UWB Vivaldi Array Using Frequency Selective Surface for Low RCS Applications

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Abstract –**In this paper, an ultra-wideband (UWB) Vivaldi array with low radar cross section (RCS) is presented. An UWB band-stop frequency selective surface (FSS) is introduced to replace the metal reflect board of the array so that the RCS of the antenna can be reduced in a wide frequency band while the radiation performances of the antenna are maintained. The proposed array operates over the frequency band between 5GHz to 12GHz. The results show that the RCS of the proposed Vivaldi array can be reduced effectively by using the UWB FSS.**

Index Terms —**Radar cross section, frequency selective surface, ultra-wideband, Vivaldi array**

1. Introduction

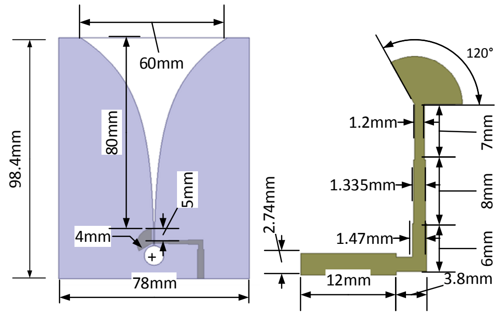
Vivaldi antenna has been widely used in UWB system since it was proposed by P. J. Gibson in 1979 [1].As a linearly polarized antenna, Vivaldi antenna has the features of high gain, simple structure and small size [2] .Based on its outstanding advantages, Vivaldi antenna is one of the best candidates unit for high-performance phased array system. Although Vivaldi antenna has a low RCS, but still cannot meet the needs of the low visible platform design.

In recent years, the RCS reduction of stealth platform has drawn more and more attention with the rapid development of stealth and detection technology. As we all knows, antennas play a major role in contributing to the overall RCS Of target objects such as airborne platform and naval ship. In order to reduce the RCS of Vivaldi antenna, many methods have been proposed [3].FSS as a two-dimensional periodic structure, itself does not absorb energy, but it can have the effect of filtering, is essentially a spatial filter. In decades, the application of FSS structures have been explored widely, such as wireless communication, Millimeter-Wave filter, multi-band antenna, while the research on the RCS reduction of UWB array is relatively limited.

This paper introduces an UWB Vivaldi antenna with a microstripe-to-slotline transition, which feed the slot-line and improve the impedance characteristics. To get a better directivity and high gain, a linear 1×4 Vivaldi array with reduced RCS is proposed. An UWB FSS is designed to realize RCS reduction.

2. Vivaldi array and FSS Design

A planar printed Vivaldi antenna is deigned and the geometry is shown in Fig. 1. The dielectric constant and thickness of the substrate is 2.65 and 1mm, separately. The proposed antenna consists of two symmetrically exponential tapered patches and a feeding transition structure, which can excite the tapered patch and realize a good impedance-matching with a 50Ω feeding cable. The feeding transition is illustrated in Fig.1 (b). The feeding structure consists of a Chebyshev four-section transformer and a radial stub which is used to achieve a wider bandwidth.



(a) (b)

Fig.1. (a) Top view of the Vivaldi unit, (b) Structure of the feeding transition.

The proposed Vivaldi antenna unit is used to compose a linear 1×4 array. Fig.2 shows the structure of the UWB array, where the element distance equals to L1=16mm. All of the element is fed in the same amplitude and phase. To reduce the back radiation and realize a better directivity, a reflect board (100mm×100mm) is placed under the array. The reflect board is a square metal sheet which is printed on a FR4 dielectric substrate (thickness h=3mm).The distance between the metal sheet and the array is set as L2=9mm.

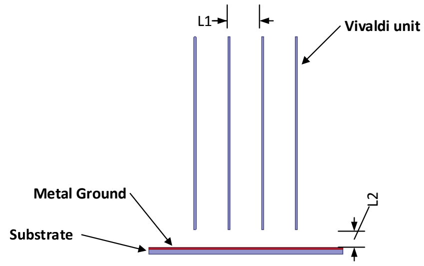
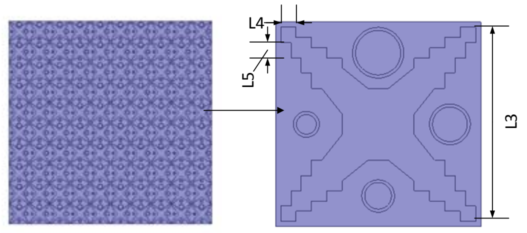


Fig.2 Front view of the reference array

In order to maintain a low RCS level out of the working band, a UWB band-stop FSS is introduced [4]. The stop band of the FSS is designed from 5GHz to 12GHz, which is consistent with the operating frequency band of the proposed array. The low RCS array is proposed by replacing the metal reflect board with the FSS in same size and remaining other parts of the reference array unchanged. Fig. 3 shows the configuration of the FSS.



