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An Array of M-Shaped Vivaldi Antennas for UWB Applications

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Abstract—In this paper, a novel M-shaped UWB Vivaldi array antenna is presented. First of all, a simple M-shaped UWB Vivaldi antenna is designed, and its properties of return loss, radiation pattern, VSWR, gain, etc. are analyzed. An array of M-shaped UWB antenna is simulated and designed after the successful implementation of the simple UWB Vivaldi antenna. The designed antenna has operating frequency from 3.25 GHz to 8.85 GHz covering 5.6 GHz bandwidth. The antenna has flat gain over entire frequency range. The proposed antenna is fabricated on a commercially available FR-4 substrate having relative permittivity of 4.4 and height of 1 mm. The proposed antenna has wide band and good flat gain over entire frequency range. The proposed antenna can be used in next generation wireless communication because of its efficiency, gain and wide bandwidth.

1. INTRODUCTION

Since the federal Communications Commission (FCC)'s choice allowed unlicensed operation band from 3.1 to 10.6 GHz in 2002, the ultra-wideband (UWB) has been getting progressively well known from the scholarly and industry fields. As an important part of a UWB wireless communication system, UWB antenna has drawn expanding consideration [1–9]. A UWB antenna ought to be designed with small size, good impedance matching, level group delay and omnidirectional radiation pattern [10]. This antenna shows stability and constant group delay over large range of frequencies. The wideband, high gain and feature of integration of Vivaldi antenna make it a good candidate in various modern wireless applications [11, 12]. Theoretically, a Vivaldi antenna has boundless scope of working frequencies with consistent beam width over the entire bandwidth [13]. In UWB communications, in addition to attaining a decent return loss and radiation efficiency, the UWB antenna ought to be non-dispersive or dispersive in an adequate range. Then again, for narrowband systems the customary parameters are sufficient to measure the enactment of the antenna, but in the ultra-wideband applications these parameters are insufficient for the applicability of the antenna. Actually the UWB antenna transmits pulses with distortions, and the antenna performance should be evaluated by means of dispersion parameters. In [14, 15], the dispersion analysis of some Vivaldi antennas has been reported.

This paper presents a modified M-shaped UWB Vivaldi antenna fabricated on a commercially available substrate of FR-4. In this paper, a novel structure for the UWB Vivaldi array antenna is proposed and analyzed in term of reflection coefficient, VSWR, gain and radiation pattern. A good agreement between the simulated and measured results is obtained.

2. ANTENNA DESIGN

The dimensions and geometry of the proposed M-shaped UWB Vivaldi antenna is shown in Fig. 1. The substrate used for the design of the antenna is FR-4 ($\varepsilon r = 4.4$ and $h = 1$ mm). The top and bottom

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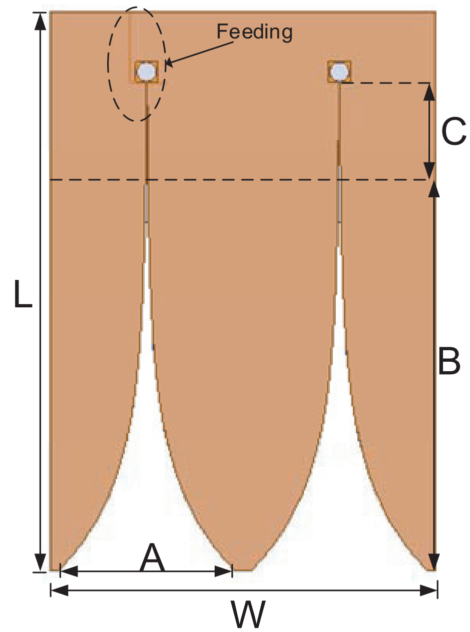

Figure 1. Top view of the proposed UWB antenna.

layers consist of copper material. The substrate and copper metal layers are cut to form an M-shaped Vivaldi antenna. A circular slot is used in the designed antenna to have enhanced bandwidth, and hence the antenna is UWB. The circular slot is optimized for the best results and has radius of 3 mm. This antenna shows a UWB operation between 3 GHz–8 GHz.

