Crescent Slot Eight Shape Microstrip Patch Antenna For Ultra-wideband

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Abstract: **A new design in microstrip structure is proposed with Crescent Slot in Eight Shape for ultra-wideband based applications. A lossless material honeycomb dielectric of dielectric constant 1.11 is sandwiched between radiating patch and ground. The main motivation for this work is to enhance the bandwidth of the Impedance. The simulation results verify that the proposed antenna has a 63 percent bandwidth for Return loss less than -10 dB which is around 3.2 GHz while covering S-Band (2-4 GHz) and C-Band (4-8 GHz) of microwave frequency bands. Different variation in proposed design is also discussed. The basic advantage of this design is its simple structure with no active element, no shorting pins and no vertical walls between the patch and the ground. The typical impedance behavior and far field radiation pattern characteristics of proposed configuration are presented. The antenna is designed, optimized and simulated using Transmission line Matrix (TLM) based software Microstripes 7.5.**

Keywords: **Butterfly shape antenna, crescent slot, eight shape patch antenna, printed circuit, ultra-wideband(UWB).**

1. INTRODUCTION

Conventional microstrip antennas in general have a radiating patch printed on a grounded microwave substrate, and have attractive features of low profile, low cost, light weight, easy fabrication, and conformability to mounting hosts. However, microstrip antennas inherently have a narrow bandwidth and bandwidth enhancement is usually demanded for practical applications. Thus, bandwidth enhancement is becoming major design considerations for practical applications of microstrip antennas [1]. Many techniques such as star shape patch, crescent patch [2] have been reported to achieve wideband microstrip antenna.

It has been shown that circular patch antennas offer performance similar to that of rectangular antennas but in some applications, such as an arrays, circular geometries offer certain advantages over other configurations. The circular geometries can be easily modified to produce a range of impedance values, radiation patterns and frequencies of operation[3]. Also, the circular or elliptical shape monopole antennas are also found to have sufficient 10 dB return loss bandwidth for ultra-wideband applications [4-12].

In this paper a novel eight shape antenna is proposed that would significantly increase the overall antenna bandwidth with simple structure. The basic structure is consists of a two merged elliptical shapes that gives eight shape geometry with internally placed crescent slot and circular patch, which is directly fed by vertically located probe feed. The outer eight shape geometry is parasitically coupled by internally placed circular geometry (fig 1). To provide protection to the antenna from unfriendly environment it is covered by another dielectric layer called as superstrate. The consideration of superstrate is taken for all simulations. A parametric study on antenna return loss in terms of antenna height, probe fed location and superstrate placement is presented through the use of TLM based software Microstrip 7.5 [13].

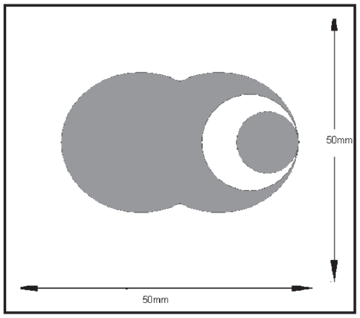


Fig 1: Top view of the crescent slot eight shape radiating patch antenna with 50X50 mm Ground plane

2. THEORY AND ANTENNA DESIGN

For the proposed structure the consideration for choice of different parameter is same as those for rectangular patch antenna. The substrate chosen is having low dielectric constant for high radiation efficiency and thicker substrate increases the impedance bandwidth. The basic antenna structure comprises a thin, conducting eight shape geometry on a dielectric backed by a ground plane. The main substrate is honeycomb dielectric. It is chosen as air dielectric substitute. The patch and ground is thin Copper layer bonded to Astro-Quartz layer. Two Copper/Kapton/Astro-Quartz layers are built to function as the radiating patch and ground plane. The eight shape patch is placed on a honeycomb dielectric structure above a conducting ground plane. The honeycomb structure is filled mostly with air as shown in fig 2 and therefore introduces only a small loss at microwave frequencies. Also, honeycomb is a product that possesses an excellent strength to weight ratio and is applicable almost anywhere, where lightness and stiffness is required.

The Copper/Kapton/Astro-Quartz layers and the honeycomb dielectric layers will be drilled to allow attachment of the feed wires to the radiating patch (fig 3).

