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Design and Modeling of Parallel Rectangular Patch Based Microwave Antenna

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Abstract: ***Microstrip has been one of the most popular microwave transmission-line formats for decades and is well characterized. Microstrip circuits find extensive applications in radar systems, microwave communication links, satellite communication systems, wireless and mobile communication systems, medical equipment, etc. In this paper, a model of rectangular patch antenna with two parallel patches is designed and simulated to evaluate the performance. The output results are taken and analyzed for their radiation pattern and transmission losses. The reference/characteristic impedance taken is 50 Ω and the operating frequency domain is.4.5 to 6.7 GHz. The whole microstrip patch antenna is encapsulated in the inert spherical atmosphere of 10 mm thickness containing air inside it.***

Keywords: Radiation pattern, far field, polar plot, finite element, simulation.

1. Introduction

The microstrip antenna, in short, also known as MSA was proposed by G.A. Deschamps in 1953, but practically developed by Robert E. Munson in 1970s [1]. The rectangular patch is generally consists of a metal mounted over a larger sheet of metal called the ground plane. The patch usually may have different shapes such as square, rectangular, circular, elliptical or triangular [2-5]. Figure 1 shows the layout of rectangular microstrip patch.

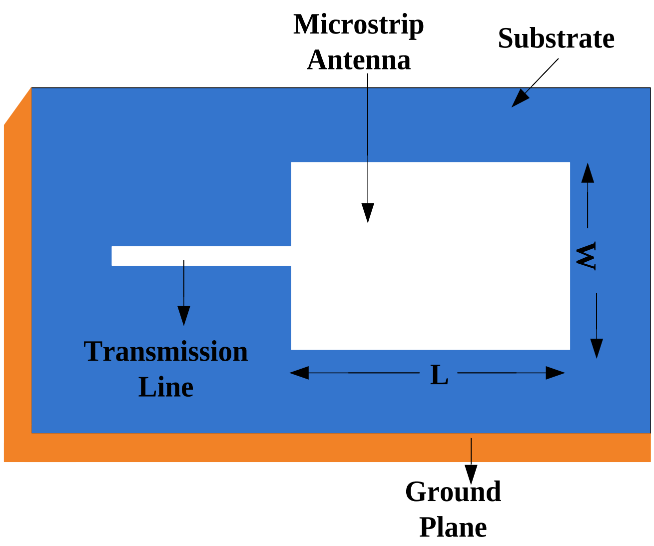

Figure 1: Rectangular microstrip patch antenna.

The selection of an antenna depends on the type of polarization required. Among these, the rectangular and circular patches are studied usually and developed. In fig. 1, the dimension *L* represents the length of the patch while *W* represents the width. The patch is placed over a metallic ground plane. The patch and ground plane are separated by dielectric material of permittivity ϵ_r and thickness *t*. The patch antenna is fed by a microstrip transmission line. The patch, transmission line and the ground plane are all made of high conductivity metal [6-8]. For better performance, the requirement is that the thickness of dielectric material is usually smaller than the wavelength of operation. Microstrip patch antenna is preferred than the bulk antennas because the microstrip patch antennas can be printed directly onto a circuit board [9]. This makes relatively easy to print an array of patches on a single substrate. One important advantage of the patch antennas are their low cost, thus, making them relatively inexpensive in comparison to other types of antennas. These antennas are easy to manufacture and design due to simple 2-D physical geometry. These can be easily modified and customize [10] [11]. Moreover, the conformal structures are also possible in these micro patches. Researchers had already proved that the patch arrays can provide much higher gains than a single patch at little additional cost. Microstrip antennas are becoming very important electronic component in communication devices, particularly with mobile phone and wireless communication systems [12]. Due to compact in size, and light in weight, they can be mounted on the exterior of aircraft and spacecraft. Now-a-days, microstrip patch antennas are preferred in satellite and military applications due to their performance, small size, and light weight [13-15].

There are several methods of feeding the input signal in microstrip antenna. All these feeding methods are generally classified into two main types, i.e., Direct Contact Feeding Method (DCFM) in which the feed line is in direct contact with the patch, and the Non-Contact Feeding Method (NCFM), in which the feed line is not in direct contact with the patch [16]. Both these methods have their own advantages and disadvantages. Several numerical simulation methods have been used to design microstrip structures of a patch antenna. These methods include finite difference time domain (FDTD), transmission line matrix (TLM), finite element method (FEM), and method of moments (MoM) [17] [18].

