Waveguide-fed Antipodal Vivaldi Antenna using an Antipodal Finline Transition

Ali Molaei*, Jose Martinez-Lorenzo*†
*Electrical & Computer Engineering, Northeastern University, Boston, MA, USA
†Mechanical & Industrial Engineering, Northeastern University, Boston, MA, USA

***Abstract*—In this paper, a new waveguide-fed Antipodal Vivaldi Antenna (AVA) for mm-wave imaging applications is presented. A waveguide-to-broadside coupled Antipodal finline transition is designed to couple the dominant mode of a WR-12 waveguide into the AVA. The transition provides a wideband and low insertion loss in the entire *E*-band. A dielectric lens is added in front of the AVA to increase the directivity in the endfire direction of the antenna. The performance of the designed antenna is evaluated in the *E*-band in terms of its return loss, gain, and radiation pattern.**

I. Introduction

Millimeter-wave imaging has been extensively investigated and utilized for different applications, such as security screening and interferometry sensing [1]. High bandwidth antennas are necessary for having high range-resolution for the aforementioned applications. The family of Vivaldi antennas are good candidates for high-resolution imaging applications, as they have a low profile, wide bandwidth, and directional broadband radiation pattern [2].

To integrate a planar Vivaldi antenna into a rectangular waveguide, a transitional stage is required. This transition could be in many forms depending on the feeding of the Vivaldi antenna. In [3], a compact waveguide-to-microstrip transition operating in the *X*-band is presented; however, the bandwidth of the transition is low (the 15-dB fractional bandwidth is 37.33%) and the insertion loss is high (larger than 10 dB) at the end of the *X*-band.

In this paper, a wideband and low loss waveguide-to-broadside coupled Antipodal finline transition is presented to feed an AVA. The performance of the waveguide-fed antenna is studied in the *E*-band, in terms of the antennas return loss, gain and radiation patterns.

II. Waveguide-to-Broadside Coupled Line Transition

The perspective view and top view of the presented transition are depicted in Fig. 1(a) and 1(b), respectively. The conductor strips on the top and bottom layers of the finline possess tapered exponential curves, (y_{ta} and y_{tf} in Fig. 1(b)), that merge into a broadside-coupled line outside of the waveguide. These exponential curves are described by the following equation [4]:

$$y_i = \pm(A_i e^{P_i(x-B_i)} + C_i). \quad (1)$$

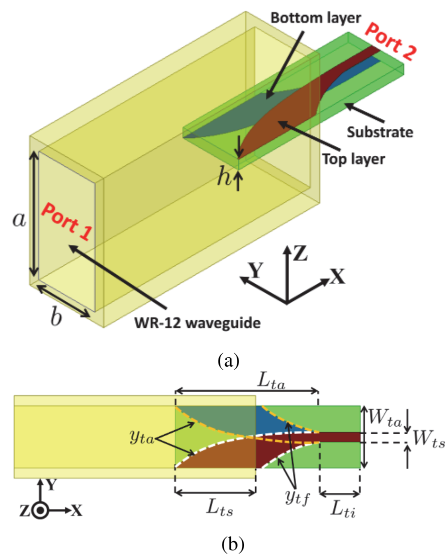


Fig. 1. (a) Perspective view and (b) Top view of the presented waveguide-to-broadside coupled line transition.

The transition transforms the high impedance of the dominant mode of the waveguide to a lower impedance. The proposed transition uses an RO3003 substrate with a relative dielectric constant of 3, a dielectric loss tangent equal to 0.0013, and a thickness of $h = 0.254$ mm. The transition is optimized to have the best performance in the *E*-band ($70-77$ GHz). The exponential equations of the optimized transition are the following: $y_{tf} = \pm(0.3e^{(-x-L_{ti})} + W_{ts}/2 - 0.3)$, and $y_{ta} = \pm(A_{ta}e^{0.2(-x-L_{ti})} - W_{ts}/2 - A_{ta})$, in which $A_{ta} = 0.5(W_{ta} + W_{ts})/(e^{0.2L_{ta}} - 1)$. Table I shows the assigned values of the remaining exponential parameters. The magnitude of S-parameters of the designed transition are presented in Fig. 2. The transition has a maximum insertion loss of 0.73 dB and a minimum return loss of 10 dB in the whole *E*-band.

