Using CTCSS Tones and DCS for Squelch Control

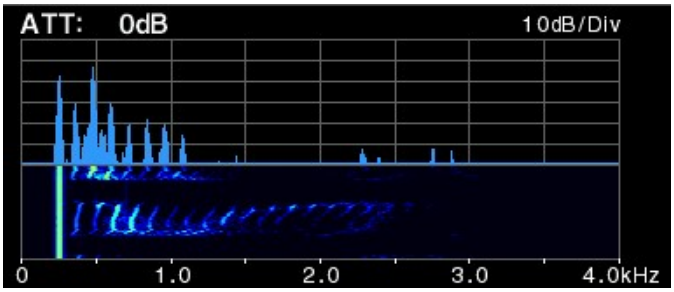
Carrier squelch is reasonably effective at keeping an FM radio quiet in the absence of a signal. Carrier squelch simply sets a threshold and when the signal is stronger than the threshold, it allows audio to pass to the speaker. It isn't adequate in high noise environments such as repeater sites and urban areas because there are often signals that exceed the threshold and cause the squelch to open with this noise.

Using a Continuous Tone Coded Squelch System (CTCSS)[1] tone or Digital Coded Squelch (DCS)[2] code is a much more effective solution in these environments. This requires the correct tone or code be sent along with the signal to insure the squelch only opens on a valid signal. CTCSS tones are often referred to as "subaudible tones" which is not technically accurate. The tones range in frequency from 67.0 to 254.1Hz which are in the audible range but receivers generally filter frequencies below 300Hz and are transmitted with lower deviation so they aren't heard during communications. These tones were chosen to insure they are not harmonically related to minimize false decodes. Digital Coded Squelch (DCS) offers similar functionality but won't be discussed in detail because it is less common in amateur radio.

Choosing a CTCSS tone or DCS code is entirely arbitrary. Any tone or code can be used. Lower frequencies take slightly longer to decode and higher frequencies are faster but more likely to be heard through the filter in the radio. DCS codes take even longer to decode (up to a half a second) but are even less prone to random false signals. This requires proper mike practice of pressing the PTT and waiting slightly before talking to insure squelches are open on a repeater and other receiver or the initial audio will be cut off.

CTCCS Tone	Motorola Code	CTCCS Tone	Motorola Code	CTCCS Tone	Motorola Code
67.0	XZ	118.8	2B	179.9	6B
69.4	WZ	123.0	3Z	183.5	None
71.9	XA	127.3	3A	186.2	7Z
74.4	WA	131.8	3B	189.9	None
77.0	XB	136.5	4Z	192.8	7A
79.7	WB	141.3	4A	196.6	None
82.5	YZ	146.2	4B	199.5	None
85.4	YA	150.0	none	203.5	M1
88.5	YB	151.4	5Z	206.5	8Z
91.5	ZZ	156.7	5A	210.7	M2
94.8	ZA	159.8	none	218.1	M3
97.4	ZB	162.2	5B	225.7	M4
100.0	1Z	165.5	none	229.1	9Z
103.5	1A	167.9	6Z	233.6	None
107.2	1B	171.3	none	241.8	None
110.9	2Z	173.8	6A	250.3	None
114.8	2A	177.3	none	254.1	0Z

These same tones are used on Family Radio Service (FRS) and General Mobile Radio Service (GMRS) radios and often called "privacy codes". Despite this name, there is no actual privacy or security. Any radio with tone decode disabled (code 0) will hear all activity on the channel. There are other trade names for CTCSS; Motorola uses *Private Line™* or *PL* and GE uses *Channel Guard*. Similarly, Motorola uses *Digital Private Line™* or *DPL* when referring to Digital Coded Squelch (DCS).

