RESEARCH ARTICLE OPEN ACCESS

Survey on Microstrip Patch Antenna, Metamaterial Structures and Comparison on Different Antenna Performance Parameters and Designs

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ABSTRACT
Microstrip patch antennas are the most employable antenna designs as they are having lots of advantages which attract the researchers such as smaller size, cost of fabrication and production is low. Even though Microstrip antennas have a lot of advantages to its name but these antennas come with few limitations as well, such as antenna gain being lower than normal and adequate bandwidth. Metamaterials are engineered designs which are designed, studied and fabricated to acquire unique properties like negative mu, negative epsilon in contrast with the available materials. A brief introduction to Microstrip Patch Antenna, Survey on different basic Metamaterial structures and comparison of various literature papers in terms of important antenna parameters like Resonant Frequency, Negative Scattering parameters, Bandwidth of the Antenna, Gain and VSWR is presented in this paper. Different designs, software platforms used and various applications are also illustrated.
Keywords —Microstrip Patch Antenna, Return Loss, Gain, Antenna Structure, Frequency Range.

I. INTRODUCTION

In recent scenarios wireless communications have grown expeditiously. It requires more minute contrivances to install multiband communications [1-2]. As an indispensable component of the wireless correspondence organization the antenna has the main part of the design effect [3-4]. The most congruous antenna for the wireless contrivances is microstrip patch antenna [5]. In designing of microstrip patch antenna the substrate is play most important role in the application and performance of the antenna. In basic antenna design ground, substrate, patch design, feed line and connectors are most important part [6].

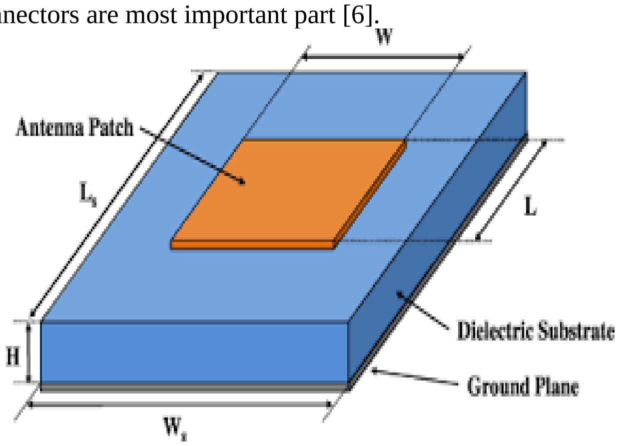

Fig. 1.Schematic of Conventional Patch Antenna

Substrate is clogged in middle of ground & a radiating small patch which becomes a basis for the patch antenna. The patch can be of various shapes and sizes which lead to different radiation patterns. The final element required for a patch antenna is the all-important feed lines. Feed lines can be of many types namely co-axial feed, microstrip thin feed, waveguide feed etc. Most of the Microstrip patch antennas have a unidirectional pattern and fabricating cost is less which makes this antenna even more usable.

Microstrip patch antennas attract researchers with their additional features like less fabrication cost, mounting cost is low, they weigh less and small size [7]. A Microstrip patch antenna is one which has ground plane at the bottom, upon which a highly conductive substrate is placed, over the substrate any shape of the patch can be designed with a feed line [3]. Usually, microstrip thin feed line is preferred with a matching impedance of 50Ω.

BroadcastinginMSAtranspiresmainlyduetoelectricandmag neticfringingfieldswheretheelectricfiled extends to the outer periphery of the patch and cause the patch to radiate. To increase the radiation, one should enhance these fields by doing any of the following a. patch width can be enlarged b. height of the dielectric can be raise dc. Choosing a substrate which has a lower εr.

