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REVIEW ARTICLE

DESIGN OF RECTANGULAR SHAPED SLOTTED MICRO STRIP ANTENNA FOR TRIPLE FREQUENCY OPERATION FOR WIRELESS APPLICATION

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ABSTRACT

This Paper represents the designing of the Tri- Band Rectangular Printed micro strip Antenna. One amongst the simplest feeding technique is employed i.e. coaxial feeding technique for feeding the antenna Tri band antenna is obtained by etching two quarter wavelength rectangular shaped slots inside the patch at the proper position to resonate over GSM, Bluetooth and Wi- MAX. The proposed antenna is realized on FR-4 dielectric substrate having a dielectric constant of 4.4 and loss tangent of 0.02, with dimensions of 46x38x1.6mm³. The design calculations are done for the frequency of 2.4 GHz. The designed antenna is simulated using EM simulation software CAD FEKO suite (7.0). The antenna covers the three bands of operation i.e. GSM (1.834-1.858GHz), Bluetooth (2.422- 2.487GHz), Wi-Max (3.519-3.583GHz) with reflection coefficient ≤ -10 dB. The overall simulation results shows that the antenna gives good impedance matching at desired frequencies with VSWR ≤ 2 . Also the radiation pattern, efficiency, gain and impedance for all four frequencies are investigated using simulation results.

KEYWORDS

Coaxial feed, Global system for mobile communication (GSM), worldwide inter-operability for microwave access (Wi-MAX), FR4 Substrate, Multiband antenna, cadfeko.

1. INTRODUCTION

The Wireless connectivity has enabled a new mobile lifestyle filled with conveniences for mobile computing users (Balanis, 1997). Consumers will soon demand the same conveniences throughout their digital home, connecting their PCs, personal digital recorders, MP3 recorders and players, digital camcorders and digital cameras, high-definition TVs (HDTVs), set-top boxes (STBs), gaming systems, personal digital assistants (PDAs), and cell phones, to connect to each other in a wireless personal area network (WPAN) in the home (Cao et al., 2015). But today's wireless LAN and WPAN technologies cannot meet the needs of tomorrow's connectivity of such a host of emerging consumer electronic devices that require high bandwidth.

A new technology is required to fulfill the requirements of high-speed WPANs. To hide several applications with common antenna might be referred as multiband antenna, rising variety of applications into same (Kumar and Chandra, 2015). Multiband systems avoid duplications of various antennas that may be used for various applications. Small strip antennas with single band, dual band, triple band and quad band operations will be integrated into a same body of divergent structure, reducing quality and creating system compact (Garg et al., 2001).

Antennas with multiband operation along with multi-polarization have become trending topic for antenna design industries because of number of special benefits (Mutiara et al., 2011). In these days, antenna design has received significant importance. The design of multi-band antenna for 2.4 GHz Bluetooth IEEE 802.11 b/g (2.4-2.484 GHz), 3.5GHz Wi-MAX IEEE 802.16 (3.4-3.6GHz), 5.2/5.8GHz WLAN IEEE 802.11 a (5.15- 5.35 GHz and 5.725-5.825 GHz) and 5.5 GHz HIPERLAN2 (5.47-5.725 GHz) due to its wide range of usability in almost all commercial communication devices

such as smart-phones, laptops, tablets, etc. is especially demanding (Ray and Kumar, 2003).

In this work the designing of the Tri- Band Rectangular Printed micro strip Antenna presented, one of the best feeding techniques is used i.e. coaxial feeding technique for feeding the antenna (Adegoke and Nyatega, 2014). Tri band antenna is obtained by cutting two quarter wavelength rectangular shaped slots inside the patch at the proper position to resonate over GSM, Bluetooth, Wi-MAX. The proposed antenna is realized on FR- 4 dielectric substrate having a dielectric constant of 4.4 and loss tangent of 0.02, with dimensions of 46x38mm². The design calculations are for the frequency of 2.4 GHz. Single band operation of antenna obtained by using optimization of feed and patch length of the antenna (Chang and Kiang, 2014). Then to get dual band and triple band operation the two rectangular shaped slots are etched from patch where current distribution is minimum (Neetu et al., 2013; Varshese and Aslam, 2015). The optimized slot length and width are for slot1 dimensions are 10x2mm² and for slot2 is 8x2mm². Antenna design is simulated using EM simulation software CADFEKO SUITE 7.0.

