Chelsea Yaesu DR-2X Repeater Setup (Desensitized)

Wesley Cardone, N8QM

July 3, 2022

Desensitized

This is the "desensitized" version of the WD8IEL repeater programming. It has been scrubbed of any secure remote control information of a secure nature. The WD8IEL repeater may or may not be configured for remote control. That information is held within the repeater administration.

Security of Remote Commands

The Yaesu DR-2X repeater has two modes of operation: Analog FM (DTMF); and Digital (C4FM). Remote commands may be given the repeater over the air via either of these two modes. However, there are distinctions between them.

DIGITAL:

The digital mode of operation offers bulletproof security in that any remote commands can only come from transceivers registered with the repeater.

At the factory, each C4FM transmitter is given a unique digital key which it, and only it, possesses in all the world. Any one Yaesu C4FM transmitter can be registered (up to 30 per repeater) with any one DR-2X repeater. This means that bullet-proof security exists in protecting the repeater from malicious threats.

In addition to this security, operating in the C4FM mode includes all of the security belonging to remote programming in Analog FM mode, described below.

ANALOG FM:

The DR-2X repeater may be programmed to operate in either a single-channel or dual-channel mode. The Chelsea WD8IEL repeater is being operated in the single-channel mode which makes the repeater's second channel available for dedicated remote programming. That is, remote programming coming to the repeater over the air does not need to share the FCC designated repeater frequency assignment of 145.450 MHz. Any FCC amateur allocated frequency may be used for remote programming from whether the 2 meters band (144-148 MHz) or the 70 cm (420-450 MHz) band.

As an additional layer of protection, the repeater will only receive on that second frequency and cannot send. Someone trying all the frequencies would have no means of feedback from the repeater to indicate success. There are some remote functions which cause an output on the actual repeater assigned frequency but there would be very much labor in a brute-force approach to finding the command frequency.

To add additional complexity to a brute-force approach, there are 64 different PL tones that would have to be worked through with each frequency. In the paragraph above it was stated that there would be "very much labor." Adding 64 PL tones would make the labor prohibitive even for a youngster working from his parent's basement.

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What the person attempting to crack the repeater would need to radically reduce the labor would be a known <u>time</u> when remote programming was being sent over the air. If the prankster knew a precise time when codes were to be sent to the repeater, he could be scanning both 2 meters and 70 cm for any activity. With a little luck he might light on the code transmission frequency value. Once he knows the exact frequency used, he would then need to make sure he had identified the PL tone which is doable but laborious.

Assuming anyone globally (but within range of the repeater) had obtained the exact B-channel repeater frequency and PL tone, he would then have as much control over the repeater as we do.

There is one additional layer of encryption that can be added. All of the remote commands have factory assigned 4-digit integer codes. For example, the code to switch the repeater output power to MID is 0020. All of these values are user definable. We could assign our own random numbers to each command. The prankster would then need those codes to do anything.

PASSWORD:

At power application or after the display has timed out from programming inactivity, the display goes blank, and a password is needed. This password does not enable operation of the repeater but merely grants access for programming. Without this password the repeater cannot be programmed without first restoring all of the factory settings. This password cannot be deleted, only changed. The factory default password for the DR-2X is: 0000. It is not disclosed in the "desensitized" version of this document whether or not the factory default password has been changed.

Introduction

In this presentation we will start with a Yaesu DR-2X Fusion repeater (shown below) that may or may not have some programming written into it. We are going to set it up to fulfill its role as an amateur radio 2 meter VHF repeater which is Fusion capable. The repeater shall operate in a single-channel mode using an uplink frequency of 144.850 MHz and a downlink frequency of 145.450 MHz. Transmit power shall be set to MEDIUM. The FCC assigned station call sign is WD8IEL.
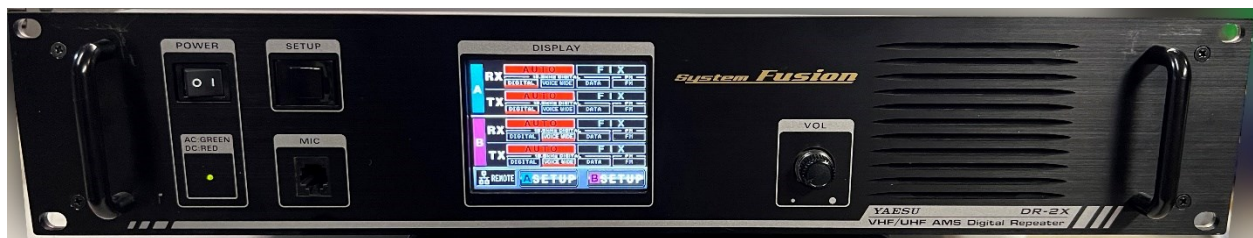

Figure 1 This is the front-face of the Yaesu DR-2X repeater.

