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RADIO COMMUNICATIONS
-Keith Conover

Any ASRC member who has been on a mission probably has had occasion to curse at a radio, at someone on the other end of the radio, or about radios in general. Efficient search management, in which we of the ASRC take so much pride, tends to break down most commonly when the radio net malfunctions: e.g.: Field Team Alpha is on the wrong frequency and doesn't know it; the RO for Field Team Bravo forgot the spare battery and now his team's radio is dead; Field Team Charlie's radio only transmits at random intervals and messages seem never to get from IC to FTL Delta and back properly until the third or fourth try. Most radio problems may be solved by someone who knows just a little about radios and about radio communications. This essay is designed to teach you just that little bit, plus some useful information that is usually hard to find.

The most common problem with radio communication is related to an audio transmitter and receiver -- you. Like anything else, getting information smoothly through a radio takes some practice, but there are a few things you can do even if you don't have a radio to play with for practice. For example:

1. Keep copies of the 2 ASRC Crib Sheets in your pack. (Save the copies in this handout, because we have lots of spares for your pack.)
2. Learn the ICAO (ITU) phonetic alphabet and the standard ASRC prowords. (See sections 5.2 and 5.3)
3. Know how to communicate effectively in marginal conditions. Know how to compose a succinct message, how to repeat each phrase, and how to spell and use "figures". You will seldom need to do this, but when communications are marginal, your ability to communicate effectively will endear you to the CO. (see section 5.2) You will probably find this will help you communicate more comfortably even in the best of conditions.
4. Hold the microphone properly: keep it a couple of inches from your mouth, perhaps at an angle (to reduce breath sounds) and talk in a normal to quiet voice. A loud voice may weaken your radio's power (RF output) with a FM radio and may cause distortion with an AM or side-band (SSB) radio. (More about the types of radios later.)

Now we'll detour to consider radio in general, then return to some details about radio hardware.

You need to know about two major characteristics of radios: mode and frequency. The mode of a radio refers to the way your voice (audio frequency, "AF", or simply "audio") is encoded onto the (radio-frequency or "RF") electromagnetic radio wave carrier output. We say the RF carrier is modulated by your voice audio. The two main modes we use are frequency modulation (FM) and amplitude modulation (AM). There is also an improved version of AM known as single side-band (SSB), but you probably won't have to deal with any side-band radios. Another mode you may hear about is continuous wave (CW), where an unmodulated carrier is turned on and off via a telegraph key, to produce Morse Code. Often, we (somewhat incorrectly) use CW to refer simply to any kind of Morse Code. The only things about the different modes you need to know are:

1. FM radios have less interference problems than AM, and FM gives you more "talk power" (RF output) for a given battery life. Listen to CB Channel 19 (CB IS AM) for a good example of AM interference and noise.
2. The louder you talk into an FM radio, the louder the audio sounds at the other end, up to the point where you get distortion. But, the louder you talk, the weaker your RF output gets. The effect is slight, but may be noticeable in marginal situations. If the other guy says you're breaking up, talk softly.

The other concept is of frequency of the RF carrier. Some radios have preset frequencies called "channels"; the frequency in a particular channel depends on which crystal, or frequency reference, is plugged in for that channel. Other radios tune across their frequency bands (range) with a dial, and some use fancy electronics to allow keyboard entry of frequencies. For instance, some amateur (ham) 2-meter VHF-FM radios have microprocessors so that the radio will put frequencies into "memories"; one may then switch between memories much as one switches channels on a crystal-controlled radio. Some of these radios may scan through the memories (or through the band) if properly set.

