Dual-pol microstrip patch antenna

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Abstract:

A dual Polarized Patch antenna edge-feeding with stable radiation pattern cantered @ 17Ghz with total Bandwidth of 10%, XPD of -26dB can be enhanced to -30dB, With isolation between the two ports of -26dB.

Introduction:

The capacity and variety of wireless communication channels can be significantly increased by installing dual-polarized antennas at the transmitter and/or receiver, as recent findings in communication theory [1] have shown. Using dual-polarized transmit and receive antennas can increase capacity threefold over a comparable system with single antennas at the transmitter and receiver. For instance, in the richly scattering environments considered in [1], a dual-polarized transmitter antenna can increase capacity by more than 50% over a single transmit antenna.

Also, in radar systems Dual polarization can achieve improvements such:

Enhanced Target Discrimination: Dual polarization facilitates the differentiation of various target kinds. Radar systems can improve the capacity to distinguish between different objects by providing further details on the size, shape, and composition of the targets through the transmission and reception of signals in both horizontal and vertical polarizations.

Problem definition:

For achieving a dual polarized patch antenna , it's required to have two orthogonal ports to feed the patch but to achieve this it is also required to have a square patch to have the same characteristics and specifications in both ports otherwise the width and length of the patch in aspect of each port would be reversed so the radiation characteristics will differ , another challenging design parameter is to achieve the highest XPD without affecting other parameters such as scattering parameters , input impedance and also the gain of the antenna , the feeding lines are also challenging that a 50ohm microstrip lines' width is about 3mm whereas the width of the patch is about 3.5 mm so this was not physically or in terms of matching applicable to have achieve matching between ports and the antenna and having input impedance of 50ohm in a relatively wideband with minimum imaginary part to be in resonance mode which is preferable for the antenna to be radiative in as it has pure real impedance, It is also required to achieve high isolation between the two ports to increase the XPD.

Design Procedure

Design Procedure

We started with initial design of a single polarized patch antenna radiating at 17Ghz, we calculated the dimensions of the patch using patch antenna calculator on internet that estimated W = 5.37 mm, L=3.37mm

But the patch is required to be square as illustrated in the problem definition section that each port will see the reversed dimensions of the other ..so we changed the Width of the patch to be equal to the length and we didn't change the length cause we found that the length of the patch corresponds to the frequency of radiation while the width of the patch corresponds to the matching (determines the S parameters values at certain frequency) so in the design W =3.155mm , L=3.155 mm.

We obtained these values through a parametric sweep that achieves best results , the matching is done by lambda/4 section of W=0.65mm the input impedance seen from the ports is almost 50ohm as intended , the isolation between the ports is achieved by widening the feeding lines , but this affects the value of XPD which found that it depends on the width of the feeding lines and contribute in the radiation so we choose to decrease the radiation of the transmission lines by decreasing its width to eliminate the fringing field out of transmission lines , but changing the width of the transmission line will change its impedance and the matching will be affected so we solve this problem by changing the thickness of the substrate instead of lambda/4 we found in many papers that we could make the substrate thickness to be lambda/10 so the new substrate thickness t=0.84mm , so we managed to decrease the width of the transmission line to be W=0.3mm and decreasing the substrate thickness also reduced the radiation of the feeding lines bur also affected other parameters of the antenna such the gain , bandwidth and the efficiency .

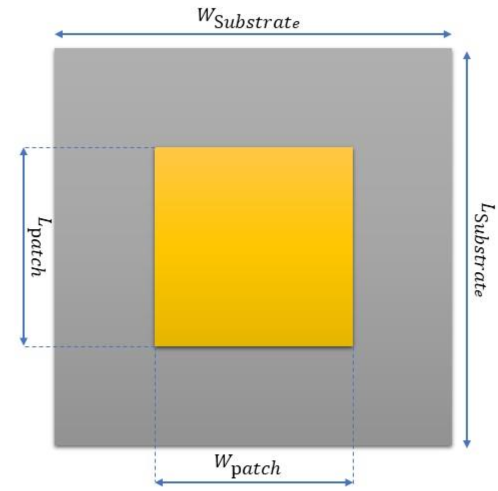

Figure 2 Antenna

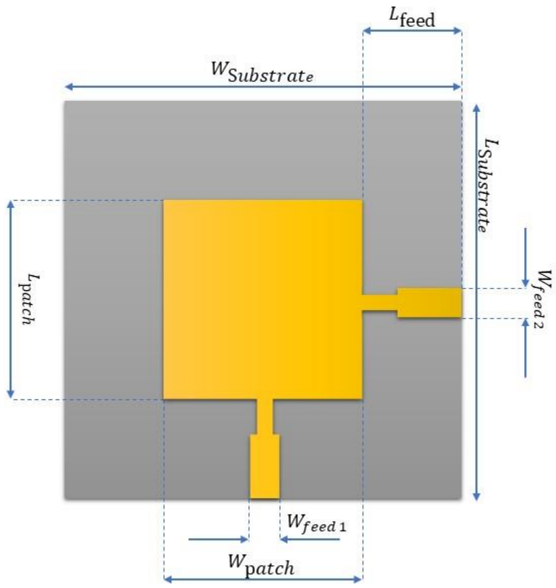

Figure 1 TOP view

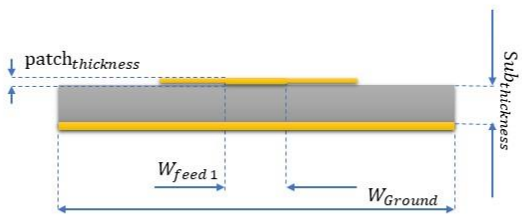

Figure 3 Front View

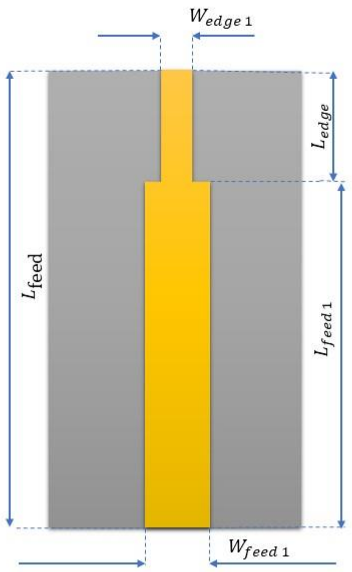

Figure 4 Feeding

Antenna Dimensions

Antenna Dimensions	
$\boldsymbol{W}_{\text{Substrate}}$	**8**
$L_{\text{Substrate}}$	**8**
$\boldsymbol{W}_{\text{patch}}$	**3.155**
$\boldsymbol{L}_{\text{patch}}$	**3.155**
$W_{\text{feed 1}}$	**0.65**
$L_{\boldsymbol{feed}}$	**2.4225**
$\boldsymbol{W}_{\boldsymbol{edge}\,\mathbf{1}}$	**0.3**
$\boldsymbol{L}_{\boldsymbol{edge}}$	**0.335**
$L_{\boldsymbol{feed}\,1}$	**2.0875**
$\text{patch}_{\boldsymbol{thickness}}$	**0.035**
$\text{Sub}_{\boldsymbol{thickness}}$	**1.6**
W_{Ground}	**8**

All dimensions in this table are in millimetres (mm).

