Newcomers and Elmers Net: HF Propagation
By Robert Gulley 8-3-14

Tuning up and down the dial is a lot of fun, regardless of what radio frequencies a radio covers.
-- I can find interesting things to listen to whether on Amateur, shortwave, police, AM & FM, aircraft or marine bands. In fact, there are far more listening opportunities than I have time for!
-- Serendipity certainly has its place and its own rewards, but if one wants to get serious about the radio hobby there comes a time when the study of propagation (or how signals get to where they're going) is a must.
-- The actual composition of the atmosphere and seasonal changes in the ionosphere are two of the biggest factors in propagation, so this is where I will start.
-- With time and experience not only will propagation become a part of your radio planning, but you will even learn to recognize optimal conditions—a propagation intuition, if you will.

Atmospheric Layers
As you probably know already, the atmosphere is made up of several layers
-- these are determined primarily by the chemical composition and the physical characteristics of each layer
-- they are marked by varying elevations
-- The uppermost layer of the atmosphere is called the ionosphere, made up of a shell of electrons and electrically charged particles.
-- This shell can either allow radio signals to pass through it into space, or it can bend some of those radio waves back toward the surface of the earth allowing communication over great distances.
-- Radio waves which are bent back to earth usually make multiple hops between the earth and the atmosphere, depending on the frequency and the strength of the signal.
-- Unfortunately no analogy fits perfectly when trying to describe this process.
-- Light striking a mirror and being refracted is an approximation of this phenomenon, but certainly an imperfect comparison.
-- Positively charged ions in the ionosphere attract electrons from the electromagnetic radio signal, energizing them for a brief moment.
-- In their highly charged state radio waves either punch right on through the ionosphere out into space, or they are bent (or refracted) back to earth.

-- Of course, all of this happens just about at the speed of light and therefore a signal traveling around the world takes only about 1/7th of a second—hardly enough time to be even noticed.

How much bending or refracting of a radio signal occurs depends on the frequency of the signal and on the structure of the ionosphere at any given time.
-- Changes in density within the ionosphere (defined as layers) allow some signals to bend while others pass through into space.
-- These layers change daily as well as seasonally. Over time scientists have learned a great deal about what to expect under a given set of conditions, in part due to experimentation and observation by radio amateurs.

While no model of propagation will guarantee signal reception on either end of the intended path, we can predict with a good deal of accuracy when we are likely to hear signals broadcast in specific portions of the radio spectrum.
-- This ability to predict what can and cannot be heard is both a blessing and a curse.
-- I regularly check propagation forecasts in several monthly radio publications to get an idea of what I am likely to hear at any given time.
-- I also check online resources to see what others are experiencing. That's the upside.
-- The downside of propagation predictions comes when one swears by them—the fact is, propagation is simply too unpredictable to say with absolute certainty something will or will not work.

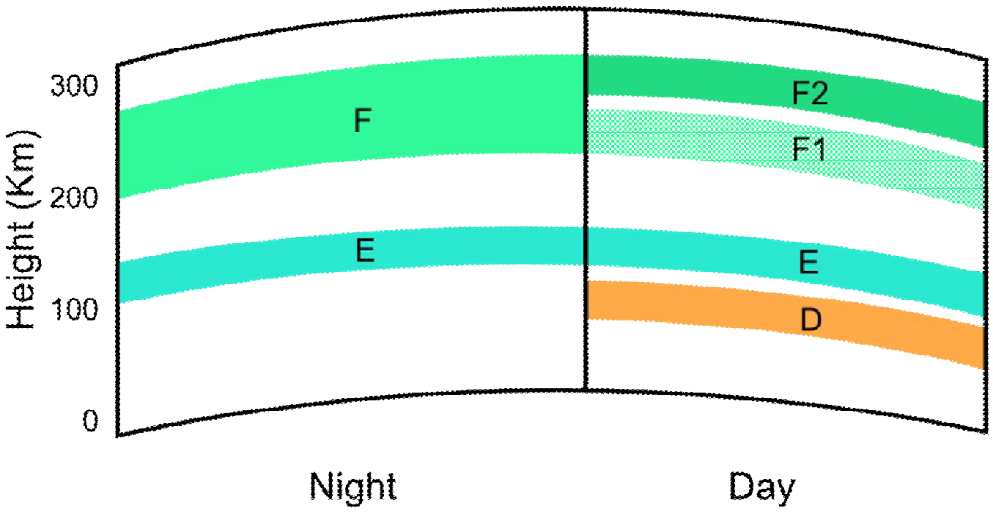
Seasonal predictions are the most accurate by far, in that changes in the earth's rotation and the subsequent changes in temperature affect propagation in predictable ways.
-- Spring and fall are good times for certain radio activities, while summer and winter are better for others.
-- However, just because something is "out of season" doesn't mean it can't happen; it just means it's more unlikely to happen.

