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Dual Band Aperture Coupled Patch Antenna For WLAN and WiMax

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Abstrat: In this paper an aperture coupled dual band microstrip antenna for application in Worldwide Interoperability for Microwave Access (WiMax) and Wireless Local Area Network (WLAN) is presented. The dual band is operable at resonant frequencies 3.6GHz and 5.2 GHz. In the design the slits have been cut at the boundaries of the rectangular shaped patch, so the resulting configuration is E-shaped patch antenna. The proposed antenna achieves an impedance bandwidth of 50.2MHz and 139MHz at frequencies 3.6GHz and 5.2GHz respectively. The VSWR of the antenna is less than 2 and the gain of the antenna is larger than 5dB. Therefore, the antenna meets well the requirements of WiMax and WLAN systems. But the bandwidth of the designed antenna is low. So to improve the bandwidth of the antenna stubs are used along the sides of the feedline. Thus the bandwidth of the upper resonant frequency band is increased to 220MHz.

Keywords: Aperture coupling; WLAN; WiMax

I. INTRODUCTION

The aperture coupled technique to feed the microstrip antenna was first proposed by Pozar in 1985 by using a circular slot as coupling aperture and thereafter a rectangular aperture was used by Sullivan and Schaubert to improve the coupling efficiency. Aperture coupled antenna use non-resonant slot to feed. So more parameters can be tuned such as the sizes of patches, slot and feed microstrip. The height and permittivity of a particular chosen substrate is constant. Aperture coupled feeding technique comes under non-contact feeding schemes in which electromagnetic field is coupled to transfer the power from the microstrip line to the patch [1],[2].

Wireless communication systems require higher operating bandwidth such as 3.43%, 3.80%, and 1.73% for WLAN applications at frequencies 2.4GHz, 5.2GHz and 5.8GHz respectively. The frequencies bands for WLAN applications are from 2.400 GHz to 2.484GHz, 5.150GHz to 5.350GHz and 5.725GHz to 5.825GHz. The percentage impedance bandwidth for WiMax applications are 7.32%, 8.18% and 10.81% respectively at 2.5GHz (2.5GHz to 2.69GHz), 3.5GHz (3.4GHz to 3.69GHz) and 5.5GHz (5.25GHz to 5.85GHz) [3].

When we cut the slits at the boundaries of the rectangular shaped patch we get the E-shaped configuration for the patch. Similar to the method of slot loading, the performance of the slit loaded patch antenna is also based on the excitation of more than one adjacent modes. The width of the frequency bands of the antenna is controlled by the length and width of the slit and its position. The slits actually divide the patch in three or more parts and each part corresponds to an equivalent circuit of resonance as shown in figure1 [4],[5].

In case of slit loaded antenna the slits play an important role to control the behavior of the antenna. But to find the geometry of the patch is really a difficult process because there are no mathematical formulas, thus we can not make the predictions. This whole process is iterative and is applied by simultaneously using a high frequency electromagnetic field simulation software. The very first step of the procedure is to

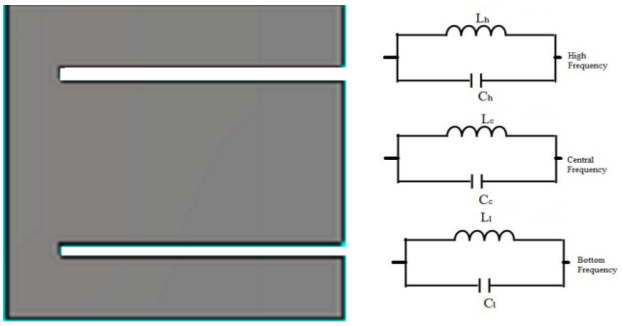

Figure 1 E-shaped patch configuration and its electrical equivalent model

select the dielectric substrate for the designing the antenna and then the designing of the initial unmodified patch. Thereafter the slits are etched and their position and geometry are iteratively adjusted to tune the required frequency and bandwidth. The whole strategy includes the steps of simultaneous small variations of the dimensions of the patch with the propose to control the frequency tuning and the bandwidth [6].

