H. Lawrence Serra, N6NC

1135 Torrey Pines Rd. Apt. 2C, La Jolla, CA 92037; **hlserra@gmail.com**

Why Summer 40 m Propagation Is So Good Between Japan and the US Pacific Coast

Summary of an investigation into the physical causes of enhanced 7 MHz summer trans North Pacific propagation.

For seven months I checked every source of data available, consulted RF, oceanographic and meteorological experts, researched and dismissed competing meteorological and RF theories, and concluded that enhanced 40 m CW summertime trans North Pacific propagation is the result of smooth sea RF reflection points under huge summertime Pacific high pressure areas

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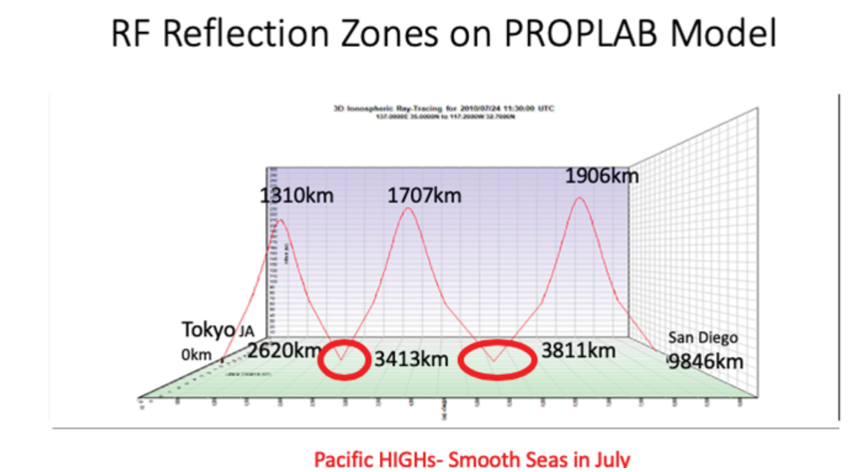

Figure 1 — *PROPLAB* 3-hop Tokyo – San Diego model for July 24,2010, with superimposed data.

CW Skimmer as a Propagation Tool

In 2008 Alex Shovkoplyas, VE3NEA, invented the *CW Skimmer* software. I saw the opportunity for a local skimmer to be an effective contest and propagation tool, so with an SDR I was set to monitor and log nightly 7 MHz CW signals received at my San Diego, California location. From San Diego, 7 MHz had always provided excellent nighttime propagation to DXpeditions on the Pacific Islands, so I was interested in HF propagation between San Diego and Japan. At the same time I designed and installed at my location, 700 yards from the Pacific Ocean, a 40 m 2-element parasitic vertical array aimed directly at Japan and the Asian coast, bore-sighted at 315°, and a switching network to feed the antenna to the SDR and *CW Skimmer* from 9 pm to 9 am local time to monitor nighttime CW signals from the Asian coast.

This was useful for a year, showing me occasional JA call signs received overnight across the Pacific. Then on a Saturday morning, July 24, 2010, I looked at the call signs collected overnight by *CW Skimmer* and discovered 141 JA call signs recorded between about 07:00Z and 15:00Z (12 am – 8 am PDT). 80% of them were in the 3 hours between 08:00Z – 11:00Z (1 am – 4 am PDT). I remember being astonished, because the *CW Skimmer* had never recorded more than a couple of JA 7 MHz call signs overnight, and I noted the event in memory.

Investigation

JE1CKA: I emailed contester Tack Kumagai, JE1CKA, to ask him why I received all those calls at one time. He said it was the date of the annual Japan summer domestic CW contests, but what astonished him was that 85% of the call signs were from 5 watt JA CW stations!

USN Radio Ops: I tried to locate retired USN radio operators who had sailed the Pacific in WWII to learn their anecdotal understandings of summertime 7 MHz propagation, but sadly most had passed.

