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Design and Simulation for Compact Microstrip Resonant Patch Cell Antenna

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ABSTRACT: Microstrip techniques are frequently used in spectral efficiency because they are lightweight, compact, conformable to planar and non-planar surfaces, and simple and affordable to manufacture using advanced printed-circuit technology.Concept of microstrip radiators was first proposed in 1953, but it was only in 1970s that practical antennas were fabricated. With features such as low cost, lightweight and Integra table on board containing RF or microwave circuits, they become popular with circuit designers. The main objective of this paper is to design and simulate a single element for Compact Microstrip Resonant Patch Cell Antennaof different shapes usingAgilent's Advanced DesignSystem 2015 adesign software\momentum simulation. These are: rectangular, square, circular,circular ring and non-uniform polygon. The other specifications are displayed with each design. The ADS results give the return loss, radiation pattern, polarization, power, absolute fields calculated parameters and some other interesting outputs that can be analyzed. The theory of microstrip antenna is simply given in this paper and the factors affecting the antenna design are explained. The design steps of below types of antenna are given and for the others antenna.

Keywords: Mobile antennas, Multifrequency antennas, Antenna measurements, Antennas and propagation, Frequency, Acoustics, Acoustical engineering, Antenna arrays, Laboratories, Signal processing, CMRC: COMPACT MICROSTRIP RESONANT CELL.

I. INTRODUCTION

Wireless communications have been one of the highest growing markets over the past two decades. The growth in the market has been continuous both in terms of the number of subscribers and number of telecommunications services offered. By April 2002, the number of world cellular subscribers reached 1 billion. To connect people and improve the overall quality of life, new third generation wireless systems have been developed that offer new multimedia capabilities, better reliability, improved battery life and efficient and more cost-effective solutions. As the wireless communication continues to develop very rapidly, the number of base station antennas has grown as well. The latest generation of wireless networking networks would necessitate new and upgraded base station antennas in the coming years. New base station antennas would be used to replace the existing sectored panel antennas and reduce the number of antennas on a base station. They will operate in the frequency band (1920 - 2170 MHz) for WCDMA or may even be dual-band or multi-band and be able to cover some or all of GSM (890 - 960 MHz), GSM1800 (1710 to 1885 MHz) and CDMA (824 – 894 MHz and 1850 – 1990 MHz) frequency bands.

II. BASIC ANTENNA AND MICROSTRIP CHARACTERISTICS

Basic antenna theory will be discussed and recommendations, supported by an understanding of the fundamentals of microstrip lines and microstrip antennas. Before going on to a more in-depth understanding of how microstrip antennas work, it's important to comprehend these fundamental principles.

2.1 Basic Antenna Theory

An antenna is a means for transmitting or receiving radio waves. It can take the form of apiece of metal rod or just a cooper wire and many other forms.Fundamentals Parameters of Antennas. Some fundamental parameters of an antenna are as follows:

1. Radiation Pattern
2. Radiation Intensity
3. Beamwidth
4. Field Region
5. Antenna Efficiency
6. Gain
7. Bandwidth
8. Polarization

These fundamental parameters will be studied to understand what determines anefficient antenna. The definitions of these parameters are explained in the following.

A.1 Radiation Pattern

The radiation pattern of an antenna is a geometric or mathematical representation of its radiation properties as a function of space coordinates. It's estimated far away and viewed as a function of directional coordinates. Antenna radiation's properties include power flux density, radiation rate, field frequency, directivity, phase, and polarization. In a radiation map, an antenna's radiation pattern as seen below, with three lobes.

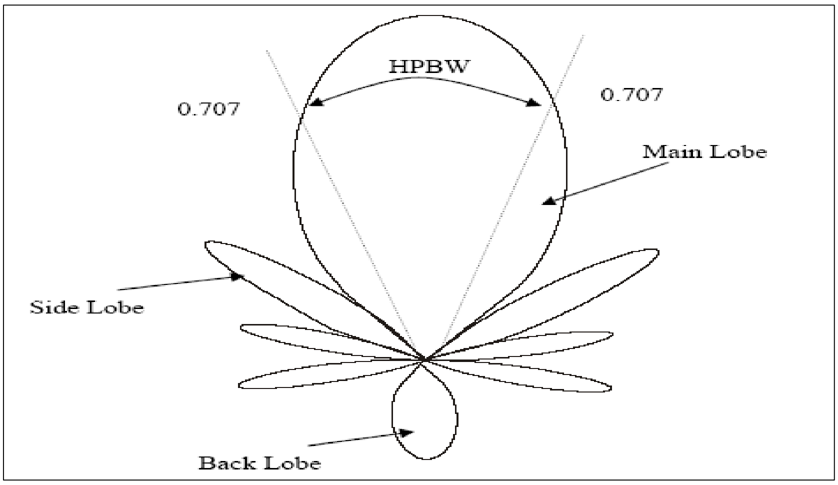

Figure 2.1:Radiation Pattern of an antenna.

Major/Main Lobe – The radiation lobe bearing the highest radiation path.
Radiation lobe in any direction other than the expected lob direction is known as a side lobe. It is normally situated next to the main lobe which takes up the entire hemisphere in the direction of the main beam.
A back lobe is a radiation lobe with a 180o axis in reference to the main beam. A small lobe that occupies the hemisphere in the opposite direction of a main lobe is generally referred to as a minor lobe.

A.2 Radiation Intensity
Radiation intensity is defined as the power radiated from an antenna pre unit solidangle. The mathematical form is
$U = r^2 W_{rad}$
U = radiation intensity (w/unit solid angle)
W_{rad} = radiation density (W/m^2)

A.3 Beamwidth

The beam width of an antenna radiation pattern is defined as the angular separationbetween two identical points on opposite side of the pattern maximum. The most widely used beam width is the Half-Power Beam width (HPBW) which is defined as: “in a plane containing the direction of the maximum of a beam, the angle between two directions in which the radiation intensity is one-half of the beam”. The beam width is inversely proportional to the side lobe.

A.4 Field Region

There are three regions surrounding an antenna naming reactive near field, radiatingnearfield (Fresnel) and far-field (Fraunhofer). They are designated to identify the field structure in each. Reactive near field which is taken to exist at a distance $R < 0.62\sqrt{D^3/\lambda}$, is defined as “that portion of the of the near-field region immediately surrounding the antenna wherein the reactive field predominates”. Radiating near-field is defined as “that region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon the distance from the antenna”. It lies in the region between $R \geq 0.62\sqrt{D^3/\lambda}$ and $R < 2D2/\lambda$. The last field which is the far-field is defined as “that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna” It lies in the region $R \geq 2D^2/\lambda$ and infinity.

A.5 Antenna Efficiency
An antenna’s efficiency can be determined by the following equation.

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$e_0 = e_r e_c e_d$
Where e_0 = total efficiency
e_r = reflection efficiency = $1-|\Gamma|^2$ where $\Gamma = (Z_{in} - Z_o)/ (Z_{in} + Z_o)$
Z_{in} = input impedance of antenna
Z_o = characteristic impedance of transmission line
e_c = conduction efficiency
e_d = dielectric efficiency

A.6 Gain

One way to describe the performance of an antenna is the gain. The gain of an antenna takes into account the efficiency of the antenna and its directivity. Inequation form the gain of an antenna is as follows:
Gain = 4π (radiation intensity/total input power)

Most of the time, relative gain which is defined as "the ratio of the power gain in agiven direction to the power gain of a reference antenna in its referenced direction" is used. The reference antenna used is normally a dipole horn or any antenna which gain is known or can be calculated.

A.7 Bandwidth

Bandwidth is defined as the range of frequency that the performance of theantenna with respect to some characteristic, conforms to a specific standard. Fornarrowband antennas like the microstrip antenna, bandwidth is expressed as a percentage of the frequency difference over the center frequency of the bandwidth. There is no unique characteristic of the bandwidth as the characteristics of each antenna is not the same.

A.8 Polarization

"The polarization of the wave radiated by the antenna" is the concept of an antenna's polarization in a given direction. Where the direction is not defined, polarization is taken in the direction of maximal gain. Polarization is a direction-dependent property that can be defined as linear, spherical, or elliptical.

2.2 Microstrip

In its simplest form, a microstrip is basically made up of a conducting strip on top of a dielectric substrate with the other side of the substrate supported by a ground plane. The most important parameters to the microstrip are the characteristic impedance Z_o and the effective dielectric Constant ε_{re} .

2.3 Single Microstrip Line

A basic microstrip transmission lines consist of a conductive strip and a ground lane separated by a dielectric as shown in the figure below.

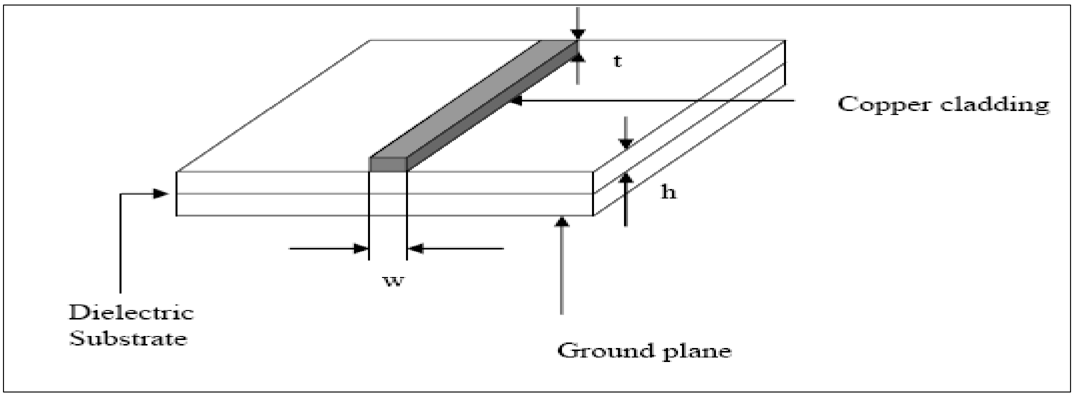

Figure 2.2: Single microstrip transmission line

Figure 2.2 illustrates the general layout of the microstrip line. A conducting strip with a diameter W and a thickness t makes up the microstrip line. It sits atop a dielectric substrate with a relative dielectric constant of r, a thickness of h, and a ground plane underneath it. We must remember how the single transmission line works since it is the cornerstone of microstrip. Microstrip transmission characteristics are characterized by two parameters: the effective dielectric constant re and the characteristic impedance, as previously described.Synthesis and measurement methods will contribute to the design of microstrip antennas. Synthesis equations are used to calculate the width and length dimensions, while analysis equations are used to determine the impedance.

2.4 Microstrip Antenna

In the most basic form, a microstrip antenna is really a metallic patch on a ground substrate that is an extension of a microstrip transmission wire. Low profile, conformable to

planar and non-planar surfaces, affordable and easy to produce, and flexible in terms of resonant frequency, polarization, pattern, and impedance are all advantages of microstrip antennas. The microstrip antenna has certain drawbacks as well. Low reliability, high Q, resulting in a small frequency bandwidth, low power, poor scan accuracy, and spurious feed radiation are just a few of them.2.4.1 Operation of Microstrip Antennas
So, how exactly does a microstrip antenna part? Figure 2.3 depicts a simple rectangular patch microstrip antenna.

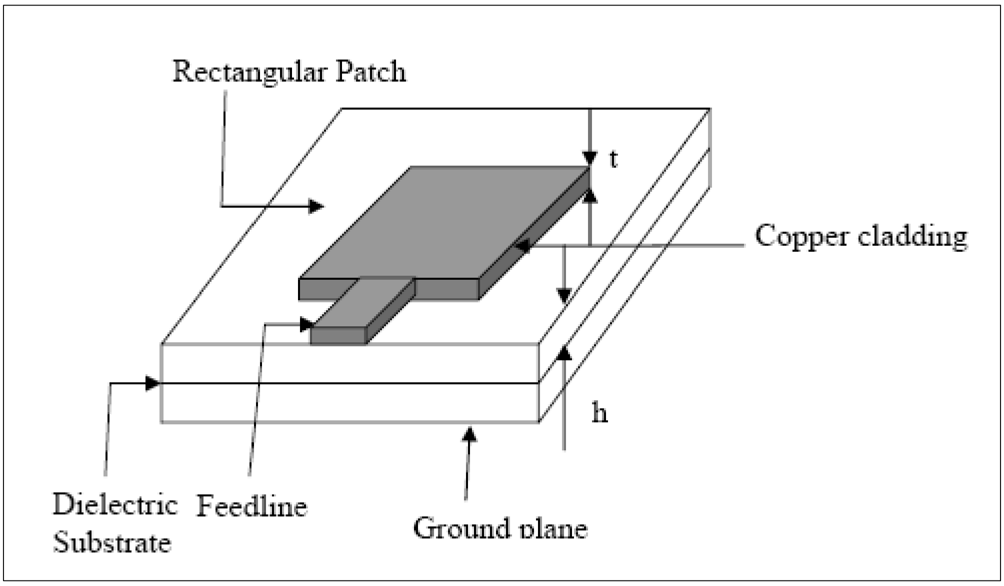

Figure 2.3: Rectangular patch antenna

When performing in the transmitting mode, current is excited on the feedline to the patch and a vertical electric field is generated between the patch and the ground plane, assuming a voltage input at the feedline. As a consequence, the patch part resonates at a certain wavelength, resulting in radiation.

2.4.2 Shapes of Microstrip Antenna

Patch antennas are also used to characterize microstrip antennas since the radiating portion is typically a patch. This radiating patch can come in a variety of shapes, including rectangle, rectangular, circle, triangular, and more. Below are diagrams of two widely used patch shapes: rectangular and circular patches.

2.4.2.1 Rectangular Patch Antenna

A simple rectangular patch antenna is shown in figure 2.4 below.

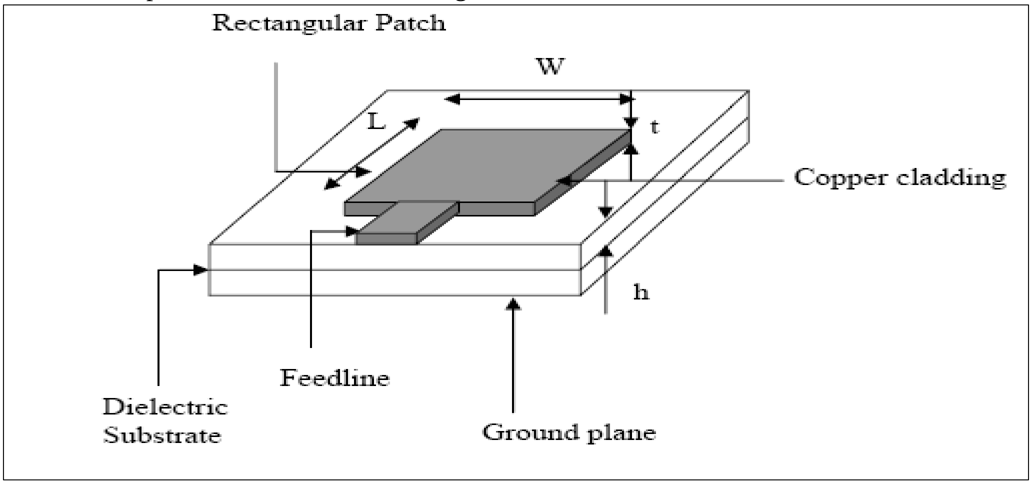

Figure 2.4: Rectangular shape patch antenna

2.4.2.2 Circular Patch Antenna

Another shape of a microstrip antenna is the circular patch antenna and is shown in this figure 2.4.

