

POLARIZATION RECONFIGURABLE ANTENNA THROUGH SWITCHABLE CPW FEEDING STRUCTURE

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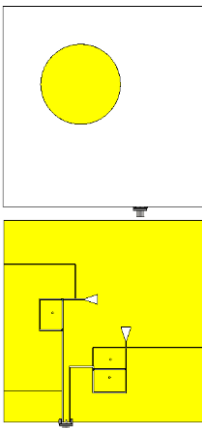
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Graphical abstract



Abstract

This paper presents the polarization reconfigurable circular patch antenna. The reconfigurability feature is realized through the alteration of the feeding network. The antenna consists of a circular patch as a radiator, and orthogonally fed by a co-planar waveguide (CPW) slotline which terminated with tapered transformer. The CPW slotline are interconnected with quarter wavelength phase delay slotline. Eight switches are placed at the CPW transmission slotline, to either activate or deactivate the phase delay slotline. Consequently, depending on the switch configurations, the polarization can be altered to the desired sense, either linear, right-hand circular or left-hand circular polarization.

Keywords: Coplanar-waveguide (CPW), feeding network alteration, polarization reconfigurability, phase shifter

Abstrak

Kertas kerja ini membentangkan kebolehubahan pengutuban antenna satah bulat. Ciri kebolehubahan ini dicapai melalui pengubahan rangkaian suapan. Antena ini terdiri daripada satah bulat sebagai pemancar, dan suapan berserenjang oleh sesatah pandu gelombang (CPW) yang disambungkan diujungnya dengan pengubah tirus. Setiap CPW laluan alur telah disambungkan dengan penganjakan fasa suku gelombang. Lapan suis diletakkan di persimpangan CPW laluan alur untuk mengaktifkan atau tidak mengaktifkan laluan penganjakan fasa. Oleh yang demikian, bergantung kepada konfigurasi suis, pengutuban boleh diubah kepada jenis yang diinginkan, samada pengutuban lurus, pengutuban putaran arah bulatan kanan atau pengutuban putaran arah bulatan kiri.

Kata kunci: Sesatah pandu gelombang, pengubahan rangkaian suapan, kebolehubahan pengutuban, penganjak fasa

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1.0 INTRODUCTION

Over the last decades, there has been an explosive growth of interest in the study of reconfigurable antennas. This is due to the facts that the reconfigurable antenna can provide great flexibility in optimizing the space. In addition, reconfigurable antennas are becoming more interesting mainly due

to the special characteristic; ability to provide flexibility on antenna parameters such as radiation pattern, polarization, operating frequency or the combination of various parameters. Unlike conventional antenna which has fixed characteristic, this unique behavior can provide additional functionality, increase the flexibility, and compact in physical size. Hence, this will result in the antenna

ability to adapt and cater with new system specifications and conditions of the modern telecommunication devices. In order to realize the multi-functional behavior, mechanically [1, 2] or electronically [3, 4] types of switches are used.

Polarization reconfigurable antennas, in particular, are attractive due to the ability to control and switch the polarization between linear polarization (LP), left-hand circular polarization (LHCP) or right-hand circular polarization (RHCP). This type of diversity provides several advantages such as immune to the interference and minimizing the polarization loss factor that eventually help to ensure the communication reliability. In addition, this diversity is also used to mitigate and reduce the multipath fading effect, especially for indoor scenario, that eventually improve the channel capacity and overall system performances [5, 6].

A few solutions have been proposed to achieve polarization diversity antenna. One of the conventional techniques presented is through chamfering corners and perturbation segment [7-9]. Some papers [10-12] discussed on accomplishing polarization diversity feature through alterations of the feeding network. However, these works are done by mounting switches on the copper feed line, which resulted in difficulty to achieve good impedance matching and complexity of the biasing mechanism. Furthermore, the work in [10, 11] has only able to switch between orthogonal LP or CP. In [12], the reconfiguration is only taking place by using artificial switch (copper strips) and implementation using real switches is not considered in the design.

Hence, this paper proposed a polarization reconfigurable antenna through modification of the CPW feeding slotline that operates in 2.4-2.5 GHz frequency band. Comparing with [14], this antenna has the capability to change to triple type of polarization modes. The reconfigurability is accomplished by using RF PIN diode. Eight switches are utilized to alter the direction of the current path on the feeding network; hence changing the polarization sense excited either LP, LHCP or RHCP. Details of the geometry and approach taken are described, and the simulated results are presented.

