JT-65 JT-9 for HF

Weak signal digital mode

- **What is JT-65**
  - 65 tones sent in 200 HZ bandwidth
  - Developed for EME
- **Setup and Operation**
  - Soundcard interface
  - WSJT-X software (free)
- **On-Air Demo**
  - PC, Soundcard & Rig

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Just the QSO Essentials

- When signals are strong and communication is essentially error free, it is easy to judge whether a QSO has taken place.
- When a rare one shows up or in a contest, rapid-fire QSOs in the pile-up generally proceed something like the following exchange:
  - 1. CQ HC8N
    - 2. NZ1Q
  - 3. NZ1Q 599
    - 4. 599 TU
  - 5. 73 HC8N
- In the above QSO NZ1Q never sends the callsign of the station he is working, because the situation has made this information clear.
- After the exchange has taken place, both stations confidently enter the QSO in their logs, and they may later exchange QSL cards to confirm that the contact took place.

The JT-65 QSO

- Following these guidelines, the minimal QSO of JT-65 operators generally proceeds like the following 6 exchanges:

from SV1BTR

- CQ SV1BTR MO43

from NZ1Q

- SV1BTR NZ1Q EL87

from SV1BTR

- NZ1Q SV1BTR -05

from NZ1Q

- SV1BTR NZ1Q R-03

from SV1BTR

- NZ1Q SV1BTR RRR

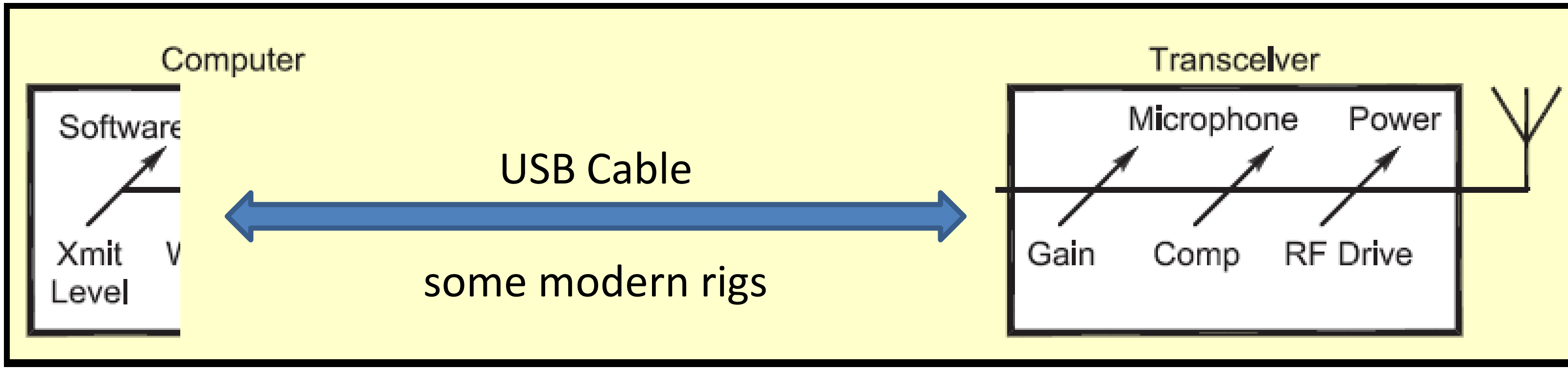
from NZ1Q

- SV1BTR NZ1Q 73

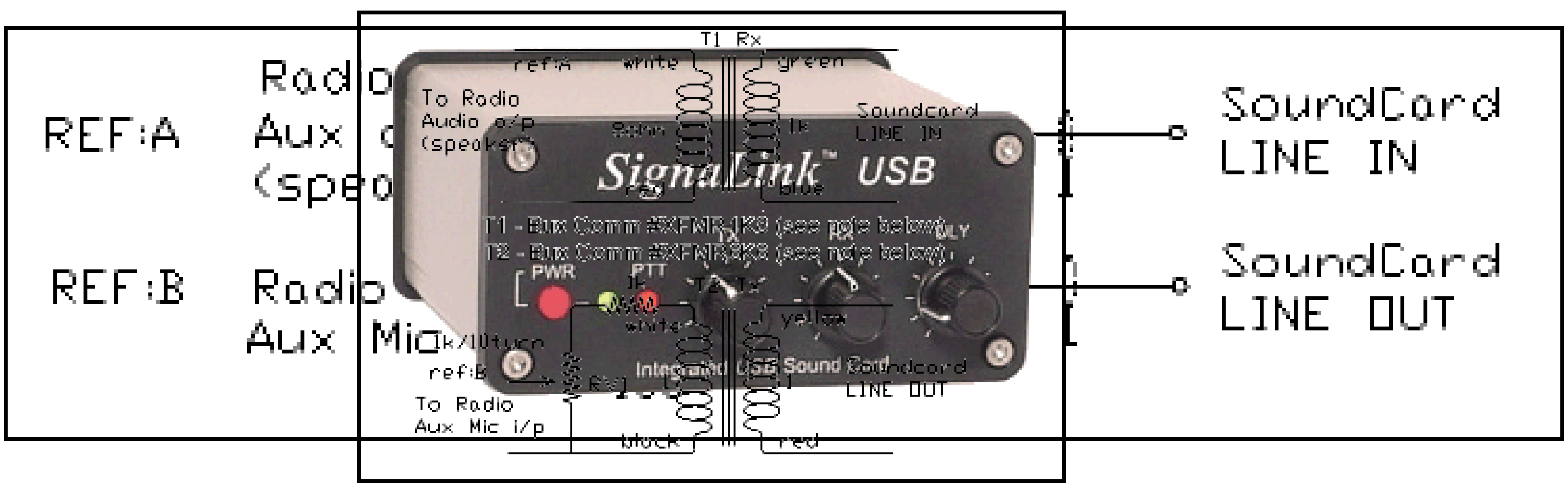
What do you need to start?

- **SSB station**
  - Minimal power, 40w is good, 5 w works
  - Any antenna
  - Any band
- **PC**
  - Sound card
  - Interface (Signal Link, Rig Blaster, etc.)
  - Cables for audio and PTT
  - WSJT-X software (free)
    - "Weak Signal Joe Taylor" Prof. Princeton Univ

Typical Hardware Setup



·An example of daisy-chained transmit level controls. Note that the controls are in series and the resultant output is affected by each of the prior control settings.



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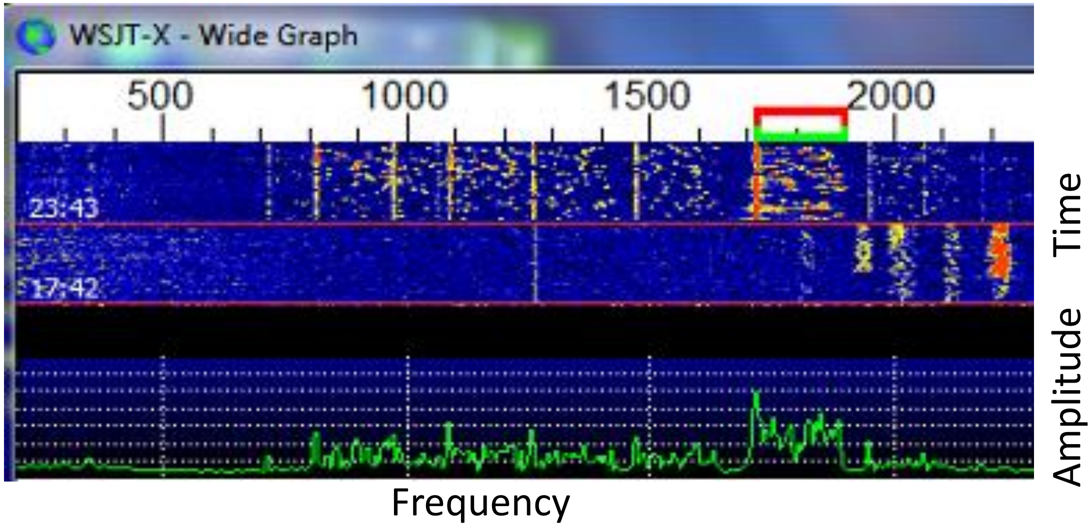
What do JT-65 Signals Look Like

WSJT-X software:

Messages alternate between stations every minute exactly on the minute.

Message xmits for 47 seconds.

