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Research Article

Design Tri-band Rectangular Patch Antenna for Wi-Fi, Wi-Max and WLAN in Military Band Applications with Radiation Pattern Suppression

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Abstract: Design tri-band rectangular patch antenna is presented. This research study focuses on designing an antenna that can operate with three bands; 2.4, 3.5 and 4.4 GHz, respectively. These bands are accepted by Wi-Fi, Wi-MAX and WLAN in Military band applications. The shape of the proposed design is based on simple rectangular patches with inset-feed on one surface of the FR4 substrate. On the other surface of FR4 substrate, is the infinite ground plane. Also Computer Simulation Technology (CST) microwave studio 2012 is used for the design of antenna. This design is fabricated using photolithographic process.

Keywords: Band suppression, patch antenna, tir-band antenna, Wi-Fi, Wi-max

INTRODUCTION

The demand for wireless communication is on the rise. This is because most communication devices require wireless applications. One of the most important wireless communication elements in any system is the antenna. As such an effective antenna is one that can work with multiple applications. Microstrip antennas have become progressively popular since 1970s. The reason behind the huge production and fast growth of microstrip antennas lies in its unique features. Microstrip antennas are mainly characterized by their light weight and simplicity in design. They are also inexpensive to produce, simple to fabricate and compatible with Microwave Integrated Circuit (MIC) and Monolithic Microwave Integrated Circuits (MMICs) (Sadat *et al*., 2006).

There are a lot of techniques that used to design multi-band microstrip patch antenna for example: put slots in the patch, change the shape E, L, H or wing shape but in this research study multi-band microstrip patch antenna without any techniques.

Feeding mechanism plays an important role in the design of a microstrip patch antenna. The four most popular feeding methods are microstrip line feed (inset-fed), coaxial feeding (Pin Feed), aperture coupling and proximity coupling (Rajeshkumar *et al*., 2012). Microstrip line feeding is suitable for developing high gain microstrip array antennas, while coaxial probe feeding is sometimes advantageous for applications like active antennas. While In cases, the suitable position for the inset length determines the input impedance (Surjati *et al*., 2010).

The microstrip patch antenna is a type of microstrip antenna that is suitable for the fabrication of many types of communication circuits. Figure 1 shows the structure of microstrip patch antenna with inset fed, it's contains of a metal "patch" on top of the dielectric substrate, while the ground is of the same metal like a patch, which is usually of the same size with the substrate. It operated at microwave frequencies of f>1 GHz. Some of the limitations of a patch antenna are its low gain and narrow impedance bandwidth (usually a few percent). Therefore, the challenge to achieve a wide impedance bandwidth with high gain for a patch antenna has become a much sought after topic in the design of a modern microstrip patch antenna design today.

The dielectric constants are usually in the range of ($2.2 \leq \varepsilon r \leq 12$). In this case, the FR4 substrate with dielectric constant is 4.3, the thickness of FR4 substrate is 1.6 mm with duple layer cupper with thickness is 35 μm.

The significant contribution of this study is to design antenna with three different bands frequency for most widely used frequency. In this research study, the design of a single microstrip patch antenna is presented. Which it is work for three bands of 2.4, 3.5 and 4.4 GHz, respectively. That is suitable for Wi-Fi, Wi-MAX and WLAN in Military band applications respectively. And each bands have different radiation pattern.

Design: There are many methods to analyses in designing microstrip antenna. The most common models are the transmission line, cavity and full wave. In this research study, the transmission line method is used to design the microstrip patch antenna. Hence, FR4 board

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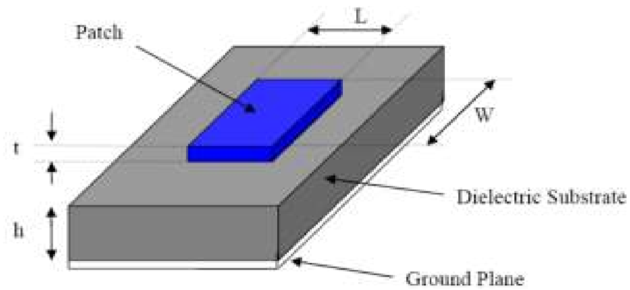


Fig. 1: Structure of rectangular patch antenna

(εr) is 4.3 with thickness of 1.6 mm is used as the substrate of microstrip patch antenna.

