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Comparative Analysis of Microstrip Antenna Arrays: Evaluating Performance between Rectangular and Square Patch Antennas

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ABSTRACT

In the rapidly evolving landscape of low-cost and compact communications, the quest for optimal frequency ranges has propelled microstrip antenna arrays to the forefront, capturing significant attention within the research community due to their inherent advantages. This paper serves as a comprehensive exploration into the realm of microstrip antenna arrays. It not only elucidates the fundamental workings of various types of antenna arrays but also delves into detailed comparisons, shedding light on the nuanced intricacies of their radiation patterns. As communication technologies continue to demand solutions that are both cost-effective and space-efficient, microstrip antenna arrays emerge as a prominent contender, presenting unique advantages that contribute to their growing popularity. The paper seeks to unravel the complexities of these antenna arrays, offering insights into their design, functionality, and applications. Furthermore, the document undertakes a comparative analysis of different antenna arrays, dissecting their respective radiation patterns. By scrutinizing these patterns, the paper aims to provide a nuanced understanding of how various types of antenna arrays perform in terms of signal propagation, directivity, and other crucial aspects. This in-depth examination contributes valuable knowledge to the ongoing discourse surrounding microstrip antenna arrays, fostering a deeper appreciation for their potential in addressing the evolving communication needs of our time.

Keywords: Antenna, Microstrip patch Antenna, Radiation pattern, Comparisons of antenna array.

1. INTRODUCTION

Voice is basic thing is which communicate with humans and message is also communication thing to passing information from one place to another place. Electromagnetic spectrum has been very a new for communication, through the use of radio waves. This resource comes in the category of natural resource. It available a lot of amount to venture this resource.

Wireless communication system has been growing as the applications of mobile phones and systems developing in use. The electromagnetic signals are major in antennas. Antenna is not active device; Antenna is such a device as wireless system the crucial component to emit and collect signals is the antenna. The working of antenna is the transmitting and receiving the electromagnetic signal's to the destination. Antenna acts like bridge between transmitting and receiving and it radiates the radiation. The advantages of antenna are high gain and less bulker.

The microstrip antenna array is suitable and prevalent antenna in use today. Their frequency range is between 1GHz to 16 GHz Microstrip antenna was first introduced in the 1950s. However, this concept had to wait for about 20 years to be realized after the development of the printed circuit board (PCB) technology in the 1970s. Since then, microstrip antennas are the most common types of antennas with wide range of applications due to their apparent advantages of light weight, low profile, low cost, planar configuration, easy of conformal, superior portability.

2. MICROSTRIP PATCH ANTENNA

A microstrip patch antenna (MPA) consists of a conducting patch of any non-planar or planar geometry on one side of a dielectric substrate and a ground plane on other side. It is a printed resonant antenna for narrow-band microwave wireless links requiring semi-hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been deeply. The rectangular and circular patches are the basic and most commonly used microstrip antennas.

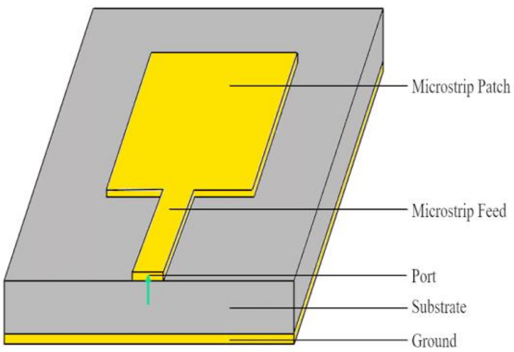

Fig 1. Microstrip patch antenna

3. DESIGN CONSIDERATION FOR PATCH ANTENNA

The three important parameters considered for constructing a Microstrip patch antenna are considered here.

• *Frequency of operation (f_0)*: The antenna has been designed for the range 3-5 GHz. 4.5 GHz is the default resonant frequency exclusive for this research arrangement.

• *Dielectric constant of the substrate (ε_r)*: Dielectric constant is one of the most sensitive parameter in Microstrip antenna, and it is taken of substrate. One of the most commonly used materials is FR4 but it supports only 2-4 GHz range. FR4 PCB also cannot handle high powers at microwave frequencies. Its permittivity is 4.2. Instead the dielectric material that can be chosen for this design which is very costly is Rogers/RT duroid 5880 tm which has a value of 2.2.

• *Height of dielectric substrate (h)*: Antennas that are used in phones are required to be light in weight and compact in size which sets a constraint to their height.

