PCI Express SDR Board

Version: 2025-06-13

Table of Contents

1 Features

- 2x2 RF transceiver (AD9361) with integrated 12-bit DACs and ADCs
- RF coverage: 500 MHz to 6.0 GHz
- RF bandwidth: < 200 kHz to 56 MHz
- Supports TDD and FDD operation
- Integrated TX/RX switch for TDD operation
- PCIe 1x standard connector
- Integrated GPS for precise time and frequency synchronization
- Clock/PPS inputs and outputs for easy chaining
- Optional sample compression to reduce the PCI bandwidth

2 Installation with the Amarisoft software

2.1 Introduction

If you have bought the OTS (Off-The-Shelve) package, then you dont need to install anything. Everything has already been installed on your PC. Otherwise, please follow through the steps below.

Decompress the `trx_sdr` archive into a convenient directory specified by `<trx_path>`.

```
tar -xzf trx_sdr-linux-YYYY-MM-DD.tar.gz -C <trx_path>
```

You have two ways to install the TRX driver for the PCIe card:

- automatic
- manual

For both cases, the installation requires some specific packages to compile the kernel module. To do this, you need to be root. In Fedora and Cent OS, you need to install *kernel-devel*, *make*, *gcc* and *elfutils-libelf-devel* packages by running the following command:

```
dnf install kernel-devel-$(uname -r) make gcc elfutils-libelf-devel
```

For Ubuntu, use the following command:

```
apt-get install linux-headers-$(uname -r) build-essential
```

Note that you'll need equivalent packages for other Linux distributions if you do not use Fedora, Ubuntu or Cent OS.

Once you have finished the installation, you need to initialize (See [Driver initialization], page 3) and upgrade your driver (See [Firmware upgrade], page 3). Please make sure to initialize the driver after each system boot if you have not activates an automatic lte service.

2.2 Automatic Installation

Automatic installation is only available on Fedora, Ubuntu and CentOS distributions. Use manual install for other distributions. To start your automatic install, use the following command where `<path>` is the path to the directory where you have already installed your LTE component (eNB or UE) and `type` should be set to `enb` or `ue` accordingly.

```
./install <path> <type>
```

Notes:

- the script would install some packages, so make sure you have root privileges when you run the script
- this install creates a symlink for the TRX driver so please do not remove this directory afterwards.

2.3 Manual Installation

To manually install the driver, let's note `<path>` the directory where Amarisoft eNB or UE software is installed. Then:

1. Compile kernel driver:
   Go to the `kernel/` directory under `<trx_path>` and start compilation:
   ```
   cd kernel
   make
   ```
2. Place driver:
   Just copy the compiled driver into `<path>` directory
   ```
   cd ..
   ```

```
cp trx_sdr.so <path>
cp libsdr.so <path>
cp libc_wrapper_sdr.so <path>
```

3. Config files:
   Copy RF driver config file. Note that there are 2 separate config directories for eNB and UE called `config.enb` and `config.ue` under your `<trx_path>`. As a result, the `<config_dir>` should be set to `config.enb` or `config.ue` accordingly.

   ```
   cp -r <config_dir> <path>/config/sdr
   ```

   Select frontend:

   ```
   <path>/config/rf_select.sh sdr
   ```

2.4 Driver initialization

Each time you boot your system, you need to perform this initialization. Note that if you are using OTS install, this step is already done by the lte service.

```
cd kernel
./init.sh
```

2.5 Firmware upgrade

Perform the following command to upgrade your PCIe card:

```
./sdr_util upgrade
```

Notes:

- If you have several PCIe cards installed, this will upgrade all cards.
- If the firmware is already up to date, this command will end directly.
- When the upgrade is over, you need your system to be powered off for the changes to take effect (not only reset, real power off).

2.6 Multiple card installation

To make several cards work together, they must be time and frequency synchronized. For that purpose you need to plug the provided black cable between each card. Connect the internal OUT connector (J4 on Figure 7.2) on the first card to the IN connector on the second card (J3 on Figure 7.2, connectors are between RoHS compliant mark and Serial number sticker). Then do the same with OUT of second card and IN of third one, etc...

When you install several PCIe cards, the mapping between the PCI connectors and the Linux devices is not predictable (but it shouldn't change after each boot). To identify the order please do the following:

```
./sdr_util -c 0 led 1
```

Then check inside PC on each board, one of them should have a led blinking. This is card 0 (`/dev/sdr0`).

Switch off the led:

```
./sdr_util -c 0 led 0
```

You can do the same for other cards:

```
./sdr_util -c <n> led 1
```

Where `<n>` is the index of the card.

To use all the cards, update eNB config file (`config.cfg`) using args parameter:

```
args: "dev0=/dev/sdrA,dev1=/dev/sdrB,..."
```

Note: this allow to change the order of the cards. For instance, if your card are from left to right have following indexes:

```
<1> <2> <0>
```

And you want first cell to be on left, second cell to be on middle and third on right, use the following:

```
args: "dev0=/dev/sdr1,dev1=/dev/sdr2,dev2=/dev/sdr0"
```

2.7 RX Channel Mapping

Commercial CPEs have different antenna configurations depending on the band used. As an exemple, Telit FN980 CPE has different TX antenna mapping in bands n41 and n78 as shown in the following table:

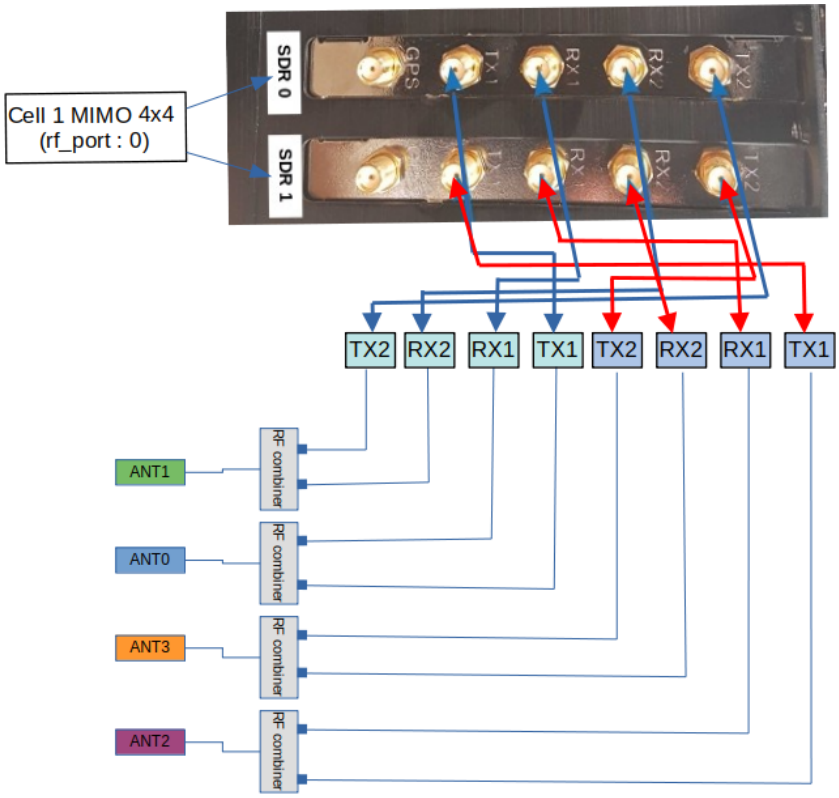
Antenna port	**TX**
ANT0	n41 diversity antenna
ANT1	n78 main antenna
ANT2	n41 main antenna and n78 diversity antenna
ANT3	No TX

Amarisoft SDR50 card has 2 RX ports: RX1 and RX2 but the main RX antenna is always considered to be RX1 by default. In case of multiple streams in UL, the RX ports are used consecutively. As an example in case of MIMO 2x2 in UL, RX1 and RX2 will be used. This static setting is not practical when testing multiple bands in conducted mode. Let's consider a cabled test with the Telit CPE FN980. In case of n78, the CPE ANT1 should be connected to the RX1 port of the SDR card while in n41, the CPE ANT2 should be connected to RX1.

In order to make the cabling easier, we have introduced a new parameter in the RF driver called `rx_chan_mapping`(See [rx_chan_mapping], page 8) which defines the list of physical RX ports to be used per RF port. This parameter is a string separated by `,` for each RF port. Inside each RF port, there is a list of physical RX port indexes that are used by each UL stream.

> `rx_chan_mapping` uses the RX port index going from 0 to the number of RX ports - 1.

Let's take an example of a configuration with one cell MIMO 4x4 in DL and SISO in UL in n78 connected by cables to a Telit FN980 CPE with 4 antenna ports as depicted below. This configuration can be run on two SDR50 boards.

