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Full Paper

Bandwidth Enhancement of Vivaldi Antenna using Triangular Shaped Slots

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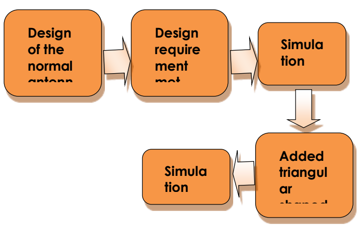
Graphical abstract



Abstract

This paper discusses about a bandwidth enhancement of Vivaldi antenna loaded using triangular shaped. Firstly, a normal Vivaldi antenna using FR-4 substrate had been designed. Then, the triangular shaped slots had been added at the upper layer of the antenna. It shows the better improvement in return loss, gain, directivity and bandwidth operated at frequency of 10 GHz after the addition of the triangular shaped slot. The advantages of a Vivaldi antenna such as simplicity, wide bandwidth, and high gain at microwave.The return loss of this Vivladiantenna with triangular slot is – 18.495 dB at resonant frequency of 10 GHz while for Vivaldi antenna is - 17.818 dB at 10 GHz for measurement result. This proposed antenna had been designed and simulated using Computer Simulation Technology (CST) simulation software.

Keywords: Vivaldi antenna, parameter, return loss, bandwidth, gain, directivity, design

1.0 INTRODUCTION

The origin of the name "Vivaldi" is not really known but the name was commonly associated with Antonio Vivaldi, a composer from the Baroque period. This Vivaldi antenna is a planar travelling wave antenna with endfire radiation. P.J.Gibson in 1979 was first proposed this types of antenna [1]. It is believed that Gibson named it after Antonio Vivaldi as he listened to Vivaldi's "Four Season" when he designed the antenna. The improvements to the initial design have been introduced in later years by E.Gazit in 1988 which he utilized an antipodal structure [2], and followed by balanced antipodal structure by Langley, Hall and Newham in 1996 [3].

Nose cone of the aircraft is to treat areas of radar detection, the distribution of electromagnetic antenna system's fire control in this area is normally very strong, which is a result of the importance of stealth antenna designs. Vivaldi antennas are widely used in the fire control system for wide bandwidth and small physical dimensions. Therefore, stealth Vivaldi antenna design is highly desirable in many airborne applications [4].Moreover, it also possess a characteristics that is perfect for multifunction communication devices such as excellent impedance matching, low interference, do not require tuning elements, low profile, and unobtrusive [5].

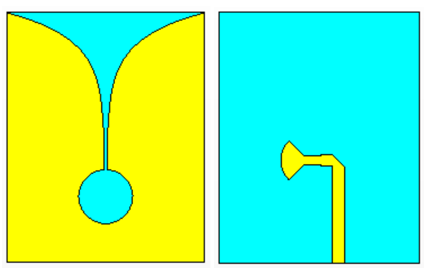
There are many research on designing the patch antenna using Vivaldi technique. For examples in [6], the proposed wideband Vivaldi shows the performance of resonant frequency at 10 GHz with return loss of – 44.53 dB and VSWR of 1.012. The other antenna design using Vivaldi technique is in [7] that design compact Vivaldi array, Tapered Slot Vivaldi Antenna for Ultra-Wide Band Application [8], and Vivaldi Antenna for radar and also for microwave imaging applications [9].

In this work, the triangular shaped slot had been added to improved the bandwidth of the Vivaldi antenna. The parameters that consider in this work are the return loss, resonant frequency, antenna gain, bandwidth, and aslo radiation pattern.

2.0 EXPERIMENTAL

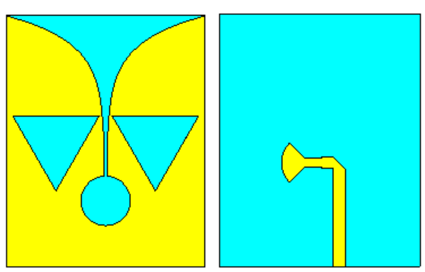
Figure 1 illustrates the geometry and dimensions of the Vivaldi antenna meanwhile Figure 2 illustrates the geometry and dimensions of the Vivaldi antenna with triangular shaped slot. The substrate chosen for this antenna design is flame retardant 4 (FR-4). Substrate has length and width of 25.2 mm x 20 mm with dielectric constant = 4.4, height of substrate, h = 1.6mm, thickness of patch copper, t = 0.035mm and loss tangent = 0.019.

The construction of the microstrip structure of the Vivaldi antenna requires the use of FR-4 board. Thus, for structure, firstly, the first layer of FR-4 board was constructed according to the designed size and shape. The design was created on a dielectric substrate with two-sided metallization.



