Design and Analysis of Triple-Band Microstrip Patch Antenna with h-shaped Slots

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Abstract— **Multi-band antennas are very important in many application systems such as mobile phone jammer. A new shape triple-band microstrip antenna is proposed in this paper. By embedding h-shaped slots placed in the centre of a microstrip patch, the triple-band character can be achieved. Procedures to select the length and location of the h-shaped slots were discussed in detail. The required antenna gain, input impedance, radiation pattern and return losses were achieved.**

Keywords- *Microstrip patch antenna; Triple-band; Slot antenna; Return Loss; Antenna impedance; Gain.*

I. INTRODUCTION

The fast advances in communications systems, motivated the researchers to develop low profile, small size, lightweight, and single-feed antennas. Such antennas were much desired to use in applications that need multi- frequencies into one piece of device [1]. Microstrip antennas attract the attention of designers because of its attractive specifications like low profile, conformal nature, low weight and ease of fabrication. Due to these advantages these antennas are used and developed in wireless and aerospace applications [2-3]. From the previous works there are many designs for different multi-band frequencies depending on the application that the antenna need to be used in. This paper will present a new shape design that works with triple-band frequency and is different from what has been reported in the literature. This design is suitable for use in wireless applications especially in mobile phone applications such as jamming of mobile phone. These new frequencies include global system mobile (GSM) 0.9, 1.8 GHz and ISM band which is used for Bluetooth and wireless local area network bands applications 2.45 GHz. Section II will present in a nutshell previous works that related to antenna patch for multi-band frequency. Then, the methodology for this work is in Section III, while Section Iv presents the results and discussion. Finally, conclusion is given in Section V.

II. ANTENNA PATCH FOR TRIPLE-BAND

Many studies have reported advance techniques for obtaining multi-band antenna [4]. The first one of these techniques is orthogonal mode, the second one is multi-patch and the third one is reactively loaded [5]. The fourth one based on the "window" or slot concept whereby windows were cut in a low frequency patch radiators to accommodate high frequency patch antennas [6]. The third one is considered the most popular technique compared with the rest [5]. There are many designs attributed to the reactively loaded, one of these designs is by etching slots on the patch [5], and this is considered a simple technique [6].

In [7], an M shape microstrip patch antenna was designed for dual/triple-band. The frequencies for this design were 2.44 and 5.77 GHz for the dual band, and 2.44, 3.55, and 5.79 GHz for the triple band. In [8], a T shape microstrip patch antenna with slotted ground plane was considered for multi-standard mobile communication systems 1920 MHz, 2045MHz, and 2442 MHz. In [9], a H-Shape antenna was designed for wireless applications at frequencies 1.57, 1900 and 2.4 GHz. This work will use a simple technique to achieve the new multi-band by using new patch shape.

III. METHODOLOGY OF DESIGN TRIPLE BAND

This section presents the methodology followed to design h-shaped slot patch antenna. First of all the specification of the printed circuit board used for this antenna is 1.6 mm-thick FR-4 substrate with a dielectric constant of 5.2 and feeding by inset feed technique. This work started with single resonant frequency 1.84 GHz. There are some parameters that should be known to design patch antenna operating with one resonant frequency. The model design formulas in [12] were used in a Matlab program to calculate these antenna parameters. The main dimensions are listed in Table 1, and the result is shown in Figure 1. These dimensions did not produce a resonant frequency at 1.84 GHz as seen in Figure 1. So to get this resonant frequency, the length and width of the patch were optimized, as shown in Figure 2. The corresponding dimensions are listed in Table 2.

After the resonant frequency has been achieved exactly as shown in Figure 2, the h slot was inserted in the patch to get multi-band frequency; the procedure in [5] was followed. The h-shape consists of three slots. These slots were inserted one by one inside the patch, where the length of each slot equal to $\lambda/4$ instead of $\lambda/2$ to reduce the size of the antenna [7][10]. The wavelength through the patch antenna is [11]

$$\lambda_d = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \qquad (1)$$

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where λ_d is the wavelength in the dielectric, λ_0 is the wavelength in air, ε_r is the dielectric constants. Now this section will be divided into subsections depend on the number of slots that will be inserted.

