

Using the RFzero™ as a beacon driver for VHF, UHF, and beyond

Central States VHF Society

July 26, 2025

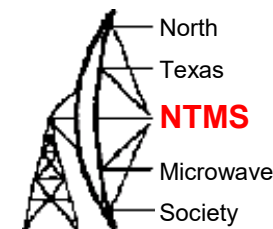
Lincoln, Nebraska

(updated 8/9/25)

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NTMS beacons¹ 50 MHz through 24 GHz



					Height					
					above					
Freq (MHz)	Call	Grid	Power	Antenna	Ground	Status		Stabilization	Freq Reference	Keying
50.073	W5HN/B	EM13sj	.5 W	Halo	180 ft	OFF THE AIR (1)	HB	Crystal	12.51825 MHz	on/off
144.280.2	W5HN/B	EM13sj	1.5 W	Halo	180 ft	ON THE AIR	HB	Crystal	12.0233 MHz	on/off
222.060	AA5C/B	EM13se	8 W	Folded Dipole	53 ft	ON THE AIR	HB	PLL	10 MHz	on/off
432.370	N5PYK/B	DM93bm	50 W	Yagi towards DFW	70 ft	ON THE AIR		XCVR		on/off
432.380	W5HN/B	EM13kf	.8 W	Halo	280 ft	ON THE AIR	HB	ADF4351	10 MHz OCXO	on/off
903.050	W5HN/B	EM13kf	9 W	Alford Slot	280 ft	ON THE AIR	HB	N5AC PLL	10 MHz OCXO	on/off
1296.375	W5HN/B	EM13kf	3 W	Alford Slot	280 ft	ON THE AIR	HB	N5AC PLL	10 MHz OCXO	on/off
2304.366	W5HN/B	EM13kf	4 W	Alford Slot	280 ft	ON THE AIR	HB	Crystal		FSK
3456.380	W5HN/B	EM13kf	250 mW	Alford Slot	280 ft	OFF THE AIR	DB6NT	Crystal X 27	128.014 MHz	FSK
3400.380	W5HN/B	EM13kf	250 mW	Alford Slot	280 ft	BEING UPGRADED (2)	DB6NT	ADF4351	125.94 MHz	on/off
5760.364	W5HN/B	EM13kf	158 mW	Alford Slot	280 ft	ON THE AIR	DB6NT	Crystal X 48	120.0079 MHz	FSK
10368.368	W5HN/B	EM13kf	2.5 W	Alford Slot	280 ft	ON THE AIR	DB6NT	Crystal X 96	108.00395 MHz	FSK
24192.300	AA5C/B	EM13sf	500 mW	16-slot WR42	75 ft	ON THE AIR	HB	Crystal	112.0015 MHz	on/off
24192.380	W5HN/B	EM13kf		10 slot Alford	280 ft	Under Construction (3)	HB	ZL PLL		on/off
47088.300	W5HN/B	?				Under Construction				

Notes

(1) Waiting for a tower climb to put antenna back up at 60ft

(2) Working on cleaning up spurs

(3) ETA 2025

Actual 10 digit grid squares

EN13sj = EM13sj91mr

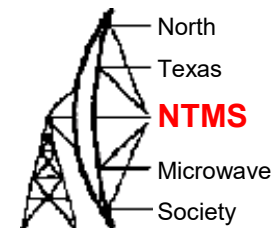
EM13se = EM13se55vi

DM93bm = DM93bm46su

EM13kf = EM13kf45pb

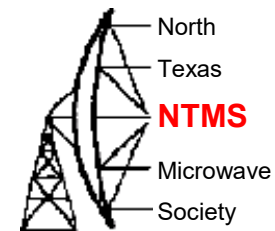
EM13sf= EM13sf89tb

Modern beacon design

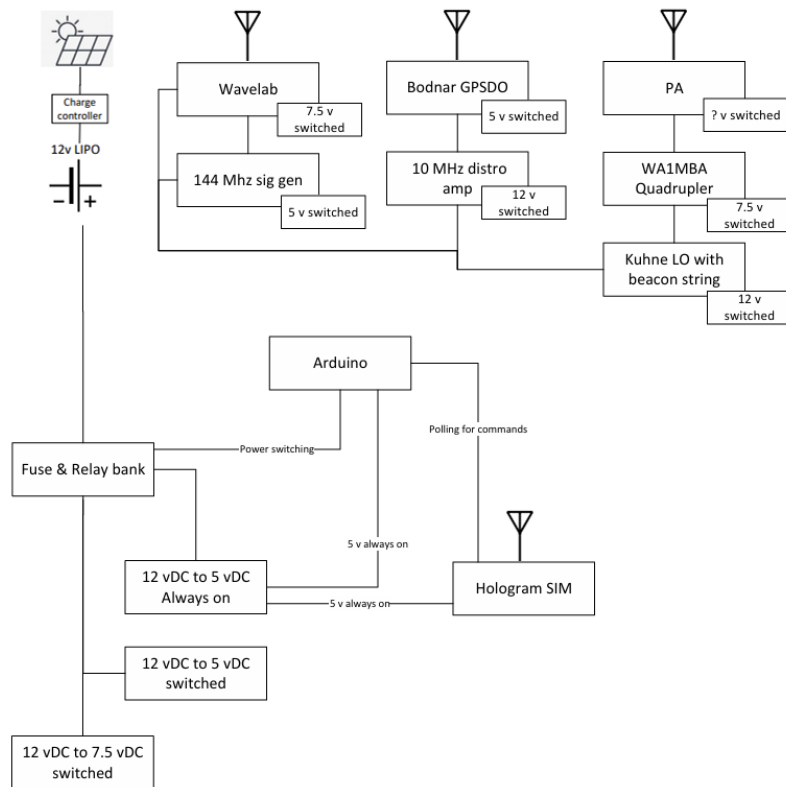


- Our strategy is to add higher powered mmWave beacons that can be remotely controlled since they do not need to run 24/7
- The original plan:
 - Use Wavelab 24 GHz system (there are many “bad RX” modules)
 - Drive Wavelab with 144 MHz sig gen with CW keyed by Arduino
 - Tom’s WA1MBA quadrupler and DB6NT LO for 47 GHz
 - 47 GHz CW string is loaded into DB6NT LO
 - Arduino controlled Hologram card for remote control
- Then we learned about the RFzero™

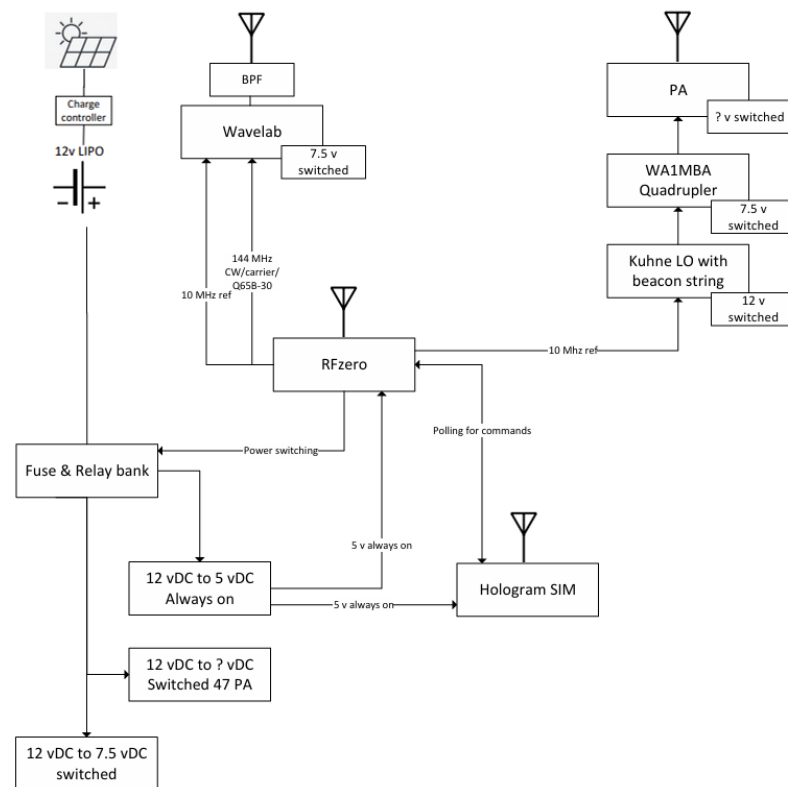
Potential design change

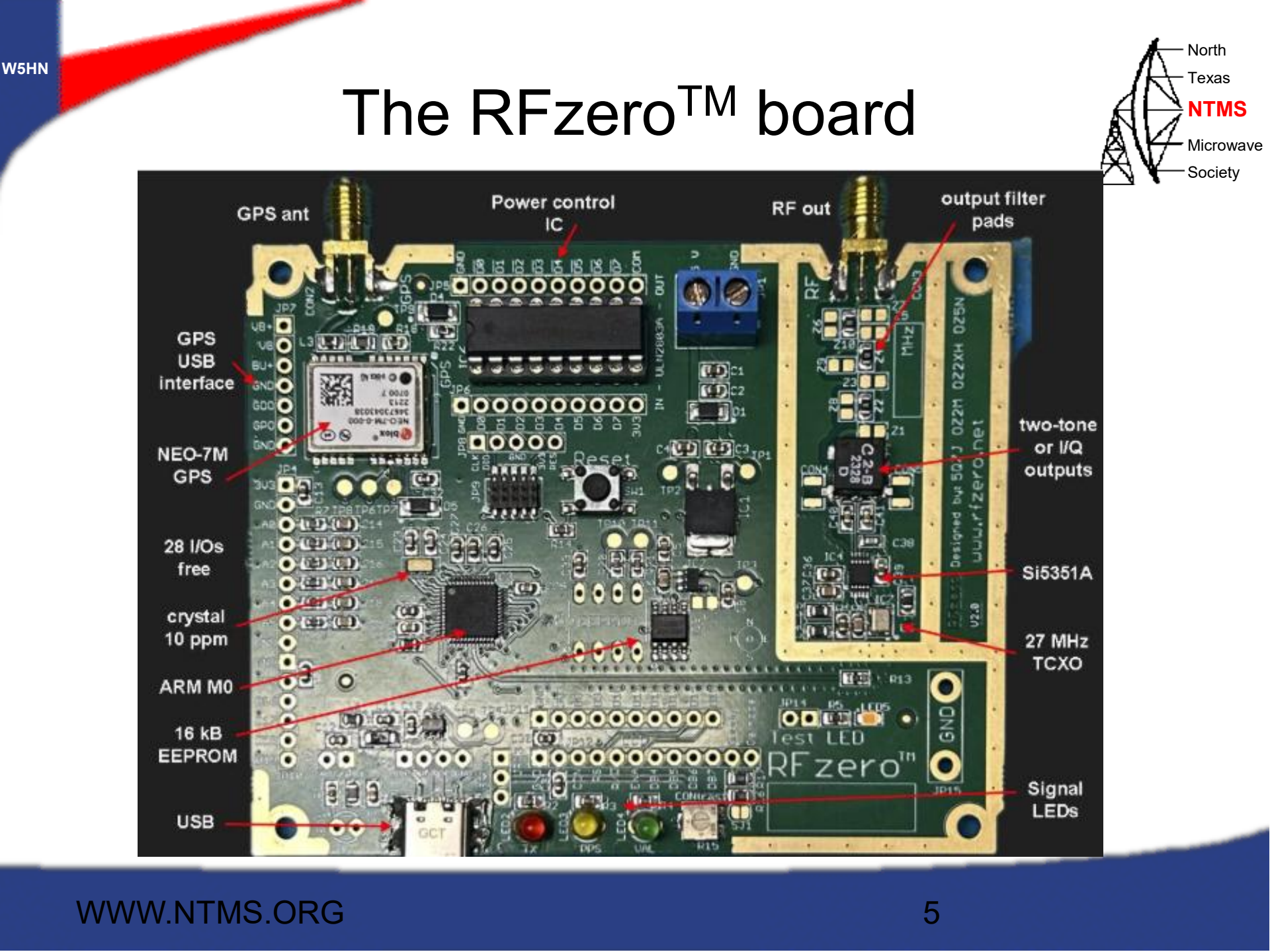


24/47 GHz Beacon v1

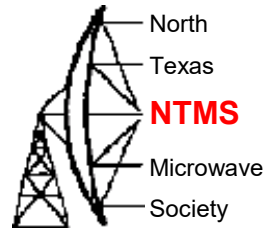


24/47 GHz Beacon v2



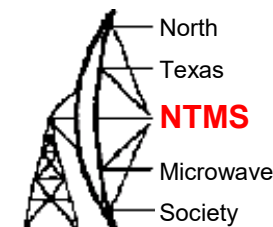


RFzero™ beacon modes



Frequencies from 2289 Hz to ~ 300 MHz (or harmonic)
CW + carrier
FT4 + CW + carrier
FT8 + CW + carrier
JS8 + CW + carrier
JT4 + CW + carrier
JT65 + CW + carrier
Q65 + CW + carrier
RTTY x 5 + CW + carrier
WSPR
Frequency compensation for multipliers up to 72 GHz
Beacon modes (not all modes shown)

RFzero™ Manager²



RFzero Manager :: www.rfzero.net :: v.1.4.1

File Communication Tools Help

```
rd cfg

Software
=====
RFzero library :: Beacon Q65 + CW + carrier :: v.1.8.0

Configuration
=====
Tl: 0: transformer*, 1: combiner, 2: none      : 0
Display: 0: none, 1: 16x2, 2: 20x4*, ...      : 1
PCF8574 I2C addr: 0, 0x20 to 0x27, 0x38 to 0x3F : 00
Warm up before transmitting: 0* to 255 s      : 0
Curr. level: 0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA* : 3

Wait for valid GPS before TX: 0: no*, 1: yes   : 0
Echo GPS data to USB 0: off*, 1: on, 2: all    : 0

Nominal beacon frequency in Hz                : 144000000
Calibration interval: 1 to 255, 5*            : 5
Keying style: 0: OOK, 1: FSK*                 : 0
CW speed: 1 to 255 ms, 100 ms* = 12 WPM/60 LPM : 100
Call, max 15 characters                       : KM5PO/B
Locator, max AA00AA00                         : EM12IL56
MGM, max 13 characters in Q65                 : KM5PO Q65 BCN
Q65 mode: 0: 15A*, 1: 15B, 2: 15C, 3: 15D, ... : 6

*: default value

RFzero config>
```

