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A Multi-band Slot Antenna for Wireless Systems

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ABSTRACT

A design of multi-band slot antenna for the application of wireless systems is proposed. A Rectangular slot with an area of 48×18 mm^2, a T-shaped feed patch and the two E-shaped stubs, are responsible for the generation of the frequency bands in the antenna. A substrate used in the antenna is FR4, which is readily available in the market. A micro-strip feed technique is used to feed the antenna. The rectangular slot is used in the antenna, which is easy to fabricate. The antenna is studied and designed using FDTD numerical method. The response of the length of slot and geometry of the feeder line on the resonant frequency of this structure are studied.The parameters like Radiation pattern, Return loss, and VSWR of the proposed antenna are analyzed. The antenna is designed to cover the applications such as IEEE 802.11b&g WLAN systems, WiMAX system and IEEE 802.11a WLAN system. The proposed antenna has VSWR value less than 2 in the operating frequency bands.

Keywords: Stub, Patch antenna, Return loss, Radiation pattern.

1. INTRODUCTION

Modern wireless systems are placing greater emphasis on antenna designs for future development in communication technology because of antenna being a key element in the whole communication system. Communication between human was first by sound through voice. The optical communication devices, utilized the light portion of the electromagnetic spectrum. With the blooming of modern wireless communication technologies, a wireless communication antenna is required to cover a very wide frequency bandwidth or several frequency bands and is expected to be small in size. The technologies of wireless communication system have been rapidly ever growing demands for broad band service and transmission speeds to support multimedia, image, speech and data communication. In order to response the rapidly growing demands, the antenna should be responsible for many frequency bands with simple structure, compact size and easy integration. Traditionally, single or dual band antennas are used to cover the one or two applications at a time. So we need two or more antennas in a device to cover the various applications. This will cause increase in space occupied by the antenna and also increase the need for power to the antennas.In order to overcome this problem, multiband antenna can be used where a single antenna can operate at many frequency bands. Microstrip patch antenna due to its advantages such as low weight, low profile planner configuration, and small size, low fabrication cost etc. is very well suited for wireless applications. The bandwidth of Microstrip patch antenna can be improved by various methods like by cutting slot and increasing substrate height, low dielectric constant of substrate, various impedance matching, feeding techniques, multiple resonators and multilayer structure.This antenna was used to cover the application at 2.4 and 3.4 GHz for WiMAX. The antenna structure has a stem, which is used to connect the two branchesby X. L. Sun, et al., [1]. The antenna was designed with a reconfigurable single folded slot, which has a metal strips to manipulate the ground size around the slot by Dimitrios E. Anagnostou, et al., [2]. In this antenna, the resonant frequency is change by changing the perimeter of the slot. Thecompact

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ultra-wideband (UWB) antenna had an octagonal slot, which is fed by stepped and bevelled rectangular patch to cover the ultra-wide band frequency ranges from (3.1 – 10.6 GHz) by M. Bod, et al., [3]. The planar slot antennas turn out to be the most popular candidates contributing in low profile, wider impedance bandwidth, suitable to be printed on the system circuit board of portable devices, and easily fabricated at low cost for practical applications by J. H. Lu, et al., [4]. The antenna was designed with an H-shaped radiator, a CPW and a Varactor diode, which was used to connect the upper and lower arms of the radiator for re-configurability. The operating frequency and mode of the antenna was selected electronically by using varactor diode by H.F. AbuTarboush et al., [5]. The antenna was designed with four branches on the top layer and a parasitic element on the bottom layer of the antenna, which is used to cover the applications such as GSM, DCS, PCS, UMTS, Bluetooth, WLAN and Wi-MAX.byW.J. Liao, et al., [6].