Results & Discussion

Results

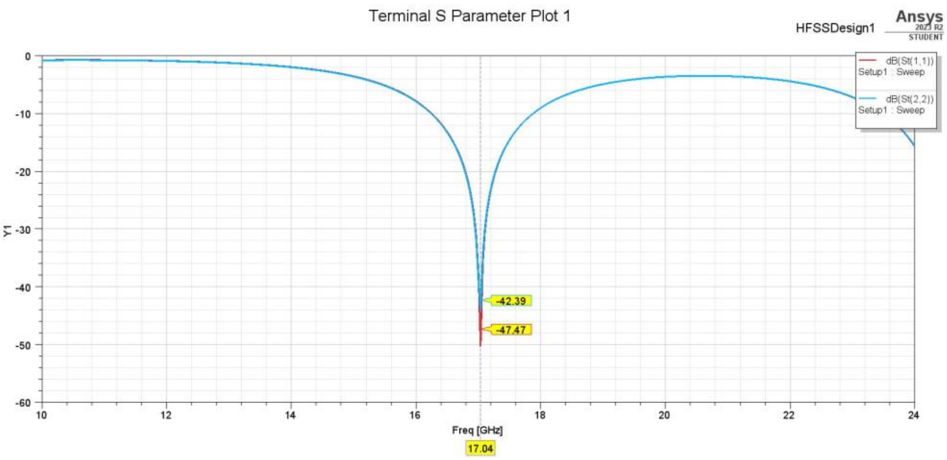

Figure 5 RETURN LOSS

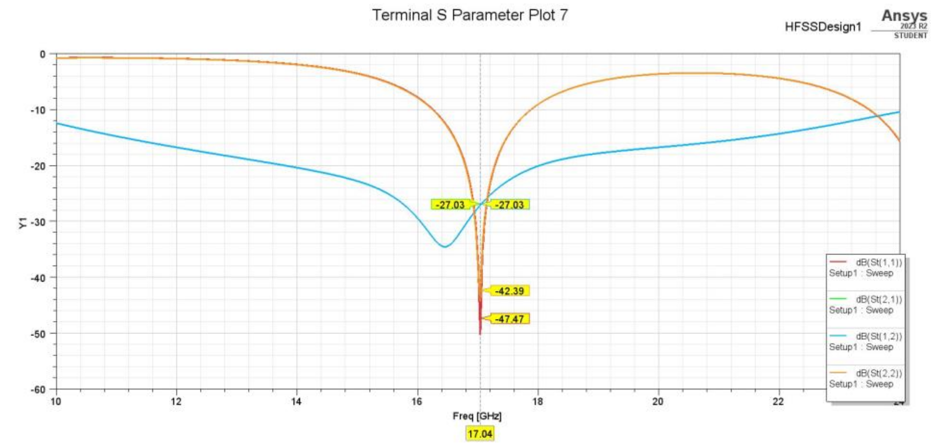

Figure 6 S PARAMETERS

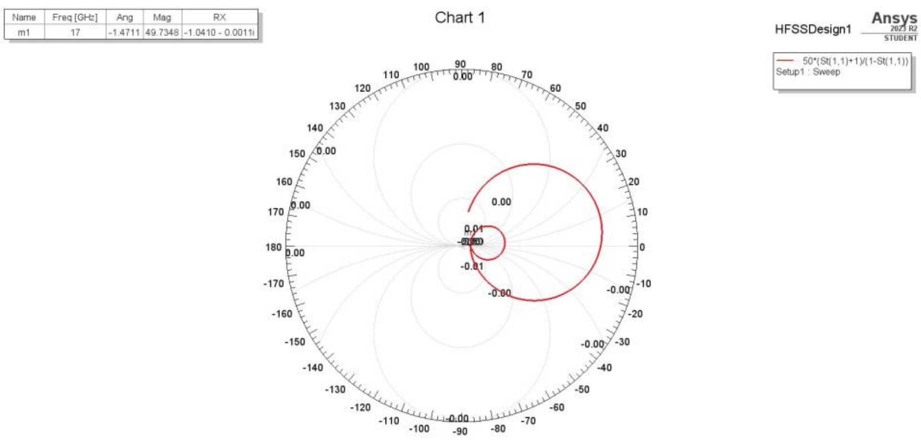

Figure 7 Input Impedance 1

Results & Discussion

Results

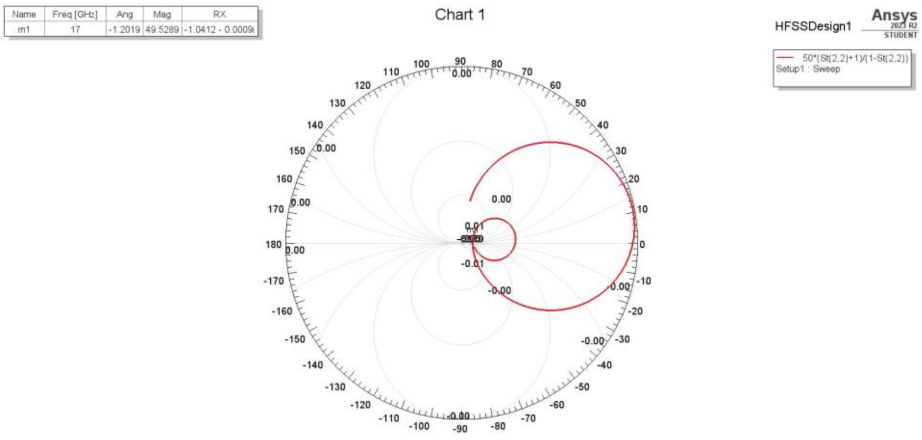

Figure 8 Input Impedance 2

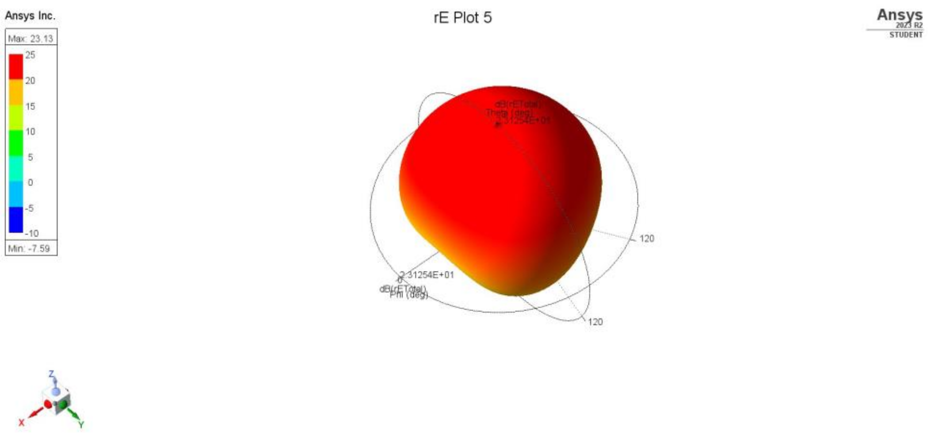

Figure 9 Radiation pattern of port 1

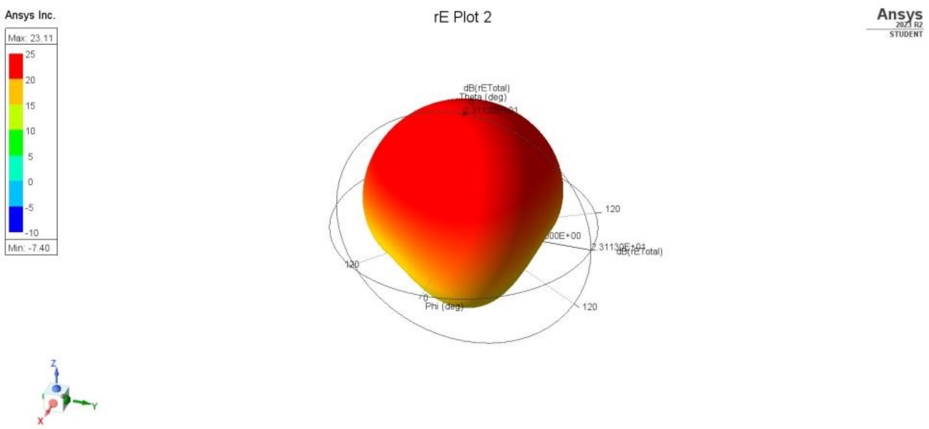

Figure 10 Radiation pattern of port 2

Results & Discussion

Results

