iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: X Month of publication: October 2021

DOI: https://doi.org/10.22214/ijraset.2021.38395

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

Design of Reconfigurable Antenna for 5G Applications

Devika Mukesh[1], Devika Hari[2], Amal J[3], Ria Maria George[4]
[1, 2, 3, 4]Department of Electronics and Communication, Amal Jyothi College of Engineering, Kottayam, India

Abstract: With rapid evolution of wireless communication and mobile networking techniques, one of the major advancements is that fifth generation (5G) is envisioned in-order to meet the perpetual demand for greater network speed and capacity. This paper provides an overview of the design of five reconfigurable antennas for 5G wireless application is introduced by varying the substrate material used. Teflon, Taconic TLY, Rogers Ultralam 1217, Rogers RT/Duroid 5880, FR4 are the substrate materials used in designing the respective antennas. The proposed antenna designs employ a leaky-wave antenna based on half-mode substrate integrated waveguide. Since this antenna is used in 5G communication systems, the centre frequency is taken as 28.5 GHz. The length width and height of each of the antennas are designed using design procedures of rectangular patch antenna for all five substrates respectively. Each antennas are compared based on their return loss, VSWR, gain, directivity and radiation pattern respectively and an inference regarding performance of each substrate is obtained. On comparing the results of all the five antennas in the ON and OFF condition of switch, the results are found to be best in case of Rogers RT/duroid 5880 with return loss of -15.2719dB, VSWR of 1.4165, gain of 4.6dB, directivity of 4.31dB in the ON condition and with a return loss of -13.0779dB, VSWR of 1.6893, gain of 3.4dB and directivity of 3.7dB in the OFF condition. Further by changing the switches and replaced it by conducting sheet switches for reduction of loss and were able to achieve improved results with return loss of-24.5026dB, gain of 5.1dB in the ON condition and return loss of -12.6608dB and gain of 3.8dB in the OFF condition which contributed to the novelty of the project. In the proposed antennas, beam steering is obtained due to the disturbances in surface current under the influence of changing voltage bias of the switches. The technologies used make the antenna design compact provides configurability, which makes this antenna a suitable candidate for 5G applications.
Keywords: 5G, reconfigurable antenna, leaky wave antenna, half mode substrate integrated waveguide, millimeter wave, beam steering

I. INTRODUCTION

This paper designs a reconfigurable antenna for 5G wireless applications and also comparison of four different substrates used in the same. Recently, technology is advancing at a rapid rate and one most remarkable advancement is transition from 4G to 5G. This becomes highly significant as 5G delivers data at very high speed, ultra-low latency, high data rate. 5G also provides more dependability, enormous network volume, increased accessibility and more consistent user experience to large users. Its highly desirable as the operation frequency, radiation pattern and antenna polarization can be reconfigurable. Antennas play an important role in daily life wireless devices [1]-[2]. Due to major summons faced by modern antennas like power consumption and vulnerability, the demands for reconfigurable antennas are on the rise. Hence to overcome this challenge the implementation of reconfigurable antenna is necessary. The operating frequency, impedance bandwidth, polarization and radiation pattern of the reconfigurable antennas is modified as per operating requirement of the host system. They have advantages like low cost, low volume and simple integration. A new integrated guided wave structure is provided by the use of HMSIW for millimetre wave (mm-wave) and microwave applications which keeps the advantages of substrate integrated waveguide (SIW) by reducing the size to half, based on which many mm-wave and microwave passive elements are developed. Leaky wave antennas (LWA) are among a class of high gain antennas with scanning capability. They are broadly used in wireless communication systems. The radiation mechanism in LWA corresponds to the leakage of the travelling wave from a guided wave structure. The leakage generally occurs through a slot on the guided wave structure and that structure can be a microstrip line or a waveguide. SIW is a compact waveguide used widely in microwave applications due to its low cost, integration capability and compactness. In this project a LWA based on HMSIW is employed as it has many attractive features such as low cost, ease of fabrication, low loss, compact size, wide bandwidth and direct integration with planar circuits [1]-[5]. Gain and bandwidth enhancement is a result of the approach of adding an underground dielectric aperture to the proposed structure. The antenna can offer a unique ability of 3D frequency scanning in real time by scanning both E and H planes simultaneously.

The safety of the antenna of a mobile phone to the human brain during parallel placement is analysed. With the evolution of mobile communication, the design of mobile structures and the emergence of new materials are worthy of attention for electromagnetic exposure of the human brain. The Specific Absorption Rate (SAR) is the measure of the rate at which energy is absorbed per unit mass by human body when exposed to radiation. It is used for impedance matching and also in reducing the amount of radiation absorbed by human brain [6]-[7].

II. MOTIVATION AND OBJECTIVE

Antennas play an important role in wireless devices which are inseparable part of everyday life. One of the main challenges of modern antennas is the vulnerability to environmental and operational changes. The implementation of a reconfigurable antenna is necessary to overcome this challenge. Power consumption is another important challenge in wireless systems. Therefore implementing antennas with high gain and low loss is crucial. The present technology also aims in enhancing the bandwidth range so that the device can be operated in a wide range of frequencies [1]-[3]. Currently, the extend of mobile usage has tremendously increased. The prior knowledge of technological generations (1G, 2G, 3G & 4G) provides a deep insight about the antenna performances on different substrates.

The aim is to design a rectangular patch antenna with five substrates (Rogers RT/duroid 5880, Dielectric constant=2.2; FR4, Dielectric constant=2.2; Rogers Ultralam1217, Dielectric constant=2.17; Taconic TLY, Dielectric constant=2.2; Teflon, Dielectric constant=2.1) and to compare the antenna parameters of the designed antennas and to reach to a conclusion regarding the selection of antenna which is most suitable for 5G.

The primary objective is to introduce a reconfigurable antenna in 5G wireless systems which aim in achieving compactness, high gain, and increased bandwidth. The aim is to design and simulate the antenna with five dissimilar substrates and hence correlate the antenna parameters and performance of each and to reach to a conclusion regarding antenna which is appropriate for 5G application.

III. 5G

In the current world 5G the fifth-generation mobile network is the most significant and emerging technology which will have a revolutionary impact on the technological, social and economic development of mankind. After 1G, 2G, 3G and 4G networks 5G is the new global wireless standard. 5G bridge everyone virtually and everything together including machines, objects and devices through a new kind of network that is designed . 5G wireless technology deliver higher multi-Gbps peak data speeds, ultra-low latency and more to large number of users.

Excessive performance and enhanced efficiency empower new user experiences and connects new industries. 5G a unified and capable interface has been outlined with an enlarged size to enable next-generation user involvement, authorize new development replicas and supply new services. 5G will expand the mobile ecosystem into new realms with high speed, superior reliability and negligible delay. 5G will affect every industry, making safer transportation, remote healthcare, precision agriculture, digitized logistics and more.

The reason for the high speed of 5G is the use of shorter frequencies which are the mm-wave frequency between 30-300 GHz. The 5G technology is empowered by eight characteristic specification requirements such as data rate, frequency bands, mobility, forward error correction, access technology, latency, spectral efficiency and connection density [8]. Low density parity check (LDPC) codes are used as a forward error correction code and to attain latency. Mobility of 5G network is beyond 500 km/hr and the spectrum efficiency is 9 bits/s/Hz. Radio transmission signals with high directivity offers beam division multiple access (BDMA) which can support many users simultaneously, thus extending the system dimensions. Low latency feature of 5G network enables the user to experience high quality video in real time.

The amount of bandwidth in mm-wave band is extremely high, but propagation is poor hence, we should have more cell sites closer to the user. The advantage of this is that it allows being more precise about the transmission to a user. As beam width is small, there are chances of blockage if the user walks past a street light or a raised source of light which can completely block a specific beam. The user can switch between multiple beams. Beamforming is a traffic signalling like system used in signal communication. Instead of broadcasting in every direction, it allows a base station to focus the beam to a specific user. This prevents interference and is more efficient. Therefore, 5G signals are transmitted through a large number of small cell stations unlike 4G, which requires a large high power cell tower to radiate signals. Use of these small cell stations are necessary because the mm-wave band used is between 30-300 GHz and to generate high speed.

IV. RECTANGULAR MICROSTRIP PATCH ANTENNA

Microstrip antennas are used in different fields in various applications where the cost, weight, size, ease of installation and high performance levels are required. Many parameters of the antenna design such as the length and width of patch, permittivity and height of the substrate control its properties. The width of patch controls the input impedance and radiation pattern and the resonant frequency is controlled by the patch of the antenna. Hence the patch and substrate play a very crucial role in determining the antenna characteristics. The development of micro strip antenna technology began in the late 1970s. Micro strip patch antenna is one of most principle component of communication systems. By definition, an antenna is a device used to transform an RF signal, travel into an electromagnetic wave in free space. The rectangular micro strip antennas due to its low-profile, small-size and light weight play a vital role in wireless communication. A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is made of conducting material such as gold or copper. The radiating patch and the feed lines are photo etched on the dielectric substrate [9]-[11]. A rectangular microstrip patch antenna general structure is shown in figure 1 [9].

A. Design of Rectangular Microstrip Patch Antenna

The following are the steps for designing a rectangular microstrip patch antenna[9]:

1) Specify the frequency of operation (fr) or resonant frequency
2) Choose a suitable substrate material
3) Decide on the substrate height
4) Determine the correct patch dimensions (width and length)
5) Select a feed approach and find the feed location

The detailed procedure and design equations for designing the rectangular microstrip patch antenna are as follows:

a) *Step 1:* The height (h) or the thickness of the dielectric substrate of the RMSA is,

$$h \leq \frac{0.3c}{2\pi f_r \sqrt{\varepsilon r}}$$

b) *Step 2:* The width (W) of the microstrip patch is calculated as,

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r + 1}}$$

c) *Step 3:* The effective dielectric constant is determined by:

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

d) *Step 4:* The effective length of the patch is found from:

$$L_e = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}}$$

e) *Step 5:* The patch length extension is obtained from

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

f) *Step 6:* The patch length is found from

$$L = L_e - 2\Delta L$$

g) *Step 7:* The length of the ground plane (Lg), and width of the ground plane is found from

$$L_g = L + 6h$$

$$W_g = W + 6h$$

h) *Step 8:* The width of a microstrip transmission line feed is

$$W_f = \frac{7.48 \times h}{e^{\frac{Z_0\sqrt{\varepsilon_r+1.41}}{87}}}$$

i) *Step 9:* The feed length is found from

$$L_f = 3h$$

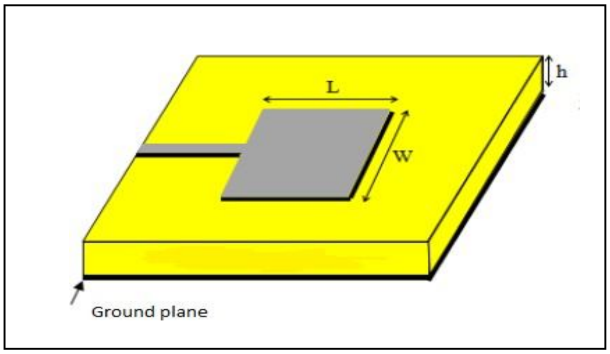


Figure 1: Rectangular Patch Antenna

V. LEAKY WAVE ANTENNA

This paper employees a leaky wave antenna (LWA) to implement the 5G wireless communication antenna. A LWA uses a guided wave structure that allows the waves to propagate along the length of the structure, with the wave continuously radiating throughout its length. It belongs to the class of travelling wave antennas similar to surface wave antennas, which possesses a cross section with dimensions about the wavelength of operation. These types of antennas maybe uniform, quasi uniform or periodic based on the modes of propagation. The incident wave in a LWA is a fast wave whose energy will be radiated along the length and hence a negligible field is obtained at the termination end. The electromagnetic field of the antenna gets excited by a wave incident at the interior or exterior of the guided structure which thus produces a current, which then propagates along its longitudinal direction.

There are two major types of leaky wave antennas. Uniform leaky wave antenna which is constant along its length, possessing some periodic modulation is the first type. They radiate into the forward quadrant and can scan in principle from broadside to endfire with beam nearer to endfire in higher frequencies. The second type of leaky wave antenna is the periodic leaky wave antenna in which some periodic modulations, which is uniform along the structure's length of the guided wave structure, are introduced. The main difference between a uniform and a periodic leaky wave antenna is that the dominant mode in the uniform LWA is a fast wave and therefore whenever the structure is open it radiates [12]-[21] .

VI. HMSIW BASED LWA

The desirable 5G wireless system can be implemented by using a reconfigurable antenna which is a leaky wave antenna based on the HMSIW. The desire to miniaturize wireless devices is on the rise. The printed circuit board (PCB) and low temperature co-fired ceramic (LTCC) technologies are among the most reliable and cost- effective technologies for miniaturization. Compactness, low cost, high gain, beam steering capability and simplicity of feeding network are among the features that make HMSIW based LWA, a suitable candidate for 5G applications like Internet of things (IoT), vehicle to everything(V2X) communications, machine to machine communication and satellite on the move and space communications. They can scan the E- and H- planes simultaneously, as a result of which it can provide a 3D image of the surrounding area [1]-[3].

The principle of a HMSIW is that for a dominant mode, it is known that the symmetric plane along the transmission direction is equivalent to the magnetic wall (MW). Thus, the half of the SIW will keep the half field distribution unchanged if the cutting plane is a magnetic wall. Actually, the open side aperture of the HMSIW is nearly equivalent to a perfect MW due to the high ratio of width to height. It is a planar form of rectangular EM waveguide (synthetic), formed in a dielectric substrate by densely arraying metallized posts/ via holes which connect upper and lower metal plates of substrate [12]-[21].

VII. ANTENNA STRUCTURE

A substrate integrated waveguide (SIW) is a rectangular electromagnetic waveguide formed in a dielectric substrate by densely arraying metallized via-holes which connect the upper and lower metal plates of the substrate. The fabrication of waveguide can be done with low-cost mass production using through-hole techniques where the post walls consist of via-fences. It has high power handling capability, higher quality factor, low cost and easy integration with other structures.

If half of top conductor plates of a SIW are removed, a structure which is more compact and called half mode substrate integrated waveguide (HMSIW) is obtained. The HMSIW not only keeps the good performance of SIW but reduces to half size. Therefore, it is chosen as the basis of proposed design. The structure is based on a PCB technology, with a leaky-wave antenna and a HMSIW and the scanning is done by an electronic scanning which is done by switching. So, implementation of cells i.e. in our proposed antenna, there are slots in which the varactor switches are placed, so this structure together is called a cell here and it's the main part of the antenna structure. The results required to derive are the return loss, bandwidth gain, radiation pattern and SAR. The results are analysed in both ON and OFF conditions of the switch. The results are obtained by simulating in HFSS software [1]-[7].

VIII. DESIGN AND SIMULATION

In the design of reconfigurable 5G antenna we have designed five antennas with five different substrates namely Rogers RT/duroid 5880, FR4, Rogers Ultralam 1217, Teflon and Taconic TLY. Here a rectangular patch antenna is used. The varactors are the switch employed with the resistor value 3.5Ω, inductor value1.25nH and the capacitor value 0.5pF in the ON condition and with the inductor value of 0.125nH and capacitor value of 0.05pF in OFF condition. The simulation results were successfully taken in HFSS.

A. *Designed Antenna With Substrate Rogers Rt/ Duroid 5880*

Rogers RT/duroid 5880 is a high frequency laminates are PTFE composites reinforced with glass microfibers with ε_r=2.2 and tanδ=0.0009.

The detailed procedure and design equations for designing the antenna with Rogers RT/duroid 5880 are as follows:

1) *Step 1:* The height (h) or the thickness of the dielectric substrate of the RMSA is,

$$h \leq \frac{0.3\times3\times10^8}{2\pi\times28.5\times10^9\sqrt{2.2}} = 0.338mm$$

2) *Step 2:* The width (W) of the microstrip patch is calculated as,

$$W=\frac{3\times10^8}{2\times28.5\times10^9}\sqrt{\frac{2}{2.2+1}} = 4.1608mm$$

3) *Step 3:* The effective dielectric constant is determined by:

$$\varepsilon reff = \frac{2.2+1}{2} + \frac{2.2-1}{2}[1+12\frac{3.38\times10^{-4}}{4.1608\times10^{-3}}]^{-\frac{1}{2}} = 2.026$$

4) *Step 4:* The effective length of the patch is found from:

$$L_e - \frac{3\times10^8}{2\times28.5\times10^9\sqrt{2.026}} - 3.679mm$$

5) *Step 5:* The patch length extension is obtained from

$$\Delta L = \frac{0.412\times3.38\times10^{-4}(2.026+0.3)(\frac{4.1608\times10^{-3}}{3.38\times10^{-4}}+0.264)}{(2.026-0.258)(\frac{4.1608\times10^{-3}}{3.38\times10^{-4}}+0.8)} = 0.176mm$$

6) *Step 6:* The patch length is found from

$$L=L_e - 2\Delta L = 3.345mm$$

7) *Step 7:* The length of the ground plane (Lg), and width of the ground plane is found from

$$L_g = L + 6h=5.373mm$$

$$W_g = W + 6h = 6.188mm$$

8) *Step 8:* The width of a microstrip transmission line feed is

$$W_f = \frac{7.48 \times 3.38 \times 10^{-4}}{e^{\frac{50\sqrt{2.2+1.41}}{87}}} = 0.848mm$$

9) *Step 9:* The feed length is found from

$$L_f = 3h = 1.164mm$$

Hence the Antenna length=5mm, height=0.4mm, width=6mm.

