Tone… to go

It's summer vacation season, and hams are on the road, taking their VHF/UHF FM radios with them. As they travel, they discover to their dismay that they can't use many of the repeaters they pass on their trip - even repeaters they hear on the air being used by local hams. That's because the repeaters are tone-guarded, and the mobile ham doesn't know the tone.

Does the FM guru have a solution? Maybe, but first, I think I'd better do the tone primer that all FM columnists must do at least once. I've been holding off, waiting to let the *CQ VHF* subscriber base build up. We're up, so it's time. Then I'll try to let the subject go for a long time and look at other stuff.

What is "tone?"

You're reading *CQ VHF,* so there's a pretty good chance you are very familiar with tone squelch. But I remember how baffled I was when I first encountered it in the early 70's. What was this mysterious technology that allowed the signals of only certain, select hams into a repeater? And I wasn't the only one in the dark. Lots of hams use tone squelch today without understanding it. Many more haven't figured out how to make it work, and are stuck on carrier-access repeaters. So here's the tone primer:

First, the **Very Simple Explanation:** tone is a system that lets a receiver accept certain radio signals on a channel and reject other signals on that same channel.

Now, I'll get **Slightly More Complex:** tone squelch is based on a low frequency, low-volume, pure sine-wave tone that is added to your voice and sent out your transmitter, and detected at a receiver to make the receiver do something, like turn on a speaker.

And to really wrap your mind around just what that tone is, here's my **Third Explanation:** tone squelch is like someone sitting in the back seat of your car, blowing a soft, very low note on a clarinet while you're talking. Really! The clarinet player holds the right note, and some receiver out there says, "Hey, that signal's for me!" No tone, and the receiver pretends there's nothing out there. (The receiver is a fan of clarinet music.)

This rose goes by many names. The generic name is **Continuously Tone Coded Squelch System**, or CTCSS for (nor very) short. The name and the initials are both awkward mouthfuls, so I just call it "tone" (or "tone squelch" when I'm feeling formal). It is probably best known as "PL," the initials of the Motorola trade name "Private Line." Almost all the old-timers call it PL, though there are a few holdouts for the name applied by other companies, like GE's "Channel Guard" (CG). If I were a real old timer, I could tell you the name used by RCA, E.F. Johnson, and a handful of other legendary brands of commercial FM radios. Write if you feel the need to remind me. It is also sometimes called "sub-audible tone," or "sub-tone."

OK, now that we're on a first-name basis, just what is tone squelch? How does it work? What can it do for you, and what *can't* it do?

Range War

Wait. I can't get into instruction without wasting some time first. That's my trademark. I'm looking at an explanation of tone squelch in a *New York Times* article by David Pogue that was reprinted in the local paper (the Raleigh *News & Observer*). In this article, Pogue takes radio makers to task for their exaggerated claims of five and seven mile range for their new GMRS handheld radios. That is the tangent I'll follow for a while before getting back to tone.

You might be familiar with the way FRS radios have claimed "2 mile range" for several years, now. Even though they rarely fulfilled that promise, the ante has been upped. You can now buy these little radios in blister-packs that have the 14 FRS channels, plus seven or more GMRS channels, two to five watts output power, and claims of up to five or seven mile range. Pogue, who does not appear to be an RF expert, notes the weasel words "up to" permit nearly unlimited exaggeration.

Pogue tested the radios in several terrain conditions (including over water), and squeaked out 3.3 miles at absolutely best case, and less than two miles in all over-land tests. Hams who have played with UHF handhelds on simplex might expect to do a little better, especially over water, but I think most of us would admit that five miles between rubber-duck equipped handhelds on level ground in a rural area is not likely. Hit a hot spot just right, and maybe you might be able to talk at that distance, but routine communications – no way.

Pogue challenged the manufacturers on their claims, and says they "call these freakishly poor results," chalking them up to "environmental factors that can affect range: humidity, wires, vegetation, buildings, clouds, hills, airplanes and even sunspots," and adds "now there's a high-tech corporate excuse you don't hear every day." How much do you wanna bet that the guy he was talking to was a ham? Sunspots? Affecting UHF handhelds?

A few years ago I ran a test between a pair of "two-mile range" Motorola FRS radios and Icom W32's (running ½ watt to match the FRS power). On a flat, straight road lined with wood-frame beach houses and no overhead power or phone lines, both radios worked well to just under a mile. They got pretty noisy after that. At the claimed two-mile limit, I could communicate over the FRS radios only when they were carefully aligned in "hot spots." Civilians would not recognize that as communications. The W32's beat the FRS radios by a hair at ½ watt. I didn't check the sunspot count.

And one other thing, as long as I'm not even pretending to be on-topic. Licensing. The GMRS radios are supposed to require a license, complete with callsign. The 10-year tab is a steep $75. Pogue says "radio makers acknowledge… that this requirement may be the most universally ignored regulation since the invention of jaywalking." He hasn't spent much time on CB.

What did you say "tone" was, again?

