LONG PATH AND SKEWED PATH PROPAGATION ON THE LOWER SHORTWAVE FREQUENCIES

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Before getting started on this article, I first would like to thank John Bryant for asking me to contribute to this issue of *Proceedings*. Since I am from the amateur radio ranks (WØZV) I was fascinated when I read a review of the 1989 *Proceedings* in our June 1990 issue of *QST*. I am mainly interested in low band DXing on the amateur bands (1.8 and 3.5 MHz) and thought I could learn from the experiences of the mediumwave and shortwave SWL communities. After reading and devouring the 1989 issue, I ordered the 1988 reprint as well as the 1990 issue, and began corresponding with John. One thing led to another and John asked me to contribute this article, which I am grateful to do in return for all the excellent articles I've read in previous *Proceedings*.

INTRODUCTION

I have been an amateur since 1957 when I first got my license at age 12. Most of my interests have been DXing on the higher amateur bands (14, 21 and 28 MHz) and I've worked all countries on our ARRL countries list except Albania. It shouldn't be long for that one the way their politics are going these days. Having worked almost everything on the higher bands, I started chasing DX on the 3.5 MHz band after I moved to a rural Colorado location in 1980. In October 1984, I put up a "temporary" antenna to operate on 1.8 MHz during a radio contest, and that was the beginning of my current love affair for what we hams call "Top Band." Currently, I have 293 ARRL countries on 3.5 MHz and 224 on 1.8 MHz, so you can see the extent of my addiction. By the way, my country totals on these frequencies equate to 204 and 140 respectively using the NASWA Countries List for reference.

Although I had been fairly successful on 3.5 MHz without using Beverages, I quickly discovered they were an absolute must to hear much of anything on 1.8 MHz. There was not much published on Beverages in those days, so I talked to anyone who had been using them to learn how to make them work. I put up my first crude one in December 1984 without a matching transformer. In August of 1985, I put up an array of seven Beverages (Figure 1) that were aimed at six population centers and one at 210 degrees for "Long Path" (more about that later). These were all properly terminated and ranged in length from approximately 600 to 800 feet. These lengths are over one wavelength on 1.8 MHz and are almost 3 wavelengths on 3.5 MHz. The directivity of these antennas (Figures 2A, 2B) really opens up a new world on the noisy low bands as anyone who has ever used one will attest. Incidentally, I have a 7 MHz rotatable Yagi up 148 feet and I find that the Beverages are at least comparable and often better than that antenna on the 7 MHz band. They are even usable up to 21 MHz, although Yagis are better on bands above 7 MHz.

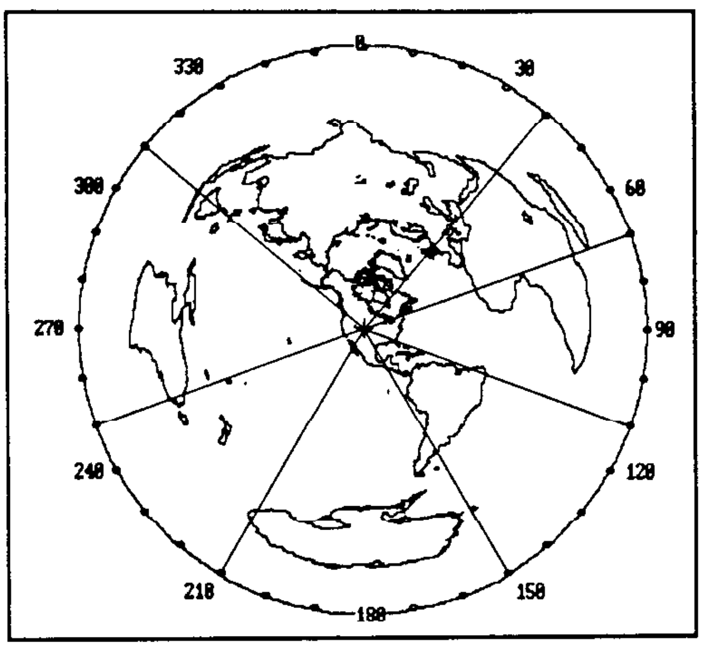


FIGURE 1. Great Circle chart showing orientation of WØZV Beverage antenna system. Map center is Berthoud, Colorado, USA. (From DX-Aid software.)

In reading the past *Proceedings* as well as a large compendium of articles on propagation which John Bryant loaned me, I was surprised to see very little mention of what we hams call "Long Path" propagation. Hence, John suggested that I write this article describing long path propagation on the low bands. Although this article is written from my perspective as a low band DXer on the amateur bands, my comments will generally apply to the 60, 90 and 120 meter shortwave bands.

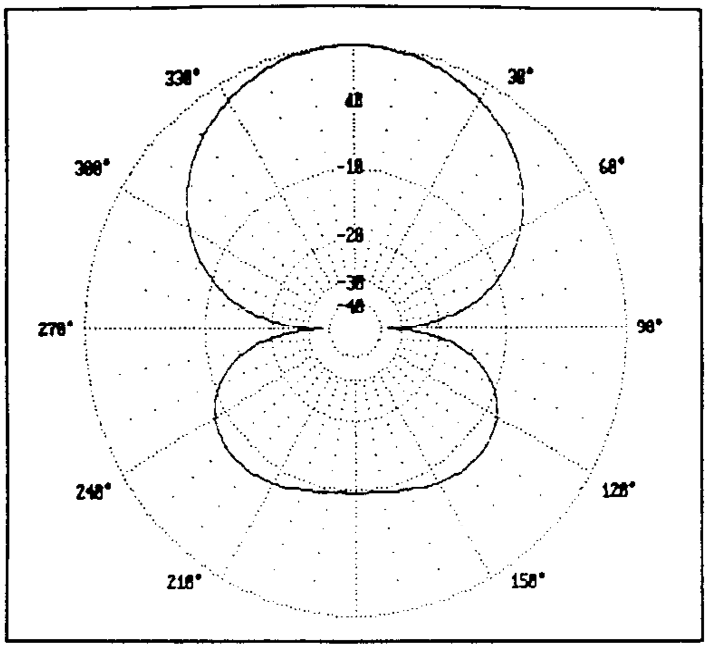


FIGURE 2A. Directive pattern of a terminated 1-wavelength Beverage antenna at 1.8 MHz. (From ELNEC Antenna Model software.)

