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Review: Dual Band Microstrip Antennas for Wireless Applications

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ABSTRACT

In this manuscript, a review of dual band microstrip antennas for wireless communication is presented. This review manuscript discusses regarding the geometric structures, different methods of analysis for antenna characteristics, and different types of wireless applications.

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1. INTRODUCTION

In modern wireless communication system role of microstrip patch antennas are tremendously increasing due to its demand wide range applications in radar, aircraft, missiles, satellite communications, bio-medical telemetry, remote sensing and different other wireless applications. Due to its wide range of applications in wireless application researchers and scientists has worked on this field. The concept of microstrip patch antenna has been reported by many researchers and the earliest introduced sources were given by Greig and Englemann [1] and Deschamp [2]. At that time spontaneous radiation from the narrow microstrip line was appreciated by various scientists and researchers and thereafter, lot of efforts were made to reduce the dimensions of the substrate and conducting strip to further enhance the radiation effects and bandwidth.

The microstrip patch antennas are similar to parallel plate capacitors. As capacitor contains two metallic parallel plates between these plates dielectric substrate is placed whereas in microstrip antennas bottom side of the dielectric substrate has metallic plate of infinitely extend to form the ground and at top is radiating patch. The size of the patch depends on the wavelength of radiating signal. The radiating patch and ground is composed of conducting metals such as copper or gold and these can be of different geometry depending on the radiating frequency. Figure 1 shows the general geometry of patch antenna. The different possible shapes of the radiating patches are such as rectangular, circular, triangular, semi-circular, sectoral square ring and angular ring are shown in Figure 2. Generally, the microstrip patch antennas are made of metallic patch of larger width and low dielectric substrate ε_r with thicker the height of substrate h. Further, to enhance fringe fields for the account of radiation of patch antenna the dielectric constant ε_r of the substrate

should be below < 2.5. The microstrip patch antenna is excited by 50Ω coaxial connector or microstrip line. The antennas resonating frequencies is effected by the dimension of the radiating patch are substrate height h, length of the patch L, and relative dielectric constant ε_r.

The microstrip patch antenna has lots of merits than other conventional antenna for communication system. Most of these antennas are low profile planar configuration which has very thin radiating patch placed in x and y coordinates direction of any shape on the dielectric substrates, smaller in volume as well as lighter in weight. Due to these features it is easily conformal to the host surface. Further, uses of printed circuit technology make it easier for mass production and this also reduces the fabrication cost. These antennas are easily integrated with microwave integrated circuit on the same dielectric substrates, capable of both linear and circular polarization and also utilized for dual and triple frequency operation. Due to these advantages microstrip patch antenna are used in the telemetry and communications antennas on missiles, radar altimeter, satellite communication, satellite imaging system, synthetic aperture radar (SAR) and microwave sensors applications etc [3-4].

The Microstrip antennas are the emerging technologies in the field of electronics. As these antenna can be fabricated on the printed circuit boards. However, these antennas are still in the development phase, so lots of new designs and analysis still had to be done. Again, this antenna can be achieved using various techniques such as loading of slot and notch, loading of active devices, stub loading, by using different feeding techniques, coplanar and stacked structures and meta-materials etc.. For designing, simulating and analyzing the microstrip antenna, there are several simulating software's are available such as IE3D, HFSS, and CST etc.

The microstrip patch antenna can fulfil the demand of various wireless applications. In this regard, review of the research papers for previous ten years manuscripts are done. A review paper is divided into designs of patch antenna, analysis techniques, applications and results at last section conclusion with future scope.