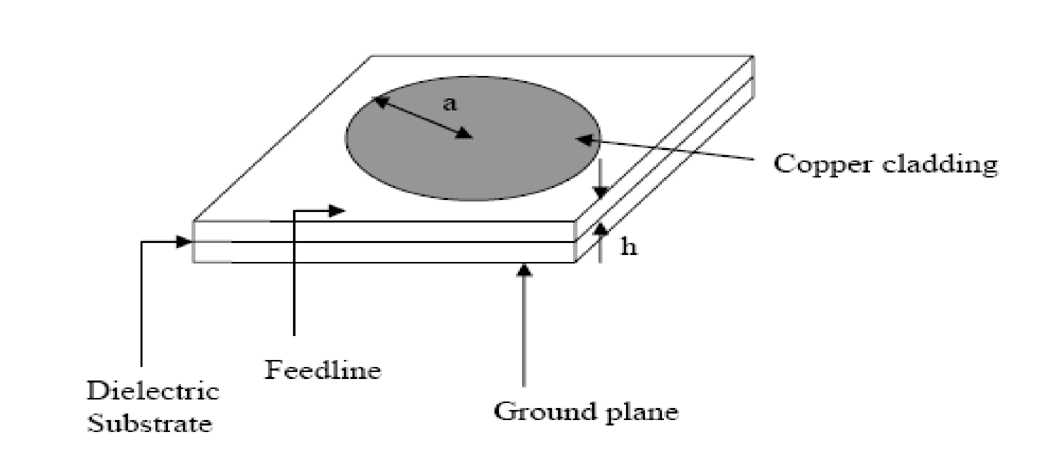

Figure 2.4: Circular shape patch antenna

III. COMPACT MICROSTRIP RESONANT CELL DESIGN (CMRC).

Due to various their small scale, light weight, and low expense, microstrip antennas are widely used in satellite and wireless mobile communication systems. Microstrip antennas can be excited in a variety of ways, but attaching the microstrip line directly to the patch edge is a good option for coplanar applications. This application has significant practical limitations because resonant microstrip antenna input impedances usually range from 150 to 400 ohm, whereas the desired impedance is 50 ohm. Microstrip antennas have the bonus of being easy to incorporate into RF systems.Despite their widespread use and ease of manufacturing, active integrated antennas are subject to fundamental shortcomings such as harmonic radiation. As a consequence, a microstrip antenna-based operating device needs very low harmonic frequency radiation. External filters capable of rejecting bogus pass-bands would usually be cascaded to reject these harmonics, but this approach increases the RF front-end size and results in an additional insertion loss.Photonic bandgap (PBG) architectures are becoming more common in microwave and millimeter-wave implementations. A defected ground structure (DGS) unit cell has been proposed as a new microstrip antenna matching technique. In addition, using a variety of PBG structures, many techniques for minimizing higher-order harmonics in microwave amplifiers, antennas, and filters have been reported. Conversely, there's really generally no literature on RF systems with PBG frameworks for both impedance balancing and harmonic reduction. Two new microstrip antennas based on a one-dimensional (1-D) PBG structure are introduced in this paper. This approach obtained impedance matching, which reduces unnecessary harmonic emission from the transmitter's front end.Since the additional effective inductance of the PBG structure influences the microstrip line's unique impedance, a microstrip line with exceptionally high impedances may be quickly realized. As a result, a basic PBG microstrip thread can be used to feed microstrip antennas. Our PBG microstrip line has a propagation loss similar to a normal line. The reflection coefficients and radiation properties of harmonic signal suppression will be discussed and considered for the study.

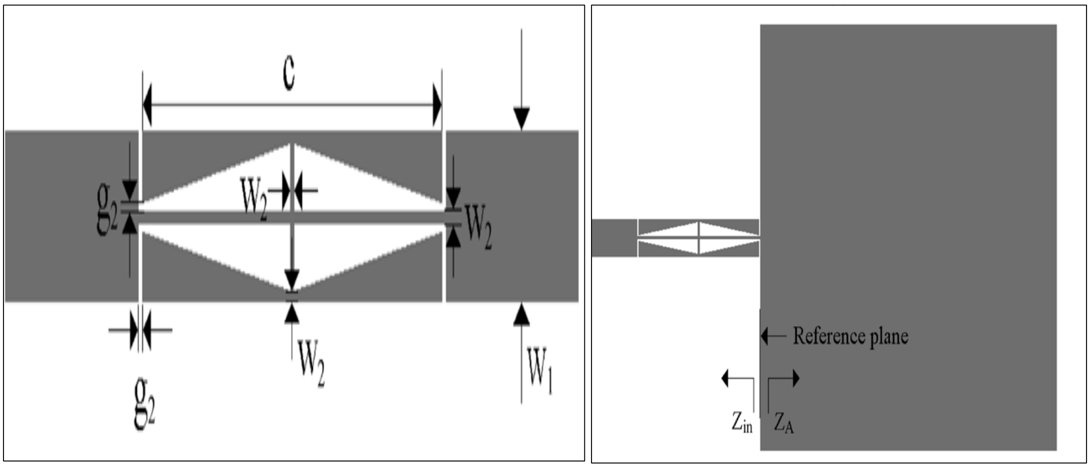

Fig (3.1) &(3.2): CMRC structure

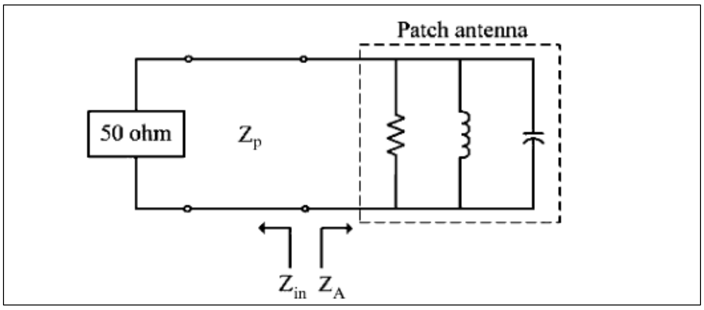

Fig. 3.3. The antenna's equivalent circuit is seen. in Fig. 3.1

A CMRC design is used as the matching network of a microstrip antenna at the first resonant frequency. At frequencies below cutoff, the propagation properties can be fine-tuned by adjusting the PBG structure's dimension. The PBG structure also has the advantage of being able to generate microwave circuits with built-in spurious rejection. First and foremost, because of its simple structure and low insertion loss, the PBG strategy is appropriate for microwave circuits.Second, the large and deep stopband of the PBG structure can be used to avoid spurious resonances at harmonic frequencies. A microstrip line with a PBG structure in a microstrip antenna is used to remove harmonics at the second resonant frequency. Since the dependence of the position and orientation of the microstrip line on the propagation constant is totally eliminated with respect to the axes of periodicity of the PBG ground plane, a one-dimensional (1-D) PBG is more robust in practical circuit implementations than a two-dimensional (2-D) configuration.In our testing, the proposed antennas achieve impedance mating and deep suppression of the second harmonic, makes them suitable for use in microwave integrated circuits (MICs). An LC equivalent circuit for compact microstrip resonant cell (CMRC) structure is derived as a result of the preceding discussions, as seen in Figure 1. (3.3). Because of these inductances, microstrip lines have a much higher signature impedance than regular lines with the same conductor diameter. It is ideally suited to lightweight and low-cost active circuit applications at microwave frequencies.

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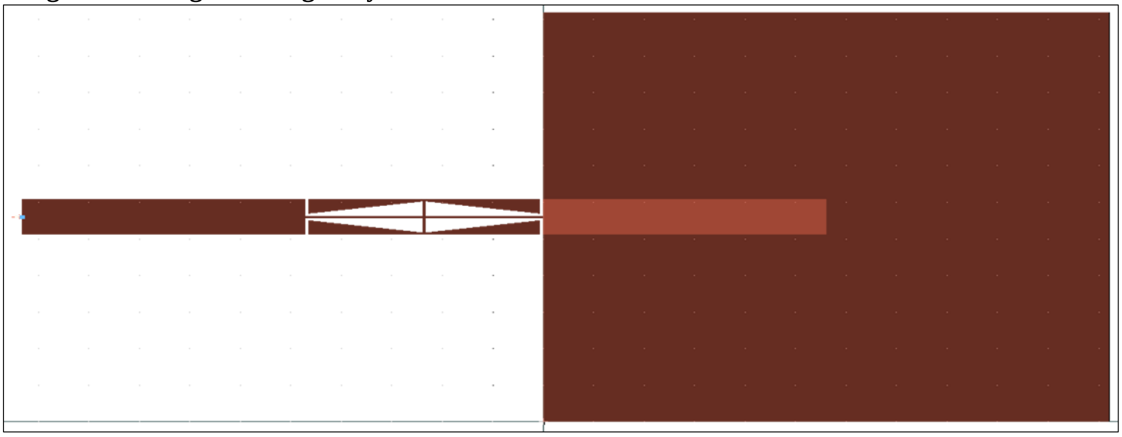
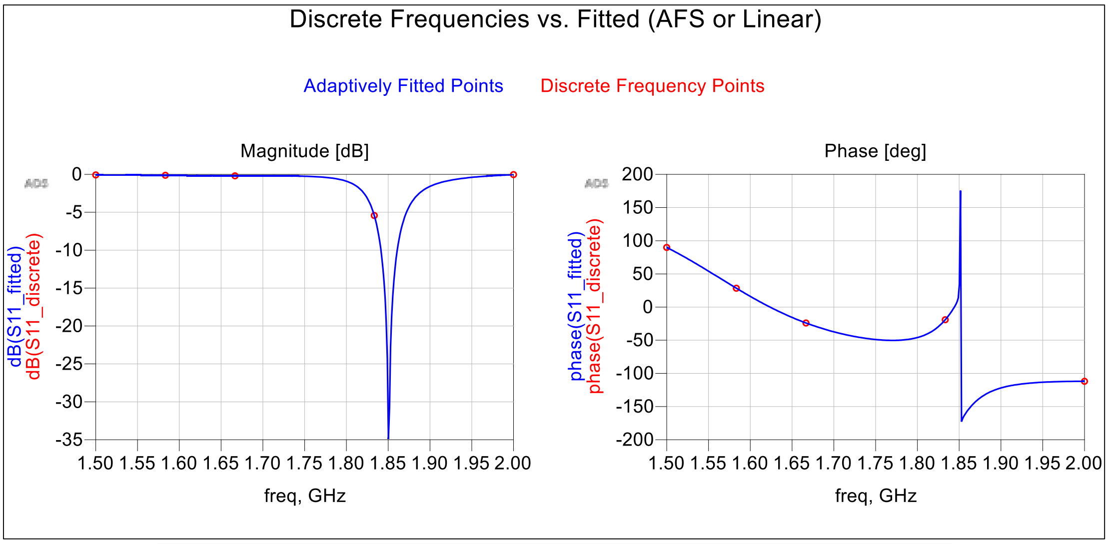
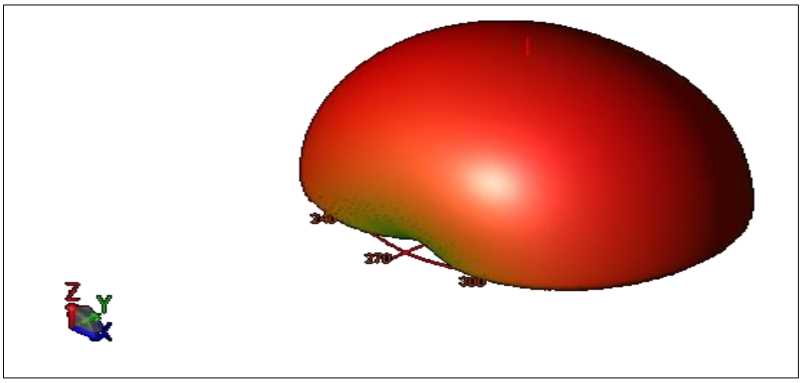
Different Design for CMRC:

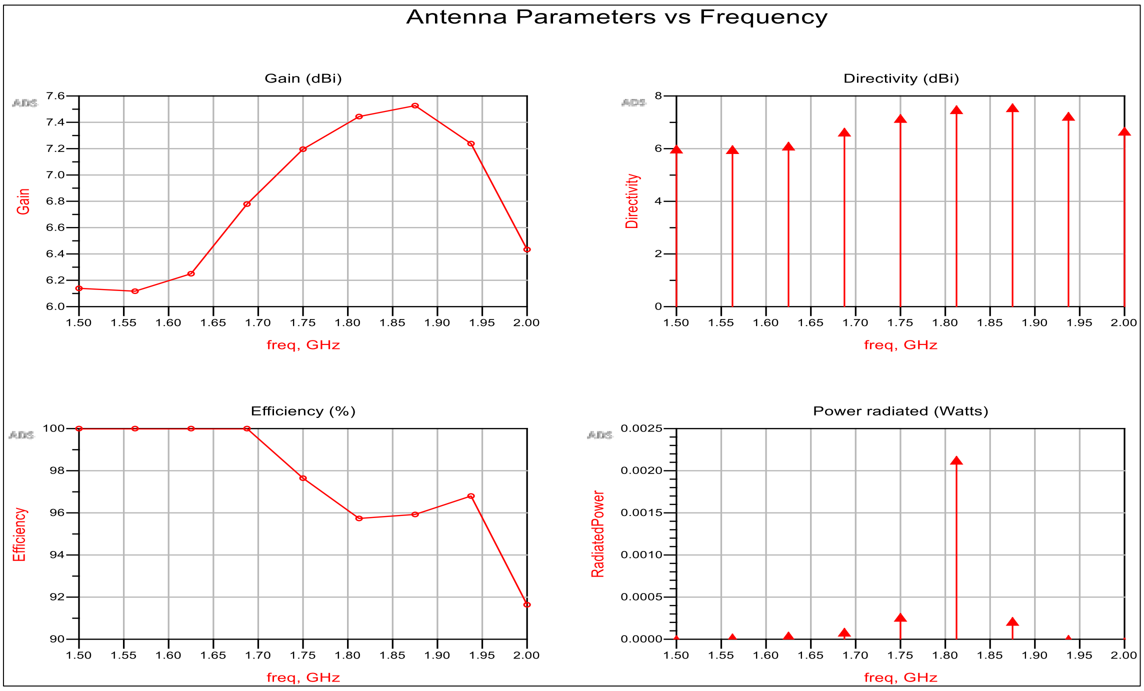
1. **Original Rectangular design -layout**