The HFSS model of designed antenna with Rogers RT/ duroid 5880 substrate is shown in figure 2 and the switch integrated antenna design with Rogers RT/ duroid 5880 is shown in figure 3.

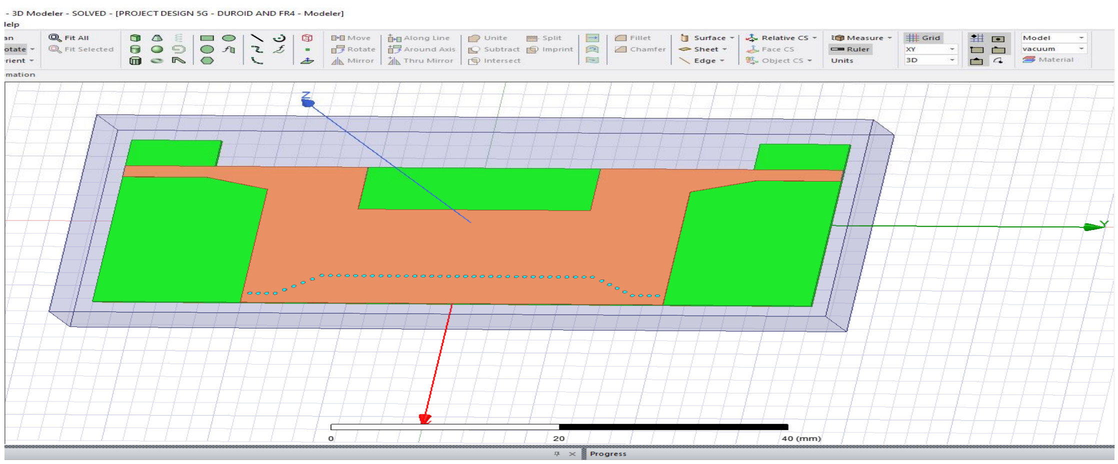


Figure 2: HFSS model of designed antenna with Rogers RT/ duroid

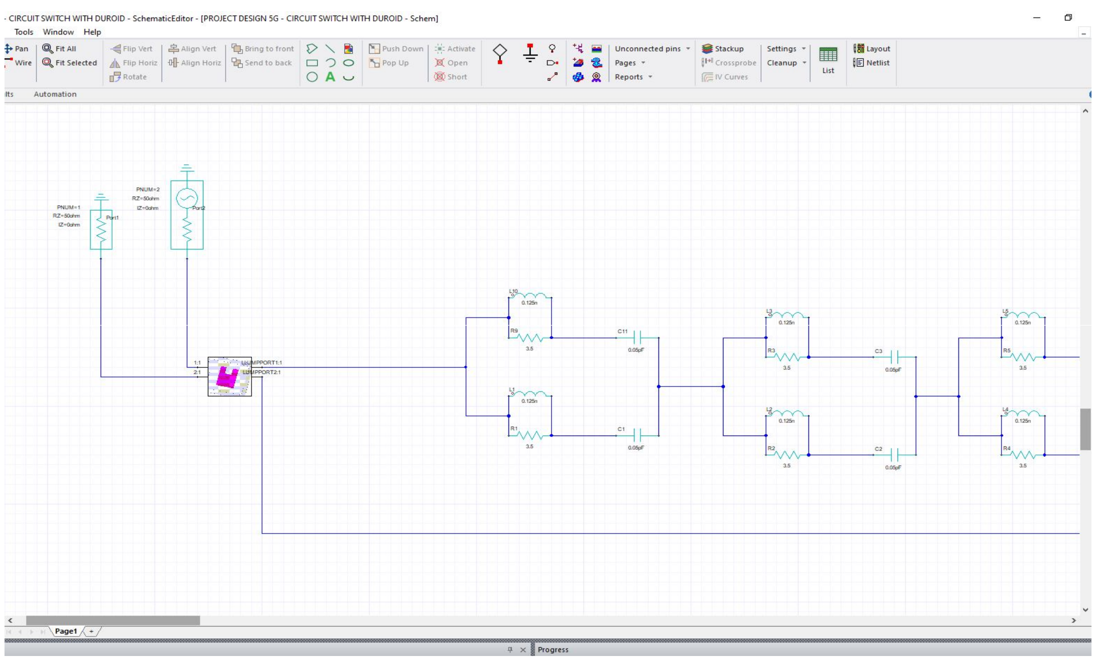


Figure 3: Switch integrated antenna design with Rogers RT/ duroid

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

a) *Simulation Of Antenna With Rogers Rt/Duroid 5880:* The simulation of the designed antenna has been carried out and various antenna parameters like VSWR, Return loss, Gain, Radiation pattern and directivity was observed, examined and measured. Rogers RT/duroid 5880 with dielectric constant 2.2 when simulated on 33GHz frequency in the ON condition of switch gives a return loss of -15.27dB at 28.5GHz which is shown in figure 4. It has a voltage standing wave ratio of 1.4165 at 28.5GHz as shown in figure 5, also it provides a gain of 4.6dB and a directivity of 4.31dB which is shown in figure 6 and 7 respectively. In the OFF condition of switch the simulation yielded a return loss of -13.0779dB which is shown on figure 8. The VSWR was found to be 1.6893 as shown in figure 9, also it provides a gain of 3.4dB and a directivity of 3.7dB as shown in figure 10 and 11 respectively

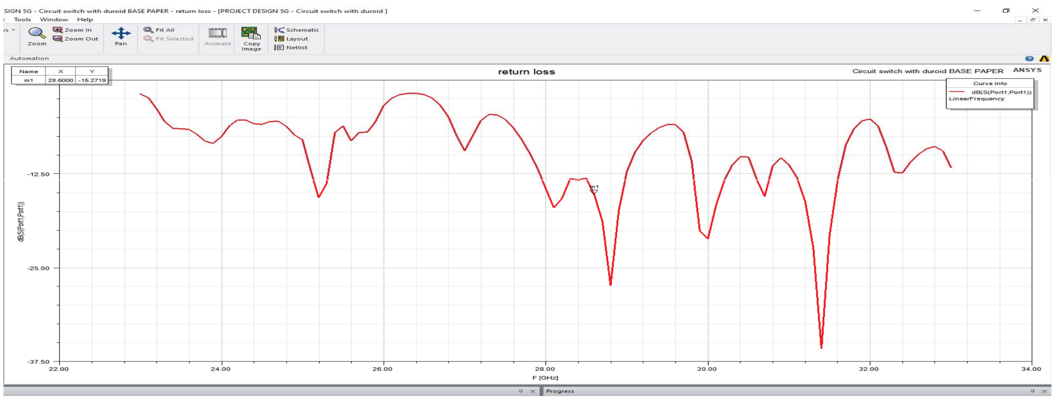


Figure 4: Return loss of designed antenna with Rogers RT/duroid in ON condition

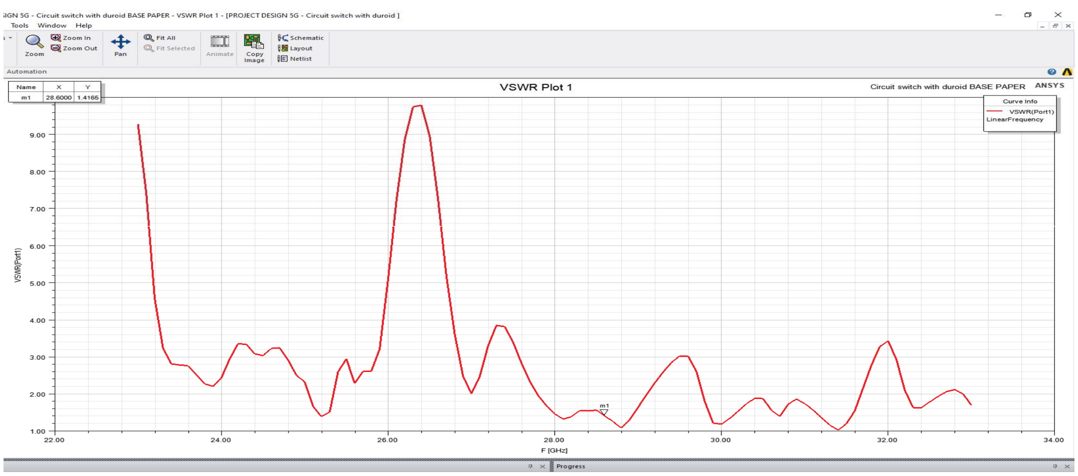


Figure 5: VSWR of designed antenna with Rogers RT/ duroid in ON condition

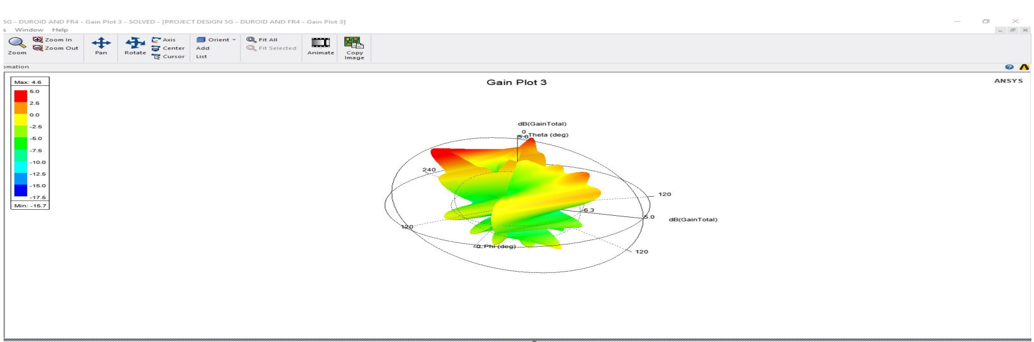


Figure 6: Gain of designed antenna with Rogers RT/ duroid in ON condition

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

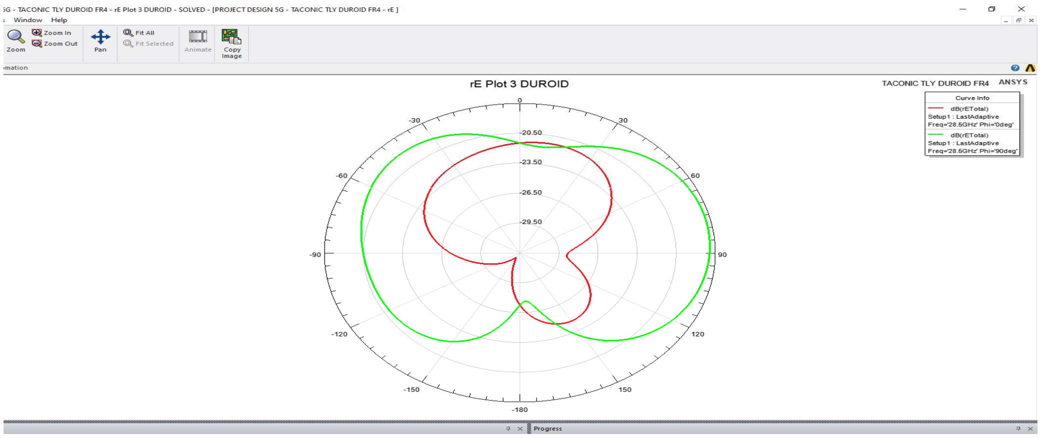


Figure 7: Radiation pattern of designed antenna with Rogers RT/ duroid in ON condition

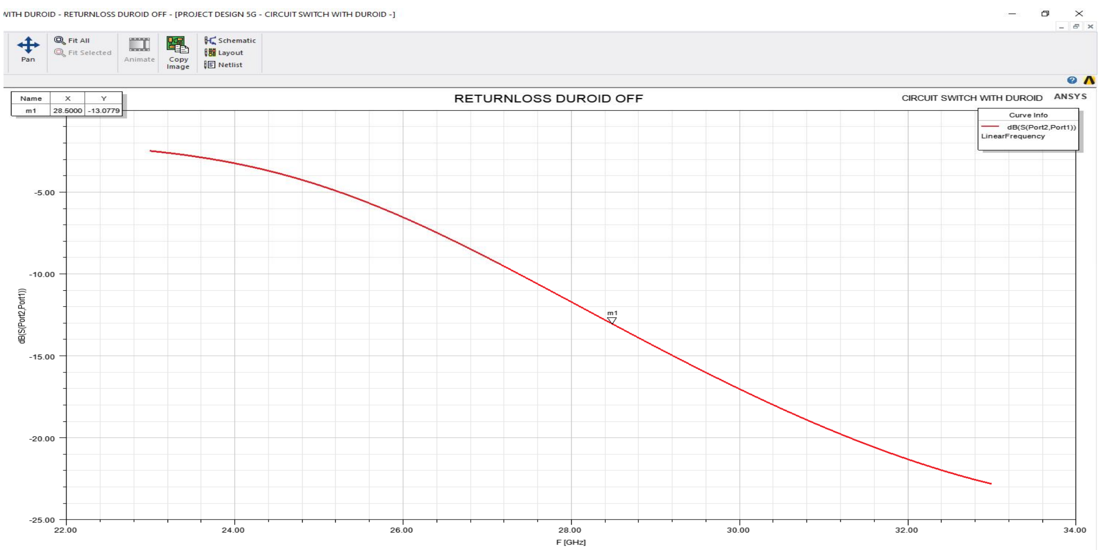


Figure 8: Return loss of designed antenna with Rogers RT/duroid in OFF condition

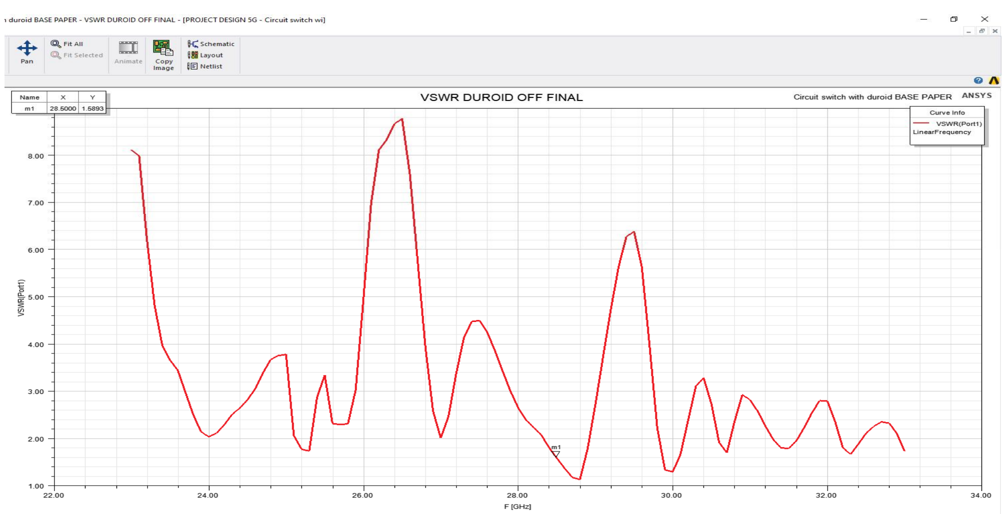


Figure 9: VSWR of designed antenna with Rogers RT/ duroid in OFF condition

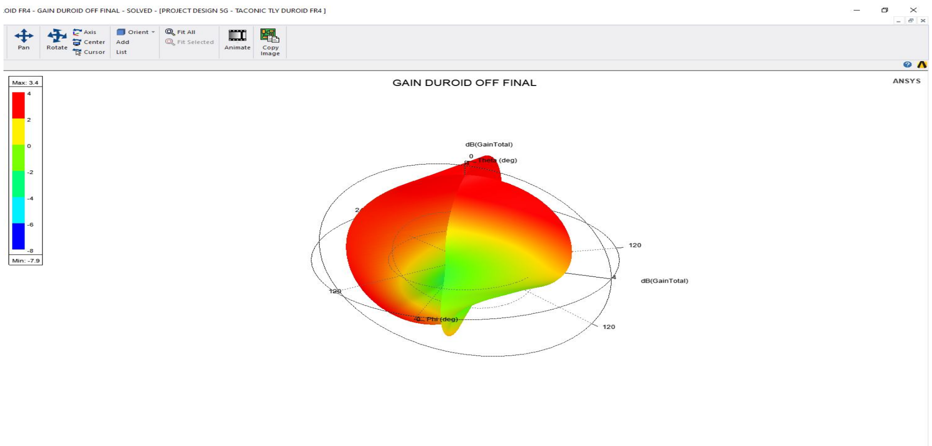


Figure 10: Gain of designed antenna with Rogers RT/ duroid in OFF condition

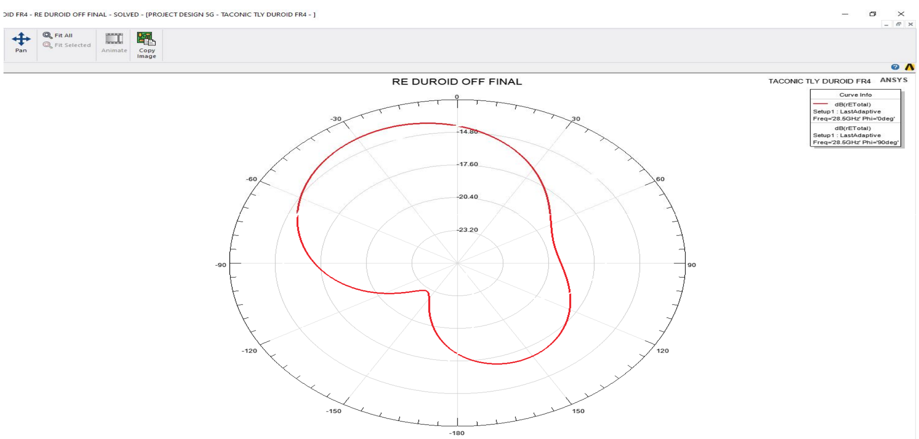


Figure 11: Radiation pattern of designed antenna with Rogers RT/ duroid in OFF condition

B. Designed Antenna With Substrate FR4

FR-4 is a NEMA grade designation for glass-reinforced epoxy laminate material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant with ε_r=2.2 and tanδ=0.0027.

