Weak Signal Digital Modes

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Weak Signal Digital Modes on HF-Bands

Content

- Introduction
- What makes these modes so popular?
- Station setup and interfacing
- Digital Modulation
- PSK 31
- JT-65/JT-9
- PSK Reporter

Weak Signal Digital Modes on HF

Typical situation for hams in Singapore:

- Limited antenna space
- Limited power options (100 W or less)
- Noisy HF environment

Solution:

- CW (still the best!)
- Digital modes

Why?

- Reduced bandwidth: 2.5 kHz to < 200 Hz
  - 10 dB noise power reduction
  - 20 dB impulse noise reduction

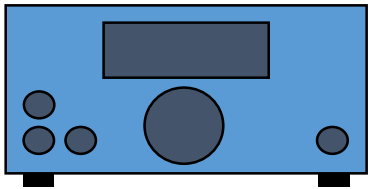
Weak Signal Digital Modes on HF - Why so popular?

- Simple interface with computer (soundcard)
- Increasing processing speed and power of computer allows for use of modern, high efficient coding/decoding algorithms
- Open source software solutions available for all platforms

- Legacy (*e.g.* RTTY)

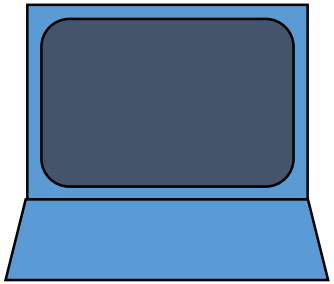
Weak Signal Digital Modes on HF-Bands Interfaces

Transceiver



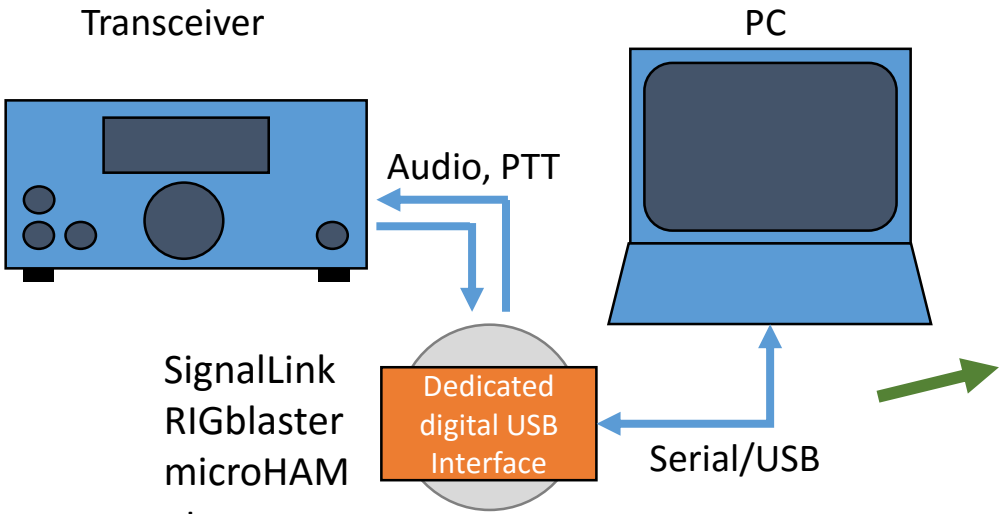
?

PC



How to connect the transceiver to the computer?

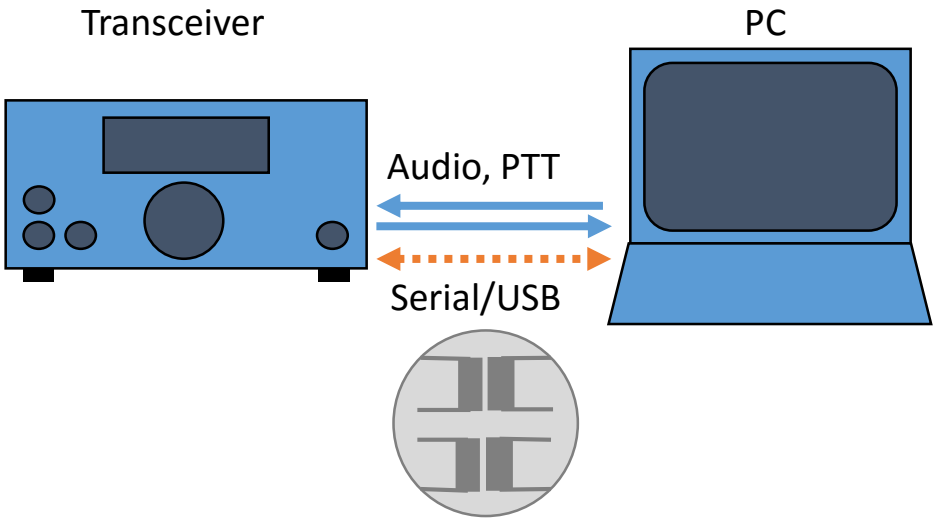
Weak Signal Digital Modes on HF-Bands Interfaces



How to connect the transceiver to the computer?

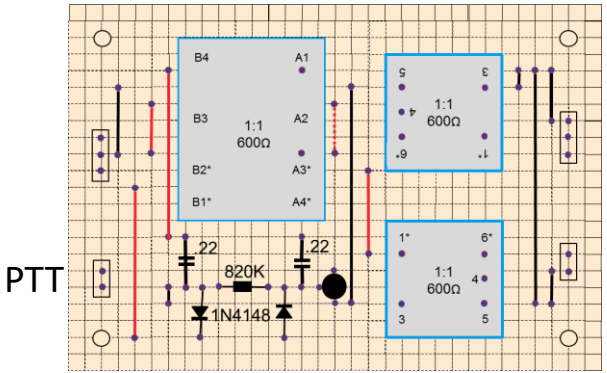
a) Dedicated digital USB Interface

Weak Signal Digital Modes on HF-Bands Interfaces

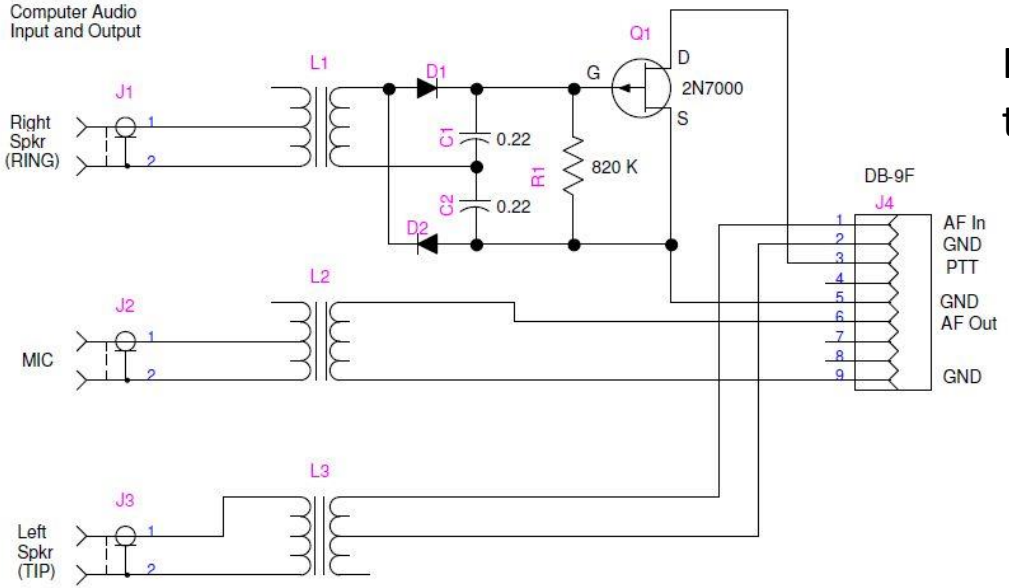


How to connect the transceiver to the computer?

b) Simple galvanic isolation



Weak Signal Digital Modes on HF-Bands Interfaces

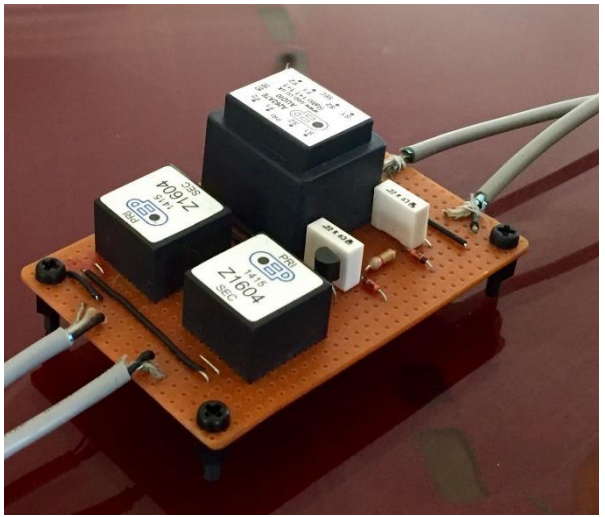


L1, L2, L3 600:600 Ohm CT Audio Transformers
D1, D2 1N4148 Small Signal Diode
J1 and J3 are a single Stereo Tip-Ring-Sleeve socket
J2 can be Stereo or Mono socket

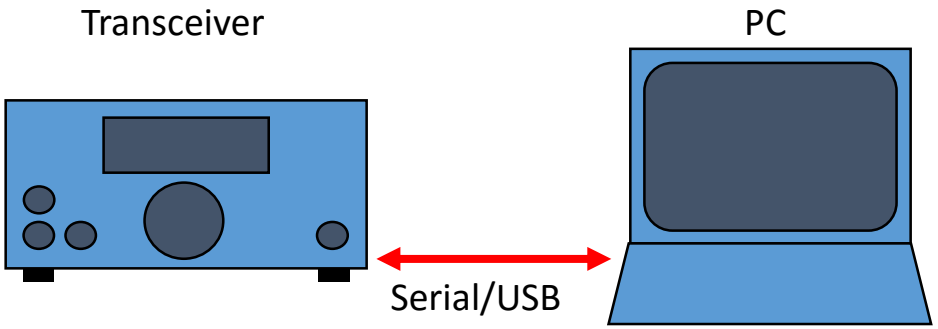
Set FLDigi to send a 1 kHz tone on the Right Speaker output channel for PTT

W5ZIT
Jun 2011

How to connect the transceiver to the computer?