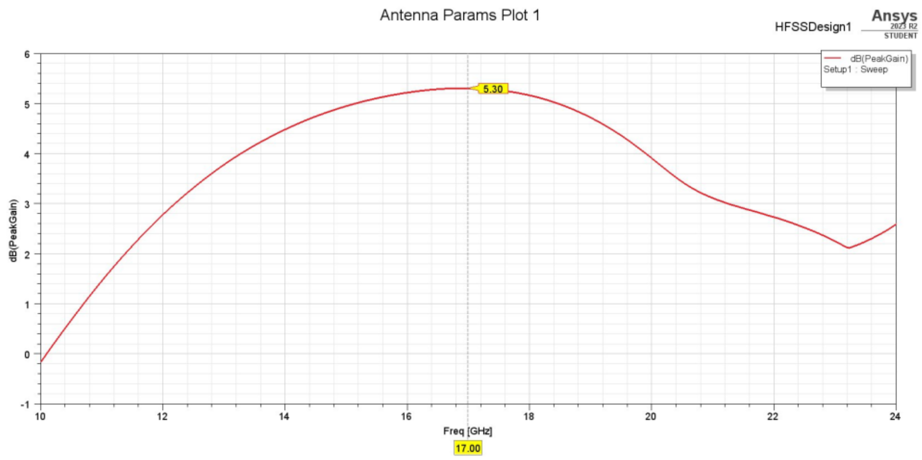

Figure 11 GAIN (dB) VS Frequency

Gain = 5.3

This gain is acceptable.

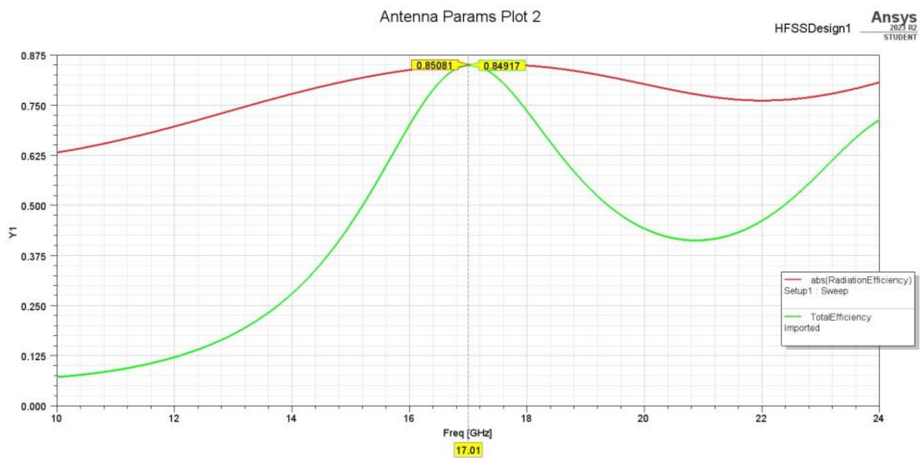

Figure 12 Radiation efficiency vs frequency

$$\textbf{Radiation efficiency} = 85\%$$

Results & Discussion

Results

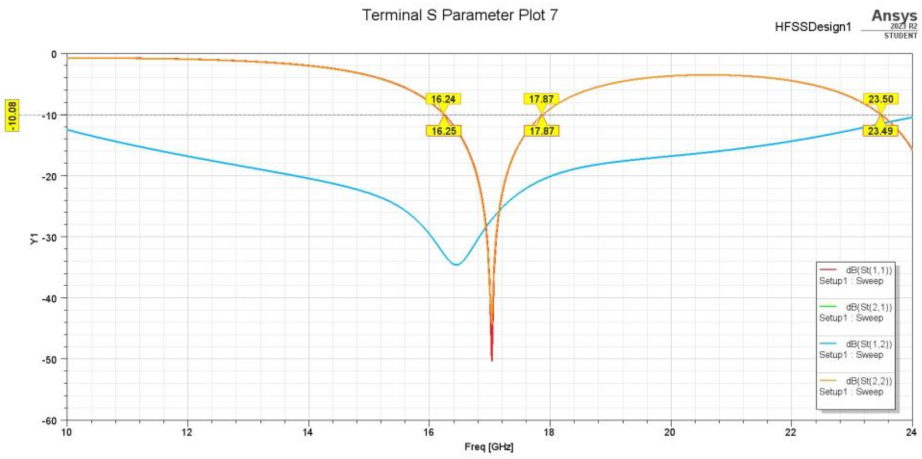

Figure 13 Bandwidth

$$\textbf{Bandwidth} = \frac{(17.87 - 16.24)}{17} = 10\%$$

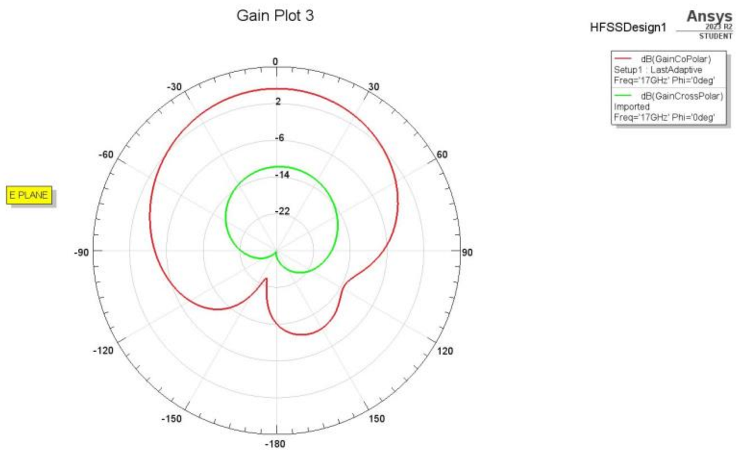

Figure 14 Co & Cross on E plane of port 1

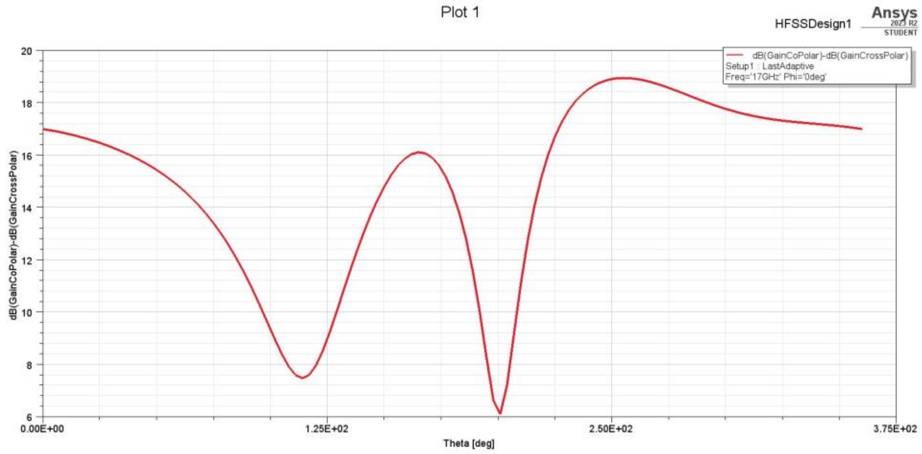

Figure 15 XPd on E plane (port 1)

