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ANALYSIS OF ANTENNA RADIATION EFFECTS ON HUMAN BODY TISSUES

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Abstract— Microstrip antennas are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. In this paper, a microstrip patch antenna for ISM2450 band is designed. This paper also presents the effect of electromagnetic waves on a model of the human skin exposed to the antenna designed. The results for reflection coefficient, VSWR and radiation pattern are presented. The simulation analysis was performed using the HFSS software.

Index Terms—Antenna, frequency, HFSS, microstrip, patch, radiation, skin.

1 INTRODUCTION

A microstrip or patch antenna is a low-profile antenna that has a number of advantages over other antennas: it is lightweight, inexpensive, and electronic components like amplifiers can be integrated with these antennas quite easily. While the antenna can be a 3-D structure, it is usually flat and hence sometimes referred to as planar antennas. Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas have several advantages compared to conventional microwave antennas; therefore many applications cover the broad frequency range from 100 MHz to 100 GHz. Some of the principal advantages compared to conventional microwave antennas are light weight, low volume, end thin profile configurations which can be made conformal, low fabrication cost, linear, circular and dual polarizations antenna can be made easily, feed lines and matching networks can be fabricated simultaneously with the antenna

The general layout of a microstrip patch antenna is shown in Figure 1.

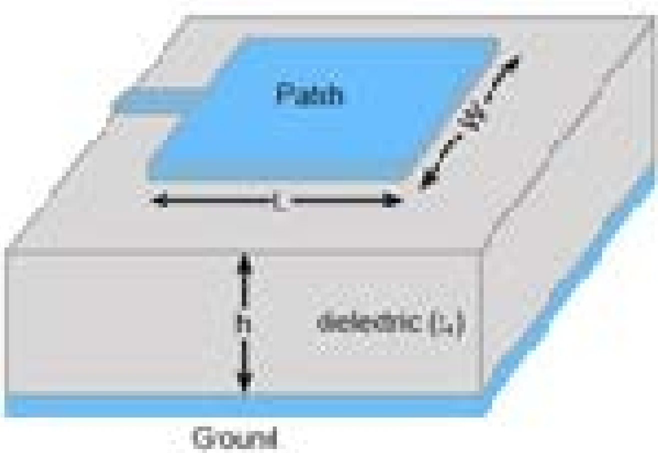

Fig. 1. Schematic diagram of microstrip patch antenna

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The substrate properties such as dielectric constant, loss tangent have a pronounced effect on the antenna characteristics. The dielectric constants range from $2.2 \leq \varepsilon r \leq 12$.In this paper, the dielectric substrate is chosen as RT/duroid 5880 whose dielectric constant is 2.2. The dielectric constant of RT/duroid 5880 laminates is uniform from panel to panel and is constant over a wide frequency range. Its low dissipation factor extends the usefulness of RT/duroid 5880 to Ku-band and above. RT/duroid 5880 laminate is easily cut, sheared and machined to shape. It has excellent dimensional stability and is resistant to all solvents. It is normally used in etching printed circuits or in plating edges and holes. The wireless communication systems specify the frequency range of 2.4 GHz to 2.5 GHz, which operate in the ISM band [1].The ISM (Industrial, Scientific and Medical) bands are frequencies that can be used for medical applications, without requesting permission from theauthorities. Frequency bands and possible limits emission levels are defined by the FCC Part 18. The ISM frequency bands [2] assigned for multiple-user applications are suitable for wireless LAN applications. These applications usually support a limited number of users in an indoor area. Thus the users are exposed to EM waves that directly come from antennas or which are reflected and scattered from objects existing in the area [3]. There is an increasing public concern about possible health hazards due to exposure to EM waves. Accordingly, many international protection organizations and regulatory agencies have proposed the safety standards for exposure to EM waves [4–5]. These standards are based on the SAR, which is a measure of the EM power absorbed in the tissue. The advantages of analyzing specific absorption rate generated by cellular phones inside a human head [6].It is widely accepted that antenna performance is significantly affected by close proximity to the human body. For example, radiation pattern fragmentation (varying propagation conditions), reduced radiation efficiency due tobulk power absorption, resonant frequency shift (antenna detuning) and changes in antenna input impedance due to antenna-body capacitive coupling are commonly reported [7]. Furthermore, the effect of the user's body on antenna characteristics are largely due to the amount of antenna-body coupling and will vary between different antennas, separation distances and near-field coupling with tissue. A microstrip patch antenna resonating at 2.47 GHz is proposed which is made of a silicon substrate. The proposed antenna is been designed for biomedical applications in human body. The designed antenna is aimed to be utilized on skin as well as inside the body taking into consideration of tissue parameters [8]. A method to reduce the effect of signal reflection from the breast skin by placing the antenna in-contact with the breast skin is performed. This reduces the signal scattering from the skin and more transmitted signal is irradiated on the tumor, thus, increasing the tumor detection sensitivity [9]. In this work, we propose to study and design a new microstrip patch antenna operating in the ISM band with a resonant frequency of 2.45 GHz.Then the skin phantom layer is placed on the top of the antenna and the antenna characteristics are studied.

