Sunrise, Sunset and Daylight in Relation to Low Band Propagation

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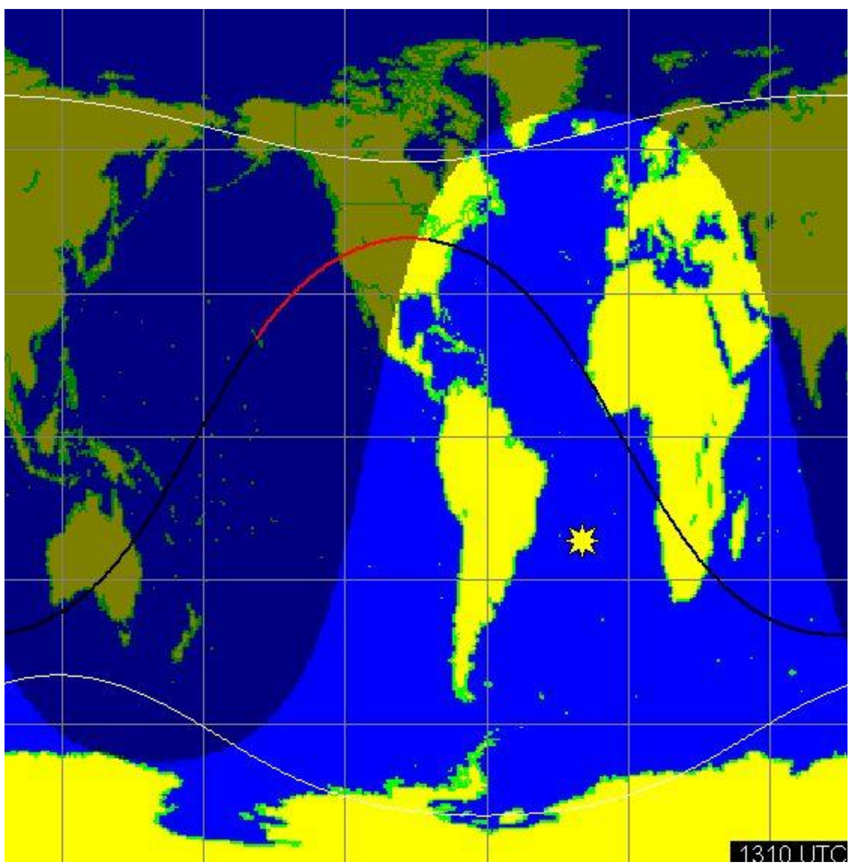
This month's column begins my 20th year of writing monthly columns about propagation and solar topics. It all began in January 1997 when I took over the Propagation column in the printed magazine WorldRadio from Bob Brown NM7M (SK). I've written about many topics over the years in WorldRadio, WorldRadio On-Line, CQ Plus and now my Monthly Features on my web site, and I will continue to do so as long as I have interesting material to write about.

In last December's ARRL 160-Meter Contest, I made some interesting QSOs Sunday morning after my sunrise. For reference, my sunrise was at 1252 UTC. These QSOs included:

KF7PG in Washington at 1255 UTC
K7QA in Montana at 1256 UTC
N5CR in Washington at 1259 UTC
KH6DX in Hawaii at 1214 UTC, still heard at 1310 UTC and after

The "most daylight" QSO (okay, it was actually a reception) was obviously with KH6DX at 1310 UTC, and the following figure (from W6ELProp's mapping feature) shows this scenario.



