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Design of Rectangular Microstrip Patch Antenna and Optimization of it with Slot in Patch for Dual Band using CST Software.

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Abstract—Microstrip patch antennas are versatile in terms of their geometrical shapes and implementation. The light weight construction and the suitability for integration with microwave integrated circuits are two more of their numerous advantages. Additionally the simplicity of the structures makes this type of antennas suitable for low-cost manufacturing. And this is also one key feature why microstrip patch antennas are used in wireless communication applications. Moreover, the microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, broad band-width, feed line flexibility. Hence an optimized (modifying parameters and adding slot) microstrip rectangular patch antenna is presented in this project for Bluetooth application along with ZigBee. Computer Simulation Technology (CST) microwave studio is used as the software environment to design and compare the performance of the antennas. Based on the results and analysis, it is noted that the optimized patch antenna shows lower return loss than the return loss of regular patch antenna. In addition, optimized patch antenna has improved VSWR than that of the circular patch.

Introduction to Microstrip Antennas

The microstrip antenna is generally a single-layer design and consists of a radiating metallic patch or an array of patches situated on one side of a thin, non-conducting, substrate panel with a metallic ground plane situated on the other side of the panel. There are numerous substrates that can be used for the design of microstrip patch antennas and their dielectric constants are usually in the range of $2.2 \leq \varepsilon_r \leq 12$. Those desirable for antenna performance are thick substrates whose dielectric constant are in the lower end of the range due to better efficiency, larger bandwidth, and loosely bound fields for radiation into space but at the expense of larger element size. It is a popular printed resonant antenna

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for narrow-band microwave wireless links that require semi-hemispherical coverage. A simple microstrip antenna with a dielectric substrate being backed by a conducting ground plate with printed patches or strips over it is shown in Figure 1 and Figure 2.

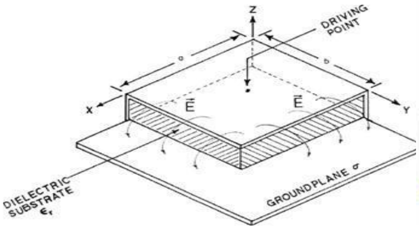

Fig. 1.Microstrip antenna [1]

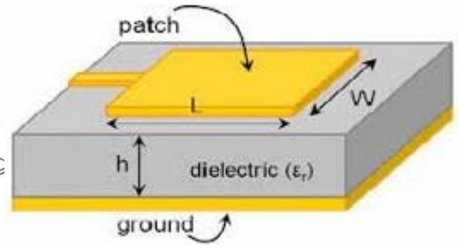

Fig. 2.Rectangular microstrip antenna.

'L'and'W' in the figure defines the length and width of the patch, and, 'h'and 'ε_r' represents the thickness and the dielectric constant of the substrate. The patch over the dielectric substrate is usually considered to be very thin ($t \ll \lambda_o$ where λ_o is free space wavelength) and is placeda small fraction of a wavelength ($h \ll \lambda_o$ usually $0.003\ \lambda_o \leq h \leq 0.05\ \lambda_o$) above the ground plane.

The metallic patch actually creates a resonant cavity where the patch is the top of the cavity, the ground plane is the bottom of the cavity and the edges of the patch form the sides of the cavity. A patch antenna is a narrow band, wide beam antenna. Feeding in microstrip is achieved through the use of feed line with a simple waveguide. The rectangular and circular patches are the basic and most commonly used microstrip antennas. A microstrip antenna is characterized by its Length, Width, Input impedance and Gain and radiation patterns.

The Context of the Antenna

Bluetooth (IEEE 802.15.1specification)is a wireless technology standard for exchanging data over short distances from fixed and mobile devices, and building personal area networks(PANs). And, Zigbee is an IEEE 802.15.4-based specification to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs. The proposed antenna fed by a 50-Ωmicrostrip line covers the frequency bands: 2.4 GHz for Bluetooth, Zigbee,IEEE 802.11b/g (Wi-Fi) and 3.18GHz for Radiolocation Service within return loss $S_{11} < -15$dB.The proposed antenna compact size is such small that it is suitable for integrating in small size devices, such as mobile handsets, laptop computers.

