ADDITIONAL NOTES ON TROPICAL BAND PROPAGATION

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INTRODUCTION

In fine tuning's *Proceeding's 1990*, we co-authored "Notes on Tropical Band Propagation" which many consider a milestone hobby article. In "Trop Prop," we called into question several fundamental beliefs about how HF radio waves travel over planetary distances, at least those waves in the 2-6 MHz segment of the HF spectrum known as the "Tropical Bands." Secondly, we proposed a new explanation for the well known "seasonality" of Tropical Band DX, notably from Asia and the Pacific. In addition to our own observations derived from monitoring the Tropical Band for many years, we cited numerous of works from the radio amateur community, the professional HF broadcasting community and from a variety of scholarly sources. Following that article we published four articles in the *Journal of the North American Shortwave Association* (NASWA) specifically on the enhancements of Tropical Band propagation which occur at dawn and dusk.

The following article is intended to update and expand the most important ideas in the 1990 article. It will also integrate ideas from the NASWA Dawn/Dusk series and introduce several concepts new to the SWBC DXing community.

COMMENT

The further we have pursued our studies of propagation, the more profound is our appreciation of the *irregular* nature of the ionosphere and its constituent "layers." Recognition that the ionosphere is a *non-homogeneous* medium is scattered throughout the professional literature, though most hobby publications continue to portray the ionosphere as a concave, perfectly reflecting mirror. Given the turbulent, ever-changing character of the ionosphere, we have come to feel that it is rather miraculous that there is *any* predictability at all to radio communications by ionospheric means. This continuously variable aspect of propagation prediction must be very frustrating for professionals in this field. However, that very unpredictability is one of the essential elements which keeps the radio hobby so challenging to us all.

MODES OF LONG-HAUL PROPAGATION

In the 1990 article, we put forward the idea that Tropical Band propagation over planetary distances (defined as beyond 1/4 planetary circumference or 6,250 miles) does *not* normally occur by the traditionally accepted multiple hop model. Instead, we proposed that most, if not all Tropical Band propagation over those distances takes place such that the radio waves do not take intervening ground "hops" at all. These waves stay aloft in or near the ionosphere until directed earthward by irregularities and/or "tilts" in the ionospheric structure near the receiver.

The multiple hop mode of HF propagation was first proposed about the turn of the century to explain how radio waves traveled further than was geometrically possible for a "one hop" signal. As we understand it, most of the proof of the multi-hop model was built upon two foundation points. The first was the fact that the long-haul communication was, in fact, happening. If communication out to about 1500 miles was happening by a (one-hop) refraction off of the ionosphere, then it was relatively easy to suppose that longer-haul signals would reflect off the ground (or sea) and essentially "bounce up and down" as they traveled until they reached their far-away target. When the most accurate clocks of the day were used to measure "delayed time of arrival," the time delay neatly confirmed that the signals were being delayed just long enough to account for the extra travel distance caused by the "bouncing up and down." With that confirmation, the multi-hop model was accepted as *THE* model of long-haul propagation. It is probably unfair for us to observe almost a century later that the same delayed time of arrival figures could be generated by waves bouncing from side to side or by other time delays, just as well as by the multi-hop "bounce up and down" model. Whatever the case, no one appears to have questioned the multi-hop model as the mode for *ALL* long-haul transmissions until after World War II.

After WWII a German propagation expert, H.J. Albrecht, resided for a time in and operated as a radio amateur from Australia. In both his professional and radio amateur work, Albrecht noted that signals from Europe were far stronger than he had been led to believe by the mathematical equations used to predict field strength at multi-hop distances. In fact, Albrecht's studies of the propagation paths between western Europe and Australia in the early 1950's were the foundation work that led to a later definitive study at Deutsche Welle (Voice of Germany). It was he that described "rays propagated in geometrically inscribed hops along the layer but not necessarily with all the ground reflections required by multi-hop theory." Albrecht called this mode "Chordal Hop."

In our 1990 article we cited the decade-long study by Albrecht and other German scientists associated with Deutsche Welle of daily transmissions between Germany and Australia. The study compared predicted and actual field strength values for early morning signals beamed on the short daylight path (16,000 Km to the southeast over Asia) and the long path (24,000 Km to the southwest across South America) which was crossing the darkness side of the Earth to reach Australia in the early evening. A daily index of satisfactory reception was also developed. [1]

The two principal findings of this exhaustive study were most interesting. When frequencies near the MUF appropriate for each of the paths were used, the reliability of the long path circuit was found to be twice as good as the short-path. Further, signal levels predicted by internationally accepted models (which assumed ground reflection losses associated with the multi-hop model) were found to be 12 dB too low for the short-path and an astonishing 25 dB too low for the long path. (One S-unit + 6 dB)

The study concluded that the unexpectedly high field strengths and more reliable reception of the long path signals could only have been caused by the phenomenon of ray-focusing gains in the near antipodal region (i.e. Australia) and longitudinal tilt-supported propagation without intermediate ground reflections.

We also noted that the International Radio Consultive Committee (CCIR), the scientific radio body of the International Telecommunications Union, had adopted consideration for a distance-dependent focusing gain (Spherical Convergence, as we shall discuss later) and this "no-intervening-hops" model for predicting field strengths of signals over paths longer than 10,000 Km as early as 1976. [2]

We were stunned when we found articles describing the DW work! To us, the DW study and the CCIR actions called into severe question the basic means by which most DX signals were reaching our antennas! We happened to find articles referring to the DW study at a critical juncture in our own studies of Tropical Band propagation. At that time, we had separately concluded that the conventional explanations of Dawn Enhancement just did not match what we had observed over several thousand sessions of DXing at "Max Dawn."

It did not take us too long to realize that the mechanics of Dawn Enhancement became easily understandable if one assumed that *ALL* long-haul Tropical Band signals were traveling by some sort of chordal hop or whispering gallery mode. Once making that "leap into the darkness" we began to see that most of the theoretical mechanics of Tropical Band propagation made much more sense and matched our real world experience much more closely if we visualized all long-haul Tropical Band propagation in this new fashion.

Our studies, as well as feedback from other radio hobbyists have strengthened our conviction that the "no-intervening-hop" model is the predominant, if not the only mode of long-haul HF propagation at least at Tropical Band frequencies. No one seriously questions the "one-hop" model of propagation out to approximately 1500 miles. However, no one has been able to cite for us *any* study which quotes *any* physical evidence that *multi*-hop HF propagation exists at all! All such "proof" that we have seen is based on the "time of arrival" of various signals. The fundamental assumption of all these time-of-arrival "proofs" of *multi*-hop propagation *ASSUME* that long distance signals are delayed in route by following longer paths. They are *ASSUMED* to be longer because the waves refracted/reflected up and down several times between the earth and certain layers in the ionosphere. Our response is that the only *long term* study of time-delay and time-of-arrival assumptions with *modern instrumentation* (Cesium clocks, computer-driven automated reception/logging) has called all findings based on time-delays into severe question![3] This glaring situation seems to have been rather conveniently ignored by the remainder of the professional propagation community!

FROM CHORDAL HOP TO SINGLE-SIDED DUCTING

The existence of the "Chordal Hop" mode of propagation has been known for several decades--certainly since the early 1950's. Other similar modes are referred to in professional circles as "Whispering Gallery" and "Single-sided Ducting." We have come to believe that usage of these three terms attempts to make a distinction where there is no actual difference--they all describe the same mode of propagation--radio signals refracting multiple times off the under-side of the ionosphere or its constituent layers with no intervening ground hops .(see Figure 1). We will refer to this mode as "whispering gallery" for the remainder of this article.

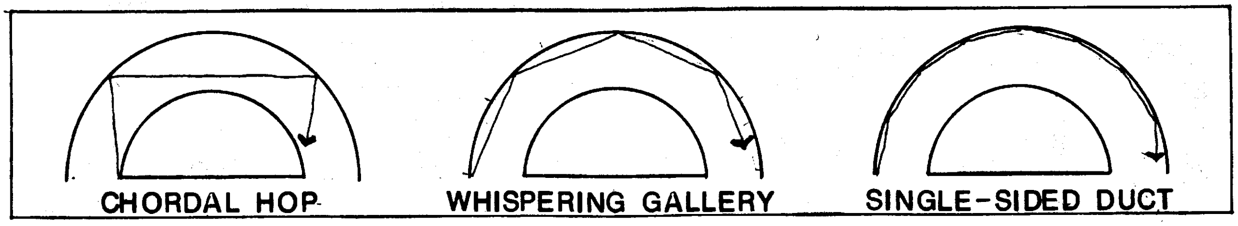


FIGURE 1: Three Terms Describing the Same Physical Phenomenon

A CASE FOR THE WHISPERING GALLERY

The professional community and conventional hobby propagation authors hold that the "whispering gallery" mode is quite rare and exceptional at HF frequencies--an "oddity." They all state that this mode's existence is absolutely dependent upon an ionospheric tilt or other anomaly near the transmitter to launch it and another near the receiver to dump the wave down to our antennas. Figure 2 is a typical representation of chordal hop mode and the ionospheric tilts believed necessary to create it.

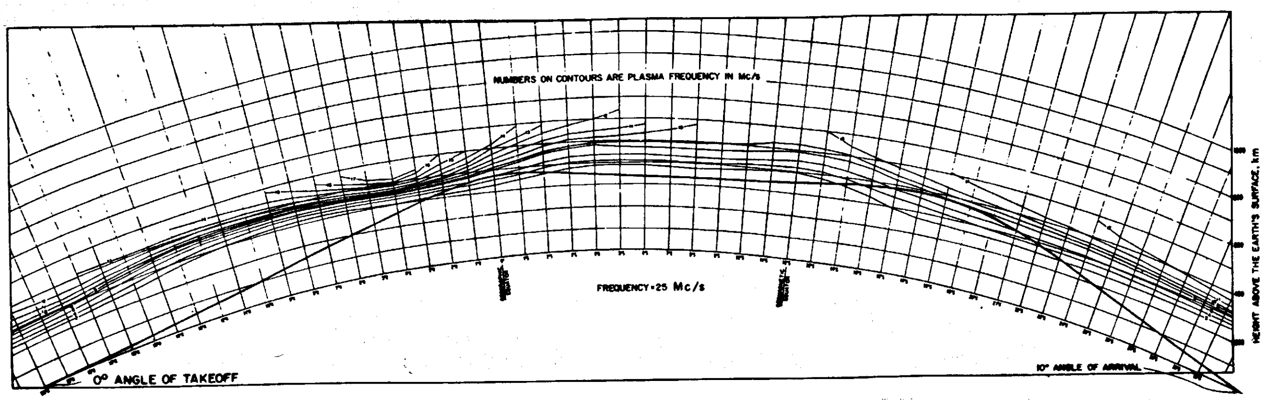


FIGURE 2. Chordal Hop

Although the dawn and dusk tilts certainly produce "non-equal angle" refracted waves and may be a source of whispering gallery signals, we have come to believe that there is another more regular source of these shallowly traveling waves... the so-called "Pedersen Rays" discussed in the next section. We do agree completely that dawn and dusk tilts are the mechanism by which these waves "skidding along the ceiling" are "dumped" down to our antennas at dawn or dusk enhancement. *However*, we contend that some significant fraction of the whispering gallery signals are also dumped down to us in the period prior to dawn and in the period after sunset. The dumping mechanisms for this form of reception may be the small random irregularities always present, even in the quietest Temperate Zone ionosphere.

We have also come to believe that some form of whispering gallery ducting is a *very common* mode of propagation at Tropical Band frequencies. We believe that the whispering gallery is a (or *THE*) normal mode of HF propagation over planetary distances and that virtually every HF transmission launches signals into this mode. In other words, there exists a strong possibility that no special tilt is required to launch a signal into the whispering gallery mode and no special tilt is required to receive these signals (at least weakly). We note the close similarity between this picture of lower HF frequency propagation and that proposed over ten years ago by well-known radio amateur DXer Uri Blanarovich in several radio amateur publications (reprinted in our 1990 article).

A final bit of evidence for the "whispering gallery" as a common mode of planetary distance propagation comes from the oil-related seismology field. John Bryant's father, Professor Glenn H. Bryant, was the seismologist on American Admiral Richard E. Byrd's Third Antarctic Expedition in the late 1930's. Prof. Bryant used the seismographic technology of the day to make the first measurements of the depth of the Antarctic ice cap. Prior to his death, he related several discussions with ionospheric specialists on the Expedition concerning the remarkable similarity between the techniques of study of ionospheric propagation and those of seismology. Both fields are concerned with the movement of wave fronts through dissimilar, non-homogeneous layers which propagate the wave front at differing speeds.

In recent private conversations between John and a mathematician/seismologist working for a major petroleum company, the same observation was made. This scientist, also a radio amateur, went further to state that in seismology there was one very common mode of propagation which cannot be analyzed or documented by normal "ray-tracing" techniques. He also said that this strange mode existed in virtually every "log" of data from field seismological soundings! Further, he stated that this mode of propagation could only be modeled or analyzed using "full wave formula" techniques which usually require the use of a super-computer. This type of work was, in fact, the main responsibility of John's friend and he used a Cray supercomputer daily. To explore the limits of his software and with understandable curiosity, this seismologist/ham input the parameters for the "international standard ionosphere" and a totally absorptive earth, both curved at the proper rate of curvature. He then propagated a spherical wave front from a point source "antenna." Apart from the expected refracted wave traveling back down to the earth, each analytical run indicated a "wave packet" propagated in what appeared to be a whispering gallery mode--parallel to the planetary surface! John has seen the "hard copy" of several of the runs. Unfortunately, the proprietary and disclosure rules of the corporation make publishing these data impossible, at present. We are hoping that hurdle can be cleared the next 12 months.

