On-Body Adhesive Microstrip Antenna for Wearable Application

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Abstract: - Modern communication systems are driven by the concept of being connected anywhere and at any time. Fuelled by the idea of a body-centric approach to modern communication technology, many research projects have been initiated to integrate antennas and radio frequency (RF) systems into clothes with regard to size reduction and cost-effectiveness; so that the wearer may not notice the existence of these subsystems. Integrating antennas with electronics is a vital role for supporting many applications, biomedical, military and commercial fields. The antenna designed for these applications should be wideband, not sensitive to human body. The antenna structure is simple and looks like an adhesive bandage, and can be placed on human tissue. This paper presents a novel planar, via-free, printed antenna which looks like an adhesive bandage is designed on RT Duroid 5880 dielectric substrate. Later in order to design a flexible antenna, the antenna is designed on flexible substrates such as fabrics for wearable application. The proposed antenna characteristics are analyzed in both printed flat and curved structure, to support all real time applications. Antenna parameters, such as return loss, radiation patterns, VSWR and gain plot were evaluated in various scenarios to validate the proposed design. The proposed antenna is designed and simulated using High Frequency Structure Simulator (HFSS version 13) software tool.

Key-Words: - Radio Frequency (RF), High Frequency Structural Simulator (HFSS), Adhesive bandage like antenna, RT Duroid 5880 substrate

1 Introduction

Our communication technology driven of being anywhere and at anytime, anyplace, any network. In microwave communication, the antenna play a vital role. It is useful for transmission and reception. The main operation is to convert voltage and current from transmission line into electromagnetic waves. Idea of on-body communication has been initiated to integrate antennas and RF system into clothes, with regard to size reduction, cost effective.

Microstrip patch antenna is well known for its beam scanning performance, their robust design, low fabrication cost, thin profile configuration design, dual characteristics, wideband not sensitive to human body, no cavity backing, maintenance – free and no installation. Linear & circular polarization, dual & triple frequency operation, frequency agility, frequency bandwidth, feed line flexibility feed lines & matching network can be used simultaneously. It is used in planar & non-planar, easy to fabricate with MMIC same like lithography to increase mass production. To design a flexible antenna, for wearable application. On – body communication channels are of increasing progressively for medical integrated with sensor applications, paramedicine. Ever developing of technology leads to reduction of electronic components, integrated with wearable fashion, creating flexible equipment by significant trends like increasing usage, reduction in power sources. These electronic devices must satisfy certain important criteria for wear ability. Though the usage of wireless communications lead to ignorance of wire connections.

The radio wave characteristics due to arrangement of antenna positioning may reduce the antenna functions. All the measurements for wearable application has to be concentrated on 2.45 GHz Industrial, Scientific, Medical (ISM) band. Wearable antennas can be used for all types of age group people for monitoring includes athletes, the aged and teenagers & youngsters. The monitoring system usage in hospitals cannot support for wearable application. The sensors handling for longer duration will be bulky and pickup noise more. To overcome these, better integrated with them.

For data acquisition purpose, the sensors are fixed and integrated with specific position and location. Even more drawbacks like interference, radiating nearby, denoising the signal, rearranging sensor position. The health parameters that may be transmitted wirelessly to remote stations. A reliable low profile antenna is required for best performance electro – textile, microstrip patches, button antennas, wearable multiple input multiple output (MIMO).Comfortable and conformal to the body shape, yet they must maintain high performance in terms of reliability and efficiency.

For wearable application, electro textile antennas are not applicable, as it contains low profile solution, even more demerits like substrate material discontinuity, adsorption of fluids. The perfect option in the field of telemedicine for monitoring of patients is applicable by wearable antenna.

This paper proposes a planar, via-free, printed antenna, which looks like an adhesive bandage (also known by the generic trademark, Band-Aid).For specific frequency bands, the antenna to be integrated with electronic devices to support connectivity with wireless to fulfill human necessity and challenges facing today. The integrated system characteristics reveals on proposed antenna efficiency. The wireless connectivity supports integration with flexibility, light weight, compactness, and low profile strength. As this antenna can be manufactured in printed circuit board, made it easy for real time practical application. In order to design antenna flexible, the antenna designed on a flexible substrates for wearable application. The patch may be of any shape rectangular, square, elliptical, and circular ring, triangular. On the other hand, these antennas should have high tensile strength for efficient bandwidth and desirable radiation properties.