2. Feeding Methods

There are so many techniques available for feeding the microstrip patch antennas and each are having their own significance and impact on these antennas. The functional characteristics and output parameters of these microstrip antennas will be affected by choosing different feeding techniques. Microstrip patch antennas can be fed in a variety of ways.1.Contacting 2.Non-Contacting. In contacting method the RF power is fed directly to the radiating patch using a connected element namely microstrip feed and coaxial feed [10].In Non-Contacting method, electromagnetic coupling is done to transfer the power between the feed line and the radiatingpatch namely Aperture coupled feed and Proximity coupled feed. Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. The disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.

In Coaxial feeding, the inner conductor of the coaxial is attached to the radiation patch of the antenna while the outer conductor is connected to the ground plane. The main advantagesof this method are easy to fabricate, easy to match and low spurious radiation [11-12].Aperture coupling consist of two different substrate separated by a ground plane. On the bottom side of lower substrate there is a microstrip feed line whose energy is coupled to the patchthrough a slot on the ground plane separating two substrates. Top substrate uses a thick low dielectric constant substrate, and the bottom substrate uses high dielectric substrate. The ground plane, which is in the middle, isolates the feed from radiation element and minimizes interference of spurious radiation for pattern formation and polarization. The main advantage of this method is allows independent of feed mechanism element [13-14].In our paper,a coaxial feeding is used.

3. Method of Analysis

There are many methods of microstrip antenna analysis. The most popular are transmission line model, cavity model and moment method. In the transmission line model, the patch is a transmission line or part of a transmission line. This is the easiest way to analyze microstrip patch antennas. Transmission line model does not produce accurate results compared with other models. In the cavity model, the patch is a dielectric – loaded cavity. The cavity model is based on the assumption that the region between the microstrip patch and ground plane is a resonance cavity. The moment model is very accurate but very complex. In our proposed paper, we use cavity model for the method of analysis.

4. Antenna Design

The operating frequency fr is known.
The width of the patch is calculated using the formula:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

The thickness of the patch is calculated using the formula:

$$h \leq 0.3 \times \frac{c}{2\pi\sqrt{\varepsilon_r}f_r}$$

The effective dielectric constant is given by the formula:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left\{\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} + 0.04\left[1 - \frac{w}{h}\right]^2\right\}, \frac{w}{h} < 1$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left\{\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}}\right\}, \frac{w}{h} \geq 1$$

The actual length, L of the patch is using the following formula:

$$L = \frac{\lambda_g}{2} - 2\Delta L$$

To determine the length extension, we use this formula:

$$\Delta L = 0.412h \left[\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right]$$

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{reff}}} = \frac{1}{\sqrt{\varepsilon_{reff}}} \cdot \frac{c}{f_r}$$

Where c is the velocity of light [15].

5. Results and Discussion

The microstrip patch antenna was first designed for 2.45 GHz and simulated using HFSS.The antenna parameters such as return loss, VSWR and radiation pattern are obtained.

