Design and Analysis of Non-Uniformly Spaced Dipole Array Antenna

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Abstract: *Dipole antenna array is designed at operating frequency of 450MHz using FR4 substrate. Uniform circularly polarized (UCP) and non-uniform circularly polarized (NUCP) dipole arrays are designed. NUCP array is achieved by placing antenna elements at unequal distance from the reference element. Low side lobe level is necessary to reduce interference with other frequencies in the band which is achieved in case of NUCP array compared UCP array. The simulation is carried out using EM flow solver HFSS. The simulation results indicate that there is a reduction in the side lobe level for the 1x7 NUCP array as compared to UCP array. To enhance the gain of the dipole array dielectric lens is used as the secondary radiator which also acts as a radome to protect the array. The maximum gain achieved is 1.59dB with lens. Return loss less than -15dB is achieved in all cases. Axial ratio less than 3dB achieved for circular polarized arrays. The designed NUCP array with lens can be used in SAR (synthetic aperture radar) applications.*

Keywords: **UCP, NUCP, Circular polarization, Axial ratio, Return loss, SAR.**

1. INTRODUCTION

In the area of communication systems, whenever the requirement of wireless communication arises, there occurs the necessity of an antenna. Antenna is the connection between radio waves propagating through space and electric currents propagating through transmission lines. In order to improve the performance of the system, antenna arrays are designed. Dipole antenna is most widely used antenna because of its small size, ease of construction and high power efficiency. One of the factors that need to be considered when designing an antenna is polarization. Antennas are sensitive to the polarization if the polarization of antenna does not match the signal, then the signal level decreases correspondingly. Circular polarization eliminates the need to align antenna modules.

Uniform linear arrays exhibit high side lobe level in the radiation pattern which causes interference of the signals which degrades the performance of the array. One of the methods to reduce side lobe levels in Circular Polarized array is by using non-uniform configuration which reduces the side lobe level compared to uniform configuration. In order to enhance the gain of the antenna arrays, hemispheroidal dielectric lens antenna is employed. Dielectric lenses are easy to fabricate, cost effective, have low dimensional tolerance and are suitable for wide frequency ranges, microwave frequency and steering applications.

2. CP & NUCP DIPOLE ANTENNA ARRAY DESIGN

The dipole antenna structure is designed at 450MHz resonant frequency using FR4 substrate of thickness 1.6mm with dielectric constant of 4.4 and loss tangent of 0.02 is shown in Figure 1. The simulated HFSS results of Return loss=-21.98dB, Gain=2.19dB and Axial ratio=96.72dB is obtained as shown in Figure 2, 3 and 4 respectively.
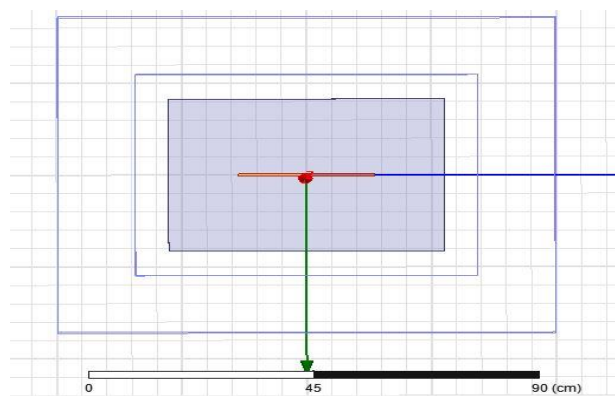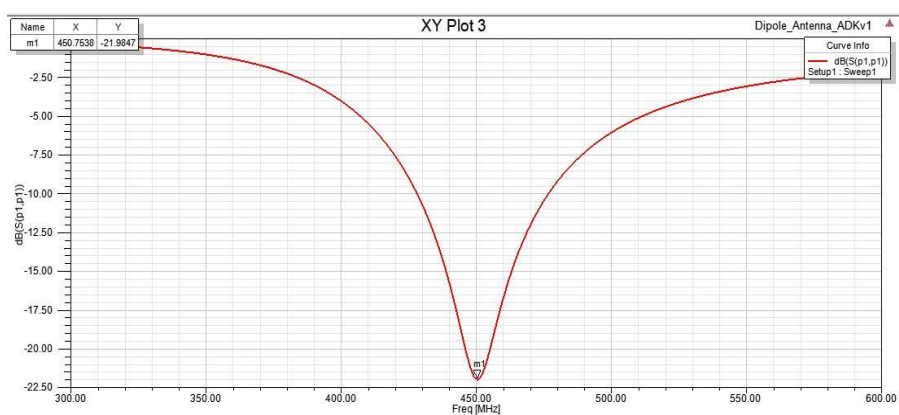
Figure 1. Dipole antenna

