Link Budget Calculations

A link budget calculation estimates whether a radio path between two nodes will work reliably before you deploy hardware. It's the single most useful tool for avoiding wasted installation trips and surprised failures.

The link budget equation

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Received Power (dBm) = TX Power (dBm)
 + TX Antenna Gain (dBi)
 − TX Cable Loss (dB)
 − Free Space Path Loss (dB)
 − Obstruction Loss (dB)
 + RX Antenna Gain (dBi)
 − RX Cable Loss (dB)

Link Margin (dB) = Received Power (dBm) − Receiver Sensitivity (dBm)
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A positive link margin means the link should work. A margin of 10 dB or more is considered reliable. Below 3 dB is borderline and not recommended for permanent infrastructure.

Key values for LoRa at 915 MHz

Receiver sensitivity by MeshCore preset

Preset equivalent (SF / BW)	Receiver sensitivity
USA/Canada (SF7 / 62.5 kHz)	~−125 dBm
Long Fast (SF11 / 250 kHz)	~−137 dBm
Long Slow (SF12 / 125 kHz)	~−141 dBm
Medium Slow (SF10 / 250 kHz)	~−134 dBm

Lower sensitivity number = can receive weaker signals = more range potential. Long Slow gives the best sensitivity but at the cost of extremely low data rate.

Free Space Path Loss at 915 MHz

FSPL (dB) = 20×log10(d) + 20×log10(f) + 20log10(4π/c)

In practical terms for 915 MHz:

Distance	Free Space Path Loss
1 km (0.62 mi)	91.6 dB
5 km (3.1 mi)	105.6 dB
10 km (6.2 mi)	111.6 dB
20 km (12.4 mi)	117.6 dB
50 km (31 mi)	125.6 dB

Note: Free space path loss assumes clear line of sight with no obstructions. Real-world losses are always higher.

Worked example: Rooftop repeater to ground-level node

Scenario: 5 km path, rooftop repeater at 30m height, portable node at 2m height.

Parameter	Value
TX Power (repeater)	27 dBm
TX Antenna Gain	+5 dBi
TX Cable Loss (1m LMR-200)	−0.1 dB
Free Space Path Loss (5 km, 915 MHz)	−105.6 dB
Obstruction/Fresnel loss estimate	−10 dB (mixed urban)
RX Antenna Gain (portable node, 2 dBi)	+2 dBi
RX Cable Loss (none for portable)	0 dB
Received Power	**27 + 5 − 0.1 − 105.6 − 10 + 2 = −81.7 dBm**
Receiver Sensitivity (USA/Canada SF7)	−125 dBm
Link Margin	**−81.7 − (−125) = +43.3 dB**

A 43 dB margin is very comfortable - this link will work reliably even with additional obstruction losses not captured in the estimate.

Fresnel zone clearance

Even in "clear" line-of-sight paths, the Fresnel zone must be 60% clear of obstructions for reliable communication. The first Fresnel zone radius at the midpoint of a path:

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r = 8.66 × sqrt(d / f_GHz) meters

Where d = path length in km, f = frequency in GHz

For 915 MHz, 10 km path:
r = 8.66 × sqrt(10 / 0.915) = 8.66 × 3.30 = 28.6 meters

Any obstruction within 28.6m of the direct path midpoint will partially block the signal.
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This is why hilltop-to-hilltop links work so well: the terrain clears the Fresnel zone naturally. For rooftop-to-rooftop links in cities, trees and building facades at path midpoints can add 10 - 20 dB of loss even when the antennas themselves have direct line of sight.

When to use a link budget

- Before installing a repeater at a new site, calculate whether it can reach your intended coverage area
- When planning a point-to-point relay link between two specific nodes
- When a deployed link is underperforming - work backwards from measured RSSI to identify where the losses are
- When comparing two candidate repeater sites - small differences in height can produce large differences in link budget

Revision #2
Created 2026-05-03 03:58:46 UTC by Mesh America Admin
Updated 2026-05-03 13:01:35 UTC by Mesh America Admin