# PI4 - PharusIgnis4
# a MGM for beacon purposes

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2015-04-26 • Bo, OZ2M

# Contents

- VUSHF beacons and transmission sequence – PI4 and the reason why
- The development of a PI4 decoder – PI-RX by Poul-Erik, OZ1CKG
- Hardware – Next Generation Beacons and other solutions

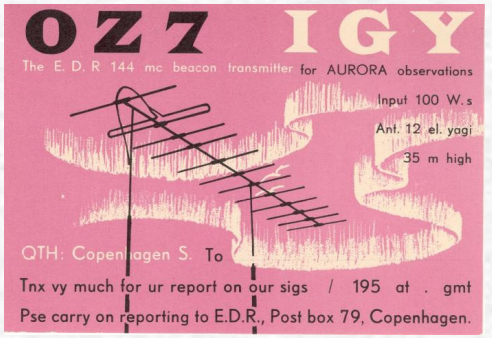
# The world's oldest beacon

- OZ7IGY has expenses of ~1800 £/year, coming from using 800 W continuously
  - ~270 £ from radio club memberships
  - ~900 £ form individual memberships
  - Member donations
  - The 70 MHz transverter project
  - The Next Generation Beacons project
- QRV
  - MHz: **28**, 40, **50**, **70**, **144** and **432**
  - GHz: **1**, **2**, **3**, 5, 10 and **24**


Bold: PI4 + CW + carrier

# What is a beacon?

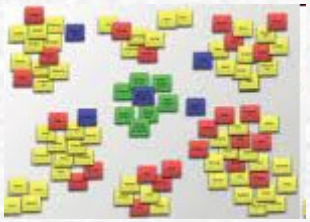
- A beacon is transmitting all the time
- It is reliable
- It is on frequency
- Status is publicly know and updated



# Collecting the requirements

- Should it be based on ideology or the users' needs?

- Digital for the sake of digital?



- What do the users say and want?

# Who are the potential users?

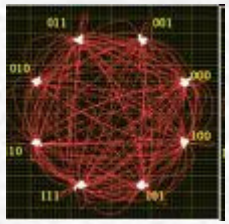
| | | |
|---|---|---|
| 1 | **FM user** | Never use beacons<br>DX-ing has no appeal<br>May become 3) |
| 2a | **Analog DXer** | Understands propagations and beacons<br>Not interested in digital communication |
| 2b | **Mixed mode DXer** | Understands propagations and beacons<br>Use whatever it takes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

Empirically found

# Don’t ask the users!

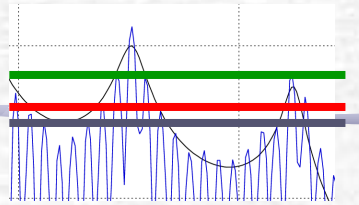
- They don’t know what they want
  - Henry Ford: “If I had asked people what they wanted, they would have said faster horses”


- The purpose of the Next Generation Beacons project was to start the discussion and identify the requirements (for OZ7IGY)



# Digital modulation is the future - today

- Sensitivity >10 dB better than CW
  - G4JNT: For easy copy CW at 18 WPM in –9.2 dB S/N is needed (2.5 kHz)
  - AMSAT: Median –14.6 dB, top quartile –17.6 dB, top 1% -20,6 dB (2.5 kHz)
- Automated monitoring of conditions and comparison to average → alarm when x dB better than average
- Long term analysis – 24 h, (7 days), 28 days, one year and 11 years
- Modulation/sequence can be changed when improvements are available



# Framework for future beacons

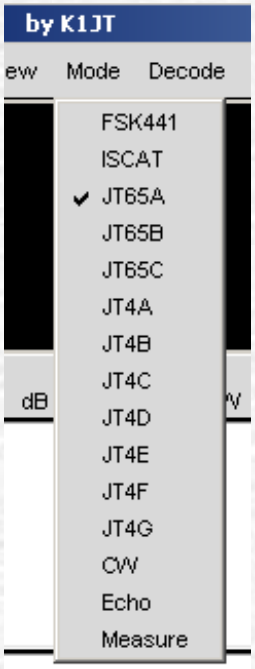
- Can be decoded both with and without a computer, like today
- Benefits from the digital capabilities
- Frequent ID to cope with QSB and "it is not a birdie"
- Possible to detect via unknown propagations
- Must be "zero beatable"
- Must fit into existing beacon spacing(s)
- Same modulation and sequence on "all" bands
- The combination may force a new sequence

# Sensitivity is nonsense

- It is not all about the lowest S/N number
- Many people are lured by the S/N value(s)
- Sensitivity is one thing robustness is just as important – it is all about link probability

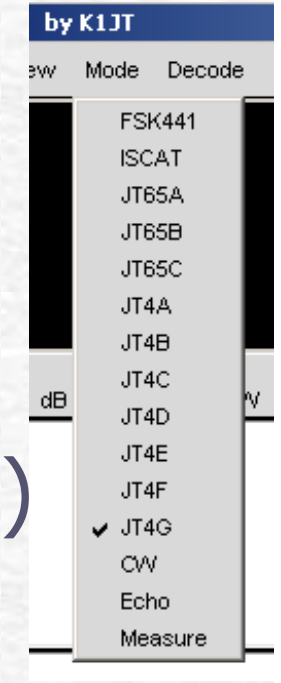
- There are no free lunches when it comes to sensitivity, flexibility, speed and robustness

