# Review on Size Reduction Techniques of the Microstrip Patch Antenna

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***Abstract*— During the past years, the patch antenna had been studied and used extensively worldwide and with various types of wireless communication devices. The design of the patch antenna consists of three layers placed on each other. The first layer is called the patch which it made of metallic material. The second layer is the substrate which it made of dielectric material. The last layer is ground plane, it made of metallic material also. This type of antenna has some merits like ease of integration with electronic circuit components. Lately, the world of communications has witnessed a great development in terms of the inclusion of some devices, such as tablets, smart watches and mobile phones, on multiple technologies in addition to the basic function of these devices. Therefore, the urgent need to reduce the components of these devices is located. Some of the main techniques that have been recently studied by researchers for the size reduction of antenna are discussed in this paper. The most important of these techniques include making defects and slots in the ground plane, shorting and folding, material loading, and reshaping the antenna. Also, each technology was discussed separately, and the main defects of each technology and its advantages were presented, and the impact of each technology on the performance of the antenna was also highlighted.**

***Keywords*— *patch antenna, miniaturization, bandwidth, dimensions, microwave frequencies***

## I. INTRODUCTION

Wireless communication devices such as cellular mobile phones, Radio Frequency Identification (RFID) systems, tablets, GPS devices, laptops, satellite phones, receivers, AM and FM radios are used on a daily basis and some of these devices are used by everyone. These devices are found everywhere at the present time and their usage is continuously increasing. The antenna, being a fundamental piece of wireless communication systems, performs a crucial function in expressing the overall performance of those systems. For this reason, an antenna for any wireless communication system must be carefully constructed so one can assure accurate system-stage performance.

Among diverse varieties of antennas, printed antennas have acquired widespread interest throughout the past few years due to their ease of integration with related electronics, and their low-profile nature, which make them to be very appropriate to be used in built-in wireless communication system components. This type of antenna is usually manufactured using printed circuit technologies. Printed antennas have been first offered throughout the 1950s. However, they did not gain a lot interest till the early 1980s. Since then, printed antenna theories have been developed by meticulously analyzing many printed circuit designs in order to better understand of their characteristics and performance. Microstrip patch antennas, printed monopoles, and dipoles are among the most common printed antennas.

Many standards of wireless communication technologies, such as Wi-Fi, LTE, 5th generation and other technologies, are determined according to microwave frequencies, in other words, within the range of 700 MHz to 36 GHz. Therefore, the traditional antenna length at the minimum frequency band is large, approximately 210 mm at 700 MHz, which is considered very large compared to the specifications of communication devices such as tablets, mobile phones and other devices. Therefore, the dimensions of antenna must be made smaller to fit the dimensions of wireless devices. Furthermore, most wireless devices need the usage of multiple antennas, especially for multiple inputs and multiple output technology. Thus, multiple antennas must be sized to fit in a specific space. Although the size of the antenna must be small, these antennas should maintain some of their characteristics such as the desired radiation and the desired frequency.

A lot of studies that published about the topic of miniaturization of antenna came to the conclusion that; When the antenna size is reduced, its bandwidth and gain change [1,2]. These studies are helpful in determining performance measures for miniaturized antennas. Lately, a lot of new miniaturized designs of antenna have appeared, such as the miniaturized designs of microstrip patch antenna and printed monopole antenna. [3–5].

## II. MICROSTRIP PATCH ANTENNA

The microstrip patch antenna is a type of printed antennas. The antenna usually consists of three layers placed on top of each other, where the first layer consists of a conductive material called the patch, the second layer consists of an insulating material called the substrate, and the last layer consists of a conductive material also called the ground plane [6]. The antenna has different shapes, rectangular, circle, pentagonal, hexagonal, F-shape, etc. The use of this type of antenna has spread in many applications, including tablets and mobile phones, because it is easy to design, as a result of the study of this type of antenna by many researchers, the ease of its manufacture and integration with other electronic devices as a result of its planer geometry, an effective cheap choice for wireless applications, and low profile. The cavity model is typically used to analyze the patch antenna [7].

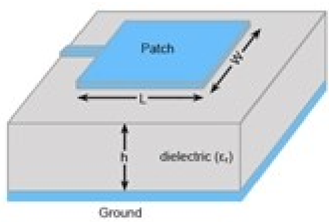


Fig. 1. Microstrip Patch Antenna

Microstrip patch antenna is considered as a cavity loaded with insulation with side walls of non-perfect electric conductor (PEC). Therefore, the radiation takes place from this cavity because of leakage from these side walls. The fields within cavities must be solved first, In order to determine the operation frequency and radiation characteristics of the patch antenna. The bottom and the top sides of the cavity are considered as PECs, while the sides are supposed to be perfect magnetic conductors (PMCs). By placing the suitable boundary terms on the walls of the cavity, the field distribution in the cavity could be found. Then, the result can be used to determine the radiation field of the antenna for various modes, and also to find the resonant frequency. From the same model, the quality factor and the input impedance can be found.

## III. Miniaturization Techniques

Antenna miniaturization techniques, including patch antennas, have been of interest to researchers for a long period of time. The first attempts to reduce the volume of the antenna were successful, and they came to the conclusion that when the antenna is reduced, it leads to reduce the gain and lower the bandwidth [1, 2, 8]. Basically, there are two methods to reduce the volume of the patch antenna. The first way is by changing the properties of the material of the substrate in order to reduce the effective wavelength in the region of the substrate. The second way is by changing the geometry of the microstrip patch antenna in order to increase the electrical size.

