Putting the Radio in Radio Control

An introductory history of RC technologies (mostly for flight)

Adam Smith / AA1N - October 2025

Aeromodeling History and RC

- Model aircraft experiments predate manned flight by hundreds of years
  - Bow-strings, rubber bands, steam, and even gunpowder used for power
- late 1930s: Radio controlled demonstrated, e.g. with the new Raytheon RK-62 tube
- 40s: 6m amateur frequencies granted in the ‘40s meant many got ham tickets for RC
- 50s: 27Mhz allocation introduced; multi-channel control systems developed
- 60s: channelized 72MHz using AM and FM for RC
- 80s/90s: revised 72MHz for RC aircraft and channelized band plans for RC in 6m to avoid growing repeater usage above 53MHz
- More recently spread-spectrum controls allowed in 2.4GHz (limited power levels) overlapping ham allocations

Ref: https://www.modelaircraft.org/early-aeromodeling, https://www.modelaviation.com/article/history-radio-control, https://en.wikipedia.org/wiki/Radio-controlled_aircraft
https://www.youtube.com/watch?v=BO3Tbkdqknw GG example

Radio Control in Military History

- Remote control of e.g. torpedos (via wires) developed before 1900 - radio controls soon thereafter
  - E.g. Nikola Tesla demonstrated & patented an RC boat model in 1898 - including a clockwork frequency change to avoid hijacking!
- The US, UK, France, and Spain all had experimentation through the First World War and beyond, controlling boats and even airplanes (often, for target practice). The Soviet Union deployed remote-controlled tanks in 1930.
- Germany fielded radio-guided missiles and bombs in WWII, though UK and American efforts quickly led to effective radio jammers. Germany also radio-guided boats full of explosives.
- American and British systems for radio controlled aircraft faced challenges and failures*, but the US did field a working system for radio guidance of bombs.
- Solid-state technology later revolutionized military radios and drones - of course modern systems are highly sophisticated and operate around the world using satellite communications and autonomous capabilities

** - Famously Lt. Joe Kennedy Jr was killed in "Project Aphrodite" while taking off a Flying Fortress refitted as a remotely-piloted bomb. Col. Elliot Roosevelt flew an escort plane in the same mission.*

Ref: https://en.wikipedia.org/wiki/Radio_control and https://www.airandspaceforces.com/article/1110bombers/

Radio History

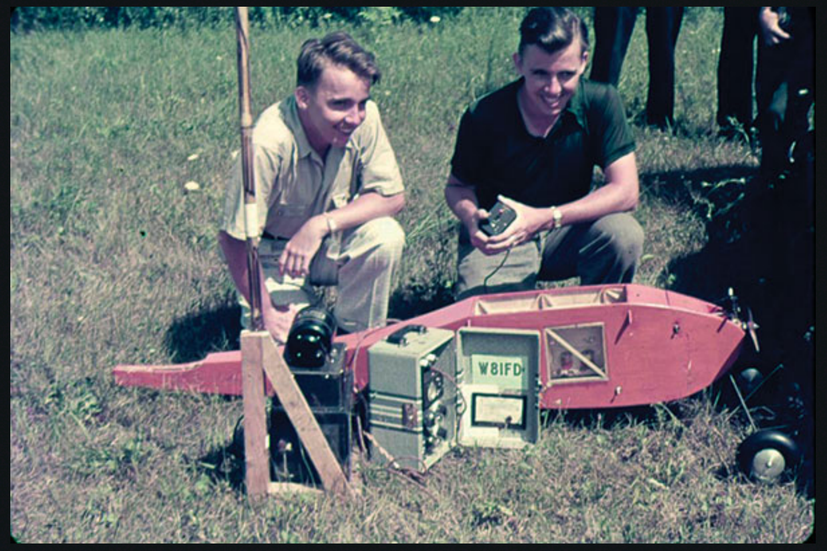
… as related

- Early radio techniques included CW and then Amplitude Modulation from the early 1900s
- Frequency Modulation patented in 1933 and popular for broadcast radio from 1960s
- Single Sideband patented in 1915 and widely used in HF phone - but not RC (?)
- Radios (AM receivers) were present in 40% of US households in 1930; 80% ten years later
- TV in US households grew even faster - <10% in 1950 to >90% in 1960
- Transistors drove smaller, more robust, and efficient devices from the 1950s

Ref: Google AI search results; https://www.radioconnection.com/reference-library/history-of-radio-2/ and … …/history-of-radio-3/

