Increasing the F_2 MUF

A supplement to the feature *Inferring 6m Propagation Modes from E_s and F_2 Probabilities* that appeared in the Winter 2007 issue of CQ VHF

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This paper discusses three mechanisms that can increase the F_2 region MUF. This is most applicable to 6m operation, as propagation via the F_2 region on 50MHz is not a common occurrence – especially when we're not around solar maximum. You are also encouraged to read the seminal paper by K6MIO/KH6 [reference 1].

Hops longer than 4000km

As the hop length increases, the MUF increases because the wave needs to encounter the electron density at more of a grazing angle for a longer hop. Our propagation prediction programs (like VOACAP) assume the maximum F_2 region hop length is 4000 km. But this 4000km limit may be too short for 6m propagation.

The 4000km limit in our propagation prediction programs is a good compromise for the frequency range of 2 to 30 MHz. It's optimistic for the low frequency end of that range, as the amount of refraction for a given electron density gradient is proportional to the square of the wavelength. In other words, the longer wavelengths (lower frequencies) are refracted more and thus don't get as high into the ionosphere before being refracted back to Earth – with the result being shorter hops. On the other hand, it's pessimistic for the high frequency end of that range. The shorter wavelengths (higher frequencies) are refracted less and thus get higher into the ionosphere before being refracted back to Earth – with the result being longer hops.

Since 50MHz is above the high end limit of our propagation predictions, a single F_2 region hop on 6m longer than 4000km may be possible. In fact, parabolic layer theory predicts this as seen in Figure 1. This is Figure 6.15 on page 175 in **Ionospheric Radio** (Davies, 1990).

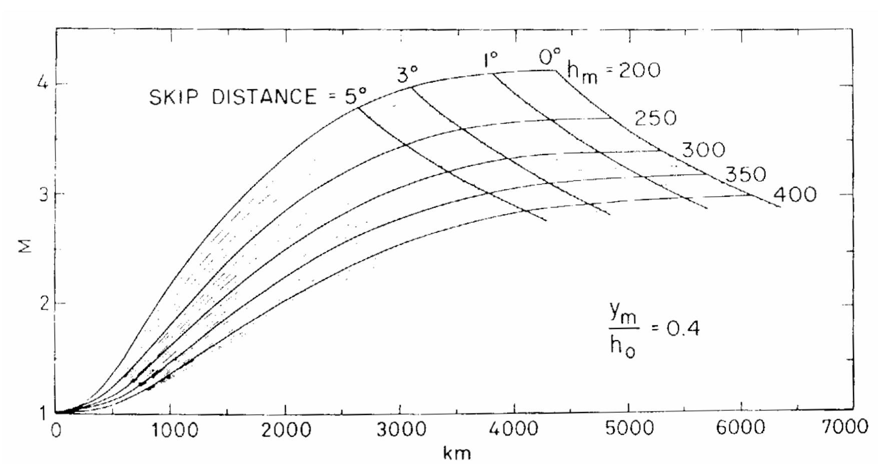

Figure 1 – Parabolic Layer Theory for Long F_2 Hops

The M-factor on the vertical scale of Figure 1 is the factor by which f_oF_2 (the F_2 region critical frequency) is multiplied to determine the F_2 region MUF. And the caveat for an extremely long hop, as can be seen, is that radiation at an extremely low launch angle is needed. This shouldn't be a problem on 6m due to typical antenna heights in terms of an electrical wavelength.

For the 6m analysis in the *Inferring 6m Propagation Modes from E_s and F_2 Probabilities* article, M-factor maps were generated in Proplab Pro (Solar Terrestrial Dispatch) to determine the M-factor for a 3000km F_2 hop out of J6. Figure 2 shows this for 1900 UTC.