2.0 ANTENNA CONFIGURATION AND APPROACH

The geometry of the proposed antenna and the polarity of the biased voltage are shown in Figure 1. The antenna is constructed on the Taconic RF-35 substrate ($L \times W$) with the dielectric constant, ϵ_r of 3.5 and thickness, h of 1.52 mm. Circular-shaped patch antenna, with a radius of r is printed on the top layer and feeding network is located in the bottom layer of the substrate. Patch antenna is orthogonally fed with coplanar-waveguide (CPW) slotline, with a width of W_w and slot width of W_{slot} , positioned on the x -axis and y -axis of the patch. The CPW slotlines which has equal

length for both ends are terminated with tapered impedance transformer (L_t, W_t). These two

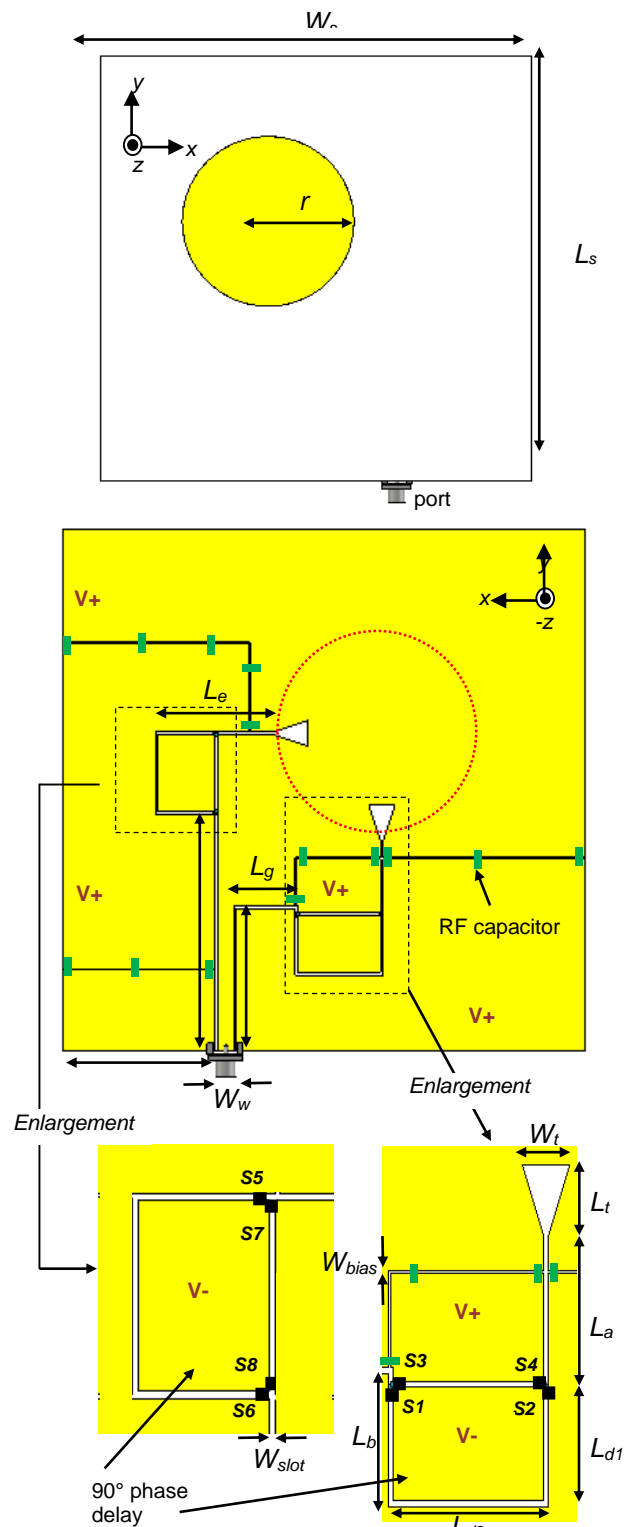


Figure 1 Geometry and the biased voltage polarity of the proposed antenna. (top) Front view. (bottom) Back view. (Yellow colour indicates the metallization of the structure and white colour for substrate)

parameters give significant influence to the impedance matching. Phase delay slotlines are introduced and interconnected on the structure of CPW feeding slotline, where the length was approximately quarter wavelength. The length of the phase delay mostly determines the response for the axial ratio (AR).

