10-Meter Long Path During Solar Cycles 21 and 22

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K9LA puts together the whole story on 10-m long-path propagation. DXers take note: Many things happen at once along the path between you and the other station.

Introduction

Although I've been a ham since 1961, my first 10-m long-path QSO (with VS6DO) was in the 1986 CQ World Wide DX Phone Contest. VS6 was a new country for me and it started my interest in 10-m long path. But a move from the Dallas/Fort Worth area back north kept me relatively inactive until the winter of 1988. Then, spurred on by N6AV's "10-Meter Long Path" article in the January 1989 issue of *The DX Bulletin*, I began working Japanese amateurs early in the morning during the spring and summer of 1989 before going to work.

Soon I was interested in gaining a better understanding of this mode and I received help from a number of people. Gus, K2ARO, supplied me with his 10-m long-path log data going back to early 1979. Yuu, JH3DPB, maintained daily schedules with me to help better understand the duration of 10-m long-path openings to Japan. I had many conversations and correspondence with Bob, NM7M, who later wrote a booklet *Long-Path Propagation—A Study of Long-Path Propagation in Solar Cycle 22*.

My intent in this article is to present the guidelines and indicators of 10-m long-path propagation so others may enjoy this mode. Although I will focus on 10-m long path from the East Coast to Australia (VK6) and Japan (JA) due to the excellent amount of data from K2ARO, I will also comment on 10-m long path to and from other geographical locations. At the end of this article is a bibliography listing all of the reference and background material quoted and utilized in this article.

I strongly suggest reading NM7M's booklet cited above. *The Shortwave Propagation Handbook* by Jacobs (W3ASK) and Cohen (N4XX), *Radio Amateur's Guide to the Ionosphere* by McNamara, and *Ionospheric Radio Propagation* by Davies are also very helpful. The monthly periodicals carry many articles on HF propagation. One very pertinent to this article is "Propagation Broadcasts and Forecasts Demystified" by NJ2L in the November 1991 issue of *QST*.

What Is Long Path?

In general an HF radio wave follows a great-circle route. This is the shortest route between two points on the Earth's surface. **Fig 1** is an azimuthal map of the world centered on K2ARO. The path was computed using Oldfield's *DXAID* software. K2ARO would normally beam northwest over Canada to work JA (6843 mi) and VK6 (11378 mi) by short path.

Under certain conditions, though, K2ARO can beam on the reciprocal heading (southeast over South America and Antarctica) to get to VK6 (13467 mi) and JA (18002 mi). This path going southeast is designated the long path.

Some Observations About the Path

In **Fig 2** I have plotted the long path from K2ARO to VK6 and JA on a Mercator projection of theEarth. The path is broken into 1610 km steps. NM7M's *ULTMTLP* software was used for analysis. It goes through the southern auroral zone, and was affected to a larger degree than a non-auroral path by the activity of the Earth's magnetic field. The terminator (sunrise/sunset line or the *gray line*) at 1100 UTC is shown for the month of April in Fig 2 and the portion of the Earth in darkness is cross-hatched. A later discussion will cover the roles of the auroral zone and the terminator on 10-m long-path propagation.

Long-Term Look at the Path

Fig 3 is a plot of K2ARO's log data from 1979 to early 1993. The vertical axis is the number of days in a given month Gus made

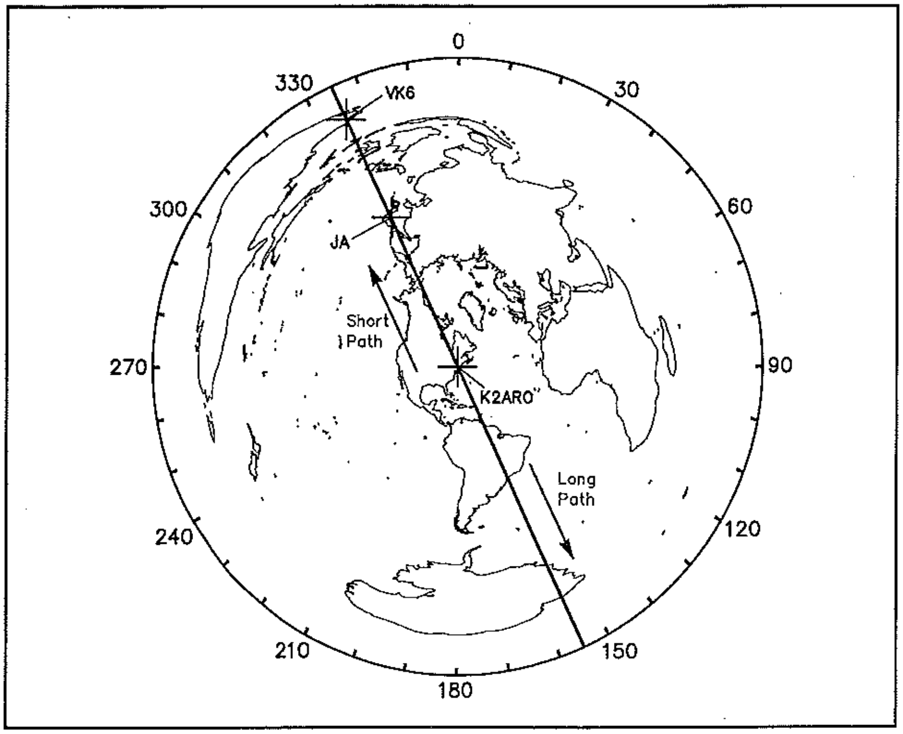

Fig 1—Plot of the long and short paths between K2ARO and VK6/JA locations.