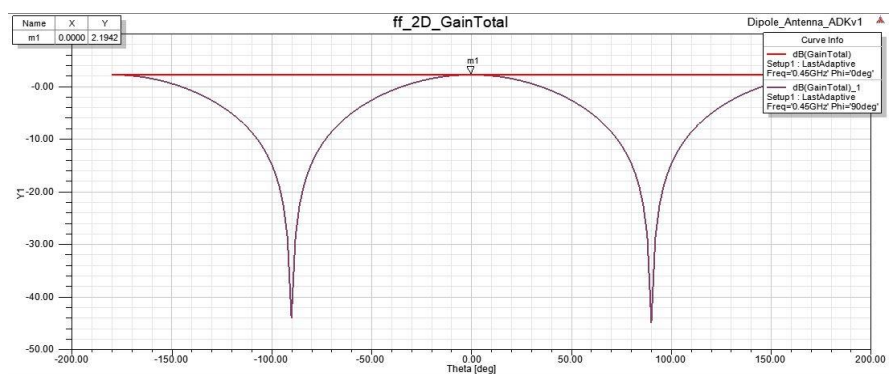**Figure 2. Return loss of dipole antenna**

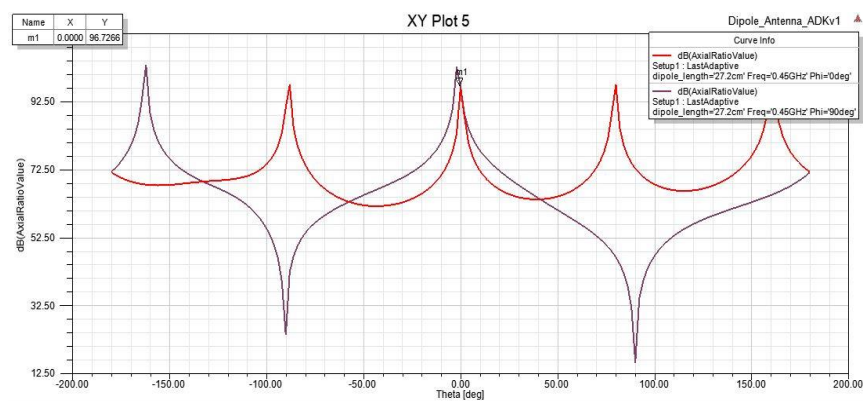**Figure 3. Radiation pattern of dipole antenna**

Figure 4. Axial ratio of dipole antenna

2.1. 1x4 UCP and NUCP Dipole Array Design

Dipole antenna operates in linear polarization. CP is achieved by arranging four dipoles on same substrate which is referred as unit cell. 1x4 UCP array is designed by placing unit cells at a distance d=λ/7 is shown in Figure 5. Return loss of -15.79dB return loss, gain of 11.32dB and axial ratio of 0.54dB is obtained. 1x4 NUCP is designed by placing unit cells at a distance of d, 2d and 3d as shown in Figure 6. Return loss of -15.76dB, Gain value of 11.81dB and AR of 0.37dB is obtained. Normalized radiation pattern of UCP and NUCP array is shown in Figure 7. The SLL for UCP array is -13.69dB and for NUCP array is -12.89dB. It is observed that the SLL for NUCP array is more than UCP array.
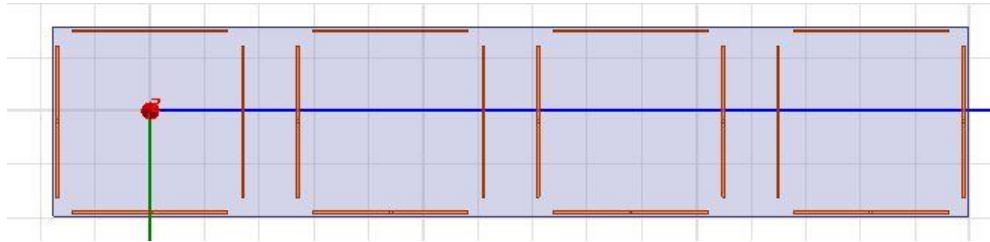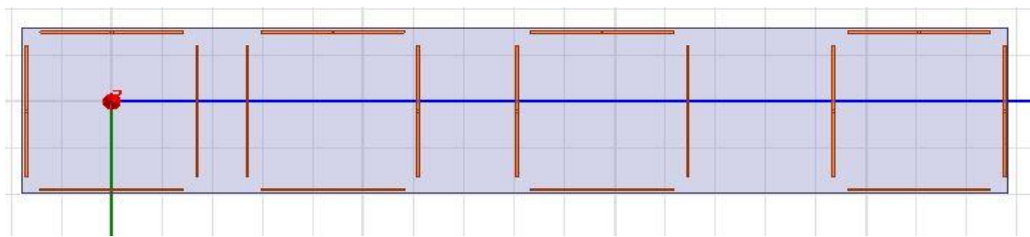

