EXPT No: 3 **Date: 13/03/2021**

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TE EXTC 2

Aim: To plot Radiation pattern for varying lengths of dipole antenna

Apparatus: MATLAB / SCILAB

Theory:

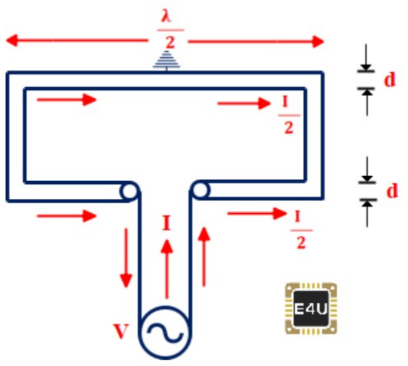
1. Write about types of dipoles.

1) Folded Dipole Antenna:

A folded dipole antenna is an array of the two-dipole antenna. If two dipole antennas are connected in parallel to forms a thin wire loop, then it is called a folded dipole antenna.
As the name implies that the form of the dipole antenna is folded back on itself. In the folded dipole antenna, two half-wave dipoles – one continuous and the other split at the center are folded and joined together in parallel at the ends. The split dipole is fed at the center by a balanced transmission line. Hence, the two dipoles have the same voltages at their ends and two identical currents are generated.
The radiation pattern of a folded dipole is the same as to an ordinary dipole but the input impedance of the folded dipole is higher and the directivity of a folded dipole is bi-directional.

2) Two-Wire Folded Dipole Antenna:

If two dipole antennas are connected in parallel to form a thin wire loop, then it is known as a two-wire folded dipole antenna.
If the radius of both the conductors is equal, then equal currents flow in both the conductors in the same direction i.e., currents are equal in magnitude and phase. If the total current fed at the terminal is ‘I’ then each dipole will have current ‘I/2’. Thus, with the same power applied, only half of the current flows in the first dipole, and hence the input impedance increases and it becomes four times. The folded dipole antenna is shown in the figure below.



Folded Dipole Antenna

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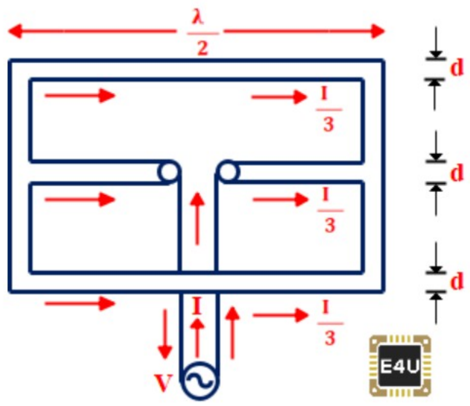
3) Three Wire Folded Dipole Antenna (Folded Tripole):

If three dipole antennas are connected in parallel to form a thin wire loop, then it is known as a three-wire folded dipole antenna or Folded Tripole antenna.

If three wire folded dipole antennas are used with equal radii, then the equal current flows in all the three conductors. If the total current fed at the terminal is ‘I’ then each dipole will have current ‘I/3’.

Thus, with the same power applied, only one-third of the total radiating current flows in the first dipole, and hence the input impedance increases and it becomes nine times. The folded dipole antenna is shown in the figure below.



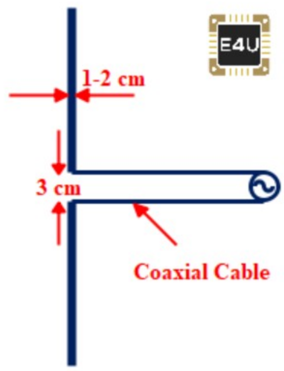
Folded Tripole Antenna

So, the folded dipole antenna or tripole antenna has an important impedance transforming properties. This makes it easy to match with a transmission line that feeds the antenna. It is also possible to change the input impedance by keeping the radius of the two dipoles unequal. In this condition, a larger current flow through a thicker dipole and hence we can maintain any desired input impedance.

4) FM Dipole Antenna:

FM dipole antenna is defined as the vertically polarized half-wave half dipole antenna. The FM dipole antenna is mostly used as it is to build and it is suitable to provide improved reception of VHF FM broadcast. The FM dipole antenna is shown in the figure below.

The radiation pattern of the FM dipole antenna is perpendicular to the axis of the antenna i.e., It is horizontal because the FM dipole antenna is a vertically polarized half-wave dipole antenna. The radiation pattern of the FM dipole antenna is shown in the below figure.



