Nat. Volatiles & Essent. Oils, 2021; 8(5): 8367 - 8376

Diamond shaped array structure to operate at multiple frequencies

Dr. N. Sivasankari[1], Poongalai[2], Bhargavi[3]
[1]*Assistant Professor, Mepco Schlenk Engineering College*
[2]*UG Student, Mepco Schlenk Engineering College*
[3]*UG Student, Mepco Schlenk Engineering College*
sivani.sivasankari@gmail.com

ABSTRACT

There are various explorations of antennas based on the arrangement by satisfying certain requirement of antenna in its directional pattern. For fulfilling this requirement, array structures can be used. The structure has to be designed to provide better performance with minimum losses. A single cell Microstrip Patch antenna is designed to operate at 10GHz frequency. It can be made to resonate at any frequencies between 1 Hz to 10GHz. The desired antenna works at ISM (Industrial, Safety and Medical) band frequency and the parameters like return loss, gain, radiation pattern and VSWR are analyzed and simulated using ANSYS HFSS software.

Key words: Microstrip structure, diamond array, return loss, resonance, radiation pattern.

INTRODUCTION

An antenna array is a single system formed by arranging various antenna elements in an appropriate manner. Basically, proper spacing and proper phase must be provided to the antenna elements or cells when it's clubbed together as an array. Whenever an antenna tries to transmit a signal over a long distance, then it is expected to possess high directive gain, but most of the time the signal gets distorted during propagation. Single antenna cell, despite having good directivity, sometimes fails to transmit the signal to the receiver without losses. For this reason, the array antenna is concerned. In the proposed cell, the array contains microstrip patch antenna and coaxial feed lines in a specific phase relationship. The radio waves radiated by each individual antenna combined, superimposed and added together to enhance the power radiated in desired directions, and cancelling to reduce the power radiated in other directions. The radiation pattern of array antenna should be a strong main beam in one direction. The larger the width of the antenna and the greater the number of component antenna elements, the narrower the main lobe, and the higher the gain which can be achieved, and the smaller the side lobes would be obtained on analysis. When the antenna is used in aircraft applications, a high-gain antenna is needed to communicate with the satellite. Moreover, the antenna needs beam steering capabilities to compensate the moving of the aircraft. Consequently, an increasing effort was made to develop compact antenna terminals complying with these needs.

LITERATURE SURVEY

Ahmed A. Kishk and Abdelmoniem T. Hassan in reference [1], proposed the concept for designing large finite arrays using a smaller array. The design gives a brief view on the construction of cells like 4x4 array and 8x8 array. For an 8x8 array, mutual coupling is given between elements from 4x4 array. This can be utilized for millimeter wave applications. The array element, the magneto-electric dipole, is excited by a narrow slot coupled to a printed gap waveguide.

Shunxi Lou, et al., [2] proposed a method that can be used for a finite array with different types of radiating elements and can also be applied to the analysis and synthesis of the three-dimensional antenna arrays. They do not depend on the input excitation of the array, which shows that they are the inherent property of an array. It is noteworthy that only the perfectly electrically conducting antennas were studied in this paper.

D L Rayne and J DeLap in reference [3] proposed a new technique in 3D field simulation that can be utilized for joint array simulation. There is also much less degradation or the suppression of the side lobes.

Cheng-Ming Chen et al.,[4] proposed a finite array, by using this method, there is a strong variation in the gain pattern of the different antenna elements. This gain pattern variation is caused by mutual coupling, edge effect. These variations strongly depend on the angle of arrival. This makes the whole array, radiation pattern as omnidirectional and more sensitive to angle of arrival than a patch array consisting of directional elements. Because of this angle of arrival dependent gain variation, the received power over the array is not the same for all the users.

Nikolaos c. et al., [5] proposed a 10 GHz cylindrical-array antenna. This cylindrical array antenna also gives great radiation pattern compared with the design in [4]. Lalit Kaushal and Ritesh K Mishra [6] constructed 4x1 and 2x1 rectangular Microstrip patch antenna array. Gain and Bandwidth and directivity are increased by this method.