Flexible material can be made into any shape like Cars, robots, buildings, human body, and human prosthesis. The approach will be thin metal films above elastic substrate. In stretched position also, metal thin film stabilize their conductivity range. The novel antennas applicable for interactive portability with satellites, beam steering, emergency communicative devices, ground – penetrating radar, which are portable, search for features in geophysical environment.

The main antenna design demerits reveals to support in new challenging environment with improper matching to deal day to day flexibility. With the ability to be flexed in either concave or convex directions, without degrading antenna performance, the small size and adhesive backing give further mounting flexibility within your product design. Section I deals with antenna design, feed excitation point. Section II describes antenna remodeling. Section III discuss about simulation results.

2 Antenna Design

Table 1: Patch antenna dimensions (in mm)

Specification	Measurement
Input Frequency	1.43 GHz
Input Impedance	50Ω
Dielectric constant of substrate	2.2
Height of substrate	1.5mm
Length of substrate	71mm
Width of substrate	13mm
Loss tangent	0.0009

As microstrip antennas are planar and easily fabricated, the flat plate on the ground plane, the conductor in the center of the coaxial cable is serving as the feed probe in order to couple electromagnetic energy in or out of the patch. It can be widely used in handheld devices (wireless) such as pager, mobile phones etc. The antenna comprised a rectangular patch and a rectangular metal ring on top of the circuit board, as well as a ground conductor on the back, 0.8-mm-thick Duroid RT5880 dielectric substrate. The losses can be reduced by increasing the thickness of the dielectric substrate. The perfect design progress leads to best design with lower cost for a best performance. Analyses of different antenna models & their proper performance create a way for best combination for use in practice, to update the recent trends and technology.

2.1 Feed Point Selection

Microstrip antennas have many feeding methods. Microstrip line and coaxial cable method belongs to contacting feed techniques, whereas aperture and proximity coupling belongs to non- contacting feed techniques, other than this co-planar wave guide feed methods are possible. There is need of impedance matching from microstrip antenna to load impedance; anyway feed technique may be microstrip line coaxial feed, coplanar waveguide. The two metal sheets together form a resonant piece of microstrip transmission line with a length of approximately one- half wavelength. The simplest patch antenna uses a patch which is one – half wavelength long, mounted a precise distance above a larger ground plane. The aspect ratio of this microstrip rectangle antenna is chosen’s each orthogonal node TM01 excited node at point A, TM10 excited node at point B. TM01 requires extra matching network to match the center of the antenna at 50Ω. TM10 matches the network without matching circuit excited at feeding point B contain the pattern maximum normal to the ground plane was selected.

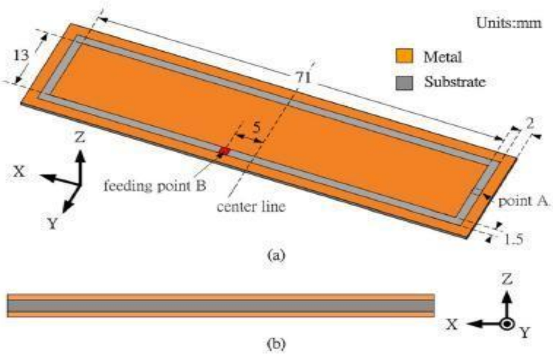

Fig. 1: Original Rectangular Adhesive-bandage – like antenna: (a) 3D View; and (b) side view

2.2 Transient Characteristics of Half Wavelength Resonant Frequency

Microstrip antenna consists of rectangular sheet or metal patch, mounted over a larger sheet of metal called a ground plane. These are usually constrained inside a plastic random, which protects the antenna structure from damage. Patch antennas are simple to fabricate & easy to modify and customize. The radiation at the edges causes the antenna to act slightly larger electrically than its ground dimensions, so in order to create resonant antenna, microstrip transmission line length slightly shorter than one – half a wavelength at the frequency is used. A patch antenna is usually constructed on a dielectric substrate, using the same materials, lithography processes to make printed circuit boards. The impedance bandwidth of a patch antenna is strongly influenced by the spacing between the patch and ground plane. When the width of the metal ring is 2 mm reduced, the rectangular metal ring is a part of the antenna, increasing the patch resonator quality factor and reducing the achieved bandwidth to 4 MHz which is enough for wireless medical telemetry service.