Results & Discussion

Results

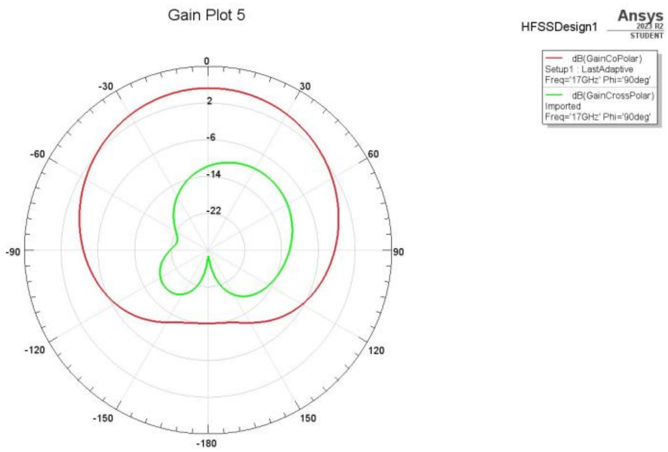

Figure 16 Co & Cross on H plane of port 1

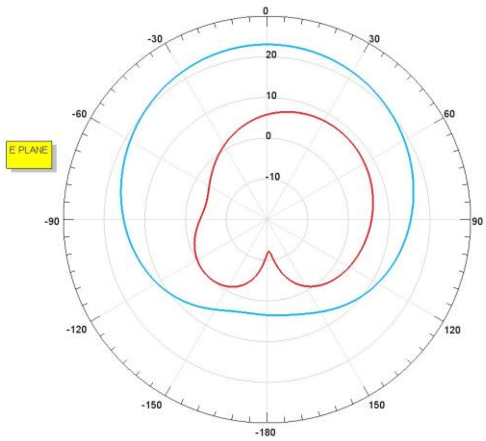

Figure 17 Co & Cross on E plane of port 2

Results & Discussion

Results

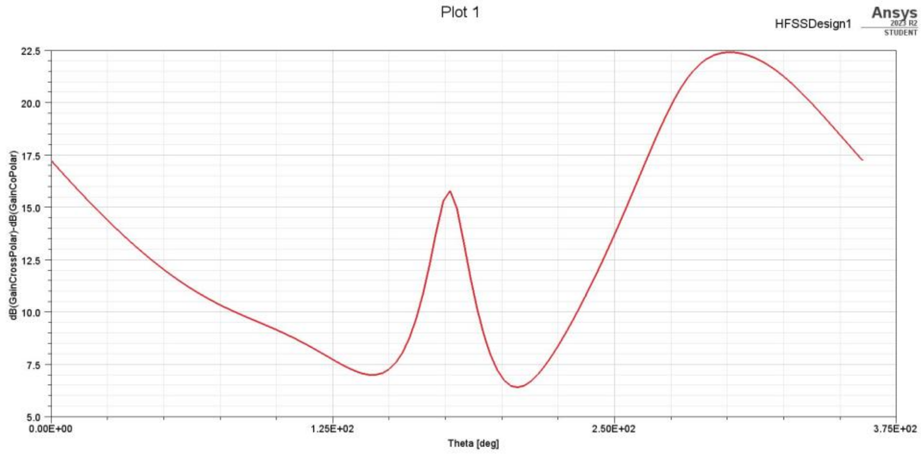

Figure 18 XPd on E plane (port 2)

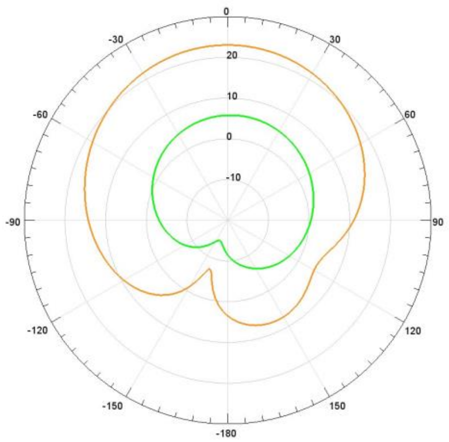

Figure 19 Co & Cross on H plane of port 2

Results & Discussion

Discussion

Figure 6: It Shows the scattering parameters S11 = -47dB that corresponds to the reflection coeficent of port 1 and the same for S22= -42dB but for port 2 at f = 17Ghz , which are very acceptable values , and S12= -27dB that corresponds to the interaction between ports , assigns how much power from port 1 transmitted to port 2 and S21 for reverse how much power transmitted from port2 to port1 .

Figure 7&8: Show the input impedance on smith chart, which is 49.7 ohm at 17Ghz for port 1, and 49.5 ohm for port 2 and these are very good values and close to 50 ohms.

Figure 9&10: Show the 3-D radiation pattern which is stable along frequency with maximum gain in the bore side (theta = 0) of 5.3 dB, the gain bandwidth is wide G>4dB [13Ghz:20Ghz]

Figure 12: shows the radiation efficiency along the frequency at 17 GHz the radiation efficiency = 85% which is a good percentage.

Figure 13: shows the Bandwidth of the S11 & S22 almost 10% which is relatively acceptable at this high frequency a bandwidth of 1.63GHz and it is the total Bandwidth as it is the smallest bandwidth of all other parameters

$$\mathbf{Bandwidth} = \frac{(\mathbf{17.87 - 16.24})}{\mathbf{17}} = \mathbf{10\%}$$

Figure 14:20 : Show the Co-polarization & Cross-polarization gain along theta , the electric field(10&11) and the magnetic field(12&13) that shows XPD (Cross Polarization Discrimination) which indicates the intended polarization to the orthogonal one which is 17dB for electric field and 17.5dB for magnetic field in Port 1 , and XPD of 17.5dB for both electric field and magnetic field for port 2 all calculated at bore side (theta = 0deg).

