The History of CW, keys, bugs, and paddles

This article is to discuss amateur radiotelegraphy, commonly known as ‘CW’.

The need to convey messages over significant distances, without a runner! , has been a goal for many years. Early on, fires on summits, smoke signals, etc. were used. Somewhat more recently flags with meanings could be hoisted on masts of ships or shore stations. Next was the use of semaphore towers to solve the communication problem. The semaphore alphabet uses two movable boards or flags in different positions to indicated corresponding letters. The Boy Scout Signaling merit badge required learning the Semaphore code in addition to Morse code. Another semaphore-like method was wig-wag This is sending Morse code with a single flag. Left was dih, right was dah . I have long since forgotten the semaphore code. Another way is a light blinker. Some may remember John Wayne as Donovan copying code via light blinker or Sean Connery as Marko Ramius doing the same in Hunt for Red October. They both were faking it, of course!

In the 1830s Samuel F. B. Morse and his assistant Alfred Vail invented the dot/dash code attributed to Morse. The understanding of electricity and magnetism in the early 1800s (Michael Faraday being the prime investigator) lead to the development of an iron core electromagnet. By sending a current through the device, a magnetic field could attract or release a metal (iron) tab or bracket. We now know these as relays. If the metal tab was carefully designed it could make a decided thump or click making the arriving current pulse audible. A doctored up relay was called a sounder. Telegraphy was born!

Demonstration by Julian Hamer AA7JH

Morse’s code was designed with these sounders in mind and was the original Morse code. The original Morse code is now called American Morse or Railroad Morse. We now have telegraphy but wires between stations are required. Now to radiotelegraphy and its history.

Understanding of what we now call radio waves or, more accurately, electromagnetic waves, led in time to the work of Marconi and others. The first transmitters were very crude by our modern standards. Various means were used to generate a strong current pulse. There were many variations but the goal was to generate sparks of high current.   This pulsing but strong current was fed to 1) an antenna directly where the antenna acted as a filter, of sorts, or 2) to a single tuned circuit (L and C) or a pair of tuned circuits and then to the antenna which would somewhat restrict the bandwidth (but not much). A quenching circuit was added to the double linked tank circuits to prevent oscillations at different frequencies ! (The frequencies of the two tank circuits). The current was keyed in various so that a morse-type code could be used to transmit messages. There was a buzz associated with the spark generation and a decaying amplitude in each pulse as power was drawn from the system. As the resulting oscillating current was not a pure sine wave, these early machines were very broad-band. This caused troubling interference to other such stations. In time, the bandwidth was restricted by various schemes but not nearly enough to meet the goal of a single frequency wave or so-called continuous wave. Such would occupy only a bandwidth determined by the keying rate. (Go check this out in any book on Fourier analysis!) A reasonable keying rate would yield a bandwidth of 100-200 cycles/sec (Hertz!). The bandwidth depended on both keying rate and the rise and fall times of the waveform.

How were these ‘signals’ detected? The first was a coherer. It happens that putting some iron filings in the presence of RF will clump together. Unfortunately they would stay clumped so some scheme was necessary to de-clump them to detect further code elements. Later on an electrolytic detector and then a crystal detector were used. These latter two detectors were basically a rectifier acting on an amplitude modulated RF signal. Headphones were required to hear the incoming signals as amplifiers as we know them had not yet been invented. Some of us used crystal sets to listen to AM radio ‘back in the day’. A galena crystal mounted in a metallic case and a whisker wire acted as a diode and rectified the incoming signal. You had to find ‘just the right spot’ with the whisker. A spark transmitter signal transmitting morse code sounded like a cheap buzzing oscillator. Frequencies were between 60 Hz and 200 Hz or so. They were easily detected by rectification of the waveform and were used for many years. These transmitters could not be used to transmit voice or music, however, as the RF was not a pure sinusoidal wave. Now on to the continuous wave’s development and its reduction in bandwidth.