The detailed procedure and design equations for designing the antenna with FR4 are as follows:

1) *Step 1:* The height (h) or the thickness of the dielectric substrate of the RMSA is,

$$h \leq \frac{0.3\times3\times10^8}{2\pi\times28.5\times10^9\sqrt{2.2}} = 0.338mm$$

2) *Step 2:* The width (W) of the microstrip patch is calculated as,

$$W=\frac{3\times10^8}{2\times28.5\times10^9}\sqrt{\frac{2}{2.2+1}} = 4.1608mm$$

3) *Step 3:* The effective dielectric constant is determined by:

$$\varepsilon reff = \frac{2.2+1}{2} + \frac{2.2-1}{2}\left[1+12\frac{3.38\times10^{-4}}{4.1608\times10^{-3}}\right]^{-\frac{1}{2}} = 2.026$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

4) *Step 4:* The effective length of the patch is found from:

$$L_e - \frac{3 \times 10^8}{2 \times 28.5 \times 10^9 \sqrt{2.026}} - 3.679mm$$

5) *Step 5:* The patch length extension is obtained from

$$\Delta L - \frac{0.412 \times 3.38 \times 10^{-4} (2.026 + 0.3)(\frac{4.1608 \times 10^{-3}}{3.38 \times 10^{-4}} + 0.264)}{(2.026 \quad 0.258)(\frac{4.1608 \times 10^{-3}}{3.38 \times 10^{-4}} + 0.8)} - 0.176mm$$

6) *Step 6:* The patch length is found from

$$\mathrm{L} = L_e - 2\Delta L = 3.345mm$$

7) *Step 7:* The length of the ground plane (Lg), and width of the ground plane is found from

$$L_g = L + 6h = 5.373mm$$

$$W_g = W + 6h = 6.188mm$$

8) *Step 8:* The width of a microstrip transmission line feed is

$$W_f = \frac{7.48 \times 3.38 \times 10^{-4}}{e^{\frac{50\sqrt{2.2+1.41}}{87}}} = 0.848mm$$

9) *Step 9:* The feed length is found from

$$L_f = 3h = 1.164mm$$

Hence the Antenna length=5mm, height=0.4mm, width=6mm.

The HFSS model of designed antenna with FR4 substrate is shown in figure 12 and the switch integrated antenna design with FR4 is shown in figure 13.

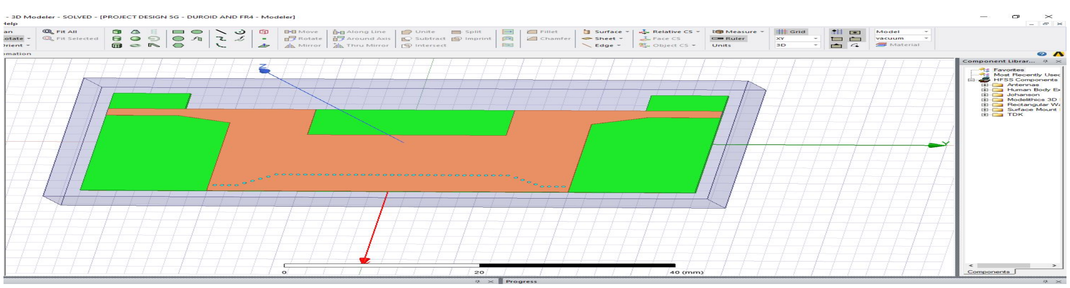


Figure 12: HFSS model of designed antenna with FR4

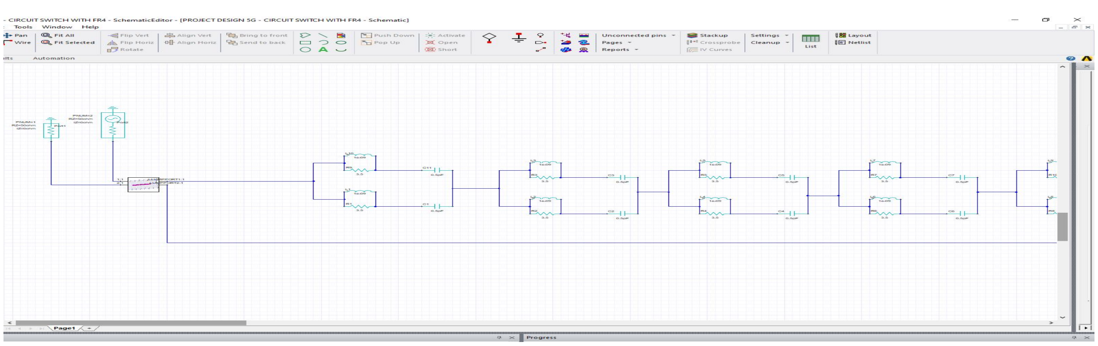


Figure 13: Switch integrated antenna design with FR4

a) *Simulation of Antenna With FR4:* The simulation of the designed antenna has been carried out and various antenna parameters like VSWR, Return loss, Gain, Radiation pattern and directivity was observed, examined and measured. FR4 with dielectric constant 2.2 when simulated on 33GHz frequency gives a return loss of -22.1016dB at 28.5GHz which is shown in figure 14. It has a voltage standing wave ratio of 1.1704 at 28.5GHz as shown in figure 15, also it provides a gain of 1.1dB and a directivity of 4.1dB which is shown in figure 16 and 17 respectively. In the OFF condition of switch the simulation yielded a return loss of -12.788dB which is shown on figure 18. The VSWR was found to be 5.4668 as shown in figure 19, also it provides a gain of 1.1dB and a directivity of 3.6dB as shown in figure 20 and 21 respectively.

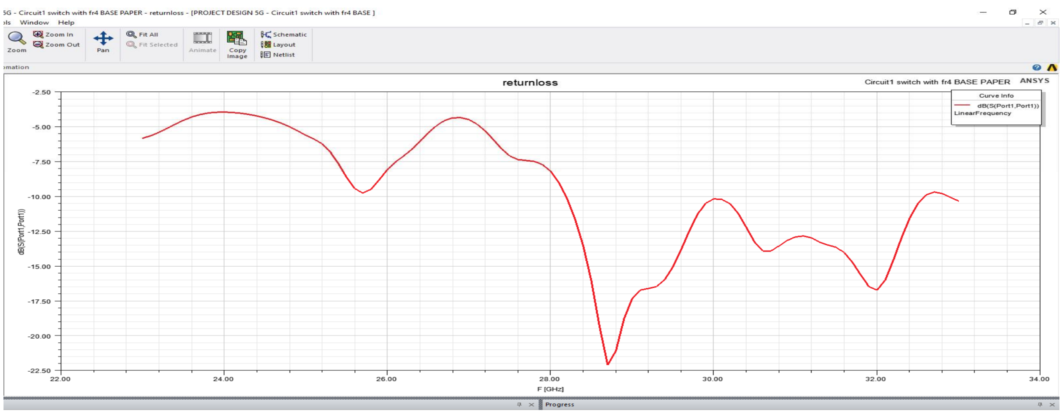


Figure 14: Return loss of designed antenna with FR4 in ON condition

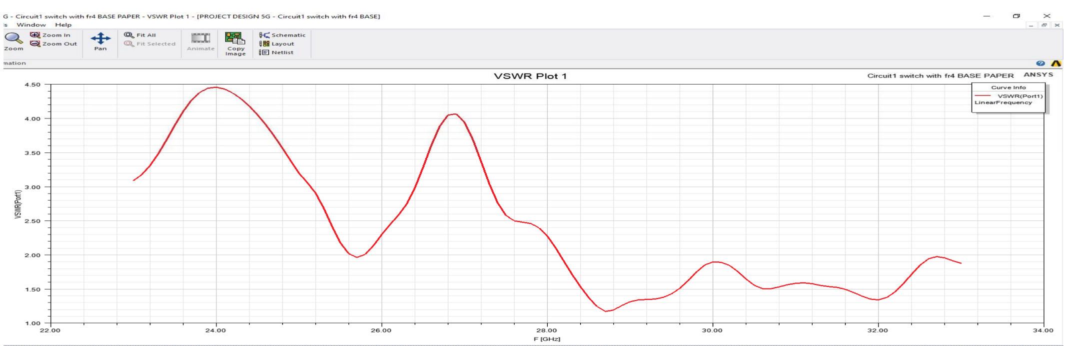


Figure 15: VSWR of designed antenna with FR4 in ON condition

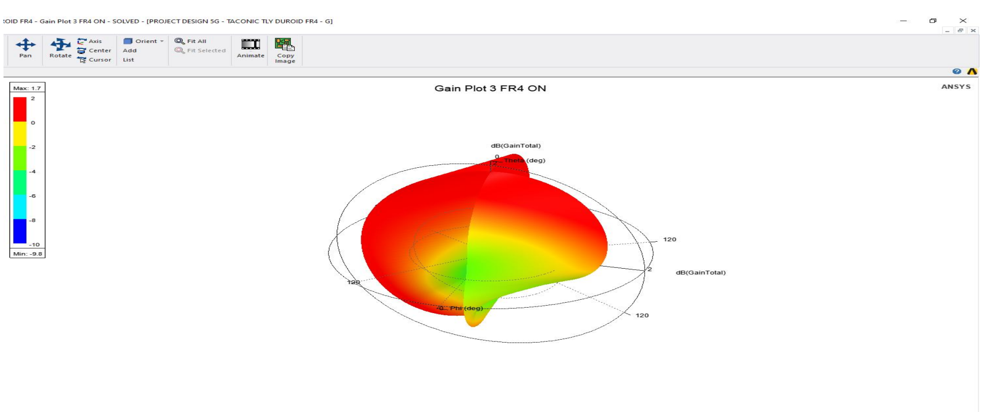


Figure 16: Gain of designed antenna with FR4 in ON condition

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

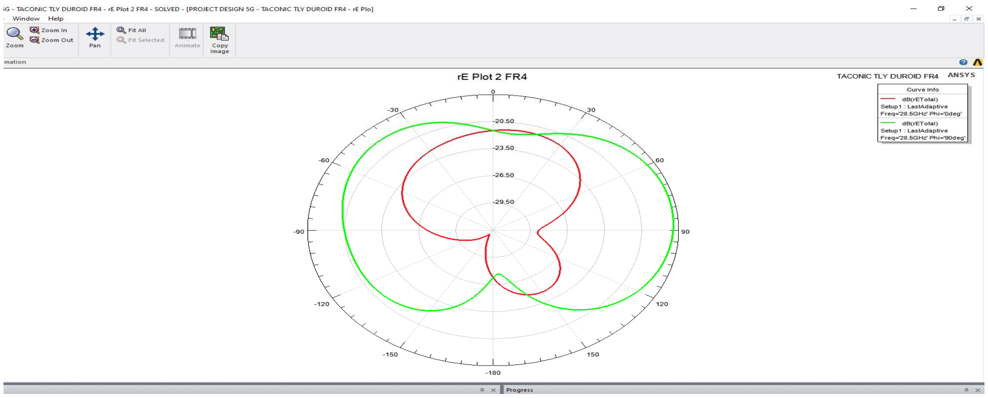


Figure 17: Radiation pattern of designed antenna with FR4 in ON condition

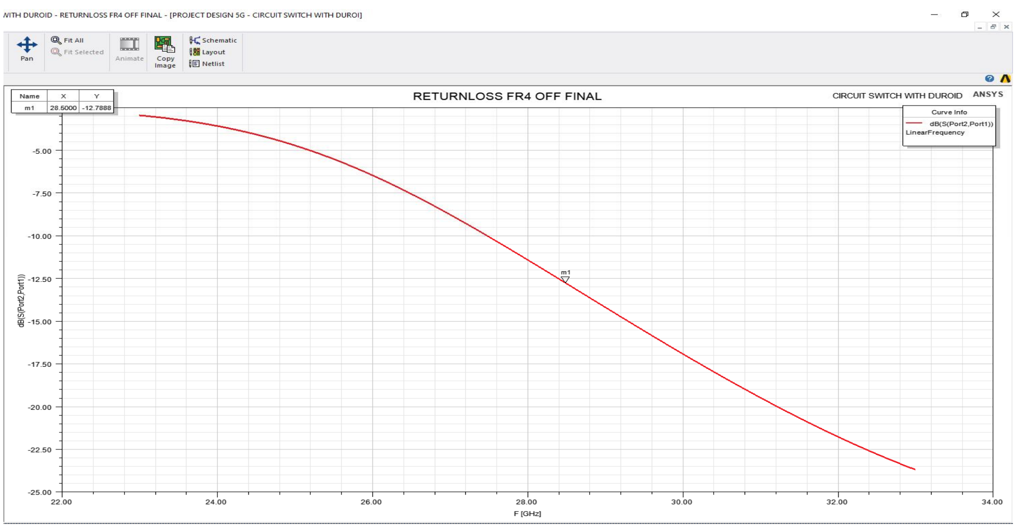


Figure 18: Return loss of designed antenna with FR4 in OFF condition

Figure 19: VSWR of designed antenna with FR4 in OFF condition

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

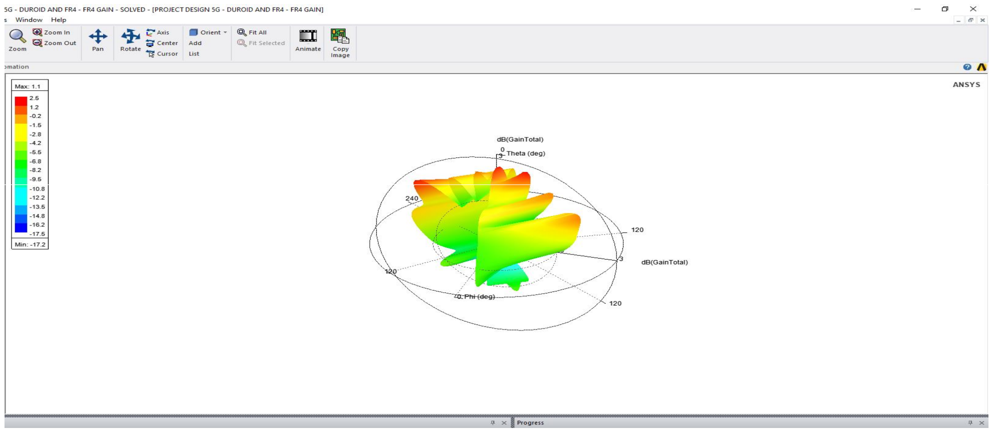


Figure 20: Gain of designed antenna with FR4 in OFF condition

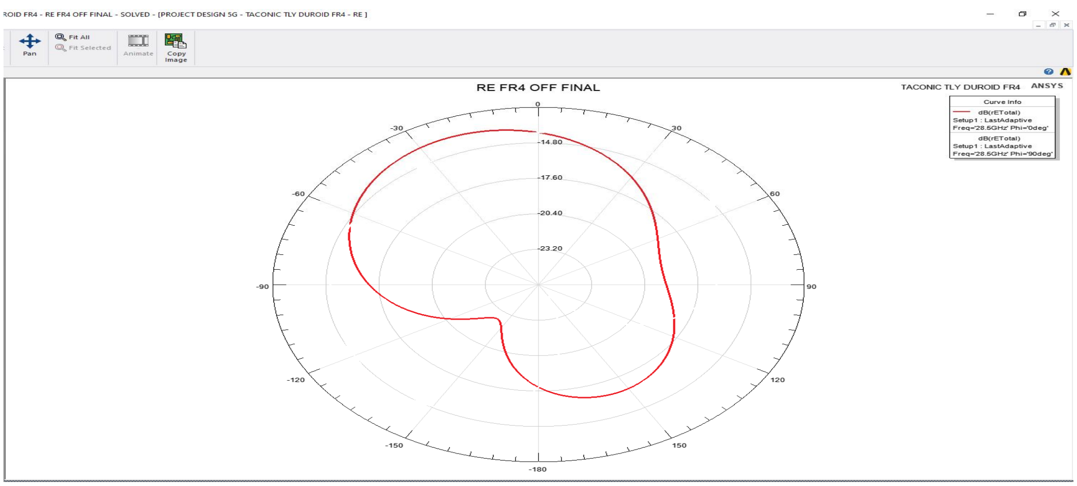


Figure 21: Radiation pattern of designed antenna with FR4 in OFF condition

C. *Designed Antenna With Substrate Rogers Ultralam 1217*

Rogers Ultralam 1217 laminate circuit material contain dielectric film which utilizes high temperature resistant liquid crystalline polymer with ε_r=2.17, tanδ=0.0009.

