Digging Deep Into VOACAP With Respect to 6 Meters

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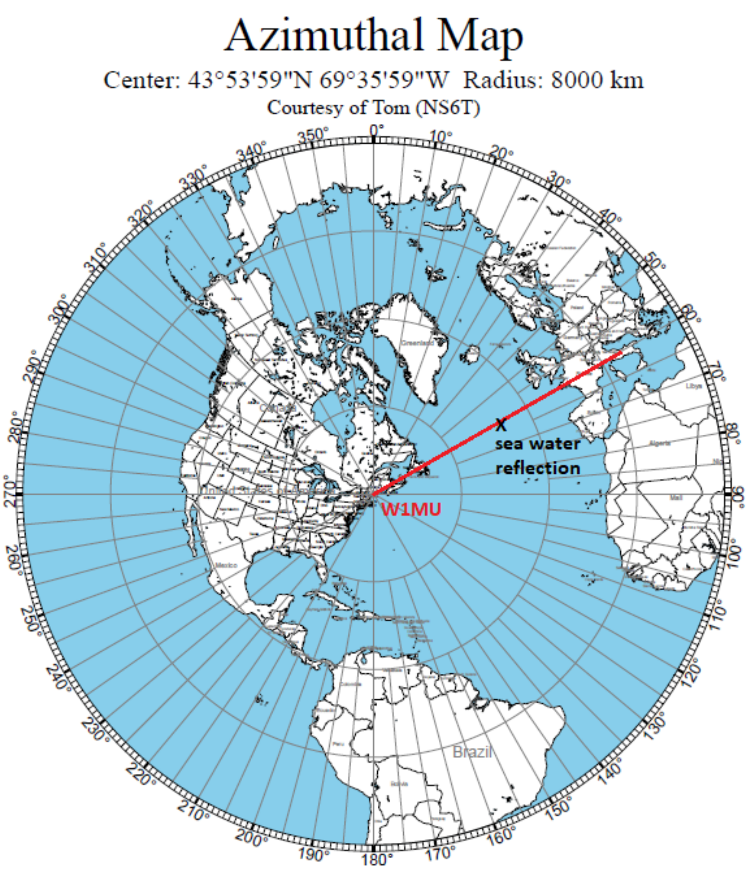
On May 25 of this year, Don Field, G3XTT, gave a great presentation about operating on 6 meters. He covered many aspects of the "magic band", and finished up with a Q&A session. One of the questions that was asked came from Mike Zak, W1MU.

> *After periods of elevated sunspot activity we always see measures of smoothed activity. But are there spikes of activity that are implied by those smoother numbers and might we expect to see F2 on the next cycle peak even though the smoothed numbers might not be inspiring?*

Unfortunately Don did not get to this question, so I sent an e-mail to Mike about monthly median values and the distribution about the median. Let's look at this a bit deeper with respect to 6 meters to gain a better understanding of our knowledge of the F2 region of the ionosphere.

Let's start with a path from W1MU in Maine (43.9ºN/69.6ºW) to Italy (42.0ºN/12.7ºE). This path is 6406 km, and we would expect two F2 hops (each assumed to be 3203 km) to cover this distance [note 1]. The image below depicts this path (from NS6T maps at https://ns6t.net/azimuth/azimuth.html with some added annotations by me). W1MU is at the center of this azimuthal equidistant map (also known as a great circle map). The black **X** shows where the signal comes down after the first F2 hop and reflects back up from the ocean.

