

A REVIEW OF MICROSTRIP PATCH ANTENNA AND PERFORMANCE IMPROVEMENT TECHNIQUE

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Abstract: *Microstrip patch antenna is a scientific field of research that has opened the door to 5G communication and future 6G communication devices. Initially the microstrip patch antenna was designed in rectangular, circular, and triangular shaped and later to improve the antenna parameters, several modifications have been done in the patch structure as well as in the ground plane structure which is basically called its structural improvement/modification. Such modification helped to cover multiband, broadband, and wideband characteristics in the 5G frequency spectrum. Many performance improvement techniques are reviewed and presented in this paper. This paper also covers the necessary improvement of antenna performance parameters while geometric modifications have done.*

Key words: *Bandwidth, Diversity Gain, Gain, Microstrip Patch Antenna, Return Loss, Mutual Coupling, Wi-MAX, WLAN*

1. INTRODUCTION

An antenna acts as a transitional structure between the medium and the transmission line to propagate electromagnetic waves in wireless communication medium. Due to the advancement of technology, the demand for new applications, services, and devices has increased. Since the invention, few decades have passed due to highly research activities in this field of antenna and electromagnetic waves. The current research supports to design the microstrip antenna for present communication system.

The microstrip patch antenna (MSA) has become an excellent radiator due to its lightweight, low fabrication cost, planer configuration, and small size. It also exhibits high-performance efficiency and they are capable to work at multiband and broadband frequencies [1]. A microstrip patch antenna comprises a copper patch on one side of a standard substrate, the other side the copper acts as the ground plane. The physical dimension of the substrate, patch, feedline, and feed width are the essential parameters of an MSA. The physical dimensions help them directly to radiate at a particular resonant frequency and multiple resonant frequencies for wide range of applications. The bandwidth, gain, and efficiency of the antenna directly depends upon the physical structure of the antenna. Due to the attractive features of the microstrip patch antenna, such as simple feeding, low profile, low manufacturing cost, and easy integration, makes it very popular applicant for mobile devices. To date, different geometries have been proposed and they have validated experimentally. Such antennas exhibit improved antenna performance and miniaturized structure as well.

2. LITERATURE REVIEW

The geometry of a microstrip patch antenna comprises a copper patch on one side of a standard substrate and the other side is kept grounded with copper material. This simple structure radiates electromagnetic waves (EM) efficiently in the air or free space medium. The radiation ability of an antenna directly depends upon its size and shape. The research work progressed up to a mark when IEEE 802.11 and IEEE 802.16 got the licence to use them commercially in mobile communication and intelligent devices in 2009. MSAs have become suitable for Long Term Evolution (LTE) and Wireless Local Area Network (WLAN) applications [2]-[3]. Many compact antennas such as inverted “L”-shaped antennas, inverted “F”-shaped antennas, and planar inverted “F”-shaped antennas are available for mobile terminals and devices. Technology demands compact antennas with better channel capacity, low channel capacity loss, and increased data rate to fulfil the demand for sophisticated next-generation mobile terminals. The literature in the next section gives the idea of different geometric modification of a patch antenna that allows necessary improvement in the antenna performance. MSAs are available in many shapes like rectangular, square, circular, semi-circular, triangular, elliptical, hexagonal, and spiral. Different structures have their advantages and limitations. English and numerical-shaped microstrip patch antennas were very popular from 2015 to 2021 and such antenna shows multiband and broadband characteristics. An MSA rectangular “spiral-shaped” antenna was designed for ISM 2.45 GHz band (A. M. Mozi et al., 2012) [4]. The antenna designed and fabricated in [4] on Rogers 5880 Duroid substrate (Dielectric Constant=2.2 and thickness=0.508 mm) is a thinner coaxial-fed “rectangular spiral microstrip patch antenna” which resonates at 2.4 GHz to support WLAN application in this band. During the time of performance comparison study between a rectangular-shaped and circular-shaped microstrip patch antenna in 2014, reflects higher return loss and lower VSWR in rectangular microstrip patch antenna than in circular patch antenna (T. F. A. Nayna et al., 2014) [5]. A circular patch antenna also offers higher bandwidth and low sidelobe power than a rectangular patch antenna. Both the rectangular and circular patch structure has their advantages and disadvantages. An inverted “S”-shaped compact antenna having two elliptical slots became popular for X-band application (M. Samsuzzaman and M. T. Islam, 2017) [7]. The result reflects improved gain after addition of slots on the conventional S-Shaped antenna. Another comparative study between the rectangular patch antenna array and the triangular patch antenna array was carried out by Mouli et al. in 2015. The study confirms the higher return loss, improved gain, and more directive properties when the size of the array increases in the rectangular patch [8]. A “Butterfly” shaped MSA [9] was designed for Radio Frequency Identification systems in 2015 to cover the 5 to 6 GHz frequency band. Dual-polarized “H” shaped slot microstrip antenna was presented by W. Li et al. [10] in 2016. The result obtained from the measurement explains the novelty of the “H” shaped antenna. Two slots used to form the H shape that is orthogonally polarized. In 2016, Karthik C Airani et al. reported rectangular with elliptical-shaped MSA for wireless power transmission [11]. Amit A. Deshmukh et al. have designed a UWB MSA by combining a rectangular shape with a circular shape patch [12]. Many authors have reported differently shaped antennas to cover GSM bands, WiFi bands, WiMAX, and X bands for 5G applications. A “G” shaped antenna was designed and simulated by M. E. Bakkali [13] in 2017. A “9” shaped antenna [14], “Pie” shaped antenna for 5G applications [15], to operate at dual-band frequency ranges from 2.38-2.8 GHz and 3.0-3.80 GHz to cover wireless devices including WLAN, LTE, and WiMAX for wireless applications. A broadband dual-polarized “L” shaped slot antenna [16], was designed by W. Shi and Q. Chu in 2018 to operate in triple mode characteristics. For USB dongle applications, a modified English alphabetical “E” shaped antenna was presented by S. Jeenawong et al. [17].

