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DESIGN AND SIMULATION OF 6G ANTENNA ARRAY USING SENSOR ARRAY ANALYZER (SAA) FOR MITIGATING AIR SPACE NETWORK CONGESTION IN COMMUNICATION SYSTEM

[1]Ahmad Aliyu Deba, [2]Aminu Hussaini, [3]Badru Ismaheel Adewale

[1,2,3] Electrical and Electronics Technology Education,
Abubakar Tafawa Balewa University, Bauchi, Nigeria

Abstract : Advancement in creation of modern Antenna array is an important aspect in communication systems as researchers are working hard in order to mitigate the over congestion issue of air space. The antenna concept is one of the most powerful solutions that address the air space congestion. Hence, this study aims at filling in the existing gap in the literature by conducting research on a digital way of designing 6G antenna arrays using Sensor Array Analyzer (SAA) of MATLAB Application in order to overcome air space network congestion for enhancing communication systems. The research adopted Computer Aided Design (CAD). MATLAB application was used as a secondary application that accommodated the computer codes in Editor while Sensor Array Analyzer (SAA) was used as primary application to input the parameters for simulating different shapes of Antenna arrays for 6G communication unlike the previous Generations (Gs) that use manual computations in their design systems. The Sensor Array Analyzer was also used to generate MATLAB codes in which the directivity of all the antenna arrays were run in the secondary MATLAB application. On the other hand, SAA parameters were used to simulate antenna arrays. It was recommended that, SAA was effective in designing and simulation of Antenna arrays.

Keywords: *Sensor Array Analyzer; MATLAB Application, Antenna Array; Air space network; Communication system.*

I.0 INTRODUCTION

Antennas are metallic structures or devices of different sizes and shapes used to transmit and receive radio electromagnetic waves. These electromagnetic waves move in air (free space) and required to transfer the power as proficiently as possible from the transmission line to the air. Thereafter, the power is received by the receiver from the air and transfers it to the transmission line again. There are always predicaments between received and transmitted signals due to the presence of air, such predicaments are produced due to scattering, path-loss and fading in free space. There are several types of antennas in which their function depends on the preferred system, properties of antenna and its frequency (Ojaroudi, Jahanbakhsh, Al-Yasir, Abd-Alhameed, Abdulkhaleq & Noras, 2019). There are limited simple terms associated with antennas, one to mention is reciprocal antenna. Reciprocal antenna is an antenna that has the same characteristics at both the transmitter and receiver. These characteristics include same polarization radiation pattern, radiation gain. For instance, if the antenna has radiating power in one of its directions for the identical radiation pattern, it similarly receives power from the identical direction. The characteristics are not the same, if there are non-reciprocal antenna constituents in the system. These non-reciprocal constituents are amplifiers and ferrite (Nagulu & Krishnaswamy, 2021). Nowadays, People often use antennas almost all over the places. Thus, every signal moving through the free space is transmitted and also received by the antennas. The top used antenna systems are TV, radio and cellular system. The cellular system is spread regularly and makes its capability to develop greatly. Fifth generation network (5G) is the latest area of research implementation.

Antenna Array is a combination of two or more antennas, or several elements in an identified shape. These elements inform of arrays are mostly same, they can also be not of the same elements, but in this case the design of the non-identical antenna elements becomes very complex. At times, the pattern of radiation of antenna with single element is not greatly directive and its gain is very low. To achieve great directivity with a higher gain, the antenna's electrical size should be increased.

Similarly, increase in dimensions of antenna with single element provides more directivity properties. The best way to increase antenna dimension without increasing in single antenna size is done by gathering the radiating elements in various antenna's geometrical shapes (Kuma, Ali & Pai, 2021). The simplest way identified by this study for calculating, designing and simulating antenna arrays is through the use of Sensor Array Analyzer (SAA) of MATLAB application.

Sensor Array Analyzer (SAA) is an application in MATLAB used for designing antenna arrays using adopted/generated MATLAB codes and antenna parameters. SAA is provided with the Toolbox called Phased Array System. The toolbox offers pop-up menu to design and also simulate simple/compound beamforming and antenna sensor array to wireless communication, image diagnostic sonar, radar and acoustic applications. Moreover, it is possible to design and analyze antenna arrays actively and passively, these include sub-array and definite geometry. According to Ahmed, Zhang and Zhang (2020), the signals being simulated can be transmitted and similarly received by the antenna arrays for the beamforming design and processing of signal algorithms. The SAA application has graphical interface that permits user to create the antenna array, manipulate some parameters' settings in order to view the essential parameters without reorganizing to Command Windows. It can be displayed from the small arrow named Apps or via the SAA command. SAA Graphical User Interface (GUI) has three main segments viz.; array characteristics, parameters and geometry. Specifically, it is suitable to nearly activate the grating diagram, azimuth patterns, 2D elevation and 3D pattern. Furthermore, it is suitable to design them in a 2×3 grid. According to Meng, Xuan, Jiang, Pan and Rui (2022), the SAA application shows plain performance features such as array dimensions and array directivity. Thereafter, it produces different directivity images and plots. Total field of antenna array is an impoprtant aspect of consideration while designing antenna array using SAA.

The total field of antenna array is defined as the field of array being calculated through addition of vectors of the total fields radiated by the antenna's individual elements. For that, same current is expected for each element (Chou, 2020). In the case of directive patterns, it seems necessary that the fields of elements of the array have a constructive interference in preferred directions and have a destructive interference in the other directions. Constructive interference refers to the elements attracted the fields but in destructive interference, they cancel one another. In order to achieve the general pattern of the antenna array, five controls were used. The first is the geometrical configuration of that general array, which means shape of the array. This shape may be circular, linear, planar, rectangular etc. Second one is the elements' relative displacement, which means the distance between the elements. The other three are the excitation phase, the relative pattern of the elements and excitation amplitude. Furthermore, the total field for antenna array is equivalent to the field of an individual element located at the origin which is multiplied by an individual factor, called an Array factor. An Array factor differs from arrays with different phase, shapes, spacing and amplitude. The simplest technique to calculate total field of array is when the elements are the same or similar, this means they have equal radiated field. In order to accomplish this, there is need to analyze the antenna arrays using Sensor Array analyzer of MATLAB application in order to determine the above specifications and capabilities of the SAA in modeling the antenna arrays. Hence, this study intends to fill in the existing gap by conducting a research on design and simulation of 6G antenna array using for mitigating air space congestion in communication system.

MATLAB is an application or software designed explicitly for scientists and engineers to model and design products and systems using MATLAB language. MATLAB language is defined as the matrix-based language that enables the best ordinary expression of mathematical computations such as creating models, development of algorithms, applications and data analysis. It has been opined by Gauhar, Rashid, Hasan, Bispo and Cardoso (2021) that, MATLAB is a language expressed with high-performance for complex computing. It involves programming, visualization and computation in good environment in which problems and solutions are presented in an ordinary mathematical way. The conventional function of MATLAB includes: engineering graphics, modeling, prototyping, computation, visualization, Algorithm development, exploration, simulation, data analysis and exploration. According to Blinowska and Zygierewicz, (2021) MATLAB is interactive software whose elementary data component comprises un-dimensioning array. This assists to solve numerous complex computing of problems particularly problems associated with vector formulations and matrix, some of the times it would be used to write a particular language in a scalar language that is non-interactive such as Fortran or C. Similarly, MATLAB contains numerous applications such as MATLAB coder, image viewer analyzer, filter builder, radar equation calculator, classification learner, application compiler, image region analyzer, image segmenter, map viewer, color thresholder, image batch processor, sequence viewer, fuzzy logic designer, linear system analyzer and Sensor array analyzer. This study intends to design and simulate 6G antenna array using Sensor array analyzer in order to diversify and justify innovative ways of antenna design.

1.1 Statement of the Problem

The wireless technology has given a proven justification for the industry to require a very efficient and consistent wireless infrastructure with great availability. The acceptance of wireless devices, particularly in the area of transportation, had led to over-congestion in airspace generated by the increase in wireless devices which may lead to a disaster if it is left unattended. According to Tan (2021), researchers work immensely to mitigate the congestion issues of air space using numerous methods, such as planning of coordinated wireless, regulatory implementation to constrain the use of frequency to reduce the radiated power and conversely introduce new frequency spectrum for users. The concept of antenna array is one of the powerful solutions that take care of the congestion issues of air space. Furthermore, the antenna array system is expected to alleviate the issue of mutual interference along the radiation path between mobile devices but the manual method of designing antenna array using formular is also considered complex and time consuming. Therefore, Sensor array analyzer is expected to provide solution to the above predicaments. Hence, the researcher intends to fill in the existing gap in the literature by conducting research on design and simulation of 6G antenna array using sensor arrary analyzer in order to mitigate network congestion in communication system.

1.2 Aim of the Study

The main aim of this study is to design and simulate 6G antenna array using sensor arrary analyzer in order to mitigate network congestion in communication system.

