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Design and Analysis of Rectangular Microstrip Patch Antenna for ZigBee Applications

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ABSTRACT
A rectangular microstrip patch antenna is presented in this paper for 915 MHz band applications. These applications include ZigBee and Bluetooth. The potential of ZigBee technology is enormous due to its tremendous advantages such as the capability to provide extremely fast data rates at short transmission distances while requiring very low power dissipation. Recently, printed antennas have played a major rule in development of antennas with different frequencies. The construction of proposed antenna is done on FR-4 epoxy substrate with thickness of 1.6 mm and ε_r =4.4. The proposed antenna operates from 902MHz to 928MHz with good omnidirectional radiation patterns, its narrow band impedance bandwidth protect it from interference problem from other applications in ISM band. Proposed antenna has compact size of (60x30)mm^2. It has advantages in simple design, narrow bandwidth, and compact in size and easy in fabrication. The measured result is in good agreement with simulated one.

Keywords
ZigBee Antenna; ISM Band Antenna; Bluetooth Antenna; Omnidirectional Antenna.

1. INTRODUCTION
In recent years, many significant developments and high attention are being paid to ZigBee technology since the license free ISM frequency spectrum for commercial communications and applications. The attractive nature of ZigBee coupled with the rapid growth in wireless communication systems has made ZigBee an outstanding technology to replace the conventional and popular wireless technology in use today like Bluetooth. The concurrent surge of wireless applications, with the high level of miniaturization and higher frequency of operation, has increased the interest in designing high performance antenna types. Various type of antennas design have been presented in literature to enhance the ZigBee performance

To maximize the performance of transceiver without changing its costly architecture, advanced antenna design should be used since the antenna is an integral part of the transceiver. Also, it has played a crucial role to increase the performance and decrease the complexity of the overall transceiver.

To maturate ZigBee technology, there are many challenges that must be overcome. One fundamental challenge is to design ZigBee antennas that can satisfy the requirements of this technology. ZigBee has a significant effect on antenna design.

The hardest challenge in designing ZigBee antenna is attaining the narrow impedance bandwidth while maintaining high radiation efficiency. A return loss of greater than 10 dB is necessary in obtaining high radiation efficiency. It is required since ZigBee transmission is very low power (below the noise floor level) and has a high sensitivity.

In this paper, rectangular microstrip patch antenna has been proposed which operates for 902-928 MHz band (ISM) using a rectangular patch. Radiating patch and a partial ground used to cover the 915 MHz band (ISM- Band) from 902-928 MHz with VSWR less than 2. The complete antenna size is 60x30 mm^2. The proposed antenna has compact size which is added advantage to use it in wireless sensor networks Mote modules.

2. ANTENNA DESIGN AND DIMENTIONS FINALIZATION
After an exhaustive literature review of the papers ranging from the year 1996-2014, there have been different types of approaches for making the small size antenna which are used only for ZigBee applications. For ZigBee technology there are various antennas used at 915 MHZ frequency, like Micro strip patch antenna or PCB antenna, Chip antenna, Helical Wound Stub antenna, Low Profile Dome antenna, Dipole antenna with flying lead etc.

Nowadays, in mobile communication systems, the requirement of small sized antenna for miniaturization purpose of mobile units has been increased. Hence, reduced size and enhanced bandwidth are the major considerations in microstrip antennas for practical applications. Therefore, study regarding small size and enhanced bandwidth of microstrip antenna has been greatly increased. In the past few years, great progress in the design of small sized micro strip antenna with dual and circular polarization, dual frequency, broadband and gain enhanced performance has been reported hence we select the microstrip patch antenna for Zigbee application. There are many types of shapes which can be selected for patch. Comparison Analysis of Different types of patch shapes are listed bellow in table 1, which is created in the basis of literature review.

