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Research Article

Improved Design and Simulation of Compact Dualband Mircrostrip Patch Antenna for WiMax and Wi-Fi Applications

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Abstract
This paper presents an improved design and simulation of compact dual band Microstrip Patch Antenna (MPA) that can be used for Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Fidelity (Wi-Fi) applications. The antenna geometry is 25 mm x 24 mm x 1.27 mm and operates at 3.65 GHz and 5.42 GHz which are suitable for WiMAX and Wi-Fi applications. The antenna was designed on RT/duroid 6010LM substrate which has a dielectric constant of 10.2. An offset feeding and optimizations in the design process were employed and the simulation results produced a gain of 4.51 dB, a directivity of 4.92 dBi at resonance frequencies of 3.65 GHz and 5.42 GHz for the first and second band. The Voltage Standing Wave Ratios (VSWRs) of the antenna are 1.2814 for the first band and 1.1870for the second band with a peak return loss (S11) of -24.6092 dBi for the first band and -25.6812 dBi for second band. With the obtained results, the antenna can be used for WiMAX and Wi-Fi applications.

Keywords: *Dual band, offset feed, WiMAX, Wi-Fi, optimization.*

I. INTRODUCTION

Microstrip patch antenna find its application in wide range of microwave system. Its versatility in applications was as a result of its light weight, low volume, low cost, low profile and ease of fabrication [1]. The reviews of some previous works related to microstrip patch antenna used for WiMAX, Wi-Fi, or both applications were presented. The WiMAX is based on the IEEE 802.16 family set of standards. Its system is becoming increasingly popular to allow broadband wireless internet access for private and business users [2]. The first system implementations of WiMAX, was based on the 802.l6-2004 specifications which was intended for fixed wireless access, have already being tested and used [2]. WiMAX has three frequency bands, the lower band which ranges between (2.5 GHz – 2.69 GHz), the middle band (3.2 GHz – 3.8 GHz), and the upper band (5.2 GHz – 5.8 GHz). WiMAX can be used for both fixed and mobile applications. The 802.16-2004 is used for fixed station application with a transmission spectrum of 10 GHz – 66GHz for single carrier, line of sight and licensed application. It also transmits at 2 GHz – 11 GHz for non-line of sight, licensed and unlicensed applications [3, 4]. On the other hand, 802.16e -2005 is used for fixed and mobile applications with a transmission spectrum of less than 6 GHz for non-line of sight, licensed and unlicensed applications [3, 4].

After some series of amendment by WiMAX forum, the 2 GHz – 11 GHz spectrum was further divided in to various channels like: 2.3 GHz, 2.5 GHz, 3.5 GHz and 5.8 GHz for both fixed and mobile applications [4]. On the other hand, Wi-Fi operates within the legally allowed Wireless Local Area Network (WLAN) channels based on IEEE 802.11protocols [1]. The 802.11 available channels are (2.4 GHz-2.484 GHz), 3.6 GHz, 4.9 GHz, 5 GHz, and (5.15 GHz – 5.825 GHz) [3]. Various techniques that can be employed to improve the performances (gain, bandwidth, etc.) of microstrip patch antenna were existed. In some previous development, slot loaded microstrip patch antenna for WLAN/WiMAX applications was designed and developed [5]. In this paper, dual loop shaped were cut from the radiator, the simulation results produced a usable band width of 840 MHz. In addition, dual band rectangular and circular slot loaded microstrip antenna for WLAN/GPS/WiMAX applications was also presented [6]. In this paper, the rectangular patch was loaded by triple rectangular slots and dual circular slots. The simulation results produced dual bands with bandwidths of 380MHz and 900MHz. Likewise, a design of modified E – Shaped microstrip patch antenna for WiMAX application was also carried out by [7]. The author designed an E–Shaped slot on the radiating element of the patch antenna, after several optimizations; the simulation results produced a gain of 4.56 dB at a resonance frequency of 3.5 GHz with a return loss of -33.9 dB. The antenna has an improved gain however; the bandwidth of the antenna is narrow and the overall size of the antenna is also large for small hand-held devices. Hence some design techniques can be employed to further improve the bandwidth while reducing the overall volume of the antenna. In 2015, a compact dual band microstrip patch antenna for Wi-Fi and WiMAX applications was developed by [8]. In this work, the two edges of rectangular patch element were removed. After several optimization, the simulation results produce dual band at 3.6 GHz and 5.3 GHz. An impedance matching was also achieved through offset feeding. A measured and simulation results produced gains of 1.01 dB and 2.9 dB at corresponding resonance frequencies of 3.6 GHz and 5.3 GHz respectively. This antenna has low gain and narrow bandwidth. The same antenna can be design with an improved gain and bandwidth if some design techniques were to be employed.

