

Effective Siting of SeaSonde Antennas

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A. Long Cables or Long Span of Land to the Water -- Which Is Better?

Background:

The ideal situation for siting any HF radar is having the antennas and the environmentally sheltered, powered electronics all located close to the water line. Often the ideal is not possible, and the sheltered electronics must be located several hundred meters back from the coast. When this is the case, there are two undesirable impacts.

- If the antennas are placed near the water, then the cable runs from the electronics are long. This means attenuation within the cables, due to ohmic losses. On transmit, the power lost in the cables directly limits the maximum range of the radar.
- If the antennas are mounted near the electronics so that the cable runs are short, then the signal must propagate across a large span of ground to get to the water. The attenuation over land diminishes the echo strength, and like the cable losses, limits maximum radar range.

Both of these effects are very frequency dependent. And, the loss mechanisms in the cables and land attenuation come from different mechanisms, and so one is not equal or even directly proportional to the other.

The Issue: Which is better, long cables and a short span between antenna and water, or the other way around? And as a more general question, how much loss does one suffer if forced to operate from a building further away than desired? What are the tradeoffs?

The Challenge: Find the better alternative: long cables or long land span to the water, for a given radar frequency and given distance between electronic equipment and water.

Summary of Methodology Used:

- Cable losses are simple. Every cable manufacturer provides losses for a given cable as a function of frequency, as dB per 100 feet (or 100 meters). For example,

RG-8 (e.g., Belden 8214) has 1.0 dB loss per 100 meters. Double that cable length and the loss in dB doubles also.

- Ground wave attenuation is not so simple. The present scenario is referred to as "mixed-path", because part of the surface-wave path is over the sea and part over land. We want to calculate how much the signal seen far out at sea is reduced as we move the transmitter back from the coast edge, using the coast-edge signal strength as the normalizing reference.

- The long part of a path from the coast out to a distant range is calculated from "SEGWave", a CODAR adaptation of an exact FORTRAN code done by the U.S. Dept. of Commerce Institute of Telecommunications Science in 1965. This gives the path loss over a spherical-earth sea surface whose electrical properties are modified to account for sea-state roughness by a technique developed by Barrick in 1971. One convenient way to represent this path loss in the algorithm output is in terms of the field attenuation normalized with respect to the free-space $1/R$ spreading; this factor would be unity if there were no added path loss.

- The short part of the path from the antenna to the coast is best calculated with NEC, where the surface can be considered flat over this small distance. Here one can also get the attenuation normalized with respect to free-space $1/R$ spreading.

- The "intuitive" synthesis suggested for calculating the total mixed-path attenuation based on using the above path segments gives a wrong answer. In this, one would just multiply the normalized factors for the land and sea portions of the path. The problem is, one gets two different answers using this method, depending on whether one starts from far out over the sea and ends up at the antenna back over land, or inverts the order starting over land and ending up at sea. This is not acceptable, because it violates the cardinal rule of reciprocity. And more important, it disagrees with measurements, as was found by tests in the 1930s.

- Millington in 1950 came up with a mixed-path method that satisfies reciprocity and agrees with measurements. In a few words, it is the geometric mean between the land=>sea and sea=>land path parts described in the preceding paragraph, normalized to produce the proper values at the coastal interface.

