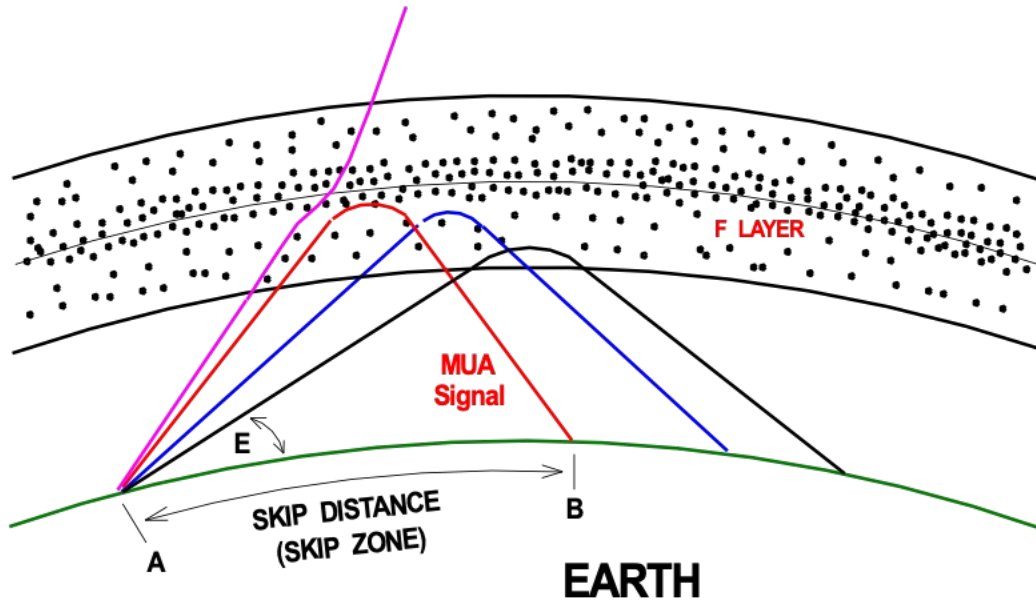
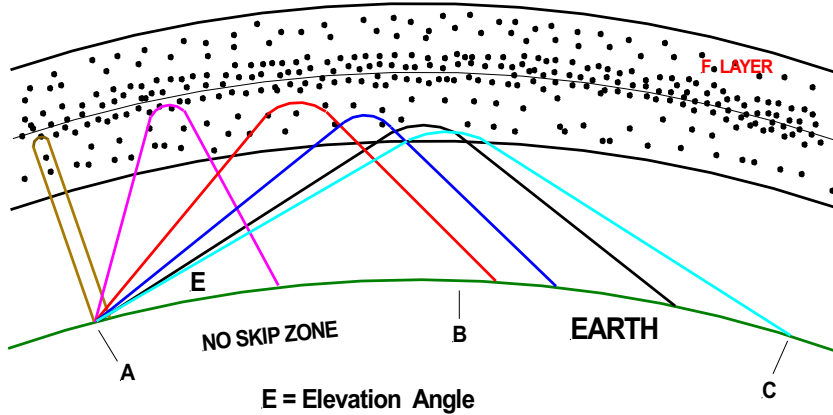


Skip Distance 80 Meter Test

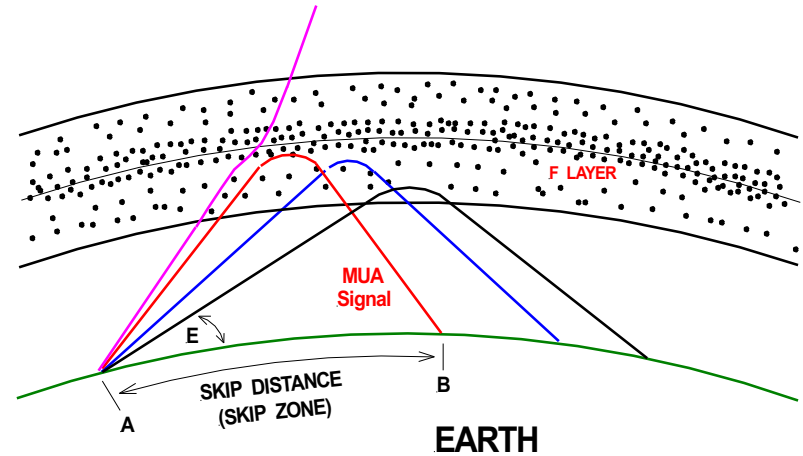


Ken Larson KJ6RZ
February 2024
www.skywave-radio.org

80 Meter Skip Distance Test



No Skip Zone if $f_c > f_o$

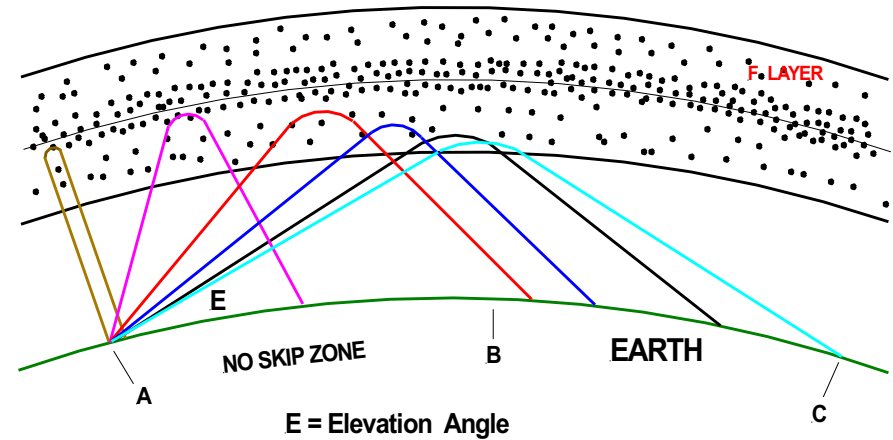
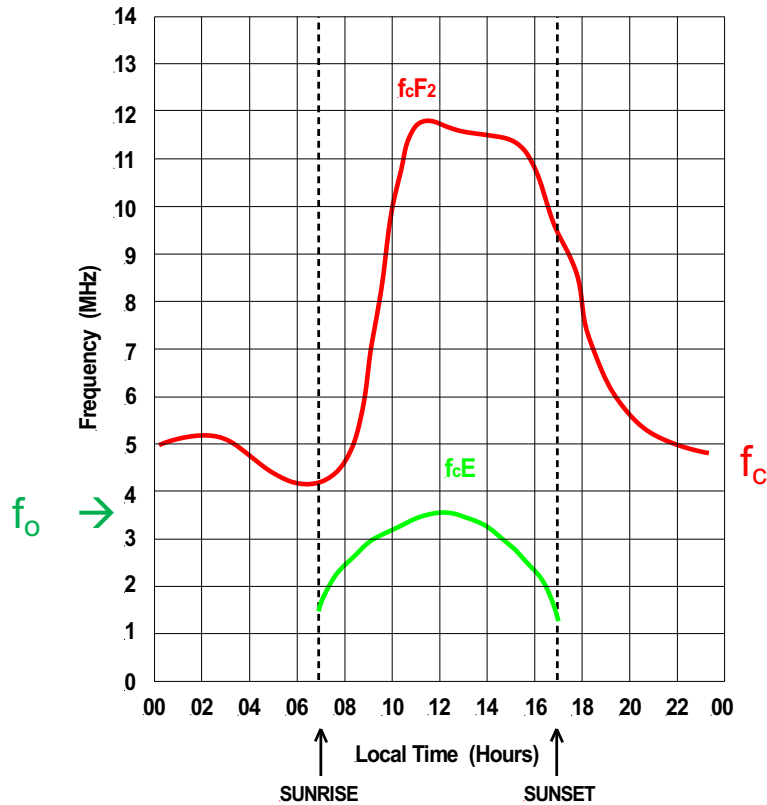


Skip Zone Present if $f_c < f_o$

- The presence of an 80 meter skip zone depends on:
 - The solar cycle,
 - The critical frequency, and
 - The time of day

80 Meter Skip Distance Test - Solar Maximum

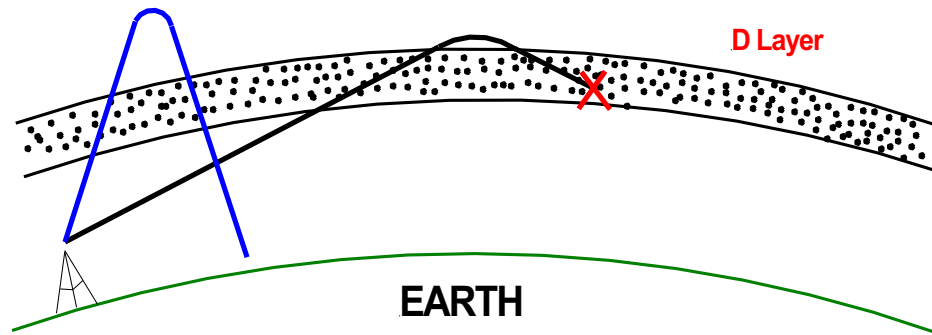
Critical Frequency - Winter Solar Maximum



Generally, no 80 meter skip zones during solar maximum

- During **solar maximum** critical frequency f_c is nearly always above the 80 meter operating frequency f_o of 3.5 to 4.0 MHz, even at night
- Consequently, during solar maximum skip zones are generally not present on 80 meters
- Meaning most stations from close in (< 10 miles away) out several hundred miles should be reachable all the time day and night – 80 meters should be a wonderful solar maximum band