(a) (b)

Figure 1 Design structure of the vivaldi antenna. (a) front view (b) back-view



(a) (b)

Figure 2 Design structure of the proposed vivaldi antenna. (a) top view (b) back-view (c) cross-sectional view

This antenna is printed on the both sides of FR-4 substrate. On front side of the substrate is the metal patch consisting tapered slot line and a transmission line as showed in Figure 1(a) and Figure 2(a). On the back side, there is a feeding structure as showed in the Figure 1(b) and Figure 2(b). the tapered slot Vivaldi antenna with feeding circuits in Figure 2

The design of the Vivaldi antenna radiating structure is based on parametric studies. The edges of the radiation strructure are exponentially tapered slot define by the equationas shown in Figure 3. The exponential curves for the transition, flare and aperture angle known as parameter a are defined by the Equation 1 to Equation 3.

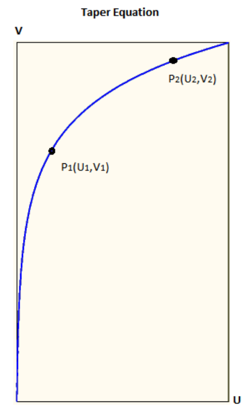


Figure 3 Exponential curves parameters for Vivaldi antenna design

$$U = C_1 e^{AV} - C_2 \quad (1)$$

$$C_1 = \frac{U_2+U_1}{e^{AV_2} - e^{AV_1}} \quad (2)$$

$$C_2 = \frac{U_1 e^{AV_2} + U_2 e^{AV_1}}{e^{AV_2} - e^{AV_1}} \quad (3)$$

Where, $C_1$is the scaling factor, A the exponential rate, and C_2 the offset. These parameters are defined for each curve in Figure 3 and Equation 1 to Equation 3.The vivaldi antenna with triangular slot consists of the following design parameter as shown in table 1 below:

Table 1 Parameter and their values used in the simulation [a]

Notation	Parameter	mm
W	Width of substrate	20
H	Length of substrate	25.2
H1	Length of exponential taper	14.2
H2	Length section slot line	4.4
B1	Height of ground	9.75
B2	Length and ground to B3	1.2
B3	Length and ground from B2	1.6
L1	Length slot line to boarder	9.86
T	Length of triangular slot	5
R1	Length and width of cylinder cavity	2.5
WS	Width of ground	1.15
WS1	Width of uniform section of slot line	0.28
WS3	Width and ground at B2	1.15
WS4	Width and ground at B3	0.83
a	Exponential curve	0.37
h	Height of substrate	1.6
t	Thickness of copper	0.035

3.0 RESULTS AND DISCUSSION

The antenna is simulated and designing by using CST software. The measured and simulated return loss versus for proposed antenna is shown in Figure 4. A satisfactory agreement between the measurement and simulation results is observed. Using an optimum value (return loss ≤ -10 dB) as benchmark because the electromagnetic wave being transmitted is more than 90% of the injected signal, it is seen from the results that the antenna operates from about 10GHz at the -17.818 dB return losses for the Vivaldi antenna meanwhile return loss for the Vivaldi antenna with triangular shaped slots is -18.495 dB at 10 GHz. It also creates another resonant frequency at 11.083 GHz with – 14.184 dB.

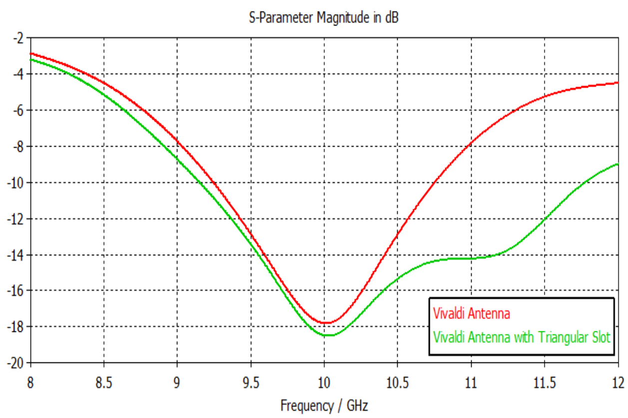
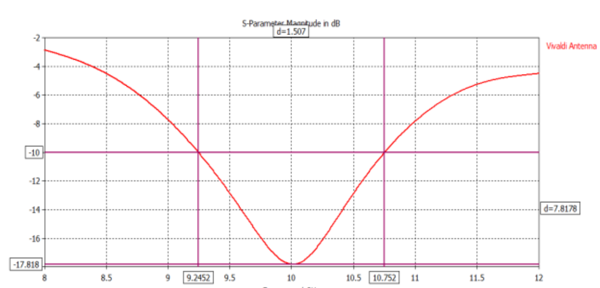
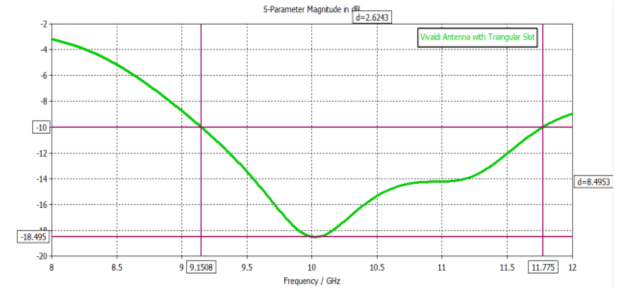


