

VHF AURORA IN 2026

By David Olean K1WHS

Auroral propagation has been a steady source of DX opportunities for VHF DXers for many years. Indeed, the first evidence of auroral propagation in the USA was noted in 1939 by W2AMJ. In 1940, hams in the US were routinely working AU DX on 56 MHz . (QST May 1940) By 1950, as technology gained in WW II filtered into ham radio, Auroral contacts were becoming routine ways for VHF DXers to increase their state totals on both 50 and 144 MHz. I heard my first ever AU signals in the early 1960's and have been fascinated by the frequency spreading and raspy tones ever since then.

In the 1980's and 90's, it was rather difficult to know when an Aurora was possible, as internet data and Solar monitoring satellites were a far away dream. You basically listened to WWV at 18 minutes after each hour to catch the Solar Terrestrial Indices report. Things that we take for granted today, did not exist back then. In 1994, In an effort to unwrap the Auroral mysteries, I felt that it was a good idea to make my own magnetometer and monitor the Earth's magnetic field directly. The results were fantastic and I had a way to watch the Aurora in real time on my chart recorder!

Since those heady days, and especially after about 2005, the incidence of Aurora has seemed to drop around the New England area. What triggered my curiosity was a comment by Jay Rusgrove, W1VD, where he stated that the Kp index had to be a 7 or an 8 before any evidence of Aurora would appear. My experience from years ago when Ed Tilton was using a telescope to monitor Sunspots, was that a Kp of 5 could trigger a radio Aurora for me in Maine. I rechecked my logs as best as I could and found that indeed, that was the case back in the 1970's and 80's. Sadly, my logbooks from 1962 thru 1968 were destroyed. There were lots of AU sessions back in the 60's as well. I tagged all of the Kp 5 and 6 Auroras that I caught in the years 1972 through 2026 and plotted them on a bar chart. The red dots show peak times when Aurora should be more common, just after the Solar cycle peak. I have listed the AU sessions in the appendix. These include all Auroras detected at my location during those years. The bar chart shows a distinct drop off of Kp5 and 6 Aurora events starting in about 1989. According to my radio logs, something was happening to make Auroras less common. What was going on, and why was W1VD's advice not squaring with my memory? There were lots of small auroras in the 1970's and 1980's. There were very few auroras after 2012, and none of them involved a Kp index of 5 or 6.

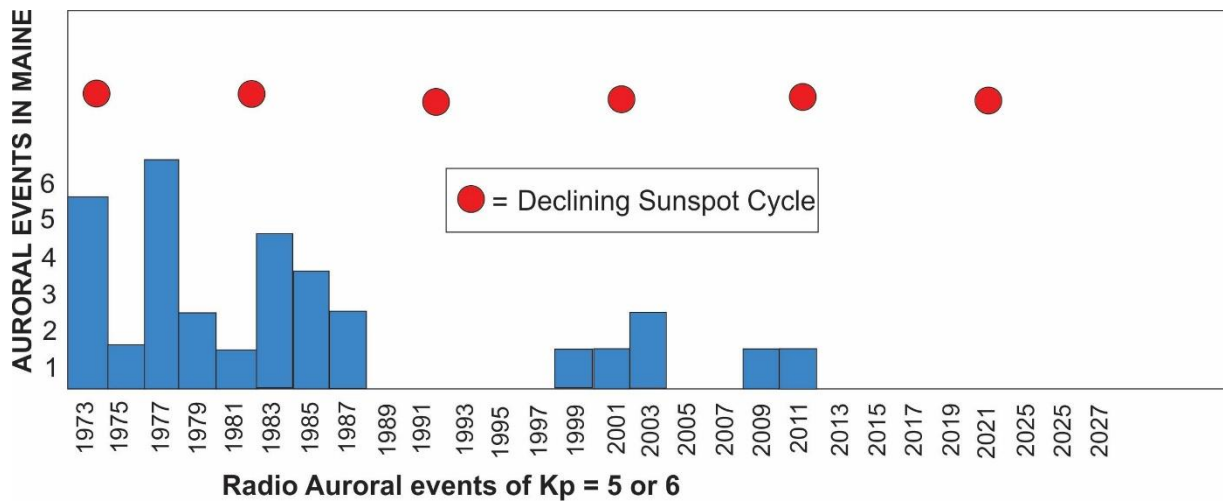


FIGURE 1

Kp 5 & 6 AURORAL EVENTS DETECTED IN MAINE FROM 1972 TO THE PRESENT

A look at this chart brings up another sticky question of why I caught no Kp 5 or 6 Auroras in the 1993 time frame. It was a very active cycle. One problem noted was that most storms appeared early and near the peak of the cycle in 1988 or 1990. They were all strong! I may also have been less active during those years. From the looks of my chart, I believe that a KP5 or 6 radio Aurora is just about impossible to have at this time in 2026. It is interesting that I have not caught a radio aurora with a Kp of 5 or 6 since 2014, a twelve-year drought. Our only detected Auroral events have involved huge storms with Kp indices of 8 or 9! Your results may have varied, but I was sure that my research was indicating a trend. A quick check confirmed the cause. Our geo magnetic field is undergoing some rather radical changes these days.

Some researchers are pointing to a magnetic pole reversal sometime in the next few hundred years. Our field is generally weakening. The magnetic pole is moving. The time is also right for a magnetic pole reversal. The Earth has experienced many pole reversals over spans of 100 to 300 thousand years. It has been over 700 thousand years since the last known reversal. According to an article printed in Nature, we are overdue for a reversal and that the North Magnetic Pole is wandering at great speed at the present time. Since the North Magnetic Pole was discovered in Canada near the Boothia Peninsula in 1831 by James Ross, it has been slowly moving Northward. Typical speed of movement was steady at about 15 km per year. In 1999 it shifted gears and started moving at about 60 km per

year. In 2020 alone the pole migrated about 78 km, or the distance between The Hilton Garden Inn in Windsor Locks, and Bridgeport, CT or Worcester, MA. This is a huge distance, and the magnetic pole has now passed the true North Pole and is still rapidly heading towards Siberia. It is estimated that between years 2000 and 2050, the Magnetic Pole will have traversed the globe from 80 degrees latitude across the pole to 80 degrees latitude on the Siberian side. The cause of this rapid movement is apparently two areas of molten metal circulating under the Earth's crust in Canada and possibly combining with another cell of molten iron on the Siberian side of the Pole. 1.

Shift in magnetic north pole (yearly position, 1590-2020)

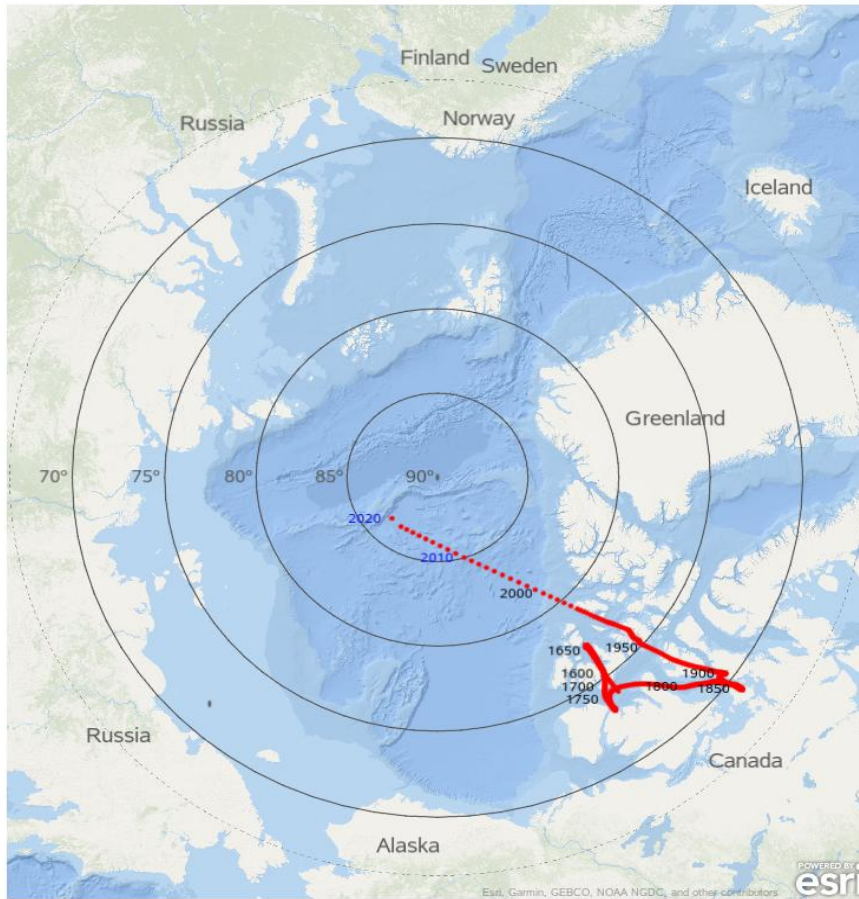


FIGURE 2

A Chart of Magnetic Pole movement 1600 to the present. Courtesy of Robert Allison at SAS.com, January 31, 2020. While North America is now farther from the Auroral Oval, Asia and Europe are much closer now, and with stronger magnetic fields.

The obvious result of this pole shifting is a change in our magnetic latitude and longitude. In years past I knew that my geomagnetic latitude was over 54 degrees North. Today it is 52 degrees and no doubt falling as I write this! Our bad news is good news for Europe. The Magnetic Pole is drifting closer to Northern Europe and away from North America. In 1972 I moved to Maine and the Magnetic Pole was 2310 miles North of me. In 2025, it is about 3210 miles away from my house. A Lucky ham in London would see the Pole drift his way during that same period. London was 2860 miles away from the North Magnetic Pole in 1970 and is now about 2250 miles away in 2025. As the auroral belt is centered on the magnetic poles, it becomes obvious that we are getting farther and farther away from the Auroral zones. Interestingly, the upper Midwest and Dakotas have not suffered quite as much with increased distance. This is due to the effect of great circle paths and a dipping magnetic latitude. It is readily observed on a globe. Alaska is much closer these days!

In March, 1990, Emil Pocock W3EP published an excellent article in QST magazine with an Aurora update.² He covered some very important points concerning Auroras that were geared toward making amateur radio operators more effective at working Auroral storms. Time of year variations and auroral path geometry were discussed. In addition, he provided a general indication of path loss vs. frequency assuming that ionization was strong enough for the higher bands to make contacts. In 2025, we are fortunate to have even more information available to understand the process of Auroral VHF propagation.