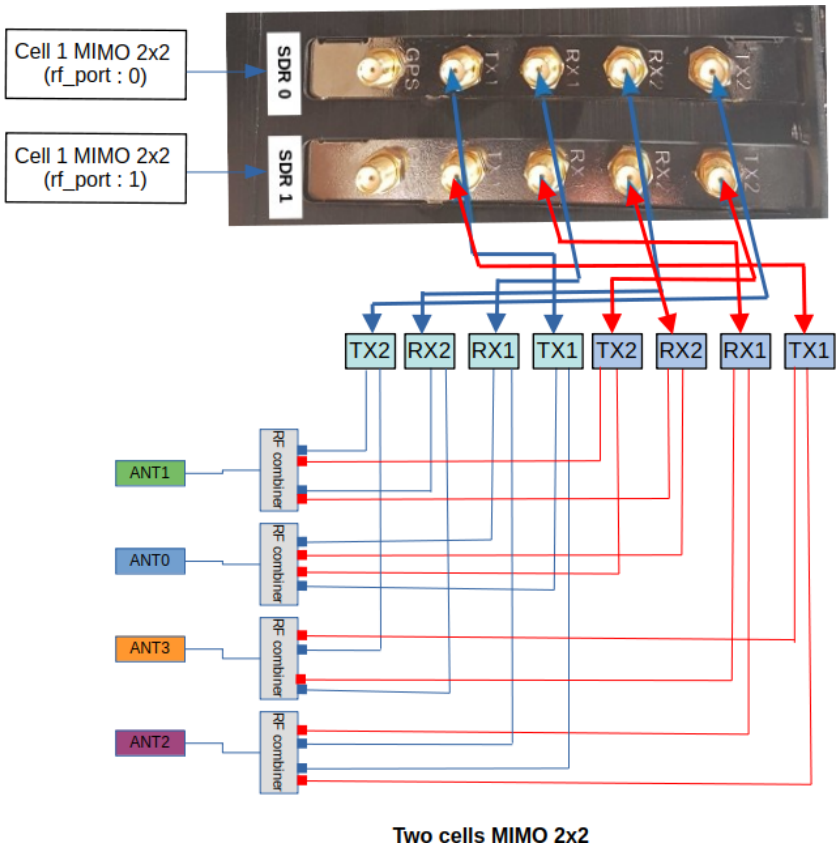


One cell MIMO 4x4

The CPE uses ANT1 as the main antenna for UL in band 78. However, the ANT1 is connected physically to TX2/RX2 as can be seen in the above figure. Setting `rx_chan_mapping` to `1` means that the SDR driver should expect to receive the UL data on the RX2 port (the index of RX2 is one). The corresponding `rf_driver` configuration is as below. There is only one single stream in UL which is mapped to RX2 and there is only one cell (one rf_port) in this example.

```
rf_driver: {
        name: "sdr",

        /* list of devices. 'dev0' is always the master. */
        args: "dev0=/dev/sdr0,dev1=/dev/sdr1",

        /* TDD: force the RX antenna on the RX connector */
        rx_antenna: "rx",

        /* synchronisation source: none, internal, gps, external (default = none) */
        // sync: "gps",

        rx_chan_mapping: "1",
}
```

Now, let's consider another example with 2 cells MIMO 2x2 in DL and SISO in UL. This configuration can be run on two SDR50 boards as depicted below.



Two cells MIMO 2x2

The first cell (rf_port 0) is in n78 and the second one is in n41. Let's consider again that a TELIT CPE is used where the UL main antenna is ANT1 in case of n78 and ANT2 in case of n41. There is still one single layer in UL. In this case, `rx_chan_mapping` should include 2 indexes, one for each RF port. The first index refers to the RX port used to receive the UL in rf_port 0 (Cell 1 in n78) while the second one is the RX port index in rf_port 1 (Cell 2 is n41).

The following `rx_chan_mapping` means that the UL stream is expected to be received on the RX2 port of the first board and the RX1 port of the second board.

```
rx_chan_mapping: "1,0",
```

Now let's consider the same example as above with 2 cells but this time UL is in MIMO 2x2 in both cells. Remember that Telit CPE uses ANT1 and ANT2 as main and diversity antenna for n78 and ANT2 and ANT0 as main and diversity antenna for n41. With respect to the cabling of the above diagram, the `rx_chan_mapping` should be as follows.

```
rx_chan_mapping: "1:0,0:1",
```

In the rf_port 0 (n78 Cell), the RX2 and RX1 ports are used to receive the UL stream 0 and stream 1 while in the rf_port 1 (n41 cell), the RX1 and RX2 ports are used.

2.8 TDD support

The board integrates a TX/RX switch for TDD operation. When TDD operation is configured, the transmit and receive are done on a single RF port (the TX SMA connector). So you only need to connect antennas on the TX1 and TX2 SMA connectors for TDD operation.

2.9 GPS usage

You can check the GPS operation when the eNodeB/UE is stopped with

```
./sdr_util gps_state
```

The GPS takes a few minutes to lock if the GPS antenna is connected. Any active GPS antenna accepting a 3.3V DC supply can be used, for example: `http: / / www . mouser . fr / Search / ProductDetail . aspx ? R=ANT-GPS-SH-SMAvirtualkey59000000virtualkey712-ANT-GPS-SH-SMA`

To ensure the PLL is correctly locked when launching the lte software, it is recommended to set the synchro to GPS beforehand with the command

```
./sdr_util sync_gps
```

2.10 Oscillator frequency fine tuning

If you don't have a GPS, it is still possible to manually fine tune the VCTCXO (Voltage Controlled, Temperature Controlled Crystal Oscillator) frequency provided you have a way to know the offset:

```
./sdr_util clock_tune n
```

where *n* is the offset in PPM (parts-per-million) from the nominal TCXO frequency. Note: the PPM offset *n* to voltage law is only approximative, so you should adjust it by successive approximation.

3 TRX driver configuration options

3.1 Single card configuration

The following properties are available:

`name` String. Set the driver to use, always set "sdr" to use Amarisoft driver.

`args` String. Set the system device names for the boards. Example:

```
args: "dev0=/dev/sdr0"
args: "dev0=/dev/sdr0,dev1=/dev/sdr2"
```

`sample_hw_fmt`
Optional enumeration (auto, ci16, cf8) (default = auto). Set the sample format used on the PCI bus. `auto` selects the best format depending on the available PCI bandwidth. `ci16` selects 16 bit complex integers. `cf8` selects 8 bit complex floats giving a 2:1 compression ratio while retaining the full 12 bit amplitude of the ADCs and DACs.

`rx_antenna`
Optional enumeration (auto, tx_rx, rx) (default = auto). Select the connector on which the RX antenna is connected. By default it is connected on the RX connector for FDD and on the TX/RX connector for TDD. This parameter is useful to force the use of the RX connector in TDD.

`fifo_tx_time`
Optional number. Set the DMA TX buffer size in us.
Decreasing this value will improve latency but may lead to signal samples loss if the PCIe chain on the motherboard is not fast enough. This can be detected with the `rf_info` monitor command of your `lteenb` or `lteue` software. If such situation happens, the percentage of `TX buffer Usage` will be 100% which means the transmission path has encountered underflows.

`fifo_rx_time`
Optional number. Set the DMA RX buffer size in us.
Same as `fifo_tx_time` for RX chain but reducing it won't improve latency.

