Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
International Conference on Communication Technology (ICCT 2015) – www.caeaccess.org

C- Shaped Microstrip Reflectarray Antenna with Microstrip Antenna Feed

Amit A. Deshmukh
Professor and Head, EXTC
DJSCE
Vile Parle, Mumbai, India

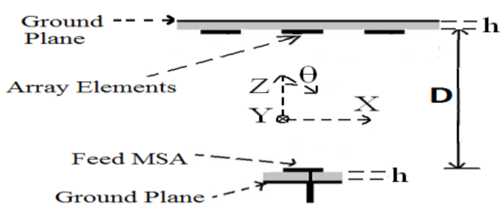
Kshitij Lele, Ami A.Desai, Saleha A.Shaikh, Sudesh Agrawal
PG Student, EXTC, DJSCE
Vile Parle, Mumbai, India

ABSTRACT
In order to reduce the size of regularly shaped microstrip antennas, compact variations are used. Ring shaped microstrip reflectarrays have been discussed previously. Four different configurations, namely 1 × 3, 3 × 1, plus-shaped and 3 × 3 were discussed. An optimum gain of 10.8 dBi and a beamwidth of 22.7˚ was obtained for the 3 × 3 configuration. Another variation of the compact microstrip reflectarray, the C-shaped reflectarray, has been presented in this paper. Similar to the ring-shaped microstrip reflectarray, the C-shaped reflectarray gives an optimum gain of 7.93 dBi and a beamwidth of 18.5˚ for the 3 × 3 configuration.

Keywords
Microstrip Reflectarray Antenna, C- Shaped Reflectarrays, Ring Shaped Reflectarrays.

1. INTRODUCTION
High gain antennas are usually realized by using parabolic reflectors [1]. However their size is large due to the curved reflecting surfaces. Instead of using a parabolic reflector, a printed array having flat surface can be used, along with a supporting structure, that reduces the size [1]. These microstrip line-fed microstrip antenna (MSA) arrays are planar but are inefficient due the feed-line losses that reduce the gain and results in spurious radiation which increases cross-polar levels. Recently, horn-fed reflectarray antennas have been reported but they are also bulky in nature [2, 3]. A printed reflectarray antenna consists of a thin reflecting surface with an array of printed elements and the feed antenna. The patches are illuminated by the feed element. The incident fields are re-radiated by the patches forming a uniform phase front. The microstrip reflectarray (MRA) combines the features of both, the printed array as well as the parabolic reflector [4, 5]. The path length between the feed and the center patch is shorter than that between the feed and the parasitic patches. In order to compensate for the difference in path lengths, MRAs with variable size patches are reported in [6]. The parasitic elements are detuned from the resonance frequency due to the changing lengths of the patches. Patches with stubs of variable lengths can also be used to compensate for the phase difference [7]. For many applications like personal mobile communications and miniaturized communication systems the size of the MSA needs to be small. The size of a regularly shaped MSA operating in the Ultra High Frequency (UHF) band is quite large because its resonant length is inversely proportional to frequency. To design a smaller or a compact antenna at these frequencies, conventional MSA configurations need to be modified [8]. Compact antennas can be designed by cutting slots inside the patch. C- shaped, H- shaped and ring shaped compact antennas are designed by cutting rectangular slots within the patch. These compact MSAs are smaller in size as compared to regular rectangular MSAs. Usually compact RMSAs have a low gain, but when used in an array the resultant gain could be sufficient. Hence, a MRA with an array of compact g shaped RMSAs was proposed in [9]. 1 × 3, 3 × 1, plus-shaped and 3 × 3 configurations were designed and fabricated. A narrow beamwidth of around 22.7° was obtained for the 3 × 3 configuration and an optimum gain of around 10.7 dBi for the plus-shaped and 3 × 3 configurations. These results are found to be better than those for compact ring-shaped broadband stacked MSAs reported in [10] where an optimum gain of 7.6 dBi is achieved. In this paper, the compact C- shaped MRA, which is a variation of ring shaped MRA, has been discussed. The same configurations, as discussed in [10], namely 1 x 3, 3 x 1, plus-shaped and 3 x 3 have been discussed. An optimum beamwidth of 18.5˚ and a gain of 7.93 dBi has been obtained for the 3 x 3 configuration. These antennas have been first analyzed using the IE3D software [11] followed by experimental verification. During measurements, fed and array patches were fabricated on Taconic substrate (ε_r = 3.2, h = 1.6 mm, tan δ = 0.001). The impedance measurements were carried out using vector network analyzer (ZVH – 8). The pattern and gain measurements were carried out using RF source (SMB 100A) and spectrum analyzer (FSC 6). The pattern and gain was measured in minimum reflecting surroundings with required minimum far-field distance between reference antenna and the MRA.