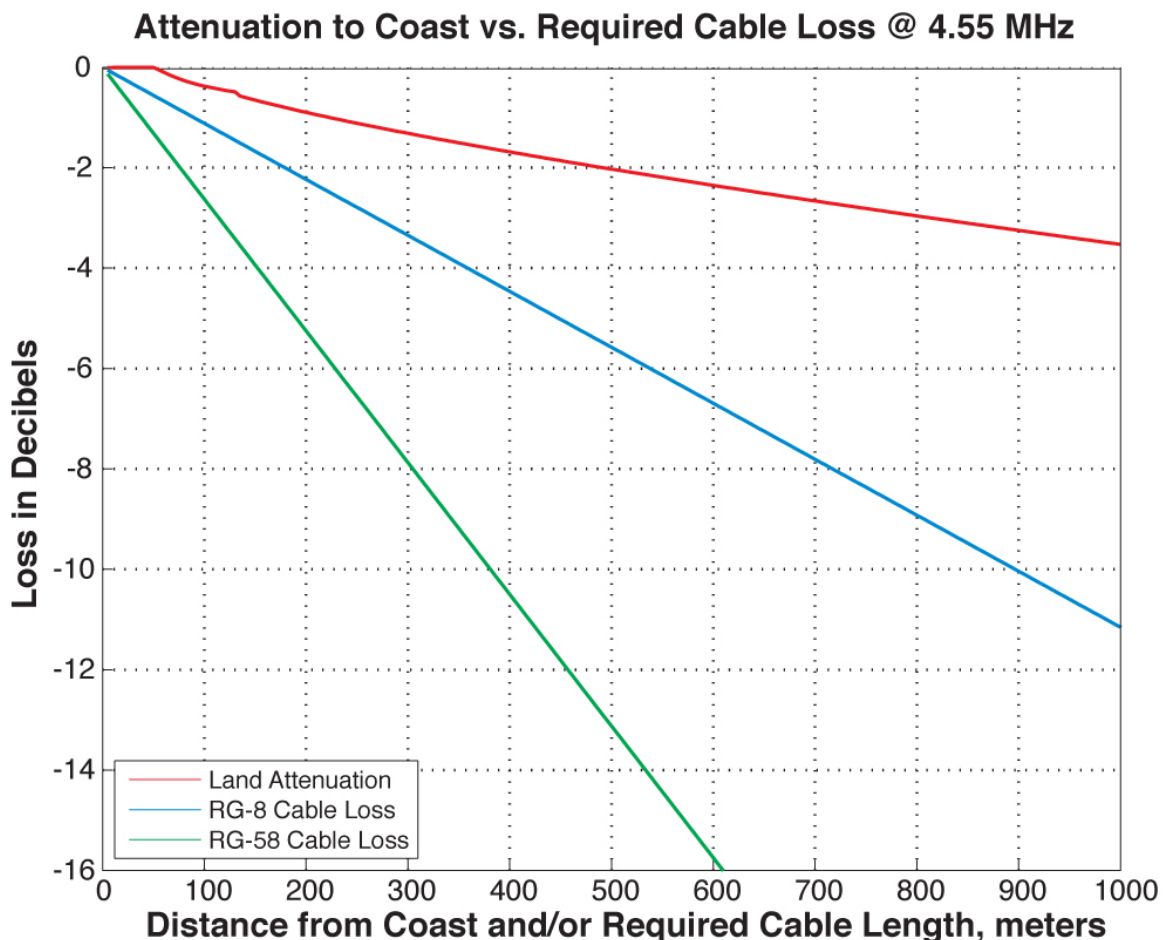
- However, this method can be reduced to a very simple equation when the distance over the sea is great compared to the distance over land. In this case -- which applies to our scenario -- the field attenuation factor is just the square root of that for the land-only piece. As stated earlier, this is easiest calculated with NEC. It is this simple method we use for the results presented below.

Results for the Four SeaSonde Frequency Bands:

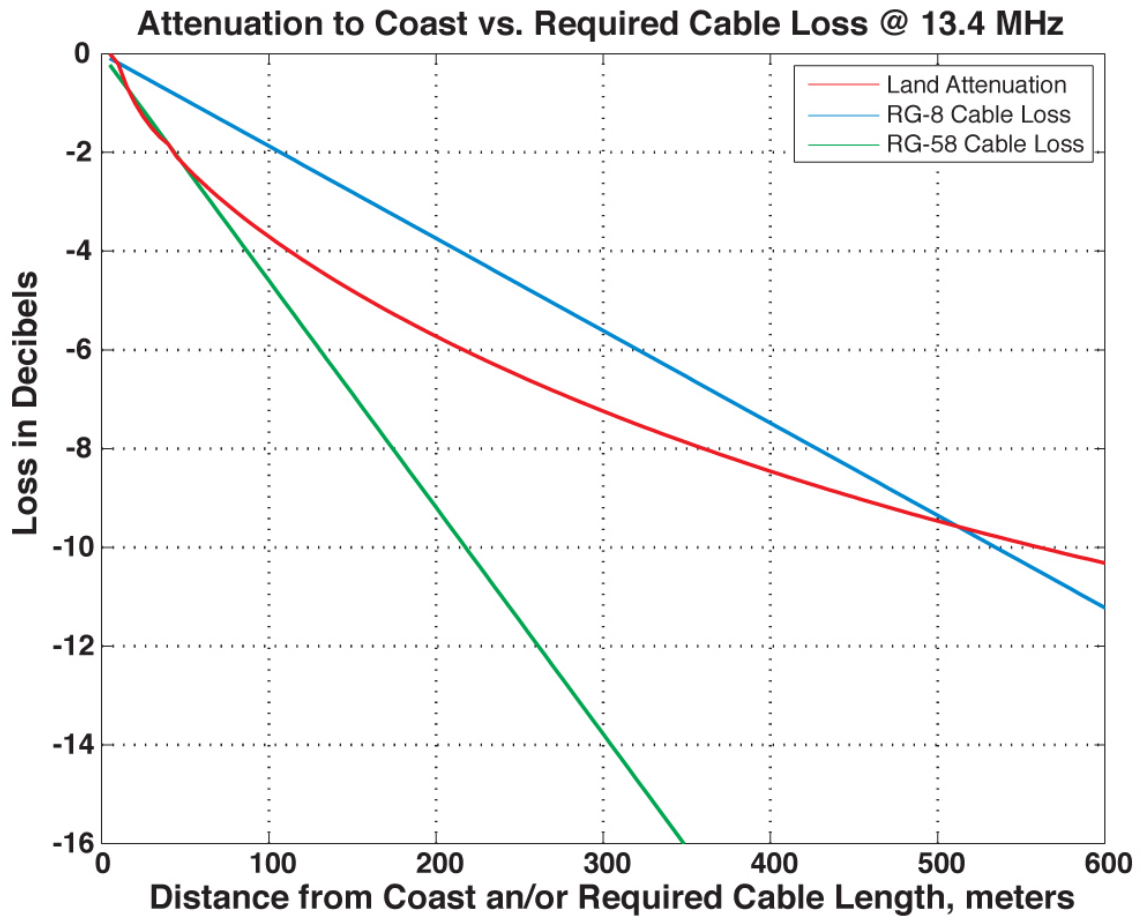
One must specify ground electrical parameters in order to calculate surface-wave loss with NEC: dielectric constant and conductivity. Tables and maps of these properties are found on the web and in handbooks. Wet ground has higher dielectric constant and conductivity, e.g., 15 and 0.02 mhos/m for these parameters, respectively. Dry ground, sand, desert have lower parameters, e.g., 5 and 0.001. We pick a value in between, 8 and 0.008 mhos/m and call this an average. Variations from this can cause perhaps up to 15% fluctuation in the path loss attenuation values we present here.

The curves below compare the path-loss attenuation from the antenna to the coast with the ohmic cable losses of the same length. Thus we are considering the question: is it better to put the antenna back a given distance from the coast (in terms of loss), or out at the coast edge and run cables across the span to the antennas? For this comparison, we use standard cable losses found in manufacturers tables.

