

Wideband CPW Fed Monopole Fractal Antenna with Defected Ground Structure

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Abstract: For the exchange of high rate information, wide band antennas are needed and their usage increased tremendously now a days. One of the major challenges in the design of wideband antenna is the design of a small size antenna while providing wide bandwidth, omni-directional radiation pattern and stable gain. The proposed antenna consists of a monopole antenna with polygon shaped patch. Fractal elements are added to the polygon patch and defected ground structure is experimented for the enhancement of bandwidth. The size of the proposed antenna is $25 \times 25 \times 1.6 \text{ mm}^3$ and is prototyped on FR4 substrate whose permittivity is 4.4. The proposed antenna should provide wideband and it is useful for wireless communication applications.

Key words: Wideband, fractal element, Coplanar Waveguide (CPW), Monopole Antenna, Defected Ground Structure (DGS)

INTRODUCTION

In 2002, the Federal Communications Commission (FCC) opened the permits of 3.1-10.6GHz frequency band for unlicensed ultrawideband measurements and communication applications with EIRP $> -41.3 \text{ dB m MHz}^{-1}$ (Ramkiran *et al.*, 2014). Since, then the UWB Antenna, which is the key component of the UWB system is studied and researched widely in the academics and industry. These antennas are used in many applications such as radars, mobile systems, biomedical imaging, tracking and they also have the capability of transmitting ultra-short pulses. Among various types of UWB antennas, special attention is given to the printed and planar monopole antennas nowadays since they possess physical features such as small size, low profile, low-cost and ease of fabrication (Fallahi and Atlasbaf, 2013).

It is remarkable that, all designs are looking for a wider commercial UWB system requires antennas with omnidirectional radiation pattern and large bandwidth (Madhav *et al.*, 2015a, b; Schantz, 2005). Recently, many techniques have been presented to enhance the antenna bandwidth which include the Truncated ground plane with use of an L-shaped notch in lower corner (Jung *et al.*, 2005, 2006) by increasing the substrate thickness and modifying the radiator, feed structure or ground plane (Mahdavi *et al.*, 2012; Nayak *et al.*, 2015; Koohestani and Golpour, 2010) and by using an Inverted t-shaped notch in the middle (Ojaroudi *et al.*, 2009). Different antennas have been designed by using the concepts of Fractals to

achieve wideband characteristics (Sundar *et al.*, 2015; Oraizi and Hedayati, 2011; Madhav *et al.*, 2015b).

It is a well known concept that the bandwidth of an antenna can be increased by increasing the diameter or thickness of the substrate. This concept is tried here to enhance the bandwidth by increasing the size of the monopole by different sizes and geometries. The direct loading of various simple geometries and iterations were tried as printed monopole. It is theoretically predicted that all geometries upon loading will result in wide band antennas. Slotted hexagonal is found to be most simple for better parametric control, fabrication, testing and theoretical analysis and hence the investigation is started with hexagonal shape. In this letter, a monopole antenna with polygon shaped patch is proposed where fractal elements are added to this polygon shaped patch to enhance the bandwidth.

MATERIALS AND METHODS

Antenna geometry: A hexagonal monopole antenna is the base for this proposed model. Here the monopole is a hexagon of side "a" on a strip at a distance 'd' from the ground plane. In this case the overall length of the antenna ($2.4a+d$) is equivalent to the length of the earlier strip monopole antenna. There is a small gap 'd' is introduced to achieve impedance matching. Figure 1 shows basic model and fractal element model with small modifications in it. Figure 2 is giving clear ideal and model design aspects in iterative manner.

