iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VIII Month of publication: Aug 2023

DOI: https://doi.org/10.22214/ijraset.2023.55355

Antenna Array with Low Side Lobe Levels for MIMO Applications

A. Lavanya[1], G. Srivalli[2]
[1, 2]ECE Dept, G Narayanamma Institute of Technology & Science Hyderabad, TS, India

Abstract: To design a single element microstrip patch antenna at a frequency of 4 GHz. A uniform planar array with 4 patch elements is designed. A non uniform planar array is designed to overcome the mutual coupling effect. Simulation of the designed uniform planar array and non uniform planar array antenna array is performed on HFSS tools. A single microstrip feed patch antenna element is designed at a frequency of 4 GHz. The substrate material used is Rogers 6002. A 2*2 array is designed by using 4 similar patch elements. The proposed model has dimensions of the substrate as 58mm x 68mm, the dimensions of the patch is 20mm x 22mm. For the proposed model slots are added to each patch with the dimensions 5mm x 1mm. The substrate material used is FR4 epoxy. It is further improved by changing the dielectric material variations, slot arm length variations, slot arm thickness variations.
Keywords: Uniform planar array, Non-uniform planar array, Mutual coupling, MIMO array, Low side lobe

I. INTRODUCTION

A single antenna is employed at the source and a second one is used at the destination in typical wireless communication methods. It occasionally runs into issues with multipath effects. High data rate speed is required for future wireless applications like the Internet of Things, as large amounts of information must really be transferred in a relatively short period of time. This means that using two or more antenna elements and sending out numerous signals both at the source and the destination will both solve the problem of multipath wave propagation and even benefit from it. Multiple Input and Multiple Output (MIMO) antenna arrays have generated interest due to their straightforward construction and superior performance. In a MIMO array, it is feasible to use the entire antenna array at once, but it is also conceivable to use a subset or a single element of the same array for various purposes, such as separate elements for various channels. MIMO is thus one of many types of smart antenna technology.

One of the key issues is that many different types of antenna arrays experience the mutual coupling (MC) effect, which reduces the performance of the antenna array [2]. The designers' biggest task will be to lower the MC between two close antenna array elements. As a result, numerous research projects have been putting forth fresh ideas every day for the past few decades to lessen the MC impact. Increasing the distance between neighbouring items, which also increases the array size, is the most typical method of lowering MC. Other techniques to lessen the MC effect include the use of metamaterial arrays [3], stacked arrays, non-uniform planar arrays (NPA), conformal arrays, circular arrays [4], unevenly placed planar arrays [5], sequentially rotated planar arrays [6], [7], planar arrays with electromagnetic band gaps [8], and planar arrays with deficient ground structures (DGS) [9]. In addition, other kinds of non-uniform arrays have gained popularity and acceptance among academics during the past few years. It still has trouble coming up with workable answers, though. Research is also required in the area of antenna array design to lessen the MC impact. In [3], a four-element (22) MIMO array with (25) metamaterial unit cells on the ground plane was suggested. With a peak gain of 9.2 dBi, 73% radiation efficiency, and more than 18 dB isolation, the suggested array has been successful. The metamaterial structure has accomplished the MC reduction. For MC reduction, an intriguing circular MIMO array with a central element has been presented in [4]. The array's highest gain with 9 radiating elements was 15.7 dB. With the suggested approach, a -17.6 dB side lobe level reduction has been made. Authors have suggested planar arrays in some works by arranging antenna elements unevenly [5]. As a result, within the same array, the antenna elements are positioned at varied distances from one another. In [6], [7], a different method of MC reduction has been suggested. To lessen the MC effect, the 22 antenna array elements in [6] are successively rotated. As a result, the proposed array has a - 24 dB insertion loss. In order to reduce MC, half-loop monopole antennas are rotated successively in a proposed four-element compact MIMO array in [7]. The suggested array has a 34.3% working bandwidth and a 3.18 dBi gain on average. The two elements are sufficiently isolated by greater than 16 dB. Antenna arrays with various slotted structures on the radiating plane or ground plane have been shown in several studies. A planar MIMO array with an EBG structure on the top plane has been suggested in [8], for example, to lessen MC. The suggested array offers improved isolation by 10 to 25 dB at 5.8 GHz thanks to the EBG construction.

In [9], [10], a 22 MIMO array with DGS has been suggested. Circular polarisation was obtained and MC was reduced by using slots on the radiating patch. Since there is more than 33 dB of isolation between two ports, the array has achieved this. According to the literature cited above, MC reduction has been accomplished by using a variety of strategies. However, researchers had to take a sophisticated design into account in order to attain great results. An innovative method for designing.
In this paper the proposed model has dimensions of the substrate as 58mm x 68mm, the dimensions of the patch is 20mm x 22mm. For the proposed model slots are added to each patch with the dimensions 5mm x 1mm. The substrate material used is FR4 epoxy. It is further improved by changing the dielectric material variations, slot arm length variations, Slot arm thickness variations to get low return loss, low VSWR.
The paper is organized in the following way : Section 1 has the introduction of the proposed model, Section 2 discusses the existing model and its summary. Section 3 discusses the proposed model 1 and 2. Section 4 shows results of the proposed models with respective figures. Section 5 briefly discusses the conclusion and future scope of this paper.

