MULTI LAYER STACKED RECTANGULAR DIELECTRIC RESONATOR ANTENNA

Richa Gupta[1], Mahender Singh[2], Arti Vaish[3] , Ankit Gaur[4]
E-Mail Id: richaguptamsit@gmail.com[1], msingh5500@gmail.com[2]
[1,4] Maharaja Surajmal Institute of Technology, GGSIPU, Delhi, India
[2]Guru Tegh Bahadur Institute of Technology, Delhi, India
[3]School of Engineering and Technology, Ansal University Haryana, India

Abstract: This paper present a design of stacked rectangular dielectric resonator antenna provides 52.57 degree beam width and gain 6.9 dBi which operate in 5 to 8 GHz range of frequencies by stacking of descending order of permittivity from 20 to 10 of 1.5mm height of every block. A 50 ohm microstrip line is employed in proposed antenna as feeding mechanism. A novel different beam aperture coupled DRA is proposed which consists of multi-layered rectangular geometry of ceramic disk of various dielectric constant joined to realize the specified height**.** The parameter of antenna is 15x18x1.5 mm^3 with grounded substrate size: 50x50 mm^2. The proposed antenna is suitable for C and X band application.
Keywords: Rectangular DRA, Stack, Permittivity, Beam width.

1. INTRODUCTION

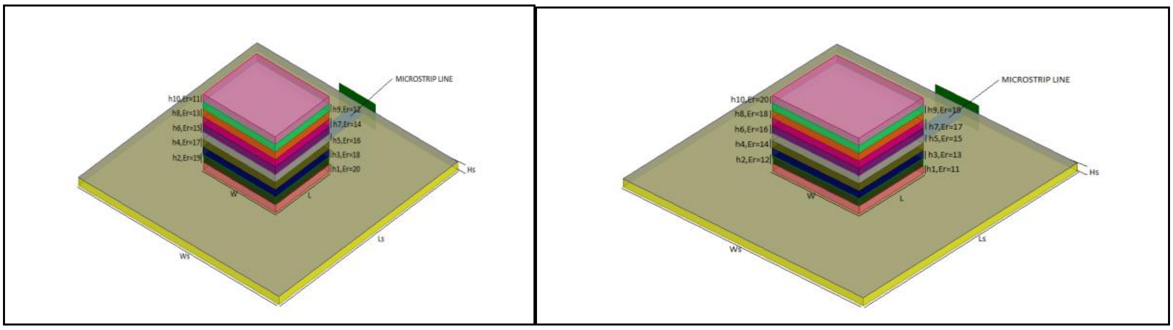
DRAs exhibit a wider impedance bandwidth and better radiation efficiency, especially at millimeter- wave frequencies where the conductor losses of metallic patches are considerable. One among the foremost crucial problems with conventional DRAs is that the dependence of their size and impedance bandwidth on the dielectric constant of material utilized in antennas. A DRA made up of a low permittivity material would have a comparatively large volume because of the inverse proportionality between effective wavelength and therefore the square root of the permittivity. It would, however, exhibit a low radiation Q-factor and thus a good impedance bandwidth[1-3]. Choice of dielectric constant of material utilized in the DRA is crucially important for wideband operation with compact design of the DRAs. Applications within the wireless and mobile communication areas require the event of radiating elements, which have as compact/low profile and wideband as possible. Hence, a great deal of research is directed towards a rise of the bandwidth of the DRAs while keeping the dimensions compact/low profile. Towards this goal, the technique of merging modes has proven to be very beneficial [4-6]. The essential concept relies on the excitation of multiple modes at nearby frequencies, in order that an overall wide impedance bandwidth will be achieved. A method is to mix the DRA modes with resonances of the feeding scheme. for example, an easy cylindrical DRA (CDRA) described in[4] is fed from a microstrip line through two parallel bowtie slots The second thanks to achieve the merging of modes is through the planning of the acceptable DRA geometry that ends up in the excitation of higher-order DRA modes[7-9] at nearby frequencies. Conceptually this technique is relatively simple, but it nevertheless comes along with an important issue, which needs to be taken into account.
The researchers are focusing on improving the gain along with getting the narrow beam and sustainable bandwidth for the satellite communication. The dielectric resonator antennas are the step forward to microstrip antennas with low metal loss, high radiation, high gain, etc. which creates the chance of more advanced antennas for different applications in satellite communication. In this paper different Rectangular stacking DRA geometries are analysed. The different dielectric constant material in increasing and decreasing order of permittivity is stacked together for improvement in gain and controlling beam-width of the antenna.