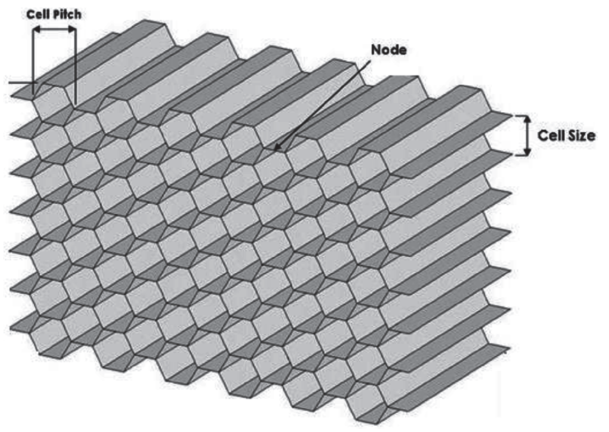


Fig 2: 3-D structure of the perforated honeycomb dielectric

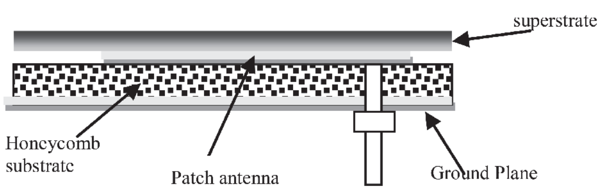


Fig 3: Side view of the proposed structure with different layers

2.1 Design parameters

The size of the ground plane is kept 50X50 mm. All the above layers are having the same size except proposed antenna. The thickness of honeycomb dielectric is optimized at the value of 10 mm. The width of the patch is 16 mm in y-direction and length is 27 mm in x-direction. A circular disk of 3.5mm radius is put with the crescent shape slot around the probe feed to compensate the effect of extra inductance introduced due to increase in length of probe feed. The dimensions of the patch are shown in fig 4.

In the proposed microstrip patch design two elliptical patch shapes are merged together in order to get the single eight shape entity. The major and minor axis value of each ellipse is optimized at 9 mm and 8 mm in x and y direction. R_{in} and R_{out} are the radius of inner circular patch and crescent slot which are kept as 3.5mm for R_{in} and a variable value between 3.5 to 7 mm for R_{out} respectively.

Design Parameter	Value
Ground	50x50 mm
Substrate height	10 mm
Patch length	27mm
Width	16 mm
Rin	3.5mm
Rout	3.5-7mm

When the two ellipse entities are combined as shown in fig. 4 they gives eight shape geometry with overall length L=27mm and width W=16mm. Center point of each individual geometry is shown in fig. 4. This greatly helps in understanding the actual design.

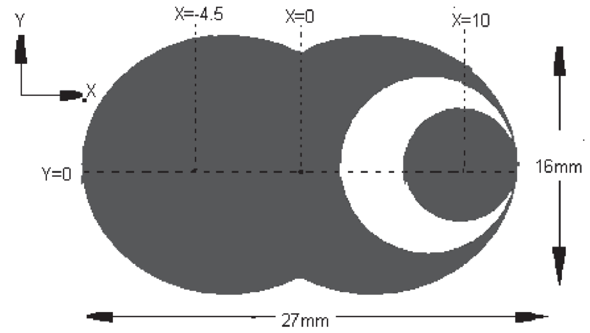


Fig 4: 2-D Geometry of the proposed CSESA with L=27, W=16, R_{in} =3.5 and R_{out} =6 (all dimensions are in mm)

2.2 Effect of using superstrate

In many applications dielectric cover is required over the microstrip antenna for protection against heat, physical damage and the environment. When the microstrip patch is covered by dielectric sheet (superstrate), its properties like effective dielectric constant, losses, Q factor, and directive gain change. The change in effective dielectric constant is more than other characteristics. The amount of change is dependent on thickness and relative permittivity of the superstrate. The presence of cover layer produces change in radiation pattern also. The H-plane is found to become narrow due to presence of cover layer. The associated increase in gain is also a useful feature of the microstrip antenna with the superstrate. As the dielectric constant of superstrate increases, the increase in gain and lowering the resonant frequency is occurred. In proposed structure FR4 (dielectric constant 4.4) used as superstrate and results are compared.

