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A COMPACT HEXAGONAL SLOT WIDEBAND ANTENNA FOR WIRELESS APPLICATIONS

V.Lavanya, A.Regi Saral

***Abstract*—In this paper, a compact hexagonal slot antenna is proposed for bandwidth enhancement. The proposed antenna is electromagnetically coupled with the hexagonal parasitic patch. The hexagonal slot antenna has a compact size of 25x25x1.6mm^3 and is powered through the microstrip line feed structure. The proposed antenna gives wide bandwidth of about 9GHz (3.6GHz to 12.6GHz) in vertex feed. Over the operating bandwidth, the maximum gain of the antenna is 4.5dBi. From experimental results, it is concluded that bandwidth enhancement can be achieved by using a parasitic patch and cutting appropriate slots in the main patch.**

***Keywords*— Hexagonal slot antenna, Vertex feed, Parasitic patch, Bandwidth Enhancement.**

I. INTRODUCTION

As there is an increased demand for wireless applications, there is a need for improvement in the existing multiband antenna techniques. The required antenna should be low-cost, compact (low profile antenna) and must cover various operating frequencies (e.g., 2.4GHz-2.484GHz-IEEE802.11b/g and 5.15GHz- 5.35GHz/5.75GHz-5.825GHz-IEEE802.11a for WLAN, 3.4GHz-3.69GHz-IEEE 802.16e band for WiMAX). The multiband techniques for wireless application are achieved by various approaches, such as employing different stub shape and microstrip feed slot techniques. However, this technique results in a small device and resonance at undesirable random frequency bands.

The compact micro strip or patch antenna was attained for high frequency application and bandwidth enhancement [1]. The various printed slot and square slot antenna are considered for parametric analysis in the past research work for bandwidth enhancement and i

mprovement in the antenna performance. The printed slot antenna with a ground plane dimension of 110 x 110mm^2 and slot dimension of 53.7 x 53.7mm^2 which gives the narrow bandwidth of 2GHz [2]. The antenna with the slot dimension of about 44 x 44mm^2 obtained the 60% of the wide bandwidth [3].

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***V.Lavanya**, Electronics and Communication Engineering, Kamaraj College of Engineering and Technology, Madurai, India, Mobile No: 7305273014*
***A.Regi Saral**, Electronics and Communication Engineering, Karpagam University, Coimbatore, India, Mobile No: 9655299648*

The printed E-shaped slot antenna with the slot dimension of about 40 x 45mm^2 which yields the wide impedance bandwidth 120% and its frequency range of 2.8-10.4GHz [4, 5]. From this past research work study if the area of the slot decreases then there is an increase in the frequency range. Followed by these researches, the antenna geometry of 70 x 70mm^2 printed square slot antenna with CPW feed [6] and rotated slot antenna with microstrip feed [7] achieves the bandwidth of 1.41GHz and 2.2GHz respectively. These large size antennas are difficult at the time of fabrication process and create the shift in the desired outputs. A back feed microstrip antenna with parasitic square patch and same shaped slot [8] use the size of 37mm x 37mm and gives bandwidth of 3.13GHz. The pentagonal slot and square slot antenna reported in [1, 8] are considered as source for this proposed work. Printed cone antenna and elliptical slot antenna design [9, 10] yield a wider bandwidth, but it is not suitable for wireless handheld devices like mobile phones. The large size antennas like the reflector, horn are also not suitable for wireless applications and in addition to some those antennas use low thickness substrates like RO3003, RO4003 and RT Duroid, which is very costly compared to others [11]. Circular polarization (CP) is commonly used and more suited to antennas used in wireless communication, due to their insensitivity to the transmitter and receiver orientation process and combat against multipath fading. Although CP operation is possible using single feed and double feed schemes, single feed system has the advantages of requiring no external polarizer or power divider networks as compared to double feed system. A widely used technique to achieve CP in single feed system is to modify the antenna structure itself. The main advantage of the slot antenna is that it can easily fabricate and with the small transmitter it can provide covert communications. The limitation of the microstrip antenna is its narrow frequency bandwidth which is mainly controlled by the device characteristics of the parallel plate transmission line. The bandwidth can be increased by increasing the substrate thickness (h) of the parallel plate transmission line and by use of high dielectric constant ε_r substrate so that the physical dimension of the parallel plate line are decreased [12]. In the following section the antenna design, parameter analysis and simulation results are discussed.