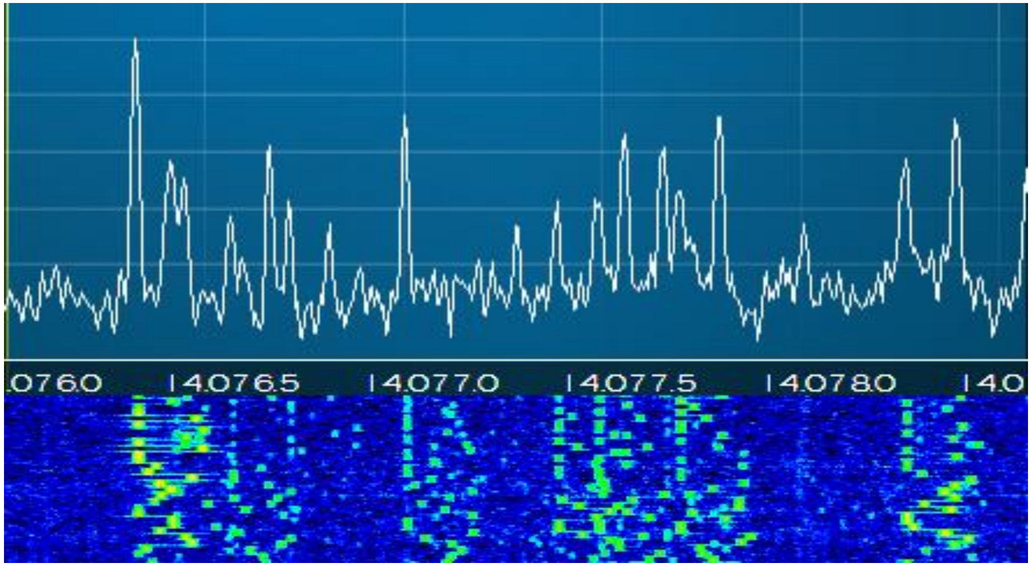


Receiver Pan Adaptor:

Pan-adaptor & Waterfall showing 2.5 KHz of the JT-65 sub-band, which is about the width of SSB.

JT-65 is 177 Hz wide, with each tone 1/3 second long.

The message is xmitted using 65 different tones (JT-65).



