DESIGN AND DEVELOPMENT OF HARMONIC TRANSPONDER FOR SEARCH AND RESCUE OPERATION IN S AND C BAND

Report submitted to the SASTRA Deemed to be University as the requirement for the course

ECE300: MINI PROJECT

Submitted by

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<u>Bonafide Certificate</u>

This is to certify that the report titled "**Design and Development of Harmonic Transponder for Search and Rescue Operation in S and C Bands "** submitted as a requirement for the course, **ECE300: MINI PROJECT** for B.Tech. ELECTRONICS & COMMUNICATION ENGINEERING programme, is a bonafide record of the work done by **Mr. G Chinmaya (Reg. No.124004417**), **Mr. G Rahul (Reg. No.124004420**), **Mr. Y Sai Sri Harsha (Reg. No.124004440**) during the academic year 2022-23, in the School of ELECTRICAL & ELECTRONICS ENGINEERING, under my supervision

Signature of Project Supervisor : 

Name with Affiliation : Dr. A Rajesh (Associate Professor /SEEE)

Date :

Project *Viva-vo*ce held on ________________

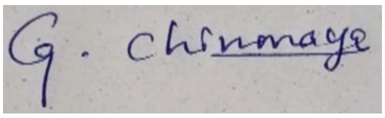
Examiner 1 **Examiner 2**

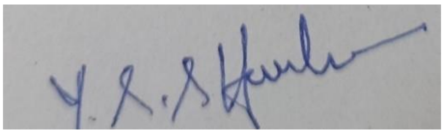
SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING THANJAVUR – 613401

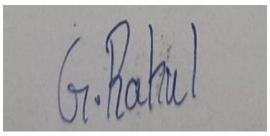
Declaration

We declare that the report titled "**Design and Development of Harmonic Transponder For Search and Rescue Operation in S and C Bands**" submitted by us is an original work done by us under the guidance of **Dr. A Rajesh, Associate Professor, School of Electrical and Electronics Engineering, SASTRA Deemed to be University** during the sixth semester of the academic year 2022-23, in the **School of Electrical and Electronics Engineering**. The work is original and wherever We have used materials from other sources, We have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar title to any candidate of any University.

Signature of the candidate(s) :







Name of the candidate(s) : Gadamchetty Rahul

G. Chinmaya

Y. Sai Sri Harsha

Date :

Abstract

It becomes extremely difficult when there is situation of Search and Rescue Operation in Maritime operations to find boats and persons as oceans are very big and it is not possible to use radars and travel long distances along the sea so to avoid this problem we use SART. SART or Search and Rescue Transponder is extremely vital equipment on the ship as it performs the job of a single man. SARTs are essentially battery-operated, hence can be operative for a long time. It is very difficult to use because they are battery operated which makes it very discomfortable. we are trying to design microstrip SART which is battery free and it is being operated at s band frequency (3 to 6 GHz). It has the name Shiv Sart So, shiv sart will reduces the size of SART and as it is battery free (operated without battery it can be used anytime).we have designed shiv sart by following some existing way of designing passive transponders where we have one Transmitting,one Receiving antenna ,Band pass filter and Frequency doubler.Instead we following existing design parameters which reduces the size of Transponder size by using microstrip frequency multiplier and removing band pass filter which have many harmonics and it depends on many parameters.So we designed shiv Sart by using one Transmitter,one Receiver,one frequency multiplier and we first designed the existing prototypes of Transmitter and Receiver and then created the new complex designs by Inserting holes and slots around the patches of Transmitter and Receiver and then we created one frequency multiplier.After this we made shiv Sart by Integrating all the components by Impedance matching between the components and after that we have dfs(Defected Ground Structures) which helps us more for reducing the clutter frequencies and we have done parametric analysis on Transponder by varying the radius of defected ground structure we have got best result at r=5 and we then made shiv sart.Shiv sart is capable of detecting the radar of distance 500 m and it used in applications like Iron dome,Search and Rescue operations of maritime and between boarders of srilanka and pakisthan.

Specific Contribution

- Making Unique Transmitter and receiver design and designing S11 below 20 db
- Design of Microstrip frequency multiplier and Integration of different components and doing Impedance matching between it.
- Observation work , presentation work and Theory papers Search

Specific Learning

- Learnt of about how to use DGS(defected ground structures) in reducing higher harmonics
- In doing Impedance matching of Transmitter, receiver and frequency multiplier
- To design Microstrip patch antenna analysis of it in CST.

Signature of the Guide Student Reg. No :124004417,124004420,124004440

Name : G. Rahul Name : G. Chinmaya

Name : Y. Sai Sri Harsha

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ABBREVIATIONS

TP - Transponder

SART - Search and Rescue Transponders

DGS-Defected Ground Structures

Tx-Transmitter

Rx-Receiver

SAR-Synthethic Aperture Radar

RAR - Real Aperture Radar

IFSAR- Interferometric Synthetic Aperture Radar

NOTATIONS

W – width of the patch

L-length of patch

tp-thickness of patch

h-height of subtrate

wg-width of ground

lg-length of ground

wf-width of feed

lf-length of feed

Eeff-effective dielectric constant

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CHAPTER 1

INTRODUCTION

It becomes extremely difficult when there is situation of search and rescue Operation in ships as ocean are very big and it is not possible to use radars and travel long distances along the sea so to avoid this problem, we use SART.SART or Search and Rescue Transponder is extremely vital equipment on the ship as it performs the job of a single man. It is a vital machine during distress for it helps in locating the position of the vessel in case it goes off-track. SART's are made of waterproof components which protects them against damage by water. SART's are essentially battery-operated, hence can be operative for a long time. SARTs are of use in ships, life boats. They are the most supportive machines in case of an unprecedented emergency. SART's are designed to remain afloat on the water for a long time in case the vessel finds itself submerged in water. The bright color of SARTs enables their quick detection, whereas the combination of transmitter and receiver enables it to transmit as well as receive radio signals.

The use of high-resolution radars such as synthetic aperture radars (SAR), millimeter -wave real aperture radar (RAR) and interferometric synthetic aperture radar (IFSAR) have been explored for identifying unique objects. However, this solution is complex and costly. By attaching a frequency doubling passive transponder to targets of interest, and using them with a compatible receiver, the frequency of the received signal reflected from the target will be twice the frequency of the transmitted signal. Hence, it will be unique from ordinary echoes and can be easily differentiated on the radar screen from clutter. Although active transponders can achieve a longer range, passive transponders have many attractive advantages. The use of batteries implies significant costs and regular maintenance. Without batteries, recurring maintenance costs can be avoided and the transponder can be very small which further reduces costs.

Proposed Methodology

1.1Principle Of Operation

In figure 1 the principle of the frequency doubling transponder is illustrated. The radar's transmitter (TX) and receiver (RX) are a distance, dTX-TP and dRX-TP away from the transponder (TP) respectively. The transmitter sends a high-powered pulse at fTX = 9.4 GHz in the direction of the transponder. Because of objects and uneven terrain around the transponder, there will be clutter seen on the radar screen due to multipath effects and reflections from the undesired targets.

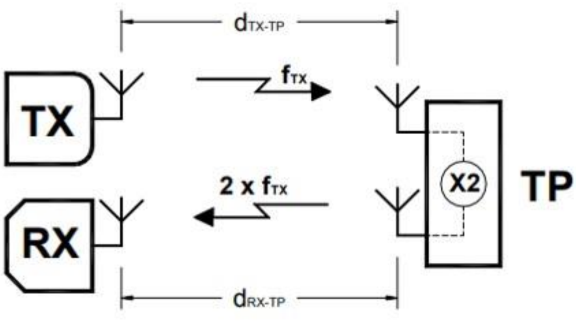

Figure 1: Operating principle of passive, frequency doubling transponder.
TX = Transmitter, TP = Transponder, RX = Receiver

Fig 1.1

The transponder doubles the signal to 2fTX and re-transmits an 18.8 GHz pulse that is unique from the unwanted reflections. An 18.8 GHz receiver at the radar receives it and the signal is easily differentiated on the radar screen. By using this technique, visibility for the radar operator is significantly enhanced

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1.2 Transponder Design

IV. TRANSPONDER DESIGN

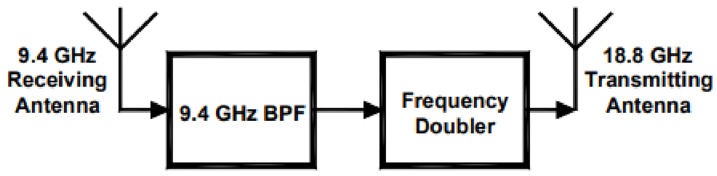


Figure 2: Block Diagram of Proposed Transponder

Fig 1.2

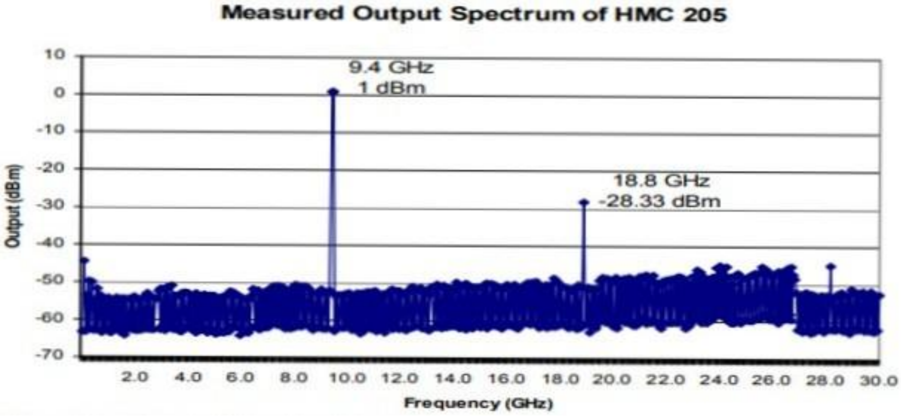
The proposed transponder consists of a 9.4 GHz receiving patch antenna, bandpass filter centred at 9.4 GHz, a passive frequency doubler and an 18.8 GHz transmitting patch antenna as shown in figure 2. The final transponder is required to be integrated and compact that can easily be attached to a target, all the components should be designed and fabricated on the same substrate.

i. Frequency Doubler

The selected frequency doubler is the HMC 205, from Hittite Corporation. The measured output spectrum is shown in figure 3. It is observed that an input signal of 4 dBm produces an attenuated 18.8 GHz signal at -28.33 dBm. This loss is almost double the loss specified in the data sheet. This is likely due to noncompliance to the recommended bonding and mounting techniques

Fig-1.3

C. Design of Frequency Doubler



Complete Passive Transponder

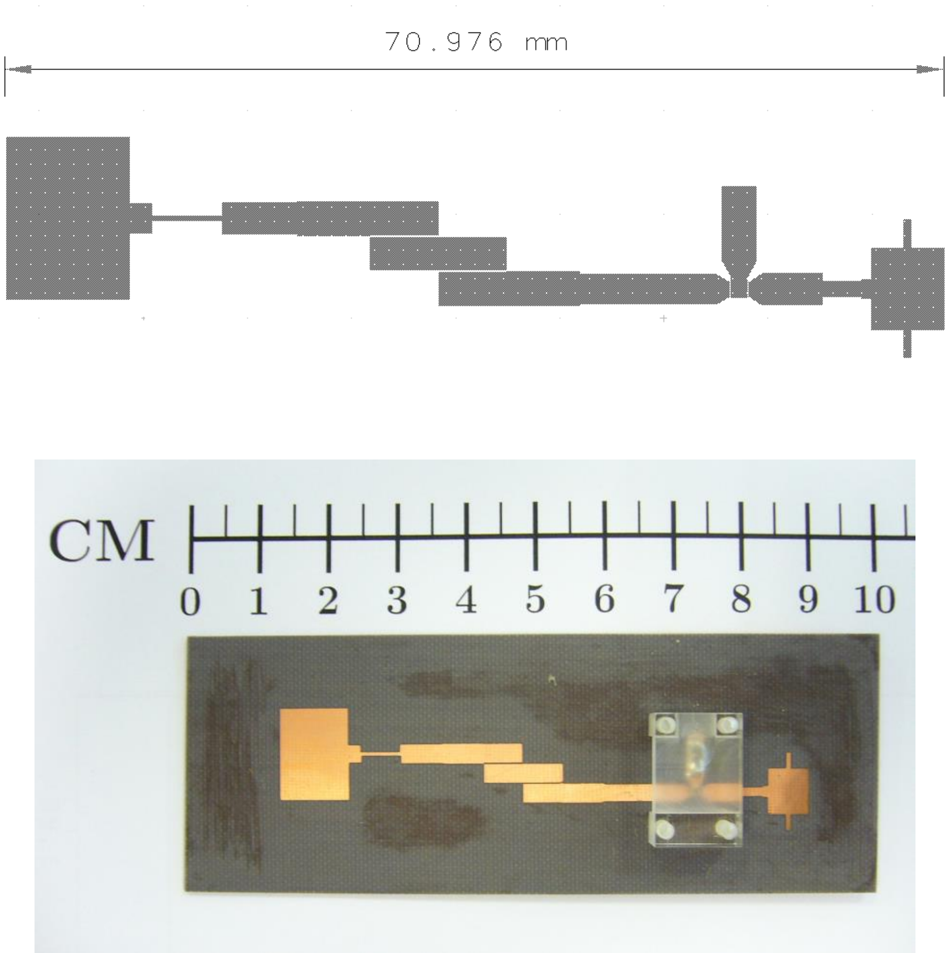
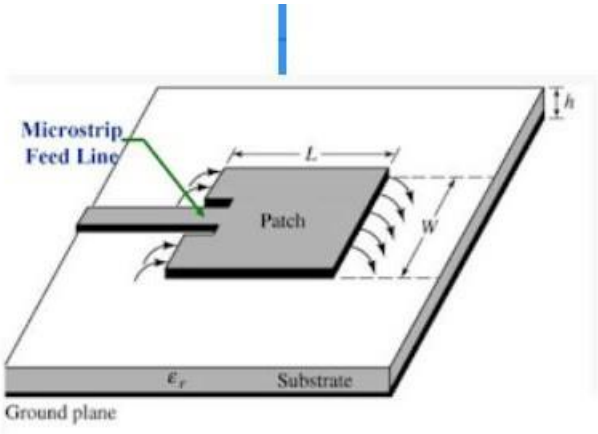


