ANTENNA BASICS

ECE516E – ANTENNA ENGINEERING & RADIO WAVE PROPAGATION

Monday, 22 September 2025

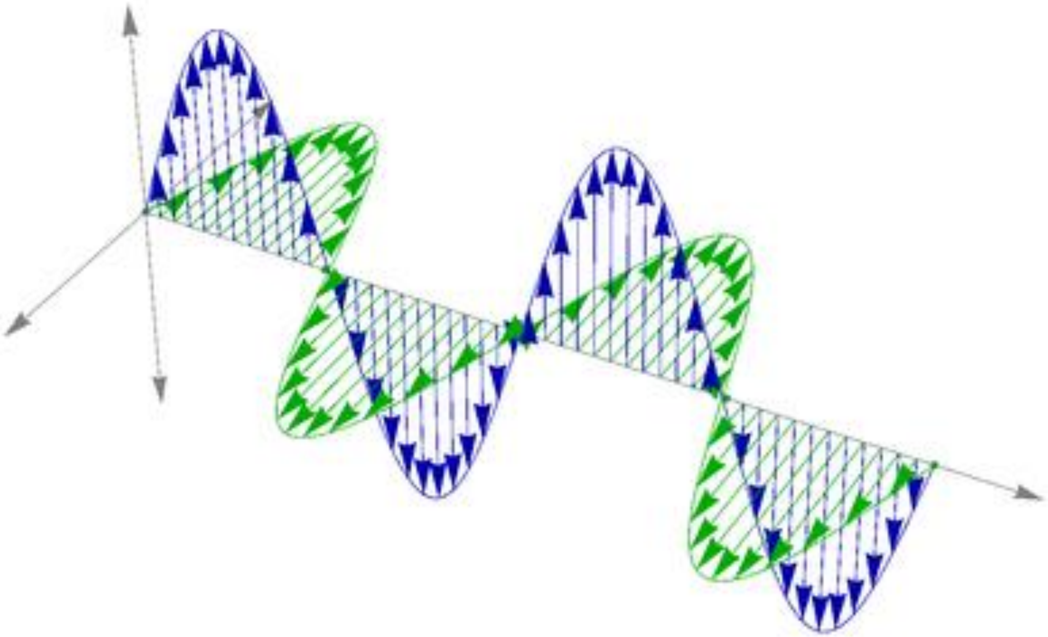
FUNDAMENTALS OF ELECTROMAGNETIC WAVES (REVISTED)

1. Radio wave signal is called an **electromagnetic wave** because it is made up of both electric magnetic fields.

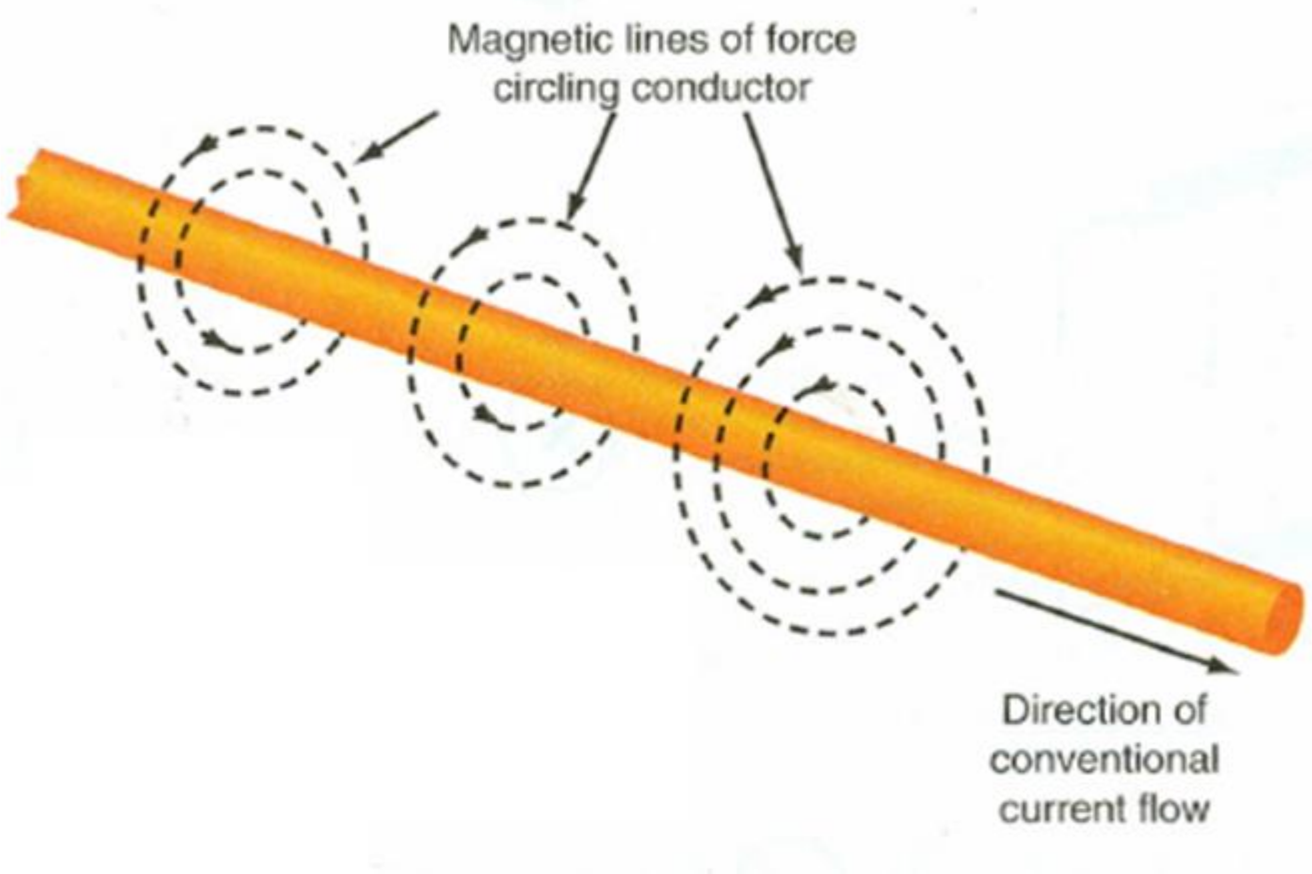
2. When voltage is applied to the antenna, an electric field is causing a current to flow in the antenna.

3. The flow of current produces a magnetic field at right angle to the electric field.

4. The two EM fields are emitted from the antenna and propagate through space over long distances at the speed of light.



MAGNETIC FIELD IN A TRANSMISSION LINE (REVISITED)



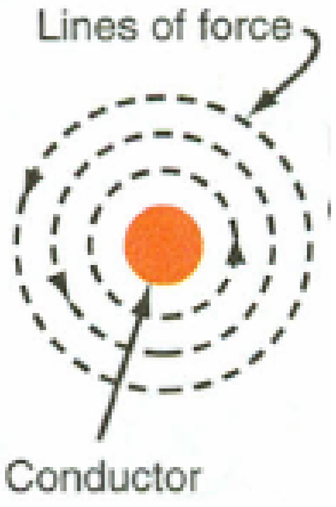
Magnetic field strength

$H = \frac{q}{2\pi d}$ **Ampere turns per metre**

Where

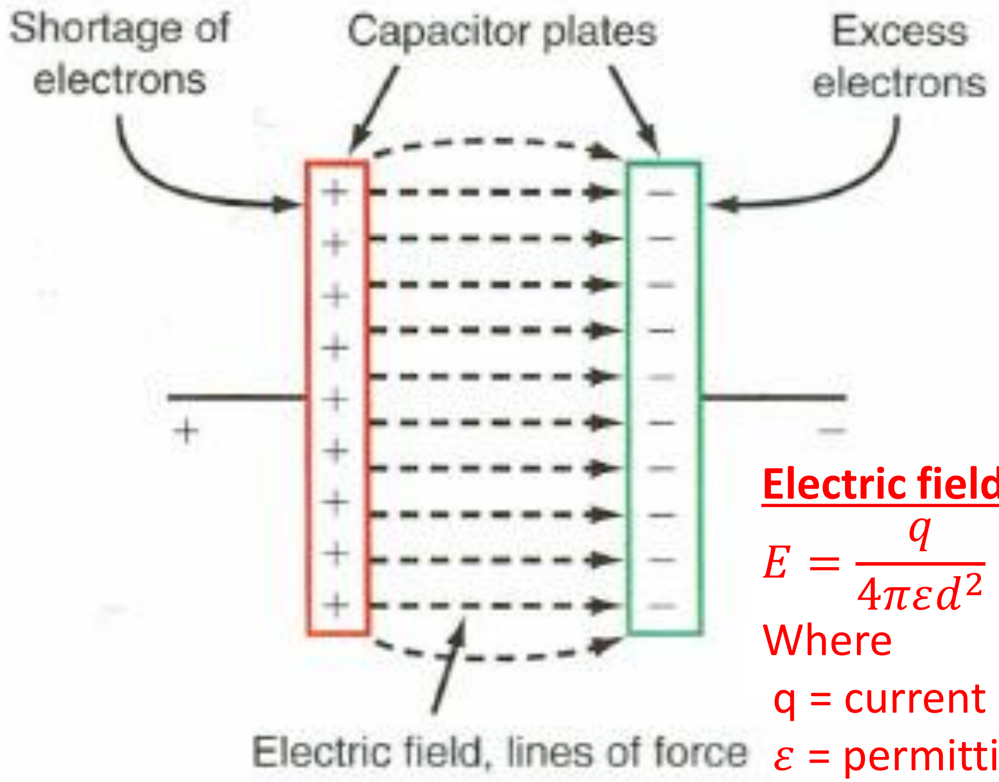
q = Current in Amperes

d = distance from the wire



End view

ELECTRIC FIELD ACROSS A CAPACITOR (REVISTED)



