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A Survey on Design and Optimization of Microstrip Patch Antenna

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ABSTRACT

Microstrip patch antenna is among the important elements of modern wireless communication systems and hence its designing and optimization has become an important aspect for improving the overall performance of the system. In this paper microstrip patch antenna geometry has been discussed along with the performance analysis of various papers over which the survey was conducted. The main objective behind writing this paper is to provide researchers with background of microstrip patch antenna geometries and optimization techniques so as to make it easier for researchers to choose the method best suited to their aims. Future scope of the study is also given which will help in further advancements in the optimization of microstrip patch antenna.

Keywords : Efficiency, Impedance matching, Metamaterials, Microstrip patch antennas.

Introduction

There has been a very rapid development in wireless communication and satellite communication over the past few decades and this has laid a dramatic impact on human life. In the previous few years, there was high development of wireless local area networks (WLAN) and this development is of great interest in the field of information as well as communication. Thus the current development in government and commercial communication systems is to develop low profile, light weight, robust and cheap antennas that are able to maintain the high performance over a large spectrum of frequencies. This technological trend has concentrated much of the effort into the design of Microstrip (patch) antennas.

Owing to simple geometry, patch antennas offer many advantages which are not commonly exhibited in other conventional antenna configurations. For example, they are light weight, extremely low profile and easy to fabricate using modern day printed circuit board technology, well-suited for microwave and millimeter-wave integrated circuits (MMIC), and have the capability to conform to planar and non planar geometries. In addition, once the shape and operating mode of the patch are selected, designs become very adaptable in terms of polarization, pattern, impedance and operating frequency. There is a large variety of design geometries associated with microstrip patch antenna in comparison with conventional antennas.

The geometry of microstrip patch antenna is discussed in section 2 where the most commonly used geometry that is the rectangular profile is being discussed. Literature survey is given in section 3. Parameters of antenna are defined in section 4 and the performance analysis based on these parameters is carried out in section 5. Conclusion and future scope is given in section 6 and 7 respectively.

2. Microstrip patch antenna

Since the mid-1970s, Microstrip patch antennas have played an increasingly important role in the field of electromagnetic, contributing towards new developments and applications. Planar techniques provide significant advantages over non lanner geometry, namely low profile and compact size, relatively low manufacturing cost, the ability to group many identical patches into an array and to integrate with circuit elements. A microstrip patch antenna is made up of a radiating metallic patch on one side and ground plane on the other side. Dielectric material substrate is sandwiched between the two. The radiating patch is generally made of a conducting material such as gold or cooper etc. Figure1 shows the basic design of microstrip patch antenna.

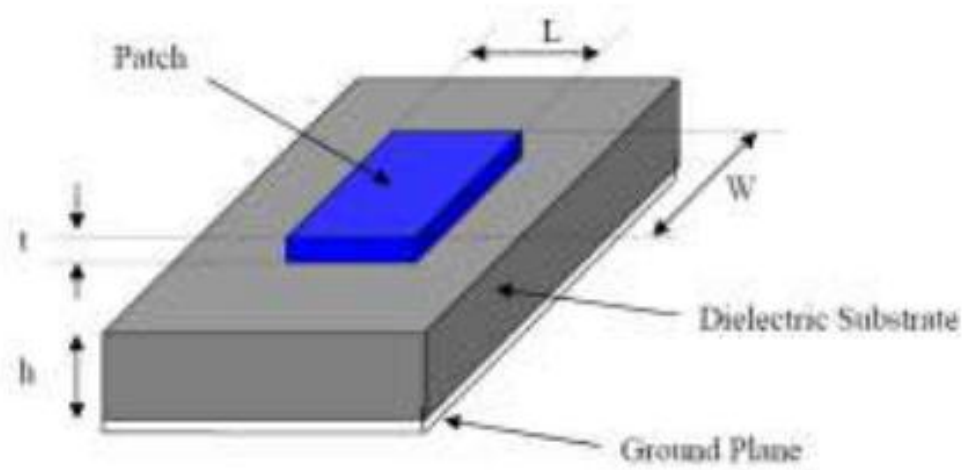

FIGURE1 Microstrip Patch Antenna

In order to simplify analysis and performance prediction, the patch is generally square or rectangular in shape but other patch shapes are also used such as triangular and elliptical or some other common shape.

