Propagation, Space Weather, and You

By Tomas Hood, NW7US

For many of us radio hobbyists, the sheer thrill of the hunt keeps us coming back into our radio shack to tirelessly tune the radio spectrum for interesting signals. Whether the hunting ground is the shortwave segment from 300 kilohertz to 30 megahertz, or perhaps the public service or military allocations on the VHF and UHF spectrum, I've been known to happily pass hours and days with pen and paper in hand recording anything I can hear. Much to the grief of friends and family, such unplanned expeditions through the electromagnetic radio signal landscape can result in too much time spent on the hunt.

Experienced VHF and UHF scanning enthusiasts can attest to the wisdom of limiting the spread of frequencies that should be scanned for new signals. Too wide a spread and the odds of actually catching a real transmission become unrealistic. Hunting on shortwave can be even more daunting, as you search for that needle in a haystack.

Even so, I've heard amateur radio operators chatting on late-night "round table" frequencies expressing such sentiments as, "I don't really need to know what the Sun is doing, I just get on the air and try my luck at catching some DX," or, "I like the thrill of the hunt; get on the radio, tune around, and just see what I can catch," or other such comments that convey the idea that exploring the science of propagation is a waste of time. A great many folks just throw up their hands at the idea of figuring out the mystery of space weather and how to predict when and where to operate on the high frequencies. Some operators have gone so far as to tell me that trying to forecast propagation conditions and plan their operation accordingly seems unsportsmanlike!

Sure – I, too, have fully enjoyed the sheer joy of randomly picking a range of frequencies and patiently tuning around to find new and exotic signals. What a pleasure to discover a radio broadcast from South Africa or the Near East. When such finds are an unplanned surprise, the warm feeling is almost like meeting a new friend. And, I did not need to know any propagation science to have a most exciting radio experience.

I've done the same thing on a lazy summer day: I grab some fishing bait, my fishing pole, some snacks, and head up a hiking path to a favorite fishing hole. I sit on the banks of the water, casting a line out randomly, while drinking in the sounds and sights of nature while hoping for a bite. It has been fun "trying my luck," fishing with no plan and no real skill. It is more than fishing: It is simply enjoying the out-of-doors.

However, there are those times when I'm out camping, and I'm hungry for a real tasty trout dinner. With a limited budget of time and bait, I want to maximize my fishing endeavor. Under these constraints, I might want to know when and where to fish.

It is considered good sportsmanship to acquire the type of equipment that helps the fisherman, or the hunter, to find and secure the hunted. A lot of money is spent for sonar, bait, scents, or anything that might give an edge to the hunt. Sports enthusiasts want to maximize their investment in time, energy, and expense.

Wouldn't it then make sense that the radio hobbyist might want to build better antennas, study space weather, apply the tools of propagation forecasting, and hone operating skills? Of course!

The logical question that arises when planning a hunting expedition on HF radio (whether a real DXpedition, or simply an afternoon or evening listening session) is, "What frequencies are most likely to be active during my operating time?" Or, "When should I turn on my radio so I can hear a particular area of the world?" Or simply, "When will good propagation occur?"

Answering these questions with some accuracy helps you plan when to set aside some time in a busy family schedule for "hunting." If you were to know that conditions are likely to be lousy this weekend but great next weekend, then you might want to plan your lawn mowing for this weekend and have the next weekend for a mini DXpedition from your favorite campground, where you could put out a Beverage antenna and catch some nice foreign signals.

Some Basics

Before an answer can be found as to when propagation will be "good," some basic concepts need to be understood about how shortwave radio signals propagate and what factors contribute to that propagation.

When talking about radio signal propagation on shortwave (the high frequency spectrum), we're most interested in receiving signals that originate from stations far away, beyond line of sight. After we move far enough away from a transmitting station and are no longer in a direct line-of-sight view, there are generally two paths that a radio signal travels (or, propagates). One path is along the ground, and propagation along this path is known as *groundwave propagation*. The other is known as *skywave propagation*.

Groundwave propagation describes how a radio wave travels away from the transmitting source, out along the surface of the Earth. In a sense, the radio signal hugs the surface for great distances as it moves out away from the generating source, bending with the curve of the Earth, until the energy of the radio wave is absorbed. Groundwave propagation is most efficient at lower frequencies where absorption is low. Groundwave is especially efficient in the low frequency (LF or longwave, 30-300 kHz) bands and below, and somewhat useful in the medium frequency bands (MF or MW, 300 kHz-3 MHz), home of domestic AM broadcast stations.

Skywave propagation describes how a radio signal that radiates up and away from an antenna is reflected or refracted by the ionosphere back toward the Earth at the opposite angle from its source, causing the radio wave to reach very distant areas. A simple way to visualize this ionospheric "bounce" is to think of the reflection of a beam of light from a flashlight. When you stand off to the side of a mirror and shine the flashlight at an angle toward the mirror, the beam will be reflected at the same, but opposite angle, toward a distant spot.

When shortwave radio signals spread out away from their source and reach the ionosphere, they may be reflected back toward the Earth. They might make such "hops" more than once, bounced back toward the ionosphere by the Earth, repeating this skip several times or more. In this way, skywave propagation allows a signal to reach around the world.

