

Design of Frequency Reconfigurable Multiband Compact Antenna

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Abstract—In order to improve the performance of the antenna, the simple reconfigurable antenna are proposed. The antenna operates at ten different frequencies between 2.2 to 6 GHz, which effectively operates at two frequency bands i.e., 2.4-2.58 GHz for WLAN (Wireless Local Area Network) and 3.5 GHz for WiMAX (Worldwide Interoperability for Microwave Access) applications between this frequency range. The patch are designed by using FR-4 material and it is simulated by using a Advanced Design System (ADS) software. There are two PIN diodes are used, which performs the switching operations. The ON/OFF conditions of switches will allow the current distribution to the antenna surface and which causes antenna reconfigurability. The mobile phones contains nearly seven to eight antennas for each applications such as 2G, 3G, 4G, Wi-Fi (wireless fidelity) and Bluetooth etc. The reconfigurable antenna will also improve the antenna performance in changing scenario and satisfy the changing operating requirements.

Keywords : Reconfigurable antenna, PIN diodes, WLAN (Wireless Local Area Network), WiMAX (Wireless Interoperability for Microwave Access) and Patch.

I. INTRODUCTION

The reconfigurable antenna is an antenna which dynamically change its behaviour such as radiation pattern, polarization and frequency due to the changes happening in the environment. The antenna is a specialized transducer. It is an electrical device which has transmitting antenna and receiving antenna converts electrical current into radio waves and vice versa. The transmitting antenna converts electrical current into radio waves and the electric field in the space converts the radio waves into electrical current, then the receiving antenna deliver the electrical current to electronic equipments [1]. The frequency reconfiguration is that which changes its frequency of operation. In some situation, several communication system coverage are made by using multiple antennas which are replaced by a single reconfigurable antenna. The frequency reconfigurability can be achieved by physically or electrically modifying the dimensions of the antenna i.e., either by adding or removing parts of its length by using switches or any tunable materials [2]. The polarization reconfiguration dynamically changes their polarization modes such as linear, circular, vertical and horizontal. The use of PIN diodes will redirect the current in the antenna surface and PIN diode is used for tuning the frequency band [3]. Compare to other switches the PIN diodes has simple functionality, very good isolation, faster switching speed, good linearity, low cost and it has capability to handle

high power and high frequency applications. The PIN diode is a current controlled resistor, which is similar to conventional PN diode [4]. The PN diode allow the current to flow in the antenna surface in forward biased region and it will block the current in reverse biased region. The PIN diode has three layers they are p-type layer, n-type layer and intrinsic layer. Similarly, the PIN diode allow the RF energy in forward biased region and it will block the RF energy during reverse biased region [5].

The most important parameter of PIN diode is isolation. From a single antenna many designs can be done by taking a small portion of an antenna and inserting a diode in that particular portion in an antenna. In this case, only when supply is given the diode should give continuity and when supply is not given, the diode should not give continuity. But in some cases, if supply is not given due to leakage the diode will provide continuity. So that the radiation pattern will be modified, because every antenna have a specific frequency range and for every frequency range corresponding radiation pattern is produced [6]. The PIN diode can also be used as voltage resistor, photodetector and RF switch. Reconfigurable and multiband antenna are same because multiband means, it has more than one frequency and reconfigurable antenna also resonate at different frequency ranges by using a diode, so it is called as reconfigurable multiband antenna. Apart from foam, epoxy and duroid, the FR4 substrate is used. The patch antenna is proposed in this paper, has single substrate, low cost, compact and it is easy to fabricate. The manufacturing period of patch is less [7]. The patch and the ground plane are separated by dielectric material. Copper conductor is used because copper is a good conductor so that the current vigorously flows on the antenna surface.

The main objective of this paper is to reduce the huge amount of antennas used in mobile phones for several applications. The major advantage of the proposed antenna can resonate at ten different frequencies ranging from 2.2 to 6 GHz by the use of PIN diode (SMP1320-079). It satisfies the requirement of 2.4-2.58 GHz WLAN (Wireless Local Area Network) and 3.5 GHz WiMAX (Worldwide Interoperability for Microwave Access) antenna applications. The patch is designed by the use of FR-4 substrate material (Flame Retardant 4), the material is sandwiched by copper conductor and air medium. The FR-4 substrate material spread its electromagnetic radiation in a high manner compare to other materials and it has induction on only one side. The various mobile phones are designed by using FR-4 substrate material.

