Modelling Circular Shaped High Gain Patch Antenna for Biomedical Application

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Abstract - With the upswing in healthcare industry and biomedical engineering, biomedical telemetry has enjoyed a rich diversification in research and patents. Implanted Biomedical Devices (IMD) have become immensely popular and these devices play a vital role to monitor the patient with the help of wireless telemetry. While there has been progress and various research works has been carried out in the field of wearable antenna for biomedical purposes, few are convenient and easy to build and fabricate. In our work we will try to find and explore the most convenient and simple process to build a high gain microstrip patch antenna either by using superstrate, metamaterial, FSS or by building a patch of different shape. For building a biomedical antenna, we have to take into account the size, weight, radiation, material of the antenna, and which part of the body it will be mounted on. Taking everything into consideration, our aim is to design a simple, non-complex, convenient high gain patch antenna for biomedical purposes.

Keywords - Antenna, biomedical telemetry, biomedical devices, microstrip patch, superstrate, metamaterial.

1.0 Introduction

In the past few years, wireless communication technologies has seen an incredible growth. Development of handy and wearable devices has made body-focused applications an important fragment of our human life. These kind of wireless devices are mainly of three types namely – On-body, Off-body and In-body. These wearable devices exhibits On-body communication. Off- body communication can be denoted as the communication between an On-body device and peripheral system. And, in-body communication contains an implantable device and an external device for health monitoring of the patient. In this kind of communication devices or instruments, antennas plays a very crucial part because the antenna performs as either transmitting or receiving antenna. And, if the performance of the antenna is not up-to the mark then it will affect the performance and result of the entire set-up.

1.1 ISM Band

In communication industry, wireless communication is the fastest growing segment. It has captured the eyes of majority of us. These systems are gaining reputation in the license-free Industrial, Scientific and Medical (ISM) frequency bands. One such emerging growth is ISM frequency band. The Industrial, Scientific and Medical (ISM) frequency bands are designated radio frequency bands. These frequency bands were kept separately for RF use for purposes except tele-communication. The ISM frequency bands are scattered from 6.78MHz to 245MHz in the radio spectrum, has been earmarked for industrial, scientific and medical purposes. Although, initially set away for non- communication purposes, several short range, low power communication systems functions inside the ISM band. Of the most common usages outside communication are induction heating for industrial and domestic uses, microwave heating for industrial and domestic applications and microwave heating for medico purposes. Lately, there have been advances in radar systems that operates in ISM bands. Some causes for this could be the upsurge in potential of Internet of Things (IOT) and Industry 4.0 uses, which will possibly bank on on low-power and short range machine type communications without the direct participation of the users.

1.2 Biomedical Antenna

In bio-medical telemetry, the Implantable Medical Devices (IMDs) and Wearable Antennas are capable of observing the patient's data in real time. These devices have the capability of communicating with another devices wirelessly. In today's world, these devices has a lot to offer and it has many useful and important applications. Now-days, biomedical devices have turn out to be very vital in many fields and presently they are being used in vast variety of medical purposes such as dental antenna for remote health-care applications, continuous real-time blood pressure measurement and intracranial pressure monitoring. These devices are also being significantly used in sugar level observation, heart beat or heart rate monitoring and other various bio- physical parameters. For working in a suitable and appropriate manner, bio-medical devices requires an efficient compact antenna that fits either inside or around implantable device. There is a need for installing an antenna capable of data transmission. In this paper, an attempt has been made to give an inclusive review of the requirements and challenges and various techniques used to meet them in the field of implantable or wearable antenna.

2.0 Background

In earlier days, high gain, low cost planar antennas enjoyed a lot of interest because of their applications in the upper microwave and millimetre-wave regions. These types of antenna were used in high-speed wireless LAN, satellite reception and various point-to-point radio links. Patch array antennas have also been chiefly good contenders, but the feeding mechanisms became prohibitive to the bandwidth and the antenna efficiency [1]. We have used the shortcomings of earlier generations of patch antenna as our motivation of work and build a high gain modern patch antenna. In [2] we can see that previous work on superstrate effects on printed circuit antennas has been carried out, but the antenna radiation efficiency is quiet low due to high substrate dielectric constant and associated surface wave effects. This is used as a motivation to investigate radiation efficiency on substrates and gain optimization by incorporating suitable superstrate materials. These instances has made us eager to perform our project in this domain and topic to try and find appropriate solutions and modifications to improve gain enhancement in patch antennas of different substrates and superstrate layers.

3.0 Approach

3.1 Different Ways of Gain Enhancement of Microstrip Patch Antenna

Out of numerous ways of gain enhancement of Microstrip Patch Antennas, following are the few ways in which we can enhance the antenna's gain:

1) **Metamaterial:** It has been proven that metamaterials enhance some specific performance parameters in both low and high profile antennas. In [3], in order to calculate the radiation field of an enhanced micro strip patch antenna with superstrate, a fast and analytical technique was developed. The cavity model and transmission line analogy sets up the base for the analytical formulation. When superstrates are used, maximum gain enhancement can be achieved and to demonstrate that, optimization results are presented.

