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A Novel Design of Multiple Band H – Shape Slot Antenna For Radar Communication

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Abstract

A compact multiple band patch feed H–shape slot antenna for RADAR application is designed and presented in this paper. The proposed H - shaped slot antenna is built on a FR4 substrate with a length of 32.248 mm and dielectric constant of 4.4, thickness of 3.432 mm, width of 36.51 mm and loss tangent of 0.018. The proposed antenna is designed over a frequency range of 1.0 to 8.0 GHz. The antenna is designed and simulated using IE3D software, which helps to obtain the analysis of antenna parameters such as efficiency, VSWR, directivity, radiation pattern (2D & 3D), return loss, gain and relation between them.

Keywords: *Feed, VSWR, Radiation Pattern, RADAR, IE3D, Slot Antenna, Return Loss*

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INTRODUCTION

In modern world the wireless devices play a vital role in providing a myriad of services, leading to increased demands for microwave communications that support multiple applications. In recent years, the development in communication systems require low cost, compact size and low profile antennas that are capable of achieving good performance over a wide spectrum of frequencies. The current trend in radar systems is to develop printed antennas at minimal cost and light weight which are able to maintain high performance over a broad frequency range. Due to low fabrication and compactness of the planar antennas, the field is attracting the researchers to work in this area[1-4]. To maintaining compactness, operating in multiple frequency bands and achieving high gain of the antenna is still a challenge to the researchers[2].

Antenna is an important device of any wireless communication system as it converts the electrical signals (propagating in the RF Transceiver) into Electromagnetic Waves (Propagating in the free space) efficiently with minimum loss. Planar Antennas (PAs) consist basically of three layers, a metallic layer with the antenna element pattern, a dielectric substrate and another metallic layer as the ground plane[4]. These antennas are relatively easy to manufacture because of their simple planar configuration and the compact structure[5]. Various kinds of planar antennas were proposed to provide dual band operation. The PAs are very well suited for applications such as wireless communication systems, radar system and satellite communication systems[6-7]. The planar antennas are very familiar for radar system due to the mode of operation. Though, traditional planar antenna has a drawback of very narrow bandwidth with respect to center frequency. To over awe this, slot antennas have been reflected a good candidate. In order to diminish the size of the antenna, recent research has been suggested for miniaturization technique with slot antennas. Wherever the fields are radiated there is opening that is called as slot antenna[8]. The shape and size of the slot, as well as resonant frequency, determine the radiation pattern. It is based on Babinet's Principle which states that the slot is having the same radiation pattern as dipole. An extension of Babinet's principle, which includes polarization and the more practical conducting screens, was introduced by Booker. The main advantages of slot antenna are its size, design simplicity, robustness and convenient adaptation to mass production using PC board technology.

To provide proper impedance matching between the cable and slot antenna an off-center feed is used and a slot antenna of λ/2 length is preferred. When the slot is vertically polarized, it gives horizontal waves. When the slot is horizontally polarized, it gives vertical waves[9-13].

The shapes of the slot not necessarily have to be rectangular but it can have any convenient shape. Rectangular and circular shapes are desirable because they can be made easily and are easy to analyze. The slot antennas are very useful in many applications like high speed aircraft. Many slots have its complementary form in wires or strips that can be used in predicting patterns and impedances of the corresponding slots. The width of the slot must be more than λ/2 to transmit energy, but it should be less than λ to suppress higher order modes. The mode of transmission of the slot antenna is TE_{10} mode. The length to width of the slot ratio is about 3. For a compact slot antenna design, increasing the length of the slot or adjusting the shape of the slot is needed[14]. By implanting variety shapes of the slots, the antenna size can be reduced for a given operating frequency. By using slot antennas, broad bandwidth can be obtained, without increasing the thickness or area of the antenna[9]. The important parameters of any type of antenna are impedance, bandwidth and return loss. The L band, S band and C Band defined by an IEEE standard with frequencies and wavelength that ranges from 1.0 to 2.0 GHz, 30 to 15 cm and 2.0 to 4.0 GHz, 15 to 7.5 cm and 4.0 to 8.0 GHz, 7.5 to 3.75 cm respectively. The operating frequency can be controlled to operate at triple band by adjusting the dimensions of the slot. The L band is used for Navigation and surveillance radar. The S band is used for Terminal air traffic control, long-range weather and marine radar. The C band is used for Communication Satellite transponder and Precision Coherent Monopulse Tracking (PCMC) Radar[15-17].