2.3 Design Analysis

From the examination of the current distribution of the circular patch radiator it has been found that the current at all frequencies is mostly concentrated on its periphery, with very low current density towards its center. When the shape of this circular patch is disturbed by varying axial ratio and adding slots the current distribution also gets changed and results in generation of new current modes. The idea of obtaining eight shape antenna is derived from the examination of the current distribution of the elliptical patch antenna, the shape of eight affects the polarization level of the antenna which is due to the cutting edge of elliptical shape radiator.

3. SIMULATION RESULTS

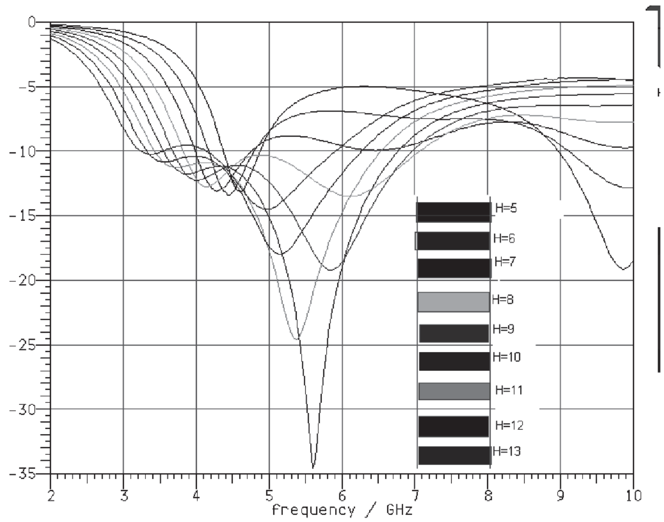
3.1 Antenna Return Losses

Numerical simulation and measurements were conducted on the eight shape patch antenna. Its return loss characteristics are shown in fig 5 and shows that it has impedance bandwidth for return loss less than -10 dB is more than 2.5 GHz for both of the cases considered. Parametric study of the effect of substrate (honeycomb dielectric) thickness, crescent slot radius, superstrate material and its thickness using microstrip 7.5 are shown in fig 5(a)-5(c).

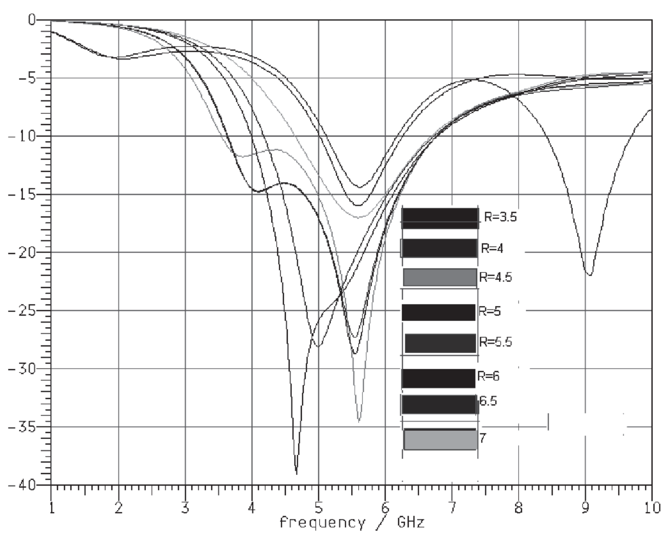
Variation in antenna return loss due to different substrate heights is shows in Fig 5(a). It verifies that the optimum value of substrate thickness is 10mm.

Fig 5(b) shows the effect of varying radius of crescent slot (R_{out}) in eight shape. To observe the effect of crescent slot radius the thickness of substrate is kept 10 mm. For all the various values of R_{out} in antenna return losses curve there is only one resonant mode except R_{out}=4mm, at which there are two resonant modes but due to less impedance matching it is not considered as a good result. The concept and mathematical formula for generation of these current modes are explained in next section. From fig 5 (b) it is observed that the antenna results are found good for R_{out}=4.5mm and 6mm.