Over a period, researchers have been involved in finding out answers for the few limitations experienced by the Microstrip Antennas. Possible solutions to up the bandwidth are

- Usage of a number of Resonators placed in a single plane.
- Vertical arrangement of resonators.
- Matching the impedance of the networks

Metamaterial is an artificially engineered material which exhibits properties that are not available by natural means. Unique electromagnetic properties such as permittivity (ε<0), permeability (μ<0) are exhibited by Metamaterials. If both ε & μ are lesser than zero, then these Left-Handed materials exhibit refractive index which is less than zero [23]. If the Metamaterial structure consists of thin wire elements preferably in the ground plane, then the composite materials demonstrate lower value of ε and μ is also lower if the design comprises of SRR rings. Metamaterials also show case interesting properties like reversal of Snell's Law, Doppler Effect. Metamaterials find wide variety of applications especially in mobile and broadband communications, wearable antennas [8].

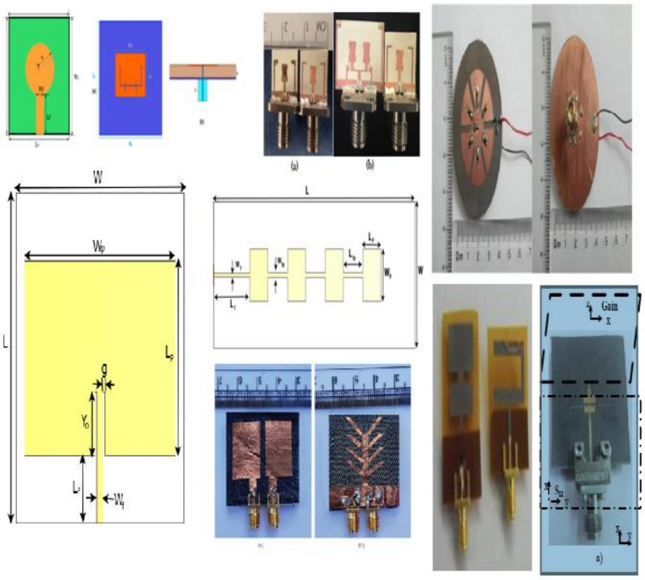

Fig. 2.Some Different Design Structure of the Microstrip Patch Antenna [7, 9-13]

II. LITERATURE SURVEY

In [5] presents the analogy between a normal conventional antenna and design with Metamaterial. This paper provides the analysis of the compared designs and a new structure of U- shaped is proposed which is productive in minimizing size of antenna as the new designed shape is etched out from the patch. The suggested antenna design is placed on dielectric having height of 1.6 mm. Feeding technique used here is co-planar waveguide. Different antenna parameters are studied which are compared between the two designed antennas. Tool used for antenna simulation is FEKO.

In [14] proposed an idea for simulation and designing of a Microstrip patch which is square in outline and uses Metamaterial. The proposed antenna design radiates at a resonant frequency between 1-3 Gega Hertz. Bandwidth achieved is of 53 Mhz and a return loss of -19.74 decibels at a frequency of 10.2 Ghz. For simulation authors use Computer simulation technology software for designing both antennas and Metamaterial structure.

In [15] designed a new antenna which radiates at a frequency of 2.45 Gega hertz. Authors claim that, the proposed antenna can be used for RF identification and its applications. A newly designed shape is of more emphasis in the paper which consist a E-shaped Metamaterial design. Its proved in the paper that, by using the new E-shaped structure, bandwidth and frequency enhancement is achieved. This designing uses CST Studio software for simulation results.

In [16] illustrated an antenna design which works for a frequency band of 4- 8 Ghz. The antenna design proves to improve its parameters. A new design of Metamaterial has been proved to achieve a depth of 2.4 in its size whereas the gain of the antenna is 4.17 decibels to isotropic value. The designed patch in the paper is a circular one which has a circular metamaterial structure.

In [17] illustrates the design of a rectangular MSA with "different C patterns" Metamaterial designs. The proposed structure has been incorporated with a height of 3.2mm for the substrate. The important feature which is extracted in the paper is negative values of both the constants which significantly improves antenna gain, operates at a good acceptable frequency and improved scattering parameters.