Connection (RFzero = Arduino Zero)

COM9 - Arduino Zero

? Refresh **Connected** Disconnect

Example programs (double click for online information)

Beacon JT4 + CW + carrier
Beacon JT65 + CW + carrier
Beacon JT9 + CW + carrier
Beacon ModeX + CW + carrier
Beacon PI4 + CW + carrier
Beacon PI4 + CW + carrier with multiplier
Beacon PI4 + CW + chirp + carrier
Beacon Q65 + CW + carrier
Beacon RTTY x 5 + CW + carrier
Beacon WSPR

Upload ☐ Verbose

? (F1) exit (F5) (F9)

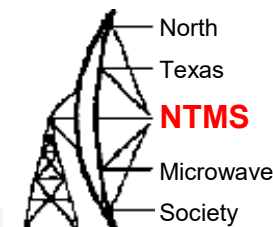
config (F2) (F6) (F10)

rd cfg (F3) (F7) (F11)

wr defaults (F4) (F8) (F12)

☐ No scroll 04:57:36 04:57:36

RFzero™ Manager



RFzero Manager :: www.rfzero.net :: v.1.4.1

File Communication Tools Help

Configuration

```
=====
wr bcn CALL          to set the CALL, max 15 characters
wr loc LOCATOR       to set the LOCATOR, max eight characters
wr mgm MESSAGE       to set the Q65 message, max 13 characters where <space> = _

wr mode MODE         to set Q65 sub-mode: 0: 15A, 5: 30A, 10: 60A, 15: 120A, 20: 300A
                                     1: 15B, 6: 30B, 11: 60B, 16: 120B, 21: 300B
                                     2: 15C, 7: 30C, 12: 60C, 17: 120C, 22: 300C
                                     3: 15D*, 8: 30D, 13: 60D, 18: 120D, 23: 300D
                                     4: 15E*, 9: 30E*, 14: 60E, 19: 120E, 24: 300E
                                     *: Not in WSJT-X, use MSHV instead

wr speed DURATION    to set the CW speed, i.e. duration in ms, 1 ms to 255 ms. 100 ms = 12 WPM/60 LPM
wr key STYLE         to set keying style: 0: OOK, 1: FSK

wr freq FREQ         to set the beacon nominal frequency in Hz from 100 kHz and up

wr cal INTERVAL      to set the number of sequences before calibrating the frequencies, 1 - 255
wr warmup SECONDS    to set the number of seconds to warm up the H/W before transmitting, 0 - 255

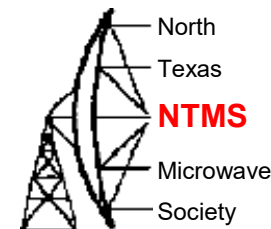
wr wait ONOFF        to turn on/off waiting for the GPS to be valid before transmitting: 0: off, 1: on
wr gps MODE          to echo GPS data on the USB port where MODE is: 0: off, 1: on, 2: all

wr defaults          to set the H/W and S/W defaults
wr tl MODE           to set the T1 hardware mode where MODE is:
                     0: transformer, 1: combiner, 2: none
wr display MODE      to set the display mode where MODE is: 0: none, 1-6 see:
                     www.rfzero.net/documentation/hardware/displays for more information
wr pcf8574 ADDR       to set the PCF8574 I2C address: 0, 0x20-0x27 or 0x38 to 0x3F
wr level LEVEL       to set the Si5351A output stages' drive strength current level where:
                     0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA*

rd cfg              to list the current configuration
```

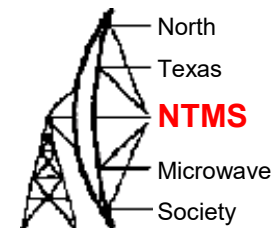
RFzero config>

Check tone spacing bandwidth



- The RFzero™ over the air WSJT-X signal at 144 MHz decoded 100%
- The 144 MHz signal generated is fundamental from the RF chip (not a harmonic)
- Observed proper timing through GPS clocking
- Observed no drift in ambient shop conditions

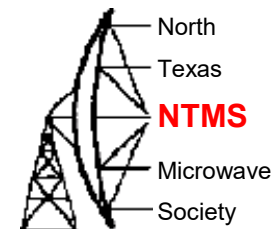
Check tone spacing bandwidth



- Referring to the Q65 Quick Start Guide³ we noted that the Q65 30 seconds T/R Period had bandwidth spreads ranging from 433 Hz (sub-mode B) to 1733 Hz (sub-mode D)

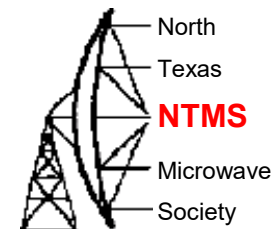
T/R Period (s)	A		B		C		D		E	
	Spacing (Hz)	Width (Hz)	Spacing (Hz)	Width (Hz)	Spacing (Hz)	Width (Hz)	Spacing (Hz)	Width (Hz)	Spacing (Hz)	Width (Hz)
15	6.67	433	13.33	867	26.67	1733	N/A		N/A	
30	3.33	217	6.67	433	13.33	867	26.67	1733	N/A	
60	1.67	108	3.33	217	6.67	433	13.33	867	26.67	1733
120	0.75	49	1.50	98	3.00	195	6.00	390	12.00	780
300	0.29	19	0.58	38	1.16	75	2.31	150	4.63	301

Check tone spacing bandwidth



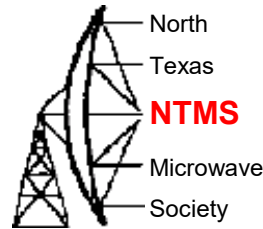
- Q65B seemed like a good place to start
- Side note: we have made contacts with Q65B-30 on 24 and 47 GHz so a digital mmWave beacon is viable
- A 10 MHz referenced HackRF module and SDR Console was used to make observations of tone spacing.

Check tone spacing bandwidth



- We used 6 dBm 10 MHz ref from Spectracom Ageless GPSSDO as input to the HackRF.
- The CLKIN port on HackRF One is a high impedance input that expects 3.3 V square wave at 10 MHz. Do not exceed 3.3 V or drop below 0 V on this input3.

Configure CLKIN port on HackRF

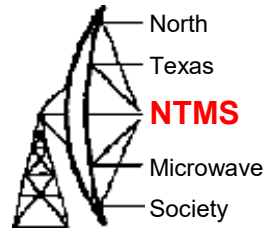


- Use Linux command line to config CLKIN port and verify reference clock signal detect

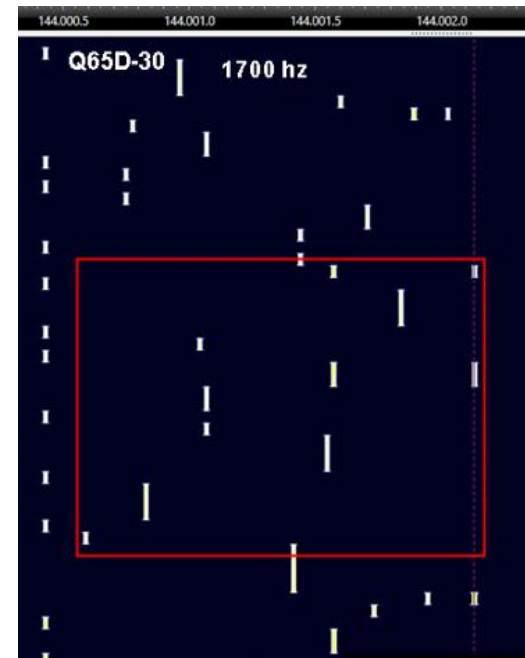
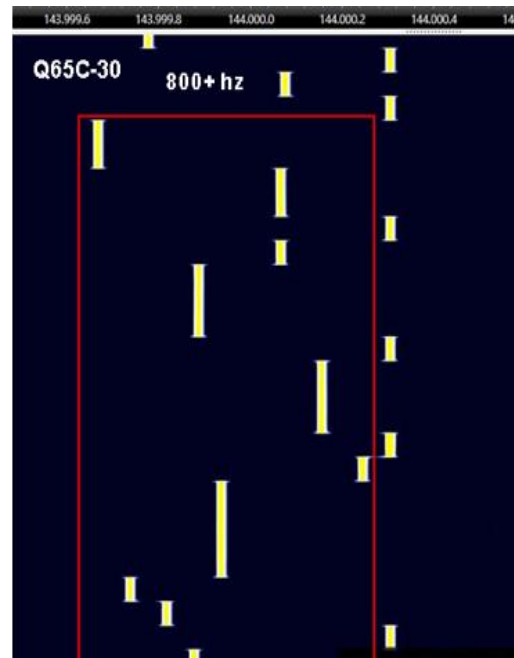
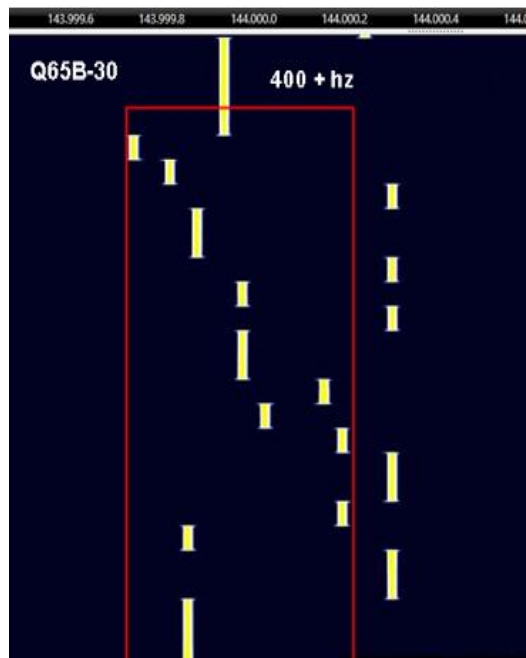
```
live@live: ~
Serial number: 000000000000000066a062dc256c639f
Board ID Number: 2 (HackRF One)
Firmware Version: 2024.02.1 (API:1.08)
Part ID Number: 0xa000cb3c 0x00664768
Hardware Revision: r10
Hardware appears to have been manufactured by Great Scott Gadgets.
Hardware supported by installed firmware:
  HackRF One
live@live:~$ hackrf_clock
An operation must be specified.
hackrf_clock - HackRF clock configuration utility
Usage:
  -h, --help: this help
  -r, --read <clock_num>: read settings for clock_num
  -a, --all: read settings for all clocks
  -i, --clkin: get CLKIN status
  -o, --clkout <clkout_enable>: enable/disable CLKOUT
  -d, --device <serial_number>: Serial number of desired HackRF.

Examples:
  hackrf_clock -r 3 : prints settings for CLKOUT
live@live:~$ hackrf_clock -i
CLKIN status: no clock signal detected
live@live:~$ hackrf_clock -i
CLKIN status: clock signal detected
live@live:~$
```

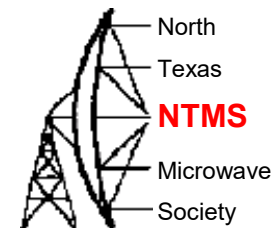
Tone spacing confirmed



- Q65B Q65C Q65D modes accurately spaced as observed in SDR receiver

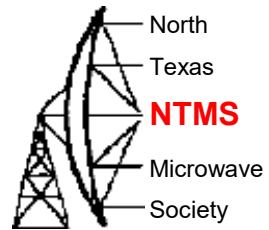


Managing harmonics

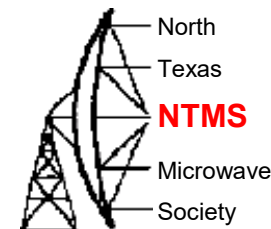


- We then moved on to harmonic testing and working to understand the “multiply” feature noted in RFzero™ documentation⁴
- Setting the SDR to receive at 1296 MHz and keeping all the same variables as the last test (Q65D-30 at 144 MHz) we expected to see 9 x 1733 Hz spacing (9th harmonic of 144 MHz) and this was confirmed with observation of approximately 15.6 KHz bandwidth

144 MHz harmonic at 1296 MHz (9th harmonic)



Managing harmonics



- Digging into the documentation we found that the correct method for programming 1296 MHz output is to write the configuration frequency as 1296 MHz and let the RFzero™ program library do the work
- The *calculateTonesMulti* function contains the math that resolves the tone spacing and bandwidth and selects the appropriate frequency (under 300 MHz) to drive the RF synthesizer.

