SRR-loaded Antipodal Vivaldi Antenna for UWB Applications with Tunable Notch Function

Debdeep Sarkar [#1], Kumar Vaibhav Srivastava [#2], *Member, IEEE*

[#] *Department of Electrical Engineering, Indian Institute of Technology, Kanpur*

[1] debdeep1989@gmail.com

[2] kvs@iitk.ac.in

***Abstract*— This paper presents design of a novel compact UWB antipodal Vivaldi antenna, where band-notch characteristics within 5-6 GHz frequency range is achieved by placing a parasitic rectangular SRR near the radiating arm, in order to reduce electromagnetic interference with IEEE 802.11a and HIPERLAN/2 systems. Simulation results show that the proposed antenna provides wide impedance band-width with satisfactory rejection in the desired band along with good gain and stable radiation pattern in the rest of the UWB regime.**

I. INTRODUCTION

Design of Ultra-Wideband (UWB) antennas for state-of-the-art wireless communication has drawn the attention of researchers since FCC first approved the rules for the commercial utilization of the unlicensed 3.1-10.6 GHz frequency band [1]. Various UWB antenna topologies have been proposed in order to overcome the challenges of achieving good impedance matching and radiation stability within compact size and low manufacturing cost [2-3]. Among them, antipodal Vivaldi antennas (AVA) are attractive choice due to their broad impedance bandwidth, symmetric end-fire beam and ease of implementation in planar PCB technology [4-6].

Electromagnetic Interference (EMI) due to the existing narrowband communication systems like WiMAX, WLAN (IEEE 802.11a, HIPERLAN-2) and X-band systems is one of the major concerns for UWB antenna engineers. Instead of using additional band-stop filters (which would increase antenna-footprint) for providing the desired notch-band, the approach of embedding different-shaped slots (C-shaped, H-shaped) in the radiator or ground plane of the antenna, acting as intrinsic filters, have become very popular in the antenna community [7-8]. Meta-resonators like complementary split-ring resonators (CSRRs) have also found application in design of UWB antennas with multiple notch-bands [9].

This paper proposes a novel compact AVA where the notch-band in the 5-6 GHz band is achieved by properly placing a single rectangular split-ring resonator (SRR) in vicinity of the radiating arm of the antenna. The SRR acts as a sub-wavelength resonator (size: $\lambda/10$-by-$\lambda/12$ with respect to the notch frequency) and produces the desired band-rejection in the IEEE 802.11a and HIPERLAN/2 WLAN frequencies along with stable far-field radiation pattern in the radiating band.

The paper is organised as follows. In section-II, design of the reference AVA is presented. In section-III, the comparison of the proposed and reference AVA are shown, which is followed by concluding discussions in section-IV.

II. DESIGN OF REFERENCE UWB AVA

The geometry of the reference balanced antipodal Vivaldi antenna is shown in Fig.1. The tapered radiation structure is designed from the intersection of two quarter-ellipses according to the principle followed in [5].

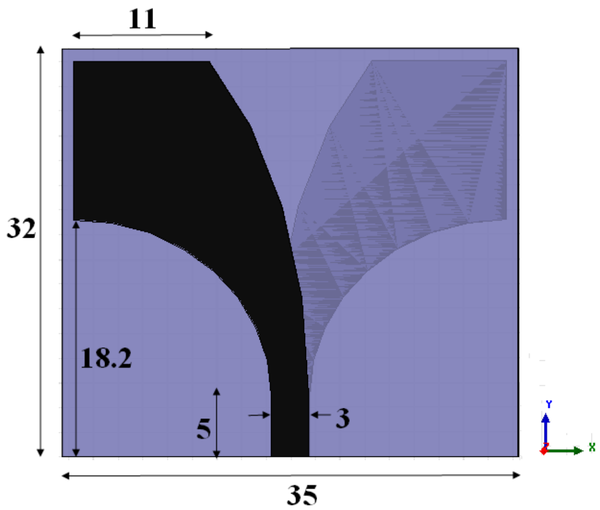

Fig. 1. Geometry of the balanced antipodal Vivaldi antenna which uses design principle in [5] (unit: mm)

Metallization is provided symmetrically on both sides of the 1.6 mm thick FR-4 epoxy substrate (dielectric constant = 4.4, loss tangent *tan* δ = 0.02) as is evident from Fig. 1. FEM-based commercial electromagnetic simulator HFSS is used for simulation of the antenna. It is found from simulation-results that the antenna provides good impedance bandwidth matching (VSWR < 2) over the UWB frequency range (3.1-10.6 GHz) along with good far-field gain.

