Design of a Triple-Band h Slot Patch Antenna

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***Abstract*— This paper attempts to design a triple band h-slot antenna by using feed line technique. These bands cover GSM mobile phone system (0.9 and 1.8 GHz) and ISM band which is used for Bluetooth and wireless local area network bands applications. The CST microwave studio software is used as a tool for simulation. This antenna is an attractive candidate for important applications like mobile phone communication systems, mobile phone jammer application, and so on.**

Keywords- ***Microstrip h-slot patch antenna; Return Losses; Gain.***

I. INTRODUCTION

The past decade has seen a rapid development of wireless communication systems. This continuous trend is bringing about a wave of new wireless devices and systems to meet the demand of multimedia applications. Multi-frequencies and multimode devices such as cellular phones, mobile phone jammer, wireless local area networks (WLAN) and wireless personal area network place several demands on the antennas. Primarily, the antennas need to have high gain, small physical size, and multi bandwidths. Recently there are many demands to design antennas that cover global system mobile (GSM) mobile phone systems and ISM ban systems for some applications. There are two bands for mobile phone 0.9 and 1.8 GHz. The band of 0.9 GHz is extended from 0.88 GHz to 0.96 GHz for lower band uplink and upper band downlink, while the 1.8 GHz starts from 1.71 GHz to 1.88 GHz for lower band uplink and upper band downlink. Also the mobile has another frequency for another application that is called Bluetooth; Bluetooth radio modules operate in the unlicensed industrial, scientific and medical (ISM) band of 2.4GHz. The (ISM) band ranges from 2 GHz to 2.8 GHz which also include WLAN according to IEEE 802.11g standard that extended throughput to up to 54 Mbit/s using the same 2.4 GHz band. This project needs to meet specific requirement design -such as small size, low cost, low profile, narrowband, gain and directivity sufficient. The microstrip patch antennas are widely used because of their many merits, such as the low profile, light weight, small size and conformity. However, patch antennas have a main disadvantage: narrow bandwidth. Researchers have made many efforts to overcome this problem and many configurations have been presented to extend the bandwidth [1]. The four most popular feeding techniques are the microstrip line, coaxial probe, aperture coupling, and proximity coupling [2] [3]. In this paper a single microstrip line-fed rectangular h-slot patch antenna is proposed to be work with the GSM, Bluetooth and WLAN bands.

Section II is a briefing on present's antenna design. then, feeding techniques is in Section III, while Section Iv presents triple band patch antenna Section v shows the results and discussion. Finally, conclusion is given in Section VI.

II. MICROSTRIP ANTENNA DESIGN

There are many different shapes of microstrip antenna such as rectangular, square, dipole, circular etc. The rectangular patch is considered the most widely used configuration. It is very easy to analyze using both the transmission-line and cavity models, which are most accurate for thin substrates [4]. In this paper the rectangular patch antenna and transmission line method are used to approximate the dimensions to design an antenna and to match the radiating patch and the transmission line impedance. This paper started with single rectangular patch antenna after that the h slot inserts in the patch. The value of parameters like the dielectric constant of the substrate (ε_r), the resonant frequency (f_r), and the height of the substrate (h) should be known when The design patch antenna is requested. The design procedures are as follows [5]:

First the width (W) is determined from

$$W = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c_0}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

where c_0 is the free-space velocity of light

Then one can determine the effective dielectric constant of the microstrip antenna using the following equation:

$$\varepsilon_{reff} = \begin{cases} \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} & for \;\; w/h \geq 1 \\ \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} + 0.041\left[1 - \sqrt{\frac{w}{h}}\right] & for \; w/h < 1 \end{cases} \tag{2}$$

Afterwards the extension of the length ΔL can be determined using

$$\Delta L = 0.412\,h \frac{(\varepsilon_{reff} + 0.3)\left[\frac{w}{h} + 0.364\right]}{(\varepsilon_{reff} - 0.258)\left[\frac{w}{h} + 0.8\right]} \tag{3}$$

The actual length of the patch can now be determined by using this equation:

$$L = \frac{C_0}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (4)$$

From these equations that mentioned above, we can see that the resonant frequencies are inversely proportional to the width, length and dielectric constant substrate.

III. FEEDING TECHNIQUES

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contact and non-contact. In the contact method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contact scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch [6] [7]. The four most popular feed techniques used are the microstrip line, coaxial probe (both contact schemes), aperture coupling and proximity coupling (both non-contact schemes) [8].

