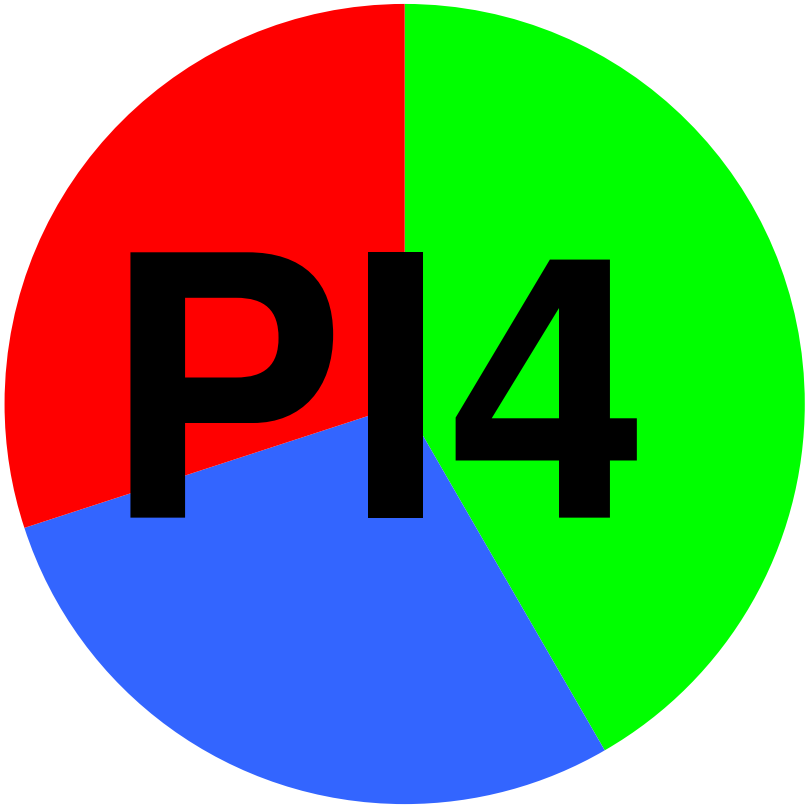
PI4 the Digital mode for Beacons and why is it a success

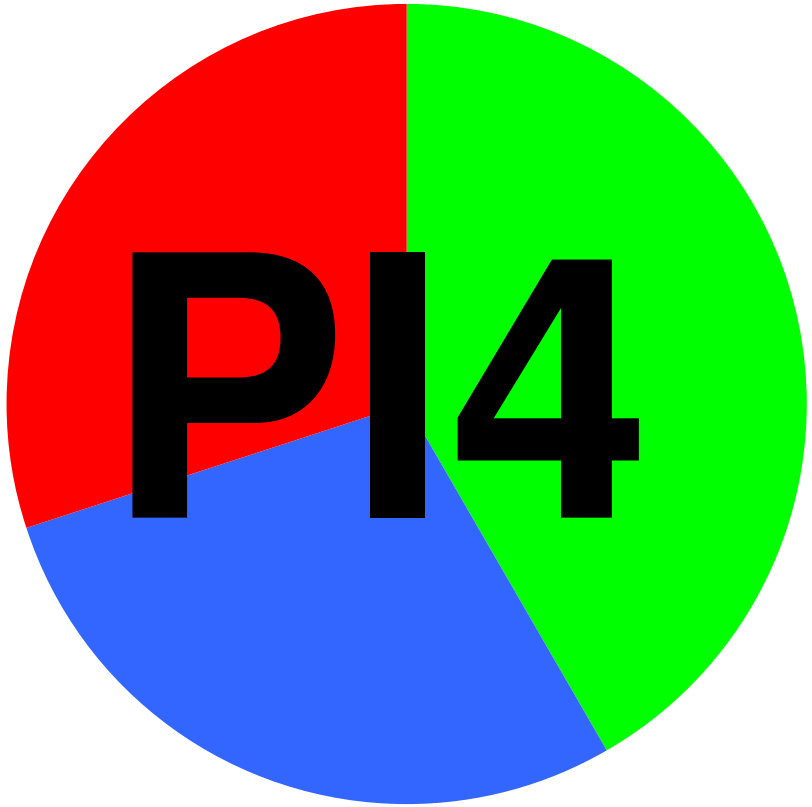
Bo Hansen, OZ2M



RSGB 2018 Convention

The success of PI4

- What is PI4
  - Why was PI4 designed
  - Why is PI4 the way it is
- The success of PI4
  - The numbers
  - What do the users say
  - The PI-RX decoder
- What's next?
  - The Synchronised Beacon Project
  - Should your beacon use PI4?