Figure 1.4 : Fabricated Passive Transponder

1.3 Calculations for Designing Microstrip Patch Antenna



Microstrip antenna with inset-feed line

$$W = \frac{c_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1.1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{1.2}$$

$$\Delta L = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{1.3}$$

$$L_{eff} = L + 2\Delta L \tag{1.4}$$

$$L = \frac{c_o}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{1.5}$$

1.4 Improve Sharpness of a Rectangular Patch

There are several ways to improve the sharpness of a rectangular patch antenna. Here are some tips:

- **Increase the substrate dielectric constant:** By increasing the dielectric constant of the substrate, the wavelength of the electromagnetic wave is reduced, and the resonant frequency of the antenna is increased. This will result in a sharper frequency response.

- **Decrease the substrate thickness:** By decreasing the thickness of the substrate, the surface wave losses are reduced, and the bandwidth of the antenna is increased, resulting in sharper frequency response.

- **Increase the length of the antenna patch :** By increasing the length of the antenna patch, the resonant frequency of the antenna is decreased, resulting in a sharper frequency response.

- **Use a parasitic patch:** By adding a parasitic patch close to the driven patch, the bandwidth of the antenna is reduced, and the sharpness of the frequency response is increased.

- **Tapering the edges of the antenna patch:** By tapering the edges of the patch antenna, the current distribution on the patch is more uniform, which results in a sharper frequency response.

1.5 Motivation to go from Active to Passive Transponder

1.1 Table – parameters for Active and Passive Transponders

Parameters	**Active Transponders**	**Passive Transponders**
Definition	An active transponder requires an external power source to amplify the signal it receives and retransmit it back to earth	A passive transponder does not require an external power and reflects the signal it reflects the signal it receives back to Earth.
Area of coverage	Active transponders can provide wider coverage areas due to the ability to amplify and boost signals. The range of coverage decreases as frequency increases due to higher signal attenuation.	Passive transponders provide coverage only in the immediate area around the satellite due to the lower signal strength. The range of coverage decreases as frequency increases due to higher signal attenuation.
Maintenance Cost	Active transponders require regular maintenance to ensure the amplification circuitry is functioning properly.	Passive transponders require minimal maintenance as they do not have any internal circuitry that can fail.
Power consumption	Active transponders consume power and require a reliable power source.	Passive transponders do not consume any power, making them ideal for small satellites with limited power budgets.
Signal quality	Active transponders generally provide higher signal quality due to the amplification of the signal.	Passive transponders provide a weaker signal that may be susceptible to noise and other interference.
Cost	Active transponders are generally more expensive than passive transponders due to the need for amplification circuitry. The cost of active transponders generally increases with higher operating frequencies due to the need for more advanced circuitry.	Passive transponders are generally less expensive than active transponders due to their simpler design. The cost of passive transponders generally increases with higher operating frequencies due to the need for more advanced antenna designs.

CHAPTER 2

OBJECTIVES

- Even if SARTs are very much useful but their being Active SART as it has to be charged and it can't last for long time and very difficult to use because they are battery operated and also they are big in size and costs around 50000-1 lakh rupees which makes its very discomfortable in terms size,money and usage.

- So we are using passive sarts which will reduces the size of SART and as it is battery free(operated without battery it can be used anytime) and cost around 2000 to 3500 rupees.So which is Economical,batteryless and easy to operate.

- So we are trying to design passive microstrip SART which is battery free and it is being operated in s band (2 to 4 GHz)and c band frequency(4 to 8 Ghz).

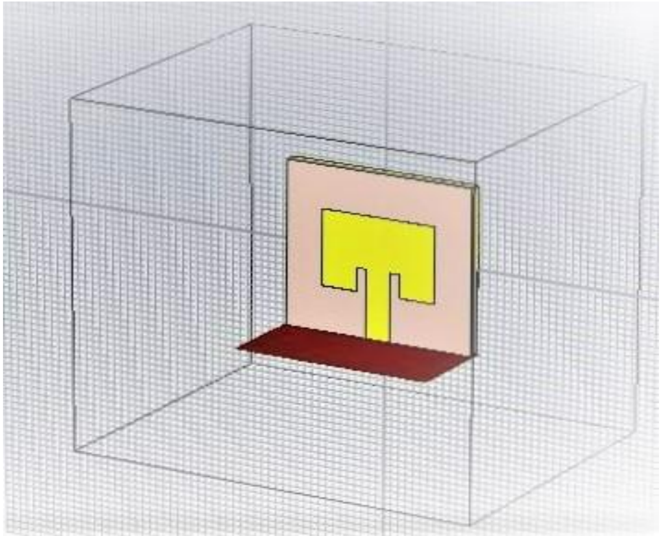
Fig 2 Active Transponders used in Maritime Search and Rescue operations which is Integrated with boats [https://gmdsstesters.com/images/radio-survey/sart.jpg]

CHAPTER 3

EXPERIMENTAL WORK

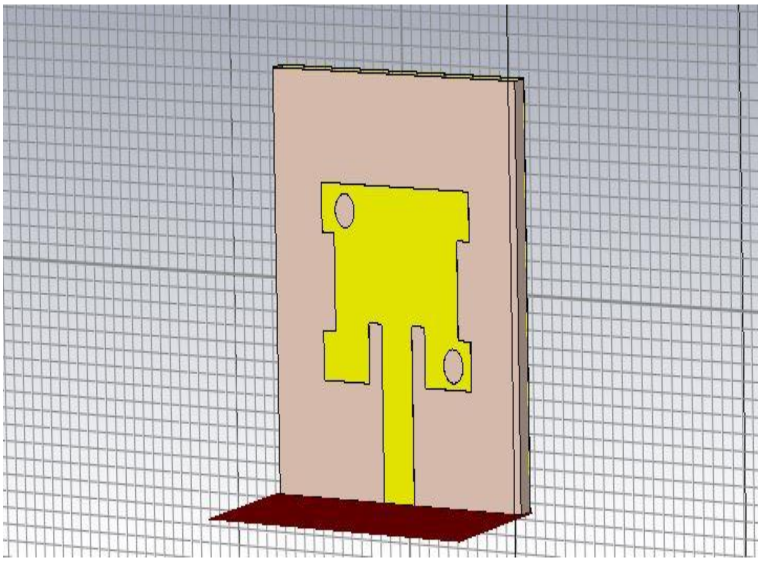
3.1 <u>SART's Transmitter</u>

Fig -3.1 Existing and Created designs



Which we created using Literature design equations of microstrip patch antenna and which we got best results by choosing correct Insertion cut lengths

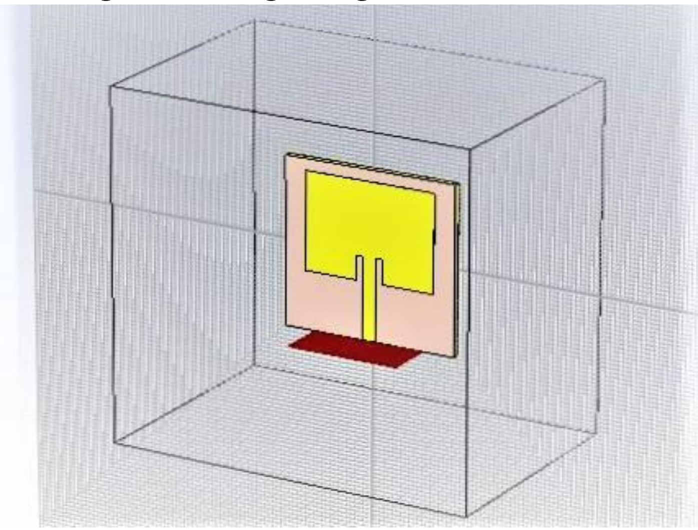
Created Design



For Existing we tired to cut the stubs on both sides with two holes on the patch to reduce unwanted harmonic Frequencies and to reduce the Fabrication cost and also to have some unique model

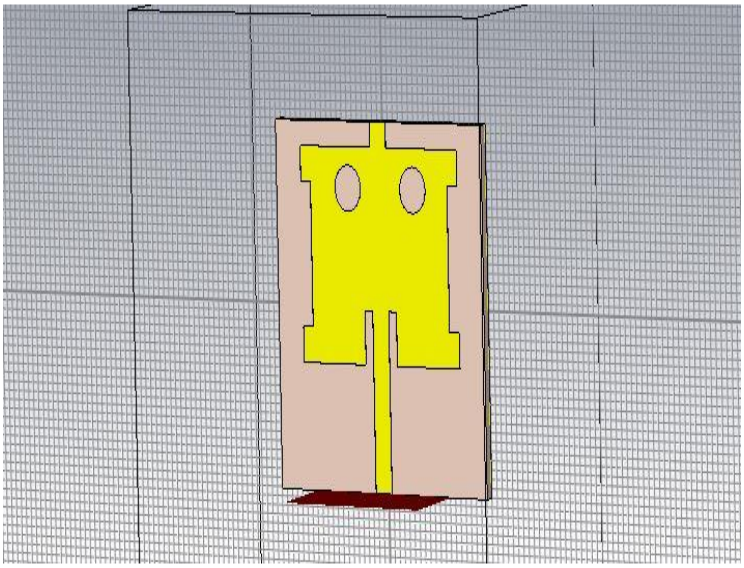
3.2 SART's Receiver

Fig-3.2 Existing Design



Which we created using Literature design equations of microstrip patch antenna and which we got best results by choosing correct Insertion cut lengths

Created Design



For Existing we tired to cut the stubs on both sides with two holes on the patch to reduce unwanted harmonic Frequencies and to reduce the Fabrication cost and also to have some unique model.We are also added stub on Top side of Transmitting antenna to have impedance matching with Frequency doubler

Dimensions

Table 1.2 dimensions of SART transmitter and receiver

Properties	**Transmitter**	**Receiver**
Substrate Type	FR4	FR4
Operating Frequency	2.908GHz	5.653GHz
Length of Patch	11.555mm	23.43mm
Width of Patch	15.21mm	30.42mm
Thickness of Patch	1.6	1.6
Permittivity of Substrate	4.3	4.3

3.3 Defective Ground Structure

- Microwave component with Defected Ground Structure (DGS) has been gained popularity among all the techniques reported for enhancing the parameters due to its simple structural design.
- Etched slots or defects on the ground plane of microstrip circuits are referred to as Defected Ground Structure.
- Single or multiple defects on the ground plane may be considered as DGS. Initially DGS was reported for filters underneath the microstrip line.
- DGS has been used underneath the microstrip line to achieve band-stop characteristics and to suppress higher mode harmonics and mutual coupling.
- After successful implementation of DGS in the field of filters, nowadays DGS is in demand extensively for various applications.

- DGS has been used in the field of microstrip antennas for enhancing the bandwidth and gain of microstrip antenna and to suppress the higher mode harmonics, mutual coupling between adjacent element, and cross-polarization for improving the radiation characteristics of the microstrip antenna.