Reverse Beacon Network (RBN): I checked the RBN data for July 24, 2010. My N6NC 141 RBN JA spots represented 14% of all RBN 7 MHz JA spots from all around the world on that date, an unusually large percentage. The average signal-to-noise ratio of those 141 reported JA call signs was 10.9 dB.

WSPR, PSK, GPS TEC Data: I examined data from *WSPR* and *PSK Reporters*, GPS satellite Total Electron Content (TEC) data, gray line enhancement and PMSEs. Specific data was either inapposite, or did not exist for July 2010.

VOACAP Propagation Data: *VOACAP* propagation data is available online to hams with interfaces such as Jari Perkiömäki's, OH6BG, app **voacap.com/hf/** and Alex Shovkoplyas', VE3NEA, *HamCAP* program **dxatlas.com/hamcap/**.

I studied *VOACAP* data. I used both ham interface programs and ran the *VOACAP* profile for 7 MHz (40 m) on July 24, 2010. To my surprise, the data showed the 7 MHz month of July propagation circuit reliability between Tokyo and San Diego to be between 90% and 100% for 5 – 6 hours/day based on years of *VOACAP* data.

K9LA *PROPLAB* Model

I corresponded with propagation guru Carl Luetzelschwab, K9LA, an RF engineer with industry experience and many amateur propagation experiments, to see if he had any idea what caused the trans Pacific propagation anomalies. Carl generally relies on the data from ionosondes located at the middle of propagation paths to determine what and how many ionospheric hops have occurred to complete the HF circuit, and he modeled for me in *PROPLAB* a 3-hop potential 7 MHz path (**Figure 1**).

So a *PROPLAB*-predicted 3-hop, 2 sea surface reflection path actually existed, and my 10.9 dB SNR average for the 141 JA call signs on July 24 was not entirely anomalous, but an unusually good time of the year for 7 MHz trans Pacific propagation.

Path-End Ionosondes

Unfortunately, there are no ionosondes located along the great circle path between San Diego and Tokyo across the North Pacific, depriving us of vertical ionospheric data along the path. I discovered that there were ionosondes located close to each end of the propagation path, so I checked the archives of the Wakkanai-Hokkaido, Japan and the Point Arguello/Vandenberg AFB (Los Angeles) ionosondes for data at each path end. I noted that virtually the entire North Pacific along the path was in the dark on that date; darkness generally reduces the MUF along the path.

The Wakkanai and Point Arguello ionosondes both reported vertical overhead MUFs of around 3.3 MHz, too low for 7 MHz propagation. However, I noticed at the bottom of the ionosonde report charts for July 24, 2010 that a table showed slant range MUFs based on low angle waves traveling long distances through a cumulatively denser ionospheric electron layer determined by the length of the hop. This scale showed at ~1550 km seaward from each coastal ionosonde — the midpoint of a ~3100 km hop — the MUF was as high as 12.4 MHz, good for 7 MHz propagation. The total electron density at 1550 km seaward from each path end caused a refraction in the ionosphere of the low angle 7 MHz HF wave back down toward the ocean's surface at a point 3100 km further seaward from both ionosondes.

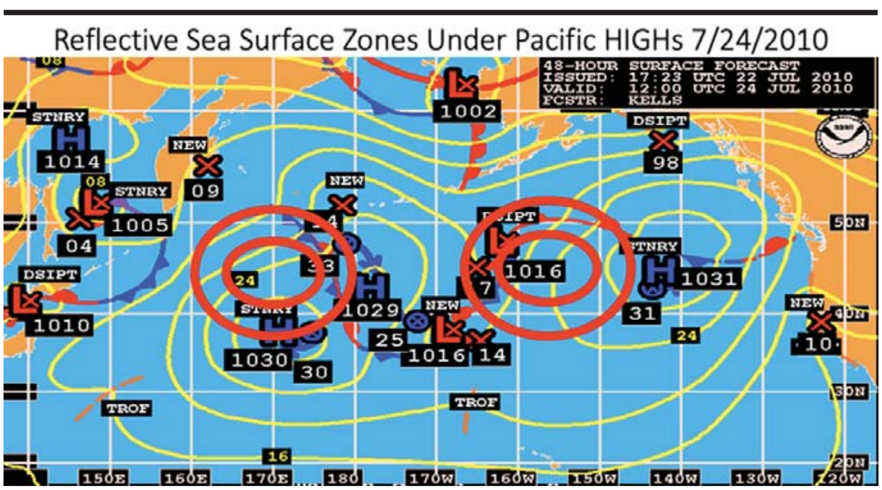

Figure 2 — The concentric shapes indicate RF graze zone / reflective sea surfaces on north Pacific synoptic weather chart.

