

CW

What is it?
Why use it?
How do I learn it?

W .--

H

A .-

T -

I ..

S ...

C -.-.

W .--

? ..--..

What is CW?

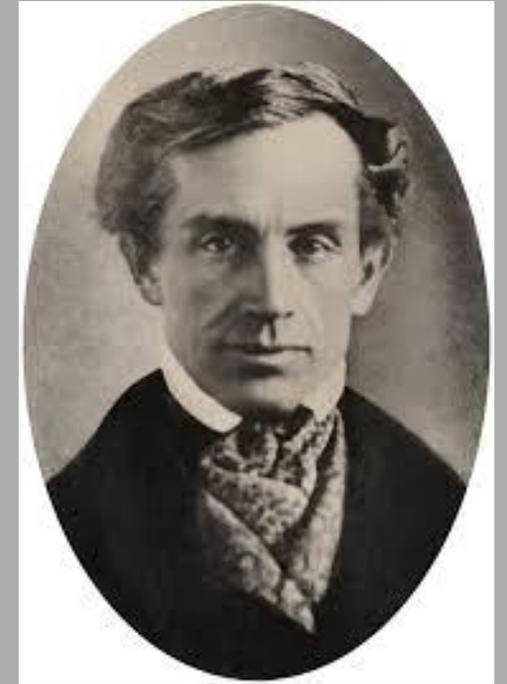
CW stands for continuous wave and is ham shorthand for radiotelegraphy, using Morse code to send and receive information over the air using amateur radio.

Samuel Morse

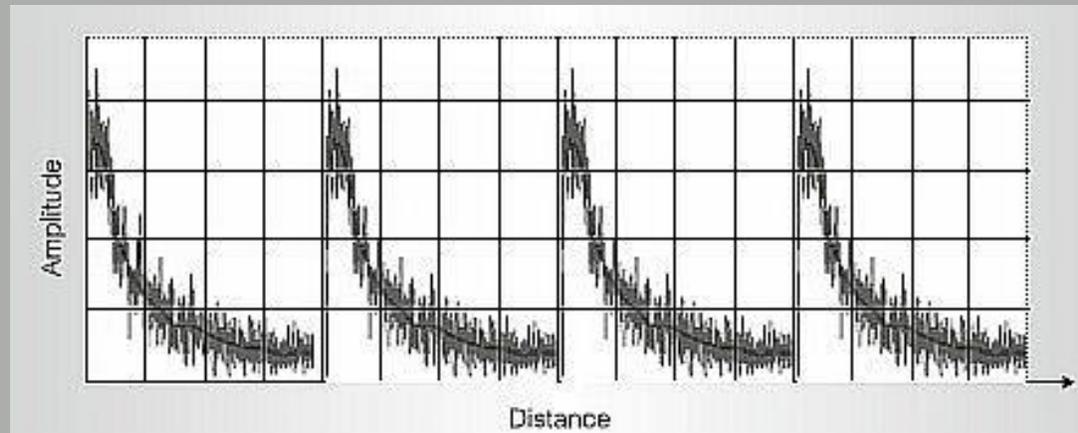
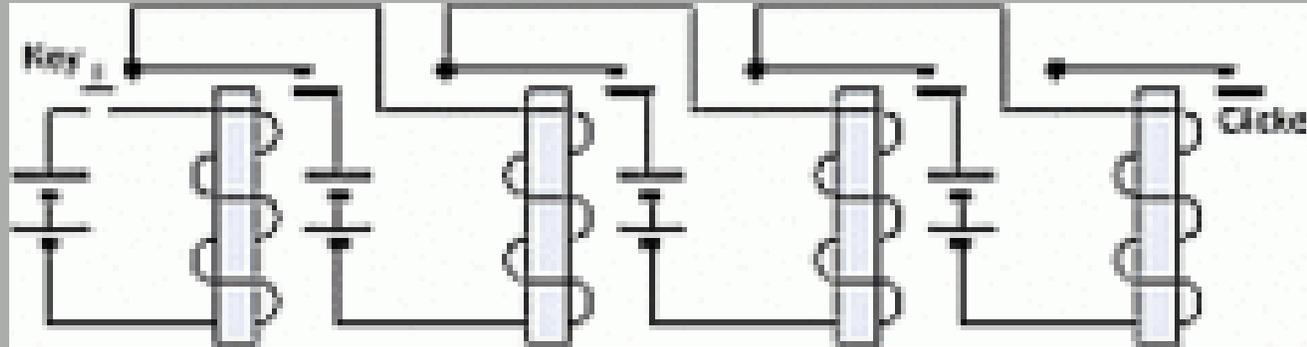
Samuel Morse was an American painter (mostly portraiture). In 1825 Morse was away from home working on a commissioned work (a portrait of Lafayette). He received a letter that said his wife was ill. The next day he got another letter explaining his wife had died. He headed for home and by the time he got there she had already been buried. Reportedly this caused him to explore means of faster ways to communicate over distances.

In 1832, he learned about electromagnetism. **Morse's insight:** Use of electromagnetism with linear coding could permit long distance transmission of information over a single wire.

Morse and Leonard Vail developed a form of repeater using electromagnetic relays (i.e., a non-linear amplifier) to permit signals to be sent over longer distances than the few hundred-yard range which served to limit the use of wired telegraphy. The big test was two miles and it proved the concept. Then Congress appropriated funds for a 38-mile demonstration.