To reiterate the point so we might be crystal clear:

We all hear night-time transmissions on the Tropical Bands which have traveled more than 6,250 miles. We hear these transmissions in our local evenings and in the hours before dawn, as well. These signals are heard quite often (though sometimes weakly) when both the transmitter and the receiver are and have for some time been in total darkness. IF one accepts the idea that the "no intervening hop" or "extended hop" or "whispering gallery" mode is the primary means of propagation of these long-haul signals THEN they MUST BE LAUNCHED AND RECEIVED BY MEANS OTHER THAN THE DAWN AND DUSK TILTS!!! We would suggest that these shallowly-traveling waves are created and dumped on a regular basis by a number of mechanisms. We would also suggest that the oh-so-obvious dawn and dusk tilts are but two of several means of AMPLIFYING processes that are already occurring.

Whatever the case, we find the "whispering gallery" mode of long-haul propagation to be a very useful visualization tool as we attempt to become more effective Tropical Band DXers.

WHISPERING GALLERY SIGNAL LAUNCH

We wish to make clear that we both view terminator-related "tilts" as extremely important in Tropical Band propagation. Without doubt, the dawn tilt is the major mechanism which brings DX signals so magically to our receivers at "max. dawn." A similar effect is noticed during "sunset-at-the-receiver" enhancements. The terminator-related tilt is certainly the basic mechanism which generates "sunset-at-the-transmitter" and "sunrise-at-the-transmitter" enhancements, too. But, if whispering gallery is a (or the) common source of long-haul Tropical Band signals, there must be mechanisms other than terminator-related tilts which launch many of the signals that we hear as Tropical Band DX during the darkness hours.

Virtually all scientific work related to propagation modes involves analysis using the previously mentioned technique of "ray tracing" originally developed in the Renaissance for investigating reflection and refraction of light with mirrors and lenses. The use of this technique in studying all forms of wave propagation from light to acoustics is time-honored and accepted by all. Even using this ancient technique, it is possible to at least infer that normal HF transmissions launch a whispering gallery mode of propagation. The conventional view assumes that this mode depends on some "ray" of the signal striking the ionosphere at such a shallow angle as to be refracted at too shallow an (equal but opposite) angle to strike the earth before again striking the ever-curving ionosphere. Figures 3 and 4 are reproductions from two of the basic scientific/scholarly propagation references. They attempt to show the wide variety of angular circumstances generated by a typical omni-directional HF transmitter. All of the rays represent waves generated at the same frequency. In Figure 3, rays are generated from the very low Ray #1 to the unrefracted vertical Ray [which should be labeled #19], which is undiverted from its path escaping into space. Notice that Ray #1 is propagated at almost zero degrees of take-off and seems to travel the furthest before striking the ionosphere; it is then refracted at the same angle downward, striking the earth at the same almost zero-degree angle. Rays #2-6 are rays of ever-increasing vertical take-off angle, traveling ever-decreasing horizontal distances. The conventional view of whispering gallery mode is that an "ionospheric tilt" refracts one of these (#1 thru #6) rays at a *NOT* equal angle, but rather at a very flat angle--beginning the "whispering gallery" or "chordal hop" mode.

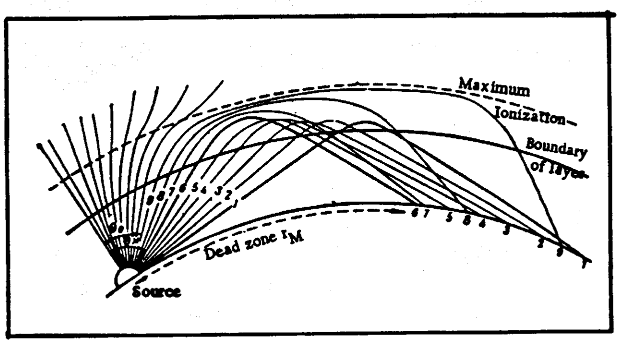


FIGURE 3.

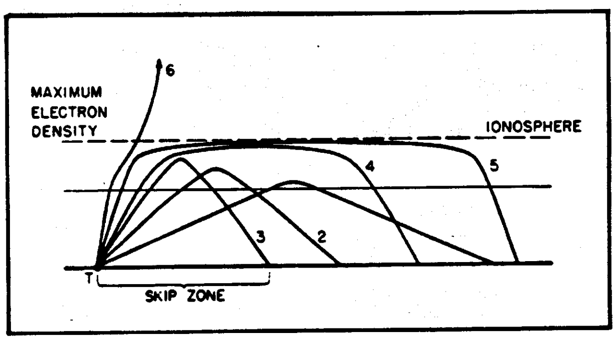


FIGURE 4.

Examine instead, Ray #8 and 9 from Figure 3, or Ray #5 from Figure 4. These are so-called "Pedersen Rays" launched at a few nearly "perfect" angles. Rays propagated at these angles are not refracted enough to return to earth (i.e. intermediate hop) but are refracted too much to escape to space. Their launch is *not* dependent on an ionospheric tilt. What happens to these rays? The answer lies almost totally in the realm of conjecture at this point, though satellite Topside Soundings and the few satellite looks *between* layers (or sub-layers) of the ionosphere may have begun to give credence to the Pedersen Ray as a potential source of long-haul HF signals.

Another argument in support of the existence of "High Transmission Angle" DX propagation view is the Australian experience with the ionospheric "Shower Service" broadcast stations which transmit on 120 Meters (2310 kHz, 2325 kHz, 2485 kHz) at night. These three widely scattered stations were built by the Australian government to provide reliable regional broadcast radio coverage to the Outback of the Northern Territory. The antennas of these three stations were designed very carefully to *eliminate* all low-angle signal radiation. The intent was to direct as much energy as possible upwards at high angles to be steeply refracted and "shower" downwards and provide strong regional coverage. Minimal energy was to be "wasted" on low-angle radiation which would travel beyond the primary coverage area. We were told that the design engineers, apparently totally absorbed by the conventional view of propagation geometry, even stated in public that the stations would likely never be heard beyond the borders of Australia, so efficient was their suppression of low-angle radiation.

There must be some very embarrassed Aussie antenna and propagation "experts" today, since reception of these three stations is regularly reported, often at quite good levels throughout the world!

We do not discount the usefulness of low "take-off" angles for the launch of long-haul signals. Several generations of radio amateurs have labored mightily to create antennas which are the reverse of the Australian Shower Service--optimizing radiation at very low take-off angles. The low angle radiators have been very successful DX transmitting antennas. It may be that very low take-off-angle waves are deviated by the normal small scale irregularities in the ionosphere into the whispering gallery mode. Since their angle of incidence with the ionosphere is very shallow, only a small refraction would be required to direct at least part of the wave's energy parallel to the layer. Thus, neither the high nor the low angle take-off of DX signals would *require* the presence of an ionospheric tilt to enter the whispering gallery mode, though both may benefit from it.

DAWN AND DUSK

We have devoted almost 40 pages to discussions of the propagational enhancements at local dawn and dusk in the *Proceedings 1990* article and the NASWA Journal articles of Spring 1991. We will summarize the main points here for the majority of *Proceedings* readers who do not belong to NASWA.

We have noted two tendencies appearing in radio hobby publications which seem to be less than useful in grappling with the complex subject of dawn and dusk propagation enhancements. First, it seems that there is a strong thrust even in professional journals to treat dawn and dusk as symmetrical propagation events. This has long been known to be untrue; it was noted decades ago that solar ionization (the build-up of the D and E layers) is a very rapid and abrupt event at dawn, while the recombination of those atmospheric ions is a much slower event continuing for some hours after local sunset. The more we read and the more we DX and observe, the stronger we feel that dawn and dusk generate *profoundly different* propagational events.

The second tendency, particularly in radio amateur writing, which we have found counter-productive is that of lumping all terminator-related propagation enhancements under the catch-all term "graylining." The two of us found our own personal thinking and discussions very confusing until we adopted specific (though cumbersome) terminology to describe the five distinct and separate propagation enhancements associated with passage of the solar terminator:

Sunrise at the Receiver (Transmitter in Darkness)
Sunset at the Receiver (Transmitter in Darkness
Sunrise at the Transmitter (Receiver in Darkness)
Sunset at the Transmitter (Receiver in Darkness)
Receiver and Transmitter Both in Twilight (True Graylining)

Having lived with these five terms for several years now, we find that we use each of these distinct propagation events very actively and productively as DXing strategies when targeting the reception of difficult DX catches. We find that our thinking and discussions are also more productive, and that we only call the last of the five events "graylining." We recognize the difficulty of developing similar nomenclature in the amateur community since there are both receivers and transmitters at each end of the circuit. Even so, some nomenclature to differentiate the various terminator-related enhancements would probably assist discussion in the amateur community as it has in ours.

TRUE GRAYLINING

If "graylining" is limited as we suggest to transmission/reception of waves which travel entirely within the twilight zone of the planet, we do not find "graylining" a very useful DX tool. We have noticed true grayline events mostly on 60 Meters at dawn, and then only very rarely. Feedback from both the radio amateur and the SWBC hobby communities indicates similar experience.There are very few cases when the well-known "seasonal" patterns of Tropical Band DX correlate well with the targets available via true graylining. In fact, this disparity which we both experienced and could not square with the conventional graylining wisdom in either the SWBC DXing or radio amateur communities was the beginning point for our joint studies in Tropical Band propagation.

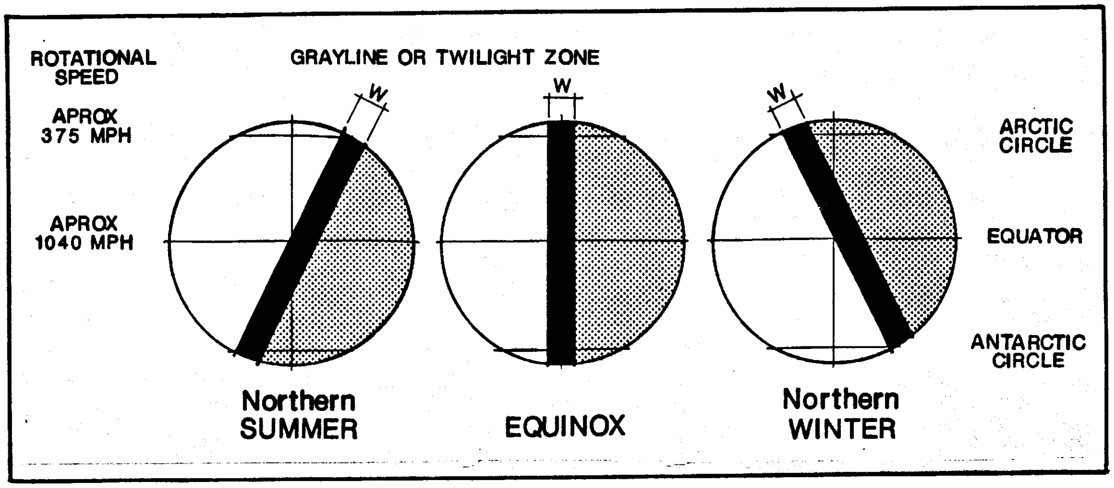


FIGURE 5.

WIDTH AND LOCATION OF THE "GRAYLINE"

Another hobby term to use cautiously is the "width of the grayline." Figure 5 is our illustration of the generic "grayline." Simple solid geometry and the laws of optics determine that the twilight zone or grayline of a planet with atmosphere is the same width at all points along its circumference. The hobby slang term "width of the grayline" refers to how much *TIME* any given point on the planet spends within the grayline or twilight zone. This time span, of course, depends on the latitude and the season of the year at any specific location.

We, like many other people in both radio amateur and SWBC DXing circles have spent a great deal of time attempting to determine the exact width (time duration) and location of the radio grayline in relation to the sunrise/sunset terminator on the ground. We now feel very strongly that this "width and location" depends on far too many factors ever to have one absolute "width and location" definition. The location and width vary widely with: the radio frequency in question, the season of the year, the current solar flux, the angular relationship between the particular propagation track in question and the terminator, along with other more subtle factors. We have found that our own DXing is more effective when we concentrate on the relative locations of the target, the receiver and local dawn or dusk on the ground.

THE MECHANISM OF DAWN ENHANCEMENT

Dawn enhancement at the receiver is the most frequently discussed terminator-related enhancement. The exact mechanics of this enhancement are open to much conjecture--most of which was summarized in our previous articles. As mentioned previously, we have never found any of the mechanisms proposed to explain dawn enhancement to be at all convincing, as long as the basic means of long-haul propagation was assumed to be the multi-hop model.

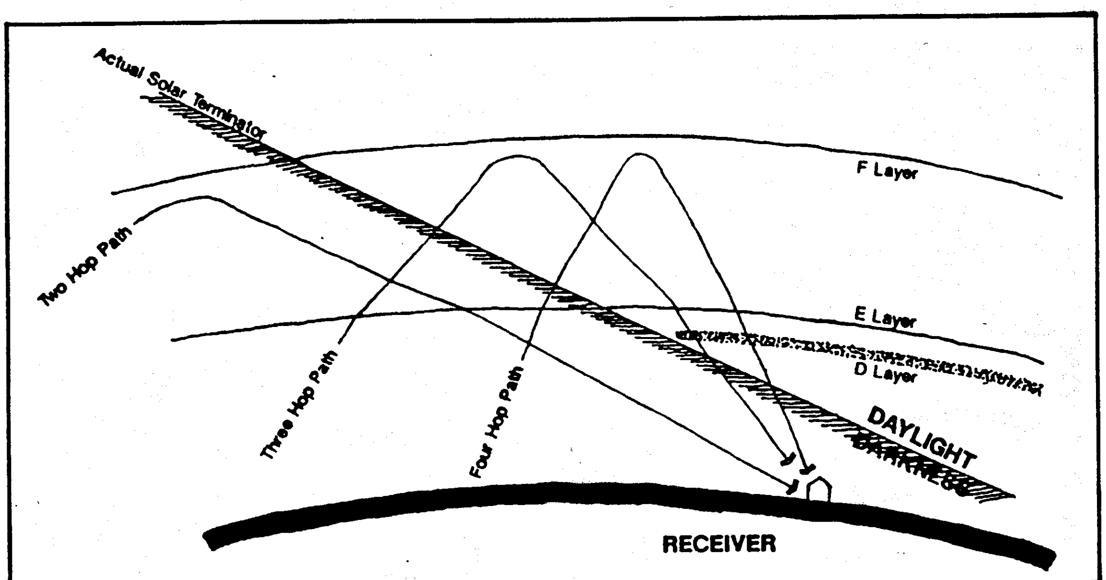


FIGURE 6. Dawn Enhancement: A Conventional Explanation

Figure 6 illustrates the most common conventional view of the mechanism of dawn enhancement. It postulates that the normal higher arrival (more hops) signals from a distant station are cut off by ionization occurring high above our heads while we listen in the pre-dawn darkness on the surface. Somehow, as these higher angle signals are cut off, the lower angle (fewer hops, therefore stronger) signals become dominant. Why these low angle, fewer hop signals weren't dominant all along is never explained. If this is the true model of dawn enhancement, we should all hear *VIOLENT* transitional multi-path destructive interference (fading and distortion) as the modes (number of hops) changed on otherwise clear and interference-free signals. We have never--not once--heard such interference under those circumstances. Rather, the signals build slowly and steadily with little or no fading as dawn enhancement begins to work its magic.

