Microstrip Patch Antenna for MIMO based WLAN Application: A Review

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Abstract: ***In today's life, wireless communication is an emerging means of data transmission. The application such as mobile, satellite, government as well as commercial required low profile, high performance with minimum cost antenna. The antenna is the intermediate between the device and the people for the data transmission and reception process. The data might be available in any form i.e., audio, video, or image form. Mobile broadcasting of LTE digital stream is directly related to new 4G developments. Taking a 3G network for analysis, one can find that its data transfer rate is 11 times lower than 5G. Nevertheless, the speed of both receiving and broadcasting LTE data is often of poor quality. This is due to a lack of power or signal strength that the 5G LTE modem receives from the station. 5G MIMO antennas are being introduced to significantly improve the quality of information distribution. MIMO is the distribution of several streams of information at once through just one channel, followed by their passage through a pair or more antennas before reaching independent receiving devices for broadcasting radio waves. Presently, the use of wireless communication is increasing very rapidly in human's day to day life as well as in any industry. The applications such as Wireless Local Area Network (WLAN), Bluetooth, Wi-Fi, WIMAX and ISM are the few applications, which are the foremost need of any electronic system operated by radio means. The antenna developers aim to design a compact, low profile, low-cost high-performance antenna. This paper aims to survey the existing work performed by many researchers using different configurations and technical aspects to obtain a high-performance WLAN antenna.***

Keywords: Bluetooth; DGS; ISM; Microstrip Patch Antenna; MIMO; WLAN; WiMAX; Slotting Technique.

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1. Introduction

In today's life, wireless communication is an emerging means of data transmission. Application such as mobile, satellite, government as well as a commercial requires antenna with a low profile, high performance with minimum cost [1]. The antenna is the intermediator between the device and the people for the data transmission and reception process. The data might be available in any form i.e., audio, video, or image form [2]. In the last couple of years, the growth in the wireless local area networks (WLAN) shows one of the foremost interests in the field of information and communication. Presently, the need of communication industries is that the antenna should operate at a different band with lightweight, low cost and high-performance rate. The general structure of the patch antenna is shown in Fig. 1 [3].

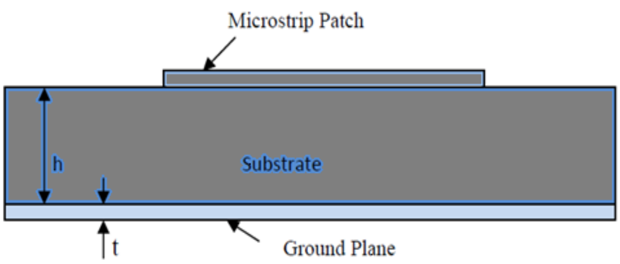

Fig. 1: General structure of Patch Antenna

A simple patch antenna might be of any shape, circular, square, rectangular an example of rectangular patch antenna is shown in Fig. 2 along with the general shapes depicted in Figure 2 [4].

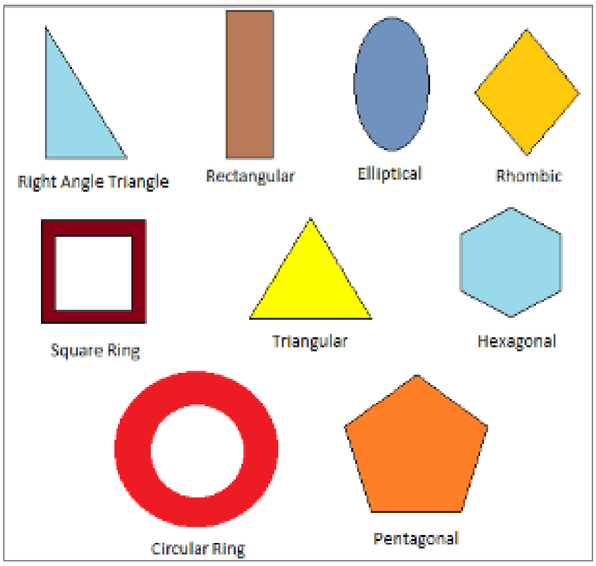

Fig. 2: Different shapes of Patch Antenna

2. Antenna Design

Before starting the design of the patch antenna, select the operating frequency, the dielectric constant of the substrate with height. Then calculate the width of the patch from the formula written in equation 1:

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad \dots\dots\dots\dots\dots (1)$$

Here, w, c, and ε_r are the width, velocity of light and dielectric constant respectively.

$$\varepsilon_{effective} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \quad \dots (2)$$

Here, $\varepsilon_{effective}$ represents the effective dielectric constant.

