T62-S-1

SEA GAIN

Randy Seaver, Chula Vista CA, USA

1. INTRODUCTION

Pat Martin in Seaside, Oregon hears many Trans-Pacific stations that other West Coast medium wave DXers seldom hear - gems from the Pacific Islands, the Philippines, low power Asians, and rare Australians.

Mark Connelly in Massachusetts often hears Trans-Atlantic stations that no other East Coast medium wave DXer reports - low powered Europeans, Middle East stations, exotic African stations, etc.

Richard Wood in Hawaii hears medium wave stations from all over the world - Europe, Africa, Asia, Oceania, the Americas.

What is the difference between these DXers and others? Do they have superior receivers, antennas, or other equipment? Are they more persistent than others? Are they language experts capable of picking out details that some other DXers miss? Does their location on the edge of a continent or in the middle of the ocean reduce noise levels or co-channel interference? These factors probably do contribute to their long-term success and reputation as excellent DXers.

I believe that one other factor is involved - their proximity to the sea. Each DXer mentioned above lives very close to the ocean, with an open expanse of 180 degrees or more. Most of the DX loggings of long distance, high quality medium wave receptions come from DXers who DX from near the sea, and most of their exotic receptions come from the direction of open expanse toward the ocean.

I obtained an article by Knight and Thoday (1969) entitled "Influence of the ground near transmitting and receiving aerials on the strength of medium-frequency sky waves" (Proceedings I.E.E., volume 116, no. 6, June, 1969, pp 911-919) from Dr. Knight of the BBC several years ago. The article describes the theoretical basis of ground loss for a transmitter or receiver, the variation of ground loss with variation from the sea, and the effect of Earth curvature and irregular terrain. Some experimental data is compared with the theoretical data to validate the hypothesis that proximity to the sea enhances signal strengths of medium wave stations, especially at low elevation angles.

The abstract of the article is of interest:

" The strength of low-angle sky waves radiated by a medium-frequency aerial depends on the conductivity of the ground extending for many wavelengths in the direction of propagation. The field strength is greatest if the aerial radiates over open sea from the coast, and falls to a limiting value as the distance between the aerial and the sea increases. Measurements confirming the theoretical variation of field strength with distance from the sea are described, and the effects of ground and ionospheric irregularities are discussed. "

The remainder of this article will provide some of the experimental data and conclusions found in the Knight article, plus some other material found in PoKempner (1980) concerning the practical methods of calculating sea gain.

2. BACKGROUND

The conductivity of the ground near the transmitter of the medium wave station and near the receiver plays a very important part in the field strength of the station observed at the receiver. This is especially true for long distance, low elevation angle propagation of vertically-polarized waves, which is the predominant mode of reception on medium wave, according to Knight and others.

In the figures and discussion presented below (most of which is taken from Knight and Thoday (1969) and PoKempner (1980)), the relative field strength and the losses in deciBels are intermingled. Figure 1 shows the relationship between relative field strength and loss in deciBels. The relative field strength is 1.0 for no loss, .5 for an absolute field strength one half of the no loss value, etc. The loss in deciBels is related to the relative field strength by the equation:

$$dB = 20 \log_{10} r \qquad (1)$$

where r is the relative field strength. Consequently, for a relative field strength of 0.5, the dB loss is 6 dB, for r=0.25, the dB loss = 12 dB, for r=0.10, the dB loss = 20 dB.

