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DESIGN AND IMPLEMENTATION OF LOG PERIODIC MICROSTRIP PATCH ANTENNA WITHOUT AND WITH DEFECTED GROUND SYSTEM

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Abstract:This paper consists of two objectives.Inthe First objective the design and implementation of LPMPA array suitable for two bands namely 9.3-12.1GHz and 12.4-14.17GHz.The 2nd objective consists of design and implementation of modified LPMPA array by employing DGS technique to eliminate the notch band frequency i.e. (12.12 to 12.40GHz) without reducing the performance characteristics. The proposed two antennas are simulated, fabricated and the performance characteristics are evaluated, the same are presented at the end.

Key words: Defected Ground Structure (DGS),Microstrip patch antenna

1. Introduction

The Microstrip antenna has an advantage over printed circuit technologies in terms of retaining surface or creating a narrow protrusion from the surface.Therefore they are used in satellite and radar communication, as well as in the medical field[1-3].Microstrip antenna is reportedly limited by its narrow strip frequency band and inability to function at high wave guide power levels.The microstrip antenna is frequently employed because of its small size and inexpensive manufacturing, however its drawback is its limited bandwidth. To overcome this, log periodic structure is used for making wideband and for improving its gain and radiation performance characteristics.Defected ground structure is etched in the ground of the planar transmission line which distributes the current distribution in the ground plane. It causes the change in the transmission line characteristics such as increase of capacitance and inductance [4]. The defected ground structure is the intentional defect which is introduced in the ground plane. It has a resonating nature and has different structures, frequency response and circuit parameters. The defect in the ground will interrupt the shielding current distribution and influence current flow of the antenna[5-8]. The defected ground structure shows the characteristics of high impedance and slow-wave effect.

2.Design of Log periodic microstrip patch antenna

In this work, log periodic rectangular MPA array with 7 elements has been considered and designed using the series microstrip line feed network. This LPMPA array has been excited by periodic branched microstrip feed line for attaining better coupling of energy between the elements and the feed line. Moreover, this feed line is capable of precise amplitude control for high frequency application. The characteristics are decided by three salient parameters namely scale factor, spacing factor and number of patches.

As the dimensions of each patch element is varied in a log periodic manner from one end to another, dimensions of larger patch are amenable to scaling when multiplied by τ.The array has same electrical characteristics at all frequencies which are related to τ. On multiplication by τ, scaling yields patch of n+1 becoming n and patch n becoming n-1.
The design principle for log periodic antenna requires scaling of dimensions for period to period so that performance is periodic with the logarithm of frequency. This principle can be applied to an array of patch antennas [9]. The patch length (L), the width (w) and spacing (s) are related to the scale factor (τ).

$$\tau = \frac{L_n}{L_n+1} = \frac{W_n}{W_n+1} = \frac{S_n}{S_n+1} \qquad (1.1)$$

If we multiply all the dimensions of the array by τ it scales into itself with element n becomes element n+1, element n+1 becomes n+2 and so on. The self-scaling property implies that the array will have the same radiating properties at all frequencies that are related by a factor of τ.
The various parameters of rectangular patch antenna are given as

$$f_r=\frac{c}{2(L+2\Delta L)\sqrt{\epsilon_{eff}}} \qquad (1.2)$$

Where, C is the velocity of light

$$\Delta L = 0.412h\,\frac{(\epsilon_{eff}+0.3)\left[\frac{W}{h}+0.264\right]}{(\epsilon_{eff}-0.3)\left[\frac{W}{h}+0.8\right]} \qquad (1.3)$$

$$\epsilon_{eff}=\left[\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\,\frac{1}{1+\left(\frac{12h}{w}\right)^{1/2}}\right] \qquad (1.4)$$

For microstrip antenna the choice of the width of the patch radiator is very important. Small values of (W) result in low antenna efficiencies. The optimum value of W is given by

$$w = \frac{\lambda_0}{2}\left[\frac{\epsilon_r+1}{2}\right]^{-1/2} \qquad (1.5)$$

