CHAPTER 3: ANTENNA CLASSIFICATIONS

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COURSE STRUCTURE

- ISOTROPIC ANTENNA
- OMNI DIRECTIONAL ANTENNA; DIPOLE
- DIRECTIONAL ANTENNAS
- TRAVELLING WAVE ANTENNAS – SINGLE WIRE, V AND RHOMBUS REFLECTOR ANTENNAS – LARGE PLANE SHEET, SMALL PLANE SHEET, LINEAR, CORNER, PARABOLIC, ELLIPTICAL, HYPERBOLIC AND CIRCULAR REFLECTOR. APERTURE ANTENNA - HORN ARRAY ANTENNAS – YAGI-UDA, LOG PERIODIC OTHER ANTENNAS – MONOPOLE, LOOP, HELICAL, MICROSTRIP.

Derive a relation to show the impedance of a folded dipole is 300 Ω or four times of single dipole.

For single Centre fed half wave dipole antenna the radiation resistance is Rrad = 73.09 or nearly 75 Ω. The power radiated (Prad) dipole = I^2rms.Rrad …(i)

But for the folded dipole having the same current Irms at the feed point, at a distance point p which is regarded as being at the same distance from both the antenna, the electric and magnetic field intensities will both be doubled.Hence the power received at the point p will be (2EΘ) (2Hϕ) = 4EΘHϕ or four times that for a single dipole antenna.

This means that (Prad) folded dipole = 4(Prad) dipole

=I^2rms (4Rrad) dipole

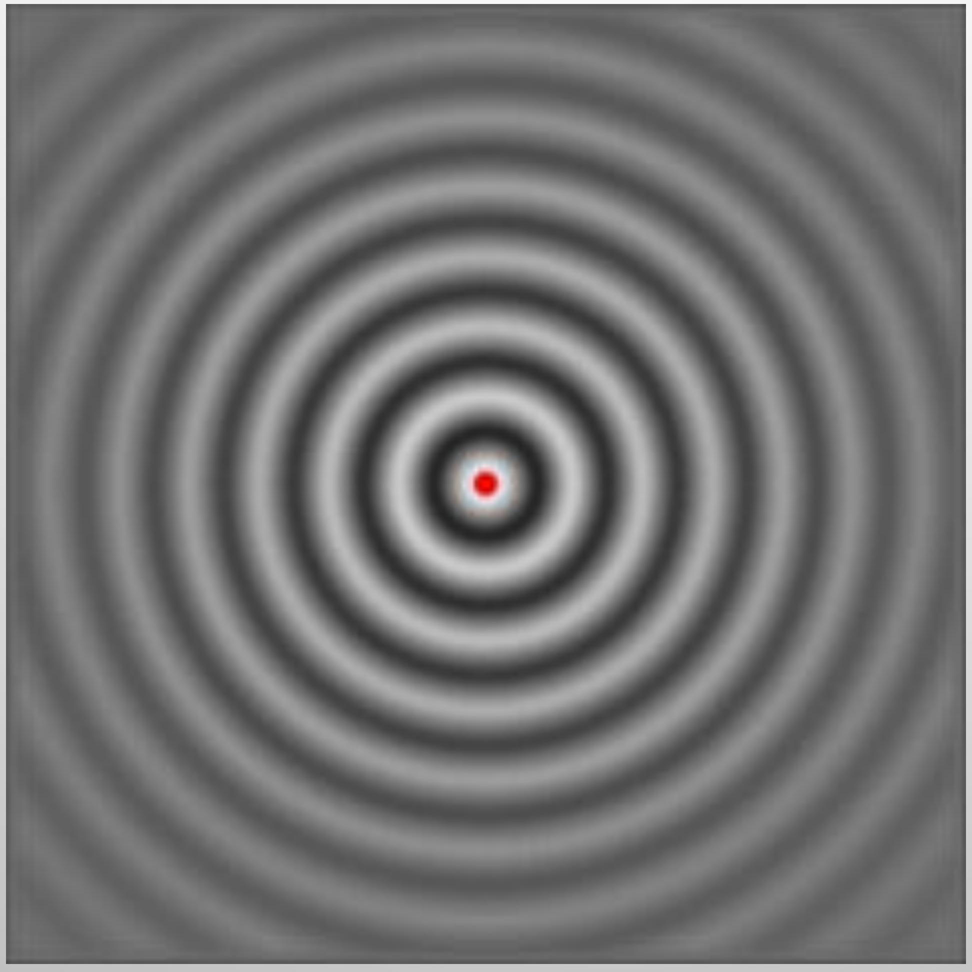
Hence (Rrad) folded dipole = 4(Rrad) dipole

= 4x75

300Ω.

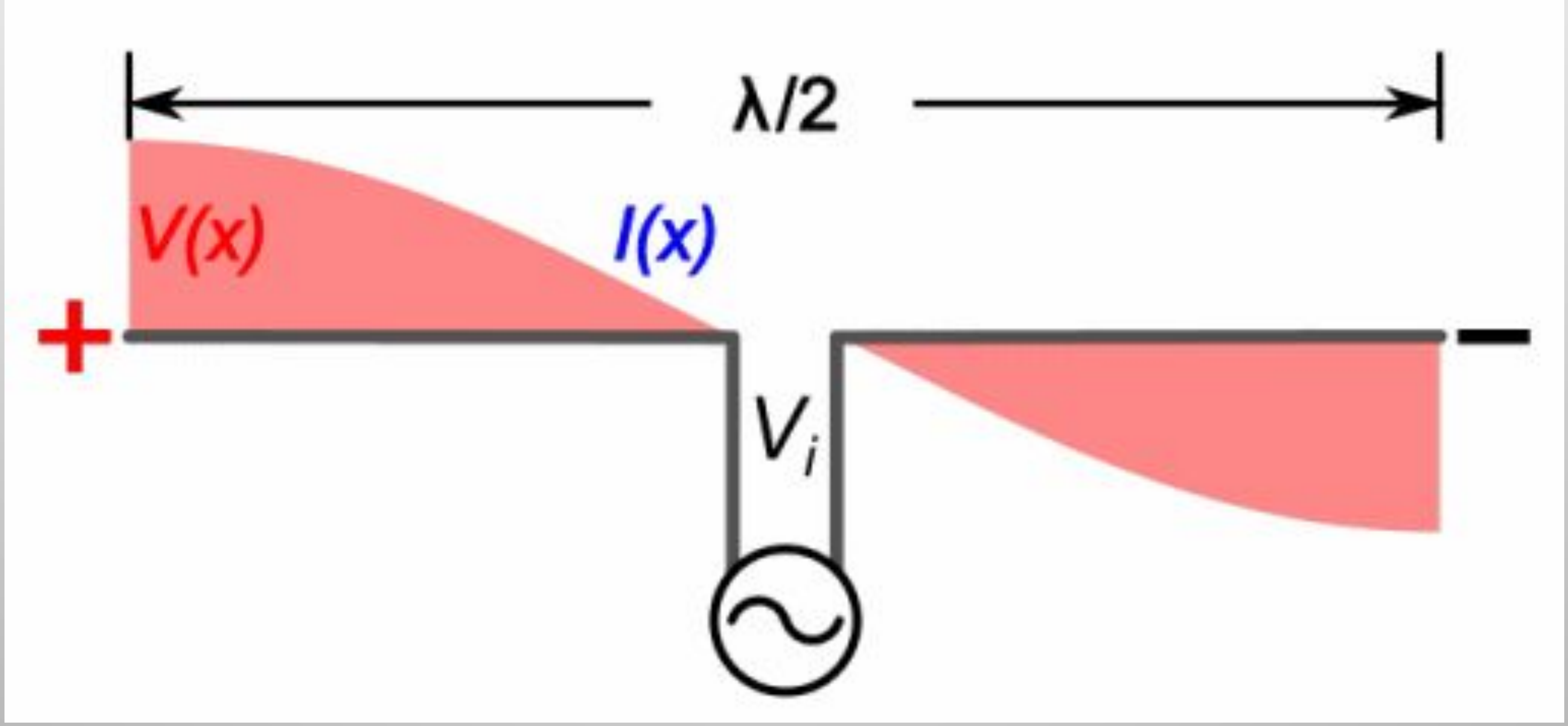
Isotropic antenna

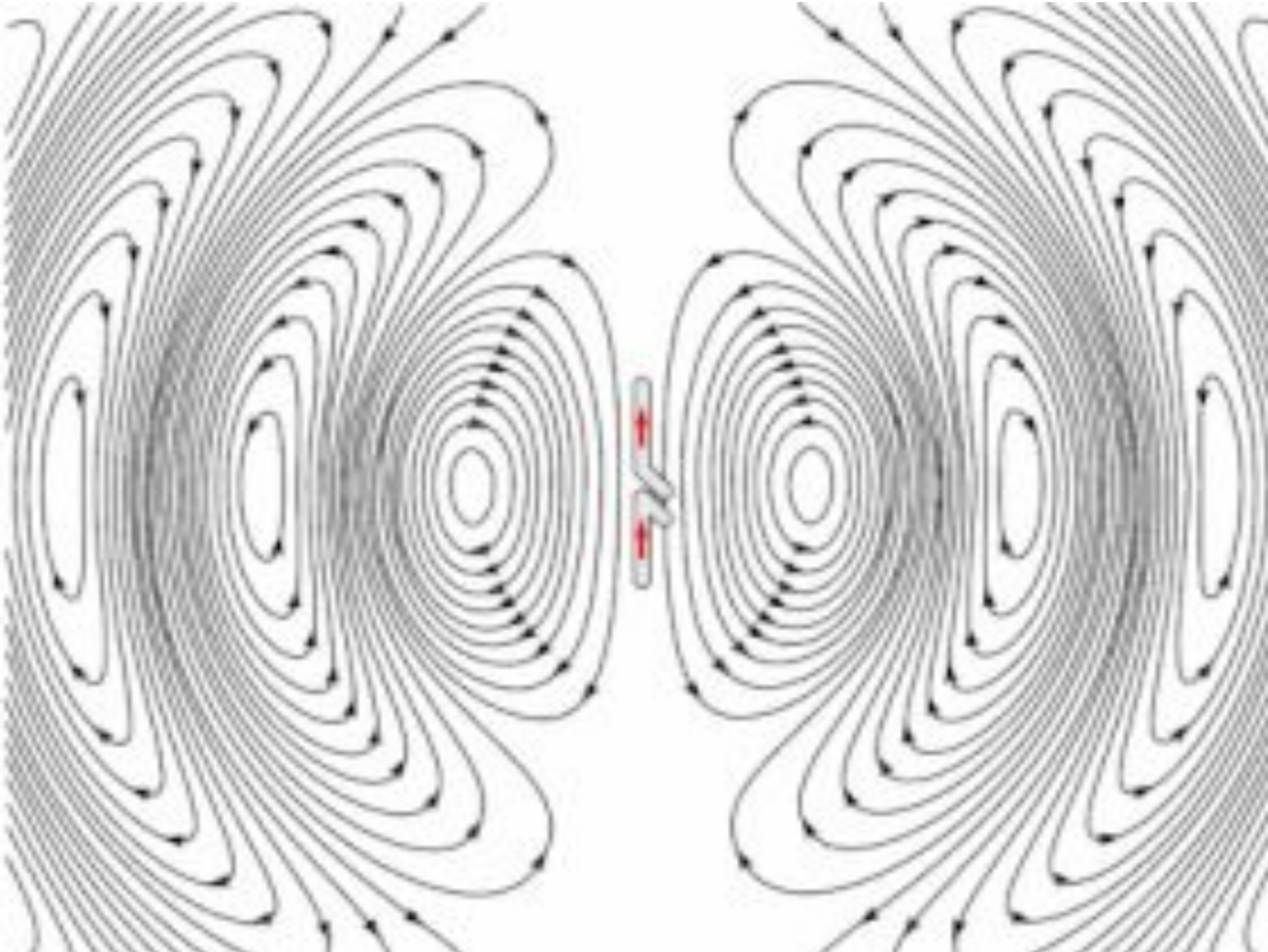
A hypothetical antenna having equal radiation in all direction is called isotropic pattern, which is independent of θ (angle of elevation) & φ (angle of azimuth). It is taken as a reference antenna for the study of properties of all typed of practical antenna parameters.



