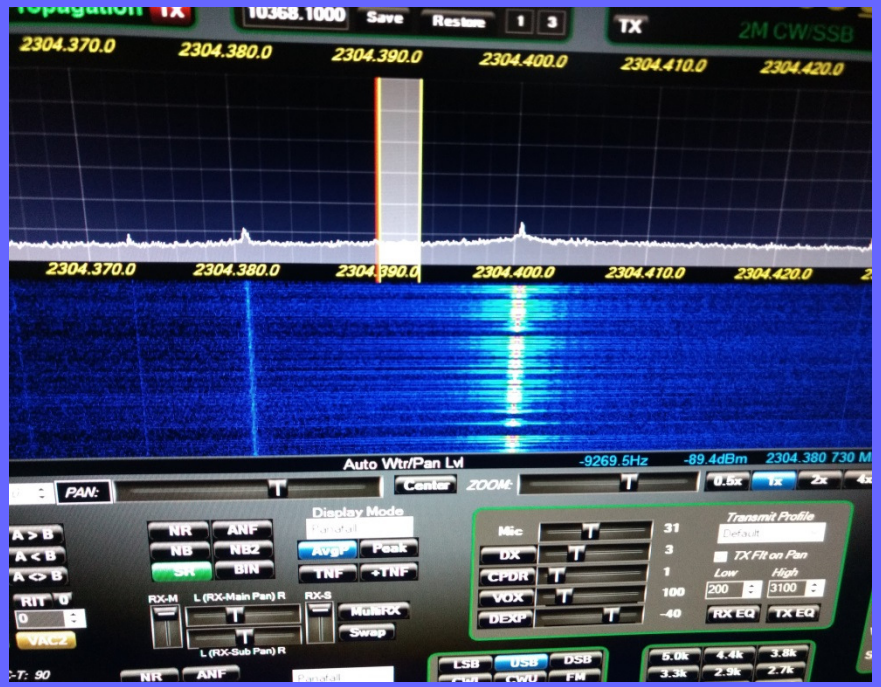
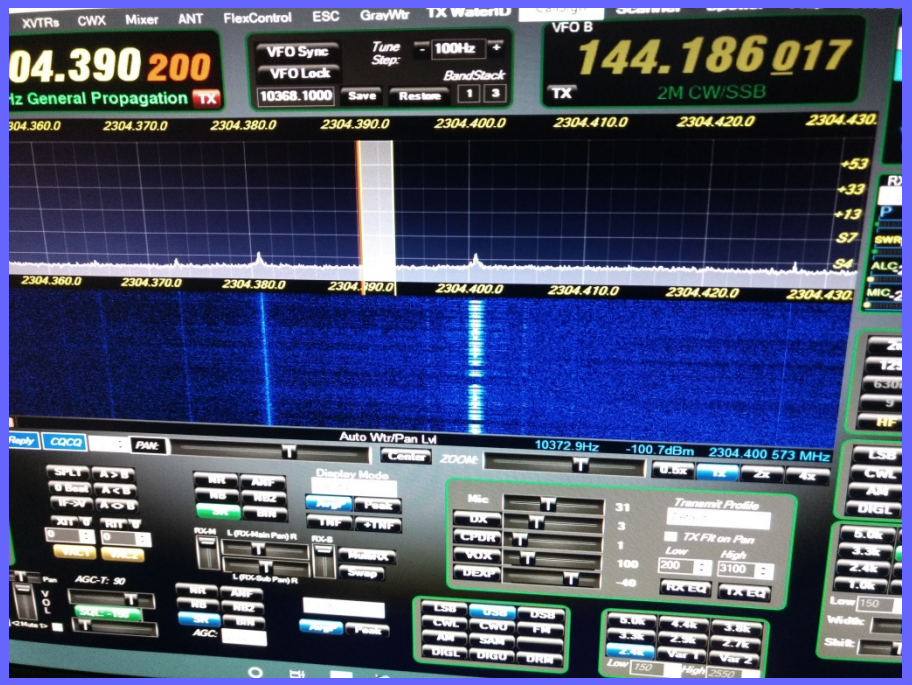
Reducing Key Clicks on Beacons with Envelope Shaping





