Propagation
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A New Year's Eve Gift: W6 to ZL on 6m – Part 1

On December 31, 2009, Bob K6QXY worked ZL3NW and ZL1RS on 6m CW at 2228 UTC and 2230 UTC, respectively. Bob reported both signals were weak – he gave them 519 reports. K6QXY's 6m antenna array consists of a four-high stack of 10-element Yagis on a 120-foot rotating tower.

K6QXY was running 1300 Watts for these QSOs, and advised that he has a very good radio horizon towards the Pacific. Figure 1 shows the path from K6QXY to ZL3NW and ZL1RS on a worldwide map of the F_2 region critical frequencies (from Proplab Pro Version 2) at 2230 UTC on December 31, 2009.

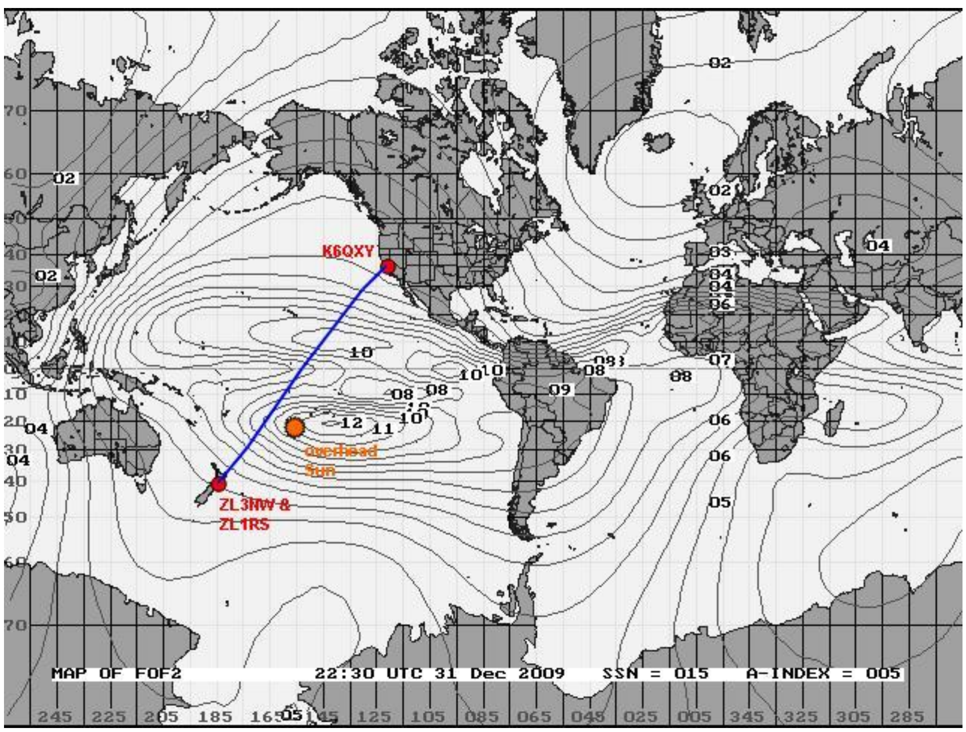

Figure 1 – K6QXY to ZL on 12/31/09 at 2230 UTC

The curved lines on the map with numbers near by are contours of F_2 region critical frequencies, with maximum usable frequencies (MUFs) typically about three times higher.

Note that the path is pretty much an equatorial path. Both ends of the path are at roughly 40 degrees geographic latitude, so the path never gets above 40 degrees North or South geographic latitude.

What’s also obvious in Figure 1 is the path’s nearness to the crests of the equatorial ionosphere – those areas around 2230 UTC in late December with high critical frequencies on either side of the geomagnetic equator at roughly 145 degrees West longitude in the Pacific. This suggests trans-equatorial propagation (TEP) via a chordal hop may have played a role in these QSOs.

Figure 1 is a view looking down on the path. Let’s take another look at the path, but now with a side view of the ionosphere. Figure 2 does this (also from Proplab Pro Version 2).