The results were simulated by using an Advanced Design System (ADS) software.

II. ANTENNA CONFIGURATION

The antenna is designed by using FR-4 material of thickness h is 1.6mm, tangential loss is 0.02 and permittivity ϵ_r is 4.3. The simulations are made by using Advanced design systems (ADS). There are two PIN diodes were used, PIN diode D1 is placed in the bottom slot of the patch and PIN diode D2 is placed in the top of the patch [8]. The values of thickness, tangential loss, width and permittivity ϵ_r are obtained from the equations. The equations are shown below. For efficient radiation, the width, W is given by

$$W = \frac{c}{2f_0} \sqrt{2/(\epsilon_r + 1)} \quad (1)$$

An effective dielectric constant can be expressed by

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} [1 + 12h/w]^{-1/2} \quad (2)$$

The effective length of the resonant frequency is given by

$$L_{\text{eff}} = C/(2f_0 \sqrt{\epsilon_{\text{reff}}}) \quad (3)$$

The extended incremental length of the patch can be expressed by

$$\Delta L = 0.412h \frac{(\epsilon_{\text{reff}} + 0.3)(\frac{w}{h} + 0.264)}{(\epsilon_{\text{reff}} - 0.258)(\frac{w}{h} + 0.8)} \quad (4)$$

The effective length of the patch L_{eff} now becomes

$$L_{\text{eff}} = L + 2\Delta L \quad (5)$$

A. Switch Design

The antenna can be switched to different frequency by using diode which causes reconfigurability. In an antenna, several designs can be done with the help of diode. The reconfigurability is an multiband system which consist of different frequencies called as multiband frequency. There are two PIN diodes used in the antenna which causes the current to flow in the antenna surface. The PIN diode switches has significant layers are p-type layer, intrinsic layer and n-type layer. The p-type and n-type layers are heavily doped and intrinsic layer is undoped. The intrinsic layer is larger in size compared to p-type and n-type layers. The ON/OFF condition of the switch causes reconfigurability which operates at different frequencies [9]. The two states of PIN diodes has four switching configuration. The PIN diode D1 is located at the middle bottom of the slot and the PIN diode D2 is located at the top of the slot. There are two PIN diodes D1 and D2 has four switching configurations. When D1 and D2 are OFF state, the feed is given to the lower section of the patch, the current are distributed to the edges of the patch. When D1 is OFF and D2 is ON state, the part of the current is distributed to the top of the patch [10]. When D1 is ON and D2 is OFF state, the current is not completely separated from top of the patch. When diode D1 and D2 is ON state, the current is distributed to both top and bottom section of the patch. When diode D1 is OFF and D2 is ON used for unlicensed ISM band

i.e., 2.4-2.48 GHz. When diode D1 is ON and D2 is OFF used for WiMAX (Worldwide Interoperability for Microwave Access) applications and when diodes D1 and D2 is ON state used for LTE (Long Term Evolution), UMTS (Universal Mobile Telecommunications System) for defense and security applications.

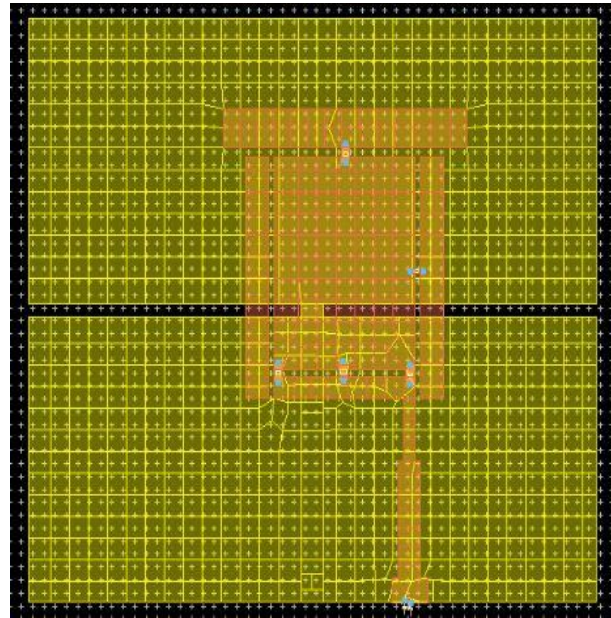


Fig. 1 Layout of antenna

The above Fig. 1 shows the top and bottom layer of antenna layout is obtained by using Advanced Design System (ADS) software. The proposed antenna is designed and simulated by using the commercial electro-magnetic (EM) field simulator. The FR-4 substrate is sandwiched by air medium. The design of patch antenna are used FR-4 material for 2.4-2.58 GHz WLAN and 3.5 GHz WiMAX applications [11]. The simulation is done by using ADS software.

