PROPAGATION

You would think that with the 160-meter band relatively close in frequency to the 80-meter band that the two would exhibit very similar propagation characteristics. Truth be told, they are worlds apart. Cary Oler of the Solar Terrestrial Dispatch and Ted Cohen, N4XX, shed some light on why 160 meters is so unpredictable and what's being done to reveal its secrets.

The 160-Meter Band: An Enigma Shrouded in Mystery
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The propagation characteristics of the 160-meter band (1800-2000 kHz) have puzzled both amateur and professional communicators for decades. While located not that far below the 80 and 75 meter bands (3500-4000 kHz), predicting propagation on Topband, as it is affectionately called, has been an exercise in futility. For example, John Devoldere, ON4UN, in has book *Antennas and Techniques for Low-Band DXing*[1] notes that "...(T)he more I have been active on 160, the more I am convinced on how little we know about propagation on that band." Attempts by Devoldere to find a correlation between solar and geomagnetic indices (e.g., sunspot numbers the **K** and **A** indices (whole day indices) and the three-hour **k**-index), and propagation on 160 meters, found little or none. Even Jeff Briggs, K1ZM, in his new book *DXing on the Edge--The Thrill of 160 Meters*[2], comments that "(T)o me, personally, the biggest task yet unmet [on Topband] is figuring out just what makes 160 meters *tick*." Briggs even went so far as to say that "...I'll bet my last dollar that no one ...out there can predict the exotic openings with any degree of real accuracy..." The information below won't put you in the position of winning that bet, but it sure will give you an appreciation for just how complex the phenomenon of radiowave propagation on Topband really is.

Electron Density in the D-Region of the Ionosphere

Signals in the 160-meter band are most strongly affected by changes in the electron density of the ionosphere's D-region[3]. During the day, the D-region is strongly ionized, and so, it is the major source of absorption on 160 meters. During the night, the density of the D-region drops dramatically (though it does not disappear completely); this results in a corresponding drop in signal absorption. Importantly, small changes in the density of the D-region can have a profound influence on absorption levels during the nighttime hours. The primary reason for this is that at low radio frequencies, electron collisions with neutral ions occur much more frequently than they do at higher frequencies. This results in what is known as a *high collision frequency*,

which, in turn, results in high levels of signal absorption. Put another way, small increases in electron density at low frequencies produce large changes in signal absorption. When conditions on the 160-meter band are so good that you momentarily believe you are listening to a good opening on the 20-meter band, what may in fact have produced these extraordinarily good conditions were unusually large depletions in electron density in the D-region. Just what can cause such large drops in D-layer electron density is still not well understood by the ionospheric scientific community.

Effects Caused by the Electron Gyrofrequency

Propagation on the 160-meter band is difficult to predict for other reasons as well. One major reason, in addition to the unpredictability of the level of D-region absorption, is that the frequencies in the 160-meter band are so close to the electron gyrofrequency (which is in the range 700 to 1600 kHz)[4].   A map of the D/E-region electron gyrofrequencies (in kHz) is shown in Fig. 1.
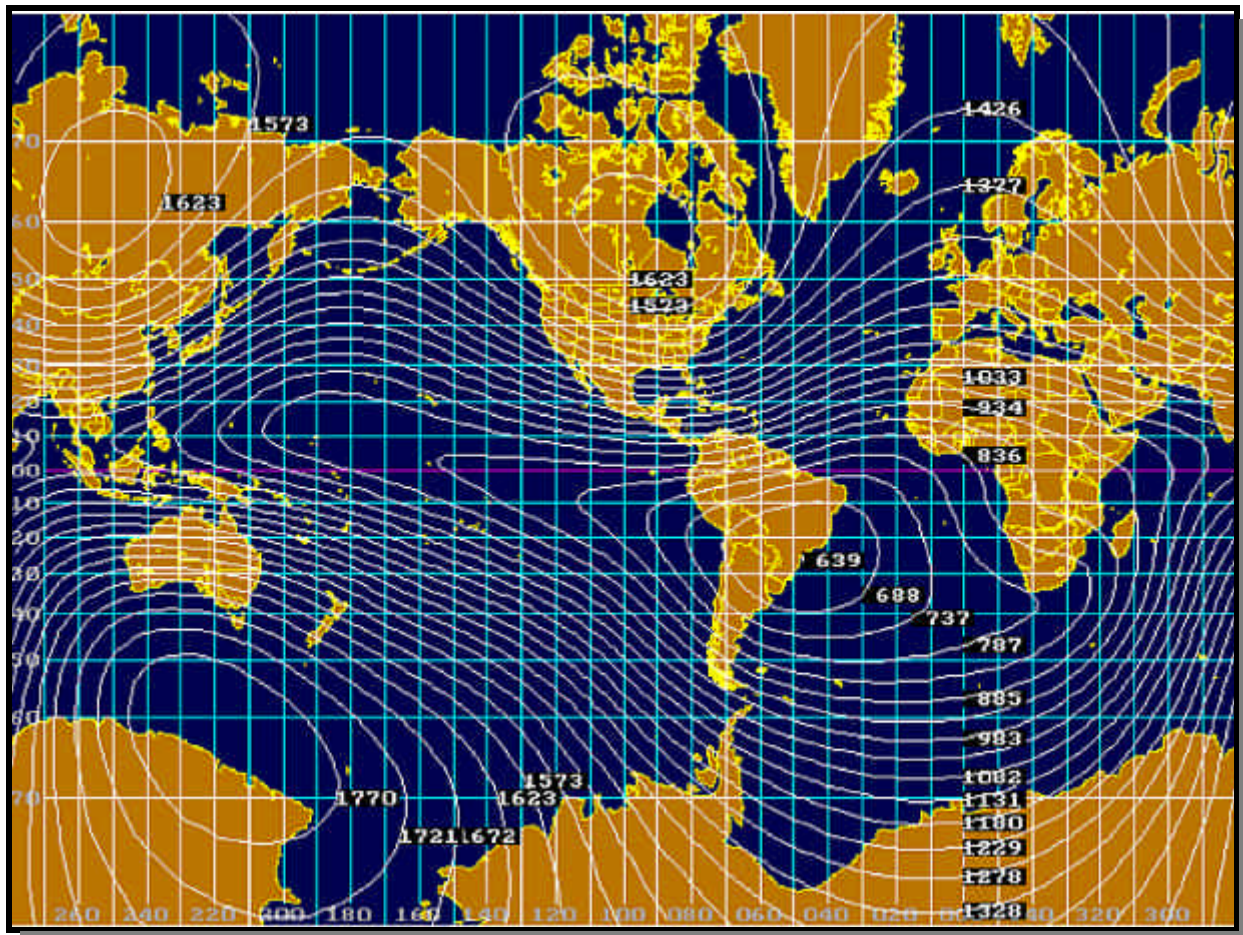

Figure 1

Basically, the gyrofrequency is a measure of the interaction between a charged particle (here, an electron) in the Earth's atmosphere and the Earth's magnetic field. The closer a carrier wave is to the gyrofrequency, then, the more energy is absorbed by the electron from that carrier wave. This is particularly true for radio waves traveling *perpendicular* to the magnetic field.