II. ANTENNA DESIGN

The aperture coupled microstrip antenna is shown in Figure 2. In the aperture coupled technique the feedline and the radiating element i.e. the patch is positioned at different substrate layers. It consists of two parallel dielectric layers as shown in Figure 2(a) and Figure 2 (b),(c),(d) shows every layer view with the dimensions. The lower dielectric layer is called the feedline substrate. At the back of this substrate there is a feed network of 50 ohms microstrip line. The radiating element i.e. the patch is printed on the upper substrate or the patch substrate. The ground plane is located between the feedline substrate and the patch substrate. A rectangular shaped aperture slot is cut in the ground and positioned at the centre of the patch

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to maximize the coupling. The ratio of slot length to width is typically 1/10.

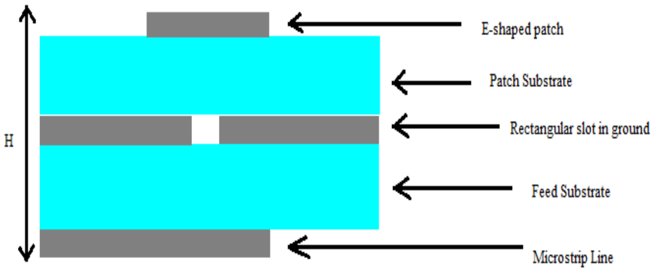

Figure 2(a) Structure of dual band aperture coupled microstrip antenna

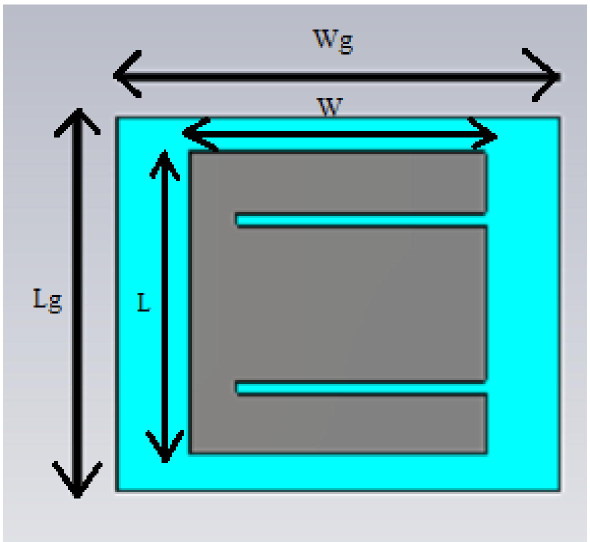

Figure 2(b) Top view of the antenna showing E-shaped patch configuration

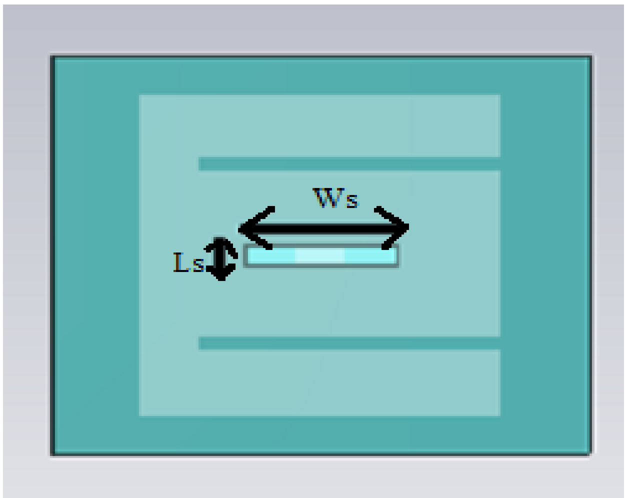

Figure 2(c) Ground plane showing rectangular shaped slot

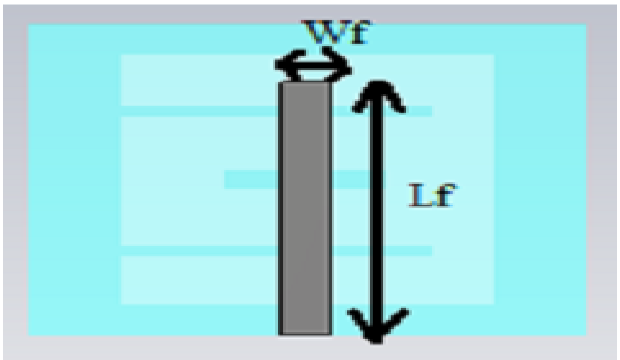

Figure 2(d) Back side view of the antenna showing microstrip feedline

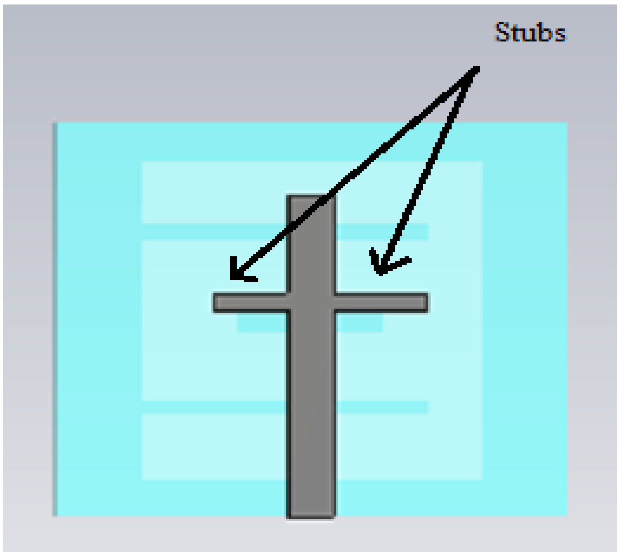

Figure 2(e) Back side view of the improved dual band antenna showing stubs along microstrip feedline

For this design FR-4 is chosen as the dielectric material (for feed substrate as well as for patch substrate) which is having the dielectric constant εr of 4.4 and thickness h of 1.57mm with the tangent loss δ of 0.0009. All the substrate dimension is Wg × Lg i.e. 34.95mm × 29.01mm . The overall size of the antenna is Lg × Wg × H. Here the overall thickness H of the antenna is 3.2mm. The length and width of the patch are 23.41mm and 23.35mm respectively. The edges of the patch along the width are called radiating edges and the edges along the length are called non-radiating edges. The coupling aperture in the ground plane is of rectangular shape having length and width as 1.6mm and 10mm respectively.