Results & Discussion

Results Adjusted XPD

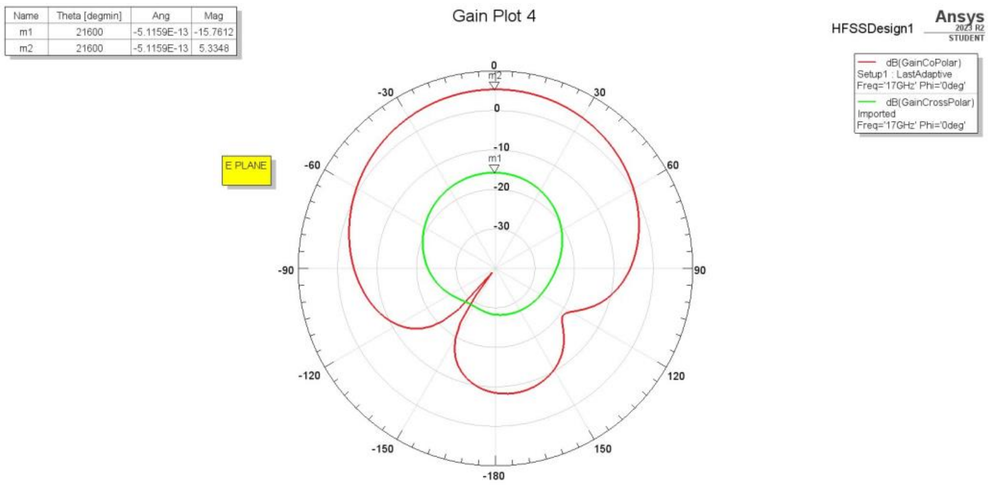

Figure 20 XPD of port 1 = 21dB

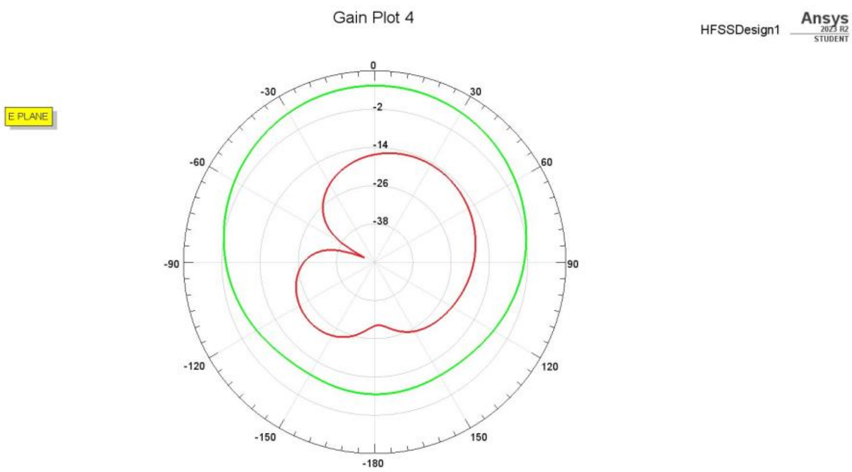

Figure 21 XPD of Port 2 =22.5dB

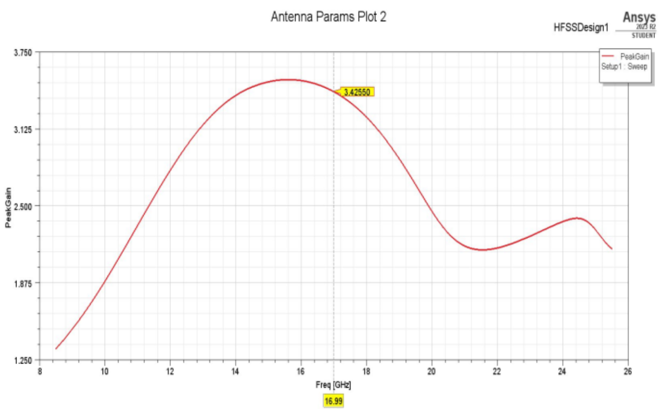

Figure 23 Gain of the second Design =3.4dB

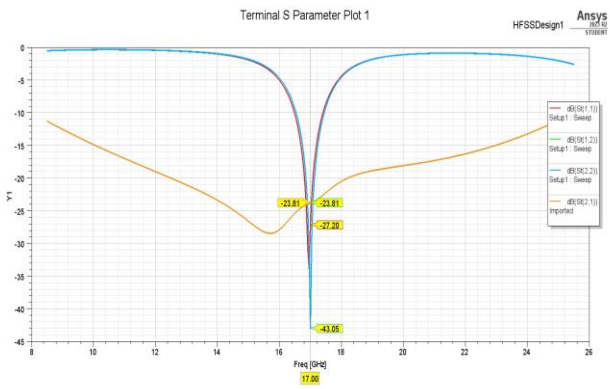

Figure 22 : S Parameters of design 2

Results & Discussion

Results Adjusted XPD

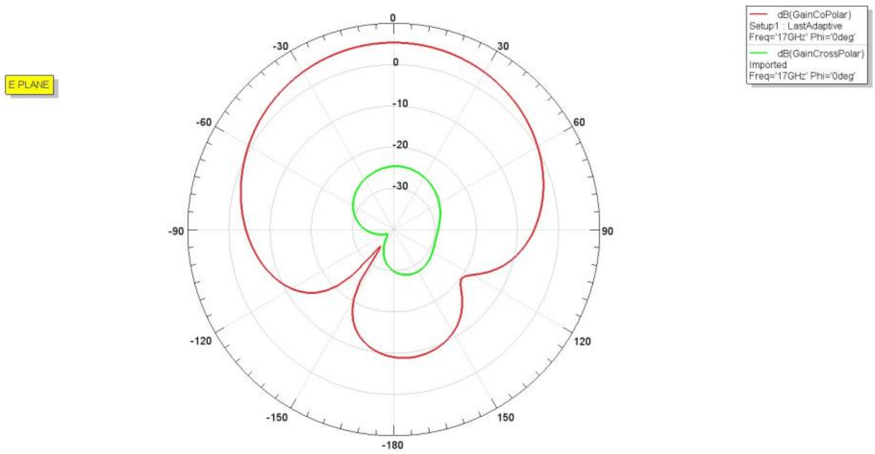

Figure 24 Co/Cross when exciting the two ports Simultaneously.

