DXING ASIANS ON THE TROPICAL BANDS
The Auroral Factor

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● INTRODUCTION

The excitement and challenge of logging domestic Asians on the Tropical Bands is alluring to many DXers. For those of us in North America, the northern auroral absorption zone straddling the polar region can present a formidable wall between ourselves and the elusive Asian DX signals.

But that proverbial wall is not impenetrable. There are ways around and especially through it, given a knowledge of great circle paths and darkness/near darkness (including Grayline) paths. Those factors can be exploited more successfully with an appreciation of the characteristics of the auroral zone and how it is affected by solar activity. In particular, one should be aware of the so-called "donut-hole" centred on the North Magnetic Pole and the manner in which, at times, it appears to usher the Asian signals to our receivers at enhanced levels.

The purpose of this article is to examine the auroral factor so the DXer will be better equiped to recognize and even anticipate those infrequent but extraordinary openings when rare Asians are waiting to be snagged.

● THE TRANSPOLAR SIGNAL PATH AND THE AURORAL ZONE

(A) The Solar Factor:

We should recognize that North American reception of Tropical Band Asian signals following the great circle path is essentially impossible via the long path during September to April, the prime DX season. Signals coming "long way around" would first be directed soutward where eventually they would be subject to "solar blanking" - 'D' layer absorption due to the perpetual daylight of the Antarctic summer.

This means that Asian reception will depend on the short path route. We must therefore look at the auroral absorption zone in the northern polar region. After all, conventional wisdom says that signals crossing this region would be typically subject to auroral absorption and distortion (flutter fading), except possibly when the geomagnetic field has been very quiet for an extended period of time.

This is not necessarily the case. Depending on the Asian target area, relative to the DXer's geographic location on the North American continent, enhanced signals will often be found when the geomagnetic field is unsettled or even active. This will be the result of some prior solar event: solar flare activity being the most common. These solar terrestial events disrupt the the earth's magnetic field with a consequent increase in the intensity of the absorptive characteristics of the ionosphere in the auroral zone. And yet, certain signals do manage to propagate through (and sometimes even around) the auroral zone, at times with greatly enhanced reception quality.

It is very useful to know how and when the Tropical Band signals from Asia may reach us via a darkness path. A "near darkness" (ideally Grayline) signal path would be preferred. But simply tuning in "at the right time" offers no assurance of reception - conditions do vary greatly from day to day. It is also important to recognize that the subject signal path passes through or near the northern auroral zone where, as mentioned, ionospheric propagation is very much influenced by the state of the geomagnetic field and by activity originating on the sun.

Solar activity, primarily associated with the extent of sunspot occurrences, tends to by cyclic and thus somewhat predictable. While the long term (11 year) cycle cannot be ignored, day-to-day reception is patterned after the 27 day solar cycle. When DX conditions are favourable, you should be prepared for recurring conditions about 27 days later - the time it takes for the sun to complete one full rotation on its axis. One should learn to recognize when conditions may offer up the chance of rare DX, based on WWV solar/geomagnetic data that is broadcast at 18 minutes past the hour (updated every three hours) and by the "feel" of the band, based on whether "indicator" stations are audible at above average strength.

In the case of the Tropical Band Asians, experience shows that there is a chance that DX signals will be rolling in just when you least expect it - when a solar disturbance has <u>recently</u> taken place and geomagnetic conditions are described as unsettled or active. The initial <u>transitional</u> period when geomagnetic conditions are migrating from quiet-unsettled to unsettled-active seems to be the optimal period.

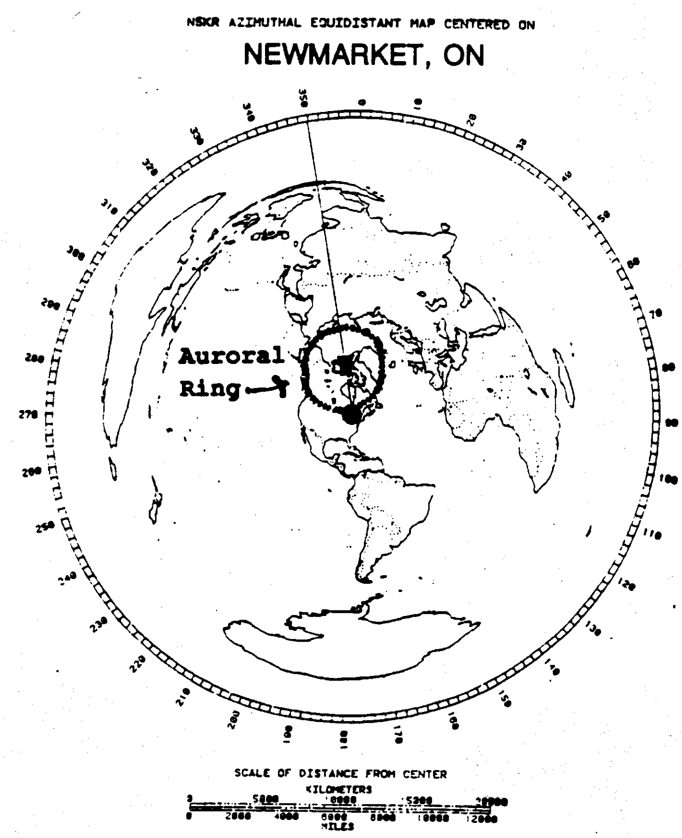
(B) Asian Great Circle Paths and The Auroral Donut:

Assuming a great circle path, the particular Asian signals which will intersect the auroral region will depend on the DXer's location at the receiving end here in North America. Since the auroral zone is centred around the North Magnetic Pole, it is not difficult using an azimuthal equidistant map centred on your location to line up which region of Asia lies directly opposite the heart of the auroral region. A straight line drawn from the centre of the map to any other point on the earth's surface indicates the shortest (great circle) path most likely to be followed by a signal reaching your receiver. Refer to maps identified as Figures 1, 2 and 3.

An azimuthal equidistant map should only be considered accurate enough if your receiver location lies within a hundred miles or so of the centre reference point. This is especially important if you wish to plot Grayline (sunrise/sunset) lines on the map. The three maps following are sufficient, however, to illustrate the text as it applies to the DXer situate in eastern, central or western continental North America.