III. DESIGN OF SINGLE BAND-NOTCHED UWB AVA: RESULTS AND COMPARISON

A. Dimensions and Positioning of Parasitic Split-Ring Resonator

The frequency response of a rectangular split ring resonator (SRR) placed in microstripline environment is studied by principle adopted in [10] for different structural parameters (length and width of split-rings, ring-spacing, split-gap dimensions). To provide the desired notch-band, the rectangular SRR is placed near one radiating arm of the reference AVA as a parasitic element. The dimensions of the SRR (as shown in Fig. 2) are chosen such that its fundamental resonance frequency lies in the middle of WLAN frequency band (5.15-5.85 GHz).

Next the SRR position is varied to find out where the best band-notch characteristics in the desired frequency range is achieved without disturbing the impedance matching in other frequency bands. Fig. 3 shows VSWR plots of the antenna for the positions of the SRR with respect to the AVA. It is observed that for position-1, the band rejection is not at all satisfactory. For position-3, although we get band-rejection in desired WLAN range, impedance-matching deteriorates for higher frequency. Hence for the proposed SRR-loaded AVA, position-2 is chosen as optimum (Fig. 4).

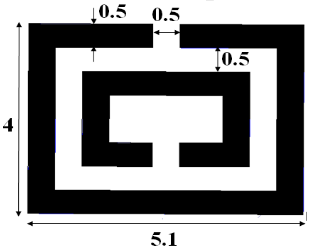

Fig. 2. Dimensions of the rectangular SRR used as parasitic element (unit: mm)

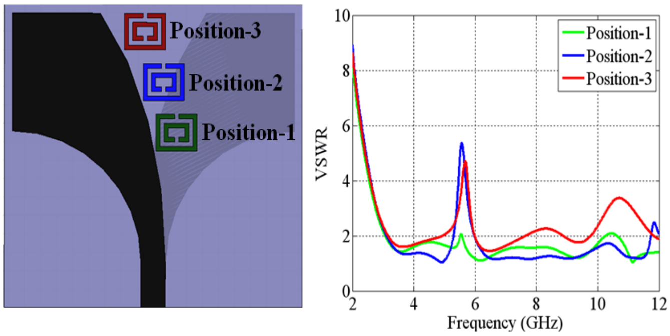

Fig. 3. Plot of VSWR of the band-notched antenna with respect to the frequency for three different positions of the SRR

B. Performance of single SRR-loaded AVA

The variation of VSWR with frequency for the proposed AVA as well as the reference antenna as shown in Fig. 1 is illustrated in Fig. 5. It is observed that the proposed antenna has impedance band-width (3.1-11.4 GHz) covering the entire UWB spectrum along with the notch band in the frequency range (5.15-6.07 GHz) which encompasses the upper-WiMAX/WLAN band. The maximum band-notch is achieved at 5.55 GHz (VSWR=6.399).

Fig. 6 shows the comparison of peak realized far-field gain of the proposed and reference antenna in the range 3-11 GHz. It is seen that the gain-plot of the proposed antenna closely follows that of the reference UWB antenna, except the desired notch band where a strong dip is observed.

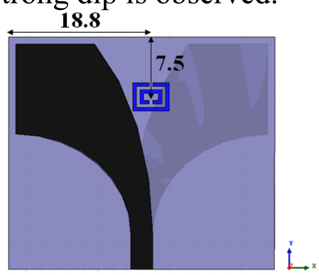

Fig. 4. Proposed band-notched AVA with optimized SRR dimension and position (unit: mm)

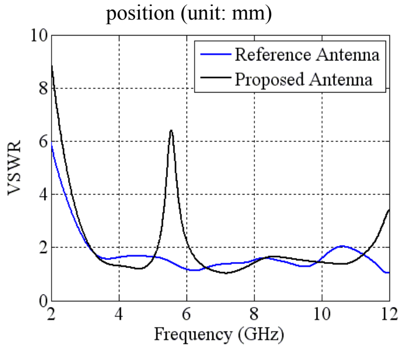

Fig. 5. VSWR versus frequency plots of the proposed antenna and the reference antenna

Fig. 7 shows the vector-plot of the surface current distribution on the radiating arms of the antenna as well as the SRR at three frequencies, the middle one being the notch frequency at 5.55 GHz to give an insight into the radiation-mechanism and the band-rejection principle of the proposed AVA. Strong surface-current density on the SRR, which acts as a high Q-resonator at the notch frequency 5.55 GHz, compared to that on the radiating arms suggest the reason for non-radiating behaviour of the proposed AVA in the desired notch band.

