Propagation column
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A More In-Depth Look at Polarization

The September 1998 column reviewed observations by G2HCG with respect to polarization on the 10m band. Using a crossed-Yagi array and phasing lines that allowed switching between various polarizations, G2HCG concluded that the polarization of a received signal at his QTH was solely determined by the last encounter with the ionosphere. How can that be? Isn't the polarization of a received signal random? The answer to that is "no, not really – there is more order to polarization than we realize".

The reason there is order to polarization is the Earth's magnetic field. The ionosphere is immersed in this magnetic field, and the magnetic field results in two characteristic waves propagating through the ionosphere. These are designated the ordinary wave (o-wave for short) and the extraordinary wave (x-wave for short). Figure 1 shows these characteristic waves over a one-hop path.

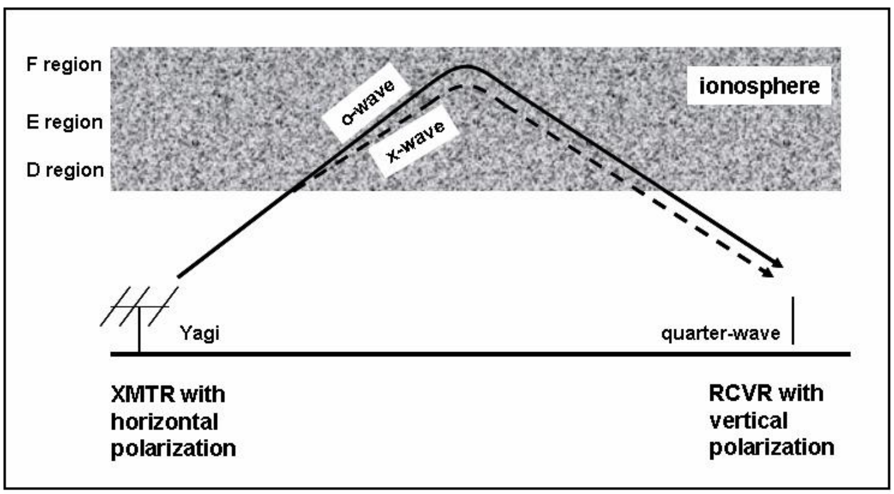

Figure 1 – Characteristic Waves

Four important concepts are shown in Figure 1. First, the polarization of the up-going wave from the XMTR is constant (horizontal for the scenario shown) until it enters the bottom of the ionosphere at the lower D region. Upon entering the ionosphere, it excites both an o-wave and x-wave (how much power goes into each characteristic wave depends on the polarization match between the up-going wave and the characteristic waves). Second, the polarizations of the two down-coming characteristic waves are constant from the bottom of the ionosphere to the RCVR. Third, the x-wave takes a different path through the ionosphere than the o-wave because the index of refraction is different for the two characteristic waves. And fourth, assuming the strength of the two characteristic waves is equal at the bottom of the ionosphere, the strongest signal at the RCVR will come from the characteristic wave that most closely matches the polarization of the RCVR (vertical for the scenario shown).

For the calculation of loss due to polarization mismatch, the concept of limiting polarization is used. Limiting polarization is the polarization of the o-wave and x-wave at the entry and exit points in the ionosphere (the latter being what G2HCG observed).

With these basics behind us, let's take a look at some practical aspects of polarization. We'll use Proplab Pro (Solar Terrestrial Dispatch) to do ray traces over a one-hop path on 160m and on 10m. For both the o-wave and x-wave, we'll review the following data: limiting polarizations at the entry and exits points of the ionosphere, power coupled into the characteristic waves, o-wave and x-wave absorption, and o-wave and x-wave paths through the ionosphere.

Figure 2 shows the ray traces on 10m, along with the pertinent data mentioned above.

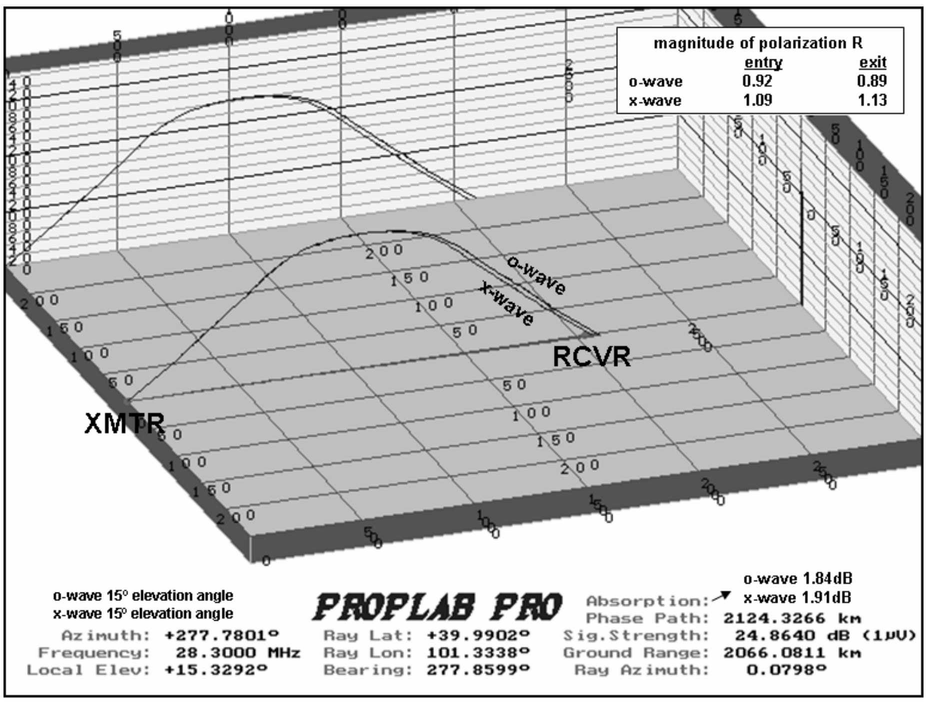

Figure 2 – 10m ray trace

As expected, the characteristic waves take slightly different paths through the ionosphere (the split into the o-wave and x-wave occurs at the entry point near the XMTR as in Figure 1, but the difference only shows up farther down the path due to the resolution of the ray trace graphic). The x-wave is refracted a bit more than the o-wave, and it ends up hitting the ground after a slightly shorter distance.

