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Frequency Reconfigurable Monopole Antenna Using Switchable Slotted Triangular Radiators

Abstract- *A new configuration of multi-state switchable wideband /multi-narrowband is demonstrated. The proposed antenna is based on a printed rectangular monopole antenna (PRMA) that covers wideband 3.3 GHz WiMAX frequency range. To generate a multi-state switchable antenna, center part of PRMA has been removed without distorting the PRMA behavior. Three PIN diode switches are used to control different operating modes. Eight-operating modes, 2^n modes (n is number of switches) are achieved by setting the switches ON or OFF. Initial results were obtained by using short and open circuits instead of implanting PIN diode. The merit of the antenna design is that it allows various groups of its operating frequency bands to be selected using different switches states. Therefore, by selecting different antenna modes, a variety of communication systems can be conveniently served by only one antenna. The designed antenna has a simple planar structure and compact size of 30×50 mm^2. Simulation and measured results show that realized gain in all operating bands is varied from -1.1 to 5 dBi. The proposed antenna demonstrates good impedance matching, stable radiation pattern and reasonable gain at all frequency bands. Simulation results have been obtained from commercial CST-2014 Microwave Studio. The antenna is fabricated and tested using R&S ZVL 13 Vector Network Analyzer (VNA). There are accepted results between the prototype and the simulated one.*

Keywords- *Monopole Antenna, cognitive radio (CR), PIN diode, fixed antenna, multiband antenna, reconfigurable antenna, compact antenna.*

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1. Introduction

Modern communication systems require a single antenna to cover several allocated wireless frequency bands**.** A switchable planar antenna is an outstanding candidate in wireless communication's apparatuses; due to it improves the capacity of the system by adaptation the resonant frequency, polarization, and radiation pattern. Furthermore, cognitive radio (CR) needs sensing and transmitting antennas that can be switched to transmit over a selected frequency band. This brought about to a raised the concern for the improvement of frequency switchable antennas to exploit the spectrum efficiently [1]. Switchable antennas are a sort of multi-purpose antenna with just one antenna is capable of replace the resonant frequencies, radiation pattern or polarisation in real time without changing the complete antenna's structure. Likewise, a noteworthy issue in communication systems is to decrease the antenna size and bringing down its profile while allowing perfect performance over the bands [2].
Planar monopole antennas, because of their desirable traits for example, affordable, low-profile, simplicity of manufacture, large bandwidth, and omnidirectional radiation pattern have got great attention for hand- held wireless applications [3].
In the literature, different methods and techniques have been reported recently to achieve reconfigurable performance. Most of frequency-reconfigurable antennas are capable only of switching between fixed different narrowband modes [4-6].Other techniques have been essentially created for switching an antenna with just on band of operation [7,8]. This is a problem for cell phones, as they regularly need to work on at least two groups at the same time. A sum of parasitic patches had been juxtaposed with respect to a ground plane in [9, 10]. Frequency switching was accomplished via join or separate one or more parasitic patches, or altering the feeding position.
In these cases, multi-reconfigurable band are achieved but the sizes are naturally large. However, it appears that providing compact, reconfigurable multiband antennas is still a challenge.
This paper addresses designing a planar compact reconfigurable multi-state antenna. Frequency configurability is achieved mainly by loading several quarter wavelength strips on a planar printed rectangular monopole antenna (PRMA), and using three PIN diode switches to control

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electrical length of the current path in these strips without increasing the overall antenna size.

Eight-operating modes are achieved by setting the switches ON or OFF. Each frequency bands group corresponds to a certain state of the switches.

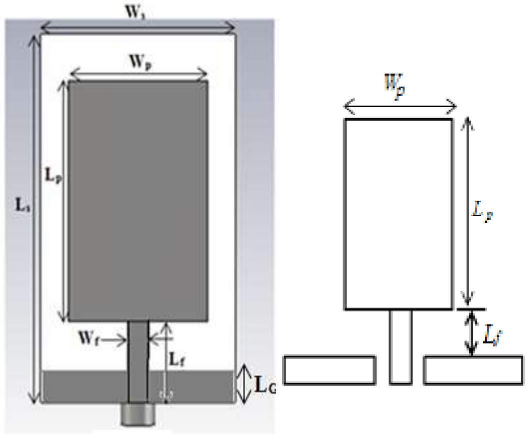
The proposed antenna has different switchable bands; these bands may serve various combinations of GSM1800, DCS, PCS, Wireless Local Area Network (WLAN), and Worldwide interoperability for Microwave Access (WiMAX) applications.

Details of the proposed switchable-based single wide-band antenna design and fixed multiband antenna design are described in section 2. Section 3 discusses the multi-state reconfigurable antenna design.

2. Antenna Configuration and Design Procedures

I. Design of Switchable Based PRMA Multi-Band Antenna:

The structure of an appropriate planar monopole radiator that can be utilized as a reference for the final switchable multi-band antenna, working over the single wide-band frequency range, is appeared in Figure 1. The reference wide-band antenna can be designated as the printed rectangular monopole antenna (PRMA). The antenna has a FR4 substrate with dimensions of $45\times30\times1.6$ mm^3, $\varepsilon_r = 4.4$, and a loss tangent of 0.025. A plain rectangular conductive ground plane of width W_g and length L_g is put on the opposite side of the substrate.



(a) (b)

Figure 1: (a) Structure of the proposed single wide-band PRMA antenna (b) PRMA's conventional form.

To estimate the lower band-edge frequency of printed monopole antennas, a formula is suggested by [11, 12]. The lower band-edge frequency in GHz is.

$$f_L = \frac{c}{\lambda} = \frac{7.2}{\{(L_c + r_c + L_f)\times k\}} \quad (1)$$

Where L_f is the length of 50Ω feed line in centimeter, the equivalent cylindrical monopole antenna's radius and height in cm is r_c *and* L_c, respectively, $k = \sqrt{\varepsilon_{reff}}$. The approximated value of ε_{reff} is given by [13].

$$\varepsilon_{reff} \approx \frac{\varepsilon_r + 1}{2} \quad (2)$$

From the PRMA structure in Figure 1b, L_c and r_c are computed in according to following relations [11]: If PRMA length is equal to L_p and width is equal to W_p, then:

$$L_c = L_p, \text{ and } r_c = \frac{W_p}{2\pi} \quad (3)$$

For FR4 substrate, its thickness is 1.6 mm and $\varepsilon_{reff} = 2.65$, and consequently, k is equal to 1.627. However, for commonly used substrate with $\varepsilon_r = 4.4$ and $h = 1.6$ mm the empirical value of $k = 1.15$ estimates lower band-edge frequency within 10% [14]. Hence, Lp is an estimated bottom boundary side, applying equation (1), is matched to 22.1 mm. However, for generating 2GHz resonant frequency, larger physical length of L_p is required. Therefore, equation (4) has been used to choose dimension of L_p=32 mm (many of $\lambda_{eff}/4$) [13].

$$L_p = \frac{\lambda_{eff}}{4} = \frac{\lambda}{4k} = \frac{c}{4kf_L} \quad (4)$$

Where, c is speed of the light and λ is the free space wavelength.

