

# Double-slot Antipodal Vivaldi Antenna for Improved Directivity and Radiation Patterns

Youngmin So<sup>1</sup>, Woojoong Kim<sup>1</sup>, Jaesik Kim<sup>1</sup>, Young Joong Yoon<sup>1</sup>, and Jinsung Park<sup>2</sup>  
<sup>1</sup>Department of Electrical and Electronic Engineering, Yonsei University, Seoul, Republic of Korea  
<sup>2</sup>Agency for Defense Development, Daejeon, Republic of Korea

**Abstract** – A conventional antipodal Vivaldi antenna has characteristics of multiple-octave operation bandwidth but also relatively low directivity, main beam offset direction and asymmetric radiation patterns with frequency variation. In order to improve the directivity and radiation patterns, a design of a double-slot antipodal Vivaldi antenna is proposed. It makes synthetic radiation patterns by complementary patterns of the double-slot structure. As a result, it has center-directional and symmetric radiation patterns. The proposed antenna has an operating frequency range of 2-18 GHz. Directivity of the proposed antenna is improved at high frequencies as compared the conventional antipodal Vivaldi antenna.

**Index Terms** — Double-slot structure, directivity, symmetric pattern, Vivaldi antenna

## 1. Introduction

The Vivaldi antenna, which was first proposed by Gibson in 1979 [1], is a classical end-fire traveling-wave antenna that has been widely used due to some features such as ultra-wide bandwidth, low profile, simple structure, and moderate directivity. However, its performances are still needed to be improved for symmetric radiation pattern, high directivity and side-lobe suppression. In addition, the main beams of a conventional Vivaldi antenna at high frequencies will split due to its thick dielectric substrates, leading to a reduction of the antenna gain and directivity [2]. In order to improve the gain and directivity, various methods are proposed such as array of Vivaldi antenna [3], employment of a director in the aperture [4], and using the zero index metamaterial (ZIM) unit cells [5]. However, they are complicated to construct and bulky. The double-slot co-planar Vivaldi antenna was proposed [6] for directivity improvement and elimination of the main beam splitting at high frequencies without increasing antenna dimensions and construction complexity. Nevertheless, it is waiting to overcome the operation bandwidth limitation by the transition from the feeding transmission line to the slot line of the antenna, which is a common characteristic of the co-planar Vivaldi antenna. To overcome bandwidth limitation by the feeding structure, the antipodal Vivaldi antenna (AVA) was proposed in 1989 [7]. The antipodal Vivaldi antenna, which is fed by a balun that is double parallel strip lines, has multiple-octave bandwidth performance but also main beam offset direction and asymmetric radiation patterns with frequency variation.

In this paper, the double-slot antipodal Vivaldi antenna (DsAVA) is proposed to improve the directivity and

radiation patterns over multiple-octave bandwidth. The proposed antenna has double-slot structure that makes center-directional and symmetric radiation patterns. Therethrough, the directivity of the proposed antenna is improved at high frequencies without increasing antenna dimensions.

## 2. Antenna Design

Fig. 1(a) shows the geometry of the double-slot antipodal Vivaldi antenna (DsAVA), and Fig. 1(b) shows the geometry of the conventional antipodal Vivaldi antenna (CAVA). Two antennas are designed on FR 4 substrate with the permittivity of 4.3 and tangent loss of 0.025, respectively. The design parameters of these antennas are listed in Table I. Two antennas have the same dimensions of 80 × 150 mm<sup>2</sup>. Each exponential curve profile of the DsAVA and CAVA is defined by the opening rate R and two points P<sub>1</sub>(x<sub>1</sub>, y<sub>1</sub>) and P<sub>2</sub>(x<sub>2</sub>, y<sub>2</sub>)

$$y = c_1 e^{Rx} + c_2 \quad (1)$$

Where

$$\begin{aligned} c_1 &= (y_2 - y_1) / (e^{Rx_2} - e^{Rx_1}) \\ c_2 &= (y_1 e^{Rx_2} - y_2 e^{Rx_1}) / (e^{Rx_2} - e^{Rx_1}). \end{aligned} \quad (2)$$

The concepts of the exponential curves described in [3].