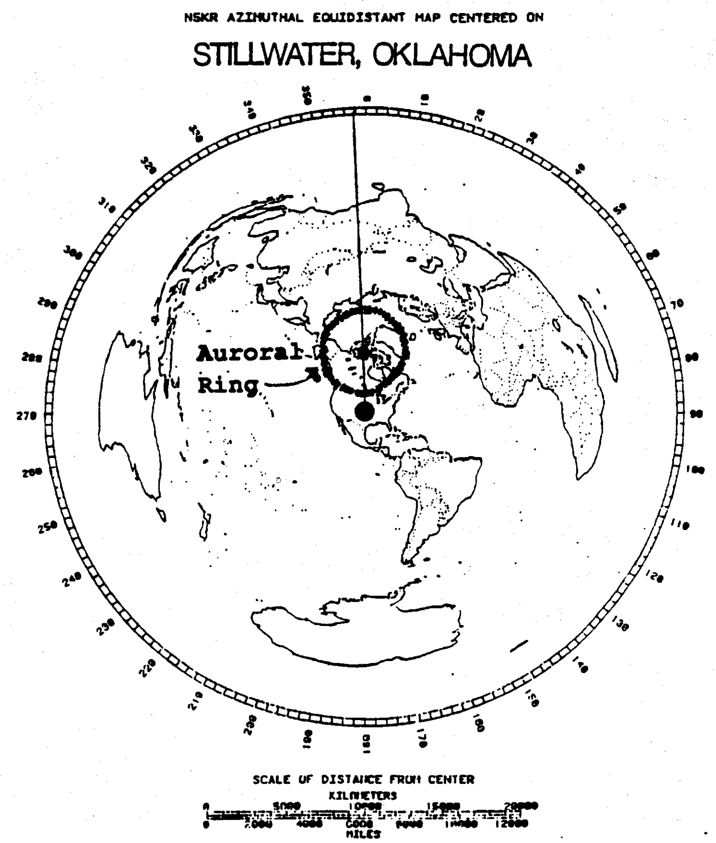
Each map shows the great circle signal path which passes through the position of the North Magnetic Pole or the "donut-hole", from the reference point in North America to the Asian side. The approximate position of the surrounding auroral ring or "donut" is also shown. Great circle signal paths between Asia and the North American reference point which intersect the ring lying 10 to 15 degrees on either side of the geomagnetic pole are more likely to incur severe auroral absorption.

Fig. 1 - ASIAN GREAT CIRCLE PATH INTERSECTING NORTH MAGNETIC POLE FROM TORONTO, ONTARIO



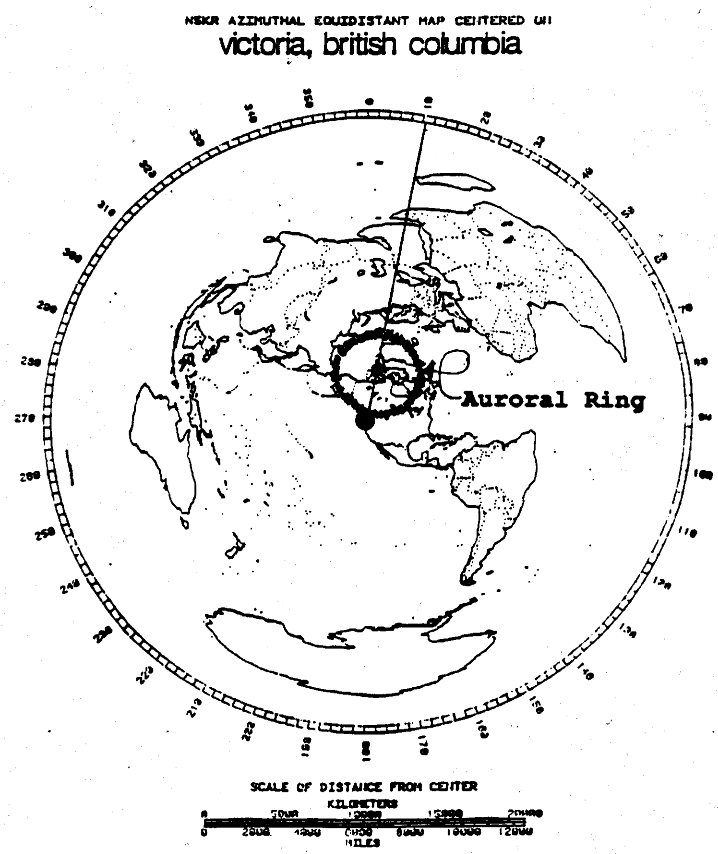
For example, using my location at Newmarket, Ontario as representative for Eastern North America (Figure 1), the geomagnetic pole is intersected on a line about 350 degrees west of true North. The Asian extension of the path reaches the central region of S.E. Asia, passes in the vicinity of the Chinese island of Hainan (and Hong Kong), along the coast of Vietnam, and practically runs through downtown Jakarta.

Fig. 2 - ASIAN GREAT CIRCLE PATH INTERSECTING NORTH MAGNETIC POLE FROM STILLWATER, OKLAHOMA



To the DXer living in mid-continental North America, however, the path to the magnetic pole shifts some 10 degrees in an easterly direction and lies in an almost True North plane over the geographic pole. You can see, using the Stillwater example (Figure 2), that we are virtually slicing continental Asia in half. The path skirts the western extremity of Mongolia, continues through Tibet and Nepal, extending southward through the eastern side of India to Sri Lanka.

Fig. 3 - ASIAN GREAT CIRCLE PATH INTERSECTING NORTH MAGNETIC POLE FROM VICTORIA, BRITISH COLOMBIA



For westcoast DXers, using Victoria, British Colombia as the example (Figure 3), the path to the magnetic pole has shifted eastward a further 10 degrees, that is, on a line about 10 degrees east of true North. In this case, the Asian polar path tracks past the Caspian Sea, through Iran and into Saudi Arabia. This is a significant advantage when it comes to Asian DXing. The great circle signal path for the sought-after targets in Southeastern and Southern Asia does not rely at all on the donut-hole: the path is comfortably clear of the auroral zone altogether!

It is important to note that I referred to paths extending through the heart of the auroral zone, for it is here, in the vicinity of the geomagnetic pole that one encounters a gaping hole in the auroral zone, colloquially known as the "donut-hole". It is through this interior hole that Asian signals can, under some propagational circumstances, find their way to our hemisphere along their great circle path. That is why it is important to be aware of the Asian path which intersects the magnetic pole based on one's own locale. As we shall see, Asian sites in line with the general direction of that path should be prime DX targets for us: Southeast Asia for eastern listeners, South-Central Asia for mid-continent listeners and South-west Asia for the western listeners.

This is not to suggest that mid-continental or westcoast reception of signals from the Southeast Asia is likely to be any less favourable than for easterners who enjoy that particular donut-hole path. In reality, were it not for the donut-hole, easterners would probably have a tough time logging low frequency Southeast Asians, period!

