Propagation
CQ Plus May 2014
Carl Luetzelschwab K9LA

**Several Short Topics: Above-the-MUF Propagation, Low and High Latitude Es, Pedersen Ray**

This month's column addresses several topics that just aren't long enough to make into a full column. The topics are above-the-MUF propagation, probabilities of high and low latitude sporadic E, and the Pedersen ray.

Above-the-MUF propagation

Most of our QSOs via the F2 region are due to refraction. This means there is sufficient ionization in both the horizontal extent and the vertical extent to bend the electromagnetic ray back to Earth. In other words, the MUF (maximum useable frequency) is high enough. To see this, take a look at Figure 1.

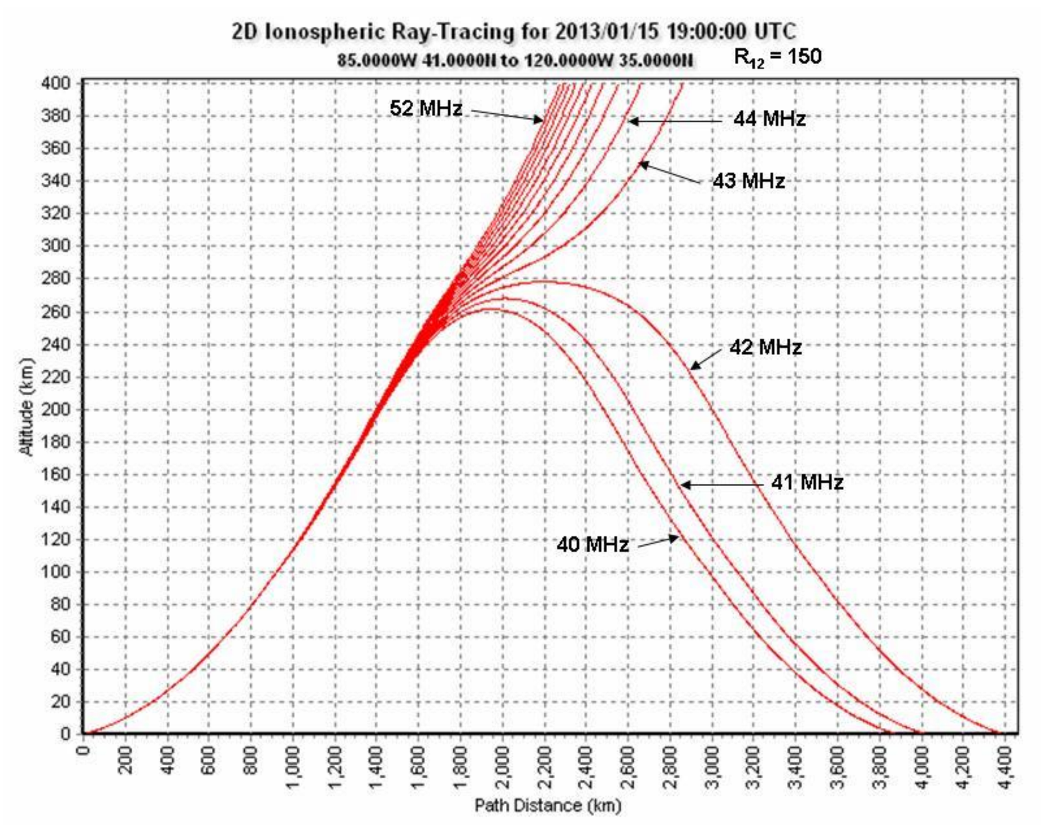


**Figure 1 – Ray traces versus frequency**

Figure 1 consists of ray traces launched at a 2 degree elevation angle (close to the horizon) during the day time for a January month at very high solar activity for a path from my QTH to California. Ray traces from 40 MHz to 52 MHz were done in 1 MHz steps. This plot comes from the PropLab Pro V3 software offered by Solar Terrestrial Dispatch (visit **http://www.spacew.com/proplab.html** for more on this software).

The path could support refraction up to 42 MHz. Any higher frequency goes thru the ionosphere. Thus our conclusion would be that 6m could not be supported on this path. But there's a possibility that a QSO could happen.

That's because ionospheric scientists observed that paths could be open even though the MUF didn't appear to be high enough. They believe this is due to a scatter mechanism. Now scatter implies additional loss, so the result of this is a rather simple equation that ties the additional loss in dB due to scatter to the operating frequency (Fop) and the MUF. The equation for the additional loss is 36 times $[(Fop/MUF) - 1]^{1/2}$. For the record, VOACAP uses this equation in its propagation predictions.

For our conditions in Figure 1, the additional loss on 50.1 MHz with the MUF at 42 MHz would be 15.8 dB – about 3 S-units. That's the bad news. But the good news is that ionospheric absorption on 6m is very low (because ionospheric absorption is inversely proportional to the square of the frequency – the higher the frequency, the less the absorption). So of all the bands, 6m could tolerate the most additional loss.

