ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 7, July 2014

Design and Analysis of Balanced Doubled Feed Square Patch Antenna using Finite Element Method

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Abstract: This paper presents the design and implementation of a square patch antenna using finite element method. A balanced square patch antenna model has been constructed using FEM (Finite Element Method) with COMSOL multiphysics environment. A parametric analysis is carried out to analzse the performance of the proposed antenna on the basis of Antenna impedance, Radiation frequency and Radiation pattern. The proposed antenna is made for 6 GHz frequency. From the simulation results it is found that very good radiation lobes with negligible side lobes are obtained. The optimum values of power density and impedance of the antenna are also obtained at optimum frequency 6.18 GHz.

Keywords: FEM, MPA, Radiation, Impedance

I. INTRODUCTION

Now days the micro strip antenna structures becomes most popular and are used for wireless communications for various band ranges such as wi-fi, wimax , C, and X band. At the time of its inception in early 1970's patch antennas were associated with many disadvantages, such as low efficiency, lower power, high Q, poor polarization purity, poor scan capability and very narrow bandwidth. In past few decades with the evolution of design technology, planar patch antennas have achieved higher bandwidth, mechanical robustness and versatility with respect to resonant frequency, improved polarization patterns and wider impedance bandwidth. There are so many techniques and numerical methods are present for the design and parametric analysis [4]. However these methods are accurate for the solution of antenna parameters such as gain , bandwidth and radiation pattern, but they are still need very length and complex calculations. So, the finite element method is the solution to obtain approximation analysis. Flexibility is the furthermost advantage of finite element method with respect to the other conventional methods. In this method the subdivisions may consist of triangles, general quadrilaterals or their combinations with or without warped sides. These can be fitted very easily to the profile of any multipart shaped domain. The grid can be made fine or coarse in different regions of the solution domain in a very flexible way as and when required [15,16]. By the use of selective lateral etching based on micromachining techniques to enhance the bandwidth and the efficiency by as much as 64% and 28%, respectively. The performance of rectangular microstrip patch antennas printed on high-index wafers such as silicon, GaAs, and InP. Micromachined patch antennas on Si substrates have shown superior performance over conventional designs [1]. The attractive properties of ferrite patch antennas were presented. The high dielectric constant of the ferrite, inherent magnetization, and external biasing all serve to minimize the size of the patch, in addition to providing pattern control and lower radar cross section over a given band. The employed hybrid FE-BI method also permitted an investigation. The nonuniform bias fields cause inhomogeneities that affect the operation frequency and overall response of the antenna and may be a cause of discrepancies between measurements and calculations [2]. Fast integral methods and their application in modeling composite and volumetric material structures were discussed and introduced volumetric modeling of magnetic materials using VIE methods and compared results with data based on the FE-BI technique. A new domain decomposition was introduced for large array evaluations [3]. To analyze the impedance properties and radiation characteristics of plannar and curved microstrip patch antennas a finite elements-boundary integral procedure was developed without any significant impact on the performance of a single patch antenna [5]. A small H-shaped micro-strip patch antenna was designed to analyze its characteristics to an operating frequency of 2 GHz. A comparison between the IE3D simulation and MATLAB result was shown. Also, it was Shown that the comparison of simulated and measured result in simulated result return loss is found to be -30.33 dB at resonant frequency 1.99 GHz while in measured result return loss is obtained -16.6 dB at fr =1.77 GHz [6]. A Dual-band microstrip antenna based on split-ring elements was introduced for GSM/DCS (900/1800MHz) applications using Finite Element Microstrip Antenna Simulator (FEMAS) and the commercially available High Frequency Structure Simulator (HFSS) [7]. A comparative study was made for the radiation problems which was based on the combined field integral equations coupled to the Method of Moments (MoM) as a numerical solution of the integral equations. Rectangular and circular micro strip patch antennas are analyzed using MATLAB and a comparison is made between them [8]. The low gain of microstrip

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Vol. 2, Issue 7, July 2014

antenna is one of the important features that restrict its wide usage the gain and bandwidth enhancement techniques were implemented on different shapes such as square, T and rectangular microstrip patch antennas were presented in [9-14]. In this study a balanced square patch antenna is designed using finite element method in COMSOL environment. The parametric study is carried out for the validation of the performance of the proposed antenna on the basis of radiation pattern, impedance and power density versus frequency.