RF waves refract in the ionosphere, and reflect from the ocean's surface. Refraction produces the offset image you see when you place a ruler in a glass of water. These slant range MUFs meant that with a similar middle hop, the 3-hop path completed and would connect the two hops emanating seaward from each coast.

PROPLAB Ray Trace Models

I returned to Carl's 7 MHz 3-hop *PROPLAB* model ray paths across the north Pacific on July 24, 2010. The three-hop model showed a 90%-100% reliable 7 MHz *VOACAP* circuit in July between Japan and the US Pacific coast based on years of *VOACAP* data. But due to ionospheric/atmospheric absorption, and likely rough sea reflection losses, I initially thought the 3-hop path across the Pacific was unlikely. That is, until I went back and reviewed the detail of the *VOACAP* data which showed the takeoff angle (TOA) of the strongest signals for the date, time, and ionospheric condition. The *VOACAP* TOA graphs showed maximum transmitted signal strength at 8° and 10° elevation TOAs. The *EZNEC* model of my two element, 40-meter parasitic array aimed at Japan showed a maximum signal elevation angle of 10° and +8 dBi gain.

While there is no direct correlation between TOAs and AOAs (angles of arrival), in discussions with Carl, K9LA, we concluded that the low angle, strongest TOAs from Asia usually arrive strongest here in San Diego at close to the same low AOAs — within ±0° to 2°. In this case both maximum signal TOAs in Japan (8° and 10°) and the 10° maximum signal elevation angle of my vertical array in San Diego were the same. I concluded it is unlikely for a 10° TOA to be received at a substantially different AOA, barring the infrequent occurrence of certain atmospheric and meteorological conditions, which did not exist on July 24, 2010.

Interferometer

To verify the assumption about TOAs and AOAs, I created a make-do interferometer with which to gauge the AOA of HF RF signals at my QTH. Over several months the interferometer was tested on shortwave signals from around the world. Remarkably, almost uniformly, the reported AOAs of these HF signals were within 0° to 2° of the reported *VOACAP* TOAs at the transmitter locations, confirming the 10° TOA and AOA of the JA RBN spots.

Smooth Sea, Calm Water RF Reflections

In a 2017 *CQ Magazine* article **[1]**, David Day, N2DAY, suggested that data analysis showed a likelihood of stronger US ham 160 m CW spots recorded in Europe when the Atlantic Ocean wave heights were less than 3 m (10 ft) high. Earlier US Navy and other research papers generally did not address smooth sea propagation under summer North Pacific Ocean high pressure centers, but the Day article tended to confirm my guess about smooth sea states enhancing signal strengths.

I found recent papers **[2]**, **[3]** dealing with the issue of the RF reflectivity from smooth or rough ocean surfaces. Li **[2]** contended that for a smooth ocean surface, RF waves refracted down from the ionosphere were reflected as specular waves off the ocean surface — that is, near perfect reflection, angle of incidence equals angle of reflection — and incur virtually no loss in reflection off the smooth ocean surface. Wang **[3]** shows the same result — near lossless HF wave reflections off a smooth sea surface, and zero loss in the ionosphere.

Specifically, Figure 3 in **[2]** gives the reflection coefficient for the calm sea vs. frequency. At 7 MHz, it's about 0.975. Thus, 20log(0.975) = –0.2 dB. For the rough sea in Figure 4 of **[2]** the reflection coefficient at 7 MHz is about 0.5, so 20log(0.5) = –6 dB. That shows 5.8 dB more loss per reflection from a rough sea compared to a smooth sea **[4]**. Smooth sea could make the difference for the propagation of weak JA CW signals on July 24, 2010.