LONG PATH PROPAGATION

Long path is a very well known phenomena on the amateur bands because most hams have rotatable Yagis on 14 MHz and higher frequencies, and can easily determine the optimum direction to receive any given signal. Given time and experience, most hams learn what direction to point their antennas at any given time of day for specific target locations. However, since many in the shortwave comunity may not have access to rotatable antennas, it may not be as well-known among shortwave circles. Simply put, there are occasions when radio signals will be propagated in a direction generally opposite to what the true Great Circle bearing is. These occasions are a function of time of day, date, and even the relative part of the sunspot cycle since all of these affect the state of the ionosphere.

Note that I said "*generally* opposite". In fact, the headings for maximum signal strength on long path are seldom exactly 180 degrees opposite to the Great Circle bearing between any two locations. Therefore, let me offer a definition of "Long Path" which is what amateurs generally mean when we use the term. *Long path is any path in which the signal is skewed by more than 90 degrees from its true Great Circle heading.* Sometimes it will be 180 degrees but often it will be less. The most common example of long path on the amateur bands is the morning path to Europe, the Middle East and Asia on 14 MHz. Both before and after local sunrise throughout North America, signals from Europe, etc. will be received by beaming approximately over New Zealand. The actual bearing is usually around 210 degrees for my location, but it's important to note that this is relatively constant whether the target area is Europe or Asia, even though the "true" 180 degree bearings for long path should be between 150 degrees and 210 degrees. For example, from my location, the direct heading for Bhutan is 346 degrees, the true (180 degree opposite) long path heading would be 166 degrees, yet the actual signal at my sunrise would be coming from about 210 degrees on the 14 MHz long path. Note that the 210 degree bearing from my location is basically oriented Southwest along my terminator during mid-winter sunrise.

This same path is also very common on 7 MHz, less so on 21 MHz and I have even seen it occasionally on 28 MHz. Thus it is not a complete surprise to us that it also exists on 3.5 MHz and even very rarely on 1.8 MHz (only one contact in my six-plus years of listening for it!)

There are also numerous other examples of long path on our higher bands. For example, working Australia by beaming east on winter afternoons on 7 and 14 MHz, Southeast Asia over South America on or after winter sunset on 7 and 14 Mhz, and even

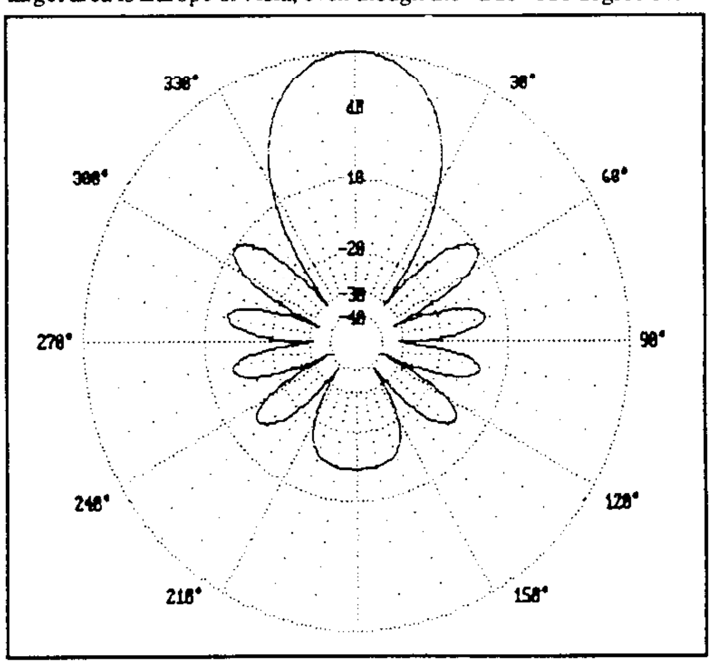


FIGURE 2B. Directive pattern of a terminated 3-wavelength Beverage antenna at 3.5 MHz. (From ELNEC Antenna Model software.)

Europe via New Zealand after local European sunrise or the Far East via South America after our local sunrise on 28 MHz. The examples mentioned for 7 MHz also exist on 3.5 MHz as we'll discuss later.

LONG PATH ON 3.5 MHZ AT USA SUNRISE

This is by far the most common long path phenomena on 3.5 MHz. It exists for stations from Boston to Seattle although it is probably most common for those of us in the western half of the USA. It also happens to be the most convenient for me because I am an early riser and am usually at home at this early hour. Such is not the case for my sunset when another long path exists, because I am usually at work long past local sunset. Incidentally, Dale Hoppe K6UA and Peter Dalton W6NLZ first described this phenomena on 3.5 MHz in their September 1975 *CQ Magazine* article titled "The Grey Line Method of DXing."

As on the higher bands, propagation is possible to Europe, the Middle East, Central and even Southeast Asia depending on the time of year. Refer to Figure 3 for a list of countries heard or worked from my location in Colorado. As observed on the higher band signals, the bearings for all target locations are relatively constant at about 210 degrees from my location. There are even a few rotary Yagis in the USA on 3.5 MHz (yes, they're huge!) and amateurs with these antennas confirm that the morning long path signals usually peak around 200 to 220 degrees, independent of the location at the target end of the long path.

The consistency of the long path signals at about 210 degrees is interesting. Although we cannot know the exact propagation path for certain, I have a premise which I will share for others to critique. As we all know, during our winter, there is an area of constant daylight over the South Pole. This area reaches a maximum at our winter solstice (December 21) covering everything from 67 degrees south latitude (the Antarctic Circle) to the South Pole. John Bryant described this area in his 1988 *Proceedings* article on Solar Blanking (Figure 4).

Although there is an area of continuous daylight and consequently high absorption, there is also an area of twilight or greyline tangent to its western edge at our local sunrise. My premise is that signals duct around this greyline area rather than propagating through the daylight area which signals would follow if they were following the true (180 degree) long path. I feel this explains the somewhat constant bearing of 210 degrees which is the bearing from my location to the western edge of the Antarctic Circle during midwinter. As you can see from John's great circle plots in Figure 4, this transition area is relatively constant at 195 to 210 degrees during the prime winter long path months of November through February. Although long path on 3.5 MHz exists from September to March (roughly but not exactly from the Fall to Spring Equinox period), it is most frequent from mid-November to mid-February. Also, I should mention that the resolution of a Beverage or Yagi is not enough to detect a change of a few degrees from the 210 degree bearing. My guess is that the signals actually track the greyline which is at the western edge of the solar blanking area but the change is too small for our antennas to detect.