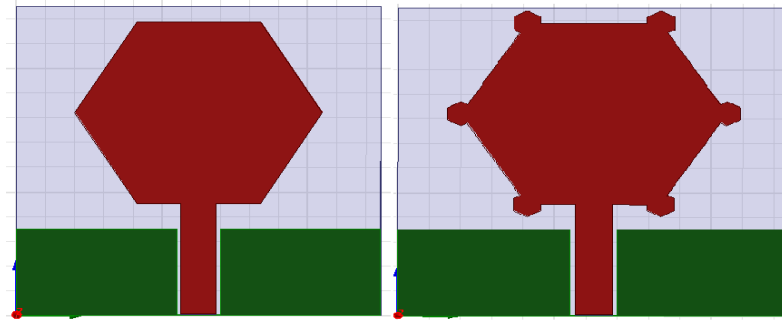


Fig. 1: a) p hexagon monopole; b) Fractal element model

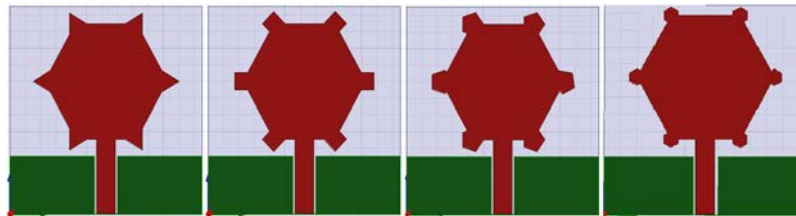


Fig. 2: Different iterations of the hexagonal model

RESULTS AND DISCUSSION

Figure 3 shows the reflection coefficient of the antenna with and without fractal element. It is been observed that with hexagonal fractal element antenna is operating in the wideband with bandwidth of 8 GHz approximately. Figure 4 and 5 shows the reflection coefficient with variation in the fractal element. The optimization is carried out for all the controlling parameters studied above. It can be seen that the sizes of the hexagon strip affect the operating frequency. The low operating frequencies decrease regularly with the increasing of “a” which is similar to a dipole. From Fig. 6 and 7 the parametric analysis is been observed for change in a and b. From Fig. 8 and 9, it is been observed that a bandwidth of 8 GHz is obtained in the desired band with 2:1 VSWR ratio.

The above radiation pattern shows the pattern is almost uniform directional along H-plane and figure of eight along E- plane. Above fig shows the radiation patterns at three frequencies for mean resonant frequencies of the wide band monopole. The antenna has almost identical radiation patterns throughout the 2:1 VSWR bandwidth. Moreover, antenna exhibits cross polar level better than 15 dB in both the planes. Gain of the antenna measured using gain transfer method is shown in Fig. 10 and 11. Antenna exhibits a peak gain of 6 dBi in the operating band. At higher frequencies gain is increased

considerably due to the slight directional characteristics. It is observed that electric current has been excited by all the fractal elements. The current distribution confirms that the elements are parts of the radiating structure and have created the resonance at 10.5 GHz.

Slotted hexagonal fractal element monopole antenna: A modified model of hexagonal fractal with slotted structure is proposed here. Figure 12-15 shows the current model and Fig. 16 shows its return loss curve with change in ‘C’ value. A bandwidth of 7.9 GHz is obtained in this case. It is <0.1 GHz from the previous case but loss is very less and gain is more compared to previous model. The cross polarization level in H-plane increases at higher frequencies. Minimum difference between co and cross polarized patterns at 4 GHz is around 5 dB for 30, 150, 210 and 330 (Fig. 16-19). The increase in cross-polarization level is due to the excitation of hybrid current distribution on the antenna radiator at high frequencies. The electric current distribution at 4.3 GHz is concentrated on the lower edge of the radiator. This means the antenna lower edge affects impedance characteristic at low frequencies. The current distribution of the proposed antenna is similar to that of the simple antenna. It is seen that the current distribution is more complicated than the first resonance frequency current distribution. The currents excited by the lower fractal elements have strongly affected and improved S11 in the middle frequencies (Fig. 20-23).

