DIY Antenna Construction

Building a 915 MHz Yagi Antenna

A yagi antenna provides significant directional gain for point-to-point links - ideal for connecting two backbone nodes across a valley, mountain, or city. Building your own 915 MHz yagi is a rewarding project that costs $10-20 in materials vs. $50-150 for a commercial equivalent.

Yagi Design Fundamentals

A yagi consists of three element types mounted on a boom:

- **Reflector** - Behind the dipole; slightly longer than a half-wavelength; increases gain in forward direction
- **Driven element (dipole)** - The active element connected to the feedline
- **Directors** - In front of the dipole; slightly shorter than a half-wavelength; focus the beam forward

At 915 MHz, a half-wavelength in free space is approximately 164 mm (6.4 inches). Note that a real resonant element is about 5% shorter than the free-space half-wave due to end effect, so a driven dipole element typically cuts to around 155 mm rather than the full 164 mm. Each element is cut to a specific length and spaced precisely on the boom, then tuned with a NanoVNA.

5-Element Yagi Plans for 915 MHz

A typical 5-element yagi provides approximately 9-10 dBi (roughly 7-8 dBd) gain with a tight forward beam. Reaching 12 dBi generally requires 7-8 elements. With clear line of sight, a full Fresnel zone, adequate height, and a matching antenna on the far end, such a yagi can support links of 10 km or more; the realistic range depends on transmit power, terrain, and spreading factor as much as on antenna gain, so treat long-range figures as best-case line-of-sight, not routine.

FCC compliance note: A yagi above 6 dBi exceeds the 6 dBi reference gain in FCC 15.247(b)(4)(i). When used at 902-928 MHz, conducted transmit power must be reduced dB-for-dB for every dB of antenna gain above 6 dBi (for example, a 10 dBi antenna requires conducted power no greater than 26 dBm). The EIRP ceiling of about 36 dBm (4 W) is a derived limit (30 dBm conducted + 6 dBi), not a bonus you add gain on top of, and there is no relaxed point-to-point antenna allowance at 915 MHz.

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Element dimensions (915 MHz, 5-element, nominal - tune with a NanoVNA):
Reflector: 178 mm (7.01")
Driven element: 163 mm (6.42") - center-fed dipole (trim toward ~155 mm for resonance)
Director 1: 151 mm (5.94")
Director 2: 147 mm (5.79")
Director 3: 144 mm (5.67")

Spacing from reflector:
Driven element: 49 mm (1.93")
Director 1: 115 mm (4.53")
Director 2: 210 mm (8.27")
Director 3: 330 mm (13.0")
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Materials

- **Elements:** 3/16" (4.8mm) aluminum rod or welding rod. Available at hardware stores.
- **Boom:** 1/2" (12mm) square aluminum extrusion, 400mm long. Also available as wooden dowel (slightly less rigid but fine for hobby use).
- **Driven element:** Built as a split (center-fed) dipole fed through a gamma match or 50-ohm hairpin match - see the construction steps below.
- **Feedline:** Use RG-174 or LMR-195 only for a short (under ~1 m) pigtail, since RG-174 loses roughly 1 dB per metre (~30 dB per 100 ft) at 915 MHz. For any real cable run, use low-loss LMR-240 or LMR-400-class coax. SMA connector at the antenna end.
- **Hardware:** 1/4-20 stainless bolts and nylon locknuts to mount elements to boom.

Construction Steps

1. Cut all elements to specified lengths using a hacksaw or pipe cutter. Deburr ends.
2. Mark boom at element spacing positions.
3. Drill 3/16" holes through boom at each position.
4. Thread the reflector and directors through their boom holes and secure with nylon locknuts (finger-tight then 1/4 turn more). These are single, continuous rods.
5. Build the driven element as a split dipole: instead of one continuous rod, use two collinear half-elements (each about a quarter-wavelength, ~38 mm) mounted on an insulating block at the boom center, with a small gap (~3-5 mm) between their inner ends.
6. Feed it with one of these matches:

- **Direct/gap feed (simplest):** Solder the coax center conductor to one half-element and the coax shield to the other half-element across the center gap. A bare split dipole presents roughly 50-70 ohms, close enough to test; add a current balun (a few turns of the coax through a ferrite at the feed point) to keep RF off the coax shield.
- **Gamma match (for a continuous-rod driven element):** If you prefer one solid driven rod grounded to the boom at its center, run a parallel gamma rod (about 1/10 the driven-element length) spaced ~10-15 mm alongside one half, connect the coax center to the gamma rod through a small series capacitor (a few pF, often a short coax-sleeve trombone), and bond the coax shield to the driven element at center. Adjust the gamma rod length, spacing, and capacitance for lowest SWR.

7. Weatherproof the feed point and connector after tuning.

Testing Your Yagi

After construction, verify performance:

- Use a NanoVNA to check SWR at 915 MHz. Target: SWR less than 2:1, ideally below 1.5:1. Adjust the match (and trim the driven element toward resonance) as needed.
- Compare RSSI at a fixed test point vs. a reference omni - the yagi should show roughly 6-10 dB improvement in its forward direction. Measured improvement varies with the environment, multipath, and reference antenna, so this is a typical figure, not a guarantee.
- Note the half-power beamwidth: a 5-element yagi has roughly 55 degree horizontal beamwidth. For best performance, aim within about +/-15 degrees (roughly half the half-power beamwidth) of the far station.