Frequency may be measured in MegaHertz, or millions of cycles per second; the following names are applied to different bands:

15 Hz - .02 MHz	Audio Frequency (AF)
3 - 30 MHz	High Frequency (HF)
30 - 150 MHz	Low-Band, Very High Frequency (VHF)
150 - 300 MHz	High-Band, Very High Frequency (VHF)
300 - 3,000 MHz	Ultra-High Frequency (UHF)

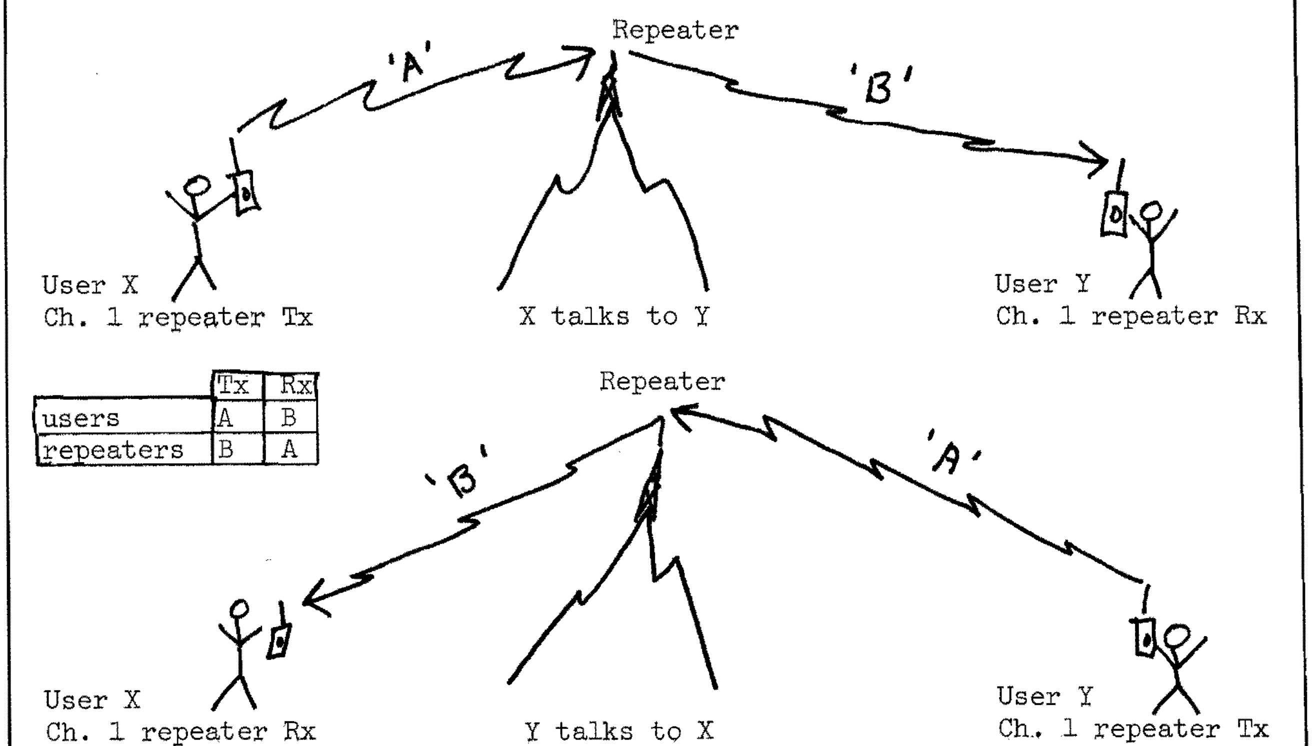
Sometimes, amateurs refer to frequency bands in terms of wavelength; wavelength is just another way of specifying frequency. For instance, the amateur VHF band 144 - 148 MHz is often called the "2-meter band." (If you'd like to convert, here are some of the radio services you might have heard of. DON'T BOTHER TO MEMORIZE ANY OF THIS!)