II. DESIGN AND MODELLING

A balanced double feed square patch antenna has been made by the following design steps as follows:
The patch antenna is fabricated on a printed circuit board (PCB) with a relative dielectric constant of 5.23. The whole backside is enclosed with copper and the front side has the pattern of the drawing as shown in Figure 1 given below.

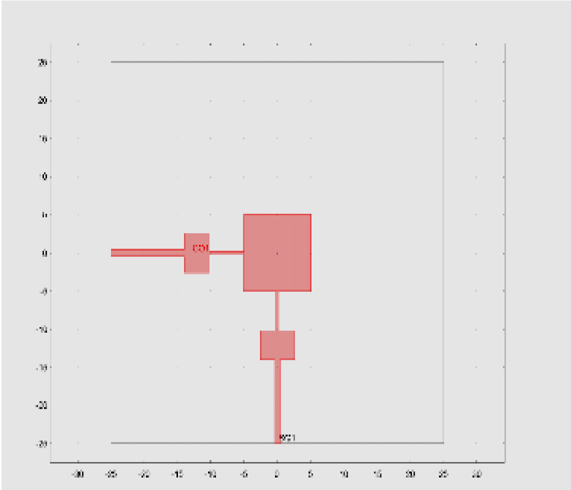

Fig. 1. The printed pattern of the patch antenna shown as a top view.

The coaxial cables have an external conductor with an inner diameter of 4 mm and a centre conductor with a diameter of 1 mm. The space between the conductors is filled with a substance with a Teflon material. There are two coaxial cables feeding the patch antenna from two sides, resulting in a balanced feed. The fabricated proposed antenna is shown in figure 2 given below.

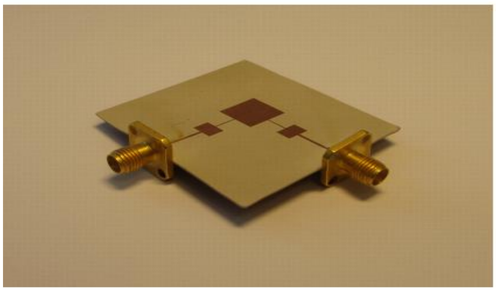

Fig. 2. Fabricated patch antenna [15,16]

For frequencies around 6 GHz the damping parameter α is 0.005, so less than 1% of the radiated signal is reflected back. In the present work h-type refinement has been taken into consideration. Figure 3 shows the 1st refinement in which there are 430666 elements. Figure 4 shows the 2nd refinement in which there are 1422549 elements and Figure 5 shows the 3rd refinement in which there are 4640336 elements. Higher is the number of elements or the order of elements, more will be the computational time and accuracy. A trade-off between the computational efforts and accuracy is thus required to be done from optimization point of view. In the present work the refinement in the proposed antenna model has been carried up to 3rd stage in which there are 4640336 3-D elements.