All this suggested Carl's *PROPLAB* three-hop 7 MHz path for July 24, 2010 was increasingly likely. But of course, this assumed smooth sea at the ocean reflection points of the HF waves. How could one ever assume that anything as big as the largest ocean in the world would have smooth sea areas?

Mariners' Observations of Dead Calm Under Summer North Pacific Highs

I discussed my findings with a 40-year sea-going captain ham friend, and we both concluded that a physical cause for the propagation most likely was the summer North Pacific highs. Any sailor who has participated in the summertime TRANSPAC Race from Los Angeles to Hawaii knows that the easterly-most summertime North Pacific high is the bane of racing sailors, because the high(s) — oval blobs sometimes stretching 800 miles wide on an E-W axis — must be skirted in order to avoid sailing through their middles where the water is often dead calm, mirror-flat with zero wind. Quoting from **[5]**:

"Within this high pressure area, winds typically are light or nonexistent. In June or July, for example, winds outside the high might range from 10 to 25 knots, whereas winds inside would range from 0 to 10 knots, the lightest wind strengths being positioned near the center. Indeed, when our sailboat has been positioned near the center of the high, we've seen a mirror-smooth, seemingly painted ocean. Sometimes the only thing left to do is to swim in 18,000 feet of ripple-less, crystalline water."

Sailing through these annually occurring highs is likely why Ferdinand Magellan named it the "Pacific" Ocean. See, generally **[6]** about summertime North Pacific wind conditions.

I compared the highs to Carl's *PROPLAB* three-hop, 7 MHz trans-Pacific path and found them to closely coincide on a slightly south-skewed path (**Figure 2**).

HF great circle propagation paths can often be skewed ±50°off the center of the path **[7]**. From **[8]**, "Evidently, with the path under midnight conditions, ionization has diminished to where the great circle signal is no longer supported, but a signal from a scatter region to the west is capable of being propagated."

Multiple Diffuse Scattering

Even more likely, the low sea state on July 24, 2010 could likely have enhanced the specular RF wave arriving at San Diego by means of multiple diffuse scattering, whereby the received signal is the sum of all possible paths — not only the specular wave.

From **[9]**, "Multiple diffuse scattering can occur for every launched wave that reflects from the ionosphere; the received signal is the sum of all possible paths, such as the one shown in orange, not just the specular reflected ray shown in red." See **Figure 3**.

Path Wave Heights

The National Weather Service (NWS) archive charts showed model-predicted maximum wave heights of 1.5 m (5 ft) during that time, see **Figure 4**. But the

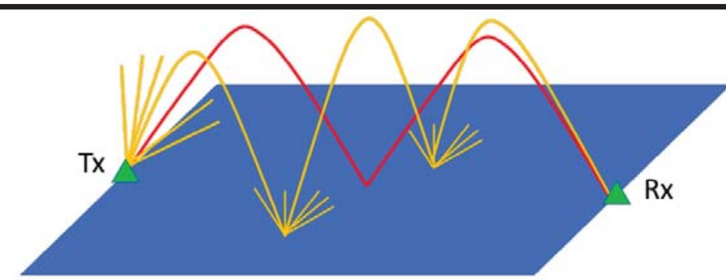

Figure 3 — Illustration of multiple diffuse scattered waves on a 2-hop model.