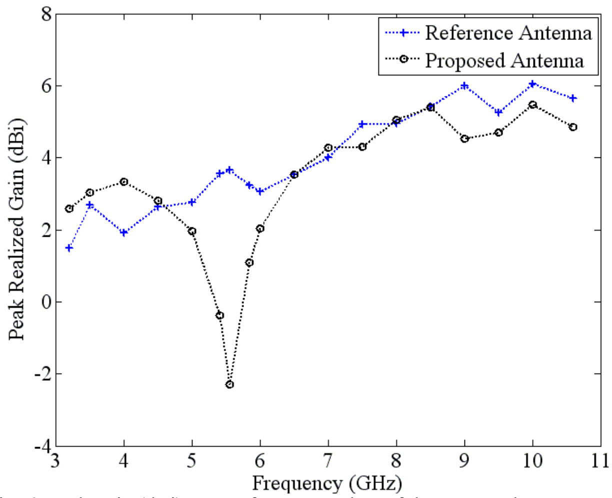

Fig. 6. Peak-gain (dBi) versus frequency plots of the proposed antenna and the reference antenna

Fig. 8 and Fig. 9 respectively show the 3D-gain plots of the reference and proposed band-notched AVA at 4 GHz (below the notch frequency) and 8 GHz (above the notch frequency). It is evident that the far-field radiation pattern is not seriously affected due to the presence of the parasitic SRR.

C. Performance of identical antenna-pairs in far-field

To validate that the proposed antenna successfully blocks out the desired notch band, we perform the simulation of a transceiver antenna system, keeping the two identical antennas in far-field (distance between antennas = 90 mm). Fig. 10 shows the simulated magnitude (dB) and phase (in degrees) of the S_{21} for the two-antenna system. The magnitude of the transmission coefficient S_{21} (dB) shows a dip in the desired region. The variation of phase of S_{21} with frequency also implies the presence of notch-band.

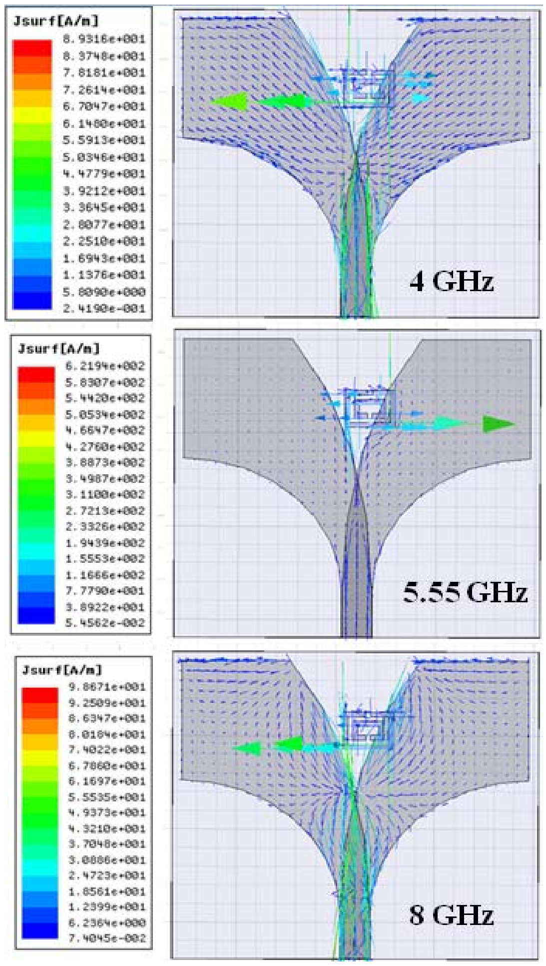

Fig. 7. Surface Current Distributions on the antenna conductors and SRR at three different frequencies