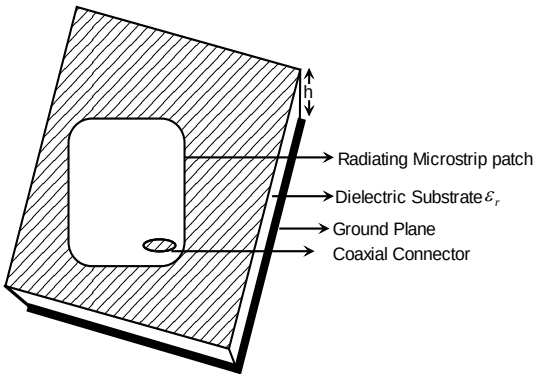

Figure 1. Geometry of microstrip patch antenna

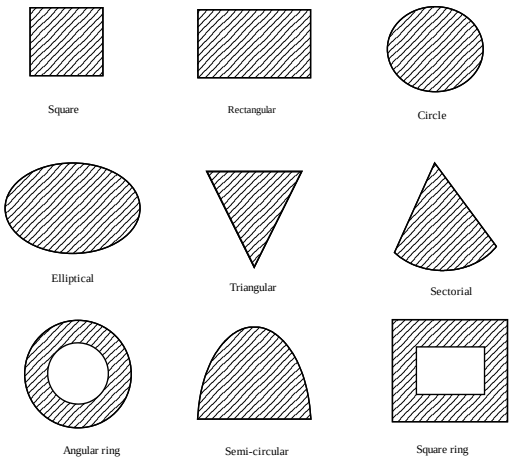

Figure 2. Different shapes of microstrip patch antenna. provided

2. DESIGNS OF PATCH ANTENNAS

Design and development of patch antenna for wireless communication has been discussed in this section. As it has been know that patch antenna can be placed on PCB for various communication devices. So, keeping this in mind researchers worked on various patch antenna designs for wireless applications.

In 1998, rectangular patch antenna for dual frequency operation was reported by Fayyaz et al. [5] in which designed antenna was fed by a microstrip line on the onside of the radiating patch while on other side of edge is shorted.

In 2001, A dual-frequency circular MSA design using single-layer, single-feed and loaded with open ring slot was reported by Jan [6]

In 2003, Chen et al. [7] reported the planar inverted-F antenna (PIFA) for the dual band applications and founded that maximum antenna gain of 2.5 dBi for both 900/1800 MHz band operations.

A compact antenna was proposed by Lin & Huang [8], they observed the S_{11} mode are generated through square patch while S_{12} mode is activated by angular patch. After that, J.W. Wu et al. [9] investigated

rectangular slot loaded antenna for dual-broadband operation in wireless local area network WLANs and obtained impedance bandwidth for two resonating frequency 2.4GHz and 5GHz as 11% and 24.6% respectively. Afterward, Zheng and Fang [10] demonstrated dual characteristic on loading two L-designed lower rectangular antenna for wireless communication devices. Further, Chang et al. [11] proposed planar quasi - Yagi antenna of wireless application and observed that antenna had dual band operation.

In 2006, Wong et al. [12] designed antenna which has the radiating structure of T- shaped and it has the radiating patch greater than ground plane which generates two resonating modes. In same year, Sze [13] proposed a circular aperture antenna with CPW fed that has slit back patch and they observed that broadside far-field pattern at both frequency bands. In same year, Guterman et al. [14] reported dual band E- shaped radiating surface back to back antenna that can be embedded in the laptops and observed two frequencies can be tuned at 1.2 to 3.5 GHz, frequency.

In 2007, Khaleghhi [15] described dual band antenna having meander line with backed ground plane for WLAN and measured 11% and 6% impedance bandwidth for lower and upper resonance frequency. Latter, Wong et al. [16] designed antenna in such a way that narrow strip generate higher frequency bands whereas other generate lower frequency band and antenna work for personnel assistant (PDA).

In year 2008, Chang [17] presented compact vertical patch antenna for WLAN operation. Latter, Callaghan and Batchelor [18] proposed disk shaped antenna with shorting wall at the edges of the patch and fundamental modes is generated at 37 mm of air as substrate.

In year 2009, Liu and Chen [19] demonstrated twin stepped patch radiators for WLAN applications. After then, Wang et al. [20] designed electromagnetically coupled antenna for dual band operation which is applicable for satellite communications. Latter, He [21] presented a high gain antenna was designed of a fork for WLAN application.

In year 2010, Hsu [22] presented E-shaped patch antenna having two resonating frequency at 2.4 and 3.5 GHz for wireless communication. Latter, Shanmuganantham and Ragharan [23] proposed a novel square patch antenna for bandwidth improvement and size reduction of the antenna.

In year 2011, Peng and Ruan [24] presented an antenna for Bluetooth and DCS applications which has been obtained from dual inverted L-shaped stub and antenna is excited though a microstrip line fed. Thereafter, Sim and Cai [25-26] designed microstrip-fed polygon slot structure for wireless local area network applications and loaded narrow slots on rectangular patch which has L-geometric slits for wireless applications. Esfahlani [27] demonstrated the frequency ratio of 4.75 can be obtained from printed patch antenna while applying coaxial fed and shorting pin on the radiating patch. Ma and Row [28] designed the dual band patch antenna which has two dielectric substrate overlapped each other and excited via a sma connector.