On January 19, 2026, there was a very strong visual aurora evident with a K index that rose to 9. To most everyone's surprise, very little Aurora propagation was detected in the USA. I know of a very few 50 MHz contacts and possibly a few 144 MHz contacts among some VE stations. Visual Auroras were observed at many Southern locations. It turns out that the conditions that will generate a visual aurora have little in common with what is needed to form a radio aurora. Visual events are initiated by charged plasma streams blasted from the Sun in the direction of the Earth. The magnetic field of the Sun extends well out away from the Sun and affects the planets in its' system. This interplanetary magnetic field undulates as it moves along with the Solar Wind. Recall that the Sun is rotating and any Solar wind with associated expanding plasma sheets will contain this rotational force along with outward movement. This will produce a pinwheel effect as it travels away from the Sun. The outward movement of plasma from the Sun is modified by vortices and uneven amounts of plasma from competing Solar regions. When the Solar wind enters the area of the Earth's magnetic field, certain things might happen. It all depends on the IMF, the Interplanetary Magnetic Field. If the field is properly positioned as it encounters the Earth, that IMF could be negatively charged and attracted to enter the Earth's magnetic field due to the positive

sign of the Earth's magnetic located at the Pole. Opposites attract, and the field lines of the IMF will connect with the Earth's magnetic field lines, allowing large amounts of plasma to enter the Earth's magnetic field.

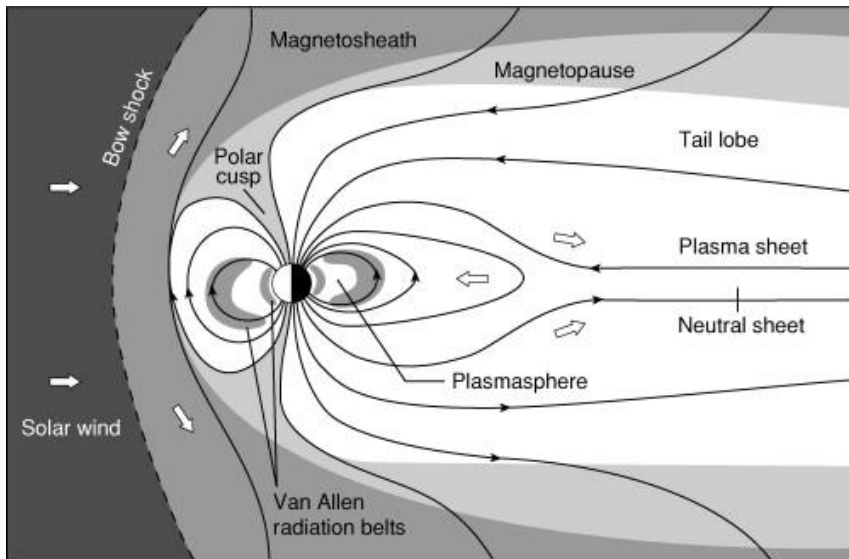


FIGURE 3

The Earth's magnetic dipole, as shown above, has field lines whose angle varies over the globe. It can be seen that the field lines are near vertical at the magnetic poles and horizontal at the equator. The Earth's magnetic dipole has the positive North pole set to attract Solar wind plasma with a negative charge. If the Interplanetary Magnetic Field (IMF) is negative, those plasma particles will be directed past the magnetosheath on the Sunward side of the Earth and then encounter the polar cusp where the magnetic fields are weak and directed straight toward the North Geomagnetic pole. Fast Solar wind speeds impart energy to the protons and electrons of the plasma in the IMF. Depending on the Solar wind speed, these particles can be propelled Earthward along the field lines, losing energy as they collide with atoms and molecules in the rarified air of the F and E layers. Such collisions with Oxygen or Nitrogen atoms will impart energy to them by blasting electrons from the atom structure. Photons are given off when the atoms shed that energy as they throw off electrons and return to a more stable state.

The visual Aurora is the result of the energy exchange as particles spiral down into the ionosphere due to the Solar wind energy. Should the energy be more than sufficient, it is possible for the Solar Wind plasma to be pushed to the more dense areas of the E layer at about 100 to 110 km altitude, and possibly into even heavier air of the D region to interact with the atoms and molecules there. Such events in the lower D region are Polar Cap Absorption events and adversely affect HF radio propagation in the area. D layer

attenuation will spike and kill off much HF propagation through the Polar regions. Radio Auroras can be quite complicated, and much is still unknown about electric currents in the Earth's Magnetotail. As the Interplanetary Magnetic Field, the IMF, collides with the Earth's magnetic field, and if the fields have the correct polarity, much plasma energy is conducted down toward the Geomagnetic poles and the Auroral oval. The field lines of the IMF and those of the Earth's magnetic field can and will connect. More energy is routed into the Magnetosphere with field lines of both systems connecting, and it ends up in the Magnetotail. The shock wave of passing Solar Wind compresses the Magnetosphere on the Sunward side of the Earth, and lengthens the Magnetotail on the Midnight side well out past the location of the Moon's orbit more than 1000 Earth radii distant. The Solar wind pushes the field lines and they can whip around in the tail, as the storm proceeds, Magnetic lines are broken and then may re connect. The amount of energy in the tail can be mind boggling. Stored energy in the tail can be released to outer space but also find its way back to the Earth's upper atmosphere thru reconnected field lines and charged particle drift into the equatorial plasma sheath thus producing large current streams of electric charges when combined with the Earth's Dynamo effect revved up by the Solar Winds of a large storm. The magnetic field lines of the magnetosphere enter the Polar cusp area and descend to the polar cap, while the field lines that are attached to the plasma sheath drop down onto the Auroral Oval. Energy from the plasma sheath is an important factor in radio Auroras.

It should be stated that the inherent energy contained in the Solar wind is not that great to always precipitate a radio aurora by itself. Solar wind speed is very important in imparting energy into Earth's magnetic field. The magnetosphere and the vast Magnetotail area are also a big factor in driving large Auroral storms.

Radio Auroras are the result of the electron and proton concentrations and development of strong Auroral currents flowing in the E layer during Solar storms. Huge voltage gradients of up to 100,000 volts develop across the polar cap area. Auroral ring currents possess currents of 5×10^7 Amperes. That is 5×10^{12} watts! The current is the result of large amounts of electrons flowing in what is known as the Auroral Electrojet. The radio scattering effect of electrons near this flow is what allows radio communication at low VHF frequencies. The Auroral Electrojet gets power from field lines connected to the plasma sheath in the magnetotail. Auroral radio scattering has nothing to do with the visual curtains that may be visible at the time. The visual aurora can extend up to 1000 km or more with intense storms, but electron content at those heights is just too low for any scattering to occur. Only in the E layer at about 100 to 110 km is there strong enough plasma content to allow radio scattering. The radio scattering area there is very uneven with quite small areas of

intense ionization drifting in that area providing the scattering medium. Interestingly, there is no advantage of using a wider beamwidth antenna pattern to obtain optimum medium coupling as is observed in tropospheric and ionospheric scattering. A very large antenna will always provide a linear improvement in signal strength with Auroral scatter. The downside is that it is harder to peak up signals with a narrow beamwidth as the electron bunching is constantly on the move. 3.

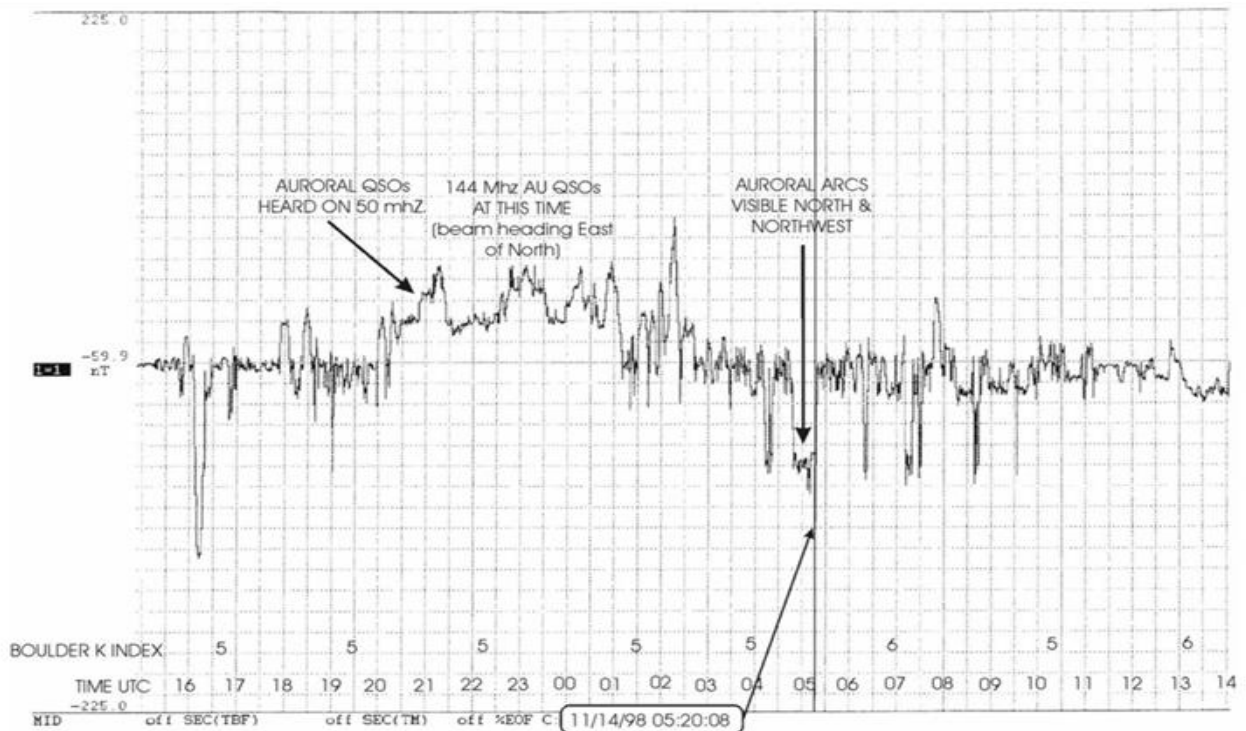


FIGURE 4

MAGNETOMETER OUTPUT FROM A TYPICAL AU SESSION 11/14/1998

The chart recording shown above, was generated in Maine in 1998 and shows a typical small magnetic storm. Note the onset of the disturbance at around 1600 & 1800 UT. It really ramped up at 2100 UT and 50 MHz QSOs were being made that afternoon. By 2300 the 144 band was involved with beam headings to the East for best results. Note the sub storms at 04:15 and 05:00. I was able to see a nice green curtain at 05:00 UT while I was away from the ham shack. When I arrived home at 05:30 the AU had subsided and the curtains disappeared. The K index was at 5. The magnetometer used for this recording was

aligned East-West and was nicely positioned to record the magnetic influence of the Auroral Electrojet. The large positive and negative surges give an indication of the presence of that Auroral Electrojet. It has also been found that ground currents of many hundreds of amperes have been detected in mid latitudes during such storms.