Groundwave tends to lose its energy through the loss it experiences traveling along

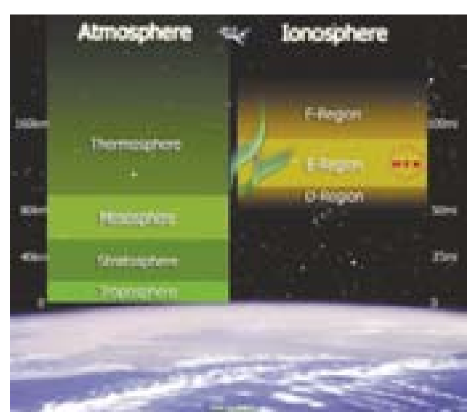

Figure 1: The ionospheric regions in relation to Earth's atmosphere. The ionosphere is composed of three main parts: the D, E, and F regions. Credit: HEX (Horizontal E-Region Experiment)

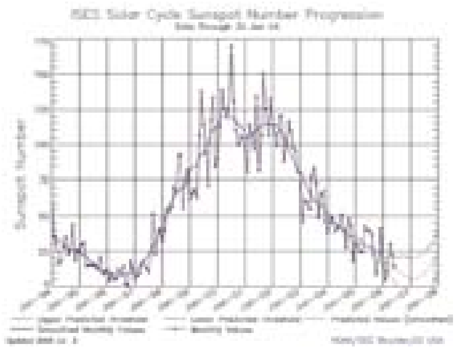

Figure 2: Sunspot Cycle 23. Source: NOAA/SEC Boulder, CO

the surface of the Earth. While skywave can be absorbed at certain frequencies in the lower regions of the ionosphere, skywave experiences much less attenuation because the majority of its journey is through the atmosphere.

At night, mediumwave signals and the lower shortwave frequency signals travel better by skywave. During the day, mediumwave signals tend to be absorbed by the lowest regions of the ionosphere, so tend to only be received by groundwave propagation. Higher shortwave frequencies may be propagated during the day by skywave, depending on the condition of the ionosphere.

Competing with these signals arriving by way of the ionosphere and earth-sky-earth bounces is interference from noise or other transmissions. In the case of noise, it could be that the noise you are hearing has been propagated from very distant sources. In addition to man-made noise, atmospheric noise from lightning and static electricity reduce the effectiveness of the signal you are hunting.

Since skywave depends completely on the condition of the ionosphere, let's take a quick look at this region of our atmosphere.

What is the Ionosphere?

Earth's atmosphere is a mixture of gases held to the surface of the Earth by gravity. These gases vary in density and composition as the altitude increases above the surface. As the atmosphere extends outward from Earth, it becomes thinner and blends with particles of interplanetary space (see figure 1).

The first sixty miles of Earth's atmosphere consist of a homogeneous mixture of various gases. This region is called the homosphere. Above the homosphere lies the heterosphere, where the gases are no longer uniformly mixed. Relatively more of the heavier gas molecules are found near the bottom of this region, and relatively more of the lighter gases are found hear the top.

The atmosphere is also divided into four regions according to temperature trends: the troposphere, the stratosphere, the mesosphere, and the thermosphere. The lowest region is the troposphere, which extends from the Earth's surface up to about six miles. The gases in this region are heavier than those in higher altitudes. The atmosphere above the troposphere is called the stratosphere, starting at about six miles out. Gas composition changes slightly as the altitude increases and the air thins. Incoming solar radiation at wavelengths below 240 nanometers is able to create ozone, a molecule of Oxygen consisting of three Oxygen atoms (O_3), in this layer. This gas reaches a peak density of a few parts per million at an altitude of about 16 miles.

At altitudes above fifty miles, the gas is so thin that free electrons can exist for short periods of time before they are captured by a nearby positive ion. The existence of charged particles at this altitude and above marks the beginning of the ionosphere, a region having the properties of a gas and of plasma.

Above the ionosphere, a vast region of charged particles known as the magnetosphere is formed by the interaction between the solar wind and the Earth's magnetic field. The magnetosphere begins at about 600 miles above the Earth's surface. It extends to a distance of about 40,000 miles on the side facing the sun, and to even greater distances on the side of the Earth that is turned away from the sun.

How is the Ionosphere Formed?

Much of the energy from the sun that reaches our atmosphere is absorbed. All of the hazardous ionizing radiation, gamma rays and x-rays are blocked before they reach the surface. Much of the ultraviolet radiation from the sun is also absorbed. The deepest-penetrating of these waves is in the ultraviolet range. The atmospheric ozone layer is the greatest absorber of ultraviolet radiation.

Atoms in the ionosphere absorb the incoming solar radiation, causing them to become highly excited. When an atom becomes energized, an electron may break away from its orbit. This produces free electrons and positively charged ions. Since the photons of energy at these ultraviolet and shorter frequencies are capable of dislodging an electron from a neutral gas atom or molecule during a collision, solar radiation at ultraviolet and shorter wavelengths is considered to be "ionizing."

At the highest levels of the Earth's outer atmosphere, solar radiation is very strong, but there are few atoms to interact with, so ionization is small. As the altitude decreases, more gas atoms are present, so the ionization process increases. At the same time, however, an opposing process called *recombination* begins to take place in which a free electron is "captured" by a positive ion if it moves close enough to it. As the gas density increases at lower altitudes, the recombination process accelerates, since the gas molecules and ions are closer together.