Electric field Strength

$$E = \frac{q}{4\pi\varepsilon d^2}$$

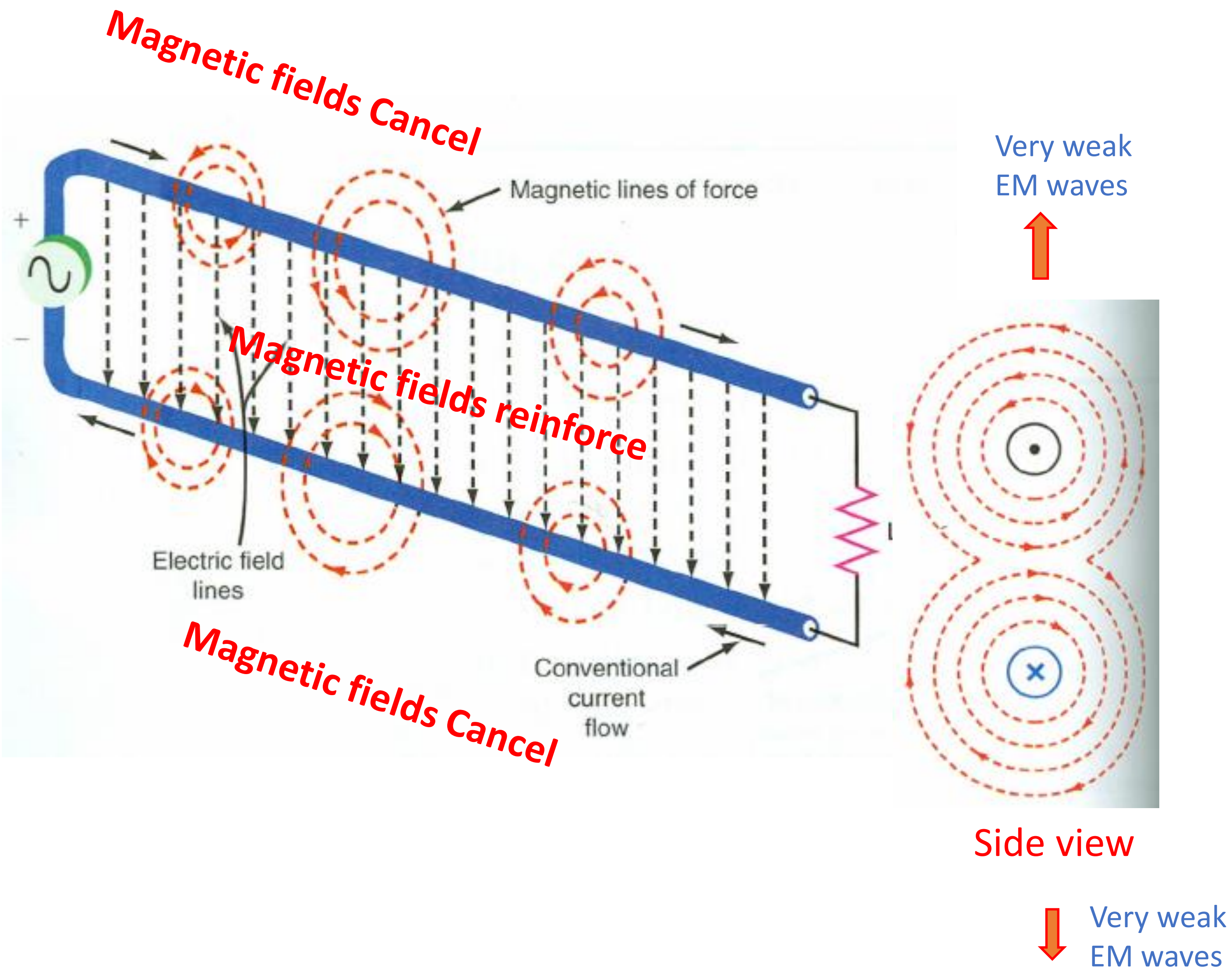
Where

q = current

ε = permittivity or diaelectric constant of the material

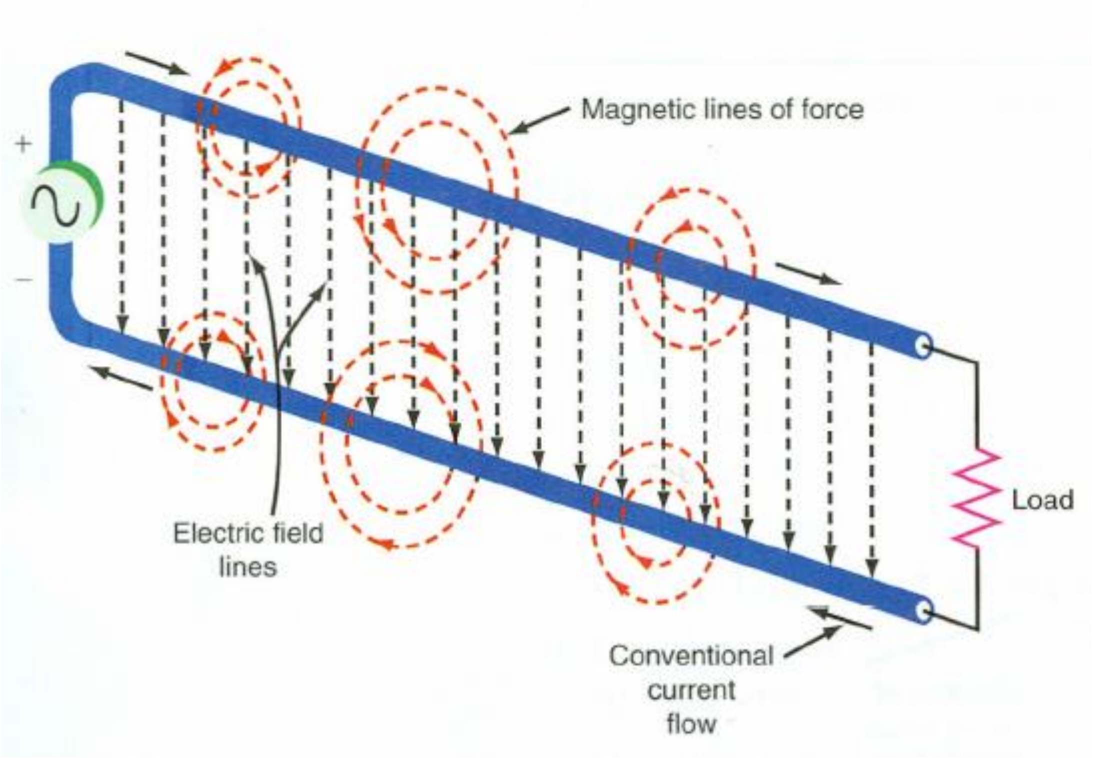
d = distance between two conductors

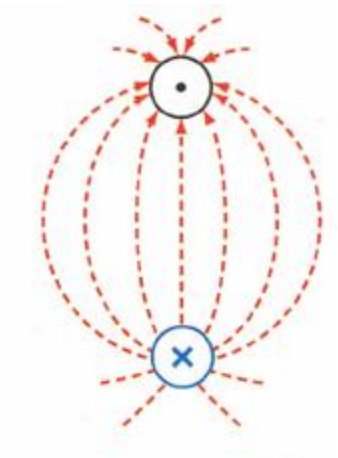
MAGNETIC FIELDS ROUND A TRANSMISSION LINE (REVISITED)



1. **The direction of current flow in one wire is always opposite that in the other wire.**
2. Therefore, the magnetic fields **reinforce one another in between** the conductors and **cancel out outside the conductors**
3. The cancellation is not complete but it makes the magnitude of the magnetic field outside the conductors very small.

ELECTRIC FIELDS ROUND A TRANSMISSION LINE (REVISITED)

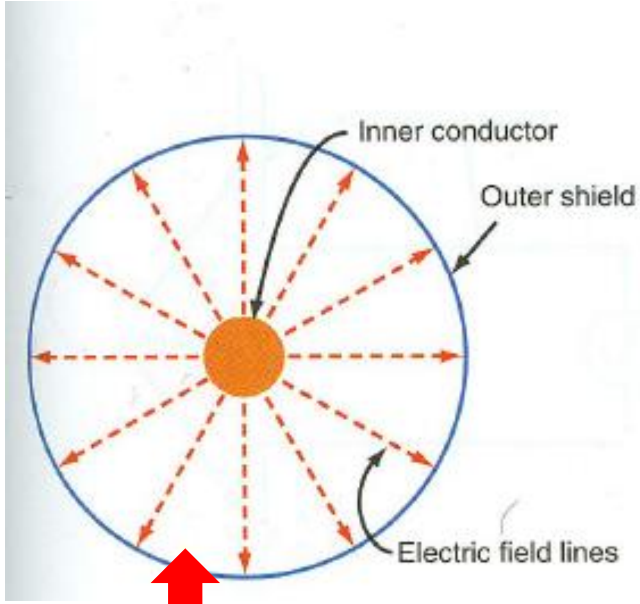




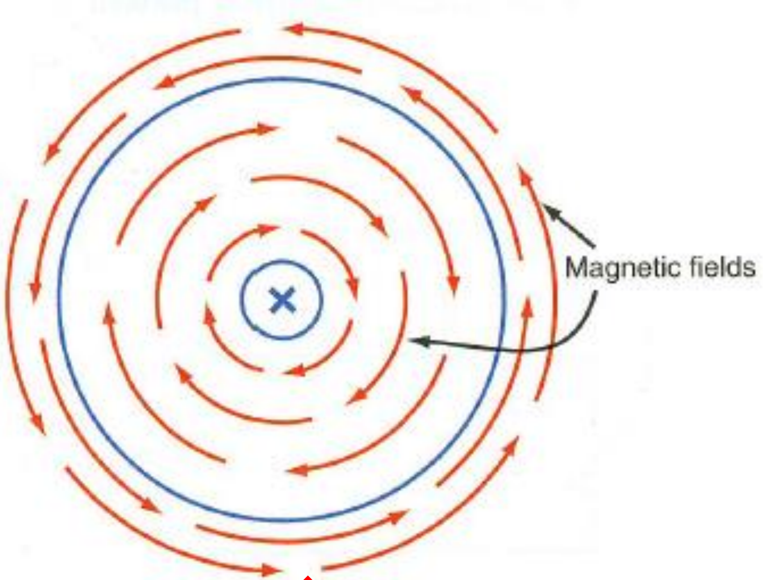
At any time, the two wires have opposite polarities