II. EXISTING MODEL

This section discusses the design of the proposed insert feed antenna using Rogers 5880 as the substrate material, which has a dielectric constant of 2.2 and dielectric loss of 0.0009 [1]. The structure that will be analyzed must first have a geometric model drawn. Selecting the substance from which the various drawn things are constructed is the following step. What comes next is an exact description of the structure's boundaries, such as those of a perfect magnetic or electrical conductor. When the structure in HFSS is fully modelled and the solution is put up, a port source must be specified to excite it. After the simulation is finished, the solution data is post-processed, which could involve showing far-field plots, smith chart graphs, or tables containing s-parameter data.

A. Simulation

The existing model design includes the following:
1) The frequency of a single inset feed patch antenna element is 5.8 GHz
2) Rogers 5880 is the substrate material in used when creating a 2*2 array, 4 comparable patch items are used
3) The patch dimension is 17.5mm x 20mm.
4) The ground dimension is 30mm x 23mm.
5) The feed dimension is 9.45mm x 0.77mm.

Fig. 1 shows the Geometry of existing model with above mentioned properties.

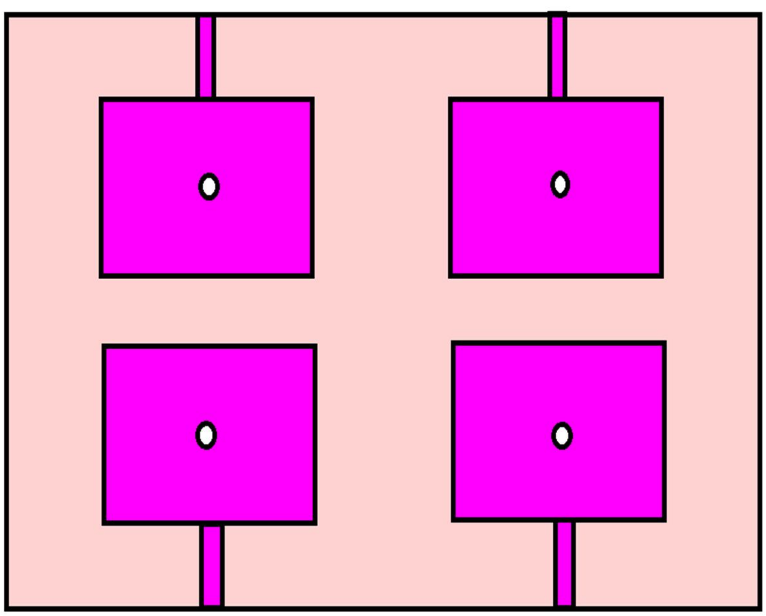

Fig. 1 Geometry of existing model design with 2*2 array

B. Results

A graph of S11 of an antenna vs frequency is called its return loss curve. For optimum working such a graph must show a dip at the operating frequency and have a minimum dB value at this frequency. The S11 graph of existing model is as shown in Fig. 2