1.3 Objective of the Study

The study seeks to achieve the following specific objectives:

i. To find out the directivity shape of Uniform Linear antenna generated from MATLAB codes.
ii. To find out the appropriate shape of Uniform Linear antenna when simulated using sensor array analyzer.
iii. To find out the appropriate shape of Custom array Antenna when simulated using sensor array analyzer.
iv. To find out the appropriate shape of Isotropic array Antenna when simulated using sensor array analyzer.
v. To find out the appropriate shape of Uniform Rectangular array Antenna when simulated using sensor array analyzer.
vi. To find out the grating lobes for Uniform rectangular array using sensor array analyzer.

2.0 Research Gap In the Literature

Study conducted by Tan (2021) on "design of Antenna array and data streaming platform for low-cost smart antenna systems". The findings of the study showed that, the antenna array designed was so crucial to complement the non-coordinated wireless infrastructures and improved the reliability, performance and wireless networks availability. Similarly, the reviewed literature is related to this study because both sought to design antenna array. Conversely, they differ in terms of scope. That is the review was on Antenna array and data streaming platform while the present study is on Antenna array design using Sensor array analyzer of MATLAB application. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on effectiveness of Sensor Array Analyzer in in design and simulation of 6G antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in digital communication system.

The study conducted by Oluseun, Usman and Asogwa, (2019) on "performance evaluation of uniform circular array and uniform linear array antenna in an urban micro cell multiple fading channel scenario". The findings of the study showed that, Simulated antenna being studied performed better concerning impulse and frequency response given by uniform circular array as compared to uniform linear array antenna. The study is similar to the current as both sought to design antenna arrays but different to the current study as the current study sought to analyze codes using sensor array analyzer. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Khan (2011) on "Performance optimization of small antenna arrays". The findings of the study showed that, small array antenna mutual coupling in Small arrays had positive impact on the pattern of radiation that resulted in best performance. The study is similar to the current as both sought to design antenna arrays but different to the current study as the current study sought to analyze codes using sensor array analyzer. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in Telecommunication.

The study conducted by Raed (2017) on "Improved smart antenna design using displaced sensor array configuration". The findings showed that, the configuration of sensor array resulted in increasing the elements of array by two and, hereafter, amplified the capacity of such system without vividly amplifying the aperture of the array. The study is similar to the current as both sought to design antenna arrays but different to the current study as the current one sought to design antenna array using sensor array analyzer while the above study used sensor array configuration. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in Telecommunication.

The study conducted by Zhou (2021) on "Design and Analysis of a Thinned Phased Array Antenna for 5G Wireless Applications". The findings showed that, radiation pattern of obtained by 5G elements of was improved by analyzed thinned Phase antenna in wireless systems. The study is related to this study because both sought to design antenna array but they differ in terms of scope and methodology. That is the review is delimited to thinned Phased Array Antenna and algorithm optimization while the present study was on Antenna array design using Sensor array analyzer of MATLAB application. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Qi, Zou, Zhao, Sun, Hei, Chen and Xia (2021) on "Power Density Case Study for 5G mm Wave Array Antennas". The findings showed that, wireless device having 5G mm Wave was significantly induced for compliance test of radio-frequency. The above study is related to this study because both sought to design antenna array but they differ in terms of characteristics. That is the review is on Power Density of Array Antenna while the present study was on Antenna array design using Sensor array analyzer of MATLAB application. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in wireless communication system.

The study conducted by Jaswinder, Theodore and Reas (2017) on "5G Uniform Linear Arrays with Beamforming and Spatial Multiplexing for Outdoor Urban Communication". The findings showed that, Uniform Linear Arrays together with spacial and Beamforming are suitable in terms of designing antenna array of 5G wireless communication. The review is related to this present study because both sought to design antenna array but they differ in terms of scope. That is the review is delimited to Uniform Linear Arrays while the present study was on Uniform Linear Arrays, custom antenna array, uniform rectangular Antenna array and isotropic antenna array design. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in communication system.

The study conducted by Wen (2014) on "optimal design of antenna arrays". The findings showed that, the designed antenna arrays were effective in power transmission to the required position and destination. The study is related to this study because both sought to design antenna array but they differ in terms of scope and methodology. That is the review is delimited to optimization of antenna array using universal method while the present study was on Antenna array design using Sensor array analyzer of MATLAB application. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Casu, Mararu and Kovacs (2014) on "design and implementation of microstrip patch antenna array". The findings showed that, the microstrip patch antenna array was effective for Wireless Local Area Networks using 2,4 GHz operational frequency. The study is related to this study because both sought to design antenna array but they differ in terms of scope and methodology. That is the review is on design and implementation of microstrip patch antenna array using IE3D software while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in communication system.

The study conducted by Yuan, Yuan and Li (2008) on "novel series-fed taper antenna array design". The findings showed that, the innovative antenna array had a good features of VSWR. The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design of microstrip antenna array while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Hussain, Abdullah, Salem, Khamis and Nasir (2011) on "optimum design of linear antenna arrays using a hybrid MoM/GA algorithm". The findings showed that, the pattern of radiation of linear antenna arrays (LAA) had a significant effect in several places. The above study is related to this study because both sought to design antenna array but they differ in terms of scope and methodology. That is the review is on optimum design of linear antenna arrays (LAA) using both MoM/GA algorithms while the present study was on Antenna array design using Sensor array analyzer of MATLAB application. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in Telecommunication.

The study conducted by Thevnot, Menudier, Elsayed, Zakka, Elnashef, Fezai, Abdallah and Monediere (2012) on "design of antenna arrays and parasitic antenna arrays with mutual couplings". The findings showed that, the designed antenna array was observed to be effective in terms of parasitic arrays. The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design of antenna arrays and parasitic antenna arrays with mutual couplings while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Kishore, Rajesh, Kumar and Srinivasulu (2014) on "design and Simulation of an 0.43GHz ultra high frequency band microstrip patch antenna". The findings showed that, the simulated results were effective at the 0.43 Gigahertz (GHz) band and those simulated parameters involed impedance, directivity, gain pattern, elevation and efficiency. The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design of ultra-high frequency band microstrip patch antenna array using conventional method while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in digital communication system.

The study conducted byYing and Aixing (2018) on "design and simulation of vivaldi antenna array". The findings showed that, the designed vivaldi antenna array was polarized antenna with high-gain. The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design of Vivaldi antenna array while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find

effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in digital communication.

The study conducted by Krishnashu and Sharma (2020) on "design and simulation of Antenna Array Configuration with MATLAB". The findings showed that, the designed antenna array resulted in low and high directivity, beam gain and width. Antenna Array Configuration with MATLAB. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Tej, Kavya and Kotamaraju (2019) on "design and simulation of 21 GHz K-band frequency phased array antenna was proposed for reducing side lobe level in mm-wave radar applications". The findings showed that, the designed phased array antenna was effective along 21 Gigahertz (GHz) band while the parameters for simulation involed return loss, angular beamwidth and distribution of surface current. The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design and simulation of phased array antenna with MATLAB while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies in digital communication system.

The study conducted by Elkwash and Abdulrahman (2021) on "comparative study of different shapes of microstrip patch antenna arrays at 2.5 GHz". The findings showed that, the designed microstrip patch antenna arrays had a higher gain than a single patch antenna array that is being recurrently utilized in wireless system. The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design of microstrip patch antenna arrays while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

The study conducted by Aneesh, Anasari, Singh and Kamakshi (2015) on "effect of Shorting Wall on Compact 2× 4 MSA Array Using Artificial Neural Network". The findings showed that, 2×4 microstrip antenna (MSA) array was effective for inserting shorting-wall with the help of artificial neural network (ANN). The above study is related to this study because both sought to design antenna array but they differ in terms of scope. That is the review is on design of 2x4 microstrip patch antenna arrays while the present study was on Antenna array design using Sensor array analyzer of MATLAB software. Therefore, the present study intends to fill in the existing gap in the literature by conducting research on Sensor Array Analyzer in order to find effectiveness of SAA in design and simulation of antenna array. Thus, the study improves the deficiency of the existing literature and serves as a justification for further studies.

Most of the works reviewed above were conducted on the design of antenna array using specific methods suitable by the research. However, to the best of the knowledge of the current researchers of this study, there is limited literature on the design of antenna using Sensor array antenna of MATLAB application. It is based on this that, the researchers intend to fill in the existing gap by conducting a research on effects of Sensor Array Analyzer (SAA) of MATLAB application in designing and simulation of 5G antenna arrays.

3.0 Methodology

3.1 Practical Parts of Sensor Array Analyzer

There are three main parts of Sensor Array Analyzer used for the purpose of this study which include Uniform Linear Analyzer, Uniform Rectangular Array Analyzer and Grating Lobe Analyzer.

3.2 Uniform Linear Array Analyzer (ULAA)

Uniform Linear Array Analyzer is an analyzer that has a sensor and its line has equally spaced elements along a line. The Uniform linear array analyzer has the following location in Sensor Array Analyzer (SAA).