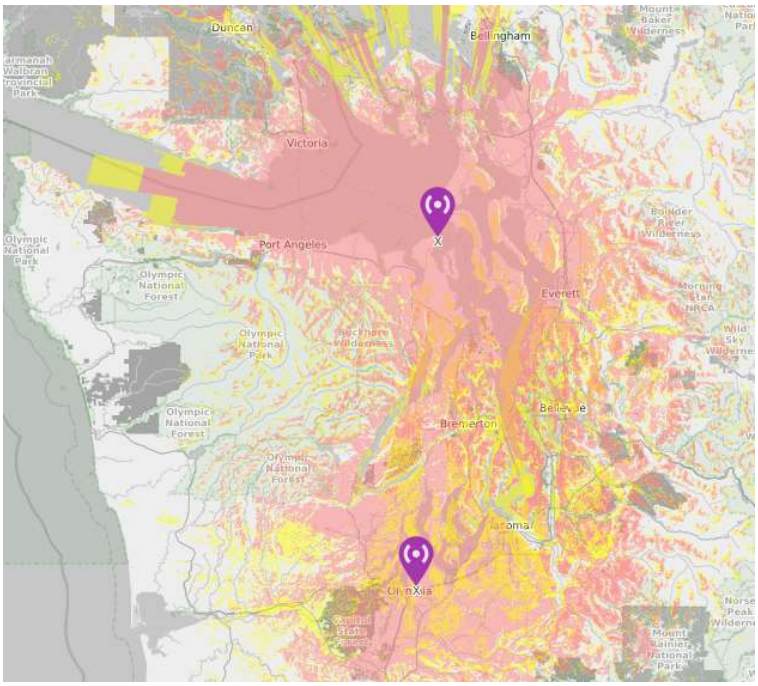


The image on the left shows the audio spectrum and a waterfall of a CTCSS encoded signal with voice modulation. The left-most peak and solid vertical line in the waterfall is the CTCSS tone. The peaks to the right on the spectrum display and wavy lines in the waterfall is the voice modulation.

Using CTCSS or DCS with Repeaters

Repeaters and radios can be configured to both transmit (encode) a tone and require a tone on receive (decode). Most repeaters require tone access so radios must transmit (encode) a tone to activate the repeater. Additionally, most repeaters will regenerate this tone on the output and transmit the same tone so repeater users can also use tone decode when operating the repeater. This allows the radio to stay quiet in high noise environments. Often the repeater will ID without a tone so users with tone decode enabled won't have to listen to it. It is also invaluable on dual mode repeaters that support analog and digital modes (FM and Yaesu System Fusion for example). The Fusion signals will sound like noise to an FM user. If tone decode is enabled on the user receiver, the Fusion signals will be squelched but the FM signals will come through perfectly fine. The Western Washington Amateur Relay Association (WWARA) has started collecting information on whether repeaters provide a tone on their output. This information is available in the latest repeater listing (generated nightly) on the WWARA website at http://www.wwara.org.

In Western Washington, all repeaters are required to supply a tone frequency when coordinating and must be using tone decode when reporting interference from other systems. Using tones on repeaters accomplishes three goals; minimizes interference from other systems at the same site, minimizes interference within the view of the often mountaintop repeater and allows the repeater to ignore users of other systems on the same frequency (co-channeled systems). There are systems with multiple receivers that use different tones to select a specific receiver best for the users. Additionally, there are only 66 repeater pairs on the 2m band in Western Washington, yet we have 96 coordinated repeaters by co-channeling systems with enough distance and terrain between them (geographic diversity).



It is not necessary to insure co-channeled systems have no overlapping coverage because they use different tones to insure users are selecting the appropriate system. Even systems at a substantial distance or with significant terrain between them do not always have exclusive coverage areas. In the summer it is quite common for an inversion layer to create a duct for signals well out of the area. During the repeater coordination process, WWARA reaches out to adjacent areas (Oregon, BC and Eastern Washington) to look for potential issues. Proper planning can reduce interference between repeaters but it

is still possible for users to hear the remote system. If users enable tone decode on their radios, they will only hear their desired system.

