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A Review on Different Logarithmic Antenna Structures for Wireless Applications

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ABSTRACT: Antenna is the most important element in wireless and wired communications systems. Antenna is one type of transducer and it transforms electrical signals into radio waves and vice-versa. The antennas are of various kinds and having different characteristics according to the need of signal transmission, gain, beam width and reception. The main objective of this paper is to study comparative analysis of different types of antennas that can be differentiated with respect to their shapes, materials used, signal bandwidth, transmission range, transmitted power etc. The main focus of this paper is to classify these antennas according to their applications. In the modern era antennas are the basic prerequisites for wireless and wired communications that is required for fast and efficient communications. This paper will help the design engineer to choose proper antenna for the desired application. The comparative analysis of various types of antennas like bow tie antenna, log periodic dipole antenna, log periodic dipole array antenna, log periodic fractal Koch antenna, log periodic microstrip patch array antenna with different feed techniques, log periodic dielectric resonator antenna with different couplings, with respect the bandwidth, frequency range and applications are studied and the same are presented at the end.

KEYWORDS: Bow Tie, Dipole, Dipole Array, Fractal Koch, Patch Array, DRA Array, Parallel Feed Line and Capacitive Coupled Antenna.

I. INTRODUCTION

Antennas are basic components of any electric system and are connecting links between the transmitter and free space or free space and the receiver. Thus antennas play very important role in finding the characteristics of the system in which antennas are employed. Antennas are employed in different systems in different forms [1-3]. That is, in some systems, the operational characteristic of the system are designed around the directional properties of the antennas or in some others systems, the antennas are used simply to radiate electromagnetic energy in an omni directional or finally in some systems for point-to-point communication purpose in which increased gain and reduced wave interference are required.

1.1 Antenna Definitions

There are several definitions of antenna, and are as follows:

- The IEEE Standard Definitions of Terms (IEEE Std 145- 1983): A means for radiating or receiving radio waves
- “An antenna is any device that converts electronic signals to electromagnetic waves (and vice versa)” effectively with minimum loss of signals as shown in Fig.1.
- An antenna is basically a transforming device that will convert impedance of transmitter output (50/75 Ohm) into free space impedance (120 π or 377 Ohms).

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- Region of transition between guided and free space propagation
- Concentrates incoming wave onto a sensor (receiving case)
- Launches waves from a guiding structure into space or air (transmitting case)
- Often part of a signal transmitting system over some distance.

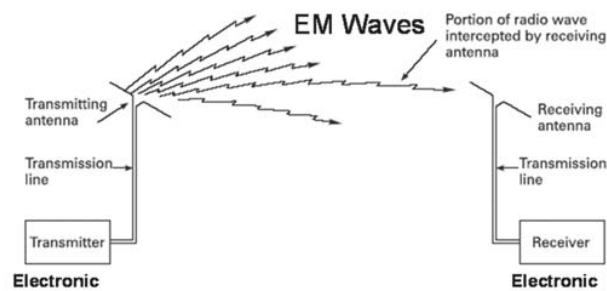


Fig.1 Wireless Communication System

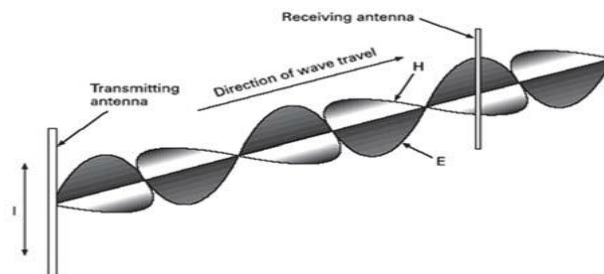


Fig.2 Propagation of EM waves

1.2. Electromagnetic Waves

Before understanding the concept of antenna one should know what are Electromagnetic wave and its propagation modes in free space. The full Electromagnetic spectrum is shown in figure 3[14]. Typical EM wave frequency band representations are shown in table 1&2, [15] Antennas dimensions are dependent on wavelength of the signal being Transmitted

$$\lambda = \frac{v_0}{f} \quad (1)$$

Here, v_0 = velocity of propagation of EM waves in free space.

