A Low-profile, Decade Bandwidth, Tightly-Coupled Vivaldi Phased Array

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***Abstract* - For the conventional tightly-coupled Vivaldi antenna array, the high profile limits its application on compact system. In this paper, a novel low profile tightly-coupled Vivaldi phased array is presented. It can reduce the height by 60% while maintaining the same operating frequency band and wide scan performance. Twin flared notches and U-shaped polls are the main methods to achieve the low profile structure. A single layer dielectric radome is also employed for better impedance match. The antenna unit is fed directly by a 50Ω stripline. Simulation results show that the low profile antenna array achieves a 10:1 bandwidth (1.8-18 GHz) and scans up to 30°.**

***Index Terms* — Vivaldi, low-profile, wideband, phased array.**

1. Introduction

There is an increasing demand for wideband electronically scanned array to integrate antennas for different applications. Tightly-coupled Vivaldi array is widely used because it can achieve more than 10:1 bandwidth and 45° scanned range[1,2]. However, its height for more than $\lambda_{low}/4$ (λ_{low} is the wavelength of the lowest frequency) may restrict its application in modern low-profile systems. Conventional tightly-coupled Vivaldi array is designed with substrate permittivity ε_r=6 and fed by stripline[1]. In order to meet the low profile requirement, an unconventional "BAVA" array was designed[3,4]. This kind of array covers decade bandwidth with active VSWR<2.75 and the profile is only $\lambda_{high}/2$ (λ_{high} is the wavelength of the highest frequency). This is a meaningful job but if measured with typical demand (VSWR<2), the bandwidth is rather narrow and the performance even decays when scanning.

In this paper, a novel method to lower the profile of traditional tightly-coupled Vivaldi array is discussed. This array shows the similar height with "BAVA" antenna while maintaining the active VSWR<2 over decade bandwidth (1.8-18 GHz). Section 2 focuses on the antenna structure and the methods of reducing profile. The performances of this novel array are given in section 3.

2. Low-profile Vivaldi array

The antenna consists of three layers: two layers of metal fins (radiator) and the central layer is a stripline connected to the feeding device.

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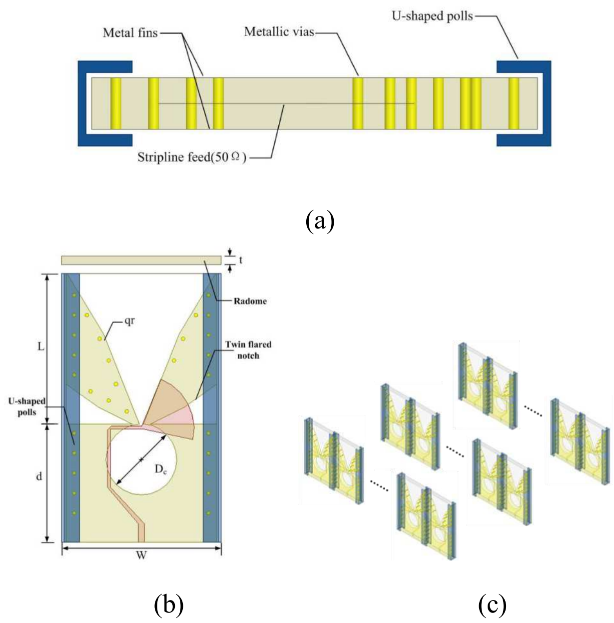


Fig.1 Configuration of the low-profile antenna (a) end view (b) front view (c) array configuration

The antenna element configuration is presented in Fig.1(a)(b). The whole dimension of the antenna unit is 8.3mm (wide) ×14.8mm (long) × 0.96mm (thickness). Profile height is 40% of the conventional design (over 40mm). The antenna is constructed using a substrate (permittivity ε_r=5.9). Some detailed sizes are shown in Table. I. This design also allows for modular fabrication of antenna elements which can reduce the processing difficulty.

A twin flare notch is firstly cut on metal fins and simulations show that the exponential rate should be consistent with the original one. This contributes to the performance of the higher frequency. As reported in reference [5], U-shaped metal polls cancel out inductive effect that limits the operating band in lower frequency. A modified metal poll is applied here which is easy to manufacture. Note that slots in metal polls should not touch the radiator directly and this demands for a solder mask to wrap the antenna unit. It is known that multiple layers of dielectric can help improve the impedance matching[6]. To further improve the performance, a single sheet of dielectric with the thickness of *t* covers the aperture with the same permittivity ε_r=5.9. Metallic vias are inserted between two metal fins to eliminate the scan blindness in E-plane.