3. Related work

A large number of researchers have worked upon the design of antenna and its optimization techniques but here a few relevant areas are referenced. Miniaturization of patch antenna was carried out in 2012[14] using split ring resonators. By optimizing the geometry of the split rings sub wavelength resonance of the patch antenna was achieved, by using slotted structures of complimentary split ring resonators for reducing mutual coupling [18]. Small patch antenna with high radiation efficiency was proposed using metamaterial[15]and lumped capacitor to increase the efficiency. Multifrequency design of antenna was also proposed in 2012[16] and optimized using genetic algorithm.[17] Focused on increasing the gain of antenna by using metamaterial. Particle swarm optimization for dual band frequency operation was done [19].

In 2014 metamaterial was used to enhance the characteristics of antenna [7] and to improve the gain by using metamaterial and split ring resonators [12].CSRR was also used for reducing the size of antenna [8] and for dual band operation [10]. To achieve better return losses and VSWR genetic algorithm was used for antenna optimization [9]. Broadband multislot antenna was presented in which two diamond slots were made in the patch to create resonance [11]. [13] proposed a single high-directivity micropatch antenna which could substitute linear antenna. It was designed using genetic algorithms [13]. Hexaband microstrip patch antenna was proposed [5].

In 2015 PSO technique was used which was based on foraging behaviour of spider monkeys [2]. A surrogate-assisted optimization method for designing of compressed patch antennas with enhanced bandwidth was proposed [3].

Emphasis has been given in the reduction of size if antenna, be it with the use of complementary split ring resonators or by using the slotted design of the same. Metamaterials have also been used as a superstrate to increase the overall gain of the antenna. Some researchers have given the methods to use the same antenna for more than one frequency applications, which may be either dual band or multiband. Increasing the gain and directivity of antenna is also focused upon. Reduction in mutual coupling, improving the bandwidth of antenna and enhancing the efficiency of antenna has also been worked upon.

3.1 Gaps in the Study

- The back lobe which occurred due to perforations in the ground plane.
- Complexity of antenna design.
- Reduction in the cost of design of optimization process.
- Non uniform antenna structures should also be optimized.
- Algorithm should be designed for improving performance of patch antenna and its array of different shapes and configurations.
- Antenna designs should be modified to have more frequency bands for various applications.
- Radiation pattern in multiband antennas can be optimized.
- patch antenna enclosed in a multilayer metamaterial structure can be optimized for its directivity.

- Size of antenna can be reduced without compromising matching and efficiency of antenna.
- Radiation patterns in multiband microstrip patch antenna can also be improved.

4. Antenna parameters

4.1 Gain and Directivity

Gain of an antenna is the radiation concentrated in a given direction to the radiation strength that would be obtained if the antenna radiates omnidirectionally to understand the concept of gain the knowledge of isotropic antenna is needed, the antenna that radiates same power in all directions equally. An isotropic antenna, however, is just a concept, as all practical antennas have directional properties. Directivity and gain are same with one difference. Directivity does not comprise the effects of power losses. When an antenna is lossless (100% efficient), then the gain and directivity (in a given direction) are the same.

4.2 Voltage Standing Wave Ratio

The voltage standing wave ratio (VSWR) is not firmly an antenna feature, but it is used to explain the performance of an antenna after attached to a transmission line. It is a measure of how well the antenna terminal impedance is matched to the characteristic impedance of the transmission line. Specifically, the VSWR is the ratio of the maximum to the minimum RF voltage along the transmission line.

4.3 Bandwidth

The bandwidth of an antenna is defined as the array of frequencies within the performance range of the antenna. In other terms, properties of antenna like gain, radiation pattern, terminal impedance must have acceptable values within the bandwidth limits.

4.4 Input impedance

There are three different kinds of impedance relevant to antennas. One is the terminal impedance of the antenna, another is the characteristic impedance, and the third is wave impedance. In general we talk of antenna impedance or terminal impedance which is the measure of voltage to the current at the terminals of antenna. For proper working impedance matching should be there.

4.5 Antenna Polarization

Polarization has many different meanings. In a firm sense, it is the orientation of the electric field component E at some point in space. If the E-field vector retains its orientation at each point in space, then the polarization is linear; but if the point of reference changes as the wave travels in space, then the polarization circular or elliptical. In general, the radiated-wave polarization is linear and is either horizontal or vertical.

