A Slotted Elliptical Antenna for Wideband Applications

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***Abstract*—** An elliptical microstrip antenna is proposed for wideband applications. This antenna is designed using the shape of an ellipse with a rectangular slot at the center of the patch. The characteristics of this antenna are investigated using CST software. The proposed antenna is fabricated and tested. The antenna impedance shows good performance over wide frequency range.

Index Terms— patch antenna, wideband, slotted elliptical patch.

1. Introduction

Printed planar microstrip antennas are getting significant for modern communication system due to their features including compact size, low cost and ease of fabrication [1].These antennas are essential in portable systems. Many extensive works on simple microtsrip geometries including rectangular, circular and triangular shaped structures have been reported [2]-[4] in recent past. However, these conventional antennas could not fulfill modern communication requirements due to their narrow bandwidths. Hence, various techniques have been proposed and several conventional antenna geometries have been modified in order to improve the bandwidth. Among these geometries, perhaps circular patch is the most extensively analyzed geometry that has been reported to improve its performance [5]-[7]. In this paper, a novel miniaturized ellipse-shape antenna with a slot in it is proposed. The proposed antenna provides an impedance bandwidth of 2.4-6.3 GHz. This antenna can be viewed as a suspended monopole antenna because there is no conductor at the back of the antenna. However, a conductor backing for 50Ω trace extend is introduced in order to form a microstrip transmission line. The optimization of the design and subsequent simulations are done by commercially available CST Microwave Studio software. The slotted ellipse antenna prototype is fabricated and tested. The measured return loss is determined. The design procedures are also discussed.

2. Antenna Design

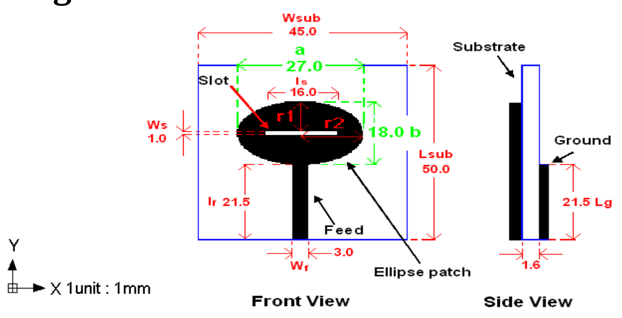


Figure 1 Structure of planar Slotted Elliptical Antenna

The slotted elliptical patch antenna for wideband communications proposed in this paper is shown in Fig.1. The elliptical patch is designed with a major axis a=27mm, and a minor axis b= 18mm (ellipticity ratio a/b=1.5), from which a rectangular region is carved out. The reason of carving out a rectangular region derives from the examination of the current distribution of the elliptical patch antenna since the currents on the elliptical patch radiator at all frequencies are mostly concentrated on its periphery, with very low current density toward its center [3]. CST Microwave Studio software is used to optimize the design. The slotted elliptical patch prototype is printed on a FR4 material of relative permittivity, ε_r=4.7 and of loss tangent of 0.01, with no ground plane directly underneath it. The substrate thickness is h=1.6. The antenna is fed by a 50-Ω microstrip transmission line which consists of a trace of width w= 3mm, printed on the surface of the substrate that is partially backed by a ground plane. The ground plane has dimensions of W=45mm and L=21.5mm, and the length extension from the ground plane edge to the substrate edge is 29.5mm (Ls=50mm).

2.1Antenna Return Loss

Numerical simulations and measurements are conducted on the slotted elliptical patch antenna with and without a switch. The simulation and optimization of the design is done by commercial simulation software, CST Microwave Studio and Rohde & Schwarz ZVA40 vector network analyzer is used for the impedance measurements. The characteristics of the return loss will be affected if one part of the ellipse patch is carved out. Fig. 2 depicts the results of return loss characteristic when a rectangular slot and a circle shape are sliced off from the ellipse patch. From the result, it shows that a rectangular slot shows better performance as compared to circle shape.