Because the composition of the atmosphere changes with height, the ion production rate also changes, and this leads to the formation of several distinct ionization regions, known as the D, E, and F layers (the F layer splits apart into three layers, F1, F2, and F3). The boundary between layers is based on what wavelength of solar radiation is absorbed in that region most frequently.

The D region is the lowest in altitude, though it absorbs the most energetic radiation, known as hard x-rays. The D region doesn't have a definite starting and stopping point, but includes the ionization that occurs below about 56 miles. This region absorbs high frequency (HF) waves between 3 and 30 megahertz or wavelengths between 100 meters and 10 meters. It refracts frequencies in the range of 3 to 30 kilohertz (very low frequencies, or VLF).

The D region is a daytime layer, due to the density of the gases. Absorption of ultraviolet and visible light radiation creates more negative ions than electrons during the day. At night these ions quickly recombine with other ionic particles, and the layer all but disappears. (Without going into great detail, the D region doesn't really disappear at night. VLF communication circuits depend on the D region ionosphere in both day and night.)

The E region of the ionosphere extends from about 56 miles to about 65 miles, where the air is considerably thinner than the layers below it. As a result of this thin air, there are fewer collisions of ions and electrons, resulting in a population of molecular ions. The E region absorbs soft x-rays. This layer is highly variable from day to night.

The F region is the largest part of the ionosphere, as well as the highest. It extends from about 65 miles up through the end of our atmosphere. Since particle densities decrease as you travel away from Earth, it is difficult to say exactly where our atmosphere ends. Since it is such a large region, the F layer is primarily divided into two sections, the daytime layer, F1, and the denser F2 region which exists during both day and night.

In the upper reaches of the ionosphere, gravity has a lessening effect on particles. As a result, particles create different layers depending on their mass. The heavier particles sink to the bottom of the F region and the lighter ones rise to the top. This explains why electron density increases with altitude.

Along the day / night meridian, electron numbers rise and fall. At sunset, electron numbers decrease, due to the recombination of these particles with ions in the F1 layer during the night. On the sunrise meridian, electron numbers increase as neutral molecules and atoms absorb solar radiation, mostly ultra-violet.

The F3 region has been discovered recently, and has only been observed as mostly existing during the high-noon hours over the low equatorial latitudes. The lowest of the F regions is the F1 region, and the highest is the F3 region.

Radio Waves in the Ionosphere

As an electromagnetic wave enters the ionosphere at the D layer, the energy sets electrons in motion. Because this layer is so dense, there is a high probability that the energy will be absorbed in a collision with nearby molecules. The electromagnetic energy is turned into kinetic energy (heat) and, as far as radio propagation is concerned, is lost. The higher the frequency and the shorter the wavelength, the higher the energy, but also the fewer collisions between free electrons and gas molecules than at lower frequencies. As a result, lower frequency signals are attenuated far more than those at higher frequencies. It is possible that the lowest frequencies are completely absorbed, while higher frequencies will make it through to the E layer.

Since the E layer is less dense than the D layer, electrons are not so quickly recombined with neighboring atoms, so losses are lower. Because these electrons are not as quickly bound with other atoms, losing energy, the electromagnetic wave is re-radiated. Because the signal is traveling in an area where electron density is increasing, the farther it will go. At the same time, the wave is bent away from the denser, and higher, area of electrons. The amount of bending, or refraction, is dependent on the frequency of the wave. The higher the frequency, the more energy that wave has, and the more likely it is to pass through the layer to reach the next higher region.

When an electromagnetic wave enters the F layer, the same science takes place. The radio signal rides the free electrons of this layer, and if the frequency of the signal is high enough, it will pass through the layer, out into space. Otherwise, it will gradually bend back away from the higher and denser layers of electrons to be sent back toward Earth.

Those frequencies that are refracted back to Earth have to pass through the lower ionospheric layers, again. D layer absorption will attenuate the signal some more. If there is enough energy in the signal, the wave may bounce between the Ionosphere and Earth multiple times, greatly extending the distance it can travel. Other times, it might be so absorbed that no communications are possible. Yet at other times, a radio wave will enter the Ionosphere, bounce off of the F layer, but then refract back up away from the E layer, doing these multiple hops until it can punch back through the E layer and back to Earth.

All of this depends on how ionized the gases become in these various layers and how dense each layer is, as well as the strength, angle of incidence, and frequency of the radio signal. Ionization depends on the direct energy from solar radiation. Would all of the layers of the Ionosphere perform identically if they each received the same amount of solar energy? No; because of the different gases found in each layer and the density of those layers, each layer has unique characteristics.

Sunspots and the Ionosphere

As you might have guessed, since the ionosphere depends on solar radiation for its existence, and since radio waves are refracted by a strongly energized ionosphere, the level of activity on the Sun is tied to radio signal propagation.

The Chinese and many other early civilizations were the first to discover sunspots. Since the time of Galilea Galileo, who made the first European observations of sunspots in 1610, observers and scientists have discovered a great deal about the Sun and its influence on the Earth and our atmosphere. Daily sunspot observations were started at the Zurich Observatory in 1749. By 1849, continuous sunspot observations were being recorded.

Over time, cycles in solar activity were revealed. The Sun's sunspot activity has a cycle that lasts for an approximate eleven year period (see figure 2 for the current cycle, Cycle 23). The cycle starts quietly with very few sunspots, peaking about three to five years later with a very high number of daily sunspots, and then decreasing in sunspot activity until the end of the solar cycle.