The effective wavelength λ_{eff} is and is defined as [15].

$$\lambda_{eff} = \frac{\lambda}{\sqrt{\varepsilon_{reff}}} \quad (5)$$

The PRMA antenna is fed with a strip-feed line with a width of W_f, and length of L_f. in order to attain (Z_0) of 50Ω of feedline impedance, the width of feedline has been determined according to the equation [13]:

$$Z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left(\frac{5.98\,h}{0.8\,W_{strl} + t}\right) \quad (6)$$

Where metal thickness t is 0.035 mm, and feed line width is W_{strl}, thus, as stated by (6) to get 50Ω feed line impedance, W_{strl} will be equal to 3 mm. To get an antenna with an expanded band that meets the WLAN and WiMAX bands, the antenna parameters made optimal using a CST 2014 package. Table 1 shows optimal parameter of the antenna of Figure 1 (a) .The result of the return loss is shown in Figure 2. The corresponding -10 dB bandwidth is 1.79GHz (2.023-3.813GHz), covering three bands; LET 2300/2500 (2305-2400MHz/ 2500-2690MHz), the 2.4GHz IEEE 802.11WLAN standard, and WiMAX operating band3.5 (3400–3690) [16].

Table1: Optimal parameters of the antenna depicted in Figure 1 (a)

Antenna Parameter	L_s	W_s	L_p	W_p	L_f	W_f
Dimension (mm)	45	30	32.5	21.5	11.1	3
Antenna Parameter	Lg			Total Volume		
Dimension (mm)			3.8	45×30×1.6 mm^3		

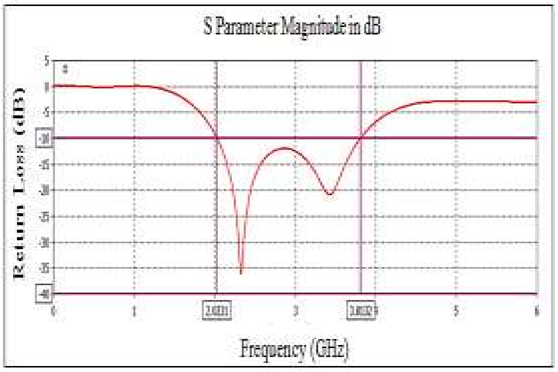
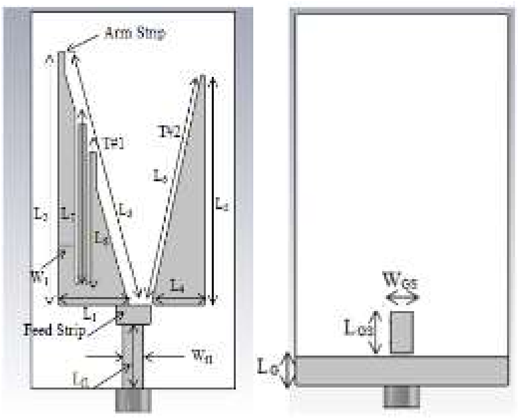


Figure 2: Proposed antenna return Loss

II. Fixed Multi Band Antenna Design

The geometry of the proposed multi-band antenna, possess five frequency bands, defined as 1, 2, 3, 4 and 5, at 1.8, 2.17, 2.8, 3.8, and 5.6GHz, respectively, are shown in Figure 3. The key parameters are described in Table 2. The antenna comprises of two right-angled triangles strips, a 50Ω- feed line, feed strip, arm strip, ground plane, and ground strip. The procedures of antenna design are depicted with the aid of Figure 4, as follows:



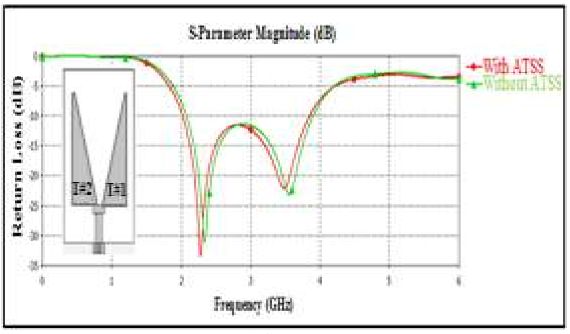
(a) (b

Figure3: The geometry of the proposed fixed multiband antenna (a) Top View; (b) Bottom View.

Table 2: Optimized parameters of an antenna of Figure 3

Antenna Parameter	L_1	L_2	L_3	L_4	L_5	L_6
Dimension (mm)	11.34	33	31.9	7.67	32.5	33.2
Antenna Parameter	L_7	L_{f1}	W_{f1}	L_G	L_{GS}	W_{GS}
Dimension (mm)	21.2	8.6	3	3.5	5.6	3
Antenna Parameter	W_1		L_8		Total Volume	
Dimension (mm)	2.5		17.4		45×33×1.6 mm^3	

Step 1: It can be proved that the current density distribution on the printed monopole antenna is often aggregated over the outside rims of the patch, with insignificant current at the center region [17]. Thus, if a section along the axis of the PRMA antenna is removed, this will not affect the entire antenna's impedance response and radiation characteristics leading to the wideband antenna [18]. In this design, an asymmetrical triangular – shaped slot (ATSS) is inserted into the center part of the PRMA in such a way that its apex arrives at the feed line without affecting PRMA's behavior, as shown in Figure 4 (a). Thus, a PRMA is changed into two different base right-angled triangles strips, named triangular #1 and #2, respectively.

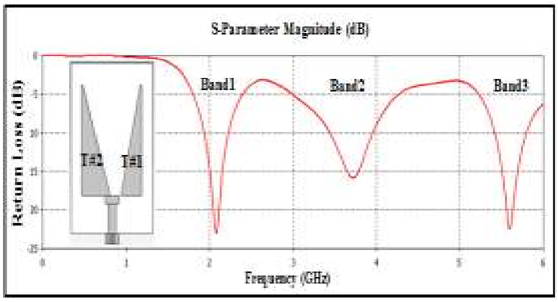


(a)

Figure 4 (a): Design steps 1 of proposed antenna in Figure 3.