Due to the fringing effect, the length of the patch might be increased by ΔL on both sides. To measure the value of ΔL the following formula has been used [5-7].

$$\Delta L = 0.412t\,\frac{(\varepsilon_{effective}+0.3)\times(\frac{w}{h}+0.264)}{(\varepsilon_{reffective}-0.258)\times(\frac{w}{h}+0.8)} \quad \dots\dots (3)$$

Therefore, the effective patch length is calculated as below:

$$L_{effective} = L + 2\Delta L \qquad \dots\dots\dots (4)$$

2.1 Multiple Antenna Systems

As everybody knows, a single antenna device on the receiver or transmitter side is used in conventional radio communication, whether it is FM radio transmitting or receiving. The antenna array later was planned to increase the range of antennas. As the name suggests, in a multi-antenna configuration, more than one antenna may be used to reap the advantages of a multi-track configuration as opposed to the old design's single antenna system. When talking about multi-antenna systems, we can increase efficiency and achieve better results in multi-track situations. If there are a number of paths are available between the transmitter and receiver, the diversion has been observed [10]. Generally, there are three main techniques are available to implement the manifold antenna systems:

i. Diversity Schemes
ii. Multiple Input Multiple Output (MIMO) Systems
iii. Smart Antenna Systems (SAS)

2.2 Antenna Diversity Schemes

The diversity technique is used assuming the likelihood of fading is very low in many statistically distinct fading networks. This results in output loss due to the multi-track blurring process. By making sure that at least one of the multiple roads is better than other roads, the efficiency can be enhanced and thus efficient contact is achieved.

The first criterion can be accomplished by the use of two forms of diversity, such as diversity transition and diversity reception. Diversity is usually determined between two antennas, and each has its own path. The base station and the service station antenna are both antenna types. The base antenna is responsible for receiving the information from the transmitting antenna as well as for storing the data. The sending and receiving stations may have a lot of antennas though [11].

Here is the way by which diversity gain can be accomplished as discussed below:

- **Time diversity:** This type of variation can be accomplished by repeatedly sending identical information on sufficiently different time slots, or repeatedly retransmitting the same signal. Multiple broadcasts must be de-correlated enough to guarantee a stronger result in diversity.

- **Frequency diversity:** By utilizing this approach, the data is sent repeatedly on various bands of frequencies. Similar information can be transmitted on a broadband channel at more than one transmission frequency. This type of diversity capitalizes on the channel's broadband features.

- **Spatial diversity:** Numerous antennas are used both on the transmitter side and on the receiver side to achieve spatial diversity. Separating antennas play a significant role in enhancing the efficiency of wireless devices. From the current analysis, the researchers said the antenna had a better output with the distances of 10 λ and 0.5 λ. Sophisticated hardware and signal processing is needed in both of these cases, preferably at the end of the receiver [12]. Visual representation of techniques of diversity, including time, frequency and spatial diversity

3. State of Art: Literature Review

R. Patel and T. K. Upadhyaya in 2017 [8] presented a patch antenna designed for WLAN application. The antenna of 29 × 29 square meters has been designed, which is being fed by a stripline. The antenna has been resonated at two frequencies 2.4 GHz and 5.5 GHz respectively [8].