The sunspot number is calculated by first counting the number of sunspot groups and then the number of individual sunspots. The "sunspot number" is then given by the sum of the number of individual sunspots and ten times the number of groups. Since most sunspot groups have, on average, about ten spots, this formula for counting sunspots gives reliable numbers even when the observing conditions are less than ideal and small spots are hard to see. It is these monthly averages of the sunspot numbers that show us the eleven year cycle in the number of sunspots visible on the Sun.

Sunspots are regions on the Sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field. Plasma flows in these magnetic field lines.

Visually, sunspots appear as dark spots on the surface of the Sun. Temperatures in the dark sunspot centers (the "umbra") drop to about 3700 K, compared to 5700 K for the surrounding photosphere. This difference in temperatures makes the spots appear darker than elsewhere. Sunspots typically last for several days, although very large ones may live for several weeks. They are seen to rotate around the sun, since they are on the surface, and the sun rotates fully every 27.5 days.

Sunspots usually form in groups containing two sets of spots. One set will have a positive or north magnetic field while the other set will have a negative or south magnetic field. The magnetic field is strongest in the darker parts of the sunspot. The field is weaker and more horizontal in the lighter part (the "penumbra").

Sunspot numbers give us a way to measure the sun's overall activity. The more active the Sun, the higher the sunspot count. Scientists have discovered a direct correlation between the Sun's sunspot activity and our ionospheric activity. The more sunspots observed, the greater the ultraviolet energy bombarding the Earth. Since the ionosphere is formed by the ultraviolet energy from the Sun, the more sunspots on the Sun, the more energized the ionosphere becomes.

By keeping close record of the sunspot number and the overall propagation conditions, scientists have developed models that help us forecast HF communication openings on any given path. Of course, there are some other space weather events that also influence the condition of the ionosphere and the Earth's geomagnetic field. But, in basic terms, the Sun's sunspot cycle directly relates to shortwave radio signal propagation.

Related to sunspot counts is the 10.7-cm flux measurement. This is a measurement of the strength of the 10.7-cm radio signal arriving from the Sun. This frequency is most closely associated with the ultraviolet energy level of the Sun, so it gives us a highly accurate gauge of how much energy is entering the ionosphere. When we look at the daily measurements of the 10.7-cm solar flux, we find that the higher this reading, the more ionized these various layers become, making it possible for higher shortwave frequencies to propagate by refraction over great distances. When the flux readings are low, the ionosphere is weaker, and only the lower shortwave frequencies will be propagated. Of course, there are many variations during the day, between regions in daylight and darkness, and from season to season.

The method used to chart the monthly solar activity is known as the Smoothed Sunspot Number, or SSN. It is important to understand that when you see the acronym SSN, it does not mean Sun Spot Number. It means Smoothed Sunspot Number, and is an average of 13 monthly RI numbers, centered on the month of interest. The RI number refers to the daily index of sunspot activity (R), defined as R = k (10 g + s) where S = number of individual spots, g = number of sunspot groups, and k is an observatory factor.

The Current Solar Cycle 23

The current sunspot cycle, number 23, started in 1996. Two activity peaks were observed: The monthly smoothed sunspot number first peaked at 120.8 during April 2000, with a second but lower peak at 115.6 for November 2001. Since these two peaks, we have seen a steady decline in the cycle's activity. Many experts feel that this cycle will end during the beginning of 2007, and the next sunspot cycle will begin.

Taking this into consideration, is there much hope for hearing rare or weak shortwave stations when the ionosphere is at its least energetic state in the current sunspot cycle? The short answer is, yes, but only on the lower frequencies of the shortwave spectrum, and only during certain times of the day and year.

Knowing the best times to catch a station can make your DX chasing more successful. You need to know when propagation will be best, as well as when a station is transmitting. Using the listings included in this magazine, as well as other resources such as various lists on the Internet (for instance, my listings at **http://swl.hfradio.org**/), you can determine the windows of time in which you might hunt for a station.

Armed with the times and frequencies, the next step is to do some propagation forecasting. The idea is to look for times when propagation is predicted to be good enough for a station's signal to propagate between its transmitter and your listening location.

Coming Full Circle

Back to the question at hand: When will good propagation occur?

When the question is asked, "When will good propagation occur?" the reader should look at more factors than just concentrating on the space-weather environment. The other factors that affect propagation are radio circuit path length and orientation, frequency, diurnal effects, as well as the transmitter power and antenna gain, and the parameters of the receiving station. Space weather and geophysical (weather, geomagnetic field, location) factors are not changeable by the average radio hobbyist. The rest of these factors are those you can control.

Whether you are an amateur radio operator or a shortwave listener, noise is always a factor limiting what you can hear. But noise is only one aspect of HF reception. The varying ionosphere makes even powerful broadcast signals come and go, and it's hard to know what to expect when you settle down for an evening of shortwave listening. Of course, you can always tune to the frequency where you last heard a favorite station, but if there is noise yet no radio signal, what then? It's frustrating to just *listen in the blind.*

Trying to figure out this complex relationship between the sunspot activity, the ionospheric conditions, signal path losses, and antenna patterns is nearly impossible if you depend on mental calculations or a notepad and pencil to work out the formulas and graphs. But fortunately, software tools have been created to assist you in planning your communications over radio signal paths between point A and point B. In addition to doing all the computations for you, the most accurate of these software tools use HF propagation models developed over a very long period of observation and validation.

