Chapter Three

Methodology

3.1 Overview:

In this chapter a design of reconfigurable dual band rectangular microstrip patch antenna is presented for WLAN and WiMax applications at dual frequencies 3.5GHz and 5.2GHz.Our design is shown in Figure 3.1. The proposed antenna consist microstrip patch, slots and PIN diodes switches. The design of proposed antenna present at two levels (Physical Parameters and Performance Parameters). Physical parameters are microstrip patch dimensions, substrate dimensions, slots dimensions, feed line and ground dimensions. For calculation of these parameters can be used MATLAB (Matrix laboratory) software system.After design rectangular microstrip chip will be design and calculate slots dimensions, shape and position of PIN diode switches and add it on microstrip chip, and also manufacture the proposed design using Printed Circuit Board (PCB). The reconfigurability of the proposed antenna is achieved by ON/OFF PIN diode switches to operate the antenna in three scenarios:

1. Dual-band 3.5 & 5.2 GHz.
2. Single-band 3.5 GHz.
3. Single-band 5.2 GHz.

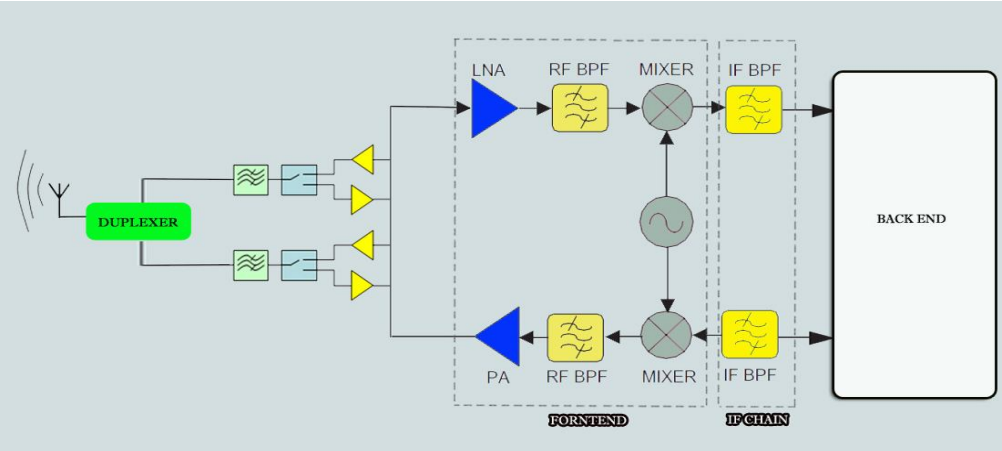


Figure 3.1: Reconfigurable Antenna for two Technologies WLANand WiMax.

The fundamental performance parameters (Gain, Radiation Patterns, Return loss of antenna, VSWR, Scattering parameters) will be simulated and figured out for deferent band in next chapter by using ComputerSimulation Technology (CST) microwave studio 2011.

3.2 Single-band Microstrip Patch Antenna:

3.2.1 General Concept:

In our design, the transmission-line model is selected as it provides a reasonable interpretation of the radiation mechanism while simultaneously giving simple expressions for the characteristics.

To calculate patch antenna dimensions must be use the matlab graphical user interface (GUI) system as shown in Figure 3.2. The basic structure of rectangular microstrip patch antenna with resonant frequency 3.5 GHz using CST microwave studio platform is illustrated in Figure 3.3. The proposed design uses cooper in radiation terminal (patch and ground plan) with thickness (M) equal 0.035 mm. There are three essential parameters for the design of a rectangular microstrip patch antenna:

- **Dielectric Constant** (ε_r): The substrate material for our design is FR-4 proxywith dielectric constant (ε_r) equal4.3.
- **SubstrateThickness**(h): To reducing size of the proposed microstrip patch antenna, the thickness of the dielectric substrate for our design is equal 1.6mm.
- **Frequency of operation** ($f_\circ$): The fixed WiMaxsystems usually use resonant frequency 3.5GHz. Hence the resonant frequency for our design is equal 3.5 GHz.