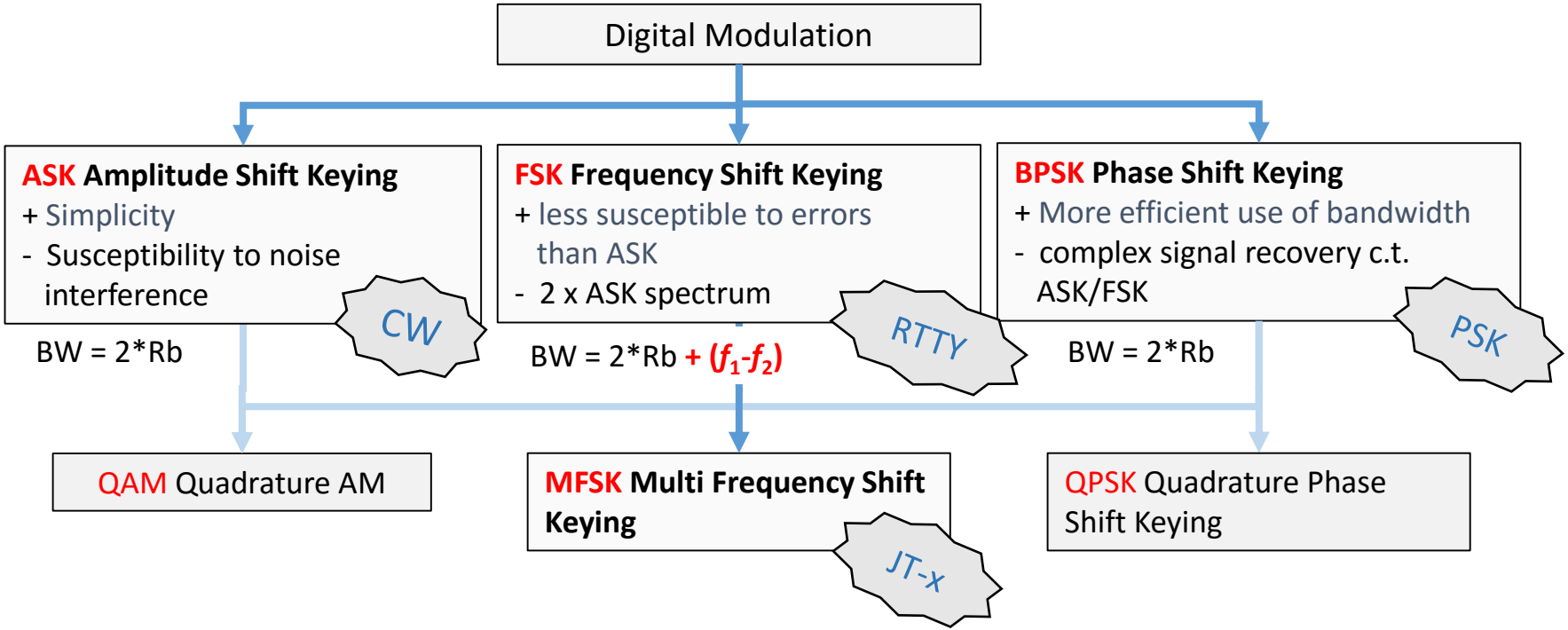
Weak Signal Digital Modes on HF-Bands Interfaces



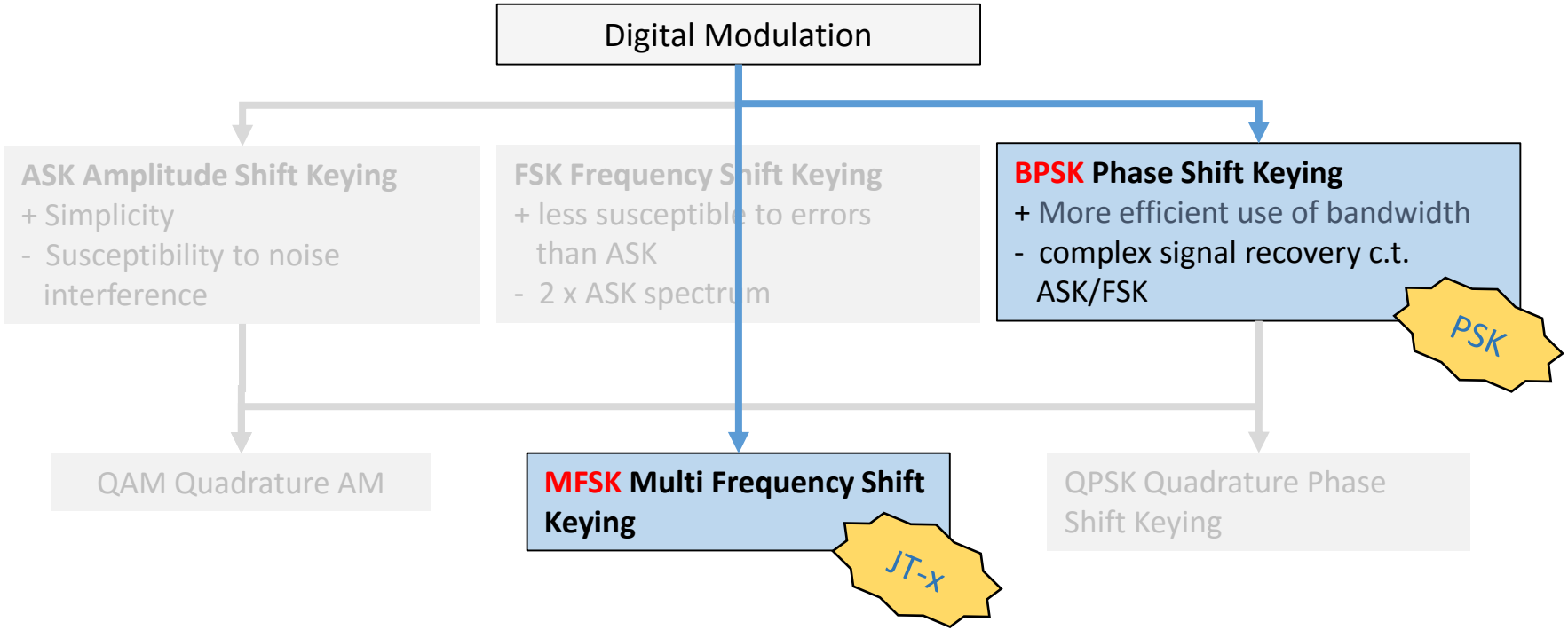
How to connect the transceiver to the computer?

c) USB cable only, e.g. IC-7300

Weak Signal Digital Modes on HF-Bands Modulation



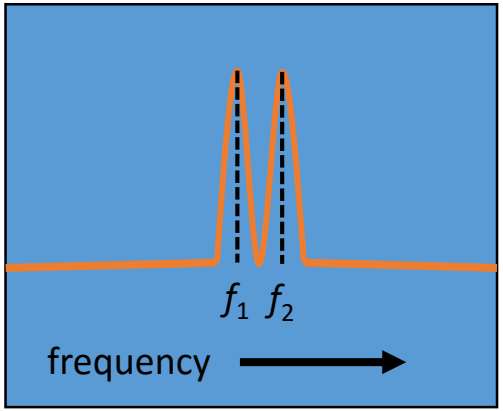
Weak Signal Digital Modes on HF-Bands Modulation



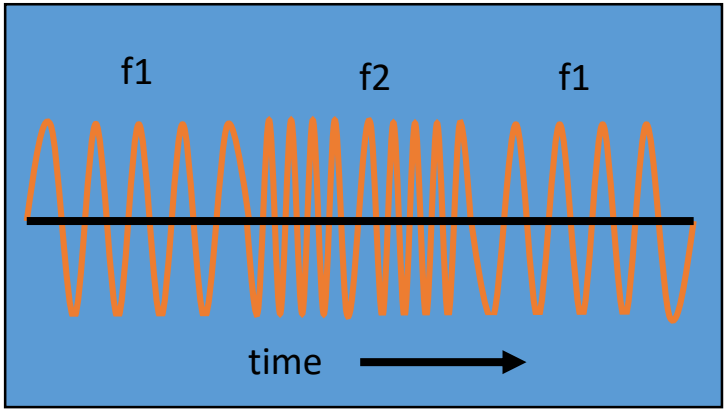
Weak Signal Digital Modes on HF-Bands

FSK (RTTY)

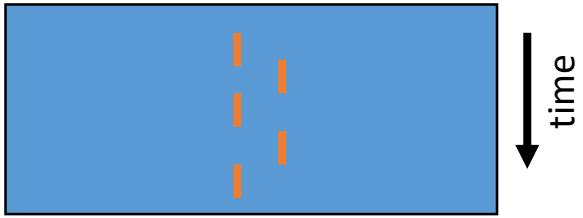
Spectrum



Oscilloscope



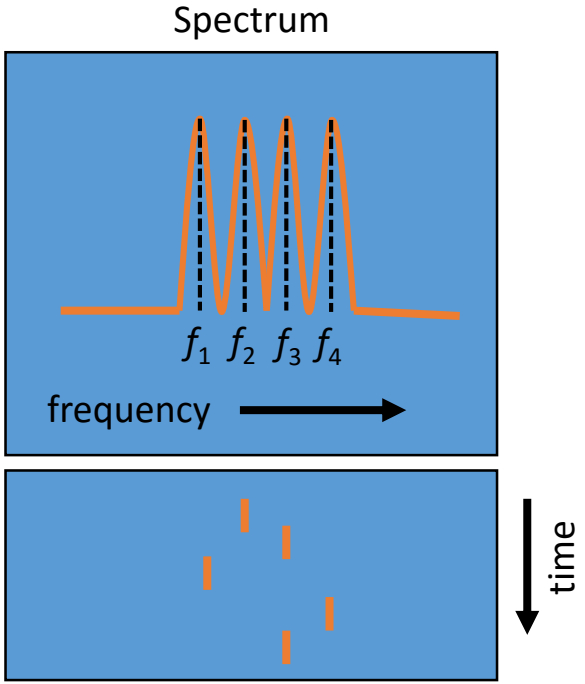
Mark and Space
= “1” and “0”



