Understanding Solar Indices

When someone tells you that the flux is up to 200 and the K is 3, do you know what they are talking about?

One of the key skills for any HF DXer is to know how to judge what band conditions may be like. Conditions may be excellent one day with many stations audible from all over the world, but a few days later it may be that only a few stations are audible. To be able to gain an idea about conditions, three main indices are used: solar flux, and the Ap and Kp indices. A good working knowledge of what these numbers represent and what they mean is an advantage even for the ham with most well-equipped station.

Synopsis

The ionosphere can be visualized as containing a number of layers. In fact, there is ionization throughout the ionosphere; the layers are really peaks in the levels of ionization. The ionosphere affects radio waves because according to the level of ionization, the signals are refracted, i.e., bent away from traveling in a straight line. Often the level of ionization is sufficiently high to enable the signals to be returned to Earth.

Conditions are continually varying on the HF bands as a result of the varying levels of ionization in the ionosphere. The radiation, coming chiefly from the Sun, hits the upper ionosphere, causing molecules to ionize, creating positive ions and free electrons. A state of "dynamic equilibrium" exists. The free electrons that affect radio waves recombine with the positive ions to reform molecules.

When levels of ionization are higher (when there are more free electrons) the ionosphere is more capable of bending back radio signals to Earth. Also, high levels of ionization mean high maximum usable frequencies (MUF), and better HF conditions.
The level of ionization at any given point above the Earth is dependent upon a number of factors including the time of day, the season and most important of all the sunspot cycle. It is found that the level of radiation from the Sun increases as the number of sunspots increases. Accordingly, the level of radiation received from the Sun peaks around the top of the sunspot cycle. In fact, it is the bright area just around the sunspot called the plage that emits most of the extra radiation.

It is not all good news, though. At the sunspot peak the level of geomagnetic activity also rises. This happens as the Sun emits vast quantities of particles. There is normally a steady flow of these particles, but at times such as when there are solar flares, the level of these emissions greatly increases. When they hit the Earth's magnetic field it becomes disturbed, creating a magnetic storm that can be detected at points around the globe. Another effect is that the ionosphere itself can be disturbed, giving rise to an ionospheric storm. This will degrade HF communications and when particularly bad it can lead to a total HF blackout. For a more in-depth recap on radio propagation, get on the Web and go to www.radio-electronics.com and navigate from there.

Solar Flux

A measure known as the solar flux is used as the basic indicator of solar activity, and to determine the level or radiation being received from the Sun. The solar flux is measured in solar flux units (SFU) and is the amount of radio noise or flux that is emitted at a frequency of 2800 MHz (10.7 cm). The Penticton Radio Observatory in British Columbia, Canada reports this measure daily. The solar flux is closely related to the amount of ionization and hence the electron concentration in the F2 region. As a result, it gives a very good indication of conditions for long-distance communication.

The figure for the solar flux can vary from as low as 50 or so to as high as 300. Low values indicate that the maximum useable frequency will be low and overall conditions will not be very good, particularly on the higher HF bands. Conversely, high values generally indicate there is sufficient ionization to support long distance communication at higher than normal frequencies. However, remember that it takes a few days of high values for conditions to improve. Typically values in excess of 200 will be measured during the peak of a sunspot cycle with high values of up to 300 being experienced for shorter periods.

Geomagnetic Activity

There are two indices that are used to determine the level of geomagnetic activity: The A index and the K index. These give indications of the severity of the magnetic fluctuations and hence the disturbance to the ionosphere.

The first of the two indices used to measure geomagnetic activity is the K index. Each magnetic observatory calibrates its magnetometer so that its K index describes the same level of magnetic disturbance, no matter whether the observatory is located in the auroral regions or at the Earth's equator. At three hourly intervals starting at 0000 UTC each day, the maximum deviations from the quiet day curve at a particular observatory are determined and the largest value is selected. This value is then manipulated mathematically and the K index is calculated for that location.

The K index is a "quasi logarithmic" number and as such cannot be averaged to give a longer-term view of the state of the Earth's magnetic field. Thus was born the A index, a daily average. At each 3-hour increment the K index at an observatory is converted to an equivalent "a" index using Table 1, and the 8 a-index values are averaged to produce the A index for that day. It can vary up to values around 100. During very severe geomagnetic storms it can reach values of up to 200 and very occasionally more. The A index reading varies from one observatory to the next, since magnetic disturbances can be local.