For the dual band operation two slits are cut at the boundaries of the patch as shown in Figure 2(b). Basically a simple aperture coupled microstrip antenna with rectangular shaped patch without any slits in it results in single band antenna. But when the slits are cut in the patch a notch is introduced within the matching band resulting dual band operation. The optimal parameters for dual band antenna are tabulated in Table I.

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Table I
Final optimized dimensions of the proposed dual band antennas

Name	Value	Description
L	23.41mm	Length of the patch
Lg	29.01mm	Length of ground plane
Ls	1.6mm	Length of the slot
W	23.35mm	Width of the patch
Wf	3.2mm	Width of feedline
Wg	34.95mm	Width of ground plane
Ws	10mm	Width of the slot
h	1.57mm	Height of FR-4 substrate
t	0.02mm	Thickness of PEC material

III. SIMULATION RESULTS

The Computer Simulation Technology (CST) Microwave Studio 2010, a high frequency electromagnetic field simulation software is used to simulate the proposed antenna. Figure 3 shows the simulated return loss graph of the antenna depicting the two resonant points. Since there are two dips in the S11 graph, therefore two loops in the smith chart as shown in Figure 4. The dual band antenna resonate at two frequencies i.e. 3.6GHz and 5.2GHz. The lower band resonance is at 3.6GHz with a return loss of -20.94dB and the upper band resonance occurs at 5.2GHz with a return loss of -41.10dB. The bandwidth of the antenna is 50.2MHz and 139MHz at lower band frequency and upper band frequency respectively. The return loss of the improved version of the antenna in which stubs are used along the sides of the feedline is shown in Figure 5. The figure shows that the lower band resonance is at 3.6GHz with return loss of -30.40dB and upper band resonance is at 5.2GHz with return loss of -26.99dB. The bandwidth of the improved antenna is 48.3MHz and 220MHz at lower and upper band frequencies respectively. The smith chart for this improved design is shown in Figure 6.