Table 1. Comparison Analysis of Different types of patch shapes

S. No.	Parameters	Rectangular shaped patch micro strip antenna	Elliptical shaped patch micro strip antenna	Annular ring shaped patch micro strip antenna	Triangular patch micro strip antenna
1.	Operating Frequency GHz	2.43 GHz	2.43 GHz	2.43 GHz	2.43 GHz
2.	Return Loss dB	-49.2762 dB	-42.4581 dB	-30.87 dB	-40.7632 dB
3.	Impact on shape on bandwidth MHz	46 MHz	47.6 MHz	34.9 MHz	42.2 MHz
4.	Impedance real part ohm	50.4380 ohm	50.0025 ohm	48.09153 ohm	50.3042 ohm
5.	Impedance Imaginary Part ohm	0.3360 ohm	0.4509 ohm	2.7686 ohm	0.1589 ohm
6.	VSWR dB	1.0220 dB	1.0152 dB	1.0589 dB	1.0185 dB
7.	Directivity =0 deg	3.8363	4.0114	0.3443	3.3706
8.	Directivity =90 deg	3.8387	4.0114	0.3318	3.3609

Hence according to the table 1, which is created in the basis of literature review, it is clear that rectangular patch is best for ZigBee band application in comparison to any other i.e. annular, elliptical etc. Therefore rectangular patch is to be selected. The flow chart for selecting the dimensions for antenna is as bellow.

The value which, get from the Convocational method is very large i.e. L=99 and W=78, so the dimensions of antenna are to be obtained by introducing external components or making some modification in dimensions of antenna. In the fig.1, the flow cart makes the whole process easy to understand.

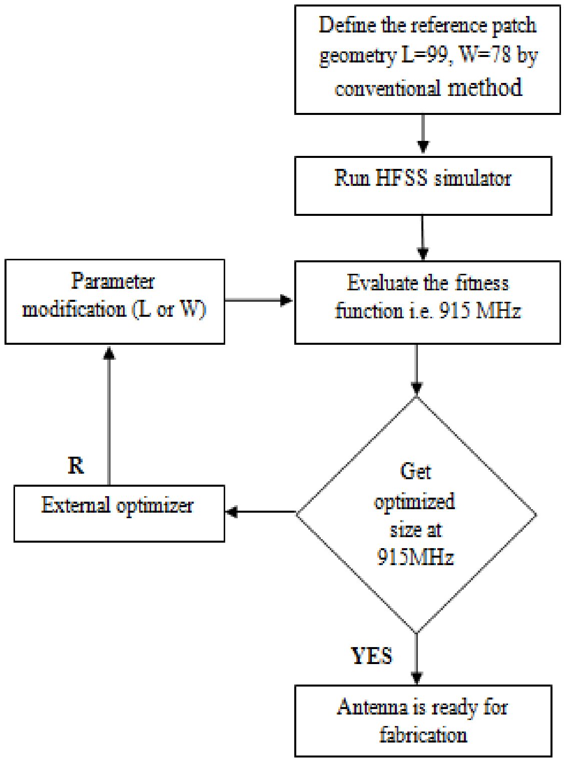


Fig. 1 Flow Chart of Antenna Dimentions Finalization

At first define the reference patch geometry i.e. the value which gets from the conventional method. After calculating the parameters, simulating software will be decided for antenna. After analyzing the antenna model with simulator, evaluate the fitness function i.e. 915 MHz frequency. If optimized size of antenna is to be obtained at desired frequency range it means antenna is to be ready for fabrication. Otherwise some external components are to be used or make some modifications in dimensions of antenna to achieved desired output. Whole process will be followed until desired output will not be achieved. The optimized dimensions of proposed antenna have shown in table 2.

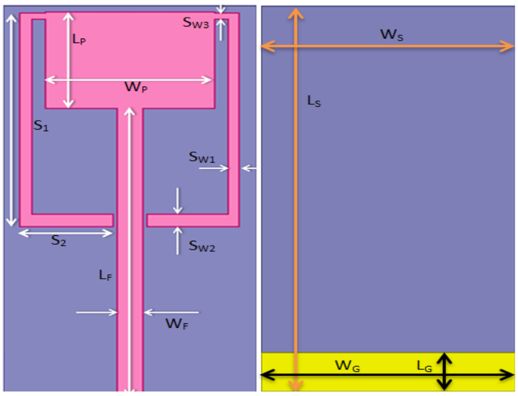
Table 2. Optimized dimensions of proposed antenna

Parameters	W_s	L_s	Wg	Lg	Lp	W_p	L_f
Unit (mm)	30	60	30	06	14.8	20	44.3
Parameters	W_f	S_{w1}	S_{w2}	S_{w3}	$S_1(L_{s1})$	S_2 (L_{s2})	S_3
Unit (mm)	03	1.4	2	1	33	9.6	1.6