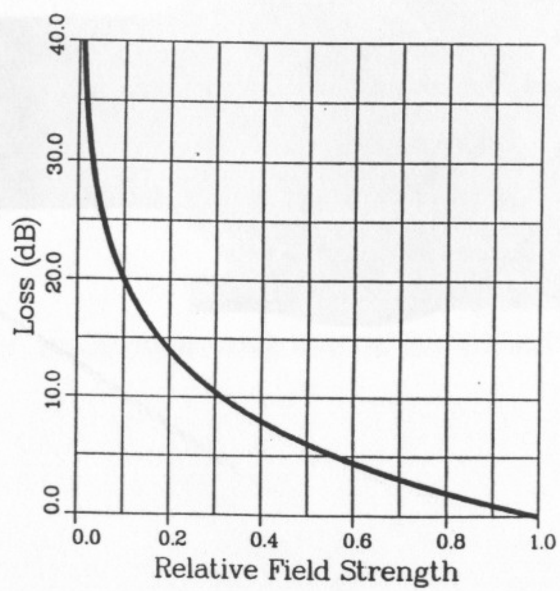

FIGURE 1. Decibel Loss vs. Relative Field Strength

Figure 2 shows the ground loss for short vertical antennas (and small loop antennas for low elevation angles) for sea water (conductivity of 4 S/m (Siemens per meter), for good ground (.01 S/m) and poor ground (.001 S/m), as a function of elevation angle to the horizontal for a wave frequency of 1 megaHertz. This data was obtained from Knight (1969) curves.

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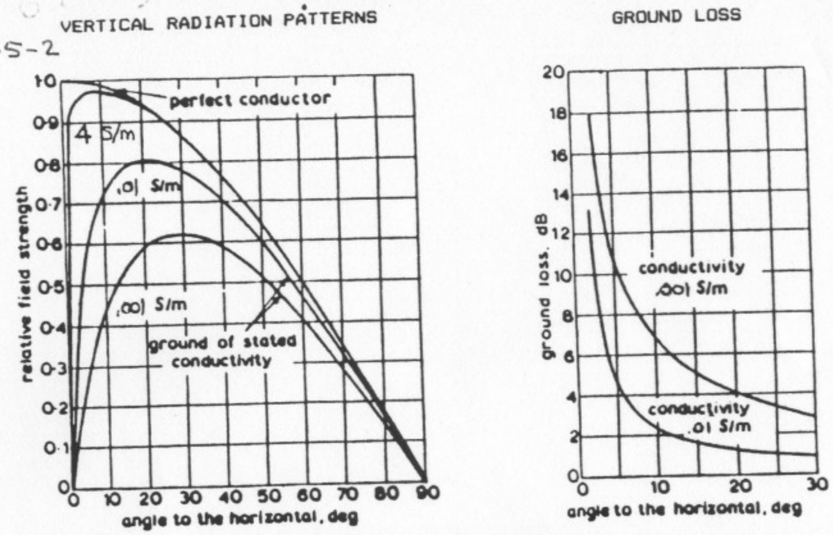

FIGURE 2. Vertical Radiation Patterns and Ground Loss for Short Antennas (Frequency = 1000 kHz)

Knight and Thoday (1969) presents the theory for a short vertical antenna a distance r from a straight coastline, as shown in Figure 3. It is immaterial whether the antenna transmits or receives because of the principle of reciprocity; the antenna length does affect the antenna gain, but that is another subject.

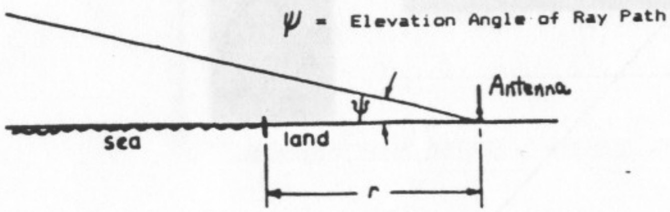

FIGURE 3. An Antenna Near a Coastline

Figure 4 shows the theoretical variation in field strength as a function of distance from the coast for four angles of arrival and for two ground conductivities (good ground, .01 S/m, and poor ground, .001 S/m). At large distances from the coast, the field strength tends to become asymptotic to the ground loss from Figure 2. It is apparent that the transition from sea to land conditions occurs over many wavelengths, especially with low angles of elevation. The potential sea gain is greatest for the lowest elevation angle and sites with poor conductivity. The theory is believed to be valid for directions within 70 degrees of the normal to the coastline, provided the distance from the coast is measured in the direction of propagation; further, it is believed to be valid for irregular coastlines. The question of hills, mountains, canyons, etc. between the antenna and the sea is not addressed in Knight and Thoday (1969). It is likely that the sea gain will be reduced by the presence of uneven ground between the antenna and the sea. This would also apply to the situation where there is land offshore; the sea gain will be reduced if there is a land - sea - land - sea path.