### *A. Material Loading*

One of the easiest ways to make the antenna smaller is to increase the relative permittivity of the substrate. The square root of relative permittivity is inversely proportional to dimensions of the patch. The result of this method is decreasing the efficiency, lowering bandwidth, and increasing the excitation of surface wave. Changing the radiation properties and poor polarization purity are caused by the truncation of the ground plane. Different researches examine several kinds of material to get the suitable miniaturized antenna to the specifications of the wireless devices.

Microstrip patch antenna with high-relative permittivity of (10, 13) and a thick substrate was examined in [9]. It was found in this study that the values of radiation characteristics and the input impedance are not similar to the values of common patch antennas. By using a thin substrate, the input impedance is less than the antenna with the thick substrate. In [10], low-permittivity substrate is used that filled partially with high-permittivity. By using this approach, 50% of the antenna size was miniaturized with gain 6 dB and bandwidth of 10%.

Many researches have been done on the usage of ceramic substrates in patch antenna miniaturization. In [14], a 1/8 miniaturization was obtained using a ceramic substrate with $\varepsilon r = 100$ as compared to the conventional antenna that used a FR4 substrate. A substrate thickness equal to ($0.031\lambda o$) was used to eliminate the problem of narrow bandwidth. The performances of the antenna were a gain of 2.8 dBi and bandwidth of 7.2%. Lots of researches have also appeared in previous years that use different and modified materials as substrates in order to reduce the size of the antenna. As explained previously, the usage of different and modified substrates can provide a great size reduction with the cost of small bandwidth.

### *B. Shorting and Folding*

The other size reduction technique is shorting posts and folding the antenna, and that lead to make the antenna electrically smaller [6]. The distribution of E-field has sinusoidal over the patch, where the E-field is at maximum amount at the edge and zero value at the middle. So, the antenna aperture could be reduced by putting the electrical wall at the center of the antenna. The resonant frequency and the Q-factor of this approach will be the same as the conventional antenna. However, this approach will reduce the directivity [6]. In [11], the antenna reduced to 1/8 of its size by folding it. The efficiency of the antenna was 90% and the bandwidth 4% was found as results of this approach. In [15], several parameters have analyzed. Multiple, double, single shorting posts were used. The size of the resultant patch antenna was 1/3 of the original patch antenna as a result of using the shorting posts.

However, this method of minimization comes with some disadvantages as it reduces the directivity and gain of the antenna. Furthermore, this method of miniaturization complicates the antenna design. But when this method is used correctly, the resulting antenna is very small with a little effect on its performance

### *C. Reshaping and Introducing Slots*

The antenna can be made smaller by adding slots to the patch or changing its shape. By reshaping the patch, a large electrical length can be obtained fits the limited space. By making slots in the patch, a good efficiency can be obtained, but the bandwidth will reduce [5]. In order to overcome this problem, layers of conductors are used, and also this approach increases the gain and the bandwidth [12]. Where, the number of layer is directly proportion to the gain and the bandwidth. The usage of five layers improved the efficiency by 30%.

Many researches have shown that by making slots in the patch of the antenna, the antenna will be reduced in size. In [16], the size of the antenna was reduced by 40–75% by making slots in the patch of the antenna. By making identical slots in the patch of the antenna, the effect of this method by making the polarization poor will be reduced to its minimum. In general, this method does not have a design methodology. Although, it widely used by a lot of researchers and in many designs.

### *D. Modifications of the Ground Plane*

By using this technology, the antenna can be made smaller by adjusting the ground plane. In order to reduce the size of the antenna, the size of the ground plane is reduced. Sometimes the reduction in size of ground plane a little bigger than the patch in order to get more reduction in the size of the overall antenna. Various studies [13, 17, 18] were analyzed and it was found that the miniature antenna was affected to its input impedance, and also had poor polarization purity. This caused by the edge diffraction, where the front lobe was decreased by the increment of the back lobe. Making slots and defects in the ground plane is one of the ways to amend the ground plane. The current path will increase inside the patch layer with the help of these holes [19]. This leads to a decrease in the resonant frequency which leads to size reduction. In [19], one slot of 1 mm was made in the ground plane, where the reduction in operational frequency was 52%, leads to a reduction in size of 90%.

## IV. CONCLUSION

In this paper, an overview of the different kinds of size reduction techniques of patch antenna had presented. The theoretical side of the patch antenna was discussed. The main limits on some metrics were indicated. The most important techniques used to reduce the volume of the antenna and the most popular among the research community were discussed. It included the following technologies: the usage of untypical and modified substrate, inserting slots in the third layer of the antenna, modifying the antenna's shape, and folding and shorting of the antenna. Some of these methods provided a good size reduction, while others reduced the size by average manner in order to maintain some antenna characteristics at the lowest acceptable value. Some of these designs are easy and cheap to manufacture, while others are difficult and very expensive to manufacture. Such trade-offs between the performance of the antenna and the percentage of the size reduction will always exist, so the designer must choose the best technology for the application required to use such techniques. Therefore, there is an urgent need to clearly define how various factors affect antenna performance for a certain size reduction techniques. Also, there is an urgent need to clarify a physical view of the use of such techniques with different bands. Given these problems, it can be predicted that antenna size reduction techniques will remain the focus of researchers over the coming years.

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