Managing harmonics

- Note Multiplier of 7 which means fundamental is at 185.14 MHz

```
RFzero Manager :: www.rfzero.net :: v.1.4.1
File  Communication  Tools  Help

Software
=====
RFzero library :: Beacon Q65 + CW + carrier :: v.1.8.0

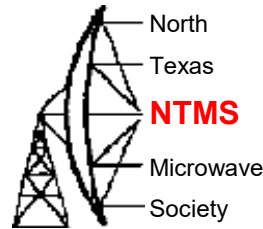
Configuration
=====
T1: 0: transformer*, 1: combiner, 2: none          : 0
Display: 0: none, 1: 16x2, 2: 20x4*, ...           : 1
PCF8574 I2C addr: 0, 0x20 to 0x27, 0x38 to 0x3F : 00
Warm up before transmitting: 0* to 255 s          : 0
Curr. level: 0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA* : 3

Wait for valid GPS before TX: 0: no*, 1: yes       : 0
Echo GPS data to USB 0: off*, 1: on, 2: all        : 0

Nominal beacon frequency in Hz                    : 1296000000
Multiplier                                         : 7
Calibration interval: 1 to 255, 5*                 : 5
Keying style: 0: OOK, 1: FSK*                       : 0
CW speed: 1 to 255 ms, 100 ms* = 12 WPM/60 LPM    : 100
Call, max 15 characters                           : KM5PO/B
Locator, max AA00AA00                             : EM12IL78
MGM, max 13 characters in Q65                     : NTMS BEACON
Q65 mode: 0: 15A*, 1: 15B, 2: 15C, 3: 15D, ...    : 8

*: default value
```

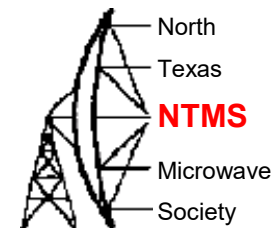
Managing harmonics



- Observe correct tone spacing of 7th harmonic



Managing harmonics



- 2nd test – set output frequency to 10368.300 MHz

```
RF Rfzero Manager :: www.rfzero.net :: v.1.4.1
File Communication Tools Help

Software
=====
Rfzero library :: Beacon Q65 + CW + carrier :: v.1.8.0

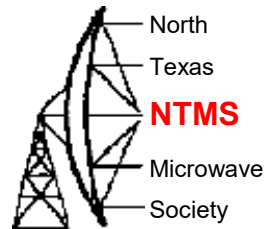
Configuration
=====
Tl: 0: transformer*, 1: combiner, 2: none           : 0
Display: 0: none, 1: 16x2, 2: 20x4*, ...           : 1
PCF8574 I2C addr: 0, 0x20 to 0x27, 0x38 to 0x3F : 00
Warm up before transmitting: 0* to 255 s          : 0
Curr. level: 0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA* : 3

Wait for valid GPS before TX: 0: no*, 1: yes       : 0
Echo GPS data to USB 0: off*, 1: on, 2: all        : 0

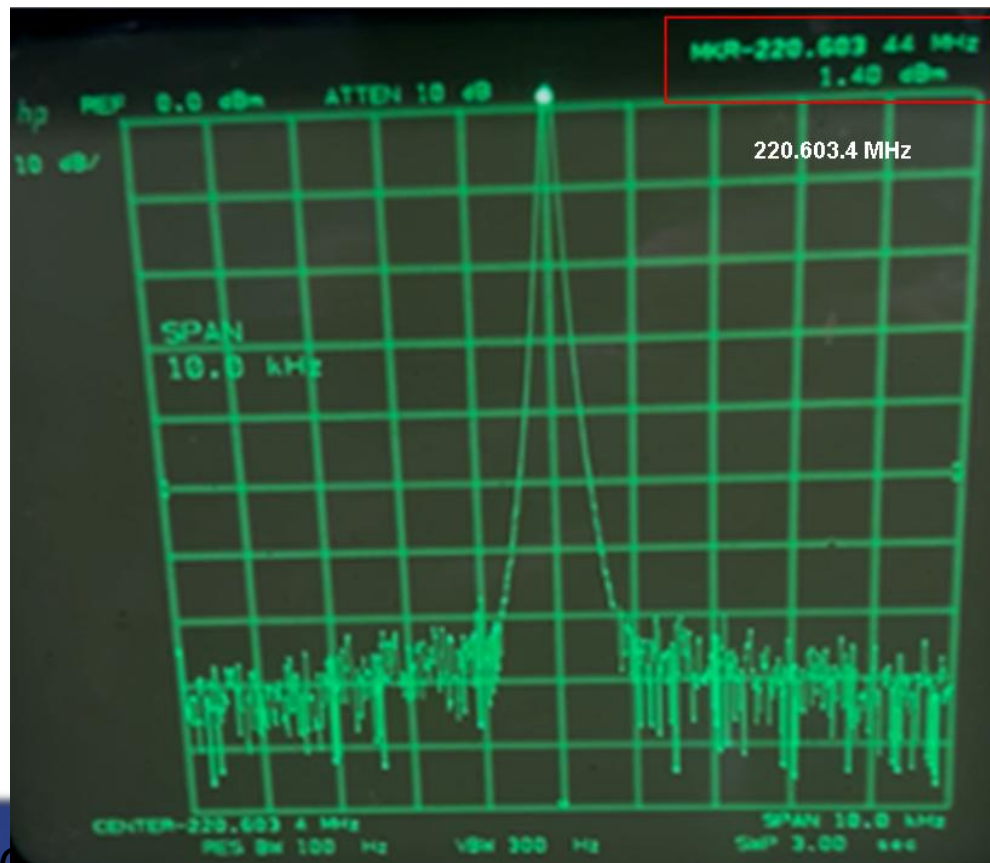
Nominal beacon frequency in Hz                     : 10368360000
Multiplier                                          : 47
Calibration interval: 1 to 255, 5*                 : 5
Keying style: 0: OOK, 1: FSK*                      : 0
CW speed: 1 to 255 ms, 100 ms* = 12 WPM/60 LPM    : 100
Call, max 15 characters                            : KM5PO/B
Locator, max AA00AA00                              : EM12IL78
MGM, max 13 characters in Q65                      : NTMS BEACON
Q65 mode: 0: 15A*, 1: 15B, 2: 15C, 3: 15D, ...   : 8

*: default value
```

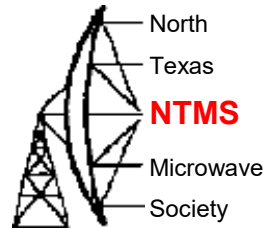
Managing harmonics



- Observe the fundamental of 220.6034 MHz



Adding filters



- To suppress harmonics there are filter pads on the board in the RF output section and standalone filter PCB boards available.
- We tested both.
- First was a band pass filter 100–150 MHz built directly on the board.

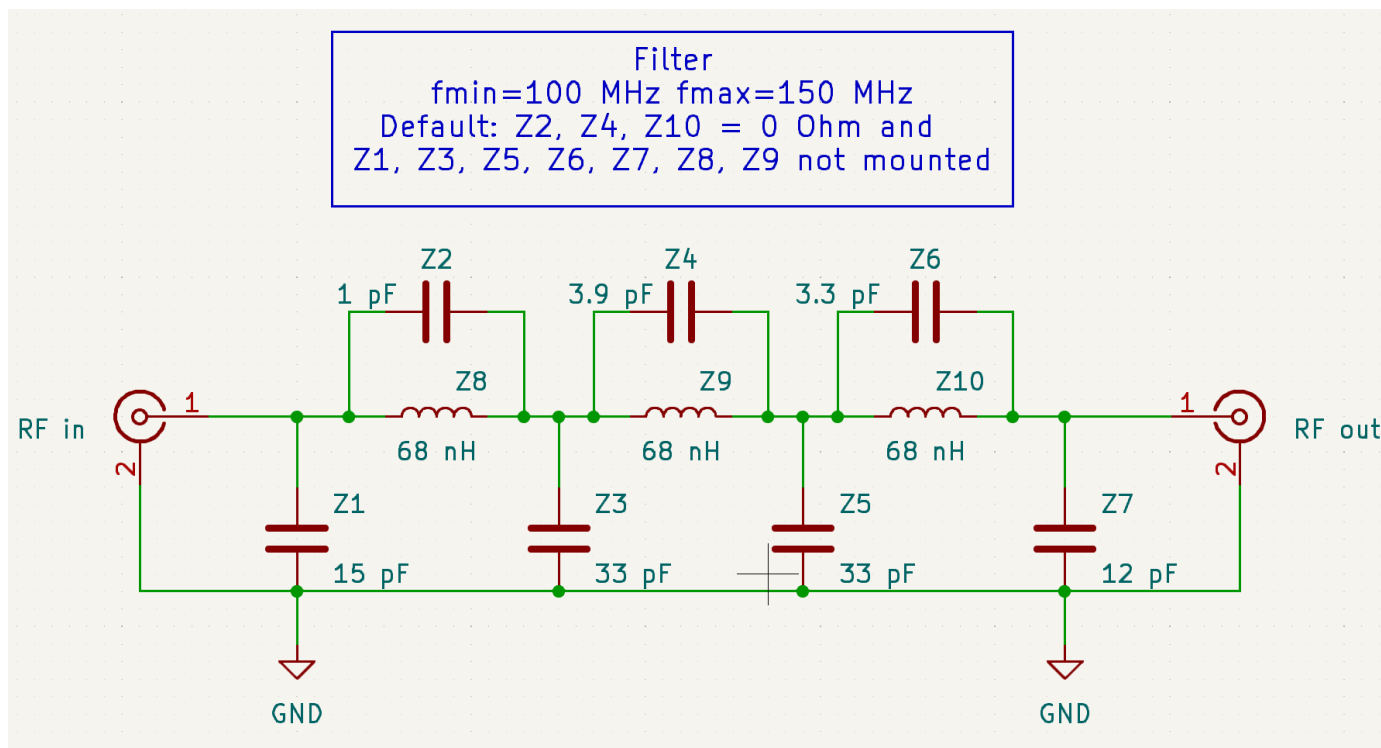
100 – 150 MHz BPF

- The Elsie filter design program⁵ is free to use and has several good features that enable filter design.
- Elsie design parameters for the 100–150 MHz band pass filter.

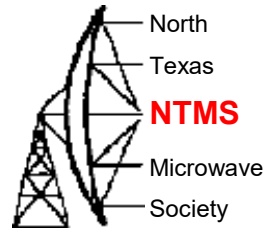
fmin	fmax	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10
100 MHz	150 MHz	15 pF	1 pF	33 pF	3,9 pF	33 pF	3,3 pF	12 pF	68 nH	68 nH	68 nH