How does one practically use this knowledge to hear rare and exotic DX? Through experience, I have found that sunrise long path propagation usually peaks about 20 minutes before local sunrise, although it also exists for more than two hours prior to and 30 minutes after local sunrise. It also seems to peak about 10-20 minutes past local sunset at the DX end of the path but can also last up to two hours past local sunset. Figure 5 illustrates several long path contacts to different target areas. The contact with RVØYF on 13 February is particularly interesting since it was almost two hours past his local sunset in Kyzyl, USSR, north of Mongolia, and more than one hour before my sunrise in Colorado. These rules of thumb are only approximate but I have found through experience that they generally apply to my location. As John Devoldere ON4UN has observed, the duration of the sunrise or sunset greyline is a function of your latitude. At the equator, openings will be much shorter than if you are at the Arctic Circle.

Let's assume I want to know the optimum time and date to hear Lahore, Pakistan on the long path. Using a sunrise/sunset table such as the one by John Devoldere shown in Figure 6, I want to determine dates which will yield approximately 30 minutes between the DX sunset time and my local sunrise

FIGURE 3. Countries heard or contacted at WØZV via sunrise long path on 3.5 MHz.

A4—Oman	**UG**—Armenia
A6—United Arab Emirates	**UH**—Turkoman
A7—Qatar	**UI**—Uzbek
A9—Bahrain	**UJ**—Tadzhik
AP—Pakistan	**UL**—Kazakh
BY—People's Rep. of China	**UM**—Kirghiz
EP—Iran	**UO**—Moldavia
FT8X—Kerguelen Island	**UP**—Lithuania
FR—Reunion Island	**UQ**—Latvia
HA—Hungary	**UR**—Estonia
HS—Thailand	**VQ9**—Chagos Islands, Diego Garcia
HZ—Saudi Arabia	**VS6**—Hong Kong
JT—Mongolia	**VU**—India
LA—Norway	**VU4**—Andaman Islands
OH—Finland	**VU7**—Laccadive Islands
OHØ—Aland Island	**XU**—Khmer Republic
OZ—Denmark	**XW**—Laos
SM—Sweden	**3B8**—Mauritius
UA—European USSR	**3B9**—Rodriguez Island
UA2—Kaliningrad	**3W**—Vietnam
UA9/Ø—Asiatic USSR	**4S7**—Sri Lanka
UB—Ukraine	**8Q7**—Maldive Islands
UC—Byelorussia	**9N**—Nepal
UD—Azerbaijan	
UF—Georgia	

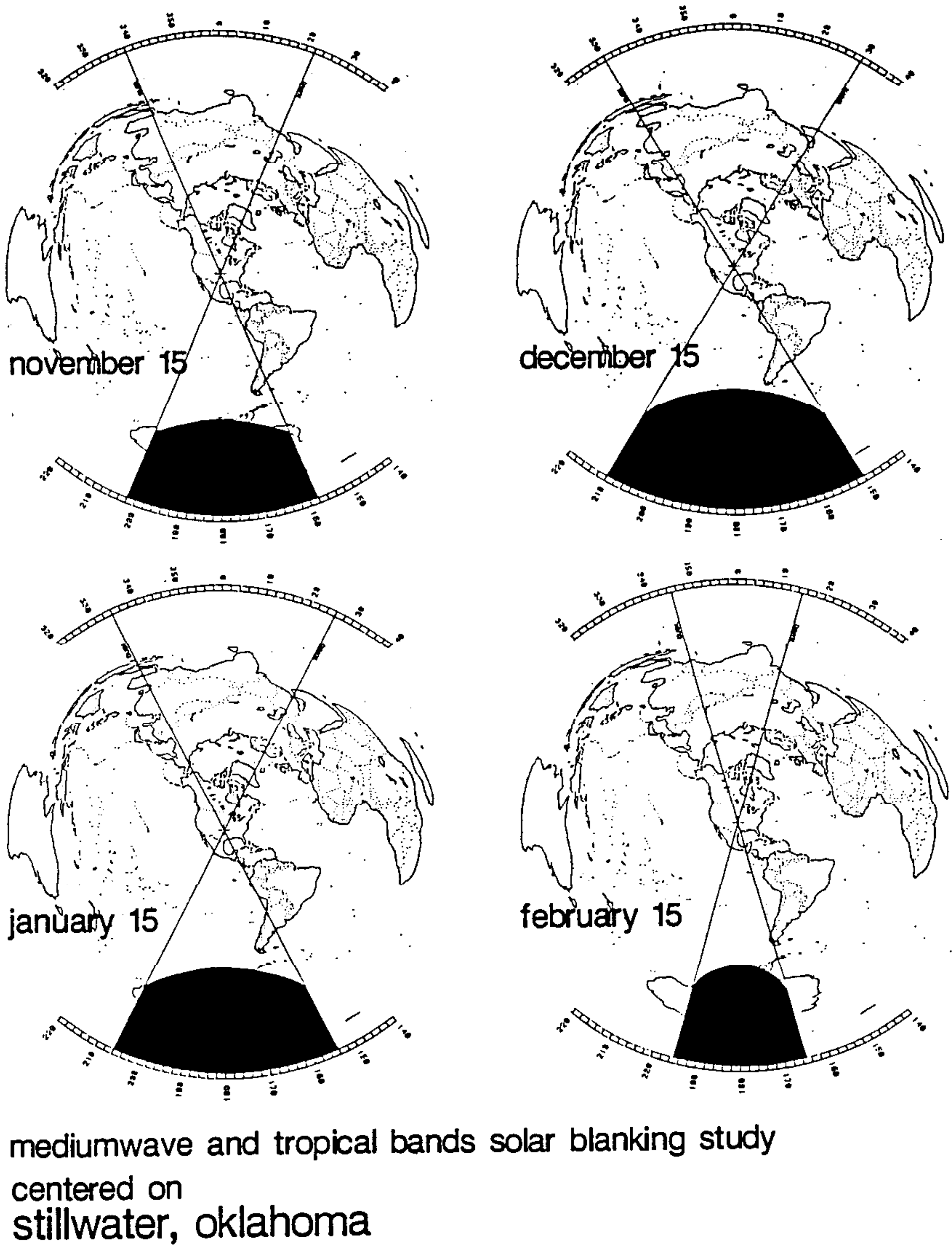


FIGURE 4. Mediumwave and tropical bands solar blanking study centered on Stillwater, Oklahoma. Reprinted from *Proceedings* 1988.