As we move west across continental North America, the Southeast Asian path swings around from the north to a more westerly plane (refer again to Figures 1, 2 and 3). Thus, unless conditions are unduly disturbed and the breadth of the auroral zone has greatly expanded, the Asians will propagate unimpeded past the outer perimeter of the zone. In addition (at least for westcoasters) signal levels will benefit greatly from the "all-water" path. Because of this bit of geographical mechanics, DXers in eastern North America are generally more dependant on the donut-hole for reception of Southeast Asians than are westcoasters who, even with average conditions, have the advantage of a non-polar and virtually all-water propagation path.

For those in central parts of the continent, it's a mixed bag. The donut-hole becomes important with respect to Southern Asia (essentially the Indian sub-continent), whereas most Southeast Asian signals may skirt around the western extremity of the auroral zone, except when conditions are more disturbed.

No matter where we live in North America, our Asian catches are influenced by the donut-hole as far as reception from one region or another is concerned. Further, we will all find certain paths are especially difficult. Typically this means signals are propagating (in great circle terms) directly at (or near the outer periphery of) the zone of greatest absorption...the "donut" itself. Again, please refer to the three maps and notice which Asian paths for your location are likely to be more severely influenced by the absorption zones on either (west/east) side of the donut-hole.

Finally, we are still left with the fact that the donut-hole is surrounded by an auroral ring. The Asian signals must find their way past this absorption ring. This leads us to a closer examination of the characteristics of the auroral zone, followed by a consideration of how signals might propagate (in a north-south direction) through the donut-hole itself.

●CHARACTERISTICS OF THE AURORAL DONUT-HOLE

(A) The Physical Situation:

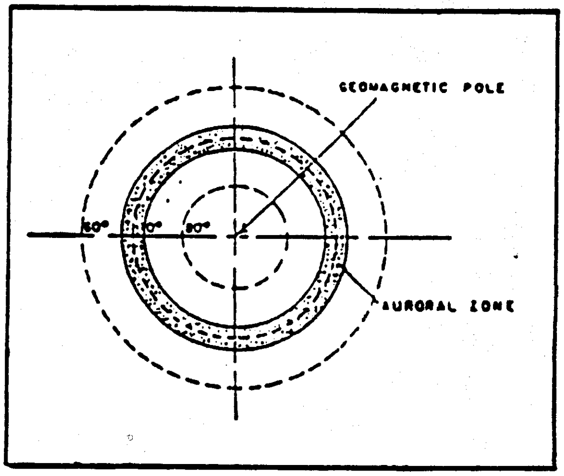
Our discussion in the preceding section has alluded to a common misconception, unfortunately fostered by some SWL and amateur radio publications, which suggests that the auroral zones in the vicinity of the geographic poles totally blanket both the northern and southern polar regions.

Due to the intensity and distribution of the earth's magnetic lines of force, the auroral zones are centred on the magnetic poles and take the shape of a circle of about 5 degrees in latitudinal width (although the northern auroral zone is rather more oblong in shape).

The ring of greatest absorption is centred about 20 degrees latitude away from the geomagnetic pole. Refer to Figure 4 - next page. Visually, we can appreciate how apt terminology like "auroral donut" and "donut-hole" were derived.

The North Magnetic Pole is presently located in a southwesterly direction from the geographic North Pole, at a position of about 77 degrees North; 105 degrees West. It's position is governed by electro-magnetic forces within the earth's core and is not constant over time. For many years, the magnetic pole has been drifting slowly in a westerly direction.

Fig. 4 - Structure and Position of the Auroral Ring



Source: The Canadian Amateur (September, 1988)

Actually, the polar projection outlining the position of the auroral ring (Figure 5 below) dates about 1960, and at that time the geomagnetic pole was deemed to be positioned near the northwest tip of Greenland. But a very recent map from the National Geographic Society shows the pole now positioned northwest of Bathurst Island in the Canadian Arctic. I have marked that position. Think of the shaded position of the ring as having shifted a bit to the west and south of that shown in Figure 5.

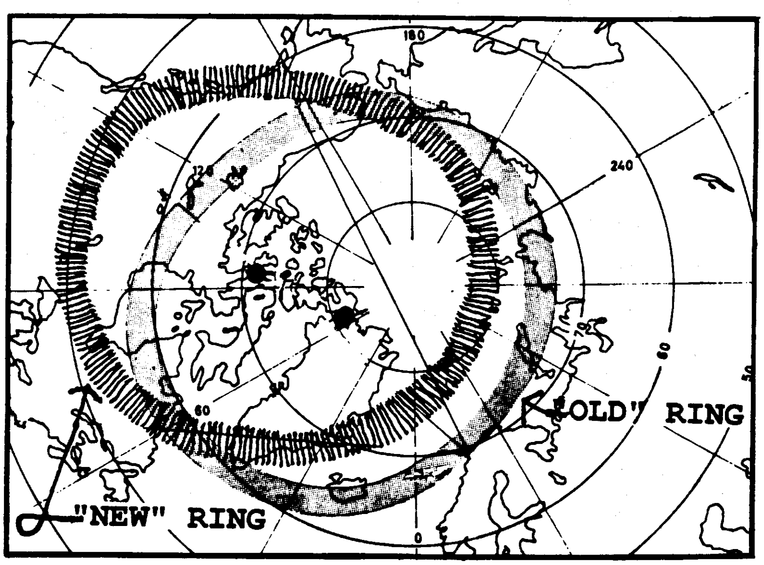


Fig. 5 -

Position of North Magnetic Pole and Auroral Ring

Source: Ionospheric Radio Communications (Plenum Press-1968)

The position of the auroral ring (or "donut") has been scientifically determined by the annual number of magnetically "quiet" and "disturbed" days.

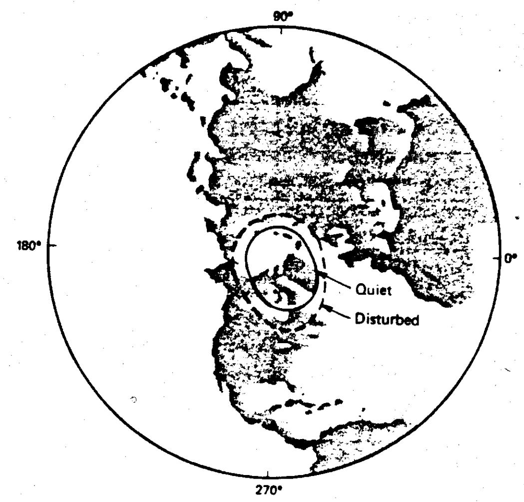
Examining Figure 6 (next page), we again see the approximate location of the auroral ring (that 5 degrees of bandwidth of maximum absorption) as indicated by the thick solid line. This is as close to the magnetic pole (some 20 degrees distant) as the ring will retract during an extended period of "quiet" geomagnetic conditions. (This source also dates back to 1960, so attribute the comment applicable to Figure 5.)