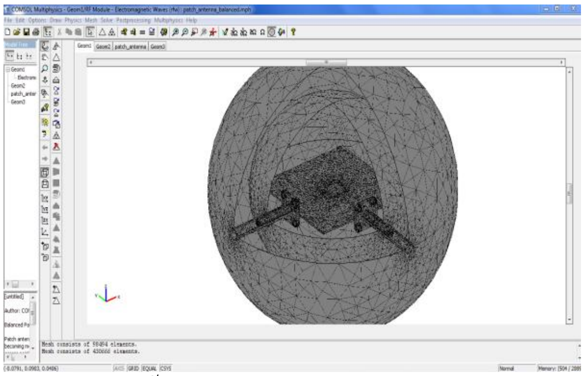

Fig. 3. 1st refinement with 430666 elements

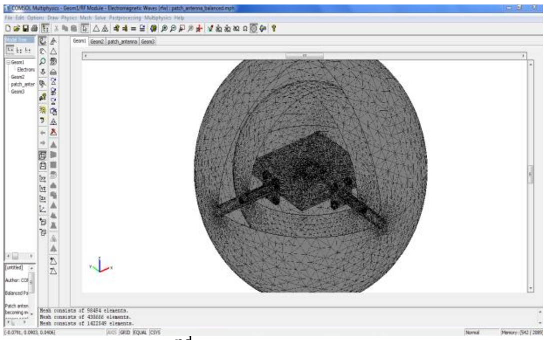

Fig. 4 . 2nd refinement with 1422549

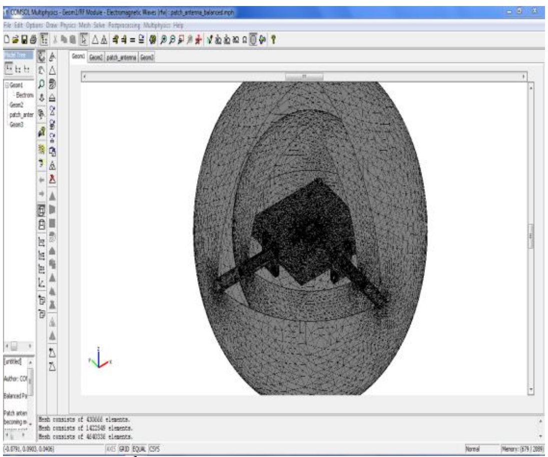

Fig. 5. 3rd refinement with 4640336 elements

III. RESULTS AND DISCUSSIONS

After making the antenna model using the finite element method in COMSOL environment the following case studies are performed to analyze the performance of the proposed antenna. Start with the cross section plots to estimate the total energy density per cubic meter over the average time period for arc-length varies from 0 to 0.01

sec. The figure 6 represents total energy density per cubic meter as for different values of the patch surface volumes given below.

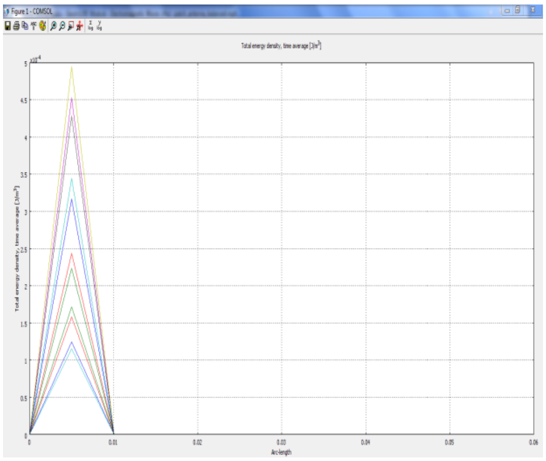

Fig. 6. Total energy density/m^3 versus arc-length for 1st cross section

Figure 7 shows the graph between the total energy density/cubic meter versus frequency. The optimum value of energy density is $6.8*10^{-7}$ (J/m^3) at 6.3 GHz.

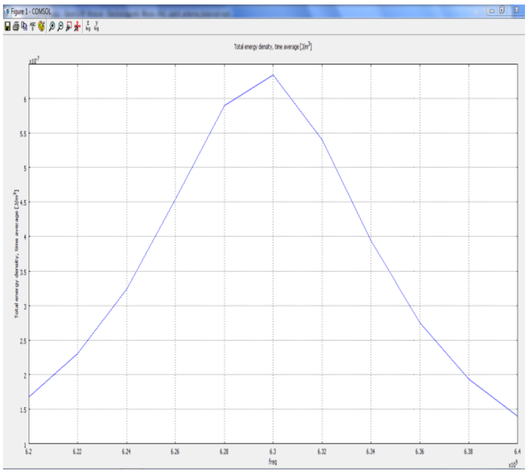

Fig. 7. Total energy density/m^3 versus frequency 2nd cross section

The electric field intensity (V/m) plot with respect to frequency 6.3 GHz as shown in figure 8 given below.

