

Worldwide Critical Frequency Maps – What They Tell Us
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Sometimes we get so involved with details that we forget the bigger picture. There's a common phrase for this – we can't see the forest for the trees. I think this can happen with propagation predictions. We concentrate so much on MUF (maximum useable frequency) and signal strength that we blindly follow the results without understanding why the specific results happen.

Here's where we can take a step back, and take a look at the bigger picture with worldwide maps of critical frequencies – both for the E region and for the F2 region. So let's get started with worldwide maps from Proplab Pro Version 3. Worldwide maps are also available in VE3NEA's DX Atlas, on-line at <http://www.spacew.com/www/fof2.html> (just the F2 region) and even in the old printed books titled Ionospheric Predictions from the Institute for Telecommunication Sciences in Boulder, CO (1971). I'm sure there are other places out there, too.

E region

Figure 1 is a worldwide map showing E region critical frequencies (foE) for mid-January at 2000 UTC at a smoothed sunspot number (R_{12}) of 50. The somewhat circular contour lines in the dark ionosphere are an artifact of the Proplab Pro V3 mapping feature, and do not suggest that there are circular blobs of ionization. For more detail, there is a larger version of this map at the end of this Monthly Feature.

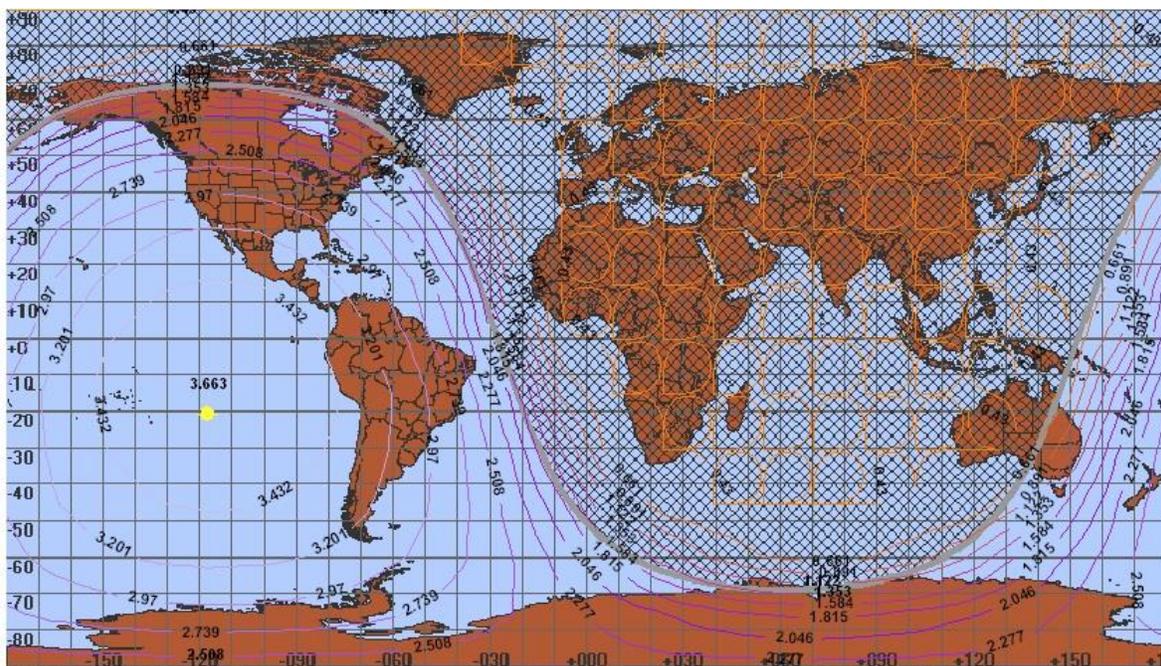


Figure 1 – E Region Critical Frequencies for January 15 at 2000 UTC at $R_{12} = 50$

Two observations stand out. First, the maximum foE value of 3.663 MHz is directly under the overhead Sun (the yellow dot at 20° S geographic latitude and 120° W longitude). Second, the foE contour lines are parallel to the terminator all around the world.

What this tells us is the E region is for all intents and purposes under direct solar control. The daytime E region critical frequency can be expressed in terms of the smoothed sunspot number R_{12} and the solar zenith angle χ . As a reminder, a solar zenith angle of 0 degrees says the Sun is directly overhead, while a solar zenith angle of 90 degrees says the Sun is on the horizon (sunrise and sunset).