DESIGN OF ANTENNA

The design methodology for the array antenna initializes with the basic array element that have a microstrip patch antenna, with 10x15 (mm) ground, 10x15x1.16 (mm) substrate, 8.6x11.1(mm)patch and 1.1 mm diameter coaxial cylindrical feeding. The radiation box is provided with perfectly matched layer. The single Microstrip patch antenna structure is shown in figure 1.

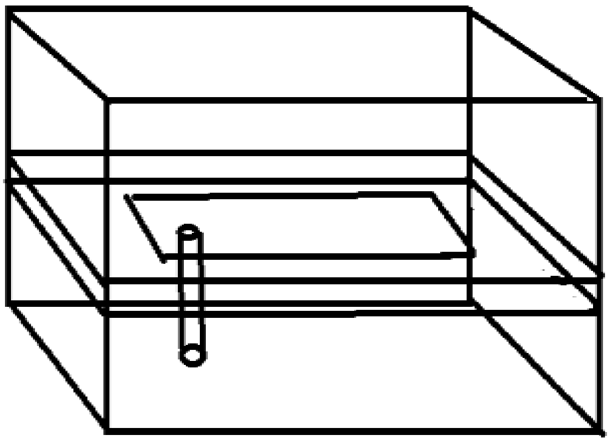


Fig 1: Single antenna cell

Individual antenna cells are designed with the following equations. Width of the antenna is calculated by

$$W = \frac{C_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

The effective dielectric constrant used for calculating effective length is determined as follows :

$$\varepsilon_{reff} = \frac{1+\varepsilon_r}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (2)$$

Extended length ΔL can be calculated from

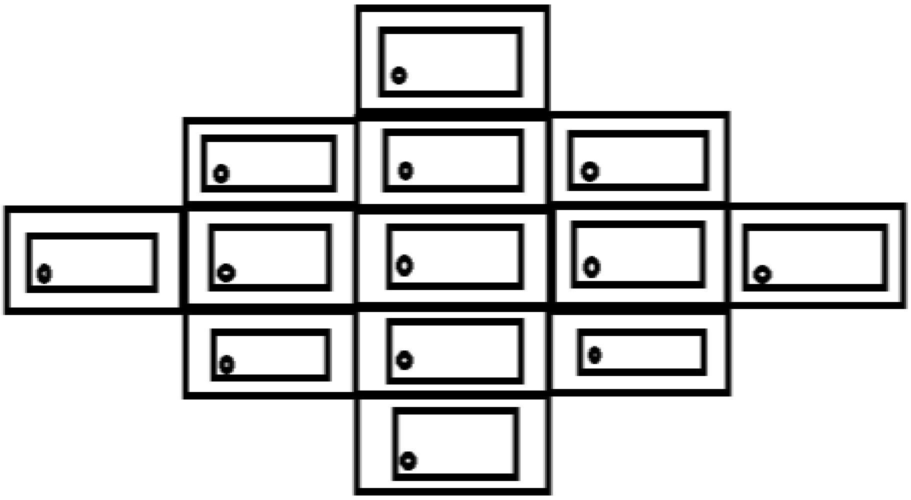
$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (3)$$

From this extended infinitesimal length, length of the patch can be given as

$$L = \frac{C_0}{\sqrt{\varepsilon_{reff}}2f_r} \quad (4)$$

Where L- Length of patch; W- Width of patch; h- Height of substrate

After constructing a diamond shaped like antenna structure the structure is shown in Figure 2. coaxial feed,



where Coaxial feeding is feeding method in which the inner conductor of the coaxial is attached to the radiation patch of the antenna while the outer conductor is connected to the ground plane. It has its own advantages which could be ease of fabrication, easy to match and produce low spurious radiation and also coaxial cable can be given at any position in the patch to achieve impedance matching.

Fig 2: Antenna array model(2D)

While implementing in High Frequency Structure Simulator (HFSS) the structure is like shown in Figure 3.