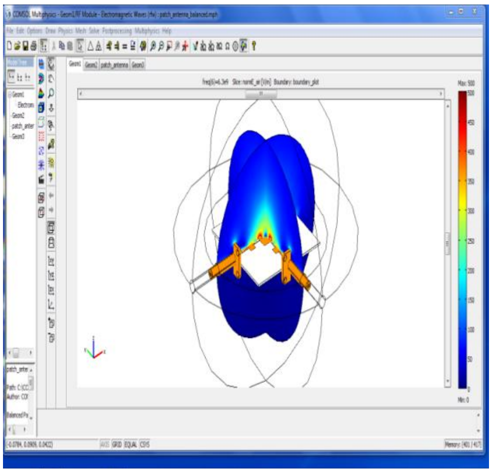

Fig. 8. Electric field intensity(V/m) versus frequency

It has been observed from the figure 8 that the electric field intensity is found to be maximum 250 V/m at 6.3GHz frequency near to the surface of the patch. The minimum value of electric field intensity is 5 V/m at far end from the surface of the patch. Figure 9 shows the radiation pattern of the antenna and show very good radiation density at far end from the patch given below

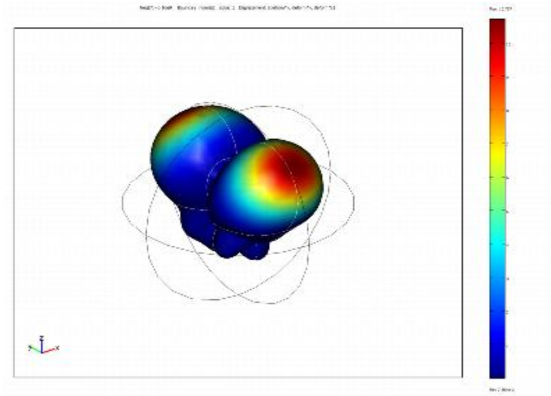

Fig. 9. Radiation Pattren

The radiation pattern is usually plotted in a lobe pattern, which is a surface representing the directional strength in all directions of the antenna. This plot is interpreted as follows the vector between the origin and a point on the surface has a magnitude that represents the radiated energy in the direction parallel to the vector. The energy is given in dB, and the 0 dB level is the maximum radiated energy (a point on the unit sphere). The lobe pattern can be created with a deformation plot, where 0 dB is no deformation and -40 dB is the maximum deformation to origin. The radiation pattern for the modelled patch antenna is shown in Figure 9 for the optimum frequency 6.18 GHz. The antenna impedance is plotted against the frequency in figure10 below and at the optimum frequency the impedance almost matches the cable impedance.

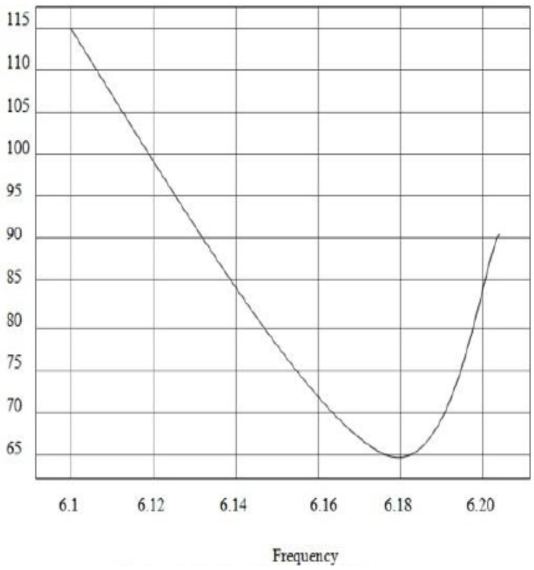

Fig. 10. Antenna Impedance versus frequency

From the above figure antenna impedance is found to be 65 ohm at optimum frequecy 6.18 GHz.

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IV. CONCLUSION

In the present work a balanced patch antenna has been analyzed at frequency of 6 GHz using finite element method. Due to the complex relationship among the geometry of the antenna and the electromagnetic fields, it is very complicated to calculate approximately the properties of a certain antenna shape. To rise above from this complexity simulation of patch antenna is done in COMSOL Multiphysics environment & a result of this the plots of radiation pattern, radiation frequency & antenna impedance are obtained. The changes in the shape of the patch can be directly related to the changes in antenna impedance, radiation pattern and antenna efficiency. From the dissimilar plots it is concluded that the most favorable frequency is located at 6.18 GHz and it is achieved by a resolved sweep of frequency in the range around 6 GHz. Also the impedance of the antenna at 6 GHz matches with the cable impedance which allows maximum transfer of power.

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