HF Propagation Models: A Brief History

HF propagation models have a long history of development, going back to the U.S. Army's *Ionospheric Radio Propagation Technical Report #9*, published by the National Bureau of Standards in 1948. The Institute for Telecommunication Sciences and Aeronomy released the first computer prediction program called ITSA-1 in 1966.

Then a second generation of ionospheric prediction programs, ITS-78, sometimes called HFMUFES-4, was developed in 1969. This led to continued work by the National Telecommunications and Information Administration's *Institute for Telecommunication Sciences* (ITS), and the well-known IONCAP model – the third generation of HF predictions programs – was eventually released to the public.

In 1985, the Voice of America selected IONCAP for their modernization program and launched a model improvement project with development by the Naval Research Laboratory, ITS, and the VOA staff led by Mr. George Lane. The NRL effort found many coding errors in IONCAP and together with ITS, added new capabilities such as area coverage predictions. The result was named VOACAP (Voice of America Coverage Analysis Program) and was released to the public in 1993. Since that time, VOACAP has been maintained by ITS in Boulder, Colorado.

Because of its decades of historical development and the many years of validation through VOA listener reports, VOACAP has emerged as the *gold standard* of HF propagation models. It is used throughout the world by government and amateur radio operators, as well as by international broadcasters. VOACAP was calibrated through measurements made during a wide range of environmental conditions, so that the resulting Signal-to-Noise Ratio (SNR) distributions implicitly include the effects of a range of disturbed conditions. The range of environmental effects is built into the model, and shows up in the statistical factors. From a radio hobbyist standpoint, it's a relief to know that even with these credentials, VOACAP is still easier to use than other models where such factors must be laboriously worked out and inputted.

ACE-HF PRO, version 2.05

One powerful and popular software package used by shortwave radio listeners and amateur radio operators alike is ACE-HF, which selected VOACAP for its computational model. The programmers of ACE-HF work directly with ITS personnel to develop new capabilities. ACE-HF funded ITS to implement the new reception area coverage predictions, which are so important to SWL enthusiasts.

Other ham radio programs utilize VOACAP, as well. However, for the purpose of illustrating concepts in this article, I have chosen to use ACE-HF because of its close tie with current VOACAP development.

If you are an amateur radio operator, you have probably heard of the *ACE-HF System Simulation and Visualization Software* that was first released several years ago. This year, a much more powerful version 2.05 has been released which is specifically designed for shortwave listeners as well as hams.

ACE-HF is derived from the professional ACE-HF Network software for government and commercial HF network operators. "ACE" stands for *Animated Communications Effectiveness*, the copyrighted technique for displaying both transmission and reception coverage on maps of the world. This key feature yields great insight into the coverage achieved by any HF station, but is especially helpful to see whether a particular broadcaster covers your listening post. You can also simulate a point-to-point circuit from any world location to your station and show the predictions graphically. All ACE-HF charts may be animated – one of the hottest features of the program.

New in this year's version are many features that will benefit both hams and SWLs. You can easily switch the software from Ham Radio mode to SWL mode. In the SWL mode, the transmitter can be set to any location, and you can pick from a database of at least 642 International Broadcast transmit locations. You can now select from thirteen service types, including many digital modes. Simulations of both ALE and conventional HF operation can now be made – features of interest to hams experimenting with Automatic Link Establishment operation as well as to utility listeners.

Antenna Tricks

Perhaps the most interesting new capability is enhanced antenna analysis. In addition to the built-in HFANTENNA program (with which you can analyze and view antenna patterns for the many supplied antenna models or for models that you create), there is a new animated chart for comparing antenna patterns with predicted elevation angles.

One of the most vexing problems in choosing antennas for your station is to figure out the best vertical radiation pattern for a given circuit. This problem is particularly troublesome when short circuits that rely on NVIS (Near Vertical Incidence Skywave) propagation must be accommodated. For NVIS, a simple vertical monopole simply won't do. But at what distance will each circuit work well with your favorite antenna?

The new ACE-HF Antenna Analysis Chart automatically graphs the antenna's vertical acceptance (take-off) pattern, along with elevation angles of the arriving propagation modes. The chart may be animated through the user's selected frequencies, and directivity gain is given for each. You can select different antennas without leaving the chart, so comparisons can easily be made. This chart is great fun to play with, and will quickly become a favored tool in your radio operation toolbox.

Putting ACE-HF to Work

If you look at the two Area Coverage Maps I created using ACE-HF PRO's animated coverage feature, you can see how the sunspot activity level affects the propagation of a 14 MHz radio signal from my location. I created one coverage map (figure 3) for the peak of the solar cycle, and the other for this year (figure 4). Each is run for the same month of the year (September), using the same antennas, power level, and so on. The only change between the two maps is the year in the current solar cycle. As you can see, during the peak of the solar cycle, a 14 MHz signal propagates over greater areas than during the minimum period of solar cycle activity.

The next two maps (figures 5 and 6) show the same comparison, but with a different antenna. Notice how drastically different the results are with this other antenna (a Yagi, instead of an isotropic antenna). This illustrates that good propagation depends on more than just space weather, but also on your equipment!

