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Design and Analysis of Slotted Microstrip Patch Antenna, A Review

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Abstract

Antennas are an inevitable part of telecommunication. In simplest words, it is a transducer that converts electrical energy into radio signals and vice-versa. The transmission and reception of signals among people that live at the physically inaccessible placescan communicate by wireless communication technology. Like any system, the wireless system also has a medium of operation, i.e., the atmosphere. Over the years, development in the field of communication has led to many types of antennas. One of these is the microstrip patch antenna which is fabricated on a substrate layer. Although microstrip antennas can provide sufficient gain, it cannot operate over large bandwidth. There must be some adjustments between various properties of the antenna. There must be some trade-off among the size of the radiating layer, number of slots on the layer, shape and size of the slots, etc. this paper presents a study of the work carried out on such antennas and presents a summary of further possible work.

Keywords: *microstrip, resonance frequency, metamaterials, split ring resonators, complementary split ring resonators, impedance matching*

INTRODUCTION

In wireless communication system, the main component used for transmission as well as reception of signals is the antenna. Over the time, communication systems have seen various types of antenna – with different shapes, sizes, orientations and designed using different materials. Different types of applications need different types of antenna structures [1]. Communication devices such as mobile phones, Wi-fi devices use microstrip antenna [1]. Microstrip antennas are mainly employed in satellite communication, military purposes, GPS and mobile phones due to its light weight and compact structure. A microstrip is a form of transmissionline that is fabricated on a dielectric substrate using printed circuit board technology [2]. As the name suggests, microstrip antennas are those which use microstrip for feeding power. Applications of microstrip are found on electronic devices in the form of patch antenna [1]. The patch antenna is designed by etching patterns from a metal layer attached to the dielectric substrate. On being fed by the feeder, the metal layer alone is a transmitting element. However, transmission properties of such a metal layer are not favourable for high gain applications. For improving the performance of the antenna, slots can be designed on the metal layer, thereby formatting the radiating surface.As radiation is done by the metal layer, introduction of slots could adversely affect the performance. It is, therefore, important to take a careful decision on the number of slots or the shape of the slots to be cut off the layer. The metal employed is usually copper, and the dielectric layer is made of FR-4 (flame-retardant) epoxy material. About the compact structure of the antenna, it is comprehensive to conclude that they can be used in almost all communication devices. Metamaterials are those which are practically engineered or designed to produce electromagnetic properties which are not usually present in nature [3]. Dimensions of conducting materials are altered to obtain permittivity, permeability or even refractive indices in the negative region, i.e., values are in the range which is not naturally obtainable.

Unlike the beginning, the interest in communication engineering has been seen to be increasing today. The means of sending and receiving information among the population without physically interacting with each other has always been an area of interest. Communication engineers have always been eager to improve the quality of the process of exchange of information using wireless methods. Antennas are the most vital part of a wireless system. The reliability of information exchange through a wireless system greatly depends on the functionality of the antennas, both transmitter and receiver. Thus, the design of a near-to-perfect antenna has always been an inevitable ambition of a communication engineer.

BACKGROUND

The introduction of microstrip antenna into the world of electronic telecommunication dates to the 1950s [4]. Despite the early introduction, it came into the real communication world in the 1970s only, following the development of Printed Circuit Board (PCB) technology [5]. Uplifted by its easy fabrication process and lightweight structure, this type of antenna came into civilian as well as military purposes. Further development in this field led to the origin of microstrip patch antenna, which has a dielectric substrate with a ground plane on one side and a patch layer on the other side [6]. Both the ground plane and the patch layer are usually made of the same conducting material (metal) as per operational needs of an antenna; microstrip antennas have various feeding techniques. A schematic diagram of a simple microstrip patch antenna is given in Fig 2.1.