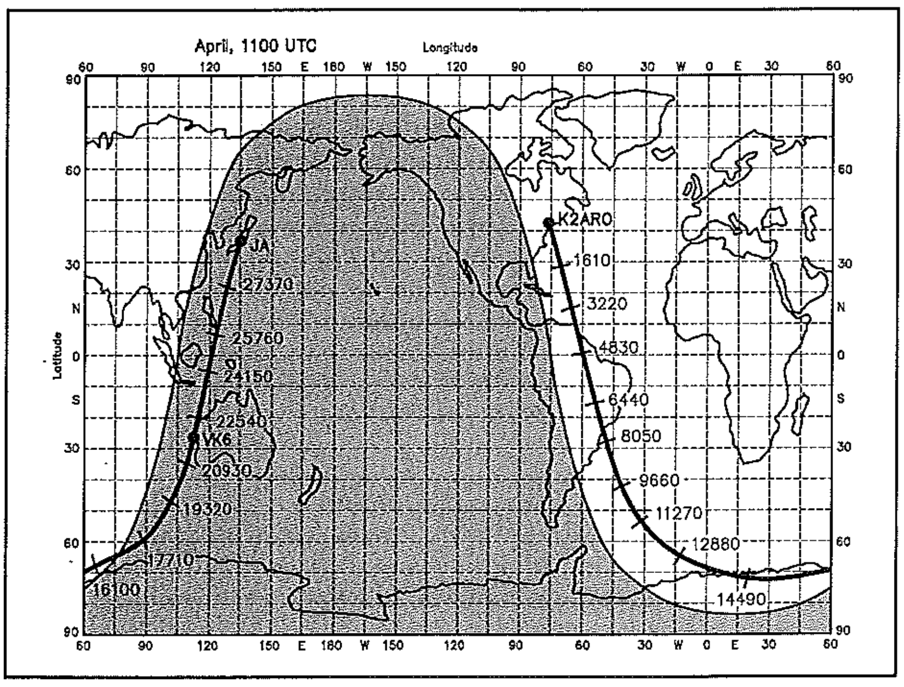

Fig 2—The same long path on a Mercator projection map. The path appears to follow the gray line.

a long-path QSO to either JA or VK6 on 10 m. No contacts were made in 1983 through 1987. The graph is compressed in the 1984 to 1986 time frame to save space.

The data clearly shows 10-m long-path was not a rare occurrence. It occurred regularly throughout certain portions of Sunspot Cycle 21 (June 1976 to September 1986) and Cycle 22 (September 1986 to late 1993). In order to provide a correlation with the sunspot cycle I plotted on the same figure the *smoothed sunspot number*. This is a 12-month running average of the monthly mean sunspot numbers and is called the *SSN* or R_{12}.

Daily *solar flux* numbers are broadcast by WWV and the ARRL station, W1AW. Use daily solar flux numbers with care, because they do not correlate well with *smoothed sunspot numbers (SSN)*. A full discussion of the calculation of the smoothed values is on page 23-13 of *The ARRL Antenna Book*, 17th Edition. Smoothed numbers can also be found in *QST* and W3ASK's Propagation column in *CQ*.

Fig 3 indicates 10-m long-path was a possibility when the smoothed sunspot number was above about 70. Unfortunately, this also shows 10-m long path is over for Cycle 22, as the smoothed sunspot number declined through 70 in early 1993.

A Seasonal Look at the Path

Note the data in **Fig 3** is plotted in terms of either a JA or a VK6 QSO. Even though the long-path heading to VK6 and JA from K2ARO is identical (as can be seen in Fig 1 and Fig 2), in reality the 10-m long-paths to VK6 and JA exhibits different characteristics when examined separately.

To demonstrate this, **Fig 4** is a plot of the number of days per month (averaged over all years) K2ARO made a JA QSO or a VK6 QSO. The path to JA opened in the spring, held up rather well throughout the summer, and gradually tapered off by the fall. In comparison the path to VK6 is more bi-modal in nature—it peaks around spring and fall, with an obvious reduction in availability in summer. The reason for this difference has to do with the path crossing the equator to get into JA and will be discussed later. The data for July is limited since it came from only one year, 1989, at the peak of Cycle 22.

A Daily Look at the Path

The long path to JA and VK6 is an early morning path for K2ARO. **Fig 5** is a plot of the earliest time and latest time (both averaged over all years) by month for a QSO into JA and VK6. It shows the path into VK6 consistently opening about a half hour earlier than the path into JA. Generally the openings to both JA and VK6 occur earlier in the summer than in either the spring or fall. The path into VK6 goes away about an hour before the JA path goes away. You can see the paths to both JA and VK6 close earlier in the summer than in either the spring or fall.

What Opens the Path

K2ARO's log data shows why the path to JA and VK6 opens early in the morning at his location. Multi-hop propagation (successive ionospheric refractions and Earth reflections) is assumed. Predictive data was taken from the F2 MUF maps in the 1971 publication *Ionospheric Predictions* from the Institute for Telecommunications Science. MUF is *maximum usable frequency*, and refers to the highest frequency propa-