3.2.2 Design Specification:

a) Patch Length (L): The formula used to calculate the length of the rectangular patch antenna is obtained by using the equations (2.1, 2.2 & 2.3) on matlab code as: L = 20.216 mm

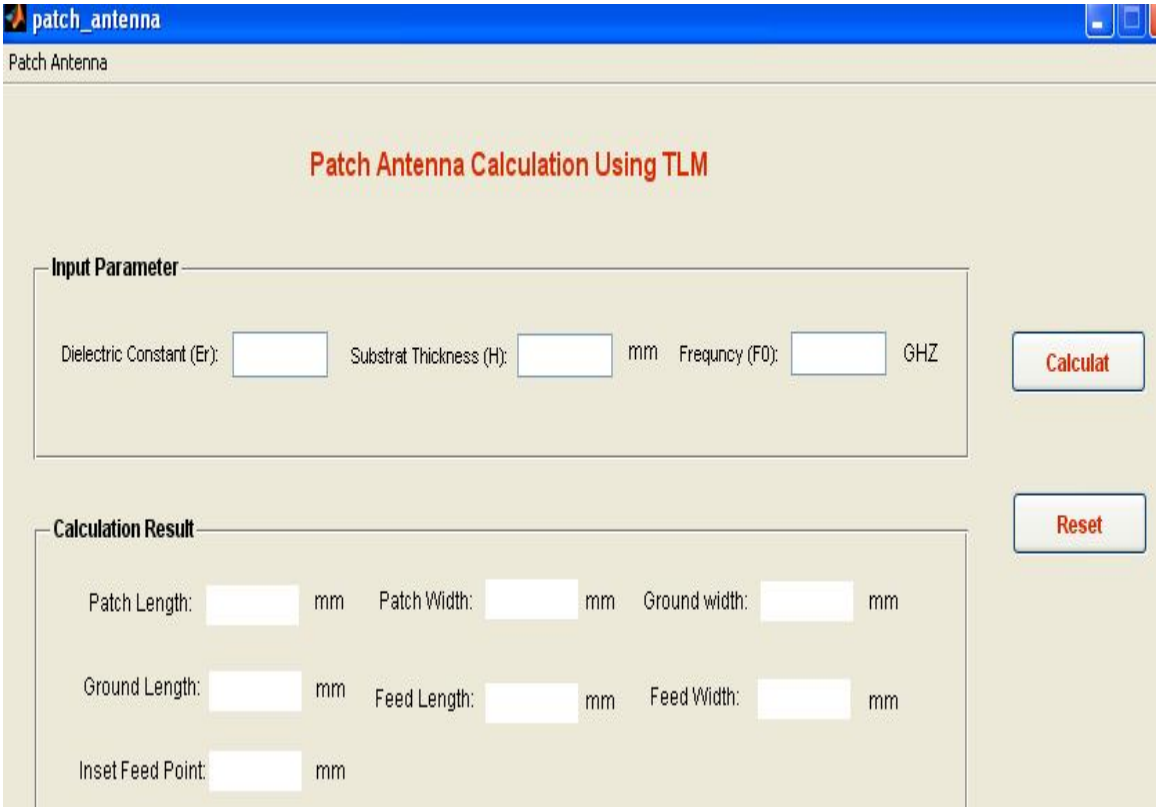


Figure 3.2: Matlab Graphical User Interface (GUI) for Calculate Patch Antenna Dimensions.

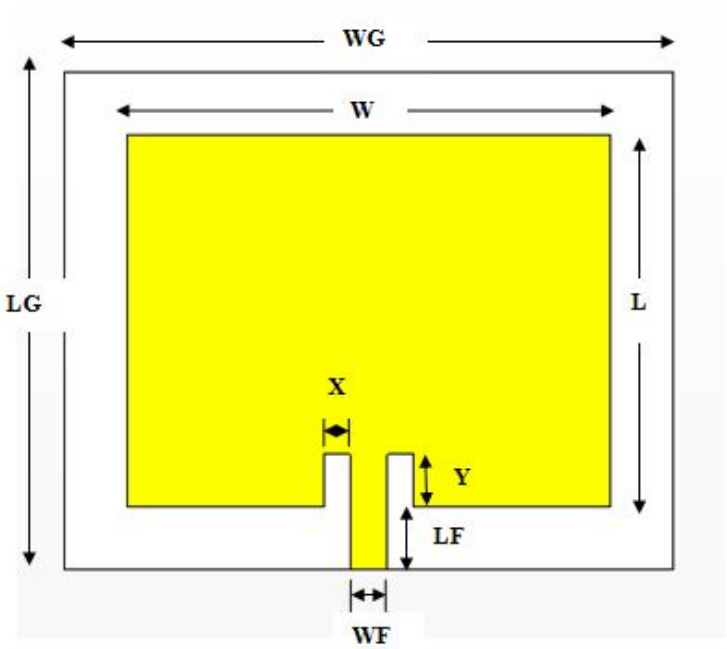


Figure 3.2: Basic Structure of proposed Rectangular Microstrip Patch Antenna.