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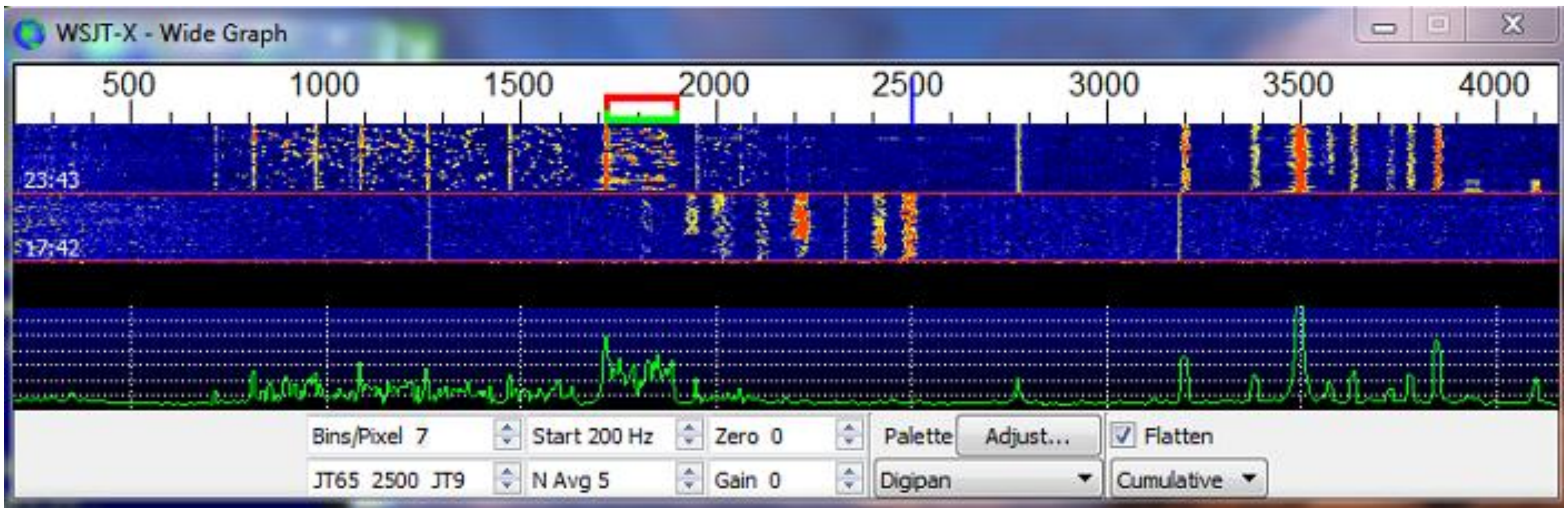
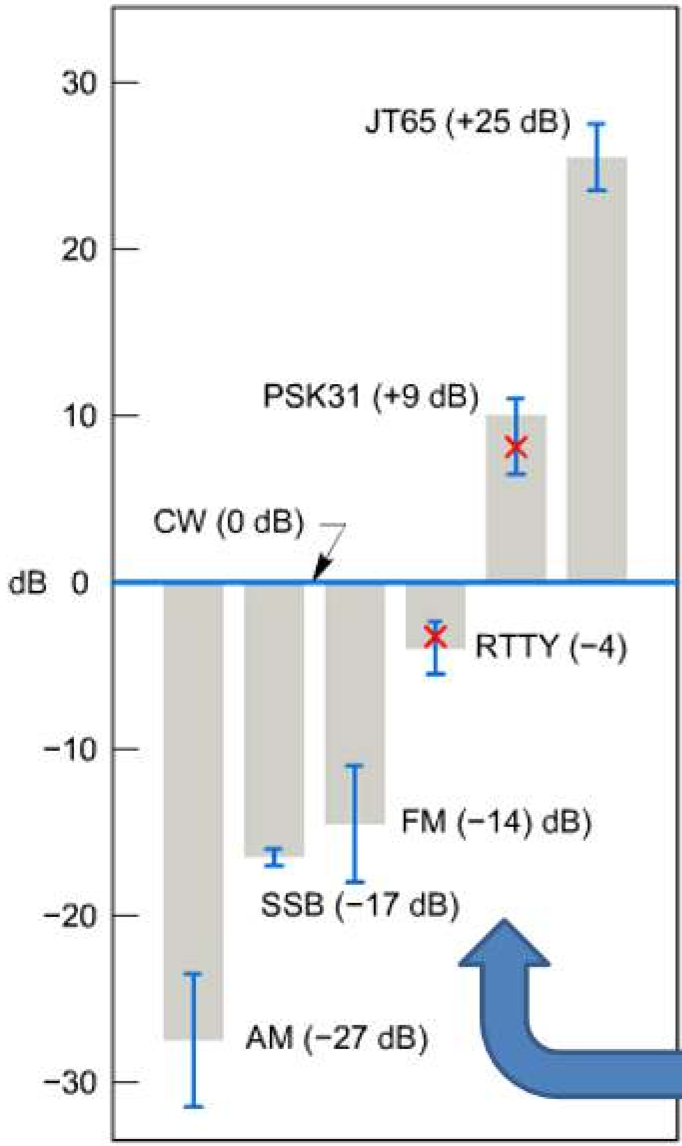
JT-65 and JT-9

PC waterfall display of
signals across both sub-bands
starting at 7.076



How Much "Punch" Can You Get from Different Modes



QST Dec 2013, P30-32

"You can target the DX station's operating mode more confidently when you know CW can out perform unprocessed SSB by 17 dB and RTTY can out perform SSB by 11 dB. If you can't get them on phone, try RTTY or better still, try CW."

Table 1
Average Power for 100 W PEP Transmitter

Mode	Average Power (W)	Compared to CW (dB)
AM	25	−2.5
SSB	25	−2.5
FM	100	+3.6
RTTY	95	+3.3
CW	44	ref: 0
PSK31	75	+2.3
JT65	100	+3.5

Table 2
Average Receiver Sensitivities

Mode	Receiver Sensitivity (microvolts)	Receiver Sensitivity (dBm)	Compared to CW (dB)
AM	0.72	−109.9	−25.1
SSB	0.22	−120.3	−14.7
FM	0.29	−117.7	−17.3
RTTY	0.096	−127.3	−7.7
CW	0.040	−135.0	ref: 0
PSK31	0.023	−139.8	+7.1
JT65	0.0035	−156.2	+21.2

Total occupied bandwidth, decoding sensitivity and band usage:

Mode	Band	BW Hz	Sensitivity dB	Range dB
JT-9	HF	15.6	-27	-50 to +49
JT-65A	HF	177.6	-25	-30 to -1
JT-65B	2m	355.3	-24	-30 to -1
JT-65C	80cm	710.6	-23	-30 to -1

Signals become visible on the waterfall around S/N = –26 dB and audible (to someone with very good hearing) around –15 dB.

