Propagation column
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Carl Luetzelschwab K9LA

Easter Island to India on 6m

In his "The World Above 50 MHz" column in the July 2001 **QST**, Emil, W3EP, reported on the 6m QSOs between CE0Y/W7XU (Easter Island) and several VU2s during the April 2 – 7 period of 2001. Some important observations were noted in the column.

First, the band opened up between 1530 and 1600 UTC. Second, the heading out of Easter Island started east of north, but moved progressively eastward with time (ending up at around 70 degrees). Third, the heading out of VU2 started somewhat west of north, and gradually moved father west with time (ending up at around 315 degrees). And fourth, on a couple days one of the VU2 stations dropped his output power down to 125 milliwatts while still maintaining contact. Using these observations in conjunction with propagation tools and an understanding of processes in the ionosphere, let's try to better understand these impressive QSOs (note that I didn't say completely understand them). We'll start with the 'big picture' of Figure 1.

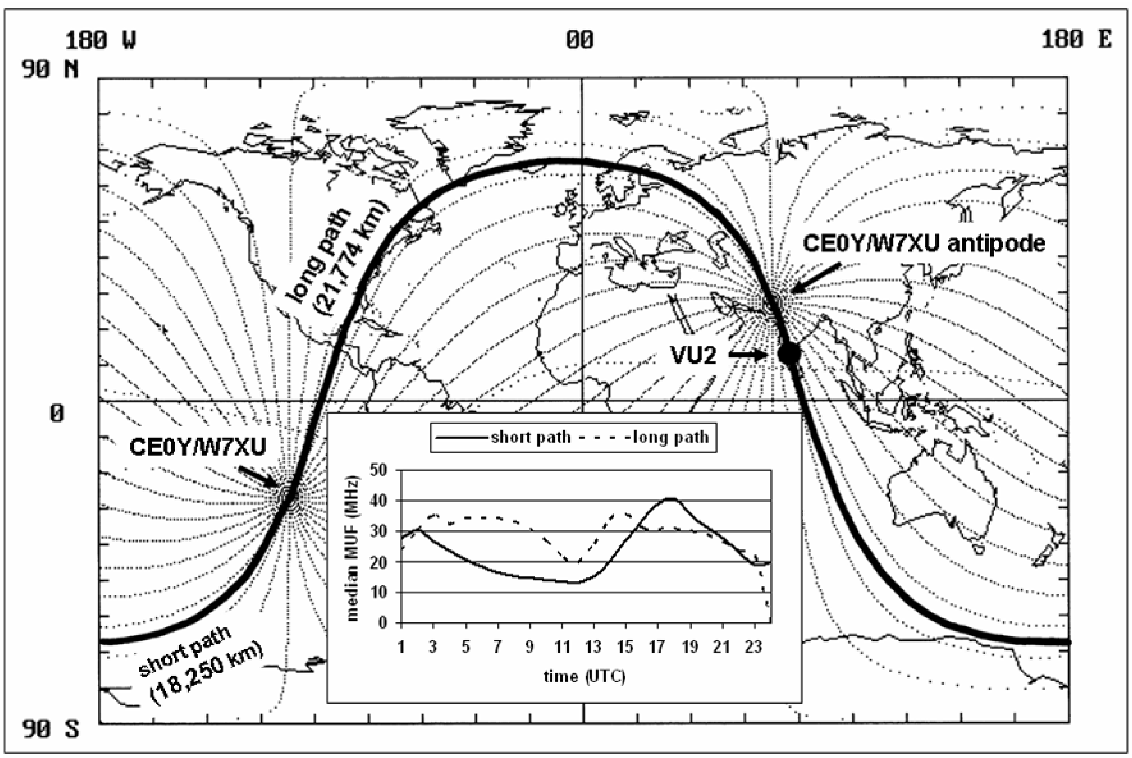

Figure 1 – Great circle paths and MUFs between CE0Y/W7XU and VU2

Figure 1 shows great circle paths out of Easter Island in 10 degree increments (the light dotted lines). The dark line highlights the true short and long great circle paths between Easter Island and VU2. The short path (204 degrees out of Easter Island and 159 degrees out of VU2) is pretty much all over water in the southern hemisphere. The long path (24 degrees out of Easter Island and 339 degrees out of VU2) goes over Central America, over the US East Coast, over Iceland, over Scandinavia, and then into VU2. The filled-in dark dot in southern VU is the location of VU2ZAP and VU2BGS, two of the stations CE0Y/W7XU worked. The antipode of Easter Island is annotated on the figure. Also superimposed on Figure 1 is a plot of the MUF (maximum usable frequency) for April 2001 on the short and long paths (using VOACAP Method 30 with a smoothed sunspot number of 120).

