Dual-layer Microstrip Antenna Design for Wireless Communications

Ghadah M.Faisal*

Electrical Engineering Department, College of Engineering, AL Iraqia University Baghdad, Iraq
*Corresponding author: Wdyaan1@gmail.com

Abstract  The present work deal with the design of a triple band, dual layer Microstrip Patch Antenna. The frequencies of three bands are 0.9GHz, 1.798GHz, 2.402GHz. the S-parameter and the gain characteristics as well as radiation pattern are investigated. The proposed antenna is suggested to be used in a mobile phone handset that covers three frequency bands which include GSM 900 (889-960), GSM 1800 DCS 1800 (1710-1885), Bluetooth and Wi-Fi/WLAN (IEEE 802.11 b/g/n) ISM 2450 (Industrial, Scientific and Medical) (2400-2500). The proposed antenna shows return loss (RL) of -17.79dB at 0.9 GHz; -18.5 dB RL at 1.798 GHz; and -44.2 dB RL at 2.4 GHz which are encouraging results . Designing and simulation of the proposed antenna were based on CST software package. Finally enact three bandwidth are got and the antenna shows an encouraging results for WLAN applications.

Keywords: triple band, dual layer, mobile

Cite This Article: Ghadah M.Faisal, “Dual-layer Microstrip Antenna Design for Wireless Communications.” American Journal of Electrical and Electronic Engineering, vol. 6, no. 2 (2018): 66-71. doi: 10.12691/ajeee-6-2-3.

1. Introduction

Antenna is a device used to transform an RF signal, traveling on a conductor, into an electromagnetic wave in free space. Microstrip antennas was introduced for the first time at 1950s [1]. It has been in use for about twenty years before development of the printed circuit board(PCB) technology in1970s. Since then the Microstrip antenna, become to be the common type of antennas due to many its advantages which they have like: light weight, low cost, low profile, planar configuration, superior port ability, easy for fabrication and easy integration with microwave monolithic integrate circuits [2,3]. They have been widely used for the civilian and military applications, such as mobile systems, and global positioning systems(GPS), satellites …ect.

In spite of the many advantages of the microstrip antennas, they have many disadvantages such as: narrow band-width, low gain, and relatively long size, One of the main drawbacks of such an antenna is the is the narrow bandwidth , there were many researches work which dealing with such a problem, S.B.Tajane et al. [4] had designed and investigation of rectangular Microstrip antenna withtri-band applications covering Bluetooth (IEEE: 802.15), WiMAX (IEEE: 802.16) and WLAN (IEEE:802.11a, 802.11b/g/n) bands of modern wireless broadband communication, The desiredtri-band operation had been obtained by proper loading for a rectangular patch antenna using slots and truncations alongside of patch width. K.R.M.Huq et al. [5] had designed a triple band microstrip patch antenna for cellular and Wi-Fi application. This will perform on the frequency 0.97 GHz, 1.35 GHz and 3.54 GHz. H-H Wang et al. [6] had designed two broad band microstrip antenna using planer line feeding, they had successfully implemented the antennas and got an enhanced band width by 25%. Yashar Zehförosh et al. [7] had design multilayer MSA to get 3.1-10.6 GHz BW for mobile applications, they increased the bandwidth by 50%. Shoichiro Hirai et al. [8] had designed a high performance ultra compact chip antenna . they got a bandwidth of 2.4-2.5 GHz. There were many other research, works devoted toward the improvement of the gain. Neala Chattorraj et al. [9] has written an algorithm for optimization of the MSA gain with and without dielectric substrate, using genetic algorithms. Abdullah AL Noman et al. [10] had designed a single layer single feed miniaturized MPNA. They had increased the bandwidth by 4.7% and got the a directivity a bone 6dB.due to the need for the multi services a multi band antennas has been invented. To get a multi-band PA, a multi-layer separated by a dielectric substrates had been used. During using the multi-layer and a dielectric substrates, study of the effects of the dielectric thickness on the performance of the antenna. Kharade A.R.Patil V.P. [11] had enhanced the gain of the MSA, using multi-layer multi-dielectric layer which is separated from patch by air as another dielectric . Hussain A.Hammas [12] had study the effect of dielectric layer substrate on the MSPA performance lick Half power beam width , antenna efficiency, radiation efficiency, antenna directivity and radiation pattern. LuLu et al. [13] had studied the effect of the variation of the patch width and length, and height and εr , of the substrate on the band-width. They designed a 2.4 GHz Bw antenna for Bluetooth application. K.H.sagidmarie et al. [14] had designed a compact dual-band dual ring printed monopole antennas for
WLAN applications. They got an antenna with bandwidth 2.4-2.48 GHz, 5.15-5.35 GHz & 5.57-5.8 GHz. M.R.C. Mahdy et al [15] for the first time they had tried to design meta material. they got an antenna of bandwidths with three center frequencies (2.5 , 3.55, 5.1 GHz ). finally. S.I.L. Mously [16] had covered most of previous works to get triple band multi-layer patch antenna . He got an antenna with bandwidth (0.9 GHz , 1.8 GHz , 2.4 GHz) , but the frequency center were not exact there were small deviations in their values.