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Program for ID and UP/Downlink Frequencies

With power application we have the screen showing as above in Figure 1.

Our first task will be to check on the call sign entry. Upon power application the home screen (Figure 2) is shown. We press the [**A SETUP**] button showing the screen illustrated in Figure 3.

We can see that the repeater is already properly programmed for the correct up and downlink frequencies.

We then touch the [**F**] button showing the next screen (Figure 5). On that next screen we touch the [**ID SET**] button revealing the screen shown in Figure 4. We can see that the FCC assigned station call sign WD8IEL is already properly programmed so we press the [**BACK**] button three times to move to the home screen.

It should also be noted in passing that the repeater firmware versions are shown on the Figure 3 screen. Here we see that the installed firmware (as of June 26, 20022) of RX1.51 and DSP version 5.02. [The latest versions of that same date available from Yaseu](#) are Main 1.58 and DSP 5.03.

Figure 3 Correct up and downlink frequencies have been s Figure 2 This is the "home" screen which appears at l power application.

A firmware update is required when it is convenient to accomplish. In order to install a firmware update an update cable will be required from Yaesu.
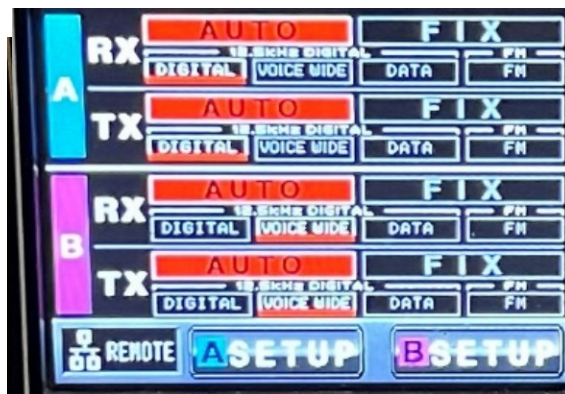

Figure 4 This is where you can set the actual station ID assigned by the FCC.

Figure 5 Display having pressed the F button from the A-Channel display.

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Program for Single-Channel Operation

The next step is to program for our single-channel mode of operation. There is also an option for remote control that we will program for future use. We will get to that in a few pages.

For single-channel use the frequencies for the B-channel are irrelevant and may be set to anything. However, in order to exercise a remote control option at a later date, we will set the B-channel UPLINK frequency to an unpublished frequency within the 2 meter amateur frequency allocation. This will serve as a control frequency, later in this document to be programmed. An acceptable transceiver (Yaesu FTM-400D, FTM-100D and FTM-3200D) can be registered with the repeater. From the time of registration, that transceiver becomes unique in all the world and the repeater will listen to it for remote instructions and programming. The repeater is capable of registering up to 30 conforming transceivers for control purposes. In order to remotely control the repeater, one would need to be using a transceiver that has been previously registered with the repeater and would need to know the uploading frequency. The frequency will not be disclosed in this document.

At this point we need to let the repeater know what purpose the B-channel set is to serve. This is done from the home screen. Please see Figure 2 to know what the home screen looks like.

From the home screen, tell the repeater that the B-channel is to act as a remote control function receiving instructions by RF from a registered transceiver. With the home screen showing as illustrated in Figure 2, touch the violet area for the B channel set and the display will change to replace the thin white line separating the RX above the TX as shown in Figure 6.

Touch that same violate area a *second time* and the display will change as shown in Figure 7. The repeater now knows that the B-Channel is to be used as a control function and will have no capability to transmit on a B-Channel frequency. It will only listen on the B-Channel.