As stated before, the goal was a ‘continuous wave’ RF source. What is this? Recall back to a high school or college math course . The shape of a sine or cosine function is the ideal for a RF source as it leads to the theoretical minimal bandwidth. A mathematical sine or cosine wave has only one frequency, but real world sine waves need to start and stop. That amounts to a modulation of some sort and leads to a very small bandwidthDeForest’s invention of the triode led to amplifier circuits. The output of an amplifier is generally 180 degrees out of phase with the input. Edwin Armstrong added a tuned circuit (LC) in a feed back loop putting the fed back signal in phase with the input of the amplifier. An inevitable random voltage excursion will lead to increasing positive feedback, oscillation, and then stabilization in amplitude, The oscillation is at a frequency determined by the LC product of the circuit. These electronic oscillators were developed and, with amplifiers the era of continuous wave began. Also it was found that a machined quartz crystal between a pair of conducting plates made a very stable LC circuit. Using so-called plate (anode) modulation, an audio signal could be piggyback on the RF signal. This amounts to a high level mixer. This worked well and was called amplitude modulation (AM). Broadcast radio had just begun! The fidelity of AM broadcast was implicitly limited by the available bandwidth of a telephone circuit. Instead of voice, keying the otherwise continuous wave or signal with morse code characters now creates what we call a CW signal. Now the question is how to detect a keyed CW signal.

Listening to a CW signal on an early AM receiver will just produce a series of thumps. There is no variation in the shape of a dah or dih, giving just a thump. It turns out that a modern AM receiver can detect a CW signal using its automatic gain control circuit (AGC) . The AGC is used to temper wild variations in the incoming signal. If listening to a CW signal with a modern AM receiver the AGC measures the carrier amplitude and sharply reduces the system gain. While the signal is present the ambient radio noise is sharply reduced leaving a quiet spot. This relative absence of noise can be interpreted an inverse morse code character. I had fun playing with this with our family car's radio. In the SF Bay area you could tune down below the 540 kc end of the broadcast band and listen to the maritime stations. Lots of fun. But a tough way to read code! Now to develop ways to turn an incoming signal into a tone, a nice sinusoidal tone.

Edwin Armstrong, a student and then professor at Columbia University, adapted an amplifier by adding a tuned circuit (LC) in a positive feedback path for a purpose other than an oscillator. This adjustable/controlled feedback turned the amplifier into the autodyne amplifier. Two significant things here. First, adjusting the amount of positive feedback leads to a greatly increase in output at certain frequencies and, secondly, if feedback increased even more it would self-oscillate and allow CW (pure sine wave RF) signals to be detected. The signal generated by feedback mixes with the incoming CW signal (heterodynes) and generates a tone. Although these autodyne detectors were somewhat tricky to adjust, they did work. CW as we know it had arrived. We now had a detected signal with a musical quality to it rather than being basically a buzzing hash. A note on the above: old timers may remember the Q multiplier produced by Heathkit. It was the same idea but at audio frequencies rather than at RF.

Now to develop a detector that is less fussy. A simple crystal or diode detector can detect (demodulate) an amplitude modulated signal (AM). This is because when examined in frequency space it consists of a center more or less steady frequency signal we call the carrier. And coming along with the carrier are sidebands on each side corresponding to frequencies in the audio signal. Lower pitches (audio frequencies) are closer to the carrier, higher are farther away, etc.. The carrier acts as a mixing reference in reconstructing the transmitted audio signal. A morse code message sent via a Continuous Wave transmitter (a CW signal) does not have such a reference with the signal. The autodyne detector mentioned above generates such a reference but it needs to be fiddled with to get it to be stable and at a desired pitch. Recall from your trigonometry course (!) the identity where a product of two sine or cosine functions (think graph) are equivalent to the sum of a sine or cosine of both the sum of frequencies and the difference of those frequencies. Let's be specific. Suppose the signal coming through the amplifier chain of a superhetrodyne receiver is at 456 kHz. If that signal is mixed (multiplied) by a signal at 455 kHz, the sum and differences will be generated. 1kHz and 911 kHz. The 911 kHz is basically filtered out and isn't amplified by the following audio amplifier. The audio signal heard is at 1000 Hz. The signal mixed in is from a so-called beat frequency oscillator (BFO). Old school receivers had two controls for this oscillator. You could turn it on and off as well as change its frequency. Turn it off to listen to AM signal, turn it on for CW. The BFO frequency adjustment knob allowed the choice of pitch for convenient listening/copying of the incoming CW signal. I usually try for a difference frequency (and thus pitch) of about 650 Hz. Back in the heyday ofAM radio, stations on nearby frequencies would have their carrier mix with the carrier of our desired station giving a (somewhat) steady tone at 10 kc. Annoying. Modern receivers in today's transceivers still have a BFO but it is part of the product detector or mixer. Its frequency is not adjustable but is fixed as part of the single sideband generation circuitry. The use of a BFO replaced, in general, the autodyne detector.