4.6 Antenna Efficiency

The efficiency of the antenna is the measure of power radiated by the antenna in contrast to the total input power. The input power supplied which is not radiated back by the antenna is converted into heat.

5. Performance analysis

Different parameters such as efficiency of antenna, gain and bandwidth range of antenna, return loss and VSWR have been considered after the review of different papers based on design and optimization of microstrip patch antenna.

5.1 Comparison of efficiencies

Different antenna's proposed by different researchers have different percentage of efficiency. Efficiency is the measure of power radiated by the aerial to the total input power. These values of efficiencies are taken in percentage and are being compared in a tabular form as shown in table 1 and the corresponding graph is also given in figure 2.

TABLE 1 Comparison of efficiencies

S.no	Antenna Design	Efficiency in %
1	[8]	88
2	[11]	94.94
3	[13]	13.7
4	[14]	79
5	[15]	73

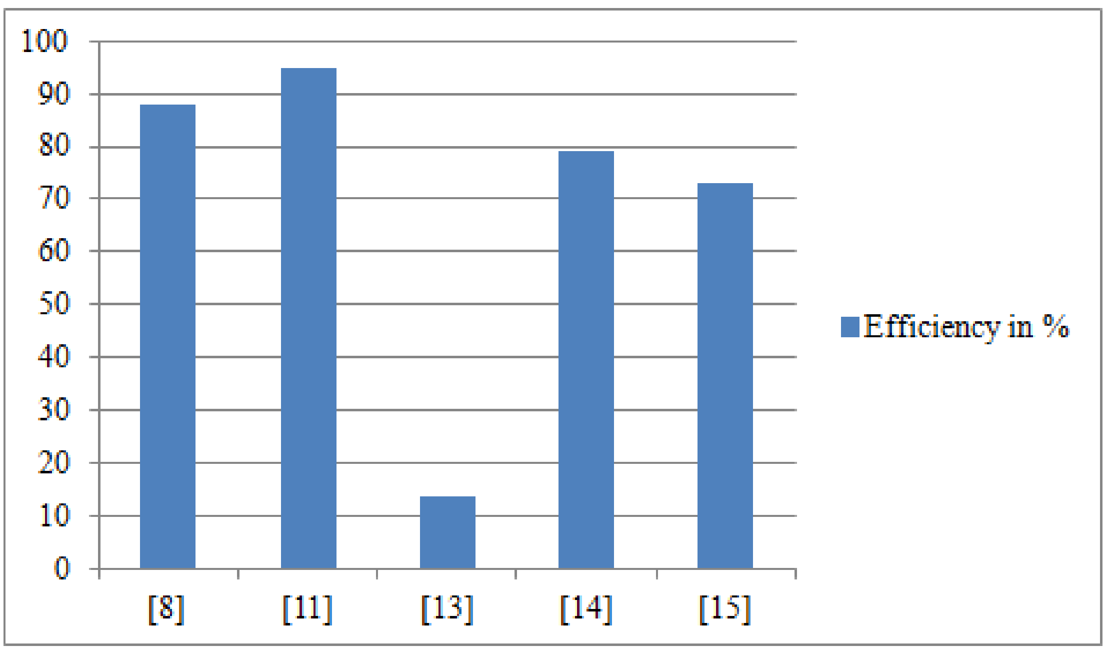

Figure 2 Graph showing comparison of efficiencies

The graph shown clearly indicates that the antenna design [11] shows the maximum efficiency when compared to all the other four designs.

5.2 Comparison of Gains and Bandwidths

A comparison among the values of gain is being carried out for the different proposed antenna design by different researchers. The gain is in decibels and the bandwidth is in gigahertz. The values of gain and bandwidth are written in a tabular form as shown in table 2, also the graph between the different antenna designs and values of gain is being plotted, as shown in figure 3.