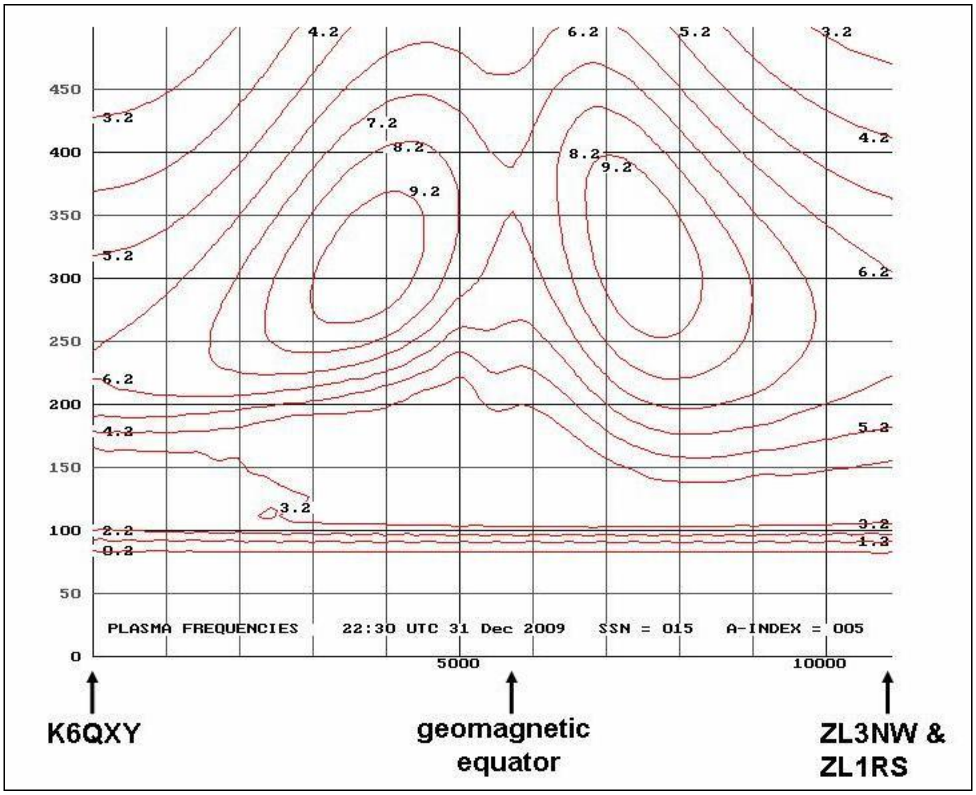

Figure 2 – Side View of Path from K6QXY to ZL

Figure 2 shows plasma frequencies (the maximum plasma frequency in a given ionospheric region is the critical frequency) versus height along the K6QXY to ZL path, with K6QXY on the left at 0 km and ZL on the right at about 11,000 km.

Figure 2 clearly shows the tell-tale ionospheric signature of TEP – two crests or “clumps” of increased electron density on either side of the geomagnetic equator. The northern crest is about 3900 km from K6QXY, and the southern crest is about 3600 km from ZL.

Let’s assume TEP played a role in these QSOs. Could one F_2 hop out of K6QXY and one F_2 hop out of ZL reach these increased electron density areas? Nope – at least not by conventional wisdom. Normally the maximum F_2 region hop distance is assumed to be 4000 km, with the encounter with the ionosphere at the mid point around 2000 km. Thus some other mode likely took place to get RF from K6QXY and ZL to the equatorial ionosphere. That mode was likely sporadic E (E_s).

E_s occurs mostly in the summer months, which would be December, January, and February in the southern hemisphere. This fits the QSO on the ZL end nicely. E_s also has a minor peak in the northern hemisphere winter month of December, and this fits the QSO on the K6QXY end nicely. Thus our hypothesis is that these QSOs involved E_s on both ends to get to the equatorial ionosphere, in which a chordal hop due to TEP occurred.

Figure 3 shows this hypothetical scenario in a rectangular coordinate system (it looks a bit odd since it is not in a spherical coordinate system as the real Earth-ionosphere system is). Note that Figure 3 is simply Figure 2 with the hop structure superimposed on it.