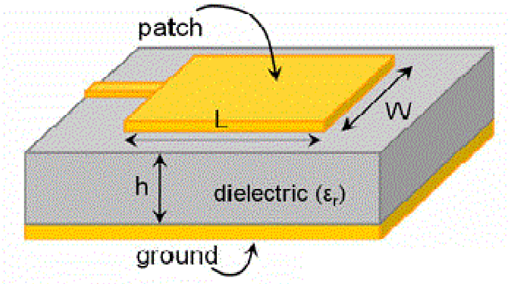

Fig. 1 *A schematic diagram of a microstrip patch antenna[7]*

The most common techniques include microstrip line feeding, coaxial feeding and aperture coupled feeding and proximity coupled feeding [8]. Each of the techniques is applicable wherever required. Microstrip antennas have very wide range of applications including mobile and satellite communication, radio frequency identification, radar, Bluetooth and broadband applications. The origin of metamaterials into the world of technology dates to 1960s when it was stated that negative permittivity and negative permeability are theoretically possible [9] and can be represented in complex equations as follows [10]:

$$\varepsilon(\omega) = \varepsilon_1(\omega) + \varepsilon_2(\omega) \tag{1}$$

$$\mu(\omega) = \mu_1(\omega) + \mu_2(\omega) \tag{2}$$

These expressions can be derived using the expressions of reflection and transmission coefficients as follows [10]:

$$S_{11} = \frac{R_{01}(1-e^{i2nk_0d})}{1-R_{01}^2 e^{i2nk_0d}} \tag{3}$$

$$S_{21} = \frac{(1-R_{01}^2)e^{i2nk_0d}}{1-R_{01}^2 e^{i2nk_0d}} \tag{4}$$

Metamaterials may be of electromagnetic, chiral, terahertz, photonic, tunable types and may be classified as double-positive (DPS), epsilon-negative (ENS), mu-negative (MNG) or double-negative (DNG) metamaterials [11]. For the design of the metamaterial antenna, simulation of the design can be done in any one of the software: IE3D, HFSS, CST Microwave Studio or Advanced Design System [12].

Microstrip Antennas

Antennas are one of the most basic components required for exchanging information using wireless communication. Antennas use air as the medium for the information to travel from the source to destination. These antennas can come in different forms and sizes according to the requirement of the application. For mobile communication, usually, the wireless devices come with microstrip antennas installed in them [13]. Microstrip antennas are structures, designed on a path layer by layer using the microstrip technology [14]. Uplifted by their key advantages over conventional wired antennas, microstrip patch antennas are used in many radio applications such as Direct Broadcasting Satellite (DBS) systems, Global Positioning System (GPS) and several mobile applications [13-21]. The operation and radiation properties including the radiation pattern, gain, directivity, current distributions of the antenna are affected by various factors. These factors include implementation of split ring resonators on the ground plane, slots on the patch layer and also the choice of the substrate [13][14]. Metamaterial technology allows us to take a material for the substrate or the patch layer and modify its dimensions to change its electrical and magnetic properties to achieve the required values of the different parameters.

Metamaterial-based microstrip antennas

Two major disadvantages associated with microstrip antennas are low gain and narrow bandwidth [22]. This has been found to be present because of the small aperture of the antenna and also the surface wave excitation in the dielectric which has been used in the antenna structure [23]. However, it is possible to expand the band of frequencies over which they can radiate. This will make them operate as ultra-wide band antennas. The expansion of the bandwidth is controlled by choosing a substrate material of low permittivity, changing the substrate thickness, using parasitic elements in the design or by introducing slots in the patch layer of the microstrip antenna [24][25][26]. It is observed that in this type of structure, i.e. metamaterial based antennas, the radiation tends to become more directional as the frequency of operation increases leading to higher gain. The energy radiated by the antenna is mainly from the monopole feed at low frequencies while metamaterial based patch layer contributes more to high ones. Also, at low frequencies, the radiation loss due to the substrate is more, so the radiation efficiency also reduces correspondingly [27].

The effective dielectric constant experienced by electromagnetic waves while travelling through air as well as a conducting medium us given as:

$$\varepsilon_r = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \text{ for } \frac{w}{h}>1$$

Where, ϵ_r is the effective permittivity of the substrate, h is the height of the substrate and w is the width of the patch.

For high directivity of radiation from the antenna, it is advisable to incorporate electromagnetic band-gap materials or frequency selective surface materials on the ground plane of the antenna. Such antennas that use metamaterials have lesser complex feeding systems [28]. Further, using zero-index metamaterials in the fabrication of the antenna can be helpful to control the direction of emission. The size of the antenna plays an important role in defining the emission properties as the aperture size of the antenna could affect on its directivity [29].