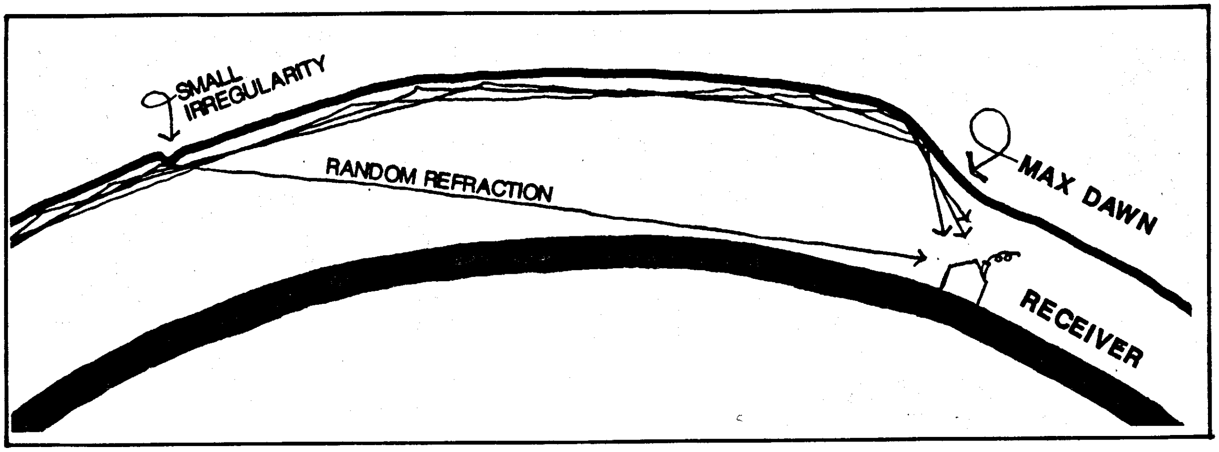


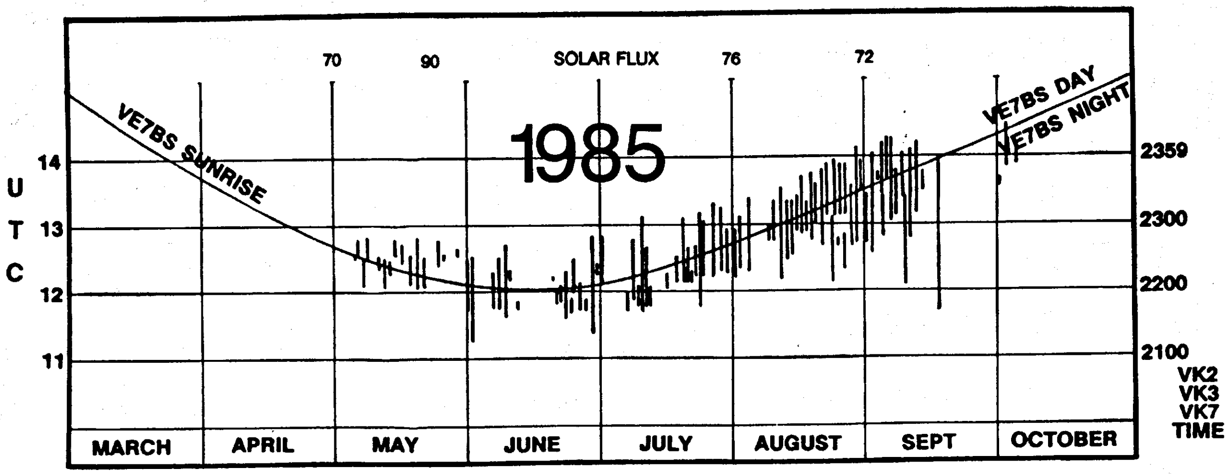
FIGURE 7. Dawn Enhancement: From The Whispering Gallery

If instead long-haul propagation is taken to be some form of the whispering gallery mode, the pattern of dawn enhancement that we *DO* experience daily and even the much lower signal levels heard from some of the same transmitters in the hours before dawn becomes very understandable. Figure 7 represents our current belief as to the mechanism of dawn enhancement of Tropical Band signals. The single arrow/ray refracted downward in the left-hand portion of the illustration has been refracted by a small random irregularity after traveling 95% of the same path length in the same trajectory. (Again, the similarity between this picture and the work of Blanarovich is noted.) One of the key pieces of evidence which would strengthen the case for the whispering gallery mode as the proper mode or geometry of events (as shown in Figure 7) is if the weak signals being heard before dawn do arrive at substantially *LOWER* angles than do those at dawn enhancement itself. This would be the exact opposite of the case put forward in the conventional "explanation" illustrated as Figure 6. Anecdotal evidence from the 160 Meter and 80 Meter amateur DXing communities indicates that high arrival angles at sunrise enhancement may well be the case. Direct experimental data (from the Farley Loop?) would be very useful in this area.

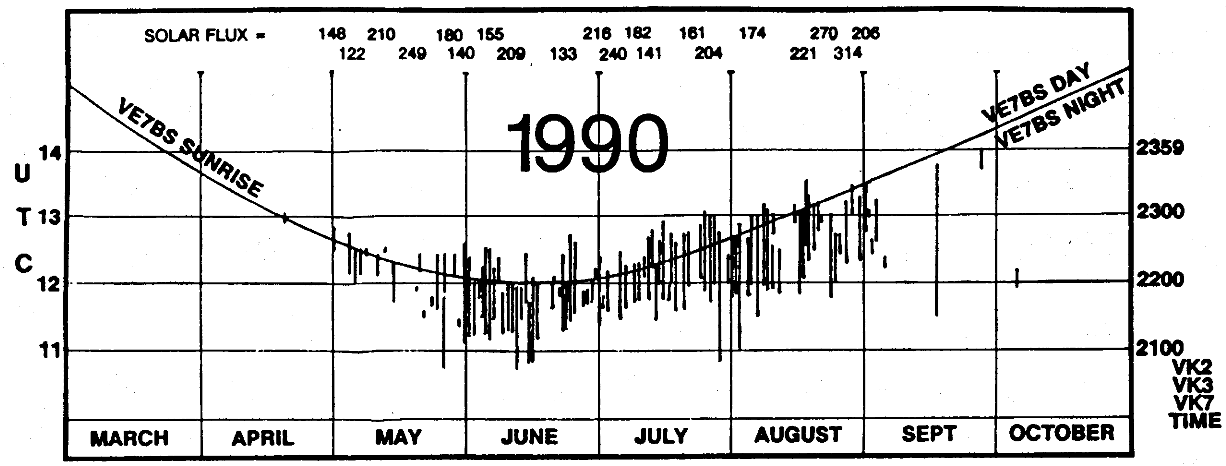
RELATIONSHIP OF DAWN ENHANCEMENT TO THE SOLAR CYCLE

Several senior NASWA DXers have mentioned to us lately that dawn enhancement doesn't seem to last as long as it used to--as long after ground sunrise, that is. We have made the same casual observation. Neither of us had seen any supporting data in either the hobby press or scholarly journals until Bob Eldridge, VE7BS, wrote and shared some of his extensive experience with us. Bob has written widely on HF matters and is a long time DXer on 160 Meters (1.8 MHz).

Figures 8 and 8A chart observed openings on 1.8 MHz between Pemberton, BC (VE7BS' location 70 mi. N of Vancouver) and Australia. Each line represents an opening on a certain day. The arcing curve from left to right indicates the time of dawn on the ground in Pemberton. When you compare the two years, you note that openings lasted far longer past dawn on almost every occasion in 1985 (solar flux generally less than 100) than they did in 1990 with solar flux running often above 200. This is particularly true during the prime three months of "the Down Under season" from late June until September. Bob's charts are the only hard data of which we are aware showing systematic study of the frequency and length of dawn enhancement and its relation to the solar cycle. Even though propagation and "openings" differ somewhat between the 160 Meter amateur band of Eldridge's study, and our favorite 90 and 60 Meter haunts, his graphs do match very well with our experience. So...since we are all again beginning a sleigh ride down the slope of the sunspot curve, there are better days ahead.



1985 160 METER OPENINGS FROM VE7 TO VK "SUMMER SEASON"



1990 160 METER OPENINGS FROM VE7 TO VK "SUMMER SEASON"

FIGURE 8 and 8A. 160 Meter Band (1.8 MHz) Openings From British Columbia to Australia. These records were kept by VE7BS. The 1985 chart represents only two-way QSO's. The 1990 chart represents both completed QSO's and reception of Australian stations where no QSO was attempted. Probably, the 1985 chart would show even a greater difference from 1985 had it also recorded reception-only openings.

THE SWEET SPOT

The final major proposal in our 1990 Trop Prop article was that there seemed to be a "Sweet Spot" of enhanced propagation trailing the sunset terminator in the Tropical Zones. We were led to the discovery of this Sweet Spot (at the transmitter) as we attempted to develop a rational explanation of the seasonality of Tropical Band DX. This Sweet Spot appeared to be about "two to three hours wide" and the "peak" appeared to be around 9 PM local time in the Tropics. The "width" and "peak" were stated to be statistical in nature, with both factors varying daily and with the presence of the Sweet Spot usually somehow linked to quiet geomagnetic conditions. We had begun to suspect such a Sweet Spot during our own DXing at our dawn enhancement. As we looked back over loggings of the weakest stations from Indonesia, Papua New Guinea and the Subcontinent, our best loggings (sometimes ONLY loggings) tended to occur when it was about 9 PM local time at the transmitter... no matter which of several time zones the station fell within!

In our extensive reading of post-war propagation/ionospheric research, we stumbled across a number of studies of Tropical Ionospheric Disturbances (TIDs.) These TIDs are also known as "field aligned irregularities" and they are sometimes known by the less precise term of "spread F." By whatever name, the TIDs themselves are gigantic cigar-shaped horizontal bubbles usually aligned with their long axes parallel to the planetary magnetic field. These bubbles rise through the tropical ionosphere on most but not all magnetically quiet evenings and have long been known to affect trans-ionospheric propagation of radio waves at all frequencies. The generation of these bubbles begins shortly after local sunset and peaks around 9 PM local time. Usually all turbulence has subsided by local midnight, although some few incidents last as late as 3 AM local time.

It is important to note that we have found no previous authors who proposed a linkage between these TID's and oblique HF propagation *below the MUF*, though Kenneth Davies and possibly others have discussed TID-supported propagation above the MUF. Our linkage of the TIDs to enhanced Tropical Band propagation, and calling the result a "Sweet Spot," is purely our own invention and has been clearly labeled as *SPECULATION*. That caution aside, the circumstantial evidence for such linkage seems almost overwhelming to any seasoned Tropical Band DXer, particularly those who listen regularly at their local dawn. Our best DX at our local "max dawn" almost always occurs in exactly the same geomagnetic conditions as those most favorable to the formation of Tropical Ionospheric Disturbances. Further, our very best reception tends to be from stations located in the center of the area behind the sunset terminator which statistically contains the greatest concentration of these bubbles. We considered our possible "discovery" of a propagational Sweet Spot to be an important contribution to the current discussions of Tropical Band propagation. We should have noted in our previous articles that this Sweet Spot is most clearly "visible" to us in and near the 90 Meter Tropical Band, though we easily note its effects in the 60 Meter and 120 Meter bands, as well.

FURTHER SWEET SPOT STUDIES

In the fall of 1990, we began what we hope will be a systematic study of the Sweet Spot by DXers throughout North America. We published projected Sweet Spot zones calculated to coincide with maximum dawn enhancement at receivers located in three parts of North America (Toronto, Stillwater, Oklahoma and Seattle.) These drawings appeared monthly in DX Ontario and in the newsletter of Fine Tuning. Dawn DXers were asked to report to us whether this alleged Sweet Spot was a useful DXer's tool. It is too early to give anything but anecdotal results. So far, however, those reporting all clearly support the Sweet Spot concept as very useful in explaining and predicting the vagaries of weak signal Tropical Band propagation.

John tracked the Sweet Spot throughout the 1990-91 season from his normal QTH in Oklahoma. He found that it tended to center around 9 PM at the transmitter in the weeks near equinox. However, the best reception spot seemed to have "scooted forward" to nearer 7:30 PM at the transmitter during the North American "Sub-continental Season" (India, Pakistan, Bangladesh, Bhutan, Nepal) of the weeks centered on December 21st. In all cases, propagation enhancements seemed markedly stronger when the transmitter was located in John's dawn Sweet Spot than when the transmitter was in its sunset terminator enhancement as John experienced "max dawn" (true graylining).

Two specific instances are worth reporting:

John watched for the normal (but previously inexplicable) winter disappearance of the PNG and Irian Jaya stations which are heard in Oklahoma at good levels throughout the summer and early fall. Sure enough, by early October all PNG and Irian Jayans had faded to nothing even though there is an "even better" all-darkness path in the winter than exists in the summer! The one anomaly noted this season in this strange annual pattern was the mornings of 20-23 October when the Spot seemed to "jump back" to New Guinea. (Refer to August through November drawings centered on Stillwater in Appendix). These drawings also accurately predicted the first and last audio from the eastern Indian regional 90 Meter transmitters (early November and mid-February) very well.