III. Waveguide-fed Antipodal Vivaldi Antenna

Figure 3 shows the AVA and the transition. The broadside-coupled line of the transition extends for a short distance; and, then, the top and bottom strips flare out in opposite directions with exponential curves (y_a in Fig. 3(b)) to form the aperture of the antenna. A half elliptical dielectric lens, which has the same material property as that of the substrate, is added in front of the antenna's aperture. This dielectric lens acts as

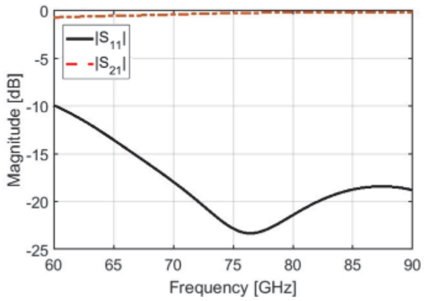
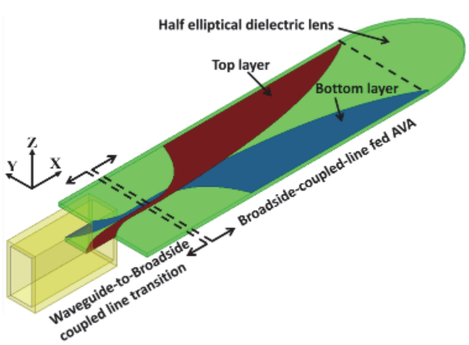
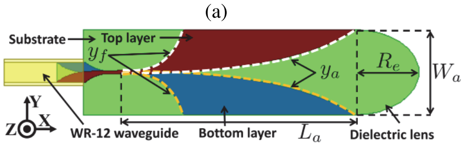


Fig. 2. Magnitude of S_{11} and S_{21} of the presented waveguide-to-broadside coupled antipodal finline transition.

a guiding structure; and it enhances the radiation pattern at the endfire direction [4], [5]. Table I shows the parameters of the design. The exponential tapers of the AVA follow the following equation: $y_f = \pm(0.23e^{0.77x} + W_{ts}/2 - 0.23)$ and $y_a = \pm(A_a e^{0.165x} - W_{ts}/2 - A_a)$, in which $A_a = 0.5(W_a + W_{ts})/(e^{0.165L_a} - 1)$. Return loss, gain, and radiation pattern of the designed antenna are studied to evaluate its performance. The integrated antenna with the transition has a return loss better than 10 dB for frequencies higher that 67.9 GHz, as shown in Fig. 4(a). The antenna has a gain varying from 11.2 dB to 14.5 dB through the *E*-band with the value of 13.7 dB at the center frequency (Fig. 4(b)). Finally, the E-plane and H-plane radiation patterns of the antenna are plotted in Fig. 5(a) and Fig. 5(b), respectively, for different frequencies. The E-plane patterns show side-lobe levels better than 10 dB for all plotted frequencies.



(a)



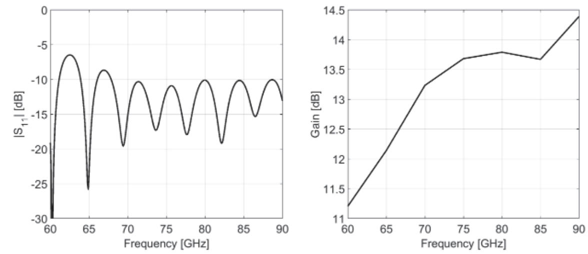
(b)

Fig. 3. (a) Perspective view and (b) top view of the waveguide-fed AVA.

TABLE I

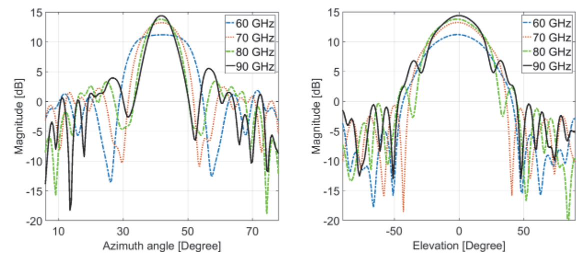
OPTIMIZED PARAMETERS OF THE TRANSITION AND VIVALDI ANTENNA.

PAR.	VALUE	PAR.	VALUE	PAR.	VALUE
a	1.55 *mm*	L_{ti}	1 *mm*	L_a	18.1 *mm*
b	3.09 *mm*	L_{ta}	3.6 *mm*	W_a	6.4 *mm*
h	0.254 *mm*	W_{ta}	3.09 *mm*	R_e	4.93 *mm*
L_{ts}	2 *mm*	W_{ts}	0.24 *mm*		



(a) (b)

Fig. 4. (a) Magnitude of S_{11} and (b) gain of the designed antenna.



(a) (b)

Fig. 5. Simulated gain pattern of the antenna at (a) E-plane and (b) H-plane.

IV. Conclusion

In this paper, a wideband and low loss finline transition has been proposed to couple a WR-12 waveguide and an AVA antenna. Due to its large bandwidth, this waveguide-fed AVA can be used in high resolution mm-wave imaging applications. The proposed transition has a maximum insertion loss of 0.73 dB through the whole *E*-band. The waveguide-fed Vivaldi antenna has a gain of 13.7 dB at the center frequency of the *E*-band and a return loss better than 10 dB for frequencies higher than 67.9 GHz.

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