On the Integration Method of Low Profile and Wide Beam Scanning Phased Array

Guang Li, Fu-Shun Zhang
National Key Laboratory of Antennas and Microwave Technology
Xidian University
Xi'an, Shaanxi 710071, China
liguang0929@foxmail.com

***Abstract*—In this paper, a novel low profile and wide beam scanning phased array on the integration method, is proposed. This integration method is the combination of a slat array, which consists of Vivaldi patch antenna elements, and the feed network in a tile architecture. Based on the integration method, a low-profile 6×6-elements phased arrays with a wide beam scanning at X band is designed and fabricated. Simulations and measurements show that the total size of Φ139.5mm×81.5mm (Φ4.65 λ×2.7 λ, λ is the free-space wavelength at the center frequency), and 45° beam scanning in elevation plane can be achieved. The VSWR ≤2.5 and the gain of ≥10 dBi are obtained in measurement.**

Keywords—phased arrays; Vivaldi array; beam scanning; low-profile

I. Introduction

Phased arrays with electronic steering are always of some special category and interest. For phased arrays, two configurations are utilized in the design of the perspective model[1-2], one way is based on slat array configuration, another way is tile array configuration. The antenna array referred to a slat array in [3], which has the advantage of low insertion, uncomplicated processing and commonly applied in the wideband system. A tile architecture is involved in [4-5], which has the advantage of low profile and highly integration.

For phased arrays antenna application, antennas should be of small size and light weight. Moreover, beam width and frequency bandwidth of antenna element should be wide. Since Gibson proposed the tapered slot antenna [6], Vivaldi antenna has a key role for phased arrays with its characteristics of small size, wide bandwidth, good efficiency and gain properties.

On the consideration of ensuring electrical performance and reducing size, this paper proposed the integration method for 6×6-elements two-dimensional beam scanning phased arrays. The measure results show the total size of Φ136mm×82 and 45° beam scanning in elevation plane can be achieved. The VSWR ≤2.5 and the gain of ≥10 dBi are obtained in measurement.

Details of the integration method and measured results are described in section II, III. The conclusions are reported in section IV.

II. The Integration Method Design

The integration method consists of a slat antenna array of 6×6 Vivaldi patch antenna elements and a tile architecture of the feed network. The integration configuration is in Fig. 1.

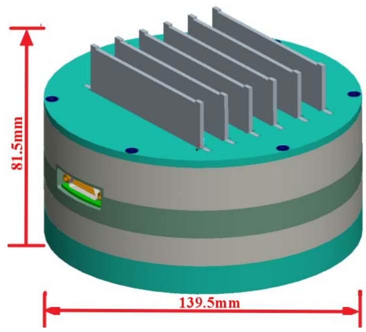
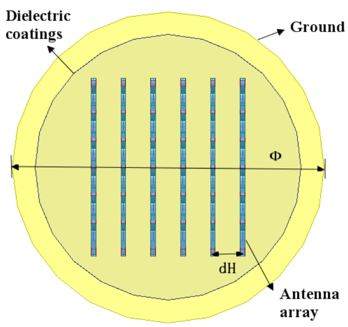


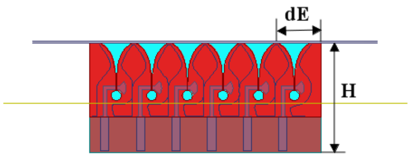
Fig. 1. Integration configuration of phased array

A. Slat Vivaldi Antenna Array

The slat Vivaldi antenna array is a square array, comprised by 36-element Vivaldi patch antenna elements. The array placed vertically in the mental ground of diameter Φ=139.5 mm. The array element spacing is dE=12 mm and dH=13mm in E plane and H plane, respectively. The height of antenna array is H=39.65 mm. Top view and side view of simulated model of slat Vivaldi antenna array can be seen in Fig. 2 (a) and (b) respectively.



(a)



(b)

Fig. 2. Slat Vivaldi antenna array construction. (a) Top view (b) Side view

Simulated results of beam width, gain and side lobe level (SLL) of the slat Vivaldi antenna array in normal direction is shown in Table I.