3.2.1 Steps for Locating Uniform Linear Array Analyzer (ULAA) in SAA

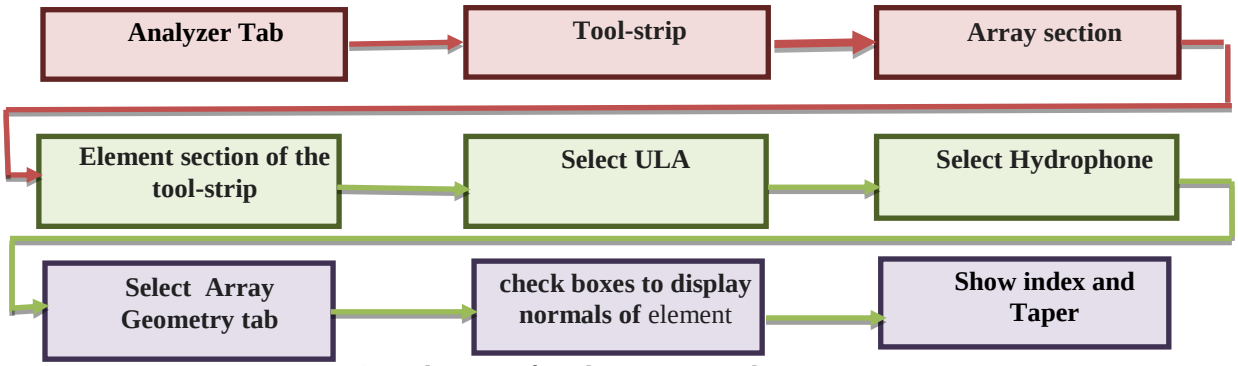

Fig.1. shows Uniform linear array analyzer.

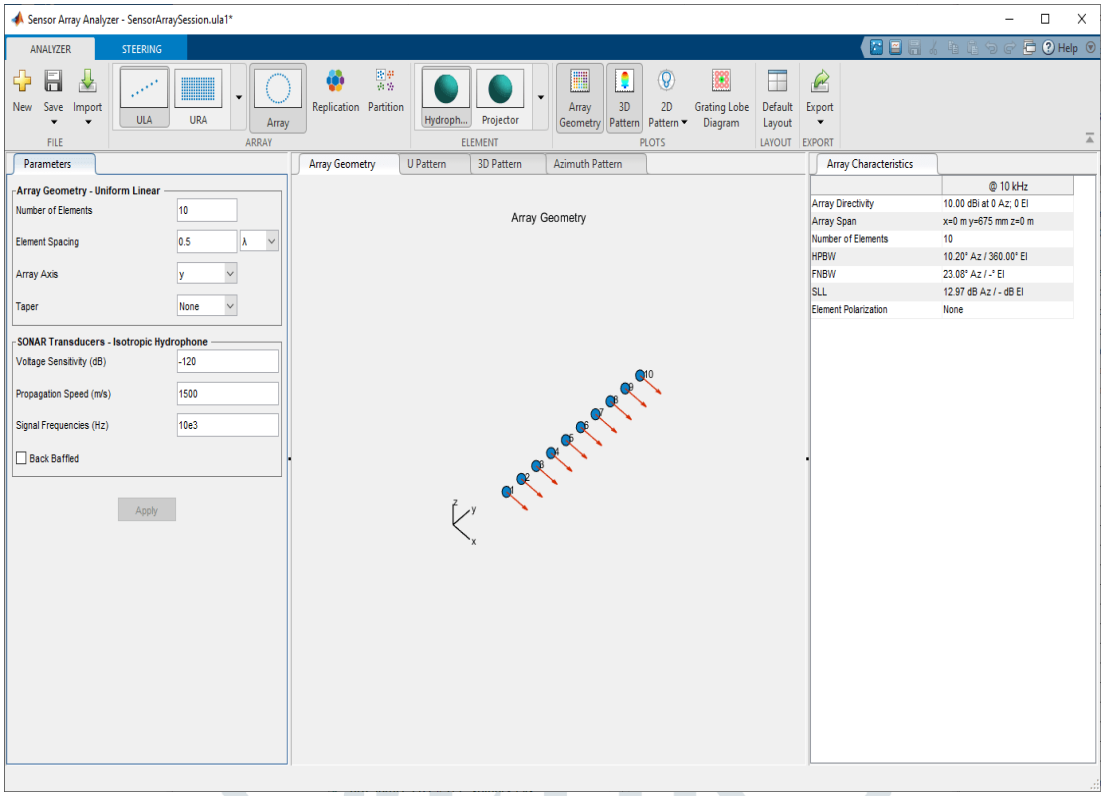

Fig.2. Uniform linear array analyzer (Mathworks, 2023)

3.3 Uniform Rectangular Array Analyzer (URAA)

Uniform Rectangular Array Analyzer is an analyzer that has sensor and its line has equally spaced elements along a rectangular path. The rectangular array analyzer has the following location in Sensor Array Analyzer (SAA).

3.3.1 Steps for Locating Uniform Rectangular Array Analyzer (URAA)

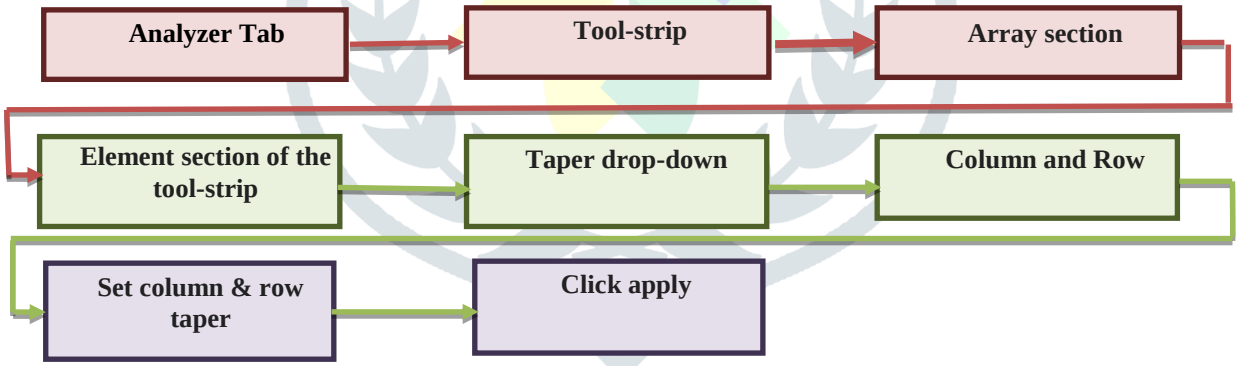

Fig.3 shows Uniform rectangular array analyzer.

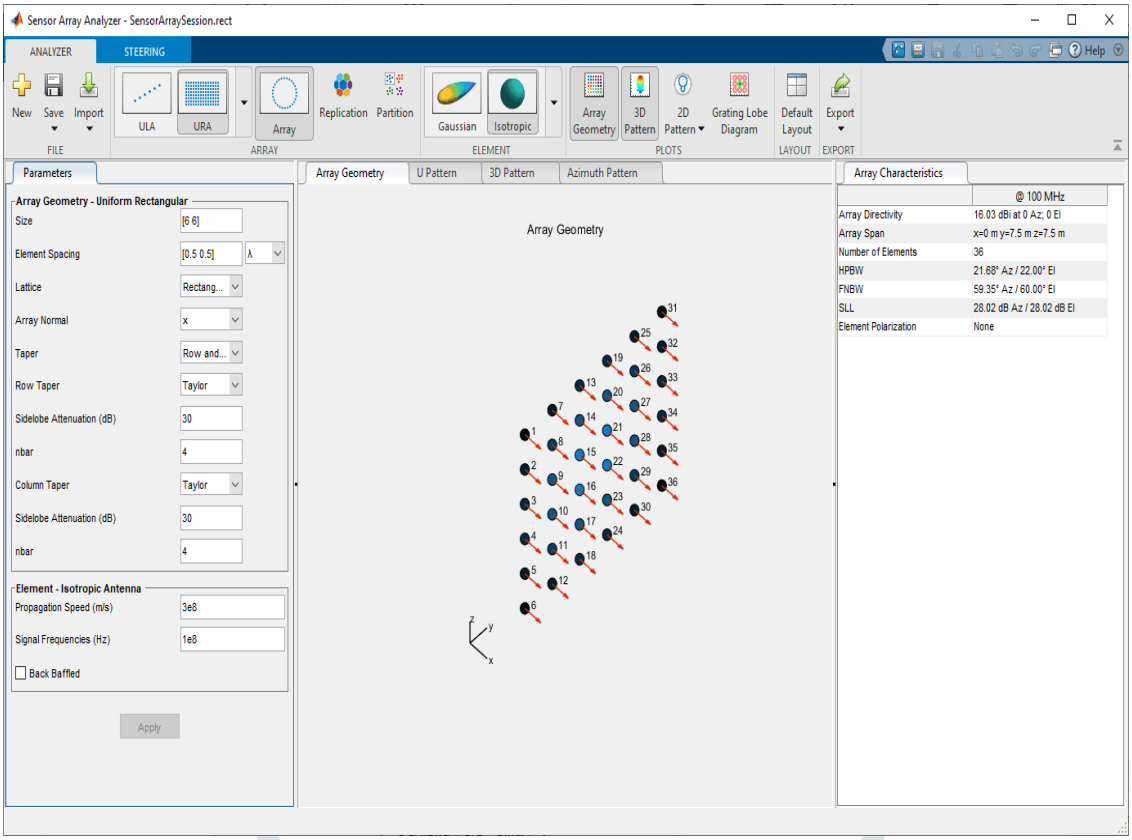

Fig.4. shows Uniform rectangular array analyzer (Mathworks, 2023)

3.4 Grating Lobe Analyzer (GLA)

Grating Lobe Analyzer is an analyzer that produces beamforming in which the main lobe that is labeled with black painted circle which is usually small in size. The multiple grating lobes in Grating Lobe Analyzer are labeled with black circle that is not filled with any colour and is normally smaller in size. physical region in grating lobe analyzer is the larger-black circle while green region indicates the main lobe.

