

# Understanding ELRS

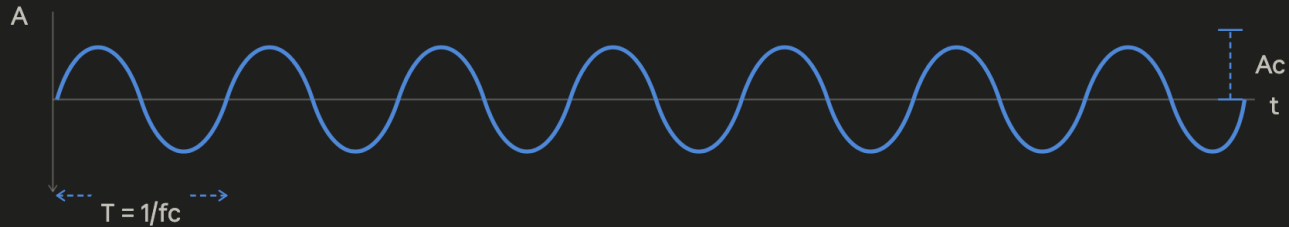
Express Long Range System

# Topics

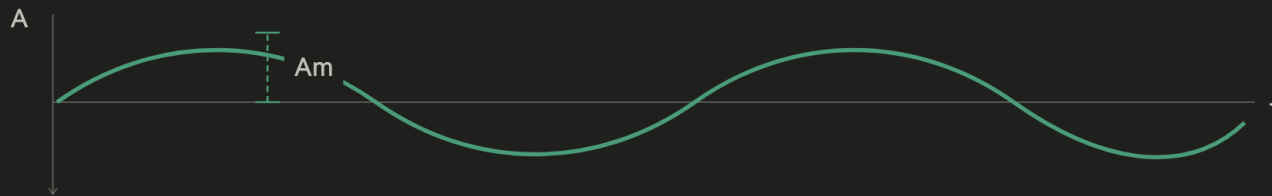
- The evolution of ELRS
- The physics of ELRS and the chirp
- Packets and binding
- Gemini & Xrossband
- Coverision and setup
- ELRS in Ukraine

# Amplitude Modulation (AM)

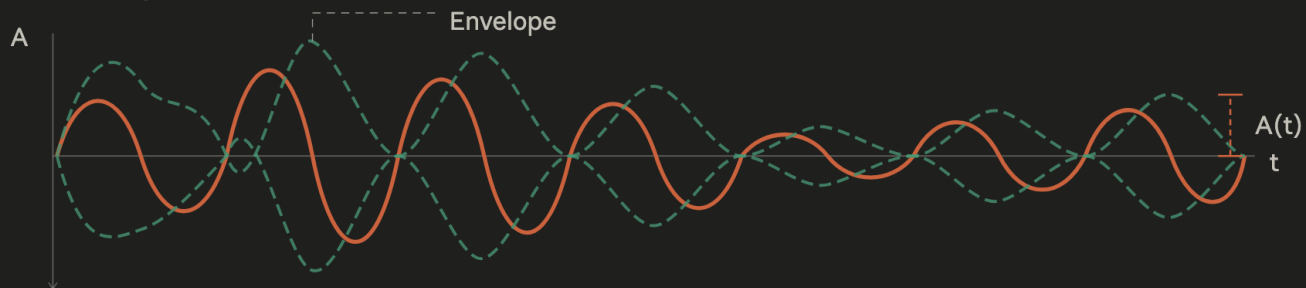
## 1. Carrier wave (unmodulated)