100 – 150 MHz BPF

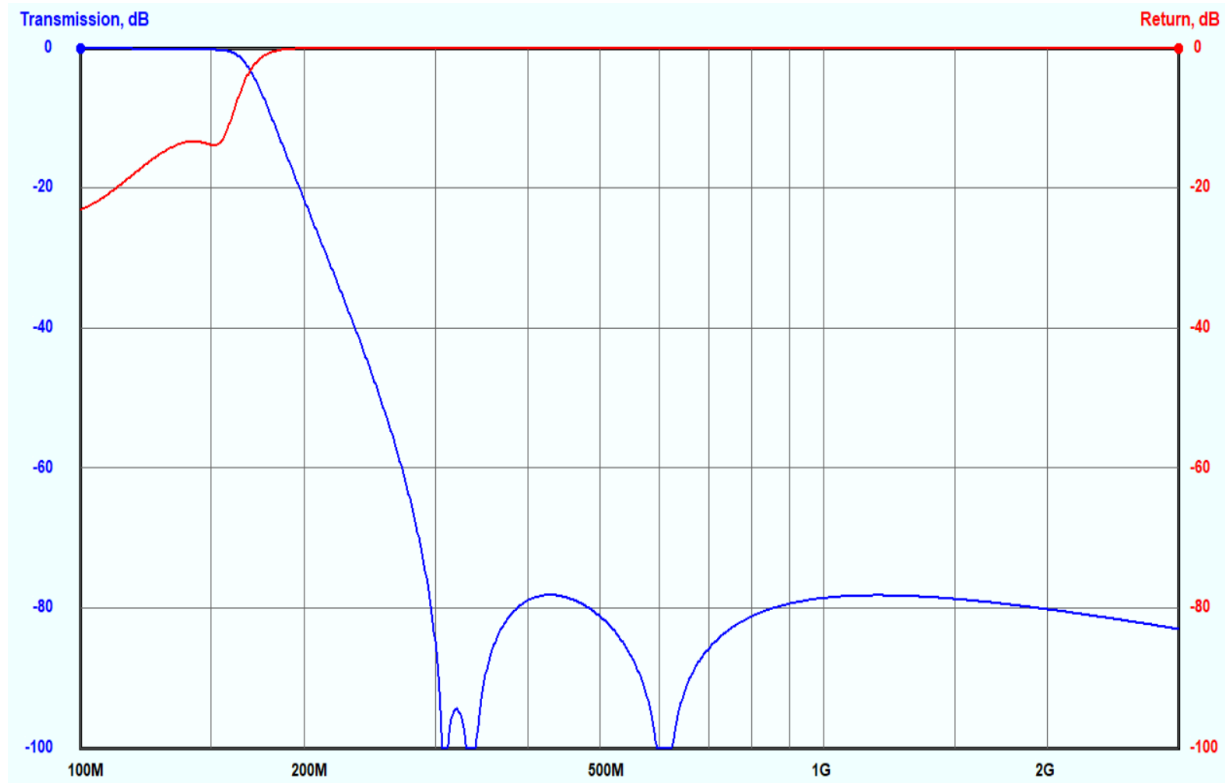
- KiCad schematic of Elsie design



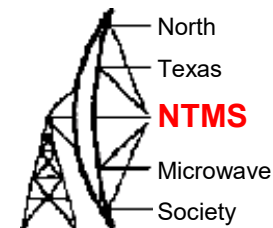
100 – 150 MHz BPF



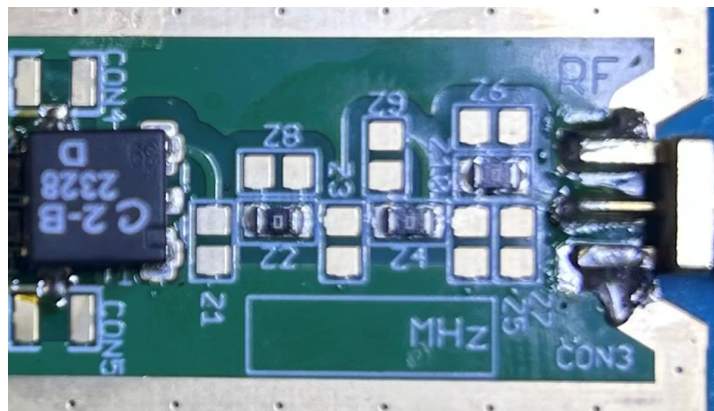
- Elsie theorized plot



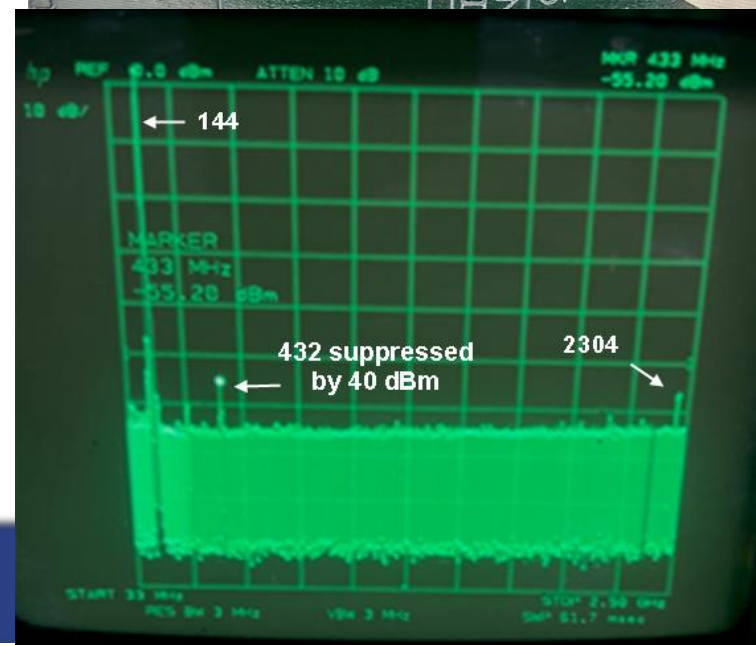
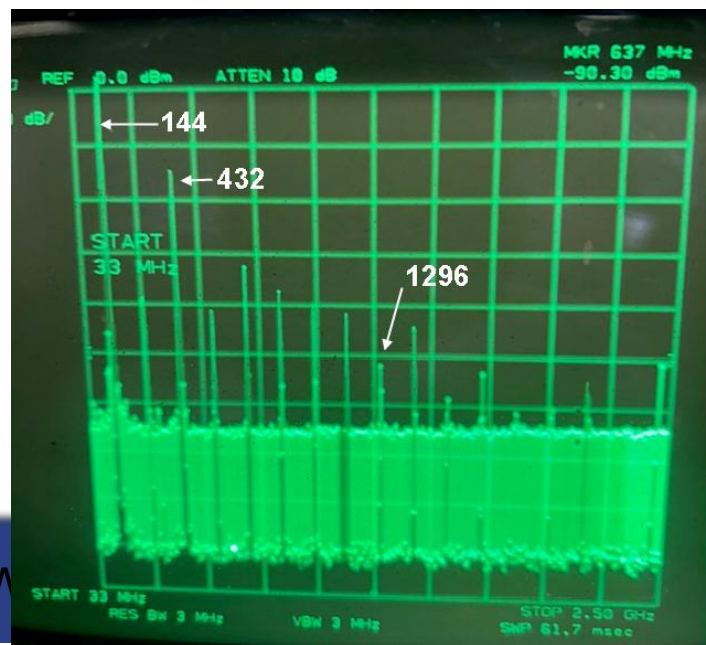
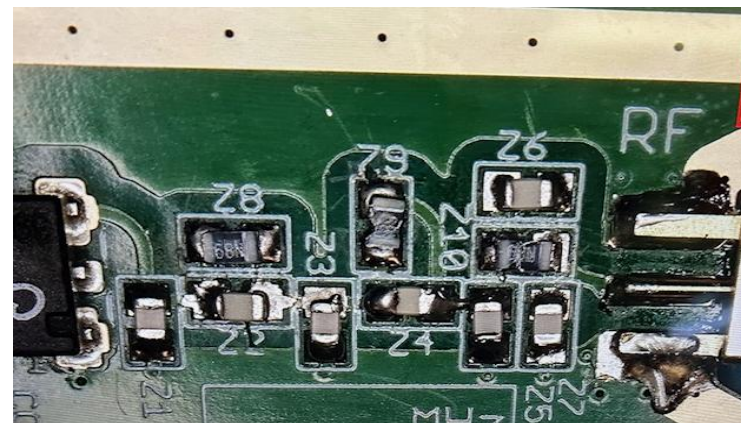
100 – 150 MHz BPF



Before filter

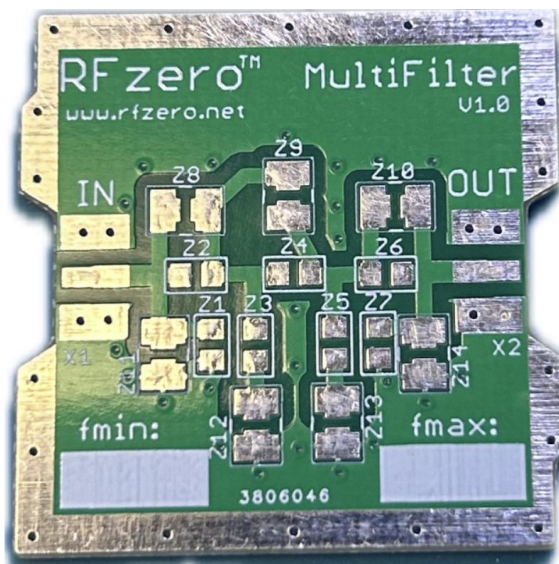


After filter



400 MHz High Pass Filter

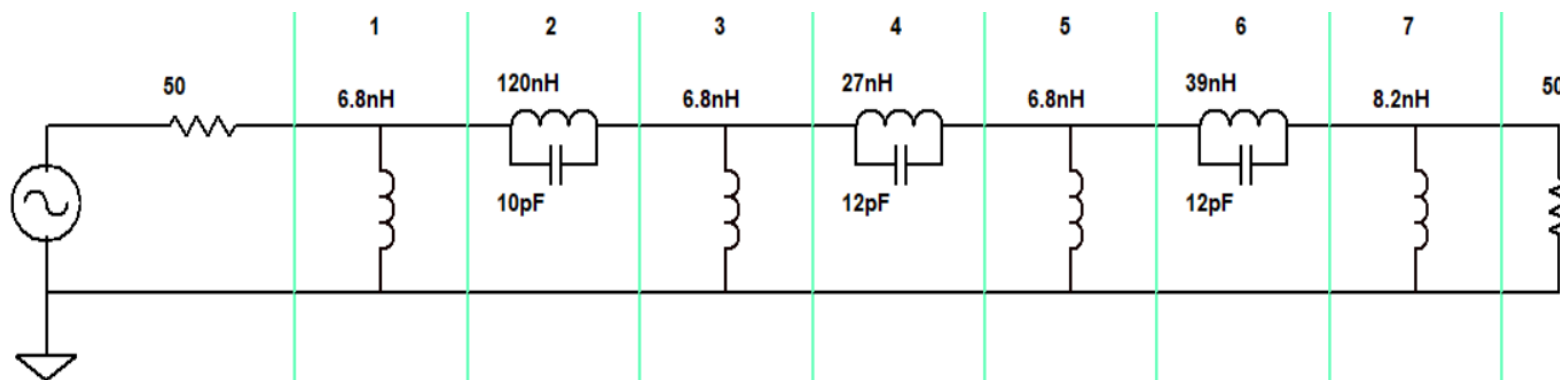
- Next, we built a 400 MHz high pass filter which would suppress below 400 MHz yet allow harmonics above 400 MHz to be usable. See standalone external filter board below.



400 MHz HPF

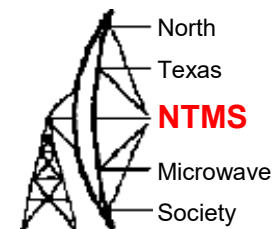
- Elsie design parms and Elsie schematic

fmin	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10
400 MHz	6,8 nH	130 nH	6,8 nH	27 nH	6,8 nH	39 nH	8,2 nH	10 pF	12 pF	12 pF