The next comparison I made using ACE-HF is for the circuit between my location in Washington State and a station in Sierra Leone (9L prefix). This time, I chose January as the month, and again chose for the first chart a smoothed sunspot count typical of the solar cycle maximum, and for the second chart, the sunspot count for this year in January. As you can see (in figure 7), during the peak of the cycle, at 1900 UTC, 10 meters is hot! But, this year, the best bands, using the same time, antenna type and power level, are 17 meters and 15 meters (figure 8). Ten meters is dead.

Listening from Riyadh

To investigate the world of international broadcasting on shortwave, I used ACE-HF PRO to simulate a shortwave circuit from the well-known WWCR (Worldwide Christian Radio) station in Nashville, Tennessee, to my pretended location in Riyadh, Saudi Arabia. There is an HFCC (High Frequency Co-or-

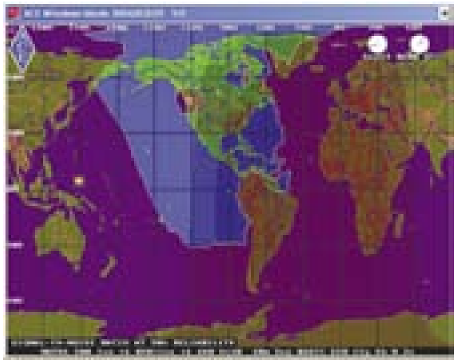

Figure 3: One slide from the ACE-HF PRO v2.05 Animated Coverage Area based on the solar cycle maximum, from NW7US in Washington State at 0200 UTC in September.

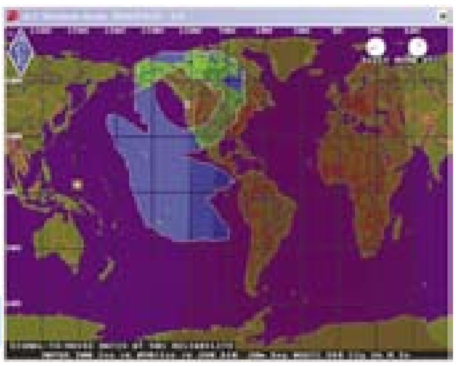

Figure 4: One slide from the ACE-HF PRO v2.05 Animated Coverage Area based on the solar cycle minimum, from NW7US in Washington State at 0200 UTC in September.

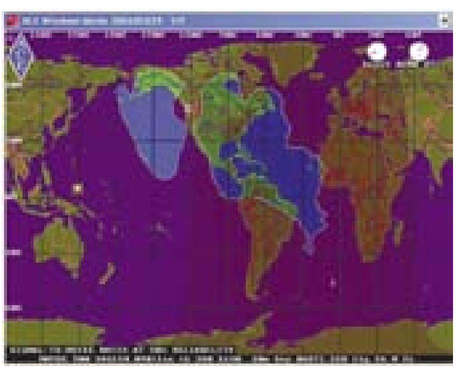

Figure 5: One slide from the ACE-HF PRO v2.05 Animated Coverage Area based on the solar cycle maximum, from NW7US in Washington State at 0200 UTC in September.

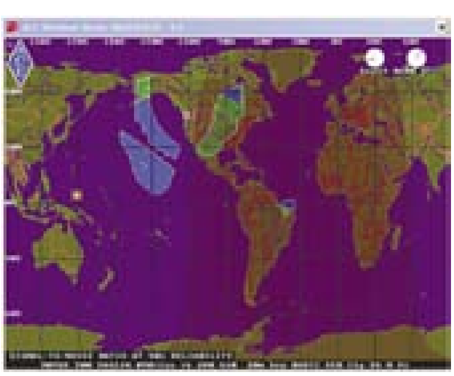

Figure 6: Same as Figure 5, but with a different antena.

Figure 7: Band opening chart created by ACE-HF PRO v2.05 for the circuit between Washington state and 9L, Sierra Leone, Africa, in January during the solar sunspot cycle maximum.

Figure 8: Band opening chart created by ACE-HF PRO v2.05 for the circuit between Washington state and 9L, Sierra Leone, Africa, in January during the solar sunspot cycle minimum.

dination Conference) database of over 640 International Broadcast transmit sites that has a new sorting feature, so I was able to quickly select the WWCR station.

I set WWCR's transmit power at 100,000 watts and selected the CONST17.VOA antenna from the more than 660 HFCC antenna models now included in ACE-HF. This general purpose 17-dBi, omni-directional antenna is recommended by the Voice of America, but I could have selected another one of the HFCC models that include curtain arrays with up to 30-dBi gain. I assumed the SWWHIP.VOA antenna for my receiver. And I selected the AM service type, although I could have chosen the new IB service type for commercial quality HF reception.

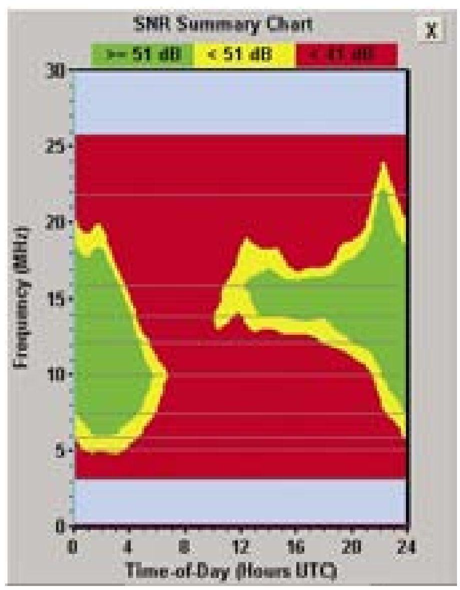

Figure 9: Summary Chart by ACE-HF PRO showing the signal-to-noise ratio between WCR and Riyadh, Saudi Arabia.

