

HAM RADIO DIGITAL MODES AN “INTRO”

FOR SOLIVITA RADIO CLUB

PRESENTED BY BY STU GALLANT, K3RZB

WHAT'S THE "FUSS" ALL ABOUT?

- As Joe Taylor, Ph.D. and inventor of many modern digital modes, said “just another tool in the ham radio toolkit”
- Adds another dimension to our abilities to communicate, besides the “conventional” CW, SSB, FM, etc. modes
- Due to the very widespread use of DSP technologies in even basic sound cards, it enables anyone with a basic HF/VHF rig to utilize the new modes
- As a note, these are not all “new” modes – RTTY, PSK, AFSK and many others have been around for decades – the technology availability has just made them and their enhancements widely available

SOME ADVANTAGES OF DIGITAL

- Able to work stations you might not otherwise even hear on “conventional” modes
- Can be used with any radio as long as appropriate interface exists from computer
- Availability of inexpensive interfaces and many choices in software make these ideal choices for many hams
- Very useful for antenna restricted areas
- Great way to learn about “information” theory and propagation
- Easier than CW!! (Except for Gerry!)

SOME DISADVANTAGES OF DIGITAL MODES

- One element removed from human-to-human contact in some modes i.e., “machine to machine”
 - CW is “wrist and fist to ear and brain”
- Radio dependent to get set-up, can be a bit tricky
- Many modes are either rare, or difficult to discern on “scope” (on computer)

JUST A LITTLE MATH.....

- In 1948 “Shannon Hartley Law” which is the basis for understanding all communications theory as:

$$C = B \log (1 + S/N)$$

C = Channel capacity

B = Channel Bandwidth

For example, a 30 KHz B/W with S/N=1 results in 30K bits/sec

LOOK AT TYPICAL SIGNAL-TO NOISE-RATIOS

SSB +10 dB

CW -15 dB

FT8 -21 dB

JT65 -25 dB s

JT9 -27 dB

WSPR -31 dB

Digital Modes

Wow. - right??

*** 2500 Hz bandwidth – critical to understand!!**

SO WHAT'S THE REALITY?

- Assume FT8 has 2.5 Hz B/W and SNR of 6dB to properly decode with few errors
- Typical SSB receiver – over “typical SSB bandwidth” approximately 30 dB ($10 \times \log(2500\text{hz}/2.5\text{hz})$)
- So, the reality is the noise floor is 24 dB higher than the signal!!
- That appears on an FT8 screen as a detection of **-24 dB** – seemingly “magic”
- How is it possible? Well....
 - Narrowband DSP filters, are implemented in typical digital mode software (FLDIGI and WSJT-X) which actually detect the “real” 2.5hz signal – and can “ignore” the noise in the rest of the band

WHAT IS THE REAL SNR THAT DETERMINES JT65, JT9, FT8 MESSAGE DECODING PERFORMANCE?

- FSK Symbol-to-Noise Power Density Ratio is $= (E_s/N_0)$
 (E_s/N_0) dB can be derived mathematically from the *Reported SNR*
- (E_s/N_0) dB = $(SNR_{reported})$ dB +
 $(10 \times \text{LOG} (2500 \text{ Hz} / (\text{FSK symbol detection BW})))$ dB

Typical Detection Bandwidths for “Digital” Modes

- JT65 FSK symbol detection BW = 2.692 Hz
- JT9 FSK symbol detection BW = 1.736 Hz
- FT8 FSK symbol detection BW = 6.25 Hz

CALCULATIONS AND WHY IT WORKS!!

JT65, JT9, and FT8 FSK Symbol-to-Noise Density Ratio (E_s/N_0) _{dB} derived from Reported SNR			
Reported SNR (dB) over a 2500 Hz Noise Bandwidth	$(E_s/N_0)_{JT65}$ (dB)	$(E_s/N_0)_{JT9}$ (dB)	$(E_s/N_0)_{FT8}$ (dB)
-30	-0.3	1.6	-4
-29	0.7	2.6	-3
-28	1.7	3.6	-2
-27	2.7	4.6	-1
-26	3.7	5.6	0
-25	4.7	6.6	1
-24	5.7	7.6	2
-23	6.7	8.6	3
-22	7.7	9.6	4
-21	8.7	10.6	5
-20	9.7	11.6	6
-19	10.7	12.6	7
-18	11.7	13.6	8
-17	12.7	14.6	9

SNR threshold referenced to a 2500 Hz BW at a 50% probability for decoding a JT9 message in AWGN

SNR threshold referenced to a 2500 Hz BW at a 50% probability for decoding a JT65 message in AWGN

SNR threshold referenced to a 2500 Hz BW at a 50% probability for decoding a FT8 message in AWGN

