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Design and Simulation of Microstrip Patch Antenna for ADS-B Operation

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ABSTRACT-

In telecommunications, a microstrip antenna (also known as a printed antenna) usually means an antenna made using microstrip techniques on a printed circuit board (PCB). They are mostly used on microwave frequencies. A single microstrip antenna consists of a patch of foil in various shapes (a patch antenna) on a PCB surface, with a foil ground plane on the other side of the board. Most microstrip antennas consist of multiple patches in a two-dimensional array. The study of compact antennas for fifth generation wireless communications, operating in K and Ka band frequencies is discussed in this paper. Antenniaturization is achieved by making a simple rectangular hole in the patch. The rapid development of wireless communications in recent years has led to the development of many wireless mobile devices such as wireless sensors, smartphones, IoT devices, wearable devices, and GPS receivers. Mobile devices for multimedia, high-quality videos, high-end gaming devices, various software applications, virtual reality, augmented reality, etc. are widely used.

KEYWORDS: Compact, Dual Band, Miniaturization Ratio, Patch. Antenna.

1. INTRODUCTION

The antenna is usually connected to the transmitter or receiver through foil-lined microstrip transmission lines. RF current is applied (or, in receiving antennas, the received signal is produced) between the antenna and the ground plane.

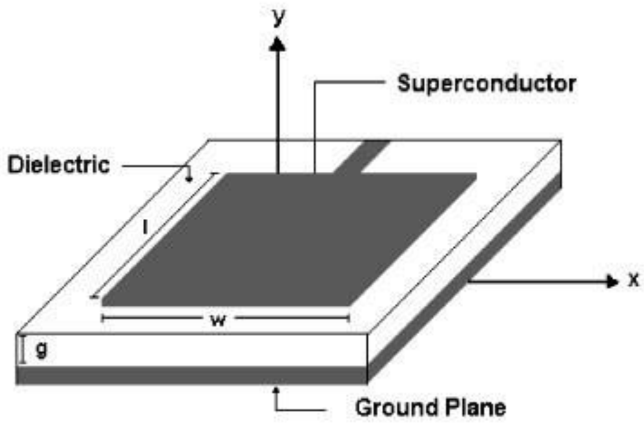

Figure.1. Microstrip antenna

2. PATCH ANTENNA

Common shapes for a microstrip antenna are square, rectangular, circular, and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and are instead made of a metal patch held above ground level using dielectric spacers; The resulting structure is less rigid but has a wider bandwidth. Because these antennas are very low profile, mechanically robust and can be shaped to conform to the curved skin of a vehicle, they are often installed on the outside of aircraft and spacecraft, or integrated into mobile radio communications equipment.

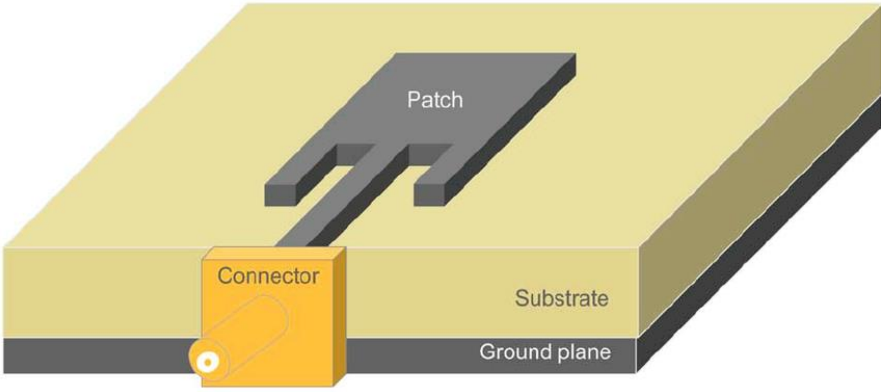

Figure.2. Microstrip antenna with connector

Microstrip antenna is one of the most common types of printed antennas. It plays a very important role in today's world of wireless communication systems. Microstrip antennas are very simple to build using traditional microstrip fabrication technology. The patch is generally made of a conductive material such as copper or gold and can take any possible shape such as rectangular, circular, triangular, elliptical or any other common shape. The radiating patch and feed lines are usually photo-etched onto the insulating substrate.

Microstrip patch antennas radiate primarily due to the fringed domains between the patch edge and the ground plane. For good antenna performance, it is desirable to use a thick dielectric substrate that has a low dielectric constant (<6) because it provides higher efficiency, larger bandwidth and better radiation. However, this configuration leads to a larger antenna size.