3. ANTENNA DESIGN AND ANALYSIS

To finalize the antenna design, all the geometry and configuration are done with the Ansoft HFSS 13. Fig 2 shows the top and back view of final proposed antenna. Thickness of 1.6 mm, relative dielectric constant of ε_r =4.4, and loss tangent of 0.02. This antenna is printed on the FR-4 substrate with The proposed antenna is fed by a microstrip feeder, and the width of the microstrip feed line is 3 mm to achieve 50-Ω characteristic impedance. There is a partial ground and UWB primary antenna Fig.1.The size of primary antenna has been chosen such that it provides a pass band of 915 MHz band (ISM), but in simple rectangular patch it was very difficult to achieve ISM pass band, so here we have introduce open stub symmetry, integrated and the dimensions which we have chosen are W_p=2o mm, L_p=44.3 mm, S_1=3mm, S_2=9.6mm and S_3=1.6mm. The partial ground is used here to control the ISM pass band i.e. W_g=30 mm, L_g=60 mm.

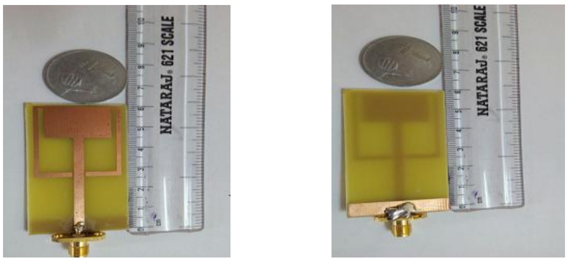
The optimized dimension of the proposed antenna has been presented in table 2. Front and back view of proposed antenna geometry has shown in fig. 2.(a) & (b), respectively.



(a) (b)

Fig.2. (a) Top view of Proposed Antenna (b) Back view of Proposed Antenna

Front and back view of fabricated proposed antenna has been presented in fig. 3.(a) & (b), respectively as bellow.



Front View **Back View**

Fig.3. Fabricated Proposed Antenna

To obtain the ISM pass band characteristic from proposed antenna, first of all calculate the dimentions of basic antenna i.e. UWB primary antenna. Then integrated two open stubs symmetry with primary antenna to achived desired frequency, in fig.2 (a), which provides the passband in ISM band. The return loss (S_{11} in dB) after integrating two open stubs symmetry is presented in fig.4. From fig. 4, it is seen that proposed antenna provides a single passband characteristic in ISM band. from fig. 4, it is seen that proposed antenna is able to operate on Zigbee Band at desired frequency 915 MHz. Simulation of proposed antenna is to be done with HFSS simulator.

HFSS is based on FEM method, so it can say that the frequency domain analysis of proposed antenna shows desired output.

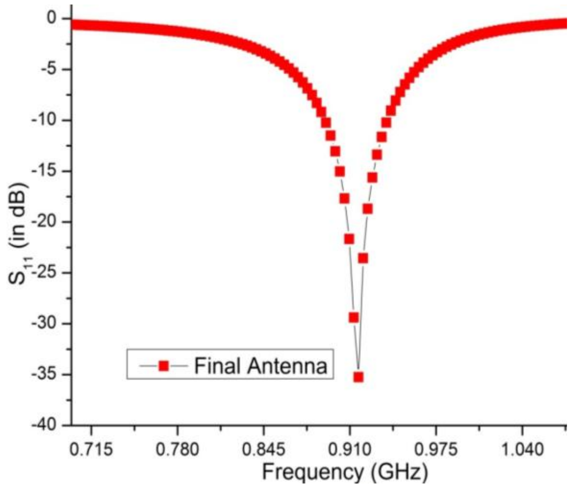


Fig. 4 .Return loss vs. Frequency graph

Length of ground namely L_g varied with a range of values and results are presented.