`pps_extra_delay`
Optional float value in microseconds, range: [-10000.0 .. +10000.0] (-10ms to +10ms)
Adds a delay between GPS pulse and start of DL frame. If the pps_extra_delay value is negative, the actual delay will be (10ms + pps_extra_delay). For instance, if you want to compensate for 250ns delay caused by cable length, you will set pps_extra_delay: -0.25, the software will add (10ms - 250ns) to the GPS pulse.

`tdd_tx_mod`
Optional number value: 0 (default) or 1. If set to 1, the TX amplifiers will be switched on and off according to the TDD state.

`rx_chan_mapping`
Optional string. By default, if radio frontend has more RX channel available than configured (Ex: more physical RX connctor on SDR or more channel in CPRI hyperframes), drvers uses the first channels of the radio frontend.
This parameter allows to select the RX channels of the radio frontend to use.
This parameter is a list of number (Must have as many number as RF port configuration) separated by colons. Each number represents the RX channel of the radio frontend to use.

Ex: If a RF port has 4 TX antenna and 2 RX antenna, by default driver will use RX1 and RX2 of first SDR board. By setting:

`1:2`

RF driver will use RX2 of first board as primary RF port channel and RX1 of second board as secondary RF port channel.

With:

`3:1`

RF driver will use RX2 of second board as primary RF port channel and RX2 of second board as secondary RF port channel.

`sync` Optional enumeration: none, internal, gps, external (default = none). Set the time synchronization source. `none` and `internal` uses the internal PPS generated from the clock. `internal` synchronizes the RX timestamps on the internal PPS. `none` does not synchronize the RX timestamps on the internal PPS for a faster startup. `gps` uses the internal GPS. `external` uses the PPS from the IN connector (J3 on Figure 7.2) if clock source is selected as `external` or from the PPS MMCX connector (PR10) if clock source is selected as `internal`.

When several cards are selected (with the `args` property), `sync` only sets the time synchronization source of the first card. The other cards are implicitly set to `external` synchronization, assuming the previous card is used as source.

`clock` Optional enumeration: internal, external (default = internal). Set the clock source. `internal` uses the internal clock (VCTCXO). If an external PPS sync source is used, the internal clock frequency is adjusted by the PPS signal. `external` uses the clock from the IN connector (J3 on Figure 7.2).

When several cards are selected (with the `args` property), `clock` only sets the clock source of the first card. The other cards are implicitly set to `external` clock, assuming the previous card is used as source.

`gpio0` Optional enumeration. Selects the signal ouput on test point TP3. See below for possible values. Default = rf_dts1.

`gpio1` Optional enumeration. Selects the signal ouput on test point TP4. See below for possible values. Default = rf_dts2.

`gpio values:`

Value	**Description**
zero	output a constant low level signal (OV)
one	output a constant high level signal (3.3V)
rf_dts1	in TDD mode, output a high level when the TX is active on channel 1. Polarity can be inverted by setting `dts_polarity`: low
rf_dts2	in TDD mode, output a high level when the TX is active on channel 2 Polarity can be inverted by setting `dts_polarity`: low
pps_selected	output a positive going Pulse per Second from the currently selected sync
pps_ext	output a positive going Pulse per Second from the EXT PPS MMCX onboard connector

pps_prev	output a positive going Pulse per Second from the IN 5 pin inter board connector
pps_gps	output a positive going Pulse per Second from the onboard GPS module
pps_vcxo	output a positive going Pulse per Second from the onboard generator
dma_tx	output a positive front on each TX DMA packet (synced on current selected PPS)
dma_rx	output a positive front on each RX DMA packet
dma_tx_100Hz	output a 100 Hz signal synced with dma_tx
dma_rx_100Hz	output a 100 Hz signal synced with dma_rx

`dts_polarity`
: Optional enumeration: high (default), low. Selects the polarity for both rf_dts1 and rf_dts2 signals.

The range for the transmit gain (`tx_gain` parameter in eNodeB/UE) is from 0 to 89.75 dB. The range for the receive gain (`rx_gain` parameter in eNodeB/UE) depends on the frequency:

Frequency	**Gain**
70-4000 MHz	3 to 71 dB
4001-6000 MHz	0 to 62 dB

The maximum sample rate is 61.44 MHz.

3.2 Multiple card configuration

All single card configuration parameters apply to multiple card mode.
To differentiate configuration for each card, the syntax of some parameter will change to a list of value separated by commas (`,`).* The first value will apply to the first board defined in `args` argument, ...

This syntax applies to the following parameters:

- pps_extra_delay
- fifo_rx_time
- fifo_rx_ratio
- fifo_tx_time
- fifo_tx_ratio
- rx_chan_mapping

4 Troubleshooting

Below are a few tips on how to handle different errors.

- The eNodeB does not start and the output of `dmesg` linux command resembles the following error message:
  `sdr: version magic '4.12.9-200.fc25.x86_64 SMP mod_unload' should be '4.12.11-200.fc25.x86_64 SMP mod_unload'`
  To resolve it, you need to recompile the SDR driver on the PC (See [Manual Installation], page 2).

