Vilniaus universitetas

Fizikos fakultetas

Taikomosios elektrodinamikos ir telekomunikacijų institutas

Kaoutar Elabbassi

MIKROJUOSTELINĖS IR VIVALDI ANTENOS MODELIAVIMAS IR OPTIMIZACIJA GHz DAŽNIŲ DIAPAZONUI

Magistrantūros studijų baigiamasis darbas

Elektronikos ir telekomunikacijų technologijų

studijų programa

Studentė	Kaoutar Elabbassi
Leista ginti	2026-05-22
Darbo vadovė	dr. Olga Suvorova
Recenzentas	dr. Edvardas Kazakevičius
Instituto direktorius	dr. **Robertas Grigalaitis**

Vilnius 2026

Vilnius University

Faculty of Physics

Institute of Applied Electrodynamics and Telecommunications

Kaoutar Elabbassi

DESIGN AND OPTIMIZATION OF MICROSTRIP AND VIVALDI ANTENNAS FOR GHz BAND

Master's final thesis

Electronics and telecommunications technology

study program

Student	Kaoutar Elabbassi
Approved	2026-05-22
Academic supervisor	dr. Olga Suvorova
Reviwer	dr. Edvardas Kazakevičius
Director of Institute	dr. **Robertas Grigalaitis**

Vilnius 2026

Table of contents

Introduction:

The rapid expansion of modern wireless communication systems has produced an increasing demand for compact, efficient, and broadband antennas capable of functioning at high frequencies with good radiation characteristics. Antennas play a fundamental role in communication systems since they are responsible for transmitting and receiving electromagnetic waves.

Therefore, the design and optimization of antenna structures have become key study subject in telecommunications and microwave engineering field. Among the many antenna technologies, Microstrip antennas have gained significant attention due to their low profile, lightweight structure, low fabrication cost, and ease of integration with microwave circuits. [1]

In addition, antenna arrays are commonly used to improve gain, directivity, and overall radiation performance. Different feeding techniques,such as Microstrip feed lines and inset-fed configurations, are commonly employed to accomplish impedance matching and effective power transmission.

However, Vivaldi and Antipodal Antennas are recognized for their ultra-wide bandwidth and directional end-fire radiation. Their tapered slot shape provides large impedance bandwidth and consistent performance over a broad frequency range, making them appropriate for broadband and high-frequency applications.

The aim of this work is: design simulation, and optimization of a few types of patch and tapered slot antenna (Vivaldi Antenna, Antipodal Antenna) by using ANSYS HFSS software.

This study examines the optimization of a Vivaldi antenna, Antipodal Antenna, a (1x2) Microstrip antenna array, and inset-fed Microstrip antennas. Impedance matching, return loss, bandwidth, and radiation properties are used to assess their performance.

1. LITERATURE REVIEW

1.1 Microstrip Patch Antenna

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. And becoming very widespread within the mobile phone market.

Patch antennas are low cost, have a low profile and are easily fabricated. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity or dielectric constant. The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation, but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded. [1]

1.1 Vivaldi antenna

Vivaldi antenna are constructed from a feed connecting to two symmetric sides of a planar metallic antenna. To the left of the feed is is a short-circuit. However, antennas are RF-type devices and therefore the short-circuit acts more like a parallel inductor. To the right of the feed is the radiating element. It can be considered a tapered slot antenna or an aperture antenna. [2]

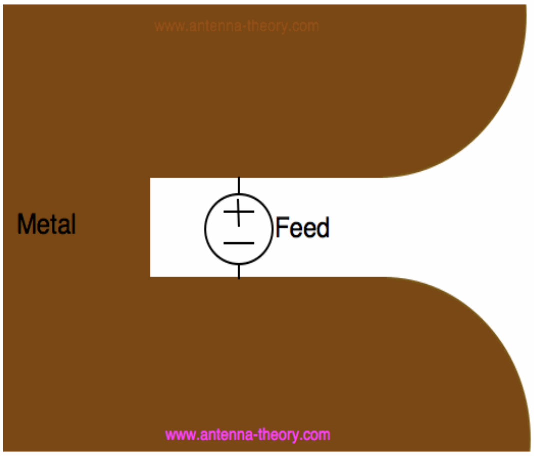


Figure 1:Basic structure and practical implementation of a vivaldi antenna

1.3 Ansys HFSS

Antennas, filters, and integrated circuit packages are just a few of the high frequency products that may be designed using the High Frequency Structure Simulator (HFSS), a 3D electromagnetic (EM) simulation tool. HFSS offers sophisticated finite element-based 3D electromagnetic field solvers along with other Engineers may quickly and accurately design high-frequency and high-speed electronic components using integral equation approaches enabled by high performance computing technology. Results of electric field plots on a few example designs made and solved in HFSS are shown in the following picture. [3]

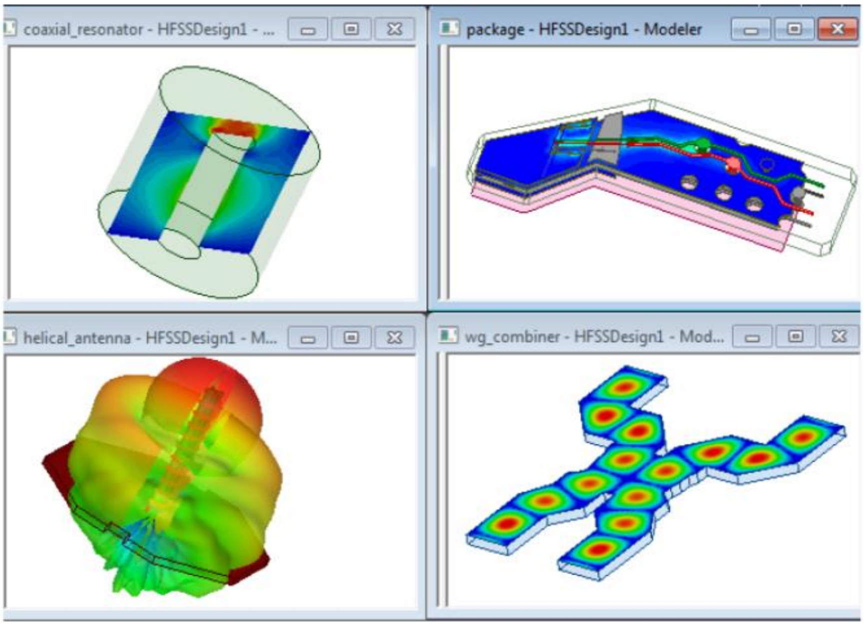


Figure 2: Representative Electromagnetic field Simulation Using ANSYS HFSS

1.3.1 Adaptive solution process in ANSYS HFSS

HFSS employs an adaptive meshing technique to ensure accurate electromagnetic simulation results. The process of simulation in ANSYS HFSS begins with the manual (or in some cases, automated) designing of geometric structure of object to be investigated. It can be a 2D or a 3D structure. Then we create initial mesh, which represents a coarse discretization of the structure for solving of Maxwell Equations numerically. After applying the boundary conditions and excitation, we start the process of computing of electromagnetic field by using of Finite Element Method.

After each iteration, the solution is evaluated based on a convergence criterion, typically defined by the maximum change in S-parameters (Max Delta S). If the solution does not meet the required accuracy, the local error is calculated and the mesh is refined in regions where higher precision is needed. This iterative process continues until the convergence condition is satisfied. Once convergence is achieved, HFSS computes the broadband S-parameters, providing reliable results for antenna performance analysis. This adaptive refinement ensures both computational efficiency and high simulation accuracy. [3]

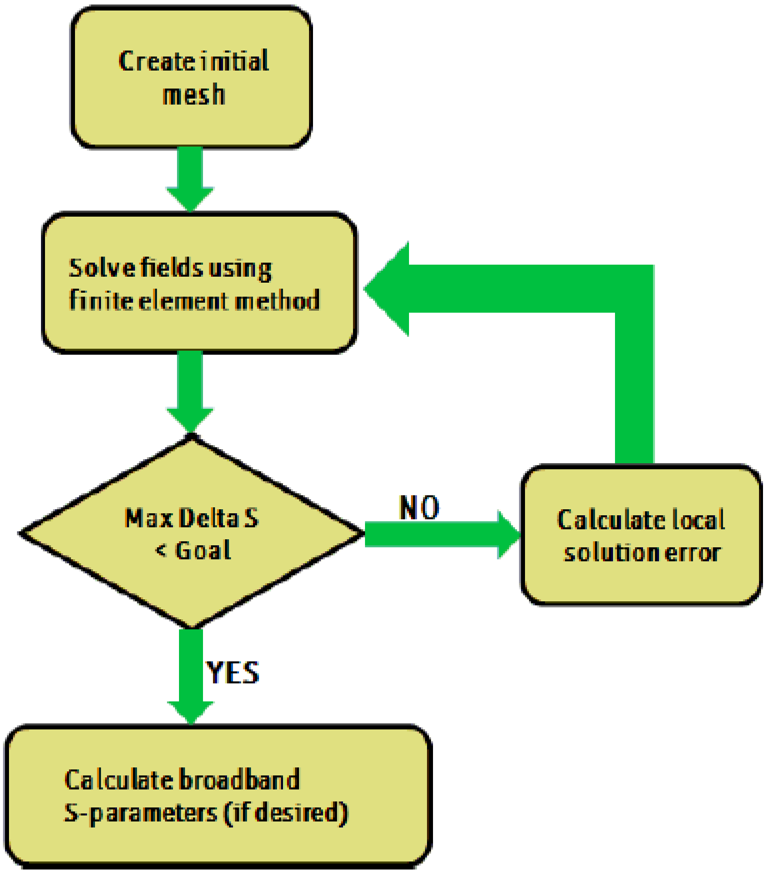


Figure 3: Adaptive Refinement Process in ANSYS HFSS

1.3.2 Solution types in HFSS

In electromagnetic simulations using ANSYS HFSS, different solution types are available, it depend on the objective of the analysis, but the main categories are Eigenmode and Driven solutions.

<u>Eigenmode</u>: Without using any external excitation, a structure’s inherent resonant frequencies can be found using the Eigenmode solution. This approach relies only on the system’s geometry, material characteristics, and boundary conditions. It offers crucial characteristics like quality factors, field distributions, and modal frequencies. These resonant frequencies physically reflect the structure’s intrinsic behavior, or how it would naturally oscillate in the presence of energy.

Driven solution: is employed when an external source, like a port or incident field, excites the structure. This kind of study is crucial for realistic antenna and microwave designs because it makes it possible to calculate radiation characteristics and scattering parameters (S-parameters), such as S11.

The most popular driven solution in RF and antenna applications is the Driven Modal method. It gives precise results for antenna performance, including radiation patterns and impedance matching, by analyzing the propagation of electromagnetic modes. On the other hand, circuit-based structures and multi-conductor transmission lines are the primary applications for the Driven Terminal solution. Because the antenna is activated through a port and the objective is to assess its reflection coefficient and radiation behavior, **the Driven Modal approach was chosen for this task**. [3]

1.3.3 Boundary Conditions

Since limitless free space cannot be accurately modeled, an air box is defined around the antenna to represent the simulation domain. Perfectly matched layers (PML) or radiation boundary conditions are added to the box's outside to stop false reflections. These limits mimic open-space circumstances by absorbing outgoing electromagnetic radiation. Depending on the application, other boundary types can be utilized, such as radiation or PML for open-region problems like antennas, Perfect Electric Conductor (PEC) for metallic sections, and Perfect Magnetic Conductor (PMC) for symmetry. In terms of solution types, HFSS offers Driven and Eigenmode solutions. Driven solutions use external excitation, whereas the Eigenmode solution finds natural resonant frequencies without excitation. Among these, In order to calculate S-parameters and analyze electromagnetic modes (TE, TM), which are crucial for antenna design. [3]