Omni- directional antenna

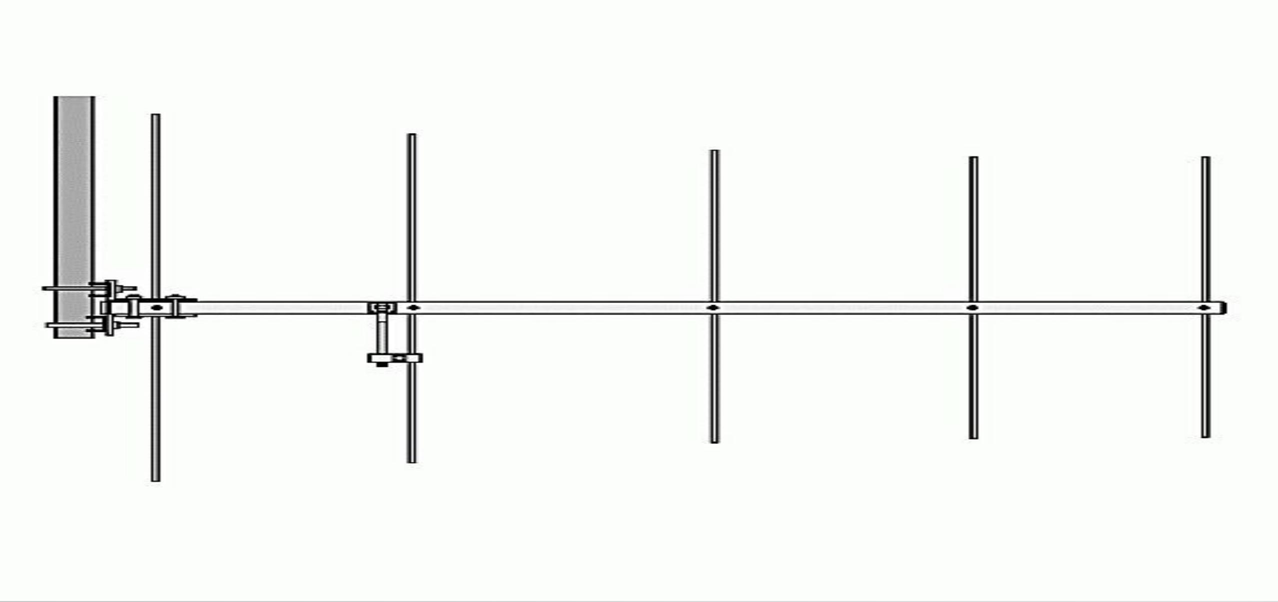
An antenna having the property of radiating or receiving E.M waves as a function of θ(angle of elevation) only is called Omni -directional antenna and it's pattern- Omni directional pattern i.e. dipoles.

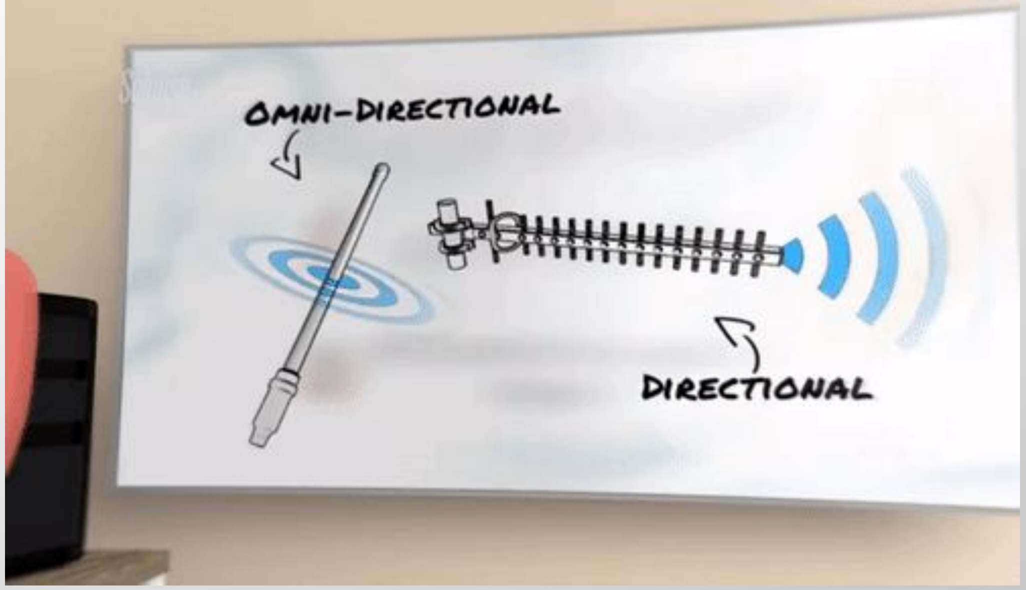




Directional antenna

An antenna having the property for radiating or receiving E.M waves more efficiently in some directions then in others is called directional antenna and its pattern the directional pattern. It is a function of θ and / or φ. i.e. V antenna and rhombic antenna.





Resonant Antenna and Non-Resonant Antenna

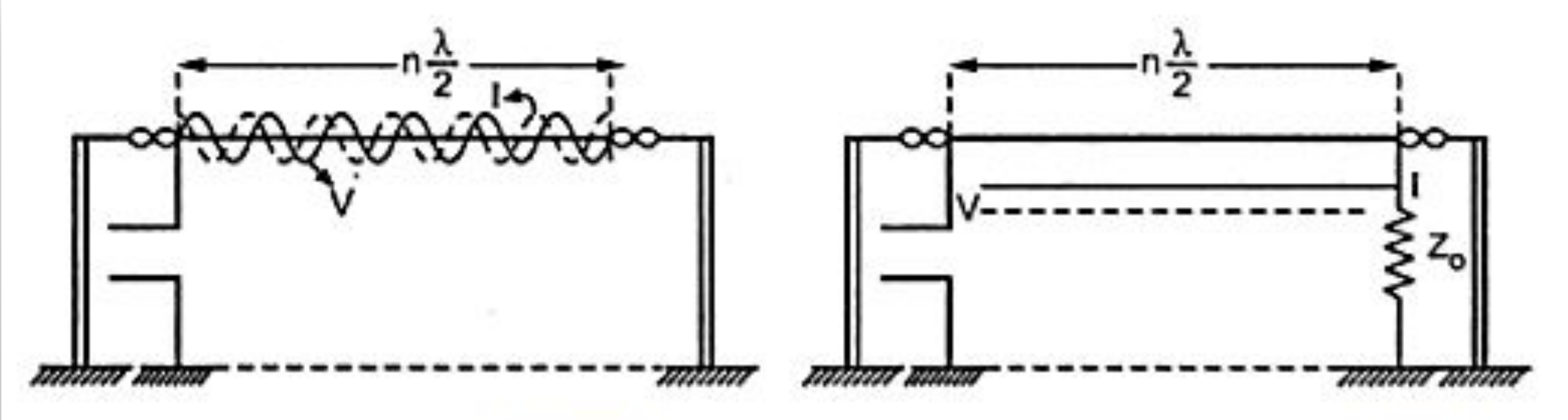
- In general, the antennas which correspond to the resonant transmission line are known as resonant antennas.
- The resonant transmission lines are unmatched antennas and used for operation at fixed frequency. In the resonant transmission lines the standing waves are observed.
- On the contrary, if the antenna on which the standing waves do not exist, then such antenna is called non-resonant antenna.
- The non-resonant antenna corresponds to a transmission line which is excited at one end while other end is required terminated so that the reflected waves are not produced and all the incident waves are absorbed.
- Thus here in non-resonant transmission line all the incident waves are absorbed; no wave is reflected back, indicates that the wave in non-resonant antenna travels in one direction. Hence the name given is travelling wave antenna.
- As the non-resonant transmission lines are terminated into the characteristic impedance, thus only the unidirectional radiation pattern is produced.
- Such a travelling wave antenna is a wideband antenna and it is not tuned to one frequency very sharply like resonant antenna, the travelling wave antenna is also called a periodic antenna.

- The typical examples of such travelling wave antennas are long wire antenna, V antenna, inverted V antenna and Rhombic antenna.
- These antennas are used specially when it is desired to operate on number of frequencies. Such as to suit the changing ionosphere conditions.

Long Wire Antenna

- A long wire antenna is linear wire antenna which is many wavelength long. It can be considered as an array of $\frac{\lambda}{2}$ elements connected in a continuous linear way such that each element acts as radiator and transmission line both.
- In general, the length of a long wire antenna is integer multiple of half wavelength i.e. $\frac{n\lambda}{2}$ .Thus a long wire antenna is defined as a single long wire, typically n times $\frac{\lambda}{2}$ long at the operating frequency.
- It is found that higher the value of n, the directivity is better.
- The directional characteristics are changed as the wire antenna is made longer in terms of integer multiples of $\frac{\lambda}{2}$.
- It is found that the radiation pattern consists various side lobes at different angles as compared to the "doughnut shape" characteristics of the single $\frac{\lambda}{2}$ antenna.
- In general a long wire antenna radiates a horizontally polarized wave at an angle which are lower about 17° to 25°, relative to the earth's surface.

- The long wire can be considered as a resonant antenna or non-resonant antenna.
- The resonant antenna means the antenna is open circuit at load end or it is unterminated.
- While the non-resonant antenna means the antenna which is terminated in the characteristic impedance of the line i.e. Zo. Consider a long wire antenna of length $\frac{n\lambda}{2}$.
- The resonant and non-resonant forms of a long wire antenna are as shown in the Fig. 3.15 (a) and (b) respectively.

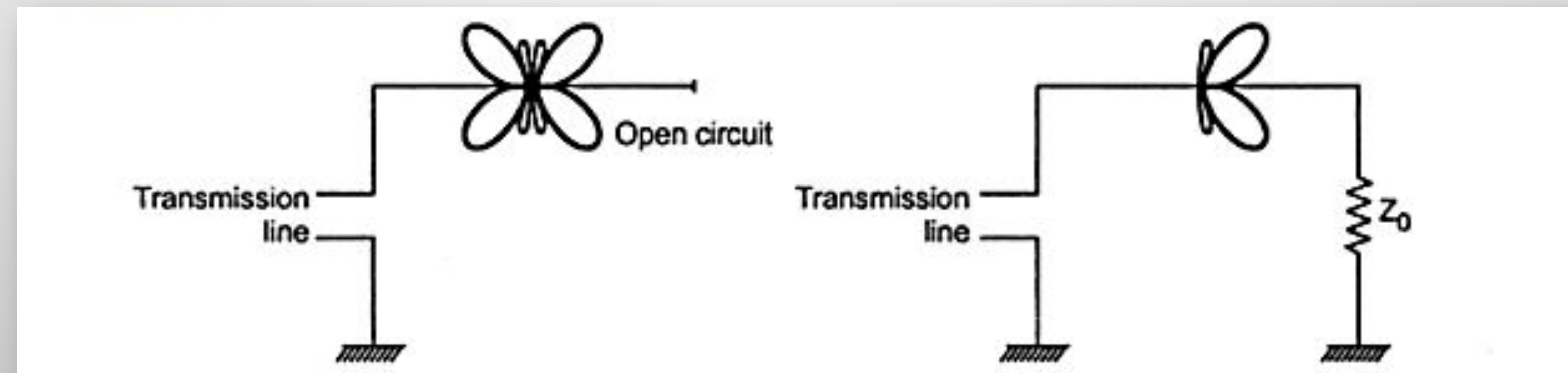


(a) Resonant long wire antenna (b) Non-resonant long wire antenna

Fig. 3.15 Different forms of a long wire antenna

- In case of resonant long wire antenna, as one end is unterminated, the standing waves are observed along the length of the antenna.

