input terminal $AA'$, both the sets of currents flow simultaneously. The antenna current ($I_A$) being in the same direction contributes to radiation while, the transmission line current being in opposite direction does not contribute to radiation (as cancelled out) but, however, contribute to the input impedance. This may now be considered as the "antenna impedance" of the folded dipole in parallel with reactance of the series connected shorted transmission lines. Thus the reactance variation of the transmission line section tend to compensate for reactance variations of the antenna. This results in more constant impedance of the antenna, around the resonance (or centre) frequency.

Not for harmonics

It may however, be noted that the folded antenna is of no use at twice the centre frequency (*i.e.* even harmonics). Because the short circuited transmission line sections are each $\lambda/2$ long now, which places a short circuit across the antenna terminals. This renders antenna useless at this frequency. This fact is of importance in connection with television receiving antenna. Further, similarly Yagi-uda antenna is also a broad band antenna as the driven element is almost always a folded dipole.

**9.2.3. *Uses of Folded Dipole.*** In conjunction with parasitic elements folded dipole is used in wide band operation such as television. In this, in the Yagi antenna, the driven element is folded dipole and remaining are reflector and director. Reflector is 5% longer than $\lambda/2$ and directors are by 5% smaller. Grounding is made at point $B$, the mid-point of unbroken arm.

**9.2.4. *Advantages.*** It has :

(i) High input impedance.

(ii) Wide band in frequency.

(iii) Acts as built in reactance compensation network.

## 9.3. YAGI-UDA ANTENNA

(AMIETE, May 1980, 1978, 1971, Dec. 1992, 1972)

Yagi-uda or simply Yagi (as generally but less correctly called) antennas or Yagis are the most high gain antennas and are known after the names of Professor S. Uda and H. Yagi. The antenna was invented and described in Japanese by the former some time around 1928 and afterwards it was described by H. Yagi in English. Since the Yagi's description was in English so it was widely read and thus it became customary to refer this array as Yagi antenna, although he gave full credit to professor Uda. Accordingly a more appropriate name the *Yagi-Uda* antenna is adopted following the practice.

It consists of a driven element, a reflector and one or more directors *i.e.* Yagi-uda antenna is an array of a *driven element* (or active element where the power from the $T_X$ is fed or which feeds received power to the $R_X$) and one or more *parasitic elements* (*i.e.* passive elements which are not connected directly to the transmission line but electrically coupled). The driven elements is a resonant half-wave dipole usually of metallic rod at the frequency of operation. The parasitic elements of continuous metallic rods are arranged parallel to the driven element and at the same line of sight level. They are arranged collinearly and close together as shown in Fig. 9.8 with one reflector and one director. The optical equivalent is also shown.

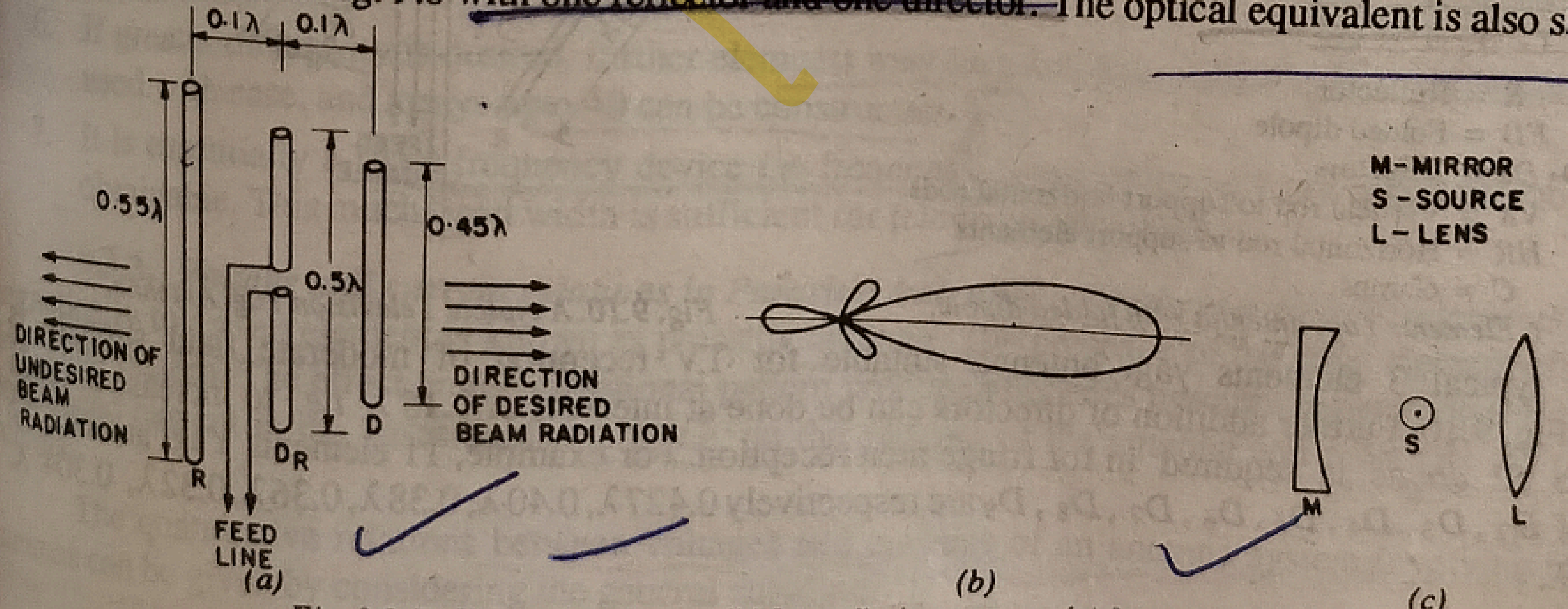



*Fig. 9.8 (a) Yagi-uda antenna, (b) Its radiation pattern, (c) Its optical equivalent*
*R = Reflector (Parasitic element) ; $D_R$ = Driven element ; D = Driector (Parasitic element).*

0.1 to 0.15λ spacing



The parasitic elements receive their excitation from the voltages induced in them by the current flow in the driven element. The phase and currents flowing due to the induced voltage depend on the spacing between the elements and upon the reactance of the elements (*i.e.*, length). The reactance may be varied by dimensioning the length of the parasitic element. The spacing between driven and parasitic elements that are usually used, in practice, are of the order of $\lambda/10$ *i.e.* $\boxed{0.10\,\lambda \text{ to } 0.15\,\lambda}$. The parasitic element in front of driven, element is known as *director* and its number may be more than one, whereas the element in back of it is known as *reflector*. Generally both directors and reflectors are used in the same antenna. The reflector is 5% more and director is 5% less than the driven element which is $\lambda/2$ at resonant frequency. In practice, for 3-element array of Yagi antenna the following formulae gives lengths which work satisfactorily.

