Coax, Connectors, and Feedline

Cable selection, RF connectors, and feedline loss minimization for LoRa installations.

- Coax Cable Selection Guide
- RF Connectors for LoRa Hardware
- Minimizing Feedline Loss

Coax Cable Selection Guide

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The coaxial cable connecting your LoRa radio to its antenna is a critical component that directly subtracts from your link budget. Every decibel of cable loss is a decibel less of received signal and, equivalently, a decibel less of radiated power. Understanding the tradeoffs between cable types helps you make smart choices for your deployment.

Understanding Cable Loss

Coaxial cable loss is caused by two primary mechanisms:

1. **Conductor (ohmic) loss:** Resistance of the inner and outer conductors dissipates RF energy as heat. Increases with frequency (skin effect drives current to conductor surface, effectively reducing conductor area).
2. **Dielectric loss:** The insulating material between conductors absorbs some RF energy. Also increases with frequency.

Both losses increase with frequency, which is why a cable that seems acceptable at VHF (150 MHz) can be disastrously lossy at 915 MHz. Always check specifications at or near your operating frequency.

Cable Loss Comparison at 915 MHz

Loss figures below are stated per 100 ft at 915 MHz, sourced from the manufacturer (Times Microwave LMR / Andrew-CommScope) and reference coax datasheets; the "per 10 ft" column is simply the per-100-ft figure divided by ten. Use these canonical values for all link-budget planning; other pages in this book reference this same table.

Cable Type	Outer Diam.	Loss (dB/100 ft) @ 915 MHz	Loss per 10 ft	Impedance	Flexibility
RG-174	2.8 mm	~28 dB	~2.8 dB	50 Ω	Very flexible; pigtails only
RG-58/U	5 mm	~20 dB	~2.0 dB	50 Ω	Flexible; common
RG-8X (mini 8)	6.1 mm	~12.6 dB	~1.26 dB	50 Ω	Semi-flex; good budget cable

Cable Type	Outer Diam.	Loss (dB/100 ft) @ 915 MHz	Loss per 10 ft	Impedance	Flexibility
RG-213/U	10.3 mm	~8 dB	~0.8 dB	50 Ω	Stiff; older mil-spec
LMR-100A	2.79 mm	~22.8 dB	~2.28 dB	50 Ω	Very flexible; pigtails/jumpers
LMR-200	5.4 mm	~9.9 dB	~0.99 dB	50 Ω	Semi-flexible; good midrange
LMR-400	10.3 mm	~3.9 dB	~0.39 dB	50 Ω	Semi-rigid; best low-loss practical
LMR-600	15.8 mm	~2.5 dB	~0.25 dB	50 Ω	Rigid; tower/commercial use
Andrew FSJ1-50A (1/4" Superflex)	7.1 mm	~4.4 dB (verify against CommScope datasheet)	~0.44 dB	50 Ω	Flexible hardline; pro installations

Practical Loss Examples

To illustrate the real-world impact, consider a typical outdoor node installation with 20 ft (6 m) of cable between the radio and antenna. The loss figures below are computed directly from the canonical per-100-ft table above (20 ft = 0.2 × the per-100-ft value). Range penalties assume free-space (inverse-square) propagation, where the range ratio = 10^(−loss_dB/20); real-world terrain makes the penalty smaller in some cases and larger in others, so treat these as approximate:

Cable Choice	Loss for 20 ft	Equivalent TX Power Reduction	Range Penalty (free space, approx.)
RG-58	~4.0 dB	17 dBm → 13.0 dBm (effective)	~37% shorter range
LMR-200	~2.0 dB	17 dBm → 15.0 dBm (effective)	~21% shorter range
LMR-400	~0.8 dB	17 dBm → 16.2 dBm (effective)	~9% shorter range

Cable Selection Recommendations

Short runs (under 3 ft / 1 m) - pigtails and jumpers

Use LMR-100A or RG-174. These are flexible enough to route in tight spaces and the short length keeps absolute loss acceptable (under 0.9 dB for a 3 ft run). This is the correct cable for the factory

pigtail from the LoRa radio to the connector panel.

Medium runs (3 - 20 ft / 1 - 6 m)

LMR-200 is the best choice: meaningful loss improvement over RG-58, flexible enough to route around obstacles, and connectors are readily available. This is the correct choice for most outdoor node installations where the radio is inside an enclosure and the antenna is a few feet above.