AURORAL RADIO COMMUNICATION EXPLAINED

It is well known that any radio wave radiating towards the Auroral Oval will only be scattered back when the wave energy is perpendicular to the magnetic field lines. What does this mean to an amateur trying to make a contact on a low VHF frequency? Any energy radiated toward the scattering area will only be returned at a precise 90 degree angle referenced to whatever the magnetic inclination is at the scattering area. The magnetic inclination varies all over the globe. It is vertical or 90 degrees at the magnetic poles, and essentially horizontal at the equator. I have included an inclination map for North America.

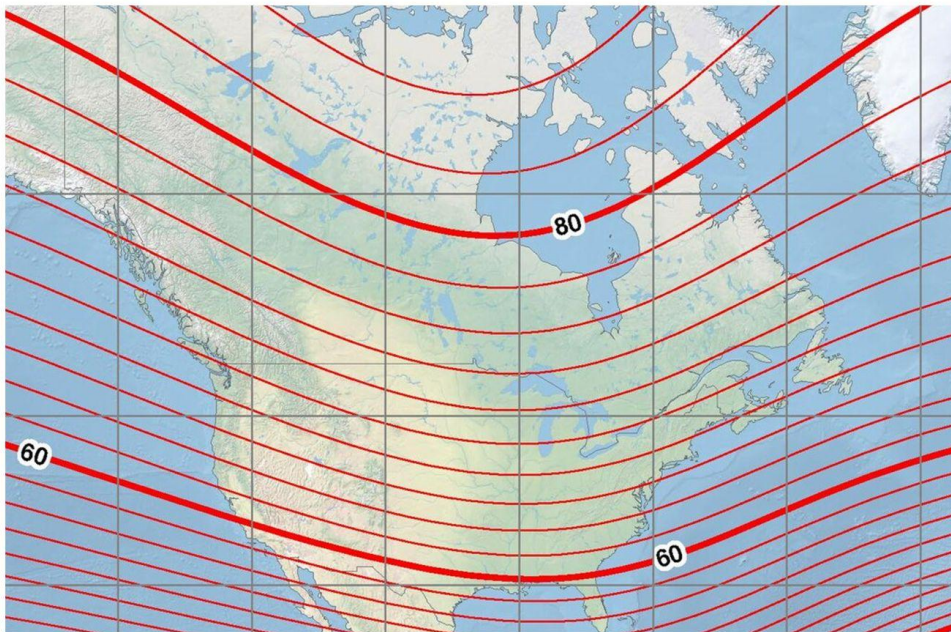


FIGURE 5

Map of Magnetic inclination for North America. Inclination is another name for the dip angle of the magnetic field. Inclination lines are every two degrees. Note that Hartford is at about 67 degrees. Chicago is at about 70 degrees inclination.

RF energy that arrives at the charged particles at the magnetic field lines must be scattered perpendicular to those field lines. If the field line is inclined at 74 degrees, the energy will scatter back at $74 + (90-74)$ or 106 degrees from vertical. A simple diagram will show what is happening.

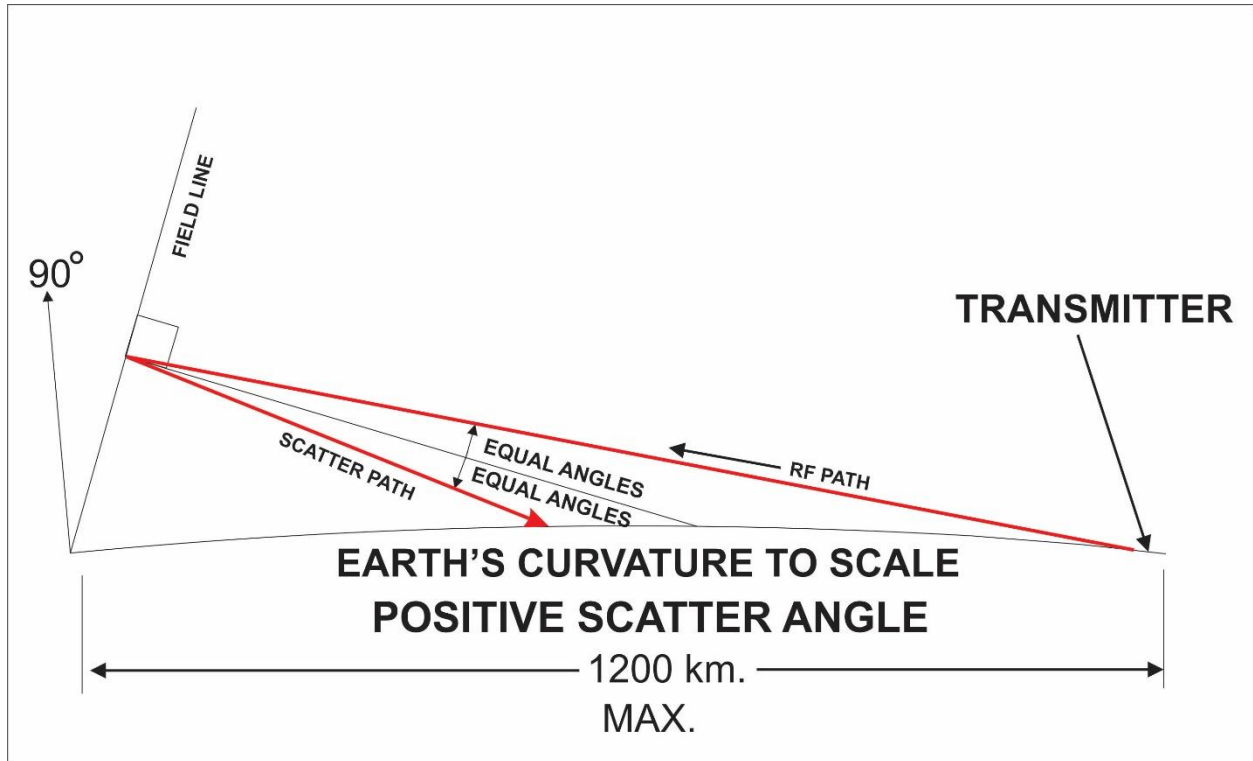


FIGURE 6

The basic geometry of an Auroral scatter signal and magnetic field lines. Each angle on either side of the perpendicular line from the field line must be equal.

It is seen in FIGURE 6, that while the arriving wave front can only scatter downward from the magnetic field line, scattering will occur along a band from East to West along that precise angle. This is a bit like the rainbow effect with Sunlight and scattering water droplets. If the wave front hits the field line at perpendicularity, it will bounce back at 0 degrees. If the wave front hits the field line at a plus angle such as +2 degrees as shown above, then the scattering path will occur at - 2 degrees. The angle of incidence must equal the angle of reflection. The scattering in the East-West plane is rather uniform, tracing a path with similarities to a rainbow. In fact, a RADAR trace will only pick up what is scattered back at the same angle. It will look much like the representation in Figure 7. The curved line is due to the distance increasing as you go away from magnetic North. The 100 km E layer appears to drop lower to the horizon due to the Earth's curvature and increasing distance.

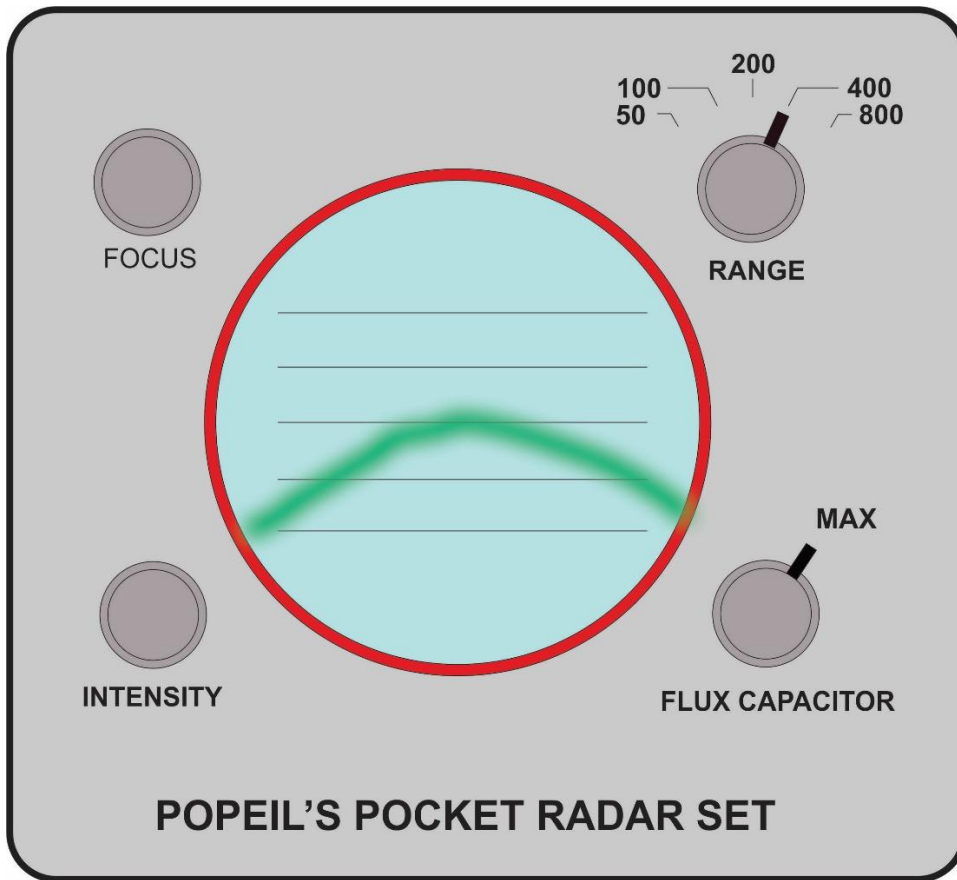


FIGURE 7

The RADAR return will be highest at the boresight heading as the echo is closest. As the RADAR scans East and West, that return signal gets lower in height as it appears farther away until it bisects the horizon and then disappears.