AN INTERESTING VIEW OF FT8/FT4

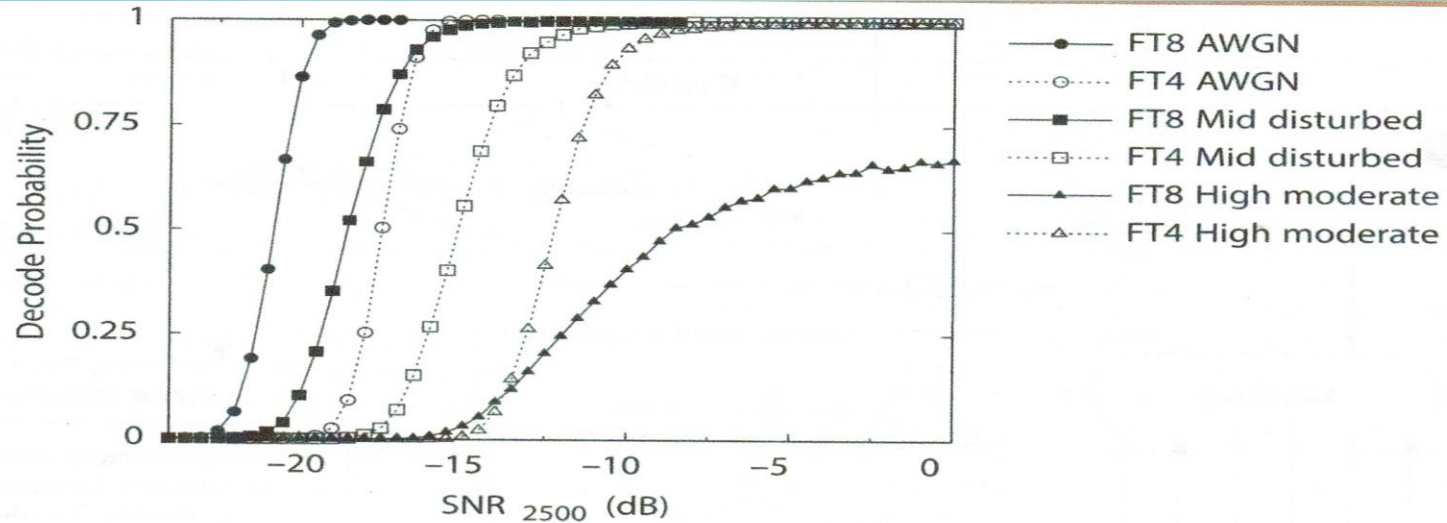


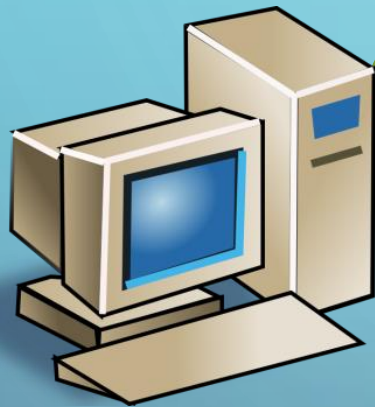
Figure 7 — Measured decoding probability as a function of SNR for FT8 and FT4, based on simulations for three propagation channels: additive white Gaussian noise (AWGN), and the ITU standards for mid-latitude disturbed and high-latitude moderate conditions. No AP information was used for these sensitivity measurements.

Table 6 - FT4 and FT8 decoding thresholds measured using simulations. In all cases, the decoder used block detection and (BP+OSD). For each channel and mode, two decoding thresholds are given. "No AP" is the threshold when no a priori information is available, and "max. AP" is the decoding threshold with the maximum amount of a priori information, at the end of a QSO when receiving RRR, 73, or RR73 from a QSO partner.

Channel	Frequency Spread (Hz)	Diff. Path Delay (ms)	FT4 Decoding Threshold (dB), no AP	FT4 Decoding Threshold (dB), max. AP	FT8 Decoding Threshold (dB), no AP	FT8 Decoding Threshold (dB), max. AP
AWGN	0.0	0.0	-17.5	-19.5	-20.8	-22.7
Mid-latitude quiet	0.1	0.5	-17.4	-19.4	-20.0	-22.4
Mid-latitude moderate	0.5	1.0	-15.8	-18.6	-18.8	-22.1
Mid-latitude disturbed	1.0	2.0	-15.2	-18.4	-18.6	-22.1
High-latitude moderate	10.0	3.0	-12.2	-17.4	-8.6	-18.9

RADIO INTERFACE TO COMPUTER

For modulation/demodulation of digital signals



soundcard-rig audio
(transformer isolation recommended)



CAT data

For Xvr PTT & freq/mode control

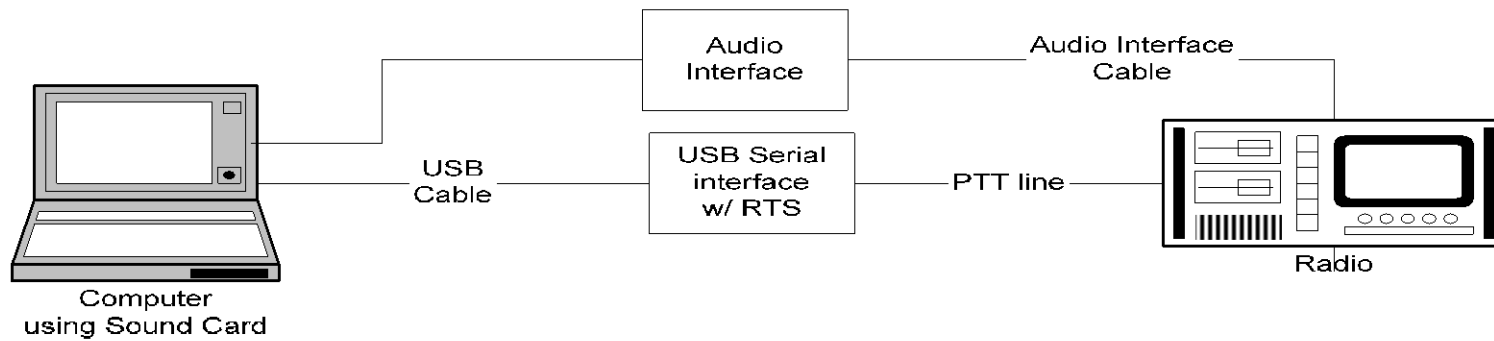
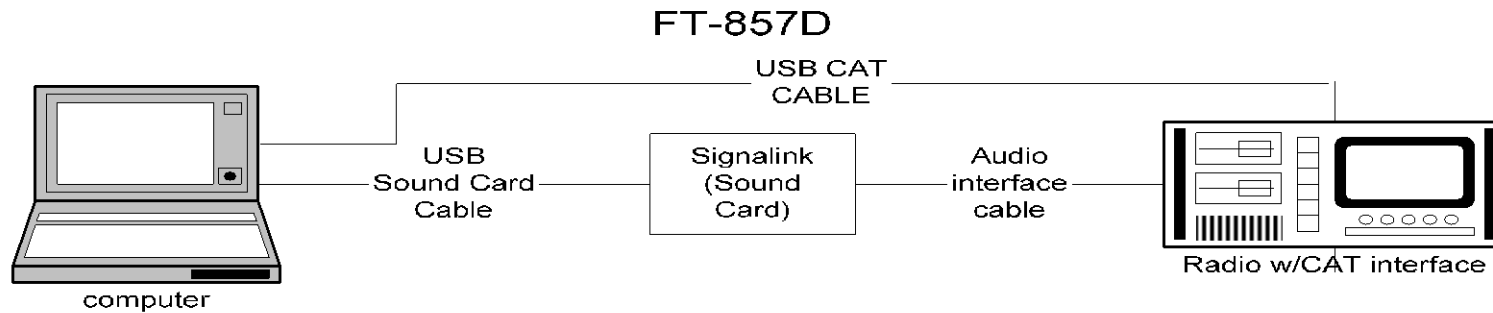
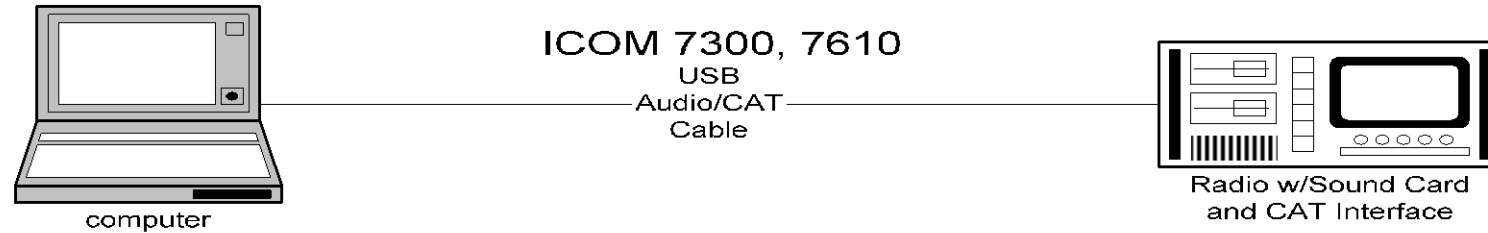