Figure 5. 1x4 UCP dipole array

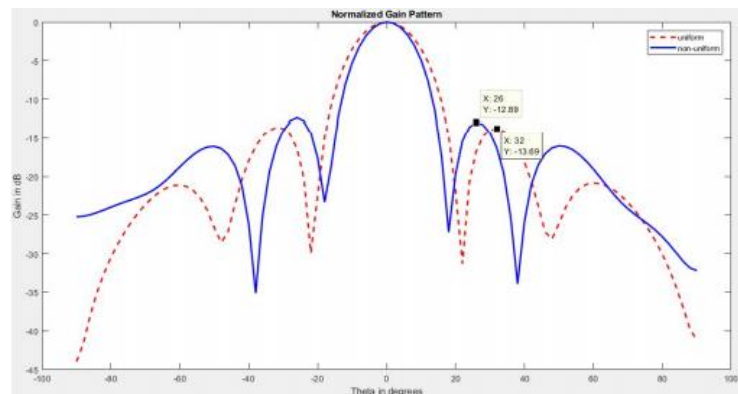**Figure 6. 1x4 NUCP dipole array**

Figure 7. Normalized radiation pattern of 1x4 UCP and NUCP dipole array

2.2. 1x7 UCP and NUCP Dipole Array Design

1x7 UCP array is designed by placing unit cells at a distance d=λ/7 is shown in Figure 8. Return loss of -16.19dB return loss, gain of 13.48dB and axial ratio of 0.60dB is obtained. 1x7 NUCP is designed by placing unit cells at a distance of d, 2d and 3d as shown in Figure 9. Return loss of -16.21dB, Gain value of 13.97dB and AR of 0.57dB is obtained. Normalized radiation pattern of UCP and NUCP array is shown in Figure 10. The SLL for UCP array is -13.54dB and for NUCP array is -15.18dB. It is observed that the SLL for NUCP array is less than UCP array.
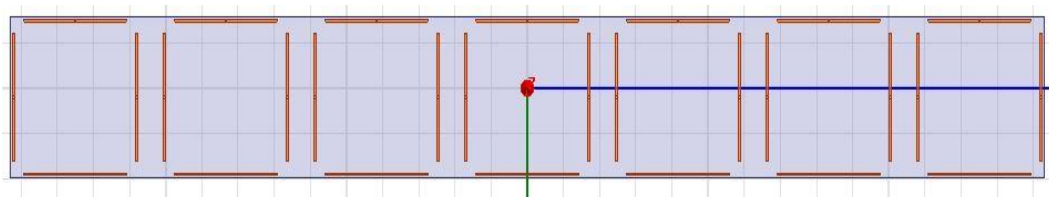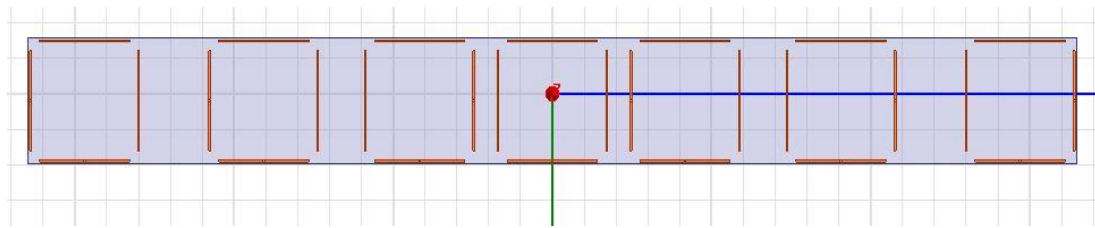