## 2. Modulating signal (message)



## 3. AM signal (modulated carrier)



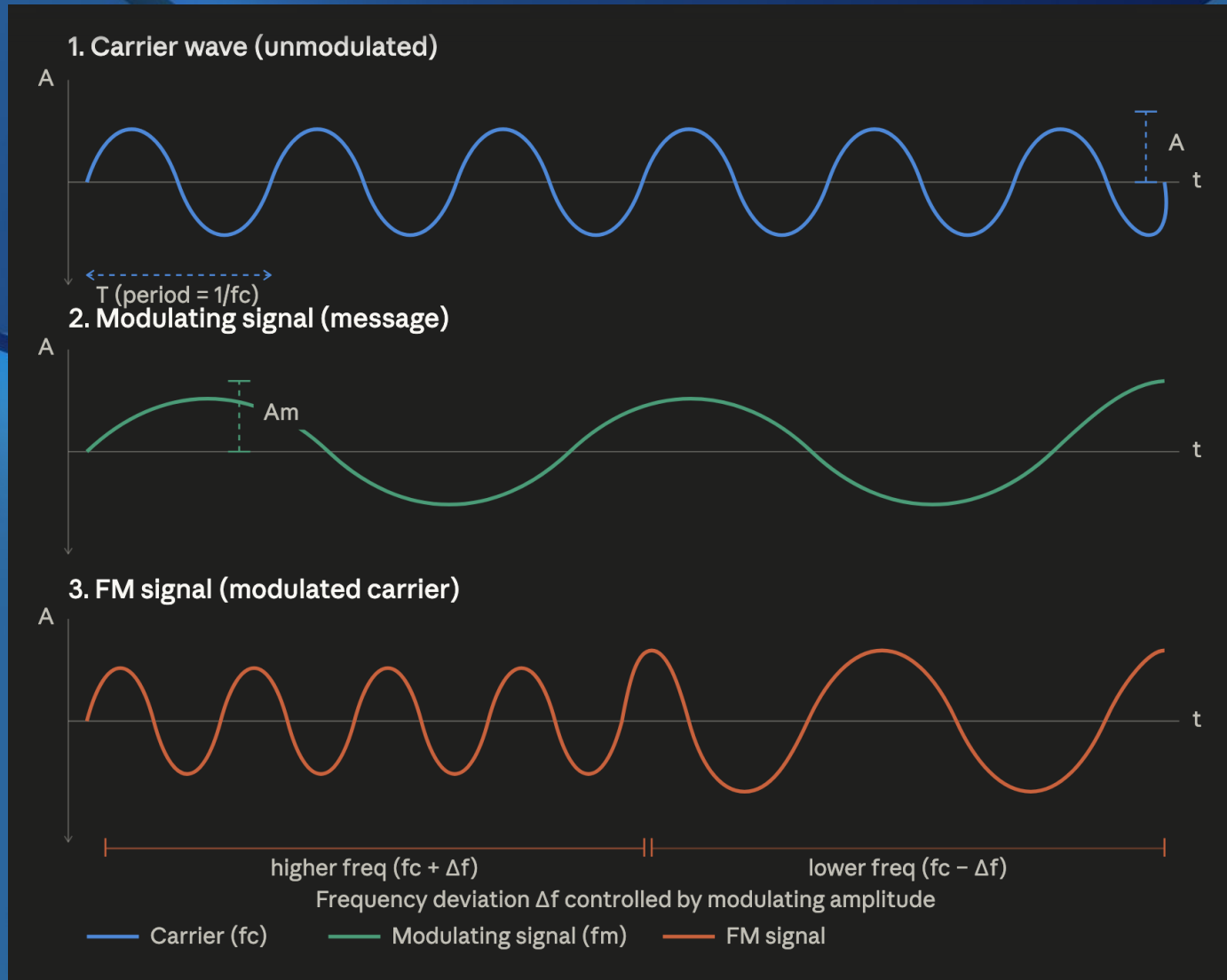
Frequency stays constant — only amplitude varies with the message signal

— Carrier ( $f_c$ )

— Modulating ( $f_m$ )