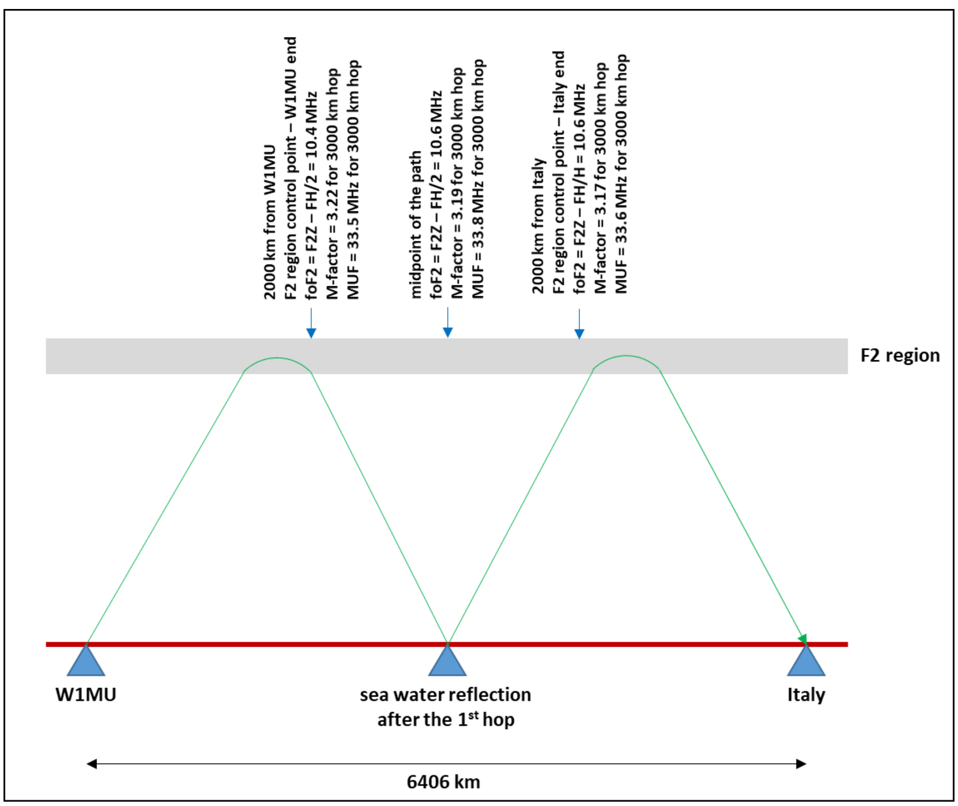


From Method 30 (Short/Long Smoothing) in VOACAP, let's list the predicted monthly median F2 region MUFs (maximum usable frequencies) for a 3000 km hop [note 2] for this path to Italy at various smoothed sunspot numbers in the month of November at 1400 UTC (around the optimum time for this path in November).

smoothed sunspot number (V2)	mode	ordinary wave monthly median MUF in MHz for a 3000 km path
50	2 F2 hops	26.1
70	2 F2 hops	28.3
115 (similar to Cycle 24)	2 F2 hops	32.6
143	2 F2 hops	35.2
215 (similar to Cycles 21 and 22)	2 F2 hops	41.0
286 (similar to Cycle 19)	2 F2 hops	46.1

Where Do These MUF Values Come From?

Using a smoothed sunspot number of 143 (a Cycle 25 that would be somewhat bigger than Cycle 24) and VOACAP's Method 1 (Ionospheric Parameters), we can retrieve the extraordinary wave critical frequency F2Z, the electron gyro-frequency FH and the M-factor [note 3] that lead to the MUF values in the above table. For this path length, VOACAP evaluates the ionosphere in five places: 1000 km from W1MU, 2000 km from W1MU, the midpoint of the path, 2000 km from Italy and 1000 km from Italy [note 4]. Here's a side view of the path.



The three texts that are above the gray F2 region area give the pertinent F2 region data from Method 1 for 2000 km from W1MU, at the midpoint of the path and 2000 km from Italy. Each of the three texts give the ordinary wave MUF for a 3000 km path at those three points.

But the actual distance for this path for one hop is 3203 km, not 3000 km. Thus the monthly median MUF for a 3203 km hop will be a bit higher (because it requires a lower elevation angle, which results in a lower grazing angle on the ionosphere). We can estimate these values by using Figure 7.3 (Logarithmic Transmission Curves for Curved Ionosphere) in IER 1-ITSA 1 *Predicting Statistical Performance Indexes for High Freq1uency Ionospheric Telecommunications Systems* by Donald Lucas and George Haydon (1966). After doing so, the lower of the three MUF values for the 3203 km path is 35.2 MHz – which is what is given in the table on page 2.

The Distribution About the Median

Now that we know the predicted monthly median MUF for the W1MU-to-Italy path in November at 1400 UTC at a smoothed sunspot number of 143 (V2), let's look at the distribution about the median. We can do this by using Equation 10b on page 5 of the ITU/CCIR document *Supplement to Report 252-2* (1978). Equation 10b is for when the operating frequency is above the monthly median MUF. Doing this gives the following results for the monthly median MUF of 35.2 MHz.

monthly median MUF in MHz	operating frequency in MHz	probability in percent	number of days of the month
35.2	35.2	50	15
	37.5	26.8	8
	40.0	13.2	4
	43.0	3.5	1
	44.0	1.2	0

As expected, an operating frequency of 35.2 MHz gives a 50% probability as it is equal to the monthly median MUF frequency. The data in this tables say 6 meters shouldn't be open at all. But the second peak of Cycle 24 offered 6 meter propagation via the F2 region, and this second peak (smoothed sunspot number of 116) was lower than the above analysis at a smoothed sunspot number of 143. So don't give up hope.