Waterfall

Weak Signal Digital Modes on HF-Bands

MFSK

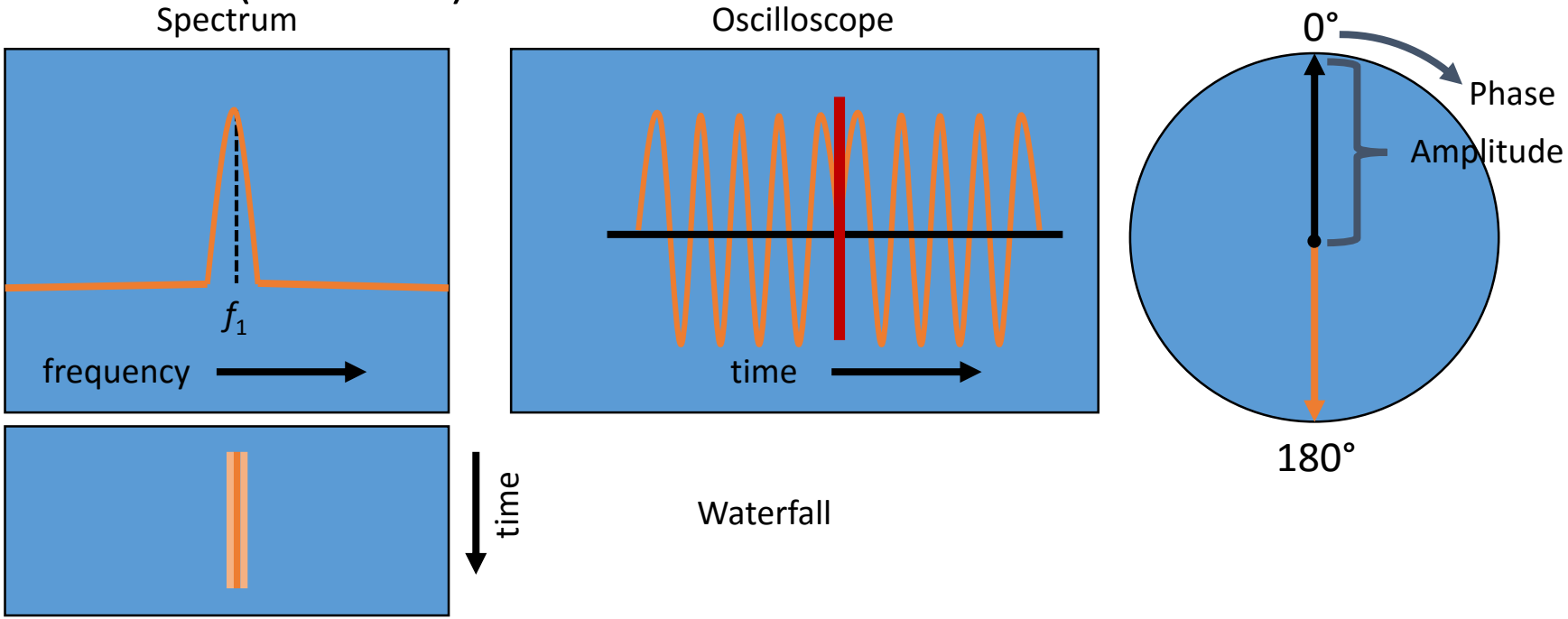


Each frequency represents a specific “symbol” of the code.
4 tones represent 2 bit symbols/timeslot, e.g.:
f_1 = 00, f_2 = 01, f_3 = 10, f_4 = 11

Waterfall

Weak Signal Digital Modes on HF-Bands

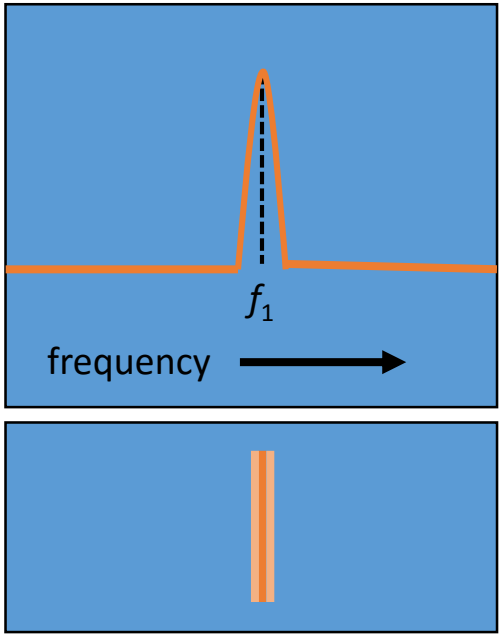
BPSK (PSK 31)



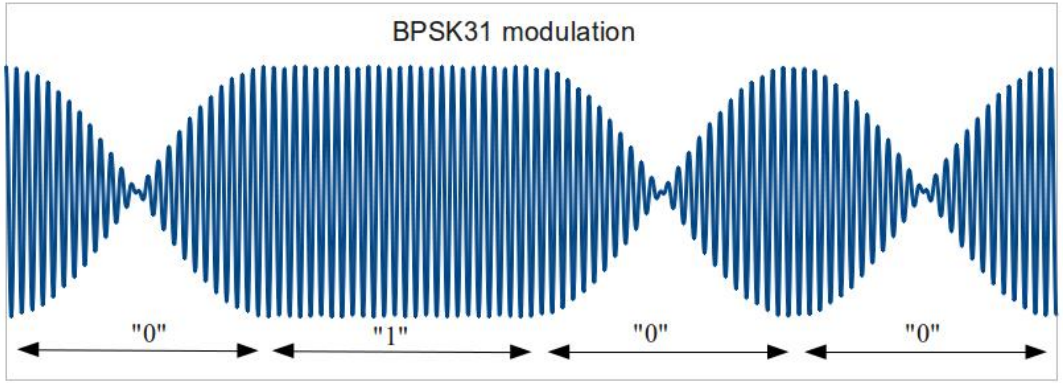
Weak Signal Digital Modes on HF-Bands

BPSK

Spectrum



Oscilloscope



Phase shift occurs at a null amplitude. A raised-cosine filter is used to smooth the rise and fall times of the audio waveform and eliminate key clicks.

PSK-31

Background

- Initially developed by SP9VRC as SLOWBPSK, later reworked by Peter Martinez, G3PLX
- TTY kind operation (keyboard to keyboard)

PSK HF Frequencies

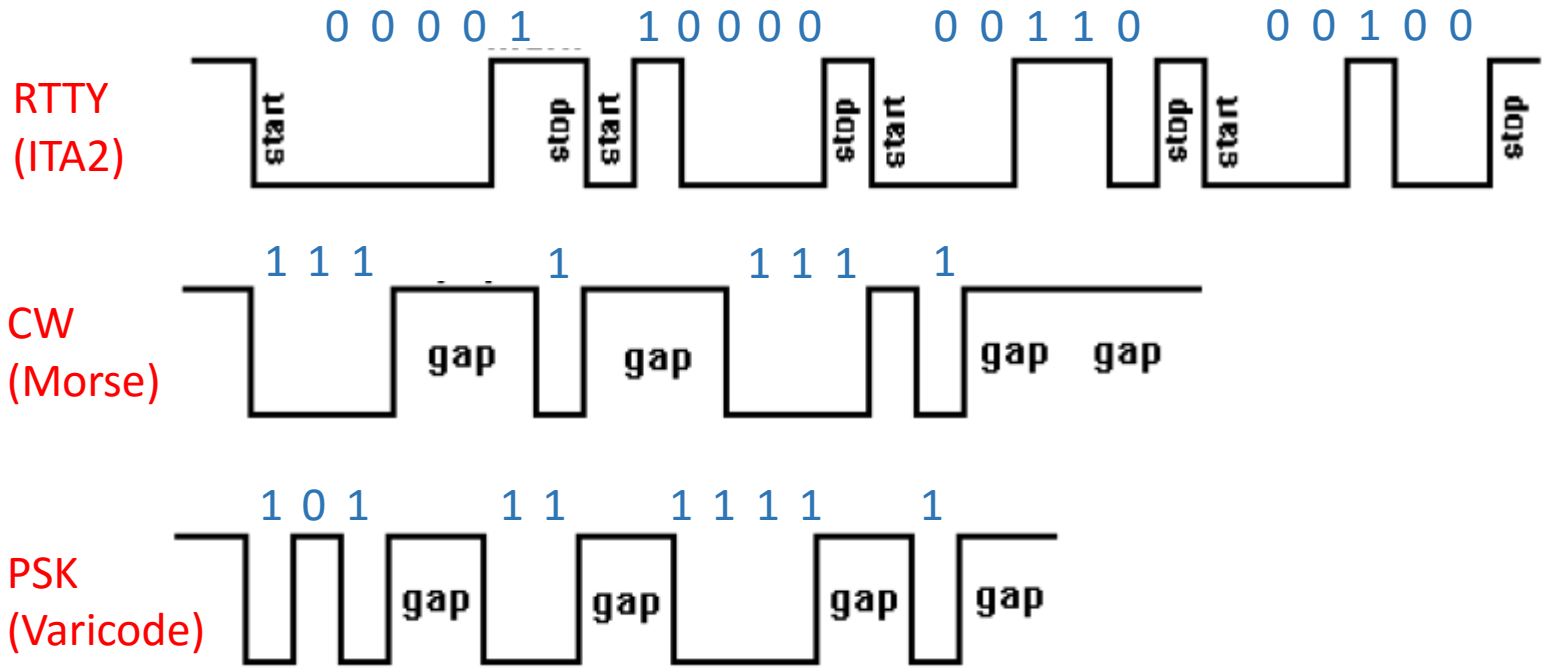
- 40 m – 7.035 MHz, 7.080 MHz
- 30 m – 10.142 MHz
- 20 m – 14.070 MHz
- 17 m – 18.100 MHz
- 15 m – 21.070 MHz
- 12 m – 24.920 MHz
- 10 m – 28.120 MHz

Weak Signal Digital Modes on HF-Bands
PSK vs FSK (RTTY)

- **BPSK 31** (ITU 60H G1B)
  - Modulations: PSK (binary)
  - Symbol rate: 31.25 baud (8 kHz/256)
  - Information rate: 50 Wpm
  - Bandwidth (practical): 60 Hz
  - Character coding: ASCII var. length "varicode"
  - Preamble: idle signal of continuous zeroes (= two tone signal)
  - Post amble: series of logical ones (= carrier signal)

- **RTTY 45** (ITU 270H F1B)
  - Modulation: FSK 170 Hz shift
  - Symbol rate: 45.45 baud
  - Information rate: 60 Wpm
  - Bandwidth (practical): 270 Hz
  - Character coding: 32/63 char/5 bit + start/stop (1.5 bit)
  - Idle condition "mark"

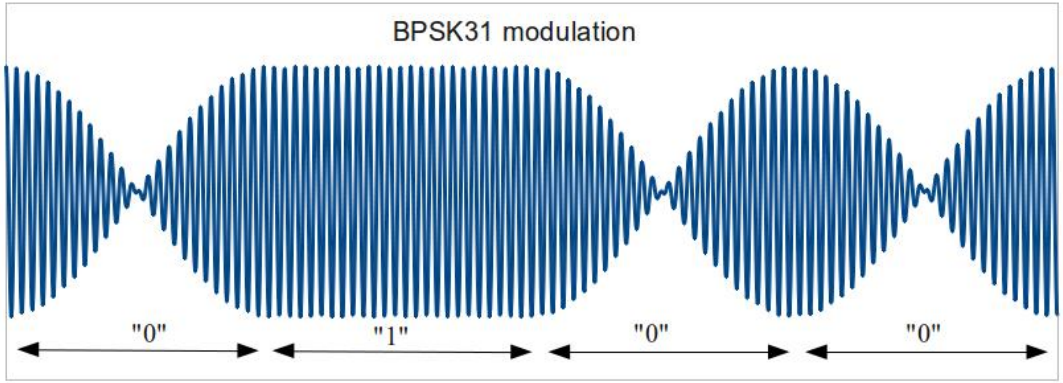
Character coding “ten ”