b) Patch Width (W): The formula used to calculate the width of the rectangular patch antenna is obtained by using the equation (2.6) on matlab code as: W =26.327 mm.

c) Ground Width (WG): The formula used to calculate the ground and substrate widths of the rectangular patch antenna areobtained on matlab code as follows [14]:

$$WG = 6h + W \quad (3.1)$$

WG= 35.927 mm

d) Ground Length (LG): The formula used to calculate the ground and substrate lengths of the rectangular patch antenna are obtained on matlab code as follows [14]:

$$LG = 6h + L \quad (3.2)$$

LG = 29.816 mm.

e) Feed Line Length (LF): The formula used to calculate the length of microstrip feed line is obtained on matlab code as follows:

$$LF = \frac{6h}{2} \quad (3.3)$$

LF= 4.8 mm

f) Feed LineWidth (WF): Microstrip feed line used for patch antenna determined to be fed for 50Ω for line impedance ($Z_\circ$). The formula used to calculate the width of microstrip feed lineis obtained by using the equation (2.20) on matlab code as:WF=3.09mm

g) Insert Feed Point (W): The formula used to calculate the inset feed point of the microstrip line is obtained by using the equation (2.21)on matlab code as:Y= 4.476 mm.

3.3 Dual- band Microstrip Patch Antenna:

3.3.1 General Concept:

The functionality of the microstrip antenna is related to the current distribution on its surface. Any change in dimension and/or slots in radiation terminal (patch & ground plane) will create new current paths and new radiation terminal, which gives the antenna new resonance frequencies. To achieve Dual-band antenna and gain enhancement to operate the antenna at 3.5GHz and 5.2GHz, the C-slot added onto the rectangular patch

and added two parallel rectangular slits on ground plan. These slots and slits using to control and optimize the result of the antenna performance and suppress the interference frequency from the nearest operating band. Optimization of the calculated parameters for proposed antenna is based on parameters study discussed in [14] to operate the antenna at dual-band. The main effects of the patch width concentrated on frequencies bands and bandwidth value. And also, the main effects of the microstrip feed line and feed line position concentrated on return loss value.

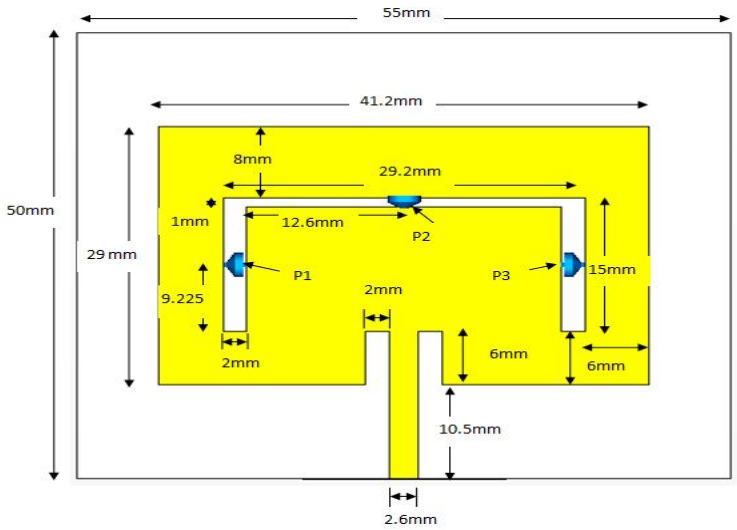
3.3.2Design Specification:

The geometry of the proposed dual-band rectangular patch antenna is showed in Figure 3.4 (a) & (b) and Table 3.1. It consist printed rectangular microstrip patch antenna on RF-4 substrate of thickness 1.6mm and dielectric constant ε_r=4.3. And also consist a copper on patch and ground design with thickness0.035mm.The slots design procedure is a set of simple design steps for the rectangular slot microstrip patch antenna with slots deeps equal 0.035mm and design formulations are defined as [35]:Slot thickness, (E) and slot width, Ws