III. PROPOSED SYSTEM

A simple reconfigurable multiband antenna is designed with two PIN diodes for WLAN (Wireless Local Area Network) and WiMAX (Worldwide Interoperability for Microwave Access) applications with the frequency of 2.4/5.8 GHz and 3.5 GHz. The antenna design is simulated by using Advanced Design System (ADS) software. Various shapes of patches are available they are rectangular, square and circular shape etc., among these shapes the rectangular patch is the most popular patch antenna. The microstrip patch antenna is fabricated by using Flame Retardant 4 (FR4) substrate. The proposed antenna resonate at different frequencies. It satisfies the WLAN and WiMAX antenna applications. The patch antenna is compact and very simple to fabricate, the manufacturing time of patch antenna is less. The patch antenna has a single substrate. The PIN diodes are used as a

switches in the patch antenna. The PIN diode composed of three layers such as P-type layer, intrinsic layer and N-type layer. The P region consist of majority of holes and N region consist of electrons, when there is no charge carriers in the intrinsic region which acts as a insulator. In the forward biased region, the electric field gives a force to move the charge carriers from P region to N region. The charge carriers unite together so that the current level increases than the level of intrinsic region. The PIN diode is used for high frequency and high power applications. The PIN diode is also used as high voltage rectifier, photo detector and radio frequency switch.

The WLAN (Wireless Local Area Network) connects two or more devices by the use of high frequency radio waves or wifi (Wireless Fidelity) signals. The WLAN is very expensive and it covers homes, small offices and educational institution while maintaining internet connections. The WLAN connection in homes has a single router which is connected to a cable or DSL modem. The router is acts as a centralized point which connects the devices such as tablets, laptop and mobile phones and establish connection between devices. The WiMAX technology provides wireless internet access for long range and it also provides broadband services for more than thirty miles. The most important application of WiMAX technology is range because the single WiMAX tower can connect other WiMAX towers by the use of line of sight. Connection of one tower to another tower called as backhaul. The WiMAX (Worldwide Interoperability for Microwave Access) provides data, voice, video making, voip (voice over internet packet) calling, 2G (Second Generation), mobile devices, internet access and high speed data transfer. The WiMAX technology applications has high bandwidth, high security, deployment ant it provides high quality service and it is also a full duplex.

A. FR-4 Substrate

The FR-4 (Flame Retardant-4) substrate splits the high electromagnetic radiations and the induction is spread only in one direction. The FR stands for Flame Retardant which is a popular substrate is commonly used as a electrical insulator. The dielectric material is sandwiched between two copper conducting layers [12]. The most commonly used dielectric material is FR-4 substrate material. It has several properties such as thermal, electrical, chemical and mechanical properties.

B. GSM (Global System for Mobile Communications)

The GSM (Global System for Mobile Communications) is not a technology is a standard developed by ETSI (European Telecommunications Standards Institute) for wireless communications. GSM operates in different frequency ranges. In 2014, it becomes as global standard for mobile communications. GSM works in international roaming, the frequency range for uplink is (1710-1785) MHz and the frequency range for downlink is (1805-1880) MHz. The service provider and the network are different in GSM. In CDMA, the service provider and network must be same and it

only works in nationalized roaming. In CDMA, each handset has specific code, all the code are available in the network [13]. The CDMA operates in 800 MHz band. When the code available in mobile phone is matched with the code present in the network, then only the CDMA establish the connection for the user. In GSM, the date stored in SIM card and the power consumption is less. The frequency band of GSM is (850-1900) MHz, so that it almost covers the entire globe and it supports 3G (Third Generation) UMTS standards, 4G (Fourth Generation) LTE Advanced standards, LTE (Long Term Evolution) and VOLTE (Voice over LTE).

The antenna results are simulated by using a software called Advanced Design System (ADS) software. The Fig. 2 shows the processing of each and every steps in ADS software.

