Proceedings of ISAP2016, Okinawa, Japan

Research on a Novel Balanced Antipodal Vivaldi Antenna for MMW Imaging System

Wang Nannan, Fang Mu, Du Tianyao, Qiu Jinghui, and Alexander Denisov
Harbin Institute of Technology, Harbin, China, 150080

Abstract **- A novel balanced antipodal Vivaldi antenna (BAVA) with asymmetric substrate cut-out and tapered slot edge (TSE) is designed to be used as a sensor for a MMW imaging system. Research on these novel features is demonstrated to enhance the gain by an average of 2dB over a band of 10-40GHz and greatly reduce the beam-tilting at E plane, which is considered to be the major defect of conventional BAVA. Furthermore, the new antenna has much lower side lobes than the conventional one, which enables this antenna to be used in an H-plane array structure. The simulated reflection coefficient is found to be less than -12 dB over a frequency range of 10-40 GHz. And the extremely wide band can fulfill the potential of higher range resolution for MMW imaging system.**

Index Terms **— BAVA, asymmetric, cut-out, tapered slot edge.**

1. Introduction

Millimeter-wave (MMW) imaging is now widely used for concealed threat detection. High resolution of this system requires a wide frequency bandwidth.

Vivaldi [1] is one of the best candidate for UWB applications with its large bandwidth and high directive pattern whereas the E-field is skewed severely at the high frequency causing a poor cross-polarization.

The balanced antipodal Vivaldi antenna [2] provides a much lower cross-polarization and balanced H-plane radiation pattern that make the antenna more suitable for its intended use in a phased array environment. However, the major deficiency of BAVA is its squint beam over upper working frequencies at E-plane [3].

In this paper, a BAVA with new features is designed to eliminate the shortcoming and improve the radiation characteristics of conventional BAVA that meet the basic requirements of MMW imaging system.

2. Antenna Design

(1) BAVA

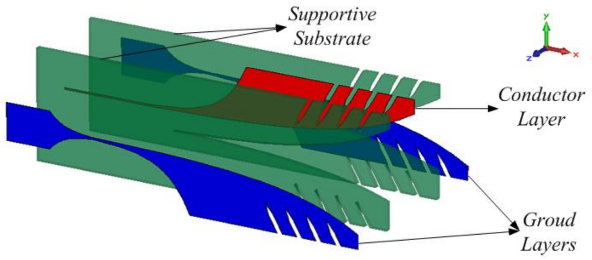

Fig. 1. Exploded view of the novel BAVA construction.

The BAVA is composed of three copper layers and two dielectric substrates (supportive substrates) as is shown in Fig. 1. The corresponding dimension is 79.9×24mm^2.

Fig. 2 illustrates the configuration and parameters of the presented antenna and the optimized values of the parameters are listed in Table I.

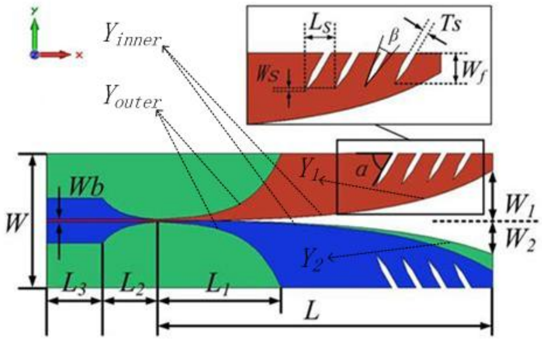

Fig. 2. Configuration and parameters of the antenna.

The inner and outer edges of the radiation flares fit the following exponential curves:

$$\begin{cases} Y_{inner} = \pm[-W_b + (W_b/2)\exp(p_1 x)] \\ Y_{outer} = \pm[(W_b/2)\exp(p_2 x)] \end{cases}$$

Two supportive substrates are made of Rogers RT5870 with relative permittivity of 2.33, thickness of 0.254mm and loss tangent of 0.0012.

TABLE I
Geometrical Parameters of the Novel BAVA

Dimension Parameters (mm)						Tapering Ratio		Angles	
W	24	W_f	4.7	L	59.9	p_1	0.0642763	α	60°
W_1	9	W_S	0.2	L_1	22	p_2	0.157475	β	20°
W_2	7.5	T_S	1	L_2	10	p_3	0.0591145		
W_b	0.7	L_S	4.6	L_3	10				

(2) Asymmetric substrate cut-out

The asymmetric cut-out is defined by the following curves (in the similar form with Y_{inner}):

$$\begin{cases} Y_1 = +[-W_b + (W_b/2)\exp(p_1 x)] \\ Y_2 = -[-W_b + (W_b/2)\exp(p_3 x)] \end{cases}$$

(3) Tapered slot edge (TSE)

The TSE is not merely applied to the copper layer but the substrates too, which means both the two substrates are also cut out in the profile of TSE.

The simulations and optimization were performed with the CST Transient Solver.

3. Result and Discussion

In order to classify the effects of these new features, we give a comparison among conventional BAVA, BAVA with symmetric cut-out (BAVA-C) and BAVA with asymmetric cut-out and TSE.

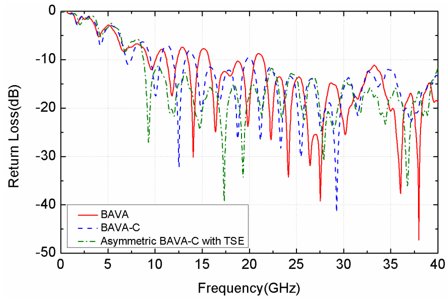

Fig. 3. Simulated S_{11} of BAVA, BAVA-C, and Asymmetric BAVA-C with TSE

Simulated S_{11} are given in Fig. 3. The lower limit frequency is reduced from 22 to 8 GHz benefiting from the tapered slot edge and substrate cut-out in TSE profile.

