e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:07/July-2024 Impact Factor- 7.868 www.irjmets.com

MICROSTRIP PATCH ANTENNA FOR AIRCRAFT SURVEILLANCE BROADCAST APPLICATION

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DOI : https://www.doi.org/10.56726/IRJMETS59820

ABSTRACT

Automatic Dependent Surveillance-Broadcast (ADS-B) is a technology that uses satellite signals for the real time tracking of the aircraft. The transponder in the aircraft is continuously transmitting its location and other status of it to the satellites. This information is broadcasted to other aircrafts and ground station control rooms with ADS-B receivers which are within the diameter of 300 Kms. In this paper, a microstrip patch antenna designed using ANSYS-HFSS to operate at the frequency of 1.03-1.09 GHz for ADS-B application is dealt with. The performance metrics such as radiation pattern, return loss, gain and Voltage Standing Wave Ratio (VSWR) are evaluated and found to be satisfactory. Microstrip patch of dimension 65×85mm is built on the FR-4 substrate whose area is $127 \times 120\ mm^2$ with a height of 1.6mm. Radiation pattern of the designed antenna is observed to be omnidirectional with the gain of 3dB. The performance of the antenna is compared for various substrate materials and the obtained results are discussed.

I. INTRODUCTION

The use of microstrip patch antennas in satellite communication is an emerging area in the antenna research. The microstrip patch antenna finds wide application due to their light weight and ease of fabrication making them ideal for applications with space and weight constraints. Some of the applications include military ,industrial applications, medicine, space exploration and in radar communication. Microstrip patch antennas are integral components in various technologies, including mobile phones, satellite communication systems, radar systems, navigation systems, and other wireless applications.

Their inherent advantages, such as ease of production and flexibility in frequency design, contribute to their widespread use. In essence, these antennas offer an effective and efficient means of wireless communication and sensing, making them indispensable in modern electronic systems where high performance and adaptability are paramount. Different types of microstrip antennas are employed in mobile communication technology, offering features like compact size and affordability. Circularly polarized microstrip patch antennas are crucial for satellite communication, particularly in global positioning system (GPS) applications, where high-permittivity substrates are utilized to achieve circular polarization, smaller size, and precise positioning.

Microstrip patch antenna is a planar configuration that includes a radiating patch on one side built on a dielectric substrate, coupled with a ground plane on the other side. The antenna can be used over a wide frequency range, from microwave to millimeter wave frequencies. The operational principle involves the emission of electromagnetic waves from the fringing fields surrounding the patch, which consist of electric and magnetic fields extending beyond the patch edges. The resonant frequency and other antenna performance metrics are dependent on the patch dimensions and the dielectric constant of the substrate.

Microstrip patch antennas can be classified based on their physical parameters, with various shapes such as square, rectangular, circular, dipole, printed, and elliptical serving specific purposes. Additionally, different slot configurations like A-slot, U-slot, H-slot, and E-slot are employed in patch antennas, each catering to distinct frequency bands. Their easy fabrication through standard printed circuit board (PCB) manufacturing techniques contributes to their cost-effectiveness. Moreover, their compatibility with other microwave components facilitates the integration of complex microwave systems within a single package.

However, microstrip patch antennas also have disadvantagessuch as narrow bandwidth, limiting their operation to a limited range of frequencies, which is a drawback for applications requiring a wider bandwidth. Additionally, their lower gain compared to antennas like parabolic dish antennas limit their application for long-range communication. Microstrip patch antennas are susceptible to environmental factors, such as obstacles or variations in the dielectric constant of the substrate, impacting their performance. Furthermore, their complex design, especially for high-performance applications, can result in higher development and production costs.

A dual band blade antenna for the frequency bands of 1.030–1.090 GHz and the 3.4–3.8 GHz is designed using a bent side and a “C”- shaped slot inside a radiation element. This antenna is suitable for ADS-B and 5G cellular communication applications. The antenna is manufactured with aluminium and FR-4 substrate materials and the performance parameters are analyzed. Due to its low profile characteristics, the designed antenna is suitable for Unmanned Aerial Vehicle Detect and Avoid technologies [1].The design of a compact microstrip patch antenna intended for ADS-B operation at the frequency range between 1.03 – 1.09GHz. The antenna is fed by a 50Ω transmission line, and a T-shaped slot is etched onto the ground plane to achieve miniaturization and improved performance [2].