2. RING SHAPED REFLECTARRAYS:
Ring shaped reflectarrays have been discussed in [9]. A ring-shaped patch is obtained by cutting a rectangular slot inside the patch. Different ring shaped reflectarray configurations, namely 1 x 3, 3 x 1, plus-shaped and 3 x 3. The 3 x 3 configuration yields optimum results. The VSWR BW of the ring shaped MRA is around 170 MHz. Its gain is around 10.8 dBi over the entire BW and a beamwidth of around 23˚. Fig 1(a, b) show the side and top view of a ring shaped MRA. The simulated and measured input impedance plot for this



configuration is shown in Fig 1(c).

Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
International Conference on Communication Technology (ICCT 2015) – www.caeaccess.org

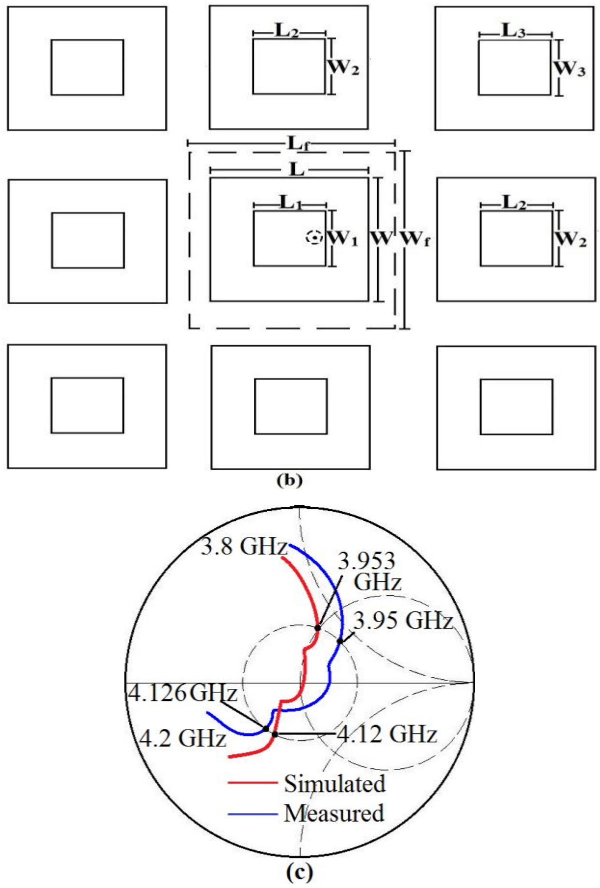


Fig 1: (a) Side view and (b) top view of compact ring shaped 3 x 3 MRA and its (c) simulated and measured input impedance plots.

Table 1 summarizes the results for all configurations discussed in [9]. It is observed that the 1 x 3 and 3 x 1 configurations have a lower gain as compared to the plus shaped and 3 x 3 configurations. Also, the beamwidth in the 1 x 3 MRA is narrower in the E- plane whereas in the 3 x 1 MRA the beamwidth is narrower in the H-plane. This is because there are more patches along the x-axis along which the E- plane is directed in the 1 x 3 MRA. The same is observed for the 3 x 1 MRA in which there are more number of elements along the y-axis along which the H- plane is directed.

