International Journal of Engineering & Technology, 7 (1.1) (2018) 494-499

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Maple leaf shaped array antenna for multiband applications

M Vasujadevi, B T P Madhav, A Shiva Skandan, P Rajeswari, K Arjun Rao, K Khyathi Reddy, M Vekateswara Rao

ALRC, Department of ECE, Koneru Lakshmaiah Education Foundation, Andhra Pradesh, India-522502
**Corresponding author E-mail: btpmadhav@kluniversity.in*

Abstract

This article presents design and analysis of maple leaf shaped array antenna for high gain applications. The proposed antenna is characterized and analyzed using ANSYS EM desktop 17. This antenna works at 2.17-2.54(S band),5.3-5.64, 6.91-7.80(C Band), 8.76-9.15(X band), 12.49-12.75, 14.78-16.65(Ku band). The bands of the proposed antenna has its applications at LTE 2.3 GHz, ISM 2.4 GHz, WLAN, ISM, Bluetooth at S-band and upper WLAN at C-band, Military applications and air traffic control at X-band. This single antenna dimensioned 21x18x1.6 mm³ is later arrayed in 1x4. This antenna has peak gain at 7.8dB and the average gain of 4.2dB. The proposed 1x4 array antenna is characterized and obtained return loss, gain, E field, current distribution and far field radiation patterns.

Keywords: *Maple leaf, ANSYS EM desktop 17, return loss, gain, E field, current distribution, far field radiation patterns*

1. Introduction

A single antenna can operate at multiple wireless standards have accoutered an importance substance to meet the difficulty of wireless device growth. By this impact, many various techniques and antenna structures have been predicted by researchers recognize multiple band applications with unique/different and compacted structures [1]. The Ultra-Wide Band(UWB) systems have succeeded in achieving importance in wireless communications due to its un licensed wide impedance band width. The technology of UWB has formed a basis for various wireless communication systems. For the design of UWB antenna with wide band width it should maintain higher gain and good radiation efficiency. [1-2]. The higher gain antennas with directive radiation features are important in various applications like high speed moving target direction, coal mines, military etc. The assemblage of radiating elements in an electrical and geometrical configuration is defined as antenna array. antenna array gives high gain and directive radiation pattern rather increasing the size of the radiating element [2]. Antenna array is used to improve the overall gain, give diversity reception, negate interference from particular direction, regulates/determines the direction of arrival of signal and maximizes the SNIR (Signal to Interference Plus Noise Ratio). Array is most sensitive to appropriate direction [3]. The antenna array performance is improved by increasing number of elements in the array. Increase in the number of elements is in the form of cost, size and the complexity increases. This is one of the main drawback. To improve the performance of a communications engineering system an array of antennas is used in different ways [4]. A new technique based on the optimization of power transmission between two antennas has been suggested for the design of antenna arrays [5]. For attaining the improvement in band width, we can increase the thickness of the substrate. Antenna performance will be degraded with some limitation i.e. height of the substrate. for the improvement of band width impedance matching is a crucial role in the antenna performance. Antenna arrays are primarily used in the communication systems to transmit the signals with high gain [6]. The key problem for UWB application is to improve the limited band width of the printed antenna. Design of feeding network is one of the basic issues in the design of array antenna [7]. As a result of high band width, low profile and ease of integration coplanar waveguide fed antennas got great consideration now a day. For the enhancement of system performance circular polarization has become popular [8]. Now days in communication systems to create communication links antennas array plays a significant role. These patch antennas are extensively used in wireless communication systems as a result they have low profile, low cost and easy to fabricate and integrate. For enhanced bandwidth and gain a variety of shapes are designed [9]. The desired antenna for a particular system depends upon the type of application, frequency, gain and so on. In most of the applications, antennas such as planar antennas, microstrip antennas, monopole antennas, dielectric resonators etc., are used because of their low profile. These antennas have an extensive application in mobile systems, WLAN, WiMAX with 3.5 GHz band, ultra-wide band(UWB) with 3.1-10.6 GHz band [10-15]. In this article array antenna is considered for multiband applications and gain enhancement. Comparative analysis has been made for the single element and Array element. The results such as return loss, gain and radiation patterns etc have been discussed in the subsequent sections.

