Ionosphere Properties and Behaviors - Part 11

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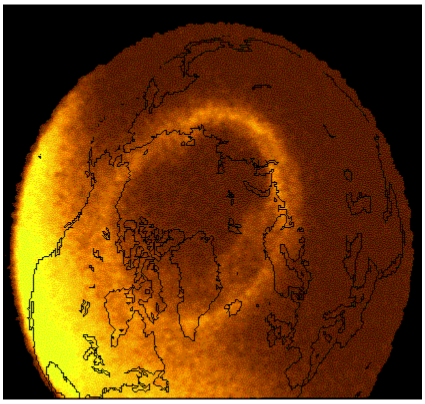
In the previous issue, I explained the origin of the aurora phenomenon and the creation of the ovals. Many monitoring stations on earth do measure the geomagnetic disturbances and publish their results available to anyone interested. Today and for more than a decade satellites have observed also these Polar Regions to inform us even better with real time pictures.

Viewing the aurora from satellites



A and K-indices inform you only of the geomagnetic activities of at least 3 hours ago. These indices give the trend of a period and what it most likely will be for the next hours. More real-time reliable information data, such as maps of the polar zones, are found on the Internet from various sources. For more than a decade we have had satellites that produce almost real-time pictures, which can give us a more up-to-date picture. Views of both North and South poles and their auroral ovals are available at the NOAA website, from the POES (Polar Orbiting Operational Environmental Satellite) satellite passes about every hour.

The POES maps are based on particle sensor readings that the satellite collects every pass over the two polar regions. The instruments on board continually monitor the power flux of the protons and electrons that could produce aurora activities. The collected readings are only valid for those longitudes where the satellite passes overhead. These readings may be considerably different at other locations along the auroral oval. However, the spacecraft has gathered data under a variety of auroral activity conditions ranging from very quiet to extremely active and a wide range of local times. These data are stored in a huge database and available to compute and estimate reliably what is most likely happening elsewhere. What the resulting maps actually display is based on a combination of real-time data and best-fit extrapolations taken from that huge database.

At **Fig. 61.1a** and **61.1b** you find typical GOES generated polar auroral activity maps. The black line shows the orbit of the satellite while making the measurements. The dots on either site of the orbit path line represent the measurements done in the direction of the stacked black dots. The red colored arrow indicates the local noon meridian, where the width of the oval is usually smallest. We find the widest auroral zone around local midnight. The normalization factor (n) indicates the degree of confidence that reasonably can be placed in the plot. Normalization factors below 2 indicate a reasonable level of confidence. Each pass over one of the polar zones is self evidently transversing and monitoring another section of the polar zones, since the earth rotated meanwhile.

It is most important for radio amateurs to have access to the size and width of the auroral ovals to be able to evaluate on a map whether a given communication path will touch or pass through the oval zone. Simplifying, we can say that the oval is a circular ring, of which the statistical average radius at midnight is found in **Table 61.1.** When you have only K index values, these data allow you to manufacture oval disks of various diameters, which can be used as an overlay on azimuthal maps to help visualize possible crossings of great circle paths with the auroral oval. Of course these oval slices do not describe how the ionization is disturbed or how energetic it may be. Summarized, the local intensity of the aurora is not the same at all points of the oval and all times of the day. ***Remember***: when using manufactured oval disks to use the magnetic pole as center point and not the geographical pole. Maps generated by the GOES satellite inform you much better about the location of the auroral oval and its intensity and width. The ***DX-Atlas*** program released by Afreet software from the author Alex Shovkoplyas, VE3NEA, allows you also to have a good picture of the positions and width of the auroral ovals with ten levels of geomagnetic disturbance levels, **Fig. 61.3a to 61.3c.**