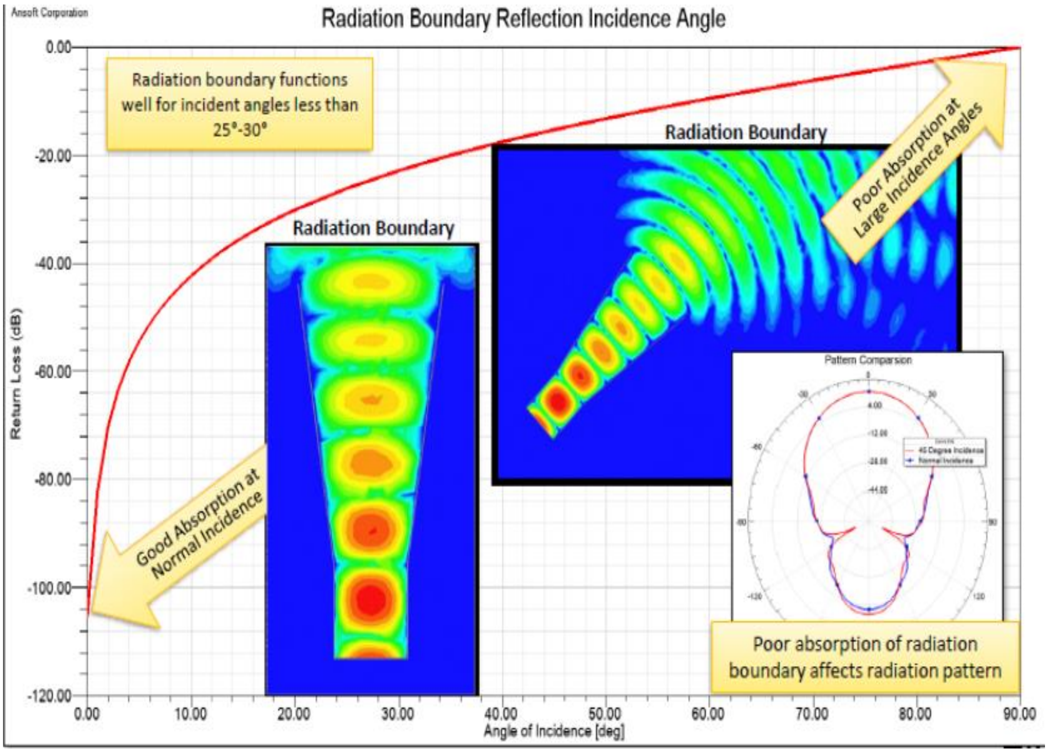


Figure 4: Radiation Boundary Reflection as a Function of Incidence Angle

By absorbing outgoing electromagnetic waves, radiation boundary conditions are frequently utilized to simulate open-space situations. However, the angle at which the waves occur determines how effective they are. The absorption is effective and there are few reflections at normal or small incidence angles. Large incidence angles, on the other hand, result in less efficient absorption and more reflections, which could skew the radiation pattern. To improve absorption over a larger range of angles, more sophisticated methods like precisely matched layers (PML) can be employed. Any object surface that touches the background is automatically defined as Perfect E boundary. [3]

1.3.4 Port Excitations

In HFSS simulations, port excitations define how electromagnetic energy is introduced into a structure. The two main types are wave ports and lumped ports. Wave ports are mainly used for transmission lines such as microstrip and coaxial lines, where HFSS calculates propagation modes and characteristic impedance using a 2D FEM solver. They support multimode excitation and de-embedding but must be placed on external boundaries. Lumped ports provide a simpler excitation by assuming a uniform electric field and a fixed impedance, usually 50 Ω. They can be placed internally, making them suitable for compact and simple designs, although they only support a single TEM mode and do not allow de-embedding. [3]

1.3.5 Frequency Sweeps

In HFSS, frequency sweeps are used to examine an electromagnetic structure's response across a given frequency range. By solving the modified mesh at every frequency point, the discrete sweep offers the highest degree of accuracy. Because of this, it produces full matrix data and field solutions for each frequency, which makes it appropriate for in-depth and accurate analysis even if it takes longer to compute.

2. MICROSTRIP PATCH ANTENNA

2.1 Design parameters

Because of their small size, low profile, ease of fabrication, and compatibility with planar circuits, Microstrip patch antennas are widely used in microwave and radar applications. So I designs and optimizes a simple Microstrip patch antenna to function at 2.4 GHz, and inset-fed rectangular

Microstrip patch antenna to function at 10Ghz ; To obtain good impedance matching without the need for additional Network, the inset-fed technique is used.

I designed a rectangular microstrip patch antenna operating at a resonant frequency of fr = 2.4 GHz for such applications like wifi and ISM band ,with a rectangular radiating patch printed on an FR4 substrate with dielectric constant of εr = 4.4 ,substrate thickness of h = 1.6 mm. and copper material used for the patch and the ground plane. For the feeding technique I used a rectangular microstrip feed line. To calculate patch dimensions I used the transmission-line model proposed by Balanis. [4]

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

$$W = \frac{3\ X\ 10^{8}}{2(2.4\ X\ 10^{9})}\sqrt{\frac{2}{4.4+1}} \approx 38 \text{ mm}$$

The effective dielectric patch length is:

$$\varepsilon\text{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r+1}{2}(1+\frac{12h}{w})^{-1/2} \qquad (2)$$

$$\varepsilon eff \approx 4.09$$

the effective patch length is:

$$Leff = \frac{c}{2fr\sqrt{\varepsilon eff}} \quad (3)$$

$$Leff \approx 30.92 \text{ mm}$$

The length extension due to fringing fields is:

$$\Delta L = 0.412h\frac{(\varepsilon eff+0.3)(\frac{w}{h}+0.264)}{(\varepsilon eff-0.258)(\frac{w}{h}+0.8)} \quad (4)$$

$$\Delta L \approx 0.74 \text{ mm}$$

For that, the final approximate patch dimensions are:

$$W \approx 38 \text{ mm} \quad , L \approx 29 \text{ mm}$$

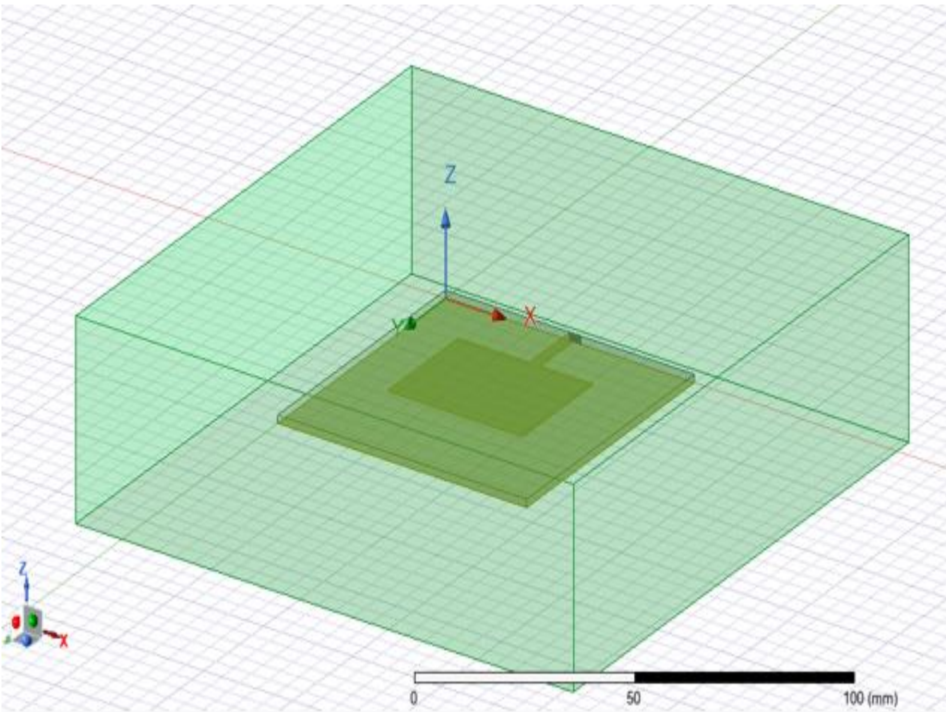


Figure 5: Simulated Microstrip antenna

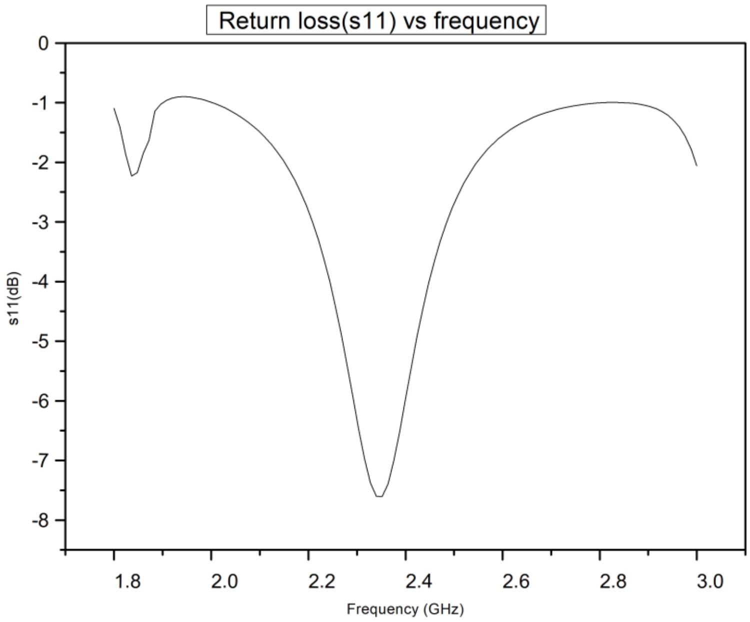


Figure 6: s11 parameter depending on Frequency

After simulation of the design, the antenna resonance was not centered at the desired frequency, It happened due that the engineering formulas for rectangular antenna is approximate ones. So, we have to make the optimization of geometrical sizes of antenna to get the resonant frequency at 2.4 GHz. By performing parametric search for length of patch L (It may also be the width W, or both of L and W), we found, that we have maximum of reflection coefficient when L=28 mm.