The present work deals with design and simulation of a triple band multi-layer patch antenna to get (0.9 GHz , 1.7987 GHz, 2.402 GHz) bandwidths. different dielectric substrates are used, their effect also are studied.

2. Antenna Design

A multi-layer triple band patch antenna is designed in this section. The designed antenna isometric geometry is given in Fig.(1a). As it is shown from Fig.(1a), the antenna consists of ground plane, dielectric substrate 1, active patch, dielectric substrate 2 and the parasitic patch. Active patch is fed by a coaxial probe fed. There is a single short pin between the ground plane and the active patch. The designed antenna parameters and physical dimensions are given in Table1 and Table2. The three bands center frequencies has been got are 0.9 GHz, 1.798 GHz & 2.402 GHz. As it is known from the theory of micro strip antenna there are different methods for designing the dual band antennas. In this work two of those methods has been hybridized to design a triple band antenna separated by a suitable distance to get the two resonance frequencies 1.8 and 0.9 GHz. A second patch which is called a parasitic patch has been added. This patch has been separated from the active patch by a substrate dielectric material. The first one is designing single layer micro strip patch antenna by putting single short pin in the same axis of the feeding point two substrates are different in their dielectric constants values and heights.

The procedure of design are: first full a simple micro strip patch antenna has been designed to get a resonance frequency of 1.8 GHz, using the following formulas: [17].

\[ f_r = \frac{c}{2W\sqrt{\frac{\varepsilon_r + 1}{2}}} \]  
\[ \varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + \frac{12h}{W} \right]^{-\frac{1}{2}} \] 
\[ L_{\text{eff}} = \frac{c}{2f_r\sqrt{\varepsilon_e}} \] 
\[ L = L_{\text{eff}} - 2h \times 0.412 \left[ \frac{\left(\varepsilon_e + 0.3\right) W}{h_l + 0.26h_l} \right] \left( \frac{W}{h_l + 0.8} \right) \] 
\[ L_g = 6h + L \] 
\[ W_g = 6h + W \] 
\[ x_f = \frac{L}{\pi} \times \frac{Z_{\text{in}}}{Z_f} \] 
\[ Z_{\text{in}} \approx 1 \] 

Where \( f_r \) is the resonant frequency of the antenna, \( c \) is the free space velocity of the light, \( W \) is the width of patch, \( h \) is the height of the substrate, \( L_{\text{eff}} \) is the effective length \( L \) is the length of the patch, \( \varepsilon_e \) is the dielectric constant of the substrate, \( L_g \) is the length of ground plane, \( W_g \) is the width of ground plane and \( x_f \) is the position of the feeding point in the x-axis. The antenna is fed with a coaxial connector modeled as a standard SMA connector with the following specifications [18]:

- Radius of inner conductor = 0.62 mm.
- Radius of insulator = 2.3 mm.
- Radius of outer conductor = 2.64 mm.
- \( \varepsilon_r \) of insulator (Teflon-lossy) = 2.1.
- Length underground plane = 2.1 mm.