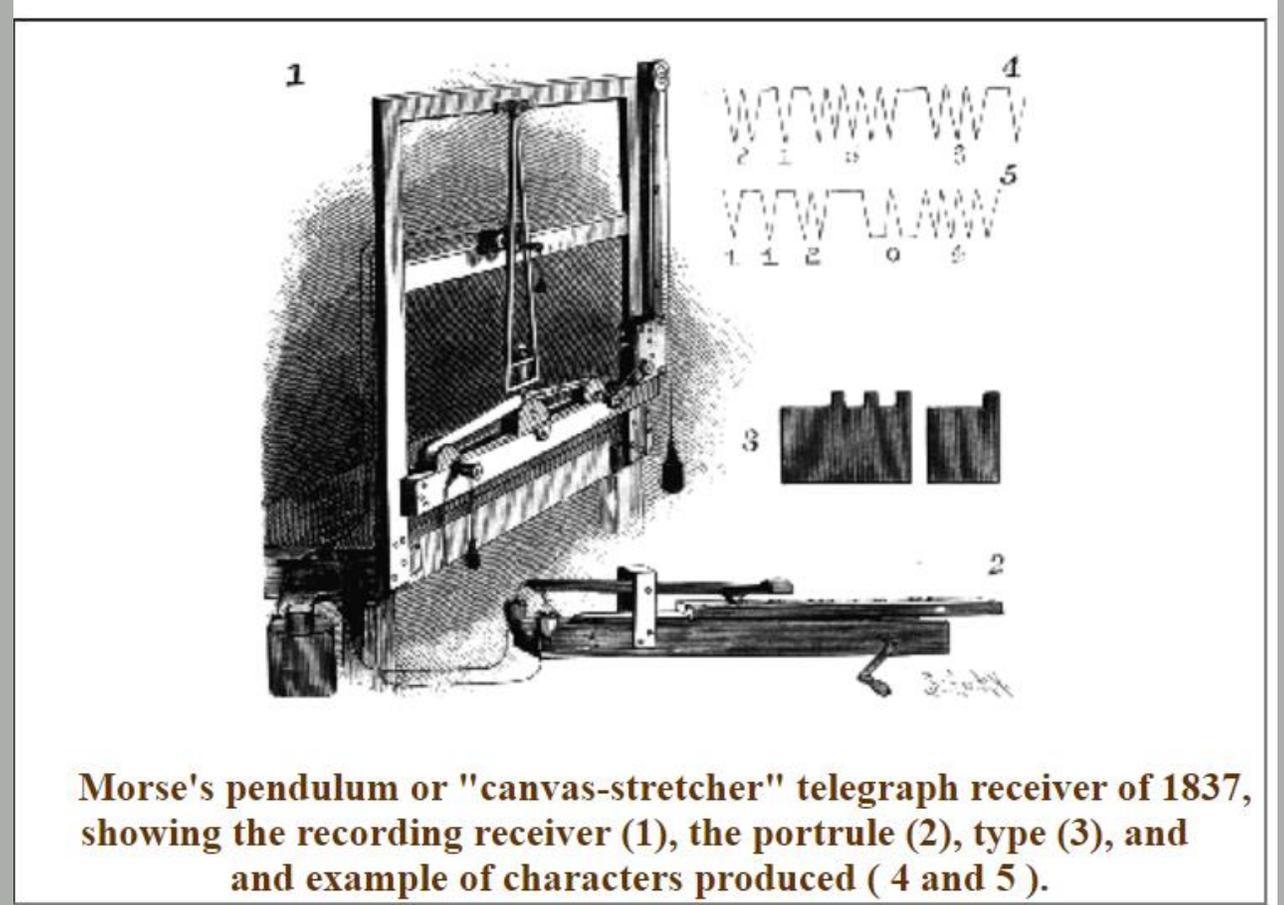
Morse's Repeater Circuit resulted in a patent



Wire stretched from the key position to the point that the signal faded at which point a relay operated to control higher voltage to retransmit the signal – essentially operating as a repeater.

Issues that Morse needed to solve

- Equipment
 - Morse spent his energy on a self-recording system that marked on a strip of paper and which could be read by the operator visually
- A usable code
 - Morse was attempting to create a code book that would allow a number to be used to represent each word



Morse's pendulum or "canvas-stretcher" telegraph receiver of 1837, showing the recording receiver (1), the portrulle (2), type (3), and example of characters produced (4 and 5).

Alfred Vail is thought to be the true inventor of what is know as Morse Code

- Vail's code became known as Morse Code and ultimately Morse who had taken all the credit for developing Morse Code, apparently tried to set the record straight and tell the world that Alfred Vail had invented the code.
- This code was first used in 1844 and was known as American Morse or Railroad Morse



American Morse Code

- American Morse Code had these elements:
 - Dot
 - Dash
 - Longer Dash
 - Space
 - Longer internal spaces
- American Morse Code was used in the USA until after the early 20th Century, about 1927. One perceived advantage was that it could be sent faster than International Morse Code.

Problems with American Morse Code

- The additional elements made it more difficult to send and to copy
- The additional elements increased the possibility of confusion or mistakes

Development of International Morse Code

- In 1848-51, the Germans and Austrians used what is called the Gerke code (Hamburg alphabet) or Continental code which was good but had some characters with more elements than currently used. This simplified the process by having only dits and dahs, and no other elements
- In about 1865 at a telegraph convention in Paris, some of the letters were modified and was called “International” Morse code (Some punctuation revisions were made in the 1930s), following these basic principles (which still apply):
 - Uniform dot and dash element lengths
 - Letters were no longer than four elements long
 - Numbers were 5 elements long
 - Punctuation marks were 6 elements long

Comparison of American Morse, Continental, and International Morse

| | American (Morse) | Continental (Gerke) | International (ITU) |
|---------|------------------|---------------------|---------------------|
| A | •• | •••• | •• |
| Ä | | •••••• | |
| B | •••• | •••••• | •••• |
| C | •••• | •••••• | •••• |
| CH | | •••••• | |
| D | •••• | •••••• | •••• |
| E | • | • | • |
| F | •••• | •••••• | •••• |
| G | •••• | •••••• | •••• |
| H | •••• | •••••• | •••• |
| I | •• | •• | •• |
| J | ••••• | •••••• | ••••• |
| K | •••• | •••••• | •••• |
| L | •••• | •••••• | •••• |
| M | •••• | •••••• | •••• |
| N | •••• | •••••• | •••• |
| O | •• | •••••• | •••• |
| Ö | | •••••• | |
| P | ••••• | •••••• | ••••• |
| Q | ••••• | •••••• | ••••• |
| R | •••• | •••••• | •••• |
| S | •••• | •••••• | •••• |
| T | •• | •• | •• |
| U | •••• | •••••• | •••• |
| Ü | | •••••• | |
| V | •••• | •••••• | •••• |
| W | •••• | •••••• | •••• |
| X | •••• | •••••• | •••• |
| Y | •••• | •••••• | •••• |
| Z | •••• | •••••• | •••• |
| 1 | ••••• | •••••• | ••••• |
| 2 | ••••• | •••••• | ••••• |
| 3 | ••••• | •••••• | ••••• |
| 4 | ••••• | •••••• | ••••• |
| 5 | ••••• | •••••• | ••••• |
| 6 | ••••• | •••••• | ••••• |
| 7 | ••••• | •••••• | ••••• |
| 8 | ••••• | •••••• | ••••• |
| 9 | ••••• | •••••• | ••••• |
| 0 | ••••• | •••••• | ••••• |
| 0 (sil) | • | • | • |