The data in the upper right hand corner shows that the o-wave is for all intents and purposes circularly polarized at the entry point (R = 1 is circular polarization), it propagates through the ionosphere with 1.84dB of absorption (from the data in the lower right hand corner), and then it exits the ionosphere being pretty much circularly polarized. The data shows that the x-wave is also pretty much circularly polarized at the entry point, it propagates through the ionosphere with 1.91dB of absorption, and then it also exits the ionosphere being pretty much circularly polarized.

What this all means is that in theory on 10m the polarization at the XMTR and at the RCVR is essentially irrelevant. At the entry point, the horizontal polarization splits its power equally into the o-wave and x-wave (since they are circularly polarized). Likewise, a vertical antenna would split its power equally. Then both characteristic waves arrive at the exit point with the same strength (since the split was equal and the absorption is equal). Finally both characteristic waves, being circularly polarized, excite the vertical equally. Likewise, they would excite a horizontal antenna equally.

In reality, horizontal polarization on both ends would be favored due to other considerations – horizontal antennas respond less to man-made noise (since man-made noise is generally vertically polarized) and they are not as dependent on ground conditions for low angle radiation (the exception would be if a vertical is over salt water).

All of this is interesting, isn't it? But wait – it gets more interesting on 160m.

Figure 3 shows the ray traces on 160m, along with the pertinent data mentioned earlier.

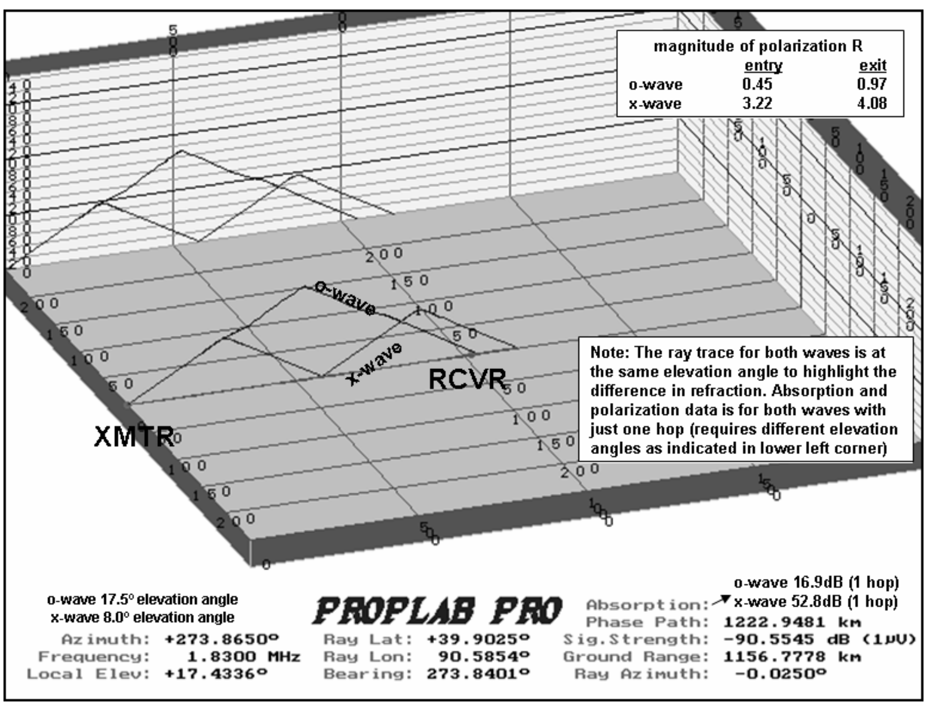

Figure 3 – 160m ray trace

Again, as expected, the characteristic waves take different paths through the ionosphere – but the difference is significantly more on 160m because 1.8MHz is very close to the electron gyro-frequency (which varies from about 0.7 to 1.7MHz worldwide depending on the intensity of the magnetic field), which significantly modifies the index of refraction of the x-wave. And as we saw on 10m, the x-wave refracts more than the o-wave.

The other obvious result is that the x-wave, over the same one-hop path, suffers significantly more absorption than the o-wave. Again, this is due to 1.8MHz being very close to the electron gyro-frequency, which significantly modifies the amount of absorption of the x-wave. Because of this, the x-wave is usually ignored in propagation studies on 160m (and on the AM broadcast band, too). This effect is also seen on 80m, but to a lesser extent.

As for polarization, the o-wave polarization at the entry point is quite a bit less than 1 – which means elliptical polarization tending towards linear polarization ($R \ll 1$ or $R \gg 1$ = linear polarization). When you work out the details for the scenario in Figure 3, the o-wave at the entry point is predominantly vertically polarized. Thus using a vertical antenna on 160m will couple the most power into the only propagating wave – the o-wave. This is generally true for those of us in North America, and also applies to 80m to a lesser extent.

That's enough about polarization for now. We've looked at the effect of the Earth's magnetic field on the three important parameters with respect to propagation (polarization, absorption, and refraction), and we've seen that the magnetic field has a profound effect on these parameters on frequencies near the electron gyro-frequency. This was a simple look over a one-hop path. This gets very complicated quickly for multi-hop paths.