From this review it can be observed that, most of these designs have either low gain or narrow bandwidth or both. Hence, this paper is aimed at improving the gain of a previous work [8] while maintaining the size of the antenna. An offset feeding was employed in order to match the antenna perfectly with the transmission line, in addition to intensive optimizations.

II. ANTENNA DESIGN

a. Dimension of Patch Element

The dimensions of the antenna were calculated from the following adopted equations [1]

The width of the rectangular patch element can be calculated using equation (1)

$$W = \frac{v_o}{2f_c}\sqrt{\frac{2}{1+\varepsilon_r}} \tag{1}$$

where:

W, is the width of the patch element.

V_o, is the velocity of light, a constant whose value is3 $X10^8 m/s$.

f_c,is the center frequency of the of the middle band of WiMAX and is given as:

$$f_c = \left(\frac{3.2 + 3.8}{2}\right) GHz.$$

Hence, f_c = 3.5 GHz.

εr, isthe dielectric constant of RT/duroid 6010LM substrate whose value is 10.2

Moreover, the effective dielectric constant ε_{eff}, was also calculated from equations (2).

$$\varepsilon_{eff} = \frac{1+\varepsilon_r}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-1/2} \tag{2}$$

Where:

h,is the height (thickness) of the substrate material and its value is 1.27 mm, all other components of the formula are already defined.

In addition, the change in length of the patch element due to fringing effectΔL, which was causes by the power radiating from the surface of patch element, was calculated from (3)

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-o.258)(\frac{W}{h}+0.8)} \tag{3}$$

Similarly, the effective change in length of the patch elementΔL_{eff}, was calculated from (4).

$$\Delta L_{eff} = L + 2\Delta L \tag{4}$$

The actual length of the patch element L, was calculated from (5)

$$L = \frac{v_o}{2f_c\sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (5)$$

b. Dimensions of Substrate material

According to Rule of Thumb [9], the distance from the patch element to the substrate, should be at least three times the thickness of substrate material. The thickness of RT/duroid 6010LM is 1.27 mm.

The Length of the substrate material Sl, should be at least six times the thickness of the substrate plus length of patch element as presented in (6).

$$Sl = 6Sh + Pl \quad (6)$$

Where:

h, is the thickness of the substrate whose value is 1.27 mm.

Similarly, the width of the substrate material Sw, should be at least six times the Thickness of the substrate plus length of the patch element as presented in (7).

$$Sw = 6Sh + Pw \quad (7)$$

c. Dimensions of Ground Plane of the Patch Antenna

The ground plane is a layer usually lied at the bottom of the microstrip patch antenna. It is normally made up of made up of conducting materials such as, aluminum, copper, etc.

A copper material is used as a ground plane in this paper whose thickness is 0.1 mm as loaded from CST microwave suit studio library.

The length Gl, and width Gw, of the ground plane should be the same as the dimension of substrate as indicated in(8) and (9).

$$Gl = Sl \quad (8)$$

$$Gw = Sw \quad (9)$$

d. Removal of Diagonal Edge of the Antenna

The simulated results of the rectangular patch antenna do not produce any desired resonance due to poor impedance matching which leads to excessive power loss between the patch element and the transmission line of the antenna. The first resonance at 3.65 GHz was obtained by removing the upper - right diagonal edge of the patch antenna of length Lm equals to 4.7 mm. Similarly, the second resonance at 5.42 GHz occurred after removing the lower left edge of the patch element with length Lk equal to 3.5 mm. The mathematical equations used to determine the length of the two edges Lm and Lk being removed from the patch element of the antenna were presented by equations (10) to (15).