The bandwidth of an antenna depends on the frequency response of the transmitted signal [30], which can be made larger by using discrete cells in the design. Such designs have split ring resonators which are electrically tunable. This fact makes it possible to control the resonance frequency by varying the antenna dimensions**.** Further, the coupling between the elements is made better by increasing the impedance matching by using slots on either side of the feed line [30]. For antennas fabricated on PCB, resonance frequency is varied by changing the dimensions of the transmission line [31]**.** Above correcting the resonance frequency, placing slots near the feeding line also increases the radiating power [31].

Omni-directionality of an antenna can be achieved by using monopoles, dipoles, magnetic loops, etc. in the structure [32]. However, these planar structures are noted to radiate with a very low gain [33]. An easy approach to overcome this problem and achieve high gain is to use metamaterials. These are artificially engineered structures to achieve electromagnetic properties that are not naturally available [4]. Instead of using a planar structure, cylindrical microstrip patch antenna can also be designed to act as the primary radiator [32]. These types of structure have aluminium walls that act as cavity walls. These walls serve to direct the radiation in the direction of interest. Such antennas have a very high radiative power and are also highly omnidirectional [33].

Depending on the design of the antenna structure, feeding sources can also be optical in nature. Metallic nano-structured metamaterials can modulate light energy through surface plasmons. The resonance frequencies, in this case, can be controlled by varying the geometrical parameters of the antenna [34].

It has been experimentally framed that electric or magnetic dipole along with a loop can be used for getting uniform radiation pattern. Coplanar waveguide transmission lines also may be put into design. This is done to make the feed structure as convenient and practical as possible. If a broadside radiation pattern is desired, it can be achieved by exciting a circular patch i.e., by designing the patch layer in the form of a circular structure [32].

Resonance Frequency and Impedance Matching

Impedance matching is the procedure to match the input impedance of an electrical load with the output impedance so that maximum power is transferred from source to load [35]. Resonance frequency indicates the frequency at which maximum desirable performance of an antenna is achieved [35]. It is basically the frequency at which the inductive and capacitive impedance of the antenna is negligible, and only the resistive impedance contributes to the antenna resistance. A depiction of resonance frequency and impedance matching are given in Fig 2.2 and Fig 2.3, respectively. Both resonance frequency and impedance matching can be controlled by varying the properties of the substrate.

Microstrip antennas can be miniaturized by using high permittivity materials for making the substrate [36]. On top of that, patch elements can be designed to have slots on it to overcome the drawbacks suffered by a conventional patch antenna. In the process of designing the antenna, it must be kept in mind that insertion loss of the antenna increases with increase in the number of complementary split ring resonator (CSRR) planted on the ground plane. Basically, the performance of a CSRR is like that of an electric dipole excited by an axial electricfield that propagation properties like a negative-permittivity medium[38][39]. There exists a stage at which the frequency of operation of the antenna becomes independent of the size of the antenna. This condition is called zeroth-order resonance [40].

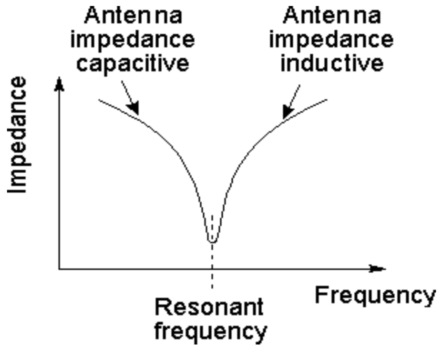

Fig. 2 *Resonance Frequency of an antenna [37]*

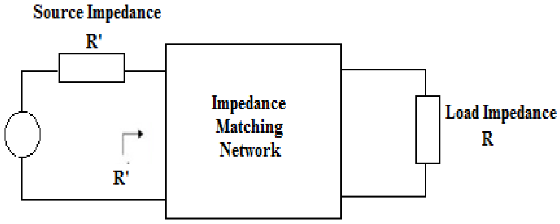

Fig. 3 *Diagram showing impedance matching [41]*

According to the need for the design, the number of dipoles may be more or less. This is possible because less number of dipoles with larger gaps can be replaced with many dipoles with smaller gaps [42].