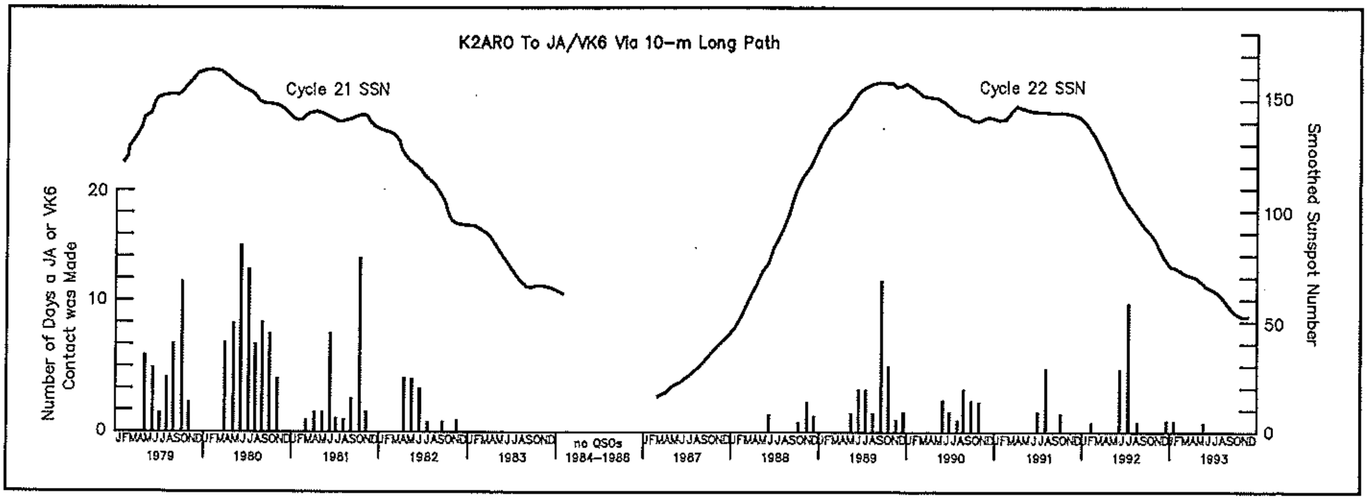

Fig 3—K2ARO's log data. Notice the correlation with the value of the smoothed sunspot number.

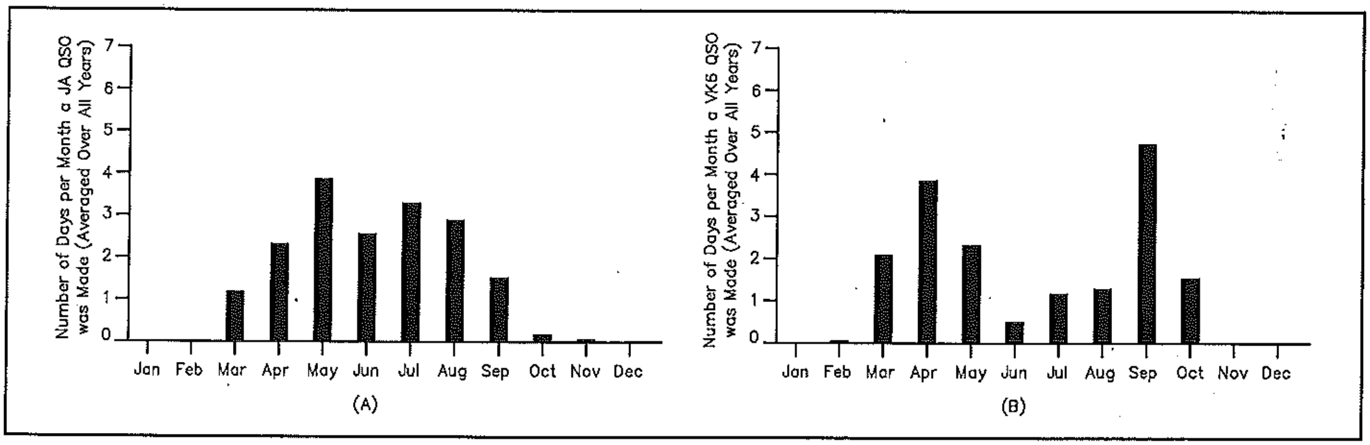

Fig 4—Seasonal variation in the number of successful QSOs. The histogram to JA shows continuous successes from spring through to fall while the histogram to VK6 has a summer null.

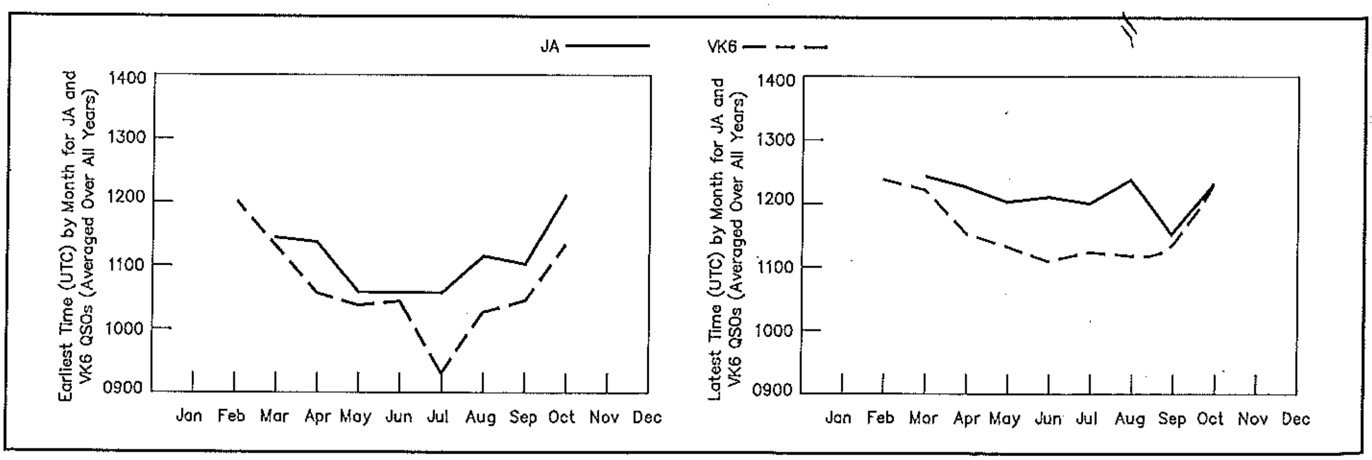

Fig 5—Early and late times for the QSOs. VK6 QSOs start and end first. Those to JA seem to lag by about a half-hour to an hour.

gated between two designated points at a given time.