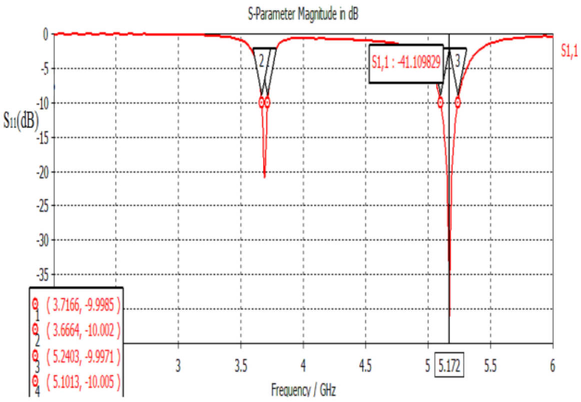

Figure 3 Simulated return loss (S11) vs. frequency plot of the dual band antenna

The input impedance curve as shown in Figures 4, 6 represents the input impedance of the antenna at the respective frequencies. It is also possible to estimate the bandwidth of the antenna from this curve by reading the frequencies at the points where the VSWR (Voltage Standing Wave Ratio) =2 circle and input impedance curve intersects.

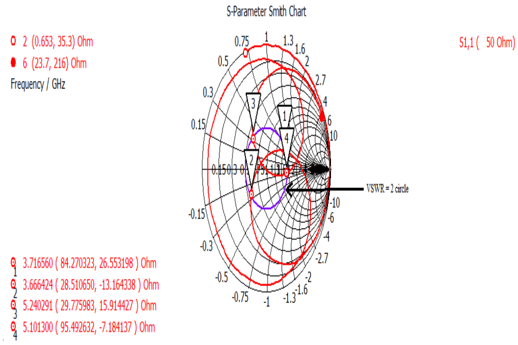

Figure 4 Smith chart showing the characteristics impedance of the dual band antenna

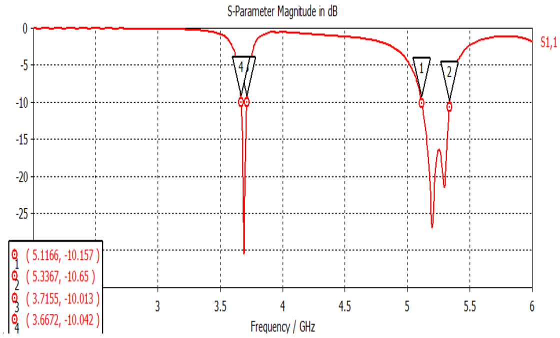

Figure 5 Simulated return loss (S11) vs. frequency plot of the improved antenna

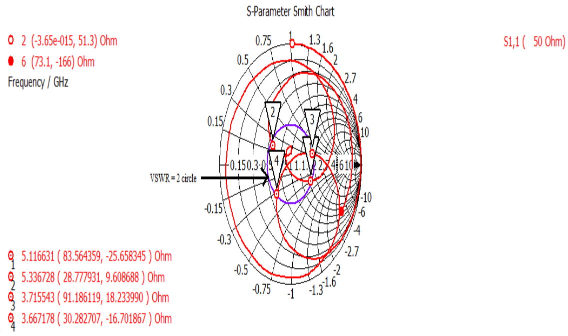

Figure 6 Smith chart of the improved antenna

Table II shows the characteristics of the radiation pattern during the simulation of dual band antenna. The proposed dual band antenna and improved version of dual band antenna shows considerable good gain and directivity value. The gain, directivity and HPBW (Half Power Beam Width) for both the antennas at both the resonant frequencies is tabulated in Tables II (a), (b).

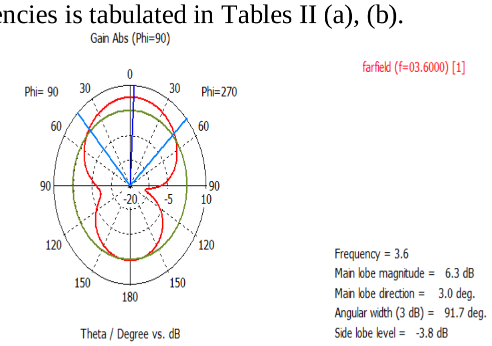

Figure 7 Polar plot of the gain of the dual band antenna at frequency 3.6GHz

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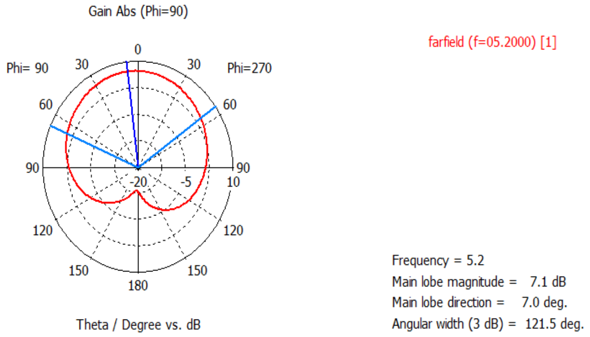