2. ANTENNA DESIGN

The Proposed rectangular shaped slotted antenna for triple frequency operation is shown in Fig.1 (a) which consists of patch of size 36.40x27.20mm² on one side of substrate. This radiating element patch is loaded with two rectangular shaped slots at the lower side of patch and at the left-hand side of the patch respectively (Nanthini et al., 2013). The dimensions for slot1 are 10x2mm² and for slot2 is 8x2mm². Coaxial feeding is used of an impedance of 50 Ω to feed the antenna and its location from the centre of the patch is (6.12, 7.17) (Puri et al., 2014; Ren et al., 2011). In this design FR4 substrate is used which has relative permittivity

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of 4.4 and loss tangent is 0.02. The dimensions for ground plane is same as dielectric substrate (Labode et al., 2015). The dimensions for proposed triple frequency antenna design are shown in Table 1.

Figure 1. Geometry of the designed Tri band antenna (a) Top View, (b) Bottom View.

The antenna is designed for 2.4 GHz frequency and calculations for antenna design are done by using following "Equations (1-8)".

$$W_P = \frac{c}{2 \times f_r \sqrt{\frac{\epsilon_r + 1}{2}}}$$

Width of patch (W_P):

Where, c is the speed of the light, f_r is the resonant frequency and ϵ_r is the relative permittivity of the substrate.

Effective dielectric constant (ϵ_{reff}):

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

Where, ϵ_{reff} is the Effective dielectric constant, ϵ_r is the dielectric constant of substrate, h is the Height of dielectric substrate and W is the Width of the patch.

Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2 \times f_r \sqrt{\epsilon_{reff}}}$$

Patch length (ΔL):

$$\frac{\Delta L}{h} = 0.412 \left(\frac{\epsilon_{reff} + 0.3}{\epsilon_{reff} - 0.259} \right) \left(\frac{W}{h} + 0.264 \right)$$

Length of substrate (L_s): Width of substrate (W_s):

$$L_s = L_p + 6h$$

Distance of feed point from L_P (X):

$$W_s = W_p + 6h$$

$$X = \frac{L_p}{2 \sqrt{\epsilon_{reff}}}$$

Distance of feed point from W_P (Y):

$$Y = \frac{W_p}{2 \sqrt{\epsilon_{reff}}}$$

Table 1: Dimensions of Proposed Antenna	
Parameters	Values(mm)
Dielectric Substrate	FR4
Dielectric constant (ϵ_r)	4.4
Substrate Height (h)	1.6
Feeding technique	Co-axial
Patch Width (W_P)	36.40
Patch Length (L_P)	27.40
Length of Ground Plane ($L_{sub} = L_{gnd}$)	38
Width of Ground Plane ($W_{sub} = W_{gnd}$)	46
Feed Points(x,y)	(6.12,7.17)
Lslot1xWslot1	10x2
Lslot2xWslot2	8x2

The antenna can generate the triple frequency bands at 2.45, 1.84, 3.55 GHz for different wireless applications. The surface current distribution for all three bands are shown in Fig.2. The rectangular patch with proper coaxial feed points generate first band (2.422-2.487GHz) for Bluetooth application. Then the rectangular slot1 is generated second band (3.519-3.583GHz) for WIMAX applications (Bhattacharya and Biswas, 2013). Then after, for third band integration we have etched second slot2 which generated (1.834-1.858GHz) band for GSM application. Then A two rectangular quarter wavelength slots is etched in to the lower region of the radiating patch to and left-hand side of radiating patch to resonate over Wi-Max band (3.4-3.6 GHz) and GSM band as shown in Figure 1 (Labade et al., 2015). For Wi-Max band (3.4-3.6 GHz): center frequency (f_w) = 3.5 GHz and $\lambda/4 = 12.98$ mm. For GSM band (1.834-1.858GHz): center frequency (f_w) = 1.84 GHz and $\lambda/4 = 24.80$ mm. where,

$$\lambda = \frac{c}{4f_w \sqrt{\frac{\epsilon_r + 1}{2}}}$$

Figure 2: Surface current distribution of the antenna at (a) at 2.45 GHz (b) at 3.55 GHz (c) 1.84 GHz

3. SIMULATION RESULTS

In this section, the parametric analysis is performed to Tri band Antenna. Then achieved simulated results are analysed and discussed on various design aspects. We have considered Reflection Coefficient (S_{11}) versus Frequency to judge the performance of the antenna.

Figure 3: Reflection coefficient versus Frequency graph for the variations of feed position (X and Y) for Bluetooth Band.