II. DESIGN OF HEXAGONAL SLOT ANTENNA

The proposed wideband antenna is designed on a commercially available FR4 substrate with dielectric constant of about 4.4, thickness of 1.6mm and loss tangent of 0.02.

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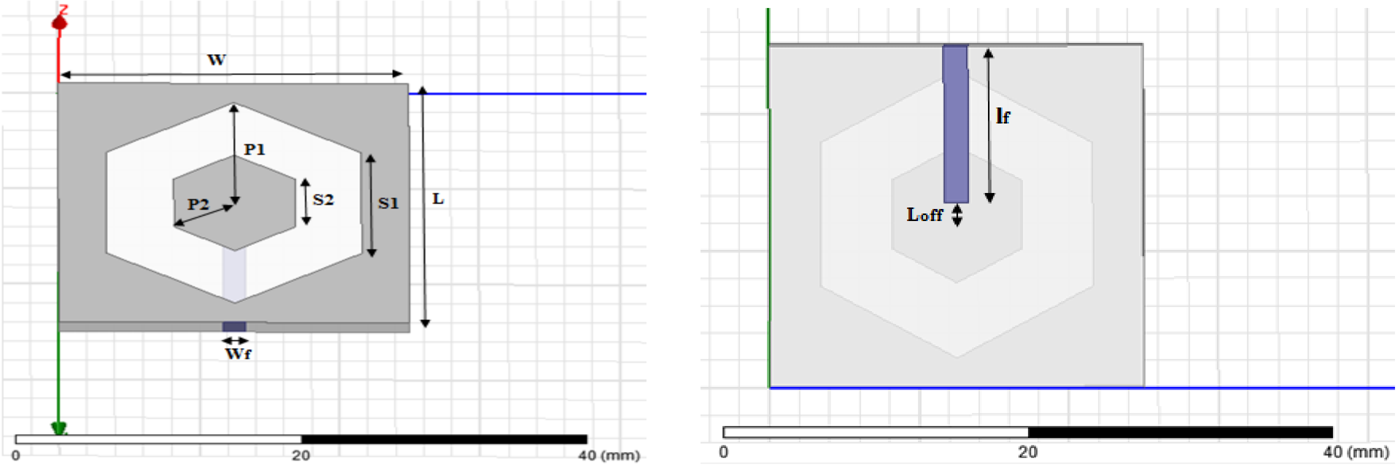

Fig. 1 Hexagonal slot antenna configuration (Front View & Back View)

The wideband antenna has a compact size of 25x25x1.6mm[3] and is fed by 50Ω transmission line using the microstrip feed. The geometrical arrangement of the proposed antenna appeared in Fig. 1.

The ground plane of the antenna with length L and width W and the hexagonal shaped slot cut from the ground plane. The hexagonal slot in the antenna substrate has a side length of S1 and the separation from its inside point (centre) to the vertex of the slot is termed as P1. There is an electromagnetic coupling in the hexagonal parasitic patch of side length S2 with separation from its centre point to the vertex being P2 printed on the similar FR4 substrate. The parasitic patch is positioned at the point of origin, which is encompassed by a wide hexagonal shaped slot. The range of this slot is controlled by either variation in P1 or P2.The hexagonal slot antenna is energized from a microstrip line feed placed underneath it, l_f in long and W_f in broad. The holes between the focal point of the parasitic hexagonal patch and upper end of the anticipated microstrip feeding line are named as L_{off}. The microstrip back feeding line energizes the parasitic patch electromagnetic coupling through the hexagonal shaped slot. The resistivity or impedance matching (50Ω) condition for the greatest transmission of signals from the microstrip feed line to the parasitic patch is achieved by the improvement in the parameters P2, feed length l_f and a gap L_{off}.