The design procedure is to find the width and the length of the patch as well as the width and the length for the feeding. The Width (W) of microstrip patch can be obtained by (Balanis, 2012):

$$W = \frac{C}{2 * f_r * \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

The effective constant ε_{reff} can calculated by:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\left(\frac{h}{w}\right)\right]^{-0.5} \tag{2}$$

The effective length L_{eff} for the desired patch antenna can be calculated by:

$$L_{eff} = \frac{C}{2 f_r \sqrt{\varepsilon_{eff}}} \tag{3}$$

The fringing Length (ΔL) can be obtained by:

$$\Delta L = 0.1412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

The actual length of the patch can be calculated by:

$$L = L_{eff} - 2\Delta L \tag{5}$$

The feed line length of inset Feed (Fi) can be calculated by (Ramesh and Yip, 2003) Fig. 2:

$$Fi = 10^4 \, (0.001699 * \varepsilon_r^{\,7} + 0.13761 * \varepsilon_r^{\,6} - 6.1783 * \varepsilon r5 + 93.187 * \varepsilon r4 - 682.69 * \varepsilon r3 + 2561.9 * \varepsilon r2 - 4043 * \varepsilon r + 6697 * L2 \tag{6}$$

The Width of feed line for the inset feed (Wf) can be obtained by:

$$Zc = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{Wf}{h} + 1.393 + 0.667 * \ln\left(\frac{Wf}{h} + 1.444\right)\right]} \tag{7}$$

The antenna structure is optimized to achieve tri-bands. The initial dimensions are as follows: W = 40.7 mm, L = 29.05 mm, Fi = 8.65 mm, Wf = 3.137 mm, Wg = 81.4 mm, Lg = 58.1 mm.

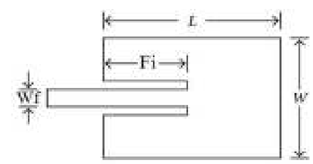


Fig. 2: Simple patch antenna with inset fed

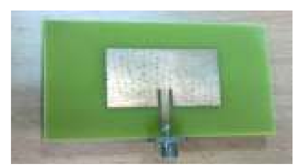


Fig. 3: Patch antenna after fabrication

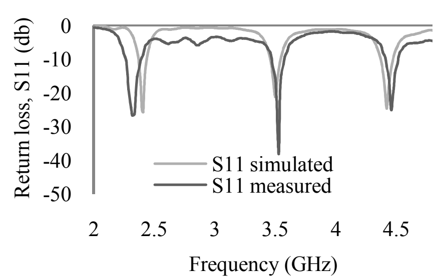


Fig. 4: The return loss (db) for simulated and measured

The design of a single microstrip patch antenna with inset-fed is matched with 50 Ω.

After we simulate the antenna by using CST microwave studio and get the best result of the tri-band rectangular patch antenna for Wi-Fi, Wi-Max and WLAN in Military band. We fabricate the antenna as shown in the Fig. 3. Subsequently, we used the network analyzer device to compare the return loss for both of real antenna and the simulation result (Fig. 4).

RESULTS AND DISCUSSION

After designing the antenna, simulation and fabrication processes are carried out to record the operation at the desired frequency bands according to return loss.

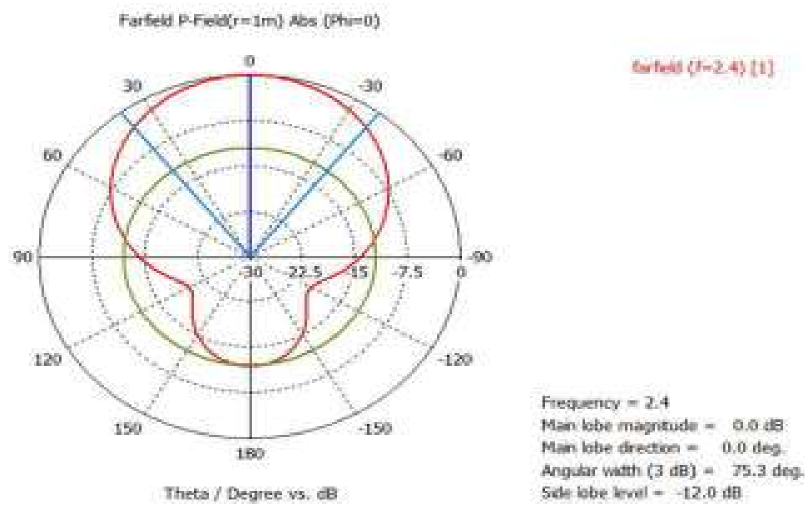
Figure 4 shows the return loss of amicrostrippatch antenna for both simulation and measured procedures for the three bands. In the first band, the simulation results records a return loss of -25.6 dB at an operating frequency of 2.4 GHz while the measured result records a return loss of -26.6 at an operating frequency of 2.31 GHz. The flaws during the fabrication process may lead to the shift of the operating frequency of measured result. The measured operating frequency has shifted about 3.492% from the simulation operating frequency.

In the second band, the simulation result records a return loss of -21.19 dB at an operating frequency of 3.5 GHz while the measured result records a return loss of -38.1 at an operating frequency of 3.53 GHz. The flaws during the fabrication process may lead to the shift of the operating frequency of the measured results. The measured operating frequency has shifted only 0.85% from the simulation operating frequency.