(B) Effect of A Solar Storm:

When a strong solar flare flare or other significant solar disturbance occurs, the geomagnetic field usually becomes destablized (progressively described as "unsettled", "active", "disturbed" or at "storm" level). The auroral ring expands outwardly in all directions, into the sub-auroral zone as indicated by the broken line in Figure 6. During more intense geomagnetic storms, the auroral effect on the ionosphere may even extend well-southward into the temperate zone.

Many readers will recall the almost constantly disturbed conditions for two weeks back in March, 1989. At that point in Cycle 22, Sunspot Region #5395 first appeared on the visible disc of the sun and was particularly violent. Numerous strong solar flares precipitated severe shortwave fadeouts, a couple of Polar Cap Absorption Events and strong Auroral Borealis displays, signifying a severe ionospheric storm, were reported as far south as the Caribbean!

Fig. 6 - Location of Auroral Ring During Magnetically "Quiet" and "Disturbed" Periods



Source: Ionospheric Radio Propagation (U.S. Government Printing Office, 1965)

The principle characteristic of an auroral disturbance is that it causes absorption of medium and shortwave signals reaching the zone, rather like the effect of an unusually concentrated 'D' layer. Skywave signals are thus generally inhibited from reaching (or returning to earth from) the refractive 'E' or 'F' layers. This does not mean the ionosphere associated with the auroral zone is totally homogeneous; inconsistencies in the concentration of charged particles within the zone can give rise to signal distortion commonly known as "polar flutter" or "flutter fading", if not outright absorption. Signal "bending" along non great circle paths may also result.

The "Polar Cap" (or "donut-hole") in the immediate vicinity of the North Magnetic Pole has a diameter of some 3000 miles or about 20 degrees latitude (greater diameter along the north-south bias). As contrasted with the auroral ring, this region exhibits relatively modest absorption and the ionosphere there is quite capable of supporting skywave propagation. This has been reported, even when a solar-originated geomagnetic disturbance is causing an outward expansion of the auroral zone.

But there is one significant exception. A particular kind of disturbance called a Polar Cap Absorption Event, while quite infrequent except during solar maxima (refer to Figure 7), will severely limit even donut-hole propagation. Proton streams orignating with the sun are directed towards the poles by the earth's magnetic field and penetrate the region within the auroral ring. Increased density in the lower layers of the ionosphere results in greater signal absorption, thus inhibiting 'F' layer refraction that would be otherwise possible.

Such was the situation in March of '89 when, for a number of days (at least in eastern North America) Asian signals coming over the top simply weren't making it at all.

Fig. 7 - Frequency of PCA Events (Cycle 21)

Recorded PCA Events

Year	PCA Events	Remarks
1978	5	
1979	8	
1980	9	
1981	14	Solar
1982	14	Maximum
1983	3	
1984	4	
1985	2	
1986	5	Solar Minimum
1987	3	

Source: The Canadian Amateur (September, 1988)

If a PCA Event should materialize, you can be sure that an auroral disturbance will soon follow. On the other hand, there are many cases when a flare-induced disturbance may suddenly commence without a prior PCA Event.

Except for the occasional incidence of a PCA Event, it seems quite plausible that Asian signals can be propagated directly across the magnetic pole, provided they are not unduly absorbed by the surrounding auroral ring. If that is the case, the simplistic view which says the entire polar expanse is blanketed by a massive zone of auroral absorption is inaccurate and quite misleading to shortwave listeners.

Now, the question to be addressed is how signals originating on the Asian side can be propagated, sometimes at enhanced levels, on a great circle north-south axis through the donut-hole (given that it is surrounded on all sides by the signal-absorbing auroral ring). Alternatively, Asian signals that would otherwise intersect the auroral ring sometimes seem to be diverted from their normal great circle path and are bent around the outer periphery on the west or east sides of the absorption zone. It seems unlikely, however, that a signal will propagate through the donut-hole and around the outer fringes of the donut at the same time.

● THEORIZING ABOUT DONUT-HOLE PROPAGATION

(A) Background:

Surprisingly, scant written attention has been given to this subject over the years by the SWL community. This is still the case, even though senior Tropical Bands specialists recognize that such propagation can and does happen.

A good deal of original work on this subject has been published by BCB DXers specializing in foreign reception. Although most of this research is now somewhat dated and in some respects subject to more recent refinement, I am quite convinced that much of it has essentially equal application to the Tropical Bands.

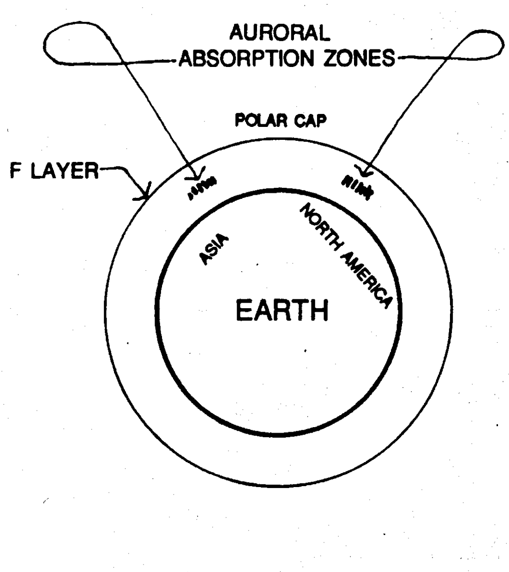
Some years ago, the Chinese government installed a powerful MW transmitter said to be located at Urumchi which operated on 1525 kHz. A number of DXers located in the northeastern United States were able to log the station, usually at sunset. Clearly its great circle path crossed the northern polar region (although rather removed from the "donut-hole" in this case) and the signal should have been absorbed in the auroral zone. The Urumchi loggings were perhaps one catalyst for a proliferation of research to explain the phenomenon by such well-known BCB DXers as Gordon Nelson, Russ Edmunds and Page Taylor.

(B) Potential Trans-Polar Modes:

The key to the mystery of donut-hole propagation begins when we recognize that we are dealing with an auroral zone concentrated in a relatively narrow-banded ring. We have noted that the Polar Cap (donut-hole) contained within the circumference of the ring is relatively free of absorption, as is the sub-auroral zone beyond the outer extremities of the ring (with due allowance for the fact the diameter of the ring itself will broaden outwardly in the event of a geomagnetic disturbance).

