Understanding Solar Indices

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Long distance HF radio communications is made possible by a region of charged particles in the Earth's upper atmosphere, 30 to 200 miles above the Earth's surface. This region is called the ionosphere.

The ionosphere is formed when extreme ultraviolet (EUV) light from the sun strips electrons from the neutral atoms in the Earth's upper atmosphere. The more familiar ultraviolet light has a shorter wavelength than visible light and is more energetic. Extreme ultraviolet light is even more energetic. When a bundle of EUV light (called a photon) hits a neutral atom, such as an oxygen atom, its energy is transferred to an electron in the neutral atom. This additional energy allows the electron to escape from the atom and dart freely around on its own. The neutral atom thereby becomes positively charged, because it has lost a negatively charged electron, and is known as a positive ion. The process in which the photon strips an electron from a neutral atom is known as photoionization. Recombination is the reverse of photoionization. Recombination occurs when a negatively charged electron and positively charged ion combine together again to produce a neutral atom. Recombination occurs continuously 24 hours a day. However, photoionization, caused by the EUV light from the sun, occurs only during day light hours. Thus the level of ionization in the ionosphere increases during the day when EUV light is present and decreases at night due to the lack of EUV energy and the continuous recombination process.

The ions in the ionosphere are too massive to respond to the rapid oscillations of a radio wave and thus have little affect on radio wave propagation. However, the free electrons are over 20,000 times lighter than the ions and do respond to radio wave oscillations.

Three major bands of ionization (called the D, E, and F layers) occur in ionosphere. The F layer (the highest layer) is the one primarily responsible for long distance HF communications.

The free electrons in the F layer, 140 to 200 miles above the Earth, interact with radio waves causing them to bent back toward the Earth's surface. The electrons react easier with low frequency radio waves than with higher frequency signals. As a result, a relative thin F layer will bend low frequency radio waves back to Earth. Long distance communications on the amateur radio low frequency 160 meter (1.8 MHz), 80 meter (3.5 MHz) and 40 meter (7 MHz) bands is possible at night when ionization in the F layer is low. The free electrons do not react as easily with the rapid oscillations of higher frequency radio waves. Thus a higher density of free electrons are required to bend radio waves in the 30 meter (10 MHz) and 20 meter (14 MHz) amateur bands back to Earth. Long distance communications on these bands are typically possible during the day and early evening hours when ionization levels in the F layer are high to moderate. Even higher densities of electrons are needed to bend radio waves in the

17 meter (18 MHz), 15 meter (21 MHz), 12 meter (24.9 MHz), and 10 meter (28 MHz) bands back to Earth. Long distance communications is generally possible on these bands only during the day light hours when ionization in the F layer is greatest. Very high levels of ionization are required to bend signals in the 6 meter (50 MHz) band back to Earth. Ionization in the F layer is never high enough to bend 2 meter (144 MHz), 1.25 meter (222 MHz), 70 cm (420 MHz), and higher frequency waves back to Earth. These radio waves travel through the ionosphere and into outer space. Frequencies in the 2 meter and above amateur bands are thus required for Earth satellite communications since they pass through the ionosphere. Terrestrial communications on these bands are confined to line of sight and repeater operation.

Recombination occurs more quickly in the E layer than in the F layer because the atmosphere at the altitude of the E layer (60 to 70 miles above the Earth) is more dense. Thus the E layer typically exists only during the day light hours. The E layer bends low frequency signals, in the 160 through 40 meter amateur bands, back to Earth during the day, providing short range day time communications on these bands. The electron density in the E layer is not sufficient to bend radio waves above 20 meters (14 MHz) back to Earth.

Recombination occurs very quickly in the D layer which is about 30 to 55 miles above the Earth's surface. The D layer only exists during the day and is not sufficiently dense to bend HF radio waves back to Earth. The primary affect of the D layer is to absorb energy from low frequency radio waves, particularly radio waves in the 160 through 40 meter amateur bands. The 160 and 80 meter bands will typically be dead during the day because of D layer absorption.

Small variations occur daily in the ultraviolet energy received from the sun. On days when relatively high energy levels are received, ionization in the F layer will increase and long distance HF communications will improve. Also, the highest usable HF frequency will increase. For example, the 15 meter band (21 MHz) my be usable for communications with Australia. On low energy level days, the F layer is not as heavily ionized, the highest usable HF frequency decreases, and long distance HF communications deteriorates. During a low energy level day the 15 meter band may be dead with 20 meters (14 MHz) being the highest usable frequency band.