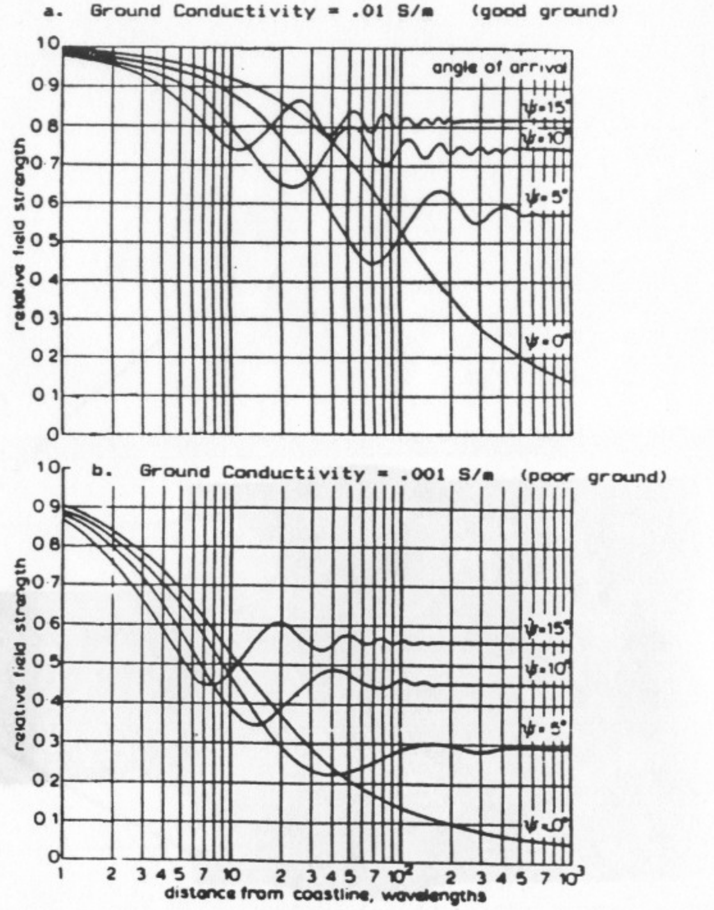

FIGURE 4. Variation of Field Strength with Distance from a Coast (Frequency = 1000 kHz)

3. EXPERIMENTAL DATA

Knight and Thoday (1969) describe an experiment conducted in Southern England along a great circle path to Rome-845, measuring field strengths simultaneously with calibrated, identical equipment at inland and coastal sites. This eliminated most of the uncertainty resulting from differences in propagation losses due to frequency, aerial gain, ionospheric losses, etc. The Rome-845 transmission path was selected because it was a clear channel, with a sky wave predominantly a single hop mode at a low elevation angle of about 4 degrees. Figure 5 shows a map of the receiving sites on a radial extending about 100 km inland from the coastal site at Pevensey. The ground inland is flat for a considerable distance, and there were no cliffs at Pevensey.

The field strength was measured simultaneously at the coastal site and each of the inland sites in turn and statistically correlated over one hour periods. Part of the field strength reduction observed was attributed to the greater distance of the inland sites from the transmitter, so a correction based on EBU/CCIR propagation curves were applied.

