An overview of

The VA2IW/B 10GHz Transmit Beacon



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This presentation covers...

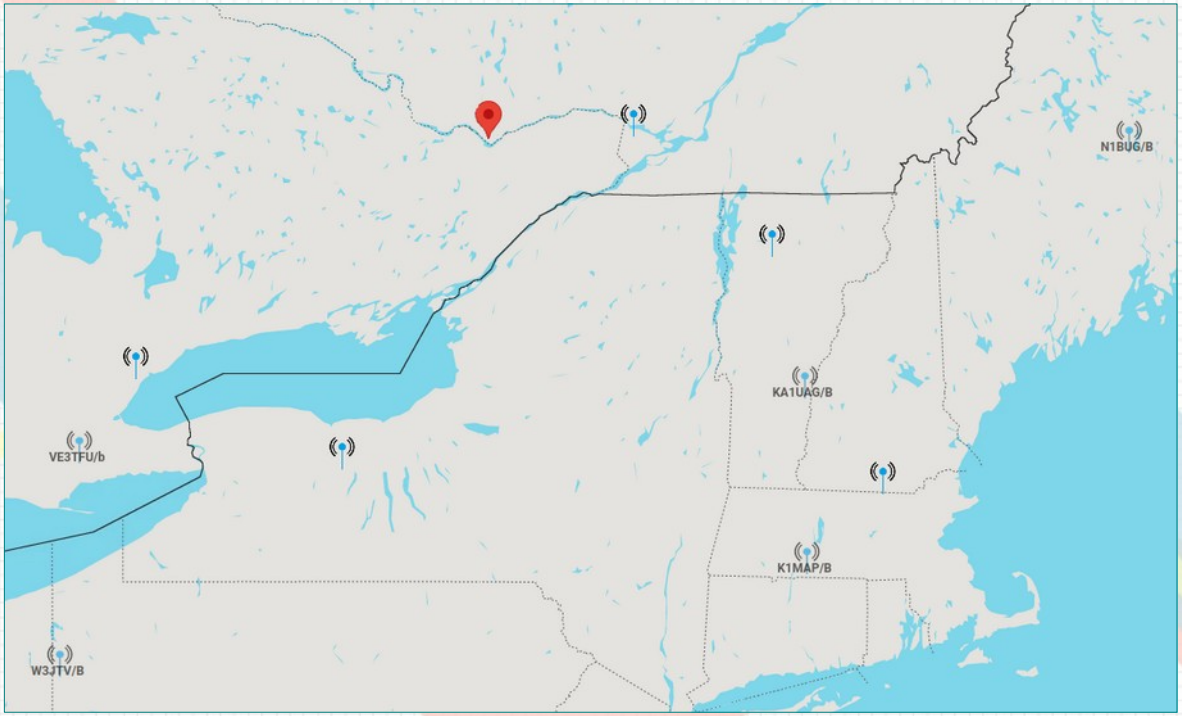
- The context: Why another beacon,
- The technical details of the 10 GHz Beacon,
- The integration process,
- The addition of the Q65 digital mode,
- The remote control interface,
- The results: Signal reports,
- Future improvements.



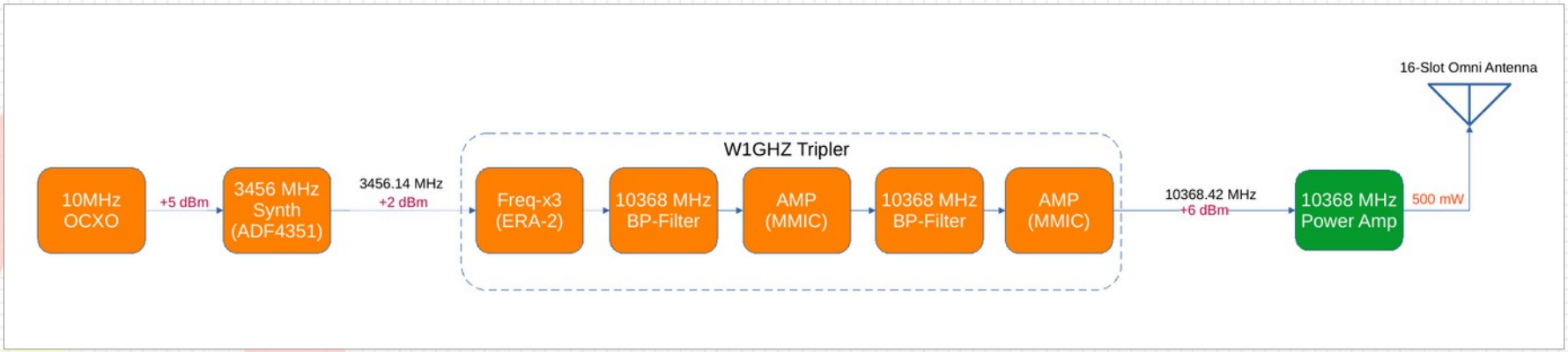
Will these inspire you on your next project?

The Context...Why another Beacon

- Local beacons are a good signal source for testing purpose.
  - No 10 GHz transmit beacon in the Ottawa area. The closest beacon is 122 km away. VE2TWO/B Mont-Rigaud QC, a very strong beacon, however not local.
- Microwave propagation (tropospheric) is hard to predict.
  - Beacons help assess propagation enhancements.



Detailed RF Block Diagram



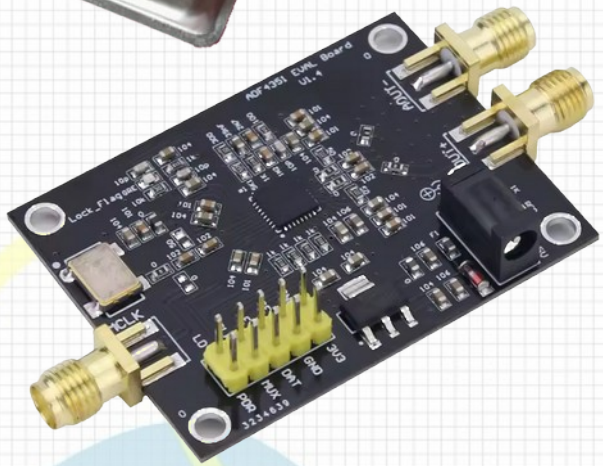
- Architecture is copied from my two previous 10 GHz systems.
- Modern, easy and cheap to build:
  - No expensive commercially-made modules (except the P.A.),
  - Synth.-based: No endless chain of multiplying stages,
  - No custom quartz crystal required,
  - OCXO-based: On frequency after short warm-up time
  - GPS-Disciplined OCXO by the controller firmware. Output frequency is within a few Hertz of 10368.420 MHz.
  - CW keyed at Synthesizer output and Tripler DC supply.

Frequency Synthesis

Readily-made board available for around $20 on AliExpress or eBay.

- ADF4351: 35-4400 MHz output.
- Programmed to 3456.14 MHz out, followed by W1GHZ Tripler board (uses pipe-cap filters) gives 10.368.420 GHz output.
- Clocked by a GPS-disciplined external 10 MHz OCXO (ovenized oscillator), Isotemp OCXO131-100 in my case. Must disable on-board crystal and reconfigure to external reference!
- Must be configured at every power up via its SPI bus.
- Not the best component layout. Requires added capacitive filtering on the +3.3V LDO regulator.
- Synth-Tripler pair puts out +5 dBm at 10,368 MHz. Not the cleanest phase noise, still a very usable RF signal.



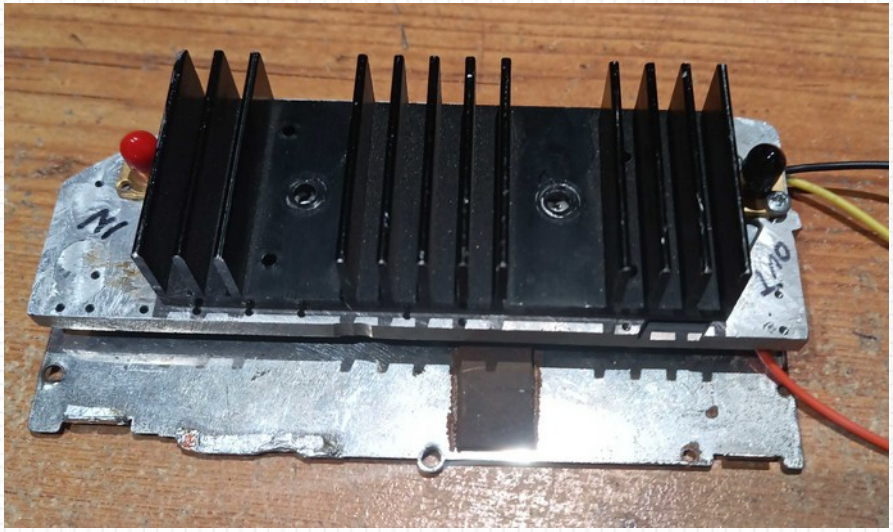


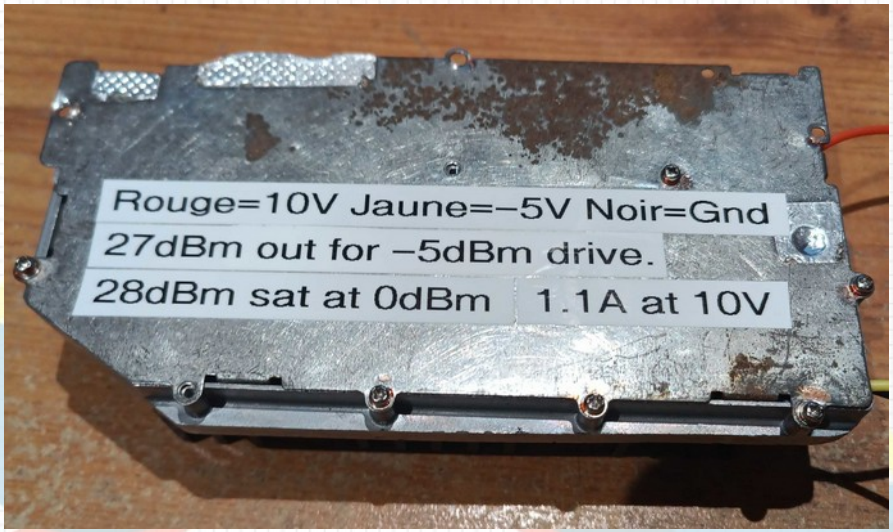


The RF Power Amplifier

Purchased used from a nice microwave enthusiast

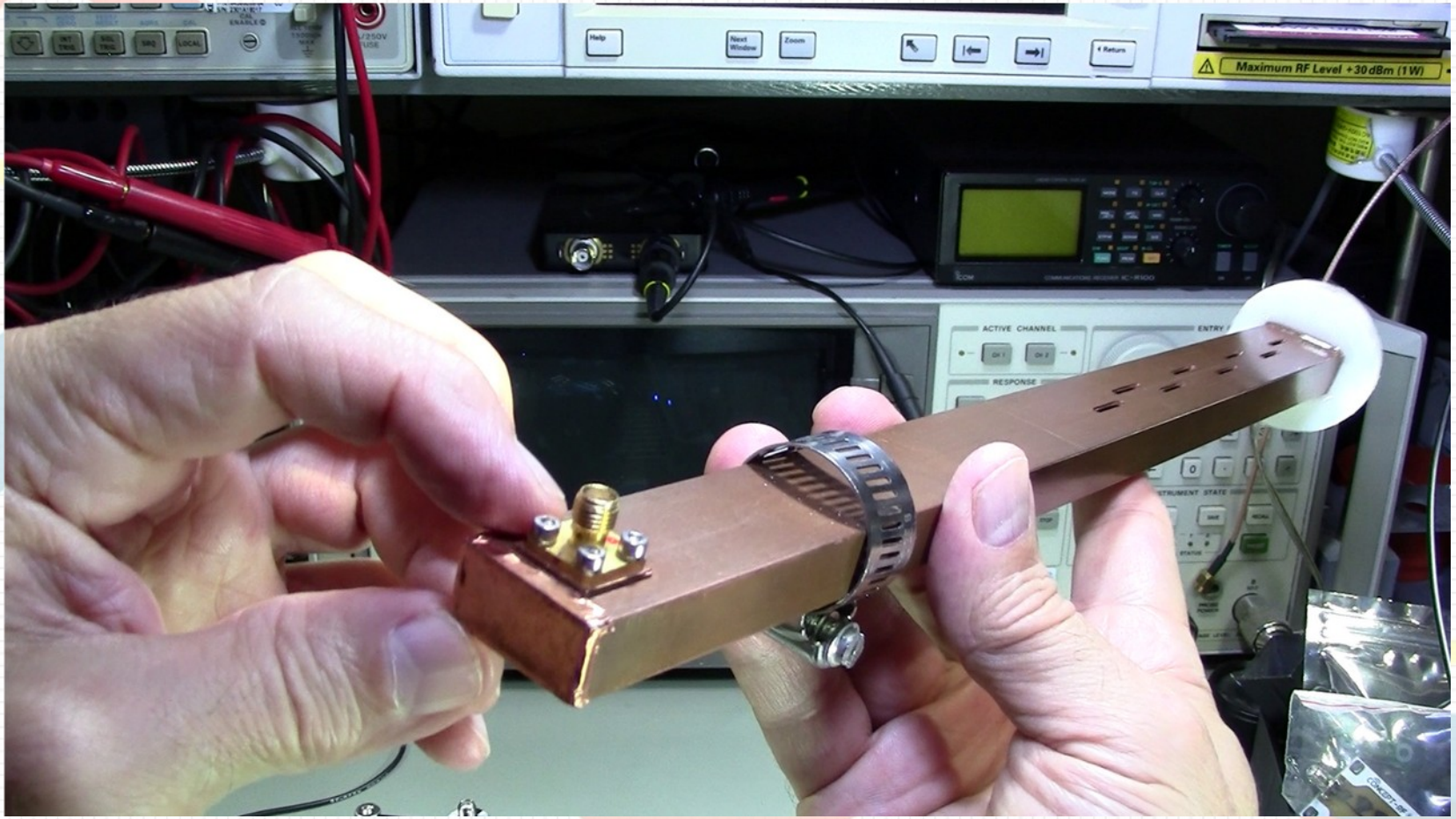
- Unknown manufacturer. Cut off from commercial transceiver system.
- 4 stages, includes RF power detector output.
- Modified and tuned for the 10.3 GHz HAM band.
- 2 mW in, ~500 mW out, varies somewhat with temperature.
- Drain supply: +10.0 Volts @ 1.1 Amp
  Gate Supply: -5 Volts @ 10 milli-Amps
- 11 W DC input… ~ 5% efficiency!!!
  → Significant cooling required.



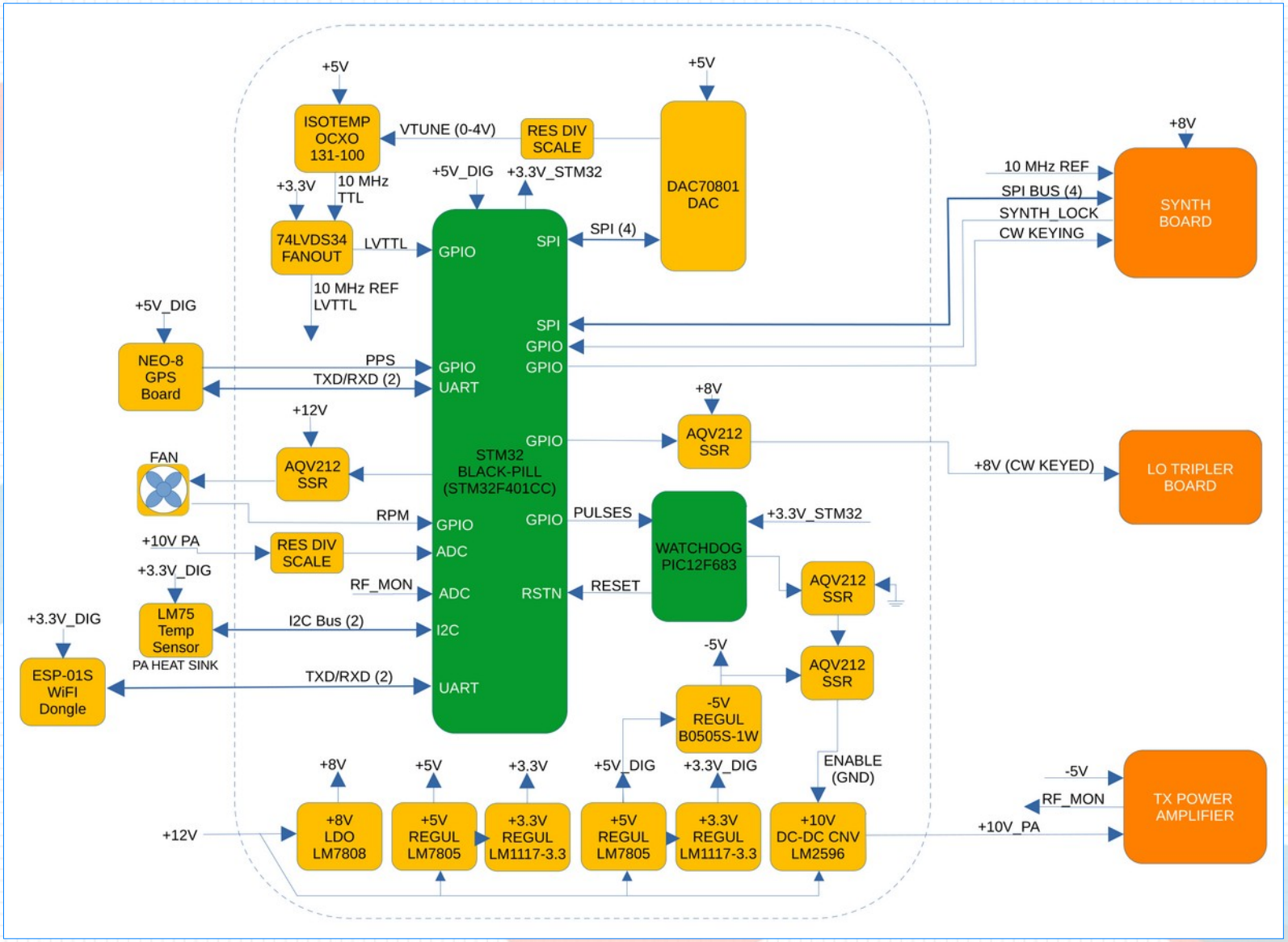


The 16-Slot Waveguide Antenna

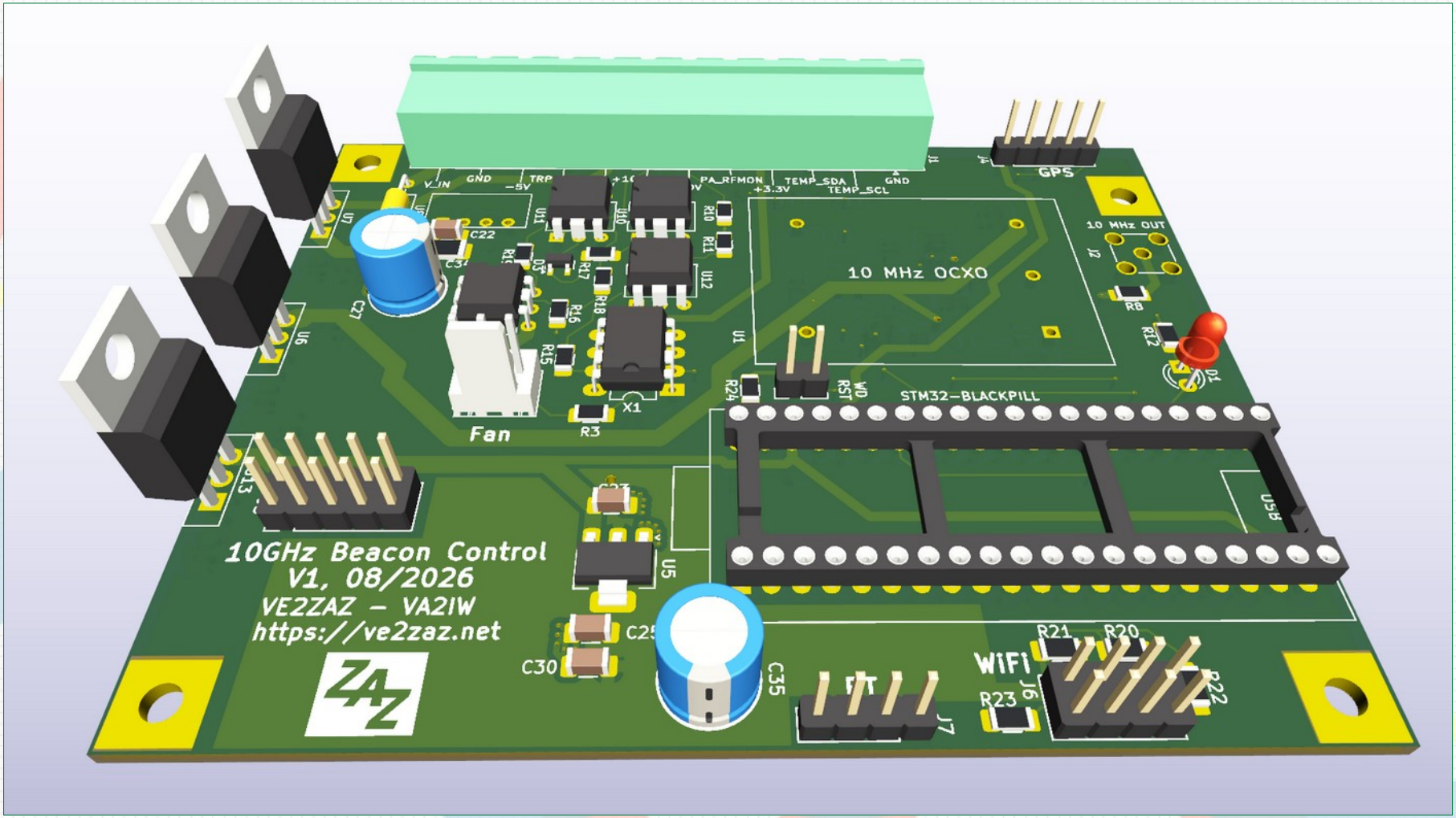
- Purchased from another nice microwave enthusiast
- Made from a 15-inch WR-90 copper waveguide, is heavy.
- Improved VSWR by changing probe length and end caps distance.



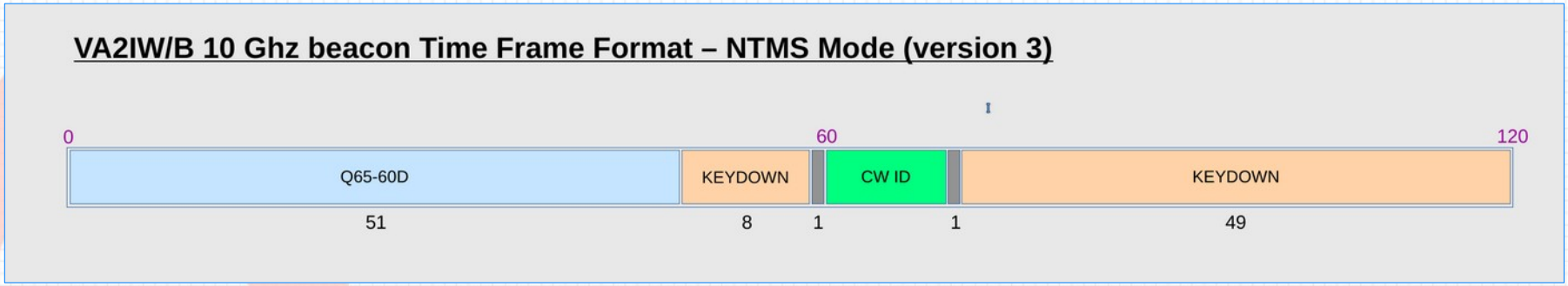
Detailed Control Block Diagram



The Control Board



The VA2IW/B 10 GHz Transmit Format



Follows the recommended North-Texas Microwave Society format

- Following a standard format allows for automated detection of beacon presence and propagation assessment.
- Transmission of the 60-second Q65 frame is at every even-numbered minute.
- Transmission of the 10-second CW identification is at every odd-numbered minute.
- The key-down durations are approximate, and depend on CW message duration.
- The start of the frame is synchronized with GPS time.

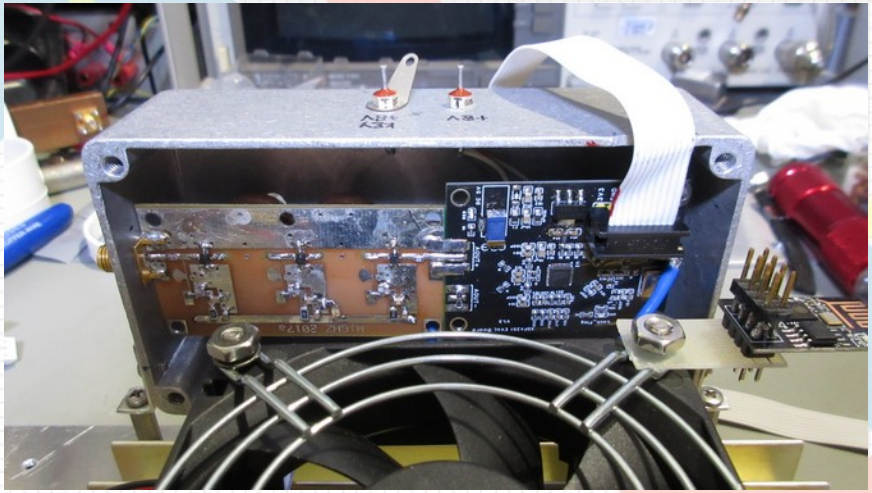
Generating Q65...An Afterthought.

Q65-60D:
- A succession of 85 tones, each lasting 600 milliseconds (51 seconds. total),
- Carrier frequency shifting by 65 possible increments of 13.33 Hz (867 Hz total).

- ADF4351 synthesizer does not offer Hz-level resolution. However the 10 MHz reference OCXO does!
- OCXO DAC resolution is 14 bits. One LSB shifts OCXO frequency by 0.848 mHz.
  → 0.88 Hz shift at 10368.420 MHz. More than enough resolution for WSJT-X Q65 decoding!
- That resolution allowed to implement the following Q65 submodes:
  15A, 15B, 15C, 30A, 30B, 30C, 30D, 60A, 60B, 60C, **60D** and 60E.
- Got lucky! For a 1.2 GHz or lower frequency beacon, this approach would not have worked (insufficient tuning range). Neither would it have worked at 24 GHz (insufficient resolution).
- Drawback: OCXO disciplining not performed while Q65 is sent (51 seconds out of 120).
- Tone pattern generation: WSJT-X includes a command prompt tool to encode any 13-character message into its corresponding Q65 tone sequence.
  "VA2IW/B FN25" → `Q65_TONE_DATA[85] = {0,1,41,10,40,44,61,3,0,25,…}`

Integration

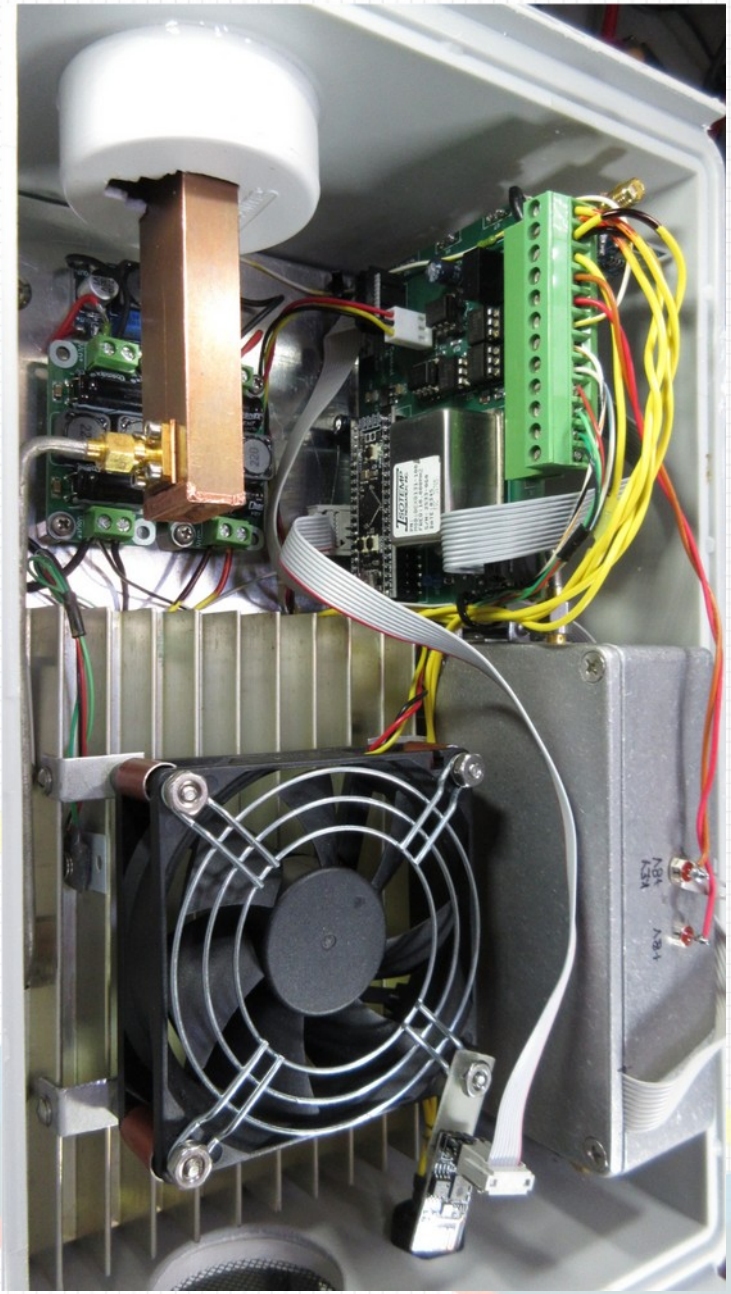
- Grey ABS plastic, IP66 rated, 11x7x5 inches (285x190x130 mm), with latches and hinges.
- Electronics mounted on an aluminum plate.
- Synthesizer and Tripler boards enclosed in aluminum box.
- 6-pin SP-13 “General Purpose Industrial Grade” watertight connectors on the outside.
- A tight fit, and significant amount of heat to dissipate.





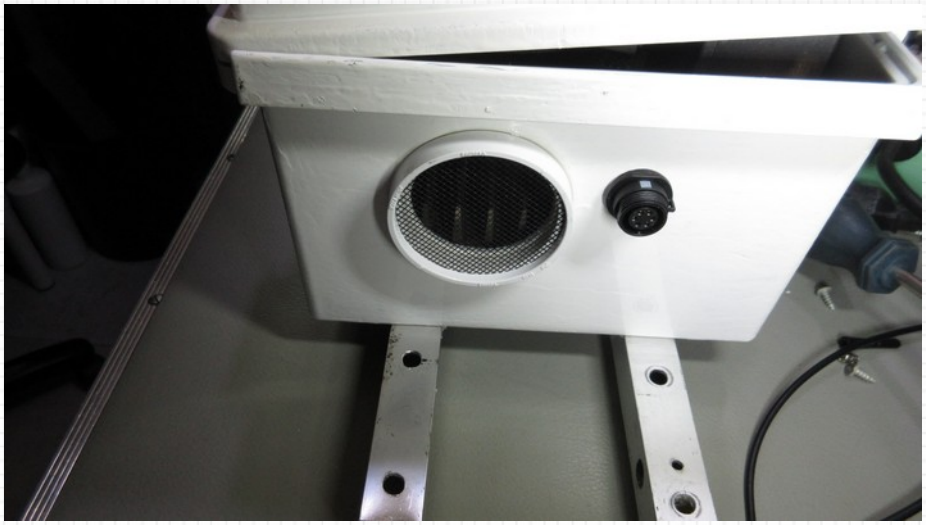
Integration (2)

- GPS mounted at top end of enclosure. Uses a built-in patch antenna.
- WiFi dongle mounted at bottom end of enclosure, away from metal parts.
- P.A. mounted at the lower end of enclosure to generate some air draft by convection.
- P.A. heat sink has 3x the area of the amplifier.
- Thermostat-driven 80mm fan keeps the Power Amplifier heat sink below 45°C.
- Additional 60°C thermal cutoff switch added to P.A. power line as extra precaution.
- EMI L-C filtering boards added to +10V DC-DC converter input and output.

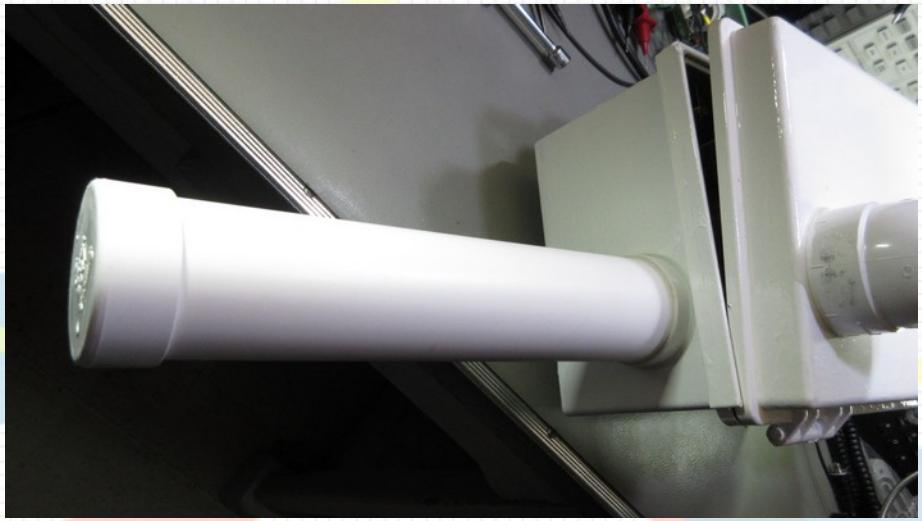


Integration (3)

- Enclosure painted glossy white to maximize heat reflection.
- Central vacuum 2-inch PVC piping for the radome and cooling vents.
- 25mm fan added on outlet vent. Fans operate intermittently when outdoor temperature above +15°C.







The Control Interface… Telnet Session

```
S|_l__p__g_s___|08455|L|00053|00100| 00000| 0.00189|________|______|12|82.3|10.16|39.5|of|135703|
S|_l__p__g_s___|08455|L|00054|00100| 00000| 0.00185|________|______|11|82.3|10.16|39.5|of|135713|
S|_l__p__g_s___|08455|L|00055|00100| 00000| 0.00182|________|______|09|82.2|10.16|39.5|of|135723|
S|_l__p__g_s___|08455|L|00056|00100| 00000| 0.00179|________|______|09|82.2|10.15|39.5|of|135733|
S|_l__p__g_s___|08455|L|00057|00100| 00000| 0.00175|________|______|10|82.2|10.16|39.5|of|135743|
S|_l__p__g_s___|08455|L|00058|00100| 00000| 0.00172|________|______|10|82.2|10.16|39.5|of|135753|
p
================================================================================
Parameter Values
----------------
Number of DAC resolution bits:              14
DAC value:                                  8455
Vtune voltage at OCXO (calculated):         2.56684
FLL operation:                              ON
Number of PPS per sample:                   10
Short cycle duration (samples):             1
Medium cycle duration (samples):            10
Long cycle duration (samples):              100
Medium cycle threshold (Hz):                0.101000
Long cycle threshold (Hz):                  0.010100
Detailed display mode:                      OFF
VT100 detailed display mode:                OFF
PI Loop Index Kp:                           1.00
PI Loop Index Ki:                           0.00
RF Output:                                  ON
Transmit Frequency (KHz):                   10368420
CW Message:                                 _VA2IW/B_
CW Speed (WPM):                             13
Q65 Sub-Mode:                               60D
Q65 Tone DAC step (LSB):                    15.13
Q65 Tone DAC step correction factor:        1.000
Q65 NTMS timing format:                     ON
================================================================================
```

The Control Interface… (2)

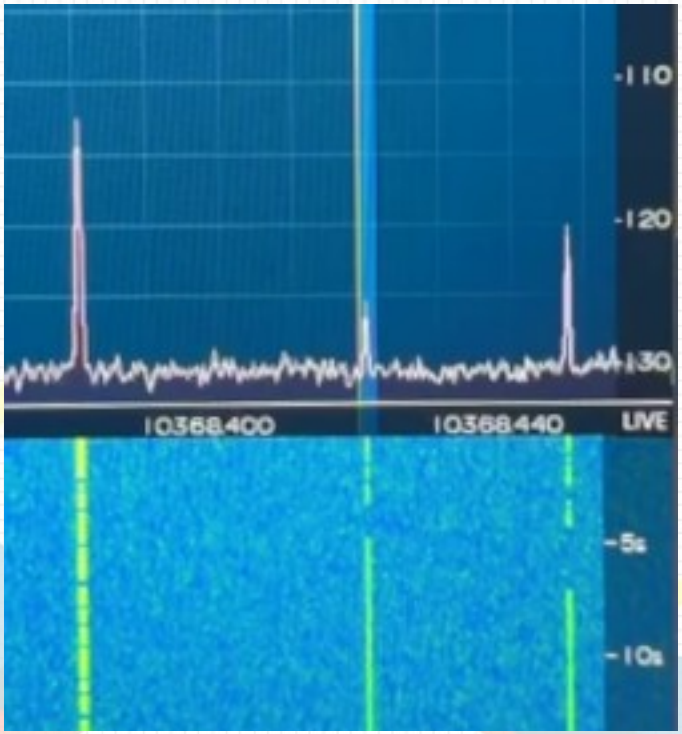
```
================================================================================
Commands:
----------
HELP or ?                              : This help.
DEFIN                                  : Help for condensed display mode fields.
DAC <0-65535>                          : New forced DAC value.
DACBIT <16/14/12>                      : The number of bits used by the DACx0501.
CYCDUR <1-65535> <1-65535> <1-65535>   : Number of samples per short/medium/long cycles.
CLRALM                                 : Clears previous alarms shown in lowercase.
FLL <ON/OFF>                           : Enable FLL.
NPPS <1-10000>                         : Number of PPS per sample.
PARAM                                  : List of adjustable parameters and their current value.
PI <0-1.0000> <0-1.0000>               : Constants Kp and Ki of the P-I loop of the FLL.
RESET                                  : Restarts the microcontroller.
REACQ                                  : Restarts the acquisition process.
THRES <0-100.0000> <0-100.0000>        : Thresholds (in Hz) for switching to medium and long cycles.
VERBOS <ON/OFF>                        : Detailed display mode.
VT100 <ON/OFF>                         : VT100 option of detailed display mode.
RFOUT <ON/OFF>                         : Enable/Disable the RF Output.
CWMSG <A-Z,0-9,/,_>                    : CW message to be sent. Max 50 characters. Use '_' for space.
CWSPD <5-50>                           : CW speed at which to send the message.
KDNDUR <1-60>                          : RF output keydown duration in seconds
Q65SUB <15/30,A-D,OFF>                 : Q65 Sub-Mode: 15A-C, 30A-D, 60A-E, OFF
Q65TST <ON/OFF>                        : Enable/Disable the Q65 Tone Test (alternating Tones #0 and #63)
Q65COR <0.500-2.000>                   : Correction factor to apply to delta dac per Q65 tone. Center: 1.000
Q65NTM <ON/OFF>                        : Enable/Disable the Q65 NTMS time format
TXFREQ <1000-100000000>                : Transmit carrier frequency in KHz, no decimal

Alarms:
--------
Uppercase letters indicate currently active alarms.
Lowercase letters indicate previous alarms. Can be cleared with the CLRALM command.
A / a                                  : In initial acquisition after startup.
D / d                                  : The DAC has reached its minimum or maximum value (limit).
F / f                                  : The FLL is off.
P / p                                  : The GPS PPS signal is missing.
R / r                                  : In long cycle, the sample is rejected because it is too far away.
L / l                                  : The FLL is unlocked because it is not in a long cycle.
O / o                                  : The OCXO does not provide a 10 MHz reference
```

The Results Are In!

- First picked up VA2IW/B from the summit of Mont-Tremblant (FN26rf), some 136 km away.
- Got several reception reports from K2UA (FN12fr (328 km) and VE3KH (FN03cg, 393 km) under various propagation conditions, both ranging from nothing received to full CW copy.
- As expected, Q65-60D decoding works very well, much better than CW, even in Rain Scatter.
- Morning (sunrise + 1 hour), evening (sunset +/- 1 hour) are good for tropospheric conditions.
- Rain Scatter is best! Snow Scatter TBD.

CW at VE3KH via Rain-Scatter



Q65-60D at K2UA via Tropo

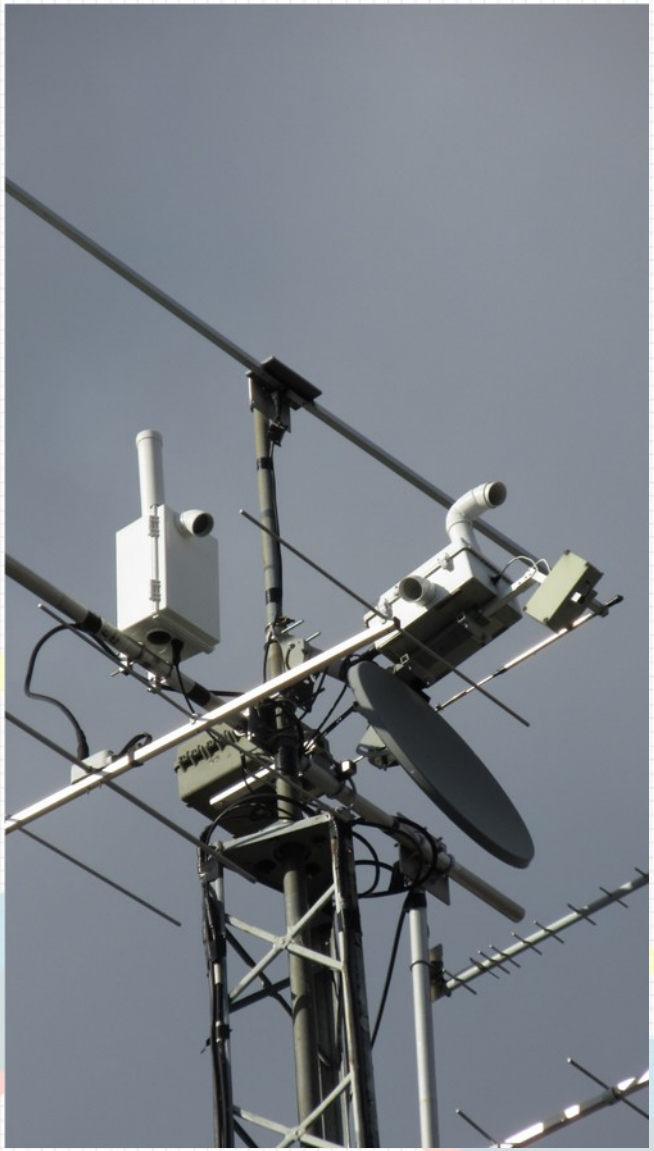
```
1316 -13 -0.8 1095 :  VA2IW/B FN25    q0
1318 -13 -0.8 1079 :  VA2IW/B FN25    q0
1320 -12 -1.0 1079 :  VA2IW/B FN25    q0
1322 -12 -0.8 1079 :  VA2IW/B FN25    q0
1326 -12 -0.8 1070 :  VA2IW/B FN25    q0
```

If I could turn back time...

- I would have incorporated a Si5351C synthesizer IC to better dither the 10 MHz reference and allow for any digital modulation schemes.
- I would have modified the antenna to make it more omnidirectional.
- I would have used a more powerful P.A., 1-2 Watts, at the cost of a higher heat generation.
- I would have used a wired interface instead of a WiFi link.

Will do:

- Change the Q65 message to “VA2IW FN25” to allow “A-Priori” decoding and gain a few more dB.



References

- Bertrand Zauhar - VE2ZAZ - VA2IW
  - Website: https://ve2zaz.net
  - YouTube: https://www.youtube.com/VE2ZAZ
    - This 10 GHz beacon project
      https://tinyurl.com/VE2ZAZ-10G-Beacon
    - Tower-Mounted 10 GHz System video series:
      https://tinyurl.com/Tower10gSystem
    - Portable 10 GHz System video series:
      https://tinyurl.com/Portable10gSystem
- Paul Wade - W1GHz
  - Website: http://www.w1ghz.org
  - Transverter and LO Multiplier section:
    https://www.w1ghz.org/xvtr/transverter.htm#10368PB

Thank You!

Questions ?



Backup Slides

Decoding Q65-60D