III. Parametric Study

Here, the parametric study is carried out to understand the characteristic of various parameters and also optimize the antenna performance of the final design. The effect of the length P1 and P2 (centre to the vertex) of the hexagonal shaped slot, feed length of the defected ground planes are considered for parametric study. For bandwidth enhancement, the length and width of the parasitic patch and the feed line of the hexagonal slot antenna is tuned. The length and width of the slot region are changed by the distance from the inside to the vertex of hexagonal parasitic patch P2 and hexagonal space or slot P1. First, for achieving the wider bandwidth the hexagonal slot P1 is varied, which couples with the substrate, ground plane and the parasitic patch. For bandwidth enhancement the length P1, P2 (centre to vertex) and l_f (feed length) are taken for the parametric study.

The coupling capacitance between the P1 and P2 are varied by varying the parasitic patch side length of the S2. Fig.2 shows the reflection coefficient of variation in P2 at constant feed length (l_f) and distance from the middle to the vertex of the slot. The reflection coefficient is goes below -10dB when increasing in the parasitic patch length P2. The two operating frequency, the lower frequency at 3.2GHz and higher frequency at 12.2GHz, are noticed at P2=4mm. As P2 area expands, the side length S2 of parasitic patch also increases. The expansion in the side length S2 of the parasitic patch enhances the coupling gap between the parasitic patch and the ground plane, which results comes about into decrease of lower and also upper operating frequency. The enhancement in the coupling capacitance shows a good impedance matching across a wide bandwidth. At P2=3.5mm a wide resonance bandwidth is observed of about 8.6GHz (3.6-12.2GHz), P2=4mm the wideband resonance increases slightly and offer a bandwidth of 9GHz (3.2GHz-12.2GHz) and their reflection coefficient at 3.6GHz is -14dB and at 5.2GHz is -19dB. At P2=5.5mm, it is observed that the wideband dual resonance of bandwidth is 3.8GHz (3.2GHz-7GHz) and 3GHz (8.6GHz-11.6GHz).

Additionally, the variation in the length P1 and the side length of slot S1 obtained the lower resonating frequency of wide band as appeared in Fig.3.

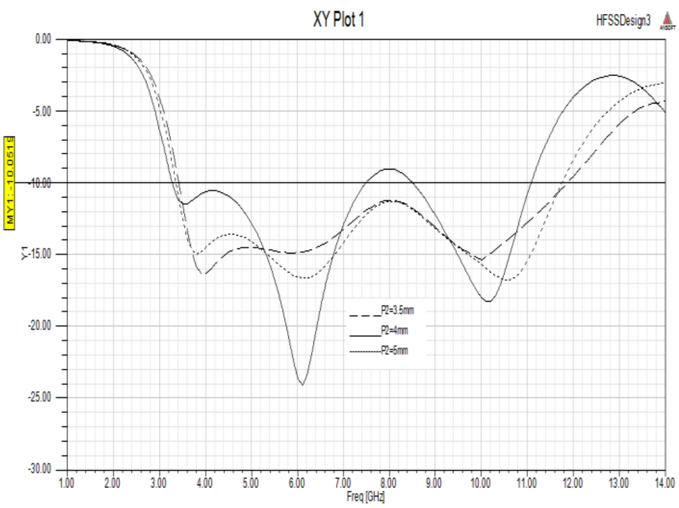

Fig .2 Return loss of hexagonal slot antenna with different P2 at W=L=25mm, P1=10.5mm, W_f=1.6mm, L_{off}=1mm and l_f=11.5mm

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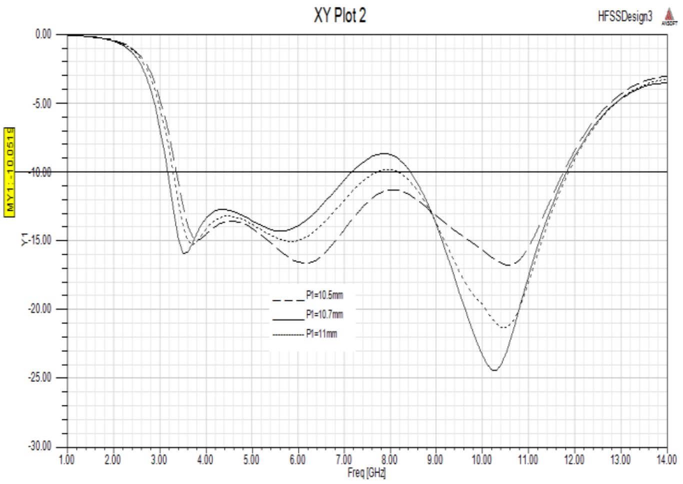