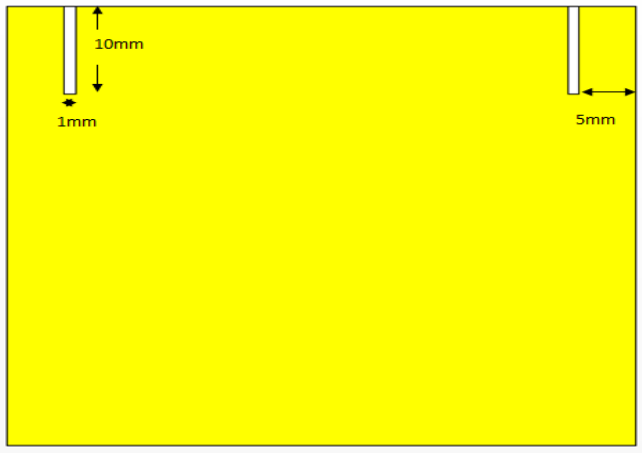
$$\mathrm{E} = \frac{\lambda}{60} \tag{3.4}$$

$$\mathrm{Ws} = \frac{\mathrm{c}}{2\mathrm{f_{low}}\sqrt{\varepsilon_\mathrm{e}}} - 2(\mathrm{L} + 2\Delta\mathrm{L} + \mathrm{E}) \tag{3.5}$$

However, the vertical slots length is15mm and width is 2mm. Also, the horizontal slot length is 29.2mm and width is 1mm. The different shape of slots and slits gives different results due to influence current distribution on the patch and ground plane. Since for improved antenna gain, the current is affected by adding 10mm slits with 1mm width on ground plan as shown in Figure 3.4 (b).



(a)



(b)

Figure 3.4: Dimensions of the Proposed Antenna: (a) Patch Plan, (b) Ground Plan.

3.4 Antenna Reconfigurability:

To achieve the reconfigurability of the antenna usethe Radio Frequency (RF) switches. The performance and suitability of reconfigurable antenna are dependent on the switch characteristics. Thus, the choice of the switch is critical step. The most popular switches using in frequency reconfigurable antennas are PIN diodes, varactor diodes and RF microelectromechanical system (MEMS).

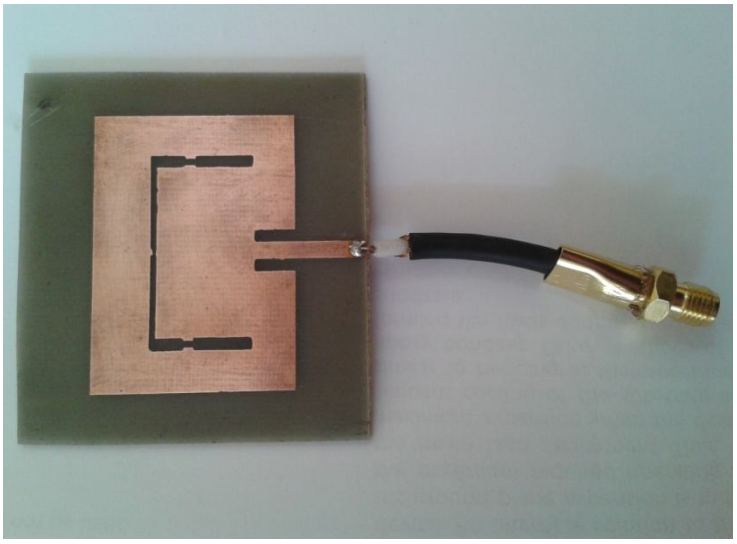
In our desgin the PIN diode is presented. A PIN diode is a semiconductor device composed of a p and n-layer, separated by an intrinsic i-layer. The advantages of PIN diode are very low driving voltage, high tuning speed (1–100 ns), high power handling capability, very reliable since there are no moving part and extremely low cost. Reconfigurability of the antenna is achieved by using ON/OFF RF PIN diode switch on the patch slots as shown in Figure 3.4 (a). There are three PIN diodes (P1, P2, and P3) inserted on the C-slots of the antenna patch. The main characteristics of these diodes are low capacitance (0.025pF) and low series resistance (3 ohm). The suitable position of PIN diode switches for proposed antenna is given at P1 & P3= 9.225 mm and P2= 12.6 mm as shown in Figure 3.4 (a).The reconfigurable antenna operates at dual frequencies (3.5GHz & 5.2GHz) at same time, only at 3.5GHz and only at 5.2GHz.