A novel planar flexible antenna which is designed in the existing system provides many advantages like compact, thin, flexible high radiation efficiency. The main disadvantages are the performance of the antenna is measured only in flat conditions and it fails to measure in bending conditions. This is because even though the antenna looks flexible due to thick dielectric substrate 0.8mm, it can be bend only to a certain angles. This problem is mainly due to the dielectric substrate RT duroid 5880 which is made of glass microfiber reinforced PTFE (Polytetrafluoroethylene) composites, the gain of the antenna achieved is also les

3 Antenna Deformation

Adaptive antennas must be developed for other applications such as in biomedical, military, and commercial fields. The antenna deformation has to be done in order to design for wearable applications. Q factor is a dimensionless parameter, that describes how under – damped an oscillator or resonator or characterizes a resonator bandwidth relative to its central frequency. As the patch is moved closer to the ground plane, less energy is radiated, more energy is stored in the patch capacitance and inductance, the quality factor Q of the antenna increases. This section describes the antenna performance after it is deformed into a curved shape.

The main problem in designing flexible antennas is that antenna performance e factors, such as resonant frequency and radiation patterns, can be affected when the antenna changes position. E-plane bending is performed since the resonant frequency is shifted only by approximately. At the driving point of the antenna, one mode is +45 degrees & other at -45 degrees to produce the required 90 degree phase shift for circular polarization. When fabricated using printed circuit techniques on a dielectric substrate, it is straight forward to create complex arrays of patch antennas with high gain, customize beam, return loss properties, other unique features at low cost.

This is caused mainly by the finite ground plane and edge diffractions. So, in order to improve the antenna gain and reduce the back radiation the extension of the shield ground plane near the two radiating slots can be done. A favorable front-to-back ratio is achieved only for the edge extension value of 8 mm.

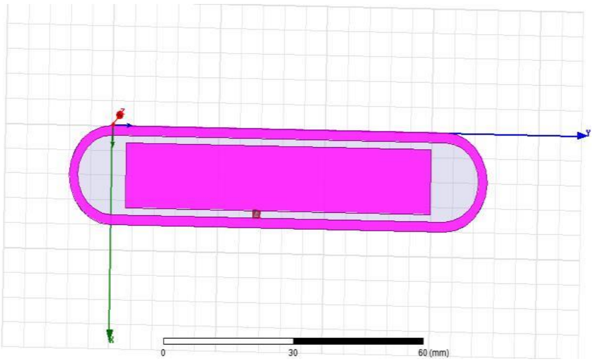

Fig. 2: Adhesive-bandage-like antenna

High performance full wave electromagnetic simulator (EM) software, High Frequency Structural Simulator (HFSS), based on the finite element method was used to model the proposed antenna. WMTS require an operating bandwidth of only 4 MHz HFSS integrates simulation, visualization, solid modeling, automation in easy learn environment where solutions to find for 3D EM problems. HFSS employs the Finite Element Method (FEM), adaptive meshing. It is used for S parameter calculation, resonant frequency, fields, full-wave SPICE extraction, electromagnetic simulation of high- frequency and high-speed components. HFSS delivers significant productivity gains to RF/Microwave and expands electromagnetic co-design to new segment work in areas of RF/Analog IC and multi-gigabit designs as well as EMC/EMI It is widely used for designing package modeling, silicon/GaAs, waveguides, filters, connectors, and PCB board designing.

4 Antenna Performance Measures

4.1.1 Shorting Ends

Due to drawback in shorting vias structure, back radiation will be high which in turn decreases the transmission quality of antenna. As the edges are extended by standard 0.8mm, the vias are protected as well as transmission quality increases, to improve antenna performance.

4.1.2 Thick Antenna Height

As antenna thickness can be reduced by change of substrate material, instead of using DUROID RT5880, good material to fabricate but too expensive, as it is US based production material. So, prefer for wearable textile materials jeans as substrate material, it can be fabricated into clothes for any shape, flexible and reliable. Jeans substrates are hundred percentages made of cotton material, as it satisfies the elastic properties and thickness of fabric, to avoid variation in dimension because of stretching and compression. Textile materials are assemblies of fibers, the electrical conductivity of these materials are low. So, these can be used as dielectric. Dielectric constants play a vital role in designing antenna. Dielectric constant vary as per substrate materials. The various cotton materials comparison are shown in Table II. Jean cotton preferred to be better improvement when compared to all other materials.

Table 2: Comparison of Various Substrate Materials.

Dielectric Materials	**Dielectric constants(ε_{r})**	**Return Loss**	**Gain (dB)**
Wash Cotton	1.45	-18	2.21
Curtain Cotton	1.47	-19	2.29
Poly Cotton	1.50	-20	2.42
Jean Cotton	1.59	-22	2.93

The antenna performance depends on return loss. Return loss, dielectric value, directivity directly proportional. If return loss increases, other two factors will also increase simultaneously.