Table 1. Beamwidths of all the configurations of the compact MRA in the E and H- plane.

Configuration	Beamwidth		Gain (dBi)	Bandwidth (MHz)
	E-plane	H-plane		
1 × 3	23.7°	24.3°	9.05	164
3 × 1	24.5°	23.9°	9.15	165
Plus	23.4°	23.2°	10.6	168
3 × 3	22.7°	22.8°	10.8	170

3. C- SHAPED REFLECTARRAYS:

A single patch consisting of a regular RMSA is used as the feed patch, as shown in Fig 3 (a). The proposed MRA is designed in the 4 GHz band, hence the feed RMSA dimensions are calculated such that it operates around this frequency in its TM_{10} and TM_{01} modes. The array patches are compact C-shaped MSAs. The center patch dimensions are L=15.55 mm and W=19 mm. The slot dimensions of the array patch directly above the feed patch are L_1 = 10.5 mm and W_1= 6 mm. The feed patch dimension are calculated to be L_f = 19.55 mm, W_f = 25 cm. To minimize the aperture blockage, a smaller finite ground plane of dimension: Length L_g = 30 mm and width W_g = 35 mm, is selected. The effect of variation of distance 'D' on gain, directivity, efficiency, and beam widths for different configurations has been studied in [6]. The maximum gain and directivity is obtained for D = $7\lambda_0/2$. Hence, the optimum D for these configurations is taken as $7\lambda_0/2$ = 262.5 mm. The path length between the feed and the center patch is shorter than that between the feed and the parasitic patches. In order to compensate for this phase difference between adjacent patches, the slot dimensions have been varied. This causes detuning of the resonant frequencies and ensures that the reflected waves are in phase with one another.

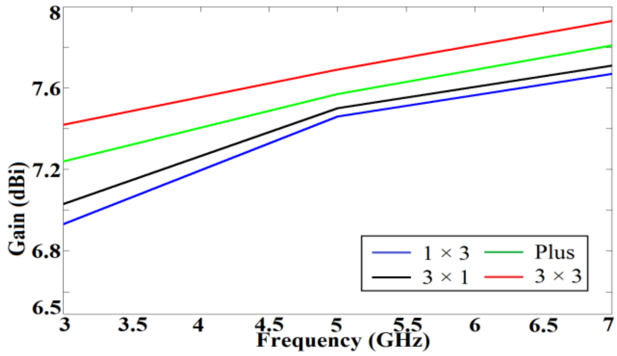
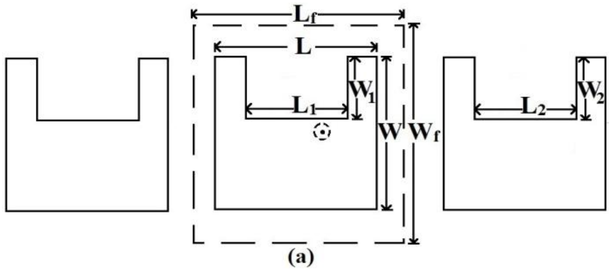


Fig 2: Plot showing comparison of gain for varying 'D'

The 1 x 3 C-shaped MRA is shown in Fig 3 (a). The slot dimensions of the adjacent patches are L_2 = 9.5 mm and W_2 = 6.5 mm. The simulated and measured input impedance plots for this configuration are shown in Fig 3 (b). It can be observed from these plots that a simulated and measured bandwidth of 140 and 125 MHz respectively, is obtained. The simulated and measured radiation pattern plots in the E and H plane are shown in Fig 3 (c, d). A beamwidth of 19.7 and 20.1 is obtained in the E and H- planes respectively. For the 1 x 3 configuration the beamwidth is narrower in the E plane as compared to the H plane as there are more number of elements along the x-axis.