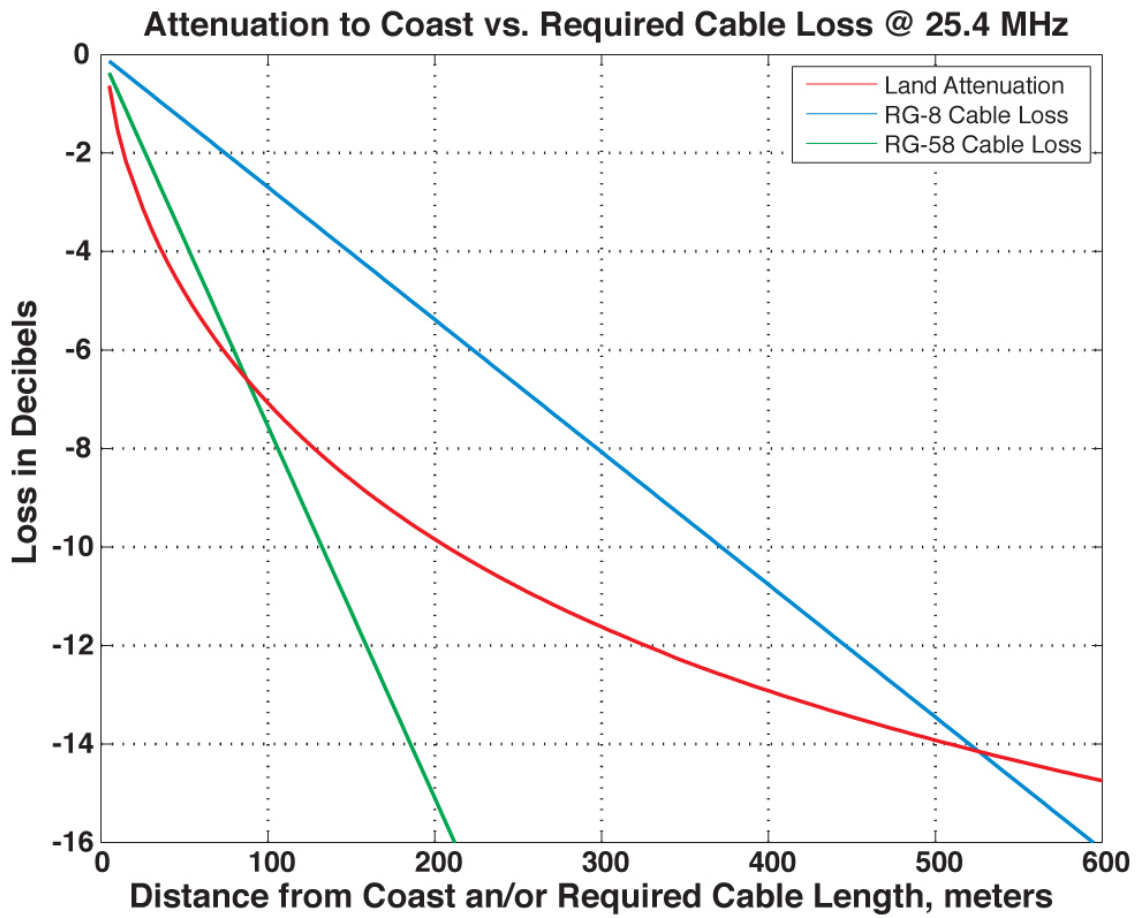
- **Long-Range Band (4.55 MHz):**



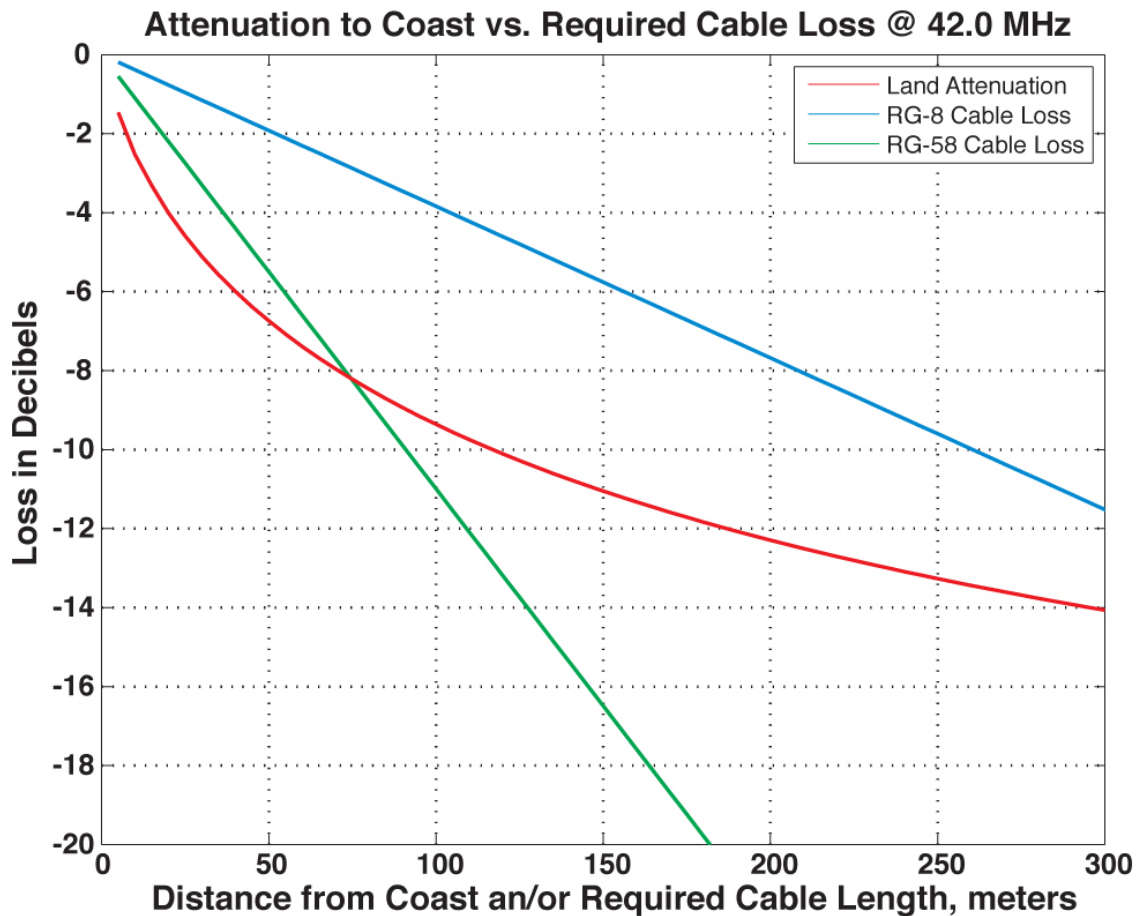
- Standard-Range Band (13.4 MHz):



- Standard/High-Range Band (25.4 MHz):