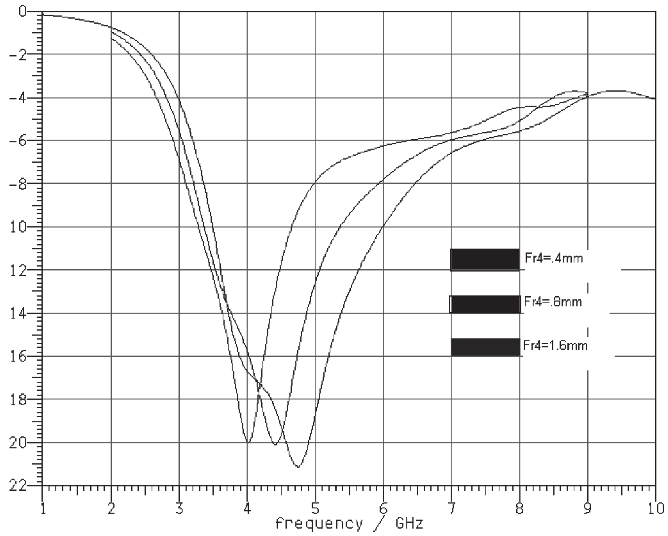
Fig 5(c) points to the effect of using various thickness (.4mm, .8mm, 1.6mm) of superstrate layer which is taken FR4 in this case. To observe this effect remaining two parameters substrate height and R_{out} chosen as 10mm and 6 mm constant respectively..



(a)



(b)

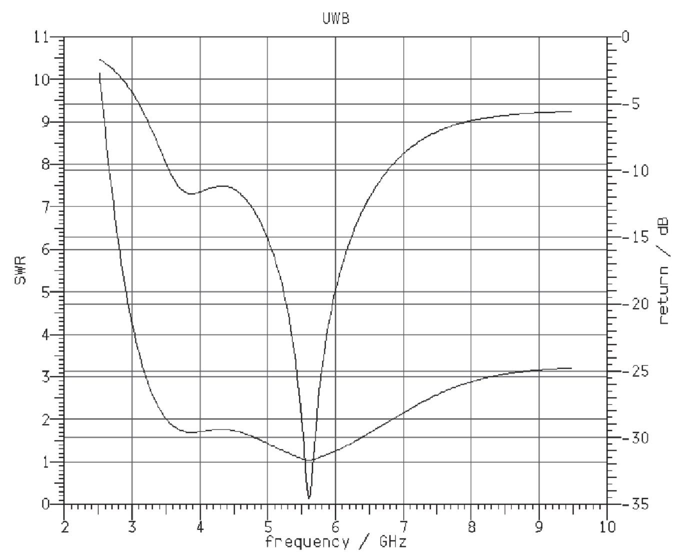


(c)

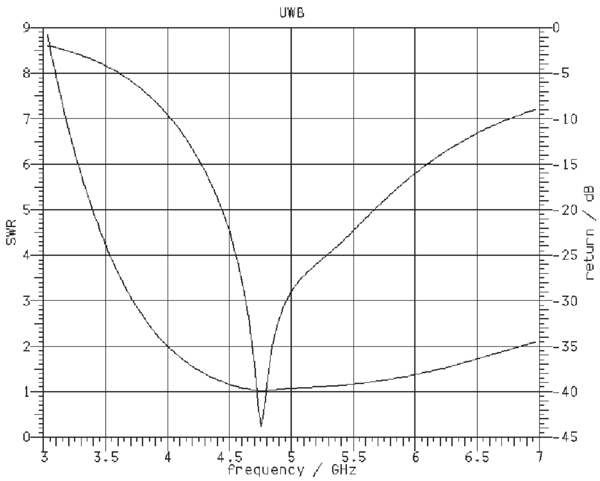
Fig 5: Parametric studies of the effect of (a) varying substrate thickness (b) variation in radius Rout (c) thickness of superstrate FR4 with H=10mm and R_{out}= 6mm constant

For comparison two cases with substrate thickness 10mm, feed location x=12; y=0, crescent slot radius 4.5 and 6 mm and with superstrate material is shown. The side view of these configurations is also shown in fig.3 as a basic antenna structure in which the dielectric constant of adhesive material is also considered to analyze the results.