The optimized parameters of the proposed antenna are given in Table 1.

Table 1. Antenna parameters summary.

Dimension	Value (mm)	Dimension	Value(mm)
L	160	W	100
A	50	B	140
C	7		

The designed linear array (8 elements) of M-shaped Vivaldi antenna is shown in Fig. 2. The gap between elements of array is kept at 10 mm. The antenna is fed with same signal parameters. The designed array antenna is investigated in term of antenna parameters. The antenna is then fabricated using an FR-4 substrate having dielectric constant of 4.4 and height of 1 mm. Return Loss, VSWR, and radiation pattern are tested in the laboratory after the fabrication of the prototype. During testing process in the laboratory BNC power divider which has 50 ohm nominal input impedance is used to insure that each element of the antenna gets the same signal power and same signal parameters. The measurements are conducted using Agilent Vector Network Analyzer (VNA) in open air conditions. For pattern measurement, the proposed antenna is fixed on a positioner or turntable. The distance between the proposed antenna and probe antenna is adjusted to 8 meters for the purpose of far-field pattern measurements.

3. RESULTS AND DISCUSSION

The results of the proposed UWB antenna design are presented here. The reflection coefficient (S_{11}), Voltage Standing Wave Ratio (VSWR) and gain of the proposed antenna are analyzed in the following

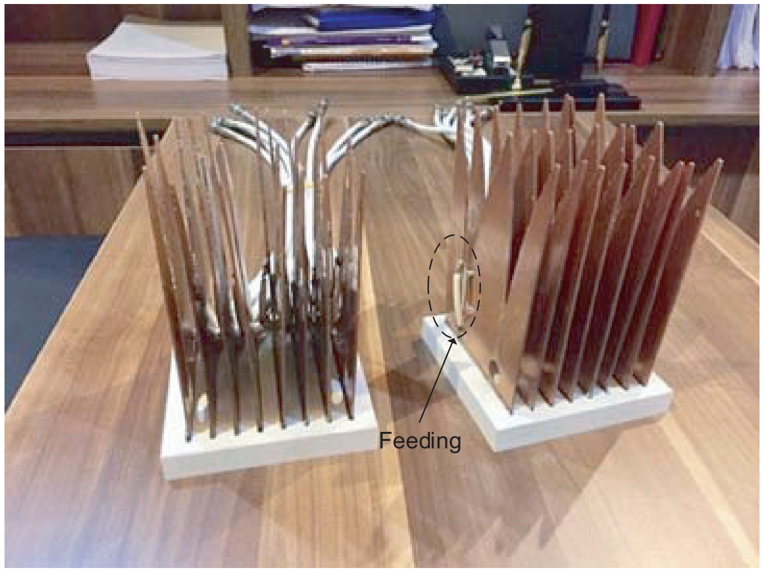

Figure 2. Fabricated antenna array.

sections. All simulations are carried out using High Frequency Structure Simulator (HFSS), using open free space boundary conditions.

3.1. Reflection Coefficient

Reflection coefficient (S_{11}) shows the fraction of power being reflected backwards from the antenna input to the excitation port.

It is obvious from Fig. 3 that the operating frequency of the proposed antenna is from 3.25 GHz to 8.85 GHz. In the proposed UWB array antenna, 10 dB bandwidth of 5.6 GHz is observed. Good agreement between the simulated and measured results is obtained.