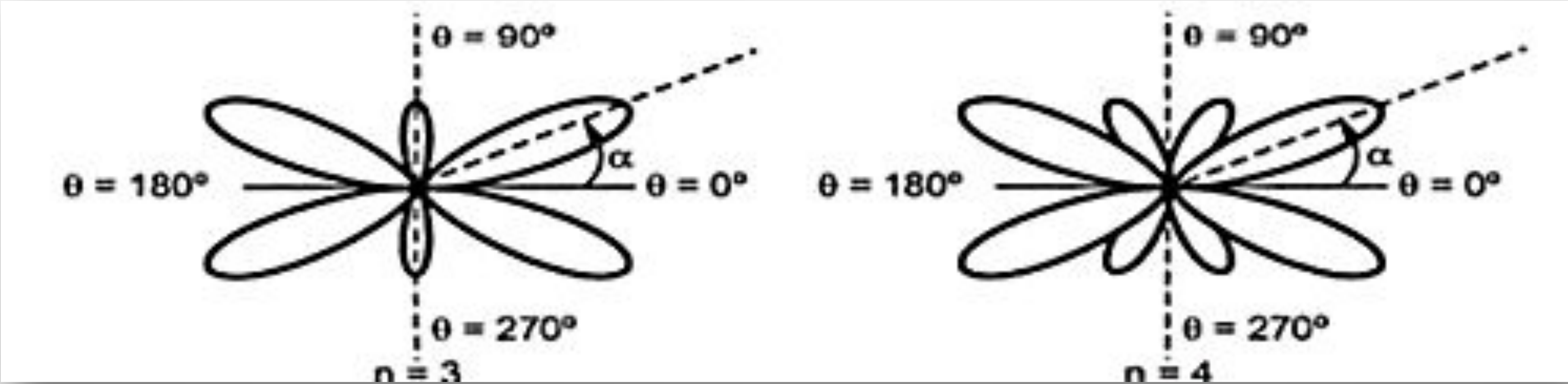
- Thus the pattern is bidirectional due to the incident and reflected waves while in case of non-resonant long wire antenna, the load end of the antenna is terminated into the characteristic impedance Zo, there will be no reflection of the wave.
- All the incident waves are absorbed, the pattern for the non-resonant long wire antenna is unidirectional.
- Also along the length of line uniform voltage and current exist.
- The patterns for the resonant and the non-resonant long wire antenna are as shown in the Fig. 3.16 (a) and (b) respectively.



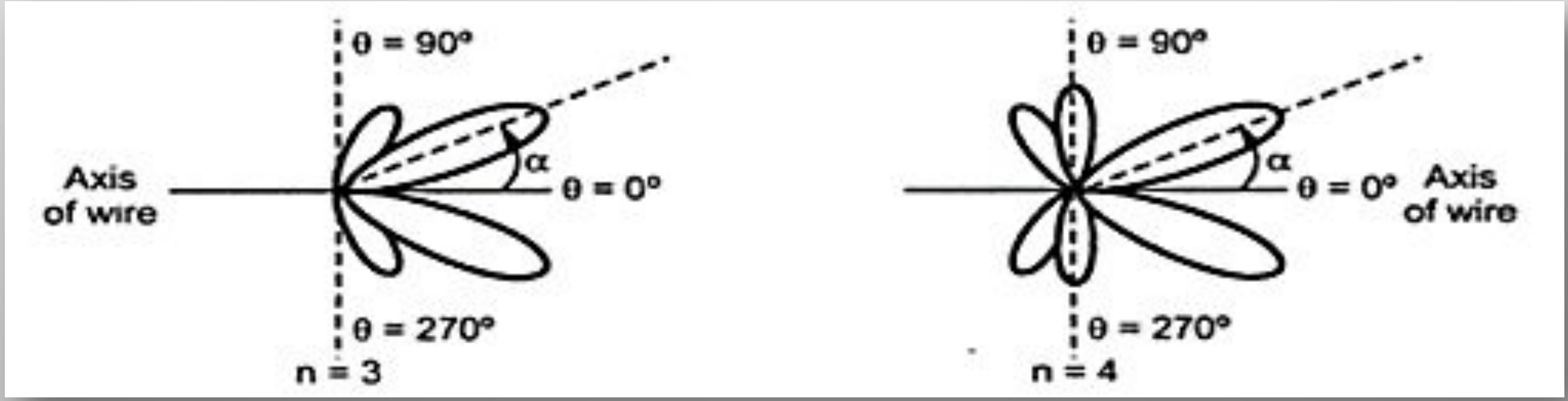
(a) Bidirectional in resonant antenna (b) Unidirectional in non-resonant antenna

Fig. 3.16 Patterns of resonant and non-resonant long wire antenna

- In case of a long wire antenna, the number of integer multiple of $\frac{\lambda}{2}$ i.e. n is very important. Depending on if n is even and odd, the directional pattern changes.
- Also if the wire is terminated we get unidirectional pattern and if wire is unterminated, then we get bidirectional pattern.
- The patterns for n = 3 and n = 4 for resonant as well as non-resonant forms are as shown in the Fig. 3.17 (a) and (b).



(a) Resonant Long Wire antenna



(b) Non Resonant Long Wire antenna

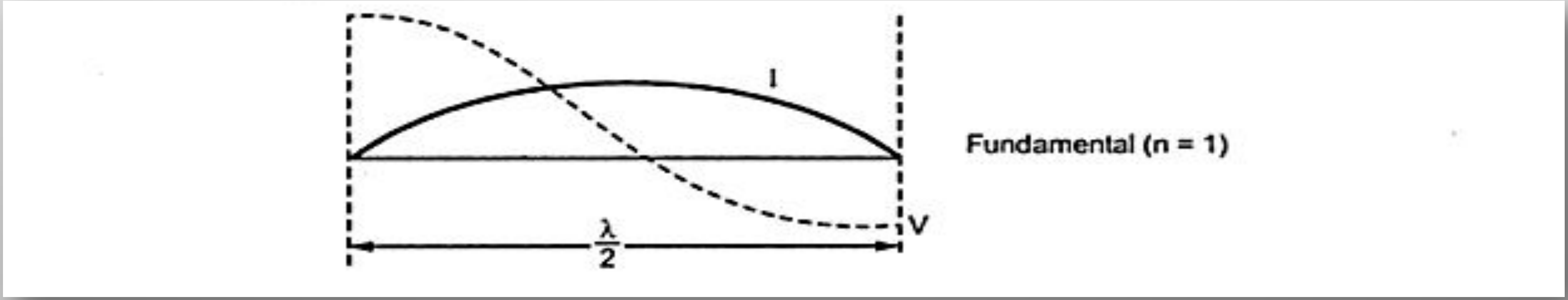
Fig. 3.17 patterns of long wire for different integer multiples i.e. n = 3 and n = 4

- For the half wavelength long wire antenna, the physical length is given by,

$$Length = \frac{492(n - 0.05)}{f(MHz)} feet$$

where n = Number of integer multiple half wavelength.

- The voltage current distribution along the resonant wire working a fundamental frequency (i.e. λ/2) and first harmonic (i.e., λ/2) second harmonic (i.e. 2λ/2) and third harmonic (i.e. 3λ /2) are as shown in the Fig. 3.18.



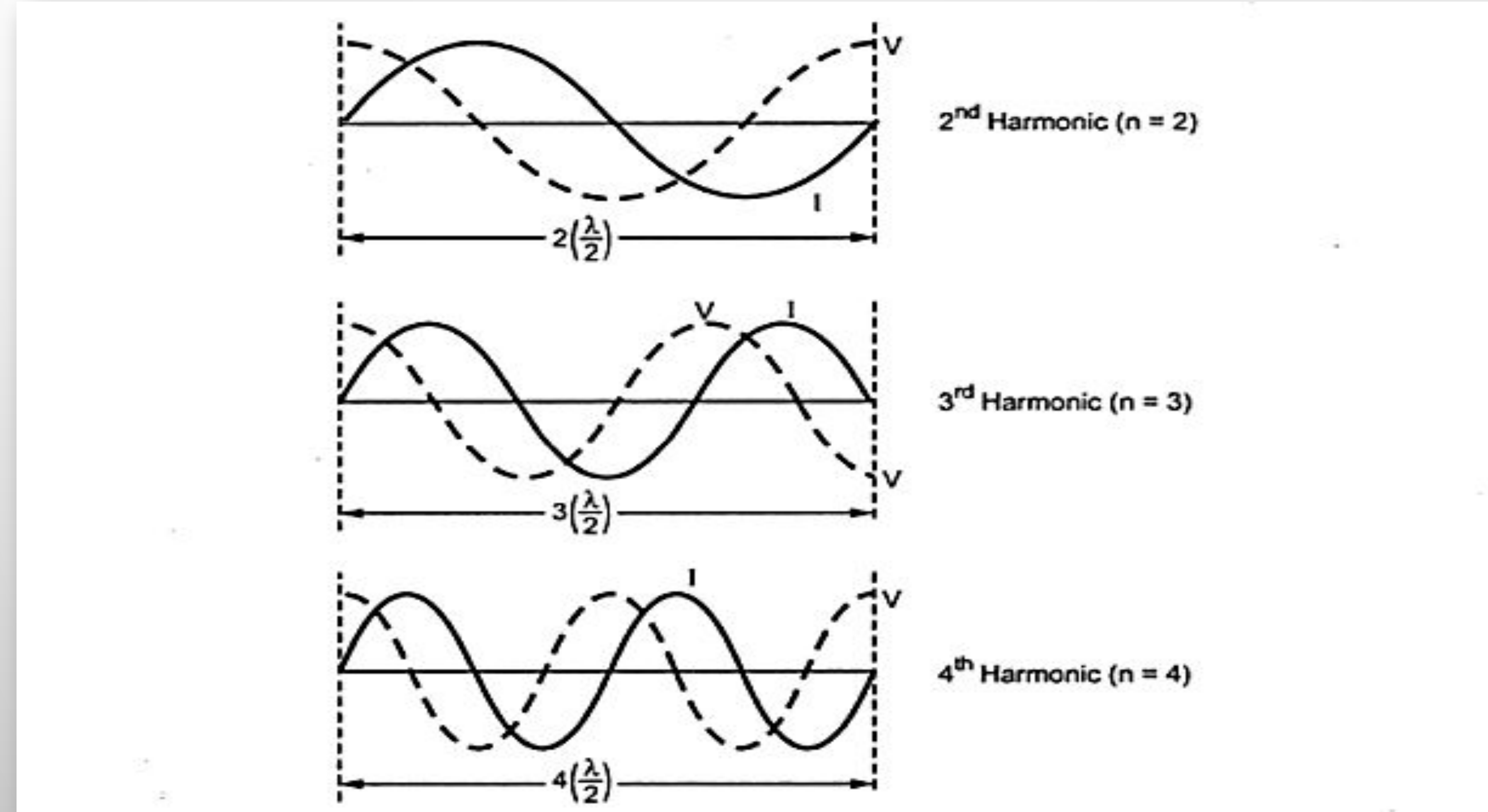


Fig. 3.18 Distribution of voltage and current along the length of the wire antenna at different harmonics

- From the Fig. 3.18, it is clear that the long wire antenna of the resonant form can be used for harmonically related frequencies.
- Now the field strength for the resonant type long wire antenna with length even and odd integer multiples times the $\lambda/2$ are given by,

$$E = \frac{60\,I\,r.m.s}{r}\,\frac{\left[\cos\left(\frac{n\pi}{2}\cos\theta\right)\right]}{\sin\theta} \quad \text{... n is odd}$$

$$E = \frac{60\,I\,r.m.s}{r}\left[\frac{\sin\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta}\right] \quad \text{... n is even} \qquad \text{... (2)}$$

- Similarly the field strength for the non-resonant type long wire antenna is given by,

$$E = \frac{60\,I\,r.m.s.\sin\theta}{r(1-\cos\theta)}\sin\left[\frac{\pi L}{\lambda}(1-\cos\theta)\right]$$

- When the integer value of n is increased, that increases the number of lobe in proportion with the major lobe.

- For the resonant long wire antenna of n wavelength long, the radiation resistance is given by,

$$R_{rad} = 73 + 69 \log_{10} n \ \Omega \qquad \dots (4)$$

- Above formula is approximate formula where n is number of half wavelength.
- The angle of maximum radiation is nothing but the angle between the maximum lobe and the axis of the wire antenna.
- This angle of maximum radiation is denoted by θmax and it is given by,

$$\theta_{max} = \cos^{-1}\left(\frac{n-1}{n}\right) \qquad \dots (5)$$

- The long wire antennas of resonant and non-resonant type are generally used to operate in the frequency range 500 kHz to 30 MHz.
- By using the long wire antennas, the directional pattern and power gain can be obtained easily.
- Due to these facts, mostly the long wire antennas are used in the arrays such as V-antenna or rhombic antennas etc.
- The long wire antennas are used in such array because their structure is simple and the cost is low, at the same time the directional pattern can be easily obtained.

TRAVELLING WAVE ANTENNA

- The antenna in which the standing wave does not exist along the length of the antenna is called travelling wave antenna.
- In general the standing waves are produced, when the line is not properly terminated which causes reflections at the output or load side.
- As discussed earlier the standing waves travel due to reflections in the resonant antenna.
- But in the travelling wave antenna, the standing waves do not exist.
- That means, the travelling wave antenna is non-resonant type antenna or aperiodic antenna.
- In case of the radio communication involving ionospheric reflections, the frequency spectrum required is wide.
- Thus the antenna used for the radio communication should have larger bandwidth.
- To fulfil larger bandwidth condition, the travelling wave antenna is the best option.
- In such antennas one of the ends is terminated into the characteristic impedance Zo while other end is connected to the input signal.
- Due to the proper termination at the load, the reflections are avoided. Because of this the unidirectional radiation pattern is obtained as shown in the Fig. 3.19.