By substituting $c = 3\times10^8$ m/s, $\varepsilon_r = 2.2$ and $f_0 = 3.5$ GHz, the values of antenna dimensions can easily be determined.

The dimensions of the antenna design used in this work are shown in Table I. In square patch the length and width of the patch are taken same.

Parameter	Microstrip patch antenna	Metamaterial patch antenna
Substrate length	76	56
Substrate width	102	82
Patch length	38	28
Patch width	51	41
Feed slot cut, Fi	12.5	12.5
Feed line length	31.5	26.5
Feed line width, Wf	8.7	6
Substrate thickness, h	1.6	8.3

TABLE I. ANTENNA PARAMETERS

4. ANTENNA DESIGN

A. Rectangular patch :

The geometry of the designed rectangular patch antenna is shown in Figure 2 (Yang, 2010). The first study conducted with the use of NiCo-ferrite films is done to determine the correct placement of the film in regards to the antenna. To be more specific, four different antennas are designed and shown in Figure 10.21(a)–(d). The first antenna, named Antenna No.1, is a control antenna and has no ferrite films placed on it. The other antennas preceded as follows: Antenna No.2 has a ferrite film placed underneath the radiating patch only, Antenna No.3 has a ferrite film placed over the entire area of the substrates top, and Antenna No.4 has the ferrite film placed between the ground and the substrate.

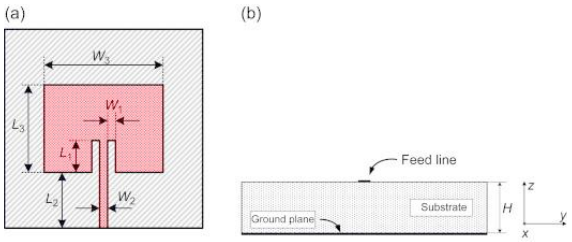

Figure 2 Geometry of the designed rectangular patch antenna. (a) Top view, L_1 = 8.0 mm, L_2 = 14.3 mm, L_3 = 22.2 mm, W_1 = 2.0 mm, W_2 = 2.0 mm, and W_3 = 30.0 mm. (b) Side view, H = 2.0 mm (Yang, 2010).

For a rectangular patch, the radiation is generated from the two edges with two equivalent slots as shown in Figure 1.39 [8,9]. The other two opposing edges that are *W* apart do not radiate so long as the feedline is at the center of the radiating edges. Thus, it can be concluded that a radiating patch can be modeled by two slots separated by a transmission line. Each slot can be represented by a parallel circuit of susceptance *X* and conductance *G* as shown by the equivalent circuit depicted in Figure 3. Note, however, that the circuit presented in Figure 1.40 does not model the mutual coupling present between the two radiating slots, nor does it account for the radiation due to the non radiating edges of the patch. Due to these limitations, this model becomes unsuitable to analyze nonrectangular shapes and hence it is very limited in its application.

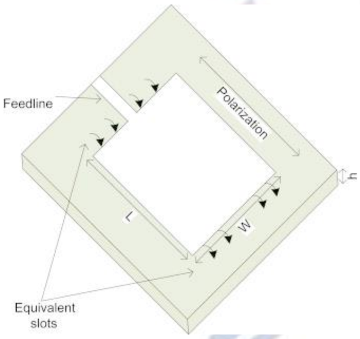

Fig 3. Patch antenna with two equivalent slots and microstrip feedline.

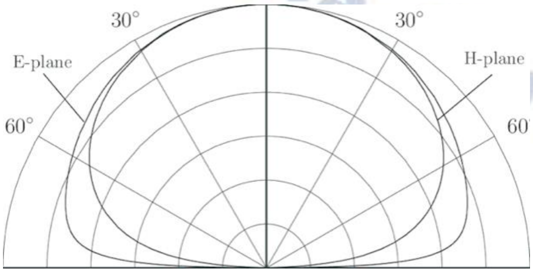

Fig 4. The radiation pattern of a rectangular patch antenna (length a and width b = 0.8a) on a dielectric slab (permittivity profile 4) in (4.3)). The thickness of the substrate is d = 0.1a.

Fig 5.3D radiation pattern of a rectangular patch antenna

B. Square patch antenna

A square patch is taken into consideration. Length and width of the patch are equal in this case. The resonant frequency of the antenna is determined by the resonant length. Due to the effect of the fringing fields the patch is in fact greater than its physical size. The inconsistency between physical size and electrical is generally reliable on the PCB thickness and dielectric constant [14-16]. The patch that has been considered is made of conducting material copper.