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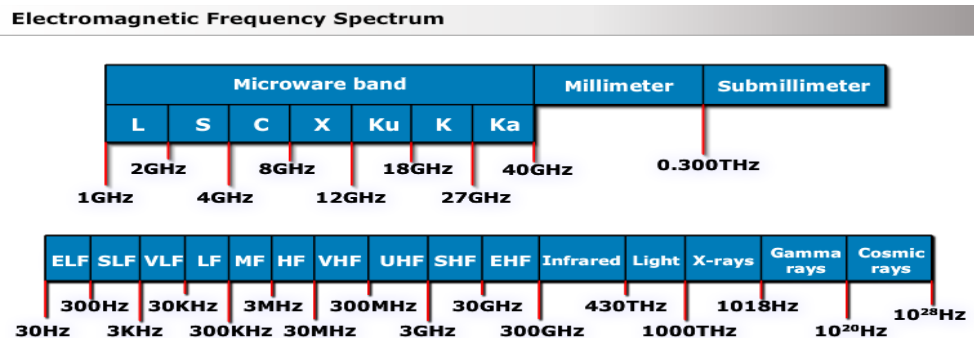


Fig.3 Electromagnetic Spectrum

A typical frequency band representation is shown in the Table-1:

Band Name	Abbreviated Band Name	Frequency	Wavelength
Extremely low frequency	ELF	30 - 300 Hz	10 mm - 100 km
Very low frequency	VLF	3 - 30 kHz	100 - 10 km
Low frequency	LF	30 - 300 kHz	10 - 1 km
Medium frequency	MF	300 - 3,000 kHz	1 km - 100 m
High frequency	HF	3 - 30 MHz	100 - 10 m
Very high frequency	VHF	30 - 300 MHz	10 - 1 m
Ultra high frequency	UHF	300 - 3,000 MHz	1 m - 10 cm
Super high frequency	SHF	3 - 30 GHz	10 - 1 cm
Extremely high frequency	EHF	30 - 300 GHz	1 cm - 1 mm

Radar bands specified by IEEE (USA) are shown in the Table-2:

Name of the band	Frequency range (GHz)	Wavelength range (cm)
L	1 - 2	30 - 15
S	2 - 4	15 - 7.50
C	4 - 8	7.50 - 3.75
X	8 - 12	3.75 - 2.50
Ku	12 - 18	2.50 - 1.67
K	18 - 27	1.67 - 1.11
Ka	27 - 40	1.11 - 0.75
mm	40 - 300	0.75 - 0.01

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1.3. Electromagnetic (EM) Wave in Free Space

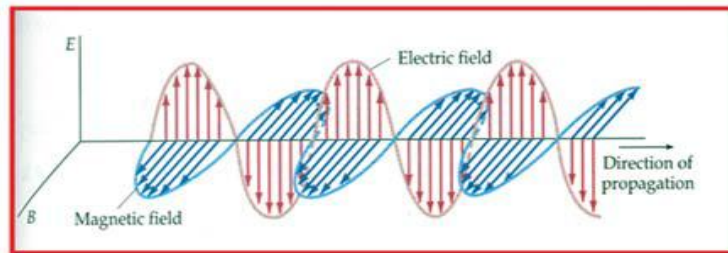


Fig.4 EM Wave in Free Space

Electromagnetic waves are disturbances to the electrical and magnetic fields. A changing electric disturbance produces a changing magnetic field at right angle to the electric field. Electromagnetic Wave originates from a point in free space, spreads out uniformly in all directions and it forms a spherical wave. An observer, however, at a grate distance from the source is able to observe only the small part of the wave in his immediate vicinity and it appears to him as plane wave just as the ocean appears flat to a person who can only see a few miles around him. Thus at a large distance from the source the wave has similar properties to the plane waves in the strip line and so by analogy of strip line the properties of EM waves in free space as follows:

- At every point in space, the electric vector field E and the magnetic vector field H are perpendicular to each other and to the direction of propagation as shown in figure 4.
- Velocity of EM wave in free space is given by $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \text{ m/s}$ (2)
- E and H oscillate in phase and ratio of their amplitude is constant being equal to 120π or 377 Ohms
- Whatever may be the frequency, the EM waves travels in space with the velocity of light.
- EM wave propagates in free space as Transverse Electro Magnetic waves (TEM mode). Equation of EM waves in free space is given by:

$$\frac{\partial^2 E_x}{\partial t^2} = \frac{1}{\mu_0 \epsilon_0} \frac{\partial^2 E_x}{\partial z^2} E_x = E_0 e^{j(\omega t \pm \beta z)} \quad (3)$$

$$\frac{\partial^2 H_y}{\partial t^2} = \frac{1}{\mu_0 \epsilon_0} \frac{\partial^2 H_y}{\partial z^2} H_y = H_0 e^{j(\omega t \pm \beta z)} \quad (4)$$

$$f = \frac{\omega}{2\pi}, \quad \lambda = \frac{1}{\sqrt{\mu_0 \epsilon_0} f}, \quad \beta = \frac{2\pi}{\lambda}, \quad Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \quad (5)$$

Where, f is frequency, ω is angular frequency, ϵ_0 is permittivity of free space,

μ_0 is permeability of free space, β is phase constant, Z_0 is intrinsic impedance of free space.

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II. DESIGN OF LOG PERIODIC ANTENNAS

2.1 Bow Tie Antenna

An antenna that consists of two triangular pieces of stiff wire or two triangular flat metal plates, arranged in the configuration of a bowtie, with the feed point at the gap between the apexes of the triangles. The antenna is designed for wideband applications over a 500 MHz-2.5 GHz frequency band.

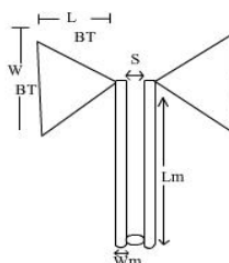


Fig.5 Design of Bow Tie Antenna

The design features a unique Y-shaped bowtie configuration to achieve ultra-wideband performance. A concept to further improve upon the impedance match and overall gain of the printed bowtie antenna is also presented. In correspondence arrange framework the thick, viable, and minimal effort gadgets has been incredibly required. In multi-band application same trademark required. The ongoing correspondences organize required less weight, minimal effort, and thick, moveable and simple working antennas gadgets. In the assembling of proposed antenna two mirrors required and put on rectangular fix. For Coplanar wave guide (CPW) lumped port is utilized. Viable utilizations of these antennas are versatile correspondence system and wireless frameworks [4]. Figure 5 shows bow tie antenna.

2.2 Log Periodic Dipole Antenna

A log-periodic antenna (LP), also known as a log-periodic array or log-periodic aerial, is a multi-element, directional antenna designed to operate over a wide band of frequencies. Electrically, it simulates a series of two or three-element Yagi antennas connected together, each set tuned to a different frequency. The log periodic antenna is used in many areas wide bandwidth levels are needed along with directivity and gain. There are several areas where the antenna is used: HF communications: Log periodic antenna arrays are often used for diplomatic traffic on the HF bands. A broadband, multi-segment, tight column, directional antenna that has radiations and impedance properties which rehash normally as a logarithmic capacity of the frequency excitation is named as log periodic antenna in media transmission. In log periodic antenna a logarithmic increment long and space of component happen from one terminal to the next. This sort of antenna is valuable for a locale which requires more prominent frequency extends however it comprise of directionality and moderate addition. These sort antennas are design due to having wide bandwidth for explicit reason [5].

The design of antenna incorporates the progressive dipoles which are on the other hand connected a reasonable transmission line named as feeder. So as to cause end case radiation shorter way, to these firmly dispersed components are associated oppositely make component and to drop the broadside radiation associated oppositely. Short coaxial utilized. Feeder is associated with the conductor of the co-pivotal link its make antenna its very own balun [6]. Figure 6 demonstrates that the design of log periodic dipole antenna.