Figure 8. 1x7 UCP dipole array
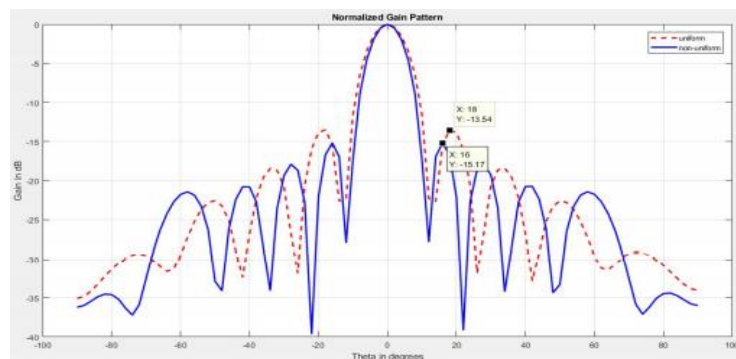
Figure 9. 1x7 NUCP dipole array

Figure 10. Normalized radiation pattern of 1x7 UCP and NUCP dipole array

2.3. 1x4 UCP and NUCP array with lens

1x4 UCP array is designed along with hemispheroidal lens of polypropylene material with dielectric constant 2.2 and loss tangent 0.002 as shown in Figure 11. The dimensions of lens is 320cmx80cm (Major axis x Minor axis) placed at an optimized distance of 4cm from array. 1x4 NUCP array along with lens is shown in Figure 12. The dimension of lens is 400cmx100cm placed at an optimized distance of 10cm. The gain enhancement of 1.52dB and 1.59dB is respectively observed in 1x4 UCP and NUCP array with lens as shown in Figure 13 and 14.
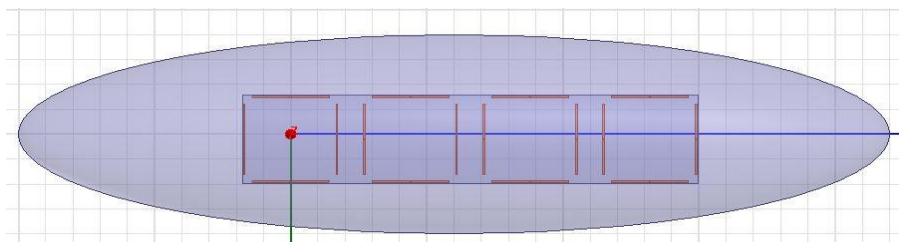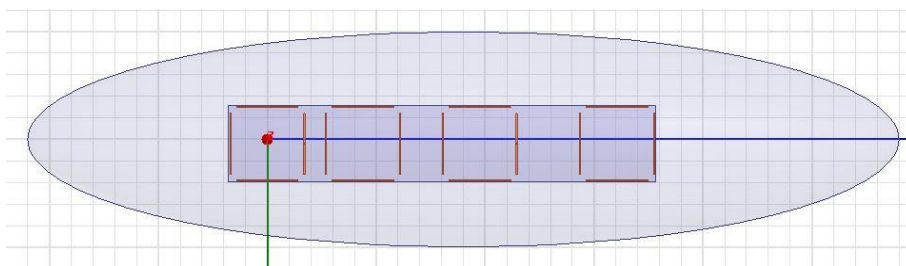

