Log Periodic Antenna (LPA)

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Frequency Independent Antenna : may be defined as the antenna for which "the impedance and pattern (and hence the directivity) remain constant as a function of the frequency"

Antenna Theory - Log-periodic Antenna

The Yagi-Uda antenna is mostly used for domestic purpose. However, for commercial purpose and to tune over a range of frequencies, we need to have another antenna known as the **Log-periodic antenna**.

A Log-periodic antenna is that whose impedance is a logarithmically periodic function of frequency. Not only this all the electrical properties undergo similar periodic variation, particularly radiation pattern, directive gain, side lobe level, beam width and beam direction. These are broadband antenna. Bandwidth of 10:1 is achieved easily and even 100:1 is feasible if the theoretical design closely approximated. Radiation pattern may be bidirectional and unidirectional of low to moderate gain.

Frequency range

The frequency range, in which the log-periodic antennas operate is around **30 MHz to 3GHz** which belong to the **VHF** and **UHF** bands.

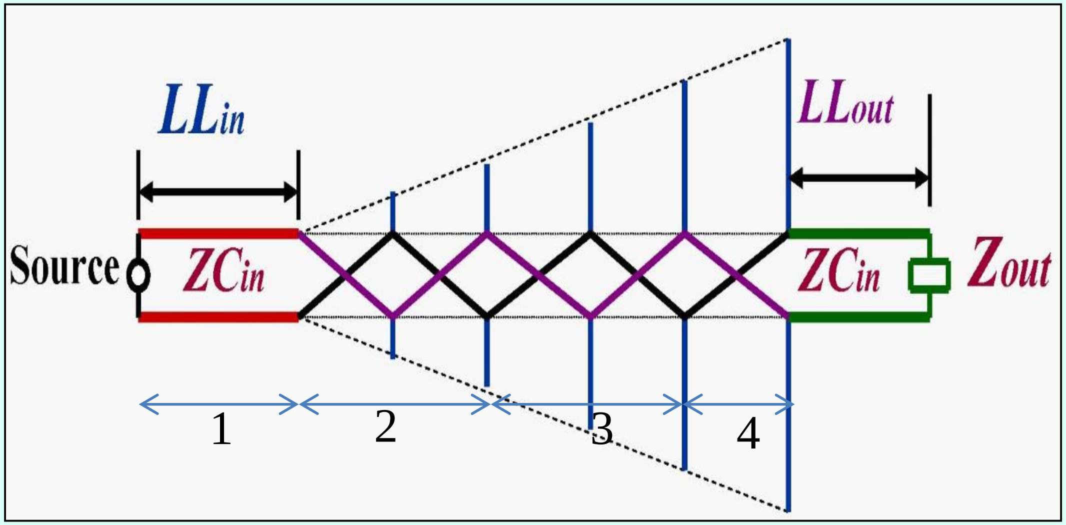
Construction & Working of Log-periodic Antenna

The construction and operation of a log-periodic antenna is similar to that of a Yagi-Uda antenna. The main advantage of this antenna is that it exhibits constant characteristics over a desired frequency range of operation. It has the same radiation resistance and therefore the same SWR. The gain and front-to-back ratio are also the same.

The image shows a log-periodic antenna.

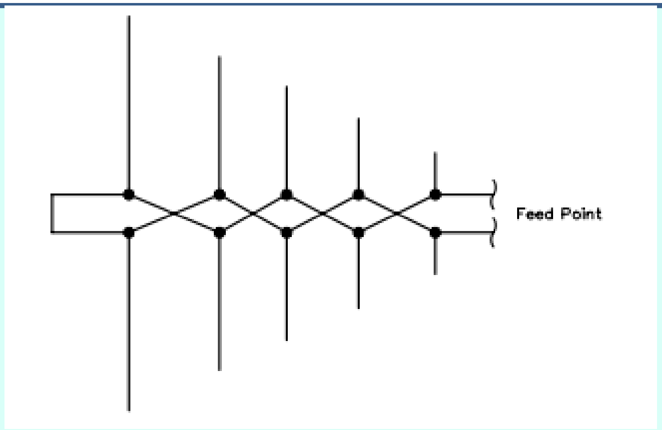
With the change in operation frequency, the active region shifts among the elements and hence all the elements will not be active only on a single frequency. This is its **special characteristic**.