An example of this just happened to me recently when I was able to work Antarctica on 20 meters . . . at 1:30 in the morning! Came in loud and clear, and I worked him on the first or second try
-- I can't even explain the propagation which allowed this as his station was in perpetual darkness at the very bottom of the earth

While normal conditions would lead me to stay away from this band overnight, other propagation conditions allowed me a great contact I might not otherwise have heard.
-- The point is, keep your options open: the propagation gods move in mysterious ways when you least expect it!

Since propagation varies so much with the season and with location, there are always bands which are open virtually any time of the day if you know where to look.
-- This is not something you learn overnight, however, so don't feel overwhelmed.
-- A good understanding of propagation and of what to expect at any given time of the year takes a long time to master—I know I have a long way to go before I would consider myself an expert!
-- Besides for me, the joy is in the journey!

Layers In The Ionosphere



Ionosphere Layers (image from NPS)

I mentioned earlier the ionosphere is made up of several layers. These layers are generally divided as follows: the "D" layer, the "E" layer, and the "F" layer (which is split into the "F1" and "F2" layers during daylight hours).
-- Each layer has its own impact on radio waves, and both "E" and "F" layers have their own MUF (as if things were not complicated enough!).

-- These maximum usable frequencies are known as the EMUF and the FMUF, respectively. Don't worry about following these numbers for now—keeping up with the MUF is quite enough as you begin learning the ins and outs of propagation!

How Each Layer Affects A Signal

The "D" layer is primarily active during the daylight hours, having minimal impact on signals at night.
-- The high ionization levels during the day cause the familiar loss of distant AM signals through *absorption*.
-- Signals are literally absorbed into the ionization field and scrambled rather than reflected.
-- At night the signals reappear as absorption levels drop drastically.
-- Winter is a great time for AM DX listening during the morning hours as the "D" layer often takes longer to form as the days shorten.
-- The shorter days also mean AM DX stations appear earlier in the evening, and nighttime medium-wave DX is fantastic during the winter months because the atmosphere is much quieter.

The "E" layer primarily reflects signals below 7 MHz, but special instances of unusual activity known as *Sporadic-E* propagation allow signals in the 50 MHz and even 2-meter range to skip long distances, sometimes as much as 1400 miles on one hop.
This activity can last for a few minutes or for a few hours, and even FM and broadcast TV can be affected.
-- as we talked about last time, Summer months are the best time to catch E-Skip conditions, but fall and spring can bring interesting opportunities as well.

The All-Important "F" Layer

The "F" layer is the primary layer for HF reflection of signals, and this is the layer which allows shortwave and Amateur radio signals to travel great distances.
-- Because the "F" layer remains throughout the day and night, DX listening is possible from around the globe.
-- While the maximum usable frequency varies throughout the day, this layer always reflects a portion of the HF band well regardless of the season.

During the day this region splits into the "F1" layer and the "F2" layer due to a separation of ionizing particles.
-- As night falls the "F1" layer merges back into the "F2" layer, allowing for radio propagation throughout the night.

-- Both layers will reflect signals, but the "F1" layer is more variable overall, and most usable during summer months.

Finally, it is the "F" layer which is most susceptible to solar conditions, something I will cover another time.
-- While radio propagation is active in this layer year-round, high sunspot cycles help raise the MUF such that 10- and 20- meter activity is greatly enhanced.
-- Signals in the 10-meter band are few and far between during low solar cycles, but when solar activity is high a few watts of power can be heard around the world!