To envisage how skywave signals might propagate on a north-south route from the Asian side, through the donut-hole and thus reach the North American side, it is useful to view the auroral ring in cross-section (see Figure 8).

FIGURE 8
NORTHERN AURORAL ABSORPTION ZONE
CROSS-SECTIONAL VIEW



This illustration shows the two auroral absorption zones on the Soviet and Canadian sides, separated on their interior extremities (ie. within the circumference of the auroral ring) by the polar cap where skywave refraction is usually possible. The signal should not intersect either of the absorption zones on opposite sides of the auroral ring.

One article entitled 'Trans-Polar DX: An Analysis of the Prospects of DX Thru the Twilight Zone', authored by Edmunds, provided a number of hypotheses of how the Urumchi signal might make it into the eastern United States. Conventional multiple hop 'F' layer refraction (called F-2 mode - Figure 9), as well as more exotic ducting modes such as "Chordal Skip" and "Whispering Gallery" paths were all considered propagationally viable, provided the skywave signal could in some way travel to avoid the auroral ring.

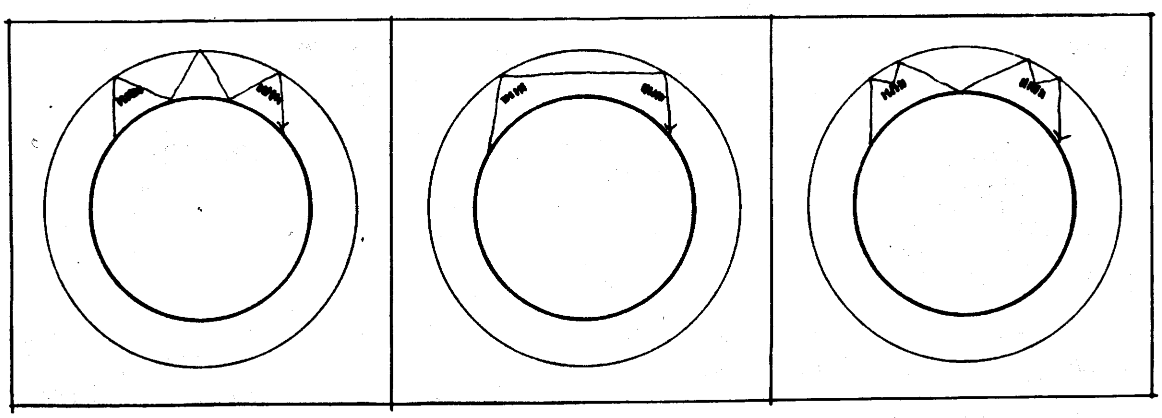
The "Chordal Skip" mode suggests that a signal launched in a dawn or dusk period will reach the 'F' layer in such a way that it is not immediately refracted back towards the earth. The trajectory of the skywave signal would follow the curvature of the earth, resulting in an extended skip distance. Eventually, the signal is returned to earth when it encounters a corresponding twilight "tilt" condition at the receiving end (refer to Figure 10). Since several intermediate hops are eliminated, absorption is greatly reduced and the signal is unusually strong.

In the "Whispering Gallery" mode, the transmitted signal is again tilted (during the twilight period) towards the 'F' layer where it is refracted and then undergoes a series of hops (without returning to earth) by travelling an extended distance between the topside of the 'E' layer and the underside of the 'F' layer. This process of multiple "reflections' between the ionospheric layers would seem to occur with minimal absorption. Eventually, with a twilight ionospheric tilt condition again occuring, an unusually strong signal is returned to earth at the receiving end (see Figure 11).

Notice that "near darkness" at both ends of the path is desirable to support the signal-enhancing "tilt' scenario (applicable to F-2 mode as well for the initial and final refractions). This works out nicely for Asian reception at dawn in North America (and at dusk for those living in the eastern part of the continent). In addition, since the Asian path through the donut-hole is essentially on a north-south axis, a Grayline condition can be expected during the Equinoctial periods! Both of these are important factors which in turn are complemented at times by the solar-geomagnetic disturbance factor.

Let's look at some of those propagational scenarios supporting a viable trans-polar route (with some fortuitous signal path geometry thrown in for good measure!):

FIGURE 9 CONVENTIONAL F-2 SKIP | FIGURE 10 CHORDAL SKIP MODE | FIGURE 11 F-2 & WHISPERING GALLERY



Source of each of the above illustrations: NRC Reprint # P17

•FACTORS CONTRIBUTING TO DONUT-HOLE RECEPTION

The confluence of three fortuitous factors would seem to improve the odds of reception significantly: (a) geography, in terms of both signal launching and receiving location; (b) a near-darkess path, ideally at both ends, and best of all if a Grayline is incident; and (c) solar activity governing the state of the geomagnetic field and its effect on the ionosphere in the auroral zone.

(A) Donut-Hole Reception - Geographical Considerations:

In terms of geographical criteria, we have already noted that for great circle paths, the origin of signals on the Asian side would ideally be within +/- 10 degrees of 350 degrees W for DXing in eastern North America, +/- 10 degrees of True North for mid-continent locations and within +/- 10 degrees of 10 degrees E for the western part of North America. This would equate to signal sources in Southeast, South-central and Southwest Asia respectively. In addition, the fact that the origin of many Asian signals is in the Equatorial Zone is advantageous. As we shall see when discussing solar "enhancement" of signals propagating across the polar cap, I believe this is an important consideration.

At the receiving end, the latitude at which the DXer is situated can also make a difference. Applying simple geometry it becomes apparent that as you move south (away from the donut-hole), the gap within the auroral ring to "shoot through" becomes narrower. The breadth of the Asian donut-hole "window" is wider for a DXer like myself at 44 degrees North than it would be for John Bryant at Stillwater: about 36 degrees N. While that window is more narrowly focussed at the southerly latitude, in that situation, signals from a larger area across the east-west breadth of Asia can be propagated on a great circle path which lies beyond the outer extremities of the auroral ring, thus affording more reliable reception in those cases.

The combination of latitude and longitude of each DXer's location (in eastern and central parts of the continent) will determine which great circle paths intersect the auroral ring itself. The particular Asian signals which would normally propagate along that path will be subject to greater absorption and thus will be "toughies", except under unusual circumstances.

By comparison, we have observed that those living anywhere near the west coast need not be concerned about the auroral zone or the donut-hole at all, except when they are DXing the western extremity of continental Asia.