From the second and third observations, it appears that the QSOs between CE0Y/W7XU and VU2 started along the true great circle long path. And looking at the MUF plot in Figure 1 indicates why the QSOs started on these headings – the MUF peaked around the time reported in the first observation [see the note at the end of the column]. But the MUF peaked only for about an hour or so, and then started decreasing. Thus propagation along the true long path didn't last too long, and soon started to fail.

The second and third observations also provide a clue as to the path mechanism towards the end of the opening. To analyze this, let's plot a 70 degree heading out of CE0Y/W7XU and a heading of 315 degrees out of VU2. Figure 2 does this.

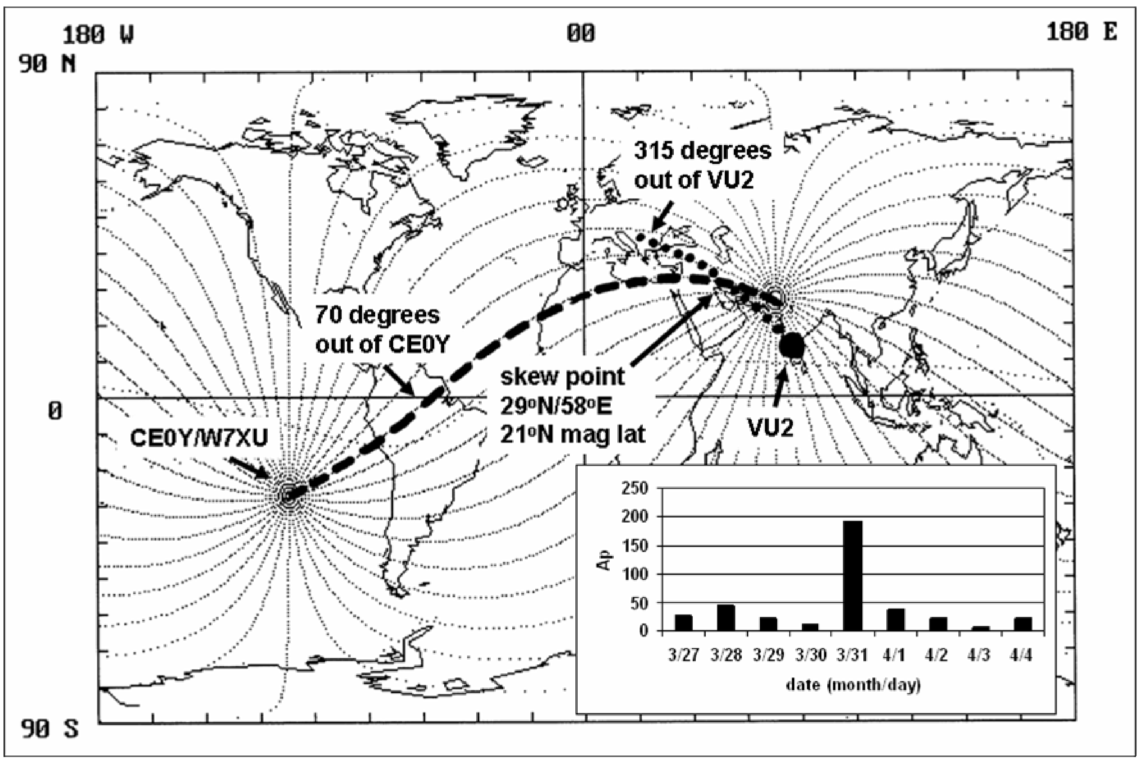

Figure 2 – Skewed path between CE0Y/W7XU and VU2

The basic map in Figure 2 is the same map as in Figure 1 – it shows great circle paths out of CE0Y/W7XU. But in Figure 2 the 70 degree great circle heading out of Easter Island is now highlighted with dark dashes, and the 315 degree great circle heading out of VU2 is highlighted with dark dots (which comes from superimposing data from a map of great circle paths out of VU2). Note that these two paths cross at approximately 29 degrees N latitude and 58 degrees East longitude. This could be a skew point – in other words, the electromagnetic wave from CE0Y/W7XU would follow the dark dashed 70 degree great circle path until it reached 29^{o}N/58^{o}E. Then something caused it to skew to the right and follow the dark dotted path into VU2. Similarly, the electromagnetic wave from VU2 would follow the dark dotted 315 degree great circle path until it reached 29^{o}N/58^{o}E. Then something caused it to skew to the left and follow the dark dashed path into CE0Y/W7XU.

So what is this 'something'? Electromagnetic waves do not go through the ionosphere willy-nilly – they follow a straight line unless reflected, refracted, or scattered by either an electron density gradient or an electron density irregularity (Figures 1 and 2 show electromagnetic waves following sinusoidal trajectories – this is due to the fact that the maps are rectangular projections of the spherical Earth). The clue here is the magnetic latitude – the 29^{o}N/58^{o}E location corresponds to a magnetic latitude of 21 degrees N (remember that geomagnetic coordinates are different from geographic coordinates because the line between the north and south magnetic poles does not align with the rotational axis of the Earth).