This publication consists of four volumes. Volume 1 shows how to use the data, and Volumes 2, 3 and 4 consist of constant contour lines of median MUF(ZERO)F2, MUF(4000)F2 and MUF(2000)E for smoothed sunspot numbers of 10, 110 and 160, respectively. For a detailed explanation of these maps and the terminology used, refer to "High-Frequency Propagation Estimations for the Radio Amateur" by K1PLP (now

MUF (3220 km) F2 in MHz, K2ARO to VK6/JA, Apr 89, R_{12} = 160

Distance (km)	Time, UTC 09	10	11	12	13	14	15	16
0 (K2ARO)								
1610	20	21	27	33	33	35	35	36
3220	23	25	31	37	39	40	41	41
4830	23	27	33	39	39	39	39	39
6440	23	26	33	39	37	36	35	35
8050	23	26	34	42	43	45	44	43
9660	23	28	34	42	45	47	46	46
11270	22	28	33	38	41	44	43	42
12880	24	28	31	33	35	37	36	35
14490	26	28	29	30	31	30	28	25
16100	29	30	30	30	28	25	22	20
17710	31	30	28	27	23	20	19	17
19320	32	31	29	26	23	20	18	16
20930 (VK6)	34	33	30	27	23	20	19	17
22540	39	37	34	32	30	28	26	23
24150	42	39	40	41	42	43	42	40
25760	33	32	32	31	32	32	35	39
27370	44	42	43	44	45	47	47	45
28980 (JA)								

Fig 6—The crosshatched area shows MUF values greater than 28 MHz.

Skeds with JH3DPB

The 2 hour, 42 minute opening Gus had to JA on 6/18/89 took me somewhat by surprise, as I had thought the 10-m long-path to JA was a rather short duration event. I was curious how long an opening the Midwest would have. To find the answer, JH3DPB and I maintained daily schedules during April 1992. April was selected only because it was a convenient month for both of us. We began calling each other at 1030 UTC and checked every 15 minutes thereafter. If contact was established, we would continue checking every 15 minutes until the path closed.

Although contact was established on many days, two days were very productive in terms of long-duration openings. On these two days contact was established at 1100 UTC (6 AM for me, 8 PM for Yuu) and continued until 1315 UTC (8:15 AM for me, 10:15 PM for Yuu). The Boulder A-index was less than 7 on both of these days. This 2 hour, 15 minute opening between the midwest and JA translates to about a 3 hour opening for K2ARO (because of his earlier sunrise). This agrees fairly well with his 6/18/89 opening.

The opening of the path was rather sudden in nature, indicating we had to wait (as expected) until the MUF on my end passed through 28 MHz. The closing was a gradual decrease in signal strength to the noise level, indicating the role of increasing absorption.

These skeds also enabled me to confirm K2ARO's data presented in Fig 5. The VK6s indeed came in earlier and dropped out earlier.

During these tests JH3DPB ran a TS-930 barefoot to a 6 element monobander at 110 feet, and I ran a TS-180 barefoot to a 4 element monobander at 72 feet.

K1TD) in the March 1972 issue of *QST*.

Generally 4000 km is used as the one-hop F2 limit. However, propagation beyond this distance can be predicted by evaluating the ionosphere at two control points, each 2000 km from the ends of the path. This technique, empirically based, is usually effective.

In Fig 2 the path is broken into 1610-km segments to present the MUF all along the

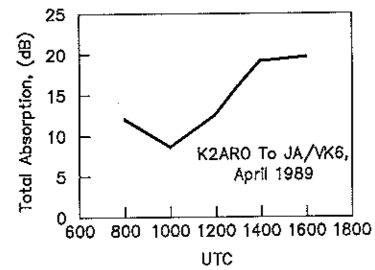

Fig 7—The path is also affected by absorption. This factor increases from 1000 until 1400 UTC.

path, not just at the common 2000-km control points. This will give us excellent insight into what is happening all along the path. The 3220-km MUF is used since it is the hop distance assumed in NM7M's *ULTMTLP* software. The path requires radiation at an elevation angle of 5°, an angle readily achievable on 10 m. Nine hops are needed to cover the distance. The 3220 km MUF is interpolated from the MUF(ZERO)F2 maps and the MUF(4000)F2 maps using Fig 5 of Volume 1 of *Ionospheric Predictions*.

Ionospheric Predictions

Fig 6 shows the results of this task. The choice of the MUFs for April 1989 allowed me to directly use Volume 4 (R_{12} = 160) of the *Ionospheric Predictions* maps (refer back to Fig 3 for R_{12} during April 1989). The figure shows how the 3220 km MUF varied all along the path from K2ARO to VK6 and JA beginning at 0900 UTC and going to 1600 UTC. F2 layer refraction, assuming multi-hop propagation, would occur at 1610, 4830, 8050, 11270, 14490, 17710, 20930, 24150, and 27370 km.

The cross-hatched MUFs in Fig 6 exceed 28 MHz and therefore allow 10-m propagation. Remember, all values given are median values. Therefore the actual MUF could be several MHz above or below the values in the table on any given day of April 1989.

The path is predicted to open up around 1100 UTC in April due to the increasing MUF on the western end of the path (K2ARO's end). This agrees very favorably with the earliest time data in Fig 5. The increase of the MUF with time (top horizontal axis) corresponds to K2ARO's sunrise and the subsequent increased ionization as the sun moves west (okay, the sun doesn't move west—the Earth rotates eastward).