Remember that the magnetic field line angles are different at any given spot on the globe. (See FIGURE 5) The field lines are near vertical at the North Magnetic pole, and just about horizontal at the equator. For radio amateurs in New England, we have conditions that are agreeable for Auroral contacts. The Auroral Oval is normally at latitude 65 or 70 degrees

North. During a Solar storm that oval will extend Southward and come within range so that Auroral contacts can be made. It is only at the bottom of the E layer where the Auroral Electrojet is located about 100 to 115 km or so above the Earth, that electron content is high enough to support the scattering effect of VHF radio waves. With the radius of the Earth at 6380 km, a 100 km height will give us a line of sight limit at about 1200 km from our antenna. In my case, the antenna lobe hits the E layer on my horizon below the Southern end of Hudson's Bay. The magnetic field lines there are at 74 degrees slanted Southward, while in Maine, the field lines dip at 68 degrees. This can be seen in the following chart.

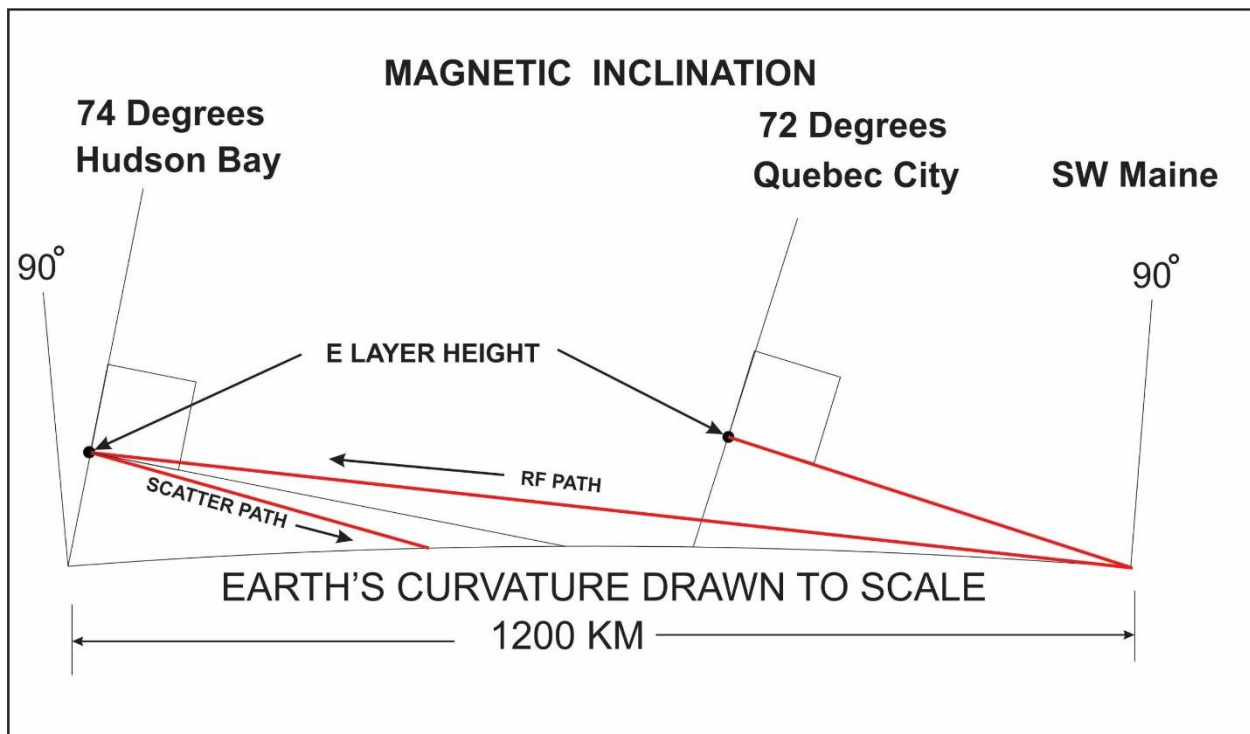


FIGURE 8

TYPICAL AURORA GEOMETRY FROM MAINE TO HUDSON'S BAY AT MAXIMUM LINE OF SIGHT DISTANCE. There is an obvious change in angles depending on the position of the path! To make these charts accurate, the 90 degree reference is the center of the Earth and varies with latitude. The ZERO degree line is just North of Quebec City.

It is interesting that scattering from Hudson Bay will require about a +2 degree transmit angle from a transmitter in SW Maine, while a more energetic storm with a scatter area farther South just North of Quebec City will result in a perfect zero degree angle when hit head on. In addition, all of the scattering angles are centered on magnetic longitude, not

geographic longitude. The declination of the magnetic field here in the Northeast is at about 15 degrees West. This means that any scattering angle will depend on the magnetic longitude as the field lines are aligned along similar longitudinal points. In short, the visual and radio Auroras are located according to the magnetic latitude and longitudes rather than any simple geographical location.

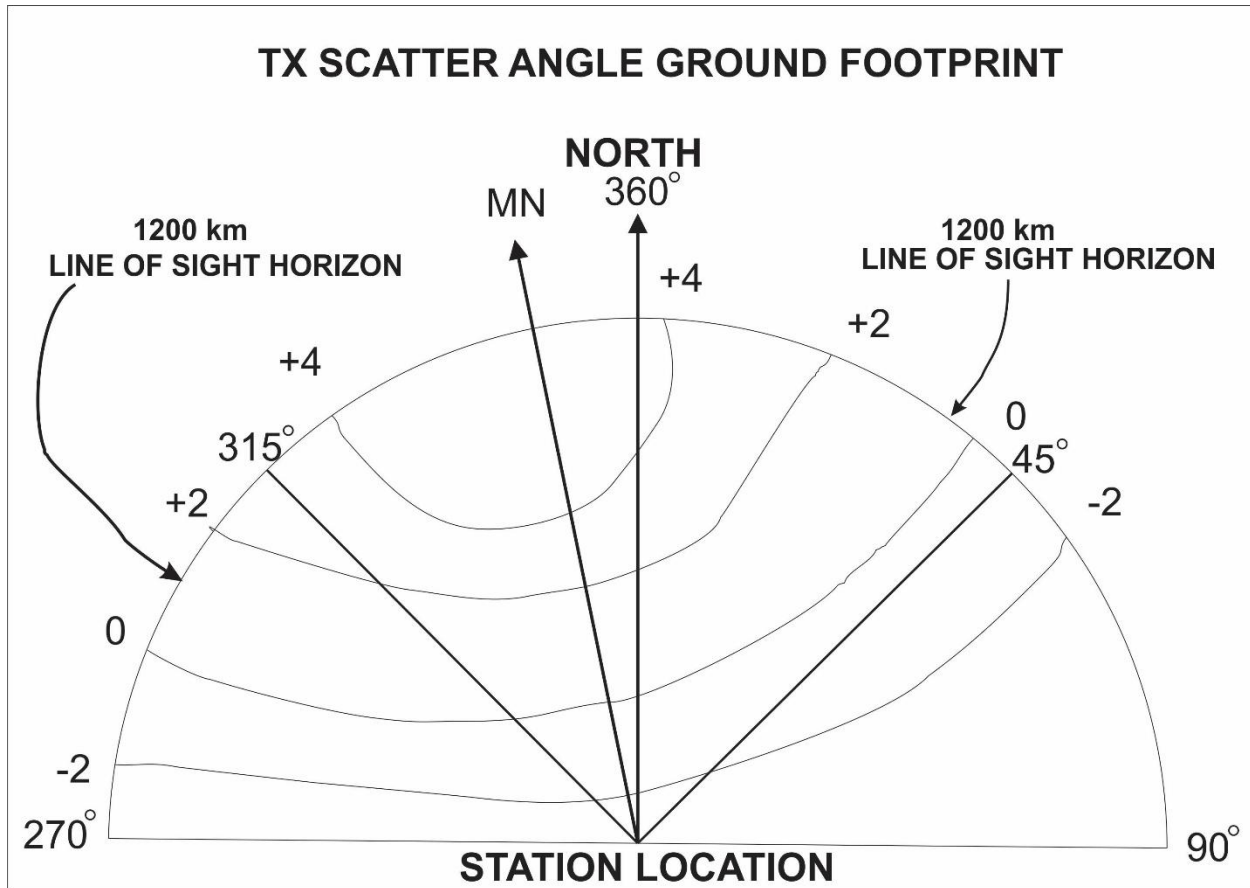


FIGURE 9

This is a stylized map showing a typical setup of scatter angle lines. This is a handy way to estimate where to point your antenna to intersect specific scatter angles. Such maps must be generated for each location on the globe, however.