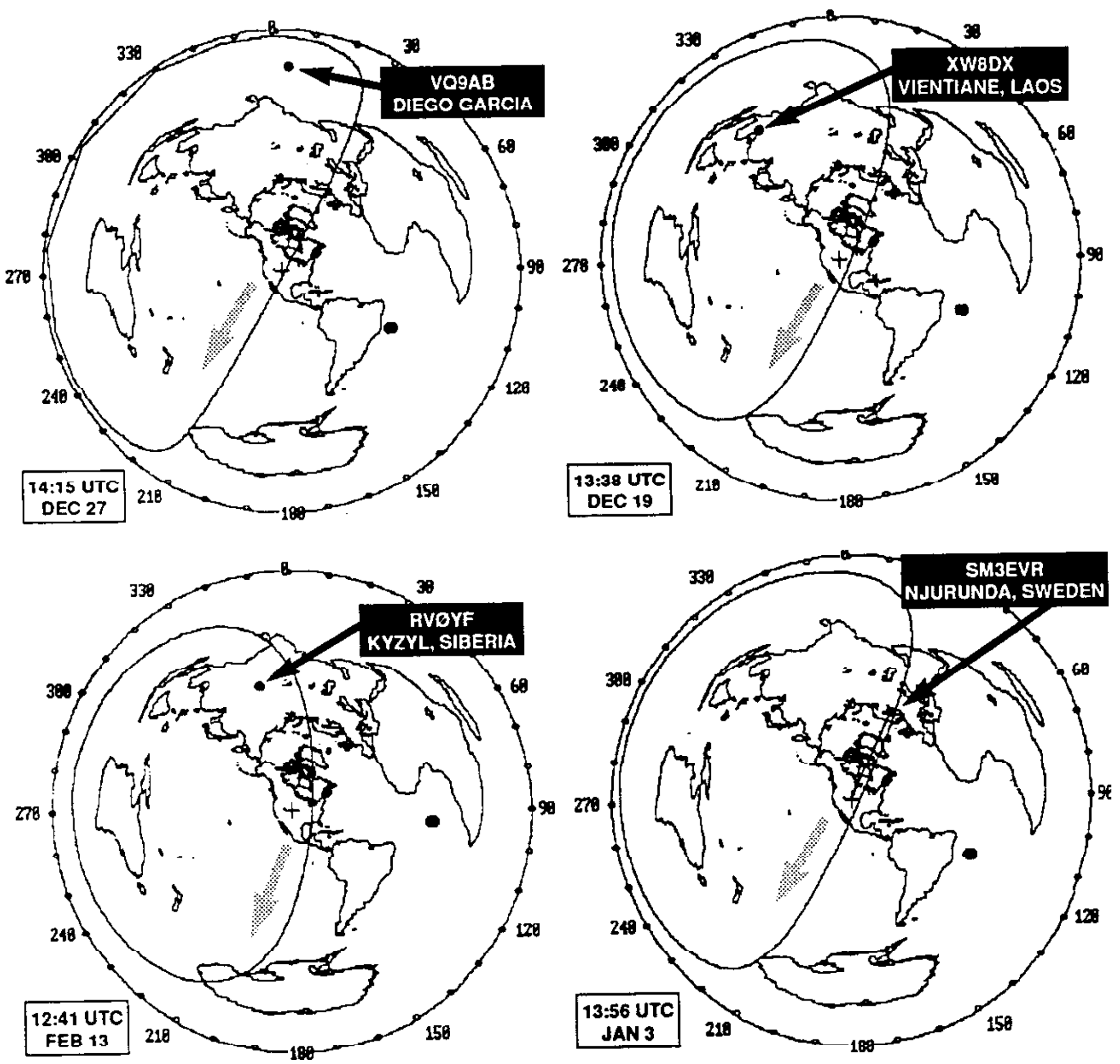


FIGURE 5. Sample Great Circle paths at WØZV sunrise. Maps are centered on Berthoud, Colorado, USA. (From DX-Aid Software.)

time. (There are also a number of software programs available which will allow you to compute these times, but be sure you check their accuracy against your own local sunrise and sunset; some are off by 15 minutes, which can be critical.) I see that on October 16, Lahore sunset is at 1231 UTC and my local sunrise is at 1311 UTC, a difference of 40 minutes. Based on this I would probably expect a peak around 1245 UTC and I would probably listen every day beginning October 1 since this propagation mode does not occur every day. Incidentally, you will notice another peak window around 1315 on March 1 when Lahore sunset is 1300 and local sunrise is 1333.

ON4UN has published a software program which computes all greyline possibilities (not just long path) for specific targets throughout the year. See Figure 7 for a sample printout. I have marked with an asterisk those paths which are typically via long path.

I have not discussed the signal strengths of these signals but they are usually fairly weak, hence the need for a good directional receiving antenna like a Beverage which is aimed in the right direction (210 degrees). It is not unusual, however, for signals to be a solid S7 during optimum conditions and I have even seen some at S9+10 dB during some exceptional openings. Keep in mind that these amateur stations are usually running less than 1 KW to simple antennas (often low dipoles, long wires, base loaded verticals, etc.)

As far as target geographies for this propagation mode, the maximum westward locations you can expect are determined by the location of the sunset terminator at the DX end at your local sunrise time on December 21. You can