What Closes the Path

The data in Fig 6 also shows the path is predicted to close after 1200 UTC due to an ever-widening area of decreased MUFs. This is shown by the expanding non-cross hatched areas between roughly the 17710 km distance point and the 20930 km distance point. The latest time data in Fig 5 agrees favorably with this prediction of closing. The area of decreasing MUFs corresponds to the part of the path between Antarctica and Australia.

The decreased MUFs may not be the only factor closing the path. I have estimated the total absorption over the entire path for the 0800 to 1600 UTC time period based on the solar zenith angles at the F-layer refraction points along the path. This data is presented in **Fig 7** and was calculated by using NM7M's *ULTMTLP* software and Figures 7.5 and 7.6 in *Ionospheric Radio Propagation*. Two items should be noted.

First, the absorption gradually increases starting at the time the path opens (about 1100 UTC). Thus the path probably begins to close as a result of both higher absorption as the western part becomes increasingly illuminated by the sun as well as the decreasing MUF in specific areas along the path as discussed earlier.

Second, the absorption is minimum at about 1000 UTC. This corresponds very closely to the time when both K2ARO and JA/VK6 are on the terminator. This condition of minimum absorption when both stations are on the terminator is not unique to K2ARO and JA/VK6—in fact this is the rule, and is in my opinion what causes the often-observed signal increase in gray-line DXing (especially on the lower-frequency bands).

The Duration of an Opening

Not only did K2ARO's log data provide the days during a month with 10-m long-path openings to JA and VK6, it also provided times (as we saw in Fig 5). Therefore, the length of an opening could be determined.

Gus made JA QSOs on 163 days and VK6 QSOs on 161 days throughout the 14-year period. I will venture an opinion that the path was open more often, but no one was available to take advantage of it.

The average duration of a JA opening was 23 minutes. The longest duration opening was 2 hours, 42 minutes (on June 18, 1989). There were a large number of short-duration openings of only several minutes.

The average duration of a VK6 opening was 17 minutes. The longest duration opening was 1 hour, 40 minutes (on April 17, 1992). Again there were plenty of short-duration openings of several minutes.

The Role of the Earth's Magnetic Field

Those of you who have read NM7M's work or those who have more than a passing interest in HF propagation realize the activ-

Ray Tracing

K2ARO and I undertook an effort to do a ray trace during a summer month to confirm a signal could overfly low MUF areas around VK6 but still proceed into JA. We picked July 1989. For this month the smoothed sunspot number was 160. We started with NM7M's *PRTYBIRD.BAS* program written to do ray tracing for satellite signals to the ground.

Gus (a retired software development manager) modified *PRTYBIRD* for our Earth-ionosphere-Earth condition, and I supplied the critical frequencies and layer heights in equation form. This information was obtained from curve fits from the MUF map data and from US Army Signal Radio Propagation Agency *Technical Report No. 9 Analysis and Prediction of Sky-Wave Intensities in the High Frequency Band*. From these equations and assumptions of electron density profiles, refractive indices versus height along the path in 2 km steps were available. Using Snell's Law in differential form, a ray was traced through the desired region.

To keep things relatively simple in this preliminary effort, we ray traced out of JA towards K2ARO for about 12,000 km. We were looking for a chordal hop to overfly VK6 and reach ground somewhere south of VK6. Our initial result at 1100 UTC is shown below. We had expected to get a single chordal hop (designated as a ^{2}F mode), but note our result is two chordal hops (designated as a ^{3}F mode) giving the first ground reflection at around 11,000 km. The first chordal hop was centered over the geomagnetic equator as expected, and the second was centered about over VK6 (see accompanying **Fig A**).

At first this double-chordal hop bothered us. But a review of Villard, Stein and Yeh's paper show they believe their backscatter-sounder records also showed ^{3}F modes. We also believe our initial result is accurate, but we're still testing the ray-trace program and we're still refining the model of the ionosphere. It's sure encouraging to see the possibility of ^{3}F modes reported elsewhere—this ^{3}F mode would certainly help explain the drop out of VK6 in the summer while JA is still maintained.

We are continuing with our efforts, focusing on starting at K2ARO and going all the way to JA. This should include both conventional multi-hops and chordal hops. K2ARO's log data will be used to confirm our results. Perhaps we'll have more to report at a later date.

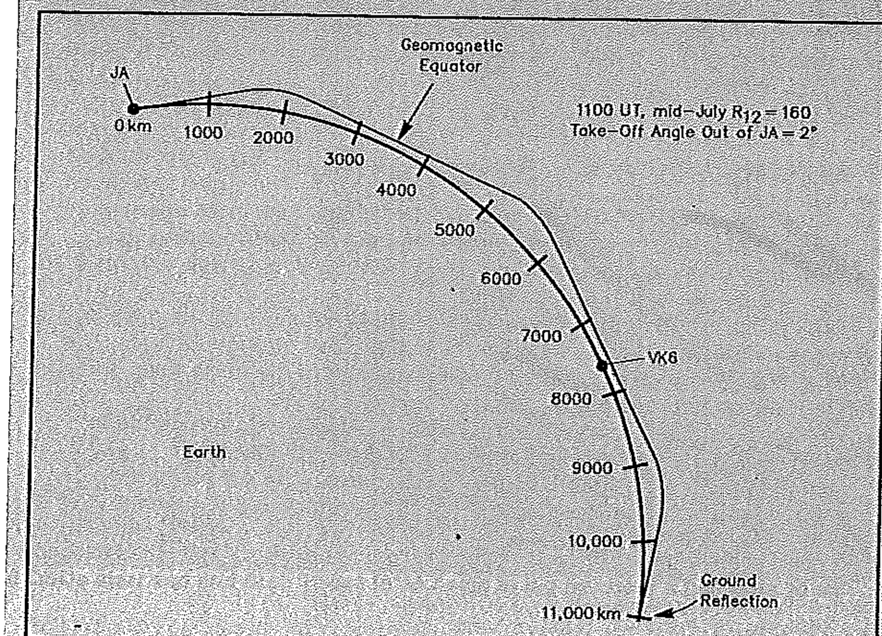

Fig A—Preliminary results showing double-chorded ray trace from JA to K2ARO.