Set the B-Channel Listening Frequency

With the home screen showing as illustrated in Figure 7, touch B-SETUP at the bottom of the screen. The repeater screen now shows as illustrated in Figure 8.
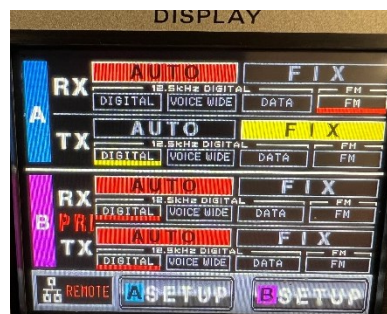

Figure 6 Home screen as it appears after having touched the violate B-channel area once. The PRI text replaces the thin white line that had separated the RX and TX text.
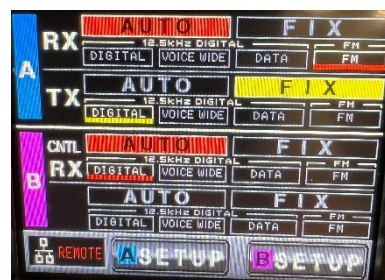

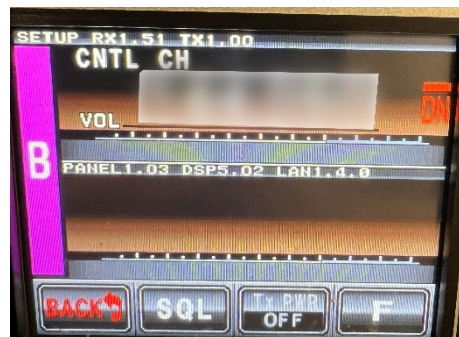*Figure 7 Home screen now shows that the B-Channel is to be used as a control function.*

Figure 8 The screen shown represents the B-Channel uplink frequency. The frequency itself has been blurred out for security reasons.

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Touch the area that is shown in Figure 8 as blurred out in this illustration for security reasons. This will cause the repeater to display the screen shown in Figure 9. Using the touchpad shown, enter the frequency. Upon entry of the final figure the repeater will enter the number and go back to the screen shown in Figure 8.

Press the red [**BACK**] button once to return to the home screen. It should look like that shown in Figure 7. There may be some minor differences owing to the fact that when doing this programming, the repeater had already been programmed.

Figure 9 This screen allows the uplink frequency for the B-Channel to be set.

Program Signaling

First we will check for the sub-audible tones. We are registered with the Michigan coordination group to use 100 Hz tones.

From the home screen touch [**A SETUP**] then [**F**] and then [**SIGNALING**]. In the illustration shown in Figure 10, the sub-audible tones have already been set. This is pretty much intuitive so set them here as shown if not already so set. Press [**BACK**] taking us to the uplink screen.

Figure 10 Programming of the sub-audible or PL tones.

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The Squelch

Next we want to look at the squelch. First notice from the uplink illustration of Figure 11, that both receive and transmit tones are turned off (R-OFF and T-OFF) which is NOT correct. One of the major benefits from using a PL tone is that atmospheric or other electromagnetic media that occurs in nature will not activate the repeater. It is also a guard against other repeaters in the distant region that might otherwise activate the repeater needlessly.

Figure 11 Setting the squelch.

Touch the [**SQL**] button which causes the repeater to show the screen illustrated in Figure 12. It is now shown that RX and TX squelch tones are off. Touch both RX and TX SQL one at a time until each shows "TONE."

Press [**BACK**] once to return to the uplink screen illustrated in Figure 13. Notice now that the Squelch button looks different reflecting the fact that the repeater is now programmed to utilize the tones in squelch functionality.

Press the [**BACK**] button two times to return to the home screen.

Do the same programming for the B-Channel which will be used exclusively for remote control on a special frequency.

July 3, 2022 EDIT:

Figure 12 Here is where the repeater may be told that it is to use sub-audio tones. The frequencies of the tones themselves may or may not have been already set. Those are separate functions.

Not shown is the menu that appears when TIMER (see Figure 11) is pressed revealing the squelch hysteresis. There are three settings available—NORMAL, HIGH, and MAX. On our first deployment of June 27th, the setting was left at its default NORMAL. It was found that this setting was not sufficient. Apparently, the NORMAL setting means that there is NO hysteresis. After consultation with other repeater managers it was decided to change this setting to MAX. However, it did not get changed and remains unknown as to its beneficial effect.