2. ANTENNA GEOMETRY

Figure 1(a) presents the geometry of a rectangular DRA using FR-4 epoxy substrate with a permittivity (εr) of 4.4.Ten rectangular layers each of height 1.5mm,making a total height of 15mm and permittivity varying in increasing order from 11,12,13,….20 is shown. The same stacked rectangular geometry is analysed in which stacking layer permittivity are varied in decreasing order from 20, 19, 10………11. All the dimensions are summarised in Table 2.1.

Table-2.1 Parametric Study of Different Geometry of DRA

Ref.	Antenna Geometry	Freq (GHz)	Feeding Technique	ε_r	Gain(dBi)	Beamwidth (degree)
[1]	Stacked cylindrical dielectric resonator antenna with meta material used as substrate.	(8.49 - 10.61 GHz)	Probe fed		12.86 dB	33.5°
[2]	Cylindrical cup	37% (7.8–11.4 GHz)	L-shaped probe	10.2	5.5	70
[3]	perforated holes cylindric al DRA	8.18 to 10.7 GHz	Probe fed			53



(a) **(b)**

Fig. 2.1(a-b) Stacking of 10 Layers of Rectangular DRA with Height 1.5mm and Permitivity Increasing from 11,12,13....,20. and Decreasing (20….11)

Table-2.2 Geometry of RDRA

	Dimensions	**Units**
Er substrate	4.4	
Substrate Dimensions	50*50*1.6	Mm
Strip Line Dimensions	31*3	Mm
Slot Size	1.568*7.84	Mm
Stub Size	5.216*3	Mm
Length	15	Mm
Width	18	Mm
Height of each stack	1.5	Mm

Stacking of DRA on top of each other increases the impedance bandwidth. The effective height of the stacked RDRAisasimplesumofslabs'height

3. MATHEMATICAL MODELLING

$$h = h_1 + h_{2+} h_3 + h_4$$

The effective permittivity (s_{eff}) of the proposed stacked RDRA is obtained as

$$\epsilon_{eff} = \frac{h}{\frac{h_1}{\epsilon_{r1}} + \frac{h_2}{\epsilon_{r2}}}$$

The frequency of rectangular DRA as follows

$$f_o = \frac{c}{2\pi\sqrt{\varepsilon_r}} \sqrt{k_x^2 + k_y^2 + k_z^2}$$

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_o^2,$$

Where, $k_x = m\frac{\pi}{a}, k_y = n\frac{\pi}{b},$ *and* $k_z \text{tag}(k_z d/2) = \sqrt{(\varepsilon r - 1)k_o^2 - k_z^2}$

4. RESULTS AND ANALYSIS

The S_{11} vs frequency response of two geometries Rectangular with 10 layers stacking as a function of frequency with increasing and decreasing permittivity levels are shown in Fig. 2.1(a-b). It can be observed that bandwidth response of proposed antenna has multiple frequency resonance. Every geometry is investigated for understanding the antenna operation. This S11 graph of Stacked 10 layer with Inc. Permittivity of 11, 12, 13...... ,20 shows that there are dips at 6.51GHz of -15.97 dB, 6.8GHz of -14.32 dB , 7.30GHz of -16.32 dB having %bandwidth 4.04%, 2.64%, 1.09%. VSWR of Stacked 10-layer Inc. Permittivity of 11, 12, 13...... , 20 RDRA is <2. This S11 graph of Stacked 10 layer with Dec. Permittivity of 11, 12, 13.... ,20 shows that there are dips at 5.54GHz of -23.88 dB, 6.93GHz of -11.13 dB, 7.83GHz of - 14.22 dB having % bandwidth 7.59%, 2.16%, 5.75%. VSWR of Stacked 10-layer Dec. Permittivity of 11, 12, 13.... , 20 RDRA is <2. Gain of Stacked 10 layer Inc. Permittivity of 11, 12, 13..... , 20 RDRA is 5.93dBi. Stacked 10 layer with Inc. Permittivity of 11, 12, 13.... , 20 RDRA has beam width i.e. 77.80 dB and having Directivity of 4.33... Stacked 10 layer with Dec. Permittivity of 11, 12, 13.... , 20 RDRA has beam width i.e. 52.57 dB and having Directivity of 5.24. All the results are summarised in table.