4.1.3 Probe Feeding Method

The vertical probe feed can be overcome by coaxial feed. It is a feeding technique for microstrip patch antenna. The inner conductor connected to radiating patch, while the outer conductor connected to ground plane.

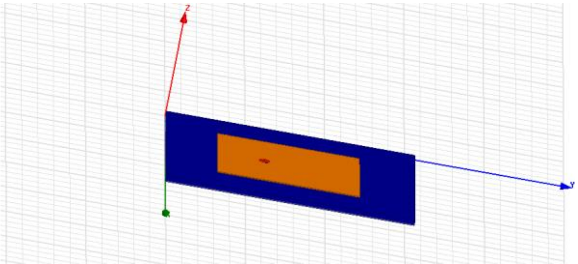

Fig. 3: Antenna with coaxial feed

The main advantage of using coaxial feed, inside the patch that can be placed at any desired location, to match its input impedance. This method easy to fabricate, low spurious radiation. While antenna tuned to 6.5 GHz, the following changes occur in enhancement.

5 Simulation Results

The performance of the antenna is analyzed by the following parameters such as gain, VSWR, return loss, radiation efficiency, radiation pattern, reflection coefficient, etc., These parameters are used to critically examine the antennas and determine how suitable for an application.

5.1.1 Return Loss Measurement

The return loss is analyzed using scattering(s) parameters. Return loss is the loss of signal power resulting from the reflection caused due to improper matching of the antenna to its feed line. An increased return loss corresponds to high VSWR.

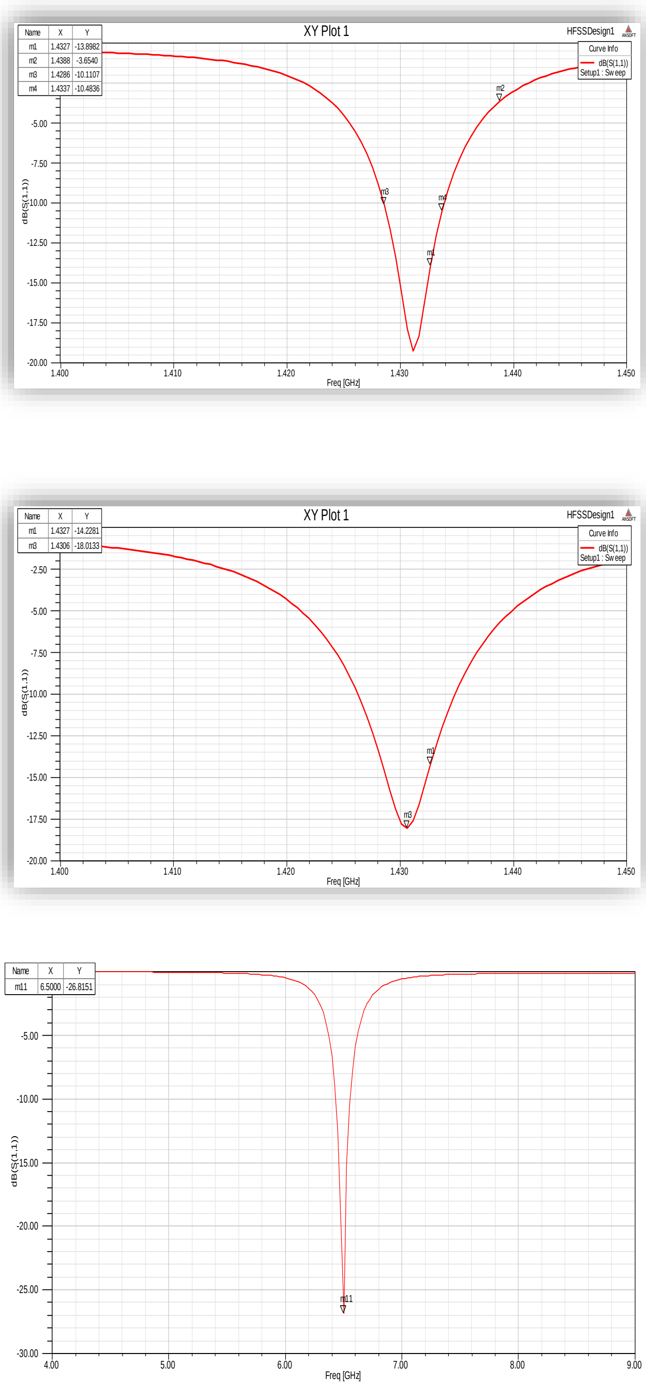

Fig 4: Return Loss Plots obtained from HFSS

5.1.2 Standing Wave Ratio Measurement

It is also a measure of mismatch between the load and the transmission line. The Standing Wave Ratio is usually defined as a voltage ratio called the VSWR. Standing wave ratio is defined as the ratio .The VSWR can be represented by VSWR=Vmax/Vmin. The VSWR is always ≥+1, VSWR values are not more than 2. VSWR considered in both case to be less than 2.VSWR is