ELECTRIC AND MAGNETIC FIELDS OF COAXIAL CABLE (REVISITED)

(a) Electric field



(b) Magnetic field



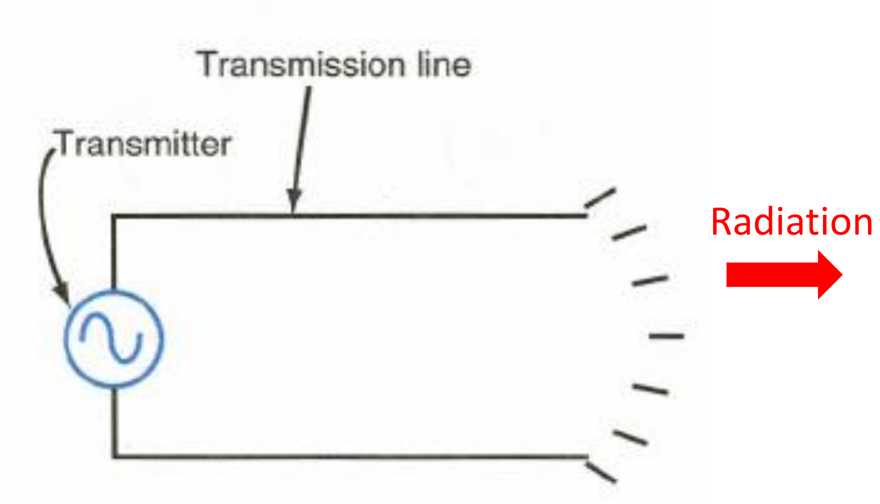
The electric field is fully contained by the outer shield of the cable. None is radiated.

The magnetic fields from the inner conductor and the shield cancel to the outside

- That is why coaxial cable is the most preferred transmission cable in most applications!

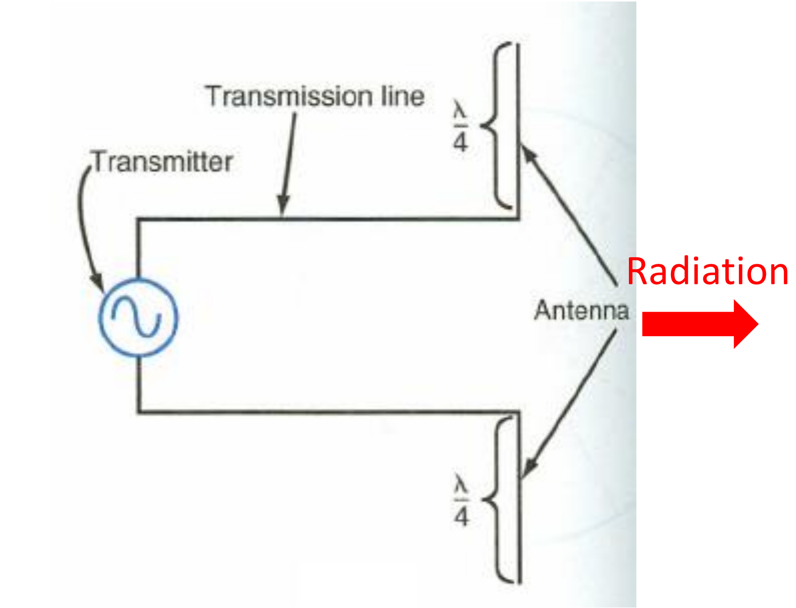
BASICS OF ANTENNA OPERATION

1. If a parallel-wire transmission line is left open, the electric and magnetic fields will escape from the end of the line and radiate into space.

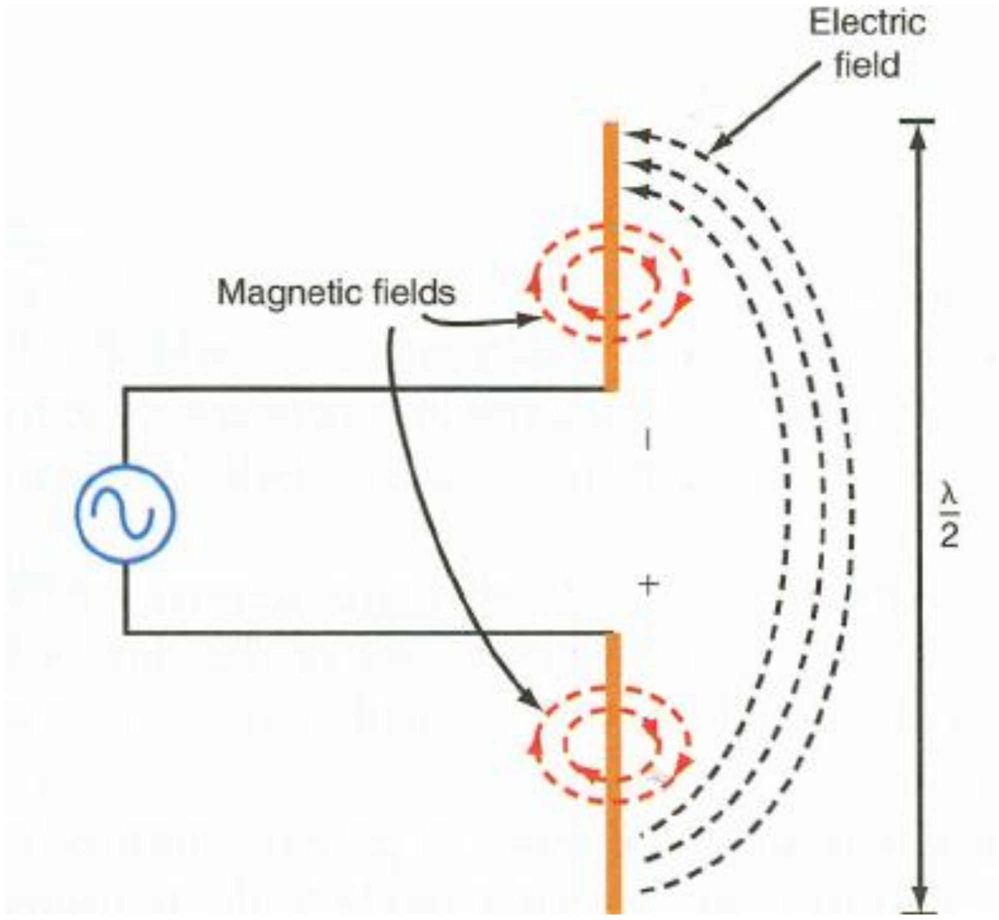


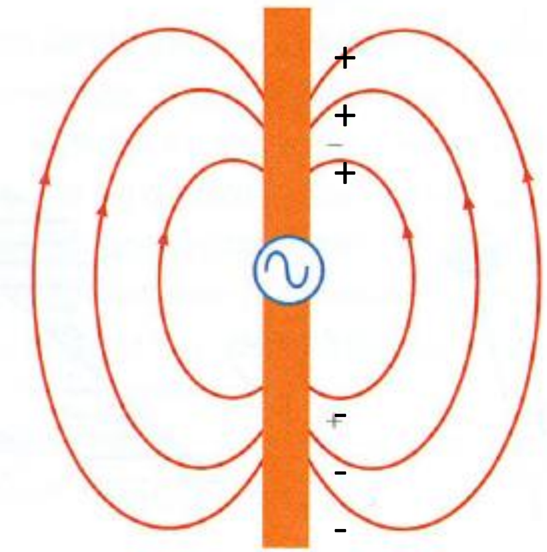
2. The radiation, however, is inefficient and unsuitable for reliable transmition or reception.

3. **However, the radiation from a transmission line is greatly improved by bending the conductors** so they are at a right angle to the transmission line. This is what Hertz discovered!