The ACE-HF design assumes that the user employs International Broadcasting schedules as posted on the Internet, where details such as transmit power, azimuth (main beam) angles, frequencies and time schedules are readily available. Two good sources for this rapidly changing data are **www.hfcc.org**, and **www.ilgradio.com/ilgradio.htm**. (Don't forget that I also have shortwave broadcast search tools at **http://hfradio.org/swbc/**).

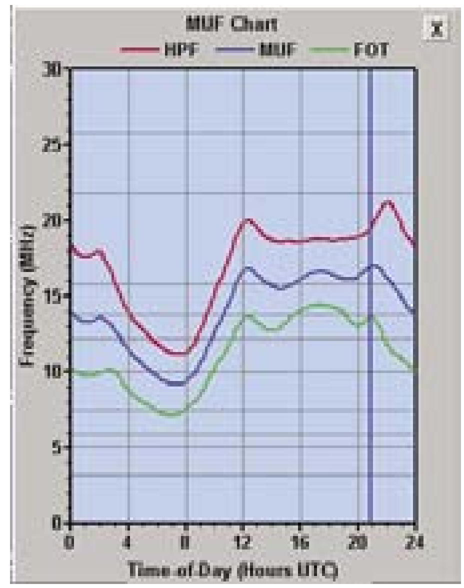

Figure 10: Maximum Usable Frequency graph by ACE-HF PRO showing the MUF during one full 24 hour period, between WCR and Riyadh, Saudi Arabia.

All these adjustments take more time to read about than to set up, so I just clicked on *Run Circuit Predictions* to see the prediction charts for my circuit. I always look first at the Signal to Noise Ratio (SNR) Summary Chart,

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SMOOTHED SUNSPOT NUMBERS FOR CYCLE 23

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	10	10	10	9	8*	9	8	8	8	9**	10	10
1997	11	11	14	17	18	20	23	25	29	32	35	39
1998	44	49	53	57	59	62	65	68	70	71	73	78
1999	83	85	84	86	91	93	94	98	102	108	111	111
2000	113	117	120	121	119	119	120	119	116	114	113	112
2001	109	104	105	108	109	110	112	114	114	114	116	115
2002	114	115	113	111	109	106	103	99	95	91	85	82
2003	81	79	74	70	68	65	62	60	60	58	57	55
2004	52	49	47	46	44	42	40	39	38	36	35	35
2005	35	34	34	32	29	29	29	28	26	26	25	23
2006	*21*	*18*	*16*	*15*	*15*	*13*	*11*	*11*	*10*	*9*	*8*	*7*
2007	*5*	*6*	*6*	*6*	*7*	*8*	*10*	*11*	*13*	*16*	*18*	*21*

* May 1996 marks Cycle 23's mathematical beginning.
** October 1996 marks the beginning of Cycle 23 according to a consensus of scientists, which NGDC is now using.
Notes: Predicted values start in January 2006.
End of Cycle 23 will be sometime between December 2006 and February 2007.

However, if you're planning on using a loop antenna for transmitting, there are several safety concerns of which you need to be aware. First, even with the MFJ 932 Mini-Loop Tuner at QRP (low power levels), the loop is "hot" while transmitting. You could get a serious RF burn by coming into contact with the loop.

Secondly, because the antenna is in the same room as the operator, you'll be in the RF field generated by the antenna. MFJ advises users to become familiar with FCC OET Bulletin 65 Version 97-01 **www.fcc.gov/oet/rfsafety**. This bulletin, an 84 page highly technical document, offers guidelines and suggestions for complying with human exposure to RF fields adopted, but not mandated, by the FCC. The relevant material regarding amateur radio is from pages 20 to 23.

I operated using only 5 watts, which comes well under the safety concerns; still, I would not want pets sticking their noses on the antenna while I was transmitting or having children in the area. You'll have to use your best judgment operating a loop in your home.

❖ Last Word

The MJF 932 Mini Loop Antenna tuner is not cheap ($99.95 plus shipping), and you'll still have to make your own loop. For SWLers I would recommend the 1020C Active SWL indoor antenna rather than the 932. It's easier to use, takes up less desk space, improves reception even on portable shortwave radios, is effective over a broader range, and is $20 cheaper.

Hams seeking to transmit from the cramped confines of their apartment or condo may find the 932 just the ticket. But, at low operating power it will be frustrating, to say the least. Consider other alternatives such as an MFJ 1622 Apartment Antenna, which is the same price as the 932 and removes the antenna from the immediate living space. It also comes with coax feed line, RF choke, and mounting bracket. Or, you could use the MFJ 16010 Random Wire tuner in conjunction with a random wire antenna you may already be using as an SWL antenna or with the PAR High-Performance "End Fedz" shortwave antenna.

(All photos courtesy MFJ Enterprises)

MFJ 1622 Apartment Antenna covers 40 through 2 meters, mounts to windows or balcony railings and comes with mounting bracket, coax feed line and RF choke for $99.95.