In North America, we would expect that signals from, say, Western Europe would traverse paths roughly perpendicular to the Earth's magnetic field, and so, they would be heavily attenuated because of their interactions with electrons in the D- and E-regions. Further, the signals should be strongly elliptically polarized, with the major axis of polarization lying in the direction of the magnetic field. (High-frequency (HF; 3-30 MHz) signals are more nearly circularly polarized.) Thus, in addition to the attenuation brought about by the proximity of the gyrofrequency to your Topband carrier frequency, the 160-meter signals you receive from, and transmit to, Europe also will arrive with decreased strength if your antenna and the antenna of the operator in Europe are not oriented to match this polarization

Finally, during geomagnetic activity, such as that experienced following the occurrence of a flare on the Sun, the orientation of the Earth's magnetic field lines can change, producing variations in received signal strength. In some cases, signals are degraded below useable levels while at other times, significant signal enhancement can occur.

Effects caused by the Auroral Oval

The auroral ovals (one around each pole) have a profound impact on radiowave propagation. If the path over which you are communicating lies along or inside one of the auroral ovals, you will experience degraded propagation in one of several different forms: strong signal absorption (which is usually what happens), brief periods of strong signal enhancement (primarily caused by tilts in the ionosphere that allow signals to become focused at your location), or very erratic signal behavior (strong and rapid fading, etc., caused by a variety of effects such as multipathing, anomalous and rapid variations in absorption, non-great-circle propagation, and polarization changes).

Fig. 2 is a map showing the great circle path from Washington, D.C., to Japan. Also shown is the position of the overhead Sun (in the south Atlantic), the terminator (it is within an hour of sunrise on the East Coast of the U.S.), the poleward position of the *very quiet* auroral zone (the green line closest to the poles), and the expanded position of the auroral ovals during weak minor geomagnetic storm conditions (the green line closest to the equator).
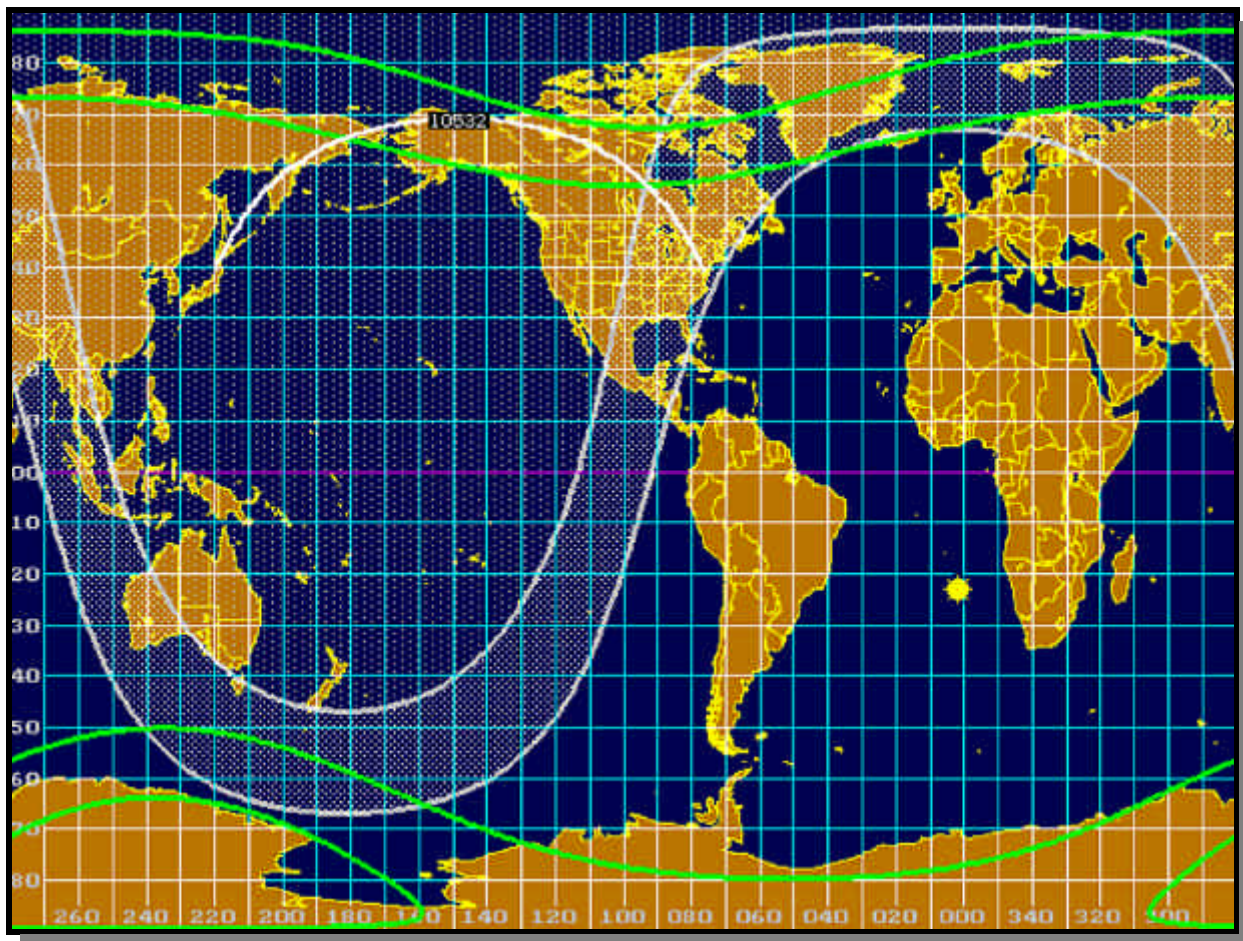
Figure 2

As shown, the great-circle path from D.C. to Japan can be influenced in one of two primary ways. During exceptionally quiet geomagnetic conditions (**k**-indices of zero lasting for more than about 8 hours), the auroral zone can contract to the approximate poleward position illustrated by the highest-latitude green line in Fig. 2 and allow the DC-Japan signal to pass relatively unscathed through the polar regions. But small increases in geomagnetic activity can produce large changes in the position of the auroral zone. If the equatorward boundary of the auroral zone crosses through the D.C.-Japan great-circle path, signal degradation will occur through absorption in the D and E regions and other instabilities of the auroral ionosphere.

