Log Periodic Dielectric Resonator Antenna for Broadband Applications

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ABSTRACT
A Log Periodic Dielectric Resonator Antenna (LPDRA) for broadband applications is presented. In this paper, a broad bandwidth antenna is formed by application of log periodic technique to the series fed electromagnetically coupled rectangular overlaid dielectric resonator array. This Log Periodic DRA is simulated using a CST microwave studio suite^{TM} 2010. The simulated results show wider impedance bandwidth covering the frequency range of 6.4 GHz to 11.1 GHz with a VSWR less than 2 and radiation efficiency greater than 95 %. Its maximum gain is 7.2 dBi. Parametric studies of the antennas with CST microwave based design data and simulated results are presented here. The scaling factor of 1.05 has been chosen for this design.

Keywords
Dielectric Resonator Antenna (DRA), Log Periodic DRA, Broadband Applications, Microstrip Line Feeding.

1. INTRODUCTION
As the demand grows for high speed data transfer and internet access, so the communication systems with wideband applications are becoming more prevalent. The increased interest in telemetry, entertainment, security and data communication services on mobile and vehicular platforms calls for the development of compact low cost and low profile wideband antennas with a high gain and tracking capabilities. Now-a-days dielectrically loaded antennas meet growing interest in wireless and satellite communication due to small dimensions, controllable properties and perfect protection from damages even in case of explosions.

Dielectric Resonator Antennas (DRAs) possess some peculiar properties which render them very promising, especially for millimeter wave applications. DRAs can be designed with different shapes such as rectangular, cylindrical and hemispherical geometries to accommodate various design requirements [1]. Rectangular DRAs can be designed with greater flexibility since two of the three of its dimensions can be varied independently for a fixed resonant frequency and known dielectric constant of the material [2]. In case of rectangular DRA, the availability of one degree of freedom more than cylindrical and spherical DRAs can be used to control the bandwidth of the antenna. As compared to the microstrip antenna, the DRA has a much wider impedance bandwidth due to their many advantageous features. These include their compact size, light weight, the versatility in their shape and feeding mechanism, simple structure, easy fabrication and wide impedance bandwidth.

Bandwidth enhancement is becoming the major design considerations for most practical applications of Dielectric resonator antennas. Several bandwidth enhancement techniques have been reported on modified feed geometries and changing the shape of the DRA including conical, tetrahedron, ring, triangular etc [3]. The gain, bandwidth and radiation performance of DRA can also be modified by using array instead of single DRA. In case of array, DRA elements of proper geometry can be assembled and fed in a suitable way [4-5]. These DRA arrays find applications in terrestrial applications as well as radars.

In this paper, we have used log periodic technique to further enhance the bandwidth of the proposed DRA array. This is a very sophisticated and effective approach to achieve broadband antenna design which has evolved from the initial work of number of researchers at the University of Illinois. The class of antennas that has resulted is called frequency-independent or log-periodic antenna which was invented by D.E. Isbell [6]. The log periodic dielectric resonator array substantially extends the useful application area of dielectric resonator antennas [7]. It provides broad bandwidth systems with a versatile, low profile, light weight antenna with conformal mounting capabilities [8]. The physical structure of log-periodic antenna is repetitive, which results in repetitive behavior in its electrical characteristics. In other words, the design of a log- periodic dielectric resonator antenna consists of a basic geometric pattern that repeats, except with a different size pattern [9].

The design of Log Periodic Dielectric Resonator Antenna (LPDRA) is proposed here for high frequency (HF) broadband applications. CST microwave studio suite^{TM} 2010 software has been used to analyze the performances such as return loss, radiation patterns, VSWR and gain of the designed antenna. The design methodology of the DRA using log periodic technique is discussed and the detail results of the proposed antenna are presented in this paper. This proposed log-periodic dielectric resonator array (LPDRA) antenna can play an important role in the modern satellite communication and radar system.

