One-Way Propagation Revisited

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One of my early columns was titled One-Way Propagation, and it was in the August 1998 issue of WorldRadio. At that time WorldRadio was a printed magazine, which then turned into an on-line magazine and then was absorbed into CQ Plus.

What instigated this topic back in 1998 was an experience in the 1997 ARRL 10-Meter Contest. I heard a W4 calling CQ on CW with a decent signal – around S4 on my old TS-180S – but I couldn't work him. He kept CQing in my face. As a result of that, I reviewed possible explanations for one-way propagation.

Possible explanations reviewed were receiver performance (perhaps one station has a receiver with less sensitivity than the other station), transmitter power (one station is running the full legal limit, but the other station is only 100 Watts or even QRP), QRN (higher man-made and/or atmospheric noise at one end), separate transmit and receive antennas (transmitting on a vertical so you're heard in every direction, but listening on a directional receive antenna), QRM (like when North America can't work Europe when a band is just opening because of all the strong signals the Europeans are hearing from other Europeans), and the ionosphere itself.

With respect to the ionosphere itself, I looked at paths on 20-Meters from W9 to 9A (Croatia) and from W9 to KH6 (Hawaii). Although the ionosphere "seen" by each end of the path is different in terms of foE (critical frequency of the E region), foF2 (critical frequency of the F2 region) and hmF2 (height of the maximum ionization of the F2 region), the elevation angles for transmit and receive on both ends were quite similar, and didn't hint at a mechanism for one-way propagation due to the ionosphere.

Note that this analysis of the ionosphere was done on 20-Meters. I made a comment at the end of the August 1998 column that 160-Meters may be different, but didn't follow through with any further analysis. So let's do that now – look at the ionosphere's contribution, if any, to one-way propagation on 160-Meters.

To do this, I used Proplab Pro V3 (sold by Solar Terrestrial Dispatch – visit their web site at **http://www.spacew.com/proplab/index.html**) to perform ray traces at 1.823 MHz on four 1700 km paths. These are one-hop paths to keep things simple, but they can be lengthened, if necessary, for a more extensive study. This was done for a winter night at a smoothed solar flux of 100.

The four paths are actually two paths – between 40N/70W and 40N/90W, and between 32.5N/82 and 47.5/78W. These two paths are east-west and north-south, respectively, and pass through the same mid point. Ray traces were done both ways for each path to assess reciprocity. I also performed this exercise on 7.1 MHz to see if the 160-Meter band is indeed different than the higher frequencies. Figure 1 shows these paths (red is the east-west path, blue is the north-south path), with elevation angle and ionospheric absorption on 160-Meters for each of the four directions highlighted with the black arrows.

