

TROPOSPHERIC PROPAGATION:

The lowest part of the earth's atmosphere is called the troposphere. Typically, the troposphere extends from the surface of the earth to an altitude of approximately 9km at the poles and 17km at the equator. This upper boundary is referred to as the tropopause and is defined as the point at which the temperature in the atmosphere begins to increase with height. Within the troposphere, the temperature is found to decrease with altitude at a rate of approximately 7°C per km. The earth's weather system is confined to the troposphere and the fluctuations in weather parameters like temperature, pressure and humidity cause the refractive index of the air in this layer to vary from one point to another. It is in this context that the troposphere assumes a vital role in the propagation of radio waves at VHF (30-300MHz) and UHF (300-3000MHz) frequencies. The meteorological conditions therefore influence the manner in which radio wave propagation occurs in the troposphere both on a spatial and temporal scale.

Refractive Index, Refractivity and Modified Refractivity

Transhorizon Radiowave Propagation due to Evaporation Ducting, The Effect of Tropospheric Weather Conditions on VHF and UHF Radio Paths Over the Sea

In general, the refractive index, n , of the troposphere decreases with altitude. To simplify the mathematics involved variations in the horizontal are neglected and horizontal homogeneity of the refractive index of the troposphere is assumed in most discussions on this topic. A typical value for n at sea level is 1.000350. A few feet above sea level, this might decrease to a value such as 1.000300. For all practical purposes, at this scale, this change in the refractive index is negligibly small, with hardly any visible deviation. However, immediately above the surface of the sea, it is often this small (but rapid) change in the refractive index profile that facilitates the formation of meteorological phenomena called evaporation ducts. A convenient way of expressing these unwieldy numbers is to use the concept of refractivity instead. Refractivity, N , is defined as follows:

$$N = (n-1) \times 10^6$$

So, for example, when $n=1.000350$, $N=350$.

A well-known approximation for refractivity N is given below

$$N = \frac{77.6}{T} \left(P + \frac{4810 \cdot e}{T} \right)$$

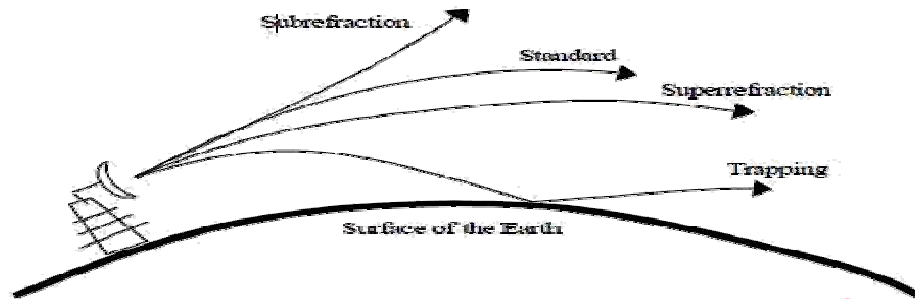
Where P =total atmospheric pressure (in mb); T = atmospheric temperature (in K);
 e =water vapour pressure (in mb).

All three terms, P , T and e fall with height in an exponential manner, resulting in a corresponding decrease in N with height. A standard atmosphere, therefore is one in which the refractivity varies with altitude according to equation. Using Snell's law, a radio ray projected into the atmosphere will have to travel from a denser to rarer medium and will refract downwards towards the surface of the earth. The curvature of the ray, however, will still be less than the earth's curvature. The gradient of refractivity in this case generally

varies from 0 to -79N- units per kilo. When the refractivity gradient varies from -79 to -157N-units per kilo, as a super refractive condition is said to prevail in the troposphere and the ray will refract downwards at a rate greater than standard but less than the curvature of the earth. A refractivity gradient that is even less than -157N-units per kilo will result in a ray that refracts towards the earth's surface with a curvature that exceeds the curvature of the earth. This situation is referred to as trapping and is of particular importance in the context of evaporation ducts. Finally, if the refractivity gradient is greater than 0N units per kilo, a sub refractive condition exists and a radio ray will now refract upwards, away from the surface of the earth.

Depending on the existing conditions in the troposphere, a radio wave will undergo any of the types of refraction: sub refraction, standard refraction, super refraction or trapping. Figure 1 illustrates the four refractive conditions discussed above.