KH6 to K9LA at 1310 UTC in the 2016 ARRL 160m Contest

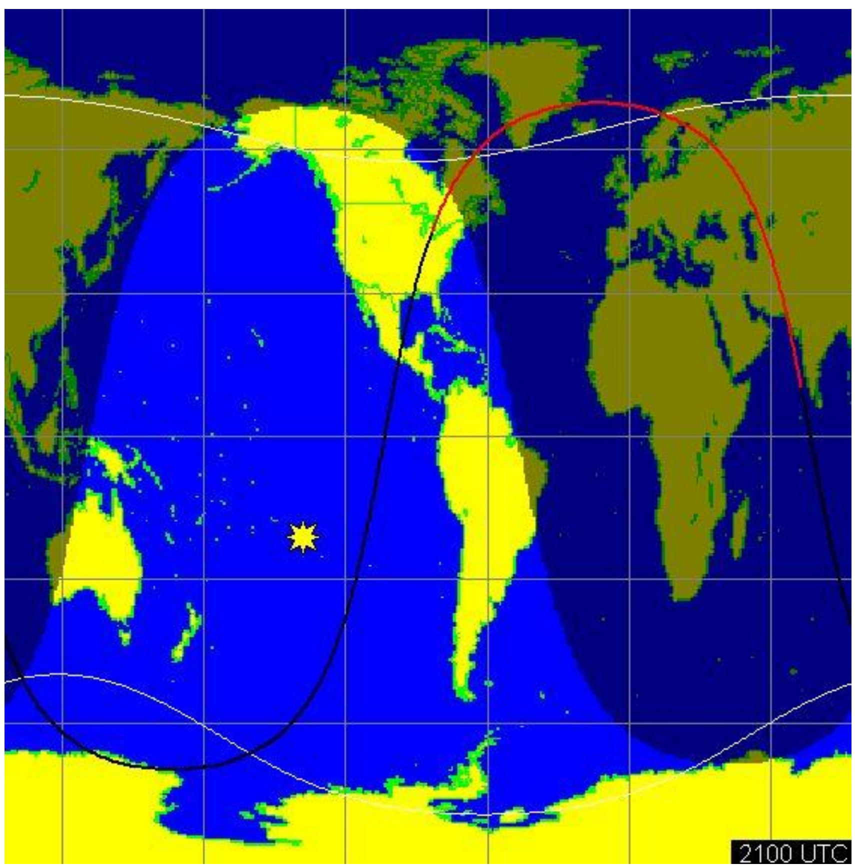
The red line is short path, with the left end at KH6 and the right end at K9LA (the black line is long path). 1310 UTC was 18 minutes past my sunrise – in other words, it was daylight at my end. As a side note, KH6DX was still heard for a bit after 1310 UTC. After 1310 UTC he gradually faded into the noise.

What's not important is what's going on overhead at my QTH (but it is a good reference point). What is important is what's going on where the RF encounters the absorbing region of the ionosphere (the D region during the day and the lower E region at night) – which is some distance to the west of my QTH. How far west? Some spherical geometry, assuming a 15 degree take-off angle, says RF would encounter the absorbing region around 300 km to the west of me. That puts it right around the terminator – so absorption would be determined by being in semi-darkness near the terminator, and not by being in daylight at my QTH.

There are many more examples of QSOs after sunrise and before sunset. For example, Tom K8BKM recently (29 November 2016) posted the following comment about 40-Meters to the CQ-Contest reflector:

"Perfect example occurred today, when spots for VU7MS (Lakshadweep) in Zone 22 started popping up on the DX cluster from stations in NA at 1900z – that's 2PM EST, folks! I didn't hear him in the Midwest until closer to 4PM local time, but it was well before the sun went down."

Here's this scenario using W6ELProp.



K8BKM began hearing VU7 at 2100 UTC on 40m on 29 November 2016

Again, the red line is the short path, with K8BKM in Michigan on the left end and VU7 just off the west coast of India on the right end. K8BKM was about an hour before sunset. That's a bunch, but this has to be tempered with the fact that this was 40-Meters and remembering that absorption is inversely proportional to the square of the frequency. In other words, 40-Meters can tolerate more daylight than 80-Meters – which in turn can tolerate more daylight than 160-Meters.

The take-away here is to pay attention to where your RF encounters the absorbing region of the ionosphere – and factor in the frequency, too. But there's another issue involved, and it's a bit more subtle.