- **Hi-Res Band (42 MHz):**



Conclusions and Recommendations Thus Far for Siting Transmit Antenna

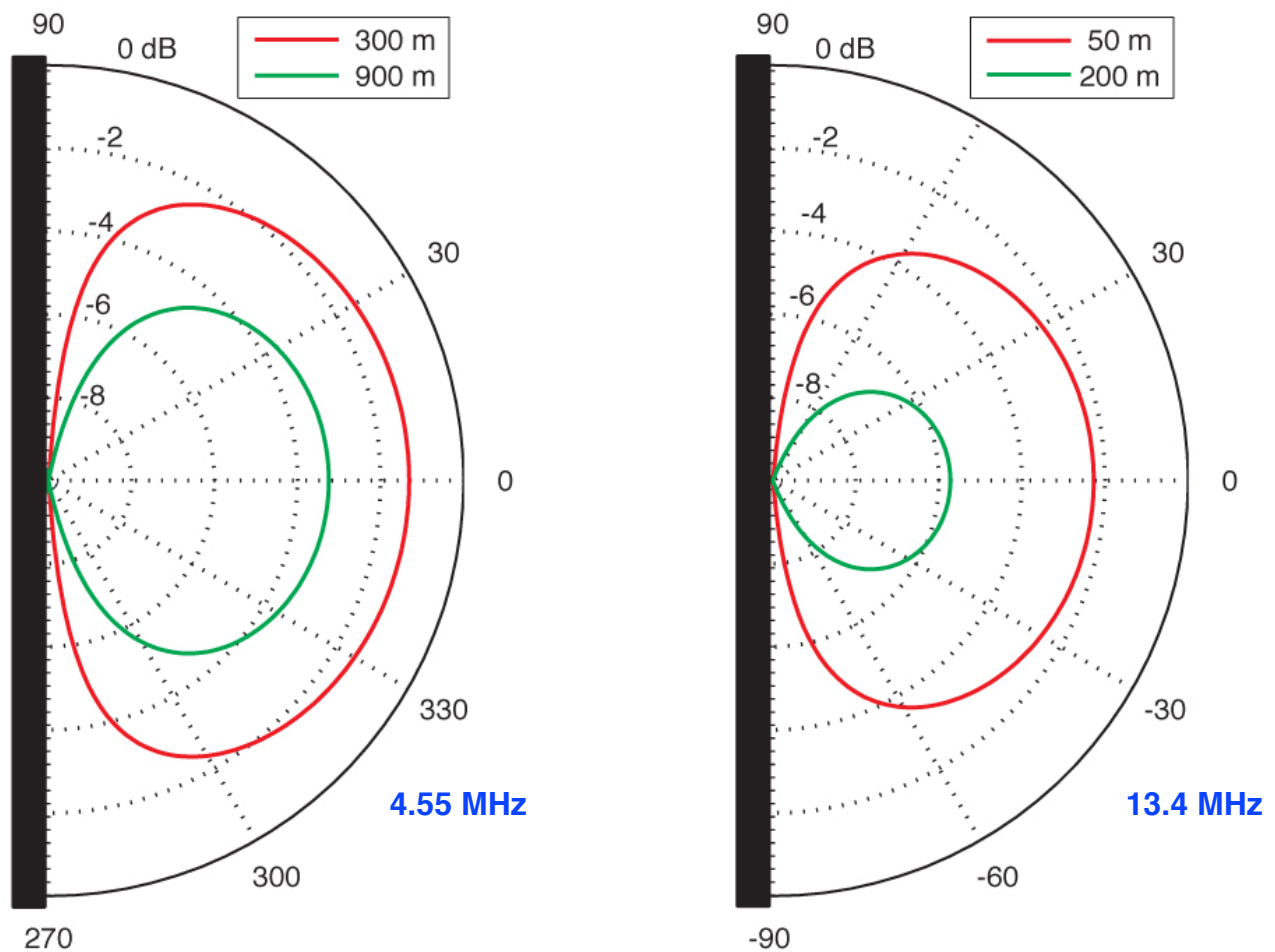
- **Locate both electronics and antenna as close to water as possible**
- **If electronics/enclosure must be farther from the coast, then:**
 - *At 4 - 5 MHz, locate transmit antenna near electronics back from coast and minimize cable run*
 - *At all other frequency bands, locate transmit antenna close to water and run RG-8 cable from electronics*
 - *Consult uppermost of the above curves to determine loss in signal and SNR expected due to distance involved*

B. Energy Pattern over Sea Resulting from Antenna Back from Coast

The Issue: The mixed-path scenario we have considered had the path going straight out from the transmit antenna, crossing the coast along its perpendicular. At any other angle, however, more land is traversed than for the shortest path to the coast. According to the the red curves, e.g., as in the first and second figures above, this longer span over land will result in greater loss and less SNR. This loss becomes extreme near the coastline tangent. In effect, this distribution with angle is an "energy pattern".

Why should one be concerned about this energy pattern for the transmit (as well as receive) antennas? Because, if the echo from one sector (e.g., straight out) is favored by 10 dB or more than that from other sectors closer to shore, bearing accuracy will be impaired in those weaker sectors. This is true for both DF systems like CODAR and also for beam-scanning phased-array systems like WERA.

Example of Energy Patterns at Lower Bands: Based on the results presented in the red curves of the preceding figures, we calculate and plot below the energy distribution pattern when the antenna is located a given distance back from the coast.



