

Signal Propagation and the Ionosphere

How those short wave signals travel around the globe

by Bert Huneault

Part I

As you tune across the HF spectrum, the loudspeaker of your receiver comes alive: "GANDER, THIS IS AIR CANADA 870. POSITION 50 NORTH 30 WEST AT 0135 FLIGHT LEVEL 350...". A slight twist of the dial and "SKYKING, SKYKING, DO NOT ANSWER. NOVEMBER QUEBEC ZULU TIME FOUR ZERO. AUTHENTICATION, PAPA WHISKEY. OIL-CLOTH OUT." A little further down the dial you hear a Spanish female sending five-figure groups: "CINCO UNO NUEVE CUATRO OCHO...".

On other dial settings the world is at your fingertips: "THIS IS LODNON CALLING IN THE NORTH AMERICAN SERVICE OF THE BBC..."; "THIS IS VOA: THE VOICE OF AMERICA." You hear HCJB's *DX Party Line* program from Quito, Ecuador... RADIO MOSCOW... RADIO NEDERLAND... THE VOICE OF NICARAGUA... RADIO BEIJING... RADIO AUSTRALIA... and countless others.

How is all this possible? How do HF (high frequency--"short wave") signals travel across hundreds or even thousands of miles to your listening post?...Enter the fascinating world of shortwave radio propagation.

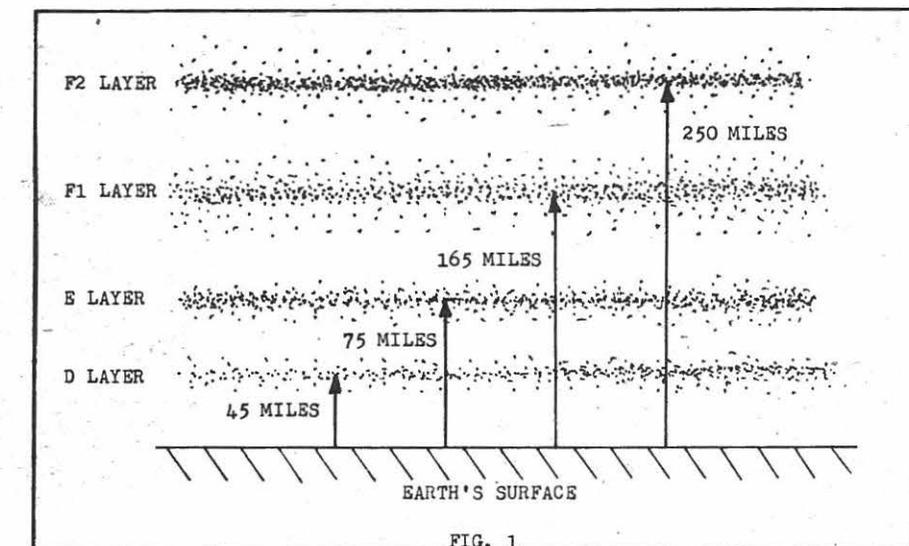
The Ionosphere

The ionosphere is that part of the upper atmosphere in which free ions (electrically charged molecules) and electrons exist in sufficient quantities to affect the propagation (signal path) of radio waves. During daylight hours, incoming solar radiation (ultraviolet and x-rays) causes oxygen and nitrogen atoms in the outer atmosphere to break up into free electrons and ions. This process is called ionization; hence the name, "ionosphere."

These electrified particles tend to be concentrated in bands or layers at various heights above the earth. Radio waves are electromagnetic in nature and may be manipulated by outside magnetic and electric forces, such as the ionosphere. They are often bent and reflected, returning to earth over long distances.

At night the ionosphere is cut off from the sun's direct radiation and the charged particles tend to recombine again to form neutral atoms, thus robbing the upper atmosphere of some of its reflective characteristic.

Because the intensity of the solar radiation changes drastically with time and geographic location, shortwave reception conditions vary widely with the time of day, the seasons of the year and the cyclic changes in solar activity which span a period of about eleven years (the "sunspot cycle"). Even meteors



entering the earth's atmosphere can cause ionization of the air, momentarily affecting shortwave propagation.