Table 3.1: Optimized Parameters of the proposed Dual-band Patch Antenna

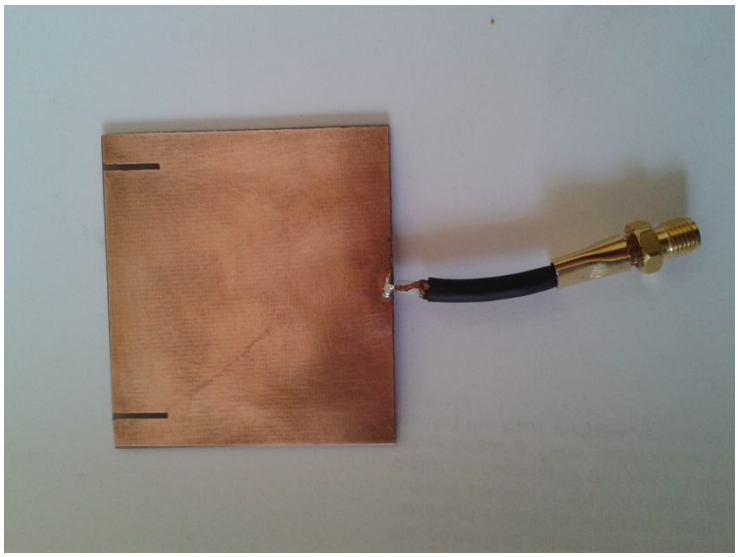
Parameters	**Optimized parameters/mm**
Width of Patch (W)	41.2
Length of Patch (L)	29.2
Width of Ground (WG)	55
Length of Ground (LG)	40
Width of Feed Line (WF)	2.6
Length of Feed Line (LF)	16
Patch & Ground Thickness (M)	0.035
Substrate Thickness (h)	1.6
Insert Width (X)	2
Insert Length (Y)	6
Vertical Slots Width	2
Vertical Slots Length	15
Horizontal Slot Width	29
Horizontal Slot Length	1

3.5 Reconfigurable AntennaManufacture:

The prototype of proposed antenna is shown in Figure 3.5. It is handling by PCB using microstrip chip with two layer board. Also, the size of proposed antenna is 50×55×1.67mm3.



(a)



(b)

Figure 3.5: Prototypes of the Proposed Antenna: (a) Patch Plan, (b) Ground Plan.

There are many steps to manufacture the proposed antenna using PCB:

Step 1: Design the proposed antenna in Eagle software platform as shown in Figure 3.6.

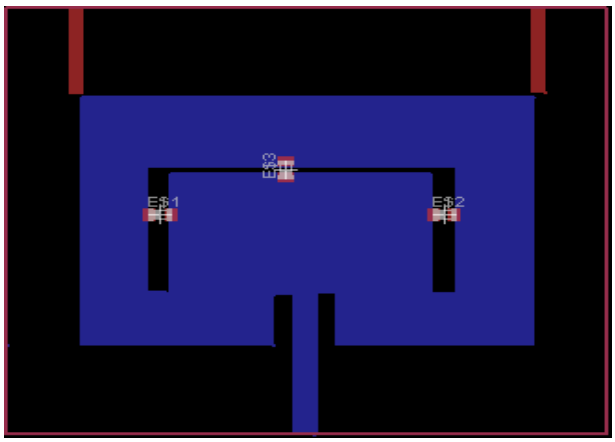


Figure 3.6: Design of the Proposed Antenna in Eagle Program.

Step 2: Printed design in hard paper using LASAR printer.

Step 3: Exposing the paper and microstrp chip of ultraviolet waves.

Step 4: Then put the paper and microstrp chip into ferric chloride.

Step 5: Finally, Clean the surface using the copper emery and welding the connector.

