

# Mountain and Complex Terrain

## Mountain and Complex Terrain Propagation

Mountain and highly variable terrain introduces propagation challenges - and opportunities - that differ fundamentally from flat-land or urban planning. Terrain masking is the dominant factor, but ridge placement can turn a liability into an asset.

### Terrain Masking

Terrain masking is the most significant propagation factor in mountains. When terrain lies between the transmitter and receiver, path loss increases dramatically - **diffraction over ridges adds 10 - 30+ dB** compared to free-space loss at the same distance.

Before planning a mountain link, verify line-of-sight using a terrain profile tool: HeyWhatsThat or Radio Mobile (web-based, easy to use) - or SPLAT! for advanced users comfortable with the Linux/macOS command line and converting SRTM terrain data to its own file formats. If the path crosses terrain, budget for the additional diffraction loss.

### Knife-Edge Diffraction

When a signal diffracts over a sharp ridge, it bends into the shadow zone on the far side. This diffraction is calculable using **Fresnel zone analysis** - the geometry of the ridge height relative to the first Fresnel zone determines how much loss (or occasionally gain) results.

Tools like Radio Mobile (based on the Longley-Rice ITM model) estimate knife-edge diffraction loss, though accuracy degrades in mountainous terrain with multiple obstacles - ITM uses a single equivalent rounded-obstacle approximation and is known to underestimate field strength in long-distance, multi-obstacle fringe cases. A sharp, isolated ridge causes less diffraction loss than a broad rounded hill, which blocks a larger portion of the Fresnel zone.

# Ridge-Mounted Repeaters

A repeater placed on a ridgeline can reach **both** the illuminated side and the shadow side of the ridge. Coverage is not symmetric, however: the illuminated side is served by direct line-of-sight, while the shadow side is reached only via diffraction, with significantly reduced range and reliability that worsens as the shadowing depth increases.

This is the key insight for mountain mesh design: **place repeaters on ridges, not in valleys**. A valley node can communicate well within the valley, but a ridgeline node covers its own valley and can reach into adjacent valleys where line-of-sight exists, with diffraction-limited reach where terrain intervenes - still multiplying usable coverage substantially per node compared to a valley-floor site.

## Valley Isolation

Nodes in valleys can communicate well within the valley but are effectively isolated from nodes in adjacent valleys without a ridge or mountain repeater bridging them. This creates natural "valley clusters" in mountain mesh networks - each valley segment is connected internally but disconnected from neighbors unless ridge nodes exist.

Planning a mountain mesh means identifying which valleys need coverage, then finding the ridgelines that can serve multiple valleys with a single node.

## Elevation vs. Range (Rule of Thumb)

For an antenna at height  $h$  meters above local terrain, the refraction-corrected (4/3-earth) radio horizon is:

“ Radio horizon distance  $\approx 4.12 \times \sqrt{h}$  km

Height Above Valley Floor	Radio Horizon
10 m	~13 km
50 m	~29 km
200 m	~58 km
500 m	~92 km

A repeater at 200 m above the valley floor sees a radio horizon of approximately 58 km. **But radio horizon is the geometric ceiling, not guaranteed coverage.** Valleys, terrain masking, and the

link budget to low, handheld nodes in the valleys will reduce real coverage well below 58 km. Use this figure only to identify candidate sites, then confirm with terrain analysis and field testing before assuming a single node blankets a region.

# Emergency Drone / Hilltop Mesh Extension

Some communities deploy temporary mesh nodes on hilltops via drones during emergencies to bridge isolated valleys. The same capability works for large outdoor events in terrain-constrained areas. A drone-carried LoRa node at 100 - 200 m AGL can bridge two otherwise-isolated valleys for the duration of its battery, providing emergency communications coverage without requiring permanent infrastructure.

Portable battery-powered repeater kits carried to hilltops on foot are another practical approach for planned events or disaster response.

## Snow Effects on Antennas

Snow has low RF absorption at 915 MHz and does not significantly affect propagation. However, **heavy wet snow buildup on antennas can detune them:**

- Use vertically-polarized antennas with a drip point design to shed snow
- Avoid horizontal radial elements in heavy-snow environments
- Wet snow accumulation on a horizontal radial can shift the resonant frequency noticeably under heavy wet-snow loading, reducing antenna efficiency and degrading SWR

For high-altitude winter deployments, sleeved dipoles and verticals with a tapered/drip-capable profile outperform flat-panel or horizontal-element designs.

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