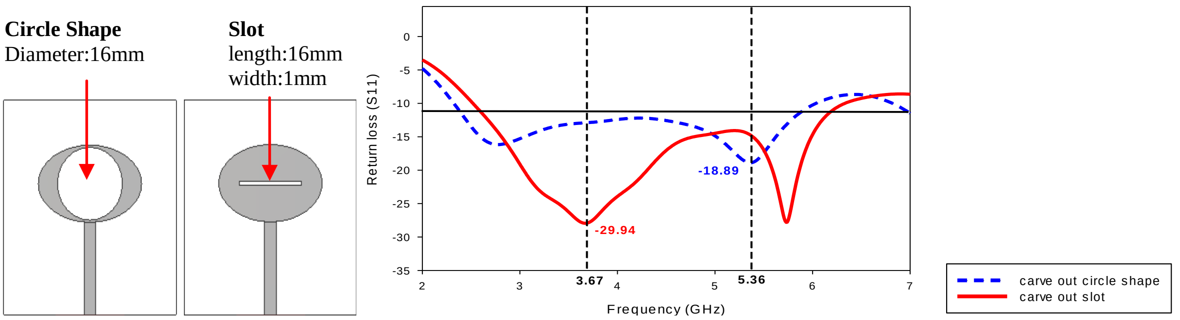
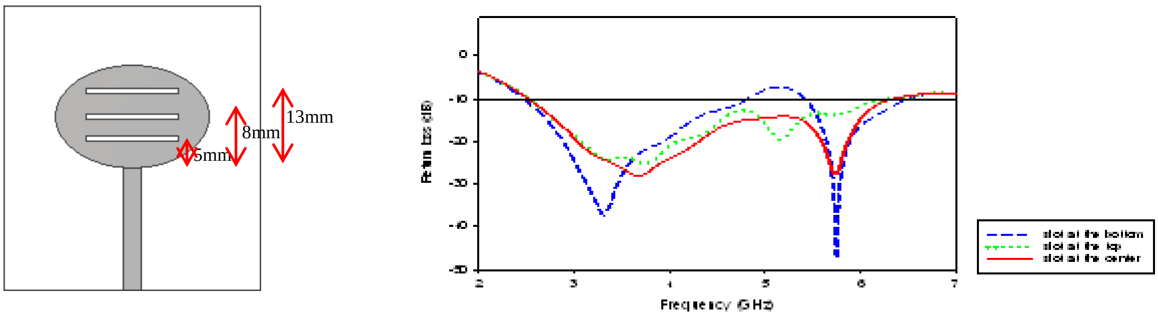


Figure 2: Slice off slot and circle shape at the center of ellipse

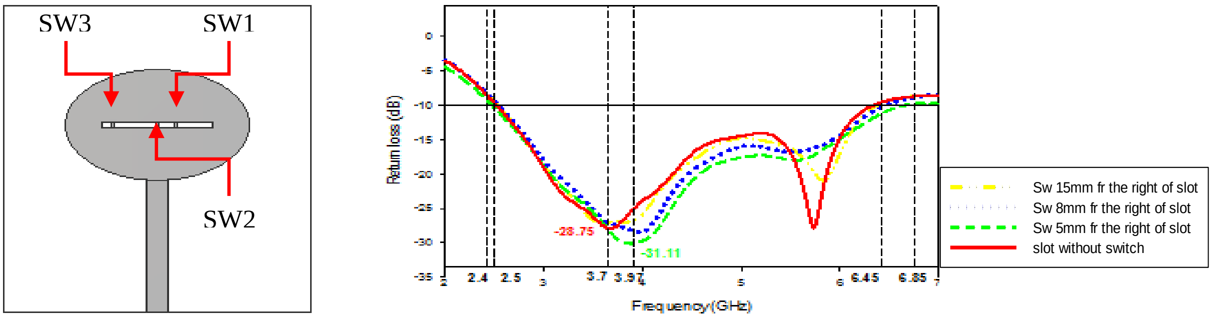
The position of the slot is changed in order to see the antenna performance. The slot is placed on the top, center and the bottom of the ellipse patch and the results are depicted in Fig.3. Due to the fact that the current is mostly concentrated on the periphery of ellipse patch and the current is lower at the center, hence the best position for the slot is at the center of the patch as shown in Fig. 3(b). The performance of the antenna is not improved even though the position of the slot is changed.



(a) (b)

Figure 3: The optimization of slot position

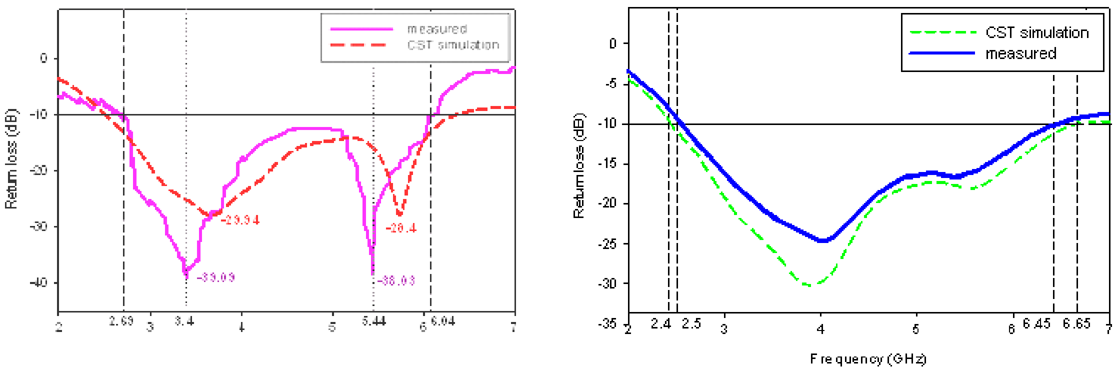
Hence, a modification for the slot has to be carried out in order to improve the performance of the antenna. A switch is integrated into the slot and the position of the switch is tuned (Fig.4) until the best results are determined. The simulation results from tuning the switch position are illustrated in Fig.4(b). From the results it is observed that the best position is when the switch is at 5mm from the right side of the slot. For comparison, the slotted elliptical antenna without a switch is also shown. It is observed from the figure that when a switch is introduced to the slot, the performance of return loss characteristic is better and the bandwidth is wider. The simulation result of slotted elliptical antenna without a switch shows that it has an impedance bandwidth for return loss less than -10 dB from 2.5 to 6.45 GHz. The value of return loss is -28.75 dB as illustrated in Fig.4(b). Meanwhile, the slotted elliptical antenna with a switch shows that the impedance bandwidth is 2.4 to 6.85 GHz. The return loss for this patch is value is -31.11 dB at resonance frequency of 3.97 GHz, which is lower than of the slotted antenna without a switch.