In this paper, an important design of microstrip patch antenna using rectangular patch is modeled and analyzed using finite element method. The design is studied and analyzed for the frequency domain of 4.5 GHz to 6.7 GHz and the results are evaluated for the far field domain and the polar graph indicating radiation patterns. Also the plot for s-parameter are studied to observe the bandwidth of the designed antenna. The next section of the paper describes the methodology used for design of the microstrip patch antenna using finite element method. The subsequent sections of the paper describe the results and discussions of an antenna and the conclusion of this work respectively.

2. Methodology

The proposed antenna is designed using finite element modelling (FEM) and is a powerful computational technique to attain the solution of differential and integral equations.

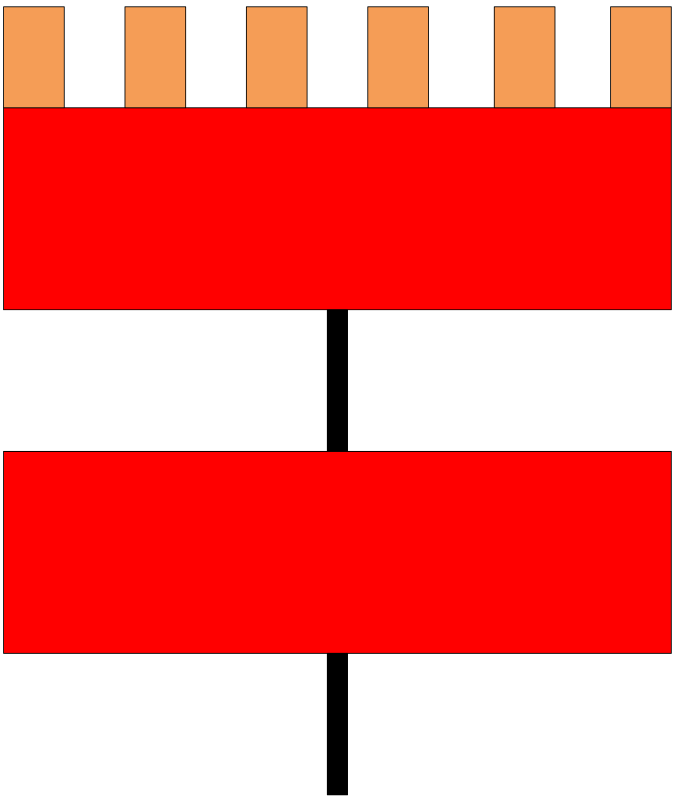

Figure 2: Structural layout of proposed patch.

The structural layout is shown in fig. 2. The essential characteristics and the dimensions of the designed antenna is optimized mathematically and is then simulated. The helping mathematical equations are taken from [16-18]. The given domain can be viewed as a set of simple geometric entities called finite elements that generate the approximation functions [17]. The FEM method solves the problem in a simple way by finite elements that are quadrangle or triangle for solving two dimensional problems, and tetrahedral, hexahedral or prism elements for solving three dimensional problems [18]. FEM models solve the problems and give good results in quick time with accurate solutions by solving multiple differential equations using piecewise approximation [15].

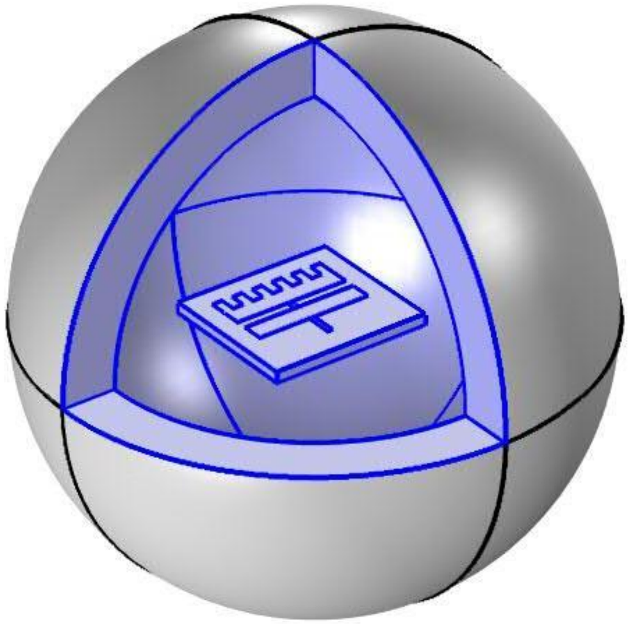

Figure 3: Designed model of an antenna in sphere.