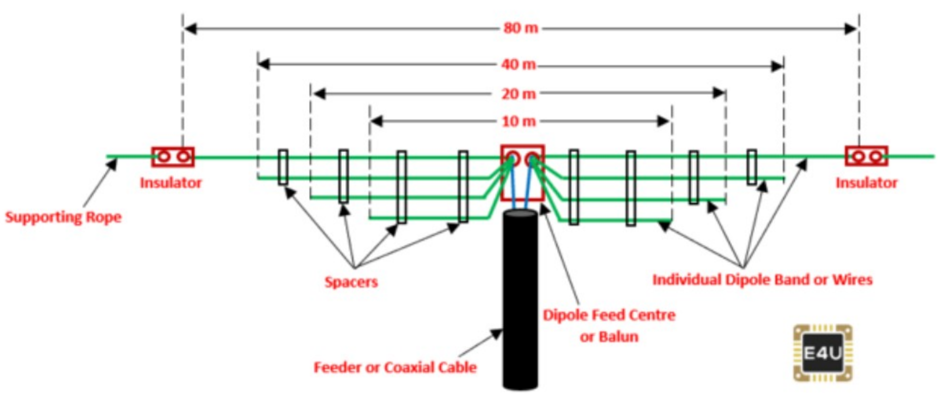
FM Dipole Antenna

5) **Fan Dipole Antenna:**

Fan dipole or Multi-band wire antenna is one in which multiple dipoles are connected with a common feed line, and they are spread out like a fan hence it is called a fan dipole antenna.

As the name implies that the form of the fan dipole antenna looks like a fan. It is also known as a Parallel dipole antenna.

In the fan dipole antenna, each dipole of the multi-band is cut from the center of the bands and connected to a common feeder. The dipole should be cut from where we want it to radiate. When the signal is transmitted, we only receive the signal from that band which is radiating, because the other dipoles have a higher impedance compared to that radiating element.



4 Bands Fan Dipole Antenna

The fan dipole antenna is shown in the above figure. It is 4 Bands fan dipole antenna. Here, we used 80 m, 40 m, 20 m, and 10 m multi-band dipole that are connected in parallel with a common feeder line.

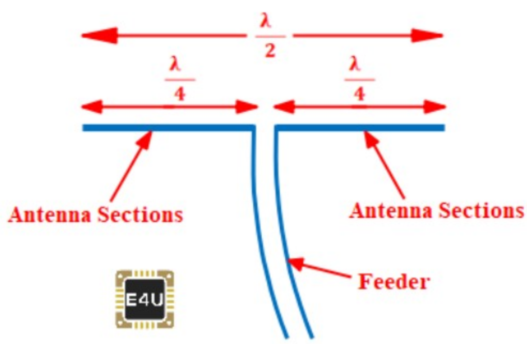
6) Half-Wave Dipole Antenna:

The Half-Wave Dipole Antenna is the most widely used type of dipole antenna. As the name suggests that, the total length of the dipole antenna is equal to the half-wavelength (\frac{\ lambda}{2}) at the frequency of operation.

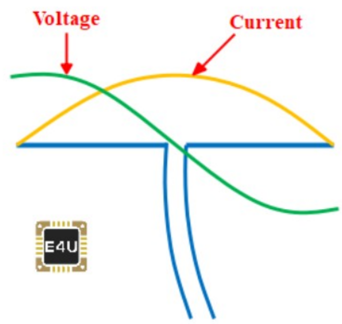
It is known as a half-wavelength dipole or simply dipole or doublet. It is also known as the Hertz antenna.

The half-wave dipole antenna consists of a two-quarter wavelength conductor with the feed point at the center. It is the symmetrical antenna in which the two ends are at the equal potential to the center point.

The current distribution in the half-wave dipole antenna is app roximately sinusoidal along the length of the dipole i.e., a standing wave in nature. The basic half-wave dipole antenna and voltage and current distribution on it are shown in the below figure.



Basic Half Wave Dipole Antenna



Current and Voltage Distribution in a Half-Wave Dipole Antenna

The radiation pattern of the half-wave dipole antenna is shown in the below figure. It shows that the directions of maximum radiation are perpendicular to the conductor or the axis of the antenna. It is also perpendicular to the direction of the antenna current.