And now back to our column. In his article, Pogue attempts to explain tone, which has now picked up some new names like "privacy code," "sub-channel," and "subcode." Here's what he says about tone in the FRS/GMRS radios:

"Each radio also offers subcodes: thin frequency slices of each channel that help prevent crosstalk from other radio owners in the area."

OK, we're done. I think that about sums it up. Thin frequency slices of each channel. Why didn't I think of that? Well, Mr. Pogue did such a nice job of skewering the big radio guys on their inflated range claims that I think we should give him a free pass for spouting utter gibberish on a technical subject that nobody really cares to understand anyway.

Nobody but hams and radio techs, that is. So now here's the bottom line:

As I said up front, CTCSS is a low frequency, low-volume pure sine-wave tone that is added to your voice and sent out your transmitter. There are about 38 separate audio frequencies used for the tone, from 67 Hz to 250.3 Hz, though most radios include a few extra "non-standard" tone frequencies. This tone is called "sub-audible" because ham and commercial radios are supposed to filter out audio below 300 Hz and not let it get to the speaker. Humans, of course, can hear those frequencies just fine if a speaker can reproduce them. If you turn up the volume with someone sending one of the higher frequency tones, you will hear it, or harmonics of it, in your speaker. In a narrowband FM radio with 5 kHz deviation, the tone should have about 700 Hz deviation. And since it's added to the voice, the voice volume has to be reduced a little to avoid over-deviation by the combined voice+tone audio signal.

The tones are generated by a circuit called an **encoder.** In the 1980s, tone encoders were separate, optional plug-in circuit boards. Older radios didn't have provisions for encoders at all, but you could buy an add-on aftermarket board and try to stuff it into your radio. Today they are just part of the radios circuitry, and controlled from the front panel.

Tone becomes useful only at the receiver end of things. There, a circuit called a **decoder** listens for the tone. When the decoder hears the tone, it can do several things. The most common thing it does for hams is to turn on a repeater transmitter. On a "tone-guarded" repeater, you have to send the correct tone or the repeater stays off the air. And that was our mobile ham's problem – what tone should he send to activate the repeater?

There is a digital version of tone, too, that has begun showing up in amateur radios over the past few years. Probably shouldn't call "tone," because it isn't. It's a data "word" sent at a low rate, using low frequency audio energy, mixed with the voice just line CTCSS tone. Kind of like sending a packet word over and over. The generic name is Digital Coded Squelch, or DCS, and some of the manufacturers even use that name instead of making up a new one. But you will find "DPL" and "DCG" in use by some big radio manufacturers. The goal is the same as tone – turn on a speaker or a repeater.

There may be some ham repeaters out there that require you to send DCS. Today, these would have to be fairly exclusive or "closed" repeaters, since most radios don't have DCS encoders and it's not something you can tack on easily (although there are "outboard" DCS boards on the market).

Our mobile ham probably doesn't have to worry about DCS for at least a few years. The repeater he can't kerchunk is probably not using DCS. It's probably just plain old tone.

But again… what tone?

Why tone?

I'll get to the *what tone* in a minute. First, let's look at *why*.

Engineers, probably hams, invented tone to solve the problem of channel congestion in the early days of commercial two-way FM radio. Bob's Towing Service and Mary's Taxi Company didn't want to listen to each other's transmissions. But there weren't enough separate RF radio channels available to let every business have their own private, quiet channel, so they had to share one. To keep Bob's speaker quiet when Mary was dispatching, and vice-versa, they both used tone squelch. Bob's radios used the tone frequency of 107.2 Hz. Mary used 156.7 Hz. And several other users on the channel used other tone frequencies. Nice, quiet radios. Problem solved.

But, as you know from physics, for every solution there is at least one new problem. In this case, Bob was giving directions to his tow-truck driver one day just as Mary received an order for a taxi ride. Her tone decoder prevented her from hearing that Bob was on the air, so she keyed the mike and called one of her cabs while Bob was still transmitting.

Bob's driver heard something like this from his speaker: "Go pick up a stalled Chevy at 245 WashingtSQUEEEP----------." Meanwhile, Mary's cab driver heard nothing at all. Not even the squeeep.

What happened? This being the old days, Bob and Mary were using simplex. Bob's tow-truck was near Mary's office, so when Mary started transmitting, her signal was a little stronger than Bob's. She captured the tow-truck driver's receiver. The squeeee sound was a bit of heterodyne. Then, the tow-truck receiver couldn't hear the tone from Bob's transmitter any more, so it turned off the speaker, even though Bob was still transmitting. Mary's taxi happened to be sitting at the gas pump in Bob's filling station, about 50 feet from Bob's antenna, after filling up with 28¢/gallon ethyl. The driver didn't hear Bob at all, of course, since his radio was set for a different tone. But with Bob's transmitter on, he didn't hear Mary, either.

The radio manufacturers tried several solutions to this problem: light a pilot light when the channel was busy (your radio may still do that); lock a transmitter out when it was receiving a signal; turn off the decoder when the mike was lifted from the hang-up bracket so the radio operator could hear the other traffic on the channel. Ingenious people found a way to defeat them all.