Why there is more than one type of footwear

Ice	✔	✘	~
Football	✘	✔	~
Hiking	✘	✘	✔
Unknown	?	?	✔

There are no free lunches when it comes to sensitivity, flexibility, robustness and speed

Who are the potential users of beacons?

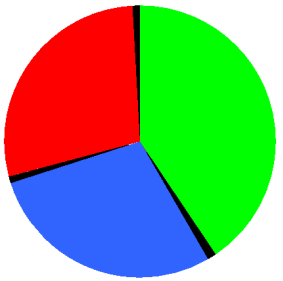
1	**FM user**	Never uses beacons DX-ing has no appeal May become 3)
2a	**Analog DXer**	Understands propagations and beacons Not interested in digital communication
2b	**Mixed mode DXer**	Understands propagations and beacons Uses whatever it takes to make a QSO and sees the benefits of both analog and digital
3	**Digital user**	Only preference is digital communication Does not really understand propagations May become 2b)

The recent OZ7IGY history

- To add a digital modulation to the OZ7IGY beacons
- What did the users say?
  - Just the way it is, i.e. CW and carrier
  - MGM only – CW only
  - More carrier, less carrier, no carrier
  - EME training beacon, i.e. JT65B
  - Identical sequence all the time
  - Frequent identification
  - MGM decodable via aurora and rain scatter
  - Fits into the existing beacon spacing(s)
  - Identical tuning for all parts of the sequence
  - More power, less power

- Conclusion: a general purpose 1 min sequence with MGM + CW + carrier

The PI4 design



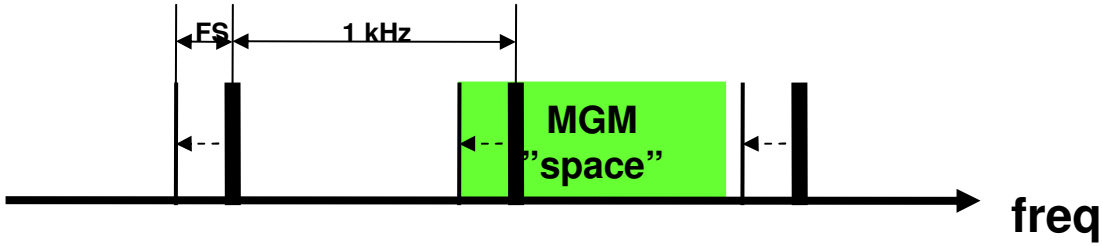
- PI4 is derived from JT4
  - All the modes found in WSJT and WSPR were evaluated
- Wide spaced (234 Hz) four tone modulation for general purpose beacons
- The wide spaced tones make PI4 robust to heavy distortion and multi-path propagations
- The sensitivity is between -22 dB and -23 dB (2500 Hz BW)
- A PI4 transmission takes 24⅓ s and has a payload of eight characters

- PI4 is part of a 60 s mixed mode sequence, PI4 + CW + carrier
  - Most WSJT modes will require a different sequence each minute
  - 360 PI4 symbol durations in 60 s making averaging simple and CPU friendly
- A mixed mode PI4 sequence has 1 s less carrier per minute than the equivalent JT4 (1093 ms) and JT65 (1344 ms) sequences
- PI4 is defined relative to the nominal beacon frequency

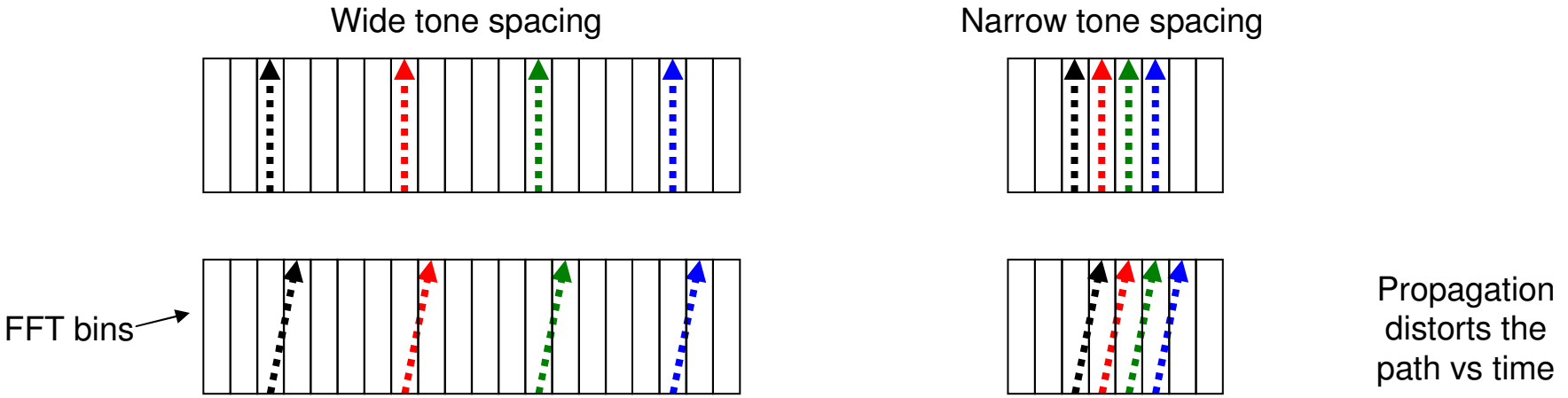
- The PI4 name comes from the ancient words for beacon, lighthouse and fire - Pharos (from Greek to Latin pharus and coming from the Lighthouse of Alexandria), Ignis (Latin: fire) and 4 for the four FSK tones

