Testing & Tuning

NanoVNA Antenna Testing

Overview

A **NanoVNA** (Vector Network Analyzer) is the essential tool for verifying antenna performance before deployment. It measures SWR (Standing Wave Ratio) and impedance - telling you how well your antenna is matched to the 50 Ω system and whether it is resonant at 915 MHz. A 10-minute NanoVNA check before mounting an antenna can save hours of troubleshooting range problems later.

Models

Model	Screen	Frequency Range	Price
NanoVNA-H	2.8″	50 kHz - 1.5 GHz	~$30 - 50
NanoVNA-H4	4.0″	10 kHz - 1.5 GHz	~$50 - 70
NanoVNA-F	4.3″ (metal case)	10 kHz - 1.5 GHz	~$50 - 70

Frequency note: Common NanoVNA models (H / H4 / F) top out near **1.5 GHz**, not 3 GHz - 915 MHz sits comfortably within range. On the basic NanoVNA-H, operation above ~900 MHz uses harmonic mode with reduced dynamic range, so 915 MHz measurements are valid but recalibrate carefully; the H4 and F perform better here. Prices above are approximate as of 2026-06-08 and vary by vendor.

Kit includes: NanoVNA unit, calibration standards (Open/Short/Load), two SMA cables, USB-C charging cable.

Five-Step Testing Procedure

Step 1 - Initial Setup

1. Charge the NanoVNA via USB-C before first use.
2. Power on.
3. Set the frequency range: **START = 850 MHz**, **STOP = 950 MHz**.

Step 2 - Calibration (Most Critical)

Calibrate every session or any time you change the frequency range. Calibration compensates for cable and connector losses - skipping it invalidates all measurements.

1. Navigate to **Menu → CAL → CALIBRATE**.
2. Connect the **OPEN** standard → select OPEN → wait for measurement.
3. Connect the **SHORT** standard → select SHORT → wait.
4. Connect the **LOAD** (50 Ω) standard → select LOAD → wait.
5. Save calibration to a slot (0 - 4).
6. Verify: reconnect LOAD → SWR should read **~1.0**, impedance **~50+j0 Ω**. This check confirms the calibration math, not absolute accuracy; the supplied standards are adequate for hobby antenna work.

Recalibrate when: changing frequency range; moving to a significantly different temperature environment; switching to different cables.

Step 3 - Configure Display

- Set **Trace 1** to **SWR**.
- Optionally set **Trace 2** to Smith Chart or R+jX for impedance detail.
- Add a **marker at 915 MHz**.

Step 4 - Connect Antenna

Caution: Disconnect or power down the LoRa radio before connecting a NanoVNA to its antenna line. A NanoVNA is a low-power test source; applying transmit power to a NanoVNA port will damage the instrument.

- Connect antenna cable to **CH0 (Port 1)**.
- Use the shortest possible cable between the NanoVNA and antenna.
- Tighten connectors finger-tight only - do not over-torque SMA.
- **Check connector type:** LoRa antennas commonly use SMA or RP-SMA. These look identical but are not compatible - verify before connecting.

Step 5 - Interpret Results

SWR Ratings

SWR	Rating	Action

1.0 - 1.5	Excellent	Deploy with confidence
1.5 - 2.0	Good - acceptable	Fine for most deployments
2.0 - 3.0	Marginal - some power loss	Investigate connector quality
3.0+	Poor - significant loss	Replace antenna or diagnose connector

Resonant Frequency

The **lowest SWR dip** on the sweep is the antenna's resonant frequency.

- Dip **at 915 MHz** - optimal
- Dip **below 915 MHz** - antenna is slightly long (resonates lower)
- Dip **above 915 MHz** - antenna is slightly short (resonates higher)

Common Problems & Diagnosis

Symptom	Likely Cause
High SWR across entire 850 - 950 MHz band	Antenna tuned for 868 MHz (European band); damaged or loose connector; missing ground plane on whip antenna
SWR varies wildly / unstable reading	Loose connector; damaged cable - wiggle connections while watching display
Excellent SWR but poor range	SWR measures *impedance match only*, not gain. SWR and gain are independent - evaluate both. A 6 dBi antenna with moderate mismatch (2:1, ~0.5 dB loss) still beats a 0 dBi matched antenna at both short and long range; only a severe mismatch (loss exceeding the gain advantage) erases the gain benefit. Evaluate antenna gain separately.