(B) Donut-Hole Reception with a Complementary Near-Darkness Path:

DXers know that long distance propagation on the Tropical Bands can be especially enhanced during a "near-darkness" situation - either at one end, with the opposite end of the signal path being in full darkness; or, better yet, if both transmitter and receiver are in a sunrise/sunset twilight period.

For E-W paths, near-darkness at both ends means the intervening path is in full darkness. For N-S paths, however, there will be times when the entire signal path traces the dividing line between the dark and sunlit sides of the earth. In that case, we have the optimal Grayline signal path.

For Eastern North America, the sunrise Grayline is focussed on a 350 degree W path a week or so after the Vernal Equinox (March 21) and again about a week prior to the Autumnal Equinox (September 21). There is also a sunset Grayline, which occurs along the 350 degree W path about three weeks prior to the Vernal Equinox and three weeks following the Autumnal Equinox. <u>Grayline propagation through the donut-hole brackets the equinoctial periods</u> and affords easterners both a dawn and dusk window to Southeast Asia.

Here in the east, the signal-enhancing effects of Grayline propagation generally seem to be more pronounced at these times of the year when a mutually complementary donut-hole and Grayline path situation are happening at the same time. As one might expect, the equinoctial period is generally "prime time" for Indonesians (donut-hole and Grayline path co-incide) at both dawn and dusk. The sunset window is not available to DXers who are located west of the Eastern Time Zone because Southeast Asia will be in full morning daylight by the time sunset approaches in the Central Time Zone.

But the Equinox is the optimum time for Indo's elsewhere in North America too, based on dawn enhancement (<u>not</u> Grayline), and the signal path (in great circle terms) is not through the donut-hole.

For central parts of North America during the equinoctial period, the co-incident donut-hole and Grayline path is focussed on the Indian sub-continent, yet reception is unreliable.

Mid-winter donut-hole (but <u>not</u> Grayline) propagation from the Indian sub-continent is especially good for DXers living in the mid-west. But here in the east, sunrise Grayline reception (centred on mid-December to late January) from South-Central Asia can be excellent at times too. The difference in this case is that the great circle path is quite removed from the donut-hole. Whereas Indonesians seem to peak near the Equinox, signals from the Indian sub-continent seem to peak in mid-winter, regardless of the DXer's location in North America.

Based on these observations, is it reasonable to conclude that the co-incident Donut-hole/Grayline path is really only significant to DXers located in the eastern parts of North America? For that matter, whether for your location or mine, why is that the Indonesians are predominant in spring and fall and the sub-continentals are limited to a short "season" in mid-winter? As DXers, I think we should to continue to research these patterns but reconcile ourselves to the fact that there will likely never be a set of "pat" answers when it comes to propagation over the polar regions.

(C) Donut-Hole Reception - The Solar/Geomagnetic Influence:

For all I've said about "donut-hole" and/or "near-darkness" enhancement of Asian signal paths (especially with regards to Eastern and Central North America), reliable reception on a day by day basis is not in the cards. The third and sometimes most important consideration is the fact that donut-hole propagation is almost always more pronounced (in particular on the Tropical Bands) when geomagnetic conditions are in transition from "quiet" to "unsettled" or "active". At times, enhanced N-S paths may even be evident when conditions have reached "major storm" levels! Figure 12 shows the qualitative descriptions for the condition of the geomagnetic field and the corresponding 'A' and 'K' values that you will hear on WWV's solar/geo-physical alerts:

Condition	A Value	K Value
* Quiet	00-07	0-2
* Unsettled	08-15	2-3
* Active	16-29	3-4
* Minor Storm	30-49	4-5
* Major Storm	50-99	5-6
* Disturbed	100-400	6-8

Fig. 12 - Relationship of 'A' and 'K' Geomagnetic Indices As Broadcast by WWV

Were it not for the great circle path through the donut-hole (or "bending" of signals along non great circle paths), one might conclude that the auroral absorption effect deriving from a geomagnetic disturbance would preclude efficient propagation over the polar region. Furtunately, such is not always the case!

(i) Comparison of E-W and N-S Signal Paths

Shortwave propagation conditions are conventionally described as good-excellent when there are no significant solar terrestrial events and the geomagnetic field is described as "quiet". Under such circumstances I have found that dawn reception from the South Pacific, including PNG and maybe even the Indonesians from adjacent Irian Jaya, could be satisfactory. This is essentially an E-W signal path for all North American DXers and does not intersect the auroral zone, except when the zone has expanded due to a geomagnetic disturbance.

Concurrently, signals from most of Southeast and South-Central Asia will be generally very poor if not absent. By themselves, the "donut-hole" and/or "near-darkness" (sometimes Grayline) paths don't usually get the job done along a N-S polar path, even when the field is "quiet".

Experience on the BCB tends to reinforce these tendancies. BCB DXers know that several consecutive days of very quiet geomagnetic conditions (daily 'A' index ranging from 0 to 5) are usually a necessary pre-requisite for good Trans-Atlantic (or Trans-Pacific) DX. The signal path from eastern North America to Southern Europe/Africa (or to the South Pacific) is essentially an E-W path and of course by-passes the auroral zone. As a general rule, good reception from the Africans and those few Europeans on the Tropical Bands would tend to reflect the possibility of a TA opening on the BCB, especially above 1400 kHz. Correspondingly, good reception from the Tropical Band PNG's and Australians suggests the possibility of a high-end BCB TP opening.

A case in point: on the morning of December 30th, 1988, from 1200 until 1300 sunrise, I encountered unusually good reception from the three 120 meter Australians, as well as most of the 90 meter PNG's. At this time I was able to tentatively log both of the Australian print-handicapped stations (500 watts each), co-channel on 1629 kHz! In the face of this E-W preferred path, the Indonesians and continental Asians were distinguished by their absence.

Let's compare reception experience along E-W paths with typical signal performance on N-S paths. Referring again to the BCB, it is a well-established fact that "auroral" conditions associated with a geomagnetic disturbance are the best opportunity for enhanced LAm signals from Central & South America (sometimes even "deep south" reception from the likes of Chile and Argentina). Skywave signals from the big NAm stations are typically weakened due to increased absorption, making the apparent strength of the Latins that much stronger. I believe, however, that the <u>actual</u> strength of the Latins is greatly enhanced under such conditions. Other BCB DXers have made the same suggestion.

An analogous situation has been experienced on the Tropical Bands. On several occasions within the past few years I have recorded absolutely "armchair copy" signals from the Falklands station on 3958 kHz (apparently off the air at present) in the early stages and even at the height of a major geomagnetic disturbance. Many other DXers have had a similar experience.