Long runs (20 - 100 ft / 6 - 30 m)

LMR-400 is strongly recommended. The loss reduction over LMR-200 is significant at these lengths. For runs over 50 ft, consider whether you are better served by moving the radio closer to the antenna (POE-powered remote radio, for example).

When to upgrade your cable

Upgrade cable when feedline loss exceeds 3 dB. At 3 dB loss, you are throwing away half your transmit power before it even reaches the antenna, and your receive sensitivity is degraded by approximately 3 dB (feedline loss ahead of the radio raises the system noise figure by close to the cable loss, depending on the radio's own noise figure) - effectively halving your effective radiated power and degrading reception in both directions simultaneously. No antenna upgrade will compensate for this.

Avoiding Common Coax Mistakes

- **Never kink or crush coax.** A sharp kink or bend beyond the cable's minimum bend radius can add significant localized loss and reflections, and can permanently damage the cable. LMR-400 has a minimum bend radius of about 1 inch; exceeding this damages the shield and dielectric.
- **Waterproof all outdoor connectors.** Water ingress between the connector and cable will corrode the connection and introduce significant loss within weeks. Use self-amalgamating tape over all outdoor connections.
- **Do not daisy-chain adapters.** Each adapter adds a small amount of loss (typically well under ~0.5 dB) and a potential failure point. If you need an N to SMA connection, use a single pigtail, not an N-to-PL259 + PL259-to-BNC + BNC-to-SMA chain.
- **Store connectors facing down outdoors.** Connector faces should point downward or be shielded from direct rainfall to prevent standing water in the connector mating face.

RF Connectors for LoRa Hardware

RF Connectors for LoRa Hardware

RF connector incompatibility is one of the most common and frustrating problems when assembling LoRa mesh hardware. Knowing which connectors are standard on which hardware and understanding adapter losses will save hours of troubleshooting and return shipping.

The Principal Connector Families

SMA (SubMiniature version A)

SMA connectors are the workhorses of small-form RF hardware. They are threaded (10-32 thread) and rated to 18 GHz in standard form. Power handling is frequency-dependent: a standard SMA handles roughly 100 W at HF, derating sharply with frequency to only a few watts near 18 GHz. (At LoRa's sub-1 W transmit power this is academic; for genuinely high-power runs use N-type or larger.) Two variants cause constant confusion:

Type	Center Pin on Male	Center Pin on Female	Notes
SMA (standard)	Pin protrudes	Socket (receptacle)	Used on most professional RF equipment and high-quality antennas

Type	Center Pin on Male	Center Pin on Female	Notes
RP-SMA (Reverse Polarity)	Socket (receptacle)	Pin protrudes	An industry convention WiFi vendors adopted to comply with FCC 47 CFR 15.203, which requires a unique (non-standard) antenna coupling so the public cannot easily fit unauthorized antennas. The FCC does not mandate RP-SMA specifically — only a non-standard coupling; RP-SMA is one common way to meet that requirement. Extremely common on consumer WiFi and found on some consumer LoRa hardware.

Critical: Standard SMA and RP-SMA are physically intermateable - the threads engage and the connector tightens - but they do NOT make electrical contact. You will have a physically connected but RF-dead assembly. Always verify polarity before tightening.

Which LoRa Hardware Uses Which?

Hardware	Connector
RAK WisBlock (RAK4631, RAK19007)	U.FL / IPEX on module; SMA via the supplied IPEX-to-SMA pigtail (not a fixed enclosure connector)
Lilygo T-Beam (most versions)	SMA female (standard)
Heltec WiFi LoRa 32 v2/v3	Varies by revision: U.FL / IPEX on PCB on some boards, board-mounted SMA on others. Verify your specific board.
Meshtastic / LilyGo T-Echo	U.FL on PCB
Seeed WIO-E5 module	U.FL on module
Dragino LPS8 gateway (indoor)	SMA female
RAK Wisgate Edge (commercial gateway)	N-female (standard)
TTGO LoRa32 v2	U.FL with bundled SMA pigtail
Adafruit Feather M0 RFM95W	U.FL; use an SMA edge-launch or U.FL pigtail

Note: Connector types can vary by hardware revision. Always verify on the actual unit or current product page before ordering cables and adapters.