Step2: Asymmetry of ATSS is further increased in the direction of right-angle triangular #1, leading to completely separate triangular #1 from the feed line, while triangular #2 remains in contact with the feed line. Separating T#1 will deteriorate PRMA wideband behavior, and this will convert single wideband antenna to triple-band antenna.

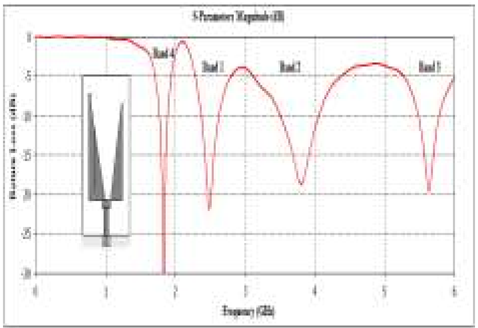
With this configuration, three prominent resonant frequencies are obtained band1 (2.1GHz), band 2 (3.65GHz), and band 3 (5.5GHz), as shown in Figure 4 (b).



(b)

Figure 4 (b): Design steps 2 of proposed antenna in Figure 3.

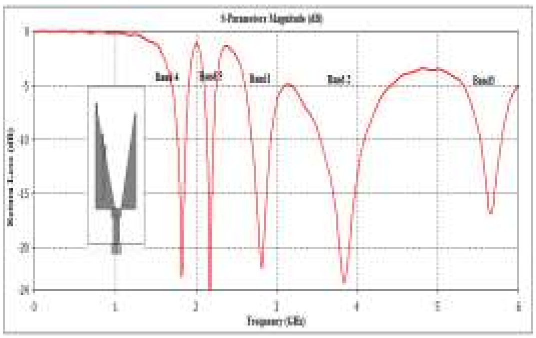
Step 3: Inserting slots on the antenna's radiator will alter the current's path, and can be used to generate dual-band or even multiple-bands operations [19]. In the proposed design, a rectangular slot is inserted into triangular #2 to change the current path, and transform triangular #2 to a pair of quarter wavelength resonators L_2 and L_8. This will generates band 4 (1.8GHz) and tune band 1 at 2.4 GHz, as shown in Figure 4(c). However, L_2, on its own, does not give exact 1.8GHz resonance, so arm strips with a length and width of 3 mm and 1 mm respectively, is added to the end of L_2 to tune it to 1.8GHz.



(c)

Figure 4(c): Design steps 3 of proposed antenna in Figure 3.

Step 4: In order to generate band 5 (2 GHz), another rectangular slot is incorporated into triangular #2 to further disturb the current path and form another resonant strip. Thus will transform triangular #2 to a triple of quarter wavelength resonators L_2, L7, and L_8. However, the length of these resonators have been optimized to generate band 4 (1.8GHz), to tune band 1 at 2.1 GHz and tune band 5 at 2.8GHz as shown in Figure 4 (d).



(d)

Figure 4(d): Design steps 4 of proposed antenna in Figure (3).

To cancel unwanted far field radiation from the current on the feed line, a ground strip with a length L_{GS} and a width of W_{GS} is placed on the bottom side of the substrate under the microstrip feed line, as depicted in Figure 3(b). However, feed strips, with length 2.5 mm and width equal to 5 mm, are also added to end of the feed line to improve antenna impedance matching. Dimensional details and return loss result of the proposed antenna shown in Figure 3, are given in Table2 and Figure 5, respectively.

From Figure5 shown that the corresponding -10 dB bandwidth for band 4, 5, 1, 2, and 3 is (1.7-1.87) GHz, (2.1-2.21) GHz, (2.6-2.9) GHz, (3.5-4) GHz, (5.5-5.7)GHz, respectively, which is suitable for DCS, PCS, GSM1800, (UMTS 2.00, 2.10, 2.19), LET 2300/2500, IEEE 802.11WLAN standard, WiMAX operating band 3.5, IEEE 802.11 WLAN standard 5.2GHz and 5.5 GHz WiMAX band.

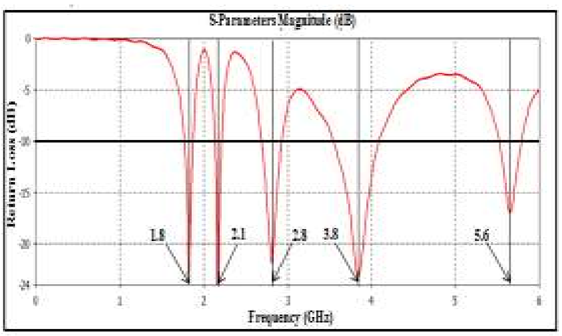


Figure 5: Proposed antenna's return loss of the Figure 3 with dimensions given in Table 2.

III. Current Density Distribution of the Proposed Design

The simulated surface current density distribution on the radiating elements at resonant frequencies (1.8GHz, 2GHz, 2.49GHz, 3.85GHz, and 5.5GHz) are shown in Figure 6. At resonance frequency 1.8 GHz of band 4, Figure 6(a) shows that the current density mainly flows along

dimension L_2 (y-direction), which indicates that the arm L_2 is the major radiating element for the antenna in this band. While at other operating bands 2,3,4 and 5 it is seen the current density is concentrated along dimensions L_7, L_8, L_1, and L_5 respectively (Figure 6(b)-(e)), which demonstrates that these dimensions is responsible for generating and controlling corresponding bands.
The major paths of current density at the five resonant frequencies, are corresponding to approximately the total resonant strip length (dimensions in our design), which is a multiple of a quarter-wavelength, and can be calculated approximately by [20].

$$L_{total} \approx n\frac{\lambda_g}{4} \quad (7)$$

Where $\lambda_g = \frac{\lambda_0}{\sqrt{(\varepsilon_r+1)/2}}$, and λ_0 is the free space wave-length