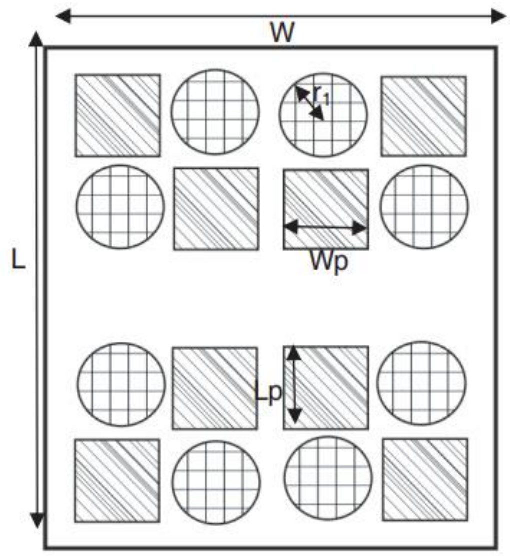

Fig. 3: Antenna proposed by R. Patel and T. K. Upadhyaya [8]

The designed antenna consists of multiple circular with square shapes having a dimension of r = 2.9 mm, with an identical length and width of 5.6 mm.

C. S. Voon *et al.* in 2018 [9] presented an antenna designed for 2.4 and 5.15 GHz frequency of size 17 mm 18 mm with 1.6 mm of thickness. The antenna finds application in WLAN and 5 G. the patch has been designed in the shape of π by slotting 2 U shaped slots on the patch as depicted in Figure 4 [9].

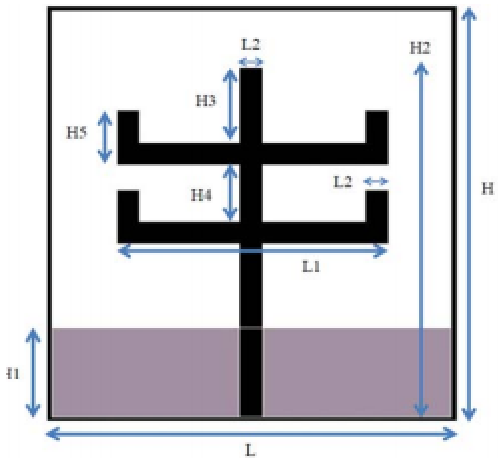

Fig. 4: Antenna proposed by C. S. Voon *et al.* [9]

Y. Zhang *et al.* [10] designed a transparent based coplanar patch antenna operated from2.36 to 2.76 GHz and from 4.92 to 6 GHz and hence utilized for WLAN applications. The transparent substrate of glass having a thickness of 1.1 mm has been used with a dielectric constant of 4.8. The antenna has been radiated with an efficiency of 45 %. The designed transparent structure is shown in Figure 5 [10].

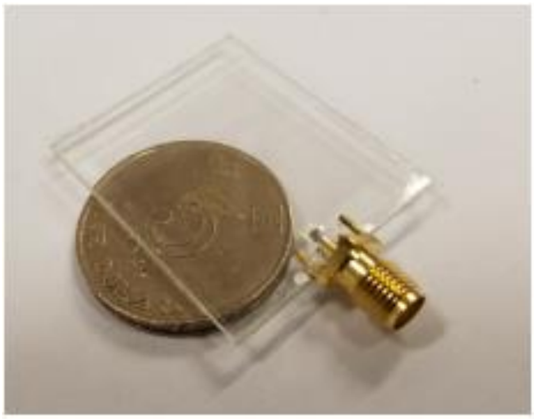

Fig. 5: Transparent Antenna proposed by Y. Zhang *et al.* [10]

J. Deng *et al.* in 2017 [11] presented an inverted F shape Multiple Input-Multiple Output (MIMO) antenna, designed to cover dual-band, one is at 2.4 GHz and the other is at 5 GHz. The antennae have been separated by 0.115λ 0 from each other. An inverted T shape slot has been used on the ground plane that helps to increase isolation between the higher and lower band. Also, to increase the impedance matching U shape slot has been created near the feeding line. The results indicate 15 dB of isolation compared to the existing design of the MIMO antenna [11].

