Ionospheric Absorption

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For a QSO to occur, two parameters must be met. There must be enough ionization to refract (bend) the signal back to earth. This is expressed as an MUF (maximum usable frequency). Early manual prediction techniques (and even some predictions generated by early personal computers) only gave MUF. They left out the other half of the story – the amount of loss. In other words, the signal must be strong enough. [note 1]

I can think of nine parameters that determine the signal-to-noise ratio. They are transmit power, antenna gains (including ground parameters), free space path loss (spreading of the wave), ionospheric absorption, ground reflection loss, the effect of multipath (short-term fading), polarization mismatch, above-the-MUF loss and the noise environment at the receiver in a designated bandwidth. This month's column looks at ionospheric absorption.

What types of absorption are there?

There are two types of ionospheric absorption: non-deviative and deviative. Non-deviative absorption occurs in the D region during the day and in the lower E region during the night when the signal is pretty much following a straight-line path – minimal bending is occurring.

Deviative absorption occurs near the top of the trajectory (the peak altitude of the hop) or anywhere along the path where marked bending takes place. This can happen in the E region during the day and in the F region during both day and night. [note 2]

What causes absorption?

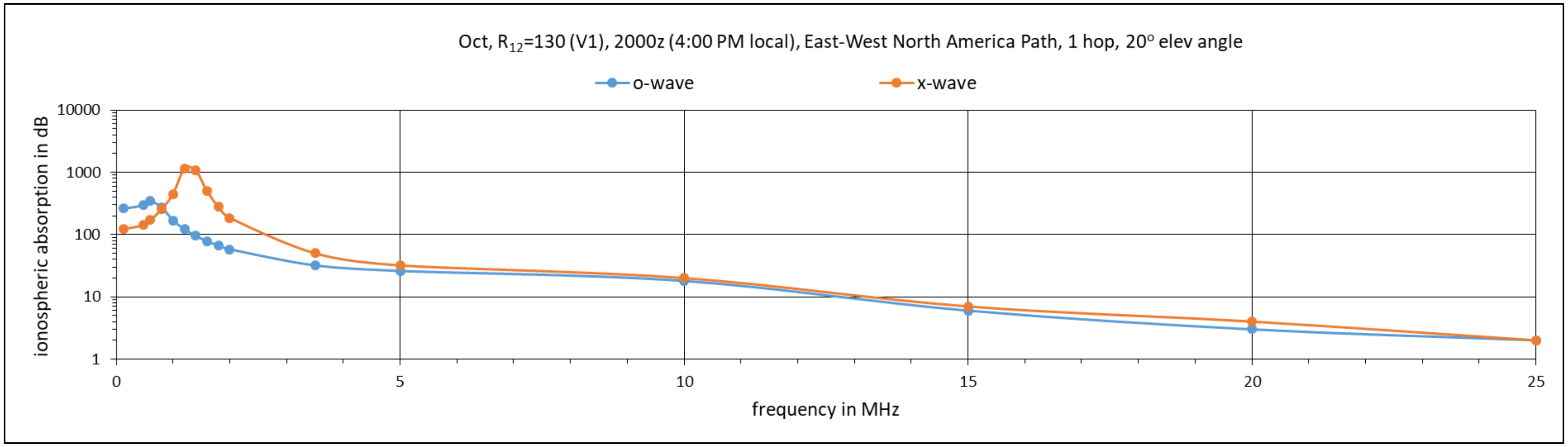
From equation 7.25 on page 216 in *Ionospheric Radio* by Kenneth Davies (Peter Peregrinus Ltd, 1990), ionospheric non-deviative absorption is dependent on the electron density and the collision frequency between electrons and neutral atmospheric constituents as follows:

absorption is proportional to $\frac{N_e \times v}{(w \pm w_L)^2 + v^2}$ (equation 1)

where N_e is the electron density (simplistically, it decreases with decreasing altitude)
v is the electron-neutral collision frequency (it increases with decreasing altitude)
w is the angular operating frequency
w_L is the longitudinal component of the angular electron gyro-frequency
the plus sign is for the ordinary wave and the minus sign is for the extraordinary wave

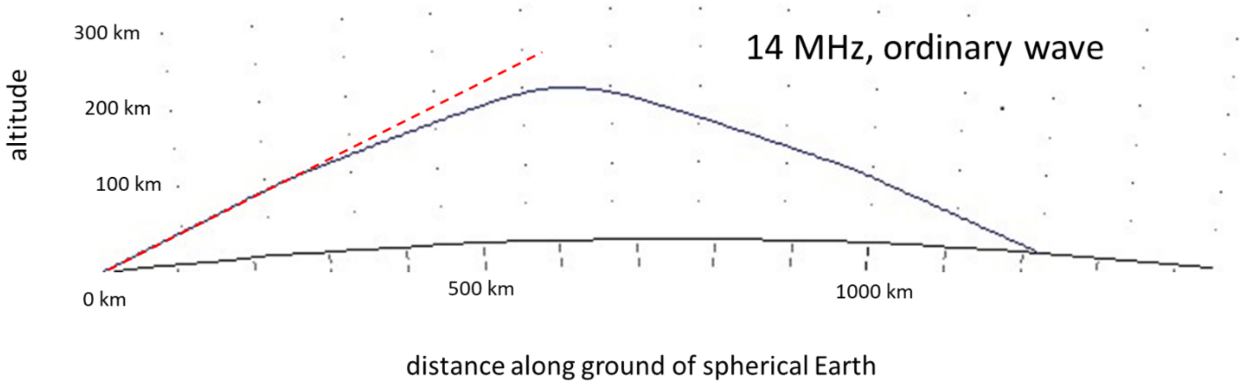
How does absorption vary?