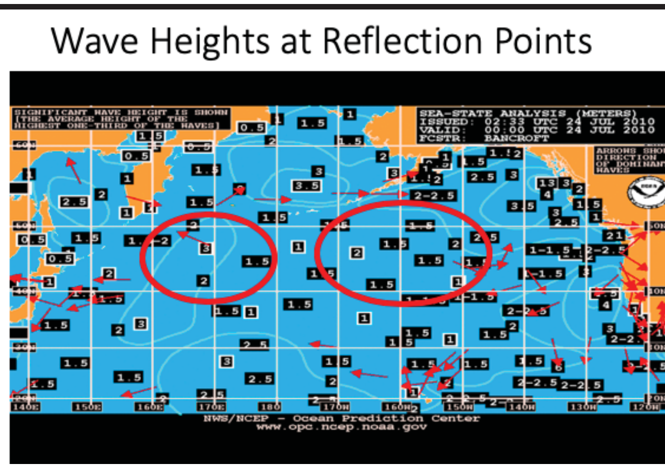

Figure 4 — NWS archival wave height chart for July 24, 2010.

actual wave heights were even lower than 1.5 m. The NWS notes state that its wave heights were calculated to warn mariners of the highest potential wave size they might encounter 48 hours in the future, and that the data for the wave height modeled predictions consider only the top one-third of wave heights likely for that period. This calculation excludes data of two-thirds of the wave heights possible, which are much lower than the 1.5 m shown on the NWS prediction chart. Sailors know that wind speeds and their resultant waves are highest during the day because the addition of solar radiation energy increases air movement, and that wind speeds drop at sunset and overnight in what sailors call the "Evening Lull." The July 24, 2010 event was at night over the darkened North Pacific. Evaluating all this in context convinced me that the NWS-modeled possible maximum wave heights under those highs likely exaggerated the actual surface wave heights between Japan and San Diego during the dark North Pacific night on July 24, 2010.

As we guessed, archived satellite coverage of the mid-North Pacific in 2010 is scanty, but my SIO classmate Gabi integrated satellite data of North Pacific wave heights near the two *PROPLAB* ocean reflection points at 2.5 hours after the July 24, 2010 propagation event. The data showed actual wave heights — "ground truth" — of between 0.77 m to 1.1 m (2.5 ft to 3.6 ft), with the majority of wave heights around 1.0 m (3.3 ft).

Eureka! That is a smooth sea for any ocean. This data confirmed that the NWS wave height prediction of 1.5 m was at least 33% higher than actual wave heights on July 24, 2010. So I believe I found some answers to what enhanced the 7 MHz CW propagation across the North Pacific on July 24, 2010 and allowed all those weak JA call signs to be copied by my San Diego *CW Skimmer*: smooth sea reflections of refracted specular and multiple diffuse scattered 7 MHz rays under North Pacific high pressure areas.

Data Checks

See **Table 1**. *VOACAP* / NWS: to be sure, I researched the 12 year period 2010 to 2021 in the NWS archives for the locations of the North Pacific highs on each July day of the JA domestic CW contests, and the highs were there each year, but not in winter where in January 2010 lows with 7 m (23 ft) wave heights and 45 kt (52 mph) took their place — rough seas! The *VOACAP* data showed only one hour of 90% 40 m propagation at 16:00Z (08:00 PST) for January compared to 5 – 6 hours in July.

RBN: I researched the RBN archives again for reported high JA spot numbers by west coast stations on the days of the July JA domestic CW contests each year from 2010 to 2021. I could find no other southern California *CW Skimmer* reports besides my own, so I relied on regular RBN 40 m reports from Robert Wilson, N6TV, in Santa Clara, CA (LAT 37° N) and Jack Reed, WA7LNW, (also LAT 37° N) in mile-high, radio-quiet Utah. Both *CW Skimmers* reported regularly over the 12 years. Of twelve month-of-July 7 MHz JA high spot count days over 12 years, six showed NWS corrected day of "*seasanal*" wave heights of 1 m or less, three of 2 m or less, two less than 3 m, with one outlier.

Ap/Kp/Wave Heights: I checked the space weather Ap/Kp indexes and wave heights for the July dates each year from 2010 to 2021. For the July high JA RBN spot dates there was a correlation with Kp index values between 0 and 1.7 (Kp range of 0 – 3) and/or NWS-reported wave heights of 2 m or less (likely corrected ground truth wave heights of 1.34 m or less), but no correlation with any Ap index values (Ap range of 2 – 15).