Fig. 3 is an excellent example of the variability that can occur in the auroral zone. This sequence of images was obtained from the POLAR spacecraft (Ref. 5). It snaps pictures of the auroral oval every few minutes that its orbit allows. The top sequence of images (beginning at 0336 UTC on 10 December 1997) show the appearance of the auroral oval in a very quiet state. Very little activity is visible and, in fact, all of the activity occurs well north of Alaska. A Topband signal crossing through the high-latitude regions would have stayed outside of the auroral zone, resulting in good signal strength and stability (compare with the poleward green-line in Fig. 2). These were the conditions that apparently existed on 8 and 9 December 1997, as well, during which time exceptional propagation conditions were observed between the East Coast and Japan

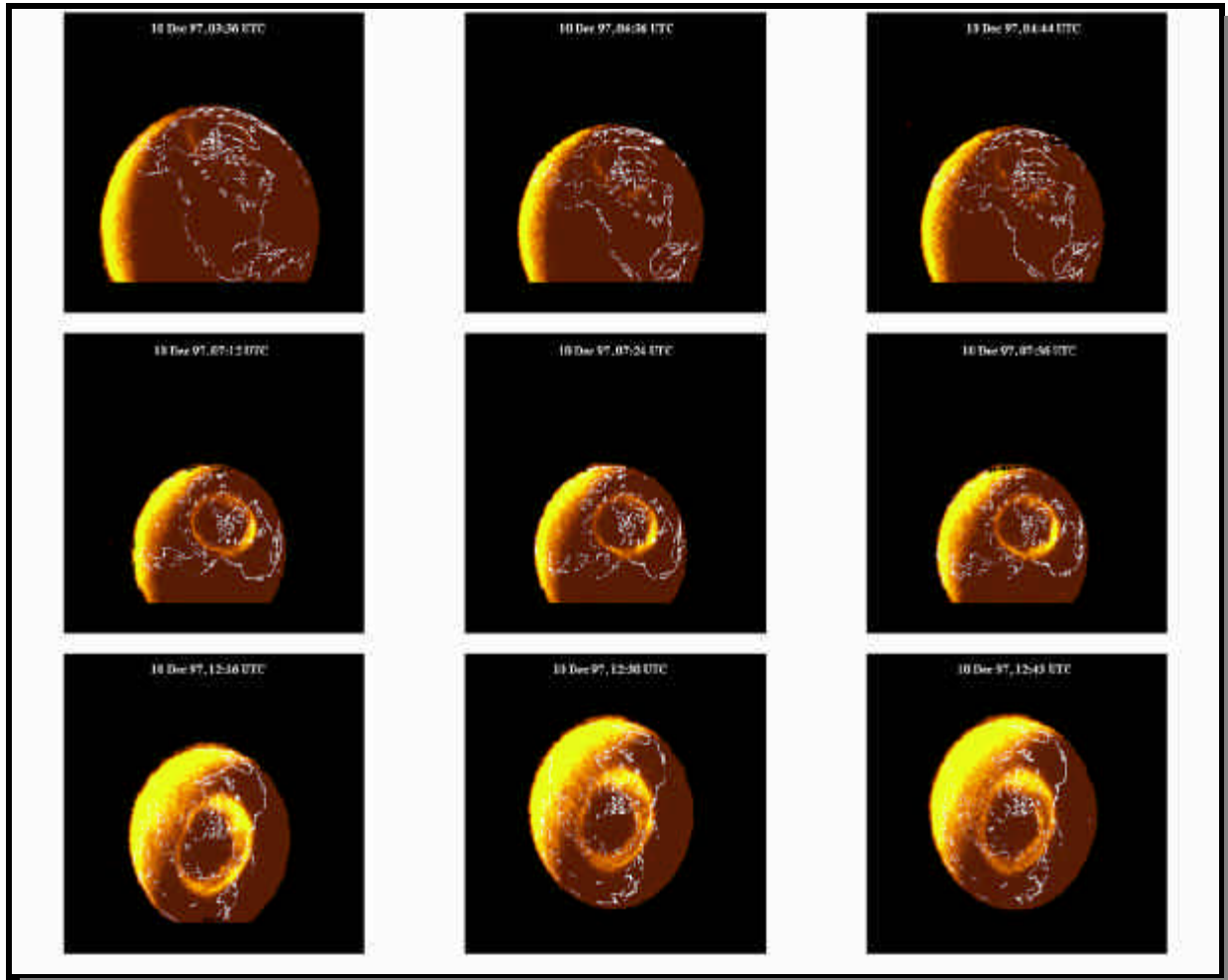in the half-hour period just before sunrise on the East Coast.

Figure 3

However, conditions changed rapidly following the arrival of a mild interplanetary disturbance at 0530 UTC on 10 December (see the middle row of images). These images show a more energetic auroral zone about an hour and a half after the arrival of the disturbance. Notice how the zones have expanded and how they now encompass a good portion of Alaska. The most intense areas of auroral activity are also located in the areas nearest the equatorward boundary of the zone of activity. Signals propagated from Washington, D.C. to Japan or from the western U.S. to Europe would have had to penetrate through these disturbed regions. In so doing, they would have been heavily absorbed by the increased D- and E- region ionization that migrated equatorward to intersect the great-circle paths by 0712 UTC. During the height of the auroral activity, the oval intensified and expanded even further southward to completely engulf the Alaskan and much of the Canadian ionosphere. Communications between Washington, D.C. and Japan around 1216 UTC (near sunrise on the East Coast) would have been highly unlikely, if not impossible.