NAME	FREQUENCY	MODES	NOTES - useful distances
Amateur 80-meter band	1.5 - 1.8 MHz	CW & SSB	several hundred miles
Amateur 40-meter band	3.0 - 3.5 MHz	CW & SSB	" & longer (3000 mi)
Civil Air Patrol HF "4585 & 4582" etc.	approx. 4.585 MHz	SSB	" & longer (1000 mi)
Amateur 20-meter band	7.0 - 7.15 MHz	CW & SSB	long distance
Amateur 15-meter band	approx. 14 MHz	CW & SSB	long distance
CB "11-meter" band	approx. 27 MHz	AM & SSB	local, some "skip"
Amateur 10-meter band	approx. 28 MHz	CW, SSB, FM	local, some "skip"
Sheriff "Lo Band" "39-5"	approx. 39.5 MHz	FM	local
Fire Service "Lo Band"	approx. 44 MHz	FM	local
Amateur 6-meter band	approx. 50 MHz	SSB, FM	local
Aircraft VHF	100 - 130 MHz	AM	line-of-sight
Amateur 2-meter band	144 - 148 MHz	FM	line-of-sight
CAP VHF	approx. 148 MHz	FM	line-of-sight
Hi-Band VHF Public Service	150 - 170 MHz	FM	line-of-sight
ASRC/MRA	155.160 MHz	FM	line-of-sight
Amateur 70cm "220" band	220 MHz	FM	line-of-sight
"Med 1-8" UHF medical telemetry		FM	line-of-sight
Amateur UHF "450"	approx. 450 MHz	FM	line-of-sight

Note that the HF frequencies are used for long-distance communications; this is because tha HF radio waves bounce off the ionospheric layer of the atmosphere, back to the earth, and are thus propagated to far-away places. VHF and UHF, on the other hand, don't bounce off the ionosphere, and are thus limited to line-of-sight communications. The low-band VHF frequencies will bend somewhat over hills, but not as much as HF will. Hi-VHF and UHF are strictly line-of-sight, however.

You should be asking by this point "Why don't we use HF for SAR?" The answer is in several parts. First, FH handhelds are very difficult and expensive to make. Second, the frequencies are very crowded, with the long range of HF. Third, efficient antennas must be a sizeable fraction of the wavelength; for 40-meter HF, a quarter-wave whip antenna would be 10 meters (about 30 feet) long, a bit unwieldy to carry around on your handheld in the woods.

There are several important <u>advantages</u> to VHF, as well. First, VHF-FM handhelds are relatively easy to build. Second, you don't have to worry about accidentally talking to someone in California when you're trying to talk to Base Camp. Third, good antennas are easy to handle. For instance, a quarter-wave whip at 2-meters is only 18" long. Finally, the problem of talking around mountains and over long distances can be solved by the use of <u>repeater stations</u>. A repeater is a powerful rebroadcasting station, usually on a mountain or radio tower. If you can get close to line-of-sight communications with the repeater, you can talk to anyone else similarly situated, even if you are not line-of-sight with them. It works like this:



	Tx	Rx
users	A	B
repeaters	B	A

Everyone transmits on 'A' and listens on 'B'; the repeater <u>listens</u> on 'A' and <u>transmits</u> on 'B'.

<u>Fig. 1 REPEATERS</u>

A repeater listens in frequency 'A' (the <u>input</u>) and retransmits what it hears on frequency 'B' (the <u>output</u>); repeater users transmit on 'A' (the repeater input) and listen on 'B' (the repeater output).

All users have the same transmit and receive frequencies, so many users may use the same repeater. Often, the channel switch on a radio is set so that Channel 1, for example, is transmit (Tx) A/Receive (Rx) B.

Since everyone is listening on 'B', what if someone were to <u>transmit</u> on 'B', the repeater output? Everyone within line-of-sight could hear this person, if the repeater didn't cover him up; but, he wouldn't be going through the repeater. This could be handy for sensitive or local communications. Channel 1 (Tx A/Rx B) only works if everyone can get into the repeater; two people who can't get into the repeater, but are standing 100 feet apart, can't talk to each other on Channel 1 (Tx A/Rx B). If they could switch to Channel 2 (Tx B/Rx B), called simplex (because everyone transmits and receives on the same frequency), they could easily talk together. (see Fig. 3)

Channel 3 (Tx A/Rx A) is another possible simplex channel, but suffers the disadvantage that the users may 'bring up' the repeater without knowing it (why?), and thus we shouldn't work simplex on a repeater input. A final possibility is Channel 4, which transmits on B (repeater output) and receives on A (repeater input). Most mobile and handheld radios, of course, cannot receive and transmit at the same time (full duplex), but must be switched by means of the push-to-talk (PTT) or transmit switch. However, if you wanted to talk to a Field Team with a radio only having Channel 1 in an area outside of the repeater coverage area, you could switch to Channel 4. A good example of this type of system is part of the Civil Air Patrol (CAP) VHF-FM repeater net (see fig. 2).