The bandwidth obtained for considered first case with R_{out}(crescent slot radius) =4.5mm is 3.2 GHz for -10 dB Return loss (RL) and 3 GHz for VSWR<2. And for second case with R_{out}=6mm it is 2.7 GHz with RL less than –10 dB. The return loss curve for both of these two cases is shown in fig 6 (a) and (b)



(a)



(b)

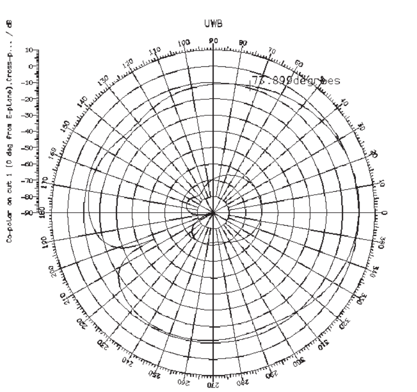
Fig 6: Return losses and VSWR for considered two cases
(a) R_{out}=4.5 (b) R_{out}=6

3.2 Current modes

Through the numerical study of the vector current distribution of the antenna prototype only one characteristic mode is found to exist with the eight shape patch over the bandwidth 3 to 7 GHz, This can be considered as a dominant mode. Since the height of the substrate h $<<\lambda_0$, the field do not vary along the z-direction. Therefore the electric field within the substrate has only z component, and the magnetic field essentially has a ρ and φ component. The solution of wave equation for the given patch assuming cylindrical co-ordinates is shown in following mathematical expressions.

$$E_Z=E_0 J_n(k\rho)\cos n\varphi \quad (1)$$
$$H\rho=-(jn/\omega\mu\rho)\, E_0 J'_n(k\rho)\sin n\varphi \quad (2)$$
$$H\varphi=-(jk/\omega\mu\rho)\, E_0 J_n(k\rho)\cos n\varphi \quad (3)$$

For n=1 minimum resonance frequency or dominant mode occurs. From the shown results it can be observed that the bandwidth of the antenna for dominant mode is of the range of 1 to 3.5 GHz for all the parametric comparisons, which is becomes outmoded for the thickness of substrate honeycomb less than 5mm. The cross polarization level for dominant mode for both of the considered cases is less than –40 dB which means the bleeding of power into nearby bands due to cross polarization is also very less. The cross polarization and co polarization for both cases are shown in fig 7(a)-7(b).



(a)

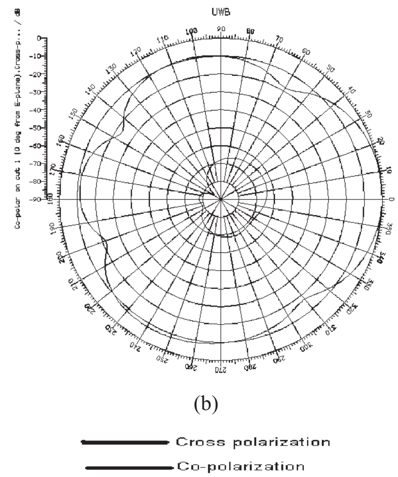
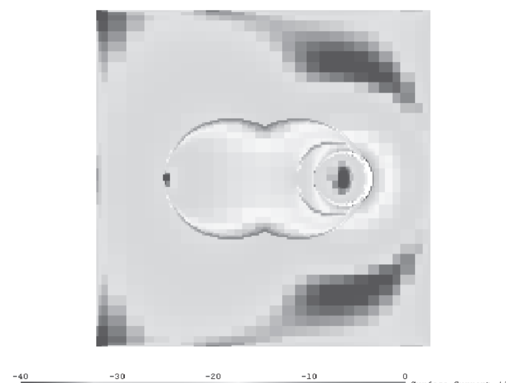
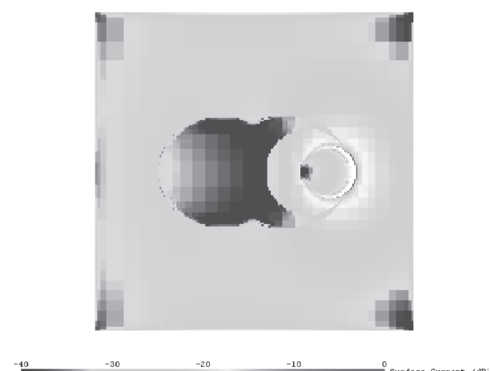


Fig 7: Co and Cross polarization for both cases (a) R_{out}=4.5 at 5.6 GHz
(b) R_{out}=6 at 4.6 GHz

The current distribution and generation of current modes for the above two cases also are shown in fig 8(a)-8(b).