- The connector model is EMC-6004G (RP-SMA gold plated type jack) form Electromaster company.
- The PIN diode model is HPND-4028 beam lead PIN diodes for Phased Arrays and Switches from Avago Technologies as shown in Figure 3.7. The HPND-4028 is designed for low capacitance, low resistance, and fast switching at microwave frequencies. These characteristics are achieved at low bias levels for minimal power consumption.The main features of PIN diodes are:
    - Low Capacitance0.025 pF Maximum at 1 MHz Guaranteed Min./Max.
    - Low series resistance 3Ω Maximum.
    - Fast Switching2.0 nsec.
    - Low Resistance at Low Bias1.5 Ω at IF = 10 mA (Typical).
    - Rugged Construction Typical 10 Gram Lead Pull.

- Silicon Nitride Passivation.

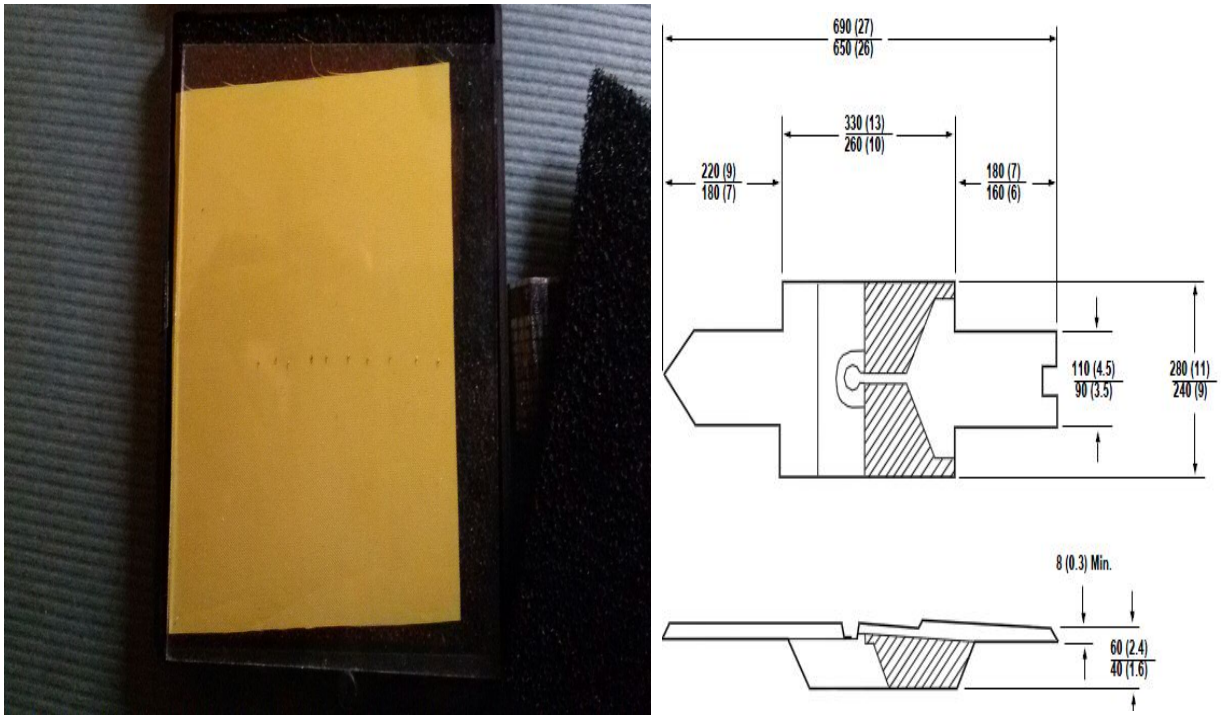


Figure 3.7:HPND-4028 PIN Diode Switches.

3.6 Chapter Summary:

This chapter introduced the methodology of design of the reconfigurable dualband microstrip patch antenna for WLAN and WiMax applications at dual frequencies 3.5GHz and 5.2GHz.The transmission-line model is selected to design structure of the proposed antenna, which using to determine the length, width of the patch and ground plane and inset point of microstrip line. Also, dual band operation is presented by adding C-slot and ground slits. And, reconfigurability of the antenna is achieved by adding RF PIN diode switch on the patch slots. Finally, investigated the antenna manufacture using PCB with microstrip chip, RP-SMA connector and HPND-4028 PIN diodes switch.