Table 1 Parameters Dimensions Of Patch Antenna Before Optimization (1.84GHz)

Parameter	Width(mm)	Length(mm)
Substrate	70	86
Ground	70	86
Patch	46.301	35.506
Feed Line	2.704	38.651

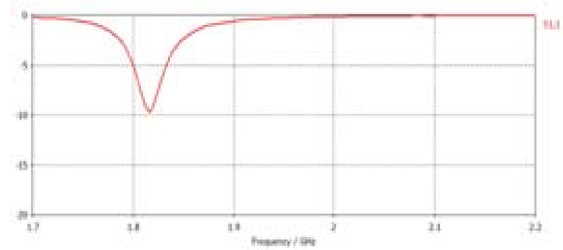

Fig 1. S_{11} in dB for the patch antenna without slot

Table 2 Parameters Dimensions After Optimization (1.84GHz)

Parameter	Width(mm)	Length(mm)
Substrate	70	86
Ground	70	86
Patch	52	34.82
Feed Line	2.704	38.651

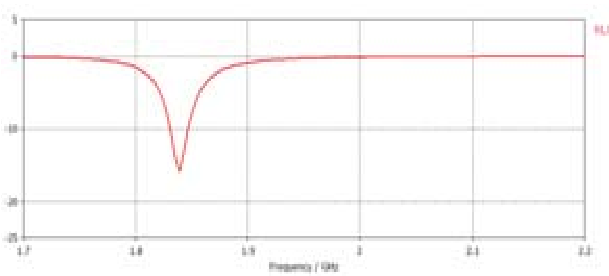

Fig 2. S_{11} in dB for the patch antenna without slot (1.84 GHz)

A. Insertion Of One Slot

First step the slot for 0.9 GHz was inserted. The patch antenna with slot is shown in Figure 3 and the result is shown in Figure 4.

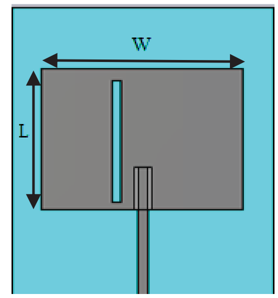

Figure 3. Patch antenna with one slot for 0.9 GHz

This slot moved from the left side of the patch by using parameter sweep to see at which point on the patch the 0.9 GHz is achieved.

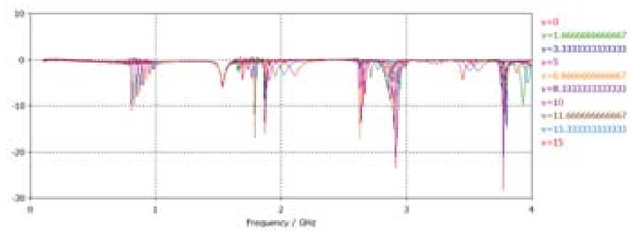

Figure 4. Plot of S_{11} (in dB) for an antenna with one slot at a resonant frequency of 0.9 GHz with the use of parameter sweeping.

As shown from Figure 4 there are many resonant frequencies due to the cavity mode. One of these resonant was 0.9 GHz at a certain point on the patch. But the return losses for this resonant was weak above -10 dB. The symbol (v) in the right side of the result figure represents the values of parameter sweep for the slot.

Second step the slot for 1.8 GHz is inserted and the result is displayed in Figure 5, which shows many resonant frequencies. One of these resonant was 1.8 GHz at a certain point on the patch. But the return losses for this resonant was good under -10 dB.

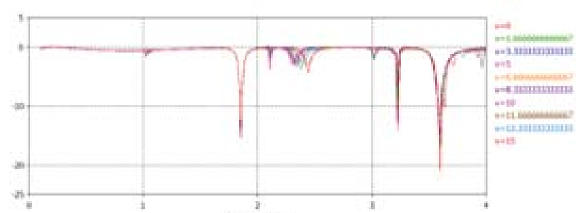

Figure 5. Plot of S_{11} (in dB) for an antenna with one slot at a resonant frequency of 1.8 GHz with the use of parameter sweeping.

Third step the slot for 2.45 GHz inserted the result shown in Figure 6. There are many resonant frequencies due to the cavity mode. One of these resonant was 2.45 GHz at a certain point on the patch. But the return losses for this resonant was weak above -10 dB. The symbol v in the right side of the result figure represents the values of parameter sweep for the slot.