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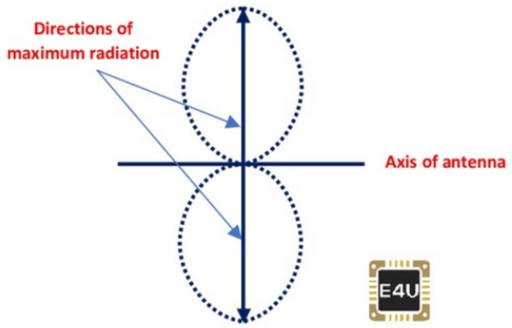


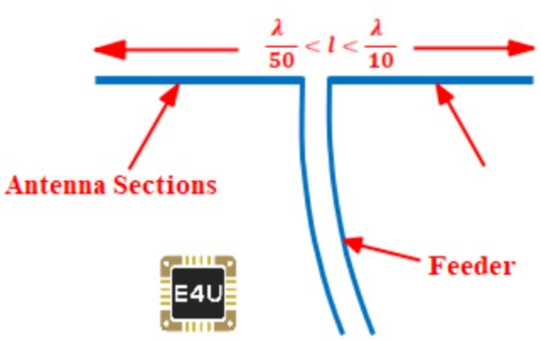
Radiation Pattern of a Half-Wave Dipole Antenna

7) Short Dipole Antenna:

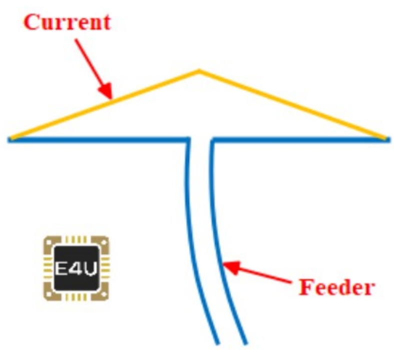
The short dipole antenna is the simplest type of antenna from all the antennas. A short dipole antenna is one in which the length of the wire is less than half of the wavelength i.e., $(< \frac{\lambda}{2})$.

In a short dipole antenna, the feed impedance starts to increases and its response is less dependent upon the frequency changes. The current distribution in the short dipole antenna is approximately triangular. The length of the short dipole antenna in between $\frac{\lambda}{50}$ to $\frac{\lambda}{10}$. i.e., $\frac{\lambda}{50} < l < \frac{\lambda}{10}$.

The current distribution on the short dipole antenna is approximately triangular. The basic short dipole antenna and current distribution on it are shown in the below figure.



Short Dipole Antenna



Current Distribution in a Short Dipole Antenna

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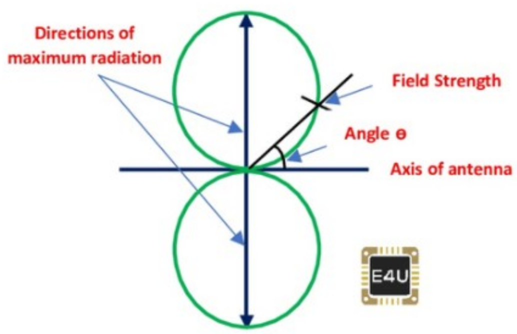
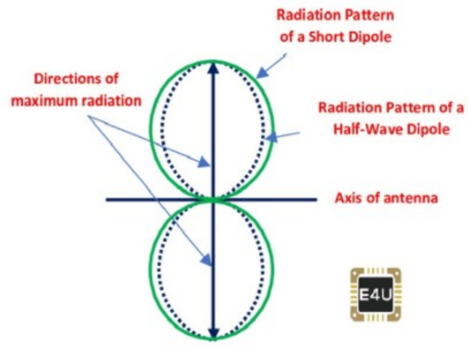
The radiation pattern of the short dipole antenna is simply a circle. It is slightly different compared to the half-wave dipole antenna. The radiation pattern of the short dipole antenna and its comparison with the half-wave dipole antenna is shown in the below figure.

A short dipole antenna is used in place of the full half-wave dipole antenna in certain applications where the full half-wave dipole antenna is too large.