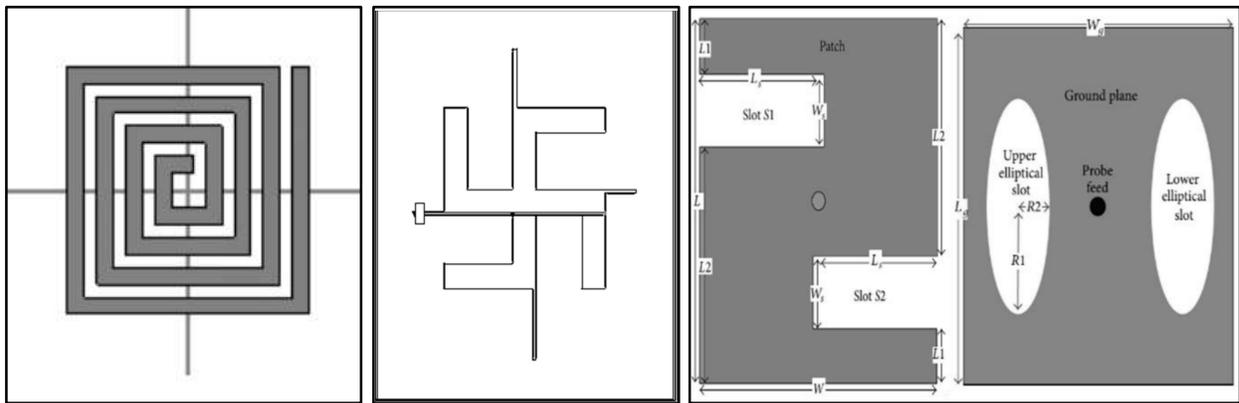


Figure 1: Rectangular Spiral Microstrip Patch Antenna [4]

Figure 2: Swastika Shaped Microstrip Patch Antenna [6]

Figure 3: Inverted S Shaped Antenna, top layer and ground layer with slots [7]

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For W-band application, an 8x8 MSA array was presented by Zhixiang Cao et al. in 2019 [20]. Proposed “Dumbbell” shaped broadband MSA covers multiple applications in 3.5/5.5 GHz WiMAX band, 5.2/5.8 GHz WLAN band, 8/12 GHz X-band, 12/18 GHz Ku-band for space and satellite communications [21]. A wideband double inverted four-element MIMO antenna having L-shaped slots for the frequency range of 2.31 GHz to 7.95 GHz in 2019 [22] presented by E. Wang et al. To improve port-to-port isolation between the MIMO antenna elements, highly integrated decoupling structure antennas have been proposed [23]. A Wideband circularly polarized antenna with L-shape slots was proposed in 2020 to achieve the frequency band 1.77 GHz to 3.52 GHz Y. Sun et al. [24]. A 4x4 rectangular microstrip antenna array achieves high gain for C-band satellite systems. It offers 560 MHz bandwidth and an overall 14.03 dB gain [25]. In 2021, several L-shaped antennas for 5G applications were reported by Jaiverdhan et al. and Y. Liu et al. [26],[27].

