OpenBTS for dummies

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Abstract

This document is to be seen as a guideline or a collection of notes for newbies to OpenBTS who struggle to get it working, or are lost in the wiki pages and wonder where to start.

Mostly, I detail here how I got it to work on my side, from step to step, with answers I found to a few issues I faced or my understanding of the problem.

I am very (very) far from being an OpenBTS expert. So, please feel free to send in corrections, and also understand that I am probably unable to help you on your specific OpenBTS issues :(If you need some more help, your best choice is certainly to read (and read again) the OpenBTS wiki [Ran], the user manual [**?**] and to subscribe to the mailing-list [opef].

Contents

1 What is OpenBTS? (brief)

Litteraly, OpenBTS is an *open Base Transceiver Station*, where a BTS is the telecom equipment the closesest to the mobile phone. See the nice GSM network diagram in [Ale09].

On an end-user point of view, with OpenBTS, GSM phones can call each other, send SMS to each other etc. From an inner perspective, OpenBTS's Wikipedia page [opec] explains it quite well:

> *"OpenBTS replaces the traditional GSM operator network switching subsystem infrastructure, from the Base Transceiver Station (BTS) upwards. Instead of forwarding call traffic through to an operator's mobile switching centre (MSC) the calls are terminated on the same box by forwarding the data onto the Asterisk PBX via SIP and Voice-over-IP (VoIP)."*

From an administrator's point of view, OpenBTS consists of a Universal Software Radio Peripheral (USRP) board, connected on a USB port of a Linux box running Asterisk, GnuRadio and OpenBTS.

2 Want to skip to configuration of OpenBTS? Get a Development Kit

As the rest of this document will show, setting up an OpenBTS takes some time. You have to

1. get the right hardware components
2. hunt for an appropriate 52Mhz clock
3. sweat on some fine soldering
4. compile multiple libraries and possibly fix numerous dependencies...
5. patch the software and configure to match your needs and setup
6. etc

If you don't have that time or skills but have a budget around 5,000 USD, you should probably consider to purchase Range Network's development kit (`http://www.rangenetworks.com/store`). It comes with an appropriate clock, daugtherboards, a pre-configured release of OpenBTS etc.

3 Hardware

3.1 Requirements

This is what you need to get OpenBTS up and running. Prices are approximate.

- **Computer**. Basically, any computer should do the work. The only thing which is really required is a USB port to plug the USRP board, but all computers usually have that...
- **USRP 1**. This board (see Figure 3) can be purchased from Ettus Research (`https://www.ettus.com/product/details/USRP-PKG`) for 700 USD. It includes an Altera Cyclone FPGA. OpenBTS also works with other boards such as USRP2, B100, N200, E100... See the wiki [Ran].

Figure 1: SIM Max card

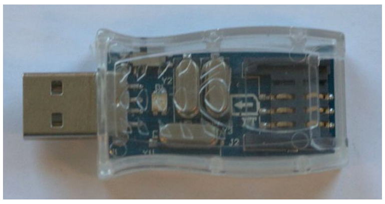


Figure 2: SIM card reader/writer

- **Daughterboard(s)**. I use a single daughterboard, but for coverage and quality of signals, it is better to use 2 daughterboards. Select the daughterboard you need according to the GSM band you want to use. RFX 900 for GSM 850/900, RFX 1800 for GSM 1800/1900. Price from Ettus: 275 USD (`https://www.ettus.com/product/details/RFX1800`) Actually, you might consider buying a RFX1800 in all cases, because it is easy to change a RFX1800 into a RFX900 (firmware flash - no hardware modification) whereas changing a RFX900 into a RFX1800 requires a hardware modication (removing an ISM filter).
- **Antenna**. 1 antenna per daughterboard. Be sure to select an antenna that matches your daughterboard. Can be purchased from Ettus for 35 USD.
- **52 Mhz clock**. Most of the time, this is required but check out Section 3.4 for more information.
- **Mobile phones**. Obviously you need one at least. It must be *unlocked*. And you need to be able to manually select a network for that phone (see Figure 12).
- **SIM cards**. ... and of course, one SIM card per mobile phone. It is possible to use a standard SIM card - the one you use in your own mobile phone[1], or you can buy a programmable SIM card (see Figure 1). Search for something like Super SIM, SIM MAX, Magic SIM, 12in1 or 16in1 SIM on the web. For each SIM card, you need to know its IMSI (section 7.1 explains how to get it). On eBay, such SIM cards are sold for approximately 1 USD.
- **Magic SIM card reader/writer**. If you use Magic SIM cards, you need to card reader and writer to program the SIM card (see Figure 2). This usually costs only a few bucks.

3.2 My personal configuration

My personal configuration is listed at Table 1.

3.3 From the USRP kit to the USRP - newbies only

The USRP usually ships in a ”kit”, but it is very easy to mount. Just need a screwdriver. You can do it, even if you are a hardware dummy :)

1. screw the mainboard onto the black enclosure

[1] no, it won’t ruin it. But backup your SIM contacts and SMS.

Type	**Specifications**
Computer	Dell Optiplex 170L, with a 2.4 Ghz processor and 1 Go RAM
USRP	USRP 1 Rev 4.5 board - bought from `www.ettus.com`
Daughterboard	1 RFX 1800, 1.5-2.1 GHz Transceiver, 100+mW output.
Antenna	VERT 900, 824-960 MHz, 1710-1990 MHz Quad-band Cellular/PCS and ISM Band Vertical Antenna, 3dBi Gain, 9 Inches, Works with WBX, RFX900, RFX1800
Clock	TXCO 52.00Mhz, frequency stability: ± 1 (max) ppm, aging 1 (max) ppm, operational temperature; -20 to 70 °C. Costs approximately 13 USD
SIM Card Reader/Writer	12in1 SIM Card USB Card Reader/Writer Copier Cloner GSM. Bought from `www.1powershop.com` for approximately 14 USD
2 Mobile phones	Nokia 6680 and Nokia N95

Table 1: Hardware specifications

2. on the mainboard, screw the special screws which make sure the daughterboards are elevated just right above the mainboard
3. connect the RFX daughterboard. If a single board, make sure to connect it on side A (notice the words RXA and TXA) on the right of the board when you are facing the USRP.
4. install and connect the ventilator to the motherboard
5. screw the RF cables on the daughterboard and have them go to the enclosure's front panel.
6. screw the antenna to the RF cable that matches TX/RX of the daughterboard. The other RF cable is unused in my case
7. close the enclosure (actually, I suggest to leave it open to be able to check everything is connected fine)
8. use the USB cable to connect the USRP to your computer
9. connect the power supply cable to power

Have a look at Ettus's web site to see what the USRP looks like in the end (Figure 3).

3.4 Clocks

3.5 Do I really need another clock?

The USRP board ships with a 64Mhz clock, but [opee] explains why it is insufficient in most situations. From an end-user perspective, basically, the risk is that the phones will be unable to see the OpenBTS network... So, basically, you need to buy a very good quality TCXO 52Mhz clock and modify your USRP to use it.

The stability of the clock's frequency is particularly important, and it is amplified with bands, because, for instance, an error of 0.05ppm corresponds to 45Mhz for low bands (800-900Mhz) but to 90Mhz for high bands (1800-1900Mhz). For proper use with OpenBTS, people **recommend a stability of 0.05 ppm[2],** or at least better than 0.1ppm. A clock with a stability of 1ppm might be suitable (especially in lower bands)... it's a matter of luck?

[2] ppm stands for ”parts per million”

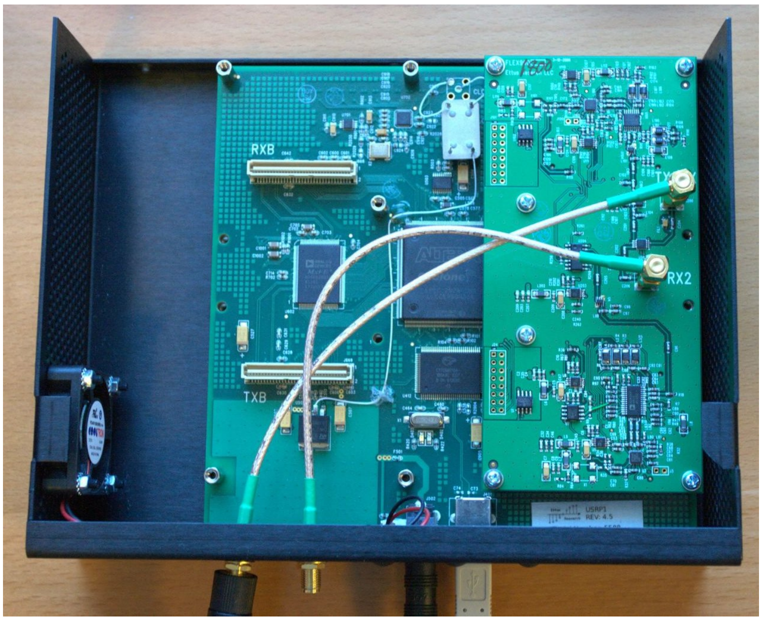


Figure 3: USRP 1 Rev 4.5 with additional 52Mhz clock

A clock with a stability of 50ppm, like the original USRP1 clock [Com] is nearly sure not to be. Actually, unless you are using RFX900 and are *very lucky*, you will require a better clock than the standard one that ships with the USRP board. There has been so many problems with the stock 64Mhz clock that the maintainers have chosen to soon discontinue support for those clocks.