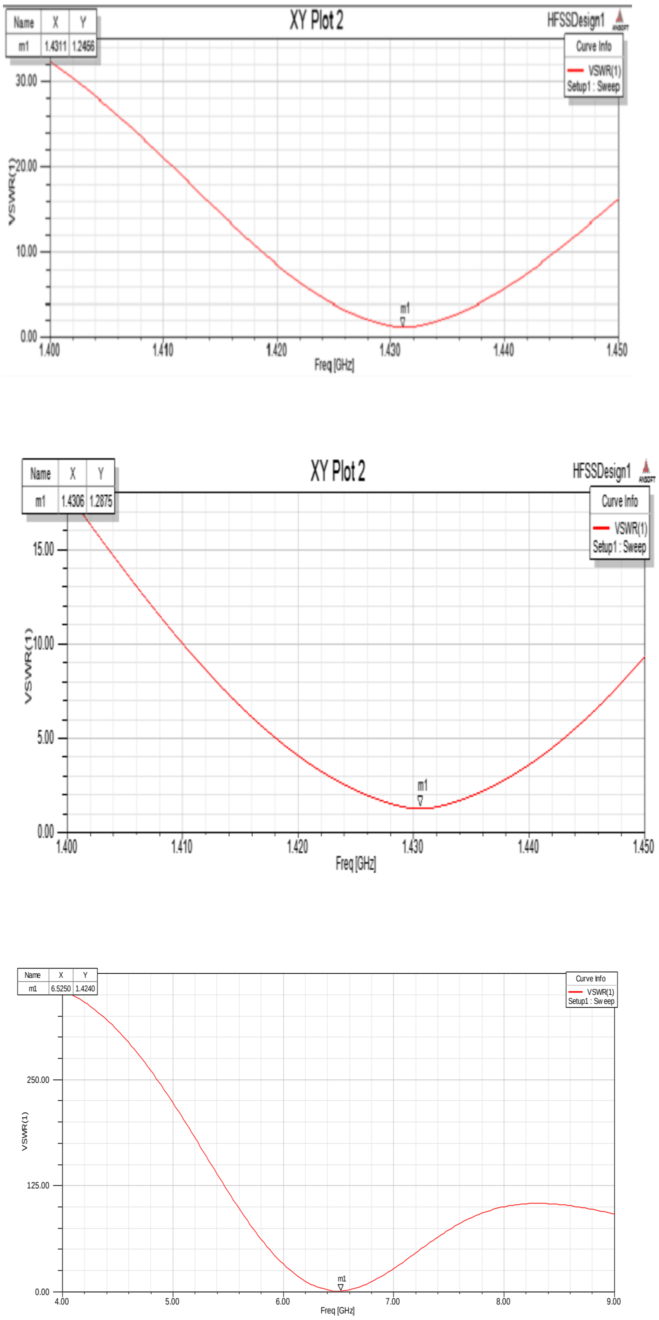

Fig 5.VSWR Plot obtained from HFSS

5.1.3 Gain Plot Measurement

Gain is defined as the ratio of power radiated by the antenna from the far field source, on the antenna beam axis to the power produced by hypothetical lossless isotropic antenna. Gain performance is more for coaxial feed.