Radiation Pattern of a Short Dipole Antenna



Radiation Pattern of a Short Dipole Antenna in Comparison With the Half-Wave Dipole Antenna

2. Derive the equation of radiation intensity of finite length dipole.

FINITE LENGTH DIPOLE:

The techniques that were developed previously can also be used to analyze the radiation characteristics of a linear dipole of any length. To reduce the mathematical complexities, it will be assumed in this chapter that the dipole has a negligible diameter (ideally zero).
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4.5.3 Power Density, Radiation Intensity, and Radiation Resistance

For the dipole, the average Poynting vector can be written as

$$\mathbf{W}_{av} = \frac{1}{2}\mathrm{Re}[\mathbf{E} \times \mathbf{H}^*] = \frac{1}{2}\mathrm{Re}[\hat{\mathbf{a}}_\theta E_\theta \times \hat{\mathbf{a}}_\phi H_\phi^*] = \frac{1}{2}\mathrm{Re}\left[\hat{\mathbf{a}}_\theta E_\theta \times \hat{\mathbf{a}}_\phi \frac{E_\theta^*}{\eta}\right]$$

$$\mathbf{W}_{av} = \hat{\mathbf{a}}_r W_{av} = \hat{\mathbf{a}}_r \frac{1}{2\eta}|E_\theta|^2 = \hat{\mathbf{a}}_r \eta \frac{|I_0|^2}{8\pi^2 r^2}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)}{\sin\theta}\right]^2 \tag{4-63}$$

and the radiation intensity as

$$U = r^2\, W_{av} = \eta \frac{|I_0|^2}{8\pi^2}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)}{\sin\theta}\right]^2 \tag{4-64}$$

The normalized (to 0 dB) elevation power patterns, as given by (4-64) for $l = \lambda/4, \lambda/2, 3\lambda/4$, and λ are shown plotted in Figure 4.6. The current distribution of each is given by (4-56). The power patterns for an infinitesimal dipole $l \ll \lambda$ ($U \sim \sin^2\theta$) is also included for comparison. As the length of the antenna increases, the beam becomes narrower. Because of that, the directivity should also increase with length. It is found that the 3-dB beamwidth of each is equal to

$l \ll \lambda$	3-dB beamwidth $= 90°$	
$l = \lambda/4$	3-dB beamwidth $= 87°$	
$l = \lambda/2$	3-dB beamwidth $= 78°$	(4-65)
$l = 3\lambda/4$	3-dB beamwidth $= 64°$	
$l = \lambda$	3-dB beamwidth $= 47.8°$	

As the length of the dipole increases beyond one wavelength ($l > \lambda$), the number of lobes begin to increase. The normalized power pattern for a dipole with $l = 1.25\lambda$ is shown in Figure 4.7. In Figure 4.7(a) the three-dimensional pattern is illustrated using the software from [5], while in Figure 4.7(b) the two-dimensional (elevation pattern) is depicted. For the three-dimensional illustration, a 90° angular section of the pattern has been omitted to illustrate the elevation plane directional pattern variations. The current distribution for the dipoles with $l = \lambda/4, \lambda/2, \lambda, 3\lambda/2$, and 2λ, as given by (4-56), is shown in Figure 4.8.

To find the total power radiated, the average Poynting vector of (4-63) is integrated over a sphere of radius r. Thus