Compared with the conventional design, length of the metal fins in this paper is reduced from 37.5mm to 8.3mm (only $\lambda_{high}/2$). This is a hard job because the performance of the lower frequency performance is achieved via the coupling between the units. The coupling decreases once the length is reduced.

TABLE I
Detail sizes of antenna units

L	*d*	*w*
8.3 mm	6.5 mm	8.3 mm
t	*Dc*	*qr*
0.45 mm	1.95 mm	0.2

3. Simulation results

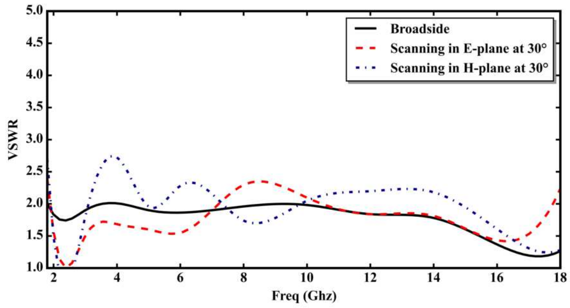
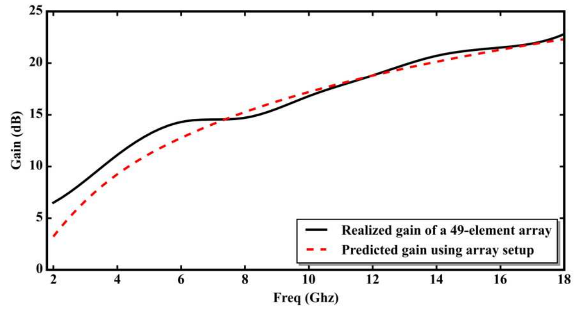
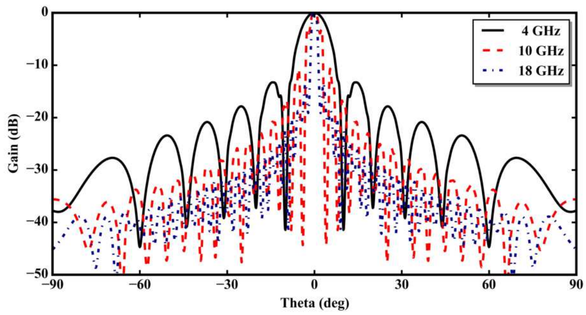


Fig.2 Active VSWR of the low-profile array at different scan angles



(a)



(b)

Fig.3 Radiation performance of a 49×3 array in E-plane (a) Realized gain (b) Radiation pattern at different frequency

Unit cell method in HFSS is suitable to predict the unit performance in an infinite array. An antenna element using this method and an array for validation are simulated in this section. The array configuration is presented in Fig1.(c).

Fig.2 shows the active VSWR of antenna unit in broadside and E-plane scanning. With the typical bandwidth measurement of VSWR<2, the operating range is 1.8-18 GHz which covers 10:1 bandwidth. The array can scan up to 30° (VSWR<2.4 in E-plane and VSWR<2.7 in H-plane). The original Vivaldi array achieves this target (VSWR<2.7) within the scanning range up to 45°. Considering the advantage of structure size, this performance loss is acceptable.

It is proved that size of the array should be more than $2.67\lambda_{low}$ to satisfy the infinite condition and this means an array needs at least 49 elements in one dimension. A 49×3 array is simulated in CST to validate the above structure. Realized gain and radiation pattern at different frequency are presented in Fig.3. As shown in the figure, the realized gain is close to the predicted gain using array setup in HFSS. This indicates that the radiation performance does not become worse when the profile gets lowered.

4. Conclusions

A tightly-coupled Vivaldi phased array with low profile is designed in this paper. Based on the remarkable previous research on wideband Vivaldi phased array, this paper explores the potential to reduce its profile height. With the technique of twin flared notch and metal U-shaped polls, antenna height decreases to 40% of the original design. Simulation results show that the bandwidth performance remains 10:1 range and the maximum scan angle is 30°. The radiation performance is also similar to the predicted result.

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