The detailed procedure and design equations for designing the antenna with FR4 are as follows:

1) *Step 1:* The height (h) or the thickness of the dielectric substrate of the RMSA is,

$$h \leq \frac{0.3\times3\times10^{8}}{2\pi\times28.5\times10^{9}\sqrt{2.17}} = 0.341mm$$

2) *Step 2:* The width (W) of the microstrip patch is calculated as,

$$W=\frac{3\times10^{8}}{2\times28.5\times10^{9}}\sqrt{\frac{2}{2.17+1}} = 4.18mm$$

3) *Step 3:* The effective dielectric constant is determined by:

$$\varepsilon reff = \frac{2.17+1}{2} + \frac{2.17-1}{2}\left[1+12\frac{3.41\times10^{-4}}{4.18\times10^{-3}}\right]^{-\frac{1}{2}} = 2.74$$

4) *Step 4:* The effective length of the patch is found from:

$$L_e - \frac{3 \times 10^8}{2 \times 28.5 \times 10^9 \sqrt{2.74}} - 3.179mm$$

5) *Step 5:* The patch length extension is obtained from

$$\Delta L - \frac{0.412 \times 3.41 \times 10^{-4} (2.74+0.3)(\frac{4.10\times10^{-3}}{3.41\times10^{-4}}+0.264)}{(2.74-0.258)(\frac{4.10\times10^{-3}}{3.41\times10^{-4}}+0.8)} - 0.1649mm$$

6) *Step 6:* The patch length is found from

$$L = L_e - 2\Delta L = 2.8492mm$$

7) *Step 7:* The length of the ground plane (Lg), and width of the ground plane is found from

$$L_g = L + 6h = 4.8952mm$$

$$W_g = W + 6h = 6.226mm$$

8) *Step 8:* The width of a microstrip transmission line feed is

$$W_f - \frac{7.48 \times 3.41 \times 10^{-4}}{e^{\frac{50\sqrt{2.17+1.41}}{87}}} - 0.837mm$$

9) *Step 9:* The feed length is found from

$$L_f = 3h = 1.023mm$$

Hence the Antenna length=6mm, height=0.3mm, width=5mm.

The HFSS model of designed antenna with Rogers Ultralam 1217 substrate is shown in figure 22 and the switch integrated antenna design with Rogers Ultralam 1217 is shown in figure 23.

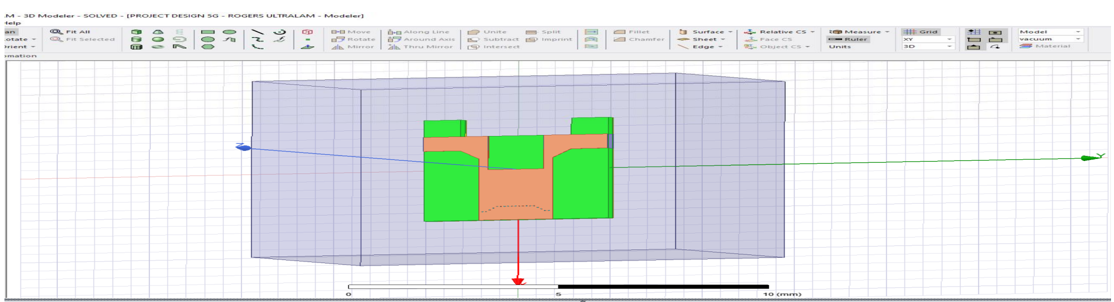


Figure 22: HFSS model of designed antenna with Rogers Ultralam

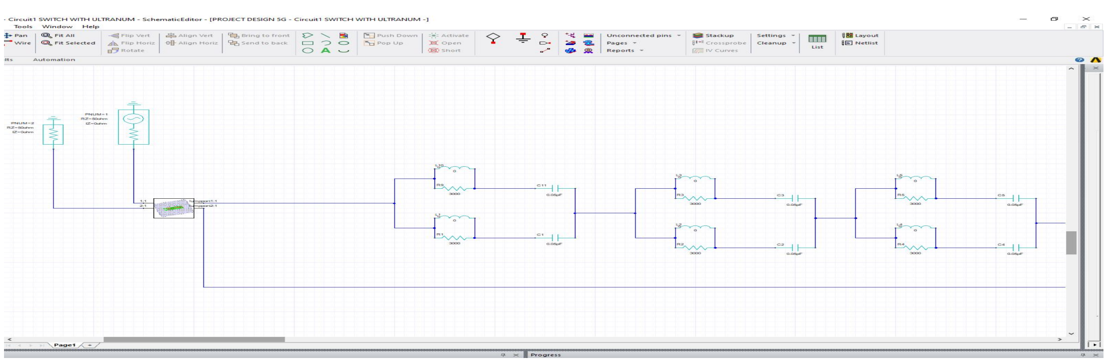


Figure 23: Switch integrated antenna design with Rogers Ultralam

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

a) Simulation Of Antenna With Rogers Ultralam 1217: The simulation of the designed antenna has been carried out and various antenna parameters like VSWR, Return loss, Gain, Radiation pattern and directivity was observed, examined and measured. Rogers Ultralam with dielectric constant 2.17 when simulated on 33GHz frequency gives a return loss of -26.0118dB at 28.5GHz which is shown in figure 24. It has a voltage standing wave ratio of 2.2981 at 28.5GHz as shown in figure 25, also it provides a gain of 2.9dB and a directivity of 4dB which is shown in 26 and 27 respectively. In the OFF condition of switch the simulation yielded a return loss of -10.5613dB which is shown on figure 28. The VSWR was found to be 7.6409 as shown in figure 29, also it provides a gain of 2.6dB and a directivity of 3.9dB as shown in figure 30 and 31 respectively.

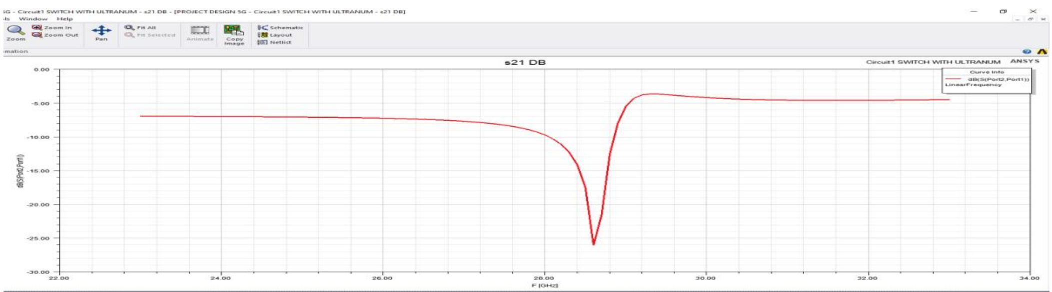


Figure 24: Return loss of designed antenna with Rogers Ultralam in ON condition

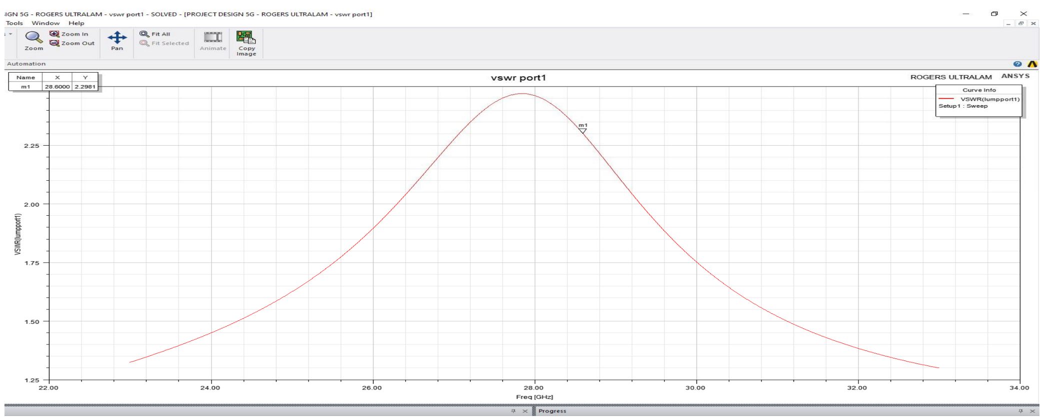


Figure 25: VSWR of designed antenna with Rogers Ultralam in ON condition

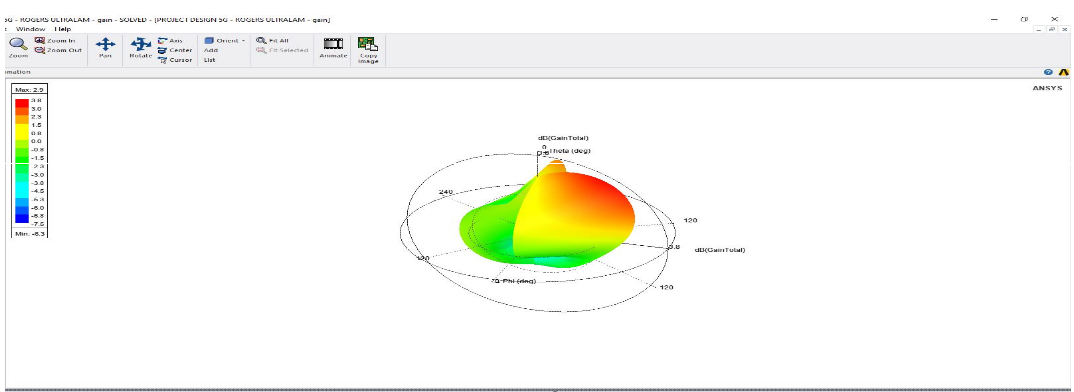


Figure 26: Gain of designed antenna with Rogers Ultralam in ON condition

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

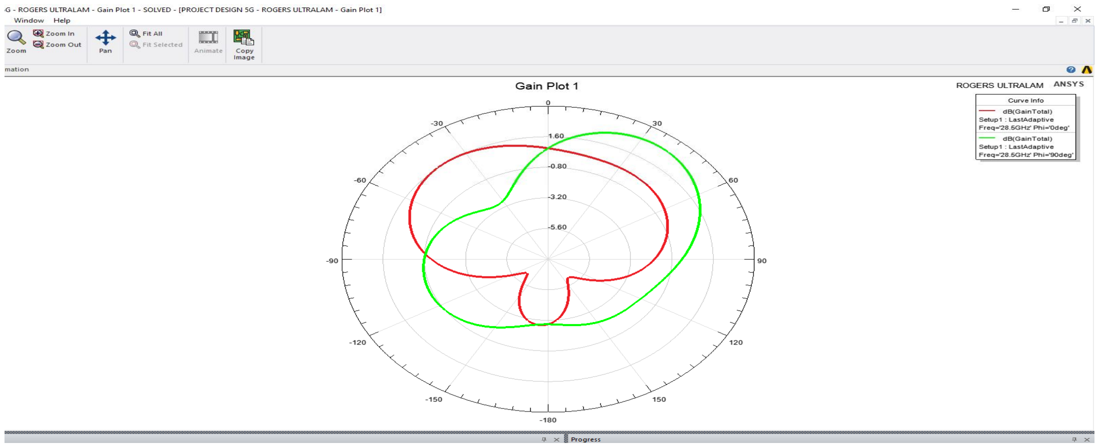


Figure 27: Radiation pattern of designed antenna with Rogers Ultralam in ON condition

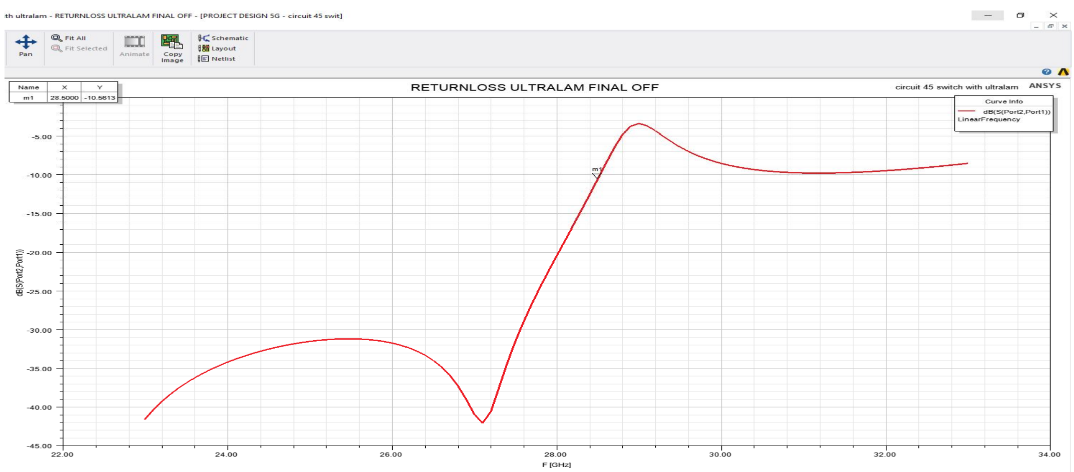


Figure 28: Return loss of designed antenna with Rogers Ultralam in OFF condition

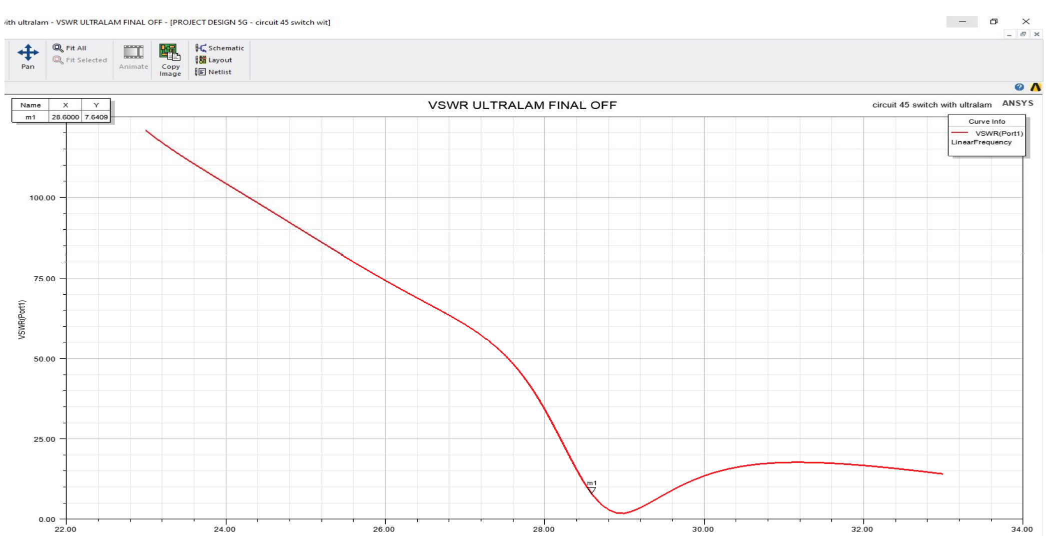


Figure 29: VSWR of designed antenna with Rogers Ultralam in OFF condition

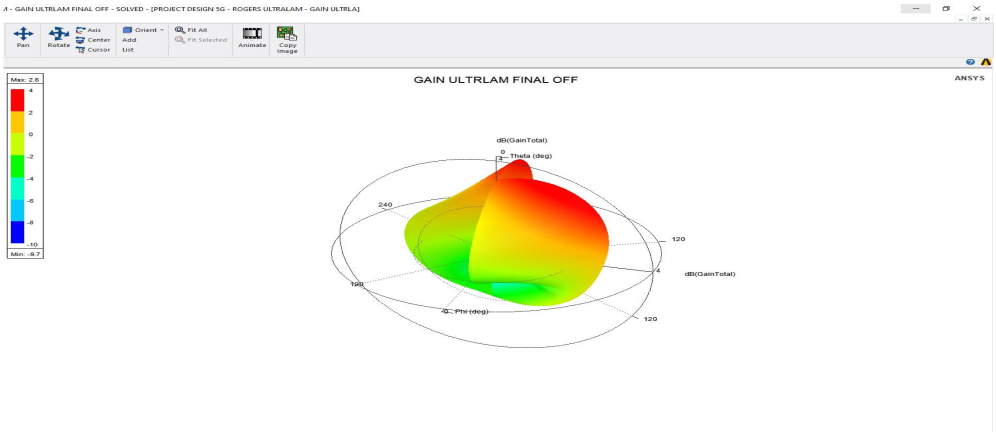


Figure 30: Gain of designed antenna with Rogers Ultralam in OFF condition

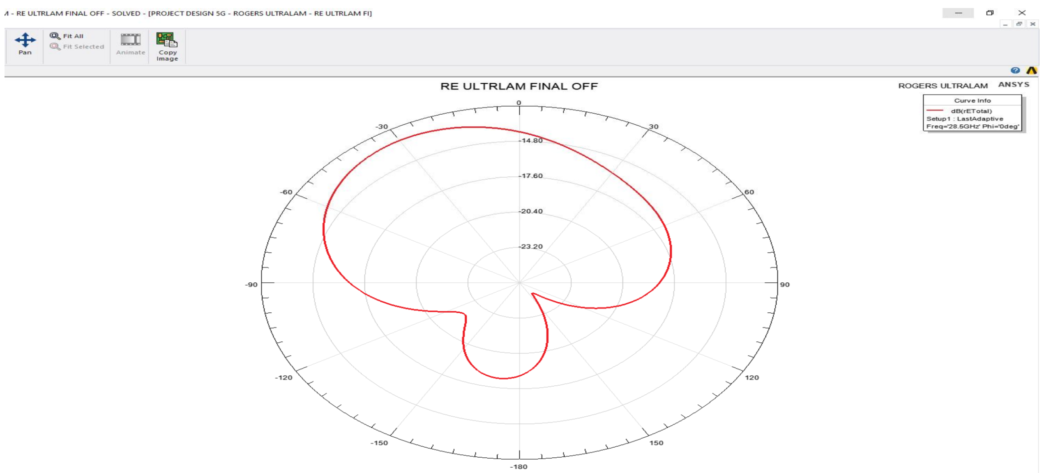


Figure 31: Radiation pattern of designed antenna with Rogers Ultralam in OFF condition

D. Designed Antenna With Substrate Taconic TLY

Taconic TLY laminates are manufactured with very light weight woven fiberglass and are more dimensionally stable than chopped fibre reinforced PTFE composites with ε_r=2.2, tanδ=0.0009 .