PC Software: NanoVNA-Saver

NanoVNA-Saver is free, open-source software (Windows/Mac/Linux - search GitHub for "NanoVNA-Saver") that connects to your NanoVNA via USB and provides:

- Larger, higher-resolution graphs
- Data export (CSV)
- Smith chart display
- Touchstone (.s1p) file export for import into antenna modeling software
- Multi-antenna comparison - overlay sweeps from different antennas

Recommended for antenna selection decisions and documentation of deployed infrastructure antennas.

Common Mistakes to Avoid

- **Skipping calibration** - all measurements are invalid without calibration
- **Calibrating at the wrong frequency range** - calibration is only valid for the range it was performed at; recalibrate if you change START/STOP
- **Testing indoors near metal objects** - nearby metal detuning antennas; test in the open or simulate the actual mounting environment
- **Using adapters without accounting for electrical length** - SMA adapters add a small but measurable electrical length; minimize adapter use
- **Confusing SMA and RP-SMA** - SMA has center pin on plug; RP-SMA has center pin on jack. Forcing mismatched connectors damages both.

SWR, VSWR, and Return Loss Explained

Before deploying an antenna on your mesh node, understanding how to measure and interpret antenna performance can save you from poor coverage or potential hardware damage.

What is SWR?

Standing Wave Ratio (SWR) - more precisely Voltage Standing Wave Ratio (VSWR) - measures how well an antenna is impedance-matched to your transmission line and radio. A perfect match is 1:1. Most radios are designed for 50-ohm impedance.

- **SWR 1.0:1** - Perfect match. 100% of power transferred to antenna.
- **SWR 1.5:1** - Excellent. ~96% power transferred. Imperceptible in practice.
- **SWR 2.0:1** - Good. ~89% power transferred. Acceptable for most deployments.
- **SWR 3.0:1** - Poor. ~75% power transferred. Antenna should be investigated.
- **SWR 5.0:1+** - Bad. Significant reflected power. Can stress or damage some unprotected transmitters over time (many modern radios fold back power at high SWR to protect the power amplifier, but don't rely on it).

Note: these labels are a simple rule of thumb. Other pages in this book (NanoVNA Antenna Testing, SWR & Antenna Analyzers) use slightly different band boundaries for the same SWR values; treat any single SWR figure near a boundary as approximate and prefer the lowest SWR you can achieve.

At LoRa power levels (typically 10-30 dBm / 10mW-1W), a high SWR is unlikely to damage hardware immediately, but it does reduce effective radiated power and range. **Exception:** never transmit with the antenna disconnected (an open or shorted port is effectively infinite SWR). Even at LoRa power, repeatedly keying into no load can damage the power amplifier - always have an antenna or dummy load attached before transmitting.

Return Loss

Return loss is another way to express the same measurement, preferred by RF engineers. It is conventionally reported as a **positive** dB value, and **larger is better** (more dB = less reflected power):

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Return Loss (dB) = -20 * log10(|Γ|) = 20 * log10((SWR+1)/(SWR-1))
  where reflection coefficient |Γ| = (SWR-1)/(SWR+1)

SWR 1.5:1 ≈ 14 dB return loss
SWR 2.0:1 ≈ 9.5 dB return loss
SWR 3.0:1 ≈ 6 dB return loss
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Higher return loss (a larger positive dB number) is better, because it means less power is being reflected back from the antenna. A return loss of 14 dB or better is considered a good antenna match. (Some instruments display the reflection coefficient S11 as a negative number, e.g. -14 dB; return loss is just the magnitude of that value, quoted as positive.)

Why Antennas Have Poor SWR

- **Wrong resonant frequency** - Antenna cut for wrong frequency. 433 MHz antennas will not match at 915 MHz.
- **Damaged antenna** - Broken internal element or damaged connector.
- **Loose or oxidized connector** - Resistance at connection point adds to mismatch.
- **Incorrect antenna for your radio's impedance** - Most LoRa radios are 50-ohm; some antennas are 75-ohm (designed for cable TV).
- **Near-field interference** - Conductive material too close to the antenna element.