Another important aspect of the auroral ionosphere is its latitudinal thickness. In the top row of

images, the auroral oval is very thin and diffuse, suggesting a much more stable ionosphere and weaker levels of ionization. A signal that passes through this auroral ionosphere would encounter its heaviest absorption only while it was within the auroral ionosphere.
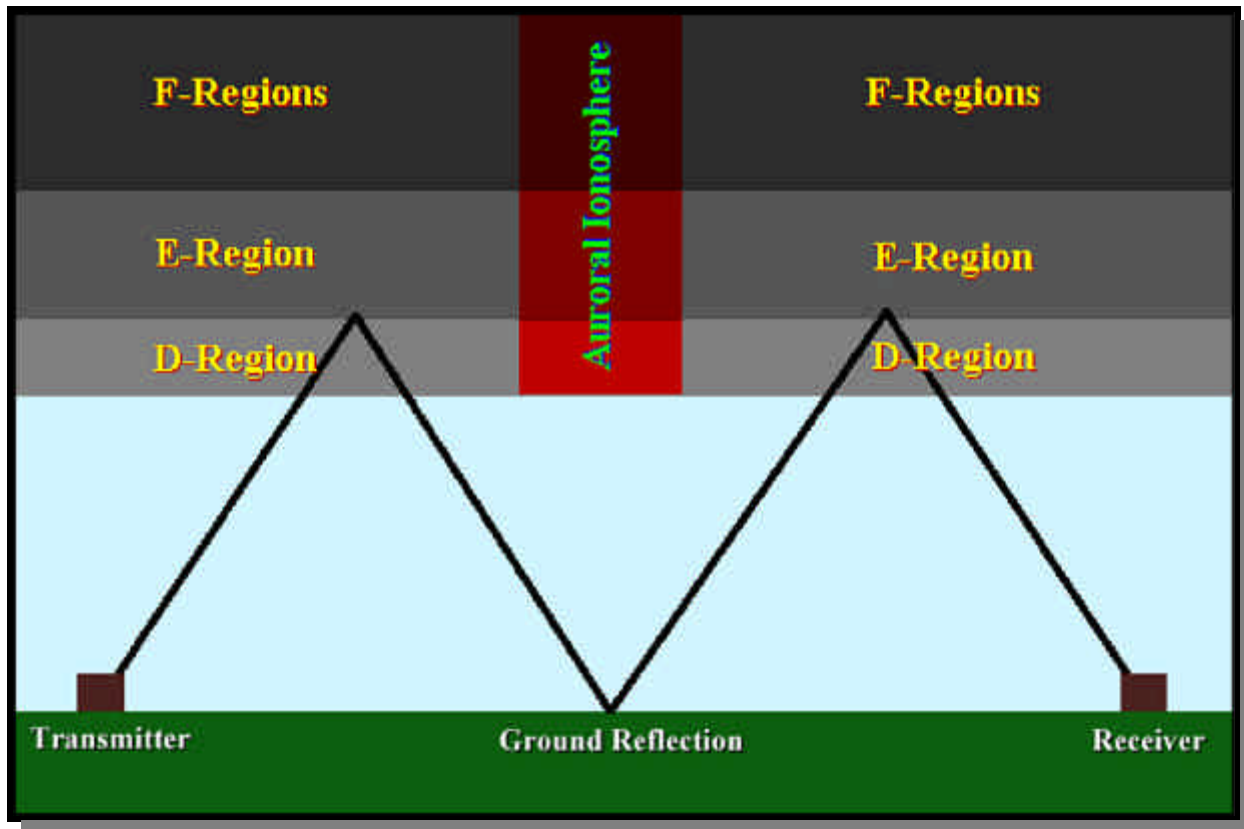

Figure 4

When the auroral zone is contracted and latitudinally thin, it is possible for a Topband signal to navigate *through* the auroral zone without being heavily absorbed by skirting *underneath* it, as Figure 4 illustrates. During periods of very quiet geomagnetic activity, areas of the auroral zone may only have a latitudinal thickness of approximately 500 kilometers (300 miles). But radio signals reflected from the E-region can travel over distances of as much as 500 to 2,200 kilometers (300 to 1,375 miles) at heights *below* the ionosphere (for low take-off angles of between 20 to 0 degrees, respectively). When the geometry is just right, 160-meter radio signals can literally skirt underneath and through the auroral zone into the polar ionosphere (which is more stable) and from the polar ionosphere back into the middle latitude ionosphere without ever coming in contact with the auroral ionosphere. Such propagation is not as rare as you might think, and it can provide unusually stable openings to transatlantic and transpacific regions. But because the auroral oval is in continual movement and changes rapidly, such conditions often do not last very long.

As nature would have it, the most heavily ionized region of the auroral ionosphere is that region nearest the local midnight sector, which, unfortunately, is an important time and region for 160-meter DX signal propagation. The midnight sector of the auroral zone is also the most

unpredictable and volatile. Look how rapidly auroral activity changes near Alaska in the bottom panel of the images in Figure 3. In only 27 minutes, activity ranged from fairly intense (at 1216 UTC) to mildly active (at 1243 UTC). A closer inspection of these images also reveals fine structures that can materialize and dematerialize in a matter of minutes. Because the visible light manifested as the auroral ovals is produced by beams of energetic electrons being sprayed into the high-latitude ionosphere, even these small-scale features can have profound impacts on absorption levels of 160-meter radio signals.

Part of the trick to successfully working Topband DX is to get your signal through the polar regions without passing into the auroral ionosphere. Operators in the western and southern regions of the United States can literally "shoot" their signals under the auroral zone, avoiding the absorption that their colleagues to the north and east unfortunately encounter. Auroral zone absorption probably accounts, in large part, for the fact that Stew Perry, W1BB (SK), recognized worldwide as the "Father of Topband DXing," never completed a two-way contact with a Japanese operator on 160 meters!