The proposed antenna has a rectangular patch with two shorting pins. Four open stubs are attached to the rectangular patch through four pin diodes, and the ability of switchingthe antenna operating frequency is achieved by using dual in-line package switches to control the states of the diodes, whereby eight different operating bands over a wide range of frequencies can be switched by T.Y. Han, et al., [7]. The proposed antenna is simply composed of a -shaped stub resonator and a monopole radiator. The special asymmetry h-shaped stub extended from the ground can achieve a new resonance as well as reduced antenna size by W. Hu, et al., [8].In this paper, we have presented the use of microstrip patch antenna with rectangular slot for multiband applications, with compact size and low return loss. The VSWR parameter was found to be less than 2 in the operating frequencies.

2. DESIGN OF THE ANTENNA

The Microstrip Patch Antenna with a Rectangular Patch, is shown in the fig. 1. The patch has a slot and a microstrip feed with impedance of 50 ohm. The slot consist of a T-shaped stub and a two E-shaped stubs on both sides of the slot. The ground plane and the patch are designed with pure copper. The Substrate is made of the FR-4 (lossy). The dimensions were selected to meet the specifications of the desired narrow band antenna.

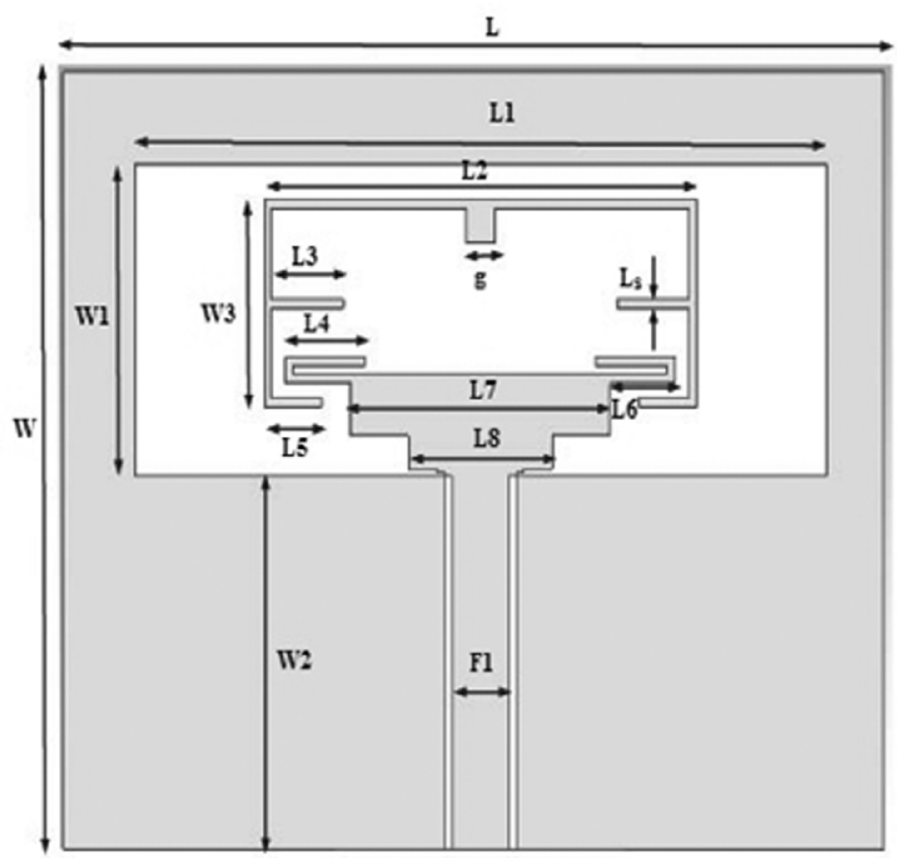
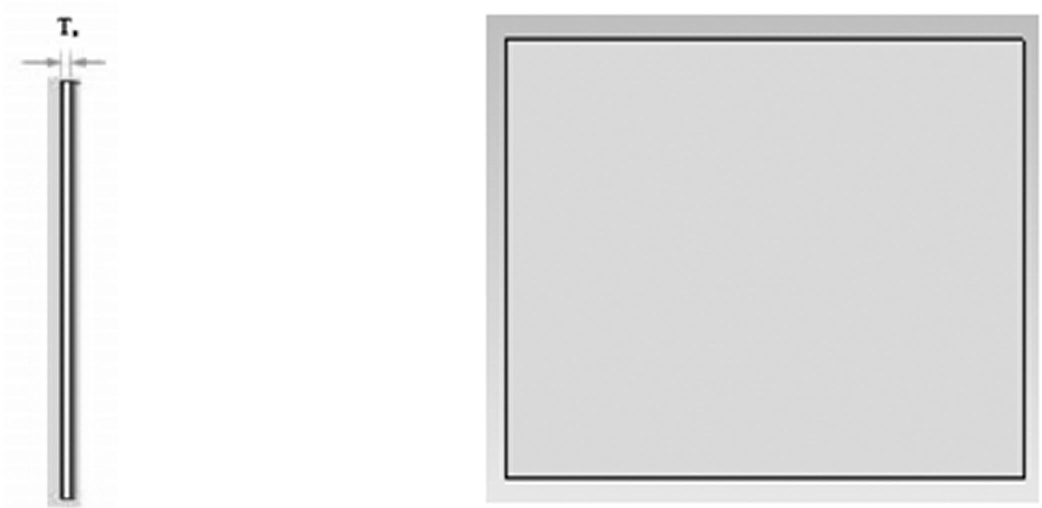