Figure 11. 1x4 UCP array with lens

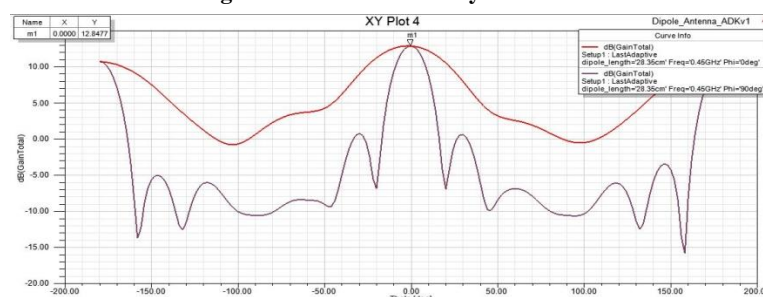**Figure 12. 1x4 NUCP array with lens**

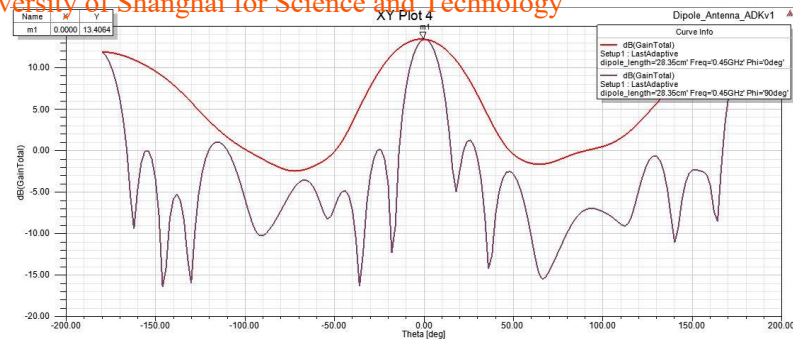**Figure 13. Gain of 1x4 UCP array with lens**

Figure 14. Gain of 1x5 NUCP array with lens

2.4. 1x7 UCP an NUCP array with lens

1x7 UCP array is designed along with hemispheroidal dielectric lens as shown in Figure 15. The dimensions of lens is 400cmx100cm (Major axis x Minor axis) placed at an optimized distance of 4cm from array. 1x7 NUCP array along with lens is shown in Figure 16. The dimension of lens is 500cmx100cm placed at an optimized distance of 10cm. The gain enhancement of 1.04dB and 1.5dB is respectively observed in 1x4 UCP and NUCP array with lens as shown in Figure 17 and 18.
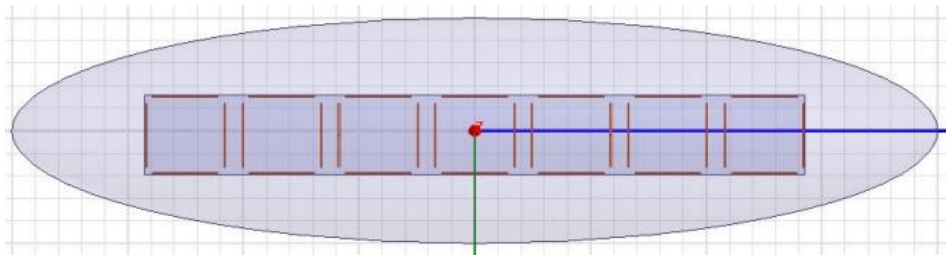
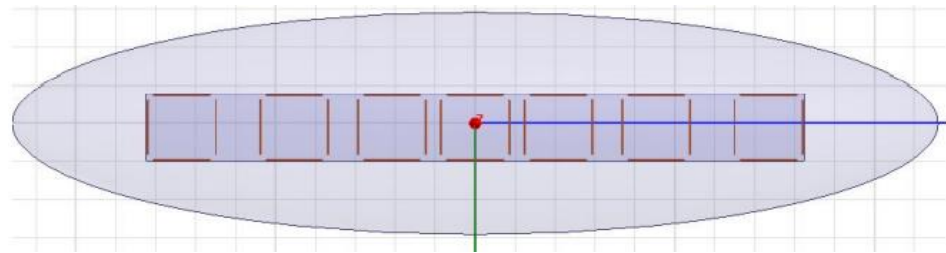