$$\text{daytime foE in MHz} = 0.9 [(180 + 1.44 R_{12}) \cos \chi]^{0.25}$$

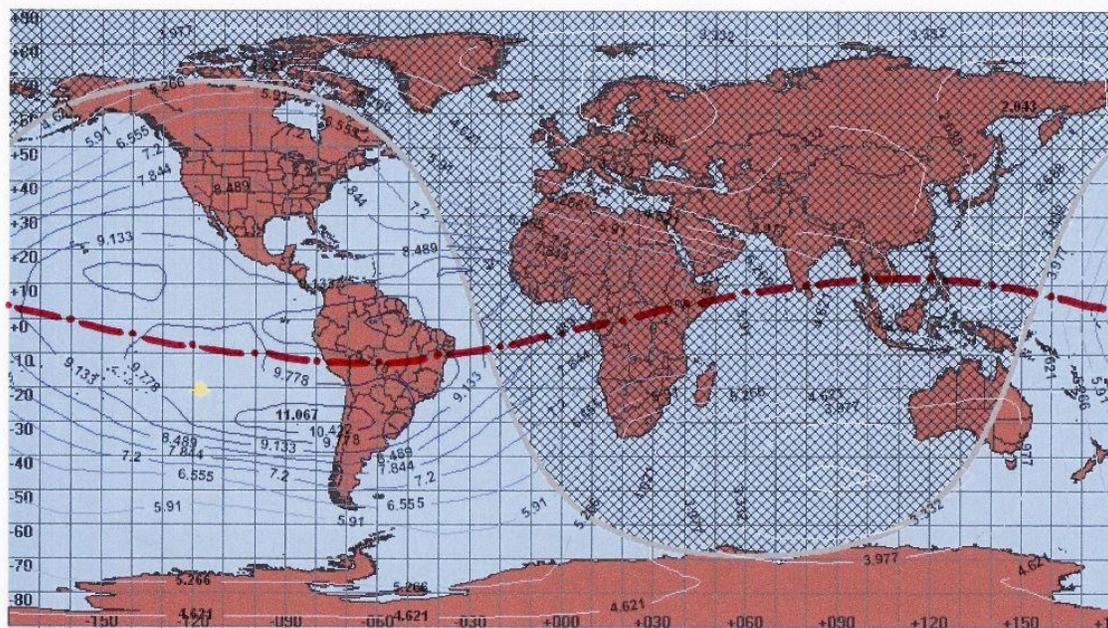
This equation is not valid for sunrise/sunset conditions, at midnight (foE varies from about 0.36 MHz at solar minimum to about 0.51 MHz at solar maximum) and at high latitudes (greater than about 70°, where precipitating electrons from auroral events add to the normal E region).

Regardless of the qualifiers in the last paragraph, the E region is well behaved, following the Sun. Of course sporadic E (E_s) is another animal.

For propagation at low elevation angles, multiply foE times 5 to get the MUF for the E region. Using this rule of thumb in conjunction with the values on Figure 1 says the daytime E region can block frequencies up to at least 14 MHz from longer F2 hops at a smoothed sunspot number of 50.

F2 region

Figure 2 is a worldwide map showing F2 region critical frequencies (foF2) for mid-January at 2000 UTC at a smoothed sunspot number (R_{12}) of 50 (same conditions as for Figure 1). For more detail, there is also a larger version of Figure 2 at the end of this Monthly Feature.



Compared to the E region critical frequencies in Figure 1, the F2 region is a heck of a lot more complicated. Three observations are worth noting for the F2 region.

First, the foF2 contour lines at low and middle latitudes are parallel to the terminator only around sunrise, which is occurring over eastern Australia and thereabouts. This says the F2 region decreases to low values throughout the night, and sunrise starts the re-ionization process in the F2 region [note 1].

Second, the foF2 contour lines at low to middle latitudes are perpendicular to the terminator around sunset, which is occurring in the middle of the Atlantic Ocean. This says the F2 region does not immediately decrease as does the E region – foF2 takes a long time to reach its lowest nighttime value. The reason for this is the recombination process at F2 region altitudes occurs much slower than the ionization process at F2 region altitudes due to the low number of collisions between electrons and positive ions after sunset.

Third, and perhaps the most important observation, is the fact that you can't express foF2 with a single equation based on the smoothed sunspot number and the solar zenith angle [note 2]. One of the big problem areas in trying to do this is the daytime and early evening equatorial ionosphere, where there are areas of increased ionization (which gives us TEP – trans-equatorial propagation – on 10m and 6m) that are not basic shapes that are easily defined.

But expressing the F2 region in equation form is possible – it just takes a lot of equations (or functions). Raymond Fricker of the BBC External Services did just this in the 1970s. He started with a main function that depended on the latitude from the magnetic equator and used four variables to define the seasons and sunspot number. An additional 22 functions refined the model to make it look like Figure 2 for any given time of day, month and sunspot number.

You may wonder why Fricker used the latitude from the magnetic equator in the main function. Take another look at Figure 2. I've included the magnetic equator (the red dot-dash line) on the figure. If you stare at Figure 2 long enough, you'll see that the contour lines are more ordered about the magnetic equator than about the geographic equator – especially in the equatorial ionosphere. This makes sense as electrons are charged particles, and they are influenced by a magnetic field.

For propagation via low elevation angles, multiply foF2 times 3 to get the MUF for the F2 region. Using this rule of thumb in conjunction with the values on Figure 2 will show you which higher bands may be open over a given path per the time, month and sunspot cycle status.