You need a 52Mhz clock, or ”you’re on your own” (i.e don’t expect any help from the maintainers or the mailing list).

3.6 52Mhz clocks

The possible solutions are:

- at one time, Kestrel Signal Processing (`http://kestrelsignalprocessing.mybigcommerce.com/categories/OpenBTS-Hardware/`) used to sell a clock for 150 USD. It’s now out of stock.
- FairWave’s Clock Tamer (`http://shop.fairwaves.ru/clock-tamer`) has a clock for 240 USD. It was sold out, re-approvisioned, and now again out of stock (should be back in stock in Febrary 2013). The long-term stability is 0.28ppm, but as the clock can be re-calibrated, usually people use it for a couple of months and then re-calibrate to keep the accuracy in the ≤ 0.01ppm.
- FA-SY1 [Gra10] (`http://www.box73.de/product_info.php?products_id=1869`) can be bought for 39.5 euros. The price is attractive but the voltage output is too high: the distribution chip AD9513 only copes up to 2V max, so here with a voltage output of 3.3V it is too high. As such, there are strong risks to damage the USRP [ope12], unless you are using an *old* USRP board which supports 3.3V. See the mailing-list [opef] for several threads on the matter.
- FA-SY2 (`http://www.box73.de/product_info.php?products_id=1870`) can be bought for 45.50 euros, and Konrad Meier reported he used it successfully.

Name	Frequency	Frequency stability	Frequency tolerance	Aging	Temperature	Voltage Output level	Approx. price
What we need	52 Mhz	good: 0.05 ppm, **at most 0.1 ppm**				≤ **2V**	
Original clock on USRP1 - Ecliptek XX017	64.00 Mhz						
ClockTamer 1.2	3.75-1137 Mhz	0.28 ppm					240 USD
FA-SY 1	10-160 Mhz		+/- 20 ppm		-40° to +85°C	3.3 V	39.50 euros
FA-SY 2	10-215 Mhz					0.7 V	45.50 euros
KT1612 TCXO	16-52MHz	+/-0.5 ppm			-30° to +85°C	0.8V	
KT2520-P52-ECW24TA	13-52 Mhz	0.5 ppm		+/- 1 ppm	-30° to +85°C	0.8V	2.54 euros
Andy Fung's custom chip	52 Mhz	+/- 1ppm		1 ppm max	-20° to +70°C		13 USD

Table 2: Clocks for USRP 1

- KT2520P52ECW24TA from `fr.mouser.com` ic cheap, and has been reported to work with OpenBTS. Its stability frequency is 0.5ppm, which is a bit too much, but may work.
- KT1612 has been announced [Kyo12] but isn't in sold yet?
- I actually used ***another*** solution: a chip bought by Andy Fung for approximately 13 USD in China. It looks like it is a TCXO from Shenzhen Jiexing Weiye Electronics, but I am actually unsure. Itsspecifications are listed at Table 1 and the description at Figure 4. Please note however that this component might not work in your case because, according to Alexander Chemeris:

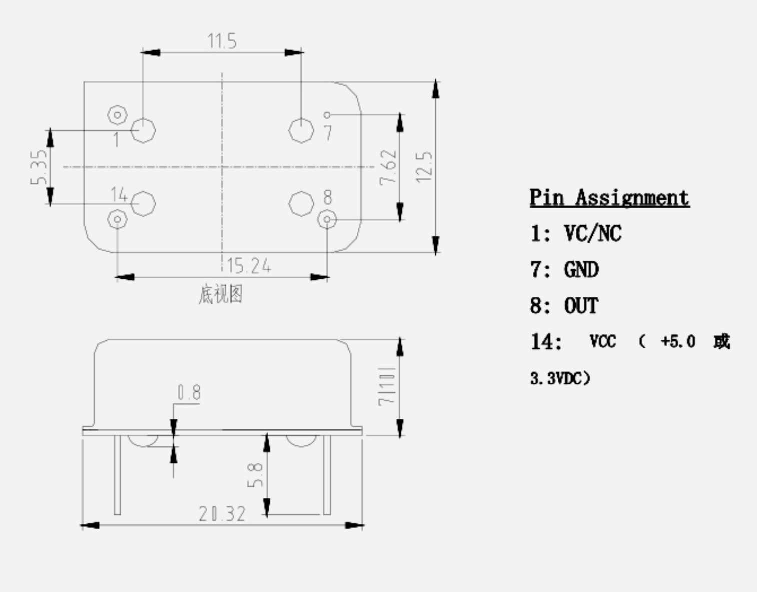
  > *"Usually oscillators with 1 ppm staibility is a kind of lottery, because frequency offset may easily become too high for many phones to find your network."*

- Use a clock generator in your lab...

Table 2 summarizes each option.

3.7 Installing the clock

Mounting a new 52Mhz clock on an USRP requires a few skills in electronics. If you do not have the proper equipment (soldering station etc) and skills (some components are very small), try and get it done by someone



Pin Assignment
1: VC/NC
7: GND
8: OUT
14: VCC (+5.0 或 3.3VDC)

Figure 4: 52 Mhz clock oscillator specifications

else.

The steps to install a new clock are the following. The labels R2039 etc are written on the USRP's board: check where all components are before starting.

- Prepare the USRP to use an external clock [oped]
  - (Difficult step). Move R2029 to R2030T. This disables the onboard clock. R2029/R2030 is a 0-ohm resistor.
  - (Difficult step). Move C925 to C926
  - Remove C924

  NB. I did not need a SMA connector in J2001 nor J2002.
- Connect the new 52Mhz clock: this step is specific to the clock I chose
  - Glue the 52MHz Crystal Oscillator on the USRP mainboard.
  - Solder the red wire (Vcc) and connected it to the 3.3V power source.
  - Solder the black wire (ground) and connected it to the ground point. For example, choose one of the ground pin of J2002.
  - Solder the white wire (52MHz) and connected it the C927.

Note 1. When you solder the wires, make sure the wires are not touching the shell of the crystal (it is a metal case); otherwise, you may create a short circuit.

Note2. The legs of the crystal chip are long. Might need to cut 2/3 out of the legs.

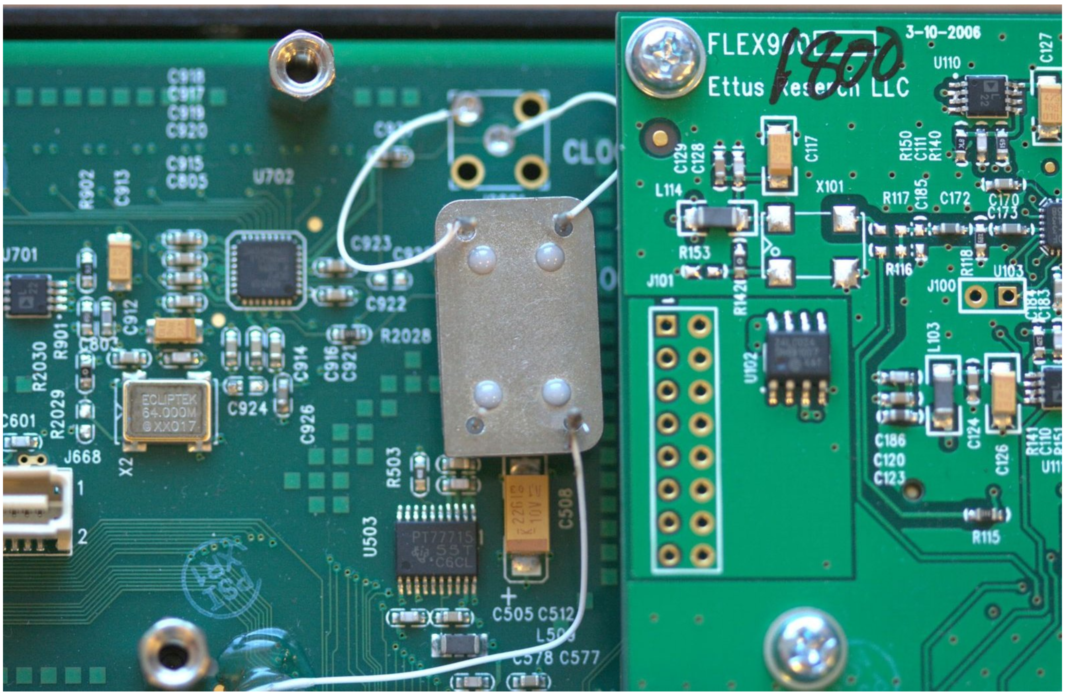


Figure 5: Close shot of the 52 Mhz clock on the USRP

3.8 Software patches

Using a 52Mhz requires a few modification of GnuRadio and OpenBTS software and configuration file. I will detail those later (see Section 9.1 and 9.2) but keep this in mind !

