Anatomy of a 20m Gray Line QSO

Carl Luetzelschwab K9LA

(this article appeared in the March/April 2003 issue of The DX Magazine)

On January 29 around 1215 UTC, Tony AA2AE worked Paran VU2AU on 20m long path with exceptional signals. This was a classic gray line path. With some help from DXAID (from Peter Oldfield) and VOACAP (free download at **elbert.its.bldrdoc.gov**), we can gain a good understanding of what made this path work.

Figure 1 (from DX AID) shows the long path (thick dark line) from AA2AE to VU2AU, along with the terminator (thin line dividing night and day) at 1215 UTC on the 29th.

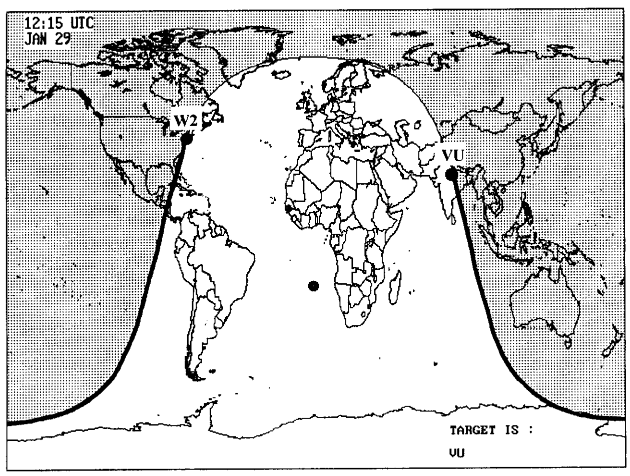

Figure 1 W2 to VU Long Path at 1215 UTC on January 29

Indeed, this is an excellent example of a gray line path, with the terminator and long path in perfect alignment around 1215 UTC.

To analyze this path, let’s begin with a review of what determines if propagation exists between W2 and VU on the long path. First, there must be enough ionization to get RF from W2 to VU. This is expressed in terms of a maximum usable frequency (MUF) for this specific path, and depends on the time of day, the month, and where we are in a sunspot cycle. I’ll assume a quiet geomagnetic field for this analysis.

Second, if the ionosphere can get a signal from W2 to VU (and vice versa), then the signal arriving at each end of the path has to be strong enough to be heard. The five major factors that affect the strength of the signal are the transmitter power, the antenna gains (including ground quality considerations and obstructions), the free space path loss (spreading loss), the amount of absorption, and the ground reflection losses for multiple hops. Ideally we should also address noise (predominantly atmospheric and manmade), but we’ll keep it simple here and just look at signal strength.

Using data from VOACAP, we can plot the MUF and the signal strength for this path versus the time of day. I assumed S9 equals 50uv and one S-unit is 5dB. The results are per Figure 2 at a predicted smoothed sunspot number of 80 for January 2003 (from **www.dxlc.com/solar**, for example).

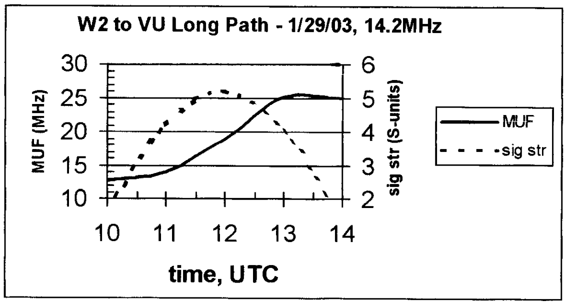

Figure 2 MUF and Signal Strength vs Time

Figure 2 shows that the monthly median MUF (which is what customarily comes out of our prediction software because the model of the ionosphere is a monthly median model) begins increasing around 1000 UTC, rises sharply between 1100 UTC and 1300 UTC, then levels off after 1300 UTC.

Figure 2 also shows that the monthly median signal strength (same comment as above applies) starts moving the S-meter around 1000 UTC, peaks around 1200 UTC, then goes back down below S2 by 1400 UTC.

Why does the MUF rise between 1100 and 1300 UTC? And why does the signal strength peak around 1200 UTC? Figure 3, a time sequence of three pictures, explains this.