Figure 4 Simulated return loss against frequency between vivaldi antenna and vivaldi antenna with triangular slot

From the simulation result the bandwidth of the basic Vivaldi antenna in Figure 5 is 1.507 GHz with reasonable accuracy covering from 9.245 GHz until 10.252GHz. It within the 10 GHz that being obtains. Meanwhile, the vivaldi antenna with triangular shaped slots have wider bandwidth which is 2.624 GHz with reasonable accuracy covering from 9.151 GHz until 11.775 GHz. The operating frequencies were at the desired frequency band.



(a)

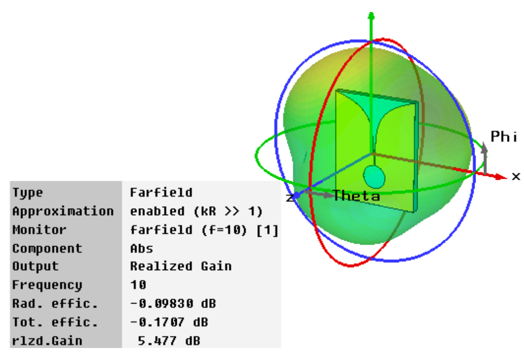


(b)

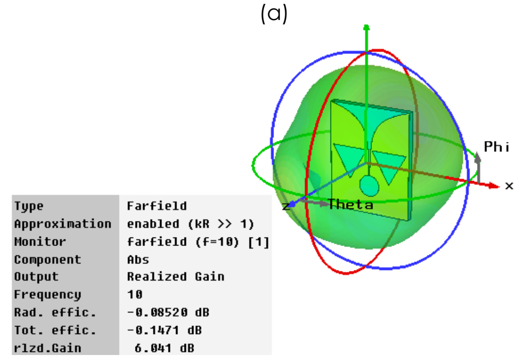
Figure 5 Simulated return loss (S11) and bandwidth (a) vivaldi antenna (b) vivaldi antenna with triangular slot

The far field, gain and directivity of the proposed antenna are also studied. Figure 6 shows the 3D directivity of vivaldi antenna and vivaldi antenna with triangular slot. It shows that the directivity performance of this Vivaldi antenna with triangular slot is 6.041 dB compare without triangular slot with only 5.477dB.

Figure 7below show the simulated gain at 10 GHz it shows that the gain performance of this Vivaldi antenna with triangular slot is 6.188 dB compare without triangular slot with only 5.647 dB.

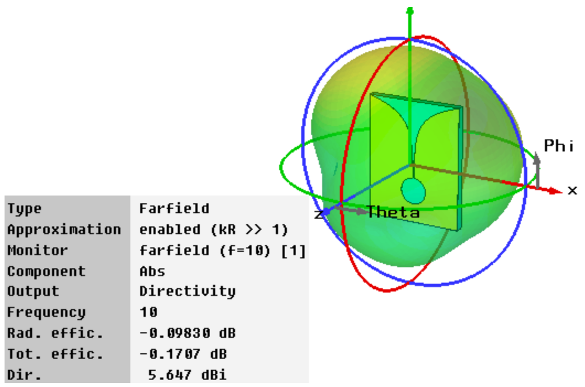


(a)

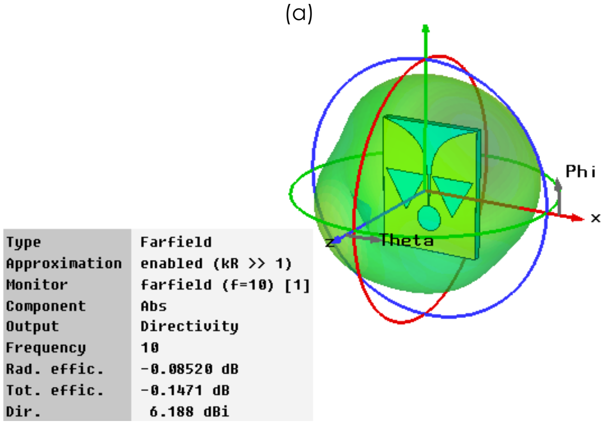


(b)

Figure 6 The far field and gain (a) the far field and gain of vivaldi antenna (b) the far field and gain of vivaldi antenna with triangular slot



(a)

