

Design of a Compact Tapered Slot Vivaldi Antenna Array for See Through Concrete Wall UWB Applications

Yazhou Wang, Aly E. Fathy

EECS Department, University of Tennessee, Knoxville, USA
ywang34@utk.edu

Abstract

An optimized 1×8 Vivaldi antenna array designed for the lower-band UWB (2-4 GHz) through-wall imaging systems has been developed. Tapered slot antennas were utilized as the array elements and optimized to have a compact size. A one to eight wideband Wilkinson power divider was designed and fabricated to compose the feed network for Vivaldi antenna array. Measured results of the manufactured Vivaldi antenna array are in excellent agreement with the simulated ones, with a gain of more than 12 dBi within the operating band. The developed array is an essential component for see through concrete wall applications, and very similar in size and gain to the previously developed Vivaldi antenna (around 10 GHz) by our group for drywall-high resolution detection.

1. Introduction

Vivaldi antennas have received considerable attention due to their high gain, relatively wide band, simple structure, easy fabrication, and wide use in UWB applications. Their small lateral dimensions and simple integration make them excellent candidates for array development [1]. Federal Communication Commission (FCC) approved a 1.99 GHz to 10.6 GHz frequency band for use in UWB through-wall imaging systems [2]. Yang et al. [3] designed a Vivaldi antenna array around 10 GHz for UWB see-through-wall radar utilizing antipodal Vivaldi antennas with Wilkinson power divider for binary feed. However, the size of this 16-element array is relatively too large if the antenna array is duplicated for the lower-band UWB applications; i.e. close to 3 GHz. Therefore, we used here only an 8-element array and optimized its performance to sustain similar almost constant gain over its operating band. Similar concepts to that utilized by Abbosh et al. [4] to design a compact UWB antipodal Vivaldi antenna have been utilized here.

In this paper, we have developed a Vivaldi antenna array for see through concrete wall UWB applications utilizing tapered slot antennas (TSA) and Wilkinson power divider. The configuration of the array element was optimized to have a compact size. Compared with the array in [3], the newly designed array operates at a lower band (2-4 GHz) with a similar size and has more than 12 dBi gain at the operating band. Details of the developed Vivaldi antenna, Wilkinson power divider, the 1×8 Vivaldi antenna array, its simulation and experimental results are presented in this paper.

2. Tapered Slot Antenna Configurations

The design parameters of the proposed TSA and the fabricated parts are shown in Figs. 1 and 2 respectively. The manufactured TSA was fabricated on Rogers RT5880 material with a relative dielectric constant of 2.2, thickness of 1.575mm (0.062") and a loss tangent of 0.0009. The top layer shows the microstrip line and the series radial stub used for feeding the tapered slot antenna. The bottom layer indicates the exponential taper profile [5] which is defined by the opening rate R and the two points $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$

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

where

$$c_1 = \frac{y_2 - y_1}{e^{Rx_2} - e^{Rx_1}} \quad (2)$$
$$c_2 = \frac{y_1 e^{Rx_2} - y_2 e^{Rx_1}}{e^{Rx_2} - e^{Rx_1}}$$

Given the highest frequency of operation (f_H), the width W of the tapered slot antenna should satisfy equation (3) to circumvent the grating lobes of Vivaldi array.

$$W < \frac{c}{f_H \sqrt{\epsilon_e}} \quad (3)$$

where ϵ_e is the effective relative dielectric constant. In addition, the TSA has been designed to match at 100Ω instead of 50Ω . Therefore, the width of the microstrip line feeder W_m should be defined to give the characteristic impedance of 100Ω . Shin et al. [6] demonstrated that the wideband performance of the Vivaldi notch antenna arrays fed by microstrip line could be improved systematically. After defining the parameters cited above, all other parameters are optimized with Ansoft High Frequency Structure Simulator (HFSS) to get both the compact size and good performance at the operating band.

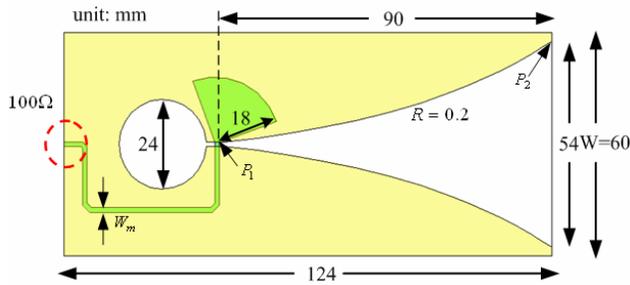


Fig. 1. Configurations of the proposed tapered slot antenna

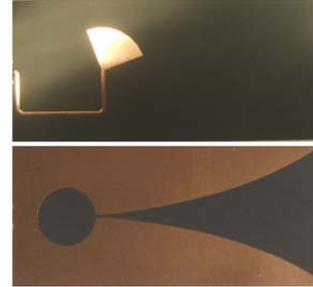


Fig. 2. Top and bottom view of the manufactured TSA

3. Design of wideband Wilkinson Power Divider

A wideband Wilkinson power divider is needed to feed the 1×8 Vivaldi antenna array. A 3-section Wilkinson power divider [7], which provides signals with balanced amplitudes and phases from the output ports, is selected to compose the 8-way feed network for the Vivaldi antenna array. The manufactured wideband Wilkinson power divider is shown in Fig. 3. The input port and two output ports are matched at a characteristic impedance of 100Ω so that the power divider can be directly connected with the tapered slot antennas. Figure 4 indicates the simulated return loss and insertion loss of the power divider. In the operating band from 2 to 4GHz, the return loss is lower than -15dB and output ports have almost equal power level with insertion loss of -3.3dB and $\pm 0.2\text{dB}$ fluctuation.