If you think about the RADAR picture in FIGURE 7, that trace would be a return from a zero degree angle. The point where the return angle bisects his horizon is where a station should aim for a contact with another ham station with a complementary angle. Other angles have footprints as well, and they are superimposed on the map of FIGURE 9. If the Auroral scattering area is near Quebec City as in FIGURE 8, then the angle I am generating is about 0 degrees. If anyone would want to contact me, they should align their antenna

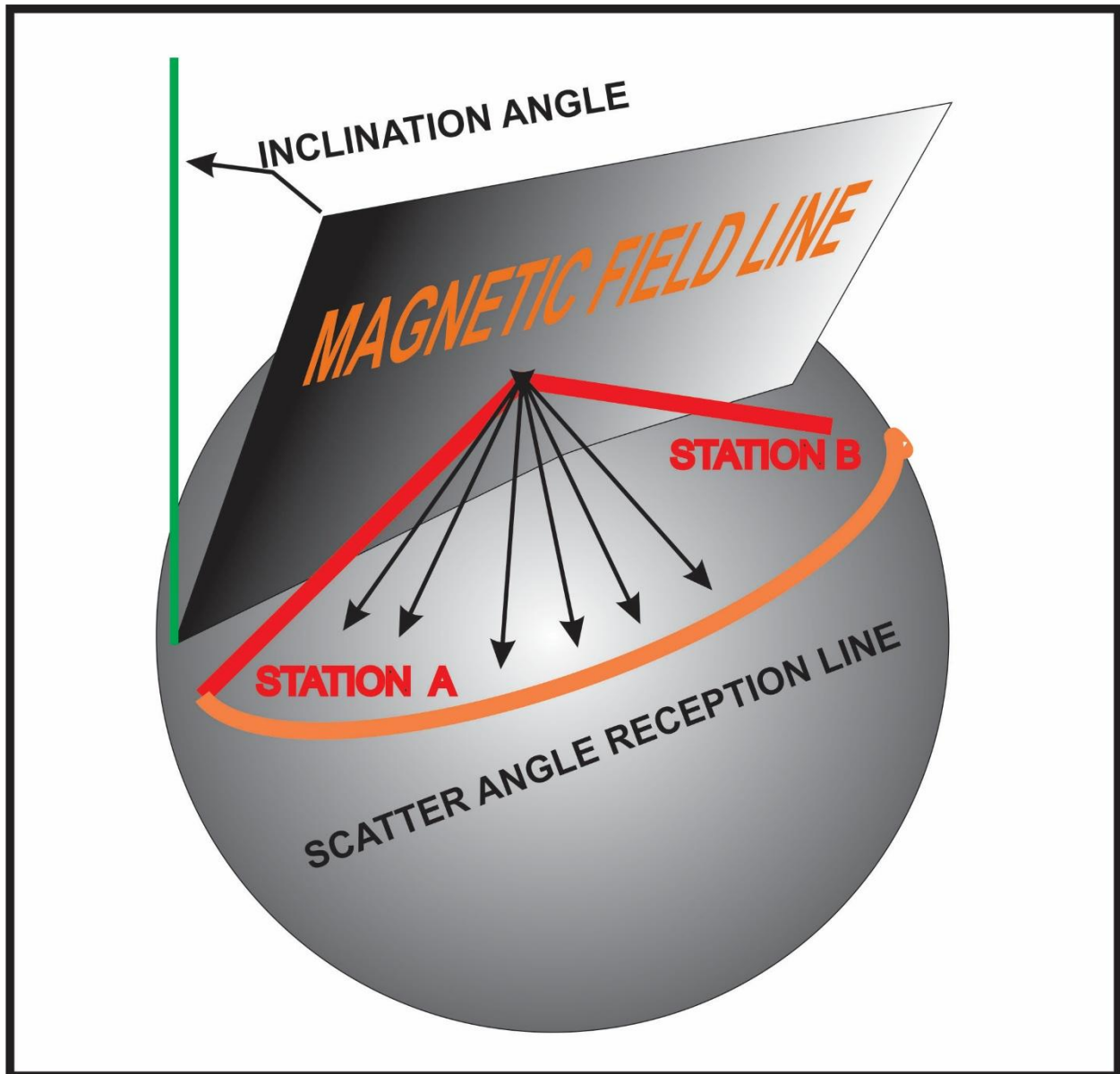


FIGURE 10

STATION A is West and is receiving STATION B, located to the East. STATION B is transmitting and is around the + 2 degree angle.

Station A has aimed at the -2 degree line for Station B, peaking up STATION B. The -2 degree line is shown in orange. Station A is aimed around 50 degrees.

Note the scattered TX signal falls all along the -2 degree line. The orange line does not include STATION B however! Station B in New England is at +2 degrees, and aimed at around 305 degrees. The Magnetic Field Line is tilted and arrayed a bit Southwest.

along the zero degree line for their location, and adjust for maximum. If my TX angle was rather at +2 degrees, then another station must align his antenna to intersect the -2 degree angle on my map. This would be the -2 degree spot for the other station . We are not really aiming at the same spot! The sum of both the TX and the RX scattered angles must equal zero to maintain perpendicularity. Your antenna beamwidth can mask this fact.

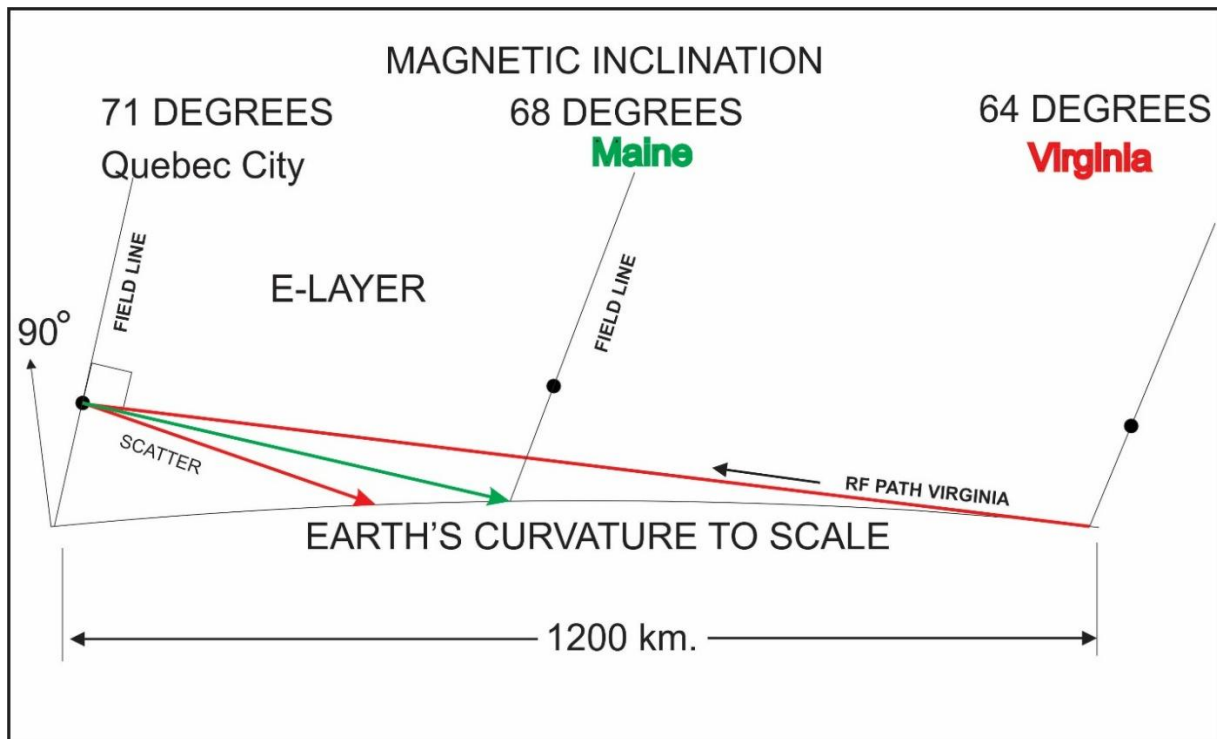


FIGURE 11

NORTH SOUTH AURORA CONTACT GEOMETRY

Figure 11 shows the geometry involved for a North - South Aurora contact. The Southernmost station must have a line of sight path to the scattering point. The Northern station will be using field lines that are much closer to him. The Southern station will have a plus angle that is greater than a station in Southern Maine. Stations farther North than my magnetic latitude might even have a negative angle. The procedure for each station is to turn their antenna a bit to the West or East and probe for the zero degree angle track of the Northern station, and the positive angle track for the Southern station. Both stations will find a spot close to magnetic North. There are maximum and minimum ranges that can be achieved with auroral scatter. The minimum range depends on how close you are to the scatter area. Too close, and your signal will travel into outer space!

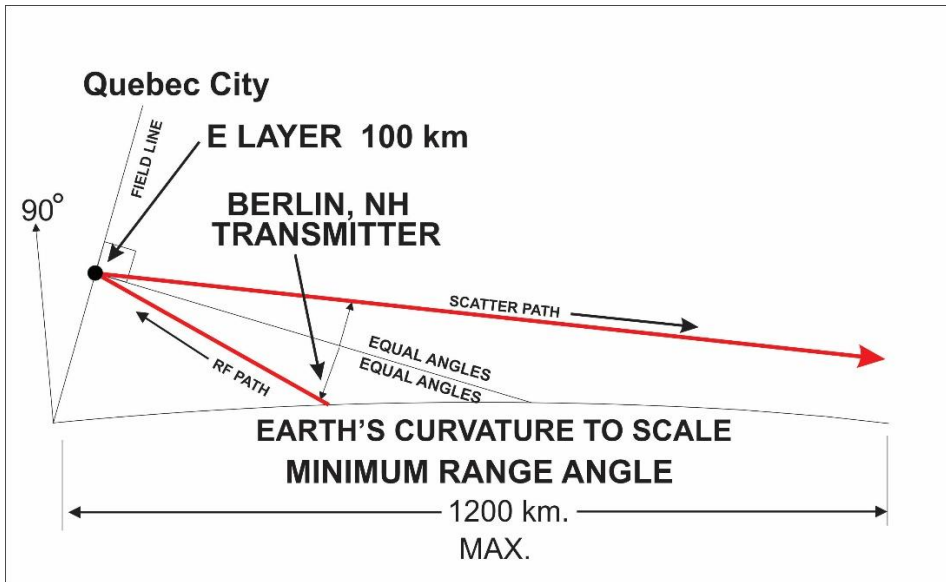


FIGURE 12

A hypothetical setup with Aurora situated near Quebec City and a station in Berlin, in Northern NH tries to make some contacts. He is shut out as the scattering area is too close to him. The scattered signal misses the Earth! Aiming East or West will not help.

Similar bad results can happen when the Solar storm gets so strong that the plasma scattering areas are pushed well south of your location. When this happens you are shut out of all the fun.