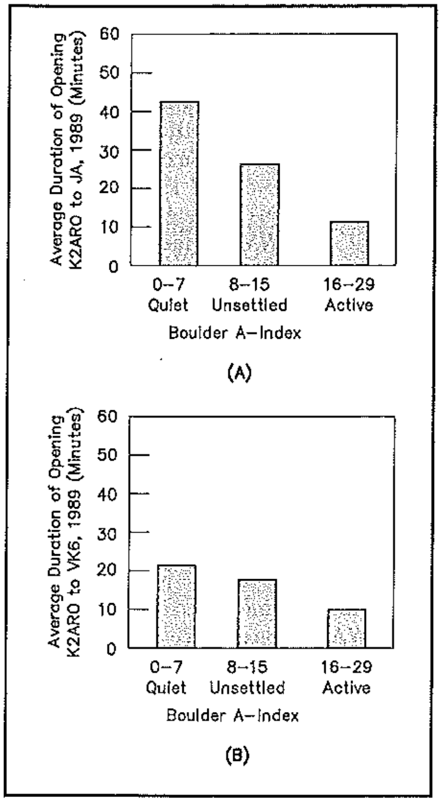

Fig 8—The plot shows the relation between the Boulder A-index and the length of openings. The effect is more pronounced to JA.

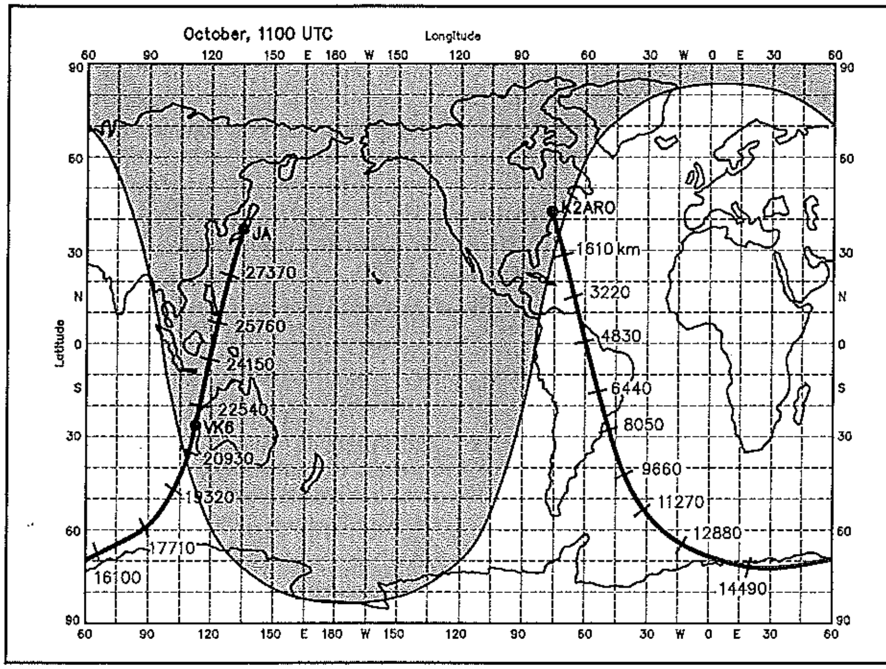

Fig 9—Long paths do not have to follow the gray line. Gray-line propagation helps but it is not a necessary factor in 10-m long path propagation.

ity of the Earth's magnetic field plays a large role in HF propagation. Taking the lead from W3EP's Table 2 in his "Predicting Transatlantic 50-MHz F-Layer Propagation" article in March 1993 *QST*, I have plotted in **Fig 8** the average duration of an opening to JA and VK6 during 1989 (based on groupings of the Boulder A-Index). I chose 1989 because it was the peak of Cycle 22 and I have back issues of QRZ DX with geomagnetic indices reported by KH6BZF. Fig 8 shows an obvious relationship of duration to the activity of the Earth's magnetic field—the quieter the magnetic field, the longer the opening.

The Role of the Terminator

The K2ARO to JA and VK6 appears to be a nearly gray-line path in Fig 2. You might wonder if this is a necessary condition for 10-m long-path. The answer lies in K2ARO's log data for QSOs prior to March 21 and after September 23. These dates are the spring equinox and fall equinox, respectively, when the terminator "flips over." Gus's path to JA and VK6 prior to March 21 and after September 23 did not hug the terminator as in Fig 2. Much of the path is in a highly sunlit area well away from the terminator, as shown in **Fig 9**.

Gus's log shows numerous QSO days occurring before March 21 and after September 23—in fact the numbers work out to about 10% of his JA total and 23% of his VK6 total. Thus the terminator is not a necessary condition for 10-m long-path. The bar graphs of Fig 4 do indicate most of the QSOs occurred when the path was oriented with the terminator (March 22 through September 22). I believe the biggest factor causing this effect is the Sun's location in the Northern Hemisphere during these months. This results in less absorption along most of the path.