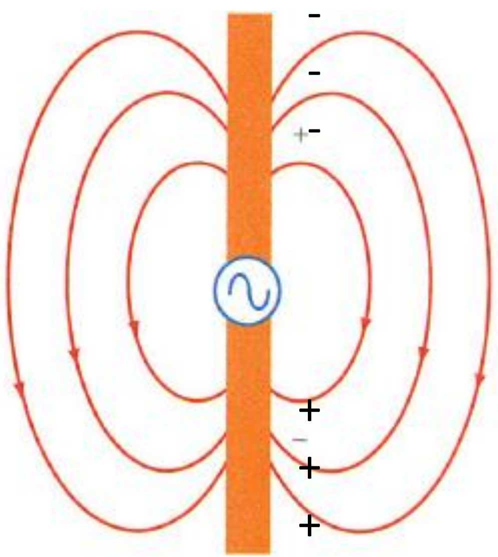


THE ELECTRIC FIELDS OF HALF DIAPOLE



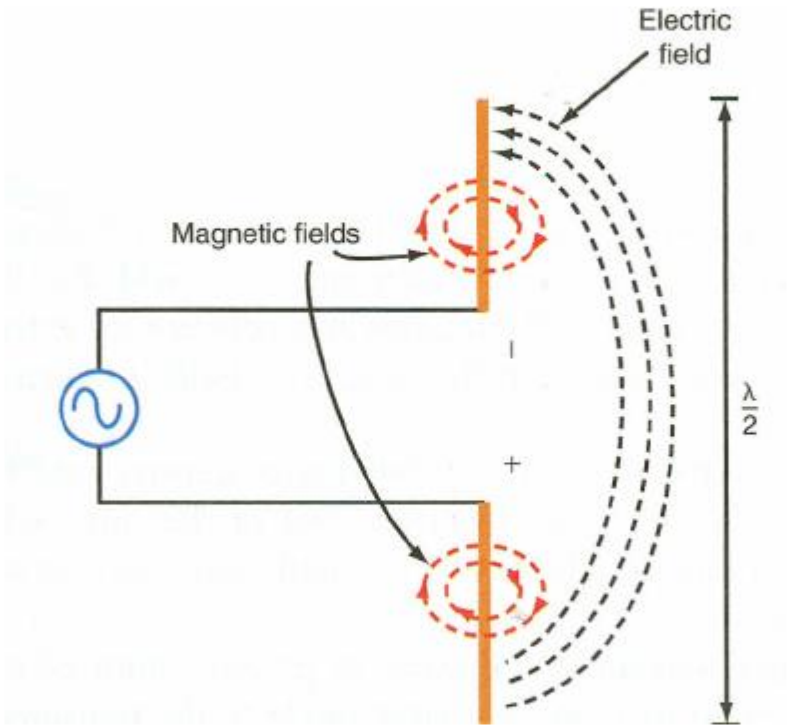


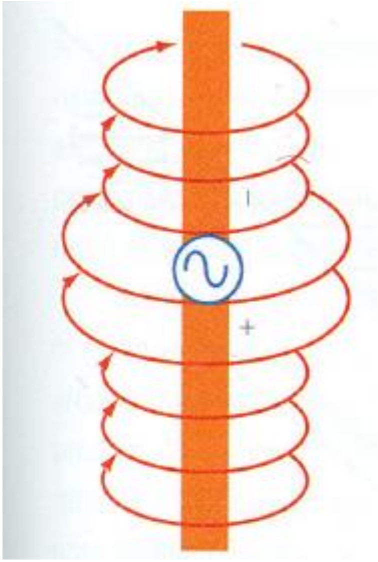
(a) One half-cycle

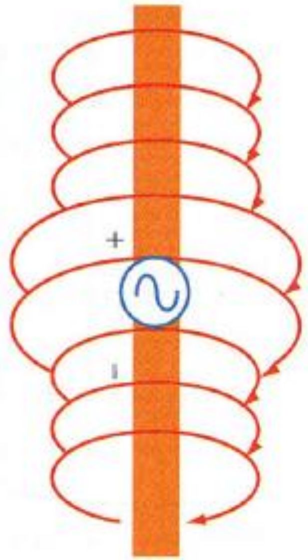


(a) Other One half-cycle

THE MAGNETIC FIELDS OF HALF DIPOLE (REVISITED)







FREE SPACE IMPEDANCE (REVISITED)

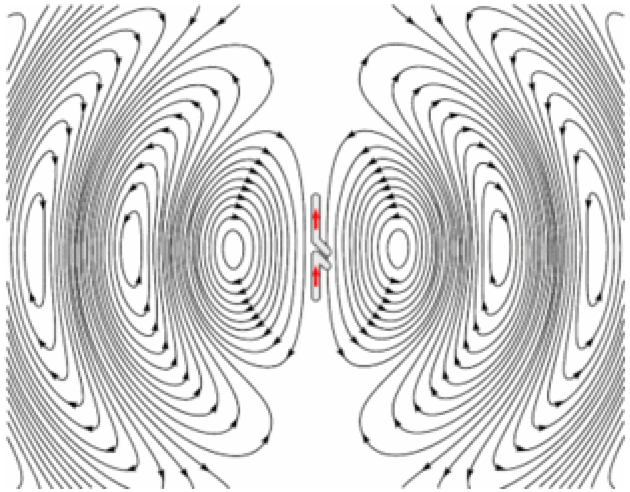
1. Changes in electric field causes changes in magnetic field.
2. E and M fields support and reinforce each other.
3. The ratio of the electric field to the magnetic field of a radiated wave is constant and is called the **wave free space impedance**.
4. Free space Impedance, $Z_o = \frac{|E|}{|H|}$ = 377Ω

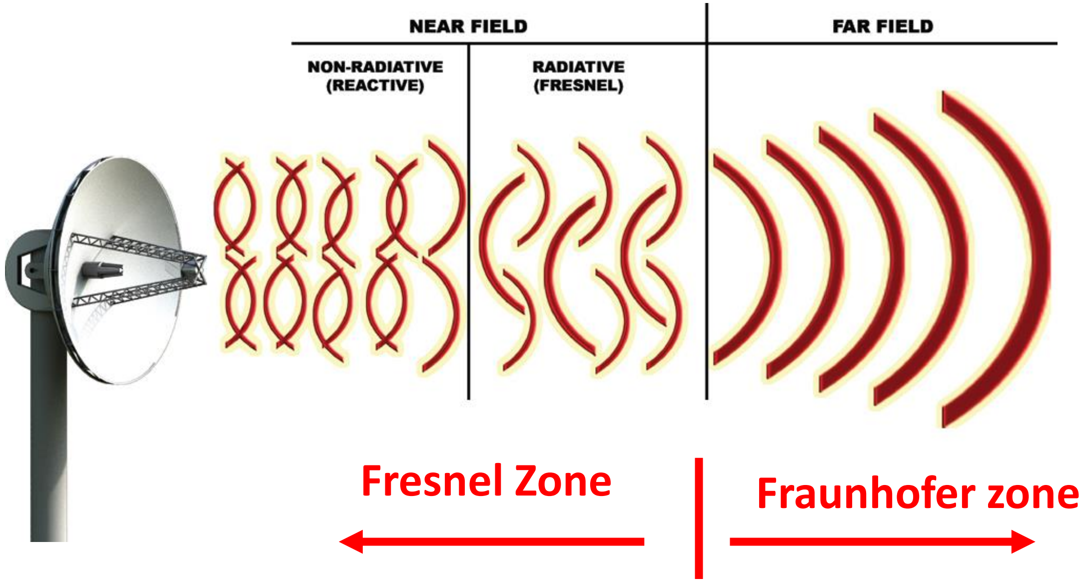
NEAR FIELD AND FAR FIELD (1)

Antennas actually produce two sets of fields, the **Near Field** and the **Far Field**.

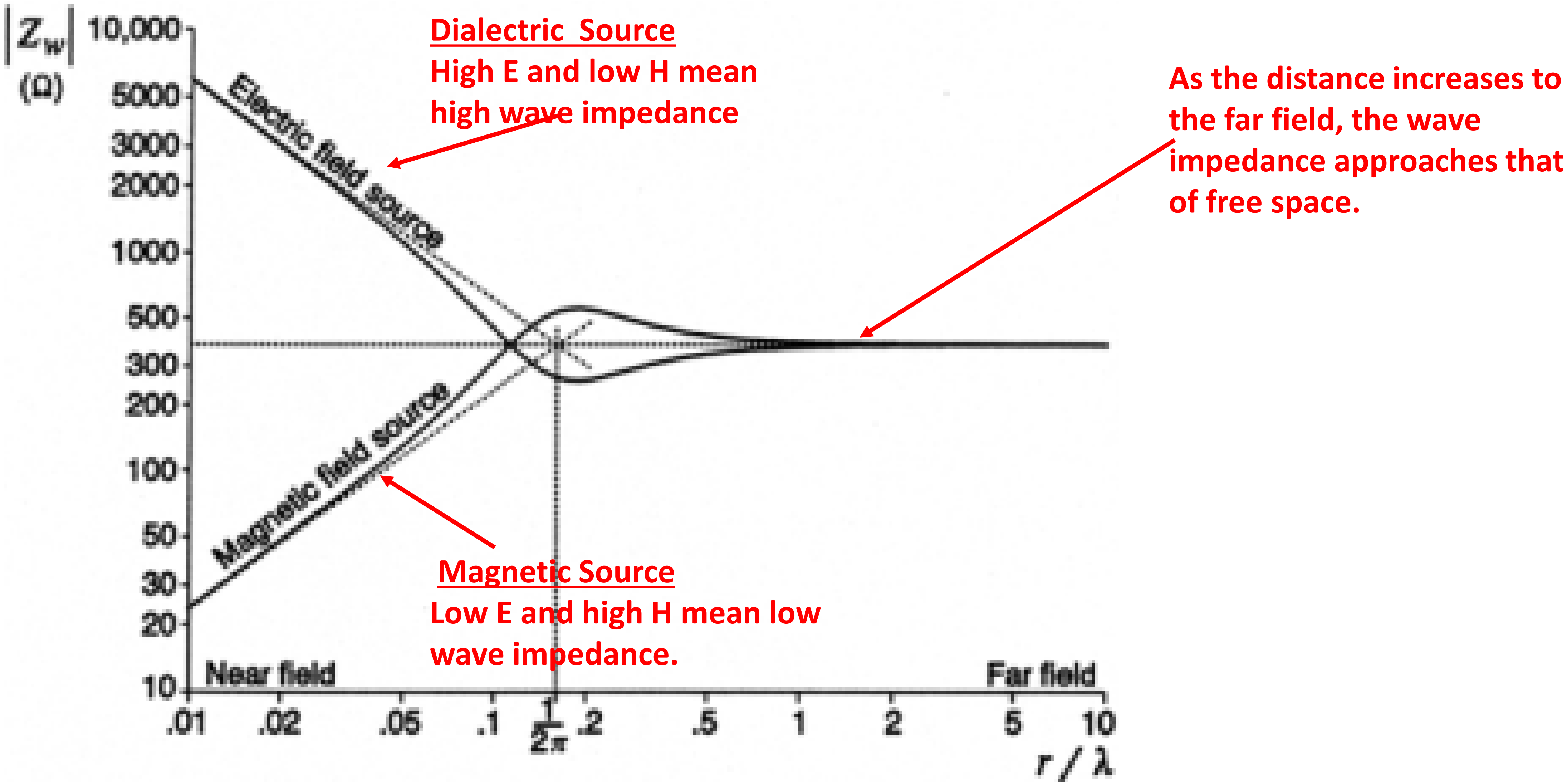
1. **The Near field** describes the region around the antenna where the electric and magnetic fields are distinct.
   a) Near fields are not the radio wave.
   b) Near fields weaken with the distance from the antenna at quadruple power of distance.
   c) The radiative part of the near field is also referred to as the **Fresnel zone**.