2. ANTENNA DESIGN
The geometry of the Log Periodic DRA, including its excitation feed line is shown in Fig. 1. The proposed DRA is a 9-element log periodic array designed to operate over 6.4-11.1 GHz. In this antenna it is normal to drive alternating element with 180^0 of phase shift from one another [10].

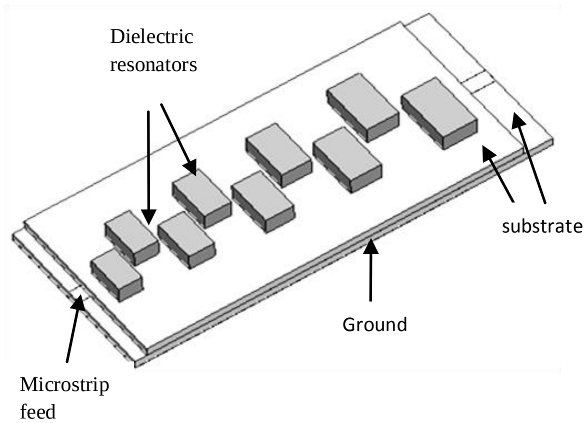


Fig 1: The proposed Log Periodic Dielectric Resonator Antenna

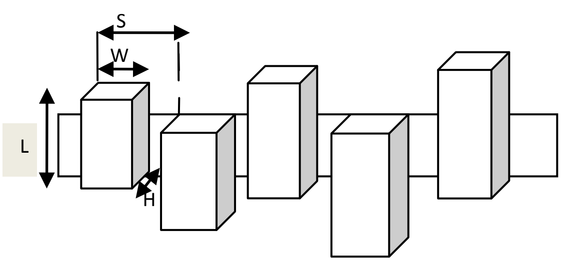


Fig. 2: Schematic view of Log Periodic DRA array

The length, width and spacing of the elements of a log periodic antenna increases logarithmically from one end to the other [11-12]. The schematic view of the Log Periodic DRA is shown in Fig.2. In the resonant approach, the microstrip line is terminated in an open circuit, which creates a standing wave on the line where the voltage maxima/minima of each wave are located at multiples of $\lambda_g/2$ from the open-circuit location. The guided wavelength λ_g can be approximated using equation (1).

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_s}} \tag{1}$$

where ε_s is the dielectric constant of the substrate.The proposed Log Periodic Dielectric Resonator Array consists of a number of dielectric resonator elements of different length and spacing, fed by a microstrip line. The array is fed at small end of the structure, and the maximum radiation is toward this end. The length (l) of the dielectric resonators and their spacing (d) are graduated in such a way that certain dimensions of adjacent elements bear a constant ratio to each other. That is, if the design ratio is designed by τ, then

$$\frac{d_1}{d_2} = \frac{d_2}{d_3} = \frac{d_3}{d_4} = \frac{1}{\tau} = \frac{l_1}{l_2} = \frac{l_2}{l_3} = \frac{l_3}{l_4} \tag{2}$$

The length, width and spacing between the DRA elements are given by the expression-

$$\tau = \frac{l_{n+1}}{l_n} = \frac{w_{n+1}}{w_n} = \frac{d_{n+1}}{d_n} \tag{3}$$

where τ is a scaling factor. If the dimension of the array is multiplied by τ it scales into itself with element n becoming element n+1, element n+1 becoming element n+2 etc [6]. This 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 value of l, w and s will be scaled into log periodic element. In this design we used dielectric resonators made from Teflon having dielectric constant (ε_{r1}) =2.1 with height (H) = 5mm. This LPDRA array is supported by FR4 substrate with dielectric constant (ε_{r2}) of 4.4 and height (h_s) of 1.6 mm. The dimension of the first dielectric resonator element were length L= 8.63 mm, width W= 6.9 mm and spacing S=7.25 mm, the dimension of other dielectric resonators were scaled by τ. The scaling factor τ is 1.05. The displacement of the radiators from the center of feed line was common for the whole array and equal to 1.25 mm. The length of array is 85 mm and width is 30 mm. Since the resonant frequency and the radiation resistance depend primarily on the dielectric resonators dimension and slightly influenced by the substrate thickness, so the height of both the substrate layer and feed line were kept constant [13-14].

