Propagation column
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Poldhu to Prince Edward Island on 160m

The Poldhu Amateur Radio Club and the Marconi Radio Club of Newfoundland, at the suggestion of Bart Lee, KV6LEE, put the Poldhu beacon GB3SSS on the air in December 2006. The beacon was at the top end of the 160m band, and ran 100W to a Marconi ‘T’ antenna. The purpose of the experiment was to gain insight into Marconi’s alleged feat in December 1901 (note that December 2006 and December 1901 were both at solar minimum), tempered by the fact that there were some key differences – for example, Marconi’s frequency could have been down around 850KHz and receivers nowadays are more sensitive. Regardless of these differences, a surprising result came out of this effort.

And it came from one of the SWLers who monitored the GB3SSS beacon on a regular basis – Jeff, K1ZM/VY2ZM. Jeff was listening to GB3SSS from his Prince Edward Island (PEI) location. Figure 1 shows the path from Poldhu to PEI, along with the location of Marconi’s receiver in Newfoundland in 1901. We’ll discuss the contour lines (0.50, 1.00, 1.50, 2.00, 2.50, and 3.00) and the ionosonde data in a bit.

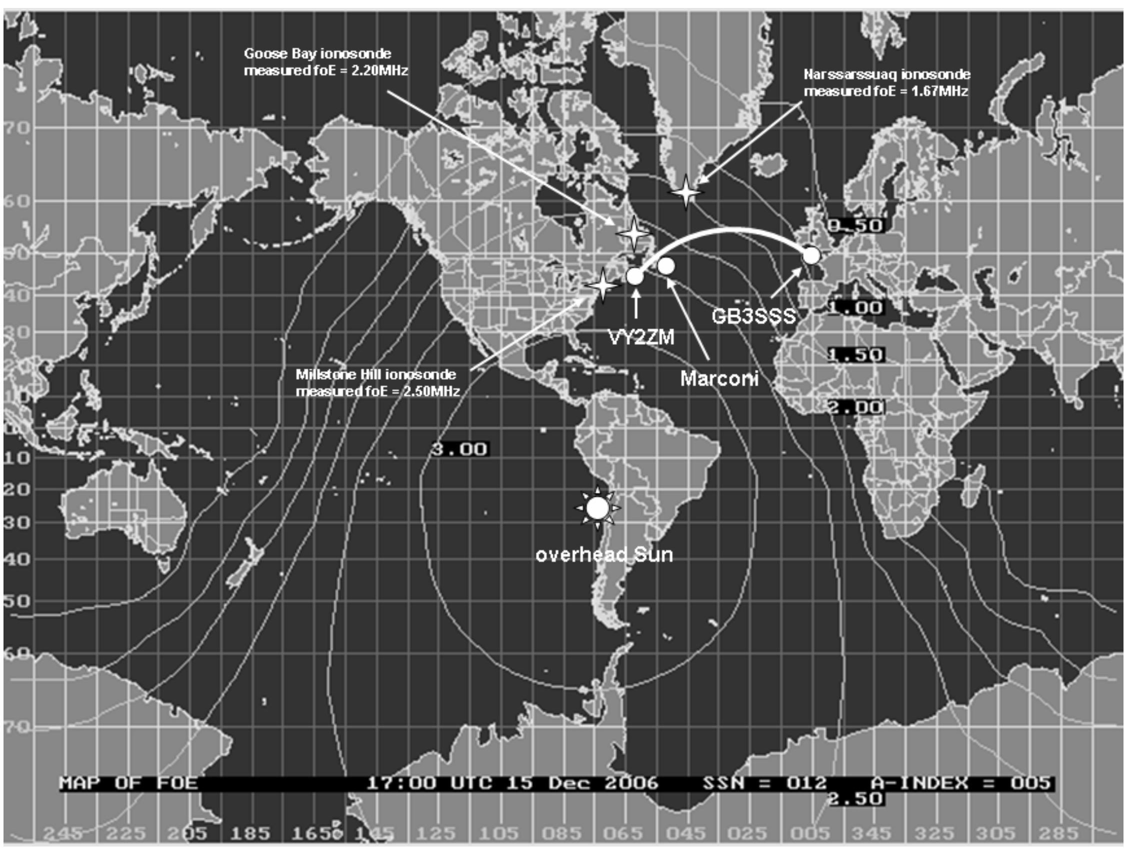

Figure 1 – Poldhu to PEI in December 2006

The path from Poldhu to PEI is very similar to the path from Poldhu to Marconi's QTH. The difference in headings to the two Canadian locations from Poldhu is only about 3 degrees, but the distance to PEI is 776km farther. Thus one might expect that a given signal strength at PEI might be stronger at Marconi's QTH. But this may be more than negated by the lower frequency used by Marconi due to more ionospheric absorption.

During December 2006, K1ZM reported that he heard the GB3SSS beacon repeatedly at around -87dBm (determined using a signal generator and a spectrum analyzer) at the times of Marconi's alleged receptions – from 1600 UTC to 1750 UTC. He further reports that he heard GB3SSS for twenty two and a half hours per day.