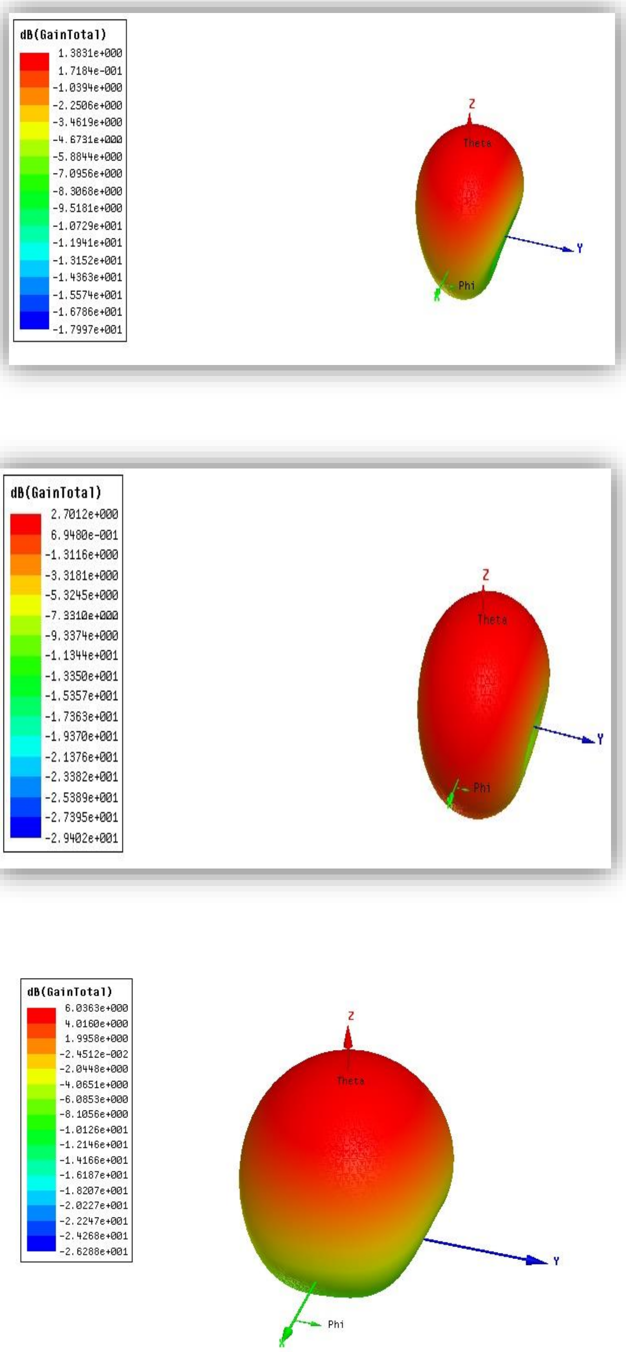

Fig 6: Gain Plots obtained from HFSS

5.1.4 Radiation Pattern Measurement

The radiation pattern of an antenna is a plot of the far-field radiation from the antenna. It is a specific plot of the radiated power from an antenna per unit solid angle or its radiation intensity U.