Tone spacing design

All the RF generated must fit into the beacon structure(s)



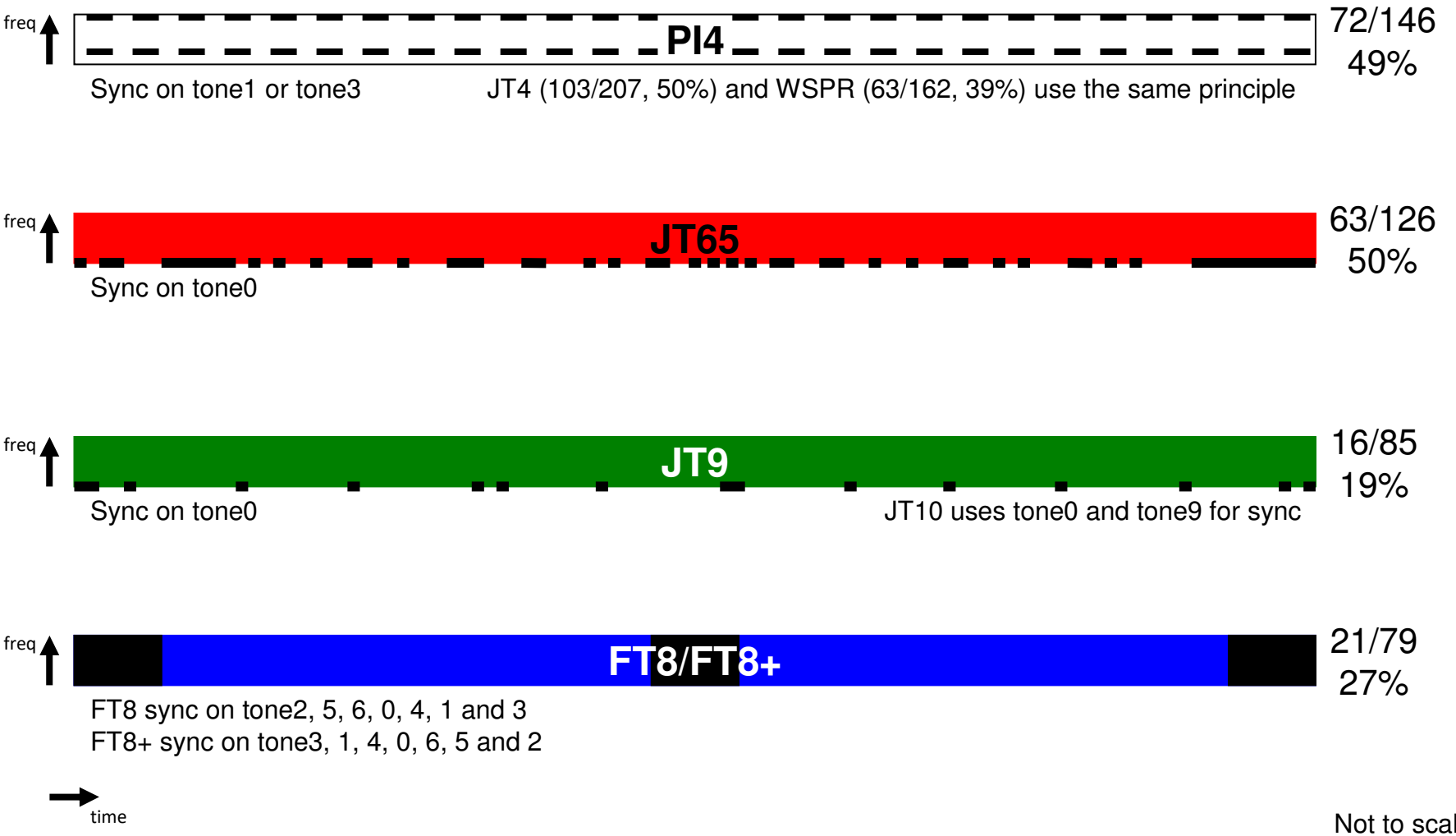
Robustness comes from wide tone spacing - among other things