2. Antenna design

The single element leaf shaped patch antenna is etched in the shape of maple leaf on fr4 substrate. Fr4 substrate has dielectric permittivity of ε_r=4.4 and loss tangent of 0.02. For the reduction of antenna size, we are considering the fr4 substrate. The dimensions of the proposed antenna are viewed in tabel1.The

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

bottom side of the substrate is layered with a partial conducting ground plan. For the enhancement of band width there is a two-step change of width at patch feed interface, which has been included and the partial ground plane is used. The single element is formed into an array of elements as shown in the fig2 with dimensions as shown in the table1. The designed antenna is simulated by using HFSS tool. Here we are using the coplanar wave guide as feed and we have given lumped port for the practical existence. We consider the results of return loss, radiation patterns and VSWR. The single element patch antenna with associated feed is repeated and arranged linearly to from four element linear array. This array structure contains two levels of feeding which looks like a binomial tree. This structure uses three T-junction power dividers. By using microstrip we design T-junction power dividers to construct the antenna as a planar structure rather than feeding multiple single element patch antennas with external power dividers.

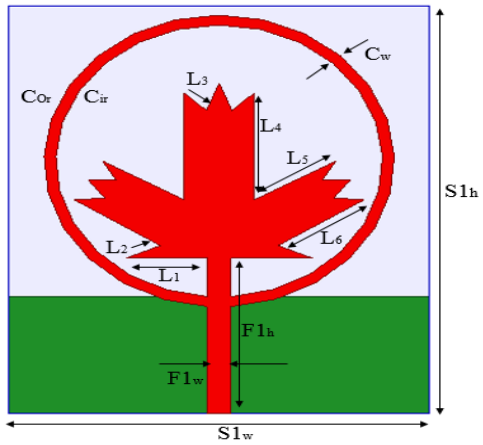


Fig. 1: Design of Single Element Leaf Shaped Patch Antenna.

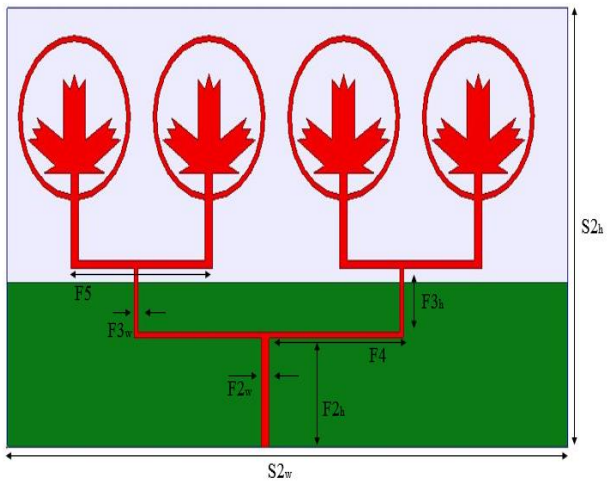


Fig. 2: Structure of proposed Four-Element(1x4) Array Antenna.

Table 1: Design Parameters of proposed Antenna (unit: mm)

Geometrical entity	Parametric values (mm)
Substrate	S1h= 21, S1w= 18, S2h= 40, S2w= 75
Feed line	F1h= 8, F1w= 1, F2h= 10.5, F2w= 1, F3h= 6.25, F3w=0.5, F4= 18, F5=19
Leaf(Patch)	L1= 3.5, L2= 1.6, L3= 1.5, L4= 5.5, L5= 4.0, L6= 4.35
Circle	Cir= 7, Cor= 7.5

3. Results and discussion

The antennas structures are designed and simulated in ANSYS High Frequency Simulator (HFSS). The simulated results in terms of return loss, radiation patterns, current distribution, E-field distributing and Gain vs frequency with neat sketches are discussed below. The simulated results of return loss characteristics of single element antenna and 4 element antennas shown in a combined plot for comparison. From the plot we can say that the number of resonances in the antenna characteristics becomes increasing when there is increase of the radiating elements compared to single element. Array antenna will work at multiple band frequencies which are shown in the table 4. The single element working bands are also shown in the table 3. Here we observed that the return loss characteristics of both single element and four element array antennas. From this we say that the proposed antenna is used for military applications, WLAN, WiMAX band applications. The four-element array antenna work under the bands i.e.; S band, C band, X band and Ku band.