- Transmissions in all modes are essentially the same length.
- At the user level, the modes have nearly identical message structures.
- JT-65 signal reports are constrained to the range –1 to –30 dB. This range is more than adequate for EME purposes, but not enough for optimum use at HF.
- By comparison, JT-9 allows for signal reports in the range –50 to +49 dB.
- JT9 is an order of magnitude better than JT-65 in spectral efficiency (bandwidth). On a busy HF band the conventional 2.5-kHz-wide JT-65 sub-band is often filled with overlapping signals. Ten times as many JT-9 signals can fit in the same bandwidth without collisions.

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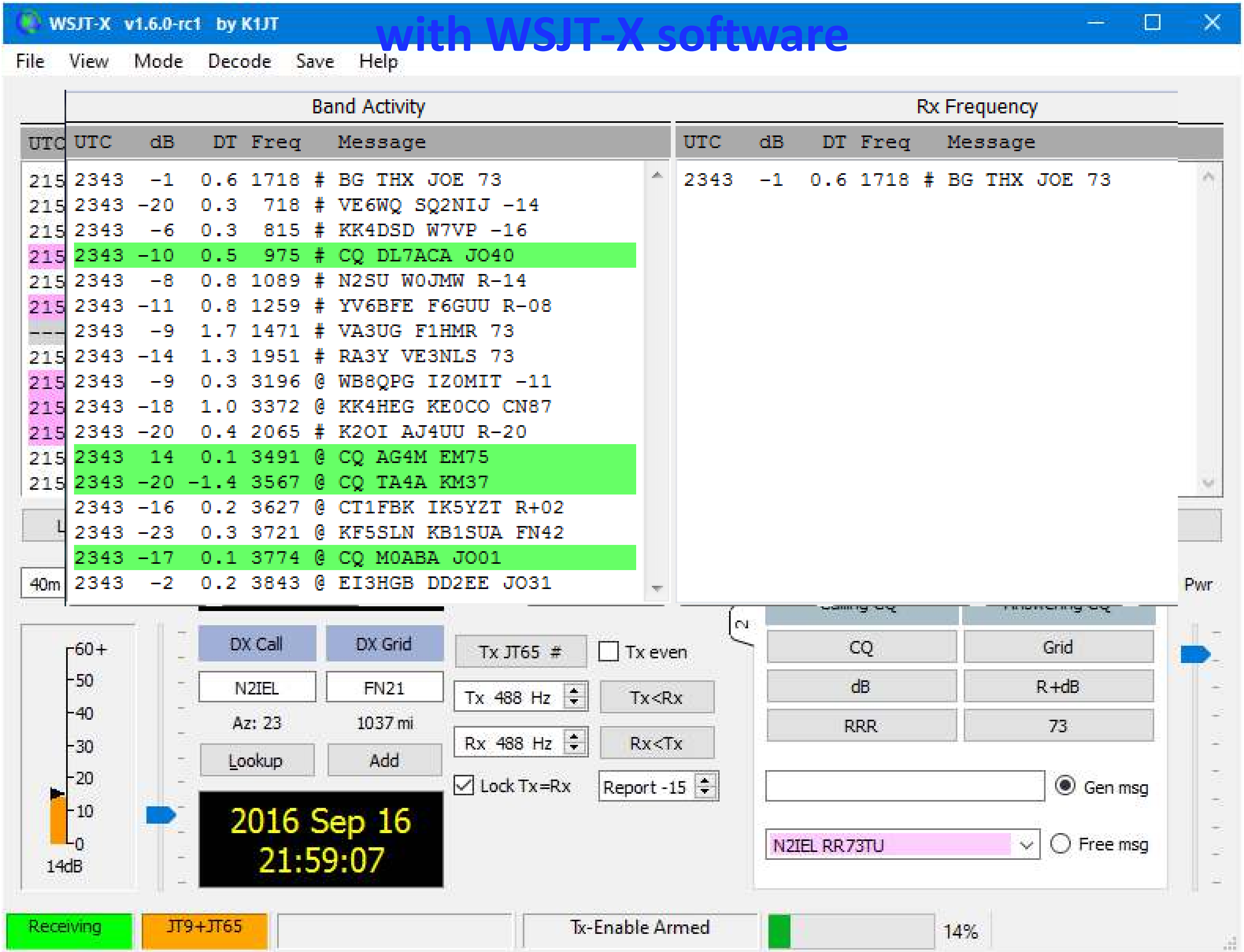
Decoding Signals

with WSJT-X software



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Hints & Kinks

Once receiver audio is reaching the Pc & software waterfall decoding can be a bit tricky . There are several things to look for:

1. The audio level in WSJT-X should be set to around 30 dB on the left bottom scale during a no signal period. The slider will let you set this, it is not critical.
2. Timing is important. The PC clock needs to be off by less than 2 sec to Internet Time, best when exactly right on. That will let you decode more signals that may vary + or – a second or two. This can ne easily done by updating the time in Windows Clock.
3. For decoding, the Monitor button should be green (active - click if not).
4. The piece of the spectrum being received from the rig needs to be at least 3 kHz wide and better at 5 kHz wide. This will help in decode and also give the waterfall's lower display (amplitude) a flatter response curve across the display.
5. The PC needs reasonable computing power. My old laptop of 10 years just can't handle the processing required during the decode period after the 47 sec xmissions.
6. "Mode" in the pull down menu should be JT-65 to start.

NZ1Q using JT-65 & JT-9
in 2 Years logged >2500 QSOs

DXCC	Total	160	80	40	30	20	17	15	12	10	6
worked	102	6	8	31	23	73	23	46	7	66	1

VE7SL and VK4YB - First 630m (472 Hz) contact between Canada and Australia!

NZ1Q JT- DXCC total to date = 102

Entity	Prefix
Monaco	3A
Sri Lanka	4S
Israel	4X
Croatia	9A
Malta	9H
Trinidad & Tobago	9Y
Oman	A4
China	BY
Bahamas	C6
Chile	CE
Antarctica	CE9
Cuba	CO
Bolivia	CP
DPortugal	CT
Madeira Islands	CT3
Azores	CU
Uruguay	CX
Federal Republic of Germany	DL
Niue	E6
Bosnia-Herzegovina	E7
Spain	EA
Balearic Islands	EA6
Canary Islands	EA8
Ceuta & Melilla	EA9
Ireland	EI
Armenia	EK
Moldova	ER
Estonia	ES
Belarus	EW
France	F
Guadeloupe	FG
MNew Caledonia	FK
Reunion Island	FR
Wallis & Futuna Islands	FW
England	G
Isle Of Man	GD
Northern Ireland	GI
Jersey	GJ
Scotland	GM
Guernsey	GU
Wales	GW
Hungary	HA
Switzerland	HB
Ecuador	HC
Colombia	HK
Saudi Arabia	HZ
Italy	I
Sardinia	IS0
Grenada	J3
Saint Lucia	J6
Japan	JA
United States	K
Hawaii	KH6
Alaska	KL7
US Virgin Islands	KP2
Puerto Rico	KP4
Norway	LA
Argentina	LU
Luxembourg	LX
Lithuania	LY
Bulgaria	LZ
Lebanon	OD
Austria	OE
Finland	OH
Czech Republic	OL
Slovakia	OM
Belgium	ON
Denmark	OZ
Netherlands	PA
Brazil	PY
FSlovenia	S5
Sweden	SM
Poland	SP
Greece	SV
Crete	SV9
Turkey	TA
Iceland	TF
Guatemala	TG
Costa Rica	TI
Cameroon	TJ
Gabon	TR
European Russia	UA
Asiatic Russia	UA0
Kaliningrad	UA2
Kazakhstan	UN
Ukraine	UT
Belize	V3
SCanada	VE
Australia	VK
India	VU
Mexico	XE
RIndonesia	YB
Latvia	YL
Romania	YO
Serbia	YU
Venezuela	YV
Cayman Islands	ZF
New Zealand	ZL
Paraguay	ZP
Republic of South Africa	ZS

JT-65 Demo

Notes and References Follow

FEC

- After being compressed into 72 bits, a JT65 message is augmented with 306 uniquely defined error-correcting bits. The FEC coding rate is thus *r = 72/378 = 0.19; equivalently one might say that each message is transmitted with a "redundancy ratio" of 378/72 = 5.25. With a good error-correcting code, however, the resulting performance and sensitivity are far superior to those obtainable with simple five-times message repetition. The high level of redundancy means that JT65 copes extremely well with QSB. Signals that are discernible to the software for as little as 10 to 15 s in a transmission can still yield perfect copy.*
- The source of this seemingly mysterious "coding gain" is not difficult to understand. With 72 bits the total number of possible user messages is 2^{72}, slightly more than 4.7×10^{21}. The number of possible patterns of 378 bits is a vastly larger number, 2^{378}, in excess of 6×10^{113}. With a one-to-one correspondence between 72-bit user messages and 378-bit "codewords," or unique sequences of 378 bits, it is clear that only a tiny fraction of the available sequences need to be used in the code. The sequences chosen are those that are "as different from one another as possible," in a mathematically rigorous sense.