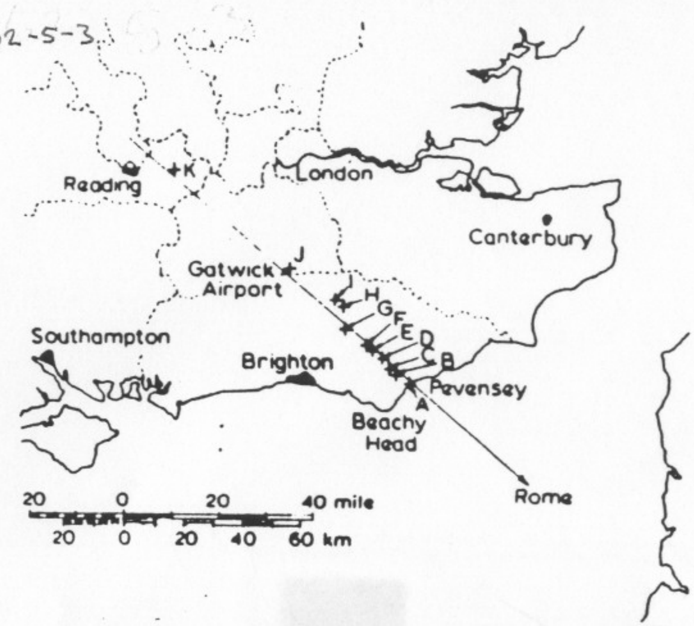

FIGURE 5. Map of Southern England Showing Measuring Sites

Figure 6 shows the results of the corrected measurements, and their 95% confidence limits. Theoretical curves for ground conductivities of .005 S/m and .01 S/m are also shown in Figure 6; these are believed to be the upper and lower ground conductivity limits for the area tested. Part of the theoretical curve for .02 S/m is also shown, since the first 10 km inland is a marshy area with that approximate ground conductivity. The theoretical curves are for an assumed elevation angle of 4.3 degrees, which was derived from ray-tracing computations.

NOTE: Letters refer to sites shown on Figure 5
Vertical lines indicate 95% confidence limits
——— Theoretical ground loss
o Measured ground loss

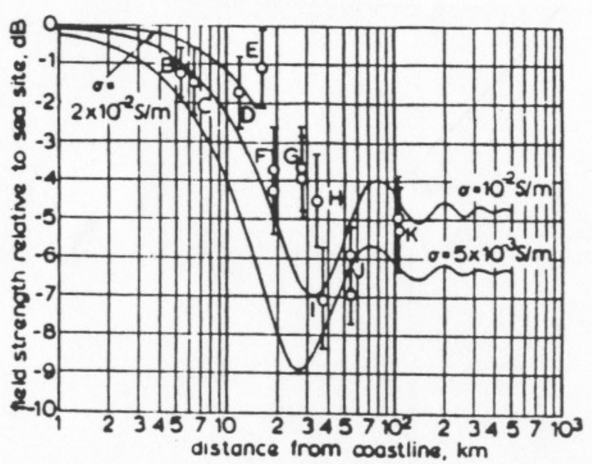

FIGURE 6. Comparison of Theoretical and Measured Ground Loss (Rome-845 Path)

4. PRACTICAL APPLICATION

PoKempner (1980) provides some empirical relations to calculate sea gain, based on the Knight and Thoday (1969) work. The relations include the sea gain when the propagation path is unobstructed in the direction of propagation, and corrections for distance from the sea and for the effects of the width of one or more sea channels, or the presence of islands.

The additional signal gain for a transmitter or receiver near sea water (but not fresh water) is given by the equation:

$$G_S = G_0 - c_1 - c_2 \qquad (2)$$

where: G_0 is the gain when the terminal is on the coast and the sea is unobstructed by land. Figure 7 defines G_0 as a function of path distance.

c_1 is the correction to take account of the distance between the terminal and the sea. The equation for c_1 is:

$$c_1 = \frac{s_1}{r_1} G_0 \qquad (3)$$

where s_1 is the distance of the terminal to the sea measured along the great-circle path

r_1 is the factor: $1000\ G_0^2 / 1.4\ (f)$

f is the wave frequency in kiloHertz.