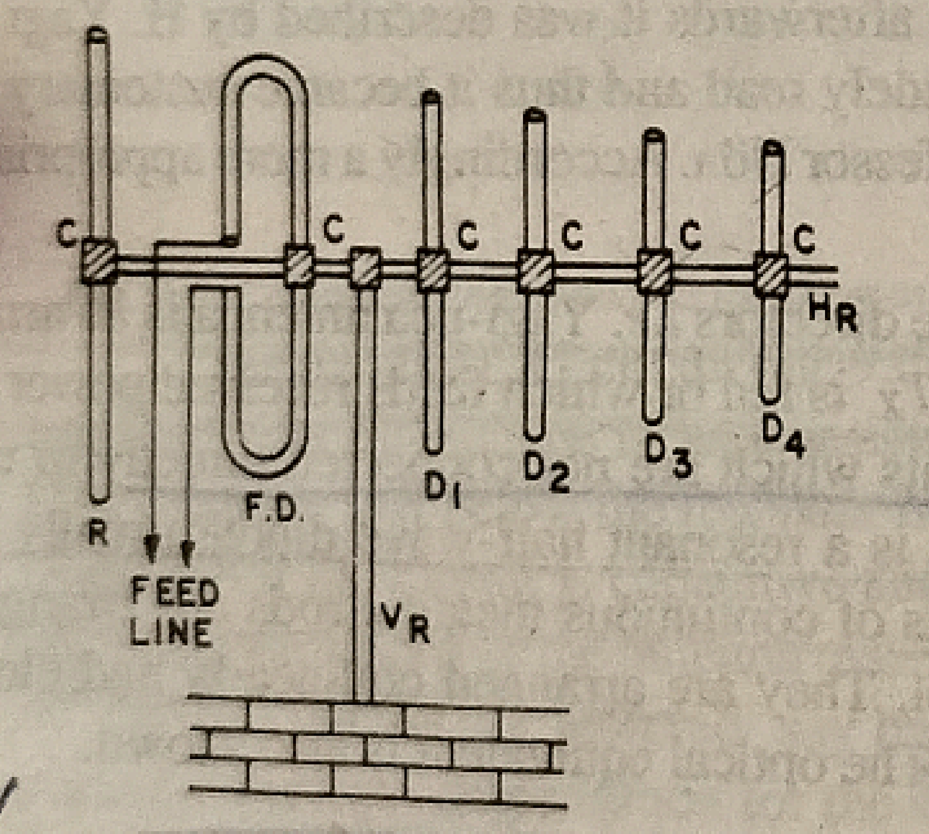
$$\textbf{Reflector length} = \frac{500}{f\,(\text{MHz})} \text{ feet} \qquad \text{... 9.8 (a)}$$

$$\textbf{Driven element length} = \frac{475}{f\,(\text{MHz})} \text{ feet} \qquad \text{... 9.8 (b)}$$

$$\textbf{Director length} = \frac{455}{f\,(\text{MHz})} \text{ feet} \qquad \text{.. 9.8 (c)}$$

Eqn. 9.8 provides average length of Yagi antenna determined experimentally for elements of length/diameter ratio of 200 to 400 and spacing from 0.10 λ to 0.20 λ. The parasitic elements can be clamped on a metallic support rod because at the middle of each parasitic element, the voltage is minimum *i.e.* there exists a voltage node. Even driven element may also be clamped if it is shunt feed. The clamping over the support rod makes a rigid mechanical structure.

Further use of parasitic elements in conjunction with driven element causes the dipole impedance to fall well below 73 Ω. It may be as low as 25 Ω and hence it becomes necessary to use either shunt feed or folded dipole so that input impedance could be raised to a suitable value, to match the feed cable. While using folded dipole the continuous rod may also be clamped to the support as shown in Fig. 9.9.




$R$ = Reflector
$FD$ = Folded dipole
$D_1\,D_2\,D_3\,D_4$ = Directors
$VR$ = Vertical rod to support horizontal rods
$HR$ = Horizontal rod to support elements
$C$ = clamps

*Fig. 9.9. 6 Elements Yagi antenna with folded dipole.*

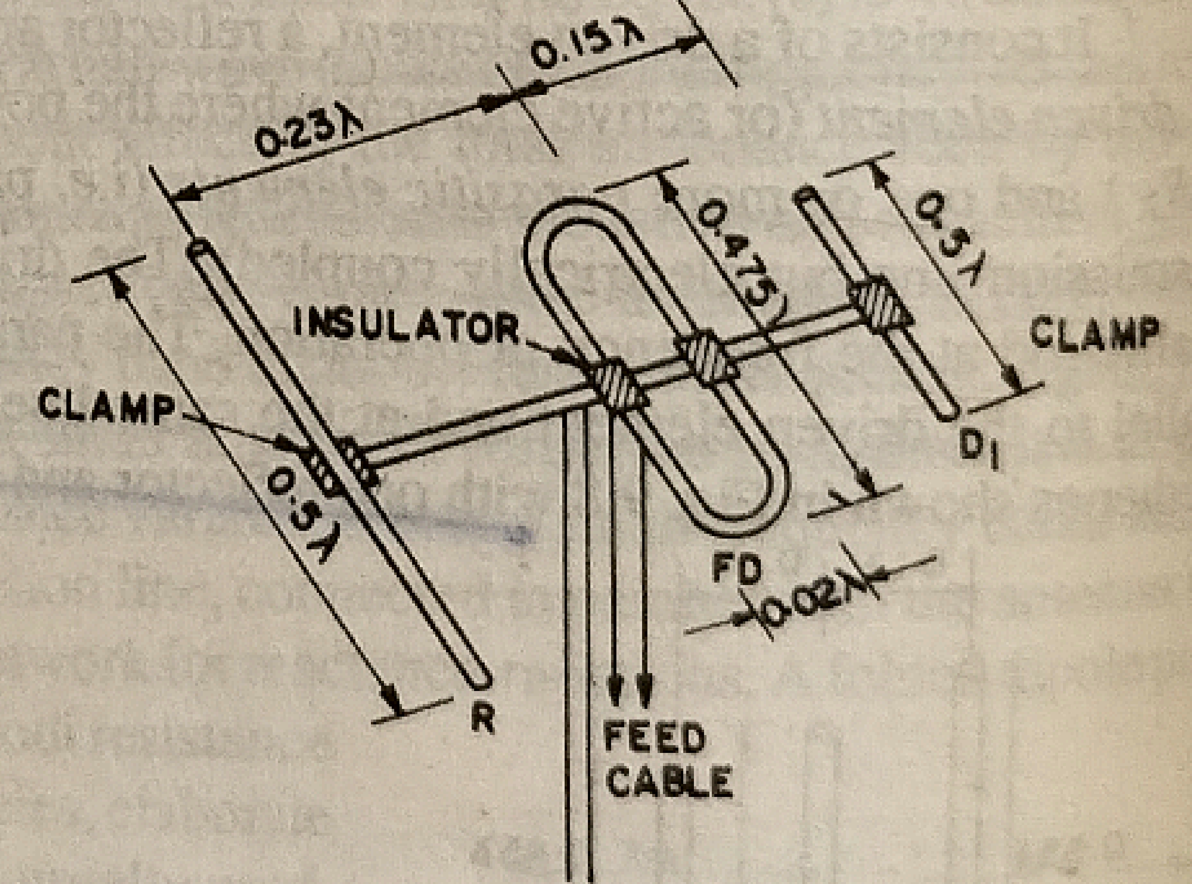



*Fig. 9.10. A typical Television Yagi Antenna.*

A typical 3 elements yagi antenna suitable for TV reception of moderate field strength is shown in Fig. 9.10. Further addition of directors can be done at intervals of 0.15 λ *i.e.* to increase the gain even upto 12 *db* as is required in for fringe area reception. For example, 11 elements Yagi antenna the lengths of $D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9$ are respectively 0.427 λ, 0.40 λ, 0.38 λ, 0.36 λ, 0.32 λ, 0.304 λ, and 0.29 λ.