3.4.1 Steps for Using Grating Lobe Analyzer (GLA)

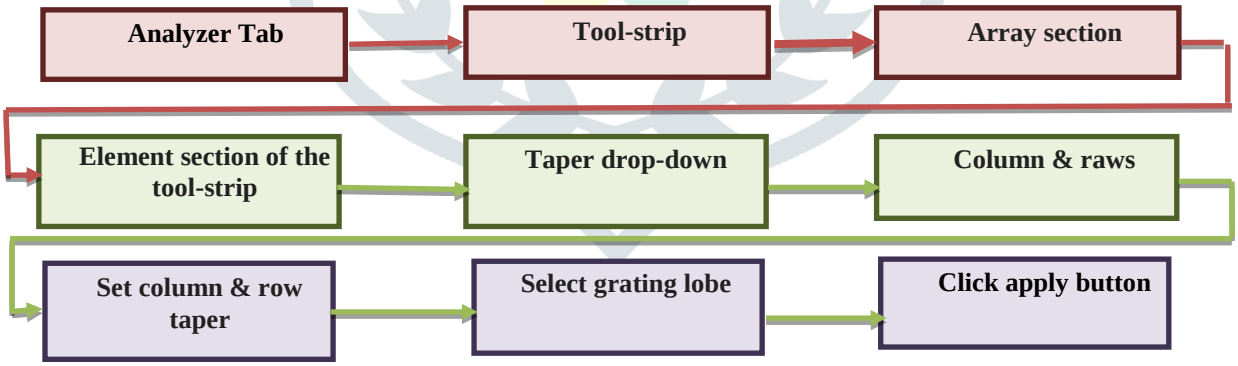

Fig.5 Shows Grating Lobe analyzer.

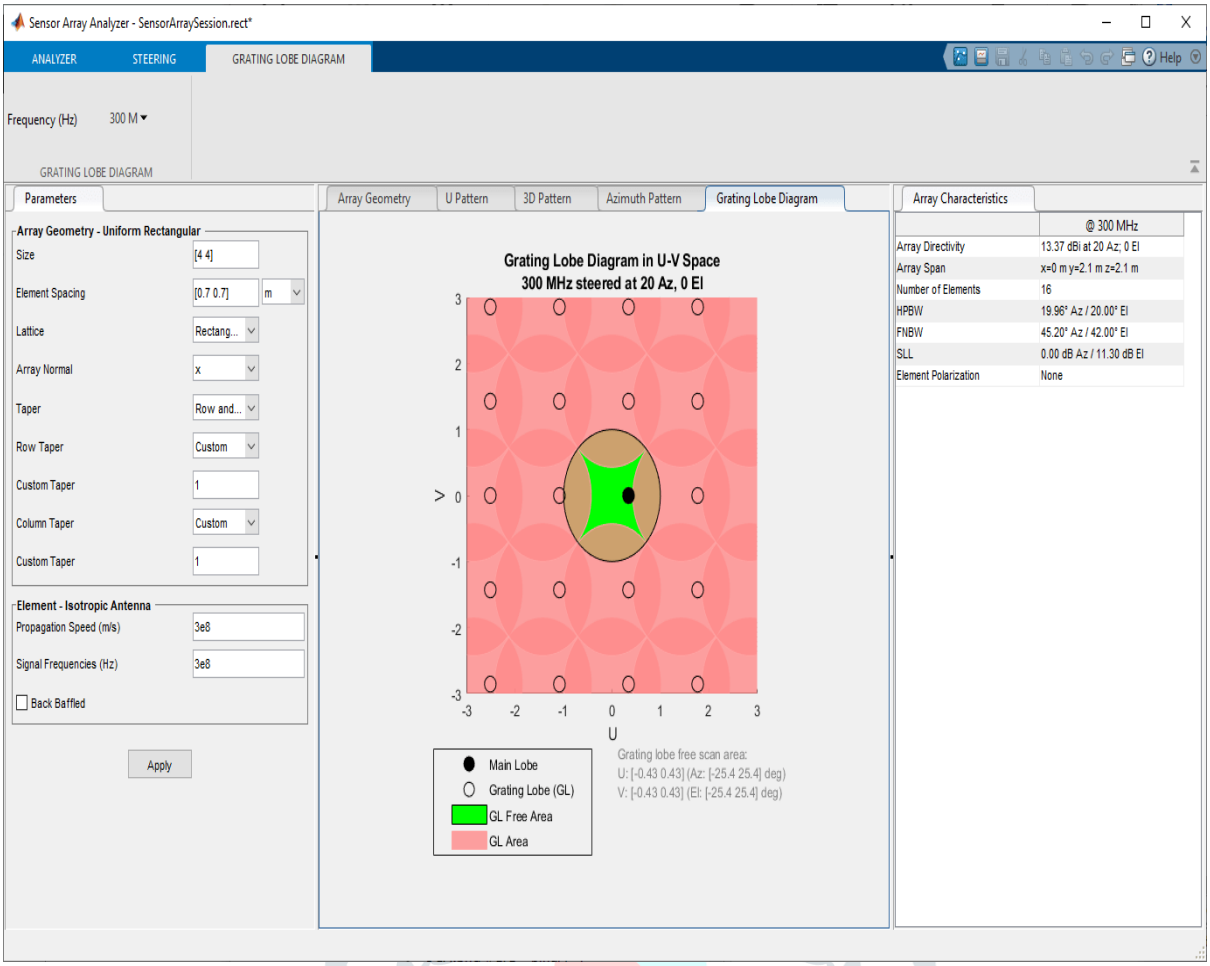

Fig.6. Grating Lobe analyzer (Mathworks, 2023)

3.5 Design of the Study

This study adopted Computer Aided Design. Timothy and Halil (2015), defined Computer Aided Design as a research design that uses computer-based application in order to design, analyze, optimize, model and modify system. The study chose Computer Aided Design because the study used Sensor Array Analyzer of MATLAB application in order to design and model antenna arrays.

MATLAB-software environment was also used to input codes in order to design directivity of antenna arrays while SAA was used to form almost all the types of antenna arrays which include linear, rectangular, circular, planar and hexagonal, circular planar, spherical, cylindrical, concentric and arbitrary array. Figure 7 below shows the interface of SAA while designing Uniform linear antenna array.

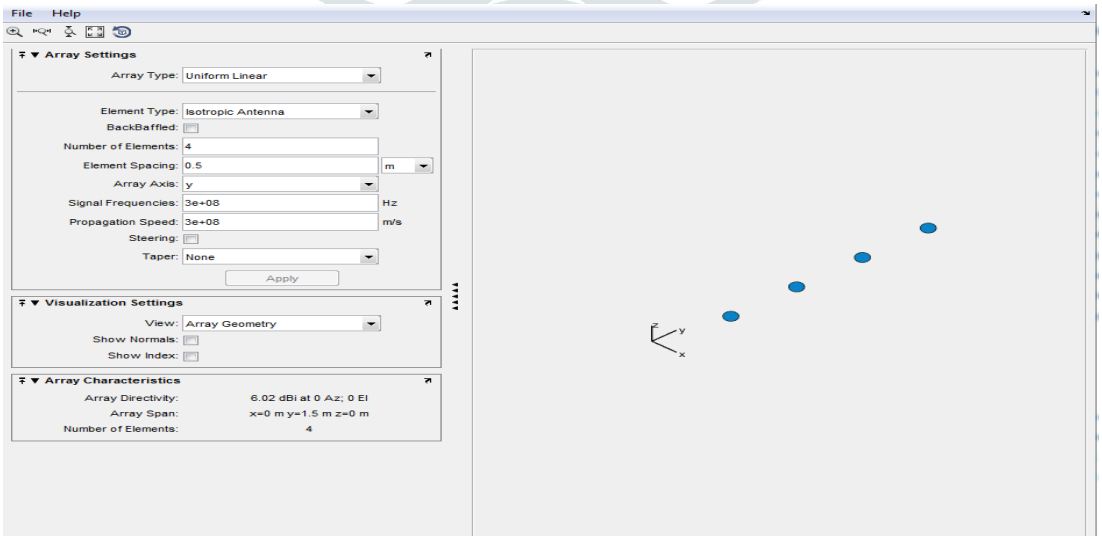

Fig.7. The view when opening Sensor Array Analyzer-toolbox (Mathworks, 2016).

3.6 Generating MATLAB Code from Sensor Array Analyzer

The flowchats below show the two different ways in which MATLAB codes can be generated.