The antenna is designed for aircraft onboard flight information signal transmitted by aircraft at fixed intervals in low band L-band frequency. TAS-D is developing a system based on the satellite acquisition of 1090 MHz extended squitter signals. This approach does not affect ADS-B equipment and does not require expensive standardization [3]. Microstrip patch antenna is design by using substrate material is FR4 and accordance with the design criteria, VSWR 1.26 return loss -16.47 dB, 330.494 MHz bandwidth, omnidirectional radiation pattern, linear polarization, and is able to display information in the form of 24 bit ICAO aircraft address, Nationality, Squawk, Altitude, Latitude, Longitude, Speed, Heading and Track[4].

The conventional Radar Technology for flight detection is replaced by ADS-B system. The designed antenna is placed in the RTL- SDR R820T2 Flight with the gain value and operational frequency as 19dB and 1090MHz. While the receiver antenna is designed to detect the flight range at the distance of 346.89 km using Harvesine formula method but the practical implementation it detect upto the range of 353 km using the software [5].The ADS-B receiver has been integrated with the IoT. The ADS-B receiver is equipped with TianTou-3 satellite for receiving and transmitting the aircraft data. This system is used for many applications like air traffic management, surveying, tracking, rescue operation of the flights [6].

The author designed an antenna by using FR-4 substrate with two rectangular patches, linear array, T-Junction feed line for power supply to an antenna and proximity coupled rationing. The Operating frequency of this antenna is 2.4GHz and working like an ADB-S operation. The results obtained at the frequency 2.5 GHz is VSWR of 1.2,Return loss of -18.5dB,antenna bandwidth of 163MHz and the gain of 6.08dB [7].The ADS-B receiver antenna is incorporated with the nanosatellite refers to the cubesat of dimension 10×10×10 cm3 by Telkom University. The microstrip patch antenna designed for the ADS-B receiver has obtained the following parameters like VSWR of 1.9 with the operational frequency 1090 MHz, gain as 1.02dB, bandwidth as 52 MHZ and signal range upto 189 Km [8].

The monopole antenna has been designed for ADS-B technology at the operational frequency of 1090MHz. The operating frequency of this antenna ranges from 982 MHz to 1262MHz. The simulation of the antenna and the parameters is obtained using the CST-MS software, Plane Plotter software and SDR. The gain value obtained for this design is 2.8dB [9].The ADS-B system has been designed using broadband patch antenna (Linear array antenna). The ADS-B system works on the frequencies of 1030 MHz and 1090 MHz.In this paper two types of patch antenna radiating elements have been described (Narrowband patch and Broadband patch). The return loss obtained at 1030 MHz is -23.14 dB and at 1090 MHz -26.49 dB[10].

MATLAB antenna toolbox is used to design and analyze the performance of square microstrip antenna at the frequency of 1090MHz for ADS-B application [11]. Microstrip patch antenna with rectangular slot cut at the zero current position to reduce H-plane cross polarization with low profile and three mode resonances obtained by appropriately adjusting the antenna structure is proposed in [12].

Antenna with defective ground structure for WLAN applications where the periodic etch configuration to adjust the resonant frequency from 13 GHz to 2.4GHz without changing the area of the substrate is discussed in [13]. The position of any Unmanned Aerial Vehicles are communicated to other flying objects and base stations using surveillance broadcast band (ADS-B) using planar antenna loaded inductively operating at zero order reference mode. The size of the antenna is minimized effectively by using double split ring resonator [14] and the authors have measured and verified the performance through simulation and prototype model. A long strip line with U-

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shaped ground plane on the rectangular substrate designed to receive ADS-B signal transmitted omni directionally is built to receive signals from aircraft and validated using airceft data [15].