D Layer Absorption

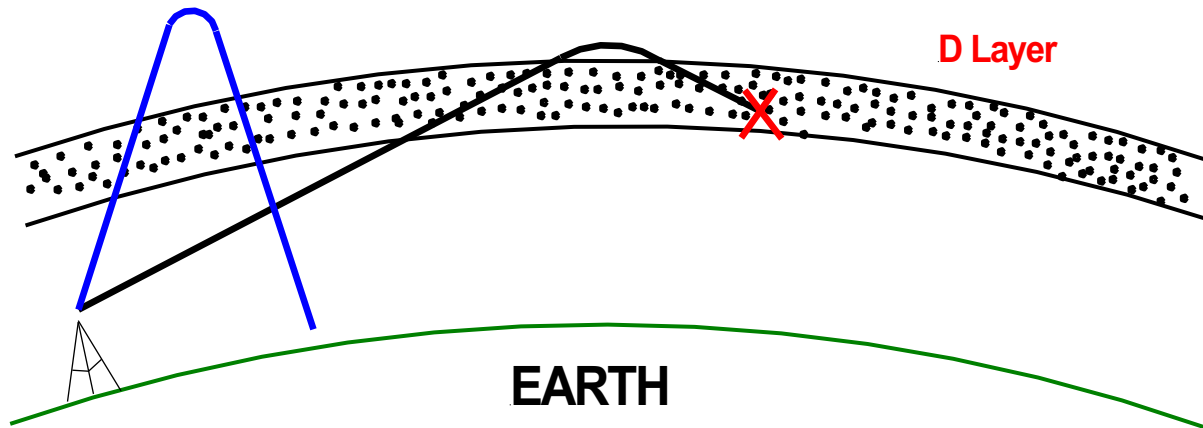


- While 80 meters does not have skip zones during solar maximum,
- 80 meter signals are heavily absorbed during the day by the ionosphere's D Layer preventing 80 meter day time operation
- D Layer absorption is inversely proportional to frequency squared

$$\text{Absorption} \propto \frac{1}{f^2}$$

- 160 and 80 meters are the two most heavily absorbed frequency bands
- Absorption on 80 meters is 4 times greater than on 40 meters and 16 times greater than on 20 meters

Long Hop Signals Are Absorbed The Most

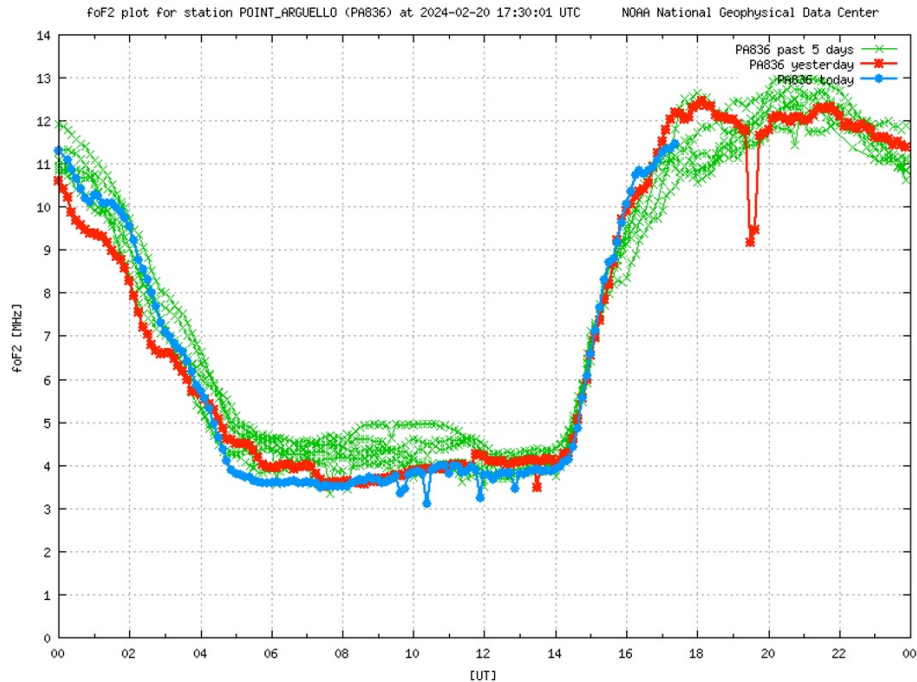


- A low elevation angle long hop signal spends more time traversing the D Layer than a high angle short hop signal
- Consequently, a low angle long hop signal is more likely to be absorbed by the D Layer than a high angle short hop signal
- This phenomena is observed in the day time 80 meter test data

80 Meter Test Parameters – 2/19/2024

- 80 meter test on 2/19/2024:
 - Sun Rise @ 6:34, Sun Set @ 17:40,
 - SFI = 152,
 - X-Ray Flux = C1.3,
 - A Index = 3, K Index = 0,
 - SSN = 64,
 - Inverted V antenna used with an apex of 32 ft
- VARA digital protocol used;
 - Contact duration of 0.18 considered a very good connections,
 - A duration of greater than 1 minute (>1:00) is a poor connection,
 - While nc = no connection
- A station with no entry means that the station could not be reached because the frequency was in use by others, a commonly encountered problem
- NA means the station was not available at the time of the test
- Transmit Frequency ranged from 5.578 to 5.596 MHz (WinLink RMS frequencies)