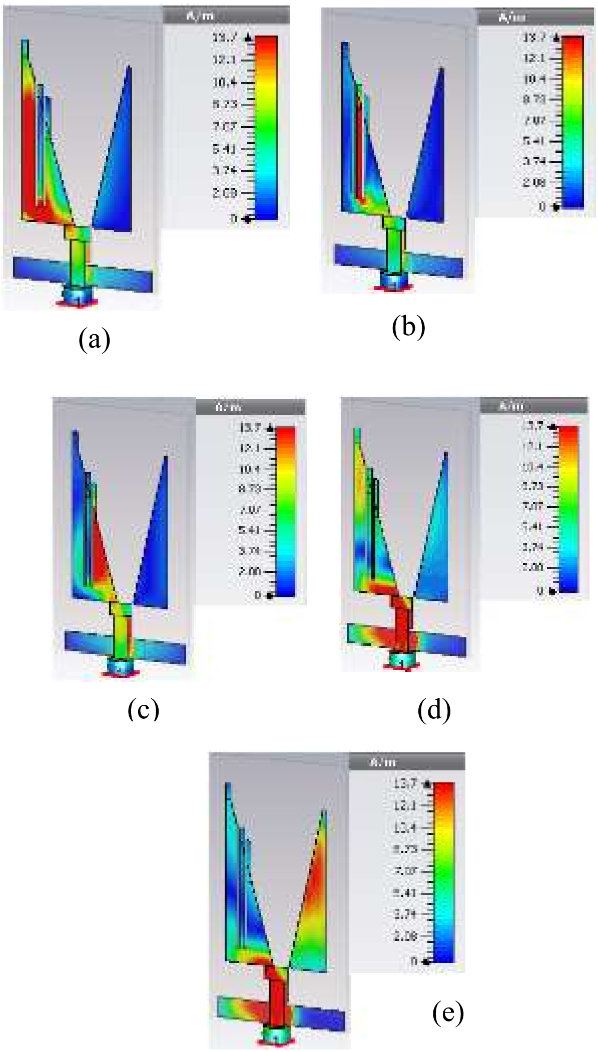


Figure 6: CST visualization for distributions of surface current density of the suggested antenna in Figure 3 at (a) 1.8GHz, (b) 2.02GHz, (c) 2.49GHz, (d) 385 GHz, (e) and 5.5GHz

3. Design of Multi-State Switchable Antenna

The former results in section 2, are utilized to design a frequency-switchable antenna. The dimensions which are used to design the frequency-switchable antenna in Figure 7, it is the same as those of Table 2. Three PIN diodes, numbered D1, D2, and D3, are integrated into antenna. The locations of the PINs are determined and optimized for switching antenna between three $\lambda/4$ resonant strips and PRMA, in the case of OFF and ON respectively. i.e., in case of the diode is off, an independent $\lambda/4$ resonant strip is generated in structure of the antenna, while in ON state, this resonant strip will be a part of PRMA, and its resonant frequency will disappear. Since, the presented antenna is just a prototype of a reconfigurable antenna. Initial results were obtained by using short and open circuits instead of implanting PIN diode. However, for explaining how PIN diode switch works, the structure of PIN diode switch will be explained.
Toggling the switches ON and OFF states depends on dc biasing voltage applied to PIN diode. For biasing PIN diodes using dc voltage, conducting strips with dimensions of 0.5×0.3 mm^2 are implant inside the slots. Furthermore, along every PIN diode, a 100-pF dc blockage capacitor is implanted in the slot to make the RF connection of the PIN diode while separate the RF signal from the dc (see Figure 7a). For switching PIN diode ON a biasing voltage of a 0.7-V supply is fed to conducting strips. The PIN diode has a 4.6 ohmic resistance in ON state, and 0.017 pf capacitance in OFF states [21]. By switching PIN diodes ON, the conducting strips are joined with the PRMA and become a part of it. By altering the state of PIN diodes, the required frequency bands group can be generated.

I. Results and Discussion

The designed antenna was simulated and analyzed using CST 2014 Microwave Studio. While the prototype antenna was tested using Rohde & Schwarz ZVA I3 vector network analyzer (VNA) (see Figure 8. The evaluations of the performance of the both samples were done in terms of the return loss, the gain, the antenna's efficiency, and radiation pattern.

II. Impedance Bandwidth for S_{11} (dB)

Comparison between simulated and measured return loss graph for various conditions of PIN diode combinations are shown in Figure 9. In this

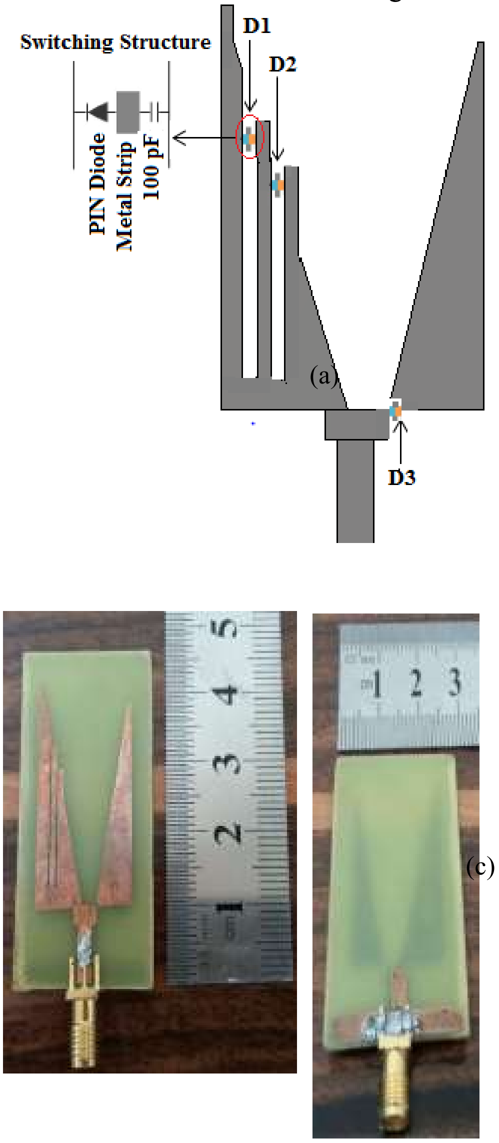


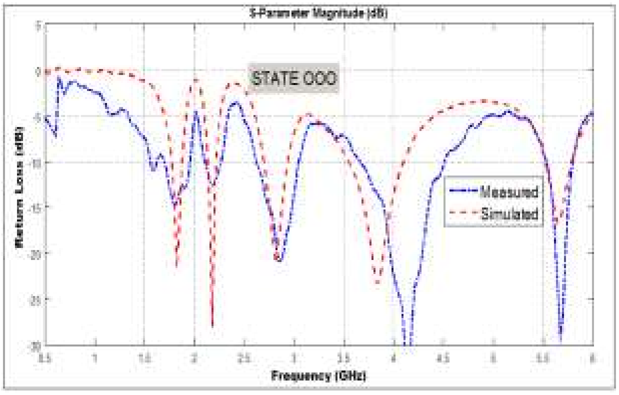
Figure 7: (a) Proposed antenna's configuration with dc biasing network, Prototype of the antenna (b) top view; (c) bottom view.