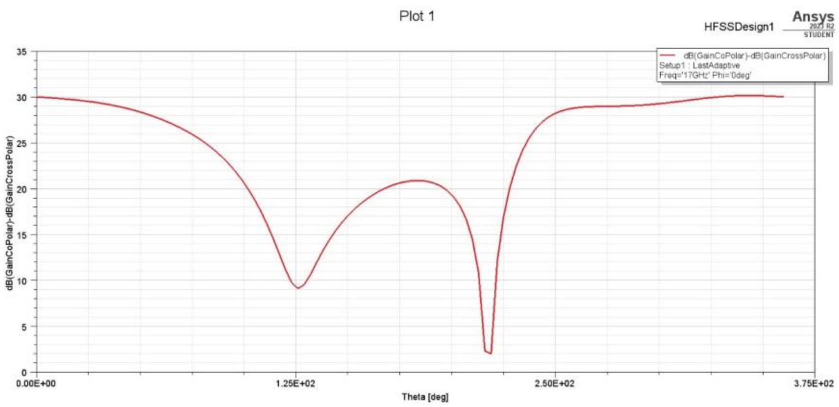

Figure 25 XPD = 30 in broad side when exciting the two ports simultaneously

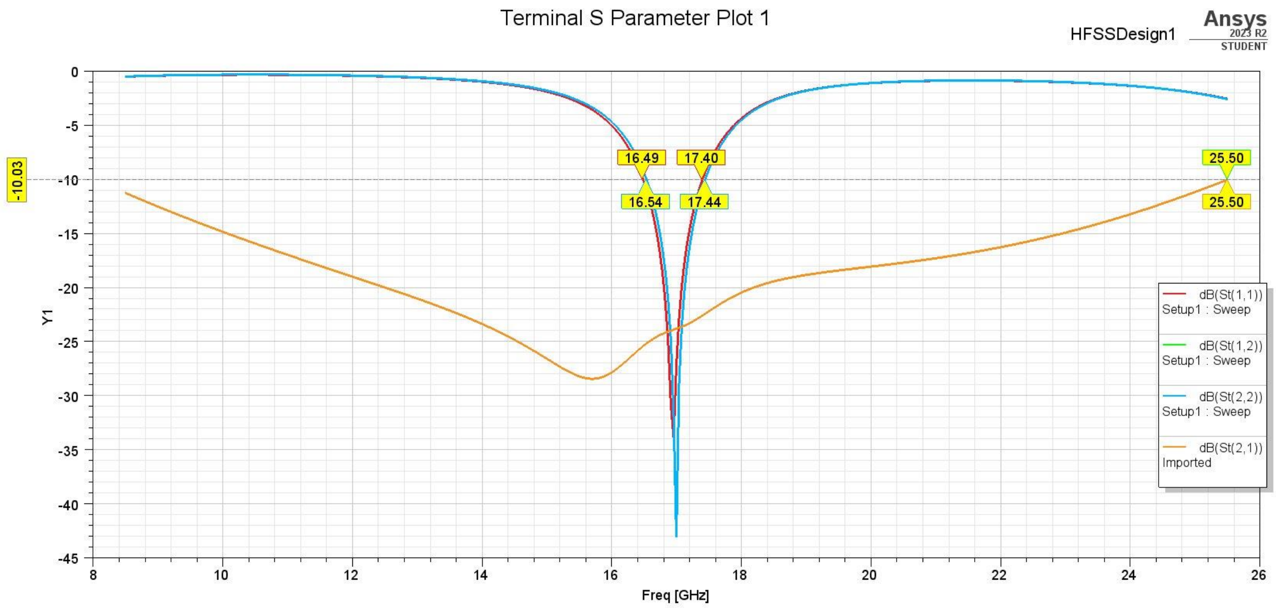

Figure 26 BW

Results & Discussion

Discussion Adjusted XPD

Adjusted XPD Design results

This Design results provide higher XPD as in fig(21:27) but less gain(fig 11), less Bandwidth, more deformed radiation pattern, less efficiency, less isolation and less S11, S22 due to reducing the thickness of the substrate and the Width of feeding lines when each port is excited separately.

When the two ports are excited simultaneously the characteristics improve and XPD get even higher to reach 30dB fig(25&26) and the other parameter also improved like(fig 27).

Adjusted XPD Design Layout

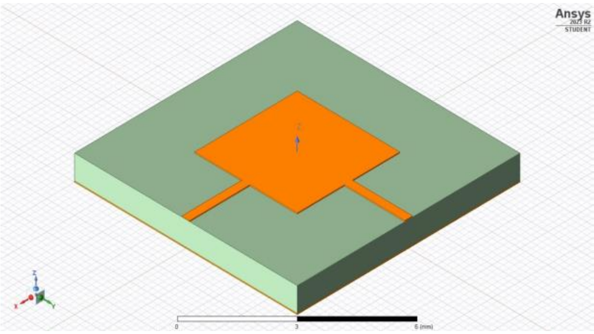

Figure 27 Adjusted XPD Design

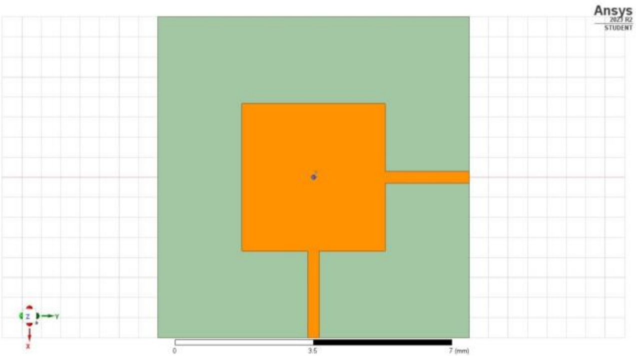

Figure 28 Top View

Circuit model

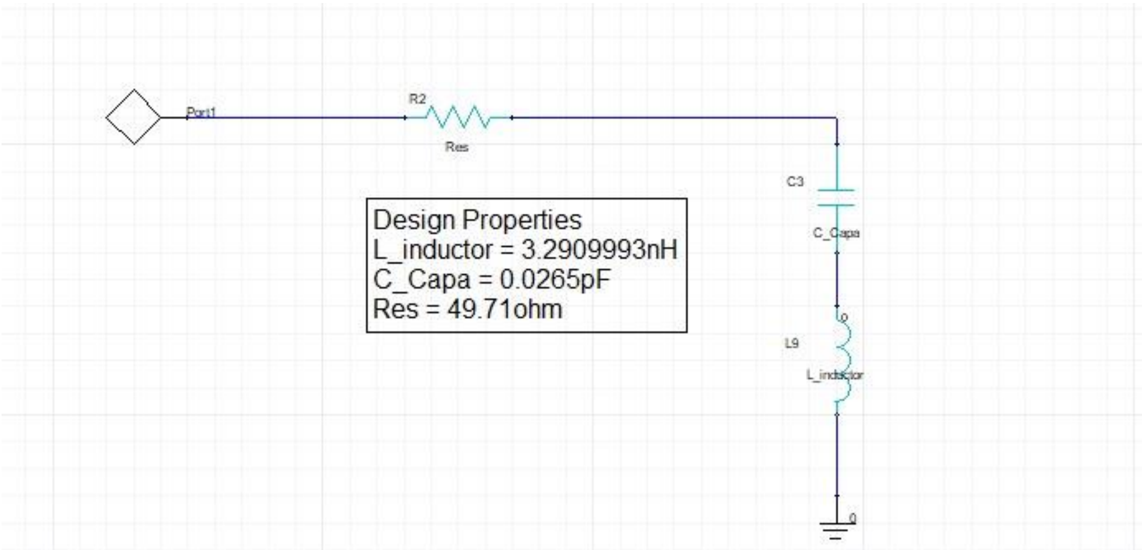

Figure 29 Circuit Model

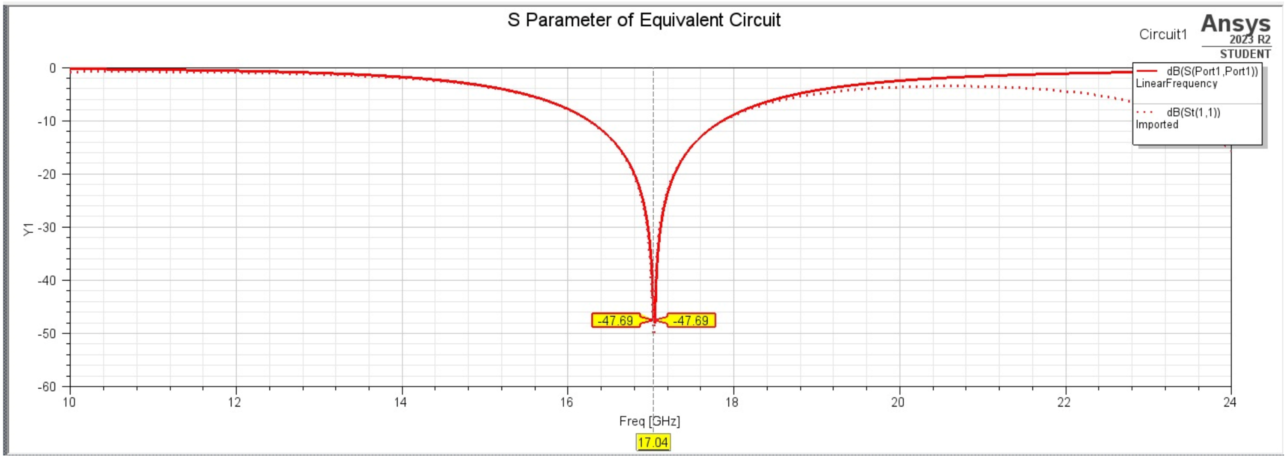

Figure 30 S11 of Circuit Model (line) & antenna design (doted)

Figure 30 shows that S11 of the Circuit Model follows S11 of the antenna design.