Fig 3.3 - Front View, Back view and Back view with DGS

- The role of DGS in the field of microwave and microstrip antennas is presented with various applications of DGS that is miniaturization, multiband performance, bandwidth enhancement, gain enhancement, mutual coupling suppression between two elements, higher mode harmonics suppression, cross-polarization suppression, notched band creation and circular polarization achievement

3.4 <u>Frequency Multiplier</u>

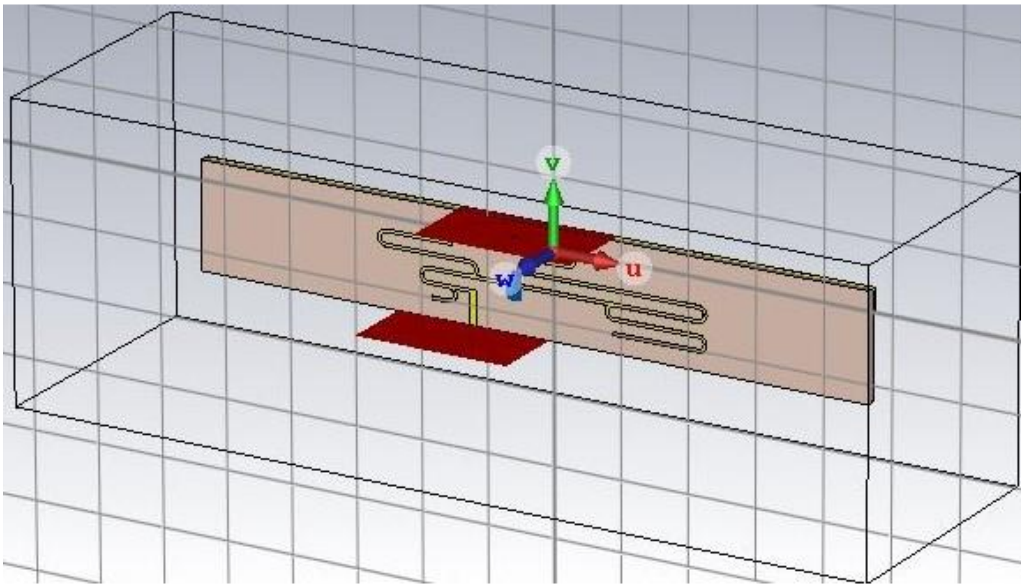
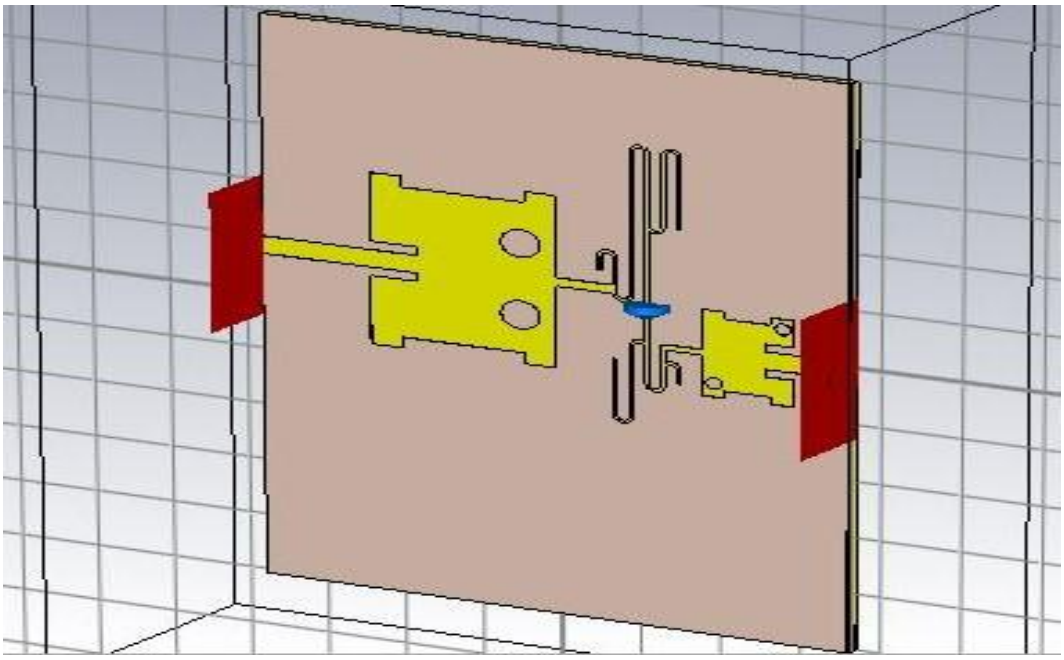


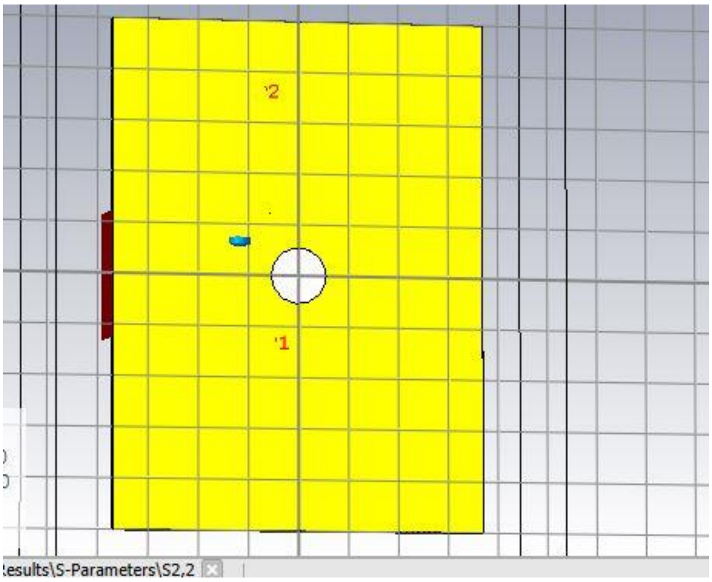
Fig3.4 – Frequency Multiplier

Here port1 is receiving antenna which have more wave length so we want bigger strip line and Port 2 which is for Transmitting Antenna which have less wave length and coupling happens in diode which is between port 1 strip line and port 2 strip line

3.5 <u>Integrated SART</u>

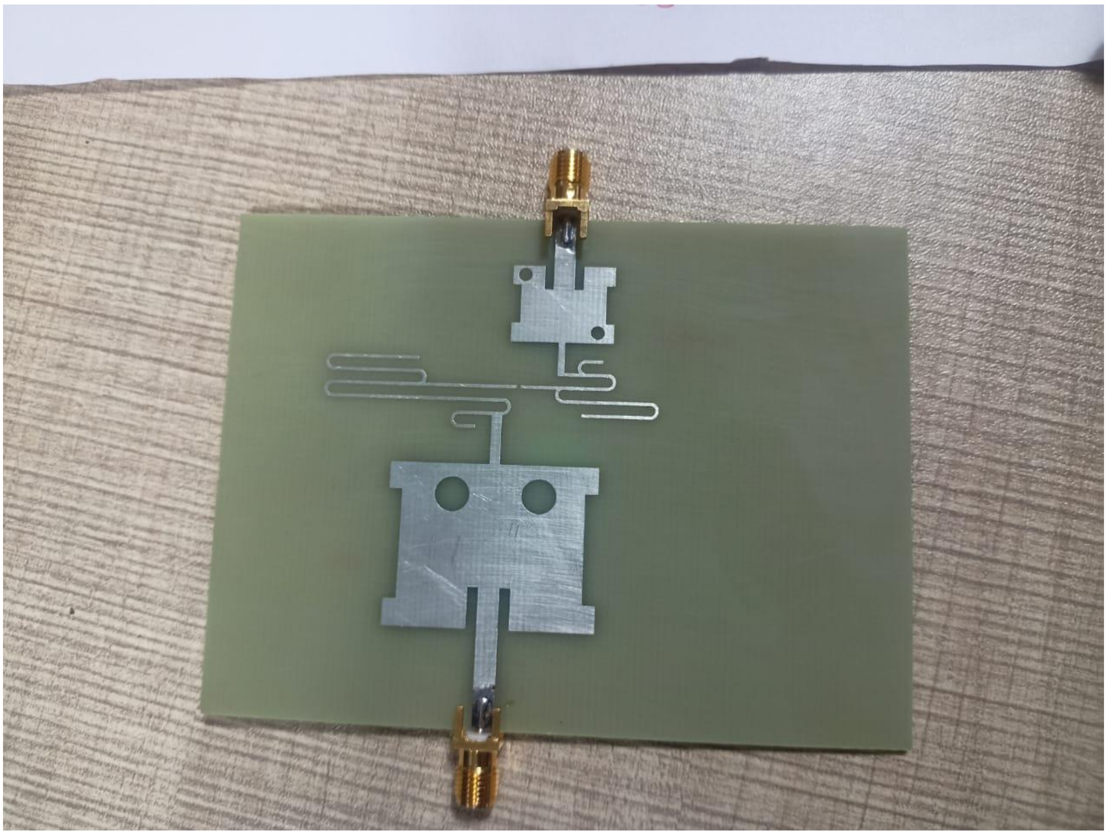
Fig-3.5 Integrated SART front view contains Transmitter, Multiplier and Receiver & Back View of Integrated SART

