Amateur Radio Technician Class License Study Guide

Week 2

Element 3: Radio wave propagation

October 10, 2023

Question pool sections: G3

Concepts covered:

G3A – Sunspots and solar radiation; geomagnetic field and stability indices

G3B – Maximum Usable Frequency; Lowest Usable Frequency; short path and long path propagation; determining propagation conditions; ionospheric refraction

G3C – Ionospheric regions; critical angle and frequency; HF scatter; near vertical incidence skywave (NVIS)

Corresponding pages of ARRL *General Class license manual*:
8-1 through 8-2, 8-7 through 8-12

Ionospheric propagation

Many of the radio wave propagation concepts covered in the Technician class exam dealt with radio waves in the VHF and UHF range (30 to 300 MHz). In contrast, the General class exam focuses almost entirely on propagation in the HF range (3 to 30 MHz). This makes sense, as a General class licensee has significantly more operating privileges in the HF range than a Technician class licensee. Lets begin with a review of some HF propagation concepts covered on the Technician examination.

Just like light, radio waves travel in straight lines, but like visible light, they can be reflected, bent, focused, and adsorbed. If radio waves travel in straight lines, you may wonder how they travel around the globe. World-wide communications occurs when HF radio waves head skyward, but are then bent back to earth by the "ionosphere", the portion of our atmosphere from 30 to over 250 miles above the Earth's surface. This type of propagation is known as "skywave" or skip. The distance between the transmitting station and the point where the signal returns to Earth is known a the "hop", with the space between known as the "skip zone".Signals from the transmitting station cannot normally be heard in the skip zone.

There are actually several layers or regions that form in the ionosphere that can bend radio waves back to earth. These regions form when solar radiation causes ionization to develop in the ionosphere. The amount of ionizing radiation that reaches the earth depends on the time of day and activity on the sun, particularly sunspots. We'll get into a much more in-depth discussion of the relationship between solar activity and HF propagation a little later.

The regions that form in the ionosphere are designated by letter, with the one *closest to the earth's surface known as the "D" region*. The D region forms in the daytime, but dissipates at night. Rather than enhancing radio wave propagation, *the D region is the most absorbent of signals below 10 MHz during daylight hours*. This absorption is why *long-distance communication on the 40-, 60-, 80-, and 160-meter bands more difficult during the day. Conditions on the lower HF frequencies may be further impacted during the summer by high levels of atmospheric noise or static*.

The next layer, the "E" region, is about 60 to 70 miles above the Earth's surface. When there is sufficient ionization to refract signals back to Earth, *a single E region hop covers approximately 1200 miles.* When heavily ionized areas, known as "clouds" form, "sporadic E" propagation can occur, which allows VHF signals to be received from long distances.

The workhorse of the ionosphere is the "F region", which is the furthest from the Earth's surface, at an altitude of 100 to 300 miles. During the daytime, the F splits into two layers, with the F1 at 100 to 140 miles and the F2 at 200 to 300 miles in altitude. At night, the F1 and F2 layers combine into a single F layer. *Because of the higher altitude of the F2 region, the skip propagation is longer than that via other ionospheric regions, with a single hop normally covering 2500 miles*. The circumference of the Earth is nearly 25,000 miles, so how do signals travel around the globe? Signals returning from the ionosphere may be reflected off the Earth's surface (land or ocean) and back skyward, allowing multiple hops to occur.

The ability of signals to travel around the globe presents another interesting phenomenon. While signals may take the direct, or "short path" between the transmitting and receiving stations, it's possible for the signal to travel from the transmitting station 180 degrees in the opposite direction and arrive at the receiving station via the “long path”. *When using a directional antenna to make a “long path” contact with another station, the antenna should be pointed 180 degrees from the short path heading*. If you are receiving *skywave signals by both short-path and long-path propagation, a slightly delayed echo might be heard*.

Frequency dependent response

Let's cover some terms used to describe skywave propagation. *The **MUF** is the **M**aximum **U**sable **F**requency that may be used for communications between two points* at any given time. The MUF is dynamic, and is *affected by factors such as path distance and location, time of day and season, and solar radiation and ionospheric disturbances*. *The **LUF** is the **L**owest **U**sable **F**requency that may be used for communications between two specific points.*

Radio waves with frequencies <u>below</u> the MUF and <u>above</u> the LUF are affected by the ionosphere by refracting them back to Earth. This is ordinary skywave communications. *Radio waves with frequencies below the LUF are usually attenuated before reaching their destination. The <u>least</u> attenuation for long-distance skip typically occurs at frequencies <u>just below the MUF</u>. When the LUF exceeds the MUF, HF propagation via ordinary skywave communication is not possible over that path.*

Two more concepts are the “critical angle” and the “critical frequency”. *The critical angle, as applied to radio wave propagation, means the highest takeoff angle that will return a radio wave to Earth under specific ionospheric conditions*. *The term “critical frequency” at a given incidence angle is the highest frequency which is refracted back to Earth*.