The microstrip line feed is used here. In this type of feed technique [3], a conducting strip is connected directly to the edge of the microstrip patch. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide for a planar structure. To match the impedance of the feed line to the patch without the need for any additional matching element can be done by the inset cut in the patch. This is achieved by correctly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the substrate thickness increases, dielectric constant decreases, radiation loss, surface waves and spurious feed radiation increases, which for practical designs limit the bandwidth (typically 2–5%). The comparison between the techniques feeding is illustrated in Table 1.

IV. TRIPLE BAND PATCH ANTENNA

There are some works that have been done in this field (Triple-band patch antenna) but for different applications and with different resonant frequency. Some of these works have been achieved the multi-band microstrip patch antennas with the three-band central frequencies. Dong –hee and etal used single patch antenna with c-shaped slots of letter in the excited patch and combining the parasitic patch and excited patch in U shape of letter on the three-layered structure.Therefore, the proposed antennas can be applied for various kinds of a mobile communication applications, including a MIMO (Multiple-Input Multiple-Output) systems [9]. Mohammed and etal presented in their paper a new design multi-band patch antenna, based on the U-shape and characterized by shorting; it has been

Table 1 Comparison of Feed Techniques [3]

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture Coupled Feed	Proximity Coupled Field
Spurious Feed Radiation	More	More	More	More
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	13%

presented for the applications of wireless communication to current 0.9, 2.2 and 5 GHz [10]. The others have presented a novel H-Shaped reconfigurable microstrip patch antenna fed by a Grounded Coplanar Waveguide (GCPW) for wireless applications. The antenna design relies on the ability to select the number of operating frequencies electronically by using a varactor diode Global Position System (GPS), a dual band mode to cover GPS and Global System for Mobile communications (GSM1900) or a three-band mode to cover GPS, GSM1900 and Bluetooth or WLAN [11]. In this paper a triple band *h* slot antenna is designed for the GSM900, GSM1800 and ISM bands. In the first stage, a single fed-line rectangular patch antenna is designed for a single resonant frequency at 1.86 GHz using a substrate with dielectric constant ε_r=5.2 and height 1.6mm. Fig. 1 shows the important parameters of the rectangular patch. Then, the *h* slot is inserted on the centre of the patch as shown in Fig. 2 with dimensions w_1,w_2, and w_3. The CST microwave studio is used to simulate the patch antenna and also to determine the optimum values for w_1,w_2, and w_3.

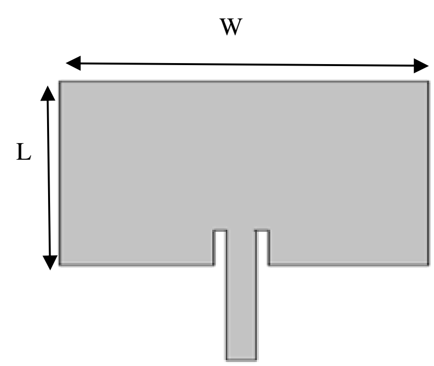


Fig 1 Patch antenna for one resonant frequency

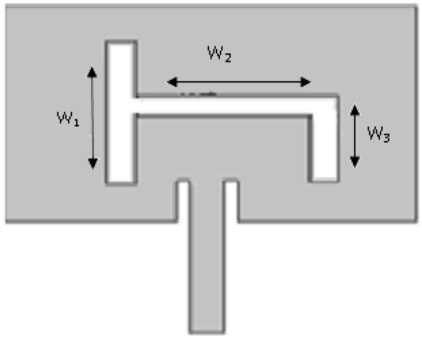


Fig 2 h slot Patch antenna for triple resonant frequency

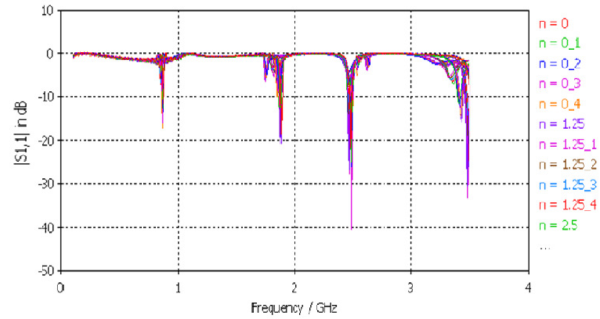


Fig 4. Resonant Frequency with h slot By manipulating the values of w1, w2 and w3 .