II. DESIGN OF MICROSTRIP PATCH ANTENNA

Microstrip patch antenna consists of a conducting patch over a ground substrate separated by a dielectric.The design of patch is done by considering the operating frequency of the antenna as 1.09GHz. The patch and ground are separated by a dielectric substrate and its dielectric constant is chosen to be high to minimize the size of antenna.

The bandwidth characteristics of the antenna can be varied by the number of layers of substrate, its thickness, loss tangent and relative permittivity. The ease of fabrication of antenna is also determined by substrate parameters like foil adhesion, bonding ability, resistance to corrosion, formability and its impact resistance. The user comfortable substrate jeans, is used in this design whose dielectric constant is 1.68 with the thickness of 1mm. The substrate material is selected based on its permittivity, thermal coefficient of resonant frequency and quality factor. Lower permittivity improves the bandwidth and higher quality factor is desirable for better selectivity of the antenna. Resonant frequency variation with respect to temperature should be lower and hence, the material with lower thermal coefficient is preferred.

The design of the patch structure is rectangular in shape as shown in fig 1(a).

Defective ground is considered for the designing of ground planes. Here the patch and feed line lies above the substrate, ground which lies below the substrate is made of copper whose thickness is about 0.02mm. The mathematical equations used for the design of the wearable microstrip patch antenna is listed below,

For the rectangular patch,

$$W = \frac{c}{2f_0\sqrt{\varepsilon_r + \frac{1}{2}}}$$

W is the Width of the patch or substrate.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\left(\frac{h}{W}\right)}}\right)$$

where ε_{eff} is a effective dielectric constant of the substrate.

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right)$$

Where L is the length of patch or substrate.