Table 1

The General Relationship between A and K Values

A	*K*	*Comments*
0	0	Quiet
2	1	Quiet
3	1	Quiet
4	1	Quiet to unsettled
7	2	Unsettled
15	3	Active
27	4	Active
48	5	Minor storm
80	6	Major storm
132	7	Severe storm
208	8	Very major storm
400	9	Very major storm

To overcome this, the indices are averaged over the globe to provide the Ap index, the planetary value.

Similarly, the Kp index is the planetary average of all the K indices at observatories around the globe. Values between 0 and 1 represent quiet magnetic conditions and this would indicate good HF band conditions, subject to a sufficient level of solar flux. Values between 2 and 4 indicate unsettled or even active magnetic conditions, and are likely to be reflected in a degradation of HF conditions. Moving up the scale, 5 represents a minor storm, 6 a larger storm and 7 through 9 represents a very major storm that would result in a blackout of HF communications.

Although geomagnetic and ionospheric storms are interrelated, it is worth noting that they are different. A geomagnetic storm is a disturbance of the Earth's magnetic field and an ionospheric storm is a disturbance of the ionosphere.

Interpreting the Figures

The easiest way to use these figures is to enter them into a propagation prediction program. This will provide the most accurate prediction of what might be happening. These programs will take into account factors such as signal paths because some will cross the poles and they will be far more affected by storms than will those across the equator.

If you don't own propagation software, it is still possible to gain a good insight into what the figures mean purely by assessing them mentally. Obviously, high levels of solar flux are good news. Generally, the higher the flux the better the conditions will be for the higher HF frequencies and even 6 meters. However, the levels need to be maintained for some days. In this way the overall level of ionization in the F2 layer will build up. Typically values of 150 and more will ensure good HF band conditions, although levels of 200 and more will ensure they are at their peak. In this way the maximum usable frequencies will rise, thereby providing good conditions.

The level of geomagnetic activity has an adverse affect, depressing the maximum usable frequencies. The higher the level of activity as reflected in higher Ap and Kp indices, the greater the depression of the MUFs. The actual amount of depression will depend not only on the severity of the storm, but also its duration.

Summary

As a broad rule of thumb, check out the levels of solar flux and the K index.
These figures can be found at a variety of places, including on the Internet at a variety of sites including www.eham.net, www.qrz.com/ , and in the K7VVV Solar Updates that are posted regularly on ARRLWeb at www.arrl.org . If you connect by radio or telnet to a DX spotting network, you can obtain this information by sending the command SHOW/WWV. Please note that the A and K indices broadcast by WWV represent the "mid-latitude" values for Boulder, Colorado, and may not be representative of conditions around the whole world.

For best conditions, the solar flux should remain above about 150 for a few days with the K index below 2. When these conditions have been met, check out the bands and expect some good DX to be about!

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Glossary of Solar Index Terms

ap index: A measure of the general level of geomagnetic activity over the globe for a given day. A mean, 3-hourly "equivalent amplitude" of magnetic activity based on K index data from 11 Northern and 2 Southern Hemisphere magnetic observatories between the geomagnetic latitudes of 46 and 63 degrees.

Ap index: A daily index determined from eight ap index values.

Geomagnetic activity: Natural variations in the geomagnetic field classified into quiet, unsettled, active and geomagnetic storm levels.

Geomagnetic storm: A worldwide disturbance of the Earth's magnetic field, distinct from regular diurnal variations. A storm occurs when the Ap > 29, a minor storm when 29 < Ap < 50, a major storm when 50 <= Ap < 100 and a severe storm when Ap >= 100.

K index—A quasi-logarithmic local index of the 3-hourly range in magnetic activity relative to an assumed quiet-day curve for a single geomagnetic observatory site. First introduced by J. Bartels in 1938, it consists of a single-digit 0 through 9 for each 3-hour interval of the universal time day (UT).

Kp index—The planetary 3-hour-range index Kp is the mean standardized K-index from 13 geomagnetic observatories between 44 degrees and 60 degrees northern or southern geomagnetic latitude. The scale is 0 to 9 expressed in thirds of a unit; e.g., 5– is $4^{2}/_{3}$, 5 is 5 and 5+ is $5^{1}/_{3}$. This planetary index is designed to measure solar particle radiation by its magnetic effects. The 3-hourly ap (equivalent range) index is derived from the Kp index.

Note: Kp, Ap and other indices can be downloaded via FTP at ftp.ngdc.noaa.gov/STP/GEOMAGNETIC_DATA/INDICES/KP_AP/. Indices can also be downloaded from www.sec.noaa.gov/Data/alldata.html.

From "A Glossary of Space Weather Terms" (www.irfl.lu.se/HeliosHome/spacew9.html) and the National Geophysical Data Center Web site (www.ngdc.noaa.gov/stp/GEOMAG/kp_ap.html).