What does VOACAP say about the reception of GB3SSS at PEI at 1700 UTC on 1.96MHz (the beacon frequency) during December around solar minimum? Using 100W at Poldhu with 0dBi antennas on both ends (verticals over average ground) at 2MHz (that's as low as VOACAP was intended to go – and it's close enough to 1.96MHz for our purposes) and a smoothed sunspot number of 12 in December 2006 gives a predicted monthly median signal level of -174dBm at PEI.

That's almost 90dB lower than what K1ZM observed (and there's no reason to quibble whether the assumed antenna gains are correct – the VOACAP results are just too far off from the observations for this to make a difference). Thus VOACAP says K1ZM never should have heard GB3SSS. Does this scenario sound familiar? It should, as this is the same issue that surrounds Marconi's alleged reception of Poldhu back in December 1901. Our propagation prediction programs (those that cover Marconi's likely frequency of 850KHz) say Marconi never should have heard Poldhu, either. So if K1ZM heard GB3SSS when our predictions said he shouldn't have, that raises doubts about the statement "our predictions say Marconi couldn't have heard Poldhu."

So what's the problem here? Why is VOACAP so far off with the GB3SSS-to-PEI path? Let's dig into the model of the ionosphere in VOACAP to see if we can identify possible areas that would account for the huge difference. VOACAP says the path from Poldhu to PEI on 1.96MHz at 1700 UTC is via three E-region hops. Thus we'll first look at the critical frequency of the E-region (foE). That's what the contour lines on Figure 1 are – they represent the model of the ionosphere in VOACAP for the electron density of the E-region peak at 1700 UTC for December 2006 at a smoothed sunspot number of 12.

The map tells us why VOACAP says the path is covered with three E hops. On the PEI end of the path, foE is greater than 2.00MHz at an ionospheric encounter point of about 1000km from PEI – thus all frequencies below 2.00MHz, regardless of elevation angle, will be refracted back to Earth by the E region. On the Poldhu end of the path, foE is around 1.50MHz – thus all elevation angles below about 50 degrees at 1.96MHz at an ionospheric encounter point about 1000km from Poldhu will be refracted back to Earth by the E region (from Fmuf equals foE times one over the sine of the elevation angle). In other words, VOACAP says the F region is out of the picture due to the E region having sufficient ionization to refract low frequency waves back to Earth. So let's compare the foE values from the model in Figure 1 to ionosonde data from stations in the vicinity of the Poldhu-to-PEI path.

I did this for the Narssarssuaq (Greenland), Goose Bay (Labrador), and Millstone Hill (MA) ionosondes (see Figure 1). There are ionosondes at the Poldhu end of the path, but that end of the path is approaching darkness with a resultant decrease in foE to the point that it falls below the sensitivity of an ionosonde (around 1.8MHz). Although Narssarssuaq and Goose Bay did not have data for all the days of the month of December 2006, there was enough data to show that the median foE measured by these two stations and by Millstone Hill (a full month's worth of data) agrees exceptionally well (within a couple tenths of a MHz) with what the model predicted (remember our model presents median values, too). Thus the electron density at the E region peak, which is the determining factor in the hop mode, does not appear to be the source of the significant signal level discrepancy. That leaves the D region – specifically absorption – as the culprit. And as I mentioned in the June 2007 column, the D region is the one we least understand – it is characterized by large variability and a small database.

In order to look at the D region, though, we'll have to switch tools – from VOACAP to Proplab Pro. Although VOACAP can give us a lot of information by using the various Methods, it tells us little about the D region (except for the amount of loss, from which absorption can be estimated). And it does not allow us to manipulate some of the D region parameters to asses their impact to signal strength. The issue we'll be looking at with Proplab Pro (a full ray trace model including the effects of the Earth's magnetic field) is absorption in light of the significant difference in observed and predicted signal strengths at PEI. This, of course, assumes that VOACAP's predicted hop structure (three E hops) is correct – and it looks like it is based on the excellent agreement between the observed and the modeled foE data.

From previous columns, we know that absorption is proportional to the product of the electron density times the electron-neutral collision frequency. Thus what I did was sift through many technical papers from the scientific community, looking for measured D region electron densities and measured electron-neutral collision frequencies to compare to the model. The goal was to find data that was in a winter month, at low solar activity, at the higher latitudes, and around the same solar zenith angle as the Poldhu-to-PEI path around 1700 UTC in December. Figure 2 summarizes the results of this effort.