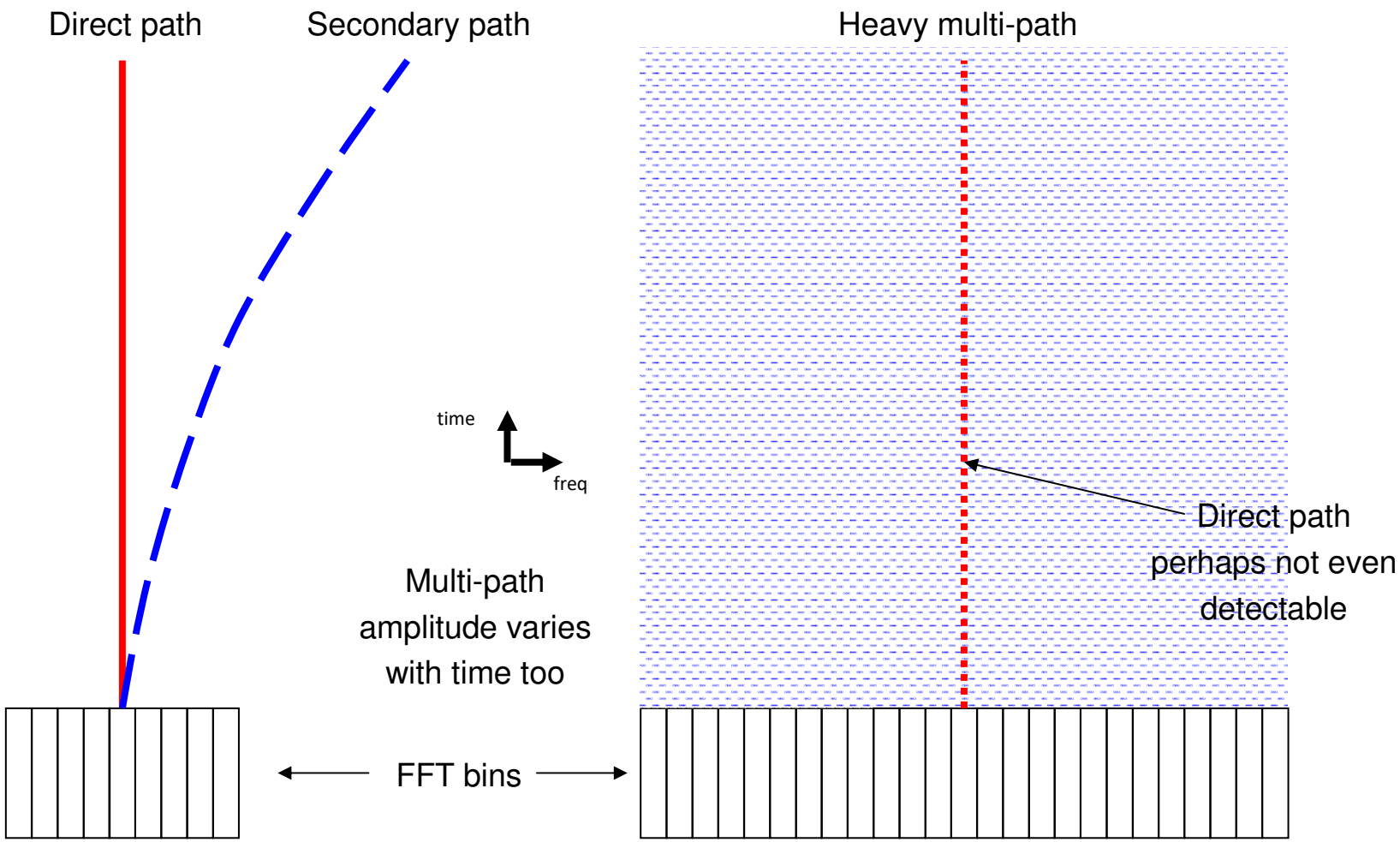
Sensitivity is nonsense

Link Probability is the ONLY