One last comment – both the foE data and the foF2 data are monthly median values. Over a month's time frame, the variation of the daily foE about the monthly median foE is significantly less than the variation of the daily foF2 about the monthly median foF2. This reiterates that the E region is pretty much under direct solar control, with no dependency on parameters other than the solar zenith angle and the sunspot number. For the F2 region, geomagnetic field activity and events in the lower atmosphere coupling up to the ionosphere also contribute to the ultimate foF2 value at any given location, and make foF2 complicated as seen in Figure 2.

Summary

If you want to develop a good intuitive feel for the worldwide ionosphere, look at these maps for different times, different months and different sunspot numbers. They may help your on-the-air activities and may help explain some of your more unusual QSOs.

Notes

1. Unless you're doing NVIS, it's important to realize that what's happening in the ionosphere over your QTH is not important. What matters is what's happening where your RF encounters the ionosphere – which could be quite a distance down the road from your QTH.
2. I should reiterate that the E region can't be described in one equation, either. As noted, the equation on page 2 is valid only for daytime conditions. Additional equations (albeit simple equations) are needed for sunrise/sunset and for midnight.

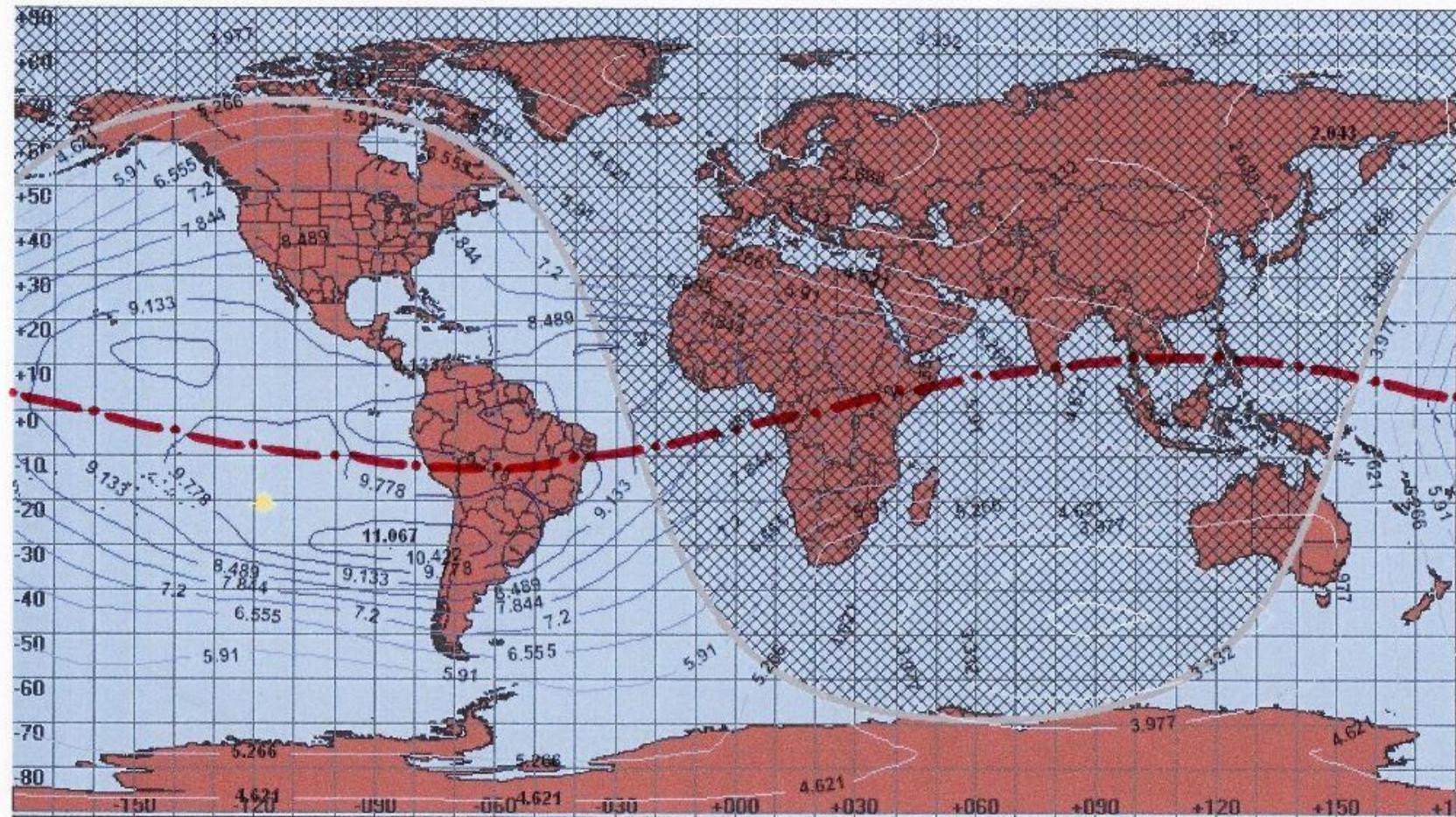


Figure 2 – Large Map of F2 Region Critical Frequencies for January 15 at 2000 UTC at R₁₂ = 50