RF to/from antenna

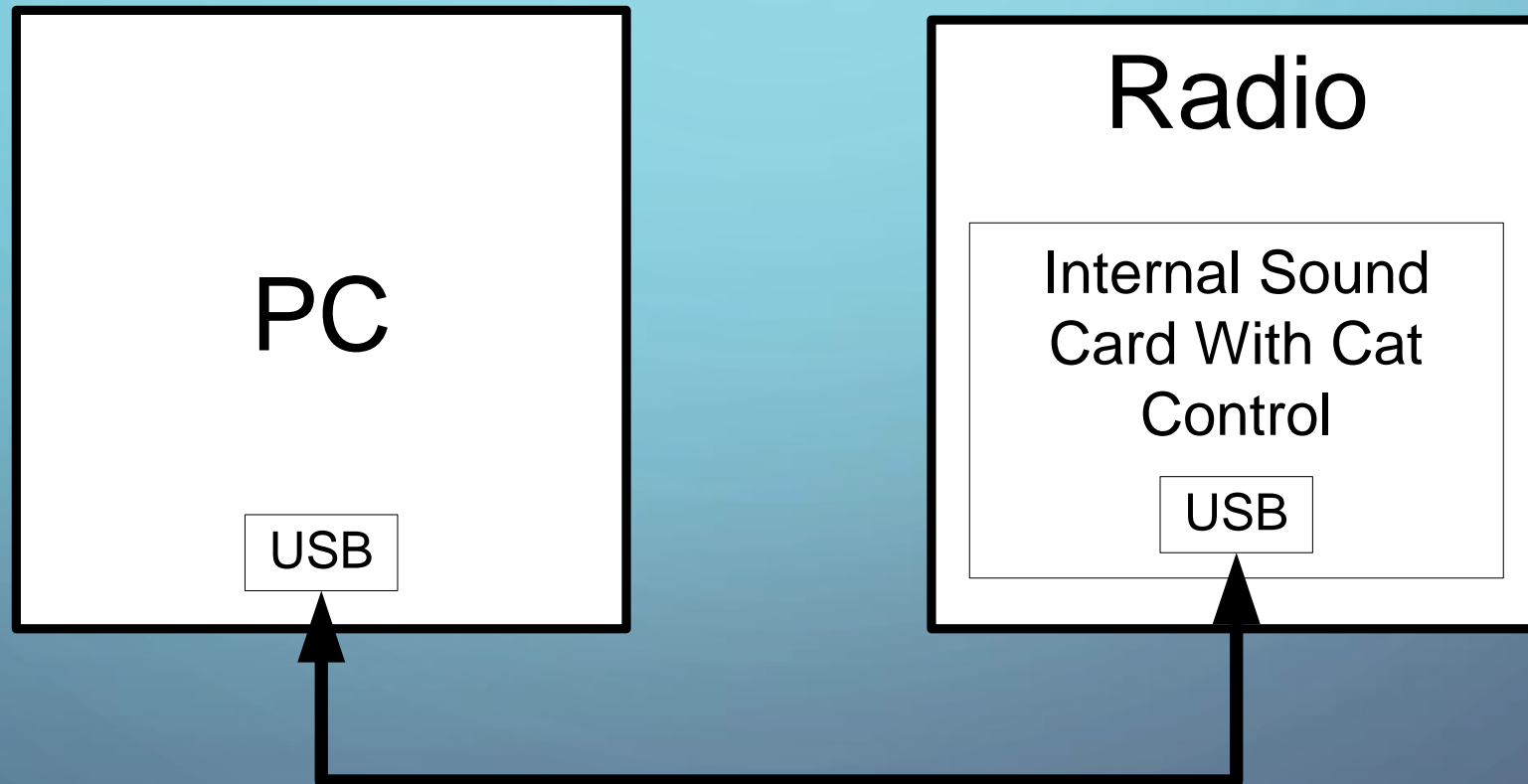


RADIO AND COMPUTER SET-UPS (EXAMPLES)