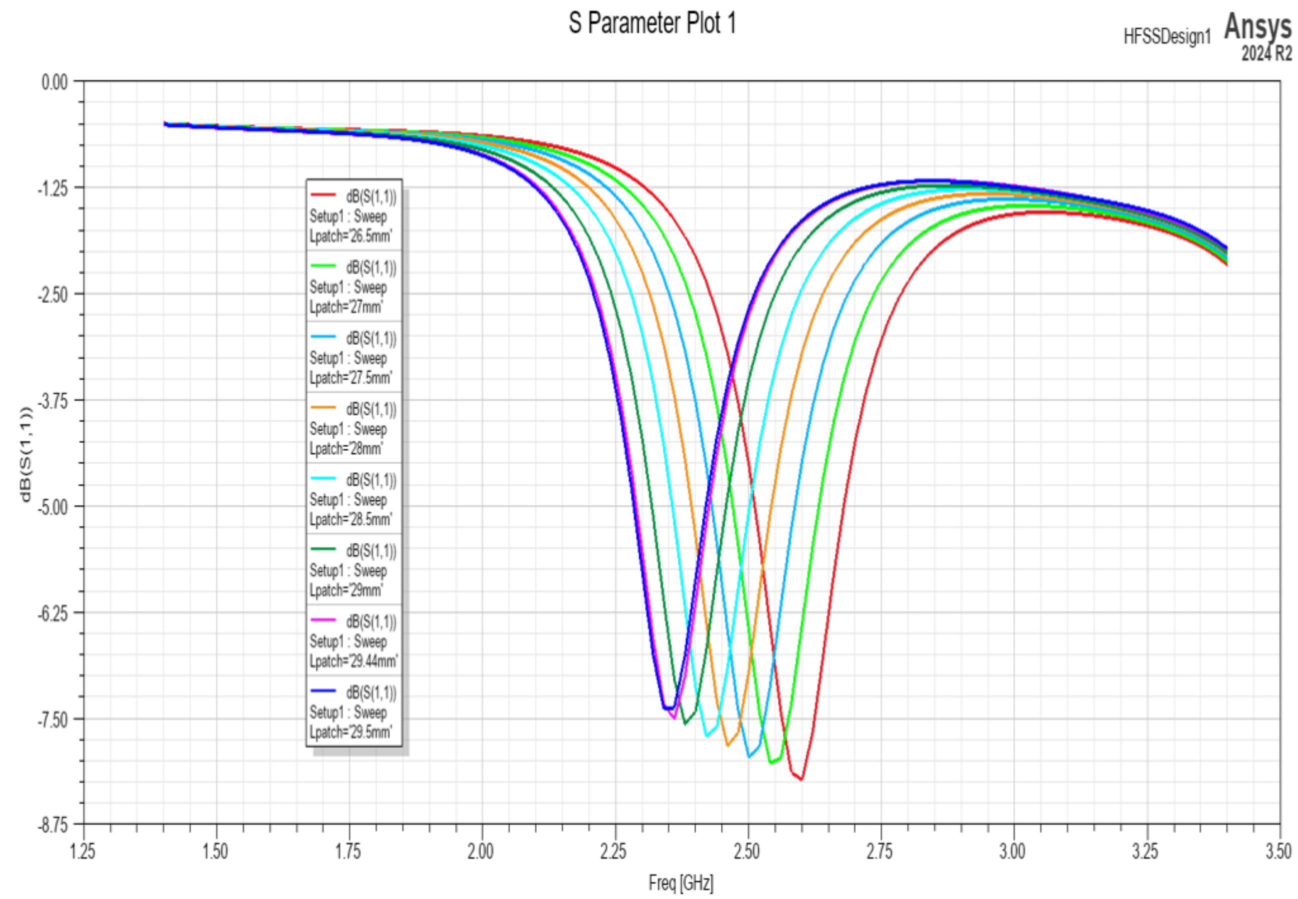


Figure 7: parametric sweep of L Patch

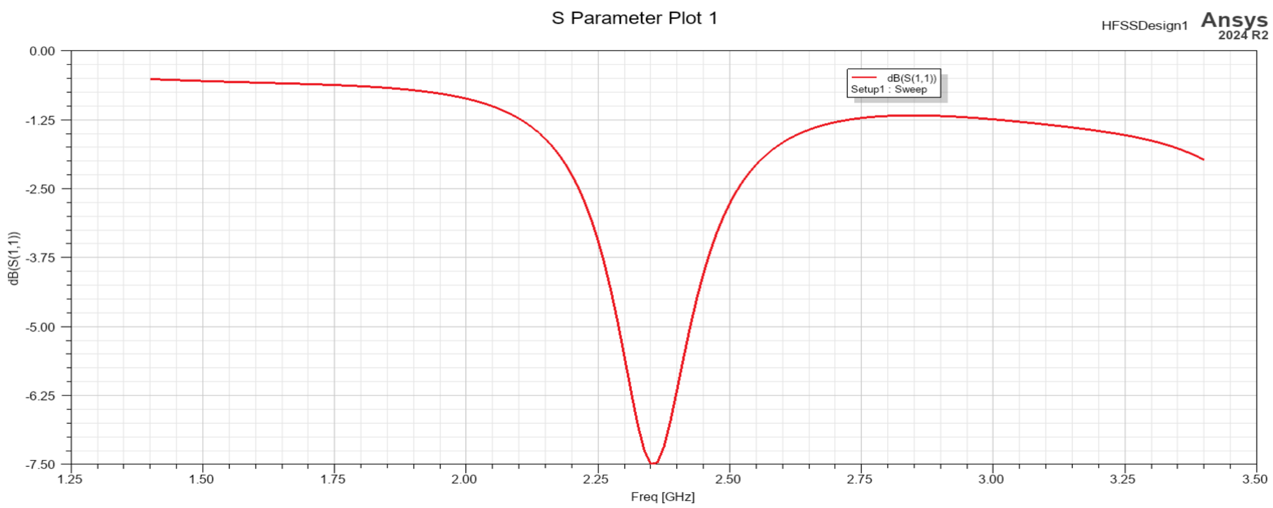


Figure 8: Return loss

As illustrated in Figure.7 and Figure.8, the antenna resonates at the desired frequency of 2.4 GHz. However, the reflection coefficient is not good, because the S11 value should be less than -10 dB. An impedance mismatch between the patch and the feed line is the root of this problem. As a result, the antenna design needs to be adjusted, and to enhance impedance matching, a different feeding method called the quarter-wavelength transformer feed is employed. The quarter-wave transformer impedance [1] is given by:

$$Z1 = \sqrt{Z0ZL} \qquad (5)$$

Where: *Z*0 is the feed line impedance and *ZL* is the antenna impedance. In our design, the feed line impedance is 50 Ω (It combine between the power handling capability which peaks around 30 Ω, and signal loss which minimized around 70 Ω), while the antenna impedance is approximately 200 Ω. Therefore:

$$Z1 = = \sqrt{50 \text{ X } 200} \approx 100\ \Omega$$

The transformer length is chosen as:

$$L = \frac{\lambda}{4} \qquad (6)$$

The wavelength at 2.4 GHz is calculated using:

$$\lambda = \frac{c}{f} \qquad (7)$$

where : $c = 3 \times 10^8 m/s$ and $f = 2.4 \times 109\ Hz$.

Thus:

$$\lambda \approx 0.125\ m = 12.5\ cm$$

Hence, the quarter-wave transformer length is:

$$\frac{\lambda}{4} \approx 31.25\ mm$$

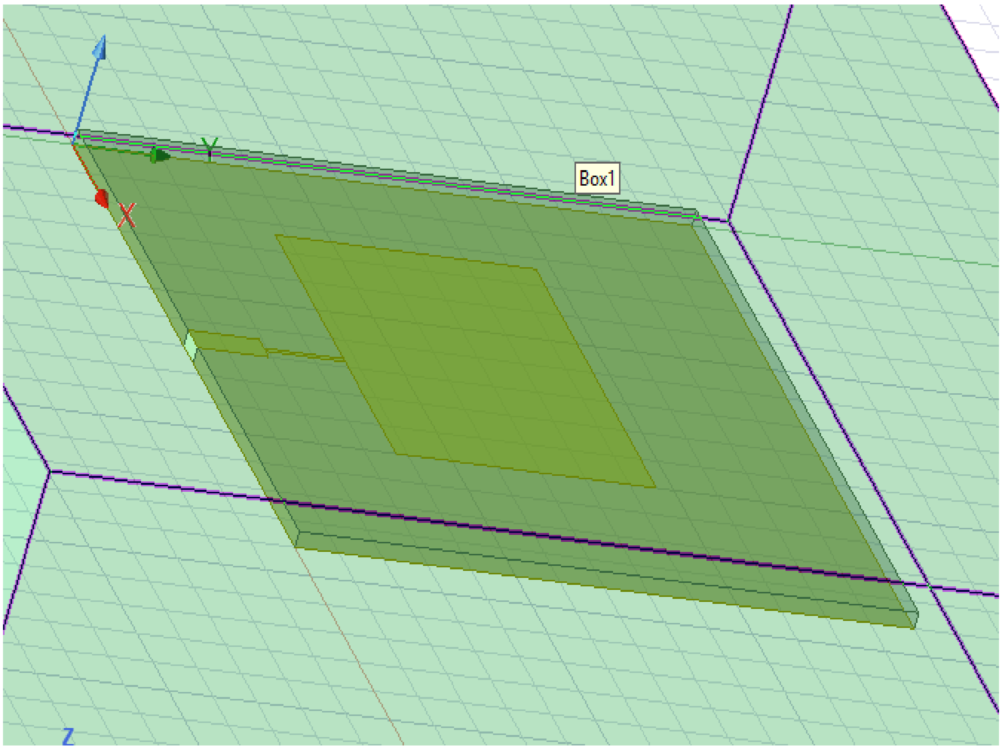


Figure 9: View of optimized antenna with transformer

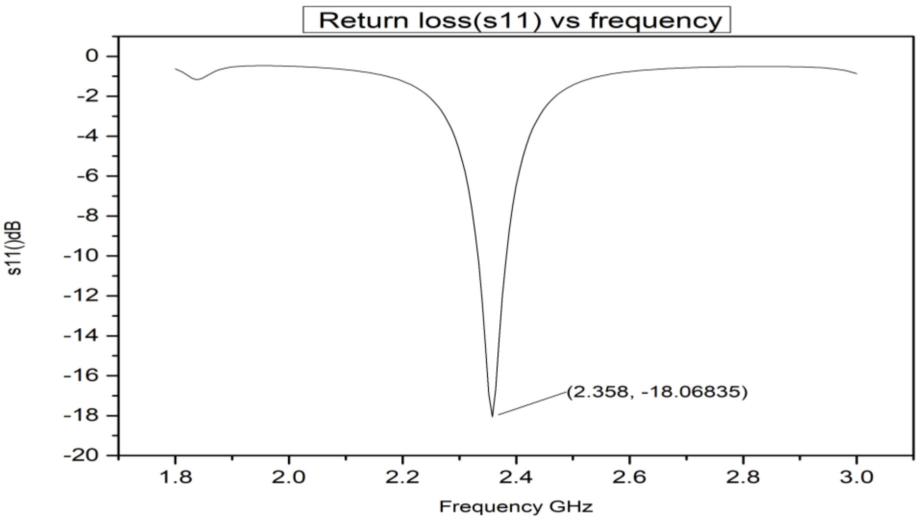


Figure 10: Return loss of patch antenna with transformer

As illustrated in Figure 10, a very good reflection coefficient is obtained using the transformer.

2.2 Inset-Fed Microstrip Antenna Design at 10 GHz

Microstrip patch antennas are frequently used in microwave and radar applications due to their tiny size, low profile, ease of manufacture, and compatibility with planar circuits. In order to operate at 10Ghz, this work constructs and optimizes a single inset-fed rectangular microstrip patch antenna. The inset-fed approach is used to achieve good impedance matching without the requirement for additional network.

2.2.1 Prototype and design

The proposed antenna is implemented on a rectangular dielectric substrate of dimensions SubL×SubW with a thickness of Subthick. A rectangular metallic patch of dimensions PatchL×PatchW is printed on the top surface of the substrate, while a full ground plane is placed on the bottom side. The patch is excited by a 50 ohm microstrip feed line characterized by a length StripL and a width StripW [6].

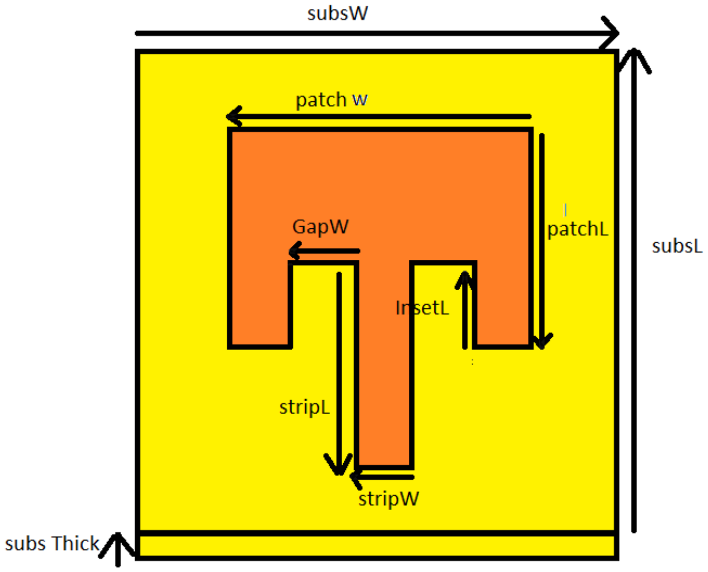


Figure 11: Prototype of inset feed antenna

Table1: geometry sizes of antenna

Name	Value	Unit
SubsL	29.3	mm
SubsW	23	mm
SubsThick	0.89	mm
StripL	2.74	mm
StripW	2.47	mm
InsetL	2.93	mm
Gap W	0.8	mm
PatchW	11.9	mm
PatchL	9.7	mm

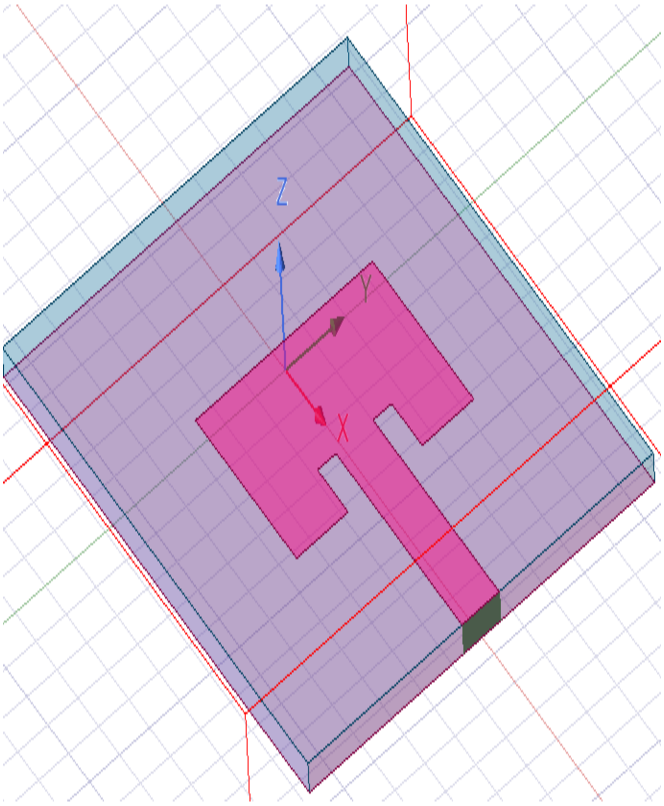


Figure 12: Simulated antenna

To improve impedance matching , using inset-fed configuration , so the feed line penetrates into the patch by an inset depth InsetL with a gap width GapeW. This feeding method allows the input impedance to be adjusted by selecting an appropriate feed position relative to the patch center, the input resistance varies due to standing-wave current distribution. By varying the main geometrical parameters of the inset-fed patch antenna, the gap width(GapW), patch width (PatchW), and patch length (PatchL), as shown in the figures below. Each of these parameters has a noticeable effect on the reflection coefficient S11 In particular, the inset gap width controls the coupling between the feed line and the patch, and an optimal value leads to a minimum S11. The patch width mainly affects the input impedance and radiation characteristics, while the patch length primarily determines the resonance frequency. By changing these parameters, the minimum return loss was achieved at the target frequency of 10 GHz.