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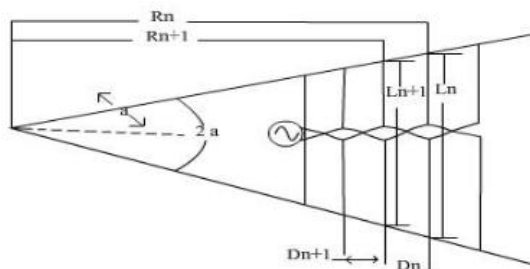


Fig.6 Design of Log Periodic Dipole Antenna

2.3 Log Periodic Dipole Array Antenna

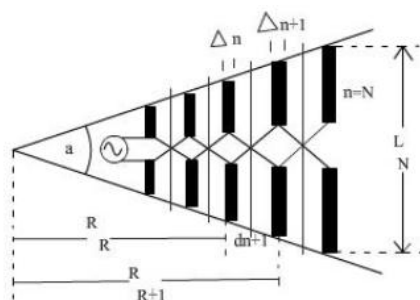


Fig.7 Design of Log Periodic Dipole Array Antenna

This antenna is helpful if there ought to be an event of wideband applications. The log periodic array antenna is work in VHF frequency run from 30 MHz to 300 MHz. log periodic antenna are classes as free antenna having bandwidth more prominent than 10:1. Raymond Duhamel is the main who imagine log periodic array structure. Log periodic dipole array is created by Isbell in 1960s. The normal for proposed antenna, the information impedance, the increase, radiation and so on. Changes occasionally in the logarithm of the frequency space. This is known as a log periodic array [7]. Figure 7 shows the structure of the log periodic dipole array antenna.

2.4 Log Periodic Fractal Koch Antenna

The log periodic fractal koch antenna (LPFKA) are used as a piece of ultra-high frequency (UHF) band contraptions. The antenna size can be short up-to 27% utilizing fractal koch process which does not influence the antenna radiation or accepting execution [8]. Nowadays' antennas are created in little sizes and less secured region with higher bandwidth, so the antennas are made various way and diverse shape [9].

Koch bend is a better than average instance of self-equivalent space-filling fractal which is used to make wideband, multiband or downsized antenna. The antenna helps in overcome the containments [10]. Figure 8 indicates log periodic fractal koch antenna.

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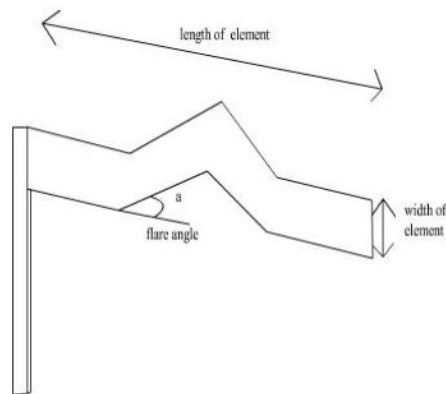


Fig.8 Design of Log Periodic Fractal Koch Antenna

2.5 Log Periodic Microstrip Patch Array Antenna with Parallel Feed Line

The novelty of this log periodic microstrip patch array (LPMPA) antenna structure is a combination of a number of patch elements to create a log periodic array with modest bandwidth. Microstrip antenna has gain popularity of their small size and light weight however a limitation of microstrip antenna is the narrow bandwidth of the basic element. The bandwidth of basic patch element is usually 1-3%.

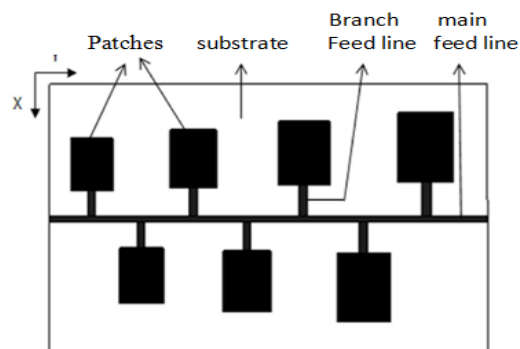


Fig.9 Design of Log Periodic Microstrip Patch Array Antenna

The implementation of microstrip patch antenna with log-periodic technique leads to log-periodic patch array antenna concept. This technique combines the advantages of both microstrip patch and log-periodic antennas, which leads to the high performance of the antenna with high bandwidth and gain. Figure 9 indicates log periodic microstrip patch array antenna.