4 Software

The major components you need for OpenBTS are:

- a Linux operating system. It might be portable to other Unix systems (haven't tried). An Ubuntu or a Debian is typically a good choice.
- GnuRadio
- a SIP PBX such as Asterisk
- OpenBTS

4.1 OpenBTS 2.8

The documentation is online [BTS] (and probably kept up to date more than this doc ;). Note that source code of OpenBTS 2.8 also ships with a user manual (in ./doc) [?].

4.1.1 Building

Basically, the steps are:

1. Download OpenBTS from the source repository

   ```
   svn co http://wush.net/svn/range/software/public
   ```

2. Download and install requirements. [BTS] mentions:

   ```
   sudo apt-get install autoconf libtool libosip2-dev libortp-dev
   libusb-1.0-0-dev g++ sqlite3 libsqlite3-dev erlang
   libreadline6-dev libboost-all-dev
   ```

   In my case, I also had to add:

   ```
   sudo apt-get install sdcc libaudio-dev sqliteman asterisk
   ```

3. Compile GnuRadio. Unfortunately the documentation reflects the procedure for newer versions, whereas, for USRP1, we need to use a version between 3.3.0 and before 3.5.0. I managed to compile with:

   ```
   ./configure --enable-usrp --disable-usrp2 --disable-volk
   make
   make install
   ```

   Note that in my case I have a USRP1, not USRP2, and volk has issues on 64-bit systems so I disabled it.

4. Compile OpenBTS as indicated online [BTS]. As I am using USRP1 with a single daughterboard, I need to specify it:

   ```
   autoreconf -i
   ./configure --with-usrp1 --with-singledb
   make
   ```

   For 2.6 users, you'll notice the OpenBTS repository now comprises several components in addition to the OpenBTS core such as smqueue, a subscriber registry, a client interface for OpenBTS.

5. As stipulated in [BTS], copy the sample SQlite databases to /etc/OpenBTS (for example). There are a few other things to do such as:

   - link to the correct transceiver in OpenBTS and std_inband.rbf (see [BTS])
   - create a directory named /var/run/OpenBTS

Table 3 lists my personal configuration.

4.2 OpenBTS 2.6

My old software config for OpenBTS 2.6 is listed at Table 4

Software	Version
Asterisk	1.8.10.1
BOOST	1.48.0.2
GnuRadio	3.42
kal	0.4.1
libaudio-dev	1.9.3
libosip2-dev	3.3.0
OpenBTS	2.8 from the source repository
OS	Xubuntu
SDCC	2.9.0

Table 3: My own software configuration for OpenBTS 2.8

Software	Version
Asterisk	1.4.21
BOOST	1.44.0
GnuRadio	3.2.2
GSL	1.14
kal	0.3
libosip2	3.3.0
OpenBTS	2.6.x - built from sources
OS	Debian 5.0 Lenny
SDCC	2.9.0

Table 4: My own software configuration for OpenBTS 2.6

4.2.1 Compiling GnuRadio

I use GnuRadio 3.2.2 which is compatible with OpenBTS 2.5.4 Lacassine and OpenBTS 2.6.0 Mamou. But you may wish to build the newer GnuRadio 3.3 (not supported by OpenBTS 2.5.4 Lacassine). The compiling procedure is the same anyway.

1. Install Boost: download from sourceforge

```
./bootstrap.sh --show-libraries
./bootstrap.sh --with-libraries=thread,date_time,program_options
./bjam --prefix=/opt/boost_1_44_0
       builds locally in:
       /home/work/boost_1_44_0
       /home/work/boost_1_44_0/stage/lib
./bjam --prefix=/opt/boost_1_44_0 install
```

2. Install SDCC from sources. Beware the installation procedure overwrites in `/usr/local/bin` and share, so backup things you might need in there.

3. Install GSL from sources. Do not use the `gsl-bin` package.

4. Install other required packages:

   ```
   apt-get install python-numpy \
   python-qt4  libqwt5-qt4-dev qt4-dev-tools \
   python-qwt3d-qt4 \
   libqwtplot3d-qt4-dev python-qt4-dev \
   libxt-dev libaudio-dev libpng-dev \
   libxi-dev libxrender-dev libxrandr-dev \
   libfreetype6-dev libfontconfig-dev \
   python-lxml python-cheetah oss-compat \
   swig g++ automake1.9 libtool libusb-dev \
   libsdl1.2-dev python-wxgtk2.8 guile-1.8-dev \
   libqt4-dev python-opengl fftw3-dev
   ```

5. Install GnuRadio 3.2.2:

   - download the sources
   - if you are using a 52Mhz clock, there are two patches to apply. The most important one is detailed in section 9.1 or [oped]. Additionally, you should patch the usrp_fft tool (included in GnuRadio) to add a new command line option to set the clock's frequency. See section 9.2.
   - set your library path to:

     ```
     export LD_LIBRARY_PATH=/opt/boost_1_44_0/lib:\
     /usr/local/lib:$LD_LIBRARY_PATH
     ```

   - configure specifying to use boost.

     ```
     ./configure --with-boost=/opt/boost_1_44_0
     ```

     It is possible to specify only the components you really need to build. Actually, this is what I tried initially, but, in the end, I think it is a bad idea because you always end up using a component you hadn't expected to and need to recompile it later. Your choice, but you have been warned.

     ```
     ./configure --with-boost=/opt/boost_1_44_0 \
     --disable-all-components --enable-usrp  \
     --enable-omnithread --enable-mblock  \
     --enable-pmt --enable-gnuradio-examples \
     --enable-docs --enable-doxygen \
     --enable-gnuradio-core --enable-gr-wxgui  \
     --enable-gruel --enable-gr-utils \
     --enable-gr-usrp --enable-gr-qtgui
     ```

   - make and then make install (if you specified a system directory, make install must be done from root)
   - ldconfig

6. Add a USRP group and assign user to that group:

   ```
   addgroup usrp
   addgroup work usrp
   ```

7. Write USRP rules file: /etc/udev/rules.d/10-usrp.rules [Ale09][3]:

   ```
   ACTION=="add", BUS=="usb", SYSFS{idVendor}=="fffe",
   SYSFS{idProduct}=="0002", GROUP:="usrp", MODE:="0660"
   ```

Once you have completed those steps successfully, it is a good idea to test your USRP to see if everything is working as expected (see section 6).

4.2.2 Compiling OpenBTS

To compile OpenBTS, follow those steps:

1. install libosip2-3.3.0 from sources. If you do not intend to use smqueue (SMS), you can install the Debian package libosip2-dev. But if you need smqueue, you'll have to recompile a newer version.
2. install other requirements:

   ```
   apt-get install libortp7-* asterisk
   ```

   For OpenBTS 2.8, you also need libusb-1.0.

   ```
   apt-get install libusb-1.0-0-dev
   ```

   or compile from sources.
3. you might have to link boost to local include:

   ```
   ln -s /opt/boost_1_44_0/include/boost /usr/local/include/boost
   ```

4. set your library path to:

   ```
   export LD_LIBRARY_PATH=/opt/boost_1_44_0/lib: \
   /usr/local/lib:$LD_LIBRARY_PATH
   ```

5. **Patching for old sources only** (this is no longer required for current downloads): if you are using a RFX1800 daughterboard (not RFX 900) you must patch the sources. See section 9.3 (recent snapshots from the git repository do not need this). If you are using a 64Mhz clock (stock), patch Transceiver/USRPDevice files. If you are using 52Mhz clock, patch Transceiver52M/USRPDevice files.
6. On OpenBTS 2.6.x, if you are using a single daughterboard, you must apply yet another patch. Make sure your daughterboard in on side A. See section 9.4.
   Again, if you are using a 64Mhz, patch the Transceiver/USRPDevice files. If you are using 52Mhz clock, patch Transceiver52M/USRPDevice files.
   On OpenBTS 2.8, no need to patch, but you must specify you are using a single daughterboard when compiling (see later).
7. download the sources. Do not download the OpenBTS package openbts-2.6.0Mamou.tar.gz as it is already obsolete. On the contrary, get the sources from git:

[3] I'm not absolutely certain this is required.

```
git clone git://openbts.git.sourceforge.net/gitroot/openbts/openbts
```

If you want to use the achemeris/sms-split branch, then do:

```
$ git branch -a
$ git checkout origin/achemeris/sms-split
```

OpenBTS-UHD is also a good choice, because it has a single branch where all work is merged:

```
$ git clone git://github.com/ttsou/openbts-uhd.git
```

For OpenBTS 2.8, get the sources from:

```
svn co http://wush.net/svn/range/software/public
```

8. build OpenBTS. Do:

```
$ autoreconf -fi
$ ./configure
$ make
```

For OpenBTS-UHD, do `./configure --enable-usrp1` instead of just `./configure`.

