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A Review on Microstrip Patch Antenna and its Miniaturisation Techniques

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***Abstract*— Microstrip patch antenna (MPA) has been widely in use since past three decades. The MPA consists of a metallic patch on the dielectric substrate over a metallic ground plane and is quite easy to design and fabricate. The minimum dimension of earlier MPA was half of wavelength which was very large for some communication devices; but recent some researchers have developed new standard for reducing the size of patch antenna. Many miniaturisation techniques have been introduced by researchers during recent years such as material loading, reshaping of antenna, shorting and folding, introducing slots and defects in the ground plane and the use of Meta materials. The major features and drawbacks of each of these approaches have been highlighted in this paper along their effects on antenna performance. This paper will provide better understanding for new researchers.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

At present, Wireless communication devices generally used are Global Positioning System (GPS), Radio Frequency Identification (RFID) system, AM and FM Radios, Mobile phones, Laptops etc. The Antenna is a vital part of these devices. Therefore, there is a requirement of such antenna which is easy to design and fabricate; also due to compactness in size of wireless devices the antenna required for these devices should be compact.

Among the various antennas, the Microstrip Patch Antenna is best suited for the entire requirement. Therefore it is very popular among the researchers of this area. The main reasons of its popularity are:

- It is a low profile antenna.
- Easy to design and fabricate.
- Easy to integrate with monolithic ICS.
- Easy to mount on any surface.
- It is easy to produce it in bulk.
- Low cost of this antenna makes it useful in daily life communication devices.

This Antenna can be designed by using printed circuit technology and was firstly presented in the 50s but it did not attain good gain. After the 80s it has appeared with lots of improved characteristics.

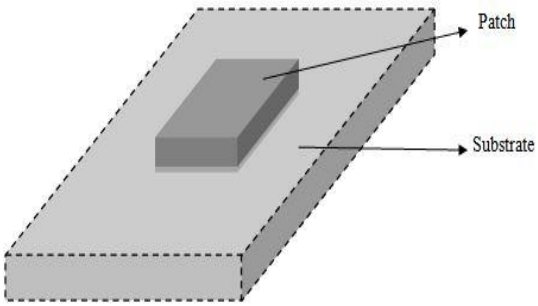
Micro strip Patch antenna (MPA) is one of the examples of printed Antenna. The other example of printed antenna is Monopole and dipole Antenna and planer inverted **F** shaped antenna (PIFA).[19]

As it is known that other parts of the communication devices are difficult to design and smaller in size but in case of antenna designing it is quite simpler because the length of antenna is the order of half of the wavelength of that frequency. Although there are so many theories given for designing the small size antenna by increasing their bandwidth and Gain but there are limited theories for the miniaturisation of Antenna structures.

In this paper, it is presented how antenna size can be miniaturised with their performance, their effects and their drawbacks.

II. PATCH ANTENNA

A micro strip antenna which is generally referred as Printed antenna is an antenna that is fabricated using micro strip techniques on a printed circuit board (PCB). These antennas generally used for the microwave frequencies. Micro strip patch antenna is a simplest form consist of a sandwich of two parallel conducting layer separated by a single thin dielectric substrate. Micro strip patch antenna are formed by overlapping two metallic plates, first is the large than the other, with a dielectric sheet in the middle. A micro strip patch antennas in its form consists of a metallic radiating patch on one side of dielectric substrate, which has a ground plane on other side. The dielectric constant should be low, so as to enhance the fringe field which account for radiation. Other performance and design requirement may dielectric constants may be greater than five. Design procedure of antenna is very simple [1 and 20]. It can easily be connected with the electronic devices and can also be used with the available substrate materials for the fabrication purpose.



a). 3D view

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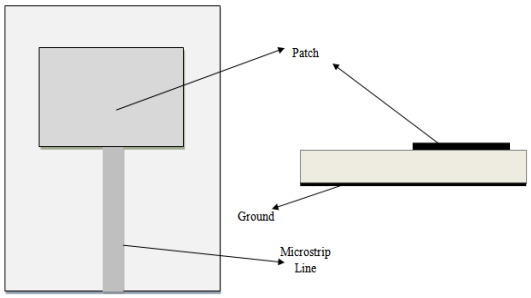

b). Top and Side view

Fig-1 Microstrip Patch Antenna

In figure -1 the simple design of microstrip patch antenna with their feed line is shown. It has already been discussed that it is a very low profile Antenna so it can be easily used in the global positioning system (GPS), laptops, tablets, Personal digital assistants (PDAs) and so on.