PSK 31

TX

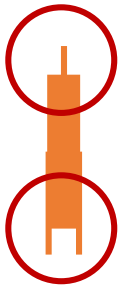
YB9RI/9



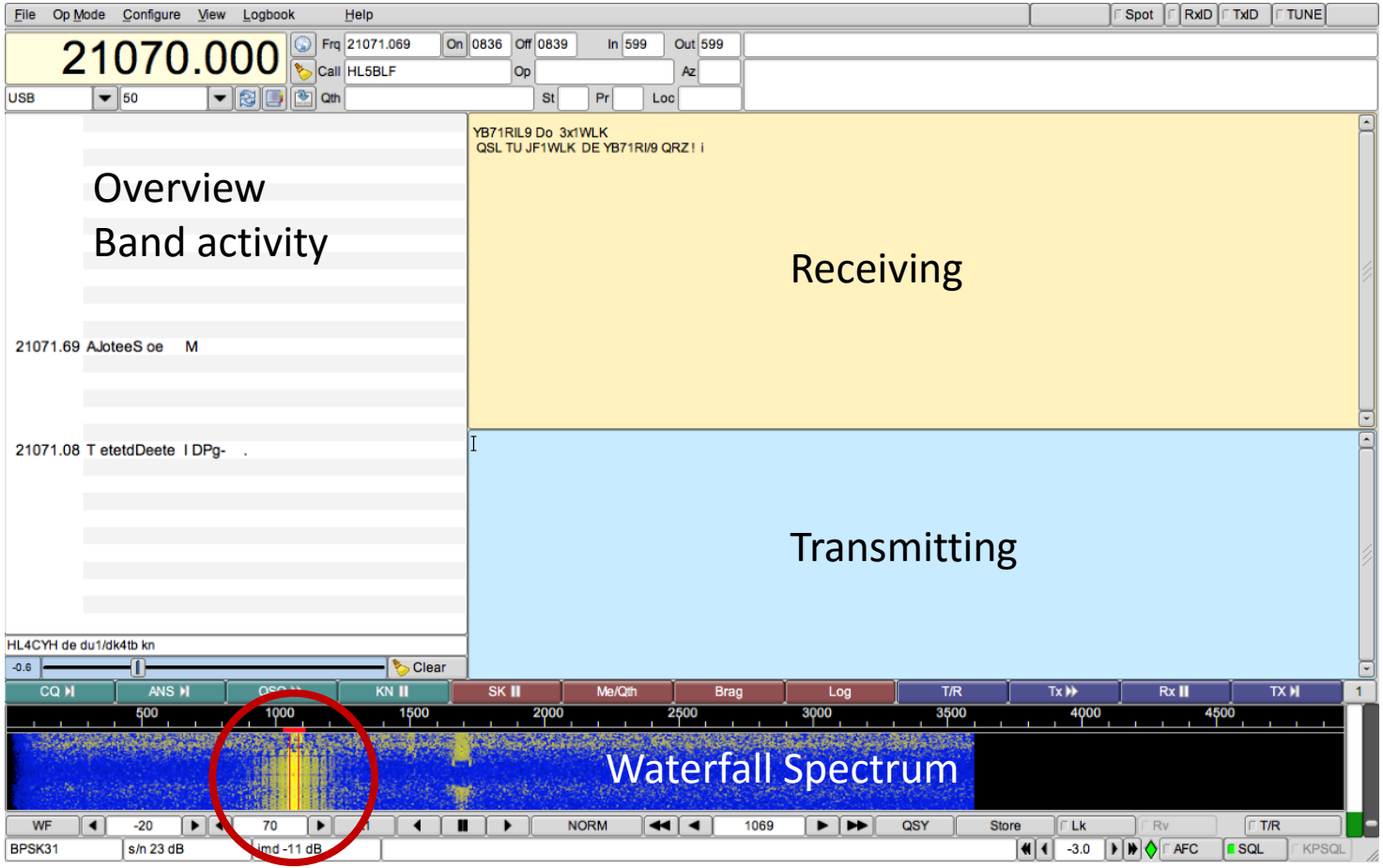
PSK-31

fldigi

Post amble



Pre amble



JT-65, JT-9

Background

- Developed by Joe Taylor, K1JT
- WSJT = Weak Signal Joe Taylor
- Originally for VHF/UHF EME, Meteor scatter
- Sub-modes JT65 A,B,C
- JT-9 intended for MF, HF

JT HF Frequencies

- 40 m – 7.039 MHz, 7.076 MHz
- 30 m – 10.139 MHz
- 20 m – 14.076 MHz
- 17 m – 18.098 MHz, 18102 MHz
- 15 m – 21.076 MHz
- 12 m – 24.917 MHz
- 10 m – 28.076 MHz

JT-65, JT-9

Background

- The first usable version of JT65 was finished in November 2003
- Open Source Programs WSJT, WSJT-X, WSPR on Windows/Linux/OS-X

JT HF Frequencies

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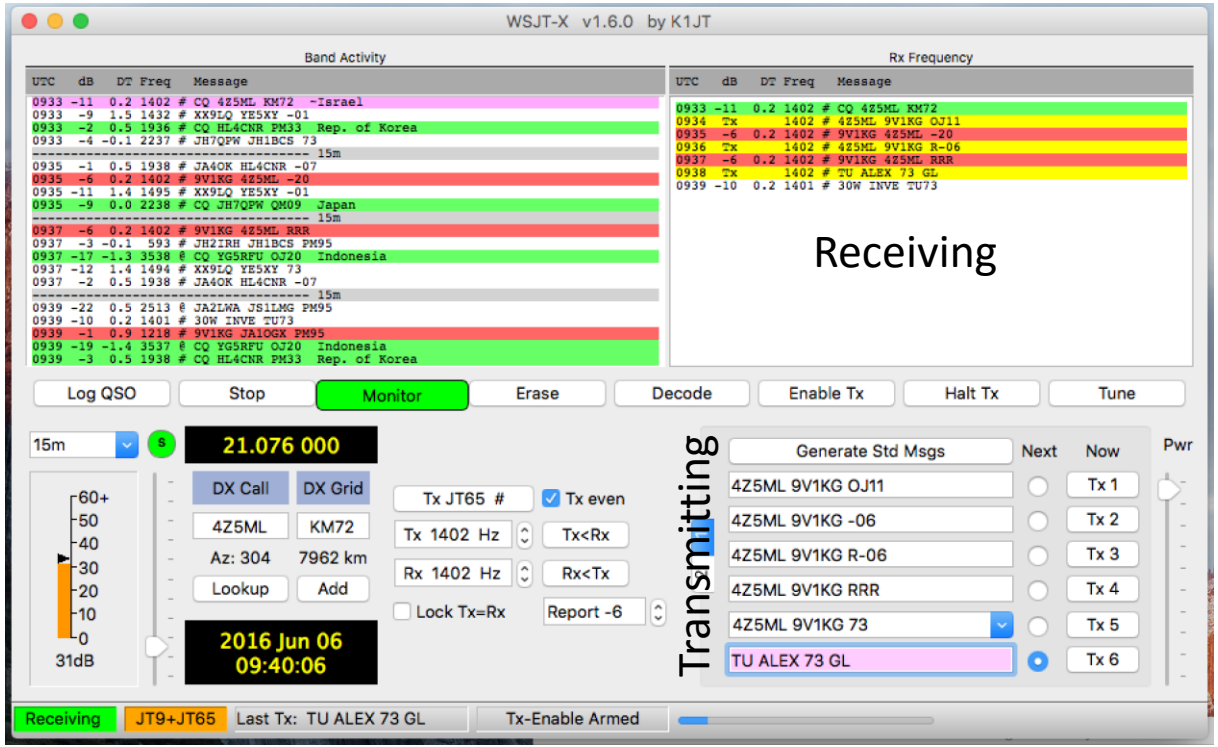
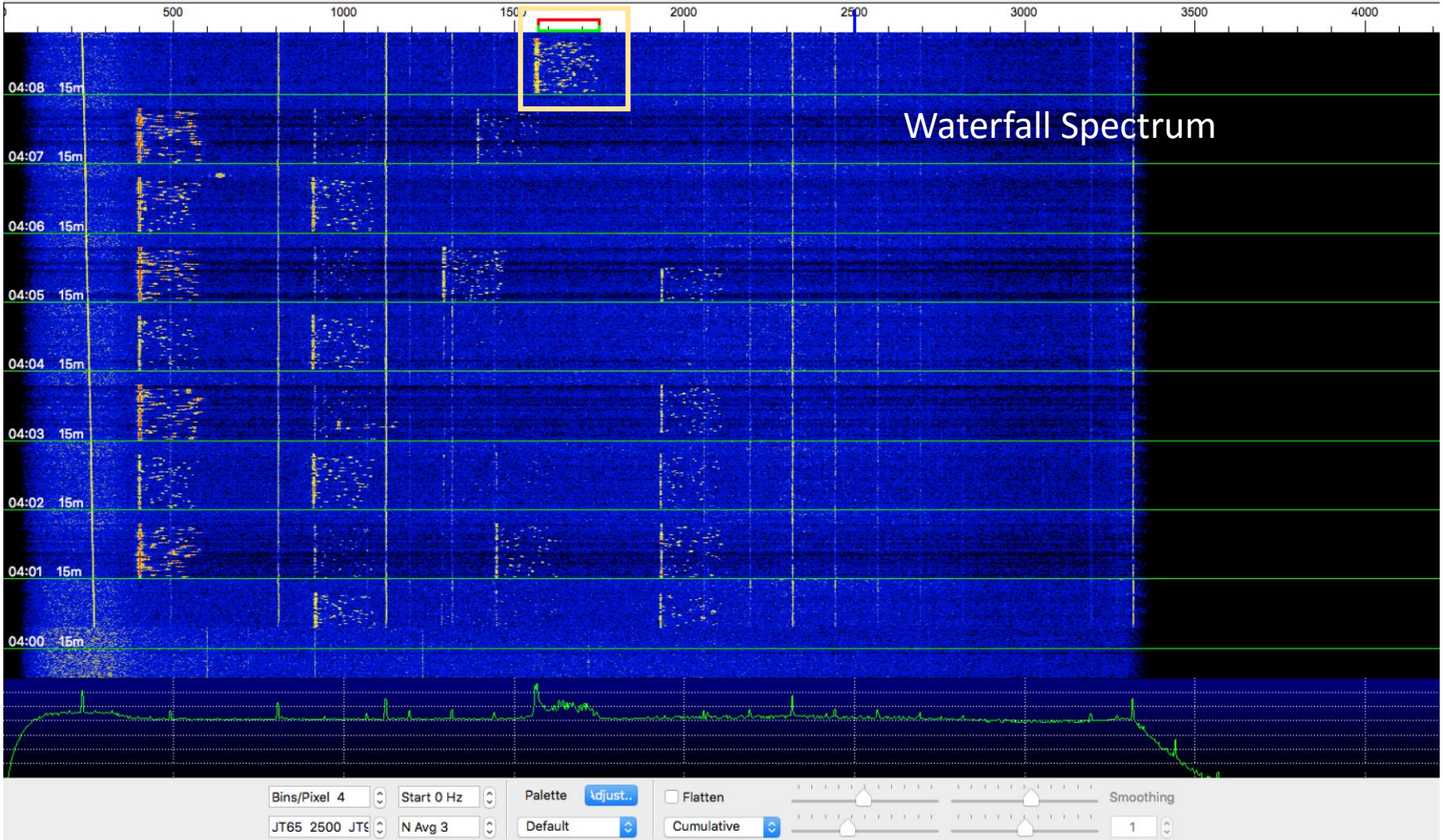
JT-65, JT 9

