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 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 a Mystery—Part I

BY CARY OLER*, AND DR. THEODORE J. COHEN**, N4XX

About the Authors

R. Cary Oler

Mr. R. Cary Oler has 15 years of professional experience in the area of solar phenomena and ionospheric radio-wave propagation. He is the founder and president of the Solar Terrestrial Dispatch (STD), a private company that provides scientific, academic, and commercial organizations worldwide with real-time solar and geophysical data and forecasts. His clients include the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC) and Jet Propulsion Laboratory (JPL), the U.S. Naval Research Laboratory (NRL), and the Russian Nuclear Physics Institute. The Solar Terrestrial Dispatch Web site is hosted by the University of Lethbridge, Lethbridge, Alberta, Canada. From there, Cary provides real-time propagation information and ionospheric forecasts, archived solar and ionospheric data, and information on STD's many products and services, including some of the most sophisticated ionospheric propagation software available today. While not a radio amateur, Cary is keenly aware of the many contributions amateur radio operators have made in the area of ionospheric propagation research, and he invites the Topband community, including shortwave listeners (SWLs), to contribute information on observed 160 meter conditions either via e-mail directly to him or through the Coordinated Amateur Radio Observation System (CAROS) Web page on the STD Web site.

Theodore J. Cohen, N4XX

Dr. Theodore J. (Ted) Cohen, N4XX, is no stranger to *CQ* readers. Over the last 30 years he has published more than 300 articles, columns, essays, and interviews in the radio amateur literature, the majority of them appearing in *CQ*. He is a co-author of *The NEW Shortwave Propagation Handbook* (written with George Jacobs, W3ASK, and Robert B. [Bob] Rose, K6GKU) and is well-known for his work relating high-frequency (HF) radio-wave propagation conditions to solar flux and geomagnetic indices. This work, described in the September 1974 issue of *CQ*, led the former National Bureau of Standards (NBS) to introduce WWV broadcasts containing current values for these parameters. (These broadcasts are heard at 18 minutes past each hour.) Now Ted has turned his attention to Topband and to the extraordinarily challenging problem of explaining radio-wave propagation in the range 1800–2000 kHz. This article is his (and Cary's) first published attempt to explain phenomena that for decades have both fascinated and frustrated the amateur community. Ted holds advanced degrees in physics and geophysics and has been licensed for over 45 years.

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, "... I'll bet my last dollar that no one ... out there can predict the exotic openings with any degree of real accuracy ... " The following information 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 (although 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 fre-

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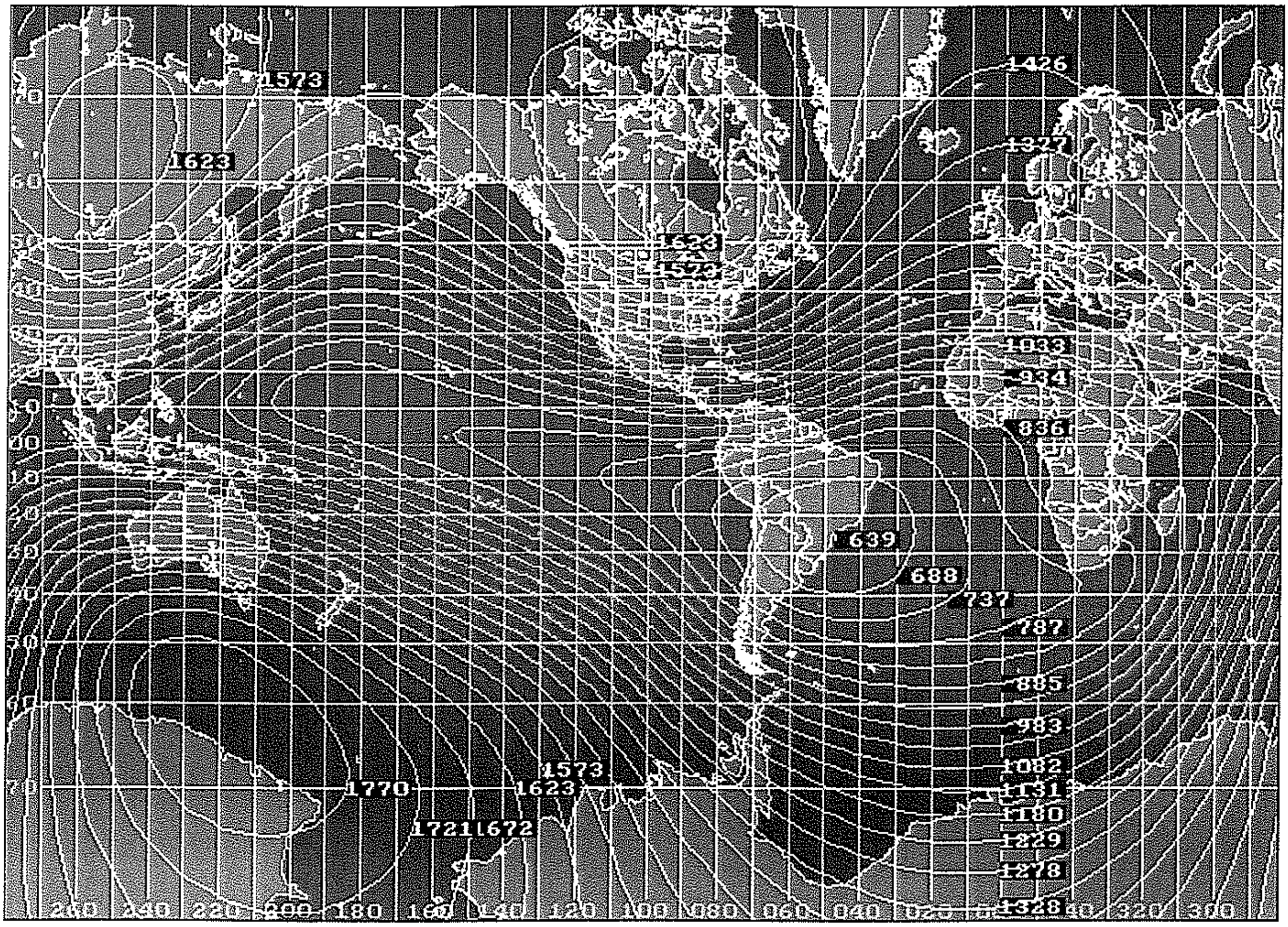