There are several type of log-periodic antennas such as the planar, trapezoidal, zig-zag, V-type, slot and the dipole. The mostly used one is log-periodic dipole array, in short, LPDA.



1. Included Transmission Line Region (Inactive region, L<λ/2, Elements are high capacitive impedance)
2. Loaded Transmission Line Region (L<λ/2)
3. Active Region (L = λ/2, Elements are resistive in nature, Elements current are large and in phase with base voltage. The current just below resonance is slightly leading and above resonance are slightly lagging)
4. Reflective Region (Inactive Region, L>λ/2, Impedance becomes inductive, causing the currents in the elements to lag the base voltage.)

Active region towards the apex angle i.e towards the shorter length is heigher frequency, at middle for Intermediate frequency and near longest elements for lowest frequencies.



The diagram of log-periodic array is given above.

The physical structure and electrical characteristics, when observed, are repetitive in nature. The array consists of dipoles of different lengths and spacing, which are fed from a two-wire transmission line. This line is transposed between each adjacent pair of dipoles.

The dipole lengths and separations are related by the formula −

$$\frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{R_3}{R_4} = ------ = \frac{R_n}{R_{n+1}} = \tau = \frac{L_1}{L_2} = \frac{L_2}{L_3} = \frac{L_3}{L_4} = ---- = \frac{L_n}{L_{n+1}} = \frac{S_n}{S_{n+1}} = \tau = \frac{1}{k}$$

Where

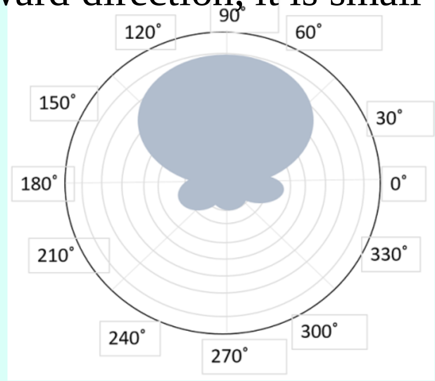
- τ is the design ratio (Scale factor) and $\tau<1$
- R is the distance between the feed and the dipole
- L is the length of the dipole.
- S is the difference between two elements
- σ is the spacing factor (S/λ)

The directive gains obtained are low to moderate.

Radiation Pattern

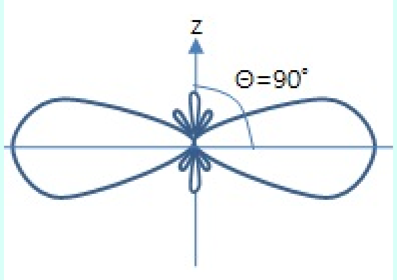
The Radiation pattern of log-periodic antenna can be of uni-directional or bi-directional, depending upon the log periodic structures.

For **uni-directional Log-periodic antenna**, the radiation towards shorter element is of considerable amount, whereas in forward direction, it is small or zero.



The radiation pattern for uni-directional log-periodic antenna is given above.

For **bi-directional Log-periodic antenna**, the maximum radiation is in broad side, which is normal to the surface of the antenna.



General Characteristics of LPDA

- LPA is excited from the shorter length side or high frequency side for one active region LPA and at the center for two active region LPA. They are fed by a balanced two wire transmission line.

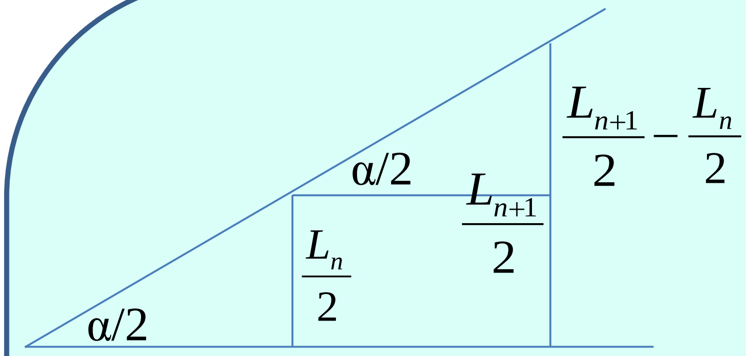
- There are an infinite variety of LP structures possible but not all structures would be frequency independent. A successful and most practical structures are few. Broad band will be with those LPAs which have small variation in periodicity properties.

- For unidirectional LPA the structure fires in backward direction (toward shorter element) and forward radiation is very small or zero (towards right). For bidirectional LPA the maximum radiation is in broadside direction i.e normal to the surface of antenna.