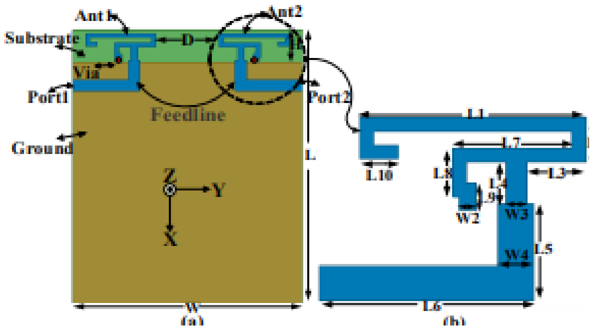

Fig. 6: Proposed Antenna by J. Deng *et al.* [11]

T. Ali *et al.* in 2017 [12] presented a low-profile patch antenna for WLAN application. The minimization of the antenna has been performed by creating a hexagonal shape slot. Also, for reconfiguration of the antenna PIN diode has been used. The ON-OFF characteristics of the PIN diode influence the distribution of current of the patch surface and hence affect the resonance as well as the reconfiguration capability of the presented antenna. In the ON state, an antenna is resonated at 2.4 and 5.2 GHz. In the case of PIN is OFF, the antenna is resonated at a single frequency. The results have been obtained with low cross-polarization and VSWR of less than 2 [12].

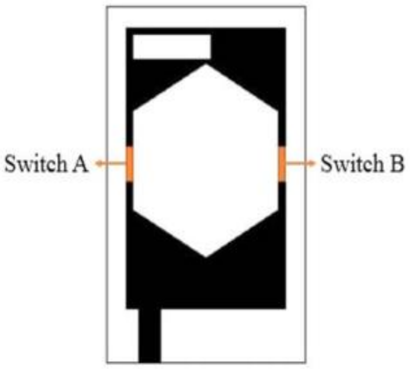

Fig. 7: Proposed antenna by T. Ali *et al.* [12]

E. Aravindraj and K. Ayyappan [13] in 2017 have designed an H-shaped patch antenna with a dumbbell-shaped slot on the ground plane known as Defected Ground Structure (DGS). The antenna of dimension 39×47×1.56 mm has been designed [13].

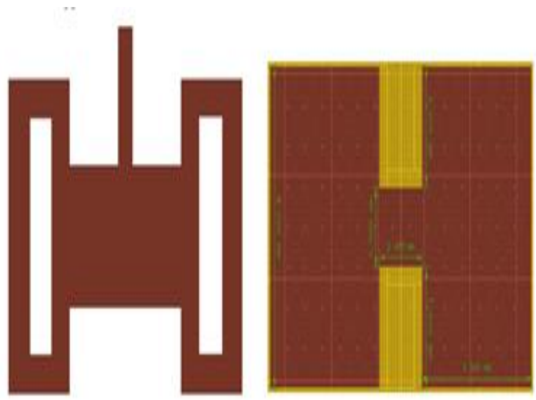

Fig. 8: Proposed H-shape with dumbbell shape DGS Antenna by E. Aravindraj and K. Ayyappan [13]

M. S. Islam *et al.* in 2018 [14] have presented a 2.45 rectangular patch antenna using DGS technology and resonated antenna for the ISM band. The designed antenna covered IEEE 802.11 g/n OFDM channel with -29.726 dB return loss [14].

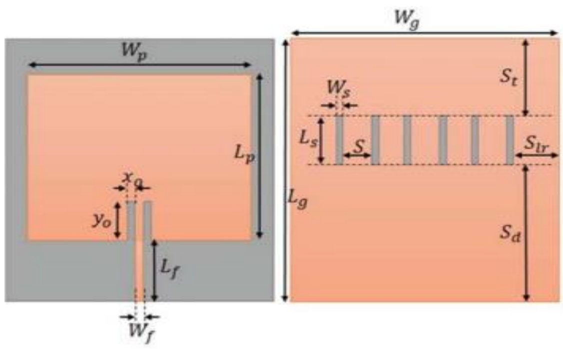

Fig. 9: Proposed WLAN antenna by M. S. Islam *et al.* [14]

D. K. Raheja *et al.* in 2018 [15] have designed a triple band patch antenna, which is being excited by coaxial feed. The antenna has been considered two resonating elements one is designed using shorted corner patch in a square shape and the other is on the upper layer of elliptical shape. The antenna has used RT Duroid 5880 as a substrate material and obtained resonance at 4.2, 4.8 and 5.8 GHz. At 4.2 and 4.8 GHz, the antenna has provided circular polarization whereas, at 5.8 GHz, linear polarization has been achieved. The maximum gain of 7 dB has been attained for all three resonating frequencies [15].