3.6.1 Flowchart of the Research Using Adopted Literature Codes

The flowchart below shows the procedure for conducting this research using the available codes obtained from literature.

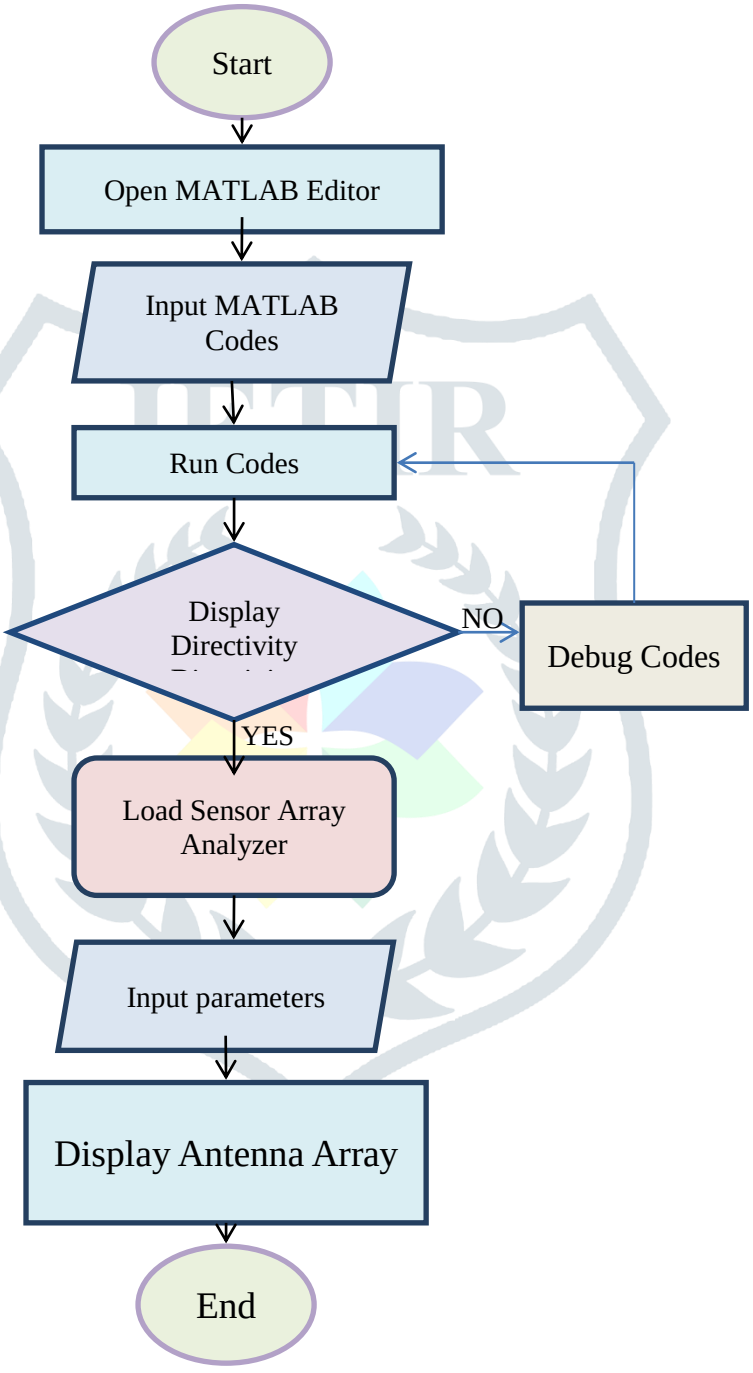

Fig.8 Flowchart of the Research Using Adopted Literature Codes

3.6.2 Flowchart of the Research Using Generated Codes

The flowchart below shows the procedure for conducting this research using the codes generated from Sensor Array Analyzer (SAA).

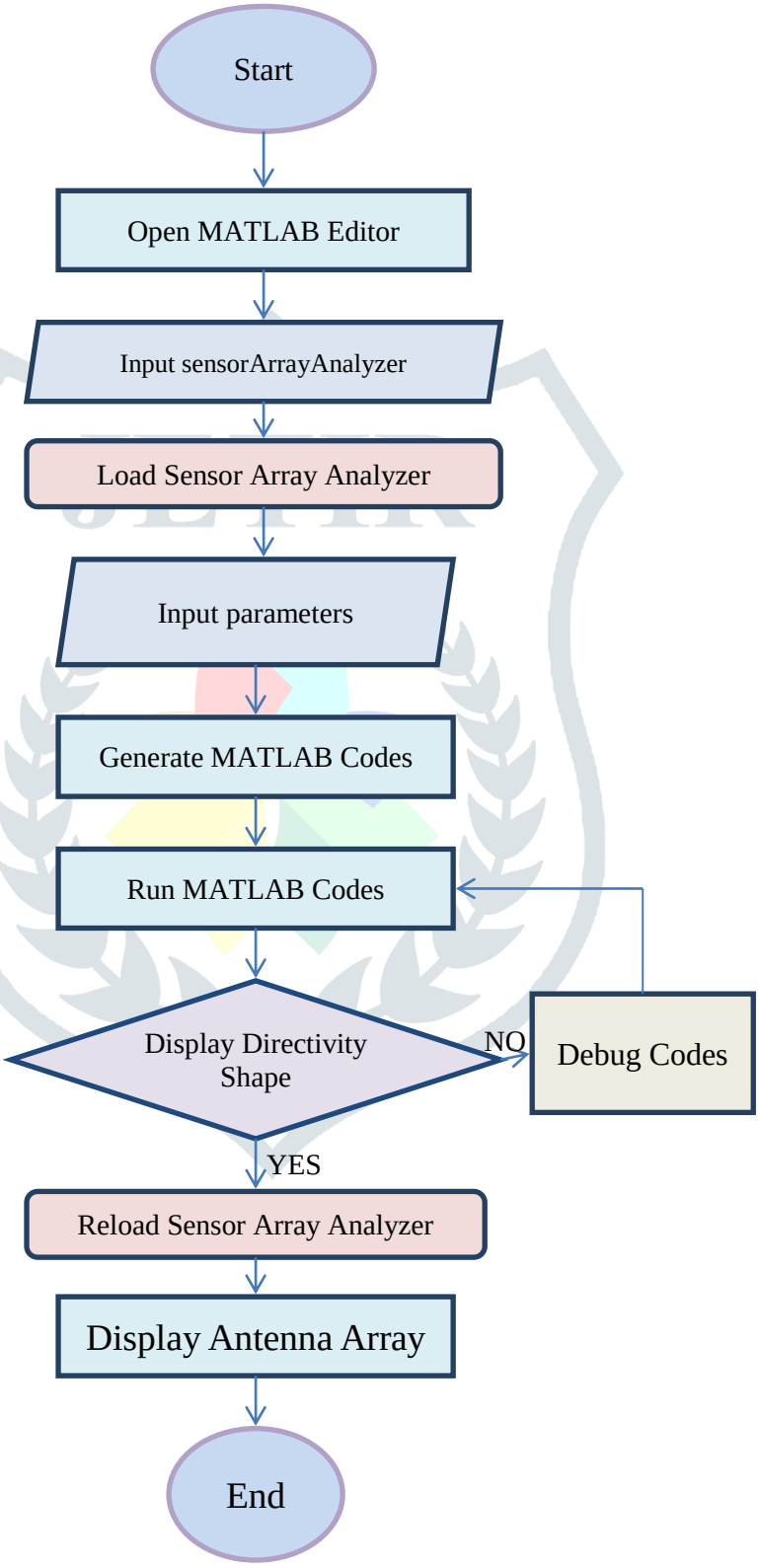

Fig.9. Flowchart of the Research Using Generated Codes

4.0 Results and Dicussion

There are six results obtained from this study: directivity shape of Uniform Linear antenna generated from MATLAB codes, appropriate shape of Uniform Linear antenna when simulated using sensor array analyzer, appropriate shape of Custom array Antenna when simulated using sensor array analyzer, appropriate shape of Isotropic array Antenna when simulated using sensor array analyzer, appropriate shape of Uniform Rectangular array Antenna when simulated using sensor array analyzer and grating lobes for Uniform rectangular array using sensor array analyzer.