Let's assume that the operating frequency is much greater than the electron gyro-frequency. This indicates that non-deviative absorption is inversely proportional to the square of the frequency – the lower the frequency, the higher the absorption. Here's a representative plot of the total monthly median absorption from Proplab Pro V3 for a one-hop east-west path in North America in October at 4 PM local time (daytime) during a moderate solar cycle.



Indeed, absorption increases as we go lower in frequency. Absorption of the ordinary wave and the extraordinary wave are quite similar at the higher frequencies, but they diverge and peak at different frequencies as the operating frequency approaches the electron gyro-frequency [note 3]. If this graph went to 50 MHz, the absorption on 6 meters would only be around 1 dB for a long hop (assuming there's enough ionization to refract it back to earth, of course).

Now let's look at non-deviative absorption versus deviative absorption. Here's the ray trace on 14 MHz.

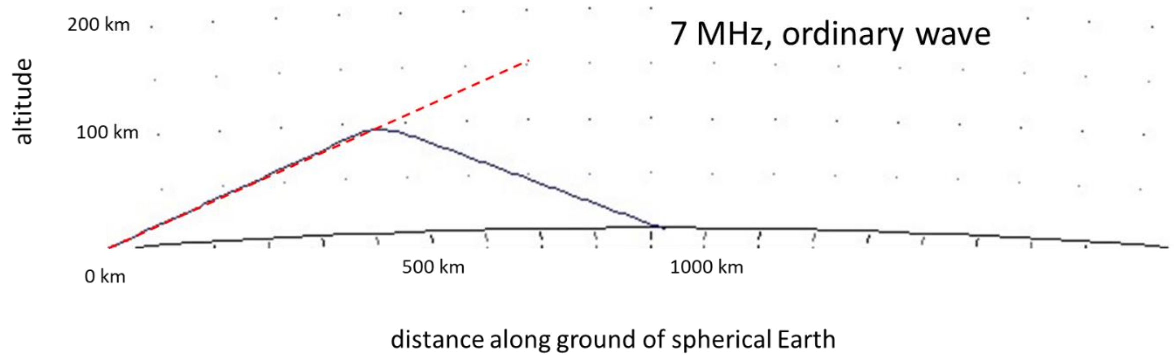


Note the dashed red line. I included it to determine when the ray starts deviating from a straight line in order to determine the deviative absorption. It appears to start deviating around 120 km as it goes through the E region. But if you look closely, after this small amount of bending it then goes straight again until it's at the top of the trajectory. So where does deviative absorption occur? From the earlier definition of deviative absorption, it occurs near the top of the trajectory or anywhere along the path where marked bending takes place.

Does the slight amount of bending going through the E region qualify as 'marking bending'? That's a subjective call, so let's assume the worst case scenario and determine the deviative absorption when it slightly bends going through the E region (on the way up and on the way down) and when it's at the top of the trajectory.

Using the Proplab Pro V3 detailed results from the ray trace, we determine the deviative absorption is 0.48 dB and the non-deviative absorption is 8.02 dB. This adds up to the 8.5 dB from the earlier plot of absorption versus frequency at 14 MHz. Thus non-deviative absorption dominates and it's due to the electron-neutral collision frequency being greater at the lower altitudes where bending doesn't occur.

Now let's do the ray trace on 7 MHz.



There's enough ionization in the E region under the assumed conditions (daytime, moderate solar cycle) to make 7 MHz an E hop. The deviative absorption only occurs very near the peak of the trajectory (as indicated by the dashed red line).

The total absorption is 28.0 dB (again, from the earlier plot of absorption versus frequency at 7 MHz), which consists of 8.27 dB for the deviative portion and 19.73 dB for the non-deviative portion. Again, the non-deviative absorption dominates, but the deviative absorption is a greater percentage of the total absorption because it occurs at the lower altitudes where the electron-neutral collision frequency is greater.

For a much more detailed look at absorption, I recommend the paper *Calculating the absorption of HF radiowaves in the ionosphere*. This paper is authored by K. A. Zawdie, D. P. Drob, D. E. Siskind, and C. Coker. It appeared in the American Geophysical Union journal **Radio Science** in

June 2017. Visit https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017RS006256 for free access to this paper.

Summary

Absorption increases as frequency is decreased. Absorption is maximum near the electron gyro-frequency, which is anywhere from 0.7 to 1.7 MHz depending on where you are in the world. And non-deviative absorption dominates over deviative absorption at HF in the daytime – but by how much depends on the frequency. At night I would expect deviative absorption at HF to dominate due to the D and E regions minimizing at night (where non-deviative absorption occurs).

Notes

1) Knowing just the signal strength may not be enough. Is the signal strength adequate in relation to your noise level? In other words, it’s best to determine the signal-to-noise ratio (SNR). The required SNR for a QSO to be completed depends on the mode being used. SSB requires the highest SNR and the digital modes require the lowest SNR. CW is in between.

2) There’s nothing magical about the concept of deviative absorption. Non-deviative absorption is when the ionosphere’s index of refraction is near 1.0 (no bending) at the designated frequency, and the wave gets through the absorbing region relatively quickly – it spends very little time in the absorbing region. Deviative absorption is when the ionosphere’s index of refraction at the designated frequency is approaching 0. The wave is bending and its group velocity slows down. Thus the wave spends more time in the absorbing region under deviative conditions.

3) The electron-neutral collision frequency also comes into play here.