thing that matters

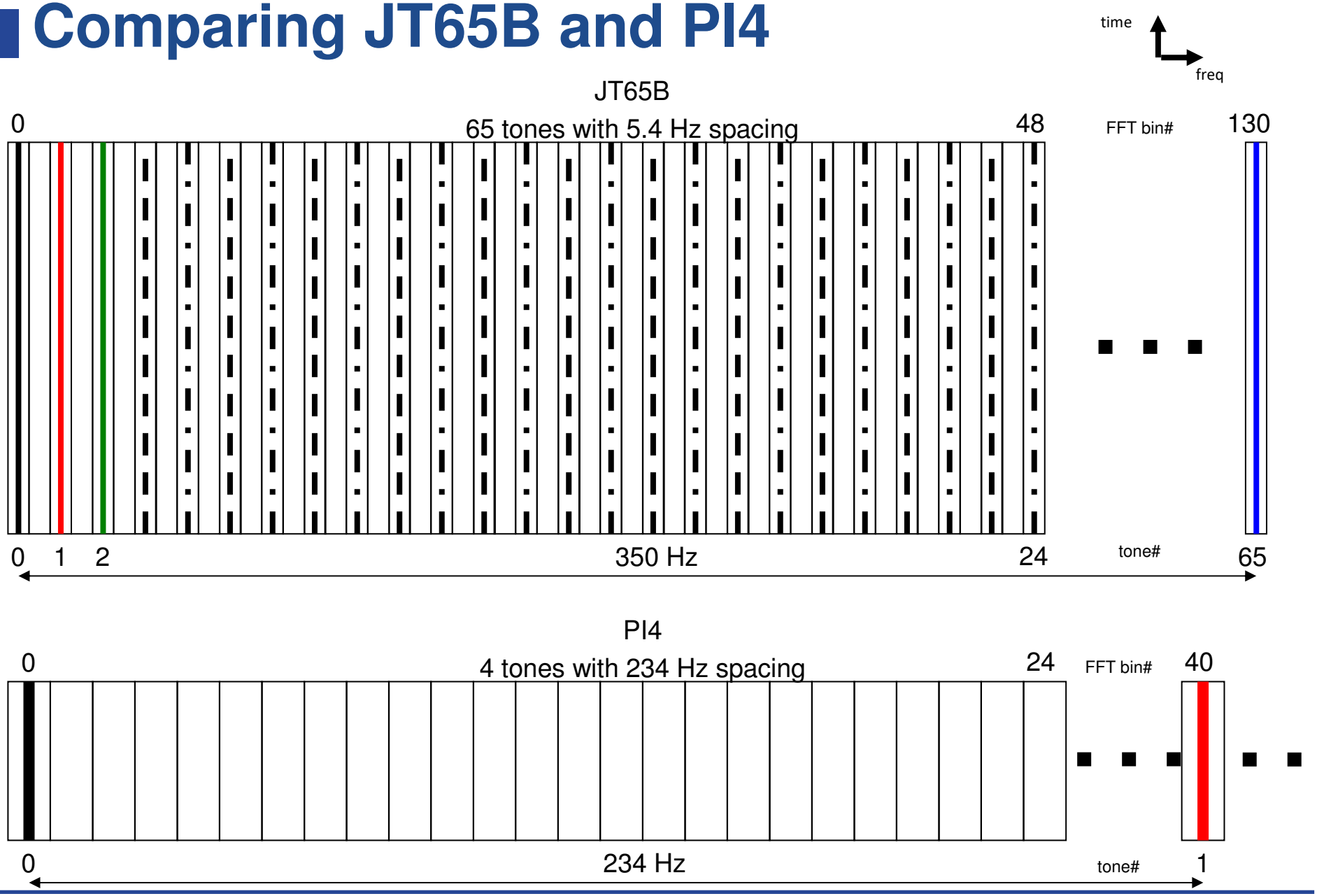
The distribution of the sync tone(s)