While dealing with radio propagation profiles, the curved radio rays are replaced with line arrays for the purpose of geometric simplicity. To account for drawing radio rays as straight lines, the earth radius has to be increased. The radius of this virtual sphere is



Known as the effective earth radius and it is approximately equal to four-thirds the true radius of the earth (i.e. roughly 8500km). A more classical form of representing n is that of modified refractivity, M . In this case, the surface of the earth is represented by a flat plane and the radio rays are constituted by curves that are determined by Snell's law and the corresponding value of M at each point along the radio link. The following is the expression for M

$$M = N + \left(\frac{h}{a}\right) * 10^6$$

$$N + 0.157h,$$

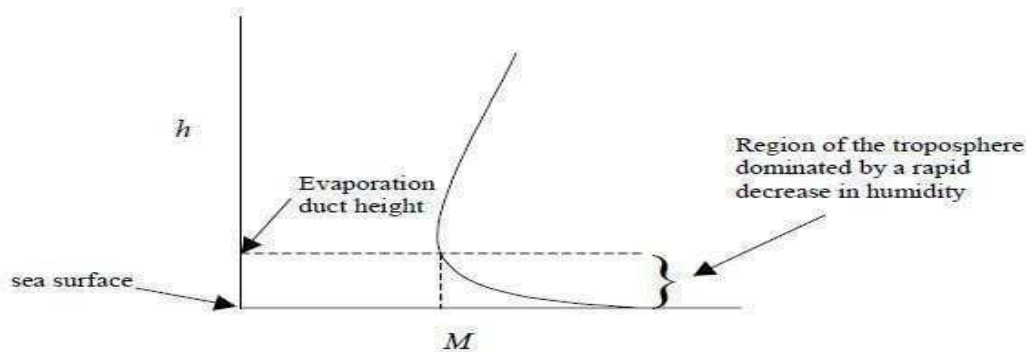
Where N =refractivity (in N-units), h = height above sea level (ins), a =radius of the earth (in s).

Formation of Evaporation Ducts

The air that is in immediate contact with these a surface is saturated with water vapour. As the height increases, the water vapour pressure in the atmosphere rapidly decreases until it reaches an ambient value at which it remains more or less static for a further increase in

height. There fore, for the first fews above the surface of the sea, it is the water vapour pressure, e , in the expression for N that dominates. This rapid decrease in e causes a steep fall in N .

This is reflected in the modified refractivity , M , which also correspondingly decreases.(The height term h ,which increases,is more than off set by the rapidly decreasing N term). This behavior can be seen in the graph of h vs M



As that portion of the curve with a strong negative M gradient. Therefore, despite the fact that the height h is increasing, it is the sharp fall in the water vapour pressure, e , that contributes to the rapid decrease in M .

Once e has reached its ambient value at a given height, a further rise in altitude does not cause a substantial change in the humidity of the troposphere. Thus, as h increases further, N decreases more (since air pressure and temperature both decrease with height). But this decrease in N is very small over large height increments. Consequently, despite a decreasing N term, it is the h term that starts to domain at e in the expression for M . Thus,

M now gradually increases with height , and can be seen as the portion of the curve that has a positive M gradient.

The point at which the M gradient changes from negative to positive is referred to as the evaporation duct height(or thickness),and is a practical and realistic measure of the strength of the evaporation duct.

Evaporation Ducts and the Troposphere

By virtue of their nature of formation, evaporation ducts are nearly permanent features over the sea surface. Typically, the height of an evaporation duct is of the order of only a fews; however, this can vary considerably with geographical location and changes in atmospheric parameters such as humidity, air pressure and temperature. In the lower regions of the troposphere where the earth's weather is confined, these parameters do, in fact, fluctuate significantly. The turbulent nature of the atmosphere contributes to its unpredictability and a variable atmosphere, in turn, is one of the major causes of unreliable wireless communications. Depending on their location and the prevailing climate, evaporation duct heights may vary from a few meters to few tens of meters. Additionally, it is observed that calm sea conditions are more conducive for the creation of ducts. As a consequence of sporadic meteorological phenomena, evaporation duct heights undergo significant spatial and temporal variations. Evaporation ducts are weather-related phenomena; their heights cannot easily be measured directly using instruments like refractometers and radiosondes.

At best, the height of an evaporation duct can be deduced from the bulk meteorological parameters that are representative of the ongoing physical processes at the air-sea boundary. The dependence of evaporation ducts on the physical structure of the troposphere signifies that changing weather conditions can indeed result in alterations in radio wave propagation.