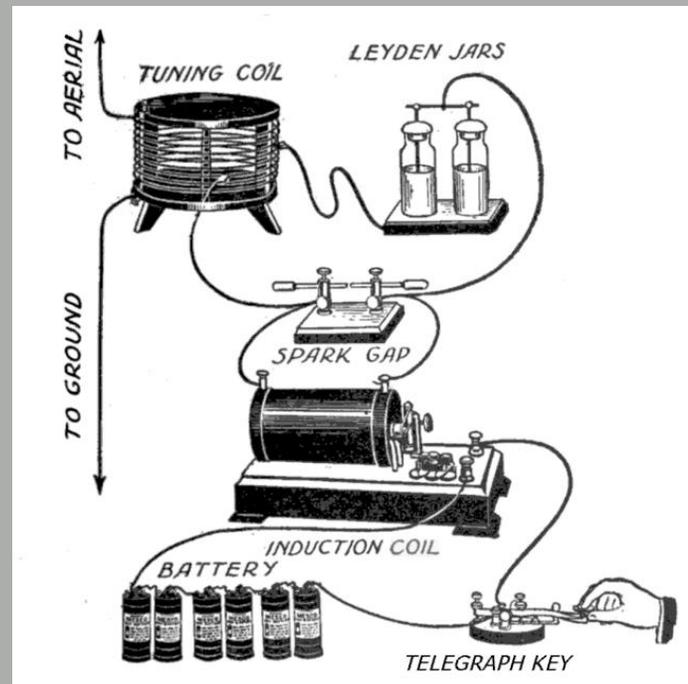
International Morse Code Characters Is Used in Ham Radio

| | | | |
|---|-----------|---|-----------|
| A | · — | N | — · |
| B | — · · · | O | — — — |
| C | — · — · | P | — · — — |
| D | — · · | Q | — — — — |
| E | · | R | — — · |
| F | · · — · | S | · · · |
| G | — — · | T | — |
| H | · · · · | U | · · — |
| I | · · | V | · · · — |
| J | · — — — | W | — — — |
| K | — · — | X | — · · — |
| L | · — · · | Y | — · — — |
| M | — — | Z | — — · · |
| 1 | · — — — — | 6 | — · · · · |
| 2 | · · — — — | 7 | — — · · · |
| 3 | · · · — — | 8 | — — — · · |
| 4 | · · · · — | 9 | — — — — · |
| 5 | · · · · · | 0 | — — — — — |

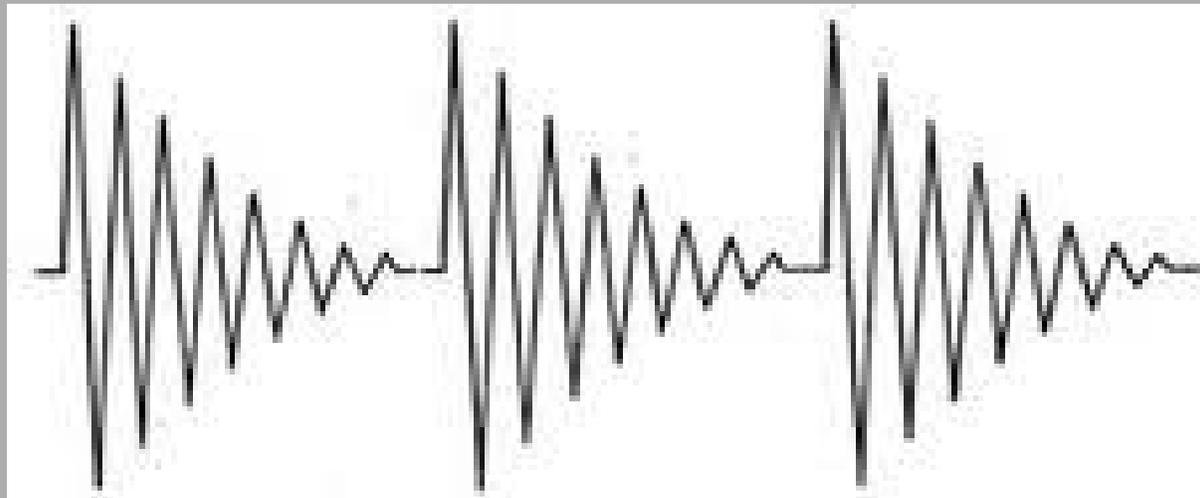
From Spark Gap to Continuous Wave

- Marconi started radiotelegraphy using a “dampened wave” using sparks – frequently called spark gap transmitters

Simple Spark Gap Transmitter



- According to K6DGW, Marconi and others discovered that a circuit could be made that was the electric equivalent of a bell, if you banged it with an electric pulse, it would ring producing dampened waves:

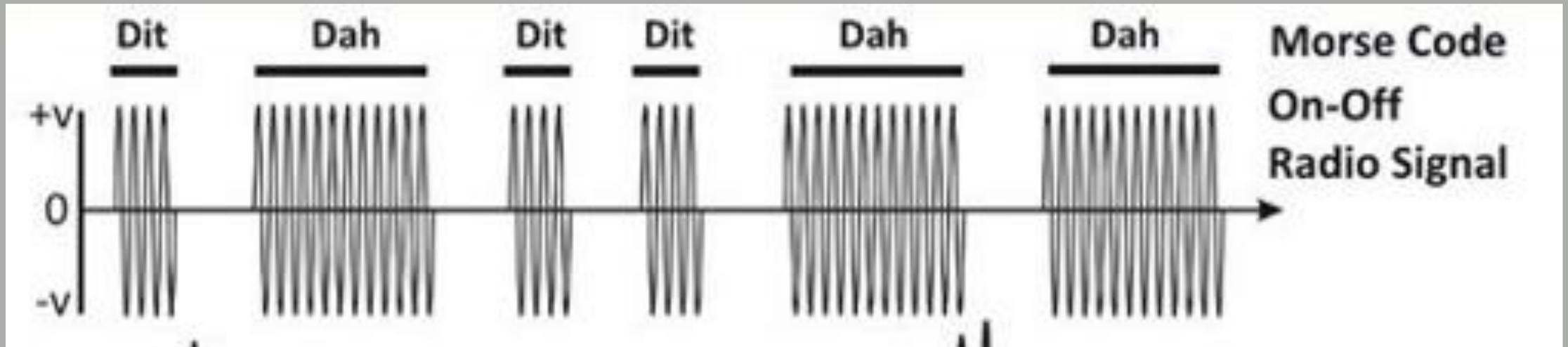


Continuous Waves Aren't Dampened Waves

- Spark gap transmissions were dampened waves which spread energy over a wide band of frequencies. The slower the decay of the dampened wave, the narrower the bandwidth. The government encouraged limitations on the rate of dampening to limit crowding of the radio spectrum.
- This led to the realization that the ideal wave would be a sine wave with zero dampening – all of the energy would be focused at a single frequency (plus a little for the skirts related to key down and key up transitions).
- Spark gap transmitters were outlawed in 1934 in the USA.
- Continuous waves are produced by an oscillator circuit