Grdinchor - lag current
capacitor → lead ''



**9.3.1. *Action.*** The spacing between elements and the lengths of the parasitic elements determine the phases of the currents. Parasitic antenna in the vicinity of radiating antenna is used either to reflect or to direct the radiated energy so that a compact directional antenna system could be obtained.

A parasitic element of equal or greater length than $\lambda/2$, will be inductive while elements of length less than $\lambda/2$, will be capacitive. Hence, phases of the currents in the former case (*i.e.* length $> \lambda/2$), will lag the induce voltage whereas in latter case (*i.e.* length $< \lambda/2$) will lead the induced voltage. Properly spaced dipoles shorter than $\lambda/2$ acts as director and add the fields of driven element in the direction away from the driven element. If more than one directors are employed, then each director will excite the next. On the other hand an element of length equal or greater than $\lambda/2$ acts as reflector and add up the fields of driven element in the direction from reflector towards driven element, if properly spaced.

Additional gain is achieved by using additional directors in the beam direction. The distance between two elements may range from $0.1\lambda$ to $0.3\lambda$, close spacing of elements are used in parasitic arrays to get a good excitation. Addition of additional director (than one in 3 elements array) must be adjusted to achieve maximum gain. The greater the distance between driven and director elements, the greater the capacitive reactance needed to provide correct phasing of parasitic current. Therefore, the length of rod is tapered off to achieve the capacitive reactance instead.

The driven element radiates from front to rear ( *i.e.* from reflector to directors).

Part of this radiation induces current in the parasitic element(s) which in turn re-radiate virtually all the radiation. By suitable dimensioning the lengths of parasitic elements and spacing between two elements, the radiated energy is added up in front and tend to cancel the backward radiation. If the distance between driven and parasitic element is decreased, then it will load the driven element, irrespective of its length. Thus input impedance at the input terminals of driven element reduces. This is why a folded dipole is invariably used as driven element so that reduction in input impedance is compensated *i.e.* raised.

**9.3.2. *General Characteristic :-***

1. If three elements array (*i.e.* one reflector, one driven and one director) is used, then such type of Yagi-uda antenna is generally referred to as **beam antenna.**
2. It has unidirectional beam of moderate directivity with light weight, low cost and simplicity in feed system design.
3. With spacing of $0.1\lambda$ to $0.15\lambda$, a frequency band width of the order of 2% is obtained. Gain = 8 dB ~~FB~~ = 20 dB
4. It provides *gain* of the order of 8 *db* or **front to** *back ratio* of about 20 *db*.
5. It is also known as *super directive or super gain antenna* (as sometimes called) due to its high gain and beam-width per unit area of the array. An antenna or array which provides directive gain, appreciable greater than that obtainable from *uniform distribution* is known as *super directive or super gain antenna.*
6. If greater directivity is desired, further elements may be used. For example, five or six elements are used with ease, and arrays upto 40 can be constructed.
7. It is essentially a fixed frequency device *i.e.* frequency sensitive and a band width of about 3% is obtainable. This much band width is sufficient for television reception.

**9.3.3. *Voltage and current relations in Parasitic Antennas.*** One or more passive elements coupled magnetically to driven element is known as parasitic antenna. The presence of parasitic element effects the directional pattern. The effect on the directional pattern produced depends upon the magnitude and phase of the induced current in the parasitic elements *i.e.* on the *spacing* of the antenna and tuning of the parasitic antenna.

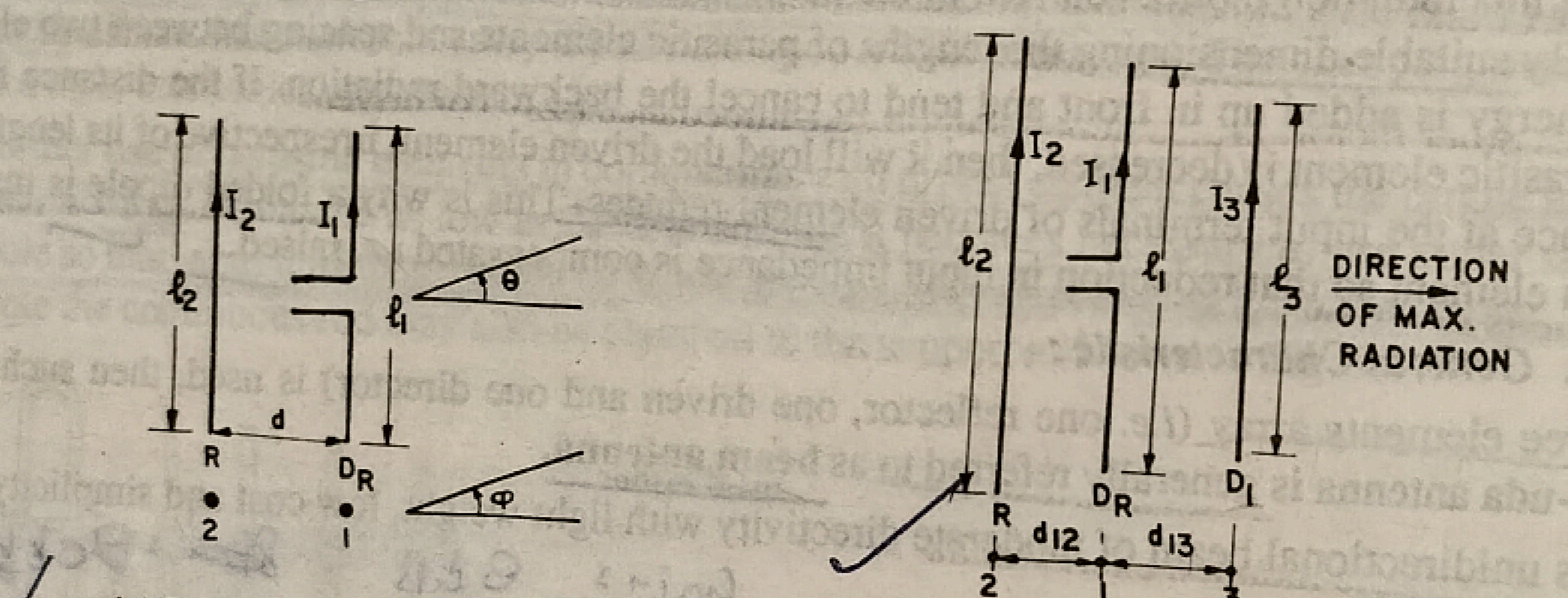
The quantitative relations between voltages and currents of an antenna system involving parasitic antennas can be given by considering the general equation.

$$V_1 = I_1 Z_{11} + I_2 Z_{12} + I_3 Z_{13} + ..... + I_n Z_{1n} \quad ...\ 9.9\ (a)$$
$$V_2 = I_1 Z_{21} + I_2 Z_{22} + I_3 Z_{23} + ..... + I_n Z_{2n} \quad ...\ 9.9\ (b)$$
$$V_3 = I_1 Z_{31} + I_2 Z_{32} + I_3 Z_{33} + ..... + I_n Z_{3n} \quad ...\ 9.9\ (c)$$
..........................................................................
$$V_n = I_1 Z_{n1} + I_2 Z_{n2} + I_3 Z_{n3} + ..... + I_n Z_{nn} \quad ...\ 9.9\ (d)$$

$V_1, V_2, V_3 ... V_n$ = Voltage applied to antenna no. 1, 2, 3, .... $n$.
$I_1, I_2, I_3 ... I_n$ = Current flowing in antenna no 1, 2, 3, .... $n$.
$Z_{11}, Z_{22}, Z_{33} ... Z_{nn}$ = Self–impedances of antenna no. 1, 2, 3, ..... $n$.
$Z_{12}, Z_{21}, Z_{13} ... Z_{31}$ = Mutual impedances between antennas of subscript *i.e.* $Z_{1n}$ means mutual impedance between antenna no. 1 and $n$.