The Role of Transequatorial Propagation

Earlier I suggested the seasonal difference seen between the VK6 path and the JA path was due to the JA path crossing the equator. Let's look at this in more depth.

Refer back to Fig 4. The JA and VK6 bar graphs tell us somehow the path to JA is maintained during the summer months even though the path to VK6 usually disappears. How can this happen? A mode of propagation known as *transequatorial propagation*, TE, causes this effect.

TE is a regularly occurring phenomena at equatorial latitudes in the early evening hours (corresponding to the path between VK6 and JA around 1100 UTC). It generally is optimum around 7 PM local time in these equatorial latitudes. It usually consists of two refractions off the F layer without an intermediate ground reflection, giving a hop (commonly called a chordal hop) much greater than the normally accepted maximum of 4000 km.

TE is the result of the unique characteristics of the ionosphere in equatorial latitudes. The electron density peaks at about 15° of latitude from each side of the geomagnetic equator and the height of the electron density peaks at the geomagnetic equator. Davies' Figure 4.26, McNamara's Figure 3.16, and NM7M's Figure 21 show these characteristics.

TE is well documented. It is discussed in sections 3.4, 3.5, and 4.1.8 of NM7M's work and section 6.5 of Jacobs and Cohen's book. Other discussions are in sections 3.6 and 9.4 of McNamara's book and Davies discusses it in his section 4.6.6. Figure 4.26 of Davies' book shows an example of ray tracing providing a 5800 km transequatorial hop without an intermediate ground reflection. Villard, Stein and Yeh provide similar but more detailed analysis and ray tracings of transequatorial chordal hops of up to 7000 km in "Studies of Transequatorial Ionospheric Propagation by the Scatter-Sounding Method" in Volume 62, No 3, September 1957 of the *Journal of Geophysical Research*.

How does TE affect our K2ARO to VK6 and JA path? As stated earlier, it allows K2ARO to make JA contacts in the summer when conventional multi-hop cannot be supported. In other words, depressed areas of MUF in the summer are similar to, but more extensive than, that shown in Fig 6, which are overflown by a very long hop. I also suspect TE is the dominant mode into JA during the spring and fall months, even though Fig 6 and a similar analysis for fall months indicates conventional multi-hop could be supported.

Transequatorial propagation would explain the time shift seen in Fig 5. The path to VK6 is a multi-hop, while the path to JA relies on TE for its final segment. The multihop path opens to VK6, but TE isn't supported until about a half hour later to get into JA.

TE also accounts for the long-duration openings to JA (remember K2ARO's 2 hour, 42 minute opening?) These are not predicted by Fig 6. It can support frequencies about 1.4 times the conventional MUF. Thus the conventional MUF can fall to the low 20s in these equatorial latitudes while still supporting 28-MHz TE. This results in the drop out of VK6 while JA hangs in there a little longer.

Other Geographical Locations

My analysis so far has focused on the East Coast 10-m long-path to JA and VK6. However, K2ARO had numerous contacts into DU, KH6, P29, VK3, KH2, VS6, KX6, YC, HL, BV and JD1 interspersed with his JA and VK6 QSOs. What about the Midwest and the West Coast? Do they have early morning 10-m long-path propagation to JA, VK6 and similar areas?

Based on my skeds with JH3DPB and QSOs with VK6s, it is obvious the Midwest has openings to JA, VK6 and similar areas. The sun rises about an hour later in the Midwest and so openings from this area will start about an hour later than from the East Coast. Thus, the window of opportunity for openings from the Midwest will be about an hour less (since the other end of the path is the same).

The later sunrise on the West Coast makes me believe there are no long-path 10-m JA and VK6 openings from this area. By the time the sun rose in W6, it would be past midnight in JA-land. During the peak of a good sunspot cycle, it's possible the F-layer could still support propagation at this time in the vicinity of JA, but then availability of JAs becomes a consideration due to the lateness of the hour. I would be interested in hearing from any W6 (or W7) who has had any experiences in this area.

If W6s do not have early-morning 10-m long-path openings to JA and VK6, do they have long-path openings to other locations? Looking back to Fig 2 and shifting the K2ARO end of the path to W6 suggests W6s have an opening to Eastern Europe and Western and Central Asia. N6AV, for one, does confirm that W6s have QSOs on this path.

The paths examined up until now have the western end at sunrise (K2ARO and W6) and the eastern end near or after sunset (JA, VK6, and Central Asia). What about the flip of this, with the western end after sunset (K2ARO and W6) and the eastern end at sunrise? N6AV reports this is a good path for W6 into the Mideast. I'm sure the East Coast has good openings after sunset, too. But is anybody there on the other end?

The twice-a-day availability of 10-m long-path openings is supported by NT5C's log data from March 1989 through April 1992. During this period he worked BY, JA, KH6, P2, S2, VK, VS6 and YB just after his local sunrise. He worked A9, DL, EA, F, FR, HA, HB, HZ, I, LY, OK, ST0, UA, UA9, UB, UH, UI, UL, VQ9, VU, YU, Z2, ZS, 3B8, 5H, 5Z and 9K starting several hours after his local sunset until around midnight. This several hour delay is possible because the F layer goes away after sunset much slower than it forms after sunrise. I examined the log data and it was quite impressive. It made me wish I was back in W5-land to take advantage of the best of both coasts!

Guidelines and Indicators for 10-m Long-Path

In this section I'll try to pull together all the observations and analyses to give general guidelines and indicators for 10-m long-path. These are not the only guidelines and indicators. That's what makes HF propagation interesting—the unexpected.

I will begin by saying 10-m long-path is much more dependent on the sunspot cycle and daylight considerations than is long path on the lower frequency bands. I found it very instructive to look at known 10-m long-paths in relation to daylight/darkness areas. From this certain trends become obvious.