In 2012, Li [29] proposed dual band antenna that has L-shaped and arc-shaped stub as radiating structure whereas Luo [30] reported dual band antenna for wireless applications which has L-shaped slots. Leal et al. [31] provided the effective way of reducing size of the patch antenna using U- shaped resonator.

In year 2013, Lee [32] proposed the techniques for size reduction and wide frequency on microstrip antennas design. Further, Ansari *et al.* [33] proposed the analysis of disk shaped antenna with L-strip feeding using method of movement and circuit theory concepts. After that, Moosazadeh and Esmati [34] presented the small planar microstrip-fed square radiator using slotted conductor backed plane.

In year 2014, trapezoidal shaped antenna was proposed by Boney [35] which has half ground and antenna is excited by the meander line fed. Further, Addaci [36] proposed an antenna for dual band operation which has PIFAs that are placed closed to each other.

In year 2015, Liu [37] presented the design of stacked E- and U-shaped patches to produce dual band at 2.6 and 3.5 GHz with peak gain of 7.1 and 7.4 dBi. Further, Wang [38] illustrated the patch antenna design that is utilized for wireless communications, the geometry is notches loaded that help in providing dual band at 1.45 and 2.35 GHz.

In year 2016, Guha and Kumar [39] have demonstrated the comparison between dielectric resonator and patch antenna using different feeding techniques. They designed the patch antenna on circular geometry and resonator on solid cylinder. Later on, Sabapathy [40] design patch antenna of Yagi Uda shaped with defected ground and analysis the antenna performance by varying the parasitic elements. Further, W.-Q. Cao [41] have designed the antenna of mushroom shaped on circular patch that is utilized for dual band operation and achieved the operating frequency at 4.42 GHz and 5.74 GHz. Thereafter, Salih and Sharawi [42] designed compact U-shaped patch antenna on Roger RO4350 dielectric substrate with defected ground plane and found that antenna resonates at 2.4 GHz and 5.2 GHz. Further, Shi [43] presented dual band patch antenna that resonates at two resonating frequencies i.e., 2.5 and 3.5 GHz and these bands was achieved because of stacked patches with angular slot.

In year 2017, Zhang [44] proposed a patch antenna of two U-shaped in such a manner that second U-shape is inside the bigger U-shape. Therefore, the combine geometry produced dual band operation.

3. ANTENNAS DESIGN ANALYSIS

To design the antennas are nowadays very easy since one have various simulation tools such as CST MWS, HFSS, and IE3D. These simulation tools work of different analysis approach such as finite element method (FEM), method of moments (MoM), multilevel fast multi-pole method (MLFMM) and shooting boundary ray (SBR), finite element integral equation, method of moments (MoM) based electromagnetic (EM) software and FIDELITY finite-difference time-domain (FDTD) respectively. After that in general the paper compares there results with simulation and experimental results. Further, various scientist and researchers has proposed other analysis techniques like artificial neural techniques (RBFNN, MLP etc.) and circuit theory concept. From the traditional analysis approaches such as transmission line model, cavity model, and multiport network model are reference for the above reported approaches or same way or the other they are correlated to each other. In this view, some different patch antenna analysis techniques presented by various scientist/ researches are discussed in the section.

In 2002, A dual band patch antenna using parallel genetic –algorithm for wireless communication was reported by Villegas et al. [45].

In Shivnarayan and Vishvakarma [46] designed a notch on the rectangular patch and also given its theoretical analysis and they observed the frequency ratio variation due to the notch loading.

Latter, Chou [47] presented the analysis of patch antenna design for WLAN and DSRC applications using genetic algorithm.

Ansari [48] designed six vertical and three horizontal slots in such a way that three U-shaped in side each other and these slots play vital role in deciding the antenna characteristics.

Mishra [49] designed the L- shaped slot on the disk patch radiator and analysis the results using circuit theory concept.

Singh [50] presented the analysis of symmetrical notches and shorting loaded patch antenna and present equivalent circuit diagram by which VSWR and return loss is calculated.

Singh [51] analyzed the half disk patch antenna loaded with shorting pin and excited via a L-strip feeding using circuit theory concept. Singh et al. [52] proposed the analysis of F-shaped narrow strip antenna similar to monopole antenna as radiation pattern.