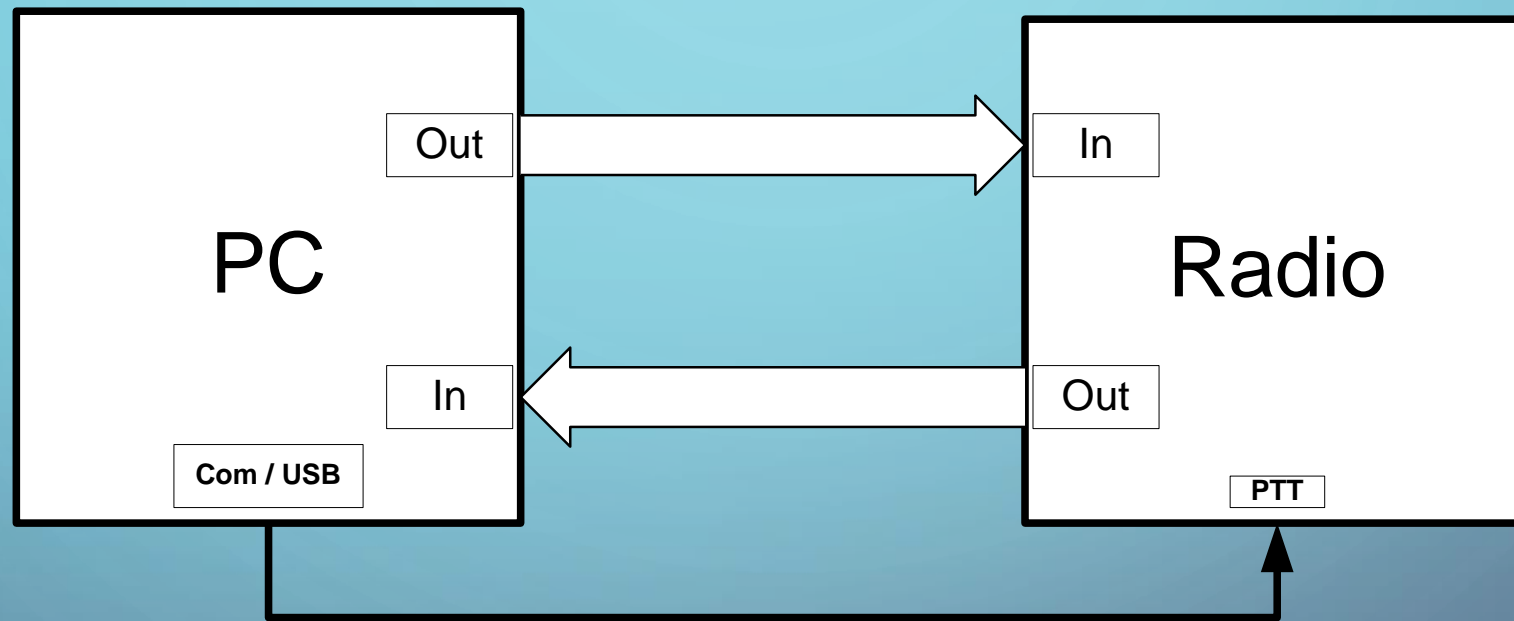
FLDIGI Hardware Examples



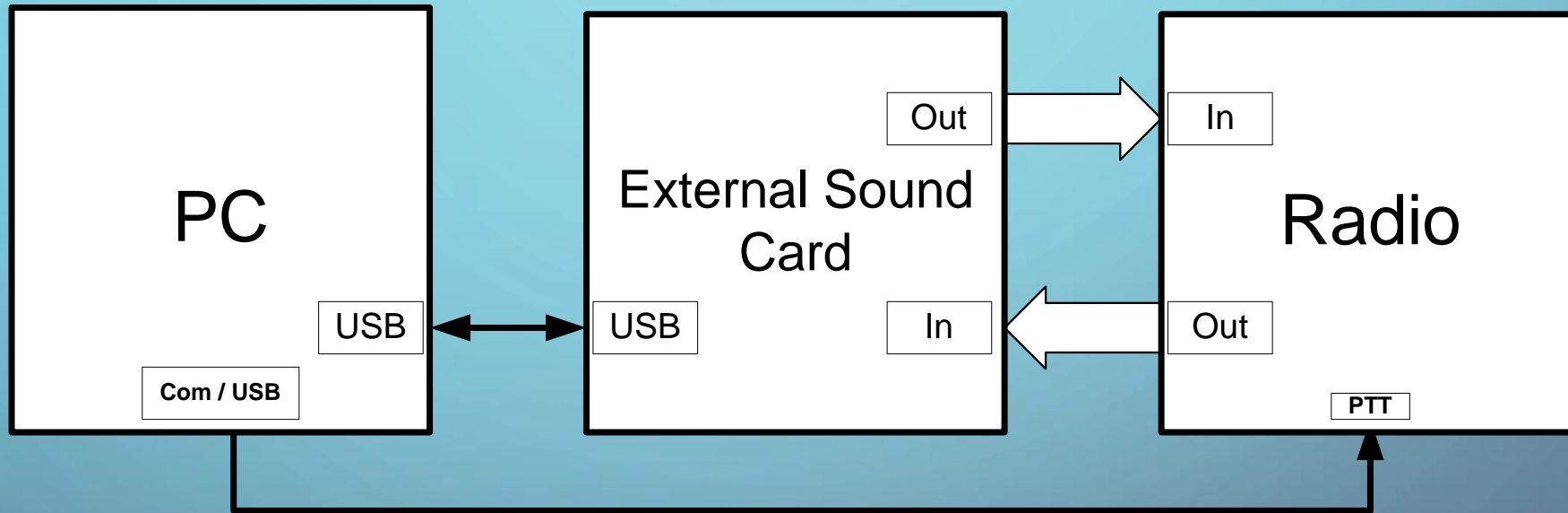
RADIO SOUND CARD (ICOM, K3/K4)



PC SOUND CARD



EXTERNAL SOUND CARD WITHOUT PTT CONTROL



WHAT ABOUT SOFTWARE?