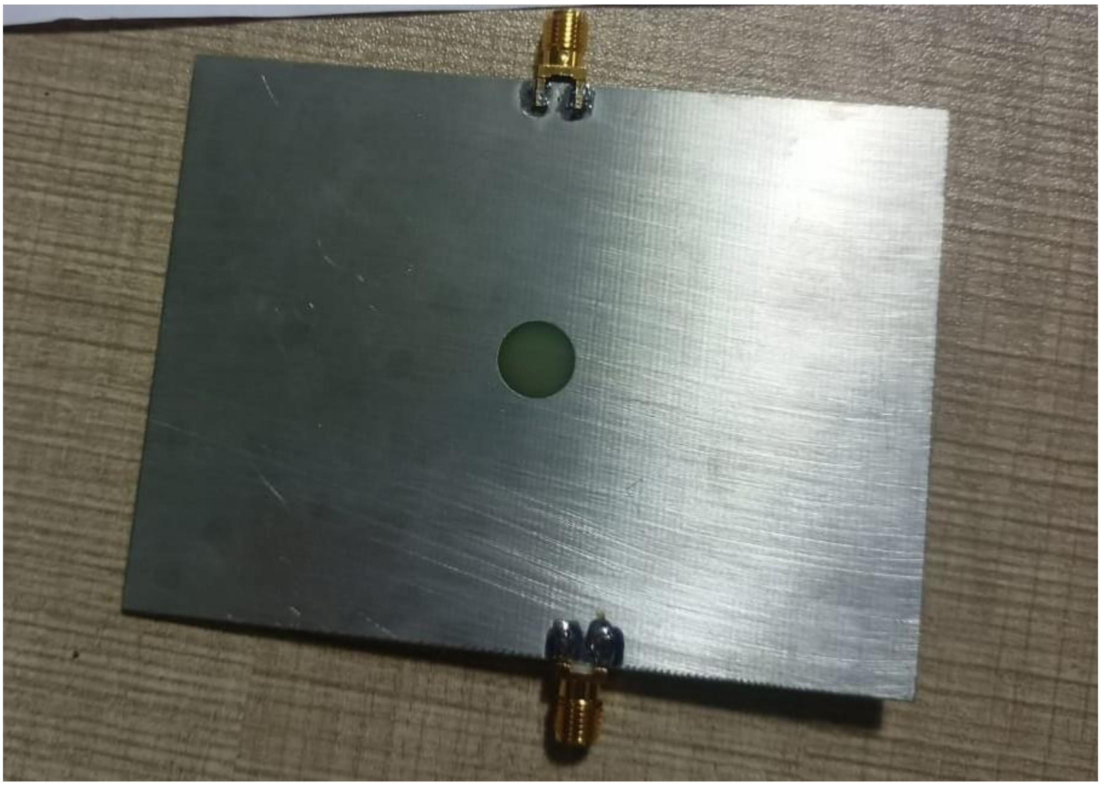


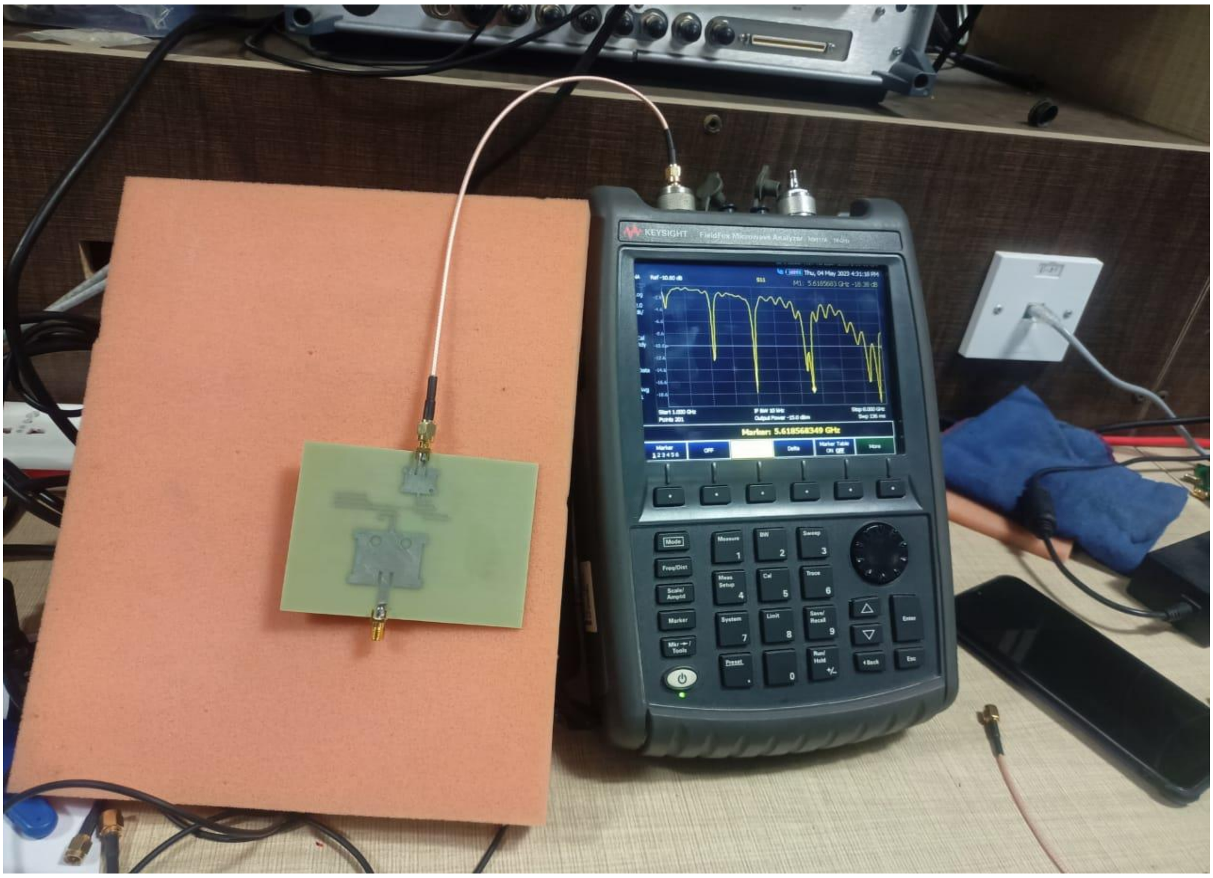


3.6 Images of Fabricated Integrated sart Top view and Bottom view

Fig 3.6 Fabricated Integrated sart Top view and Bottom view






KEYSIGHT
Marker: 5.618568349 GHz

CHAPTER 4

RESULT/DISCUSSION

4.1 <u>Reflection Coefficient of Transmitter:</u>

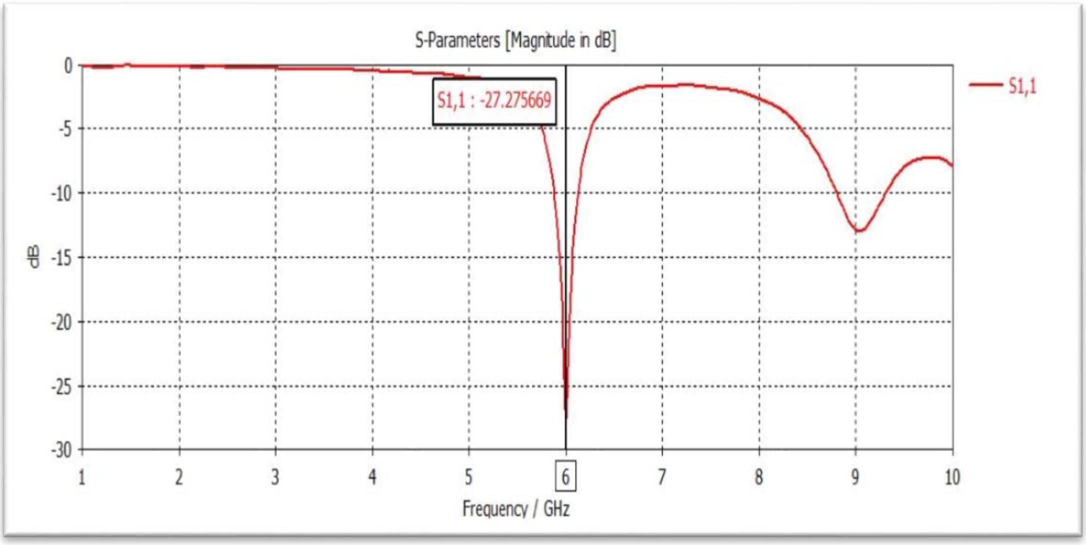


Fig 14 Existed Design output

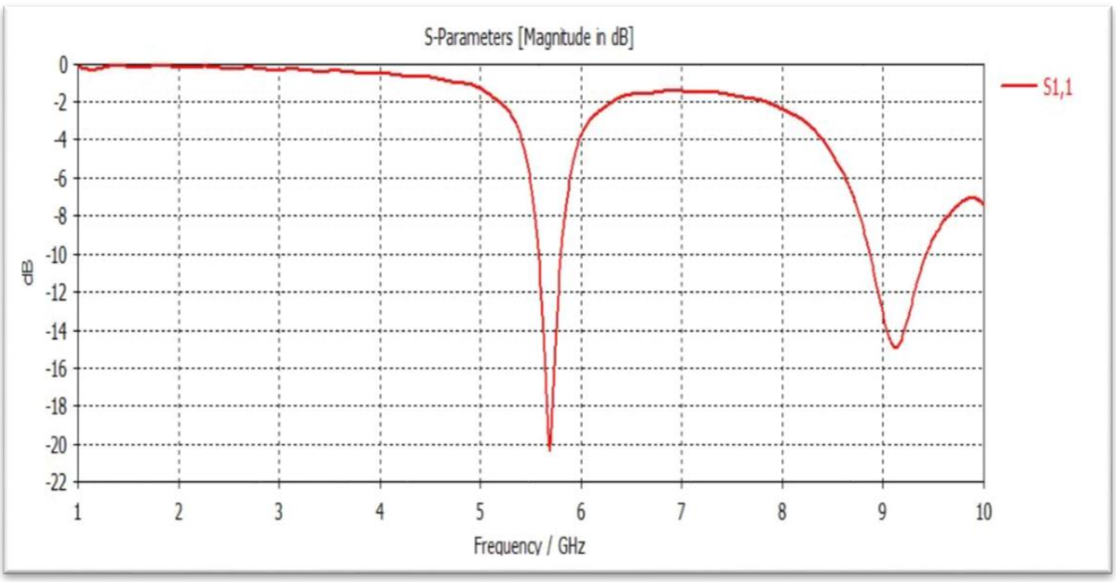


Fig 15 Created Design output

4.2 <u>Reflection Coefficient for Receiver</u>

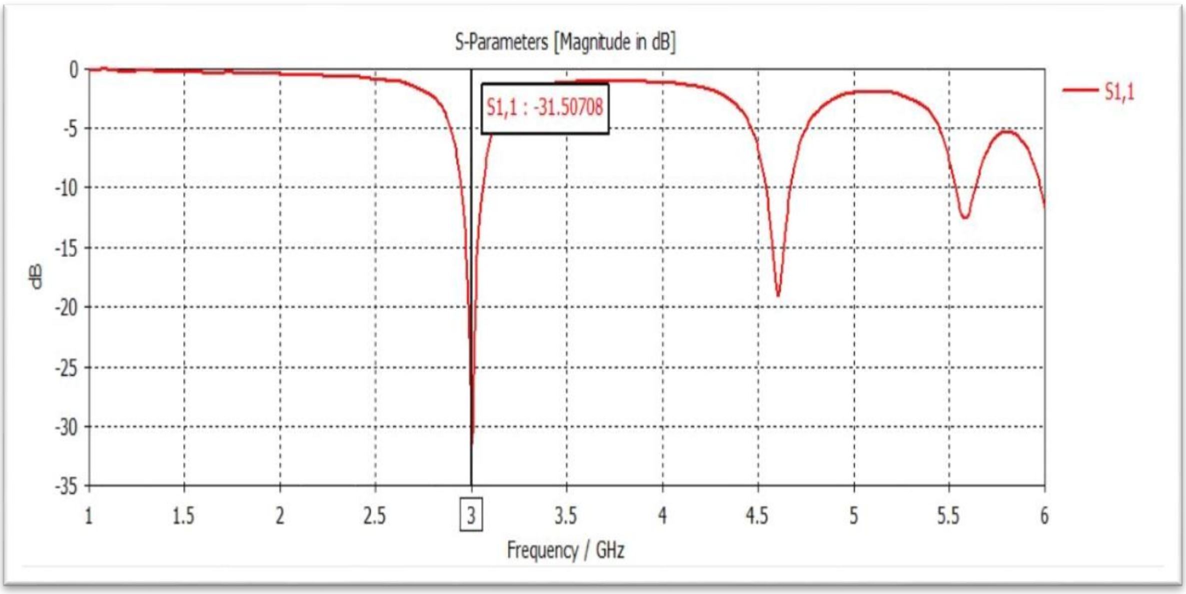