Figure 1: Top View of the antenna.



(a) (b)

Figure 2: (a) Side View (b) Bottom view of the antenna.

Table 1
Dimensions of the antenna in mm

L	W	L1	W1	L2	W2	L3	L4
57	45	48	18	20	21.6	5.5	5.5
L5	L6	L7	L8	F1	L_S	T_S	g
4	4.5	18	10	4	0.5	0.8	2

Thusthe designed antenna can be used in application areas like Industrial, Scientific and Medical band, WiMAX (Worldwide Interoperability for Microwave Access) and WLAN (Wireless Local Area Network) applications. Proposed Narrow band antenna with rectangular slot and stubs, scattering parameter and radiation pattern are designed and simulated. By using the tools in the FDTD simulator, the Microstrip patch antenna is constructed. The patch and the ground is composed of pure electrical conductor material. The substrate is filled with the dielectric material of FR-4 substrate. The dielectric material is having the permittivity of 4.3. A rectangular patch was etched on the top portion of patch one side of FR4 substrate with initial dimensions of length L_1 and width W_1. The thickness of the FR4 substrate in the proposed antenna is 0.8 mm. A 50 ohm microstrip line of width g_2 and length W_2 was adopted for feeding the patch. For this proposed antenna microstrip feeding is used. The antenna can generate three frequency bands at 2.4, 3.5 and 5.4 GHz for different wireless applications. The dimension of the proposed antenna is shown in the table1. The antenna structure as shown in Fig.1 and Fig. 2. The Thickness of the substrate used is 0.8 mm. The T-shaped feed line, which is used to feed the antenna, is placed on the top patch of the proposed antenna.

3. ANTENNA STUDY

The return loss parameter is used to study the effect of change frequency bands due to the change in the antenna radiating elements. The parametric analysis of the antenna is carried out by varying the size of the active radiating elements, which is sensible to the particular frequency bands. The frequency band of the antenna is affected by some parameters of the antenna such as L3, W3 and g. The change in dimensions of these parameters leads to the shift in frequency band of the antenna. The FDTD method is used to study the effect of shift in operating frequency bands due to the change in the antenna parameters. In this proposed antenna, the slot is etched at the top layer of the antenna. This slot responsible for the generation of resonant frequency. The E-shaped stubs and the T-shaped stubs in the slot, will generate the other operating frequencies. The change in the dimensions of the active elements in the slot, will affect the frequency bands. Fig. 1 shows the top view of the antenna with the dimension of L × W (57×45 mm^2). The slot is etched on the top layer of the antenna with dimension of (48×18 mm^2).