- Many to choose from!
- “Regular” (text, etc. type modes) include FLDIGI, HRD, DM 780
 - All of these encode and decode PSK31, RTTY, Olivia, Throb and numerous others
- “Weak Signal” types, mainly suite from WSJT-X (Joe Taylor)
 - JT65, JT9, FT8, WSPR and numerous others
 - Really superb for “below the noise” contact

CONFIGURATIONS!

- Almost innumerable choices depending upon radio, computer, sound card – if, type, etc.
- Some experimentation will likely be necessary for each set-up – be patient!

A FEW "MUST DO'S"

- Use some type of time synchronization software – **do not depend upon internet time** synchronization (FT8)
 - Examples include timesynctool.net, meinberg, timeis and others
- Be careful that the audio set up (if using a sound card) is properly adjusted in your PC/MAC – meaning the audio channels, volumes, etc. are matched to your radio
- Double check your **RECEIVE** filter bandwidth!! Must match to mode selected via the software

EXAMPLE-WSJT-X SET-UP - OVERVIEW

Settings

General | Radio | Audio | Tx Macros | Reporting | Frequencies | Colors | Advanced

Station Details

My Call: My Grid: AutoGrid IARU Region:

Message generation for type 2 compound callsign holders:

Display

- Start new period decodes at top
- Blank line between decoding periods
- Display distance in miles
- Tx messages to Rx frequency window
- Show DXCC,grid,and worked-before status
- Show principal prefix instead of country name

Font...
Decoded Text Font...

Behavior

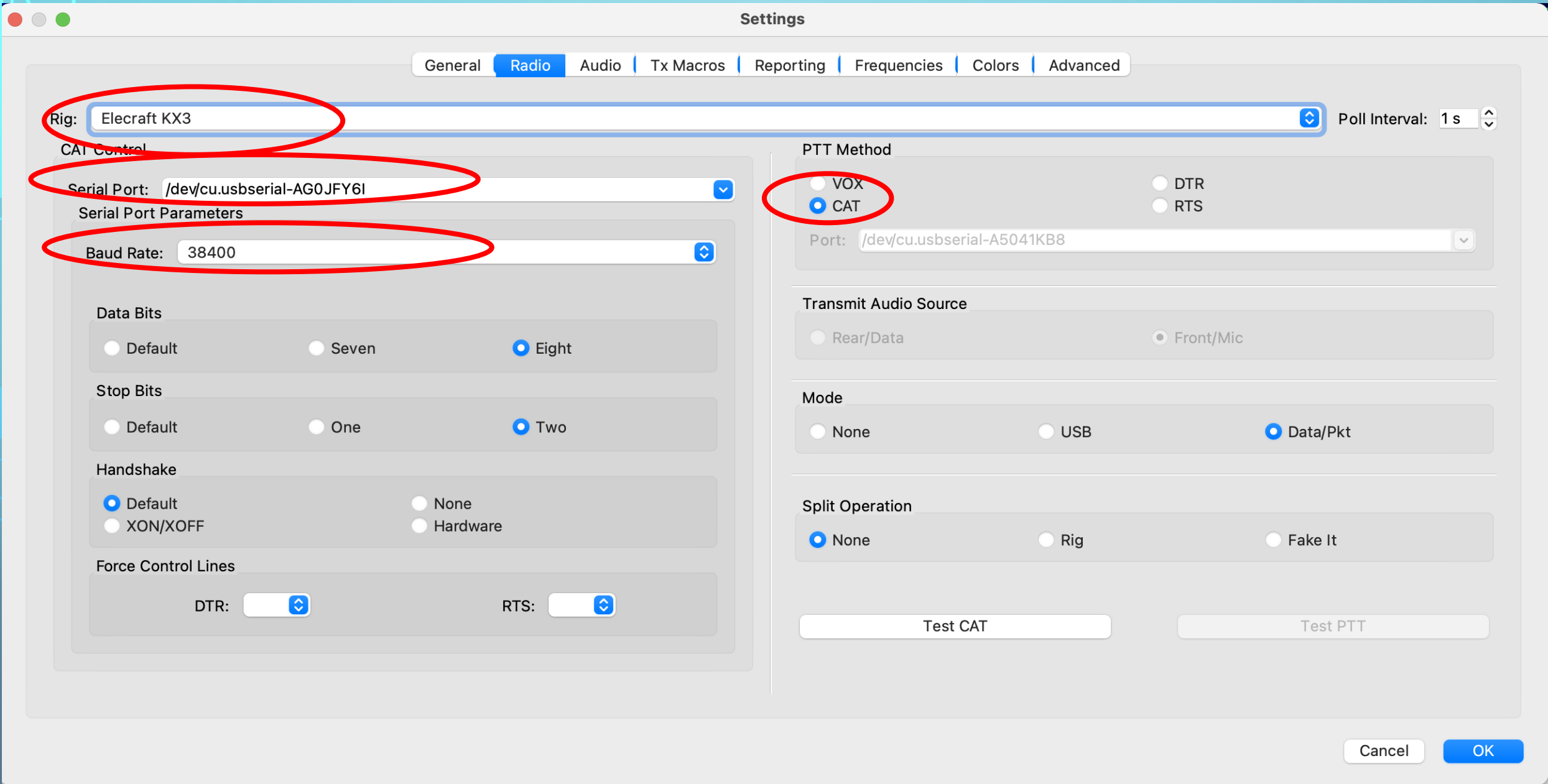
- Monitor off at startup
- Monitor returns to last used frequency
- Double-click on call sets Tx enable
- Disable Tx after sending 73
- Calling CQ forces Call 1st
- Alternate F1-F6 bindings
- CW ID after 73
- Enable VHF/UHF/Microwave features
- Allow Tx frequency changes while transmitting
- Single decode
- Decode after EME delay

Tx watchdog:

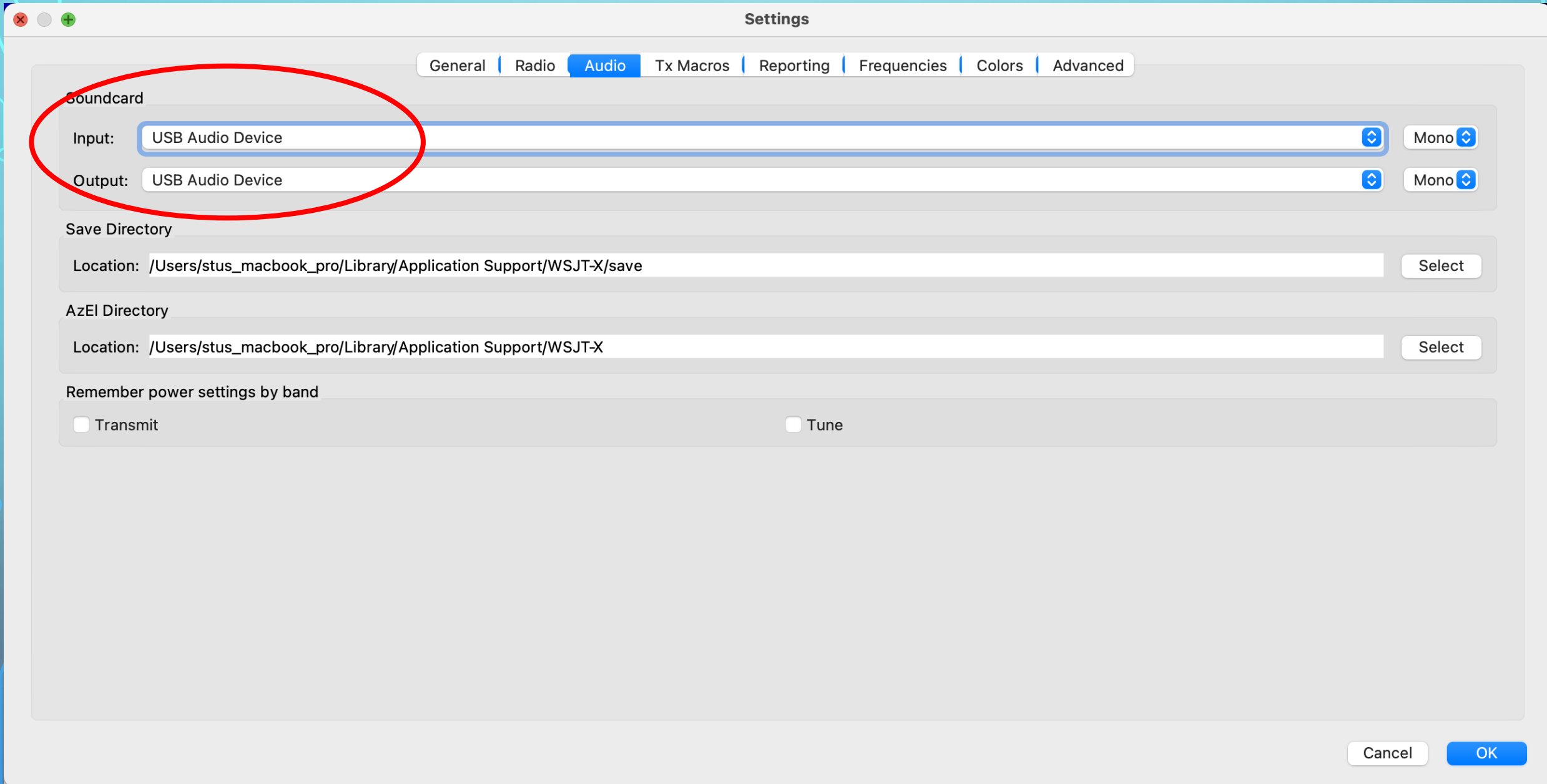
Periodic CW ID Interval:

Cancel OK

EXAMPLE-WSJT-X SET-UP – “RADIO” SCREEN SHOT



EXAMPLE-WSJT-X SET-UP – “AUDIO” SCREEN SHOT



TYPICAL WSJT-X MESSAGE EXCHANGE

S52D's Messages

TX 1: CQ S52D EN53

Tx 2: AA5AU S52D -15

Tx 3: AA5AU S52D RR73

AA5AU's Messages

Tx 1: S52D AA5AU EL49

Tx 2: S52D AA5AU -09

Tx 3: S52D AA5AU 73

FT-8 (FRANK & TAYLOR 8 FREQUENCY) EXAMPLE

WSJT-X File Configurations View Mode Decode Save Tools Help Thu Jul 15 10:03 AM

WSJT-X - Wide Graph

Controls 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400

14:03:00 17m
14:02:30 17m
14:02:00 17m
14:01:30 17m
14:01:15 17m
14:00:45 17m

Bins/Pixel 2 Start 220 Hz Palette Adjust... Flatten Ref Spec Spec 20 %

WSJT-X v2.2.2 by K1JT, G4WJS, and K9AN

140230	-5	-0.1	977	~	DL4MM W8UN R+00	140130	4	0.2	1668	~	KX3C W9TD EN52
140230	-14	-0.0	1659	~	CQ EA4ZM IM68	140147	Tx		1837	~	W9TD K3RZB EL98
140230	-14	0.0	1696	~	CE1PTT W4FCC EM63	140130	0	1.0	1900	~	CQ W8DOL FM19
140230	-16	0.0	1449	~	CQ L21RCA GG02	140149	Tx		1837	~	W8DOL K3RZB EL98
140300	-5	1.0	1897	~	K3RZB W8DOL RR73	140200	-1	1.0	1897	~	CQ W8DOL FM19
140300	23	-0.0	1257	~	ES5QA VE3XN EN93	140215	Tx		1837	~	W8DOL K3RZB EL98
140300	-4	0.1	638	~	N4LDF KC2RDX 73	140230	-2	1.0	1897	~	K3RZB W8DOL -07
140300	8	-0.0	1140	~	I21JLG W4PKU -13	140245	Tx		1837	~	W8DOL K3RZB R-02
140300	16	0.1	2217	~	AB0GT W3PH FM09	140300	-5	1.0	1897	~	K3RZB W8DOL RR73
140300	13	0.1	1455	~	CQ AA5HH EM21	140315	Tx		1837	~	W8DOL K3RZB 73