John made a brief visit to Seattle in mid-March and he and Guy Atkins were able to DX with Beverages for one night from the Pacific Coast. (Refer to 15 March drawing for Seattle). Sure enough, even the weaker Sumateran and Western Javan transmitters seemed "like locals" while even the moderately strong transmitters from central Java eastward were virtually all inaudible!

David tracked the Sweet Spot in some detail from the beginning of the 1990-91 season until the Sub-continental season pettered out, in late January at Newmarket (near Toronto, Ontario). His primary observations during this five-month period are contained in a two-page chart - Appendix 'A' at the conclusion of our article.

As the DX season matured near the Autumnal Equinox, David was watching for the *first significant seasonal opening* from various Asian transmitter sites as a basis for detecting the emergence of seasonal enhancement patterns. He also made notes of *unexpected* or *unusual* openings so that without the influence of any pre-conceived notions, we could observe and attempt to deduce how these fitted into the scheme of things.

For each selected logging judged to have met these criteria, a subjective rating has been assigned to indicate the quality of the opening *for that particular station*. You can see at a glance the UTC sunrise time at Newmarket, the sunset time at the transmitter, and the time at which reception was judged to have peaked. Most importantly for this exercise, you can see how the period of optimum reception compared with transmitter sunset, expressed in local evening times. It is instructive to compare these findings with the Appendix 'B' drawings showing the sunset terminator and the projected Sweet Spot Zone, centred on Toronto.

After the completion of our "Trop Prop" article, we began to suspect that the Sweet Spot might be centred closer to 7:30 PM at the transmitter (the mid-point of the post-sunset generation phase of spread F), rather than at the statistical maximum around 9:00 PM. Indeed, as the terminator worked its way westward and became more steeply inclined with the approach of the Winter Solstice, David found, as did John, that "max dawn" enhancement was much earlier in terms of the source transmitter's evening hour. In particular, that was the case with the Sub-continentals, many of which are situate in the geographic band between 25 degrees N (Tropic of Cancer) and 30 degrees N latitude. The chart shows a relatively consistent peak for these signals between 6 and 6:30 PM at the transmitter (sometimes 7 PM during "late" openings), typically between one and two hours after sunset.

North of the 30th parallel, considering Mongolia for example, the usual peaks were around 8 PM, but again, this tended to be centred on two hours after sunset at the transmitter. Just below the Tropic of Cancer, Vietnamese regionals would also peak two or more hours after sunset, near 7:30 PM local time.

Finally, turning to Indonesia and Papua New Guinea, lying within 10 degrees of either side of the Equator, equinoctial reception from the Island of New Guinea corresponded with our original 9 PM supposition. In the later fall, however, signals originating from sites within the middle of the three Indonesian time zones (UTC+8) exhibited a tendancy to peak
around 8 PM, yet-again about two hours following their tropical sunset.

We should bear in mind that David's survey is representative of part of only a single season just-following solar maximum. Nonetheless, there is a good deal of evidence to suggest that *the "max dawn" Sweet Spot in Eastern North America corresponds with about 8 PM at Asian transmitter sites for a substantial part of the Tropical Band season. The somewhat earlier peak of the Sub-continentals is probably accounted for by the fact that even at Winter Solstice, only the leading edge of the Sweet Spot Zone has reached the eastern extremity of India by the time "max dawn" enhancment is being experienced.*

Well known SWBC DXer Art Delibert of suburban Washington, DC reported similar experiences from his QTH and used the Sweet Spot technique to finally log Radio Manus (3315 kHz.) located in the Admiralty Islands of Papua New Guinea. Art calculated when his local dawn would coincide with 9 PM local time in the Admiralty Islands and found this to be in mid-March. Sure enough, mid-March arrived and so did Radio Manus at Art's "max dawn."

Bob Montgomery of Levittown, PA uses the vaunted R-390A receiver and has been tracking propagation enhancements at dawn. He wrote:

"I have been doing studies of propagation for some time and have come up with the same conclusions you have...the Sweet Spot is of special interest to me as I have been keeping records on Radio Australia broadcasts (referring to the 2.3 and 2.4 MHz Northern Territory "Shower Service" stations) **with various graphs and have noticed this, as well. I have never found a name for it, but your terminology fits it exactly."**

Bob Eldridge, VE7BS, also reports that the relative signal strengths of Aussie amateurs seem to vary in a pattern similar to that predicted by our Seattle-based Sweet Spot drawings. David recently found our most persuasive supporting data for a Sweet Spot when wandering through the dusty archives of ODXA sometime after the publication of our 1990 article. He was stunned when he found a 1970 article by the well known and respected Scandinavian DXer, Anker Petersen. It was published by the Danish Shortwave Clubs International. Mr. Petersen undertook an extensive and very precise year-long study (1969) of 60 Meter DX openings from Denmark to the rest of the world. Making thousands of loggings, he compared when each DX circuit "should be open" to the quality and length of actual openings. This is such an important work that we would like to quote a particularly important observation that Mr. Petersen made after his extensive study:

"The signal strength increases steadily from the stations' fade-in at the beginning of darkness on the path as absorption becomes lesser. ***In many cases, but not in all, a peak occurs about two hours after fade-in, followed by 3-4 hours with weaker signal strength.*** *Then the signal strength increases again and stays on a good level until the station fades out when sunrise reaches the first reflection point."*

Although this does not exactly describe our new-found Sweet Spot, it comes very close.

Figure 9 illustrates one of Anker Petersen's graphic records from that 1969 survey. Notice that the incidence of reception from Southeast Asia in his native Denmark is heavily concentrated near receiver sunset (RSS), and then again near transmitter sunrise (XSR). While it is fair to say there weren't too many "all-nighters" to be heard from Southeast Asia, note the virtual absence of signals throughout the period after RSS and before XSR when the entire signal path is in total darkness. This chart also tends to support the Tropical Band Sweet Spot proposition quite nicely! (Dusk reception in Europe equates with dawn reception here in North America, trailing transmitter sunset by several hours in each case during the DX season).

We should point out that in plotting the seasonal migration of the sunrise and sunset lines on the time scale, Mr. Petersen assigned their positions relative to the "first reflection point" which was assumed to be about 2,000 miles along the path from the transmitter and the "last reflection point," about 2,000 miles before completion of the circuit at the receiver. (He was assuming a conventional F2 multi-hop propagation mode).

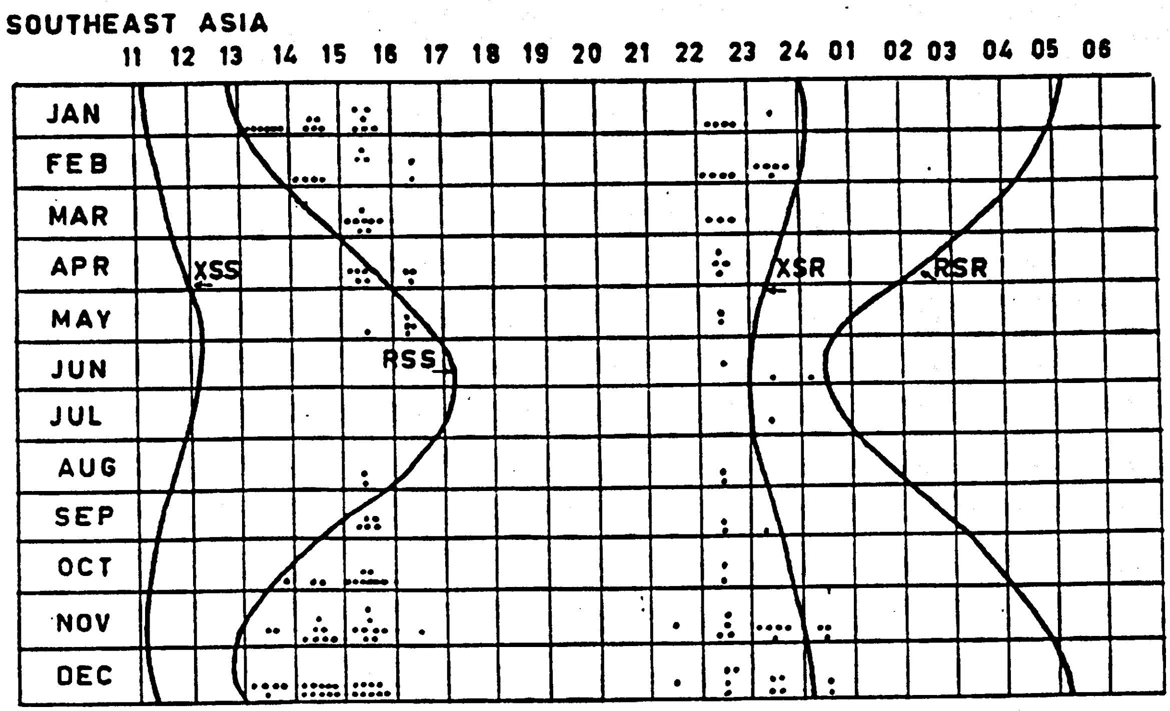


FIGURE 9. Survey of Reception Pattern of Southeast Asians on 60 Meters during 1969 near Copenhagen, Denmark. The number of stations heard during a given hour/month is shown by the number of dots within the box; the vertical position of the dots is indicative of relative signal strength.

"SEANCE" AND THE SWEET SPOT

As noted earlier, Bob Eldridge, VE7BS, is in almost daily contact "during the season" on 160 Meters (1.8 MHz) with radio amateurs in Australia. Actually, he and Bill Tippett, W0ZV, are two of the anchors of the SEANCE net (South-East Australia to North America Communications Exchange). The SEANCE net is organized to assist "first timers" across the Pacific on 160 Meters. It also is run from the Australian end to provide reliable propagation indicators for experienced North American 160 Meter operators. [More on that later].

Just as we were completing the final draft of this article, Bob forwarded the following excerpt of a letter from VK4YB, Roger Crofts, one of the main Aussie anchors of SEANCE and a widely experienced 160 Meter DXer.

"At last [people] who would be really interested in studying our log books...We of course have the raw data to support [the Sweet Spot] hypothesis:

1. **The sharply defined Season mid-May to end-August;**
2. **Peak signals at 9-9:30 local time at western end of circuit;**
3. **Sharply defined geographic region for enhanced signals (West, Midwestern USA);**
   (At times, they also work into Illinois earlier in the Australian evening);
4. **High reliability, openings on at least 90% of days.**

"I have often listened for a peak at our sunset. I have never noticed one yet. The [North American] signals don't appear until around 9 PM. At 27 degrees South Latitude, I am just outside, or rather on the edge of the enhancement zone. Of course I do sometimes work stations earlier, e.g. K6XK is often audible on 1811 CW. If I raise a reply from him it is always by transmitting on the vertical. A sure indication that another mode of propagation is in use because as we know, the horizontals at the western end of the circuit, at least, always seem to have the edge. This is one area where we are able to supply additional information to [the SWBC DXers]. I'm sure all their BC stations are using verticals--the enhancement would be more noticeable if they had dipoles."
(Roger knows though that some tropical broadcast stations use high angle antennas, like the Australian example).

"According to the [Proceedings 1990 Sweet Spot charts], we should expect an enhanced path to Japan at about 1230 UTC in mid-December. I have never noticed the JA's being anything except surprisingly weak all year."

We were riveted by Roger's letter. If we could have described what ought to be happening "under" the Sweet Spots, the SEANCE experience Down Under would be it!!! What a perfect match! Naturally, we are in contact with Roger and SEANCE and we are all interested in exploring the situation more thoroughly.

We cannot help but carry Roger's thoughts further...in our terms, he and the other VKs are *"DXing SUNRISE AT THE TRANSMITTER AT 9 PM THEIR LOCAL TIME"* (the local Sweet Spot).

We have no data on whether this reciprocal effect might work here in North America--especially north of 27 North Latitude. We do have some Asian loggings, and there are a few scholarly works which indicate that the Sweet Spot (or TIDs) may at times extend rather far above the Tropics (at least to 40 degrees N.). For us, this is a whole new thought.

**IT'S 9 PM, YOUR LOCAL STANDARD TIME.
DO YOU KNOW WHERE YOUR DAWN TERMINATOR IS?**

For SWBC and MW DXers west of the Mississippi as well as the amateur community, there are several other items of importance in Roger's letter.

"[To facilitate propagation studies] I am most careful to synchronize my watch with WWV so that the first CQ goes out at exactly 1100Z to the second. I call CQ for exactly 90 seconds on the DIPOLE and listen for 30 seconds. If no reply I call CQ at 1102Z on the VERTICAL and listen for 30 seconds. I have had some difficulty in doing this recently because the frequency is often occupied by VKs ragchewing. I deliberately chose the then hardly used 1832 because our freq last year of 1826 was full of VK ragchewers. Now, everyone is on 1832--the problem of success!"

DXING WITH THE SWEET SPOT

Our Dawn and Dusk series in the NASWA Journal also discussed the possible impact of the Sweet Spot trailing sunset at the transmitter on African and Latin American Tropical Band DXing. This situation would occur in the North American late afternoon and evening. We have not as yet published any drawings detailing this phenomenon and suggest that you produce your own. The dawn drawings in the Appendix to this article were made by defining the Sweet Spot as extending from the Tropic of Cancer to Capricorn, from 7:30 to 9:30 PM mean solar time at the Equator. The sides of the Spot were drawn running parallel to the terminator.

To conclude this section of our discussion, we suggest that at least four relationships between the Sweet Spot and the receiver or transmitter are worthy of special interest:

A) **When the Sweet Spot is over the transmitter at your own "max dawn" enhancement**--the situation shown in the Sweet Spot drawings following this article. (These drawings apply only for the receiver locations and times/dates noted, of course.)

B) **When the Sweet Spot falls over the transmitter during local receiver sunset enhancement.** This situation would occur from some North American receiver locations to some parts of Latin America. However, it appears that this situation would be much more useful for DXers located on the Eurasian landmass.

