Development and testing of radio modules for robot communication

Semester Project

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EPFL

June 2017
Replace the current transceiver \textbf{nRF905} in amphibious robots with a better transceiver.
Identified Requirements

- 433 MHz or 868 MHz
- Transceiver: RX and TX
- Well documented
- Widely available
Survey of Available Transceivers

13 transceivers from 10 manufacturers.

Criteria:

- RX Sensitivity
- TX Power
- datarate
- package, RX current, TX current
- documentation
- features and ease of use
- availability
<table>
<thead>
<tr>
<th>Part</th>
<th>Mfr.</th>
<th>RX Sensitivity</th>
<th>TX power</th>
<th>Max data</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2-LP</td>
<td>ST</td>
<td>-130dBm</td>
<td>+16dBm</td>
<td>500kbps</td>
</tr>
<tr>
<td>SPIRIT1</td>
<td>ST</td>
<td>-118dBm</td>
<td>+16dBm</td>
<td>500kbps</td>
</tr>
<tr>
<td>Si4455</td>
<td>SiLabs</td>
<td>-116dBm</td>
<td>+13dBm</td>
<td>500kbps</td>
</tr>
<tr>
<td>MRF89XA</td>
<td>Microchip</td>
<td>-113dBm</td>
<td>+12.5dBm</td>
<td>200kbps</td>
</tr>
<tr>
<td>CC1310</td>
<td>TI</td>
<td>-124dBm</td>
<td>+15dBm</td>
<td>50kbps</td>
</tr>
<tr>
<td>nRF905</td>
<td>NRF</td>
<td>-100dBm</td>
<td>+10dBm</td>
<td>50kbps</td>
</tr>
<tr>
<td>ATA5428</td>
<td>Atmel</td>
<td>-116.5dBm</td>
<td>+10dBm</td>
<td>20kbps</td>
</tr>
<tr>
<td>ADF7020</td>
<td>analog</td>
<td>-119dBm</td>
<td>+13dBm</td>
<td>200kbps</td>
</tr>
<tr>
<td>ADF7025</td>
<td>analog</td>
<td>-104.2dBm</td>
<td>+13dBm</td>
<td>384kbps</td>
</tr>
<tr>
<td>RF69W</td>
<td>hoperf</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CMT2300A</td>
<td>cmostek</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MAX2904</td>
<td>maxim</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table: Chips comparison, ordered from best to worst performance.
## Survey of Available Transceivers

### Overall performances:

- **S2-LP**
- **SPIRIT1**
- **Si4455**
- **MRF89XA**
- **CC1310**
- **nRF905**
Available Parameters:

- frequency
- modulation
- datarate
- frequency deviation
- bandwidth
- output power
Measurable performance:

- range
- RSSI
- packet loss
- preamble quality indicator
- synchronization quality indicator
Testing and Evaluation of the SPIRIT1

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Testing and Evaluation of the SPIRIT1

UART protocol

RF protocol
Testing and Evaluation of the SPIRIT1 UART protocol

<table>
<thead>
<tr>
<th>Start=0xA5</th>
<th>Length</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>

![Diagram](image)
Testing and Evaluation of the SPIRIT1
UART protocol: generator

- definition.xml
- Generator
- constants.h
- constants.py
- callbacks.c/h
<?xml version="1.0"?>
<protocol>
    <constants>
        <constant>
            <name>CONSTANT_NAME</name>
            <description>
                Constant description for documentation purpose which is added as comment in the generated source files.
            </description>
            <value>![CDATA[(1<<0) // Arbitrary code]]></value>
        </constant>
    </constants>
    <registers>
        <register>
            <name>REGISTER_NAME</name>
            <description>
                Register description for documentation purpose which is added as comments in the generated source files.
            </description>
            <address>0x0001</address> <!-- The address is 18 bits long. -->
            <length>1</length> <!-- The indicative length < 64 -->
        </register>
    </registers>
</protocol>
Testing and Evaluation of the SPIRIT1 UART protocol: Streamed Variables

```
SVLST
SVITM 0x00,0x01,'VARNAME0\0'
SVITM 0x01,0x01,'VARNAME1\0'
SVITM 0x02,0x01,'VARNAME2\0'
SVITM 0x03,0x01,'VARNAME3\0'
SVITM...
SVVAL,0x00,0x0032B32B
SVVAL...
```
Testing and Evaluation of the SPIRIT1 Radio protocol

Three commands:

1. NOP: empty packet. (PING)
2. ACK: response to NOP. (PONG)
3. RADIOCONF: new radio configuration.
Testing and Evaluation of the SPIRIT1 GUI Interface

![Generic Radio Evaluation Software](image)

<table>
<thead>
<tr>
<th>COM port</th>
<th>COM4</th>
<th>Reconnect</th>
<th>WP# 1</th>
<th>Next</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0 RSSI</td>
<td>164</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x1 PQI</td>
<td>255</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2 SQL</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x3 Acknowledged</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x4 Not acknowledged</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x5 Sent</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x6 Round-trip time</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x7 From</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x8 Burst</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **xtal_offset_ppm**: 0
- **frequency_base**: 868000000
- **channel_space**: 100000
- **channel_number**: 0
- **modulation_select**: 0
- **datarate**: 500000
- **freq_dev**: 125000
- **bandwidth**: 800100

Buttons: Read from device, Write to device, Send to peer, REINIT, Burst
Results
Antenna characterization

RSSI with respect of rotation around z axis of the receiving node

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Results
Antenna characterization

RSSI with respect of rotation around y axis of the receiving node

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Antenna characterization

RSSI with respect of rotation around x axis of the receiving node
Results

Antenna characterization

RSSI with respect to the orientation

Orientation

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Range comparison of FSK and MSK in two environments
Module

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Possible failure causes:

“The LOCKWON state may persist indefinitely in two cases:

- in case of hardware problem (bad XTAL or chip soldering).
- if a TX, LOCKTX, RX, LOCKRX command is sent with a bad VCO calibration word (RCO_VCO_CALIBR_IN[1:0]) or if the VCO calibration fails.”

Possible solution: standard schematic instead of TX boost mode.
<table>
<thead>
<tr>
<th>RIR</th>
<th>Frequency band</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIR1008–06</td>
<td>868.0–868.6 MHz</td>
<td>25 mW e.r.p. / 1 % DC</td>
</tr>
<tr>
<td>RIR1008–07</td>
<td>868.7–869.2 MHz</td>
<td>25 mW e.r.p. / 0.1 % DC</td>
</tr>
<tr>
<td>RIR1008–20</td>
<td>863.0–870.6 MHz</td>
<td>25 mW e.r.p. / 0.1 % DC / FHSS</td>
</tr>
<tr>
<td>RIR1008–21</td>
<td>865.0–868.0 MHz</td>
<td>25 mW e.r.p. / 1 % DC / FHSS</td>
</tr>
</tbody>
</table>

SPIRIT1 hop time: 54 $\mu$s
nRF905 hop time: 650 $\mu$s