The presented antenna is competent to perform variety of multiband with the variety of RF switches configuration. Figure 9 (a)-(d) illustrates the reflection coefficient for first four states **000**, **001**, **010**, and **011**, respectively. In these states, article OFF and ON of PIN diode states are represented as ‘0’ and ‘1’, respectively.

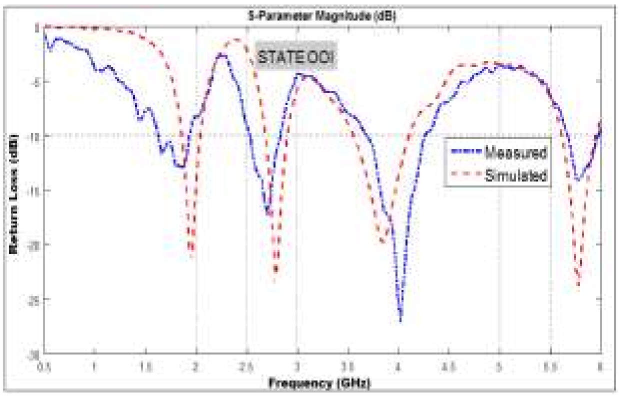
the antenna is capable to operate at different sets of frequency bands in the range from 1.8GHz to 5.6GHz.
In the other three states **1 0 0, 1 0 1,** and **1 1 0,** there is the bands are close to each other as shown in Figure 9 (e)-(g), this is because D3 is ON in all three states. Since T#2 resonator has dominant effect on dispersion of current density, and consequently on bands than the two slots in T#1. So, switching D1and D2 will not have a significant effect on changing bands. Besides, the proposed antenna is designed to operate between 2 GHz to 3.8 GHz, when all RF switches are ON (**1 1 1 state**), as in Figure 9 (h). The summary for various states of PIN diode combinations results in terms of operating resonant frequency bands are displayed in Table 3.
The cable and connector was used in measurements may be contribute a small dissimilarity between the simulated and measured results, which they were not considered in simulation. In addition, the antenna's manufacturing tolerance may be having an effect on measured results. However, in the simulation the switch is modeled using equivalent circuit of PIN diode, while in the fabrication process, a lump solder is used to short circuit the switch in case of ON state, and in OFF states as open circuit.

Figure 8: Return loss measurement of the antenna using ZVA 13 vector network analyzer.

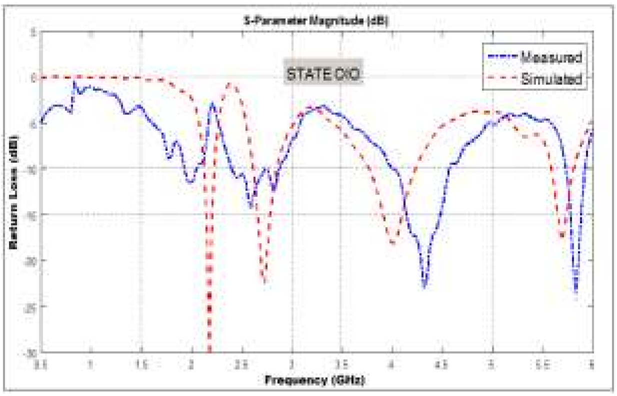
Figure 9: Reflection coefficient evaluation and measurements f various switch state