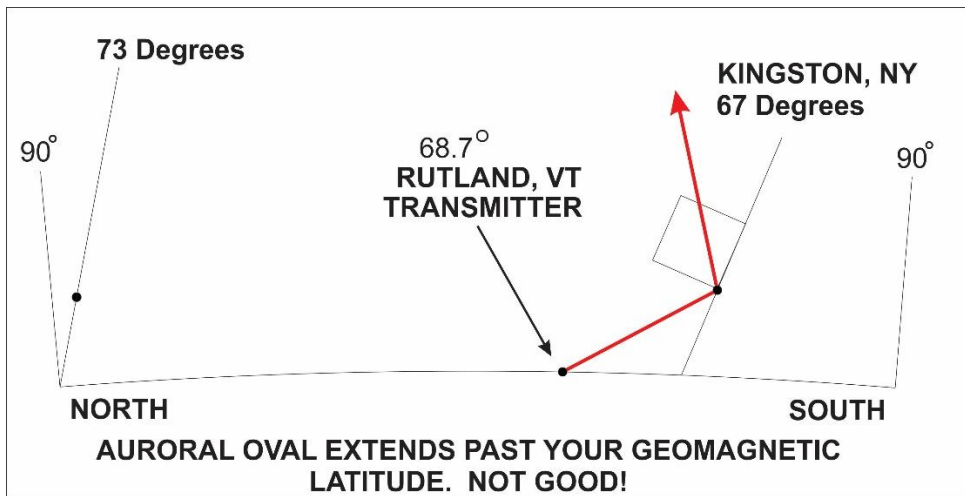


FIGURE 13

When considering these many scattering cases presented, it should always be remembered that by aiming your antenna well to the East or the West, you are still

maintaining the same angles in relation to the perpendicularity of the scattering along the magnetic field lines as long as the distance to the scatter point stays the same. The paper that these diagrams are printed on is two dimensional and we live in a three dimensional world!

W3EP published a map of long distance QSOs made in the big February 1986 Aurora. The dark lines indicate contacts with distances between stations of over 1500 km.

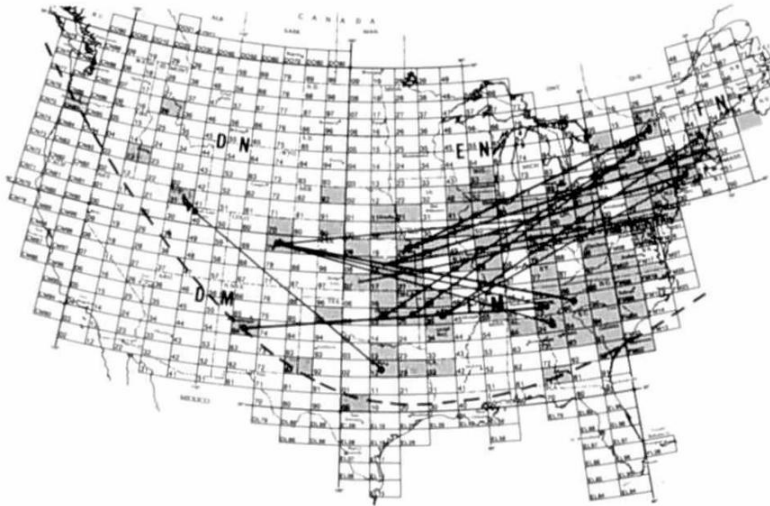


FIGURE 14

Map of the February 8-10, 1986 Aurora by W3EP showing long distance contacts during the height of that storm. Contacts of over 1500 km are shown. Note the position of the contacts.

Compare this map (above) of Auroral contacts made during the large Auroral storm of February 8,9 and 10, 1986 with the map of North American magnetic Inclination. (FIGURE 15) Do you notice anything unusual? The contact map, Figure 14, is courtesy of Emil Pocock. The Great Aurora of February 1986, QEX, Jan 1987.

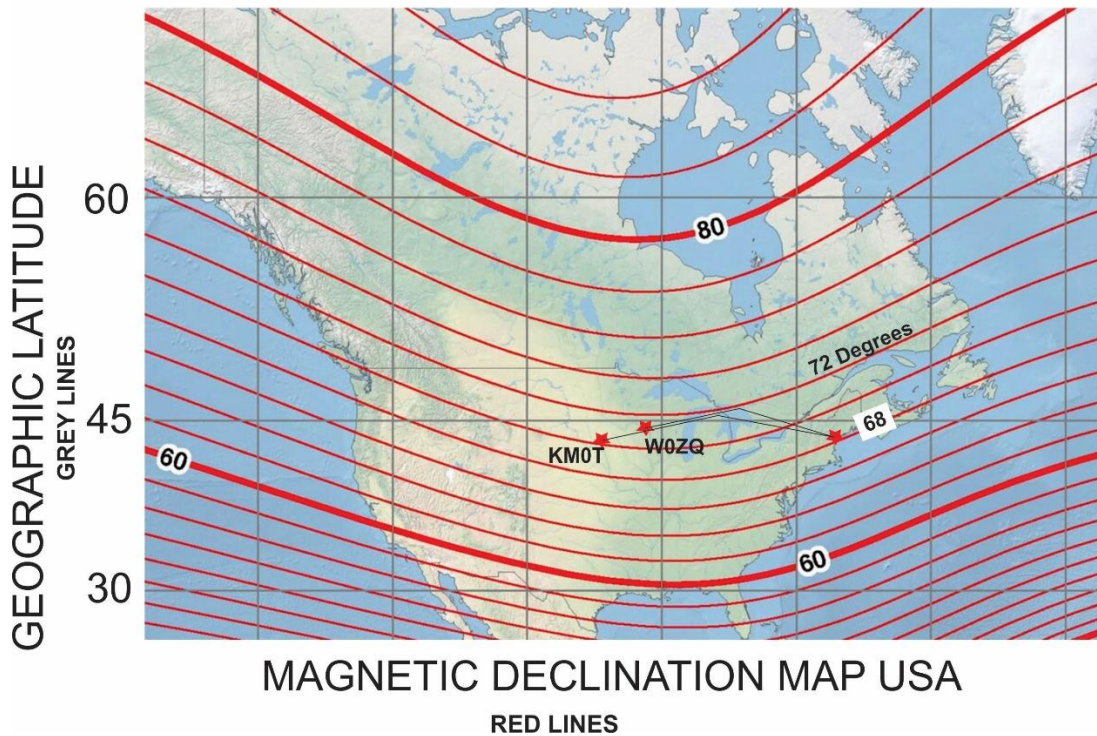


FIGURE 15

Magnetic Inclination Map of North America. This is similar to Figure 5, but with some actual 222 MHz scatter paths shown to indicate possible propagation paths.

All of the long distance contacts are made parallel with lines of equal magnetic inclination. This is the direction and area where long distance contacts are normally made. To get ranges of nearly 2000 km, the scatter point must be midway between the stations. Those scatter points will be located along those field lines, with each station located fairly close to the field line to lengthen the possible East West path. From the look of the contacts made, it seems the maximum Southward extension of field lines energized with plasma at the height of the storm in February of 1986, were possibly just North of New York City with an inclination or dip of 66 degrees at that spot.

You can also see that some long distance contacts were made from the plains states Eastward and that they also follow the inclination lines trending to the Southeast from that part of the country. We know that the distance to a true perpendicular scatter point is roughly 450 km or 280 miles North of me in Maine. The energy bounces off the field line right back to me at zero degrees. When the field lines move closer to me, I can simply aim

West along the field line to optimize the scatter angle closer to zero. Magnetic field lines moving closer to you can provide an excellent chance for East-West DX. Those long distance contacts happen at that time when the Aurora surges Southward. This can be early in the Auroral event, so be prepared. Such DX opportunities can be brief.

I would like to show a first attempt at diagnosing an Aurora opening on my part, and would like to use actual contacts on 222 MHz from January 20th, 2026. I plotted two contacts on Figure 15. I put a star on the inclination map, Figure 15, to show the location of W0ZQ in Minneapolis, and KM0T in Sioux City Iowa. Both were QRV during the energetic VHF & 222 MHz Aurora on January 20, 2026. I was varying my antenna between about 280 and 325 degrees during the opening. A look at the inclination map and a guess at where the Auroral Oval had extended at that time, makes me think that The Scatter point was at the top of lower Michigan and just a bit East of there in Lake Huron. I did manage to work W0ZQ in Minnesota. I was also called by KM0T in EN13, on January 20th as well around that time, but I could not copy his call. I did hear him call several times at a 2037 km distance. (I had bad line noise and the signals were very weak.) A look at his location, and you can see that the path to KM0T and W0ZQ is quite similar and parallel with the field lines. I worked KM0T with better signals on Aurora on May 10, 2024 and my heading for him was around 285 degrees. This makes perfect sense when you look at the map. For such a long path, the scatter point should be midway between KM0T and K1WHS. Remember that both parties must have line of sight to the scattering point or about 1200 km. The heading on the map for me to the KM0T scatter point is about 285 degrees with the scatter point likely located just East of Northern Michigan. W0ZQ was at 305 degrees azimuth from Maine, slightly East of the midpoint and I peaked up on his signal. The scatter point for W0ZQ was probably just East of the northern edge of Lake Huron. He was probably aimed a bit more to the East when I peaked him up. If W0ZQ had been aiming a bit more to the North, I would aim more to the West. The exact placement of the scatter angles has not been worked out yet for these spots, so a more detailed study is not possible. A scatter angle map has to be compiled for both locations. The junction of the actual scatter angle and where it touches the horizon can give you a reasonable idea of where to point for those long distance contacts. I measured the distance to the scatter point near Northern Michigan for KM0T, and it is about 1100 km distant from Maine. If the E layer is at 100 to 110 km height, then I have a few more km available to work slightly farther West than Sioux Center, Iowa. I suspect a contact at 2100+ km is possible if the station is located in the correct place and has a good low horizon. Such long Auroral distances require a good low horizon angle at both locations for best results.

What is the Harang Discontinuity?

During any large Solar storm, as the Solar wind impacts the Earth, we know that much energy spirals down the magnetic cusp at the poles whenever the vertical IMF polarity is negative to match polarity of Earth's field. Additional energy is caught up in the Earth's Magnetosphere due to interconnections of the IMF and the Earth's field lines. Currents in the magnetic field form a very complex pattern of at least 7 different types of currents, so any discussion here is a simplified view. A very large part of any Solar storm on Earth involves large masses of energy being transferred from the Magnetotail and the neutral Magnetosheath at the Equator up to and back from the field lines that connect down to the Auroral Zone. It is this power that sets up the Auroral Electrojets. These are two cells of energy rotation centered on the Auroral Oval and located in the E layer of the ionosphere where the VHF scattering also takes place.