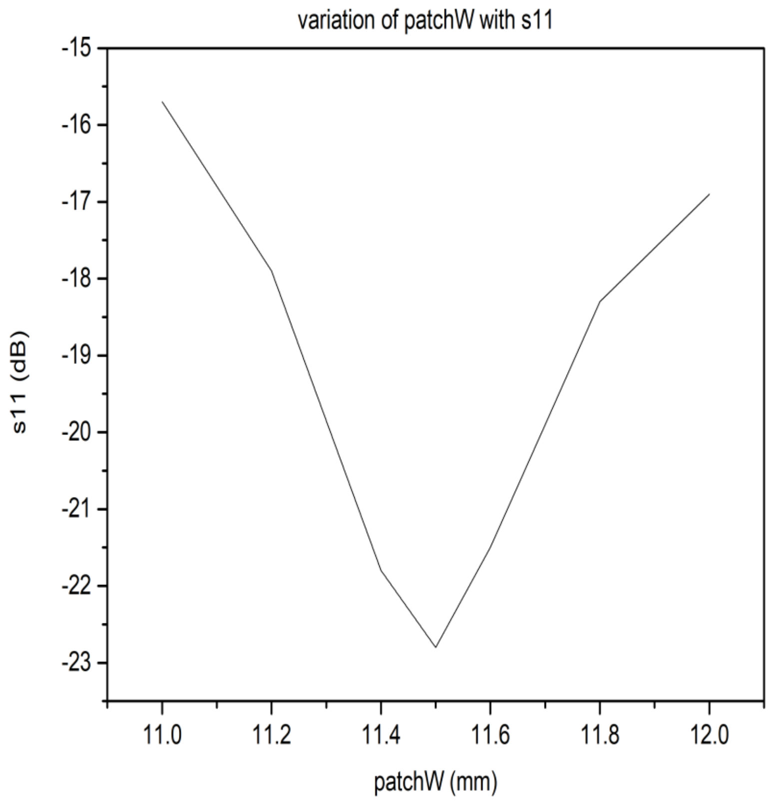


Figure 13: Return loss varying with PatchW

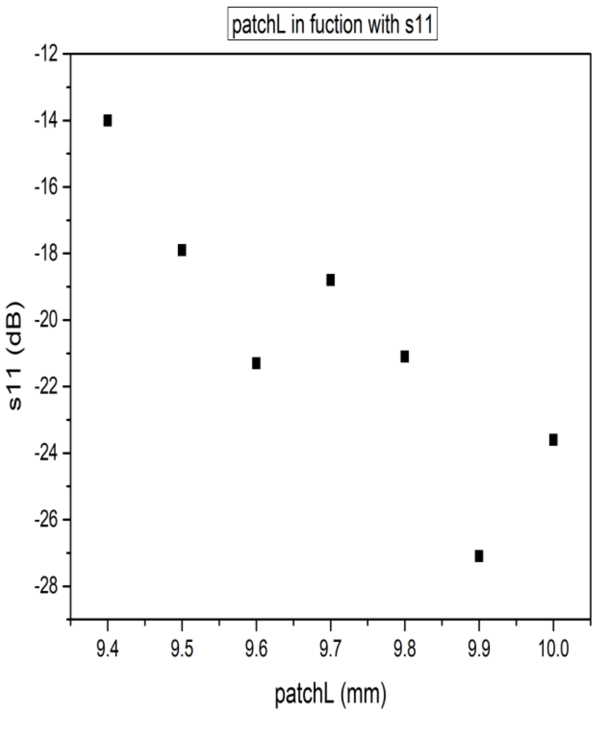


Figure 15: Return loss depending on Patch L

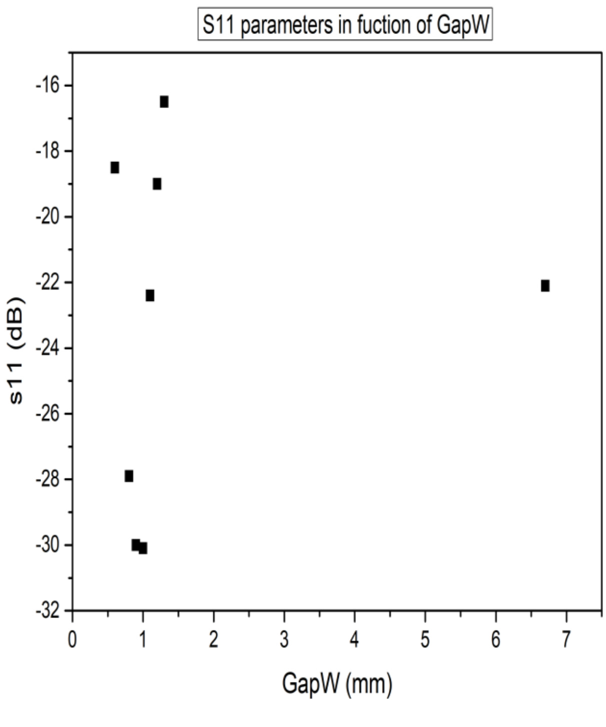


Figure 14: Return loss depending on Gap W

2.2.2 Performance

The simulated results confirm that the antenna operates efficiently at the target frequency of 10 GHz. The reflection coefficient S11 exhibits a clear resonance below 10 dB, indicating good impedance matching, which is consistent with the VSWR response showing a minimum value close to 1 at the same frequency. The Smith chart demonstrates that the input impedance approaches the center of the chart near resonance, confirming a near 50 ohm match. The radiation results show a stable broadside pattern with a realized gain of approximately 8 dB and comparable directivity, indicating efficient radiation and low mismatch losses.