For OpenBTS 2.8, if you are using a single daughterboard (on side A), don't forget to specify it:

```
./configure --with-usrp1 --with-singledb
make
```

4.2.3 Compiling smqueue

To have mobile phones in your network send SMS to each other, `smqueue` (included in OpenBTS) must be running.

In the main branch, smqueue is included in the OpenBTS package, but it is not compiled when you build OpenBTS. You must manually invoke smqueue's Makefile:

```
cd ./smqueue
make -f Makefile.standalone
```

Building smqueue requires libosip2 version 3.3.0 or greater. Install it or it will fail to build. Also, you might need g++ v4.3.

In the achemeris/sms-split branch, smque is automatically compiled when OpenBTS is.

KEYSTRING	VALUESTRING	Module	Comment
GSM.Radio.Band	1800	openbts	This is the GSM band
GSM.Radio.C0	880	openbts	This is the ARFCN channel
Control.LUR.OpenRegistration	.*	openbts	Do this to enable open registration for any IMSI. The value string corresponds to a regexp of IMSIs to accept

Table 5: My personal configuration

5 Configuration

5.1 Basic steps

The configuration of OpenBTS mainly consists on the following parameters:

- setting the GSM band
- setting the ARFCN channel for this band
- configuring registration of subscribers
- configuring logs (if required)

With OpenBTS 2.6 those parameters typically go into configuration files (editable with any text editor), whereas in 2.8 they have been moved to SQLite databases (editable with standard SQLite tools: sqlite3, or GUIs such as sqliteman, or via the OpenBTS client interface OpenBTSCLI).

5.2 Configuring 2.8

Some of these changes can be dynamically taken into account. Others requires the corresponding daemon to be restarted. The OpenBTS client interface usually warns when this is the case.

Example of configuration modification:

```
# sqlite3 OpenBTS.db
UPDATE CONFIG SET VALUESTRING='1800' WHERE KEYSTRING='GSM.Radio.Band';
```

In the OpenBTS client interface, configuration can be done using the 'config' command:

```
config GSM.Radio.Band 1800
```

In OpenBTS 2.8, logs are re-directed to the syslogd daemon on the local7 facility. So, you have to configure syslog appropriately. For instance, on Ubuntu, in /etc/rsyslog.d/OpenBTS.conf, we tell the system to write all local7 facility logs to file /var/log/OpenBTS.log:

```
local7.* /var/log/OpenBTS.log
```

Then, restart the syslog daemon:

```
$ sudo service rsyslog restart
```

Then, the log level of each file can be configured such as:

```
Log.Level.CallControl.cpp INFO
Log.Level.SMSControl.cpp INFO
Log.Level.RadioResource.cpp DEBUG
Log.Level.GSML2LAPDm.cpp INFO
Log.Level.MobilityManagement.cpp DEBUG
Log.Level.SubscriberRegistryp.cpp INFO
Log.Level.SIPEngine.cpp DEBUG
```

5.3 Configuring 2.6

The OpenBTS configuration file is located in the ./apps directory: openbts.config. See also [Ale09].

Use the default configuration file with the following customization:

- There are two log files (`Log.FileName`) for global logging and for TRX logging. For TRX logging, beware that setting the level to `DEBUG` will cause very heavy logging !

  ```
  Log.Level INFO
  Log.FileName openbts26.log
  $static Log.FileName
  ..
  TRX.LogLevel INFO
  $static TRX.LogLevel
  TRX.LogFileName TRX26.log
  $static TRX.LogFileName
  ```

- If you are using a 52Mhz, modify the TRX path to **../Transceiver52M/transceiver**

  ```
  #TRX.Path ../Transceiver/transceiver
  TRX.Path ../Transceiver52M/transceiver
  $static TRX.Path
  ```

- Open registration (for a first test)

  ```
  Control.OpenRegistration
  $optional Control.OpenRegistration
  ```

  but then, it probably better not to leave it as such, because this allows any phone to register to your system. Caleb Pal remarks that *"this could introduce legal issues, someone tries to dial the emergency number, can't connect, etc."*

- Set the mobile country code and network code in OpenBTS. You should be particularly cautious not to use anything a real operator is already using. Country codes are listed at [WMC]. Network codes are listed at [WMN].

```
# 001 = test country code
GSM.MCC 001
# 01 = test code
GSM.MNC 01
```

The MCC and MNC need not match the ones of your SIMs/MagicSIMs (but if you set your MagicSIM to a particular unused MCC/MNC, then it's obviously a good idea to configure the same MCC/MNC in OpenBTS config).

- Set the GSM band and channel. You do not need to set the uplink or downlink frequency.

```
GSM.Band 1800
$static GSM.Band
GSM.ARFCN 880
$static GSM.ARFCN
```

- Notify end-users you do not support emergency calls:

```
GSM.RACH.AC 0x400
...
Control.NormalRegistrationWelcomeMessage Normal Registration Message.
Welcome to OpenBTS! AGPLv3 openbts.sf.net. We do not support
emergency calls. Your IMSI is
```

5.3.1 smqueue

Disable ipv6 for smqueue not to complain about binding to the address.

Configuration of smqueue is located in `./smqueue/smqueue.config`. The default configuration is usually okay except for:

- add `Log.Alarms.Max 10`.otherwise smqueue crashes in some circumstances such as sending a registration SMS.
- create a savedqueue.txt in the `./smqueue` directory.
- run smqueue as **root**. Indeed, smqueue launches asterisk, and tries to read files such as `/etc/asterisk/sip.conf` which are usually only accessible to root.

5.4 Asterisk configuration

See also [Ale09]. You need to set two files: `/etc/asterisk/extensions.conf` and `/etc/asterisk/sip.conf`.

Basically, at the end of extensions.conf, add one extension per mobile phone you want to add to your network:

```
[sip-local]
exten => 2102,1,Macro(dialSIP,IMSI208123456789012)
exten => 2103,1,Macro(dialSIP,IMSI208555555555555)
```

The numbers 2102 and 2103 are the phone numbers: to call the first mobile phone, dial 2102. To call the second phone number, dial 2103. Of course, you can change the number !

The tag IMSI208123456789012 is like a name for your SIM card. It must match the tag specified in `sip.conf`.

In sip.conf, add one tag per SIM card:

```
[IMSI208123456789012] ; Axelle SIM card IMSI
canreinvite=no
type=friend
context=sip-external
allow=gsm
host=dynamic
```

The tag acts as a section name. You can change it, as long as you use the same name across `sip.conf` and `extensions.conf`.

6 Testing GnuRadio

6.1 USRP Benchmark

Connect the USRP to the computer, compile GnuRadio and then:

```
$ export LD_LIBRARY_PATH=/opt/boost_1_44_0/lib: \
  /usr/local/lib:$LD_LIBRARY_PATH
$ cd /usr/local/share/gnuradio/examples/usrp
$ ./usrp_benchmark_usb.py
```

The script tests USB throughput. You should see several OKs. See [Ale09] for an example.