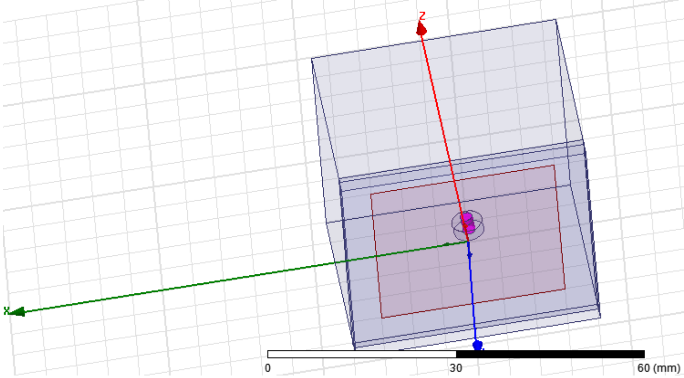

Fig. 2. Microstrip patch antenna

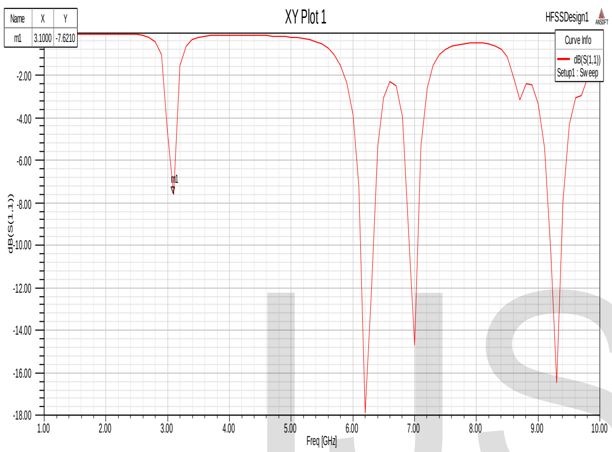

Fig. 3. Return Loss of Microstrip patch antenna

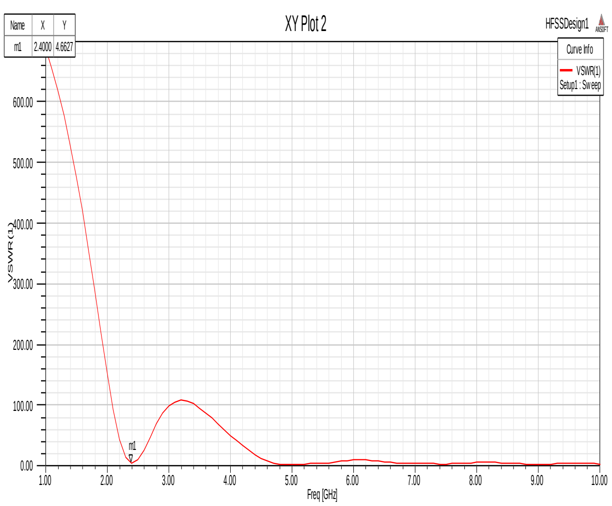

Fig. 4. VSWR of Microstrip patch antenna

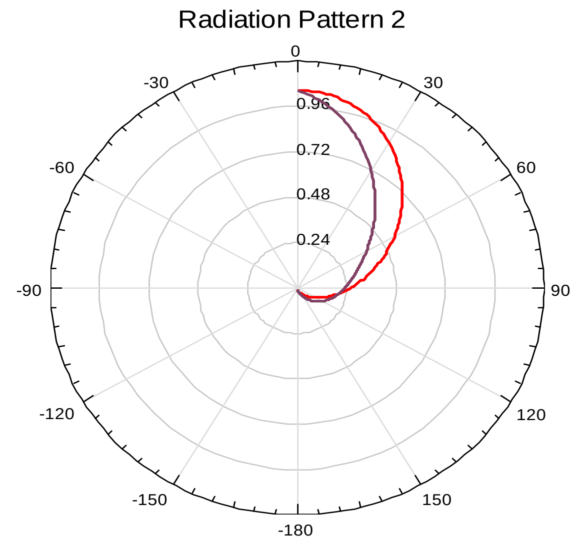

Fig. 5. Radiation Pattern of Microstrip patch antenna

From the graphs,it is seen that the antenna designed for 2.45 GHz radiates oat the frequency of 3.1 GHz. This is due to the fringing effect of the microstrip antenna. Now,we redesign the antenna using the length extension formula and parameters return loss,VSWR and radiation pattern are obtained.