One can see on the left that for the long-range band, the pattern for the antenna 300 m back from the coast (red curve) is nearly omni-directional, till one gets to about 10° from the coast (where it has dropped about 2 dB from the max). The pattern 900 m back (green curve) is only a bit more directional, but not much; however, the amplitude directly offshore has dropped 3.2 dB from what it would be if the antenna is at the coast.

The pattern directionality is more severe at 13.4 MHz, on the right. For 50 m back, the 3 dB falloff from the max occurs about 10° from the coast, which is not critical. When 200 m back, the pattern beamwidth is narrower, but still occurs at 20° from the coast. However, as shown in the previous section, for either of these 13 MHz cases, one is better off putting the antenna at the coast and using longer cables. The improvement using RG-8 cable vs. ground loss is about 1 dB when the distance is 50 m and 2 dB for 200 m. (We do not consider the upper two bands, because longer cables are unquestionably better than a long path over ground.)

C. For Antennas Back from Coast, Wouldn't Raising Them Help?

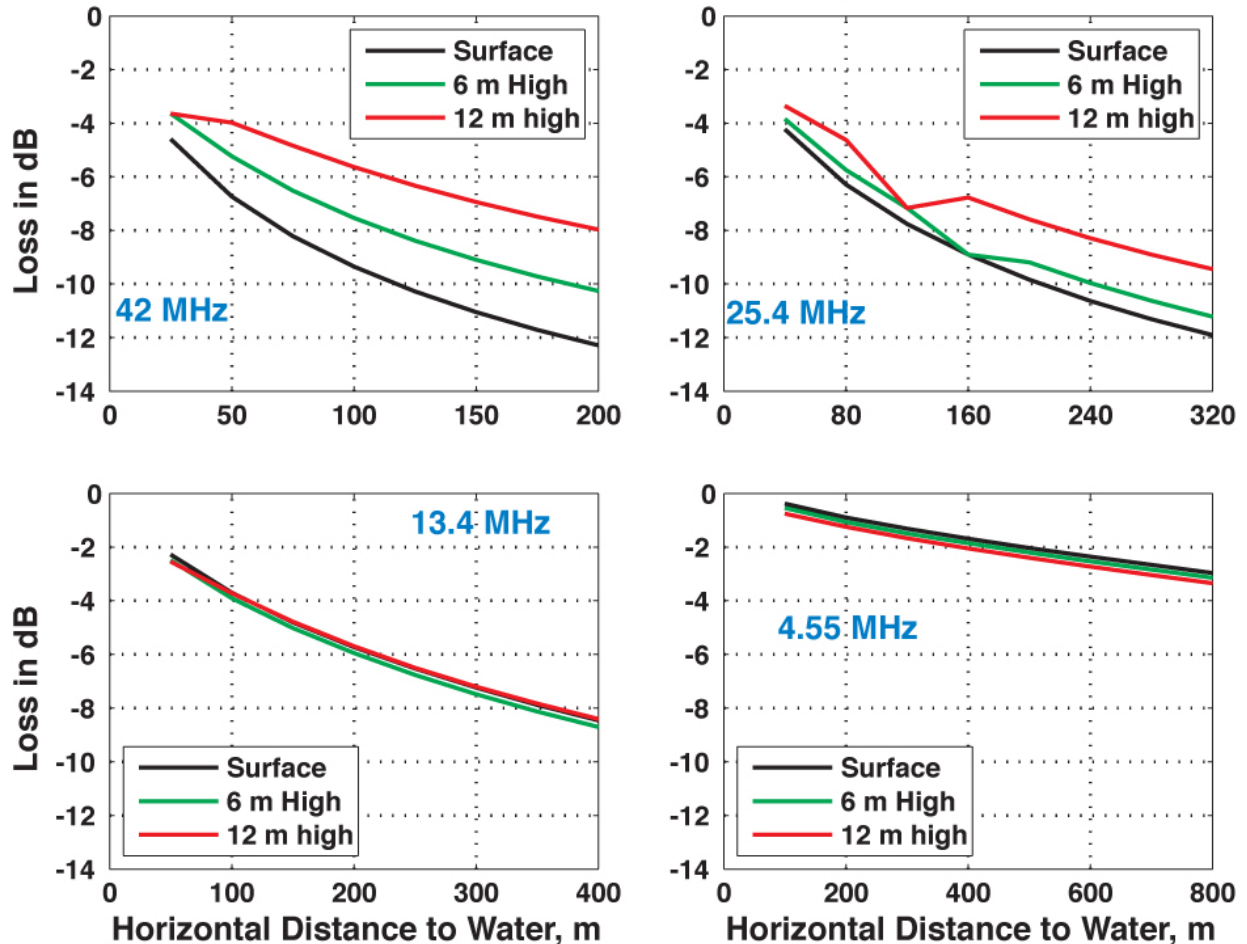
The Issue: We revisit a question often asked: if the antenna is located back away from the coast, wouldn't raising it higher help gain back the loss over land? The answers we provide here are based on the semi-empirical Millington methodology we used above. We show the effect by curves in the following figure for the four different SeaSonde frequency bands; for the same ground dielectric/conductive properties; and normalize with respect to a perfectly conducting ground. We consider two heights of the antenna center above the ground: 6 m (about 20 feet) and 12 m (about 40 feet). These are manageable heights -- anything more than 40 feet is probably not practical. These could include antennas mounted on the roof of a building, on a mast so that the antenna feed is at the height shown above the sea-level ground below the building.