Regarding bandwidth of the array, the governing equation is

$$B_o = \frac{f_H}{f_L} \qquad (1.6)$$

Where f_H and f_L are the highest and lowest resonant frequencies.
For log periodic case, the desirable bandwidth B_d has to be more than B_0. This bandwidth is given in equation (1.7) and (1.8)

$$B_d = B_0 B_r \qquad (1.7)$$

$$B_d = B0\,[1.1+7.7\,(1-\tau)^2 cot\alpha] \qquad (1.8)$$

Where B_r is the active region bandwidth of log periodic antenna.
For LPMPA array with series fed microstrip line, the dimension of largest resonators are linked to the lowest resonant frequency whereas the dimension of smallest resonators are related to the highest frequency as shown by the equations (1.9) and (1.10)given below

$$L_{max}= K1\,\lambda_{max} \qquad (1.9)$$

$$\lambda_{max} = \frac{c}{f_{min}\sqrt{\epsilon_r}} \qquad (1.10)$$

Where λ_{max} is the wavelength corresponding to the lowest frequency f_{min} , C is the velocty of light and ϵ_r is the relative permittivity of the dielectric resonator.The width of the patch element is represented by the following equation.

$$W = 0.8 * L \quad (1.11)$$

It is imperative to note that

$$W < s \leq \tau.L \quad (1.12)$$

Using the above equations (1.11) and (1.12) spacing between the adjacent resonators may be found. As the τ value for this design is 0.96 (<1), the dimensions of other dielectric elements may becalculated from the equations (1.1),(1.2) and those are tabulated in table 1. Table 2 shows the geometric parameters of the LP rectangular MPA antenna with and without DGS.

Table 1-Design Dimensions of log periodic MPA array Antenna

Patches(largest to Smallest)	L(mm)	W(mm)	S(mm)
Patch1	9.63	7.67	11.3
Patch2	10.03	7.99	10.848
Patch3	10.45	8.32	10.414
Patch4	10.88	8.67	9.99
Patch5	11.33	9.03	9.599
Patch6	11.81	9.41	9.213
Patch7	12.3	9.8	--

Table 2- Geometric parameters of LPMP array without and with DGS

Parameter	Dimension in mm
length of the substrate (L_s)	80mm
Width of the substrate (w_s)	50mm
Height of the substrate(h)	1.6mm
length of the ground	74mm
width of the ground	70mm
feed line width	2.5mm
width of DGS	7.5mm
length of DGS	2mm

The design of a Log periodic micro strip patch antenna array without DGS in Fig 1.A LPMPA array with dimensions of 80mm×50mm×1.6mm with seven similar parch elements is presented in Fig 2. The FR4 substrate is chosen as a dielectric constant with ε_r as 4.4. Table 1.2 shows the dimensions of the substrate and ground plane. Microstrip feed line is employed on this antenna model as shown in Fig.1 and Fig 2 .The fabricated prototypes of LPMPA array without and with DGS are presented in Fig.3 and Fig.4.

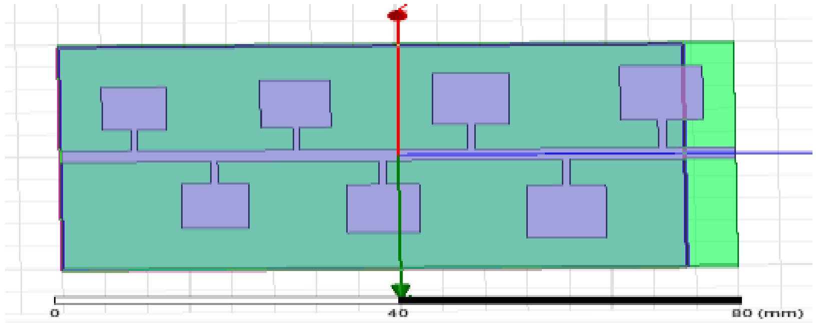


Fig.1. Simulation design of 7-element Log periodic Micro strip patch antenna array without DGS

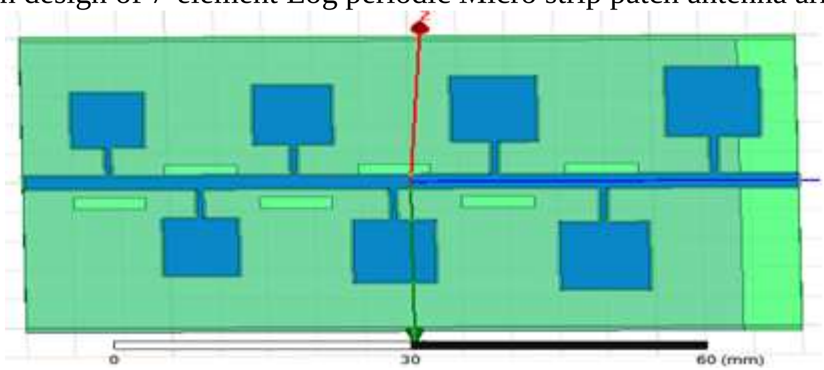


Fig.2. Simulation design of 7-element Log periodic Micro strip patch antenna array with DGS