Interrupted Continuous Wave

- A continuous wave is switched on and off to generate the RF that is transmitted. You could think of this as the carrier wave being modulated by a very slow square wave, the on and off of the key or keyer (more precisely: interrupted continuous wave)



Originally purloined from the Web, but I see it on the Ham Radio School Website too

CW has upper and lower side bands

- The keying wave form results from two signals:
 - The carrier (i.e., the sinusoidal wave at the VFO frequency) and
 - The very slow frequency of the on and off of the key or keyer (a square wave with slower rise and fall times)
- This mixing creates sum and difference products; upper and lower side bands
- Since the frequency of the keying is so low compared to the carrier, the sidebands are incredibly narrow.
- Making rise and fall times less steep helps limit the harmonics generated and the key clicks heard

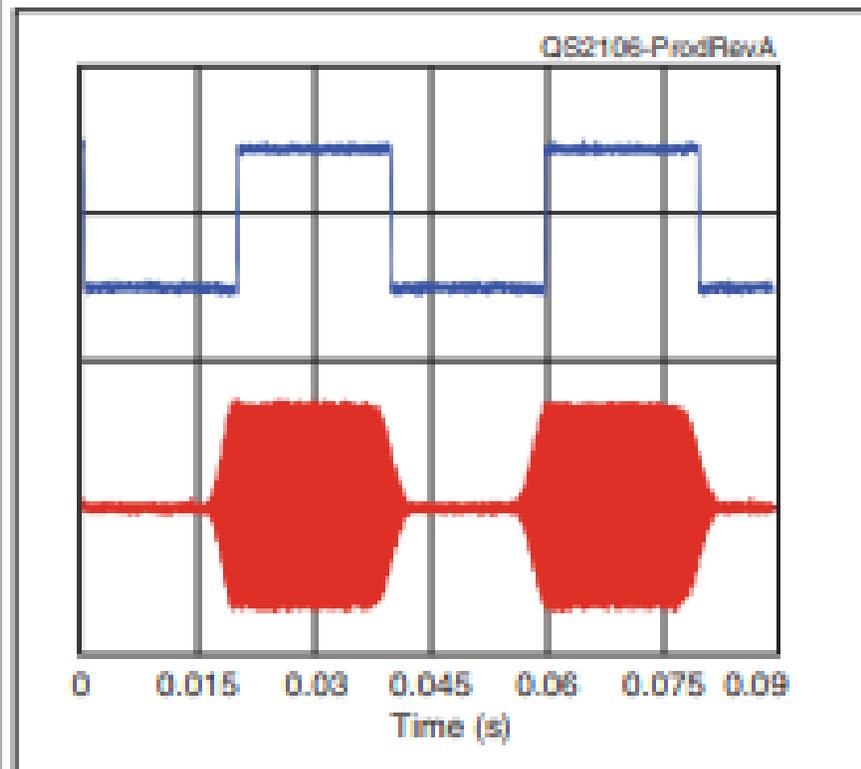


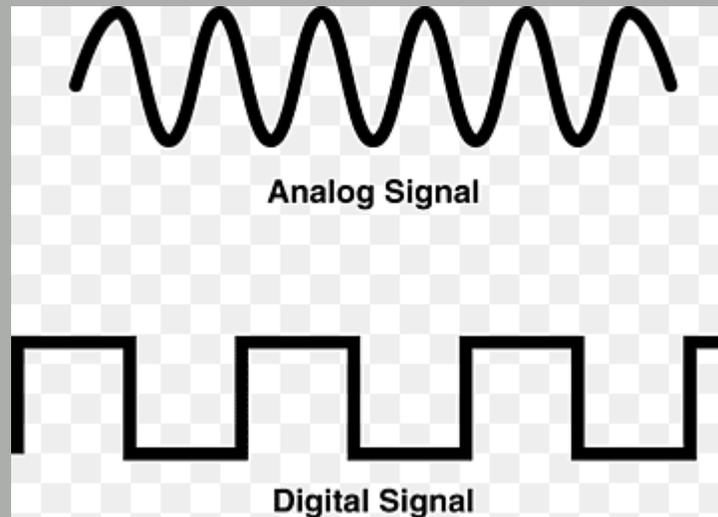
Figure A — The CW keying waveform for the Yaesu FTdx10, showing the first two dits in full-break-in (QSK) mode, using external keying and the default 6-millisecond rise time setting. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) Horizontal divisions are 10 ms. The transceiver was being operated at 100 W output on the 14 MHz band.

Advantages of using continuous wave:

- Continuous waves have an advantage over dampened waves because energy is focused at a single frequency, thereby limiting interference with adjacent signals
- Could be used to transmit over longer distances with the same output power

The Original Digital Mode

- CW is a digital mode in that it uses a simple on-off state to send information as contrasted with analog data which has a range of values to convey information