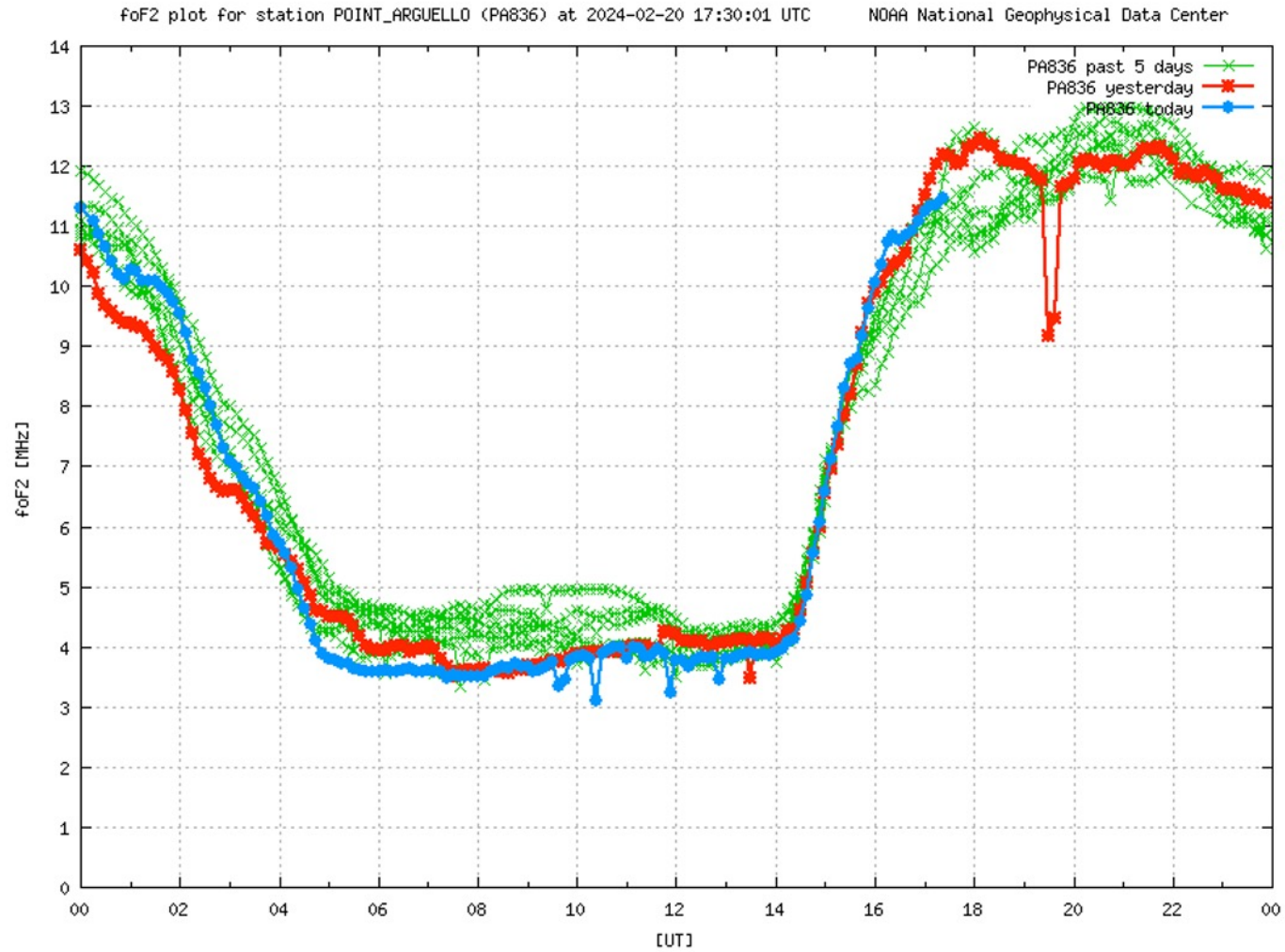
Critical Frequency on 2/19/2024



During the test the critical frequency ranged from 12 down to 3.8 MHz

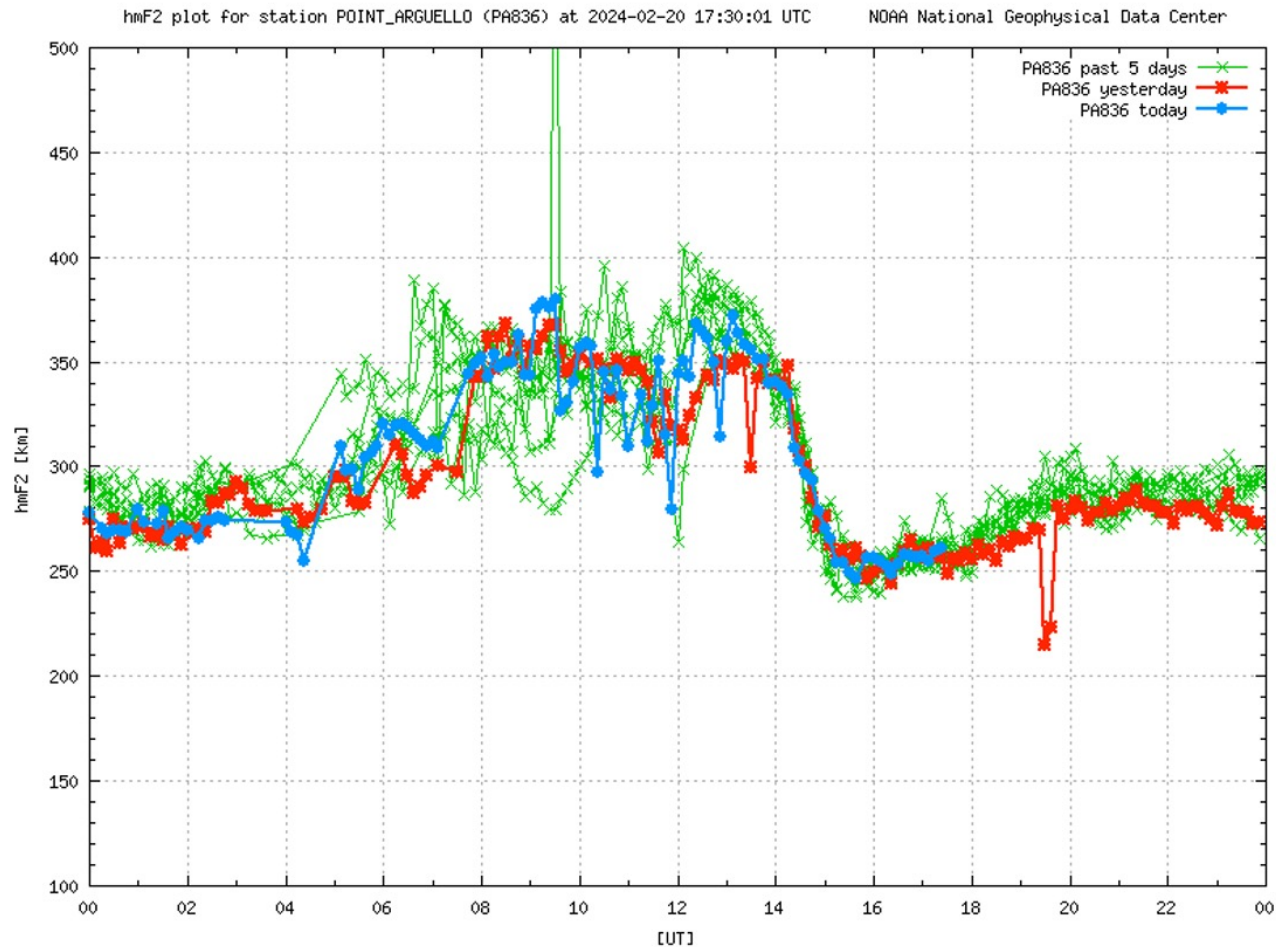
- Blue trace is the critical frequency for “today” 2/20/2024 in Universal Time (UT)
- Red trace is the critical frequency for “yesterday” 2/19/2024 in UT time
- The 80 meter test ran from 13:00 PST 2/19/2024 = 21:00 UT “yesterday” to 21:30 PST 2/19/2024 = 5:30 UT “today” 2/20/2024
- Critical frequency ranged from 12 MHz at 13:00 PST (21:00 UT yesterday) to 3.8 MHz at 21:30 PST (5:30 UT today)

Critical Frequency on 2/19/2024



- Expanded view

Height of Ionosphere's F2 Layer on 2/19/2024



- The height of the Ionosphere's F2 Layer during the 2/19/2024 test was around 275 km
- The color scheme and UT times are the same as for the critical frequency chart

80 Meter Day Time Propagation Data – 2/19/2024 @ 13:30 hours

Time	Frequency KHZ	Call	Distance Miles	Contact Duration (min)	Power Watts	Antenna	Tries	Comments
					50	Yellow		Fc = 12 MHz
	3595.500	KE6NYT	9	NA				Camarillo, CA
13:33	3594.000	W6BI	11	3:07				Simi Valley, CA
13:37	3595.500	AJ7C	31	0:23				Culver City, CA
13:39	3591.000	KN6BKT	48	0:18			2	San Gabrile, CA
13:41	3582.500	N7OP	52	0:23				Lancaster, CA
	3578.000	K9NEY	68	NA				Chino Hills, CA
13:43	3590.200	XE2BC	160	nc			2	Tijuana, Mexico
13:45	3587.500	KO0000	252	nc			2	North Las Vegas, NV
13:47	3588.500	K7OI	301	abort				Meadview, AZ (E of Los Vegas in AZ
13:52	3594.500	KD7NHC	320	1:00				Wellington, NV. [SE of Carson City]
13:56	3596.500	W7DEM	345	nc			2	Minden, NV [S of Carson City]
13:58	3588.500	N0DAJ	348	nc			2	Wickenburg, AZ. [NW of Phoenix]
14:00	3585.000	KL7RI	368	nc			2	Reno, NV
14:01	3591.500	KJ7GSK	386	nc			2	Chandler, AZ. [SE of Phoenix]
14:03	3585.500	K7RRR	411	nc			2	Gilbert, AZ. [SE of Phoenix]
14:05	3592.500	KD6OAT	585	nc			2	Sandy, UT
14:06	3586.500	AG7MM	638	nc			2	Burley, ID. [E of Twin Falls]
14:08	3585.000	KG7AV	693	nc			2	Bend, OR

- During the middle of the day close in stations from 11 out to 52 miles were the only stations that could be reached, the high elevation angles of their signals penetrated the D Layer
- Stations further away than 52 miles in general could not be reached
- Their signals were absorbed in the ionosphere's D Layer

80 Meter Data Approaching Sunset – 2/19/2024 @ 16:30 hours

Time	Frequency KHZ	Call	Distance Miles	Contact Duration (min)	Power Watts	Antenna	Tries	Comments
					50	Yellow		Fc = 11 MHz
	3595.500	KE6NYT	9	NA				Camarillo, CA
16:11	3595.500	AJ7C	31	0:23				Culver City, CA
16:13	3591.000	KN6BKT	48	0:16				San Gabriel, CA
16:14	3582.500	N7OP	52	0:23				Lancaster, CA
	3578.000	K9NEY	68	NA				Chino Hills, CA
16:16	3590.200	XE2BC	160	0:37				Tijuana, Mexico
16:18	3587.500	KO0000	252	0:51				North Las Vegas, NV
16:20	3588.500	K7OI	301	abort			2	Meadview, AZ (E of Los Vegas in AZ
16:23	3594.500	KD7NHC	320	0:27				Wellington, NV. [SE of Carson City]
16:26	3596.500	W7DEM	345	0:20				Minden, NV [S of Carson City]
16:28	3588.500	N0DAJ	348	nc			2	Wickenburg, AZ. [NW of Phoenix]
16:29	3585.000	KL7RI	368	nc			2	Reno, NV
16:31	3591.500	KJ7GSK	386	1:03			2	Chandler, AZ. [SE of Phoenix]
16:34	3585.500	K7RRR	411	0:25				Gilbert, AZ. [SE of Phoenix]
16:36	3592.500	KD6OAT	585	nc			2	Sandy, UT
16:38	3586.500	AG7MM	638	nc			2	Burley, ID. [E of Twin Falls]
	3585.000	KG7AV	693					Bend, OR
16:41	3594.000	W7INL	741	1:01				Rigby, ID
16:43	3595.500	KF7RFI	764	nc			2	Mosier, OR (E of Hood River)
16:45	3593.500	K7UNI	769	nc			2	La Grande, OR (SE of Pendleton)
16:46	3586.000	KD7ZDO	795	nc			2	Oregon City, OR. [S of Portland]
16:48	3583.200	W7OWO	798	nc			2	Dundee, OR. [SE of Portland]
16:51	3587.000	KD0SFY	845	1:55				Colorado Springs, CO
16:56	3591.000	KB2PCN-8	894	0:40				Evergreen, CO (N of Aspen)
16:58	3585.000	K7RHT	899	nc			2	Kerville, TX (NW of San Antonio)
17:00	3587.500	K7HTZ	917	nc			2	Olympia, WA. [SW of Tacoma]
17:01	3589.500	N7LOB	920	nc			2	Aberdeen, WA. [On coast W of Olympia]
17:03	3591.500	VA7PF	1054	nc			2	BC, Canada
17:05	3586.500	VE7GN	1063	nc			2	Gabriola, BC, Vancouver Island
17:07	3585.000	KA0ZIS	1219	nc			2	Pierre, SD

- In the late afternoon, an hour prior to the 17:40 sunset, station out to 411 miles were reached as the D Layer diminished
- However, stations from 585 out to 1,219 miles still could not be reliably reached since they were still being absorbed in the D Layer

80 Meter Data Following Sunset – 2/19/2024 @ 18:30 hours

Time	Frequency KHZ	Call	Distance Miles	Contact Duration (min)	Power Watts	Antenna	Tries	Comments
					50	Yellow		Fc = 8 MHz
18:21	3595.500	KE6NYT	9	0:27				Camarillo, CA
18:26	3595.500	AJ7C	31	0:23				Culver City, CA
18:29	3591.000	KN6BKT	48	0:18				San Gabrile, CA
18:30	3582.500	N7OP	52	0:18				Lancaster, CA
18:32	3578.000	K9NEY	68	0:27				Chino Hills, CA
18:33	3590.200	XE2BC	160	0:18			2	Tijuana, Mexico
19:26	3587.500	KO0000	252	0:21				North Las Vegas, NV
19:28	3588.500	K7OI	301	1:32			2	Meadview, AZ (E of Los Vegas in AZ)
18:36	3594.500	KD7NHC	320	0:27				Wellington, NV. [SE of Carson City]
18:40	3596.500	W7DEM	345	0:18				Minden, NV [S of Carson City]
19:35	3588.500	N0DAJ	348	0:18				Wickenburg, AZ. [NW of Phoenix]
18:48	3585.000	KL7RI	368	0:24				Reno, NV
18:50	3591.500	KJ7GSK	386	0:18				Chandler, AZ. [SE of Phoenix]
18:51	3585.500	K7RRR	411	0:18				Gilbert, AZ. [SE of Phoenix]
18:52	3592.500	KD6OAT	585	0:17				Sandy, UT
18:53	3586.500	AG7MM	638	0:40				Burley, ID. [E of Twin Falls]
18:55	3585.000	KG7AV	693	2:01				Bend, OR
18:58	3594.000	W7INL	741	0:18				Rigby, ID
19:01	3593.500	K7UNI	769	0:37				La Grande, OR (SE of Pendleton)
19:02	3586.000	KD7ZDO	795	nc			2	Oregon City, OR. [S of Portland]
19:04	3583.200	W7OWO	798	nc			2	Dundee, OR. [SE of Portland]
19:07	3587.000	KD0SFY	845	0:38				Colorado Springs, CO
19:37	3591.000	KB2PCN-8	894	0:18				Evergreen, CO (N of Aspen)
19:14	3587.500	K7HTZ	917	0:54				Olympia, WA. [SW of Tacoma]
19:16	3589.500	N7LOB	920	1:08	QRM			Aberdeen, WA. [On coast W of Olympia]
19:18	3591.500	VA7PF	1054	0:49				BC, Canada
19:20	3586.500	VE7GN	1063	0:17				Gabriola, BC, Vancouver Island
19:22	3585.000	KA0ZIS	1219	nc			2	Pierre, SD