In year 2016, K. Noguchi [53] proposed patch antenna of E-shaped using modal theory and designed the equivalent circuit diagram further they have given the parametric analysis E-shaped antenna theoretically. Thereafter, Liu [54] reported the dual band patch antenna of ring shaped and analysed the designed antenna using cavity model.

4. ANTENNA APPLICATIONS

In this section, patch antenna has been discussed according to there application in various fields of wireless communication such as bio-telemeter, data telemeter wireless sensor networks and other wireless applications.

In 1995, Salvador [55] reported patch antenna that can be utilized in S and X bands applications which has array of four patches arranged in such a manner that there is spacing between two patches.

In1998, Lazzi [56] investigated experimental and numerical results for high gains, low SAR signal band and dual band microstrip patch antennas covering the frequency band (825 -895 MHz and1830-1930 MHz) .

In 2000, Lelaratne and Langley [57] investigated a single layer, multi band microstrip patch antenna operating over the frequency 1.6-2.5 GHz.

In 2001, Tong *et al.* [58] reported a dual band antenna for GSM and DCS applications, its radiating structure is overlapped over two different dielectric substrates. Thereafter, Shum and Luk et al. [59] reported dual band L-probe patch antenna operating in GSM/PCS systems.

In 2003, Yeh [60] reported compact dual bond planes inverted F-shaped antenna GSM/DCS application. , Latter, Chen [61] reported the PIFA antenna for the dual band operation in mobile communication and investigated that maximum antenna gain of 2.5 dBi for both 900/1800 band operations.

In 2004, Jung and De Flaviis [62] observed dual frequency operation for WLAN application by using rectangular patch with 4-bridges. Further, Ho-Yung Kim [63] reported patch antenna with shorting wall for wireless applications. Afterwards, S.H. Choi [64] demonstrated dual frequency patch having a backed microstrip line for industrial, scientific and medical radio and measured radiation patterns at 2.4 and 5.8GHz. After that, dual frequency MSA for high precision for GPS application was reported by Broccia [65].

In 2005, Hwang *et al.* [66] developed dual band printed antenna for CDMA (824-849MHz) and PCS (1750-1870MHz) band and measured maximum radiation gains of 0.94 and 1.89dBi for lower Q appear resonance frequency respectively.

In 2006, Lim and Leung [67] discussed dual wide band rectangular dielectric resonator antenna (BRA) and measured return loss, antenna gain and pattern radiation. Joseph *et al.* [68] proposed a compact dual band antenna for GSM and Bluetooth applications with linear polarization

In 2007, Sim and Tu [69] proposed slotted planner inverted-F antenna (PIFA) for WLAN application. Latter, Huang [70] studied dual frequency narrow strip antenna energised through electromagnetically coupled fed for WLAN and measured 3.4% and 13% bandwidth for upper and lower resonance frequency. Thereafter, Tao [71] presented dual band slot antenna for WLAN application and investigation experimentally its impedance bandwidth, radiation pattern and gain. Afterward, Encheng [75] reported printed microstrip antenna for dual frequency which has dielectric substrate of organic material for WLAN communication. In same year, Ren [72] demonstrated a compact T- shaped patch antenna for wireless communications. Thereafter, W. C. Liu [73] presented G-shape patch with CPW feed for dual band operation.

In year 2008, Rmili and Floch [74] demonstrated the design V-shaped patch for DCS/ Bluetooth applications. Latter, Ren [75] proposed the patch antenna that covers the required bandwidth of (2.4-2.485 GHz) and (5.15-5.825 GHz) with satisfactory radiation characteristics.

In year 2009, Lee [76] presented U-shaped patch antenna for wireless communications. Subsequently, Zhang [77] reported double T-shaped slot antenna for radio frequency identifications applications. Thereafter, Zeng and Chu [78] presented a slotted coupled antenna for dualband passive radio frequency identification (RFID). Latter, Choi [79] reported a novel K-shaped patch antenna for WLAN applications and measured gain ranging from 3.66 to 4.58 dBi. After then, Wang [80] described about the use of organic material as dielectric substrate for printed patch antenna in various wireless applications.