A wideband antenna having circular polarization characteristics at the lower frequency of the 5G band ranging from 1.0 GHz to 1.6 GHz was proposed in 2013 by Z. Y. Zhang et al. [28]. The gain of the antenna was improved by using a pair of “bowtie” dipoles near the patch to achieve a 2 dB gain improvement in the operating band. A square-shaped periodic structure was proposed in a circular pattern to increase the bandwidth by 19.26 percent from 4.38 percent [29]. The bandwidth and radiation efficiency improvement by using a Complementary Split Ring Resonator (CSRR) at the ground plane was proposed by F. Alizadeh et al [30]. The CSRR at the ground plane increases bandwidth, efficiency, compactness, and directivity over a conventional patch antenna. A microstrip antenna with a fractal “U” shaped slot was proposed by P. P. Chandran and S. Viswason [31] to improve the gain and bandwidth of the antenna in 2014.

Particle Swarm Optimization (PSO) technique to optimize a wideband antenna using an “H” shaped slot to improve the bandwidth of the rectangular microstrip patch antenna was proposed by V. R. Ekke and P. L. Zade in 2015 [32]. A net improvement of 300 MHz bandwidth has been reported by A. Das et al. Array-based structure was proposed by M. Farhan in 2016 [33] to achieve higher gain and bandwidth of an MSA. M. Farhan suggests improving the gain by increasing the number of radiating patches. D. Mittal et al. [34] demonstrated to improve the performance of the microstrip patch antenna by a significant amount after adding CSRR and Planar Split Ring Resonator (PSRR) to the antenna structure.

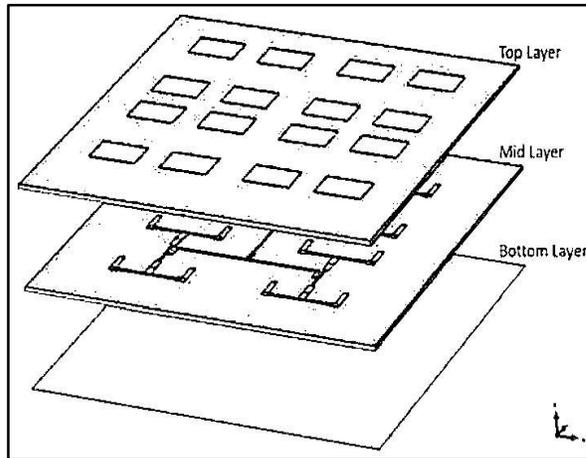


Figure 4: Structure of stack-based antenna [26]

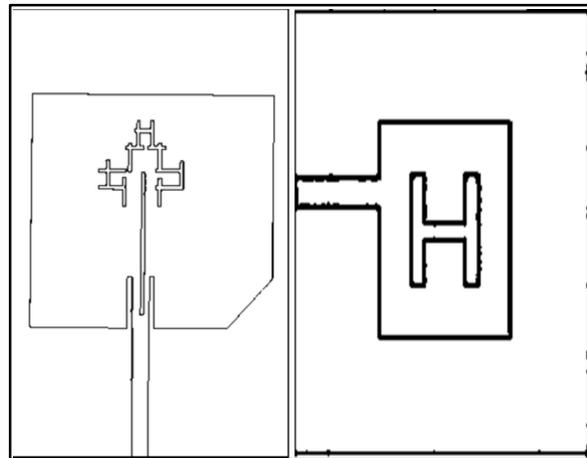


Figure 5: Fractal U-shaped slot antenna [32] and Wideband H slot antenna [33]

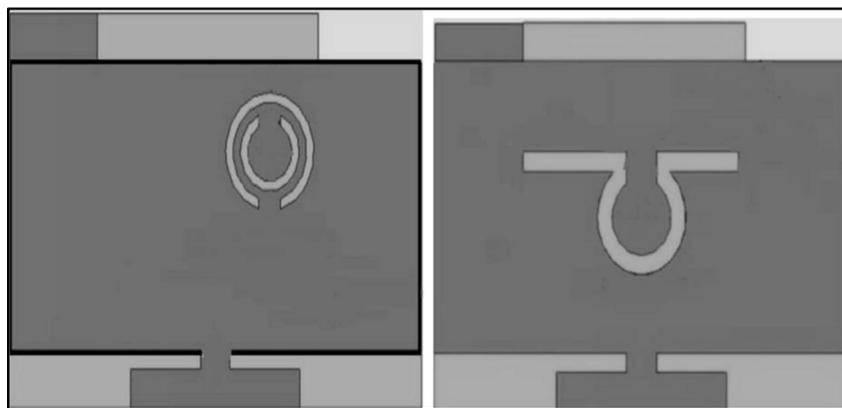


Figure 6: Rectangular CSRR loaded microstrip patch antenna [34] and rho shaped PSRR loaded microstrip patch antenna [35]