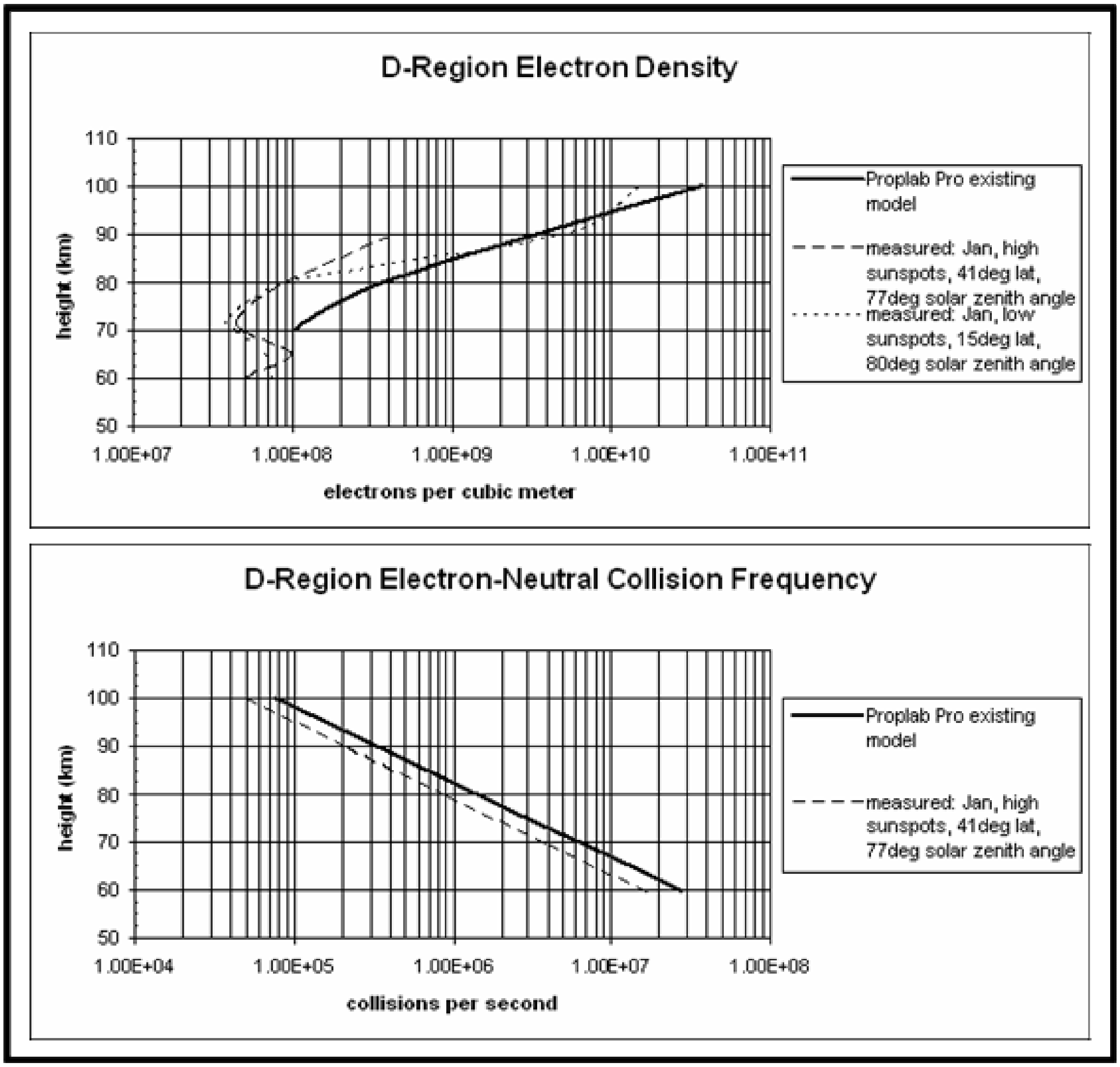

Figure 2 – Electron Density and Collision Frequency Comparisons

With respect to electron density (top plot), the two measured profiles are the ones that came closest to the four conditions set forth earlier. The dashed profile meets the month, the latitude, and the solar zenith angle parameters – but it was measured at a high solar activity. The dotted profile meets the month, the solar activity, and the solar zenith angle parameters – but it was measured at a low latitude location. Note that both measured data indicate less electron density than the model, and both indicate a valley around 70km (which the model does not have) – both of these issues will result in less absorption than the model.

With respect to the electron-neutral collision frequency (bottom plot), it does not vary significantly over season, location, or sunspot conditions. I used the measured data from the technical paper with the dashed electron density profile. Note that the measured data is less at 100km, and does not increase as much at the lower heights – both of these issues will result in less absorption than the model.

After modifying Proplab Pro to the measured dashed-line electron density and to the measured electron-neutral collision frequency (in reality, I forced the product of the electron density times the electron-neutral collision frequency in Proplab to agree with the product of the electron density times the electron-neutral collision frequency in Figure 2), Proplab predicts a signal level of -93dBm at PEI. That's darn close to K1ZM's observed -87dBm, and indicates the "K1ZM at PEI shouldn't have heard Poldhu" problem is likely due to the model of the D region having too high an electron density (with the valley around 70km in actual measurements playing a very important role) and too high an electron-neutral collision frequency (not as significant as the electron density issue, but nonetheless important). For the record, the model of the ionosphere in Proplab Pro is the 1995 version of the International Reference Ionosphere (IRI). The latest IRI version (2001) gives the same results as the 1995 version.

This was an interesting exercise – we manipulated the D region (within the bounds of measured data) and found that our 160m prediction now agrees favorably with actual results. In the February 2008 column this knowledge will be applied to the Marconi path of 1901. This will out of necessity also review what the ionosphere and the Earth's magnetic field looked like in 1901.