c_2 is the correction to take account of the width of one or more sea channels, or the presence of islands. The equation for c_2 is:

$$c_2 = \left(1 - \frac{s_2}{r_2}\right) G_0 \qquad (4)$$

where s_2 is the distance of the terminal to the next section of land, measured along the great circle path.

r_2 is the factor: $1000\ G_0^2 / 1.2\ (f)$

The equation for the c_2 factor applies if there is only one sea channel, or if more than half the distance between s_2 and a great circle distance equal to r_2 is occupied by land. If less than half the distance between s_2 and r_2 is occupied by land, then c_2 is set equal to zero.

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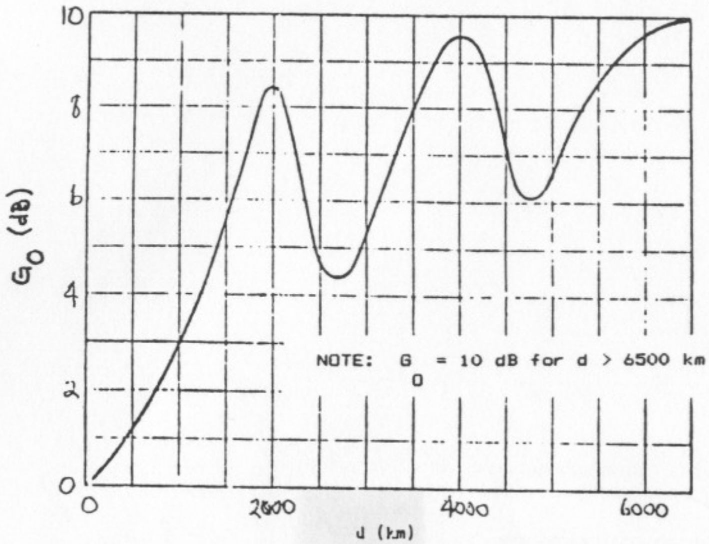

FIGURE 7. Sea Gain (G_0) for a Single Terminal on the Coast

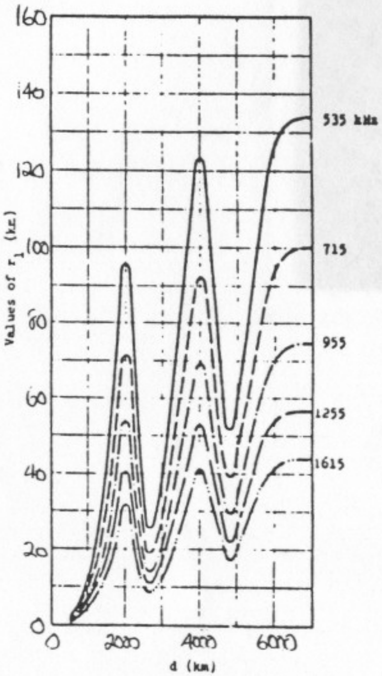

FIGURE 8. Values of r_1

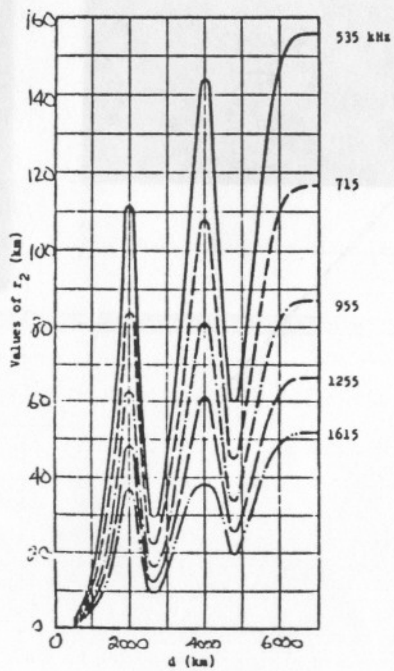

FIGURE 9. Values of r_2

Figure 8 shows values for the sea gain factor r_1 calculated for different values of path distance (d) and frequency. The distance r_1 is the maximum distance for any sea gain. The curves undulate due to the variation in the sea gain factor G_0.

