Switchable-Feed Reconfigurable Ultra-Wide Band Planar Antenna

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***Abstract*— Reconfigurable antennas capable of radiating in only specific desired directions increase system functionality in applications like direction finding and beam steering. This paper presents the design simulation, fabrication and measurement of a horizontally polarized, direction reconfigurable Vivaldi antenna, designed for the lower-band UWB (2-6 GHz). This design employs eight circularly distributed independent Vivaldi antennas with a common port, electronically controlled by PIN diodes acting as RF switches. Experimental results show that the reconfigurable antenna has a bandwidth of 4 GHz (2-6 GHz), with 5 dB gain in the desired direction and capable of steering over the 360° range.**

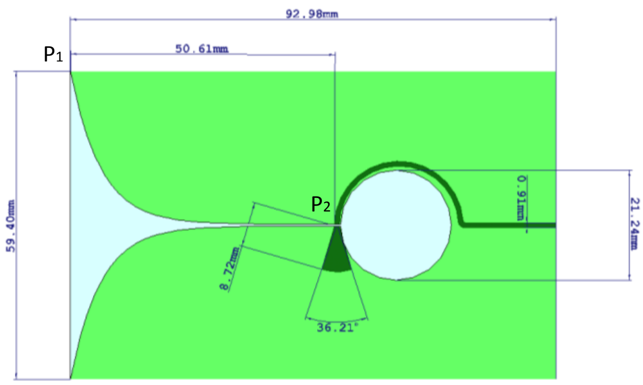
Keywords*— *reconfigurable antenna; ultra-wide band; Vivaldi antenna

I. Introduction

Antennas are critical components of the rapidly progressing field of wireless communication technology. Reconfigurable antennas have recently been a very active field of research [1] and play a very important role in achieving increased functionality for various specialized applications like MIMO [2] and direction of arrival detection [3].

In this paper, we use eight switchable feed Vivaldi antennas which are controlled using PIN diodes as RF switches to electronically direct the radiation in the desired direction.

Vivaldi antennas have a simple planar structure and are easy to fabricate and therefore are frequently used in UWB applications [4], [5]. These antennas are also very directive with a consistent high gain over a wide frequency range, making it suitable for reconfiguration applications.



Fgure 1- Vivaldi element design

II. Vivaldi Element Design

The individual Vivaldi elements used in the reconfiguration antenna implemented in this paper utilize the tapered slot antenna [4]. The design incorporates an exponential taper profile and a microstrip line with a series radial stub used for feeding the tapered slot antenna, as shown in Figure 1.

The exponential taper profile is defined by the opening rate *R*, the two points P_1 (x_1, y_1) and P_2 (x_2, y_2) [4], [6] defining the limits of the taper profile, t_s defines the opening width of the taper profile while t_d defines the diameter of the circular short opposite to the taper profile. The geometric parameters of the Vivaldi antenna used in this configuration are listed in Table 1.

The Vivaldi antenna was designed on RO4003 substrate with dielectric constant ε_r=3.55 and thickness h=0.81 mm and simulated using CST Microwave Studio 2015. This model was optimized using the Nelder Mead Optimizer to achieve a good impedance match across the frequency range.

Table 1- Geometric Parameters of the Vivaldi Antenna Used in the Array

x_1	0
y_1	0.5 x t_s
t_s	0.295 mm
x_2	51.954 mm
y_2	27.488 mm
t_d	20.344 mm
R	0.148

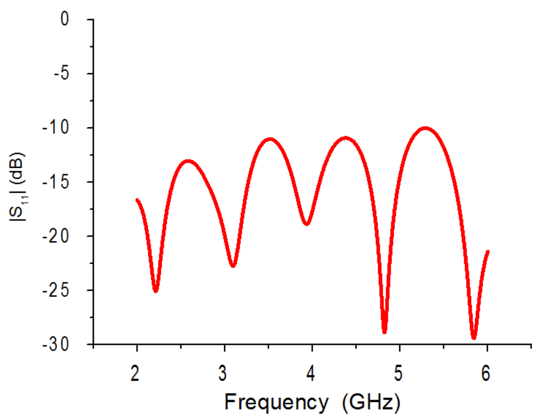


Figure 2- Reflection coefficient of a single Vivaldi antenna

Figure 2 shows the simulated results for the scattering parameters of the single Vivaldi antenna.

The simulated result shows a return loss better than 10 dB over the frequency range from 2 to 6 GHz. This element can now be used to implement a reconfigurable Vivaldi antenna based on a switchable feeding network.

III. RECONFIGURABLE ANTENNA DESIGN

In this design, we use eight Vivaldi elements described in the previous section, distributed in a circular pattern and fed using a common 50 Ω SMA connector. There are eight microstrip feeding structures, each connected to the SMA connector via a PIN diode and feeding each of the eight Vivaldi elements respectively. The geometry of the reconfigured antenna is shown in Figure 3.