There is also a possibility of designing microstrip antennas with one or two arms. Such antennas are called transmission-line metamaterial antenna [43]. For the type with more than one arm, each can operate at different frequencies. In such antennas, the resonance frequency is independent of the number of unit cells in the structure. An antenna structured on the Rogers RT/durad substrate which has relative permittivity $\varepsilon_r = 2.2$, could be diagnosed to be exhibiting larger inductance and conductor loss, which greatly affects the radiation pattern. Impedance matching for the one-arm structure is relatively harder because the antenna resistance (which can be expressed as the sum of radiation resistance and loss resistance) is highly sensitive to the variations in the frequency ofoperation [44]. The matching is simpler in the two-arm structure, but care must be taken in the matching of each arm so as not to interfere in the radiating process by the antenna. One disadvantage of the two-arm structure compared to that of one-arm is that it suffers almost double the return loss[45]. The metamaterial patch size is much smaller than that of the conventional microstrip antenna and such structures can be used as double resonance antennas [46].

Split Ring Resonators (SRRs)

Split ring resonators are structures meant to improve the radiating properties of an antenna by inductively loading the loading element [45]. It consists of two metallic rings which may be circular or square, with gaps across opposite sides. Two different types of SRR are shown in Fig 2.4. The geometric parameters of the splits greatly affect the resonant frequency of the antenna [44]. SRRs are designed rather easily using metamaterial technology.

Metamaterials can be categorized as µ-negative or ϵ-negative. A simple way to make a substrate behave like a metamaterial is by creating splits separated by an offset angle of 45^o [47]. Two offset structures are possible in this way: one with normal cuts which behave as a normal patch antenna and other with offset-cut structure which shows metamaterial behaviour. So, a microstrip antenna with splits having offset cuts is expected to exhibit metamaterial behaviour [47].

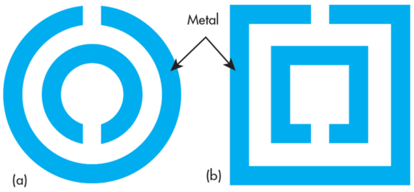

Fig. 4 ***(a)*** *Circular SRR and* ***(b)*** *Square SRR [48]*

Normally, high permeability metamaterial is preferred for designing microstrip antenna [49]. Further, if the axis of the split ring resonator is made parallel to the magnetic field in consideration, magnetic resonance is produced [49]. In an SRR structure, the coupling between the SRR and the patch layer creates capacitive coupling which helps in reducing the resonance frequency [50]. The size of the microstrip antenna can be reduced by designing it using SRR structures on a metamaterial based substrate. Thus, the orientation of SRRis very important in the antenna structure [49].

In addition to controlling the gain and directivity of the antenna, it is also possible to frame the radiation pattern of the antenna by varying the dc voltage of the feed structure. Another approach to alter the radiation pattern is to design small antennas into a single aperture antenna. A common example of this structure is a 4x4 array antenna excited by a small loop antenna. However, it must be remembered that coupling between elements of such array should be as minimum as possible to reduce dispersion of surface waves. Also, source matching near the resonance frequency gives efficient radiation. Also, the resonance frequencies of each of the individual array element can be controlled to control the direction of emission of the overall structure [51].

The frequency of dominant resonant mode of a split ring resonator (SRR) is given as:

$$f_{SRR} = \frac{c}{2\pi^2}\sqrt{\frac{3(r_2 - r_1 - w)}{\mathrm{Re}(\varepsilon_\mathrm{r})\mathrm{r}_1^3}}$$

where, c is the speed of electromagnetic waves, r_1 and r_2 are the outer radii of the inner and outer rings of the SRR, w is the width of the ring, ϵ_r is the effective permittivity of the FR-4 epoxy substrate.