If the individual antennas are not excited, then corresponding applied voltages *e.g.* $V_1$, $V_2$, $V_3$, etc. are zero. Thus in an antenna system involving parasitic antennas, the voltages are zero in case of transmitting while in receiving case these applied voltage are the voltages induced in each parasitic antenna by the electromagnetic waves.

Now considering the simplest case with one driven element (subscript 1) and one parasitic antenna (subscript 2) as shown in Fig. 9.11.




(a) *Driven element with one parasitic.* (b) *Driven element with two parasitic.*

*Fig. 9.11.* $\varphi$ = *Horizontal plane.*
$\theta$ = *Vertical plane.*

From general eqn. 9.9, we can write

$$V_1 = I_1 Z_{11} + I_2 Z_{12};\ V_2 = I_1 Z_{21} + I_2 Z_{22} \quad (\because Z_{12} = Z_{21};\ Z_{13} = Z_{31} \text{ etc. and } V_2 = 0 \text{ being parasitic})$$

$$\therefore \quad V_1 = I_1 Z_{11} + I_2 Z_{12} \quad ...\ 9.10\ (a)$$
$$0 = I_1 Z_{12} + I_2 Z_{22} \quad ...\ 9.10\ (b)$$

or $I_1 Z_{12} = -I_2 Z_{22};\ I_2 = -I_1 \left(\frac{Z_{12}}{Z_{22}}\right)$

$$I_2 = -I_1 \left|\frac{(R_{12} + j X_{12})}{(R_{22} + j X_{22})}\right| \frac{\angle \tan^{-1} \frac{X_{12}}{R_{12}}}{\angle \tan^{-1} \frac{X_{22}}{R_{22}}} \quad ...\ (9.11)$$

Putting eqn. 9.11 in 9.10 (a), we have

$$V_1 = I_1 Z_{11} - I_1 \left(\frac{Z_{12}}{Z_{22}}\right) \cdot Z_{12} = I_1 \left(Z_{11} - \frac{Z_{12}^{\ 2}}{Z_{22}}\right)$$

End 2



$$\boxed{I_1 = \frac{V_1}{Z_{11} - \dfrac{Z_{12}^2}{Z_{22}}}} \qquad \ldots (9.12)$$

or

$$I_2 = -I_1 \frac{Z_{12}}{Z_{22}} = -\frac{V_1}{\left(Z_{11} - \dfrac{Z_{12}^2}{Z_{22}}\right)} \left(\frac{Z_{12}}{Z_{22}}\right) = \frac{-V_1 (Z_{12})}{Z_{11} Z_{22} - Z_{12}^2}$$

and

$$\boxed{I_2 = \frac{V_1}{\left(Z_{12} - \dfrac{Z_{11} Z_{22}}{Z_{12}}\right)}} \qquad \ldots (9.13)$$

From eqns. 9.12 and 9.13, the input impedances of driven and parasitic elements are given by

$$Z_1 = \frac{V_1}{I_1} = Z_{11} - \frac{Z_{12}^2}{Z_{22}} \qquad \ldots (9.14)$$

and

$$Z_2 = \frac{V_2}{I_2} = Z_{12} - \frac{Z_{11} Z_{22}}{Z_{12}} \qquad \ldots (9.15)$$

Eqns. 9.14 and 9.15 indicate that presence of parasitic elements modifies input impedance of driven elements as the mutual impedance term $Z_{12}$ exists in the eqn. 9.14. Also the input impedance of parasitic element, besides other factor, is also dependent on self-impedance ( $Z_{11}$ ) of driven element. Further the field distribution of the antenna system is obtained by assuming a constant current in the driven element and calculating the magnitude and phase of current in the parasitic element. The field pattern $E_o$ ($\varphi$) in the horizontal plane is given by

$$E_\theta (\varphi) = k (I_1 + I_2/\beta d \cos \varphi) \qquad \ldots (9.16)$$

where $k$ is a constant and $I_1$ and $I_2$ are eqns. 9.12 and 9.13. A compact directional pattern is obtained due to the fact that parasitic antenna close to driven antenna is used either to reflect (by parasitic reflector) or to direct (by parasitic director) the radiated energy in the desired direction.

A still another typical values of Yagi–Uda antenna are $l_1 = 0.5\,\lambda$, $l_2 = 0.58\,\lambda$ and $l_3 = 0.45\,\lambda$ and $d_{12} = d_{13} = 0.1\,\lambda$. *For reflector, usually a spacing $\lambda/4$ is kept. However, for director a spacing $\lambda/4$ is less effective and hence a spacing of $0.15\,\lambda$ is commonly used. In practice, the effective impedance at the centre is achieved by cutting the length of parasite more or less (about 5%) than a $\lambda/2$ length.*

**9.3.4. *Adjustments.*** The most convenient way to adjust the parasitic antennas, for transmitting case, is to excite the driven element. Place a receiver at a convenient distance in the desired direction. Now vary the tuning of the parasitic antenna by cut and try until the best results are achieved.

For the array for receiving case, place a transmitter of small power at some convenient distance in the *undesired direction*. Then adjust the parasitic antenna by cut and try until a minimum response is indicated in the receiver associated with receiving antenna.

## 9.4. BICONICAL ANTENNA

The bi...

kept more than 15°.

## 9.16. FREQUENCY INDEPENDENT-LOG PERIODIC (DIPOLE ARRAY) ANTENNAS

(AMIETE, Nov. 1967, Dec. 1993)