# Something exists, but ...

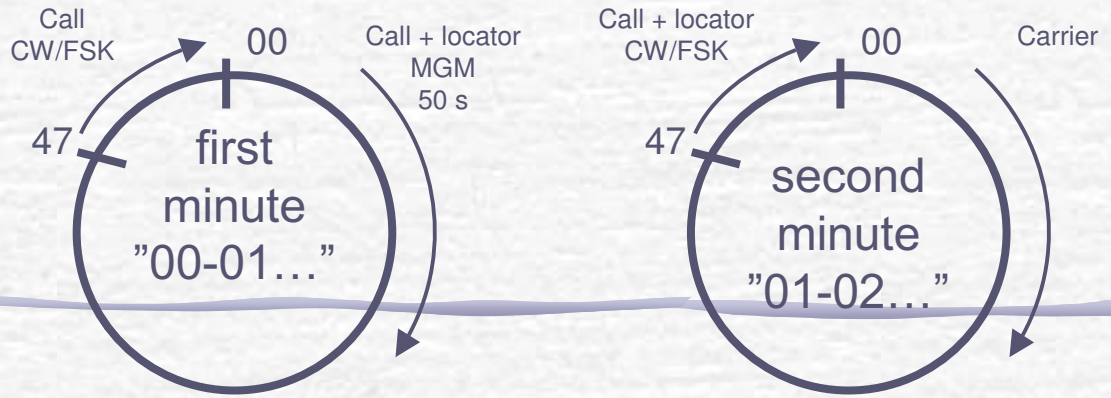



- JT9/WSPR
  - Designed for HF, OK for 6 m but not above
  - 2 min sequence and no CW ID
  - Not resistant to distortion or frequency jitter
  - "Birdie like" from an analog point of view
- JT65
  - Designed for EME, tropo and ionoscatter
  - 1 min sequence and no CW ID, or 2 min with CW ID
  - Only somewhat resistant to distortion

# How about JT4x then?




- Designed for VUSHF communications
- Robust modulation and S/N –23.6 dB
- Can be used for 10 GHz EME (JT4F/G)
- Sequence
  - 1 min native (47 s)
  - 2 min with CW ID and carrier



# Not for human beings

| | | | |
|---|---|---|---|
| 01) | 0:00-0:30 | **(MGM)** | OZ7IGY/B JO55WM ***Only if GPS fix is valid*** |
| 02) | 0.30-1.00 | **(CW)** | VVV OZ7IGY/B JO55WM **HHMMz** ***see C)*** |
| 03) | 1:00-1:30 | **(CW)** | VVV OZ7IGY/B JO55WM **HHMMz** |
| 04) | 1:30-2:00 | **(BPSK)** | Carrier, ***see B)*** |
| 05) | 2:00-2:30 | **(MGM)** | OZ7IGY/B JO55WM ***Only if GPS fix is valid*** |
| 06) | 2:30-3:00 | **(CW)** | VVV OZ7IGY/B JO55WM **HHMMz** ***see C)*** |
| 07) | 3:00-3:30 | **(CW)** | VVV OZ7IGY/B 85 MASL **HHMMz** |
| 08) | 3:30-4:00 | **(CW)** | VVV OZ7IGY/B JO55WM **HHMMz** |
| 09) | 4:00-4:30 | **(MGM)** | OZ7IGY/B JO55WM **Only if GPS fix is valid** |
| 10) | 4:30-5:00 | **(CW)** | VVV OZ7IGY/B JO55WM **HHMMz** ***see C)*** |
| 11) | 5:00-5:30 | **(CW)** | VVV OZ7IGY/B 10 W MLOOP **HHMMz** |
| 12) | 5:30-6:00 | **(VAR)** | Carrier, ***see A)*** |

**HHMMz** is the GMT time from GPS
If non valid GPS data at the end of a CW message it append a **"NOGPS"**
If no supply from AC source at the end of a CW message it append a **"ACLOSS"**

**A)** Send a RF carrier > 5 s max power > 5 s -6 dB power > 5 s no power > 5 s -6 dB power > max power to the end of segment

**B)** Send a BPSK carrier for 30 s segment of alternate 1 s phase +-180° from 1 PPPs GPS timing

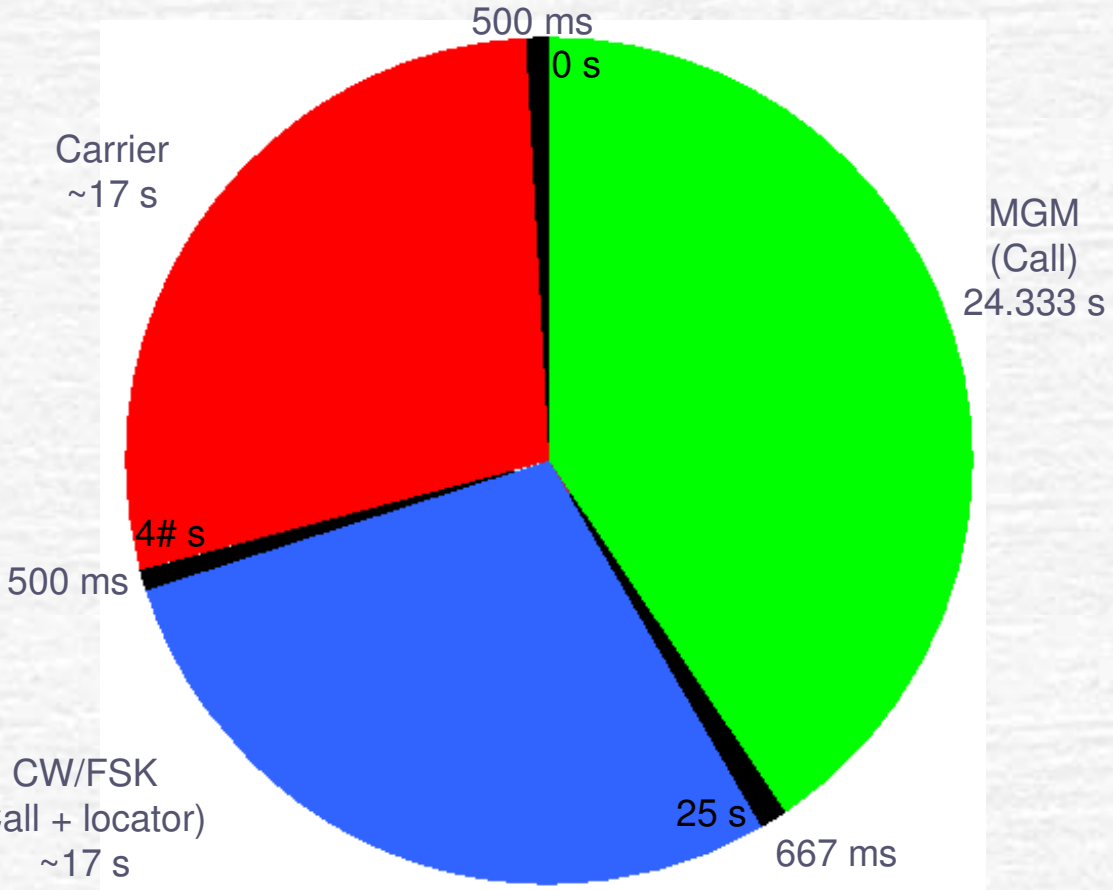
**C)** This line is ignored, except at boot-up and for loss of GPS signal. The first two sequence of group (1 min) are used for ***MGM*** if no GPS it send a "85 MASL 10 W MLOOP" CW message for two segment of 30 s.
The output carrier 50.471 MHz is locked to a GPS reference of +-0.1 Hz max var.