Reflection coefficient versus Frequency diagram for the varieties of feed position (x and y) is appeared in Fig.3. Feed position controls the impedance matching. So, we have done parametric investigation for feed positions. From Fig.3 we can state that, subsequent to performing number of reproductions for different feed positions, at that point at $x = 2$ mm and $y = 7$ mm from the focal point of the transmitting patch, a Bluetooth band from 2.405 - 2.475 GHz is accomplished (Lee and Sun, 2009). The parametric investigation of different sustain positions is as appeared in Fig.3. From the Fig.3 nourish position at $x = 2$ mm and $y = 7$ mm, a most extreme reflection coefficient (S_{11}) of -38.5dB is accomplished. For other feed positions, S_{11} is not greater than exactly -20dB.

Figure 4: Reflection coefficient versus Frequency graph for the variations of Length of patch (L_p)

Reflection coefficient versus Frequency diagram for the varieties of Length of patch (L_p) is appeared in Fig. 4. By expanding the patch length (L_p), the middle recurrence of Bluetooth band continues diminishing. At $L_p = 27.40\text{mm}$, we accomplished the Bluetooth band with focus recurrence 2.44GHz . As Length of the L_p expands, the lower recurrence of Bluetooth band moves left with changing peak. As we realize that L_p controls the thunderous recurrence. As we increment the L_p , Inductive reactance increments and Resonant band moved down that is from 2.36 to 2.54GHz for Bluetooth band as appeared in Figure 4. coefficient versus Frequency graph for the variations of Length of patch (L_p) is shown in Figure 4.

Figure 5: Reflection coefficient versus Frequency graph for the variations of Length of slot1 (L_{slot1})

The rectangular slot inserted below the feed point on the radiating patch is resonating at Wi-Max band ($3.47\text{--}3.53\text{GHz}$). By changing the width of the slot the impedance bandwidth of the Wi-Max band can be controlled, while by increasing the length of the slot, the Wi-Max band shifts to the lower edge frequency with the varying peak. By parametric analysis of length and width the Wi-Max band $3.47\text{--}3.53\text{GHz}$ with a peak -16dB is obtained as shown in the Fig.5 and Fig.6. The optimized dimensions of the rectangular slot is $L_{\text{slot}}=11\text{mm}$ and $W_{\text{slot}}=2\text{mm}$.

Figure 6: Reflection coefficient versus Frequency graph for the variations of width of rectangular slot1 (W_{slot1}).

The rectangular slot inserted left side the feed point on the radiating patch is resonating at GSM band ($1.834\text{--}1.858\text{GHz}$). By changing the length of the slot the impedance bandwidth of the GSM band can be controlled, while by increasing the width of the slot, the GSM band shifts to the lower edge frequency with the varying peak.

Figure 7: Reflection coefficient versus Frequency graph for the variations of Length of slot2 (L_{slot2})

By parametric analysis of length and width the GSM band $1.834\text{--}1.858\text{GHz}$ with a peak -16dB is obtained as shown in Fig.7 and Fig.8. The optimized dimensions of the rectangular slot is $L_{\text{slot}}=8\text{mm}$ and $W_{\text{slot}}=2\text{mm}$.

Figure 8: Reflection coefficient versus Frequency graph for the variations of width of rectangular slot2 (W_{slot2}).

The antenna has shown similar characteristics in case of reflection coefficient and VSWR to get the triple frequency operation. Based on the optimized parameters of the proposed tri band rectangular antenna, we obtained the bandwidths of an antenna ranging from for GSM ($1.834\text{--}1.858\text{GHz}$), for Bluetooth ($2.422\text{--}2.487\text{GHz}$), for Wi-Max ($3.519\text{--}3.583\text{GHz}$) as shown in Fig.9.

Figure 9: Reflection coefficient versus Frequency graph for the tri band antenna

Figure 10: Simulated (a) Graph of VSWR (≤ 2) vs. Frequency for Tri Band Antenna, (b) Graph of Impedance vs. Frequency for tri band Antenna.

Fig .10. shows $VSWR \leq 2$ for all three bands are 1.33 , 1.38 , and 1.62 respectively. Fig.11 (a) shows the efficiency vs. frequency graph of the tri band antenna. Impedance vs. frequency graph is shown in Fig.11 (b) which shows that impedance for gsm, Bluetooth and wimax is 40.1Ω , 53.7Ω and 58.8Ω respectively. Here it has been seen that for Bluetooth band, antenna efficiency is approximately 50% as shown in Fig. 11. And it is decreased after 3GHz . Fig.12. Shows the radiation pattern for elevation plane (E-plane or $\theta=90^\circ$) and azimuth plane (H- plane or $\phi=0^\circ$) at $f=2.451\text{GHz}$, $f=3.55\text{GHz}$, $f=1.84\text{GHz}$ and $f=5.22\text{GHz}$. It describes how an antenna directs the energy it radiates (Nanthini et al., 2013). It shows an Omni-directional radiation pattern along the H-plane and a directional radiation pattern along the E-plane.