Just a Button

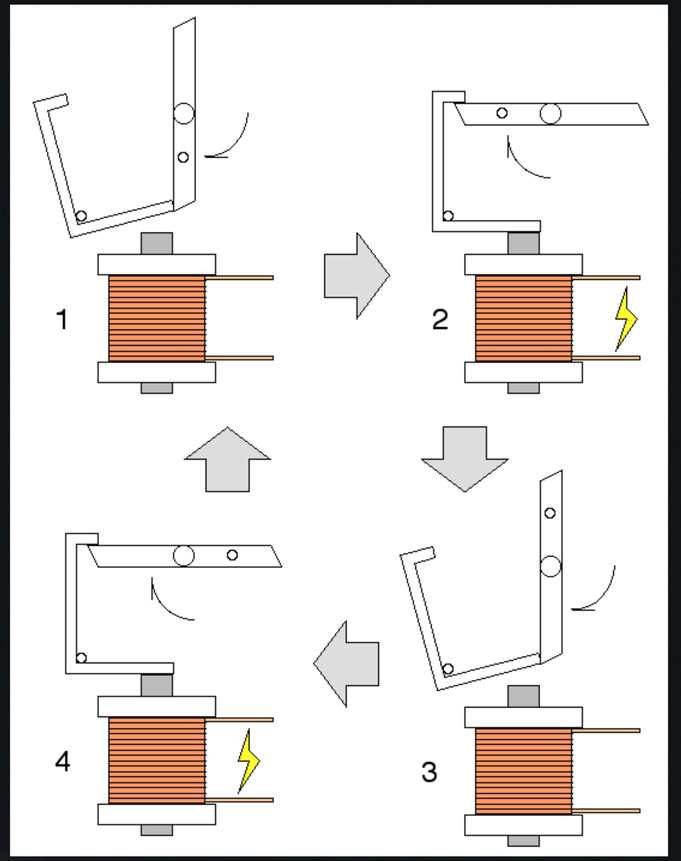
Maybe Just Enough?



- Early systems utilized a single control channel!
- A single-tube, super-regenerative receiver was used to activate a relay/solenoid
- In turn, a rubber-band powered escapement cycled the rudder position
- The receiver weighed 2lbs; the plane had an 8-foot wingspan, a modified free-flight design
- The transmitter sat on the ground; appears to have used a doublet antenna on a mast (?)

Photo from: https://www.modelaviation.com/legendary-life showing Walt and Bill Good with Walt's Big Guff model
See Bill and Walt at: https://youtu.be/jduj1wkGFT0?si=6qqswU7l5E5pNfW6

Escape(ment)ism?



- Single-channel RC systems directly activated a relay or solenoid
- A rubber band wound before flight caused an “escapement” to advance through repeating positions with each “click”
- Later systems used cascaded escapements to produce complex combinations of controls
- Operator had to know the control sequence and remember where they were
- Early competitions flew “flat” patterns but over time more complex maneuvers were added

Diagram (public domain) from: https://en.wikipedia.org/wiki/Servo_(radio_control)#/media/File:RCEscapement.png
Also Ref: https://www.rfcafe.com/references/popular-electronics/compound-escapements-servos-2-1955-popular-electronics.htm

Multi-Channel Evolutions

Tuned Reeds

- By the early 1950's, receivers were developed using "tuned reeds"
  - Multiple resonant tines on a comb-like structure were excited by different audio frequencies modulated from the received audio
  - Effectively an early AFSK encoding, but with a physical "decoder"
  - The tip of each reed would make electrical contact to close a relay, allowing control of separately supplied voltages to a motor, or control of multiple escapements
  - Multiple outputs could be decoded at once, within limits of harmonics (but rare in practice)
- Used into 1970s and co-existed with early transistor based receivers and proportional servos

Ref: https://en.wikipedia.org/wiki/Reed_receiver

Multi-Channel Evolutions

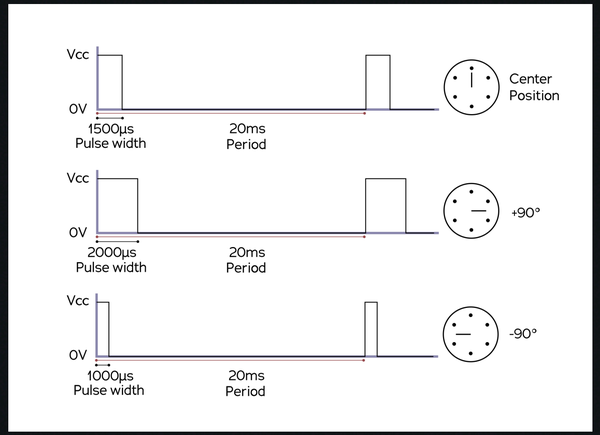
Galloping Ghosts!

