FT8 – Avoiding Harmonics and Audio Settings

By Mike Black/W9MDB and Eric Spero/WA1SXK

Changes

Apr 4, 2024

- Just some format changes

Jan 25, 2023

- Update WSJT-X website

Dec 3, 2022

- Change minimum audio level to 70db for WSJTX and 80dB for JTDX
- Add setting AGC to slow
- Add notes for FTDX10

Dec 18, 2021

- added note for 40dB minimum signal strength with JTDX since it uses peak power instead of RMS.

The FT8 sound card mode is an MFSK mode with redundancy and error checking. If you have been hearing about this new mode or have been using it, this article can aid you to set up and operate the FT8 data mode with good clean signals. FT8 allows you to view and decode dozens of signals at once with the waterfall display. This means your audio setup and bandpass settings will be of utmost importance while operating the FT8 sound card mode. The settings in this article also work for other digital software (FLDigi, MMTTY, CWSkimmer, etc.) but the other software will have to adjust their sensitivity levels for a lower audio signal than most people use. The settings in here maximize the dynamic range instead of what your ear hears. For example, Eric and I use FLDigi and WSJT-X interchangeably without changing any audio settings. For CW or phone, you will likely have to adjust rig levels for your ears.

FT8 is an immensely popular sound card mode thanks to the WSJT-X team's efforts. See http://physics.princeton.edu/pulsar/K1JT/wsjtx.html for the software and check out the references for lots of details. A sound card mode is what you might call a poor-person's SDR (since the software is free you can be poor to enjoy it). All the FT8 relevant modulation/demodulation/bit-correction/error-checking is taking place in the WSJT-X software. During this process, your FT8 messages (exchanges) are being encoded with additional information that allows for error detection and bit corruption correction which the receiving side can use to process and validate the received message. The WSJT-X software sound card modes can be used with any rig, new or old. FT8 can demodulate dozens of signals (50hz wide each) in up to 5000Hz of bandpass including overlapping signals. As you can see, many hams can operate at the same time in the same bandwidth. This approach allows new operating paradigms like FT8 Fox&Hound mode that DXCC teams are now using where they can process multiple QSOs simultaneously (see FT8_DXpedition_Mode.pdf).

One of the areas that seems to be misunderstood while operating FT8 is the how the radio's bandpass settings affect the operations of this mode. Many of the hams who operate some of the other modes like SSB and CW, use the default bandpass settings in their rig which are frequently too narrow for FT8. Note that most rigs can set the overall bandpass and not separate the Rx/Tx bandpass. Your rig's bandpass is hopefully at least 200Hz-2400Hz and preferably 200Hz-3000Hz since there are quite a few operators who transmit above 2500 (see Figure 1 with 200Hz-3000Hz).   You can view your bandpass in the WSJT-X waterfall by turning off "Flatten", below that change the pulldown to "Current" and set "N Avg" to 3 or less and "Start 0 Hz" so we can see the changes more easily. What you should see is something like Figure 3, where you have a noise level signal rolling-off at lower and upper ends of the bandpass.

You should adjust the Bins/Pixel and window width, so you can see your entire FT8 signal bandwidth. Then you need to learn your bandwidth controls in your rig, so you can maximize both the low end and high-end cutoff points. Once you have your bandwidth set in your rig as wide as you can make it you can change the "Start 0 Hz" to "Start 200 Hz".   Then adjust the right side of graph until it is inside your upper bandwidth limit. Then turn on "Flatten". Note that Flatten does not like having the edges of your bandpass in the waterfall and will not behave as well if you adjust this incorrectly. The signal bandpass area between the lower and upper limits of the waterfall window is where the FT8 signals will be displayed and decoded in the software. The frequency limits of the waterfall determine what gets decoded.

Remember your goal for FT8 is to adjust your rig for as much TX/RX bandwidth as possible…you can run it up to 5kHz for WSJT-X (as much as WSJT-X can do right now). Most rigs should do at least 2400Hz. Many rigs have bandwidth settings called NAR/MID/WID filters and the WID settings should always be used and it can usually be adjusted for the largest bandwidth. If you can't find your rig's bandwidth settings after consulting with your manual feel free to contact one of the authors.

Once you have your bandwidth set correctly you are now ready to set up your receive signal's path:

#1 Open the sound control panel on your computer, right-click your rig sound device, select Properties, and set the Level of your sound card Playback device (and Recording device) to 0dB. You can get to the sound control panel in Windows 10 by right clicking the speaker icon and select "Open Sound Settings" and find the "Sound Control Panel" entry and your audio is probably called "USB Audio CODEC". Right click the device for your rig and select "Properties". Select the Level tab and right-click in the level slider to set the scale to dB instead of the default percentage.