TABLE I. SIMULATED RESULTS OF ANTENNA ARRAY

Frequency	E-Plane			H-Plane		
	Gain	*Beamwidth*	*SLL*	*Gain*	*Beamwidth*	*SLL*
8GHz	16.6	29	-13.4	16.6	24	-13.2
10GHz	18.8	22	-12.8	18.7	20	-13.6
12GHz	20.5	16	-14.3	20.5	16	-13.3

The manufacture antenna is fabricated on a 1mm FR4 substrate having relative dielectric constant of 2.65. In order to maintain the distance between antenna elements, antenna array is placed on a metal plate. But this metal plate also have ground plane effect that will disturb the radiation pattern of antenna array. So position of ground plate is also optimized to achieve good results. Hence ground plane causes increase in gain and reduction of back lobe level of antenna array. Fabricated antenna is shown in Fig. 3.

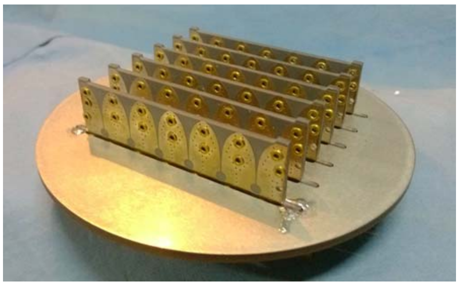


Fig. 3. Fabricated slat Vivaldi antenna array

B. Tile Phased Array System

The tile phased array consists of antenna array, feed network and beam controller. The structure of the tile phased array with 36 radiating elements is shown in Fig. 4.

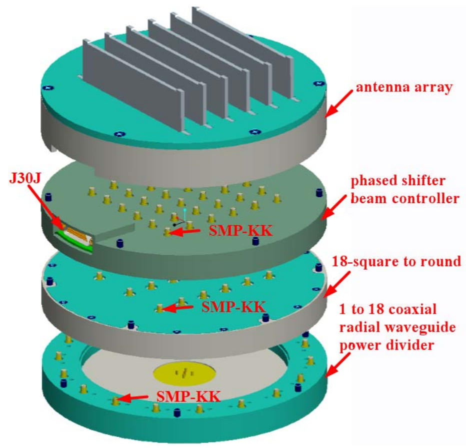


Fig. 4. Architechture of the tile phased array

III. MEASURED RESULTS

When RF signals of same power level and phased are applied to all 36 elements of the phased array, it will radiate in normal direction. Fig. 5 shows the active VSWR of the phased array in normal direction.

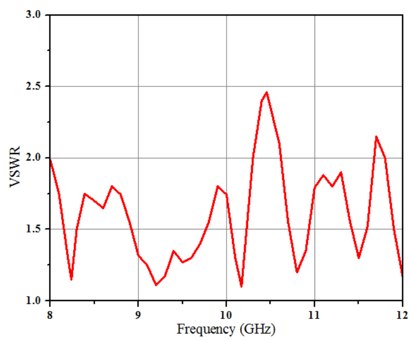
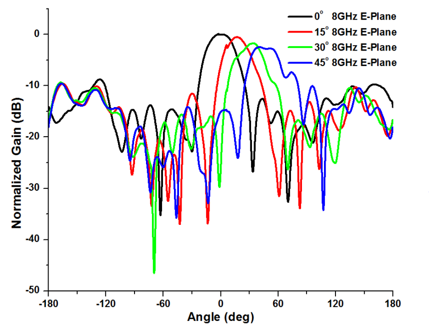
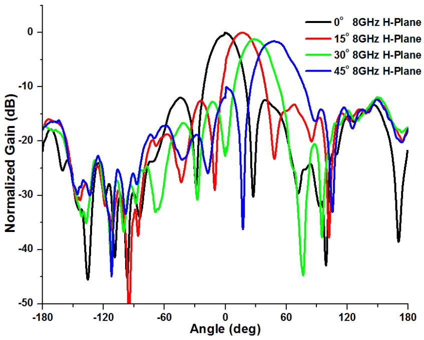