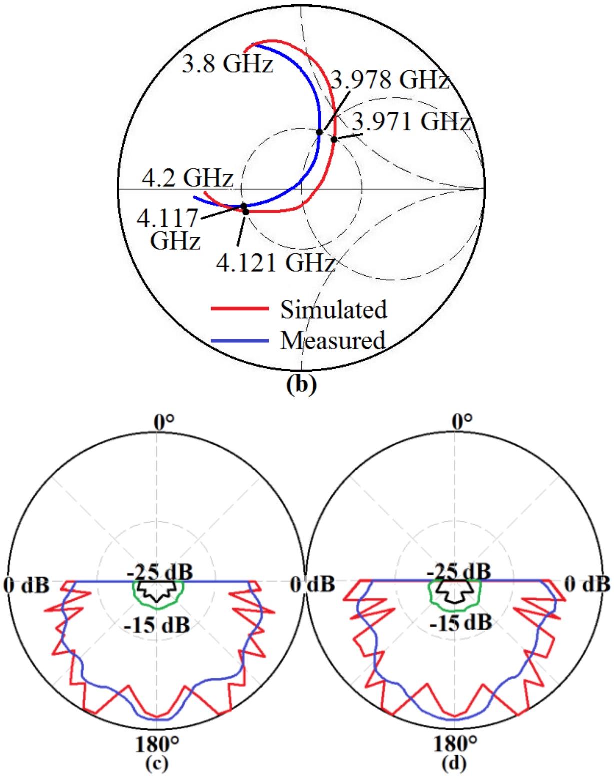


Fig 3: (a) top view of compact C- shaped 1 x 3 MRA, its (b) simulated and measured input impedance plots and radiation pattern plots in the (c) E and (d) H- plane at 4 GHz.

The 3 x 1 C-shaped MRA is shown in Fig 4 (a) and the simulated and measured input impedance plots for are shown in Fig 4 (b). A simulated and measured bandwidth of 137 and 121 MHz respectively is obtained. Fig 4 (c, d) show the simulated and measured radiation pattern plots in the E and H plane. A beamwidth of 19.6 and 19.9 is obtained in the E and H- planes respectively. For this configuration the beamwidth is narrower in the H- plane as compared to the E- plane as there are more number of elements along the x-axis.