#2 In the Advanced tab set your sample rate to 48kHz 16-bit. Also, ensure all enhancements or spatial sound effects are turned OFF. In WSJT-X set your Input and Output sound device to the left channel. If you do not see decoding, try the right channel. Same goes for transmitting. You may have to use Mono but single-channel operation is preferred if it works.

#3 As of the WSTJ-X 2.1.0 64-bit version the Windows Mixer is also in the audio chain. Search for "Mixer" and open the "Sound mixer options". Select your output audio device for the rig and set the device level to 100% and, with WSJT-X running, set WSJT-X to 100%.

#4 You are now ready to adjust the level in the WSJT-X meter to around 70dB (80dB for JTDX since it shows peak power instead of RMS) on a quiet spot. You should set your AGC to slow. You can adjust

your external sound card knobs if you are using one, and your rigs output level to achieve this. Do NOT make this adjustment using sound controls on the computer…in most cases that is not necessary.   The meter in WSJT-X should look something like Figure 4. Again, note this is on a quiet spot on the band with no signals present.

Now let's talk about your transmit signal path…

 A rig that has too much input audio will create a dirty tx signal with significant harmonics that can disrupt a QSO and everybody can see on the waterfall…. but…here is the problem…you won't know about it unless you can monitor your own transmitted signal. Any harmonics will show up at multiples of your Tx offset setting in the WSJT-X waterfall of everybody that receives your signal. For example, you can clearly see the noise bars at around 2480 in Figure 1 which is the 3rd harmonic of the signal at 829. In Figure 2 you can see an extreme example with multiple harmonics. Running WSJT-X's optional rig split mode or fake it mode will prevent harmonics from showing up in your transmitted signal since harmonics will show up above 3000Hz which is normally outside the transmit passband. But it's better not to generate them in the first place as your signal also gets affect by the clipping. ALC (Automatic Level Control) is one indicator of clipping and is an easy, roundabout way to know if you are clipping your signal. Another way is to ensure that dB level controls in WSJT-X and your soundcard behave as they should.

To set your transmit levels use the procedure below. This procedure is designed to ensure your signal is just enough to drive the rig without any ALC taking place. Please note that ALC is not the cause of any harmonics but is the canary-in-the-coal-mine telling you that your levels are unnecessarily high. You MUST understand what your ALC meter is telling you and where "no ALC" is shown. You can look at the rig settings in Table 1 to see if your rig is in there or if your rig is similar as models tend to behave the same for the same manufacturers.

Things you need to know to do this procedure:

- How much power your rig can transmit for FT8. Many rigs cannot use full power for this type of mode and some rigs can't even do their rated power on a constant envelope signal without hitting the ALC.
- How to read and understand your rig's ALC meter. Anything above 0dB ALC (i.e. 0dB attenuation) is potentially bad for some rigs and FT8/digital modes (see exceptions in Table 1). The question is, how does your rig show 0dB ALC? For most older rigs 0dB is the left-hand side of the meter or just a red-light indicator when ALC is in effect. On newer SDR rigs you do want to see some ALC action as 0dB is not the left-hand side of the meter…read your manual. The procedure below will help you confirm how your meter behaves.
- How to set the rig output power level
- How to set rig audio input level (RAIL) – this is the audio level that the rig sees from the computer or the external sound card. We will also be adjusting any external sound card like a SoundBlaster or SignaLink (if you have one) and the RAIL together.   To start make your rig's audio level (MIC control or menu control for USB input audio level) zero. Many (most?) rigs want minimum gain at the rig as we will be feeding full-level audio to it.

#1 Use a dummy load and set your rig power level to the maximum it can do for CW mode (look at the rig specs – could be anywhere from 30-100% of full power). We just need to ensure we have enough "room" in the rig setting so that we can feed a signal and not be any more than 50% of the rig's power setting.

#2 Set WSJT-X to full power on the Pwr slider

#3 Confirm your sound card playback device is 0dB and 1-channel 48kHz sample rate. Recording should be the same 0dB, 1-channel 48kHz. Set WSJT-X to one channel (usually the left channel). Also ensure your sound card audio playback is NOT the default device. If you make it the default then all your windows sounds (beeps, YouTube, etc.) will playback through your rig. You need to right-click another audio device (like your real speakers) and select it as the default. If you have to use the line out or speaker out from your computer, you should listen to the audio and may have to reduce the playback level to avoid distortion from the computer.