$$L_k = 2aSin\theta \quad (10)$$

Also, L_k can be expressed as

$$L_k = \frac{2}{\sqrt{2}}P_l - \frac{2}{\sqrt{2}}d \quad (11)$$

But using Pythagoras theorem,

$$a = \frac{L_k}{\sqrt{2}} \quad (12)$$

Similarly, that of the upper right edge,

$$L_m = 2bSin\phi \quad (13)$$

Also, L_m can be expressed as

$$L_m = \frac{2}{\sqrt{2}}P_w - \frac{2}{\sqrt{2}}c \quad (14)$$

But using Pythagoras theorem,

$$b = \frac{L_m}{\sqrt{2}} \quad (15)$$

were,

Lk is the length of the lower diagonal edge

Lk is the length of upper diagonal edge

e. Offset feeding

In order to properly match the antenna impedance with that of the transmission line, an offset feeding was used in this paper. This involves shifting the position of the feedline of the antenna from the central position of the patch element to a point 1.8 mm right ward of the antenna. This point was obtained through an intensive optimization using the design software.

f. Structure of the Rectangular Patch Antenna

The complete structure of the patch antenna is presented by Fig. 1

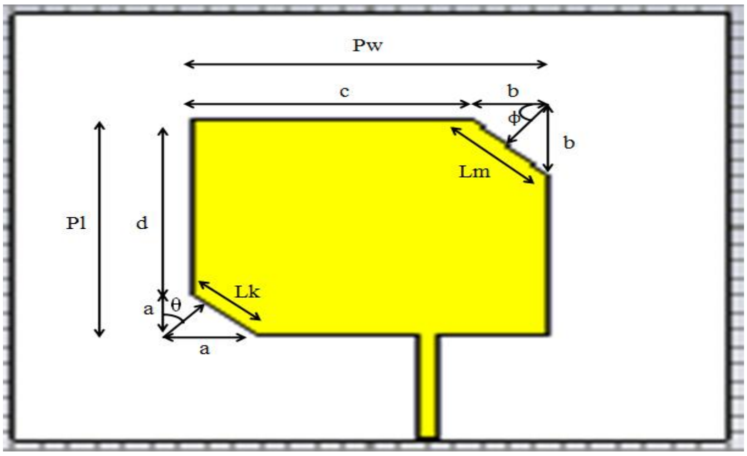

Fig.1 Structure of the antenna

Fig1 presents the complete structure of the antenna displaying the dimensions of length and width of the patch element as presented by the appropriate letters; the dimensions of diagonal edges were also indicated.

III. DESIGN PARAMETERS

The antenna has been designed on substrate RT/duroid 6010LM which has a dielectric constant of 10.2 and loss tangent of 0.002, the high value of dielectric constant lead to a compact size of this antenna. The other parameters used to design the configuration of the antenna were indicated the in Table 1.

Table 1 Design Parameters

PARAMETERS/UNITS	VALUE
Operating Frequency (GHz)	3.65 and 5.42
Patch Length, Pl (mm)	13
Patch Width, Pw (mm)	12.9
Patch Thickness, Pt (mm)	0.035
Substrate Length (mm)	26
Substrate Width (mm)	24.9
Substrate Thickness (mm)	1.27
Length of ground plane, Gl (mm)	26
Width of ground plane, Gw (mm)	24.9
Thickness of ground plane, Gt (mm)	0.1
Length of Rectangular Slot (mm)	2.1
Width of Rectangular Slot (mm)	1.3
Thickness of Rectangular Slot (mm)	0.035

IV. SIMULATION RESULTS AND DISCUSSION

Various simulation results of this antenna were presented in this part along with appropriate descriptions.