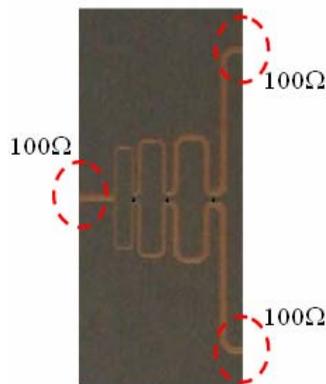


Fig. 3. Manufactured Wilkinson power divider

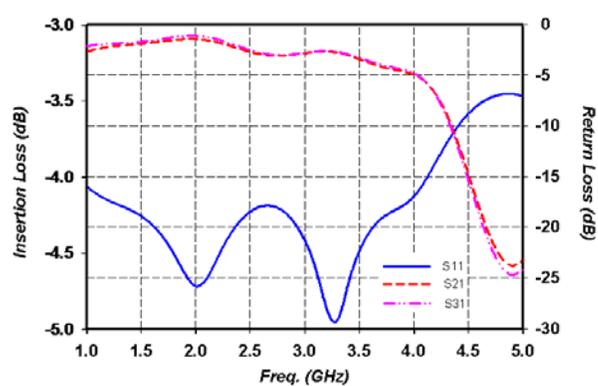


Fig. 4. Simulated return loss and insertion loss of Wilkinson power divider (normalized to 100Ω)

4. Design of the 1×8 Vivaldi Antenna Array

An eight-element Vivaldi antenna array was designed to operate over the 2 to 4 GHz frequency range, and was printed on Rogers RT5880 material with relative dielectric constant of 2.2, thickness of 1.575mm (0.062”) and loss tangent of 0.0009. Fig. 5 demonstrates the top layer and bottom layer of the manufactured array, where eight single Vivaldi antennas were fed by cascaded Wilkinson power divider network. As shown in Figs. 1 and 3, TSA and binary Wilkinson power divider are both matched to 100Ω . At the feed port of the 8-element array, two Wilkinson power dividers were shunted together to make the array matched to 50Ω . The spacing between the two adjacent single elements “W”, indicated in Fig. 1, is $0.8\lambda_0$ at the highest operating frequency 4 GHz. The overall size of the array is $480\text{mm} \times 210\text{mm}$ ($8'' \times 19''$).

Measured and simulated results of the Vivaldi antenna array are shown in Figs. 6-8. Measured results in Fig. 6 indicate that the array can operate from 1.2 to 4.2 GHz with a return loss of lower than -10dB. A gain of more than 12dBi is sustained over the frequency range 2 to 4 GHz, as shown in Fig. 7. Fig. 8 demonstrates a good radiation pattern of the Vivaldi antenna array at 2, 3 and 4 GHz, which shows that the side lobes are 15dB lower than the main beam in the azimuth plane.



Fig. 5. Top of bottom view of the manufactured 1×8 Vivaldi antenna array

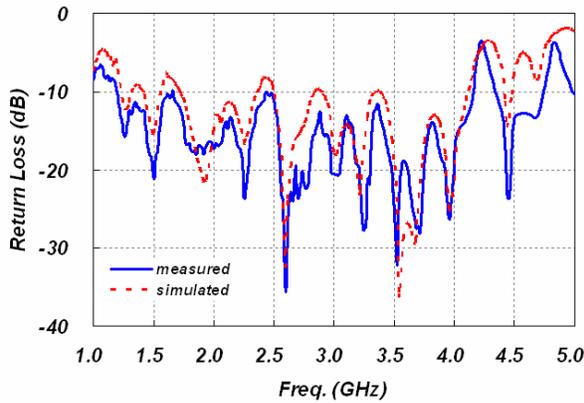


Fig. 6. Measured and simulated return loss of the Vivaldi antenna array (normalized to 50Ω)

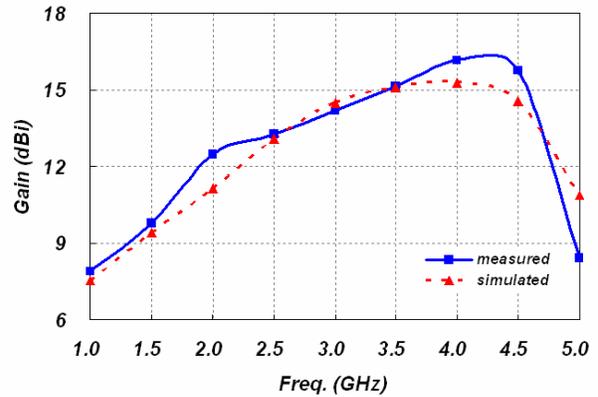


Fig. 7. Measured and simulated Gain Vs. Frequency of the Vivaldi antenna array