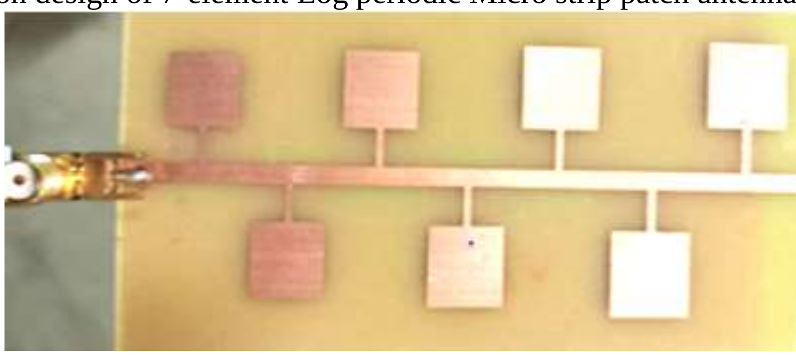


Fig 3. Fabricated prototype of 7-element Log periodic Microstrip patch antenna array without DGS

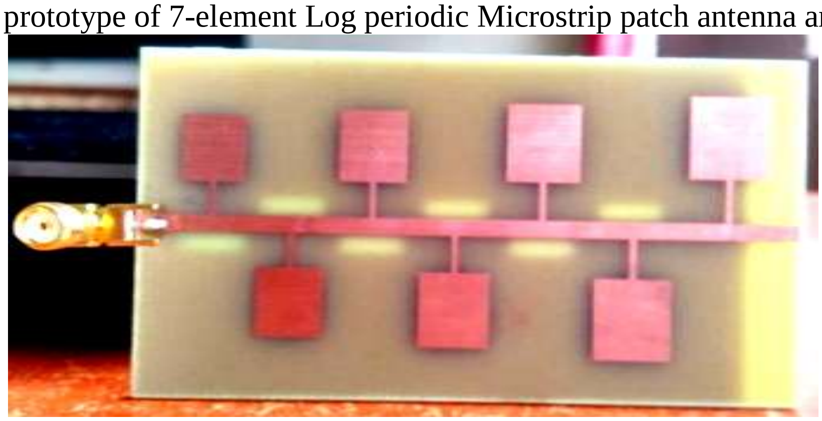


Fig 4. Fabricated design of 7-element Log periodic Microstrip Patch Antenna array with DGS

The substrate, ground, and patch dimensions of the Log periodic Micro strip patch antenna array without DGS are the same as the above models discussed Fig 3. Additionally, the DGS technique is employed on the ground plane to log periodic micro strip antenna array with DGS model. A set of six DGS slots are employed between the micro strip patch elements. The dimensions of DGS slots are 2mm×7.5mm. A total of 6 rectangular slots are subtracted from the ground to enhance the electrical path length and to improve the radiation characteristics. They are aimed to reduce the mutual coupling between the patch elements and enhance the gain. The fabricated proto type Log periodic Micro strip patch antenna array with DGS model is presented in Fig 4.

3. Results and Discussion

The simulation and experimental results are reported and compared for two antenna array models in Table 3. The performance characteristics for both the models are evaluated and presented in the following figures shown below.

CASE-1: Log Periodic Micro strip patch antenna array without DGS

The simulated and measured Return loss vs frequency, VSWR vs Frequency and Gain vs Frequency plots of Log Periodic Micro strip patch antenna array without DGS are shown in fig 5, 6, and 7. It shows that the design antenna model resonate at 11.24 GHz with return loss value of -26.34dB, VSWR of 1.124 and the maximum gain is reported as 5.9dB.The simulated 2D and 3D radiation pattern of LPMPA without DGS is shown fig.8 and 9.Fig 10 shows the current distribution of the Log periodic MPA array antenna without DGS.