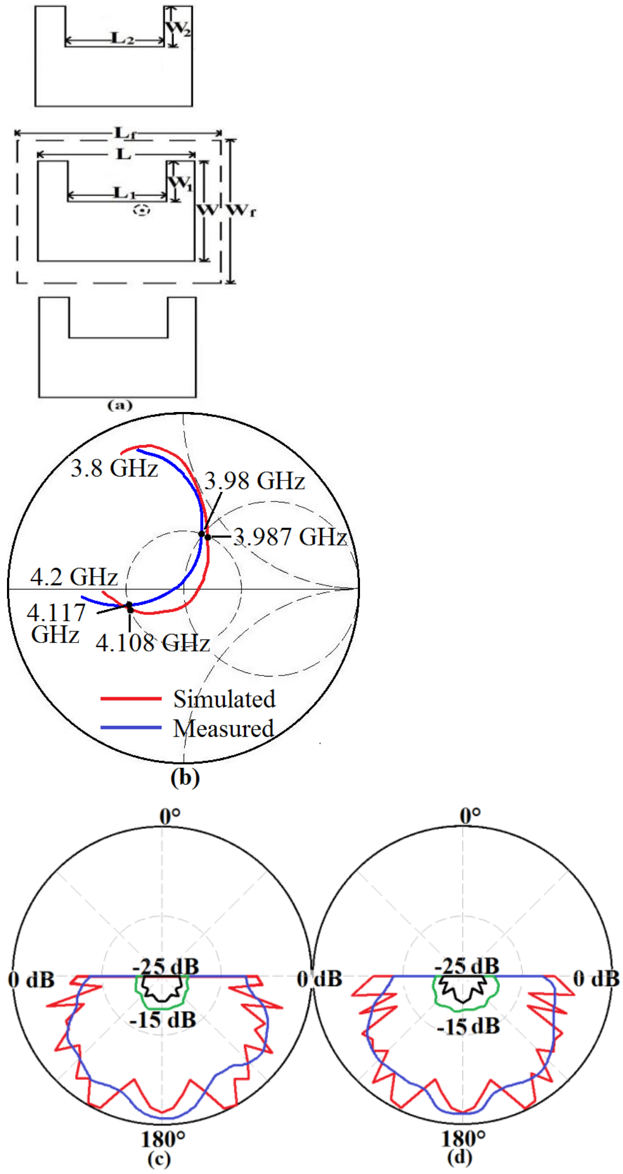


Fig 4: (a) Top view of compact C- shaped 3 x 1 MRA, its (b) simulated and measured input impedance plots and radiation pattern plots in the (c) E and (d) H- plane at 4 GHz.

The plus-shaped configuration of the C-shaped MRA is shown in Fig 5 (a) and the slot dimensions of the adjacent patches is the same as the that taken for the 1 x 3 and 3 x 1 configurations as their distance from the center patch is the same .The simulated and measured input impedance plots for are shown in Fig 5 (b). A simulated and measured bandwidth of 150 and 135 MHz respectively is obtained. Fig 5 (c, d) shows the simulated and measured radiation pattern plots in the E and H plane. A beamwidth of 18.9 and 18.8 is obtained in the E and H- planes respectively. For this configuration the beamwidth is the same in both planes as the number of elements along both the x and y-axis is the same. The plus-shaped configuration has a peak gain of 7.81 dBi. The gain for this configuration is more as compared to the 1 x 3 and 3 x 1 as the effective area of the MRA increases.