TABLE 2 Comparison of gains

S.no	Antenna Design	Gain in dB	Bandwidth in GHz
1	[16]	6	1.7-2-5
2	[10]	0.75	2.4-25
3	[12]	20.44	2.4-2.8
4	[13]	12	3.3-3.9
5	[4]	9.8	3.2-4.1
6	[9]	5.69	1.9-2.5
7	[11]	N/A	7.84-8.81

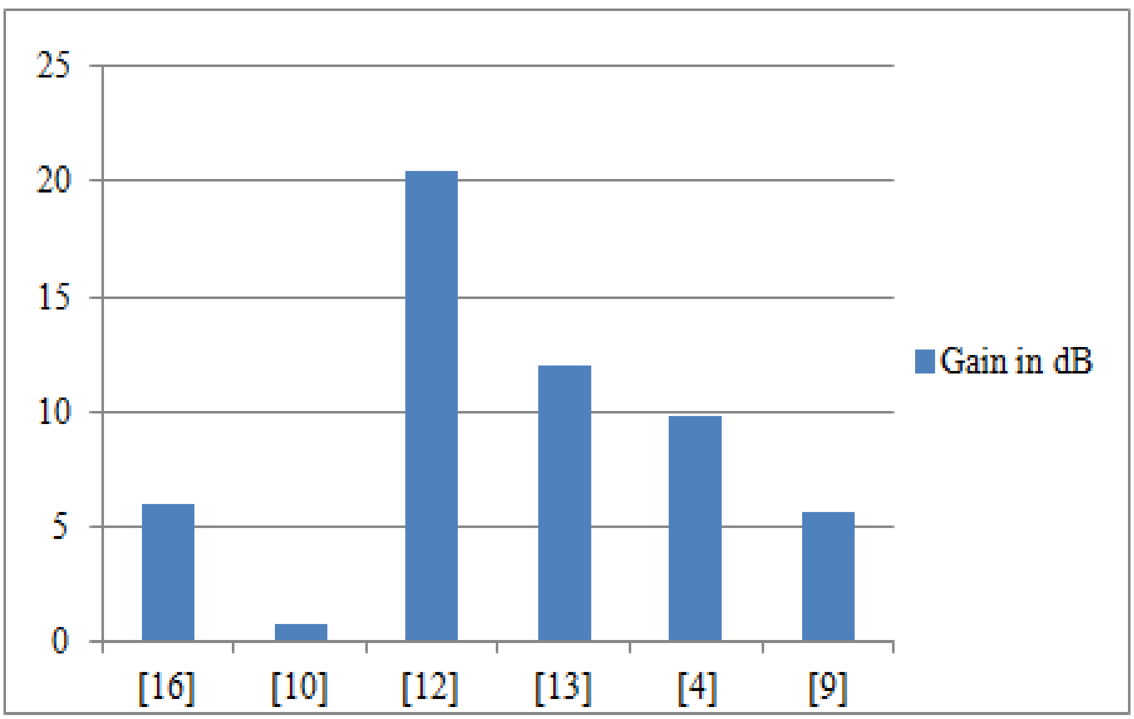

Figure 3 Graph indicating respective gains

From the above graph it can be depicted that the antenna design [12] has the maximum gain. Hence it is better than the other five proposed designs in terms of gain.

5.3 Comparison of Return Loss and VSWR

The values of return loss and VSWR are compared between two antenna designs. Return loss is in decibels while VSWR is the ratio so it has no units. The comparison table in shown in table 3, also two different graphs ,the first one comparing the values of return losses and the second one comparing VSWR are shown in figure 4 and 5 respectively.

TABLE 3 Comparison of return loss and VSWR

S.no	Antenna Design	Return loss(dB)	VSWR
1	[9]	-28.52	1.077
2	[5]	-21.02	1.19

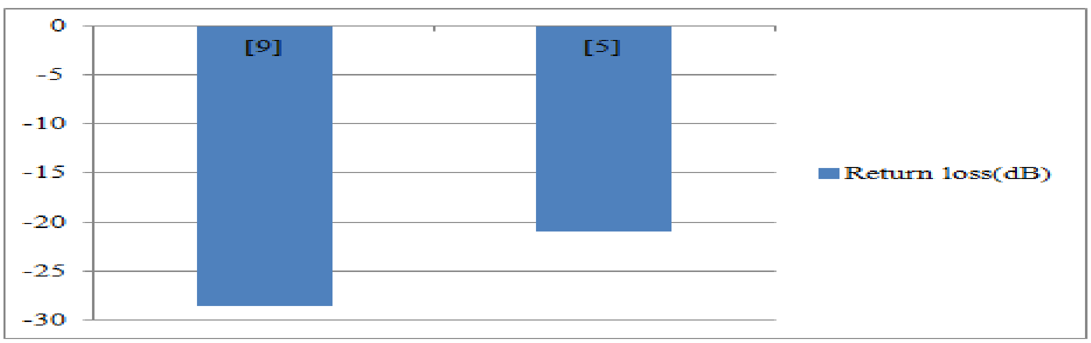

Figure4 Graph showing a comparison of return losses

The above graph is plotted on negative y-axis. By seeing the graph a comparison could be made and concluded that the design [9] has better value of return loss.