2. **The Far field** starts approximately **10 wavelengths** from the antenna is the radio wave with composite electric and magnetic fields.
   a) The strength of the far field diminishes with the square of the distance
   b) The far field is also called the **Fraunhofer zone**.

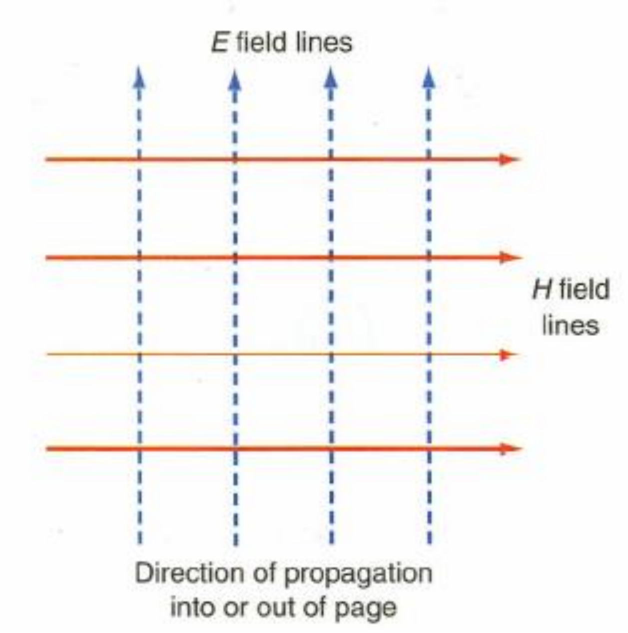


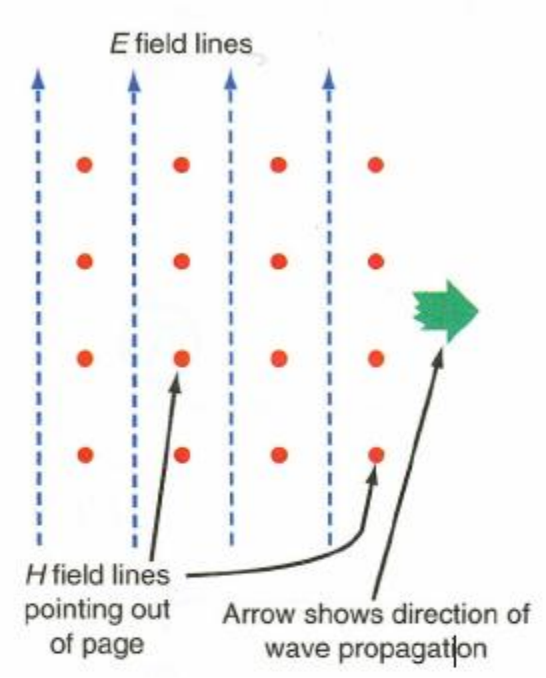


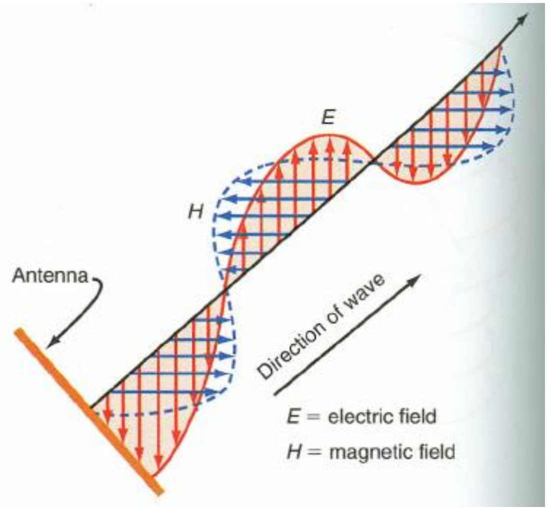
NEAR FIELD AND FAR FIELD - CAMPARISON OF MAGNETIC & DIAELECTRIC SOURCES

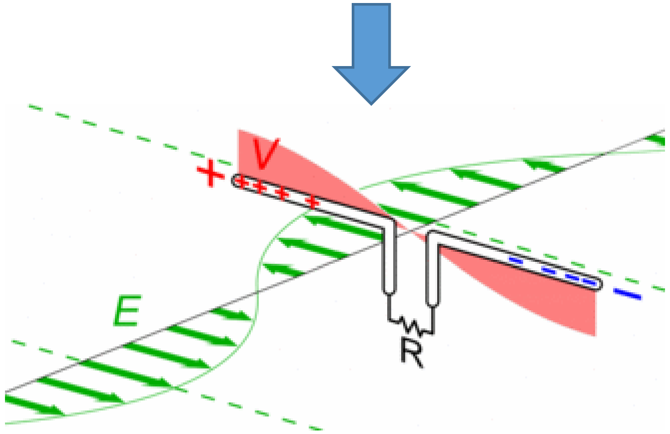


VISUALIZATION OF THE RADIO ELECTROMAGNETIC WAVE







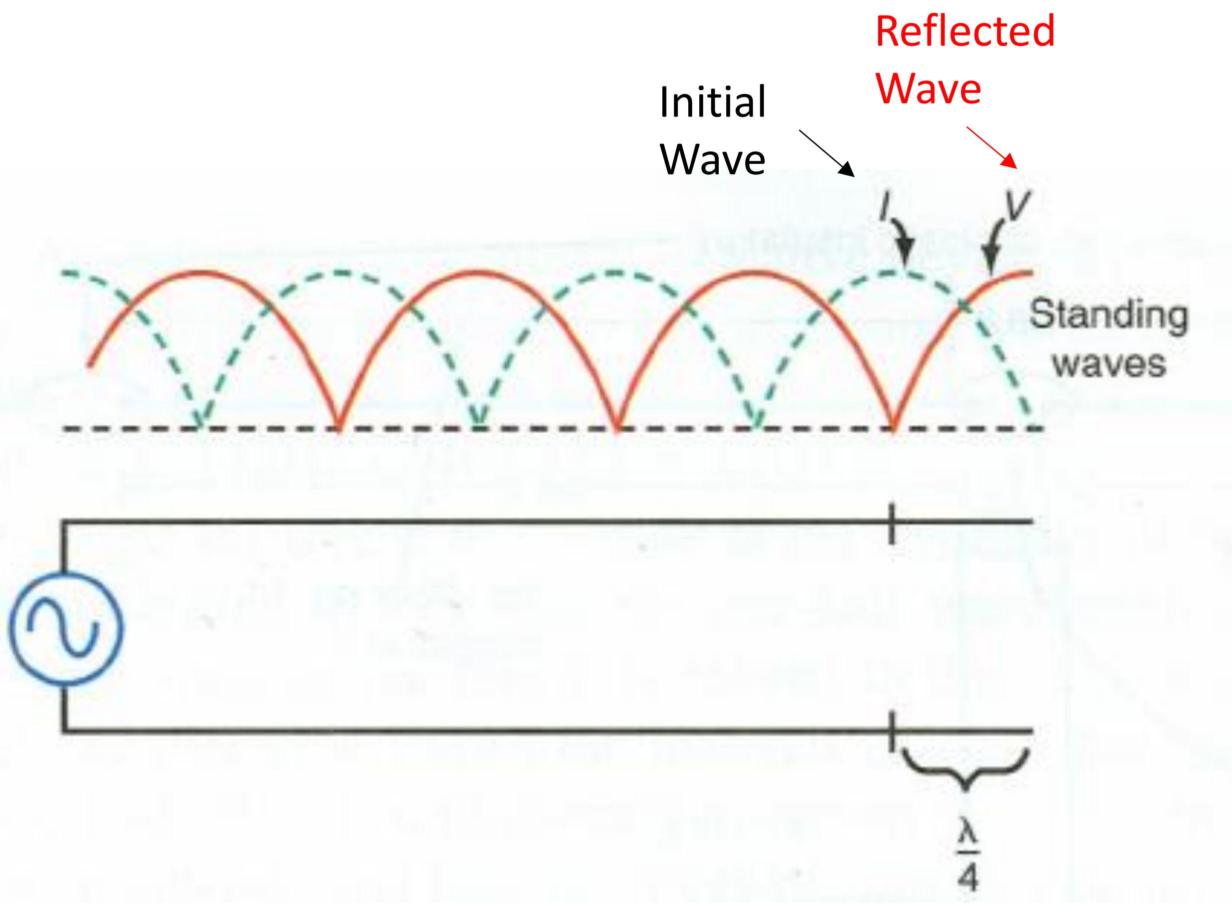


APPLICATIONS OF NEAR FIELD(1)

Common application of near fields include Near Field Communication and proximity cards.