Complementary Split Ring Resonators (CSRR)

Split ring resonators serve to aid in producing the desired magnetic susceptibility of a conducting material. If an SRR is etched from the conducting patch layer of an antenna, then it is called the complementary split ring resonator [52]. CSSR is primarily used to reduce couplingbetween the antenna elements [53]. Two different types of CSRR are shown in Fig 2.5.

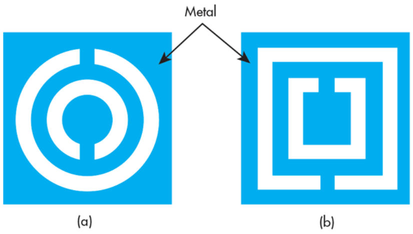

Fig. 5 ***(a)*** *Circular CSRR and* ***(b)*** *Square CSRR[48]*

An antenna can be made to operate at different resonance frequencies according to different bandwidth requirements. It can be varied from one to another by varying the dimensions of the complementary split ring resonator (CSRR), which is designed on the ground plane. A few approaches of carrying out this process are by modifying the geometry of the ground plane, using multi-layered substrate or by introducing slots on the substrate [54]. Although, the most user-friendly approach is to introduce slots, however, the size of the slots and the gap between two slots are very important. It is often desirable to design small slots with large gap size rather than using larger slots with small gap size [43]. Changes in any of these two parameters can affect the resonance frequency of the antenna. To make maximum use of these properties, the effect of the presence of other parameters isminimized by using CSRR of larger radius [43]. Also, larger radius-CSRR contributes to good radiation parameters at lower frequencies [50].

The properties of the dielectric substrate that contribute to the radiating properties of the antenna can be controlled by controlling the amount of conducting and non-conducting parts of the substrate. If multiple dipoles are used for feeding the antenna, the gaps between each pair of dipoles are very important. The size of the gaps is also significant. The resonance frequency of the antenna can be reduced by reducing the gap size. There are two different types of resonances: electric and magnetic [55]. The properties of radiation of an antenna are mainly due to the magnetic resonance. The magnetic resonance is mainly affected by the dielectric properties of the substrate, i.e., the dielectric constant. The choice of substrate is important because the radiation pattern can be distorted if the current distribution in the substrate is not uniform. A common way of reducing this problem is stacking of two or more layers of different materials to form a stacked substrate [55].

A planar metamaterial antenna with one or more slots on the patch gives better performance [56]. They are generally in the form of rectangle and CSRR on the ground plane. The presence of CSRR serves to reduce the electrical size of the antenna and reduces return loss [56]. Further, the presence of slot and notches on the antenna induces changes in the inductance and capacitance of the antenna. However, the resistive effect of the circuit is negligible. The changes in these properties of the circuit shift the resonant frequency. Also, the quality factor of the physical antenna improves with the slots and notches. On the other side, the CSRR on the antenna has a negative effect on the value of the quality factor but also increases fractional bandwidth. If there is a need to cause a huge shift in resonance frequency, the overall effects of the slots, notches and the CSRR are considered. Over experimentation, it can be proved that antennas with metamaterial-based ground plane have reduced electrical size and higher gain [57].

Loading and Feeding Techniques

The most common approach for designing a microstrip patch antenna is by meta-material loading. The return loss of a microstrip patch antenna decreases with increasing transmitted frequency. In case, where dual resonant frequencies are required, split ring resonators are used instead of CSRR [58].

Coming to the loading of the microstrip antenna, generally, there are two types: electronic band gap (EBG) loading and electric-LC (ELC) loading [59][60]. In an ELC loaded antenna, a monopole radiator is used along with an ELC element. In structures where both ELC and EBG loading are used, periodic unit cells made of metallic patches on the same side of the ground plane are designed [56]. This type of loading has an impedance matching which is significant in the ultra-wide band (UWB). Both EBG and ELC loading contribute to stable omnidirectional radiation patterns and can be used for WLAN and WiMAX technologies [61].

Although antennas designers prefer high permeability materials, sometimes, negative-permeability media are also used to act as a small antenna element [62]. This is done to structurally amplify the gain and increase the bandwidth. If the antenna is fed by using a monopole, then by increasing the length of the monopole or by decreasing the substrate thickness, the resonant frequency can be lowered [63].