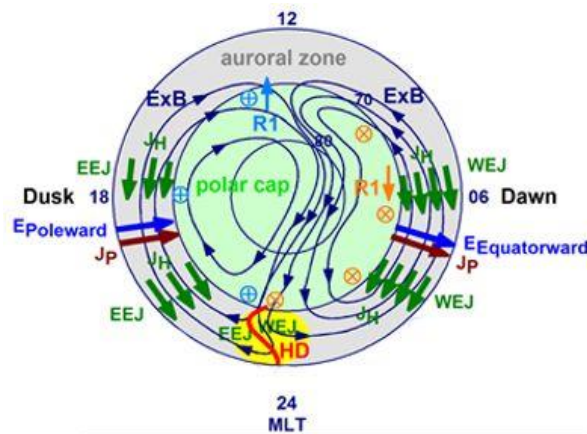


FIGURE 16

Idealized view of Auroral Electrojet as seen from above the magnetic pole. “HD” is the Harang Discontinuity Green arrows are showing current flow in the electrojets. 4

The evening or dusk electrojet has current traveling towards the magnetic midnight side of the Earth. That is counterclockwise as viewed from well above the North Pole. In addition to this current travel, there is energy coming and going from the field lines that surround the planet. Large currents flow towards the pole on field lines from the dusk side of the Electrojet, while currents flow towards the equator from the morning side electrojet. As most dedicated VHFers know, the Dusk side electrojet is the stronger and most developed. The better auroras typically occur before magnetic midnight.

Research utilizing the SuperDARN RADAR systems has helped to unravel the mysteries of the electrojets. SuperDARN stands for **Super Dual Auroral Radar Network**. It consists of a network of solid state 8 – 20 MHz low power phased array radars that can map plasma densities in the ionosphere. The antennas may be either log periodic arrays or wire arrays. Early installations utilize log periodic arrays phased in a line, while later sites utilize wire implementations of similar antenna patterns.

Many of these radars are employed in both hemispheres near the Auroral zones. Some of the Northern Hemisphere locations are shown below.

Northern Hemisphere SuperDARN Radars

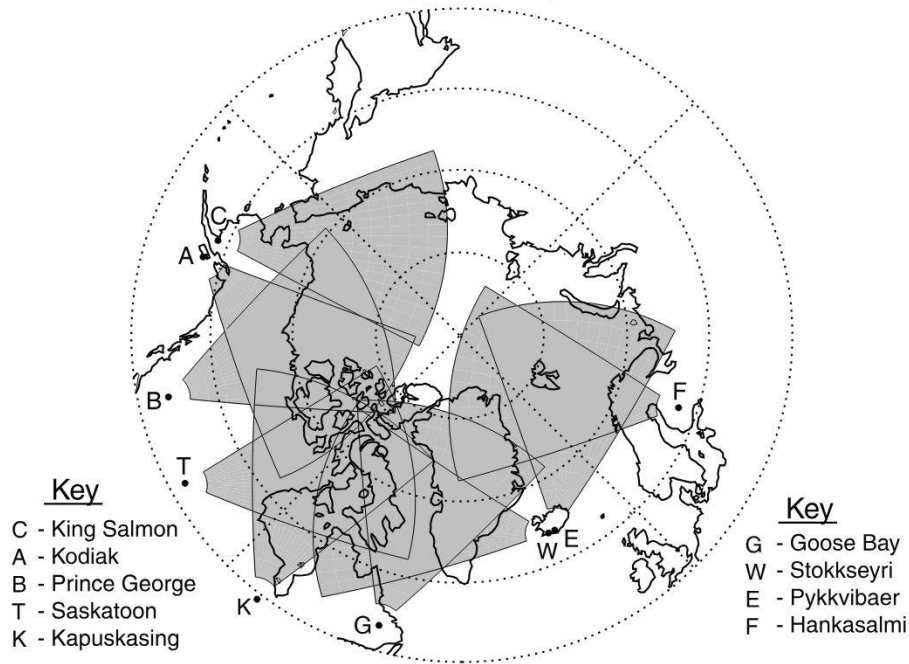


FIGURE 17

SuperDARN RADAR SITES NORTHERN HEMISPHERE

Mapping of the Auroral Electrojets with such an HF Radar system has produced very effective representations of what is transpiring during Auroral storms.

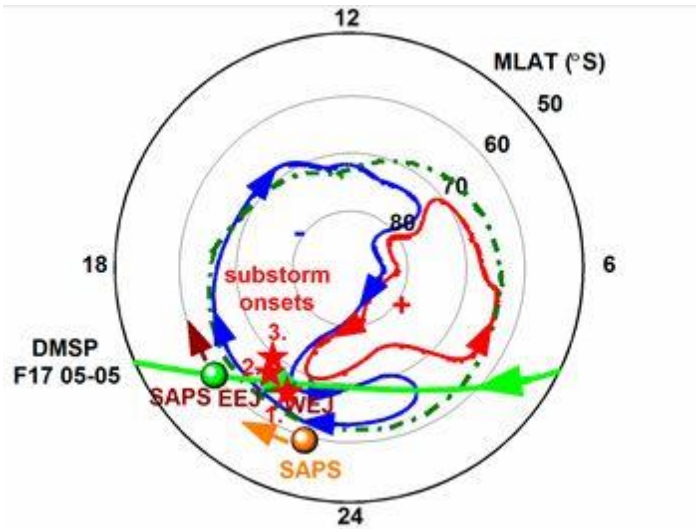


FIGURE 18

An example of mixing that can occur with the two Auroral Electrojets to change the time of the Harang Discontinuity passage at local midnight. Arrows are electron drifts,

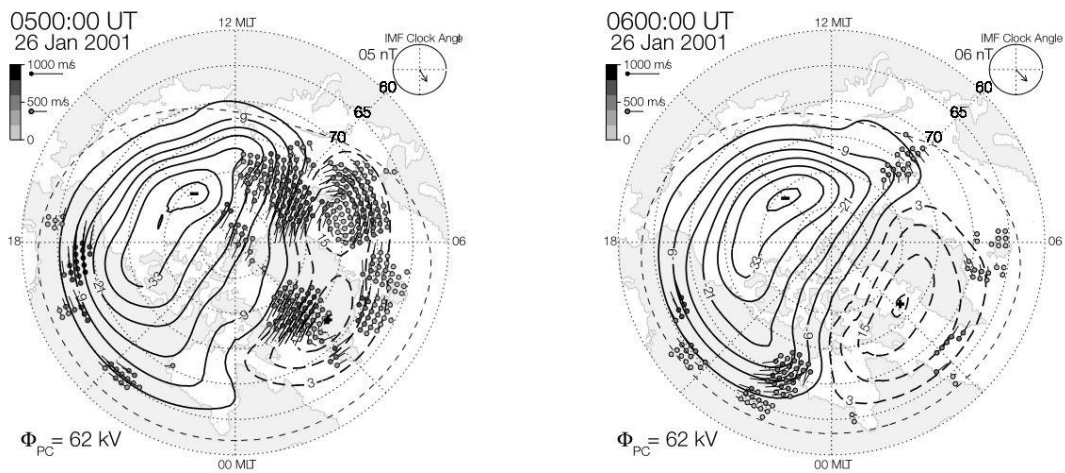


FIGURE 19

These figures of the Auroral Electrojet are from “SuperDARN observations of the Harang discontinuity during steady magnetospheric convection” by J.M. Hughes & W.A. Bristow *Journal of Geophysical Research* vol 108 NO. A5

If you look at the two representations of the Auroral Electrojet in Figure 19, you will notice a spot where the intense electrojet currents do not flow at the dividing spot between the two systems. This is the Harang Discontinuity. It occurs at approximately midnight local magnetic time. Due to the 15 degree West magnetic declination in New England, local

magnetic midnight occurs at about 11 PM local time. This time can vary as the two ring systems can fold over each other and cause the apparent discontinuity point to vary with time as in Figure 18. At the onset of the Harang Discontinuity, the high current of the electrojet is not overhead, and this will affect Auroral radio scattering and cut it off. As the Earth rotates under the ionosphere and your own geographical area approaches the junction of these two current structures, a large drop in plasma concentrations will occur. Aurora curtains can persist, but radio Aurora will fade when the Harang Discontinuity passes your location. Auroral scatter will start up again as the morning side electrojet starts to move into position. This morning system has current moving clockwise towards the midnight sector away from the Sunlit side of Earth. Notice that the dawn system is typically less well developed than the dusk side jet. ⁶

The movements in the electrojet system can swirl and vary markedly, as in Figure 18, and it is not uncommon for the Harang area to get rather convoluted as one jet swirls over the other, but there will be a definite drop in plasma intensity at the E layer height to cause radio Auroras to cease somewhere around 0300 to 0400 UT in New England. Magnetic midnight leads local midnight by about an hour. If you study Figure 19, you can see that the discontinuity is located over Hudson's Bay at 0500 UT on January 21, 2001. This is approximately North of Western Pennsylvania or Eastern Ohio. The Harang Discontinuity will be overhead to the North at this time. The structure of the Auroral Electrojet and the position of the Harang Discontinuity at magnetic local midnight is the reason why we see radio Auroras fade late in the evening near midnight, but then see them return again an hour or so later almost as strong as before. A fine example of the effects of the Harang Discontinuity is shown in an activity graph taken from data from the large March 1989 Aurora event, one of the greatest storms in recent memory. Charles Newton, G2KFZ analyzed all of the contacts made in Europe during that event and plotted them against time. The discontinuity is very obvious. G2KFZ has postulated that Auroral Es propagation is possible at this time of plasma reversal. ⁷ I am not sure about that. Auroral Es is another subject that could generate many conflicting theories.

The Harang Discontinuity also delineates two different types of visual Aurora patterns. The evening side currents produce curtains, while the morning side, after Harang passage, produces pulsating flashes of light.