#4 Set your RAIL to minimum and your playback/outgoing/transmit sound card to minimum.

#5 Set the TX offset to 1500 – we want to ensure the tone we generate is in this "sweet spot".

#6 Press "Tune" on WSJT-X -- at this point you should have no power being transmitted. If you see power, go check your settings again.

#7 Set your external audio device (if you have one) to about 50% or 12 o'clock. This should be a moderate output level from most any external soundcard.

#8 Increase RAIL SLOWLY until you get about 20W (assuming your rig is set at 100W or use 20-50% of whatever your rig power setting is). Whatever your ALC meter says at that point is probably what you want and is below 0dB. On most rigs the ALC meter won't even move or barely move. If your ALC is more than minimal at this setting, then you probably have an Elecraft K3 which wants 4 bars + tickling the 5th bar to operate at capacity. It's important you understand what your ALC meter is telling you. You do not want any ALC on an FT8 signal (or any other digital signal).

#9 Bring up RAIL until ALC starts increasing, then decrease gain back to where it was. For the K3 and such you should be able to put out max power without exceeding the K3's 4bars+5th.   Some rigs are very touchy and finding the right combination of rig gain and audio device gain takes some experimentation. We've found several rigs where mic gain is just above zero to give no ALC indication.

#10 Sanity check – the Pwr slider on WSJT-X should show 50% power loss for every 3dB down. So, if you are 100W at full scale (0dB on the Pwr slider) then -3db should be 50W and -6dB should be 25W (linear behavior). If your power does not decrease close to that (give or take 10%), then your audio is still wrong. You could be overdriving the A/D in your rig which may also clip your signal. An example is the FT-450D which has a 60mV input with a SignaLink that provides up to 100mV. If you put over 60mV into the FT-450D your signal will clip. The Pwr slider in WSJT-X is an indicator when this is occurring since dropping from 100mV to 80mV won't matter to the rig and the -3dB Pwr slider setting will still show 100W. Another example is the IC-7300 – the USB MOD LEVEL of 23 may be too high and lowering it to 22 or 21 may be needed to see 50W at -3db and 100W at 0dB.

#11 Repeat step 10 for the lower and upper limits of what you believe is your bandpass. You should see the same power level behavior for your entire bandpass. If you see the maximum power level reduce at any point, then your bandpass or notch filters may be the reason…double check them. If you run WSJT-X in either "Rig Split" or "Fake It" (in Settings/Radio) than your audio will always be 1500-2000Hz and actually allow you to work signals beyond your bandwidth (i.e. if you can decode them, you can work them).

You should now be seeing maybe 80-100% of your rig's power level (depending on rig) with no ALC being tickled (or the 4bars+ as explained above). That's how you want to operate FT8 to ensure a clean signal. You can leave your rig power level at the maximum and adjust your transmitted power from WSJT-X (except for the K3 where you should adjust on the rig only due to the K3's power hunting feature) and your signal will always be clean. Changing rig power on the rig or audio levels in the rig or sound card that you have already set may end up triggering the ALC again so be vigilant that the ALC is always where it should be.

Hope to see you on the bands with a clean FT8 signal!

Notes:

- The Playback device in Windows should have no "green checks" on it. You can right-click another playback device and click the two "Default" settings.
- Windows updates can and will change your audio devices and levels and need to be rechecked after every update.
- On all rigs if you do not get 50% power at -3dB then you are not in the linear range of your rig settings. Normally lowering the gain at the rig will fix this.
- For most rigs set the audio input device to the left channel and the output to the left channel too.
- IC-7300 – set the Input device to the left channel and the output to Mono. It seems the IC-7300 won't operate on just the left channel.
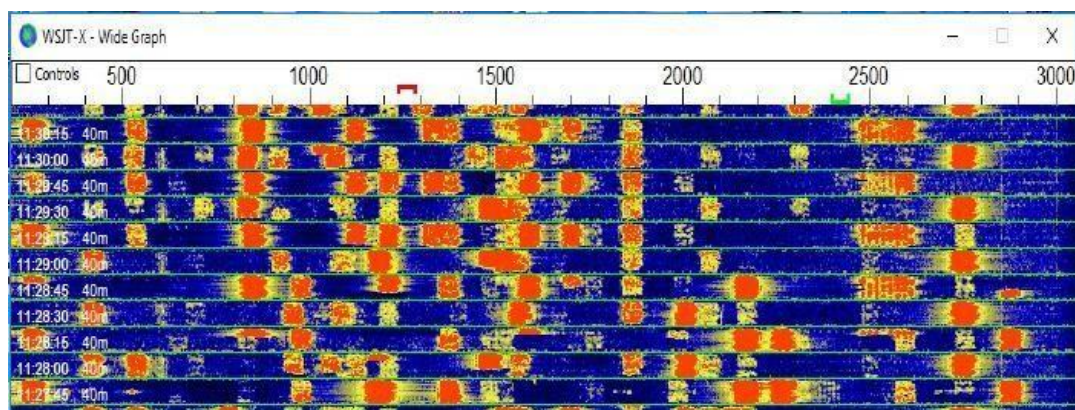
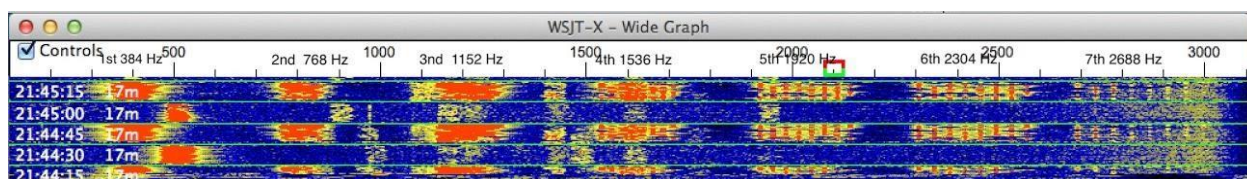Figure 1 – Example noise typically seen

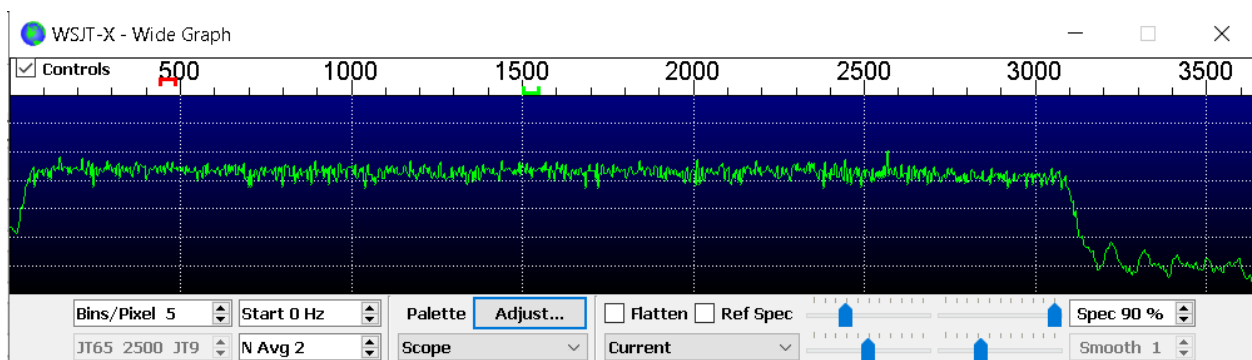Figure 2 – Thanks to Dave K4DET for generating this image of clipping noise.

Figure 3 – Bandwidth view – note the edges of the bandpass which are visible when expanded far enough and flatten is turned off.
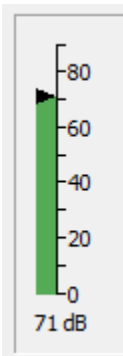
Figure 4

Table 1 – Observed Rig Settings – ALC=0 means no deflection on ALC Meter/LED, Audio Tx dB means the Windows Playback control level

Manuf	Model	Audio	Audio Tx	Rig Power	Menu	Menu Set	ALC Meter	Net Power	Notes
Elecraft	See Attachment 1 below								
Icom	IC-706MKIIG	SignaLink	10 o'clock	100	N/A	N/A	0	90	
Icom	IC-7300	USB	0db	100	USB MOD LEVEL	35	35%	100	35% ALC is Will give full power
Icom	IC-765	SignaLink	7 o'clock	100	Data Button On		0	100	RX 8 o'clock, 0dB recording, 0dB WSJT-X Very touchy
Kenwood	TS-590/S/SG	USB	-20 to -25 dB	100	71/72	1/2	Bouncing on every band	100	ALC can go up to the 1st or 2nd ALC line
Ten-Tec	Omni VII	SignaLink		100					
Yaesu	FTDX-10	USB	-20 dB	50		1	0	50	USB Mode for bandwidth
Yaesu	FTDX-5000	SCU-17	12 o'clock	200	70	2	0	200	USB Mode, Menu 103=DATA, Bandwidth=100-4000, Menu 099=100, Menu 101=4000, 6dB
Yaesu	FT-897D	SignaLink	12 o'clock	100	Line Gain	30	0	100	

