How Antennas Work at 915 MHz

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An antenna is a transducer that converts electrical energy (RF current on a transmission line) into electromagnetic waves and vice versa. Understanding the physics of this conversion is essential for making informed antenna choices in LoRa mesh deployments at 915 MHz.

The Electromagnetic Wave

When alternating current flows in a conductor, it creates an oscillating electromagnetic field that detaches from the wire and propagates through space as a wave. At 915 MHz, the wavelength in free space is approximately 32.7 cm (about 13 inches), calculated by:

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λ = c / f
λ = 300,000,000 m/s ÷ 915,000,000 Hz
λ ≈ 0.328 m (32.8 cm)
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This wavelength determines the physical dimensions of resonant antenna elements. A half-wave dipole at 915 MHz is about 16.4 cm long; a quarter-wave monopole is about 8.2 cm. These are the building blocks of virtually all practical antennas.

Radiation Patterns

The radiation pattern describes how an antenna distributes power in three-dimensional space. It is typically depicted as a polar plot showing relative power density in different directions from the antenna.

- **Omnidirectional:** Radiates equally in all azimuthal (horizontal) directions, forming a donut-shaped pattern around a vertical axis. Most LoRa node antennas are omnidirectional.

- **Directional:** Concentrates energy in one or more preferred directions. Used for long-range point-to-point links or sector coverage.
- **Main lobe:** The primary direction of maximum radiation.
- **Side lobes:** Minor lobes at other angles, generally undesirable and wasting power.
- **Null:** Directions where radiated power drops to near zero. High-gain vertical antennas often have a null straight up and straight down.

Antenna Gain: dBi vs dBd

Gain is the most frequently misunderstood antenna specification. Antenna gain does not mean the antenna amplifies power - it cannot; antennas are passive devices. Gain describes how effectively an antenna concentrates available power in a specific direction compared to a reference antenna.

Reference	Symbol	What It Means	Relationship
Isotropic radiator	dBi	Gain relative to a theoretical point source radiating equally in all directions	Base reference; always used in link budgets
Half-wave dipole	dBd	Gain relative to a free-space half-wave dipole	dBd = dBi − 2.15 dB

A manufacturer claiming "5 dBd gain" actually means approximately 7.15 dBi. Always convert to dBi before doing link budget calculations. Be cautious of inflated gain claims on inexpensive antennas - omni gain above about 8 - 9 dBi is achievable, but it progressively narrows the vertical beamwidth, creating coverage gaps for nearby and high-angle nodes. This is the practical (not a hard physical) ceiling for terrestrial mesh: taller stacked collinears with higher gain exist, but their narrow elevation pattern makes them a poor fit for most node sites.

Isotropic vs Real Antennas

The isotropic radiator is a mathematical construct - a perfect point source that radiates uniformly in all directions. No real antenna achieves this. The simplest real antenna, the half-wave dipole, already has 2.15 dBi of gain because it concentrates radiation into its broadside plane rather than wasting energy off the ends.

Real antennas introduce additional losses: conductor resistance (ohmic loss), dielectric loss in radomes or matching components, and impedance mismatch. These losses subtract from the antenna's directivity to give its gain:

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Gain (dBi) = Directivity (dBi) − Loss (dB)
  where Loss (dB) = −10 · log10(η), and η is the efficiency fraction (≤ 1)
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Equivalently: Gain (dBi) = Directivity (dBi) + 10 · log10(η)
  Since η ≤ 1, the 10·log10(η) term is ≤ 0, so gain is always ≤ directivity.
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For example, an efficiency of $\eta = 0.90$ (90%) gives $10 \cdot \log_{10}(0.90) \approx -0.46$ dB of loss. A well-made antenna will have efficiency above 90%; cheap or electrically small antennas can fall to 50% or lower (a loss of 3 dB or more), turning claimed gain into a fiction. Note that efficiency expressed as a percentage and the loss expressed in dB are two views of the same quantity: a higher percentage means a smaller (less negative) dB loss term.

Near Field vs Far Field

The space around an antenna is divided into regions based on the character of the electromagnetic field. The boundaries below assume an antenna whose largest dimension is roughly a half-wave dipole ($D \approx 0.16$ m at 915 MHz); the radiating-near-field upper bound scales with that assumed D:

Region	Approximate Boundary	Characteristics
Reactive near field	$r < \lambda/2\pi \approx 5.2$ cm at 915 MHz	Stored energy dominates; reactive components (not yet waves); field shape varies with distance
Radiating near field (Fresnel)	~0.052 m to ~0.16 m (using $D \approx 0.16$ m, so $2D^2/\lambda \approx 0.16$ m)	Fields begin propagating but pattern shape still changes with distance
Far field (Fraunhofer)	$r > 2D^2/\lambda$	Radiation pattern stabilized; power density drops as $1/r^2$; all link budget calculations apply here

Note: the $2D^2/\lambda$ far-field criterion applies to antennas that are large compared with a wavelength. For small LoRa whips (D smaller than a wavelength), the reactive boundary $\lambda/2\pi$ dominates and the far field effectively begins at a few centimeters.

For practical LoRa mesh purposes, you are always operating in the far field - links are meters to kilometers long. The near field is relevant in two situations: when mounting antennas close to metal objects, where reactive fields can detune the antenna and alter its pattern significantly; and for RF human-exposure. The reactive near field is where RF exposure is highest - avoid placing body parts within a few wavelengths (roughly within tens of centimeters at 915 MHz) of a transmitting antenna, and consult FCC RF-exposure (MPE) guidance (FCC OET Bulletin 65 / 47 CFR 1.1310) for high-power or high-gain installations.

A key takeaway: as a rule of thumb, keep antenna elements at least $\lambda/4$ (about 8 cm at 915 MHz) away from metal surfaces, and preferably $\lambda/2$ or more; the exact clearance needed depends on the element type and ground-plane design. Even a metal enclosure lid placed too close to an antenna can shift its resonant frequency and reduce efficiency measurably - potentially by several dB, depending on proximity and geometry.

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