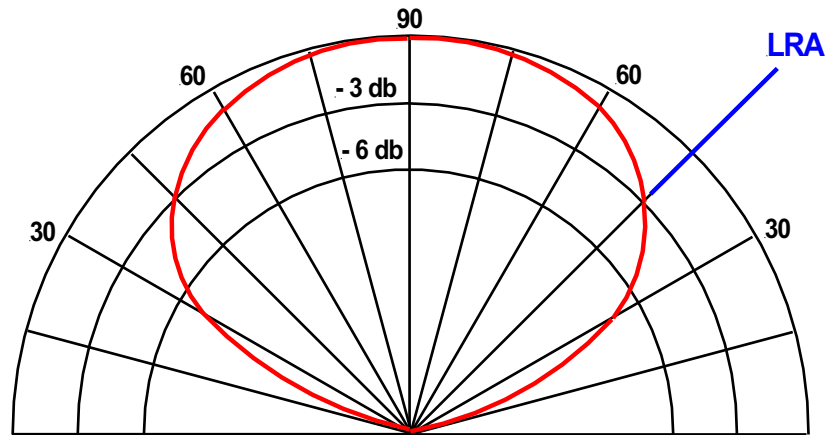
- Sunset occurred at 17:40 (5:40 PM)
- 45 minutes to an hour later the absorbing D Layer had mostly disappeared
- Allowing stations from close in (9 miles) out to 1,063 miles to be reached

80 Meter Evening Data – 2/19/2024 @ 21:00 hours

Time	Frequency KHZ	Call	Distance Miles	Contact Duration (min)	Power Watts	Antenna	Tries	Comments
					50	Yellow		Fc = 3.8 MHz
20:39	3595.500	KE6NYT	9	0:27				Camarillo, CA
20:42	3595.500	AJ7C	31	0:17				Culver City, CA
20:43	3591.000	KN6BKT	48	0:25				San Gabriel, CA
20:45	3582.500	N7OP	52	0:18				Lancaster, CA
20:46	3578.000	K9NEY	68	0:19				Chino Hills, CA
20:49	3590.200	XE2BC	160	0:25				Tijuana, Mexico
20:51	3587.500	KO0000	252	0:20				North Las Vegas, NV
20:52	3588.500	K7OI	301	0:27				Meadview, AZ (E of Los Vegas in AZ
20:54	3594.500	KD7NHC	320	0:27				Wellington, NV. [SE of Carson City]
20:56	3596.500	W7DEM	345	0:18				Minden, NV [S of Carson City]
20:57	3588.500	N0DAJ	348	0:18				Wickenburg, AZ. [NW of Phoenix]
20:58	3585.000	KL7RI	368	0:16				Reno, NV
21:00	3591.500	KJ7GSK	386	0:16				Chandler, AZ. [SE of Phoenix]
21:01	3585.500	K7RRR	411	0:18				Gilbert, AZ. [SE of Phoenix]
21:02	3592.500	KD6OAT	585	0:18				Sandy, UT
21:04	3586.500	AG7MM	638	0:26				Burley, ID. [E of Twin Falls]
21:05	3585.000	KG7AV	693	1:06				Bend, OR
21:08	3594.000	W7INL	741	0:18				Rigby, ID
21:11	3582.500	K7UNI	769	0:28				La Grande, OR (SE of Pendleton)
21:42	3586.000	KD7ZDO	795	1:48			2	Oregon City, OR. [S of Portland]
21:17	3583.200	W7OWO	798	0:49				Dundee, OR. [SE of Portland]
21:24	3587.000	KD0SFY	845	0:17			3	Colorado Springs, CO
21:25	3591.000	KB2PCN-8	894	0:17				Evergreen, CO (N of Aspen)
21:28	3587.500	K7HTZ	917	0:25				Olympia, WA. [SW of Tacoma]
21:30	3589.500	N7LOB	920	0:42				Aberdeen, WA. [On coast W of Olympia]
21:31	3591.500	VA7PF	1054	0:25				BC, Canada
21:33	3586.500	VE7GN	1063	0:41				Gabriola, BC, Vancouver Island
21:35	3585.000	KA0ZIS	1219	0:44				Pierre, SD

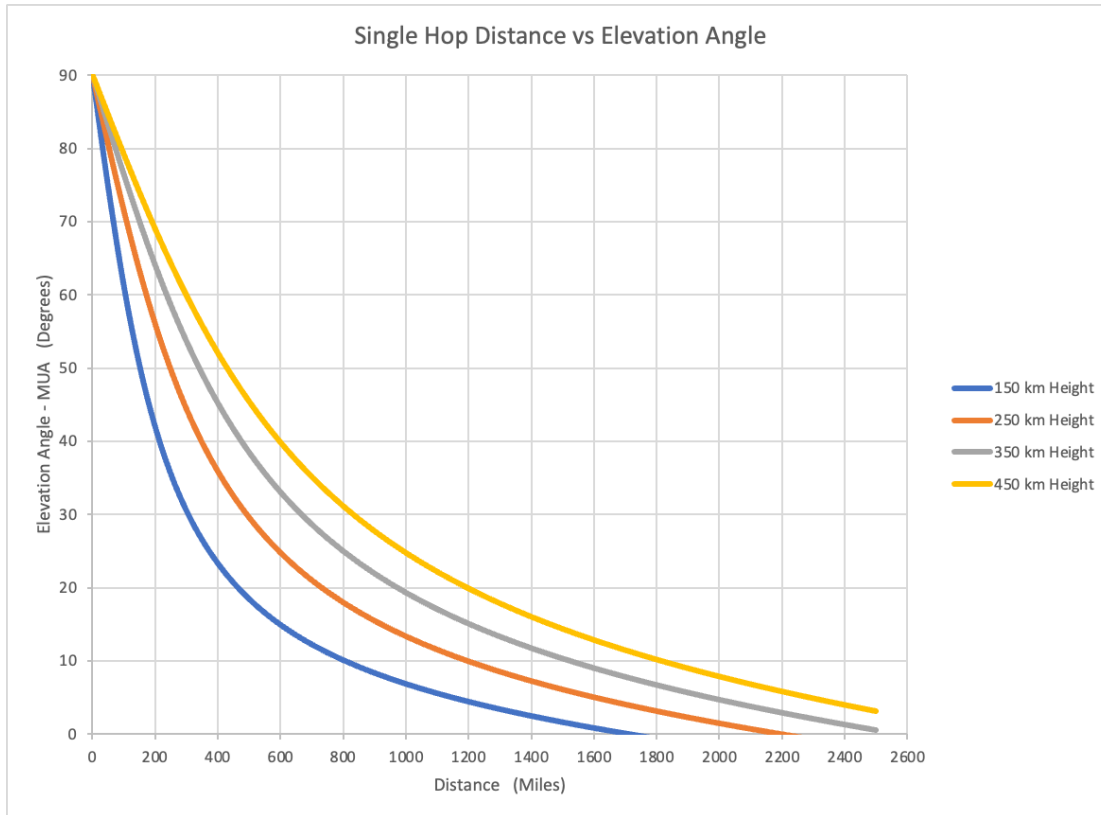
- In the evening (21:00 hours) stations from 9 out to 1,219 miles were easily reached indicating:
- The lack of an 80 meter skip zone, and
- The absence of the ionosphere's D Layer

80 Meter NVIS Antenna Pattern



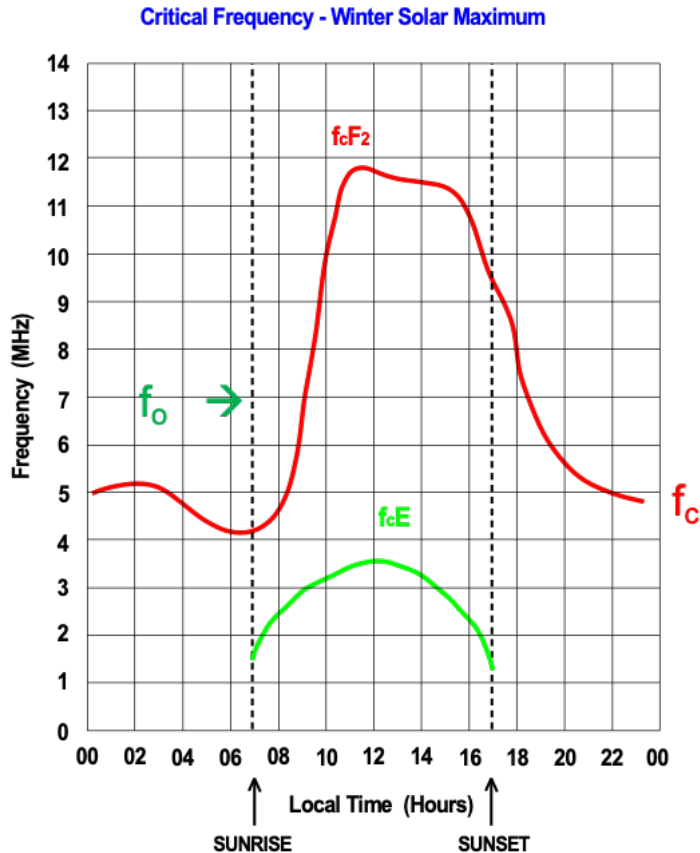
- 80 meter NVIS antennas radiate well at elevation angles from approximately 40 to 90 degrees