This is an example of "deep south" reception. The signal has travelled from the Southern Temperate Zone, across the Equatorial Zone and into the Northern Temperate Zone. Similar if less dramatic results can often be encountered from Tropical Band Latin signals originating within the Equatorial Zone.

For DXers like myself located in the eastern part of the continent, the short path to Southeast Asia is right through the donut-hole. All the other factors I have addressed are in place too: the great circle path is essentially oriented N-S and signals are originating from within or near the Equatorial Zone. The early phase of a geomagnetic storm more often than not brings enhanced reception, nothwithstanding the trans-polar path across the auroral zone.

I made reference to one of the better examples I can cite in an article which appeared in <u>Proceedings 1988.</u> On the morning of April 4th, 1988, I logged Radio-Television Hong Kong on 3940 kHz with a truly outstanding signal at maximum dawn - thirty plus minutes after sunrise. Some DXers in other parts of North America reported hearing RTVH that morning but with considerably greater difficulty. Other Southeast Asians <u>in line with the donut-hole</u> (eg. RRI, Jakarta - 4774.7 kHz) were audible as late as 1300, two hours past sunrise!

<u>On that date, a major geomagnetic storm was in progress and the 'K' index at 1200 was 6.</u>

I also mentioned the short mid-winter period when easterners and those living in the mid-west can at times enjoy excellent reception along N-S paths from South-Central Asia. In the east, a sunrise Grayline path is beneficial but a glance back to Figure 1 indicates that signals from Indian regionals, Nepal, etc., barely skirt by the eastern boundary of the auroral zone. This suggests that reception is most likely when the geomagnetic field is quiet, yet from my location, reception has usually been best when the field was unsettled to moderately active. If the signals were to be bent around the outer edge of auroral zone they would be lost to daylight absorption. So, either they are propagating across a widened auroral zone (and so maintaining a great circle/Grayline path), or they are being bent into the region of darkness and propagating on a non great circle path through the donut-hole. While you ponder that one, consider this:

From the mid-west, many South-Central Asian signals are directly in line with the donut-hole (check Figure 2) so one might expect enhanced conditions during the commencement of a geomagnetic disturbance. Wrong again! Don Jensen advises that from his Wisconson location, sub-continentals are consistently heard best following an extended period of very quiet conditions.

In terms of a great circle path through the donut-hole, enhanced mid-winter reception of sub-continentals from Don's location just doesn't seem to fit the mould. So much for the auroral factor in this situation!

(ii) Effects of a Solar Disturbance

A major solar flare is the most violent kind of solar disturbance and is generally considered to be one of the prime causes of geomagnetic storms and associated auroral disturbances. The effects of a solar flare are two-fold and I believe it is important to make the distinction.

When the eruption first takes place (usually associated with an active sunspot region) large quantities of ultraviolent energy and X-rays are immediately discharged and reach our ionosphere in about 8 minutes, since they are travelling at the speed of light. The lower regions (especially the 'D' layer) of the ionosphere are affected such that signal absorption is increased dramatically, beginning with the lower frequencies.

The common result of this "Sudden Ionospheric Disturbance" (SID) is a fairly brief shortwave fadeout (on the daylight side of the Earth). The 'D' layer then returns to normal quite quickly due to rapid recombination.

It seems obvious that when that burst of strong ultraviolet radiation first reaches the ionosphere, it must also affect the F2 layer whose signal refracting qualities would thus be increased. Since the process of recombination is much slower in the F2 layer, the increased levels of ionization should endure, at least for the succeeding nighttime period.

The proposition, then, is that the F2 layer (especially in the Equatorial Zone where the ionizing effect is likely to be greatest because it is most directly in line with the sun) will exhibit much stronger than normal refracting properties for a subsequent 12-24 hour period. And so, skywave signals originating in (or passing through) the zone should be refracted more efficiently by the nighttime F layer. The result would be stronger than usual signals eventually arriving at our receivers.

I believe this could be a viable explanation for the effect that many of us have noted. For it is in these particular circumstances, signals originating in or on the opposite side of the equatorial zone and which reach us on a N-S path, are oftimes much better than the "norm" (or indeed may only be audible under such circumstances), at least for a brief period of time. During this short initial stage following a flare, the geomagnetic field remains quiet and an auroral effect is not underway. So I am suggesting that signals arriving with an extra "kick" are doing so primarily because of more efficient skywave refraction (ie. less absorption) at source in the equatorial region. (I should mention that scientific studies do indicate that as a geomagnetic disturbance subsequently develops, the F layer is actually weakened, at least within the auroral zone).

The second effect of the flare, which happens to be called a "sudden commencement", occurs on a delayed basis, 18-36 hours later (sometimes preceded by a PCA Event as previously outlined). Unusually large quantities of charged particles (electrons and protons), which are also emitted at the time of the disturbance on the sun, are carried towards the earth by the solar wind. Upon reaching the "magnetosphere" (the outer limits of earth's atmosphere above the F layer), the shock wave disrupts the earth's magnetic field and many of these charged particles eventually become trapped in the field and gravitate towards the magnetic poles. Here, the almost vertical lines of force draw these particles into the lower regions of the ionosphere, thereby causing increased absorption. This "precipitation event" is compounded by the release of other charged particles which are dislodged from their trapped state in the Van Allen radiation belts due to the sudden change in the state of the magnetic field (see Figure 13).

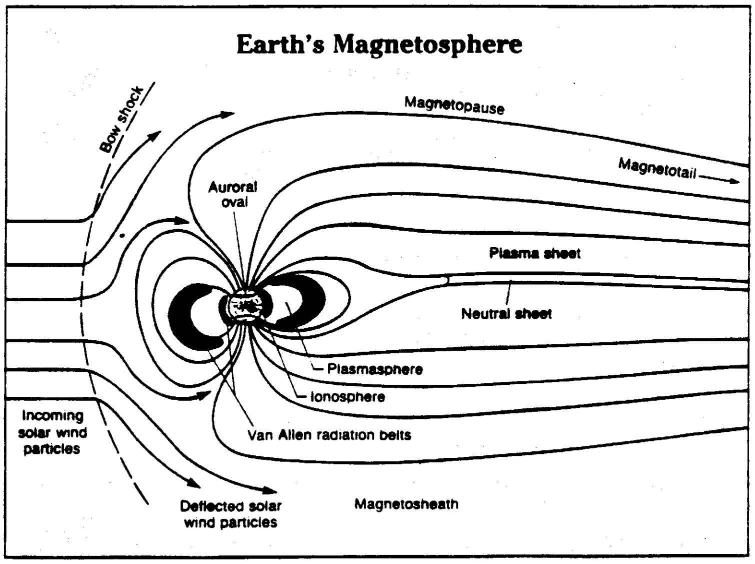


Fig. 13 -

Structure of Earth's Magnetosphere

Source:

Sky & Telescope (October, 1988)

The auroral effect has its origins in the geomagnetic disturbance and takes place as a result of the interaction of the charged particles with the ionosphere around (though some distance removed from) the magnetic poles. This is called an Ionospheric Storm. As contrasted with the effect of an SID, it is interesting to note that in this case it is the higher shortwave frequencies that are first-affected.

