Study of the Electromagnetic Waves. Lecher Wire System.

1. Electromagnetic Field

Electrodynamics is the physics of electromagnetic radiation. *Classical electromagnetism* (*classical electrodynamics*) is the theory of electromagnetism, which it was developed in the 19th century, and the main contribution is that of James Clerk Maxwell. Electromagnetic radiation exhibits both wave properties and particle properties at the same time according to the wave-particle duality. Electromagnetic radiation that exhibits wave properties is the electromagnetic wave.

2. Electromagnetic Waves

A changing electromagnetic field propagates away from its origin in the form of an *electromagnetic wave*. As a wave, electromagnetic wave consists of successive troughs and crests. The distance between two adjacent crests is the wavelength λ. The Maxwell's equations predict the electromagnetic waves with a lower frequency than visible light. They were discovered by Heinrich Hertz. Maxwell was the first who proposed that light is an electromagnetic wave. In 1886, Hertz developed a dipole antenna which is an antenna with a center-fed driven element for transmitting or receiving radio frequency energy.

Sources of electromagnetic waves: dipole antenna, open oscillation circuit – dipole (Fig. 1), the Sun, heart, mobile phones.

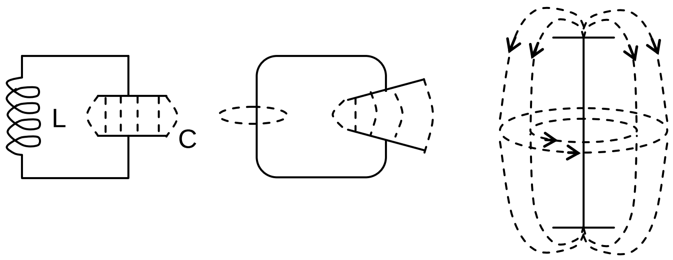


Fig. 1

In P, the electric field lines are perpendicular to the magnetic field lines (Fig. 2). The electromagnetic field is generated around the dipole and when it becomes periodical it propagates through space as electromagnetic waves. The dipole is a point source, which generates the electromagnetic field.

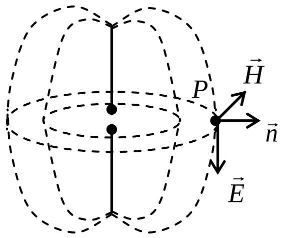


Fig. 2

The electric field $\vec{E}$ and the magnetic field $\vec{H}$ propagate through space with the velocity v (Fig. 3).

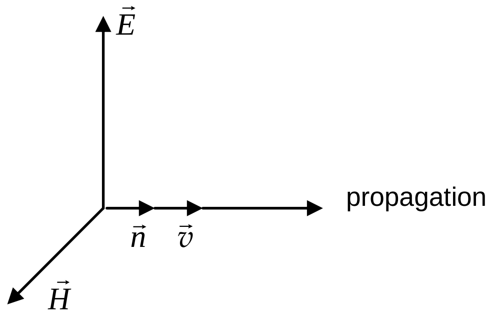


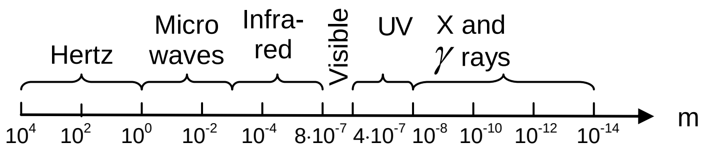
Fig. 3

Electromagnetic waves are transverse waves. In vacuum v= $c = 3 \cdot 10^8$ m/s, the speed of the light. The vectors $\vec{E}, \vec{H}$ and $\vec{n}$ are perpendicular one each other and $\vec{n}$ is the unit vector of the direction of propagation. These components oscillate in plane perpendicular each other and to the plane which contains the direction of propagation, and are in phase with each other. The direction of propagation of the wave is the same direction as $\vec{E} \times \vec{H}$.

Electromagnetic waves carry energy and momentum, which may be imparted when it interacts with matter.