If no GPS the carrier 50.471 MHz use internal reference at +-5 Hz max variation

# The users wanted

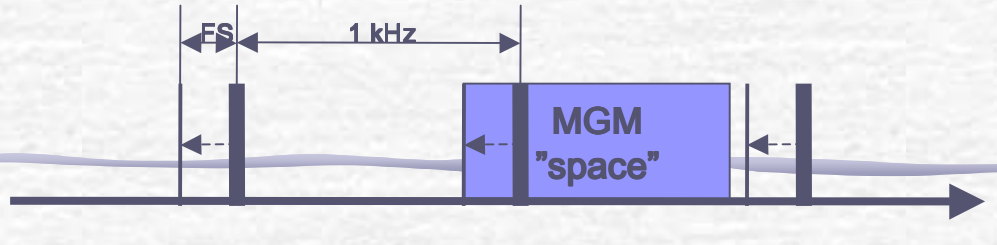
- Just the way it is, i.e. CW and carrier
- MGM only – CW only
- More carrier, less carrier, no carrier
- EME training beacon, i.e. JT65B
- Identical sequence all the time
- MGM decodable via aurora and rain scatter
- Fits into the existing beacon spacing(s)
- Identical tuning for all parts of the sequence

# 1 min MGM + CW ID + Carrier



# PI4 - PharusIgnis4

- A digital modulation (MGM) for beacons
- Maximum reuse of K1JT's JT4 modulation
  - Class C transparent
  - Omit locator from message, i.e. faster message
  - 4 tone FSK designed for beacon spacing
    - Tones spaced ~234 Hz, or ~709 Hz wide
    - Leaves guard space for above beacon using CW FSK
    - Wider spacing possible if needed, e.g. SHF bands
  - 800 Hz offset



# Comparing

## JT4

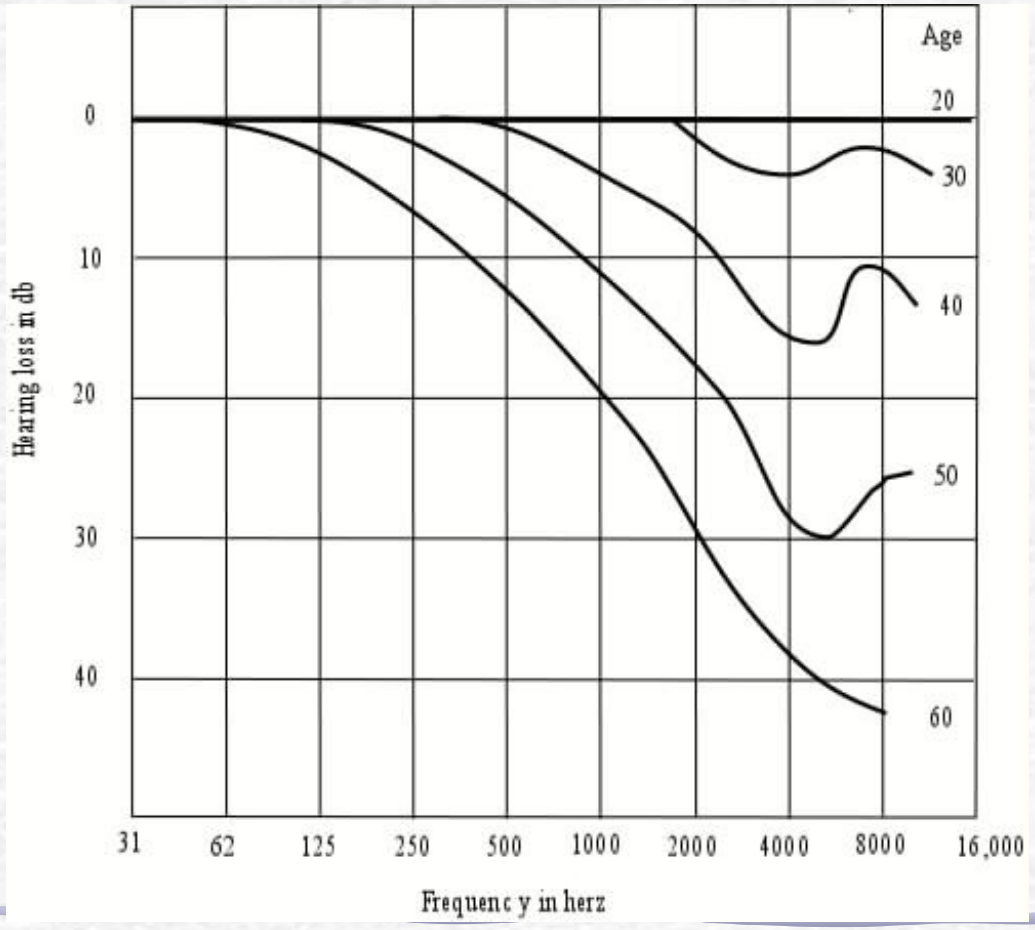
- Duration is 47.3 s
- 2 min sequence
- 13 char. message
- Call and locator
- “A”-“Z”, “0”-“9”, “/+-.?<space>” in total 42 chars
- ~F narrow, ~G wide
- S/N 23.6 dB
- Already in WSJT
- 262.5 time slots per min