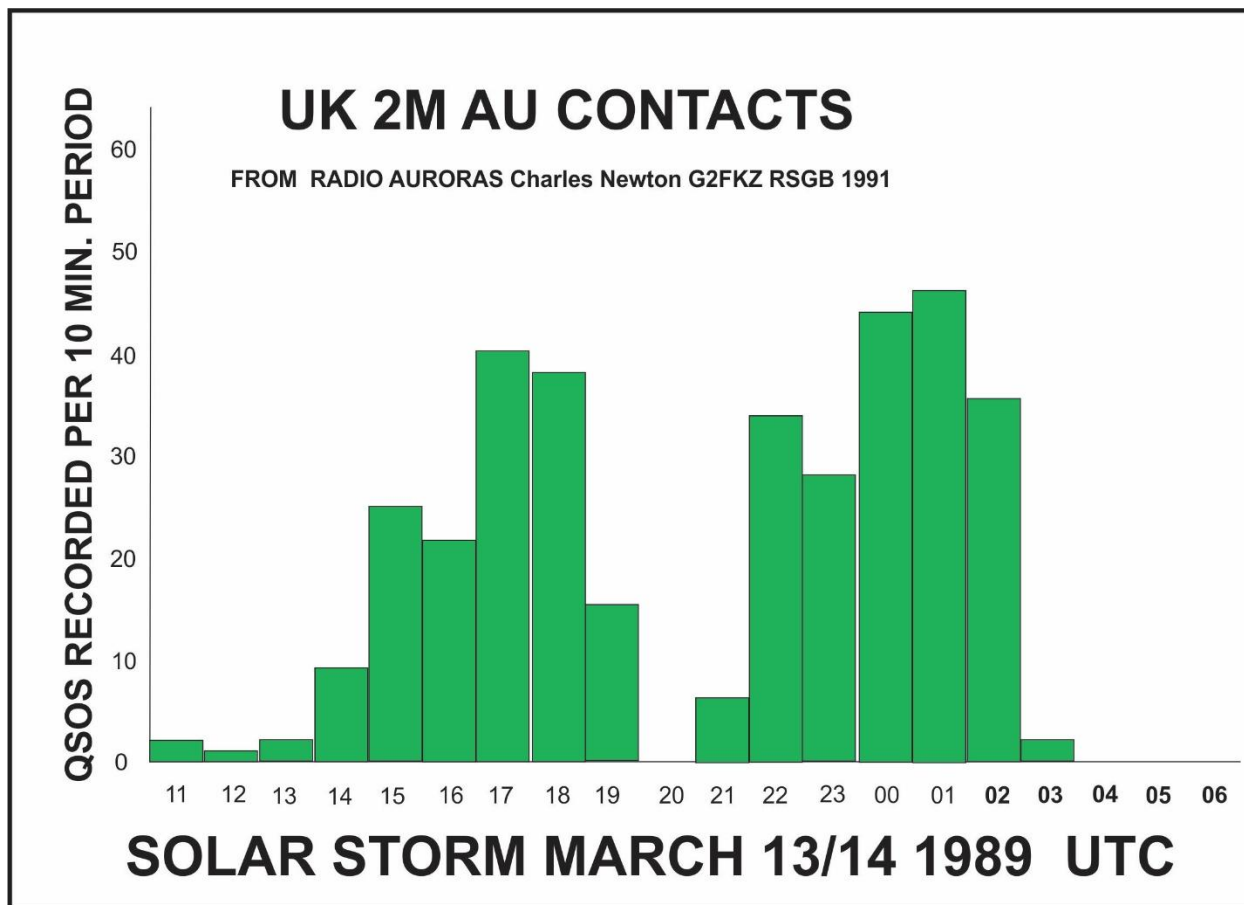


FIGURE 20

CONTACT TOTALS PER TEN MINUTE PERIODS FOR THE GREAT SOLAR STORM OF MARCH 13 & 14, 1989. Compiled by Charles Newton G2FKZ for the RSGB Propagation Committee.

Much has been presented here, but much remains untouched in unraveling the mysteries of Auroral scatter. The geometry of actual contacts can be quite difficult to decipher. The areas that are possible to cover depend on the magnetic data for those same areas. A look at Figure 5 demonstrates this fact. The line of equal inclination extends Southwestward from New England all the way to the Mississippi Valley, and then turns a bit towards the Northwest as you go West of the Mississippi. This allows contacts with many Southern States from areas in the Northeast. It also can prevent contacts with stations that are too far North. Maximum distances along this general direction will approach 2000 km with well equipped stations. The longest paths are realized the closer you are to a zero degree scatter angle. On North – South paths, possible distances are much less, on the order of 1000 km.

This is due to the line of sight distance to the scatter medium from the Southern station coupled with the minimum distance that the Northern station must be from the same scatter volume. Evaluating possible auroral scatter paths is difficult but very rewarding once you understand all of the variables involved.

The next time you experience an Aurora, visualize the possible path and try moving your antenna based on the principles outlined in this paper. I hope that knowledge gained here will translate into longer successful paths. Gud DX!

Footnotes

1. Nature Geoscience, Vol 13, May 2020. Livermore, Finlay and Bayliff. pp 387-391
2. Practical Radio Aurora, Pocock, Emil W3EP, QST. March 1990 pp. 20-25
3. Personal Communication, Dr. David Hysell, Cornell University May 2024
4. Harang Discontinuity Observed by Multi-Instrument satellites in the Topside Ionosphere During Substorms, Ildeko Horvath and Brian Lovell, Atmosphere, 2025, vol 16
5. Magnetosphere–Ionosphere Conjugate Harang Discontinuity and Sub-Auroral Polarization Streams (SAPS) Phenomena Observed by Multipoint Satellites, Ildeko Horvath and Brian Lovell, Atmosphere, 2024, vol 15.
6. SuperDARN Observations of the Harang discontinuity during steady magnetospheric convection. Journal of Geophysical Research, Vol 108 No. A5, 10/29/2002
7. Radio Aurora, Charles Newton, G2FKZ, RSGB, 1991
8. Radio Aurora, R. Miller VE3CIE, QST Jan 1985 pp. 14-19

References :

Magnetospheric Currents, Thomas Potemra Editor, Geophysical Monograph #28, American Geophysical Union, Washington, DC. 1984

An Aurora Detector, How to monitor the Earth's Magnetic Field, David Olean, K1WHS, July 1999 CSVHF Conference,
<https://directivesystems.com/information/tech-notes/magnetometer-for-auroral-detection/>

The Great Aurora of February 1986, Emil Pocock, QEX, Jan 1987.

APPENDIX 1.

Kp 5 & 6 Auroras recorded in Lebanon, ME. 1972 through 2026 Kp 5 & 6 are shown with an asterisk on the right side.

Logged auroras at K1WHS

DATE	STATIONS WORKED	STRENGTH nT	Kp	* = Kp 5 to6
10/31/1972	ant at 12 ft FM29, K1PXE!	-199	8	
06/06/1973	K8III 144	XX	5?	*
09/09/1973	K8, VE2, W2	-79	8	
11/24/1973	K8III 144	-59	5	*
07/05/1974	AU Es W7FSA W9 W8,4	-77	7-	
07/08/1974	50 MHz VE2 W2	-60	6-	*
09/15 16/1974	W2, W4, W3	-159	8-	
10/14/1974	W9YYF W8KPY	-85	6	*
11/11/1974	EN50 EM99	-78	6+	*
01/07/1975	50 MHZ W1, W2	-59	8-	
03/10/1975	Illinois, Ohio	-90	7	
04/20/1975	Ohio. MI.	-70	6-	*
03/26/1976	Ill. Ind.	-226	8	
04/01/1976	K0DAS, K0WLU BIG	-218	8+	
05/02/1976	FM16	-107	8+	
07/29/1977	W4 W9	-94	7-	

10/27/1977	VE3 W9	-133	7-	
01/05/1978	W3, W8,W9	-121	6	*
03/27/1978	W8, W4	-98	7-	
04/11/1978	VE1 W8	-114	8-	
04/13/1978	ve1 w8	-80	7-	
04/30/1978	50	XX	5?	*
05/01/1978	W4, W8, W9 BIG	-150	8+	
06/01/1978	W3, W8	XX	5?	*
06/04/1978	W4 W8	-71	6+	*
06/10/1978	VE1, W8 220 W1	XX	5?	*
07/05/1978	W3,W4,W8	-99	7	
09/08/1978	W8, W4	-79	6-	*
01/05/1979	W6 SHORT	-83	5+	*
03/29/1979	50 W3, W9	-129	7-	
08/13/1979	FM09 W9, W8	-71	7+	
08/29/1979		-140	8-	
01/01/1980	W8, W3	-100	5	*
04/12/1981	EN70	-163	7	
04/13/1981	EM84, EM96	-311	8+	
07/25/1981	EN50, EN60	-226	8+	
08/23/1981	EM78,	-101	6+	*
04/10/1982	EN70 FM05	-137	7	
07/14/1982	EN91	-325	9	
03/02/1983	EM99 EM69 FM16	-167	7	
07/24/1983	EN70 EN80	-74	6	*

11/01/1983	EN70, EN72	XX	5?	*
02/13/1984	220 contacts made	-59	5+	*
04/05/1984	FN13	-108	6+	*
09/23/1984	Visible AU no QSOs	-75	7	
06/09/1985	50 MHz Contest	-77	6-	*
08/13/1985	W8, W9	-51	6	*
08/12/1986	K2TTI 144	XX	5?	*
01/02/1988	EM77	-88	5+	*
01/14/1988	EN90 FN03	-147	7	
03/28/1988	EM79 EM83	-121	6	*
08/29/1989	EM79 FM07	-152	7+	
10/21/1989	Big 144	-268	8+	
06/30/1992	W8, W9 W4	-89	7-	
11/14/1998	144	-109	5+	*
11/07/2001	EN34 EN81	-292	9-	
09/08/2002	EM37 EN34	-181	7+	
10/01/2002	EN50 EM39	-176	7+	
05/01/2003	FN20	-78	7-	
05/29/2003	FN21 W9	-144	8+	
06/09/2003	EN80, EN82	XX	5	*
06/16//2003	EN51 6M	-68	6	
07/11/2003	FN31 6M	-105	7-	
07/18/2003	W1, W2	-90	6	*
10/29/2003	EM66 EM78	-350	9	
10/30/2003	FM02 EM84	-383	9	

10/31/2003	220 432	-307	8+	
11/20/2003	222 MHz EM59	-422	9-	
07/27/2004	EM59 EM77	-170	9-	
04/04/2005	EN50 EN34	-54	6	*
07/10/2005	EN34 FM06	-78	6+	*
12/15/2006		-162	8+	
10/25/2011	EN52 EM89	-147	7+	
04/23/2012		-106	6-	*
07/15/2013	6m EN51 2m	-74	5+	*
04/24/2023	222	-213	8	
05/10/2024	222 EN50	-351	9-	
05/11/2024	222 EM55 EN12	-412	9	
10/11/2024	222, 432	-335	8+	
01/20/2026	222 EN34	-218	8-	