The speed of electromagnetic waves is connected to the wavelength λ and frequency ν:

$$v = \lambda \nu \qquad (1)$$



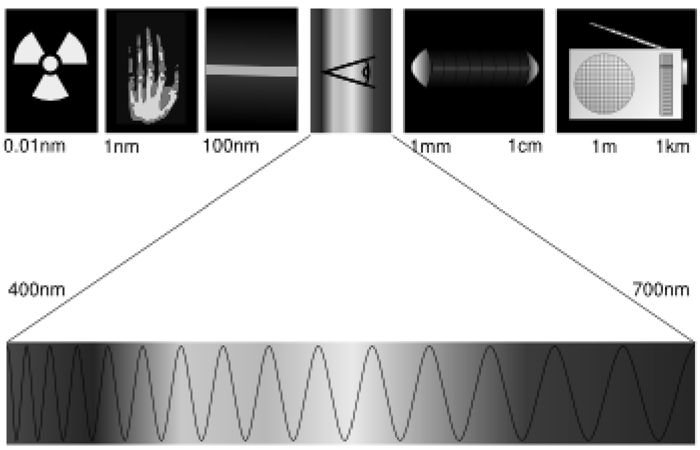


Fig.4 Electromagnetic spectrum*

The speed of light is a universal constant, dependent only on the electrical permittivity and magnetic permeability of the medium or vacuum.

Speed of propagation in dielectrics is given by:

$$v = \frac{1}{\sqrt{\varepsilon\,\mu}} = \frac{1}{\sqrt{\varepsilon_0 \mu_0 \varepsilon_r \mu_r}} . \quad (2)$$

In vacuum one gets:

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} . \quad (3)$$

Refractive index of a medium is given by:

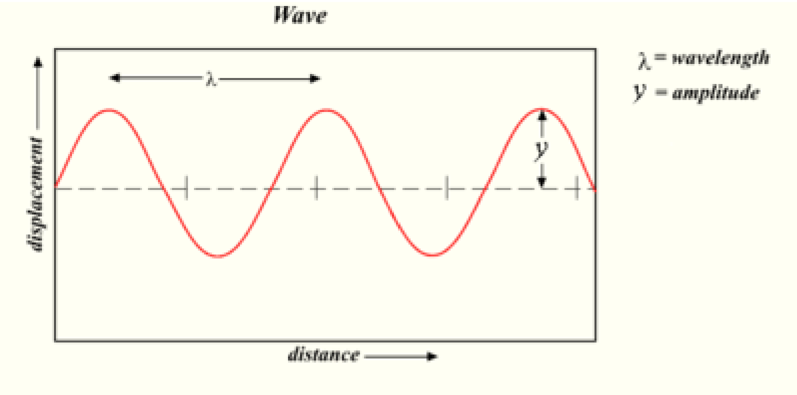
$$n = \frac{c}{v} = \sqrt{\varepsilon_r \mu_r} . \quad (4)$$

3. Lecher Wire System

Determing the frequency of the oscillations due to a generator using the Lecher wire system. Electromagnetic waves appear between two conductors and the speed is given by:

$$\mathrm{v} = \lambda \nu = 2\lambda_{st} \nu , \quad (5)$$

where λ_{st} is the waveleght of the standing waves and ν is the frequency of the oscillations due to the generator. A *standing wave* in a transmission line is a wave in which the distribution of current, voltage, or field strength is formed by the superposition of two waves propagating in opposite directions.



The frequency is gyven by the Thomson relationship:

$$\nu = 1/2\pi\sqrt{L/C} , \quad (6)$$

where L is the inductance of the coil and C is the capacitance of the capacitor.

Apparatus and Equipment

Two parallel conductors of copper, close of them is placed an oscillation circuit (LC) which is fed by a generator. The generator produces electromagnetic oscillations of high frequency. This system is the Lecher wire system (Lecher wires, Lecher lines). Lecher lines are a form of parallel conductor that can be used at UHF (ultra high frequency, frequency is between 300 MHz and 3.0 GHz) for creating resonant circuits. By induction, in conductors appear electromagnetic oscillatios, and a current wave. Between the conductors appears a electromagnetic wave, and in the points where this electromagnetic wave reaches the conductors a variable current will appear. The electrons travel with small velocities (cm/s). At the fix ends of the conductors the electromagnetic wave is reflected. There are two waves: the direct wave and the reflected wave. Distance between two crests of the electric field E_{st} is the wavelenght of the standing waves $\lambda_{st} = \lambda / 2$. The maximum of the field corresponds to the maximum of potential (voltage) and the position of the crets can be determined with a small bulb.

Measurements

Determing the frequency with (5) by measuring the wavelenght of the standing waves. The velocity is $v = c = 3 \cdot 10^8$ m/s, which is the speed of the light. The position of the crests of the electric field is determined with a small bulb. The wavelenght of the electromagnetic wave is twice the value of the wavelenght of the standing waves.

Results and errors

No. crt.	v (m/s)	λ_{st} (m)	λ (m)	ν (Hz)

average value $\overline{\nu}$

(root) mean-square error E_a

confidence interval $\nu \in (\overline{\nu} - E_a, \overline{\nu} + E_a)$

percentage error E_r