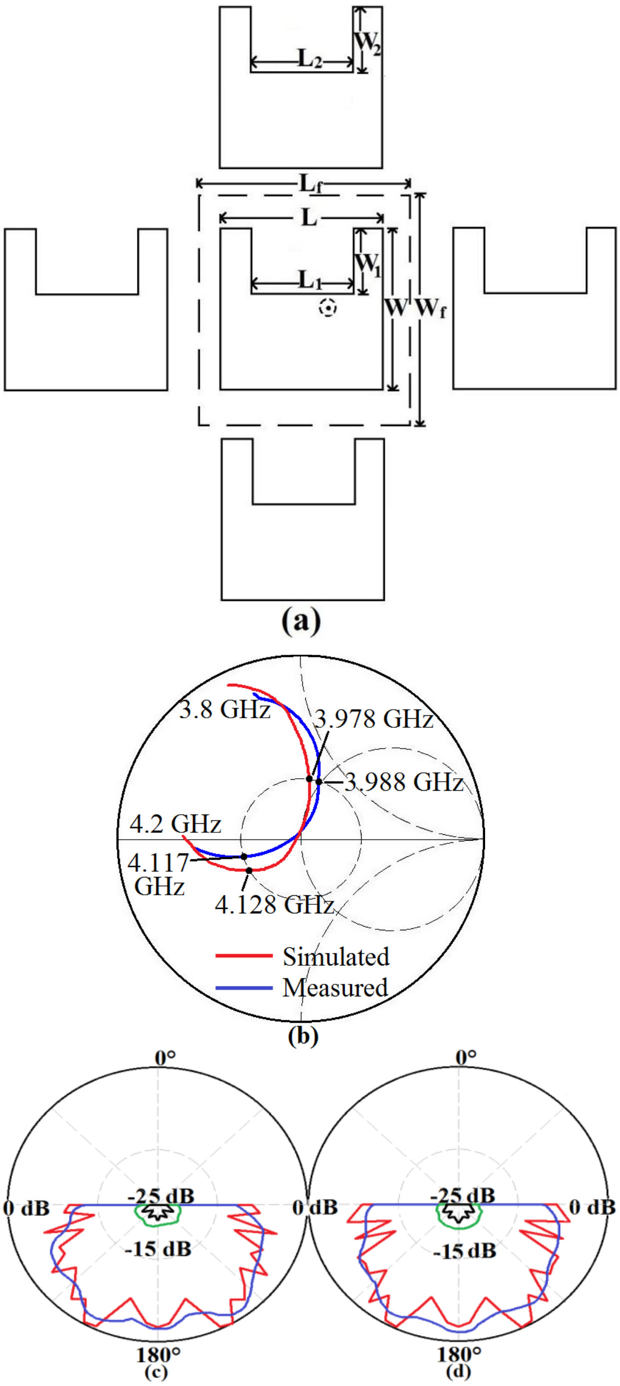


Fig 5: (a) Top view of compact C- shaped plus MRA, its (b) simulated and measured input impedance plots and radiation pattern plots in the (c) E and (d) H- plane at 4 GHz.

The 3 x 3 configuration of the C-shaped MRA is shown in Fig 6 (a) and the simulated and measured input impedance plots for are shown in Fig 6 (b). A simulated and measured bandwidth of 161 and 143 MHz respectively is obtained. Fig 18.5 and 18.6 shows the simulated and measured radiation pattern plots in the E and H plane. A beamwidth of 150 and 143 is obtained in the E and H- planes respectively. For this configuration the beamwidth is the same in both planes. The beamwidth is narrower as compared to the plus-shaped configuration as the total number of elements are more. This configuration has a peak gain of 7.93 dBi. The gain for this configuration is slightly higher as compared to the plus-shaped configuration as the effective area of the MRA increases only marginally.

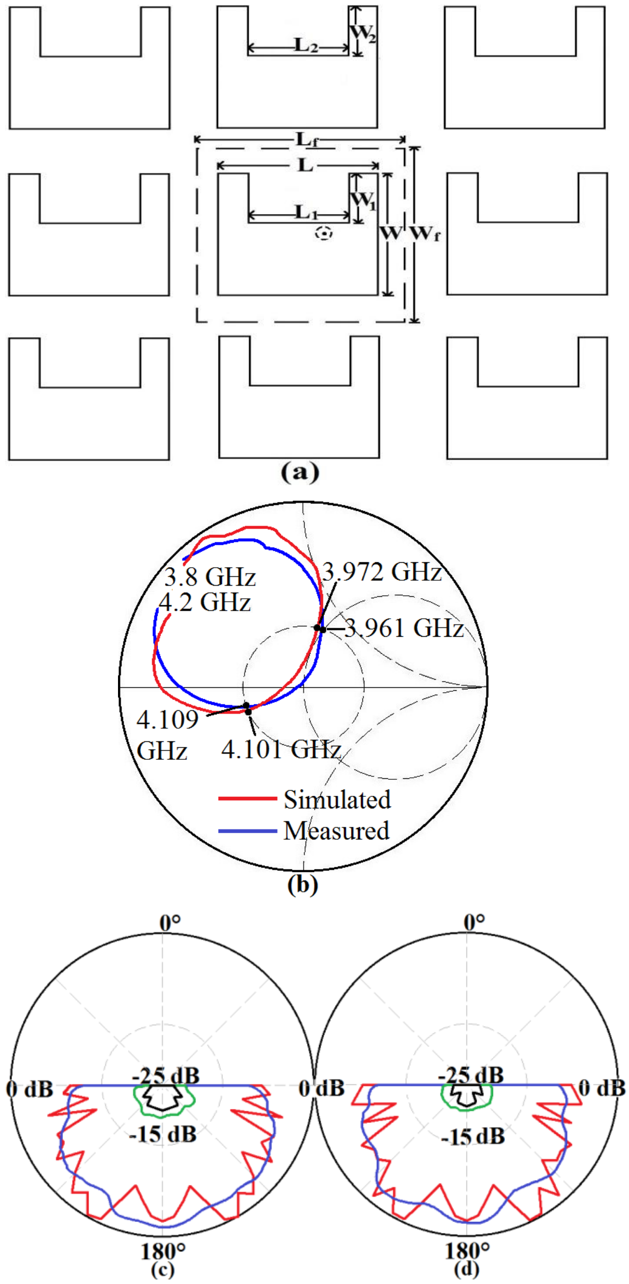


Fig 6: (a) Top view of compact C- shaped 3 x 3 MRA, its (b) simulated and measured input impedance plots and radiation pattern plots in the (c) E and (d) H- plane at 4 GHz.