(a)

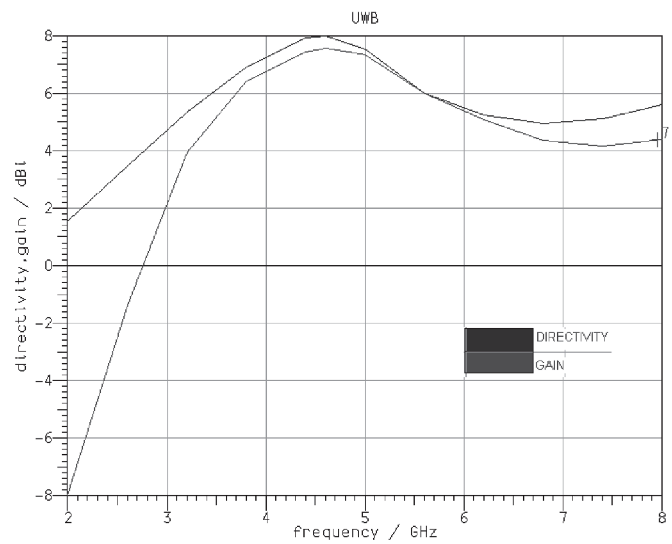


(b)

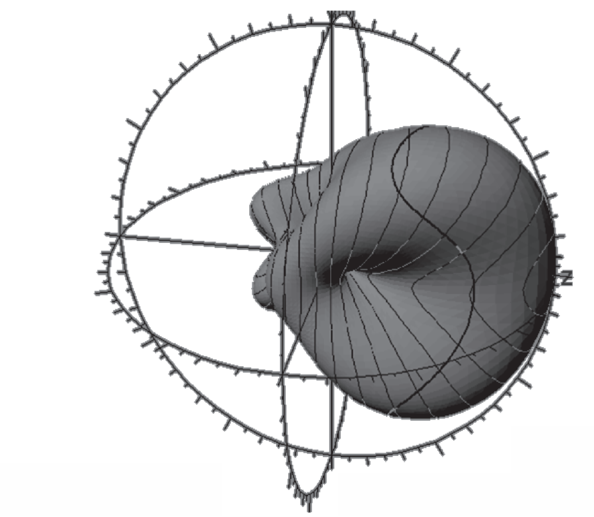
Fig 8: Current distribution at dominant mode frequencies
(a) R_{out}=4.5 at 5.6 GHz (b) R_{out}=6 at 4.6 GHz

3.3 Radiation pattern

The antenna gain for R_{out}=4.5 is 6dBi at 5.6 GHz and for R_{out}=6 it is 7.2dBi at 4.6 GHz. The antenna Gain and directivity curve for both cases are shown in fig 9 (a) and fig 10(a). The radiation pattern in broadside direction of the proposed antenna for above discussed cases are shown in fig 9 (b) and 10(b). This facilitates in understanding the behaviour of the antenna in direction of maximum radiation.

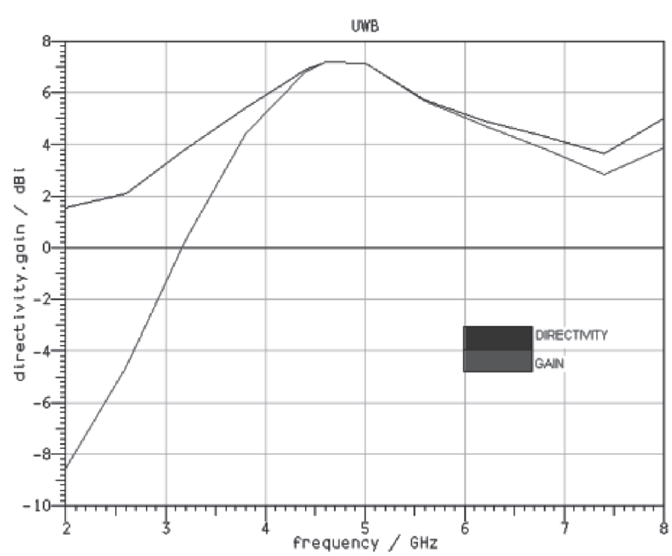


(a)