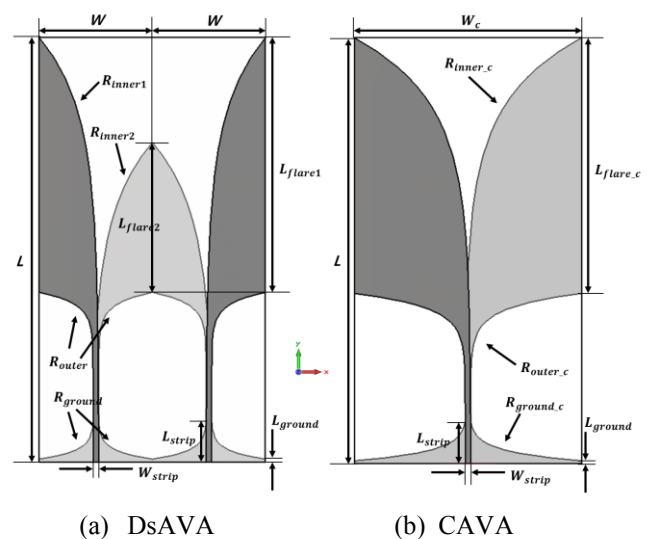


Fig. 1. Geometries of the simulated antennas

TABLE I  
Design Parameters of the Simulated Antennas

Parameters	Value	Parameters	Value
$W$	40 mm	$L_{ground}$	1 mm
$W_c$	80 mm	$R_{inner1}$	0.04
$L$	150 mm	$R_{inner2}$	0.04
$W_{strip}$	1.85 mm	$R_{inner\_c}$	0.045
$L_{flare1}$	90 mm	$R_{outer}$	0.25
$L_{flare2}$	53 mm	$R_{outer\_c}$	0.2
$L_{flare\_c}$	90 mm	$R_{ground}$	0.35
$L_{strip}$	15 mm	$R_{ground\_c}$	0.3

As shown in Figure 1(a), the DsAVA consists of two asymmetric antipodal slots and two feeders. The mirror-like two slots, which are complementary structure excited in inverted phase, will make cancelling of the radiation pattern at the center direction. In order to make the two slots be excited in uniform phase, the two feeders are excited in inverted phase as 0 degree and 180 degrees on simulation.

### 3. Results and Discussion

The proposed DsAVA and the CAVA are numerically tested on the CST Microwave Studio. As shown in Fig. 2, the simulated antennas are satisfied operating frequency range over 2-18 GHz. The DsAVA structure does not affect noticeably on the return loss characteristic of the CAVA. Fig. 3 shows comparison of the farfield radiation patterns for the DsAVA and CAVA at 2-18 GHz frequencies. As shown in Fig 3, the proposed DsAVA has center-directional and symmetric radiation patterns. Furthermore, the DsAVA eliminate the main beam splitting at high frequencies. It is observed from this figure that the double-slot structure makes the radiation patterns improved. From the directivity shown in Table II, we can observe the DsAVA has high directivity up to 5.3 dB at high frequencies resulted from improved radiation patterns as compared the CAVA.

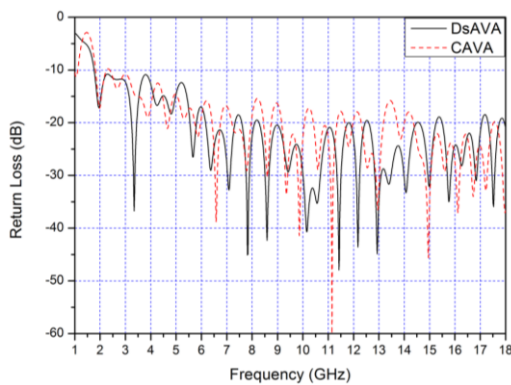


Fig. 2. Return loss of the simulated antennas

TABLE II  
Farfield Directivity of the Simulated Antennas (Theta=90°)

Frequency (GHz)		2	6	10	14	18
Directivity (dBi)	DsAVA	5.0	10.6	14.9	14.7	12.4
	CAVA	5.4	9.7	9.9	9.4	9.6

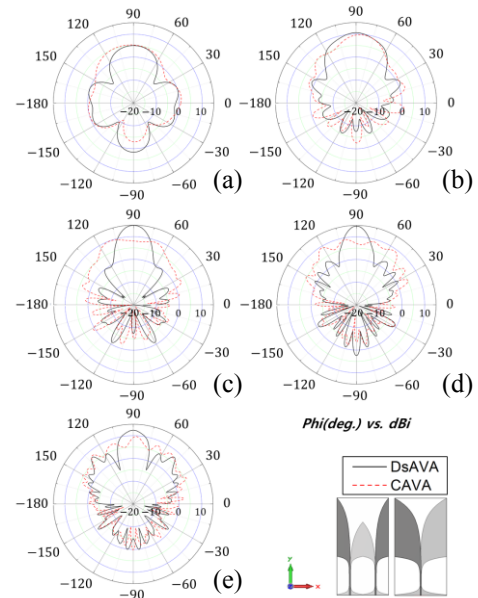


Fig. 3. Radiation patterns of the simulated antennas (Theta=90°)  
(a) 2 GHz (b) 6 GHz (c) 10 GHz (d) 14 GHz (e) 18 GHz

### 4. Conclusion

A conventional antipodal Vivaldi antenna has not only ultra-wide bandwidth but also low directivity with unwanted tilting and splitting beam pattern. In this paper, a novel double-slot antipodal Vivaldi antenna (DsAVA) is proposed to improve the directivity and radiation patterns of the conventional antipodal Vivaldi antenna. The double-structure makes the farfield radiation patterns center-directional and symmetric. Consequently, the directivity of the proposed antenna is improved up to 5.3 dB at high frequencies compared to the CAVA. Also, the operation bandwidth of the proposed antenna is wider than 2.5-15 GHz frequency range of the double-slot co-planar Vivaldi antenna [6].

### Acknowledgment

This work was supported by Agency for Defense Development, Korea.

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