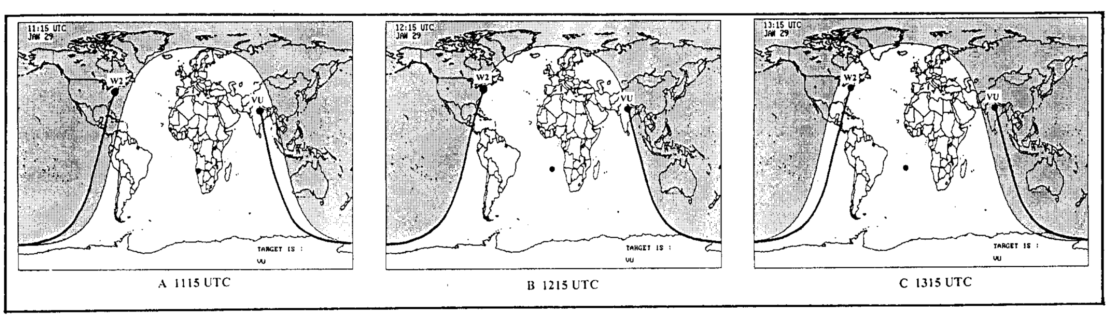

Figure 3 Time Sequence for the W2 to VU Long Path

Figure 3a (left) shows the long path and terminator an hour prior to the QSO at 1115 UTC. The VU end of the path has been in sunlight all day, so the MUF is high. On the other hand, the W2 end of the path has been in darkness all night. Thus the MUF on the W2 end has decreased to its nighttime value –which Figure 2 shows to be around 12.5MHz. As the terminator approaches the W2 end of the path, the F region on that end starts getting illuminated and thus starts building around 1100 UTC. It rises through 14MHz just after 1100 UTC.

Figure 3a also sheds light on why the signal strength peaks around 1200 UTC. The VU end of the path, being in lots of daylight, incurs much absorption. Now look at Figure 3c (right). It's one hour after the QSO at 1315 UTC, and now shows the W2 end of the path in lots of daylight, incurring much absorption. It is logical to assume that absorption along the entire path would minimize in between these two extreme conditions – in other words, it would minimize when the terminator aligns with the entire path, putting the entire path at equal illumination as seen in Figure 3b (center). Indeed, VOACAP says the system loss minimizes around 1200 UTC. It's safe to assume that this is due to absorption minimizing, as the other two losses (spreading loss and ground reflection loss) do not change versus time. It's important to note that absorption doesn't go to zero along the terminator (or even in the dark ionosphere, for that matter) – this is especially critical on the lower frequencies.

Thus what opens the W2 to VU long path is the increasing MUF on the W2 end of the path in conjunction with decreasing absorption along the entire path as the terminator aligns with the path. What closes the path is increasing absorption on the W2 end of the path as it goes more and more into daylight.

Does the data of Figure 2 say this path should be there every day around the end of January? No, because the data is monthly median data. The MUF and the signal strength vary on a day-to-day basis about their monthly median values, and they're not necessarily in step. On some days, the MUF may not be high enough when the signal strength peaks. On other days, the signal strength may not peak high enough even though the MUF is high enough. And on even other days, neither may be high enough.

What about the reports from AA2AE and VU2AU that "the signals were exceptional"? The S5 prediction from VOACAP certainly isn't "exceptional" (it was based on their power levels and my best estimate of their antenna system gains). Being a monthly median value, the peak signal strength for this path could vary from roughly 20 dB below to 10 dB above S5 on any given day (from eyeballing the 90% and 10% values of transmission-loss variability in the tables in CCIR Supplement to Report 252-2). This could account for signal strengths up to about S7 on 'good' days (and down to about S1 on 'bad' days).

Another possibility that could improve signal strengths even further is a chordal hop across the geomagnetic equator on the VU end of the path. That end of the path is at the right time of day to give the ionospheric tilts that are necessary for a chordal hop, and a chordal hop would offer one less ground reflection and two less traversals of the absorbing region. As a side note, chordal hops and other ionosphere-ionosphere modes are discussed in my May 2003 and June 2003 Propagation columns in Worldradio.

Finally, it's interesting to look at this path on the next higher band (17m) and on the next lower band (30m). With absorption inversely proportional to frequency squared, the signal strength on 17m would be roughly 1 S-unit stronger at the peak time. But now would the MUF be high enough? Figure 2 suggests that any opening on 17m, while offering stronger signals, would on average be of a shorter duration as the MUF wouldn't get high enough until the signal strength started decreasing.

On 30m, again due to absorption being inversely proportional to frequency squared, the signal strength at the peak time would be roughly 3 S-units weaker. Except around solar minimum, the MUF on 30m would be high enough throughout the day so that it's out of the picture. Thus it comes down to being solely an absorption issue on 30m (and on lower frequencies, too). Another subtle issue comes into play as we go lower in frequency – refraction is also inversely proportional to frequency squared. So the electron density gradient across the terminator makes it tough for a low frequency signal to follow a great circle route when the terminator is nearby – it wants to refract, or skew, away from the higher density in daylight to the lower density in darkness.

In summary, analyzing a gray line path is no different than any other path. Whether the path is open depends on the answer to two questions: *Is the MUF high enough?* and *Is the signal strength high enough?* When you think about it, MUF and signal strength are like that old Frank Sinatra song about love and marriage - they go together like a horse and carriage. For propagation to be possible, you can't have one without the other.