6.2 USRP FFT

The usrp_fft tool (in GnuRadio) is useful to test the USRP responds correctly, and also to check whether a given frequency is used or not.

```
$ export LD_LIBRARY_PATH=/opt/boost_1_44_0/lib: \
/usr/local/lib:$LD_LIBRARY_PATH
$ /usr/local/bin/usrp_fft.py
```

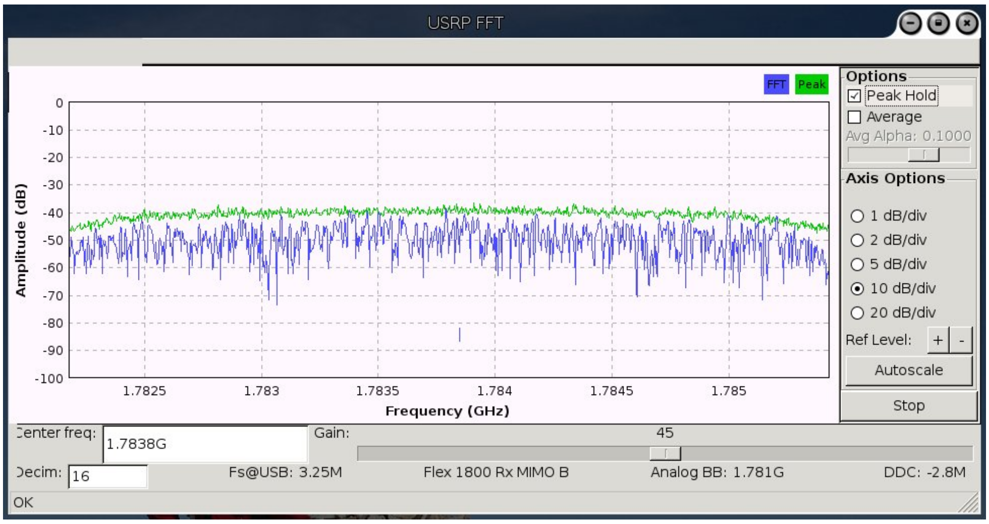
Let's see how to check if a given channel is available. First, we need to pick up an available channel for GSM 1800.

[Aub] provides a GSM 1800 uplink and downlink table. For example, if we select channel 880, this correspond to uplink frequency 1783.8 Mhz and downlink frequency 1878.8 Mhz. To use this channel, we need to check those frequencies are not used by someone else. Launch usrp_fft.py as root (and make sure OpenBTS is not running).

```
# usrp_fft.py -f 1.7838G &
```

You should get a relatively ”flat” curve such as Figure 6 if the frequency is not used. If it is, pick up another channel.

To test the USRP responds correctly, simulate use of the uplink and downlink frequencies:



Options
☑ Peak Hold
□ Average
Avg Alpha: 0.1000

Axis Options
○ 1 dB/div
○ 2 dB/div
○ 5 dB/div
● 10 dB/div
○ 20 dB/div

Center freq: 1.7838G
Gain: 45
Decim: 16
Fs@USB: 3.25M
Flex 1800 Rx MIMO B
Analog BB: 1.781G
DDC: -2.8M
OK

Figure 6: Frequency 1783.8 Mhz is not used

```
# usrp_siggen.py -f 1783.8M
Using TX d'board A: Flex 1800 Tx MIMO B
uU
```

Do not bother about the uU, oOs you may see as output. [Ham08] explains their meaning:

> ”a” = audio (sound card) ”O” = overrun (PC not keeping up with received data from usrp or audio card) ”U” = underrun (PC not providing data quickly enough)
>
> aUaU == audio underrun (not enough samples ready to send to sound card sink) uUuU == USRP underrun (not enough sample ready to send to USRP sink) uOuO == USRP overrun (USRP samples dropped because they weren't read in time.

Check you see a peak at the corresponding frequency (as in Figure 7).
Do the same for the downlink frequency.

6.3 Calibrating the clock

Kal is a tool to calibrate the clock. The latest version (v0.4.1 [opeb]) does not work with GnuRadio 3.2, only GnuRadio 3.3, so you must retrieve an older version from the mailing-list [opea].

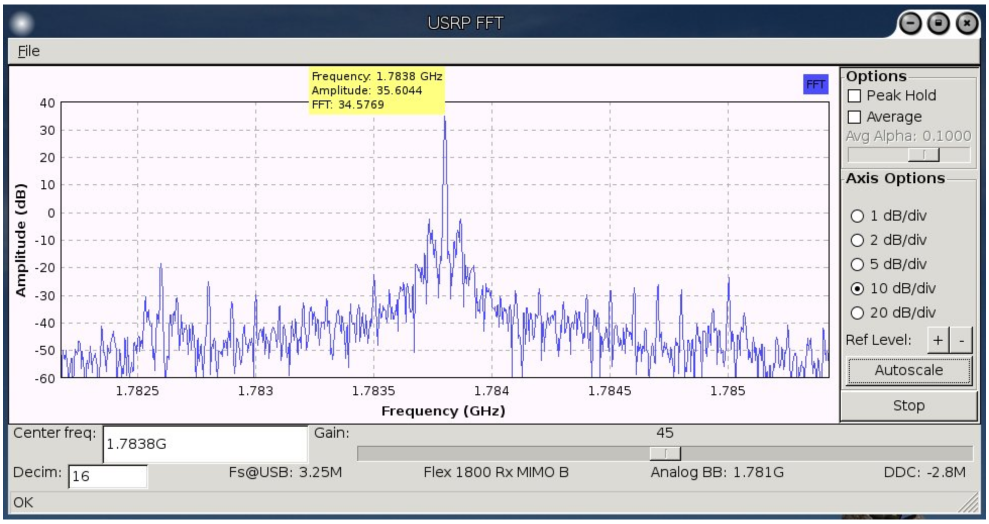
If the clock source is not adjustable, kal will tell you how much your clock is off by, but you will be unable to do anything about it...

6.3.1 Kal v3

To compile kal, install libncurses5-dev:

```
apt-get install libncurses5-dev
```

Then, run kal.



Frequency: 1.7838 GHz
Amplitude: 35.6044
FFT: 34.5769

● 10 dB/div

Center freq: 1.7838G
Gain: 45
Decim: 16
Fs@USB: 3.25M
Flex 1800 Rx MIMO B
Analog BB: 1.781G
DDC: -2.8M
OK

Figure 7: Frequency 1783.8 Mhz is used

```
# ./kal -f 1783800000 -F 52000000 -R A
USRP side: A
FPGA clock: 52000000
Decimation: 192
Antenna: RX2
Sample rate: 270833.343750
error: fcch not detected in 20 frames
```

From Caleb Pal:

> *"The fcch error indicate the power level is too low to detect the FCCH and calculate timing offset. Try using an ARFCN of a commercial tower that has a strong(er) signal in your area."*

6.3.2 Kalibrate v0.4.1

With Kal v0.4.1,

```
$ sudo ./kal -R A -A 0 -v -s DCS
kal: Scanning for DCS-1800 base stations
DCS-1800:
     chan: 647 (1832.2 Mhz + 996kHz)    power: 874.13
```

This means that my clock runs 996kHz faster than a clock of a base station running at ARFCN 647. Then, we can calculate the offsets:

```
$ sudo ./kal -v -c 647 -b DCS
kal: Calculating clock frequency offset.
Using DCS-1800 channel 647 (1832.Mhz)
   offset   1: 964.45
   offset   2: 1143.18
   offset   3: 1091.53
...
```

7 Using OpenBTS

7.1 IMSI

SIM cards are identified by their IMSI.

7.1.1 Get your IMSI

If you already have an operational SIM card and want to use it in OpenBTS, you must retrieve its IMSI. To do so, there are several solutions

- **Python script** in [Ale09]
- Install a **IMSI-retrieving application** on the phone.
  - Symbian v9 and +. Install [opeg]. Beware that application wants to send an application registration SMS. Put the mobile offline if you do not want to send that SMS.
  - Android. Install ”Android Device ID” [**?**]
- **From OpenBTS itself.** Turn off the handset, remove and replace the battery, then try to register. Look at OpenBTS’s logs.
- **AT commands.** Issue the AT+CIMI command.

7.1.2 Set your IMSI

If you are using a Magic SIM, you can program it to use a given IMSI using pySIM [Mun]. Plug the USB card writer and SIM to your computer. Set the following:

- argument x for the mobile country code
- argument y for the mobile network code
- argument d for the USB drive the card writer is connected to
- argument t set to ’auto’ to automatically detect the card’s type

```
./pySim.py -n 26C3 -c 49 -x 001 -y 01
-t auto -z "Random string here" -j 0 -d /dev/ttyUSB0
Generated card parameters :
 > Name    : 26C3
 > SMSP    : 00495...
 > ICCID   : 8949262...
 > MCC/MNC : 001/01
 > IMSI    : 00101111111111111...
 > Ki      : 6ea1ce93440...
```

```
Autodetected card type fakemagicsim
Programming ...
Done !
```

7.2 Running OpenBTS

If you have completed all previous steps, you can now start using OpenBTS. Plug the OpenBTS box. It's better to put it 40cm away (see Section 8.2) however do not lock it too far away ;)

7.2.1 OpenBTS 2.6

Run the OpenBTS daemon and the smqueue messaging queue. Smqueue needs to run as root:

```
./apps/OpenBTS
sudo ./smqueue/smqueue
```

7.2.2 OpenBTS 2.8

There are several daemons to start, *as root*:

- smqueue. handles SMS
- sipauthserve. subscriber registry
- OpenBTS. the main OpenBTS daemon
- OpenBTSCLI. its client interface

I personally like to start all of these in a seperate window:

```
#!/bin/bash

OPENBTS_DIR=YOUR-OPENBTS-PATH

echo "OpenBTS launcher script"

if [ "$(id -u)" != "0"]; then
  echo "This script must be run as root" 1>&2
  exit 1
fi

mkdir -p /var/run/OpenBTS
xterm -n "Smqueue" -e $OPENBTS_DIR/smqueue/trunk/smqueue/smqueue &
xterm -n "SipAuth" -e $OPENBTS_DIR/subscriberRegistry/trunk/sipauthserve &
xterm -n "OpenBTS" -e "cd $OPENBTS_DIR/openbts/trunk/apps/ && ./OpenBTS" &
xterm -n "OpenBTS CLI" -e $OPENBTS_DIR/openbts/trunk/apps/OpenBTSCLI &
```

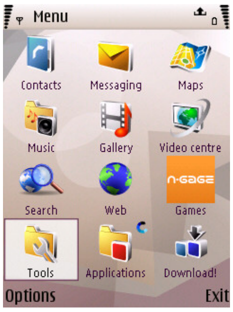


Figure 8: Application menu

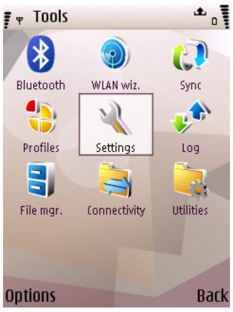


Figure 9: Tools menu

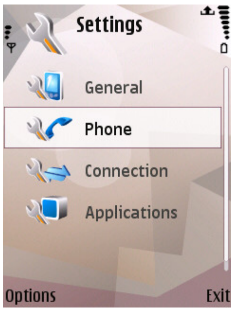


Figure 10: Settings menu

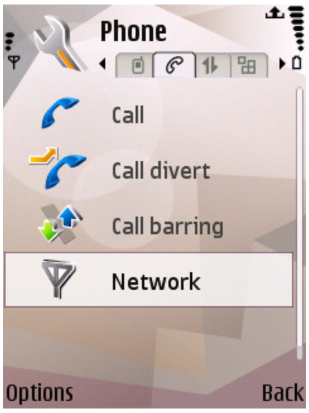
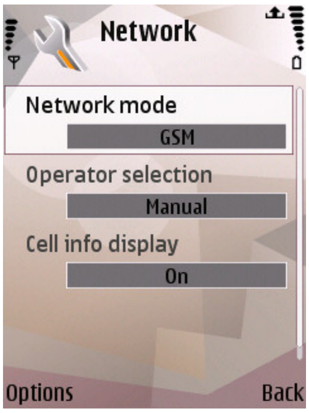


Figure 11: Phone settings



Network mode
GSM

Operator selection
Manual

Cell info display
On

Figure 12: Network settings

7.3 Having phone scan for the OpenBTS network

Power on your mobile phone and force it to use the OpenBTS network:

- **Nokia**. Go to `tools` (Figure 9), `settings` (Figure 10), then `phone` (Figure 11), then `network` (Figure 12). Select GSM only (not dual mode, nor 3G) and select operator manually (not automatically).
- **iPhone**. Go to `Settings`, then `Operator` and manually scan for available operators.
- **Android**.Go to `Settings`, `Wireless and networks`, `Mobile networks`, and then `Operator selection`.
- **Windows Mobile**. Go to `Settings`, then `Phone`, then `Network`, then select manual scan and select OpenBTS.
- For other phones, see [ope09].

Wait for a while, while the phone is scanning available networks. You should see the OpenBTS network popup. Select it.

7.4 Registering to the OpenBTS network

Once you have selected the OpenBTS network, OpenBTS will register your phone depending on its configuration.

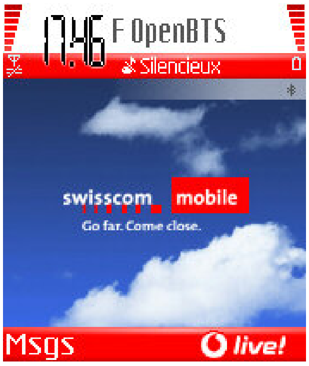
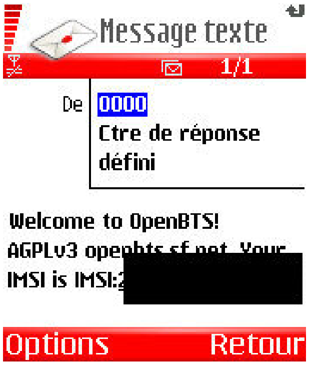


Figure 13: The phone has registered to the OpenBTS network



Message texte

1/1

De 0000

Ctre de réponse défini

Welcome to OpenBTS!
AGPLv3 ope
IMSI is IMSI:[redacted]

Figure 14: Welcome message sent to the phone

With open registration and SMS auto-provisioning, this is what happens (NB. This is only an example and depends on your config):

- Wait, the OpenBTS network should send you a welcome SMS. The exact message depends on the configuration of OpenBTS (openbts.config)

- Send back the phone number you wish to use by SMS to the special registration short number. By default it's 101, but that depends on configuration of course.

  This is what you typically see in the logs: OpenBTS sends an SMS asking you to send your desired phone number by SMS:

  ```
  bounce_message: Bouncing 378--vypfd from IMSI208123456789012 to 2103:
  Cannot determine return address; bouncing message.
  Text your phone number to 101 to register and try again.
  ```

  If that phone number is already in use or if you are already assigned a given phone number, OpenBTS will let you know.

  For example, in the case below, phone with IMSI 208123456789012 was already assigned phone number 2102.

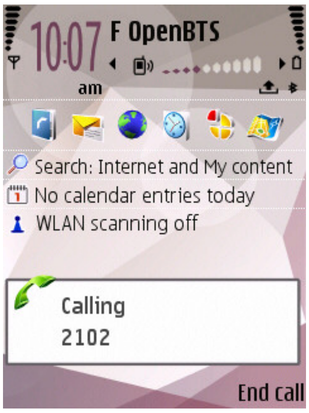
  ```
  Got SMS '273--lnobw' from IMSI208123456789012 for 101.
  Responding with "202 Queued".
  Short-code SMS 101(2102).
  answering "Your phone is already registered as  ."
  ```

- You are ready to use the phones. You can try the echo service (dial 600 - by default), or dial 2102 to call another phone (see Figure 15). You can also get system status by dialing 411 (by default).

7.5 TMSIs

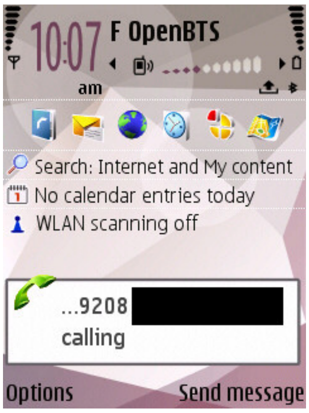
Once phones have registered, you should be able to list the Temporary Mobile Subscriber Identities (TMSI):

The TMSI list is available from the OpenBTS console (which is accessible from the OpenBTSCLI in 2.8 or directly in OpenBTS in 2.6).



10:07 F OpenBTS
am
Search: Internet and My content
No calendar entries today
WLAN scanning off
Calling
2102

Figure 15: The phone is calling another one



10:07 F OpenBTS
am
Search: Internet and My content
No calendar entries today
WLAN scanning off
...9208 [redacted]
calling

Figure 16: The phone is receiving a call

```
OpenBTS> tmsis
TMSI        IMSI               IMEI                age  used
0x4ce547c0 208123456789012                   ?  113h   84s
0x4ce547c1 208111111111111                   ?  113h  113h

2 TMSIs in table
```

If you want phones to re-register, clear the TMSI table.

7.6 Sending SMS

It is possible to send SMS from the OpenBTS console, or have phones send each other SMS messages.

7.6.1 From the console

On OpenBTS 2.8, there is a dedicated console in the client interface, OpenBTSCLI.

In OpenBTS 2.6, the console is directly accessible from the OpenBTS command prompt.

```
OpenBTS> sendsms 208123456789012 24567
blah blah
```

From the OpenBTS 2.6 achemeris/sms-split branch, the sendsms command is enhanced as follows:

```
OpenBTS-achemeris> sendsms 208123456789012 24567 0000
enter text to send: Hello from console
message submitted for delivery
```

where:

- 208123456789012 is the IMSI of the phone to send the SMS to
- 24567 is the source phone number (does not need to exist – unless you expect an answer!)
- 0000 is the number of the SMSC (not sure this is used yet)

7.6.2 SMS PDU

In OpenBTS 2.6 achemeris/sms-split branch, it is possible to send an SMS PDU:

```
OpenBTS-achemeris> sendsmsrpdu 208304424439206 24567
enter text to send: 014603a1000000138003a121f30000117042711404e104d4f29c0e
message submitted for delivery
```

This sends an SMS to IMSI 208304424439206, from 24567, with text ”Test”.