M. Mabaso and P. Kumar in 2018 [16] have designed a rectangular patch antenna, which is operated at 2.4 and 5.8 GHz. The coaxial feeding technique has been used to excite the antenna. Two rectangular strips and one elliptical shape slot has been interested, which resulted in a dual-band with enhanced bandwidth. The results revealed that the antenna is suitable for Bluetooth and WLAN applications. The concept of DGS has been used to achieve better performance and reduce the size. The structure helps to reject unwanted frequencies and hence offers wider bandwidth [16].

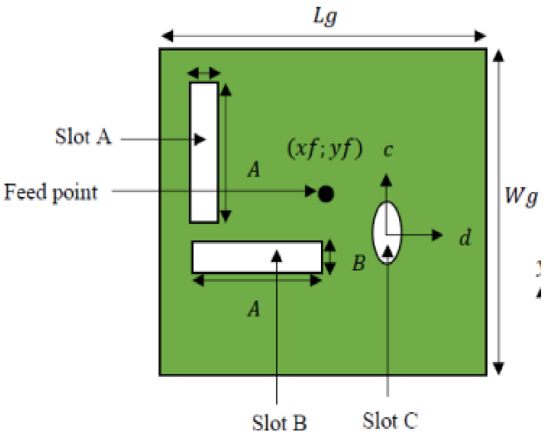

Fig. 10: DGS antenna designed by M. Mabaso and P. Kumar [16]

N. Yan *et al.* in 2017 [17] presented a directional dual-band antenna designed for WLAN application by using suspended line (SISL) technology. Using this technique, multilayer substrate has been used. In this research, the authors have used a five-layer substrate integrated with H shaped strip with a rectangular slot inbuilt, so that the antenna is resonated on 2.43 – 2.54 GHz [17].

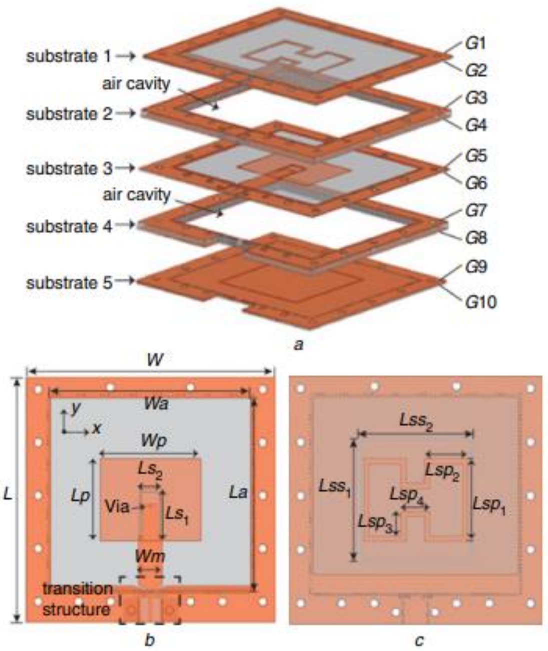

Fig. 11: SISL technique-based antenna designed by N. Yan *et al.* [17]

A. Kumar *et al.* in 2020 [18] introduced an ultra-compact including two-port in the frequency range of 3.1 to 10.6 GHz with dual band-notched ultra-wideband (UWB) features of top and bottom MIMO antenna. The complete size of this presented 2-port antenna is 19×30×0.8 mm^3 and the minimum isolation is greater than 18dB along with obtained envelope correlation coefficient (ECC) has less than 0.13. The gain of the antenna lies in the range of 1.2–2.91 dBi with a difference of 1.71 dBi only. The obtained radiation frequency has been higher than 70% throughout the operating frequency band [18].

Figures 11 and 12 correspondingly represents the proposed two-element dual band-notched UWB-MIMO antenna of radiating patches in top view and ground plane in bottom view.