4.1 Directivity shape of Uniform Linear antenna generated from MATLAB codes

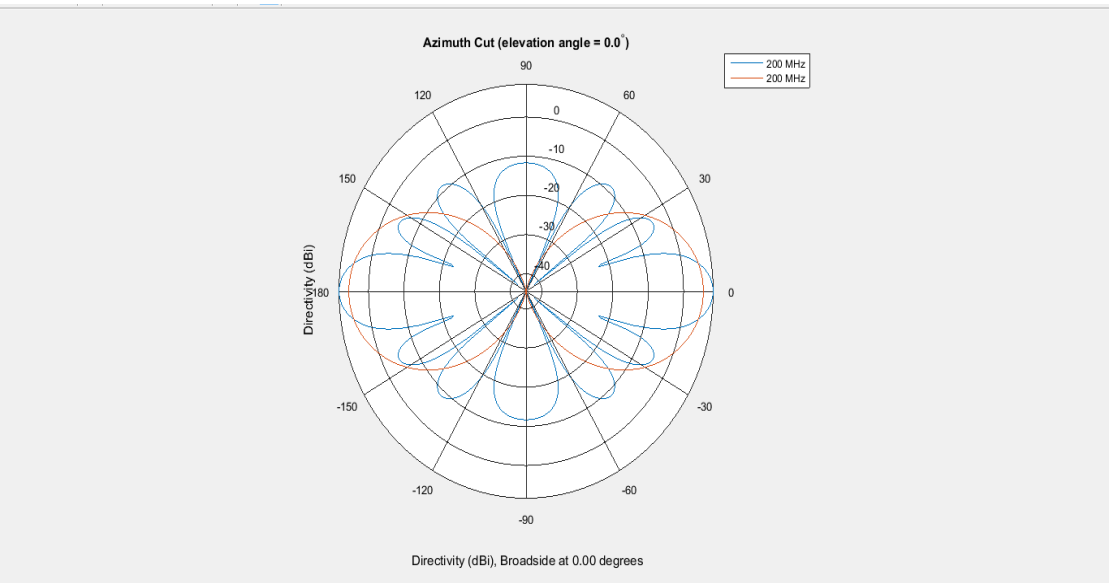

Fig.10. Directivity of Uniform Linear antenna generated from MATLAB codes (Mathworks, 2016)

Figure10 shows directivity of Uniform linear antenna array having radiation pattern seven (7) elements. These number of elements located in the directivity diagram indicated the pattern of radiation of the uniform linear antenna array. The finding is in harmony with the findings of Luo, Zhang, Chen, Huangfu and Ran (2019) where the researchers found out radiation pattern with less than ten (10) elements for both hamming tapered and non-tapered array. The result is also in line with the findings of Ojiro, Kawakami, Gyada and Ohira (2011) where the researchers also found out radiation pattern of antenna array with less than ten (10) elements for both tapered and non-tapered array.

The blue line indicates the pattern of radiation which is called non-tapered while the line in orange indicated pattern of radiation which is called Hamming-tapered. The spacing of antenna array was 0.5 λ between each element. It can be seen from figure 10 above that, SAA of MATLAB application was effective in desing and simulation of the directivity of Uniform Linear Antenna Array (ULAA) by using the generated codes. Section 4.1.1 below showed the codes used in generating directivity of Uniform Linear Antenna Array (ULAA).

4.1.1 Uniform Linear Array Antenna Codes

```
%MATLAB Code from Sensor Array Analyzer App
%Generated by MATLAB 8.5 and Phased Array System Toolbox 3.0
%Generated on 31-May-2024 03:35:01
% Create a uniform linear array
h = phased.ULA;
h.NumElements = 5;
h.ElementSpacing = 0.5;
%Create Custom Antenna Element
el = phased.CustomAntennaElement;
el.FrequencyVector = [0 1e+20];
el.FrequencyResponse = [0 0];
el.AzimuthAngles = -180:180;
el.ElevationAngles = -90:90;
el.RadiationPattern = zeros(181,361);
h.Element = el;
%Assign frequencies and propagation speed
F = 300000000;
PS = 300000000;
%Create figure, panel, and axes
fig = figure;
panel = uipanel('Parent',fig);
```

```
hAxes = axes('Parent',panel,'Color','none');
%Plot 3d graph
fmt = 'polar';
pattern(h, F(1), 'PropagationSpeed', PS, 'Type','directivity', ...
    'CoordinateSystem', fmt);
%Adjust the view angles
view(hAxes,[135 20]);
title = get(hAxes, 'title');
title_str = get(title, 'String');
%Modify the title
[Fval, ~, Fletter] = engunits(300000000);
steeringString = 'No Steering';
title_str = [title_str sprintf('\n') num2str(Fval) ' ' Fletter 'Hz ' ...
    steeringString];
set(title, 'String', title_str);
```

4.2 Appropriate shape of Uniform Linear antenna when simulated using sensor array analyzer

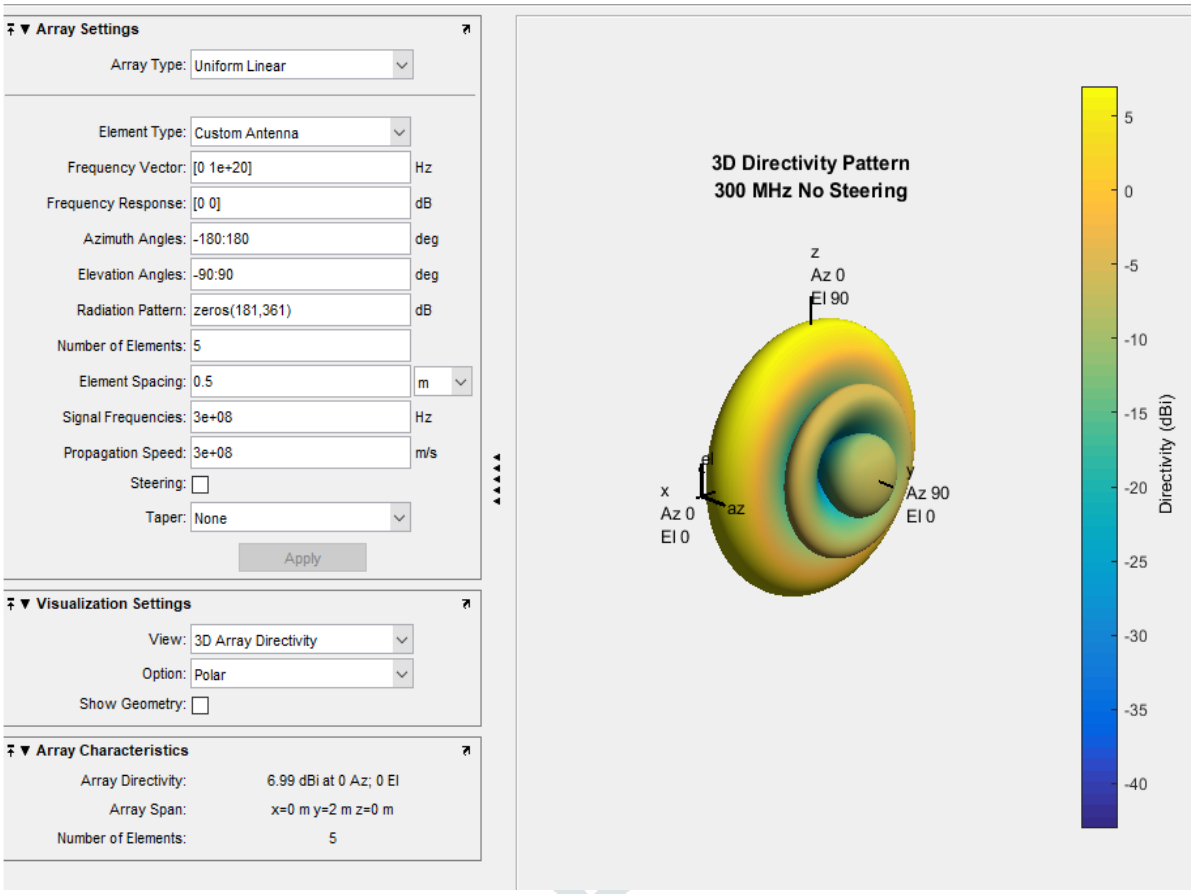

Fig.11. parameters for uniform linear antenna (Mathworks, 2016)

The above result in figure 11 that the designed and simulated uniform linear antenna array has the following input parameters in Sensor Array Analyzer which include: Frequency vector from 0 to 1e + 20Hz, azimuth angles stated from -180 to 180 deg, elevation angle which stated from -90 to 90^0, 5 number of elements, 0.5m element spacing and 3e + 08 Hz signal frequencies. The shape of uniform linear antenna was designed and simulated in 3D. This showed that, Sensor array analyzer was effective for simulating the appropriate shape for uniform linear antenna. This result is in line with the finding of Narandzic, Kaske, Schneider, Milojevic, Landmann, Sommerkorn and Thoma (2017), it is also in harmony with the finding of Lu, Tolli, Pirainen, Juntti and Li (2021) where the researchers suggested that 3D array system gives the best shape in simulation of uniform antenna array.