4. RESULT AND DISCUSSION

Simulated frequency response of reflection coefficient, VSWR, Radiation pattern are discussed under this section. Fig. 3 shows the simulated result of Return loss of the proposed antenna. Return loss parameter is an easy way to analyse the input and output relation. Thus the return loss shows that, how much the power is reflected from the antenna, if the return loss is 0 db means then there is no power is radiated from the antenna. All the powers radiated from the antenna are reflected back.

From the above graph, it clearly shows that the proposed antenna has three operating frequency bands. The band1 has operating frequency of 2.4–2.5 GHz (ISM band). The band2 has the frequency of 3.5 GHz for WiMAX application. The band3 covers the frequency range of 5.2-5.8 GHz for the application of WLAN. All the operating frequency bands have the return loss as less than -10 db.The simulated result of Voltage standing wave ratio (VSWR) is shown in the Fig. 4.

This parameter is an important one in the antenna design, which shows that how the antenna is matched with the cable impedance. The ideal value of the VSWR is one. The Value of VSWR is less than two in all operating frequency bands (VSWR<2). The graph shows that the antenna is merely perfect matching.

The radiation pattern of the proposed antenna at various operating frequency bands are shown in the fig. 5. The directivity of the antenna achieved, at 2.4 GHz is 6.9 dbi, at 3.5 GHz is 5.18 dbi and at 5.4 GHz is 8.9 dbi.

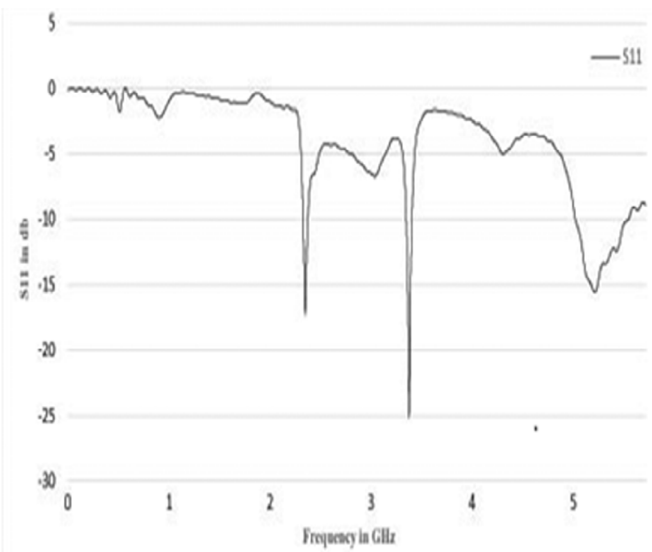


Figure 3: Simulated Return loss.