Figure 15. 1x7 UCP array with lens

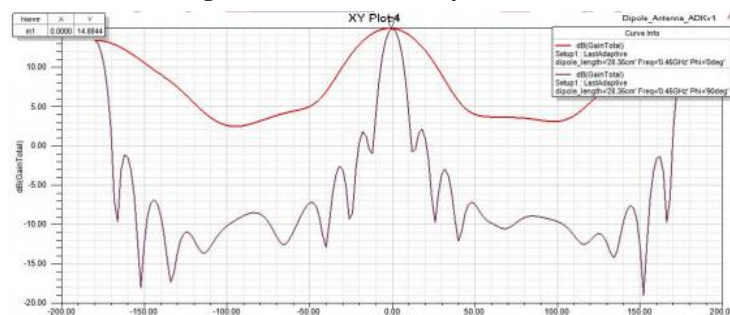**Figure 16. 1x7 NUCP array with lens**

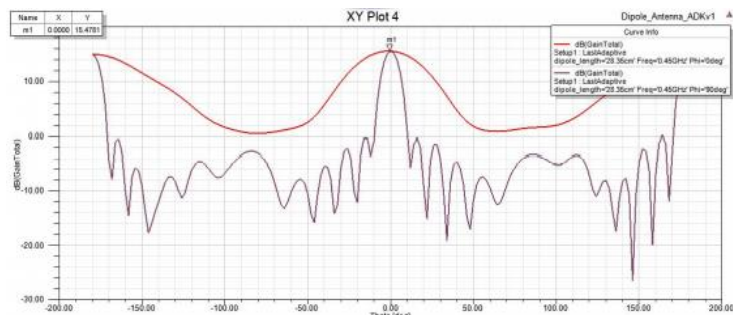**Figure 17. Gain of 1x7 UCP array with lens**

Figure 18. Gain of 1x7 NUCP array with lens

The results for gain with and without lens for all cases are tabulated in Table 1.The maximum gain enhancement of 1.59dB is observed with lens in case of 1x4 NUCP array. The beam steering employed for the designed dipole array for SAR applications. The Figure 18, 19, 20 and 21 respectively shows beam steering plots for 1x7 UCP, NUCP, UCP with lens and NUCP with lens. It is observed from the simulation results, the maximum scan angle possible is $\pm 30^0$ without deteriorating the radiation pattern and gain.

Table 1. Comparison of gain without and with lens

Array structures	Gain without lens (dB)	Gain with lens (dB)
1x4 UCP array	11.32	12.84
1x4 NUCP array	11.81	13.40
1x7 UCP array	13.48	14.88
1x7 NUCP array	13.97	15.47
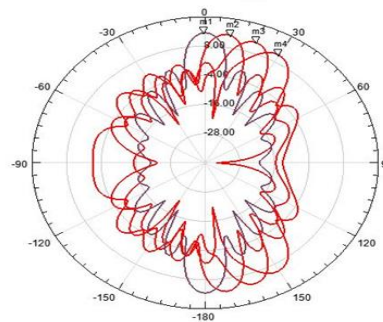
Figure 18. Beam steering of 1x7 UCP array
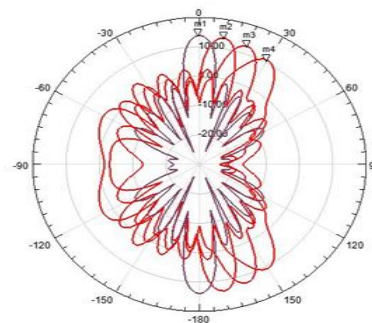
Figure 19. Beam steering of 1x7 NUCP array

Figure 20. Beam steering of 1x7 UCP array with lens

Figure 21. Beam steering of 1x7 NUCP array with lens

3. CONCLUSION

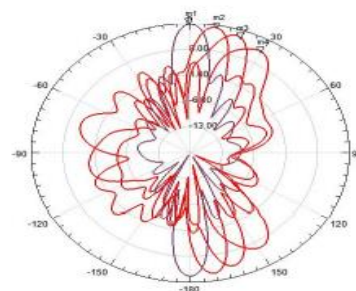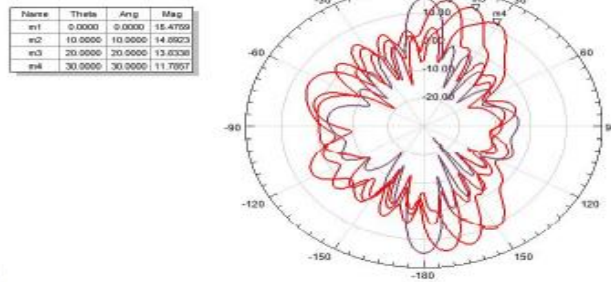The design of 1x4 and 1x7 UCP and NUCP dipole arrays is presented. The arrays are designed and simulated using HFSS software. From simulation results it is observed that the sidelobe level of 1x7 NUCP array is less compared to 1x4 NUCP array. The array gain is enhanced by using a dielectric lens of hemispheroidal shape. The low loss dielectric material Polypropylene is used for the lens. The maximum gain enhancement of 1.59dB is observed with lens in case of 1x4 NUCP array. The arrays have the capability to scan the beam till $\pm30^0$ by retaining the shape of the pattern with minimal gain reduction. The same effect is observed with lens also. The designed NUCP array with lens is used for SAR applications.

ACKNOWLEDGEMENT

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