An MPA can be analysed using the rectangular cavity model in which there is a rectangular shaped cavity which is covered with top and bottom of the conducting sheets referred as (Perfect Electric Conductors) PECs. These are filled with the dielectric substrate and their side walls work as a (Perfect Magnetic Conductors) PMC and the radiation will occur through the side walls of the cavity due to the leakage of field lines and the resonance of these field lines can be calculated by applying the boundary conditions on the cavity walls for different modes of resonant frequency**. [3]**

The resonant frequency can be obtained using the formula –

$$f_r(mnp)=\frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{h}\right)^2+\left(\frac{n\pi}{l}\right)^2+\left(\frac{p\pi}{w}\right)^2}$$

h=height of substrate
l=length of patch
w=width of patch
μ=permeability of material
ε=permittivity of material

III. EXCITATION METHODS OF MPA

An MPA can be excited through different ways. The excitation methods of MPA are co-axial feed excitation, micro strip feed excitation, and transmission line feed excitation **[3].** The simplest Feeding technique is used for MPA is transmission line feeding excitation in which a conducting strip is attached to the edge of patch as shown in fig-2.

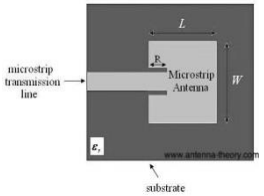

Fig.2Transmission Line Feed[7]

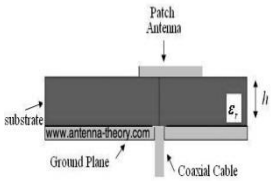

Fig.3 Co-axial Line Feed [7]

In other techniques like Coaxial Feed Line Method, the inner conductor of a co axial line is connected to the patch while the outer conductor is connected to the ground. [3] The conducting strip is smaller in width as comparison to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure as shown in fig -3. but there is a limitation in both excitation methods that they limit the bandwidth of MPA [2,4]. There are alternative approaches like proximity coupled and aperture coupled feeding techniques to minimize the above problem.

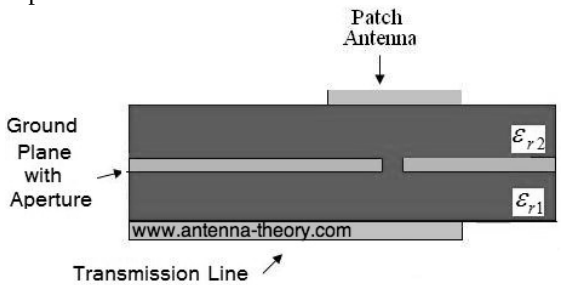

Fig.4 Aperture feed [7]

These methods are called as indirect feeding of MPA and are of very complex design and rarely used. They provide the wider operating bandwidth.

IV. MINIATURISATION OF PATCH ANTENNA:

Miniaturisation of patch antenna is a very important factor for the designing of Antenna but lowering the size of Antenna results in lowering of bandwidth and reduction in gain **[5]** but after several researches it has been concluded that if a small antenna is enclosed in a sphere of radius "a" then quality factor is given by-

$$Q = (1/ka) + (1/ka)^3$$

where k is wave number. By this evidence, if quality factor is increased then efficiency and gain will also be increased but bandwidth will be reduced.

There are many basic techniques to Miniaturise the antenna in which some are following:-

V. USE OF METAMATERIALS

Metamaterials are those materials which are artificially designed to provide material properties. These materials are not commercially available, metamaterials are desined in a such a way that it has near zero value permittivity or negative permittivity or permeability ; or it has simultaneous negative permittivity and permeability.

A material having only negative permittivity is called epsilon negative(ENG),where as only negative permittivity is called μ-negative(MNG)materials. And finally a material which has both negative permittivity and permeability is called as double negative(DNG).

These materials are widely used in RF, microwaves and photonics devices to achieve interesting properties. The concepts of metamaterials and their structures have also been used to design various antennas to enhance their characteristics like-gain, efficiency etc.

For example the design of rectangular microstrip patch antenna with DNG metamaterial provides tetra band resonance falling between 4GHz and 9GHz. [14-15]

VI. INTRODUCTION OF DIFFERENT SLOTS

An MPA can also be miniaturised by using different types of Shapes and slots on the patch antenna that creates large electrical length **[6]** and smaller in size but reduces the bandwidth of antenna.

Modification is done by using different slots in the microstrip antenna ,if the slots are properly designed then it increases the electrical length for the propagation of the current, and also reduces the resonant frequency .After several studies it is found that a single slot of 1mm width reduces size and its resonant frequency. Initially MPA will be resonated at 2.87 GHz with slot after introducing a slot the MPA will be resonated at 1.38GHz which represents 52% decrease. If 3 slots are introduced the resultant antenna size is 50% decrease and if multislot (4 slots) are introduced in the MPA then its Bandwidth will be reduced to 26.92% from 27.62% and the better return loss (-28dB) is obtained at 1.88 GHz.[10]