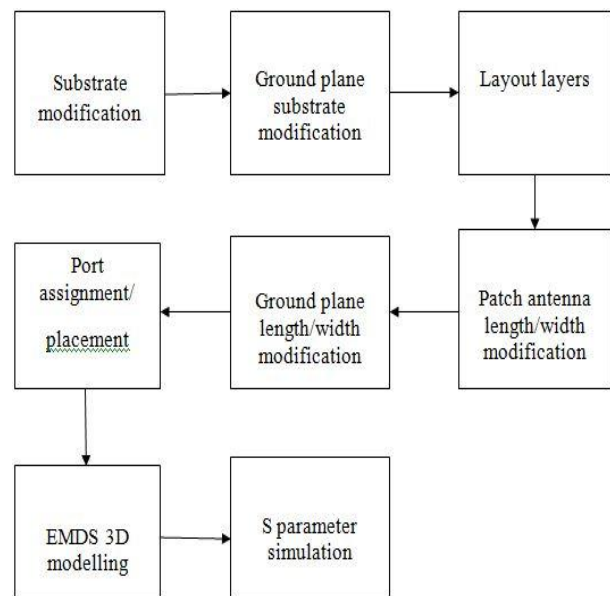


Fig. 2 Processing of advanced design system

The Advanced Design System software is an electronic design automation software system is produced by a unit of agilent technologies. It also provides a integrated designs for the designers of RF products such as mobile phones, radar systems, satellite communications, pagers and high speed data links. The ADS software supports every steps of design process such as schematic capture, layout, time domain and frequency domain simulation. The Advanced Design System software is a sophisticated circuit simulator and it can take maximum amount of time to learn the complex features. The ADS can be used in various operating systems (OS). ADS is the innovative and most popular software for wireless communications. It is the simplest software and easy to handle compare to other antenna software. The Advanced Design System (ADS) software has three different simulation techniques they are direct dense, iterative dense and direct

compressed methods. Momentum is the part of the Advanced Design System (ADS) software which provides simulation tools to design and evaluate the RF products [14]. The momentum is an electromagnetic solver which computes s-parameter for the planar circuits. The printed circuit boards (PCB) and multilayer communication circuits can also be simulated in ADS software. With the help of momentum tool the performance of antenna and integrated circuits can be predicted. The momentum provides 3D (3-Dimensional) preview for the user during simulation [15]. The antenna design starts in ADS layout window, the layout window consist of several tools such as file, options, edit, tools, EM, design guide, help, window, schematic, view, insert, select [16]. Click on momentum selecting substrate and moves to create/modify, a dialog box will be open in that, the type of substrate, real and tangential loss value is selected. Then moving to layout layers, the medium and the strip of the conductor is selected. The shape of the patch is selected and by selecting the patch, the height and width of the patch is modified [17]. Similarly, the height and width of the ground plane is also modified, then the port is connected to the two parts of the circuit by selecting ports and editor in momentum which acts as two port network. By selecting 3D EM preview in momentum provides the 3-Dimensional view of the patch antenna. The 3D preview shows the various views of patch antenna.

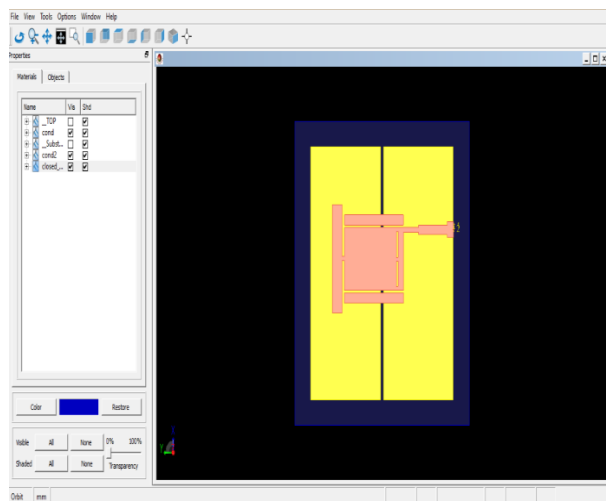


Fig. 3 3D EM preview

The above Fig. 3 shows the 3D EM preview of the patch. The radiation pattern is used to view the directivity of the antenna based on the major lobe, the graphical representation of radiation is referred as radiation pattern of the antenna. The radiation pattern can also be defined in terms of directivity, the antenna propagates the electromagnetic waves in particular direction where the size of major lobe is large. The antenna works effectively in the larger major lobe direction is referred to as directivity of the antenna. Several designs can be done with a single antenna by using diode

switches. Every designs has particular frequency range, each frequency range has a specific radiation pattern. The radiation pattern changes for every frequency. By computing the radiation pattern menu bar in the layout window, the radiation pattern is displayed. The Fig. 4 shows the radiation pattern of the patch.