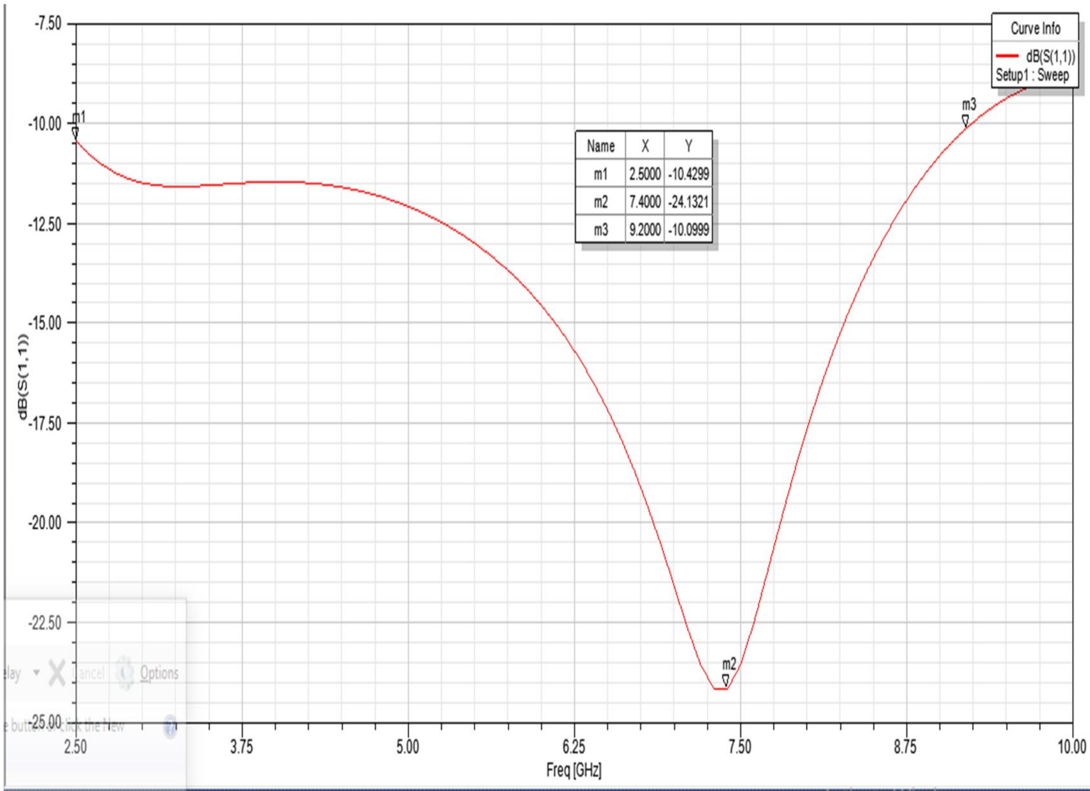

Fig. 2 S11 graph results of existing model design with 2*2 array

III.DESIGN OF PROPOSED ANTENNA

A geometric model of the structure that will be studied must first be created. The next step is choosing the material that will be used to create the various sketched objects. The boundaries of the structure, like those of a perfect magnetic or electrical conductor, are then precisely described. A port source needs to be supplied in order to excite the structure in HFSS once it has been fully modeled and the solution posted. The solution data is post-processed when the simulation is complete, which may involve displaying far-field plots, smith chart graphs, or tables with s-parameter data.

A. Antenna Structure

A microstrip feed antenna is the one that is being proposed.When creating a 2*2 array, 4 comparable patch items are used. The material was Rogers 6002. The substrate is 68 mm by 56 mm in length. At a frequency 4 GHZ . Every patch receives a slot.

B. Simulation process

1) Step 1: Start Ansoft HFSS

Click the Microsoft Start button, choose Programs, and then choose the Ansoft> HFSS program group to open Ansoft HFSS. Toggle HFSS. Launch Window appears.

2) Step 2: Opening a New Project

To open a new project:

a) Click File > New from the menu in the Ansoft HFSS window.

b) Select Insert HFSS Design as in from the Project menu.

3) Step 3: Geometric Model 1

a) Create the ground and substrate as shown in Fig. 3.

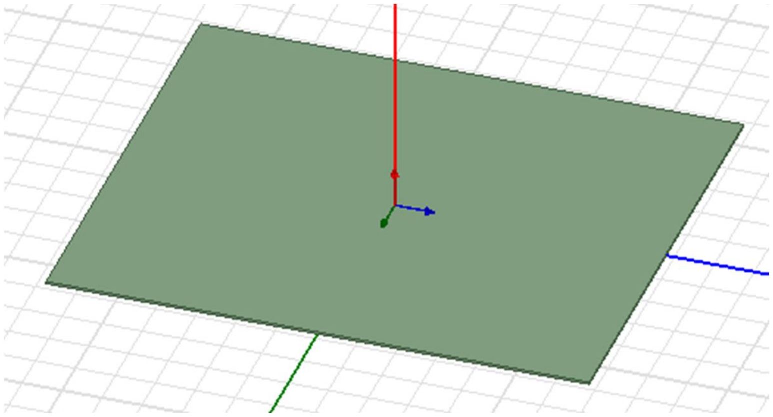

Fig. 3 Geometric view after creating ground and substrate

b) Choose the substrate material as Rogers 6002

c) Draw 4 patches and add 4 feeds on the substrate as shown in Fig. 4.

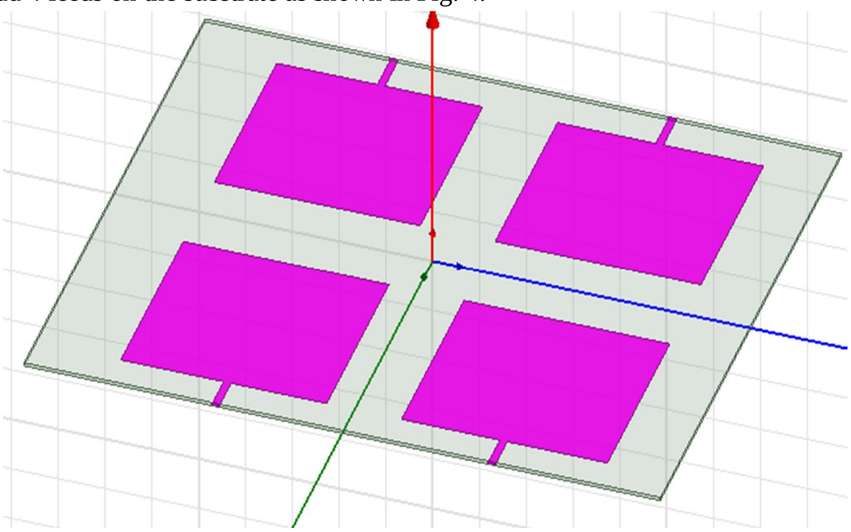

Fig. 4 Geometric view of patches with feed lines

d) Create the port and add 4 cylindrical slots as shown in Fig. 5.

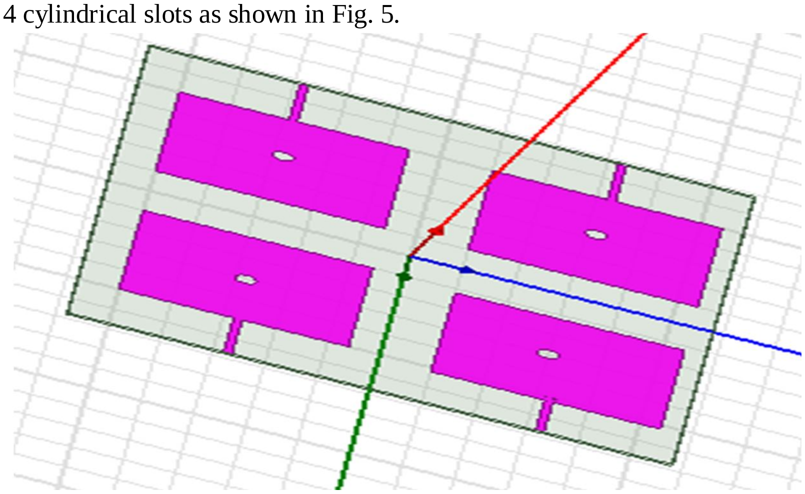

Fig. 5 The geometric view of after creating cylinder slots on patches

e) Create the radiation box and add Perfect E-boundary for ground and patch as shown in Fig. 6.