Fig. 1– Global map of electron gyrofrequencies, in kHz.

quencies 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. 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 usable 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).

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 D.C.-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) shows 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.

Conditions, however, 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 netrate through these disturbed regions. In so doing, they would have been heavily absorbed

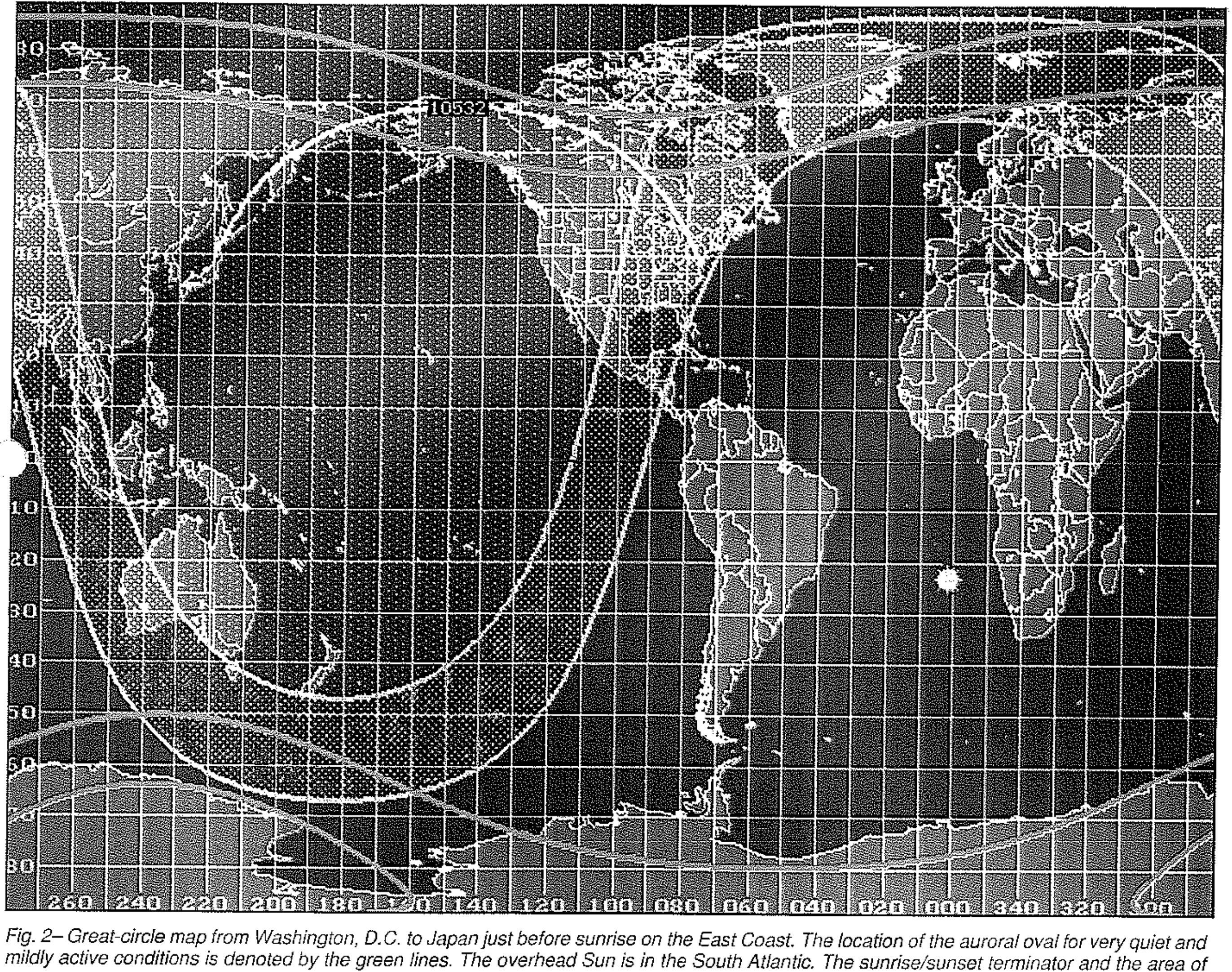

Fig. 2– Great-circle map from Washington, D.C. to Japan just before sunrise on the East Coast. The location of the auroral oval for very quiet and mildly active conditions is denoted by the green lines. The overhead Sun is in the South Atlantic. The sunrise/sunset terminator and the area of the Earth where the Sun is 12 degrees below the horizon is shown by the grayline region.