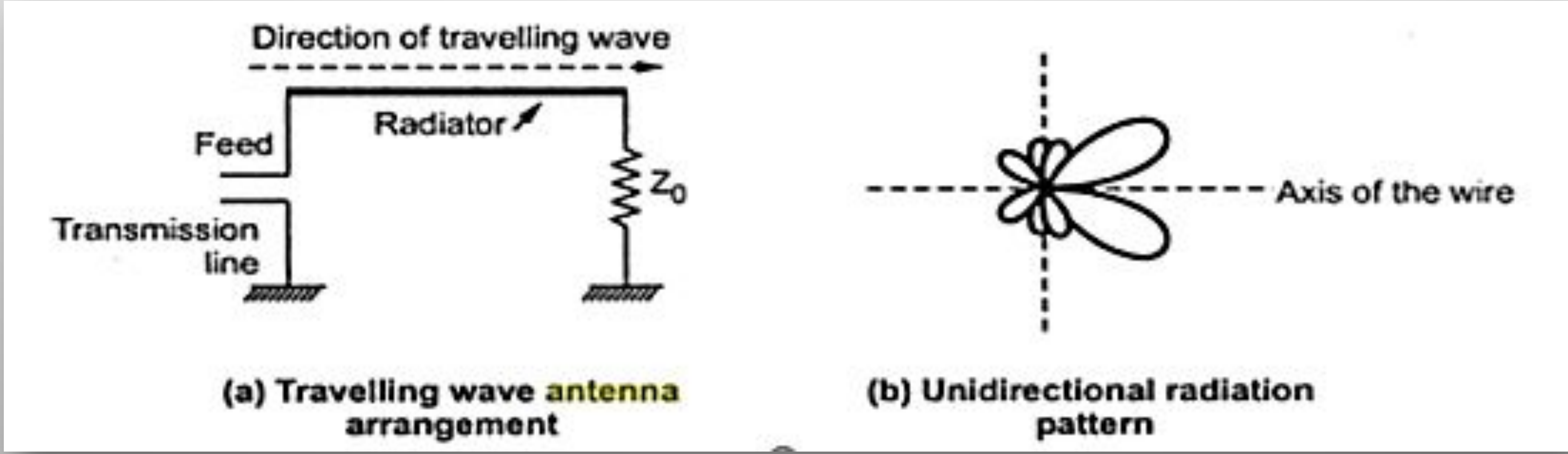


Fig. 3.19 Travelling wave antenna and its radiation pattern

- The long wire radiator as shown above in the Fig. 3.19 (a) can be assumed to be made up of number of Hertzian dipoles connected back to back.
- Now in such arrangement the current will change phase with distance which is nothing but the progressive phase change which is observed in the end fire array case of the collinear Hertzian dipoles.
- Now if we assume velocity of light same in wire as well as the free space, the radiation pattern will be similar to end fire array with sharp null in the forward direction as shown in the Fig. 3.19 (b).
- The strength of the electric field at a distance r away from the radiator is given by,

$$\boxed{E = \frac{60\,I_{r.m.s.}}{r} \cdot \left(\frac{\sin\theta}{1-\cos\theta}\right) \sin\left(\frac{\pi L}{\lambda}[1-\cos\theta]\right)} \qquad \ldots (1)$$

where

r = Distance at a point from radiator.

L= Length of the wire or radiator.

- The angle of major lobe and the amplitude of the major lobe depends on the length of the wire.
- As the length of the wire increases, the angle of major lobe with respect to the axis of wire decreases.
- Hence the major lobe comes closer to the axis of wire as the length increases.
- Also with the increase in the length, the amplitude increases.
- The Table 3.1 given below indicates different values of angle of major lobe and amplitude of the lobes for the increasing length.

Length of the travelling wave	Angle of Major Lobe (β)	Amplitude of Major lobe
$L = \frac{\lambda}{2}$	68°	1.25
$L = \lambda$	48°	2.0
$L = 2\lambda$	35°	2.9
$L = 4\lambda$	24°	4.2
$L = 8\lambda$	17°	5.8

Table 3.1

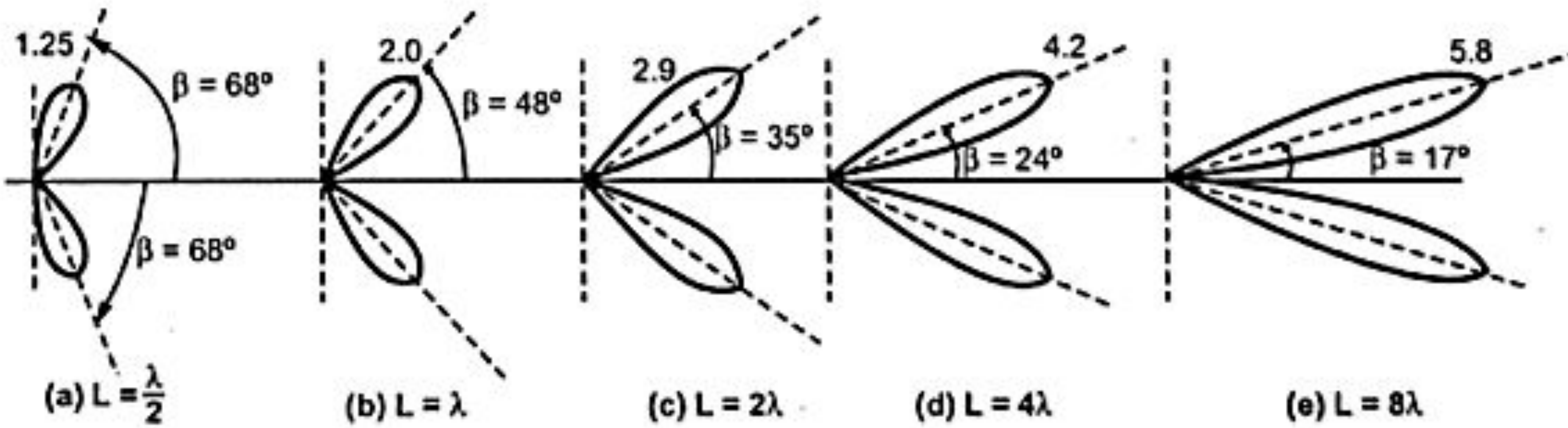


Fig. 3.20 Radiation pattern for different lengths of the travelling wave antenna

- From the Table 3.1 it is clear that as length increases, the angle of major lobe decreases and the gain increases as amplitude increases.
- The major lobe moves towards the axis and becomes narrower.

V ANTENNA

- The V antenna is made up of two long wire antennas which are arranged in the form of the horizontal V and it is fed at the apex by the transmission feed line.
- The long wire antennas are called legs of the V antenna. A typical arrangement for the high frequency resonant V antenna is as shown in the Fig. 3.21.

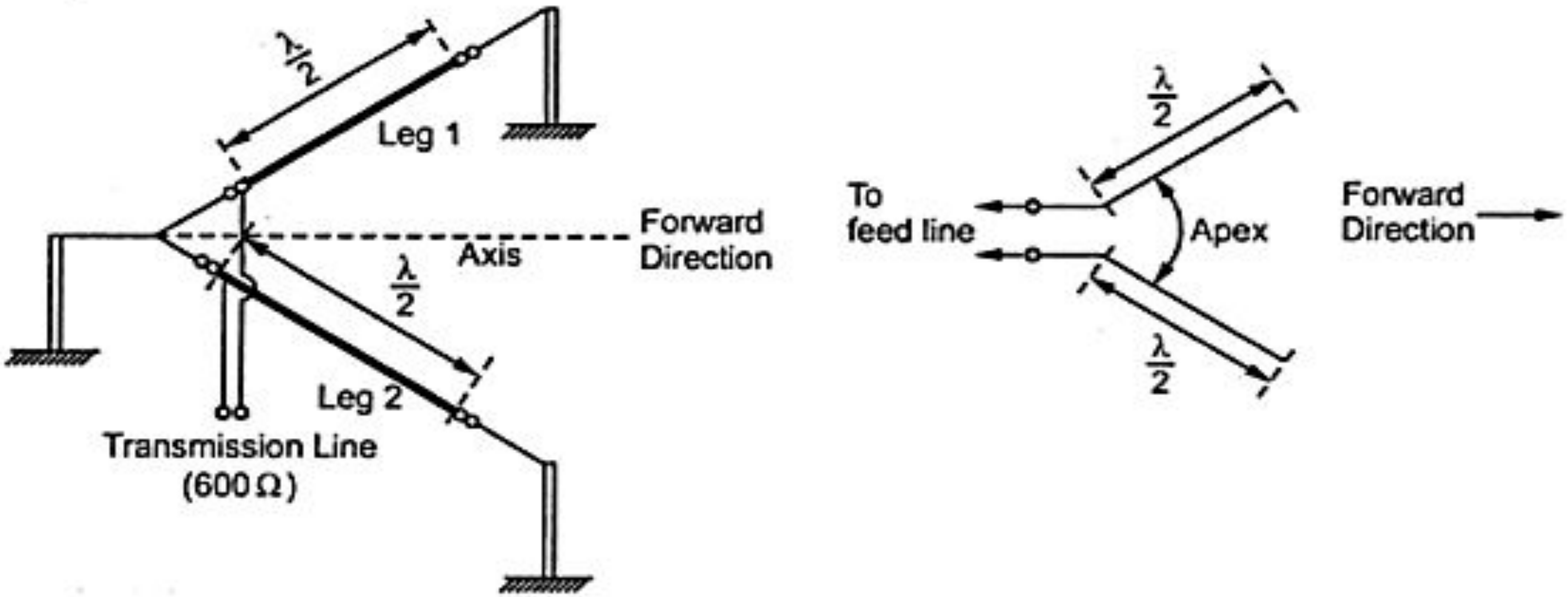
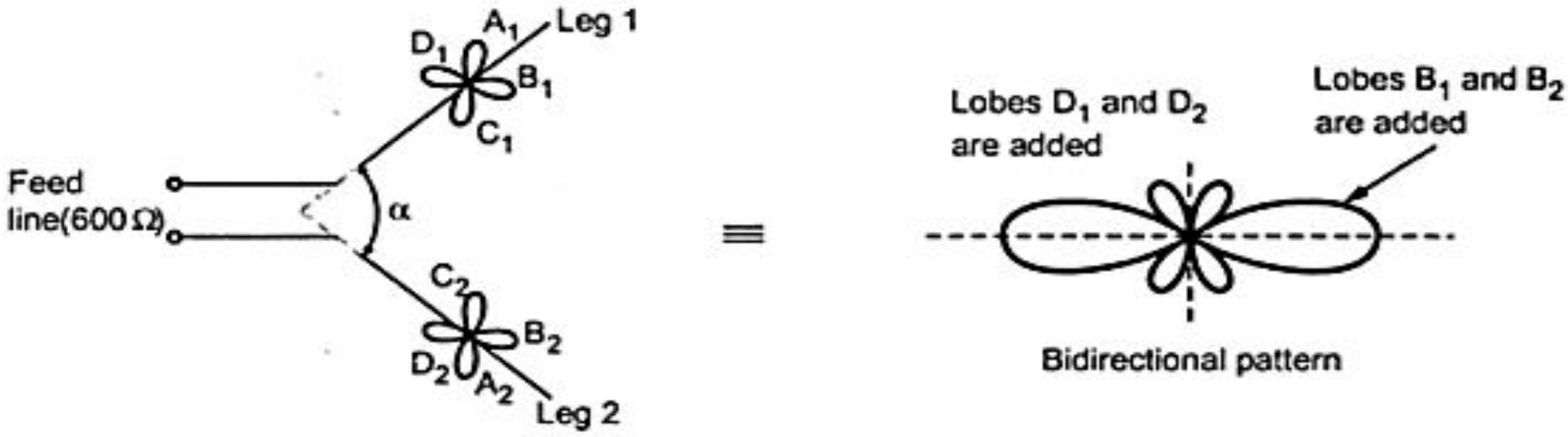