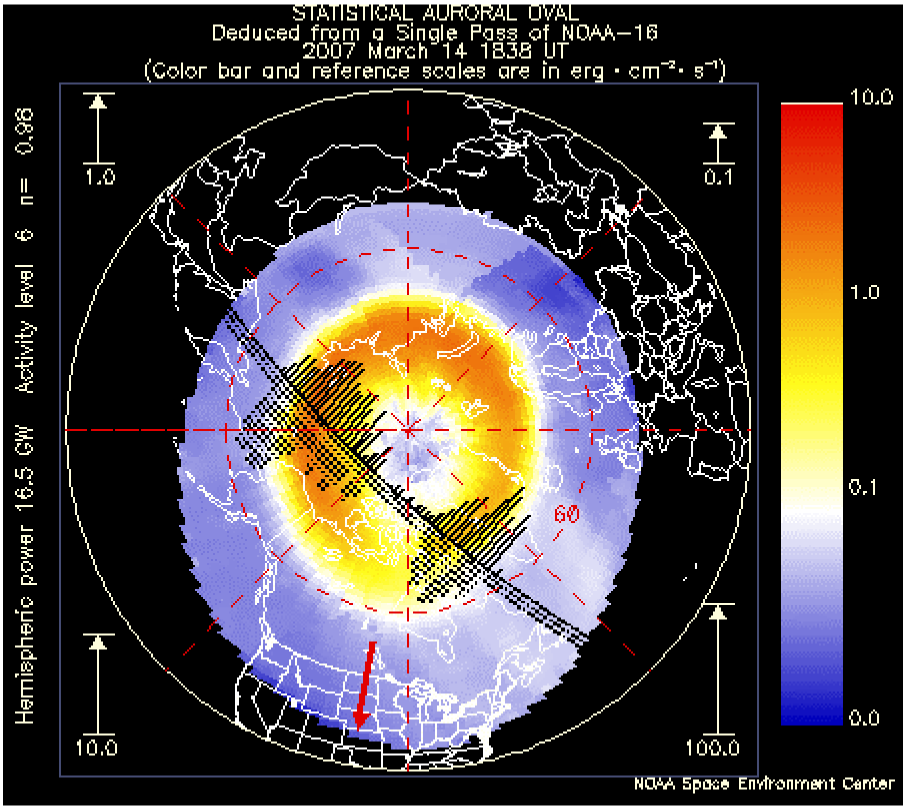


Fig. 61.1a. *A single pass measured and computed statistical auroral oval by the POES satellite at midday central USA*

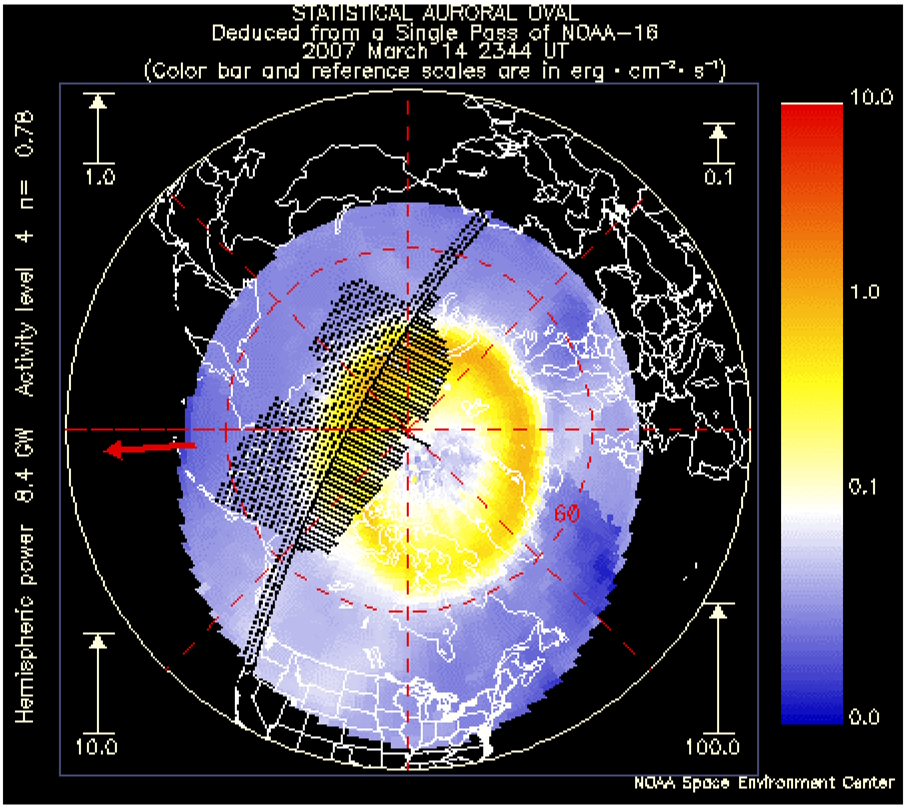


Fig. 61.1b. *A single pass measured and computed statistical auroral oval by the POES satellite at the same day, late afternoon central USA*

Effects caused by Auroral activity on HF propagation

The auroral ovals (also called the auroral donuts) have a profound impact on propagation. If the communication path goes along or through the ovals, then the result is usually degraded propagation caused by strong absorptions of the signal. This happens in particular for the low frequency ham bands where the signals are easily totally absorbed. On the higher bands (20m and up) fast selective fading and multipathing is a common sign of aurora influences.