The detailed procedure and design equations for designing the antenna with FR4 are as follows:

1) *Step 1:* The height (h) or the thickness of the dielectric substrate of the RMSA is,

$$h \le \frac{0.3\times3\times10^8}{2\pi\times28.5\times10^9\sqrt{2.2}} = 0.338mm$$

2) *Step 2:* The width (W) of the microstrip patch is calculated as,

$$W=\frac{3\times10^8}{2\times28.5\times10^9}\sqrt{\frac{2}{2.2+1}} = 4.1608mm$$

3) *Step 3:* The effective dielectric constant is determined by:

$$\varepsilon reff = \frac{2.2+1}{2} + \frac{2.2-1}{2}\left[1+12\frac{3.38\times10^{-4}}{4.1608\times10^{-3}}\right]^{-\frac{1}{2}} = 2.026$$

4) *Step 4:* The effective length of the patch is found from:

$$L_e = \frac{3 \times 10^8}{2 \times 28.5 \times 10^9 \sqrt{2.026}} = 3.679mm$$

5) *Step 5:* The patch length extension is obtained from

$$\Delta L = \frac{0.412 \times 3.38 \times 10^{-4}\,(2.026+0.3)\left(\frac{4.1600 \times 10^{-3}}{3.38 \times 10^{-4}}+0.264\right)}{(2.026-0.258)\left(\frac{4.1600 \times 10^{-3}}{3.38 \times 10^{-4}}+0.8\right)} = 0.176mm$$

6) *Step 6:* The patch length is found from

$$L = L_e - 2\Delta L = 3.345mm$$

7) *Step 7:* The length of the ground plane (Lg), and width of the ground plane is found from

$$L_g = L + 6h = 5.373mm$$

$$W_g = W + 6h = 6.188mm$$

8) *Step 8:* The width of a microstrip transmission line feed is

$$W_f = \frac{7.48 \times 3.38 \times 10^{-4}}{e^{\frac{50\sqrt{2.2+1.41}}{87}}} = 0.848mm$$

9) *Step 9:* The feed length is found from

$$L_f = 3h = 1.164mm$$

XHence the Antenna length=5mm, height=0.4, width=6mm.

The HFSS model of designed antenna with Taconic TLY substrate is shown in figure 32 and the switch integrated antenna design with Taconic TLY is shown in figure 33.

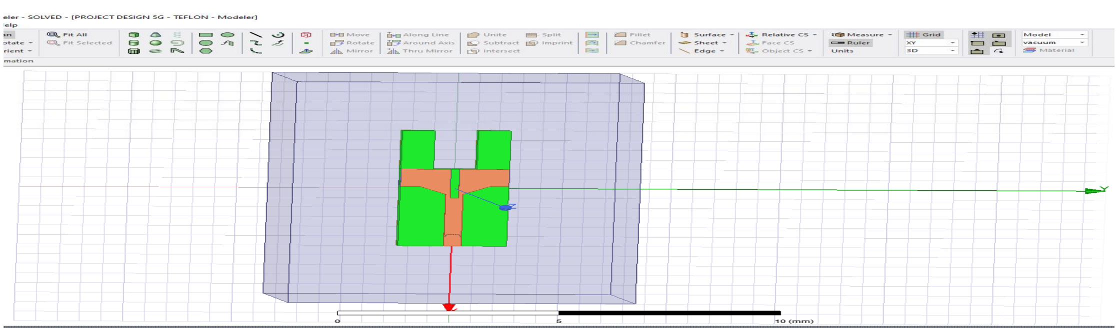


Figure 32: HFSS model of designed antenna with Taconic TLY

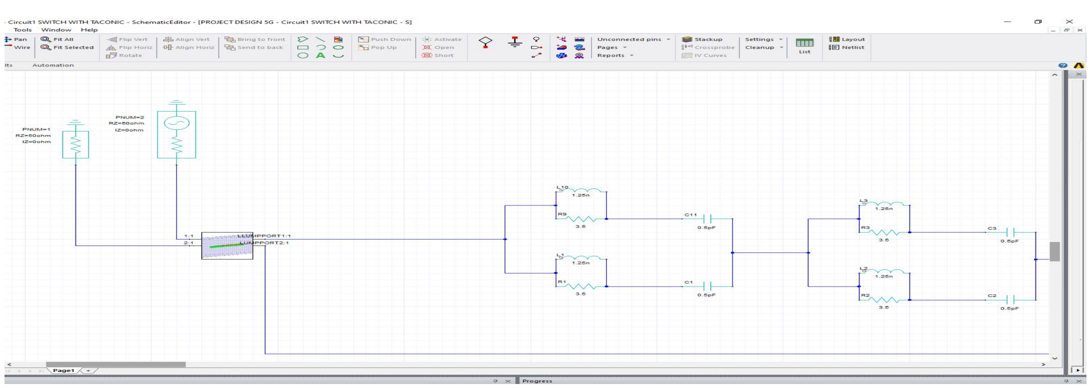


Figure 33: Switch integrated antenna design with Taconic TLY

a) Simulation Of Antenna With Taconic TLY: The simulation of the designed antenna has been carried out and various antenna parameters like VSWR, Return loss, Gain, Radiation pattern and directivity was observed, examined and measured. Taconic TLY with dielectric constant 2.2 when simulated on 33GHz frequency gives a return loss of -9.8057dB at 28.5GHz which is shown in figure 34. It has a voltage standing wave ratio of 4.7660 at 28.5GHz as shown in figure 35, also it provides a gain of 1.81dB and a directivity of 4.1dB which is shown in figure 36 and 37 respectively. In the OFF condition of switch the simulation yielded a return loss of -13.0779dB which is shown on figure 38. The VSWR was found to be 2.0675 as shown in figure 39, also it provides a gain of 3.4dB and a directivity of 3.7dB as shown in figure 40 and 41 respectively.

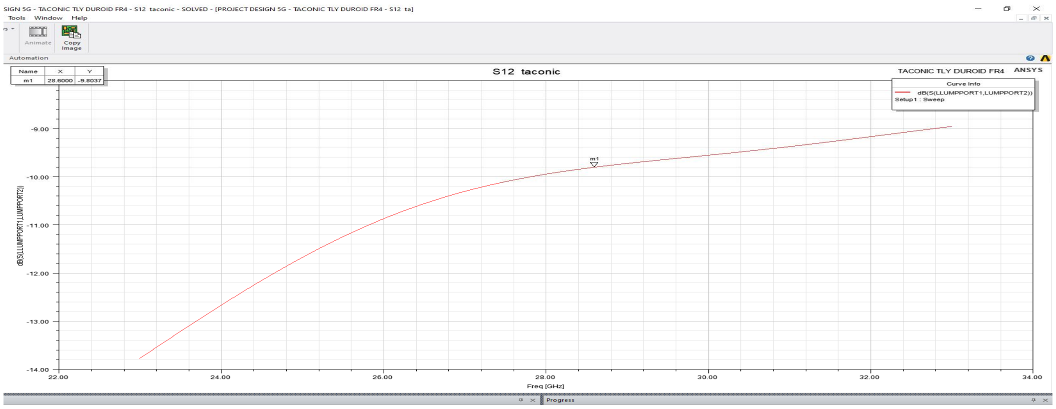


Figure 34: Return loss of designed antenna with Taconic TLY in ON condition

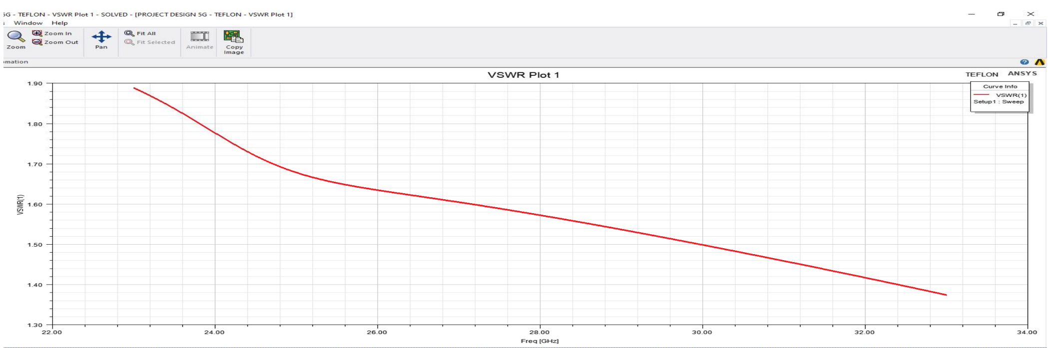


Figure 35: VSWR of designed antenna with Taconic TLY in ON condition

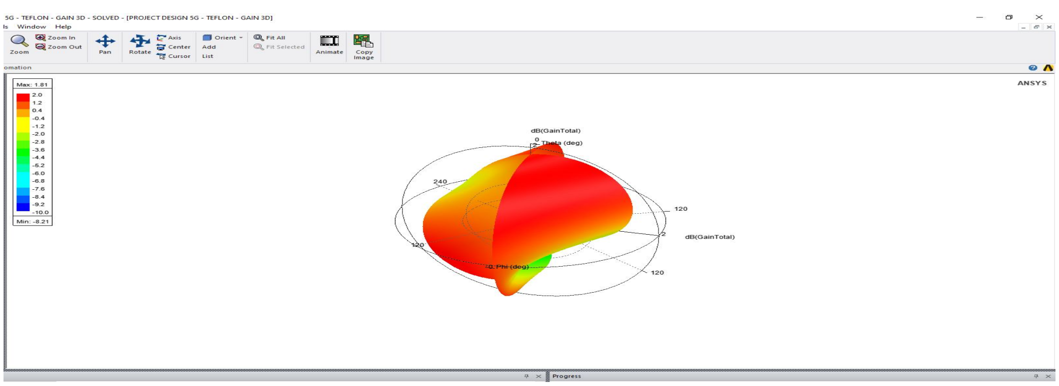


Figure 36: Gain of designed antenna with Taconic TLY in ON condition

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

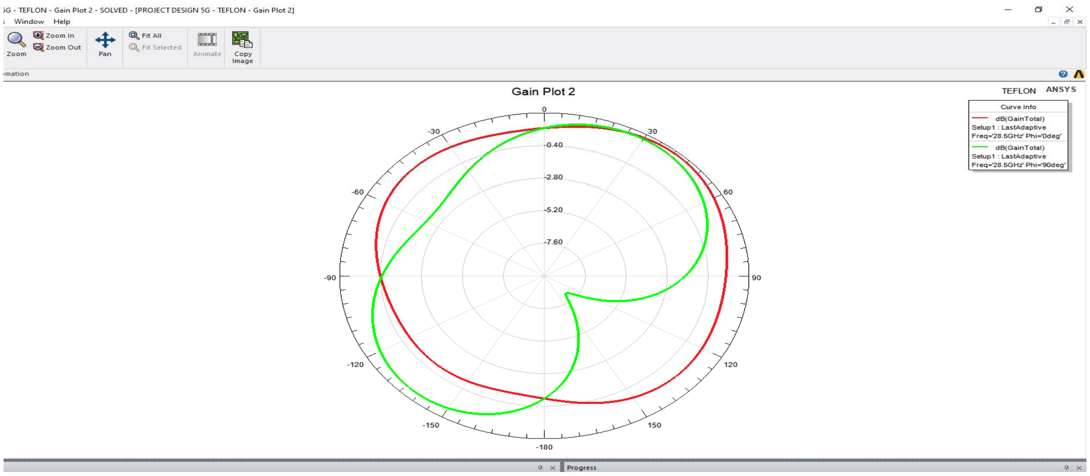


Figure 37: Radiation pattern of designed antenna with Taconic TLY in ON condition

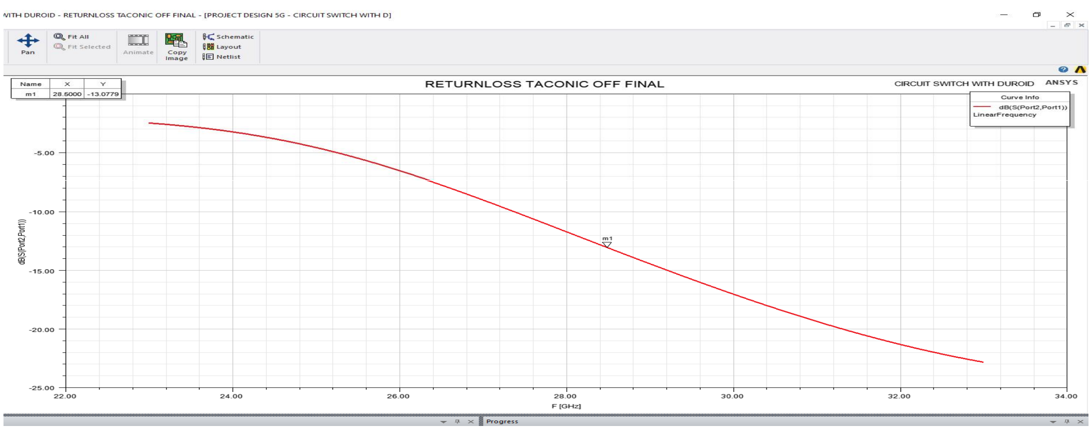


Figure 38: Return loss of designed antenna with Taconic TLY in OFF condition

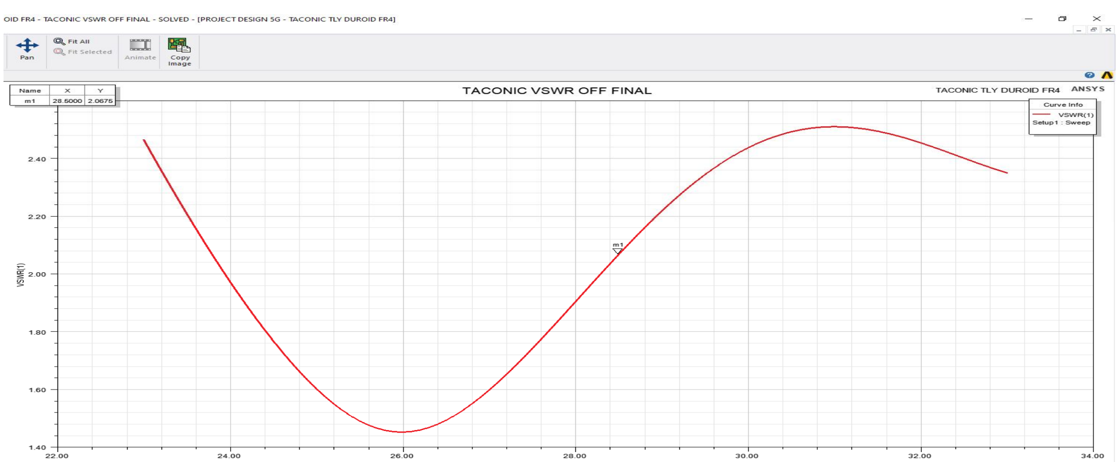


Figure 39: VSWR of designed antenna with Taconic TLY in OFF condition

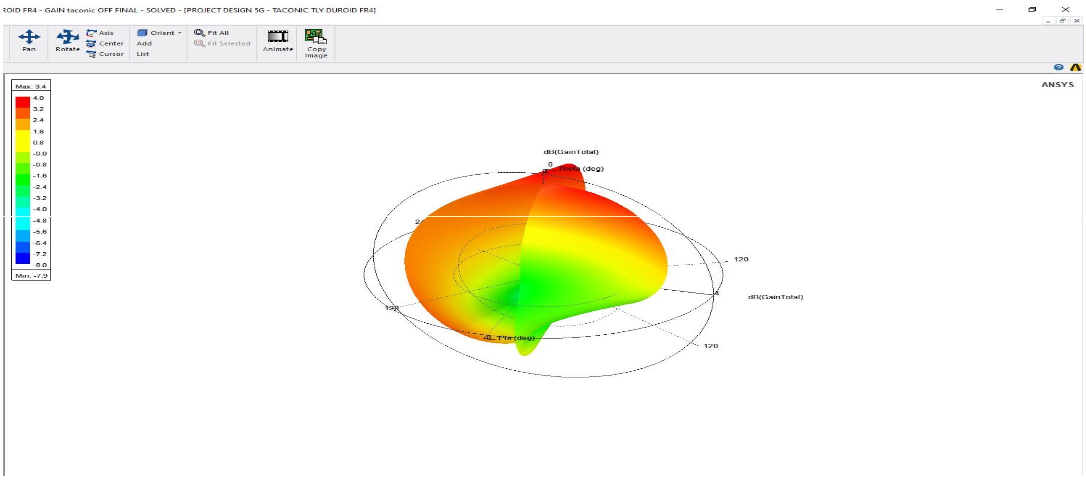


Figure 40: Gain of designed antenna with Taconic TLY in OFF condition

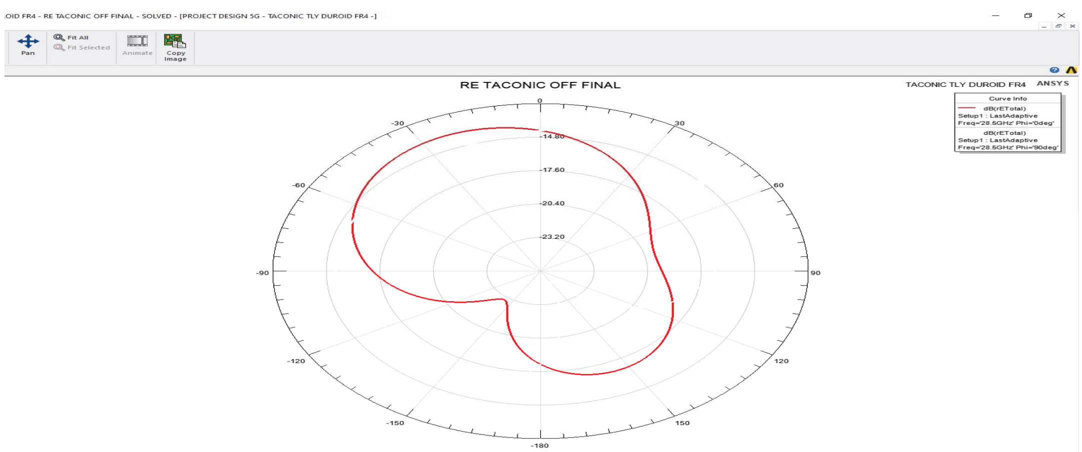


Figure 41: Radiation pattern of designed antenna with Taconic TLY in OFF condition

E. Designed Antenna With Substrate Teflon

Teflon/PTFE substrates are high frequency and have very low losses and very high thermal conductivity. This PTFE substrate for high frequency/millimeter wave use offers both excellent dielectric characteristics and low water absorption.