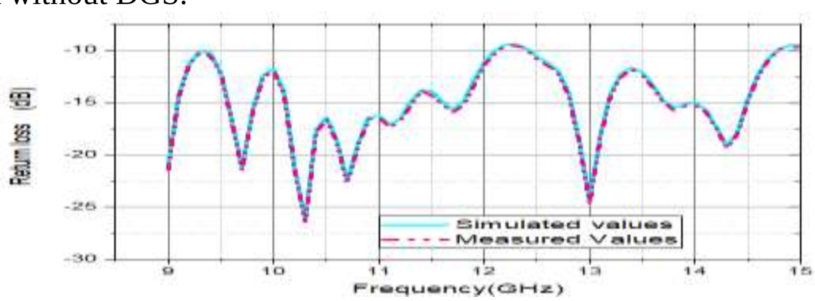


Fig.5. Return loss plot of 7-element Log periodic MPA array without DGS

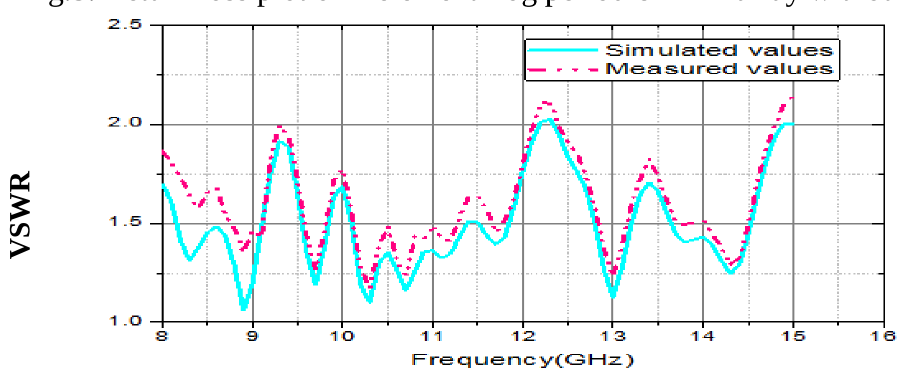


Fig 6. VSWR plot of7-element Log periodic MPA array without DGS

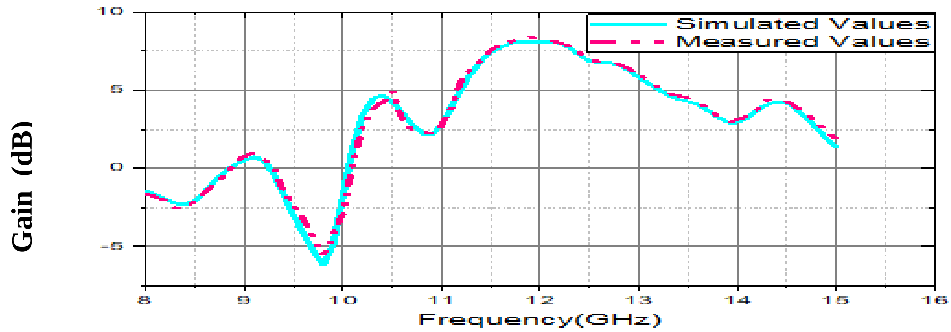
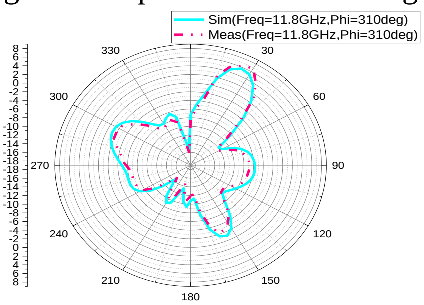