- Employed an electric motor driven alternating directions resulting in a continuous oscillation fed into a cam
- Used a pulsed control signal, with the pulse width and pulse rate controlling separate channels mechanically through an actuator
- Bias in the physical trim of the control surfaces allows control based on average position
- Allows multi-channel and proportional controls over a single radio input

Ref: https://www.youtube.com/watch?v=BO3Tbkdqknw and https://www.youtube.com/watch?v=IBxXsRwRn1M Galloping Ghost demonstration videos on YouTube

Out of Proportion?

“Digital” Proportional Control



- Developed in the 1960s, “digital” proportional radios provided a new level of control
- Paired with motor-driven servos, the radio could command a specific control position
- The use of transistors over tubes allowed for smaller, more reliable devices
  - This also helped eliminate relays and heavy secondary batteries
- The transmitter sent Pulse Position Modulation (PPM) signals, with a long sync pulse followed multiple short pulses; the length of the gaps between pulses encode channel values
- The receiver sent Pulse Width Modulation (PWM) signals to each servo separately
  - Timed pulses carry data, with the width of the pulse encoding the value

Ref: https://en.wikipedia.org/wiki/Servo_control and https://en.wikipedia.org/wiki/Pulse-position_modulation; PWM Image credit: Wikimedia user Hforesti (CC-BY-SA 4.0)

Frequencies and Modulations

- Initial Proportional systems used AM modulation in the 6m ham band or 27MHz CB band
  - 465MHz usage was also possible (and license-free before CB), but with a 5W limit
- In 1965 the FCC introduced specific channelized allocations for RC at 72MHz (later split in the late 1980s)
- From the late 1960's into the 70's, FM replaced AM to provide better reliability
- Further reliability and resolution gains were achieved through Pulse Code Modulation (PCM), becoming popular in the 1980s.
  - Early systems paired analog RF sections with digital ICs performing logic and timing functions
  - Increasing use of ICs allowed "computerized" transmitters with multiple models and programmable mixing
- Next big jump was to 2.4GHz, but that required another change...

Doing the Frequency Hop

DSM, FASST, and friends

- Frequency-Hopping, Spread-Spectrum techniques came to RC in the mid-2000s
  - Paired use of 2.4GHz frequencies and digital encodings similar to WiFi and Bluetooth technologies
  - 2.4GHz antennas are also much more convenient than 72MHz whips!
- Avoids static interference/noise and reduces collisions with other transmitters
- Transmitter and receiver “hop” through two or more frequencies
  - synchronized through a “binding” process (pairing); input from “wrong” source can be discarded
- Removed the need to communicate channels in use at the flying field (or impound transmitters)
- With modern radios, hundreds of planes can fly at once on the same field

Ref: https://en.wikipedia.org/wiki/Frequency-hopping_spread_spectrum

Analog FPV

- “First-Person View” video sent from a flying craft back to a screen or goggles
- Analog generation systems used small security camera boards
- NTSC or PAL encoding (over FM)
- Interference or obstruction cause snow, rolling sync, or signal loss
  - (but degradation could be smoother than early digital systems)
- Typically on 5.8GHz to avoid interfering with 2.4GHz controls
- Channels usually manually selected from common layouts (8-16 channels)
- Circularly polarized antennas improve rejection between adjacent channels

Digital FPV

- Most drone pilots today use digital video systems
- Digital encoding like H.265 stream compressed video signals over QAM
- RF uses modern modulations like OFDM and may do frequency-hopping
- Configurable bitrates and resolution can be suited to task
- Signal telemetry returned to video transmitter allows automatic adjustments
- Can even use link quality data to inform frequency hopping algorithm

Open (Source) for Business

- Open software and hardware - ExpressLRS project on GitHub
  - multi-frequency (900MHz and 2.4GHz)
  - uses LORA (and other?) radio protocol
  - bitrate, redundancy, telemetry, and latency settings for purpose-specific optimization
  - possible to run signals on both bands, or in-band different signals to two antennas
- In addition to flexible, reliable controls - drives cost of hardware down and innovation up

Ref: https://www.expresslrs.org/quick-start/transmitters/lua-howto/?h=lora#packet-rate-and-telemetry-ratio

RemoteID

- Requires even relatively small RC craft to carry a “transponder”
- Broadcast info includes identifier, position, and flight path
- Can be built into craft, or as an independent module
- Radio Tech: 2.4GHz / ISM bands with consumer radio protocols
  - Uses WiFi and/or Bluetooth Low-Energy (BLE)
  - Effectively requires that the craft carry a GPS/GNSS receiver

Reference: https://en.wikipedia.org/wiki/Remote_ID

Thank you!