Fig. 5. Measured active VSWR of tile phased array

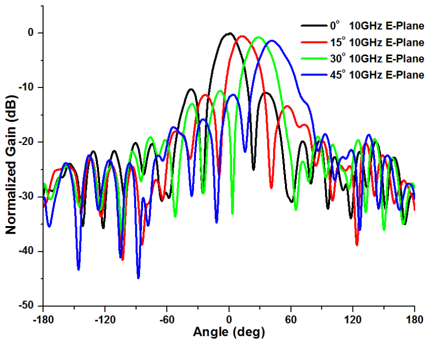
For electronic beam scanning, there must be phase difference between antenna elements. 6 bit digital phase shifter is connected with each antenna element of 6×6 antenna array. By controlling the phase shifter, phase shift of required value is applied between antenna elements. Hence beam scanning is achieved. Fig. 6 shows the measured beam scanning pattern.



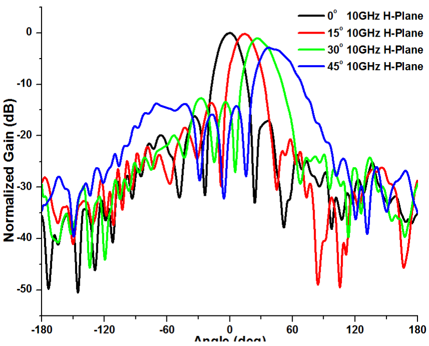
(a) 8GHz E-Plane



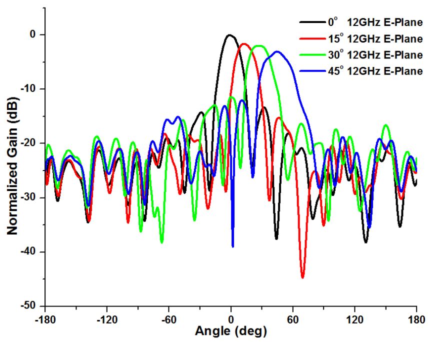
(b) 8GHz H-Plane



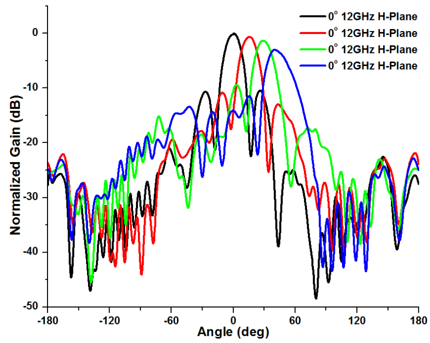
(c) 10GHz E-Plane



(d) 10GHz H-Plane



(e) 12GHz E-Plane



(f) 12GHz H-Plane

Fig. 6. Measured beam scanning pattern of phased array

Measured results of phased array show side lobe level of around 10dB which is closer to the theoretical results of antenna array when antenna elements are fed with same power level and phase.

IV. Conclusion

On the integration method of low profile and wide beam scanning phased array is proposed. Phased array fulfills the requirements of input VSWR, low profile and 45° beam scanning in elevation plane.

References

[1] Jeffrey S. Herd and M. David Conway, "The Evolution to Modern Phased Array Architechtures," Proceedings of the IEEE. Vol. 104. 2016.

[2] Jeffrey S. Herd and S. M. Duffy, "Overlapped digital subarray architecture for multiple beam phased array radar," Proc. 5th Eur. Conf. Antennas Propag.(EUCAP), Rome, Italy, Apr. 2011.

[3] Junaid Tahir, "Design of 4×4 Antenna Array for Actively Electronic Scanned Array Radars," Proceedings of 2018 IBCAST. January, 2018.

[4] Shashi Sanzgiri, "A Hybrid Tile Approach for Ka Band Subarray Modules," IEEE Trans. on Antennas and Propagation. Vol. 43. 1995.

[5] Erik Lier and Dan Purdy, "Study of Deployed and Modular Active Phased Array Multibeam Satellite Antenna," IEEE Antennas and Propagation Magzine, Vol. 45, No. 5, October, 2003.

[6] Gibson. P. J. "The Vivaldi aerial," Proceedings 9th Eur. Microwave Conference, June, 1979.