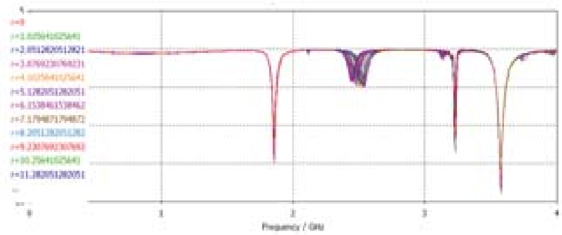

Figure 6. Plot of S_{11} (in dB) for an antenna with one slot at a resonant frequency of 2.45 GHz with the use of parameter sweeping.

B. *Insertion Of Two Slots*

Fourth step the slots for 0.9 GHz and 1.8 GHz were inserted in the patch at same point that they were achieved these resonant frequencies. The patch antenna with two slots is shown in Figure 7, and the result is shown in Figure 8. From the last figure the 0.9 and 1.8 GHz were achieved. But the return losses were weak.

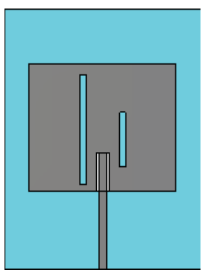

Figure 7. Patch antenna with slots for 0.9 and 1.8 GHz

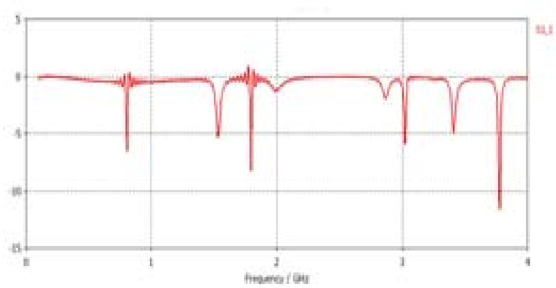

Figure 8. Plot of S11 (in dB) for an antenna with resonant frequency at 1.9 and 1.8 GHz

C. *Insertion of Three Slot*

Fifth step the slots for 0.9, 1.8 and 2.45 GHz were inserted in the patch at same point that they were achieved these resonant frequencies. The patch antenna with slot is shown in Figure 9, and the result is displayed in Figure 10. This figure shows that the 0.9, 1.8 and 2.45GHz were achieved, but the return losses were lower than expected. Using parameter sweeping technique, the optimum dimensions for the patch antenna with the h slot were obtained. The patch antenna with the h slot is shown in Figure 11, and the result is shown in Figure 12. The dimensions of the antenna are shown in Table 3.

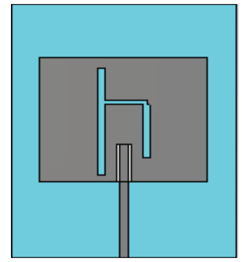

Figure 9. Patch antenna with slots for 0.9 , 1.8 and 2.45 GHz

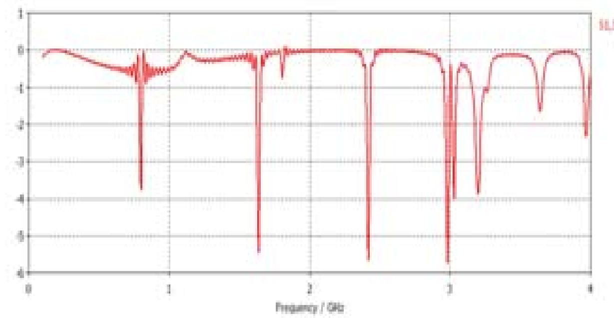

Figure 10. Plot of S_{11} (in dB) for an antenna with resonant frequency at 0.9, 1.8 and 2.45 GHz

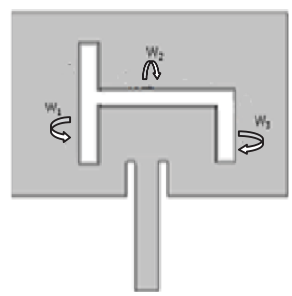

Figure 11. Optimized Patch antenna with three slots with resonant frequencies at 0.9, 1.8 and 2.45 GHz.

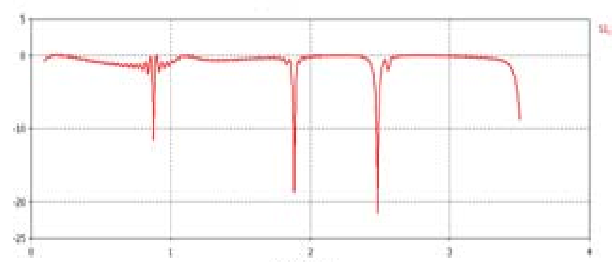

Figure 12. Plot of S11 (in dB) for an optimized antenna with resonant frequency at 0.9, 1.8 and 2.45 GHz.