Table-4.1Summarised Results

	S11 (GHz)	VSWR	Z11 (ohm)	GAIN 2D(dB)	Beam Width (dB 10)	% Band-width	Centre frequency (GHz)	Directivity (mag)
10 layer rectangular Increasing Permittivity (11,12....,20) With height 1.5mm each	6.3-6.56 6.72-6.9 7.26-7.34	<2	66.09	5.93	77.80	4.04% 2.64% 1.09%	6.43 6.81 7.3	4.33
10 layer rectangular Decreasing Permittivity (11,12....,20) With height 1.5mm each	5.19-5.60 6.85-7.0 7.6-8.05	<2	58.43	6.9	52.57	7.59% 2.16% 5.75%	5.395 6.925 7.825	5.24

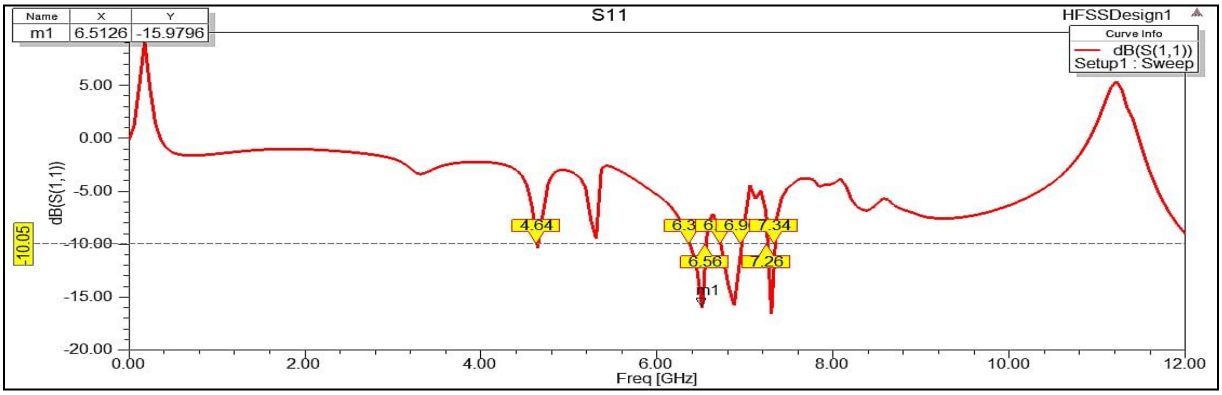


Fig. 4.1 S11 Stacked 10 layer Inc. Permittivity RDRA

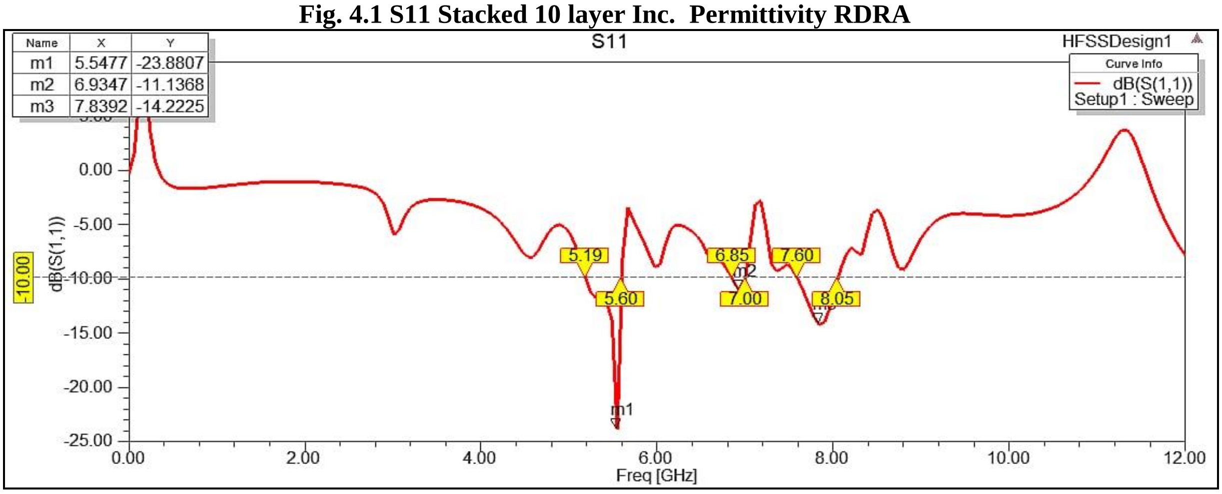