In addition to daily variations, the amount of ultraviolet energy received varies over an 11 year cycle in accordance with sunspot activity on the sun's surface. During a sunspot minimum there will be few if any sunspots visible on the sun's surface, ultraviolet energy from the sun will be at its lowest level, and the 20 through 10 meter amateur bands may be unusable for months at a time due to low F layer ionization. Over the following several years sunspots will gradually appear and increase in number reaching a maximum approximately 5½ years after the sunspot minimum. At the sunspot maximum over 200 sunspots are typically visible. Ultraviolet energy from the sun will be at its highest level during a sunspot maximum and reliable HF communications on the 160 through 10 meter amateur radio bands will be possible on a regular basis. The sunspots will then begin decreasing, causing a deterioration in long distance HF communications, until the next sunspot minimum is reached.

The amount of energy received from the sun is measured daily in terms of the solar flux. The solar flux can vary from as low as 50 to as high as 300. During a sunspot maximum, solar flux values will typically exceed 200 resulting in excellent long distance HF communications on the 20 through 10 meter amateur bands. Solar flux values will range from 50 to 80 during sunspot minimums yielding poor long distance communications with 40 meters (7 MHz) typically being the highest usable frequency band.

An increase in solar flux values for a period of several days generally indicates an improvement in long distance HF communications during that time period. For example, the highest usable frequency will generally increase and HF communications improve if the solar flux has been running about 110 and then jumps to around 130 for several days. In contrast, the highest usable frequency will decrease and HF communications deteriorate if the solar flux instead falls to 90.

Solar Flux	Expected Band Conditions
50 - 70	Bands above 40 meters unusable
70 - 90	Poor to fair propagation on 20 meters and below
90 - 120	Fair conditions up through 15 meters
120 - 150	Fair to good conditions on all bands up through 10 meters
150 - 200	Excellent conditions through 10 meters with openings on 6 meters
> 200	Reliable communications on all bands through 6 meters

The sun is continuously ejecting large quantities of changed particles (atoms stripped of their electrons) into space. Some of these particles eventually arrive at the Earth and interact with the Earth’s geomagnetic field. The amount of charged particles ejected by the sun varies from day to day and also with the 11 year sunspot cycle. The amount of particles arriving from the sun increases as the cycle approaches the sunspot maximum. Small numbers of particles arriving from the sun have relatively little affect on the Earth’s geomagnetic field. Under these conditions the geomagnetic field is considered to be quite. Large numbers of charged particles can cause considerable disturbances in the geomagnetic field. A disturbed geomagnetic field is called a geomagnetic storm.

For any given solar flux value, HF communications will improve when the geomagnetic field is quiet, and worsen during a geomagnetic storm. A geomagnetic storm cause the F layer to become unstable, fragment, and even seem to disappear. Storm conditions are more severe in the regions around the Earth’s magnet poles since the charged particles from the sun are drawn to the poles by the Earth’s magnetic field. As a result, signal paths that traverse the polar regions will be more affected by a geomagnetic storm than signal paths that cross the equator.

The condition of the geomagnetic field is measured in terms of A and K values in accordance with the following table:

A	K	Geomagnetic Field	A	K	Geomagnetic Field
0 - 3	0	Quiet	48 - 79	5	Minor storm
4 - 6	1	Quiet to unsettled	80 - 131	6	Major storm
7 - 14	2	Unsettled	132 - 207	7	Severe storm
15 - 47	3 - 4	Active	208 - 400	8 - 9	Very major storm

The occurrences of solar flares also increases with increasing sunspot activity. A solar flare creates a burst of additional EUV energy and also ejects large quantities of charged particles into space. The EUV energy reaches the Earth in about 8 minutes creating what is know as a Sudden Ionospheric Disturbance (SID). The burst of EUV increases the ionization levels in the D, E, and F layers. The increased F layer ionization may help the propagation of high frequency signals (15 meters and above). However, the increased ionization in the D and E levels may result in the complete absorption of radio signals in the 160 through 40 meter bands and seriously degrade propagation at 30 and 20 meters. A SID may last from a few minutes to several hours, with conditions gradually returning to normal. The charged particles from the flare will arrive at the Earth in 20 to 40 hours. The particles will generally create a geomagnetic storm on their arrival.

Improved HF band conditions are thus indicated by higher than normal solar flux values and low A and K values.

Mid latitude solar indices (solar flux, A, and K values) are broadcast at 20 minutes after the hour by radio station WWV on 5, 10, 15, and 20 MHz. They are also available on the Internet at www.qrz.com and in the K7VVV Solar Updates that are posted regularly on the ARRLWeb at www.arrl.org. The K7VVV updates are very good and provide links to other web sites for more information on solar indices and HF propagation. A good discussion of solar indices is also provided in the September 2002 QST magazine.

K7VVV reports that the solar flux mean for December 26 through January 1 was 117.1 while the planetary A index mean was 17.1. The average daily solar flux for the past six year is shown in the table below:

Year	1997	1998	1999	2000	2001	2002
Solar Flux	81	117.9	153.7	179.6	181.6	179.5

This is an interesting chart since it indicates that the current sunspot maximum, as measured by solar flux values, was reached in 2001. Moreover, solar activity has remained near this peak for the last 3 years!