## PI4

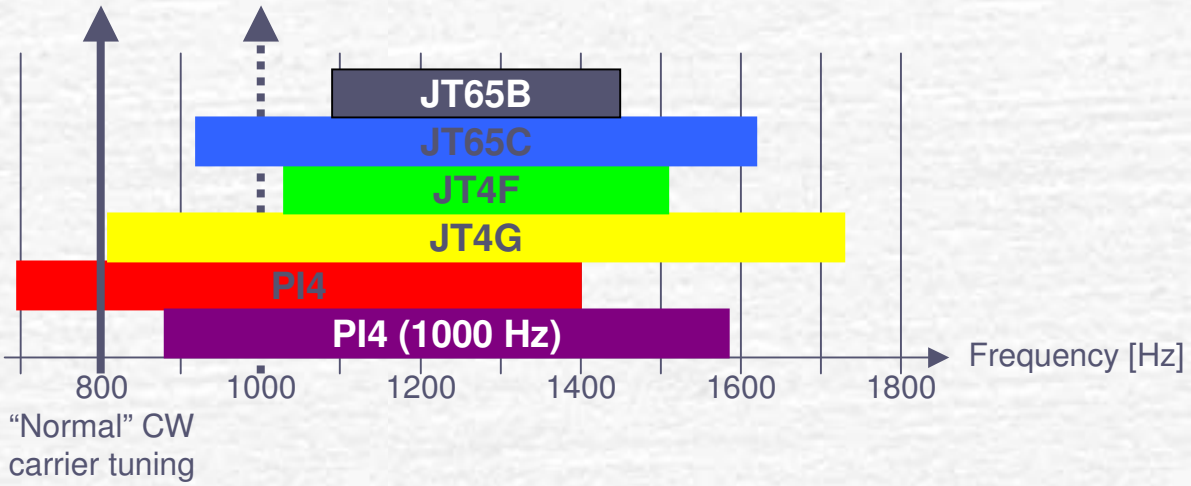
- Duration is 24.333 s
- 1 min sequence
- 8 char. message
- Call, or other msg.
- “A”-“Z”, “0”-“9”, “/<space>” in total 38 chars
- BW 709 Hz, just right
- S/N 22.2 dB
- PI-RX decoder
- 360 time slots per min

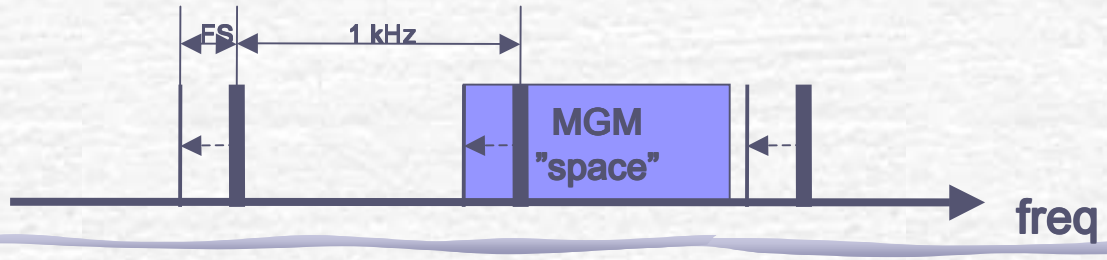
# Human tuning offset – 800 Hz

- SM6ESG says that he hears PI4 tone0 better than the carrier/CW from OZ7IGY



# Frequency comparisons



# Time for some carrier!

| JT4 + CW + carrier + CW + carrier [ms] | | PI4 + CW + carrier [ms] | |
|---|---|---|---|
| 47314 | JT4 | 24333 | PI4 |
| 500 | Pause | 667 | Pause |
| 17000 | CW | 17000 | CW |
| 500 | Pause | 500 | Pause |
| 30000 | Carrier | 17000 | Carrier |
| 500 | Pause | 500 | Pause |
| 17000 | CW | 24333 | PI4 |
| 500 | Pause | 667 | Pause |
| 6186 | Carrier | 17000 | CW |
| 500 | Pause | 500 | Pause |
| | | 17000 | Carrier |
| | | 500 | Pause |
| Total carrier | 36186 ms | Total carrier | 34000 ms |

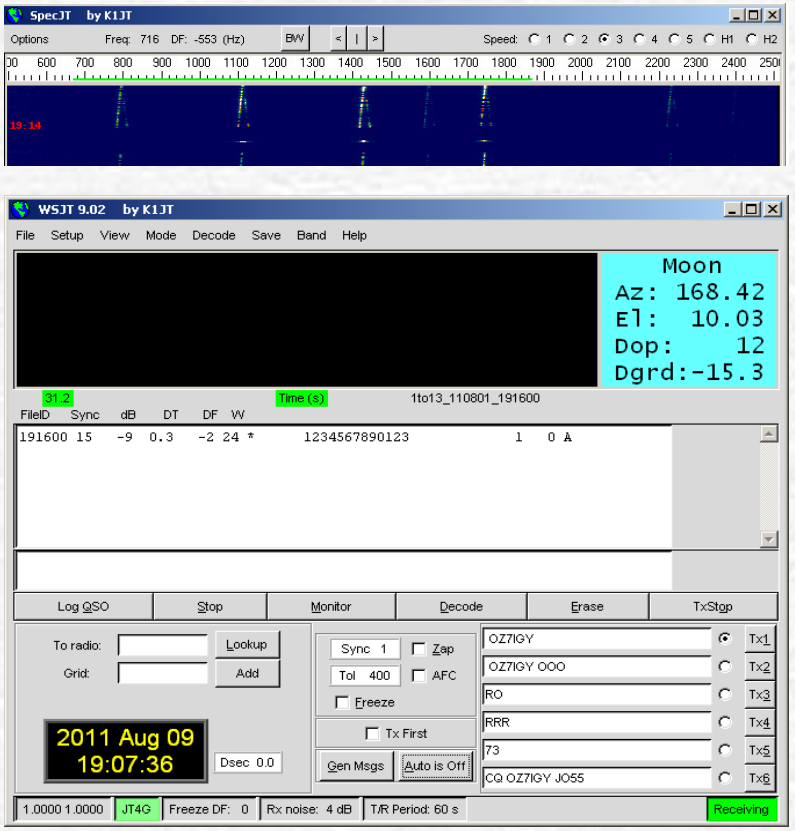
Conclusion: there is 2 s more of carrier in a typical JT4-based sequence than a PI4-based sequence or 1 s more per minute