The split ring resonator implemented in a microstrip antenna is very important. If the size of the resonator is much smaller in comparison to the resonant wavelength, the structure acts as a compact dual-band antenna. Dual band antennas are formed by combining two different resonance modes [64]. Mutual coupling between conductors and the soldered parts add to the shift in the resonant frequency at higher frequencies. Thus, it should be optimal for design that the interaction between these is minimized as much as possible. The mentioned interaction is a source of lower and higher modes. Lower modes are due to the split ring resonator structure while higher modes are the result of implementing complementary split ring resonator. The higher modes produce comparatively more gain [64].

Composite right/left-handed transmission lines can be made use of in multiband transmission systems. Such structures can exhibit infinite transmission bandwidth at zeroth order resonance. This means that the frequency of operation of the antenna is independent of the physical dimensions of the antenna [65]. Such antennas with zeroth order modes are capable of producing high directivity and very low dissipative loss. Though, a trade-off is necessary between reduction in antenna size and the resulting bandwidth [66].

Simulation Techniques

Metamaterials having negative permittivity and permeability have exhibit Snell's law, Doppler Effect, etc. [67][68]. These materials are significant in the microwave frequency range i.e. 300MHz to 30GHz. Due to the difference in properties between the metamaterials and the conventional FR-4 epoxy substrate, the antennas made on them are also of different sizes [69]. To make easy the choice of material and design for fabrication of the antenna, simulation software is required to examine the properties of the proposed antenna.

Fig. 6 *ANSOFT HFSS 13.0 [70]*

HFSS is the standard software for getting 3-D full electromagnetic field simulation of an antenna. The licensed version of ANSOFT HFSS 13.0 is depicted in Fig 2.6. HFSS serves to provide S-, E- and H-field parameters and thus, an efficient way to generate a solution to the problem [11].

This software provides virtual counterparts of real-time components used for making a physical antenna. A variety of materials that could be opted for as a choice for the substrate of the antenna, metal for the patch layer or even the different types of ports that can be used for feeding the antenna are available.The designed model can be simulated over a desired range of frequencies. Besides retune loss, the results may be in the form of gain, radiation pattern, directivity, radiation intensity, etc. Thus, any property of antennas can be studied after simulation of the model using this software.

Effect of choice of materials and design on antenna parameters

The HFSS software has been used to simulate different designs of the antenna and also, their performance studied. It has been seen that antenna performance is affected by the design and the choice of materials use to fabricate the physical antenna [71][72]. The presence of SRRs and CSRRs enhances the performance of a microstrip antenna by giving higher bandwidth, multiple resonance frequencies and reduced physical size [71][72][73]. The effect of slots and notches on the return loss suffered by a slotted microstrip antenna along with the corresponding is depicted in [53]. The performance of the antenna in interest has been tested in three cases as in effect of: (a) patch with and without slots (b) patch and CSRR at ground plane (c) patch, notches and CSRR at theground plane as shown in Fig 2.7.