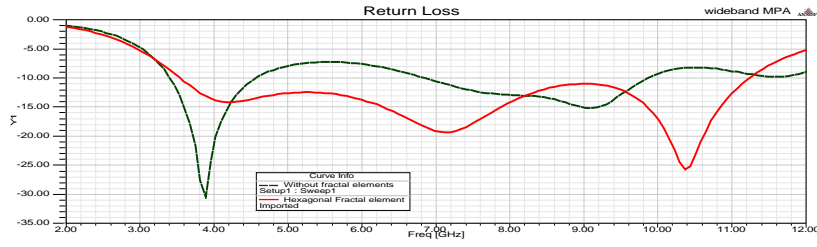


Fig. 3: Reflection coefficient for model 1a and b

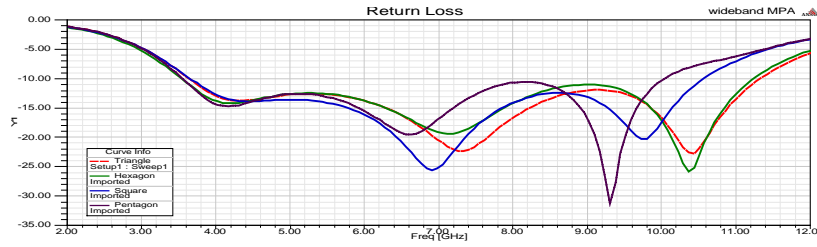


Fig. 4: Reflection coefficient of different iterations of hexagonal model

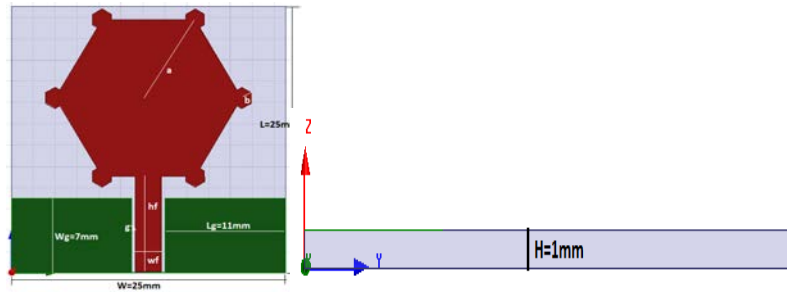


Fig. 5: Optimized fractal element antenna model ($L = 25$ mm, $W = 25$ mm, $H = 1$ mm, $L_g = 11$ mm, $W_g = 7$ mm, $g = 0.3$ mm, $W_f = 2.4$ mm, $H_f = 8.95$ mm, $a = 8.8$ mm, $b = 1$ mm)