The detailed procedure and design equations for designing the antenna with Teflon are as follows:

1) *Step 1:* The height (h) or the thickness of the dielectric substrate of the RMSA is,

$$h \le \frac{0.3\times3\times10^{8}}{2\pi\times28.5\times10^{9}\times\sqrt{2.1}}=0.346\text{mm}$$

2) *Step 2:* The width (W) of the microstrip patch is calculated as,

$$W=\frac{3\times10^{8}}{2\times28.5\times10^{9}}\sqrt{\frac{2}{2.1+1}}=4.2274\text{mm}$$

3) *Step 3:* The effective dielectric constant is determined by:

$$\varepsilon_{reff}=\frac{2.1+1}{2}+\frac{2.1-1}{2}\left[1+12\frac{0.346}{4.2274}\right]^{-1/2}=1.9406$$

4) *Step 4:* The effective length of the patch is found from:

$$L_{e}=\frac{3\times10^{8}}{2\times28.5\times10^{9}\sqrt{1.9406}}=3.778\text{mm}$$

5) Step 5: The patch length extension is obtained from

$$\Delta L=\frac{0.412\times0.346(1.9406+0.3)(\frac{4.2274}{0.346}+0.264)}{(1.9406-0.258)(\frac{4.2274}{0.346}+0.8)}=0.182\text{mm}$$

6) *Step 6:* The patch length is found from

$$L=l_e-2\Delta L=3.414\text{mm}$$

7) *Step 7:* The length of the ground plane (L_g), and width of the ground plane is found from

$$L_g=L+6h=5.49\text{mm}$$

$$W_g=W+6h=6.3034\text{mm}$$

8) *Step 8:* The width of a microstrip transmission line feed is

$$W_f=\frac{7.48\times0.346}{e^{\frac{50\sqrt{2.1+1.41}}{87}}}=0.8817\text{mm}$$

9) *Step 9:* The feed length is found from

$$L_f=3h=1.038\text{mm}$$

Hence the Antenna length=5mm, height=0.4, width=6mm.

The HFSS model of designed antenna with Teflon substrate is shown in figure 42and the switch integrated antenna design with Teflon is shown in figure 43.

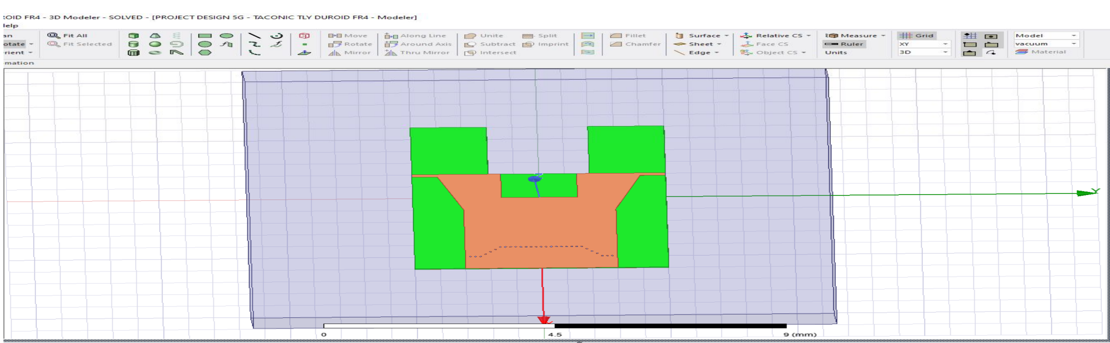


Figure 42: HFSS model of designed antenna with Teflon

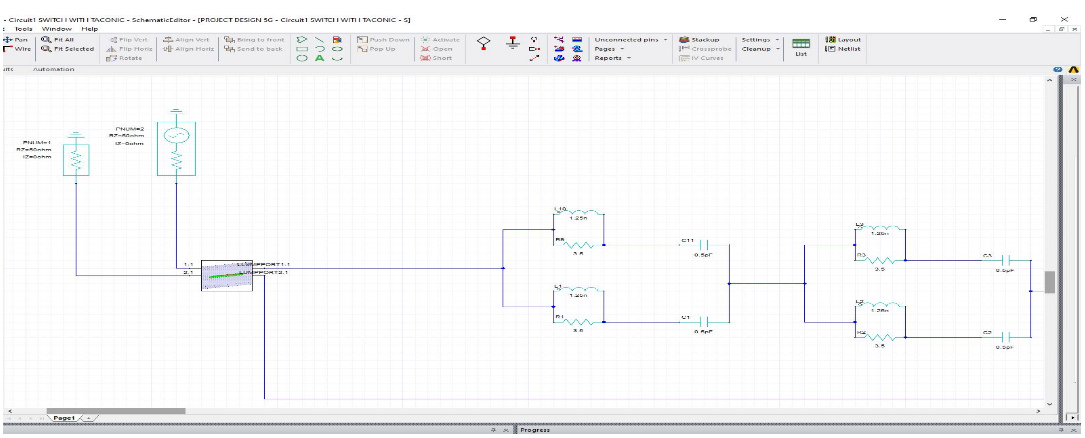


Figure 43: Switch integrated antenna design with Teflon

a) *Simulation of Antenna with Teflon:* The simulation of the designed antenna has been carried out and various antenna parameters like VSWR, Return loss, Gain, Radiation pattern and directivity was observed, examined and measured. Teflon with dielectric constant 2.1 when simulated on 33GHz frequency gives a return loss of -16.9685dB at 28.5GHz which is shown in figure 44. It has a voltage standing wave ratio of 1.551 at 28.5GHz as shown in figure 45, also it provides a gain of 3.68dB and a directivity of 2.08dB which is shown in figure 46 and 47 respectively. In the OFF condition of switch the simulation yielded a return loss of -9.0279dB which is shown on figure 48. The VSWR was found to be 1.5547 as shown in figure 49, also it provides a gain of 1.81dB and a directivity of 2.082dB as shown in figure 50 and 51 respectively.

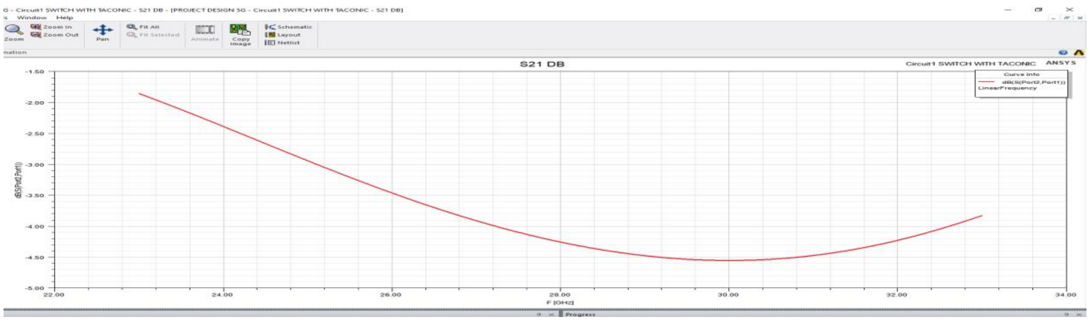


Figure 44: Return loss of designed antenna with Teflon in ON condition

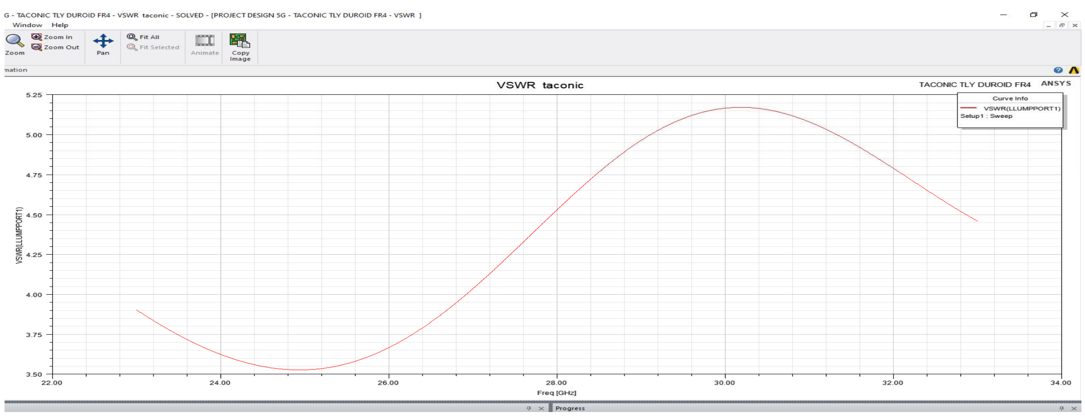


Figure 45: VSWR of designed antenna with Teflon in ON condition

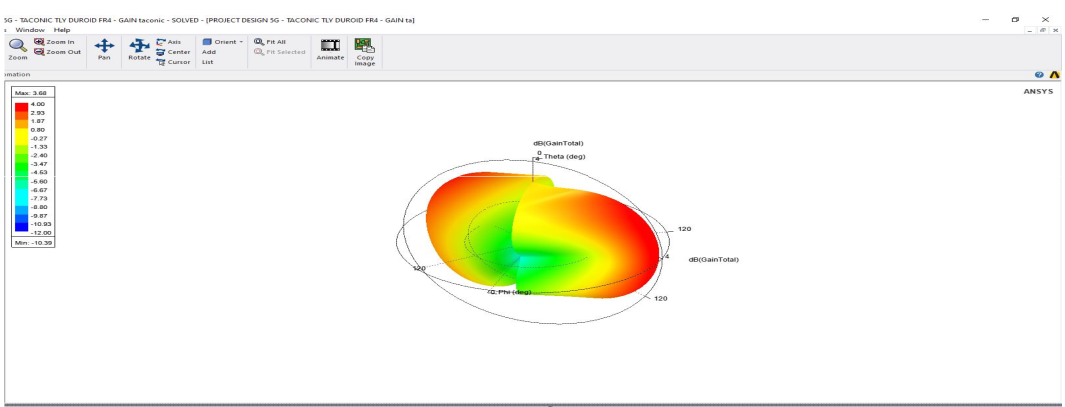


Figure 46: Gain of designed antenna with Teflon in ON condition

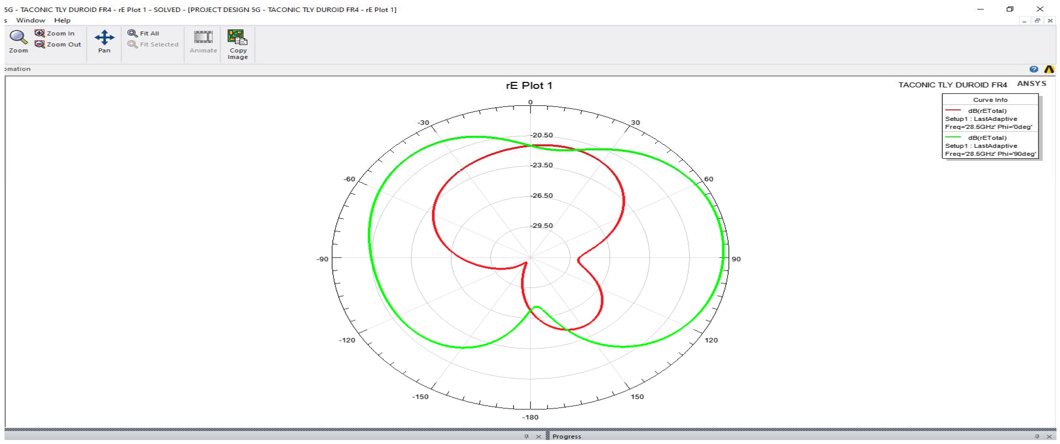


Figure 47: Radiation pattern of designed antenna with Teflon in ON condition

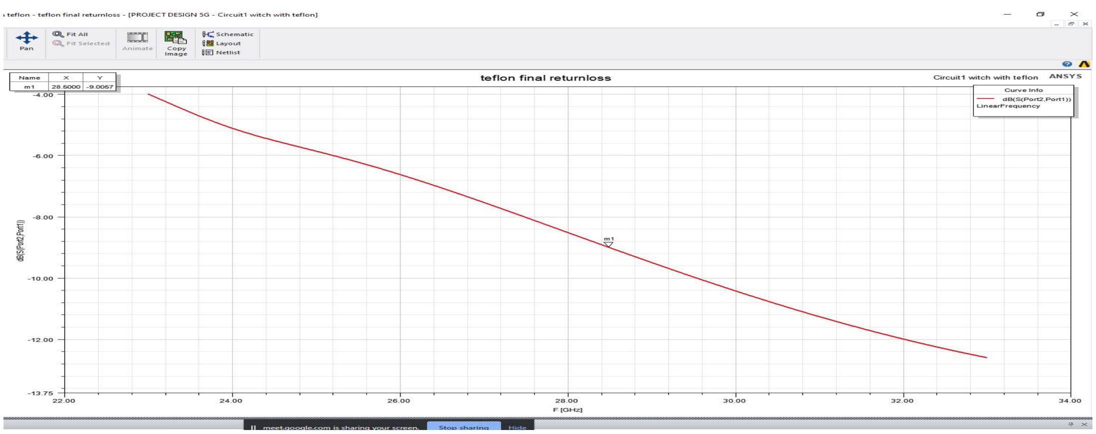


Figure 48: Return loss of designed antenna with Teflon in OFF condition

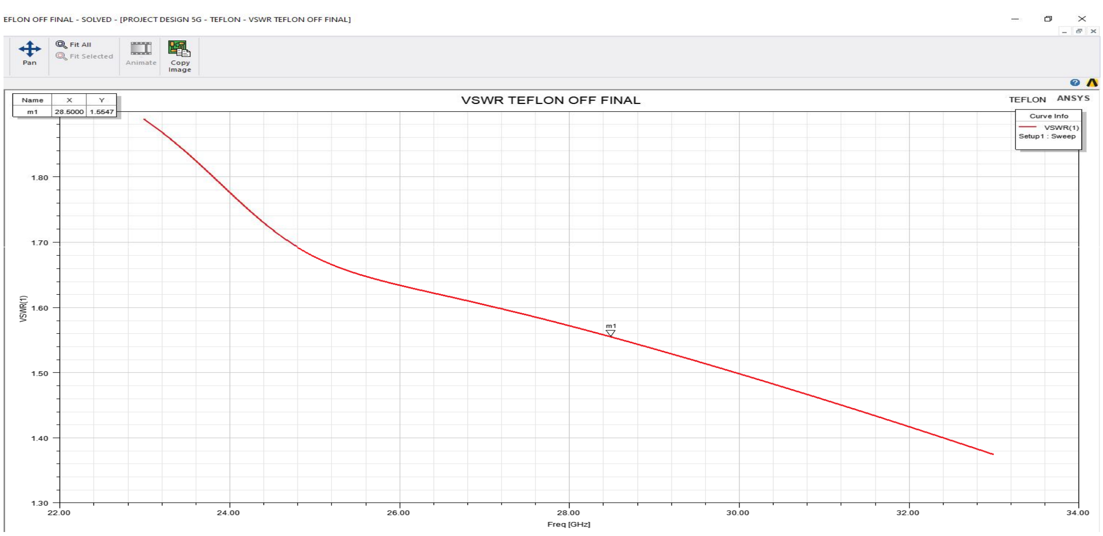


Figure 49: VSWR of designed antenna with Teflon in OFF condition

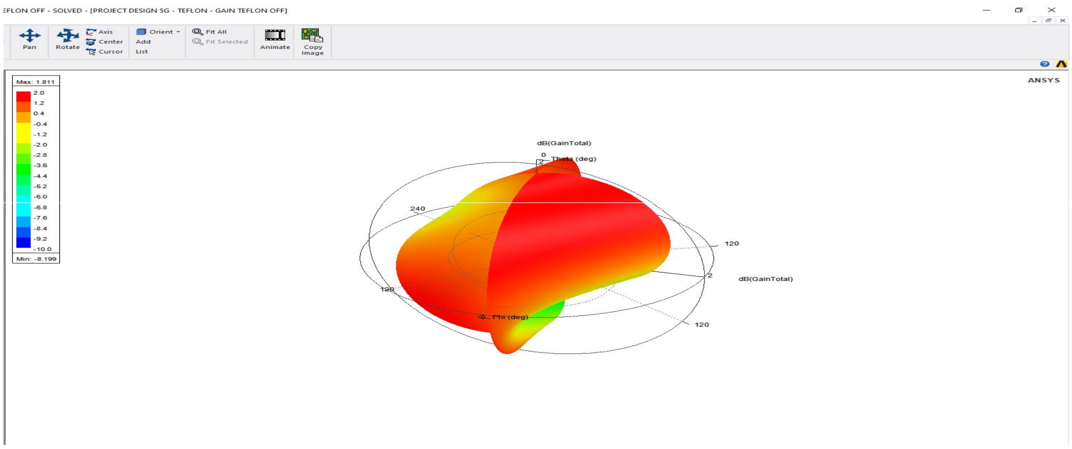


Figure 50: Gain of designed antenna with Teflon in OFF condition

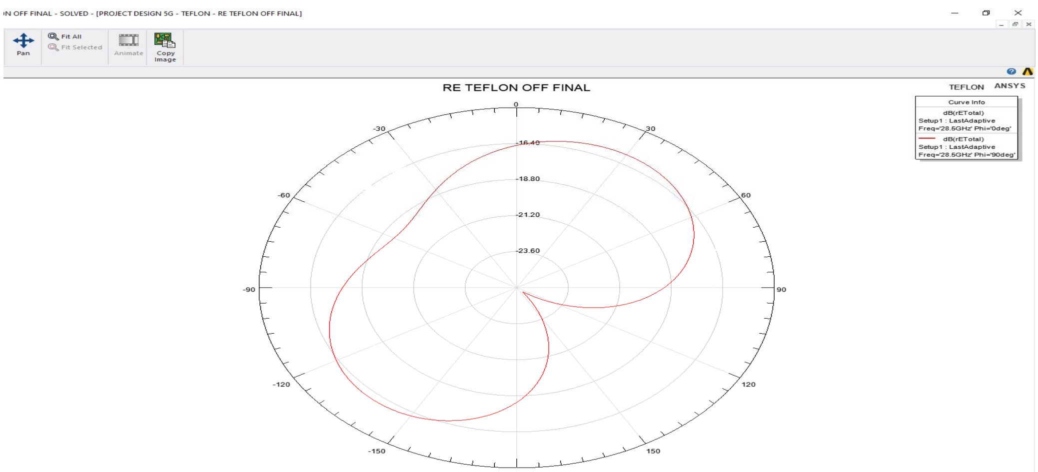


Figure 51: Radiation pattern of designed antenna with Teflon in OFF condition

F. Designed Antenna With Substrate Rogers Rt/ Duriod 5880 With Conducting Sheet Switches

From the above five comparison Rogers RT/duroid 5880 was found to be the best. To further improve the results and to reduce the losses varactor switches was replaced by conducting sheet switches. The HFSS model of designed antenna with conducting sheet switches in Rogers RT/ duroid 5880 in ON condition is shown in figure 52 and the HFSS model of designed antenna in OFF condition is shown in figure 53.