Eight RF switches (Infineon BAR 50-02L) are embedded at the interconnection of the phase delay slotline therefore altering the direction of the current. For biasing purposes, narrow slots with a width of W_{bias} are incorporated in the design. This step was taken to separate the region of the negative and positive direct current (DC) voltage. RF capacitors with a value of 100 pF are located across the narrow slots to preserve the flow and continuity of the RF currents on the structure. The anodes of the diodes are connected to the copper area inside the phase delay slotlines. In this common copper region four switches are supplied with the negative terminal of the DC voltage. Meanwhile, the anodes of the PIN diodes are connected to the remaining area of the ground plane and been supplied with positive DC voltage.

The operation of the proposed antenna is as follows. CP is generated when the circular patch is excited by dual orthogonal degenerated resonant modes that equal in amplitude but in phase quadrature. Thus, the proposed design fulfils these conditions by prolonging one of the feeding slotline from a distance of a quarter wavelength. The switches are used to control the path of the current through activating or deactivating the phase delay slotline. Another type of orientation (orthogonally) of the CP is excited when the configuration of the switches is set oppositely. Conversely, LP is produced when the circular patch is fed by the equal length slotline, thus the modes are equal in magnitude and phase. Therefore, by controlling the feeding network, the polarization excited can be altered accordingly. The switch configurations and its respected polarization sense are summarized and tabulated in Table 1.

The reconfiguration process of the proposed antenna was taking place to the modification of the feeding network without disturbing the radiating element, thus minimizing the influences of the switches and the biasing network to the antenna performances. In addition, slotline type of feeding is chosen compared to copper feed line because of easier to be mounted and integrated with RF switches. Hence, the impedance mismatch due to the integration of the switches can be avoided. The optimized dimension of the proposed antenna is as follows (unit in mm): $L_s = 90$, $W_s = 90$, $L_f = 6$, $W_f = 4.4$, $W_w = 2.8$, $W_{slot} = 0.5$, $W_{bias} = 0.2$, $L_a = 11.43$, $L_b = 24.5$, $L_c = 40.75$, $L_{d1} = 10.23$, $L_{d2} = 15.25$, $L_e = 20.33$, $L_f = 26.2$, $L_g = 11$, $L_h = 12.5$.

Table 1 Switching configuration of the proposed antenna

Ant	State of the switch								Polarization
	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	
A1	X	X	O	O	X	X	O	O	LP
A2	O	O	X	X	X	X	O	O	RHCP
A3	X	X	O	O	O	O	X	X	LHCP

O: On state ; X: Off state

3.0 PARAMETER STUDIES AND SIMULATED RESULTS

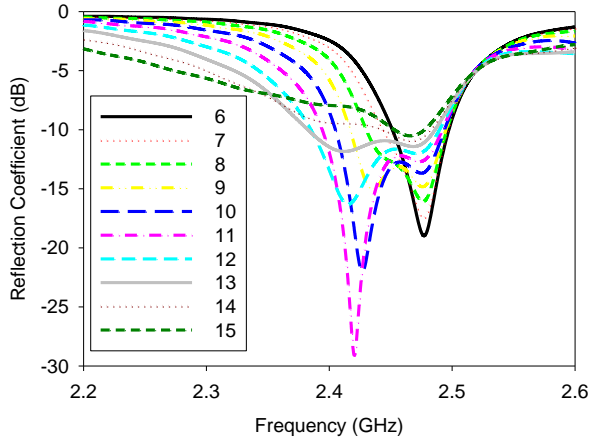
The simulation process is carried out using Computer Simulation Technology (CST) Microwave Studio full wave simulator. For accuracy of the simulation results, the RF PIN diode was included in the simulation process. This step was done by using the touchstone block contains s2p file which can be obtained from the manufacturer. This touchstone file comprises of the s-parameter information of the diode for the ON and OFF condition. DC block capacitors are also taken into account in the simulation.

Three parameters which are mainly influencing the performance of the antenna are investigated and studied. These two parameters, L_{d1} which influencing the AR and parameters L_f and W_f which affecting the impedance matching are optimized. To expedite the simulation process and analysis, the parameter study is carried out by using ideal diode (copper strips) for the Configuration A3-LHCP.