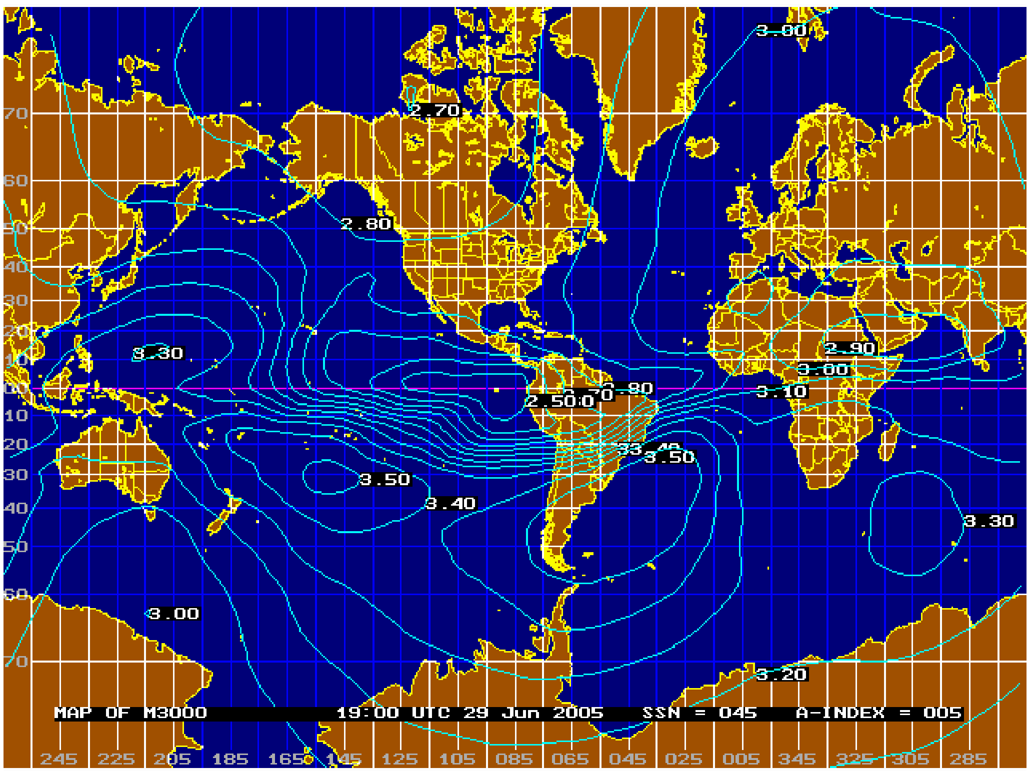

Figure 2 – Contours of 3000km M-factors

For the J6-to-EU path, Figure 2 indicates an M-factor of 3.00 for a 3000km hop. From Figure 1, this gives a height of 325km. Moving along a constant height in Figure 1 gives an M-factor of 3.30 at 5000km.

Thus for a long F_2 hop of 5000km, the MUF would be 3.30/3.00 = 1.10 times the 3000km MUF.

<u>Help from the underlying E region</u>

The MUF for the F_2 region is a function of the electron density (measured in terms of the critical frequency f_oF_2) and the angle at which the electromagnetic wave encounters the F_2 region (which in turn is dependent on the height of the layer). Due to the spherical

Earth-ionosphere geometry, the lowest angle at which a wave launched at a 0 degree elevation angle can normally encounter the F_2 region is around 20 degrees. This limits the MUF per the first-order formula:

$$F_2 \text{ MUF} = f_oF_2 \text{ / sine of the encounter angle}$$

To achieve a higher MUF, a lower encounter angle is needed (more of a grazing angle). Table 1 gives typical data for the F_2 region without and with help from an underlying E region.

Launch angle	Underlying E region?	Angle with respect to ionosphere	M-factor
0^o	No	19.79^o	2.95
0^o	Yes	16.97^o	3.43

Table 1 – Increase in M-factor due to underlying E region

Thus with some help from the underlying E region, the MUF with the underlying E region would be 3.43/2.95 = 1.16 times the MUF without the underlying E region

Over-the-MUF Mode

Often signals are received at frequencies above the standard MUF (even taking into account the upper statistical bound of the median MUF). The F_2 region can be regarded as a number of separate patches of ionization with differing maximum electron densities, so that each patch has its own MUF.

Section 6.5 starting on page 5 of **Propagation at Frequencies Above the Basic MUF** (Report ITU-R P.2011-1, International Telecommunications Union, 1997-1999) gives an equation to estimate the additional loss due to an operating frequency (Fop) greater than the F_2 region MUF:

$$\text{over-the-MUF loss in dB} = 36 \text{ times } [\text{Fop/MUF} - 1]^{1/2}$$

Table 2 shows the over-the-MUF losses on 6m for various MUFs.

Fop	MUF	Additional loss
50.1MHz	50.1MHz	0dB
50.1MHz	45MHz	12.1dB
50.1MHz	40MHz	18.1dB
50.1MHz	35MHz	23.6dB

Table 2 – Over-the-MUF losses on 6m

Since loss due to absorption is inversely proportional to the square of the frequency, 6m can have quite a bit of margin for other losses such as over-the-MUF losses. It would therefore not be unreasonable to use the 18.1dB value.

Thus over-the-MUF propagation could allow propagation on 50.1/40.0 = 1.25 times the ‘normal’ MUF.

Summary

The three mechanisms discussed, when multiplied together, could increase the normal 3000km MUF by 1.60 when considering 6m operation.

This is recognized as a crude analysis, but it allows our theoretical understanding of the ionosphere to generally agree with our observations on 6m.

References

1. J. R. Kennedy K6MIO/KH6, *50MHz F_2 Propagation Mechanisms*, www.ham-radio.com/n6ca/50MHz/K6MIO_50MHz_F2Prop.pdf