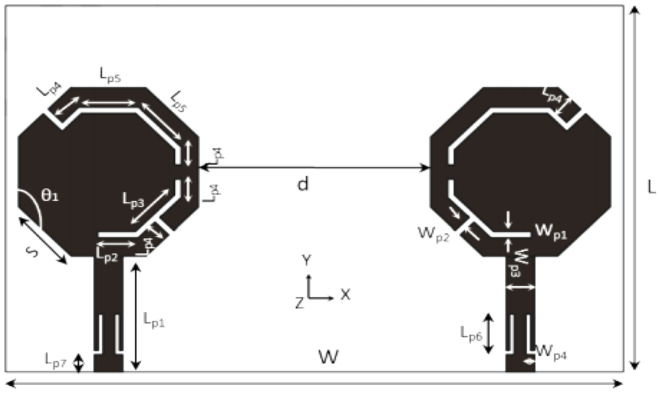

Fig. 11: Proposed Architecture of MIMO antenna (radiating patches -top view) by A. Kumar *et al.* [18]

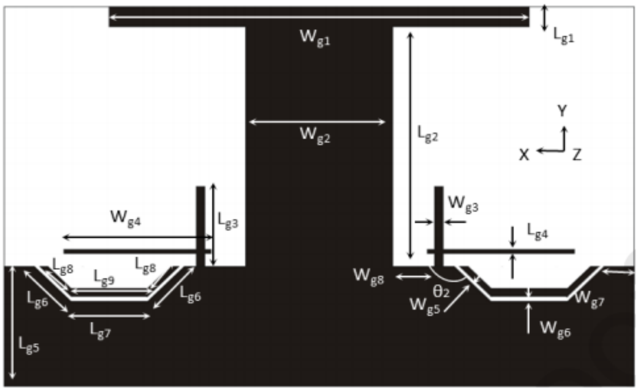

Fig. 12: Proposed Architecture of MIMO antenna (ground plane -bottom view) by A. Kumar *et al.* [18]

K. V. Babu and B. Anuradha in 2020 [19] proposed a compact Minkowski patch antenna to raise the return loss along with reduced mutual coupling in the MIMO system. Mutual coupling is the major challenge of the MIMO system which occurred due to the smaller spaces among the number of antennas. For better performance of the approach, the mutual coupling needs to be reduced, thus the separation between two antennas is large enough and it shows enhanced results as compared to the existing approach [19].

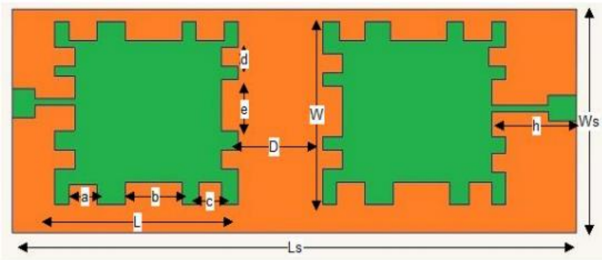

Fig. 13: Proposed MIMO antenna by K. V. Babu and B. Anuradha [19]

N. Ojaroudi *et al.* in 2020 [20] presented an 8-port antenna array that operates in the frequency ranges of 2.6 GHz band (2550–2650 MHz) for MIMO. The configuration strategy of this presented design has composed of 4-pairs low-profile dual-polarized slot antennas placed symmetrically at the corners of a mobile-phone mainboard. It also involves a petal-ring slot radiator differently fed through a pair of 50 ohms rectangular microstrip lines and operates at 2.6 GHz [20].

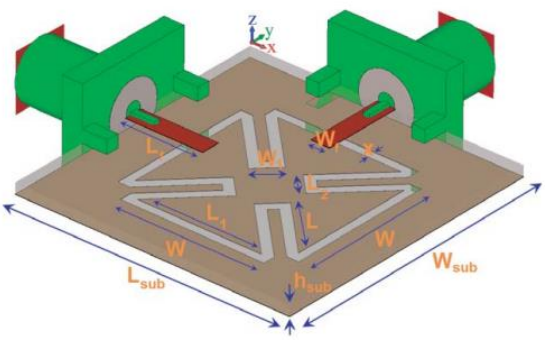

Fig. 14: Proposed MIMO antenna by N. Ojaroudi *et al.* [20]

Z. Ren and A. Zhao in 2019 [21] developed a dual-band 4-element MIMO antenna system based on compact self-decoupled pairs of antennae for 5[th] generation operation in mobile terminals. The presented dual-band 4-antenna MIMO system has been fabricated and measured along with a better agreement between the simulation, as well as measurement. Through sharing one common grounding branch for two adjacent antenna units, dual-band pairs of antennae with high isolation have been obtained [21].