In [18] designed a Microstrip patch antenna which can resonate for 3 different frequencies. Metamaterial is employed for designing the proposed patch antenna which uses SRR rings. Initially a conventional patch antenna is designed which has an operating frequency of 3.56 Gega Hertz. The Metamaterial is now involved in the structure which makes the antenna radiate at a higher frequency giving much better useful range of frequencies and hence the antenna finds its applications for WiMAX. Two different shapes are designed to provide triple operating bands of three different frequencies. An innovative design of H- shaped cavity is proposed by the author for improvement in gain of the antenna

Proposed model in [19] includes a very high gain antenna which is based on the Left-handed artificial pattern. The authors claim that the suggested layout will enhance the antenna gain. The gaps in the Metamaterial layout brings the variation in the frequencies and also utilization of power decreases to a greater extend and hence these structures can be replaced with an individual antenna.

Bandwidth enhancement and much lower value of return loss is accomplished at a resonant frequency of 1.89 Gega Hertz. In the [20] performs the investigation of Microstrip antenna taking up the Metamaterial layout into consideration with the height of the antenna being taken as 3.2 millimeters. A 32.64 decibels of reduction is possible with the specified model design and the bandwidth rises up to a value of 29.2 Mega-hertz. Few advantages of Microstrip patch antenna are listed out in the paper which are accomplished with simulation results.

Not only Split Ring arrangement gives rise to Metamaterial outline but various innovative shapes and cuts are also developed by the researchers. One such is reciprocal layout of the ring called as Complementary split ring. This paper [21] implements both the split rings and comparison is done between the two to achieve less cross polarization. Using the split ring outline a multiple mode patch antenna is fabricated in the paper. The feeding techniques taken for designing is dipole butterfly. The resonant frequency achieved is 2.75 Gega-hertz in one orientation and 3.33 Ghz in the other orientation. This antenna can be widely usable for wireless communication applications as this design provides multiple bands of operation and a good selectivity for radiation pattern [22].

Design and investigation of two frequency bands resonating at 3.5 and 5.8 Gega-hertz is the main purpose of the written paper. Etching is done in the patch and the ground as well. Two slits are made in upper patch & three slits are done in lower plane. This antenna layout is relevant for wireless broadband communication [23].

Etching process is adopted for designing the antenna. Initially the ground plane is placed and then the orientation of substrate layer comes upon which the patch is placed. Patch can be of any shape and size. Researchers have modified the shapes and sizes of the patch to achieve new and unique layouts. Finally comes the input to the antenna which is by means of a feed line. Feed lines are also extensively being studied and investigated for the authors to identify which feeding mechanism yields better resonant frequency and lower s-parameter for comparison. In [24] gives a unique pattern of annular ring which is placed on the patch. Locating the ring in different coordinates brings out a great sharpening in the transmission characteristics and antenna specifications is the outcome derived. Deflecting appropriately in the plain and traditional dimensions of the structure, can give provision for upliftment of many antenna's limitations.

Metamaterial structures if clubbed with Microstrip antennas can become a source for effectiveness of the antenna model. An array arrangement of circularly placed waveguide antennas which provide higher gain is being demonstrated in [25]. Metamaterials are researchers catch due to their advantages over traditional materials are being utilized for constructing the antenna here. The array arrangement used is of copper and its property enhances when a electromagnetic signal is allowed to pass through it. Intensifying the E-field this design provides an enriched rise in the antenna gain.

A substantiate lessening in the size of the antenna can be carried out with the help of outlines which are not naturally getable like the Metamaterials. Comparison between the normal antenna and Metamaterial packed antenna is examined in the paper [25]. Authors prove that sharpness in the main beam is boosted by a measure of 1.5 dB isotropic respectively.