1. Designing of Rectangular Microstrip Antenna

To design a rectangular microstrip patch antenna the essential parameters are

1. The operating frequency (f_0).
2. Dielectric constant of substrate (ε_r).
3. The height of the dielectric substrate (h_s).
4. The height of the conductor (t).

A. Other parameters

1. The width of the patch (W).
2. The Length of the patch (L).
3. The length and width of the ground plane (Wg)(Lg).

There are lot of methods for analysis microstrip patch antenna:

1. The Transmission Line model.
2. The Cavity model.
3. Method of Moments (MoM).

B.Transmission Line equations [2]:

1. To find the width (W)

$$W = \frac{C}{2f_0\sqrt{\frac{(\epsilon_r + 1)}{2}}}$$

2. To find the effective dielectric constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{\frac{-1}{2}}$$

3. To find the effective length

$$L_{eff} = \frac{C}{2f_0\sqrt{\epsilon_{reff}}}$$

4. To find the fringing length(ΔL)

$$\Delta L = 0.412h\left[\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} - 0.8\right)}\right]$$

5. To find the actual length Land the width and length of the Ground. The input impedance is usually 50Ω.

$L = L_{eff} - 2\Delta L; \quad L_g = 2L; \quad W_g = 2W;$

6. The length of inset (fi)

$$f_i = 10^{-4}(0.001699 * \epsilon_r{}^7 + 0.13761 * \epsilon_r{}^6 - 6.1789 * \epsilon_r{}^5 + 93.187 * \epsilon_r{}^4 - 682.69 * \epsilon_r{}^3)$$

The resonant frequency of the primary patch is chosen to be around 2.45 GHz. The substrate used for the antenna is FR-4 with dielectric constant, ε_r = 4.7, loss tangent 0.019 and the thickness is 1.6 mm. The thickness of the ground material is 0.035 mm. The size of the feed line is adjusted to make sure that the impedance of the antenna is 50Ω. The size of the slits may also effect the impedance. The calculated value of parameters are tabulated in the Table 1 below. However, in simulation, the parameters have to be turned to get a better and more accurate antenna response. Therefore, the final (optimized) dimensions of a reconfigurable microstrip patch antenna (shown in Figure 4 and Figure 3) operating at frequencies 2.45 GHz and 3.18 GHz.

Table 1. Parameters of Antenna.

Parameters	**Calculated Dimension(mm)**	**Optimized Dimension(mm)**
Patch Width, W	37.02	48.0
Patch Length, L	28.4	28.0
Substrate Width, W_g	46.6	55.0
Substrate Length, L_g	38.0	50.0
Feed Length, L_f	4.8	8.0
Feed Width, W_f	2.88	3.0
x_0	0.5	2.0
y_0	4.0	4.0
Width of Slots	-	1.0
Length of Slot1, Sl_1	-	16.0
Length of Slot2, Sl_2	-	9.0
Slot Spacing from Patch Edge	-	4.3

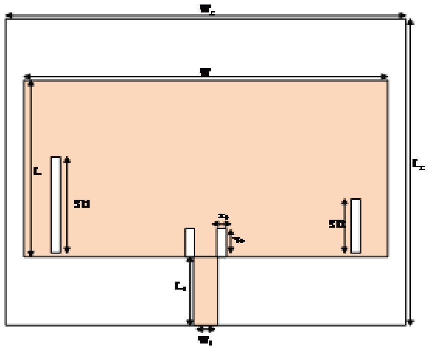

Fig. 3. Optimized rectangular microstrip antenna.

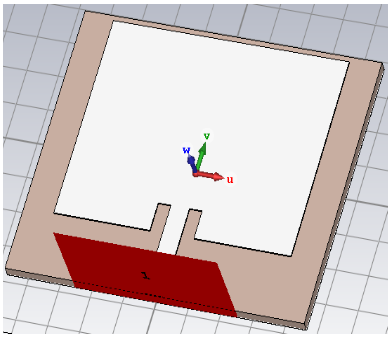

Fig. 4. Designed regular rectangular patch using CST.