- Transmission line inactive region (between active and vertex) must have proper characteristic impedance with negligible radiation.

- In active region currents magnitude and phasing should be proper so that strong radiation occur along backward direction and zero or negligible radiation along forward direction (in case of unidirectional) and broadside for bidirectional.

- In inactive reflective region there should be rapid decay of current within this range for a successful F.I antenna i.e. here the structure should be truncated, effectively.



$$\tan\alpha/2 = \frac{\frac{L_{n+1} - L_n}{2}}{S} = \frac{L_{n+1} - L_n}{2S}$$

$$\tan\alpha/2 = \frac{L_{n+1}(1 - \frac{L_n}{L_{n+1}})}{2S} \qquad \tan\alpha/2 = \frac{L_{n+1}(1 - \frac{1}{K})}{2S}$$

$$L_{n+1} = \frac{\lambda}{2}$$

$$\tan\alpha/2 = \frac{\lambda(1 - \frac{1}{K})}{2x2S} \qquad \tan\alpha/2 = \frac{(1-\tau)}{4\sigma} \qquad \alpha/2 = \tan^{-1}\frac{(1-\tau)}{4\sigma}$$

$$\alpha = 2\tan^{-1}\frac{(1-\tau)}{4\sigma}$$

$$\sigma = \frac{S}{\lambda} = \frac{(1-\tau)}{4\tan\alpha/2}$$

Advantages

The following are the advantages of Log-periodic antennas −

- The antenna design is compact.
- Gain and radiation pattern are varied according to the requirements.

Disadvantages

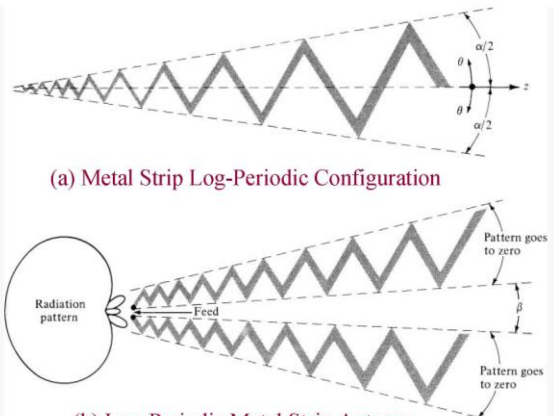
The following are the disadvantages of Log-periodic antennas −

- External mount.
- Installation cost is high.

Applications

The following are the applications of Log-periodic antennas −

- Used for HF communications.
- Used for particular sort of TV receptions.
- Used for all round monitoring in higher frequency bands.



(a) Metal Strip Log-Periodic Configuration

(b) Log-Periodic Metal Strip Antenna

Fig. 11.5

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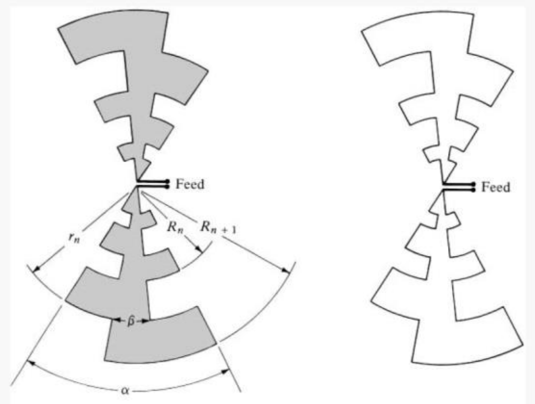
Frequency Independent Antennas, Antenna Miniaturization, and Fractal Antennas



(a) Planar **Fig. 11.6** (b) Wire

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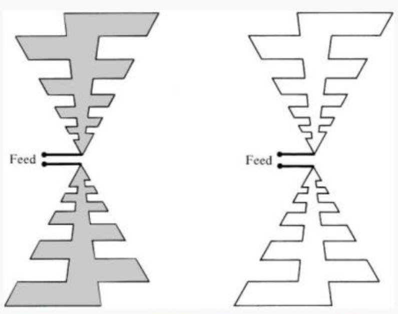

(a) Planar **Fig. 11.7** (b) Wire

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Geometric Ratio τ (defines period):

$$\tau = \frac{R_n}{R_{n+1}} < 1 \qquad (11\text{-}23)$$

Width of Slot:

$$\chi = \frac{r_n}{R_{n+1}} < 1 \qquad (11\text{-}24)$$

$$\tau = \frac{f_1}{f_2} < 1, \qquad f_2 > f_1 \qquad (11\text{-}25)$$

f_1 and f_2 are one period apart.