-AP-			-WO-COLO-		
PAKISTAN		(LAHORE)	USA		(DENVER)
31.58 DEG.N.		-74.30 DEG.W.	39.73 DEG.N.		105.00 DEG.W.
DATE	SUNRISE	SUNSET	DATE	SUNRISE	SUNSET
JAN 1	02.02	12.10	JAN 1	14.21	23.46
JAN 16	02.03	12.22	JAN 16	14.19	00.01
FEB 1	01.56	12.37	FEB 1	14.08	00.19
FEB 16	01.44	12.50	FEB 16	13.51	00.37
MAR 1	01.31	13.00	MAR 1	13.33	00.51
MAR 16	01.12	13.11	MAR 16	13.10	01.07
APR 1	00.52	13.22	APR 1	12.44	01.24
APR 16	00.34	13.32	APR 16	12.21	01.39
MAY 1	00.18	13.42	MAY 1	12.01	01.54
MAY 16	00.06	13.52	MAY 16	11.45	02.08
JUN 1	23.59	14.02	JUN 1	11.34	02.22
JUN 16	23.57	14.09	JUN 16	11.31	02.30
JUL 1	00.01	14.12	JUL 1	11.35	02.32
JUL 16	00.08	14.09	JUL 16	11.45	02.27
AUG 1	00.18	14.00	AUG 1	11.59	02.14
AUG 16	00.27	13.47	AUG 16	12.12	01.57
SEP 1	00.38	13.28	SEP 1	12.28	01.32
SEP 16	00.47	13.09	SEP 16	12.42	01.08
OCT 1	00.56	12.49	OCT 1	12.56	00.44
OCT 16	01.06	12.31	OCT 16	13.11	00.20
NOV 1	01.18	12.15	NOV 1	13.28	23.59
NOV 16	01.31	12.04	NOV 16	13.45	23.44
DEC 1	01.44	11.59	DEC 1	14.02	23.36
DEC 16	01.56	12.02	DEC 16	14.15	23.37

FIGURE 6. Sunrise/Sunset for Denver, Colorado and Lahore, Palistan. (From ON4UN Sunrise/Sunset Tables.)

see an example of this for my location on the DX Edge shown in Figure 8. From here, Denmark, Hungary and Reunion Island are my most westerly contacts on long path. However, from Seattle, virtually all of Europe is possible. Practically speaking, the most easterly contacts are on a line approximately beginning around 330 degrees from my location.

For reasons I do not understand, approximately 330 degrees seems to be the transition between propagation by long path and direct path at sunrise in Colorado. For example Ulan Bator, Mongolia (339 degrees) Vientiane, Laos (331 degrees) Hong Kong (322 degrees) Irkutsk, USSR (342 degrees) have all been worked on both long and direct paths around local sunrise. They typically are barely audible on the direct path well before sunrise, then switch to long path peaking about 20 minutes before local sunrise, and then switch back to direct path after sunrise. There is seldom any deep fading on long path signals, even for these transition cases.

Almost 100 percent of my contacts to Central Asia and the Middle East have been via long path. From Colorado, we have very infrequent 3.5 MHz openings over the North Pole to these areas during our evening hours (sunrise at the DX end). Unfortunately long path is almost nonexistent on 1.8 MHz, and this almost exclusively accounts for the much lower country totals on that band.

I have not mentioned the incidence of long path propagation relative to the sunspot cycle. In general, it is better during sunspot maxima, although it seems to exist at varying probabilities throughout all stages of the cycle. The probability of long path is very difficult to predict based on solar activity indices, and there is just no substitute for consistent listening as all true blue low band DXers know. I suppose that is what really makes it exciting to get up and listen every morning!

As mentioned previously, the sunrise long path does exist for East Coast locations, but obviously they cannot penetrate nearly as far West because of the location of the sunset terminator at their sunrise. However, East Coast stations have another path which we will cover now.

YOUR LATITUDE IS 40.3 DEG. NORTH — YOUR LONGITUDE IS 105.15 DEG. WEST
TIME OF YEAR (MONTH/DAY) = 3 / 1
YOUR SUNRISE IS AT 13.34 UTC — YOUR SUNSET IS AT 00.52 UTC
GRAY LINE WIDTH IS 36 MINUTES. — MINIMUM TARGET DISTANCE IS 4000 KM.

	PREFIX	COUNTRY	CITY	KM.	START	END	MIN/TARG
*	8Q	MALDIVE	MALE	15058	13.16	13.30	20
	CEOA	EASTER ISL.		7505	13.16	13.20	20
	CE9..9J	ANTARCT.	MIRNYY	16873	13.16	13.49	52
	FB8Z	AMSTERDAM ISL.		19644	13.21	13.41	20
*	JW	SVALBARD		6358	13.16	13.52	444
*	OX	GREENLAND	THULE	4387	13.16	13.52	327
*	UA	EUR. USSR	KAZAN	9055	13.44	13.52	64
*	UA1	FRANZ JOSEF LAND		6469	13.16	13.52	1440
*	UA9-0	AS. USSR	CELYABINSK	9317	13.16	13.52	62
*	UH8	TURKOMAN	ASHKHABAD	11146	13.42	13.52	33
*	UI8	UZBEK	TASHKENT	10913	13.16	13.31	37
*	UJ8	TADZHIK	DUSANBE	11214	13.16	13.34	34
	VKO	HEARD ISL.		18567	13.51	13.52	32
*	VQ9	CHAGOS		16178	13.21	13.41	20
*	VU	INDIA	BOMBAY	13412	13.16	13.24	20
*	VU	INDIA	NEW DELHI	12341	13.16	13.20	24
*	VU7	LACCADIVE ISL.		14408	13.16	13.28	20
*	YA	AFGHANISTAN	KABUL	11669	13.16	13.33	29

FIGURE 7. Greyline table. (From ON4UN Greyline Software.) * = longpath.

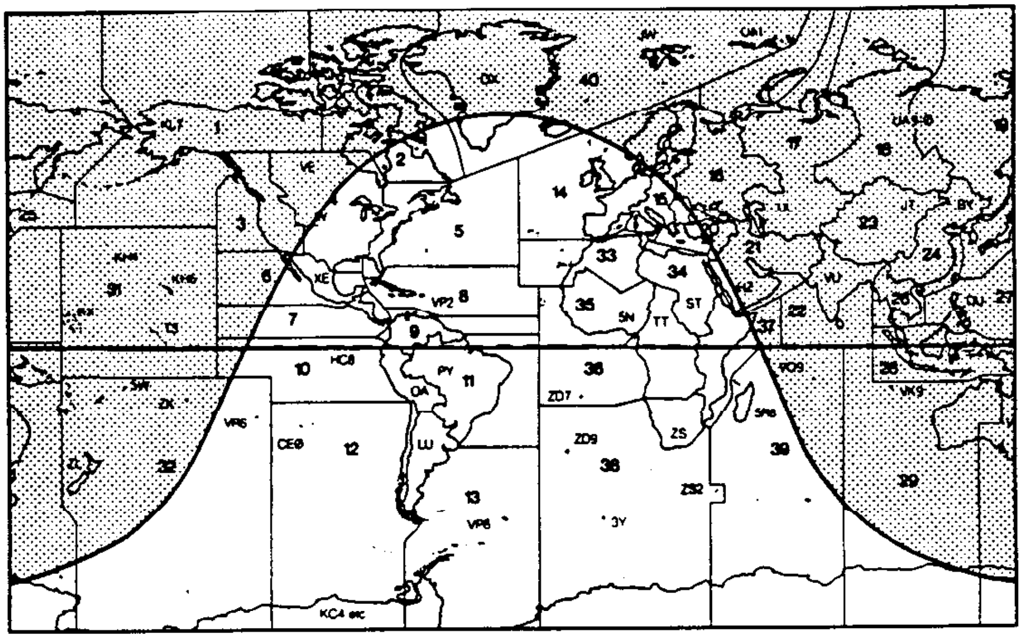


FIGURE 8. DX Edge Terminator on December 15 at WØZV sunrise.