One possibility for propagation still occurring on 6 meters is short-term ionospheric events that aren't fully captured in our monthly median model. There is much research nowadays going on in this area to better understand the short-term variability of the F2 region.

A second possibility for propagation still occurring on 6 meters is a path longer than 4000 km. In general, the longer the distance the higher the MUF.

A third possibility for propagation still occurring on 6 meters is the above-the-MUF mode (which I believe has an important role in FT8 QSOs), which we'll review in the next section.

Before leaving this section, let's look at data like that in the above table for a smoothed sunspot number of 215 (similar to Cycles 21 and 22).

monthly median MUF in MHz	operating frequency in MHz	probability in percent	number of days of the month
41.0	41.0	50	15
	45.0	19.7	6
	50.0	3.7	1

And here's the data for a smoothed sunspot number of 286 (similar to Cycle 19 – the largest in recorded history).

monthly median MUF in MHz	operating frequency in MHz	probability in percent	number of days of the month
46.1	46.1	50	15
	50	22.3	7

As the smoothed sunspot number increases, 6 meters is predicted to be open for more days of the month.

Above-the-MUF Mode

With ionospheric absorption inversely proportional to the square of frequency, there is little absorption on 6 meters when there is a sufficient amount of ionization to refract 6 meter RF back to earth. For example, ray tracing with Proplab Pro V3 shows only 1 dB of absorption at 50 MHz on the 2-hop W1MU-to-Italy path at a smoothed sunspot number of 200. Although the free space path loss increases as you go up in frequency, the less absorption at 6 meters more than compensates for this. In other words, ionospheric absorption is so low that there is extra room for additional loss at 50 MHz.

With the above-the-MUF mode being tied to scatter instead of pure refraction when the operating frequency is above the MUF, additional loss is incurred with the above-the-MUF mode. This additional loss can be acceptable on 50 MHz, where absorption is extremely low. The exact amount of loss is not pinned down satisfactorily. Here's an example when the MUF is 45 MHz and the operating frequency is 50 MHz.

method	additional loss
Wheeler	2 dB
ITU	12 dB

The two methods are quite different, so there are some important questions in order to understand the difference and determine which one may be more accurate. The bottom line is the amount of additional loss may be tolerable due to the extremely low amount of absorption on 50 MHz. Now combine this with the SNR advantage that FT8 has over CW (about 6 dB), and this is a reasonable explanation for why SSB/CW ops hear nothing but FT8 ops are making QSOs.

Summary

Our understanding of the ionosphere is statistical in nature, and is a correlation between monthly median ionospheric parameters (most of the time we want to know the MUF and the signal strength) and a smoothed sunspot number (or a smoothed solar flux number). We've seen how the monthly median MUF varies with sunspot number.

We've also looked at the distribution of the MUF about the monthly median value to calculate how many days of the month 6 meters should be open versus the smoothed sunspot number.

Cycle 25 may end up being a small cycle, but don't give up on 6 meter F2 propagation in the fall and winter months around solar maximum. It happened with Cycle 24 and it can happen with Cycle 25.

A final comment – I remember one of Bob NM7M's often-repeated sayings – *MUF is not enough*. That recognizes that ionospheric absorption needs to be considered – not just if there's enough ionization to refract signals back to earth. On 6 meters, as mentioned earlier, absorption is minimal. But on the lower bands, it is all important.

Notes:

1) The literature usually says the maximum F2 region hop distance is 4000 km. This is a frequency dependent value and 4000 km is reasonable for frequencies at the higher end of our HF bands (10 meters and 12 meters). As we move down in frequency, 3000 km is a good value for 20 meters. At 160 meters, 2000 km is reasonable. On 6 meters, 4000-5000 km is possible – if there are enough sunspots.

2) This is the first column in the Method 30 output.

3) In Method 1, the ordinary wave critical frequency foF2 is the extraordinary wave critical frequency (F2Z column) minus one-half the electron gyro-frequency (FH/2 column). Multiply this by the 3000 km M-factor (M3000 column) to determine the MUF for a 3000 km hop for the ordinary wave.

4) The points at 1000 km from each end of the path are for evaluating the E region. The points at 2000 km from each end of the path are for evaluating the F2 region. These points are called control points, and are used in the control-point method of determining if ionospheric propagation can occur. It has been found empirically that if these points can refract signals back to earth on the desired frequency, then the path will be available.