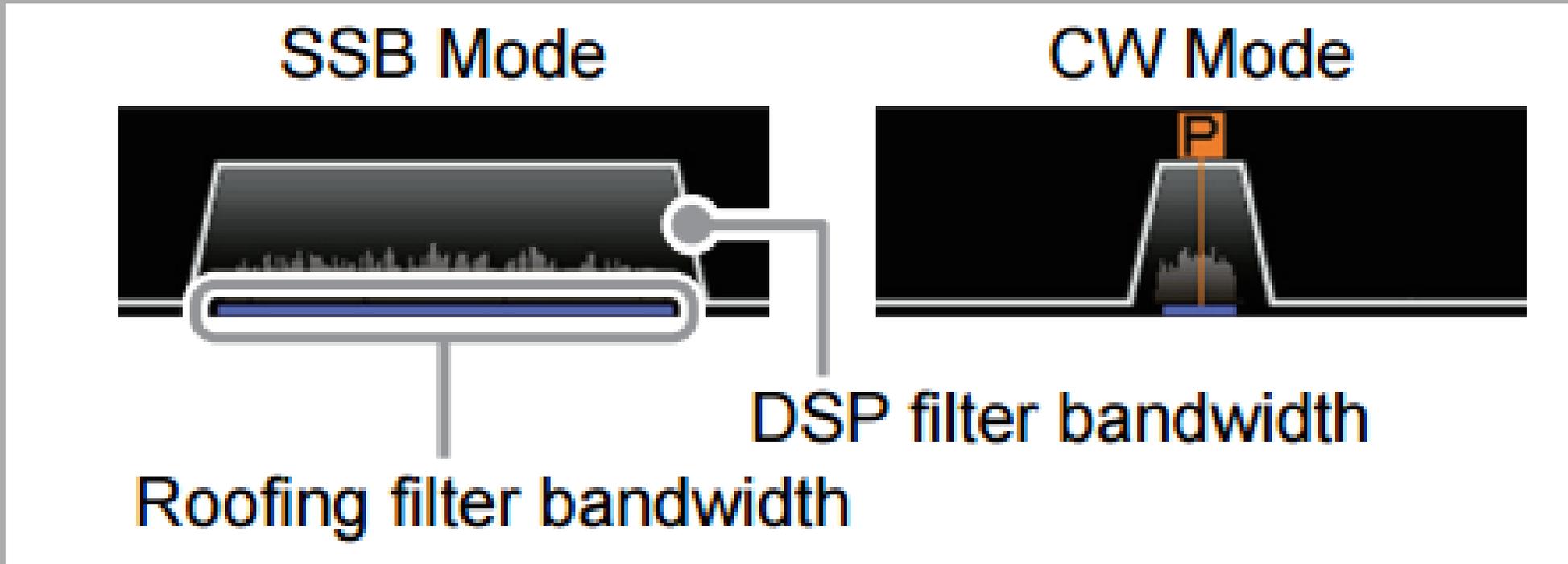
Digital, But Not Binary

- It differs from the traditional binary state (base-2) on-off system (only on and off states, with no variation in length) since CW uses short and long “on” states (dit and dah) and short and long and longer “off” states (intra-character, inter-character, and inter-word) to convey information, but since it is only on or off, it is a digital mode
- CW is not a digital mode in the sense commonly used in ham radio – because it does not necessarily use a computer to code and/or decode the transmission

Why Use CW?

- CW used to be required in order to be licensed to operate
- The equipment required for CW is simpler than for AM, SSB or Digital
- It is a universal language.
- It is fun to have a skill that took effort and practice to learn

CW Bandwidth is Narrower



Power output is more concentrated

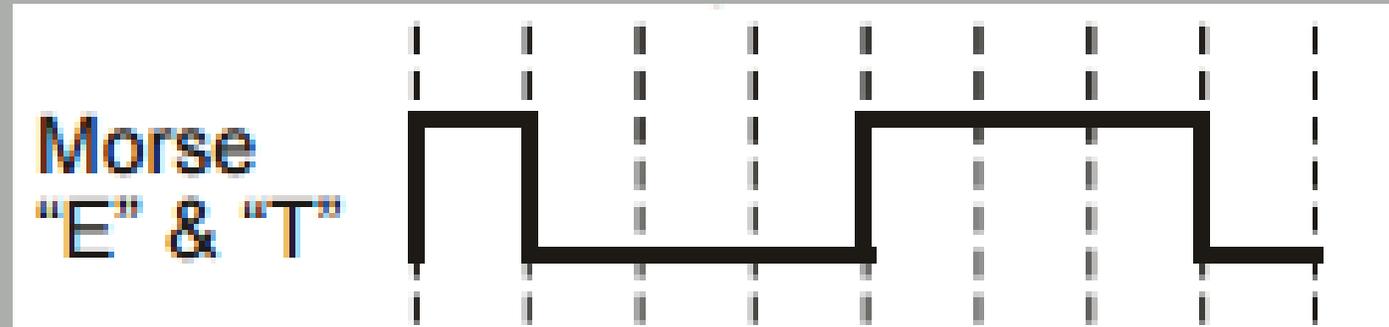
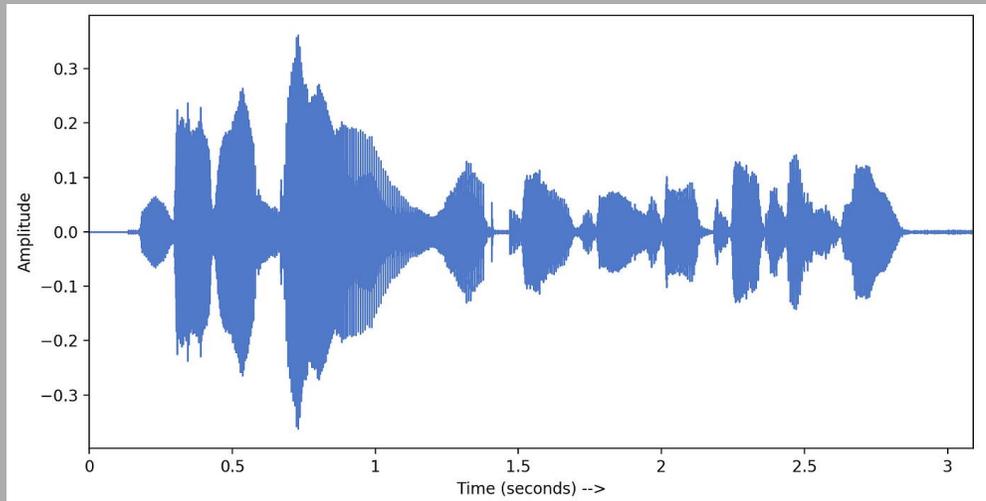
- Since the CW signal bandwidth (approx. 4 times the character speed in wpm) is a fraction of the bandwidth for SSB, the same power from the transceiver generates a several dB advantage for CW:
 - Bandwidth of CW is dependent on speed of sending and on the shape of the waveform (The “K” factor, steeper is $K = 5$, shallow <5). Assuming 25 wpm sending speed, the following is a close approximation:
 - SSB signal takes 2000 Hz therefore average power density at 100W is .05 W/Hz (i.e., $100 \text{ W} / 2000 \text{ Hz}$) – assuming transmission at 100%
 - CW signal at 25 wpm with 100 Hz bandwidth (approximate for 25 wpm) has a power density of 1 W/Hz (i.e., $100 \text{ W} / 100 \text{ Hz}$).
 - Gain of CW over SSB = $10 \log(100/2000) = 13 \text{ dB}$ (approx.).

How much is a 13 dB advantage?

- It has the effect (but not the actual realization) of two S unit advantage
- A 13 dB advantage from using CW with a 100-watt rig is like running an amplifier at 2 kW for SSB. It's a huge advantage.
- Operating CW QRP at 5 watts is like SSB at 100 Watts.

Easier to distinguish than language

- CW is either tone or no tone so it is either on or off (the skirts are sloped, however, to prevent a square wave and the resulting key clicks), while SSB relies on modulation across the sent signal width – so CW is easier to copy than SSB as you get closer to the noise floor.



Depiction of both side bands (AM) vs CW

What do you want to be able to do using CW?