To be specific, the antenna is mounted on a mast raised up from the ground or from a building edge. *This analysis does not apply to an antenna that sits on a sloping hill back from the coast.* The ground constituting the hill negates any height advantage, because it couples to the propagating electromagnetic signal and directs it into the ground, thereby draining energy from the surface-wave and constituting a path loss. The antenna center must be about a wavelength higher than the ground in order to decouple.

The figure below shows the loss in dB as a function of horizontal distance back from the coast, for the two antenna heights. The black curve represents the antenna being very near the ground so that its height can be taken as zero. These analyses apply to both transmit and receive antennas, with respect to the sea echo signal. I.e., if the

same antenna is used for transmit and receive, then double the dB loss to get the total, or the overall reduction in SNR of the sea echo.

Signal Increase Due to Antenna Height over Ground



Conclusions about Raising the Antenna(s):

- *Improvement is best at the highest band, 42 MHz. One-way loss drops by 3-4 dB when raising as high as 12 m (nearly two wavelengths). Double this improvement if the same antenna is used on transmit and receive. For comparison, this two-way SNR improvement is equivalent to increasing radiated power from 40 watts to between 160 and 300 watts.*
- *There is modest improvement at 25 MHz, but only if the antenna is raised higher than 6 m, i.e., it must be closer to a wavelength or more in height before a gain is realized.*

- *At the lower two bands, no improvement results from the heights examined here. At these bands, the antenna is less than half a wavelength above the ground.*

D. How Do These Results Differ for Transmit vs. Receive Antennas?

- **The Above Results Apply Most to Transmit Antennas Because:**
 - *The transmit antenna must be an efficient radiator -- every dB lost due to generated energy not getting out over the sea is a dB drop in SNR.*
 - *The transmit energy must not be too concentrated into a narrow direction; ideally it should illuminate uniformly the 180° sector over the sea and be zero back over land. This ideal is impossible practically.*
- **Possible Alternative Conditions for Receive Antenna:**
 - *Regardless of whether the receiver is external or internal noise limited, the antenna should be placed as near to the coast as possible:*
 - *If external noise limited -- because it typically comes from all directions and is not confined within a surface-wave mode -- noise remains the same if it is located at the coast or far back over land.*
 - *A long cable running to the coast reduces the signal and noise: therefore SNR stays the same, until the internal noise level is reached.*
 - *A short cable running to the antenna back over land allows increased noise into the receiver because cable loss goes to zero. However, signal path loss over the land segment is greater. Therefore SNR decreases.*
 - *If the receiver is internal noise limited (i.e., it doesn't see external noise), then SNR will also be reduced by the added path loss over the land segment for the echo when located back from the water.*