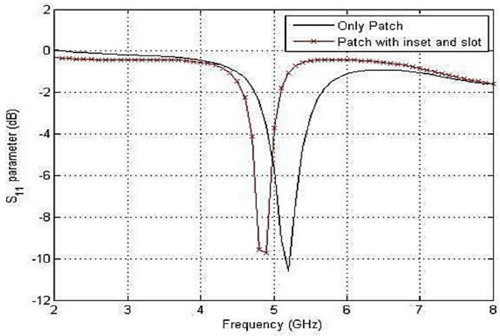

Fig. 7(a) *Resonant frequencies of the antenna with and without the slots. [56]*

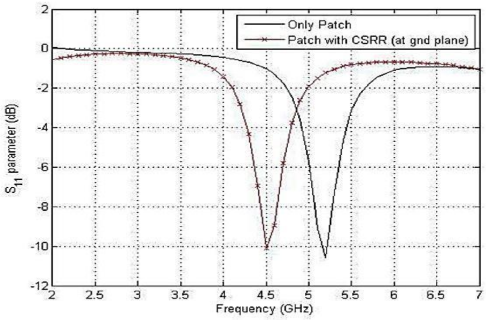

Fig. 7(b) *Resonant frequencies of the antenna with CSRR at ground plane. [56]*

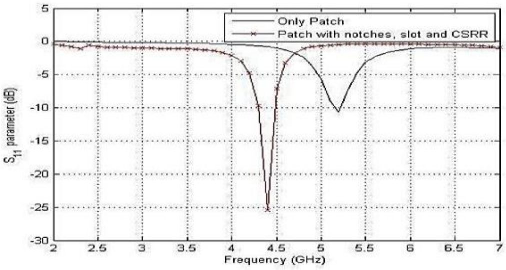

Fig. 7(c) *Resonant frequencies of the antenna with slots and CSRR at the ground plane. [56]*

The analysis done by Sivaranjan *et al.* leads to an interpretation that resonance frequency of an antenna is affected by the presence of slots, notches and split ring resonators. The quality factor of the electrical equivalent circuit improves with slots and notches. Further, the presence of CSRR in the ground plane induces more shifts in resonance frequency compared to those caused due to slots and notches only. The combination of slots and notches in the antenna patch and the CSRR in the ground plane gives even more flexibility to the resonance frequency of the antenna.

M.Z.M. Ziani *et al.* present the comparison of the performance of the antenna in terms of return loss or S_{11} parameter of antennas designed on an FR-4 epoxy substrate and that on a metamaterial substrate in [74]. The common structures that could be employed in such a design are split ring, symmetrical ring, S and omega structures [75]. The performance of the antenna in terms of return loss and the corresponding resonance frequencies are shown in Fig 2.8.

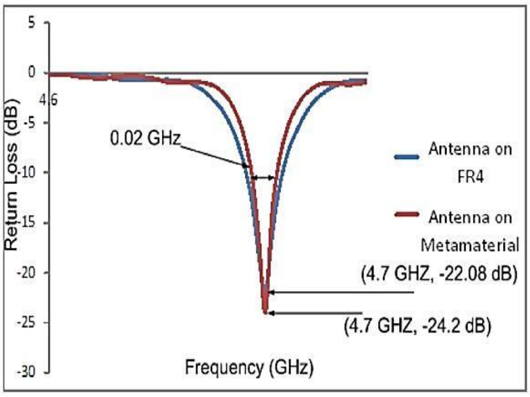

Fig. 8 *A comparison of return losses of the antenna fabricated on FR-4 epoxy substrate and metamaterial substrate [75]*

This graph shows that, even though the difference is not large, an antenna designed on metamaterial substrate produces lesser return loss than that designed on the FR-4 epoxy substrate.

Overall, the performance of the antenna can be enhanced by incorporating features such as patches, slots, notches, split ring resonators, complementary split ring resonators, etc. and by choosing a material for designing the substrate.

Effect of slot size on the performance of the microstrip antenna

The size of a microstrip antenna can be reduced and bandwidth can be enhanced by making slots of proper size in the ground plane [76][77][78]. The dependence of the performance of the microstrip antenna on the size of the slots has been described by Raj Kumar *et al.* in [79]. The slots have been made in the ground plane of a rectangular microstrip antenna of dimensions 29.57 mm x 38.08 mm, having a patch of the same size and the substrate is an FR-4 epoxy material of relative permittivity $\epsilon_r = 4.3$. This antenna has the feed position 5.3 mm below the centre of the antenna.

The performance of the antenna in relation to the size of the slots has been shown in the following tables.

Table. 1: *Performance comparison of antenna in [79] for different slot widths*

Slot Width (mm)	f_r (GHz)	Return Loss (dB)	B.W. (MHz)	Gain (dB)	% η
1	2.3999	-9.018		7.035	92.40
1.5	2.3901	-27.68	39.9	7.007	91.65
2	2.377	-20.39	42.9	7.005	91.55
2.5	2.3493	-19.84	41.5	7.065	92.59
3	2.3454	-20.16	39.5	7.103	93.32
4	2.3417	-22.23	38.8	7.362	98.29
5	2.3381	-22.88	37.6	7.326	98.68
6	2.3359	-23.16	36.6		

Table. 2 *Performance comparison of antenna in [79] for different slot lengths and slot width = 1.5 mm*