The position of the PIN diodes and the element spacing from the centre of the port are crucial for achieving the required frequency response. By slightly adjusting the placement of the switches and leaving a small soldering pad as shown in Figure 4, a desired frequency response similar to that of an isolated Vivaldi element can be achieved.

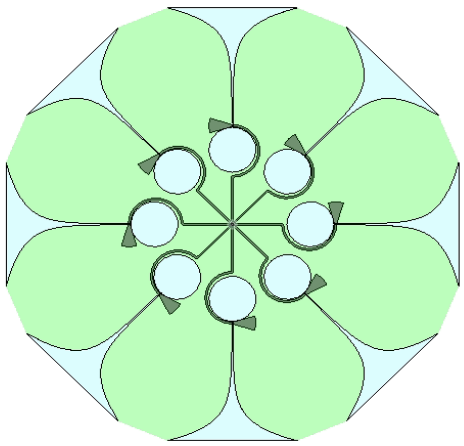


Figure 3- Reconfigurable Vivaldi Design

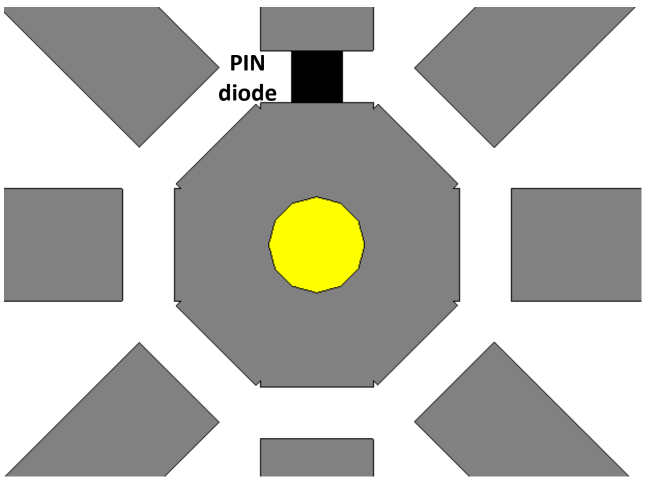


Figure 4- SMA fed mirostrip structure

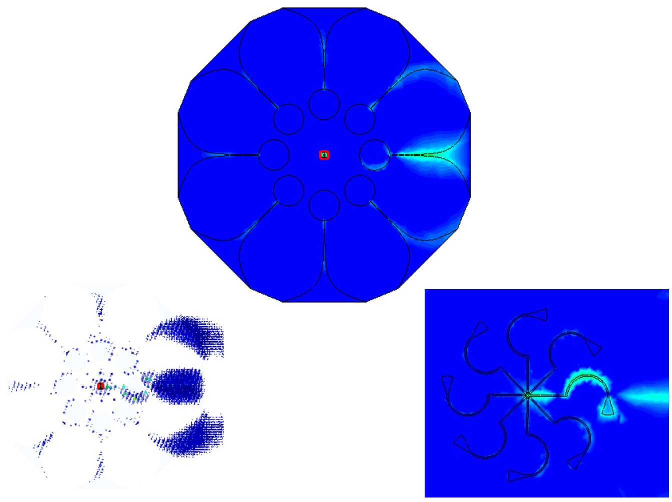


Figure 5- Reconfigurable antenna electric field charecteristic

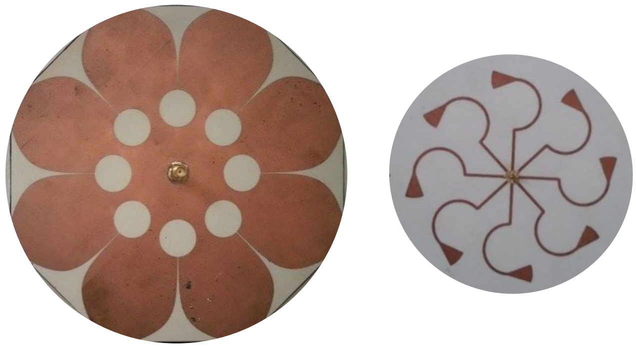


Figure 6- Reconfigurable Vivaldi antenna prototype

The PIN diodes act as voltage-controlled RF switches, leading to the activation of the Vivaldi element coupled to that specific line. This effect can be seen in Figure 5, where the electric field is only evident in the activated element.

Based on the synthesis process, optimum performance was achieved with an element spacing of 31 mm from the centre with the PIN diodes implemented 0.75 mm away from the port. A prototype of the reconfigurable antenna shown in Figure 6 was fabricated and tested. The PIN diodes are activated using a control circuit implemented on an external circuit board.

IV. RESULTS

The reconfigurable antenna was modelled and simulated using CST MWS 2015. The manufactured model was tested using a Rhodes and Schwarz Vector Network Analyzer in an anechoic chamber where both the radiation pattern and the scattering parameters were measured.

Figure 7 shows the antenna’s measured and simulated reflection coefficient. Figure 8 compares the simulated reflection coefficient for different offsets of switches. Figure 9 compares the simulated and measured antenna patterns with the 0° feed activated using the PIN diode. The antenna behaves as expected.