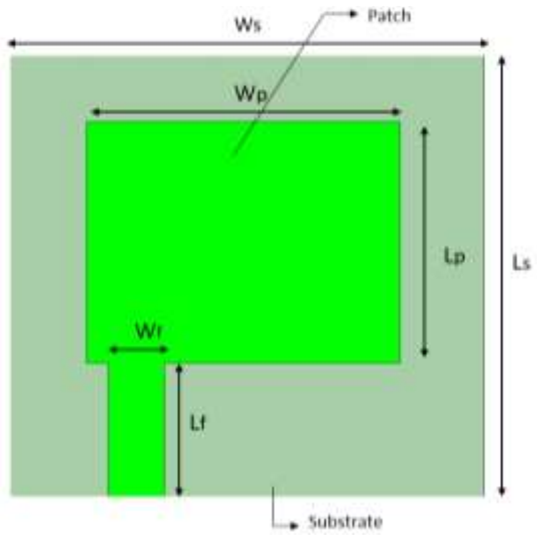

Fig 1(a): Front view of the microstrip patch antenna

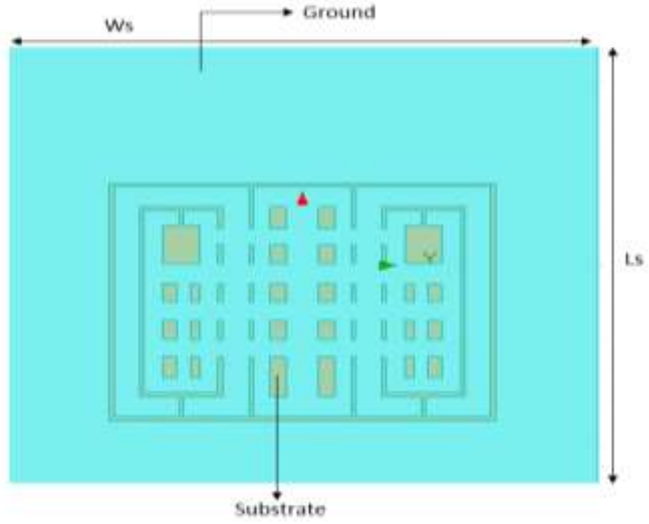

Fig 1(b): Back view of the designed patch antenna

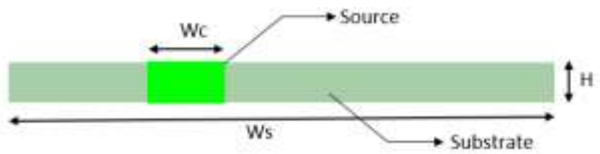

Fig 1(c): Side view of the microstrip patch antenna

PARAMETER	VALUES (MM)	PARAMETER	VALUES (MM)
WS	127	LP	65
LS	120	WF	14.875
H	1.6	LF	37
WP	83	WC	14.875

In this work we have introduced the following changes from the our previous work.We have changed the substrate from **FR4** to**Taconic substrate.** The ground plane has been modified which shown in figure 1(d).The another changes is width of the feedline is slightly reduced by 2 cm so the original width of the feedline Wf is 12.875cm.

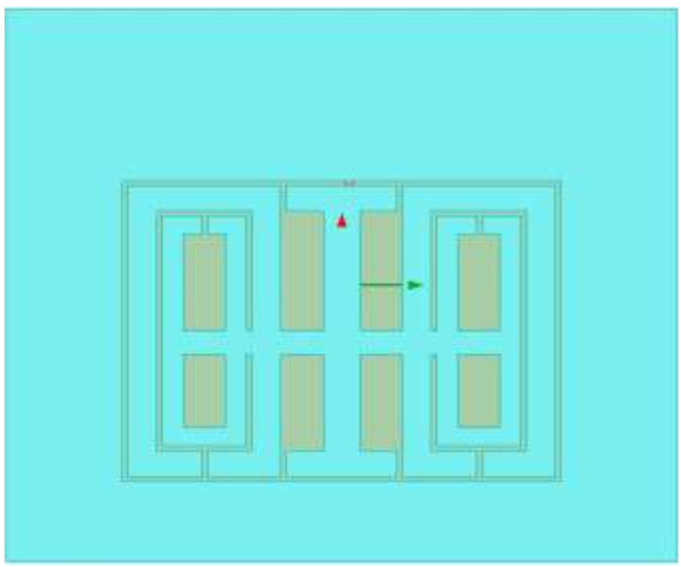

Fig 1(d): Modified Ground plane

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III. COMPARISON BETWEEN FR4 AND TACONIC SUBSTRATE

In Fr4 substance receiving the signal loss is large which leads to crashing of Aeroplanes each other due to signal loss, But In Taconic Substance the loss is less Which makes the Collision Avoidance. Frequency range of Fr4 is Minimum which results in coverage of Smaller Radius. But in Taconic due to large coverage of Radius We can Cover Maximum distance. The thermal stability of Fr4 is unbalanced but in Taconic the thermal stability is Balanced. These are the reasons For not using Fr4 & using Taconic Substance.

IV. RESULTS AND DISCUSSIONS

The design and simulations of the patch antenna in the WB frequency for Aircraft application are done using Ansys HFSS software. The antenna design is optimized for better performance characteristics like return loss, radiation pattern, gain and VSWR.

[A].Return Loss:

The return loss is the ratio of the reflected power to the incident power of the antenna. The return loss of the antenna should be greater than -10dB.

The return loss for the antenna we've designed is around -13dB at a frequency of 1.09GHz by using FR4 Substrate as shown in the Fig. 2(a).

