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

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Questions to the audience

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 oscillator of the Raspi
- Programmable divider
- GPIO-output
  - Very limited output
  - Very sensitive for statics
  - Output is square wave
- Clock oscillator 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 $x \cdot I_{\text{rated}}$

Distant measurements (PS)
Different power supplies on different days

<table>
<thead>
<tr>
<th>Date / time</th>
<th>TX</th>
<th>Frequency</th>
<th>SNR</th>
<th>pwr</th>
<th>RX</th>
<th>Locator</th>
<th>dist</th>
<th>azim</th>
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<td>JO43</td>
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</table>
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
  - Rectangle (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)
- Practical real amplifiers
  - Nonlinear with mixing effects
  - Tuning elementes to reduce harmonics
  - Adapt the load impedance
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 length K = 32
  rate r = 1/2
- 4-cont. Phase FSK (CPFSK) S = 1.46 Bd;
  \( \Delta f = 1.46 \) Hz
- \( h = \Delta f \cdot T = 1.46 \cdot 1 / S = 1 \) (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)
- time needed synchronized within 1 s (TX + RX)
- RX send results to Internet-Database

What is WSPR and what is it used for?
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)

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 \cdot power = energie / bit
- My project:
  → whisper (WSPR) during vacancies
  to be at the „other side“
Advantage over other modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Signal to Noise Ratio Threshold</th>
<th>Power Equivalence</th>
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<tr>
<td>WSPR</td>
<td>-27 dB</td>
<td>5 W</td>
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<tr>
<td>JT65</td>
<td>-24 dB</td>
<td>10 W</td>
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<tr>
<td>Olivia</td>
<td>-17 dB</td>
<td>50 W</td>
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<td>PSK31</td>
<td>-7 dB</td>
<td>500 W</td>
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<tr>
<td>CW</td>
<td>-1 dB</td>
<td>2000 W</td>
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<tr>
<td>RTTY</td>
<td>+5 dB</td>
<td>8000 W</td>
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<tr>
<td>SSB</td>
<td>+10 dB</td>
<td>25000 W</td>
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</tbody>
</table>

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

What can be found in INet-log?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td></td>
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<td>SNR</td>
<td>Drift</td>
<td>Grid</td>
<td>Pwr</td>
<td>Reporter</td>
<td>Grid</td>
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</table>

1. UTC
2. Transmitter Callsign
3. Frequency of RX
4. RX measured 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 (website wspr.org)

1 h
Alle Bänder
Am 4.11.14
Von 7:30-8:30
20 mW

Website map of one day

6 h
30, 20, 17, 15, 10m
4.11.14
11-17 UTC
20 mW
SSN=110
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 sufficient 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 electrostatics

GPIO isolation

Lowpass

C-Betrieb
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

- Travel ready equipment
- 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

S-Aufgang

S-Untergang

SNR [dB] →

UTC-Stunde →

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/distrikt/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?