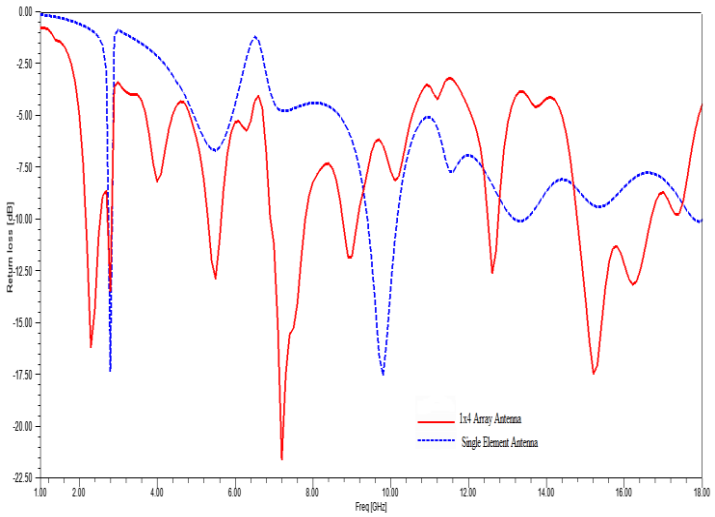


Fig. 3: Simulated Return Loss characteristics of Single element and Four element array antenna.

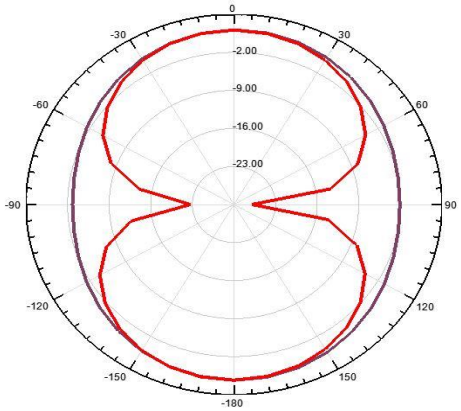
Table 2: For single element

Frequency Range (GHz)	Working Band	Band width
2.6 – 2.85	S Band	0.25 GHz
9.4 – 10.16	X Band	0.76 GHz

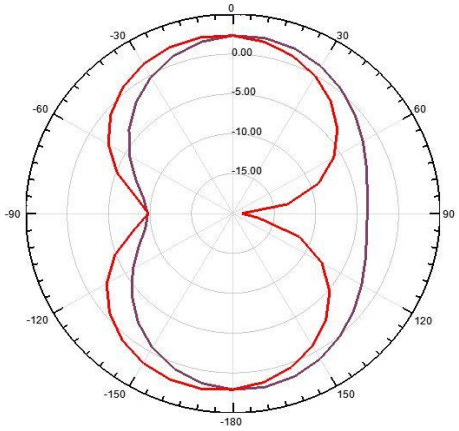
Table 3: For 1x4 Array antenna

Frequency Range (GHz)	Working Band	Band width
2.17 – 2.54	S Band	0.4 GHz
5.30 – 5.64	C Band	0.34 GHz
6.91 – 7.80	C Band	0.89 GHz
8.76 – 9.15	X Band	0.39 GHz
12.49 – 12.75	Ku Band	0.26 GHz
14.78 – 16.65	Ku Band	1.87 GHz

