

Part 1 - Theory

LoRa (& LoRaWAN)

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1. Introduction

IoT devices can collect and exchange data, monitor and control various processes, and enable smart solutions for domains such as agriculture, health, smart cities, and industry. However, IoT devices also face several challenges, such as limited battery life, low data rates, long ranges, and security issues.

LoRa



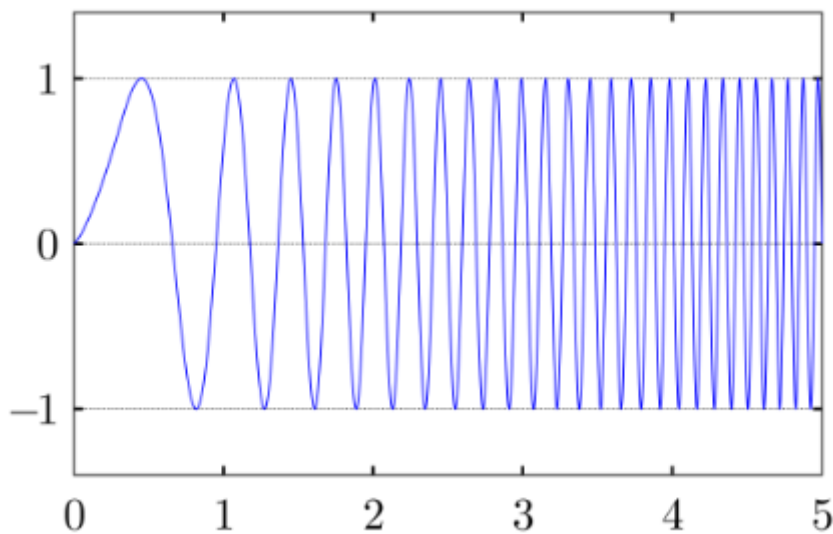
LoRa and LoRaWAN are two technologies aimed at overcoming these challenges and providing a low-power, long-range, and secure wireless communication platform for IoT applications.

- **LoRa** is the physical layer technology that uses a proprietary modulation technique based on Chirp Spread Spectrum (CSS) to encode data onto radio waves.
 - **LoRaWAN** is the network layer protocol that defines how LoRa devices communicate with each other and with a central server, utilizing a star-of-stars topology.
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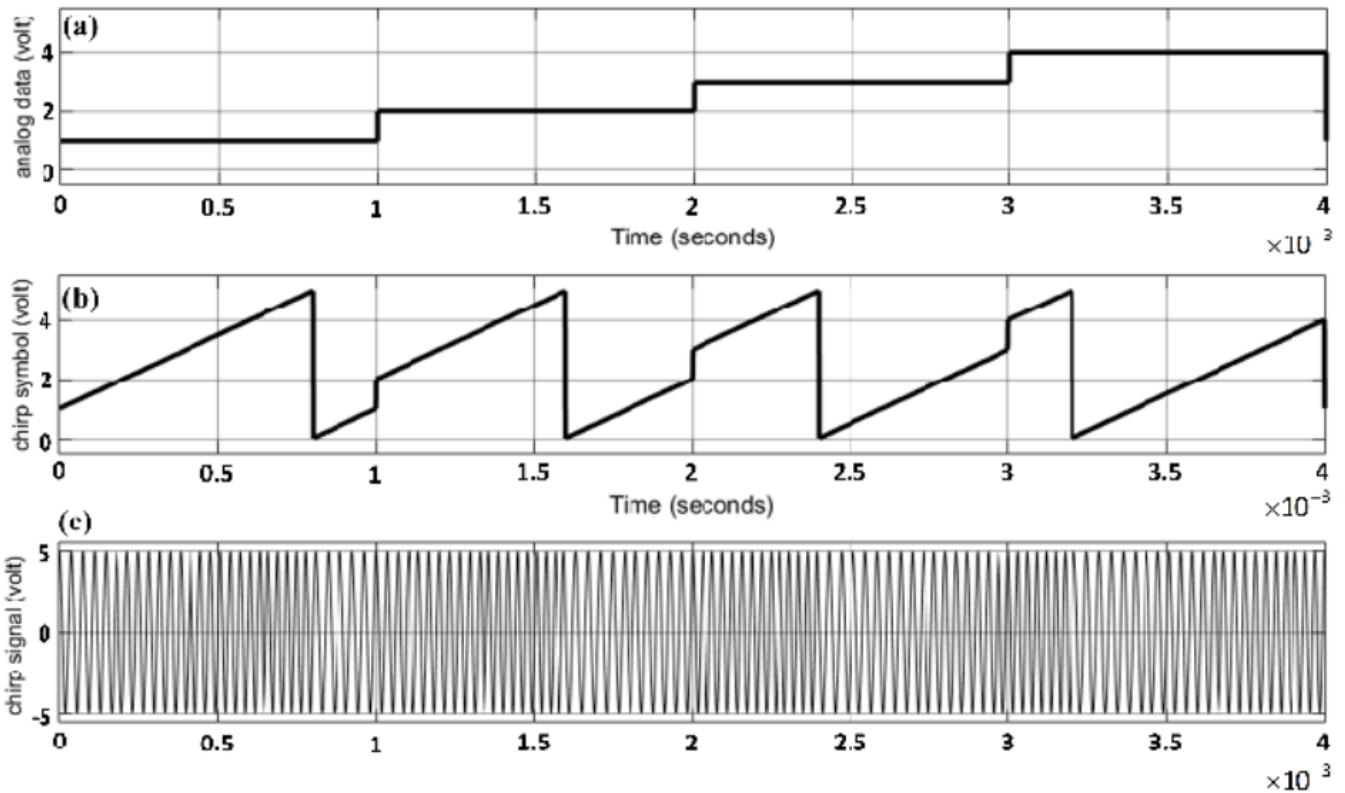
2. LoRa Modulation