2.6 Log Periodic Microstrip Patch Array Antenna with Parallel Inset Feed Line

Inset feed is a type of microstrip line feeding technique, in which the width of conducting strip is small as compared to the patch and has the advantage that the feed can provide a planar structure. [2] The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch input impedance without the need for any additional matching element. This can be achieved by properly adjusting the inset cut position and dimensions. [6]

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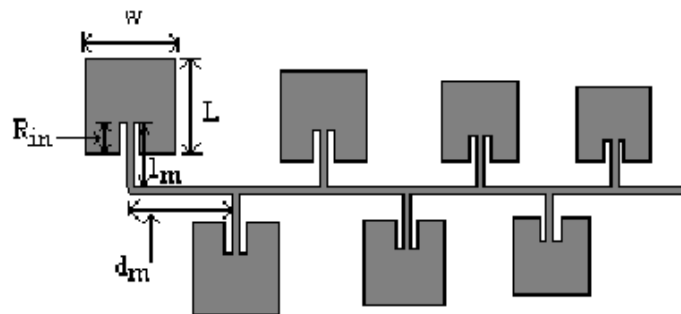


Fig.10 Log Periodic Microstrip Patch Array Antenna with Parallel Inset Feed Line

The implementation of Inset fed microstrip patch antenna with log-periodic technique combines the advantages of both microstrip patch and log-periodic antennas, which leads to the high performance of the antenna with high bandwidth and gain. Figure 10 indicates log periodic microstrip patch array antenna with parallel inset feed line.

2.7 Capacitive Coupled Log Periodic Patch Array Antenna

The elements of the array are directly coupled to the feed line which results in more compact and low loss array antenna. In this capacitive coupled log periodic patch array antenna The weight of the array and the volume may also be reduced using this series microstrip line feeding. to achieve wide bandwidth with low conductor losses. The replacement of patches with DRA elements gives more efficient results. Figure 11 indicates capacitive coupled log periodic patch array antenna.

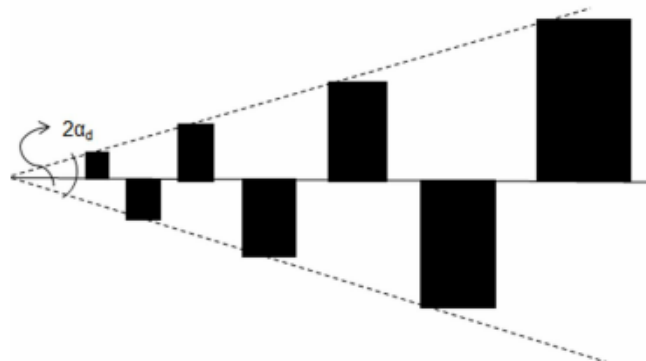


Fig.11 Design of Capacitive Coupled Log Periodic Microstrip Patch Array Antenna

2.8 Log Periodic Dielectric Resonator Antenna with Parallel Feed Line

In log periodic fashion, the elements of the LPDRA array are arranged. the log periodic branched microstrip feed line excites the antenna that results in a better coupling of energy between the feed line. The precise amplitude control for high frequency applications is enabled by this feed line technique. the latest Developments of low loss DRA array and wideband log periodic technique is basis for this antenna Design.

In some cases Dielectric resonator antenna is superior to microstrip antenna as it has negligible metallic loss and high efficiency at microwave frequencies. DRAs produce a high radiations efficiency and high gain in

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contradiction of microstrip antenna due to low loss of the Dielectric materials. Figure 9 indicates log periodic dielectric resonator array antenna with parallel feed line.

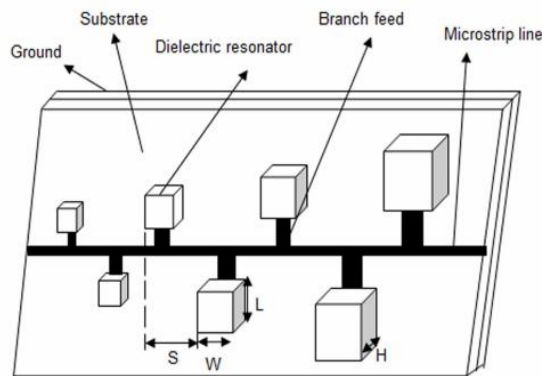


Fig.12 Design of Log Periodic Dielectric Resonator Antenna with Parallel Feed Line