Fig. 4.2 S11 Stacked 10 layer Dec. Permittivity RDRA

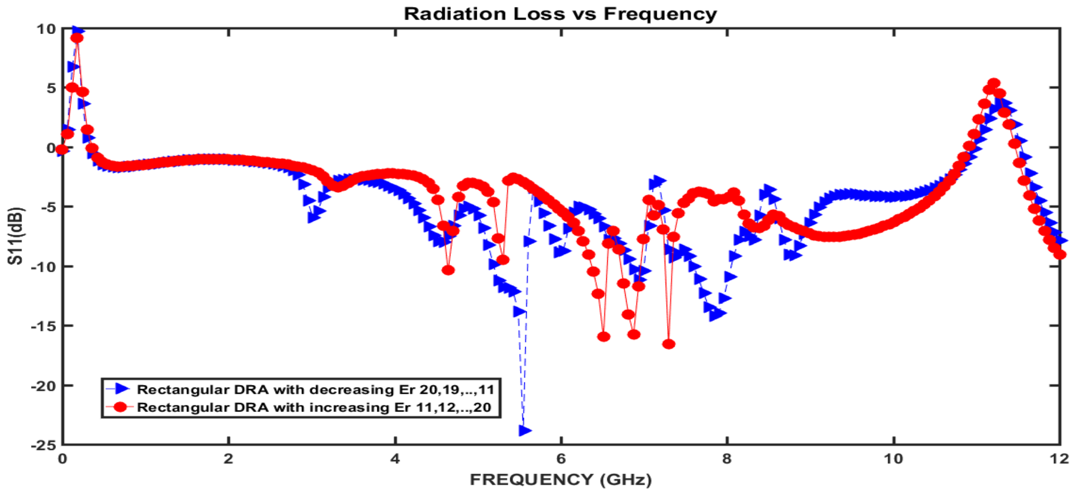


Fig. 4.3 S11 Stacked 10 layer Dec and inc. Permittivity RDRA

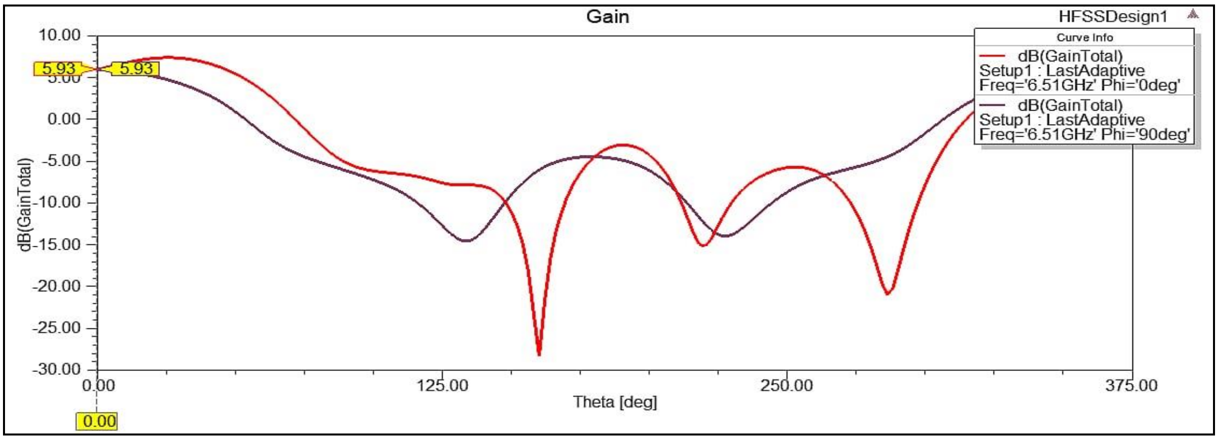


Fig. 4.4 Gain Stacked 10 Layer Inc. RDRA

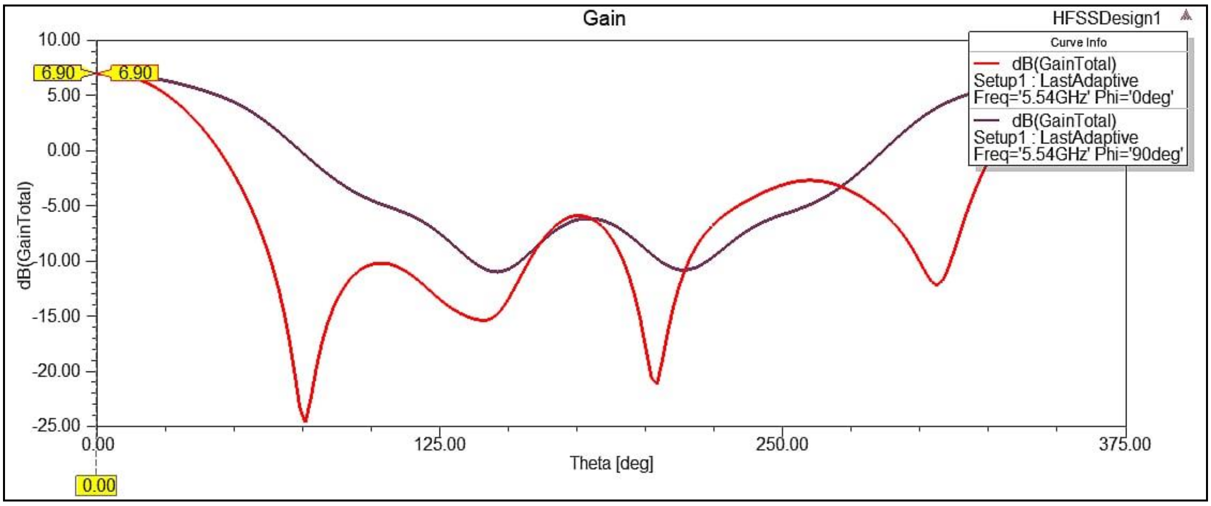


Fig. 4.5 Gain Stacked 10 Layer Decreasing Permittivity RDRA

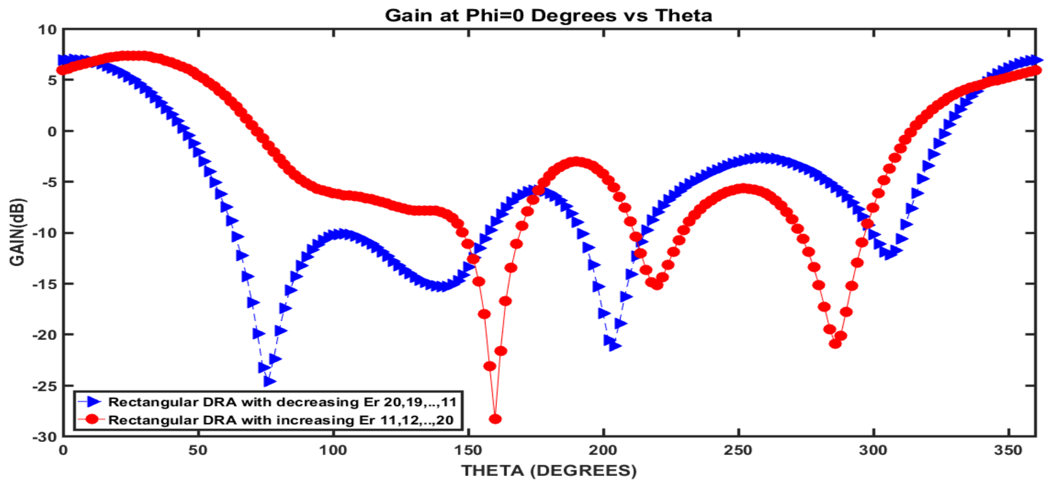


Fig. 4.6 Gain Stacked 10 Layer Dec and inc. Permittivity RDRA

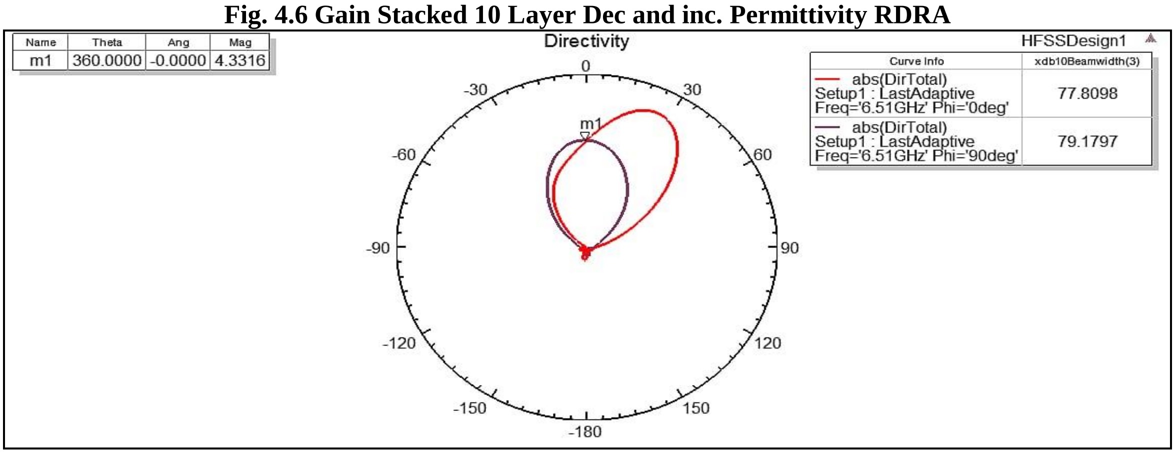


Fig. 4.7 Directivity Stacked 10 Layer Inc. RDRA

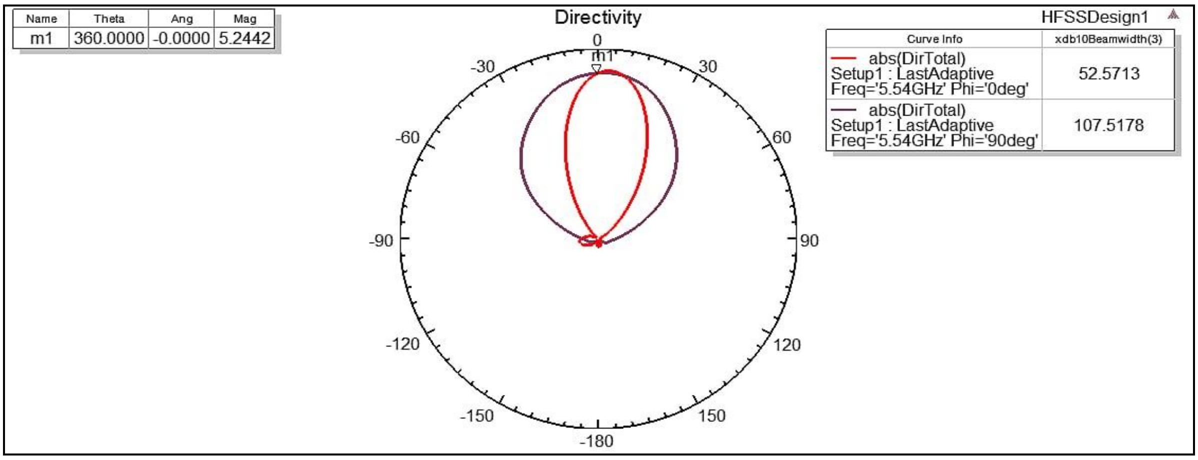


Fig. 4.8 Directivity Stacked 10 Layer Inc. RDRA

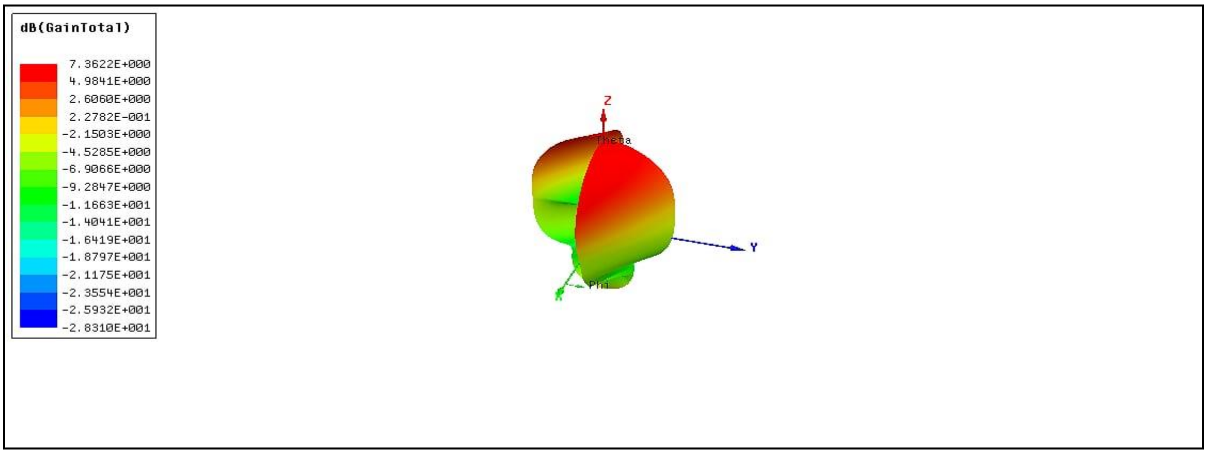