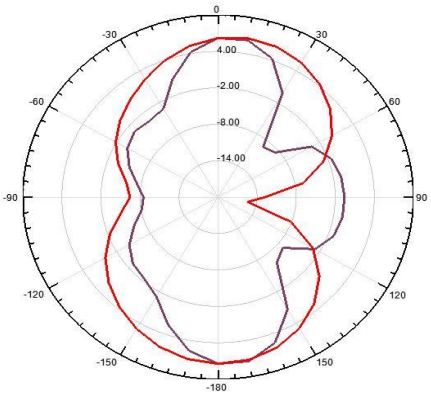
The far field characteristics of the single element antenna and four element array antennas are given at different resonant frequencies within the ultra-wide band. Radiation pattern performs a crucial role to assess the gain and far field distribution of the antenna. The proposed antenna radiation characteristics in both E plane and H plane. The far field pattern of an antenna is determined experimentally at an antenna range. The far filed radiation pattern can also be calculated from the antenna shape by using HFSS. From the radiation pattern we can describe the power patterns. From below figures we asses that the radiation patterns occur at different frequencies i.e. 2.3 GHz,2.8 GHz,5.5 GHz. From the replicated radiation patterns, we say that at 2.3 frequency at E field we get the dipole shaped pattern and at H field we get the omni directional pattern. At 2.8 there is a change in the shape and we get the E and H field distribution some what change. At last at 5.5 we there is tilt in the shape of the pattern. Here the 3D radiation plots are also replicated at different frequencies i.e.; 4.5GHz,4.46GHz, 5.7GHz, 8.17 GHz. We can observe the change in the radiation patterns at each frequency.



(a) At 2.3 GHz

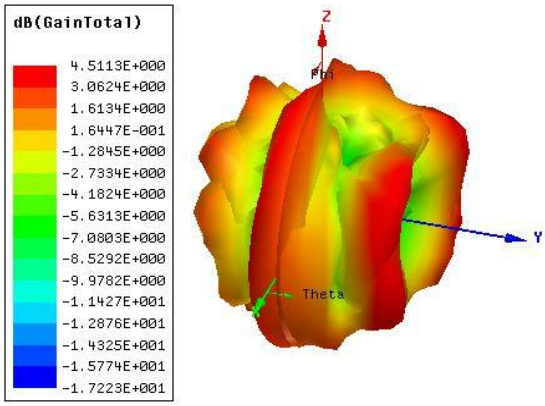


(b) At 2.8 GHz

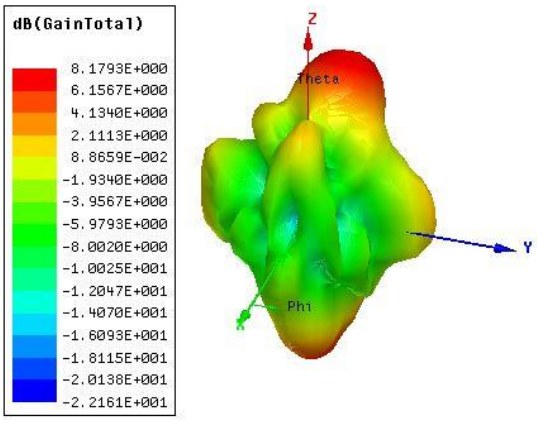


(c) At 5.5 GHz

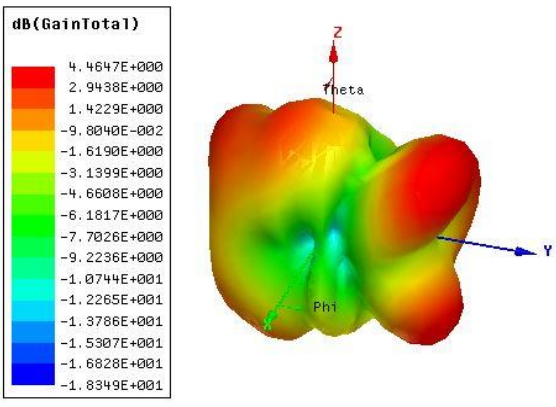
Fig. 4: 2D Radiation patterns (E-plane and H-plane) of Four-element array antenna.