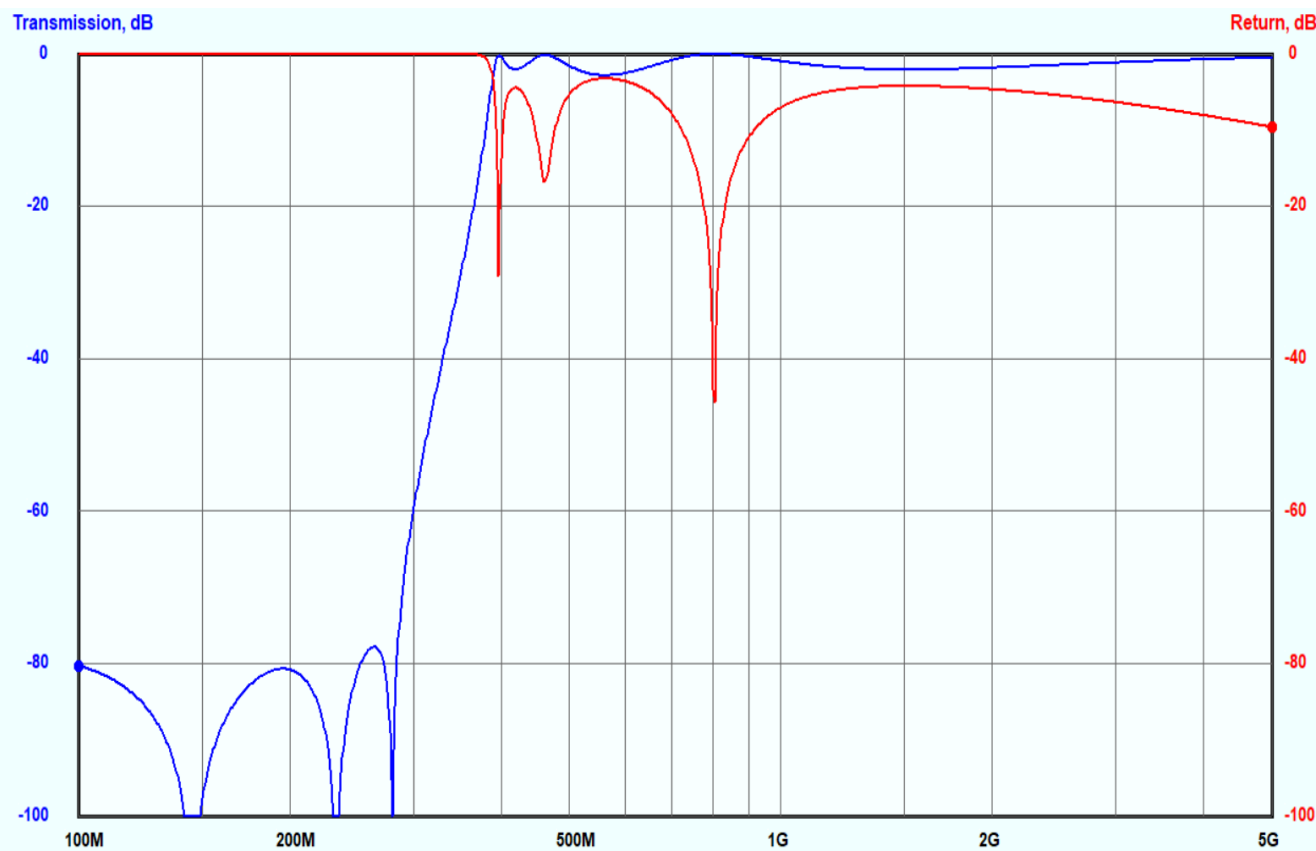


Had to sub 120 nH inductor for 130

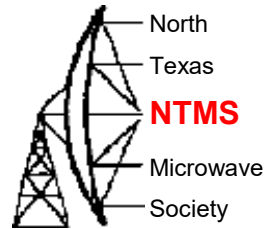
400 MHz HPF



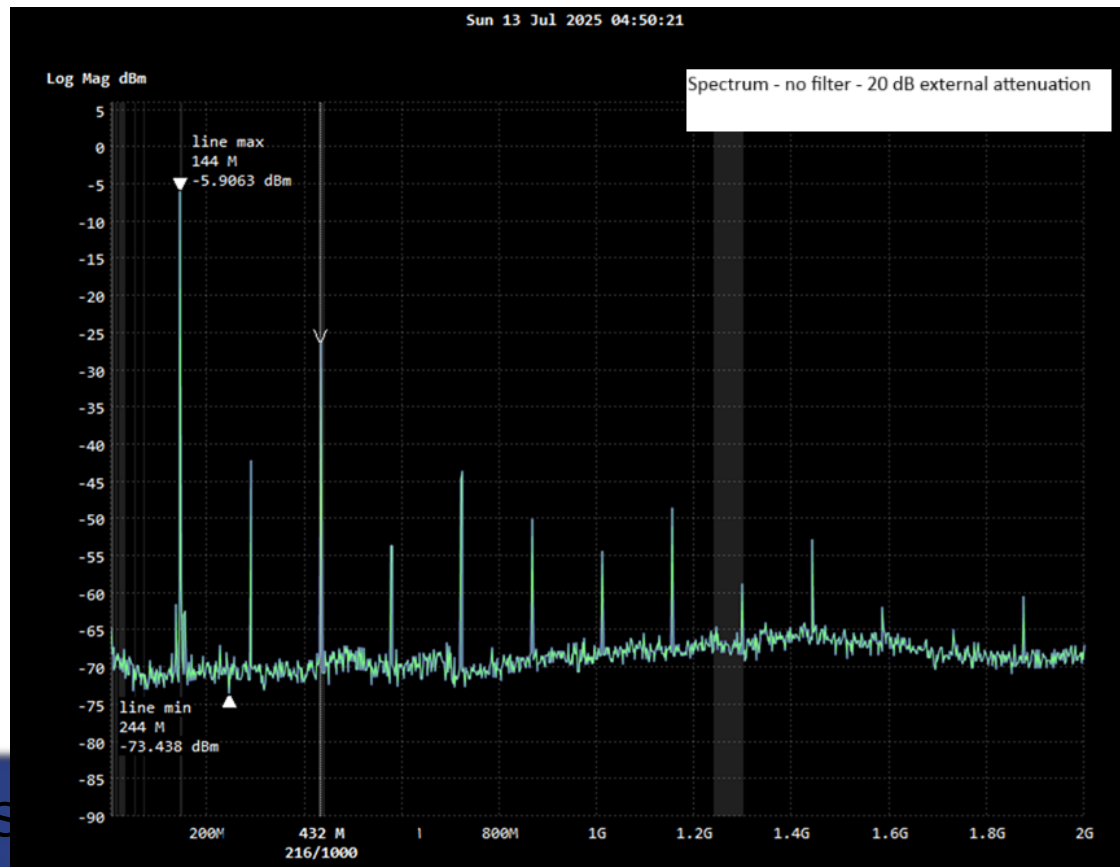
- Elsie theorized plot



432.300 programmed no filter

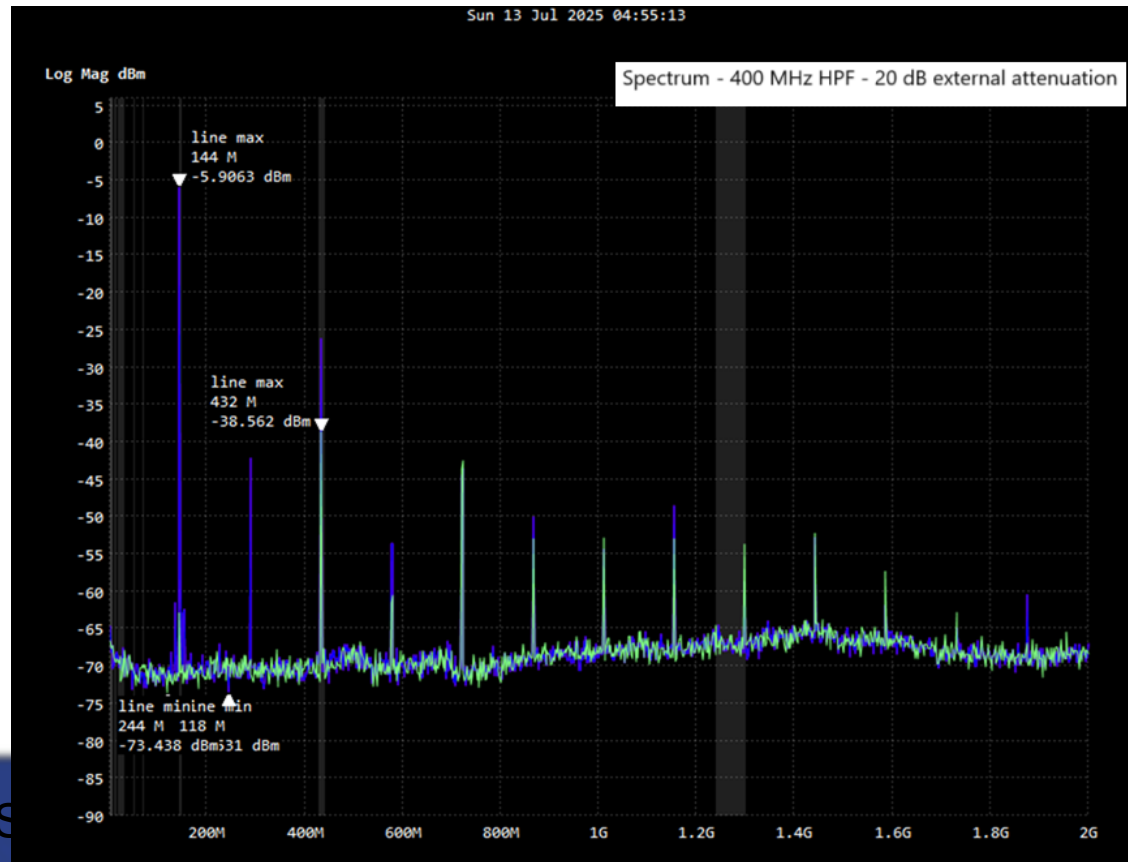


- RFzero™ programmed for 432.300, no output filter.
- 144.100 fundamental is +14.1 dBm
- 432.300 harmonic is -7 dBm



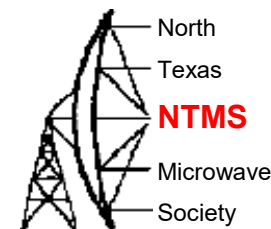
High pass filter in place

- 400 MHz High Pass Filter (external) added
- 144.100 fundamental is -43 dBm – suppressed 57 dB
- 432.300 harmonic is -18 dBm – dropped 11 dB

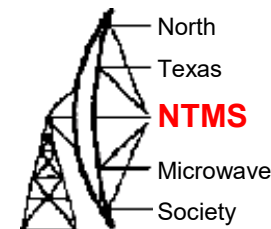


Test setup

- Test setup with external 400 MHz HPF

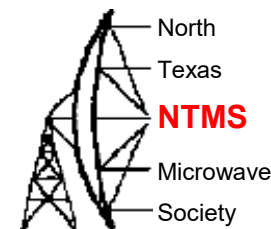


Driving a 24 GHz Wavelab unit

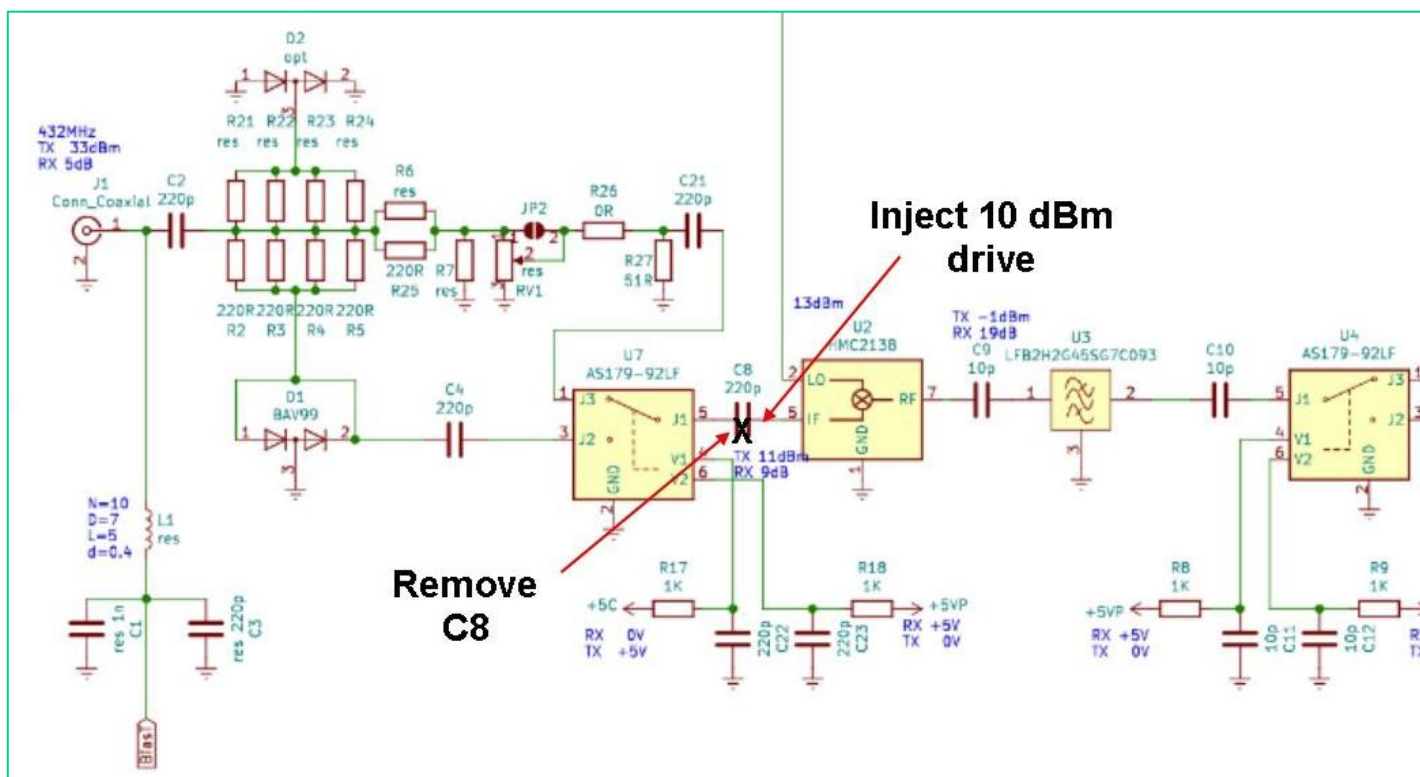


- Use RFzero™ board with 100-150 MHz BPF
- Program and adjust RFzero™ to 144.360 MHz output to 10 dBm
- Program the mode to use “Q65B-30/Carrier/CW”
 - Digital first half of even minute
 - Carrier second half of even minute
 - CW string first half of odd minute
 - Remainder of odd minute is carrier
- Inject the 144.360 MHz signal ahead of the Wavelab mixer
- This will drive the Wavelab to full output (approx. 31 dBm) at 24192.360

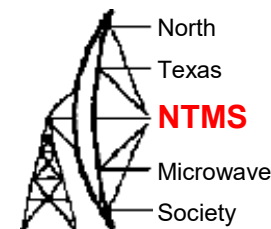
Driving a 24 GHz Wavelab unit



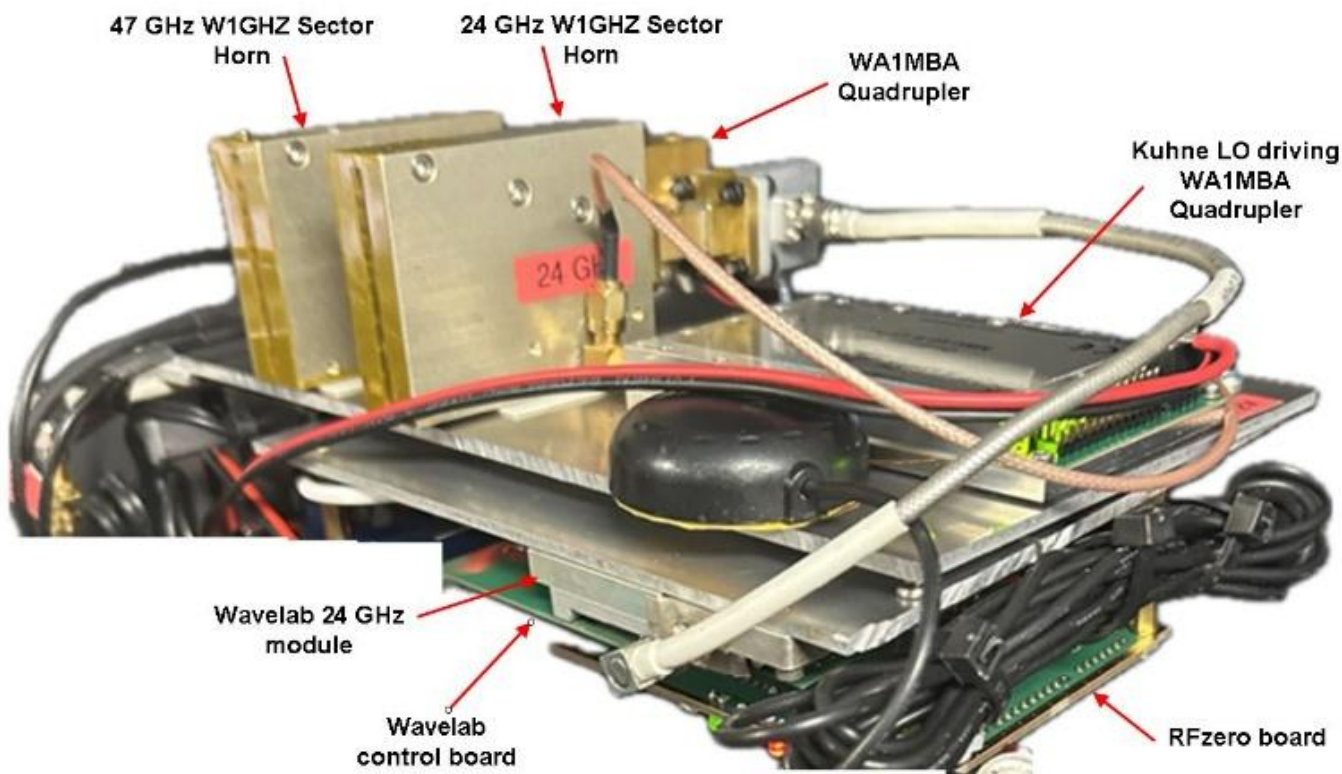
- Remove C8 and inject on pad closest to mixer
- Put Wavelab into TX mode