The basic design of DRA array is similar to that of a normal log periodic array. As microstrip line feeding offers the advantage of easy and cost-effective fabrication of DRA, so the proposed DRA array is excited by microstrip line feeding. This antenna design is used where a wide range of frequencies, moderate gain and directionality are required.

3. RESULTS AND DISCUSSIONS

The result of nine element log periodic antenna is discussed in terms of bandwidth response, VSWR, input impedance, gain & directivity and radiation pattern characteristic.

3.1 Bandwidth Response, VSWR and Input Impedance Characteristics

A Log Periodic DRA for broadband applications has been designed and analyzed using CST Microwave studio suite™ 2010. The simulation result of input return loss for the nine elements LPDRA is shown in Figure 3. The bandwidth from the simulation result is 57%. The resonances of the antenna can be seen by observing the dip in the return loss. The simulation result gives a good approximation. Any changes in the dimension will affect the resonance frequency of the antenna.

The simulation results of proposed log periodic DRA were also showing very good Voltage Standing Wave Ratio (VSWR) values over the entire frequency range. Fig. 4 shows the simulated VSWR against frequency. It is remarkable that VSWR values are lower than 2 over the entire bandwidth.

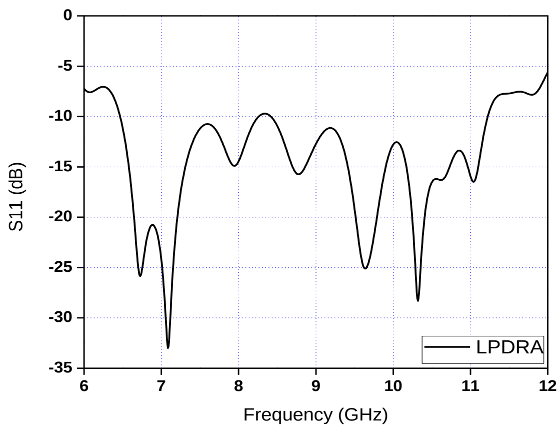


Fig 3: Return loss plot of a 9 element Log Periodic DRA array (LPDRA)

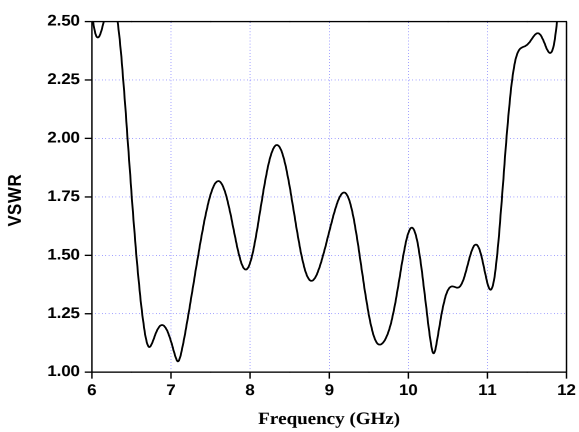


Fig 4: Simulated VSWR against frequency

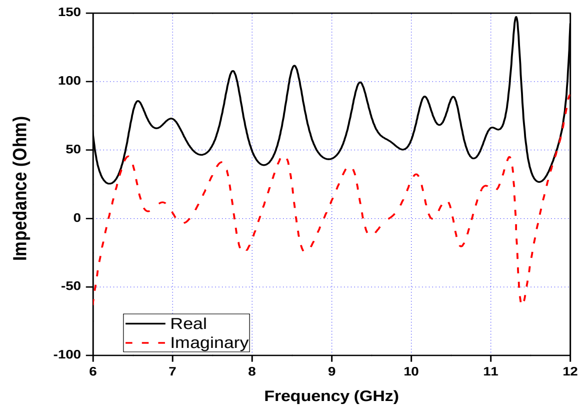


Fig. 5: Simulated Input Impedance curve of Log Periodic Dielectric Resonator Antenna