WSJT-X




500
1000
1500
2000
2500
3000
3500
4000
04:08 15m
04:07 15m
04:06 15m
04:05 15m
04:04 15m
04:03 15m
04:02 15m
04:01 15m
04:00 15m
Waterfall Spectrum
Bins/Pixel 4
Start 0 Hz
JT65 2500 JT9
N Avg 3
Palette
Adjust..
Default
Flatten
Cumulative
Smoothing
1

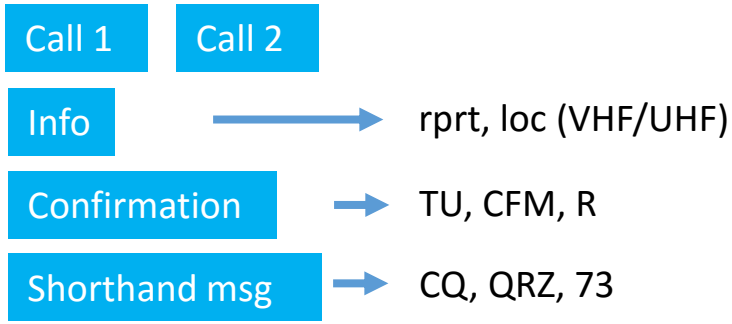
Weak Signal Digital Modes on HF-Bands JT-65A/JT-9

Typical Pile-up DX CW QSO

CQ DX DE 9V1KG UP	164 bit
1. DE DK3YD DK3YD	152 bit
2. DK3YD 5NN	99 bit
3. TU 599 5NN 73	151 bit
4. 73 TU 9V1KG	135 bit

Average information per message: 140 bit

QSO elements



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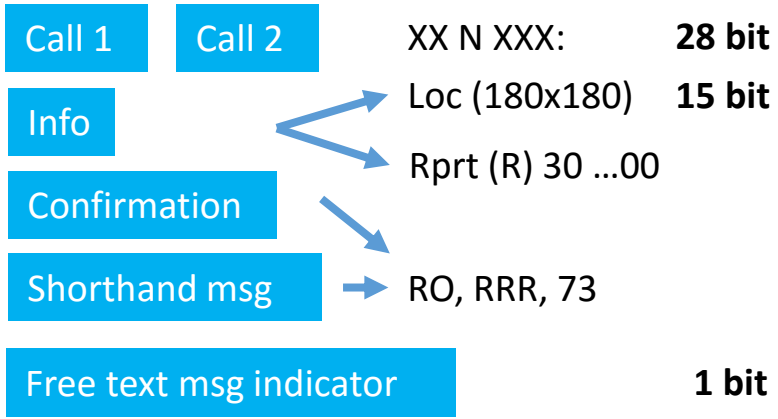

Weak Signal Digital Modes on HF-Bands JT-65A/JT-9

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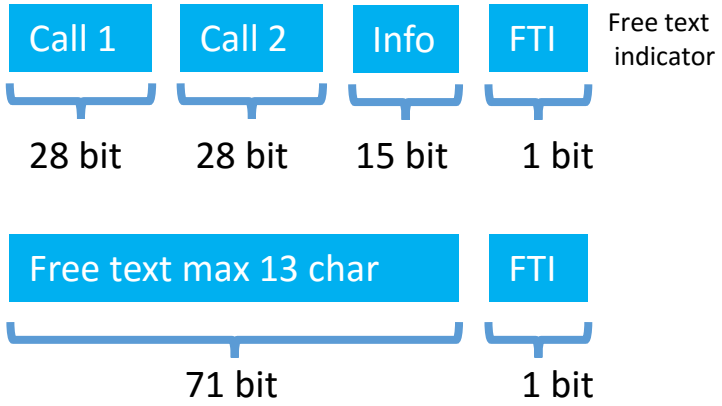
Average information per message: 140 bit

JT message structure



Source Coding: 72 bit

71 bit for 43 symbols -> 13 char

Weak Signal Digital Modes on HF-Bands JT-65A/JT-9

Typical Pile-up DX CW QSO

CQ DX DE 9V1KG UP
1. DE DK3YD DK3YD
2. DK3YD 5NN
3. TU 599 5NN 73
4. 73 TU 9V1KG

Average information per message: 140 bit

Typical JT HF qso

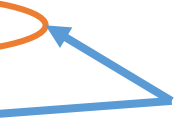
CQ DX 9V1KG OJ11
1. 9V1KG DK3YD JN58
2. DK3YD 9V1KG -14
3. 9V1KG DK3YD R-10
4. DK3YD 9V1KG RRR
5. TU KLAUS 73GL
6. DK3YD 9V1KG 73

per message: 72 bit

Weak Signal Digital Modes on HF-Bands JT-65A/JT-9

Typical Pile-up DX CW QSO

CQ DX DE 9V1KG UP
1. DE DK3YD DK3YD
2. DK3YD 5NN
3. TU 599 5NN 73
4. 73 TU 9V1KG



"FEC"
Forward Error Correcting

JT-9 FEC

72 bit information get added 31 bit error correcting and repeated twice:

(72 + 31) * 2 = 206 data bits

So called "Convolutional code K=32 r=1/2"

Average information per message: 140 bit

Data bits per message: 206 bit

Weak Signal Digital Modes on HF-Bands JT-65A/JT-9

Typical Pile-up DX CW QSO

CQ DX DE 9V1KG UP
1. DE DK3YD DK3YD
2. DK3YD 5NN
3. TU 599 5NN 73
4. 73 TU 9V1KG

Duration: 20 s

QSO rate: 180/h

Typical JT HF qso

CQ DX 9V1KG OJ11
1. 9V1KG DK3YD JN58
2. DK3YD 9V1KG -14
3. 9V1KG DK3YD R-10
4. DK3YD 9V1KG RRR
5. TU KLAUS 73GL
6. DK3YD 9V1KG 73

Duration: always 6 min

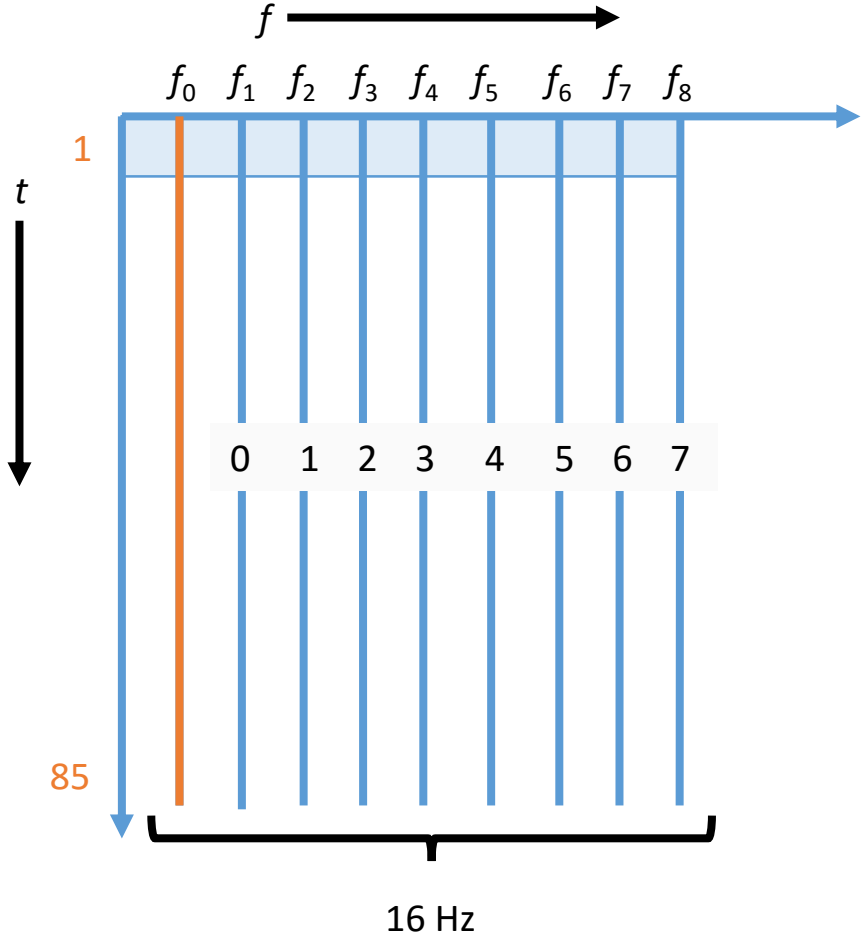
QSO rate: 10/h

No wrong calls or other errors, either correct or no decode!