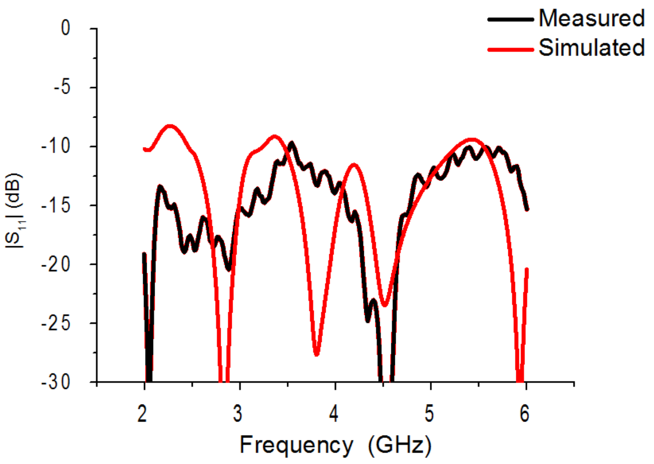


Figure 7- Simulated vs. measured scattering parameters

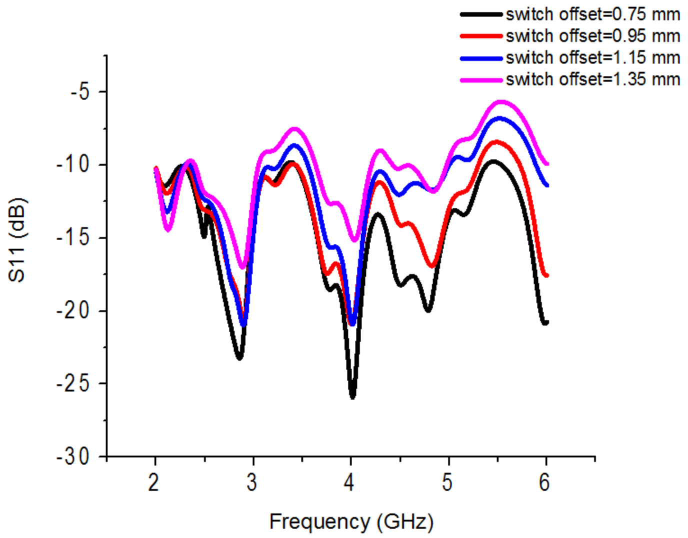


Figure 8- Simulated reflection coefficient with varying switch offset

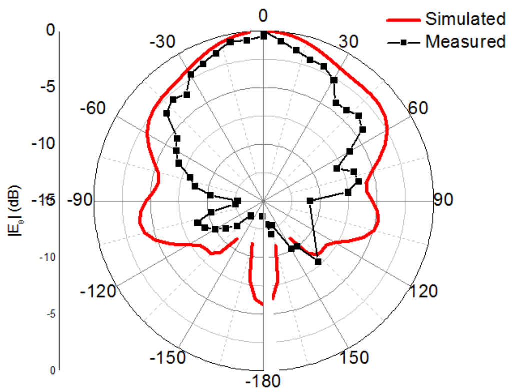


Figure 9- Simulated vs. measured radiation pattern for antenna in the 0° configuration

V. CONCLUSION

In this paper, the design of a low cost, electronically controlled, wideband reconfigurable planar Vivaldi antenna is presented. By electronically controlling the state of the PIN diodes, the proposed antenna shows a consistent 5 dB gain over the entire 360° range within the frequency range of 2-6 GHz.

The reported results demonstrate the reconfigurable properties of the proposed design over a wide frequency range which can be implemented to achieve greater system performance in various applications.

REFERENCES

[1] Christos G. Christodoulou, Youssef Tawk, Steven A. Lane and Scott R. Erwin, "Reconfigurable Antennas for Wireless and Space Applications" Proc. IEEE, vol. 100, No. 7, July. 2012.

[2] A.Grau, Hamid Jafarkhani, F. De Flaviis, "A reconfigurable multiple-input multiple-output communication system", IEEE Trans Wireless Communications, vol. 7, No. 5, pp. 1719-1733, May. 2008.

[3] V. Vakilian, H. V. Nguyen, S. Abielmona, S. Roy, "Experimental study of direction-of-arrival estimation using reconfigurable antennas", 27th Canadian Conf., Elec. And Comp Science (CCECE), Toronto, May 2014, pp. 1-4.

[4] Yang, Y., Wang, Y. & Fathy, A.E. 2008, "Design Of Compact Vivaldi Antenna Arrays For Uwb See Through Wall Applications," Progress In Electromagnetics Research, vol. 82, pp. 401-418.

[5] Sang-Gyu Kim, Kai Chang, "A low cross-polarized antipodal Vivaldi antenna array for wideband operation," Antennas and Propagation Society International Symposium, Volume 3, June 2004, pp. 2269-2272.

[6] P.J. Gibson, "The vivaldi aerial," in Proc. 9th European Microwave Conf., Brighton, U.K., 1979, pp. 101-105