Table 1. Parameters and dimensions of the designed antenna.

Input Parameters	*Values*
Input Impedance	50 Ω
Frequency range	4.5 GHz – 6.7 GHz
Input Voltage	1.0 V
Patch length	40 μm
Patch width	60 μm
Substrate dimensions	80 x 80 μm^2
Thickness	5 μm
Relative Permittivity (ϵ_r)	3.38
Relative Permeability (μ_r)	1
Density	1600 kg/m^3
Electrical Conductivity	0.00

The model that is designed using an electromagnetic wave (EMW), frequency domain solver is shown in fig. 3. The antenna is enclosed in a sphere containing air inside it. The spherical domain of diameter 80 mm and the layer thickness with 10 mm of the sphere is selected. The material selected inside the spherical domain is air. The spherical domain is surrounded by a perfectly matched layer (PML) so as to absorb the radiation from the antenna with minimum reflection. The dimension of the selected material along with the input parameters for microstrip patch antenna is shown in Table 1.

3. Results and discussions

Figure 4 shows the meshing design of the proposed patch antenna model. For effective computational analysis, tetrahedral meshing is preferred. The maximum element size selected is 35. The design was simulated on the computational machine having 3.6 GHz processor speed. The virtual memory used while simulation was 2.1 GB. For higher element size, the processor speed of the machine needs to be fast. Optimum element size is selected to reduce the computational load and to attain the convergence plot.

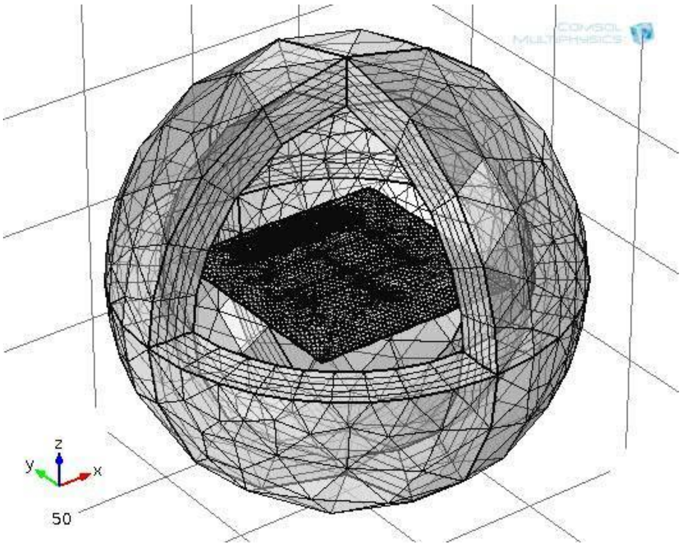

Figure 4: Meshed design of the proposed model of an antenna.

Mesh settings give a mesh that is sufficiently fine in most parts of this design, including the minimum required 2 - 3 second-order elements across the thickness of the PML.

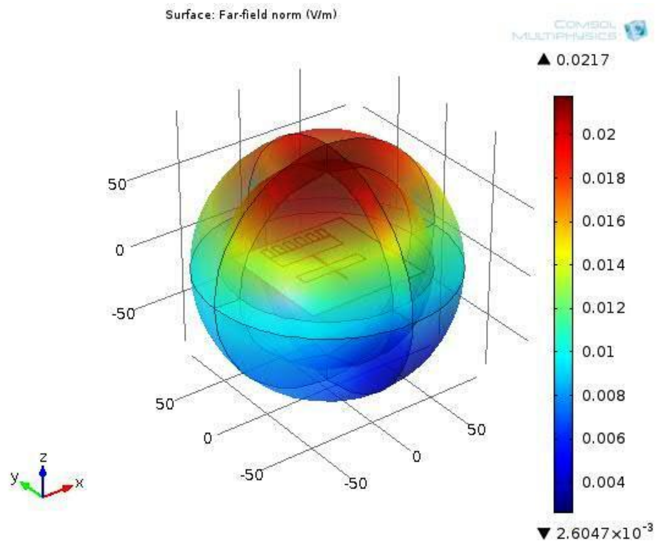

Figure 5: Far field domain of an antenna.