In order to design a compact microstrip patch antenna, a substrate with a higher dielectric constant (less than 12) must be used, which results in lower efficiency and narrower bandwidth. Hence a compromise must be made between antenna dimensions and antenna performance. Excitation directs the source of electromagnetic energy to the patch, generating negative charges around the feed point and positive charges on the other part of the patch. This difference in charges creates electric fields in the antenna that are responsible for the radiation from the patch antenna.

Three types of electromagnetic waves radiate. The first part radiates into space, which is "useful" radiation. The second part is deviating waves, which are reflected back into the space between the patch and the ground plane, contributing to the actual energy transfer. The last part of the wave remains trapped in the dielectric substrate due to the total reflection at the dielectric air-separating surface. Waves trapped in the substrate are generally undesirable. Different types of antennas have different shapes and sizes. Microstrip antennas can be classified into four subtypes: patch microstrip antennas, microstrip dipoles, printed hole antennas and traveling wave microstrip antennas.

Rectangular Patch

The most common microstrip antenna is a rectangular patch that looks like a cut microstrip transmission line. It is about half a wavelength long. When air is used as the dielectric substrate, the length of the rectangular microstrip antenna is approximately half the wavelength of free space. When the antenna is loaded with insulation as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The resonant length of the antenna is slightly shorter due to the extension of the electrical "ventilation fields" which slightly increase the electrical length of the antenna. An early model of a microstrip antenna is a segment of a microstrip transmission line with equivalent loads on both ends to represent radiation losses.

Specifications

The dielectric loading of a microstrip antenna affects both the radiation pattern and the impedance bandwidth. As the dielectric constant of the substrate increases, the bandwidth of the antenna decreases which increases the Q-factor of the antenna and thus decreases the impedance bandwidth. This relationship does not immediately follow when using the transmission line model of the antenna, but appears when using the cavity model introduced in the late 1970s by Lo et al. The radiation from a rectangular microstrip antenna can be understood as a pair of equivalent apertures. These apertures act as an array and have highest directivity when the antenna has an air dielectric and decrease as the antenna is loaded with materials with an increasing relative dielectric constant.

The half-wavelength rectangular microstrip antenna has a virtual shorting plane along its center. This can be replaced by a physical shortening plane to create a quarter wavelength microstrip antenna. This is sometimes called a half-patch. The antenna has only one radiation edge (parabolic aperture) which reduces the antenna's directivity/gain. The impedance bandwidth is slightly less than a full half-wavelength patch as the coupling between the radiating edges has been eliminated.

3. LETERTUE REVIEW

B Mazumdar (2016) - A compact single square microstrip antenna is proposed in this paper. Two L-slits are inserted at the right edge of the patch to study the effect of the slit on the radiative behavior with respect to conventional microscopic patches. A comprehensive analysis of the return loss, radiation pattern, and efficiency of the proposed antenna is presented in this paper. To obtain the optimal value for the slit parameters, the antenna resonant frequencies are obtained at 2.16, 2.68, 3.22, and 4.37 GHz with corresponding bandwidths of 11.02 MHz, 13.07 MHz, 35.86 MHz, and 48.56 MHz and a return loss of about -23.4, -15.2, and -30.6µ. -20.3 dB respectively. For the lowest spectral frequency (2.16 GHz), the antenna size was reduced by 71.14% when compared to the conventional rectangular micropattern. The properties of the designed structure are studied using a MoM-based electromagnetic analyzer, IE3D. The simple configuration, low profile nature, low size and quad band characteristics of the proposed antenna make it suitable for operation in the frequency bands 2.165-2.176, 2.673-2.686, 3.208-3.244 and 4.343-4.392 GHz.

Nita Kalambe (2017) - According to Microstrip Patch Antenna (MPA), it provides low and low volume, so it is used in communication devices nowadays. It has been studied that MPA targets small sized microstrip antenna layout. A printed monopole antenna can be used in radio communication devices in different operating frequency bands. In this fast dynamic world of wireless communications, dual or multi-band antenna plays a major role in meeting the needs of wireless services. In this paper, a microstrip patch antenna with a clockwise circular radiation patch with an I-cut in the middle aperture using 3.5 GHz is proposed. The size of the microstrip antenna is 19.99 × 26.08 (L × W) mm2. The MPA performance parameter such as return loss, VSWR, polar height pattern and 3D rendering of the radiation pattern are simulated using Zeland Software Manager (IE3D).