The antenna geometry is shown in Figure 1. All the dimensions are given in mms.

![Figure 1](image-url)
The dimensions and parameters got for \( \varepsilon_{r1} = 4.4 \), and \( h_2 = 0.8 \text{mm} \) are: \( W = 50 \text{mm}, L = 36.38 \text{mm} \), \( \varepsilon_{r2} = 5.2, (x_f = 11.58 \text{mm}, y_f = 0) \). Simulating the designed antenna using the previous values a first resonance frequency \( f_{r1} \) equal to 1.35 GHz was got as shown in Figure 2a. Since the dimensions of the patch is inversely proportional to the frequency, then they has been decreased to \( W = 35.3 \text{mm}, L = 34.0 \text{mm} \) in order to increase the resonance frequency to 1.8 GHz as shown in Figure 2b. A single short pin has been put in the origin \((0,0)\), \((x_f = 10 \text{mm}, y_f = 7.3 \text{mm})\) from the center of antenna \( f_{r1}, f_{r2} \) got were not exactly of the desired values as shown in Figure 2c. As it is known with decreasing the height of the substrate the resonance frequency increase. This phenomena has been used to choose the height of the substrate#1 and the height of substrate#2 by changing one of them and keeping the other constant and vise versa. The process of changing with their results are given in Table 1, Table 2 and Table 3. From the Table 1 noticed that if \( h_1 \) increase \( f_{r2} \) increase and \( f_{r3} \) decrease and from the Table 2 noticed that if \( h_2 \) decrease \( f_{r2} \) decrees and \( f_{r3} \) increase to avoiding increase the dimensions of the antenna \( h_1 \) has been decrees as shown in Table 3. The final chosen values for the dimensions of the active patch#1 and parasitic patch#2 are given in Table 4 with the specifications of the simulated MPA layers. Table 5 explains the dimensions and positions of the two rectangular patches used in the adopted antenna. The detailed return loss of the final triple-band MPA is shown in Figure 3. The design simulated using CST software package [19].

| \( h_1 \) in mm | \( f_{r2} \) in GHz | \( |S|11 \) in dB | \( f_{r3} \) in GHz | \( |S|11 \) in dB |
|----------------|-----------------|----------------|----------------|----------------|
| 1.5            | 0.89            | -17            | 1.82           | -18            |
| 1.4            | 0.9             | -35            | 1.78           | -18            |
| 1.3            | 0.9             | -6             | 1.63           | -36            |
| 1.2            | 0.9             | -6             | 1.62           | -30            |
| 1.1            | 0.9             | -6             | 1.618          | -30            |

| \( h_2 \) in mm | \( f_{r2} \) in GHz | \( |S|11 \) in dB | \( f_{r3} \) in GHz | \( |S|11 \) in dB |
|----------------|-----------------|----------------|----------------|----------------|
| 0.8            | 0.91            | -7.5           | 1.65           | -27            |
| 0.9            | 0.91            | -7.5           | 1.64           | -36            |
| 1              | 0.905           | -6             | 1.64           | -36            |
| 2              | 0.904           | -14            | 1.815          | -22            |

| \( h_2 \) in mm | \( f_{r2} \) in GHz | \( |S|11 \) in dB | \( f_{r3} \) in GHz | \( |S|11 \) in dB |
|----------------|-----------------|----------------|----------------|----------------|
| 0.7            | 0.9             | -15            | 1.8            | -20            |
| 0.765          | 0.9             | -17.79         | 1.798          | -18.5          |
| 0.762          | 0.9             | -18            | 1.798          | -18            |
| 0.761          | 0.9             | -18            | 1.796          | -18            |
| 0.760          | 0.9             | -18            | 1.798          | -19            |
| 0.75           | 0.9             | -18            | 1.798          | -19            |
| 0.751          | 0.9             | -18            | 1.798          | -19            |
| 0.752          | 0.9             | -18            | 1.798          | -19            |
| 0.753          | 0.9             | -18            | 1.798          | -18            |
| 0.754          | 0.9             | -17            | 1.798          | -18            |
| 0.756          | 0.9             | -17            | 1.798          | -18            |
| 0.747          | 0.9             | -17.5          | 1.798          | -19            |
| 0.743          | 0.9             | -17.5          | 1.798          | -19            |
| 0.742          | 0.9             | -17            | 1.798          | -19            |
| 0.741          | 0.904           | -14            | 1.815          | -22            |