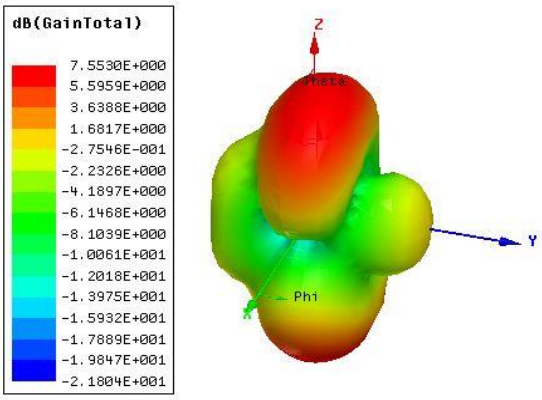
(a) At 4.5 GHz



(b) At 8.17 GHz



(c) At 4.46 GHz



(d) At 7.5 GHz

Fig. 5: 3D Radiation patterns (E-plane and H-plane) of Four-element array antenna.

The simulated results of the proposed antenna for gain versus frequency are shown below in the plot. Here we can observe the plot for the single element antenna gain is below 2.5. when we consider for four elements array we declare that that the gain is maximum and it reaches till 7.5. from this we say that for an array antenna the gain is improved.

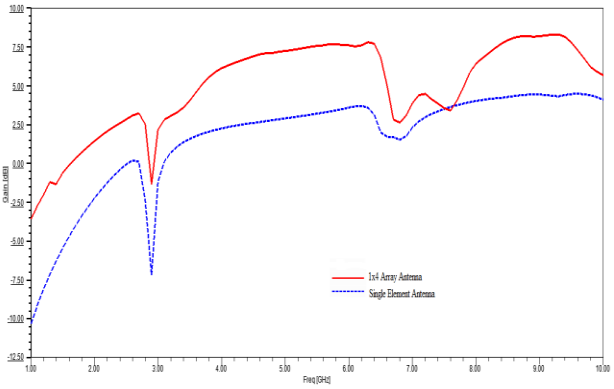
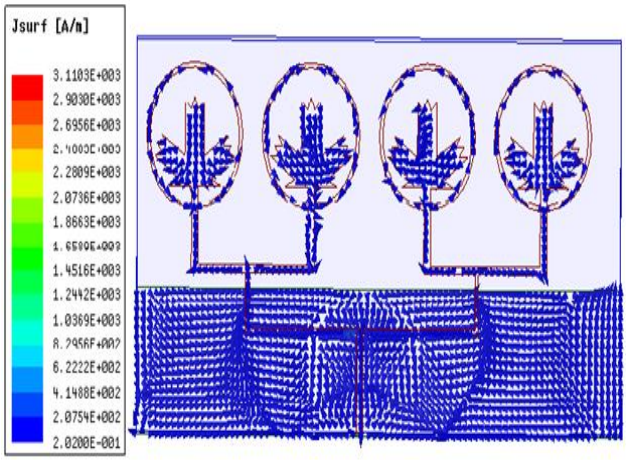
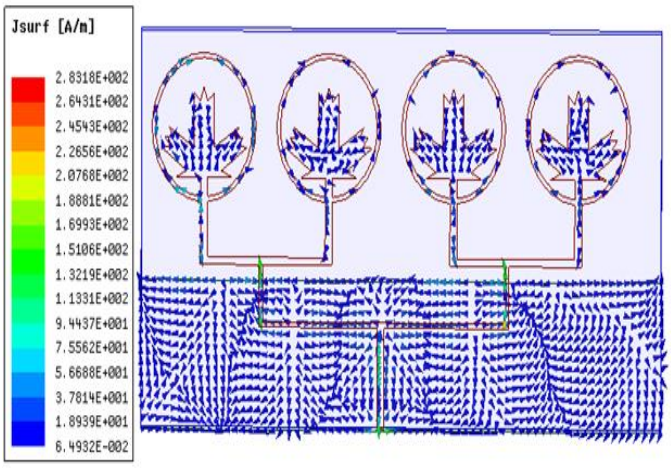