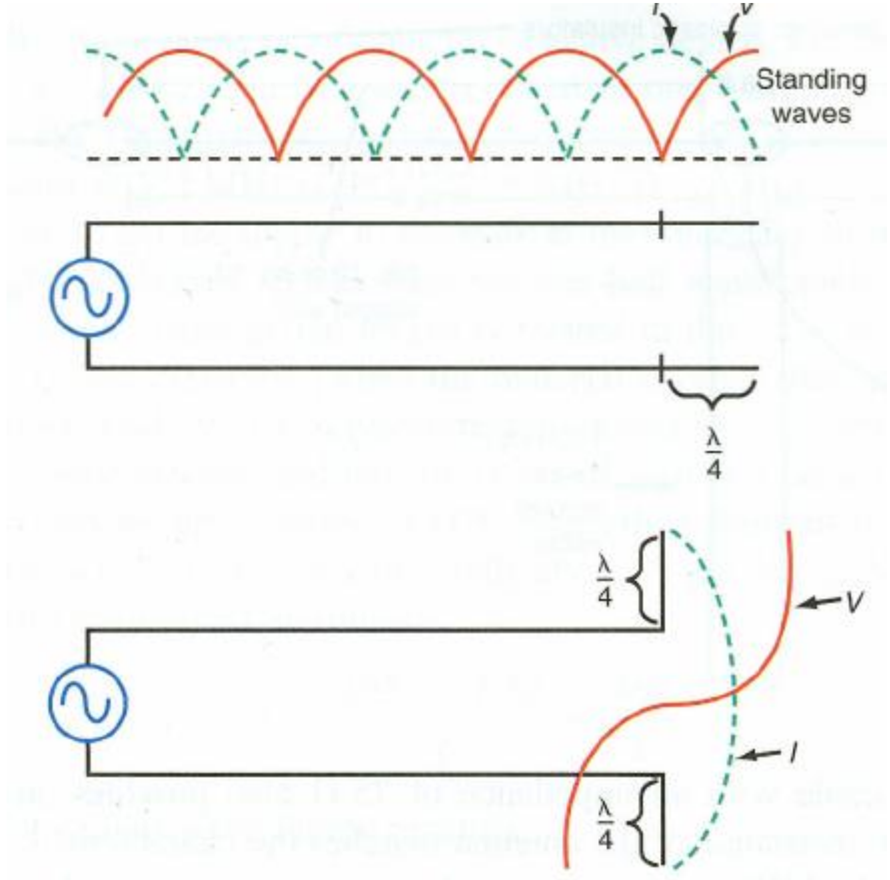
1. **Near field communication (NFC)** is a set of communication protocols that enable two electronic devices, one of which is usually a portable device such as a smartphone, to establish communication by bringing them within a short distance of each other.
2. **Proximity cards** - The Nairobi-based Citi Hoppa bus company has partnered with Beba to offer **NFC enabled proximity cards** for fare payments. Citi Hoppa staff use the Huawei Sonic NFC enabled phone to process these transactions.

STANDING WAVES ON OPEN TRANSMISSION LINE (REVISITED)

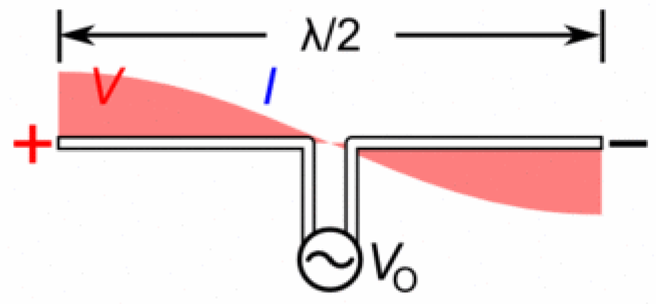


1. The wave goes across the transmission line and is reflected at the other end, because the line is not terminated properly.
2. This creates a standing wave on the line, i.e. a wave that oscillates but does not appear to travel.
3. The standing wave is a combination of two waves (the initial wave, and the reflected wave) traveling in opposite directions.

STANDING WAVES ON HALF WAVELENGTH ANTENNA (REVISITED)



1. The majority of antenna designs are based on the resonance principle.
2. This relies on the behaviour of moving electrons, which reflect off surfaces where the dielectric constant changes.
3. The reflective surface is created by the end of a conductor, normally a thin metal wire or rod, which in the simplest case has a feed point at one end where it is connected to a transmission line.
4. The conductor, or element, is aligned with the electrical field of the desired signal usually perpendicular to the line from the antenna to the receiver.



THE DIPOLE ANTENNA

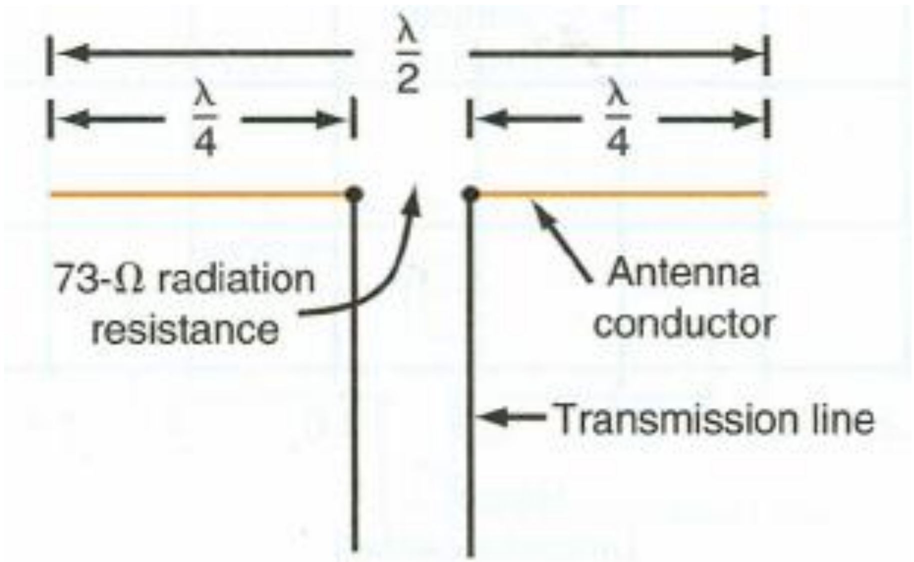
ECE 516E – ANTENNA & RADIO WAVE PROPAGATION

Monday, 23 September 2024

THE HALF WAVE DIPOLE ANTENNA

1. The **Half wave Dipole antenna** is also known as the **Hertz antenna** or **a doublet**.

2. It consists of **two pieces of wire, rod, or tubing** that are one-quarter wavelength long at the operating resonant frequency.



REVIEW QUESTIONS

1. A dipole antenna is 1 metre long. What is its resonant frequency?
2. What are the appropriate lengths of a dipole antenna operating at the following frequencies
   (a) 900 MHz
   (b) 1800 MHz
   (c) 2100 MHz
   (d) 3500 MHz

SOLUTION

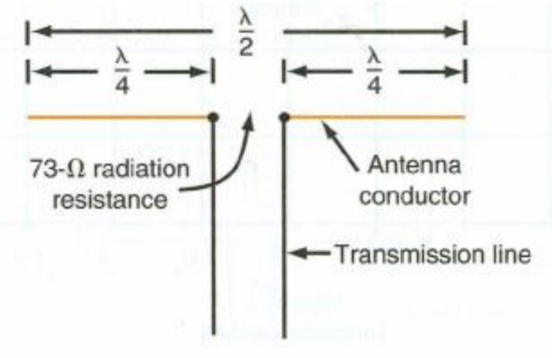
1. The speed of light, $c = 3 \times 10^8$