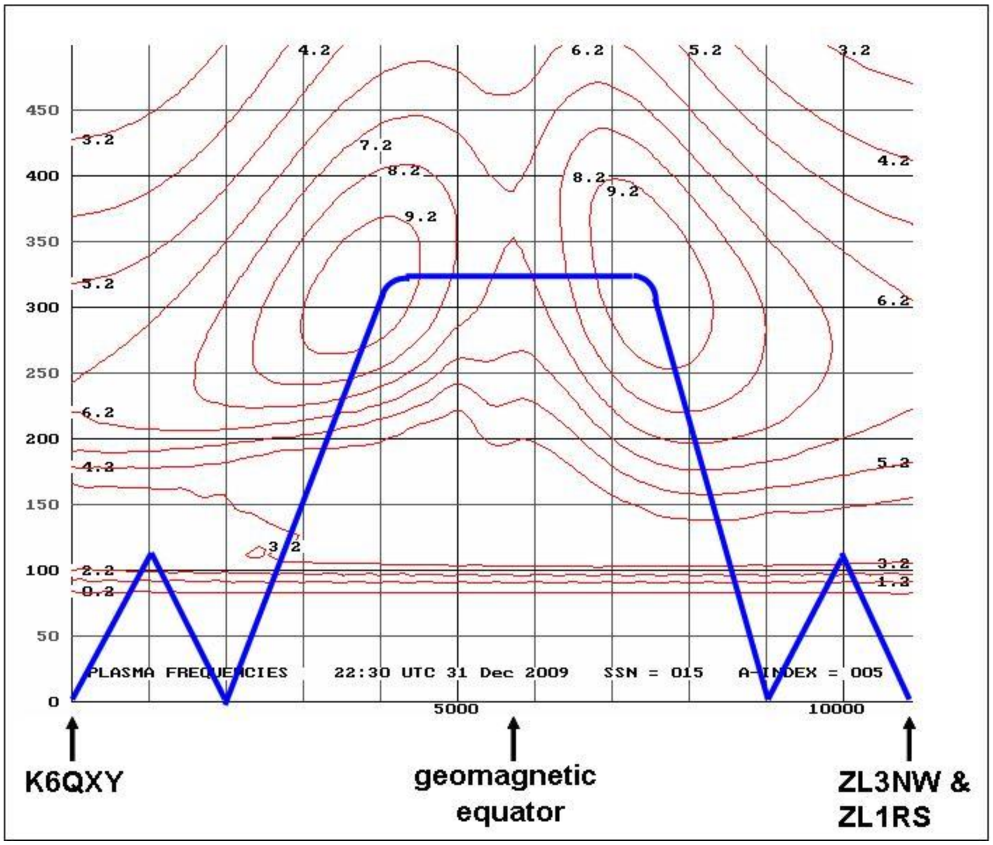

Figure 3 – Hypothetical Hop Structure

Ok, that's enough for this month. We've covered the easy part (putting words on paper) by proposing a hypothesis for these QSOs. Next month we'll tackle the hard part – seeing if we can capture evidence to support this hypothesis. In other words, can we back this up with some hard data?

To do this, we'll look at ionosonde data for the E_s portions of the path, and do some ray tracing for the TEP portion of the path. So stay tuned – it gets both interesting and frustrating.

Part 2 follows.

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A New Year's Gift: W6 to ZL on 6m – Part 2

Last month's column reviewed K6QXY's QSOs with ZL3NW and ZL1RS on 6m CW around 2230 UTC on December 31, 2009. The result of that column was the hypothesis that these QSOs took place via a sporadic E hop on each end coupled with a chordal hop across the geomagnetic equator compliments of trans-equatorial propagation. This month's column will try to dig up data to support that hypothesis.

The data we'll look at is ionosonde data. Thus we need to find ionosondes along or near the W6 to ZL path. Figure 4 (continuing the numbering scheme from last month's column) is Figure 1 from the June column with the available ionosondes indicated by blue stars.