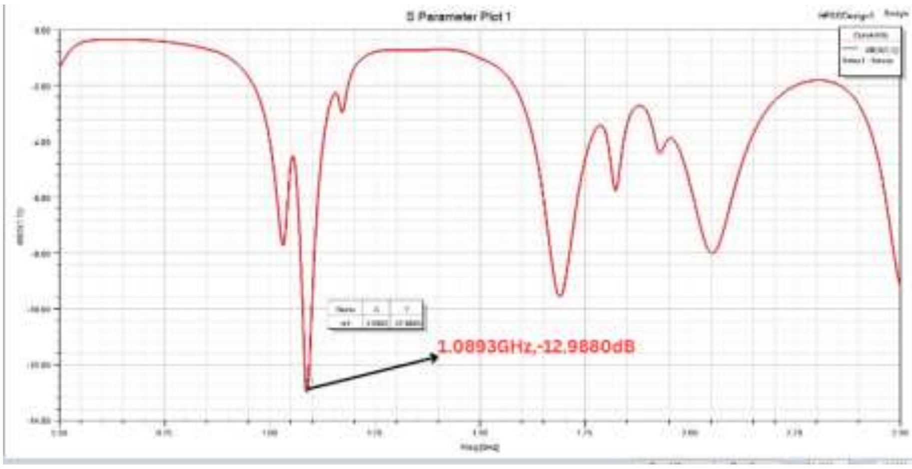

Fig 2(a): Return Loss using FR4 substrate.

After changing the FR4 into Taconic substrate of our antenna the Return loss is very high compare to the previous work. The return loss obtained is -28dB at 1.09GHz frequency as shown in fig 2(a1).

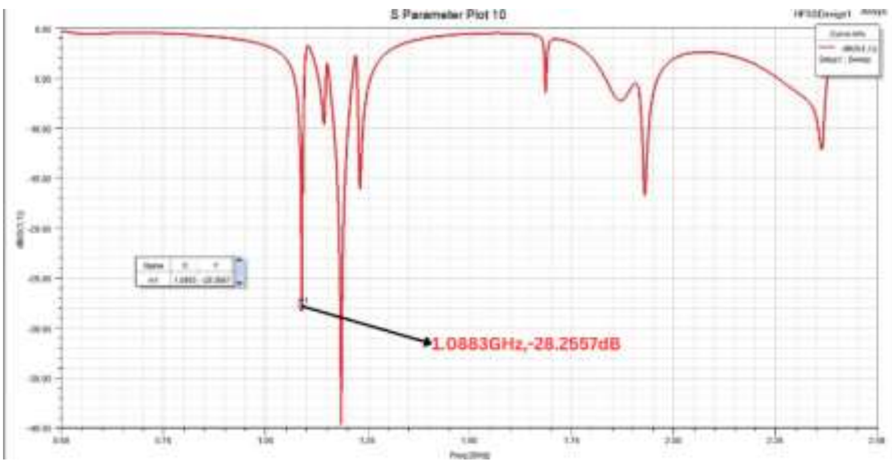

Fig 2(a1): Return loss Using Taconic Substrate.

[B] Voltage Standing Wave Ratio (VSWR):

It measures the loss at the feeder because of mismatch. It normally ranges between 0 to infinite. For the practical antennas if the value is less than 2, then the antenna is said to be matched. The VSWR obtained for our

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proposed antenna at the frequency 1.09GHz is1.59. The Voltage Standing Wave Ratio of microstrip patch antenna using FR4 substrate is shown in fig 2(b)

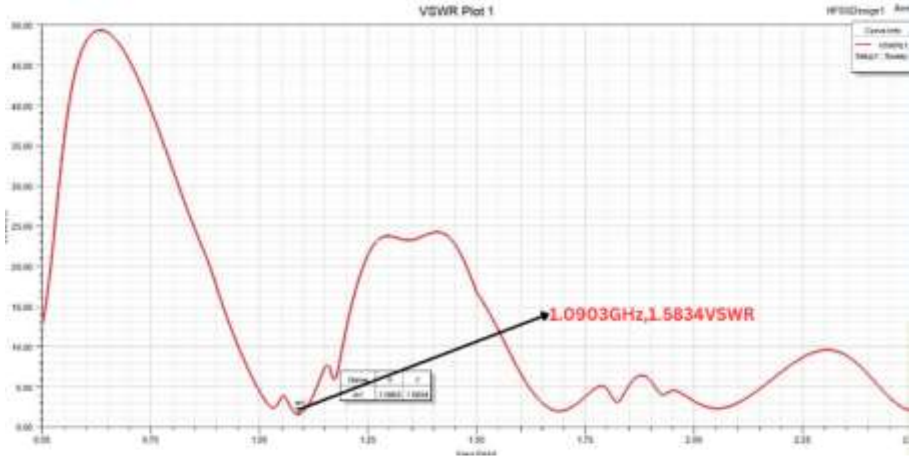

Fig 2(b): VSWRusing FR4 substrate

After changing toTaconic substratein our antenna,the VSWR obtained at the cutoff frequency 1.09GHz is 1.24 as shown in the fig 2(b1).