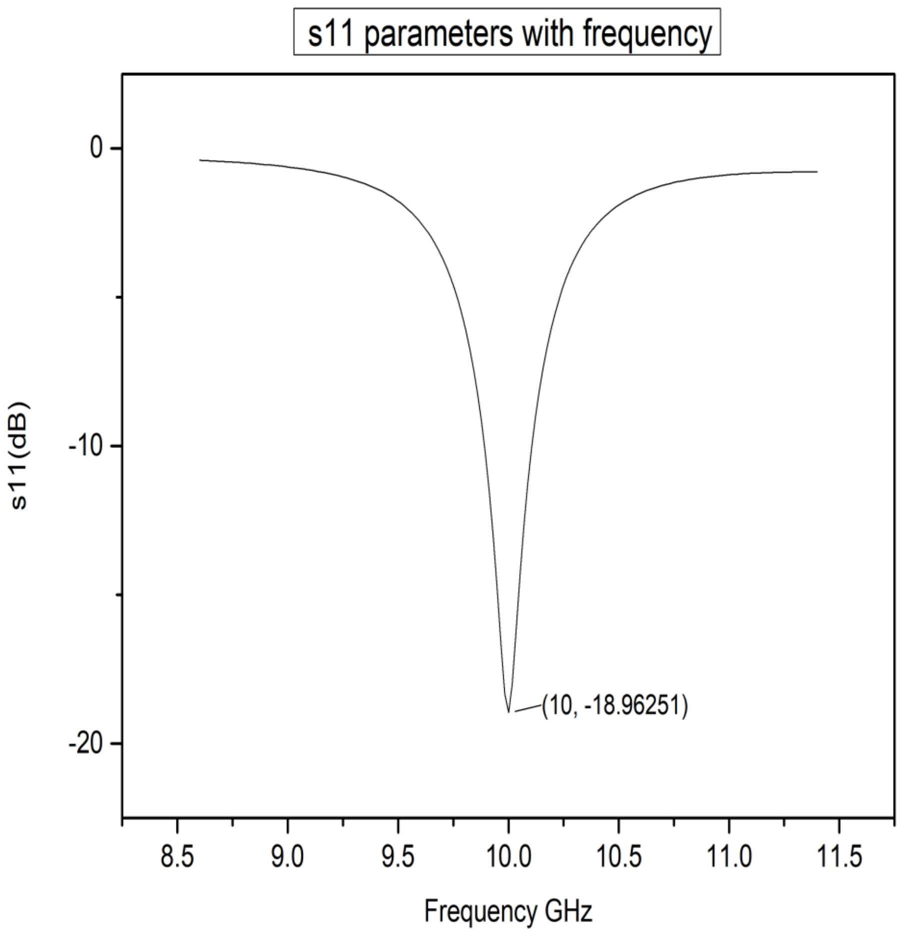


Figure 16: Return loss optimized

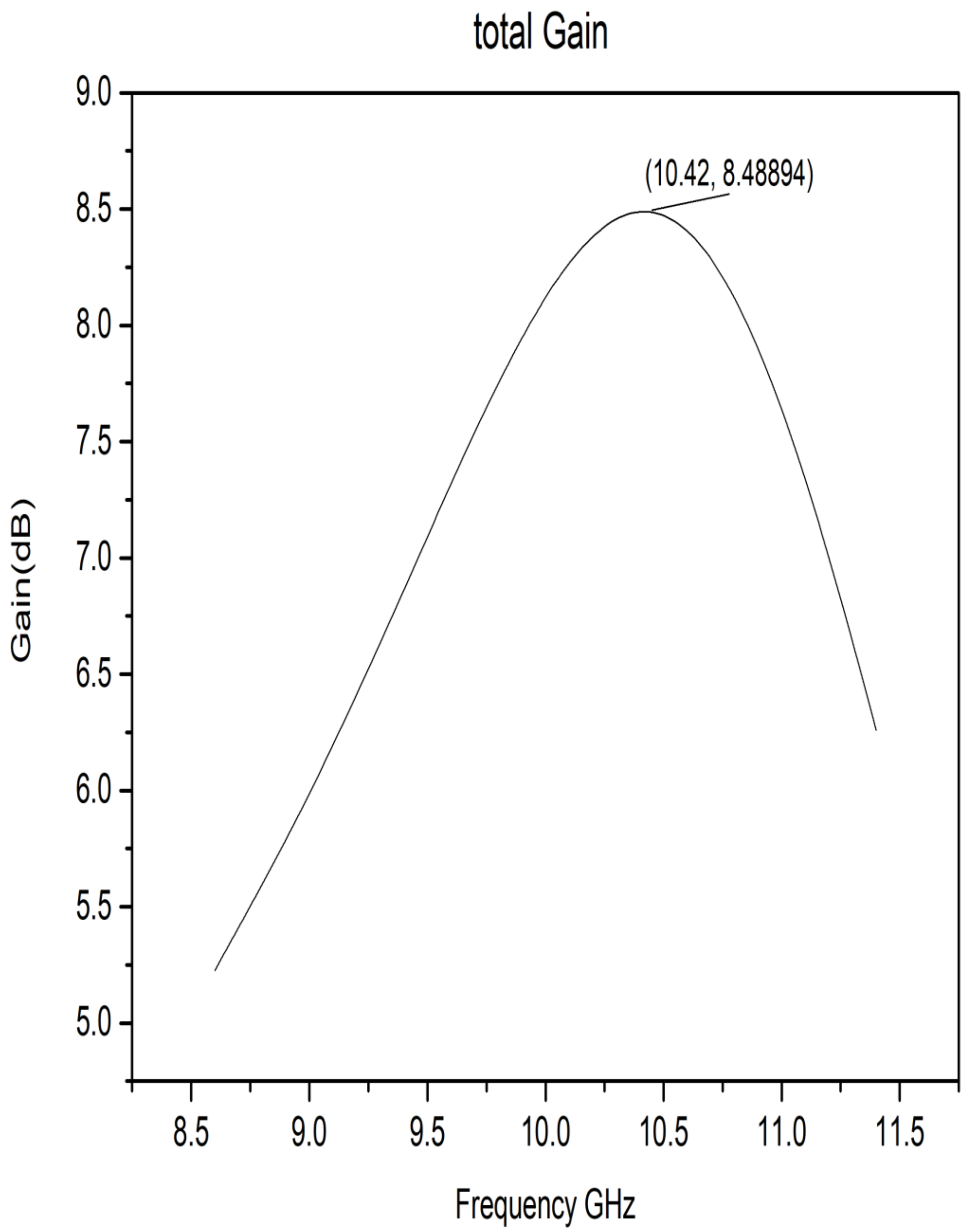


Figure 17: Gain optimized

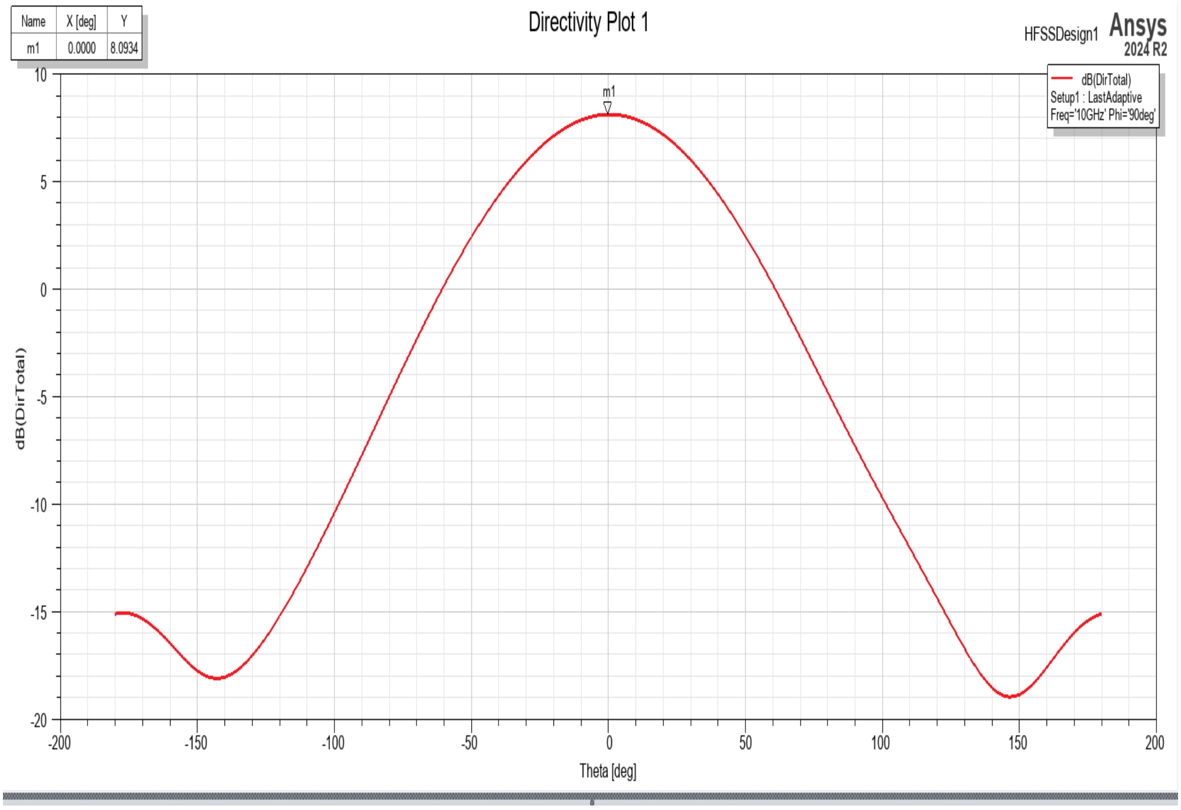


Figure 18: Directivity optimized

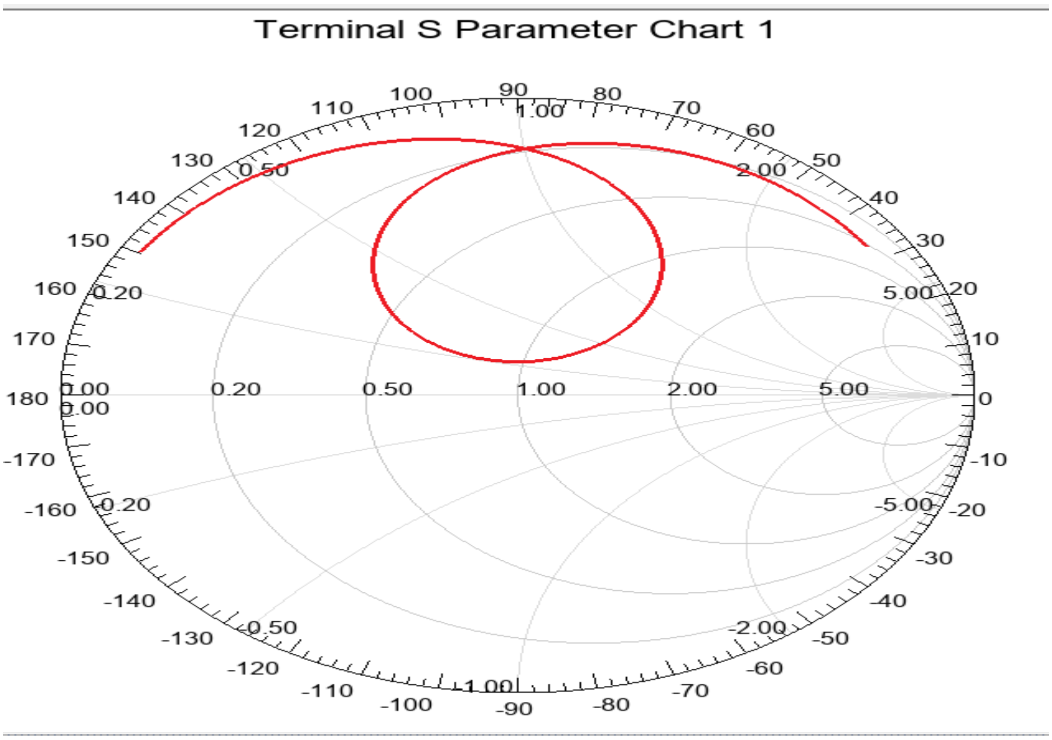


Figure 19:Terminal s parameter chart1

2.3 1×2 PATCH ANTENNA ARRAY

The 1x2 microstrip ptch antenna array designed to improve the antenna gain and directivity in compare with 1 single antenna, from same improved simple we made an array antenna with same geometrical parametres, but we have to be careful to :

When we design a microstrip antenna array, the feeding impedance of the individual elements is not equal to 50 Ω as in a single-element configuration. Instead, the impedance transformation is required to have a proper matching at the input port after power division. In a 1 × 2 antenna array using a corporate feed network, the input power is equally divided between two branches. To preserve a 50 Ω input impedance at the main feed, each branch must then present a higher impedance, typically 100 Ω, such that the parallel combination of the two branches results in an equivalent input impedance of 50 Ω.. This combined approach ensures equal power division, phase coherence, and efficient impedance matching of the antenna array [6].

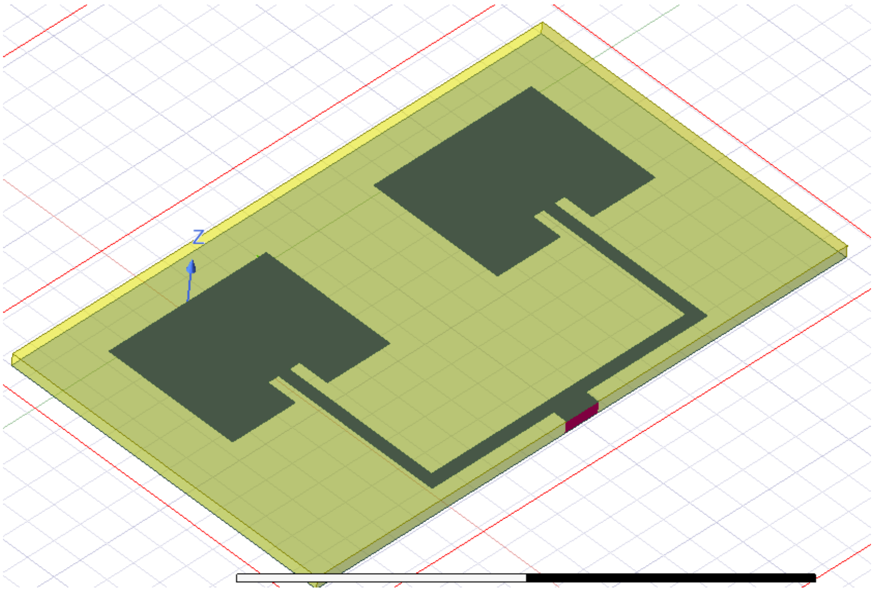


Figure 20: Simulated inset feed array (1x2)

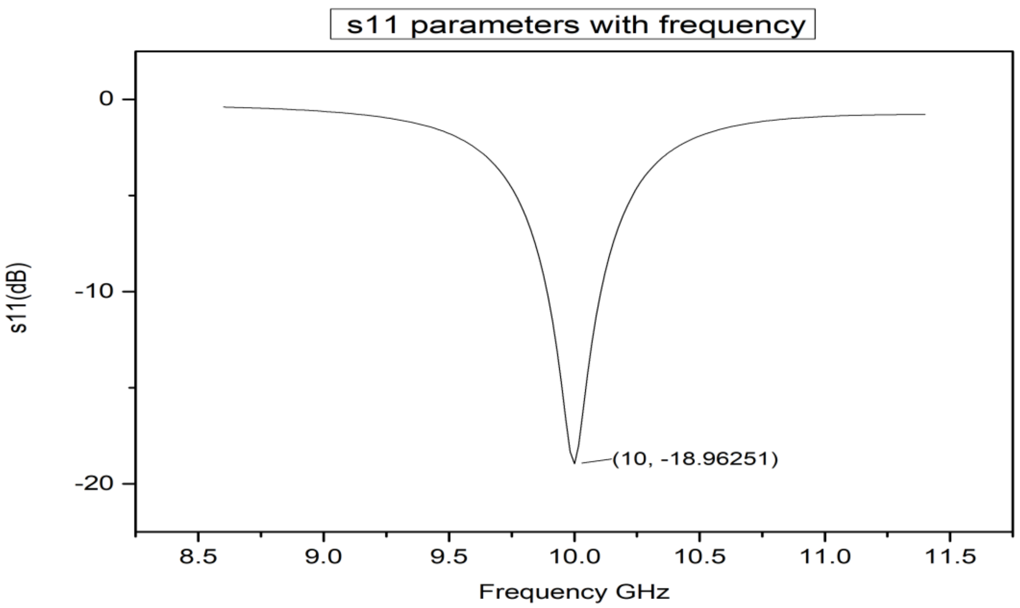


Figure 21: Return loss of array antenna

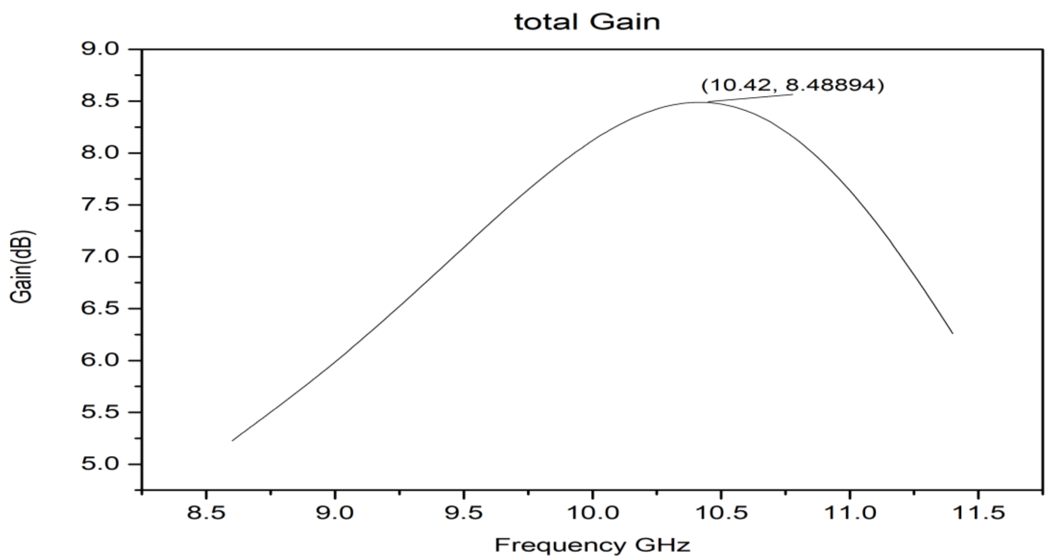


Figure 22: Gain for array antenna

2.4 Comparison between single patch antenna and patch antenna **array 1x2**

Table 2: Performance comparison of the Proposed Antennas.

Parameter	Single Inset-Fed Patch Antenna	1x2 Patch Antenna Array
Operating frequency	10 GHz	10GHz
Feeding technique	Inset-Fed microstrip line	Corporate feed witch inset-fed elements
Number of elements	1	2
Minimum S11	-19 dB	- 20.5 dB (good matching)
-10 dB bandwidth	215 MHz	327 MHz
Minimum VSWR	1.25	Close to 1
Peak realized gain	8 dB	9.7 dB(gain enhancement)
Peak directivity	8 dB	9.6 dB (increased directivity)
Radiation pattern	Broadside	Broadside with narrower main beam
Main advantage	Simple structure ,compact	Higher gain and directivity
Typical application	Single-element x-band systems	High-gain4 x-band radar systems

3. VIVALDI ANTENNA (4.6-5.6 GHZ)

The Vivaldi antenna is an exponentially tapered slot antenna that operates by gradually changing a guided slot line mode into a radiated wave along a flared aperture. Using Roger RT/duroid 5880 as a substrate for our antenna, This last one's geometry is determined by the taper length TL, microstrip length ML, microstrip width MW, and slot width d(x), where x is the longitudinal coordinate of the antenna. the exponentiel taper profile is given by:

$$d(x) = d0e\alpha x,\ 0 \leq x \leq TL\ [2] \qquad (8)$$

where d0 is the initial slot width and α is the opening rate controlling the impedance transition.

