

# 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

Gain	Approximate Vertical Beam Width	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	~25°	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

- **+3 dB** = doubles effective radiated power (roughly +40% range in ideal conditions)
- **+6 dB** = 4× effective radiated power (roughly doubles range in ideal conditions)
- **+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 - but typically only 30 - 60% more range in practice.

## 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
10 km	~111 dB
20 km	~117 dB

LoRa with SF12 has a link budget of approximately 154 dBm, meaning theoretical line-of-sight range can exceed 50 km under ideal conditions. Real-world terrain, vegetation, and building losses reduce this significantly.

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