2. Simulation Results of Regular Rectangular Patch Antenna

A.Return Loss

It is a parameter that is used to measure the power reflected by the antenna due to the mismatch of the transmission line and antenna. Let us consider an example, if the return loss is 0dB there is nothing to radiate by the antenna because the power provided to the antenna is completely reflects by the antenna. Lower value of the return loss provides the high efficiency of antenna. The return loss of the antenna performed is shown in theFigure 5.

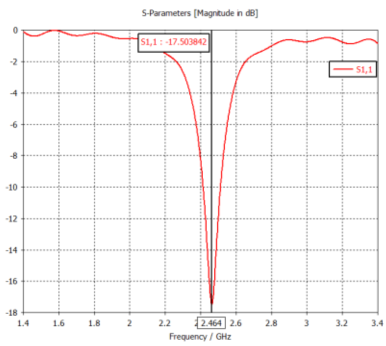

Fig. 5. Return loss for regular rectangular antenna.

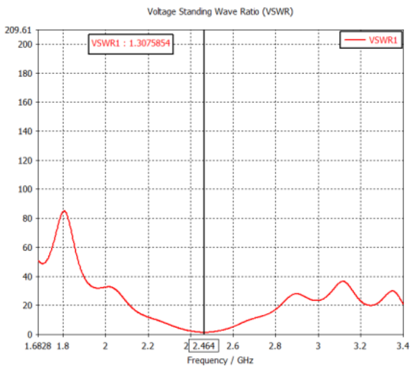

Fig. 6. VSWR for regular rectangular antenna.

B.VSWR

VSWR stands for voltage standing wave ratio. It is defined as the ratio between the maximum value of standing wave voltage to its minimum value. The minimum VSWR for an antenna would be 1. The antenna with less VSWR has the better return loss compared to the other antenna. The VSWR of the microstrip patch antenna is shown in theFigure 6.

C.Far-Field Pattern

The three dimensional view of the microstrip patch antenna is shown inFigure 7.

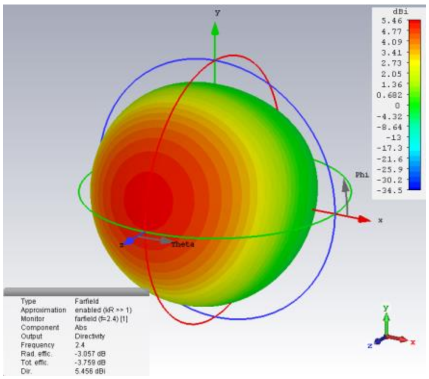

Fig. 7. Far field for regular rectangular antenna.

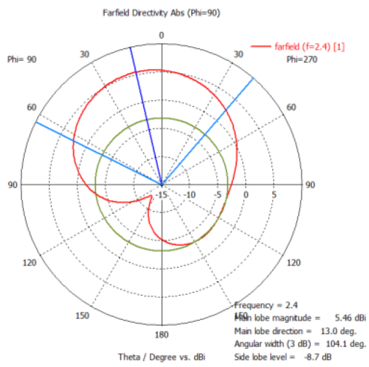

Fig. 8. Regular rectangular antenna polar plot.

D.Polar Plot

Far field radiation is shown in Polar coordinate inthe Figure 8.

3. Simulation Results of Optimized Rectangular Patch Antenna

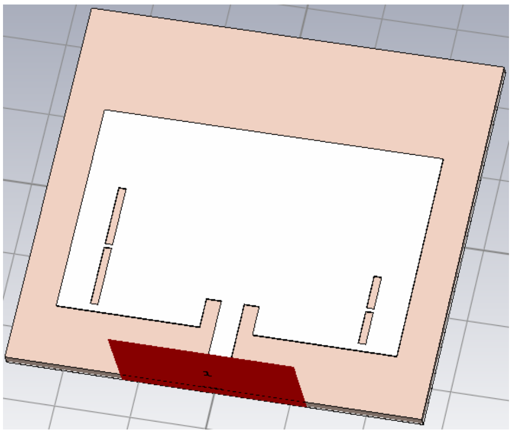

Fig. 9. Designed Optimized patch using CST

A.Return Loss

The return loss of the antenna performed is shown in theFigure 10.