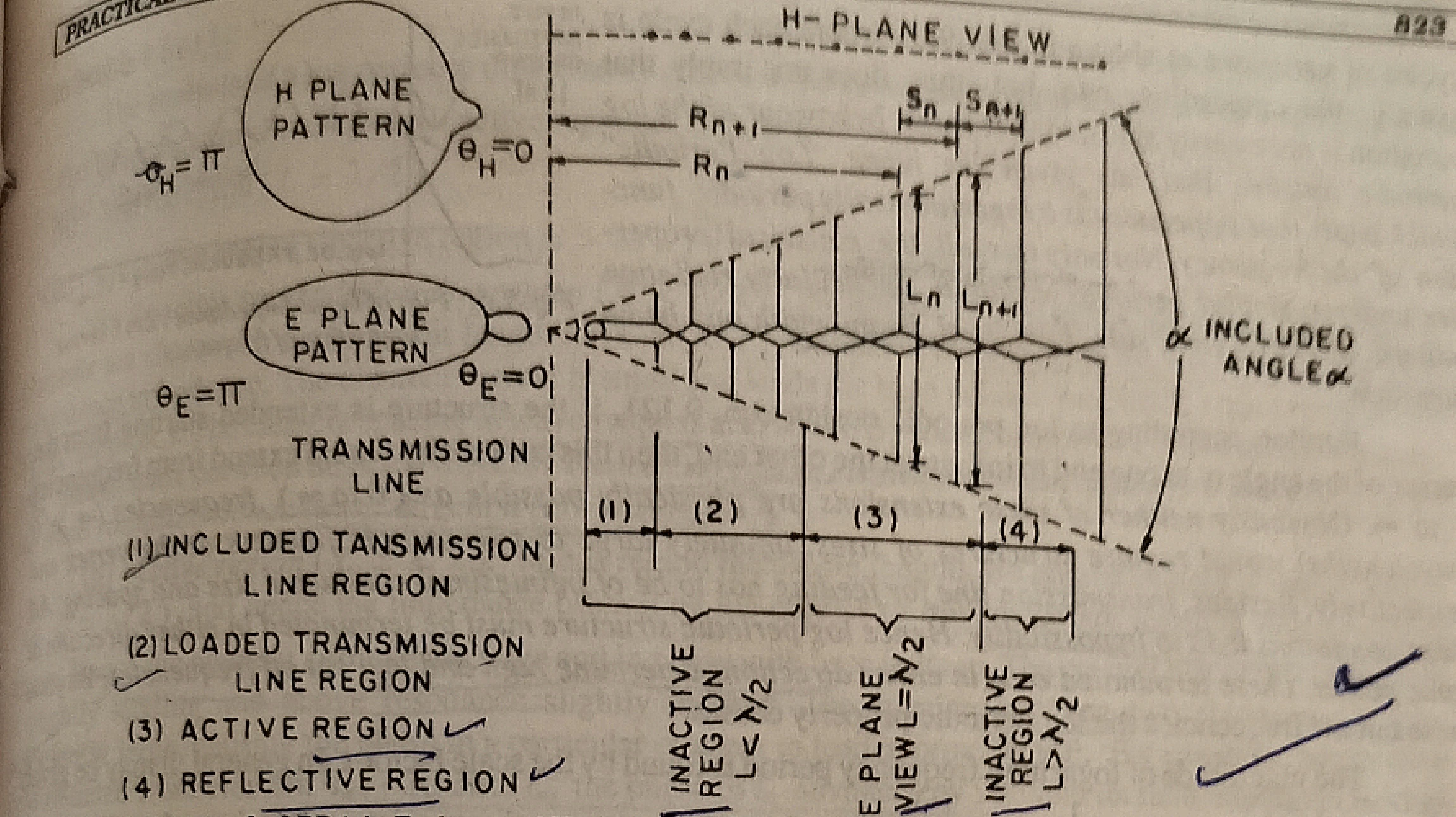
According to V.H. Rumsey, an antenna which is defined only interms of angles should have characteristics of frequency independent. A frequency independent (F.I.) antenna may be defined as *"the antenna for which the impedance and pattern (and hence the directivity) remain constant as a function of the frequency"*. Thus, in order that an antenna to be frequency independent, the antenna should expand or contract in proportion to the wavelength or if the antenna structure is not mechanically, adjustable, the size of active or radiating region should be proportional to the wavelength.

An effective approach to get broad band antenna design has been developed from the initial work of Rumsey, Dyson, Isbell and Duttamel. The development on the frequency independent concept was the Log Periodic Antennas.

Duttamel, starting from angle concept, reasoned that it is possible to force the radiation from otherwise "Angle structure" with the properly located discontinuities Log Periodic antennas are a class of antenna as rather than one type, as there are many different physical appearances. Even the name Log Periodic seems to the very much restrictive as it refer only one aspect of their behaviour. Log Periodic antennas are broad band antennas. Bandwidth of 10 : 1 is achieved easily and even 100 : 1 is feasible if the theoretical design closely approximated. The broad band characteristics of Log Periodic antennas include both impedance and pattern. Radiation pattern may be bi-directional or unidirectional of low to moderate directive gain. Much higher directive gain can be achieved by using them as an elements of an array. They are most recent, having first, been proposed in 1957.

The geometry of Log Periodic antenna structure is so chosen that electrical properties must repeat periodically with the logarithm of the frequency. Frequency Independence can be obtained when the variation of the properties over one period, and hence all the periods, is small.

The design of log periodic antenna involves a basic geometric structure that is repeated but with a changing size of the structure. The structure size changes with each repetition by a *constant scale factor* so that the structure expand or contract. The log periodic principle can be understood by the "**Log Periodic Dipole**




(b) Radiation pattern of a LPDA in E-plane and H-plane. (a) A log periodic dipole array with main region of operation.
Fig. 9.60.

Array" (LPDA) of Fig. 9.60. This LPDA is due to D.E. Isbell. It is seen that all the dimensions increase in proportion to the distance from the origin. It has a number of dipoles of different lengths and spacings and is fed by a balanced two wire transmission line which is transposed between each adjacent pairs of dipoles. It is fed at narrow end and the maximum beam radiation is as shown. The dipole length increases along the antenna such that included angle α is constant. The lengths and spacings are graduated in such a way that certain dimensions of adjacent elements bear a constant ratio to each other. These dimensions are length $L$ and spacing $R$ (or $S$). The scale factor or design ratio is designed by τ (Tou) whose value is less than 1. Thus dipole, lengths and spacings are related as

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

or

$$\boxed{\frac{R_n}{R_{n+1}} = \frac{L_n}{L_{n+1}} = \tau} \qquad \ldots 9.121\ (a)$$

$\frac{R_n}{R_{n+1}} = \frac{L_n}{L_{n+1}}$ -2

τ is known as, design ratio, or scale factor or Periodicity factor. Alternatively eqn. (9.121) may also be written sometimes, as

$S_{n+1}$

$$\frac{S_{n+1}}{S_n} = \frac{L_{n+1}}{L_n} = \frac{1}{\tau} = k$$

or

$$\boxed{\frac{S_{n+1}}{S_n} = \frac{L_{n+1}}{L_n} = k; \quad k > 1} \qquad \ldots 9.121\ (b)$$

Obviously, these two conditions cause the ends of the dipoles to lie along two straight lines that meet at an angle α at one end and converges at the other end of the structure. The typical values of α = 30° and τ = 0.7. The characteristic of an frequency independent antenna that it can be defined in terms of an angle is met here. From this structure, it is seen that there is a repetitiveness in the physical structure which provides repetitive behaviours of the electrical characteristics.

If now a graph is plotted between input impedance | $Z_{in}$ | (or SWR on the feed line) and frequency a repetitive variation will be observed. If this plot is made against the logarithm of the frequency, (instead of frequency itself) this variation will be periodic. In other words input impedance | Zin | will go through identical

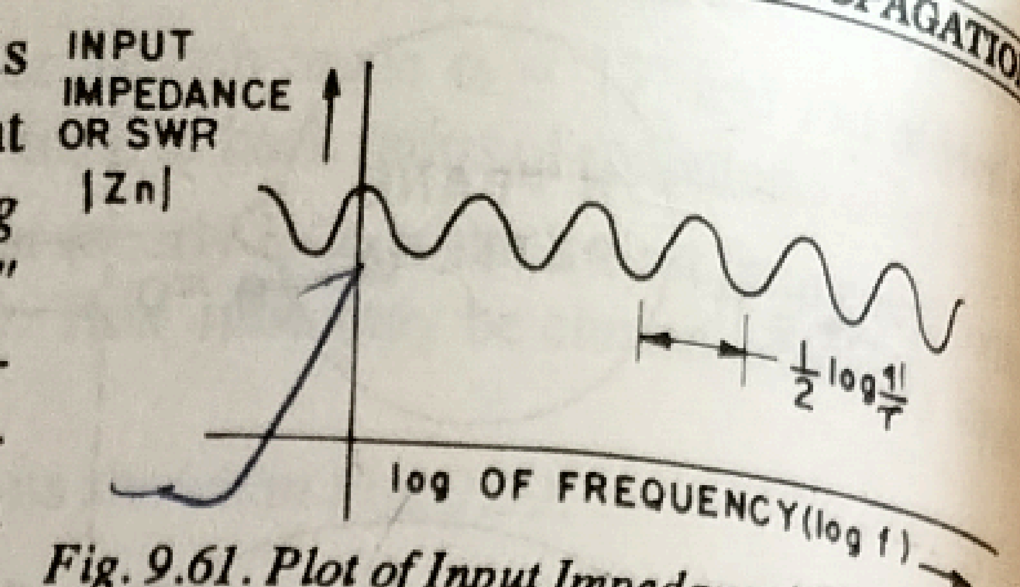



*Fig. 9.61. Plot of Input Impedance | Zin | versus logarithm of frequency.*

cycles of variations as shown in Fig. 9.61 where each cycle is exactly like preceding one but this does not imply that variation is necessarily sinusoidal. *It is this behaviour of the log periodic antenna that has given the name "Log Periodic" which imply that impedance is a logarithmically periodic function of the 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.*