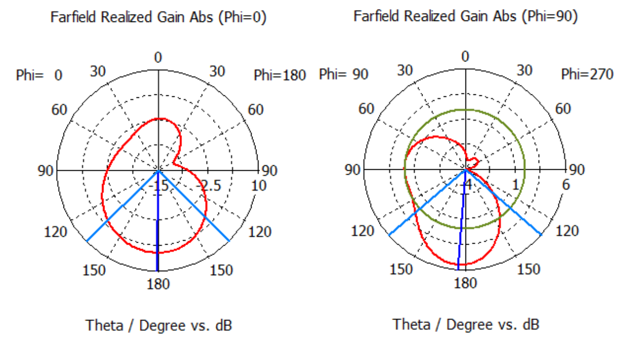


(b)

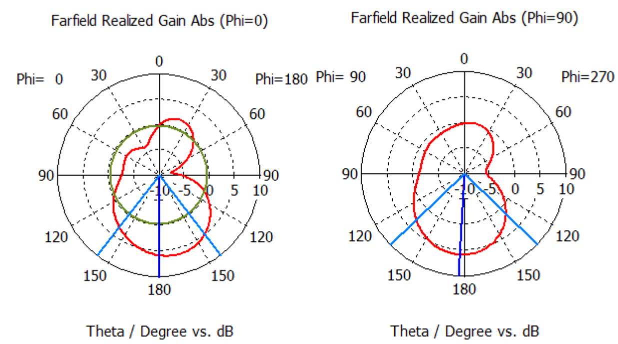
Figure 7 The far field and directivity (a) the far field and directivity of vivaldi antenna (b) the far field and directivity for vivladi antenna with triangular slot.

Figure 8 shows the 2D radiation pattern of the Vivaldi antenna and vivaldi antenna with triangular slot at two different phase of phi = 0^0 and phi = 90^0. For figure 8 (a) it show the radiation pattern performance for Vivaldi antenna. For phi = 0^0, it shows that the shaped is circular shape with a small back loop. For phi = 90^0 shows the oval shaped with minor side loop effect.

For figure 8 (b) it show the radiation pattern performance for vivaldi antenna with triangular slot. After the addition of the slot, it effect the radiation pattern become circular with more larger back loop shaped for phi = 0 while become red bean-like shaped for phi = 90. For phi = 0, the radiation pattern has two unequal major lobes at 28^0 and 167^0 while for phi = 90 shows he elevation angle at 21^0 and 183^0.The half power bandwidth (HPBW) for radiation pattern at phi = 90is wider compared to radiation pattern at phi = 0.



(a)

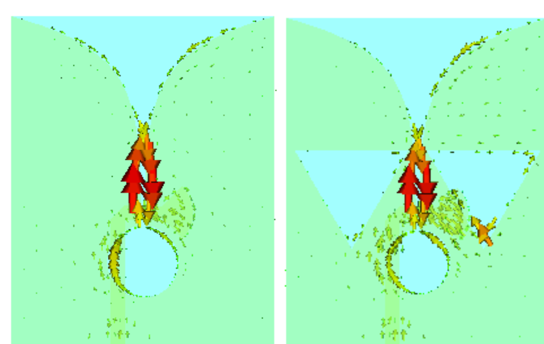


(b)

Figure 8 Simulated radiation pattern of the antenna (a)radiation pattern vivaldi antenna (b) radiation pattern of vivaldi antenna with triangular shaped

From the surface current analysis based on Figure 9, it shows the surface current of Vivaldi antenna and Vivaldi antenna with triangular slot. After adding the triangular slot, it shows the surface current are concentrate at the triangular slot. Which is it create another resonant frequency at 11.083 GHz.

For future RF system design like in this paper of [10], this Vivaldi antenna design is useful to combined with other device such as filters such as in [11-13], SPDT switch [14-15] and amplifier [16]. Other technique such as defected microstrip structure [17-18] or split ring resonator [19-20] can be combine to improved the performance of the Vivaldi antenna.



(a) (b)

Figure 9 Computed surface current distribution at 10GHz (a) vivaldi antenna (b) vivaldi antenna with triangular slot

4.0 CONCLUSION

In this paper, the comparison between Vivaldi antenna and vivaldi antenna with triangular slot is proposed which is operate at the frequency 10 GHz. The operating frequency is at 10 GHz with was designed, simulated and compared in term of return loss, gain, directivity, radiation pattern and surface current. The key features of vivaldi antenna besides being efficient and lightweight, its capable of working over a large frequency bandwidth and produce a symmetrical end-fire beam with appreciable gain and low side lobes. Dimensions of the antenna are 25.2 mm wide by 20 mm long by 1.6 mm of thickness. This proposed antenna has small size, easy to design and fabricate.The antenna demonstrates acceptable radiation pattern characteristics and return loss through simulation.The characteristics of the proposed antennas have been investigated through simulation. The proposed antenna achieved good performance over operating frequency band.

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