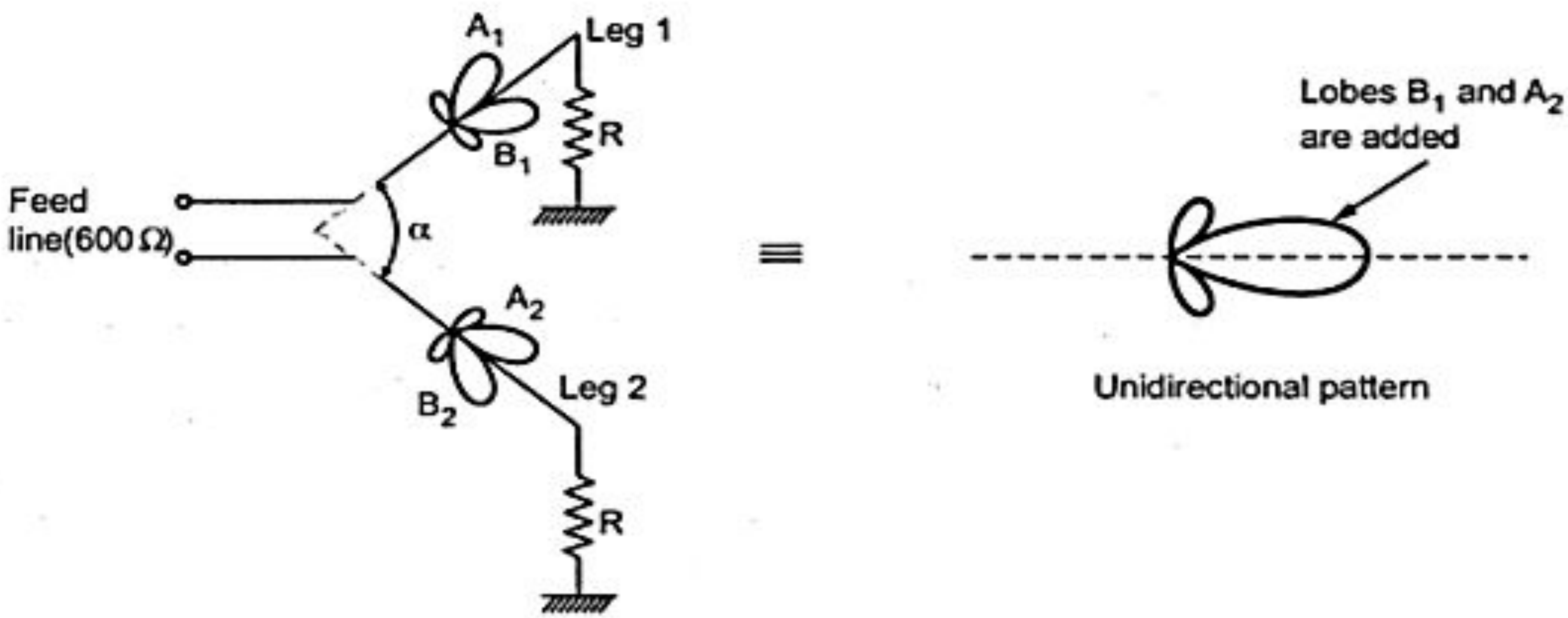
Fig. 3.21 Arrangement for high frequency V antenna

- The angle made by the two legs of the V antenna is called apex angle which is denoted by α.
- When the apex angle is equal to two times the angle that the cone of maximum radiation of each leg makes with axis of the V antenna, then the cones from each leg gets added together in the direction of the axis of antenna.
- This bisects the apex angle α and produces a maximum radiation along the axis.
- Note that the two legs are fed with 180° out of phase with respect to each other.
- To increase the gain and directivity in the desired direction, the lengths of the legs are increased in proportion.
- Because of this, the side lobes get cancelled out and the major lobes get added together.
- Thus the radiation pattern obtained is much sharper than that obtained with same length single long wire antenna.
- The arrangement for the resonant V antenna is as shown in the Fig. 3.22 (a) where both the legs are not terminated at one end.
- Thus in such arrangement we get bidirectional pattern.
- If the two legs of the V antenna are terminated into the non inductive i.e. resistive characteristic impedance, we get non-resonant V antenna.
- In such non-resonant V antenna, the pattern produced is unidirectional.
- The bidirectional and unidirectional patterns obtained in the resonant and non-resonant V antenna respectively are shown in the Fig. 3.22 (a) and (b).

- Consider the resonant V antenna in which the two legs are producing similar patterns individually.
- But in the resultant pattern, the lobes D_1 and D_2 will be added being in same backward direction.
- Similarly the lobes B_1 and B_2 will get added in the forward direction as both are in same directions.
- But the lobe A_1 and C_1 will get cancelled due to the lobes A_2 and C_2 because they are respectively in the opposite directions.
- Thus we get the resultant pattern as the bidirectional pattern with increased gain and directivity in both the directions.
- Now in case of the non-resonant V antenna with proper termination of the legs into resistive component, the lobes B_1 and A_2 get added being in the same direction while lobes A_1 and B_2 get cancelled out being in the opposite directions to each other.
- Thus the resultant pattern is the unidirectional pattern with increased gain and directivity.



(a) Resonant V antenna with bidirectional pattern



(b) Non-resonant V antenna with unidirectional pattern

Fig. 3.22 Unidirectional and bidirectional patterns of resonant and non-resonant V antennas

- Typically the gain of the V antenna is two times the gain of the single long wire antenna which has length equal to the length of leg in V antenna.
- For each leg of length 8λ. the gain achieved is very large i.e. 12 dB.
- Another important parameter of the V antenna is the apex angle which varies accordingly with the length of the leg.
- For the variation in the length of the legs of V antenna from 2λ to 8λ, the apex angle typically varies from 72° to 36°.
- Hence to operate V antenna over a wide range of frequency, the apex angle is selected as average between the apex angles for the highest and lowest frequencies interms of $\frac{n\lambda}{2}$ in each leg.
- The directivity of the V antenna can be increased further by using an array of resonant V antennas in stacked form, one above others.
- With this arrangement, bidirectional pattern with increased directivity is obtained.
- To make it unidirectional, one more V antenna is stacked at a distance of odd multiple of $\frac{\lambda}{4}$ in the back and exciting the next with certain phase difference of 90°.
- Hence the resonant V antenna is found to be the cheapest transmitting and receiving antenna at high frequency which provides a low angle beam along the axis for fixed frequency operation.
- In general, the main drawback of the V antenna (either of resonant or non-resonant type) is that the minor or side lobes are also of high strength.

ADVANTAGES

THE FOLLOWING ARE THE ADVANTAGES OF V-ANTENNA −

- CONSTRUCTION IS SIMPLE
- HIGH GAIN
- LOW MANUFACTURING COST

DISADVANTAGES

THE FOLLOWING ARE THE DISADVANTAGES OF V-ANTENNA −

- STANDING WAVES ARE FORMED
- THE MINOR LOBES OCCURRED ARE ALSO STRONG
- USED ONLY FOR FIXED FREQUENCY OPERATIONS

APPLICATIONS

THE FOLLOWING ARE THE APPLICATIONS OF V-ANTENNA −

- USED FOR COMMERCIAL PURPOSES
- USED IN RADIO COMMUNICATIONS

RHOMBIC ANTENNA

- The rhombic antenna is based on the principle of the travelling wave radiator or the travelling wave antenna.
- In the rhombic antenna, four long wires are connected together in such a way to form a diamond or rhombus shaped structure in the horizontal plane above the ground.
- It can be considered as structure with two inverted V antennas connected in series.
- It may also be considered as two V antennas connected end to end forming obtuse angles.
- The rhombic antenna is called travelling wave rhombic antenna as it is based on the principle of the travelling wave antenna.
- It is also known as diamond antenna due to the similar structure formed by the long wire antennas.
- The size and physical form of the rhombic antenna is decided by the tilt angle which is always acute and the length of the side of a rhombus.
- Each side of the rhombus formed by the wires is called leg of the rhombic antenna.
- Consider a rhombic antenna of four wires each of length L and installed horizontally over the ground or earth at height h as shown in the Fig. 3.25.

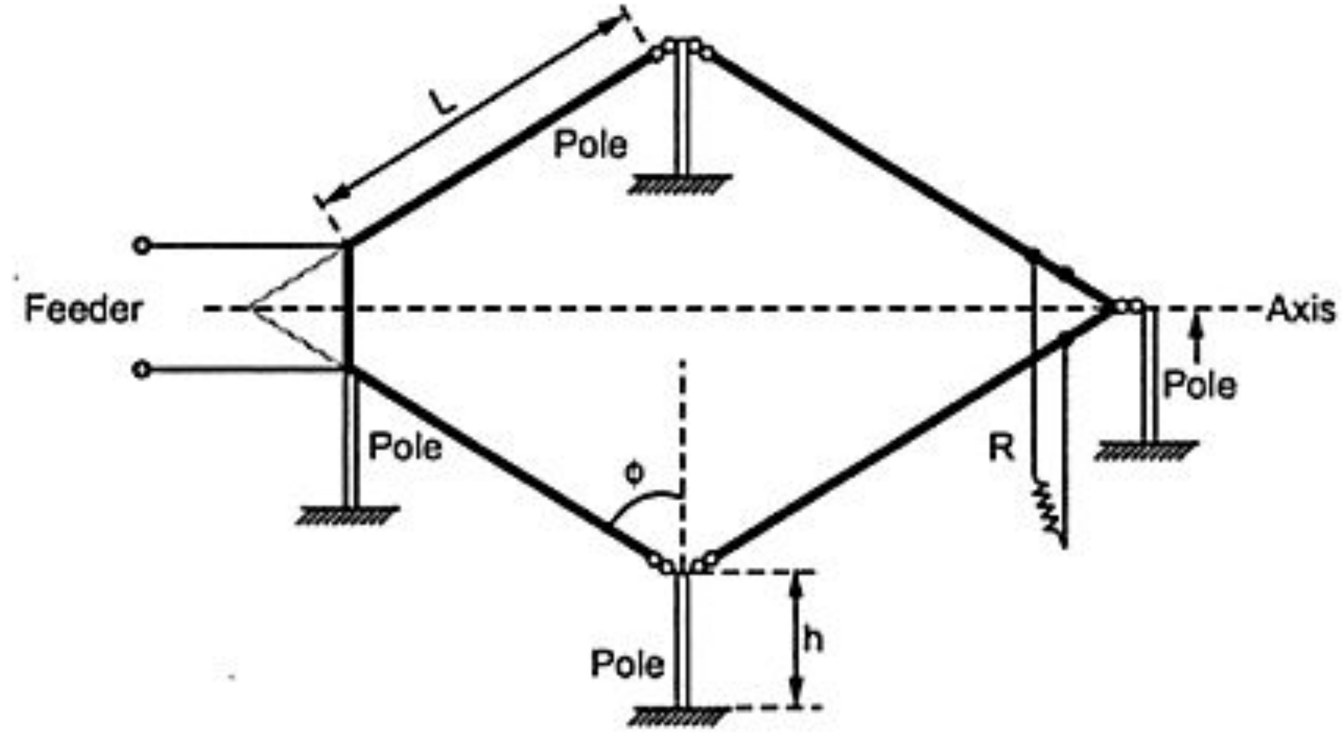
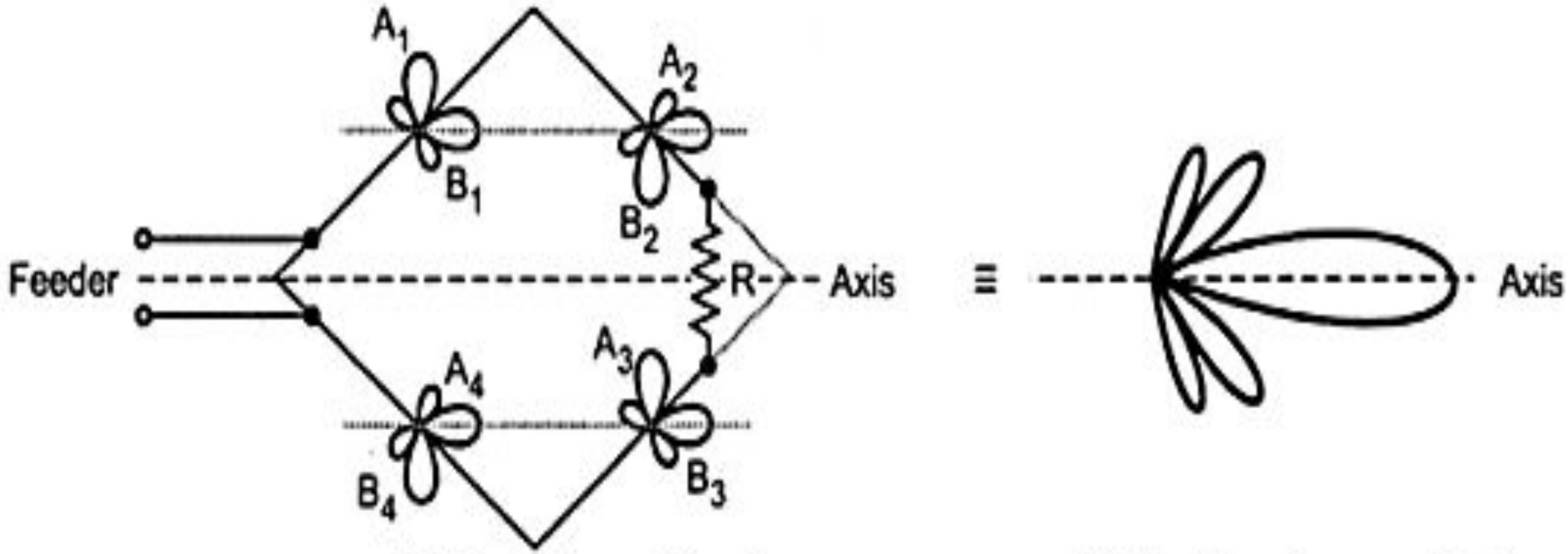