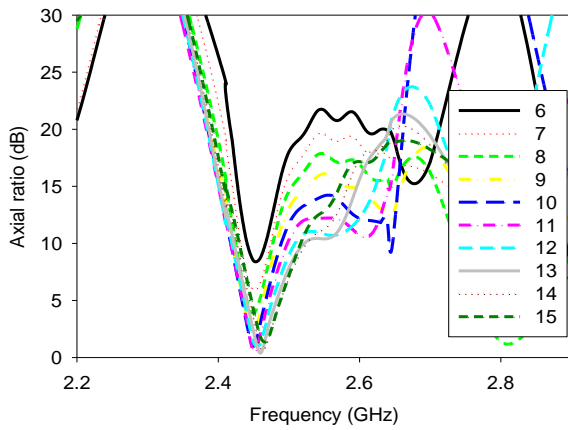
Firstly, the effect of the phase delay slotline towards S_{11} and AR is investigated and is shown in Figure 2(a) and (b). The parameter L_{d1} is varied from 6 mm to 15 mm. From these figures, it is noted that at the range of 10 mm to 15 mm of the slotline length, the AR has dropped below than 3dB. It is also clearly can be seen in Figure 2(a), within the range, the two resonant modes are excited at the close frequency. However, as the phase delay slotline is shortened or lengthened (outside the range), the value of AR is seen increasing above the threshold 3dB value, indicates the CP is no longer excited.

Figure 3 and Figure 4 illustrate the plots of reflection coefficient (S_{11}) for the variations of the L_f and W_f , respectively. The S_{11} values are found to be greatly influenced by these two parameters. It is noticed that by increasing the length of L_f (while W_f was set at 4 mm), it give effect to the changing of the operating frequency due to different feeding point location and distance. Meanwhile, the variation of the W_f that was varied from 1 mm to 7 mm (while L_f was set at 6 mm) provides significant effects to the impedance matching.

Parameters studies have helped to identify the effect of the most important parameters. It provides a useful evaluation of their effects on the antenna performance to obtain optimized design.



(a)



(b)

Figure 2 Effect of the L_{d1} (mm) towards the (a) S11 (dB), and (b) axial ratio.

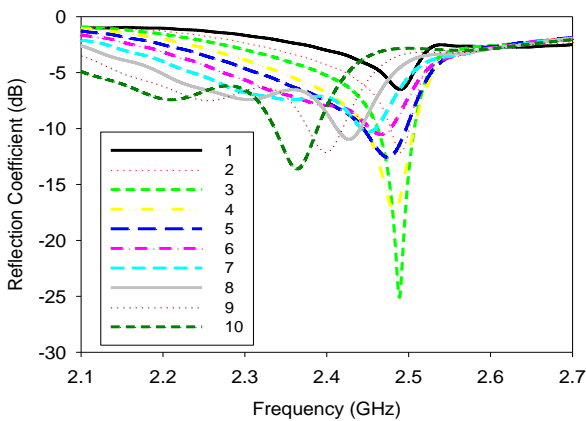


Figure 3 Effect of the L_t (mm) towards the S11 (dB) result

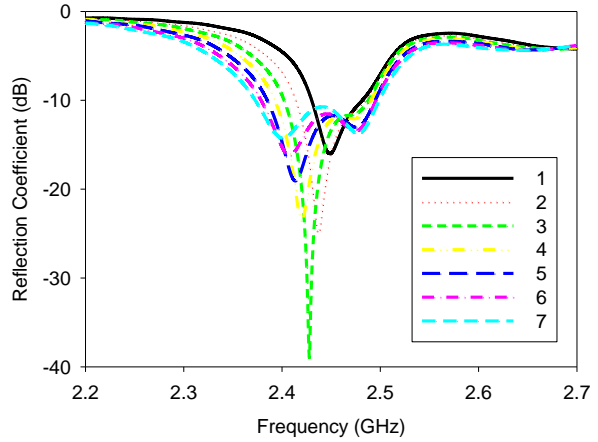


Figure 4 Effect of the W_t (mm) towards the S11 (dB) result

Figure 5 shows the simulated reflection coefficient (S11) of the proposed antenna for all switch configurations. As shown in the figure, throughout the WLAN frequency band (2.4-2.48 GHz), good impedance matching is obtained for all three configurations. The impedance bandwidth of reflection coefficient for A1-LP, as referred to -10dB is 53 MHz (2.419-2.472 GHz). It is clearly seen that the impedance bandwidth for CP is much wider as compared to LP operation. Even though at certain frequencies of A2-RHCP and A3-LHCP configuration, the value of reflection coefficient is above -10 dB, but still considered acceptable as the highest value is -8 dB, or about 15.8 % of reflection.