Empirical testing

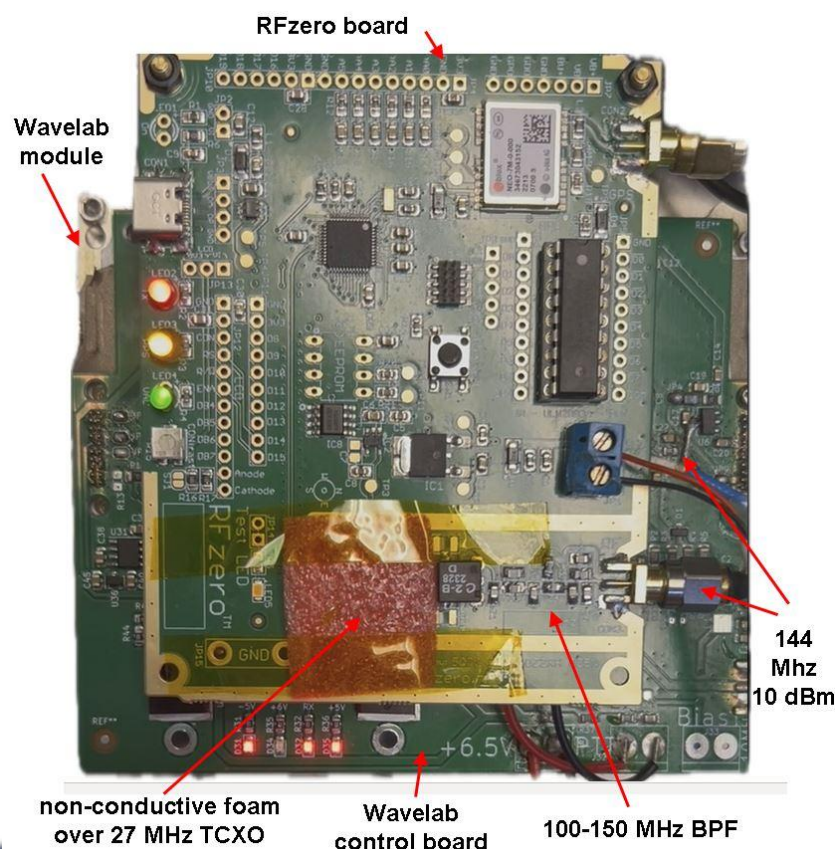


- Use W1GHZ sector horn for both 24 and 47 GHz

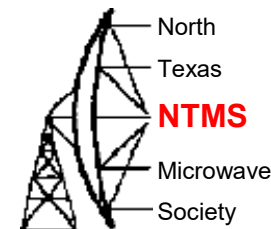


Empirical testing

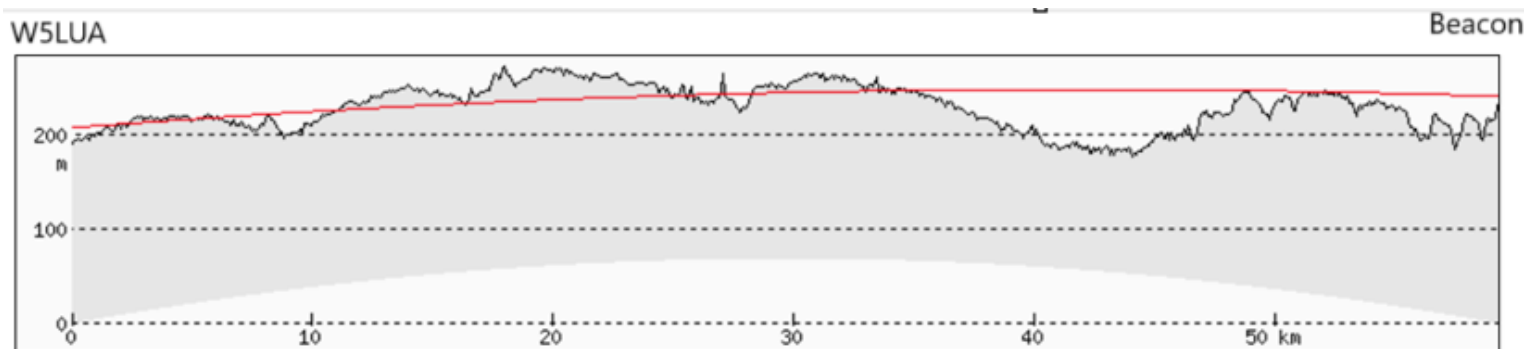
- RFzero™ and Wavelab board/module. Note perturbation shield⁶ over 27 MHz TCXO



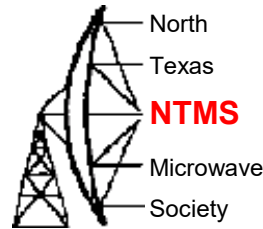
Empirical testing



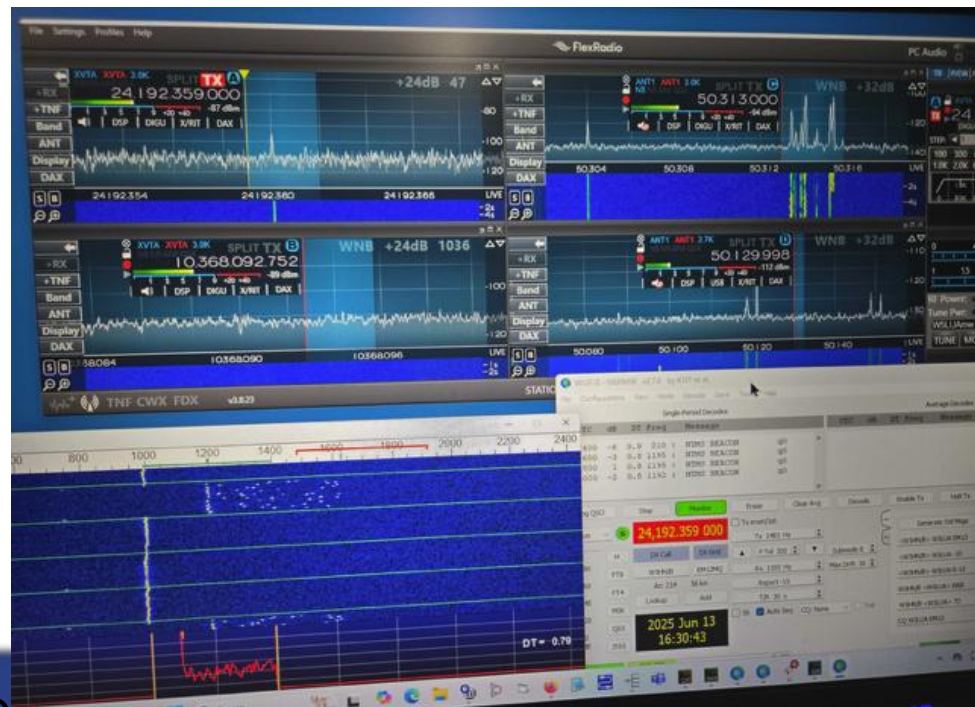
- Using a trailer mounted telescoping mast, the beacon assembly was raised to approximately 30 feet.
- The WSJT-X Q65B-30 signal was strong at 60 km and decoded 100% by Al Ward, W5LUA.



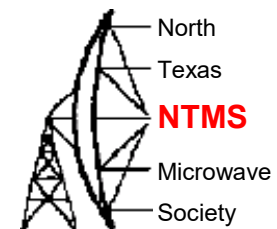
Empirical testing



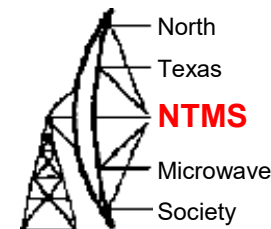
- Rotating the beacon 180 degrees, the WSJT-X Q65B-30 signal was decoded at -23 illustrating the W1GHZ broad pattern Sector Horn. Video is available⁷



Field setup

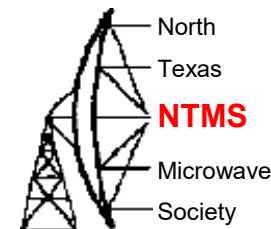


Conclusion



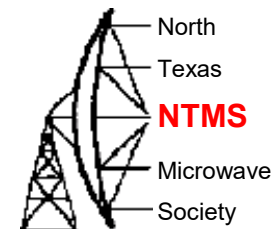
- The RFzero™ has been available for several years and offers a good choice as a beacon driver as well as other functions.
- A large user group exists, and the company provides prompt responses to questions.
- New releases of the Arduino scripts are made as corrections are found to be necessary.
- Note: use the latest release of the RF Manager which is version 1.9.0 (May 31, 2025 release)

Conclusion



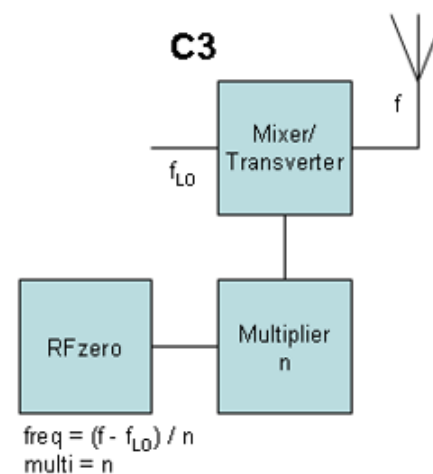
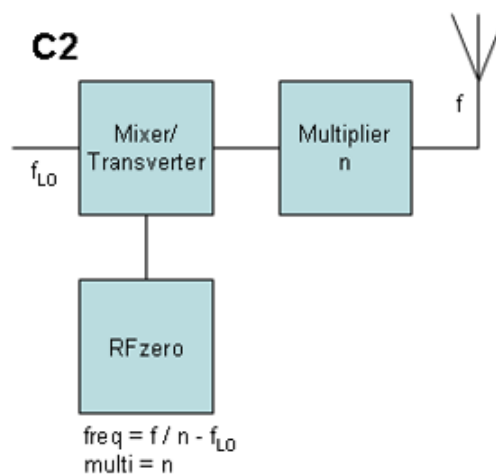
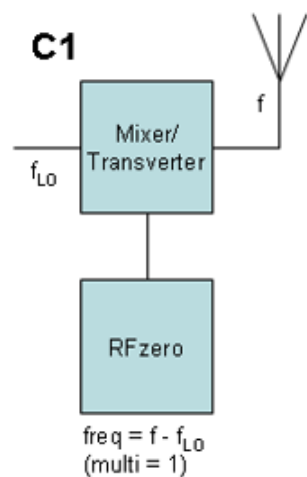
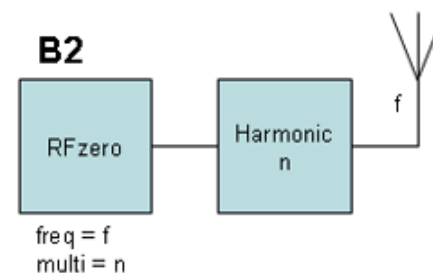
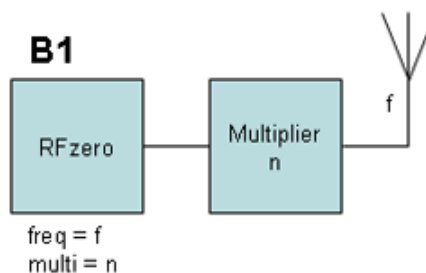
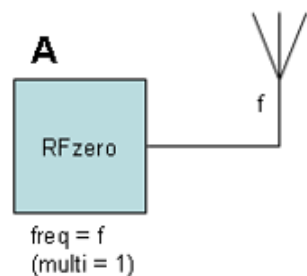
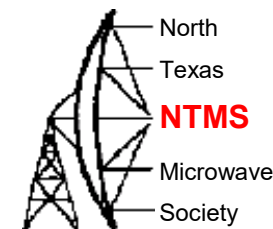
- Stability is sufficient to enable WSJT-X modes at VHF and UHF with attention paid to shielding the 27 MHz crystal oscillator.
- For microwave frequencies, use a transverter principle where the RFzero (IF) signal is below 280 MHz.
- NTMS will implement the power control IC, the on-board GPS and the Arduino C++ coding (allowing modification of existing sketches) to reduce the parts count in our original design.

Addendum

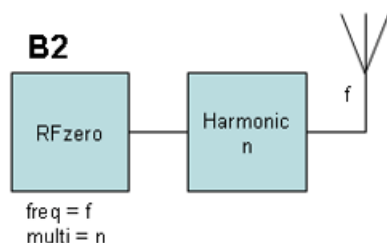


- If we place a “South” beacon system in DFW then let’s add 10 GHz with Q65/CW/Carrier.
- So now we need 10/24/47 GHz driven by RFzero beacon boards.
- How does the RFzero produce integral WSJT tones through mixer and multiplication strategies?

Application models by Bo Hansen OZ2M



B2 Example



10368360000/47=

220.603404 MHz

Fundamental

Multi=47

Q65 tone width and bandwidth is 1/47th of required tone width and bandwidth at the fundamental signal.