This other issue is the solar zenith angle along the path. What is the solar zenith angle? It's the angle between directly overhead and where the Sun is. For example, if the Sun is directly overhead at a given location, then the solar zenith angle is 0^o. If the Sun is 45^o above the horizon, the solar zenith angle is 45^o. If the Sun is on the horizon, the solar zenith angle is 90^o (which says it is sunrise or sunset). Solar zenith angles greater than 90^o put the Sun below the horizon.

The tie to the ionosphere is the fact that the ionization in the D region and in the E region are related to the solar zenith angle as follows:

$$\text{D region ionization is proportional to } (F_{12} \cos X)^{0.5}$$

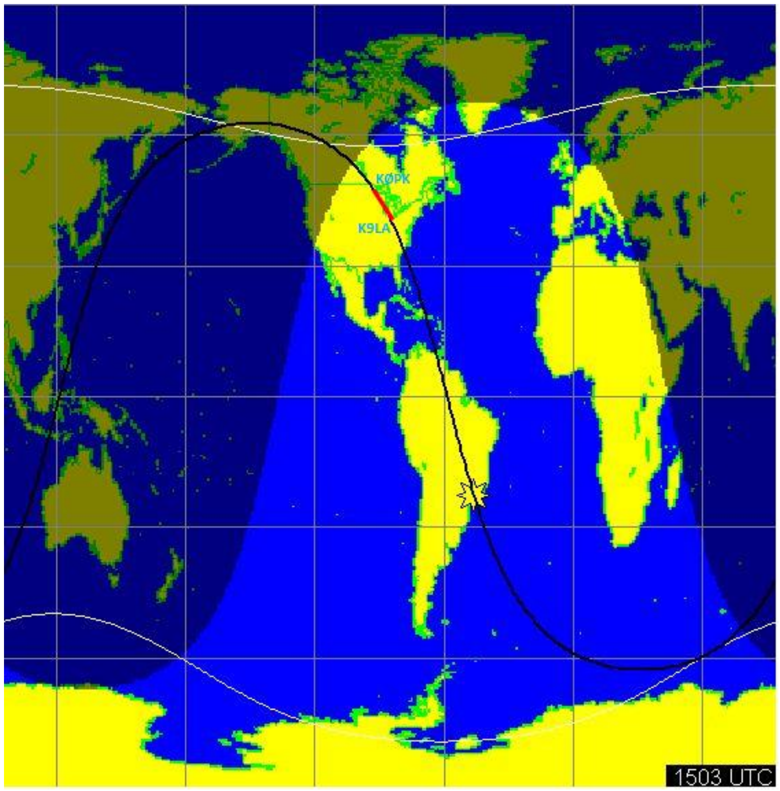
$$\text{foE (daytime)} = 0.9\,[(180 + 1.44\,R_{12}) \cos X]^{0.25}$$

where F_{12} is the smoothed 10.7 cm solar flux, X is the solar zenith angle, foE is the E region critical frequency and R_{12} is the smoothed sunspot number.

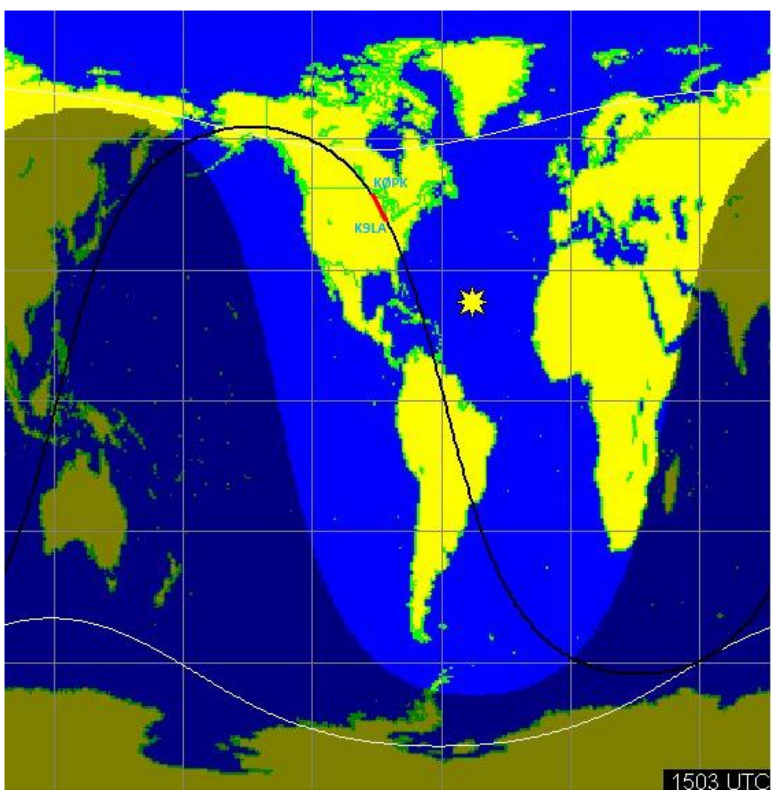
For both regions, when the solar zenith angle is 0^o (Sun overhead), ionization is highest. That means absorption in the D region is highest, and foE is highest. When the solar zenith angle is 90^o (Sun on the horizon), ionization is lower – which means lower absorption and lower foE [*note 1*].