— AM signal

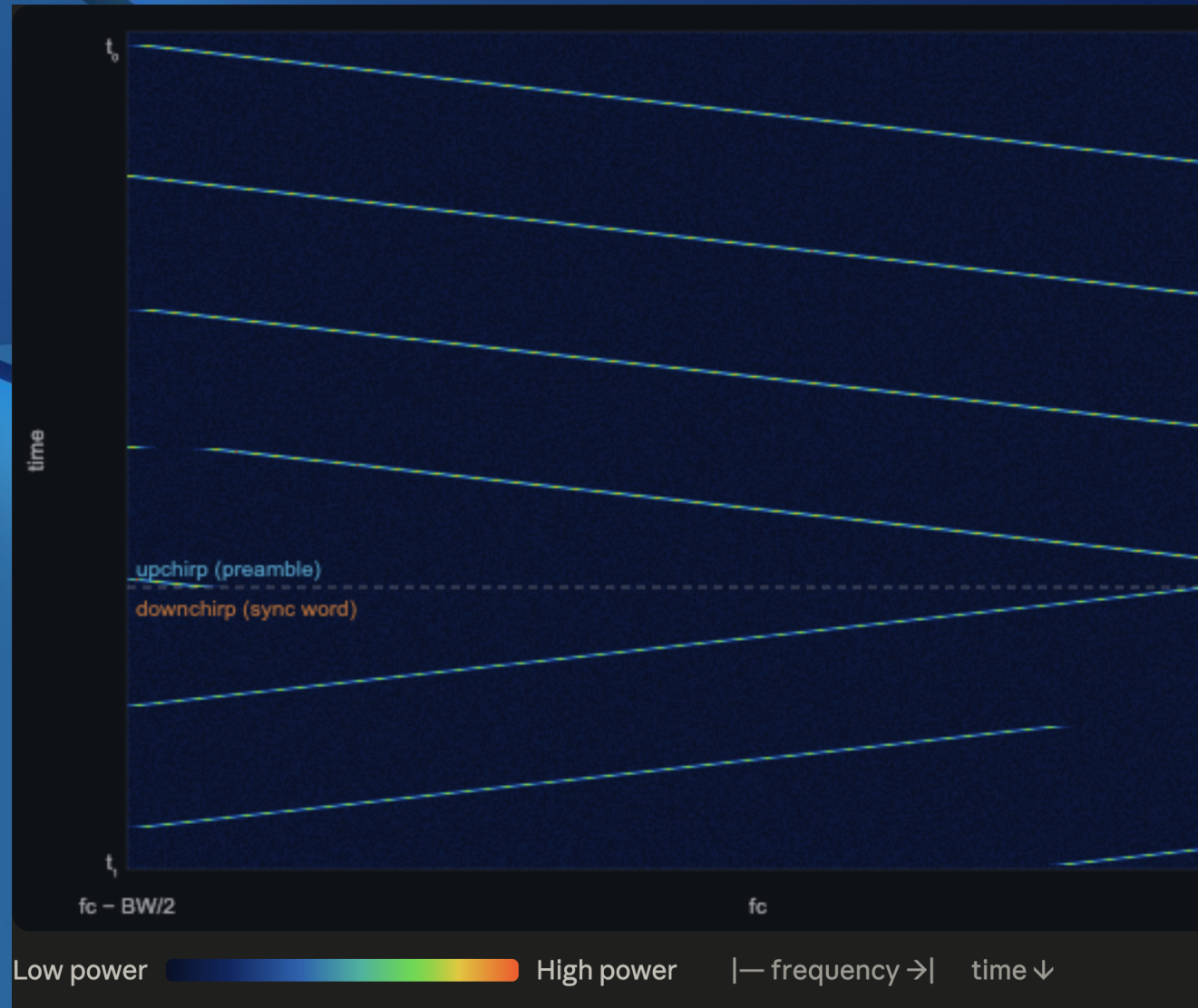
# Frequency Modulation (FM)