LONG PATH ON 3.5 MHZ AT USA SUNSET

This path is one which is quite useful for stations on the East Coast. It allows propagation to the Far East, Indonesia and Southeast Asia by beaming Southeast. Although I have only made a few contacts on this path (to Diego Garcia, India and the Maldive Islands), I would speculate that the propagation path is similar to the morning path, i.e. via the eastern end of the solar blanking area at a bearing of about 150 degrees.

Bob Eshleman W4DR is the premier USA DXer on 3.5 MHz and I believe he is second worldwide only to John Devoldere ON4UN in 3.5 MHz country totals. He uses an array of four phased quarter wave verticals which he feels are comparable to Beverages in directivity. Since I am seldom at home during local sunset, Bob graciously supplied me records of his long path contacts at sunset from his location near Richmond, Virginia. See Figure 9 for samples of several long path contacts Bob made by beaming southeasterly over South America. Figure 10 illustrates the range of different countries logged by Bob.

Judging from the contacts Bob supplied me, I believe the same general rules apply as noted previously in my comments on the sunrise openings, i.e. the peak occurs after local sunset and before sunrise at the DX end. Incidentally, this path is probably what the stations in Europe and Asia experience when they are working me at my sunrise. They are beaming Southeast at their sunset.

John Kaufman W1FV, another preeminent 3.5 MHz DXer from Maynard, Massachusetts, read an earlier draft of this article and added several interesting observations. "In general, my own experiences with long/skew path propagation appear to closely parallel yours. From the Boston area, the sunrise long path is best during the peak of the cycle, with openings to Siberian USSR from the Southwest being most common. During low sunspot years, however, it is my experience that the morning long path disappears almost completely. In general, the openings last no more than 10 or 15 minutes, peaking just before sunrise. Those openings which persist after sunrise often skew fron Southwest to Northwest after the sun comes up. On the other hand, the sunset long path opens most frequently during sunspot cycle troughs, with Japan, Far Eastern USSR and Perth, Australia being most common."

John adds "I agree completely with your statement that the Beverages really open up a new world on the low bands. (He has two dual-wire switchable 450 footers aimed at NE, SE, SW and NW). Many DXers have commented on my consistently hearing and working the long path. You really ought to emphasize that the long path on the low bands is a marginal (but exciting) mode of propagation and that a low dipole or random wire simply won't hack it." I don't completely agree with John's last comment for some of the openings I've observed from Colorado, but I value his observations for the Northeast.

LONG PATH ON 1.8 MHZ

Unfortunately, this will be a very short discussion because long path is extremely rare on 1.8 MHz. I have only made one contact with UA9UCO in Prokopyevsk, Siberian USSR, in 6 years of active listening (Figure 11). I first began hearing this station on September 12-14 at my sunrise. He could not hear me then and I speculate that it was because of high thunderstorm static over Southeast Asia at that time of year. We finally made two-way contact