Radio Channels

	Tx	Rx
Repeater	143.900	148.150
Simplex	148.150	148.150
Reverse	148.150	143.900

fig. 2

User Radios

	Channel	Tx	Rx
repeater	1	A	B
simplex	2	B	B
don't use	3	A	A
reverse repeater	4	B	A

Fig. 3

In public service bands, the interval between repeater inputs and outputs are not fixed, but on the amateur 2-meter band, "offsets" of 600 kHz (.6MHz) are standard. Many 2-meter radios allow one to set the receive frequency on a dial or channel switch, and provide switches for "+600, -600, simplex". On "+600" for instance, the radio automatically shifts the frequency up .6MHz when you press the PTT. The general rules for offsets are:

Rx	Offset
145.21 - 145.49	-600
146.61 - 146.995	-600
147.0 - 147.39	+600

fig. 4

Many public service frequencies are shared by several users/agencies. A particular agency doesn't want to listen to the other people on the frequency; he wants to hear only his own people. A way to do this, knows as continuous subaudible tone squelch, "CTCSS", "private line", but best known as "PL", has gained wide acceptance. With this system, a particular subaudible tone (below normal hearing range) is added into the audio of each transmitter, by an encoder. Each receiver is provided with a decoder attuned to that particular PL tone. When a signal with the proper PL tone is detected by the decoder, it turns the receiver's speaker on; if a signal without the proper PL is detected, the speaker stays off. Thus the annoyance of having to listen to everyone else on the frequency is overcome. It would be easy, however, to pick up the mike and interfere with the others you can't hear. (This is an important point: different PL tones are not the same as different frequencies.) Therefore, you should always disable the "tone squelch" or "PL decode" (by turning it off) before transmitting. This way, you will hear anyone else on the frequency, PL or not, so you will be sure to not interfere with them. Some mobile radios are provided with a mikeswitch which disables the tone squelch (if it is on) when you pick up the microphone from the mike clip. This way, if someone else is on the frequency, you'll hear them as soon as you pick up the mike.

Now, with a general understanding of how radios work, you should have fewer problems such as being on the wrong frequency or having your PL decode turned on.

Let's finish up with some practical details about handling radios on a mission. The first and most important aspect of radio use in the field is antennas. Say you have a handheld with a rubber duckie antenna on it, and you have a "Low-1W/High-4W" switch for the power output. You will stay on the low power setting most of the time to save power, as the high power setting uses about 4 times as much power. All other things being equal, going to high power gives you about twice as much 'talk power' to get back to COMCTR. (You have to increase power by 4 to increase talk power by 2.) When you got from 1W to 4W, you double your power twice (1W → 2W, 2W → 4W), and we say you increase signal strength by three decibels (3dB) each time it doubles; thus, going from 1W to 4W is a 6dB gain (3dB + 3dB). Now, it turns out that a rubber duckie is not very good as an antenna, and one of the reasons is that it sends a lot of RF energy straight up in the air, and all of this energy is wasted. It turns out that if you switch from a duckie to a quarter-wave whip ($\lambda/4$) (an 18" long piece of wire), COMCTR hears you just as if you had doubled your power; the $\lambda/4$ antenna concentrates the RF energy in the horizontal plane. So, 1W with a $\lambda/4$ whip sounds like 2W with a duckie. There are two great advantages to the $\lambda/4$ whip, however - you still actually put out only 1W of power, thus saving your batteries; it also turns out that you hear COMCTR as if they had increased their power by two! A 1/4 wave whip gives you 3dB gain both transmit and receive, without increasing battery drain. It gets even better - if you use a 5/8 wave whip (48" of wire plus a loading coil at the bottom) you signal is even more directional, and you get 6dB (both Tx and Rx) over a duckie! So low power with a 5/8 wave whip is the same 'talk power' as high power with a duckie, plus 6dB of gain on receive. Ther is also a "flexible J-pole" antenna available which is midway between the 1/4 wave and 5/8 wave antennas in performance, is made of flexible wire, and stuffs easily in a pocket. So if you want to carry something to make your team's radio work better, grab a couple of extra antennas.