Building a Collinear Vertical Antenna

This page covers two simple, easy-to-build omnidirectional verticals for 915 MHz - a J-pole and a 5/8-wave vertical - both a significant improvement over the stock rubber duck antennas included with most LoRa boards. (A true multi-element collinear, which stacks several half-wave sections in phase to reach ~3-6 dBd, is described conceptually below but is a more advanced build not detailed here.) The J-pole and 5/8-wave verticals below are straightforward to build with basic tools.

How a Collinear Works

A collinear antenna consists of multiple half-wave dipole elements stacked vertically and fed in phase. Each additional element increases the gain and makes the radiation pattern more disk-shaped (more horizontal, less toward sky/ground) - which is exactly what you want for a terrestrial mesh network. Note that the two single-element verticals built on this page (the J-pole and the 5/8-wave) are *not* multi-element collinears; they are simpler designs with dipole-class gain, included here as practical starting points.

Simple J-Pole Vertical for 915 MHz

The J-pole is one of the simplest omnidirectional verticals to build. It is an end-fed half-wave radiator fed through a quarter-wave parallel matching stub (the "J") - it is **not** a collinear. Its gain is essentially that of a half-wave dipole, about ~0 dBd (~2.15 dBi); the widely-repeated "~3 dBd J-pole" claim is a myth. Its real advantages are a clean omnidirectional pattern and an easy feed, not extra gain. A J-pole gives roughly 2-3 dB more than a basic quarter-wave ground plane, not 3.5 dBd.

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915 MHz J-Pole dimensions:
Radiator: 163 mm (6.42") - connects to matching section
Matching section: ~82 mm (3.23") - quarter-wave parallel stub (half the radiator length)
Shorting bar: 40 mm (1.57") - connects bottom of radiator to top of short arm
Feed point: 37-42mm from bottom of matching section (tune for min SWR)

Material: 3/32" or 1/8" brass rod, or stiff copper wire (14 AWG solid)
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Tuning the feedpoint: attach the coax at about 40 mm up from the bottom of the matching stub, sweep SWR with a NanoVNA (see the Testing & Tuning pages), and slide the tap a few millimetres up or down toward the lowest SWR at 915 MHz. The exact feed position depends on conductor diameter, so expect to fine-tune. These dimensions are a starting point - verify against a 915 MHz J-pole/Slim Jim calculator and tune with a NanoVNA.

5/8 Wave Vertical

A 5/8 wavelength vertical with a ground plane offers roughly 3 dB of gain over a quarter-wave whip - that is about 1-1.5 dBd (~3 dBi) over a dipole, **not** 3 dBd. Its main benefit is a lower takeoff angle than a quarter-wave, which is excellent for long-range terrestrial links:

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5/8 wave vertical at 915 MHz:
Vertical element: 203 mm (7.99") nominal; trim ~5% shorter for end effect, tune with a NanoVNA
Ground plane radials: 4x at ~82 mm (quarter-wave), angled 45 degrees downward
Feedpoint: SMA or N connector at base
Impedance: a 5/8-wave element is NOT naturally 50 ohms - it presents
  capacitive reactance and generally needs a base matching/loading coil.
  (Drooping radials alone match a quarter-wave, not a 5/8-wave.)
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Weatherproofing a DIY Antenna

Any antenna installed outdoors needs weatherproofing to survive years of exposure. Any DIY antenna installed outdoors must also be grounded and surge-protected (see Grounding and Lightning Protection) and kept well clear of overhead power lines during and after installation; solder in a well-ventilated area.

- **UV protection:** Coat metal elements with cold galvanizing compound or clear lacquer spray. Aluminum naturally oxidizes to a protective oxide layer against bulk corrosion, but that oxide raises contact resistance at joints and connectors, so bare aluminum joints still need protection; copper and brass oxidize to patina that increases resistance - coat with lacquer.
- **Connector protection:** Wrap SMA/N connector base with self-amalgamating tape (silicone rubber tape that bonds to itself). Apply starting from the cable, overlapping onto the connector, then back. Provides a reliable weatherproof seal.
- **Mounting:** Stainless steel hardware is the practical choice; it is only moderately compatible with aluminum, so in coastal or salty environments use anti-seize or dielectric isolation to limit galvanic corrosion. Coat any carbon steel hardware with cold galvanizing compound.

- **Housing:** For clean installations, insert the antenna inside a length of PVC pipe (Schedule 40, 3/4" inside diameter for most quarter-wave to collinear antennas). PVC is RF-transparent at 915 MHz with minimal loss.

Gain Comparison: Antennas for 915 MHz

Gains below are given in both dBd (relative to a half-wave dipole) and dBi (relative to an isotropic source). Convert with **dBi = dBd + 2.15**.

Antenna Type	Gain (dBd / dBi)	Pattern	Build Difficulty	Best Use
Stock rubber duck	-3 to 0 dBd / -0.85 to 2.15 dBi	Omnidirectional	None (included)	Portable/indoor only
Quarter-wave with radials	~0 dBd / ~2 dBi	Omnidirectional	Easy	Basic outdoor fixed
J-Pole (end-fed half-wave)	~0 dBd / ~2.15 dBi	Omnidirectional	Easy	Home repeater
5/8 wave vertical	~1 dBd / ~3 dBi (≈3 dB over a quarter-wave whip)	Omni, low angle	Medium	Long-range omni
5-element yagi	~7-8 dBd / ~9-10 dBi	Directional ~55°	Medium	Point-to-point link
Commercial 5 dBi fiberglass	~3 dBd / 5 dBi	Omnidirectional	None (buy)	Outdoor repeater

Note: antennas above 6 dBi require a dB-for-dB reduction of conducted power under FCC 15.247(b)(4)(i) in the 902-928 MHz band - see the FCC Regulations and EIRP Reference page.