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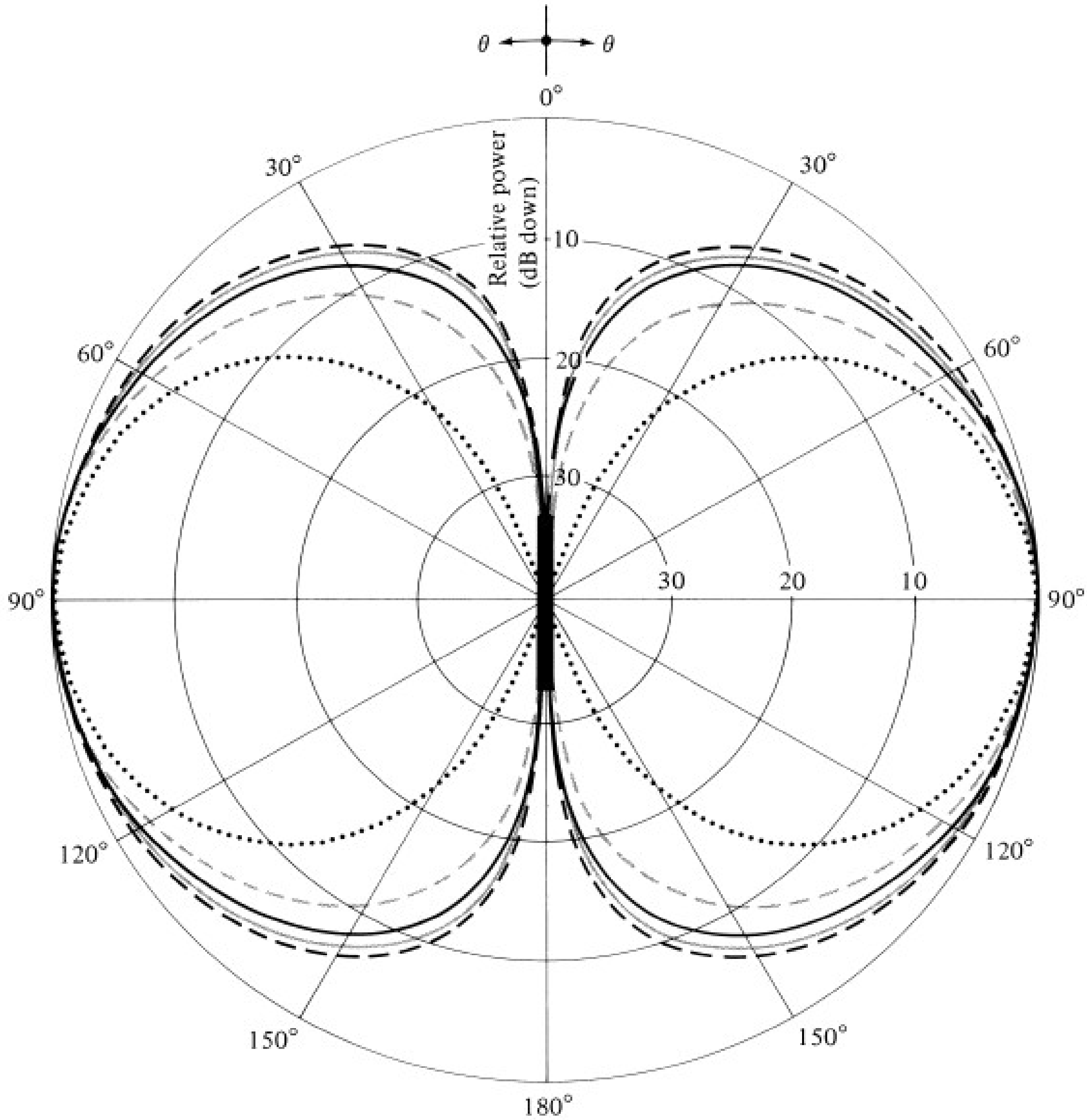
$$P_{\text{rad}} = \oiint_S \mathbf{W}_{\text{av}} \cdot d\mathbf{s} = \int_0^{2\pi} \int_0^{\pi} \hat{\mathbf{a}}_r W_{\text{av}} \cdot \hat{\mathbf{a}}_r r^2 \sin\theta \, d\theta \, d\phi$$

$$= \int_0^{2\pi} \int_0^{\pi} W_{\text{av}} r^2 \sin\theta \, d\theta \, d\phi \qquad (4\text{-}66)$$



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$l = \lambda/50$	$l = \lambda/50$	3-dB beamwidth = 90°
$l = \lambda/4$	$l = \lambda/4$	3-dB beamwidth = 87°
$l = \lambda/2$	$l = \lambda/2$	3-dB beamwidth = 78°
$l = 3\lambda/4$	$l = 3\lambda/4$	3-dB beamwidth = 64°
$l = \lambda$	$l = \lambda$	3-dB beamwidth = 47.8°

Figure 4.6 Elevation plane amplitude patterns for a thin dipole with sinusoidal current distribution ($l = \lambda/50, \lambda/4, \lambda/2, 3\lambda/4, \lambda$).