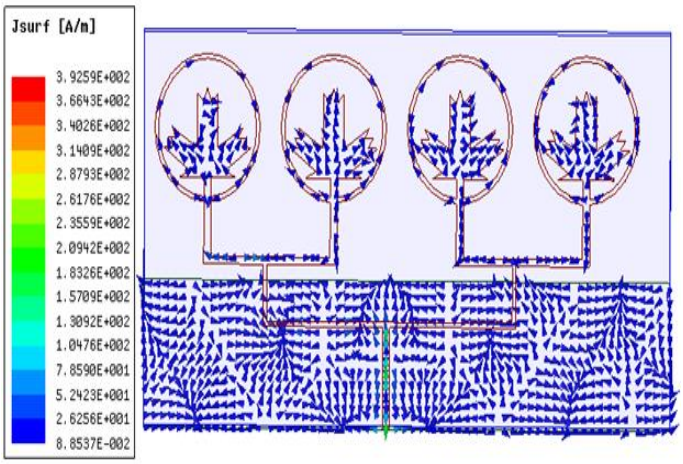
Fig. 6: Simulated results of gain and frequency.



(a) At 7.2 GHz

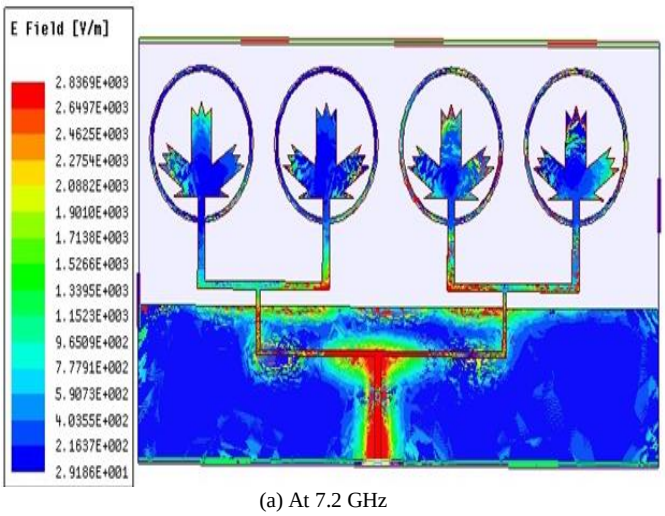


(b) At 12.6 GHz

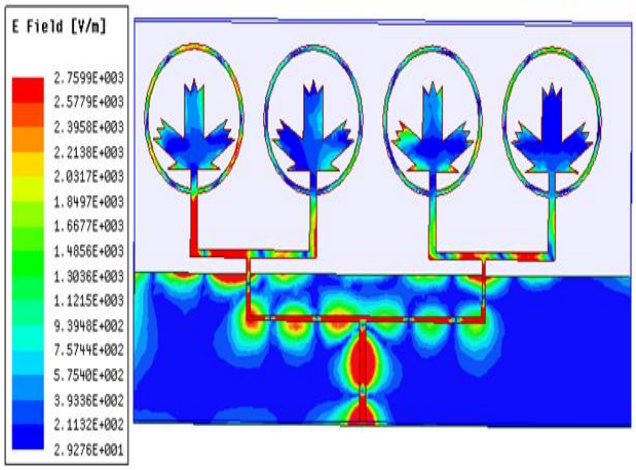


(c) At 15.2 GHz

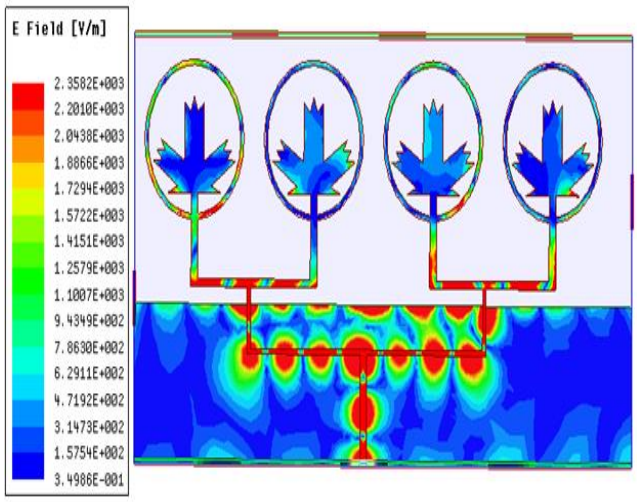
Fig. 7: Current distributions at respective frequency.