   Dipole antenna length $L = \frac{\lambda}{2}$

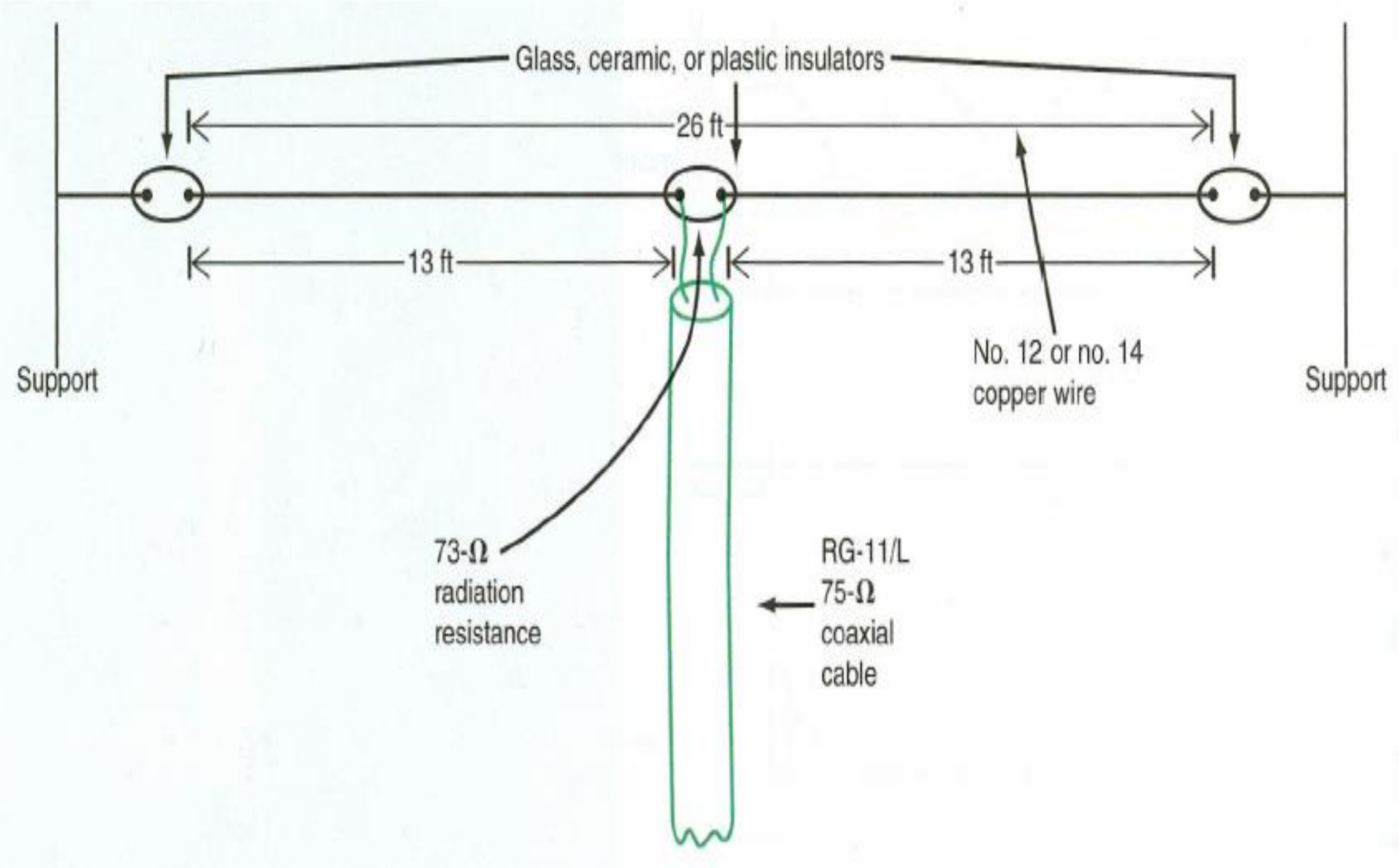
   Therefore $\lambda = 1 \times 2 = 2\ m$

   Frequency = $\frac{3\times10^8}{2} = 1.5 \times 10^8 = 150 \times 10^6\ Hz$

   = 150 MHz



HALF-WAVE DIPOLE USED IN SHORTWAVE RADIO TRANSMITTER



Short wave radio transmitter station – Example can be seen at KBC Langata and Ngong Radio transmission stations.

IMPEDANCE OF HALF-WAVE DIPOLE

1. The dipole has an impedance of 73Ω at its centre when the conductor is infinitely thin and the antenna is in free space.
2. At the resonant frequency, the dipole appears to be a pure resistance of 73Ω .
3. For maximum power transfer it is important that the impedance of the transmission line match the load.
4. A **73Ω coaxial cable e.g. RG-59/U** is a perfect transmission line for a dipole antenna.
5. As the conductor thickness increases, the radiation resistance decreases.
6. The resistance can drop to as low as 55 Ohms when large tube conductors are used.

Reactive Impedance

Represents power stored in the near field of the antenna

$$Z_{in} = R_{in} + jX_{in}$$

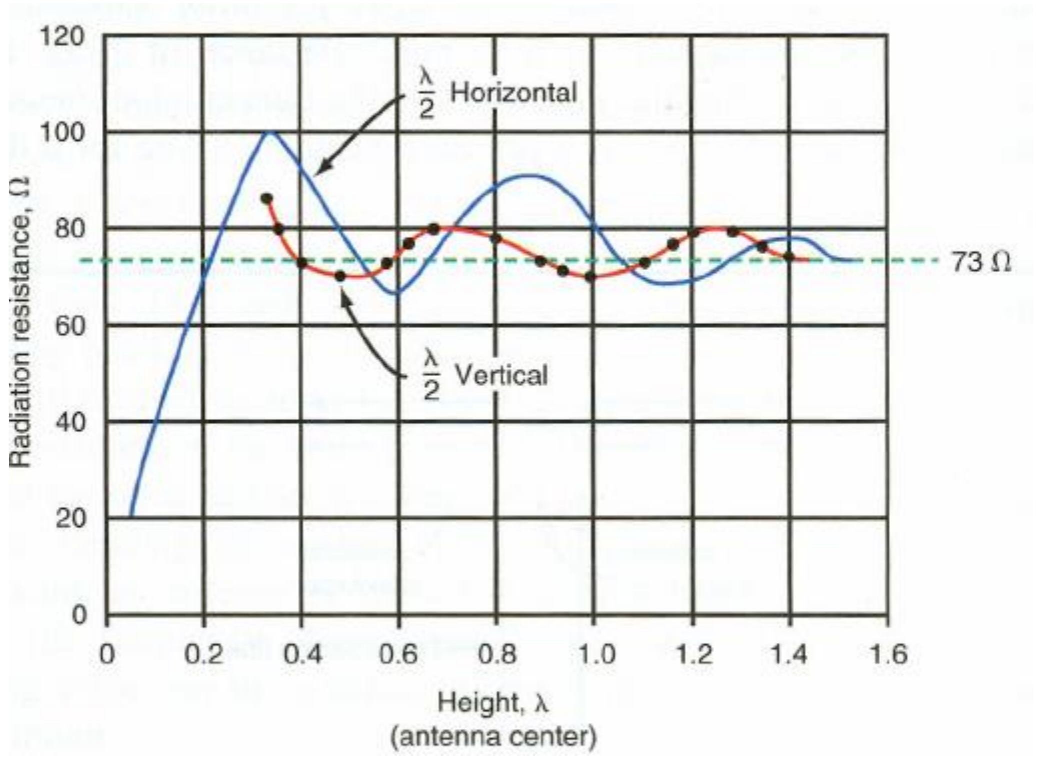
Resistive Impedance

Represents dissipation of power through heating (ohmic losses) and radiation (radiation losses)

EFFECT OF THE GROUND ON RADIATIVE RESISTANCE

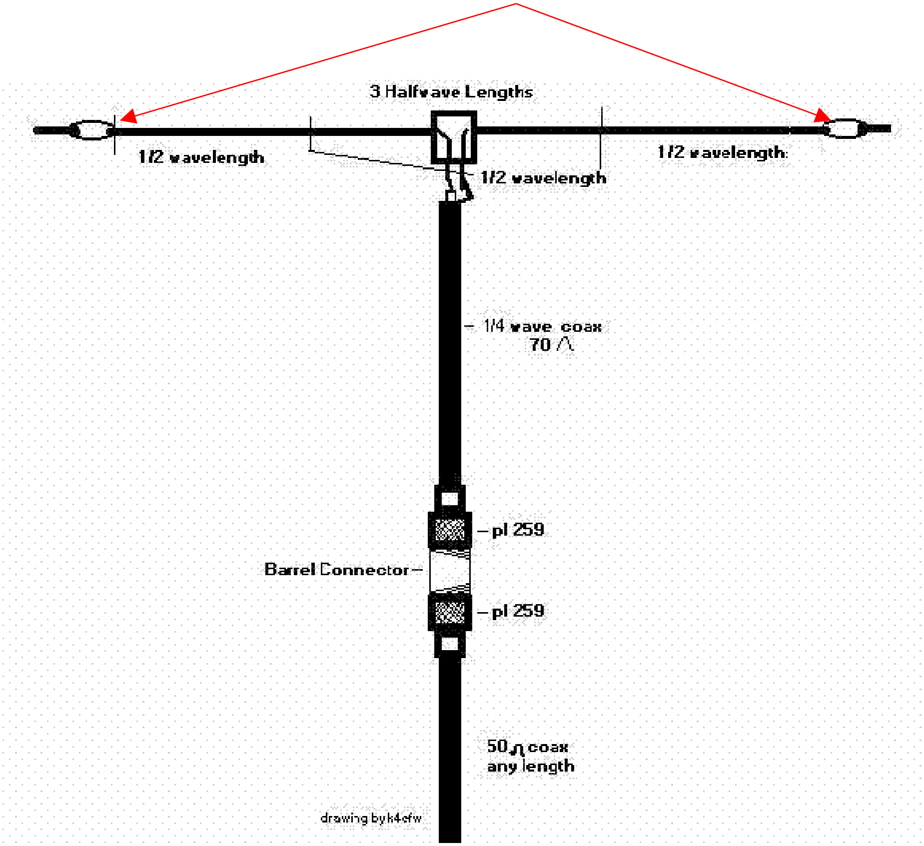
1. Radiation resistance is affected by the ground, thickness and other physical structures in the neighbourhood, it often varies around 73 Ohms.

2. The higher the antenna, the less effect the earth and surrounding objects have on it, and the closer the radiation resistance is to the theoretical ideal of 73 Ohms.



END-EFFECT IN DIPOLE ANTENNA

Support insulators
Crete the end-effect



1. **End effect** is a phenomenon caused by any support insulators used at the ends of the wire antenna and has the effect of adding a capacitance to the end of each wire.