5 Miscellaneous utilities

5.1 sdr_util

```
usage: sdr_util [options] cmd [args...]

Options:
-h                          help
-c device_num               select the device (default = all)

Available commands:
version                     dump the FPGA version
sync_state                  dump the synchro and clock state
gps_state                   dump the GPS state
sync_gps                    select GPS as sync source, wait for stable state
gps_cal [-s]                uses the GPS sync to tune VCXO, optionnaly stores
                            the value in flash
temp                        dump the temperature of the board components
led [0|1]                   enable/disable led blinking
clock_tune n                tune TCXO frequency offset to n ppm
upgrade [options]           upgrade the FPGA firmware
  upgrade options are:
  -force                    force upgrade even if identical or
                            previous version
```

5.2 sdr_spectrum

`sdr_spectrum` is a real time spectrum analyzer, sample viewer and I/Q file recorder. It handles several channels at the same time. It can be invoked without arguments. The following options are available:

`-h` help

`-args str` set the device arguments (default="dev0=/dev/sdr0")

`-rx_freq freq`
set the RX frequency in Hz (default=2400000000)

`-rate rate`
set the sample rate to 'rate' Hz (default=30720000)

`-rx_gain gain`
set the RX gain in dB (default=60)

`-channels c`
set the number of RX channels to 'c' (default=1)

`-rx_bw` set the analog receive bandwidth in Hz (default=same as sample rate)

`-sync source`
set the sync source to 'source' (none, internal, gps, external) (default=none)

`-clock source`
set the clock source to 'source' (internal, external) (default=internal)

`-save_path path`
set the directory where the recorded samples are saved (default=/tmp)

`-duration d`
: set the recorded sample file duration in seconds when saving (default=1.0)

`-save` starts recording samples automatically from program start.

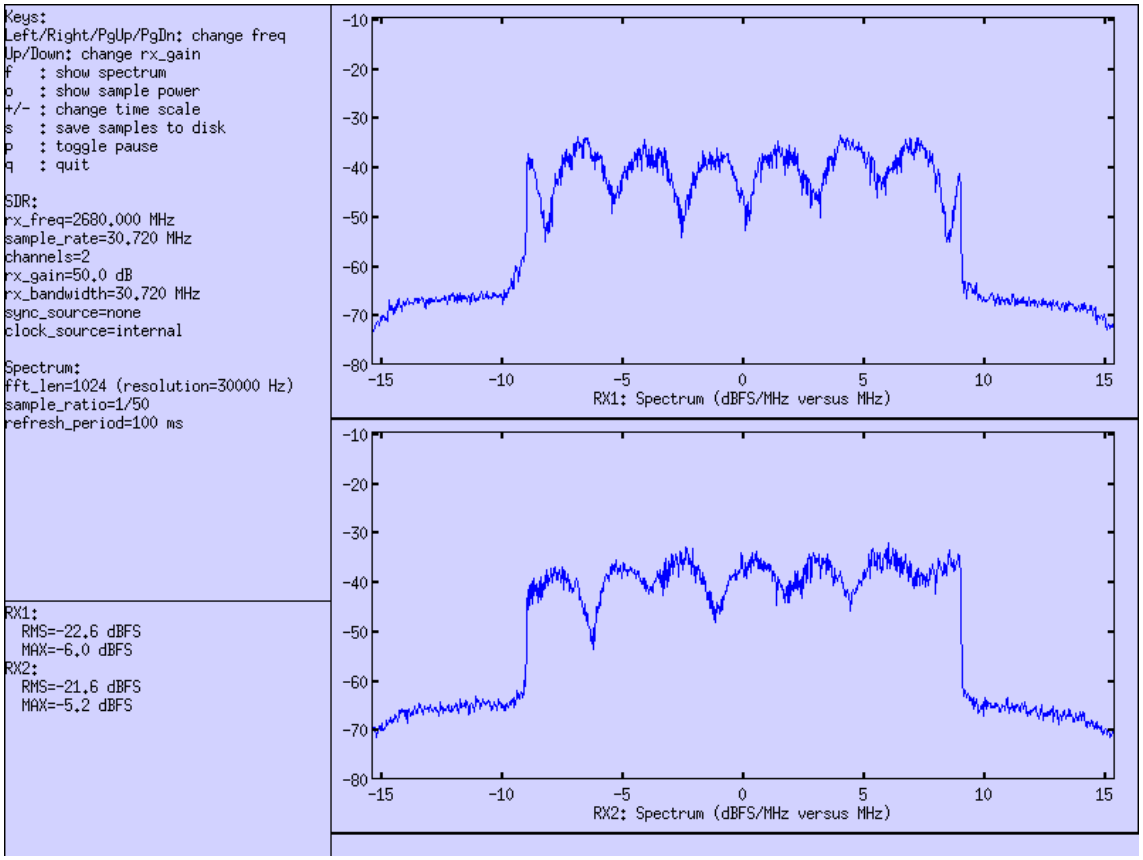
`-save-and-exit`
: same as `-save` but program will quit at end of recording.

When saving the recorded samples, one file is generated per channel. The filename contains the UTC date, the frequency and the channel number. The I/Q samples are saved as little endian 32 bit float values, in I/Q order. The sample values are between -1 and 1.

Invocation example:

```
./sdr_spectrum -channels 2 -rx_gain 50 -rx_freq 2680e6 -rate 30.72e6
```

Resulting output:



`sdr_spectrum` is interactive and allow actions during runtime:

`keys`
: available keys are indicated in the left side text area.

`left mouse button`
: select a range and the X-Y values are displayed on the bottom of the graph.

`right mouse button`
: in spectrum mode, highlight a range and get a measure of the power inside the range.

