Predicting 6 Meter F_2 Propagation
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In his article *Predicting Transatlantic 50-MHz F-Layer Propagation* in the March 1993 issue of **QST**, Emil W3EP derived a statistical plot that forecasted transatlantic 6 meter propagation from New England to Europe via the F_2 region. The plot was based on data for the months of November, December, January, and February around solar maximum at the optimum times of day.

The purpose of this article is to introduce a method to predict 6m F_2 propagation for any path, for any phase of a solar cycle, for any month, and for any time of day. If you're a seasoned 6m operator, more than likely you won't need any help with predicting 6m F_2 propagation. But if you're new to 6m or in an unfamiliar location, you may find this method useful.

This method will use one of our HF propagation prediction programs – specifically VOACAP (Voice of America Coverage Analysis Program), which is the Voice of America version of the well-respected IONCAP (Ionospheric Communications and Analysis Prediction) program. For a brief tutorial of VOACAP, including download instructions, visit **http://mysite.verizon.net/k9la/id9.html** and read the file *Downloading and Using VOACAP*.

An Initial Run with VOACAP

Since VOACAP is an HF prediction program (2 – 30 MHz), we suspect it won't do very well on 6m paths. We can verify this by running a prediction from North America to Europe during the good days of November 2001. Then from observations during this period in *The World Above 50 MHZ* column by W3EP in the February 2002 **QST**, we can evaluate VOACAP's 6m performance. Figure 1 shows the path under analysis.

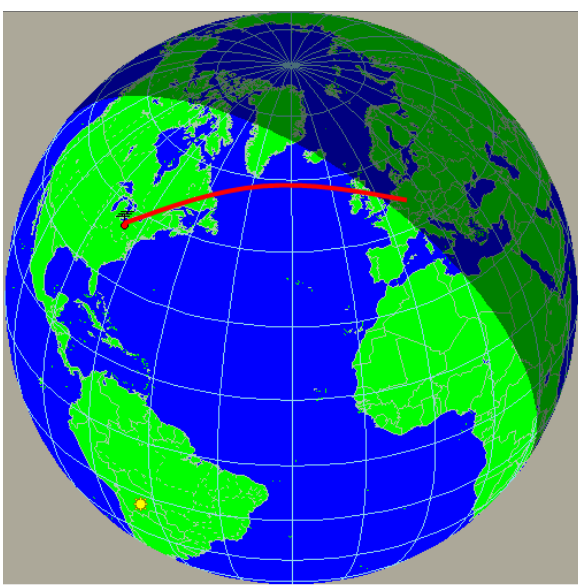

Figure 1 – The Western W3 to DL Path

We’ll use Method 30 in VOACAP at 1600 UTC for a path from Western Pennsylvania to Germany. And since our propagation prediction programs were developed based on the correlation between a smoothed solar index (either smoothed solar flux or smoothed sunspot number) and monthly median ionospheric parameters, we’ll run the prediction using the November 2001 smoothed solar flux of 194 (from the plot *ISES Solar Cycle F10.7cm Radio Flux Progression* at **http://www.swpc.noaa.gov/SolarCycle/**).

VOACAP predicts the monthly median MUF (maximum usable frequency) for our W3-to-DL path to be 37.2 MHz (this is the value given in the left-most column of the results). We can determine the distribution about the median MUF by using the tables of MUF variability in our ionospheric literature (for example, in the booklet *Predicting Statistical Performance Indexes for High Frequency Ionospheric Telecommunications Systems*, Technical Report 1-ITSA 1, 1966).

From this we see that on 10% of the days of November 2001 (3 days) the actual MUF is predicted to be as high as 41.3 MHz. This also says the probability of the MUF being high enough for 50.1 MHz is zero. But there was 6m F_2 propagation in November 2001 as noted in the aforementioned *The World Above 50 MHZ* column, and thus our initial suspicion that VOACAP doesn’t do well on 6m is confirmed.

A Solar Index Issue

One problem with VOACAP for 6m predictions (and with any of our other HF prediction programs, for that matter) is tied to the solar index used. The use of the heavily-averaged smoothed solar flux value of 194 for our prediction belies the fact that the solar flux was significantly higher right before November 11 through November 19, the period when most of the 6m openings occurred. Figure 2 plots the daily solar flux for November 2001.