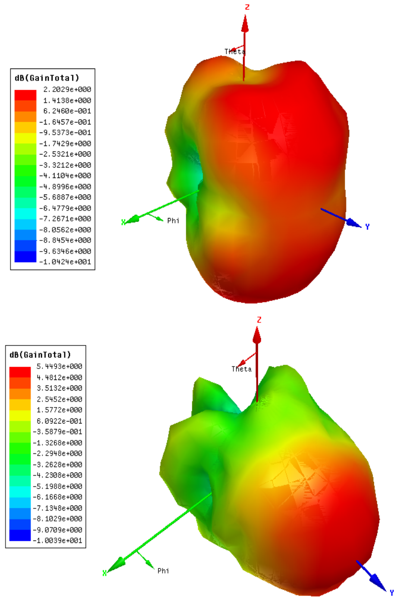

Fig. 8. 3D-gain plots of the reference AVA at 4 GHz (top) and 8 GHz (bottom) respectively

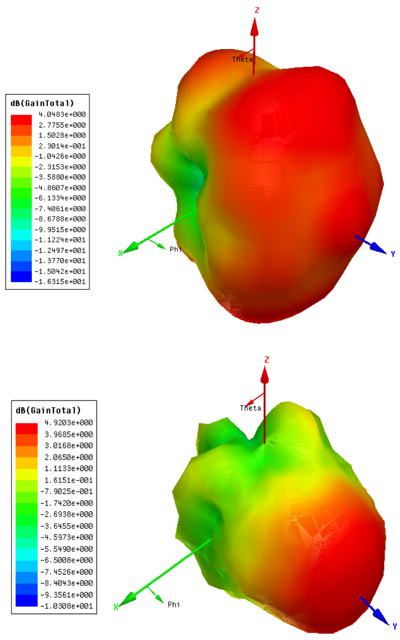

Fig. 8. 3D-gain plots of the proposed AVA at 4 GHz (top) and 8 GHz (bottom) respectively

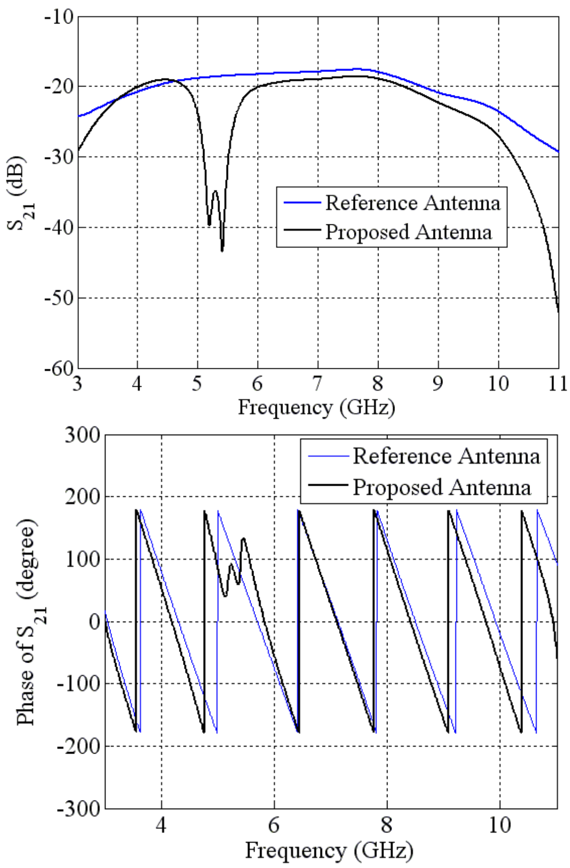

Fig. 10. Magnitude (dB) and phase (in degree) of S_{21} for two identical band-notched AVA placed in far-field region

IV. Conclusion

An SRR-loaded antipodal Vivaldi antenna having UWB characteristics with notch band in the 5-6 GHz frequency range has been designed. The impedance bandwidth and far-field behavior of the proposed antenna has been investigated by HFSS simulations.

The proposed antenna is low-profile and uses low-cost FR-4 substrate. To validate the simulation results, the antenna would be fabricated and tested in near future. Since the band-rejection property is achieved via the rectangular SRR element placed near the radiating arm of the antenna, it can be tuned by changing SRR dimensions and positions. Hence, multiple band-notched antennas for UWB applications can be designed using the principle used in this paper.

Acknowledgment

The authors would like to acknowledge all the members of the Microwave circuit and Microwave Metamaterials Laboratory (Department of Electrical Engineering, IIT Kanpur) for their inspiration and IIT Kanpur authority for the financial assistance.

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