5.3 sdr_play

`sdr_play` is an I/Q file player. Several channels can be played at the same time and they can be time synchronized on an external clock. One file must be provided per channel. The following options are available:

`-h` help

`-args str` set the device arguments (default="dev0=/dev/sdr0")

`-tx_freq freq`
set the TX frequency in Hz (default=2400000000)

`-rate rate`
set the sample rate to 'rate' Hz (default=23040000)

`-tx_gain gain`
set the TX gain in dB (default=70)

`-channels c`
set the number of channels to 'c' (default=1)

`-tx_bw bw` set the analog transmit bandwidth in Hz (default=same as sample rate)

`-loop` play the file in loop

`-sync source`
set the sync source to 'source' (none, internal, gps, external) (default=none)

`-clock source`
set the clock source to 'source' (internal, external) (default=internal)

`-time_offset n`
offset the output by n samples (default=0)

The sample files should contain the I/Q values as little endian 32 bit floats, in I/Q order. The sample values should be between -1 and 1.

5.4 sdr_test

`sdr_test` is a general diagnostic tool for SDR boards.
usage: sdr_test [options] cmd [args...]

`-h`
help

`-c device_num`
select the SDR device number (default=0)

`-d channel`
select the device channel (default = 0). useful for CPRI boards.

`dma_loopback_test [n][sec]`
test DMA loopback on 1 or n devices for sec seconds (def: 10)

`rfic_tx_test sample_rate freq tx_gain waveform [tone_freq/ofdm_bw]`
test RFIC TX (freq in Hz, tx_gain in dB from 0 to 90)
waveform can be:

```
zero for no signal
prbs for PRBS simulation,
tone for CW at specified offset from center freq (default = 7.68e6)
ofdm for OFDM simulation on specified bw (default = auto)
```

`flash_check`
: verify checksum of code in onboard FPGA.

`flash_reload`
: reload FPGA code from onboard flash

`gps_read`
: GPS read test (best with GPS antenna)

`led`
: blinks onboard led during 5 seconds for identification

`synchro_set [src]`
: Set the source for PPS synchronisation

```
0=internal
1=GPS
2=slave
3=ext PPS
4=CPRI
5=ext CLK
```

`synchro_state`
: Show current status of clock and synchro source for SDR device

```
Example:
 sync_source = 0 (internal)
 pps_locked = 1
 clock_source = 0 (internal)
 clock_pll_locked = 1
```

`version`
: Show SDR device Hardware and firmware information

```
Example:
 Board ID:         0x4b01
 Board master:     0x0
 Board revision:   0x0
 FPGA revision:    2022-06-07 16:29:58
 FPGA status:      operational
 Software version: 2022-02-25
```

`dump_info`
: dump fpga and RF chip information (similar to sdr_util version)

```
Example:
PCIe SDR TRX driver 2022-02-25
PCIe RFIC /dev/sdr0@0:
  Hardware ID: 0x4b01
  DNA: [0x107149909461141596]
  Serial: ''
  FPGA revision: 2023-06-27  15:31:17
  FPGA vccint: 1.00 V
  FPGA vccaux: 1.79 V
  FPGA vccbram: 1.00 V
  FPGA temperature: 42.6 C
  AD9361 temperature: 18 C
  AGC: Off
  Sync: internal (locked)
```

```
Clock: internal (locked)
Clock tune: -0.7 ppm
NUMA: 0
DMA: 1 ch, 64 bits, SMem index: On
DMA0 TX_Underflows: 65535  RX_Overflows: 65535
PCIe bus: bus=0xb4 FPGA PCI gen2 x1 (4.0Gb/s)   OK
```

`gpio 0|1 [value]`

Get or set the signal available on GPIO points on the board
See `gpio0` and `gpio1` in chapter `TRX driver configuration options`;

6 C API

The PCIe SDR board can be used in other projects with its C API. The C API allows to send and receive I/Q samples and to change the various parameters (frequency, sample rate, bandwidth, gains, ...). The Amarisoft TRX driver, `sdr_play` and `sdr_spectrum` are built using this API.

The C API is described in `libsdr.h`. The corresponding Linux x86_64 dynamic library is `libsdr.so`.

Amarisoft does not provide any support for this API and can modify it without notice.

7 Physical specifications

7.1 Summary

- RF power output < 10 dBm
- Max RF input power: ~ -10 dBm RMS (+2dBm peak)
- 4 SMA female (TX1, TX2, RX1, RX2), AC coupled
- 1 SMA female (GPS antenna with 3.3V DC power supply)
- 2 internal 5-pin connectors for inter-card time synchronization
- 1 internal MMCX connector for external PPS input
- PCIe gen2 x1, full height, short length
- Uses single 12V power supply from PCI connector
- ADC/DAC Sample Rate: maximum 61.44 MS/s
- ADC/DAC Resolution: 12 bits
- Frequency Accuracy: 2 ppm
- LTE 20MHz 64QAM EVM < 2 %rms (f < 2.6 GHz)
- LTE 20MHz 64QAM EVM < 4 %rms (f < 3.5 GHz)
- Full size (L x W x H): 128mm x 115mm x 20mm
- Weight: 0.100 kg
- Power (PCIe 12V): 210mA idle => 2.5W, 460mA maximum (2x2 max tx_gain) => 5.5W

7.2 Connectors

The following figure depicts the location and functionality of each connector in the PCIe board.