The simplest square patch antenna is shown in figure6.

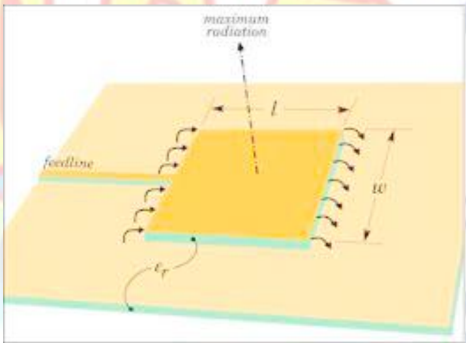

Fig 6. The simplest square patch antenna is shown in figure6.

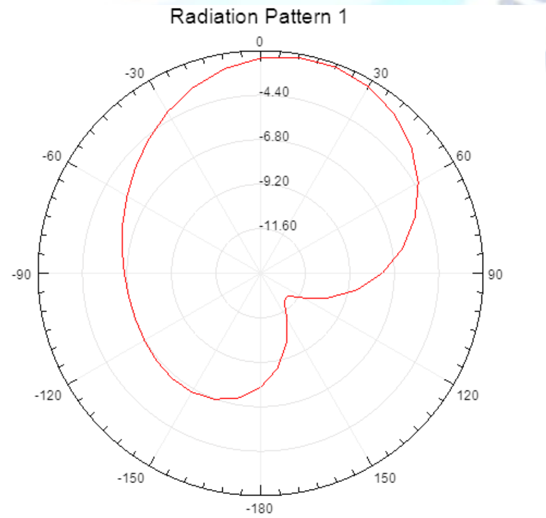

Fig 7. Radiation pattern of square patch antenna

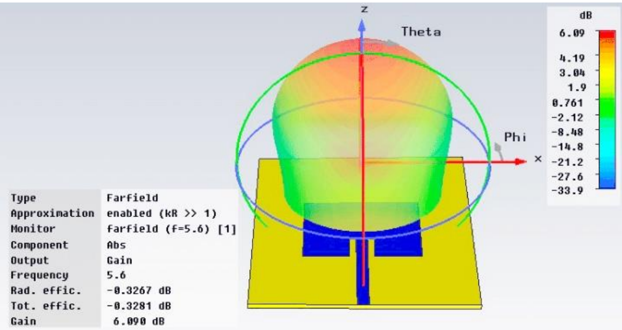

Fig 8. 3D Radiation pattern of square patch antenna

5. COMPARISONS

Parameter of comparison	*Rectangle patch antenna*	*Square patch antenna*
Frequency	*3.5GHZ*	*3.5GHZ*
Relative permittivity	*2.2*	*2.2*
Dielectric substrate	*Rogers RT/droid 5880 tm*	*Rogers RT/ droid 5880 tm*
Impedance matching	*50ohms*	*50ohms*
Feeding Technique	*Microstrip line feed*	*Microstrip line feed*
Return loss	*-7.8 dB*	*-11.2 dB*
Peak gain	*2.7736*	*2.6224*
Peak directivity	*2.8101*	*2.622*
Radiation efficiency	*0.9074*	*0.9743*

The following points can be analyzed from the simulation results

- Different shapes of patch antennas have been designed and a comparison between them is made by taking bandwidth as the main parameter. Figure 4, 5, 6 shows this comparison. The rectangular and the square micro-strip patch antenna have nearly equal maximum allowable bandwidth.
- The difference between these two patch antenna is size, return loss and Radiation efficiency.

6. CONCLUSION

This paper demonstrates a comparative simulation between rectangular, square patch antenna on HFSS software. Resonance frequency and radiation pattern have a significant effect on changing the feeding mode. The nature of the antenna is also modified by changing the dielectric substrate. The work is done with various shapes of the patch and comparison is been done of these structures. This analysis shows the effect of altering shape of patch from rectangular to square and hexagonal patterns. The square shaped patch results in a reduced size of the patch, and requires for wireless communication the polarization which is to be circular. Hexagonal patterns of the patch results in improved gain and radiation pattern. The gain of patch antenna is improved in both rectangular and hexagonal shapes. From comparison with previous work, it was observed that the ability of using different patch antenna designs with same performance characteristics did not have a major impact on the radiation efficiency.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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