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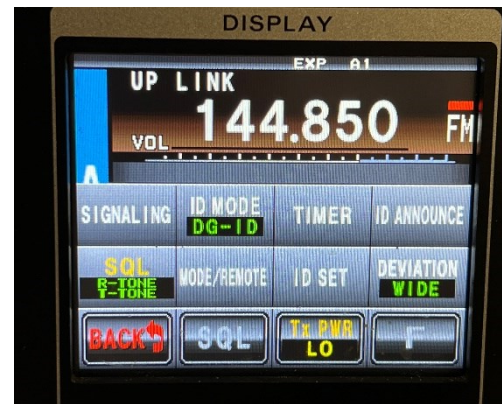
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Figure 13 The repeater now knows that it is to implement sub-audible tones. The exact audio frequencies may or may not yet have been set. That is a separate operation.

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Program Announcements

From the home screen press [**A-SETUP**] and then [**F**]. Then press [**ID ANNOUNCE**]. The screen illustrated in Figure 14 appears.

The FCC requires station identification every ten minutes. This can be accomplished in a variety of ways. For the time being we are programming the repeater to output its station identification (WD8IEL) by means of CW tones. It would be nice to have a voice announcement but I have not figured that out yet. CW tones will work and are warmly accepted by the amateur community so we will go with that mode for now.

Figure 14 This is the announcements screen where the station ID credentials are periodically transmitted.

Touch the [**ANNOUNCE**] button. The screen illustrated in Figure 15 is displayed. The screen you see may differ slightly from what is shown. What is shown is that the repeater will transmit its station ID in a CW mode without the use of sub-audible tones. Discarding the use of sub-audible tones is important because that way, anyone tuned to the repeaters downlink frequency (145.450 MHz) will hear the tones. If we were to program the repeater to use its sub-audible tone, then depending on any one transceiver's programming, they may or may not hear the station ID.

Figure 15 Here is where the mode of station identification is defined.

It was also considered a best choice for a low announcement level and a relatively fast CW speed. Nobody is interested in learning CW from listening to station IDs but most amateurs would like it if the station ID could be done pretty quickly.

Press [**BACK**] four times to arrive at the home screen.

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Adjusting the Squelch Level

From the home screen touch [**A SETUP**] but NOT F. Instead of pressing F, press the [**SQL**] button which is a grey tone taking you to the screen illustrated in Figure 16. From this screen press [**SQL**] showing at the bottom of the screen.

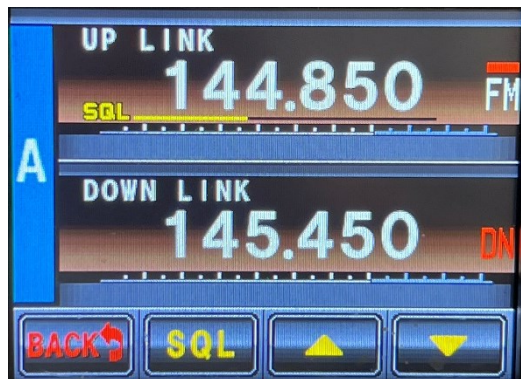Setting the squelch is somewhat intuitive at this point.

Figure 16 From the home screen we arrive at the SQL page from a simple press of A SETUP.

Setting the DG-ID Number

The DG-ID number is only used for having groups that have exclusive use of the repeater. We can ignore this part of the repeater programming. For reference, the repeater DG-ID number will be set to 00 which opens it up for all amateurs to use.

However, we do want to register individual transceivers that will then be capable of programming the repeater remotely over the air. This is a specialized task that is too complicated to take up space here presenting. But it's not hard to do.

Setting the Remote Control

Remote control of the DR-2X repeater is only possible with one of six Yaesu transceivers (as of October 2020).

1. FTM-100D
2. FTM-400XD/D
3. FTM-300D
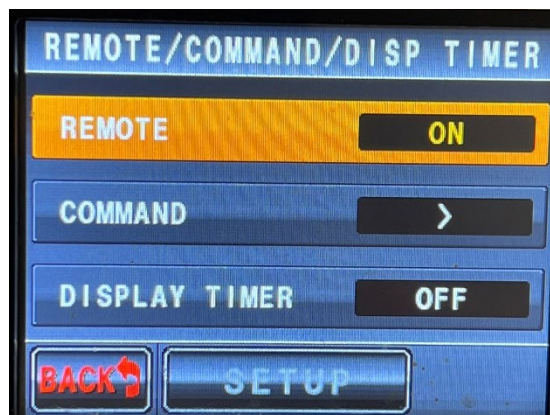4. FTM-7250D
5. FTM-3207D
6. FTM-3200D

Remote control is possible via analog FM but this is less secure. Therefore, we will only establish remote control via C4FM. Also, remote control by analog requires the optional FVS-2 card which the repeater DOES NOT HAVE.