The rest of the paper is divided as follows. Secondly, the system model is discussed. Thirdly, the parameter for study of an antenna is presented. Fourthly, explanation of the simulation results and finally the conclusion is given.

SYSTEM MODEL

In the system model various techniques and shapes of slot antennas like H–shaped Micro-strip patch antenna[1], U slot patch antenna[2], circular slot[3], double U–slot patch antenna[4-5], U–Slot loaded patch for dual operation[6], multiple slotted antenna[7], E–Shaped patch antenna[10], W–Slot antenna[18] have been previously proposed by many researchers. The structure of the proposed H Shape slot antenna is shown in Figure 2 and 3. The antenna is realized on FR4 substrate with dielectric constant 4.4 and a loss tangent of 0.018. The thickness of the antenna is 3.432 mm. The antenna must be resonated at different frequency bands. The proposed antenna resonates at 3.9 GHz (S–band) and 6.9 GHz (C–band) respectively[19-23]. The feeding is the important consideration for energizing the antenna[15]. Among center, coaxial and patch feed, the patch feed is proposed in the antenna structure shown in Figure 2 and the design flow diagram as shown in Figure 1.

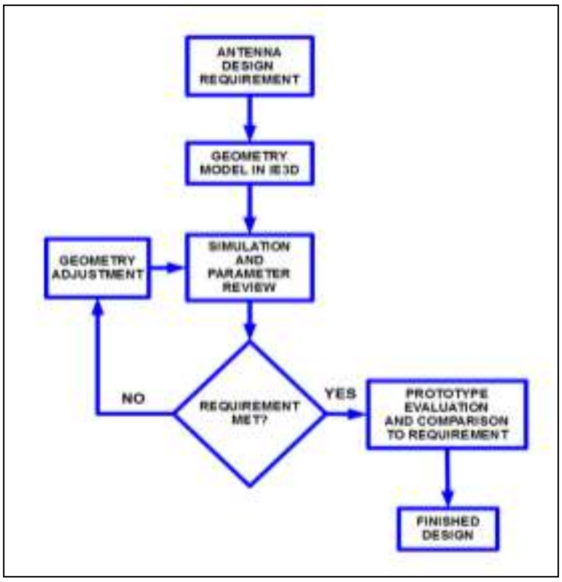

Fig. 1: *Design Flow Diagram.*

DESIGN CONSIDERATION

There are some parameters that affect the antenna performance. Two noticeable parameters that determine the performance of the antenna are width (W) and length (L) of the dimension[15]. The return losses vary according to parameter changes. A tradeoff relationship exists between antenna size and bandwidth[17]. Generally, the relationship of width, height and effective dielectric constant of substrate are related as in Eq. (1)

$$\varepsilon_{eff}=\left[\frac{(\varepsilon_r+1)}{2}+\frac{(\varepsilon_r-1)}{2}\right]*\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \quad \text{Eq. (1)}$$

The proposed antenna structure can be designed using the following equations[24,25]. The height and width of the dielectric substrate are given in

Equation (2) and (3) as follows:

$$h\geq\frac{0.06\lambda}{\sqrt{\varepsilon_r}} \quad \text{Eq. (2)}$$

$$w=\frac{c}{2f_0}*\frac{\sqrt{2}}{\varepsilon_r+1} \quad \text{Eq. (3)}$$

The actual length (L) of patch can be obtained by the following Eq. (4). The dimension of proposed antenna is given in the below Table 1.

$$L=L_{eff}-2\Delta L \quad \text{Eq. (4)}$$

If number of slots increase in the antenna (i.e., array of slot) the gain of the antenna is also increases gradually. In general, VSWR value of the antenna is around the range of 1 to 2, tha gain and directivity of the antenna is increases.

Table 1: *Physical Parameter of Antenna.*

S. No.	Description	Value
1	Patch dimension (L*W)	32.248 * 36.5 mm
2	Longer slot length (L1)	10 mm
3	Longer slot width (W1)	3 mm
4	Shorter slot length (L2)	3 mm
5	Shorter slot width (W2)	10 mm
6	Feed length (L3)	10 mm
7	Feed width (W3)	1.5 mm
8	Relative Permittivity (Σr)	4.4
9	Substrate Material	FR 4
10	Dielectric loss tangent (tanδ)	0.018
11	Thickness	3.432 mm
12	Bandwidth	20.806

The proposed H shape slot antenna is shown in Figure 2.