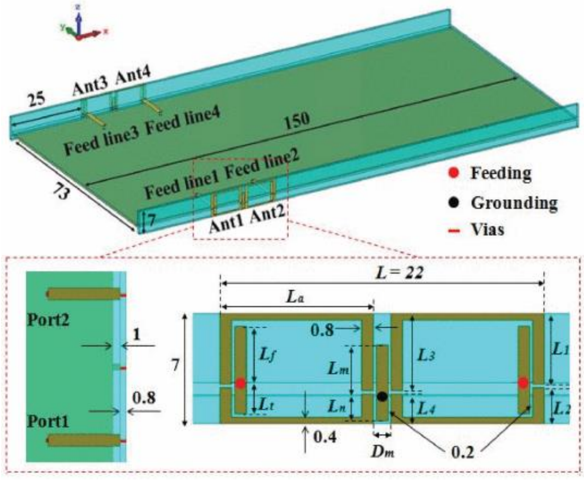

Fig. 15: Proposed 4-element based MIMI by Z. Ren and A. Zhao [21]

X. Zhang *et al.* in 2019 [22] proposed a UWB 8-port MIM antenna array in smartphones through an open slot metal frame for 5[th] generation communication. This proposed framework can be operated in the frequency range of 3.3 GHz to 6 GHz, that composed of almost all 6 GHz bands in 5[th] generation applications. The highest agreement between the measured with simulated outcomes has been obtained which leads to presented work producing promising performance [22].

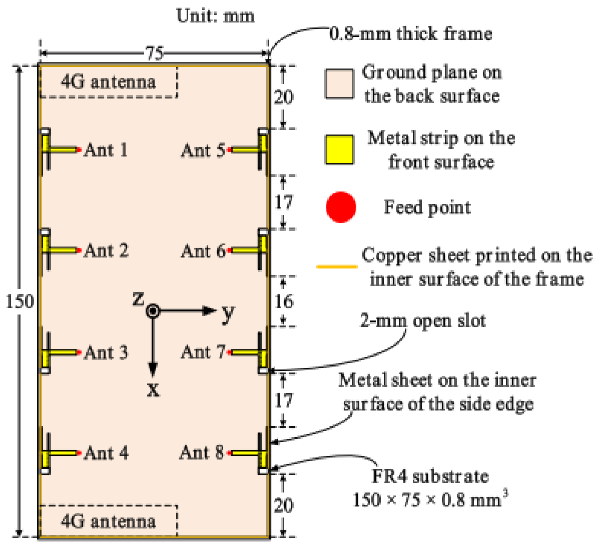

Fig. 16: Proposed architecture of MIMO antenna by X. Zhang *et al.* [22]

Z. Tang *et al.* in 2019 [23] presented a novel 4-element UWB-MIMO antenna which operates in the UWB ranges of the band including the band-rejection ability to operate in WiMAX band, WLAN band, and X-band, 3.3-3.7GHz, 5.15-5.875GHz and 7.1-7.9GHz. The 4 elements of the presented approach have identical, symmetrical and orthogonally distributed on both sides of the substrate. Moreover, the presented framework involves reduced mutual coupling, lesser envelop correlation coefficient (ECC), higher multiplexing efficiency, stable gain, with quasi-omnidirectional radiation patterns at the entire impedance bandwidth [23].