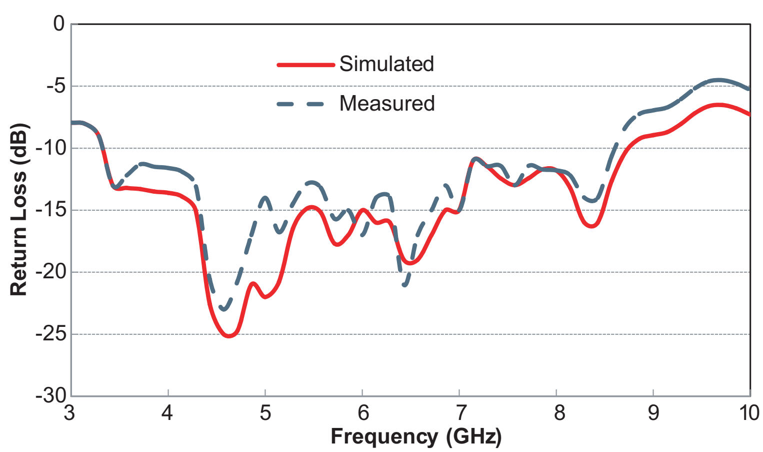

Figure 3. S_{11} of the proposed antenna.

3.2. Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio of the maximum to minimum voltage (or electric fields) along the transmission feed line of the proposed antenna. Fig. 4 compares the simulated and measured results of the proposed UWB array antenna. The proposed antenna has VSWR < 2 for all frequencies from 3.25 GHz to 8.85 GHz.

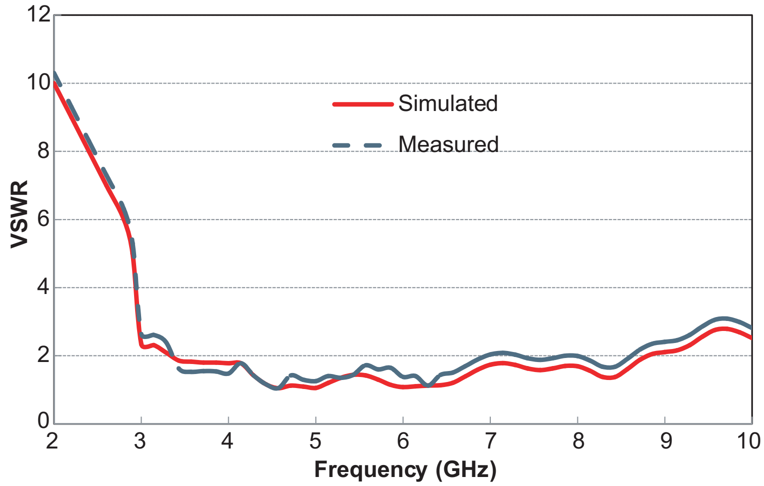

Figure 4. Simulated and measured values of proposed UWB antenna.

A good agreement between the simulated and measured results is observed.

3.3. Radiation Characteristics

The radiation characteristics of the UWB array antenna are analyzed at 5 GHz. Simulated and measured radiation patterns for phi = 0 and phi = 90 are shown in Fig. 5 and Fig. 6. The sharp angles appear in the radiation pattern because of geometry of the proposed antenna. On higher frequency most of the gains are directional since this is monopole type antenna which has sharp edges, due to which some parts of the antenna act to distort the radiation pattern.

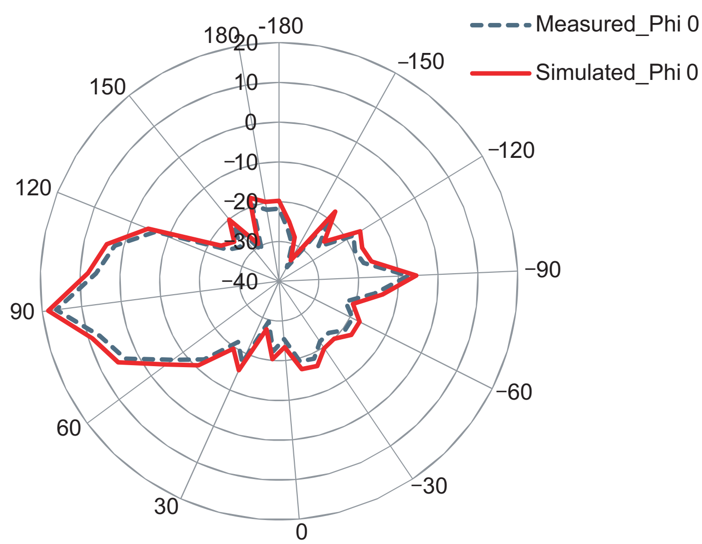

Figure 5. Radiation Pattern at Phi = 0 of the proposed UWB antenna at 5 GHz.