Drive level

After your computer and your radio are set, you should adjust your sound card interface audio level to drive the transmitter to 50 percent power output or less. There are two reasons for doing this—to eliminate production of a wide and distorted signal and to prevent overheating of the transmitter's power amplifier. Less than full power output ensures that you won't overdrive the transmitter, cause distortion and overtax the amplifier.
Most digital mode duty cycles are continuous and full power operation for an extended time can overheat the transmitter.

According to K1JT, the *WSJT software modes contain only single* tones at any instant and cannot easily produce intermodulation distortion (IMD), although IMD is possible with other digital modes if drive levels are excessive.

Signal coding technique: JT65 was designed for making minimal QSOs via EME ("moon-bounce") on the VHF and UHF bands. A detailed description was published in QEX for September-October, 2005. Briefly stated, JT65 uses 60s T/R sequences and carefully structured messages. Standard messages are compressed so two callsigns and a grid locator can be transmitted in just 71 information bits. A 72^{nd} bit serves as a flag to indicate that a message consists of arbitrary text (up to 13 characters) instead of callsigns and a grid locator. Special formats allow other information such as add-on callsign prefixes (e.g., ZA/K1ABC) or numerical signal reports (in dB) to be substituted for the grid locator. The basic aim is to compress the most common messages used for minimally valid QSOs into a minimum fixed number of bits. After compression, a Reed Solomon (63,12) error-control code converts 72-bit user messages into sequences of 63 six-bit channel symbols.

JT65 requires tight synchronization of time and frequency between transmitting and receiving stations. Each transmission is divided into 126 contiguous tone intervals or "symbols" of length 4096/11025 = 0.37s. Within each interval the waveform is a constant-amplitude sinusoid at one of 65 pre-defined frequencies (tones). Frequency steps between intervals are accomplished in a phase-continuous manner. Half of the channel symbols are devoted to a pseudo-random synchronizing vector interleaved with the encoded information symbols. The sync vector allows calibration of time and frequency offsets between transmitter and receiver. A transmission nominally begins at $t = 1$s after the start of a UTC minute and finishes at $t = 47$ seconds. The synchronizing tone is sent in each interval having a "1" in the following pseudo-random sequence:

100110001111110101000101100100011100111101101111000110101011001 101010100100000011000000011010010110101010011001001000011111111

Encoded user information is transmitted during the 63 intervals not used for the sync tone. Each channel symbol generates a tone at frequency 11025 × 472/4096 + 11025/4096 × (N+2) × m, where N is the value of the six-bit symbol, $0 \le N \le 63$, and m is 1, 2, or 4 for JT65 sub-modes A, B, or C. Sub-mode JT65A is always used at HF.

References

The JT65 Communications Protocol
Joe Taylor, K1JT

Abstract. JT65 is a digital protocol intended for Amateur Radio communication with extremely weak signals. It was designed to optimize Earth-Moon-Earth (EME) contacts on the VHF bands, and conforms efficiently to the established standards and procedures for such QSOs. JT65 includes error-correcting features that make it very robust, even with signals much too weak to be heard. This paper summarizes the technical specifications of JT65 and presents background information on its motivation and design philosophy. In addition, it presents some details of the implementation of JT65 within a computer program called WSJT, together with measurements of the resulting sensitivity and error rates.
http://physics.princeton.edu/pulsar/K1JT/JT65.pdf

WSJT-X User Guide version 1.6.0
1. Introduction
WSJT-X is a computer program designed to facilitate basic amateur radio communication using very weak signals. The first four letters in the program name stand for "Weak Signal communication by K1JT," while the suffix "-X" indicates that *WSJT-X* started as an extended (and experimental) branch of the program *WSJT*.
http://physics.princeton.edu/pulsar/k1jt/wsjtx-doc/wsjtx-main-1.6.0.html#INTRO

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