Correlation of 160-Meter Signal Strength with Sunspot Numbers

It is interesting to note that 160-meter signal strengths are very difficult to correlate with solar activity, but there *is* a weak correlation. (Ref. 6)

The correlation between sunspot numbers and signal strength is only about 5% as strong as the correlation on higher frequencies. In fact, the correlation is so low that most empirical algorithms that predict signal strengths of 160-meter signals completely disregard sunspot numbers or solar flux levels. The weak correlation is primarily due to the fact that lower frequency signals (e.g., 1800-2000 kHz) are reflected by the lower regions of the *night-time* ionosphere, when solar ionizing radiations have dropped to minimal levels. This explains why attempts to correlate conditions on the 160-meter band with sunspot numbers (or the 2800 MHz solar flux) fail.

Dxing by means of Ionospheric Ducts

You may not realize it, but a considerable number of DX openings on Topband over distances greater than 4,000 kilometers may owe their occurrence to a phenomenon known as *signal ducting*. A ball thrown into a narrow tunnel will bounce around the walls of the tunnel while maintaining its general direction of travel. In essence, it is "ducted" through the tunnel. Similarly, a radio signal that is "shot" into an ionospheric "tunnel" will duct between the walls of the tunnel until the walls either disappear or become weak enough to permit the signal to break through. The walls of an ionospheric "tunnel" are the edges of the ionospheric layers. The D-region is normally insufficiently ionized to allow radio signals in the MF and HF bands to duct. However, the increased electron densities in the E- and lower F-regions are sufficient for Topband signals to be ducted *if* they can enter these regions at just the right angles and *if* the right conditions exist.
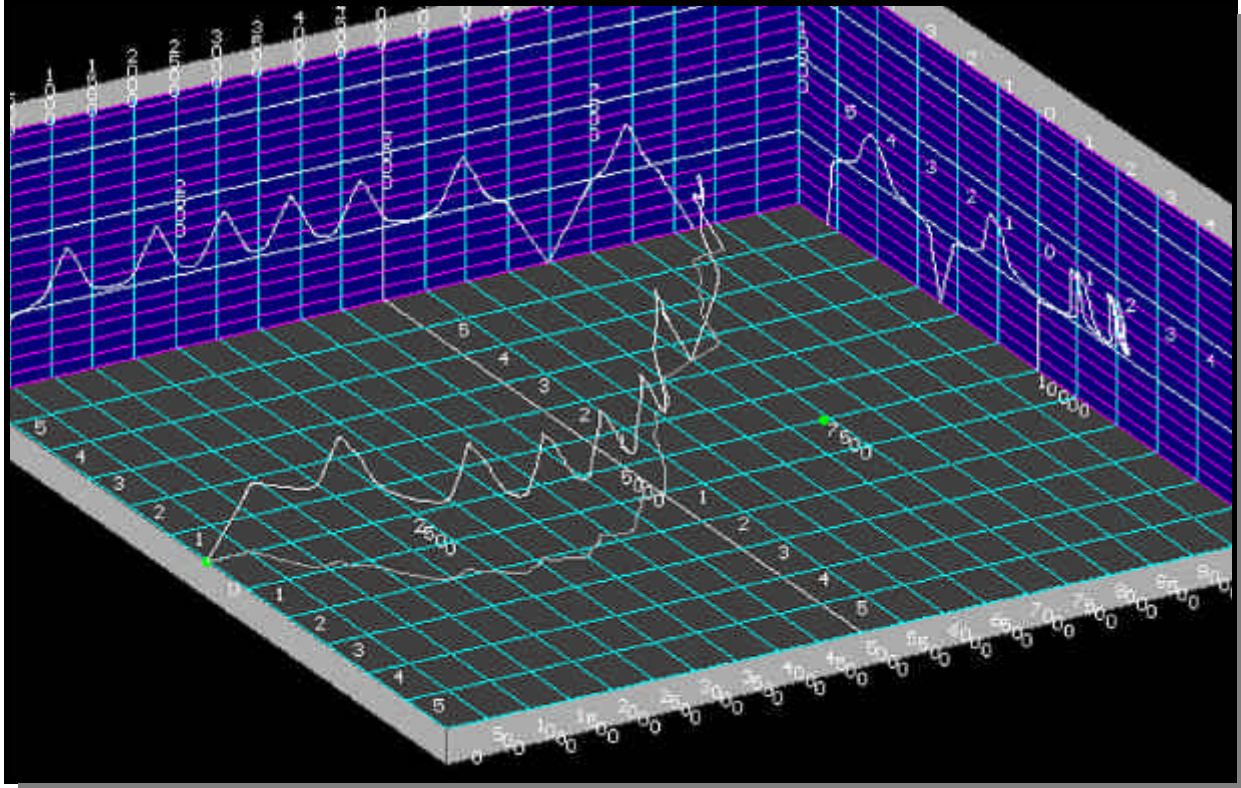
Figure 5

One such example of ducting, shown here in Fig. 5, was visualized by simulating what happens to a signal as it travels into and through the Earth's ionosphere. This figure shows the path the ordinary (primary) component of a 1850 kHz radio signal takes as it travels from Washington, D.C. to Hungary in December under quiet geomagnetic nighttime conditions. The transmitter (Washington, D.C.) is identified as the green dot on the left-hand side of the three-dimensional graph. The receiver (Hungary) is located just under 7,500 kilometers away (see the associated green dot). The line connecting these two green dots (labeled with the number zero) represents the great-circle path from Washington, D.C. to Hungary. The "wall" at the top and left part of the figure shows the altitude of the signal above the surface of the Earth (each line on this wall is separated by 20 kilometers in altitude). The wall on the right side shows the deviation that the signal takes *away* from the great-circle path, in kilometers. The signal itself starts at the Washington, D.C., green circle and travels at a 10 degree takeoff angle toward the ionosphere. The *ground-track* of the signal can be seen on the base of the three-dimensional plot. It stays precisely on the great-circle path until the signal reaches the base of the ionosphere. It then abruptly pulls equatorward (due to magneto-ionic splitting of the signal into *ordinary* and *extraordinary* components) about one kilometer from the great-circle path as it traverses through the D-region. The signal encounters its greatest absorption as it transits the D-region.

At this particular take-off angle, the signal is refracted and bent just enough to allow the signal to begin ducting between the base of the F- region and the top of the E-region, within what is known as the *E-valley region*. Because this region of the ionosphere is in darkness, it is fairly stable and

allows the ducting to continue unimpeded for almost 6,500 kilometers - a respectable distance, indeed!