Hashibul Alam (2018) – A rectangular microstrip patch antenna was designed on a three-layer substrate for a UWB (Ultrawide Wireless Communication System). The proposed UWB antenna simply consists of a rectangular patch with a microstrip line feed and on a three-layer substrate. Where the permittivity of the substrate used is 2.2, 2.33 and 4.4, it is placed at ground level. The proposed rectangular microstrip patch antenna covering the range from 6.9 to 8.7 GHz is simulated. Study here the return loss graph, input impedance, 2D radiation pattern and 3D radiation pattern.

Prof. Shupankar Paul (2019) – As per Microstrip Patch Antenna (MPA), it provides low and low volume, so it is used in communication devices nowadays. In this paper study of the past few years, it is shown that most of the employment in MPA is aimed at planning a small sized microstrip antenna. A new printed broadband monopole antenna could be used in wireless communication devices. In this fast dynamic world of wireless communications, dual or multi-band antenna plays a major role in implementing the needs of wireless service. In this paper, we study microstrip patch antenna design with substrate shape, feed and slot techniques for UWB-based system applications.

J. Salai Thillai Thilagam (2020) Sixteen (hexadeci) simulations of microstrip patch antenna design using edge slit are discussed here. This antenna is fed using a probe feed model. It is simulated using the IE3D electromagnetic simulator. The simulated results for the antenna check radiation parameters such as scattering parameter (S parameter), radiation pattern, and voltage standing wave ratio (VSWR). In parameter S, the value of parameter $S11 < -10$ dB is reached for the resonant frequencies 0.9 GHz and 0.87 GHz to 0.90 GHz and a value of VSWR < 2 is obtained for the same frequencies. The proposed antennas will be useful for the 900 MHz band in wireless communications applications.

Settapong Malisuwan (2020) – In this paper, a simple design of a broadband rectangular patch antenna using an asymmetric feed and ground level reduction with an appropriate gap distance is presented. The frequency-dependent characteristic impedance included in the proposed procedure is processed to remove potential errors in high-frequency broadband applications. The antenna proposed in this paper provides a bandwidth of 2.3 GHz (frequency range: 0.9 GHz - 3.2 GHz) which can be used in various broadband applications such as remote sensing, biomedical and mobile radio.

Sohag Kumar Saha (2021) - This paper presents the design and simulation of a mini-E patch antenna that exhibits wide operating frequencies for different wireless applications. This antenna will provide the wide bandwidth required in many applications such as remote sensing, biomedical application, mobile radio satellites, wireless communication etc. Axial feeding or probe feeding technique is used in the experiment. The performance of the designed antenna was analyzed in terms of bandwidth, gain, return loss, VSWR and radiation pattern. The design is optimized to meet the best possible result.

Jagtar Singh (2022) Microstrip antennas are designed to have many shapes and geometries but rectangular and circular microstrip patches have been used in many applications. Microstrip patch is preferred antenna structures for its low cost, low light weight, conformal modulation, high efficiency, and compact design of wireless system. These antennas are popular for low level applications with frequencies above 100MHz. A microstrip patch antenna in its simplest form consists of a radiating patch on one side of an insulating substrate and a ground plane on the other side. It consists of a flat rectangular plate or "patch" of metal, which is fixed to a larger sheet of metal called the ground level. A rectangular micro patch antenna consists of a rectangular patch of dimensions width (W) and length (L) above a ground plane with substrate thickness (H).

4. POLARISATION AND RADIATION OF MICROSTRIP ANTENNA

The polarization of the antenna is determined by the wave radiating in a certain direction corresponding to the direction of the electric field. The instantaneous electric field vector tracks a number in time. If the path of the electric field vector follows a line, the antenna is said to be linearly polarized. If the electric field vector rotates in a circle, it is called circularly polarized. To characterize polarization, the axial ratio is used. It is defined by the following relation:

$$T = \frac{\text{Large diameter of the ellipse}}{\text{Small diameter of the ellipse}}$$

Polarisation is said to be linear if $T \rightarrow \infty$ or $T = 0$, and circular if $T = 1$.

6. APPLICATIONS OF MICROSTRIP ANTENNA

Communication based applications. Microstrip patch antenna finds many applications in the field of wireless communications. For example, satellite communications require circularly polarized radiation patterns, which can be achieved with a square or circular microstrip antenna. In global positioning satellite systems (GPS), circularly polarized microstrip antennas are used. It is very small and very expensive due to its location.