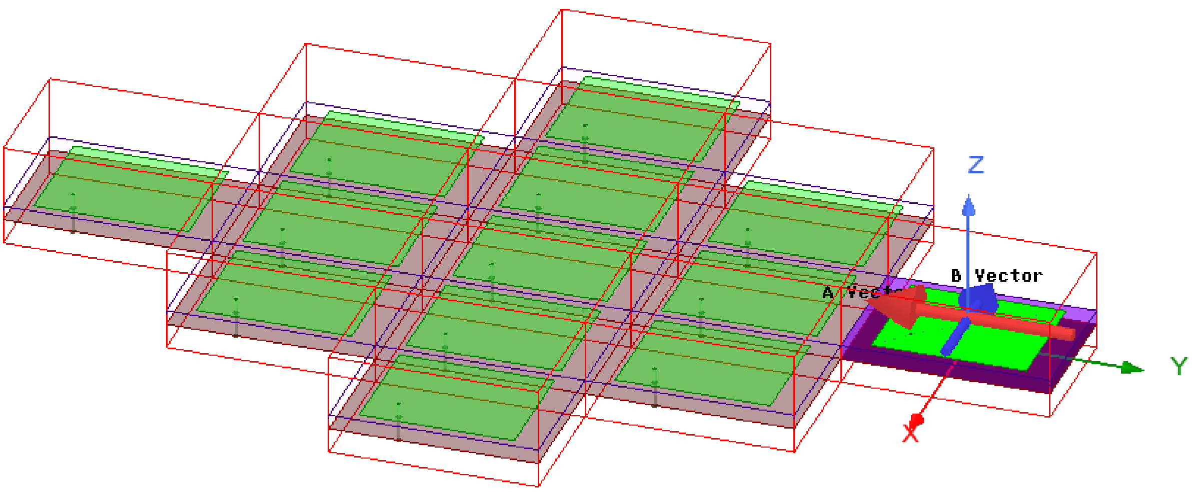


Figure 3: Diamond Antenna Array structure model (3D)

The radiation box is provided with open1 boundary and the patch & substrate are with perfect Electric field boundary. The array element is now excited and the path to create array

Results and discussion

The Proposed antenna structure is implemented in ANSYS HFSS v2020. The array antenna is now designed for a frequency of 10GHz over the basic array element and is set for analysis after validation check is done. The antenna array set up is built as Hybrid array solution set-up. Simulated parameters used up in the bounded line up antenna for a single cell are tabulated and their corresponding responses are visually represented.

Table 1: Simulation dimensions

Parameter	**Proposed Design**
Operating frequency	10GHz
Length of patch(L)	8.6mm
Width of patch(W)	11.1mm
Height of substrate(h)	1.16mm
Dielectric constant	2.65
Dielectric material	Arlon AD260A

A. Return loss analysis

Return loss is the amount of signal get reflected or returned. Table 2 tabulates the return loss value measured at various antenna array elements.

Table 2: Return loss values at various cells

Cell array indices	Return loss(dB)
dB(S(A[1,3]1,A[1,3]1))	-4.629
dB(S(A[2,2]1,A[1,3]1))	-51.249
dB(S(A[2,3]1,A[1,3]1))	-49.21
dB(S(A[2,4]1,A[1,3]1))	-54.66
dB(S(A[2,4]1,A[1,3]1))	-67.164
dB(S(A[3,1]1,A[1,3]1))	-82.2
dB(S(A[3,2]1,A[1,3]1))	-79.76
dB(S(A[3,3]1,A[1,3]1))	-82.734
dB(S(A[3,4]1,A[1,3]1))	-86.833
dB(S(A[3,5]1,A[1,3]1))	-103.52
dB(S(A[4,3]1,A[1,3]1))	-99.89
dB(S(A[4,4]1,A[1,3]1))	-93.37
dB(S(A[5,3]1,A[1,3]1))	-94.78
dB(S(A[1,3]1,A[2,2]1))	-51.249
dB(S(A[2,2]1,A[2,2]1))	-4.6
dB(S(A[2,3]1,A[2,2]1))	-39.64
dB(S(A[2,4]1,A[2,2]1))	-61.72322
dB(S(A[3,1]1,A[2,2]1))	-54.2874
dB(S(A[3,2]1,A[2,2]1))	-49.007
dB(S(A[3,3]1,A[2,2]1))	-55.035

From the above table, it is clear that the range of return loss is -4.629(6.6 dB) to -103.52(20.2 dB). The maximum return loss is -103.52(20.2 dB) which is obtained at {A [3,5]1,A [1,3]1}.