Fig 7. Gain plot of 7-element Log periodic MPA array without DGS



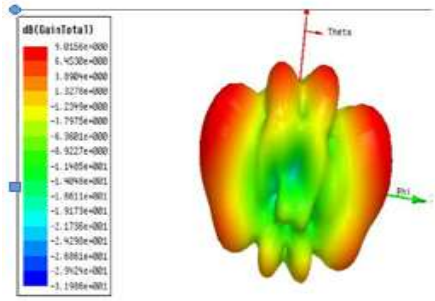


Fig 8. Radiation plot of Log periodic MPA array without DGS

Fig 9.3D polar plot of Log periodic MPA array without DGS

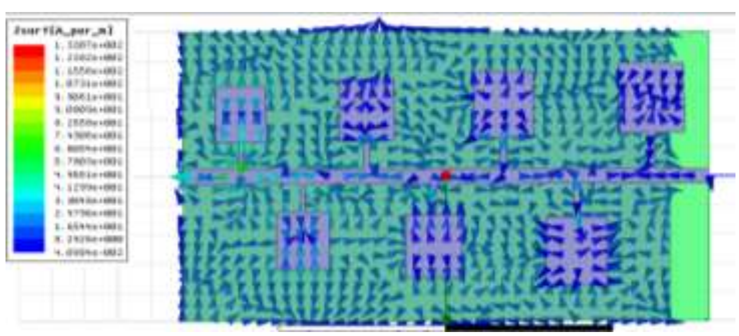


Fig 10. Current Distribution of 7-element Log Periodic MPA array without DGS

CASE-2: Log Periodic Microstrip patch antenna array with DGS

The simulated and measured Return loss vs frequency, VSWR vs Frequency and Gain vs Frequency plots of Log Periodic Microstrip patch antenna array without DGS are shown in fig 11, 12 and 13. It shows that the design antenna model resonate at 12.0 GHz with return loss value of -21.1dB, VSWR of 1.19 and the maximum gain is reported as 6.9dB.The simulated 2D and 3D radiation pattern of LPMPA without DGS is shown fig 14 and 15. Fig 16 shows the current distribution of the Log periodic MPA array antenna with DGS.

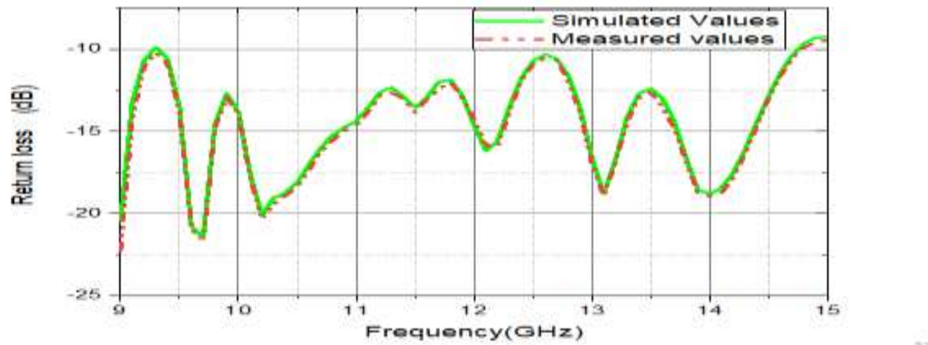


Fig .11 Return loss graph of 7-element Log periodic MPA array with DGS

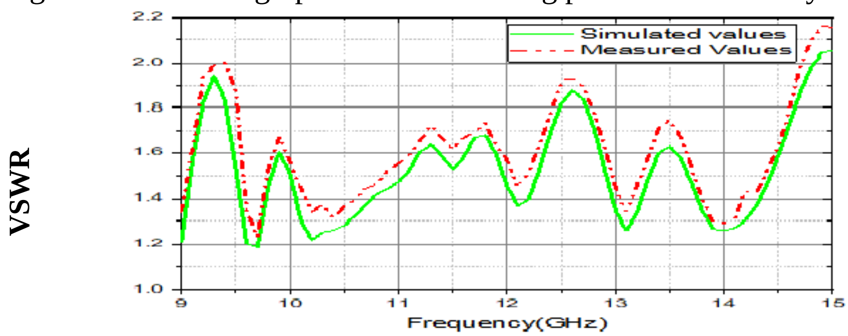


Fig .12. VSWR graph of 7-element Log periodic MPA array with DGS

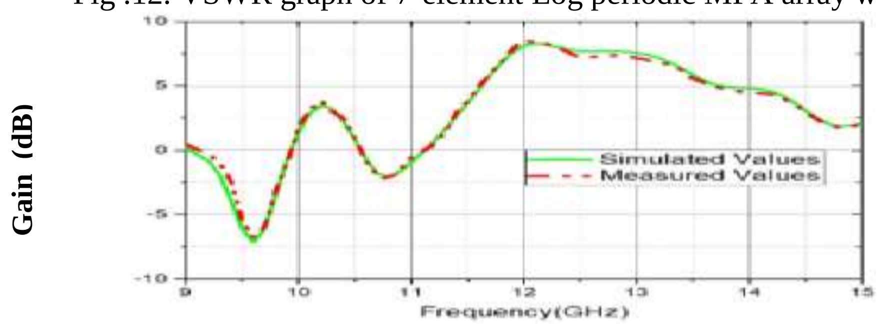
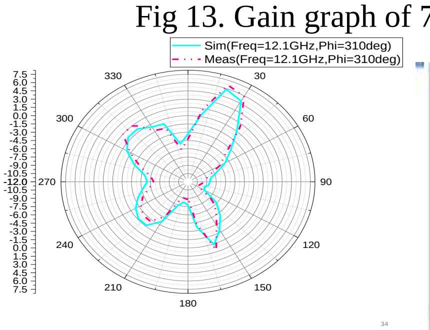