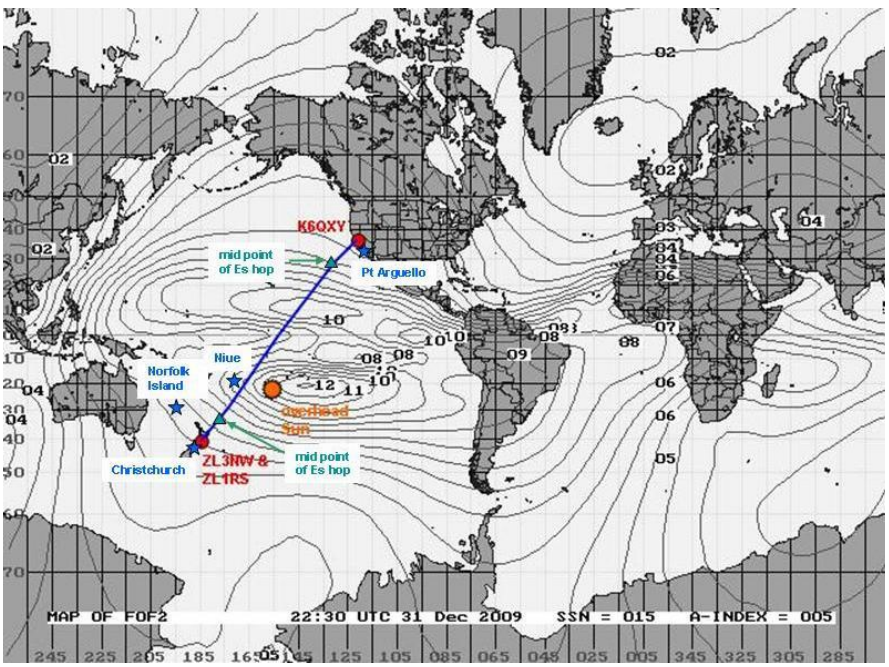

Figure 4 – Ionosondes Along or Near the Path

With this path being mostly over water, it's not surprising to see that the available ionosondes are few and far between. That's nothing unusual – if you've been a regular reader of this column you know that ionosondes generally aren't in the right place to properly analyze a path. That's frustrating, but we'll just have to make do as best we can.

Let's first look at the Point Arguello ionosonde. It's in southern California, and it is 856 km northeast of the mid point of the sporadic E hop out of K6QXY (the mid point is the green triangle). Going to **http://www.swpc.noaa.gov/ftpmenu/lists/iono_month.html** showed no tabular data. That's not good. But we do have another option – let's look at the raw ionogram data at **http://car.uml.edu:8080/common/DIDBFastStationList**. Figure 5 shows the ionogram at 2030 UTC, which is 2 hours before the QSOs.