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VE2UG. 2020

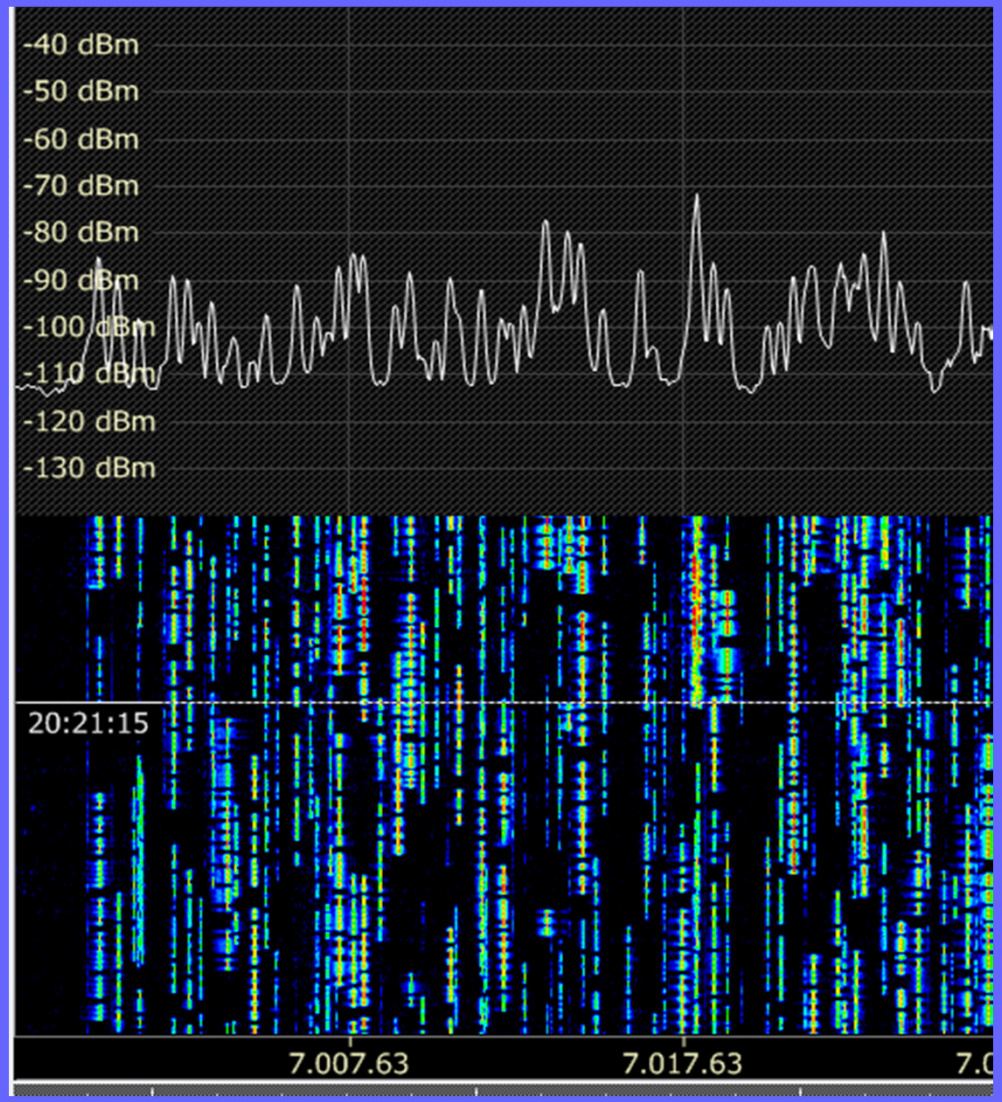
Living close to a beacon…

- Key clicks, elevated noise.
- Beacons are often homebrew repurposed FM crystal gears.
- Simple keying, fast rise/fall time add bandwidth, many KHz away.
- OK if beacon is weak. Over S9? :-/
- Disabling noise blanker help but not a solution.
- Had to close 2M beacon at VE2FUT.

Example – Beacon with Keyclicks

Keyclicks 19 dB down

Mitigation methods



- HF operation in contests gives a clue.
- Limit bandwith!

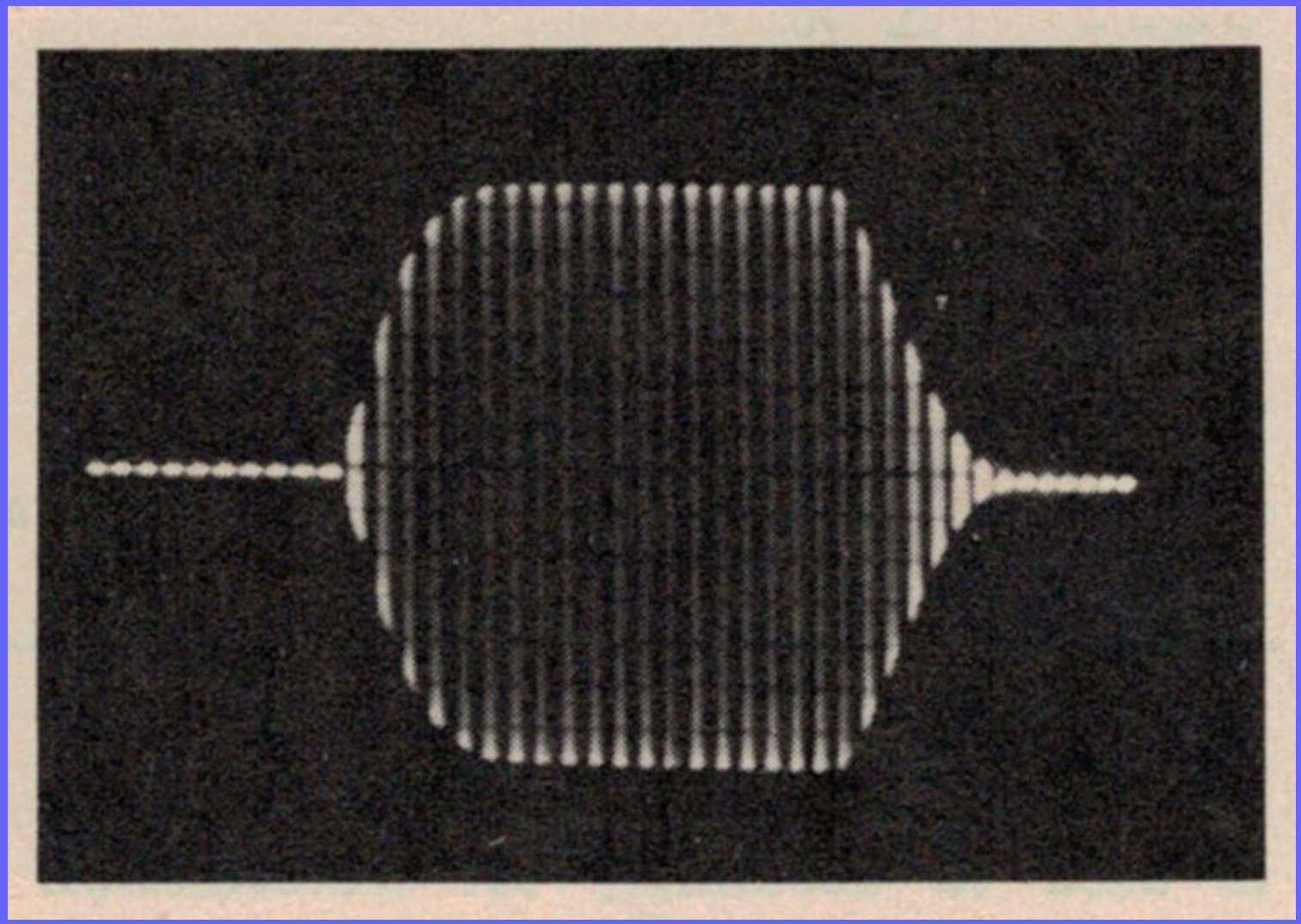
Mitigation methods

- With quality radios and SDR it is possible to have many strong signals within a few KHz. TX purity is key.
- How to implement TX purity on a beacon ? A few solutions exists.
- Normally, simple and effective are mutually exclusive..

RC keying of radio

- RC keying, good, not perfect.
- Used in early radios.
- Easily done at low stages, difficult with PAs. Backwave difficult to control.
- If too close of crystal oscillator it will induce chirps.
- Rise and fall time partially controlled, still fair amount of key clicks.

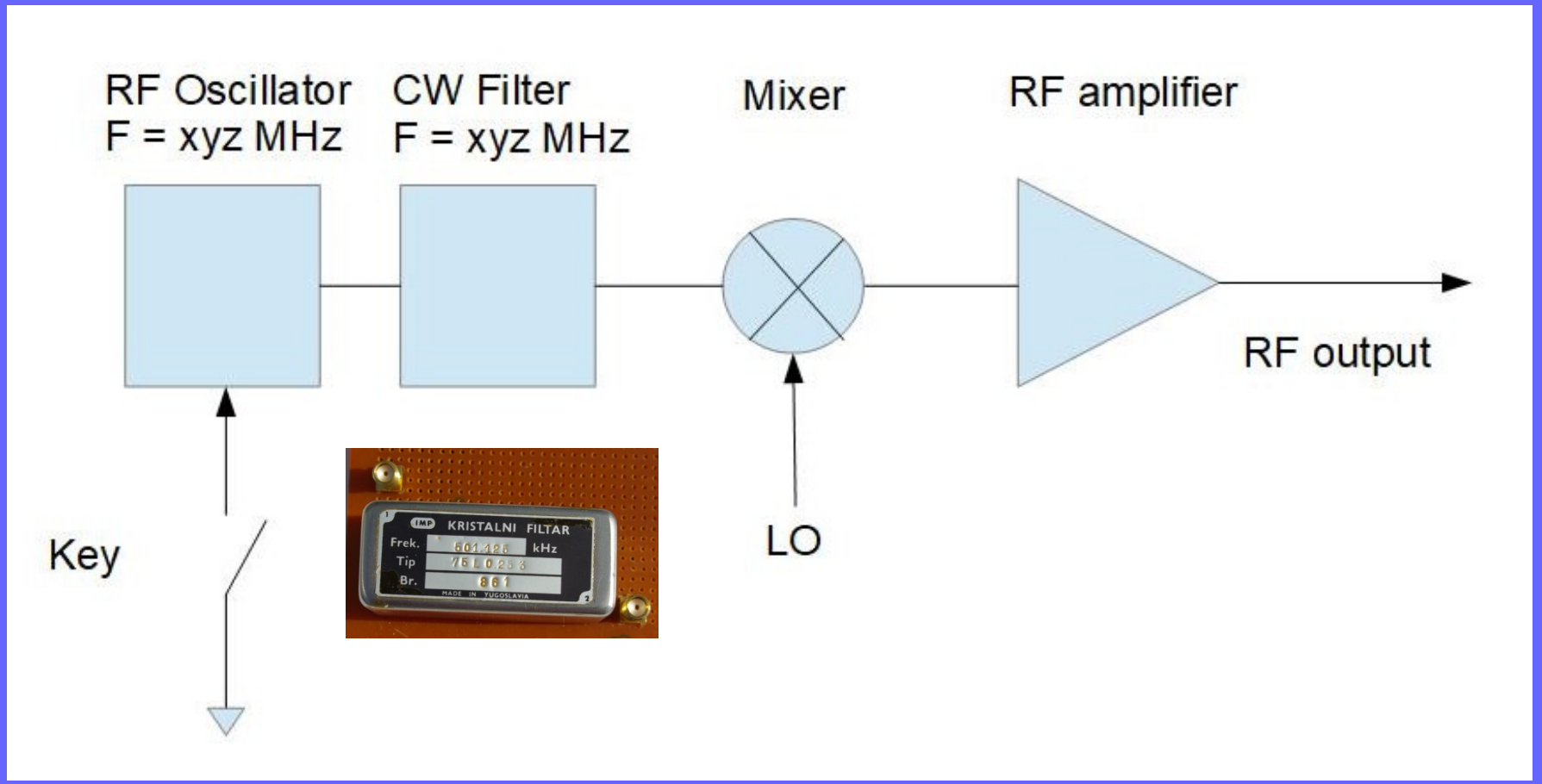
RC keying of radio



Use of SSB/CW filter

- Some quality radios use their receive filter in transmit.
- CW modulated IF pass through the filter, which hard limit the bandwidth. SSB filter is good. CW filter, 250/500 Hz, is better.
- Add complexity to a beacon. You need to work with an IF, filter, mixer, LO…

Use of SSB/CW filter



Dedicate a all modes rig

- Simple but expensive.
- Old radios with VFO will drift and still have key clicks (RC keying).
- Modern radios will do but who will dedicate a IC-375A on 222 MHz?
- Still limited to VHF and UHF. No microwave all modes rigs exists.
- HF rig and transverter will work.

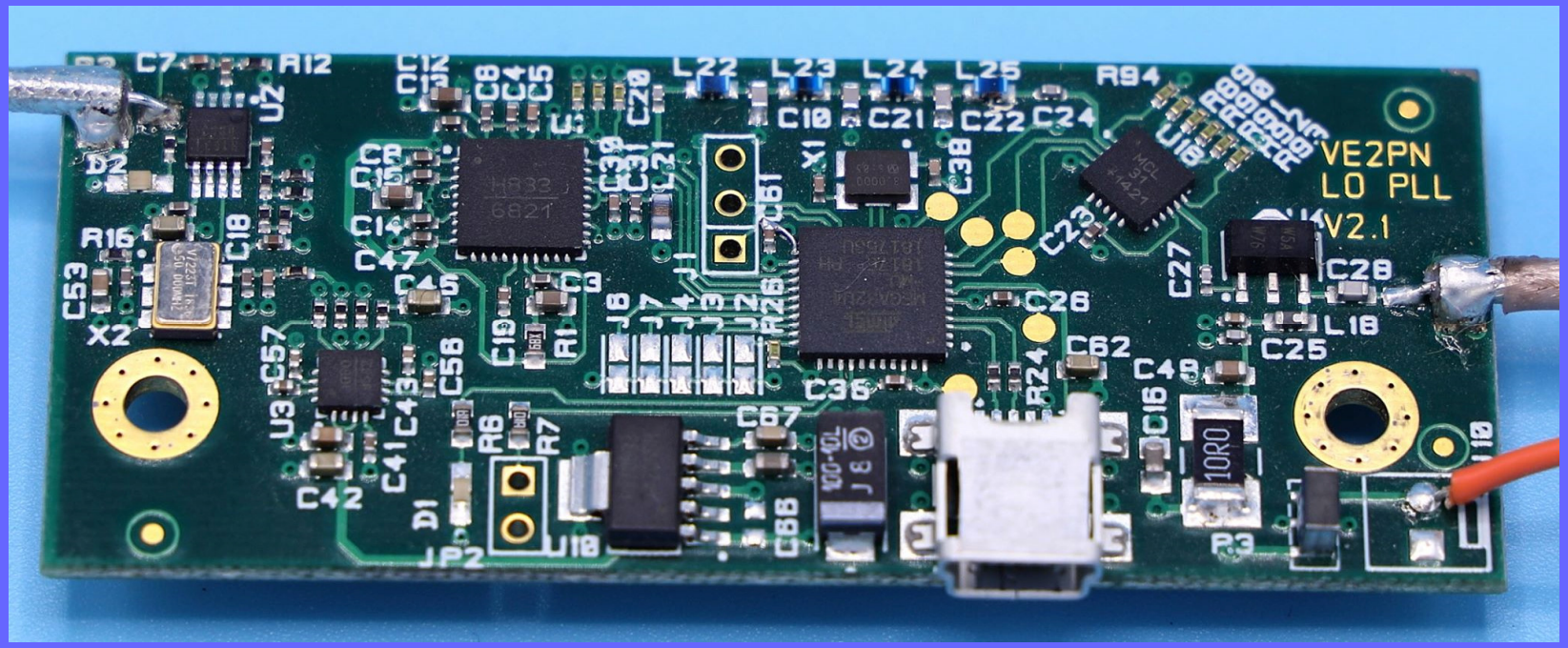
RF Envelope Shaping

- QRP Labs use it on his 5W amplifier. D/A controlling the PA supply.
- Gaussian, or Raised Cosine, are best to limit bandwidth.
- Can be used up to 6M, but not higher in frequency. PCB and FET not designed for it.
- We need a way to accurately control the RF output.

Digital RF attenuators

- 31 dB digital attenuator from Mini-Circuits DAT-31A.
- Crude Offset Cosine in 20 steps with lookup table. 1 step every 250 microseconds, ~5 milliseconds total.
- Only 31 dB of depth. Not good to tame backwave.
- We can still play with other stages at low level to add isolation.

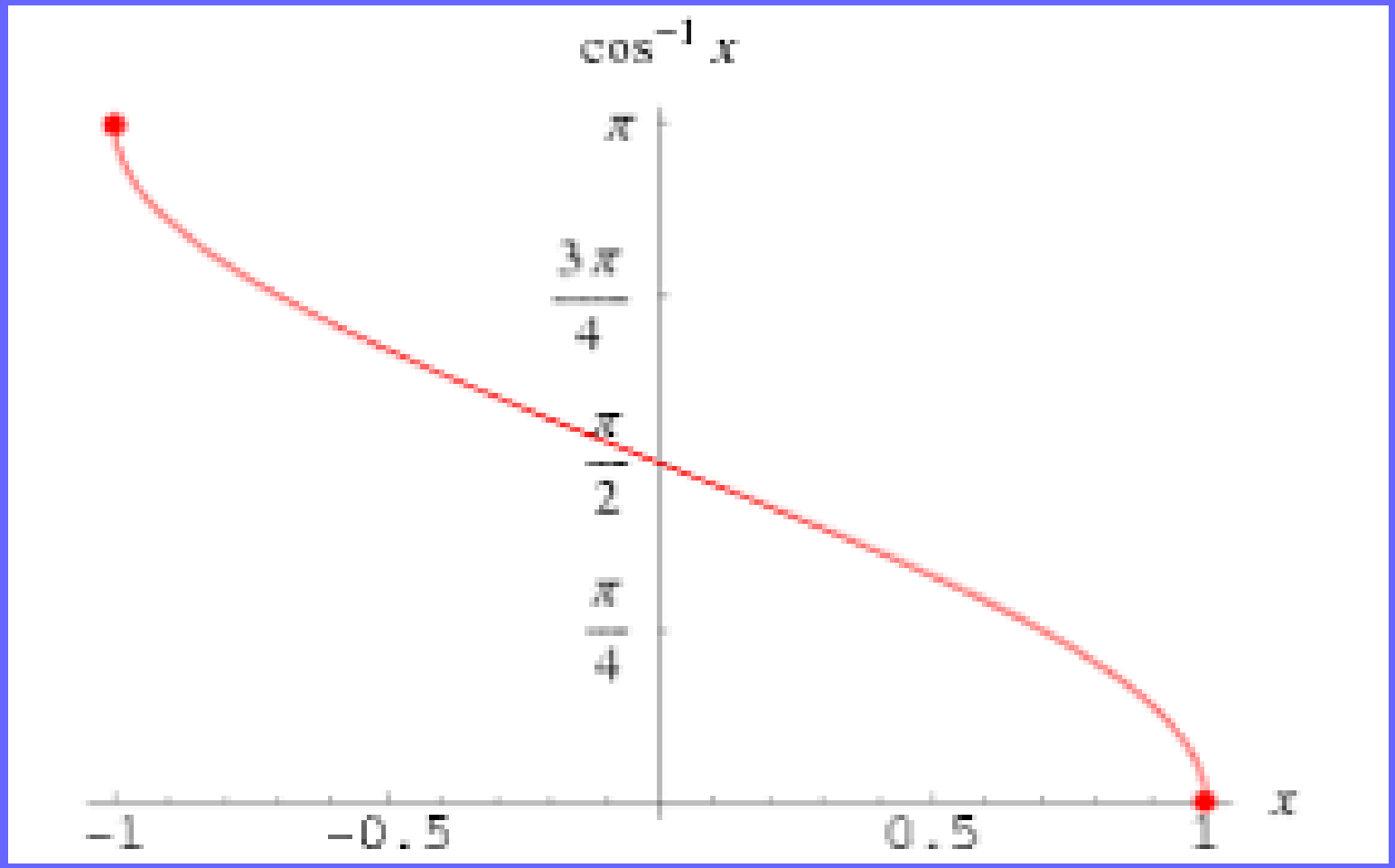
VE2PN PLL Board



VE2PN PLL Board

- HMC833 PLL 50-6000 MHz, HMC1031 Jitter filter. SPI digital attenuator.
- Pololu 32U4 with Arduino bootloader. Programmable with Arduino IDE. Runs at 8, not 16 MHz.
- The .json file is configured for 8 MHz.
- http://www.alphatronique.com/package_VE2PN_index.json
- PLL, digital attenuator and some IO pins all programmable.

“Offset Cosine” 1-Cos(θ)



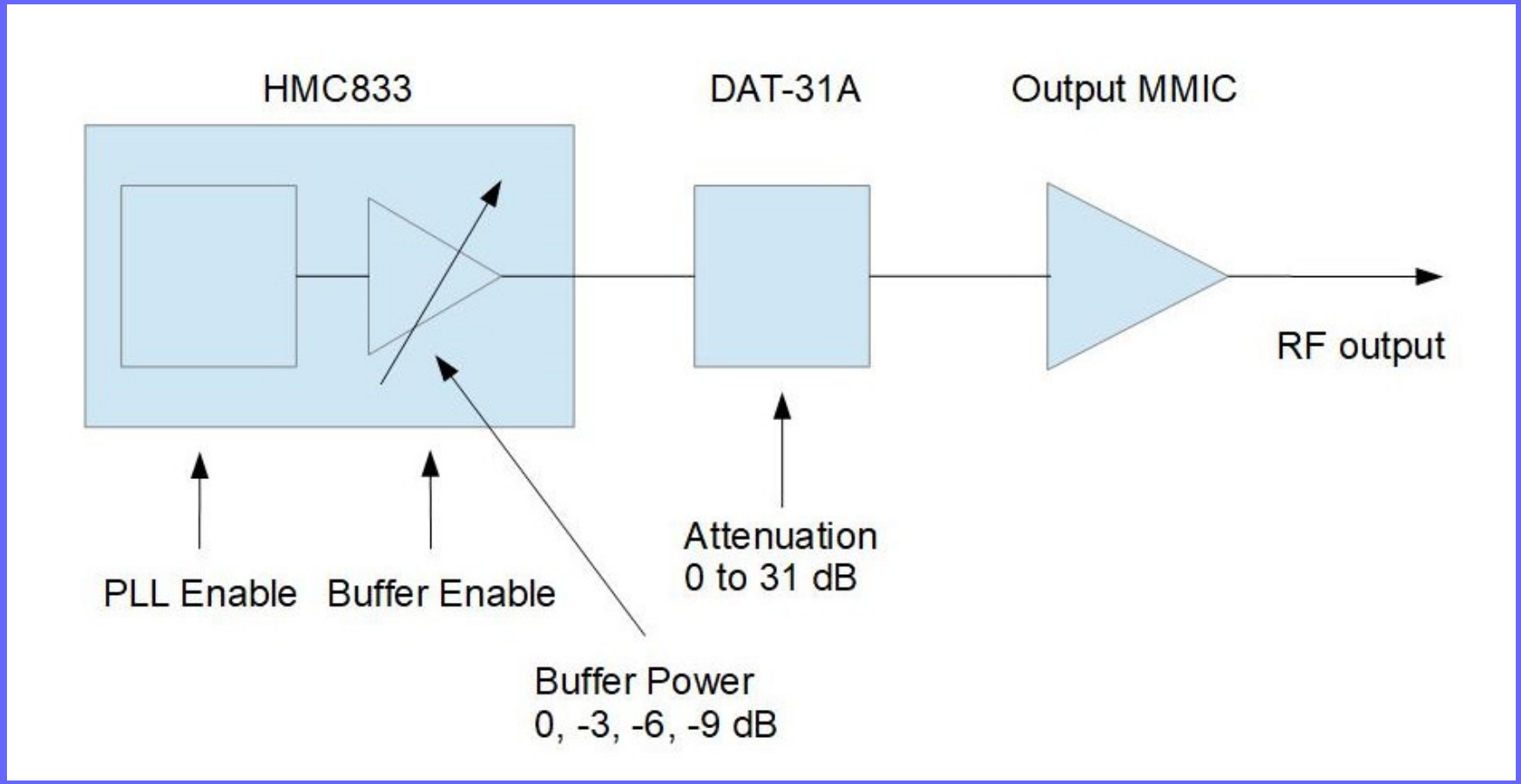
How to limit backwave

Ramp-Up sequence:

- HMC833 PLL Enable.
- External control of multipliers/PA supply with IO pin.
- HMC833 Internal Buffer.
- Attenuator ramp

Ramp-Down reverse the steps

PLL Controls



Ramp-Up

T	Angle	Angle radians	Cosine	1-Cosine	10Log(1-Cosine))	Attenuation dB
0	0	0	1	0	No output	Synth ON
0	0	0	1		Very Low	PA/Mult ON
0	0	0	1	0	Low	PLL Buffer ON, Att = 31
1	4,5	0,07853982	0,99691733	0,00308267	-25,1107349	25
2	9	0,15707963	0,98768834	0,01231166	-19,09683408	19
3	13,5	0,23561945	0,97236992	0,02763008	-15,58617864	16
4	18	0,31415927	0,95105652	0,04894348	-13,10305122	13
5	22,5	0,39269908	0,92387953	0,07612047	-11,18498553	11
6	27	0,4712389	0,89100652	0,10899348	-9,625994975	10
7	31,5	0,54977871	0,85264016	0,14735984	-8,316208715	8
8	36	0,62831853	0,80901699	0,19098301	-7,190052762	7
9	40,5	0,70685835	0,76040597	0,23959403	-6,205239996	6
10	45	0,78539816	0,70710678	0,29289322	-5,332906832	5
11	49,5	0,86393798	0,64944805	0,35055195	-4,552476106	5
12	54	0,9424778	0,58778525	0,41221475	-3,848764746	4
13	58,5	1,02101761	0,52249856	0,47750144	-3,210253187	3
14	63	1,09955743	0,4539905	0,5460095	-2,627998007	3
15	67,5	1,17809725	0,38268343	0,61731657	-2,094920672	2
16	72	1,25663706	0,30901699	0,69098301	-1,605326337	2
17	76,5	1,33517688	0,23344536	0,76655464	-1,154568854	1
18	81	1,41371669	0,15643447	0,84356553	-0,738811723	1
19	85,5	1,49225651	0,0784591	0,9215409	-0,354853831	0
20	90	1,57079633	6,1257E-17	1	-4,82164E-16	0

Going without VE2PN board

- The Arduino program can be modified for other PLLs, attenuators.
- If using external PLL just comment the PLL configuration and controls.
- The attenuator can be external. You can buy a SPI DAT-31A, or RF Step Attenuator SPI Module from SV1AFN.
- No need to change the routine. They have the same command structure.

Staying linear

- Output MMIC have lot of gain at low frequency.
- We need to adjust HMC833 power to prevent saturation at VHF.
- Internal buffer have a range of 9 dB in 4 steps. Code added to adjust.
- Later stages should be linear to prevent distortion of the ramp.
- Could be a problem with multipliers.

Staying linear

- Bit manipulation without affecting others.

```
//Set HMC833 buffer power to -9 dB from maximum (bit 14 = 0, bit 13 = 0).
//To keep output MMIC from saturating.

VCO_Reg_Buffers[2] &= ~(1<<14);  // Set 14th bit of VCO_Reg_Buffers[3] to 0.
//VCO_Reg_Buffers[2] |= (1<<14);  // Set 14th bit of VCO_Reg_Buffers[3] to 1.

VCO_Reg_Buffers[2] &= ~(1<<13);  // Set 13th bit of VCO_Reg_Buffers[3] to 0.
//VCO_Reg_Buffers[2] |= (1<<13);  // Set 13th bit of VCO_Reg_Buffers[3] to 1.
writeRegister( VCO_Reg_Buffers[2]); // Writer buffer power value in PLL.
```

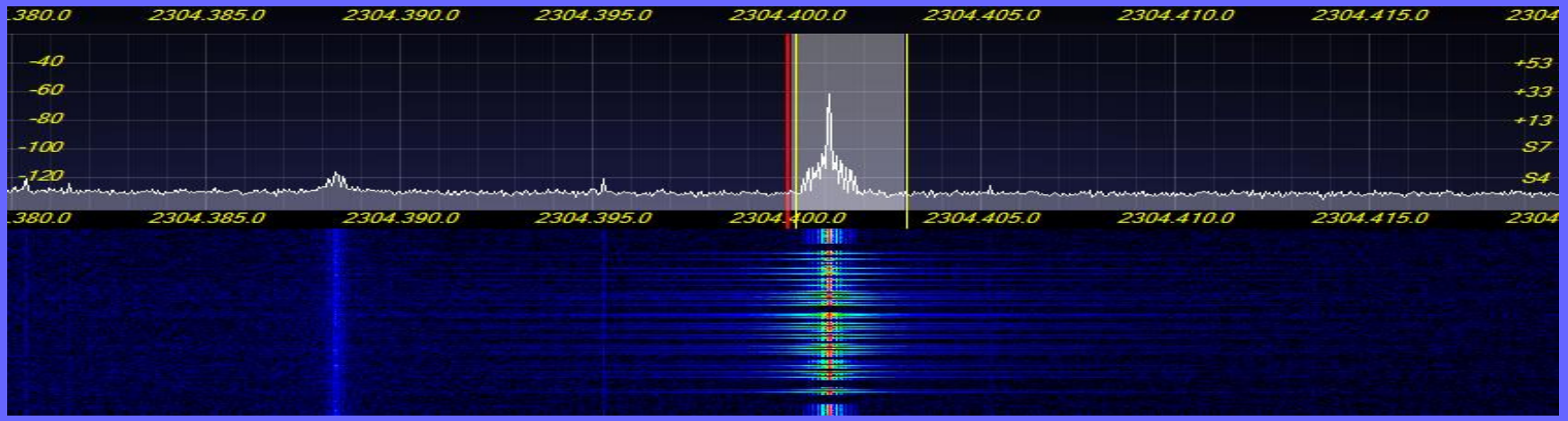
We cannot shape everything

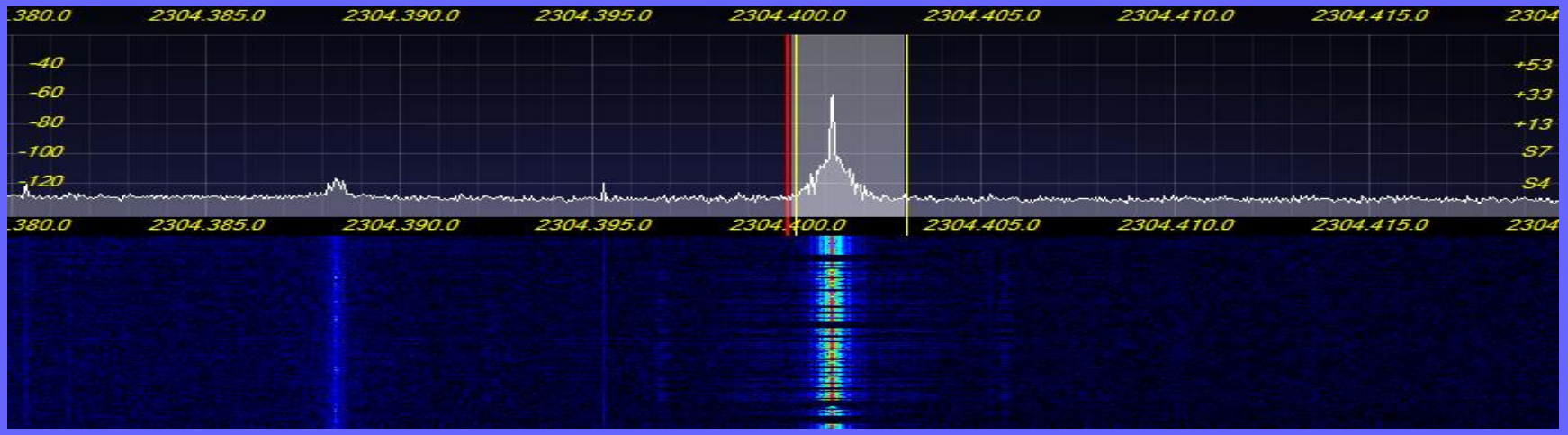
- **Phase noise**.
- It is there whenever the carrier is present.
- It will varies with the digital attenuator, but cannot be removed.
- Definitely there from VHF to microwaves, on strong signals.
- Good PLL design is important.

Internal Keyer

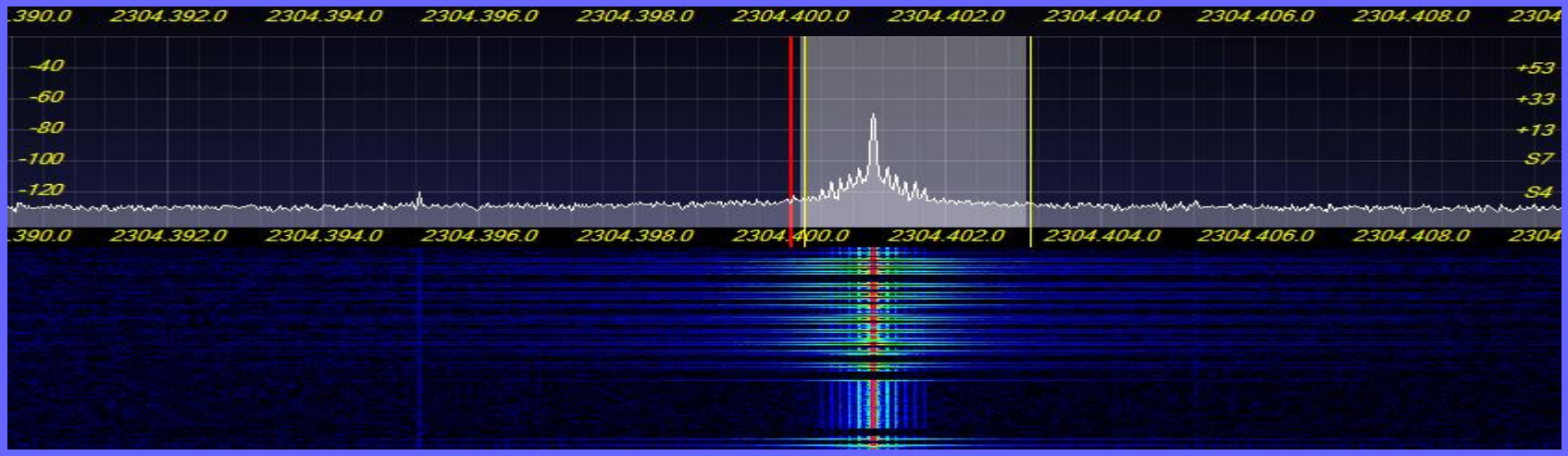
- Written by Mark VandeWettering K6HX.
- Free to use with mention of the author.
- Easy to change Message/Speed.
- Added function to insert long carrier at the end.

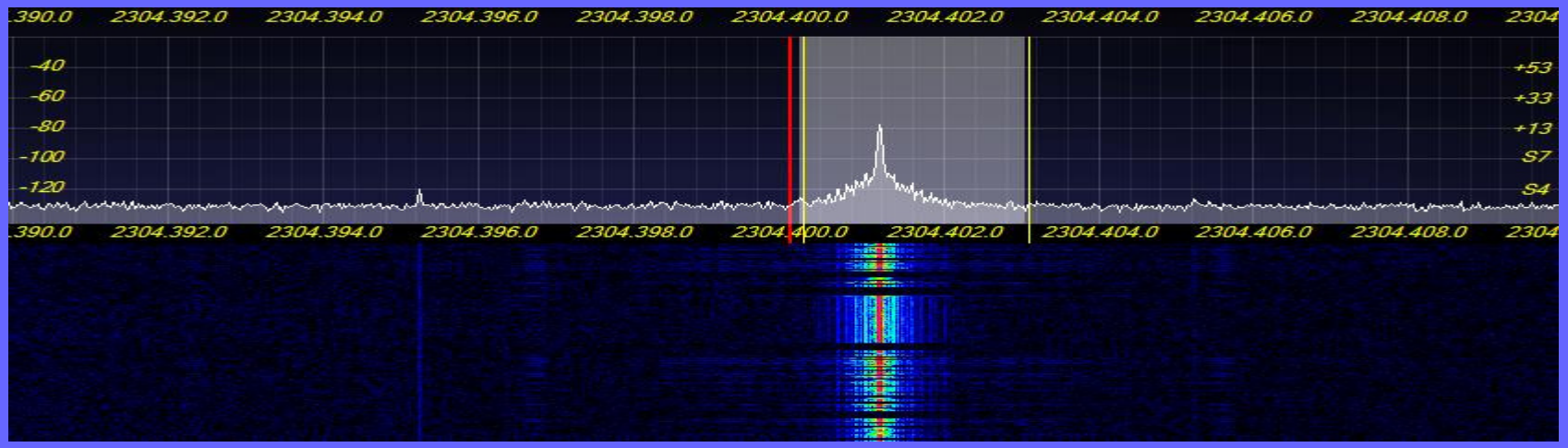
Without and with shaping





Without and with shaping





Videos…

Wrap-Up

- Envelope control can help a beacon be a good neighbor.
- Can be programmed from VHF to the lower microwaves bands.
- VE2PN is working on a lower cost board. HMC833 really expensive.
- Reference Conditionner really help taming noisy references.

Future work

- All is not lost with those converted FM beacons.
- Will test envelope control using power control loop/SWR protection.
- IF OK we might use a D/A and custom ramp to control the RF.
- No end to experiments!

Special Thanks

- Thanks to Marc VE2PN!
- He had the the foresight to add a controllable digital attenuator, and designed from the ground up for low phase noise.
- Arduino a real plus for custom applications.

- Questions?