During exceptionally quiet geomagnetic conditions, such as K indices of zero for at least 8 hours, the auroral belts might shrink to a major axis of about 40% compared to heavily disturbed geomagnetic conditions. When these extended fully quiet conditions are met, the oval belt width might be reduced to a few hundred kilometers and the D- and E-layer ionization reduced to low levels. Under such circumstances most polar paths can get through or along this small and almost undisturbed area and signals will suffer hardly any degradation.

However, during disturbing conditions the auroral oval can rapidly grow to an average diameter of 7 000 to 8 000 km. Under such conditions, all paths crossing or touching this extended oval will be affected by severe absorption in the D and E region and by other instabilities, such as flutter and Doppler shift caused by the moving and migrating (shrinking and expanding) auroral ionosphere.

During periods of very quiet geomagnetic activity and a contracted auroral zone there is much more chance that the radio waves may shirt underneath the ovals without suffering heavy absorption. Radio signal propagation with rather low angles are favorable for traversing the auroral oval zone because the chance that they enter or hit the absorbing belt is much lower. With proper take-off angles the signals can literally skip underneath and through the disturbing and attenuating zones into the polar ionosphere inside the auroral donut hole, where the ionosphere is more stable. They then continue the path by refraction from the polar F-region back underneath the opposite part of the oval into the ionosphere at latitudes below the auroral belt, without ever coming in contact with the lossy region of the belt itself, **Fig. 61.2a and 61.2b.** The possibility to undershooting the auroral donuts not only depends on the geomagnetic activity but also on the distance your location is away from the outer edge of the belts. This usable distance depends also on the ionization density and the height of the F-layers surrounding the ovals and at the donut hole. The refraction height at the F region within the belt may not be too high or the waves will encounter the belt either at the upward reflection from the earth surface or the downward refraction from the F-layer.

K index	Oval Average Radius (km – miles)	Oval Average With (km - miles)
0	1800 – 1118	500 – 311
1	2050 – 1274	800 – 479
2	2300 – 1429	1100 – 689
3	2550 – 1584	1400 – 870
4	2800 – 1740	1700 – 1056
5	3050 – 1895	2000 – 1243
6	3300 – 2051	2300 – 1429
7	3550 – 2206	2600 – 1616
8	3800 – 2362	2900 – 1802
9	4050 - 2517	3200 – 1989

Table 61.1. *The average oval radius and belt width with different K index values*

The auroral belt ionization has a column field aligned structure, (see later) and easily screens off or scatters the incoming signals waves. Therefore, depending on your location interpreted from the oval position, certain areas of the globe will be much more difficult to reach and make contacts. Use azimuthal maps of your location that include the ovals plus a few extrapolated straight lines to discover these difficult to contact DXCC countries, **Fig. 61.3a to 61.3c.** From my QTH, as an illustration, a great part of the Pacific Ocean islands are situates in this screened-off area. Even with low auroral activity it is not so easy to reach that part on the globe. But that makes the hunt interesting and fascinating, isn't it?