CQ only Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx Tune Menus

17m **18.099 990**

Tx even/1st Tx 1837 Hz Hold Tx Freq

Rx 1897 Hz Report -5 Auto Seq Call 1st

Generate Std Msgs Next Now Pwr

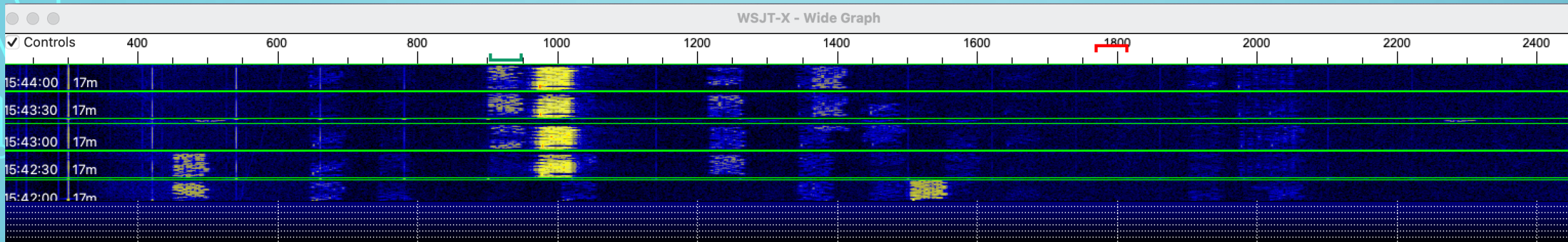
W8DOL K3RZB EL98	<input type="radio"/>	Tx 1
W8DOL K3RZB -05	<input type="radio"/>	Tx 2
W8DOL K3RZB R-05	<input type="radio"/>	Tx 3
W8DOL K3RZB RRR	<input type="radio"/>	Tx 4
W8DOL K3RZB 73	<input checked="" type="radio"/>	Tx 5
CQ K3RZB EL98	<input checked="" type="radio"/>	Tx 6

70 dB

2021 Jul 15 14:03:41

Receiving KX3 FT8 Last Tx: W8DOL K3RZB 73 10 WD:6m

ANOTHER...K3RZB GOT CALLED FROM WA9THI



Station calling me

I answered caller

WSJT-X v2.2.2 by K1JT, G4WJS, and K9AN

154300	-10	0.1	1900	~	IK2HAB F1ZVHF -12	154200	-5	-0.0	1346	~	K3RZB VE3VQS -08
154300	-10	0.2	1438	~	WO2T W4MGL FM16	154215	Tx		1769	~	VE3VQS K3RZB R-05
154330	8	-0.0	904	~	K3RZB WA9THI R-05	154230	-6	-0.0	1347	~	K3RZB VE3VQS RR73
154330	26	-0.6	975	~	CQ N4HID EM66	154245	Tx		1769	~	VE3VQS K3RZB 73
154330	6	-0.8	1219	~	W7DLZ N9JOD 73	154300	4	0.0	906	~	K3RZB WA9THI EM69
154330	1	-0.2	1367	~	WP4RJO KF0AIT EN14	154317	Tx		1769	~	WA9THI K3RZB +04
154330	-14	0.0	1903	~	IK2HAB PT2VHF -12	154330	8	-0.0	904	~	K3RZB WA9THI R-05
154330	-15	-0.0	2018	~	CQ N7DBS DM26	154345	Tx		1769	~	WA9THI K3RZB RRR
154400	4	0.0	903	~	K3RZB WA9THI 73	154400	4	0.0	903	~	K3RZB WA9THI 73
154400	31	-0.6	974	~	CQ N4HID EM66	154415	Tx		1769	~	WA9THI K3RZB 73

CQ only
 Log QSO

 Menus

17m **18.100 000**

Tx even/1st
 Hold Tx Freq

Tx 1769 Hz
 Rx 903 Hz
 Report 4

Auto Seq
 Call 1st

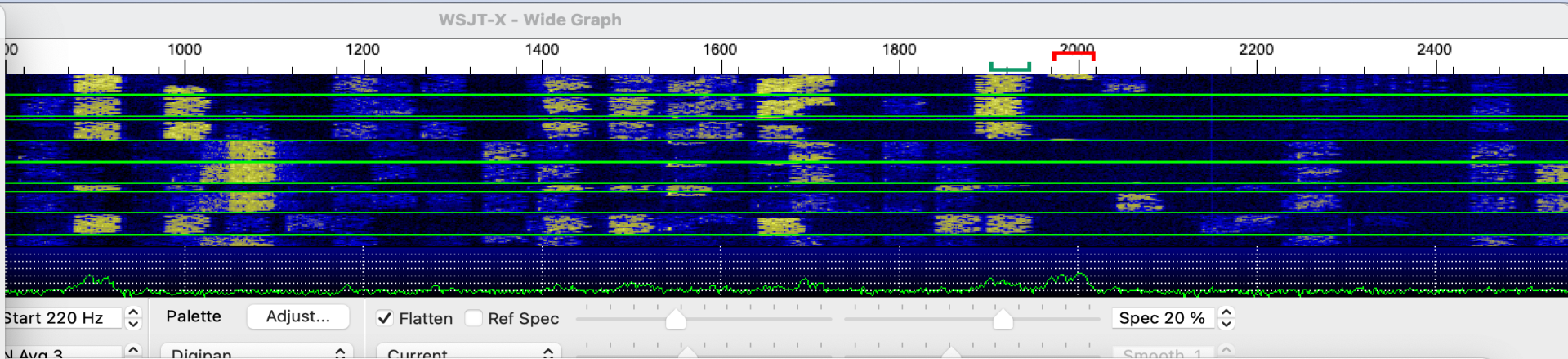
WA9THI K3RZB EL98	<input type="radio"/>	Tx 1
WA9THI K3RZB +04	<input type="radio"/>	Tx 2
WA9THI K3RZB R+04	<input type="radio"/>	Tx 3
WA9THI K3RZB RRR	<input type="radio"/>	Tx 4
WA9THI K3RZB 73	<input checked="" type="radio"/>	Tx 5
CQ K3RZB EL98	<input checked="" type="radio"/>	Tx 6

DX Call: WA9THI
 DX Grid: EM69
 Az: 340
 845 mi
 Lookup
 Add

2021 Jul 21
 15:44:29

FT-8 QSO CONFIRMATION SCREEN

WSJT-X v2.2.2 by K1JT, G4WJS, and K9AN - Lo...