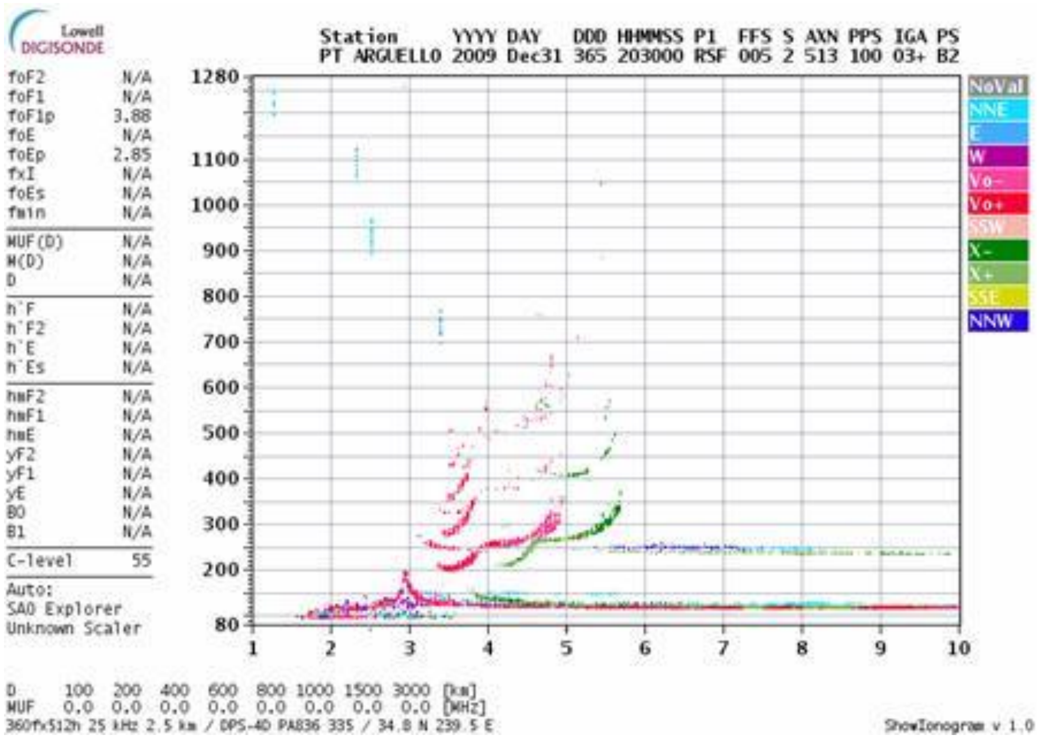

Figure 5 – Pt Arguello Ionogram

The horizontal axis is frequency in MHz, and the vertical axis is altitude in km. What's important to note is the horizontal red and green echo traces at just above 100 km all the way out to 10 MHz (and maybe even higher). The red traces are for the ordinary wave and the green traces are for the extraordinary wave. With the sporadic E maximum usable frequency (MUF) about five times the sporadic E critical frequency (which is what the traces just above 100 km are), it's easy to see that sufficient sporadic E was occurring in the vicinity of the K6QXY end of the path to support 6m – albeit a couple hours earlier.

Now let's look at the ZL end of the path. For the record, the ionosondes with data that are along or near the path are Christchurch (about 1300 km southwest of the mid point of the sporadic E hop on the ZL end), Norfolk Island (about 1500 km west of the mid point) and Niue (about 1900 km northeast of the mid point). Unfortunately there's nothing closer than 1300 km, which is even worse than the K6QXY end. The tabular data show no sporadic E of sufficient magnitude over the Christchurch ionosonde. But the Norfolk Island and Niue ionosondes show sufficiently high critical frequencies to support 6m for about an hour, but not at 2230 UTC. Again, all we can say is sporadic E was in the general area at times other than 2230 UTC.

That leaves the middle portion of the path – that which was hypothesized to be a chordal hop due to trans-equatorial propagation. With no ionosondes even remotely close, all we can do is perform ray tracing using the monthly median ionospheric parameters from our prediction programs. Figure 6 does this for 2230 UTC on December 31, 2009.

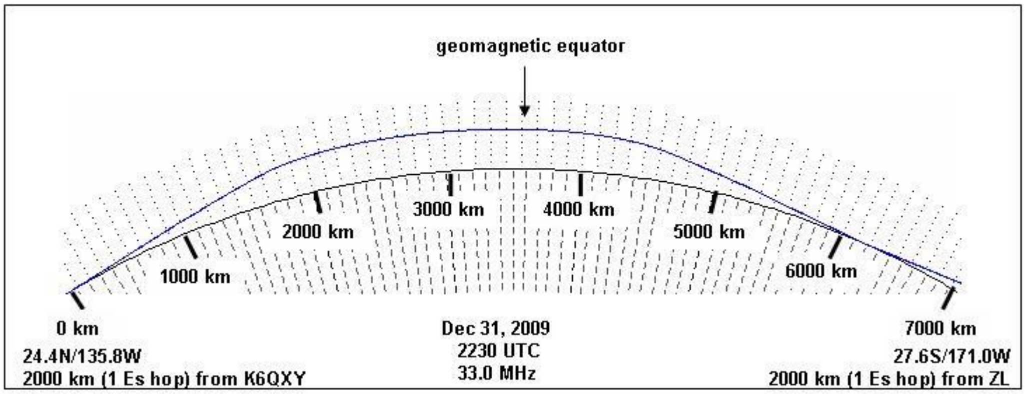

Figure 6 – Ray Trace Showing Trans-Equatorial Proapgation

The start of the ray trace (at 0 km on the left side of Figure 6) is where the hypothesized 2000 km sporadic E hop out of K6QXY comes back to Earth. The ray trace shows a nice chordal hop of 6200 km across the magnetic equator.