Fig. 3 Return loss of hexagonal slot antenna with different P1 at W=L=25mm, P2=4mm, W_f=1.6mm, L_{off}=1mm and l_f=11.5mm

Return loss plot in Fig.3 demonstrate that by keeping all the parameters as similar as used in P2, but only tuning the slot area of P1 gives wideband operation. The three resonating modes operating at 3.8GHz, 6.2GHz, 10.8GHz and their S11 parameter are -16.5dB, -18.5dB, -26.5dB respectively. They overlap with each other to form a wide bandwidth of around9GHz (3.2-12.2GHz) and it is accomplished by tuning hexagonal slot side length of S1=10.5mm and slot length P1=10.7mm.

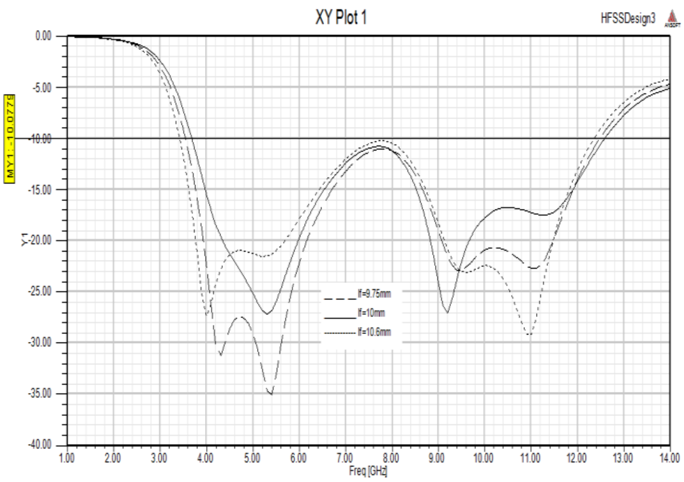

Fig. 4 Return loss of hexagonal slot antenna with different l_f at W=L=25mm, P1=10.7mm, P2=4mm, W_f=1.6mm

Secondly, the upper edge frequency f_2 (12.2GHz) is increased further by tuning the total coupling capacitance behaviour between the parasitic patch and the feed line length, i.e., increasing the coupling gap from the origin to the starting point of the feed line L_{off} which results the wider bandwidth [1]. At the feed line length l_f =9.75mm, 10mm, 10.6mm the wide bandwidth achieve of about 9GHz (3.6-12.6GHz), 9.2GHz (3.8-13GHz), 8.8GHz (3.4-12.2GHz) respectively as depicted in Fig.4. The feed length of 9.75mm has a minimum reflection of about -44dB and -26dB at 4.2GHz and 9GHz respectively. The feed length 10mm has wide bandwidth of 9.2GHz but their reflections are high when compared to feed length of 9.75mm. By comparing all the parameters, finally, it is chosen that P1=10.7mm, P2=4mm and l_f=9.75mm.The chosen parameters achieved a wide bandwidth of around 9GHz (3.6GHz-12.6GHz). Thus the bandwidth enhancement is obtained by the tuning coupling capacitance between the parasitic patch and hexagonal slot. Further, the impedance matching is achieved by the tuning coupling effect between hexagonal slot and the feed line using parameter P1and l_f.

IV. Result and Discussion

The performance analysis of the proposed hexagonal slot antenna is discussed in this section. The proposed antenna is simulated using HFSS (High Frequency Structural Simulator) simulator. The various design parameters are optimized by using design dimensions. From this, optimal dimensions of the hexagonal slot antenna with vertex feed are considered as follows: ground plane dimension of W=L=25mm, hexagonal slot vertex P1=10.7mm (slot side length S1=10.5mm), parasitic patch P2=4mm, (parasitic patch side length S2=5mm), feed length l_f=9.75mm (L_{off}=2.75mm).