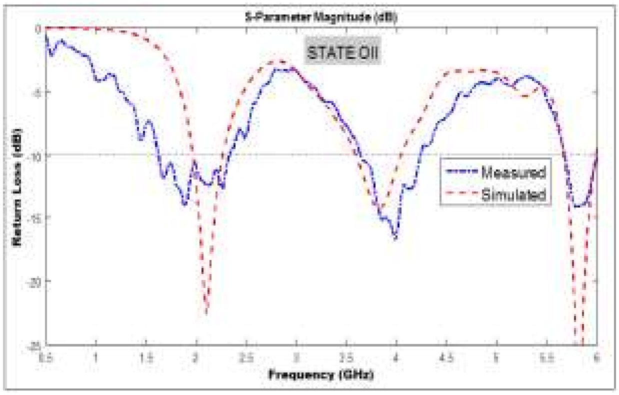
(a) STATE OOO



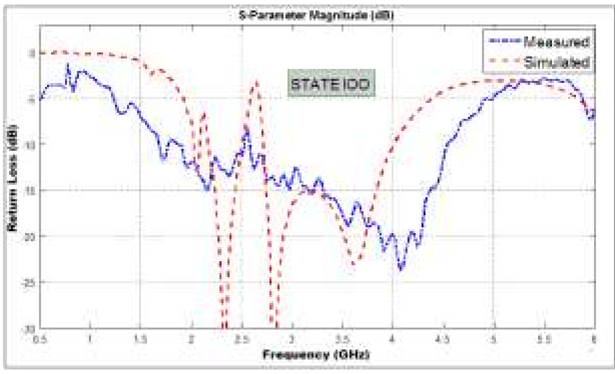
(b) STATE OOI



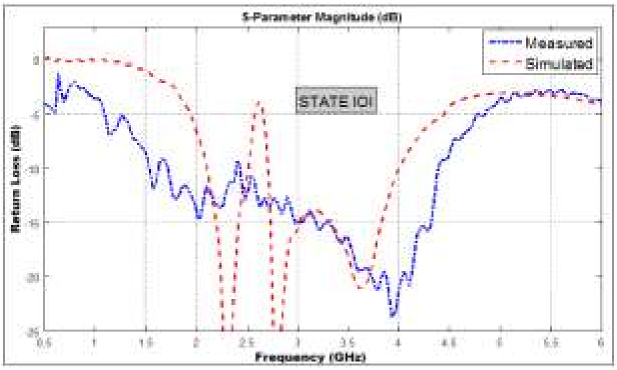
(c) STATE OIO



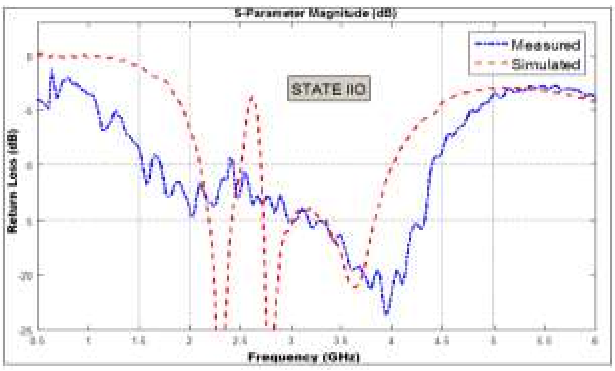
(d) STATE OII



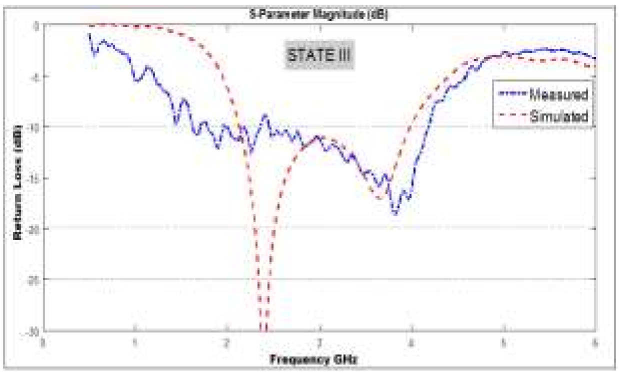
(e) STATE IOO



(f) STATE IOI



(g) STATE IIO



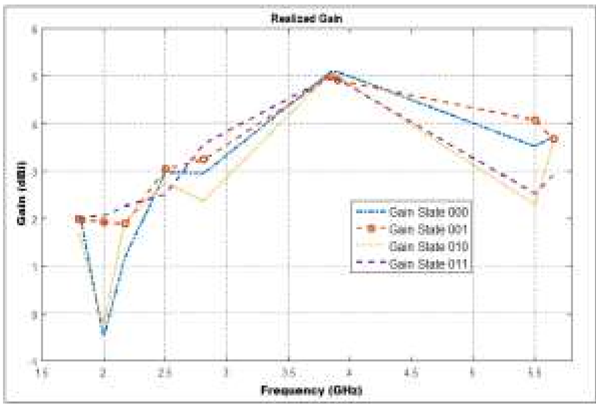
(h) STATE III

Table 3: PIN diode configurations cases with operating frequency bands, simulated gain, measured gain and antenna's efficiency

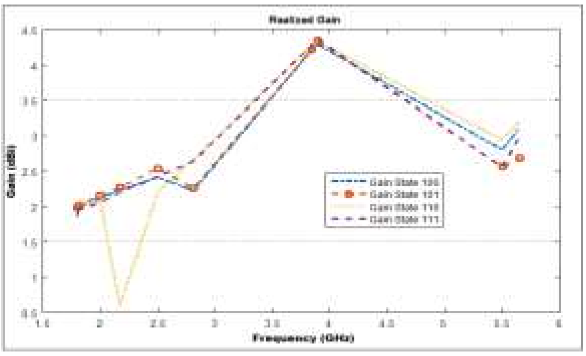
Type of Switch	RF Switches			Operating Bands (GHz)	Realized Gain (dBi)	Measured Gain(dBi)	Total Antenna's Efficiency (%)
Number of PIN diode switch	D_3	D_2	D_1				
	0	0	0	1.68-1.85	1.93	2.4	97
				2.13-2.21	1.17	2.29	77.8
				2.6-2.93	2.97	3.3	88.5
				3.55-4.1	5.08	5	92.4
				5.38-5.58	3.52	2.77	75.2
	0	0	1	1.85-2	1.98	2.03	90.3
				2.68- 2.89	3.04	2.3	89.3
				3.58-4.22	4.97	4.76	91.9
				5.52 - 5.99	4.07	3.51	75.8
	0	1	0	1.76-1.88	1.69	1.98	89.1
				2.2-2.6	1.91	2.2	92.2
				3.56 -4.22	5.05	5.17	89.8
				5.54- 5.8	3.58	4.18	73.6
	0	1	1	2.0 - 2.3	2.51	1.4	90.9
				3.65 -4.13	4.99	4.46	41
				5.41-6	2.91	3.44	68.7
	1	0	0	2.1-2.43	2.23	1.95	91.3
				2.7-4.1	4.29	3.74	94
	1	0	1	2.1-2.5	2.27	1.68	88.6
				2.1-4	4.34	3.15	89.2
	1	1	0	2.22 - 4	4.34	4.51	87.1
	1	1	1	2 - 3.8	4.28	3.83	88.3

III. Antenna Gain and Radiation Efficiency:

The proposed antenna's gain at all resonant frequencies and for all switch configurations are shown in Figure 10, a, b respectively. Table 3 demonstrates simulated gains, measured gains, and corresponding simulated radiation efficiency for different operating bands. Depending on acquired result in Table 3 the proposed antenna may be operate for multi-standard wireless applications efficiently.



(a)



(b)

Figure 10: Antenna's simulated gain for different switch configurations; (a) for first four states, (b) for second four states.

IV. Radiation Pattern

The proposed multiband antenna's radiation patterns were measured utilizing device under test (DUT) (in this paper; proposed multiband antenna) equipment’s, together with VNA, and five omnidirectional antennas as transmitters (each antenna for a band). The distance among omnidirectional antenna (TX-antenna) and DUT is set in 1.5_m distance with regard of proposed antenna, as shown Figure11.