Figure 9 shows values for the sea gain factor r_2 calculated for different values of path distance (d) and frequency. The distance r_2 is the minimum distance for which the presence of offshore land affects the sea gain.

The total sea gain for a particular path can be calculated if the path great circle distance in kilometers, the wave frequency, the distance from the terminal to the sea and the distance of the terminal to the next section of land is known by subtracting the factors c_1 and c_2 from the basic sea gain factor G_0.

The procedure for calculating the sea gain is thus:

a) Estimate the basic sea gain factor G_0 from the path distance, d, from Figure 7.

b) Estimate the distance r_1 for the given path distance (d) and the frequency from Figure 8.

c) If there is a sea channel, then estimate the distance r_2 for the given path distance and frequency from Figure 9.

d) Calculate the factor c_1 from equation (3) above for the distance from the antenna to the sea (s_1), r_1 and G_0.

e) If there is a sea channel, and the offshore land width is more than one-half of the distance r_2, calculate the factor c_2 from equation (4) above for the distance from the antenna to the offshore land (s_2), r_2 and G_0.
If c_2 is less than zero, then set c_2 = 0.

f) Calculate the sea gain G_S from equation 2, knowing G_0, c_1 and c_2.

As an example, Figure 10 shows a scaled map of the San Diego area, and my location in Chula Vista. For a path to 2ZB-1035 in Wellington, New Zealand, the path distance is about 10,800 km on a 225 degree bearing. The distance to the sea on this bearing is about 12 km, and there is no offshore land in this direction. The estimated sea gain parameters for this path are:

G_0 = 10.0 dB (from Figure 7 for d=10,800 km)

r_1 = 70 km (from Figure 8 for d=10,800 km and f=1035 khz)

s_1 = 12 km

c_1 = (12)*(10.0)/(70) = 1.7 dB

c_2 = 0 dB, since there is no offshore land.

The sea gain is thus:

G_S = 10.0 - 1.7 - 0.0 = 8.3 dB

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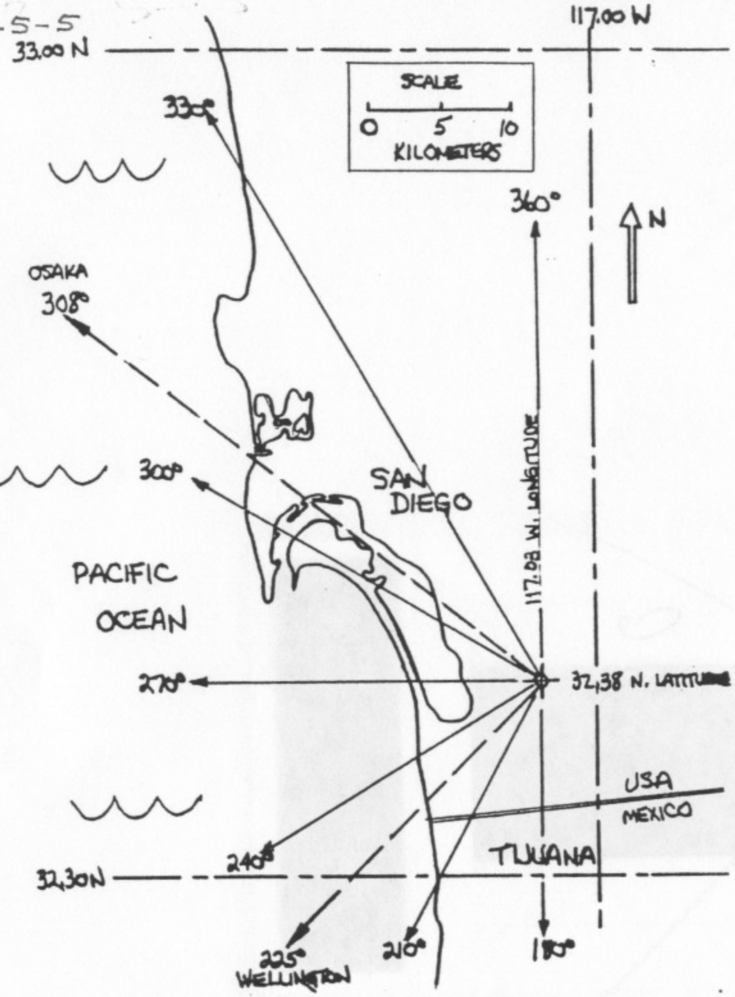