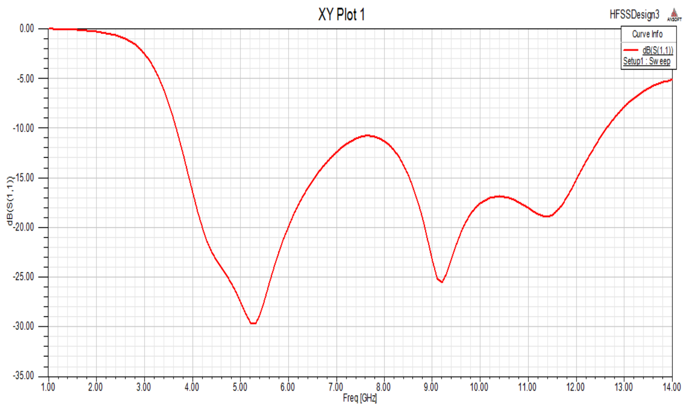

Fig. 5 Return loss of hexagonal slot antenna at W=L=25mm, P1=10.7mm, P2=4mm, W_f=1.6mm, L_{off}=2.75mm and l_f=9.75mm

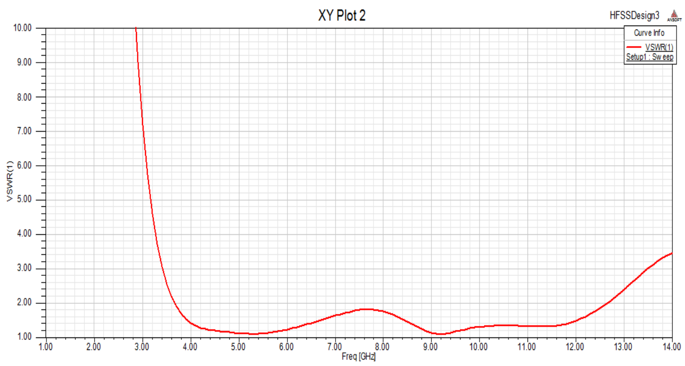

Fig. 6 Simulated VSWR

The simulated reflection coefficient (dB) against frequency (GHz) of the proposed hexagonal slot with microstrip feed antenna is shown in Fig. 5. The simulated result of the operating bandwidth is 9 GHz (3.6GHz-12.6GHz) it is obtained by varying the P1, P2, and l_f. Fig.6 shows the simulated VSWR (Voltage Standing Wave Ratio) of the hexagonal slot antenna. Generally, VSWR with less than or equal to 2 impedance bandwidth, is acceptable for the practical application uses. The proposed antenna VSWR impedance bandwidth is ≤2 at 9GHz (12.6GHz-3.6GHz). The designed compact (low profile) hexagonal slot antenna suites for IEEE 802.11d WiMAX application operating at the frequency range of 3.32 -6.75GHz and also utilized for the application like network access for example web security and observation.

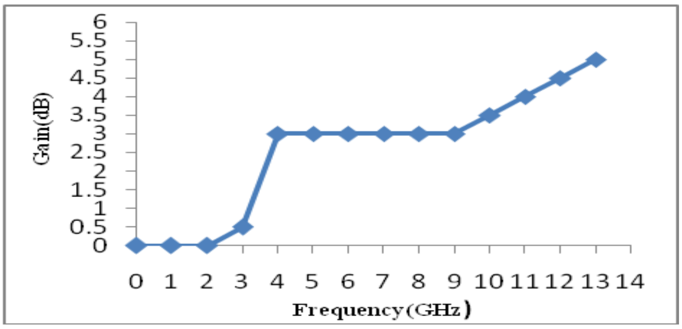

Fig. 7 Gain

Gain is one of the important parameters of the antenna. Although the gain of the antenna is directly proportional to the directivity of the antenna with some proportionality constant, it is a measure that takes into account for the radiation efficiency of the antenna as well as its directional capabilities. The gain is constant at 3.01dB over a frequency range of 3.5GHz – 8.5GHz and the gain is increased at 11GHz and 12GHz (4.5 & 5 dB respectively) as shown in Fig.7. From that, the gain is more or less invariable over the relative operating frequency.