Fig. 3.25 Arrangement for rhombic antenna

- In case of rhombic antenna as a transmitting antenna, one end of the antenna is fed through the balanced transmission line as feeder, while the other end of the antenna is terminated into the non-inductive resistor.
- The value is adjusted such that the travelling waves are set in all the four legs of the rhombic antenna with no reflection and hence no standing wave exists in any of the legs of the antenna.
- The line joining the feed point and the termination point is called axis of the rhombic antenna.
- When the four legs are terminated in the resistor equal to the characteristic impedance, it gives non-resonant condition, thus the legs provide unidirectional distribution.
- Thus with a proper design of the rhombic antenna, it provides the maximum radiation along the axis of the antenna with the polarization of the wave in the plane of the rhombus formed by the four legs.
- It is represented in the Fig. 3.26 (a) and (b).



(a) Radiation pattern in each leg

(b) Unidirection resultant radiation pattern

Fig. 3.26 Radiation pattern of properly terminated rhombic antenna

- To get resultant unidirectional pattern, the lobes B1, A2, B2, A4 are added.
- Even though the polarization of the wave is in the horizontal direction, which is in the plane of rhombus formed by the four legs, due to the effect of ground i.e. earth, the lobe is slightly elevated in the upward direction keeping horizontal polarization intact. The angle of elevation is denoted by β as shown in the Fig. 3.27.

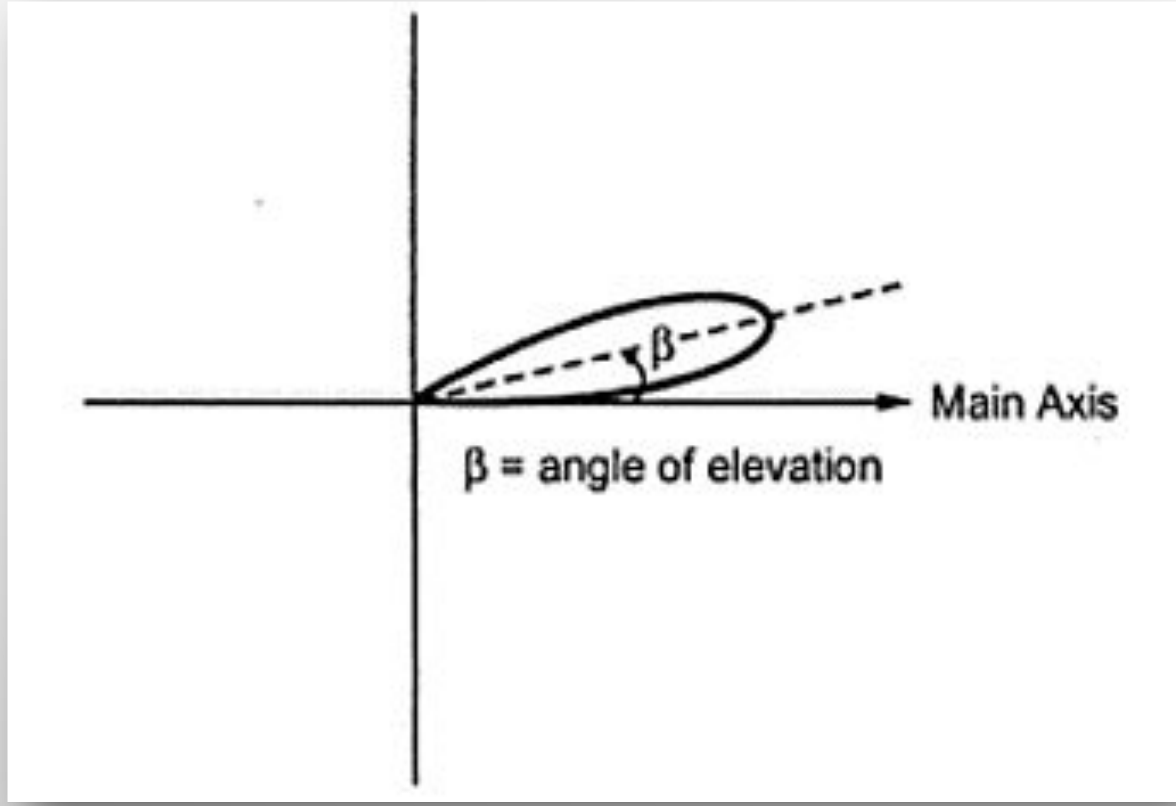


Fig. 3.27 Elevated lobe by angle of elevation β due to the effect of the earth

- The angle of tilt is denoted by ϕ.
- This angle is chosen approximately 90° less than the angle of major lobe with the axis.
- Note that the angle of major lobe for an individual leg varies only from 24° to 17° for 4 to 8 wavelength variation in the length of the leg.
- Thus the rhombic antenna can be operated over a wide frequency band.

- The terminating resistor used is of the value 600 Ω to 800 Ω to match with the characteristic impedance of 600 Ω feeder transmission line.
- Under this matched condition, the terminating resistor dissipates half of the power output.
- The resistor used at the termination is non-inductive with capacitance of negligible value.
- For low power systems, the ordinary resistor can be used as the terminating resistor.
- But for high power systems, special types of resistors are often used.

Advantages of Rhombic Antenna

There are number of advantages of the rhombic antenna which make it suitable for number of applications.

1. The input impedance and radiation patterns do not vary rapidly over a considerably large range as compared to any other radiating system.
2. It is a broadband antenna with highly directive pattern where radiated or received power is maximum along the main axis which is the longer diagonal of the rhombic antenna.
3. Due to the high efficiency it is highly used for radio communication.
4. It is most suitable for the applications where space for installation of the antenna is not critical.
5. The rhombic antenna is most extensively used for F-layer propagation because of its low vertical angle of radiation.
6. It can be used for short wave application with very low height.
7. As it is untuned antenna (non-resonant) it is useful for wideband application where rapid frequency switching is desired.
8. Its input impedance is twice as that of single side radiator
9. Now a days a array of the rhombic antenna is used for the long distance short wave reception of horizontally polarized waves. The structure is called Multiple Unit Steerable Antenna (MUSA).
10. The construction of the rhombic antenna is simple and it is easy to erect at a lower cost..

Disadvantages of Rhombic Antenna

Following are the disadvantages of the rhombic antenna.

1. It requires very large space for installation.
2. It produces number of side lobes along with highly directive major lobe.
3. It dissipates half of the output power in the terminating impedance, hence the transmission efficiency is poor.

Applications

The following are the applications of Rhombic antenna −

- Used in HF communications
- Used in Long distance sky wave propagations
- Used in point-to-point communications

LOG PERIODIC ANTENNA

- In general, any antenna when defined in terms of angles only, then it comes under the category of the frequency independent antenna.
- Its characteristics are found to be frequency independent.
- In any frequency independent antenna, the impedance and the radiation pattern both are independent of frequency.
- So the basic concept to obtain frequency independent characteristics is that the antenna structure should be adjusted i.e. either expanded or contracted, in proportion to wavelength.
- If it is not possible to adjust antenna mechanically, then the size of the radiating region in the pattern should be in proportion with the wavelength.
- The log periodic antenna is a broadband antenna in which the geometry of the antenna structure is adjusted such that all the electrical properties of the antenna are repeated periodically with the logarithm of the frequency.
- Thus the basic geometric structure is repeated with the structure size changed.
- For every repetition, the structure size changes by a constant scale factor, with which the structure can either expand or contract.
- Thus the principle of the log periodic antenna can be understood with the help of a array of the log periodic antenna known as Log Periodic Dipole Array (LPDA).

- A typical log periodic dipole array (LPDA) consists number of dipoles of different lengths and spacings.
- A typical arrangement is as shown in the Fig. 3.28 such an array is fed using a balanced transmission line and it is further transposed between each adjacent pairs of terminals of dipoles.
- The feed line is connected at narrow end or apex of the array.
- The length of the dipoles increases from feed point towards other end such that the included angle a remains constant.
- The increase in the length of the dipole (L) and the spacing in wavelength between two dipoles (s) are adjusted such that the dimensions of the adjacent dipoles possess certain ratio with each other.
- The dipole lengths and the spacings between two adjacent dipoles are related through parameter called design ratio or scale factor which is denoted by τ.
- Thus the relationship between S_n and Sn+1 and L_n and Ln+1 is given by

$$\frac{s_n}{s_{n+1}} = \frac{L_n}{L_{n+1}} = \tau \qquad \dots (1)$$

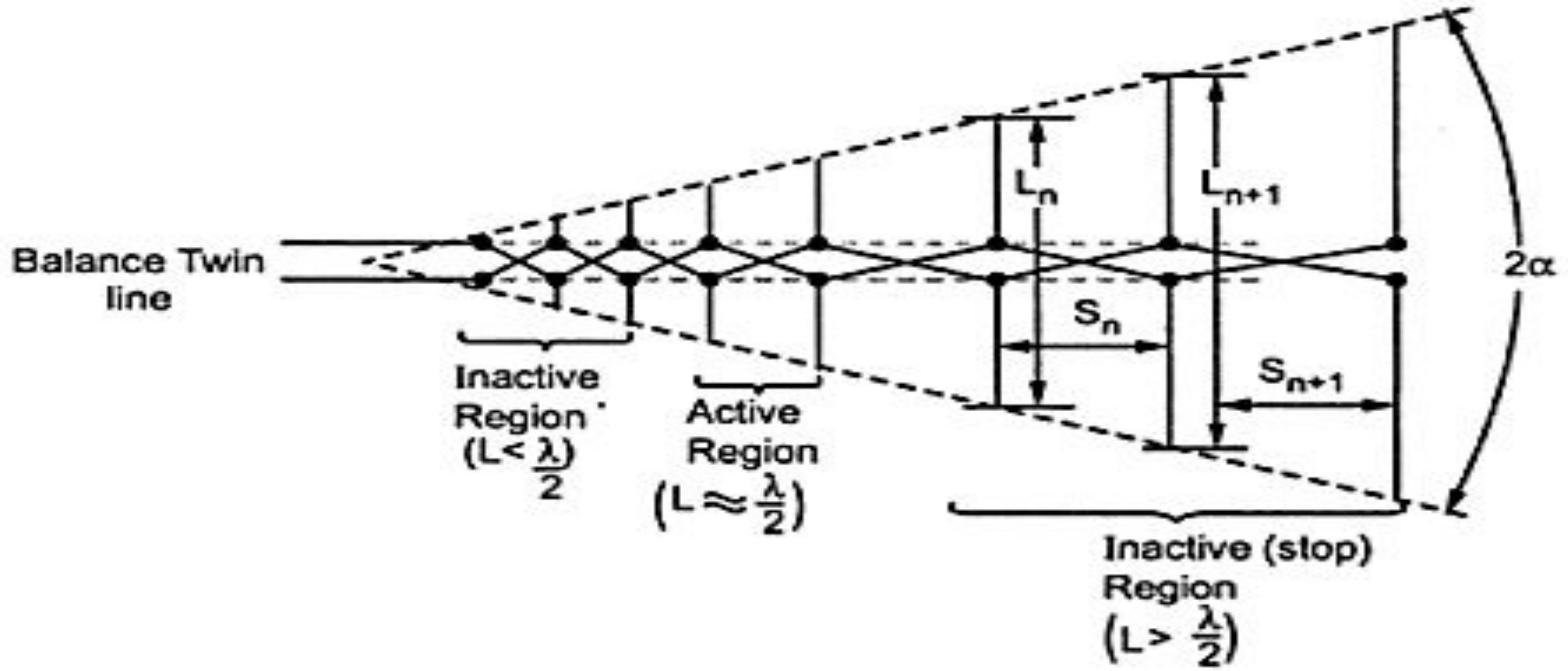


Fig. 3.28 Log Periodic Dipole Array (LPDA)

- This τ is also called periodicity factor which is always less than 1.The same expression can be written in terms of constant K as

$$\boxed{\frac{s_{n+1}}{s_n} = \frac{L_{n+1}}{L_n} = \frac{1}{\tau} = K} \quad \text{... (2)}$$

- The ends of the dipoles lie along straight lines on both the sides
- These two straight line meet at feed point or apex giving angle 2α which is angle included by two straight line. **OR**

The dipole lengths and separations are related by the formula –

$$\frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{R_3}{R_4} = T = \frac{l_1}{l_2} = \frac{l_2}{l_3} = \frac{l_3}{l_4}$$

Where

- τ is the design ratio and $\tau<1$
- R is the distance between the feed and the dipole
- L is the length of the dipole.