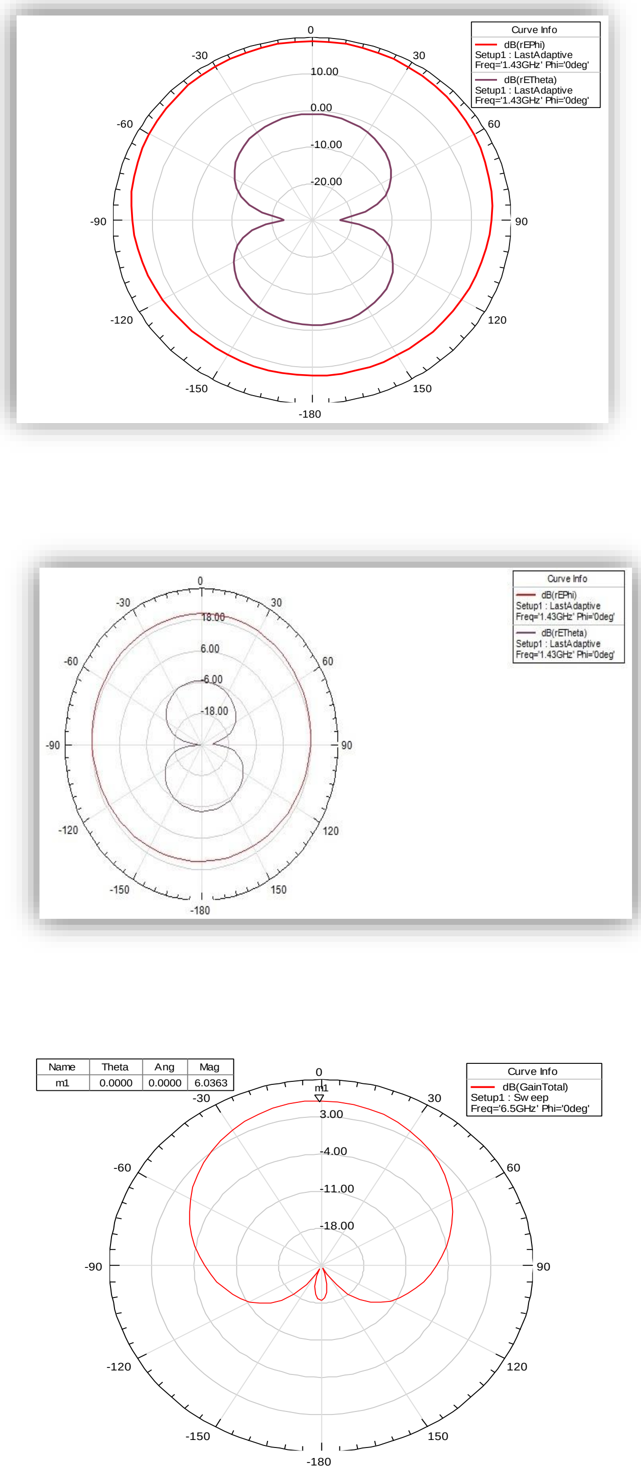

Fig 7:Radiation Pattern obtained from HFSS.

Table 3: Comparison of Various Antenna Parameters

Parameters	**Without Edge Extension**	**With Edge Extension**	**Coaxial Feed**
Max U	0.10606	0.14565	0.24319
Gain (dB)	1.375	1.8626	4.091
Return Loss	-13.8982	-14.2281	-26.8131
VSWR	1.2456	1.2875	1.4240
Directivity	3.1585	2.7957	6.4838
Radiation Efficiency	0.43534	0.63096	0.66626

5.1.5 Smith Chart for Antenna without Edge Extension

The normal impedance value is found to be closely releated to 1, which means 50 ohms resistance. It is noticed from this value, proper matching occurs, so that proper transmission occurs.

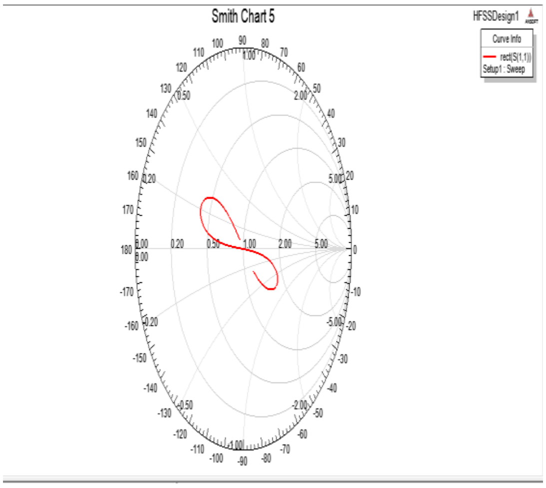

Fig 8:Smith chart for Antenna without edge extension

5.1.6 Smith Chart for Antenna with Edge Extension

The normal impedance value is found to be closely releated to 1.