As already discussed in the previous lines that introducing different slots reduces the resonant frequency as well size of antenna .Further introducing a H-shaped patch (w=5mm; L=26.33mm) shown in fig-5a ,additional 4 vertical slots (L=10mm;w=5mm) shown in fig-5b ,four more horizontal slots with (w=3mm;L=10mm) are added shown in fig-5d ,it reduces the resonance frequency to 888MHz , 801 MHz, 680MHZ and 570MHz.[11-13]

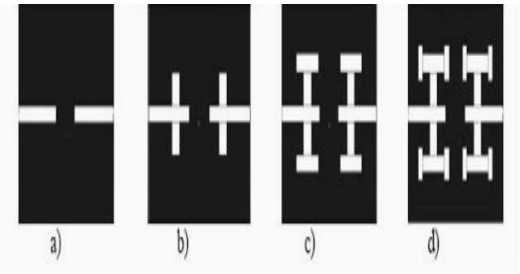

Figure 5 Notch modifications in H shaped antenna[11]

VII. DESIGN OF DEFECTED GROUND STRUCTURE

With the use of different discontinuities in microstrip lines improves the performance of different passive circuits, including size reduction of amplifiers, enhancements of filter characteristics and the applications to suppress harmonics in patch antenna.

Defected ground structure disturbs the current distribution on ground plane. This disturbance creates some resonators which will be added to main structure, but it has no unwanted radiation from its ground. Hence it enhances the electrical length of microstrip lines and disturbs the current distribution across the patch, then the effective capacitance and inductance of microstrip line increases and accordingly microstrip patch antenna with Defected Ground structure (DGS) has slow wave characteristics which leads to reduction of antenna size.

For example with the introduction of a spiral structure as Defected Microstrip Structure (DMS) in order to shift resonance frequency, results shift of resonant frequency occur from 5.8GHz to 2.69 GHz. Since DMS presents a slow wave structure so it has more discontinuities provides a longer trajectory to the EM waves [8].

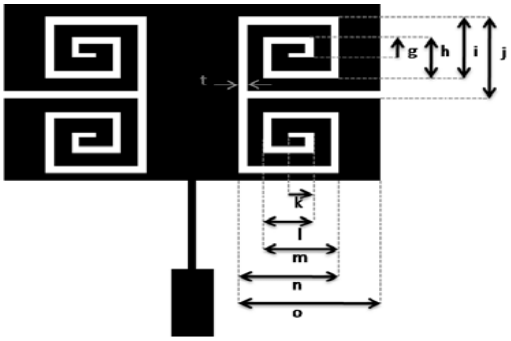

Figure 6 Spiral shaped defected ground structure[8]

Further it is observed that a size reduction of 56.68% has been achieved by taking out 'I' shaped slot from both patch and ground ,results new antenna has return loss of -14.34 dB at 5.54GHz and -16.56dB at 6.27GHz while a conventional antenna exhibits -3.90dB at 5.45 GHz and -5.27 dB at 7.00GHz.[9]

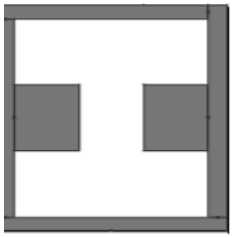

Figure 7 'I' Slot on patch and ground[9]

VIII. USE OF SHORTING PINS

In the recent times miniaturization of antenna is in demand. In wireless devices, the antenna still remains a matter of concern as regard to its size in an antenna it is desired that all antenna parameters like polarisation, radiation pattern and input impedance should be same. Therefore, short circuit microstrip antennas are used because this antenna can realize same resonant frequency and required half the size of standard micro strip antenna.

The shorted microstrip antenna is constructed by short circuiting the zero potential plane of an ordinary microstrip antenna exited with a dominant mode. In physical manner this short circuit may be complete by wrapping a copper strip around the edge of antenna or it may be simulated by shorting post. From the manufacturing point of view construction of shorting post is much easier than wrapping of copper strip around the edge.

For example in rectangular microstrip antenna if shorting post is done at the centre line of patch then it produces two lowest resonant frequencies with same polarisation. If this shorting is done in circular antenna at the centre line of patch then it also produces two resonant frequency one is linearly polarised (occur at lower frequency)and other is circularly polarised (occur at higher frequency),this will reduced the area with a factor 5 at the lower frequency end.[16-18]

IX. CONCLUSION

This paper presents the various miniaturisation techniques for the micro strip Patch antenna, the fundamentals and the different points about the Antenna size, bandwidth and gain.

The various methods used for the miniaturisation of the patch antenna are use of Meta materials, introduction of different slots, design of defected ground structure and use of shorted pins. Some techniques used for this method provide higher level of miniaturisation while some provide the lower level to maintain its bandwidth, gain, and efficiency ratio. This paper also defines about the feeding methods of MPA and generally uses direct feeding which included transmission line, coaxial line feeding and indirect feeding that includes aperture feeding.

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