Fig 16 Existed Design output

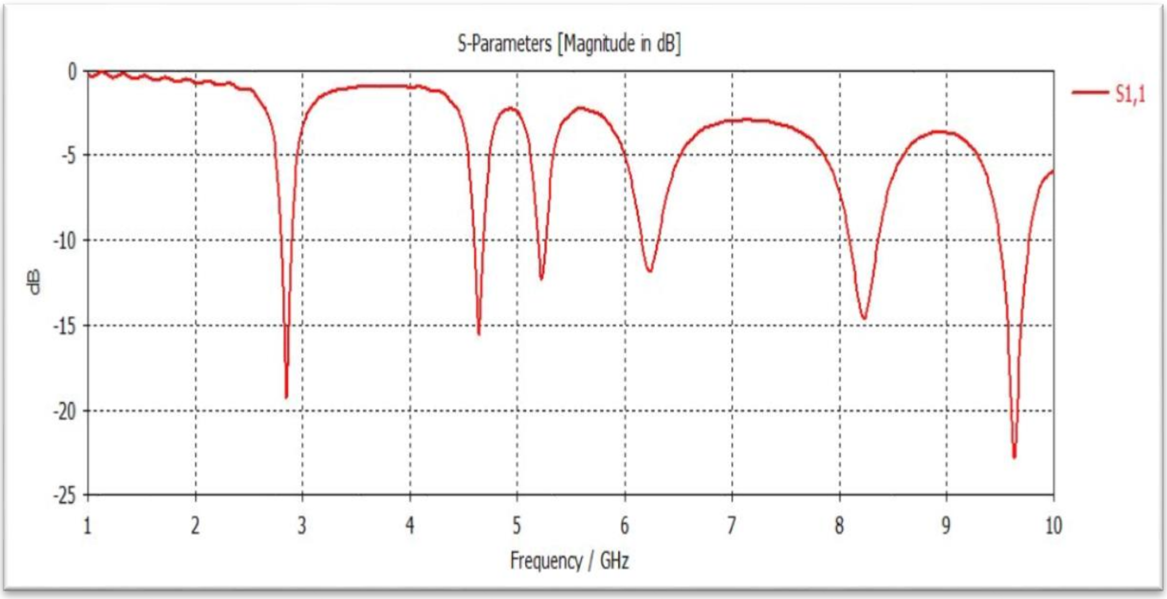


Fig 17 Created Design output

4.3 S parameters for Frequency Doubler/Multiplier

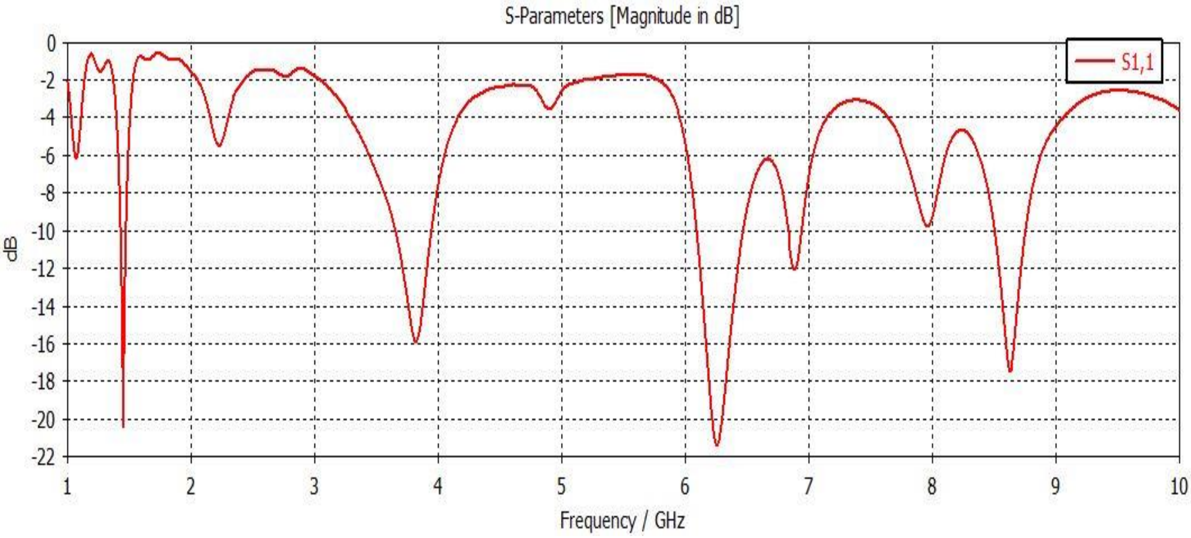


Fig 18 S11

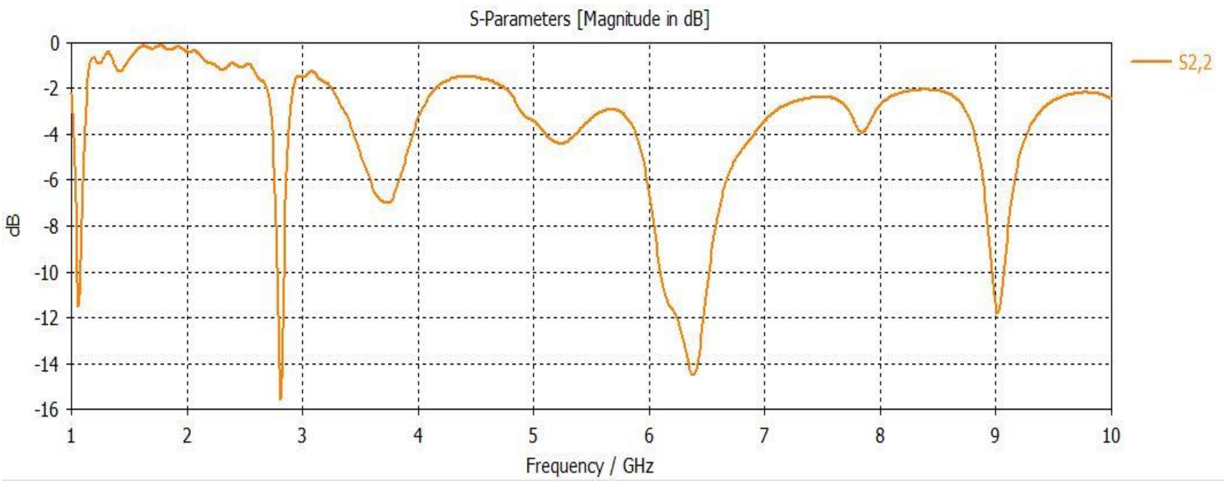


Fig 19 S22

4.4 S Parameters for Integrated SART

At r=5

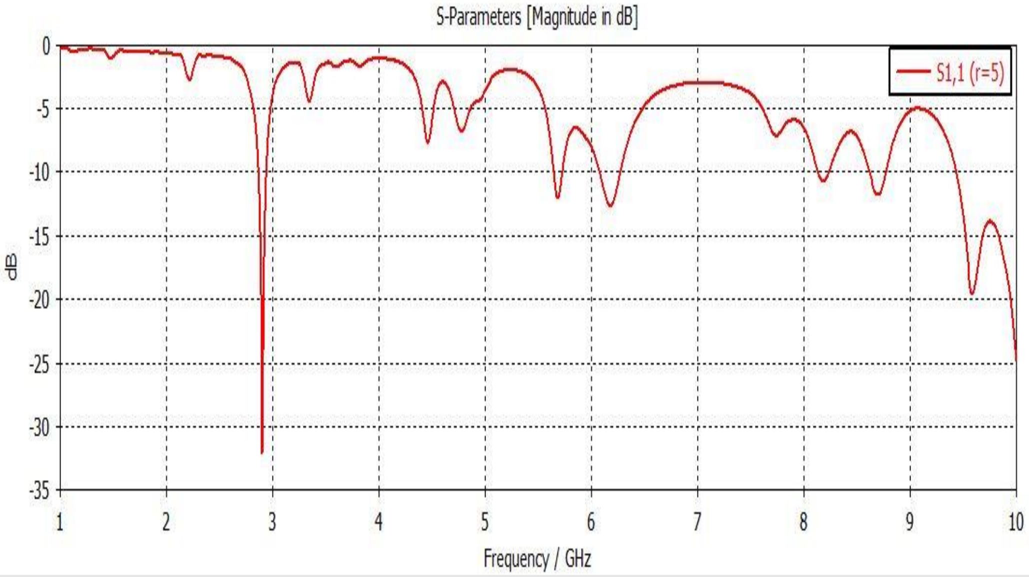


Fig 20 – S11

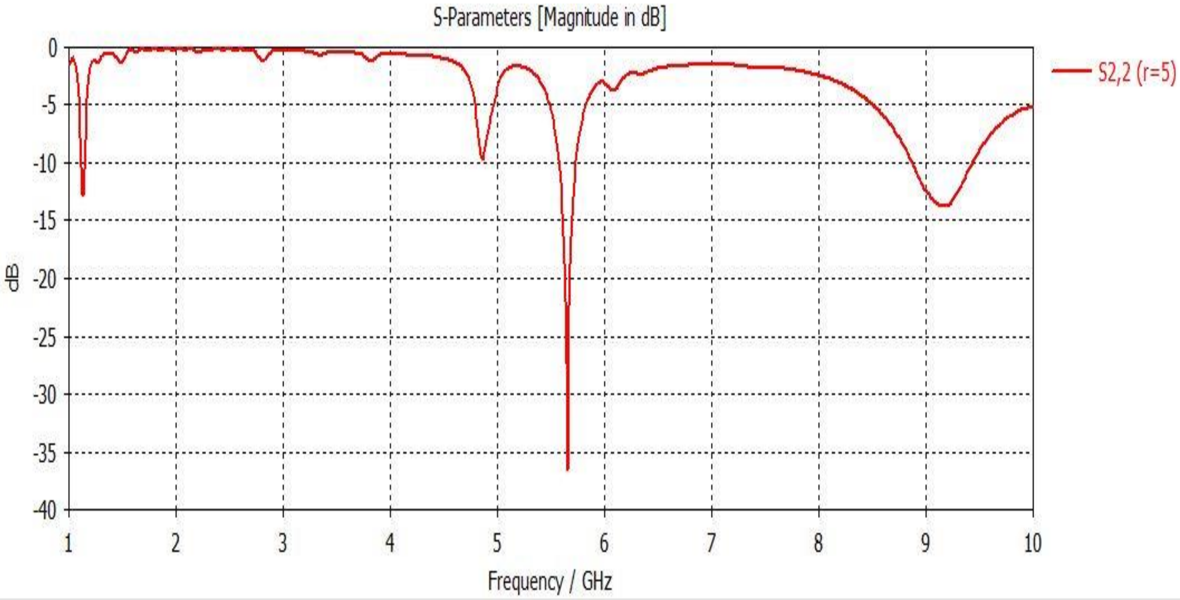


Fig 21-S22

Fig 4.5 Parametric Analysis

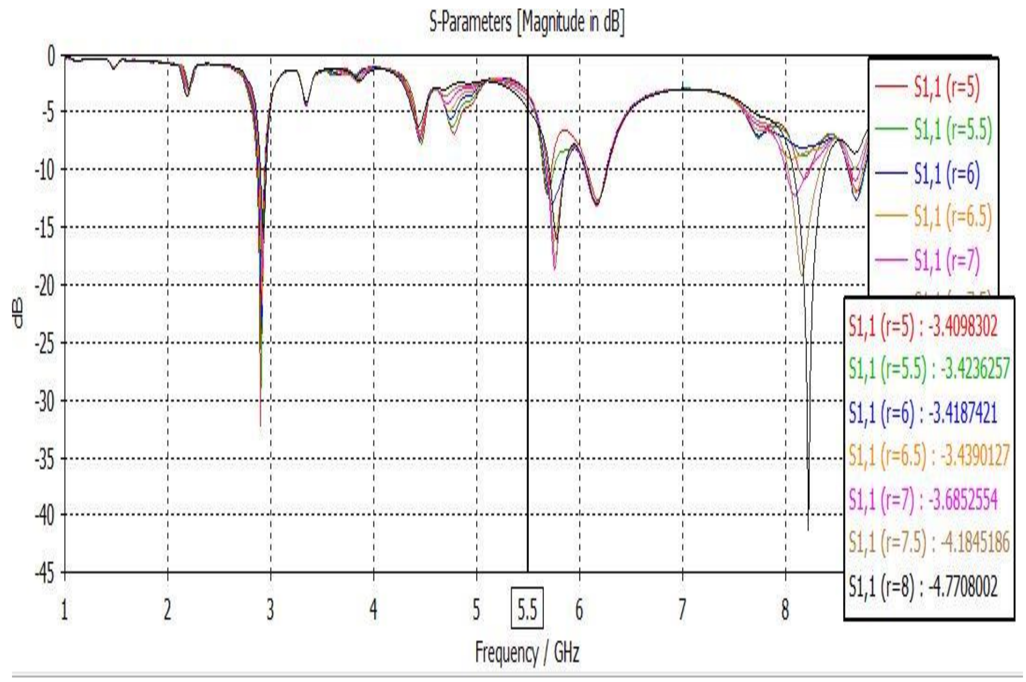


Fig 22 – S11

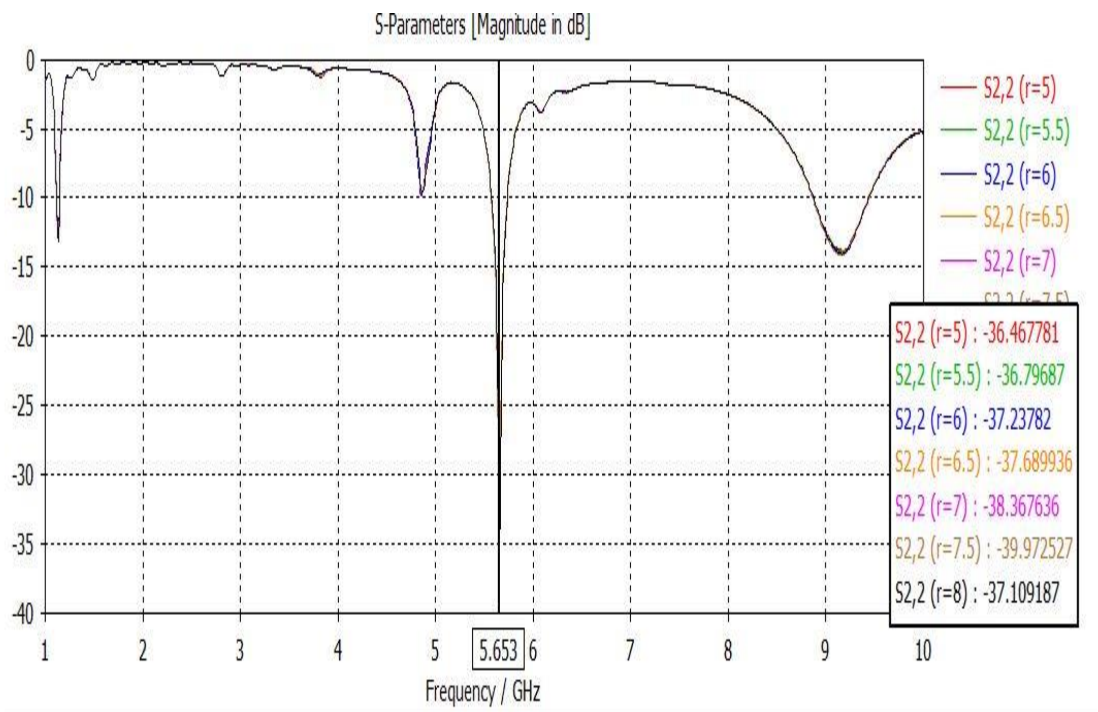
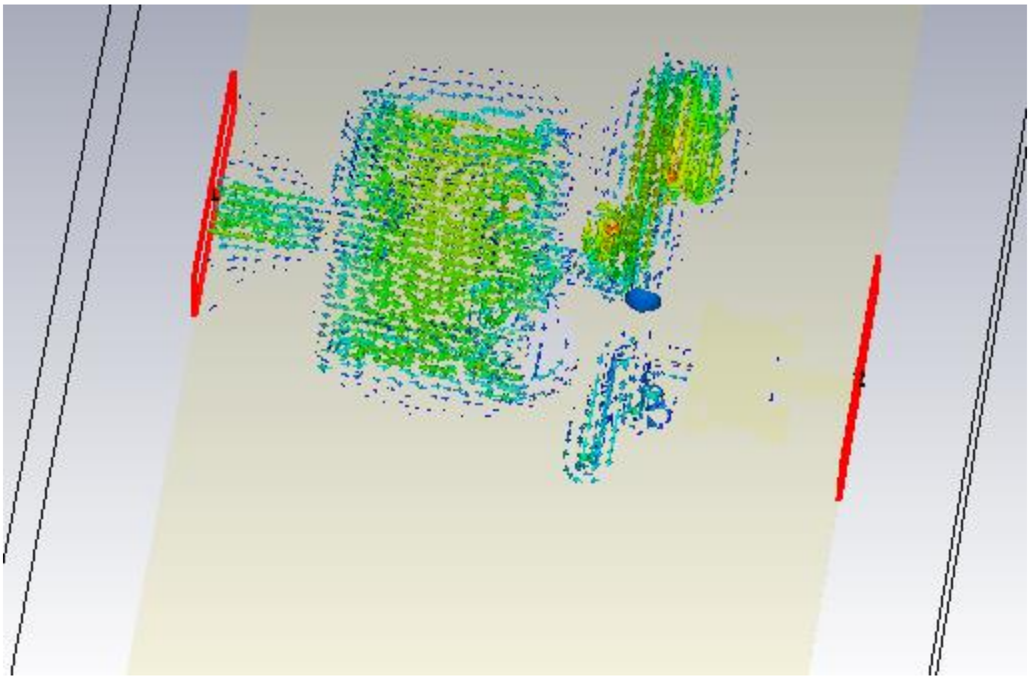