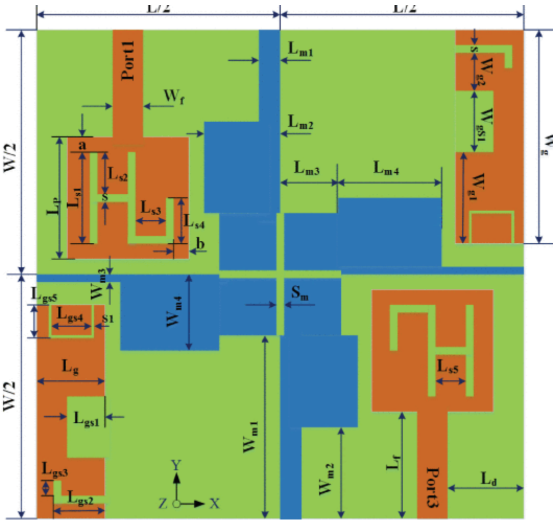

Fig. 17: Proposed MIMO antenna by Z. Tang *et al.* [23]

K. Yu *et al.* in 2018 [24] presented a 3-dimensional meta-material structure that has been developed as well as integrated through a 2-element MIMO antenna array to minimize the mutual coupling. The implemented metamaterial unit has a non-planar structure, composed of an upper M-shaped patch along with two lower U-shaped patches and that are connected through two shorted pins. By utilizing the presented meta-material structure in which reduction of greater than 18 dB mutual coupling has been achieved that greatly improves the isolation without affecting the operating bandwidth along with radiation behaviours [24].

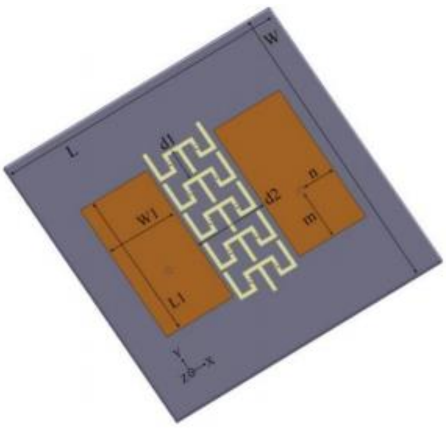

Fig. 18: MIMO antenna presented by K. Yu *et al.* [24]

A. Zhao and Z. Ren in 2018 [25] presented an antenna element that not only restricted to the property of self–isolated but also had a compact size presented for 5th generation MIMO system for smartphone devices. Mainly the size reduction is done by introducing the two vertical stubs into the original self-isolated antenna element. It has to be demonstrated that enhanced isolation, as well as efficiency of antenna for 8-antenna MIMO system, can be obtained without utilizing the additional isolated elements or, decoupling techniques. The proposed scheme is composed of a T-shaped feeding element with an inverted U-shaped radiating element including two extra vertical stubs [25].

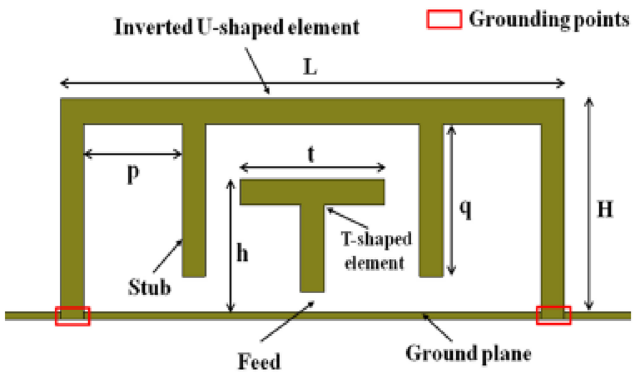

Fig. 19: Proposed antenna design by A. Zhao and Z. Ren [25]

4. Conclusion

This paper has provided a state of art or the efforts adopted by various researchers to resonate antenna at 2.4/5 GHz, which is used for wireless local area network (WLAN) operation. Multiple ways have been discussed through which the antenna has been designed to be resonated at WLAN application or for more than one application like as Bluetooth, WiMAX and 4 G etc. the authors have used Defected Ground structure, slotting in different shapes either on patch or on the ground plane and using PIN diode and multiplayer patch and substrate techniques. The performance of the antenna has been improved by optimizing the physical dimension of the antenna as well as the slots used in the design. In future, the work can be performed by integrating the above-mentioned strategies that can be useful to achieve WLAN antenna with higher performance.

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