2.9 Capacitive Coupled Log Periodic Dielectric Resonator Antenna

The elements of the array are directly coupled to the feed line which results in more compact and low loss DRA array. The volume and weight of the array can also be reduced by using this series microstrip line feeding. This array is developed to achieve wide bandwidth with low conductor losses. The replacement of patches with DRA elements gives more efficient results with increased bandwidth. The advantages of DRA over Microstrip Patch are shown in figure 13 indicates capacitive coupled log periodic dielectric resonator array antenna.

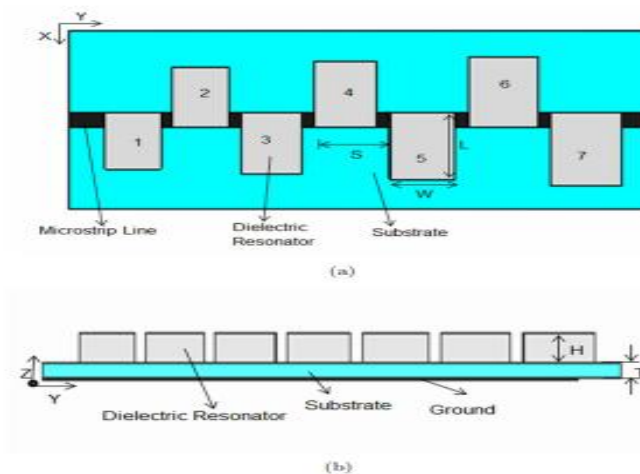


Fig.13 Design of Capacitive Coupled Log Periodic DRA Array Antenna (a) Front View (b) Side View

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III. COMPARISON OF VARIOUS LOG PERIODIC ANTENNAS

The following Table shows that the comparison of various types of log periodic antenna structures, specifically frequency ranges covered, bandwidth and the corresponding applications.

Table.3 Comparison of various Log Periodic Antenna structures

Year	Type of Antenna	Frequency Range	Bandwidth	Application
1958	Dipole Antenna	174-216 MHz	≈ 42MHz	GSM Techniques
1958	Dipole Array Antenna	30-300 MHz	≈ 270 MHz	5G Wireless Cellular Networks
1958	Log Periodic Microstrip Patch Array Antenna with Parallel Feed Line	3GHz-30GHz	Upto 8 GHz (depends on number of elements)	Satellite Communications.
1983	Capacitive Coupled Microstrip Patch Array Antenna	3GHz-30GHz	Upto 4 GHz (depends on number of elements)	microwave and Home appliances
1988	Fractal Koch Antenna	2.12-2.40 GHz, 4.70-4.83 GHz, 7.40-7.60 GHz and 8.82-10 GHz	Upto 2.2 GHz	WLAN/Wi-MAX
2001	Log Periodic Microstrip Patch Array Antenna with Parallel Inset Feed Line	3GHz-30GHz	Upto 3 GHz (depends on number of elements)	RADAR and Satellite applications.
2001	Log Periodic Dielectric Resonator Array Antenna with Parallel Feed Line	3GHz-30GHz	Upto 8.5 GHz (depends on number of elements)	RADAR Applications and Satellite Communications
2011	Bow Tie Antenna	300MHz-3GHz	≈ 2.7GHz	Ground Penetrating Radar (GPR)

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2013	Capacitive Coupled Dielectric Resonator Array Antenna	3GHz-30GHz	Up to 4.5 GHz (depends on number of elements)	Microwave and RADAR Applications.
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IV. CONCLUSION

In this paper, tremendous data about various types of logarithmic antennas is investigated for radar, Microwave and satellite based communications. It is concluded that even though a lot of work has been done on microstrip patch antenna array but little work has been done on logperiodic microstrip patch antenna arrays and log periodic DRA structures with different feeding techniques. So the proposed log periodic MPA arrays, log periodic DRA arrays with appropriate feedings are suitable for wireless, radar, microwave and satellite based communications. HFSS software or CST MS simulation software will be used for designing the log periodic MPAs and log periodic DRA structured antennas,

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