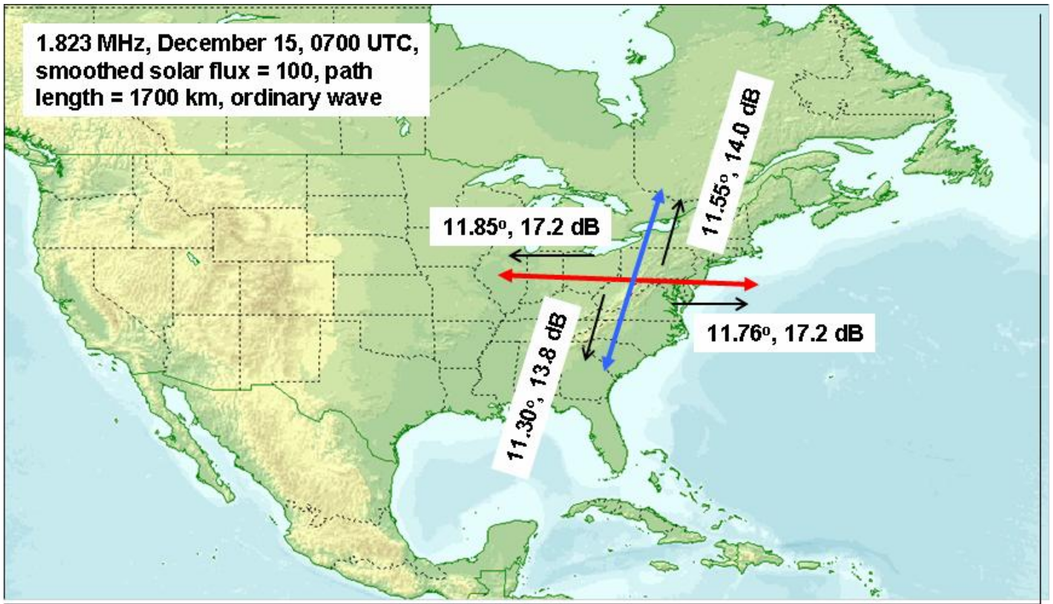

Figure 1 – Summary of 160-Meter Ray Traces

For the east-west path, the elevation angle and ionospheric absorption are essentially identical regardless of whether the electromagnetic wave is going east or is going west. Likewise, for the north-south path, the elevation angle and ionospheric absorption are again essentially identical regardless of whether the electromagnetic wave is going north or is going south. Thus our conclusion is that on 160-Meters for a basic 1700 km one-hop path, the direction of the path doesn't matter – in other words, it's reciprocal – the same either way.

But note the difference between an east-west path and a north-south path. The north-south (or south-north) path incurs about 3 dB less ionospheric absorption than the east-west (or west-east) path. Is there a physical reason for this? Yes, there is – it's tied to the electron gyro-frequency.

The electron gyro-frequency is the frequency at which electrons in the ionosphere gyrate in a helical path about magnetic field lines. Worldwide the electron gyro-frequency varies from about 700 KHz to about 1.7 MHz depending on the strength of the Earth's magnetic field. Now for the paths in Figure 1, the electron gyro-frequency is around 1.5 MHz. Thus 1.8 MHz (160-Meters) is close enough to the electron gyro-frequency to impact absorption depending on the direction of travel of the electromagnetic wave. When the wave is parallel to the magnetic field, absorption is less than when the wave is perpendicular to the magnetic field.

I mentioned that I also did ray traces over the same paths on 7.1 MHz. As expected, the elevation angles and absorption values are for all intents and purposes identical regardless of an east-west, west-east, north-south or south-north path. For the record, the elevation angles are 16.3 degrees plus-or-minus 0.5 degrees, and absorption is 0.57 dB plus-or-minus 0.03 dB. There is not a big difference on 7.1 MHz with respect to the direction of the electromagnetic wave. From this, I would expect 75-Meters and 80-Meters to start showing the effects of the electron gyro-frequency – but not to the extent of 160-Meters.

Okay, so 160-Meter north-south paths incur less absorption than 160-Meter east-west paths. How does this translate to the real world with paths longer than 1700 km? That would depend on how much east-west travel occurs versus how much north-south travel occurs along the entire path – the more the north-south travel, the less the absorption.

This exercise shows the effect of the electron gyro-frequency on absorption with respect to the direction of the path on 160-Meters. This is one of several interesting aspects of propagation when the operating frequency is near the electron gyro-frequency. Another aspect is absorption with the ordinary and the extraordinary wave. On 160-Meters, the extraordinary wave incurs significantly more absorption than the ordinary wave, and is why Figure 1 says I ray traced with the ordinary wave. For operating frequencies below the electron-gyro-frequency, as is our 476 KHz (630-Meter) experimental band, the ordinary wave is out of the picture and it’s the extraordinary wave that dominates. We’ll look at this in an upcoming column about propagation on 630-Meters.

In summary, again I see no hint of one-way propagation directly attributable to the ionosphere – even on 160-Meters. But this analysis uses our monthly median model of the ionosphere. This model does not capture the dynamic short-term variations of the ionosphere. So I believe it’s best to leave this open for future investigation when more specific data is available for an apparent observation of one-way propagation.