Tone and ham radio

Public safety radio users – police, fire, medical – typically didn't have to share channels within their community. But they did have to share them with other users 50 to 100 miles away. Close enough that they could hear each other during band openings (yes, the commercial radio services get the same band openings we hams do, but they don't enjoy them as much). So they use tone to keep their radios from hearing their neighbors down the pike.

And that's one of the main reasons ham repeaters use tone. Ham repeaters are typically located about 100 miles apart. Sometimes more, rarely less. Most of the time, that's far enough apart to avoid serious interference. But too often a ham using one repeater will put a weak signal into the neighboring repeater, especially if that ham is near the half-way point, running a bit of power from a good location. Better operating procedure, like running less power or a directional antenna, might solve some of those problems, but not all of them. Band openings, which we otherwise enjoy, can make the repeater problem worse. So the repeater owner adds a tone decoder to the repeater to kill the signals from hams using the neighbor repeater.

A second problem that makes repeater owners "go tone" is noise at the repeater site. Repeaters are often located at busy RF sites. Everyone wants to be on the building, hill or tower that provides high elevation, so the ham repeater has a lot of commercial neighbors with antennas only a few feet away. A carrier squelch repeater could be keyed up a lot with bleeps and squawks from intermod and other RF gremlins. These can be hard to track down, and expensive to eliminate even if they can be found. Easier to add tone decode and keep the repeater quiet, even though you're not really eliminating the offending signal from the receiver.

So the repeater owner elects to trade problems (he might use the word "solve," but just wait). He adds tone to the repeater, and quickly discovers two new problems.

One is the slings and arrows from the local hams who can't use the repeater any more. This may be because they have relic radios that don't have tone (or have just one tone frequency). Or it may be because they have very modern radios with an inch-thick manual, and the tone settings are buried seven layers deep in a "set and forget" menu of some kind.

Either way, user education is one of the problems the repeater owner finds he traded for. He's got to let everyone know what the tone frequency is, and help some people get their radios working with the tone. Those of you who have never been through "user education" may scoff, but just try it.

The second problem is that he has just masked his RF problems. He hasn't solved them. If a moderately strong signal appears on the repeater input without tone, it will still interfere with users. It just won't key up the repeater. If the interference is strong enough, it will make a weaker user signal "go away." Most repeater users get very confused when that happens.

Masking the problem may be the best you can do with the time and financial resources you have, but you should understand the compromise, and educate your users about it.

Back on the road

Ok, let's get back on the road with our vacationing ham. He's passing your tone-guarded repeater, and he'd like to talk. Or maybe he even has an emergency to report. But he doesn't know your tone. His options are limited, and none of them are perfect. Here's my list. You can probably think of a few things I'll miss.

1. Look it up. If he's got a repeater directory, he can attempt to look up the repeater and see if the tone is listed. I don't recommend this for a solo driver, though, unless you enjoy bouncing off bridge abutments. This is something that's better done in advance, marked on a map in BIG letters and numbers, and programmed into memory (finally a use for those memory channels above #11!). Do that and you'll improve your odds of getting into repeaters along the route. But repeater directories are not flawless, and the tone listings are error-prone. It's not the directory editor's fault. Getting up-to-date information from some repeater owners is impossible. Not that they are belligerent or deliberately uncooperative. It's just not a high priority in their busy lives.
2. Scan for the tone. *If* the repeater is currently transmitting, and *if* the repeater sends its tone, and *if* the ham has tone-scanning in the radio, he can scan for the tone. This won't help when the repeater isn't on the air, of course. Newer radios include tone scanning that isn't too hard to find, but it still may require dangerous multi-button manipulation by a solo driver. It would be nice if tone scanning was a one-button feature, but buttons are a limited resource on shrinking front-panels. Which one do you want to trade?
3. If the radio doesn't have tone scanning, he can do it manually by turning on tone decode and clicking through the tones until the speaker opens up. Again, not recommended for a solo driver.
4. If the repeater is not on the air, then he could select a tone, kerchunk, change the tone, kerchunk again, across the tone spectrum until the repeater keys up. I've done this a few times when it was the only way to find a tone.

Repeater owners could help some by having the repeater announce the tone frequency on the ID, if you've got a voice ID. A lot of repeaters do it that way as a courtesy to traveling hams, or as part of the local ham education campaign.

There are some "blue sky" solutions, too. Repeater controller manufacturers could agree on a standard "bypass" for tone guard. It could be a long touch-tone zero (LTZ) or other digit that would cause the repeater to announce its tone, or allow carrier access for a few minutes (an idea suggested in mail from Mike Urich, KA5CVH). I've seen some limited attempts at a "universal" second tone that all repeaters would respond to. Say, 100 Hz. Could you keep all the users from just plugging in 100 Hz and avoiding the hassle of learning the primary code? And I've seen "regional" tones, where most repeaters in a defined geographic area use the same tone, so if you found *one*, you found them *all*. I don't expect to see any of these implemented widely, but once again, if we talk about it enough, we might get a following.

In the meantime, none of the current options is perfect. Repeater owners choose tone access as a convenience or necessity for local operators at the expense of travelers. That's just the way it is. If you want to minimize the impact, keep your repeater information up to date with your local repeater council, and announce your tone on your ID.