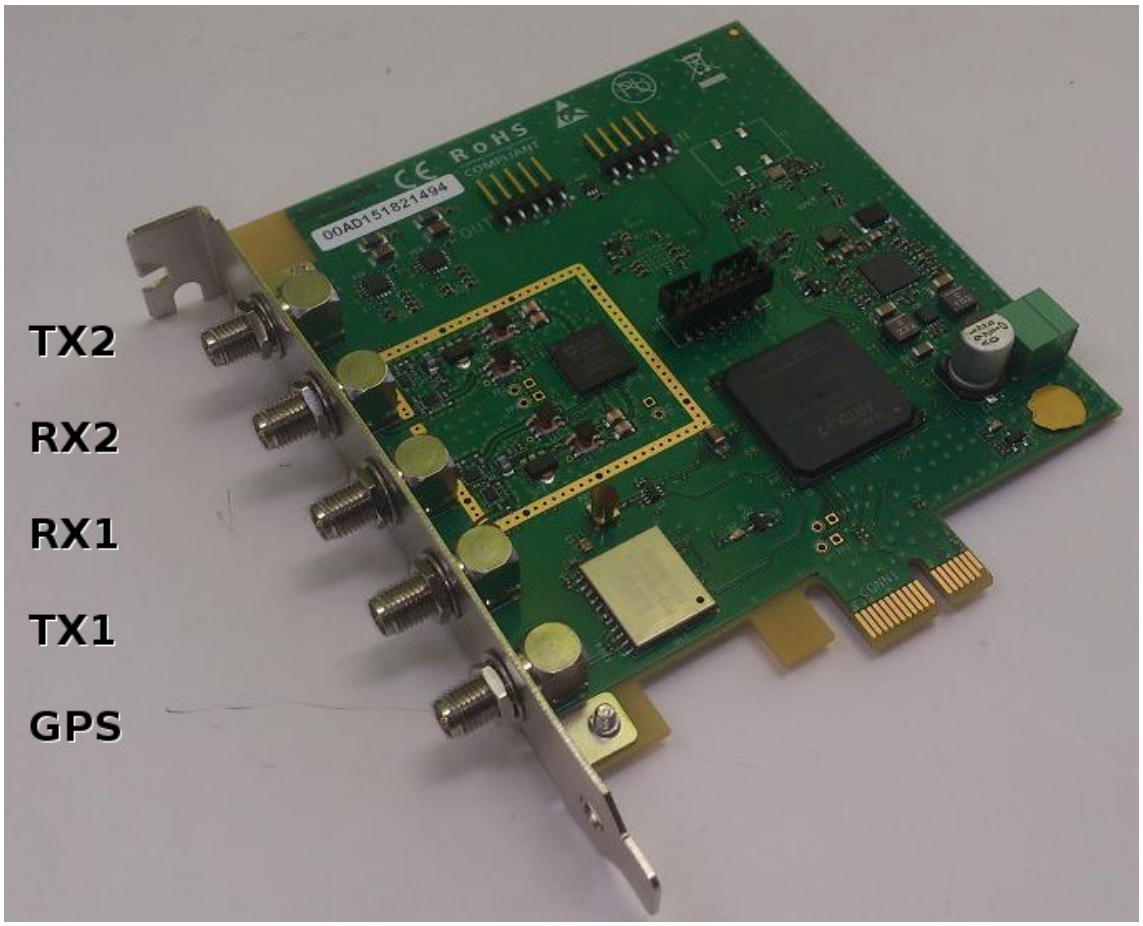


Figure 7.1

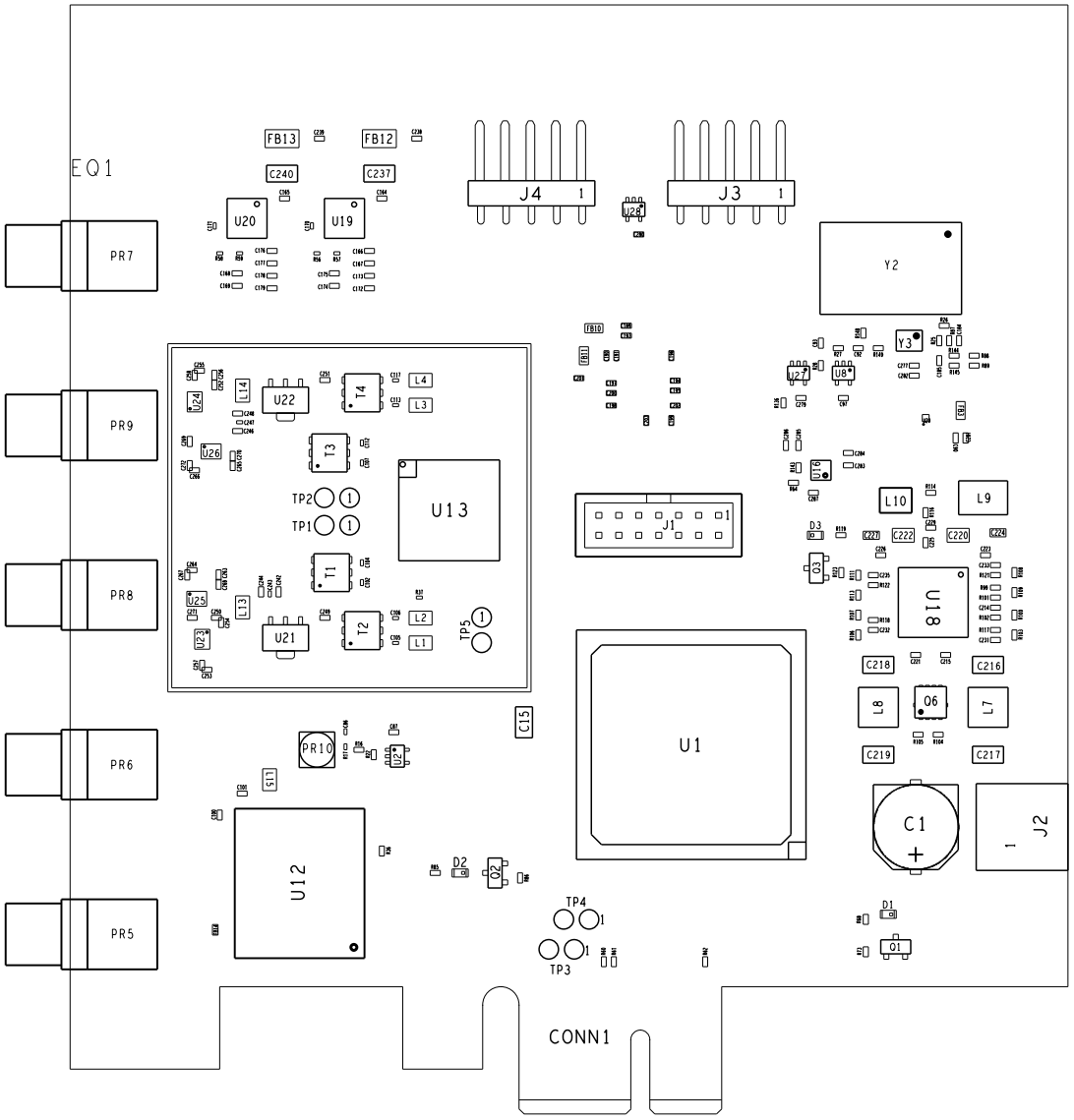


Figure 7.2

7.2.1 SMA connectors

See Figure 7.1 for the location.

On Figure 7.2, the connector names are:

PR7	TX2 (and RX2 for TDD)
PR9	RX2 (for FDD)
PR8	RX1 (for FDD)
PR6	TX1 (and RX1 for TDD)
PR5	GPS

7.2.2 PPS/Clock connectors

OUT connector (J4):

1	PPS_OUT
2	REFCLK_OUT_N
3	REFCLK_OUT_P
4,5	GND

PPS_OUT is a LVCMOS 3.3V output.
REFCLK_OUT is a standard LVDS signal with AC coupling.

IN connector (J3):

1	PPS_IN
2	REFCLK_IN_N
3	REFCLK_IN_P
4,5	GND

PPS_IN is a LVCMOS 3.3V input (> 3.3V input is not accepted).
REFCLK_IN is a standard LVDS signal with 100 ohm impedance and AC coupling.
This reference clock is 38.4 MHz when used to synchonize between SDR boards. It can also accept a 10.0 MHz reference clock (auto detect).
5 or 4 pin USB2 motherboard PC cables can be plugged in J3 and J4. When using a 4 pin connector, pin 5 can be left unconnected.

7.2.3 PPS MMCX connector

PR10	MMCX input connector for external PPS source
Imped.	50 ohms.
Level	CMOS, positive pulse.

7.2.4 JTAG connector (J1)

JTAG connector:

1,3,5,7,9,11,13	GND
2	VCC (3.3V)
4	JTAG_TMS
6	JTAG_TCK
8	JTAG_TDO
10	JTAG_TDI
12,14	NC

7.2.5 Test Pins for TDD mode

See Figure 7.2 for the location. These pins are 3V3 CMOS output, they are driven high when RF port is in TX mode. They can be used to signal external RF circuitry in TDD mode.

`TP3` see `gpio0` option in chapter `TRX driver configuration options`; default value = rf_dts1 (TDD switch for TX1 port)