80 Meter NVIS Hop Distance



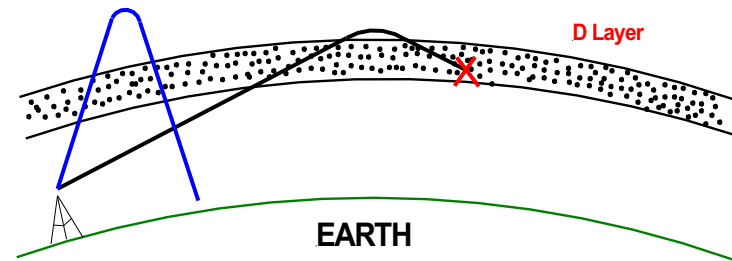
- The maximum single hop distance for an 80 meter NVIS antenna occurs at an elevation angle of approximately 40 degrees
- This is the antenna's Lowest Radiated Angle (LRA)
- At this angle, the single hop distance is approximately 350 miles when the height of the F2 layer is 250 km
- Distances longer than this require multiple hops and
- Multiple passes through the ionosphere's energy absorbing D Layer
- In the test data, stations more than roughly 400 miles away were probably reached by multiple hops

NVIS Gap



- The NVIS gap is the period of time between the critical frequency (f_c) dropping below the 40 meter band (below $f_o = 7$ MHz) and roughly sunset when the ionosphere's absorbing D Layer disappears
- During the gap, NVIS propagation is not possible on either 40 or 80 meters
- A skip zone preventing NVIS operation develops on 40 meters when the critical frequency drops below 7 MHz
- During the day a strong D Layer absorbs 80 meter signals preventing 80m NVIS operation
- Consequently, an NVIS gap occurs between the time the critical frequency drops below 7 MHz and disappearance of the D Layer at sunset
- Once the D Layer disappears, excellent 80 meter NVIS operation persists throughout the night until sunrise the next morning, provided the critical frequency remains above 4 MHz
- An 80 meter skip zone quickly develops, cutting off NVIS operation, if the critical frequency drops below 4 MHz (below 3.7 MHz for WinLink op)

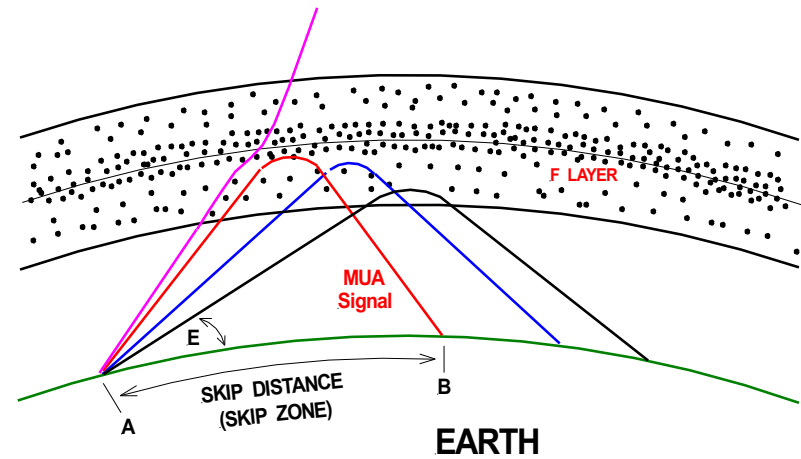
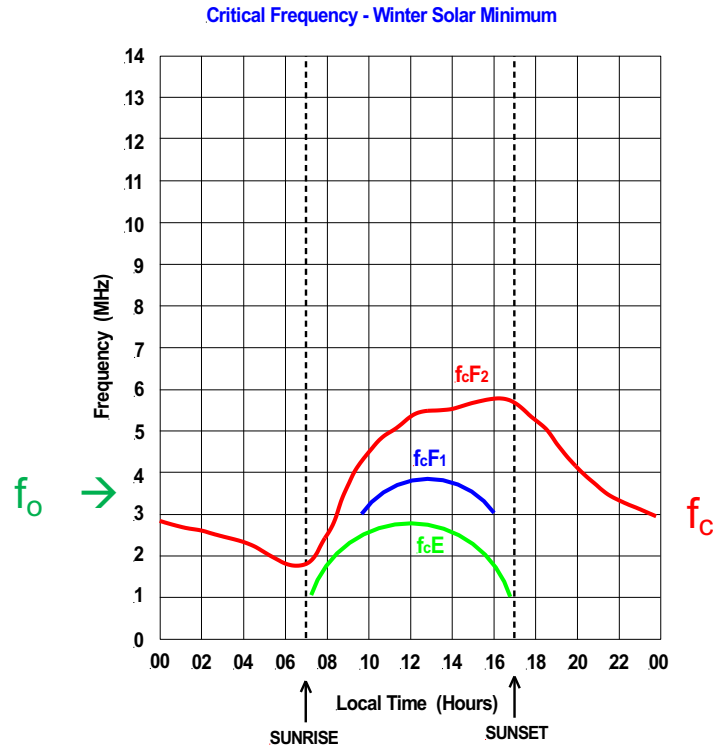
NVIS Gap – Close In Stations



Time	Frequency KHZ	Call	Distance Miles	Contact Duration (min)	Power Watts	Antenna	Tries	Comments
					50	Yellow		Fc = 12 MHz
	3595.500	KE6NYT	9	NA				Camarillo, CA
13:33	3594.000	W6BI	11	3:07				Simi Valley, CA
13:37	3595.500	AJ7C	31	0:23				Culver City, CA
13:39	3591.000	KN6BKT	48	0:18			2	San Gabriel, CA
13:41	3582.500	N7OP	52	0:23				Lancaster, CA
	3578.000	K9NEY	68	NA				Chino Hills, CA
13:43	3590.200	XE2BC	160	nc			2	Tijuana, Mexico
13:45	3587.500	KO0000	252	nc			2	North Las Vegas, NV
13:47	3588.500	K7OI	301	abort				Meadview, AZ (E of Los Vegas in AZ)
13:52	3594.500	KD7NHC	320	1:00				Wellington, NV. [SE of Carson City]
13:56	3596.500	W7DEM	345	nc			2	Minden, NV [S of Carson City]
13:58	3588.500	N0DAJ	348	nc			2	Wickenburg, AZ. [NW of Phoenix]
14:00	3585.000	KL7RI	368	nc			2	Reno, NV
14:01	3591.500	KJ7GSK	386	nc			2	Chandler, AZ. [SE of Phoenix]
14:03	3585.500	K7RRR	411	nc			2	Gilbert, AZ. [SE of Phoenix]
14:05	3592.500	KD6OAT	585	nc			2	Sandy, UT
14:06	3586.500	AG7MM	638	nc			2	Burley, ID. [E of Twin Falls]
14:08	3585.000	KG7AV	693	nc			2	Bend, OR

- The test data shows that stations within roughly 50 miles can be reached on 80 meters even during the middle of the day when the D Layer is fully developed
- The high elevation angle of these signals (the blue trace) causes them to quickly traverse the D Layer with little signal loss
- Lower elevation angle longer hop signals to stations over 50 miles away spend longer traversing the D Layer and are absorbed preventing them from reaching their destinations

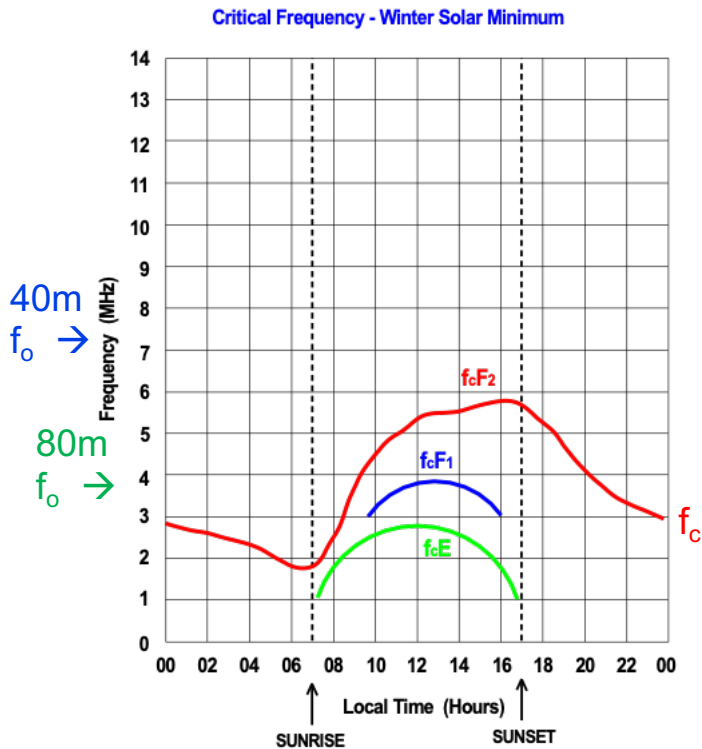
80 Meter Skip Distance Test - Solar Minimum



An 80 meter Skip Zone is present at night when $f_c < f_o$

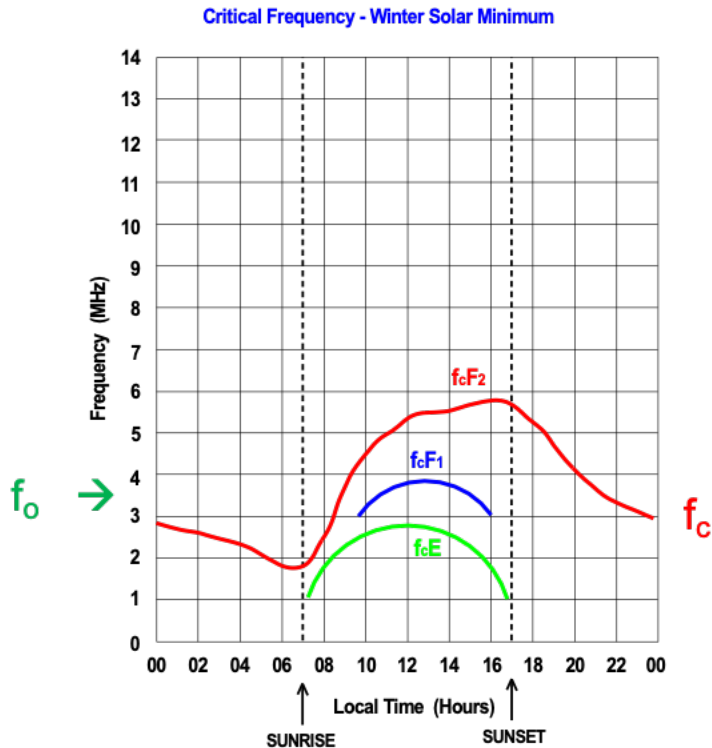
- During **solar minimum** critical frequency f_c is less than the 80 meter operating frequency f_o of 3.5 – 4.0 MHz during the night, typically from 10 PM (22:00) until 9 AM the next morning
- Consequently, during **solar minimum** an 80 meter night time skip zone is present