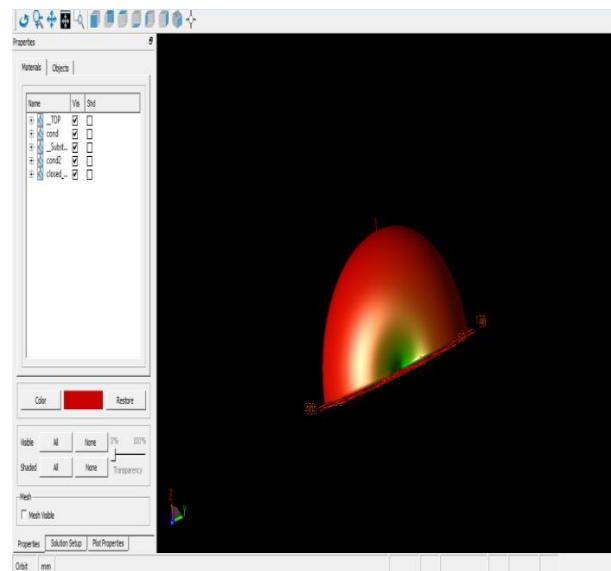


Fig. 4 Radiation pattern of the patch

Then by selecting simulate and s-parameter in the momentum, finally the simulated results are displayed i.e., the phase and magnitude of the plot, the frequency response and s-parameter graph are shown. To satisfy the requirements of WLAN (Wireless Local Area Network) and WiMAX (Worldwide Interoperability for Microwave Access), the patch antenna is designed and simulated using Advanced Design System (ADS) software.

C. Advantages

The major advantage of proposed paper is the space occupied by the antennas are mitigated. The antenna resonate at ten different frequency. Only two PIN diode switches are used. The pin diodes are low cost, have faster switching speed, good isolation and easy to fabricate for optimal performance. The PIN diode also offers a good linearity and it is effectively used for high frequency and high power applications.

IV. EXISTING SYSTEM

A compact triple band two element MIMO antenna is used to cover 2.2-6 GHz frequency range. The three bands which are obtained from this frequency ranges are 2.37-2.64GHz, 3.39-3.58GHz and 4.86-6.98GHz. When isolation is not good between two antenna, the current flow in the antenna surface so that the frequency range changes and radiation

pattern gets affected [18]. The mobile phones contains nearly seven to eight antennas for various applications such as 2G (second generation), 3G (third generation) UMTS standards, 4G (Fourth Generation) LTE Advanced standards, Bluetooth, WIFI (Wireless Fidelity) etc. Some mobile phones contains nearly twelve antennas also. So the large number of antennas in the mobile phones occupies large space [19]. Several switches were used to redirect the current flow, so the switch occupies large space and Method of Moments (MoM) approaches are utilized which is costly for two parameters one is matrix filling and another is matrix inversion. Some switch designs has biasing circuits which could adversely affects the radiation pattern of the antenna. In some cases, the antenna performance cannot be ameliorated without modifying the structure of the antenna. In order to improve the performance of the antenna, the antenna dimensions are modified either physically or electrically or by improving the performance of parameters.

The antenna elements based on liquid crystal technology has multilayer substrate, nearly it contains six substrates and it is difficult to fabricate. It takes significant amount of time to manufacture the antenna [20]. The radiation pattern is the most important parameter of antenna which varies based on type of antenna used. The different types of antenna has different radiation patterns [21]. When several antennas are used more space will be occupied, because of improper isolation the frequency range modified and radiation pattern gets affected. In some cases, the prototype is not created, a prototype is an original or first model from which other copies are derived. The prototype is mainly created to verify the correctness of the design. The antenna is developed in order to overcome the problems and to provide a satisfactory solutions to the wireless communications. So MIMO (Multiple Input Multiple Output) systems are introduced which consist of several transmitting and receiving antennas. It is mainly used for server to server connection in order to provide wide bandwidth. Therefore huge number of antennas were used in mobile phones for each and every applications, so it occupies large area in mobile phones and the device becomes large in size. In order to fulfil the problems, the multiple antennas are replaced by single reconfigurable antenna. The reconfigurable antenna is suitable for multiple applications.