Notice the crooked path of this signal. ***It does not precisely follow the great circle path, but deviates northward and southward according to changes in the shape of the ionospheric layers and the orientation of the signal to the Earth's magnetic field through which it is being ducted.*** (Most Topband operators who have multiple, directional receiving antennas (e.g., Beverages) will tell you that the signals from distant stations often arrive on azimuths off the great circle path.) Finally, about 6,500 kilometers from Washington, D.C., the E-region is no longer ionized sufficiently to refract the signal back to the base of the F-region. So, the signal breaks out of the duct and travels back to the Earth's surface. In doing so, it crosses through the absorbing D-region a second time. It then bounces back into the ionosphere and completes one more hop before the simulation ends. A close examination of the signal near the end of its path (where the signal begins moving almost directly away from our line of sight) shows the very odd behavior of a Topband signal. It is not straight and linear as you might expect. Indeed, it suffers from kinks and twists that can change the angle of arrival of a signal as well as its direction and polarization characteristics. This is typical behavior for Topband signals, and it is the result of the signals close proximity to the electron gyrofrequency. The situation gets even worse as the carrier frequency more closely approaches the gyrofrequency.

Our intended recipient in Hungary never heard this signal because the signal fell short of the receiver by about 500 kilometers. Instead, a fellow Topband operator in Czechoslovakia heard the signal loud and clear. If his transmitter and antenna were capable of transmitting enough radiated power at the right angle of elevation required for the signal to enter this same duct, it would begin ducting right back to the operator at Washington, D.C., thereby permitting a two-way conversation.

The strength of this 1850 kHz signal received in Czechoslovakia would have been fairly strong because the signal only crossed through the D-region two times: once when it left the transmitter at Washington D.C., and again after ducting for almost 6,000 kilometers. It also did not suffer a passage through the auroral zone, but instead, passed under it thanks to the very quiet state of the geomagnetic field. ***This mechanism probably accounts for the inability of a given station to hear a DX signal that fellow operators only a few hundred kilometers away are copying with exceptional strength.***

Ducting of 160-meter signals is more easily (and more frequently) accomplished than is ducting at shorter wavelengths because the Topband signal can be refracted to a much greater extent at higher angles of elevation than can signals at shorter wavelengths. Stated another way, Topband signal ducting is most likely to occur when transmission elevation angles of between about 5 to 30 degrees are used. At shorter wavelengths (e.g., 80 to 20 meters), most signals need to be transmitted using shallower angles of elevation of between 0 to 15 degrees to enter the main ducting regions. But since most Amateur antennas can't radiate sufficient energy at transmission elevation angles much lower than about 10 degrees, the total signal energy that enters the duct at higher frequencies will be much lower than the energy emitted into a duct by a 160-meter antenna at Topband frequencies. The end result can be higher signal strengths from 160-meter ducted

signals.

Some ducts are very sensitive to changes in ionospheric conditions, take-off angles, and changes in antenna azimuth. This explains why some DX openings are short-lived or change rapidly with time, or are of poor quality. Other ducts are less sensitive to changes, and they may be quite stable for hours and extend over broad ranges of signal azimuth and elevation.

Some ducts suffer from non-reciprocity, as well, which means you may hear someone but be unable to get them to hear you. This is much more common on 160 meters than on higher frequencies. If you suspect the DX to be the result of ducting, the best advice is to determine the proper azimuth to the DX contact and try to "shoot" your signals skyward using your antenna with the lowest take-off angles possible. (Given the size of most 160-meter antennas, you may not have much of a choice from which to choose!)

Tips for Improving your Topband DX Operations

There are several important components that can improve your chances of successfully working DX on Topband.

The first, and probably the foremost, tip is to *wait for very quiet geomagnetic conditions*. The trick here is to wait for *sustained* intervals of quiet conditions *over the high latitude regions*. Using Boulder **k**-indices broadcast on WWV/WWVH at 18 minutes past each hour will not suffice because Boulder, CO, is far from the auroral ovals. The **k**-indices acquired at Arctic stations such as Inuvik, Baker Lake, and Cambridge Bay (all in Canada) are much more suitable for this application because these stations are located within the auroral oval. So, sustained three-hour **k**-indices of zero at these stations for periods of time lasting at least eight hours should prove to be a more accurate measure of the potential for 160-meter DX openings along high-latitude circuits. The reason for this is that research has shown that the auroral ovals require at least eight hours to contract to their most poleward positions (Ref. 7).

Sustained periods of zero **k**-indices are most common during the rising phase of the solar cycle, which we are now experiencing! They are the least common in the declining years of the solar cycle, when the appearance of low (solar) latitude and transequatorial coronal holes keep the Earth's geomagnetic field in a relatively continual state of flux. So, for the next two to four years, there should be a fairly large number of sustained quiet geomagnetic periods. Put another way, DX openings on Topband should be at their best during the next two to four years.

For reasons that are still uncertain, there often are periods of time immediately following the arrival of interplanetary disturbances when propagation on Topband is momentarily enhanced. This may be due to the fact that large changes can occur in the chemical makeup and neutral wind patterns of the ionosphere following the arrival of interplanetary disturbances from the Sun. It is entirely possible that changes in neutral winds might produce rarefied areas of D-region electron densities, resulting in abnormally low absorption levels for Topband signals. These conditions are, so far, mostly unpredictable, and they cannot be easily detected except through the

observation of unusual DX on Topband or by means of specialized ionosondes. Greater research efforts into the nature and response of the neutral winds to interplanetary stimuli is required to solve this important problem.

Low and stable background x-ray flux values (in the 1 to 8 Ångstrom band) *may* help contribute to lower nighttime D-region electron densities and better Topband DX conditions.

Alternatively, although the D-region does for the most part dissipate after sunset, high x-ray flux values observed during the day can considerably increase electron densities in the dayside D-region. Speculative reasoning, then, suggests that residual effects on the night-side may become manifest (particularly during the first few hours after sunset) through the action of the neutral winds. In other words, during periods of high background x-ray flux values, propagation on Topband may be poorer for a slightly longer length of time after sunset...again, depending on the flow of the neutral winds at D-region altitudes.