Solar Minimum NVIS Gap



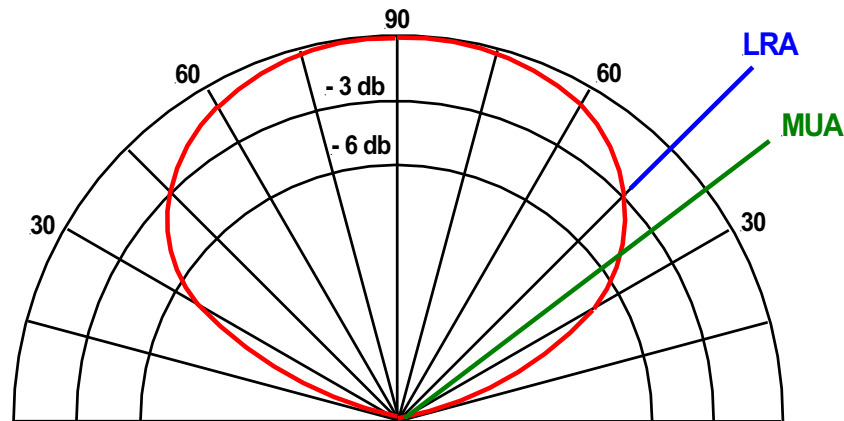
- During solar minimum the critical frequency f_c is generally lower than the 40 meter operating frequency f_o of 7.0 to 7.3 MHz
- The low critical frequency results in a 40 meter skip zone that is present most of the time preventing the use of 40 meter NVIS
- However, longer hop propagation to stations beyond the skip zone is still possible and extensively used
- It is the close in 40 meter NVIS communications (within 300 to 400 miles) that is lost due to the low critical frequency
- During the day the D Layer absorbs most 80 meter signals with the possible exception of those transmitted to stations within 50 miles
- The result is a day long NVIS gap that lasts until sunset

Solar Minimum NVIS Gap - continued



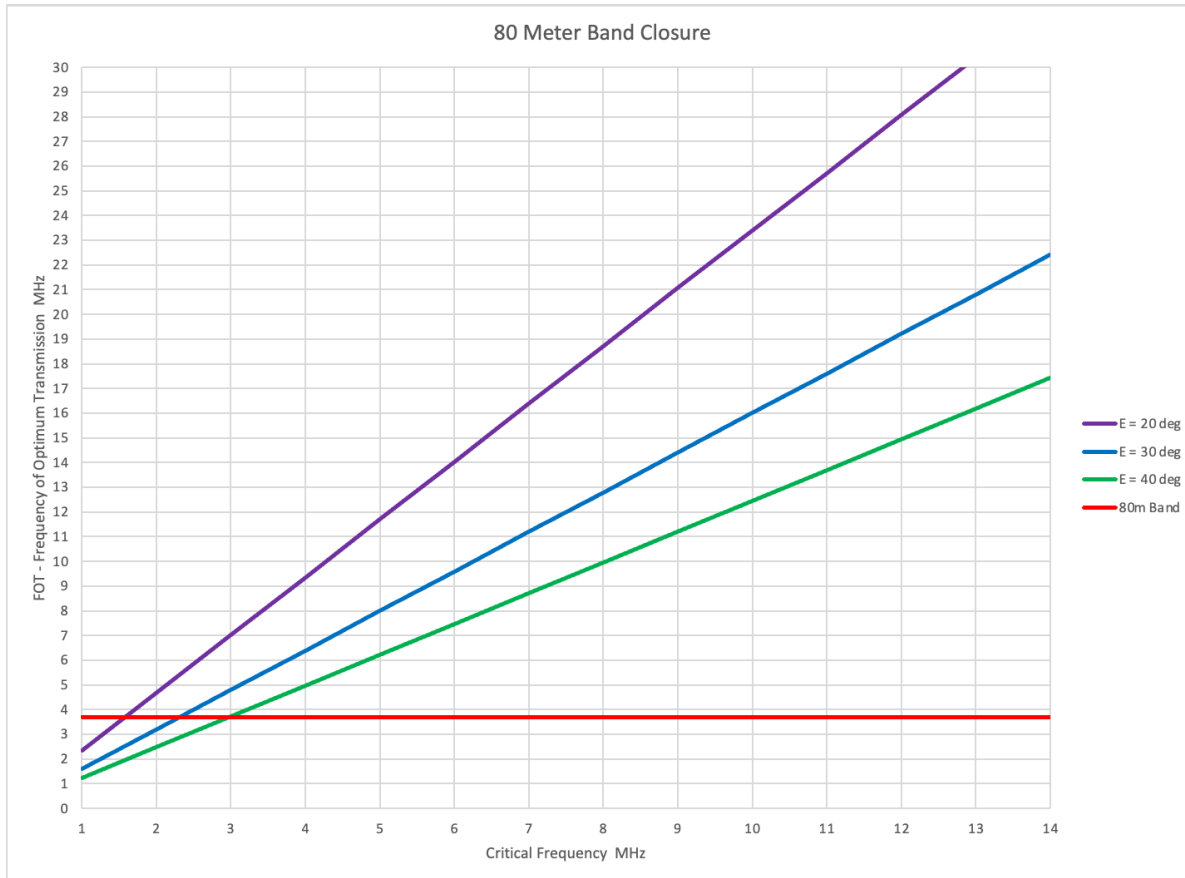
- Following sunset the D Layer disappears allowing a nearly ideal 80 meter NVIS band to immerge
- NVIS conditions typically last for about 3 hours from sunset around 17:00 until 20:00 when the critical frequency drops below 4.0 MHz
- An 80 meter skip zone quickly develops as the critical frequency drops under 4.0 MHz, terminating NVIS operation
- Long hop communications with stations beyond the skip zone typically continue another couple of hours until the critical frequency drops below 3 MHz
- This usually occurs around 22:00 hours
- At a critical frequency below 3 MHz, nearly all of the energy radiated by an 80 meter NVIS antenna is lost to outer space concluding use of the 80 meter band

Lowest Radiated Angle (LRA)



- Lowest Radiated Angle (LRA) is the lowest angle at which an antenna can radiate a signal
- This is generally defined as the angle at which the antenna's radiated power drops 3 db below its peak level
- Beyond this point the antenna's radiated power falls off very quickly
- The LRA for an 80 meter NVIS antenna is typically around 40 to 45 degrees
- The ionosphere's Maximum Usable Angle (MUA) is the highest angle signal that can be transmitted without penetrating the ionosphere
- The only part of an antenna's radiated energy that can be used for communications is that part below the MUA
- Consequently, nearly all of an antenna's radiated energy will be lost to outer space if the ionosphere's Maximum Usable Angle is less than an antenna's Lowest Radiated Angle

Band Closure For 80 Meter NVIS Antenna

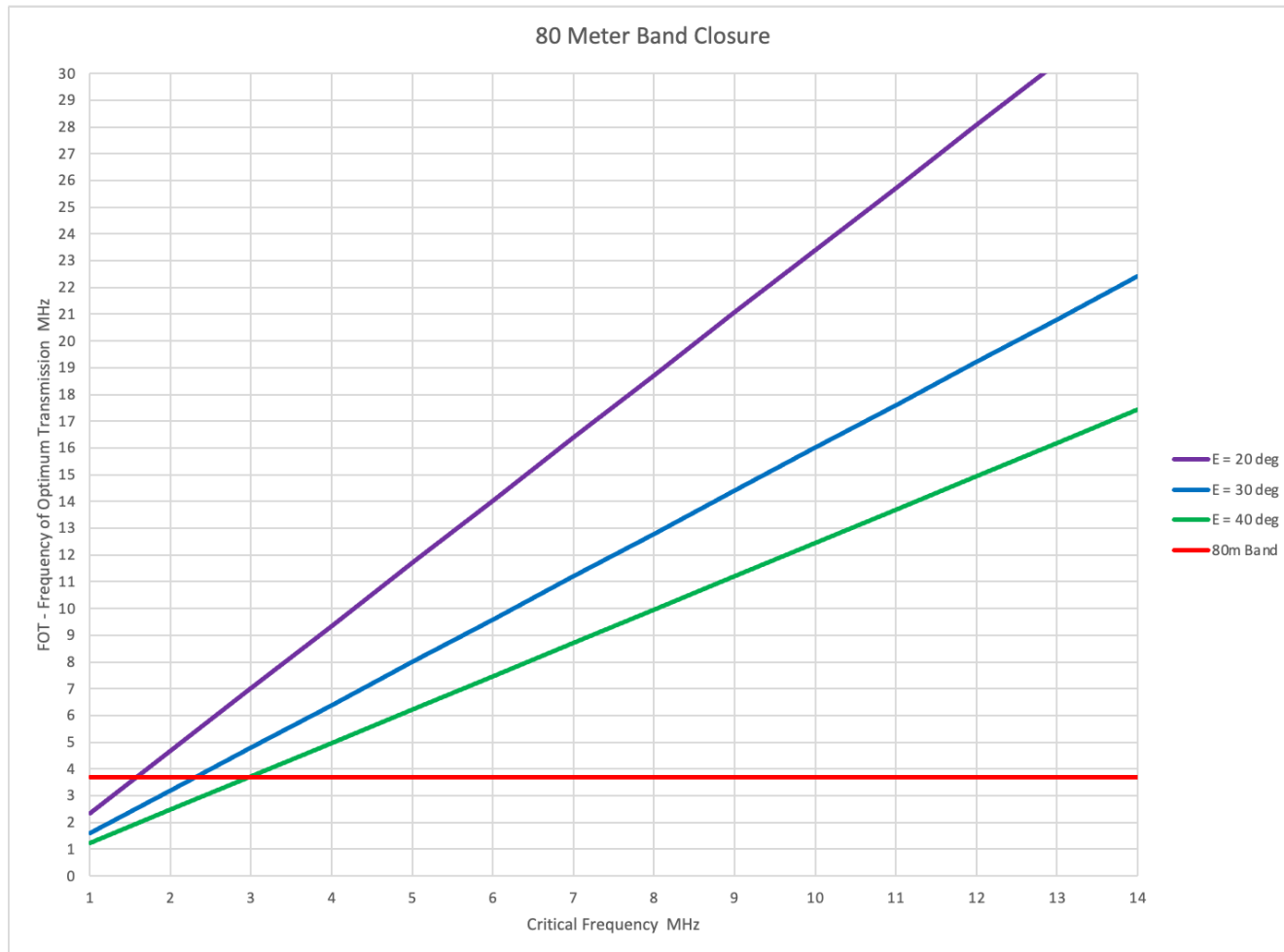


- At an elevation angle of $E_m = LRA$, the Frequency of Optimum Transmission (FOT) given by