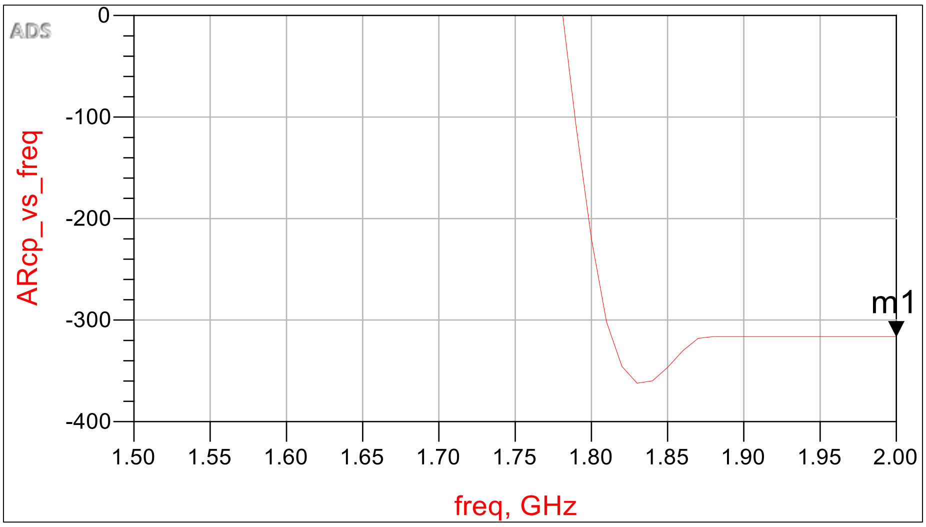






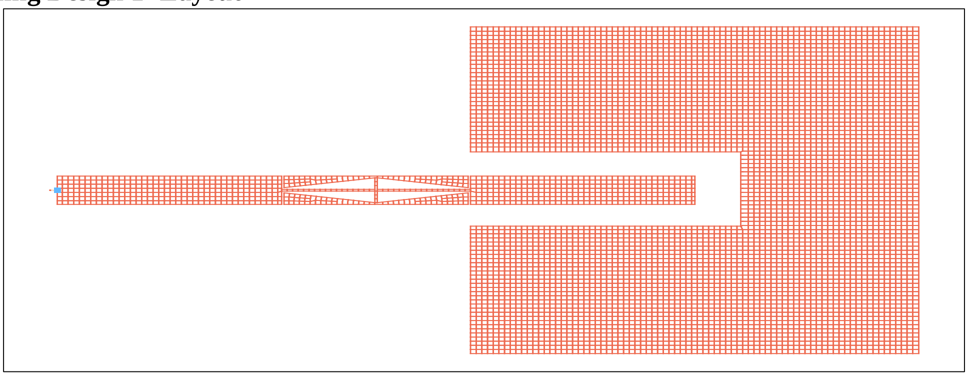
Radiation Pattern





Axial ration versus Frequency

2. Matching Design 1 -Layout



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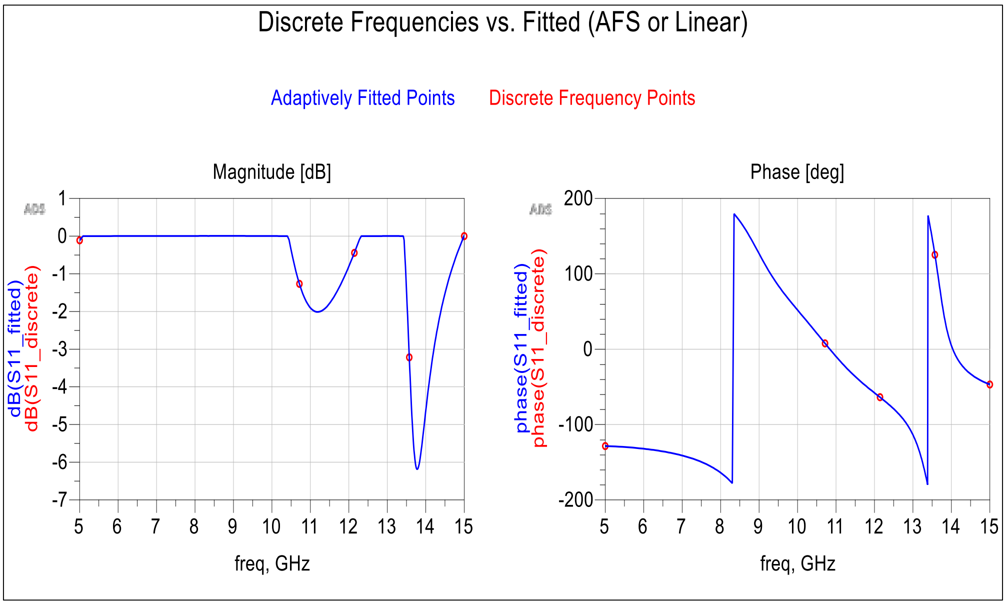
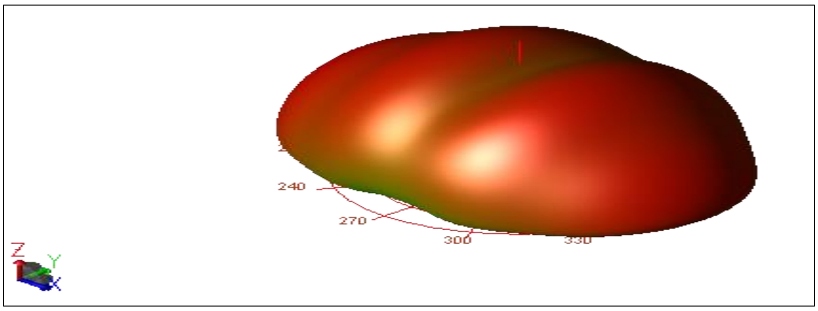
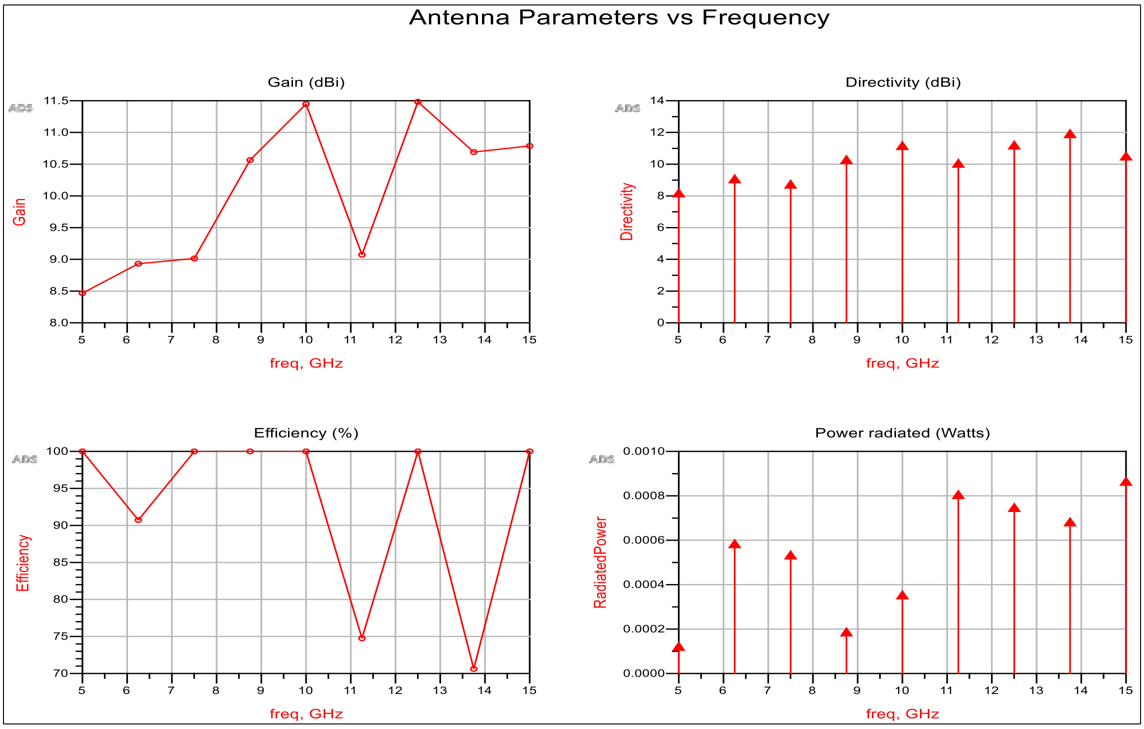




Radiation Pattern



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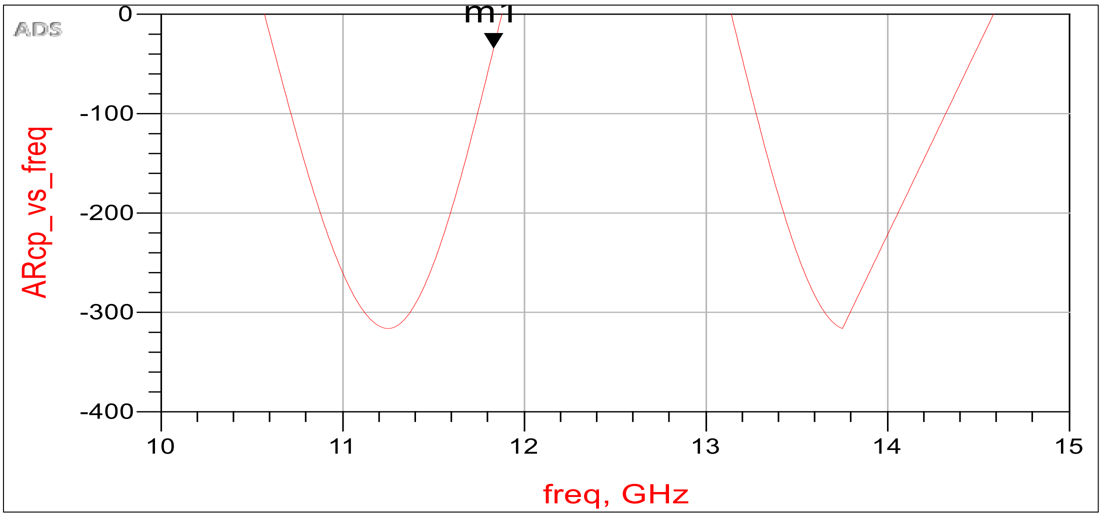
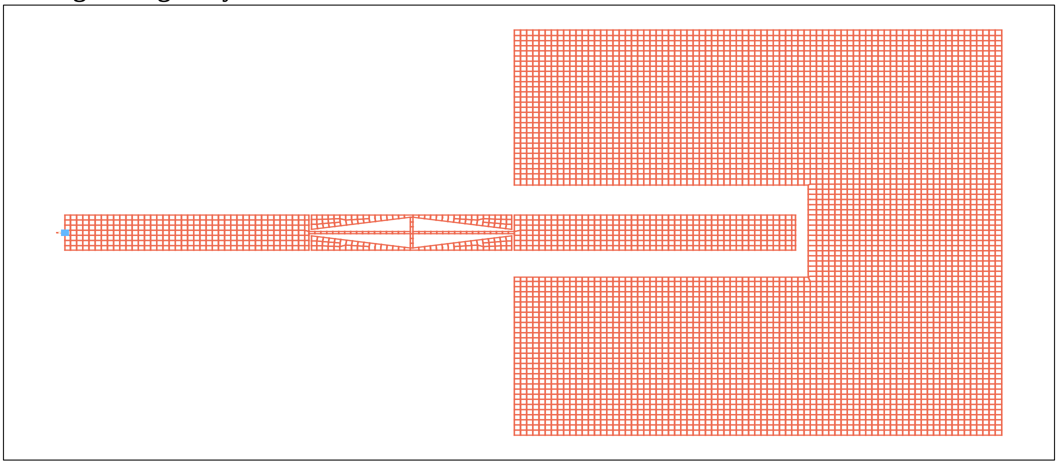
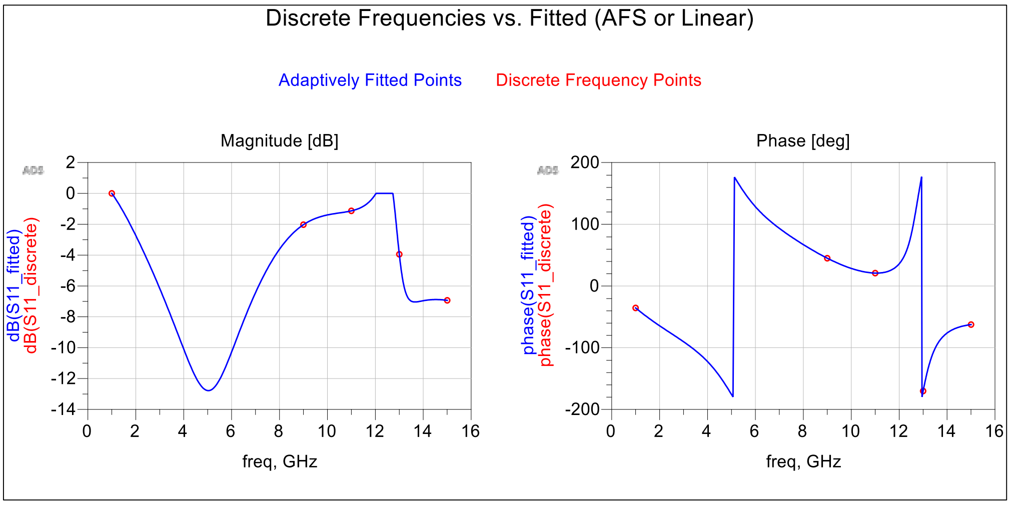
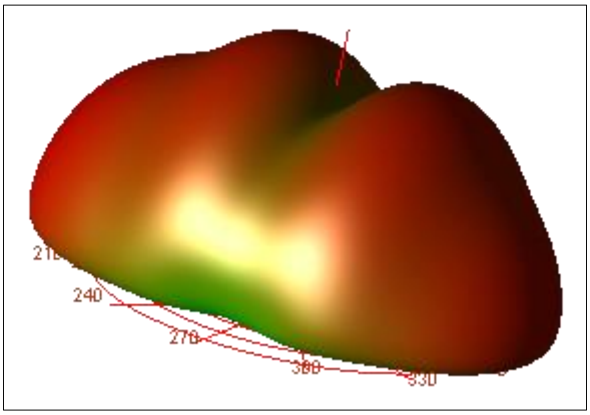