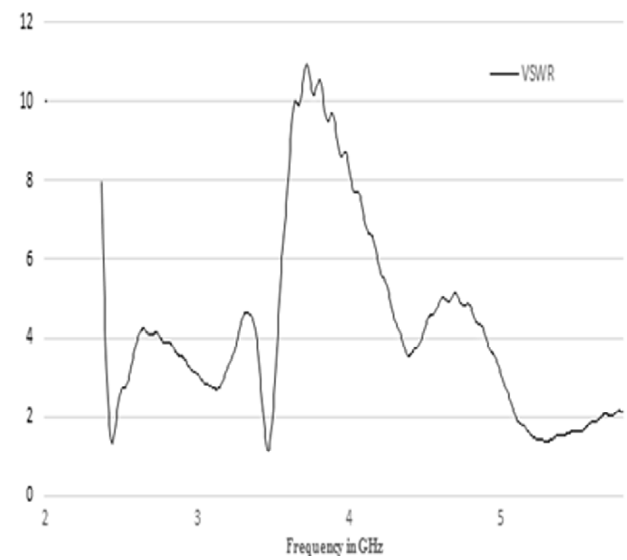
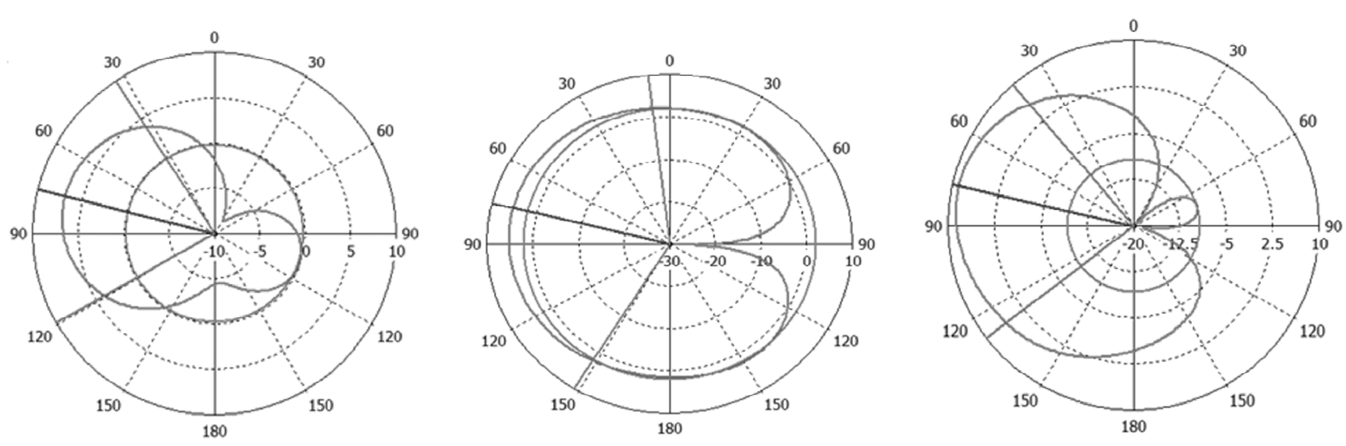


Figure 4: Simulated VSWR of the antenna



(a) (b) (c)

Figure 5: Radiation pattern of the antenna at (a) 2.4 GHz (b) 3.5 GHz (c) 5.4 GHz.

5. PARAMETER ANALYSIS OF THE ANTENNA

This section presents how the change in parameter value of the proposed antenna affects operating frequency bands.

The change dimensions of the active element in the antenna design alters the resonant frequencies. Fig. 6 shows the change in frequency bands due to change in the parameter L4. Due to the increase in the length of L4 causes the shift in the operating frequency bands. The change in the L4 largely affects the third frequency band. The return loss value is greater than-10 for the third frequency band. Fig. 7 shows the effect of change in W2 in the return loss.

Decrease in the slot size on the patch affects all the frequency bands generated by the antenna. The return loss is merely zero in all the frequency bands. So the optimal value of the W2 is 21.6 mm.The change in the dimension of L7 affects the return loss in all frequency bands and also produces some unwanted frequencies. The increase in the length of L7 improves the return loss value for band3, but generate some additional frequency, which is not suitable for any common application. Fig.8 shows how the change in the dimension of L7 affects the return loss of operating frequency bands.