Further, according to log periodic design eqn. 9.121, if the structure is extended starting from the vertex of the angle $\alpha$ at one end to infinite at the other end, then this periodicity would extend from frequencies 0 to $\infty$. *Obviously neither of these extensions are physically possible as ( 0 to $\infty$ ) frequencies ($\infty$ to 0 wavelengths) would require structures of sizes, infinitely large to microscopic fineness at the vertex end respectively. Besides, transmission line for feeding has to be of infintesimal conductor size and spacing. All these conditions lead to impossibility. Hence log periodic structure must be terminated in either direction at some points. These terminated ends in either directions determine high and low cut off frequencies.* Beyond these cut off frequencies the log periodic property ceases.

The magnitude of logarithm frequency period is found by the scale factor $\tau$. In general, it may be given by $\left(\log \cdot \frac{1}{\tau}\right)\left(\text{sometimes } \frac{1}{2} \log \cdot \frac{1}{\tau}\right)$. Therefore, if two consecutive maxima, of the impedance variation occurs at frequencies $f_1$ and $f_2$, then they are related as

$$\log \frac{f_2}{f_1} = \log \frac{1}{\tau} \text{ or } \frac{f_2}{f_1} = \frac{1}{\tau}$$

or

$$\boxed{f_1 = \tau f_2 \qquad f_2 > f_1} \qquad \text{... (9.122)}$$

This indicates that whatever properties a log periodic antenna is having at frequency $f$, the same properties will be repeated at frequencies given by $(\tau^n f)$ or at $\frac{f}{\tau^n}$ where $n$ is an integer, provided these frequencies are within cut off limits of the antenna.

When the log periodic antenna is operated at a given frequency, it is observed that all the structure does not radiated but only a certain portion radiates known as "active region". Active region is that region in which dipoles have nearly resonant length *i.e.* $\lambda/2$. The cut off frequencies are those frequencies at which the longest and shortest dipoles are nearly half wavelength (*i.e.* resonant length). Hence the active region of the antenna is towards apex (shorter element) for highest frequencies at middle for intermediate frequencies and near longest elements for lowest frequencies. In other words phase centre of the antenna shifts from longest end to shortest end as the frequencies change from minimum to maximum. The maximum to minimum ratio of frequencies determines the bandwidth.

The radiation pattern of a log periodic antenna may be bi-directional (for structures having two active regions and fed at the centre, to be seen latter) and unidirectional (for structure having only one active region like this) depending upon the log periodic structures. The input impedance depends chiefly on the characteristic impedance of the transmission line that feeds the antenna.

The gain for a properly designed antenna lies between 7.5 *db* to 12 *db* in comparison to isotropic antenna. For a particular bandwidth, higher value $\alpha$ and smaller value of $\tau$ give more compact design. Whereas in *vice-versa* condition *i.e.* smaller value of $\alpha$ and higher value of $\tau$ give improved performance but the size of structure increases. Hence larger value of gain and smaller variation in impedance and pattern is obtained at the cost of a large structure in this case. The value of $\tau$ lies between 0 to 1. The input impedance lies between 50 Ω to 200 Ω. The raditsyion patterns in *E*-plane and *H*-plane are shown in Fig. 9.60 (b). A typical values for a 11 element Log Periodic dipole arrays are $\alpha = 30°$, $n = 11$, $\tau = 0.8$. Directivity = 6 (8 *db*).

Bandwidth = 3 to 1.

The analysis of a log periodic dipole array can be done by considering three region of the antenna :

(i) Transmission-line region (Inactive region $L < \lambda/2$),

(ii) Active region ($L \simeq \lambda/2$)

(iii) Reflective region (Inactive region $L > \lambda/2$)

(i) ***Inactive transmission line region*** ($L < \lambda/2$). At middle of the operating range, the antenna elements are short with the resonant length *i.e.* $L \le \lambda/2$, therefore, the elements present a relatively high capacitance impedance. The element current is small and leads the base voltage supplied by transmission line by 90° (approx.). The element spacing in wavelength is also small. By transposition of transmission introduces 180° phase shaft between adjacent dipoles. *Hence currents in elements of these region are small and hence the small radiation in backward direction (towards left).*

(ii) ***Active region*** ($L \simeq \lambda/2$). In this region the dipole lengths are approximately resonant length (*i.e.* $L \simeq \lambda/2$) and hence the impedance offered by the dipoles of this region are resistive appreciably in nature. Hence the element currents are large and in phase with base voltage. The current just below resonance is slightly leading and above resonance slightly lagging. The spacing between two elements are now sufficiently large, causing the phase in a particular element to lead approx. by 90°. For example, by the time field radiated from element $l_{n+1}$ reaches $l_n$, the phase of $l_n$ advances by 90° and its field add to the field of $l_{n+1}$ elements, in phase producing a large resultant field towards left. Hence there is strong radiation towards left in backward direction and a little radiation towards right.

(iii) ***Inactive reflective region*** ($L > \lambda/2$). The element (dipoles) lengths are longer than the resonant length (*i.e.* $L \ge \lambda/2$) hence the impedance becomes inductive, causing the currents in the elements to lag the base voltage. The base voltage supplied by transmission line is now very much small as almost all the energy transmitted down the line has been attracted and radiated by the active region. This region presents a large reactive impedance to the line and thus, any small amount of incident wave from active region is reflected back towards backward direction.

**9.16.1. *General Characteristics.*** From the analysis of *LPDA*, it is apparent that

(1) Log Periodic antenna or array is excited from the shorter length side or high frequency side for one active region Log Periodic antenna and at the centre for two active region Log Periodic antenna. They are fed by a balanced two wire transmission line.

(2) There are an infinite variety of Log Periodic structures possible but not all structures would be frequency independent. A successful and most practical structures are few. Broad band will be with those log periodic antennas which have small variation in periodicity properties.

(3) For unidirectional Log Periodic antenna the structure fires in backward direction (towards shorter element) and forward radiation is very small or zero (towards right).

For bidirectional L.P. antenna the maximum radiation is in broadside direction *i.e.* normal to the surface of antenna.

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

(5) 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.

Typical values are $\lambda/4$ spacing and 90° phase (zero phase for bidirectional).

(6) 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.