N-Type Connector

The N-type is a larger, weatherproof threaded connector rated to 11 GHz (standard) or 18 GHz (precision). It is the connector of choice for any serious outdoor installation - towers, rooftop

gateways, commercial deployments. N-type connectors have excellent weatherproofing when properly assembled, low contact resistance, and are designed for repeated mating cycles.

- **Used on:** Commercial gateways (Dragino, RAK Wisgate, Kerlink, MultiTech), tower-mount antennas, LMR-400 and larger cable installations
- **Loss:** Typically 0.05 - 0.1 dB per connector pair at 915 MHz
- **Availability:** Widely available; both solder and crimp versions for all major coax types

U.FL / IPEX / MHF1 Connector

U.FL (the Hirose trade name) or IPEX/MHF1 (equivalent generic and Amphenol variants) are ultra-miniature snap-lock coaxial connectors used on PCBs to connect the RF IC to an external antenna pigtail. They are rated to only about 30 mating cycles, so they are not designed for repeated disconnection.

- **Used on:** Almost all LoRa and GPS modules mounted on PCBs - Heltec, RAK module cores, TTGO, and most other SoC-level boards
- **Important:** Extremely fragile and rated for only ~30 mating cycles; do not repeatedly disconnect/reconnect. Lock in place and leave. If you need a permanent connection, solder a small bead of hot glue after mating to prevent accidental disconnection.
- **Pigtails:** Use only U.FL-to-SMA (or RP-SMA) pigtails made with RG-178 or similar micro-coax. The connector at the board end is U.FL female (socket on pigtail). The connector at the panel end should match your application (SMA, N, etc.)
- **Loss:** The U.FL connector itself adds only ~0.05 - 0.1 dB at 915 MHz; a typical U.FL pigtail (connector + thin coax) adds ~0.2 - 0.5 dB total, most of which is the thin pigtail coax.

Adapter Losses

Each adapter in the RF path adds loss and a potential failure point. Typical losses at 915 MHz:

Adapter Type	Typical Loss at 915 MHz	Notes
SMA(M) to SMA(F) barrel	0.1 - 0.2 dB	Use only when necessary; prefer direct cable
SMA to N-type	0.1 - 0.3 dB	Acceptable for indoor patch panels; not preferred outdoors
RP-SMA to SMA	0.1 - 0.2 dB	Common necessity when mixing hardware
U.FL to SMA pigtail	0.2 - 0.5 dB	U.FL connector + cable loss; unavoidable for PCB boards
PL-259/SO-239 (UHF)	0.3 - 0.8 dB	Not designed for 915 MHz; avoid entirely

Quality Matters

A cheap SMA connector or adapter purchased in a $3 bag of 20 pieces is not equivalent to a $5 Amphenol or TE Connectivity connector. Differences include:

- Contact resistance: quality connectors use silver or gold plating; cheap ones use brass or tin that oxidizes
- Dimensional tolerances: loose tolerances cause intermittent contact at vibration or thermal cycling
- Dielectric quality: cheap connectors use low-grade PTFE substitutes that absorb moisture
- Thread quality: soft aluminum threads strip after a few matings

For outdoor permanent installations, spend the money on proper connectors. For bench development, economy connectors are acceptable. Never use economy connectors in a deployed outdoor node.

Minimizing Feedline Loss

Minimizing Feedline Loss

Feedline loss is the silent enemy of RF system performance. Unlike antenna gain (which you buy) or transmit power (which you set), feedline loss just silently destroys the performance you already have. This page provides the tools to quantify, minimize, and budget feedline loss in your LoRa mesh installations.

The Link Budget Impact of Feedline Loss

Feedline loss hits you twice - once on transmit and once on receive. On transmit, every dB of cable loss reduces your effective radiated power by 1 dB. On receive, cable loss before the receiver's low-noise amplifier (LNA) degrades the noise figure of the entire receive chain by 1 dB per 1 dB of cable loss. (On the common SX126x/SX127x LoRa transceivers the LNA is on-chip, so essentially all feedline and connector loss precedes it.)