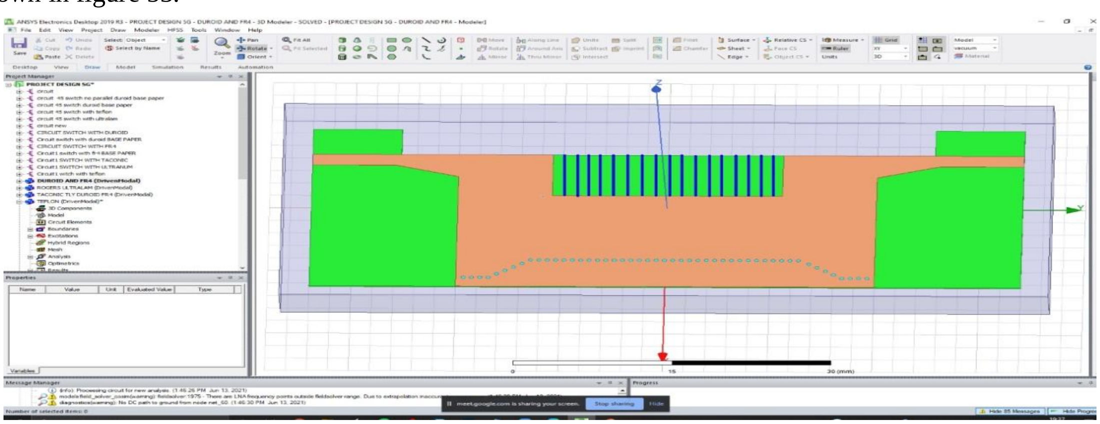


Figure 52: HFSS model of Rogers RT/duroid 5880 with conducting sheet switches in ON condition

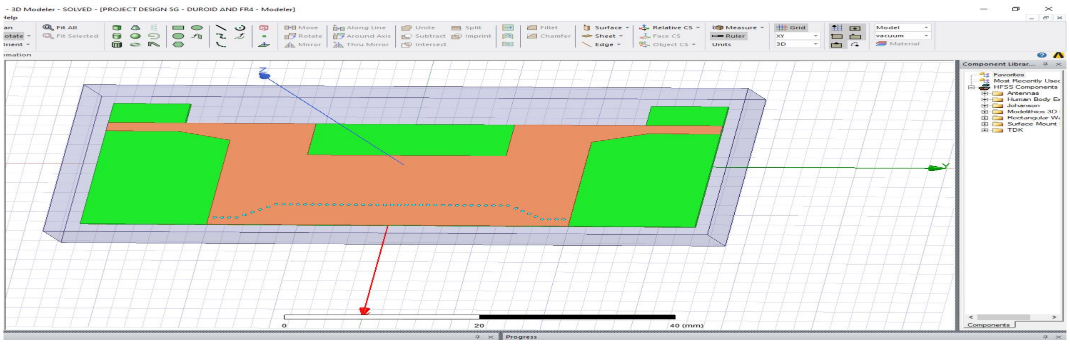


Figure 53: HFSS model of Rogers RT/duroid 5880 with conducting sheet switches in OFF condition

1) *Simulation Of Antenna With Rogers Rt/Duroid 5880 With Conducting Sheet Switches:* The simulation was carried out and S11 was found to be -24.5026dB as shown in figure 54, S21 was found to be -7.24dB which is shown in figure 55 and gain was found to be 5.1dB as shown in 56 in the ON condition of the conducting switch whereas in the OFF condition S11 was found to be -12.6608dB as shown in figure 57, S21 was found to be -10.9262dB which is shown in figure 58 and gain was found to be 3.8dB as shown in figure 59, which was found better than the observed results with varactor switches.

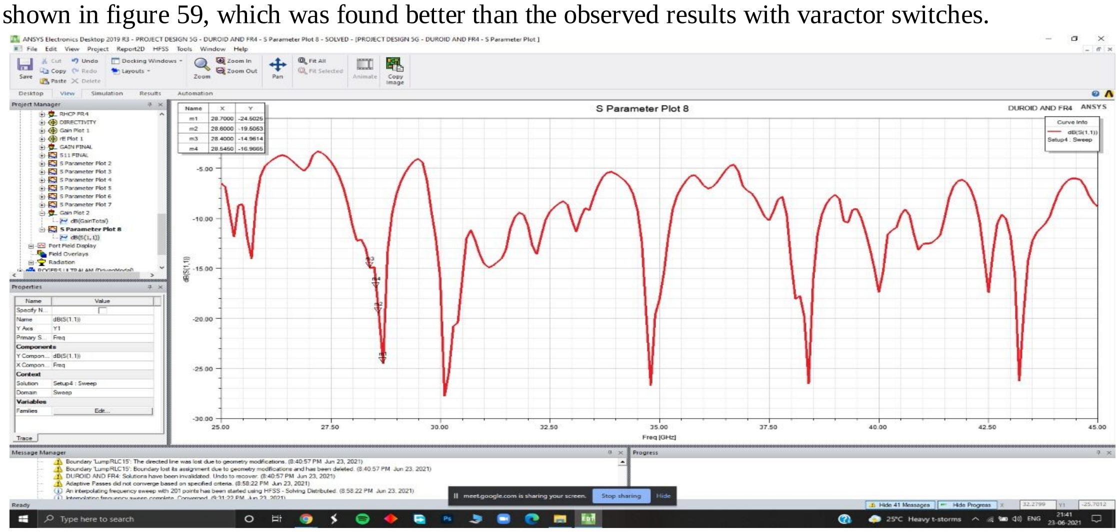


Figure 54: S11 of Rogers RT/duroid 5880 with conducting sheet switches in ON condition

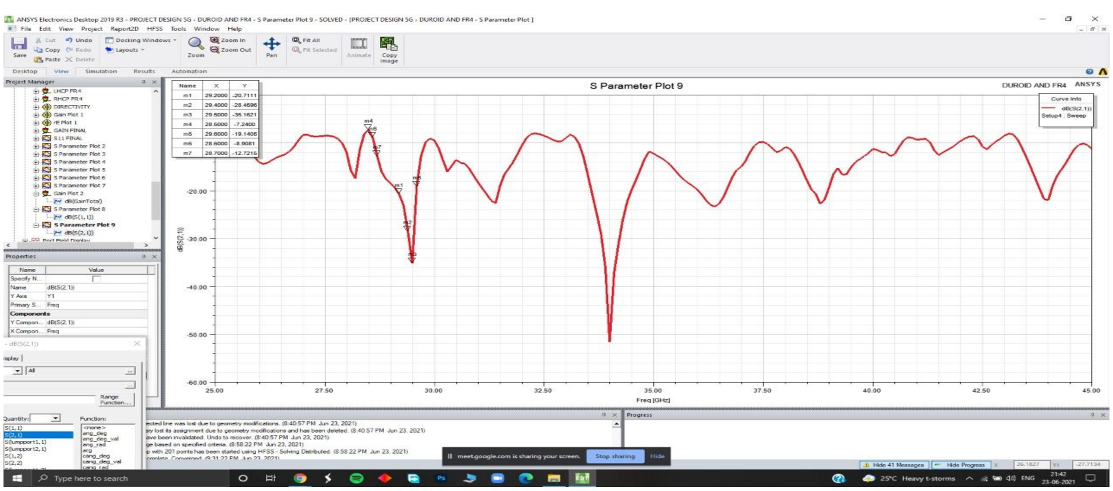


Figure 55: S21 of Rogers RT/duroid 5880 with conducting sheet switches in ON condition

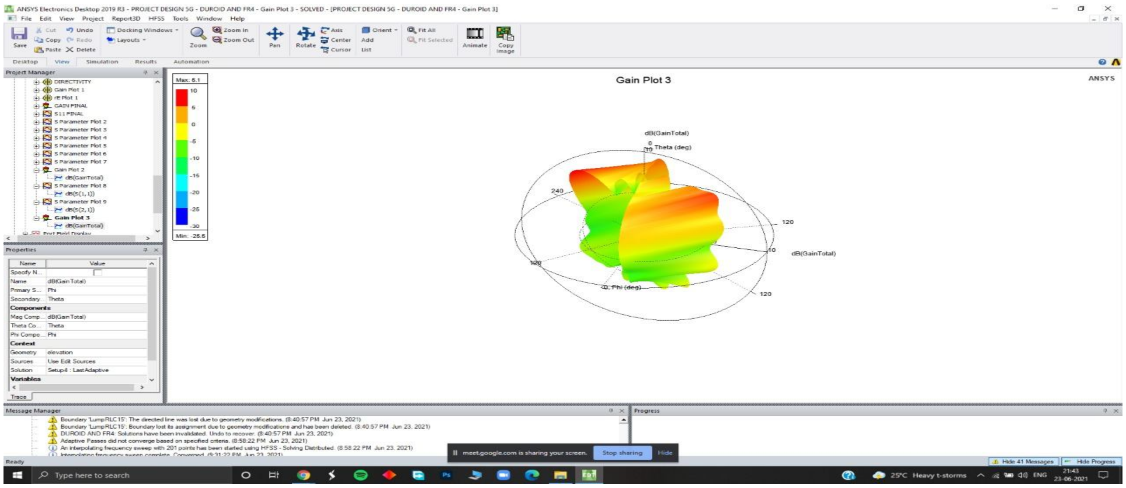


Figure 56: Gain of Rogers RT/duroid 5880 with conducting sheet switches in ON condition

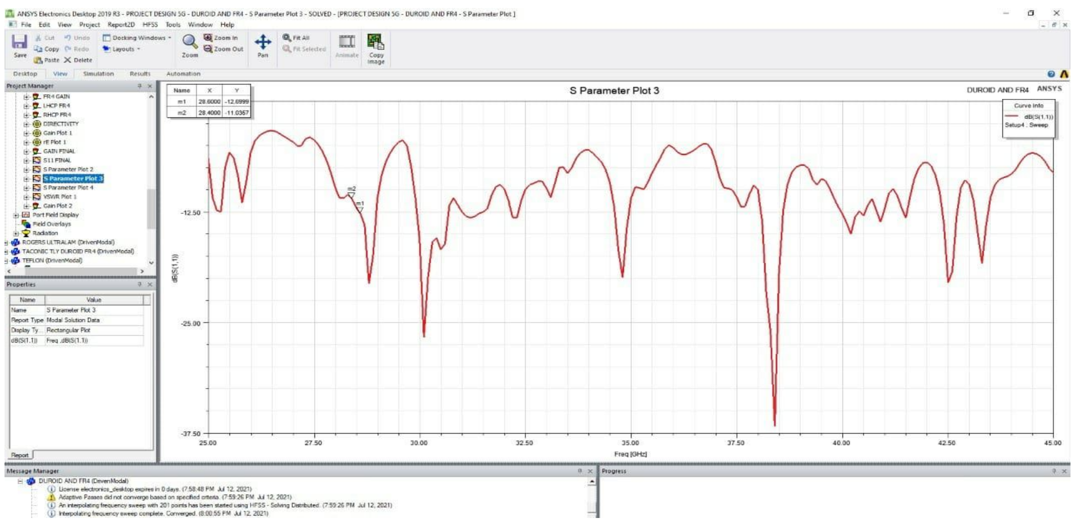


Figure 57: S11 of Rogers RT/duroid 5880 with conducting sheet switches in OFF condition

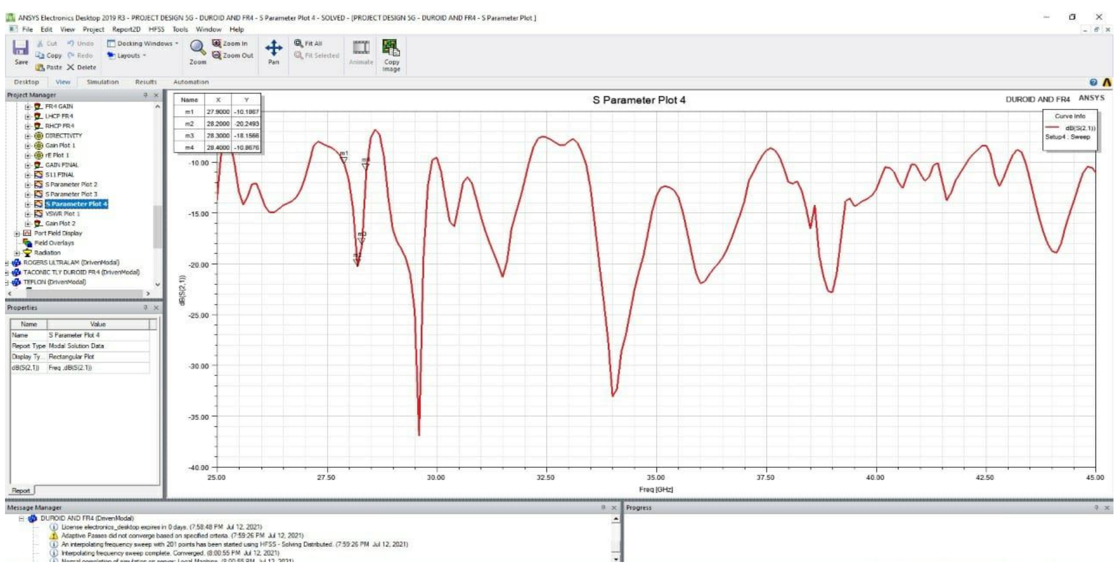


Figure 58: S21 of Rogers RT/duroid 5880 with conducting sheet switches in OFF condition

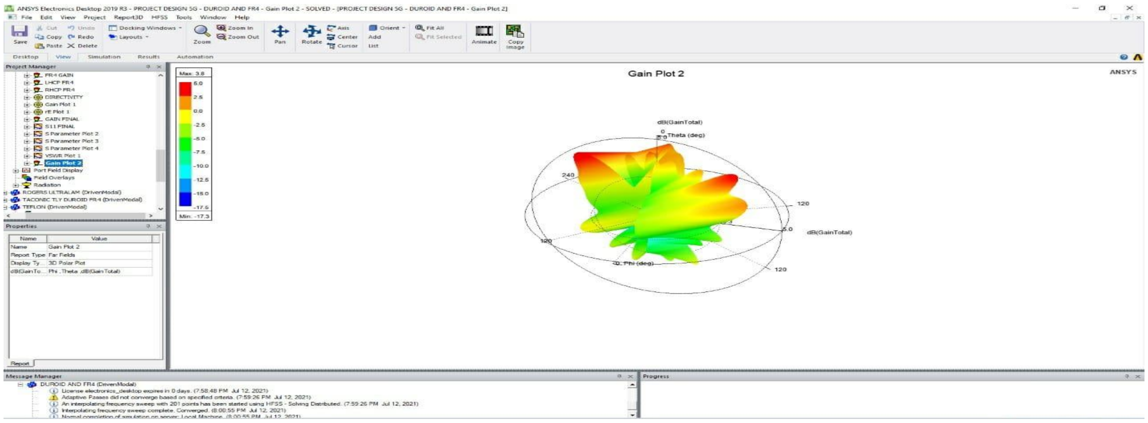


Figure 59: Gain of Rogers RT/duroid 5880 with conducting sheet switches in OFF condition