2) **FSS**: In [4] for gain enhancement, frequency selective surface [FSS] is proposed. From the same antenna, three different versions were created and their S-parameters were simulated via software. One of the three antennas were then simulated with a FSS. Then the two devices, FSS and antenna were also manufactured and their S-parameters were measured in the laboratory. During simulation it was found that the gain increased when the FSS was used as a superstrate on the antenna compared to when it was not. The simulated results and the measured results in the lab were compared and they matched.

3) **EBG:** To increase the gain of an antenna, EBG superstrate may be used. In [5] we see that EBG superstrate is used as spatial angular filters and by sharpening of the radiation patterns, filtering of undesired radiation is achieved. To increase the gain of the antenna, often the effect on antenna input impedance bandwidth as a consequence is neglected. EBG superstrates which were previously used can be reused to increase gain of an antenna while at the same time, input impedance bandwidth is adversely affected. So a new EBG superstrate which increases both gain and input impedance bandwidth is introduced.

4) **AMC:** Artificial magnetic conductor(AMC) are used in antenna designs as it is a metamaterial which mimics the behavioural characteristics of Perfect magnetic conductor(PMC) which is naturally unavailable. Various improvements in performance can be achieved through it like in [6] where it is combined together with superstrate resulting in improvement of the radiation performance. By using CMOS technology, AMC structures can be fabricated with integrated circuits and is a low-cost approach.

5) **DGS:** In [7] we can see the gain enhancement of a microstrip patch antenna which is inset feed and uses H-shaped Defected ground structure (DGS). In DGS technology, by reducing higher order harmonics the gain of the antenna can be increased. Simulation results prove that there is a high increase in gain when the antenna is used with DGS compared to when it is not.

4.0 Designing

After considering our options and examples of gain enhancement techniques, we have decided to proceed with designing two different versions of a similar shaped antenna. The antenna will be circular shaped with a rectangular feedline. A superstrate layer will be added on one of the antennas for further studying their comparative gain enhancement.

4.1 Designing a High Gain Circular Shaped Biomedical Antenna

For this experiment we have designed two types of patch antenna to find maximum efficiency in our results. Both the antennas contain a circular shaped patch with a rectangular feedline.The first antenna is a simple circular shaped patch on a square substrate, while the second antenna contains a square superstrate made of metamaterial over the circular shaped patch. In fig 1.1 we can see that the antenna is built on a square substrate of each side 70mm and thickness of 3.6mm with a circular patch in the centre, of radius 16.87mm.The circular patch has a rectangular feedline of 29.9mm in length and 3mm in width. This antenna with same design will be used as base for the second antenna with a superstrate.

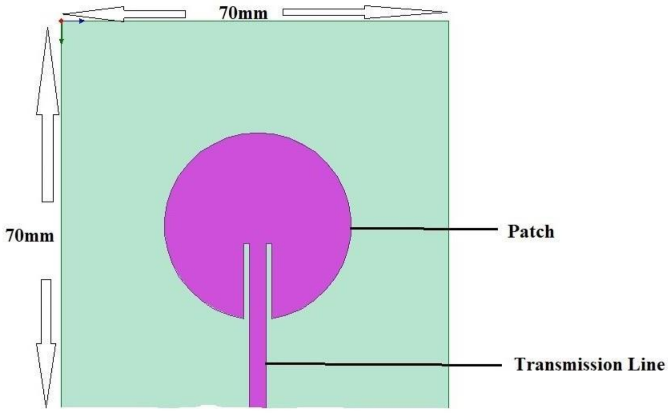

Fig 1.1: Top View of Antenna

4.11 Modelling

We have used ANSYS HFSS software to model both the patch antennas. For the antenna without superstrate we have taken a square shaped ground plane made of copper sheet for finite conductivity with each side being 70mm long.On top of the ground plane we have added a square substrate of same dimensions and with thickness of 3.6mm.We have chosen FR4 epoxy as the material for the substrate. On top of the substrate we have added a circular shaped patch made of copper sheet for finite conductivity with radius of 16.87mm.This circular patch is fed with a 29.9mm long and 3mm wide rectangular feedline made of copper sheet. The antenna is fed with a 50 ohm transmission line. For the second antenna we have used the same model as base. On top of the base we have added a superstrate made of metamaterial and at a distance of 12.5mm from the base. We have used FR4 epoxy but with a manipulated dielectric constant of 4.3 and a loss tangent of 0.01 as our superstrate material. The superstrate is square shaped with each side 70mm and thickness of 1.48mm. During fabrication, the superstrate will be attached to the substrate with the help of copper screws.