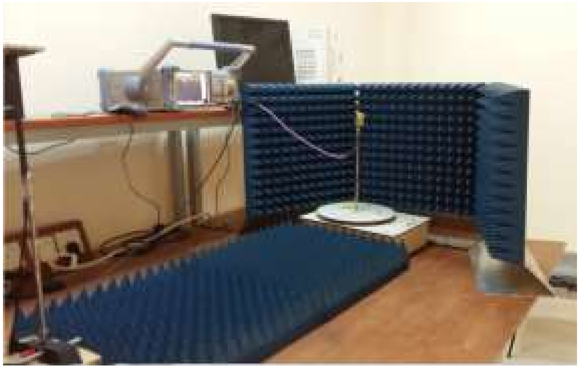


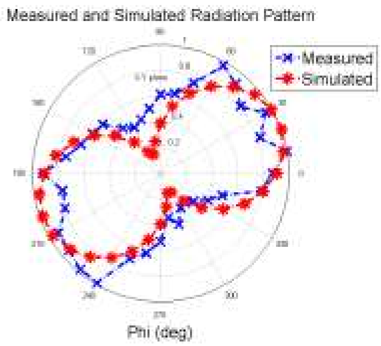
Figure11: Radiation pattern measurement of the proposed antenn

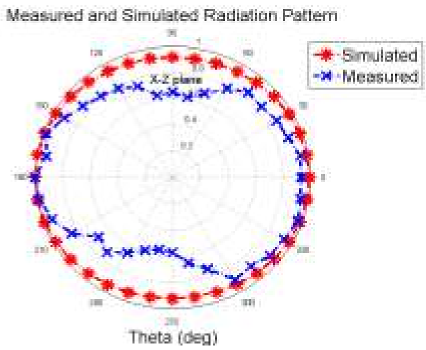
The normalized simulated and measured radiation patterns at five resonant frequencies (state **000**) of 1.82, 2.17, 2.81, 3.84 5.65 GHz, are shown in Figure12. The radiation patterns at these bands are measured and studied because it include almost all other states or abut them.

From Figure 12 (a) , (b) and (c), it can be seen that the antenna at the first three resonant frequencies of 1.82GHz, 2.17GHz, and 2.81 GHz, exhibited nearly an omnidirectional radiation on the H-plane (XZ-Plane), while the E-plane (XY-plane) pattern is found to be figure eight (8) shaped, which shows a bidirectional pattern. However, from Figures 12 (d) and (e), unidirectional patterns in both E and H-plane are observed, which may be due to its radiation behavior being reasonably affected partly from antenna's ground plane. As noticed from the current density distribution, in Figures 6 d, and e, the ground plane contributes to radiation to a certain extent

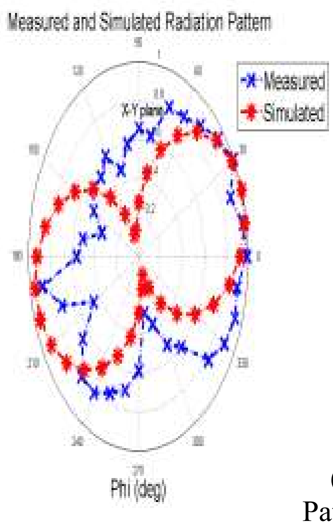
X-Y Plane

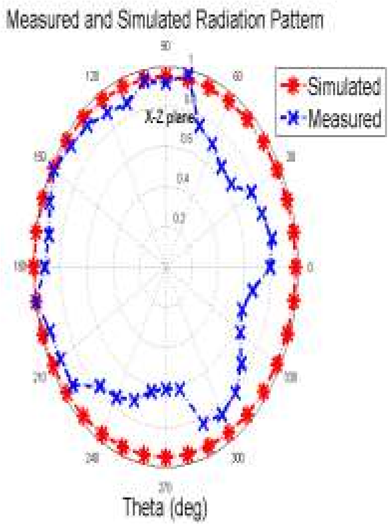
X-Z



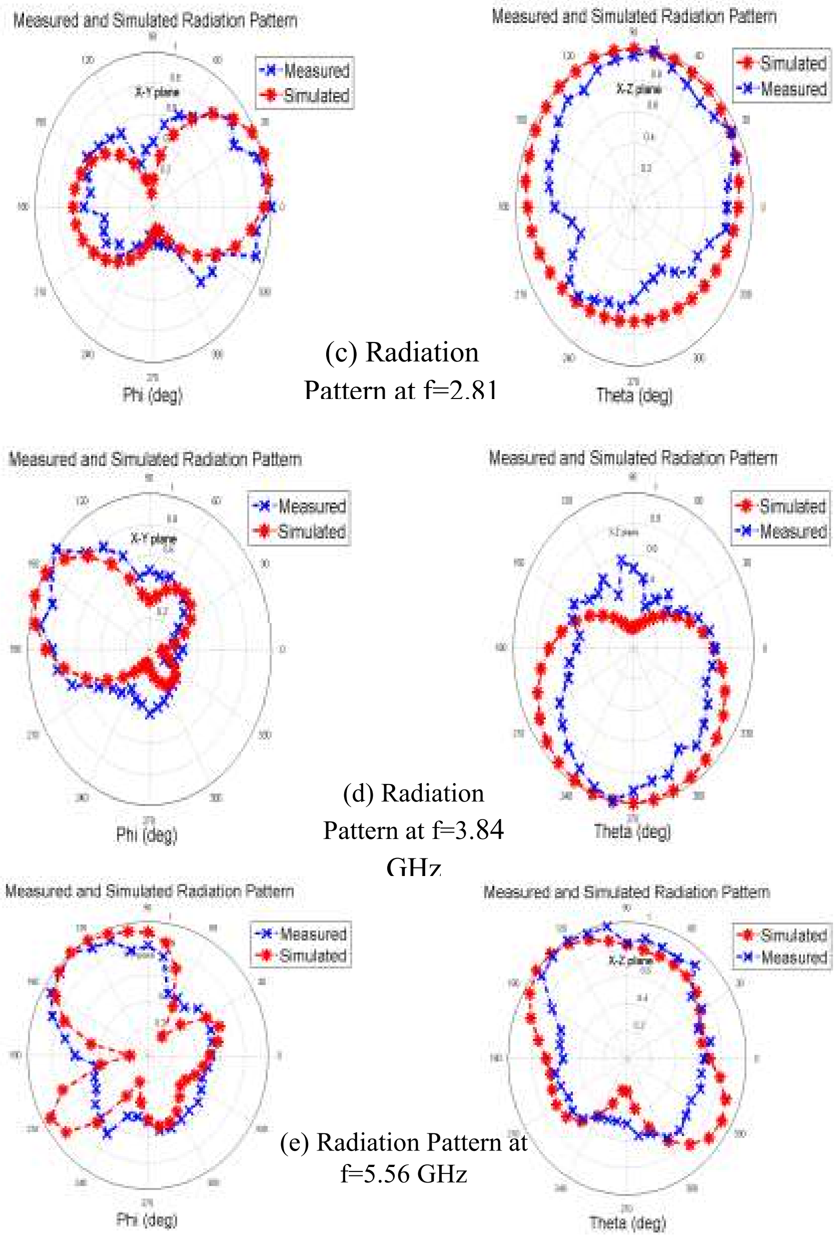


(a) Radiation Pattern at f=1.82 GHz





(b) Radiation Pattern at f=2.17 GHz



(c) Radiation Pattern at f=2.81

(d) Radiation Pattern at f=3.84 GHz

(e) Radiation Pattern at f=5.56 GHz

Figure 12: Radiation patterns of the simulated antenna and prototype antenna (a) 1.82GHz, (b) 2.17GHz, (c) 2.81GHz, (d) 3.84GHz, and (e) 5.65GHz.