B. ANTENNA PARAMETERS ANALYSIS

Obtained values from this design is tabulated in 3**.**

Table 3: Antenna parameters analysis

Parameters	**Formula**	**Obtained values**
Maximum Radiation Intensity (W/rad)	$U_{max} = \frac{P_{radiated}}{solid\ angle}$	23.6694
Peak directivity(dB)	$D = \frac{4\pi\ (Radiation\ Intensity)}{P_{radiated}}$	10.84
Peak gain(dB)	$G = \epsilon_T D$	10.836

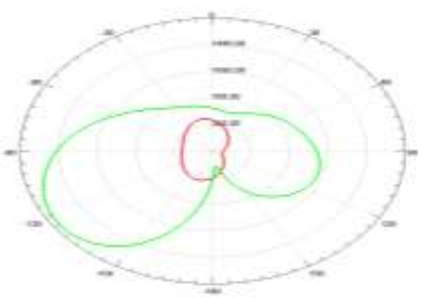
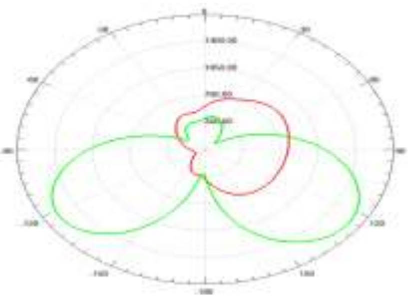
Radiation efficiency (no unit)	$\varepsilon_T = P_{radiated}/(P_{input})$	0.002195
Total efficiency (no unit)	$\varepsilon_T = M_L \varepsilon_R$	1.839
Beam area(m$^{2)}$	$\Omega_A = \frac{4\,\pi}{D}$	21.83

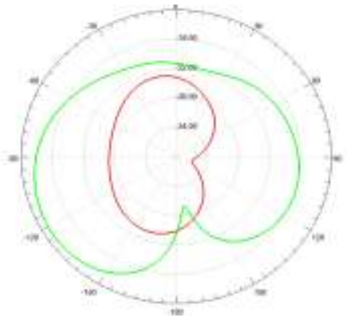
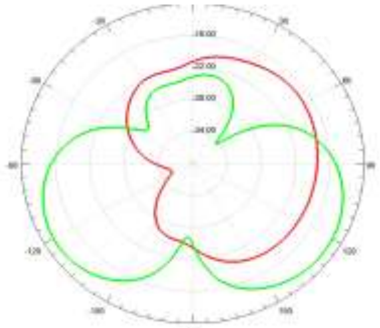
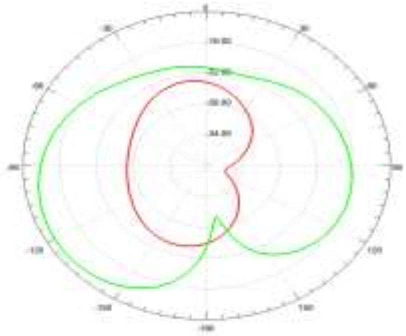
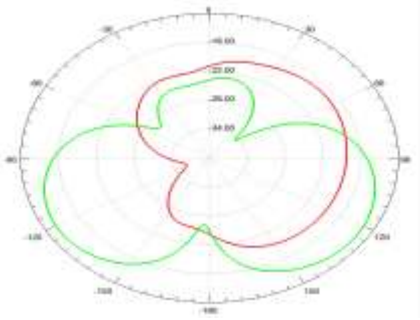
C. Orientation of electromagnetic waves

Polarization is characterized as the orientation of an electromagnetic wave's electric field. The antenna defines the initial polarization of radio waves. The vector of electric field remains constantly in the same plane with linear polarization. Reflections over the transmission path normally less affect the vertically polarized radiation. There are different types of polarization. Polarization is represented via an ellipse. The linear polarization and circular polarization are two special cases of elliptical polarization.

Omni directional antennas are often polarized vertically. Such reflections cause differences in the obtained signal intensity with horizontal polarization. Horizontal antennas are less likely to absorb artificial interference which is usually polarized vertically. In circular polarization the electric field vector appears to be revolving in the direction of propagation with circular motion, allowing one complete turn for each RF loop. The spin can be right hand or left hand. Antenna parameters such as Radiation pattern, Directivity and Gain orientation are plotted in Table 4 for both E and H plane.