Table 3 Parameters Dimensions for h Slot patch antenna

Parameter	Width(mm)	Length(mm)
Substrate	80	86
Ground	80	86
Patch	54	35.72
W1	5	26
W2	20	5
W3	5	16

IV RESULT AND DISCUSSIONS

This work started with 1.84 GHz, after that the slot for 0.9 GHz inserted in the patch and move from left to the center by variable value equal to v=1.6 mm (that means the slot was shifted from left to center by 1.6mm step by step) to show at which point this slot can achieved 0.9 GHz, from the Figure 3 there are multi-frequency due to the cavity mode properties but one of these frequencies the 0.9 GHz was achieved at specific point, but with weak return losses. The same steps with the slots 1.8 and 2.45 GHz. When the two slots inserted for 0.9 and 1.8 GHz inserted at the point that achieved 0.9 and 1.8 GHz, the resonant frequency almost around this rang as shown in Figure 8, but also with weak in return losses. When the three slots inserted for 0.9, 1.8 and 2.45 GHz at the point that achieved 0.9 and 1.8 GHz, but the slot for 2.45 placed vertically as shown in Figure 9. The resonant frequency almost around this rang as shown in Figure 10, but also with weak return losses. Finally, Figure 9 was optimized by using parameter sweep. The resonant frequency is shown in Figure 12. And the Figure 11 has shown the patch antenna shape. Characteristics of this antenna are shown in table 3 and the radiation pattern is shown in Figure 13.

Table 4 Gain, return losses and line impedance

Field monitor (GHZ)	Gain (dB)	Return losses (dB)	Line impedance (ohm)
0.9	8.783	-11.618	56.403
1.8	5.863	-18.538	
2.45	7.903	-21.533	

V CONCLUSIONS

In this paper, a new antenna design for dual GSM and single ISM (Bluetooth and wireless local area networks) band frequency was achieved by insert in h-slot in the patch antennas. This antenna is designed to work with mobile phone systems or jammer system applications. The simulation results obtained from the CST software showed that the gain and return losses were good for these bands compared with others shape reported in the literature.

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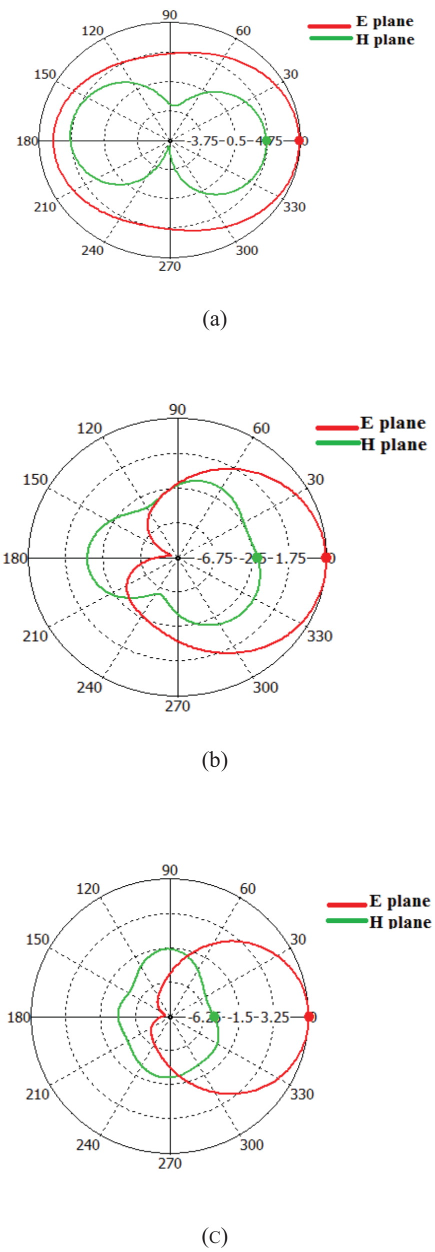

Fig. 13 simulation gain radiation pattern in 2D for (a) 0.9 GHz (b) 1.8 GHz (c) 2.4 GHZ respectively.

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