Fig. 4.9 Radiation Pattern Stacked 10 Layer Inc. RDRA

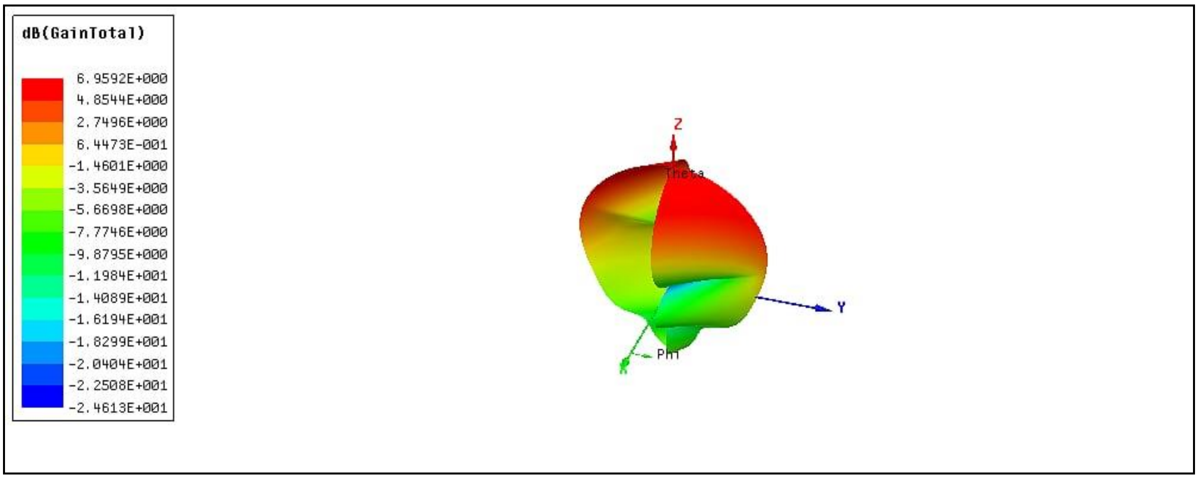


Fig. 4.10 Radiation Pattern Stacked 10 Layer dec . RDRA

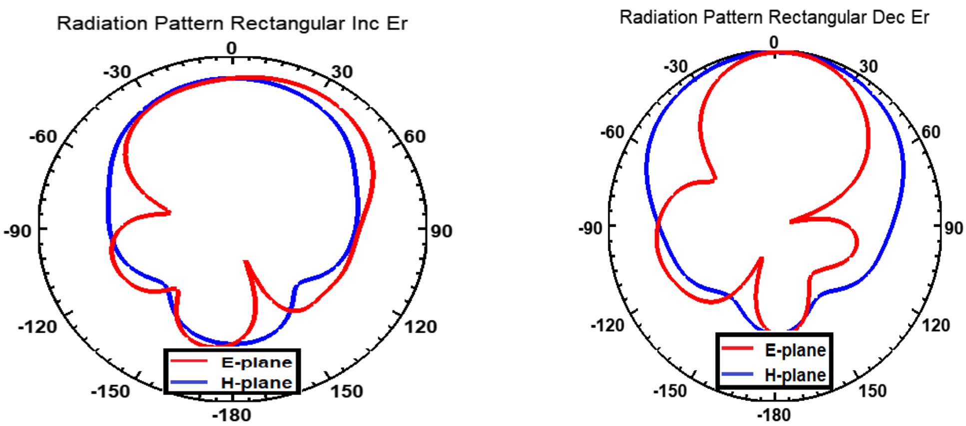


Fig. 4.11 Radiation Pattern Stacked 10 layer dec and inc RDRA

DOI Number: https://doi.org/10.30780/specialissue-ICACCG2020/005
Paper Id: IJTRS-ICACCG2020-005

CONCLUSION

A comparative analysis for various permittivity stacked geometries rectangular DRA, are presented to extend the gain of the antenna, along to form the beam more directive and hence reducing the beamwidth. 