The importance of electron gyrofrequencies cannot be understated. A successful Topband operator should keep in mind that signals will be less strongly absorbed and behave more like a conventional signal is expected to, *the farther away from the electron gyrofrequency is the carrier frequency*. To this end, it is wise to consult an electron gyrofrequency map when contemplating paths you want to use. Using paths that have steadily decreasing gyrofrequencies will have less of a degratory effect on signals than will paths that are associated with increasing gyrofrequencies.
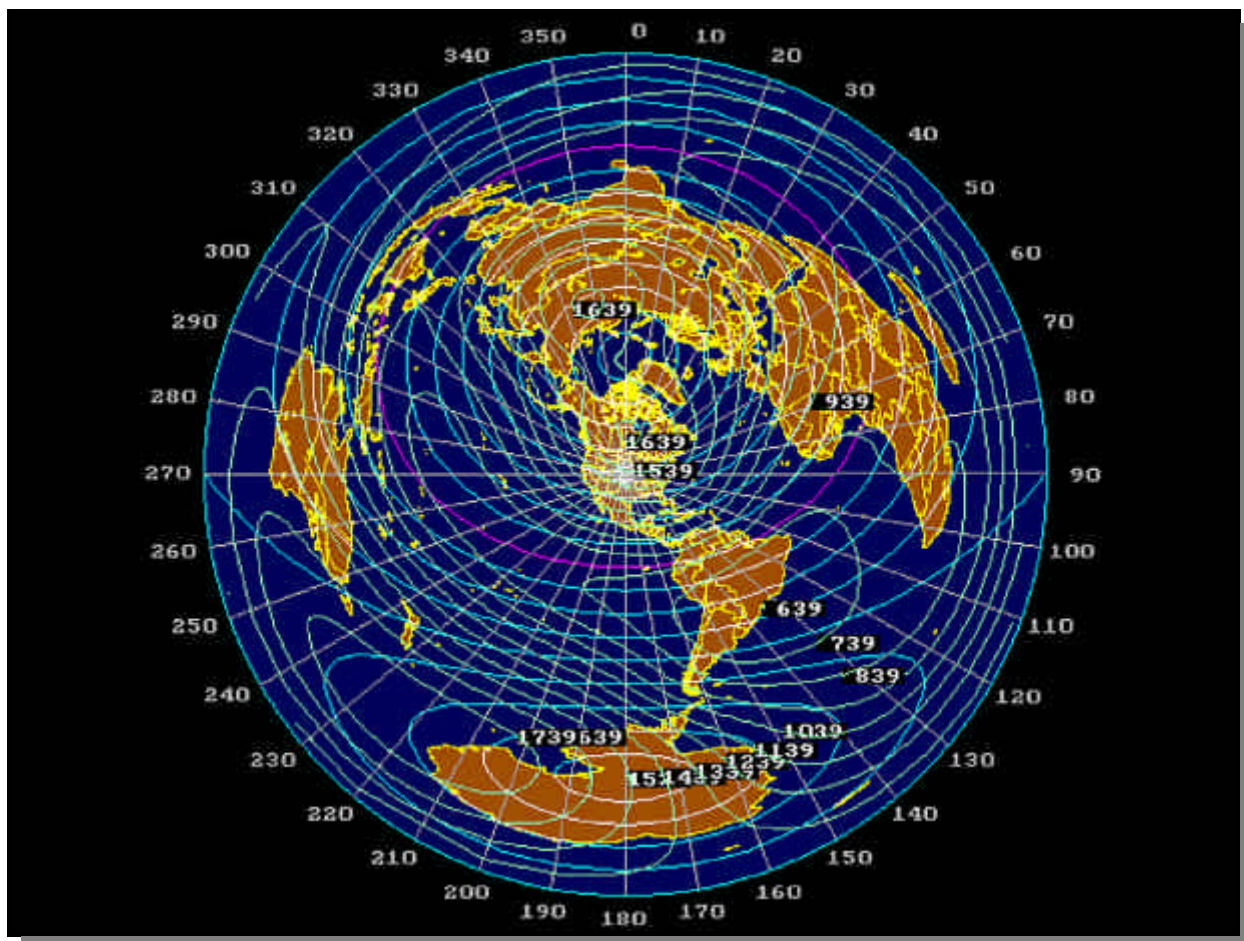
Figure 6

A very useful and unique map, centered on the United States and shown in Figure 6, can help individuals in the United States determine what the electron gyrofrequencies are for any signal azimuth. The radial azimuth "spokes" in Figure 6 are labeled on the outside of the image. The blue ovals are lines of geographic latitude (the red oval is the equator) and the whitish-green contours are the electron gyrofrequencies, given in *kHz* and spaced at intervals of 100 kHz. Fortunately for amateurs in the United States, the electron gyrofrequencies decrease on most signal paths except those that pass into Canada, the Arctic, and Siberia. Gyrofrequency conditions are best towards South America and Africa. Unfortunately for amateurs in the United States, electron gyrofrequencies are about as high as they can get, ranging from about 1300 to 1600 kHz. Propagation of Topband signals within South America and even from South America to South Africa are much less affected by the gyrofrequency than are paths from North America to these regions because of the much lower electron gyrofrequency in South America and Africa.

Topband signals are very susceptible to sporadic-E. Even weak sporadic-E "clouds" that might not affect the higher frequencies noticeably can have a substantial impact on 160-meter signals by increasing absorption or refracting signals in wanted or unwanted ways. The only benefit that sporadic-E might provide for Topband operators is if signals reach the sporadic-E cloud from above (that is, on the way down from an F-layer reflection). In these instances, the signal will be

reflected back to the F-region, which will effectively increase the distance traveled by the signal, (in some cases, perhaps considerably). However, keep in mind that sporadic-E clouds are sometimes non-linear in shape and may contain bulges or other non-uniform structures that might scatter your signals instead of uniformly reflecting them along the great-circle path. Remember, too, that 160-meter signals are *easily* refracted, even by fairly low electron densities.

The ionosphere is a chemically active, electrically charged, fluid-like environment. Ripples in the electron density at the base of the ionosphere (and, indeed, at the bases of each of the layers in the ionosphere) exist and are continually traveling from place to place through the action of the neutral winds. This is important for propagation on lower frequencies because signals that encounter large traveling ripples in electron density can suffer from absorption fading, a periodic fading phenomenon that can produce moderately deep fading of Topband signals, as well as signal divergence (defocusing) and multipathing.

