bandwidth reaches up to 13%, which is two times more than that of traditional SIW slot antenna array.

Fig. 8 shows the simulated gain of the proposed array at the boresight direction. We can observe that the simulated gain is above 12.5dBi from 16.8 GHz to 18.7 GHz and the peak gain can reach up to 15.5 dBi at 17.5 GHz. The normalized simulated radiation patterns in E-plane and H-plane of the array at 17.5 GHz are plotted in Fig. 9. Their 3 dB beamwidths in E-plane and H-plane are about 29^0 and 33^0. The sidelobe levels (SLLs) are below -16 dB in the E-plane and below -17 dB in the H-plane.

Conclusion

A novel substrate integrated waveguide (SIW) slot antenna array is proposed. The array consists of a broadband SIW 4-way power divider and 4 radiating SIWs each supporting 4 radiating slots. The 4-way power divider uses the self-compensating phase shift technique, which can make the feeding network operate over a broadband. Comparing with conventional SIW slot antenna arrays, this array has simple structure and broadband bandwidth.

REFERENCES

[1] K. Wu, D. Deslandes, and Y. Cassivi, "The substrate integrated circuits—a new concept for high-frequency electronics and optoelectronics," in *Proc. 6th Int. Conf. Telecommunications Modern Satellite, Cable Broadcasting Service (TELSIKS'03)*, vol. 1, Oct. 1-3, 2003, pp. P-III-P-X.

[2] Xiao-Ping Chen, K. Wu, Liang Han, and Fanfan He, "Low-Cost High Gain Planar Antenna Array for 60-GHz Band Applications," in *IEEE Trans. Antennas Propag.*, vol. 58, No. 6, Jun. 2010, pp. 2126-2129.

[3] J. F. Xu, W. Hong, P. Chen, and K. Wu, "Design and Implementation of Low Sidelobe Substrate Integrated Waveguide Longitudinal Slot Array Antennas," in *IET Microw. Antennas and Propag.*, 2009, vol. 3, pp. 790-797.

[4] Y. J. Cheng, Wei Hong, and Ke Wu, "94 GHz Substrate Integrated Monopulse Antenna ArraY," in *IEEE Trans. Antennas Propag.*, vol. 60, No. 1, Jan. 2012, pp. 121-129.

[5] Bing Liu, Wei Hong, Zhang-cheng Hao, and Ji-xin Chen, "Alternate Phase Substrate Integrated Waveguide (SIW) Power Divider," in *Acta Electronica Sinica*, vol. 35, no.6, pp. 1061-1064, Jun. 2007.

[6] Y. J. Cheng, W. Hong, and K. Wu, "Broadband Self-Compensating Phase Shifter Combining Delay Line and Equal-Length Unequal-Width Phaser," in *IEEE Trans. Microw. Theory Tech*., vol. 58, no.1, pp. 203-209, January. 2010.