10 layers stacked rectangular geometry with decreasing permittivity presents the best gain (6.9 dBi) compared to the other geometry alongside reasonably controlled beamwidth

REFERENCES

[1] Sahu, Bhagirath, Mayank Aggarwal, PankajTripathi, and Rajesh Singh. "Stacked cylindrical dielectric resonator antenna with metamaterial as a superstrate for enhancing the bandwidth and gain." In 2013 IEEE international conference on signal processing, computing and control (ISPCC), pp. 1-4. IEEE, 2013.
[2] Kishk, Ahmed A., Ricky Chair, and Kai Fong Lee. "Broadband dielectric resonator antennas excited by L-shaped probe." IEEE Transactions on Antennas and Propagation 54, no. 8 (2006): 2182-2189.
[3] Chair, R., A. A. Kishk, and K. F. Lee. "Experimental investigation for wideband perforated dielectric resonator antenna." Electronics Letters 42, no. 3 (2006): 137-139.
[4] Almpanis G., Fumeaux C. and Vahldieck R., "Novel broadband dielectric resonator antenna fed through double-bowtieslot excitation scheme", ACES Journal, Vol. 22, No. 1, pp. 97-104, 2007.
[5] Li B., and Leung K.W., "Strip-fed rectangular dielectric resonator antennas with/without a parasitic patch", IEEE Transaction Antenna and Propagation", Vol. 41, No. 10, pp. 1390-1398, 1993.
[6] Chair R., Kishk A. A., and Lee K. F., "Wideband simple cylindrical dielectric resonator antenna", IEEE Microwave and Wireless Components Letters, Vol. 15, No. 4, pp. 241-243, 2005.
[7] R. Gupta, R. Yaduvanshi "Embedded cylindrical magneto-hydrodynamic antenna", International Journal of Ultra-wideband Communication, Inderscience , vol. 3, no. 2, pp. 68-72 , 2015. ISSN online: 1758-7298.
[8] R. Gupta, R. Yaduvanshi "High gain and wide band Rectangular DRA, International Journal of Ultra-wideband Communication", Inderscience, vol. 3, no. 2, pp. 107-114, 2015. ISSN online: 1758-7298.
[9] R. Gupta and R. Yaduvanshi, "Superstrate Embedded Hybrid MHD Antenna" in IEEE International Conference INDICON-2015 ,pp 1-5, 2015, ISBN 978-1-4673-6540-6.