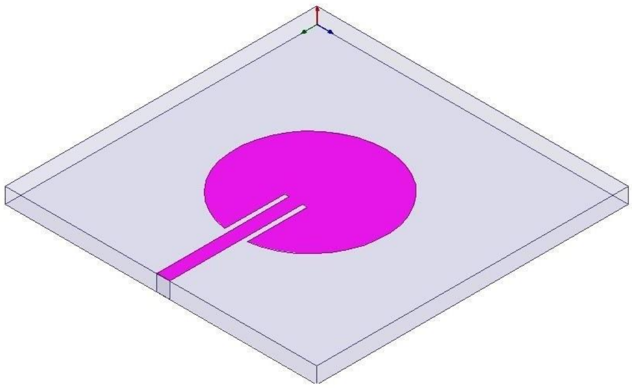

Fig 1.2: Antenna without superstrate

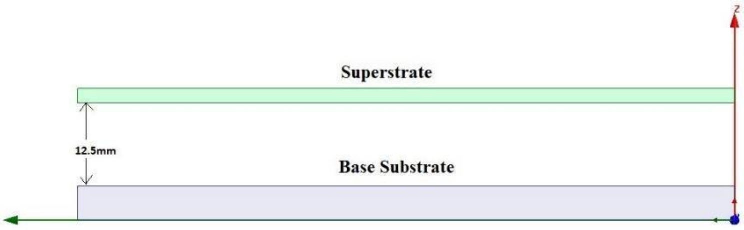

Fig 1.3: Side view of antenna with superstrate

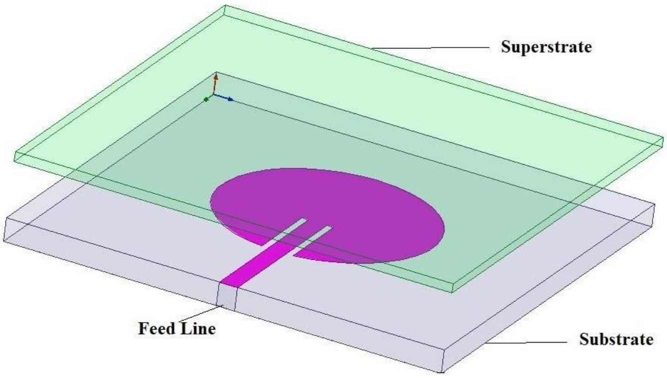

Fig 1.4: Diametric view of antenna with superstrate

4.12 Simulation and Result

We have simulated the models with the help of ANSYS HFSS software. Through simulations our aim was to find the S11 graph and the radiation pattern of the antennas. An ideal S11 graph will have a peak lesser than -10 dB, through our simulations we have managed to achieve that. In fig 1.5, during s11 graph plotting we have taken the antenna without superstrate as our reference antenna and the one with superstrate as our loaded antenna. The reference antenna achieved a peak value of about -32.5db while the loaded antenna reached a peak of -15.2db. Both the antennas were simulated at 2.45 GHz. The shift in peak of the values in the s11 graph is expected due to the addition of superstrate layer and the result is satisfactory and within desired limits. We have also found out the gain of the antennas through radiation pattern plot. We can notice big positive change in gain from antenna without superstrate to antenna with superstrate. This result is favourable and satisfactory in terms of the aim of our project.

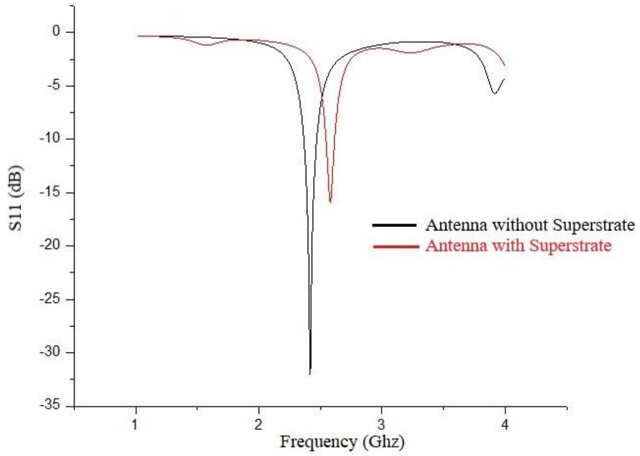

Fig 1.5: Stimulated S11 of proposed antenna with and without superstrate

5.0 Conclusion

We have designed a circular shaped high gain patch antenna. To better understand and modify the gain we have built two types of antenna model, one with the base model and the other one with a metamaterial superstrate layer over it. By performing simulations and examining the outcomes we can infer that both the types of antenna are of very high gain. Although adding a metamaterial superstrate layer over it further increases the gain and thus are more favorable to work with. We have built these antennas for the purpose of use in biomedical applications. In that aspect they can be easily used as their design is simple and the materials used are readily and cheaply available. These characteristics make the antennas low cost, efficient and readily available.

6.0 Reference

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