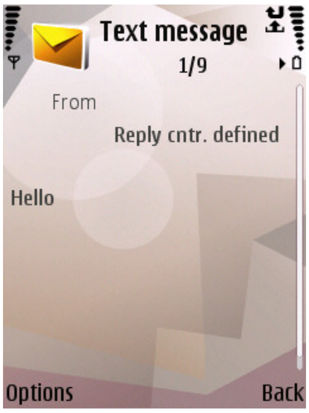
7.6.3 SMS from one phone to another

Of course, the phones must be registered and be assigned a phone number. Also, be sure to have the smqueue daemon running and watch the logs.

For example, below 2102 is sending a SMS to 2103.

```
Got SMS ’48--keagw’ from IMSI208123456789012 for 2103.
Responding with "202 Queued".
75 seconds til Request Destination SIP URL for 48--keagw
Got SMS 200 Response ’48--keagw’.
Got 200 response for sent msg ’48--keagw’ in state 7
Deleting sent message.
```

and the SMS should appear on 2103 phone.



From

Reply cntr. defined

Hello

Figure 17: The phone received an SMS

7.7 Sniffing GSM packets

1. In OpenBTS.config:
2. Re-compile and install a recent version of Wireshark (e.g 1.4.2) on the capture host.

8 Miscellaneous

8.1 Legal restrictions

Disclaimer: I am absolutely not an expert in this area, please check for yourselves.

Authorities usually regulate the use of some GSM bandwidths. You should check in your country what is authorized, if you need a test license or must use a given channel etc.

In France, the use of GSM bandwidths is regulated by the ARCEP. For limited internal test cases, the use of GSM frequencies is allowed [ARC05]:

> ”Les acteurs non soumis à la déclaration [..] des exploitants de réseaux internes , c'est-à-dire ” entièrement établis sur une même propriété, sans emprunter ni le domaine public y compris hertzien - ni une propriété tierce. ” Ainsi, les réseaux établis par exemple dans les hôtels et les centres commerciaux privés sont exempts de déclaration ;”

Please check for yourselves.

8.2 Health

Disclaimer: I am absolutely not an expert in this area, please check for yourselves.

As far as health is concerned, there are two different limits to understand:

- **RF exposure** guildelines are established by the ICNIRP. For 1800Mhz frequencies, they limit exposure to 0.08 W / kg [IEE98]. In practice, the maximum RF exposure levels of a 1 W antenna are already below ICNIRP limits at less than 10cm [Eri04]. OpenBTS uses a 100mW (so even smaller) antenna, so the RF exposure should even be below.
- **Electromagnetic interferences**. The limit is set to 3 V/m (for non-life supporting equipment such as the OpenBTS). In practice, for a 100mW, this limit is met at 40cm or more. This means that further than 40cm there should be only very little risk that the antenna can cause electromagnetic interference with sensitive equipments such as a pacemaker or hearing aids.

Conclusion: having the OpenBTS at 40cm or more of anybody should be really safe?

9 Patches for OpenBTS 2.6

As far as I know, there are no required patches for OpenBTS 2.8.

Don't know how to patch? Please read the manual for the `patch` command. Usually, you'll end up doing something like this:

```
$ cd openbts-directory
$ patch -p2 < mypatch.diff
```

9.1 52Mhz patch for GnuRadio

This patch is described at [oped]. If you followed the steps in 4.2.1, normally, you should have patched your sources. If not, then you absolutely must do it if you are using a 52Mhz clock.

In usrp/host/lib/legacy/usrp_basic.cc, line 116 should read:

```
d_verbose (false), d_fpga_master_clock_freq(52000000), d_db(2)
```

In usrp/host/lib/legacy/usrp_standard.cc, line 1024 should be commented out:

```
// assert (dac_rate() == 128000000);
```

In usrp/host/lib/legacy/db_flexrf.cc, line 179 should read:

```
return 52e6/_refclk_divisor();
```

9.2 usrp_fft patch for 52Mhz

This patch adds support for 52Mhz clocks for the usrp_fft GnuRadio tool. Once applied, you may specify the -F option to set the clock's frequency (52000000).

```
diff --git a/gr-utils/src/python/usrp_fft.py b/gr-utils/src/python/usrp_fft.py
index eda9bd5..3bf4ec2 100755
--- a/gr-utils/src/python/usrp_fft.py
+++ b/gr-utils/src/python/usrp_fft.py
@@ -61,6 +61,8 @@ class app_top_block(stdgui2.std_top_block):
                           help="select Rx Antenna (only on RFX-series boards)")
         parser.add_option("-d", "--decim", type="int", default=16,
                           help="set fgpa decimation rate to DECIM [default=%default]")
+        parser.add_option("-F", "--fpga-freq", type="eng_float", default=None,
+                          help="set USRP reference clock frequency to FPGA_FREQ",
+                           metavar="FPGA_FREQ")
         parser.add_option("-f", "--freq", type="eng_float", default=None,
                           help="set frequency to FREQ", metavar="FREQ")
         parser.add_option("-g", "--gain", type="eng_float", default=None,
@@ -99,6 +101,9 @@ class app_top_block(stdgui2.std_top_block):
           #contains 2 Rx paths with halfband filters and 2 tx paths (the default)
           self.u = usrp.source_c(which=options.which, decim_rate=options.decim)

+        if options.fpga_freq is not None:
+            self.u.set_fpga_master_clock_freq(long(options.fpga_freq))
+
         if options.rx_subdev_spec is None:
             options.rx_subdev_spec = pick_subdevice(self.u)
         self.u.set_mux(usrp.determine_rx_mux_value(self.u, options.rx_subdev_spec))
```

9.3 GSM 1800 patch

Recent snapshots taken from the OpenBTS git repository do not need this patch any longer.

This patch is to use OpenBTS with RFX 1800 daughterboards. It is *not* required:

- for RFX900 daughterboards
- for recent snapshots of OpenBTS (e.g from the git repository, it works straight away)

Note the patch below modifies the USRPDevice files in the Transceiver directory. If you are using a 52Mhz, this directory is not used, it's the Transceiver52M directory you need to patch.

```
--- Transceiver/USRPDevice.cpp 2010-02-25 10:12:28.000000000 +0100
+++ Transceiver/USRPDevice.cpp 2010-07-08 15:01:00.334544272 +0200
@@ -59,7 +59,14 @@
        unsigned *N,
        double *actual_freq)
 {
-
+  if (freq < 1.2e9) {
+    DIV2 = 1;
+    freq_mult = 2;
+  } else {
+    DIV2 = 0;
+    freq_mult =1;
+  }
+
   float phdet_freq = 64.0e6/R_DIV;
   int desired_n = (int) round(freq*freq_mult/phdet_freq);
   *actual_freq = desired_n * phdet_freq/freq_mult;

--- Transceiver/USRPDevice.h 2010-02-25 10:12:28.000000000 +0100
+++ Transceiver/USRPDevice.h 2010-07-08 14:44:45.870543535 +0200
@@ -126,8 +126,8 @@
   static const unsigned CP2 = 7;
   static const unsigned CP1 = 7;
   static const unsigned DIVSEL = 0;
-  static const unsigned DIV2 = 1;
-  static const unsigned freq_mult = 2;
+  unsigned DIV2;
+  unsigned freq_mult;
   static const unsigned CPGAIN = 0;
   static const float    minFreq = 800e6;
   static const float    maxFreq = 1000e6;
```

9.4 Single daughterboard patch

On OpenBTS 2.6, if you are using the USRP with a single daughterboard, and not two daughterboards, you need to patch OpenBTS to have all work done on the same daughterboard.

Note the patch below modifies the USRPDevice files in the Transceiver directory. If you are using a 52Mhz, this directory is not used, it's the Transceiver52M directory you need to patch.