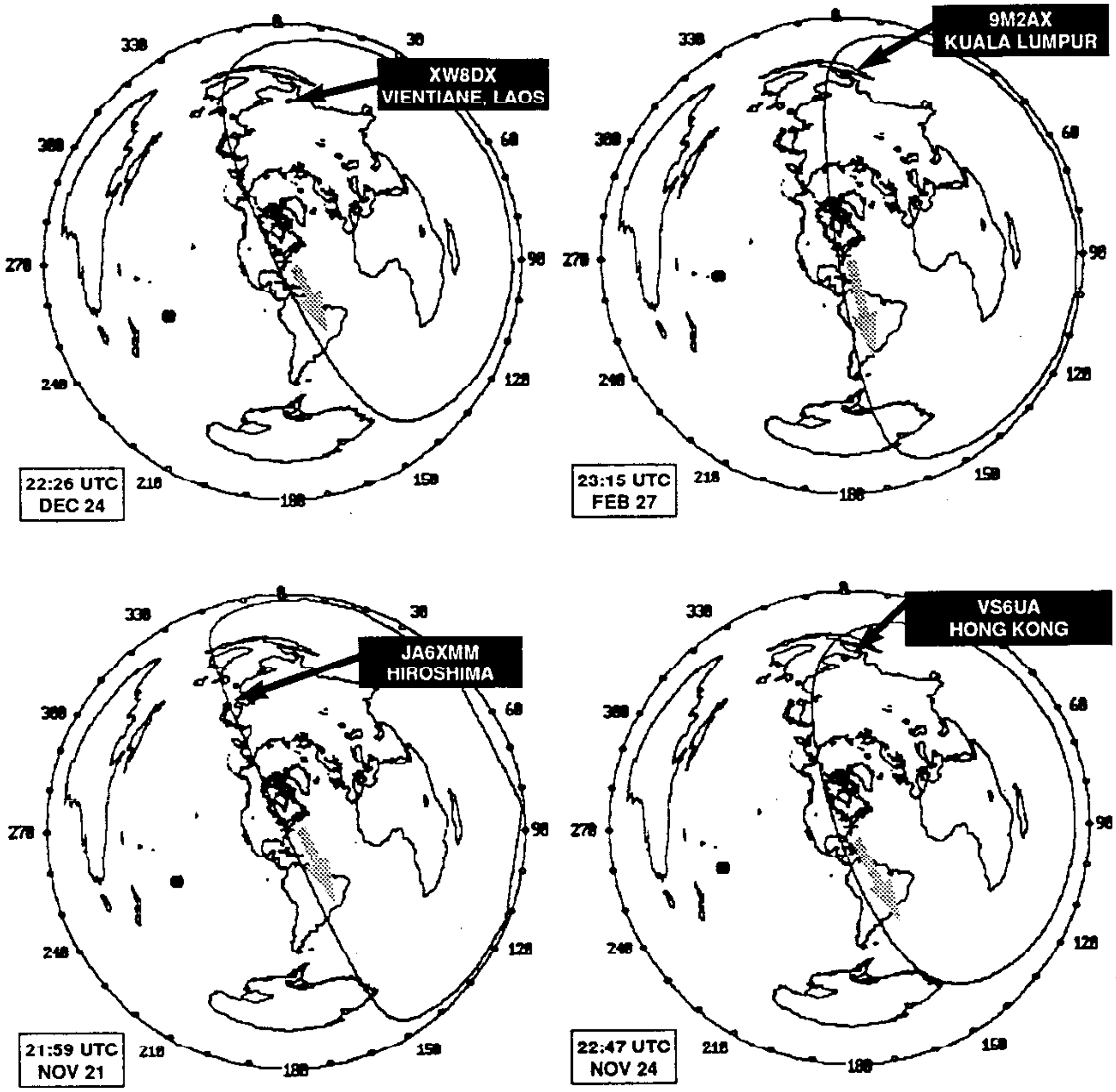


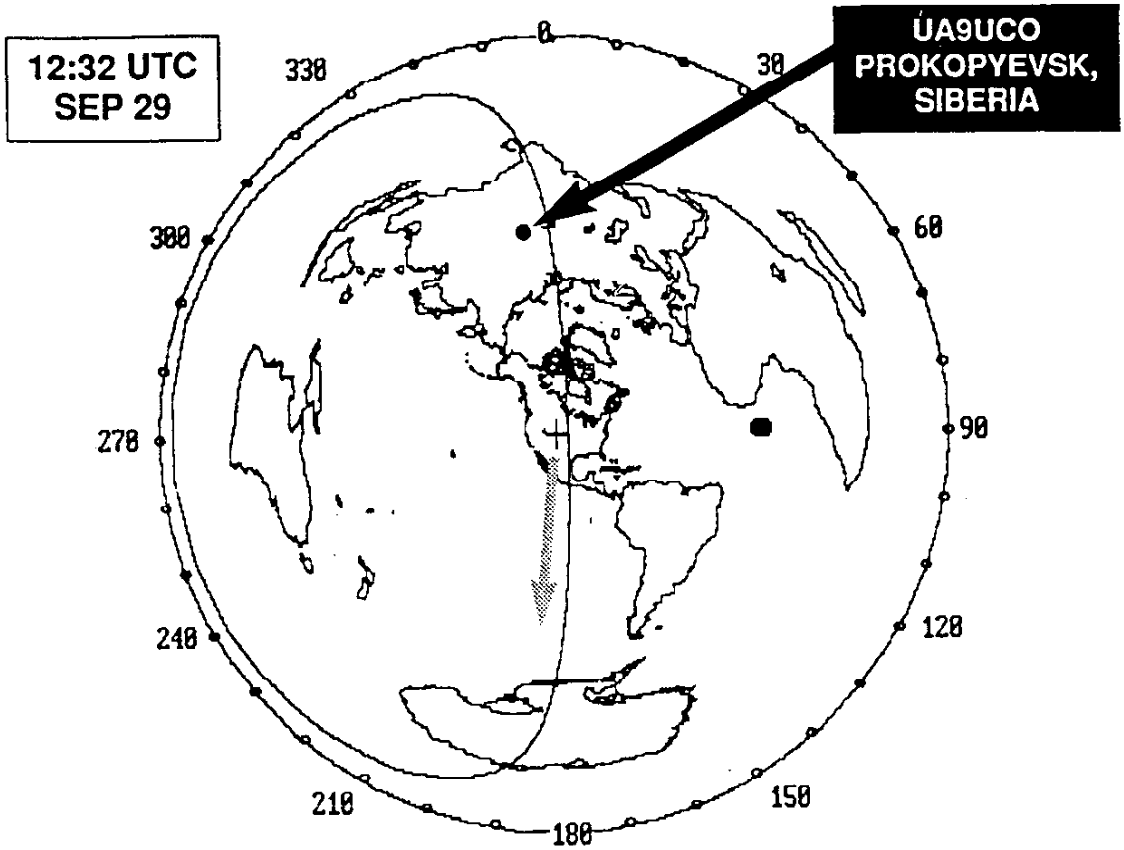
FIGURE 9. Sample Great Circle paths at W4DR Sunset. Maps are centered on Richmond, Virginia, USA. (From DX-Aid software.)

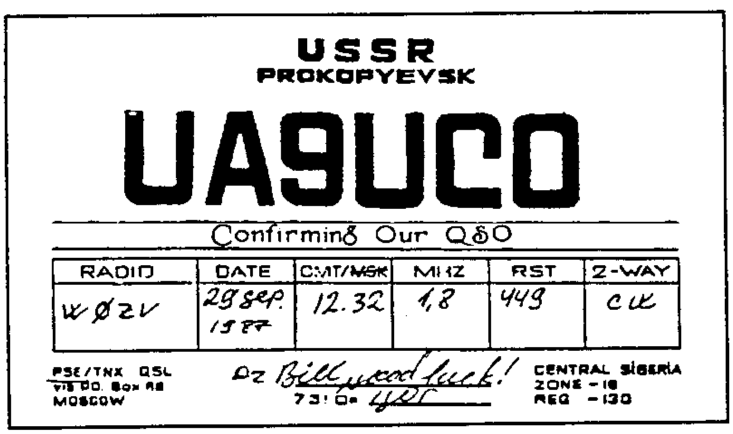
on September 29 about halfway between his sunset and my sunrise which were then almost exactly 1 hour apart. I have listened many times for long path during our winter but have never heard a whisper. I can only speculate that the ionosperic absorption over the Southern hemisphere is just too great to allow long path propagation during our winter. However, it may be that during the Equinox (when I contacted UA9UCO in Siberia) the absorption between the two hemispheres was equalized allowing a short window for long path propagation at this time of year.

John Kaufman W1FV adds, "I have heard 9M2AX (West Malaysia) long path at sunset on 1.8 MHz and he has been worked by others in the Northeast. Hong Kong has been heard long path in New England and Indonesia has been worked, I believe. Perth, Australia has been worked at sunset and there have been rumors of long path Japanese stations being heard, but I can't confirm those. I am not aware of any sunrise long path openings from the East Coast."

