Ground wave propagation

characteristics

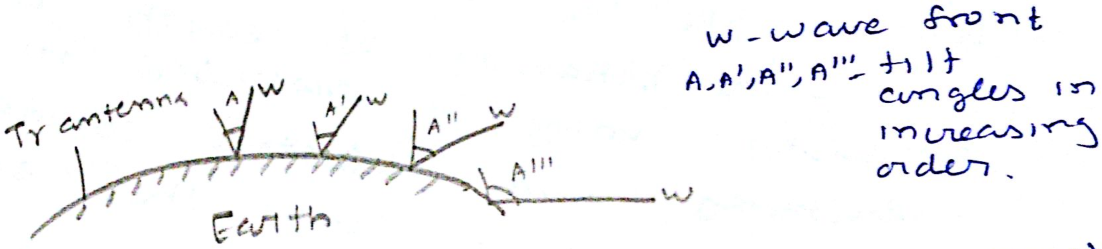
- It is important at broadcast & lower frequencies
- It is guided along the surface of earth
- The ground wave propagation along the surface of the wave, induce charges in the earth.
→ These charges travel with the wave & constitute a current
→ while carrying this current earth behaves like a leaky capacitor.
- The behaviour of earth as a conductor may be described in terms of conductivity and dielectric constant k.
- while passing over the surface of earth, the surface wave looses some of its energy by absorption
- The ground wave suffers amount of attenuation while propagating along the curvature of earth, depends on
1) Frequency 2) surface irregularities
3) permittivity 4) conductivity.
- Earth attenuation increases as frequency increases
- suitable for low & medium frequency (up to 2MHZ)

parameters - wave tilt

- Apart from ground attenuation, the surface wave is attenuated due to diffraction & tilt in the wave.

- As the wave propagates over the curvature of the earth, the wave fronts start gradually tilting more and more.

- This increase in the tilt of wave causes more short circuit of the electric field component & field strength reduces.



- At some distance from the transmitting antenna, the surface wave dies.

Flat and spherical earth considerations.

The field strength at a distance from the transmitting antenna due to ground wave has been calculated from the maxwell's equation.

$$E = \frac{120\pi h_t . h_r . I}{\lambda d} \quad v/m$$

120π - Intrinsic impedance.

h_t, h_r - Effective ht of tr & Rx antenna

I - antenna current

λ - wavelength

d - distance between transmitting & receiving points.

According to sommerfeld, the field strength for ground wave propagation for a flat earth is

$$E_g = \frac{E_0 A}{d}.$$

E_0 → Ground wave field strength at the surface of earth, at unit distance from the tr. antenna.

E_g → Ground wave field strength

A → attenuation factor.

d → distance from Tr antenna.

unit distance field strength E_0 depends upon.

(i) power radiation of tr. antenna.

(ii) Directivity in vertical & horizontal planes.

If the antenna is non-directional in the horizontal plane, producing a radiated field which is proportional to the cosine of the angle of elevation.

Then

$$E_0 = \frac{300\sqrt{P}}{d} \text{ v/m} = 300 \text{ mV/m}$$

P → radiated power in kw. [1 kW]

d → distance in km [1 km]

- For a short vertical unipole antenna the field strength E_0 at a distance of d on a hypothetical flat perfectly conducting earth is

$$E_0 = \frac{\sqrt{90 P}}{d} \text{ v/m}$$

P - radiated power in watts

d - distance in meters.

$$E_0 = \frac{300\sqrt{P}}{d} \text{ v/m}$$

P = 1 kW = 1000 W
d = 1 km = 1000 m

$$E_0 = \frac{300\sqrt{P}}{1.609} \text{ mv/miles}$$

d → miles.

- The attenuation factor A accounting for earth losses, depends on
  (i) frequency (ii) dielectric constant
  (iii) conductivity of the earth.

A → fn of above factors
→ expressed in terms of 2 variables
① numerical distance p
② phase constant b.

→ These 2 are determined by
① frequency ② distance
③ dielectric characteristics.