Microstrip antennas are also used in the RFID (radio frequency identification), mobile communications and healthcare industries. The RFID system mainly consists of a tag and a reader. Generally, it uses frequencies between 30 Hz and 5.8 GHz.

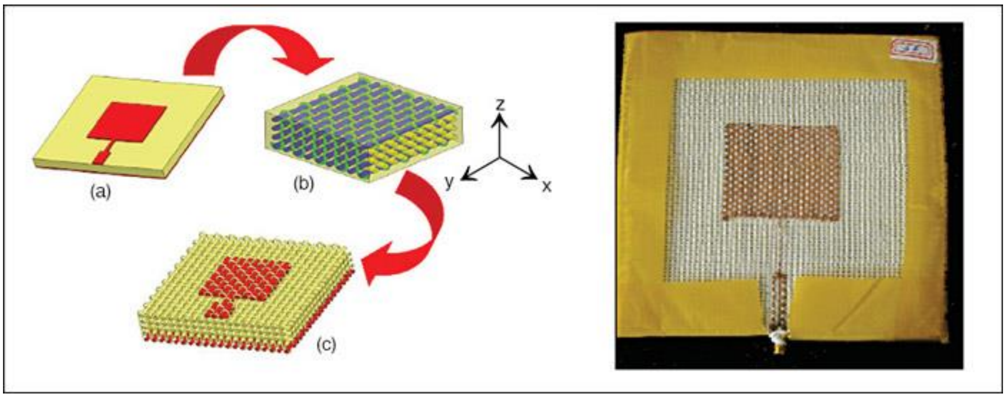

Figure.3. Geometry of textile antenna

The IEEE 802.16 standard is known as WiMax (Worldwide Interoperability for Microwave Access). It can reach a radius of 48 km (30 miles) at a data rate of 70 Mbps. Microstrip antennas can resonate with more than one frequency. So they can be used in WiMax based communication equipment.

Some of the communications-based applications for microstrip patch antennas are radio altimeters, command and control systems, remote sensing, environmental devices, feed elements in complex antennas, satellite navigation receivers, portable radio, integrated antennas, biomedical radiators, intruder alarms, Doppler and other radars, satellite communications and live broadcast services..

Mobile communication- Mobile communications require small, low-cost, low-profile antennas. In some mobile phones, semiconductor-based diodes or detectors are used as antennas. They are very similar to p-n diode photodetectors but operate at microwave frequency. Often the omnidirectional antenna is used in cell phones. There are different types of antennas such as the flat inverted F antenna, the inverted folded antenna, and the monopole. The retractable whip antenna is also commonly used in mobile phones.

Medical applications- In the treatment of malignancies, microwave energy is said to be the most effective method of inducing hyperthermia. The coolant that will be used for this purpose should be light in weight, easy to handle and durable. Only a patch radiator meets these requirements.

Initial designs of microstrip radiators to induce superheating relied on printed dipoles and toroidal rings that were modeled on the S band (2–4 GHz). Later, the design was based on a circular microstrip disk in the L band (1-2 GHz). Two lines connected by precise tape with flexible separation are used to measure the temperature inside the human body. Figure 5 shows a flexible patch rod operating at 430 MHz.

7. ADVANTAGES

Microstrip antennas are relatively inexpensive to manufacture and design due to their simple 2D physical geometry. They are usually used at UHF and higher frequencies because the antenna size is directly related to the wavelength at the resonant frequency. A single patch antenna provides a maximum directive gain of about 6-9 dBi. It is relatively easy to print a batch of patches onto a single (large) substrate using lithographic techniques. Patch arrays can provide much higher gains than a single package at little extra cost; Matching and phase tuning can be performed using printed microstrip feed structures, again in the same processes that form the radiating spots. The ability to create high gain arrays in a low level antenna is one of the reasons patch arrays are popular in aircraft and in other military applications.

The inherent advantage of patch antennas is the ability to vary polarization. Patch antennas can easily be designed to have vertical, horizontal, right side circular (RHCP) or left circular polarization (LHCP), using multiple feed points, or a single feed point with asymmetric patch structures. This unique characteristic allows patch antennas to be used on many types of communications links that may have varying requirements.

8. METHODOLOGY

A small, compact, single-feed ribbon antenna is proposed in this analysis. Comprehensive analysis of the return loss, radiation pattern, and efficiency of the proposed antenna. The simple configuration, low profile nature, low size and quad band characteristics of the proposed antenna make it suitable for operation in various frequency bands. One technique for designing a compact microstrip antenna is to cut holes or slits on the radiation swath to increase the surface current swath length.