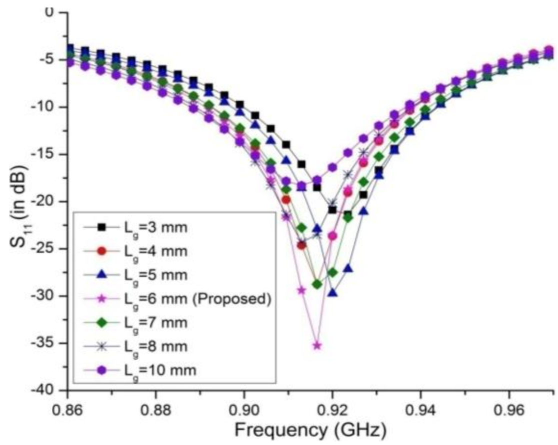


Fig. 5. S_{11} in (dB) vs Frequency graph for variation in length of graund

From fig.5, it is seen that with the length of ground L_g at 3 mm, 4 mm and 5 mm, our desired ISM band can not be achieved but with 6 mm, desired band is achieved. The width optimization of Sutbs S_{w1} and its effect on the S_{11} has been shown in fig. 6. Proposed width S_{w1} is 1.4 mm.

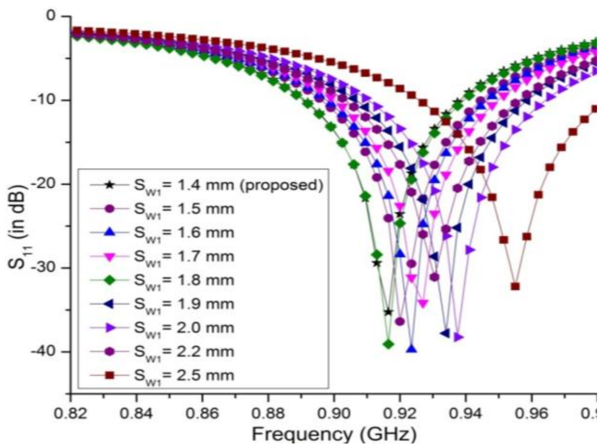


Fig. 6. S_{11} (in dB) Vs Frequency graph for variation in Width of stub S_1

Stubs 'S_2' which is integrated with primary antenna, varied with a range of values and results are presented.

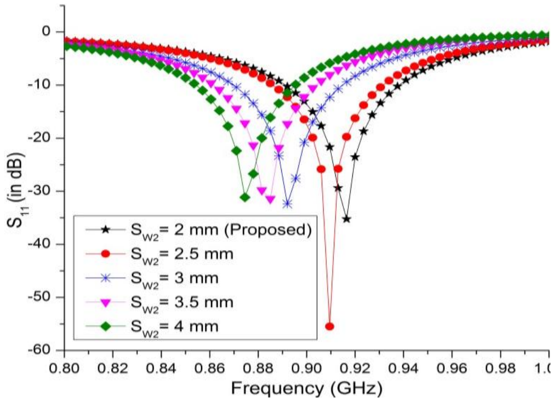


Fig.7. S_{11} (in dB) Vs Frequency graph for variation in Width of stub S_2

From fig.7, it is clear that with the width of S_2 at 2.5 mm, 3.0 mm, 3.5 mm and 4.0 mm, our desired ISM band can not be achieved but with 2.0 mm, desired band is achieved. The stubs S_2 width optimization and its effect on the S_{11} has been shown in fig. 7. Proposed width of stub S_2 is 2.0 mm.

In order to observe the effect of open stubs on current distribution, from fig. 8 it is seen that due to the stub current density is highly disturbed so there is a resonance at 915 MHz frequency. It is clear from the Fig.8 that the accumulation of current density near the edges of the slot is very strong that shows a positive sign to create the resonance at ZigBee band.