(i) For vertically polarised wave.

$$p = \frac{\pi}{x} \cdot \frac{d}{\lambda} \cos b$$

$$b = \tan^{-1}\left(\frac{\epsilon_r + 1}{x}\right) = 2b_2 - b_1$$

$$x = \frac{1.8 \times 10^{12} \sigma}{f(1+2)} \text{ mhos/cm}$$

(ii) For horizontally polarized wave.

$$p = \frac{\pi d}{\lambda} \cdot \frac{x}{\cos b}$$

$$b = 180° - b_1$$

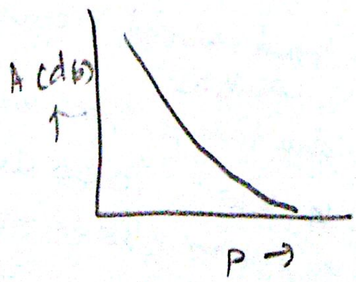
$$b_1 = \tan^{-1}\left(\frac{\epsilon_r - 1}{x}\right)$$

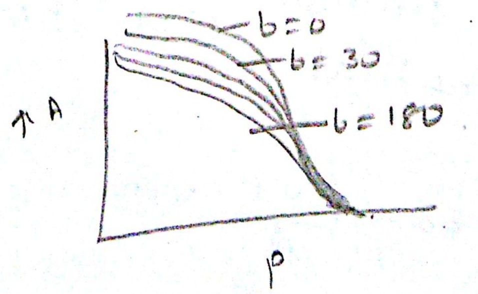
$$b_2 = \tan^{-1}\left(\frac{\epsilon_r}{x}\right)$$

b_2 - power factor angle of the impedance
σ - conductivity
ϵ_r - dielectric const
λ - wavelength

Ground wave attenuation factor A.

The relation between numerical distance p and phase constant b is shown





The numerical distance p depends upon the frequency, ground constants and the actual distances to the transmitter.

- It is proportional to the distance & the Sqaure of the frequency

for $b < 5^\circ$

$$A \simeq \frac{2 + 0.3p}{2 + p + 0.6p^2}$$

For all b

$$A = \frac{2+0.3p}{2+p+0.6p^2} - \sin b \sqrt{\frac{p}{2}} \cdot e^{-5/8 p}$$

$$p = \frac{0.582\, d_{km}\, f^2_{(MHz)}}{\sigma\,(mS/m)}$$

- Earth offers a resistive impedance to the flow of radio frequency currents when $b = 0$ for vertical polarization.
for horizontal polarization.

- $b = 180^\circ$ for horizontal polarization

- $b = 90^\circ$ - offers a capacitive impedance on either polarization.

For 1) $p < 1$ → A differs only slightly from unity with the increase of p & reduces slowly
- ground losses are not significant

2) $p > 1$ → As the numerical distance $p > 1$, the A decreases rapidly.

3) $p > 10$ → $A \propto \frac{1}{d}$ & $E \propto \frac{1}{d^2}$

- The value of numerical distance p of the plane earth ground wave attenuation factor ignores the effect of diffraction and ground permitivity.

$$d_{max} = \frac{100}{f^{1/3}} = \frac{100}{\sqrt[3]{f}} \text{ km}$$

typical range - 125 km to 90 km

- by including ϵ_r then

$$\tan b^\circ = \frac{(\epsilon_r - 1) f}{18\sigma}$$

$$p = \frac{0.582\, d \cdot f^2 \cos b^\circ}{\sigma}$$

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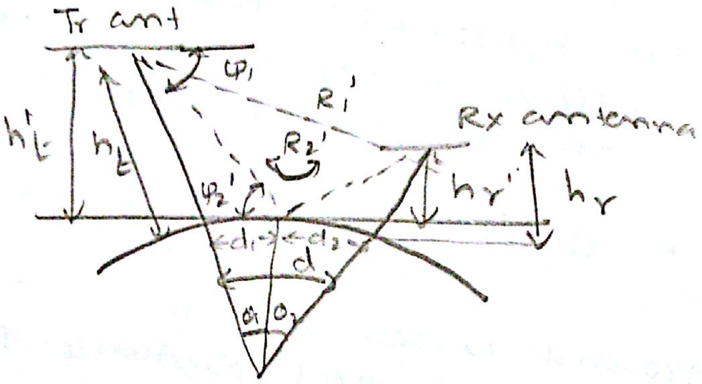
Spherical - Earth propagation.

- Flat earth gives correct answers only at short distances,
  it cannot yield correct results at large distances

- the distance $d = \frac{50}{f^{1/3}_{MHz}}$ miles, beyond which the actual field strength starts to deviate from that computed on the plane earth assumption



- The curvature of the earth affects the propagation of the ground wave signal in several ways.

1. The buldge of the earth prevents the surface wave from reaching the receiving point by a straight line path.
   The surface wave, which does arrive at the receiver, reaches it by diffraction around the earth & refraction in the lower atmosphere above the earth.

2. For elevated antennas, the space wave is affected in two different ways
   a) the ground reflected wave is now reflected from a curved surface, and its energy is diverged more than the case when it is from a flat surface.