Because the density of the atmosphere changes at different altitudes, ionization tends to be concentrated in four distinct layers: at heights of approximately 45 miles (D layer); 75 miles (E layer); 165 miles (F₁ layer); and 250 miles (F₂ layer) above the earth. These heights are approximate and they change from day to night and season to season.

These layers are not sharply defined; each is a fairly thick layer consisting of a region of intense ionization sandwiched between regions of moderate to weak ionization above and below. For example, the band of intense ionization in the F₂ layer is approximately 40 miles thick (see figure 1).

The D Layer

The D layer, being the lowest, is not as intensely ionized as the others. It reaches maximum intensity at about noon, local time, when the sun is highest in the sky, and virtually disappears shortly after sunset when recombinations between electrons and ions occur rapidly because atoms are fairly closely spaced at this low altitude.

For all practical purposes, the D layer does not reflect or bend high-frequency radio waves; instead, the electromagnetic waves are partly absorbed as they pass through this region. The lower the frequency of the HF signal, the more severe the absorption. Thus, the D layer is a nuisance layer for MF (medium frequency: 300-3000 kHz) and the lower range of HF (3000-30,000 kHz) signals

The E Layer

Located only 30 miles or so above the D layer, the E layer is also mostly a daytime phenomenon; however, the intensity of ionization in the E layer is much greater than in the D region. HF signals can therefore be reflected back to earth by the E layer during daylight hours, but recombinations take place after sunset and the E layer practically disappears at night.

Because of its relatively low altitude, the E layer generally results in short-skip propagation, up to approximately 1000 miles.

The F Layers

By far the most important region of the ionosphere for long-distance HF propagation is the F region. Comprised two distinct layers during the day (F₁ and F₂). The F₁ layer actually disappears at night while the highly charged F₂ layer remains ionized around the clock because the recombination rate is slow in this rarefied region of the upper atmosphere.

The height of the F₂ layer varies between 150 and 250 miles on the dark side of the earth, supporting DX (distant) radio communications throughout the night.

Antenna Propagation

As electromagnetic waves escape from a transmitting antenna, they travel outward (propagate) in various directions. Based on their angle of radiation, the waves can be classified into ground waves, direct waves and sky waves (see figure 2).

Ground Waves

Ground waves tend to hug the surface and follow the curvature of the earth. They are subject to absorption by the ground, the amount of which depends upon the nature of the surface (land or water) as well as the frequency of the radio waves.

In general, the lower the frequency the less the absorption, so that while HF ground waves can hardly "get out of town," VLF (very low frequency: 30-300 kHz) and ELF (extremely low frequency: 30-300 Hz) ground waves can be used for long distance communications. As a matter of fact, high-power ELF waves can be used for worldwide naval communications with submerged submarines!

Direct Waves

Direct wave propagation involves waves traveling from transmitting antenna to receiving via a direct path in space, without contacting the ground. Examples include microwave relay towers in TV and telephone networks; the VHF and UHF waves linking TV and FM transmitters to home receiving antennas; and the VHF/UHF waves used by aircraft for communications with control towers and flight service stations.

Direct wave coverage is limited to "line-of-sight" distances; therefore, the higher the antenna, the longer the distance over which reception is possible. The approximate VHF line-of-sight distance (in miles) may be calculated by multiplying the square root of the antenna height (in feet) by a factor of 1.4. For example, the distance from a 900-foot TV tower to the horizon is about $30 \times 1.4 = 42$ miles.

But we shall confine our discussion to short wave signal propagation. Let's move on.

Sky waves: The big hop

Shortwave listeners depend upon the sky wave mode of propagation. The sky wave component of electromagnetic waves emitted by a transmitting antenna travels upwards towards the ionosphere; there, depending upon the density of ionization, the frequency (or wavelength) of the waves, and the angle that they make with the ionosphere, the radio waves may: be bent or reflected back to earth, thus providing useful communications; penetrate right through the ionosphere and be lost in space; or be completely absorbed by the ionosphere, rendering sky wave communications impossible.

Therein lies the somewhat "iffy"--though largely predictable and highly interesting--nature of long distance HF radio communications. Next month we conclude this two part series on signal propagation. ■