Axial ration versus Frequency

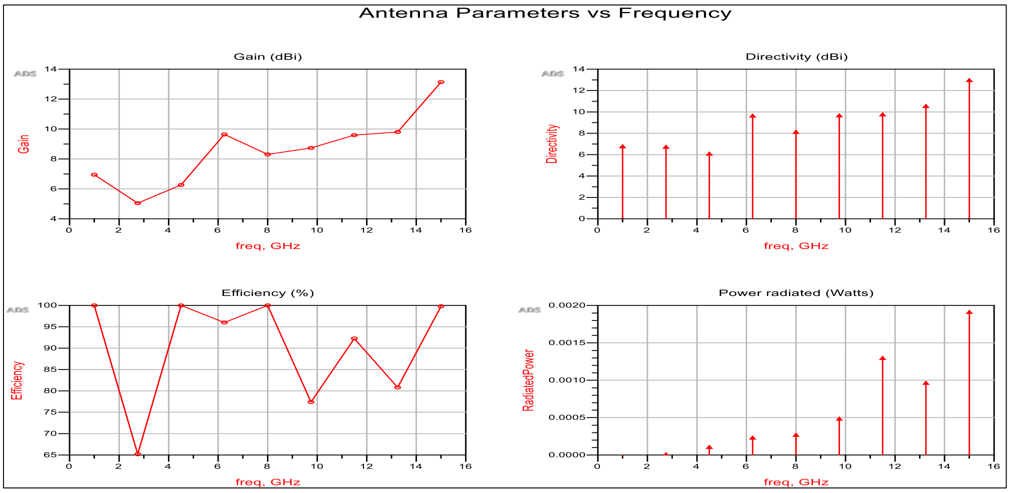
3. Matching 4 design -layout

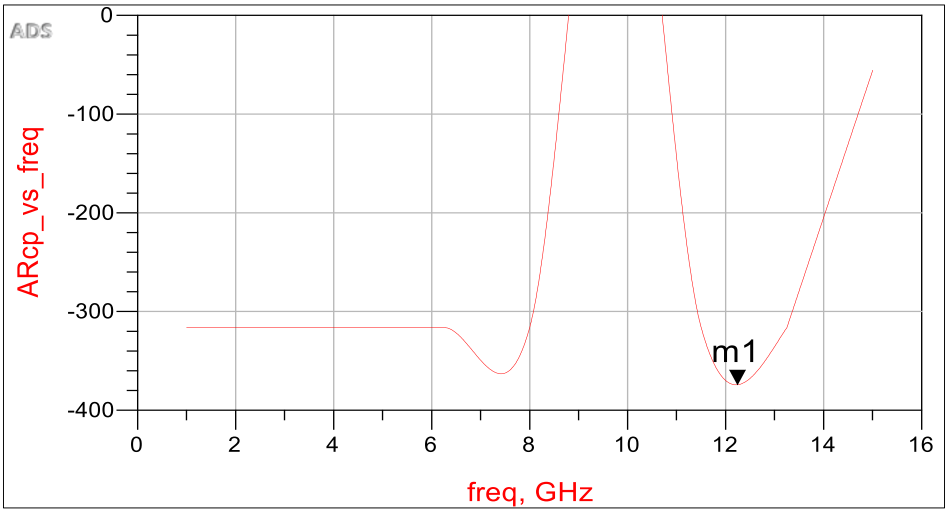






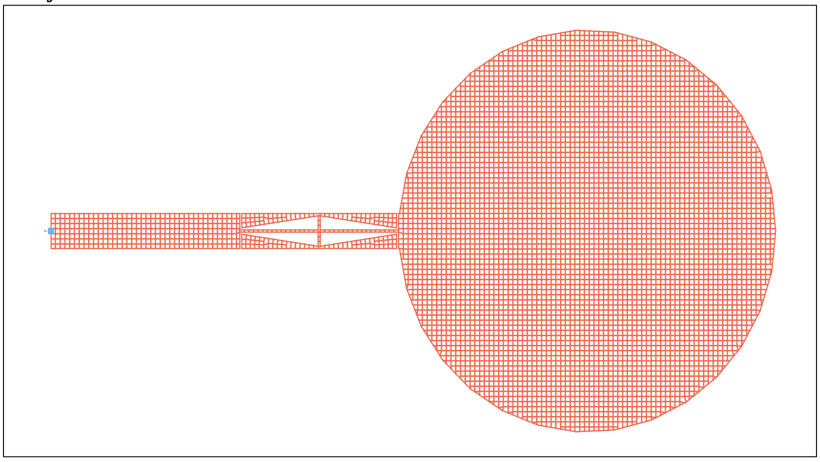
Radiation Pattern

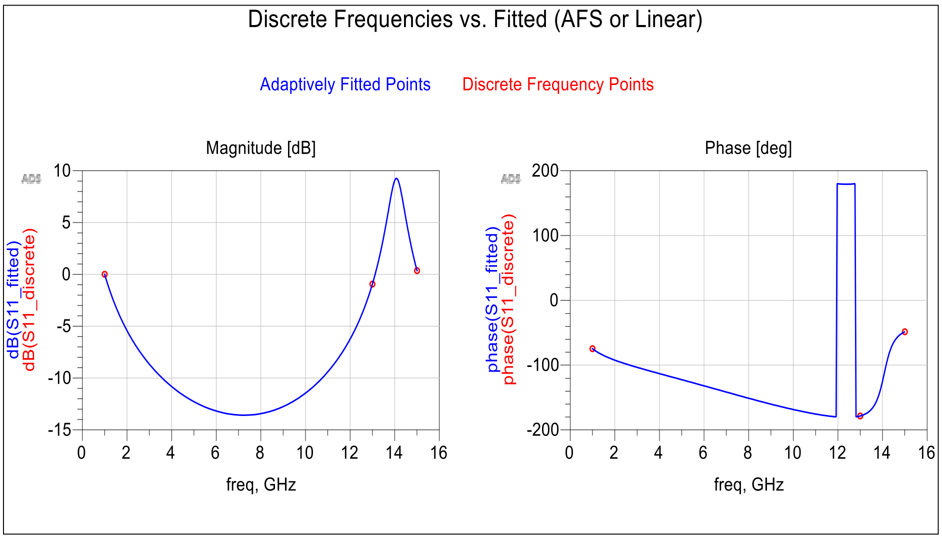


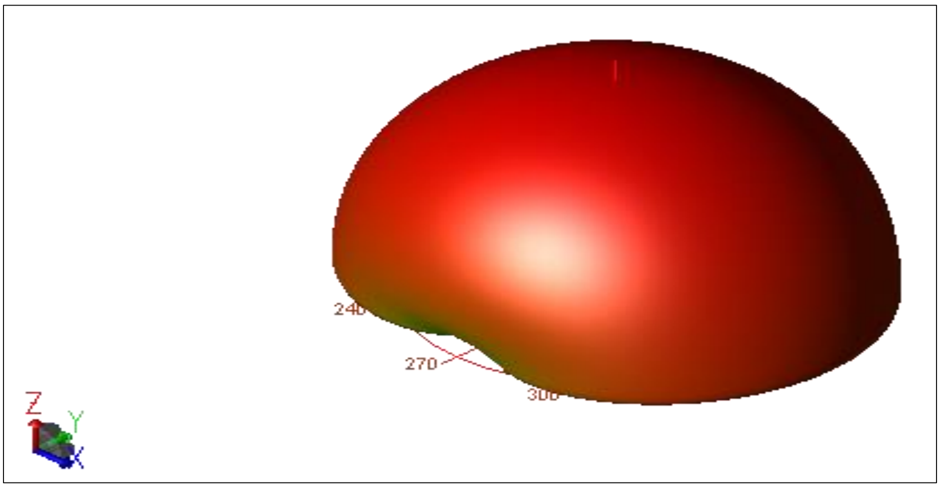


Axial ration versus Frequency

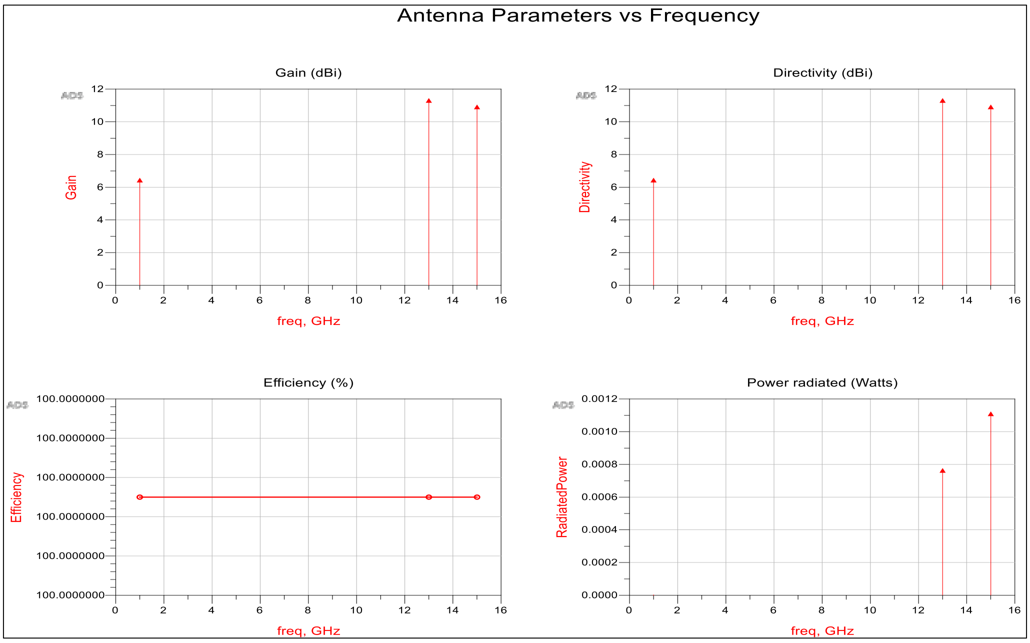
4. Circle Design -layout

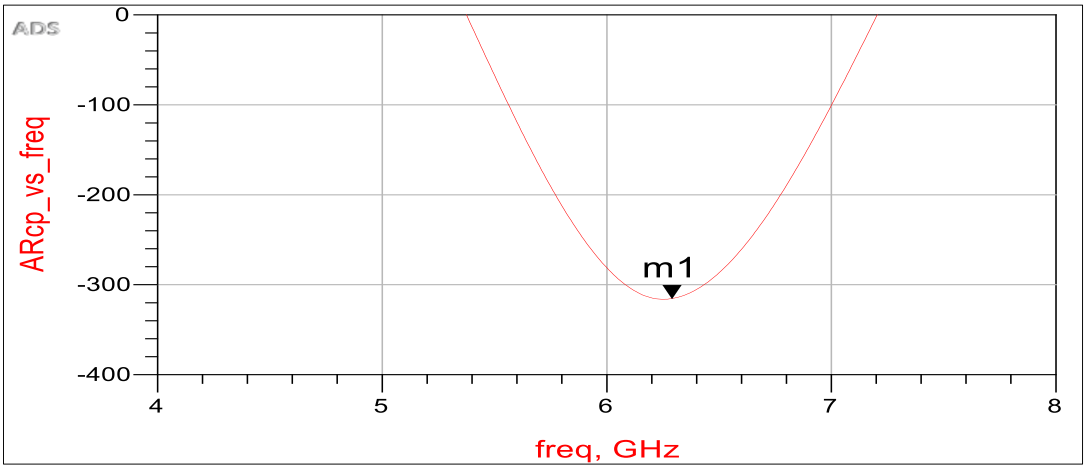






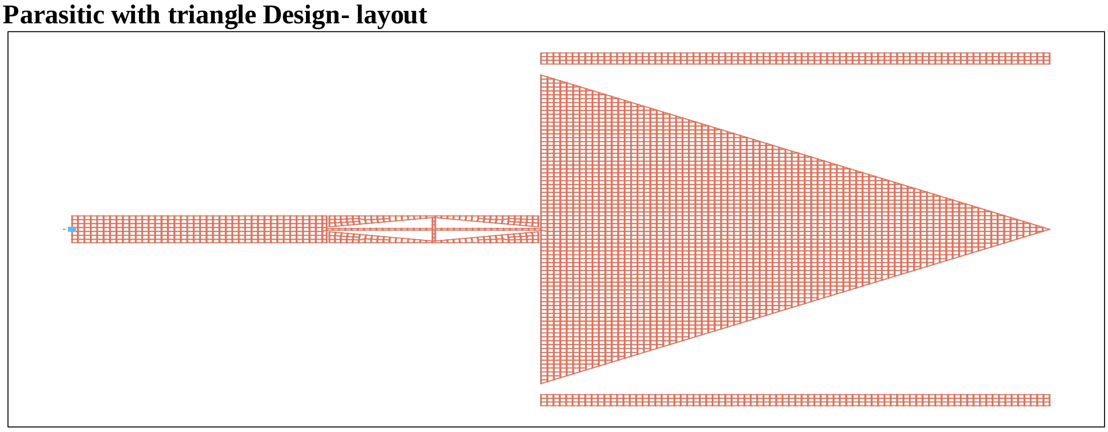
Radiation Pattern

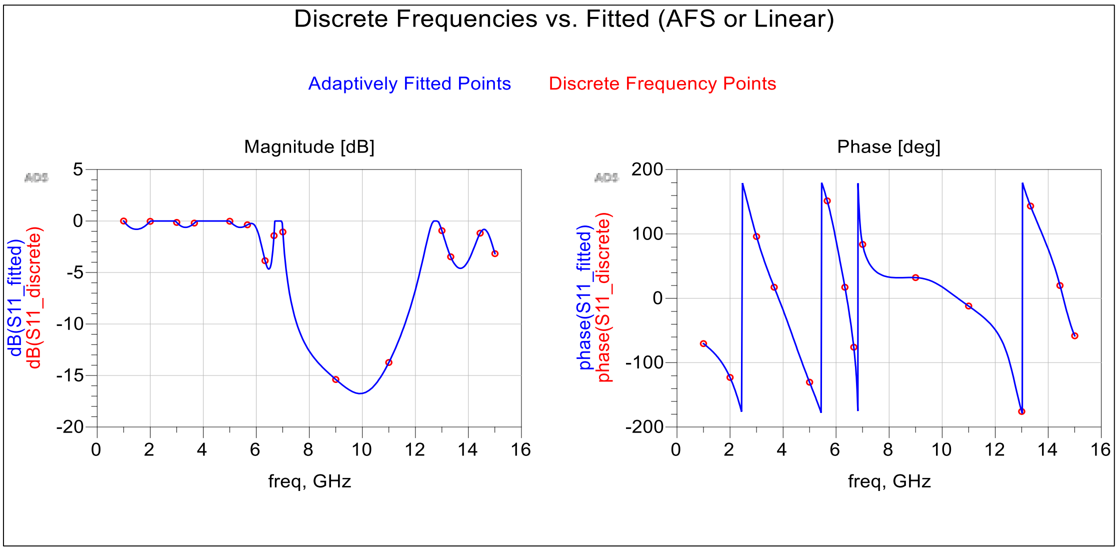


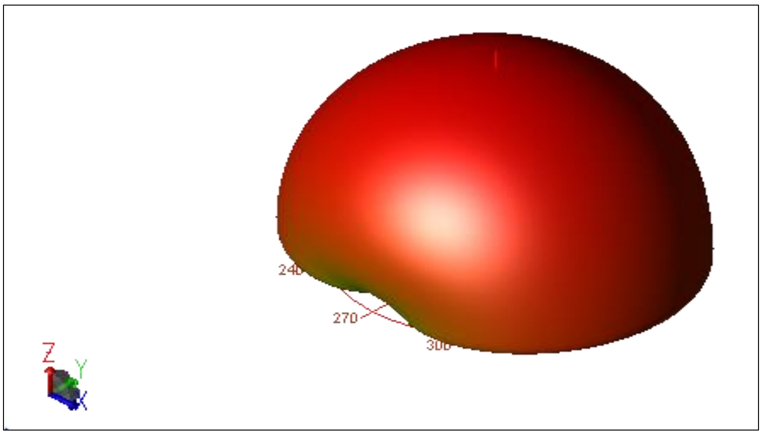


Axial ration versus Frequency

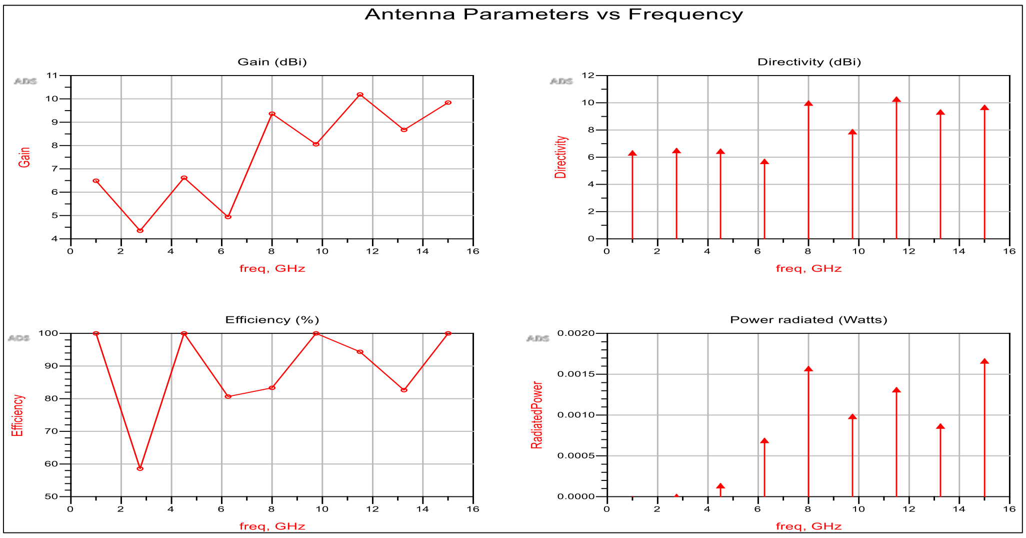
5. Parasitic with triangle Design- layout