Your goals may change, but they will help you decide what equipment you will want to learn with and your approach to learning:

- Ability to have a conversation at real slow speed (<10 wpm)
- Ability to participate in SKCC events (15 - 20 wpm)
- Ability to chase DX and Contest (25 - 40 wpm)
- Ability to have QSOs at moderate speeds (20 - 25 wpm)
- Ability to have real conversations at higher speeds (25 - 30 wpm)
- Ability to operate QRQ (>30 wpm)

How Do I learn CW?

- CW is audio
- Transcription or head copy?
- Timing and spacing
- Paddles and keyer, straight key, cootie, or bug for learning?
- What other equipment is needed to learn?
- Learning methods

CW is audio; learn the sounds

- DO NOT:
 - Translate what was heard into dits and dahs and then figure out the character based on that, essentially a look-up table
 - Create visual mnemonics charts
 - Try to learn phrases that have the same rhythm (e.g., Q which is dah-dah-di-dah and God Save the Queen).
 - Start with trying to copy code at very slow speeds, planning on working to speed it up later. Slow code creates bad habits that must be broken later.
- Do:
 - Learn the sound of the character at a speed that discourages counting dots and dashes, i.e., never slower than 18 wpm, preferably 20 to 25+ wpm character speeds (ignoring the effect of Farnsworth spacing).
 - Learn the sound of common words

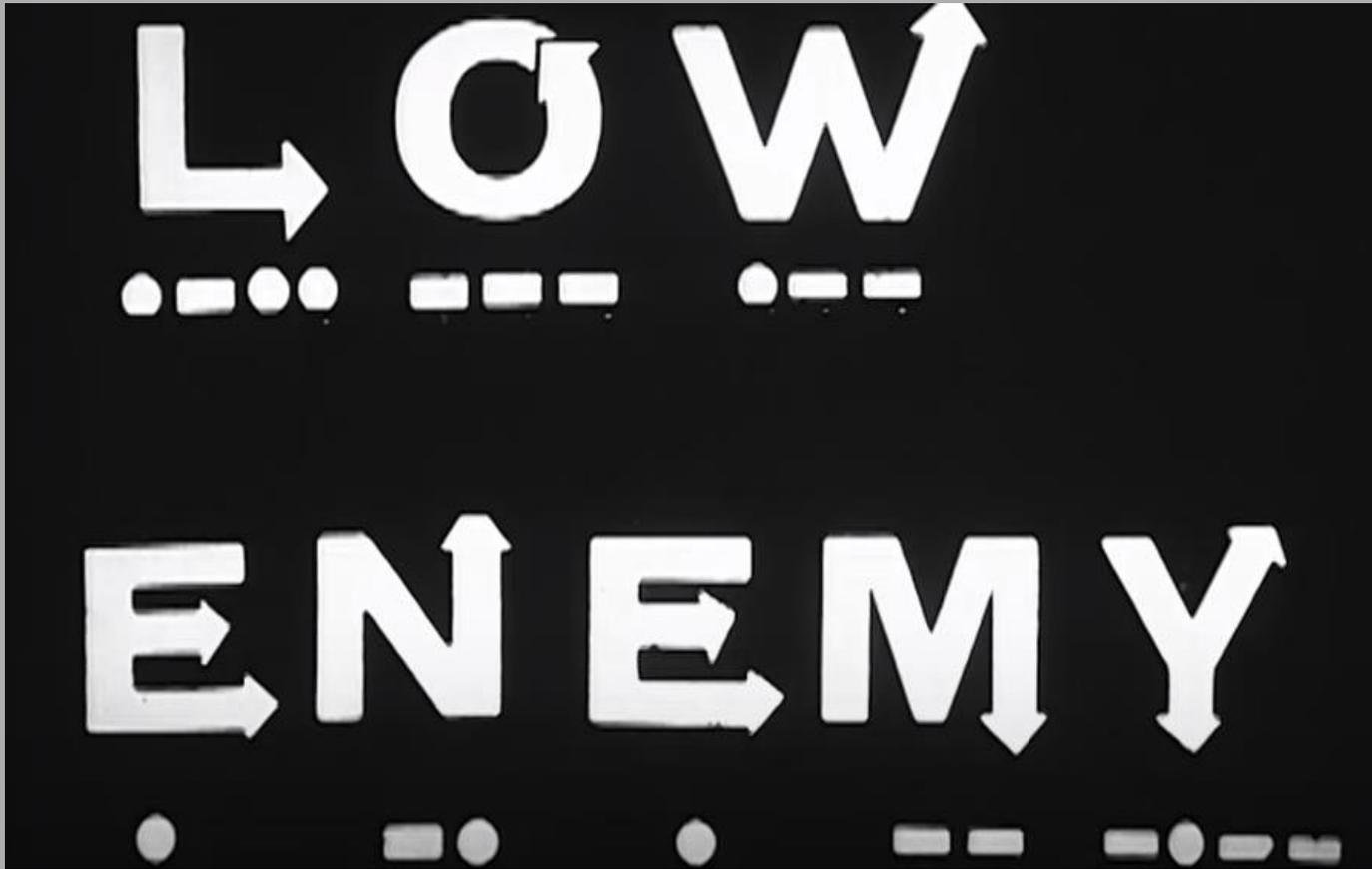
Timing and spacing

- Definitions:
 - Elements – the dits and dahs (and spaces) that make up a character
 - Character – a letter, numeral, punctuation mark, or Prosign (this is a special character, two or more letters sent as one)
 - Timing – this is the gap between the elements of a character
 - Spacing – this is the gap between letters and words
- Proper timing and spacing:
 - A dit length is one
 - A dah length is three
 - The time between elements of a character is equal to one
 - The spacing between characters is equal to three
 - The spacing between words is equal to seven