The non-available unique properties of the Metamaterials are always a source of invitation to the authors and workers in this domain. There exists handful of methods which are derived to calculate these unique properties. Different methods like these have been deeply investigated and studied in the paper [30]. Few of which are short circuit analysis, wave perturbation approach, Nicolson Ross method.

Metamaterials finds large applications due to its additional properties where they allow the antenna to radiate in various frequencies just with a small change in their shapes. Framed Square outline of rings, distinct C pattern, square & circular outlines were considered in the paper. A substantial rise and boost in the useful range of frequencies is the central point of consideration for the paper to take up the Metamaterial patterns [31]. Split Ring Resonator is the important component in creating and shaping the Metamaterial. Another design available to the workers is its complementary part, which can also be considered to do the same job in a more effective manner. This paper presents a innovative arrangement of antennas stacked by the rectangular shaped Complementary Split Ring Resonators, popularly known as CSRR. The antenna manufactured here consists of two patch arrays. Using the concepts of duality and Babinet principle, the Complementary SRR ring gives the negative images of Split Ring Resonator. It is proved in the paper that addition of the CSRRs has improved the frequency about 5 Gega-Hz of the conventional layout to 3.8 Gega- Hz. An additional reduction in size is obtained with the new structure of Complementary Split Ring Resonators (CSRR) [32]. Microstrip patch antenna employing metamaterial structures is one of the most innovative antennas designs because the narrow bandwidth property of microstrip patch antenna can be improved to a wide bandwidth and at times ultra-wide bandwidth. Contraction or making a cut in the ground will substantially provide a wider bandwidth. This paper shows that, by implementing metamaterial structures, the antenna performance with respect to the bandwidth is much widened by 189%. More improvement can be worked out by placing a volume of metamaterial unit cells instead of a single cell on a single patch antenna [33].

Table 1. Comparative Study of some previous work done on MSA

Ref No.	Gain	Return Loss	Freq. Range	Used Software	Design	Summary	Applications
[5]	4.4 dbi	—	1.2 GHz	CAD FEKO	U-Shaped	A traditional MSA is manufactured and fabricated. A new scheme of MSA employing Metamaterial is also investigated. Analyzing the	Wireless communication

						distinct characteristics of both the designs are listed and focus is on achieving improved gain.	
[14]	5.66 dbi	-24.2 dbi	4.6 - 4.9 GHz	CST MWS	Circular	IEEE standard of C-frequency range is the main application of focus in the paper. Layout is designed using CST and emphasis is on lower reflection coefficient.	Wi-Fi
[15]	7.5 dbi	-27.3 dbi	2.45G Hz	CST MWS	E-Shaped	A new structuring of a E-shape cut in the patch is fabricated for better S11 value. Two designs are manufactured, namely normal MSA and Metamaterial MSA with the unique said shape using CST for Wireless applications.	Wireless Communication
[16]	-	-19.7 dbi	1 - 3 GHz	CST MWS	Square	Enriched bandwidth is attained by implementing negative material artificial structures. Aim is to layout a structure of 1-3 Ghz frequency and bandwidth improvement with reduced coefficient.	Wi-Max & WLAN
[17]	Improved by 1.493 dB	Reduced by 21.72 dB	Bandwidth increase ed by 30.7 Mhz	CST	A lens of five SRR Rings	5 SRR rings placed in a unique manner which results in a pattern that leads to compact layout of the MSA. Elemental SRR is recommended and suggested for further improvements in the near future.	Wideband communication applications
[18]	1.2-3.5 dbi	-20 dbi	3.567G Hz	Super Lens	Rectangular	Antenna which radiates three frequencies is proposed. Wireless LAN & WiMAX are the major areas of applications targeted here. Primary focus is on evaluating the negative epsilon. SMA & HFSS is taken for simulating.	Wi-Max & WLAN
[19]	-	-33.6 dbi	4.807G Hz	ADS 2011.05	Multi-Band Ring	Opening remarks with defining and surveying on MSA structures, further an antenna for the frequencies of 2 Gega- Hertz to 8 Gega-Hertz is designed using left-handed layouts.	Wireless Communication
[20]	4.154 dbi	-32.6 dbi	1.899G Hz	CST MWS	Rectangular	Scrutiny of rectangular MSA is done. For better	Satellite Communicati