The input impedance vs. frequency curves of the proposed antenna has been presented in Fig. 5. The input resistance at resonant frequencies of the LPDRA is found to be nearly 50Ω providing very good impedance match to 50 Ω microstrip line feed.

3.2 Parametric Study

The gain, bandwidth and radiation performance of DRA can be modified by using array instead of single DRA. In case of log periodic DRA, bandwidth variation is also achieved by altering the scaling factor τ. A parametric study is carried out by varying the scaling factor of LPDRA to achieve optimum antenna performance. Fig. 6 shows the simulated VSWR with different values of scaling factor τ such as 0.95, 1.0 and 1.05. For the case τ = 1.05, broad bandwidth with VSWR less than 2 is observed.

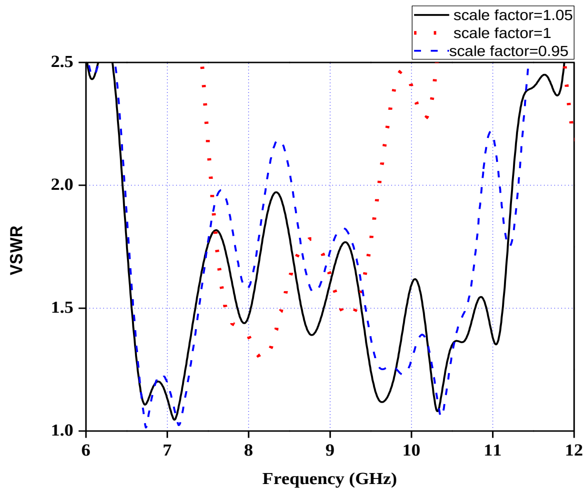


Fig 6: Simulated VSWR with different values of scaling factors

3.3 Gain & Directivity

The gain of this antenna is from 3.8 to 7.5 dBi, as shown in Fig 7. The highest gain is at frequency 9.7 GHz. The lowest gain is 3.8 dBi at 6.7 GHz. At any frequency, the number of array elements contributing to the radiation is dependent on the bandwidth of the individual radiators, and the scaling factor used in constructing the array. Therefore, adding more elements does not increase the peak gain. Instead, a reduction in peak gain is seen, possibly because the efficiency is degraded when more elements are added.

The simulated peak directivity varies from 3.5 dBi to 7 dBi within the overall band. The directivity versus frequency plot is also shown in Fig 7.

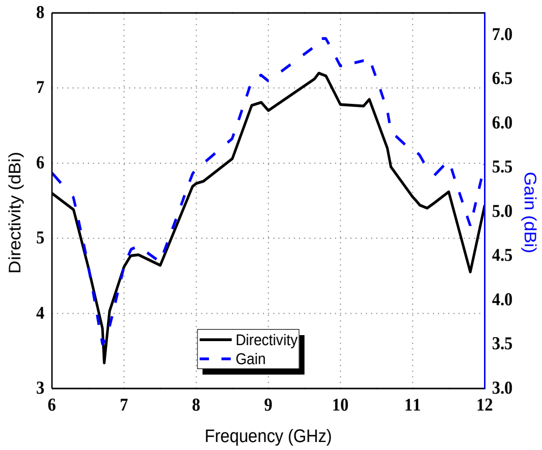
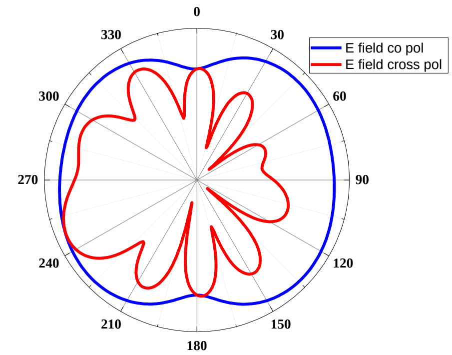
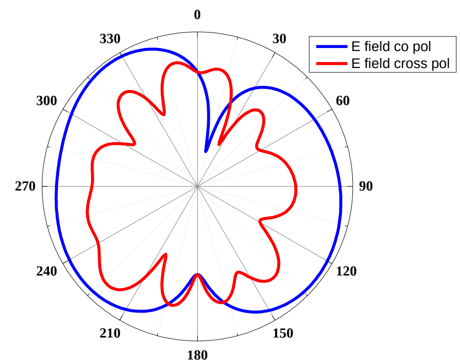