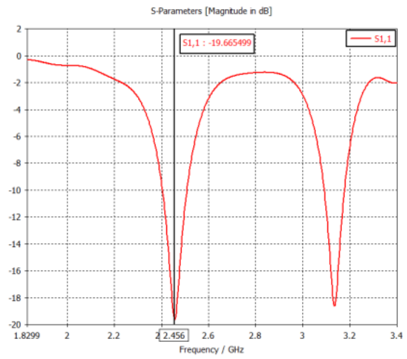

Fig. 10. Return loss for optimized rectangular antenna.

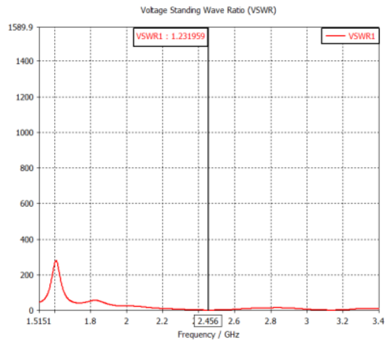

Fig. 11. VSWR for optimized rectangular antenna.

B.VSWR

The VSWR of the microstrip patch antenna is shown in theFigure 11.

C.Far Field Pattern

The three dimensional view of the antenna is shownin the Figure 12.

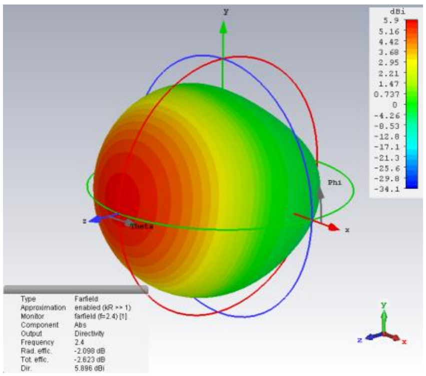

Fig. 12. Far field for optimized rectangular antenna.

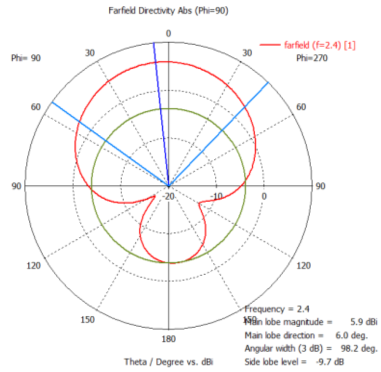

Fig. 13. Optimized rectangular antenna polar plot.

D.Polar Plot:Far field radiation is shown in Polar coordinate in the Figure13.

4. Result and Discussions

Table 2. Comparison of normal calculated patch antenna and optimized patch antenna.

Sl	**Parameter**	**CalculatedAntenna**	**OptimizedAntenna**	
		2.45GHz	2.45GHz	3.18GHz
1	Return Loss	-17.50 dB	-19.67 dB	-18.637 dB
2	VSWR	2.464	1.23	1.26

From the above Table 2, optimized antenna has good results compared to regular rectangular antenna. More negative values of Return losses gives the better results and the optimized antenna has a little bit better return loss. In the case of VSWR, the optimized antenna provides it as half of the normal patch antenna. It indicates a much less power is reflected in optimized antenna [2].

5. Conclusion

By adding two simple rectangular slots in a regular patch antenna and by varying antenna parameters, an optimized antenna has been designed and using CST microwave studio, simulation of the both antenna has carried out. The simulation result shows the addition of new band (for ZigBee application) in the optimized antenna along with the previous band. Both the antenna configurations show quite good results on perspectives of return loss, VSWR and radiation efficiency, for Bluetooth band applications. However, from the perspective of VSWR, the optimized patch configuration shows better performance.

6. References

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