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Example: 20 dBm TX, 5 dB cable loss, 5 dBi antenna
EIRP = 20 dBm + 5 dBi − 5 dB = 20 dBm

Example: Same cable with a 2 dBi antenna
EIRP = 20 dBm + 2 dBi − 5 dB = 17 dBm

Conclusion: 5 dB of cable loss ERODES the benefit of the better antenna.
The 5 dBi antenna with 5 dB of cable loss (EIRP 20 dBm) still beats the 2 dBi
antenna with the same 5 dB of cable loss (EIRP 17 dBm) by 3 dB. What the loss
destroys is the UPGRADE relative to a no-loss case: with no cable loss the 5 dBi
antenna would deliver 25 dBm EIRP, so the 5 dB of cable swallowed the entire
5 dB the antenna could have given. Reducing the cable loss recovers more than the
antenna upgrade itself provided.
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FCC note: these EIRP figures (20 dBm, 17 dBm) are far below the limit. Under 47 CFR 15.247 the regulatory ceiling at 915 MHz is on *conducted* output power - 1 W (30 dBm) into an antenna of up to 6 dBi - with a derived EIRP ceiling of about 36 dBm (4 W). Feedline loss subtracts from EIRP, so adding cable can only move you further below the limit, never above it.

Cable Length Math

To calculate cable loss for a given run, use the loss per 100 ft specification from cable data sheets. The per-100 ft figures below are the canonical 915 MHz values from the book's feedline-loss reference (Times Microwave LMR datasheets):

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Loss (dB) = (Loss per 100 ft at 915 MHz) × (Run length in feet) ÷ 100


Examples for a 15 ft run:
 LMR-100A: 22.8 dB/100ft × 15/100 = 3.42 dB
 LMR-200:   9.9 dB/100ft × 15/100 = 1.49 dB
 LMR-400:   3.9 dB/100ft × 15/100 = 0.59 dB
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For metric calculations (loss per 100 m):

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Loss (dB) = (Loss per 100 m at 915 MHz) × (Run length in meters) ÷ 100
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The Full System Loss Budget

Account for every component in the RF path between radio and antenna:

Component	Typical Loss	Notes
U.FL connector (at PCB)	0.2 - 0.5 dB	Present on most PCB-based LoRa boards (typical U.FL insertion loss at ~1 GHz)
U.FL-to-SMA pigtail (6")	0.3 - 0.5 dB	RG-178 pigtail from PCB to enclosure panel (RG-178 ~0.5-0.8 dB/ft at 900 MHz plus connectors)
SMA to N-type adapter	0.1 - 0.2 dB	Quality adapter, if converting at the enclosure panel
Main feedline (LMR-200, 10 ft)	~1.0 dB	From enclosure to antenna base (9.9 dB/100 ft at 915 MHz × 10/100)
N-type connector at antenna	0.1 dB	Quality N-type connector
Lightning arrestor	0.1 - 0.3 dB	If inline gas discharge tube used
Total example	**~1.8 - 2.6 dB**	

In this example, a real system with 10 ft of LMR-200 would have about 2 dB of total system feedline loss. This is acceptable. If you replace the LMR-200 with RG-58 (~20 dB/100 ft at 915 MHz), the 10 ft main cable alone goes from ~1.0 dB to ~2.0 dB - adding ~1 dB extra and pushing total loss toward 3 dB or more, where you start losing meaningful range. RG-58 is a poor choice at

915 MHz.

Inline Connectors Double Loss

Every barrel connector, adapter, or splice in the cable run adds loss and a potential water ingress point. For outdoor installations:

- Plan your cable routing so you can run a single unbroken cable from the enclosure to the antenna
- If you must make a field splice, use a waterproof N-type barrel connector (not SMA) and seal with self-amalgamating tape
- Adapters at the radio or antenna end are sometimes unavoidable; minimize them everywhere else

When Cable Loss Is Unavoidable: Remote Radio Head

For installations requiring very long cable runs (tower top, building rooftop with equipment room far from the rooftop), consider placing the radio module in a weatherproof enclosure directly at the antenna mounting point. Power is delivered via a long DC cable, and data is retrieved via Ethernet or WiFi (or just on-board storage). This approach reduces feedline loss to the short U.FL pigtail and short jumper, typically under 1 dB total.

Checking Your Cable with SWR

A cable that looks fine externally can have significant internal damage (crushed, kinked, or water-damaged dielectric). A quick SWR check with a NanoVNA or antenna analyzer can reveal the problem. Connect the analyzer to one end with the other end open or shorted. A healthy cable will show predictable impedance; a damaged cable will show irregular spikes or elevated VSWR at unexpected frequencies due to impedance discontinuities at the damage point.