C) **When the Sweet Spot lies between the transmitter and the receiver, especially when the long axis of the Sweet Spot is parallel to the propagation path.** This situation applies to late winter afternoon reception of African stations from North America and for enhanced evening reception of various areas of Latin America from some locations in North America.

D) **When it is 9 PM local standard time at your location (or, maybe 3 hours past sunset) try DXing sunrise-at-the-transmitter and/or sunset-at-the-transmitter.** This of course, is our possible new Sweet Spot tool found by the Australians.

Finally, we suggest that the true test of the existence of a Sweet Spot of enhanced tropical transmission/reception will be whether it becomes a tool commonly used by Tropical Band DXers around the world. If it is a chimera, it will soon sink back into the DXers' Dustbin of strange ideas hatched after too long at the dials. You decide.

SPHERICAL CONVERGENCE

"Spherical convergence" is our term for a little known and poorly understood physical phenomenon which materially effects the signal strength of every signal of whatever frequency which is propagated ionospherically and which travels more than 6,250 miles between transmitter and receiver. It effects Low, Medium and High Frequency alike. From reader feedback to the 1990 article, we are aware that spherical convergence was the most difficult concept to grasp, probably because it seems so wrong-headed. The concept accepts that signals traveling from a transmitter get weaker as they spread out. This is true for the first 6,250 miles. After that, and ignoring other losses, signals get progressively stronger each mile that they travel! This is due to the spherical nature of the planet and its more-or-less concentric ionosphere.

The only data we have found which gives actual gain figures resulting from spherical convergence is in the Deutsche-Welle study [1] which found that **this phenomenon alone, added several S-units to the strength of D-W signals received in Australia.**

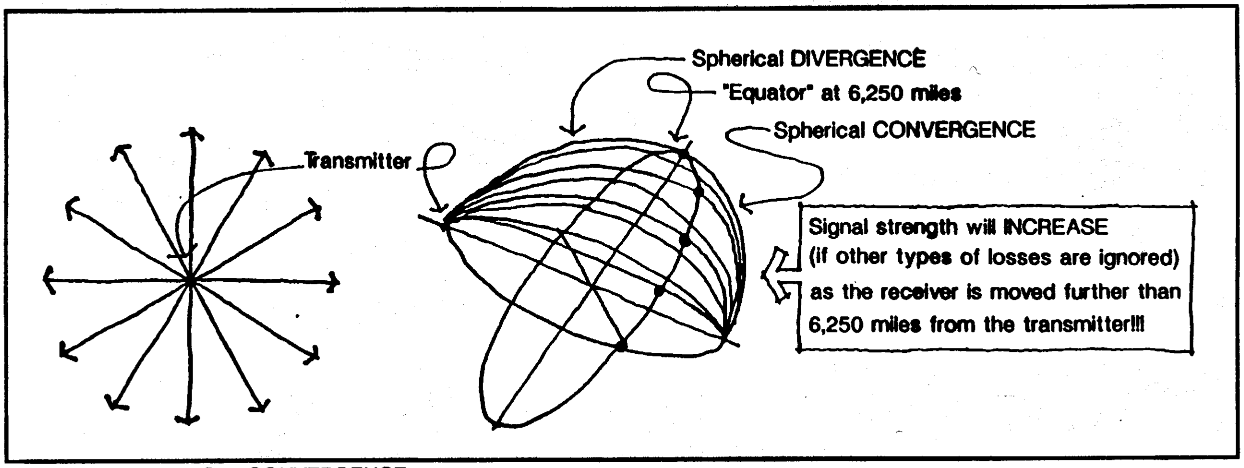


FIGURE 10. SPHERICAL CONVERGENCE
Note: Since this effect is operative at all ionospherically propagated frequencies, the effect of day/night is not shown.

Figure 10 was our attempt at explaining this phenomenon. However, many readers still had difficulty visualizing it. The following exercise helped us understand this slippery concept: We are all familiar with the "stone dropped in a still pool of water" analogy of a signal traveling outward in concentric ring-like waves from a transmitter. As the concentric waves spread to ever-larger circumference, their height decreases proportionally. So does the field strength of the analogously transmitted radio signal. We could get the same effect *in reverse* in the pool by having an adjustable metal ring in the water. If we could suddenly make the ring just a bit smaller, that movement would create an inward-traveling small circular wave. As that wave came closer to the center, it would build in height as the wave's circumference got ever smaller. (Right?? Right!!)

Now, place a "transmitter" rock at the north pole of an all-water surfaced planet, which is 25,000 miles in circumference. The ultimate receiver will be at the south pole of the same planet. Use your north polar rock transmitter to create a 6-foot high single wave at the north pole. As this tidal wave rushes outward, the wave crest will get ever-lower as the total wave circumference gets ever-larger. By the time that this tidal wave reaches the equator, it will have traveled 6,250 miles from the transmitter and that formerly 6-foot high tidal wave will be, say 1/1000 of a foot high as it simultaneously crests all points of the equator. Now, rush around to your receiving position at the south pole. You will hardly notice the 1/1000 of a foot tidal wave rushing at you, yet as the circumference of this inward-rushing wave decreases, its height builds rapidly! (So would the signal strength of an analogous radio wave after it travels 6,250 miles from the transmitter). Measured at any point past 6,250 miles, the tidal wave is getting ever-higher! Finally, it converges at your south pole location. Unless you are at least 7 feet tall, you are gonna get a mouth full of water! So, too, with the signal strengths of ionospherically propagated radio waves on a spherical planet.

This phenomenon, which we call "Spherical Convergence," is discussed briefly in some professional works using terminology such as "ray re-focusing" and/or "near antipodal focusing." We find both terms very misleading and unnecessarily obscure. Since the effect on the Germany-to-Australia circuit was 2 to 3 S-units and since this phenomenon effects *every* ionospherically propagated signal which travels more than 6,250 miles (not just from near your particular planetary antipodes) we commend Spherical Convergence to every serious DXer's consideration.

We are not aware of any propagation predicting programs which takes this mathematically simple concept into account!

THE RECIPROCITY ASSUMPTION

The Reciprocity Assumption is apparently especially dear to radio amateurs and professional propagationists. In our 1990 article, we noted that one aspect of our own observation might be a "receive only" phenomenon. No other single statement garnered such comment from our readers. We were assured by a number of folks that there was no such thing as a "receive only" phenomenon--the "reciprocity assumption" would not allow it! The reciprocity *ASSUMPTION* states that, in propagational matters, one may interchange the position of the receiver and the transmitter and not effect signal strength, propagational geometry, etc.

We are unsure why this assumption is so dear to so many and agree that it is a reasonable "most of the time" assumption. However, like all things in physical science, one should "never say never!" Our best reference documents a NATO-funded study of HF propagation in the Arctic. Scientists established matched transmitter/receiver/antenna at several sites in the sub-arctic and performed extensive propagation path testing.[4] They defined "non-reciprocity" as when there was at least 10 dB of difference between the received strength of a signal sent from Point A to Point B and that sent in the reverse direction the next instant. Since all differences of transmitter, antenna and receiver were designed out of the experiment, any instances of non-reciprocity would be due to propagation. Over 80 percent of the transmissions were non-reciprocal! Although 10 dB is less than 2 S-units of difference, the fact that such exists is very strong evidence that true "receive only" phenomena do occasionally exist.

An associated study is also worth mentioning: researchers found that the ionosphere in the Arctic was so turbulent that the strength of long distance transmissions arriving at two receivers separated by as little as 30 km varied radically. In some tests, one receiver would report a strong signal while the nearby receiver reported no signal at all! The implications of this study on weak DX signals attempting to transit either polar region must be quite profound. Similar "non-reciprocity" may or may not exist elsewhere in the ionosphere. We are not sure that anyone has ever actually tested the "reciprocity" assumption in the "more normal" temperate latitude ionosphere.

INTER and INTRA LAYER DUCTING

There is ample evidence that "true" ducting exists as a mode of radio propagation. If "layers" of higher density ionization are interspersed with layers of much less dense ionization, it is easy to visualize that wave packets traveling almost parallel to these ionospheric layers will be continuously refracted around the planet. Some speculation has appeared in scholarly journals that the regions of the ionosphere which we think of as distinct layers (D, E, F, F1, F2) may be each composed of a number of mini-layers. We understand that rocket-borne instruments have not been sensitive enough to measure such possibly very subtle vertical gradients of electron density. If this "many mini-layers" picture of the ionosphere is true, there may be *INTRA* as well as *INTER* layer ducting of radio signals.

The conventional view of "true" (that is, double-sided) ducting is that it only occurs at frequencies higher than the current Maximum Useable Frequency (MUF)--that is, generally above 25 MHz. Ducting as a mode was probably discovered because no conventional ionospheric means of propagation existed at these very high frequencies. The signals "should" have gone into free space, but did not. Why? Thus, a search and the discovery of ducting.

Since the conventional view of HF propagation (the multi-hop model) is now called into question, it is at least reasonable to speculate that ducting *MIGHT* play a significant and regular role in HF propagation over planetary distances. We have no means to determine whether the primary mode of long-haul Tropical Band propagation is whispering gallery/single-sided ducting or "true" double-sided ducting. We understand that a Canadian ionospheric research satellite will be launched via the much-delayed Space Shuttle in 1993 or 1994. It is supposed to fly at altitudes which will allow a highly detailed look at the structure of the ionosphere. We can hope that part of this project will address the behavior of the ionosphere at the lower High Frequencies.

LONG PATH/BENT PATH PROPAGATION

A major development in our own study of dawn/dusk enhancements in the past year was David's discovery that the signals of Indonesian and Southeast Asian stations sometimes audible on North American winter afternoons (primarily an East-of-the-Mississippi-only phenomenon) were coming from the South! David stumbled into this when he and DXing buddy Cedric Marshall constructed a permanent two-wire Beverage at their Ontario antenna farm. This type Beverage (refer to ARRL *Antenna Book* or Misek's *Beverage Handbook*) is switchably uni-directional off either end. Imagine David's shock when he switched the antenna pattern from north to *south* and those weak afternoon Indo's boomed in!

David was especially startled since he is one of the best known DXers of these particular DX signals and since he had spent several pages in his well-received article "DXing Asians on the Tropical Bands--The Auroral Factor" (*Proceedings 1989)* explaining how those very same winter afternoon Asians came in from the *north* through the Arctic "doughnut hole" or by "skewed" path around the northern auroral region. This northerly short path route was and is the explanation of these signals common among veteran North American Tropical Band DXers and we both fell in the same trap. Not only have we all been conditioned to "think" short path as the normal mode, but also it was assumed that Tropical Band propagation on the reciprocal (long) Great Circle path from Southeast Asia to eastern North America in mid-winter was not possible. That was because the path (from Sumatera/Singapore, for example, at 180 degrees from true North) intersects Antarctica which is bathed in twenty-four hour daylight during the southern hemispheric summer, thus implying total signal absorption or "solar blanking."

Matters only became clearer when it was recognized there is a sunset grayline from eastern North America which runs tangent to the eastern extremity of Antarctica in mid-winter and passes through the vicinity of Ujung Pandang on the Indonesian island of Sulawesi. Remembering that a grayline path is always a Great Circle path, this means that David's dusk reception of Ujung Pandang (on 4719.3 or 4753.3) is an entirely plausible example of true graylining via the long path. (January 1st Newmarket sunset = 2151; Ujung Pandang sunrise = 2153). The January 1st position of the grayline also means that most of Southeast Asia is still in pre-dawn darkness at the time of David's sunset. The Beverage antennas confirmed the conclusion that the signals from most of Jawa and all points further to the west must be adopting a bent or "deviated" long path, exhibiting as much as 30 degrees of skew from the reciprocal Great Circle path in terms of the transmitter location. The arrival of these signals from a southeasterly heading also squares with David's observation that reception of the afternoon Asians is distinguished by a total absence of characteristic polar or auroral "flutter" fading.

It is also noted that those mid-winter long path signals from Sumatera, Singapore and the Indo-China region attain their best peaks, albeit briefly, during the particular period when one-half hour past sunset at the receiver coincides with one-half hour prior to sunrise at the transmitter--the classic definition of a low-band, long path opening.

We have stated that dawn and dusk Tropical Band signal enhancements are not symmetrical propagational events. With particular reference to the Southeast Asians, dawn Sweet Spot enhancement is typically accompanied by a relatively quiet geomagnetic field, although we are finding that this is not always the case. Conversely, at dusk the initial "positive phase" after commencement of an ionospheric/geomagnetic disturbance is almost invariably the necessary criterion for a day or two of enhanced long path reception of the Asians. Given ideal conditions, certain stations can be heard at signal levels which far exceed their typical strength during dawn enhancement! We have yet to see a substantive explanation, in the hobby press or elsewhere, of this phenomenon of dusk trans-equatorial enhancement as it applies to Tropical Band frequencies.

Secondly, downward refraction of signals at dusk must be assumed to be geometrically quite different than at dawn--at least on the lower HF bands. We noted that recombination rates in the D and E layers beginning at dusk are slower that the process of rapid ionization beginning at dawn. Furthermore, the circular shape of the earth means that the F region will begin to be affected by the sun well before dawn at ground level. The opposite effect occurs at sunset. All of this implies to us that the ionospheric tilting mechanisms during dusk enhancement may result in different arrival angles and different ray-focussing of the signals than at dawn enhancement. The extent to which these suppositions might be important for the reception of long path Asians is unknown to us at this time.

In any case, we had mistakenly assumed that "long path" propagation--reasonably well known in amateur circles--was either a high frequency phenomenon (20/15/10 Meters) or was far too rare to use as a conscious DXing strategy on the lower frequencies. We feel that David's "discovery" that "long path" can be a useful Tropical Band DXing strategy is a another major contribution to our collective effort to hear ever weaker DX. We are especially grateful that Bill Tippett, W0ZV, an outstanding veteran 80 and 160 Meter DXer, has contributed his insightful article on Long Path/Skewed Path Propagation to *Proceedings 1991.*

SUMMATION AND CONCLUSIONS

As our title suggests, we view this article as a scrapbook of "Notes" and an interim report on our own maturing thoughts on Tropical Band propagation. At this point, we do not think it useful to reach conclusions beyond those contained in the text of this article. We would be less than honest, though, if we did not say that we, and probably some of you, are beginning to see an emerging picture of Tropical Band propagation which is so unconventional as to be considered heresy in many circles. Neither of us is particularly comfortable with this state of affairs and we often begin to "backslide." When this happens, we go over our reasoning carefully; we examine again the real-world experience of ourselves and others and again read the documents that we have cited. The results of this re-examination are always substantially the same, no matter how uncomfortable they seem to us and others.