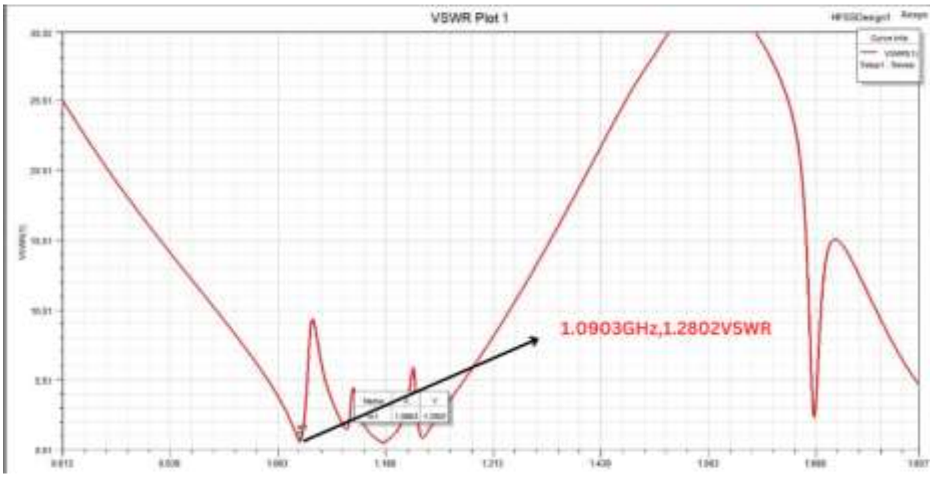

Fig 2(b1): VSWR using Taconic Substrate.

[C] GAIN:

Antenna gain is the ability of the antenna to radiate more or less in any direction compared to a theoretical antenna. If an antenna could be made as a perfect sphere, it would radiate equally in all directions.

In real time the gain of the antenna should be high. They are highly directional. The maximum directive gain provided by the designed patch antenna is 2.8dBusing FR4 substrate as shown in Fig.2(c).

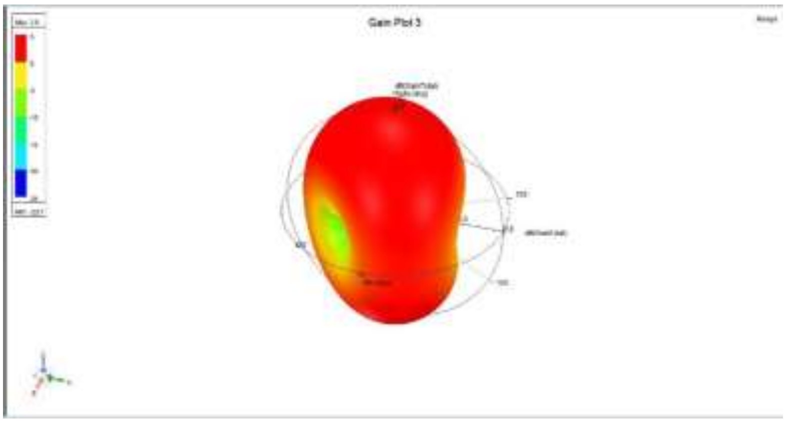

Fig 2(c): Gain in dB using FR4 substrate.

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By using Taconic substrate, the maximum directive Gain is 3.2dB as shown in fig 2 (c1).The gain obtained using Taconic substrate is better when compare to FR4 substrate.