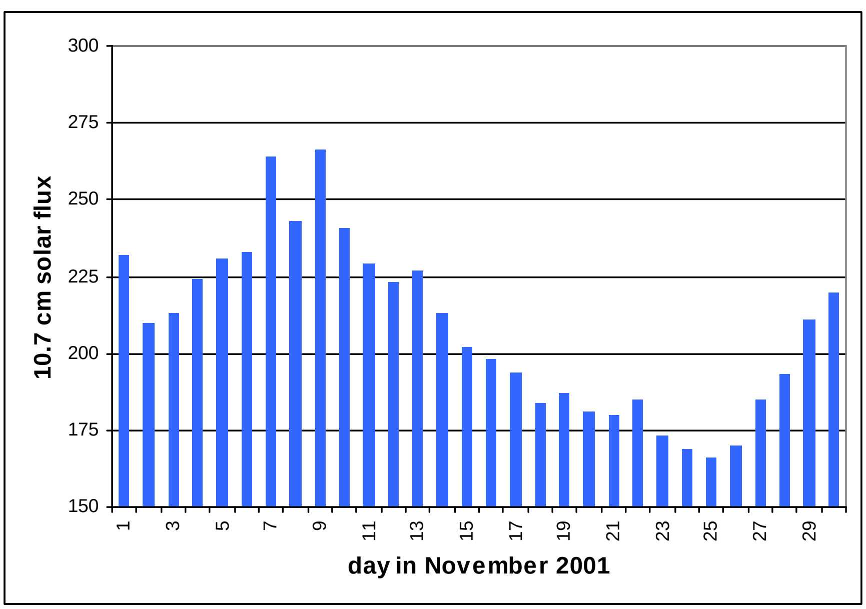

Figure 2 – Daily Solar Flux for November 2001

Thus it appears that we need a shorter-term solar flux measurement for input to VOACAP. We could use daily solar flux, but unfortunately the state of the ionosphere does not correlate well with daily solar flux. Figure 3 shows this by plotting the daily MUF over the Goose Bay, Labrador ionosonde (which is along the path from Western Pennsylvania to Germany) and the corresponding daily solar flux for November 2001.

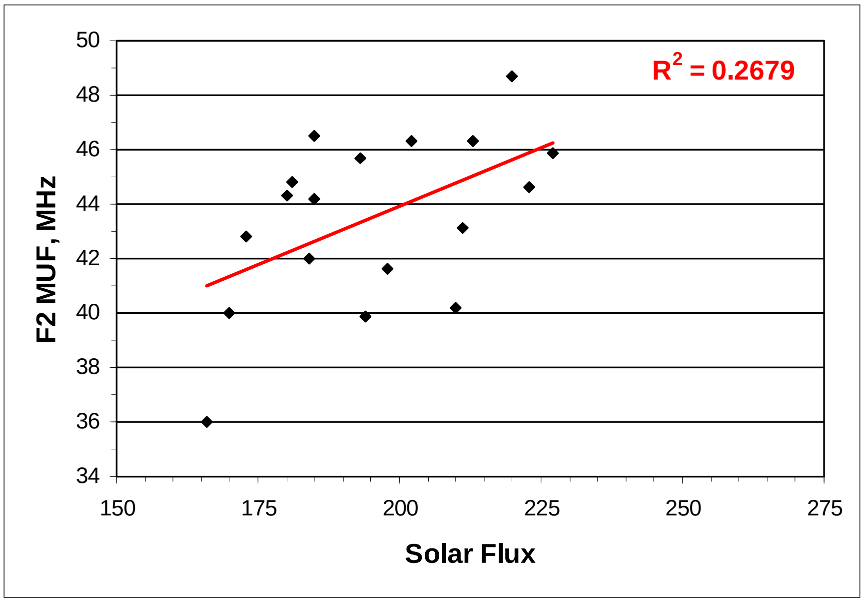

Figure 3 – Daily MUF versus Daily Solar Flux for November 2001

The R^2 value in the upper right hand corner of Figure 3 tells us how well the two parameters (daily MUF and daily solar flux) are correlated. An R^2 value of 0.00 indicates no correlation, and the data points would be widely scattered about the red regression line (as they are in Figure 3). An R^2 value of 1.00 indicates perfect correlation, and all the data points would fall right on the red regression line. With an R^2 value of 0.2679, we confirm that there is little correlation between MUF and solar flux on a daily basis. For example, a solar flux of around 195 resulted in a MUF as low as 40 MHz on one day and as high as 46 MHz on another day.