# Improving PI4

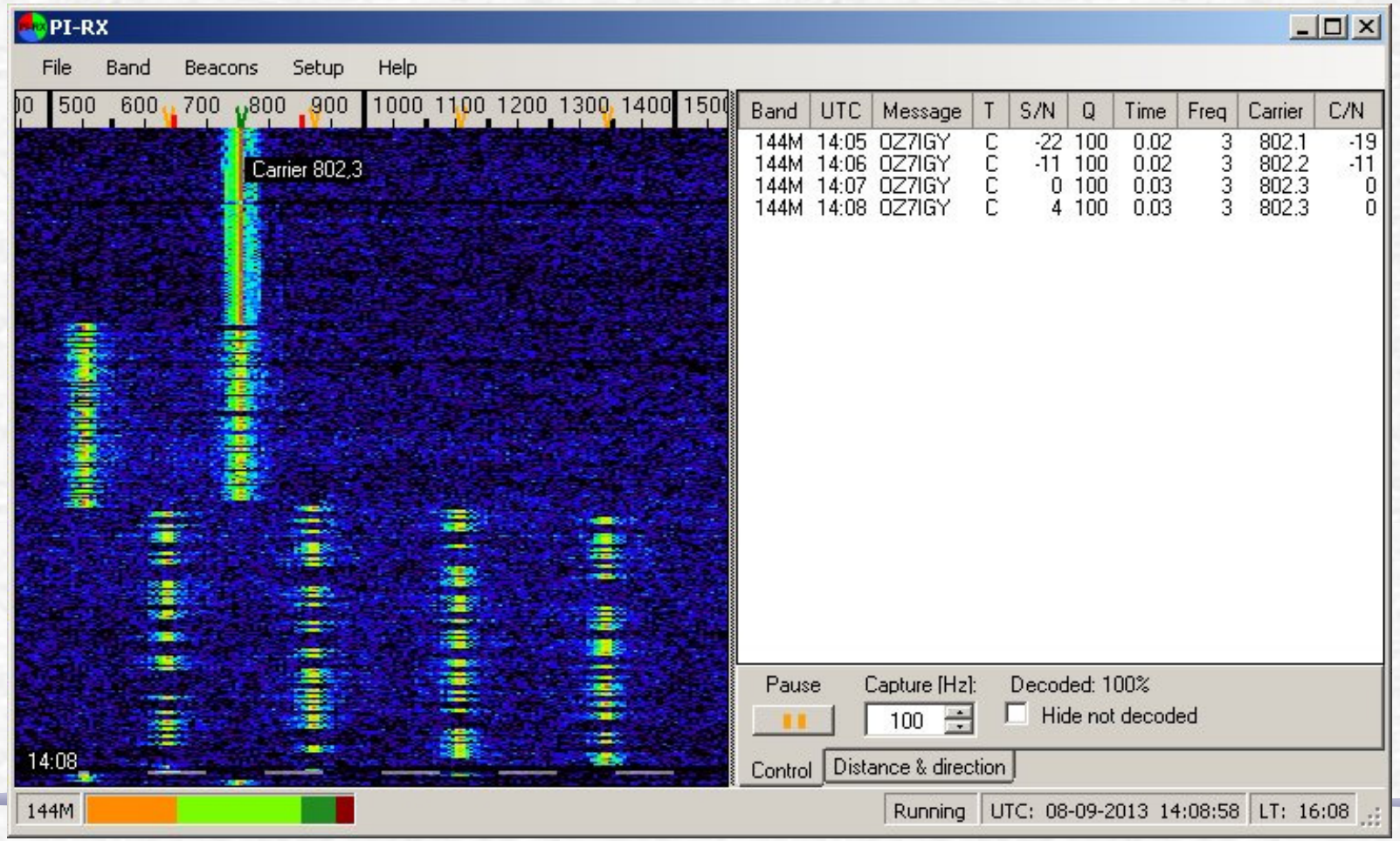
- Even before using PI4 we knew we could have improved the sensitivity by 0.8 dB by not being close to JT4
- In hindsight we should not have pursued the WSJT path
- Improved sensitivity by some 2 dB but more complex encoding yet same way of sync
- (Four times as fast PI4 repeated four times, 6 dB worse S/N, avg. improvement up to 3 dB)
- (A PI8 with eight tones and sync across all)