4.3 Appropriate shape of Custom array Antenna when simulated using sensor array analyzer

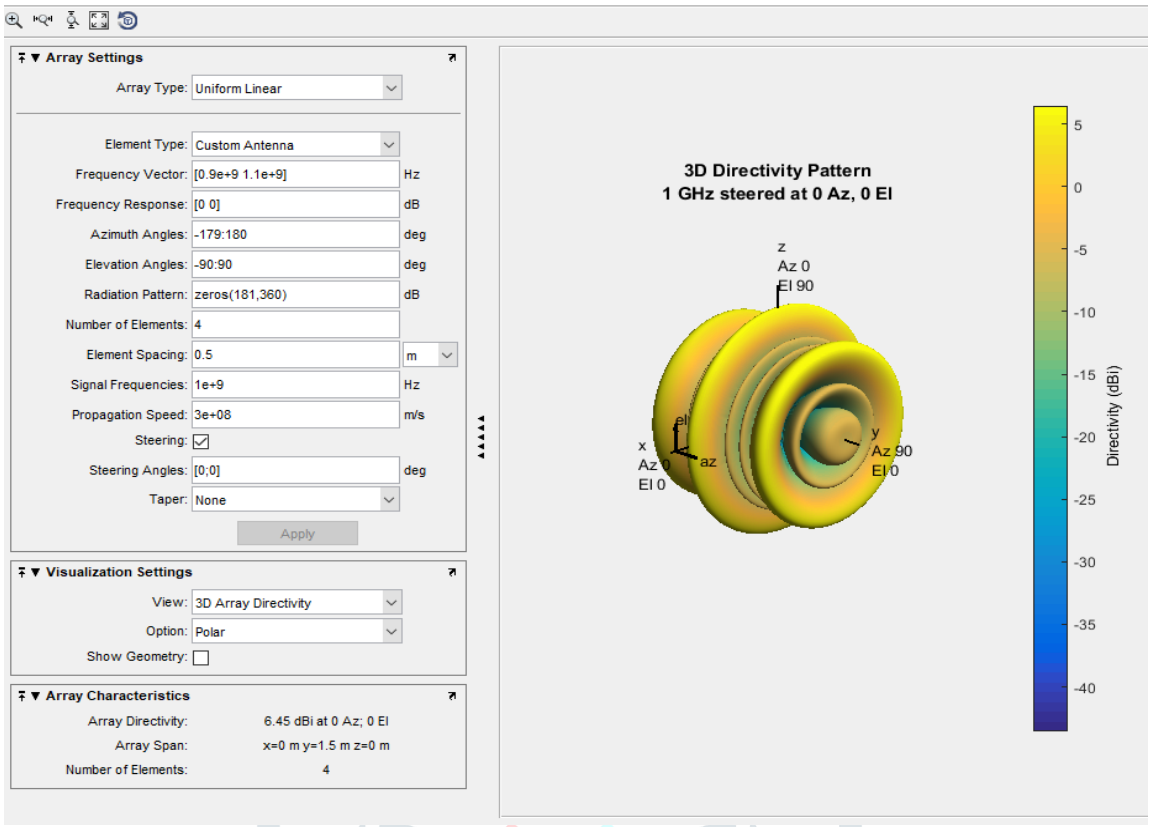

Fig.12. Parameters of Custom Antenna (Mathworks, 2016)

The above result in figure 12 showed that the designed and simulated uniform linear antenna array has the following input parameters in Sensor Array Analyzer which include: Frequency vector from 0.9e + 9 to 1e + 9Hz, azimuth angles stated from -179 to 180 deg, elevation angle which stated from -90 to 90^0, 4 number of elements, 0.5m element spacing and 1e + 9Hz signal frequencies. The shape of uniform linear antenna was designed and simulated in 3D. This showed that, Sensor array analyzer was effective for design and simulating the appropriate shape for Custom antenna array. This result is in line with the finding of Delorenzo, Lo, Enge, and Rife (2012), it is also in harmony with the finding of Huang, Calhourn and Tjeoelker (2016) where the researchers suggested that 3D array system gives the best shape in simulation of custom antenna array.

4..4 Appropriate shape of Isotropic array Antenna when simulated using sensor array analyzer

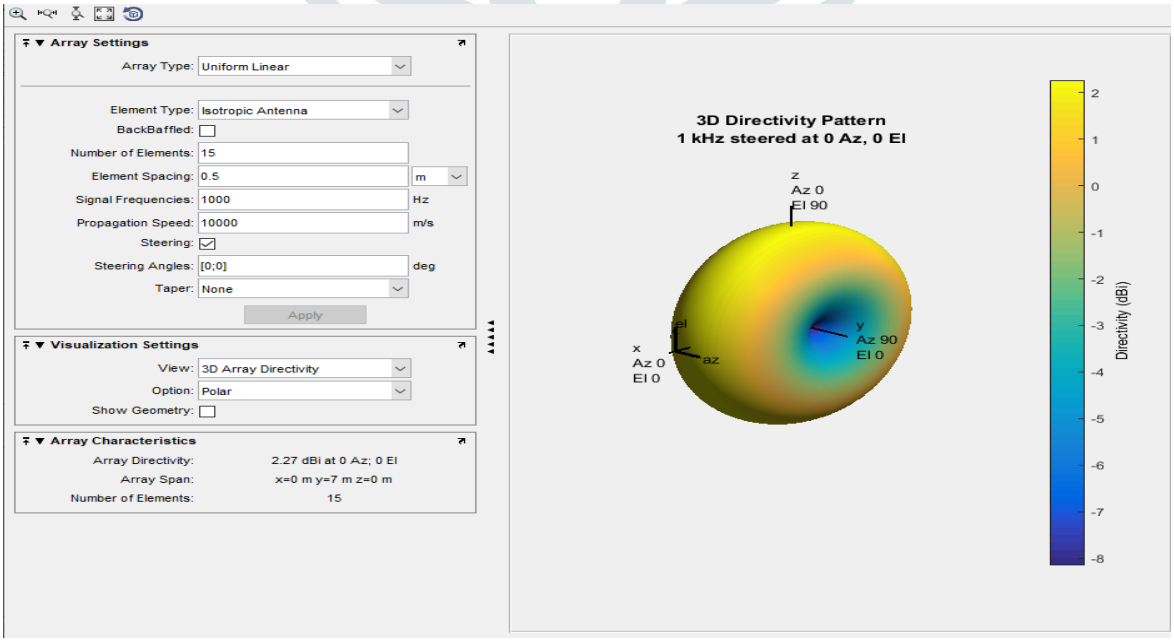

Fig.13. Parameters ofIsotropic Antenna Array (Mathworks, 2016)

The result in figure 13 showed that the designed and simulated Isotropic antenna array has the following input parameters in Sensor Array Analyzer, which include: 15 number of elements, 0.5m element spacing, 1000Hz signal frequencies and 10,000 m/s propagation speed. The shape of Custom antenna was designed and simulated in 3D. This showed that, Sensor array analyzer was effective for simulating the appropriate shape of Isotropic antenna array. This result is in line with the finding of Huang, Calhourn and Tjoelker (2019), it is also in harmony with the finding of Rattan, Patterh and Sohi (2019) where the researchers suggested that 3D array system gives the best shape in simulation of Isotropic antenna array.

4.5 Appropriate shape of Uniform Rectangular array Antenna when simulated using sensor array analyzer

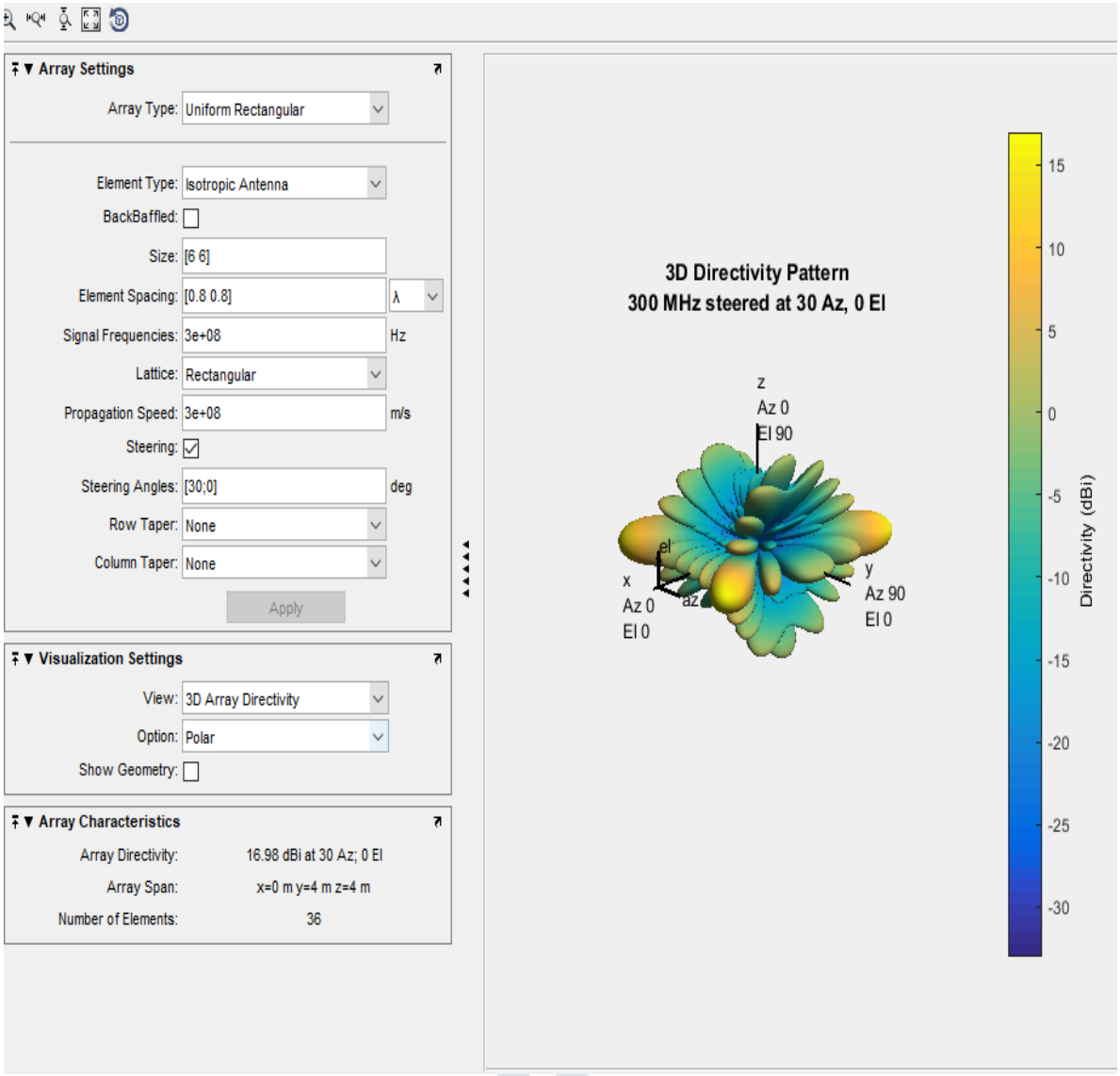

Fig.14. Parameters of Uniform Rectangular Antenna (Mathworks, 2016)