Fig 23 – S22

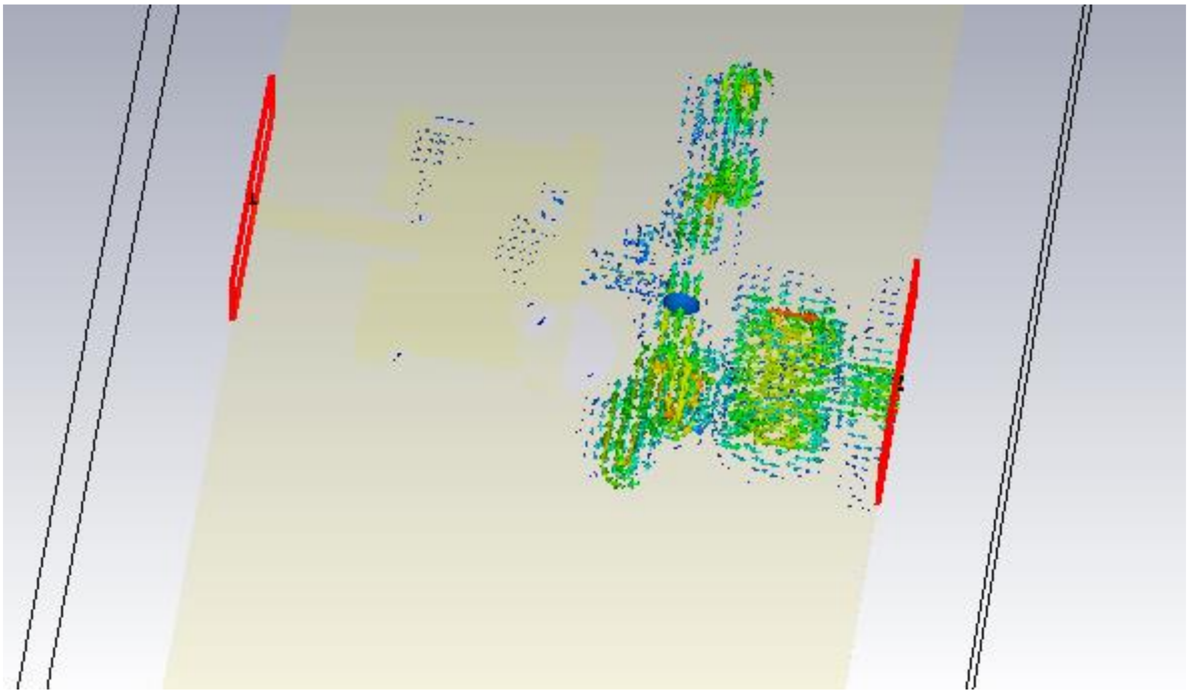
4.5. Directivity, Axial ratio, Surface currents, E-field, H-field, Gain, VSWR

Fig 4.6 Surface current at 2.899



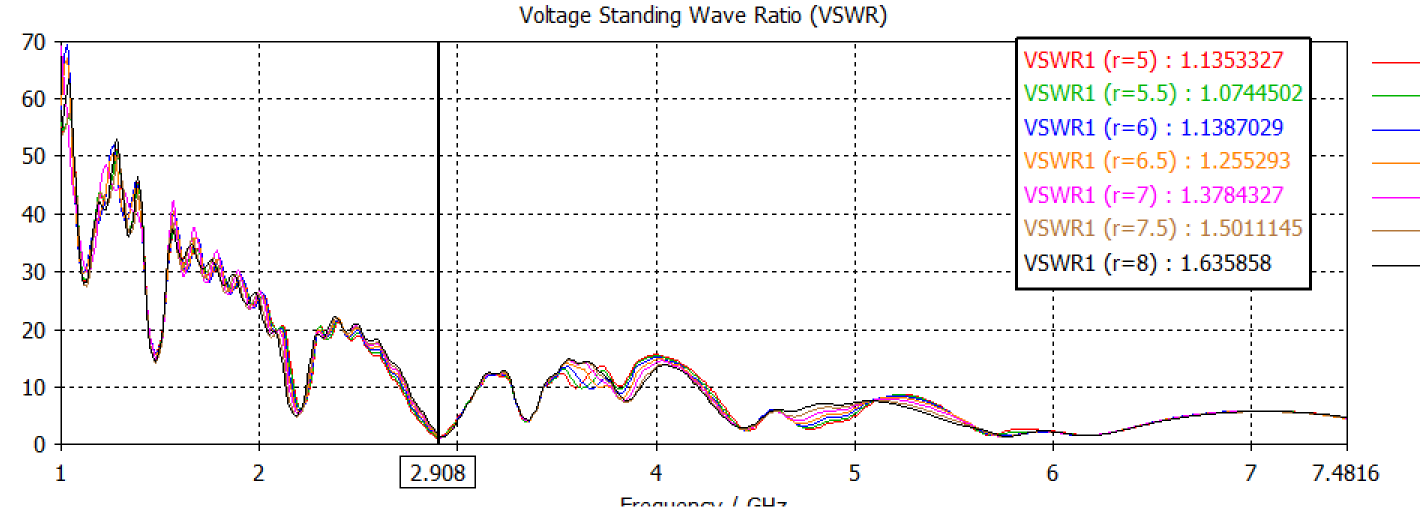
For this we can observe how the Surface current from port 1 is Inducing the surface current at port 2

Surfacecurrentat5.653



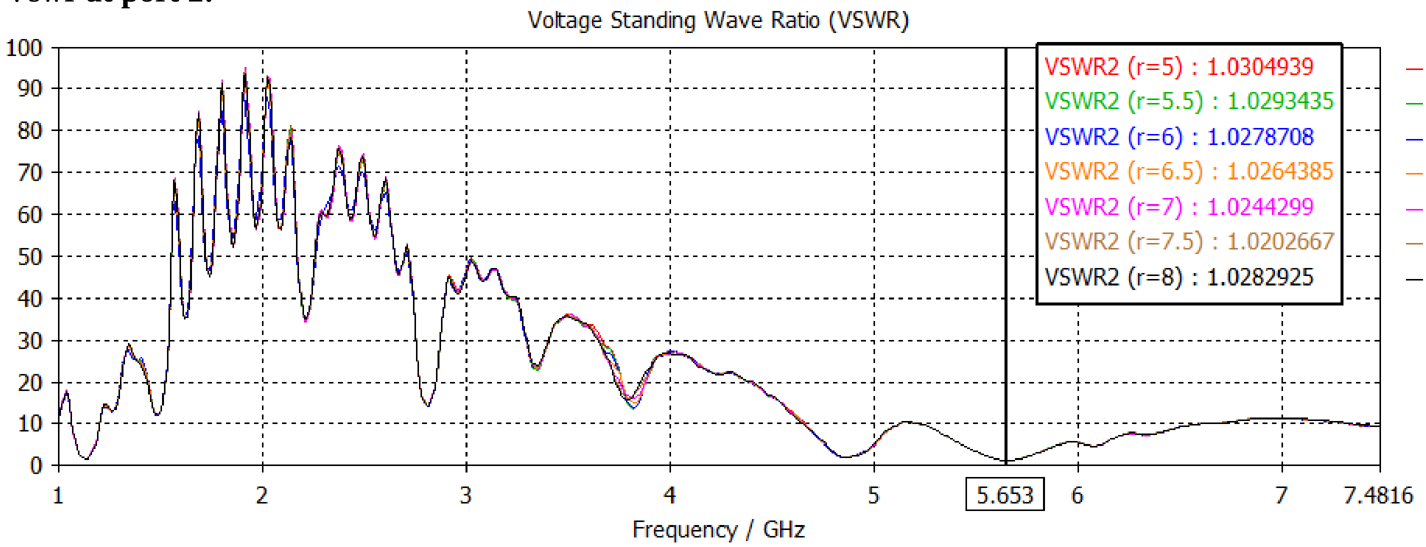
For this we can observe how the Surface current from port 2 is Inducing the surface current at port 1