**9.16.2. Design of Log Periodic Dipole Array.** The most recognized log periodic antenna structure, atleast to a lay man, is the configuration shown in Fig. 9.60 which is due to D.E. Isbell. LPDA consists of a sequence of side by side parallel linear dipole forming a coplanar array. The dipole array antenna has similar directivity as the Yagi-Uda array nearly 7 *db* to 12 *db* but they are achievable and maintained at much wider bandwidth. The geometrical dimensions of the Yagi-Uda array elements, on one hand, do not follow any set pattern, the Lengths (Ln's), spacings (Rn's), diameters (dn's) and even gap spacings at dipole centres ($a_n$'s) of the Log Periodic Dipole Array (LPDA) antenna, on the other hand, increase logarithmically as inverse of the geometric ratio $\tau$. Thus combining eqn. 9.121 (a, b) we have

$$\boxed{\frac{L_{n+1}}{L_n} = \frac{S_{n+1}}{S_n} = \frac{R_{n+1}}{R_n} = \frac{d_{n+1}}{d_n} = \frac{a_{n+1}}{a_n} = \frac{1}{\tau}} \quad \text{... 9.121 (c)}$$

where $n = 1, 2, 3 \ldots\ldots n.$

Still another parameter which is normally associated with LPDA design is the **spacing factor** ($\sigma$) defined as

$$\boxed{\sigma = \frac{R_{n+1} - R_n}{2 L_n} = \frac{S_n}{2 L_n}} \quad \text{... 9.121 (d)}$$

The straight lines through the dipole ends meet to form an angle (a wedged shape cone) which is a characteristic of frequency independent structures.

The log-period dipole array shown in Fig. 9.60 is a popular design. The dipole lengths increases along the antenna so that the included angle $\alpha$ is a constant and the length $L$ and spacing $S$ of adjacent elements are scaled so that

$$\boxed{\frac{L_{n+1}}{L_n} = \frac{S_{n+1}}{S_n} = k = \frac{1}{\tau}} \quad \text{... 9.121 (b)}$$

where $k$ = constant.

Since at any given frequency only a fraction of the antenna is used where the dipoles are about $\lambda/2$ long. From the geometry of the Fig. 9.62 for a section of the array, we have

$$\boxed{\tan \alpha/2 = \frac{\left(\frac{L_{n+1} - L_n}{2}\right)}{S} = \frac{(L_{n+1} - L_n)}{2S}} \quad \text{.. (9.123)}$$

But from eqn. 9.121 (b) $\quad \dfrac{L_{n+1}}{k} = L_n$

and for active region $\quad L_{n+1} \equiv \lambda/2$

We may write eqn. (9.123) as

$$\tan \alpha/2 = \frac{L_{n+1} - \frac{L_{n+1}}{k}}{2S} = \frac{L_{n+1}\left(1 - \frac{1}{k}\right)}{2S}$$

$$= \frac{\lambda\left(1 - \frac{1}{k}\right)}{2 \times 2S} \qquad \text{Since } L_{n+1} \equiv \lambda/2$$

$$\boxed{\tan \alpha/2 = \frac{\left(1 - \frac{1}{k}\right)}{4\, S/\lambda}} \quad \text{... (9.124)}$$

$\frac{L_{n+1}}{k} = L_n$

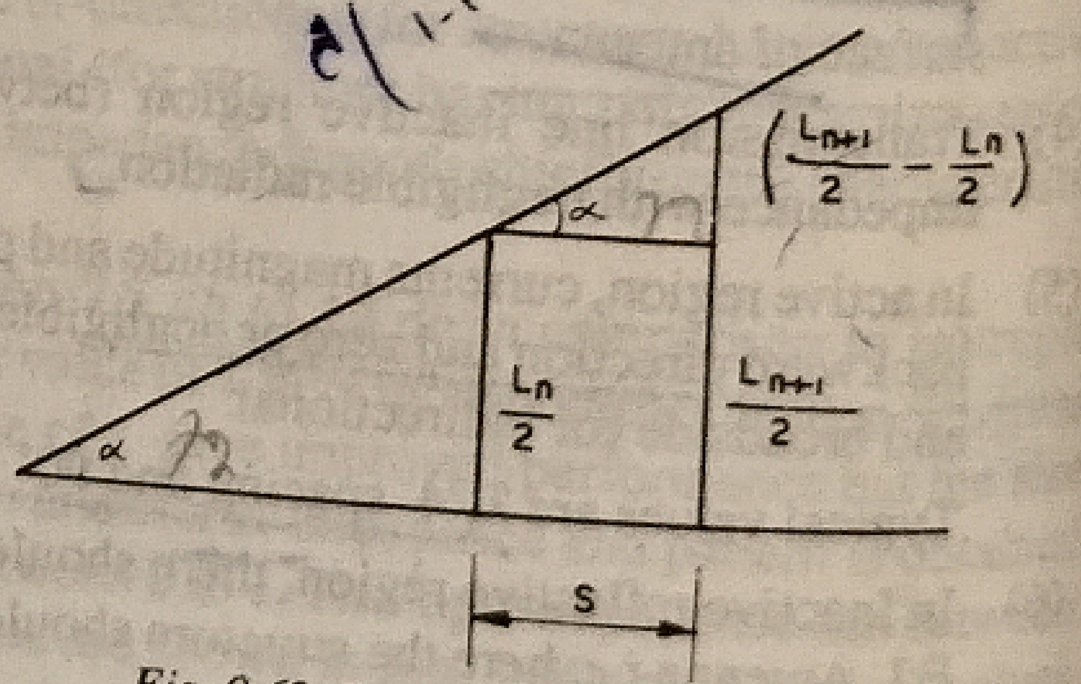



*Fig. 9.62. Section of log-periodic array and determination of parameters.*

where $\alpha$ = Apex angle ; $k$ = scale factor

$S/\lambda$ = spacing in wavelength shortward of $\lambda/2$ elements.

By specifying two parameters out of three parameters ( $\alpha$ , $k$ , $S/\lambda$ ) the third one can be determined. Now the length ( $L$ ) for any element $n + 1$ is $k^n$ greater than for element 1 or

$$\frac{L_{n+1}}{L_1} = k^n = F \text{ ( say )} \qquad \text{... (9.125)}$$

where $F$ = Frequency ratio or bandwidth.

Hence for optimum design ( *i.e.* maximum gain for a scale factor $K$) due to "Carrel R.L. is

$$k = 1.19 \text{ ; Then for } n = 4$$

$$F = k^n = (1.19)^4 = 2.0053$$

$$F \simeq 2$$

and elements $= n + 1 = 4 + 1 = 5$

Hence for 5 elements dipole array and $k = 1.19$, the frequency ratio ( $F$ ) is 2 : 1.

The design of the LPDA involves the determination of the spacing factor ($\sigma$) and scale factor $\tau\left(\frac{1}{k}\right)$. The spacing factor gives the successive dipole spacing and the scale factor determines the length of the successive dipoles forming a wedge shaped cone.