All that starting from the minimal frequency of our desired bandwidth to find λ value

using :

$$\lambda = \frac{c}{fmin\sqrt{\varepsilon eff}} \qquad (9)$$

For the feed region, where $d \ll \lambda$, the electromagnetic field stays guided, while radiation begins when the local slot width approaches $d \approx \lambda/2$. The taper length is typically chosen such that:

$$TL \geq \lambda min/2\ \ [2] \qquad (10)$$

Guaranteeing the lowest operational frequency's effective radiation. A directional end-fire radiation pattern is produced and wideband impedance matching is made possible by this gradual transition.

Table 3 below provides a summary of the optimal geometrical parameters of the suggested Vivaldi antenna. In order to precisely estimate conductor losses, we use copper with thickness of 0.049 mm, and the antenna is constructed on a dielectric substrate with a thickness of 0.8 mm. Wideband traveling-wave propagation via the tapered slot is supported by the fixed total antenna length of 76 mm, which provides enough electrical length.

The radiating region is defined by the effective slot length of 25 mm, which also has a direct impact on the lower operating frequency.

The taper rate of 60 controls the exponential taper [2], which minimizes reflections throughout the operating band and ensures a smooth impedance transition from the feeding region to the open aperture. To improve field confinement close to the feed region, a slot extension parameter of 1 mm is included. The feeding structure is done using a microstrip line with a width of 2 mm, followed by a quarter-wave matching section of 10mm in length to achieve optimal impedance matching between the microstrip feed and the slotline. At the feed point, a narrow slot width of 1 mm is employed to improve coupling efficiency and stabilize the input impedance. The dimensions of the microstrip line are calculated using microstrip line online calculator [7].

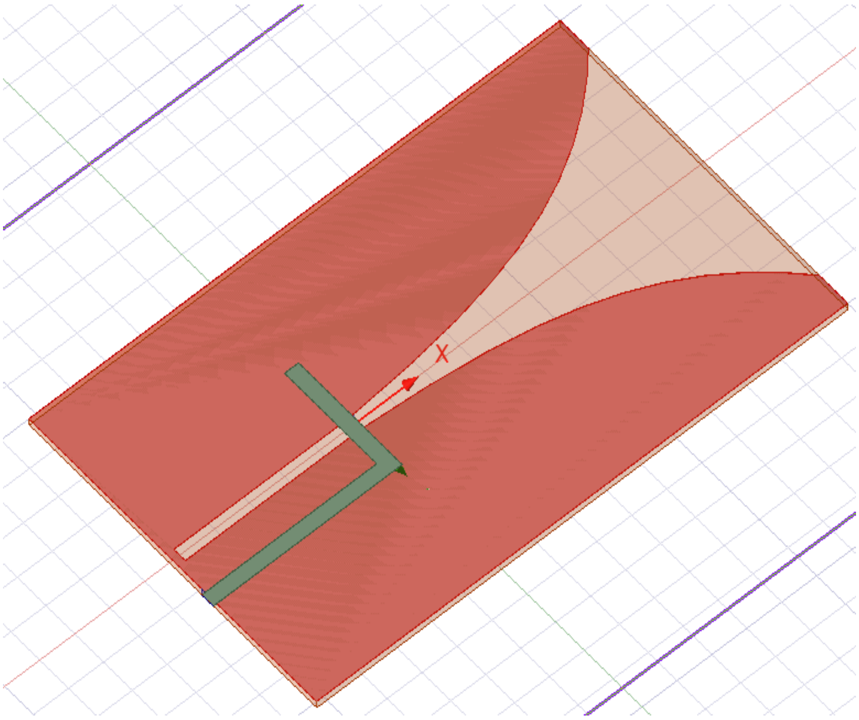


Figure 23: Simulated Vivaldi antenna from down view

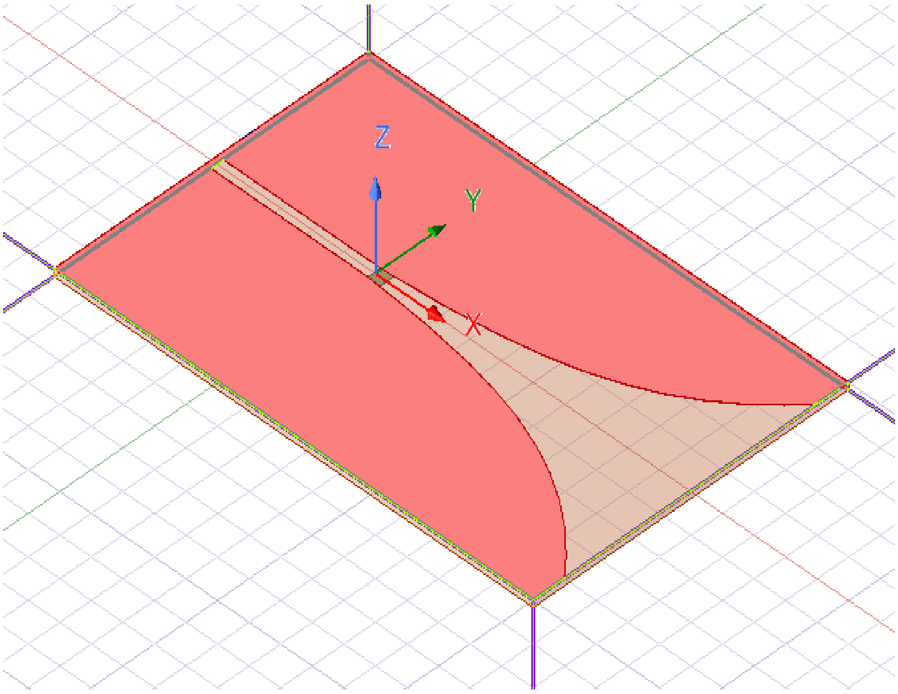


Figure 24: Simulated Vivaldi antenna (top view)

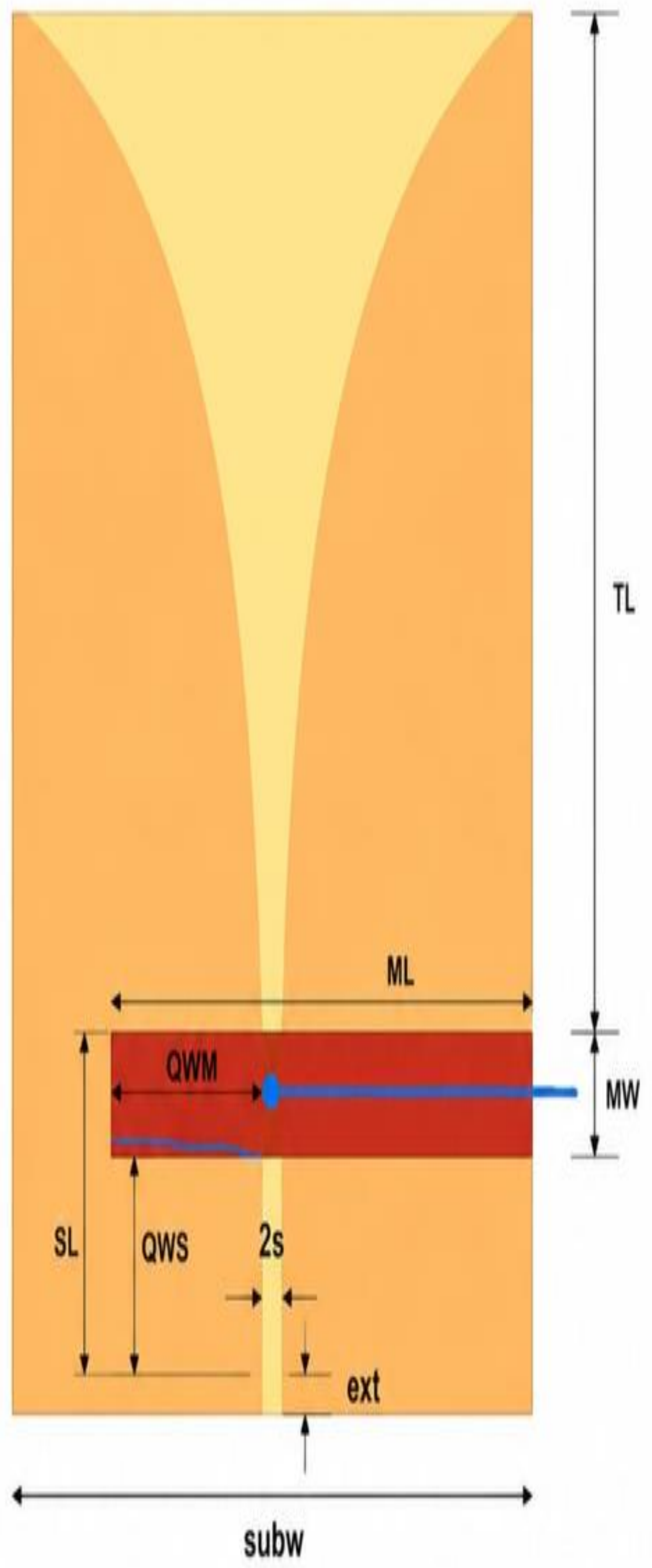


Figure 25: Antenna Prototype

Table 3 : Geometrical parameters

Name	Value	Unit
Slot gap S	1	mm
Taper length TL	50	mm
rate	60	
Slot line sL	25	mm
Slot extension ext	1	mm
CopperThickness C	0.049	mm
Substrate Thickness Sub T	0.8	mm
Microstrip width MW	2	mm
Quarter wave matching length QWM	10	mm
Substrate width subW	60	mm

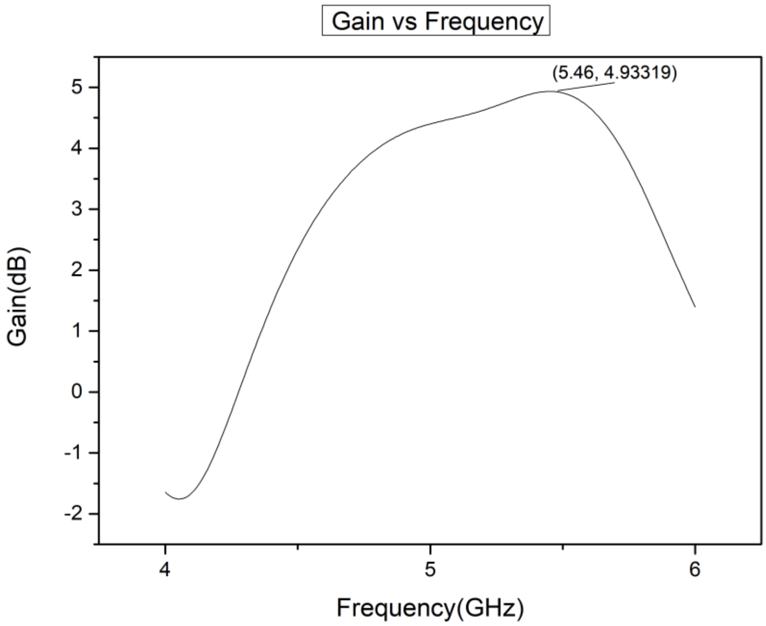


Figure 26: Gain of initial Vivaldi antenna

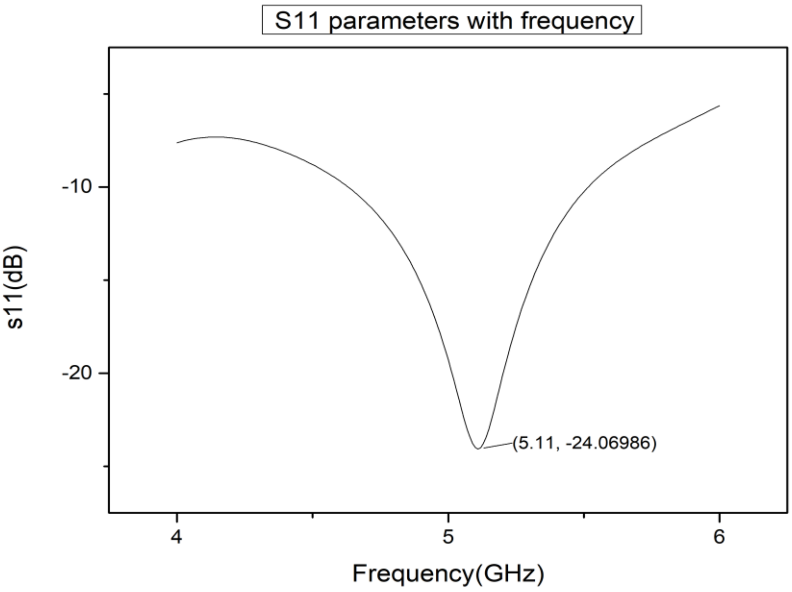


Figure 27: Return loss of initial Vivaldi antenna

3.1 Optimization

After choosing the good value for taper length (TL),we made also a parametric sweep of rate value, to improve more s11 parameter and gain:

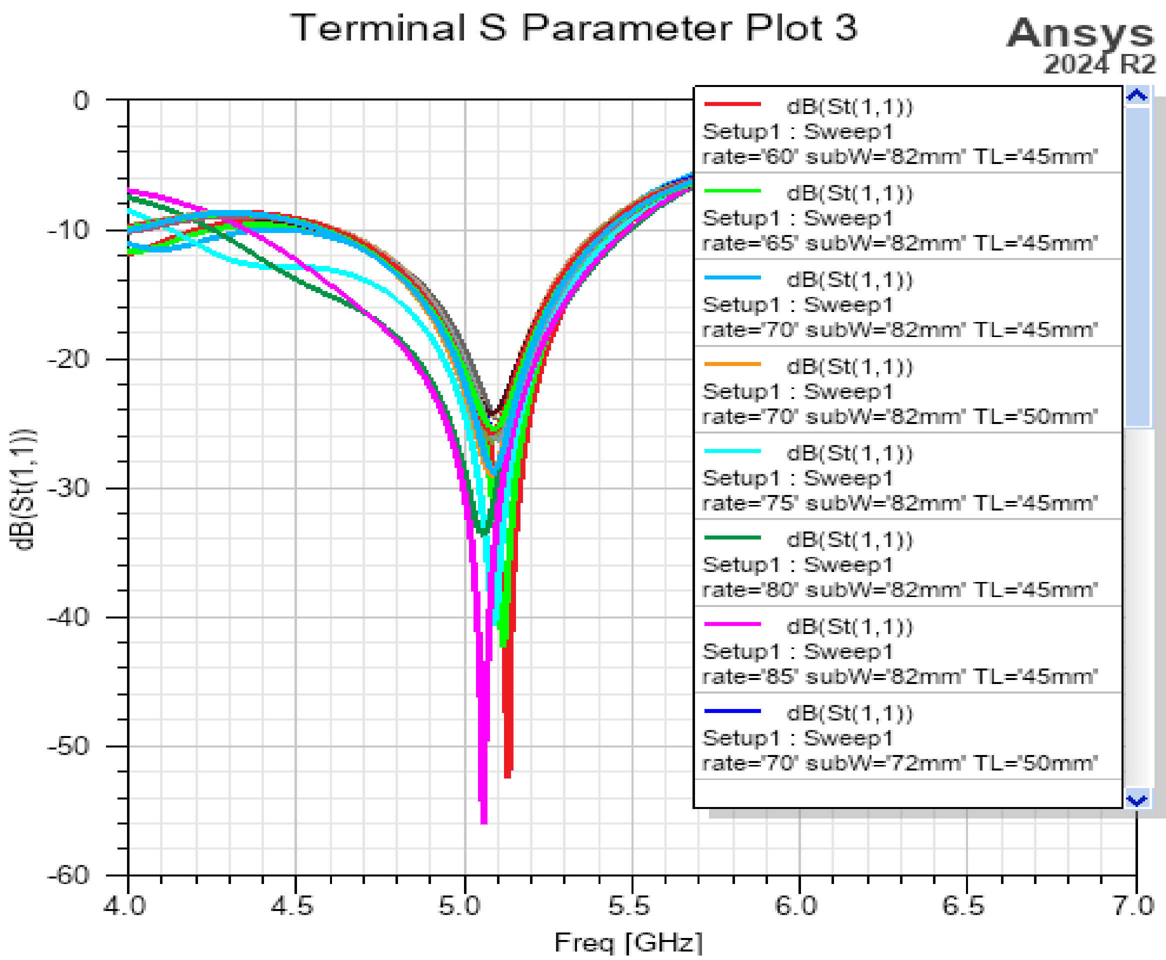


Figure 28: Parametric search of opening (rate opening parameter) of Vivaldi antenna

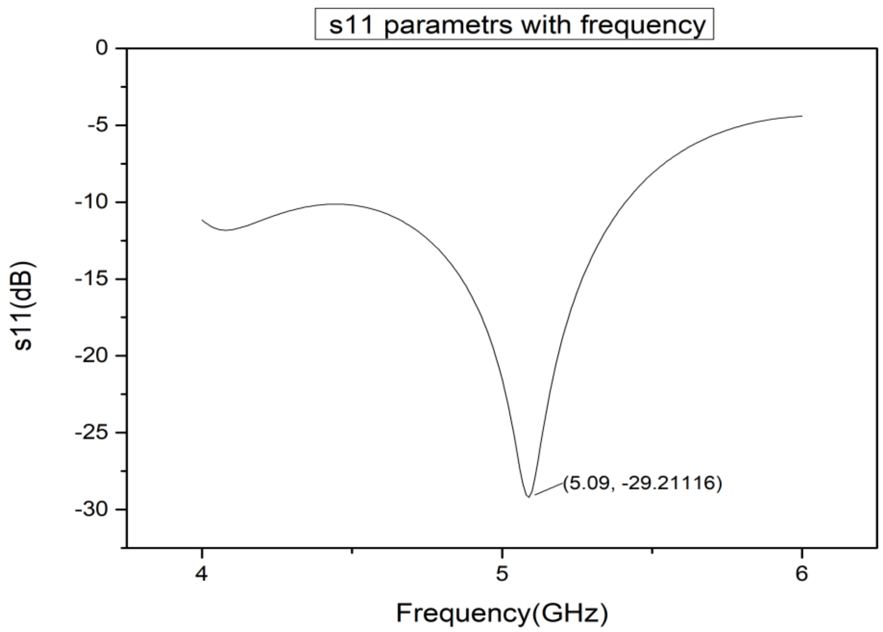
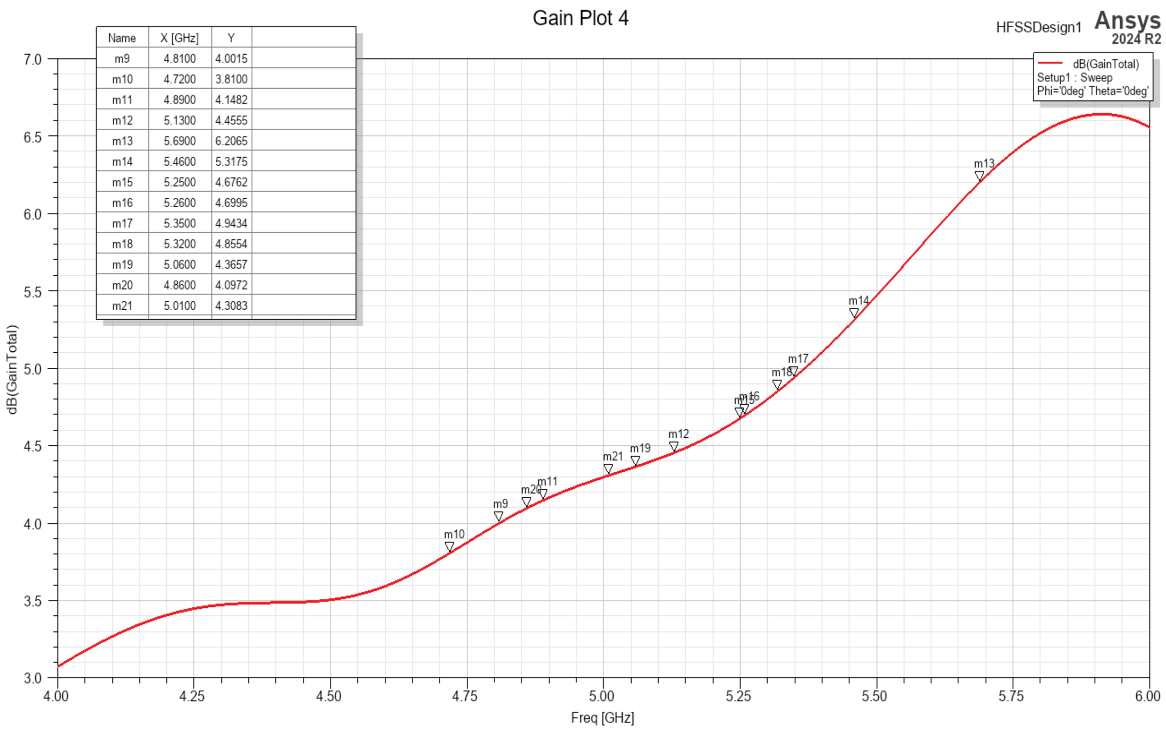


Figure 29: Return loss of optimized Vivaldi antenna



Name	X [GHz]	Y
m9	4.8100	4.0015
m10	4.7200	3.8100
m11	4.8900	4.1482
m12	5.1300	4.4555
m13	5.6900	6.2065
m14	5.4600	5.3175
m15	5.2500	4.6762
m16	5.2600	4.6995
m17	5.3500	4.9434
m18	5.3200	4.8554
m19	5.0600	4.3657
m20	4.8600	4.0972
m21	5.0100	4.3083

Figure 30: Gain of optimized Vivaldi antenna

4. ANTIPODAL VIVALDI ANTENNA (2.5 GHZ -10 GHZ)

As mentioned above, Vivaldi antennas are among the most popular broadband architectures. According to literature courses, the types of Vivaldi Antennas are the following: the tapered slot Vivaldi antenna, the antipodal Vivaldi antenna, and the balanced antipodal Vivaldi antenna [8] [9]. The basic shape of a Vivaldi antenna consists of a feed line, which is usually a microstrip line, and a radiation structure. In this part, we investigate an antipodal Vivaldi antenna, and we make its comparison with conventional Vivaldi antenna.

As the previous one, AVA antenna is designed on a Rogers 5880 substrate. In this type of Vivaldi antenna one of the layers is printed on top and the other one which is tapered in opposite direction is printed on the bottom of the dielectric substrate material [10]. This antenna can be fed easily by the connector to the two sides of the substrate material. We started with similar dimension of antenna which described for conventional (simple) Vivaldi antenna, then by long and effort consuming process of tuning, we were able to obtain the antenna with good performance.

The final dimensions of antenna are: thickness of substrate h=1.27 mm, width of feed line is 5 mm, length of antenna is 140 mm. Antenna includes two main parts: a feed line and radiation flares. The shape of the flares was chosen to be exponential. It is one of the optimal curvatures [11].