Now we have a tone, more or less stable, to convert into alphanumeric characters. In the course of the spark era and into the CW era, Morse code morphed into variants based more on pitch than on thumps or clicks. The American or Railroad morse was not suitable for a tone based system as it is for a sounder. A version suitable for CW was developed in Europe was called the Continental or Gerke code . Another version was developed in the US and eventually became the base for the reconciled version now called Internal Morse code. A few foreign countries have adapted it to suit their unique alphabets (Japan and Korea) with 5 element code characters.

Learning to receive (decode) Morse code takes time and study but can be done. There are programs that will display received morse characters on a screen. So-called morse readers still take some finesse to use. The pitch needs to be adjusted suitably to match the frequency the reader wants, and a reasonable guess as to the sending speed also needs to be made. If you really want to learn morse, don't rely on a code reader! In receiving Morse it is best to think in terms of the SOUND of the code elements: dah and dih and NOT dot and dash. Every Morse character has its own sound and rhythm. In general, musically inclined people are better at copying code. The goal in military usage was to train operators to copy code directly to a 'mill' (typewriter) with little retention but most amateurs write the copy on paper or do 'head copy'. I tend to mostly listen and write down notes occasionally as I go along. If the code is reasonably fast I tend to form mental buffers building up words. Too slow and I lose concentration. The old three license classes required Morse receive and send at 5, 13, and 20 wpm. 13 proved to be a roadblock for some. I find 22 wpm to be a nice coasting speed. There, morse is quite conversational. I slow down a bit for Summits on the Air and, especially, Parks on the Air ops.

Who uses morse today? Contesters and DXers, of course. But not as much activity on CW as in the 60s through 2000s. There has been a resurgence in use of CW the past decade or two. This is mostly due to SOTA and POTA and portable operation in general. Every Field Day club or group is looking for an old timer to run their CW setup. There has been quite a resurgence of CW activity with the advent of both the Summits on the Air and the Parks on the Air programs. Probably 75% of SOTA activity is CW while POTA is more like 30-50%. I get a real kick from being called by JG0AWE or F4WBN on 20m CW when I am on the summit of a local peak. With CCRs and HOAs, some hams operate mostly from portable situations. WA7RAR and N7EU come to mind.

CW is the ideal mode for low power and portable operating. Also, there are several online clubs and organizations that carry on or enhance the CW traditions. Among these groups are the FISTS CW club, CW ops, Straight Key Century Club, Long Island CW club, A1 ops, etc. There is even the Sunday morning online meeting of the Church of the Continuous Wave…

Here is why CW gets through in rough conditions. The key is putting all your transmitter's RF energy into a very narrow bandwidth. It will lead to a several dB advantage compared with SSB, AM or FM. Imagine a rectangle 2400 units wide and 10 units high. The area of it is 24000. Let this represent a normal SSB signal. Now imagine a rectangle of 100 units wide. Its height will be 2400 units to have an equal area. In this example the power density per Hertz increased by 24 times. Of course to be fair one should take the logarithm of that ratio, and also note that the energy in the sidebands is not nearly uniform, as I have assumed.

How to generate Morse code:

The traditional hand key was actually invented by Alfred Vail, an assistant to Samuel FB Morse. It has been copied ever since. The military version is the J-38 or J-37. They come with a shorting bar (for tuning the transmitter) and a slot to plug in a special connector tied to a 'bug' or semi-automatic key. The length and spacing of each element of a character is done by the operator. It helps to know what good code sounds like, though.

Semi-automatic hand keys, called bugs, made by Vibroplex corp, have a bug /or insect on its logo. They go waaay back. . There are other manufacturers of bugs but Vibroplex is still the dominant supplier. Bugs work by making dits with a vibrating spring / rod with weights on it for adjustment. Correctly setting up a bug is somewhat fussy but to the operator's taste. Being mechanical and with moving parts, bugs can go out of adjustment. Serious commercial CW operators would carry their bug with them in a special carrying case and just plug it into the hand key's shorting bar slot. The bug I brought with me is from 1945 and is their Original Deluxe model. Their models include: Original, Lightning Bug, Blue Racer, etc. with some having DeLuxe variants. I couldn't afford a Vibroplex as a kid but had a Speed-X. I sold it when I went to the university. I have four now and had to carefully resist the several bugs for sale at the recent swapmeet.