Table 4. Antenna parameter analysis

Antenna parameters	**With E Field**	**With H field**
1.Radiation pattern		

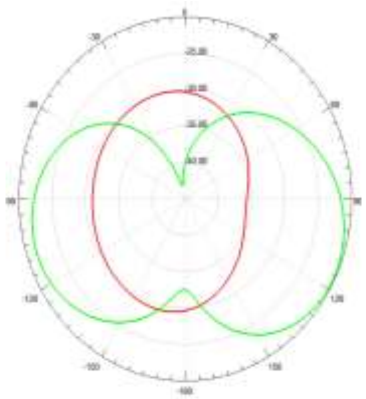
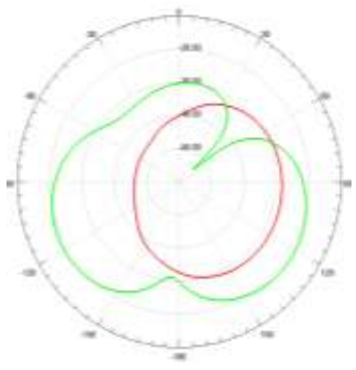
2.Directivity $D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}$. **Directivity for array:** $D = \frac{\left[\sum_{-n_z}^{n_z} A_n\right]^2}{\sum_{-n_z}^{n_z} A_n^2}$		
3.Gain(dB) **G=KD** (G-gain K-Efficiency D-directivity)		

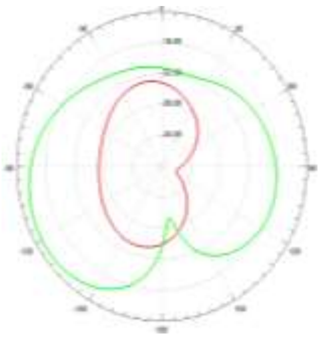
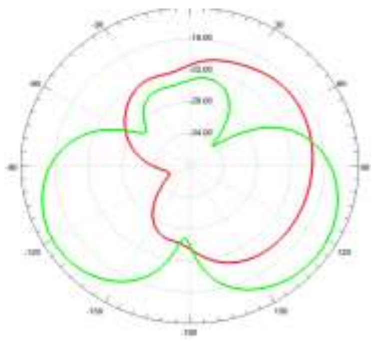
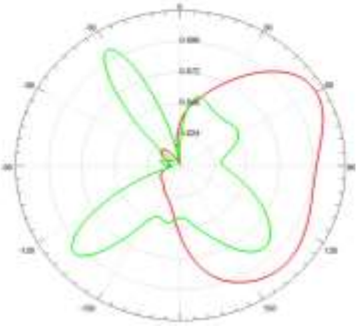
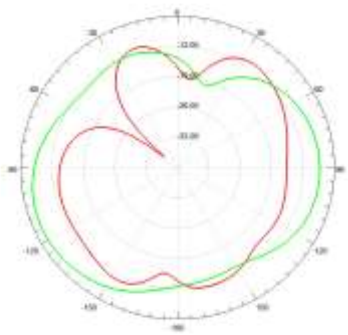
From the plot, it can be inferred that it is End fire array with improved major lobes and suppressed side lobes. Peak gain (in dB) is 10.86 and peak directivity is 10.831dB.

D. Dimensionality analysis for various antenna parameters

With various dimensions for different frequencies, directivity is plotted and tabulated in Table 5.

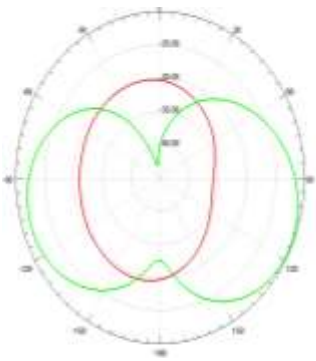
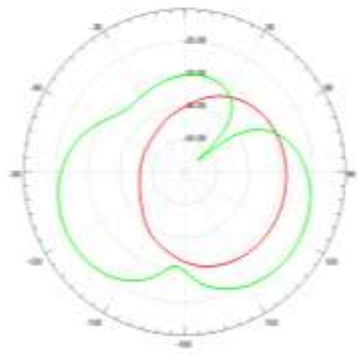
Table 5: Directivity for various dimensions