Radiation Pattern



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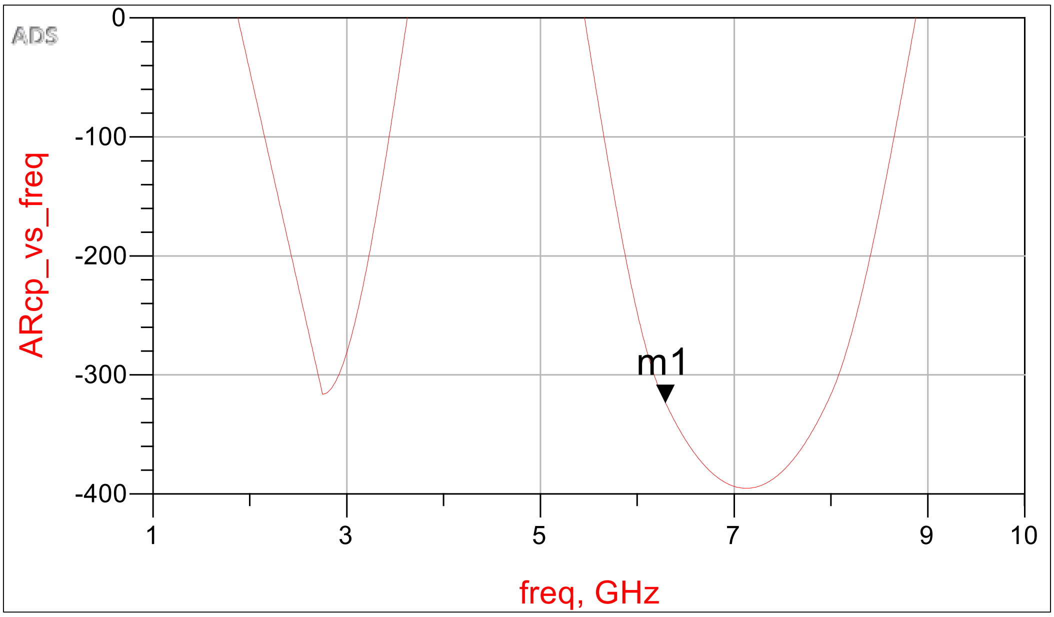
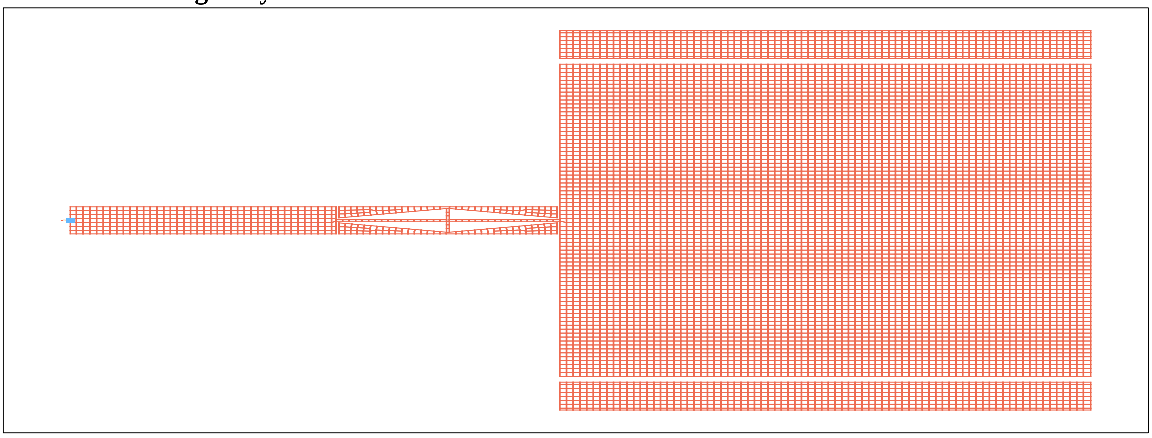
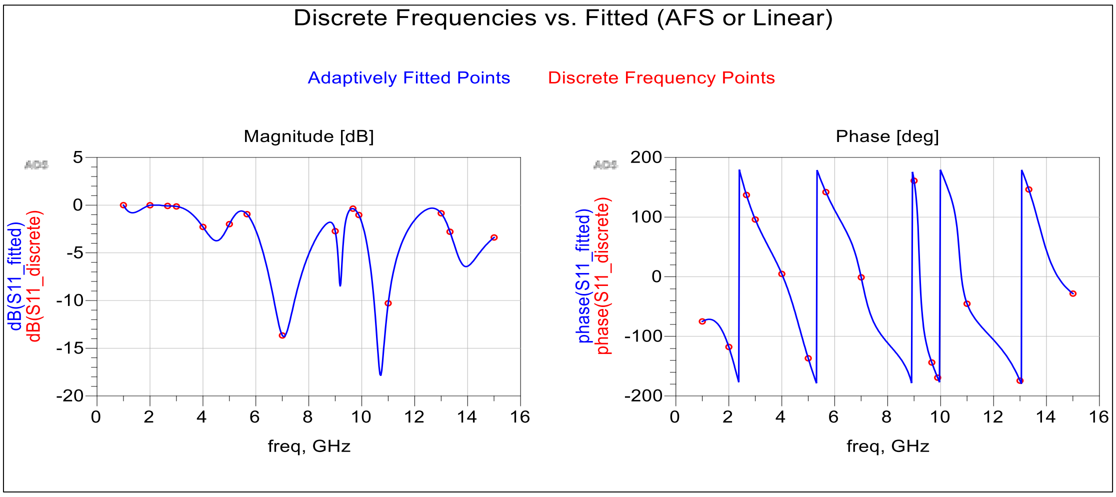


Axial ration versus Frequency

6. Parasitic 2 design -layout





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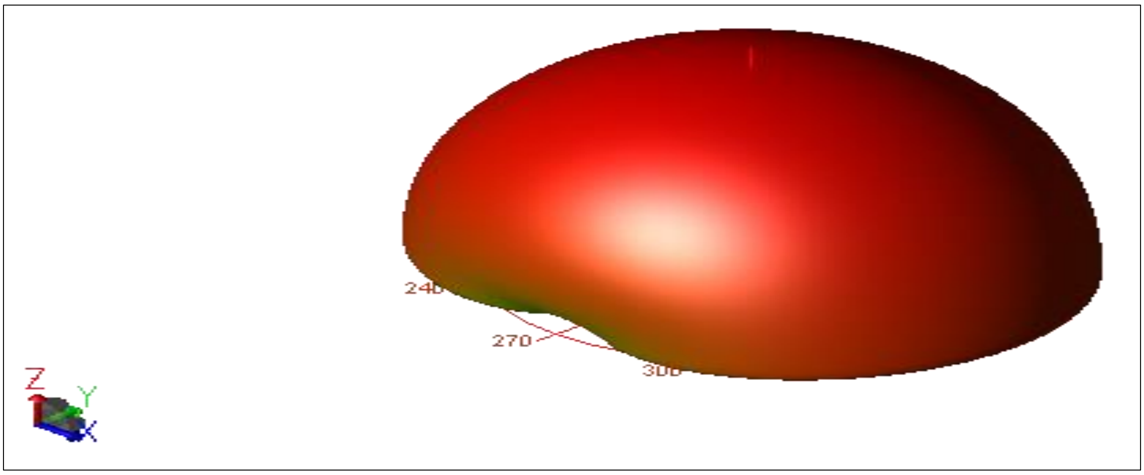
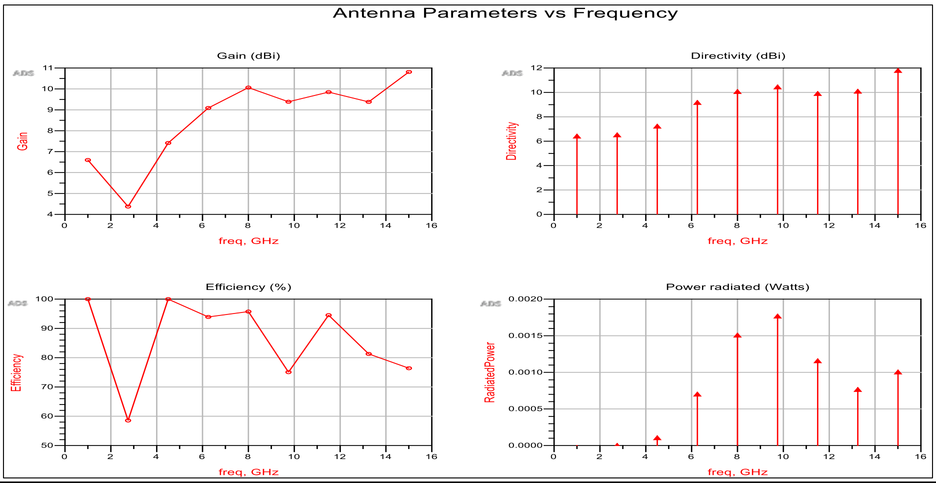
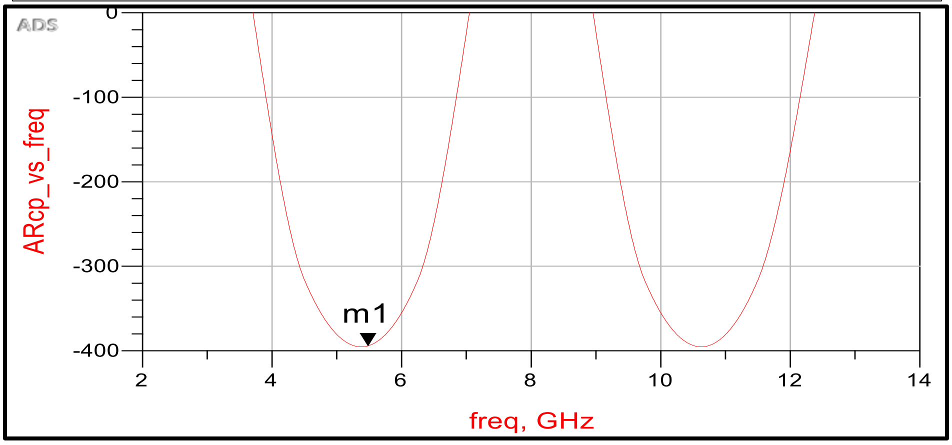


Radiation Pattern





Axial ration versus Frequency

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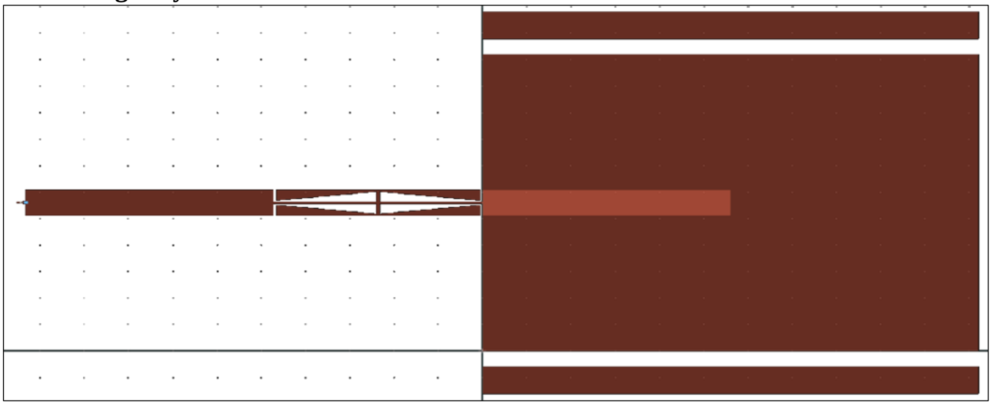
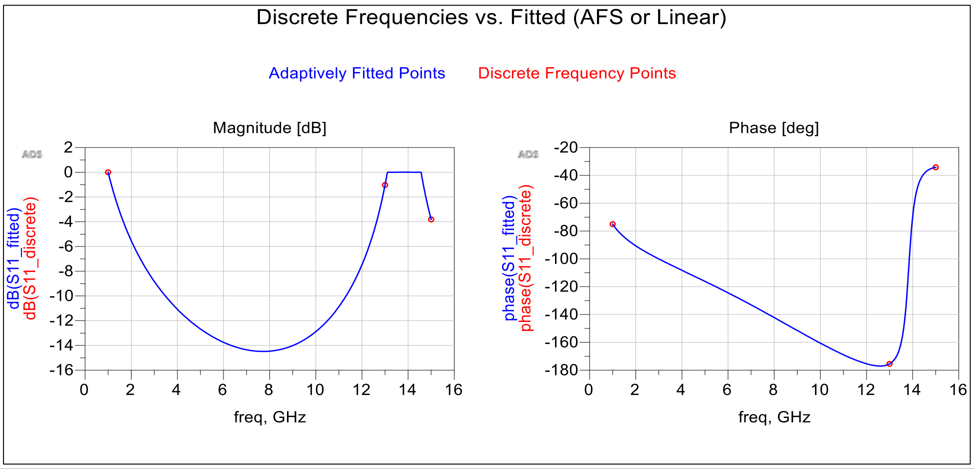
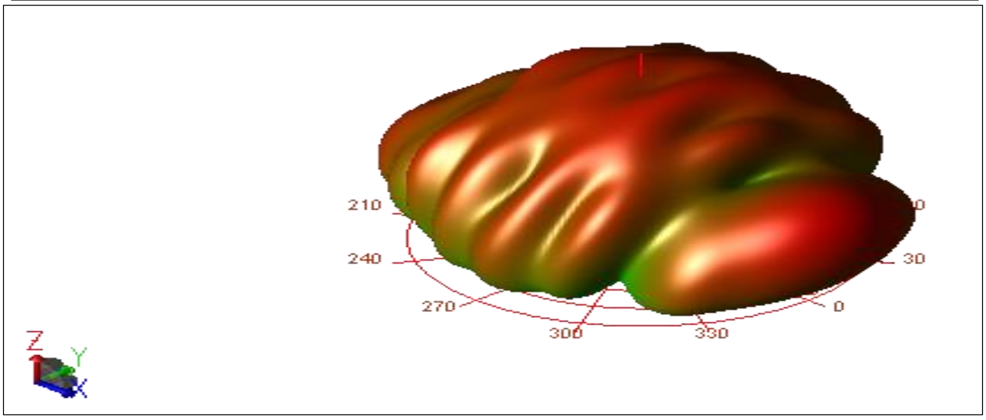
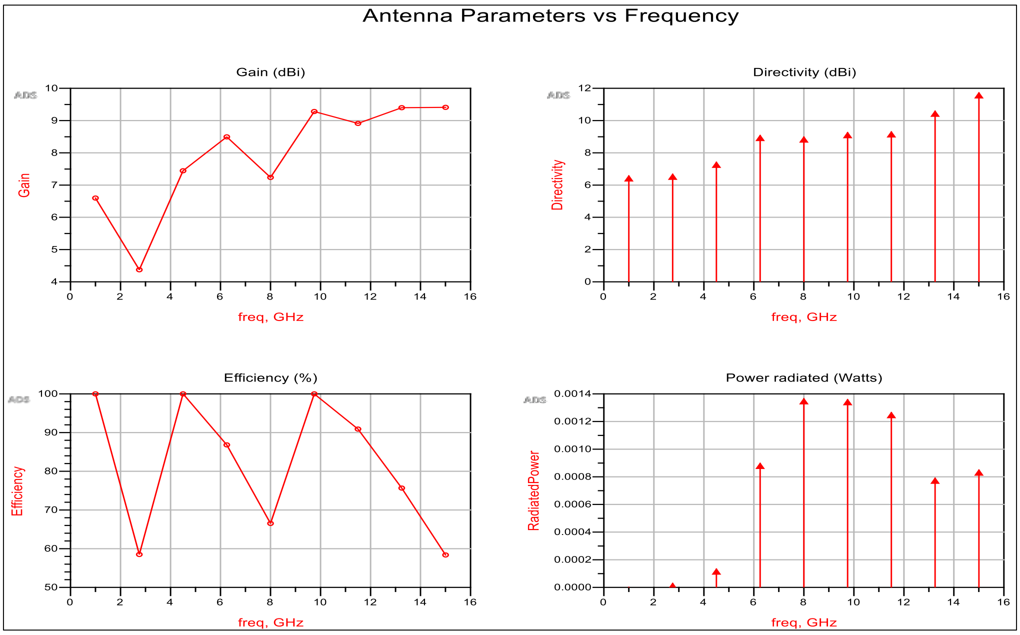
7. Parasitic 3 design-layout