$$FOT = \frac{0.8 f_c}{\sin E_m}$$

- steadily decreases as the ionosphere's critical frequency f_c drops

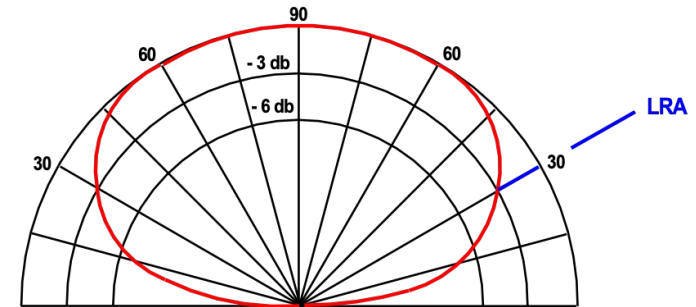
Band Closure For 80 Meter NVIS Antenna - continued



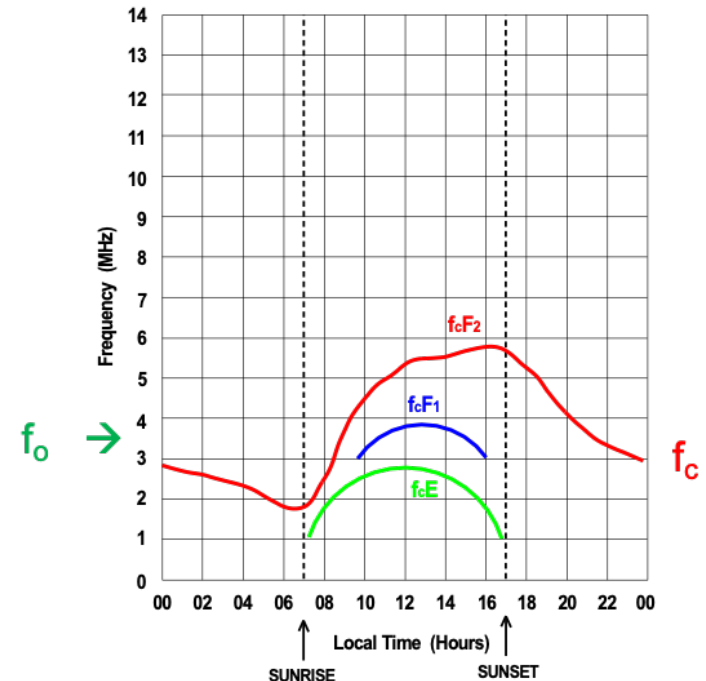
- The maximum usable frequency for communications (\sim FOT) falls below the 80 meter band (\sim 3.7 MHz) at a $f_c = 3$ MHz when using an NVIS antenna with an $E_m = LRA = 40$ degrees
- That is, an 80 m NVIS antenna can no longer be used for transmitting when f_c is below 3 MHz

Increasing The 80 Meter Operating Time

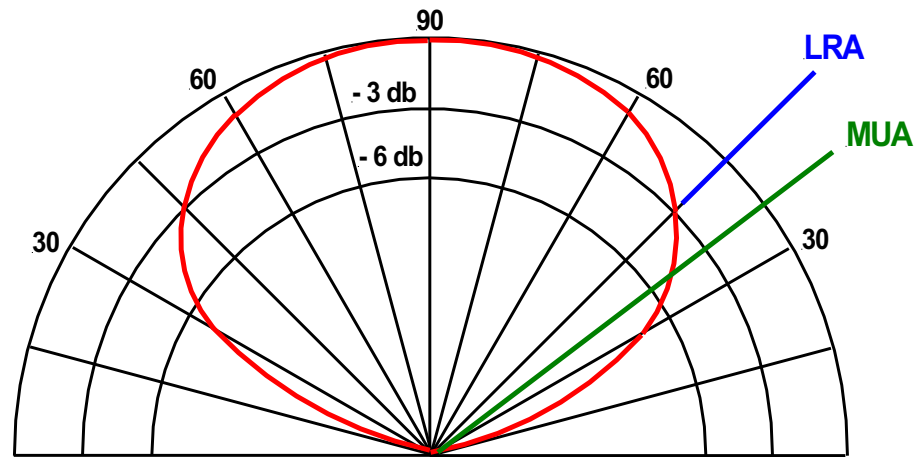
- The operating time of an 80 meter NVIS antenna during solar minimum can be extended beyond roughly 22:00 by
 - Using a higher antenna, and
 - Increasing transmitting power
- Increasing the height of the antenna from 1/8 to 1/4 wavelength above ground drops the antenna's LRA from roughly 40 to 30 degrees
- This allows the antenna to operate at a critical frequency down to approximately 2.4 MHz as illustrated in the previous slide
- Increasing the antenna's height allows operation to perhaps 2 AM in the morning



Critical Frequency - Winter Solar Minimum

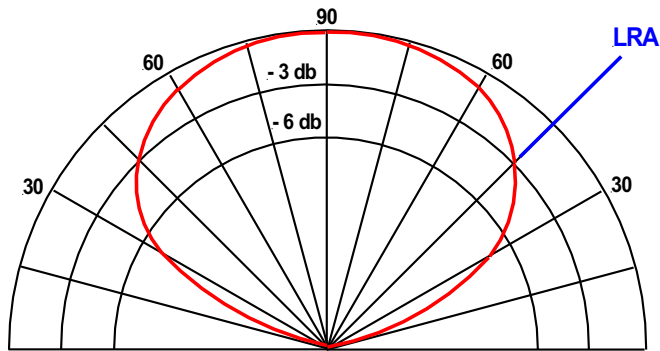


Increasing 80 Meter Transmit Power

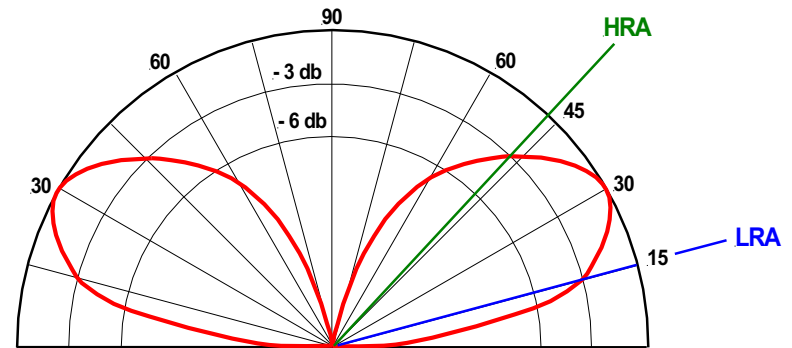


- While only a “sliver” of the antenna’s radiated power is useful when the antenna’s $LRA > MUA$
- Increasing transmitting power increases the amount of power radiated by that sliver
- A small amount of power ~ 10 watts can sustain successful communications out to a 1,000 miles or so
- Transmitting at 500 watts to get 10 watts of useful radiated power is not very efficient, but it can get the job done