Multi-path propagation examples

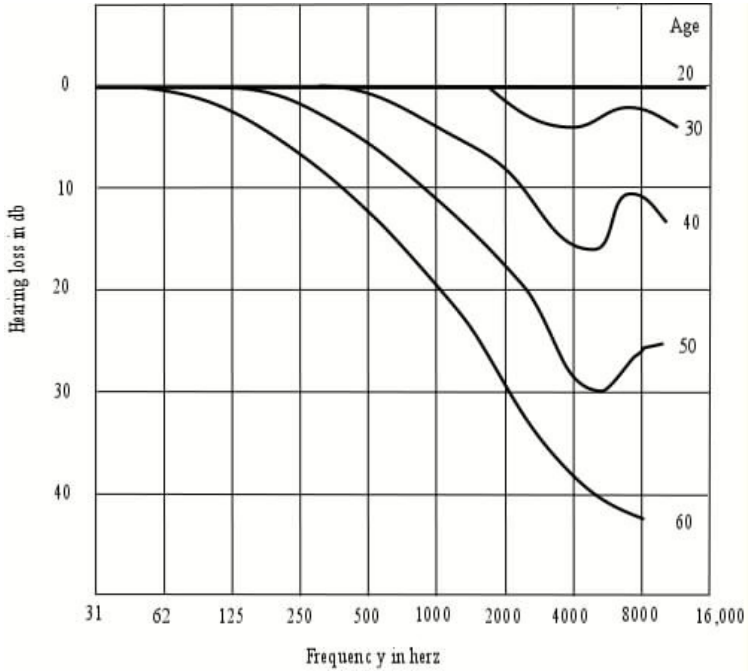


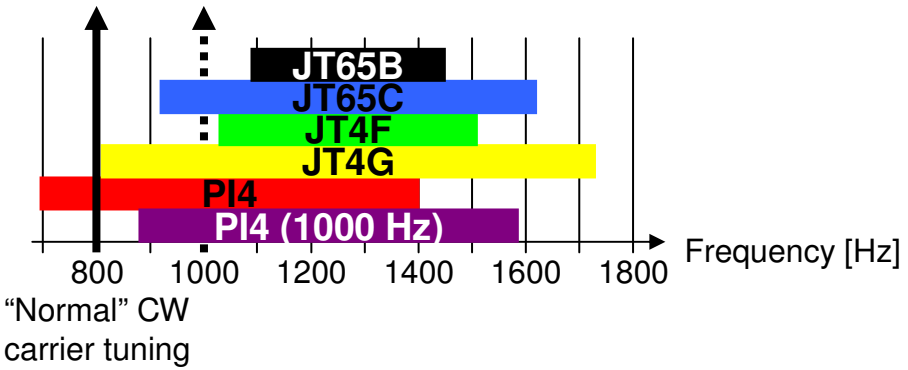
Comparing JT65B and PI4



Don’t leave the humans behind

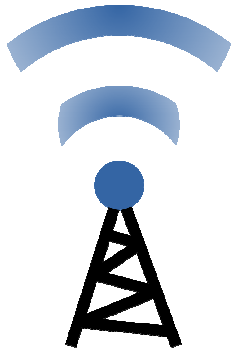
- The PI4 + CW + carrier sequence uses identical and normal beacon tuning offset for the entire sequence
- Traditionally the CW beat tone is 800 Hz but many use 600 Hz to 700 Hz
  – PI4, MSHV and PI-RX don’t care!
- Morgan, SM6ESG, says that he hears the PI4 tone0 better than the carrier/CW from OZ7IGY





“Normal” CW carrier tuning

The success of PI4 beacons



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European MGM beacons on beaconspot.uk use PI4

Hardware implementations

19 different devices and from kHz to GHz

D. Auras
Raspberry Pi

PA0AG
AD9851

SR9RMF
AD9957

G4JNT
AD9852, LMX2470/2571

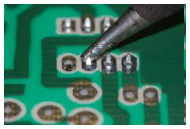
G8ACE
RDDS

DL8AAU
PLVCXO

OZs
NGB, PI4ino (13), RFzero

G0UPL
Ultimate3S

VA2GKA
TinyBeacon



In PLLs wide spaced tones are easier to implement than narrow ones

Feedback from the questionnaires (1)

- On what bands are you QRV?
  - From HF to 24 GHz
- How often do you listen to a PI4 beacon?
  - During openings, several times a month, weekly, daily
- What is your primary use of a PI4 beacon?
  - Checking propagations and station/antennas
- Why is a PI4 beacon useful to you?
  - Automatically check conditions, propagation baseline, meaningful consistency and calibration

Feedback from the questionnaires (2)

- What disadvantages do you see in a PI4 beacon?
  - Difficult to implement on old H/W, short openings difficult to detect, to many MGMs around, dedicated S/W
- What is your view on the PI4 + CW + carrier sequence?
  - Very good, good mix of old (human modes) and new (MGM)
  - To much MGM in the sequence better to have 1:4, 1:5 …
- Are there other modes and/or sequences you prefer?
  - No don't change it
  - Opera (easier to implement)
  - Not prefer but like too: FT8, JT4G and WSPR

Feedback from the questionnaires (3)