Software

RFzero library :: Beacon Q65 + CW + carrier :: v.1.9.0

Configuration

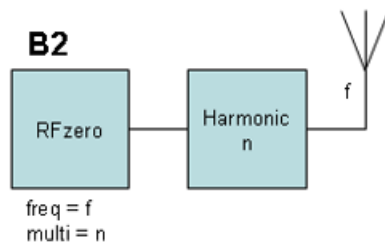
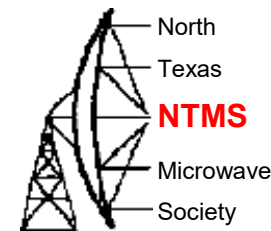
```

Tl: 0: transformer*, 1: combiner, 2: none      : 0
Display: 0: none, 1: 16x2, 2: 20x4*, ...      : 1
PCF8574 I2C addr: 0, 0x20 to 0x27, 0x38 to 0x3F : 00
Warm up before transmitting: 0* to 255 s      : 0
Curr. level: 0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA*: 0

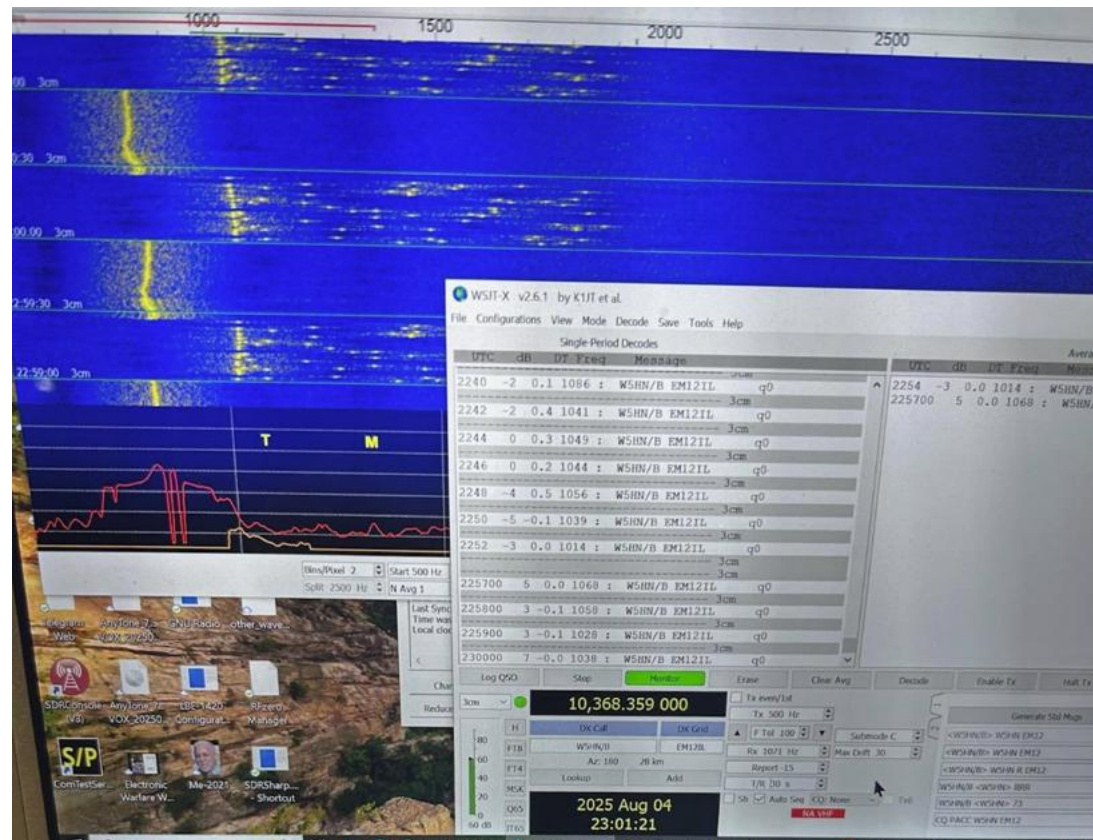
Wait for valid GPS before TX: 0: no*, 1: yes   : 0
Echo GPS data to USB 0: off*, 1: on, 2: all    : 0

Nominal beacon frequency in Hz                 : 10368360000
Frequency multiplication: 1 to 255, 1*         : 47
Calibration interval: 1 to 255, 5*            : 5
Keying style: 0: OOK, 1: FSK*                 : 0
CW speed: 1 to 255 ms, 100 ms* = 12 WPM/60 LPM : 200
Call, max 15 characters                        : W5HN/B
Locator, max AA00AA00                        : EM12IL78
MGM, max 13 characters in Q65                 : W5HN/B EM12IL
Q65 mode: 0: 15A*, 1: 15B, 2: 15C, 3: 15D, ... : 12
  
```

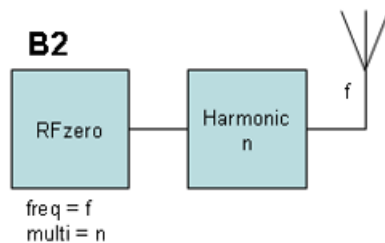
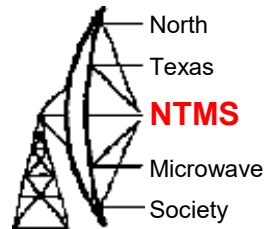
B2 Example



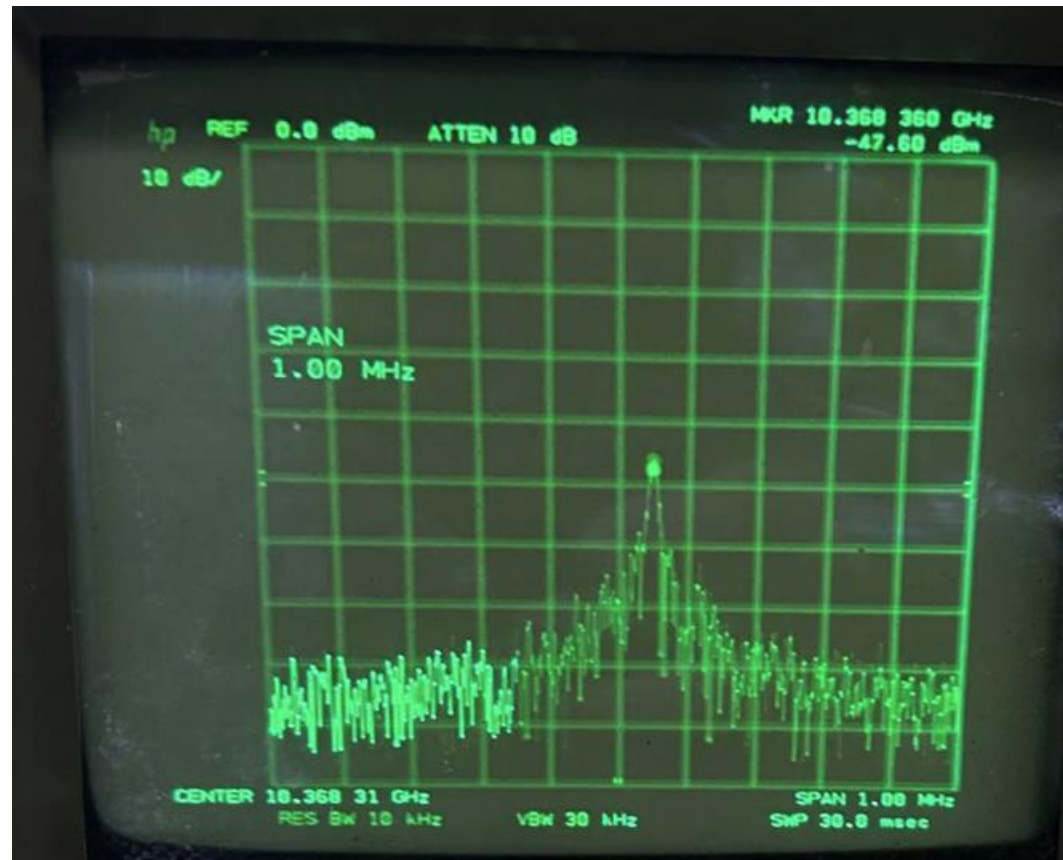
RFzero signal
transmitting OTA at 47th
harmonic is decoding
100% but is “wiggling”
(1 pps freq correction)
in frequency (24 hours
of testing)



B2 Example

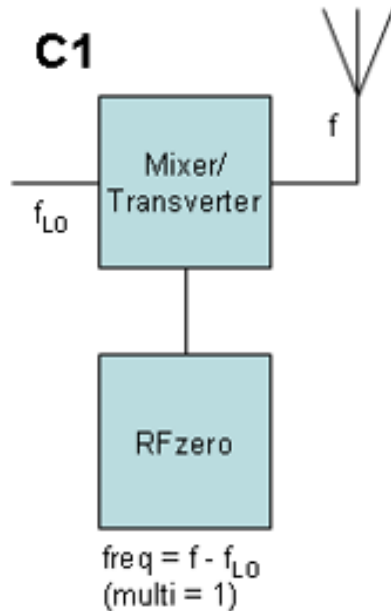
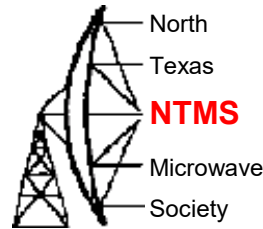


RFzero signal
transmitting OTA at 47th
harmonic is spot on
frequency but we can
get better stability.



C1 Example

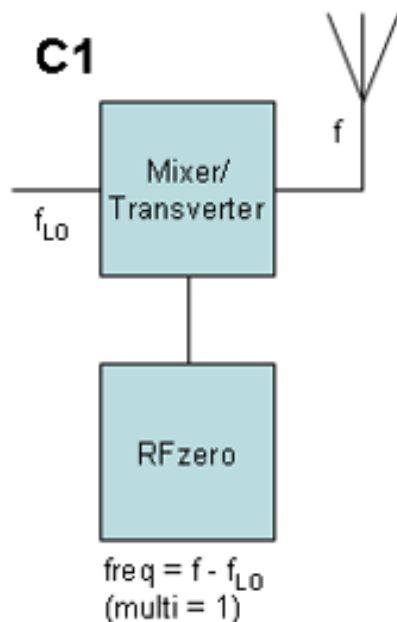
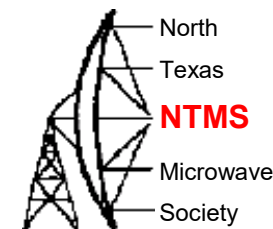
24 GHz beacon



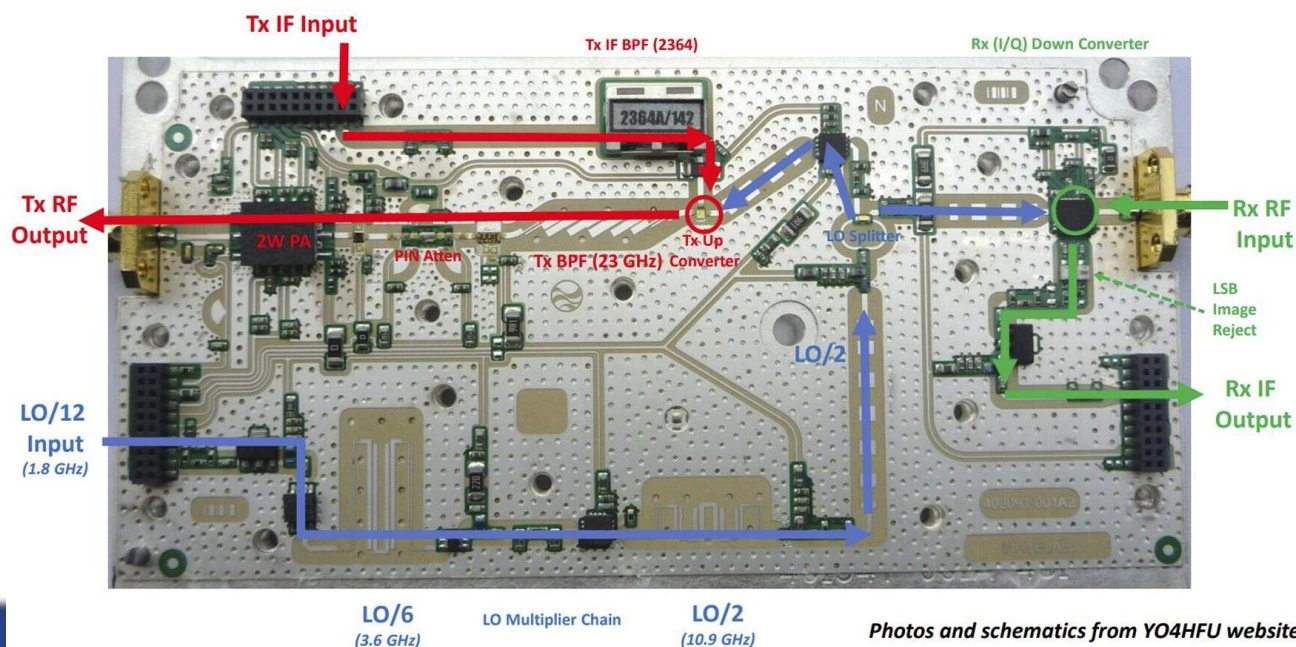
- $f_{LO} = 24048$ Mhz (locked)
- $freq [RFzero] = 144.360$ MHz
- $f = 24192.360$ MHz
- multi=1
- Q65 tone width and bandwidth is the required mode tone width and bandwidth at the fundamental signal (144.360)
- Double mix stages on next slide

C1 Example

24 GHz beacon



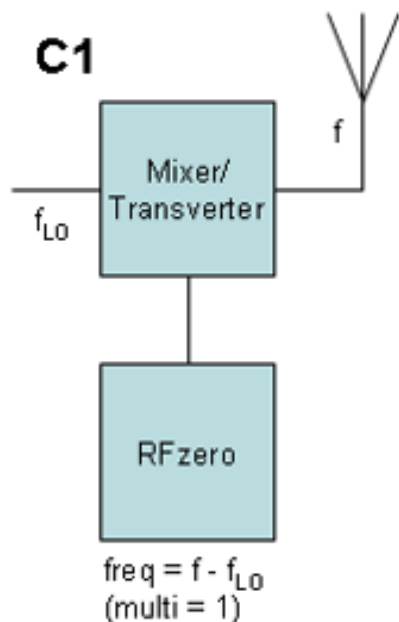
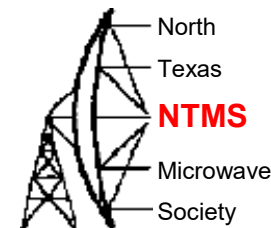
In the Wavelab implementation, the 144 MHz IF from RFzero is mixed with LO₂ 2220 MHz on the control board which results in 2364 MHz which is then mixed in the module with the 21828 MHz LO₁ = 24192 MHz. Q65 modulation is never multiplied, only added through mixing.