V. RESULTS AND DISCUSSIONS

The simulation of patch antenna has been designed and characterized using Advanced Design System (ADS) software. The figure shows the effects of the PIN diodes on the simulated antenna in different switching states with different resonant frequencies. Several frequencies are achieved by using PIN diode switches. The above Fig. 5 depicts the resonating frequency of proposed patch antenna is 2.4 GHz. The reconfigurable antenna is simulated with the PIN diode in order to achieve a good agreement. The patch and the ground plane are isolated by a dielectric material. The patch is designed with FR4 (Flame Retardant 4) substrate material.

The substrate is sandwiched with two copper conductors and the outer layer of the conductor is covered with air medium. The antenna was simulated using Advanced Design System (ADS) software, with diodes, capacitors and inductors are incorporated into the ADS design. The ADS software is simple and easy to handle compare to other antenna software.

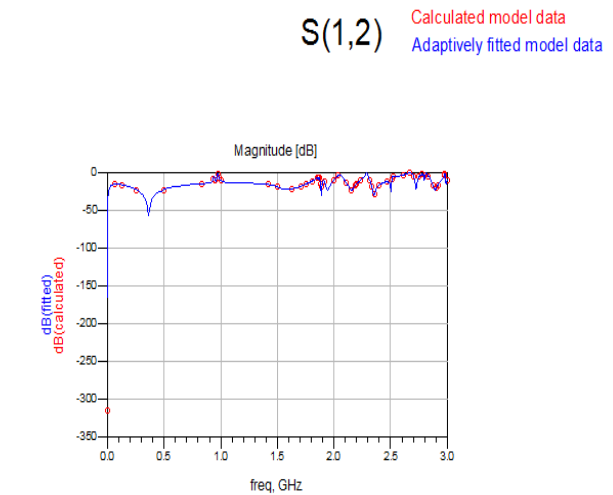


Fig. 5 Frequency response graph

When high frequency is given, the electrons in the cable are exceed out of the cable. At high frequency, how much the electrons are travelled from the cable are shown in the Fig. 6 given below.

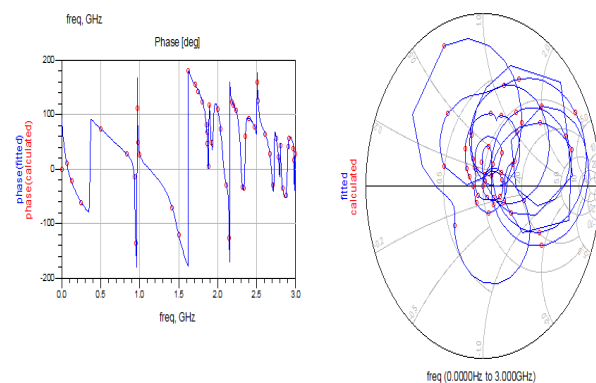


Fig. 6 S-parameter of the antenna

VI. CONCLUSION

The reconfigurable multiband antenna is designed using Advanced Design System (ADS) software. The single reconfigurable antenna is designed with two PIN diodes, the

use of diode allow the current to flow in the antenna surface, which resonate at different frequency between 2.2 - 6 GHz frequency range and it satisfies the requirements of 2.4 – 2.58 GHz WLAN (Wireless Local Area Network) and 3.5 GHz WiMAX (Worldwide Interoperability for Microwave Access) antenna applications.