An antenna with triple-band characteristics for wireless application using a Dielectric Resonator Antenna (DRA) was proposed by G. Varshney in 2016 [35] to support the improvement of bandwidth and radiation characteristics besides triple-band characteristics. V. R. Ekke et al. proposed Substrate Integrated Waveguide (SIW) for gain enhancement of an MSA [36]. SIW approach has improved the reflection coefficient, VSWR, gain, and bandwidth of the microstrip antenna compared to the conventional antenna.

Another gain enhancement and bandwidth improvement technique was proposed by M. Assadi et al. in 2017 using the “Holey” superstrate fed by a power divider aperture coupling technique [37]. An MSA based on a periodic arrangement of Reactive Impedance Surface (RIP) was proposed to support miniaturization as well as bandwidth improvement by A. Ghosh and S. Das in 2018 [38]. Another corner-cut dipole antenna was presented by K. E. Kedze and I. Park to enhance the antenna performance [39]. In 2019 G. Srinivas et al. proposed a simple pentagonal-shaped MSA with a RIP structure to improve the gain and bandwidth simultaneously [40]. To improve the gain of a rectangular microstrip patch antenna, multiple slots have proposed by D. Madhavi in 2019 [41]. P. Kamphikul et al. have proposed a metamaterial-inspired Electromagnetic Band Gap (EBG) structure to increase the gain of an MSA [42].

Table 1 Performance comparison of different antenna structures

Ref. No.	Performance Comparison of Patch Antenna			
	Method Used	Parameter Improvement	Before improvement	After improvement
[28]	Modification of Patch	Gain	7.0 dBi	9.0 dBi
[29]	EBG	Bandwidth	4.38 %	19.26 %
[30]	CSRR	Bandwidth and Radiation Efficiency	-	Efficiency: 89%
[31]	Fractal Slot	Gain and Bandwidth	-	Gain: 18.6% Bandwidth: 100%
[32]	“H” shaped slot	Bandwidth	300MHz	600MHz
[33]	Array Based Antenna	Bandwidth	-	700 MHz
[34]	CSRR and PSRR	Gain, Impedance Bandwidth and Return loss	Bandwidth: 367 MHz Return Loss: -16.61 dB Directivity: 5.95 dBi Gain: 5.81 dBi	Bandwidth: 818 MHz Return Loss: -24.93dB Directivity: 6.43 dBi Gain: 6.30 dB
[35]	DRA	Gain and Bandwidth	Gain: 5.9 dBi Bandwidth: 350 MHz	Gain: 8.1 dBi Bandwidth: 1600 MHz
[36]	SIW	Return Loss, VSWR, Gain, and Bandwidth	Return loss: -20.5250 dB, VSWR: 1.2078, Gain: 8.3649 dBi Bandwidth: 4.89%	Return loss: -30.9301 dB, VSWR: 1.0585, Gain 9.4341 dBi, Bandwidth: 10.98%
[37]	Superstrate	Gain, Bandwidth, and Radiation Efficiency	-	Radiation Efficiency: 92 %, Gain: 16 dBi, Bandwidth: 15.35 %
[38]	RIP	Miniaturization and Bandwidth	-	Miniaturization: 55.03%, Bandwidth: 38.54%

[39]	Modified Patch by corner cut	Miniaturization, Gain, and Radiation Efficiency	-	Miniaturization:25.3%, Gain: 9.12 dBi, Radiation Efficiency: 98%
[40]	Superstrate and RIP	Gain and Bandwidth	Gain: 3-4dBi Bandwidth: 7.26 %	Gain: 8-9dBi Bandwidth: 11.80 %
[41]	Slot	Gain	3.06 dBi	6.181 dBi
[42]	Metamaterial inspired EBG	Gain	4.65 dBi	12.97 dBi

3. CONCLUSION

This review work presents various modification of patch antenna structure. The necessary modifications have been carried out to improve antenna parameters such as gain, bandwidth, return loss, isolation and many more. Thus, a microstrip patch antenna has become a successful candidate for future generation mobile and wireless communication devices.

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