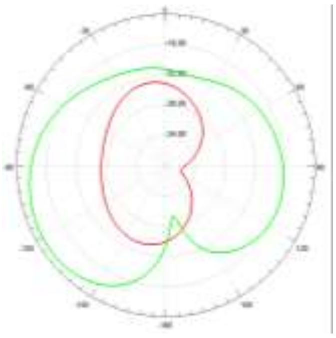
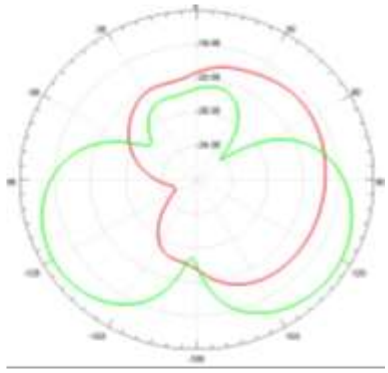
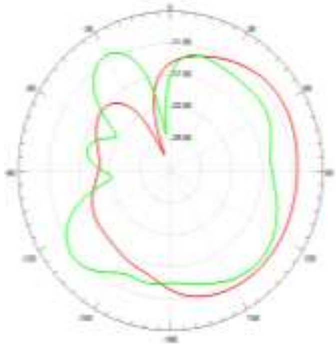
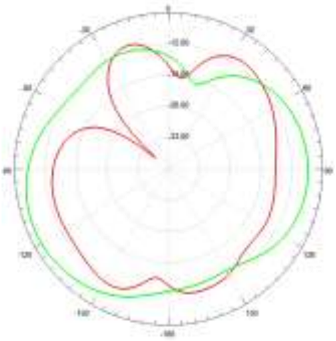
DIMENSIONS	**OPERATING FREQUENCY (in GHz)**	**WITH E FIELD (Phi =0 degree)**	**WITH H FIELD (Phi=90 degree)**
L =18mm W=22mm h=1.16mm	5		

L =8.6mm W=11.1mm h=1.16mm	10		
L =4mm W=5.55mm h =1.16mm	20		

From the above graphs, it is confirmed that directivity increases with increase in frequency. similarly, the gain value is also plotted in Table 6.

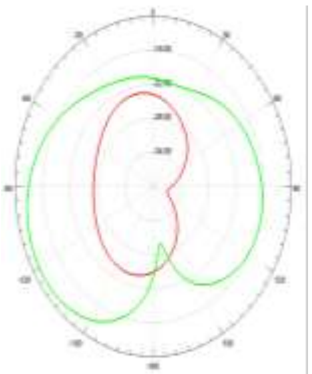
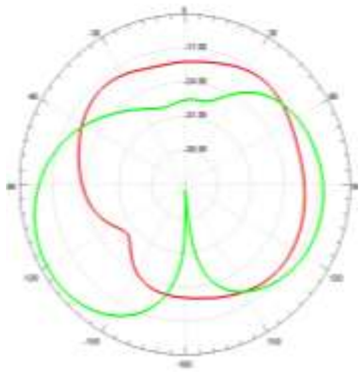
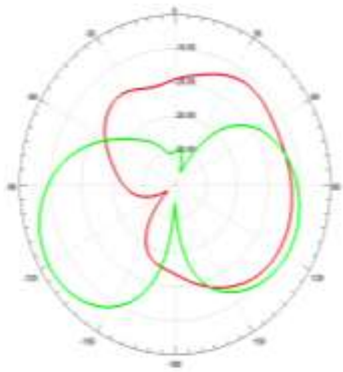
Table 6: Gain plot for various dimension
s