Figure 11: Simulated (a) Graph of Efficiency vs. Frequency for tri band, (b) Graph of Gain vs. Frequency for Tri Band Antenna

Figure 12: Simulated radiation patterns observed in E-plane and H-plane at (a) 2.45GHz (b) 3.55GHz. (c) 1.84GHz

3. CONCLUSION

In this work, Design of Rectangular Shaped slotted Micro strip Antenna for Triple Frequency Operation for remote application is presented. This antenna covers triple frequency operation which includes GSM (1.834-1.858GHz), Bluetooth (2.422-2.487GHz), Wi-Max (3.519-3.583GHz) with Return loss ≤ -10 dB and VSWR ≤ 2 . For achieving Tri band operations two rectangular slots are etched from radiating patch and the location of feed point optimized in such way that the antenna operates in triple frequency bands. Also optimization of various parameters of antenna is done.

REFERENCES

Adegoke, O.M., Nyatega, O.C., 2014. Design of Dual Band Coax Patch Antenna for GSM and Bluetooth Applications. *International journal of science and research*, 3 (12), Pp. 998-1002.

- Balanis, C.A., 1997. *Antenna Theory, Analysis and Design*, second edition, John Wiley and Sons, New York.
- Bhattacharya, B.N., Biswas, 2013. A Parametric Study on Microstrip Patch Antenna. *International Journal of Electronics & Communication Technology*, 5 (2).
- Cao, Y.F., Cheung, S.W., Yuk, T.I., 2015. A Multi-band Slot Antenna for GPS/WiMAX/WLAN Systems. *IEEE Transactions on Antennas and Propagation*, 63 (3), Pp. 952-958.
- Chang, T., Kiang, J.F., 2013. Compact Multi- Band H-Shaped Slot Antenna. *IEEE transactions on antennas and propagation*, 6 (8), Pp. 101-109.
- Garg, R., Bhartia, P., Bahl, I., Ittipiboon, A., 2001. *Microstrip antenna design hand-book*, Artech House, Boston.
- Kumar, S., Chandra, D., 2015. Multiband Star Shape Slotted Microstrip Patch Antenna Design for wireless communications. *International Journal of Electronics and Electrical Engg.*, 3 (5), Pp. 402-405.
- Labade, R., Deosarkar, S., Pishoroty, N., 2015. A Novel Integrated Bluetooth Dual Band UWB Antenna for Wireless Communication. *International Journal of Microwave and Optical Technology*, 10 (3), Pp. 195-201.
- Lee, Y.C., Sun, J.S., 2009. A new printed antenna for multiband wireless applications. *IEEE Antennas Wireless Propag. Lett.*, 8, Pp. 402-405.
- Mutiara, A.B., Refianti, R., Rachmansyah, 2011. Design Of Microstrip Antenna For Wireless Communication At 2.4 GHz. *Journal of Theoretical and Applied Information Technology*, 33 (2), Pp. 184-192.
- Nanthini, N., Dinesh, V., Vijayalakshmi, J., Dhivya, K.T., 2013. A Survey on Design of Multiband Monopole Antenna for Wireless Applications. *International Journal on Recent and Innovation Trends in Computing and Communication*, 1 (12), Pp. 949 – 954.
- Neetu, Banas, S., Bansal, R.K., 2013. Design and Analysis of Fractal Antennas based on Koch and Sierpinski Fractal Geometries. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 2 (6), Pp. 2110-2116.
- Puri, S., Kaur, K., Kumar, N., 2014. A review of antennas for wireless communication devices. *International Journal of Electronics and Electrical Engg.*, 2 (3), Pp. 199-201.
- Ray, K.P., Kumar, G., 2003. *Broadband microstrip antenna*, Artech House, Boston, London.
- Ren, F.C., Zhang, F.S., Bao, J.H., Chen, B., Jiao, Y.C., 2011. Compact Triple-frequency Slot Antenna for WLAN/WIMAX Operation. *Progress in Electromagnetic Research Letters*, 26, Pp. 21-30.
- Varghese, A., Aslam, K., 2015. Design and Simulation of compound Fractal antennas for multiband Applications. *International Journal of Science and Research*, 4 (5), Pp. 501-504.