Configuration	Beamwidth		Gain (dBi)	Bandwidth (Sim) (MHz)
	E-plane	H-plane		
1 × 3	19.7°	20.1°	7.65	137
3 × 1	19.6°	19.9°	7.67	140
Plus	18.9°	18.8°	7.81	150

3 × 3	18.5°	18.6°	7.93	161

4. CONCLUSIONS
The compact C- shaped MRA, which is a variation of ring shaped MRA, has been discussed. Four different configurations, namely 1 × 3, 3 × 1, plus-shaped and 3 × 3 were discussed. An optimum gain of 10.8 dBi and a beamwidth of 22.7˚ was obtained for the 3 × 3 configuration. Another variation of the compact microstrip reflectarray, the C-shaped reflectarray, has been presented in this paper. Similar to the ring-shaped microstrip reflectarray, the C-shaped reflectarray gives an optimum gain of 7.93 dBi and a beamwidth of 18.5˚ for the 3 × 3 configuration.

5. REFERENCES
[1] D M Pozar, S D Targonski, and H Syrigos, “Design of millimetre wave microstrip reflectarrays”, IEEE Trans. Antennas Propagation, Vol. AP‐ 45, no. 2, pp. 287‐ 95, Feb. 1997.

[2] J Huang, “Microstrip reflectarray”, IEEE Intem. AP-S/URSI Symp. Digest pp. 612-615, June 1991.

[3] G Berry, R G Malech, and W A Kennedy, “The reflectarray antenna”, IEEE Trans. Antennas Propagation, Vol. AP‐ 11, no. 6 pp. 645‐ 51, Nov. 1963.

[4] R D Javor, × D Wu, and K Chang, “Design and performance of a microstrip reflectarray antenna”, IEEE Trans. Antennas propagation, Vol. AP‐ 43, no. 9, pp. 932‐ 9, Sep. 1995.

[5] D M Pozar, and T A Metzler, “Analysis of a Reflectarray Antenna Using Microstrip Patches of Variable Size”, Electronics Letters, Vol. 29, no. 8, pp. 657‐ 8, 1993.

[6] K. P. Ray, Amit A. Deshmukh and Ameya A. Kadam, “Linearly Polarized Microstrip Reflectarray with Microstrip Antenna Feed”, IETE Journal of Research, Vol. 59, Issue 4, pp. 294-301, July-August 2013.

[7] Lenin Naragani and Dr. P. Hanumantha Rao, “Stub Loaded Microstrip Reflect Array”, in ElectroMagnetic Interference and Compatibility (INCEMIC), pp. 486-9, Feb. 2006.

[8] Girish Kumar, K.P. Ray, “Broadband Microstrip Antennas”, Artech House, 2003.

[9] Amit A. Deshmukh, Kshitij Lele, S. A. Shaikh, N. V. Phatak, S. B. Nagarbowdi, A. A. Desai, S. Agrawal, “Ring Shaped Compact Microstrip Reflectarray Antenna”, Proceedings of ICCT-2015, 25th and 26th September 2015, Mumbai, India, (IJCA – ICCT-2015, No. 1, pp. 15 – 19, September 2015.

[10] A. A. Deshmukh, G. Kumar, “Compact Broadband Stacked Microstrip Antennas”, Microwave and Optical Technology Letters, Vol 48, Issue 1, January 2006.

[11] IE3D 12.1, Zeland Software, Fremont, USA, 2004.