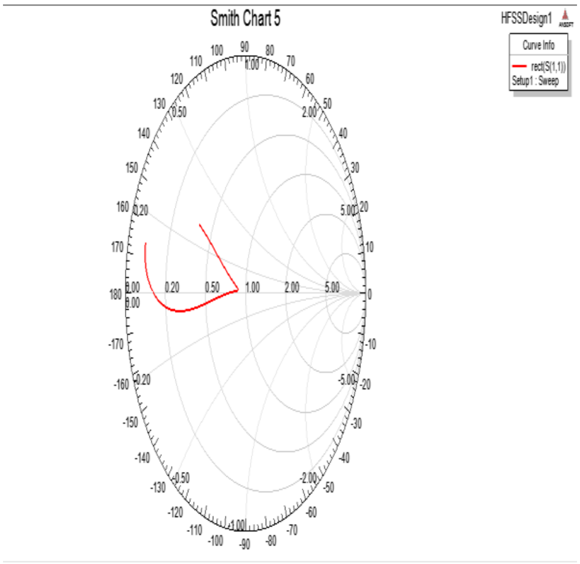

Fig 9:Smith chart for Antenna with edge extension

5.1.7 Smith Chart for coaxial feed technique

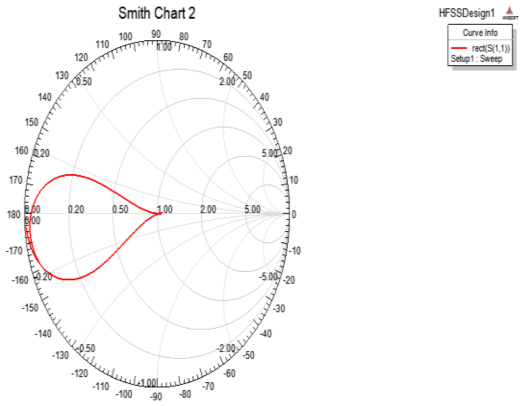

Fig 10:Smith chart for antenna with Coaxial feed

5.1.8 Electric-Field Distribution:

The following figures shows E-field distribution,

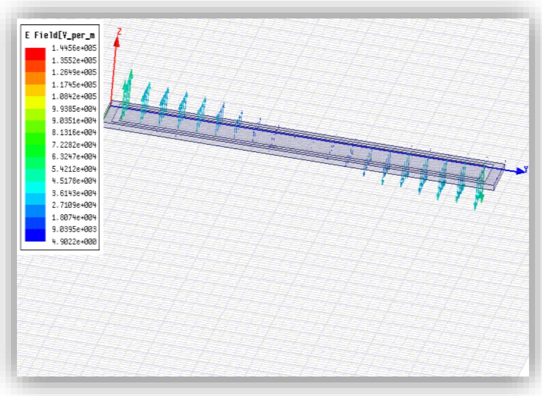

Fig 11:Electric field distribution for antenna without co-axial feed.

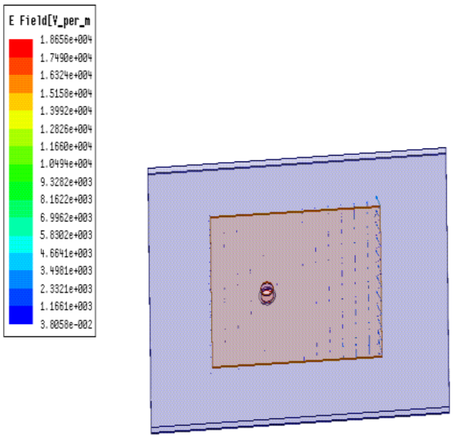

Fig 12:Electric field for antenna with Coaxial feed

5.1.9 Magnetic-Field Distribution:

The following figures shows H-field distribution,

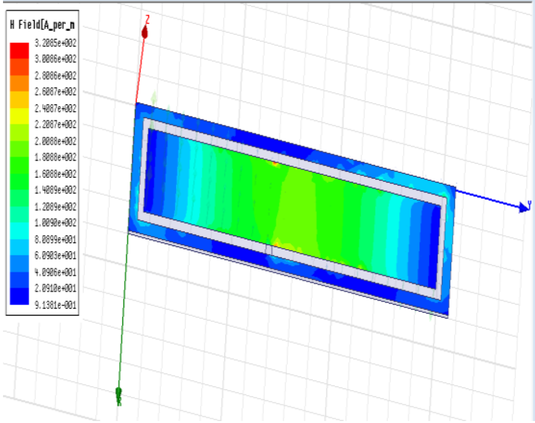

Fig 13: Magnetic field for antenna without co-axial feed

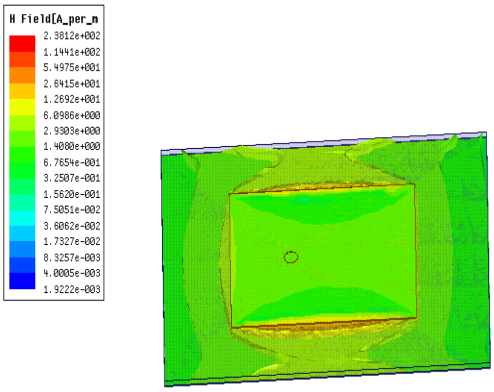

Fig 14: Magnetic field for antenna with Co-axial Feed

5.1.10 JSURF

The current surface distribution of the antenna,

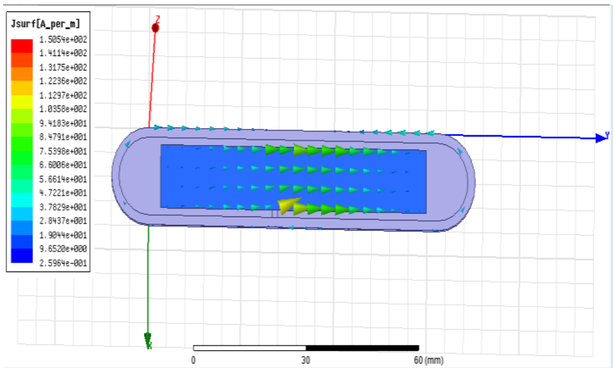

Fig 15:Surface current distribution

6 Conclusion & Future Work

The antenna performance improved by modified coaxial feed structure, in terms of return loss, VSWR, radiation pattern, gain, directivity.

The values of SAR changes occur at each and every frequency due to difference between dielectric contrasts, different internal structure cause different distribution in penetrating radiation to skin, fat, muscles, bones. The future work deals with the reduction of SAR.

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