Vswr at port1:-

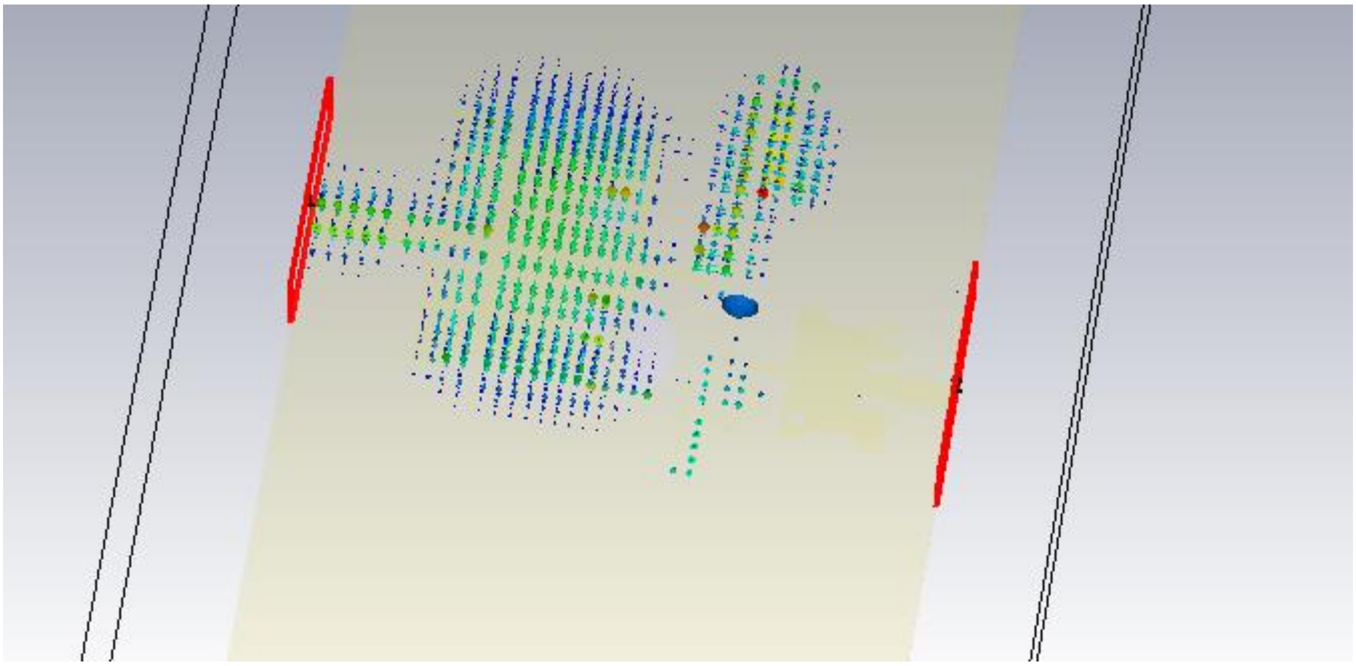


We can observe vswr around 1.07

Vswr at port 2:-

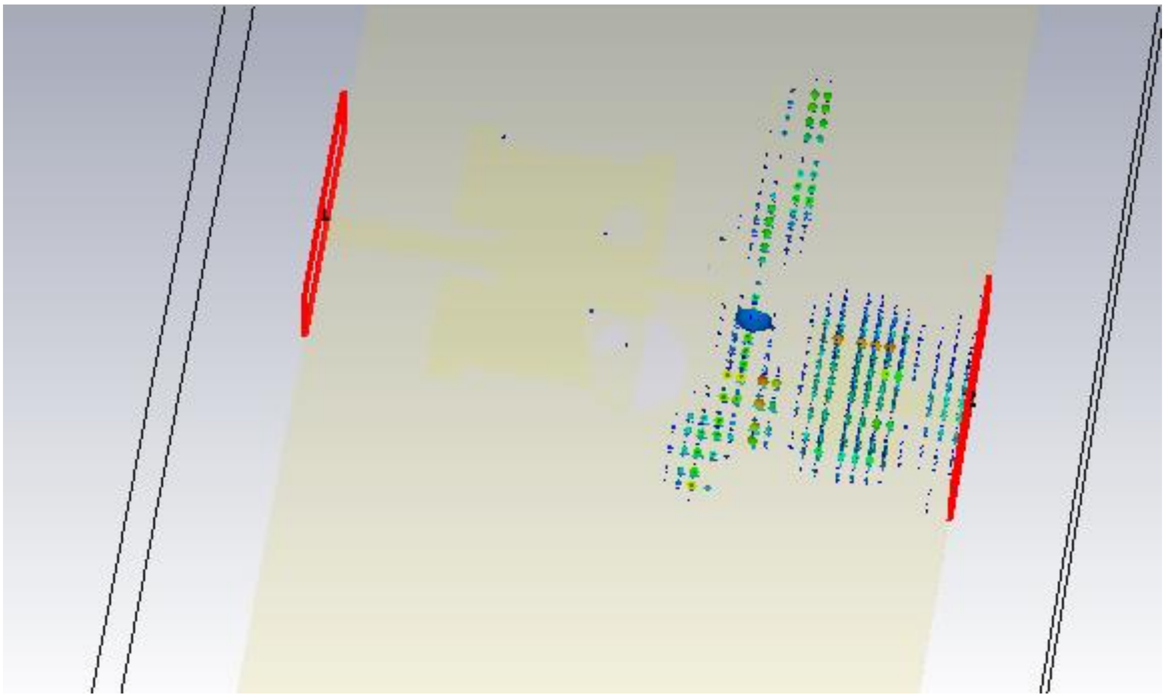


H field at 2.899



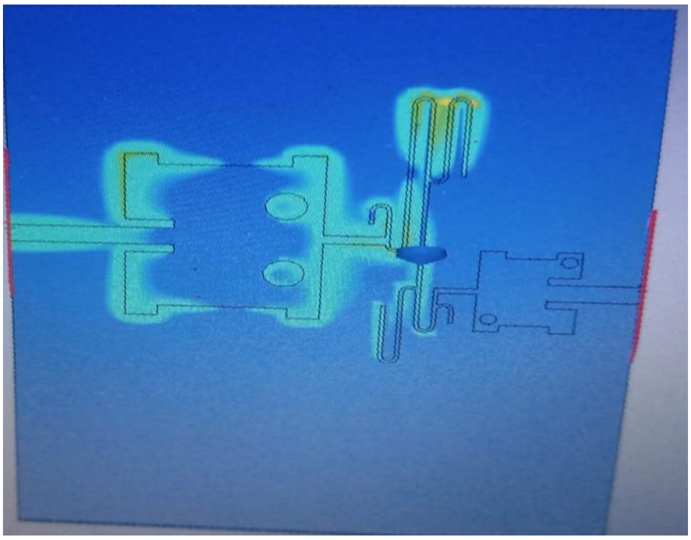
For this we can observe how the H field from port 1 is Inducing the H field at port 2

H field at 5.653



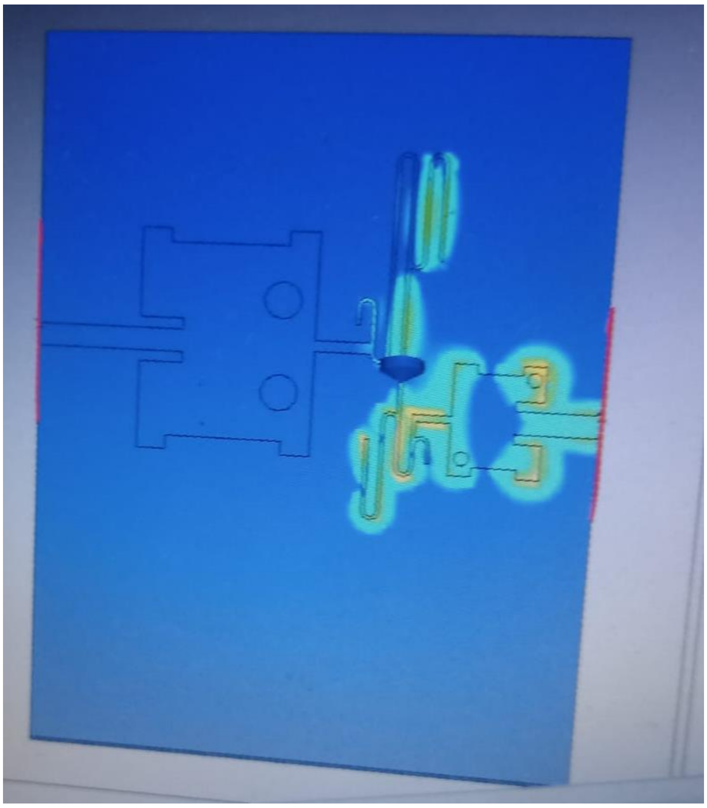
For this we can observe how the H field from port 2 is Inducing the H field at port 1

E field at 2.899



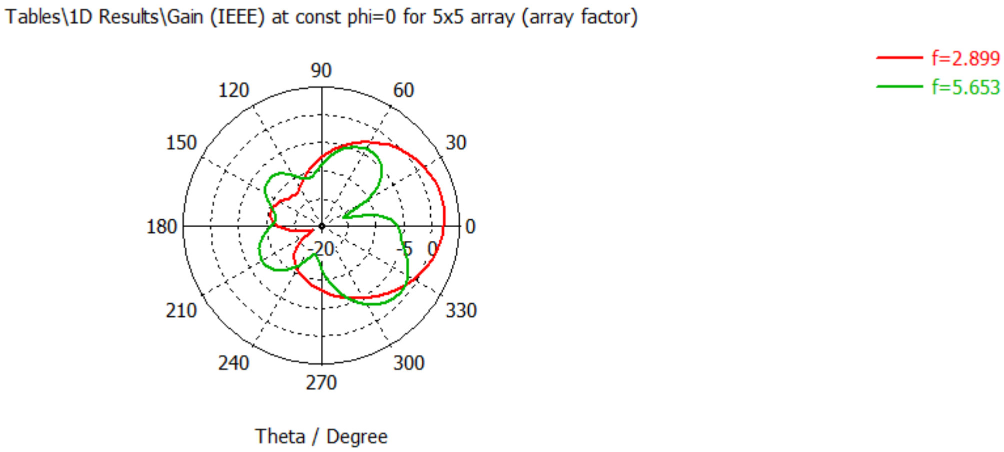
For this we can observe how the E field from port 1 is Inducing the E field at port 2

E field at 5.653



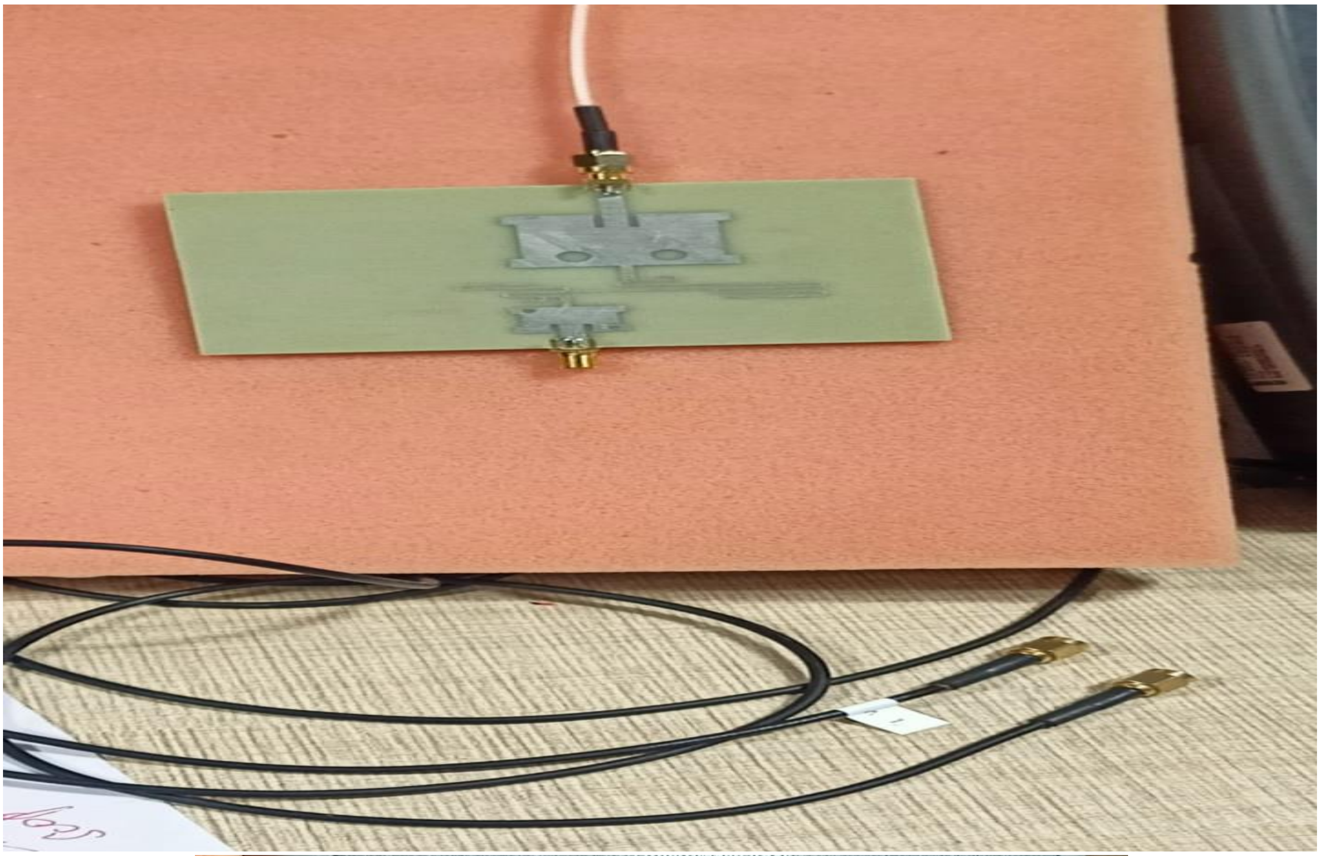
For this we can observe how the E field from port 2 is Inducing the E field at port 1