# Decoding digital modulation

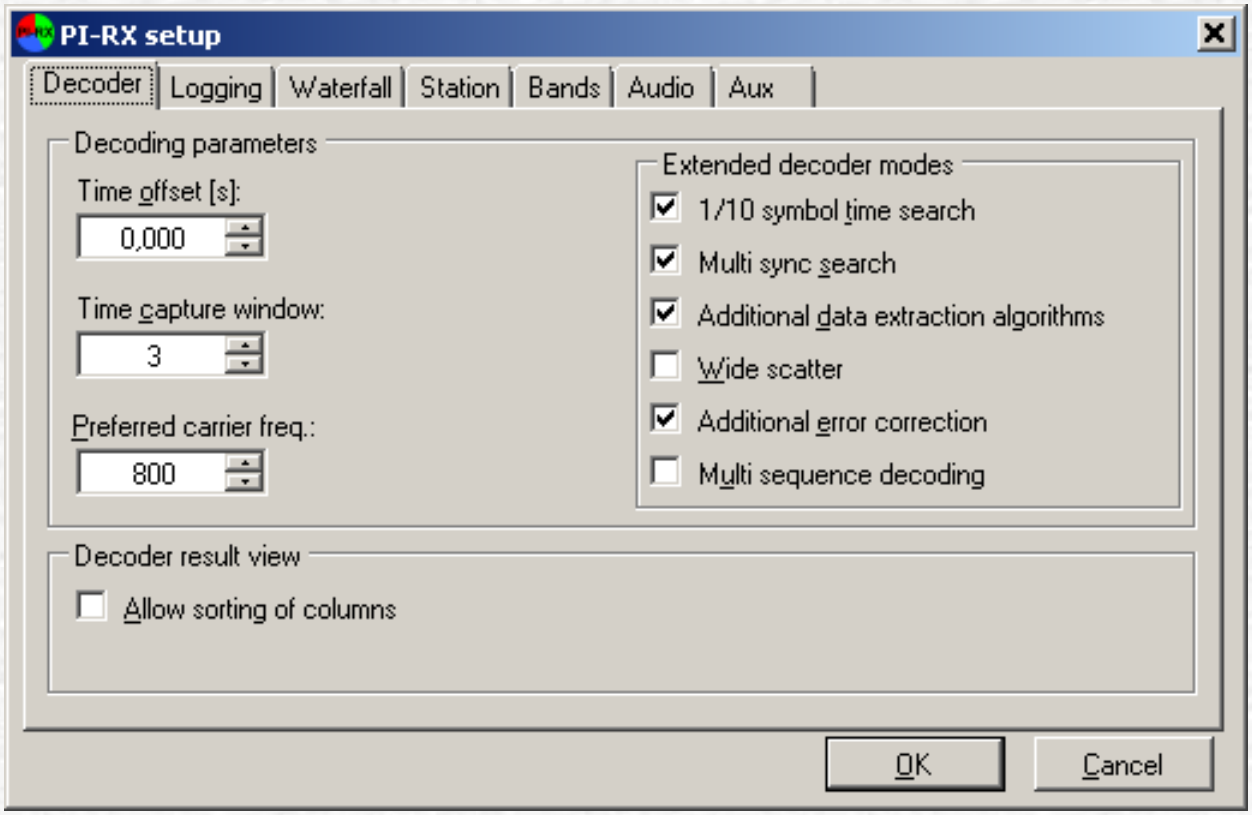
- The leading VUSHF digital modulation program is WSJT
- We had hoped to persuade Joe, K1JT, to implement a PI4 decoder but no response



# PI-RX by OZ1CKG



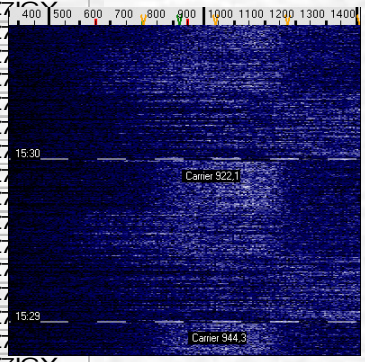
# PI-RX decoder settings



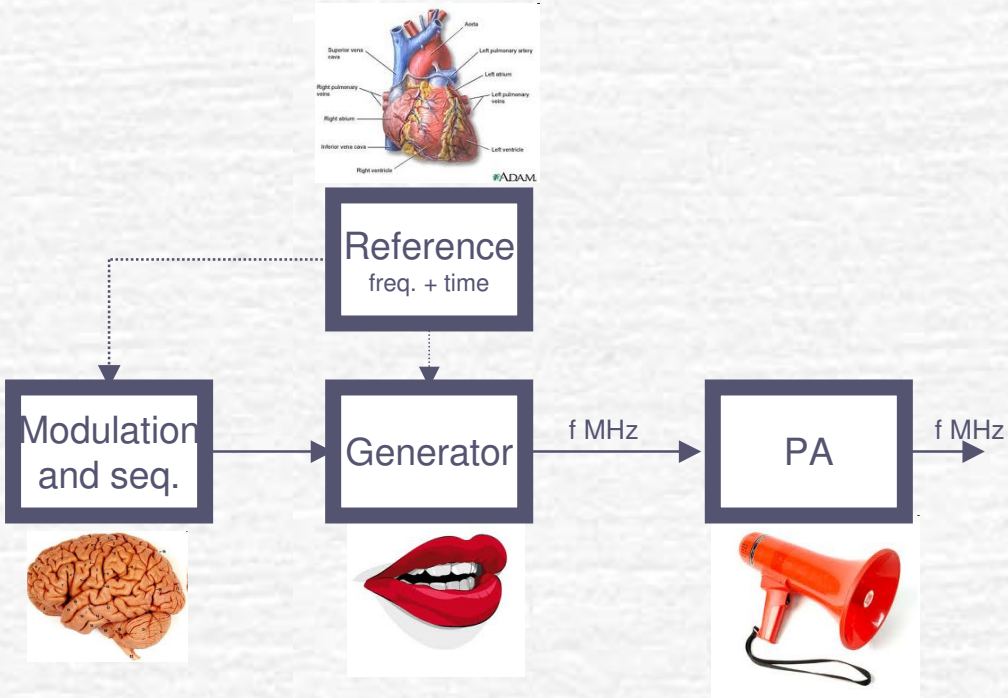
# PI-RX decoder development

- 0.9.0.4, ~5, ~9, 0.9.0.10
- Aurora recordings by Jan, LA3EQ on 7 June 2013
- From 33% to 100% aurora decodes by optimizing the decoder performance
- Added wide scatter mode
- Handles multipath and MS

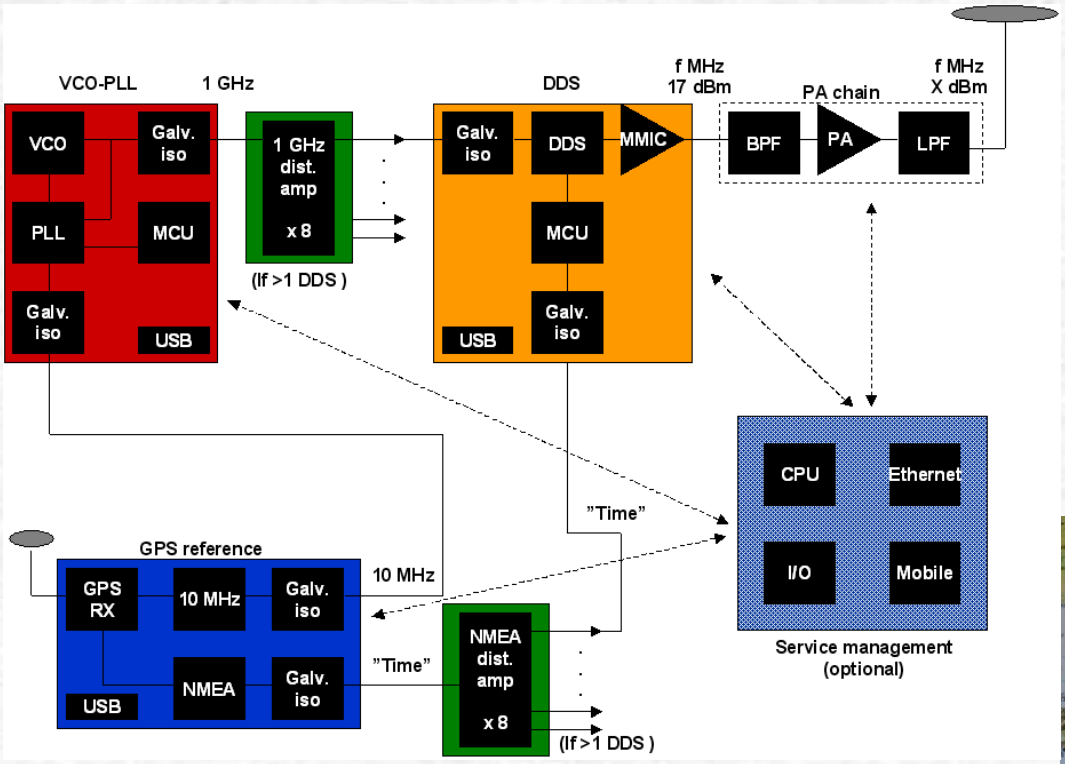
| Decoder: | 0.9.1.0 | 0.9.1.9 | 0.9.2.0 |
|---|---|---|---|
| 04:31 | ----- | OZ7IGY | OZ7IGY |
| 04:32 | ----- | ----- | OZ7IGY |
| 04:33 | ----- | OZ7IGY | OZ7IGY |
| 04:34 | ----- | ----- | OZ7IGY |
| 04:35 | ----- | ----- | OZ7IGY |
| 04:36 | ----- | ----- | OZ7IGY |
| 04:37 | ----- | ----- | OZ7IGY |
| 04:38 | ----- | OZ7IGY | OZ7IGY |
| 04:39 | ----- | OZ7IGY | OZ7IGY |
| 04:40 | ----- | OZ7IGY | OZ7 |
| 04:41 | OZ7IGY | OZ7IGY | OZ7 |
| 04:42 | ----- | ----- | OZ7 |
| 04:43 | ----- | ----- | OZ7 |
| 04:44 | ----- | OZ7IGY | OZ7 |
| 04:45 | ----- | OZ7IGY | OZ7 |
| 04:46 | OZ7IGY | OZ7IGY | OZ7 |
| 04:47 | OZ7IGY | OZ7IGY | OZ7 |
| 04:48 | ----- | OZ7IGY | OZ7 |
| 04:49 | ----- | OZ7IGY | OZ7 |
| 04:50 | ----- | OZ7IGY | OZ7 |
| 04:51 | OZ7IGY | OZ7IGY | OZ7 |
| 04:52 | OZ7IGY | OZ7IGY | OZ7 |
| 04:53 | OZ7IGY | OZ7IGY | OZ7 |
| 04:54 | ----- | OZ7IGY | OZ7IGY |
| 04:55 | OZ7IGY | OZ7IGY | OZ7IGY |
| 04:56 | ----- | OZ7IGY | OZ7IGY |
| 04:57 | ----- | OZ7IGY | OZ7IGY |
| 04:58 | OZ7IGY | OZ7IGY | OZ7IGY |
| 04:59 | OZ7IGY | OZ7IGY | OZ7IGY |
| 05:00 | OZ7IGY | OZ7IGY | OZ7IGY |
| 05:01 | OZ7IGY | OZ7IGY | OZ7IGY |
| 05:02 | OZ7IGY | OZ7IGY | OZ7IGY |
| 05:03 | ----- | OZ7IGY | OZ7IGY |
| 05:04 | ----- | OZ7IGY | OZ7IGY |
| 05:05 | ----- | ----- | OZ7IGY |
| 05:06 | ----- | OZ7IGY | OZ7IGY |



# Beacon hardware for dummies



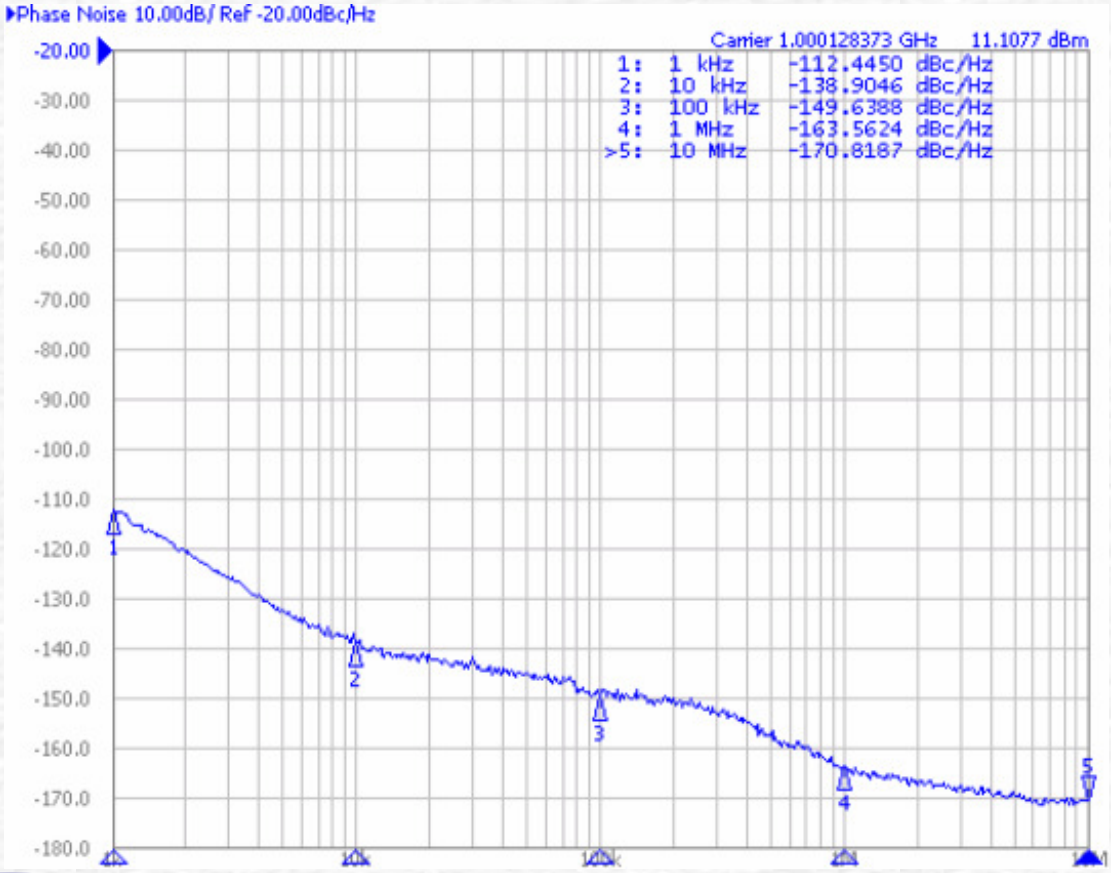
# Next Generation Beacons





# Please take care!

- It is not just about harmonics
- Phase noise
- Inband spurii



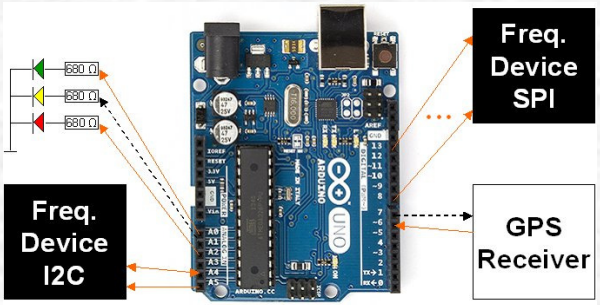
# Alternative hardware

SP5MX

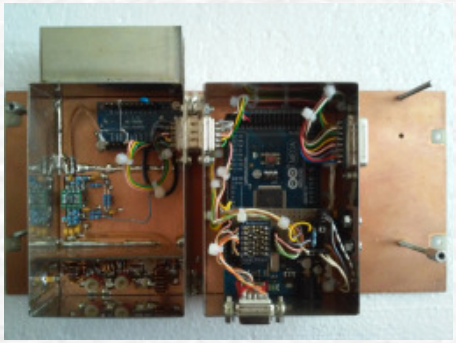
GI0GDP

PI4ino

EA3HMJ

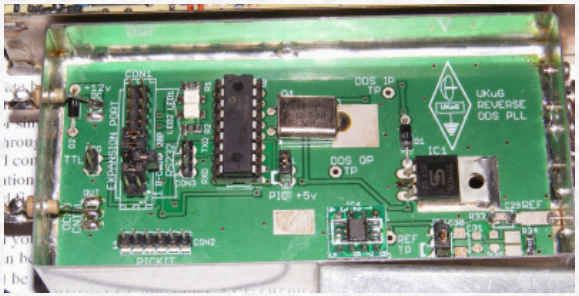



PE1MXP

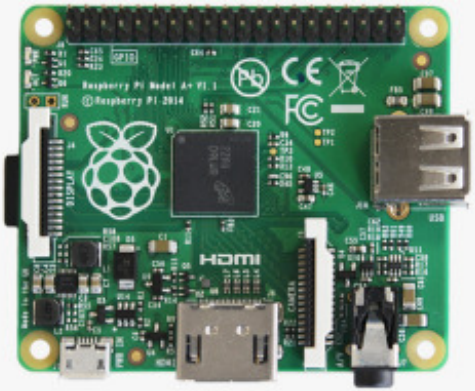


G4JNT

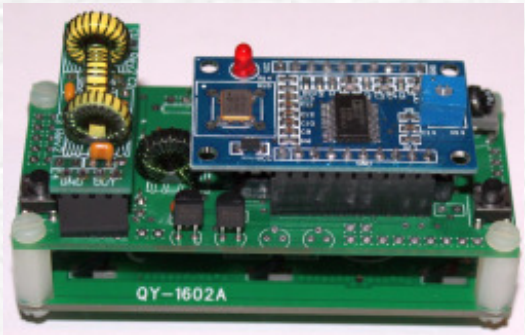
G8ACE



Dominik Auras



G0UPL




Devices: AD9850, AD9851, AD9852, AD9912, ADF4351, LMX2470, LMX2541, Si570, Si5351A and audio (Rasp. Pi, Arduino)

# PI4 beacons on the air

- OZ7IGY – March 2013, 2 m and 6 m (all)
- IW9GDC/B – August 2013, 4 m
- DB0JG – February 2014, 70 cm
- DB0IH – July 2014, 70 cm
- ED5YAE – August 2014, 3 cm
- PE1MXP/B – September 2014, 4 m
- DB0LTG – January 2015, 23 cm
- GB3MHZ – April 2015, 3 cm
- GB3CFG – May? 2015, 4 m
- SK4MPI – Spring 2015, 2 m
- Next Generation Beacons hardware supplied to OH, K and VK
- Another handful is in the pipeline for 2015

# Conclusion

- Find out what the users want and what is needed – don't just use what is available
- PI4 has been decoded using PI-RX via aurora, rain scatter and EME → PI4 is a general purpose MGM for beacon purposes
- Users really like the PI4 + CW + carrier sequence
- Available hardware solutions from state of the art to eBay-level and roll-your own

# More information

- PI4 specification
  - www.rudius.net/oz2m/ngnb/pi4.htm
- PI-RX, PI4 decoder program
  - www.rudius.net/oz2m/software/pi-rx
- OZ7IGY home page
  - www.oz7igy.dk