Weak Signal Digital Modes on HF-Bands JT-65A/JT-9

- Transmission 1 sec after start of UTC minute
- Even minutes and odd minutes
- Message duration ≈ 49 s
- Decoding between 49 s and 60 s

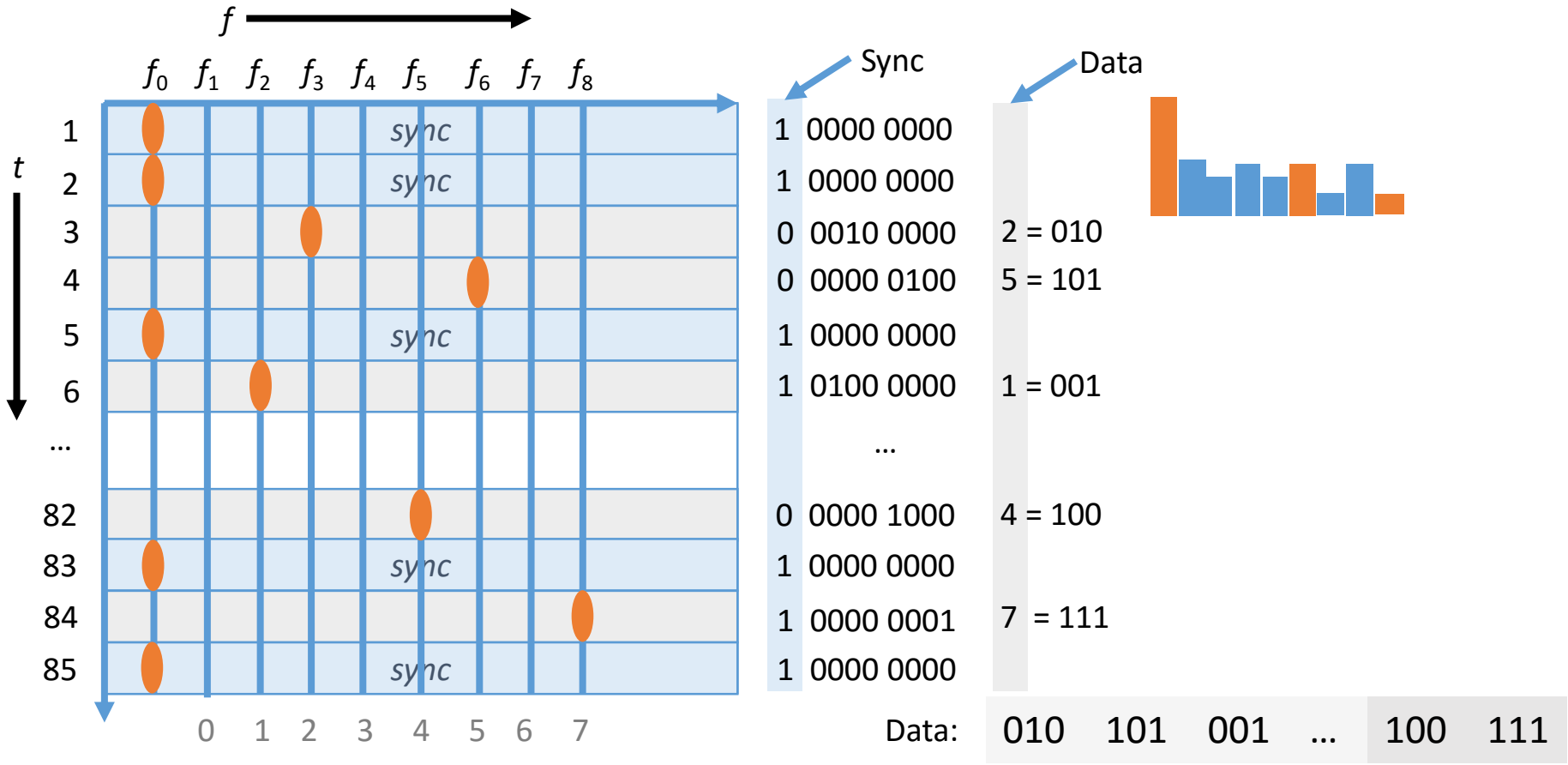
- Requirement: clock within +/- 1 sec of UTC

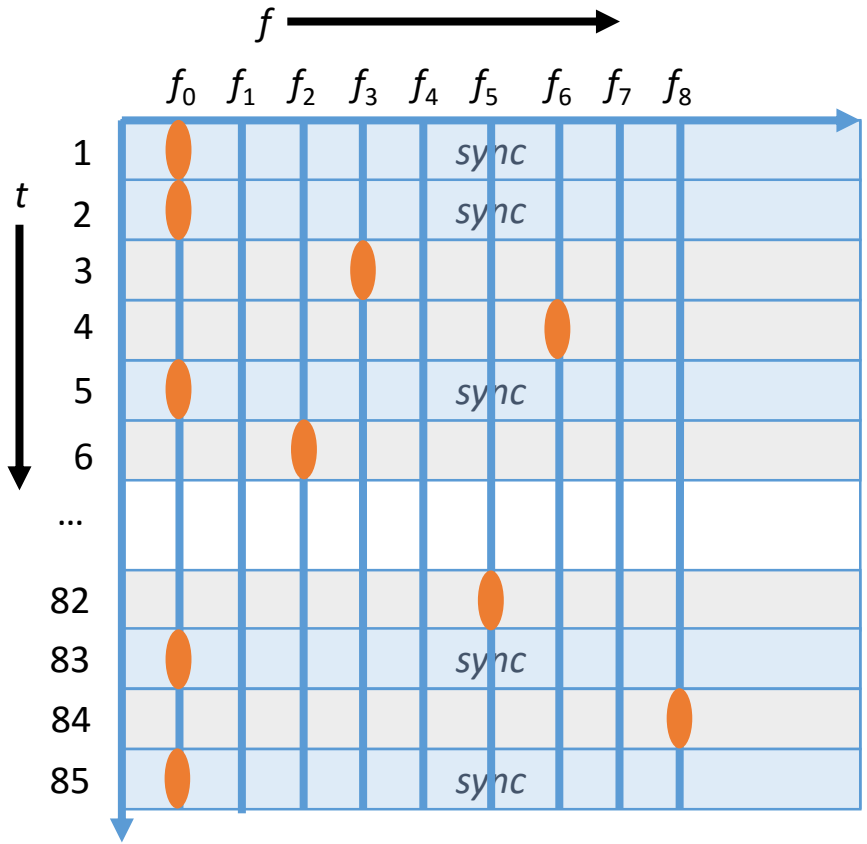


JT-9

- 9-FSK: 9 tones: f_0 … to f_8
- Bandwidth: 9 * 1.74 Hz per tone ≈ 16 Hz
- Sync tone: f_0 on 1270.5 Hz
- Sample rate: 12 kHz
- 1 timeslot (symbol) lasts 6912*) samples (0.576 s)
- 8 data tones can represent 3 bit information
- (72 + 31) * 2 = 206 bit data to transmit
- 206/3 = 69 timeslots + 16 sync bits: 85 timeslots

*) $6912 = 2^8\ 3^3$ FFT = PFA

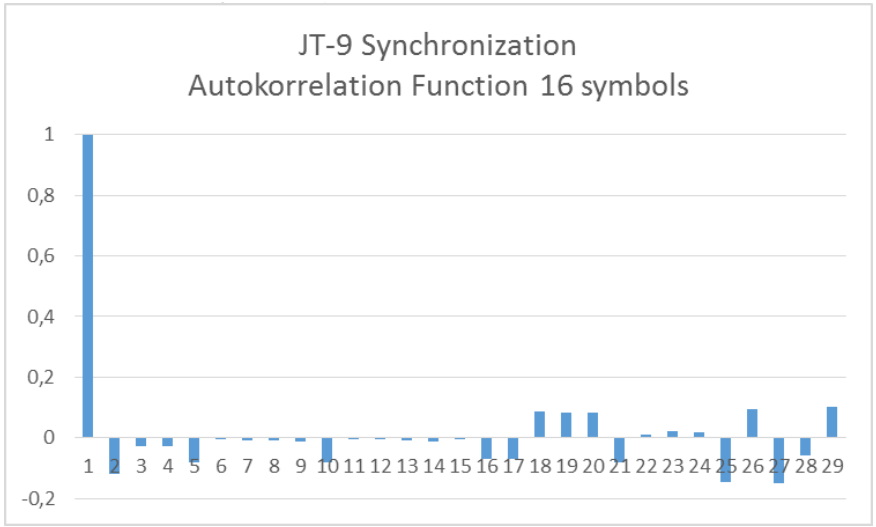

f
f_0 f_1 f_2 f_3 f_4 f_5 f_6 f_7 f_8
t
1 sync
2 sync
3
4
5 sync
6
...
82
83 sync
84
85 sync
0 1 2 3 4 5 6 7
Sync
Data
1 0000 0000
1 0000 0000
0 0010 0000 2 = 010
0 0000 0100 5 = 101
1 0000 0000
1 0100 0000 1 = 001
...
0 0000 1000 4 = 100
1 0000 0000
1 0000 0001 7 = 111
1 0000 0000
Data: 010 101 001 ... 100 111

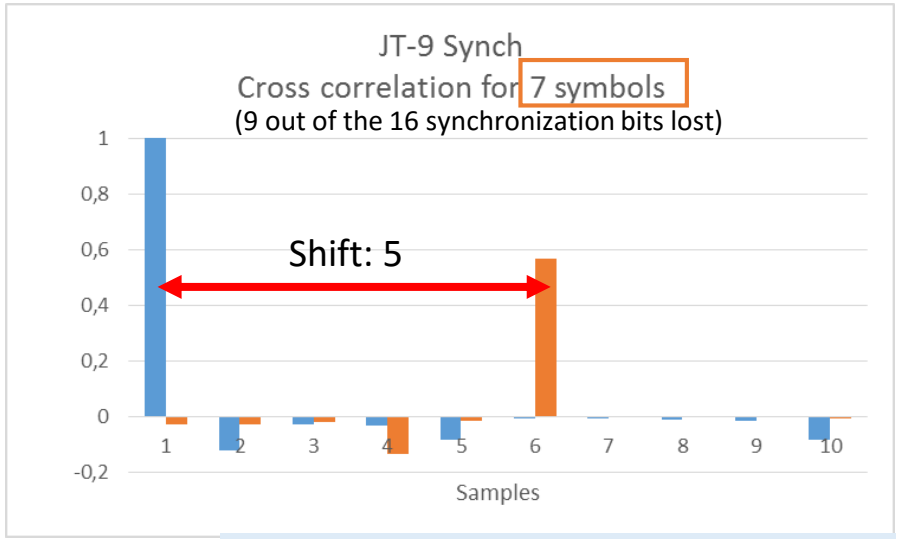


Sync:	110	001	101	...	0	101
Data:	010	101	001	...	100	111

Weak Signal Digital Modes on HF-Bands
JT-9

- Synchronization means tuning the signal to match the filter





Sync: 110 001 101 ... 0 101

Weak Signal Digital Modes on HF-Bands JT-65/JT-9

JT Signal reports

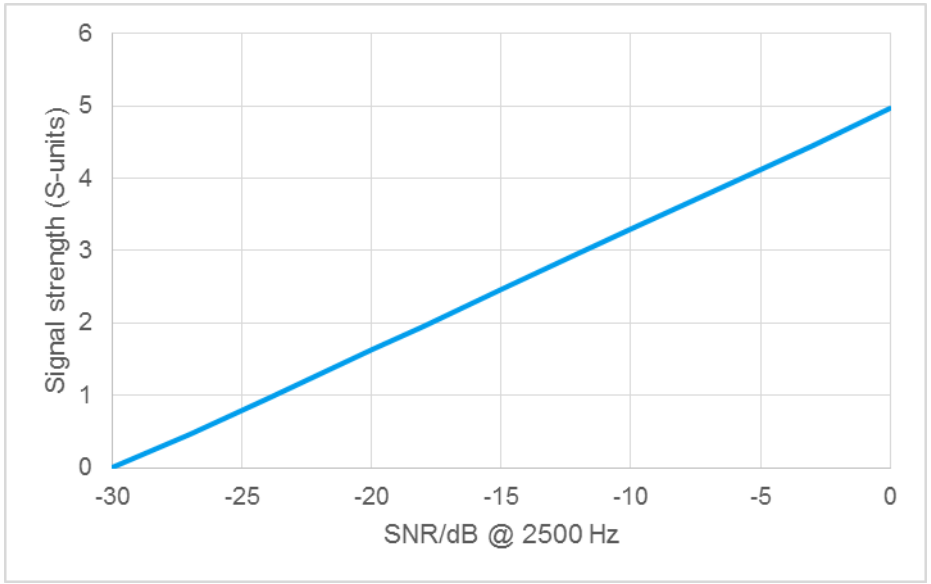
Range:

- JT-65: -30 … - 01 (dB)
- JT-9: -50 … +49 (dB)

- S/N in dB @ 2500 Hz BW

- Actual S/N @ 2.7 Hz BW: + 30 dB
- Visible: > -26 dB
- Audible: >-15 dB
- Decodable: ≈ -25 dB ≈ 4 … 6 dB S/N

- RST reports vs JT-65



Weak Signal Digital Modes on HF-Bands
JT-65A vs JT-9

JT-65 (ITU 180H F7B)

- Modulation: 65 tone MFSK (65-FSK)
- 63 data + 63 sync = 126 timeslots (symbols)
- Information rate: 2.6 WPM (13/5)
- Bandwidth (practical): 180 Hz (65 * 2.7)
  2.7 Hz per tone
- FEC: Reed Solomon RS(63,12)
  306 error correcting bits
- Data bits: 378
- Sync tone: 1270.5 Hz
- Frequencies: 1270.5 + 2.6917 (*N*+2) *m*
  N: 0 … 63, m: 1,2,3 = sub mode A, B, C

• **JT-9** (ITU 16H F7B)

- Modulation: 9 tone MFSK (9-FSK)
- 69 data + 16 sync = 85 timeslots (symbols)
- Information rate: 2.6 WPM (13/5)
- Bandwidth (practical): 16 Hz (9 * 1.736)
  1.74 Hz per tone
- FEC: Convolutional code K=32 r= ½
  31 error correcting bits 2 times
- Data bits: 206
- Sync tone: 1270.5 Hz
- Frequencies: 1270.5 + 1.7361 *N*
  N: 0 … 8

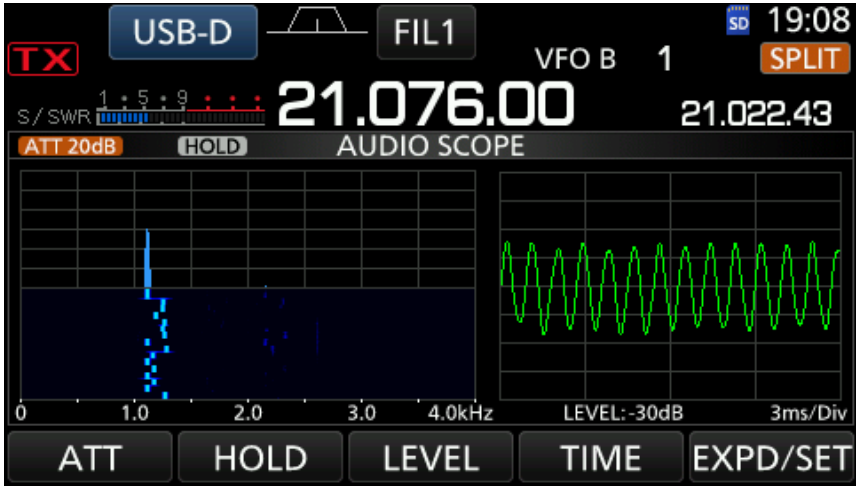
Conventional reference bandwidth = 2500 Hz

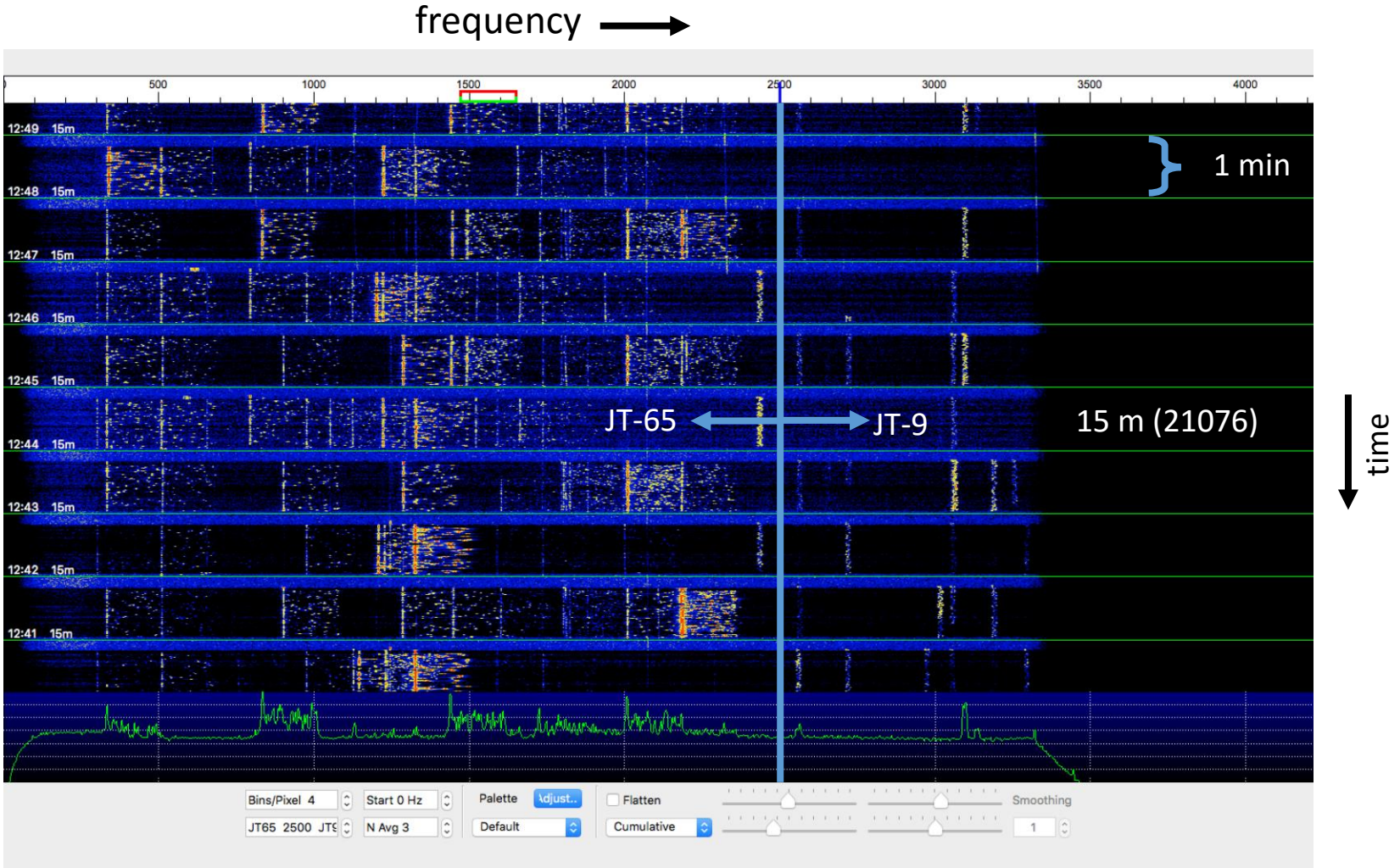
Weak Signal Digital Modes on HF-Bands
JT-65/JT-9

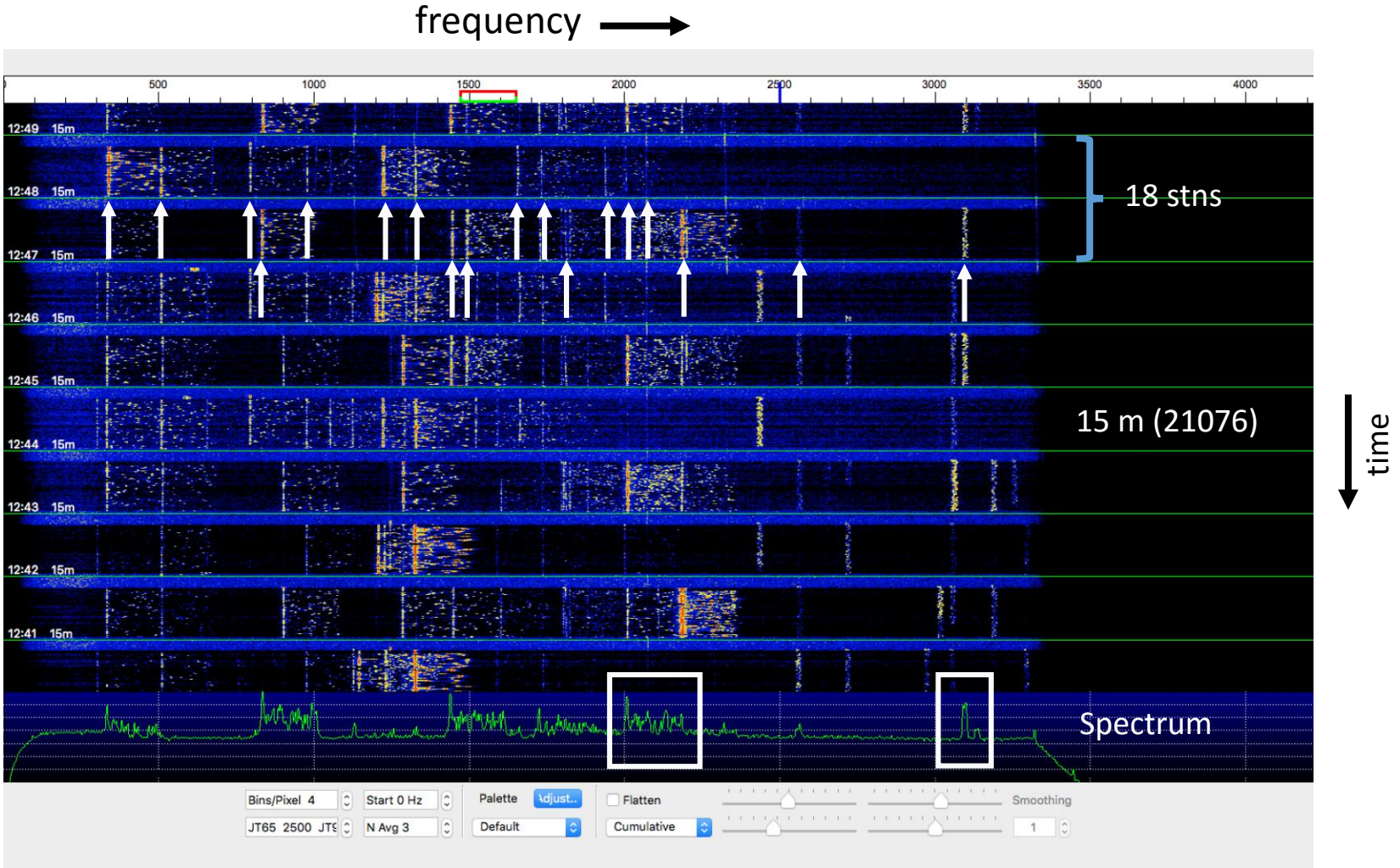
JT-65 TX

JT-9 TX

RX




frequency
500
1000
1500
2000
2500
3000
3500
4000
12:49 15m
12:48 15m
12:47 15m
12:46 15m
12:45 15m
12:44 15m
12:43 15m
12:42 15m
12:41 15m
1 min
JT-65
JT-9
15 m (21076)
time
Bins/Pixel 4
Start 0 Hz
JT65 2500 JT9
N Avg 3
Palette
Adjust..
Default
Flatten
Cumulative
Smoothing
1


frequency
500
1000
1500
2000
2500
3000
3500
4000
12:49 15m
12:48 15m
12:47 15m
12:46 15m
12:45 15m
12:44 15m
12:43 15m
12:42 15m
12:41 15m
18 stns
15 m (21076)
time
Spectrum
Bins/Pixel 4
Start 0 Hz
Palette
Adjust..
Flatten
Smoothing
JT65 2500 JT9
N Avg 3
Default
Cumulative
1