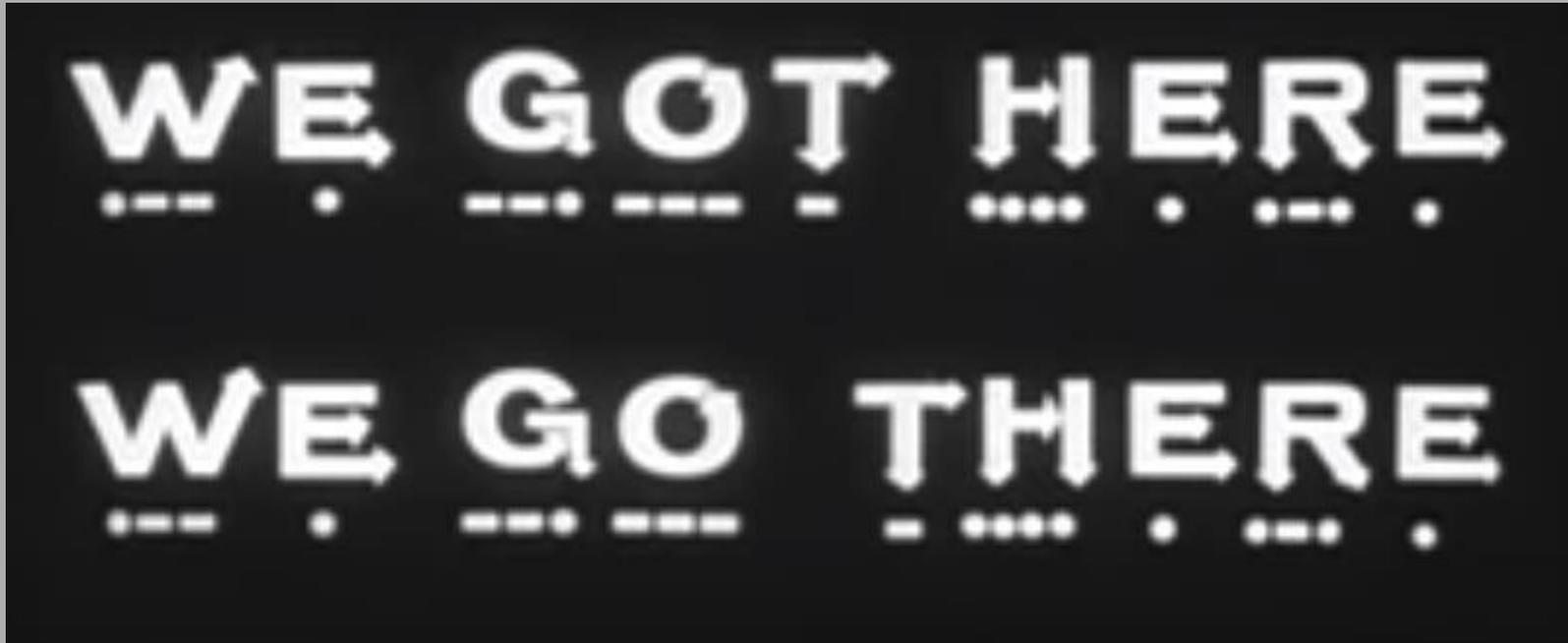
How timing and spacing matter

- The word “an” is sent didah dahdit.
- If the timing and/or spacing is wrong,
 - it can come out as separate letters
“a” and “n” didah dahdit
 - it can come out as “P” didahdahdit
 - It can come out as “we” didahdah dit
 - Compare “an,” “a” “n,” “p” and “we”

Timing issues (same elements (not characters),
different timing):



Spacing issues (these have the exact same characters and elements, different spacing):



Army Morse Code pt. 01

Koch Method

- This involves learning two characters at full speed and once you are able to copy random groups of those two letters with 90% accuracy, adding a third letter and once you can copy random groups of those three at 90% accuracy, adding a fourth letter, and so on.
- Each character is added at full speed, so all the learning is at the target speed

Farnsworth Method

- When you start, always, always, have the character speed at 20 to 25 wpm or higher. You use adding space between the letters and the words. The goal is to shrink the extra space between letters and words as you get more proficient, until the sending has no extra space (either between the letters or words).
- As Thomas Edison said: “It is not the speed at which a letter is sounded that perplexes the learner, but the rapid succession in which they follow each other.”

Note: Farnsworth means you are not using the timing and spacing discussed earlier

Stages of learning to copy CW

- Focus: **head copy**
- Learn the sound and associate it with a character (note: Do not listen to the character, break it into dots and dashes, and then identify the character – the correct process involves only: **hear it, identify it**)
- Instant Character Recognition – recognize characters immediately
- Assemble recognized characters into words and then words into sentences (mental blackboard, ticker tape, or news crawler)
- Instant word recognition
- Phonic copy - as you hear characters use them to assemble sounds and assemble the sounds into words and sentences (skipping the mental blackboard process)

Benefits of Phonic Copy

- When you start, letters are graphic representations of sounds and Morse code is an aural representation of graphic representations of sounds.
- At the beginning levels of learning CW one hears code, converts to letters, assembles letters into words and then words into sentences (mental blackboard).
- Speed will increase but there is a limit
- **PHONIC COPY*** - This is where Morse code is an aural representation of a phonic sound. This removes two steps, conversion to letters and adding letters together to form words. Here is a good posting on phonic copy:
<https://n6ev.com/articles/phonic-method/>
- The benefit to phonic copy over the mental blackboard is like the difference between reading and hearing speech

*The term phonic copy has been attributed to W5ALT.

Progression of sending skills

- Read and form each character with correct timing – this is more than merely having the dits and dahs in the correct order. If you are straight key you also need to learn to form dits and dahs themselves so that the lengths are exactly what they should be – a huge disadvantage. While listening to your own sending to confirm it was sent correctly.
- Read written text and send text with correct timing and spacing. The goal here is to be able to see each character and send it without the intervening step of thinking which elements need to be used to send the letter – it should be automatic; you see the letter and send it without consciously forming each element.
- Send words told to you (that you do not read off a screen or page) – automatically without thinking about each element prior to keying it
- Figure out what you want to say, how you want to say it, and then spell it out as you send it – nothing written down – all without having to think about each element as you send

Pick Paddles To Learn (or straight key if you must and you are a glutton for punishment)

- After you have determined your goal, you need to decide how you want to learn to send.
- Old timers almost always say learn with a straight key first – it helps cement the letters in your brain as dots and dashes – but this is old school.
 - Using a straight key may be inconsistent with your goal
 - Remember we don't necessarily want to memorize dots and dashes
 - If you take this approach, there is a benefit to learning to copy all the characters before you start sending –takes longer to get on the air
- **I strongly recommend starting with paddles** because it is easier to send good code and you can learn to do it faster than you can a straight key
- Whichever key you choose, stick with it until you have accomplished your goal then you can learn to send with a different type of key

Straight key:

- You open and close to form the dits and dahs and the spaces (i.e., a normally open SPST switch)
- Much harder than paddles to do well – need to form each dit and dah
- Best to learn to copy before trying sending
- Hard to use at faster speeds
- SKCC eligible
- Can cause glass arm – consider a horizontal straight key



J-38 Straight Key



Horizontal torsion bar
straight key

Cootie or Sideswiper:

- Easier on the arm than a straight key, but harder to learn than a straight key
- You alternate elements left and right, sending what ever element needs to be sent, so dits and dahs are sent from the left and also from the right, which ever side is next
- The difficulty is that you need to send both dits and dahs from each side, depending on which element is next
- Much harder to send easy to copy code since you need to have the dit and dah lengths formed with both the thumb and the index/middle finger
- There is a limit on speed
- SKCC eligible



Cootie key

Bug:

- The hardest to learn. They are complex mechanically.
- Dits are formed by a weight on a pendulum that vibrates at a speed set by moving a weight on the pendulum
- Dahs are formed manually like a straight key
- Hardest to use to send easy to copy code
- Difficult to adjust for any operation
- Needs re-adjustment to change speeds
- Most bugs fall out of adjustment quickly as they are being used
- SKCC eligible



Bug

Paddles:

- Need a keyer
- Close the contact on one side and a dit is created, on the other side, a dah is created, each with the correct duration
- Hold down a side and that element is repeated
- There are single lever and dual lever paddles
- Squeeze dual paddles together and the elements alternate (this is iambic, like iambic pentameter)
- Code is easier to copy, dits and dahs are perfectly formed
- Works well at much higher speeds
- Not eligible for SKCC



Dual Paddle

Equipment for Practicing

- Rig with break-in turned off or power out turned off
- Key and code oscillator
- Other devices (e.g., Morserino)



Besides The 40 Basic Characters What Do I Need To Know to Get On The Air?

Q codes

These are sent with and without a “?”

- **QRL** – Is there anyone using this frequency?
- **QTH** – What is your position?
- **QRM** – I have man made interference
- **QRN** – I have trouble with noise
- **QSB** – Signals are fading
- **QRS** – Should I slow down?
- **QRP** – Low power
- **QRT** – Operations are being suspended
- **QRZ** – Who is calling?
- **QSY** – change frequency

There are many other Q codes besides these.

Abbreviations

There are many many abbreviations. You need to learn these; they are frequently used. Some are obvious, but others are not. This is a short list of the possibilities:

- **ABT** – about
- **ANT** – antenna
- **C** – yes; correct
- **CUL** – see you later
- **CUZ** – because
- **CX** – conditions
- **DX** – foreign
- **ES** – and
- **FB** – fine business; good
- **FER** - for
- **GUD** – Good
- **Hi Hi** or **HEE HEE** - laugh
- **HPE** - Hope
- **HW** – how
- **K** – over
- **NR** – number
- **OM** – old man
- **OP** – operator
- **PSE** – please
- **PWR** – power
- **R** – roger
- **RPRT** – report
- **TT** - that
- **TU** or **TNX** – thank you
- **U** – you
- **UR** – your or you're
- **WX** – weather
- **XYL** – wife
- **YL** – Young lady
- **73** – best regards

Prosigns

Not too many of these to learn, but you will need them. These are sent as a single character, not as two separate characters

- $\overline{\text{AR}}$ – End of message
- $\overline{\text{AS}}$ – Must pause for a few minutes
- $\overline{\text{BK}}$ – Break in the conversation
- $\overline{\text{BT}}$ – Start new section
- $\overline{\text{KN}}$ – Go ahead, but only the specified station
- $\overline{\text{SK}}$ – End of contact
- $\overline{\text{SOS}}$ – No literal translation (not save our ship). Requests assistance when loss of life or catastrophic loss of property is imminent

Cut numbers

- A hot topic in CW circles is do I or don't I use "cut numbers". There are strong opinions on both sides.
- The cut numbers are:

0 – T 5 – E

1 – A 6 – 6

2 – U 7 – G

3 – V 8 – D

4 – 4 9 – N

- The most common cut numbers are N and T
- My recommendation, don't use them except for 5NN

Basic format of a QSO:

- DXing QSO
- SOTA/POTA QSO
- Contesting QSO
- Conversational QSO

What on-line tools are there to learn CW

- Learn CW Online <https://lcwo.net/>
 - Complete system based on Koch method
 - Code sent in blocks of 5 and the user types in the copied characters and they are scored
 - Lots of additional tools: code groups, plain text, words, call signs, etc.
- Morse Code Ninja
<https://morsecode.ninja/misc/index.html>
 - 300+ practice sets at all speeds
 - 20,000 hours of materials available
 - Be sure to follow the instructions to listen to them as podcasts
 - There is a QRQ syllabus too
 - Lots of wonderful material here. Please check it out.



Other Tools:

- Morse Code Trainer: <https://morsecode.scphillips.com/trainer.html>
- RufzXP: <http://www.rufzxp.net/> Great for practicing call signs.
- Morse Runner: <http://www.dxatlas.com/morserunner/> great for contest CW practice
- CWA practice files: <https://cwops.org/level-2-practice-files/> More interesting than the W1AW files.
- AA9PW's site: <http://aa9pw.com/morsecode/> Several practice tools. A way to practice QSOs.
- Morse Camp: <https://morse.camp/> Good practice for listening to words.
- CWGet: <https://www.dxsoft.com/en/products/cwget/> The best way to see if you are sending comprehensible code is to send and see if a decoder can understand your code.
- Quote of the day: <http://www.morseresource.com/podcasts.php> A way to have daily code copy practice, using a podcast that publishes daily.
- Listen to CNN or NN9u's practice tables: <http://cw.dimebank.com:8080/>
- W1AW CW practice transmissions: <http://www.arrl.org/w1aw-operating-schedule>

Can I take classes?

- There are two primary “schools” for learning CW. They have dramatically different approaches.
- Each has its own pros and cons.
- I am a CWA advisor and am partial to its approach – but it is not for everyone



- The CW Operators Club offers 4 levels of CW classes through CW Academy:
 - Beginner
 - Fundamental
 - Intermediate
 - Advanced
- Designed to take someone from no experience to operating at 25 wpm.
- Courses are offered in 3, two-month semesters, meeting twice a week for 8 weeks, one hour per session (Jan-Feb, May-June, and Sept-Oct).
- Students are expected to practice an hour per day during the term
- The classes are **FREE**
- CWA has several hundred students each semester



- Offers members of LICW about 75 class sessions each week
- Attend a class when you want and progress at your own speed
- Classes are held via Zoom
- LICW offers more than the typical beginner, intermediate, and advanced classes (e.g., bugs, code buddies, Morserino group, antennas, fist checking, etc.)

CW Clubs

- FOC – First Class Operators Club – Invitation only, limited to 500 worldwide
- CWops – CW Operators Club – Invitation only, need to be operating at 25 wpm
- LICW – Long Island CW Club - open to all
- SKCC – Straight Key Century Club (free) – open to all
- FISTS – Fists CW Club (free) – open to all



Not all ham radio operators are equal – some know how to operate CW.