FIGURE 10. San Diego, California Map Showing Example Cases

As a second example, consider JOBB-828 in Osaka, Japan; the path distance is about 9400 km on a 308 degree bearing. The distance from my location to San Diego Bay is about 9 km on this bearing, but land is encountered at 20 km, and open ocean at 26 km. The estimated sea gain parameters are:

G_0 = 10.0 dB (from Figure 7 for d=9,400 km)

r_1 = 88 km (from Figure 8 for d=9,400 km and f=828 khz)

s_1 = 9 km

$c_1 = (9)*(10.0)/(88) = 1.0$ dB

r_2 = 103 km (from Figure 9 for d=9,400 km and f=828 khz)

s_2 = 20 km

$c_2 = (1.-20/103)*(10.0) = 8.0$ dB

However, since the intervening land is only 6 km wide, which is less than one half of r_2, the value for c_2 is set equal to zero. The estimated sea gain is thus:

$$G_S = 10.0 - 1.0 - 0.0 = 9.0 \text{ dB}$$

A case could be made that since San Diego Bay is shallow, the sea gain should be calculated for the distance s_1 = 26 km (open sea), which results in c_1 = 3.0 dB, and a sea gain of 7.0 dB.

The effects of distance from the antenna to the sea is the major factor in sea gain. The table below shows the sea gain for the Chula Vista to Osaka-828 path (assuming a variable distance and no offshore land, with r_1 = 88 km):

Distance s_1 (km)	Sea Gain (dB)
0 km	10.0 dB
10 km	8.9 dB
20 km	7.7 dB
30 km	6.6 dB
40 km	5.5 dB
60 km	3.2 dB
80 km	0.9 dB

The effects of frequency are significant, as shown in the table below for the Chula Vista to Osaka path (assuming s_1 = 26 km and no offshore land):

Frequency (khz)	r_1 (km)	Sea Gain (dB)
535 khz	135 km	8.0 dB
828 khz	88 km	7.0 dB
1255 khz	57 km	5.3 dB
1610 khz	44 km	4.1 dB

It is evident from the equations, curves and examples presented above that sea gain will be highest for path distances greater than 6500 km, for antennas very near the sea, and for low medium wave frequencies, with no offshore land. Substantial sea gain can be accounted for even at distances of 40-60 km from the sea, especially at low frequencies.

5. CLOSURE

This article has described the theoretical basis for the sea gain phenomena, described some experimental data that validates the theory, and presented a practical method for estimating sea gain. All of this information was obtained from Knight and Thoday (1969) and PoKempner (1980), except for the examples. The papers should be consulted for additional background, theory and discussion if the reader desires more information. I have a limited number of the Knight and Thoday paper available for an stamped self-addressed envelope (44 cents, please).

6. REFERENCES

Knight, P. and Thoday, R.D.C., "Influence of the ground near transmitting and receiving aerials on the strength of medium-frequency skywaves", Proceedings I.E.E., vol. 116, no. 6, June, 1969, pp 911-919.

PoKempner, Margo, "Comparison of Available Methods for Predicting Medium Frequency Sky-Wave Field Strength", NTIA Institute for Telecommunication Sciences, Boulder, Colo., NTIA Report 80-42, June 1980. (Available from NTIS, Accession number PB 211444)