The 21^{o}N magnetic latitude puts us in the vicinity of the northern crest of the equatorial ionosphere. As a refresher, clumps of higher-than-normal electron density form on both sides of the geomagnetic equator during certain times of the day (usually in the late afternoon) and during certain seasons (the equinoxes are best). If great enough, these increased electron densities could refract (skew) a 50MHz electromagnetic wave off of one great circle path onto another. Interestingly, the electron density of these clumps can be enhanced even further at unusual times by elevated geomagnetic field activity (a relevant paper on this effect is titled *Unusual early morning development of the equatorial anomaly in the Brazilian sector during the Halloween magnetic storm*; Batista, et al; **Journal of Geophysical Research**; Volume 111; May 2006).

Now you know why there's a plot of Ap (the planetary A index) on Figure 2. On March 31, the Ap index spiked up to 192 (the corresponding 3-hour Kp indices were between 6 and 8 for the entire day). The effects on the F2 region of this large a disturbance would likely last for several days – and could even be seen in the equatorial ionosphere as electron density enhancements – perhaps enough to refract 50MHz.

Now let's address the fourth observation – the QRP QSOs. First let's look at how far down we can hear. A typical MDS (minimum discernible signal) of a 6m rig in the SSB mode is on the order of -132dBm (from the FT-847 Product Review data with 'preamp on' in **QST**). We'll assume man-made and atmospheric noise does not limit our sensitivity as it does on the HF bands (this is a very reasonable assumption for 50MHz). For 90% intelligibility in an SSB bandwidth, we need an SNR (signal-to-noise ratio) of about 12dB. Thus the signal power at the receiver must be greater than -120dBm (which is simply the -132dBm MDS plus 12dB for SNR).

Now let's estimate the signal power on the receive end of the path by making some assumptions based on the narrative in W3EP's column. For example, we'll use modest

6m Yagis with 8dBi free space gain (6dB gain over a dipole in free space) and we'll use a transmit power of 125 milliwatts (+21dBm) on the VU2 end. From this, the signal power at CE0Y/W7XU would be +21dBm minus the free space path loss (153dB) plus the antennas gains at reasonable heights over ground (each about +12dBi after some ground reflection gain is added in) minus ionospheric absorption minus ground reflection losses and minus polarization mismatch loss (a simple approximation of 3dB on each end since the electromagnetic waves at the entry and exit points of the ionosphere will be circularly polarized on 50MHz and the assumed antennas are linearly polarized). This works out to a signal power of -114dBm not including absorption and ground reflection losses.

Assuming a 5-hop path, the ground reflection losses would have four ground reflections. Figure 1 indicates the first two would be over water and the last two would be over land. From extrapolated data (from the **National Contest Journal**, Propagation column, November/December 2001), the ground reflection losses would be on the order of 15dB. For absorption losses, absorption is inversely proportional to the square of the frequency, so absorption would be quite low. Indeed, using Figures 7.5 and 7.6 in **Ionospheric Radio Propagation** (Davies, 1965) for a 5-hop path, the absorption extrapolates to around 6dB on 50MHz. Applying these two estimates to the -114dBm signal power in the previous paragraph results in a signal power of around -135dBm.

The -135dBm estimate for signal received power is far enough below the -120dBm requirement to suggest the possibility of an ionosphere-ionosphere mode (ducting or chordal hops), as this would reduce absorption losses (by reducing the number of transits through the absorbing region) and reduce ground reflection losses (by reducing the number of ground reflections). Invoking an ionosphere-ionosphere mode would also help explain propagation through the higher latitudes (where the MUFs are lower) on the true long path at the beginning of the opening.

Ok – let's summarize everything. It is likely that the CE0Y/W7XU to VU2 QSOs started out via an ionosphere-ionosphere mode along the true great circle long path. As the MUF along the long path decreased, a skewed path closer to the equator was maintained compliments of the robust equatorial ionosphere – and maybe even with some help from increased equatorial electron densities due to a spike in geomagnetic field activity. Signal strengths were sufficient, even at QRP power levels, probably because of an ionosphere-ionosphere mode.

I readily admit we don't fully understand what happened here. But the scenario above is a reasonable guess. It's also encouraging that our understanding of the processes in the ionosphere matches the reported observations, and vice versa.

Note: If you're wondering how a MUF of only 37MHz can propagate a 50MHz electromagnetic wave, note that the predicted MUF in Figure 1 is a monthly median value – on any given day the actual MUF could be higher. Additionally, an F2 hop longer than the generally accepted 4000km limit could occur on 6m. These two effects could put the MUF in the ballpark of 50MHz.