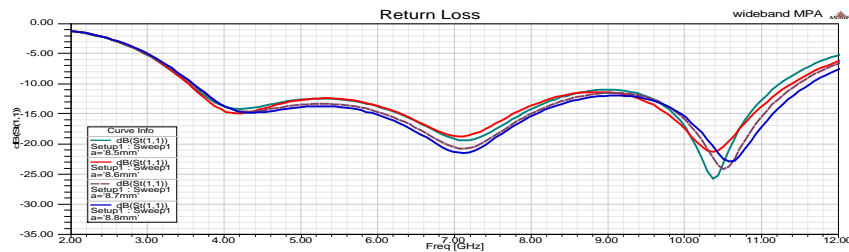


Fig. 6: Reflection coefficient of different iterations for $a = 8.8$ mm

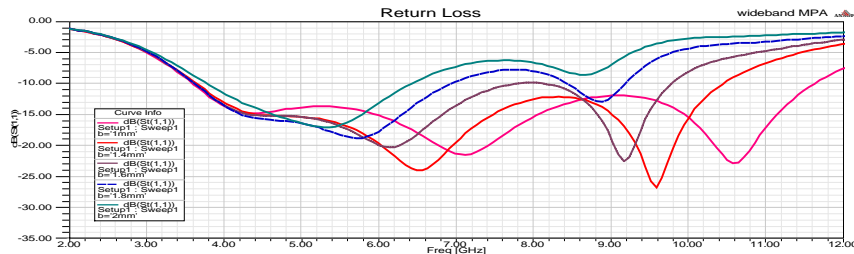


Fig. 7: Reflection coefficient of different iterations for $b = 1$ mm

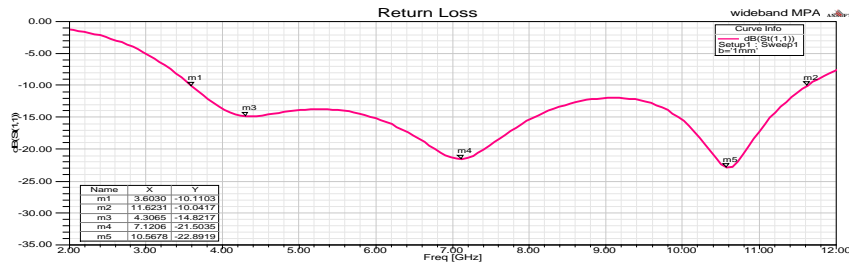


Fig. 8: Return loss of optimized fractal element antenna

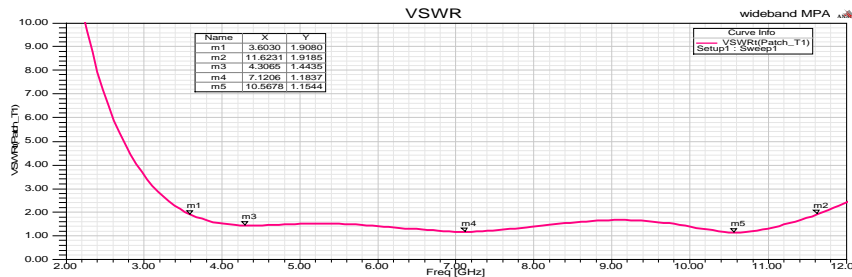


Fig. 9: VSWR vs frequency with 2:1 ratio in the desired band

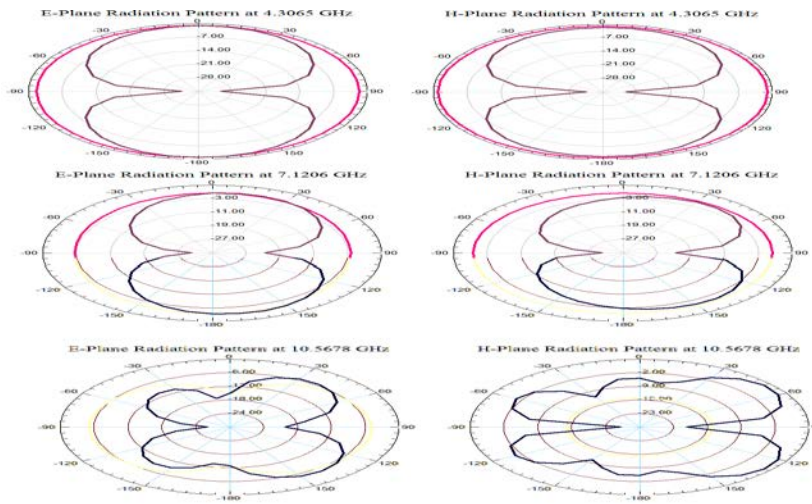


Fig. 10: E-plane and H-plane radiation patterns at resonant frequencies 4.3065, 7.1206 and 10.5678 GHz

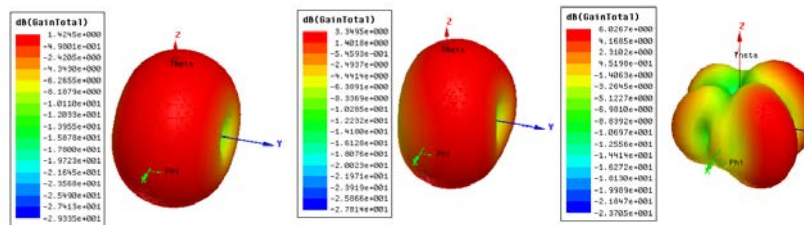


Fig. 11: Peak gains 1.4245 dB at 4.3065 GHz, 3.3495 dB at 7.1206 GHz and 6.0267 dB at 10.5678 GHz

Fractal monopole with defected ground structure: Figure 24 shows the defected ground structured

wideband antenna in HFSS and Prototype on FR4 substrate. Circular slots are created on the ground