Notes:
- Many (most?) rigs want very low MIC/DATA gain. When the computer is putting out full-scale 16-bit data (as it should be doing) rigs are converting that into a voltage that feeds into the ALC circuit. Since it's already full-scale there is typically little gain needed.
- The TS-590/S/SG may have inconsistent power levels by band without a little bit of ALC action. The TS-590 and the DX10 are the only rigs so far that require lowering the Windows Playback level to -20dB to -25dB to avoid harmonics.
- FTDX10 requires -20dB on both Playback and Record level and setting menu

Setting Elecraft transceivers for soundcard digital
Don Wilhelm W3FPR

The setup for soundcard digital modes using Elecraft transceivers (K3/K3S/KX2/KX3 and also the K2) is different than the setup advice for other amateur transceivers. That is because the Elecraft transceivers are different from other amateur transceivers, mainly in the way the power is controlled.

The "common internet advice (and some software application instruction)" does not work well with the Elecraft gear. That advice is usually of the form – set the power for your maximum desired power and use the audio level to control the power output. That will cause "Power Hunting" problems with Elecraft transceivers. Ignore that advice if you are operating an Elecraft transceiver.

So how to set up Elecraft transceivers for soundcard digital modes?

1.   First set the audio level correctly. There are 3 possible variables. First the soundcard setting for "Speaker" in the computer – set it for about 50% using the slider for the soundcard. Second is the "Power" slider in the software application – set that initially to about 50%.

2.   Now attend to the Elecraft gear. First, you should be using DATA A mode (AFSK A for MMTTY or other RTTY applications). Set the K3/K3S MIC SEL to LINE and set the level to about 30 (midrange). For the KX2, KX3 you will be using the MIC input rather than LINE IN, but the MIC Gain setting should be a mid-range value. If set at a high or a low value, you may not be able to achieve the proper resolution in the audio setting. Should you not be able to achieve a midrange setting, you may have to add an attenuator between the soundcard speaker output and the MIC input to the KX3/KX2. A 10k resistor in series with the audio line followed by a 1k resistor from the line to ground will usually suffice.

3.   Do a "transmit" from the software application and adjust the audio level initially with the soundcard "speaker" slider and the software application "Power" slider until you have about 4 bars indicated on the "ALC" meter.

4.   Then use the K3/K3S/KX3/KX2 MIC GAIN to refine the level to produce 4 bars solid with the 5th bar flickering on the ALC meter.

5.   Don't worry about the "ALC" indication. The ALC meter scale in DATA A mode indicates the onset of ALC at the 5th bar. The lower bars are there as an aid in

setting the audio level. The 5th bar is the "NO ALC" point for the K3/K3S/KX3/KX2 – this is consistent with the internet advice to not drive the transceiver into ALC.

6.   Once the audio is set, adjust the desired power output with the POWER knob, and all should be well.

7.   For the K2, the situation is similar, except that there are no ALC bars to assist in adjusting the audio level. Increase the audio until you begin to see the ALC meter display 1 bar, and then back off until it is no longer displayed.

8.   You may have to make slight adjustments of the audio level when changing from one digital software application to another, but the change should be small. Observe the number of ALC meter bars for each application before going on the air with a real signal.

I cannot emphasize enough that the Elecraft transceivers control power differently than all other amateur transceivers. You must set the audio properly, and adjust the power with the POWER knob, in contrast to the common internet and software instructions which are written for transceivers that control the power in an open loop by setting the drive level. The Elecraft transceivers control power by measuring the actual power output and comparing it to the power requested by the POWER knob and adjust the drive accordingly.

That means if you set the power knob for 100 watts and attempt to control the power using the audio level (as indicated by the internet advice), the Elecraft transceiver will attempt to increase the power even with the audio level at a low level to 100 watts. It will be unable to do that due to the low audio level, and thus the saga of "Power Hunting" will begin.

The Elecraft method of power control is superior in that it allows you to achieve any power level you desire without regard for the RF gain of the transmit stages differing from band to band. For instance, setting the power knob to 5 watts will result in 5 watts power no matter what the gain of the RF transmit chain may be. But if the Transmit audio is insufficient, full power may be difficult to achieve, and the result is the "Power Hunting" referred to above.

Because of this closed loop power control mechanism, the Elecraft transceiver must be handled differently than other transceivers in the amateur arena.

Don Wilhelm W3FPR