2. At frequencies up to about 30 MHz, end effect shortens the resonant frequency antenna length by about 5 percent.

USE OF THICK RODS

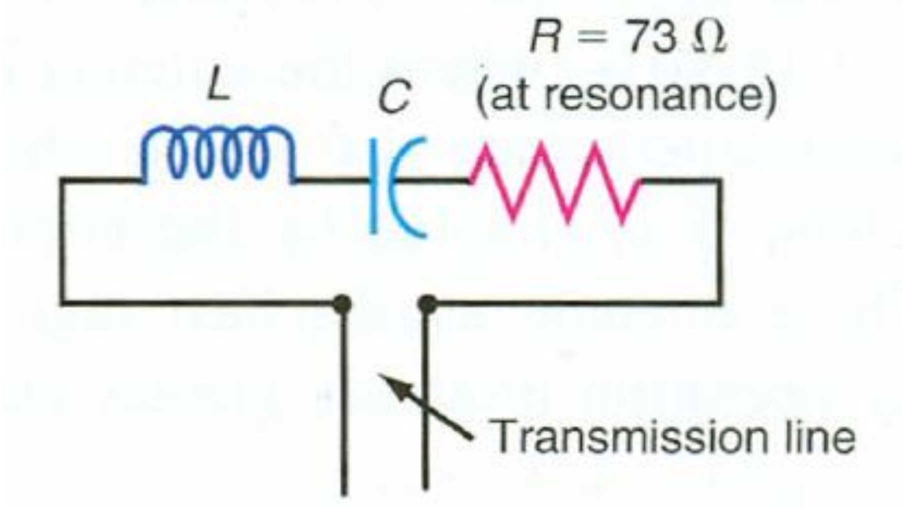
1. At frequencies above 30 MHz, the conductor are usually made from rods or tubing, rather than wire.

2. Using thicker materials shortens the theoretical resonant frequency length by factor of about 2 to 3 percent.

(a) Cross-dipole using thick rods

EQUIVALENT CIRCUIT OF A DIPOLE

1. To the generator, the antenna looks like a series resonant circuit with the following components:
   a) The **inductance** represents the magnetic field,
   b) the **capacitance** represents the electric field,
   c) The **resistance** is the radiation resistance and varies depending on antenna conductor thickness and height.



2. If the signal applied to the antenna is such that the antenna is exactly one-half wavelength long, the equivalent circuit will be resonant and the inductive reactance will cancel the capacitive reactance. The signal will radiate at maximum level.
3. If the dipole is used at a frequency other than its resonant frequency, the antenna impedance no longer matches the transmission line impedance, so the **SWR rises and power is lost**.

BANDWIDTH OF ANTENNA (1)

1. The bandwidth of an antenna is determined by the frequency of operation and the Quality factor (Q) of the antenna according to the familiar relationship:

$$BW = \frac{f_c}{Q}$$

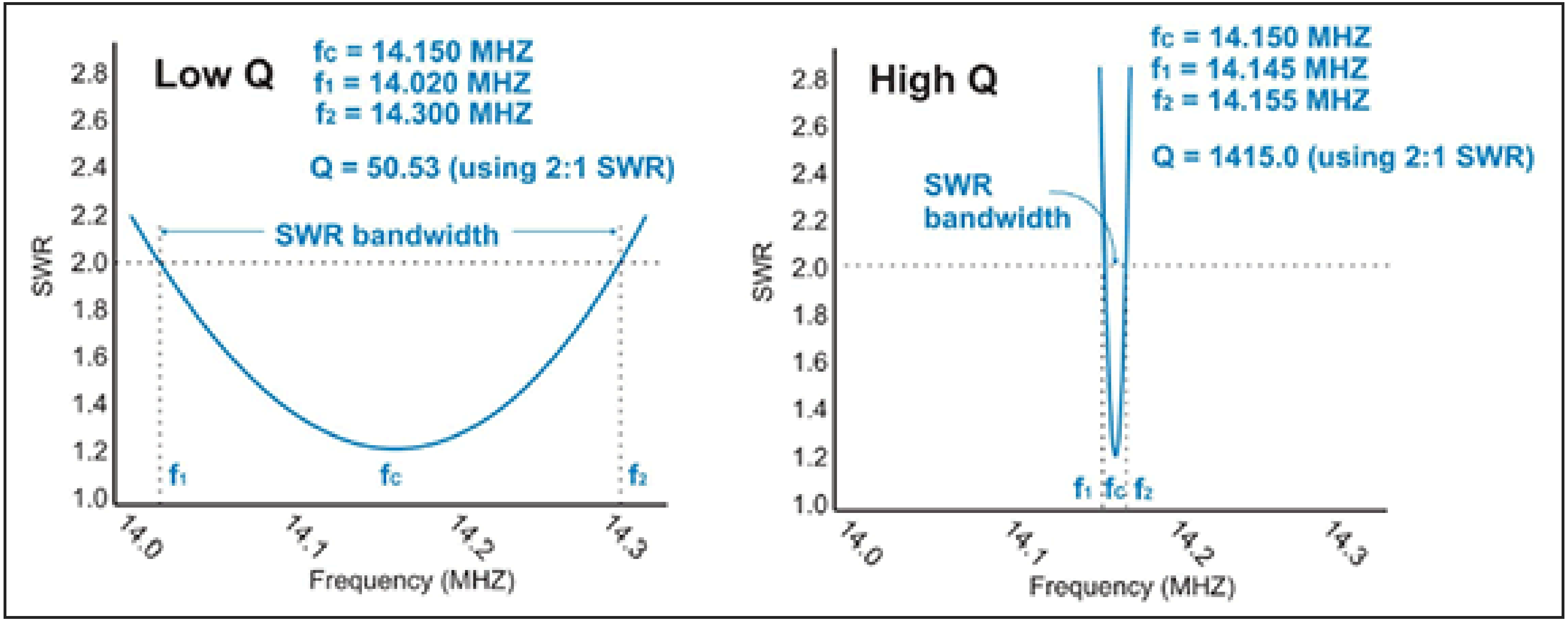
Where

f_c is the resonant frequency

Q is quality factor

2. The higher the Q, the narrower the bandwidth BW.

BANDWIDTH OF ANTENNA (2)

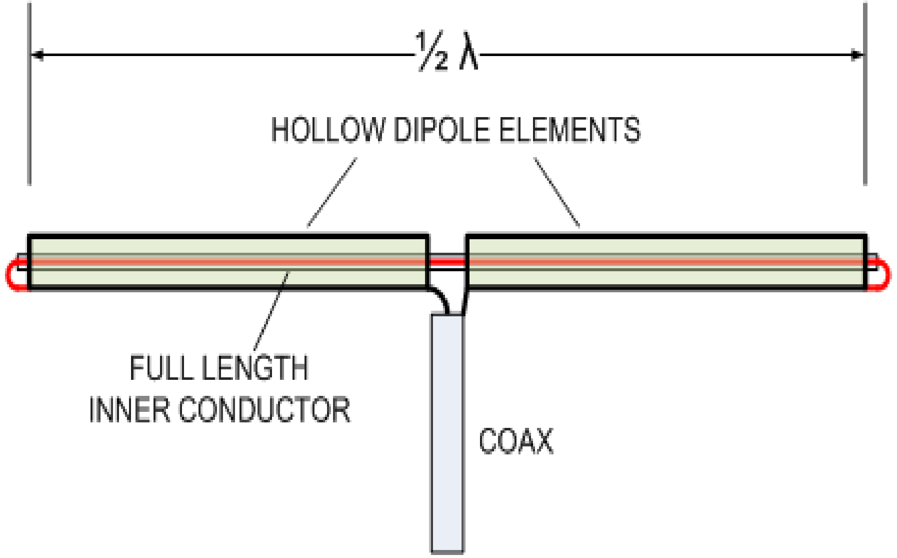


BANDWIDTH OF A DIPOLE ANTENNA

1. The Q and thus the bandwidth of a dipole antenna are determined primarily by the ratio of the length of the conductor to the diameter of the conductor.

2. If the antenna conductors are made of larger-diameter wire or tubing, the length-to-diameter ratio and Q decrease, resulting in a wider bandwidth.

3. **At UHF and microwave frequencies, dipole antennas are typically made of short, fat conductors, such as tubing.** It is not uncommon to see conductors with diameters as large as 2cm. The result is wider bandwidth.



ELECTRICALLY SMALL DIPOLES

ECE516E – ANTENNA ENGINEERING & RADIO WAVE PROPAGATION

Monday, 22 September 2025

ELECTRICALLY SMALL ANTENNAS

1. **Electrically small antennas Antenna** have dimensions which are much smaller than a wavelength.
2. Electrically small antennas can also be defined as antenna that can fit inside a radiansphere, where the radiansphere is defined as an area of diameter:

$$D_{rs} = \frac{\lambda}{2\pi} \cong \frac{1}{6}\lambda$$

3. Although electrically small antennas are inefficient, other factors such as size, weight, cost and mobility make it necessary to design such antennas.

Further Reading:

https://www.highfrequencyelectronics.com/Feb07/HFE0207_tutorial.pdf

WORKED EXAMPLE

The GSM phone transmits at 890MHz.

(a) What is the is the diameter of the radiansphere of this frequency.

(b) What is the maximum height for such an antenna if it is to qualify to be called an electrically small antenna?

SOLUTION

- The wavelength of the antenna is given by:

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{890\times10^6} = 33.7\text{cm}$$

- Therefore, the diameter of the radianshere is:

$$D = \frac{\lambda}{2\pi} = \frac{33.7}{2\times3.14159} = 5.36\text{ cm}$$