

LoRa Technology Explained

LoRa stands for **Long Range**. It is a wireless radio modulation technique invented by a French startup called Cycleo and acquired by Semtech in 2012. LoRa chips appear in millions of devices worldwide today, from smart utility meters to wildlife trackers to community mesh nodes. To understand why LoRa is so effective for mesh networking, you need to understand the core technique it uses: **Chirp Spread Spectrum**.

What Is Chirp Spread Spectrum?

Most radio systems transmit data on one fixed frequency. A chirp spread spectrum (CSS) system does something different: it sweeps the signal continuously across a range of frequencies, rising or falling in pitch over time (like a bird's chirp - hence the name). The receiver looks for this specific sweep pattern rather than listening at one spot.

Why does this matter? Several reasons:

- **Noise rejection.** Man-made interference tends to be concentrated at specific frequencies, while a CSS signal is spread across the whole channel. Because the signal is spread across a wide band, any noise at one frequency only affects a small fraction of the signal. The receiver can mathematically reconstruct the original data even when much of the band is noisy.
- **Multipath resistance.** Radio signals bounce off buildings, hills, and trees. These echoes arrive at the receiver slightly delayed and can cancel out the original signal. CSS is much more resilient to this effect than narrowband modulation.
- **Low detectability.** A spread-spectrum signal looks almost like background noise to anyone not specifically looking for it, making it robust in RF-noisy environments.

Processing Gain and Extraordinary Sensitivity

The key metric for a radio receiver is its **sensitivity** - the minimum signal power it can decode. A conventional FM radio might have a sensitivity of around - 100 dBm (decibel-milliwatts). LoRa achieves sensitivities around - **134 to - 137 dBm** at the bandwidths used for mesh (BW125-250 kHz, SF12), and as low as ~- 148 dBm only at very narrow bandwidth (7.8 kHz) not used by Meshtastic/MeshCore. That is roughly 50 dB better than FM, which means LoRa can receive signals

tens of thousands of times weaker.

This extraordinary sensitivity comes from **processing gain**: the mathematical process of correlating the received sweep against an expected template. The more time and bandwidth the receiver spends correlating, the more gain it recovers. LoRa lets you tune this trade-off with a parameter called the **Spreading Factor**.

What Spreading Factor Actually Does

The Spreading Factor (SF) is a number from 5 to 12 on modern LoRa chips (SX126x); older SX127x chips are used with SF7-12. It controls how many chips are used to encode each symbol (and each symbol carries SF bits).

- **Low SF (e.g., SF7):** fewer chips per symbol → faster data rate → shorter range → lower battery use per packet. Used when nodes are close together.
- **High SF (e.g., SF12):** more chips per symbol → very slow data rate → very long range → more battery use per packet. Used when you need maximum range.

Think of it like this: shouting a word once at normal speed (SF7) versus repeating every syllable ten times very slowly (SF12). The slowly repeated version can be understood even with a lot of background noise, but it takes much longer to say.

A common community mesh preset uses **SF10** or **SF11**, which balances range and throughput for typical text messaging workloads. Meshtastic's default "LongFast" channel uses SF11 on 915 MHz.

The Range / Speed / Power Triangle

In radio, you almost never get something for nothing. LoRa is no exception. The three variables - range, data rate, and power consumption - are always in tension:

- To go farther (more range), you must slow down (lower data rate) or transmit louder (more power).
- To go faster (higher data rate), you must accept shorter range or higher power.
- To save power, you must accept either shorter range or slower speed.

LoRa's key achievement is that it pushes this triangle to extremes: it can achieve very long range at very low power, but only by accepting a very slow data rate. A LoRa packet might carry 50 - 250 bytes of useful data. The raw over-the-air data rate at SF12 is about 250 bits per second. That is slower than a 1990s dial-up modem. But for text messages, GPS coordinates, and sensor readings, it is entirely sufficient - and few technologies match that range at that power level in unlicensed spectrum.

LoRa vs. FSK vs. GFSK

To appreciate LoRa, compare it with the modulation techniques used by competing low-power radios:

Modulation	How it works	Typical sensitivity	Typical range (open field)	Used in
FSK (Frequency Shift Keying)	Switches between two fixed frequencies for 0 and 1	- 112 dBm	~1 - 2 km	Many 433/915 MHz modules, older APRS
GFSK (Gaussian FSK)	FSK with a Gaussian filter to reduce bandwidth	- 105 to - 115 dBm	~1 - 3 km	Bluetooth, ANT, older Nordic proprietary radios
LoRa (CSS)	Frequency sweep across entire channel bandwidth	- 137 to - 148 dBm	5 - 15+ km	Meshtastic, MeshCore, LoRaWAN

The ~30 - 40 dB sensitivity advantage is large: in ideal free space a 30-40 dB advantage corresponds to 30-100x the distance of FSK at the same transmit power. Over real terrain the practical gain is smaller (several times the range) but still dramatic. This is why LoRa took over the low-power, long-range wireless market.

Link Budget: The Simple Version

A **link budget** is just an accounting exercise: you add up all the gains and losses between transmitter and receiver and check whether the signal is still strong enough at the end. Here is a simplified example:

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Transmit power: +30 dBm (1 watt)
Transmit antenna gain: + 2 dBi
Path loss (10 km): -120 dB (including ~8 dB excess/ground loss over the ~112 dB free-space value)
Receive antenna gain: + 2 dBi
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Received signal: -86 dBm
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LoRa sensitivity (SF11, 250 kHz as used by LongFast): -131 dBm
Link margin: +45 dB (plenty of headroom)

A positive link margin means the link can work; in practice you want 10-20 dB of spare margin for fading. A larger margin means you have room to lose (walls, foliage, less-than-perfect antenna placement). The extraordinary sensitivity of LoRa gives you a huge margin even for difficult paths through vegetation or inside buildings.

LoRa Is Not LoRaWAN

One important clarification: LoRa is just the physical-layer radio modulation. It says nothing about how multiple devices share the channel, how data is addressed, or how the network is organized.

LoRaWAN is one specific network protocol built on top of LoRa - but it is not the only one.

Meshtastic and MeshCore are entirely different protocols, also built on LoRa. The next page compares all four of these in detail.

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