The electronic keyer was developed starting in the early 50s. The goal was to replace the mechanical spring motion generating dits with an electronic version. An additional goal was to generate dahs in a similar way. The first real electronic keyers came out in the 1970s.They are run by manipulating what we call a paddle. Paddles come in two variants: single lever and dual lever or iambic The Curtis chip and the PCB kit called the WB4VVF keyer lead the way. Several companies make single lever and iambic (dual lever) paddles. Most common is the Bencher BY series. A very nice limited production paddle was made by N2DAN. Those are very rare and prized. Bencher made a very good knockoff of the N2DAN paddle. (Bencher was half-owned by Bob Locher, W9KNI, who lives in Grants Pass). MFJ made some knockoffs of the Bencher paddles. Mechanical masterpieces are made by Pietro Begali of Italy although his full size paddles are a bit showy for me. I have two small iambic paddles that mount on the front of my Elecraft SOTA/POTA radios. They are a master work of the machinist art! Making small portable paddles is a cottage industry in the SOTA community.

Now more on keyers. An early design was the Ultimatic keyer but it was complicated to build and a bit tricky to master. The original tube version used a free running multivibrator: the operator had to somehow sync his sending with it! All versions of the Ultimatic used dual levers giving options in sending by using dot and dash memories. You could insert a series of dots in a string of dashes, and visa versa. All character elements were self-completing. It was never a successful commercial product, however. In the 70's keyers based on the Curtis chip and WB4VVF keyers both used a new keying method, Iambic. Both use a dual lever (iambic) paddle. When both levers of a paddle were held together (squeezed) an iambic keyer would begin the alternating sequence dih-dah-dih-dah….   Or dah-dih-dah… This made certain letters more easily keyed. C, K, R come to mind while other letters were no simpler. In designing iambic keyers, the question comes up as to what to do when the squeeze is lifted/removed simultaneously? One implementation would simply stop (unless one lever was still held). The other version would remember which lever was held before both were squeezed and, upon release would add the opposite element automatically. Unless one trains for this it can be a surprise. When an A is intended, slightly incorrect timing would produce an R. This timing, Iambic-B, requires fewer strokes but at the price of more critical timing I used a WB4VVF keyer for several years and found it tricky. Just recently I found out why. (The WB4VVF keyer uses Iambic mode B.) Then, later, I acquired another keyer (the SuperCMOS3 or Logikey keyer) which didn't do

Iambic-B out of the box. My accuracy and speed both jumped! Unfortunately most keyers built into radios offer only Iambic-B (although some give a choice of –A or –B). The external keyers that I know about have several mode choices. The K1EL WINKEY USB has Ultimatic among several others while the LogiKey has a slightly different set of modes.The choice of Iambic-A or Iambic-B or Ultimatic or … is basically religion and equally divisive. Doing a count of strokes, the Ultimatic keyer has a very slight advantage over either version of iambic. Some characters are problematic for one method, others for the other. P and X are easy with Ultimatic while C and K are easy with iambic. I personally prefer an external memory keyer and avoid internal keyers. A memory keyer, with memory buttons built into its case, is much easier to use than searching for the appropriate button on the radio front panel. In general, the advantages of a good keyer are many: greater accuracy and consistency vs. a bug or hand key, near instant speed change, macros can be set up with stock messages (this is where FT8 got the idea!), etc. Contest logger programs all have a keyer built in or made available outboard. The internal keyer can be run from an external paddle or from the computer keyboard. Serious contesters (I am not one anymore) can run at amazing speed without removing their hands from the keyboard.

The fourth type of keying device, then, is a CW keyboard. Usually it is a program running on a computer.

Very high speed CW requires a keyboard for speeds above 50 wpm or so.

Historically getting the keying out of a computer logger or keyboard to a transceiver has been an issue. Back in the earliest days the 25-pin parallel port was used. Attach a gadget with a few open collector transistors and you get keyline out, PTT out, and, if you add a 3/c jack you can control the computer keying program from your external paddle. But, alas, the parallel port is unavailable on current computers. A fix has emerged: use the USB output to an external USB gadget to do the actual keying. K1EL did this with his WINKEY USB. Recent versions of the WINKEY also have a stand-alone keyer built in. It is pretty slick. Two key outputs, two PTT outputs, and paddle in. When controlled from the logging program, the operator can alternate between two radios and the K1EL keyer will track. This is called SO2R (single operator, two radios). Also, the PTT output will, in general, slightly lead the keying output. This can save your amplifier…! Hot switching is hard on the relays in an amplifier! Keying amplifiers with full break-in (QSK) is an art unto itself. Listening to your backscatter between code elements is a fun treat.

Allan Taylor K7GT April 2025