Slot Length (mm)	f_r (GHz)	Return Loss (dB)	Gain (dB)
3	1.714	-23.29	6.106
5	1.704	-31.94	6.109
8	1.608	-30.54	5.98
10	1.544	-18.72	5.865
12	1.465	-15.22	5.588
14	1.388	-17.19	5.57

The analysis of the microstrip antenna in [79] in relation to the varying size of slots in the ground plane has been described. Raj Kumar *et al.* reports that increase of slot length and width reduces the resonant frequency. However, reduction of the size of an antenna is more contributed by slots in the patch. Further, bandwidth and gain are more affected by slots in the patch. The impedance matching of the antenna is a function of both the slot length and width. By optimising feed, slot length and width, the antenna performance can be enhanced and efficiently utilized for mobile communications.

Current Status

The increase in demand for wireless communication and information transfer using mobile devices has created the need for development of antennas. The most common type which fits easily in all communication devices is the microstrip antenna. Due to its compact and light weight structure, these antennas can fit anywhere in the communication circle [80]. In addition to physical parameters, it is also important to keep in mind the effect of the power radiated from the battery spice of the device on the human body. All these considerations have led to the design of a smaller but efficient antenna structure. Microstrip antennas are one such structure on which antenna designers are focussing. In the recent times, there has been an incorporation of fractal structures, which are popular because of the space filling and self-similarity properties [81][82]. Self-similarity implies that an object is exactly like a part of itself at different dimensions. Space-filling is the process of reduction of the total area occupied by the antenna thus contributing in the miniaturisation process. In this case, the resonance frequency of the antenna is affected by the size of the ground plane [83][84]. On the other hand, it has also been stated that a quarter-wavelength antenna inscribed on the FR-4 epoxy substrate has its radiating properties independent of the size of the ground plane [85]. Further, a proper variation of the dimensions of the proposed structure can produce optimal performance [86][87].

STATE OF THE ART

The present growth in the combined field of electronics and communication demands better performance in the expense of low power, devices of lesser size and still reliable performance [88]. Microstrip antenna with slots on the radiating patch layer is currently the major focus point of antenna design. It is true that if we want to make sufficiently large radiating layer, then radiated power should also be maximum. However, the performance is not optimum in this case. The antenna performance is affected not only by the number of slots, but also the shape in which the slot is made on the layer [89]. Therefore, there may be a need to make some features on the radiating layer. This is expected to change the radiation pattern of the antenna and further, the gain and thus the performance may be optimized. However, precise dimensional calculations of such a small structure may be a challenge.

The research into the metamaterial based antenna has become a promising paradigm; however, due to the practical requirements such as low ohmic loss, wide operating bandwidth, simple structure, etc., the progress in metamaterials has not yet created the expected impact on the research community. Therefore, more attention must be paid towards the development of metamaterial based antenna for UWB applications.

Metamaterials are artificial structures to provide electromagnetic properties not readily available in nature. From this generalised concept, the focus of the research and development of metamaterial can be in any quadrant if the proposed artificial structures feature the unique electromagnetic properties.

To address the variety of engineering challenges in the field of UWB communication, technologies based on metamaterial can be developed. In this regard, the considerable objective is to design a metamaterial based microstrip slotted antenna for UWB applications. Analysis of the designed antennas would be done on the parameters like S_{11} (input port voltage reflection coefficient), S_{12} (reverse voltage gain), S_{21}(forward voltage gain), S_{22} (output port voltage reflection coefficient), overall gain, directivity of the antenna, etc. to meet the goal of the current trends in UWB communication.

CONCLUSION

The presence of slots of various shapes and sizes incorporated on the patch layer of a microstrip antenna gives a structure known as slotted microstrip antenna. The various properties such as gain, radiation pattern, directivity and return losses are affected by the type of slots used on the radiating layer. Another approach of altering these properties is the use of metamaterial technology in which the dimensions of the substrate as well as the patch layer can be varied in order to achieve the desired values of the antenna parameters. Over the recent years, development of better and better designs of the described microstrip antennas have been proposed, and there has been acceptance of some of the models. The research into this field has not stopped, and further models are still being designed, and their performance tested.

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