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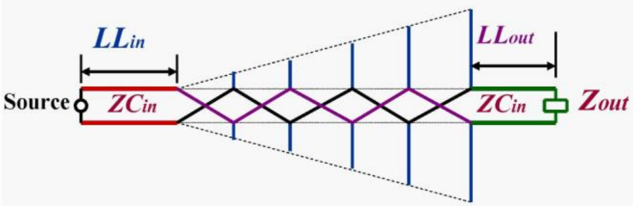
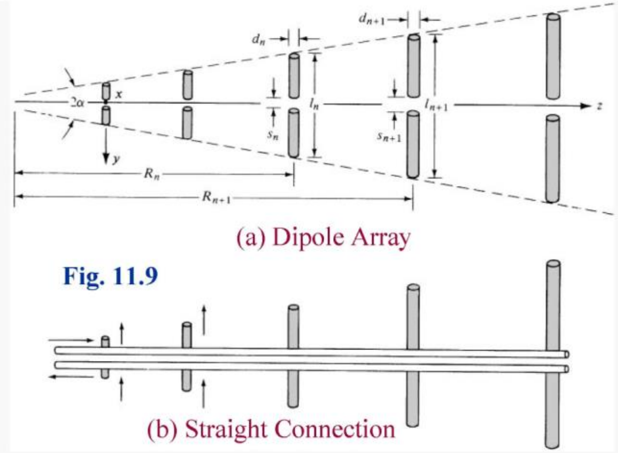
Geometry of

Log-Periodic Dipole Array

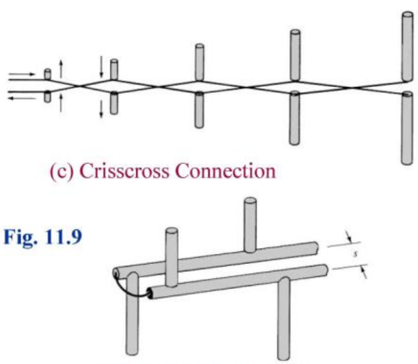




(a) Dipole Array

Fig. 11.9

(b) Straight Connection



(c) Crisscross Connection

Fig. 11.9

(d) Coaxial Connection

Log-Periodic Dipole Array:

$$\frac{1}{\tau} = \frac{\ell_2}{\ell_1} = \frac{\ell_{n+1}}{\ell_n} = \frac{R_2}{R_1} = \frac{R_{n+1}}{R_n}$$

$$= \frac{d_2}{d_1} = \frac{d_{n+1}}{d_n} = \frac{s_2}{s_1} = \frac{s_{n+1}}{s_n} \qquad (11\text{-}26)$$

Spacing Factor σ:

$$\sigma = \frac{R_{n+1} - R_n}{2\ell_{n+1}} \qquad (11\text{-}26a)$$

Log-Periodic Dipole Array (LPDA)

1. Most commonly used VHF channel antenna (all channels)
2. Becoming popular UHF channel antenna (all channels)
3. Capable of constant gain and input impedance over a bandwidth of 30:1
4. Gain of 6.5-10.5 dB (to $\lambda/2$ dipole); Practically 6.5-7.5 dB.

The dipoles are connected to a central transmission line with a phase reversal between the dipoles. This is required so that radiation is in backfire direction (toward smaller elements). If the phase reversal is not used, radiation will occur in end-fire direction (toward larger elements). This causes scalloping in amplitude patterns and leads to erratic impedance behavior. This is referred to as end effect.

The Central Transmission Line Takes 2 Forms

2. Low Impedance: Designed for a 75-Ohm line. It is made of 2 parallel conducting booms over the length of the antenna forming a low-impedance 2-conductor transmission line. Phase reversal between dipoles is accomplished by alternating the attachment of the dipoles along the two-boom transmission line.

A coaxial feed line may be placed within one of the booms and connected to the short-dipole end of the array.
In this configuration the array acts as a Balun.

References

- **Antenna Theory by Constantine A Balani**
- **Antenna & Wave Propagation by K D Prasad**
- **Antenna Theory (Tutorials Point) https://www.tutorialspoint.com/antenna_theory/antenna_theory_broad_side_array.htm**