At this stage, I suspect the auroral ring itself may actually prove to be of benefit, at least in the initial stages of a disturbance. It is generally accepted that under some circumstances, signals reaching the auroral zone can be bent around the zone (or perhaps through the donut-hole) and in that sense deviate from their normal great circle path. If we remember that every signal is not just a narrow beam but a widely dispersed rush of energy, it follows that a certain proportion of an Asian signal source is already focused on the donut-hole, while other elements of the signal energy are actually propagating towards the (east/west) sides of the ring.

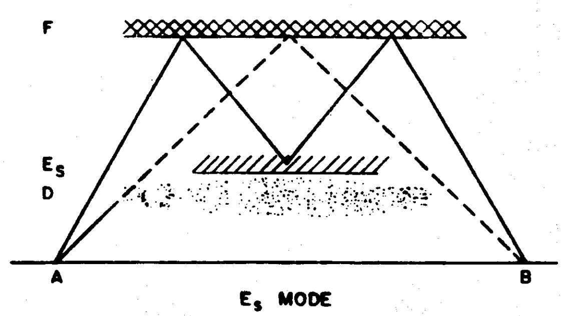
It would seem that one or another (or both) of the following effects then take place. A portion of the signal energy might be bent around the perimeter of the auroral zone (at least before it expands outwardly as the disturbance intensifies) and thus reach us via a "crooked" (non great circle) path. One problem with this idea would be that the arrival time of the signal components propagating through the donut-hole and those elements arriving in a roundabout fashion would be different. In this case, one would expect multi-path distortion to occur and this is rarely noticable.

Perhaps in situations where a signal is bent around the ring, conditions are such that very little energy propagates through the donut-hole. Don Jensen offers an observation that would tend to support this. He notes that from his mid-west location, reception from eastern Java and points east skirts the donut-hole and reception is often definitely enhanced by the start of active geomagnetic conditions. Don surmises that this would likely be a case of signal energy being bent outward, away from the perimeter of the auroral ring.

Alternately, let us suppose that a certain proportion of the signal energy which was propagating towards the sides of the auroral ring is actually bent inwards, rather than towards the perimeter. In this case, the amount of signal energy passing through the donut-hole would be increased. This complementary "ray focusing" effect would be somewhat analogous to the unusual signal strengths sometimes experienced with "antipodal" reception.

Skywave propagation through the donut-hole might be possible by conventional "F2" mode, or could also be supported by a version of the "Whispering Gallery" mode called "Auroral Sporadic E". The "Es" layer, which can be thought of as a cloud of charged particles, often develops at night (and we are dealing with darkness or near-darkness paths!) during the latter stages of a geomagnetic storm. It could serve as a 'reflector' to inhibit the refracted signal from returning to earth until it has traversed both sides of the auroral absorption ring. Refer to Figure 14 (solid line).

Fig. 14 - "Es" Propagation



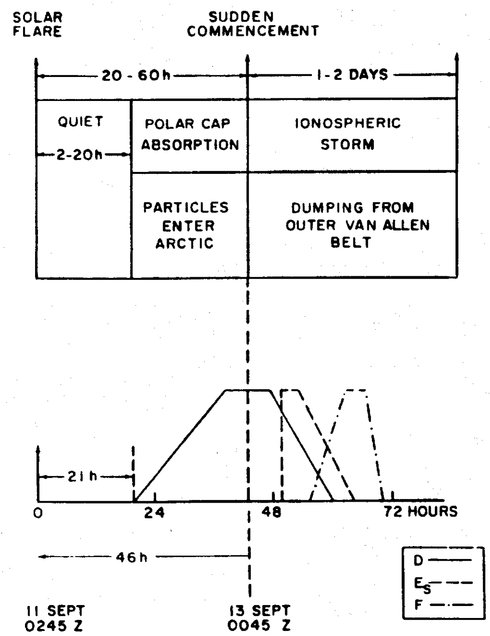
Source: 'Arctic Communications Following Solar Disturbances' in The Effect of Disturbances Of Solar Origin On Communications (The MacMillan Company, 1963)

Figure 15 (next page) graphically captures the sequence of ionospheric events following a solar flare over a typical time scale. Variations in the pattern and time sequence will depend on the intensity of the flare.

In the Legend, 'D' characterizes the pattern of increased absorption in the D layer; 'Es' characterizes the later formation of a pronounced sporadic Es layer, lasting for a short time; and 'F' characterizes the eventual weakening of the F layer in the latter stages of the geomagnetic disturbance.

Fig. 15 -

Sequence of Ionospheric Events In The Polar Region After A Solar Flare



Source:

(as for Fig. 14)

In summary, we as DXers we are faced with the reality that significantly enhanced trans-polar reception through and/or around that auroral wall is almost invariably associated with the onset of a solar disturbance. That said, Jensen's experience of optimal sub-continental propagation through the donut-hole after an extended period of very quiet geomagnetic conditions remains as a significant discrepancy to challenge our thinking.

●WRAP-UP

To conclude, I would like extend special thanks my friend John Bryant who was of great assistance to me in the preparation of this article. Thanks also to Don Jensen for sharing the benefit of his experience and to other members of the 'Review Panel' for their valuable comments and suggestions. Finally, a tip of the hat to my DXing buddy, Cedric Marshall of the ODXA, who got me into this Asian game in the first place! I hope that other DXers will be encouraged to "come out of the closet" and contribute their knowledge and experience. Feedback is welcome!

DXing Asian signals on the Tropical Bands, dependent as it is on the anomolies of trans-polar propagation, continues to be a source of fascination and is perhaps the "last frontier" for many North American DXers. We should be glad that the unpredictable ionosphere will always keep the rabbit out in front of us so that one day, you or I could log Azad Kashmir Radio at Muzzaffarabad, Radio Kashmir at Jammu or the lowliest of the slowly disappearing Indonesians on 120 meters. Keepin' the dream alive! Good DX.

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