Photos and schematics from YO4HFU website

C1 Example

24 GHz beacon



Software

RFzero library :: Beacon Q65 + CW + carrier :: v.1.8.0

Configuration

```

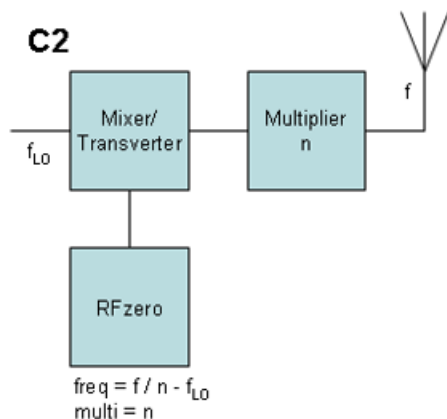
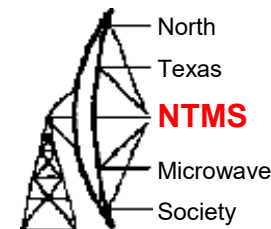
T1: 0: transformer*, 1: combiner, 2: none          : 0
Display: 0: none, 1: 16x2, 2: 20x4*, ...           : 1
PCF8574 I2C addr: 0, 0x20 to 0x27, 0x38 to 0x3F : 00
Warm up before transmitting: 0* to 255 s          : 0
Curr. level: 0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA* : 3

Wait for valid GPS before TX: 0: no*, 1: yes       : 0
Echo GPS data to USB 0: off*, 1: on, 2: all        : 0

Nominal beacon frequency in Hz                     : 144360000
Calibration interval: 1 to 255, 5*                 : 1
Keying style: 0: OOK, 1: FSK*                      : 0
CW speed: 1 to 255 ms, 100 ms* = 12 WPM/60 LPM    : 100
Call, max 15 characters                            : W5HN/B
Locator, max AA00AA00                              : EM12IL78
MGM, max 13 characters in Q65                      : CQ W5HN EM12
Q65 mode: 0: 15A*, 1: 15B, 2: 15C, 3: 15D, ...   : 12
  
```

C2 Principle

10 GHz beacon



$f_{LO} = 3.255$ GHz locked via GPSDO (DigiLO works)

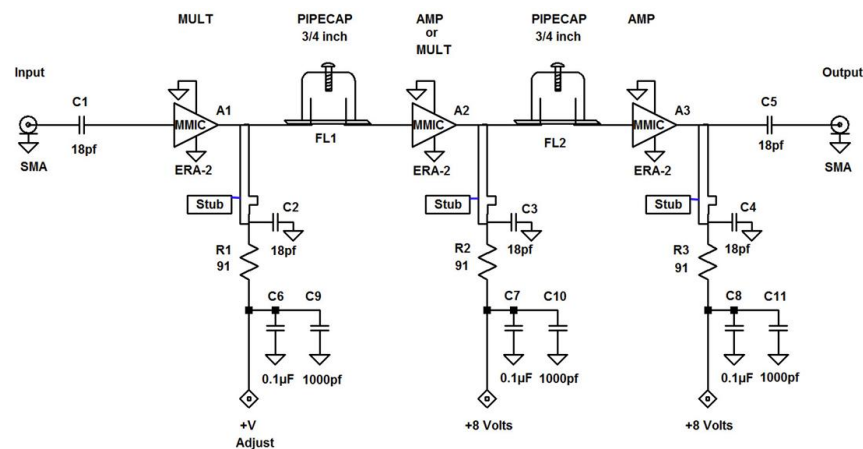
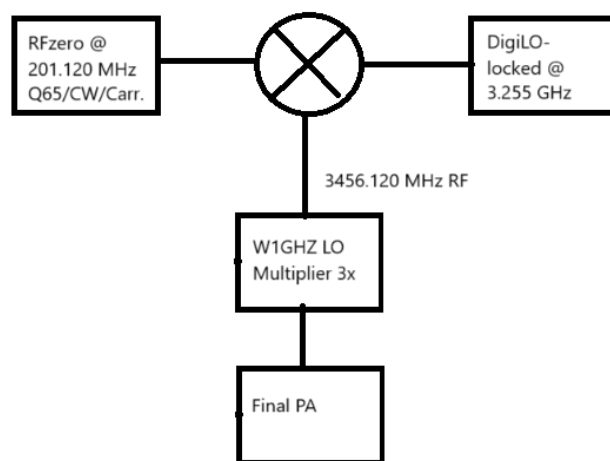
multi = 3

freq [Rfzero] = 201.12 MHz

Mixer RF out = 3456.12 MHz x 3 = 10368.360 MHz

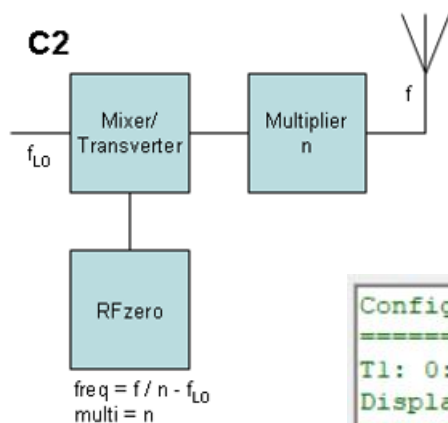
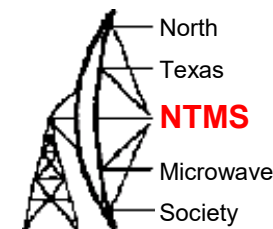
Q65 tone width and bandwidth is 1/3rd of required tone width and bandwidth at the fundamental signal (201.12 MHz).

Use W1GHZ “LO Multiplier and Filter”



C2 Principle

10 GHz beacon



Configuration

```

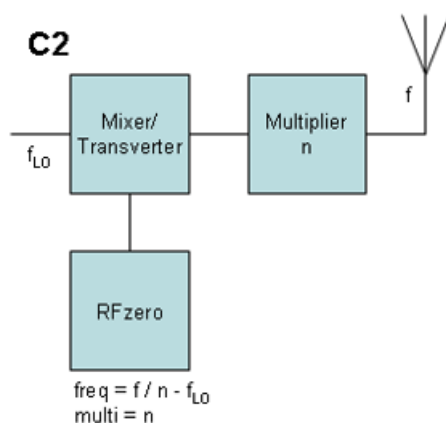
=====
T1: 0: transformer*, 1: combiner, 2: none           : 0
Display: 0: none, 1: 16x2, 2: 20x4*, ...           : 1
PCF8574 I2C addr: 0, 0x20 to 0x27, 0x38 to 0x3F : 00
Warm up before transmitting: 0* to 255 s          : 0
Curr. level: 0: 2 mA, 1: 4 mA, 2: 6 mA, 3: 8 mA* : 0

Wait for valid GPS before TX: 0: no*, 1: yes       : 0
Echo GPS data to USB 0: off*, 1: on, 2: all        : 0

Nominal beacon frequency in Hz                     : 201120000
Frequency multiplication: 1 to 255, 1*             : 3
Calibration interval: 1 to 255, 5*                 : 5
Keying style: 0: OOK, 1: FSK*                      : 0
CW speed: 1 to 255 ms, 100 ms* = 12 WPM/60 LPM    : 50
Call, max 15 characters                            : W5HN/B
Locator, max AA00AA00                              : EM12IL78
MGM, max 13 characters in Q65                      : W5HN/B EM12IL
Q65 mode: 0: 15A*, 1: 15B, 2: 15C, 3: 15D, ...   : 7
  
```

C2 Principle

47 GHz beacon 2



Cadillac version, more cost but stable and low spuri

$f_{LO} = 11.500$ GHz via locked Kuhne LO

Mix 11.500 LO with 272.090 MHz IF [RFzero]

Mixer RF out = 11.772.09 MHz x 4 = 47.088360 GHz

Our current beacon is using a Kuhne LO at 11.772.09 MHz

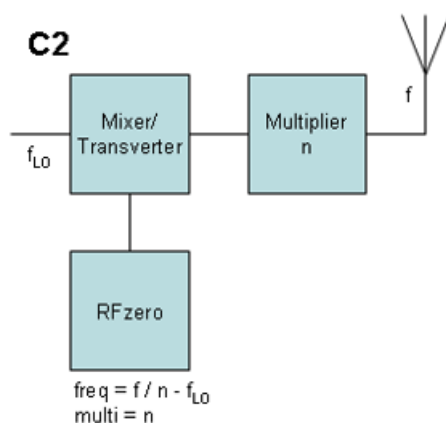
Multi = 4

Q65 tone width and bandwidth is 1/4th of required tone width and bandwidth at the mixer input IF signal (272.090 MHz). Once added to the LO frequency it will expand back to required tone width and bandwidth at 4 x or 47.088360 GHz.

Use WA1MBA Quadrupler for 4 x input 11.7 output 47 GHz

C2+ Principle

47 GHz beacon 2



Lower cost, some phase noise will be present

$f_{LO} = 3.8333333$ GHz via locked ADF4351

Take the 3rd at 11.500 GHz (requires a multiplier/filter)

Mix 11.500 LO with 272.090 MHz IF [RFzero]

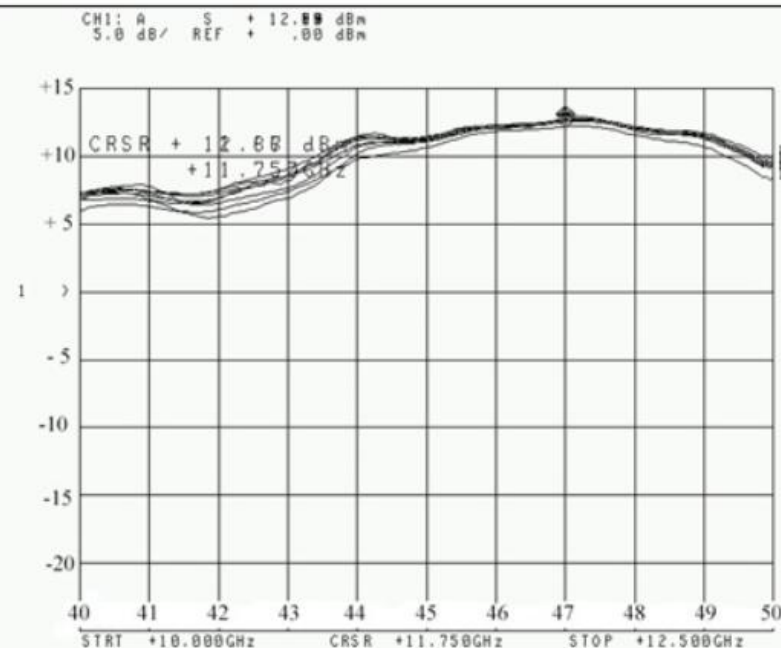
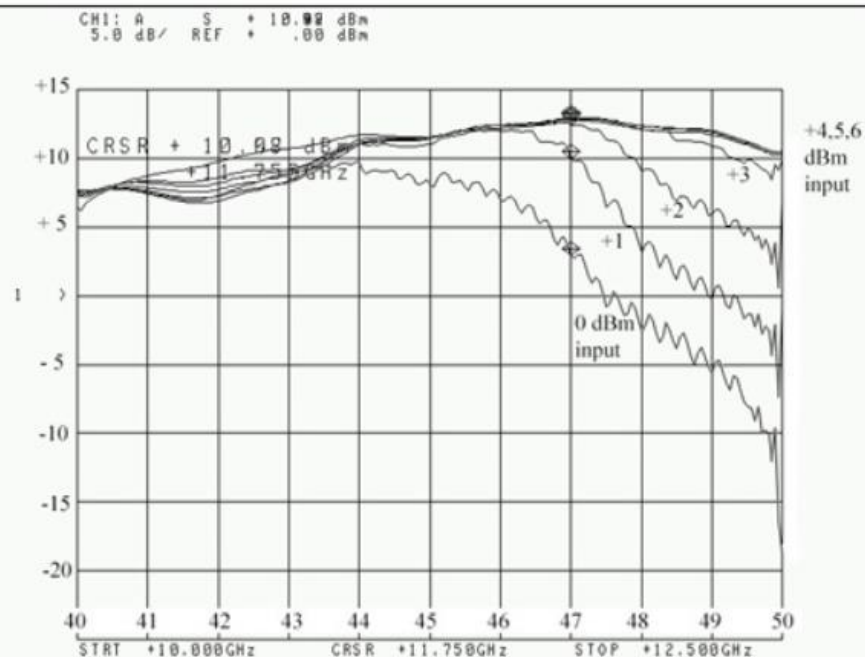
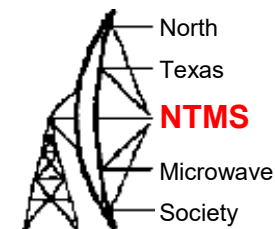
Mixer RF out = 11.772.09 MHz x 4 = 47.088360 GHz

Multi = 4

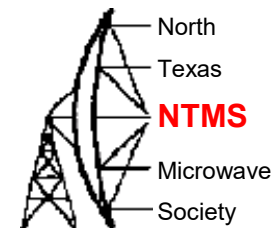
Q65 tone width and bandwidth is 1/4th of required tone width and bandwidth at the mixer input IF signal (272.090 MHz). Once added to the LO frequency and then quadrupled it will expand to proper tone width and bandwidth at 47.088360 GHz.

Use WA1MBA Quadrupler for 4 x input 11.7 output 47 GHz

WA1MBA Quadrupler



References



1. NTMS Beacon listing,
http://www.ntms.org/files/NTMS_Beacons_Oct_30_2022.pdf
2. RFzero Manager app, <https://rfzero.net/documentation/rfzero-manager/>
3. Quick Start Guide to Q65, pp 2, and
https://wsjt.sourceforge.io/Q65_Quick_Start.pdf
4. Tones Multiply functions <https://rfzero.net/documentation/software/library/>
5. Elsie filter designer, <https://tonnesoftware.com/elsie.html>
6. Perturbation shield, <http://www.rfzero.net/documentation/modifications/>
7. Video of 24 GHz beacon reception by W5LUA at 60 km,
<https://youtu.be/NDserMUyc6s?si=IoTrqHPPTpt2Sn5d>

Questions?