The example at right shows a repeater in Port Townsend with coverage of north Puget Sound area and a repeater in Olympia that covers the south Puget Sound. These systems are on the same frequency but use different tones. The red represents areas of strong coverage and yellow areas are weak. It is orange where the coverages overlap. There are significant areas of overlap that are outside their intended coverage areas (even a few inside). Users in these areas can operate either system by selecting the appropriate tone. Any user in this overlap area will hear both systems unless tone decode is enabled on their receiver. Even if users in the Olympia area can hear the Port Townsend system, the Olympia system will be significantly stronger. If both transmit at the same time, FM capture effect[4] will allow Olympia users to clearly receive the Olympia system and Port Townsend users to clearly receive the Port Townsend system. It is important to recognize that simply hearing another station does not represent interference[3]. It is very likely that using tone encode/decode and FM capture effect[4], both communications can continue normally.

Well-engineered transmitters in radios and repeaters use a "reverse CTCSS" or simply stop encoding CTCSS tones shortly before the end of the transmission. This allows the receiver to close the squelch before the signal ends eliminating the noise burst associated with the squelch tail when used with tone decode in a receiver.

Using CTCSS or DCS on Simplex

Even simplex channels can benefit from encoding and decoding a tone. There are a limited number of designated simplex channels defined in the 2m band and even fewer on 70cm. Repeater pairs that are not used in a given area are available for simplex use on a non-interference basis. Simplex generally offers limited coverage and channels can and are often reused in geographically diverse areas. This is very common with emergency communications teams. This means unrelated, undesired conversations are often heard when monitoring and can be confusing. If users encode a tone when transmitting, this allows users experiencing interference to simply enable tone decode and mute the undesired transmissions.

There are some limitations to using tones on simplex frequencies and it should be used prudently. Because a user will no longer hear others on the channel, they could accidentally transmit on top of them and cause interference. It should be noted a signal will still be visible on the radio's signal strength meter so looking at the radio before talking will resolve the issue. Many radios have a "monitor" feature that opens the squelch to allow monitoring the transmit frequency before transmitting. Icom uses the term "XFC" for "Transmit Frequency Check". Most radios also have a feature called "Busy Channel Lockout" or "BCLO" that won't allow transmitting when a signal is detected on the channel. Additionally, as long as the one signal is some distance away and weaker, FM capture effect[4] will allow the stronger signal to be decoded while ignoring the weaker signal.

Encoding a tone on simplex is the recommended technique on the federal interoperability channels. The National Interoperability Field Operations Guide (NIFOG)[5] offers the following guidance –

Default operation should be carrier squelch receive, CTCSS 167.9 transmit. If the user can enable/disable CTCSS without reprogramming the radio, the indicated CTCSS tone also could be programmed for receive, and the user instructed how and when to enable/disable.

The land mobile and public safety spectrum was required to move to narrow band FM[6] by January 2013. Changing the deviation and channel steps to 12.5kHz nearly doubled the available channels and could work similarly for the amateur spectrum. Although many radios support narrow and wide band FM, they commonly use a wide band receiver for both. This makes them susceptible to interference from adjacent narrow band channels. Using tone decode on the receiver will become more critical as we transition to narrow band FM. This tends to be less of an issue when using narrow band digital modes.

Programming Radios with CTCSS Tones

True amateur radios (FCC rules part 97) generally have two tone modes; encode only (only transmit a tone), encode and decode (transmit a tone and require one for receive). Once the tone mode is selected, the actual tone frequency (or frequencies) must be selected in a different menu. Note that most amateur radios can only encode and decode the same frequency. Encoding one tone and decoding another (split tones) is generally not possible even if there are two separate menu options. When programming a radio by hand, it is important to select the tone mode before the tone frequency to ensure the correct tone is sent (particularly on Kenwood radios). Similarly, on radios with two tone frequency settings (Icom), it is best to program both settings with the appropriate frequency so that a tone mode change will still use the correct tone.

Land mobile radios (FCC rules part 90) require setting encode and decode tones separately. The radios currently coming from China generally follow the land mobile, part 90 guidelines and require setting both encode and decode values explicitly. These radios have no “tone mode” concept. An encode or decode tone is selected or not. These radios do support split tones by simply selecting the appropriate encode and decode tone. This does require careful attention to when and which frequencies are selected in both of menus.