Weak Signal Digital Modes on HF-Bands
Some Practical Tips

- PSK needs amplifiers w/o phase distortion –
  reduce audio for no ALC
- PSK typical power < 30 W
- JT-65 and JT-9 are "**weak signal modes**" (QRP) and should be used on HF with low power output (5 … 30 W)
- Double check your computer clock running within 1 sec of UTC
- Use split frequency operation for rare stations in JT
- You can shorten JT QSO: 9V1KG RRR + 9V1KG 73 = 9V1KG R73

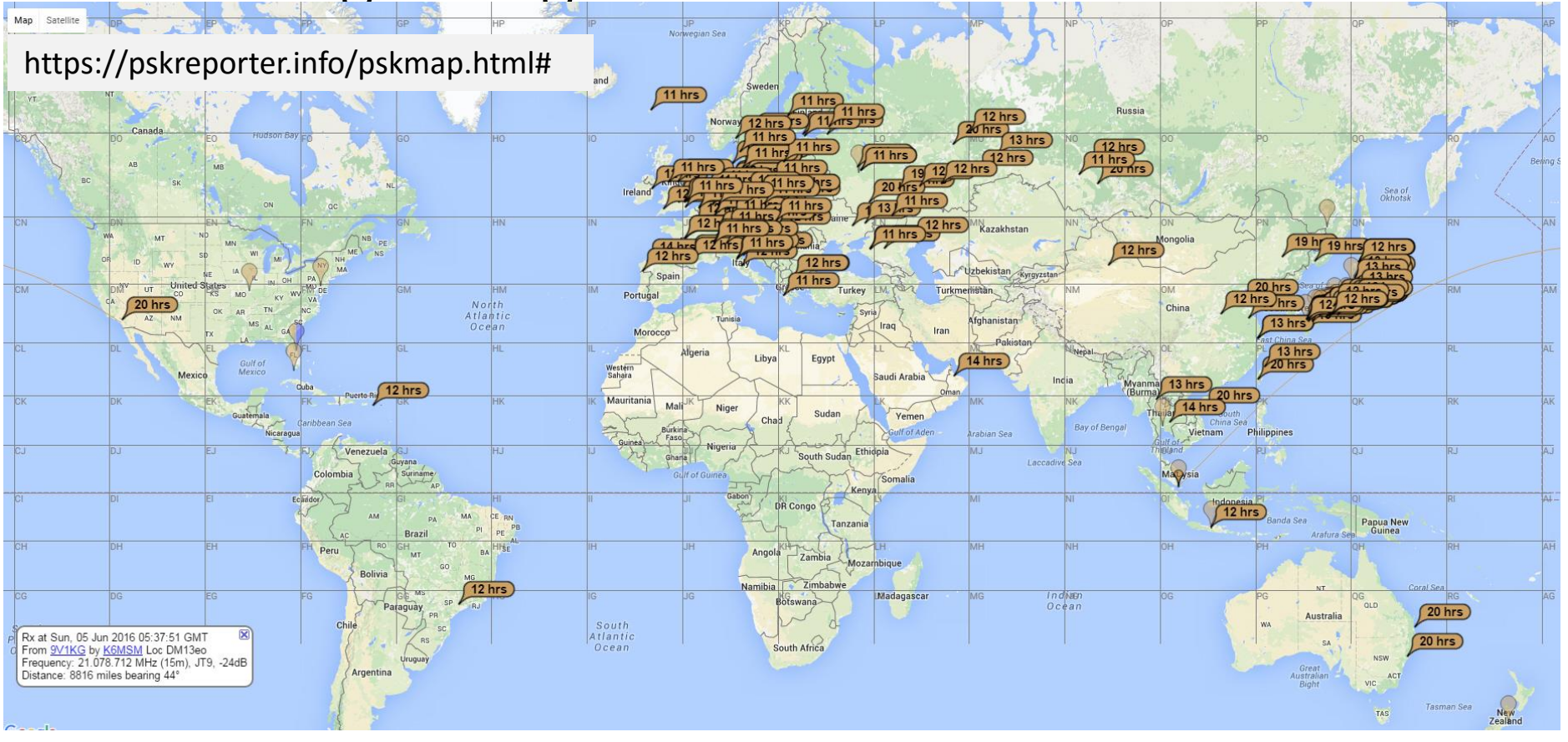
Weak Signal Digital Modes on HF-Bands

PSK Reporter

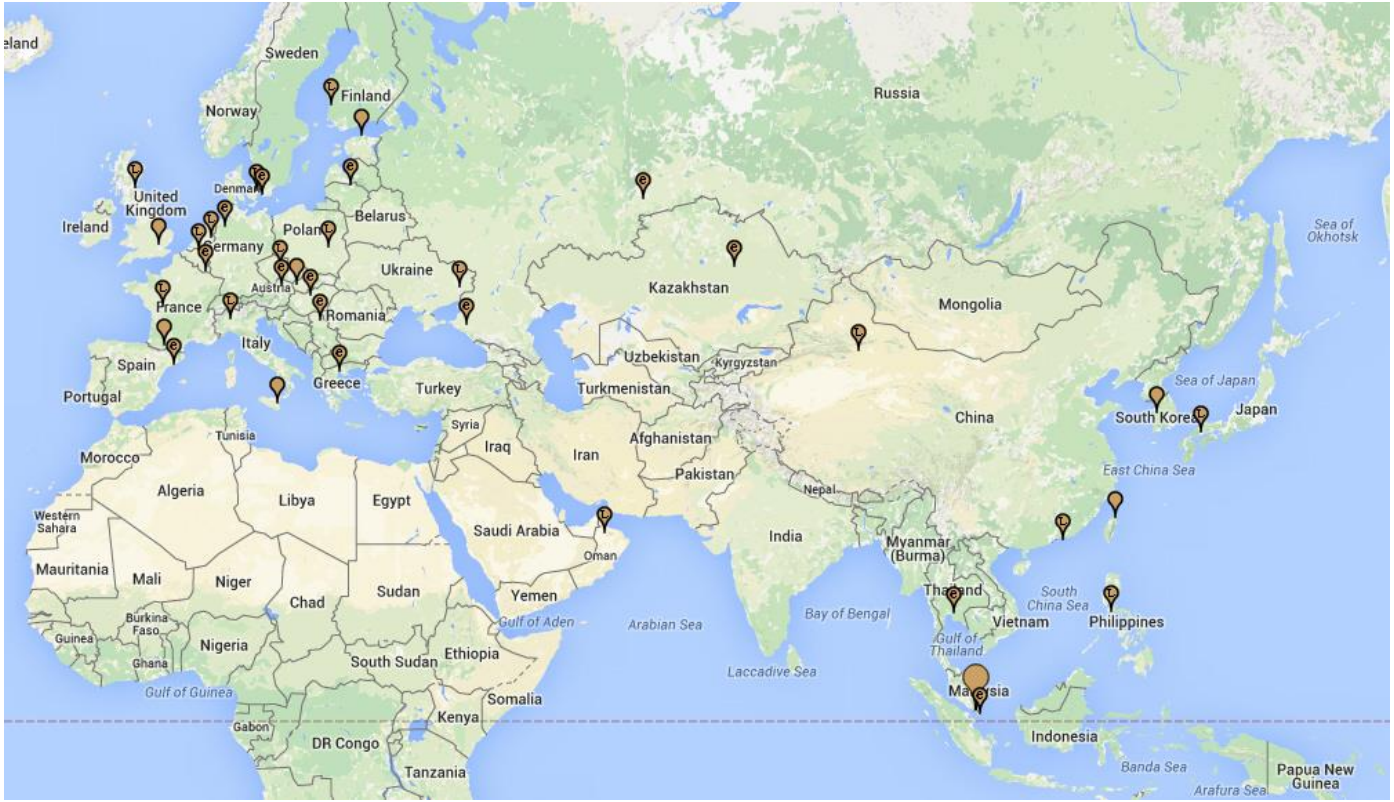
by Philip Gladstone

- Web server that gathers reception reports sent by various other programs, including WSJT-X.
- Information is made available in near real time on a world map
- Statistical summaries of various kinds.
- Map showing world-wide JT65 activity on all amateur bands over the past hours.
- Link: https://pskreporter.info/pskmap.html#

Weak Signal Digital Modes on HF-Bands



Weak Signal Digital Modes on HF-Bands



Weak Signal Digital Modes on HF-Bands

More information:

- PSK31: A new radio-teletype mode with a traditional philosophy. Peter Martinez, G3PLX: http://det.bi.ehu.es/~jtpjatae/pdf/p31g3plx.pdf
- The JT65 Communications Protocol, Joe Taylor, K1JT: http://pulsar.princeton.edu/~joe/K1JT
- W5ZIT Interface from fldigi manual: http://www.w1hkj.com/FldigiHelp-3.21/html/w5zit_rt_channel_page.html
- Amateur Radio HF Digital Mode Frequencies: http://ciarc.org/downloads/Digital_Mode_Band_Plan.pdf
- IC-7300 and fldigi: http://klsin.bpmsg.com/ic-7300-and-fldigi/
- This presentation: http://klsin.bpmsg.com/?p=275

Weak Signal Digital Modes on HF-Bands

Thank You!

9V1KG
Klaus Goepel
Aug 2016