a. Return loss of the antenna

The return loss of the improved antenna is presented by Fig.2

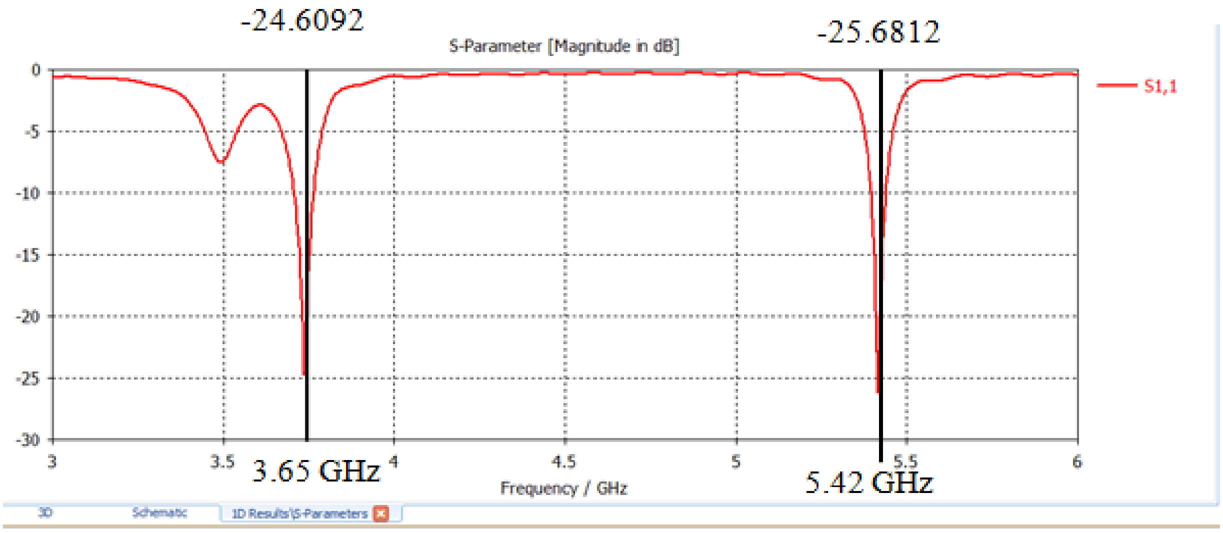

Fig.2 S_{11} parameter of the antenna

Fig.2 is the return loss plot of the MPA, from this plot it can be observed that, the first deep sharp curve terminates at -24.6092 dBi at a resonant frequency of 3.65 GHz; similarly, that of second band is -25.6812 dBi at a resonant frequency of 5.42 GHz. However, that of (Amal etal,2015), the first band terminates at -17.2140 and -22.1024 for the second band. This shows that, the improved design has perfect scattering parameters however, all the antennas were within the acceptable region (-10 dBi).

b. The gain of the antenna

The gain of the improved antenna can be obtained from Fig.3

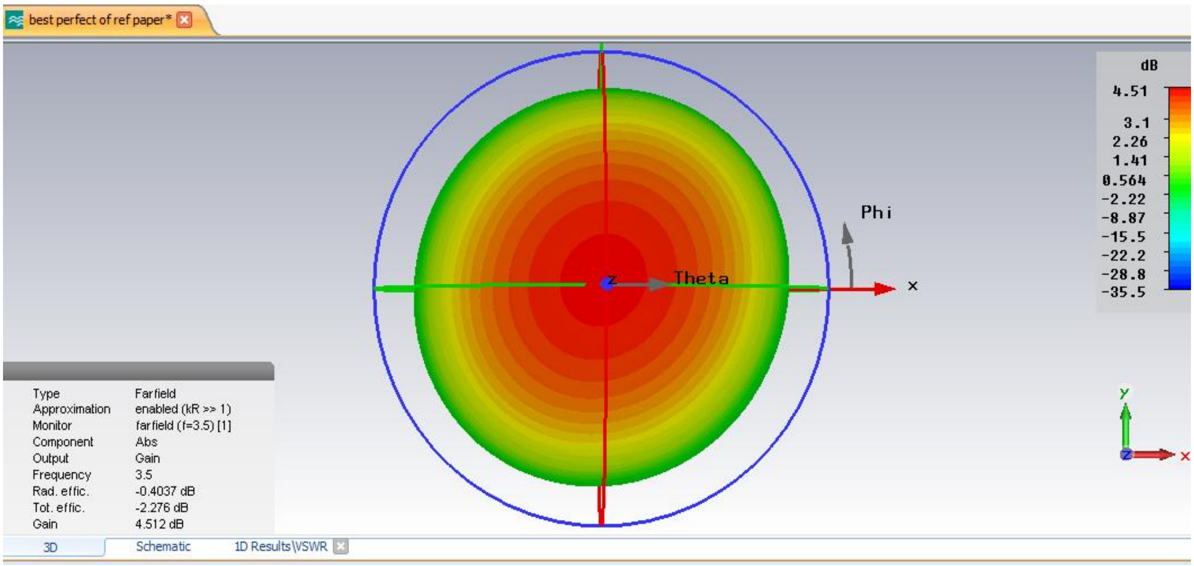

Fig.3 3D plot of the antenna

Fig.3 is the 3D radiation of the microstrip patch antenna; from this plot it can be observed that, the gain of the antenna is 4.51 dB, however that of [9] is 2.9 dB. This shows that, the improved design has a comparatively higher gain compared to the referenced one. The increase in the gain was a result of offset feeding and optimizations employed in the design process.