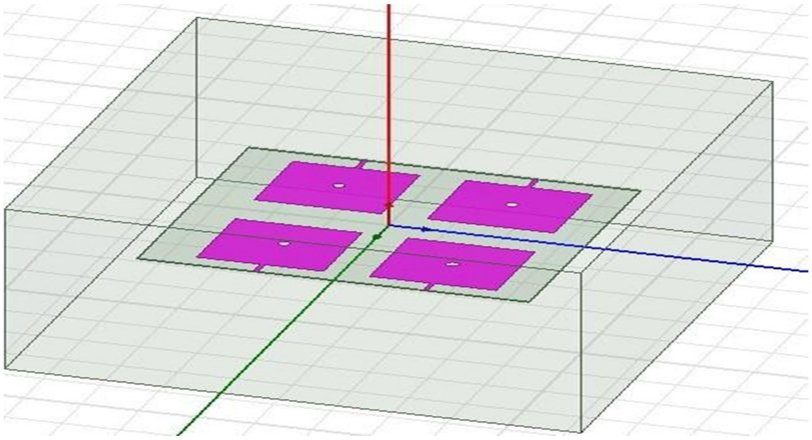

Fig. 6 Perfect E Boundary Of Patch and Ground

f) Assign the Radiation Boundary as shown in Fig. 7.

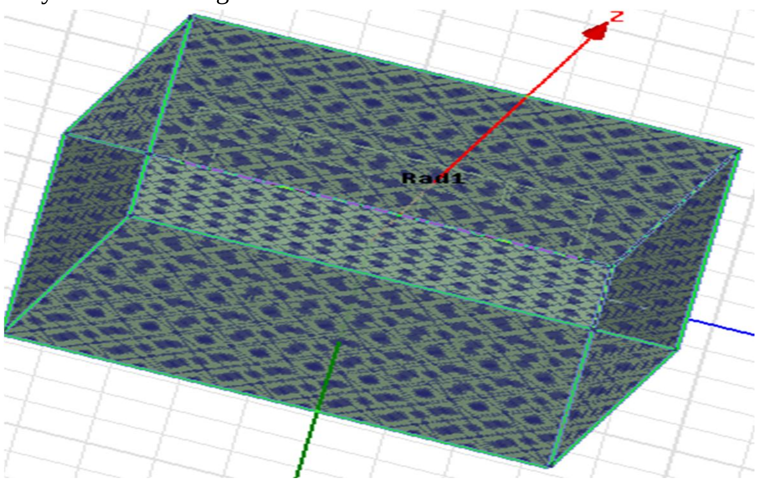

Fig. 7 Radiation Boundary

g) Setup the radiation and frequency sweep.
h) Save the model , perform the validation check and analyze all

4) Step 4: Geometric Model 2

For the geometric model 2, we are using Fr4 Epoxy as the dielectric material, and the resonant frequency is 4GHz. Slots are given to each patch. Create 4 slots in the 4 patches as shown in Fig. 8.

Fig. 8 The final model after creating the slots in every patch.

The variations done for this model 2 are

a) Effect of dielectric material variations : The effect of different dielectric materials for the substrate is seen. Dielectric materials like fr4 epoxy, RT/Duroid 5870, RT/Duroid 5880 and RT/Duroid 6006 are used for the proposed design
b) Slot arm length variations : Slot arm length variations are done. Different slot arm dimensions like 11mmx9mm, 11mmx8mm and 11mmx10mm are used for the design and checked for the maximum return loss.
c) Slot arm thickness variations : Slot arm thickness variation is done for the proposed model 1. Different slot arm thicknesses like 0.58mm, 0.6mm, 0.8mm, 1mm and 1.5mm are used in this study to check the maximum return loss.

IV. SIMULATION RESULTS

A. Results of Model 1

1) Return Loss

The S-parameter is the most crucial result of HFSS. One of the S-parameters that is important in the analysis of antennas is S11, which is also known as return loss. An antenna's return loss gauges the amount of received signal power lost owing to mismatch. In a perfect world, the receiver would only receive electricity from the source, with no reflections. 90% of the electricity is really received, just 10% is reflected. To respect this reality, the return loss (maximum value) is set at a level of -10 dB. Damage to the transmission line or an imbalance in the load at the receiver end in communication systems are the causes of the reflected power. Decibels (dB) are used to express it. Additionally, it serves as a gauge for how well-matched transmission and receiving equipment or transmission lines are. A good match results in lower insertion loss if return loss is large, and vice versa.

$$\text{Return(dB)} = 10 \log_{10} \text{Pin/Pre}$$

where Pre is the reflected power and Pin is the incident power.