For both my QSO with KH6DX on 160-Meters and K8BKM hearing VU7 on 40-Meters, the common theme for these two events is a northern hemisphere winter month when the Sun is down in the southern hemisphere (around 25^o South latitude). The two W6ELProp maps clearly show this – which says the solar zenith angles were high giving minimal absorption and lower foE values. The minimal absorption means a stronger signal, while the lower foE value means our RF can get through the E region easier for a longer hop via the F2 region as stated by Frank W3LPL in his reply to K8BKM's post.

To better understand how the position of the Sun impacts a path, let's look at a QSO I made in last December's Stew Perry 160-Meter contest. I worked KØPK in northern Minnesota at 1503 UTC. That's a 914 km path, and 1503 UTC is 10:03 AM in Fort Wayne. W6ELProp shows this December path, with the red line again the short path. Also shown after the December scenario is the same path at the same time in June.



K9LA to KØPK at 1503 UTC in December



K9LA to KØPK at 1503 UTC in June

Note where the overhead Sun is in December versus June – it's much closer to the path in June. Using Proplab Pro V3 (offered by Solar Terrestrial Dispatch), we can do ray traces to compare the mode (the number of hops and the region involved) and the amount of ionospheric absorption. We can also estimate the received signal power assuming 1 kW and 0 dBi antennas (and remembering to take into account the required elevation angle). The following table (with solar zenith angle abbreviated sza) gives these results.

month	midpoint sza	midpoint foE	mode	absorption	received signal power
Dec	79°	2.0 MHz	1E	44.0 dB	-97 dBm
Jun	43°	3.05 MHz	1E	71.6 dB	-125 dBm

As expected, December, with a higher solar zenith angle, has less E region ionization and much less ionospheric absorption. Since this QSO occurred on 160-Meters (1.8 MHz), the E region still dictates the mode since foE is greater than 1.8 MHz (regardless of the elevation angle). The received signal power in December is estimated to be around S4 (about what it really was), and in June it's estimated to be well below the typical noise floor of most stations due to the external noise environment.

In summary, pay attention to where your (and the other guy's) RF encounters the absorbing region of the ionosphere – and factor in the frequency, too. And realize that the winter months will give a better opportunity on the northern higher latitude paths due to the Sun being in the southern hemisphere. In general, 160-meters in winter will be better due to less ionospheric absorption (as in my QSO with KØPK) and 40-Meters in winter will be better due to less E region ionization allowing a longer F2 hop. 80-Meters will be somewhere in between.

Note 1 – Why does a higher solar zenith angle (the Sun lower on the horizon) give less ionization (which in turn gives a lower foE and lower absorption)? It's because solar radiation has to plow through more atmosphere when the Sun is low on the horizon. In essence plowing through more atmosphere reduces the photon's energy even more as each electron-ion pair is created. The sketch below shows this. Important – this does not apply to the F2 region – it is anomalous.