Figure 8 Polar plot of the gain of the dual band antenna at frequency 5.2GHz

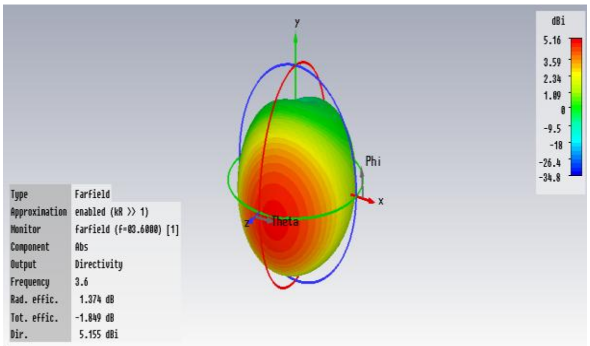

Figure 9 3-D radiation pattern of directivity at frequency 3.6GHz

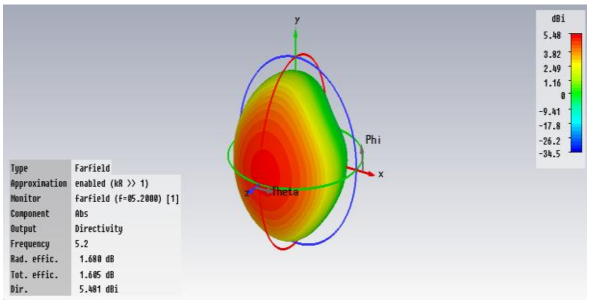

Figure 10 3-D radiation pattern of directivity at frequency 5.2GHz

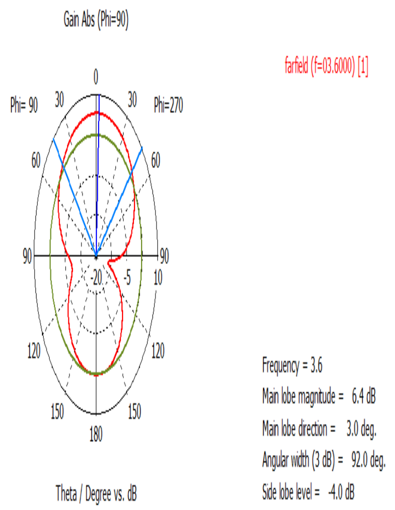

Figure 11 Polar plot of the gain of the improved dual band antenna at frequency 3.6GHz

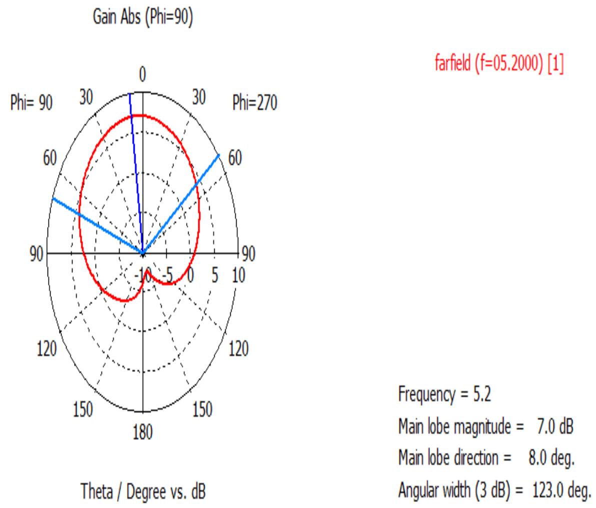

Figure 12 Polar plot of the gain of the improved dual band antenna at frequency 5.2GHz

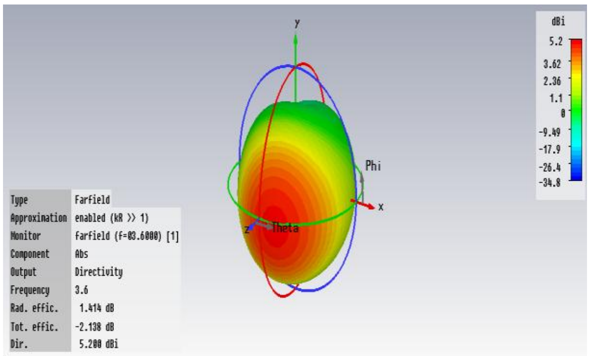

Figure 13 3-D radiation pattern of directivity of improved dual band antenna at frequency 3.6GHz