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.

YAGI-UDA ANTENNA

- Yagi-Uda arrays or Yagi-Uda antennas are high gain antennas.
- The antenna was first invented by a Japanese Prof. S. Uda in early 1940's.
- Afterwards it was described in English by Prof. H. Yagi.
- As the description was in english, it was read worldwide and the antenna became popular.
- Hence the antenna name Yagi-Uda antenna was given after Prof. S. Uda and Prof. H. Yagi. Prof. Uda performed several experiments.
- He measured gains and patterns with single parasitic reflector, single parasitic director and with a reflector and as many as 30 directors.
- He found that highest gain is possible with the reflector of length equal to $\frac{\lambda}{2}$ located at a distance $\frac{\lambda}{4}$ from the driven element, along with director of length approximately 10% less than $\frac{\lambda}{2}$ located at a distance $\frac{\lambda}{3}$ from the driven element.
- A basic Yagi-Uda antenna consists a driven element, one reflector and one or more directors.
- Basically it is an array of one driven element and one of more parasitic elements.
- The driven element is a resonant half wave dipole made of a metallic rod.
- The parasitic elements which are continuous are arranged parallel to the driven elements and at the same line of sight.
- All the elements are placed parallel to each other and close to each other as shown in the Fig. 3.34.

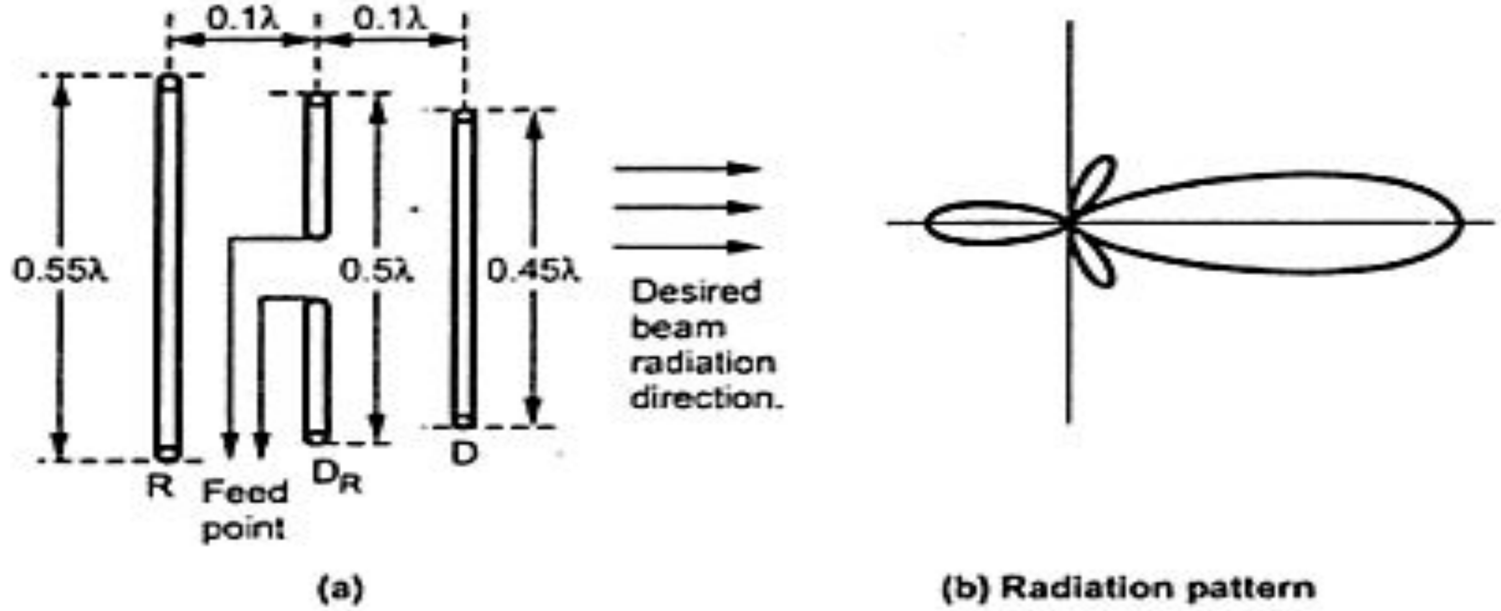


Fig. 3.34 Yagi-Uda antenna

- The parasitic element receive excitation through the induced e.m.f. as current flows in the driven element.
- The phase and amplitude of the currents through the parasitic elements mainly depends on the length of the elements and spacing between the elements.
- To vary reactance of any element, the dimensions of the elements are readjusted.
- Generally the spacing between the driven and the parasitic elements is kept nearly 0.1λ to 0.15 λ.
- A Yagi-Uda antenna uses both the reflector (R) and the director (D) elements in same antenna.
- The element at the back side of the driven element is the reflector. It is of the larger length compared with remaining elements.
- The element in front of the driven element is the director which is of lowest length in all the three elements.
- The lengths of the different elements can be obtained by using following formula.

$$\text{Reflector length} = \frac{152}{f\,(\text{MHz})}\ \text{meter}$$

$$\text{Driven element length} = \frac{143}{f\,(\text{MHz})}\ \text{meter}$$

$$\text{Director length} = \frac{137}{f\,(\text{MHz})}\ \text{meter}$$

Let us consider the action of the Yagi-Uda antenna. The parasitic element is used either to direct or to reflect, the radiated energy forming compact directional antenna. If the parasitic element is greater than length $\frac{\lambda}{2}$, (i.e. reflector) then it is inductive in nature. Hence the phase of the current in such element i.e. in reflector lags the induced voltage. While if the parasitic element is less than the resonant length $\frac{\lambda}{2}$ (i.e. director), then it is capacitive in nature. Hence the current in director leads the induced voltage. The directors adds the fields of the driven element in the direction away from the driven element. If in array, more than one directors are used, then in such cases the first director excites next and so on. Exactly opposite to this, properly spaced reflector adds the fields of the driven element in the direction towards driven element from the reflector. To increase the gain of the Yagi-Uda antenna, the number of directors is increased in the beam direction. To get good excitation, the elements are closely spaced. If the distance between the driven element and the directors is greater, then for correct phasing of the parasitic current more capacitive reactance is needed which is achieved by tapering the rod.

The radiation is in the direction front to rear. Part of this radiation induces currents in the parasitic elements which actually reradiate almost all radiations. With the proper lengths of the parasitic elements and the spacing between the elements, the backward radiation is cancelled and the radiated energy is added infront. When the spacing between the driven element and the parasitic element is reduced, the driven element gets loaded which reduces the input impedance at the terminals of the driven element. To overcome this the driven element used is the folded dipole which maintains the impedance at the input terminals.

The Yagi-Uda antenna is the most widely used antenna for television signal reception. The gain of such antenna is very high and the radiation pattern is very much directive in one direction. The Yagi-Uda antenna along with its field radiation pattern is as shown in the Fig. 3.35.

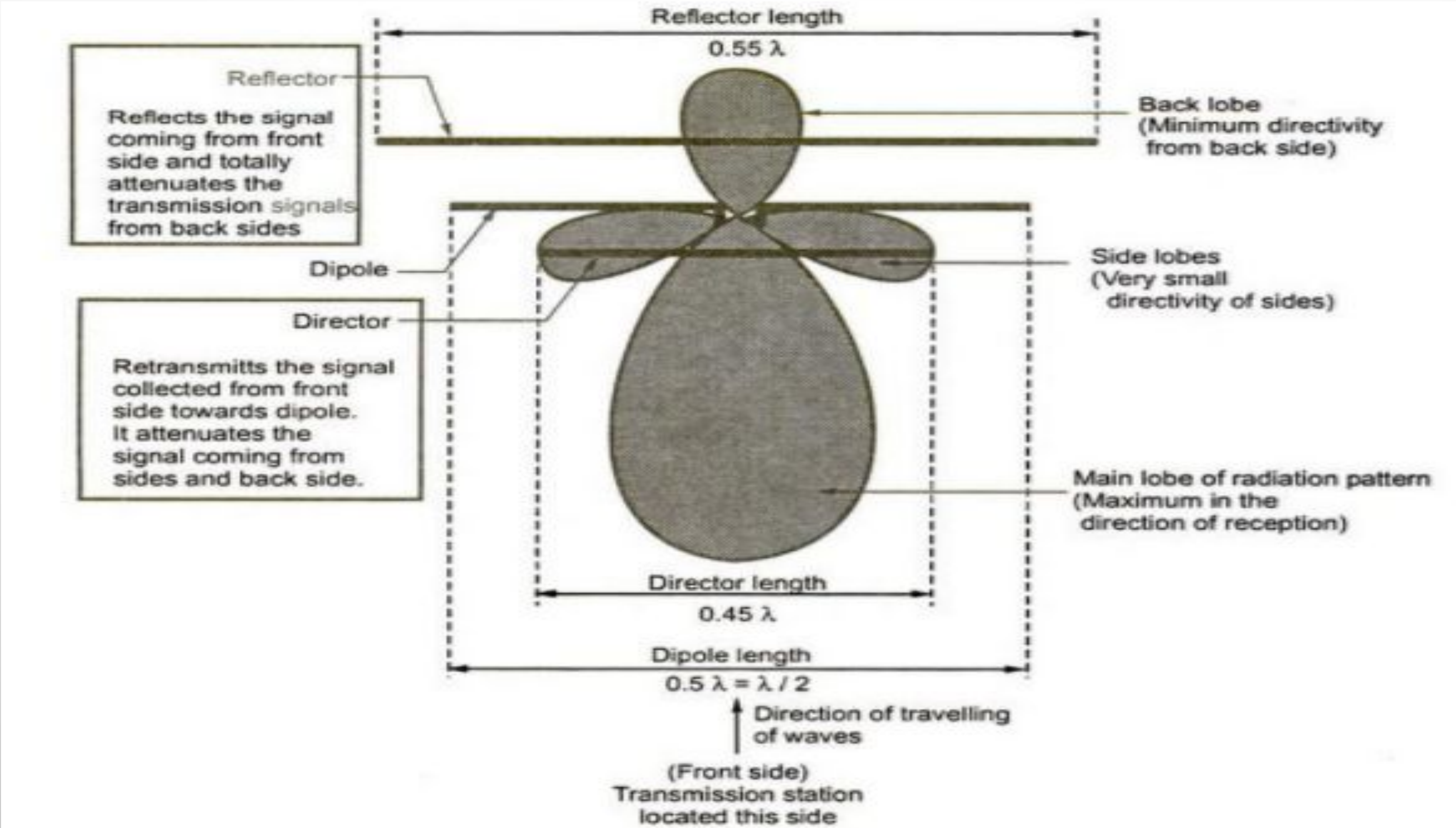


Fig. 3.35 Yagi antenna and its field radiation pattern

The signal strength of the Yagi-Uda antenna can be increased by increasing number of directors in antenna. A typical practical Yagi-Uda antenna with more than one directors is as shown in the Fig. 3.36.