3.4. Gain

The simulated maximum gain of the proposed UWB array antenna is shown in Fig. 7. It is very clear from Fig. 7 that the proposed UWB array antenna has somewhat flat gain for all passbands. The proposed antenna has maximum gain of 16.4 dB at 5 GHz.

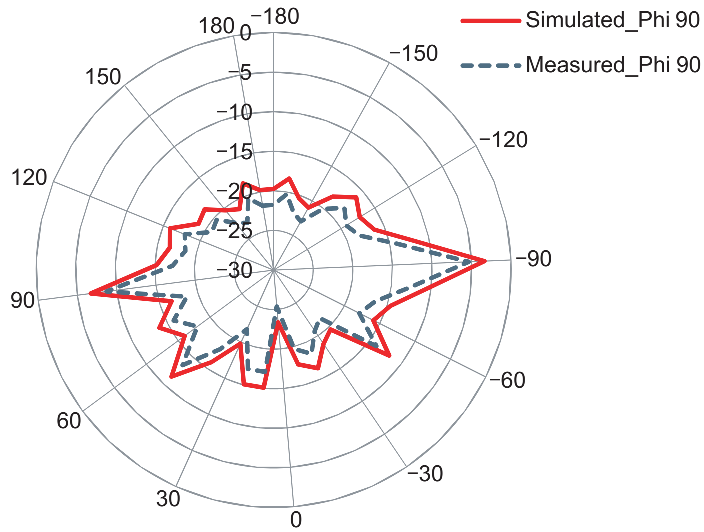

Figure 6. Radiation Pattern at Phi = 90 of the proposed UWB antenna at 5 GHz.

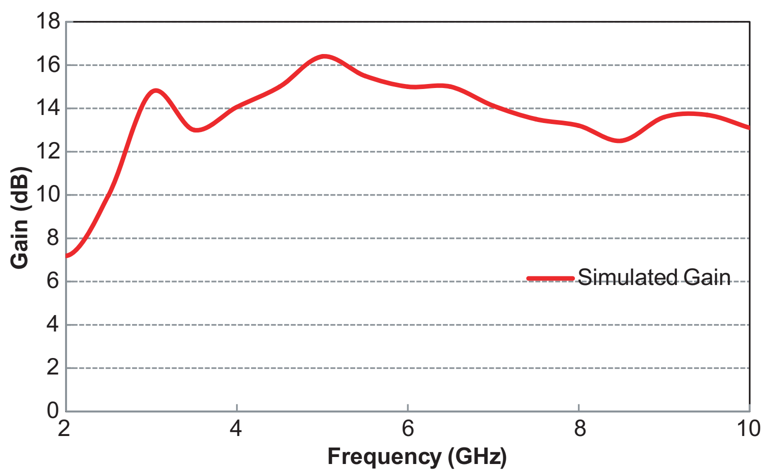

Figure 7. Simulated gain of the proposed array antenna.

4. CONCLUSION

In this work, a new model of an M-shaped Vivaldi UWB array antenna is designed, fabricated and measured. The designed antenna can be used for frequencies from 3.25 GHz to about 8.75 GHz covering a 10 dB bandwidth of 5.6 GHz. The designed antenna has high gain at the whole passband. The fabricated UWB array antenna is measured in the laboratory, and the antenna parameters of return loss, VSWR and radiation pattern are compared with simulated results. The simulated and measured results of the antenna show a reasonable agreement.

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