FIGURE 10. Countries heard or contacted at W4DR via sunset long path on 3.5 MHz.

- JA—Japan
- JT—Mongolia
- VK—Australia
- VK9X—Christmas Island
- VK9Y—Cocos-Keeling Island
- VS6—Hong Kong
- VU4—Andaman Islands
- XW—Laos
- YB—Indonesia
- 3W—Vietnam
- 9M2—West Malaysia
- 9M6/8—East Malaysia
- 9V—Singapore




USSR
PROKOPYEVSK
UA9UCO
Confirming Our QSO

RADIO	DATE	GMT/MSK	MHZ	RST	2-WAY
WØZV	29 SEP 1987	12.32	1.8	449	CW

PSE/TNX QSL via Box 88 MOSCOW
Dz Bill good luck! 73! Op
CENTRAL SIBERIA ZONE - 18 REG - 130

FIGURE 11. Great Circle path to UA9UCO (Prokopyevsk, USSR) for WØZV long path contact on 1.8 MHz, and resulting QSL.

SKEW PATHS ON 3.5 AND 1.8 MHZ

Let me first define what I mean by "Skew Path." *Skew path is any path in which the signal is skewed by less than 90 degrees from its true Great Circle bearing.* This is a completely different phenomena from the Long Path discussed above. I feel it is caused primarily by auroral disturbances when the signal must avoid or "skirt" the auroral zone. Typically I observe this as follows: From Colorado, my 40 degree Beverage is usually optimum for receiving Europe during our evening hours. However, when the geomagnetic field is disturbed (WWV A-index greater than 10), the European signals often peak stronger at 70 degrees than 40 degrees. East Coast stations usually observe the same effect when working Japan during their morning hours. Rather than coming via their direct heading (about 330 degrees from New England), signals are skewed south, but not as far south as long path signals. The greater the disturbance, the greater the skew. For instance, I once worked Sweden on 1.8 MHz during a severe ionospheric disturbance (A-index was 103) with signals peaking on my 110 degree Beverage even though the direct bearing from Colorado is 27

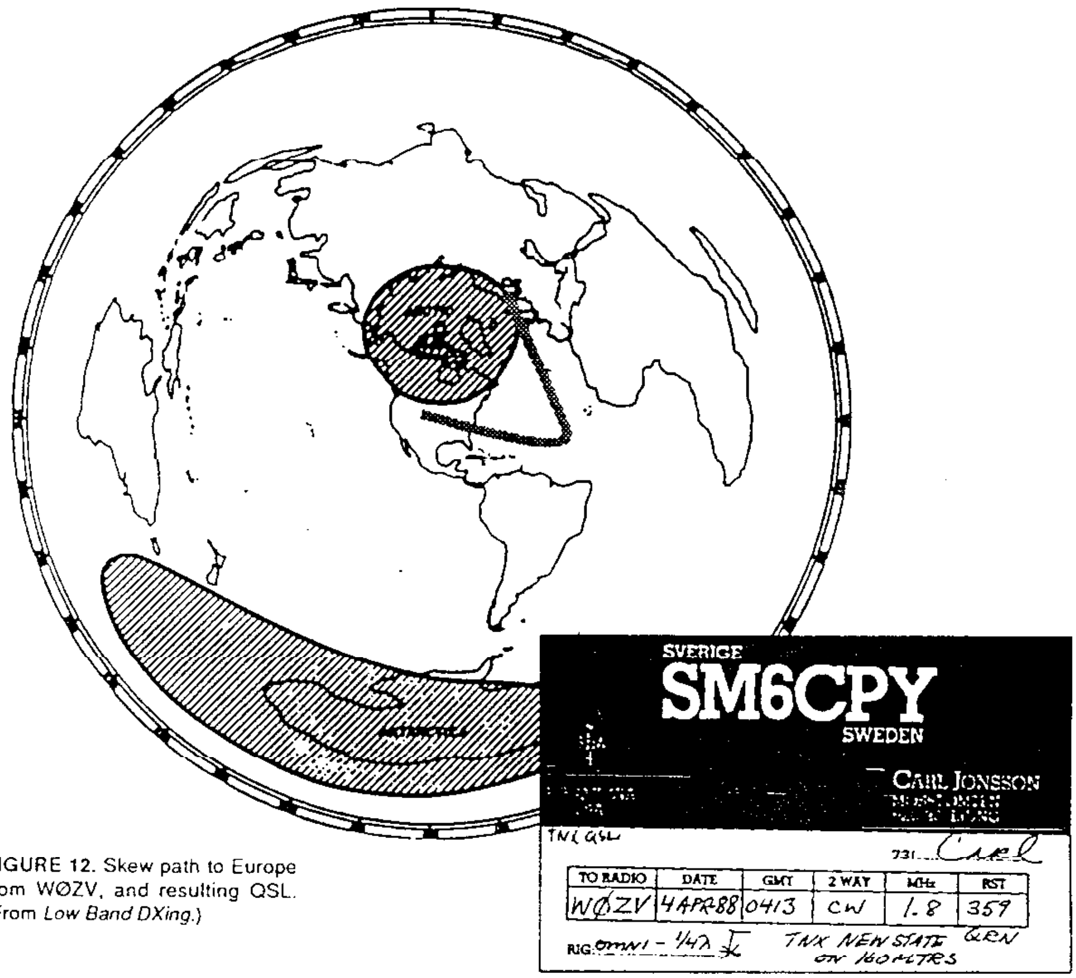


FIGURE 12. Skew path to Europe from WØZV, and resulting QSL. (From *Low Band DXing*.)

degrees! The Swedish station confirmed that he was receiving me over South America (see Figure 12).

Conversely, I have never observed signals from Japan skewed South and East Coast stations seldom observe European signals skewed South. I believe the reason for this is the relative location of the magnetic North Pole. From Colorado, it is at a bearing of 13 degrees, so the auroral zone interferes with Europe but not Japan. The converse is true for stations in New England since Magnetic North for them is about 350 degrees.

CONCLUDING REMARKS

I hope this article has been of some help to all of you whether you are from the mediumwave, shortwave or amateur communities. I feel we all have a lot of common experiences and interests which we can share with each other. Good luck on the low bands—the home of a dedicated group of radio DXers!