(a) (b)

Figure 4: The optimization of switches position along the slot

Fig.5 depicts the return loss characteristics of both simulated and measured results for slotted elliptical antenna with a switch. The return loss for measured result is slightly lower as compared to the simulated result. On the other hand, the bandwidth of the measured results is greater than simulated results. However, there is a slight discrepancy between the measured and simulated return loss results in terms of frequency. The return loss for measured result is slightly lower compared to simulation result in which value at 3.4 GHz is -39.09 dB and -38.03 dB at 5.44 GHz. There is also a disagreement between the measured and simulated return loss results in terms of frequency. The inconsistency between simulation and measured results are due to some factors that would affect the results such as inappropriate handling during measurement process, soldering process and improper fabrication process.

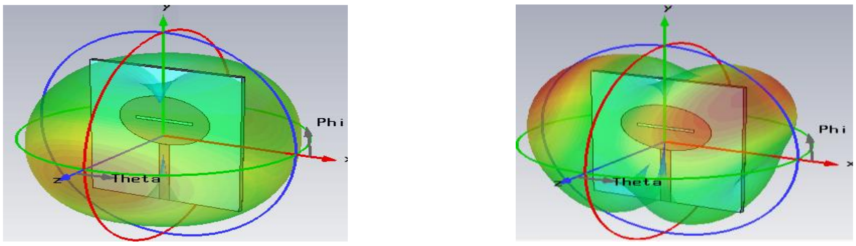


(a) (b)

Figure 5: Comparison S_{11} characteristic of simulation and measured results. (a) without a switch (b) with a switch

2.2. Radiation Patterns

The simulated results of the radiation patterns of the slotted elliptical antenna without a switch are presented in Fig. 6. The results include polarization in the E(*yz*)-plane and the H(*xz*)-plane. The lobes cover 360^o directions at the first resonance frequency of 3.97 GHz. A donut shape with an approximately omnidirectional in the H-plane pattern is also shown in Fig.6. The deformations appear due to the induced currents, causing in inclining the beam away from the broadside direction in the E-plane. The radiation pattern is inclined at 45^o elevation angle. In addition, the radiation pattern of the antenna is affected by the ground plane whereby the omnidirectional pattern is degraded significantly at frequencies and the radiation pattern of the antenna becomes more directional as the frequency increases beyond 5.0 GHz. This is due to the fact that as the frequency increases, more and more of higher order current modes are excited. The value of radiation efficiency is 93.2% at 3.97 GHz and 91.2% at 5.5 GHz.



(a) (b)

Figure 6: Simulated farfield radiation pattern in 3D at (a) 3.97 GHz (b) 5.5 GHz

The structure of the slotted elliptical antenna described in the previous section has been fabricated and measured. The prototype of the antenna is shown in Fig. 7.

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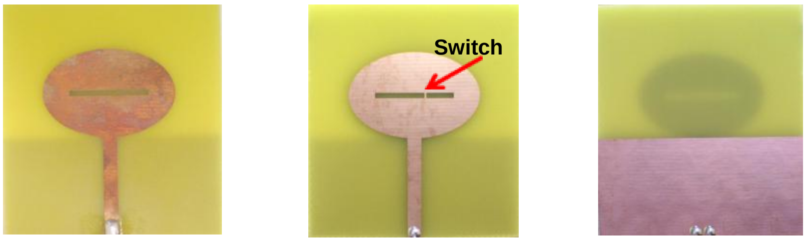

(a) Front View (b) Front View (c) Back View

Figure.7: Prototype of slotted elliptical antenna: (a) Without switch, (b) With a switch (c) Ground area

3. Conclusion

A slotted elliptical antenna is proposed for broadband applications. Parametric studies of the antenna characteristics are presented and the return loss at resonance frequency of the prototyped antenna is compared with those of the simulated results. A switch is added to the slotted elliptical antenna and the performance of the antenna after adding a switch is discussed. Finally, the design formulas are given relating the resonance frequency and the lowest frequency in its operational band to the outer perimeter of the antenna.

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