LoRa (Long Range) is a wireless modulation technique enabling long-distance communication with low power consumption. It operates in license-free sub-gigahertz frequency bands (e.g., 433 MHz, 868 MHz, 915 MHz) and achieves data rates ranging from 0.3 kbit/s to 27 kbit/s, depending on modulation parameters.

Chirp Spread Spectrum (CSS)



Linear frequency modulated up (upchirp) in the time domain



Four cyclic-shift chirp symbols and signals: (a) analog data, (b) 4-cyclic shift chirp symbols, and (c) 4-cyclic shift chirp signal.

CSS uses chirp pulses to transmit data. A chirp is a signal whose frequency increases (upchirp) or decreases (downchirp) linearly over time.

- **Cyclic Shift Chirp:** A chirp that wraps around when it reaches the maximum or minimum frequency. These are used to encode symbols (units of information).
- **Advantages:** CSS spreads the signal over a wide bandwidth, increasing immunity to noise and interference. It provides high processing gain and can handle the Doppler effect effectively.

LoRa Parameters

The performance of LoRa modulation is defined by three main configurable parameters:

1. **Bandwidth (BW):** The frequency range of the signal (**Use 923MHz for Asia**)
2. **Spreading Factor (SF):** The number of bits per symbol (ranges from SF7 to SF12).
 - *Higher SF* = More range, higher sensitivity, but lower data rate and longer transmission time (airtime).
 - *Lower SF* = Faster data rate, shorter range.
3. **Coding Rate (CR):** Adds redundancy for error correction (4/5, 4/6, 4/7, 4/8). Higher redundancy improves reliability but decreases data rate.

LoRa Data Rate Formula

The data rate can be calculated using the following formula:

$$R_b = SF * \frac{\left[\frac{4}{4+CR} \right]}{\left[\frac{2^{SF}}{BW} \right]} * 1000$$

SF = Spreading Factor (6,7,8,9,10,11,12)

CR = Code Rate (1,2,3,4)

BW = Bandwidth in KHz
(10.4,15.6,20.8,31.25,41.7,62.5,125,250,500)

Rb = Data rate or Bit Rate in bps

3. Signal Characteristics & Propagation

Understanding radio characteristics is crucial for optimizing LoRa links.

RSSI and SNR

- **RSSI (Received Signal Strength Indicator):**
 - Represents the received signal power in dBm (decibel-milliwatts).
 - It is typically a negative value; values closer to 0 indicate a stronger signal (e.g., -30 dBm is stronger than -100 dBm).
 - The practical noise floor for LoRa receivers is often around -120 dBm.
- **SNR (Signal-to-Noise Ratio):**
 - The ratio of signal power to noise power, expressed in dB.
 - **Positive SNR:** Signal power is greater than noise power.
 - **Negative SNR:** Signal power is lower than noise power.
 - Unlike standard FSK modulation, LoRa can demodulate signals with an SNR as low as -20 dB (at SF12), allowing communication even when the signal is buried below the noise floor.

Radio Propagation and Free Space Loss

- **Free Space Path Loss (FSPL):**
 - As a radio signal travels through space, its power density decreases. This attenuation is known as FSPL.

- Loss increases with distance and frequency.
- The Friis transmission equation for FSPL in dB is:

$$FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 32.44$$

Where:

- d : Distance in kilometers (km)
- f : Frequency in Megahertz (MHz)

- **Propagation Factors:**

- **Line of Sight (LoS):** The direct path between transmitter and receiver yields the strongest signal.
 - **Fresnel Zone:** An elliptical region around the LoS path. Obstructions within this zone (buildings, trees, ground) cause diffraction and signal loss. For optimal performance, at least 60% of the first Fresnel zone must be clear.
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