Evaporation Ducts and Radio wave Propagation

Over the years, much research has been undertaken to explain the mechanism of radio wave propagation in evaporation ducts. A key reason why evaporation ducts are so important for radio communications is because they are often associated with enhanced signal strengths at receivers. An evaporation duct can be regarded as a natural waveguide that steers the radio signal from the transmitter to a receiver that may be situated well beyond the radio horizon. The drop in the refractive index of the atmosphere within the first few meters above the surface of the sea causes incident radio waves to be refracted towards the earth more than normal so that their radius of curvature becomes less than or equal to that of the earth's surface. The sudden change in the atmosphere's refractivity at the top of the duct causes the radio waves to refract back into the duct, and when it comes in contact with the surface of the sea, it gets reflected upwards again. The waves then propagate long ranges by means of successive reflections (refractions) from the top of the duct and the surface of the earth.

Since the top of an evaporation duct is not 'solid' (as in the case of an actual waveguide), there will be a small but finite amount of energy leakage into the freespace immediately above the duct. However, despite this escape of energy, radiowaves are still capable of travelling great distances through the duct, with relatively small attenuation and path loss. The ducting effect then results in radio signals reaching places that are beyond the radio horizon with improved signal strengths. This naturally has far reaching implications on practical radio propagation patterns. For this reason, evaporation ducts and their impact on radio wave propagation have been studied extensively over the years. Numerous statistical models have been proposed to describe evaporation ducts and compute the duct heights under different atmospheric conditions.

The presence of evaporation ducts might not always indicate enhanced signal strengths. For instance, if there is an unwanted distant transmitter also located within the duct, then there is always the possibility of the system under consideration being susceptible to signal interference and interception. This is dependent on the location of the radio paths being investigated. An other scenario that might arise is the interference between the various propagation modes that exist within the evaporation duct itself. Depending on the separation of the transmitter and receiver and the prevailing atmospheric conditions, there could be destructive interference between the direct and reflected rays, the latter of which is comprised of the various multiple hop (one-hop, two-hop, and so on) propagation modes. Additionally, signal degradation may also occur if there is destructive interference between various modes that arrive at the receiver after refraction from different heights in the troposphere. All these situations could possibly cause key problems in the domain of cellular mobile communication systems in littoral regions. Thus, in addition to aiding radio wave propagation, evaporation ducts could also be principal limiting factors in beyond line of sight over-the-sea UHF propagation.

UNIT V

WAVE PROPAGATION-II

Introduction of Sky Wave Propagation or IONOSPHERIC Wave Propagation

Medium and high frequencies of 2 to 30 MHz

Reflection from the ionized region in the upper atmosphere called Ionosphere (50Km to 400Km above earth surface).

Ionosphere – act as a reflected surface

More than 30 MHz- not reflected & penetrate into Ionosphere.

Reflection from Ionosphere called as ionosphere propagation.

Suitable for 2 to 30 MHz called as short wave propagation.

Long distance point to point communication called as point to point propagation.

Possible with multiple reflection extremely long distance communication.

STRUCTURE OF THE IONOSPHERE

As we stated earlier, the ionosphere is the region of the atmosphere that extends from about 30 miles above the surface of the Earth to about 250 miles. It is appropriately named the ionosphere because it consists of several layers of electrically charged gas atoms called ions. The ions are formed by a process called ionization.

Ionization

Ionization occurs when high energy ultraviolet light waves from the sun enter the ionospheric region of the atmosphere, strike a gas atom, and literally knock an electron free from its parent atom. A normal atom is electrically neutral since it contains both a positive proton in its nucleus and a negative orbiting electron. When the negative electron is knocked free from the atom, the atom becomes positively charged (called a positive ion) and remains in space along with the free electron, which is negatively charged. This process of upsetting electrical neutrality is known as IONIZATION. The free negative electrons subsequently absorb part of the ultraviolet energy, which initially freed them from their atoms. As the ultraviolet light wave continues to produce positive ions and negative electrons, its intensity decreases because of the absorption of energy by the free electrons, and an ionized layer is formed.

The rate at which ionization occurs depends on the density of atoms in the atmosphere and the intensity of the ultraviolet light wave, which varies with the activity of the sun.

Since the atmosphere is bombarded by ultraviolet light waves of different frequencies, several ionized layers are formed at different altitudes. Lower frequency ultraviolet waves penetrate the