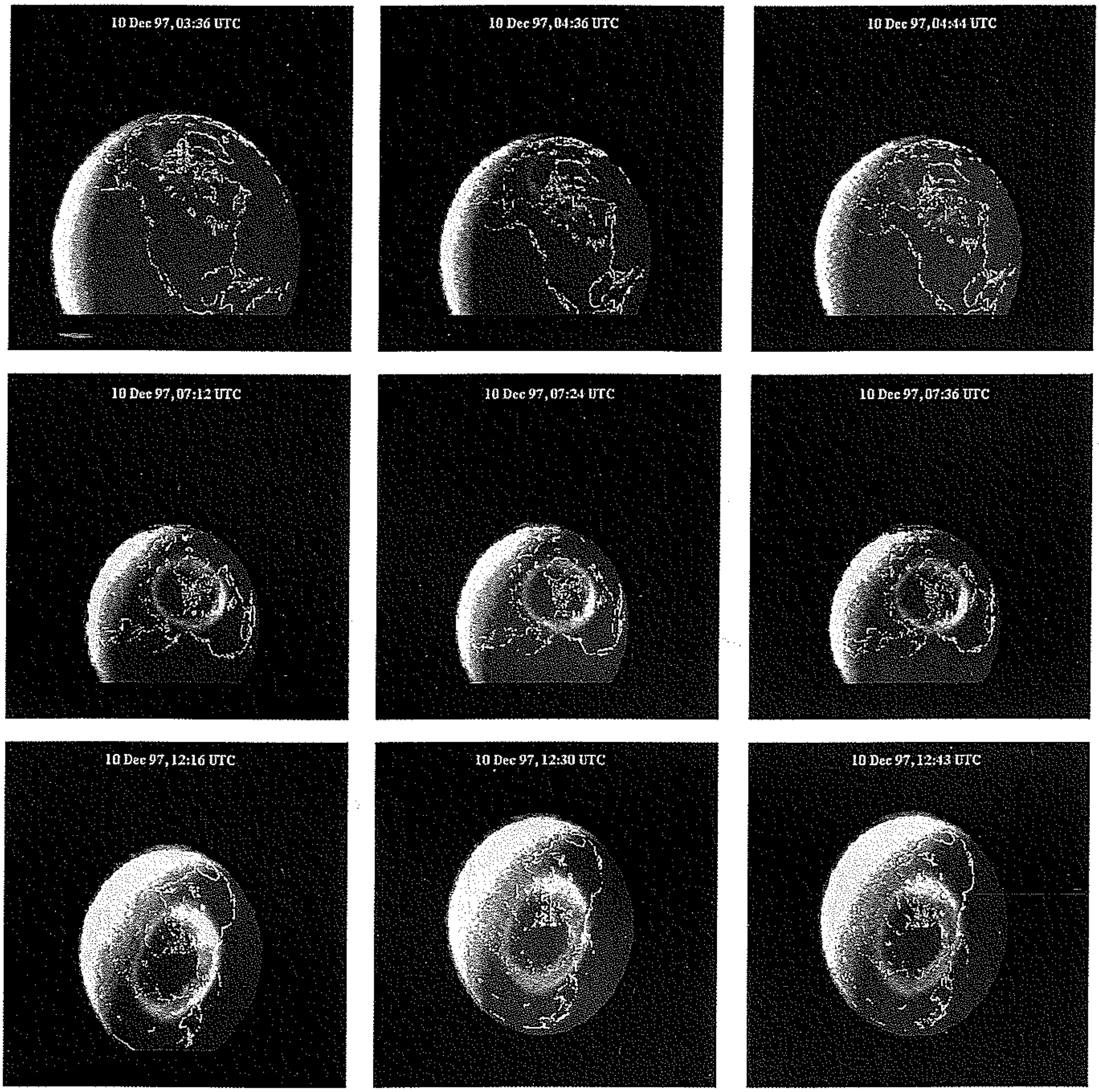

Fig. 3– The sequence of images is from the POLAR Spacecraft and shows the northern polar auroral oval. Top three images: very quiet auroral oval. Middle three images: intensifying auroral oval. Bottom three images: minor auroral storm conditions.

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.

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 fig. 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 move-

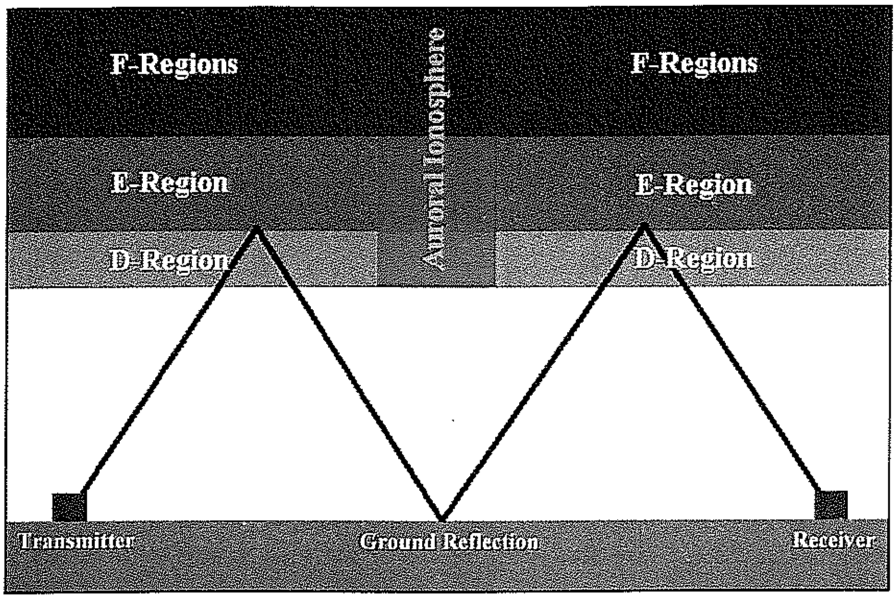

Fig. 4– An example of how a 160 meter signal can pass through the auroral zone without interacting with the disturbed conditions in the auroral ionosphere.

ment 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 fig. 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 Top-band 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 to Japan to the south of 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 Top-band 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. However, 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 *nighttime* 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.

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.
3. Jacobs, G. (W3ASK), T. J. Cohen (N4XX), and R. B. Rose (K6GKU), *The NEW Shortwave Propagation Handbook,* CQ Communications, Inc., Hicksville, NY, 1995.
4. Davies, K., *Ionospheric Radio Propagation,* Dover Publications, Inc., New York, NY 1966.
5. These images were acquired with the Earth Camera which is one of three cameras in the Visible Imaging System (VIS). The design and assembly of the VIS was performed by the VIS team at the University of Iowa. The VIS is one of twelve instruments on the POLAR satellite of the NASA Goddard Space Flight Center. The Principal Investigator is Dr. L. A. Frank and the Instrument Scientist and Manager is Dr. J. B. Sigwarth.
6. Ebert, W., "Ionospheric Propagation on the Long and Medium Waves," Tech. Doc. 3081, European Broadcasting Union, Brussels, 1962.

(Continued Next Month)