Available Computer Software Tools

Today, there are substantial software tools available to the Amateur and professional radio communicator that were not available a few years ago and that can be used to help monitor Topband conditions. One of the more substantial ones for analyzing signal paths is the Proplab-Pro software package. Most of the maps and the ray-traced examples in this article were produced using this software. Another very substantial tool is a software package known as SWARM (Solar Warning And Real-time Monitor). This software can be used to monitor everything from geomagnetic and ionospheric conditions to solar activity and solar wind conditions, all in *real-time*. It is particularly valuable for the prediction of quiet geomagnetic intervals and the arrival of interplanetary disturbances.

In January 1998, the ACE (Advanced Composition Explorer) spacecraft began sending nearly continuous measurements of the solar wind from its vantage point outside of the Earth's magnetosphere (about a million kilometers "upstream" of the Earth, between the Earth and the Sun). This distance is fortuitous in that the spacecraft is able to detect the arrival of interplanetary disturbances up to an hour before they impact on the Earth. Because the data provided by the ACE spacecraft will be nearly continuously transmitted to the Earth, users of the SWARM software will be able to detect the arrival of these disturbances up to an hour before they actually reach the Earth's magnetosphere. This is sufficient time for radio communicators to prepare to take advantage of the momentary enhancements that can occur in Topband (and other band) conditions shortly after the arrival of these disturbances. The software will also audibly alert you when geomagnetic activity surpasses certain threshold levels. These audible alerts can be useful for radio communicators who may stop looking for DX opportunities on Topband if geomagnetic activity spawns **k**-indices of perhaps 4 or higher. The software will even fetch current solar flux values and sunspot numbers, solar imagery, auroral imagery from the POLAR spacecraft, up to 19 different types of daily, weekly and monthly reports from forecast centers around the world, plot sunspot regions and other activity on a simulated image of the Sun, monitor x-rays for solar flares and protons that can devastate polar-path radio signals, and much more.

These software packages can be, to the serious radio communicator, as important as a good rig on a mountain top.

For additional information, contact the main Internet web pages for these software packages at:

- http://solar.spacew.com/www/swarm.html
- **http://solar.spacew.com/www/proplab.html**.

The Solar Terrestrial Dispatch (STD): A Superb Source for Information on the Sun and its Effects on the Space Environment near the Earth

For readers who wish to investigate further the effect of the Sun on our ionosphere and on the propagation of their signals, whether on Topband or at frequencies higher in the radio frequency spectrum, the Solar Terrestrial Dispatch (STD) invites you to visit **http://solar.spacew.com** on the World Wide Web. This site provides current information on the state of the Sun and its effect on the Earth and on the space environment near the Earth. Current ionospheric maps of maximum usable frequencies, critical F2-layer frequencies, auroral activity sightings, solar activity observations and much more is available at this site. The numerous services provided there are made possible through the kind cooperation of the University of Lethbridge, Canada.

Coordinated Amateur Radio Observation System (CAROS)

The Solar Terrestrial Dispatch is currently studying 160 meter propagation in greater depth, with a hope of isolating some of the more influential factors that might lead to improved models of propagation. They are, therefore, soliciting the involvement of all individuals who communicate or regularly listen on 160 meters. Although the 1997-1998 season for Topband will soon be over, we would appreciate receiving as much input as possible regarding observed contacts and propagation conditions on Topband. Further, we would like to continue to receive reports throughout the northern hemisphere's summer and on into the 1998-1999 Topband season.

In support of this and other radio communicators on higher frequencies, we have developed CAROS, which can be accessed through the STD on the World Wide Web (see below). We hope that Topband operators, as well as those that work the higher frequencies, will contribute their observations to our CAROS system. All reports are archived. The contributed reports can then be analyzed in detail and studied in combination with ionospheric data. It is hoped that through a collection effort such as this, we will be able to pry loose some of the secrets of 160-meter propagation. But the success of this project is dependent upon the number of reliable reports that are received. Please submit any observations you make to the CAROS system at: **http://solar.spacew.com/www/subcaros.html**. The latest observations submitted to CAROS can be seen at: **http://solar.spacew.com/www/caros.html**.

Other Available Internet Services

You may like to know that the STD is now offering solar and geophysical (including ionospheric) reports, alerts and warnings, etc, to the public, free of charge. Anyone can subscribe to this service by visiting **http://solar.spacew.com/www/sublists.html** on the Web.

The STD also has constructed a Web page devoted specifically to 160-meter propagation that contains parameters that are thought to be reasonable indicators of potentially favorable Topband DX conditions. Included on this page are near-realtime images of the auroral oval and current geomagnetic indices for key Arctic stations. Armed with this information, and knowing the great-circle path your Topband signal is taking, operators should be able to determine whether DX propagation on Topband to various locations around the world might be possible. Keep in mind that this page is still experimental and that its developers do not yet claim to provide reliable propagation predictions for 160-meter signals. But the Web page represents a good start that will serve as a base upon which to build theories and models. And it will provide Amateurs with the information required to help us prove or disprove the reliability of the propagation models employed. Here is the URL: **http://solar.spacew.com/www/topband.html**.

The Solar Terrestrial Dispatch is also offering a course over the Internet that teaches individuals how to predict space weather and radio propagation conditions. It is the most comprehensive course that can be taken over the Internet, and it covers all of the topics that have been discussed in this article, including topics such as the prediction of coronal mass ejections from the Sun and ionospheric disturbances and processes that can affect radio propagation. A complete list of topics and materials can be found at: **http://solar.spacew.com/www/course.html**.

Conclusions

Topband is one of the last frontiers for radio propagation enthusiasts. It involves regions of the Earth's environment that are very difficult to explore and are poorly understood. These factors have led to our failure to predict propagation conditions with any level of accuracy. They also account for our inability to explain some of the puzzling mixtures of conditions that make this one of the most interesting and volatile bands available to the Amateur service.

Topband may be the lowest band in the amateur spectrum, but it has one of the most promising and exciting futures possible!

Footnotes and Comments

1. Devoldere, J. (ON4UN), *Antennas and Techniques for Low-Band DXing*, The American Radio Relay League, Newington, CT, 1994, p.1-21.

2. Briggs, J. (K1ZM), *DXing on the Edge: The Thrill of 160 Meters,* The American Radio Relay League, Newington, CT, 1997, p. 14-2.

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