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Assignment - II

1. Explain the mechanism by which waves are bent back by ionospheric layers with the aid of Snell's law.
2. Explain the following terms with respect to ionospheric propagation.
   i) Critical Frequency ii) Maximum usable Frequency (MUF) iii) skip distance
3. What is the Field strength due to ground wave according to sommerfeld? What are the factors that are incorporated into this formula?
4. What is ground wave? Describe the phenomenon of group wave propagation.
5. Derive the relation for the refractive index (or dielectric constant) of the ionospheric layer in terms of its plasma Frequency.

EMT - Assignment 2

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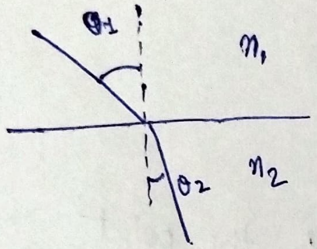
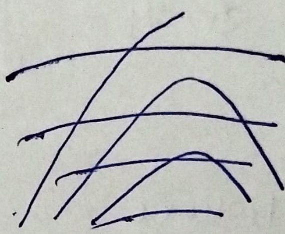
[1] When a wave is transmitted into an ionised layer, refraction, or bending of a wave occurs. Refraction is caused by abrupt change in velocity of the upper part of radio wave as it strikes or enters a new medium.



$\Rightarrow$



$\theta_2 < \theta_1$ because $n_2 > n_1$, Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$.

As a wave enters a region of increasing ionisation, the increase in velocity of the upper part of the waves causes it to be bent back toward earth.

[2] i) Critical Frequency

Each ionosphric layer has a maximum frequency at which radio waves can be transmitted vertically and refracted back to Earth.

Radio waves transmitted at frequencies higher than the critical frequency of a given layer will pass through the layer and be lost in space.

ii) Max^m Usable Frequency (MUF)

higher the frequency of a radio wave, lower the rate of refraction by an ionised layer. For a given angle of incidence and time of day, there is a maximum frequency that can be used for communications between two given locations, known as Max^m Usable frequency.

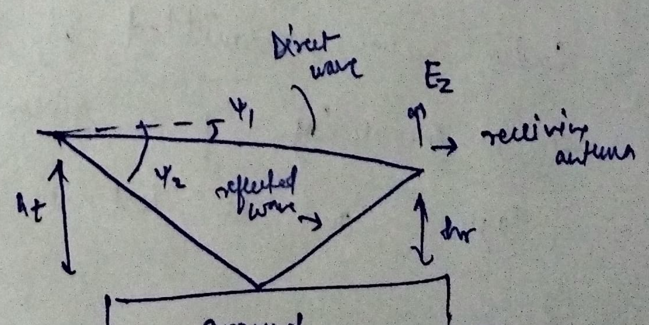
$$\sin\phi_i = \sqrt{1 - \frac{81 N_{max}}{f^2_{MUF}}}.$$

iii) Skip Distance

The distance from the transmitter to the point where the sky wave is first returned to Earth. The size of the skip distance depends on the frequency of the wave, ange of incidence, and degree of ionisation present.

$$d_{skip} = 2h\sqrt{\left(\frac{f_{MUF}}{f_c}\right)^2 - 1}$$

[3] In 1909, Sommerfield solved the general problem of the effect of finite conductivity of the ground on the radiation from a short vertical antenna at the surface of plane Earth.



Field strength due ground wave at reciever is

$$E = \frac{2E_0}{d} \sin\left(\frac{2\pi h_t h_r}{\lambda d} \right)$$

$d \rightarrow$ distance b/w transmitter & receiver

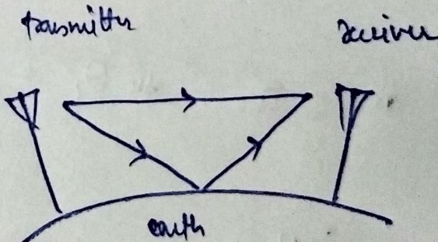
$h_t \rightarrow$ effective height of transmitter

$E_0 \rightarrow$ amplitude of directed and reflected wave,

if $\frac{2\pi h_t h_r}{\lambda d} < 0.5$ (for large d)

$$\Rightarrow E = \frac{2E_0}{d} \left(\frac{2\pi h_t h_r}{\lambda d} \right) = \left(\frac{4\pi h_t h_r}{\lambda d^2} \right) E_0 .$$

$\boxed{4}$ The wave which travel directly from the transmitting to the recieving antenna through the surface of the earth is called ground wave or surface wave, the phenomenon is ground wave propagation.



Propagation of EM wave near earth surface, also tend to follow earth's curvature. As wave travels the surface, it weakens due to absorption of some of its energy, which is the power loss in earth's resistance to the flow of current. Surface is considered plane as long as distance b/w Rx, Tx doesn't exceed

$$d = \frac{50}{F(MHz)} \text{ (in miles)}$$

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as ~~8×17~~ $n = \sqrt{1 - \frac{81N}{f^2}} = \sqrt{\varepsilon_r}$.

$$\varepsilon_r \approx 1 - \frac{\omega_p^2}{\omega^2}$$

for frequencies $\omega > \omega_p$, effective dielectric constant is less than unity but the propagation constant is real. Hence, wave will be refracted by the plasma according to the variation of ε_r with altitude.

if we subdivide into many tiny layers,

$$n_0 \sin\theta_i = n_1 \sin\theta_1 = n_2 \sin\theta_2 = \dots n_K \sin\theta_K \dots$$

TIR at Kth layer,

$$n_0 \sin\theta_i = n_K \sin 90^\circ = n_K$$

as $n_0 = 1$, $\sin^2\theta_i = n_K^2 = \varepsilon_{r,K}$

as $\varepsilon_{r,K} = \sin^2\theta_i = 1 - \frac{81 N_{min}}{f_{MUF}^2}$

$$\frac{81 N_{max}}{f_c^2} = 1 \Rightarrow f_c = 9\sqrt{N_{max}}$$

$f_c \rightarrow$ is critical frequency,

$$\sin^2\theta_i = 1 - \cos^2\theta_i$$

$$= 1 - \frac{81N}{f_{MUF}^2}$$

$$f_{MUF} = 9\sqrt{N_{max}}\sec\theta_i$$

$$= f_c \sec\theta_i$$