American Journal of Electrical and Electronic Engineering
Figure 2. (a): first resonance frequency $f_{r_1}$ equal to 1.35 GHz, (b): increase the resonance frequency $f_{r_1}$ to 1.8GHz, (c): get a second resonance frequency $f_{r_2}$ of value 0.935GHz, (d): get the third resonance frequency $f_{r_3}$ equal to 2.375GHz, (e): obtain $f_{r_3}=2.4$ GHz
Figure 3. Simulated return loss of triple-band MPA

Table 4. The designed MPA layer specifications

| Layers   | Material       | Height $h_1, h_2$ | $\varepsilon_r$ |
|----------|----------------|-------------------|-----------------|
| Substrate #1 | CEM-1 (lossy) | $h_1=0.765 \text{ mm}$ | 4.4 |
| Substrate #2 | Simulated dielectric material | $h_2=1.1 \text{ mm}$ | 1.2 |

Table 5. Designed MPA active, parasitic patches dimensions and positions

| Patches | Type       | positions       | Width $W$ | Length $L$ |
|---------|------------|-----------------|-----------|------------|
| Patch #1 | active      | On Substrate #1 | 26 mm     | 39.8 mm    |
| Patch #2 | parasitic   | On Substrate #2 | 47 mm     | 57.8 mm    |

The percent bandwidth is calculated using the following equation [20]:

$$B_W = \frac{f_h - f_l}{f_c} \times 100\%$$

where $f_h$ and $f_l$ are the upper and lower cut of frequencies of the band respectively at a return loss -10 dB and $f_c$ is the center frequency of the operating band. The bandwidth at each band is given in Table 6.

Table 6. The triple-band designed MPA antenna

| Band of | Resonance frequency (GHz) | RL (dB) | Bandwidth | VSWR |
|---------|---------------------------|---------|-----------|------|
| $f_1$   | 0.9                       | -17.79  | 2.122     | 1.35 |
| $f_2$   | 1.798                     | -18.5   | 1.700     | 1.3  |
| $f_3$   | 2.402                     | -44.22  | 1.370     | 1.0  |

3. Results and Discussion

The S-parameters for the designed antenna is shown in Figure 3. As it is clear the center frequencies are 0.9GHz, 1.798GHz & 2.402GHz. This work is rare up to now. I thing that it will be very useful for the mobile communication and the internet services. The dimension of the designed antenna was (60mm, 50mm). It is suitable for mobiles having an internet services. And the screen today for such a mobiles must be little bit large.

4. Conclusions

A triple band dual layer patch antenna was designed. three center frequencies were 0.9GHz, 1.798GHz & 2.402GHz. The bandwidth for each frequency was 21 MHz, 17 MHz , 13.7MHz respectively. This work is rare up to now. I thing that it will be very useful for the mobile communication and the internet services. The dimension of the designed antenna was (60mm, 50mm). It is suitable for mobiles having an internet services. And the screen today for such a mobiles must be little bit large.