Just a few more things about antennas. Now that you know that antennas are directional in the horizontal plane, you know to hold your antenna straight up and down (unless you're talking to an airplane overhead). Also, antennas on handhelds work best with a ground plane underneath; that's why a 1/4 wave antenna on a car roof works better than one held in your hand. The handheld and your body provide a ground plane, but not a very good one. Setting the radio on a metallic object like a car roof might improve your antenna's performance. And, since VHF is almost line-of-sight only, a few feet of additional elevation may make a world of difference. Since even the wavelength of VHF (2-meters) is comparable in size to bridge struts, trees, boulders, and human bodies, many reflections may superimpose to produce "dead" spots or good spots. A few seconds experimentation with moving your antenna this way or that may easily make a 10dB difference in communications.

The two radio controls you will fiddle with most often, volume and squelch, deserve some quick comments, even though you probably know how to use them. The volume control knob controls the audio amplifier feeding the speaker, but nothing else. By changing the volume setting, you change the loudness of the sound issuing from the speaker, but the radio receiving qualities of the radio are unaffected. During transmit (when you depress the PTT switch), the volume setting has no effect whatsoever on the radio. The loudness of your outgoing signal is affected only by the loudness of your voice and how you hold the microphone. The transmit "volume" control is on the circuit board inside the radio. It is set when the radio is serviced, and is almost impossible to adjust in the field without really screwing up the radio.

The squelch control is similar to the volume control in that it affects the sound issuing from the speaker, but otherwise does not influence the operation of the radio circuitry. The squelch circuit turns the speaker off; it will then turn the speaker back on only under certain conditions. For instance, the PL decoder "tone squelch" explained earlier will turn the speaker back on only when it hears the proper PL subaudible tone. The standard squelch on most radios, known as carrier squelch, turns the speaker back on only when it hears a strong enough signal. How strong is "strong enough"? You set that by turning the squelch control knob. The next time you have a chance to play with an ASRC or Ham 2 meter radio, do the following:

1. Turn the squelch all the way down (counterclockwise on most radios). You should hear white noise from the speaker; this is normal background noise. At this squelch setting, even background noise is "strong enough" to cause the squelch circuit to turn the speaker on. The squelch is now off even though the speaker is on, because the squelch is not interfering with the radio by turning the speaker off.
2. Have someone with another radio give you a test transmission, just carrier with no audio modulation. Note the way the background noise disappears when your radio picks up the carrier; this is quieting, and you can tell the other station he's "full quieting" at your location, because his signal is blocking out all the background noise.
3. You can probably appreciate that listening to the background noise all the time you're waiting to get a call could be a pain in the ear, and that is the main reason for having the squelch control. Turn up the squelch level to where the background noise just disappears; you have just told the squelch circuit that an incoming signal has to be slightly stronger than the background noise level before it should turn on the speaker. This is where you should normally set the squelch.

There are two things regarding the squelch which are perhaps obvious, but bear repeating. If you turn the squelch all the way up, you will probably miss a lot of communications from weaker stations. Also, if you have the squelch set at the normal level and you still have trouble copying a station, sometimes it helps to turn the squelch all the way down for a minute. Turn the volume down first to avoid being blasted by the background noise.

I hope this hasn't been too tedious, and that some of this may be of use to you on a mission some day.