Conclusion

It took a decade, but I believe I've solved the mystery of the normally good, but sometimes superb, annual summertime 7 MHz propagation across the North Pacific. What I experienced on July 24, 2010, and what other western US stations experienced over 12 years, was regular good 7 MHz summer propagation across the North Pacific enhanced by the presence of the relatively smooth ocean surfaces below the regularly occurring Pacific highs. The smooth sea reflections likely reduce loss and produce composite stronger RF signals at the path end than rougher seas would produce.

Contributors

The author acknowledges and thanks RF engineer Carl Luetzelschwab, K9LA; meteorologist Jim Bacon, G3YLA, of the UK MET (ret.); EE and Oceanography Prof. Gwyn Griffith, G3ZIL, of the UK NOC (ret.); Univ. of Scranton EE Prof. Nathaniel

Table 1 – Tabular data of RBN western US-JA 7 MHz RBN spots 2010 to 2021

(a) RBN US West Coast JA Spots.

(b) Great Circle Pacific Wave Heights (NWS Maps & Satellite).

Pacific highs are present in all data.

Year	*(a) WA7LNW*	*(a) N6TV*	*(a) N6NC*	*(a) N6WIN / W6YX*	*(b) Wave Heights*	*10.7 cm SFI*	*SSN*	*A-Index AP*	*K-Index Kp1*
2010 7/24	N/A	N/A	141		0.77m-1.0m (Satellite data)	85.5	47	4	1.7
2011 7/23	172	N/A	N/A		2.5m-4.5m	86.3	43	7	2.3
2012 7/21	76	226	33		2.0m	104.6	29	8	2.3
2013 7/27	187	N/A	96		1.0m	109.3	68	9	2.7
2014 7/26	168	N/A	3		2.0m-3.0m	114.6	58	6	1.3
2015 7/25	128	N/A	N/A		1.0m	93.7	34	7	2.3
2016 7/26	58	297	N/A		1m -2m	88.9	27	7	2.0
2017 7/22	1	243	N/A		1m	90.4	0	15	3.0
2018 7/21	342	410	N/A	N6WIN, 236	2m	70.2	12	10	1.7
2019 7/20	128	115	N/A		0m-0.5m	68.3	0	2	0
2020 7/18	151	96	N/A		2m-3m	68.1	0	3	1.3
2021 7/17	269	51	N/A	W6YX , 377	1.0m	78.1	48	3	1.0

Frissell, W2NAF; Distinguished Prof. of Oceanography Lynne Talley, and Corey Gabriel, PhD JD, of Scripps Institution of Oceanography/UCSD; NOAA/Southwest Fisheries oceanographer and data analyst Gabriel Arce; EE Prof. Nozomu Nishitani of Nagoya University in Japan; Manuel Cervera, PhD, and Prof. Stuart Anderson, Adelaide Univ., consultants to Australian MOD, for their guidance, comments, research and data contributions to the final form of this article.

HL Serra, N6NC, has been a licensed amateur since 1959. He has held a USCG Master's license, served in the US Merchant Marine (1964-65) and the US Navy (1968-70) as an OOD, navigator and naval intelligence officer in Vietnam and Cambodia. He has sailed the Atlantic and Pacific Oceans, the Caribbean Sea, sailed to all the countries of the Western Pacific Rim, transited the Pacific from Japan to San Diego, and transited the Panama Canal. In 2009-2011 he quarterbacked the successful legal defense of San Diego radio amateurs against a proposed ordinance intended to prevent the erection of HF antennas in the City of San Diego. His strategy was adopted by the ARRL and serves as the template for defense against similar local measures. He retired as a practicing lawyer and law professor in 2013, and in 2016 earned a masters degree from Scripps Institution of Oceanography/UCSD, with an interest in the physical causes of meteorological and climate events. He has published articles in QST *and* NCJ *on antennas that he designed and built, and he assembled and captained the 6E2T contest team that won the 1995 ARRL DX CW Contest (DX WORLD M/2 class) from Ensenada, Mexico. Since then he contests with the NX6T team remotely to the WA6TQT Anza Radio Ranch contest station.*

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