9. RESULTS AND DISCUSSION

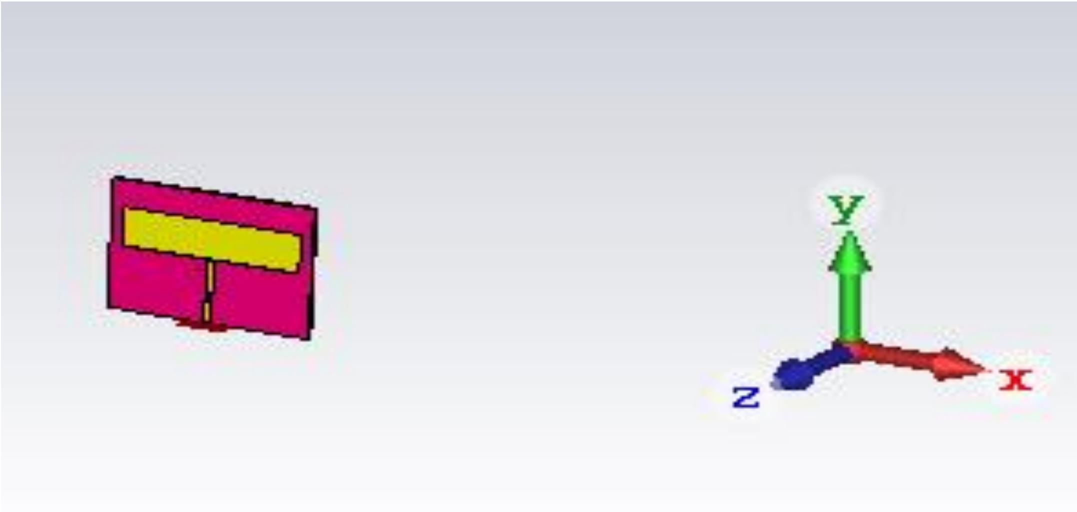

Figure.4. Model of Antenna

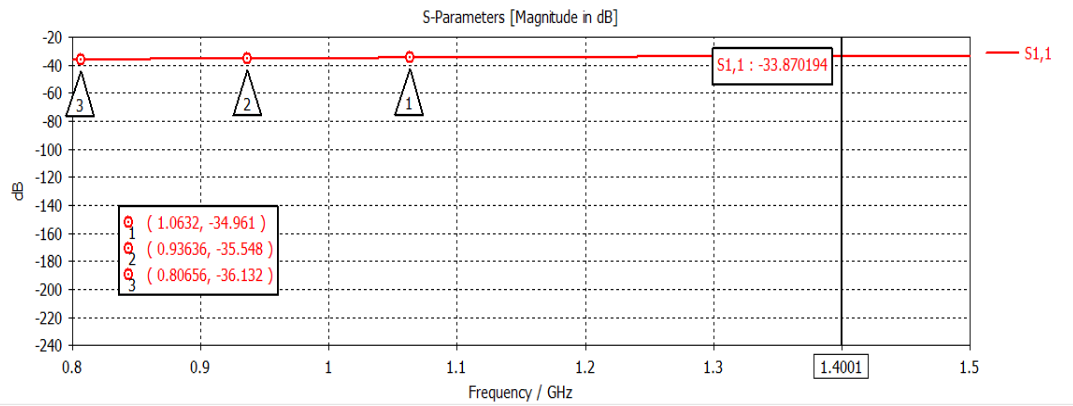

Figure.5. S- Parameter

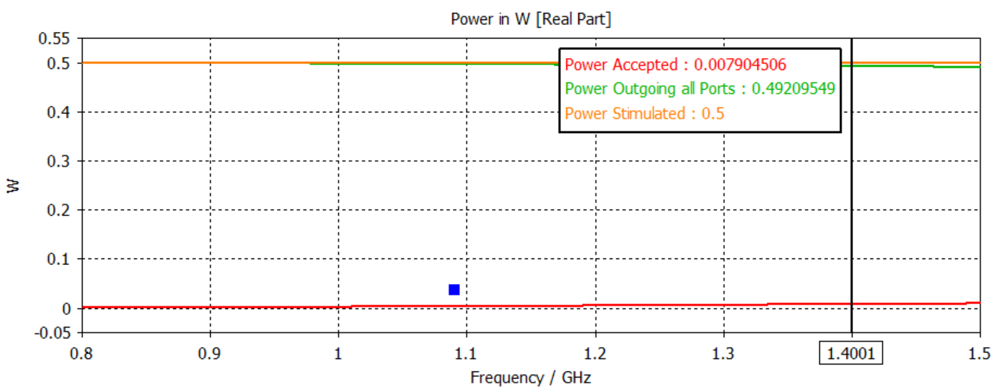

Figure.6. Power in W

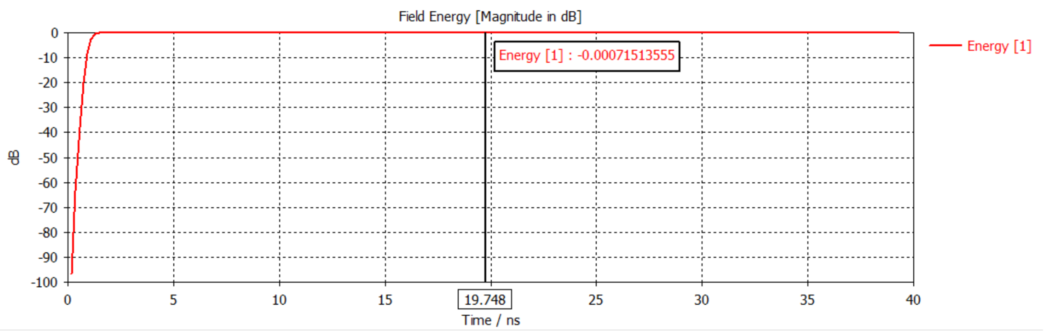

Figure.7. Field Energy

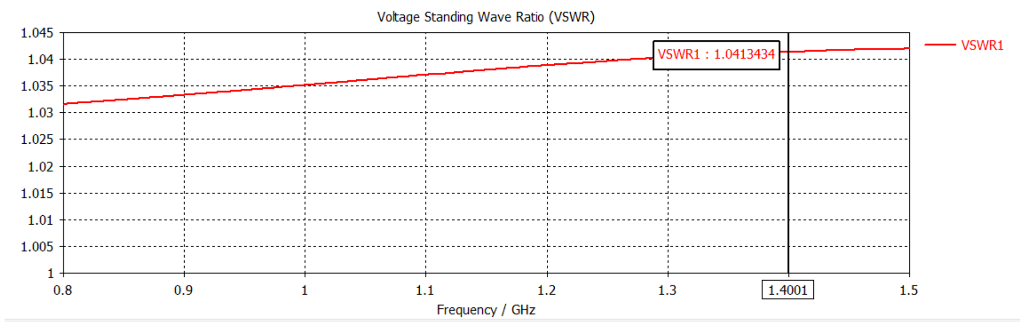

Figure.8. VSWR

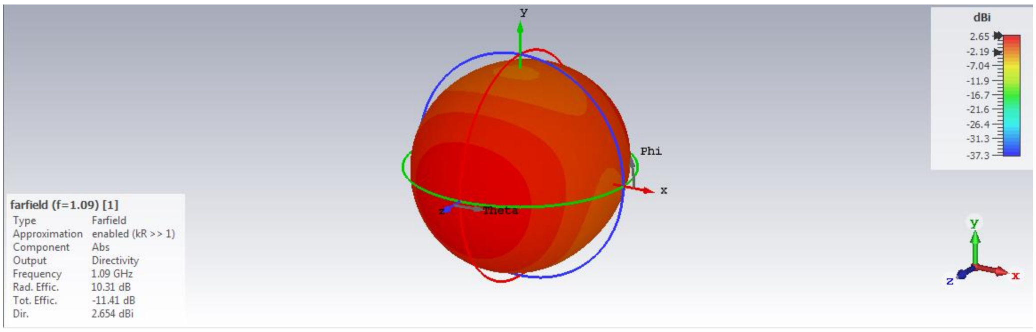

Figure.9. Farfield

10. CONCLUSIONS

The most common type of microstrip antenna is the patch antenna. It is also possible to use spot antennas as component elements in the array. A patch antenna is a narrowband broadband antenna made by etching an antenna element pattern into a metal trace attached to a dielectric substrate, such as a printed circuit board, with a continuous layer of metal attached to the opposite side of the substrate forming a ground plane. The antenna resonates at 1.09 GHz typical for ADS-B applications. The predicted gain of the ADS-B antenna is from 1dB to 5dB whereas the measured gain is about 3.875 dB. , W_1 = 70 mm , the return loss of -36.132 dB.

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