The return loss is expressed as a reflection coefficient Γ in dB

$$\text{Return(dB)} = -20 \log_{10} |\Gamma|$$

The S11 graph obtained by simulation of model 1 is as shown in below Fig. 9.

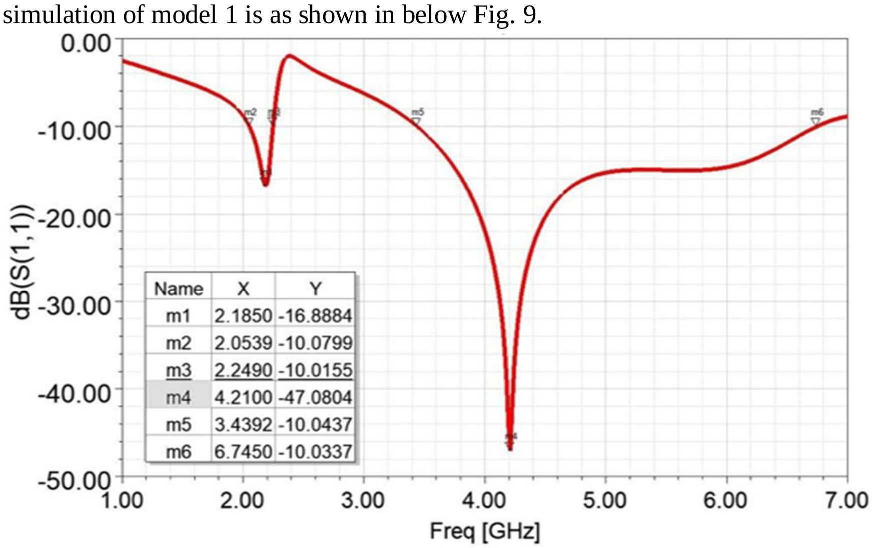

Fig. 9 Return loss plot for Proposed Model 1

2) Voltage Standing Wave Ratio (VSWR)

Standing Wave Ratio (SWR) is another name for VSWR. VSWR measures how well an antenna's impedance matches that of the linked transmission line. It is associated with the reflection coefficient, which measures the amount of power reflected from the antenna. Its definition in terms of the reflection coefficient Γ is given by

$$\text{VSWR} = (1 + |\Gamma|) / (1 - |\Gamma|)$$

The VSWR is an actual, positive number without any units. Less VSWR results in improved antenna and transmission line matching, which increases the power that the antenna receives. When the VSWR is 1, no power is reflected, which is the ideal value. It is well matched if VSWR is less than 2.

The VSWR plot is obtained by simulation as shown in Fig. 10

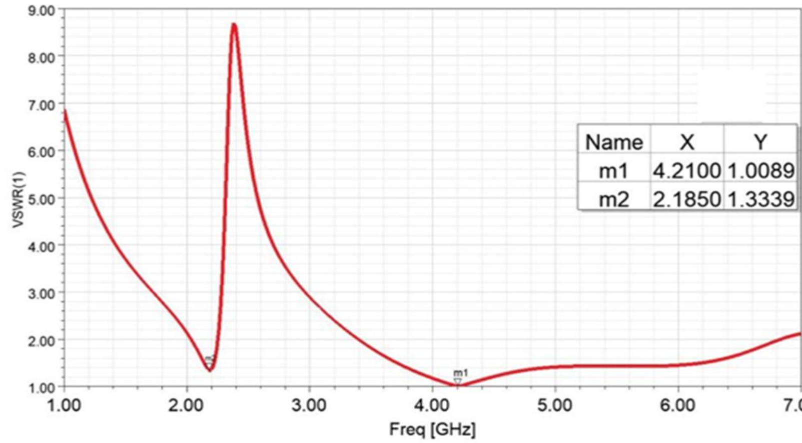

Fig. 10 VSWR Plot For Proposed Model

B. Results of Model 2

1) *Return Loss :* The return loss plot for the model 2 will be obtained as shown in the Fig. 11

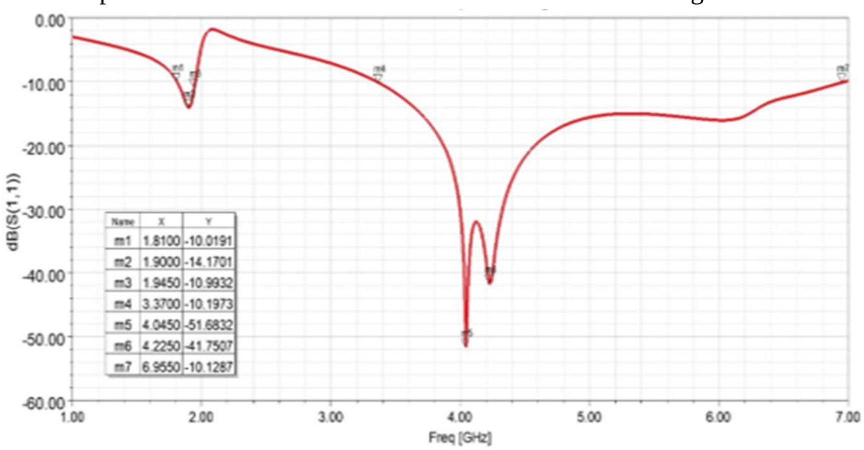

Fig. 11 Return Loss plot for Proposed Model 2

2) Voltage standing wave ratio VSWR : The VSWR plot for the proposed model 2 is obtained as shown in the Fig. 12