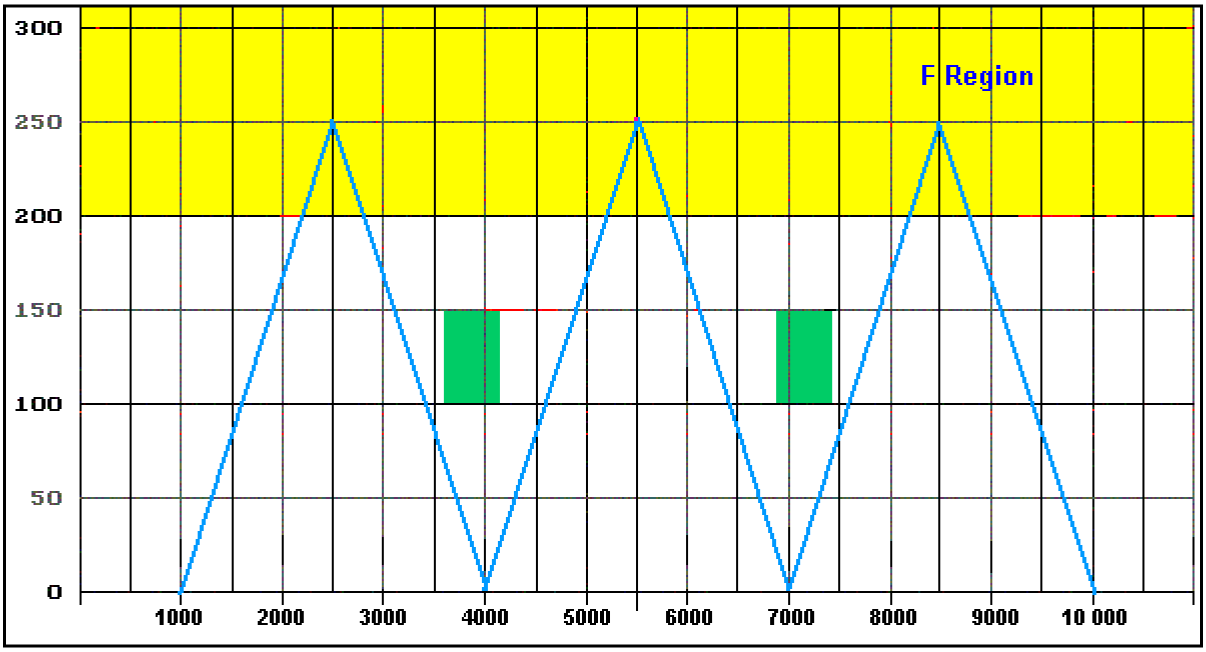


Fig. 61.1a. *Simplified picture of the oval belt width and location with an undisturbed polar zone. The field aligned E region column structured ionizations is indicated with green shading. Low angled propagating signal waves might undershoot the oval belts and traverse this zone without major attenuation.*

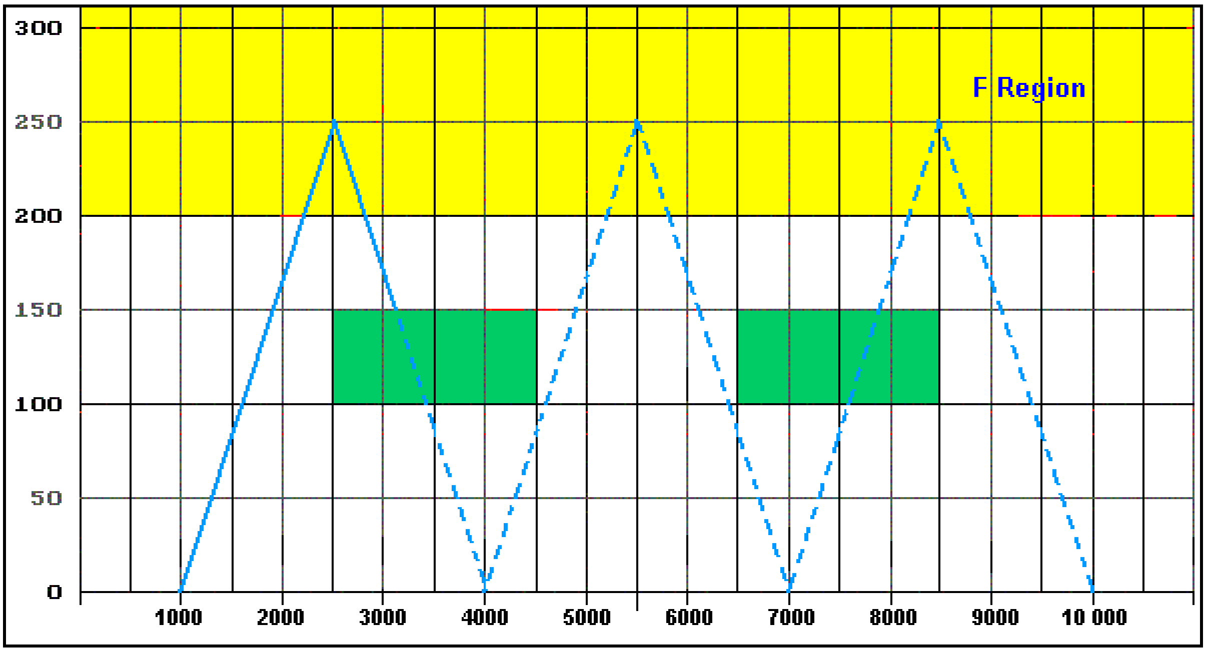


Fig. 61.2b. *The oval belt width and location with a disturbed polar zone, (level 5). The same propagation path as seen in illustration* ***Fig. 61.2a*** *will now encounter the much wider and expanded auroral belt and be screened-off.*