The result in figure 14 showed that the simulated Uniform rectangular antenna array has the following input parameters in Sensor Array Analyzer, which include: Rectangular lattice, 4 number of elements, 0.8 element spacing, propagation speed of 3e + 08m/s and steering angle of 30^0. The shape of uniform rectangular antenna was designed and simulated in 3D. This result is in line with the finding of Li, Su, Zang, Zhao, Yu, Xiao and Xu (2013), it is also in harmony with the finding of Heidernreich, Zoubir and Rubsamen (2012) where the researchers suggested that the simulation of uniform antenna array can best be done in 3D array system. This showed that, Sensor array analyzer was effective for simulating the appropriate shape of Uniform rectangular antenna array.

4.6 Grating lobes for Uniform rectangular array using sensor array analyzer

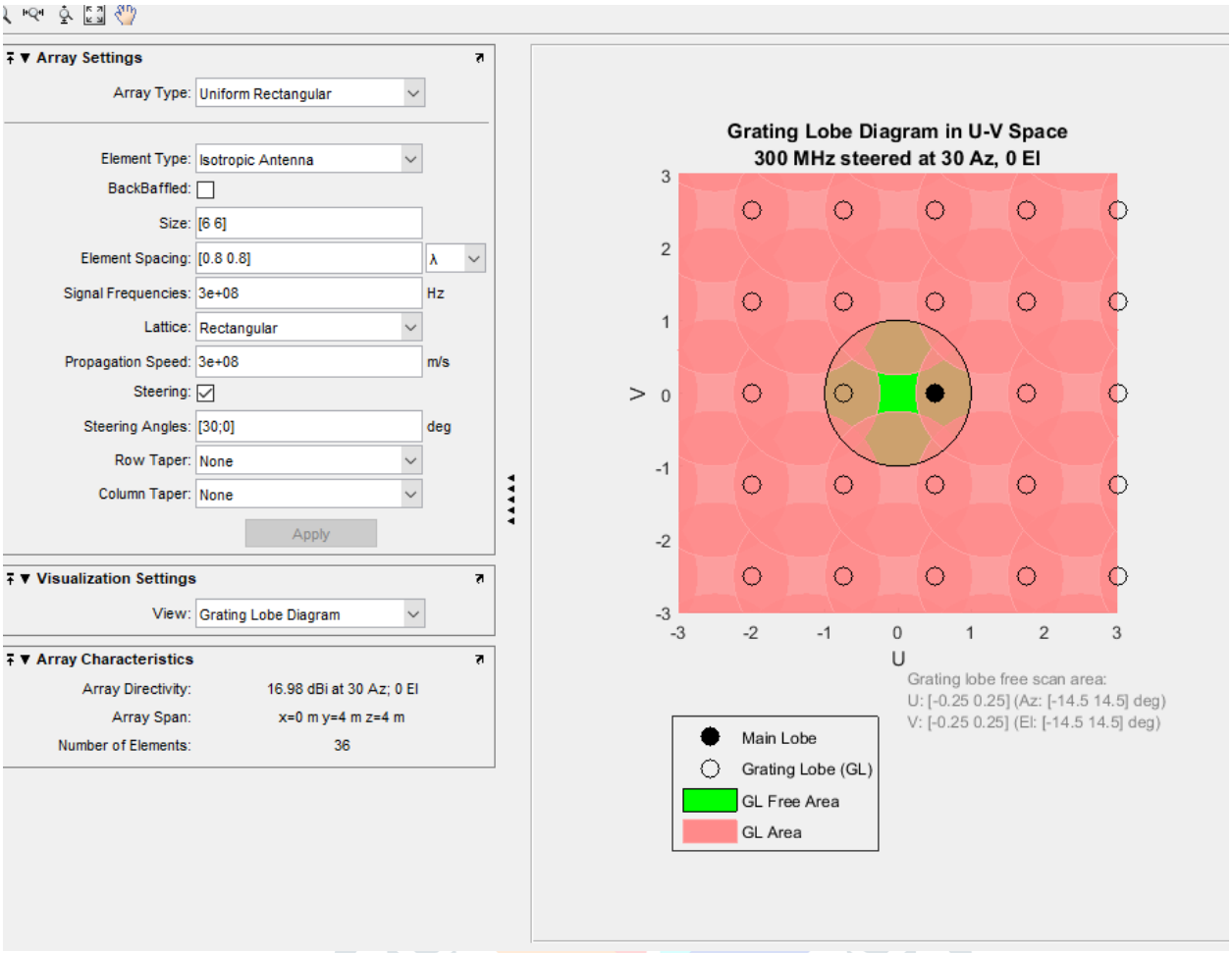

Fig.15. Grating lobe diagram for 5x5 uniform rectangular array (Mathworks, 2016)

Figure 15 indicated that the red area shows the area for grating lobe. The black circle shaded with black colour shows main lobe, the colourless circle shows the real grating lobe, the rectagle shaded with green colour shows grating lobe free area and lastly the red rectangle shows grating lobe area.. Parameters for plotting grating lobe having 5x5 dimension of uniform rectangular array. The spacing of 0.8λ spacing was inserted between each element and angle of [30,0] was inserted. This result is in line with the finding of Iqbal and Pour (2018), it is also in harmony with the finding of Vosoogh and Kildal (2016). This indicated that Sensor array analyzer was effective in design and simulation of grating lobe of uniform rectangular array.

5.0 Findings of the Study

The results of the study revealed the following findings:

1. MATLAB was effective in designing and simulating the directivity of Uniform Linear antenna generated from MATLAB codes.
2. Sensor Array Antenna (SAA) was effective in designing and simulating the appropriate shape of Uniform Linear antenna.
3. Sensor Array Antenna (SAA) was effective in designing and simulating the appropriate shape of Custom array Antenna.
4. Sensor Array Antenna (SAA) was effective in designing and simulating the appropriate shape of Isotropic array Antenna.
5. Sensor Array Antenna (SAA) was effective in designing and simulating the appropriate shape of Uniform rectangular array Antenna.
6. Sensor Array Antenna (SAA) was effective in designing and simulating the grating lobes for Uniform rectangular array.

5.1 Conclusion

Sensor Array Analyzer was effective for design and simulation of antenna arrays of different types. Few to mention are Uniform array antenna that operates with frequency vector from 0.9 GHz to 1.1 GHz, Azimuth angles set from -180 to 180, spacing 0.5λ. Custom antenna that operates with frequency vector from 0.9 GHz to 1.1 GHz, Azimuth angles set from -179 to 180, spacing 0.5λ, 4 number of elements. In addition, SAA was effective in design and simulation of grating lobe having elements that are greater than 1λ.

5.2 Limitation of the Study

In the course of carrying out this study, the researchers experienced the following limitations:

1. Difficulties in the use of MATLAB especially when debugging the generated codes.
2. Inability of Sensor array analyzer to include mutual coupling serves as a great limiting factor to this study.
3. Inability of SAA to handle complex form for beamforming, such serves as a great weakness in making antenna array.

5.3 Contribution to Knowledge

The available literature showed that, studies on antenna array were carried out on specific or narrow scope of antenna array, but this study was conducted in a broader scope that different types of antenna arrays were designed and simulated. Similarly, there is limited literature on designing and simulation of antenna arrays using Sensor Array Analyzer, that is why the study intends to fill in the existing gap. The design and simulation of antenna arrays using SAA in this study will help University and polytechnic lecturers of Electrical engineering especially those that specialize in telecommunication to put this research in to justification.

5.4 Suggestions for Further Study

Based on the findings of the study and conclusion, under which the study was carried out, the following suggestions are made:

1. There is need to replicate similar study on other signal and communication applications such as wavelet design & analysis app, window design & analysis app etc.
2. The study should be replicated on other types of antenna arrays such as Uinform circular, Uniform hexagonal, circular planar, concentric, spherical, cylinder and arbitrary geometry.
3. The study should be replicated on other element types such as Omnidirectional microphone, Cardioid microphone etc.

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