Fig 13. Gain graph of 7-element Log periodic MPA array with DGS



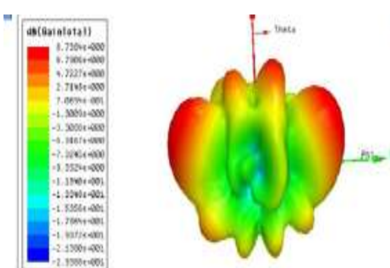


Fig 14. Radiation plot of Log periodic MPA array with DGS

Fig 15. 3D polar plot of Log periodic MPA array with DGS

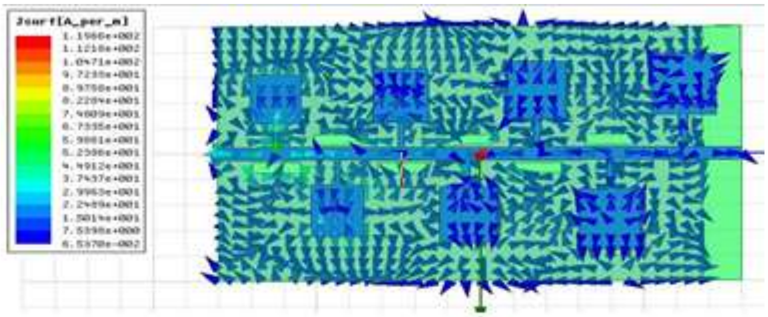


Fig 16. Current distribution of 7-element Log periodic MPA Array with DGS

Fig .17. Measurement set up of 7-element Log periodic microstrip Patch antenna array without DGS

Fig 18. Measurement set up of Log periodic microstrip Patch antenna array with DGS

Table 3 Comparison of simulated and measured results of Log periodic MPA array without and with DGS

Parameters	**Log periodic MPA antenna array without DGS**		**Log periodic MPA antenna array with DGS**	
	Simulated	**Measured**	**Simulated**	**Measured**
Operating band	Band 1: 9.3 to 12.1GHz Band 2: 12.4 to 14.7GHz	Band 1: 9.3 to 12.1GHz Band 2: 12.4 to 14.7GHz	9.3 to 14.7GHz	9.3 to 14.7GHz
Resonant Frequency(GHz)	11.8	11.24	12.1	12
Return loss(dB)	-25.8dB	-26.34dB	-21.1	-21.54
VSWR	1.07	1.124	1.2	1.19
Gain(dB)	6.0	5.9	7.0	6.9
Bandwidth	Band 1: 2.8GHz Band 2: 2.3 GHz	Band 1: 2.8GHz Band 2: 2.3 GHz	5.4 GHz	5.4 GHz
	12.14GHz to 12.4	12.14GHz to 12.4	-	-

Notch Band	GHz	GHz		
%Bandwidth	Band 1: 26.4% Band 2 : 17.03%	Band 1: 26.4% Band 2 : 17.03%	46.18%	46.18%

4. Conclusion

In this work, Log periodic rectangular MPA array with and without DGS structure using microstrip line feed technique is considered and the same are simulated and fabricated. The performance characteristics of the fabricated antenna array are evaluated experimentally. From the results it shows that the return loss of log periodic MPA array without DGS is -26.346dB, VSWR is 1.124, the peak gain is 7.0dB and bandwidth is 2.8GHz.Also, the bandwidth of the LPRMPA array is improved by 5.8GHz without degrading the other performance characteristics namely return loss, VSWR and gain by implementing the DGS technique. The measured results of log periodic MPA antenna Array with DGS shows better performance characteristics in terms of bandwidth and more number of resonant frequencies. The two proposed antenna arrays may be used for satellite uplink and downlink frequency applications in the X-band frequency range.

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