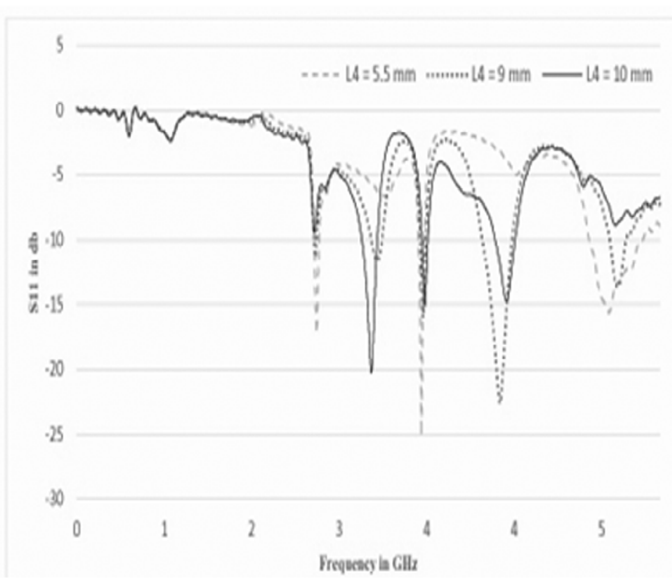


Figure 6: Simulated Return loss for different values of L4.

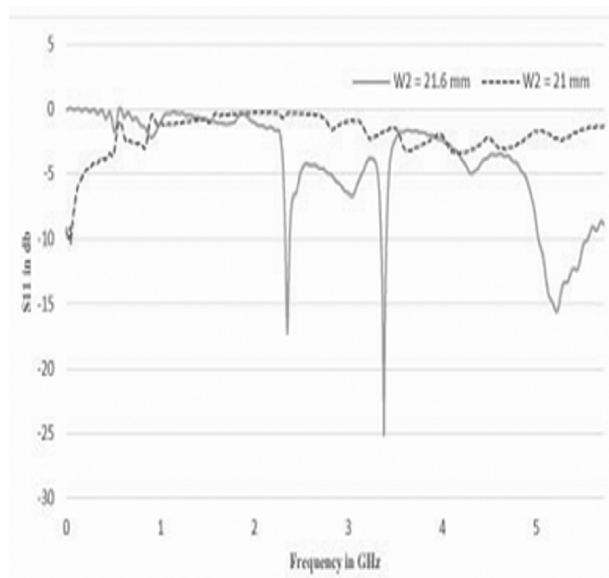


Figure 7: Simulated Return loss for different values of W2.

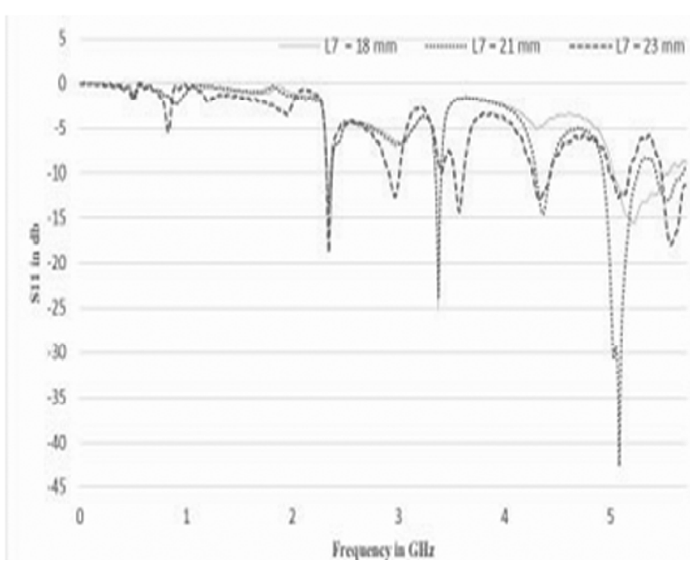


Figure 8: Simulated Return loss for different values of L7.

6. CONCLUSION

The multi-band slot antenna for different wireless applications is proposed in this paper. This antenna consisting a single slot with T-shaped feed patch and two E-shaped stubs, which are all responsible for the generation of multiple frequency bands. The return loss, VSWR and Radiation pattern are studied for all the operating frequencies. This antenna covers the wireless application in the frequencies such as 2.4 GHz for ISM band, 3.5 GHz for WiMAX and 5.8 GHz for WLAN. In future, the antenna will be fabricated and tested using network analyzer. And then the simulated results are compared with the tested results.

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