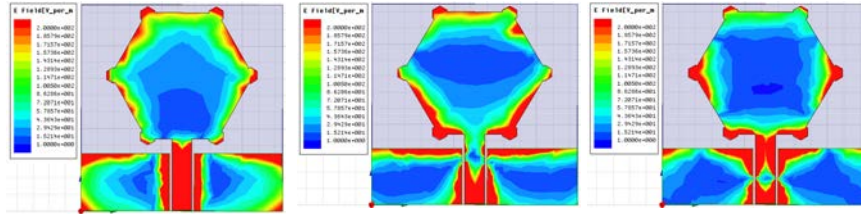


Fig. 12: E-field distribution at 4.3065, 7.1206 and 10.5678 GHz

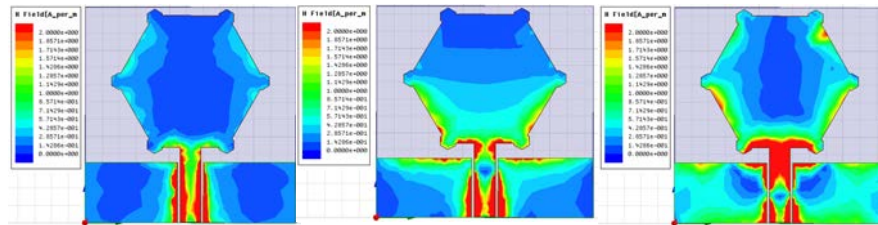


Fig. 13: H-field distribution at 4.3065, 7.1206 and 10.5678 GHz

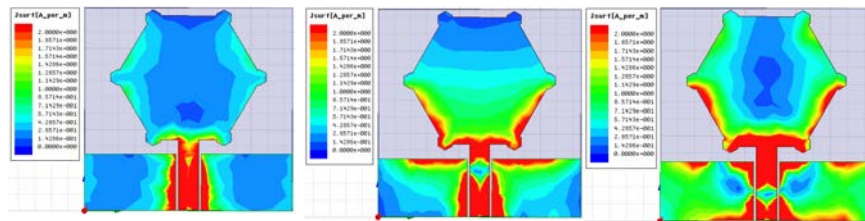


Fig. 14: Current distribution at 4.3065, 7.1206 and 10.5678 GHz

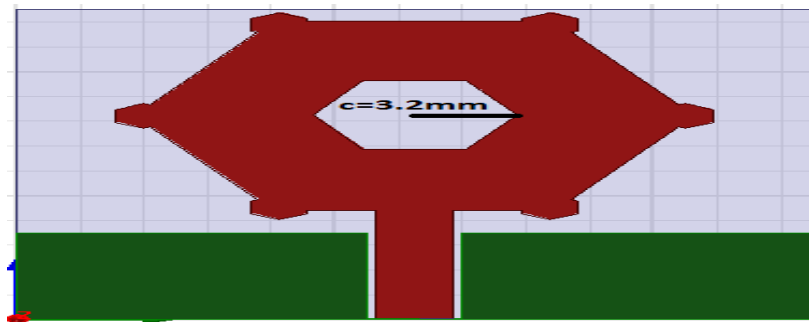


Fig. 15: Slotted hexagonal fractal element monopole antenna

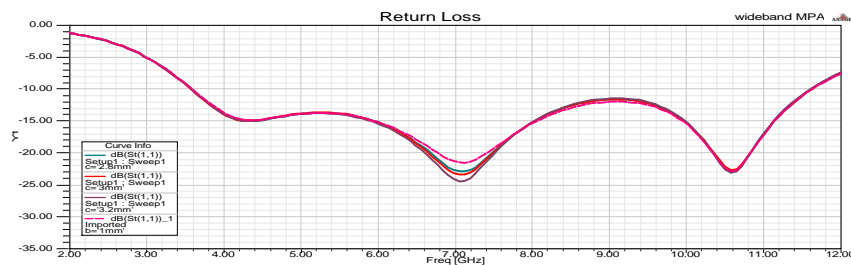


Fig. 16: Parametric analysis with change in 'C'