4. Conclusion

In this paper, a compact fixed and switchable multi-state single-wideband and multi-narrowband antenna are designed, constructed and analyzed. The suggested antenna exploits reconfigurable slots form structure to introduce the switchable capability. The proposed antenna's trait is low-profile, and easy to design, manufacture and utilizes three PINs diode to switch on the required bands of frequencies. The proposed antenna can works at eight variant switching conditions with a sensible reflection coefficient. Additional operating bands can be accomplished by implanting more slots and PIN's diodes as switches within the antenna's framework. Acceptable radiation patterns with reasonable gain results were got for various switch-cases of the suggested switchable configuration antenna. Multi-standard frequency wireless usages and cognitive radio can be served by the suggested antenna.

References

[1] H. Boudaghi, M. Azarmanesh, and M. Mehranpour, "A Frequency-Reconfigurable Monopole Antenna Using

Switchable Slotted Ground Structure," IEEE Antennas and Wireless Propagation Letters, Vol. 11, pp. 655-658, 2012.

[2] J. Lim, Ch. W. Song, Zhe-Jun Jin, Tae-Y. Yun, "Frequency reconfigurable planar inverted-F antenna using switchable radiator and capacitive load," IET Microw, Antennas Propag., Vol. 7, Iss. 6, 430–435, 2013.

[3] A. Foudazi, H. Hassani and S. ali nezhad, "Small UWB Planar Monopole Antenna With Added GPS/GSM/WLAN Bands," IEEE transactions on antennas and propagation, Vol. 60, NO. 6, 2987-2992, 2012.

[4] Z. Faiza, M.T. Ali, S. Subahir and A.L. Yusof, "Design of Reconfigurable Dual-Band E-Shaped Microstrip Patch Antenna," International Conference on Computer and Communication Engineering (ICCCE 2012), Kuala Lumpur, Malaysia, 113-117, 2012.

[5] H.F. AbuTarboush, R. Nilavalan, and T. Peter, "PIFA based Reconfigurable Multiband Antenna for Wireless Applications," International Conference on Electromagnetics in Advanced Applications, Sydney, Australia, 2010.

[6] Gh. Mansour, P. S. Hall, P. Gardner, and M.K.A. Rahim, "Switchable Multi-Band Coplanar Antenna," Loughborough Antennas & Propagation Conference, Loughborough, UK, 2011.

[7] F. Yang and Y. Rahmat-Samii, "Patch antenna with switchable slots (PASS): Reconfigurable design for wireless communications," Antennas and Propagation Society International Symposium, San Antonio, TX, USA, USA, p: 462-465, 2002.

[8] I.T.E. Elfergani, and R. A. Abd-Alhameed, "A Compact Size Reconfigurable PIFA Antenna for Use in Mobile Handset," General Assembly and Scientific Symposium, URSI, pp. 1-**4,** Istanbul**,** Turkey 2011.

[9] H.F. Abutarboush, R. Nilavalan, and S.W. Cheung, "A Reconfigurable Wideband and Multiband Antenna Using Dual-Patch Elements for Compact Wireless Devices," IEEE transactions on antennas and propagation, Vol. 60, NO. 1, 36-42, 2012.

[10] H.F. Abutarboush, R. Nilavalan, and S.W. Cheung, "Compact Printed Multiband Antenna with Independent Setting Suitable for Fixed and Reconfigurable Wireless Communication Systems", IEEE transactions on antennas and propagation, Vol. 60, NO. 8, pp. 3867-3874, 2012.

[11] K. Ray, "Design Aspects of Printed Monopole Antennas for Ultra- Wide Band Applications," International Journal of Antennas and Propagation, vol. 2008.

[12] N. Agrawall, G. Kumar, and K. Ray, "Wide-Band Planar Monopole Antennas," IEEE Trans. on Antennas and Propag, Vol. 46, No. 2, 294–295, 1998.

[13] Y.A. Fadhel, KH.H. Sayidmarie, "Design and implemtation of ultra wideband antenna for imaging application", Ph.D thesis, Electrical Engineering Dept. University of Mosul, Iraq, 2013.

[14] M. John and M.J. Ammann, "Optimization of Impedance Bandwidth for the Printed Rectangular Monopole Antenna," Microwave and Optical Technology Lett. vol. 47, no. 2, pp. 153–154, 2005.

[15] A. Foudazi, H. Hassani, and S. Nezhad, "Small UWB Planar Monopole Antenna with Added GPS/GSM/WLAN Bands," IEEE Trans. on Antennas and Propag. vol. 60, no. 6, pp: 2987–2992, 2012.

[16] M. Khan, and M. Morsy, "Dual Band Antenna for Wireless Network (WLAN) Applications," IEEE International Symposium on Antennas and Propagation (APSURSI), Spokane, WA, USA, pp: 1397–14003, 2011.

[17] R.K. Gupta, "Printed Tri-Band Monopole Antenna Structures for Wireless Applications," Microw. Opt. Technol. Lett., vol. 51, no. 7, pp. 1781–1785, 2009.

[18] W. Li, L. Cai, B. You, and C. Huang, "Design of Printed Notched-Monopole UWB Antenna," IEEE International Conference, Intelligent Computing and Intelligent Systems, Shanghai, China, 271–274, 2009.

[19] H. Abutarboush, R. Nilavalan, S. Cheung, and K. Nasr, "A Reconfigurable Wideband and Multiband Antenna Using Dual-Patch Elements for Compact Wireless Devices," IEEE Trans. on Antennas and Propagation, vol. 60, no. 1, 2012.

[20] S. Mohammad A .Nezhad and H. Hassani, "A Novel Tri-Band E-Shaped Printed Monopole Antenna for MIMO Application," IEEE Antennas Wireless Propag. Lett., vol. 9, pp. 576–579, 2010.

[21] Avago Technologies, San Jose, CA, "HPND-4005 beam lead PIN diode," Data sheet, 2006, [Online]. Available: http://www.avagotech.com/docs/AV01-0593EN.

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Paragraph (2.5 cm height*2 cm width)

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Paragraph (2.5 cm height*2 cm width)

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