Antenna Fundamentals

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.

Connector Types & Coax Cable

Connector Types & Coax Cable

Using the wrong connector or cable is one of the most common and frustrating mistakes when setting up LoRa hardware. This page covers everything you need to know to buy and connect antennas correctly.

SMA vs. RP-SMA

SMA (SubMiniature version A) and RP-SMA (Reverse Polarity SMA) look nearly identical but are **not interchangeable**. Connecting a mismatched pair results in no signal or very poor signal even though the connectors physically engage.

Connector	Male	Female	Common Devices
SMA	Pin in centre, external thread	Socket in centre, internal thread	Heltec V3/V4, RAK WisBlock, many antennas
RP-SMA	Socket in centre, external thread	Pin in centre, internal thread	Some LilyGo devices, Wi-Fi routers, some Meshtastic builds

Before buying an antenna: check your device datasheet or photos to confirm whether it uses SMA or RP-SMA. The Heltec V3 and V4 both use SMA Male on the board (the antenna plugs SMA Female onto the board connector).

N-Connector

N-connectors are larger, more weatherproof, and lower-loss than SMA. Used on outdoor base station antennas and feedlines. The ALFA 5 dBi Mini uses N-Male. For base station builds with significant coax runs, N-connector systems are preferred over SMA.

Coax Cable Selection

Coax cable introduces loss that subtracts directly from your effective radiated power and receive sensitivity. At 915 MHz, cable loss is significant for runs over 3 metres.

Cable Type	Loss at 915 MHz	Use Case

RG174	~1.5 dB/m	Short pigtails only (<30cm); avoid for longer runs
RG316	~0.9 dB/m	Short internal pigtails; better than RG174 but still lossy
RG58	~0.5 dB/m	Acceptable for runs up to 3 - 5m
LMR-200	~0.3 dB/m	Good for runs 3 - 10m; flexible
LMR-400	~0.14 dB/m	Long runs (>10m) or base stations; less flexible

For a DIY solar repeater with the node inside the enclosure and the antenna immediately outside, a 30cm RG316 pigtail is fine. For a base station where the coax runs 10 metres from the node to the roof antenna, use LMR-200 or LMR-400.

SWR and Cable Quality

Poor-quality connectors and cables produce poor SWR readings even with a good antenna. If your NanoVNA shows unexpectedly high SWR, suspect the cable and connectors before the antenna itself. Wiggle the connector while monitoring - if SWR changes, the connector is the problem.

Weatherproofing Outdoor Connections

Outdoor N-connector and SMA connections must be weatherproofed. Water intrusion corrodes the connector and increases loss. Use self-amalgamating (self-fusing) tape: stretch it over the connector and cable and overlap each wrap by half. It bonds to itself and forms a watertight seal without adhesive. Cover with UV-resistant electrical tape for UV protection.