V. RESULT AND DISCUSSION

The dimensions of the single fed-line rectangular patch antenna are determined using equations (1) to (4) and the dimensions results are shown in Table 2, and the resonant frequency shown in Fig.3. When the *h* slot inserted inside the patch, the two variable (*n* , *l*) was used where *n* represent change in width for w_1, w_2 and w_3. *l* represent change in length for w_2 after that the CST software was used to determine the optimum values for w_1,w_2, and w_3 . Fig 4 shows the resonant frequency for this optimization, subsequently the best dimensions that achieve the requested triple band frequency have been chosen Table 3 shows that and Fig 5 shows the triple band that are requested for this paper . The gain and return losses for these frequencies is illustrated in Table 4. Fig 6(a-c) shows the radiation pattern in 2D and for these bands 0.9, 1.8 and 2.4 Ghz respectively.

Table 2 Parameters Dimensions without Slot

Parameter	Width(mm)	Length(mm)
Substrate	80	86
Ground	80	86
Patch	52	34.44
Feed Line	2.704	38.36

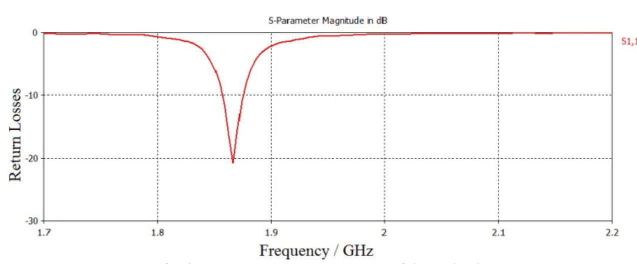


Fig 3 Resonant Frequency without h slot

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

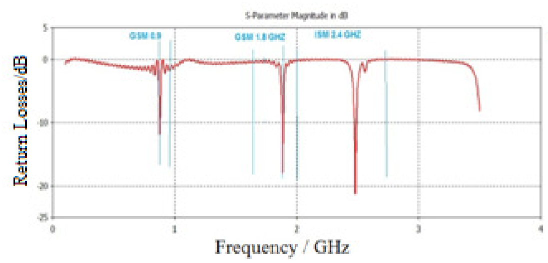
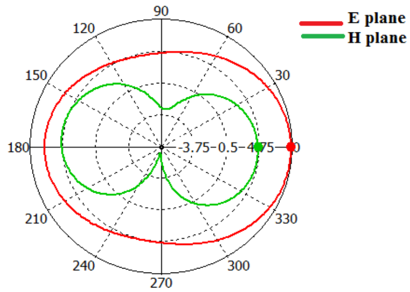


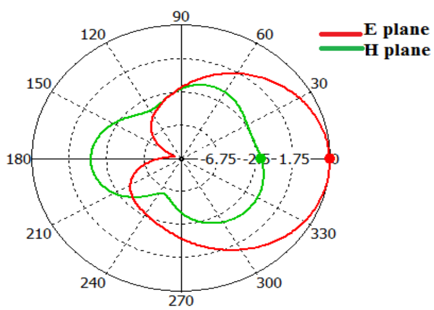
Fig 5. Triple Resonant Frequency with h slot

Table 4 Gain and return losses

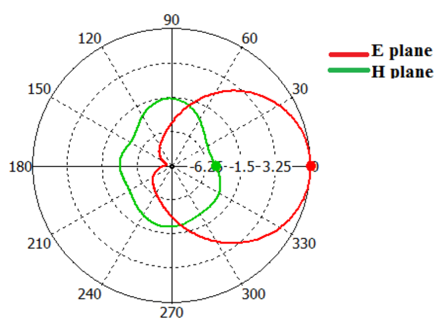
Field monitor (GHZ)	Gain (dB)	Return losses (dB)
0.9	8.783	-11.618
1.8	5.863	-18.538
2.4	7.903	-21.533



(a)



(b)



(C)

Fig. 6 simulation gain radiation pattern in 2D for (a) 0.9 GHz (b) 1.8 GHz (c) 2.4 GHZ respectively.

VI. CONCLUSIONS

In this paper, the small triple-band h-slot microstrip patch antennas are designed. The parameters, gain, return losses, co-polar and cross-polar are shown. The feed line technique and CST microwave studio software for simulation are used. The gain and return losses were good for these bands. The antenna is designed to be used in multi-band mobile phone systems or jammer system applications, covering the GSM and ISM bands.

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