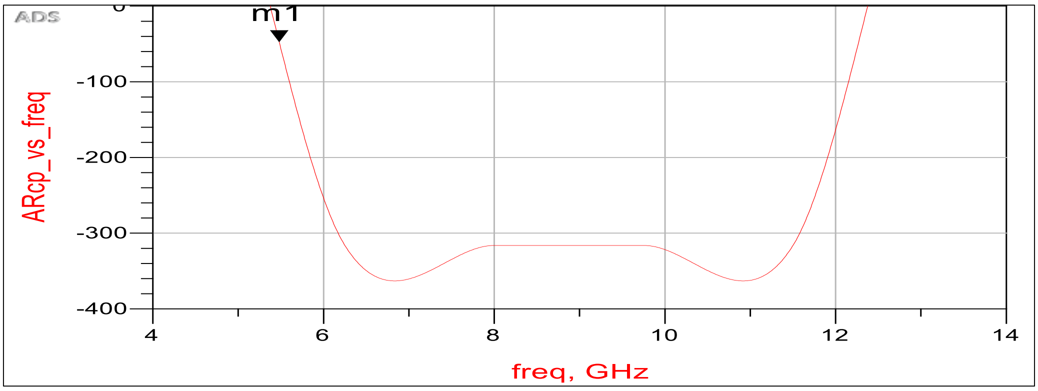






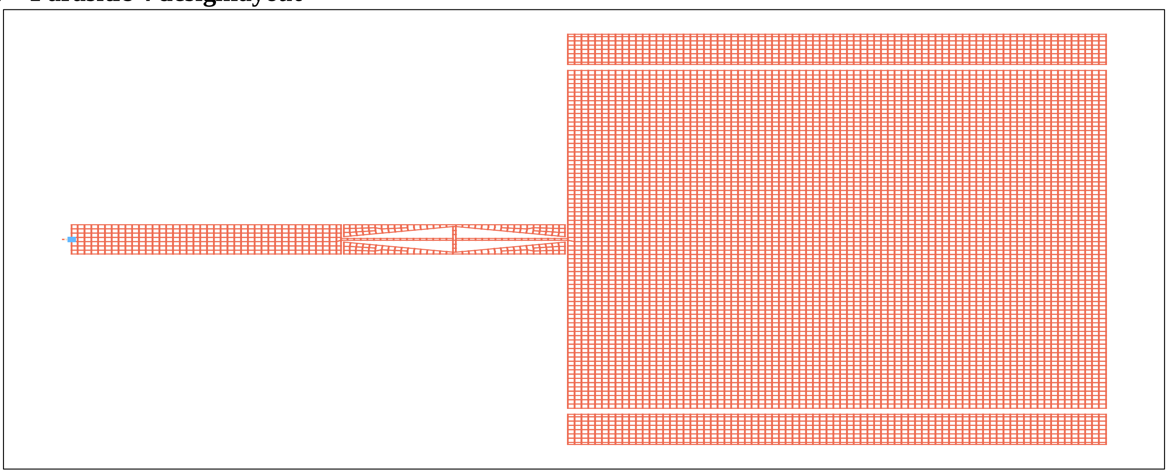
Radiation Pattern

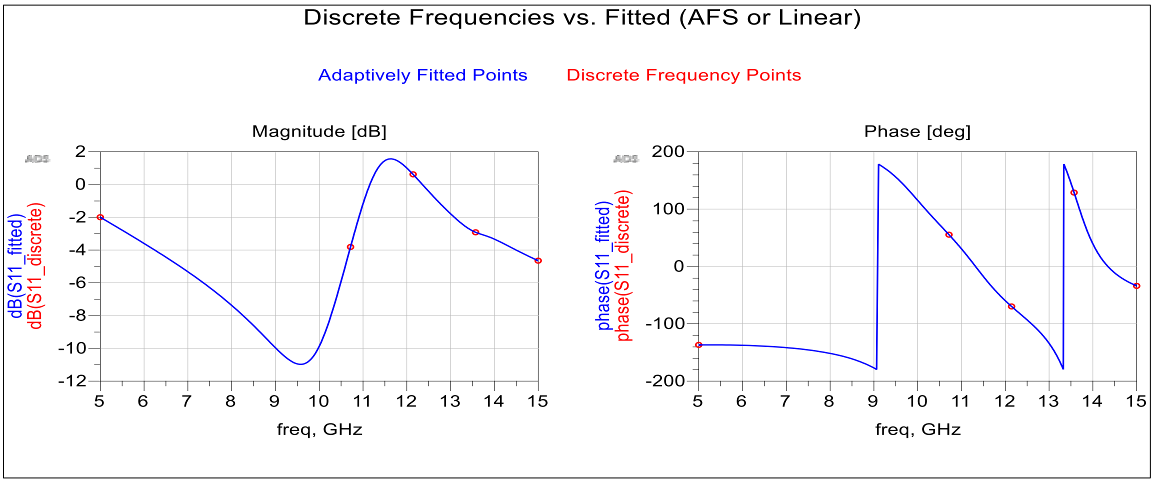


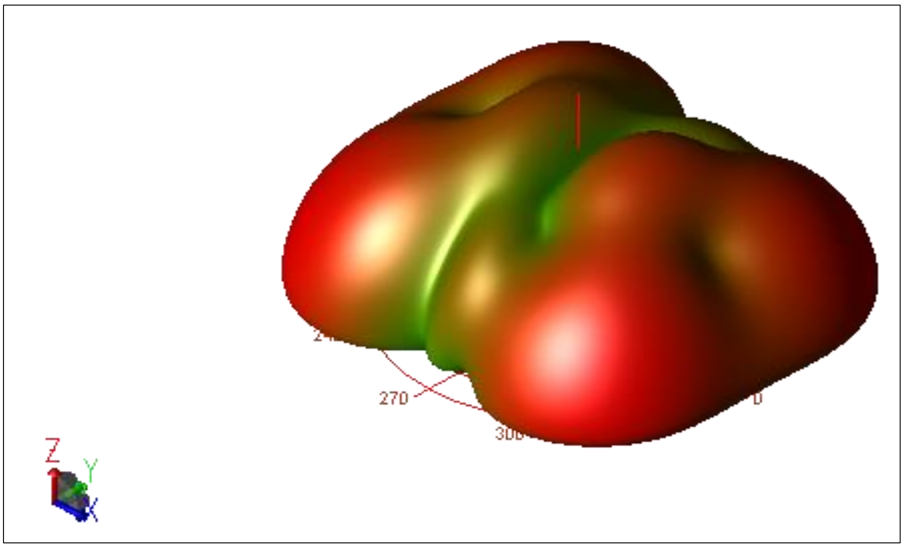


Axial ration versus Frequency

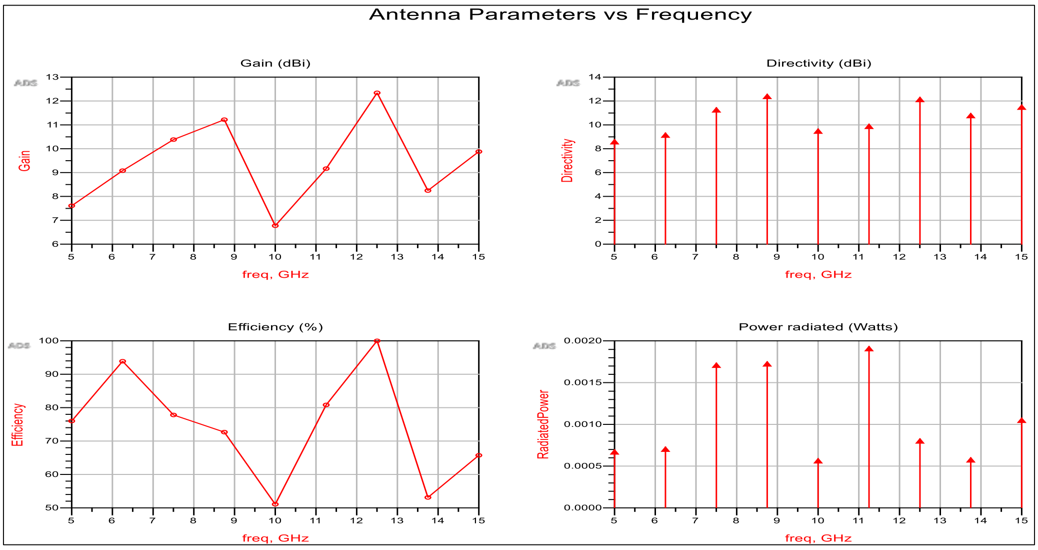
8. Parasitic 4 designlayout







Radiation Pattern



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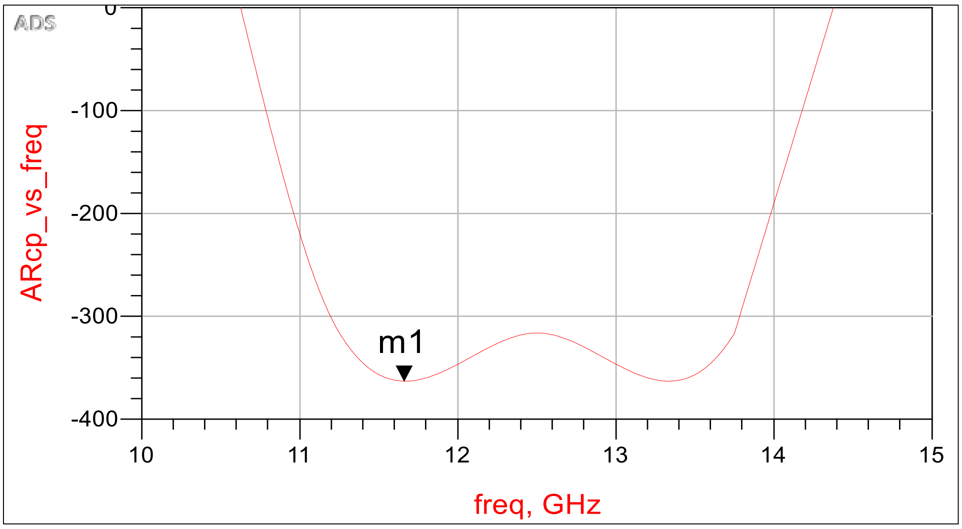
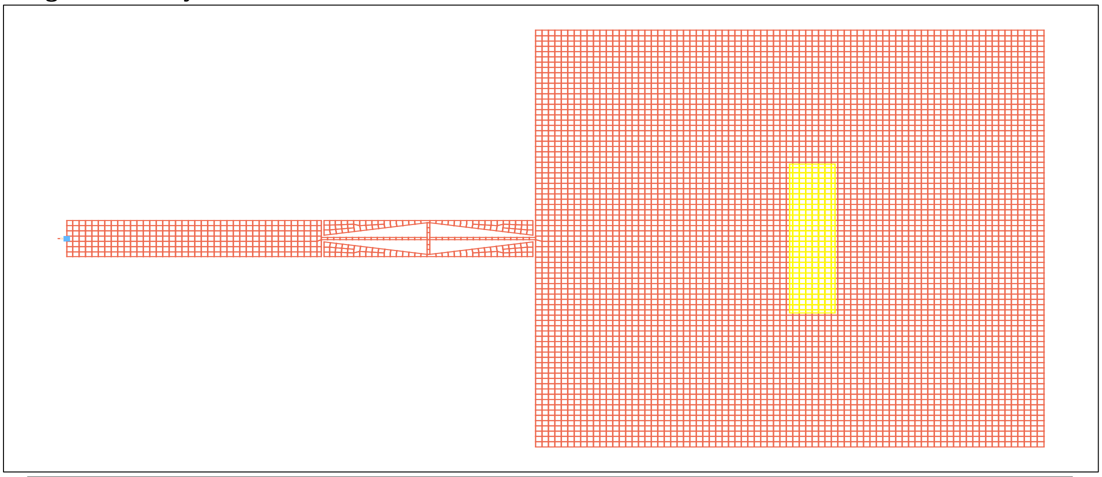
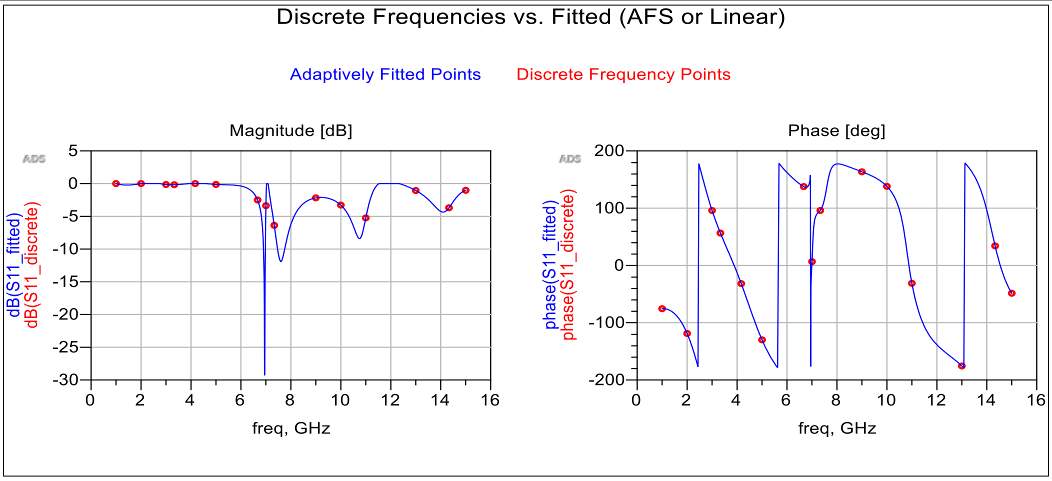
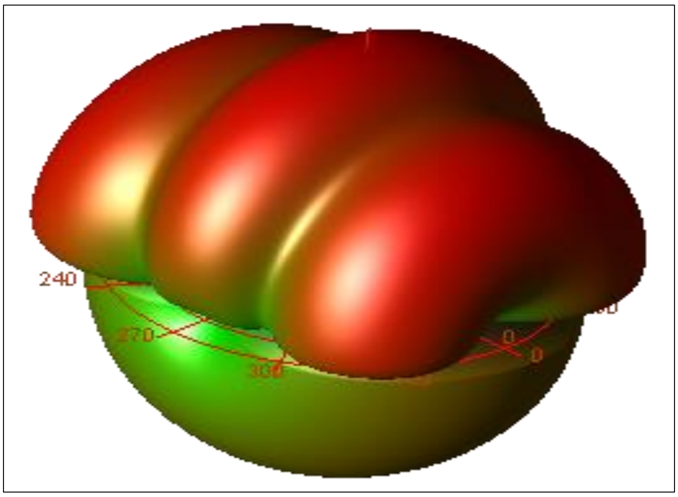