Figure 17 First screen in setting remote control.

Remote control also requires the optional LAN-01A card installed in the repeater which has been done.

First, we will tell the repeater that remote control via a digital mode (C4FM) is enabled. Press [**A SETUP**] and then [**F**] and then [**MODE/REMOTE**]. This display as illustrated in Figure 17 is shown. If in your case the

Figure 18 Second step in remote control setup.

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REMOTE option does not show ON, then touch REMOTE until it does.

Touch [**COMMAND**] twice. The display will show as illustrated in Figure 18. If in your case the CONTROL MODE does not show as DIGITAL, touch CONTROL MODE until it does. Touch [**BACK**] four times to return to the home screen.

Here is a list of the applicable remote control command functions that are available. There are others but they are not applicable for what we have programmed the repeater for.

1. ACTIVATE - Repeater becomes active
2. DEACTIVATE (LOCAL) - Repeater is effectively shut off
3. DEACTIVATE (ALL) - This is like #2 but intended for linked repeaters.
4. FIX DIGITAL - Repeater ONLY operates in C4FM mode.
5. AUTO - Repeater automatically changes mode to meet conditions.
6. HIGH TX POWER
7. MID TX POWER
8. LOW TX POWER
9. REC MESSAGE - A message can be recorded that will play periodically over the repeater.
10. PLAY MESSAGE - Play a recorded message
11. CLEAR MESSAGE - Clear a recorded message

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Final Configuration Showing on the Front Face

The final configuration sets the repeater up in a quasi-digital mode. That is, it receives both analog FM and C4FM. However, it ONLY transmits by means of Analog FM. The B-channel is reserved for control only. It will listen to its assigned frequency for the purpose of command receipt. It cannot transmit on this frequency. The frequency itself, nor its PL tone, is not named in this document.

Figure 19 This is how the front face of the repeater shows when programmed with the final configuration.

The advantage of a quasi-digital mode of operation is that this is the most friendly and transparent to all amateur radio operators operating on 2-meters. No one at any time will hear digital noise where a voice would be expected.

The repeater will at all times listen for both analog FM and digital C4FM. When it repeats an incoming analog FM signal, it will simply repeat it in analog FM on the transmission output. However, when it receives an incoming C4FM digital signal it will translate it into analog FM and repeat that analog FM duplication. The repeater output will be exclusively analog FM so that no amateur stations tuned to the repeater frequency will hear a data stream signal.

The advantage of this quasi-digital mode is that the magnificent clarity of digital will appear at the repeater input. It will be free of bacon. The repeater will first transform the incoming digital signal to analog FM and then put it on the output as analog FM. It goes without saying that the disadvantage is that the magnificent quality of audio at least starts out on the output with magnificent clarity but will pick up bacon as the distance to receiving station increases.

For the A-channel we see an AMS (automatic) mode selected indicating that the repeater will automatically recognize incoming (RX) C4FM or analog FM signals. On the transmit side (TX) a FIX mode is selected. As the name suggests, there is no automatic selection. The output mode of transmission is fixed, in this case, for analog FM.

For the B-channel we have something that may possibly not be readily recognized by many. The B-channel is set up to receive ONLY. It cannot transmit. Its uplink frequency will not be published for security reasons. The uplink frequency can be any frequency within the FCC allocation for both 2-meters and 70-cm that is not otherwise assigned for specific use such as other repeaters. The uplink signal may or may not have a PL tone defined for it.
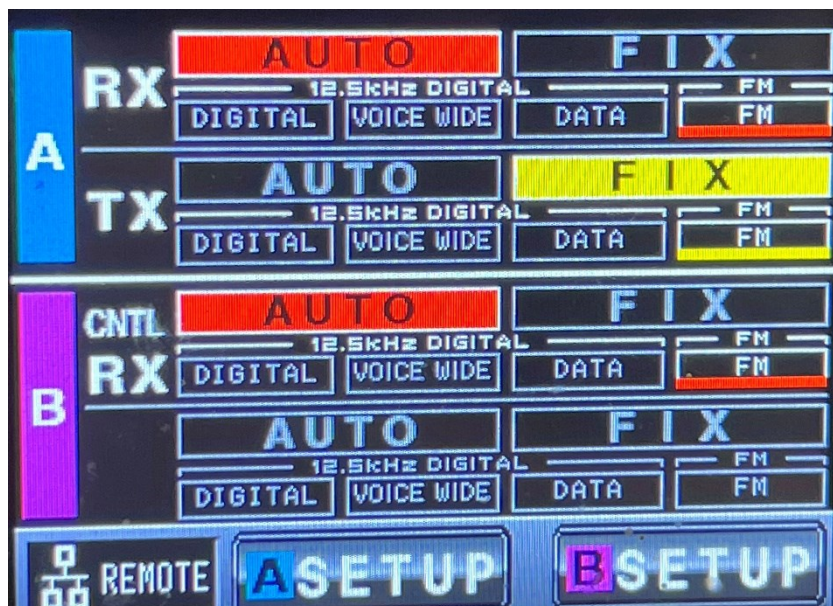
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Testing and Scheduling Procedure

