TROPOSPHERE WAVE PROPAGATION

Troposheric 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 9 km at the poles and 17 km 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 7o 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 (30-300 MHz) and UHF (300-3000 MHz) 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”, S D Gunashekar, D R Siddle and E M Warrington]

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 s 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:

$$N = (n-1)*10^6$$

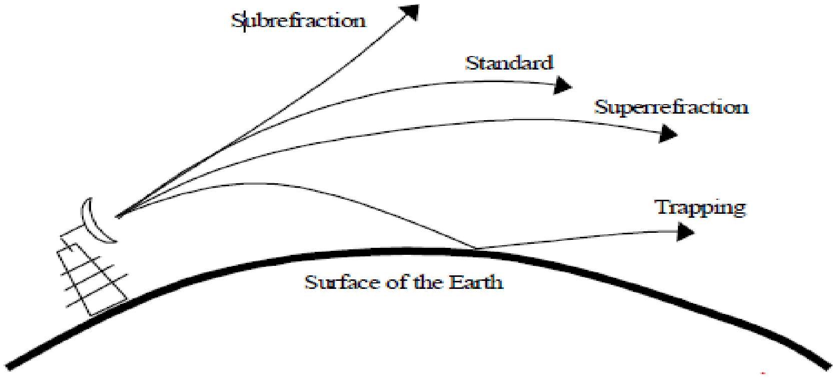
So, for example, when n = 1.000350, N = 350.
A well-known approximation for refractivity N is given below

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

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 –79 N-units per kilo. When the refractivity gradient varies from –79 to –157 N-units per kilo, 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 –157 N-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 0 N 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. Figure1 illustrates the four refractive conditions discussed above.



While dealing with radio propagation profiles, the curved radio rays are replaced with linear rays 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 8500 km). 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 (in s), a = radius of the earth (in s).

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