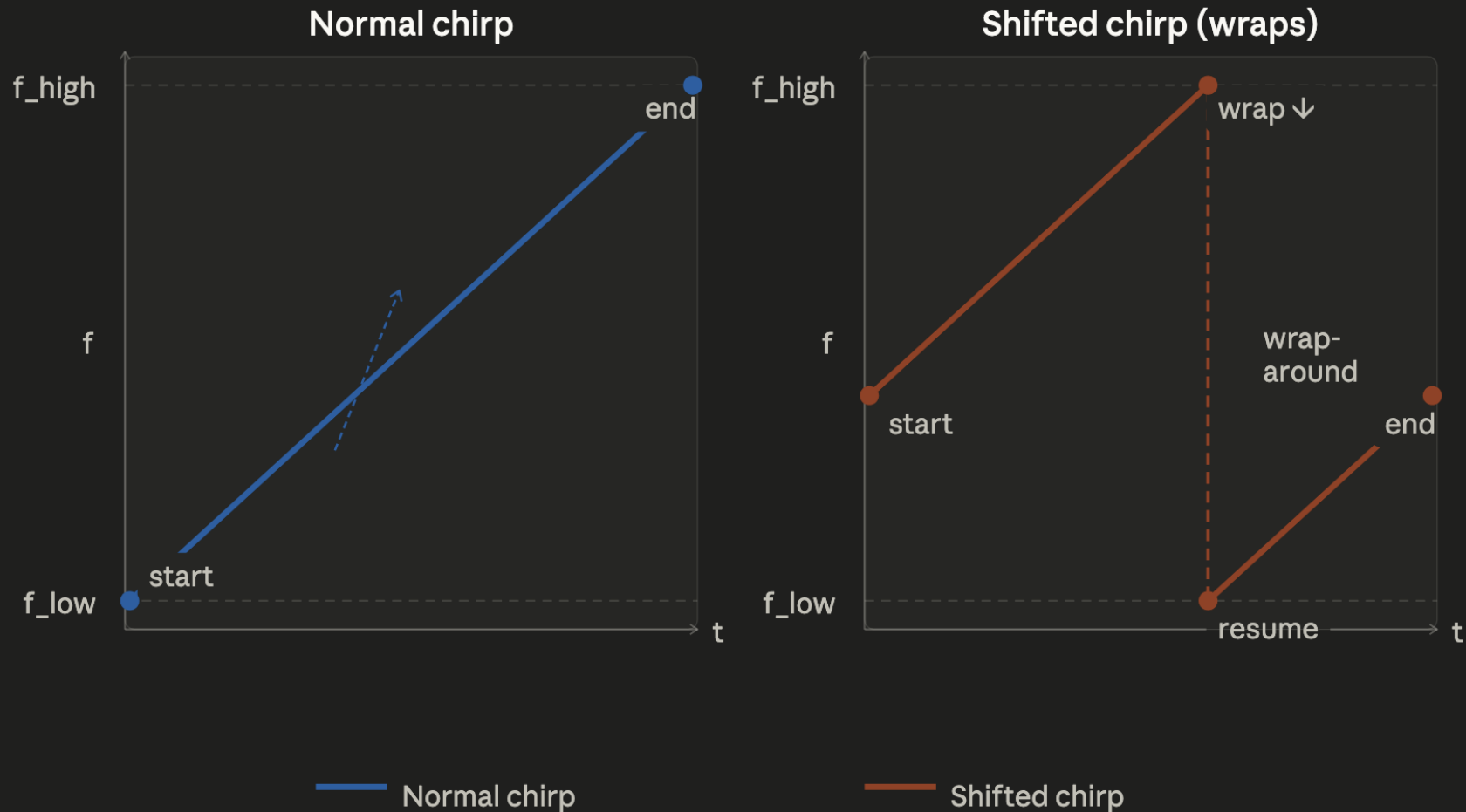
# ExpressLRS vs PPM Key Differences

| Feature        | Chirp Spread Spectrum (CSS)                                 | Frequency Shift Keying (FSK)                               |
|----------------|-------------------------------------------------------------|------------------------------------------------------------|
| Frequency Use  | Continuously changing (sweeping) over a bandwidth.          | Static; jumps between discrete, fixed frequencies.         |
| Noise Floor    | Can operate <b>below</b> the noise floor (very long range). | Must stay <b>above</b> the noise floor to be detected.     |
| Bandwidth      | Uses a wide bandwidth (Spread Spectrum).                    | Uses a narrow, specific bandwidth.                         |
| Complexity     | High; requires complex digital signal processing (DSP).     | Low; simple to implement with basic hardware.              |
| Main Advantage | Robustness and extreme range at low power.                  | Simplicity and higher data rates at short-to-medium range. |