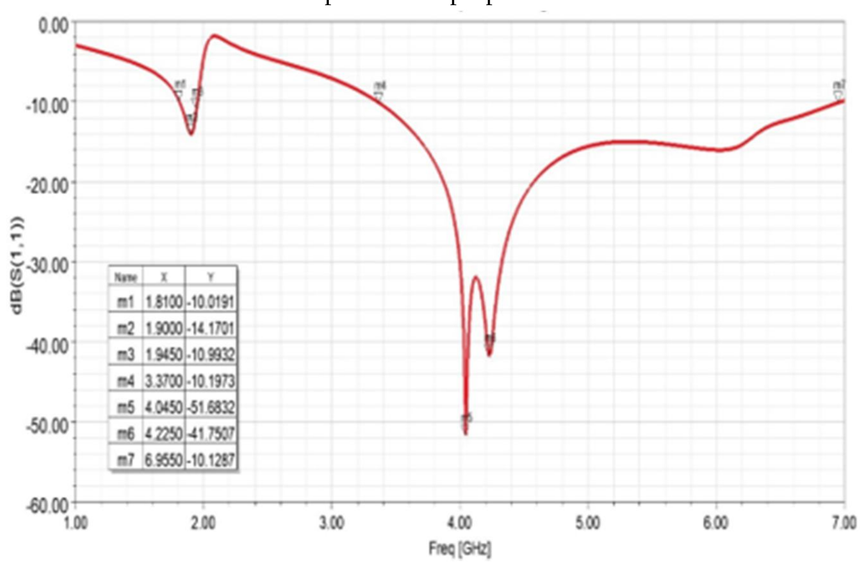

Fig. 12 VSWR Plot for proposed model 2

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VIII Aug 2023- Available at www.ijraset.com

3) The Unidirectional Radiation pattern without Side lobes of the given model is as shown in Fig. 13.

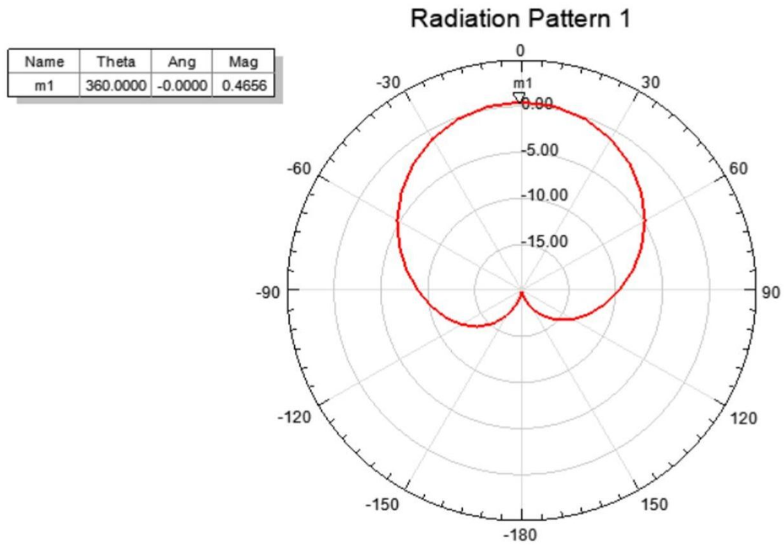

Fig. 13 Unidirectional Radiation pattern without Side lobes

C. Parametric Study

1) Effect of Dielectric Material

The impact of several dielectric substrate materials is observed in this parametric investigation. The proposed design uses dielectric materials including fr4 epoxy, RT/Duroid 5870, RT/Duroid 5880, and RT/Duroid 6006. Fig. 14, illustrates how FR4 epoxy has a large return loss when compared to all other materials. As a result, the suggested model 2's substrate is made of FR4 epoxy.

