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

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dBi = dBd + 2.15


Examples:
0 dBd (dipole reference) = 2.15 dBi
3 dBd = 5.15 dBi (approximately 5 dBi)
5.85 dBd = 8 dBi
9 dBd = 11.15 dBi (approximately 11 dBi)
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Which is Used in Practice?

Most commercial antenna manufacturers use dBi because the numbers look higher (marketing benefit). For the 902-928 MHz ISM band that matters here, FCC Part 15 expresses its EIRP and antenna-gain limits using the isotropic (dBi) reference - so convert any dBd spec to dBi (add 2.15) before checking it against the 4 W (36 dBm) EIRP ceiling or the 6 dBi antenna-gain threshold. Most link budget calculators accept either unit, 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	~0 to 2 dBi	~-2 to 0 dBd
Quarter-wave with ground plane	~5 dBi (ideal ground plane; less in practice)	~2.85 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

Note: a quarter-wave monopole over an *ideal* (infinite, perfectly conducting) ground plane radiates into a half-space and so has roughly 3 dB more gain than a dipole - about 5 dBi. Real, finite ground planes deliver less than this, but it is not equal to a plain dipole. Use this table as the single canonical reference for stock-antenna gain figures across the wiki.

What Gain Actually Buys You

Every 3 dB of additional gain (all else equal) doubles the effective radiated power. Because free-space range scales with the square root of the power ratio (range $\propto \sqrt{\text{EIRP}}$), gain translates to range as:

- 3 dB gain improvement ≈ 41% range increase in free space ($\sqrt{2} = 1.41$x)
- 6 dB gain improvement ≈ 100% range increase / double in free space ($\sqrt{4} = 2$x)
- 10 dB gain improvement ≈ 216% range increase in free space ($\sqrt{10} = 3.16$x)

These are free-space figures. In practice real-world gains are lower due to terrain and building losses, and higher-gain antennas are also constrained by the 4 W (36 dBm) EIRP limit - you often cannot legally or usefully realize the full theoretical range gain. Still, the relative improvement from a better antenna (within the legal limit and with good siting) is significant.

Revision #5
Created 2026-05-03 06:56:28 UTC by Mesh America Admin
Updated 2026-06-08 19:45:22 UTC by Mesh America Admin