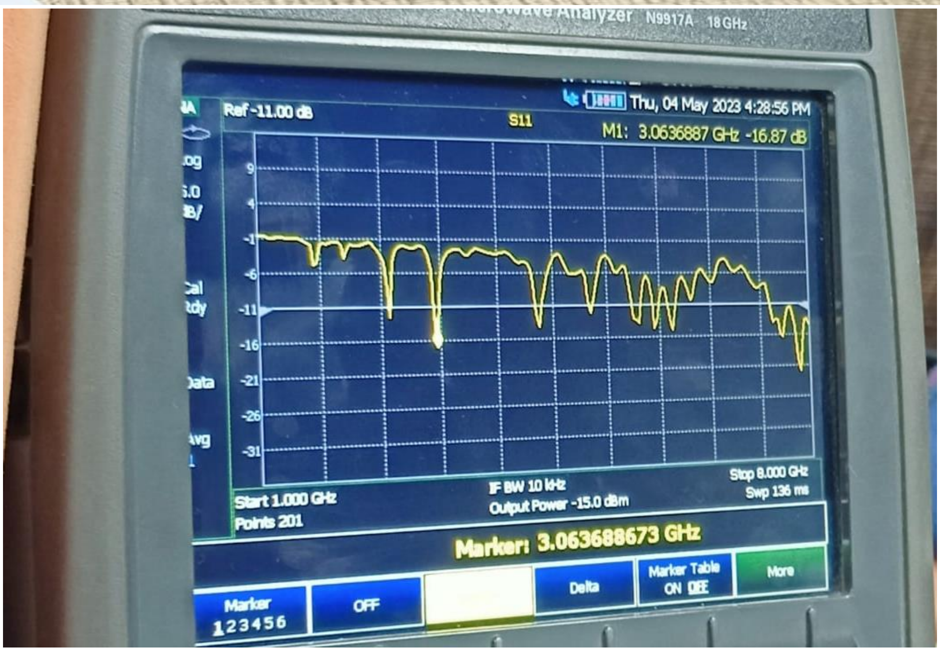
Gain(IEEE standards):-



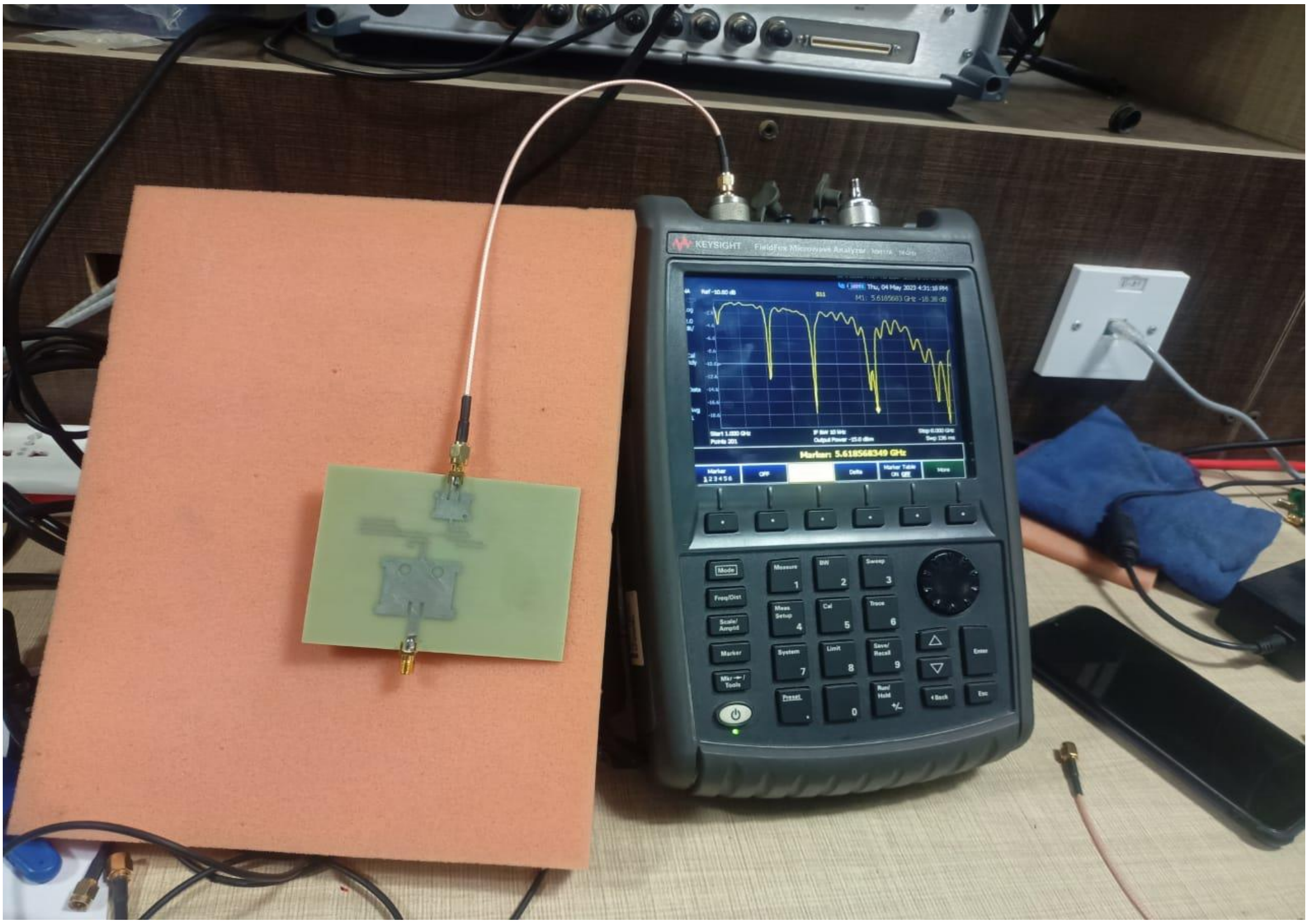
4.6. <u>S parameters Testing of Fabricated Integrated sart using VNA (Vector Network Analyzer):-</u>

Fig – 4.7 Reflection Coefficient for port 1 and port2



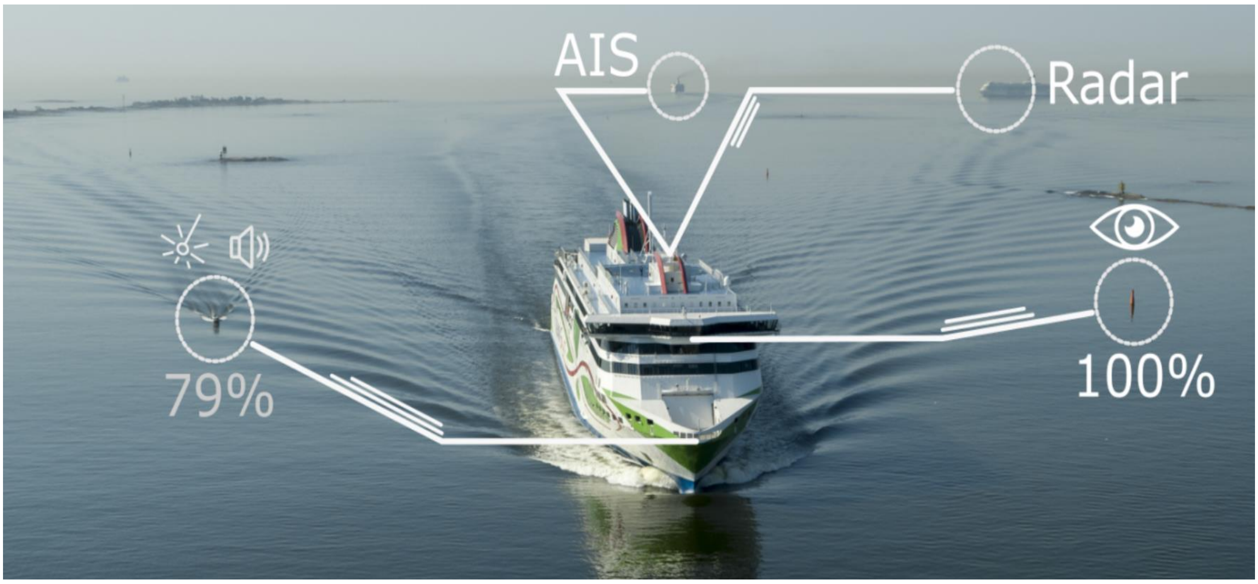

N9917A 18 GHz
Thu, 04 May 2023 4:28:56 PM
Ref -11.00 dB
S11
M1: 3.0636887 GHz -16.87 dB
9
4
-1
-6
-11
-16
-21
-26
-31
Start 1.000 GHz
Points 201
IF BW 10 kHz
Output Power -15.0 dBm
Stop 8.000 GHz
Swp 136 ms
Marker: 3.063688673 GHz
Marker
123456
OFF
Delta
Marker Table
ON OFF
More

Port-2



- **<u>Applications: -</u>**

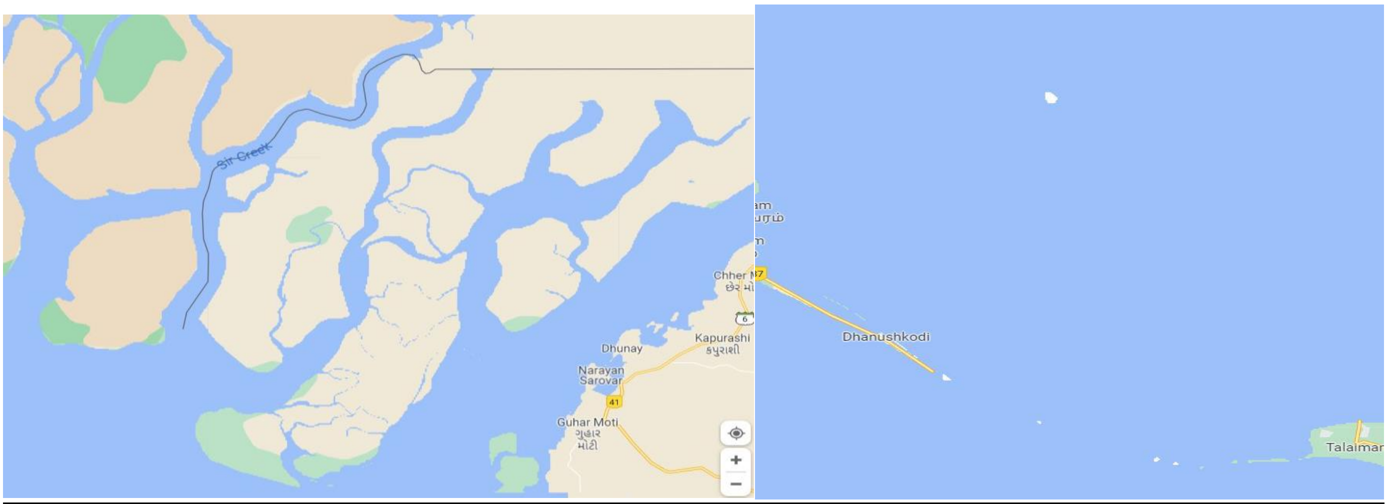
<u>Traditional Active sarts used in search and rescue operations[https://marinegyaan.com/wp-content/uploads/2016/06/SART-IMAGE.jpg]</u>



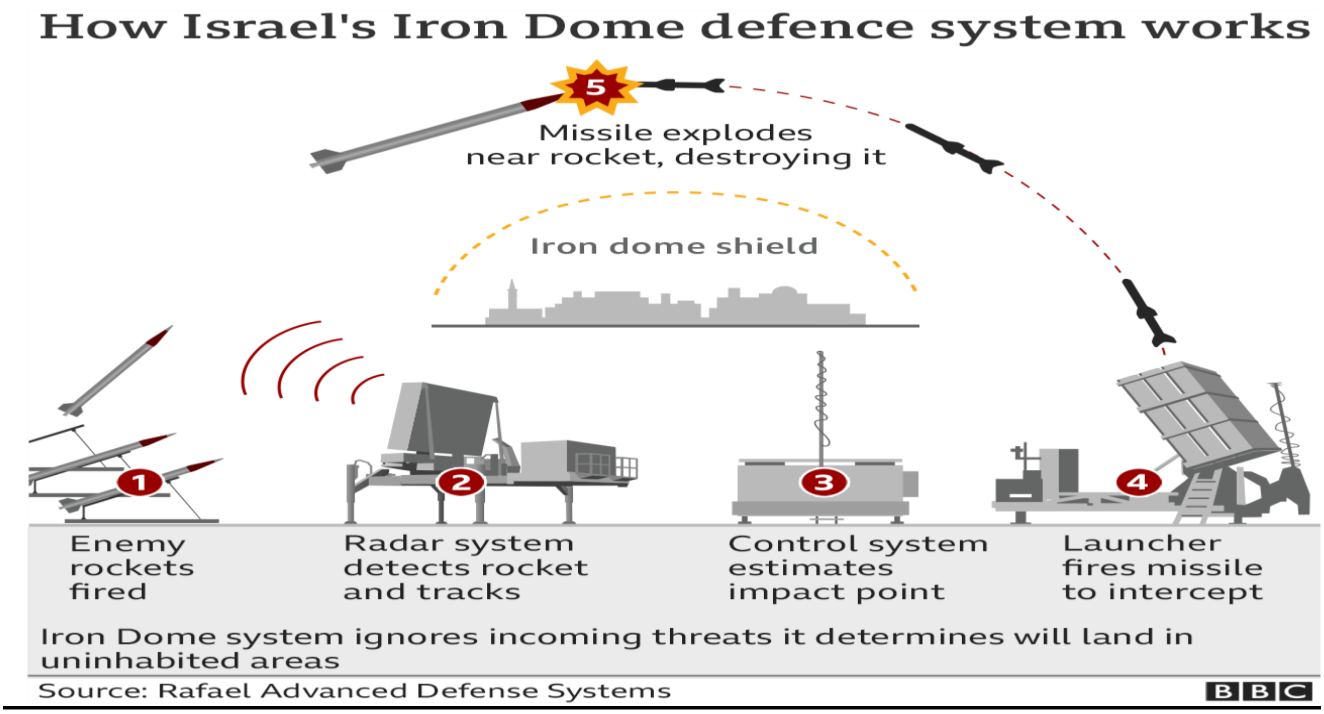
Maritime operation setup in cruise boat[https://www.superyachtmarinestore.com/marine-electronics/ais/what-is-ais-sart/]

- In search and rescue operations of maritime. We have several navigation methods to do SAR operation but when it come to certain Applications passive transponders have more gain over active transponders.

- In general, as active Transponders are big in size. They are Installed to the boats and passive transponders to the jackets of cruise people
- We can use it track the fisher man ships and it is less in cost which around
- It can track upto 500 meters and no need battery to maintain it.
- In recent news we have heard about where Indian fishermen from gujarat had accidentely entered to pakisthan maritime route for fishing instead we can use this transponders and can detect our civilian ships and enemy civilian ships and we can protect them from not entering the enemy sea shore.



- Same like this case with Sri Lanka and Indian marine borders in near Kachchatheevu Island .
- So radars are introduced near the borders and so that they can track our transponders which are attached with fishermen boat or jackets and Instead of using Active we will use this passive transponders and best because mainly because of their cost which is have cost of around 2000-3000 rupees



- In Iron dome technology developed by Israel we can use this kind of transponders to track the intercepting missiles .So this way we can use it in various applications of search and rescue or search and track or tracking etc:-

Conclusion:-

So we can conclude the passive Transponders have high advantage over Active Transponders in terms of cost,Maintance,operating and size in Maritime search and Rescue Operations and with this project we got the experience to design of Transponders,Antenna,Use of Dgs(defected Ground strutures) in Antenna design,Impedance matching between the components,Hardware testing and Applications of it in Maritime Search and Resuce operations.

Further work:-

So the sart we have been designed work under the range of 500 meters and we can Increase its range by Increasing the operating frequency that is Transmission and Receiving Frequency

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- "The Design of Microwave Bandpass Filters Using Resonators With Nonuniform Q" by Andrew C. Guyette, Ian C. Hunter, Senior Member, IEEE, and Roger D. Pollard, Fellow, IEEE
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