Note that the comment about vertical and horizontal extent in the first paragraph in this section is very well demonstrated in Figure 1. At 42 MHz, the ray needs 40 km in vertical extent and over 1000 km in horizontal extent to bend back to Earth. Thus the ray does not turn around at a single point in the ionosphere. Of course the vertical and horizontal extent become smaller as the frequency is lowered (which comes from the fact that the amount of refraction is inversely proportional to the square of the frequency – the lower the frequency, the more the ray is bent).

In essence, over-the-MUF propagation can make the MUF look higher than it really is.

<u>Probabilities of Low and High Latitude Sporadic E</u>

Most of you who are reading this live in the mid latitudes in North America. Thus we are probably quite familiar with mid latitude sporadic E (Es for short). It occurs with the highest probability in the summer months, with a late morning peak (local time) and an early afternoon peak (local time). There's also a lesser probability in December in the late morning hours (local time). The Figure 1 plot on my web site (**http://k9la.us**) in the article titled "Summer 6m Es Probabilities" in the VHF link on the left on the home page shows these probabilities.

Es occurs at low latitudes and high latitudes, too. The probabilities for these Es openings are probably not so well known to most of us. The best presentation I've seen of the low latitude and high latitude probabilities of Es is in Figure 5.17 in **Ionospheric Radio** by Kenneth Davies (published by Peter Peregrinus, 1990).

At high latitudes, the highest likelihood for Es is in the late evening (local time) throughout the entire year. At low latitudes, the highest likelihood is around noon (local time) throughout the entire year.

To see Figure 5.17 in **Ionospheric Radio**, click on the VHF link on my web site and open the article titled *Es Probabilities at High, Mid and Low Latitudes*. The plots show the probability that foEs (the Es critical frequency) is above 5 MHz. This means the Es MUF will be above about 25 MHz.

Pedersen Ray

Most of the time low elevation angles are the norm for our DX QSOs via the F2 region on the higher bands. Of course there are exceptions to this, and incidences of these occurrences are documented in the Amateur Radio literature. These instances of higher elevation angles usually are normal one or two hop mechanisms over shorter distances – for example, North America to the Caribbean or North America to Europe via two higher elevation angle hops.

But there's another mechanism involving even high elevation angles, and this mechanism also involves longer distances. It's called the Pedersen ray, and was first demonstrated in the late 1950s by Canadian scientists at the Defense Research Telecommunications Establishment in Ottawa (E. Warren and E. L. Hagg; *Single-Hop Propagation of Radio Waves to a Distance of 5,300 km*; **Nature**; January 4, 1958). Conceptually the Pedersen ray is ray 5 in Figure 2.

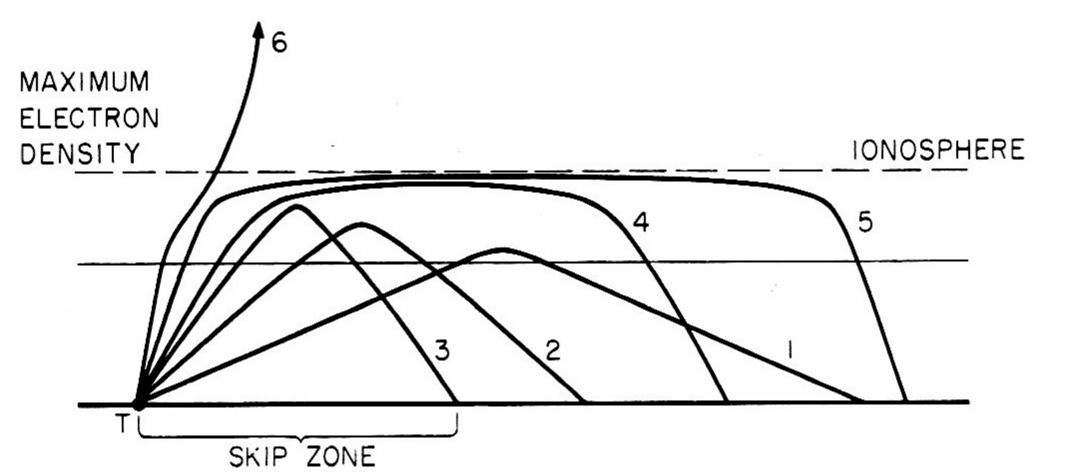


**Figure 2 – The Pedersen ray**

Rays 1, 2 and 3 are low elevation angle rays, and the distance covered is progressively less as the elevation angle goes higher. But ray 4 ends up even farther down the road than ray 1. Ray 5 is the highest elevation angle that still propagates to a distant location, and the distance is the farthest. Ray 6 goes through the ionosphere.

Please realize that Figure 2 is a rectangular projection of the spherical Earth-ionosphere system. Thus the Pedersen ray follows the curvature of the Earth over a long distance. This requires a very stable ionosphere over a very long distance. This leads to the comment that the Pedersen ray, when it ocurrs, tends to peak near noon at the mid point of the path when horizontal gradients of the electron density along the path are at a minimum.

Thus the usefulness of the Pedersen ray is somewhat suspect. It may happen, but it may happen only very occasionally and for a short period of time. There’s not a lot in the ionospheric literature on the Pedersen ray, so we don’t have a lot of previous research on which to rely.