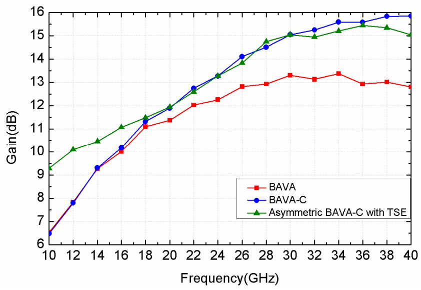

Fig. 4. Simulated gains of BAVA, BAVA-C, and Asymmetric BAVA-C with TSE

Fig. 4 shows the simulated gains for the three antennas. The gains improvement promoted by substrate cut-out is significant over upper working frequencies by an average of 2dB, but one side-effect cannot be ignored that the E-plane side lobe level increases in the band of 10-22 GHz (Fig. 5.).

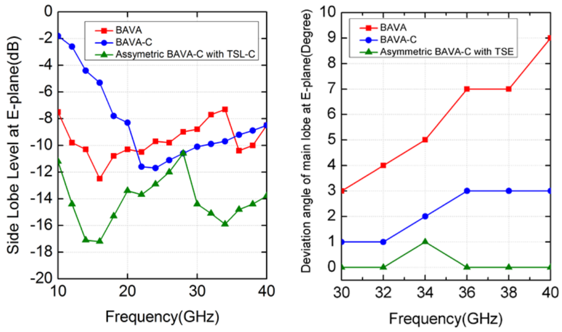

Fig. 5. Simulated SLL (left) and deviation angle of main lobe (right) at E-plane of BAVA, BAVA-C, and Asymmetric BAVA-C with TSE

The tapered slot edge provides gain improvement at low frequencies (10-15GHz) while at the same time maintaining its radiation characteristics at upper frequencies. Furthermore, SLL at E-plane is reduced greatly compared with BAVA-C and the sidelobe behavior is even better than the conventional BAVA in the whole working band.

The symmetric substrate cut-out has markedly reduced the beam-tilting at upper frequencies and the asymmetric cut-out makes a further improvement that deviation angles of main lobe at 30, 32, 34, 35GHz are reduced to zero which is illustrated in Fig. 5 and fig. 6.

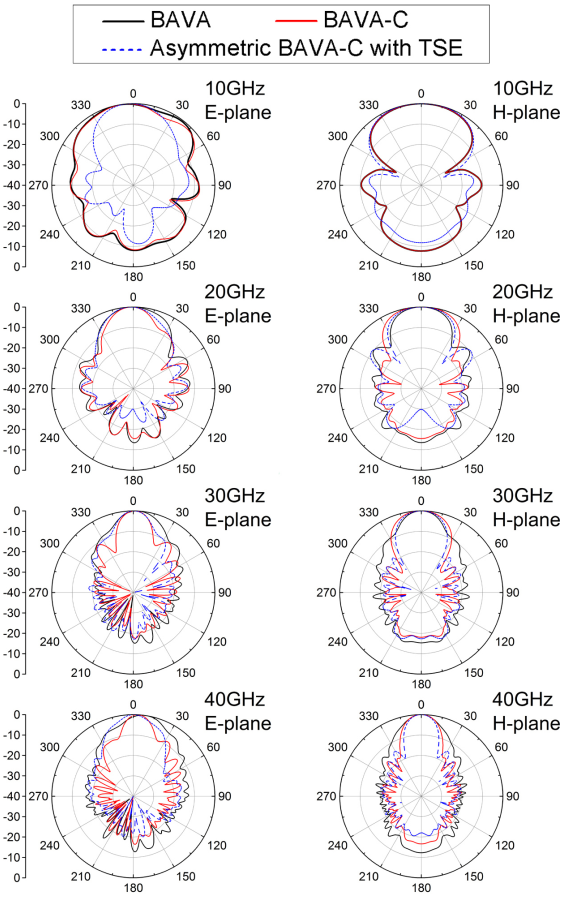

Fig. 6. Simulated radiation patterns of BAVA, BAVA-C, and Asymmetric BAVA-C with TSE at 10, 20, 30, 40GHz

4. Conclusion

A BAVA with asymmetric substrate cut-out and TSE working at 10-40GHz has been designed and simulated which effectively negates the major defect of conventional BAVA and improves the radiation performance while keeping the basic advantages of BAVA. It is noticeable that no additional components are needed hence controlling the cost and complexity of fabrication.

The suitable characteristics make the antenna an excellent option for MMW imaging system.

References

[1] P. J. Gibson, "The Vivaldi aerial," in *Proc. 9th Eur. Microw. Conf.*, 1979, Brighton, U.K., pp. 101-105.

[2] J. Langley, P. Hall, and P. Newham "Novel ultrawide-bandwidth Vivaldi antenna with low crosspolarization," *Electron. Lett.*, vol. 29, no. 23, pp. 2004-2005, 1993.

[3] Ali Molaei, Mohsen Kaboli, Seyed Abdullah Mirtaheri, Mohammad S. Abrishamian, "Dielectric lens balanced antipodal Vivaldi antenna with low cross-polarisation for ultra-widebandapplications," *IET Microwaves, Antennas & Propagation.*, vol. 8, pp. 1137-1142, 2009.