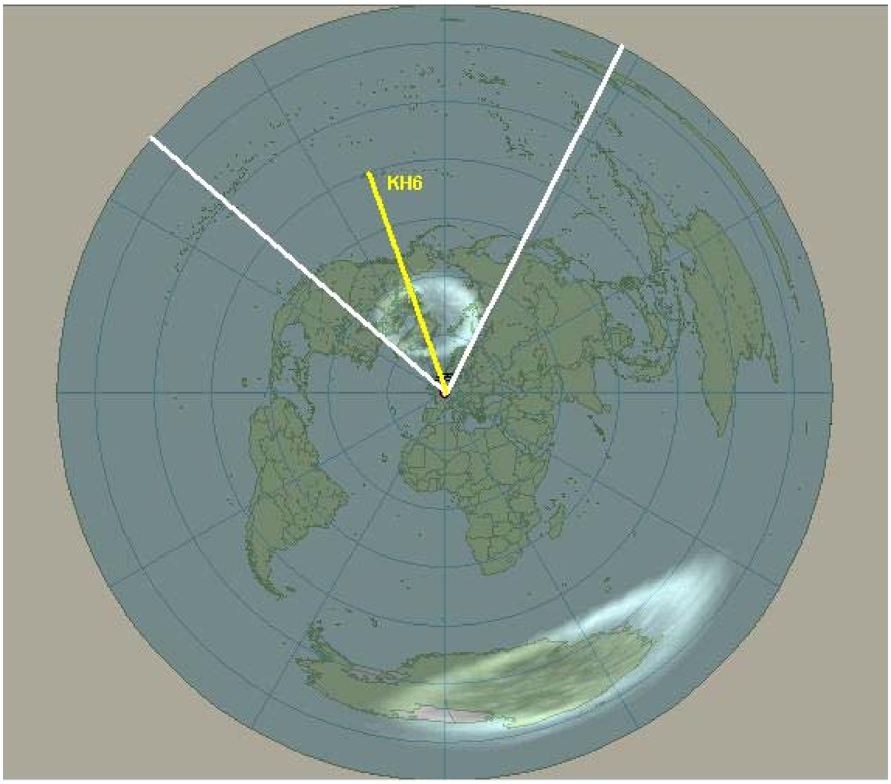


Fig. 61.3a. *Azimuthal map of my location with the auroral ovals added with lowest activity. The lines indicate the often screened-off area. An sample communication path: the Hawaiian Islands, which has to cross the auroral oval zone. The north-West part of the USA and Canada and Alaska are often not reachable due to the aurora position.*