(a) At 7.2 GHz



(b) At 12.6 GHz



(c) At 15.2 GHz

Fig. 8: E field distributions at respective frequency.

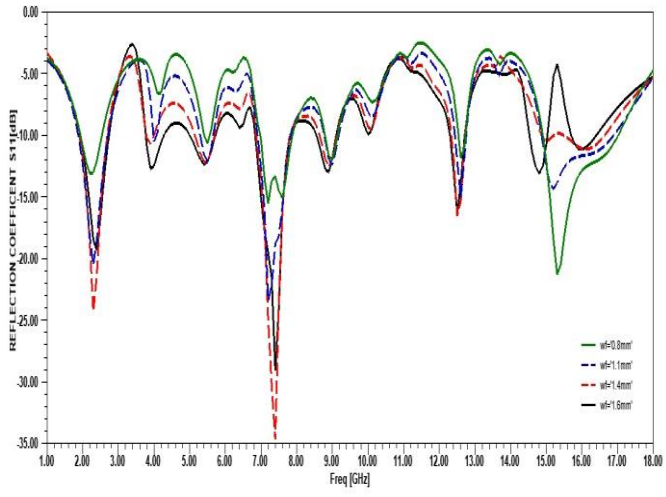


Fig. 9: parametric study when varying the width of the feed.

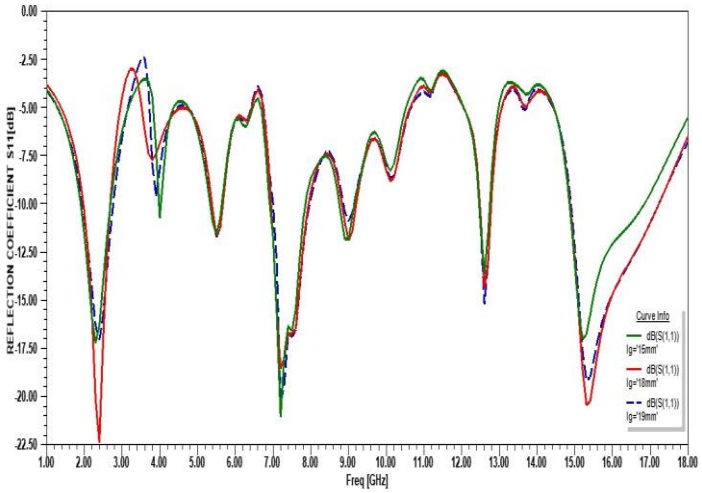


Fig. 10: parametric study when varying the length of the ground.

4. Conclusion

The single maple leaf shaped antenna is suitable for LTE 2500 applications and the peak gain is 1.99 dB and later it is converted into 1x4 array antenna which is suitable for LTE 2300, LTE 2500, lower WLAN, upper WLAN, and Military applications and the peak gain is 7.8 dB. The four-element antenna is analyzed using HFSS tool and it shows that by increasing the radiating elements the improved characteristics has been noticed in antenna parameters especially in Gain 1.99dB-7. 8dB.The proposed antenna has many applications in the ultrawideband region. The analyzed results shown good agreement for bandwidth and gain enhancements

Acknowledgement

The authors deeply express their gratitude to ALRC Research Centre, Department of ECE, K L University for their encouragement during this work. Further, we express our gratitude to DST through ECR/2016/000569, FIST SR/FST/ETI-316/2012 and EEQ/2016/000604

References

[1] Cai, Yang, et al. "Electrically Large Resonant Cavity Loaded with Negative Metamaterials." IEEE Antennas and Wireless Propagation Letters, Vol 15, 2016, pp 294-297.