Using (4-63), we can write (4-66) as

$$P_{\text{rad}} = \int_0^{2\pi} \int_0^{\pi} W_{\text{av}} r^2 \sin\theta \, d\theta \, d\phi$$

$$= \eta \frac{|I_0|^2}{4\pi} \int_0^{\pi} \frac{\left[\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)\right]^2}{\sin\theta} d\theta \qquad (4\text{-}67)$$

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3. Draw the current distributions on dipoles of different lengths

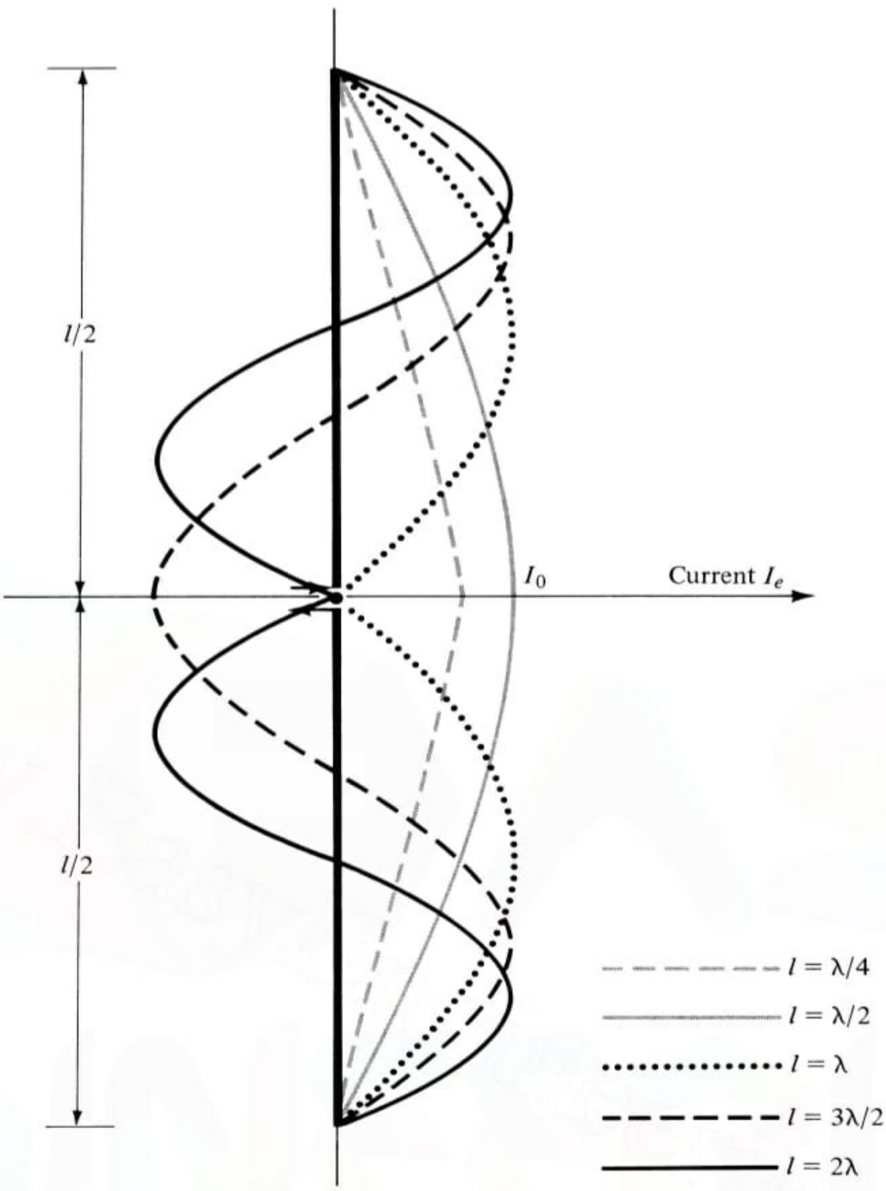

Figure 4.8 Current distributions along the length of a linear wire antenna.

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Observation:

```
clc;
close all;
clear all;
theta = 0:pi/180:2*pi;
lambda=1;
k=2*pi/lambda;
subplot(2,4,1)
l=1/50;
U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)
polar(theta,U)
title("Radiation Pattern of l = 1/50")
subplot(2,4,2)
l=1/10;
U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)
polar(theta,U)
title("Radiation Pattern of l = 1/10")
subplot(2,4,3)
l=1/4;
U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)
polar(theta,U)
title("Radiation Pattern of l = 1/4")
subplot(2,4,4)
l=1/2;
U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)
polar(theta,U)
title("Radiation Pattern of l = 1/2")
```

```
subplot(2,4,5)

l=1;

U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)

polar(theta,U)

title("Radiation Pattern of l = 1")

subplot(2,4,6)

l=3/2;

U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)

polar(theta,U)

title("Radiation Pattern of l = 3/2")

subplot(2,4,7)

l=2;

U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)

polar(theta,U)

title("Radiation Pattern of l = 2")

subplot(2,4,8)

l=3;

U = power((cos(k*l/2 .* cos(theta))-cos(k*l/2))./sin(theta) ,2)

polar(theta,U)

title("Radiation Pattern of Small Dipole l = 3")
```