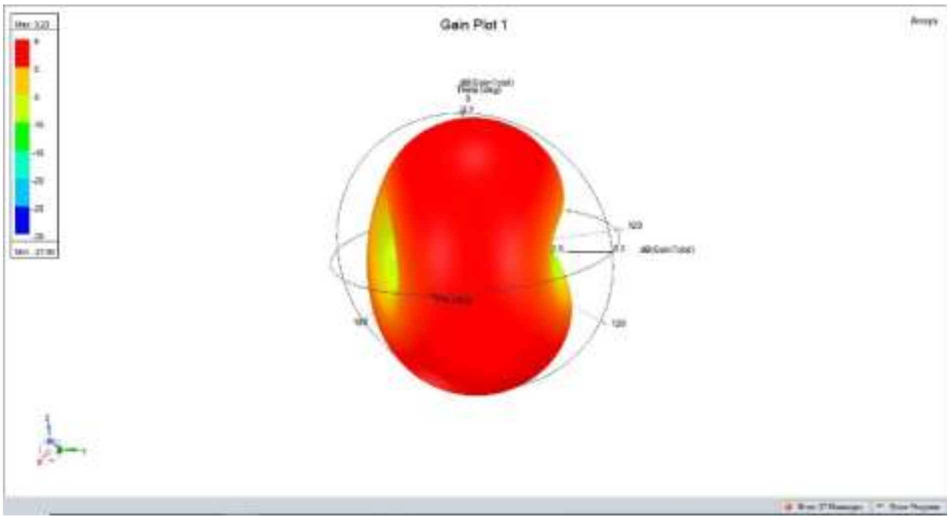

Fig 2 (c1): Gain in dB using Taconic substrate.

[D] Radiation Pattern:

Radiation pattern defines the energy radiated by the antenna.

The Radiation pattern for the antenna that we designed is around 20.4 dB using FR4 substrate as shown in Fig.2(d).

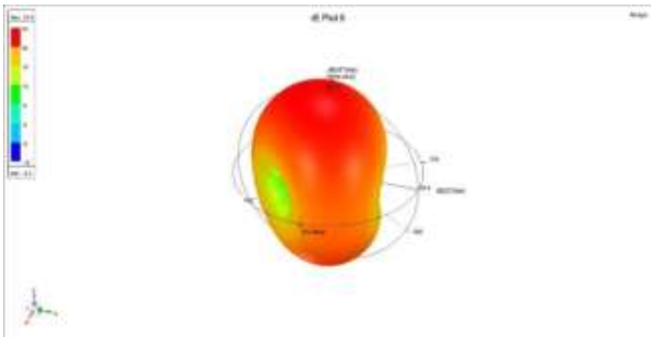

Fig 2(d): Radiation Pattern using FR4 substrate.

The Radiation pattern obtained for the proposed antenna design for the Taconic substrate is around 21dB as shown in Fig.2 (d1).

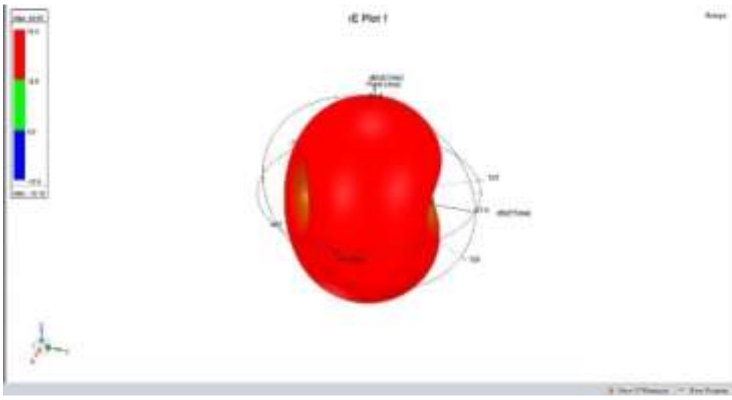

Fig 2(d1): Radiation pattern using Taconic substrate.

V. CONCLUSION

Thus we have designed the antenna for Aircraft Surveillance using ADS-B methodology. FR4 has been used as the substrate material and the results were obtained as designed and the antenna radiated in omnidirectional pattern. While changing the substrate material from FR4 to Taconic material the overall obtained results were better when compared with our design using FR4 substrate.The designed antenna is used for many applications like air traffic management, surveying, tracking, rescue operation of the flights.

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