$$X(t)=t \quad , \quad Y(t)=Se^{Rt} \quad , Z(t)=0 \tag{11}$$

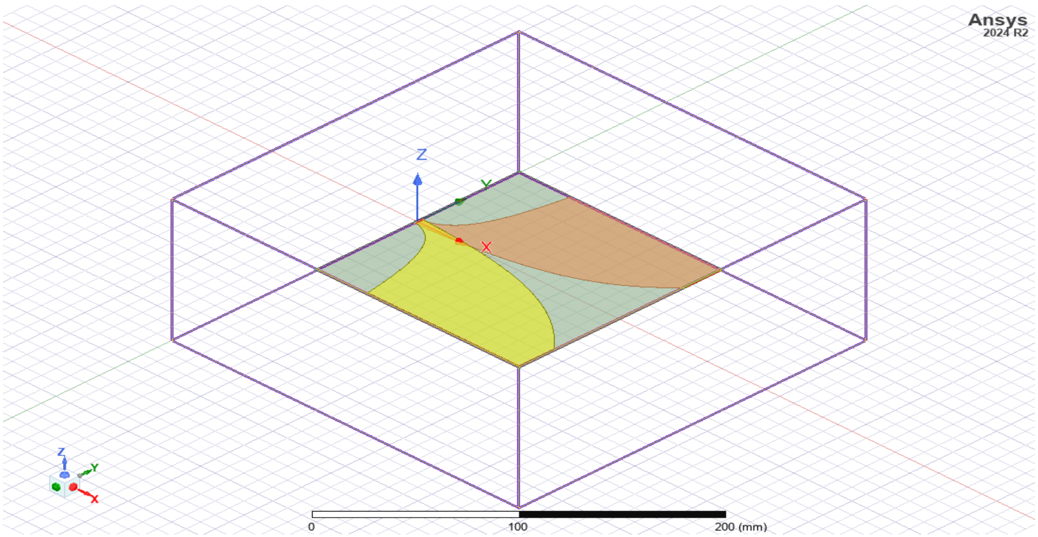


Figure 31: Simulated Antipodal Antenna

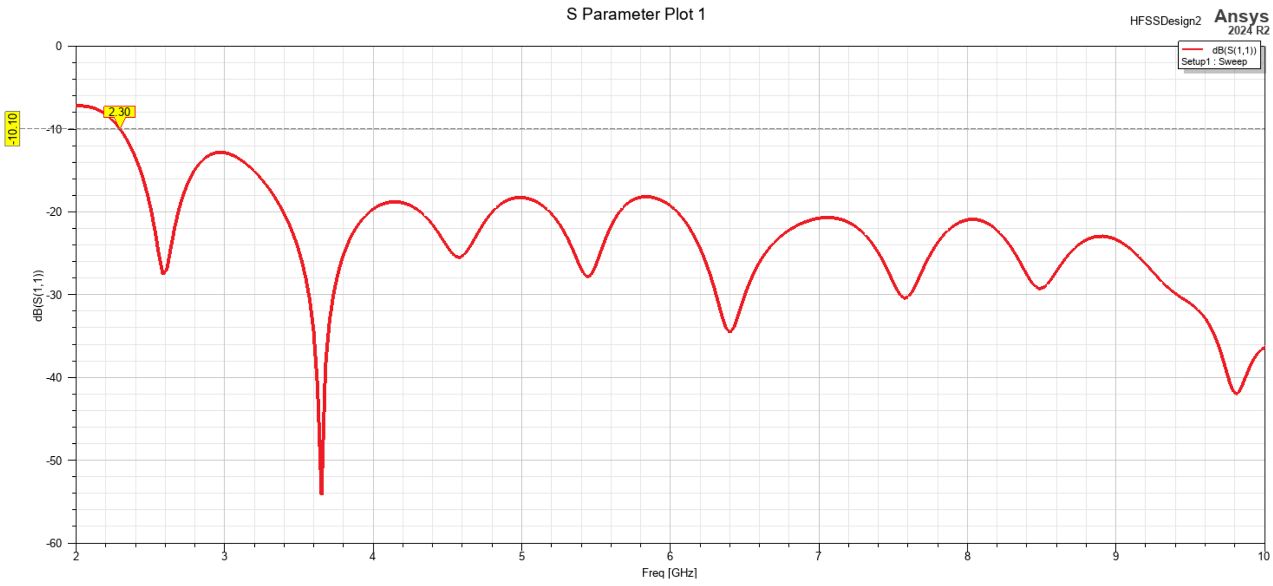


Figure 32: Return loss of Antipodal antenna

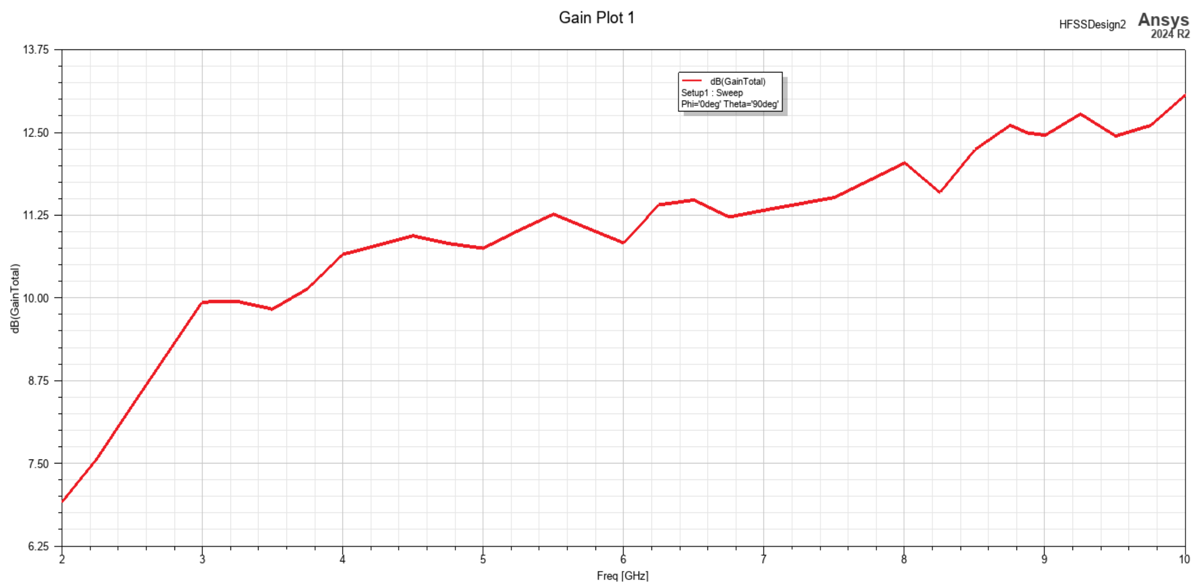


Figure 33: Gain of Antipodal Antenna

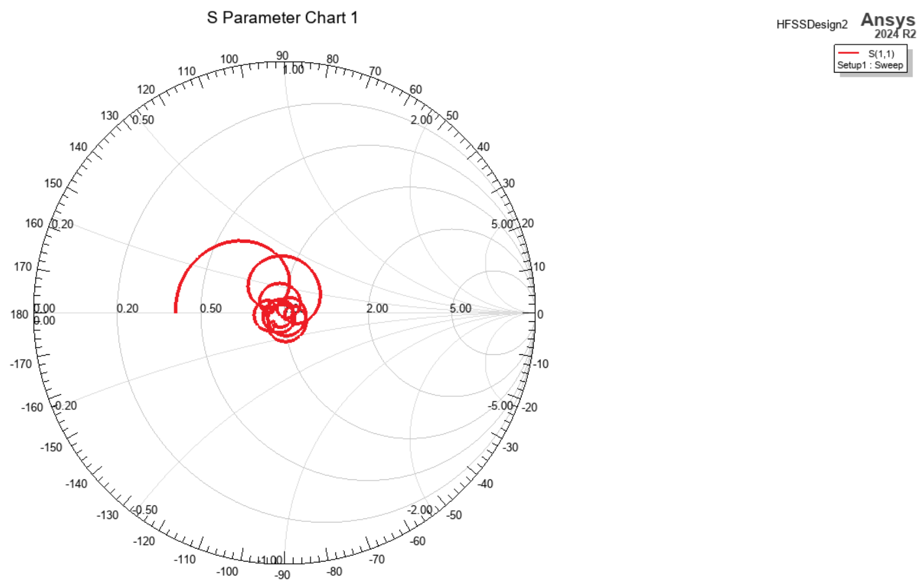


Figure 34: S parameter Chart of Antipodal Antenna

In spite of the upper frequency limit of a Vivaldi antenna is infinite in theory, the upper limit of real antenna depends on flare opening rate (or on impedance matching), and on losses in substrate. By optimization of flare shape and their dimensions, and due to the smooth transition between the radiation flares and the feeding line, our AV antenna demonstrates high bandwidth from 2.5 GHz to at least to 10 GHz. In this frequency range simulated reflection coefficient S11<10 dB. The good matching of is confirmed by Smith chart. It allows to produce the high gain in frequency range mentioned above.

Conclusion:

1. In this work, All the different antenna structures, that include a 2.4 GHz Microstrip patch antenna, a 10 GHz inset-fed microstrip antenna, a 1×2 corporate-fed antenna array, a Vivaldi antenna, and an antipodal Vivaldi antenna were successfully designed and simulated using ANSYS HFSS. The results approved good impedance matching and satisfactory radiation characteristics.

2. The 1×2 microstrip antenna array provide higher gain and directivity in compare with the single patch antenna while maintain a simple and efficient feeding network. The inset-fed technique also improved impedance matching without requiring additional matching circuits.

3. The optimized Vivaldi antenna achieved a wide operating bandwidth from 4.6 GHz to 5.6 GHz with stable end-fire radiation characteristics and good impedance matching.

4. The Antipodal Antenna achieved wide operating bandwidth from (2.5 GHz to 10 GHz) in compare with Vivaldi one, and very good impedance matching. The work also provide us with a deeper understanding of antenna design principles, feeding techniques, antenna arrays, and electromagnetic simulation using ANSYS HFSS.

Summary

This work focuses on the design, simulation, and optimization of different antenna structures using ANSYS HFSS electromagnetic simulation software, which is one of the standards for electrical engineering software.

The following antenna for GHz waveband were investigated: patch antenna with microstrip feed line (2.4 GHz), an inset fed microstrip antenna for operation at (10 GHz). Two element antenna array using a corporate feeder was implemented for 10GHz. It had shown better gain and directivity in comparison with single element antenna, in the same time it had the simple feeding line.

Also, a Vivaldi antenna was designed and optimized as an ultra-wideband (UWB) antenna. Compared to microstrip patch antennas, the Vivaldi antenna provides much wider bandwidth and stable radiation characteristics over a broad frequency range. The obtained results show good impedance matching and satisfactory radiation performance.

And last for Antipodal Antenna designed for (2.5 GHz to 10 GHz), showed very good bandwidth in compare with the simple Vivaldi antenna ,and better impedance matching.

We made a conclusion, that microstrip antennas are compact and can be the efficient solutions for resonant frequencies, while Vivaldi and Antipodal antennas demonstrates large bandwidth and end-fire radiation behavior. Also, this work provided a deeper understanding of antenna design principles, feeding techniques, array configurations, and practice of electromagnetic simulation using ANSYS HFSS.

Santrauka

Šiame darbe daugiausia dėmesio skiriama skirtingų antenų struktūrų projektavimui, modeliavimui ir optimizavimui naudojant ANSYS HFSS elektromagnetinio modeliavimo programinę įrangą, kuri yra vienas iš elektrotechnikos programinės įrangos standartų.

Buvo tiriamos šios GHz dažnių juostos antenos: pleistro antena su mikrobangų juostos tiekimo linija (2,4 GHz), įdėklo tipo mikrobangų juostos antena, skirta veikti (10 GHz) dažniu. 10 GHz dažniui buvo įdiegtas dviejų elementų antenų masyvas, naudojant korporacinį tiekimo liniją. Jis parodė geresnį stiprinimą ir kryptingumą, palyginti su vieno elemento antena, tuo pačiu metu turėdamas paprastą tiekimo liniją.

Taip pat buvo suprojektuota ir optimizuota „Vivaldi“ antena kaip ultraplačiajuostė (UWB) antena. Palyginti su mikrobangų juostos pleistro antenomis, „Vivaldi“ antena pasižymi daug platesniu pralaidumu ir stabiliomis spinduliuotės charakteristikomis plačiame dažnių diapazone. Gauti rezultatai rodo gerą varžos atitikimą ir patenkinamas spinduliuotės charakteristikas.

Ir galiausiai, antipodinė antena, skirta (2,5 GHz–10 GHz) dažnių juostai, parodė labai gerą pralaidumą, palyginti su paprasta „Vivaldi“ antena, ir geresnį varžos atitikimą.

Padarėme išvadą, kad mikrojuostelinės antenos yra kompaktiškos ir gali būti efektyvūs rezonansinių dažnių sprendimai, o Vivaldi ir Anitpodal antenos pasižymi dideliu pralaidumu ir spinduliuotės savybėmis. Be to, šis darbas suteikė gilesnį supratimą apie antenų projektavimo principus, maitinimo būdus, gardelių konfigūracijas ir elektromagnetinio modeliavimo praktiką naudojant ANSYS HFSS.

References

[1] Antenna-Theory.com, "Microstrip (Patch) Antennas," Antenna-Theory.com, [Online]. Available: https://www.antenna-theory.com/antennas/patches/antenna.php. [Accessed 3 2026].

[2] V. antenna, "https://www.antenna-theory.com/antennas/aperture/vivaldi.php," [Online].

[3] ANSYS, "Ansys High Frequency Structure Simulator (HFSS) Tutorial," 2018.

[4] C. A. Balanis, Antenna Theory:Analysis and Design, Hoboken,NJ: Wiley, 2016.

[5] D. M. Pozar, Microwave Engineering, 4 ed., Wiley, Ed., Hoboken, NJ, 2012.

[6] M. I. Hasan, R. Azim, M. R. Islam, M. T. Islam and Liton chandra Paul, "Design of High Gain Microstrip Array Antenna and Beam Steering for X-Band RDAR Application," in *2020 Joint 9th International Conference on Informatics ,Electronics and Vision (ICIEV)*, 2020.

[7] M. L. Calculator, "https://www.rf.net.tw/Design_tools/Microstrip-Line-Calculator_e.html," [Online].

[8] F. Peng, J. Yong-chang, H. Wei and Z. Fu-shun, "A Miniaturized Antipodal Vivaldi Antenna with Improved Radiation characteristics," *IEEE Antennas and Wireless Propagation Letters*, pp. 127-130, 2011.

[9] Z. Aaron, K. Tutku and T. Erdem, "A Small Antipodal Vivaldi Antenna for Ultrawide-Band Applications," *IEEE Antennas and wireless Propagation Letters*, vol. 7, pp. 656-660, 2008.

[10] https://www.radartutorial.eu. [Online].

[11] G. Teni, N. Zhang, J. Qiu and P. Zhang, "Research on a Novel Miniaturized Antipodal Vivaldi Antenna with Improved Radiation," *IEEE Antennas and Wireless Propagation Letters*, pp. 417-420, 2013.