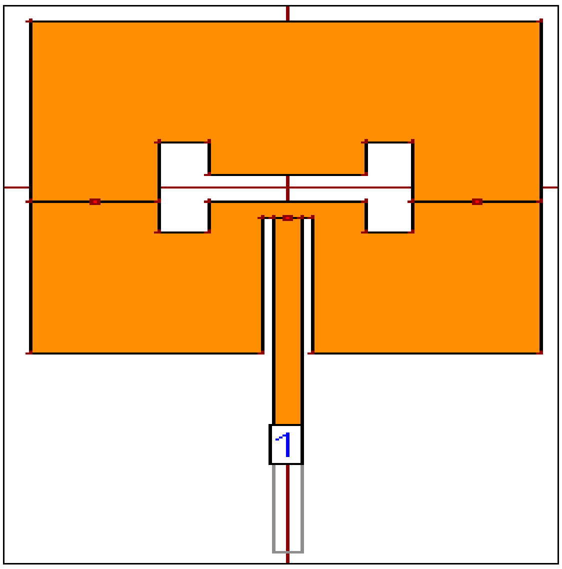

Fig. 2: *Proposed H–Shape antenna (2D).*

SIMULATION AND RESULTS

The proposed H – shape slot antenna is simulated using IE3D simulator and various parameters (VSWR, Gain etc) are measured. It is found that the antenna resonates at 3.9 and 6.9 GHz respectively. In the resonant frequency, the return loss is -13 and -6 dB respectively shown in Figure 4.

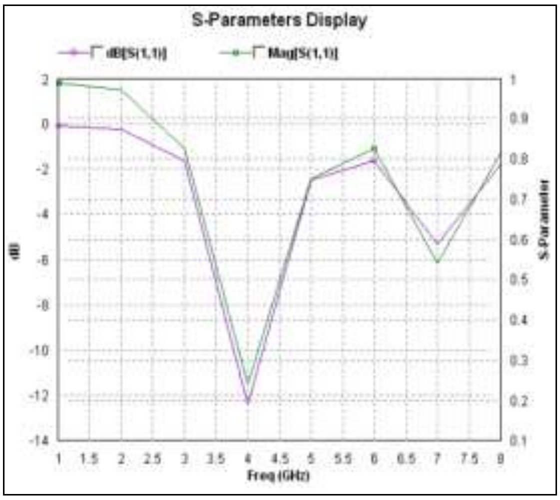

Fig. 4: *Simulated S–Parameter Value.*

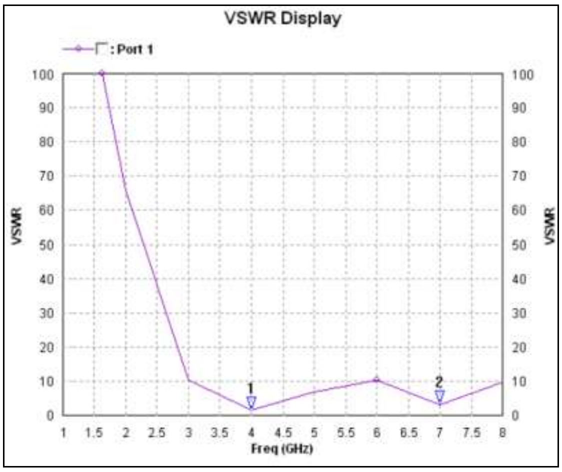

Fig. 5: *Simulated VSWR Value.*

The VSWR describes the amount of power reflected by an antenna. In practical, the VSWR should be between 1 and 2 for less reflection losses. The VSWR of the proposed antenna is 1.04 and 2.01 respectively is shown in Figure 5. The radiation pattern of the proposed antenna is shown in Figure 6 and 7. The corresponding gain of the proposed antenna is 6.06 dB at 3.9 GHz and 3.33 dB at 6.9 GHz is shown in Figure 8. The obtained directivity is 11.36 and 17.5 dB respectively shown in Figure 9.