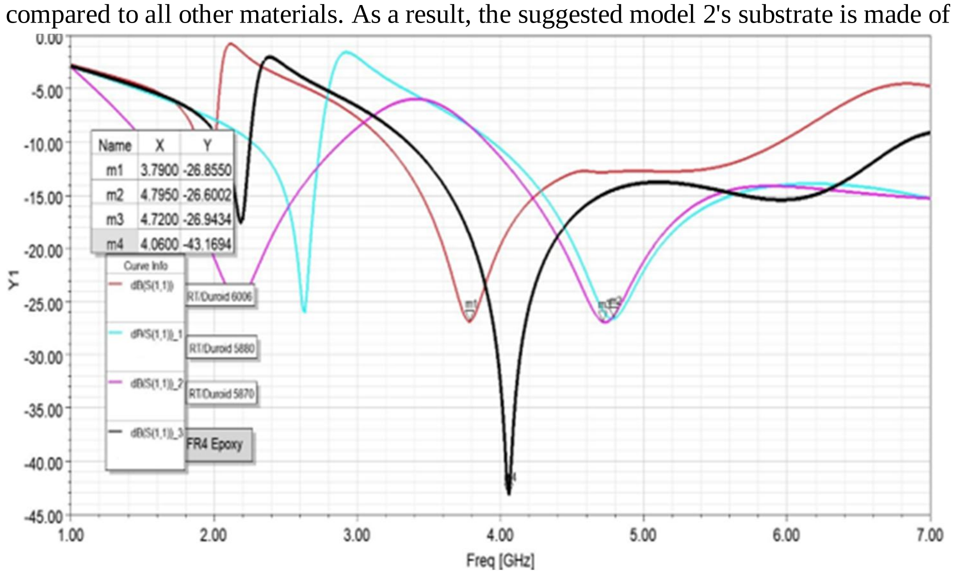

Fig. 14 Effect of Dielectric material variation

2) Slot Arm Length Variation

Variations in slot arm length are done in this parametric study. Various slot arm sizes, including 10mm x 11mm, 11mm x 9mm, 11mm x 8mm, and 11mm x 10mm, are employed in the design, and the maximum return loss is evaluated. Maximum return loss is attained as illustrated in Fig. 15, when the vertical length of the arm is 11mm and the horizontal length of the arm is 10mm. So, 11mm and 10mm are selected as the slot arm dimensions for the proposed model 2 and for the further parametric study.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VIII Aug 2023- Available at www.ijraset.com

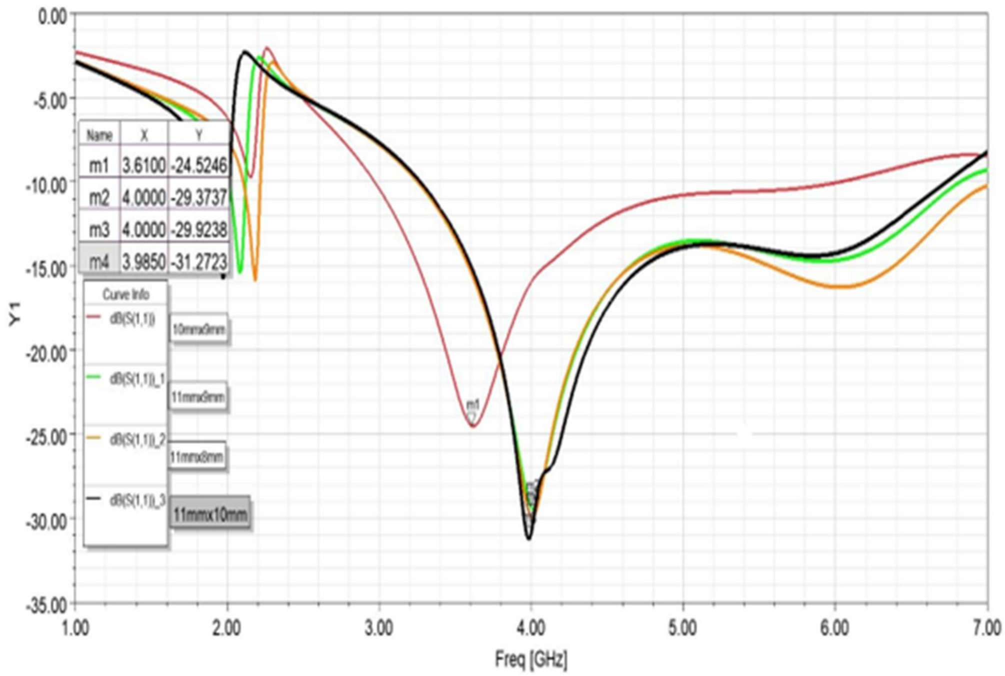

Fig. 15 Slot Arm Length variation plot

3) Slot Arm Thickness Variation

For the suggested model 2, the slot arm thickness change is carried out. In order to check the maximum return loss, different slot arm thicknesses, including 0.58mm, 0.6mm, 0.8mm, 1mm, and 1.5mm, were used in this investigation. The slot thickness of 1.5 mm, as shown in Fig. 16 , has the highest return loss when compared to all other thickness values. So, 1.5mm is selected as the S slot arm thickness for the proposed model 1.

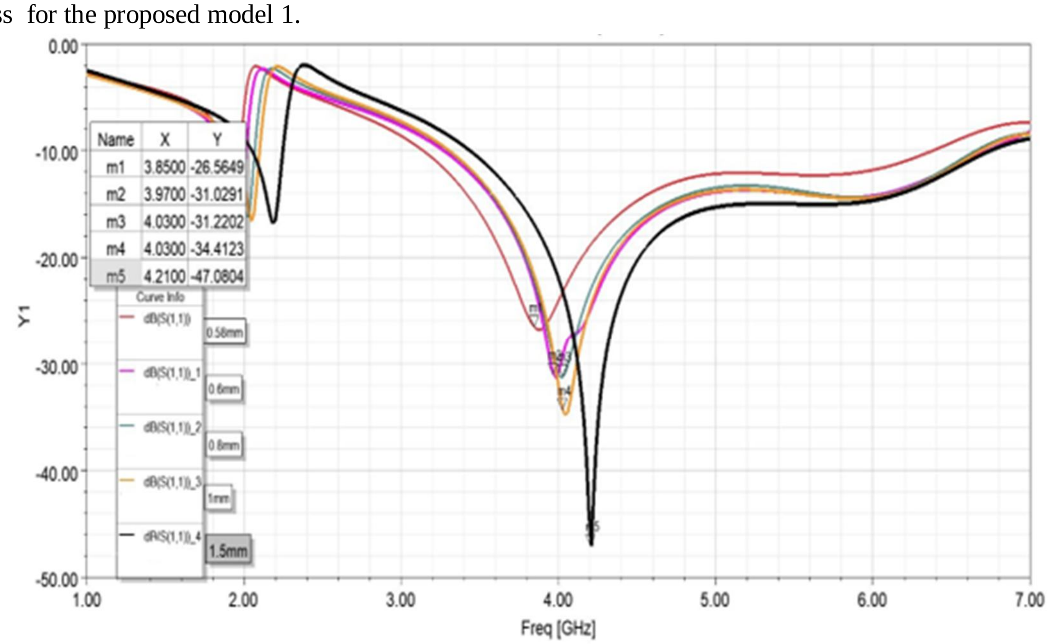

Fig. 16 Slot Arm Thickness Variation Plot

4) Comparison between proposed model 1 and model 2 :