						effectiveness of the model, Metamaterial is outlined. Initially a conventional MSA was fabricated and studied with its characteristics, later on design was improved.	on
[21]	-	-21 dB	3.22 Ghz for SRR 3.3 Ghz for CSRR BW= 200 Mhz	ANSYS HFSS	Using SRR and CSRR loadings	Miniaturized antenna with slots. Using Complementary SRR along with normal SRR frequency lowering is accomplished and improvement in cross polarization with the said design.	Wireless Application
[22]	Gain varies from 5.12 dB to 7.27 dB (Peak value s of Gain)	-22.49 dB -18.86 dB -23.35 dB	2.75 Ghz 3 Ghz 3.33 Ghz	ANSYS HFSS	Butterfly with two SRR rings	Using dipole with butterfly structure on one side of the antenna and other side has 2 SRR rings (SRR1 becomes the reflector and SRR2 becomes the director)	Wireless Application
[23]	3.9 4.91	-32.04 dB 21.5 dB (VSW R 1.05 at 3.5 Ghz and 1.18 at 5.8 Gega-hz)	3.5 Ghz 5.8 Ghz	CST	Rectangular Slit	Two-Band MSA with two rectangular slits done in the patch and 3 rectangular slits done in the ground plane	Wimax Application
[24]	-	-24.27 dB	3.95 Ghz BW= 0.131 Ghz	CST	Annular Ring Microstrip Antenna	MSA with an annular ring is designed. Improvement on negative S11 parameter alongside shaping in bandwidth is accomplished. Practical results obtained by VNA.	Wi-Fi
[25]	7 dB improvement	-	-	HFSS	Square Lattice arrangement	Metamaterial of square lattice thin wire array, 2 and 4 element arrays for circular waveguide antenna	Different antenna applications
[30]	-	-25 dB -35.7 dB -41.2 dB	10 Ghz 15.37 Ghz 12.21 Ghz	HFSS	Rectangular	Designing a rectangular patch antenna and U shaped SRR with 1 & 2 ports. Bandwidth enhancement is accomplished with the proposed layout and major employment of antenna is in RFID Technology	RFID Application
[31]	-	-24 dbi	2GHz	CST MWS	Rectangular	Higher gain is accomplished	WLAN

						implementing a new layout of various C shaped markings on the design. Project is guided mainly by Metamaterial and the major application is for a frequency of 2.5 gega-hertz	
[32]	0.8 dB improve ment in gain	-	- 47% size reduction	CST	CSRR	CSRR array is etched on Rogers4003 substrate and compared with non- loaded one	Wimax Communicati on System
[33]	-	-7.5 dB for 1-element MTM -34 dB for 3-element MTM	13.8 Ghz for 1-element MTM 13.4 Ghz for 3-element MTM	CST	One & three element SRR layout	Comparing LHM and RHM with SRR, 1 and 3 element MTM structures are fabricated. Ultra- wide band is made possible by the design using metamaterial structure. Capacitive loading is explained in depth and with all minor and major interpretation of strips.	Ultra Wide Band Application

III. CONCLUSION

MSA is a structured pattern extensively investigated subjects in the RF i.e Radio Freq. domain for its large found applications in microwave systems. To improve antenna performance, its parameters like radiation, directivity, beam width, return loss, bandwidth, gain, size reduction, unique metamaterial designs are developed and employed. Using metamaterial adds on to the advantages of antenna parameters like size reduction, better gain, increased bandwidth, lower return loss. A review of Microstrip antenna & basic Metamaterial designs and structures is explained in the paper alongside a detailed comparison and literature survey of different metamaterial designs and structures is also presented.

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