The repeater has been programmed to receive and automatically determine the nature of the received signal. The received signal can be

1. Analog FM
2. C4FM Fusion digital

Further, there are transceivers that are bi-modal such as several Yaesu C4FM capable transmitters. It is necessary to verify that such C4FM radios will operate properly when set to:

1. FM only
2. Auto detect FM vs C4FM
3. C4FM only

The mode dichotomy together with transmitter options therefore defines a large number of permutations. Not all of the permutations need to be tested. I have listed below the permutations that are likely to be relevant. We will substitute the Yaesu DR-2X for the Hamtronics at Don's house and perform the following testing.

1.	non Yaesu (Analog FM)	--	non Yaesu (Analog FM)
2.		--	C4FM enabled
3.		--	C4FM capable but set to Analog FM
4.	C4FM enabled	--	non Yaesu (Analog FM)
5.		--	C4FM enabled
6.		--	C4FM capable but set to Analog FM
7.	C4FM capable but set to Analog FM	--	non Yaesu (Analog FM)
8.		--	C4FM enabled
9.		--	C4FM capable but set to Analog FM
10.	Wes' registered Remote control[1]	--	Change power out and back again
11.		--	Record a message (not yet implemented)
12.	Jim's registered Remote control	--	Change power out and back again
13.		--	Record a message (not yet implemented)

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[1] Remote control is accomplished only using (a) transceiver(s) previously registered with the repeater. The present plan is to register Jim's and Wes' Yaesu FTM-3200D transceivers with the repeater. The WD8IEL implementation adds a double layer of security using an unpublished control frequency that must be used to transmit the commands. In both transceivers, a memory location will be added where the correct frequency, modulation mode, and sub-audible tones will reside. This facilitates an easy and quick way for both Jim and Wes to send remote commands to the repeater. Only those person's having a need to know will have the frequency.

14. The water tower
    a. Schedule a visit to the water tower to install the repeater there.
    b. Ask if it will be possible for us to make a vector impedance measurement of the antenna at its input at the top of the water tower.
    c. Inform the water tower that we would like to have three (3) visits in the immediate future.
        i. Visit 1
            1. To install the repeater
            2. To make vector impedance measurements of the antenna input at the water tower top if permitted. This measurement will be used by Wes to design a tuning stub to optimize the repeater output.
        ii. Visit #2
            1. To install a tuning stub
        iii. Visit #3 (optional if needed)
            1. To remove or make changes to the tuning stub.
15. Perform varied testing for learning purposes while we wait for water tower installation
    a. Get some metrics over the next few days on the difference between
        i. Power out:
            1. LOW,
            2. MEDIUM, and
            3. HIGH power output.
        ii. Squelch
            1. RX and TX Squelch options
        iii. Other things not thought of earlier.
    b. Make some decisions on refinement of repeater programming that are not available for change by remote.
16. Visit #1 at the water tower with equipment
    a. Install the repeater at the water tower
    b. Make vector impedance measurements of the water tower antenna.
        i. At coax connector at water tower base
        ii. At antenna input on top of the water tower if permitted.
        iii. These measurements will be used to design a tuning stub for the antenna.
    c. Confirm that the repeater works as programmed.
    d. Confirm with the water tower person that we plan these visits in the next couple of weeks as requested earlier.
    e. Assure the water tower person that our intent is to minimize our visits to their facility.
17. Visit #2 at the water tower
    a. Install the tuning stub
18. Visit #3 at the water tower (may or may not be needed)