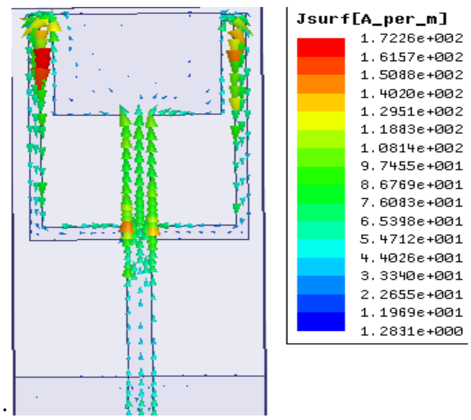


Fig. 8. Vector current distribution due the stub S_1 at 915 MHz

4. RESULT AND DISCUSSION

The fabricated antenna was tested and by using vector network analyzer for calibration the return loss variation graph for simulated and fabricated antenna is to be obtained which has shown in Fig.9. Measured result shows good agreement with the simulated result. The antenna with ISM band (915 MHz), maintaining the required bandwidth (902-928 MHz) with VSWR less than 2. The simulated radiation pattern at 915 MHz has been shown in Fig.10. At the 915 MHz frequency 3-D polar plot of gain is presented in Fig.11. From Fig.11 it is seen that the gain is dB, as it is known that the ISM band applications required a very low power rating so achieved gain is sufficient to fulfill the required gain in this band. The proposed antenna is able to display good omnidirectional radiation patterns in the H-plane and dipole like radiation patterns in E- plane as shown in Fig.10.

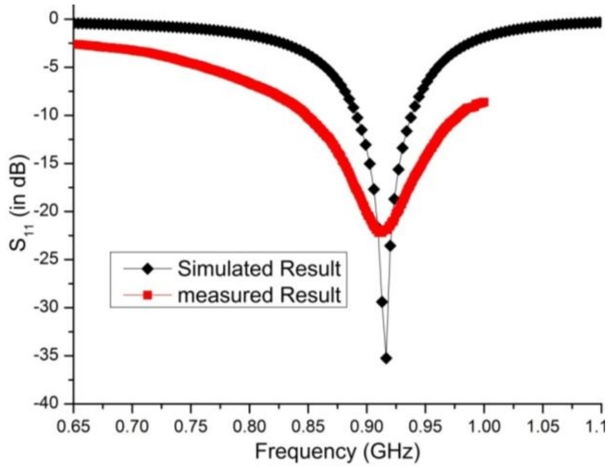


Fig. 9. S_{11}Vs frequency

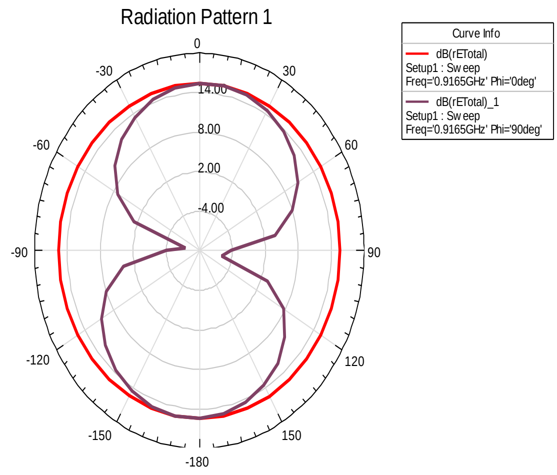


Fig. 10. Radiation patter at 915MHz of proposed antenna.

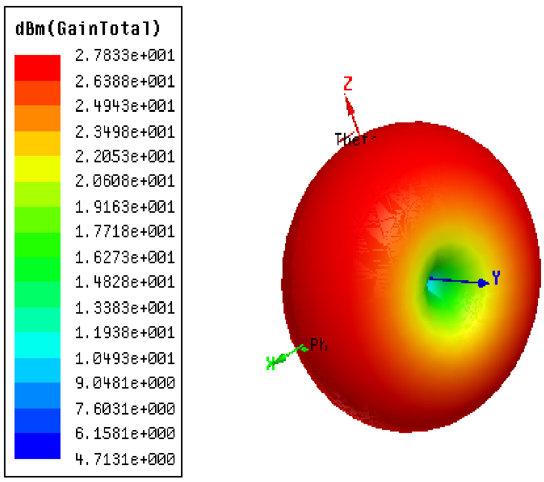


Fig. 11. 3-D Polar plot of gain at 915MHz of proposed antenna.

5. CONCLUSION

A compact ZigBee antenna is presented in this paper. This antenna has simple structure and compact size of (60 x 30) mm $^{2.}$ This is easy to be integrated in miniature devices. Proposed antenna covers frequency band from 902-928 MHz, where simulated and measured results are good in agreement. The performance parameters while simulated are return loss -

35dBi, gain 2.73dBm and directivity 2.83dBm and while it is tested are return loss -30dBi, gain 2.46dBm and directivity is 2.52dBm. Results & analysis of this antenna indicates that it is applicable in miniature devices, simple design & compact size as added advantage, which can easily be used in embedded wireless system applications. Surface current distributions were used to show the effect of these slots in getting the ISM band.

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