All this theoretical stuff is great, but at some point you may want to know if the band you want to use is actually open to the regions that you want to contact. There are a few ways to get an idea. One is to listen for propagation beacon stations on the band in question. That won't tell you where your signal will be heard. *One method to determine current propagation on a desired band <u>from</u> your station is to use a network of automated receiving stations on the internet to see where your transmissions are being received*.

There are some conditions where signals may propagate within the skip zone. One of the more common is *scatter propagation*. Scatter occurs when reflections from features on the Earth's surface (ocean or mountain ranges) return some of the wave back to the transmitting station. Because the ionospheric regions are not perfect reflectors, waves can also be scattered from within the ionosphere. Scatter is a type of *propagation allows signals to be heard in the transmitting station’s skip zone. HF scatter signals in the skip zone are usually weak because only a small part of the signal energy is scattered into the skip zone. Signals propagated by HF scatter often have a fluttering sound. HF scatter signals often sound distorted as the energy is scattered into the skip zone through several different paths.*

A technique that allows signals to be heard within the skip zone is the use of <u>NVIS antenna system</u>. *Near vertical incidence skywave (NVIS) propagation is short distance MF or HF propagation at high elevation angles.* This occurs when the signal is sent nearly straight up and is reflected back to Earth by the ionospheric layer directly overhead.

Solar radiation
Now it's time to discuss the engine that drives conditions in the ionosphere and Earth's magnetic field, our neighborhood fusion reactor, the sun. The sun emits more kinds of energy than just the visible light spectrum that humans see. This includes the *increased ultraviolet and X-ray radiation from a solar flare*. This kind of energy travels at the speed of light, *and can to affect radio propagation on Earth in approximately 8 minutes*. *A sudden ionospheric disturbance can impact the daytime ionospheric propagation, disrupting signals on lower frequencies more than those on higher frequencies*.

Another form of solar energy that arrives at Earth is the "solar wind". This consists of a stream of charged particles called plasma, that are ejected from the sun as part of a coronal mass ejection or CME. The velocity of the plasma is variable, but much slower than the speed of light. *It takes 15 hours to several days for a coronal mass ejection to affect radio propagation on Earth*.

While the ultraviolet and X-radiation interact with the ionosphere, the energy from CMEs interacts with the <u>Earth's geomagnetic field</u> and can trigger a geomagnetic storm. *A geomagnetic storm is a temporary disturbance in Earth's geomagnetic field*. Strong *geomagnetic storms can affect HF propagation, degrading high-latitude HF propagation*. In general, *long distance radio communication usually affected by the charged particles that reach Earth from solar coronal holes* (CME's), *with HF communication being disturbed*. On the upside, *high geomagnetic activity can benefit radio communications by creating auroras that can reflect VHF signals* (a beautiful sight, if you are lucky enough to see it).

The sun is VERY dynamic, and monitored closely from Earth and by satellites. The sun goes through a cycle that repeats approximately every 11 years. The number of sunspots visible from Earth, goes from a minimum to a maximum in about 5.5 years. We are now approaching the maximum for cycle 25 (humans began tracking sunspots over 300 years ago, with the 11 year cycle identified in 1843). *Higher sunspot numbers generally indicate a greater probability of good propagation at higher frequencies*. *The <u>least reliable</u> bands for long-distance communications during periods of <u>low</u> <u>solar</u> <u>activity</u> are the higher frequency HF bands, 15 meters, 12 meters, and 10 meters*. Fortunately, *the 20-meter band usually support worldwide propagation during daylight hours <u>at</u> <u>any</u> <u>point</u> in the 11-year solar cycle*.

Solar parameters are measured and reported daily. These include *the K-index (a measure of the short-term stability of Earth's geomagnetic field), the A-index (long-term stability of Earth's geomagnetic field), and the solar flux index (a measure of solar radiation with a wavelength of 10.7 centimeters)*. Solar conditions also change on a much shorter cycle, *due to rotation of the sun's surface layers around its axis, causing HF propagation conditions to vary periodically in a 26- to 28-day cycle*. This rotation causes sunspot regions to appear, move across the visible solar disk, then disappear, only to return a few weeks later.