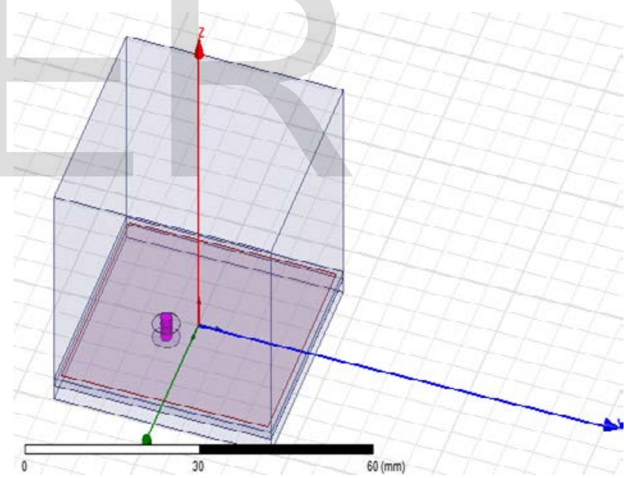

Fig. 6. New Microstrip patch antenna

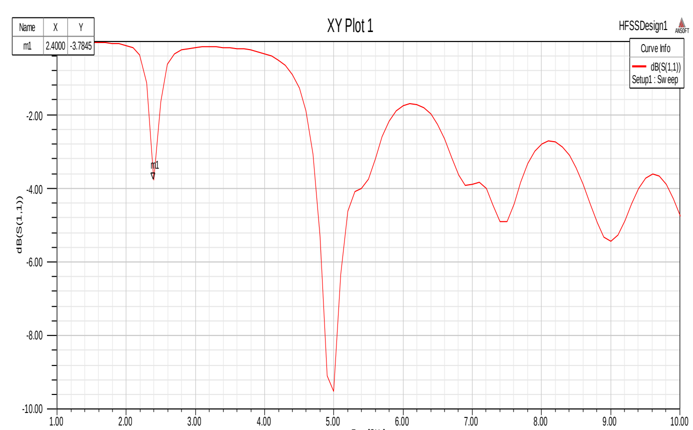

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Fig. 7. Return Loss of New Microstrip patch antenna

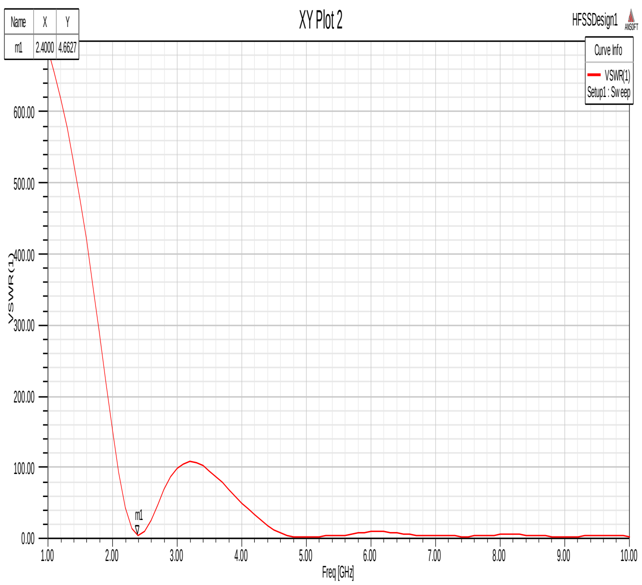

Fig. 8. VSWR of New Microstrip patch antenna

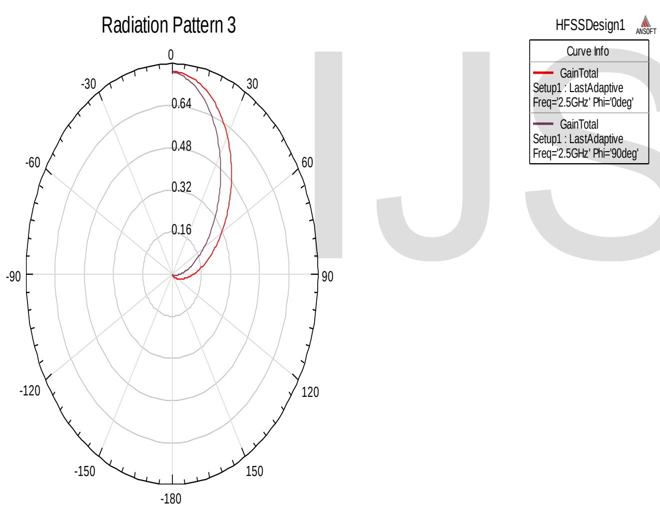

Fig. 9. Radiation Pattern of New Microstrip patch antenna

From the above characteristics,it is seen that the antenna now radiates at 2.4 GHz.Now,we place a skin phantom on the new microstripantenna.The skin phantom has the following characteristics

Relative Permittivity- 37.952

Conductivity - 1.4876

Loss tangent - 0.28184

The antenna parameters are now simulated.