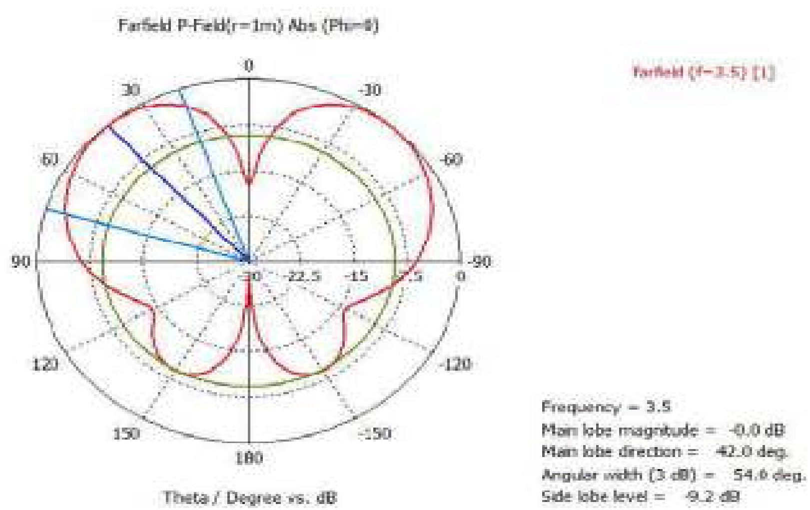
In the third band, the simulation result records a return loss of -24.6 dB at an operating frequency of 4.42 GHz while the measured result records a return loss of -25.09 at an operating frequency of 4.46 GHz. The flaws during the fabrication process may lead to the shift of the operating frequency of measured result. The measured operating frequency has shifted only 0.949% from the simulation operating frequency. Table 1 shows the return loss, bandwidth and radiation angle for each of the bands. In the first band, the estimated bandwidth is 2.891%. In the second band, the bandwidth estimated is about 2.637%. In the third band, the estimated bandwidth is 2.395%.

Table 1: The bandwidth and radiation angle for tri-bands

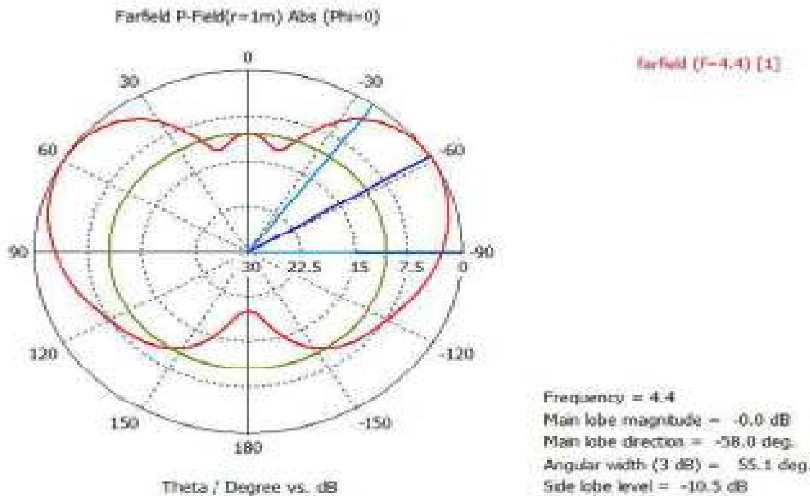
Band (GHz)	Return loss (dB)	Bandwidth MHz	Radiation angle (deg.)
2.4	-25.6	69.4	0.0°
3.5	-21.1	92.3	42.0°
4.4	-21.4	105.4	58.0°



(a)



(b)



(c)

Fig. 5: The power pattern at; (a): 2.4 GHz; (b): 3.5 GHz; (c): 4.4 GHz

Table 2: Level of suppression

Radiation angle (deg.)	First band (dB)	Second band (dB)	Third band (dB)	Level of suppression
0.0°	0.000	-17.50000	-10.48	High
42.0°	-4.212	-0.04139	0.00	Marginal
58.0°	-7.177	-1.13100	0.00	Low

Figure 5 shows the power pattern of the antenna at 2.4, 3.5 and 4.4 GHz, respectively. Each band has different radiation angle.

We can also see the suppression in the radiation angle for three desired directions. The desired direction for first, second and third band is 0.0°, 42.0° and 58.0°, respectively (Table 2).

Applications: This antenna proves to be useful for wireless communication system devices, operate with 2.4, 3.5 and 4.4 GHz bands with bandwidths 69.4, 92.3 and 105.4 MHz, respectively. Many devices can operate with these bands such as Wi-Fi devices, Wi-Max devices and WLAN military devices.

CONCLUSION

This research study presents the simulation and fabrication of a simple rectangular patch antenna work in three bands: 2.4, 3.5 and 4.4 GHz, respectively that can operate with Wi-Fi, Wi-Max and WLAN in Military Band applications. Each band shows a different radiation angle. The differences recorded in the results between the simulation and measured results could be due to several possibilities. One possibility is due to inaccurate of etching. Another possibility is due to the loss at the connection between the SMA connector and the part to the network analyzer, as not all the frequency samples are considered during the measured of results from the network analyzer. The other possibility is due to the soldering of SMA connector. The measurements for the antenna are recorded using Advantest R3767CG network analyzer.

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