The MUF, EMUF, FMUF, and LUF—Enuff Already!
Among many different propagation factors the MUF (Maximum Usable Frequency) and the LUF (Lowest Usable Frequency) are two very important numbers.
-- These terms represent measurements of the ionosphere which determine the range of usable frequencies at any given time of the year.
-- Roughly speaking the MUF represents a monthly prediction which says propagation/transmission at or below the maximum predicted frequency will be successful 50% of the time during a given month. (repeat!)
-- Just to further complicate the issue, reliable transmission is usually estimated to be between 80-90% of the MUF on any given day.

An illustration will help clarify this: if the predicted MUF is for 21 MHz on a given day, a realistic optimum working frequency might be around 18 MHz (21 MHz – 15% = 18 MHz).
-- Much higher than 21 MHz and signals will not likely be heard. Some days will be better than this, other days not as good.
-- These propagation numbers serve as guides to *likely* propagation, not absolute propagation.
-- They are starting points to suggest which frequencies will work reasonably well for a given time of year.
-- The numbers are reliable enough that shortwave broadcast stations often adjust their operating schedule on a seasonal basis to optimize their reach.

During winter months the MUF is at its highest during the day for HF frequencies, and the noise level is at its lowest since the summer storm season is over.
-- This means stations which might normally be in the noise floor during the summer will come in fine in the winter.

-- The downside of this condition is the shorter daylight hours means a lower MUF overnight.
-- Winter days are great for higher frequencies, while summer nights are better for the higher frequencies. (This is due to the ionosphere staying more active during the shorter summer nights.)
-- Some folks see these differences as a nuisance because their favorite stations might not come in, or they might not be able to work their favorite Amateur bands.
-- Rather than a negative, I see these seasonal changes as opportunities to explore different bands at different times of the year. I guess it all depends on your perspective!

The LUF
The LUF is the lowest frequency on which one can expect to get reasonable propagation roughly 90% of the time each month.
-- This number is perhaps even more relative than the MUF simply because what is acceptable to one person is not acceptable to another.
-- With so many variables involved in signal reception, reliable numbers are difficult to pin down.
-- I find I am willing to put up with more noise and therefore work more to dig out signals than some of the other radio folks I know.
-- I rather expect to hear signals "down in the mud" when I am trying to get the stations most distant from me—I take it as a necessary part of the hobby.
-- Other folks simply prefer listening to stronger, clearer signals, which means their LUF is higher than mine.

Still, when calculating the lowest usable frequency, assume the number may actually be a bit higher than predicted.
-- A projection of, say 5 MHz, may translate more realistically into 6 or 7 MHz depending on local conditions.
-- At other times the number might be a bit too conservative, and a LUF of 5 MHz actually is more accurately 4 MHz. Again, these numbers are meant to be guides, not hard-and-fast rules.

The heating of the earth's atmosphere is the primary factor in seasonal adjustments of the maximum usable frequency, and so the MUF and LUF are different for different parts of the world.
-- Sometimes I catch myself thinking everybody is experiencing the same conditions as me, but of course, winter here is summer south of the equator, and vice-versa.
-- Propagation prediction software is available as well as near real-time Internet sites which will give you starting MUF numbers based on your location and the locations you wish to hear.

Gray-Line Propagation
Gray-line propagation is a condition where signals traveling north and south along the light/dark line show good strength. As darkness turns into day, HF signals are enhanced.
-- By the way, the same thing happens in the afternoon in reverse; as darkness comes in the north/south line between light and dark again enhances signal strength.

Resources:

ARRL
- http://www.arrl.org/qst/propcharts

Popular Communications Magazine
- monthly propagation forecasts and solar activity summaries

Podcast – "NW7US Space Weather and Radio Propagation Podcast"
- http://podcast.hfradio.org

Propagation Maps
- http://propagation.hfradio.org/
- http://www.kg7hq.wetnet.net/node/55
- http://www.spacew.com/www/realtime.php