Figure 6 presents simulated AR over frequency for configurations A2-RHCP and A3-LHCP. The 3dB AR bandwidth is 71 MHz (2.431-2.502 GHz) and 75 MHz (2.433-2.508 GHz) for configuration A2-RHCP and A3-LHCP, respectively. It can be noticed that the bandwidth of the AR lies within the desired frequency. Since the operation of the proposed antenna is polarization reconfigurability, the available working bandwidth will mainly depend on the bandwidth of AR.

Figure 7 plots the simulated radiation pattern (x - z plane and y - z plane) at 2.45 GHz. Directional type of radiation pattern is produced with 3dB beamwidth of over 90 degrees. Meanwhile, the simulated variation of gain over frequency for all switch configurations is shown in Figure 8. At 2.45 GHz, the simulated gain for A1-LP is 1.2 dB higher than CP configuration. The simulated electric field for A3-LHCP at 2.45 GHz is illustrated in Figure 9. It can be seen that the orientation of the electric field rotated on the clockwise direction (LHCP) from the facing of the antenna point of view.

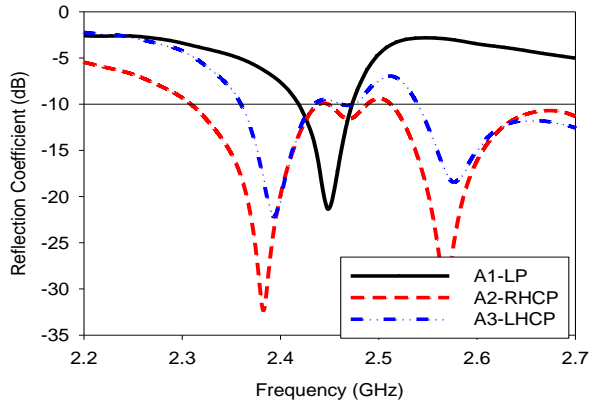


Figure 5 Simulated reflection coefficient of the proposed antenna for all switch configurations