A comparison graph shown below for VSWR shows that the antenna design [9] has better performance since it has less value of VSWR.

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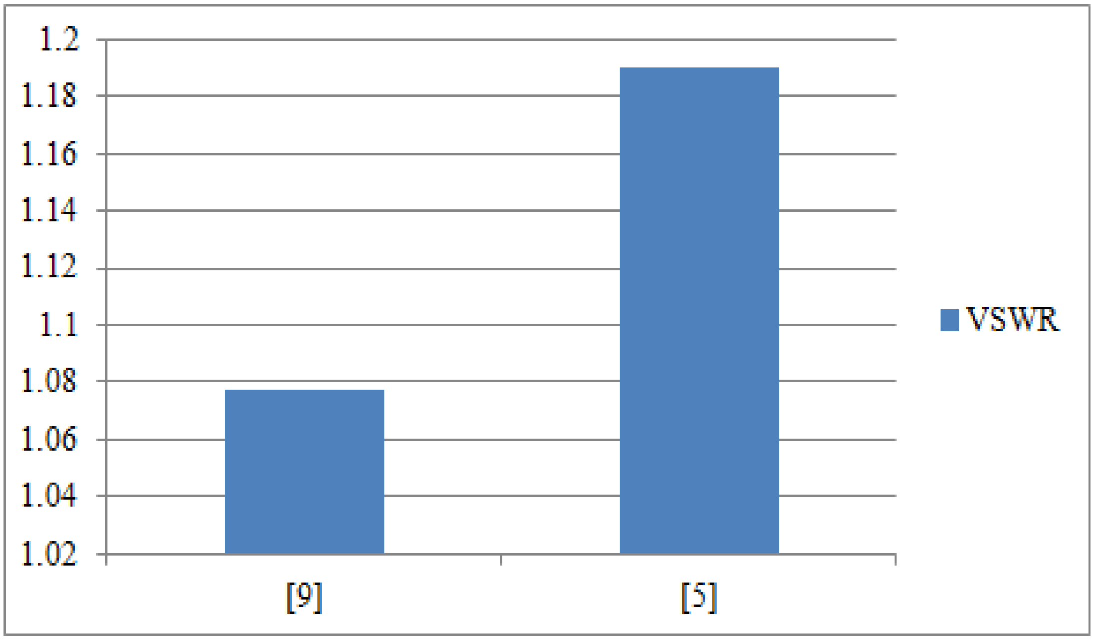

Figure 5 Graph indicating VSWR values

5.4 Conclusion

A comparison among different parameters of antenna like gain bandwidth, efficiency has been successfully made and it can be concluded that the antenna design [11] has the highest efficiency. The value of gain is maximum for antenna design [12] and return loss and VSWR is better for antenna design [9].

6.Conclusion

In this paper review is made on the different approaches used for the optimization of antenna by different researchers. Enhancing the gain or increasing the efficiency of the patch is the main work that has been carried out by the researchers using different approaches. The main parameters of antenna are discussed and a comparison is being made upon these parameters for different techniques used. The best results obtained are tabularized as well as evaluated graphically.

7. Future scope

- The back lobe and side lobes which may occur due to perforations in the ground plane can be reduced without compromising the efficiency of the antenna
- Complexity of antenna can be decreased by designing the antenna in a simple way.
- Reduction in the cost of design of optimization process can be worked upon.
- Work can be done for the optimization of Non uniform antenna structures as well.
- Algorithm should be designed for improving performance of patch antenna and its array of different shapes and configurations.

- Antenna designs should be modified to have more frequency bands for various applications.
- Radiation patterns in multiband antennas can be optimized.
- Patch antenna embedded in a multilayered artificial dielectric structure can be optimized for its directivity.
- Work can be done to make a single antenna efficient to perform different functions at different frequencies
- Size of antenna can be reduced without compromising matching and efficiency of antenna

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