Fig 7: Simulated Gain and Directivity of the Log Periodic DRA versus Frequency

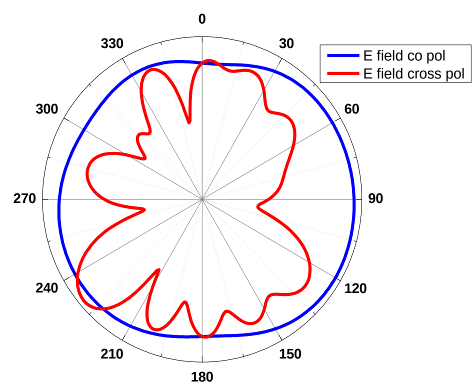
3.4 Radiation Pattern Characteristics



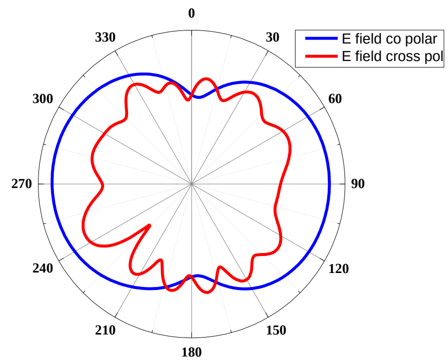
(a) 6.7 GHz



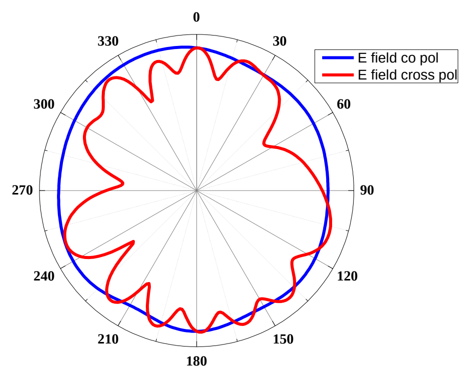
(b) 8 GHz



(c) 9 GHz



(d) 10.7 GHz



(e) 11.2 GHz

Fig. 8. Simulated E plane radiation patterns of Log Periodic DRA

Fig. 8 shows the simulated radiation patterns for the nine elements LPDRA at different frequencies (6.7 GHz, 8 GHz, 9 GHz, 10.7 GHz and 11.2 GHz). It has been observed that the E plane radiation patterns are in broadside direction against frequency.

4. CONCLUSION

The Log Periodic DRA arrays have the inherited advantages over single DRAs, most noticeably the high radiation efficiency from DRA elements. The proposed DRA is a log periodic antenna with 9 dielectric resonator elements. The matching is better than -10 dB in the working bandwidth. The bandwidth of this antenna is from 6.4 GHz to 11.2 GHz with a VSWR less than 2 and maximum radiation efficiency is 95%. The gain of the antenna ranges from 3.8 to 7.5 dBi. The radiation pattern is in the broadside direction. This antenna can be used for broadband applications like communication satellites and high resolution, close range targeting RADARs.

5. ACKNOWLEDGEMENT

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