c. Directivity of the antenna

The directivity of the improved antenna if presented by Fig.4

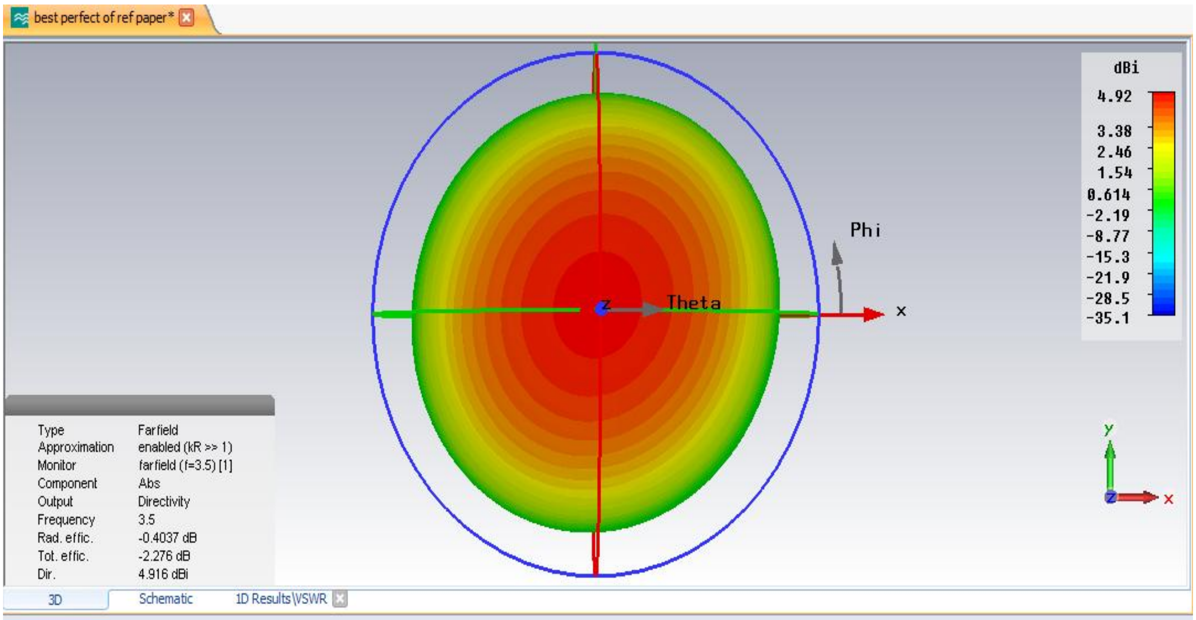

Fig.4 directivity of the antenna

Fig.4 presents the 3D radiation of the microstrip patch antenna, from this plot it can be observed that, the directivity of the antenna is 4.92 dBi, this shows that, the antenna is highly directional.

d. The VSWR of the antenna

The VSVR of the improved design of the patch antenna is presented by Fig.5.

