

Antenna and RF FAQ

- [Do I need an external antenna?](#)
- [What is the difference between dBi and dBd antenna gain?](#)

Do I need an external antenna?

The stock antenna that comes with most LoRa boards is a rubber duck (flexible whip) antenna, typically 3-5 dBi gain. For many use cases, this is adequate - but upgrading to an external antenna is one of the most cost-effective improvements you can make.

When the Stock Antenna is Fine

- Indoor portable use (office, home) within 200-500m of your nearest mesh node
- Temporary deployments where you're moving frequently
- Testing and development before a permanent installation
- Dense urban areas with many nearby nodes (short hop distances)

When You Should Upgrade

- **Fixed outdoor installation** - Any permanent outdoor node should use an external antenna rated for outdoor use. Stock rubber ducks are not weatherproof.
- **Coverage issues** - If you can't reach nodes you'd expect to reach, a better antenna is the first thing to try.
- **Backbone repeater** - Repeaters covering a neighborhood or city need the best possible antenna. A 5-8 dBi fiberglass omni provides 5-8 dB more gain than a typical rubber duck - roughly doubling the effective range.
- **Point-to-point link** - If you're trying to bridge two specific locations, a directional yagi provides 10-15 dBi gain and extends range dramatically.

What External Antenna to Buy

For most fixed outdoor deployments, a 915 MHz fiberglass omnidirectional antenna is the right choice:

- **Taoglas TI.92.2113 (3 dBi)** - \$15-20, compact, good for moderate ranges
- **Proxicast 5 dBi (ANT-DB5-5)** - \$25-35, good all-around outdoor omni
- **Taoglas FXP73 (5 dBi, mag base)** - \$25-40, great for vehicle or temporary mounts
- **L-com HG908U-PRO (8 dBi)** - \$45-60, excellent for high-gain omni backbone nodes

Connector Adapters

Most LoRa boards use SMA (male pin/female body on the board) or u.FL connectors. External antennas typically use N-connector or SMA. Match your connectors:

- **Heltec V3, T-Beam:** SMA female on board - use SMA male on pigtail or antenna
- **RAK4631:** u.FL (IPEX) connector - needs u.FL to SMA pigtail (~\$5) to connect to any standard antenna
- **T-Deck, T-Echo:** SMA female - use SMA male pigtail or direct-connect SMA antenna

What is the difference between dBi and dBd antenna gain?

Antenna gain specifications use two different reference points - dBi and dBd - and confusing them leads to incorrect [link budget calculations](#). Here's what each means and how to convert between them.

The Reference Antennas

- **dBi (decibels relative to isotropic)** - Compares gain to a theoretically perfect isotropic radiator (a point that radiates equally in all directions - a perfect sphere). This is a theoretical reference that doesn't exist in practice.
- **dBd (decibels relative to dipole)** - Compares gain to a half-wave dipole antenna, which is the most common practical antenna type and a natural reference for antenna engineers.

The Conversion

$$\text{dBi} = \text{dBd} + 2.15$$

Examples:

$$0 \text{ dBd (dipole reference)} = 2.15 \text{ dBi}$$

$$3 \text{ dBd} = 5.15 \text{ dBi (approximately 5 dBi)}$$

$$5.85 \text{ dBd} = 8 \text{ dBi}$$

$$9 \text{ dBd} = 11.15 \text{ dBi (approximately 11 dBi)}$$

Which is Used in Practice?

Most commercial antenna manufacturers use dBi because the numbers look higher (marketing benefit). The FCC uses dBd for regulatory calculations in some contexts. Most link budget calculators accept either, as long as you're consistent.

Rule of thumb: When comparing antennas, make sure you're comparing the same units. A "5 dBd" antenna and a "5 dBi" antenna are NOT equivalent - the dBd antenna is 2.15 dB better. This

difference can mean the difference between a reliable link and a marginal one.

Practical Antenna Gain Reference

Antenna Type	Typical Gain (dBi)	Typical Gain (dBd)
Stock rubber duck	-3 to 0 dBi	-5 to -2 dBd
Quarter-wave with ground plane	2.15 dBi	0 dBd
Half-wave dipole	2.15 dBi	0 dBd
5/8 wave vertical	4-5 dBi	2-3 dBd
3-element yagi	7-8 dBi	5-6 dBd
5-element yagi	10-11 dBi	8-9 dBd
Commercial 5 dBi fiberglass	5 dBi	2.85 dBd
Commercial 8 dBi fiberglass	8 dBi	5.85 dBd

What Gain Actually Buys You

Every 3 dB of additional gain (all else equal) doubles the effective radiated power. Practically:

- 3 dB gain improvement \approx 41% range increase in free space
- 6 dB gain improvement \approx 100% range increase (double) in free space
- 10 dB gain improvement \approx 216% range increase in free space

Real-world gains are lower due to terrain and building losses, but the relative improvement from a better antenna is significant and consistent.