The proposed models 1 & 2 have similar parameters like Substrate materials, patch length and width etc,but different slot dimensions. The comparison between the implemented model and the proposed models is shown in the below Table. 1.

Table. 1 Comparison between implemented model and proposed models

Parameters	Existing model	Proposed model 1	Proposed model 2
S11(dB)	-27 dB	-47 dB	-51.6832 dB
VSWR	2.3	1	1.0229

V. CONCLUSIONS

A new technique of designing a non-uniform antenna array has been proposed in this paper . In this research, HFSS software was used to design the proposed microstrip feed antenna with a slot. For the proposed model slots are added to each patch with the dimensions 5mm x 1mm. The substrate material used is FR4 epoxy. It is further improved by changing the dielectric material variations, slot arm length variations, Slot arm thickness variations to get low return loss, low VSWR. Use of a multilayer dielectric design can considerably enhance impedance bandwidth, a crucial aspect of an antenna.

The architecture put out in this research work can be expanded to allow MIMO applications for LTE and WiMAX-capable devices. Future research can concentrate on the analysis and design of antennas for cutting-edge technologies like cognitive radio and ultra-wideband. To accommodate Massive Multiple Input Multiple Output (MIMO) for 5G mobile radio transmission technology, the design described in this thesis work can be expanded.

REFERENCES

[1] Sahad, Asif Jamil & Islam, Md & Islam, Md & Asadullah, G. M. & Adnan, Noor. (2020). Design and Analysis of a Non-Uniform Planar Antenna Array. 10.1109/TENSYMP50017.2020.9230690.

[2] M. S. Islam, M. I. Ibrahimy, S. M. A. Motakabber, A. K. M. Z. Hossain, and S. M. K. Azam, “Microstrip patch antenna with defected ground structure for biomedical application,” Bull. Electr. Eng. Inform., vol. 8, no. 2, pp. 586–595, Jun. 2019.

[3] N. L. Nguyen and V. Y. Vu, “Gain enhancement for MIMO antenna using metamaterial structure,” Int. J. Microw. Wirel. Technol., vol. 11, no. 8, pp. 851–862, Oct. 2019.

[4] M. Zaid, M. R. Islam, M. H. Habaebi, A. Z. Alam, and K. Abdullah, “Optimum concentric circular array antenna with high gain and side lobe reduction at 5.8 GHz,” IOP Conf. Ser. Mater. Sci. Eng., vol. 260, p. 012038, Nov. 2017.

[5] W. Liu and Z. Wang, “Non-Uniform Full-Dimension MIMO: New Topologies and Opportunities,” IEEE Wirel. Commun., vol. 26, no. 2, pp. 124–132, Apr. 2019.

[6] M. Fairouz and M. A. Saed, “A Sequentially Rotated, Circularly Polarized Microstrip Antenna Array with Reduced Mutual Coupling,” Electromagnetics, vol. 36, no. 7, pp. 422–433, Oct. 2016.

[7] N.-S. Nie, X.-S. Yang, and B.-Z. Wang, “A compact four-element multiple-inputmultiple-output antenna with enhanced gain and bandwidth,” Microw. Opt. Technol. Lett., vol. 61, no. 7, pp. 1828– 1834, 2019.

[8] Y. Alnaiemy, T. A. Elwi, and L. Nagy, “Mutual Coupling Reduction in Patch Antenna Array Based on EBG Structure for MIMO Applications,” Period. Polytech. Electr. Eng. Comput. Sci., vol. 63, no. 4, pp. 332–342, Oct. 2019. 68

[9] L. Malviya, R. K. Panigrahi, and M. V. Kartikeyan, “Circularly Polarized 2×2 MIMO Antenna for WLAN Applications,” Prog. Electromagn. Res., vol. 66, pp. 97–107, 2016.

[10] I. M. Rafiqul, W. S. A, S. Rafiq, M. S. Yasmin, and M. H. Habaebi, “A 2X2 MIMO Patch Antenna for Multi-Band Applications,” Indones. J. Electr. Eng. Inform. IJEEI, vol. 5, no. 4, pp. 383-389– 389, Dec. 2017.

[11] N. Majidi, G. G. Yaralioglu, M. R. Sobhani, and T. Imeci, “Design of a quad element patch antenna at 5.8 GHz,” in 2018 International Applied Computational Electromagnetics Society Symposium (ACES), Mar. 2018, pp. 1–2.

[12] M. S. Islam, M. I. Ibrahimy, S. M. A. Motakabber, and A. K. M. Z. Hossain, “A Rectangular Inset-Fed Patch Antenna with Defected Ground Structure for ISM Band,” in 2018 7th International Conference on Computer and Communication Engineering (ICCCE), Sep. 2018, pp. 104–108