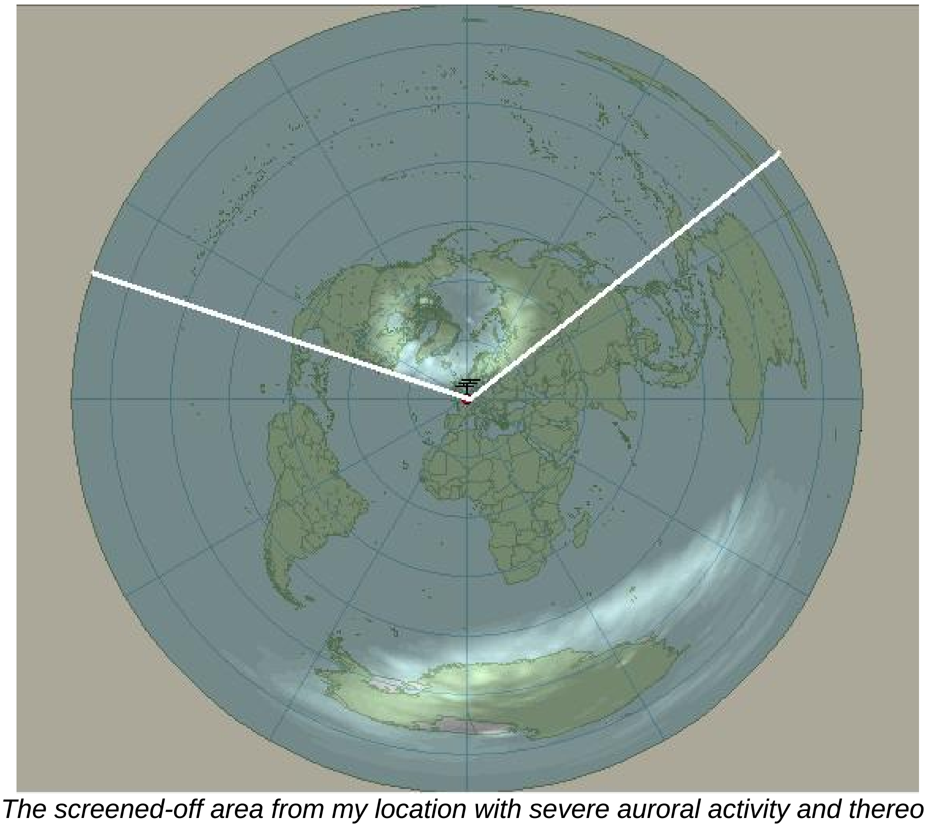


Fig. 61.3b. *The screened-off area from my location with severe auroral activity and thereof nearly 60% more expanded auroral ovals. The screened-off zone is practically twice the size compared with no activity times.*

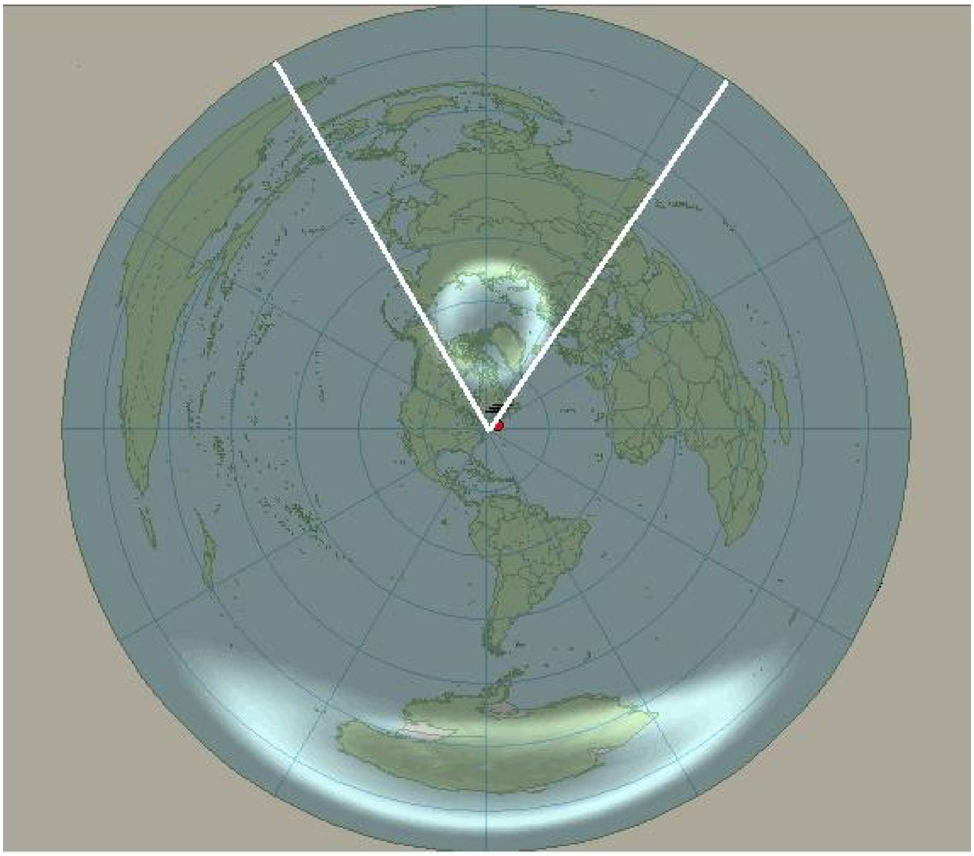


Fig. 61.3c. *An azimuthal map of the New York location, displaying the screened-off area, which is here most of the Siberian area.*

The enhanced ionization in the auroral zone also creates horizontal ionization gradients at the F-layers surrounding these ovals. These horizontal gradients create a tilted ionosphere and refract signal waves in the horizontal plane. Therefore, stations outside the oval might profit with aurora by launching their signals in a non-great-circle route so that they are bent away from the auroral oval in a so-called crooked or skewed path. This was explained in Part 9 of this series.

