The Structure of the Ionosphere

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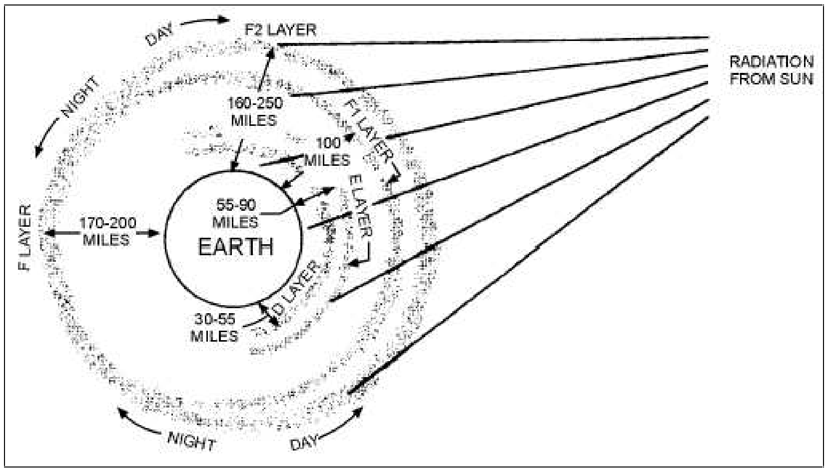
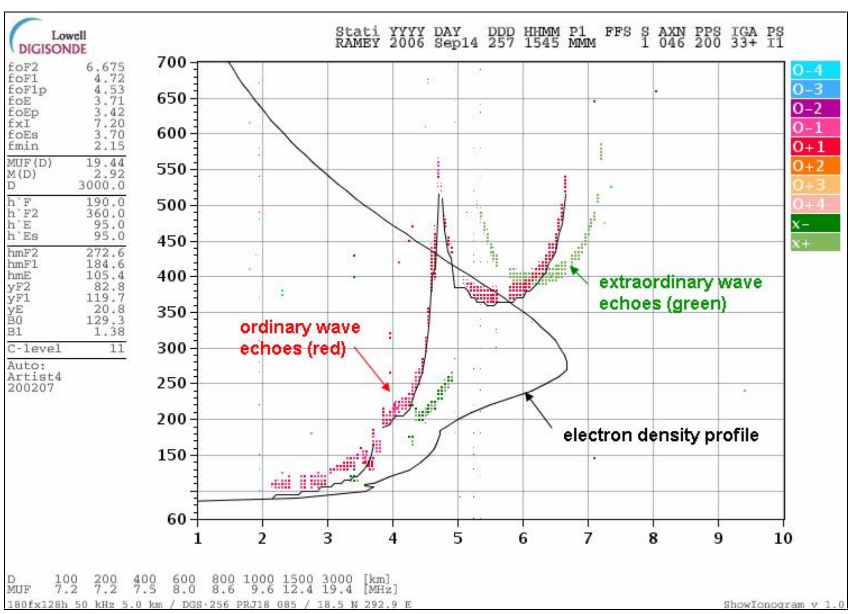
You've probably seen the following image (or something similar) in a discussion of HF propagation. It's a simplified view of the structure of the ionosphere to show the various layers of the ionosphere and to show the difference between daytime and nighttime.



But it's so simplified that it can lead you astray. How can that happen?

One way to be led astray with the simplified view is the depiction of distinct layers – with nothing in between each layer. For example, one could hypothesize that during the day an electromagnetic wave could duct between the F1 and F2 layers. In reality, that is highly unlikely as the true structure of the ionosphere is an electron density versus altitude with maximums and inflection points – not distinct separate "layers". The following image shows a representative electron density profile (the indicated black line).



This image is from an ionosonde, which is for all intents and purposes a radar station pointing straight up. The ordinary wave swept-frequency echoes are translated into the electron density profile. For the record, this is a daytime ionogram from the Ramey (Puerto Rico) ionosonde on September 14, 2006 at 1545 UTC.

It's obvious that the electron density (the horizontal axis, with the electron density expressed in terms of frequency through the equation $F = 9 \text{ x } (N_e)^{1/2}$) increases with an increase in altitude (the vertical axis in km). It's also obvious that there are no distinct separate "layers", and thus we really shouldn't use the terminology "layers" – it would be better to use the terminology "regions" instead.

There are two maximums in the plot – one small one for the E region (around 3.7 MHz at 105 km) and one big one for the F2 region (around 6.7 MHz at 273 km). The transition from the D region to the E region is not very discernible – nothing like the simplified view. The F1 region only has an inflection point (around 4.8 MHz at 185 km), and this is why I said earlier that ducting between the F1 and F2 regions is not very likely – there's really no upper and lower boundary to duct in as one would assume from the simplified view.

Another way to be misled with the simplified view is the lack of an E region at night. There still is residual ionization during the nighttime, and it has a profound effect on absorption and refraction on our lower frequencies (160m and 80m).

And yet another way to be led astray with the simplified view is the lack of information with respect to the 'strength' of each region. One could hypothesize that all electromagnetic waves, regardless of frequency, reach the same height in the ionosphere. But due to the increase in electron density versus altitude, lower frequencies (160m and 80m) do not get as high into the ionosphere as higher frequencies (15m, 12m, and 10m) because the amount of refraction (bending) for a given electron density is inversely proportional to the square of the frequency. That has important implications when talking about propagation to extremely long distances – the lower frequencies necessarily end up with shorter hops, and incur more absorption.

In summary, an actual electron density profile is in stark contrast to the simplified view of the ionosphere. The simplified view is good for very basic talking purposes, but the true structure is necessary to understand the real mechanisms of HF propagation.