[2] B. T. P. Madhav, T. Venkateswara Rao and T. Anilkumar, "Design of 4-element printed array antenna for ultra-wideband applications," International Journal of Microwave and Optical Technology, vol. 13, no. 1, pp. 8-17, Jan. 2018.

[3] B.T.P. Madhav, V.G.K.M. Pisipati, Habibulla Khan, V.G.N.S. Prasad, K. Praveen Kumar, K.V.L. Bhavani and P.V. Datta Prasad, "Microstrip 2x2 Square Patch Array Antenna on K15 Liquid Crystal Substrate", International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 6, Number 9 (2011) pp. 1099-1104.

[4] B T P Madhav, J Sowjanya, V Swathi, P Tanmayee, Circular Array Antenna Synthesis based on Element Spacing, International Journal of Applied Engineering Research, ISSN 0973-4562, Volume 9, Number 20, Sep-2014, pp. 6959-6965.

[5] D S Ramkiran, Nimmagadda Haritha, R Sree Ramya, Kalyani M. Vindhya, Sai P Abhishek, Design and analysis of microstrip slot array antenna configuration for bandwidth enhancement, Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, Issue 25, July-December 2014, pp 72-83.

[6] Sri Jaya Lakshmi, Habibulla Khan, Design and analysis of high gain array antenna for wireless communication applications, Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, Issue 26, January-June 2015, pp 89-102.

[7] M L S N S Lakshmi, Habibulla Khan, Novel Sequential Rotated 2x2 Array Notched Circular Patch Antenna, Journal of Engineering Science and Technology Review, ISSN: 1791-2377, Vol 8, issue 4, Dec-2015, pp 73-77.

[8] Midasala, V. and Siddaiah, P., 2016. Microstrip Patch Antenna Array Design To Improve Better Gains. *Procedia Computer Science*, *85*, pp.401-409.

[9] Bhavanam, S.N. and Kalyan, R.S., 2016. Design of a novel coaxial feed triple frequency patch antenna with slots and shorting pin. *Procedia Computer Science*, *85*, pp.345-351.

[10] Bhavanam, S.N. and Narayana, B.L., 2015. Design & Simulation of Tripple Frequency Triangular Patch Antenna by Using HFSS 14.0. *International Journal of Applied Engineering Research*, *10*(20), pp.1087-1090.

[11] Sekhar, M., Bhavanam, S.N. and Siddaiah, P., 2014, December. Triple frequency circular patch antenna. In *Computational Intelligence and Computing Research (ICCIC), 2014 IEEE International Conference on* (pp. 1-3). IEEE.

[12] Ali, M., Jalil, Q. and Bhavanam, S.N., 2015. Verification of GPS Data Using REB-4216 Card During Satellite Communication System. *International Journal of Applied Engineering Research*, *10*(17), pp.1087-1090.

[13] S.S. Mohan Reddy, P Mallikarjuna Rao, Enhancement of CPW-Fed Inverted L-Shaped UWB Antenna Performance Characteristics using Partial Substrate Removal Technique, 3rd International Conference on Signal Processing and Integrated Networks (SPIN-2016), 978-1-4673-9197-9/16/$31.00 ©2016 IEEE, pp 454-459

[14] B.T.P.Madhav, P. Syam Sundar, K. Sarat Kumar, A.N.V.Kishore, Ankit Kumar Jain, "Liquid Crystal Polymer Dual Band Pan Slot Antenna", Wireless and Optical Communications Networks (WOCN), Aug-22-24. 978-1-4673-1989-8/12/$31.00 ©2012 IEEE. Pp 1-5.

[15] B T P Madhav, Jayasree Gogineni, Harini Appana, Jyothi Prathusha Chennam, Durga Sai Sruthi Thota, Priyanka Kotte, "Analysis of Compact Coplanar Waveguide Fed Slot Antenna with EBG Structure", Spaces-2015, IEEE, pp 219-225.