80 Meter Vertical Antenna



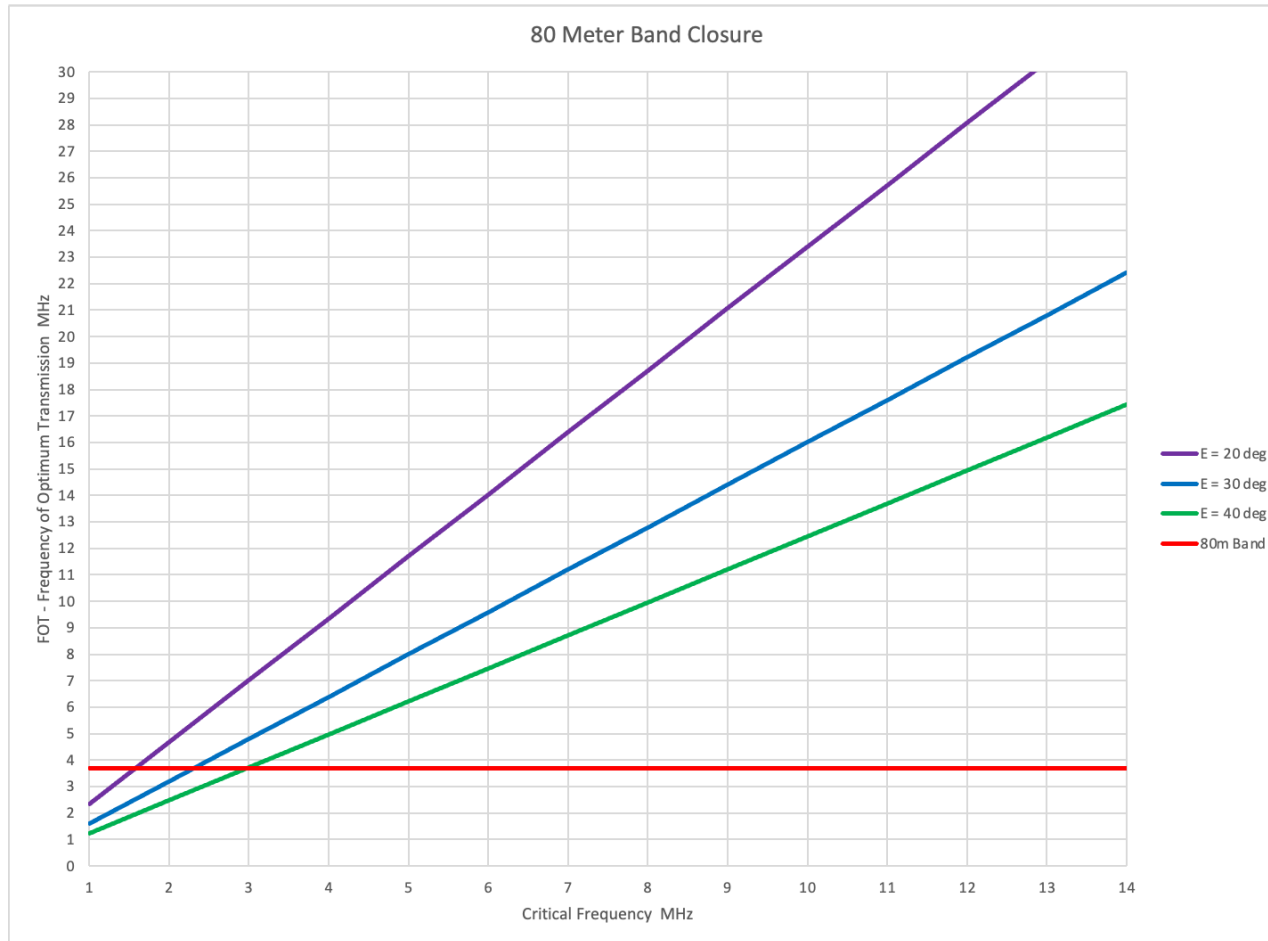
80 Meter NVIS Antenna.



80 Meter Vertical Antenna

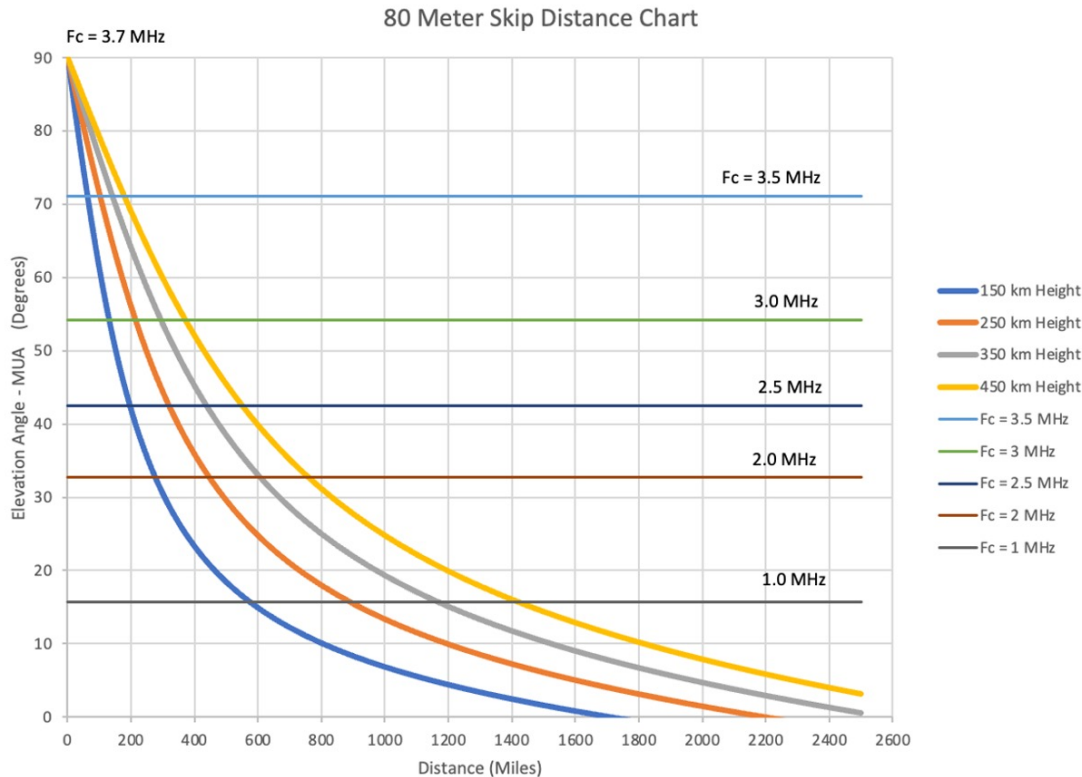
- An 80 meter vertical antenna may be a better antenna choice during solar minimum
- An 80 meter vertical antenna has a LRA of 15 to 20 degrees allowing it to operate at a critical frequency down to nearly 1MHz
- A vertical antenna is the only option for operating throughout the night during solar minimum
- However, the vertical antenna's Highest Radiated Angle (HRA) of only 50 degrees prevents its use as an NVIS antenna for reaching close in stations
- The HRA for an NVIS antenna is 90 degrees
- During solar minimum, a combination of both an 80 meter NVIS and 80 meter vertical is ideal

Band Closure For An 80 Meter Vertical Antenna



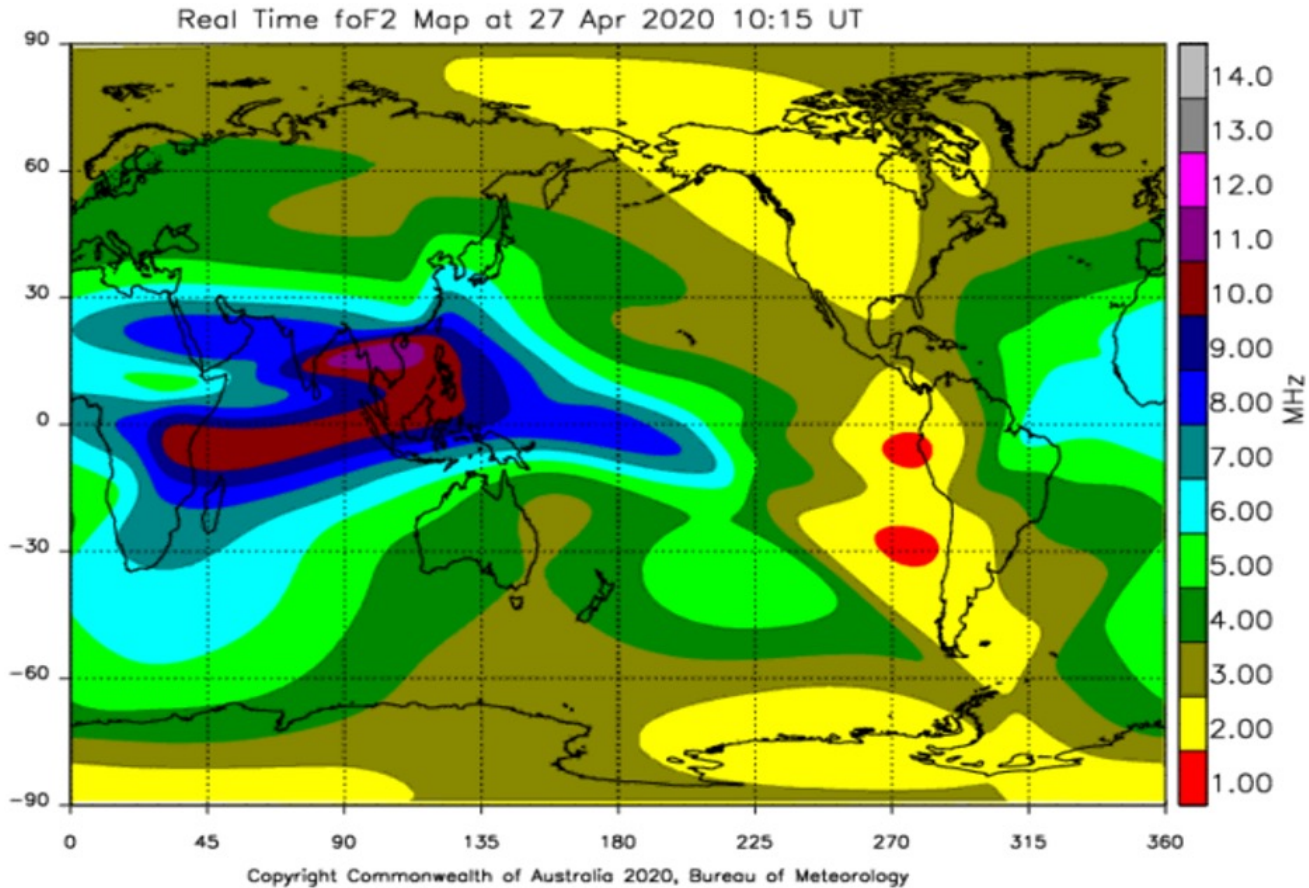
- The maximum usable frequency for communications (\sim FOT) falls below the 80 meter band (\sim 3.7 MHz) at a $f_c = 1.5$ MHz when using a vertical antenna with an $E_m = LRA = 20$ degrees
- An 80 meter vertical antenna can operate later into the night than an NVIS antenna

When An 80 Meter Skip Zone Is Present



- Skip distance can be estimated using the 80m Skip Distance Chart by first determining the current critical frequency using the Global Critical Frequency Map (see next slide)
- At a critical frequency of 2 MHz and a typical ionosphere F2 Layer height of 250 km
- The skip distance is determined by reading down to the Distance axis from the intersection of the 250 km curve and Fc = 2 MHz
- This skip distance is approximately 450 miles
- The MUA of 32 degrees for Fc = 2 MHz is too low for an NVIS antenna
- A vertical antenna will be required

Global Critical Frequency Map



- The above critical frequency map is for 10:15 UT (2 AM in the morning) on April 27, 2020 during solar minimum
- At this particular time the critical frequency above the United States was 2 MHz