(a) (b)

Fig.3. (a) FSS ground. (b) The dimension of the FSS unit

As shown in Fig. 3 (b), the FSS unit consists of a toothed cross structure and four metal rings. The toothed cross structure can provide new resonance points to make better transmission characteristics. Four metal rings are designed in order to improve the band-stop performance. The parameters are set to be L3=9.5mm, L4=0.75mm and L5=0.75mm。The inside diameters of the four rings are 1.1mm, 0.85mm, 0.6mm and 0.35mm, respectively.

3. Performance of low RCS array

The S21 of the FSS illuminated by incident wave in various theta is shown in Fig.4. It can be seen that the S21 is lower than -6dB in the frequency band of 5GHz-12GHz, which is coincide with the bandwidth of the proposed array. Fig .5 shows the radiation patterns of the proposed array and reference array at 9GHz. It can be obviously seen that the reference array and the proposed array have relatively stable radiation patterns.

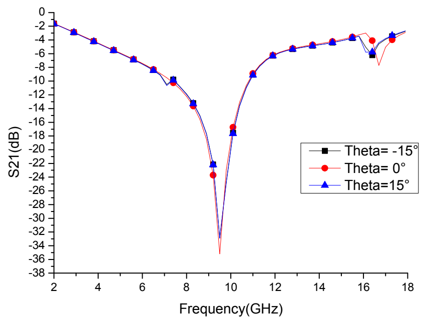
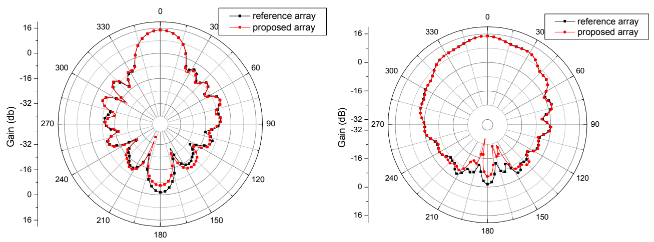


Fig.4 The S21 of the FSS



(a) 9G H-plane (b) 9G E-plane

Fig.5.Comparison of radiation pattern of both array in 9GHz.

In Fig.6, we can see that the gain of the two arrays keep relatively the same trend against frequency. Fig. 7 shows the comparison of RCS for reference antenna with proposed antenna in the case of the incident wave angles θ=0°, φ=0°.The RCS of the proposed antenna is reduced in the frequency ranges of 2.5GHz to 5GHz and 12GHz to 17GHz.The maximum reduction is 7dBsm at 16.4GHz.

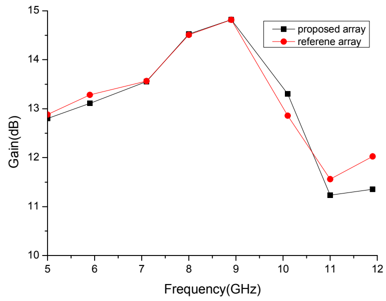


Fig.6.The gain of the reference and proposed array

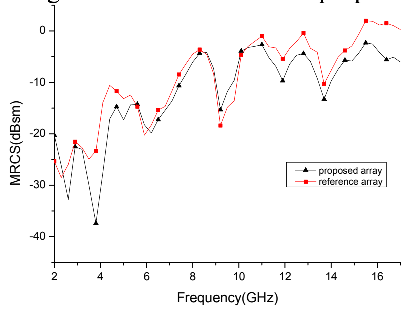


Fig.7 The RCS of the reference and proposed array

4. Conclusion

An ultra-wideband (UWB) Vivaldi array with reduced RCS is proposed by replacing the metal ground with a UWB band-stop FSS. The results show that the RCS of the array can be reduced efficiently in a wide frequency band while the radiation performance change little .The maximum RCS reduction is 7dBsm. The proposed Vivaldi array is a good alternate for using in a low-observation platform.

Acknowledgment

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