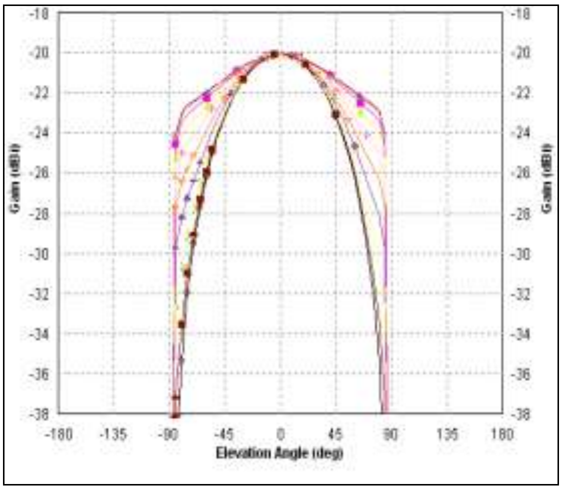

Fig. 6: *Radiation Pattern (2D).*

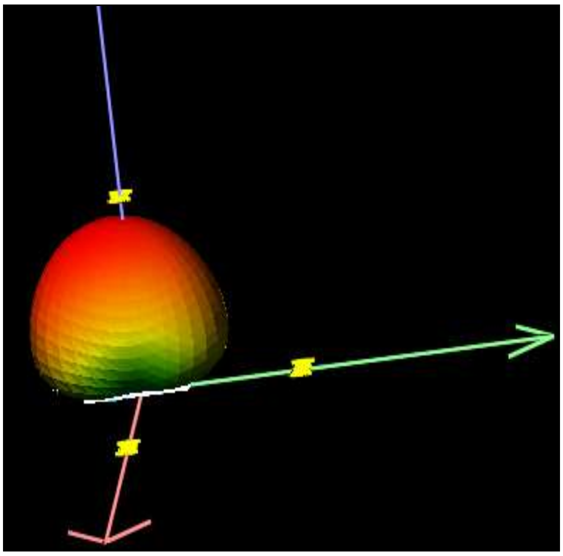

Fig. 7: *Radiation Pattern (3D).*

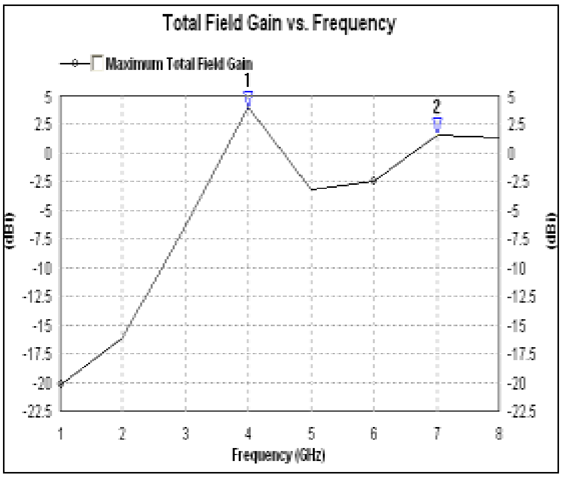

Fig. 8: *Simulated Gain Value.*

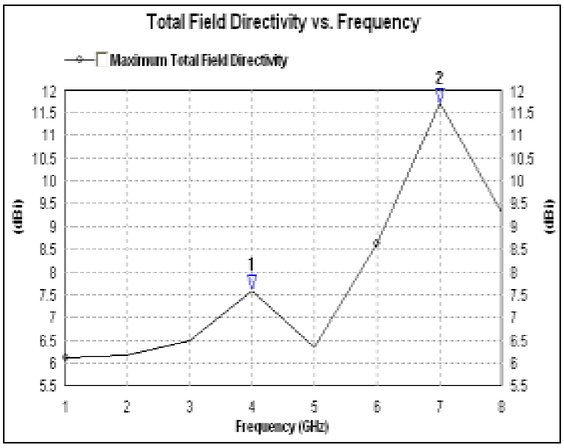

Fig. 9: *Simulated Directivity Value.*

The above results can be tabulated in Table 2 as follows

Table 2: *Simulated Results.*

S. No.	Performance Parameters	Observed Value
1	Return loss	-13 dB at 3.9 GHz -6 dB at 6.9 GHz
2	VSWR	1.04 at 3.9 GHz 2.01 at 6.9 GHz
3	Gain	6.06 dB at 3.9 GHz 3.33 dB at 6.9 GHz
4	Directivity	11.36 dB at 3.9 GHz dB at 6.9GHz

CONCLUSION

The present work has been successfully simulated and designed. The proposed structure was designed on FR4 Substrate with single slot shape structure for operating at multiple band frequencies and the results gave appreciable gain and directivity.

The proposed antenna was successfully tested using network analyzer and the results are same as like simulated results. In future, it can be developed with using multiple slots in a single structure to accommodate for WLAN, Bluetooth, WiMax and RADAR applications in all microwave frequency bands.

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BIOGRAPHY

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