Field Aligned Propagation

As already discussed, the electrons required for radio auroras are trapped in columns aligned to the earth's field angle or dip angle. These ionized columns have little depth north-south along the lines of the magnetic meridians, but extend east-west along the electrojets for considerable distances. They are also moving at about the speed of sound. It is this migrating movements that gives rise to the Doppler shift on signals so characteristic of auroral signals. Keep in mind that in the vertical plane we are only interested in that part of the ionosphere at the E-layer height where the electric currents are flowing and the dense ionized columns exits, which height is from 100 to 130 km.

Therefore. the backscatter angles that I shall discuss in next issue, are in a very narrow part of the ionosphere in the vertical plane but are rather wide in the azimuth or east through west plane. There is also the line-of-sight limit, due to the earth's curvature and also the E-layer curvature. With a zero degree signal take-off elevation angle, the signal grazes the ground and this puts a limit on the maximum usable distance range, in practice to about 1 230 km from the station.

One of the best ways to understand field-aligned propagation, although it has nothing to do with auroras, is to look at a rainbow. You will notice that the sun is always behind you and the rainbow in front. This is because the raindrops refract and reflect the light back to where you are, but bend it in different amounts for different light frequencies, with red always on the outside and violet on the inside. The important rule is here is that due to the angle the light is refracted and reflected, it is not possible to see a rainbow sideways or at an angle. It is always in line with the sun and the observer, and in fact aligned. In some respects a radio aurora acts similarly; it is also field aligned.

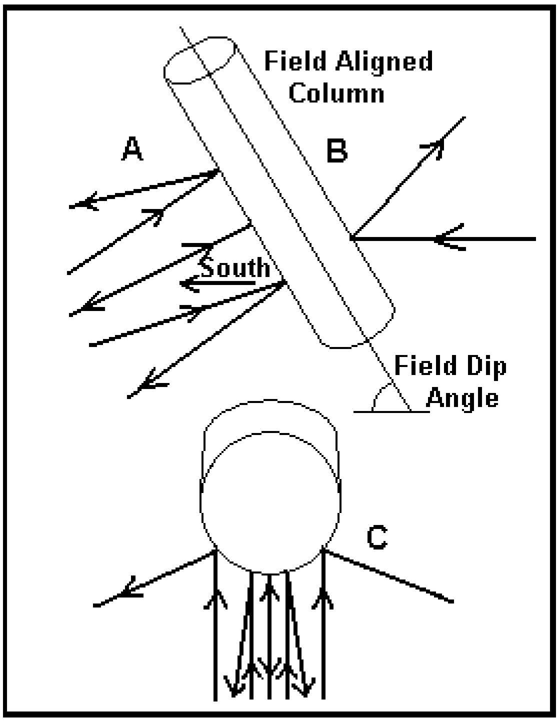


Fig. 61.4.

In **Fig. 61.4,** we can see more clearly at the **A** illustration that we have to be south of the auroral field aligned column due to the magnetic dip angle to experience back scatter. At the **B** illustration, we see that signals coming from the opposite direction will be scattered up into space and not return back to earth. At the **C** illustration we see how signals coming from the south can scatter backward in differentiated azimuthal directions or angles. As the gyrating electrons are held in column-like structures, aligned along the magnetic field lines, the backscatter is not precisely at any angle but covers all the angles the wave front can see. In practice only the zero difference angle can truly send the signal back to where it came from. However, we have to be careful here. Do not think that the backscatter process is precise like a mirror. There are millions of electrons in very many column-like structures, all very slightly different in position from each other. So, the backscatter tends to be rather broader than we would expect. It is more correct to say that we have an optimum specular angle, which gives the highest signal level and as we depart from it, that then the signals gets weaker.

This is only part of the auroral field alignment story. In the next issue I shall dig a bit deeper into the backscatter properties, which are important to understand and necessary to VHF auroral communications especially. Stay tuned. **–30-**

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