

Understanding Gain and dBi

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Antenna gain is one of the most misunderstood topics in practical LoRa deployment. More gain is not always better - understanding what gain actually does will help you choose the right antenna for each deployment scenario.

What dBi Means

dBi (decibels relative to an isotropic radiator) measures how much an antenna concentrates radio energy in a particular direction compared to a theoretical antenna that radiates equally in all directions. An antenna with 0 dBi is a theoretical perfect sphere of radiation. An antenna with 5 dBi concentrates the same total energy into a narrower pattern.

The key insight: antennas do not add power. They redistribute it. Higher gain means more energy focused in the desired direction and less energy wasted in other directions.

Gain vs. Beam Angle

The figures below are approximate vertical (elevation) beamwidths for typical vertical omni antennas. They are illustrative, not exact: gain and beamwidth are always inversely proportional, but the actual beamwidth of a given antenna depends on its specific design. Use them to understand the trend, not as precise specifications.

Gain	Approx. Vertical (Elevation) Beamwidth – illustrative	Best Use Case
0 dBi	~80°	Indoor, short range, omnidirectional coverage needed in 3D
2 - 3 dBi	~60°	Handheld portable, varied terrain
5 dBi	~40°	Standard outdoor omni, modest height, moderate terrain
8 dBi	~20°	High-site omni with flat terrain and long-range targets
12+ dBi	<15°	Directional point-to-point links only

The High-Gain Trap in Hilly Terrain

An 8 dBi antenna on a rooftop in hilly terrain will have a dead zone directly below and nearby because its beam is concentrated nearly horizontally. Nodes at ground level within a few hundred metres may receive a worse signal than they would from a 5 dBi antenna at the same height. For community mesh networks with nodes at varying elevations, 5 - 6 dBi is typically optimal for omni antennas at medium-height fixed sites.

Practical dB Math

The range rules below assume free-space (inverse-square) propagation. In free space, range scales as $10^{(\text{gain_dB}/20)}$, so +6 dB doubles range and +3 dB adds about 40%. In real terrain — with obstructions, vegetation, and buildings — propagation is worse than inverse-square, so the actual range gain is smaller (often only 30 - 60% for +6 dB).

- **+3 dB** = doubles effective radiated power (\approx +40% range in free space; less in real terrain)
- **+6 dB** = 4× effective radiated power (\approx doubles range in free space; typically only +30 - 60% in real terrain)
- **+10 dB** = 10× effective radiated power

Range does not scale linearly with power because signal propagation follows an inverse square law (or worse in real-world conditions with obstructions). Going from 22 dBm to 28 dBm is +6 dB - 4× the power - which in free space would roughly double range, but in real terrain typically yields only 30 - 60% more range.

Placement vs. Gain

Moving an antenna from ground level to a rooftop 10 metres up provides far more range improvement than switching from a 3 dBi to an 8 dBi antenna at ground level. Elevation eliminates obstructions and increases radio horizon. Always optimise placement before spending money on higher-gain antennas.

Free Space Path Loss at 915 MHz

Free space path loss (FSPL) increases with distance. At 915 MHz:

Distance	Free Space Path Loss
1 km	~91 dB
5 km	~105 dB

Distance	Free Space Path Loss
10 km	~111 dB
20 km	~117 dB

LoRa with SF12 has a link budget of roughly 150 - 160 dB (note: a link budget is a difference of two dBm values, so it is expressed in dB, not dBm — the exact figure depends on transmit power and antenna gain). Under ideal, fully clear line-of-sight conditions, SF12 links can reach tens of kilometres; record links far exceed this. However, real-world terrain, vegetation, building losses, and Fresnel-zone obstruction reduce achievable range dramatically, and typical installations achieve far less. See the Fresnel Zones and Link Budget pages for how to estimate realistic range for your site.

Revision #3

Created 2026-05-03 03:10:10 UTC by Mesh America Admin

Updated 2026-06-08 21:55:07 UTC by Mesh America Admin