References

[1] Yong Lin, Li-Ming Si Meng Wei “Some Recent Developments of Microstrip Antenna” International Journal of Antenna and Propagation, Vol.2012, Articale ID u28284.
[2] I.J. Ball and P. Bhrrtin, “Micro strip Antenna Theory and design”, Peregrinus, 1981.
[3] D. M. Pozar, “Micro strip antennas”, Proceeding of the IEEE, Vol, 8, no, 1, pp-79-91-1992.
[4] S.B. Tajane, Prof S.R.Gagare, Prof. R.P. Labade “Design Of Triple Band Microstrip Patch Antenna For WLAN and WiMAX Applications” International Journal of Recent Trends in Engineering & Research (IJRTER) Volume 02, Issue 06; June – 2016.
[5] K.R. M.Huq, A.S.Siraj,M.I.Khan, N. Shama, "Design of a triple band microstrip patch antenna for cellular and Wi-Fi application", 2014 International Conference on Informatics, Electronics & Vision (ICIEV)23-24 May 2014.
[6] H.H., K., Yang, Z.Y. Lei and C. I.Li “Broadband Micros trip Antennas using Co- planar Feed line”, Progress In Electromagnetic Research Letters, vol, 20, 129-136, 2011.
[7] Yashar Zehforoosh, changiz Ghoabadi, Javad Nourinia, “A novel Multi Layer Micro strip Antenna for ultra Wideband Applications”, proceedings of 5th WSEAS International conference on Telecommunications and information’s, Istanbul, Turkey, May 27-29-2006 (pp239-242).
[8] Shoichiro Hirai Naoya Arakawa, Takahiro Ueno, Hiroki Hamada, Isao Tomomatsu and Yoichio “Ultra-Compact chip Antenna for the 2.4-2.5 GHz Band”.

[9] Neela Chattoraj, Jibendu Sehher roy, “Application of Genetic Algorithm for the Optimization of Micro strip Antennas with and without Substrate”. Mikrotalasuna revija Nov, 2006.

[10] Abdullah AL Noman Ovi, Mahdy Rahman Chowdhury, Md. Rashidul Alam Zaboraj and Md. Abdul Matin, “Design of Miniaturized Dual Band Micro strip Antenna Loaded with Asymmetric J slot”, AL Noman Ovi etal, jElectron Technol 2012, 2: 1.

[11] Kharade A.R., Patil V.P., “Enhancement of Gain of Rectangular Micro strip Antenna Using Multi layer Multi dielectric structure”, IOSR Journal of Electronics and Communication Engineering (IOSRJECE) ISSN:2278-2834 volume 2,Issue 6(Sep-oct2012), PP35-40, www.io srjournals.org.

[12] Hussain A-Hammas, “Radiation Performance Evaluation of Microstrip Antenna Covered With a Dielectric Layer” Eng.&Tech. Journal, vol.27, no.7, 2009.

[13] Lulu and Jacob Carl Letzee, “Characteristics of a Two-Layer Micro strip Patch Antenna for Bluetooth. Applications” 90301028@nus.edu.sg,elejei@ nus. edu. sg. [Dept.of Electrica and Computer Engineering, national University of Singapore,4 Engineering Drivers, Singapore 117576.

[14] K.H. Sayidmarie and T.A. Nagem” COMPACT DUAL-BAND DUAL RING PRINTED MONOPOLE ANTENNAS FOR WLAN APPLICATIONS”, Progress In Electromagnetics Research B, Vol. 43, 313-331, 2012.

[15] M.R.C. Mahdy, M.R.A. Ziburaj, A.A.N.Ovi and M.A. Matin “Novel Design of Triple Band Rectangular Patch Antenna Loaded with Meta material” progress In Electromagnetic Research Letters, Vol.21, 99-107, 2011.

[16] S.I. Al-Mously, “Design and Performance Enhancement of Cellular Handset Antennas and Assessment of Their EM Interaction with a Human”, PhD Thesis, Academy of Graduate Studies, School of Applied Science and Engineering Dept. of Electrical and Computer eng. –Libya. Aug., 2009.

[17] C. A. Balanis, “Antenna Theory, Antenna and design”, John Wiley &Sons Inc., 2nd Edition, 2005.

[18] K. Parikh, “Simulation of Rectangular, Single Layer, Coax-Fed Patch Antennas Using Agilent High Frequency Structure Simulator (HFSS)”, MSc. Thesis, Faculty of the Virginia Polytechnic. Institute and State University. December 2003.

[19] Computer Simulation Technology: http://www.cst.com/.

[20] L. Warren, and A. Gary, “Antenna Theory and Design” 2nd. Edition, New York, ISBN 0-471-02590-9, 1998.