In year 2010, Shanmuganantham and Ragharan [23] proposed a novel square patch antenna for bandwidth improvement and size reduction of the antenna. Further, Park [81] reported a open stub microstrip antenna for dual frequency operation that can be used for different wireless applications.

In year 2011, Sim and Cai [25] designed microstrip-fed polygon slot antenna for WLAN applications in the 2.4/5.2/5.8 GHz bands. Panda and Kshetrimayum [82] presented narrow patch placed over dielectric substrate with microstrip line feeding used for wireless communications. A compact notched CPW-fed wide-slot antenna for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMax) applications was proposed by Lin [83].

In year 2012, Lu and Liu [84] designed reactive loaded array antenna microstrip line fed having 50Ω with gain of 14.1 dBi for 4G and WiMax applications. After that, Batra and Sharma [85] the demonstrated the method to combine the aperture and DRA patch antenna can utilized in wireless applications. Further, Salar Rahimi [86] designed electromagnetic coupled band gap antenna using circular patch that are place on dielectric evenly like an array. Later on, Tan and Ismail [87] designed compact dualband tag antenna for radio frequency identification (RFID) systems whereas Xiong and Gao [89] proposed the design of compact dual frequency microstrip antenna in such a way that it can be utilized for multi-band operation in wireless operations.

In year 2013, Ojaroudi and Ojaroudi [90] designed reactive loaded patch antenna that is energised by coplanar wave guide used for wireless communication such as PCS/ Bluetooth applications. Further, Chen [91] investigated an antenna design for GPS and UTMS which is loaded with shorting pin on the radiating patch. In same year, A novel compact reconfigurable patch antenna for tuning two frequency bands of 3G and 4 G mobile communication was proposed by Bekali and Essaaidi [34]. Ying song Li [92] studied the use of shorting wall and capacitance for enhancing the characteristics of microstrip antenna for wireless local area network (WLAN) applications.

In year 2014, Chakraborty [93] designed rectangular microstrip patch antenna that has two narrow rectangular apertures on the radiating surface as well as it aperture on the ground plane which can be utilized for WLAN Application. Later, Lin-Chuan Tsai [94] investigated a bow-tie-shaped CPW-fed slot antenna consists of a coaxial connector and two conducting strips for wireless communication applications.

In year 2015, Sharma [95] designed π slot on the patch antenna for dual band operation using aperture feeding and its size reduce on loading the slots, so can be used for wireless applications. Latter on, Bakariya [96] proposed the design of non contacting feeding to patch i.e., electromagnetic coupling between the V-shaped radiating patch and fed microstrip, it can be utilized for wireless applications such as bluetooth, WiMax, and WLAN.

In year 2016, Mathew [97] demonstrated the designed patch antenna that has V-shaped slot that is etched on circular geometry and they found that antenna resonate at two different frequencies i.e., 2, 3.5 and 5.6 GHz having gain of 4.4, 3.5 and 2.8 dBi respectively. Thereafter, Zhu [98] presented the U-shaped patch antenna for dual band operation and they observed that antenna resonates at two frequencies i.e., 2.45 and 5.8 GHz having gain of 1.37 and 4.37 dBi respectively.

In 2017, Zhang [44] designed antenna for 4G communication that has gain of 7.3 dBi and has two operating band at 1.9 and 2.6 GHz.

5. CONCLUSION

It is concluded that the microstrip patch antenna holds promising future. The dual band, wide band, and broad band antennas can fulfils the demand of various wireless applications. It has been observed from the last ten years papers that researches on microstrip patch antenna was increased and since large number of paper were reported. In these reported papers different shapes of antennas has been proposed by various research and scientists. In which E-shaped, C-shaped, U-shaped, F-shaped and H-shaped are disused more frequently by the scientists. Further for the antenna characteristics analysis were done by various scientists/researchers. They applied different techniques such as artificial neural network (RBFN, MPLN etc.) circuit theory concept, and simulation part is lacking to explain the desire characteristics patch for uneven shaped geometries. Thereafter, more different ANN tool, after that most of the paper compared there experimental results with simulated (HFFS, CST, AWR, and IE3D) results, few of them compare their results with circuit theory concept and ANN results. In this view, lots of papers has been proposed every year but still there is more possibility of more patch antenna to be designed for different shapes and geometries. Furthermore, still analysis techniques and circuit theory concept has to be proposed for patch antennas. The application of the patch antenna is also considerable part i.e. it should be lying in microwave bands.

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