To improve more accuracy in the results, extra-fine mesh size are recommended where the field gradients are steep, like, on the patch and the ports. Figure 5 shows the far field domain for the proposed rectangular microstrip patch antenna. This is clear that the maximum far field domain for the rectangular microstrip patch antenna is 0.0217 V/m.

Figure 6 shows the polar graph showing electric and magnetic field radiated in the surroundings. The beam of the antenna should be very sharp and thus increases the performance in propagating signals.

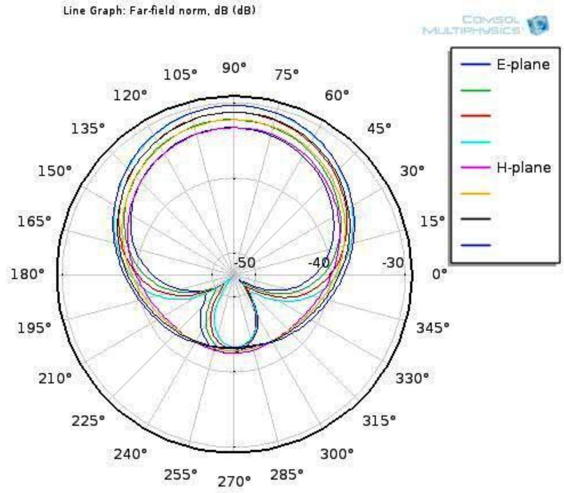

Figure 6: Plot showing polar graph of an antenna.

The polar plot shows the formation of radiation pattern with lesser standing waves that leads to smaller return losses. The high value of return loss means that the reflection wave return back to the source is very small and the amount of radiation power is very high. Figure 7 show the graph obtained for return losses and from the graph it is clear that the resonant frequency for the designed microstrip patch antenna is 6.0 GHz. Moreover, the bandwidth is estimated to be 0.8 GHz.

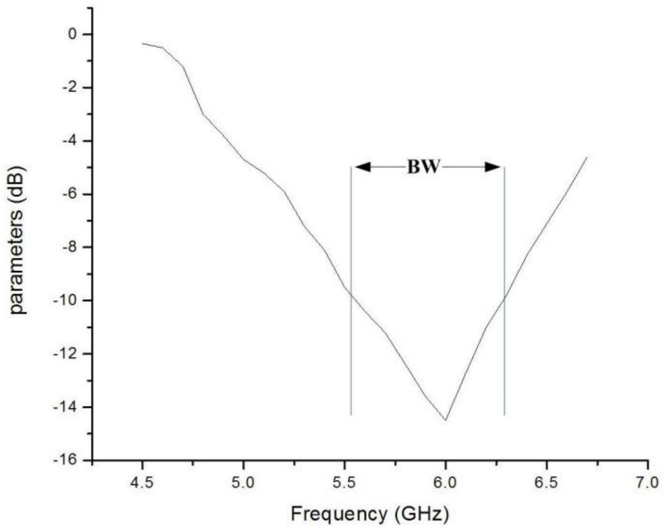

Figure 7: S-parameters showing return losses of an antenna.

All these evaluated results show that the variation of the parameters changes the resonance frequencies of the antenna. Hence, there are several parameters that should be optimized to attain proper performance. The operating frequency also depends on the useful frequency band in microwave range.

4. Conclusion

This paper presents a unique design of microstrip patch antenna that is self-effacing and economical for wireless communication applications. The design simulated to determine the output parameters like, far-field radiations, polar plots and the insertions losses. The results showed that the designed patch antennas operates successfully for the frequency domain of 4.5 GHz to 6.7 GHz and the obtained bandwidth is nearly about 0.8 GHz. The resonant frequency obtained is 6.0 GHz.

Our future work will comprise of improving the design to be operated at any frequency for wireless communication purposes. Designs using different substrate and structure can be taken into consideration for the future research.

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