The most introductory, practical and complete design procedure for a LPDA is due to R.L. Carrel. The general configuration of a log periodic array is described by parameters $\tau$ , $\sigma$ and $\alpha$ which can be obtained from eqn. 9.124.

$$\tan \alpha/2 = \frac{1 - \frac{1}{k}}{4\, S/\lambda} = \frac{1 - \tau}{4\, S/\lambda}$$

or

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

or

$$\boxed{\sigma = \frac{1 - \tau}{4 \tan \alpha/2}} \qquad \text{... 9.121 (e)}$$

Alternatively,

$$\tan \alpha/2 = \frac{1 - \tau}{4\sigma}$$

or

$$\alpha/2 = \tan^{-1}\left(\frac{1 - \tau}{4\sigma}\right) \qquad \text{... 9.121. (f)}$$

or

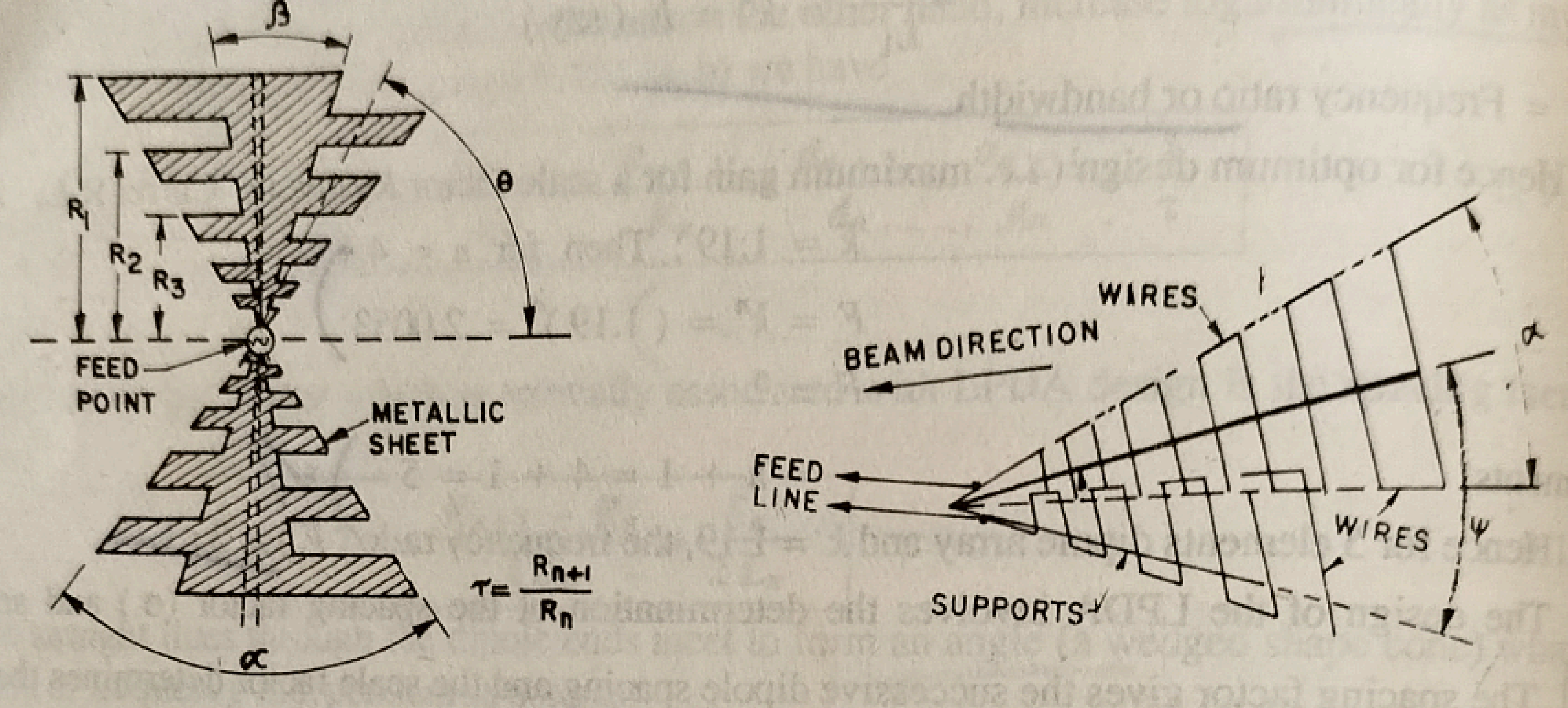
$$\boxed{\alpha = 2 \tan^{-1}\left(\frac{1 - \tau}{4\sigma}\right)} \qquad \text{... 9.121 (f)}$$

Once out of three parameters ( $\sigma$, $\tau$ and $\alpha$ ) two are specified, the third is determined.

**9.16.3. *Practical Log Periodic Structures.*** Since there are unlimited structures have been found suitable for Log Periodic antennas, only — few which are most successsful and practical — are sketched as representative.

The trapezoidal tooth Log Periodic antenna metallic version Fig. 9.63 (a) and wire version Fig. 9.63 (b) are shown. The latter being commonly used as a moderately directive steerable HF communication antenna. It has two arms converging at the vertex of antenna. Each arm has usual characteristic angle $\alpha$ for the design, while the angle $\psi$ influence the directional characteristics. When $\psi$ = 180° a structure of

Figure. Fig.. 9.63 (a) is obtained. Fig. 9.63. (a) has bi-directional pattern and normal to plane of antenna. If angle $\psi$ is acute the pattern changes to undirectional towards vertex. Infact *LPDA* (Fig. 9.61) structure is specialized form of trapezoidal tooth structure Fig. 9.63 (b), if width of teeth is reduced to zero, and angle $\psi$ is reduced from 180° to 0°, and two branches have been folded over until they are in same phase but without electrical contact. Radiation pattern of Fig. 9.63 (a) is bi-directional in broadside way *i.e.* perpendicular to paper.




*(a) A planar (Trapezoidal Tooth) log periodic structure.* *(b) Wire Trapezoidal tooth antenna.*

*Fig. 9.63.*

As L.P. structure demands thickness of the metallic sheets and diameter of the wire should increase linearly with distance from the vertex of the half structures, theoretically. However, this is not necessary in practice for a bandwidth of 5 : 1. for greater bandwidth more tapering is needed. Bandwidth of 20 : 1 is achieved with ease and bandwidth of 100 : 1 is feasible with careful design etc. etc.

### 9.16.4. *Uses.*

(1) Like rhombic the uses of Log Periodic antennas lie mainly in the field of HF communication where multiband steerable (rotatable) and fixed antennas are generally used. However it has advantage that no power is wasted in terminating resistance.

(2) Log Periodic is also used for television reception where only one Log Periodic design will suffice for all the channels even upto UHF band.

(3) It is best suited for all ~~round monitoring~~ in which case a single L.P. antenna will cover all the higher frequencies bands, if the cost in the installation is no problem.

## 9.17. MICROWAVE ANTENNAS

(AMIETE Dec. 1993)

UHF and SHF bands are respectively 300—3,000 MHz and 3,000—30,000 MHz but the microwave region starts from 1000 MHz and extend upto 100,000 MHz. The corresponding wavelength is in centimeters 1 cm and less. The transmitting and receiving antennas for use in the microwave spectrum (1000—00 MHz) tend to be directive *i.e.* high gain and narrow beam—width in both horizontal and vertical

Theoretically all the antennas and antenna-arrays studied so far could be used at all frequencies but n practice the actual shape of antenna depends to a large extent on the frequency band for which it is designed. Although wire or rod antennas can be and are used either singly or in arrays at UHF and SHF but other types utilizing reflecting or radiating surfaces are generally more practical and hence used extensively. As the frequency increases, the wavelength decreases and thus it becomes easier to construct an antenna system that are large in terms of wavelengths, and which therefore can be made to have greater directivity. At microwaves frequencies the physical size of a high gain antenna becomes small enough to make practical the use of suitably shaped metallic reflectors to produce the desired directivity. *Here Reflectors are curved surfaces, unlike previously where it was plane surface.* The most important practical antennas in microwaves