Axial ration versus Frequency

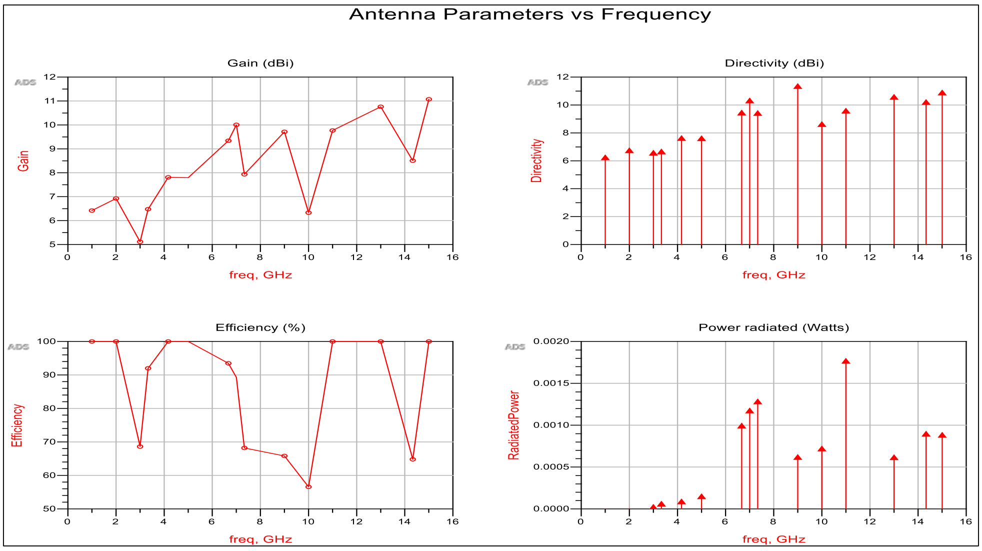
9. **Design slot 1 -layout**

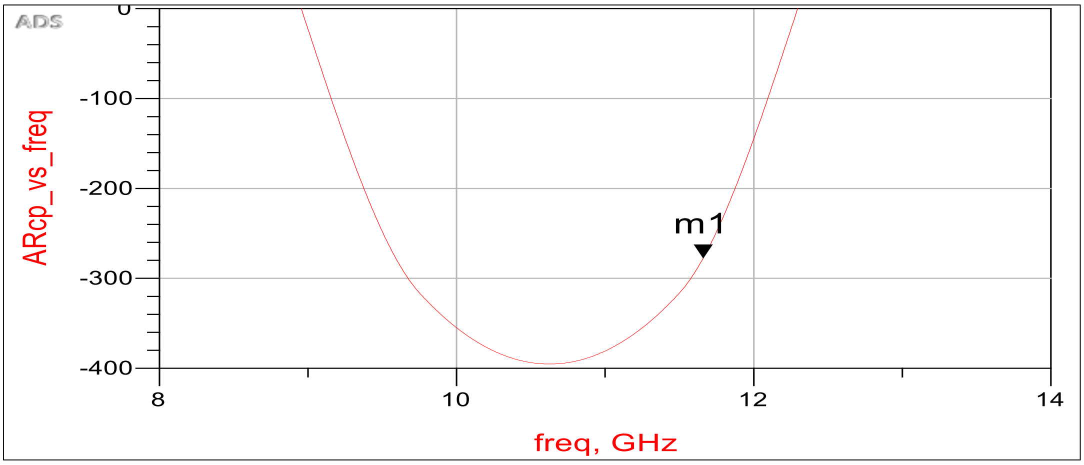






Radiation Pattern





Axial ration versus Frequency

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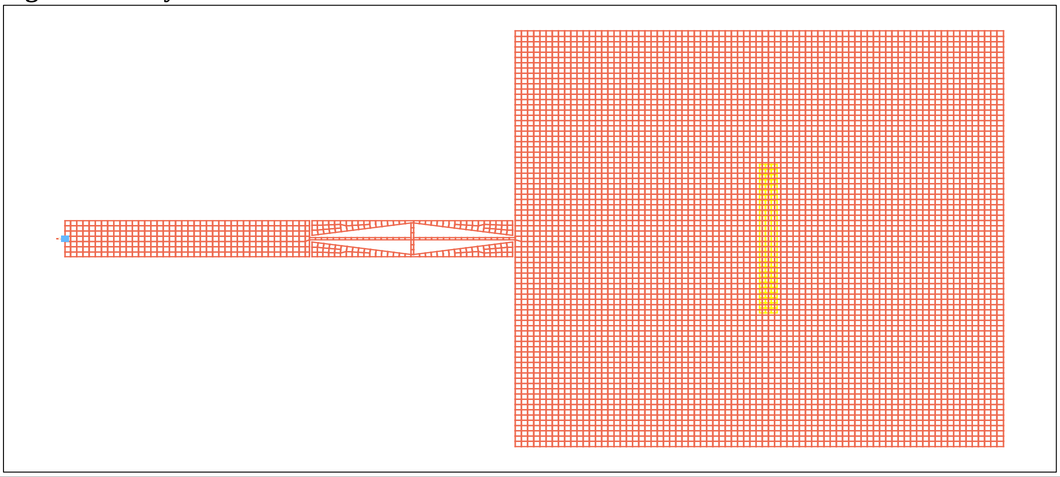
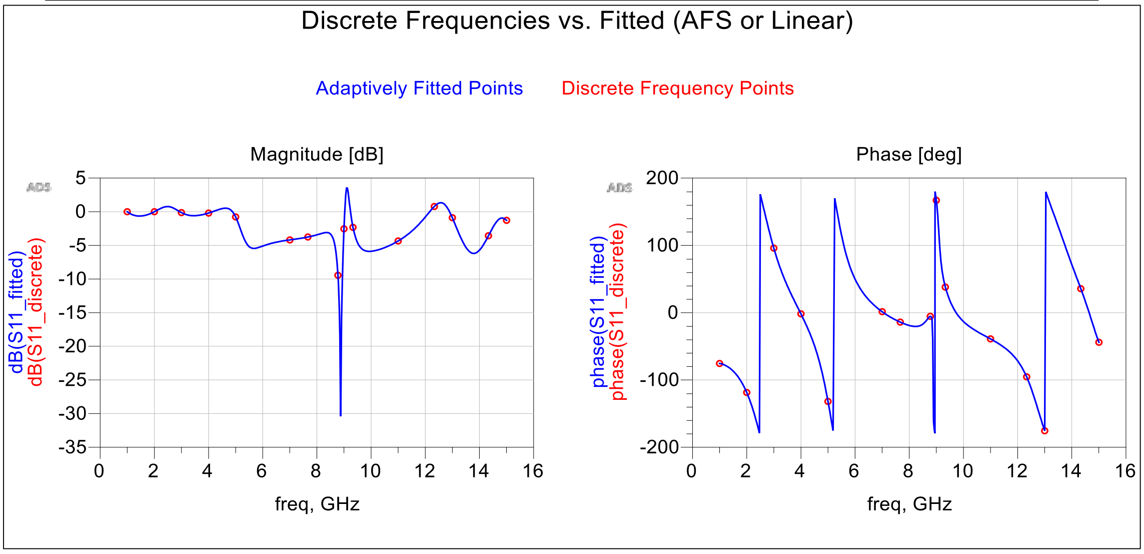
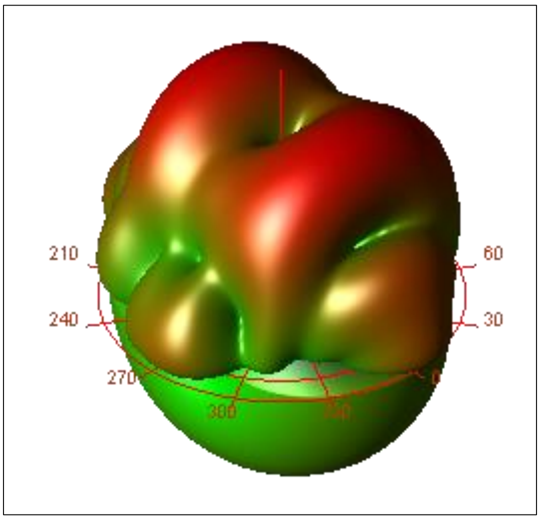
10. Design slot 2- layout







Radiation Pattern

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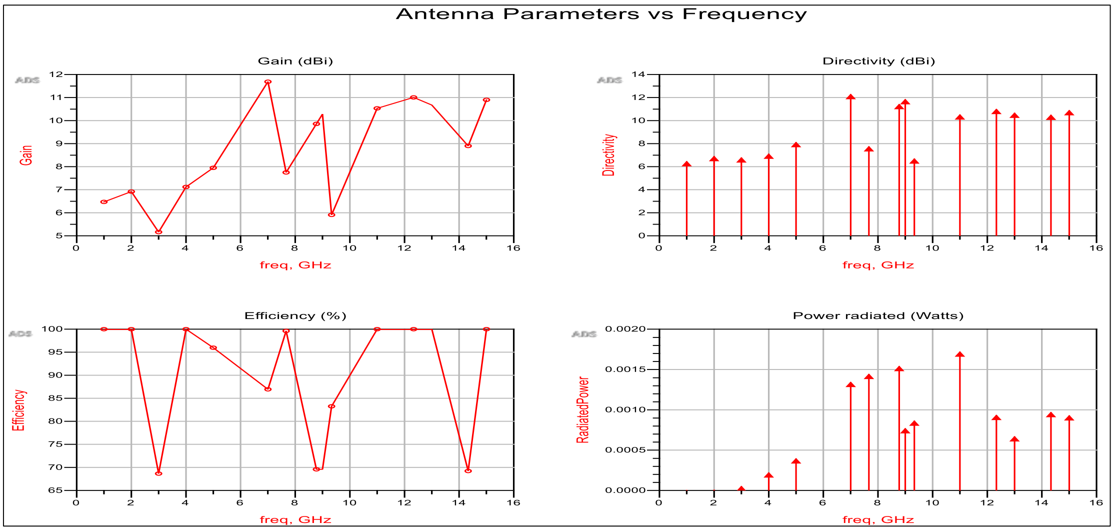
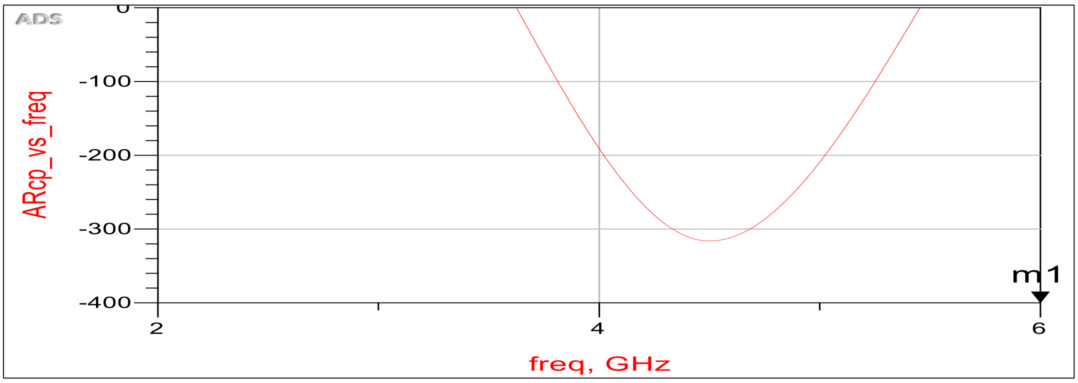
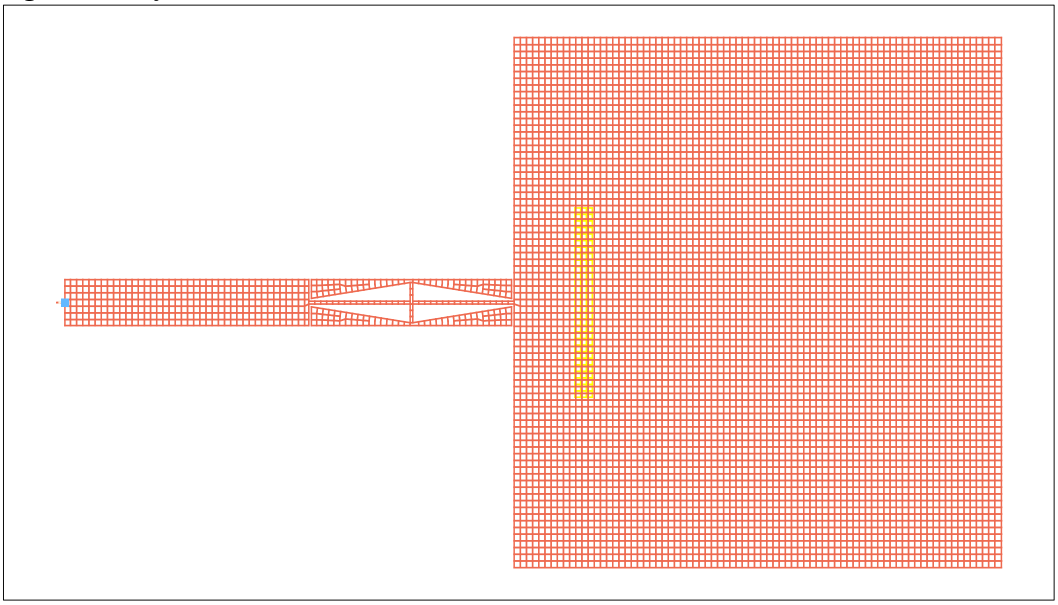
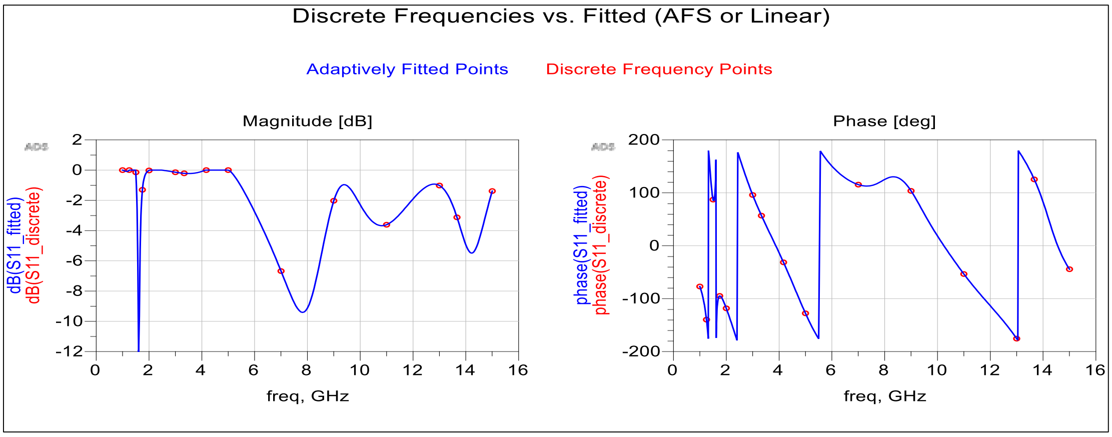