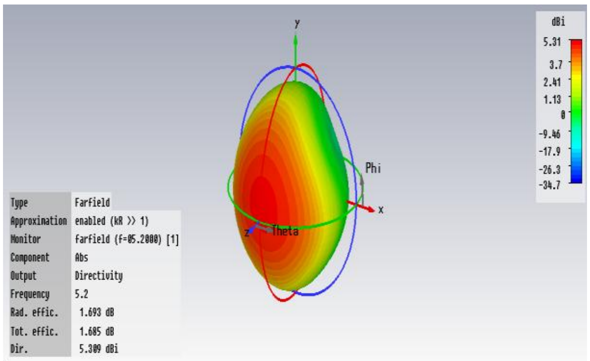

Figure 14 3-D radiation pattern of the directivity of the improved dual band antenna at frequency 5.2GHz

Table II(a)

Simulated radiation pattern characteristics of dual band antenna

Freq (GHz)	Proposed Antenna		
	Gain (dB)	Directivity (dBi)	HPBW(deg)
3.6	6.3	5.155	91.7
5.2	7.1	5.481	121.5

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Table II (b)

Simulated radiation pattern characteristics of improved antenna

Freq (GHz)	Improved Antenna		
	Gain (dB)	Directivity (dBi)	HPBW(deg)
3.6	6.4	5.200	92.0
5.2	7.0	5.309	123.0

Table III shows the return losses and a VSWR result of the proposed antennas for both the operating frequencies. The VSWR of the designed antennas is less than 2 at both the operating frequencies.

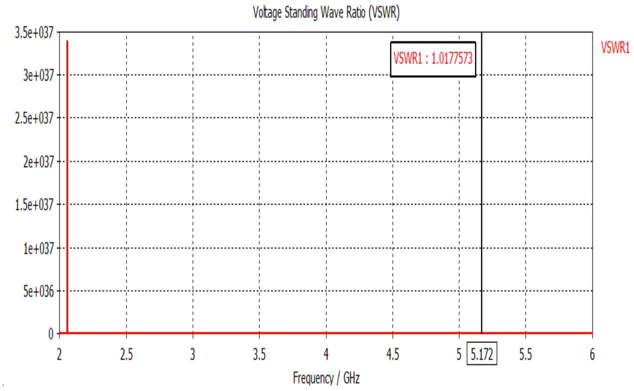

Figure 15 VSWR plot of the dual band antenna

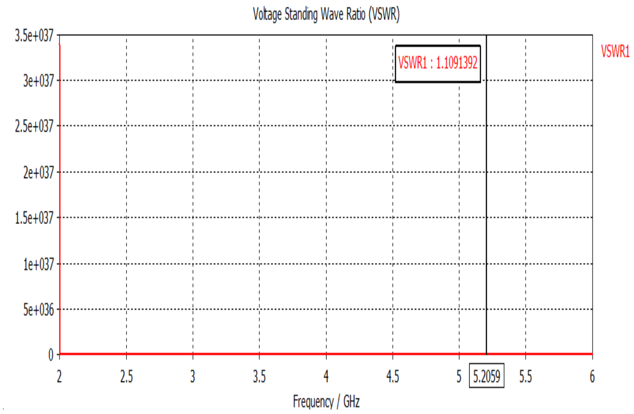

Figure 16 VSWR plot of the improved antenna

Table III

Return loss and VSWR of the antenna and the improved antenna

Frequency (GHz)	Proposed Antenna		Improved Antenna	
	Return Loss(dB)	VSWR	Return Loss(dB)	VSWR
3.6	-20.94	1.197	-30.40	1.062
5.2	-41.10	1.017	-26.99	1.093

IV. CONCLUSION

In this paper an aperture coupled dual band antenna is designed for wireless system applications. The antenna achieves an impedance bandwidth of 50.2MHz and 139MHz with return loss < -10dB. Then this antenna is improved by using the stubs along the sides of the feedline, which achieved the impedance bandwidth of 48.3MHz and 220MHz. The characteristics of the radiation can be confirmed through the simulation software CST Microwave Studio 2010. The gain of the antenna is larger than 5dB, so the antenna meets well the requirements of WiMax and WLAN systems.

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