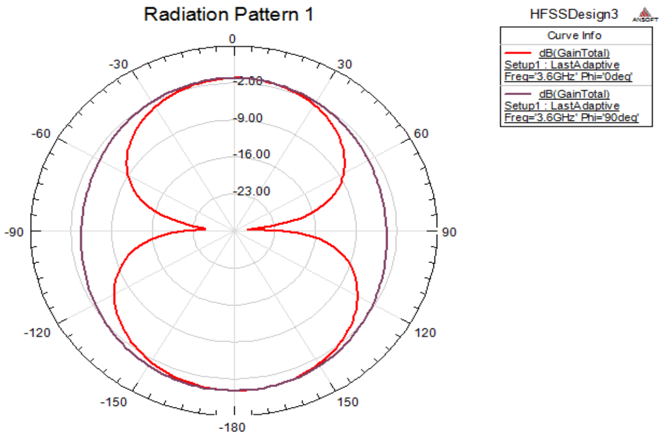

Fig. 8 Radiation pattern of the proposed antenna 3.6GHz

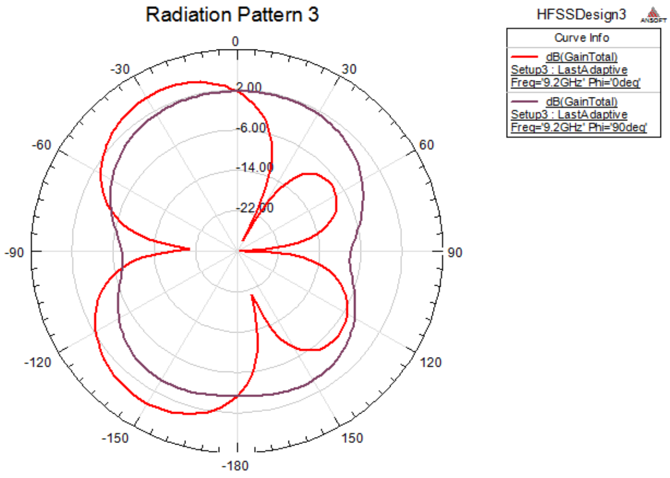

Fig. 9 Radiation pattern of the proposed antenna 9.2GHz

The efficiency is about 0.9 in most of the resonating frequency. The proposed antenna could be suited in high information rate remote dongle for indoor correspondence, supported by the IEEE 802.11a standards at bands 5.2/5.8GHz. Fig. 8 exhibits 3.6GHz and 9.2GHz radiation pattern in E- plane and H-plane with co- polarization and cross polarization over the resonating bandwidth of 9GHz. The E- plane pattern is parallel to the vertical axis and represents the antenna works in bidirectional in the E-plane and the H-plane pattern is Omni-directional in the H-plane. At most of the higher edge frequency, the radiation pattern in the H-plane is almost Omni-directional.

V. CONCLUSION

The proposed compact hexagonal slot vertex feed antenna is designed with the dimension of 25x25x1.6mm^3 and it yields a wider bandwidth of 9GHz (3.6GHz-12.6GHz). It also exhibits good phase linearity property over the wider operating bandwidth and has good impedance matching. The proposed antenna has a constant radiation pattern across the most operating frequency with a maximum gain of about 4.5dBi and the radiation efficiency of 79% and also there is an improvement in the directivity. It is used for the multiband wireless applications such as WiMAX (3.32-6.75GHz), IEEE 802.11a WLAN 5.2GHz (5.15GHz-5.25GHz and 5.2GHz-5.35GHz),HIPERLAN/25.5GHZ(5.470GHz-5.725GHz) and adapt for indoor remote applications in upper UWB band and also suitable for military applications (X or Ku band) and satellite services.

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