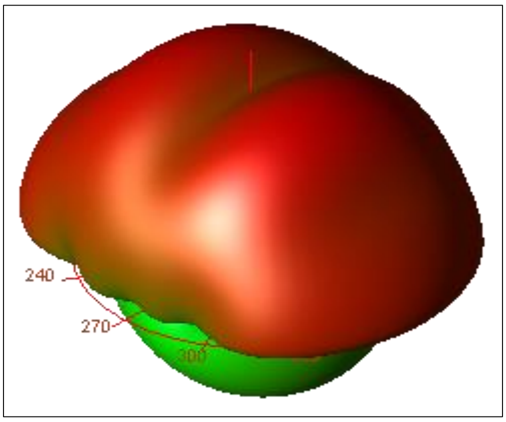


Axial ration versus Frequency

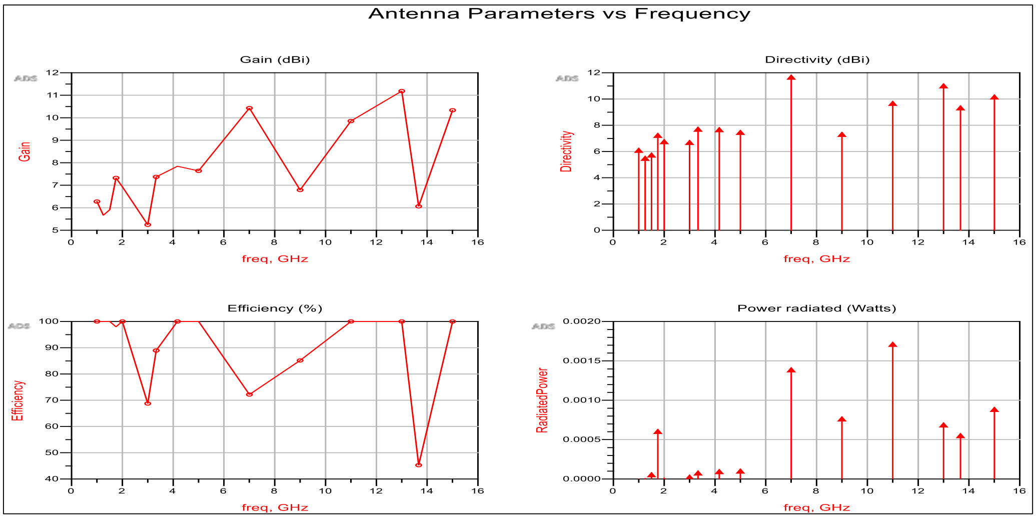
11. **Design slot 3**-layout







Radiation Pattern



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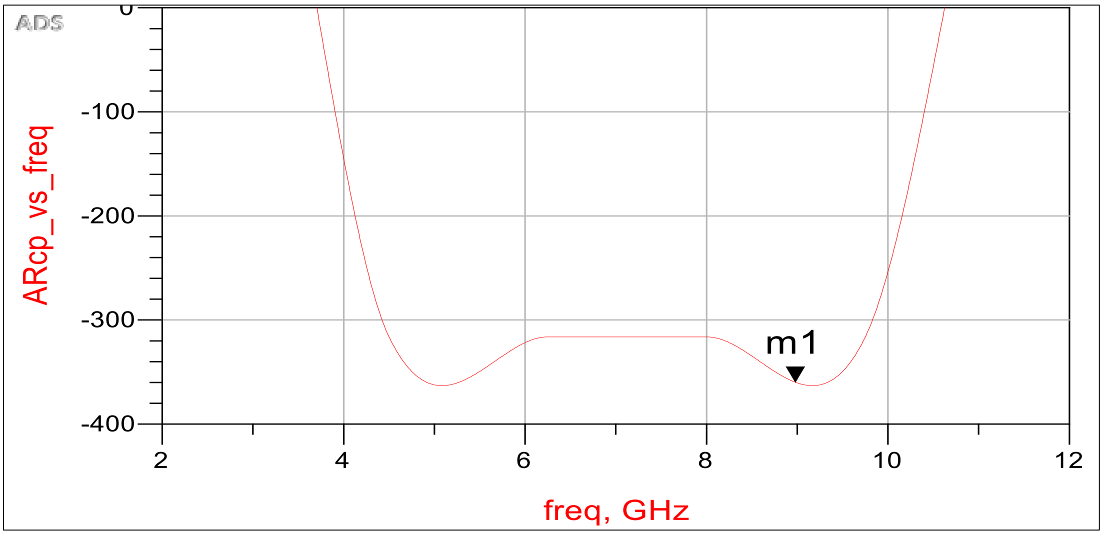
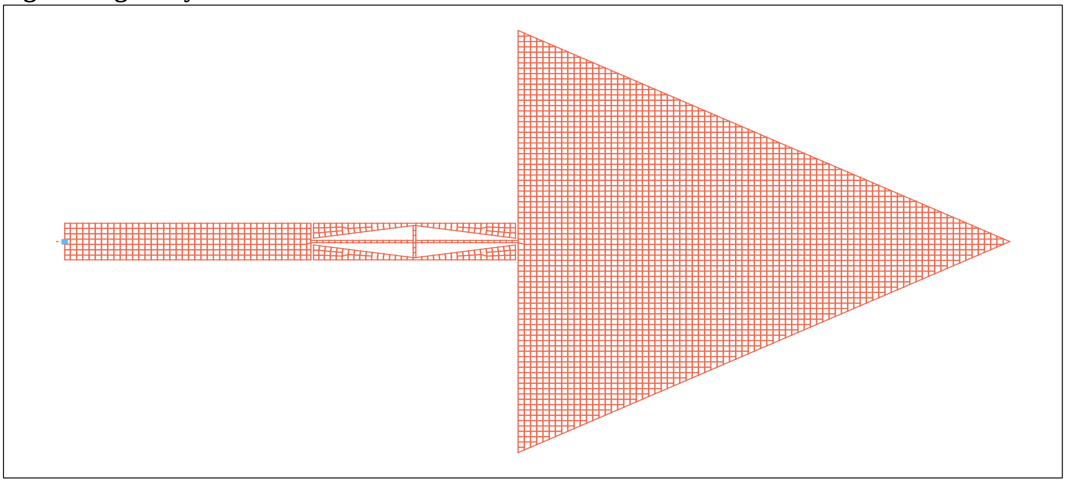
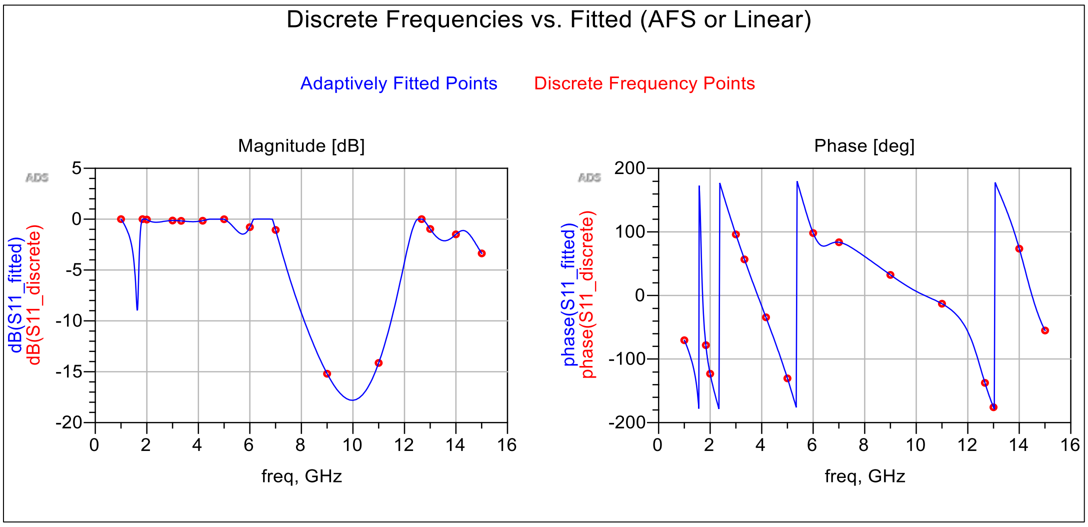
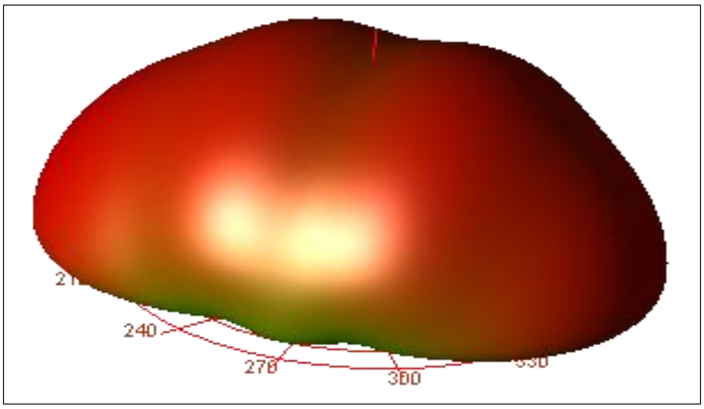


Axial ration versus Frequency

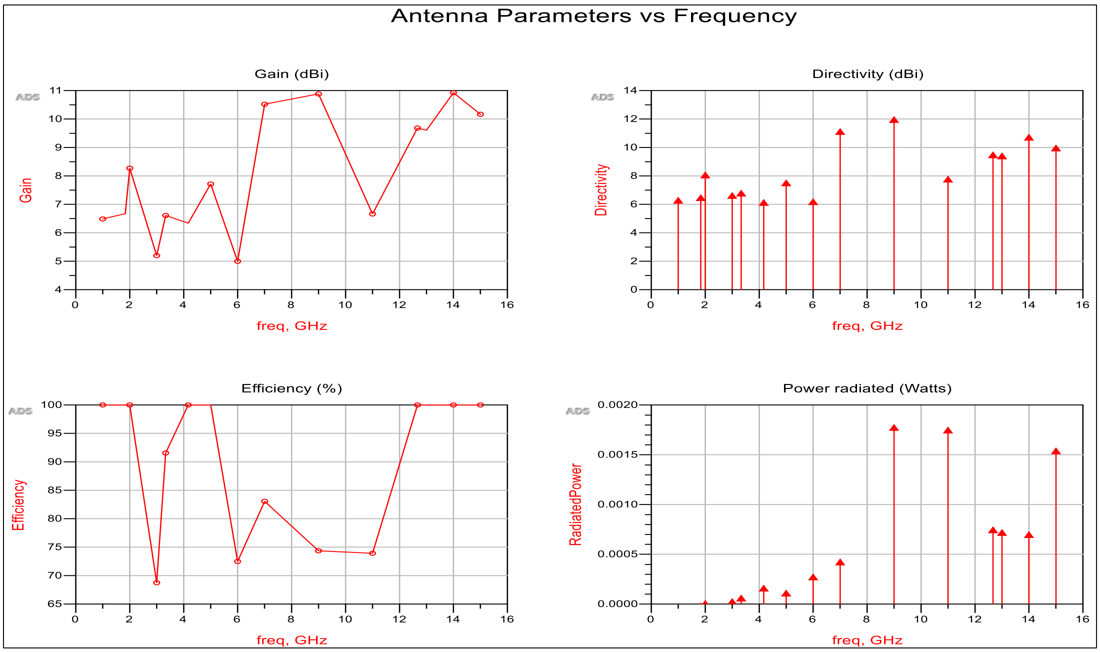
12. design triangle -layout

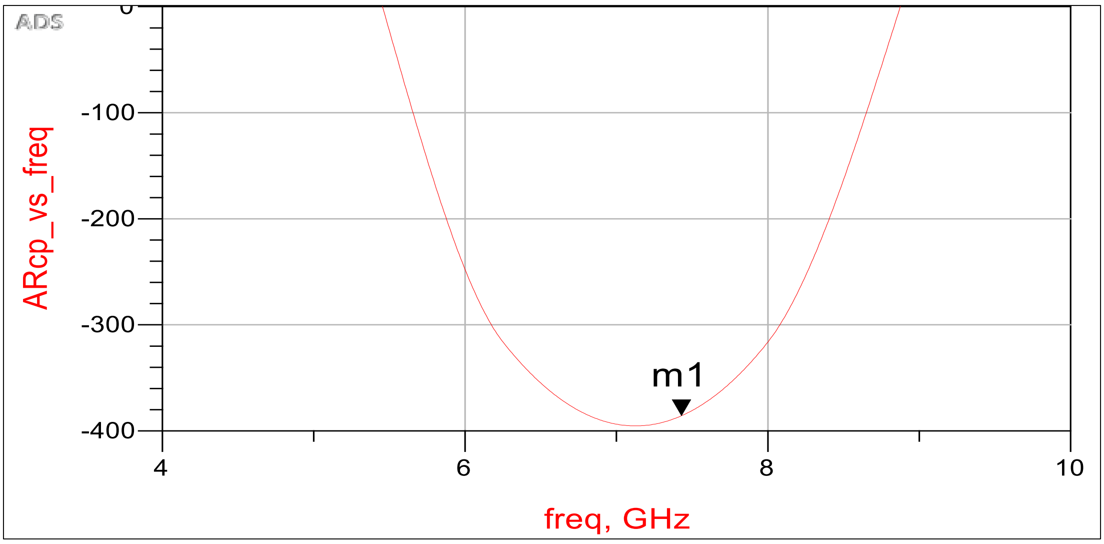






Radiation Pattern





Axial ration versus Frequency

Geometry Design of Microstrip patch Antenna		Parameter						
		Gain (dB)	Bandwidth (GHZ)	Polarization	Directivity (dB)	Efficiency %	Power radiated (W)	Axial ration BW (GHZ)
1	Original Rectangular design	7.5	.25	linear	7.5	100	.0025	1.5
2	Matching Design 1	11.5	-	linear	12	100	.0008	3
3	Matching 4 design	13	2	linear	13	100	.0020	2
4	Circle Design	11	8	linear	11	100	.0015	2
5	Parasitic with triangle Design	10.25	3	linear	10	100	.00155	3
6	Parasitic 2 design	11	1.5	linear	12	100	.00155	4
7	Parasitic 3 design	9.5	8	linear	12	100	.0014	6
8	Parasitic 4 design	12.5	1	linear	12.5	100	.0020	3
9	Design slot 1	11	.5	circular	12	100	.00125	2.5
10	Design slot 2	11.5	.25	circular	12	100	.00155	1.5
11	Design slot 3	11	.25	circular	12	100	.0015	4
12	design triangle	11	4	linear	12	100	.0015	3

IV. CONCLUSION

The extensive research of microwave and RF field has been carried out over the past decade. Microstrips have been widely used in these fields and their advantages made them play an important role in today's communications. In this paper, the various aspects of microstrips are surveyed and suitable methodologies are applied. Rectangular, square, circular, circular ring, triangle, parasitic, and polygon patch antennas have been designed. The details of design of rectangular patch antenna are given in steps. For the other designed shapes, the design formulas were not given in this report, but anyone can take them from suitable reference.

The simulation is done by Advanced Design System 2015.ADS program is very important software for microwave designer and it is recommended her to learn more and more about this special software. The resulting return loss value (less than -25dB) is very attractive in the X-band but in pay of decreasing the efficiency of the antenna. The limitations and numerical calculations of the program must be not forgotten.

For future improvement of these designs, one can make trade off the parameters of the antenna to get the desired aim. Arrays of microstrip patch antennas can also be designed and simulated here and this is left to whom he wants to complete this project.

Antennas designed in this project used microstrip line feed and this method takesup certain amount of space in the circuit. More compact antennas can be design using other feeding methods such as probe feed. Beam steering capabilities array antenna could also be designed to enhance the learning knowledge of design microstrip antennas.

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