On a broad scale, 10-m long-path is possible during any portion of the sunspot cycle when the smoothed sunspot number is above about 70. When I took a long term look at the path early in the article, I stated 10-m long-path is over for Cycle 22. When will it be back? It will be back when the next cycle, Cycle 23, ascends through a smoothed sunspot number of 70 or so. Based on long-range predictions and statistics on an average sunspot cycle, 10-m long-path won't be back until the turn of the century.

Most of the openings occur from April through October. Don't rule out February/March and November—it's a possibility, although rare. Look for early morning openings generally from southeast through south just after sunrise for several hours, with the summer months opening a little earlier than the spring and fall months (because of an earlier sunrise). Don't be surprised if a heading a little west of south produces results, too. Look for late-evening openings from south through southwest for several hours.

During spring and fall months, the early-morning long-path can be available into locations both north and south of the equator. In the summer, expect the locations south of the equator to disappear, but locations north of the equator can remain, compliments of transequatorial propagation.

On a given day, the best bet for an opening occurs when the Boulder A-index is 7 and below (quiet conditions). This will give the longest-duration openings. Don't count out A-indices of 15 and less (unsettled conditions). Since the A-index is reported on WWV for the previous day, you need to follow the trend for the past several days to estimate what it is on the day in question. An alternative is to use the coarser K-index transmitted at 3-hour intervals throughout the day. An A-index of 7 corresponds to a K-index of 2, and an A-index of 15 corresponds to a K-index of 3. The NOAA/SESC BBS (1-303-497-5000) provides a three-day prediction of the planetary A-index.

Take advantage of the 10-m beacons. *The ARRL Operating Manual* has an extensive list of them. I have personally used the VK6RWA beacon on 28264 kHz as an indication of both VK6 and JA longpath.

Finally, don't be afraid to call "CQ Long Path" with target areas identified. It just may attract someone's attention.

Final Comment

Although I tried to present historical data to take the mystery out of 10-m long-path, there are still surprises. For example, NM7M and GM4IHJ report several instances of 29.4 MHz signals from the RS-12 satellite coming across the dark polar cap. It appears they were able to see propagation off drifting patches of ionization at F-layer heights. As Bob puts it, "By all that is holy and quite conventional, that should not happen!"

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Notes and Bibliography

The following material was used to prepare this article:

J. Hagen's article, "10-Meter Long Path," appeared in *The DX Magazine.* Contact POB 50, Fulton CA 95439 for more information.

Copies of NM7M's book *Long-Path Propagation—A Study of Long-Path Propagation in Cycle 22,* are available from the author for $10 postpaid. Write to Bob Brown, 504 Channel View Drive, Anacortes, WA 98221. Bob is also the author of the *ULTMTLP* and *PRTYBIRD* software. Write him for further information.

The Shortwave Propagation Handbook was written by G. Jacobs, W3ASK, and T. Cohen, N4XX (CQ Publishing, Port Washington, NY, 1979).

L. McNamara, *The Radio Amateur's Guide to the Ionosphere* (Malabar, FL: Kreiger Publishing Co.)

K. Davies, *Ionospheric Radio Propagation* (US Government Printing Office, Washington D.C. 1965.)

R. Healy, NJ2L, "Propagation Broadcasts and Forecasts Demystified," *QST,* Nov 1991, p 20.

The *DXAID* software used is available for $25 postpaid. Write to Peter Oldfield, 251 Chemin Beaulne, Piedmont, Quebec J0R 1K0, Canada.

You can find additional information on smoothed sunspot numbers on page 23-13 of *The ARRL Antenna Book,* 17th Edition (1994). Smoothed numbers can also be found in *QST* each month below the band opening charts. They are also included in W3ASK's monthly propagation column in *CQ* (CQ Communications, 76 North Broadway, Hicksville NY 11801).

The publication *Ionospheric Predictions* was used extensively in the work described in this article. It was originally published by the Office of Telecommunications as *Telecommunications Research and Engineering Report 13* (Boulder, CO 1971). As noted in the text, it consists of four volumes. Volume 1 shows how to use the data, and Volumes 2, 3 and 4 consist of constant contour lines of median MUF(ZERO)F2, MUF(4000)F2 and MUF(2000)E for smoothed sunspot numbers of 10, 110 and 160, respectively. Unfortunately it is out of print. Certain portions may still be available by contacting the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. If you need some selected information please contact Carl, K9LA, at the address at the beginning of this article and he will try to help.

For a detailed explanation of these maps and the terminology used in *Ionospheric Prediction,* refer to "High-Frequency Propagation Estimations for the Radio Amateur," by Jerry Hall, K1PLP (now K1TD) in Mar 1972 *QST,* p 14.

E. Pocock, W3EP, "Predicting Transatlantic 50-MHz F-Layer Propagation," *QST,* Mar 1993, p 32.

QRZ DX is one source of past values of geomagnetic indices based on my groupings of the Boulder A-Index. For further information write to POB 832205, Richardson, TX 75083-2205.

Villard, Stein, and Yeh, "Studies of Transequatorial Ionospheric Propagation by the Scatter-Sounding Method," *Journal of Geophysical Research,* Volume 62, No. 3, Sep 1957.

US Army Signal Radio Propagation Agency Technical Report No. 9, *Analysis and Prediction of Sky-Wave Intensities in the High Frequency Band* is an out-of-print publication used by the author. Unfortunately no source of this report is currently known.

The ARRL Repeater Directory and *The ARRL Operating Manual* include a list of 10-m beacon stations. Although there are frequent changes, they are a useful guide to stations you might check to find open propagation paths.