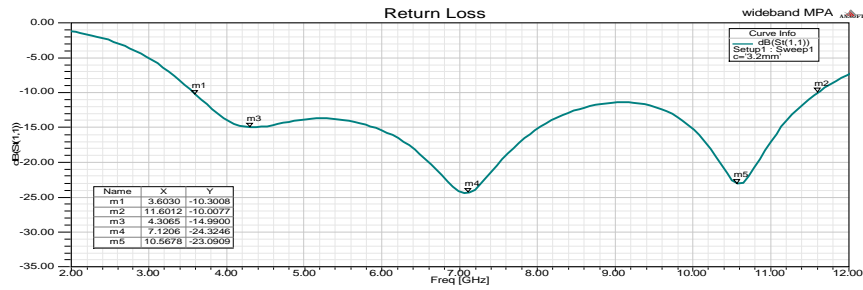


Fig 17: Return loss curve for proposed model

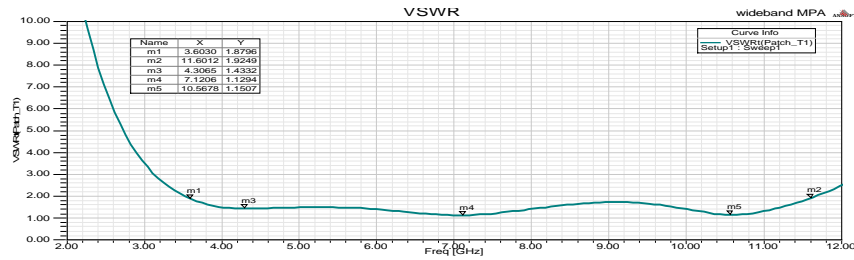


Fig. 18: VSWR vs. frequency for proposed model

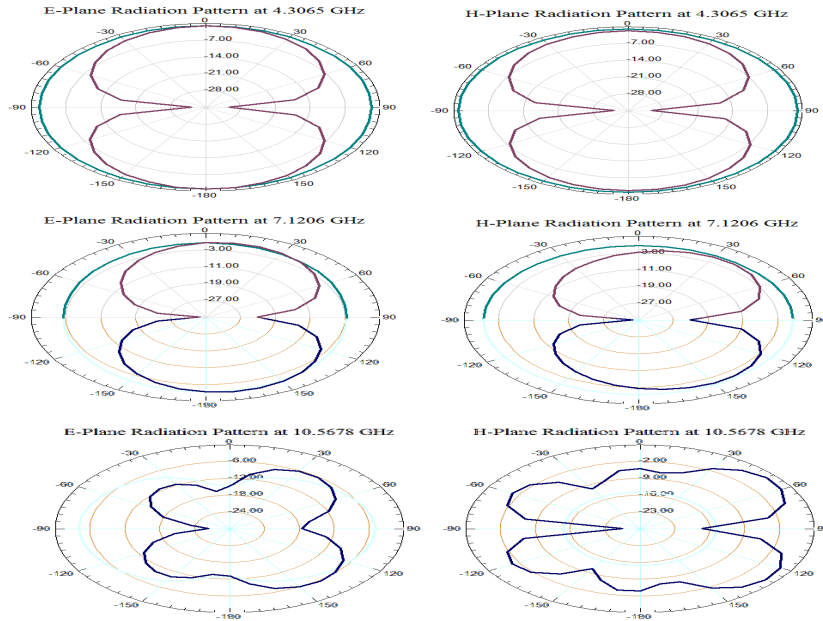


Fig. 19: E-plane and H-plane radiation patterns at resonant frequencies 4.3065, 7.1206 and 10.5678 GHz

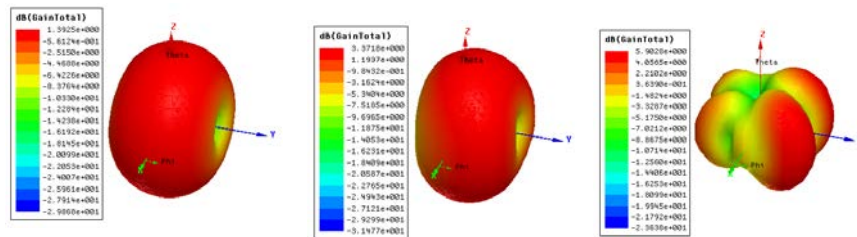


Fig. 20: The 3D gain for the model at 4.3065, 7.1206 and 10.5678 GHz

structure to enhance the bandwidth of the antenna by 4% more compared with earlier design by maintaining stable gain over the operating band. Figure 25 shows the return loss curve for the proposed DGS wideband monopole antenna. Average gain of 3.5 dB is

attained from the current design. Figure 26 shows the VSWR of the proposed antenna. The operating band is shifted to higher frequency due to mismatch in the impedance at slot position on ground plane.