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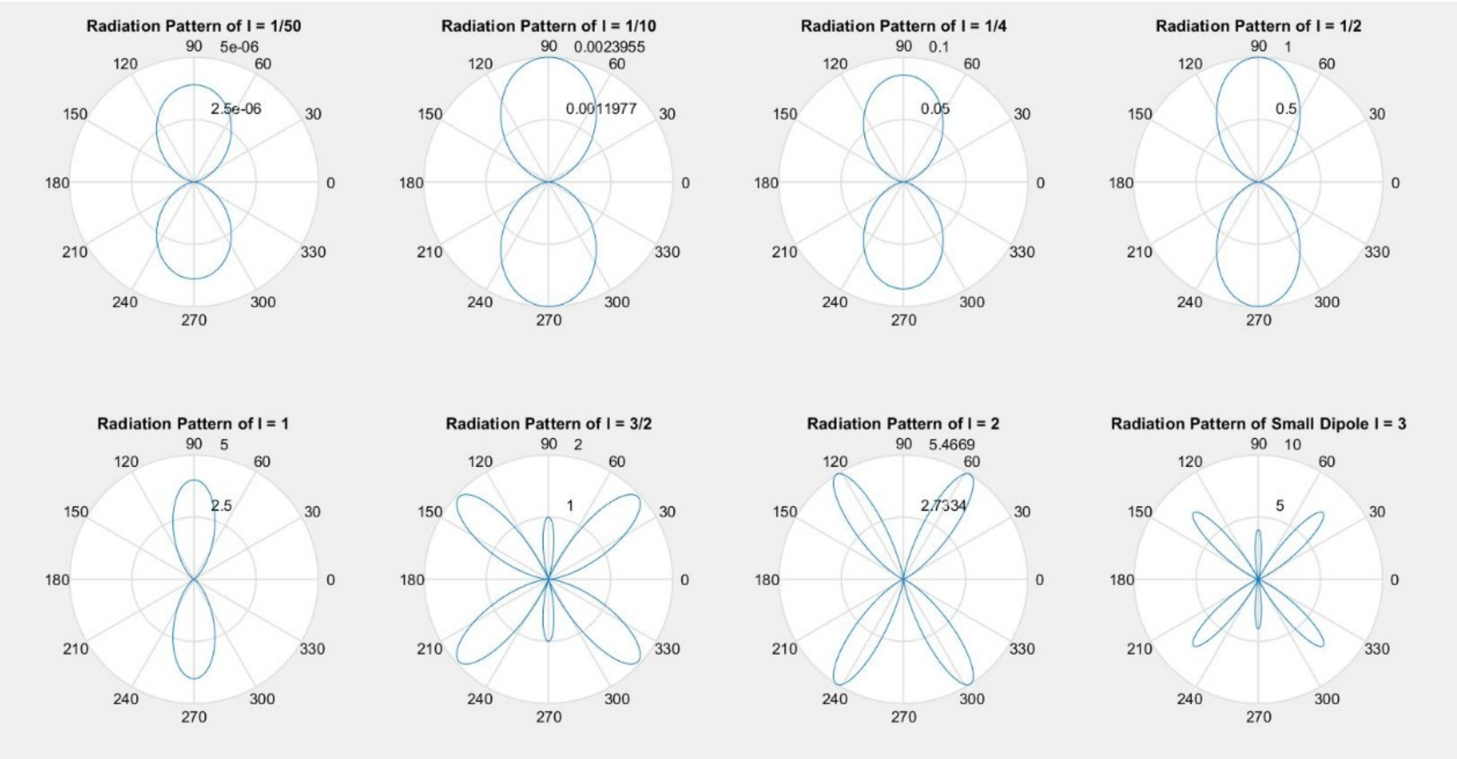
Output:



Conclusion:

We can say from the above experiment that there is change in directivity when there is change in value of length. The directivity increases from lambda/50 to lambda distinctly and there is reduction in directivity from lambda to 2 times lambda and further. Also, increase on grating loops means decrease in directivity.