`TP4` see `gpio1` option in chapter `TRX driver configuration options`; default value = rf_dts2 (TDD switch for TX2 port)

7.3 RX power

Maximum RX power on any RX port to avoid damage: -10dBm RMS.

7.4 TX power

Maximum RMS TX Power versus RF frequency, measured on OFDM bandwidth = 20MHz.
Also Peak dBm tone power, about 12dB higher due to average peak/RMS ratio.
Both were measured using sdr_test rfic_tx_test with ofdm and tone options.
(sdr_test version dated after November 2024 needed for actual maximum range).
Actual power reached may vary by a few dBm because of hardware variations.

RF Frequency (MHz)	**OFDM (dBm/MHz)**	**OFDM (dBm)**	**Tone (dBm)**
500	-10.0	3.0	14.5
1000	-10.0	3.0	14.5
1500	-14.0	-1.0	12.0
2000	-15.0	-2.0	10.0
2500	-15.5	-2.5	10.0
3000	-17.5	-4.5	7.5
3500	-17.5	-4.5	7.5
4000	-18.5	-5.5	6.5
4500	-22.0	-9.0	2.0
5000	-27.5	-14.5	0.0
5500	-31.0	-18.0	-4.0
6000	-31.0	-18.0	-4.0

8 Remote API

SDR driver implements the `trx` remote API.

Message definition:

`command` Optional string. Can be:

- clock_tune

Exemple:

```
{
    "message": "trx",
    "command": "clock_tune"
}
```

Here are the additional request and response field depending on `command` value:

8.1 clock_tune

Request fields:

`offset` Optional number. If `command` is `clock_tune`, defines the clock drift to set in ppm.

9 Change history

9.1 Version 2025-06-13

- Added `rx_chan_mapping` configuration parameter

9.2 Version 2024-06-14

- Added remote API support

9.3 Version 2023-09-08

- Added NUMA support

9.4 Version 2023-06-10

- Added tdd_tx_mod configuration parameter
- New FPGA firmmware version 2023-05-24

10 License