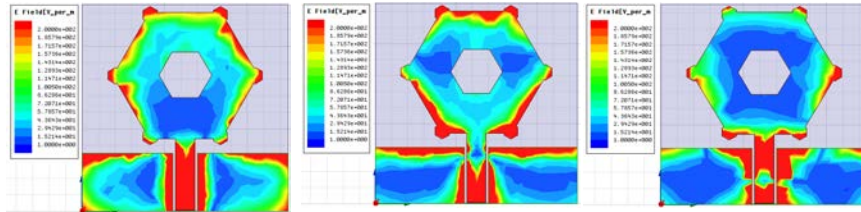


Fig. 21: E-field distribution at 4.3065, 7.1206 and 10.5678 GHz

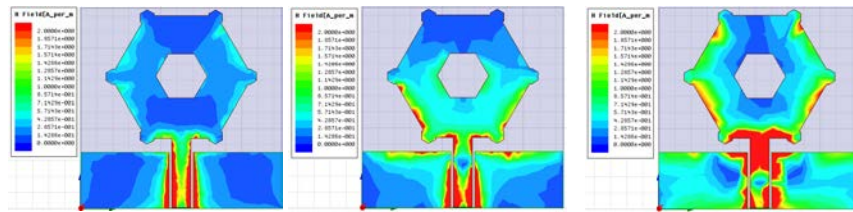


Fig. 22: H-field distribution at 4.3065, 7.1206 and 10.5678 GHz

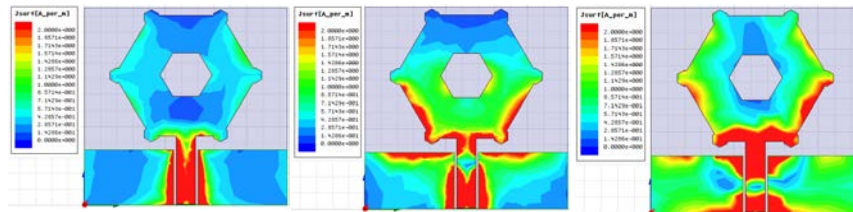


Fig. 23: Current distribution at 4.3065, 7.1206 and 10.5678 GHz

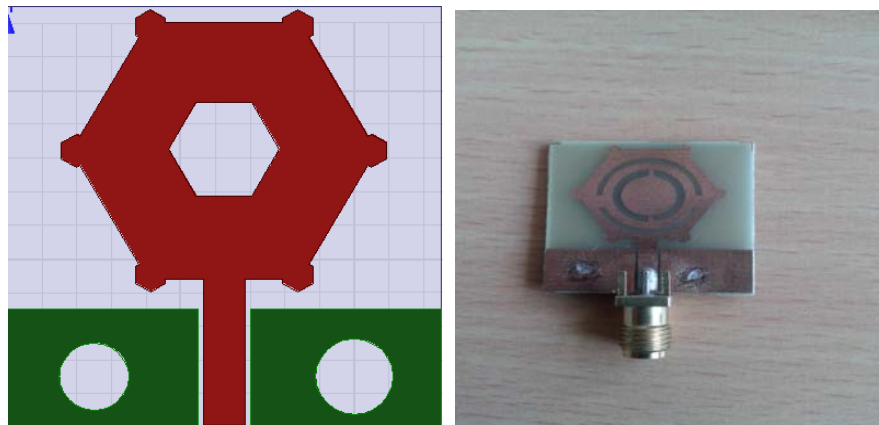


Fig. 24: Wideband antenna with DGS

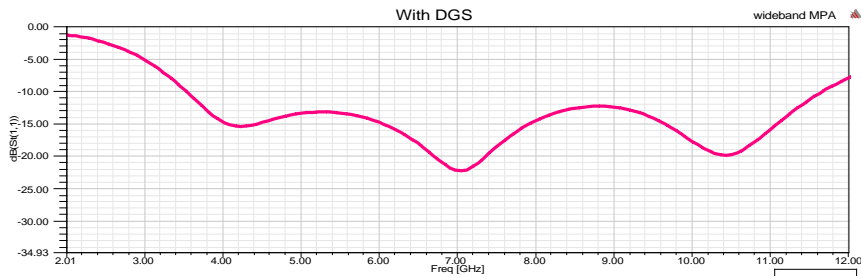


Fig. 25: Frequency vs. Return loss of wideband DGS antenna

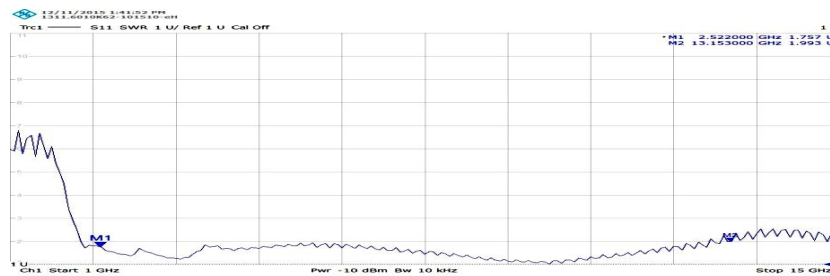


Fig. 26: Measured VSWR from ZNB 20 VNA

CONCLUSION

A monopole antenna with hexagon shaped patch and fractal elements with DGS is proposed and designed in this project. The model consists of hexagonal fractal elements attached to the vertices of a hexagon to improve the bandwidth and ground is extended vertically towards the two sides of the single radiator with circular slot on the surface. The size of the proposed antenna is $25 \times 25 \times 1.6 \text{ mm}^3$ and is prototyped on FR4 substrate whose permittivity is 4.4. The proposed antenna model provides wideband and it is useful for wireless communication applications like WI-FI, WI-MAX, WLAN, bluetooth etc.

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