Water and Coastal Propagation

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Water surfaces create some of the most favorable RF propagation conditions at 915 MHz. Coastal and over-water deployments can achieve ranges that far exceed typical terrestrial links.

Over-Water Propagation

At low grazing angles, calm water reflects RF efficiently, behaving somewhat like a "mirror." But the long ranges seen over water are not driven by reflection alone: low-loss line-of-sight, specular reflection at low grazing angles, and - frequently the dominant factor - **evaporation ducting** (a refraction mechanism in which a near-surface humidity gradient bends signals beyond the geometric horizon) all contribute. A higher sea state roughens the surface, scatters the reflected ray, and degrades the "mirror" behavior. Compared with land (rough, absorptive, and cluttered), open water still provides a much better reflective ground plane and an effective radio horizon that extends further than over land.

The Two-Ray Model Over Water

Over a flat, reflective surface like open water, two signal paths exist between transmitter and receiver:

1. The **direct ray** traveling line-of-sight
2. The **ground-reflected ray** bouncing off the water surface

These two rays interfere constructively or destructively depending on antenna heights and distance. The transition point is the two-ray breakpoint distance, $d \approx 4 \cdot h1 \cdot h2 / \lambda$. For two nodes at 5 m height over water at 915 MHz ($\lambda \approx 0.328$ m), the breakpoint is roughly **300 m** - not 1 - 2 km. *Below* the breakpoint the received field oscillates through a pattern of nulls and peaks; *beyond* the breakpoint, received power falls off steeply and monotonically (roughly d^{-4}, about 40 dB/decade), with no further oscillation. The long over-water ranges operators report are sustained mainly by clear line-of-sight and evaporation ducting, not by the two-ray interference pattern.

Raising antenna height pushes the two-ray breakpoint to greater distances and generally improves over-water performance.

Documented Long-Range Links Over Water

Some LoRa operators report **50 - 80 km links** across large lakes or bays with elevated antennas, but these are best-case results - they depend on antenna height, calm water, clear line-of-sight, and atmospheric ducting, and are not a routine or guaranteed outcome. Do not plan a network assuming them; verify any over-water link by field test. Reported and documented figures include:

- Favorable over-water conditions have produced 50 - 80 km links with 5 - 8 dBi antennas at 10 - 20 m height, but results vary widely and depend on sea state, ducting, and clear LOS
- As of 2024, the LoRa/LoRaWAN distance record is **1,336 km** (ground-based trackers on a boat/buoys near Sesimbra, Portugal reaching a Canary Islands gateway - not balloon-assisted), surpassing the earlier 832 km balloon record. Treat all such records as exceptional best-case LOS, not representative range
- Over-water links of **30 - 50 km** with standard hardware and good antenna heights (10+ m) are achievable in favorable over-water conditions with clear line-of-sight, but results are not guaranteed

These distances are not achievable over land with equivalent hardware and height - the over-water propagation advantage is real and significant, but the figures above are best-case ceilings, not dependable planning numbers.

Coastal Network Planning

Islands, peninsulas, and coastal communities benefit greatly from over-water propagation. A node on a bluff or sea cliff can cover:

- Coastal marine traffic (boats, kayaks, vessels with LoRa-equipped trackers)
- Island communities at ranges exceeding typical land deployments
- Adjacent coastal nodes along the shoreline

For coastal networks, prioritize elevated nodes on headlands, bluffs, and sea cliffs. Even modest elevation (10 - 20 m above sea level on a coastal promontory) provides excellent coverage over water. As a horizon reference, a 10 - 20 m height gives roughly a 30 km line-of-sight radio horizon over water - present longer ranges as best-case, not typical.

Marine Environment Hardware Considerations

Coastal humidity and salt air accelerate corrosion of connectors, coax, and metal mounting hardware. Coastal deployments require additional weatherproofing measures compared to inland installations:

- Use **marine-grade stainless steel** hardware (316 SS or better) for all mounting
- Apply **NO-OX-ID A-Special** or equivalent anti-oxidant compound to all coax connectors
- Inspect weatherproofing tape, heat shrink, and connector boots **more frequently** than inland sites - annually at minimum, semi-annually in high-exposure locations
- Use sealed junction boxes (IP67 or better) for any exposed connections
- Consider conformal coating for PCBs in equipment enclosures near the waterline

Troposcatter

At longer distances over water, tropospheric scatter occasionally enables beyond-horizon propagation. Troposcatter occurs when RF energy scatters off irregularities in the troposphere and some portion reaches a beyond-horizon receiver.

Troposcatter is rare, unpredictable, and unsuitable as a network planning basis - you cannot count on it being available when needed. However, it explains occasional unexpectedly long contact distances reported by LoRa operators over open ocean or large lakes. If you observe an anomalously long contact, troposcatter (or evaporation ducting under temperature inversion layers) is the likely explanation.

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