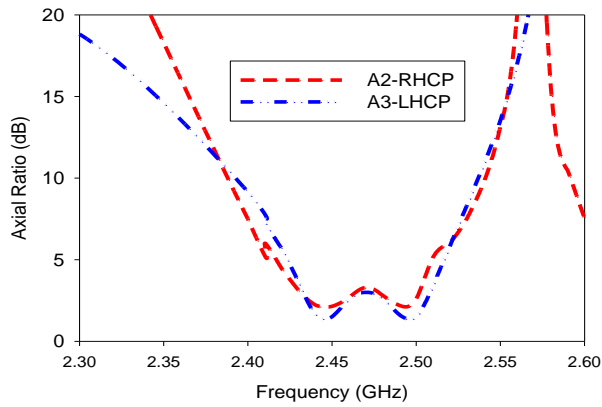


Figure 6 Simulated axial ratios over frequency for CP operations

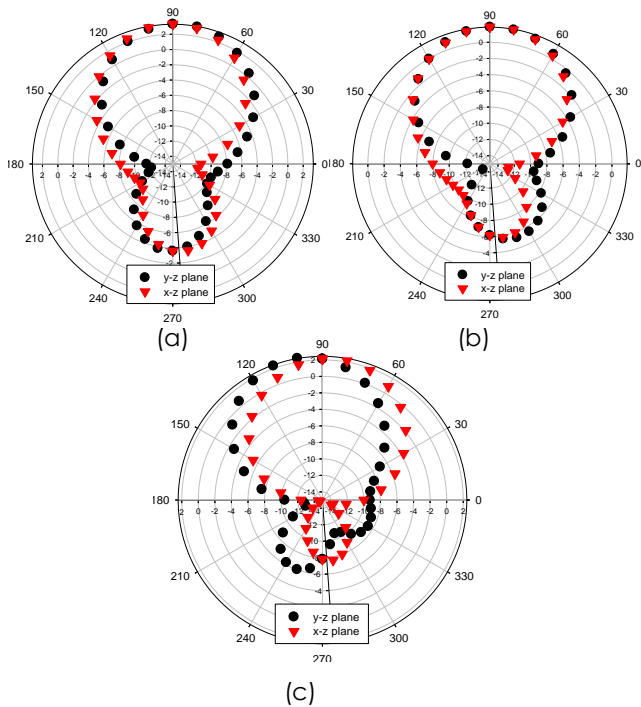


Figure 7 Simulated radiation pattern (x-z plane and y-z plane) at 2.45 GHz for configuration (a) A1-LP. (b) A2-RHCP. And (c) A3-LHCP

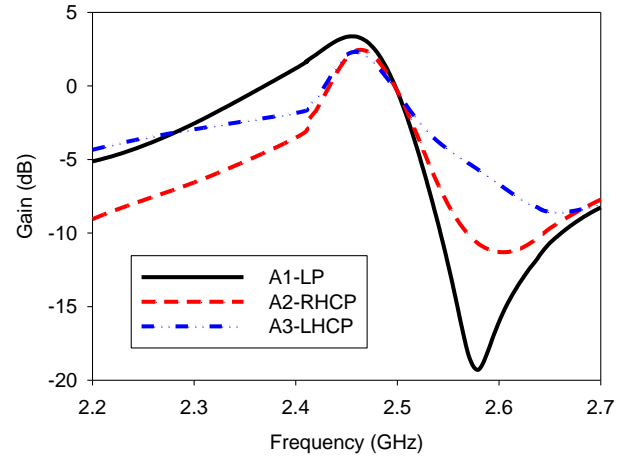


Figure 8 Simulated gain over frequency for all switch configurations

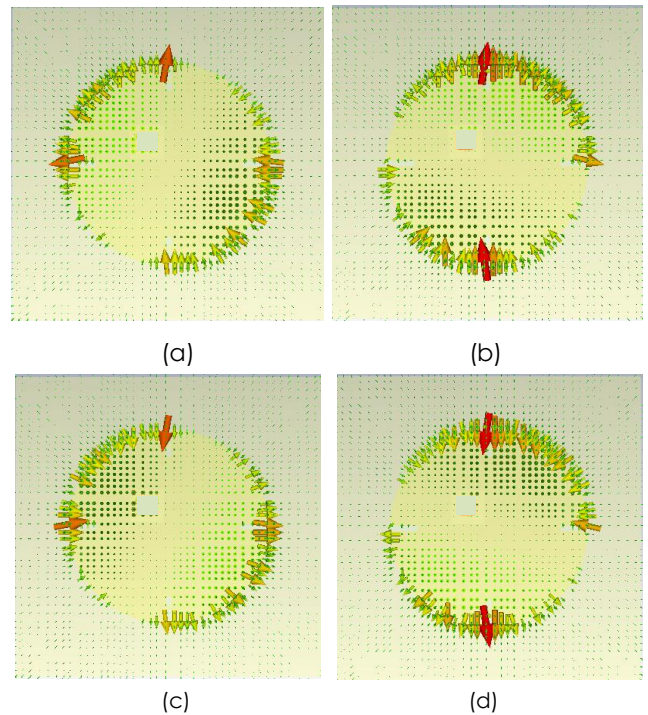


Figure 9 Simulated electric field at 2.45 GHz for A3-LHCP at phase of (a) 0° (b) 90° (c) 180° (d) 270°.

4.0 CONCLUSION

In this paper, a circular patch antenna with polarization diversity feature is presented. The polarization is altered through modifying of the feeding network. Eight switches are interconnected in the CPW feed slotline. Depending on the configuration of the switches, the polarizations can be switched between LP, LHCP and RHCP. Simulated results proved that good impedance matching and AR bandwidth are achieved at the desired operating frequency. Using this method, second port could be

introduced on the same structure by utilizing the odd and even mode of the CPW, resulting good in isolation between port and compact in size [14]. The antenna is designed to operate in the 2.4 to 2.5 GHz frequency band for wireless local area network (WLAN) applications such as Multiple-Input-Multiple-Output (MIMO) systems.

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