# Upchirp and Downchirp



# Normal & Shifted chirp

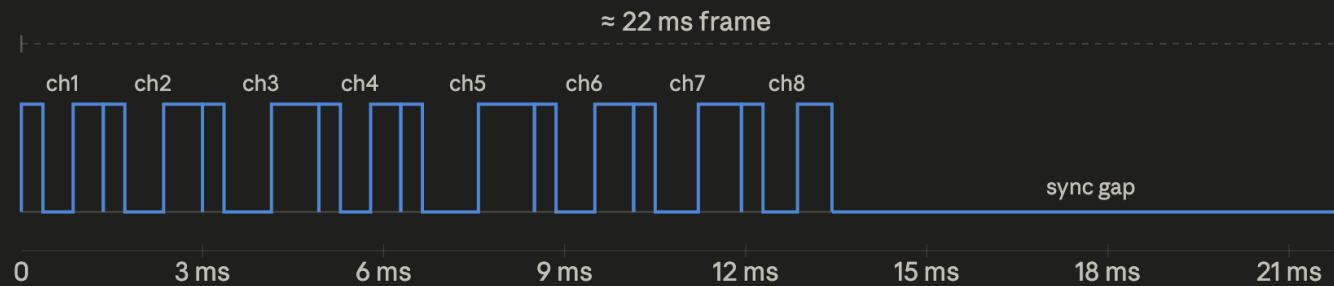


A shift offsets the start frequency — the sweep wraps from  $f_{\text{high}}$  back to  $f_{\text{low}}$  mid-symbol

# PPM vs ELRS Timelines (8 Channels)

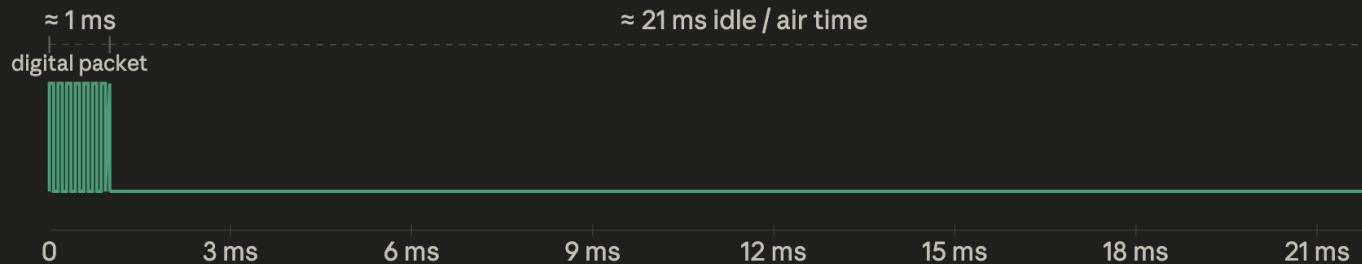
## PPM

pulse-position modulation



## ELRS

ExpressLRS digital packet



— PPM — ELRS

Same time scale — both axes span 0 → 22 ms

## How PPM and ELRS handle 16 channels

### PPM

Like sending a sequence of 16 separate letters in the mail, one after another.  
(One *frame*)

More channels equals longer frames and lower frame rate.

### ELRS

Like putting a list of 16 instructions onto a single sheet of paper, folding it up, and sending it in one envelope.  
(One *packet*)

Packets are sent at the same speed (100Hz or 500Hz, but up to 1000Hz), regardless of the number of channels.

# What a packet contains

- Preamble: ~8 to 12 chirps (used for the receiver to "wake up" and sync).
- Sync Word: ~2 chirps (the "handshake" that identifies the packet as yours).
- Payload: This is the actual data. Depending on the settings, the 16 channels might be compressed into as few as 8 to 20 "data chirps."

Channels 1,2 3, and 4 are sent as high-resolution (1024 positions), channels 5-16 are compressed and may be sent as "round-robin" data (Switch 1 in one packet, Switch 2 in the next, etc.).

To send all 16 channels, the radio might emit a "burst" of roughly 20 to 30 chirps in total.