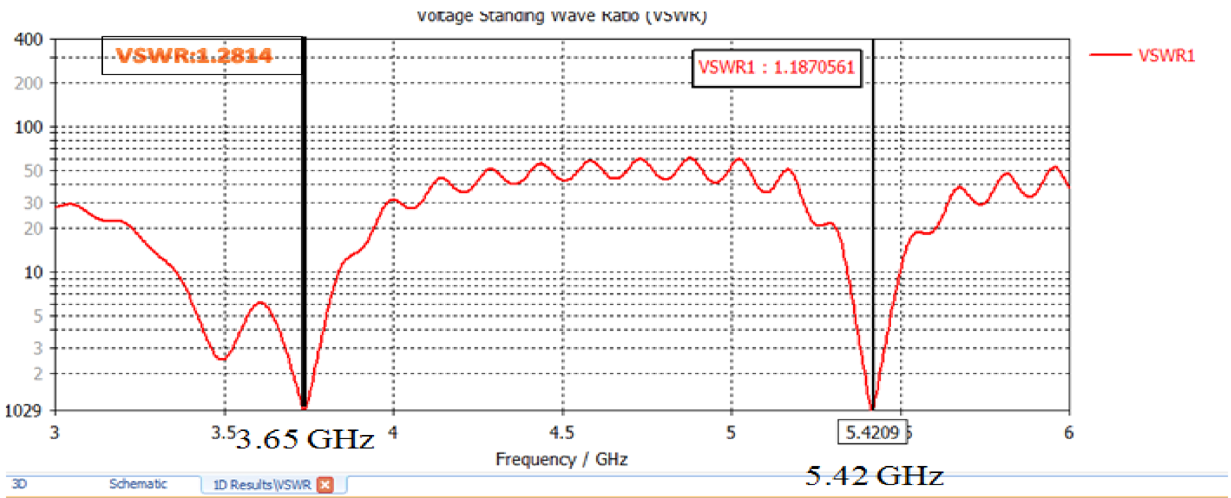

Fig.5 VSWR of the antenna

Fig.5 presents the VSWR of the microstrip patch antenna, from this plot it van be observed that, the VSWR for the first band is 1.2814 while that of the second band is 1.1871 respectively. This shows that, the antenna was perfectly matched since the VSWR is closer to the ideal value (1.0) in all the two bands.

e. The polar radiation of the antenna

The polar radiation of an improved antenna is presented by Fig.6

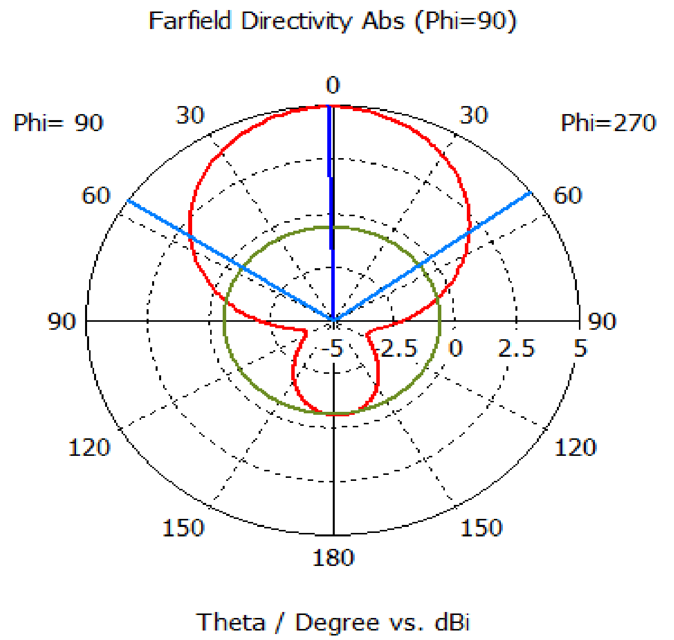

Fig.6 polar radiation of the antenna

Fig.6 presents the polar radiation of the microstrip patch antenna; from this plot it can be observed that, the front to back ratio of the antenna is 7.75 dB and the beam width of the antenna is 109.1 degree. In addition, the directivity of the antenna is 4.51 degree at an angle of 1.0 degree. This shows that, the antenna is directional antenna. Since the main lobe direction is nearly zero degree.

Table.2 Comparison of Results for the Improved and Reference Designs

Publication (Reference)	Operating Frequency (GHz)	Gain (dB)	Directivity (dB)	S11 (dB)	Beam width (Degree)	VSWR
Referenced [12]	3.6 & 5.3	2.9	-------	-17.2140 & -22.1024	148.7	--------
Improved design	3.65 & 5.42	4.51	4.92	-24.6092 & -25.6812	114	1.3814 & 1.1871

From Table 2 it can be observed that, with the improvement in the design processes, the gain and directivity of the antenna are 4.51 dB and 4.92 dB. Thisincrease in gain and directivity was as a result of an offset feed and optimizations employed in the improved design process. Similarly, the VSWR is closer to the ideal value (1.0) in all the two bands.

V. CONCLUSION

This paper presents the design and simulation of an offset feed compact dual band microstrip patch antenna for Wi-Fi and WiMAX applications. An offset feed and optimizations were employed in the design process and the simulation results produced a gain of 4.51 dB, a directivity of 4.92 dBi and a VSWR of 1.2814 and 1.1871for first and second band at resonance frequencies of 3.65 GHz and 5.42 GHz. However, the gain of the referenced design is 2.9 dB. Hence, the improved design has a higher gain compared to the referenced design. In addition, the VSWRs of the improved design are closer to the ideal value in all the two bands, hence with the obtained results, the antenna can be used for WiMAX and Wi-Fi applications.

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