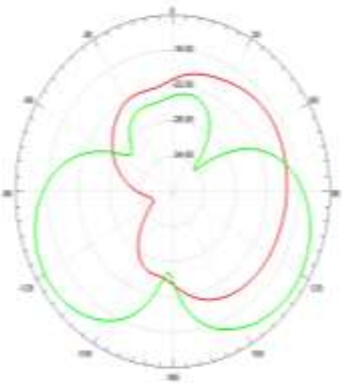
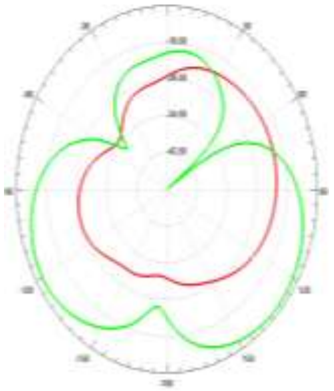
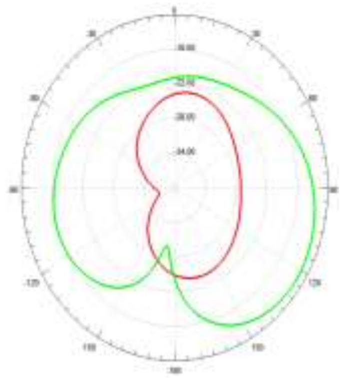
DIMENSIONS	**OPERATING FREQUENCY (in GHz)**	**WITH E FIELD (Phi =0 degree)**	**WITH H FIELD (Phi=90 degree)**
L =18mm W=22mm h=1.16mm	5		

L =8.6mm W=11.1mm h=1.16mm	10		
L =4mm W=5.55mm h =1.16mm	20		

The plots of gain for various values of Φ from 0 to 180 degree are plotted and tabulated in the table 7.

Table 7: Variation in gain plot with respect to Φ(in degrees)

Φ(in degrees)	**0°**	**40°**	**60°**
Gain plot			
Φ(in degrees)	**90°**	**120°**	**180°**

Gain plot			

After analyzing gain plot for various phi values, it can be concluded that optimum gain(10.368dB) can be obtained at Phi=90 degree (H field).

CONCLUSION

The finite array antenna has been designed by concatenation of single element which is further improved to obtain the large planar array. The parameters required to determine the proper design of proposed model after simulation are listed out for different set of frequencies. The effective directivity and gain values for the different dimensions have been reported. Thus, the diamond shaped array antenna configuration is analyzed successfully over the HFSS software platform. This work can be extended with different diamond shaped dimensions.

REFERENCES

[1] A. A. Kishk and A. T. Hassan, "Design of Large Finite Array Antennas and its Feeding Network," *2019 IEEE International Conference on Computational Electromagnetics (ICCEM)*, 2019, pp. 1-3, doi: 10.1109/COMPEM.2019.8779178.

[2] S. Lou, B. Duan, W. Wang, C. Ge and S. Qian, "Analysis of Finite Antenna Arrays Using the Characteristic Modes of Isolated Radiating Elements," in IEEE Transactions on Antennas and Propagation, vol. 67, no. 3, pp. 1582-1589, March 2019, doi: 10.1109/TAP.2018.2883664.

[3] S. Lou, B. Duan, W. Wang, C. Ge and S. Qian, "Analysis of Finite Antenna Arrays Using the Characteristic Modes of Isolated Radiating Elements," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 3, pp. 1582-1589, March 2019, doi: 10.1109/TAP.2018.2883664.

[4] S. Lou, B. Duan, W. Wang, C. Ge and S. Qian, "Analysis of Finite Antenna Arrays Using the Characteristic Modes of Isolated Radiating Elements," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 3, pp. 1582-1589, March 2019, doi: 10.1109/TAP.2018.2883664.

[5] N. C. Athanasopoulos, K. A. Mourtzoukos, G. E. Stratakos, R. J. Makri and N. K. Uzunoglu, "Development and testing of a 10 GHz phased-array cylindrical-antenna transmitting system incorporating a least-squares radiation-pattern synthesis technique," in *IEEE Antennas and Propagation Magazine*, vol. 50, no. 6, pp. 80-88, Dec. 2008, doi: 10.1109/MAP.2008.4768927

[6] Lalit Kaushal, Ritesh K Mishra, “Linear Arrays of Rectangular Microstrip Patch Antennas: Analysis & Performance Assessment (2015)” International Journal of Innovations in Engineering and Technology, ISSN: 2319 – 1058, Volume 5 Issue 4 August 2015., Page.180-188.