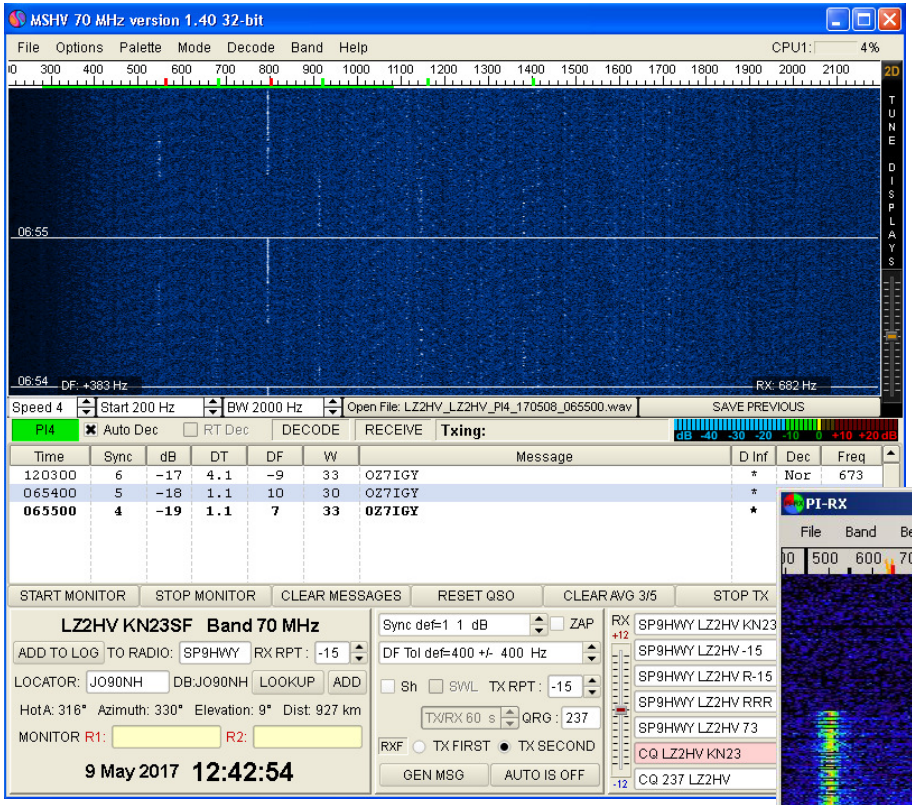
- Other comments
  - CW is decoded by ear and before JT4G, Opera or PI4
  - It is a battle of MGMs
  - Beacons are now built by young OPs only
  - Digital modes push the limit
  - All exiting beacons should be converted

Importance and findings

	Average	Lowest
Both analog and digital sequence	4.4	2
Same sequence every minute	4.2	2
The sequence does not sound like a “birdie”	4.0	2
GPS locked (frequency and time)	4.2	2
Robustness of PI4 (aurora, FAI, rain scatter)	4.5	4
How sensitive do you find MSHV/PI-RX	4.4	4
How easy to use do you find MSHV/PI-RX	4.5	4