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figure 9, and it wasn't surprising to see that this long circuit of nearly 12,000 km favored the higher frequencies. This was confirmed by the MUF (Maximum Usable Frequency) Chart, figure 10, which showed a median MUF of about 16 MHz at the current time-of-day (about 2100 UTC). And finally, the SNR chart, figure 11, for WWCR's 15.82 MHz frequency, predicted *good* connectivity at the current time.

Already, I was ahead of the game. I could now tune to 15.82 MHz with confidence, and the program should be heard loud and clear at my Riyadh listening post!

Who else could I hear from my Riyadh location? ACE-HF can make Reception Area displays to show areas covered from your location, and an example is shown in figure 12. This figure shows 15.82 MHz at 2100 UTC, but the display can be animated over a range of frequencies or times of day. Since the receive location was fixed, the software, in its complex scientific number crunching, effectively moves the transmitter all over the world to create a display of good reception coverage. Using an average up-to-date computer with 1.8 GHz processing speed, I ran 61 by 61 points, times 10 frequencies, times 24 hours. That equals 893,040 equivalent point-to-point circuit predictions, which only took a little over 2 minutes to complete!

Folks often ask which propagation program is the most accurate. Some years ago, the U.S. Navy funded the authors of ACE-HF to determine which HF propagation program was the most suitable for their HF networks. The resulting study selected VOACAP as the most highly validated model. During its development, every potential improvement on VOACAP was subjected to more than 500,000 circuit path-frequency hours comparisons with field data for paths at all latitudes and ranges.

If you have questions about ACE-HF PRO, you may contact Dick Buckner at *RichardPBuckner@cs.com*. My in-depth reviews are provided at **http://hfradio.org/ace-hf/**.

What will Sunspot Cycle 24 be like?

In March 2006, a team led by Mausumi Dikpati of the National Center for Atmospheric Research (NCAR) announced that the next cycle, 24, will be the most intense solar maximum in fifty years. They forecast that the next sunspot cycle will be 30 percent to 50 percent stronger than the previous one. If this holds true, the solar activity in just a few years will be second only to the historic solar cycle maximum of 1958.

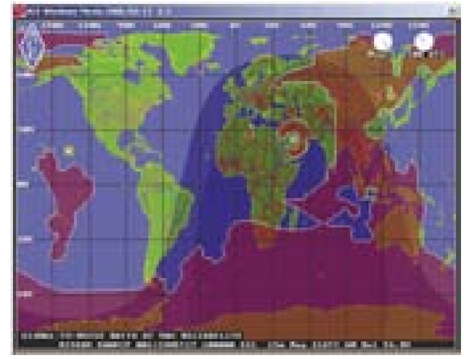

Figure 12: What areas can be heard in Riyadh, Saudi Arabia, on 15.82 MHz? ACE-HF PRO's Animated Coverage Maps can show you.

Veteran radio hobbyists remember that cycle, when solar activity was so strong that Aurora was sighted three times in Mexico. Propagation in the 50 MHz range was open world-wide and for great lengths of time. World-wide propagation was experienced on most of the HF spectrum, around the clock.

Next month, I will present the outlook for the rest of this year and a look into 2007. Let me know your questions and observations. Whether you are on a "fishing expedition" for any interesting catch that comes your way, or whether you are a dedicated hobbyist who enjoys sharpening your radio skills to achieve a specific goal, I hope you have found this month's discussion useful. To take the subject further, you may be interested in the space weather and radio propagation discussion at **http://hfradio.org/forums/**

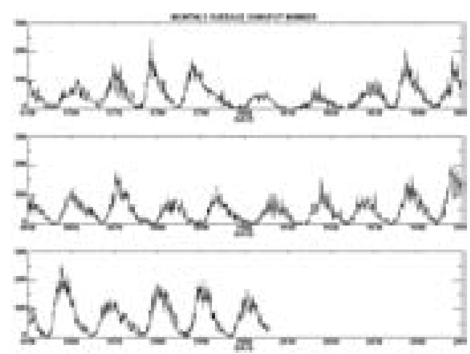

Figure 13: Sunspot cycles last an average of eleven years from start to finish. This graph shows the cycles since records were kept. Notice how the last two cycles have been less active than the one in the 1950's. The next cycle, Cycle 24, is expected to be as active as that one, making for great shortwave and low-VHF world-wide propagation. (Credit: NASA)

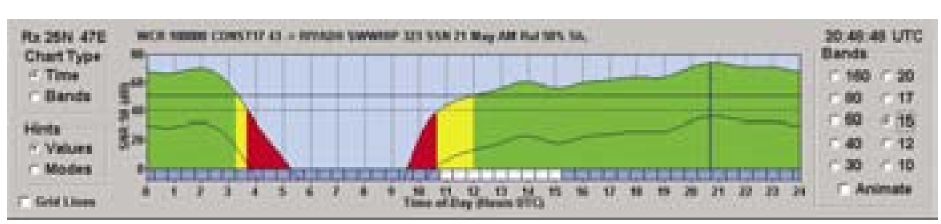

Figure 11: The ACE-HF PRO showing the SNR on the selected frequency of 15.82 MHz during one full 24 hour period, between WCR and Riyadh, Saudi Arabia.