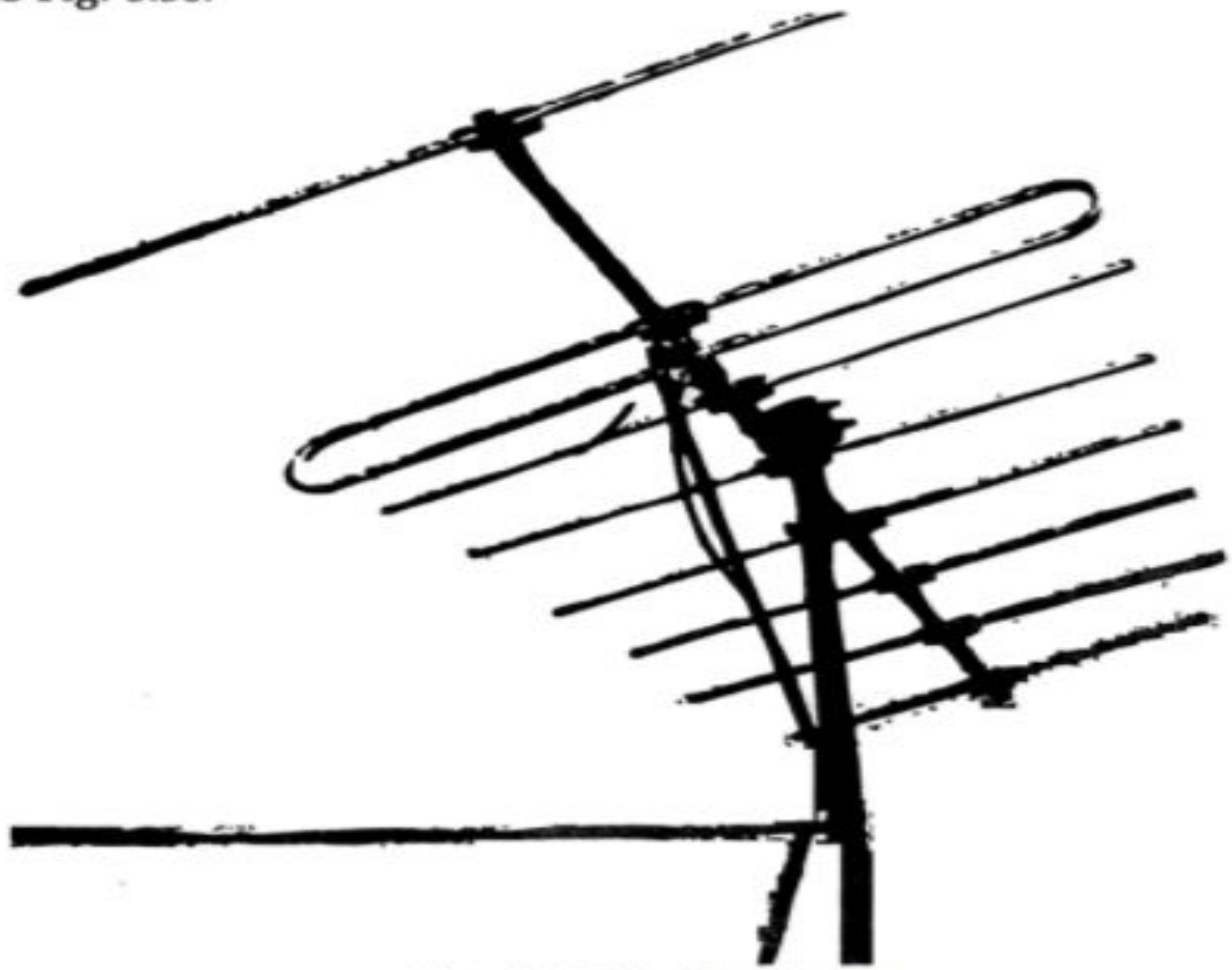


Fig. 3.36 Yagi antenna

3.17.1 General Characteristics of Yagi-Uda Antenna

Following are the general characteristics of the Yagi-Uda antenna.

1. The Yagi-Uda antenna with three elements including one reflector, one driven element and one director is commonly called **beam** antenna.
2. It is generally a fixed frequency operated unit. This antenna is frequency sensitive and the bandwidth of 3 % can be easily obtained. Such bandwidth is sufficient for television reception.
3. The bandwidth of 2 % to 3 % can be easily achieved if the spacing between the elements is between 0.1 λ to 1.5 λ.
4. The gain of the Yagi-Uda antenna is about 7 to 8 dB. Its front to back ratio is 20 dB.
5. This antenna gives a radiation beam which is unidirectional with a moderate directivity.
6. The Yagi-Uda antenna is light weight, low cost and simple in feeding with signal.
7. To achieve greater directivity more number of directors are used. The number of directors may range from 2 to 40.
8. The Yagi-Uda antenna provides high gain and beamwidth greater than that is obtainable from the uniform distribution. Thus Yagi-Uda antennas are called **superdirective** or **super gain antennas**.

SUMMARY OF DESIGN PARAMETER

ELEMENT	SPECIFICATION
Length of the Driven Element	0.458λ to 0.5λ
Length of the Reflector	0.55λ to 0.58λ
Length of the Director 1	0.45λ
Length of the Director 2	0.40λ
Length of the Director 3	0.35λ
Spacing between Directors	0.2λ
Reflector to dipole spacing	0.35λ
Dipole to Director spacing	0.125λ

If the specifications given above are followed, one can design an Yagi-Uda antenna.

ADVANTAGES

- THE FOLLOWING ARE THE ADVANTAGES OF YAGI-UDA ANTENNAS −
- HIGH GAIN IS ACHIEVED.
- HIGH DIRECTIVITY IS ACHIEVED.
- EASE OF HANDLING AND MAINTENANCE.
- LESS AMOUNT OF POWER IS WASTED.
- BROADER COVERAGE OF FREQUENCIES.

DISADVANTAGES

- THE FOLLOWING ARE THE DISADVANTAGES OF YAGI-UDA ANTENNAS −
- PRONE TO NOISE.
- PRONE TO ATMOSPHERIC EFFECTS.

APPLICATIONS

- THE FOLLOWING ARE THE APPLICATIONS OF YAGI-UDA ANTENNAS −
- MOSTLY USED FOR TV RECEPTION.
- USED WHERE A SINGLE-FREQUENCY APPLICATION IS NEEDED.

FOLDED DIPOLE ANTENNA

It is the important modification of the conventional half wave dipole in which the two half wave dipoles have been folded and joined together as shown in the Fig. 3.37. One of the half wave dipoles in continuous while other is split at the centre.

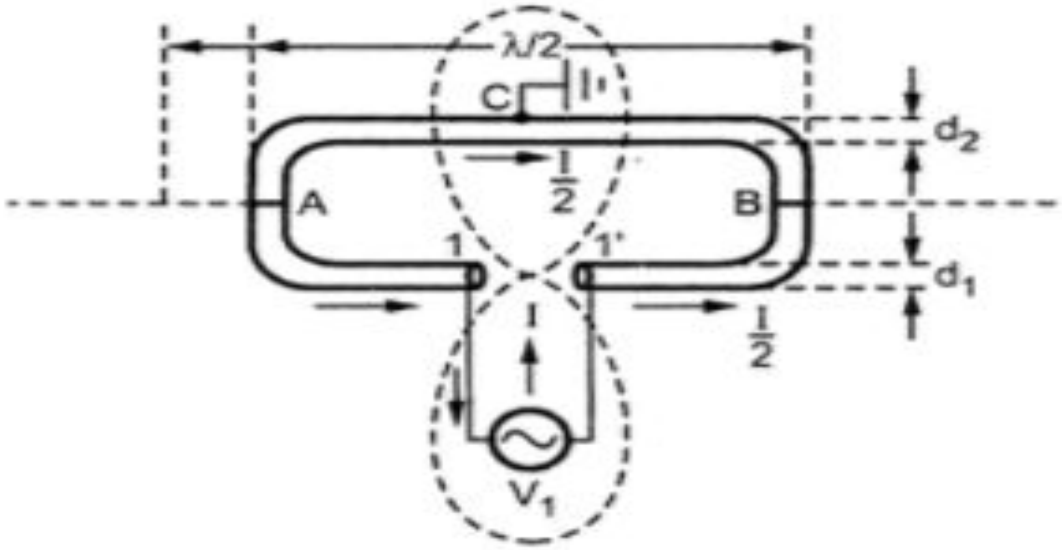


Fig. 3.37 Folded dipole and radiation pattern

The folded dipole which is splited at the centre is fed with the balanced transmission line. As a result the voltages at the ends of two dipoles are same. When the radiation fields are concerned, the two dipoles are found to be in parallel essentially. Note that the radiation pattern of the conventional half wave dipole and that of the folded dipole are exactly same. But the main difference between the two is that the input impedance of the folded dipole is much higher than that of the conventional half wave dipole. There are two more important factors which differ folded dipole from the conventional half wave dipole. They are directivity and bandwidth.

If the conductors of the folded dipoles are of same radii, then the currents with equal in magnitude and phase flows through the two dipoles.

Consider that the total current flowing into terminals 1 - 1' is I. Now if the radii of the conductors are equal then the dipoles will carry equal currents of magnitude $\frac{I}{2}$. Now if this had been a straight dipole, the total current would flow in first only dipole arm. Now if the power applied is same, only half of the current flows in first dipole. As the power $P = I^2R$, the input impedance of the folded dipole becomes 4 times that of the straight dipole. As the transmission line is delivering the same power but at only half of the current. Hence for the line impedance is higher. Hence input impedance i.e. radiation resistance of the folded dipole becomes

$$R_{rad} = (2)^2\, 73 = 4(73) = 292\ \Omega$$

3.19 Derivation for Input Impedance of Folded Dipole Antenna

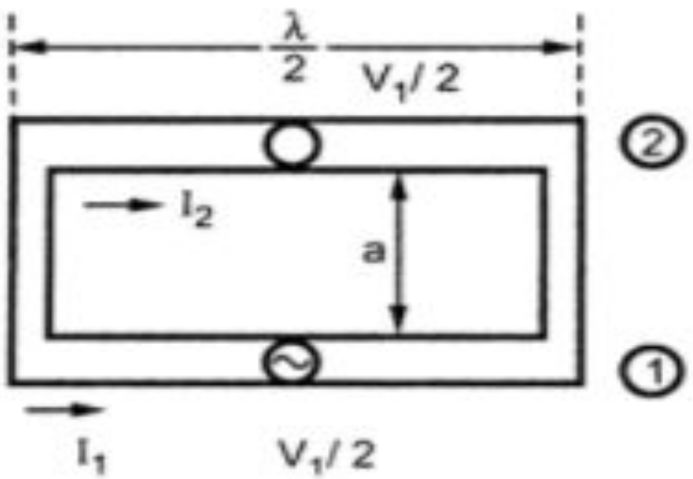


Fig. 3.40 Equivalent circuit of folded dipole of λ/2 length

Let us consider a folded dipole as shown in the Fig. 3.37. The equivalent circuit of two wire folded dipole of length $\lambda/2$ is as shown in the Fig. 3.40.

The applied voltage V_1 which is applied across terminals 1 - 1' gets equally divided in each dipole as voltage $\frac{V_1}{2}$. Then equation can be written as,

$$\frac{V_1}{2} = Z_{11} I_1 + Z_{12} I_2 \qquad \ldots(1)$$

Note that Z_{11} is the self impedance of dipole ① and Z_{12} is the mutual impedance between dipoles ① and ②. The currents I_1 and I_2 are the currents through the respective dipoles. Assuming both the dipoles of equal radii, we can have condition,

$$I_1 = I_2 \qquad \ldots(2)$$

Hence equation (1) becomes,

$$\frac{V_1}{2} = (Z_{11} + Z_{12}) I_1 \qquad \ldots(3)$$

If the two dipoles are very close to each other such that the spacing between the two is of the order of $\frac{\lambda}{100}$ then we can approximate that self impedance is equal to the mutual impedance between the two dipoles, i.e. $Z_{11} = Z_{12}$. Hence equation (3) becomes,

$$\frac{V_1}{2} = (Z_{11} + Z_{11})\, I_1$$

$$\therefore \quad V_1 = 2(2Z_{11})\, I_1 = 4\, Z_{11}\, I_1 \qquad \text{...(4)}$$

Thus the input impedance of the antenna is given by

$$Z = \frac{V_1}{I_1} = 4\, Z_{11}$$

The self impedance of dipole 1 of length $\lambda/2$ is nothing but its radiation resistance which is of value 73 Ω.

$$\therefore \quad \boxed{Z = 4\,(73) = 292\ \Omega} \qquad \text{... (5)}$$

Thus the input impedance of two wire folded dipole of length $\frac{\lambda}{2}$ is equal to 292 Ω.

THANK YOU