IX. SIMULATION COMPARISON AND ANALYSIS OF RESULTS

The antenna designed with five different substrates namely Rogers RT/duroid 5880, FR4, Rogers Ultralam 1217, Taconic TLY and Teflon which are used for the fabrication of antenna have been studied in detail. In the ON condition of switch the antenna designed with Rogers RT/duroid has the highest gain of 4.6dB and also a high directivity of 4.31dB compared to the other substrates. The VSWR of RT Duroid is 1.4165 for the same resonant frequency and the return loss is -15.2719dB. The FR4 substrate shows a return loss of -22.1016dB and voltage standing wave ratio of 1.1704 at 28.5GHz frequency. The gain of 5G reconfigurable antenna designed with FR4 shows a low gain of 1.7dB and a directivity of 4.1dB. The third antenna designed with substrate shows a return loss of -26.0118dB and VSWR of 2.2981 at the designed frequency. It shows a gain of 2.9dB and directivity of 4.1dB. The Taconic TLY substrate designed antenna has a return loss of -9.8057dB and standing ratio of 4.7660. This antenna shows a gain of 1.81dB and a directivity of 4.01dB. The antenna designed with the fifth substrate Teflon shows a return loss of -16.9685dB and VSWR of 1.551. It provides a gain of 3.68dB and directivity of 2.08dB. In the OFF condition of switch the antenna designed with Rogers RT/duroid has the highest gain of 3.4dB and also a high directivity of 3.7dB compared to the other substrates. The VSWR of RT Duroid is 1.6893 for the same resonant frequency and the return loss is -13.0779dB. The FR4 substrate shows a return loss of -12.788dB and voltage standing wave ratio of 5.4668 at 28.5GHz frequency. The gain of 5G reconfigurable antenna designed with FR4 shows a low gain of 1.1dB and a directivity of 3.6dB. The third antenna designed with substrate shows a return loss of -10.5613dB and VSWR of 7.6409 at the designed frequency. It shows a gain of 2.6dB and directivity of 3.9dB. The Taconic TLY substrate designed antenna has a return loss of -13.0779dB and standing ratio of 2.0675. This antenna shows a gain of 3.4dB and a directivity of 3.7dB. The antenna designed with the fifth substrate Teflon shows a return loss of -9.0279dB and VSWR of 1.5547. It provides a gain of 1.81dB and directivity of 2.082dB. On comparing the results of all the five antennas in the ON and OFF condition of switch, the results are found to be best in case of Rogers RT/duroid 5880. Further we also changed the switches of Rogers RT/duroid 5880 and replaced it by conducting sheet switches for reduction of loss and were able to achieve improved results which contributed to the novelty of our project [22]-[23]. The table 1 shows the values for different parameters for all the substrates considered indicating the performance analysis of the substrates in the ON condition of switch and the table 2 shows the values for different parameters for all the substrates considered indicating the performance analysis of the substrates in the OFF condition of switch. The improved results of Rogers RT/duroid 5880 are shown in table 3.

Table 1: Comparison of results of all five antennas in ON condition of varactor switch

Parameters	Rogers RT/duroid 5880	FR4	Rogers Ultralam 1217	Taconic TLY	Teflon
ε_r	2.2	2.2	2.17	2.2	2.1
$\tan\delta$	0.0004	0.0027	0.0009	0.0009	0.0001
Frequency	28.5GHz	28.5GHz	28.5GHz	28.5GHz	28.5GHz
Return loss	-15.2719dB	-22.1016dB	-26.0118dB	-9.8057dB	-16.9685dB
VSWR	1.4165	1.1704	2.2981	4.7660	1.551
Gain	4.6dB	1.1dB	2.9dB	1.81dB	3.68dB
Directivity	4.31dB	4.1dB	4dB	4.01dB	2.08dB

Table 2: Comparison of results of all five antennas in OFF condition of varactor switch

Parameters	Rogers RT/duroid 5880	FR4	Rogers Ultralam 1217	Taconic TLY	Teflon
ε_r	2.2	2.2	2.17	2.2	2.1
$\tan\delta$	0.0004	0.0027	0.0009	0.0009	0.0001
Frequency	28.5GHz	28.5GHz	28.5GHz	28.5GHz	28.5GHz
Return loss	-13.0779dB	-12.788dB	-10.5613dB	-13.0779dB	-9.0279dB
VSWR	1.6893	5.4668	7.6409	2.0675	1.5547
Gain	3.4dB	1.1dB	2.6dB	3.4dB	1.81dB
Directivity	3.7dB	3.6dB	3.9dB	3.7dB	2.082dB

Table 3: Improved values of Rogers RT/duroid 5880 with conducting sheet switches in ON and OFF condition

Substrate	Parameters	Obtained Value using Varactor switches	Obtained value using Conducting sheet switches
Rogers RT /duroid 5880 (ON Condition)	S11	-20.9dB	-24.5026dB
	S21	-5dB	-7.24dB
	Gain	-6dB	5.1dB
Rogers RT /duroid 5880 (OFF Condition)	S11	-10.2dB	-12.6608dB
	S21	-5.4dB	-10.9262dB
	Gain	4dB	3.8dB

X. APPLICATIONA AND FUTURE SCOPE

5G technology is causing great recognition in the research community. ITU and FCC has recently allocated 5G bands which generated a great deal of engrossed activities in the research community to enable appropriate technologies for these allocated millimeter-wave frequency bands. The main objectives of 5G wireless systems is to provide high data rates in urban areas, cover vast number of wireless devices, and reduce the power consumption. 5G wireless systems should have wider bandwidth as compared to current 4G networks in order to cover more device and transfer data faster. On increasing the operating frequency the losses incurred are higher which is a result of diffraction, penetration, and propagation. However, if the gain and beam steering capability of the antenna is increased, the path loss can be compensated. This is where reconfigurable high gain antenna can play a major role. Hence, LWA which are high gain beam-steerable antennas becomes crucial for efficient communications in 5G networks. Hence using reconfigurable antenna in the 5G communication networks is more attractive than ever [1]-[7].

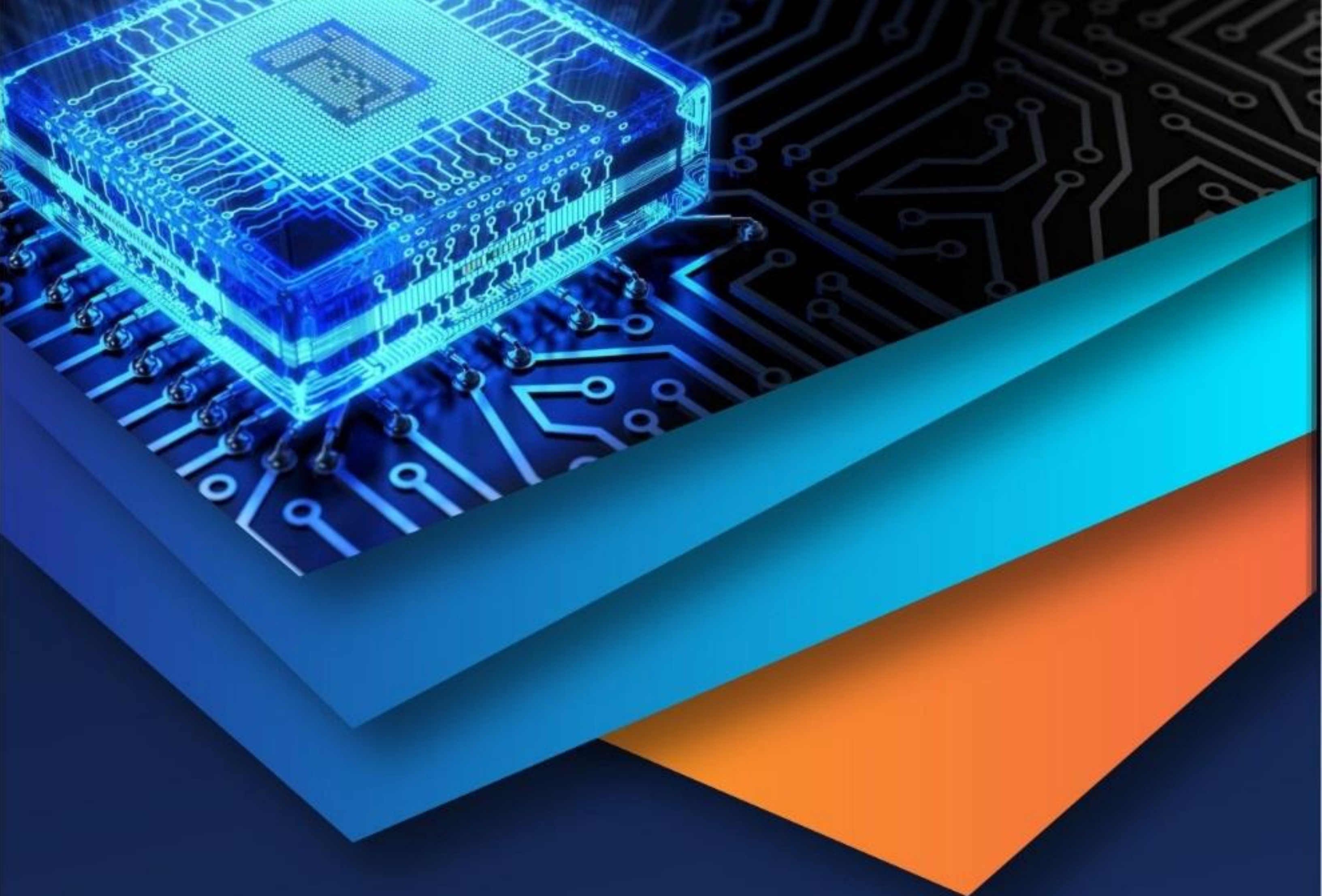
The designed antenna has a limited bandwidth which can be increased by increasing the antenna dimensions. Being part of an era in which usage of cellular device is at its zenith there is also an increased exposure of humans to harmful radiations which makes SAR a factor of major concern. Taking this concern into forefront importance to the study on Specific absorption rate in 5G should be given great focus in the future and to achieve a minimized SAR value in 5G wireless systems should be a major goal. The fabrication of this designed antenna can be done in future which will help us to see the antenna behaviour and measure the antenna parameters more practically.

XI. CONCLUSION

A reconfigurable leaky wave antenna based on HMSIW has been designed. Because of the need for high data speed, reliability and increased data carrying capacity, the conversion from 4G to 5G becomes highly relevant in the present world. In this paper a novel reconfigurable antenna was introduced for 5G application based on PCB technology. Due to its compactness, configurability and high gain the proposed antenna can be widely performed in 5G wireless systems. The suggested antenna provide the unique ability of 3D electronic scanning in real time at a fixed frequency which is achieved by introducing sets of switches in the structure. Five different substrates Rogers RT/duroid 5880, FR4, Rogers Ultralam 1217, Taconic TLC and Teflon, which are used for the fabrication of microstrip patch antenna, have been studied. The antenna with five substrates has been designed and the antenna parameters has been measured, compared and analyzed. Better results regarding the return loss, VSWR and gain of -15.2719dB, 1.4165 and 4.6dB in the ON condition and -13.0779dB, 1.6893 and 3.4dB gain is obtained for RT duroid substrate. When the varactor switches were replaced by conducting sheets the return loss, gain obtained was -24.5026dB, 5.1dB in the ON condition and -12.6608dB and 3.8dB in the OFF condition which gave the best result

REFERENCES

[1] Nima Javanbakth, Barry Syrett, Rony E. Amaya, "Miniaturized Reconfigurable Antenna Based on Half Mode Substrate Integrated Waveguide", 2019 IEEE.
[2] Nima Javanbakth, Barry Syrett, Rony E. Amaya, "Electronically Steerable Quasi-Uniform Leaky Wave Antenna Based on Substrate Integrated Waveguide", Canadian Conference of Electrical and Computer Engineering, 2019 Crwon.
[3] Harish Chandra Mohanta , Abbas Z. Kouzani , Sushanta K. Mandal," Reconfigurable Antennas and Their Applications," Universal Journal of Electrical and Electronic Engineering 6(4): 239-258, 2019.
[4] N. Trong, L. Hall, and Ch. Fumeaux, "Transmission-line model of nonuniform leaky-wave antennas," IEEE Trans. Antennas Propag., vol. 64, no.3, pp. 883-893, Mar. 2016.
[5] Wei Hong, Bing Liu, Yuanqing Wang, Qinghua Lai, Hongjun Tang, Xiao Xin Yin, Yuan Dan Dong, Yan Zhang, and Ke Wu, "Half Mode Substrate Integrated Waveguide: A new Guided Wave Structure for Microwave and Millimeter Application",2006 IEEE.
[6] Yaqiong Li and Mai Lu," Study on SAR Distribution of Electromagnetic Exposure of 5G Mobile Antenna in Human Brain", Journal of Applied Science and Engineering, Vol. 23, No 2, Page 279-287, Received: Oct. 20, 2019, Accepted: Jan. 13, 2020.
[7] Jihoon Bang and Jaehoon Choi,"A SAR Reduced MM-Wave Beam-Steerable Array Antenna with Dual-Mode Operation for Fully Metal-Covered 5G Cellular Handsets", DOI 10.1109/LAWP.2018.2836196, 2018 IEEE.
[8] W. Hong, K. Baek, and S. Ko, "Millimeter-wave 5G antennas for smartphones: overview and experimental demonstration," IEEE Trans. Antennas Propag., vol. 65, no. 12, pp. 6250-6261, Dec. 2017.
[9] Houda Werfelli, Khaoula Tayari, Mondher Chaoui, Mongi Lahiani, Hamadi Ghariani, "Design of Rectangular Microstrip Patch Antenna," in 2nd International Conference on Advanced Technologies for Signal and Image Processing - ATSIP'2016 March 21-24, 2016, Monastir, Tunisia.
[10] Ġsa ATAġ1 , Teymuraz ABBASOV2 , M. Bahattin KURT3, "Design And Analysis of Directive Microstrip Array Antenna," Advanced Research in Electrical & Electronics Systems Vol 1, Number 1, 2016.
[11] Akaninyene B. Obot1, Gabriel A. Igwue2 , Kufre M. Udofia, "Design and Simulation of Rectangular Microstrip Antenna Arrays for Improved Gain Performance," in International Journal of Networks and Communications 2019, 9(2): 73-81.
[12] N. Javanbakht, M. S. Majedi, and A. R. Attari, "Periodic leaky-wave antenna with transverse slots based on substrate integrated waveguide," 24th Iranian Conf. Elect. Eng., Shiraz, 2016, pp. 608- 612
[13] J. Liu, D.R. Jackson, Y. Li, C. Zhang, and Y. Long, "Investigation of SIW leaky wave antenna for endfire radiation with narrow beam and sidelobe suppression", IEEE Trans. Antennas Propag., vol. 62, no. 9, pp. 4489-4497, Sep. 2014.
[14] J. Xu, W. Hong, H. Tang, Z. Kuai, and K. Wu, "Half-mode substrate integrated waveguide (HMSIW) leaky-wave antenna for millimeterwave applications," IEEE Antenna Wireless Propag. Lett., vol. 7, pp. 85–88, 2008
[15] N. Javanbakht, B. Syrett, R. Amaya, "Leaky-wave antenna based on modified aperture half-mode substrate integrated waveguide," IEEE Int. Symp. Antennas Propag. USNC-URSI Radio Science Meeting, Boston, 2018, to be published.
[16] N. Javanbakht, B. Syrett, R. Amaya, and J. Shaker, "Low temperature co-fired ceramic half-mode substrate integrated waveguide leakywave antenna," IEEE Int. Symp. Antenna Tech. Applied Electromagnetics, Waterloo, 2018, to be published.
[17] Y. J. Cheng, W. Hong, K. Wu, and Y. Fan, "Millimeter-wave substrate integrated waveguide long slot leaky-wave antennas and two-dimensional multibeam applications," IEEE Trans. Antennas Propag., vol. 59, no. 1, pp. 40-47, Jan. 2011.
[18] Y. Mohtashami and J. Rashed-Mohassel, "A butterfly substrate integrated waveguide leaky-wave antenna," IEEE Trans. Antennas Propag., vol. 62, no.6, pp. 3384-3388, Jun. 2014.
[19] S. A. Razavi, M. H. Nehsati, "Design investigation of a leaky-wave antenna using HMSIW technique," 6th Int. Symp. Telecommunications, Tehran, 2012, pp. 29-32.
[20] N. Trong, Th. Kaufmann, and Ch. Fumeaux, "A Semi-analytical solution for a tapered half-mode substrate integrated waveguide with application to rapid antenna optimization," IEEE Trans. Antennas Propag., vol. 62, no. 6, pp. 3189-3200, Jun. 2014.
[21] Z. Miao, et al., "140 GHz High-gain LTCC integrated transmit-array antenna using a wideband SIW aperture coupling phase delay structure," IEEE Trans. Antennas Propag., vol. 66, no. 1, pp. 182- 190, Jan. 2018.
[22] M. Karthigai Pandian* and T. Chinnadurai, "Design and Optimization of Rectangular Patch Antenna Based on FR4, Teflon and Ceramic Substrates," in Recent Advances in Electrical & Electronic Engineering, 2019, 12, 00-00.
[23] Anzar Khan and Rajesh Nema, "Analysis of Five Different Dielectric Substrates on Microstrip Patch Antenna," in the International Journal of Computer Applications (0975 – 8887) Volume 55– No.18, October 2012.



10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

SJIFactor Scientific Journal Impact Factor TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY