Some Results of experiments using Raspberry Pi as a SDR-TX

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Questions to the audiance

Active audience!

- Who used a Raspberry Pi ? (all)
- Who used a Raspberry Pi as Transmitter? (3)
- Who uses power line internet at home? (3)
- Who is a radio ham? (nearly 50 %)
- What are different ways of ham radio?
  1. developer
  2. user
  3. special mode (radio competitions, collecting, services, RF-network, antenna, propagations, sat, HF, VHF - THz)
- Myself: combination of developer, user, service, multi purpose

Overview

- How is a Raspberry Pi a Transmitter?
- What power supply can be used?
- What modulation is recommended?
- What is WSPR and what is it used for?
- Some results?

How is the Raspberry Pi a Transmitter?

- Clock oszillator of the Raspi
- Programmable divider
- GPIO-output
  - Very limited output
  - Very sensitive for statics
  - Output is square wave
- Clock oszillator can be checked via NTP

Raspberry Pi as SDR-Transmitter

PiFM: Oliver Mattos, Oskar Weigl; engl. Ham Dan, MD1CLV made 1. program for WSPR

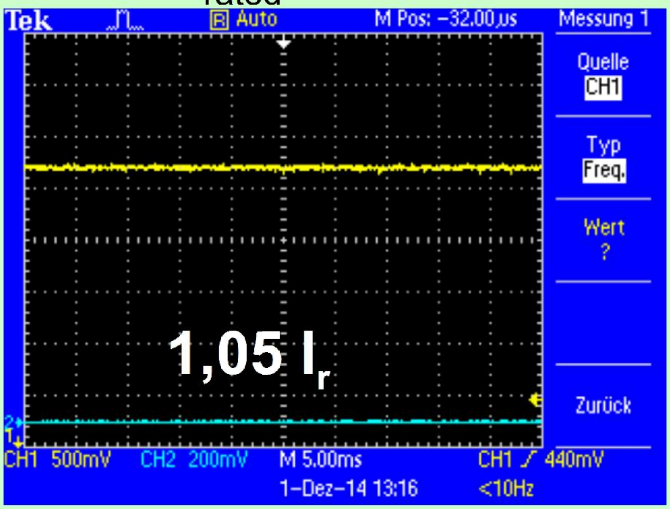
- RF-signals up to 250 MHz
- Phase and Frequency modulation
- No HDMI-video output, if used
- Output: 3,3 V, max 10 mA ~ 10mW (R_i ~ 100 Ω)
- Examples:
  - FM-TX (Broad and narrow FM)
  - SSTV (by PE1NNZ)
  - Slow digital modulation 4-fsk (WSPR)

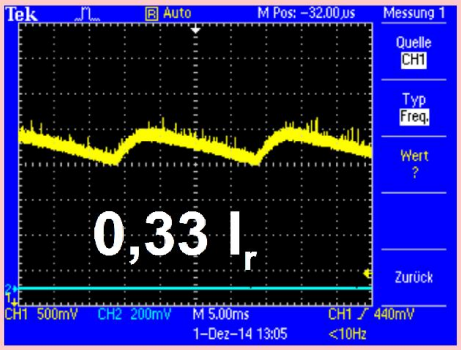
Which power supply?

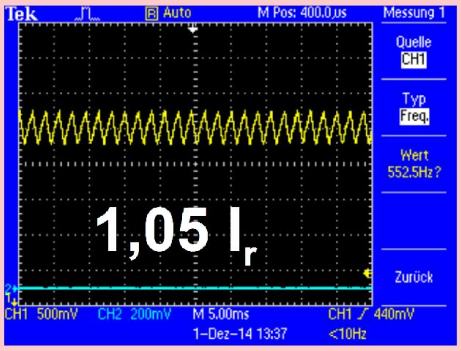
- **5V, > 600 mA**
- **Voltage under load?**
- **Selected:**
  - I >1 A
  - 9 compared
- **Measured with resistive load**

measurement of loaded PS

Output voltage under load with x·I_{rated}







Distant measurements (PS)

Different power supplies on different days

Date / time	TX	Frequency	SNR	pwr	RX	Locator	dist	azim
2014-12-01 11:34	DK5HH	28.126.185	-27	0.01	LZ1OI	KN22jc	1703	129
2014-12-01 11:34	DK5HH	28.126.085	-12	0.01	LZ1OI	KN22jc	1703	129
2014-11-28 10:54	DK5HH	28.126.107	-28	0.01	LZ1OI	KN22jc	1703	129
2014-11-28 10:54	DK5HH	28.126.007	-15	0.01	LZ1OI	KN22jc	1703	129
2014-11-28 10:34	DK5HH	28.126.142	-25	0.01	UR/SWL56	KN56jk	1735	106
2014-11-28 10:34	DK5HH	28.126.042	-11	0.01	UR/SWL56	KN56jk	1735	106
2014-10-25 12:10	DK5HH	28.126.172	-30	0.05	DL8BBY	JO43	48	13
2014-10-25 12:10	DK5HH	28.126.122	-4	0.05	DL8BBY	JO43	48	13

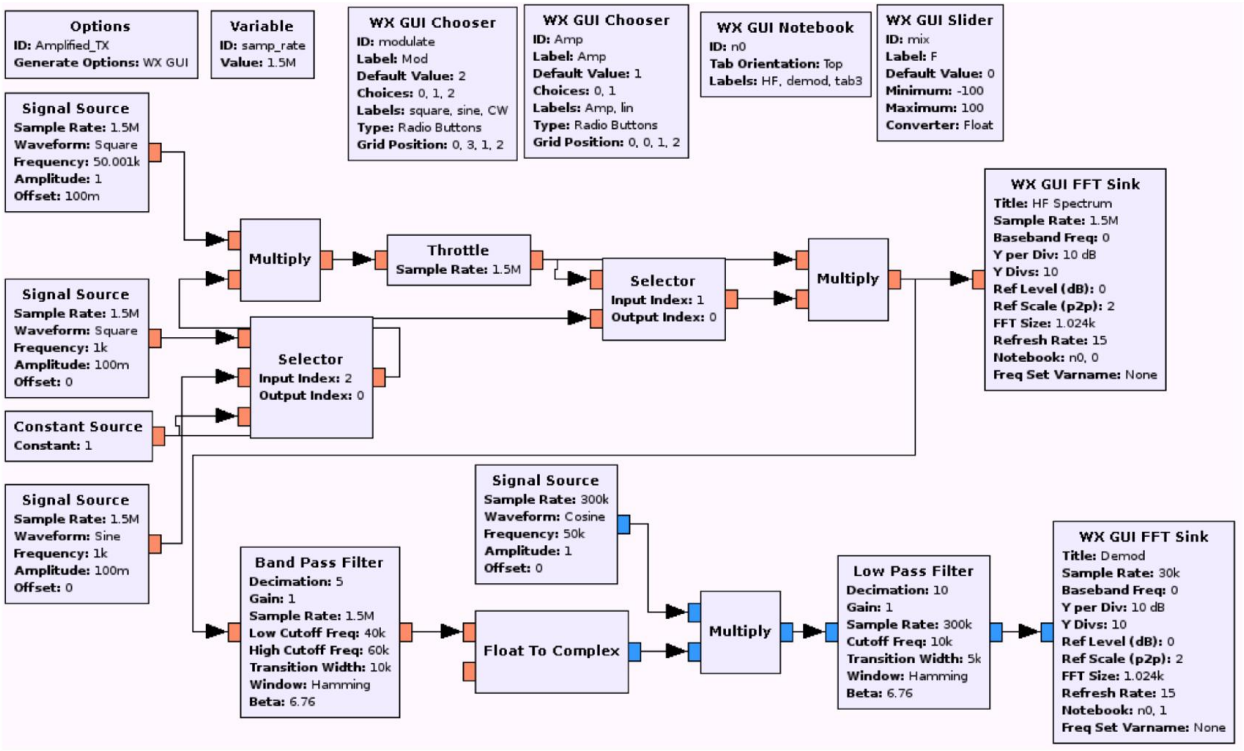
How to possible amplify – and avoid disadvantages

- Preassumption: signal is clean!!!! → later foils
- know disadvantages
  - Harmonics
  - Mixed back to base frequency
- Make a grc to check
  - Rectange (square) signal form output of raspi
  - Linear amplifiers have square TF for large signals
  - Try modulate with 1 kHz 10% (sine or square)
  - HF = 50 kHz (as an simulation example)

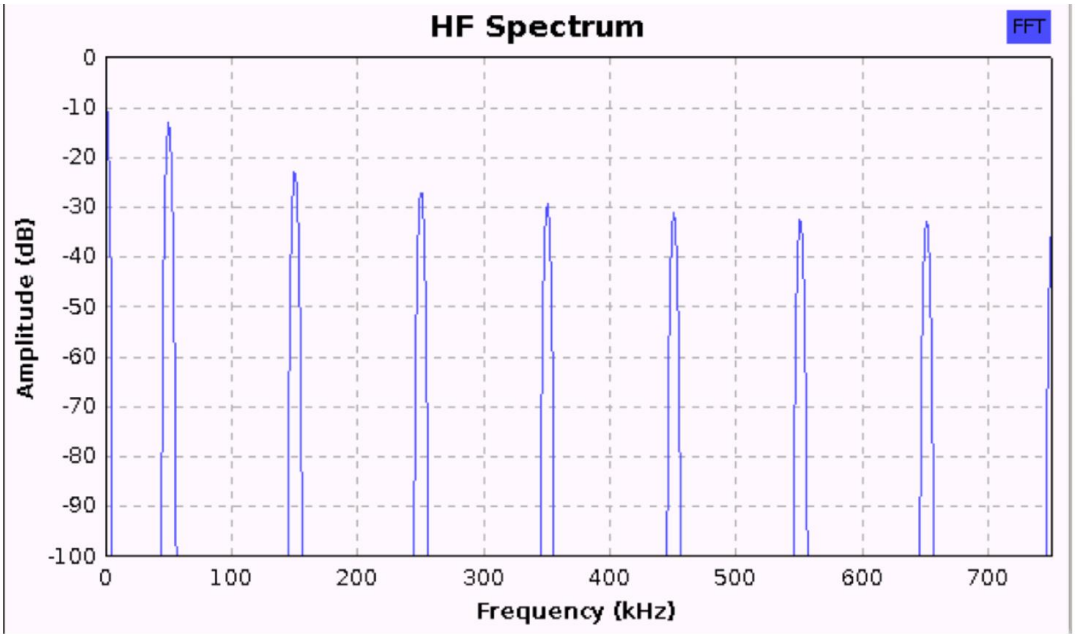
Amplifier in principal

- Ideal Amplifier
  - linear
  - Every frequency (no tuning elements)
- Pratical real amplifiers
  - Nonlinear with mixing effects
  - Tuning elementes to reduce harmonics
  - Adapt the load impadance

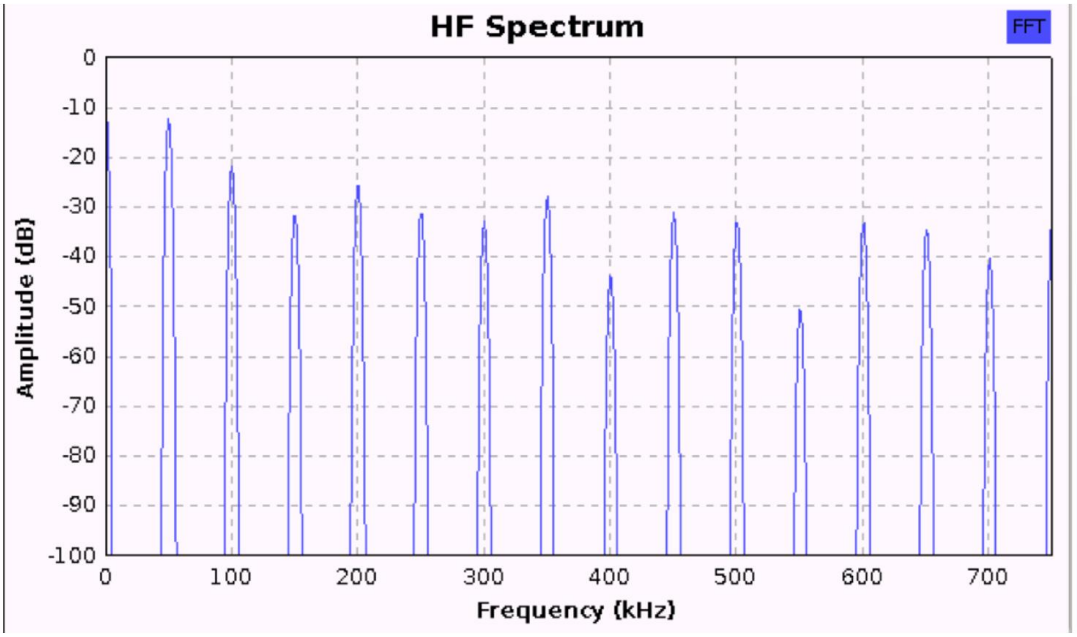
GRC model of amplification



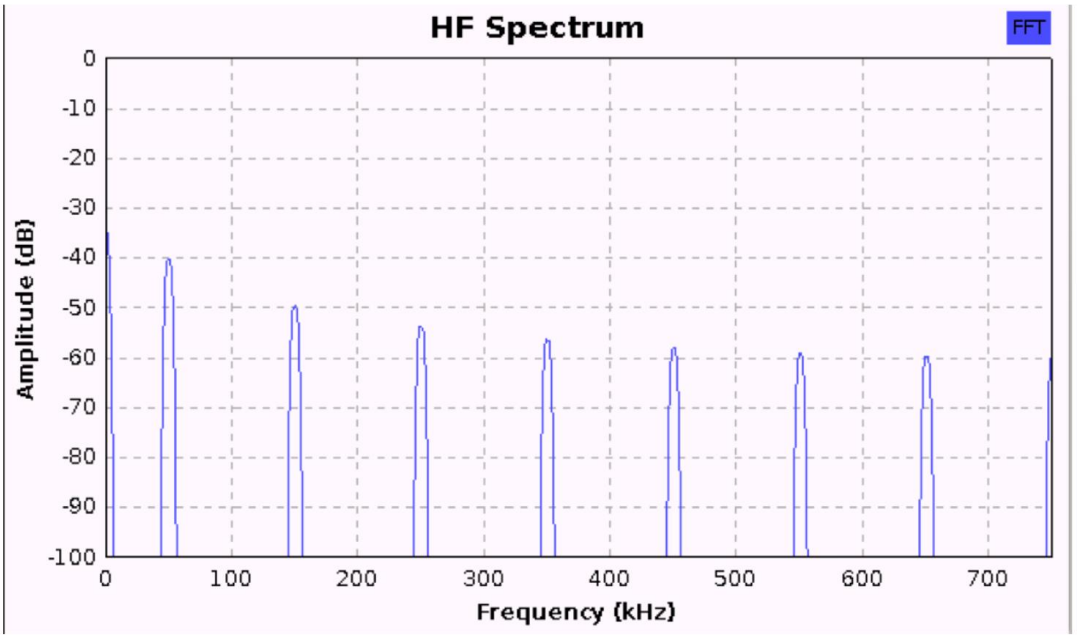
Harmonics of 50 kHz-HF (linear)



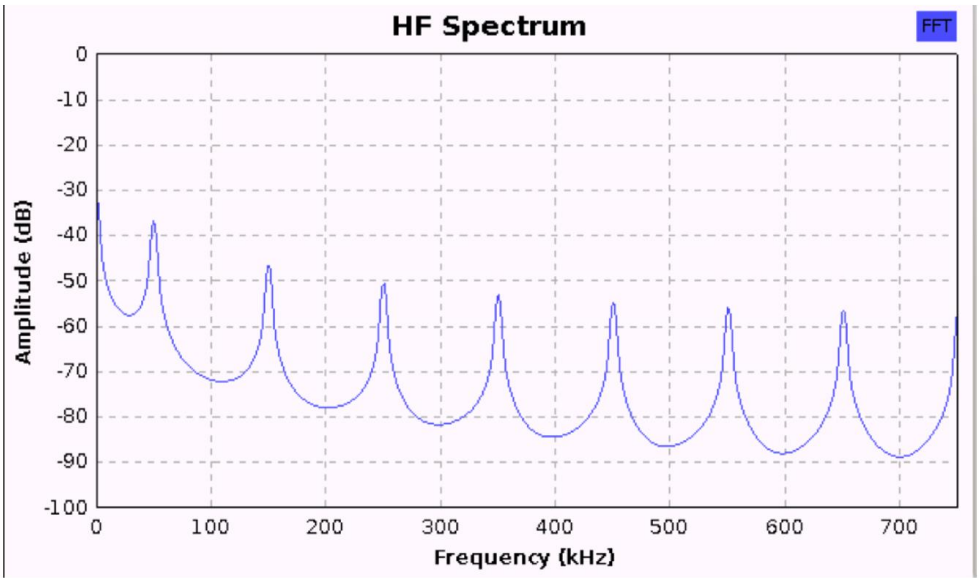
Harmonics of the 50 kHz-HF (amplified)



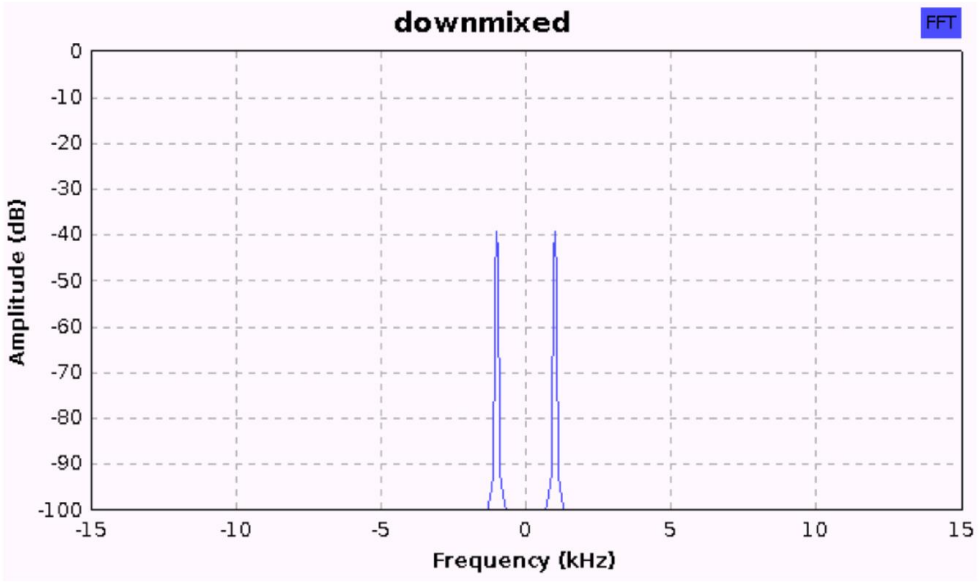
Harmonics of the 50 kHz-HF (amplified) modulated sine 1 kHz



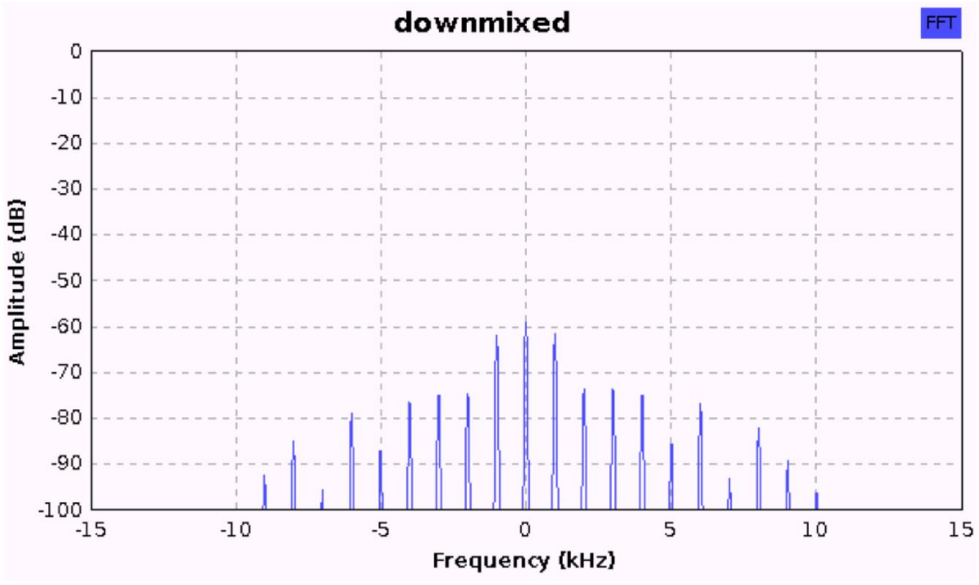
Harmonics of the 50 kHz-HF (amplified) modulated rectangle 1 kHz



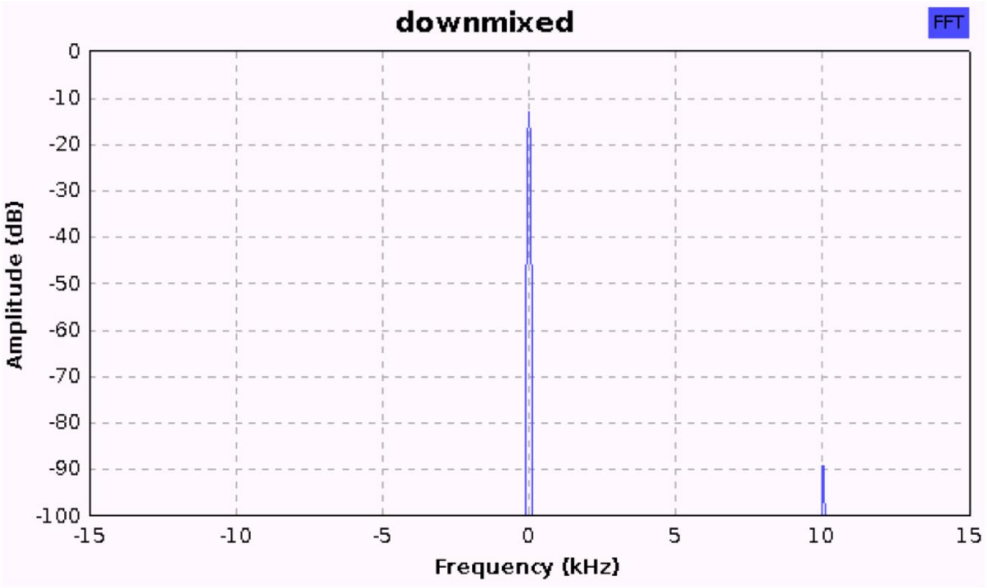
Baseband modulated sine 1 kHz



Baseband modulated square 1 kHz



Baseband unmmodulated



summary of the simulation results

If you have clean signal:

- Use a nonlinear amplifier
- No amplitude modulation – only use PM / FM
- Try to isolate electro statics of the antenna
- Use harmonics suppressing output filters
  - Higher order to supress harmonics > 40 dB
  - http://www-users.cs.york.ac.uk/~fisher/lcfilter

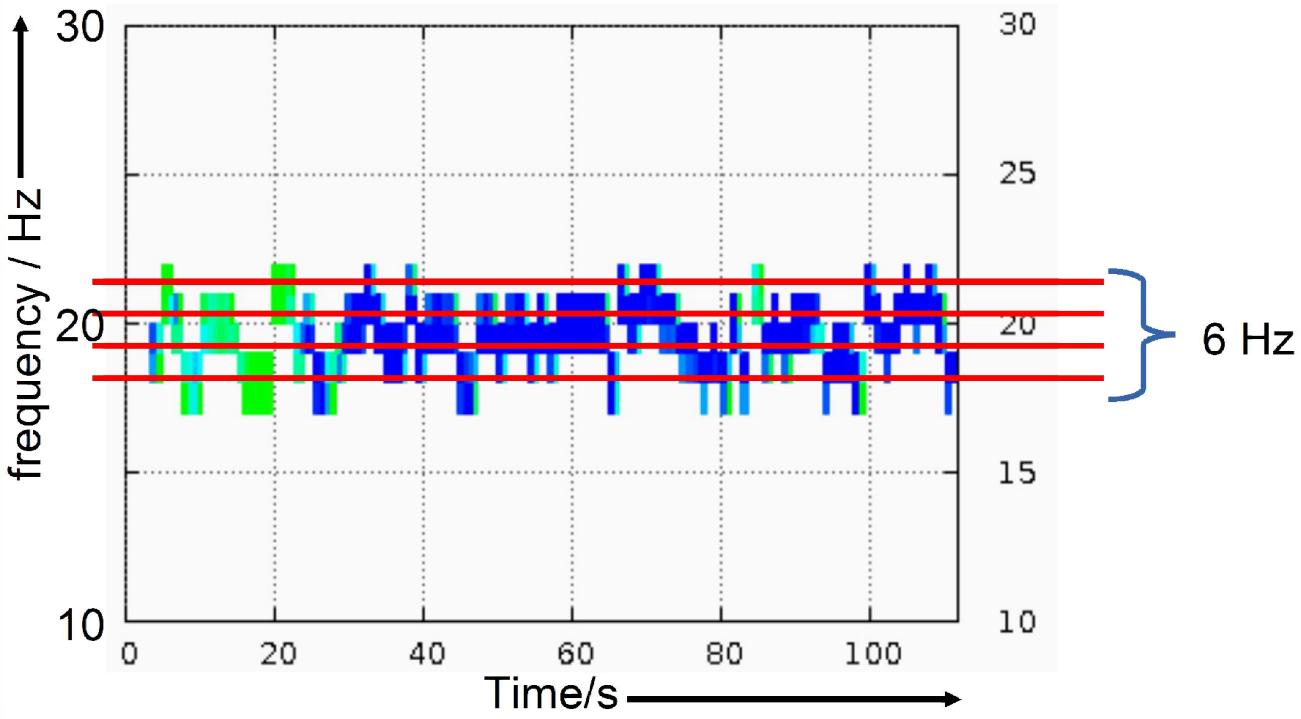
Example: 4-FSK-Signal

WSPR

originated by John Taylor, K1JT

Developed by international ham team

Spectrogram of 4-FSK rcvd. sig



WSPR-frame in detail

- 50 bit payload + FEC = 162 bit / 110s
- distributed synchronisation bits
- FEC convolutional Code with lenght K = 32
  rate r = 1/2
- 4-cont. Phase FSK (CPFSK) S = 1.46 Bd;
  Δf = 1.46 Hz
- $h = \Delta f\, T = 1.46 \cdot 1 / S = 1$ (2-FSK (opt.): 0.71)
- $B = [\,(M-1)\,h + (1+r)\,] / Ts = [3 + 1]\ 1.46 = 5.9$ Hz
- In parallel within 200 Hz : > 33 parallel stn

WSPR payload

- Total 162 Bit in 2 min with payload
  - Call (e.g. DK5HH)
  - Locator 4-characters e.g JO20
  - power in dBm (17 = 50 mW)

  } 50 Bit
- time needed synchronized within 1 s (TX + RX)
- RX send results to Internet-Database

What is WSPR and what is it used for?

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WSPR – what is it?

- Weak Signal **Propagation** Reporter
- digital beacon mode

- (2-way-mode - not attractive, not used)
- TX-sequence: 110 s (every even minute start)
- Received signals are reported to an INet-DB
- now: 255 Mio + 310 T / Tag (15 T / h)

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Ham radio digital modes

- **> 30 digital modes are well known**
  - all applications (speech, text, image)
  - mutual, beacon
  - In combination with and without INet
- **modes for low power**
  - Principles: time · power = energie / bit
- **My project:**
  → whisper (WSPR) during vacancies
  to be at the „other side“

Advantage over other modes

Mode	Signal to Noise Ratio Threshold	Power Equivalence
WSPR	-27 dB	5 W
JT65	-24 dB	10 W
Olivia	-17 dB	50 W
PSK31	-7 dB	500 W
CW	-1 dB	2000 W
RTTY	+5 dB	8000 W
SSB	+10 dB	25000 W

Quelle: Dr. Carol F. Milazzo, KP4MD; http://www.qsl.net/kp4md/wsprmodes.htm

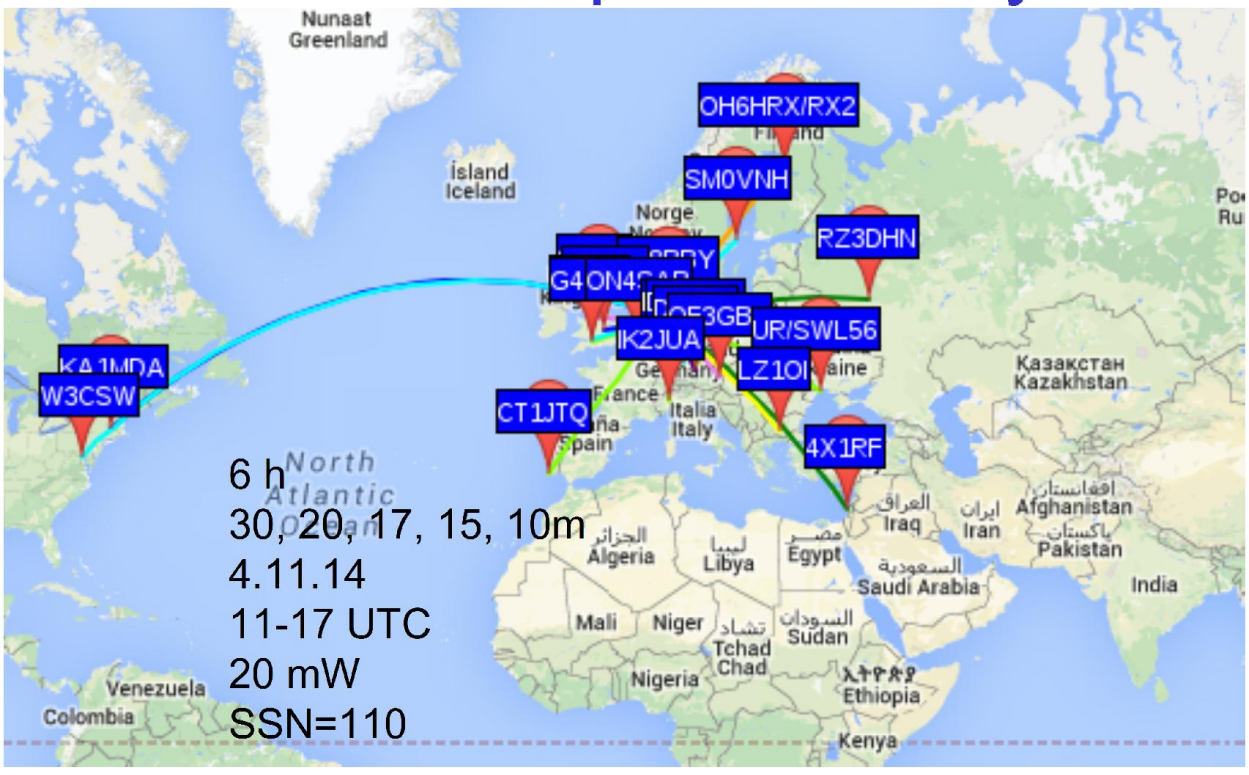
What can be found in INet-log?

1 Timestamp	2 Call	3 MHz	4 SNR	5 Drift	6 Grid	7 Pwr	8 Reporter	9 RGrid	10 km	11 az
2014-11-04 08:02	DK5HH	28.126015	-22	1	JO43jb	0.02	4X1RF	KM72ls	3070	127
2014-11-04 07:56	DK5HH	14.097038	-22	0	JO43jb	0.02	F5OIH	JN06ci	967	223
2014-11-04 07:54	DK5HH	10.140111	-22	1	JO43jb	0.02	LA5GOA/RX2	JO29oi	734	344
2014-11-04 07:44	DK5HH	14.097036	-21	0	JO43jb	0.02	F5OIH	JN06ci	967	223
2014-11-04 07:44	DK5HH	14.097030	-10	0	JO43jb	0.02	OE3GBB	JN87aq	788	136

1. UTC
2. Transmitter Callsign
3. Frequency of RX
4. RX mesured SNR (2500 Hz)
5. Drift of TX
6. Maidenhead Grid TX
7. power TX / W
8. RX-Callsign
9. RX-locator
10. distance / km
11. direction TX to RX

Geographic placement (webside wspr.org)

Website map of one day



What is WSPR for?

- Analyse antenna diagram
- Propagation experience
- What can be reached with a few mW?
- Internet combined with radio
- beacon mode
- statistics about parameters

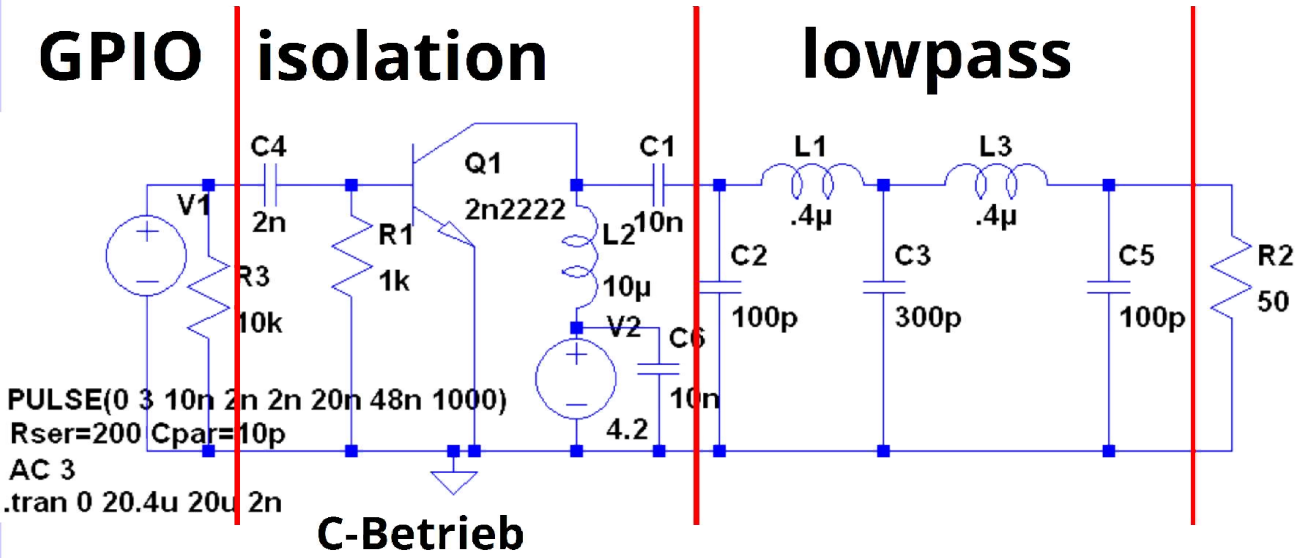
WSPR anywhere

- TX: Raspberry Pi (special program)
- RX: FiFiSDR + Raspi with WiFi
- NTP via hub of cellphone / gps-time
- parametrize by Tablet / Cellphone via ssh
- cron script to switch TX frequency mixture time dependant
- USB power supply check for sufficiant power and voltage (and USB extension cable!!)

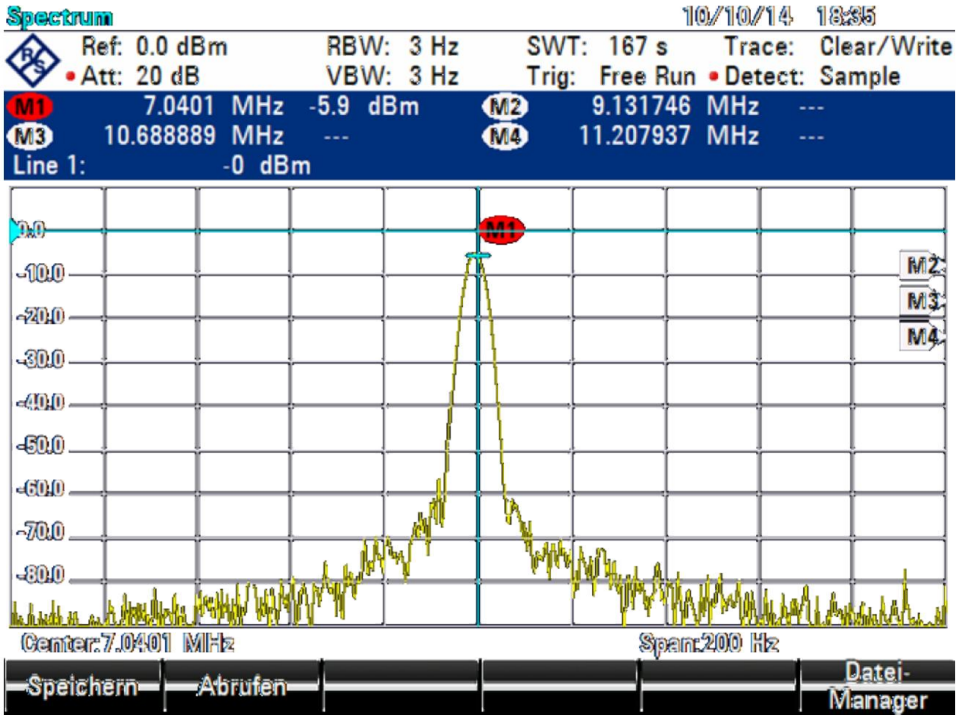
TX-Program for Raspberry Pi

- GPIO-output 4 → FM-TX
- generates 4-FSK-Signal with
  - Repetition started with even minute
  - Bandhopping
  - random Frequenz +- 80 Hz
  - absolute frequency given with ppm-deviation
  - self calibration with ntp kernel adjust
- WSPR-Band = 200 Hz!!! – exact absolute frequency
- called via command line

Isolating against electro statics

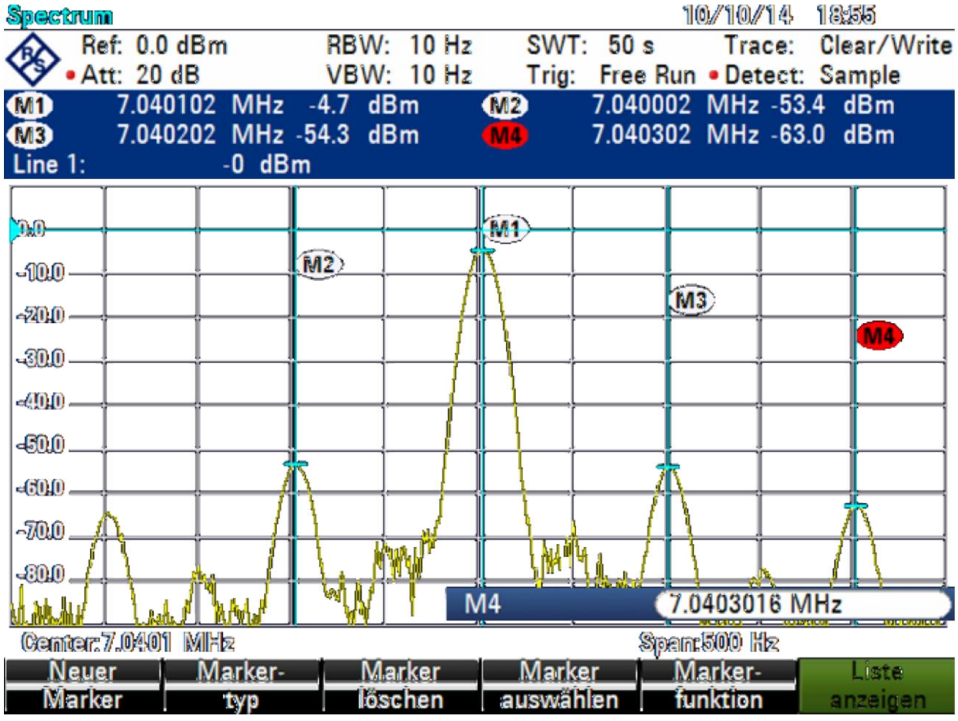


measured spectrum



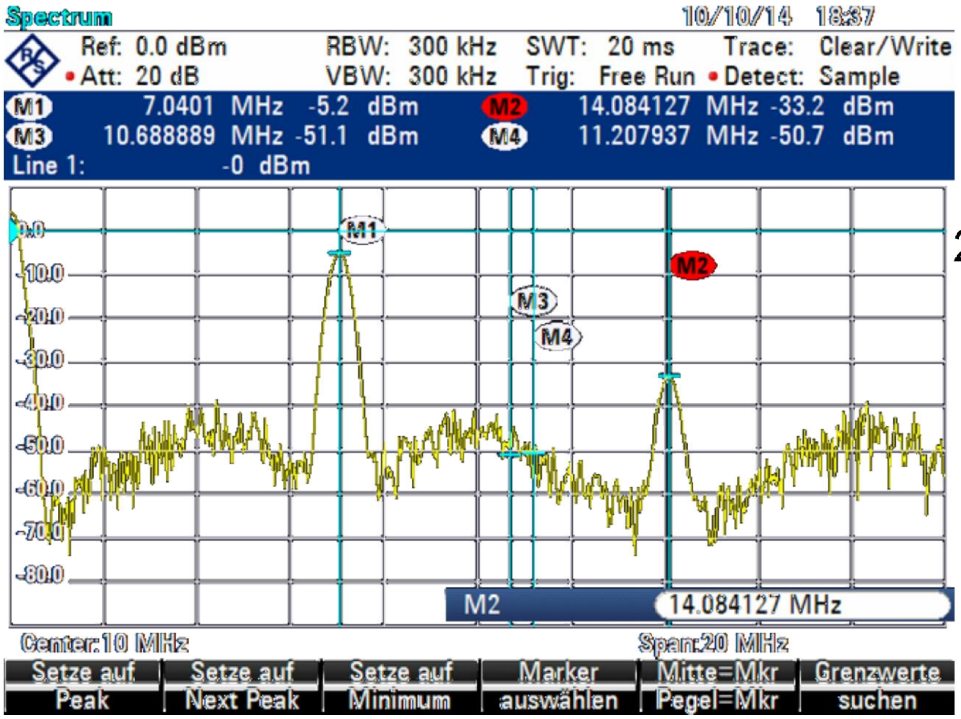
200 Hz span

sidebands n·100 Hz



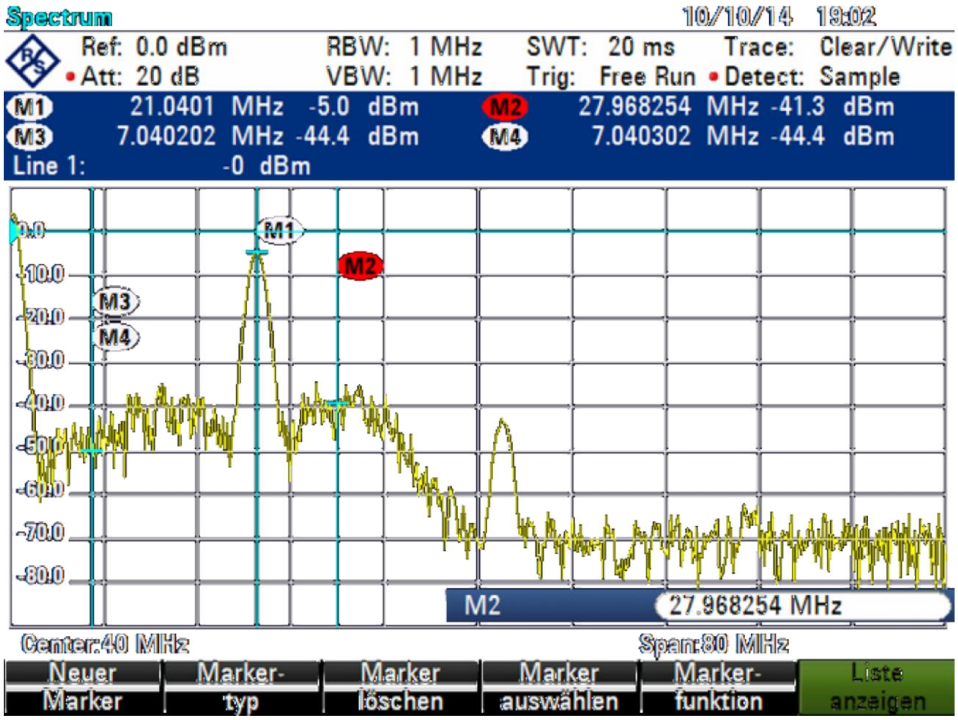
500 Hz span

Measured harmonics (7 MHz)



20 MHz span

21 MHz and LP 30 MHz

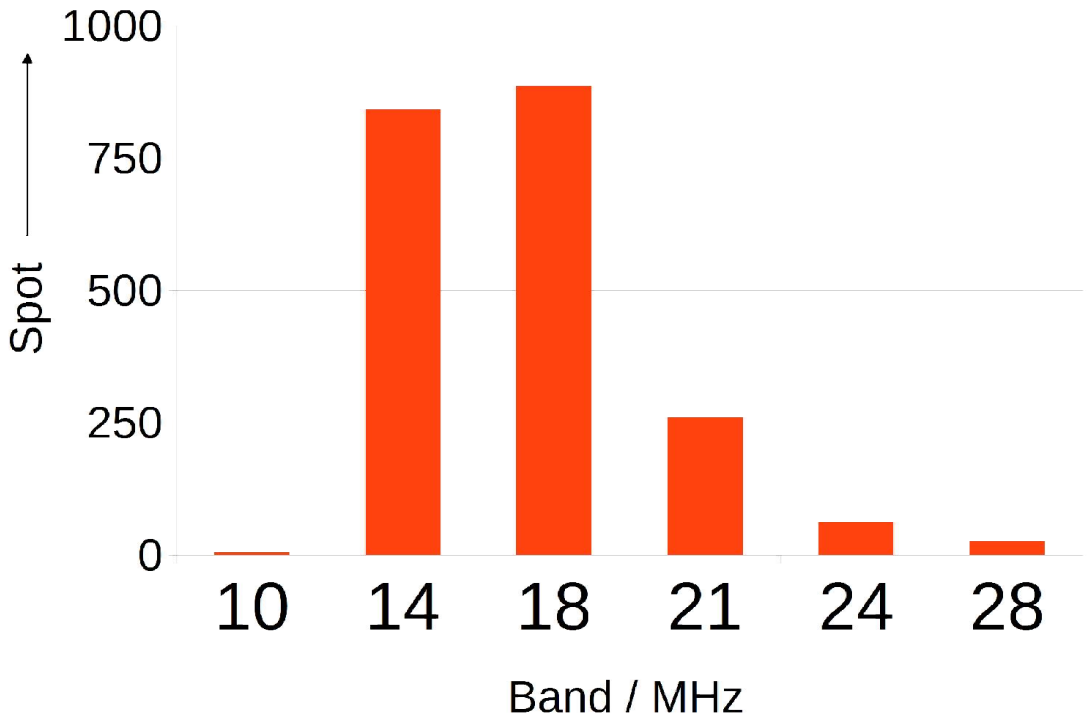


80 MHz span

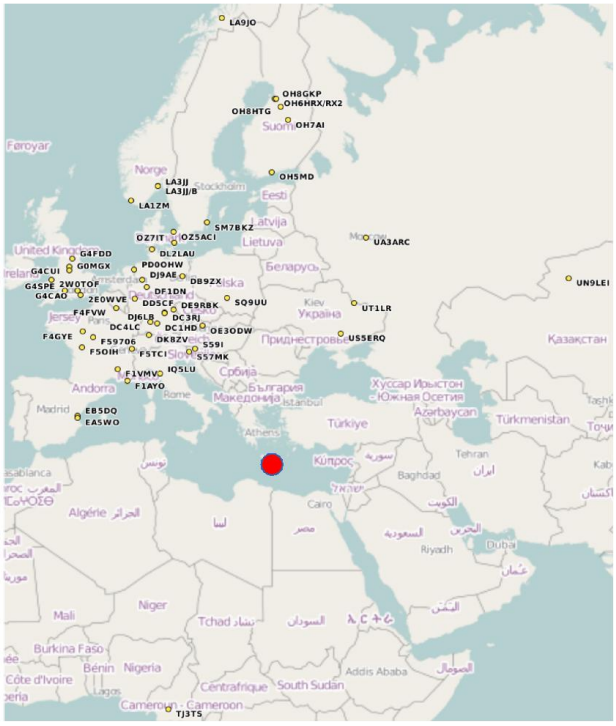
Summary for prepare the vacancy

- eravel ready quipment
- Cellphone als Accesspoint + Inet
- FiFiSDR
- Raspberry Pi als TX-only
- Tablett/Laptop
- Prefabricated antenna wire + terminals
- Twine ti rigging

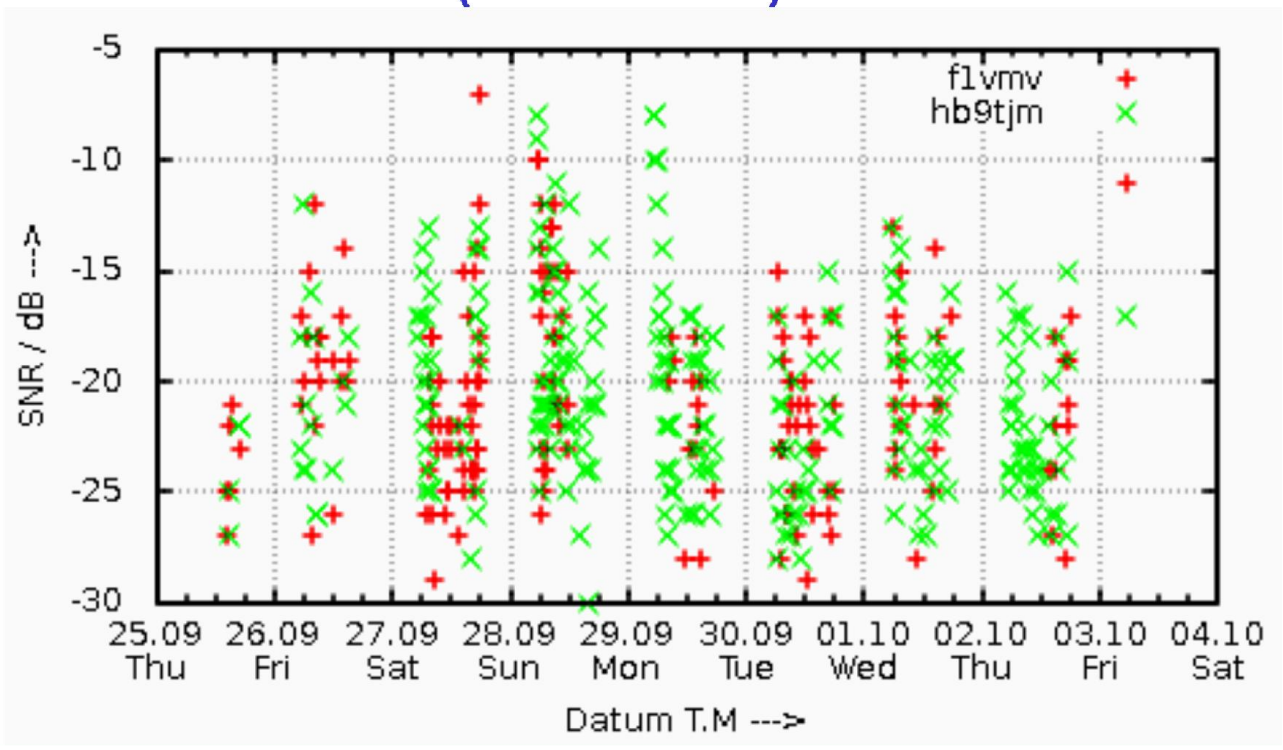
Spots / Band (8 days Crete)



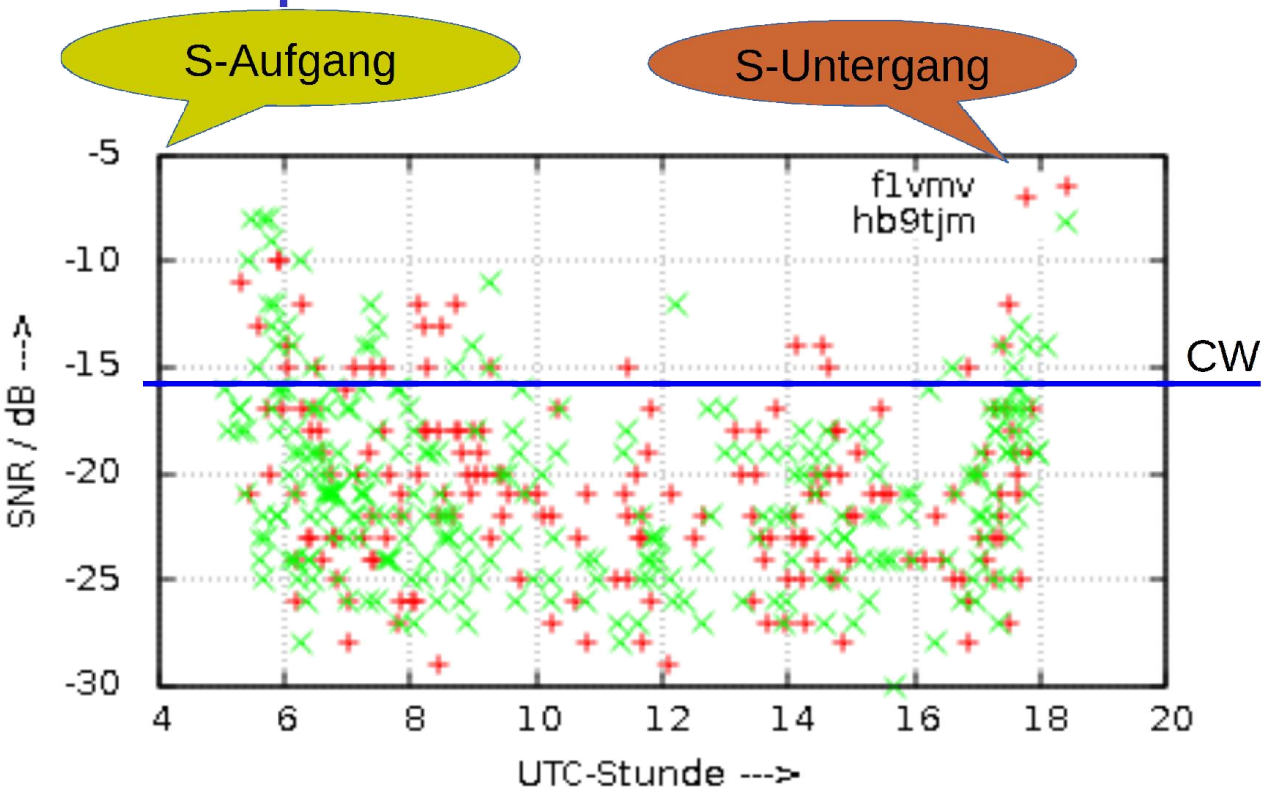
Spots (8 days in Crete)



comparison F1VMV HB9TJM (18 MHz)



Comparison based on hour



My Lessons learned

- WSPR with 10 mW equals to 50 W SSB
- Limited flight package can be fullfilled
- Use of wire antenna
- Raspi needs Acesspoint (adjust time)
- cron script → minimal time consuming

- Raspi can be used as a FM/PM SDR-Tx
- Power supplies should be selected
- Vacncy can be relaxing even with ham radio

references

- **wsprnet.org**
- www.darc.de/de/distrikte/b/31/5-technik-betriebstechnik/wspr/
- http://www.dj0abr.de/german/technik/dds/wsprbanana.htm
- http://home.arcor.de/dl5swb/mept/wspr_de.html
- http://www.dk5rk.de/PDF/Vortrag_Garitz-2009_WSPR.pdf
- https://github.com/JamesP6000/WsprryPi
- http://www-users.cs.york.ac.uk/~fisher/lcfilter
- **Many other useful references → trust your lovely search engine**

discussion?