REFERENCES

- [1] A.A. Ibrahim, A.M.E. Safwat and H. El-Hennawy, "Triple-band microstrip-fed monopole antenna loaded with CRLH unit cell," *IEEE Antennas Wireless Propag. Lett.*, vol. 10, pp. 1547-1550, 2011.
- [2] C. Caloz and T. Itoh, *Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications*, Hoboken, NJ: Wiley Inter., 2006.
- [3] C. H. See, R. A. Abd-Alhameed, Z. Z. Abidin, N. J. McEwan and P. S. Excell, "Wideband printed MIMO/Diversity monopole antenna for WiFi/WiMAX applications," *IEEE Trans. Antennas and Propag.*, vol. 60, no. 4, pp. 2028-2035, Apr. 2012.
- [4] C. Kuo, C. Liou and S. Mao, "Miniaturized triple-band antennas with high isolation for MIMO antenna system applications," *Microw. Opt. Technol. Lett.*, vol. 57, no. 11, pp. 2555-2558, Nov. 2015.
- [5] C. Y. Wu, Y. P. Ma, and J. Xu, "An Efficient Approach for Reducing the Complexity of Reconfigurable Antennas," *Applied Computational Electromagnetic Society Journal*, vol. 30, pp. 237-244, Sep. 2015.
- [6] D. Peroulis, K. Sarabandi, and L.P.B. Katehi, "Design of reconfigurable slot antennas," *IEEE Trans. on Antennas and Propagation*, vol. 53, pp. 645-654, Feb. 2005.
- [7] D. Rodrigo, Y. Damgaci, N. Biyikli, B. A. Cetiner, J. Romeu, and L. Jofre, "Mems-reconfigurable antenna based on a multi-size pixelled geometry," *In Antennas and Propagation EuCAP 201 0*, pp.1-4, Apr. 2010.
- [8] D. S. Weile and E. Michielssen, "Genetic algorithm optimization applied to electromagnetics: a review," *IEEE Trans. Antennas Propag.*, vol. 45, pp. 343-353, Mar. 1997.
- [9] e. M. Coleman, E. J. Rothwell, and J. E. Ross, "Self structuring antennas," *IEEE Antennas and Propagation Magazine*, vol. 44, pp. 11-23, Jun. 2003.
- [10] e.J. Panagamuwa, A. Chauraya, and J.e. Vardaxoglou, "Frequency and beam reconfigurable antenna using photoconducting switches," *IEEE Trans. on Antennas and Propagation*, vol. 54, pp. 449-454, Feb. 2006.
- [11] J. Constantine, S. Al-Saffar, C. G. Christodoulou, and C. T. Abdallah, "Reducing redundancies in reconfigurable antenna structures using graph models," *IEEE Trans. Antennas Propagat.*, vol. 59, pp. 793-801, 2011.
- [12] J. F. Li, Q. X. Chu and T. G. Huang, "A compact wideband MIMO antenna with two novel bent slits," *IEEE Trans. Antennas and Propag.*, vol. 60, no. 2, pp. 482-489, Feb. 2012.
- [13] J. L. Araque Quijano and G. Vecchi, "Optimization of an innovative type of compact frequency reconfigurable antenna," *IEEE Trans. Antennas Propagat.*, vol. 57, pp. 9-18, 2009.
- [14] J. Li, Q. Chu, Z. Li and X. Xia, "Compact dual band-notched UWB MIMO antenna with high isolation," *IEEE Trans. Antennas and Propag.*, vol. 61, no. 9, pp. 4759-4766, Sept 2013.
- [15] J. Sun, H. Fang, P. Lin and C. Chuang, "Triple-band MIMO antenna for mobile wireless applications," *IEEE Antennas Wireless Propag. Lett.*, vol. 15, pp. 500-503, 2016.
- [16] M. Ibrahim and A.M.E. Safwat, "Metamaterial inspired penta-band monopole antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 12, pp. 1684-1687, 2013.
- [17] N. Ojaraoudi and M. Ojaraoudi, "A novel design of triple-band monopole antenna for multi-input multi-output communication," *Microw. Opt. Technol. Lett.*, vol. 55, no. .6, pp. 1258-1262, Jun. 2013.
- [18] N. Ojaraoudi, M. Ojaraoudi and K. Halili, "Design of triple band monopole antenna with meander line structure for MIMO application," *Microw. Opt. Technol. Lett.*, vol. 54, no .9, pp. 2168-2172, Sep. 2012.
- [19] N. Ojaraoudi, N. Ghadimi, M. Mehranpour, Y.Ojaraoudi and S. Ojaraoudi, "A new design of triple-band WLAN/WiMAX monopole antenna for multiple-input/multiple-output applications" *Microw. Opt. Technol. Lett.*, vol. 56, no .11, pp. 2667-2671, Nov. 2014.
- [20] S.M.A. Nezhad and H.R. Hassani, "A novel triband E-shaped printed monopole antenna for MIMO application," *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 576-579, 2010.
- [21] Y.K. Choukiker, S. K. Sharma and S. K. Behera, "Hybrid fractal shape planar monopole antenna covering multiband wireless communications with MIMO implementation for mobile handheld devices," *IEEE Trans. Antennas and Propag.*, vol. 62, no. 3, pp. 4759-4766, Mar. 2014.