We are also very conscious that our articles have not covered all major aspects of radio propagation at Tropical Band frequencies. That was very intentional.... we are still doing a great deal of "homework."

TOWARD THE FUTURE

Although we have made a start toward a clearer understanding of Tropical Band propagation, much remains to be done. We would greatly appreciate assistance from other veteran DXers who dwell mostly below 6 MHz. We would appreciate input directly to either of us or in the form of article proposals for future editions of *Proceedings*. We are sincerely interested in assistance in the following areas:

A) True Double-Sided Ducting at Tropical Band Frequencies. We feel rather strongly that this type of propagation exists at low HF frequencies. It may exist in place of or co-exist with whispering gallery/single - sided duct mode.

B) Although Bob Eldridge's work (Figure 9 and discussion) on the relationship between Dawn Enhancement and the Solar Cycle begins to clarify this issue, a whole host of other "sunspot" cycle issues remain.

The most important is determining at which points in the cycle are the best general DX conditions. Conventional wisdom has always been that high bands were at their best in high sunspot-count years, and that low bands were at their best in very low sunspot-count years. There is growing discontent with this old saw from experienced SWBC DXers, MW DXers and amateurs who haunt bands from 6 MHz downward.

C) We have also to date, steered clear of writing of our views of the very complex relationships between hourly/daily/monthly solar events and "real time" DX conditions. We are both very interested in the observations of veteran DXers concerning this aspect of Tropical Band Propagation.

D) We would appreciate hearing from anyone in the amateur or SWBC DXing community who systematically DXes over planetary distances at frequencies between 6.0 and 1.4 MHz. concerning their general impressions of our proposals and their impressions of the Sweet Spot.

E) We would appreciate any leads or citations of formal *primary* research papers which support the *MULTI-HOP* model of HF propagation at any frequency. However, we are only interested in research papers which support this model with physical data and/or findings based on anything other than tradition, secondary quotations or *DELAYED TIME OF ARRIVAL.*

We would like to thank all of those who have participated in the Sweet Spot study, so far, and also those members of our sister radio hobbies who have been so much help in furthering our understanding of propagation and who have been most helpful in clarifying our understanding of these sometimes arcane matters.

Finally, we hope that you have found reading this article half as interesting as we have found the writing of it. We also urge you to remember that no article or book on this subject is completely true and accurate. At best, all such represent the truth as the authors believe it to be at the time they write it.

Happy (**Tropical Band**) DXing!

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END NOTES:

We have refered to several previous articles published in other editions of *Fine Tuning's Proceedings*. These are: "Terminator Mechanics and Trans-Polar Solar Blanking" by Bryant (*Proceedings 1988*); "DXing Asians on the Tropical Bands: The Auroral Factor" by Clark (*Proceedings 1989*); "Notes on Tropical Band Propagation" by Bryant and Clark (*Proceedings 1990*). Fine Tuning's Special Publications is attempting to keep all years of *Proceedings* actively in print. Inquiries may be sent to Fine Tuning's Special Publications in care of John Bryant at the above address.

We have also made numerous references to a series of four articles which we jointly authored in the Spring of 1991 in the "DXer's Forum" of the *Journal of the North American Shortwave Association*. The first two of these articles focused on Dawn Enhancement and the latter two on Dusk Enhancements of Tropical Band propagation. Reprints of this series, Known as "Dawn and Dusk" are available at nominal cost from **The NASWA Company Store**, 2216 Burkey Dr., Wyomissing, PA 18702.

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[3] Rose, Robt. B. "High Resolution HF Time of Arrival Measurements (1981-85)". THE EFFECT OF THE IONOSPHERE ON COMMUNICATION, NAVIGATION AND SURVEILLENCE SYSTEMS, IES'87. Office of Naval Research, 1988.

[4] Jull, G.W. "HF Spatial and Temporal Propagation Characteristics and Sounding Assisted Communications". IONOSPHERIC RADIO COMMUNICATIONS, Folkestad, K., ed.. Plenum Press, New York, 1968

APPENDIX A

TROPICAL BAND SWEET SPOT SURVEY: SEPTEMBER/90 - JANUARY/91 AT NEWMARKET, ONTARIO

DATE / QUALITY	STATION / FREQ	RCVR SR XMTR SS (UTC)	PEAK / XMTR SS (PM)	PM PEAK AT XMTR / NOTES
9/16/90 Poor	AIR-Hyderabad 4800	1100 1246	1200 6:16	*5:30* SR+1 hr, SS-45 min; Skewed Path?
9/22/90 Poor-Fair	V of Myanmar 4725	1107 1130	1200 6:00	*6:00* Heard much better near mid-winter
9/22/90 Poor-Fair	AIR-Port Blair 4760	1107 1143	1200 5:13	*5:30* 1157 s/on-1210 fade under Kunming
9/30/90 Very Good	R Enga-PNG 2410	1116 0819	1125 6:19	*9:25* Also RRI-Sorong 4874.6 good to 1230+ Late!
10/13/90 Fair-Good	R Nepal 5005	1132 1150	1200 5:55	*6:05* Best on NW Beverage; skew from Grayline?
10/14/90 Fair-Good	RPH-Melbourne 1629	1133 0835	1115 7:35	*10:15* Also RPH-Canberra 1620kHz at 1105
10/20/90 Good	Xizang BS-Tibet 4750	1141 1119	1200 7:19	*8:00* Ulaan Baator 4995 @ 1205 fair (8pm at xmtr)
10/21/90 Fair	CBS-Taipei 3335	1142 0920	1140 5:20	*7:40* 1st log; no PNG! Ulaan Baator 4828 @ 1205 (8pm)
10/21/90 Good	AIR-Delhi 4860	1142 1214	1243 5:44	*12:43* Ahead of "season" and SR+ 1 hr at s/on
10/22/90 Good	R Nepal 5005	1143 1142	1145 5:27	*5:30* Ahead of "season" but True Grayline
10/28/90 Poor-Fair	RRI-Palankaraya 3325	1151 1013	1155 6:13	*7:55* Tough catch in Ont. RRI-Ternate 3345 vy good
11/04/90 Fair	RRI-Palu 3959.8	1200 0948	1155 5:48	*7:55* New xmtr but usually just carrier
11/05/90 Fair	RPDT2-Ngada 2904.8	1202 0952	1155 5:52	*7:55* Hets from other RPDs in UTC+8 time zone
11/18/90 Good	R Bangladesh 4880	1219 1111	1230 5:11	*6:30* Subcontinental "season" kicks off
11/24/90 Very Good	AIR-Kurseong 3355	1226 1112	1230 4:42	*6:00* Dominant over PNG; best AIR "indicator" on 90m
11/25/90 Very Good	AIR-Shillong 3255	1227 1100	1230 4:30	*6:00* Also AIR outlets on 3235/3277 6-6:30 peak

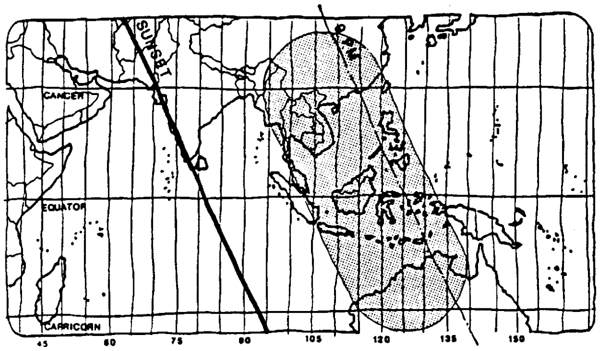
DATE / QUALITY	STATION / FREQ	RCVR SR XMTR SS (UTC)	PEAK / XMTR SS (PM)	PM PEAK AT XMTR / NOTES
12/01/90 Fair-Good	SLBC-Ekala 4870	1234 1221	1245 5:51	***6:15*** New xmtr but not usually audible (presumed log)
12/08/90 Fair	Lao Cai BS-Vietnam 5597.7	1242 1019	1240 5:19	***7:40*** Ha Tuyen BS 4816.5 @ same time - readable
12/09/90 Good	AIR-Gauhati 3375	1243 1100	1235 4:30	***6:05*** Note Indian Regionals consistently 6-6:30pm
12/10/90 Fair	AIR-Bhopal 3315	1244 1204	1235 5:34	***6:05*** Faded under PNG 1240+ AIR-Lucknow 3205 - good
12/15/90 Very Good	RRI-Dili 3306.1	1248 0950	1250 5:50	***8:50*** RRI-Ternate 3345, same time - excellent (9:44pm)
12/15/90 Very Good	RRI-Nabire 5055.4	1248 0902	1305 6:02	***10:05*** Audible to 1400 switch to 6127.5 - fade 1405!
12/22/90 Excellent	AIR-Kurseong 3355	1252 1118	1150 4:48	***5:20*** Long Path - SW Bev! Short Path - NE Bev @1235
12/23/90 Very Good	AIR-Delhi 4860	1253 1158	1300 5:15	***6:30*** Long Path-SW Bev; Major flare 12/22 at 2246
12/23/90 Very Good	R Bangladesh 4880	1253 1115	1300 5:15	***7:00*** Long Path on SW Bev;
12/24/90 Excellent	R Nepal 5005	1253 1129	1315 5:14	***7:00*** Skewed Path on NW Bev; Major flare 12/23 @ 0952 PCA Event 12/24 at 1200+ Audible past 1410!
12/24/90 Good	Bhutan BS 5023.1	1253 1112	1305 5:12	***7:05*** Skewed Path on NW Bev; Audible past 1330!
12/25/90 Poor-Fair	AIR-Jammu 3345	1253 1159	1238 5:29	***6:08*** Tentative // AIR-3355
12/30/90 Poor	AIR-Ranchi 3304.5	1255 1141	1240 5:11	***6:10*** Threshold (tentative); Also AIR-Jammu 3345
12/31/90 Poor-Fair	AKR-Muzaffarabad 3662.6	1255 1204	1250 5:04	***5:50*** Better than 1st (presumed log) on 12/30
01/03/91 Fair-Good	RRI-Gorontalo 3264.7	1255 1124	1215 6:24	***7:15*** Sumatera can be much better at receiver SS!
01/04/91 Very Good	R Nepal 3230.1	1255 1135	1245 5:20	***6:30*** Better than //5005!
01/20/91 Very Good	AIR-Kurseong 3355	1249 1137	1230 5:07	***6:00*** Long Path-SW Bev; Last good Subcontinent date

APPENDIX B
DAWN ENHANCEMENT SWEET SPOT CHARTS
for
EAST COAST NORTH AMERICA

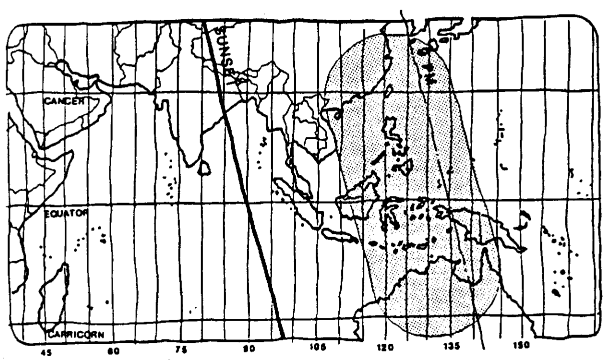
WINTER / SPRING

These charts document the statistically probable location of an area of enhanced propagation of Tropical Band signals. This enhancement may be associated in some as yet unknown fashion with Tropical Ionospheric Disturbances (TIDs) which are generated on most magnetically quiet evenings. The TID generation begins at sunset and generally peaks about 9pm mean solar time at the Equator. The chart records the statistical placement of the majority of the "creation phase" and the beginning of TID dissipation. Most TIDs dissipate by local midnight, though very unusual conditions may cause TIDs to remain active until nearly local dawn. The "Sweet Spot" on these charts is drawn from 7:30pm until 9:30pm mean solar time at the Equator. The sides are drawn parallel to the Sunset Terminator and generally extending from the Tropics of Capricorn to Cancer. The moment selected for the chart is that of:

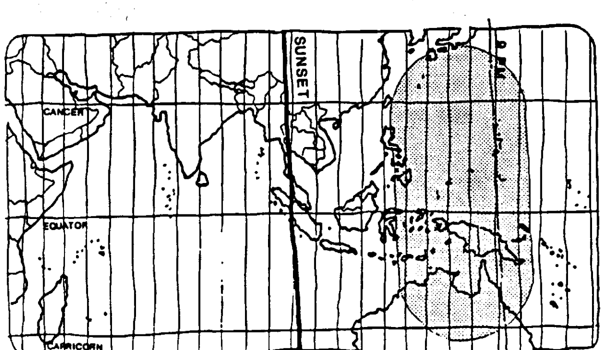
DAWN AT GROUND LEVEL in TORONTO



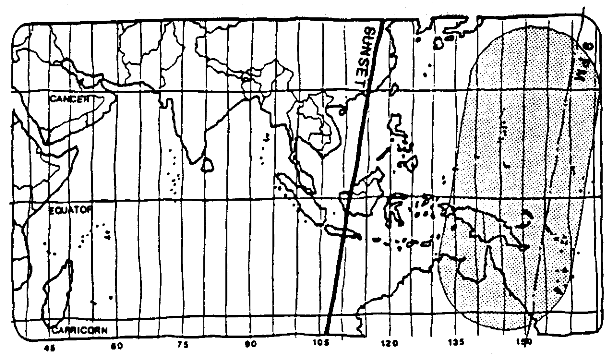
EASTERN toronto 15 JANUARY 1248 UTC



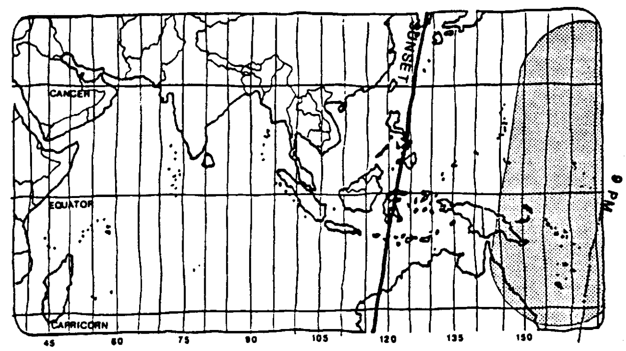
EASTERN toronto 15 FEBRUARY 1216 UTC



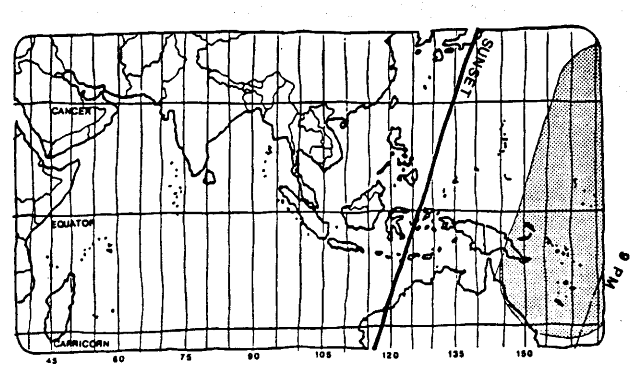
EASTERN toronto 15 MARCH 1130 UTC



EASTERN toronto 15 APRIL 1035 UTC



EASTERN toronto 15 MAY 0952 UTC



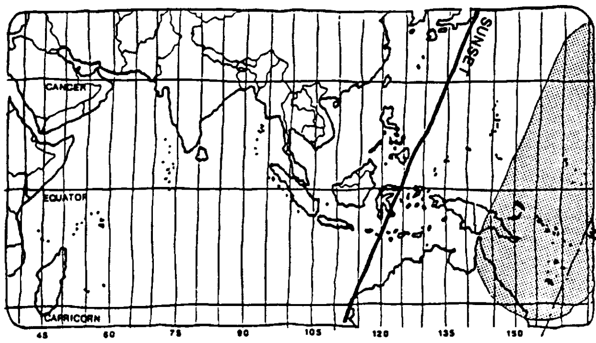
EASTERN toronto 15 JUNE 0935 UTC

APPENDIX B
DAWN ENHANCEMENT SWEET SPOT CHARTS
for
EAST COAST NORTH AMERICA

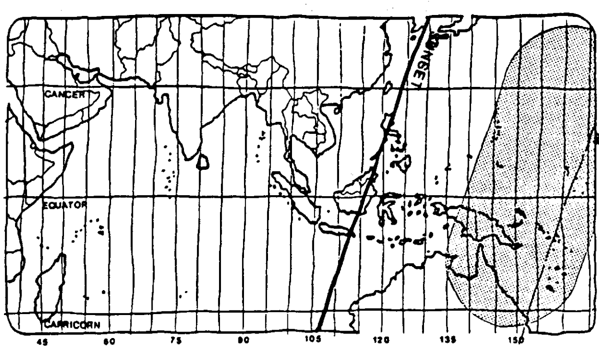
The moment selected for the chart is that of:

DAWN AT GROUND LEVEL in TORONTO

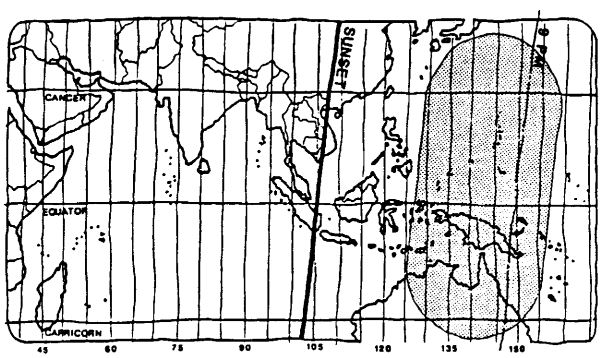
SUMMER



EASTERN toronto 15 JULY 0949 UTC

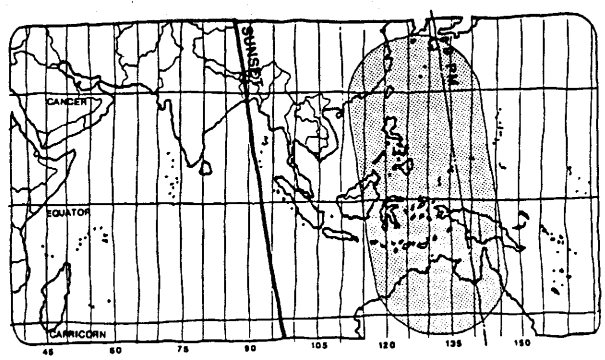


EASTERN toronto 15 AUGUST 1021 UTC

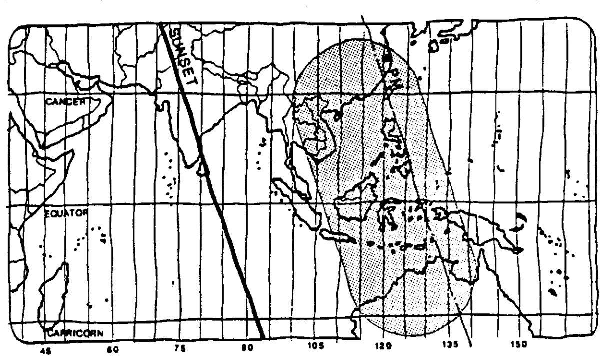


EASTERN toronto 15 SEPTEMBER 1056 UTC

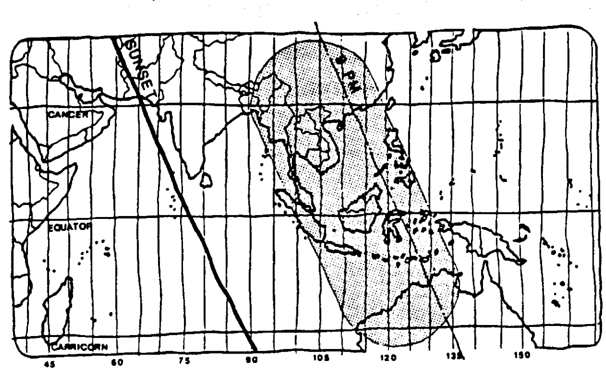
FALL



EASTERN toronto 15 OCTOBER 1131 UTC



EASTERN toronto 15 NOVEMBER 1211 UTC



EASTERN toronto 15 DECEMBER 1244 UTC

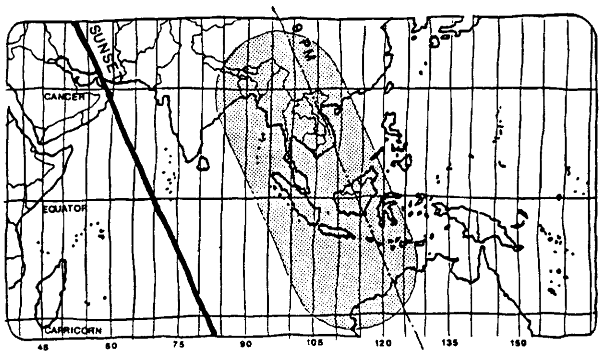
APPENDIX B
DAWN ENHANCEMENT SWEET SPOT CHARTS
for
CENTRAL NORTH AMERICA

WINTER

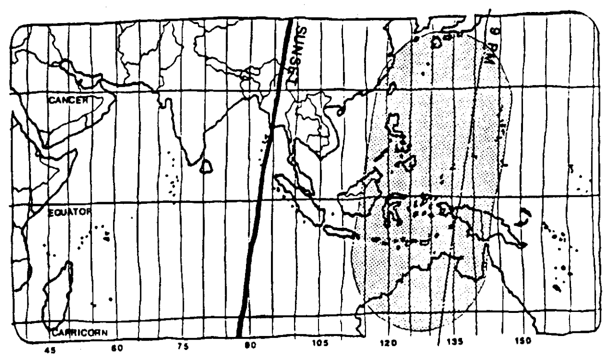
SPRING

These charts document the statistically probable location of an area of enhanced propagation of Tropical Band signals. This enhancement may be associated in some as yet unknown fashion with Tropical Ionospheric Disturbances (TIDs) which are generated on most magnetically quiet evenings. The TID generation begins at sunset and generally peaks about 9pm mean solar time at the Equator. The chart records the statistical placement of the majority of the "creation phase" and the beginning of TID dissipation. Most TIDs dissipate by local midnight, though very unusual conditions may cause TIDs to remain active until nearly local dawn. The "Sweet Spot" on these charts is drawn from 7:30pm until 9:30pm mean solar time at the Equator. The sides are drawn parallel to the Sunset Terminator and generally extending from the Tropics of Capricorn to Cancer. The moment selected for the chart is that of:

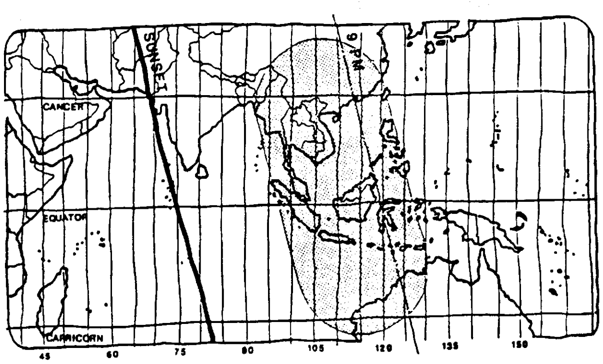
DAWN AT GROUND LEVEL in STILLWATER, OK



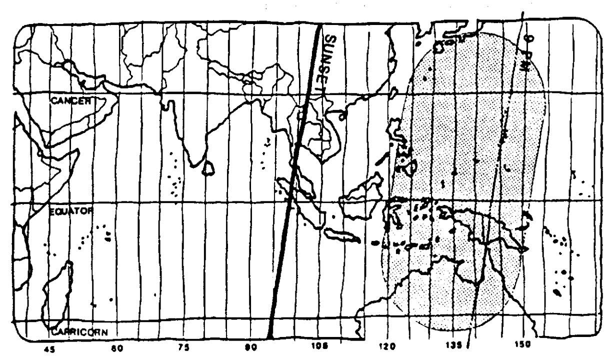
CENTRAL stillwater 15 JANUARY 1338 UTC



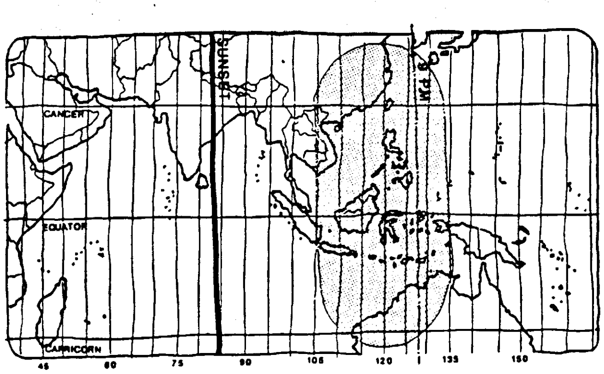
CENTRAL stillwater 15 APRIL 1155 UTC



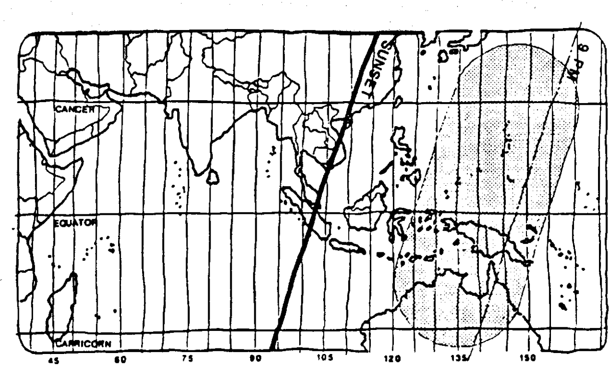
CENTRAL stillwater 15 FEBRUARY 1316 UTC



CENTRAL stillwater 15 MAY 1122 UTC



CENTRAL stillwater 15 MARCH 1239 UTC



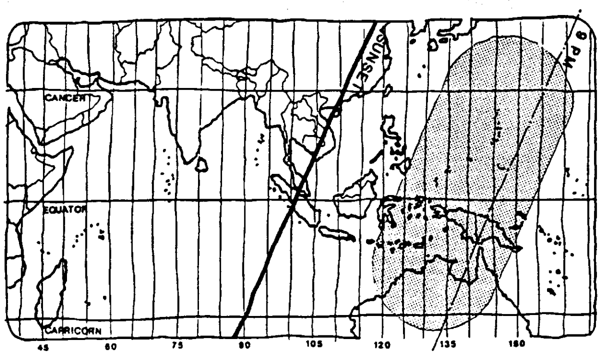
CENTRAL stillwater 15 JUNE 1110 UTC

APPENDIX B
DAWN ENHANCEMENT SWEET SPOT CHARTS
for
CENTRAL NORTH AMERICA

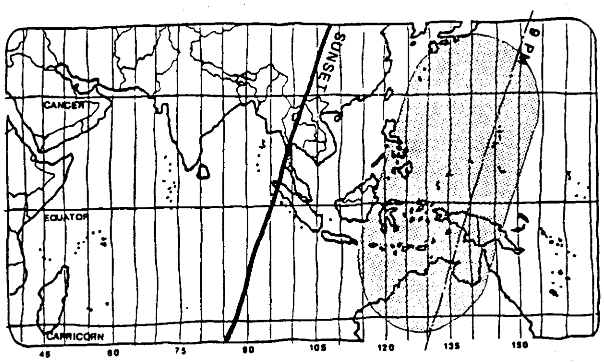
SUMMER **FALL**

The moment selected for the chart is that of:

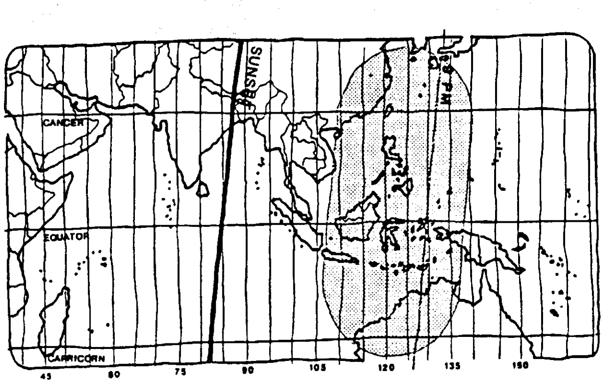
DAWN AT GROUND LEVEL in STILLWATER, OK



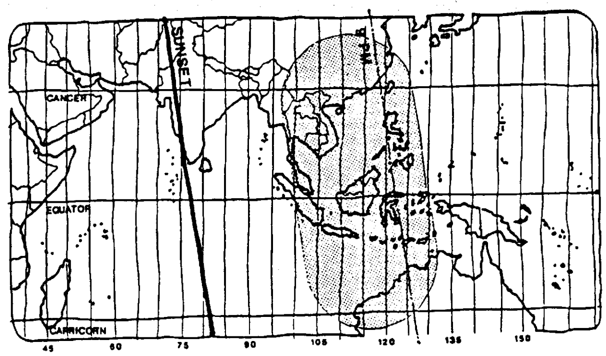
CENTRAL stillwater 15 JULY 1122 UTC



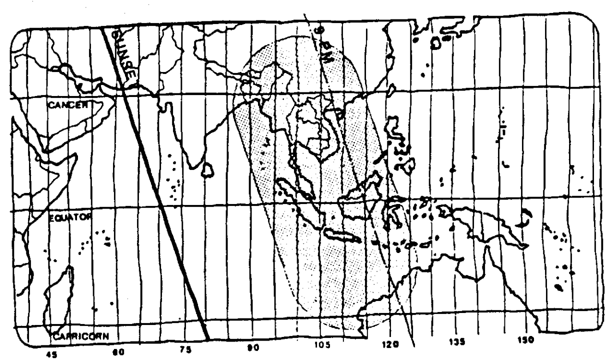
CENTRAL stillwater 15 AUGUST 1146 UTC



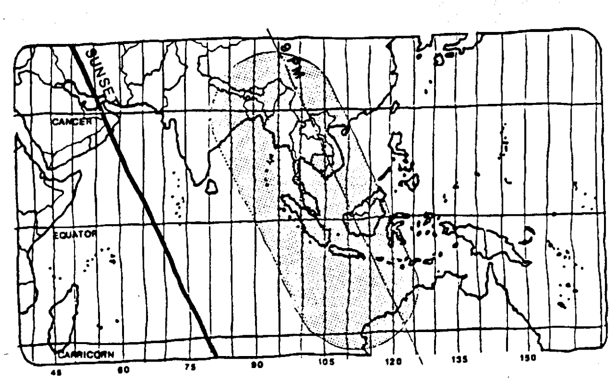
CENTRAL stillwater 15 SEPTEMBER 1210 UTC



CENTRAL stillwater 15 OCTOBER 1235 UTC



CENTRAL stillwater 15 NOVEMBER 1305 UTC



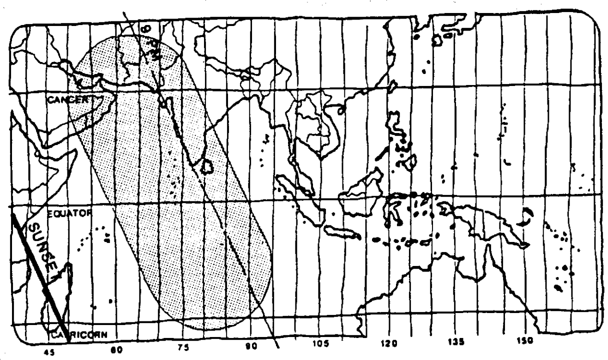
CENTRAL stillwater 15 DECEMBER 1332 UTC

APPENDIX B
DAWN ENHANCEMENT SWEET SPOT CHARTS
for
WEST COAST NORTH AMERICA

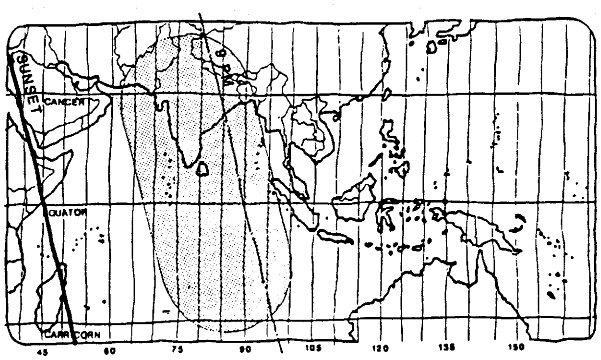
These charts document the statistically probable location of an area of enhanced propagation of Tropical Band signals. This enhancement may be associated in some as yet unknown fashion with Tropical Ionospheric Disturbances (TIDs) which are generated on most magnetically quiet evenings. The TID generation begins at sunset and generally peaks about 9pm mean solar time at the Equator. The chart records the statistical placement of the majority of the "creation phase" and the beginning of TID dissipation. Most TIDs dissipate by local midnight, though very unusual conditions may cause TIDs to remain active until nearly local dawn. The "Sweet Spot" on these charts is drawn from 7:30pm until 9:30pm mean solar time at the Equator. The sides are drawn parallel to the SWunset Terminator and generally extending from the Tropics of Capricorn to Cancer. The moment selected for the chart is that of:

DAWN AT GROUND LEVEL in SEATTLE

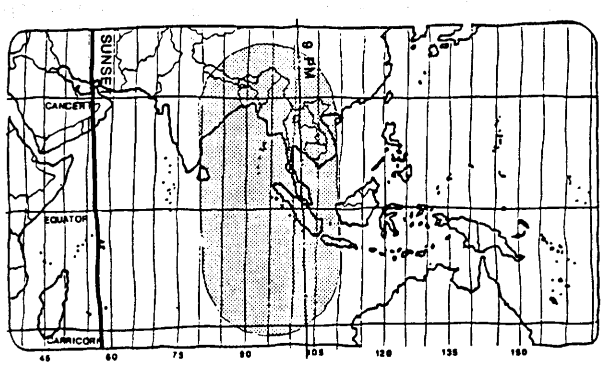
WINTER



PACIFIC seattle 15 JANUARY 1553 UTC

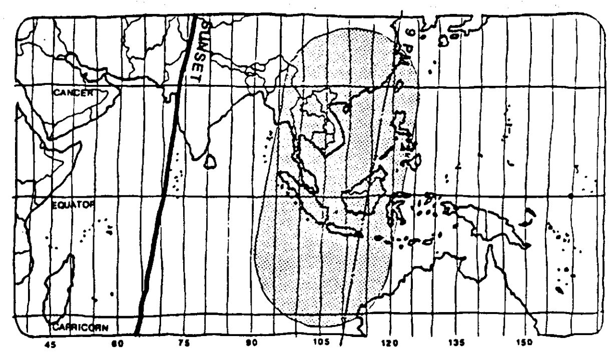


PACIFIC seattle 15 FEBRUARY 1515 UTC

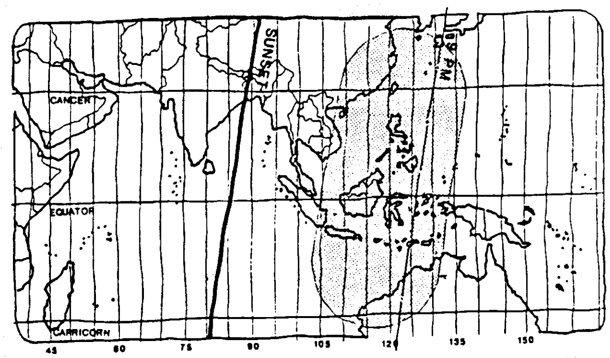


PACIFIC seattle 15 MARCH 1422 UTC

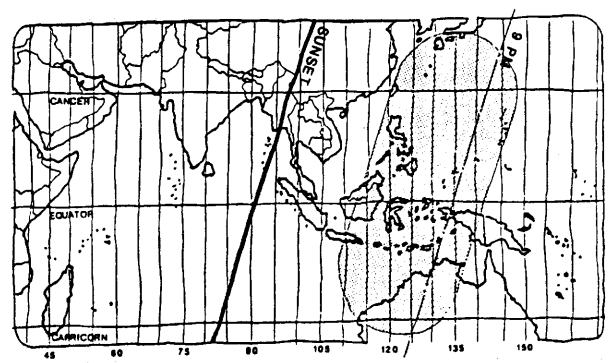
SPRING



PACIFIC seattle 15 APRIL 1321 UTC



PACIFIC seattle 15 MAY 1232 UTC



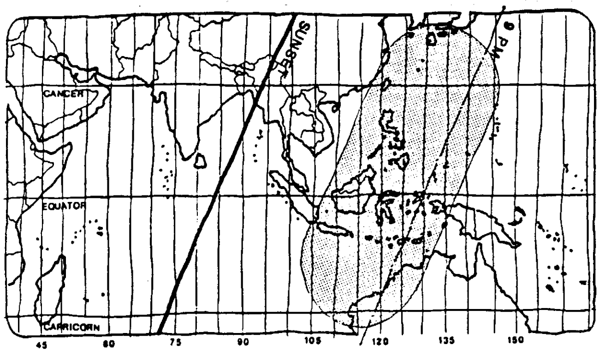
PACIFIC seattle 15 JUNE 1211 UTC

APPENDIX B
DAWN ENHANCEMENT SWEET SPOT CHARTS
for
WEST COAST NORTH AMERICA

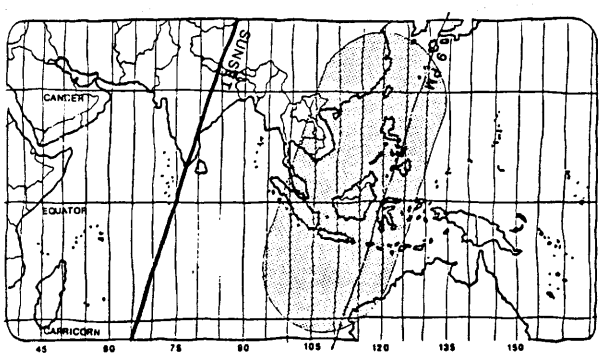
The moment selected for the chart is that of:

DAWN AT GROUND LEVEL in SEATTLE

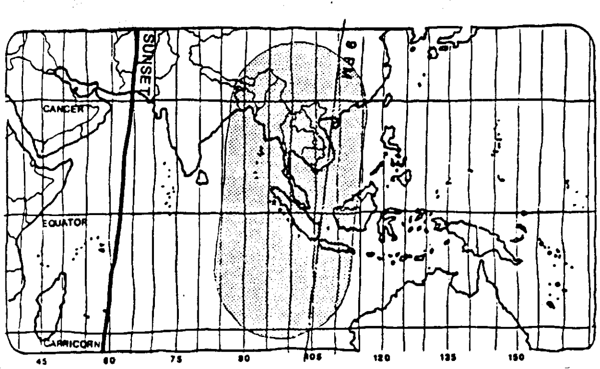
SUMMER



PACIFIC seattle 15 JULY 1227 UTC

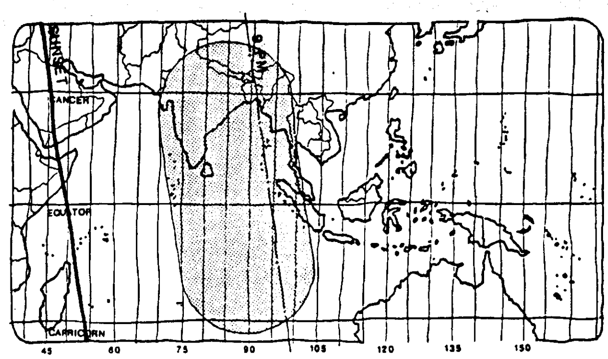


PACIFIC seattle 15 AUGUST 1305 UTC

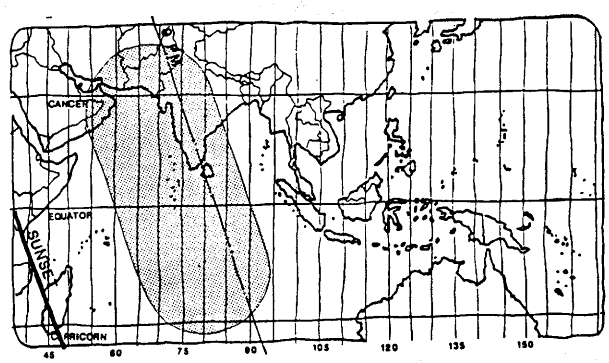


PACIFIC seattle 15 SEPTEMBER 1346 UTC

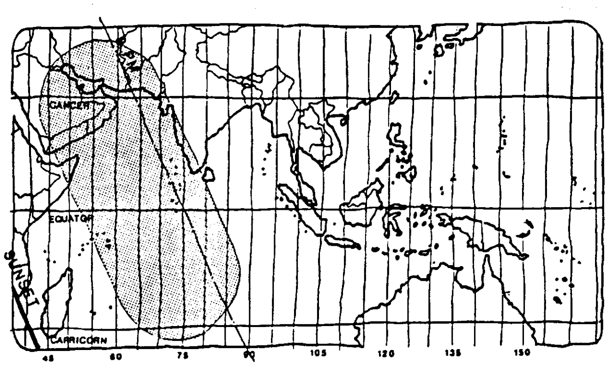
FALL



PACIFIC seattle 15 OCTOBER 1428 UTC



PACIFIC seattle 15 NOVEMBER 1514 UTC



PACIFIC seattle 15 DECEMBER 1551 UTC