There are many ways to describe the use of CTCSS tones which often creates confusion. Even handheld or mobile products from the same manufacturer often use different terminology. Encode tones are shown as *Tx Tone* and decode tones are *Rx Tone* in the chart below. The chart shows the *squelch type* available, the *menu* name used to set the tone mode, the tone *setting* options and finally, what will appear in the *display* when that tone mode is set. This is a small sample for illustration.

Radio	SQL Type	Menu	Setting	Display
Alinco DJ-G7	Tx Tone	TONE	CTCSS encode	T
	Tx/Rx Tone	TONE	CTCSS ENC/DEC	TSQ
Baofeng UV-5R	Tx Tone	T-CTS	*Frequency*	CT (on PTT)
	Rx Tone	R-CTS	*Frequency*	CT
Icom ID-51	Tx Tone	DUP/TONE	Repeater Tone	TONE
	Tx/Rx Tone	DUP/TONE	TSQL Frequency	TSQL
Kenwood TH-F6A	Tx Tone	TONE	T	T
	Tx/Rx Tone	TONE	CT	CT
Wouxun KG-UV9D	Tx Tone	Tx-CTC	*Frequency*	CT (on PTT)
	Rx Tone	Rx-CTC	*Frequency*	CT

Yaesu FT-60	Tx Tone	SQL TYP	TONE	T
	Tx/Rx Tone	SQL TYP	TSQL	T SQ
Yaesu VX-8R	Tx Tone	SQL TYPE	TONE	TN
	Tx/Rx Tone	SQL TYPE	TONE SQL	TSQ

Summary

- CTCSS and DCS decode can help eliminate interference, unwanted signals and squelch tails.
- When using CTCSS and DCS leave extra time when transmitting to not be cut off.
- Using CTCSS and DCS tones allows multiple operations on the same channel.
- Using Busy Channel Lockout can reduce interference potential using CTCSS and DCS decode.
- Using CTCSS encode on simplex allows users to decode if necessary. Not encoding eliminates this option.
- It is important to use CTCSS and DCS with multimode and narrow band FM repeaters.

Credits

The Western Washington Amateur Relay Association (WWARA) is a nationally recognized frequency coordination organization who coordinates the use of amateur spectrum in western Washington to minimize interference between and amongst amateur operators. The WWARA was formed in 1976 as a public non profit organization.

The amateur radio frequency spectrum allocation is a fragile and finite resource. With the explosion of new amateur radio operators and modes using our allocated spectrum we have more incentive to conduct cooperative operation between not only individual amateur radio operators, but amateur relay stations (repeaters). The WWARA provides the local vehicle to accomplish this keeping the needs and desires of the amateurs in western Washington in focus. The WWARA offers technical resources to assist repeater owners and publishes the latest band plans and the latest repeater listings on a daily basis.

Experience has determined that the coordination of repeater systems is essential to maximize the finite spectrum resources allocated to amateur radio and minimize interference between systems in our area and adjacent areas. Continued support of our band plans and especially frequency/spectrum coordination councils such as the WWARA is essential to our mutual enjoyment of amateur radio.

The Western Washington Amateur Relay Association (WWARA) is THE repeater coordination body for Western Washington State. In addition to coordinating Amateur Repeaters, the WWARA publishes band plans for Western Washington, works with neighboring Repeater Coordinating bodies to resolve interference issues, as well as repeater owners in Western Washington. WWARA publishes the authoritative coordinated repeater list nightly in multiple formats including PDF, CSV and CHIRP. Repeater coordination is offered at no charge and WWARA membership is open to ALL amateur radio operators for a modest fee. Find further whitepapers, repeater lists, band plans and become a member on the WWARA website at https://www.wwara.org.

[1] https://en.wikipedia.org/wiki/Continuous_Tone-Coded_Squelch_System
[2] https://wiki.radioreference.com/index.php/DCS
[3] FCC part 97.3(23) Harmful interference. Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with the Radio Regulations.
[4] https://en.wikipedia.org/wiki/Capture_effect
[5] https://www.dhs.gov/publication/fog-documents
[6] https://www.fcc.gov/narrowbanding-overview