where 1: not important/agree/true, 5: very important/agree/true

The success of PI4 decoders

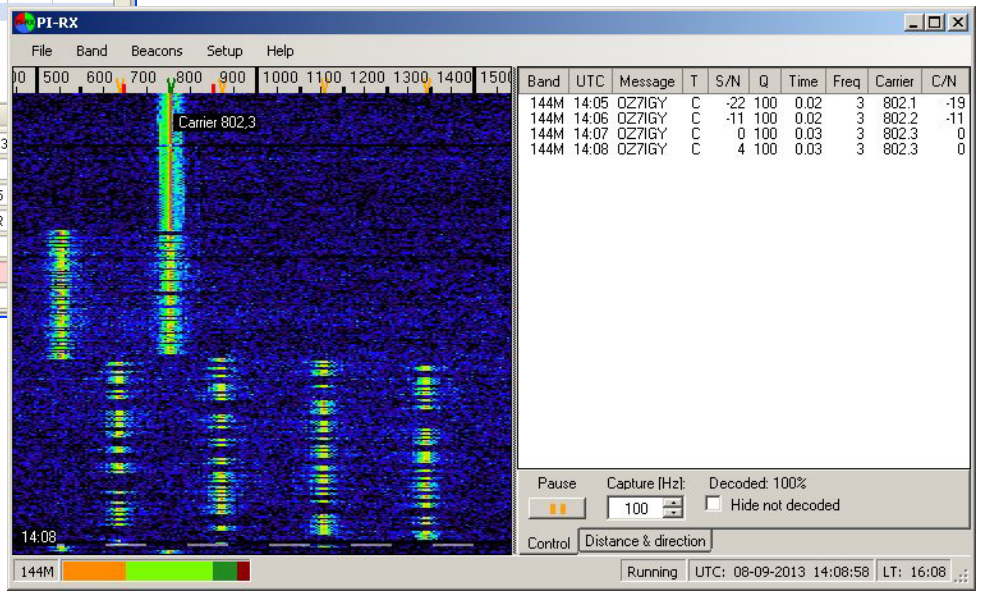


MSHV: WSJT JT4 decoder 1:1 translation

Two completely independent decoder programs

PI4 has been decoded via aurora, meteor, multi-path and rain scatter

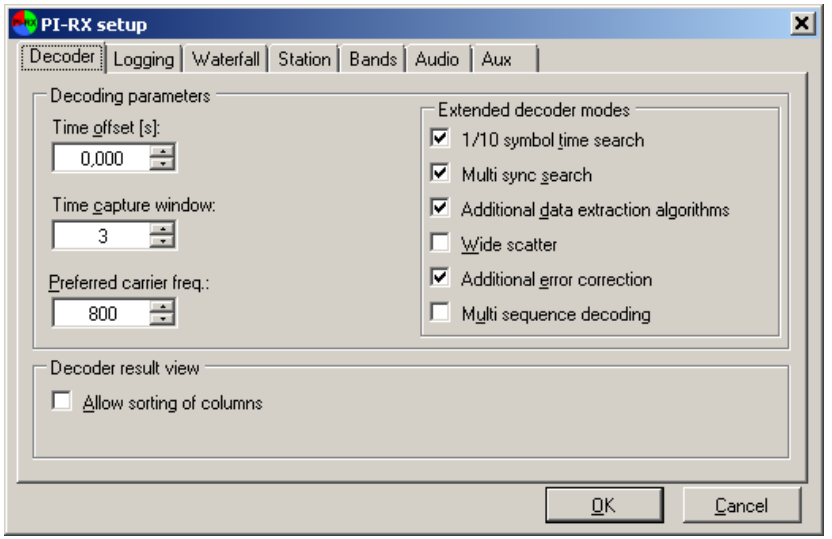
PI-RX



PI-RX: Poul-Erik, OZ1CKG, own design on top of a Fano decoder

The PI4 decoders (1)

- 1/10 symbol time search
  - The decoder uses a series of 16 ms time width overlay methods to identify the signal
  - Good to find multipath signals

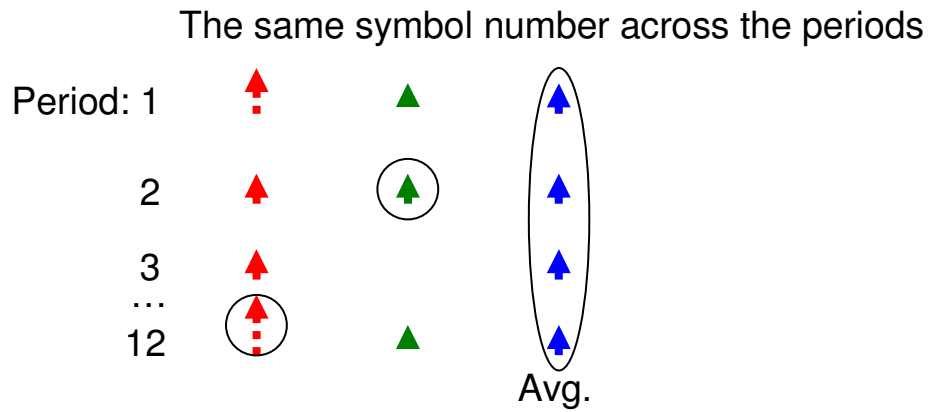


- Multi sync search + wide scatter
  - Different algorithms with different bandwidths, search range and dynamic compressors. All algorithm are based on a cross correlation between the FFT, the actual signal, and the PI4 sync vector
  - Good to find (very) distorted signals

The Pl4 decoders (2)

- Multi sequence decoding
  - Looks across up to 12 periods for the best symbol vs time and combines the various symbols from each period into the best decoding performance
  - Good to find weak signals

  - Empirical data shows that this can increase the S/N performance by up to a couple of dB



The Syncronised Beacon Project

- The SBP is an IARU recommendation to implement a network of time and frequency multiplexed beacons on 50 MHz

- 10 x 1 kHz per IARU region, thus 30 kHz in total
- Five beacons per 1 kHz
- I.e. 150 beacons for a full minimum roll-out but frequency reuse is possible
- Each beacon transmits for 1 minute then waits 4 minutes before next cycle

- The SBP beacons use PI4 + CW + carrier

- How about a condx monitoring box?
  - Dedicated monitor, embedded decoder and dongle

Should your beacon use PI4?

- What type of footwear should you put on?
- Should the mode(s) be for one particular propagation or for general purpose?
- Who do you think will listen to the beacon?
- PI4 is a good, and popular, choice if you are looking for a general purpose beacon for everybody
- … and best of all – you will be a young OP!

Find out more…

The PI4 + CW + carrier specification

www.rudius.net/oz2m/ngnb/pi4.htm

The PI4 decoders

MSHV: www.lz2hv.org

PI-RX: www.rudius.net/oz2m/software/pi-rx

www.rsgb.org