Layout

Design Layout

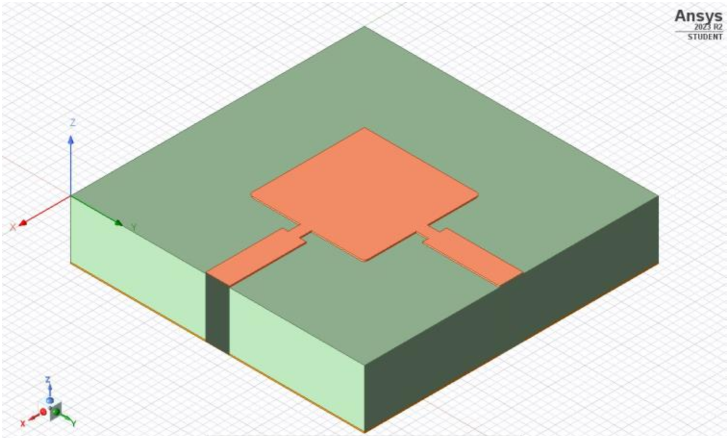

Figure 34 Isometric View

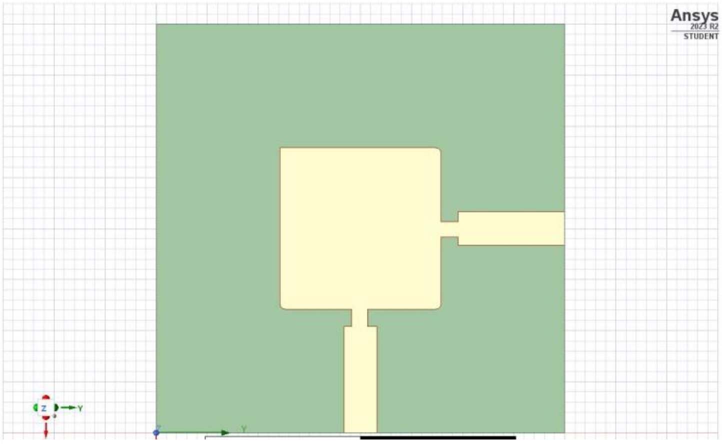

Figure 35 Top View

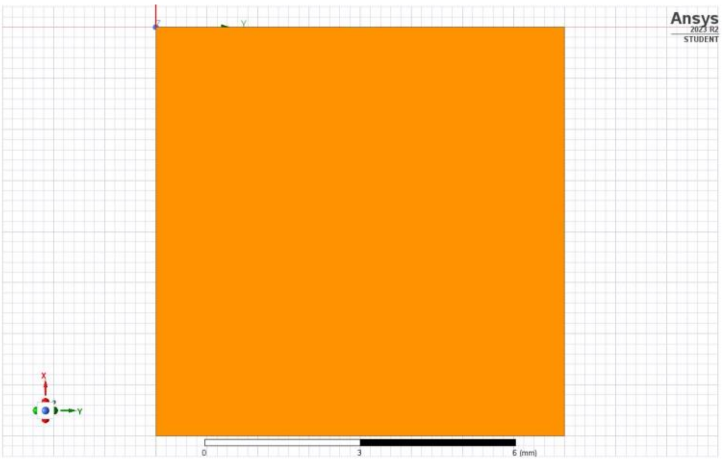

Figure 32 Bottom View

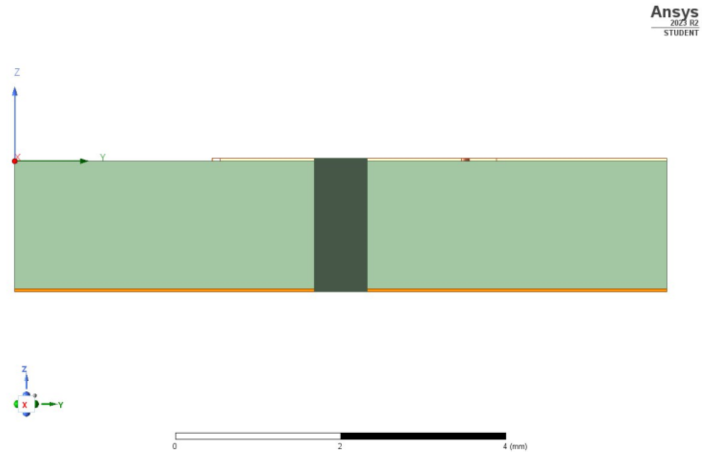

Figure 33 Front View

simple Dipole antenna achieves parameters near to that in the same design in the paper and verified by this paper[3]

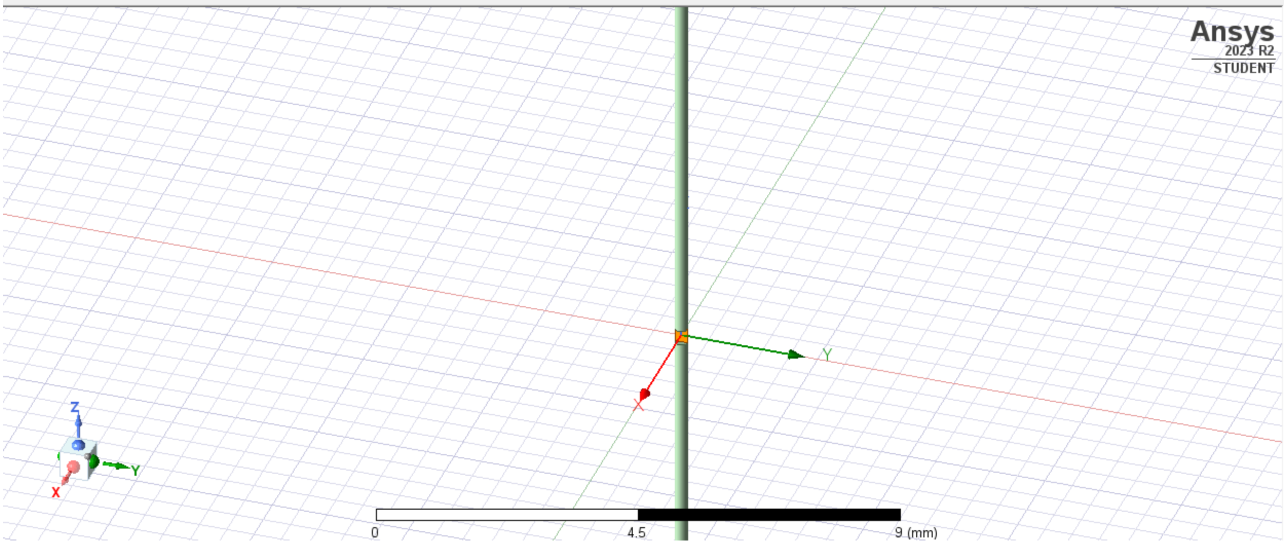

Figure 36 Schematic of the dipole for verification

L = 55 mm **R=0.115 mm** **gap=0.275 mm**

Dipole results:

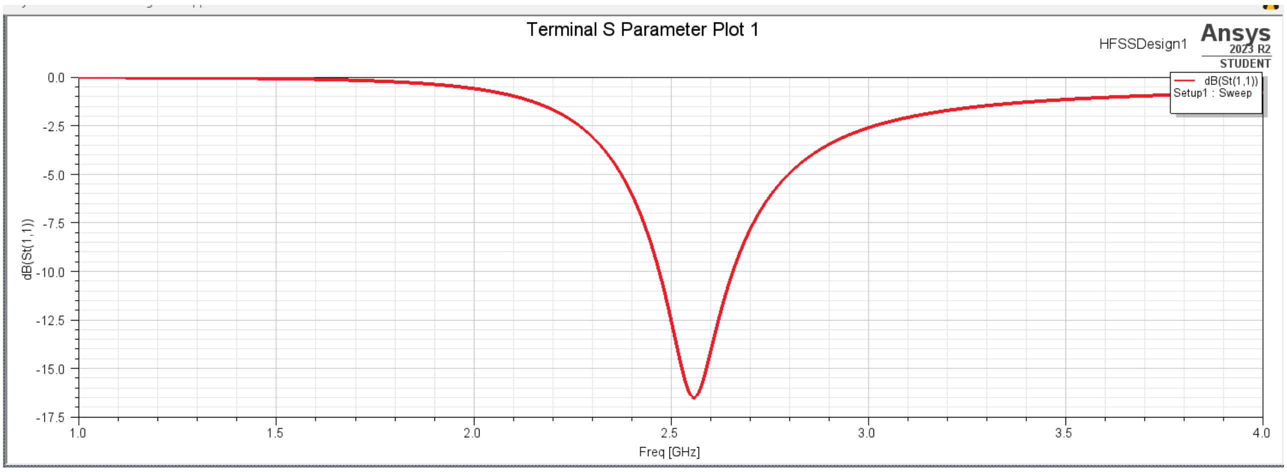

Figure 37 s11 for the dipole.

Verification of tool

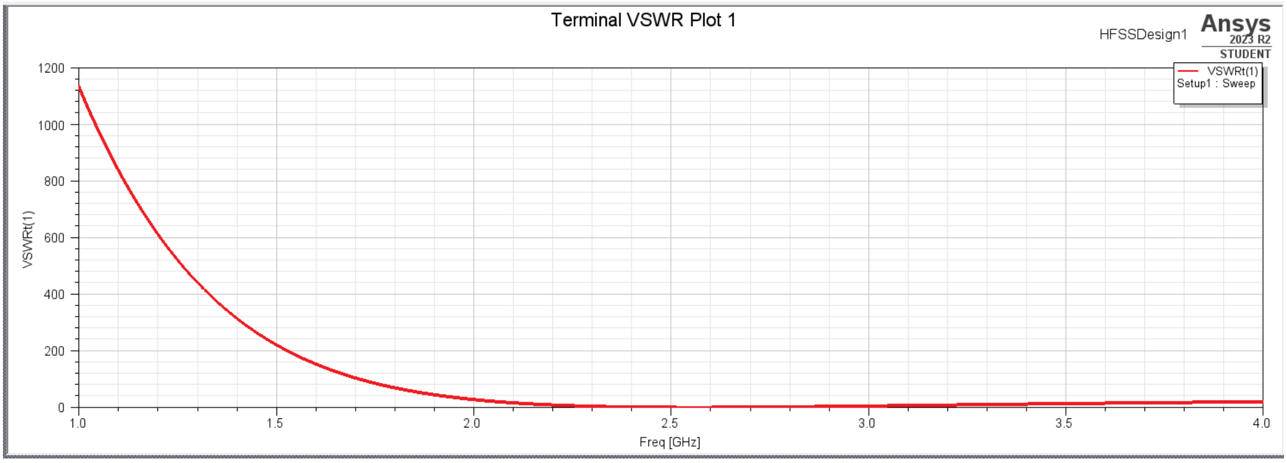

Figure 38 VSWR of the dipole.

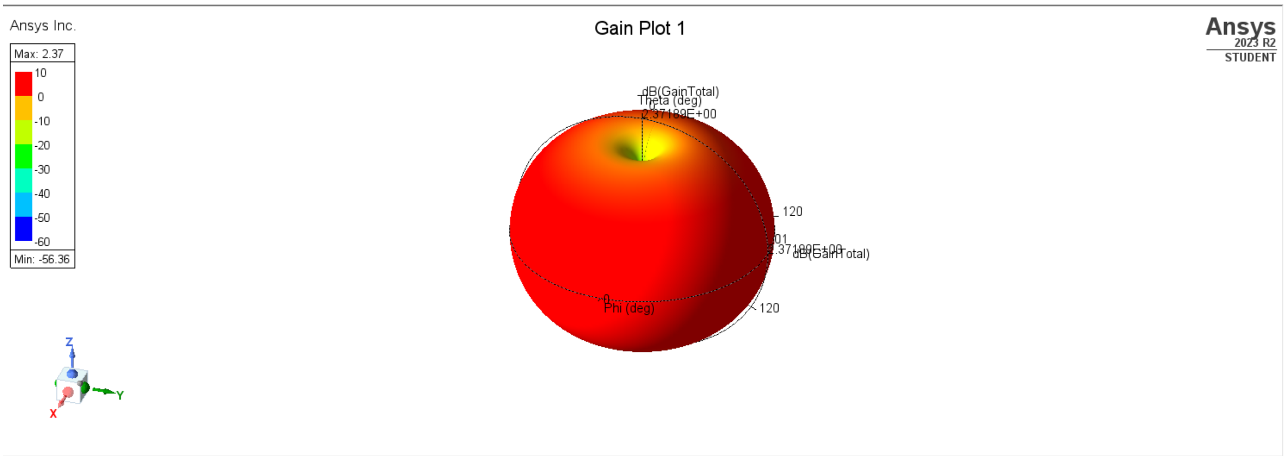

Figure 39 Gain of dipole on 3_D

as shown of the previous figures the results are very near to that in intended paper.

Conclusion & References

Conclusion

In this report, The Dual Polarized microstrip patch antenna has been designed and analysed at operating frequency 17GHz using HFSS Tool. The specifications required for the cross polarization (XPD) and isolation between the 2 ports have been achieved as shown in the above graphs in details.

References:

[1] G. J. Foschini and M. J. Gans, “On limits of wireless communications in a fading environment when using multiple antennas,” Wireless Personal Communications, vol. 6, no. 3, pp. 311–335, March 1998.

[2] Singh, S. P., Singh, A., Upadhyay, D., Pal, S., & Munde, M. (2021, May). Design and Fabrication of Microstrip Patch Antenna at 2.4 GHz for WLAN Application using HFSS. IOSR Journal of Electronics and Communication Engineering, Special Issue - AETM'16, 1, e-ISSN: 2278-2834, p-ISSN: 2278-8735.

[3] Onu, I. P., & Orakwue, S. I. (2020). Design Analysis for A Half-Wave Dipole Antenna For 2.4ghz Wireless Application using CST Microwave Studio. *ResearchGate*.