Click OK to confirm the following QSO:

Call	Start	End			
3IQ	15/07/2021 14:44:00	15/07/2021 14:45:00			
Mode	Band	Rpt Sent	Rpt Rcvd	Grid	Name
FT8	20m	-05	-21	EN90	
Tx power	<input type="text"/>				
<input type="checkbox"/>	Retain				
Comments	<input type="text"/>				
<input type="checkbox"/>	Retain				
Operator	<input type="text"/>				
Exch sent	<input type="text"/>	Rcvd	<input type="text"/>		
<input type="button" value="Cancel"/>		<input type="button" value="OK"/>			

144445	-8	0.1	575	~	3Z9W	N6NRD	R-19
144445	-12	-0.1	621	~	<OR40NOL>	W4NEG	EM84
144445	-10	-0.4	535	~	K5UHF	N9BPE	EM59
144445	-14	-0.1	1165	~	CQ	F4DIA	JN36
144445	-8	0.3	713	~	CQ	KD1PV	FN32
144445	-17	-0.1	1213	~	KG0GGY	KJ7TLV	73
144445	-7	0.1	1485	~	<OR40NOL>	KN4FLW	EL95

WSJT-X v2.2.2 by K1JT, G4WJS, and K9AN

144345	-2	-0.6	1266	~	K5VYT	W6OEM	EM25
144345	4	-0.8	1900	~	CQ	W3IQ	EN90
144402	Tx		1972	~	W3IQ	K3RZB	EL98
144415	-5	0.0	1900	~	K3RZB	W3IQ	-21
144430	Tx		1972	~	W3IQ	K3RZB	R-05
144445	1	0.0	1901	~	K3RZB	W3IQ	RR73
144500	Tx		1972	~	W3IQ	K3RZB	73

CQ only Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx Tune Menus

20m **14.074 000**

DX Call	DX Grid
W3IQ	EN90
Az: 2	853 mi
Lookup	Add

2021 Jul 15
14:45:11

Tx even/1st
Tx 1972 Hz Hold Tx Freq

Rx 1901 Hz

Report 1

Auto Seq Call 1st

Generate Std Msgs		Next	Now
W3IQ K3RZB EL98	<input type="radio"/>	<input type="radio"/>	Tx 1
W3IQ K3RZB +01	<input type="radio"/>	<input type="radio"/>	Tx 2
W3IQ K3RZB R+01	<input type="radio"/>	<input type="radio"/>	Tx 3
W3IQ K3RZB RRR	<input type="radio"/>	<input type="radio"/>	Tx 4
W3IQ K3RZB 73	<input type="radio"/>	<input type="radio"/>	Tx 5
CQ K3RZB EL98	<input checked="" type="radio"/>	<input type="radio"/>	Tx 6

FLDIGI EXAMPLE (BPSK-31)

fldigi ver4.1.18.05 / RigCAT - K3 - K3RZB

File Op Mode Configure View Logbook Help Spot RxID TxID TUNE

14070.000

14005.000	USB	CW	800
14070.000	USB	BPSK31	1000
14070.000	USB	BPSK31	1000
18100.000	USB	BPSK31	1000
21005.000	USB	CW	800

USB 2800

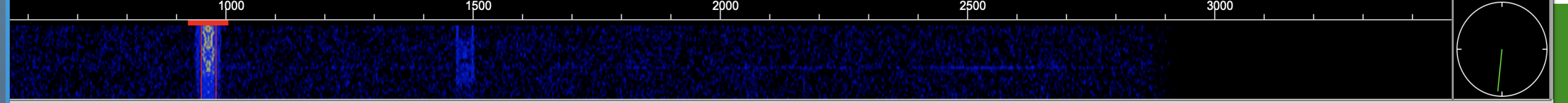
```
=====  
Read macros from: /Users/stus_macbook_pro/.fldigi/macros/macros.mdf  
=====  
n  
# t e r t e g o o e  
oo  
oo t out. i'd like to know what you find out my email is na6y34@gmail.com.e ;  
ih  
  
iaKB9LBP KB9LBP de KJ4KPW KJ4KPW KJ4KPW kn  
KJ4KPW...KJ4KPW...KJ4KPW de KB9  
Before RSID: <<2021-07-15T14:21Z BPSK-31 @ 14070000+0967>>  
eP FB , Thnxs Fer The Contact,  
  
NAME: Steve...Steve  
QTH: Fairfield, Alabama...Fairfield, AL...15 miles Southwest of Birmingham  
GRID LOC: EM63 mj  
  
RST: 599, 599 On The First Pass  
  
So HWS Copy? BTU , KJ4KPW de KB9LBP KN
```

14071.49 h a n l e a r m i n g a

14070.97 W de KB9LBP KN

3.0 Clear

RsID CQ ANS QSO KN SK Me/Qth Brag RTTY Contest T/R Tx Rx TX



The image features a light blue background with a subtle grid pattern. In the corners, there are decorative elements consisting of thin, light blue lines that resemble circuit traces or data paths, ending in small circles. The text is centered and reads:

**ENJOY AND HAVE
FUN WITH DIGITAL
MODES!!**