The result of Figure 3 is typical of results using data from other months and other years. Even bringing geomagnetic field activity into the picture (through a K or A index) doesn't improve the correlation to any significant degree on a daily basis.

What this tells us is that there are other processes that ultimately determine the amount of F_2 region ionization in the ionosphere. Solar flux is certainly the instigator (strictly speaking, solar flux at a wavelength of 10.7 cm is a proxy for the true ionizing radiation at wavelengths between 10-100 nm), but geomagnetic field activity on a longer-term basis and events in the lower atmosphere coupling up to the ionosphere also play important roles. This is why our propagation prediction programs were developed as monthly median models using a smoothed solar index. The developers never meant them to be used for daily predictions, as they well understood the scatter seen in Figure 3.

<u>Path Geometry Issues</u>

The other problem with VOACAP for 6m predictions (and again with any of our other HF prediction programs) is path geometry issues. There are three fundamental assumptions under suspicion for 6m propagation.

The first assumption is that hop lengths are 3000 km. That value is a good compromise for the 3 to 30 MHz HF range, with shorter distances at the lower frequency end (because there's more refraction at the lower frequencies, giving shorter hops) and longer distances at the higher frequency end up to the generally accepted HF limit of 4000 km. We would therefore expect 6 meter propagation could have hops greater than 4000 km, with resulting higher MUFs since the electromagnetic wave would graze the ionosphere at an even lower angle of incidence (W3EP cited two papers discussing propagation above 30 MHz with hops significantly greater than 4000 km in his March 1993 **QST** article). There's also evidence from other QSOs suggesting that propagation on 6m at times can involve ionosphere-ionosphere modes (chordal hops or ducting), which also results in higher MUFs.

The second assumption is that an electromagnetic wave follows a great circle path. This ignores the fact that some deviation from the great circle path can occur, which is due to an encounter with the ionosphere where MUFs are higher (generally at a more southerly latitude).

The third assumption is that pure refraction occurs. This ignores scatter-type paths (VOACAP does have an over-the-MUF algorithm that assumes scatter, but it doesn't help our efforts since VOACAP only goes to 30 MHz). Although scatter-type paths incur additional losses, the amount of D region absorption on 6m is minimal. Thus 6m is more forgiving than the HF bands, and it can tolerate more loss due to a scatter mechanism.

<u>Forcing VOACAP to Agree with 6m Observations</u>

We know that the "stock" VOACAP does not do too well with 6m predictions, and we also know the issues that appear to cause this – the use of the heavily-averaged smoothed solar index and assuming only refraction over 3000 km hops along the great circle path.

For the solar index issue, we'll use a 7-day average of solar flux. That better represents what the ionosphere is doing short-term (it's not perfect – but it is better than the use of daily solar flux). For the path geometry issues, we'll apply a multiplying factor (derived from W3EP's 1993 **QST** article and from observations in W3EP's February 2002 column) to the F_2 region through the *foF2 Fprob* option in VOACAP's set-up menu. Using a 7-day average of solar flux certainly gets VOACAP closer to 6m reality, but the multiplying factor is still needed to account for "non-HF" modes on 6m.

The Method to Predict 6m Propagation

The development of the method is mostly based on sound physical principles, but I readily admit some of it is akin to "arm waving" since our understanding of propagation in the ionosphere is statistical in nature – it is not deterministic.

The method can be summarized in four steps.

Step 1 – Determine the short-term solar flux by taking the 7-day average prior to the desired period.

Step 2 – Change the multiplier in the *foF2 Fprob* option in VOACAP from 1.00 to 1.20.

Step 3 – Run Method 30 in VOACAP using an operating frequency of 30 MHz (VOACAP defaults to 30 MHz if you try to input 50 MHz, but that's ok as we're really not concerned with any operating frequency we input). Note the MUF in the first column of data (ignore the data in the 30 MHz column).

Step 4 – If the MUF in the first column is around 45 MHz, you should start looking for 6 meter F_2 propagation. The higher the MUF with this method, the higher the probability will be for 6m F_2 propagation.

Geomagnetic Field Activity

Along with extremely high solar flux comes the likelihood of geomagnetic field activity. In general, the F_2 region will be depleted when this occurs, so high solar flux values will not necessarily always imply 6m propagation. In essence, this method will work best when the geomagnetic field activity is either low to start with or returns to quiet conditions.

Acknowledgements

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