Measuring SWR Without a VNA

If you don't have a NanoVNA, you can still estimate antenna performance:

- **Two-node range test** - The most practical field test. Compare RSSI/SNR at a known distance with the suspect antenna vs. a known-good stock antenna.
- **RF power meter + dummy load** - Measure forward and reflected power at the transmitter to derive SWR. Be careful with frequency coverage: inexpensive SWR/power meters often top out below ~500 MHz, so a sub-$50 meter may not actually cover 902-928 MHz. Meters or directional couplers that accurately cover 915 MHz generally cost more - verify the meter's rated frequency range includes 915 MHz before relying on it.
- **RSSI comparison** - Place a second node 100m away. Compare received RSSI with the suspect antenna vs. the stock rubber duck. A 3 dB higher RSSI means the receiver got about 2× the power - i.e. one antenna outperforms the other by 3 dB in that direction. This is a rough field comparison, not an SWR measurement, and it is sensitive to placement, orientation, and multipath.

Field Antenna Testing Without Lab Equipment

Professional antenna testing requires a vector network analyzer and anechoic chamber. Field testing with simple tools can still tell you whether an antenna is working as expected for your deployment.

The Two-Node RSSI Test

The most practical field test for comparing antennas:

1. Set up a reference node at a fixed location (indoors at a window, or on a tripod outdoors). Keep the reference node's own antenna unchanged for the whole test.
2. Connect your test antenna to the mobile node
3. Walk to a consistent test point 50-200m away
4. Record RSSI (in dBm) **at the fixed reference node** - it is the end that "hears" the antenna under test. Take several readings (e.g. 10-20 over a minute or two) and average them, since LoRa RSSI swings several dB from multipath and orientation moment to moment. View RSSI in the Meshtastic app.
5. Replace the antenna on the mobile node with a known reference (stock rubber duck or a calibrated dipole)
6. Return to the same test point and record the averaged RSSI at the reference node again

The change in averaged RSSI at the reference node when you swap the test antenna approximates the test antenna's gain change: a +3 dB improvement means the new antenna has roughly 3 dB more gain than the reference, in that direction. This only holds if transmit power, position, and the reference node's antenna are all held constant, and only on the receiving end - so always read RSSI at the fixed reference node, not "either node." A single test point cannot capture pattern differences (for example, a high-gain collinear may show *less* RSSI to a nearby high-angle node despite more boresight gain), so treat the result as a rough comparison, not a precise gain measurement.

Important: Test at multiple azimuths (compass directions) for directional antennas. Omnidirectional antennas should show similar RSSI regardless of direction.

Checking for Antenna Resonance with an SDR

An RTL-SDR dongle (~$25-40 depending on model and vendor, as of 2026) can help confirm an antenna is "alive," but note that bare noise-floor observation is **not** a reliable resonance test:

1. Connect the test antenna to the SDR via an appropriate adapter
2. Open SDR# or GQRX
3. Look at the noise floor across 900-930 MHz while the antenna is connected vs. with a dummy load or no antenna
4. A working antenna will generally raise the received noise floor versus no antenna, confirming it is receiving - but a rise (or lack of one) does not cleanly prove resonance at 915 MHz, since ambient noise depends on what is transmitting nearby, not solely on antenna resonance.

This noise-floor check only tells you whether the antenna is receiving at all; it is not a resonance or SWR measurement. For a real resonance check, use a NanoVNA to measure return loss, or transmit a known low-power carrier from a second node and compare the received level across frequencies. An RTL-SDR with a noise source and a directional coupler can also reveal resonance notches, but a bare dongle cannot.

Common Field Issues and Quick Diagnosis

Symptom	Likely Cause	Quick Test
RSSI much worse than expected	Wrong frequency antenna, damaged element, or loose connector	Swap with known-good antenna; check connector seating
Range varies wildly with orientation	Antenna is directional (yagi, patch), or near-field coupling to enclosure	Mount antenna away from metal surfaces
Range degrades after outdoor installation	Water ingress into connector or pigtail	Inspect connector for corrosion; re-weatherproof
Node transmits but no one hears it	Open circuit in antenna path (broken cable, wrong adapter)	Verify continuity/SWR with a NanoVNA (receive-only) *before* transmitting, then swap the cable

Caution: Do not key or transmit with a suspected open or disconnected antenna line. Transmitting into an open or badly mismatched port can damage the radio's power amplifier. Check continuity and SWR with a NanoVNA (which is receive-only) first, or transmit only briefly with a dummy load attached - never transmit without an antenna or dummy load connected.

Documentation for Installations

For permanent outdoor installations, document your baseline measurements:

- Date of installation
- Antenna model and supplier
- SWR at 915 MHz (from NanoVNA if available)
- RSSI to 2-3 reference nodes at known distances
- Photos of antenna mounting and connector weatherproofing

This documentation makes troubleshooting future performance issues much faster - you have a baseline to compare against.