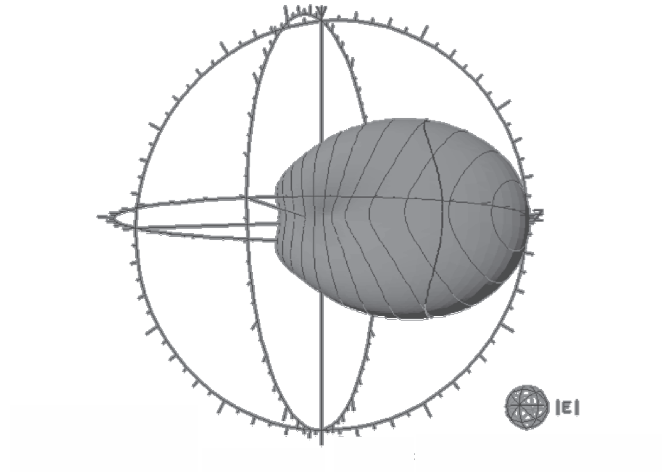


(b)

Fig 9: Directivity Gain and Radiation pattern for R_{out}=4.5
(a) Directivity, Gain Vs Frequency curve (b) Radiation pattern



(a)



(b)

Fig 10: Directivity Gain and Radiation pattern for R_{out}=6
(a) Directivity, Gain Vs Frequency curve (b) Radiation pattern

5. CONCLUSION

A crescent slot eight shape patch antenna was proposed for ultrawideband application in 3-6 GHz. A parametric study of the antenna characteristics is discussed. The proposed antenna is good for wireless and Wi-Max 802.16e applications. The operating frequency of antenna gives less fading due to rain as compare to 2.4 GHz thus more application oriented.

REFERENCES

[1] Kin Lu Wong, "Compact and Broadband Microstrip antenna " A Wiley-Interscience Publication, John Wiley & Sons. pp 45-79.

[2] Ntsanderh C. Azenui and H. Y. D. Yang, "A Printed Crescent Patch Antenna for Ultrawideband Applications" IEEE Antennas Wireless Propag. Lett, vol. 6, 2007.

[3] Ramesh Garg, Prakash bhartia, Inder Bahl, Apisak Ittipiboon " Microstrip antenna design handbook" Artect House BOSTON, LONDON.

[4] M. Hammoud et al., "Matching the input impedance of a broadband disc monopole," Electron. Lett., vol. 29, pp. 406–407, Feb. 1993.

[5] N. P. Agrawall, G.Kumar, and K. P. Ray, "Wide-band planar monopole antennas," IEEE Trans. Antennas Propag., vol. 46, pp. 29–295, Feb.1998

[6] J. Powell and A. Chandrakasan, "Differential and single ended elliptical antennas for 3.1–10.6 GHz ultra wideband communication," in IEEE APS Int. Symp., Jun. 2004, vol. 3, pp. 2935–2938

[7] H. G. Schantz, "Planar elliptical element ultra-wideband dipole antennas," in IEEE APS Int. Symp., 2002, vol. 3

[8] M. J. Ammann and Z. J. Chen, "Wideband monopole antennas for multi-band wireless systems," IEEE Antennas Propag. Mag., vol. 45, pp. 146–150, Apr. 2003

[9] C. Ying and Y. P. Zhang, "A planar antenna in LTCC for single-package ultrawide-band radio," IEEE Trans. Antennas Propag., vol. 53, no. 9, pp. 3083–3093, Sep. 2005

[10] L. Jianxin, C. C. Chiau, C. Xiaodong, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," IEEE Trans. Antennas Propag., vol. 53, no. 2, pp. 3500–3504, Nov. 2005.

[11] Z. N. Low, J. H. Cheong, and C. L. Law, "Low-cost PCB antenna for UWB applications," IEEE Antennas Wireless Psropag. Lett., vol. 4, pp. 237–239, 2005.

[12] G. Lu, S. Mark, I. Korisch, L. Greenstein, and P. Spasojevic, "Diamond and rounded diamond antennas for ultra-wide-band communications," IEEE Antennas Wireless Propag. Lett., vol. 3, pp. 249– 252, 2004.

[13] MICROSTRIP 7.5, www. Flomerics.com.

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