# ELRS Frequency Bands

| Frequency | Best For           | Characteristics                                                                                      |
|-----------|--------------------|------------------------------------------------------------------------------------------------------|
| 2.4 GHz   | Racing & Freestyle | High packet rates (up to 1000Hz), small antennas, excellent for most pilots.                         |
| 900 MHz   | Extreme Long Range | Better penetration through trees/buildings, but uses larger antennas and has lower max packet rates. |

# Which Mode to Use

| Mode          | Frequency Bands               | Simultaneous?                              | Key Hardware Requirement         |
|---------------|-------------------------------|--------------------------------------------|----------------------------------|
| PPM           | 1 (2.4GHz)                    | No                                         | Any standard TX/RX               |
| Standard ELRS | 1 (2.4 or 900)                | No                                         | Any standard ELRS TX/RX.         |
| Gemini        | 1 (2.4 or 900)                | <b>Yes</b><br>(2 frequencies on same band) | Gemini-capable TX and Gemini RX. |
| Xrossband     | <b>2</b> (2.4 <b>and</b> 900) | <b>Yes</b> (2 bands)                       | Dual-band (LR1121) TX and RX.    |

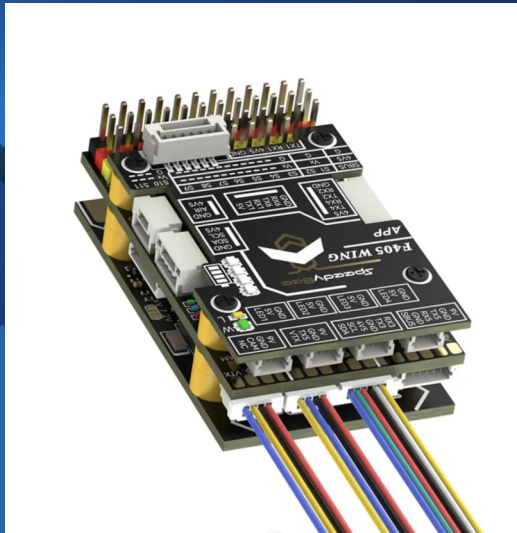
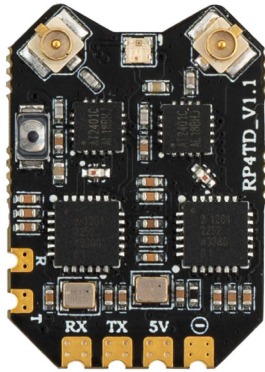
# RadioMaster 2026 Product Comparison, Part 1

| Model         | Price Range | Target User                             | Key Features                                                                    | Main Downsides                                                                |
|---------------|-------------|-----------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| <b>T8L</b>    | ~\$40       | Simulator users, absolute beginners     | Low cost, solid feel, simple to use.                                            | No screen, only supports one model profile, limited output power (100mW).     |
| <b>Pocket</b> | \$60 - \$70 | Budget-conscious beginners, backpackers | Extremely portable, folding antenna, full EdgeTX support, removable stick ends. | Small screen, low 100mW output power, "toy-like" appearance.                  |
| <b>Boxer</b>  | Mid-range   | All-around pilots                       | Full-sized gimbals, compact but ergonomic, 1W output power.                     | Fewer switches than higher-end models, limited to 2.4GHz (original version).  |
| <b>Zorro</b>  | Mid-range   | Gamepad-style enthusiasts               | Great ergonomics, high-quality A01 nano gimbals, many switches for its size.    | <b>Very short battery life</b> (18350 batteries), lower output power (250mW). |

# RadioMaster 2026 Product Comparison, Part 2

| Model                 | Price Range | Target User                       | Key Features                                                                               | Main Downsides                                                             |
|-----------------------|-------------|-----------------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| <b>GX12</b>           | Mid-range   | Daily drivers, long-range pilots  | Tons of switches, Dual-band Gemini support, OLED screen, very compact for its capability.  | Gimbals are not full metal CNC/less adjustable from the front.             |
| <b>TX-15</b>          | Mid-range   | Tech-focused pilots               | Large color touchscreen, dual-band (2.4GHz & 900MHz) support, AG02 CNC gimbals.            | No Diversity/Gemini support, flatter switch profile may not suit everyone. |
| <b>TX16S Mark III</b> | Flagship    | Pro pilots, "full fat" radio fans | Massive color touchscreen, 1W output, Dual-band Gemini/Diversity, built-in handle antenna. | Very large and heavy ("a behemoth"), overkill for casual users.            |

# ELRS Receivers and PWM



Separate receiver  
and flight controller  
(FC)

Requires connection

Integrated receiver and  
flight controller

Essentially plug & play