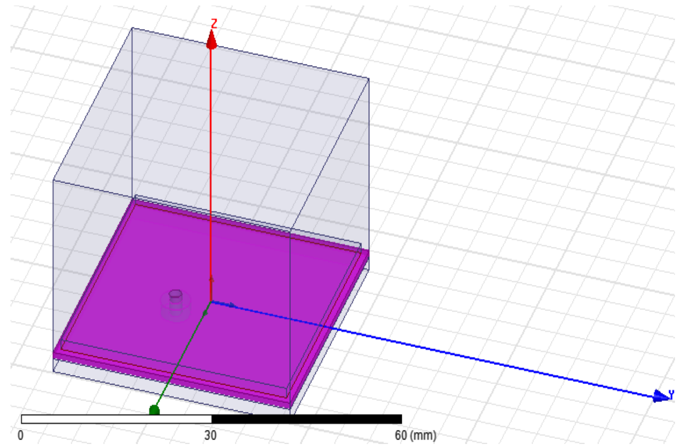

Fig. 10. Microstrip patch antenna with skin phantom

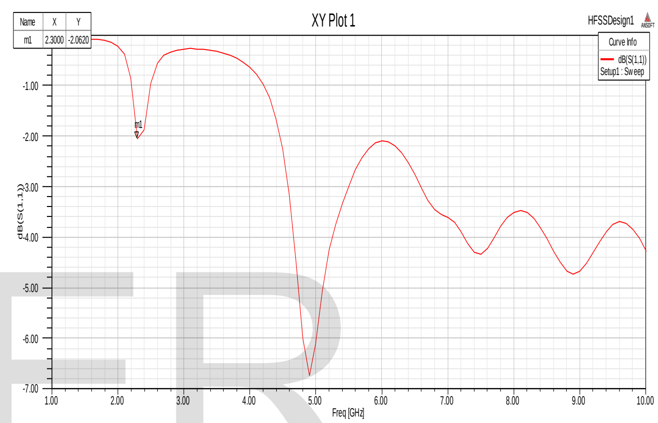

Fig. 11. Return Loss of Microstrip patch antenna with skin phantom

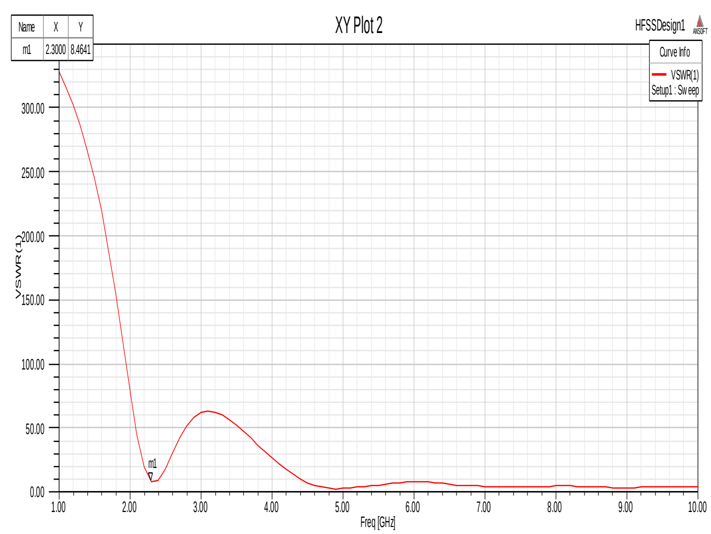

Fig. 12. VSWR of Microstrip patch antenna with skin phantom

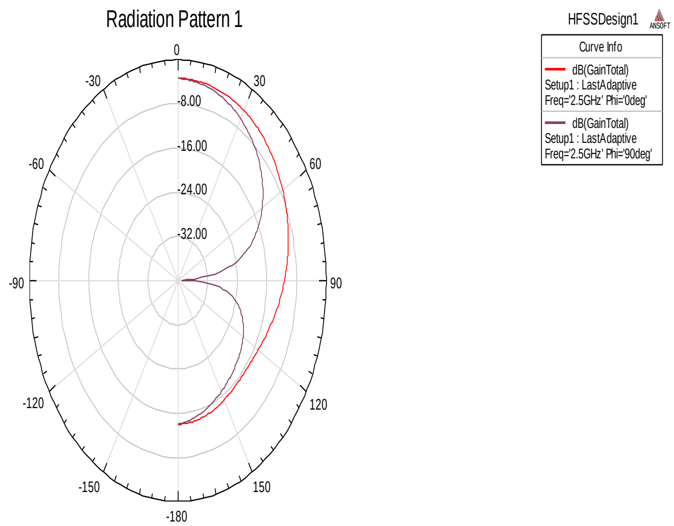

Fig. 13. Radiation Pattern of Microstrip patch antenna with skin phantom

The figures show the comparison between simulated results for microstrip patch antenna and microstrip patch antenna with skin phantom.It can be observed that the resonant frequency shifts to 2.3 GHz with an increased gain and VSWR.

6. Conclusion

An analysis of microstrip patch antenna and microstrip patch antenna with skin phantom has been carried out at 2.45 GHz. Simulation models are developed for both cases using High Frequency Structure Simulator (HFSS). Finally, a comparison among the developed simulation models is performed and conclusions are extracted. From the simulated results, it is observed that there is a frequency shift when a skin phantom is placed over the designed microstrip patch antenna.The same work can be extended for the detection of cancer.

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