There are two observations here. First, it would have been nice if the ray trace would have gone a bit farther – ideally to about 7000 km, which would put it around 2000 km out of ZL for a sporadic E hop into ZL. But I'm not too troubled by that. That's because the second observation is likely more important.

The second observation is annotated on the figure - the ray trace frequency was 33.0 MHz. That was the highest frequency I found to be supported by trans-equatorial propagation. That's quite a way from 50 MHz, so let's dig a bit deeper here.

Note that I said the ray tracing was done with monthly median ionospheric parameters. That means the actual MUF in the equatorial region on December 31 could have been higher. How much higher? A good estimate can be made using the tables of MUF variability built into our prediction programs (and available in references such as Supplement to Report 252-2 published by the International Radio Consultative Committee, abbreviated CCIR, in 1978).

Knowing that 2230 UTC is around noon local time in the equatorial portion of this path as seen in Figure 4, we can use the 'smoothed sunspot number less than 50' table in Report 252-2 to determine that the ratio of the upper decile to the median MUF is 1.24. Plugging various operating frequencies into the equation that approximates the true chi-squared probability distribution of MUF variation gives Table 1.

Table 1 – MUF Probabilities

Operating frequency in MHz	Number of days in the one-month period centered on Dec 31 that propagation should be possible
33.0	15.5 (half the days – the median)
35.0	10.5
40.0	3.9
44.0	1.1
45.0	0.6

Thus we predict that 44.0 MHz could have been supported on one day of the month of the one-month period centered on December 31, 2009. That's close, but no cigar. But there's a clue in the June column that suggests something else might have been occurring. The clue is the reported weak signal strengths.

To understand this, we can estimate the ZL signal power at K6QXY by using the transmit antenna gain (13 dBi for a single small Yagi on the ZL end), the receive antenna gain (21 dBi for a 4-high stack of 10-element Yagis on the K6QXY end), the ZL transmit power (assumed to be 100 Watts = +50dBm), the free space path loss (147 dB), the ground reflection losses (6 dB from two ground reflections at 3 dB each), and the loss due to ionospheric absorption (since absorption is inversely proportional to the square of the frequency, it's going to be very low on 50 MHz – I assumed a pessimistic total of 6 dB). Going through the math gives a signal power of -75 dBm. This is around S9, and assumes pure refraction. Since K6QXY reported a much lower received signal power, it very well could be that some forward scatter (with additional losses) was occurring to allow frequencies somewhat higher than 44.0 MHz to propagate via a chordal hop.

This forward scatter mode is known as an over-the-MUF mode. What we're interested in is the additional loss incurred for frequencies higher than the pure refraction MUF. That's not tough to determine as the over-the-MUF mode is documented in the ITU (International Telecommunications Union) publication Report ITU-R P.2011.1. The equation in that reference estimates that the additional loss for a 50.1 MHz frequency with a pure refraction MUF of 44 MHz would be on the order of 14 dB. That's about three S-units, and would reduce the pure refraction signal power estimate from S9 to S6. That's still quite a bit above what K6QXY reported, which suggests even more forward scatter might have been occurring with the chordal hop due to an even lower pure refraction MUF than our estimated 44.0 MHz. Or for that matter, some forward scatter could have also been occurring with the sporadic E hops.

That's about as far as we can go. What can we say in summary about these unusual 6m QSOs? All we can really say is our hypothesis of two sporadic E hops coupled with a chordal hop due to trans-equatorial propagation is feasible and is supported by the limited data we uncovered. Will we ever know what truly happened to enable these QSOs? I seriously doubt it, so all we can do is make our best guess.