On OpenBTS 2.8, you don't need any patch to use the USRP with a single daughterboard, but you must specify it at compilation:

```
./configure --with-usrp1 --with-singledb
make
```

```
--- /openbts-2.6.0Mamou/Transceiver52M/USRPDevice.cpp 2010-11-07 02:06:29.643681105 +0100
+++ /singleRFX900_2.6.0Mamou/Transceiver52M/USRPDevice.cpp 2010-11-12 20:11:18.695717220 +0100
@@ -133,17 +133,17 @@
   if (R==0) return false;
   writeLock.lock();
-  m_uRx->_write_spi(0,SPI_ENABLE_RX_B,SPI_FMT_MSB | SPI_FMT_HDR_0,
+  m_uRx->_write_spi(0,SPI_ENABLE_RX_A,SPI_FMT_MSB | SPI_FMT_HDR_0,
      write_it((R & ~0x3) | 1));
-  m_uRx->_write_spi(0,SPI_ENABLE_RX_B,SPI_FMT_MSB | SPI_FMT_HDR_0,
+  m_uRx->_write_spi(0,SPI_ENABLE_RX_A,SPI_FMT_MSB | SPI_FMT_HDR_0,
      write_it((control & ~0x3) | 0));
   usleep(10000);
-  m_uRx->_write_spi(0,SPI_ENABLE_RX_B,SPI_FMT_MSB | SPI_FMT_HDR_0,
+  m_uRx->_write_spi(0,SPI_ENABLE_RX_A,SPI_FMT_MSB | SPI_FMT_HDR_0,
      write_it((N & ~0x3) | 2));
   writeLock.unlock();

-  if (m_uRx->read_io(1) & PLL_LOCK_DETECT)  return true;
-  if (m_uRx->read_io(1) & PLL_LOCK_DETECT)  return true;
+  if (m_uRx->read_io(0) & PLL_LOCK_DETECT)  return true;
+  if (m_uRx->read_io(0) & PLL_LOCK_DETECT)  return true;
   return false;
 }

@@ -249,34 +249,34 @@
   // power up and configure daughterboards
   m_uTx->_write_oe(0,0,0xffff);
   m_uTx->_write_oe(0,(POWER_UP|RX_TXN|ENABLE), 0xffff);
-  m_uTx->write_io(0,(~POWER_UP|RX_TXN),(POWER_UP|RX_TXN|ENABLE));
-  m_uTx->write_io(0,ENABLE,(RX_TXN | ENABLE));
+
+  m_uTx->write_io(0, ENABLE, ENABLE | RX_TXN | POWER_UP); /* power up inverted */
   m_uTx->_write_fpga_reg(FR_ATR_MASK_0 ,0);//RX_TXN|ENABLE);
   m_uTx->_write_fpga_reg(FR_ATR_TXVAL_0,0);//,0 |ENABLE);
   m_uTx->_write_fpga_reg(FR_ATR_RXVAL_0,0);//,RX_TXN|0);
   m_uTx->_write_fpga_reg(40,0);
   m_uTx->_write_fpga_reg(42,0);
-  m_uTx->set_pga(0,m_uTx->pga_max()); // should be 20dB
-  m_uTx->set_pga(1,m_uTx->pga_max());
+  m_uTx->set_pga(0,m_uTx->pga_min()); // should be 20dB
+  m_uTx->set_pga(1,m_uTx->pga_min());
   m_uTx->set_mux(0x00000098);
-  LOG(INFO) << "TX pgas: " << m_uTx->pga(0) << ", " << m_uTx->pga(1);
+
   writeLock.unlock();

   if (!skipRx) {
     writeLock.lock();
-    m_uRx->_write_fpga_reg(FR_ATR_MASK_0  + 3*3,0);
-    m_uRx->_write_fpga_reg(FR_ATR_TXVAL_0 + 3*3,0);
-    m_uRx->_write_fpga_reg(FR_ATR_RXVAL_0 + 3*3,0);
+    m_uRx->_write_fpga_reg(FR_ATR_MASK_0  + 1*3,0);
+    m_uRx->_write_fpga_reg(FR_ATR_TXVAL_0 + 1*3,0);
+    m_uRx->_write_fpga_reg(FR_ATR_RXVAL_0 + 1*3,0);
+    m_uRx->_write_fpga_reg(41,0);
     m_uRx->_write_fpga_reg(43,0);
-    m_uRx->_write_oe(1,(POWER_UP|RX_TXN|ENABLE), 0xffff);
-    m_uRx->write_io(1,(~POWER_UP|RX_TXN|ENABLE),(POWER_UP|RX_TXN|ENABLE));
-    //m_uRx->write_io(1,0,RX2_RX1N); // using Tx/Rx/
-    m_uRx->write_io(1,RX2_RX1N,RX2_RX1N); // using Rx2
-    m_uRx->set_adc_buffer_bypass(2,true);
-    m_uRx->set_adc_buffer_bypass(3,true);
-    m_uRx->set_pga(2,m_uRx->pga_max()); // should be 20dB
-    m_uRx->set_pga(3,m_uRx->pga_max());
-    m_uRx->set_mux(0x00000032);
+    m_uRx->_write_oe(0,0,0xffff);
+    m_uRx->_write_oe(0,(POWER_UP|RX2_RX1N|ENABLE), 0xffff);
+    m_uRx->write_io(0, ENABLE | RX2_RX1N, ENABLE | RX2_RX1N | POWER_UP); /* power up inverted */
+    m_uRx->set_adc_buffer_bypass(0,true);
+    m_uRx->set_adc_buffer_bypass(1,true);
+    m_uRx->set_pga(0,m_uRx->pga_max()); // should be 20dB
+    m_uRx->set_pga(1,m_uRx->pga_max());
+    m_uRx->set_mux(0x00000010);
     writeLock.unlock();
     // FIXME -- This should be configurable.
     setRxGain(47); //maxRxGain());
@@ -312,8 +312,8 @@
   if (!m_uTx) return false;

   // power down
-  m_uTx->write_io(0,(~POWER_UP|RX_TXN),(POWER_UP|RX_TXN|ENABLE));
-  m_uRx->write_io(1,~POWER_UP,(POWER_UP|ENABLE));
+  m_uTx->write_io(0, POWER_UP, (POWER_UP|ENABLE));
+  m_uRx->write_io(0, POWER_UP, (POWER_UP|ENABLE));

   delete[] currData;

@@ -361,8 +361,7 @@
         m_uRx->set_pga(2,0);
         m_uRx->set_pga(3,0);
    }
-   m_uRx->write_aux_dac(1,0,
-        (int) ceil((1.2 + 0.02 - (dB/rfMax))*4096.0/3.3));
+   m_uRx->write_aux_dac(0,0,(int) ceil((1.2 + 0.02 - (dB/rfMax))*4096.0/3.3));

    LOG(DEBUG) << "Setting DAC voltage to " << (1.2+0.02 - (dB/rfMax)) << " "
<< (int) ceil((1.2 + 0.02 - (dB/rfMax))*4096.0/3.3);
```

10 Troubleshooting

You must not use the stock 64Mhz clock that comes with USRP1. If you do, be prepared for several errors, failing to register and strange behaviour. There has been so many problems with that clock that the maintainers have chosen to remove support for those clocks (soon to be done), and the mailing-list will probably not help you with it. Use a good 52Mhz clock and then come back to the troubleshooting section.

10.1 Can you help me? can I send you an email?

As I said in the introduction, I am an OpenBTS newbie. My job is about reverse engineering, detection and research of *mobile viruses* which is quite loosely related... So, probably, no I can't help you, and no, please don't email me directly for questions on OpenBTS. It's not that I don't want to help, but that I can't. The best way to get an answer is to post on the OpenBTS mailing-list [opef]. If by luck I know the answer, I'll answer on the list.

10.2 usrp_fft is very slow

In my case, this occurred in two situations: a) when I had forgotten to apply the 52Mhz patch to GnuRadio (see section 9.1) - in that case usrp_fft was really very very slow and b) when I check the button to keep the peaks or average.

Also, make sure you applied the usrp_fft patch, section 9.2.

10.3 Impossible to set the frequency to xxxx Mhz !

In my case, this occurred when I had forgotten to apply the 52Mhz patch to GnuRadio (see section 9.1).

10.4 OpenBTS logs say TX fails to tune

In my case, this occurred when I had not applied the GSM 1800 patch (see section 9.3).

10.5 OpenBTS logs complain about not being able to set the RX or TX gain

In my case, this occurred when the OpenBTS configuration file was wrong and was using the Transceiver directory instead of Transceiver52M (52Mhz clocks).

```
TRX.Path ../Transceiver52M/transceiver
```

10.6 OpenBTS complains no transceiver process is found but system is ready

You get this log with OpenBTS 2.8

```
ALERT TRXManager.cpp:406:powerOn: POWERON failed with status -1
transceiver: no process found
system ready
```

This log is ok. It looks for an old running transceiver first. As it doesn’t find it, it reports ”no process found”. But as in the end it says ”system ready”, everything is fine.

10.7 Some of my phones fail to see the OpenBTS network

This could be a clock issue. Check your clock matches the requirements and see `http://gnuradio.org/redmine/projects/gnuradio/wiki/OpenBTSClocks` for why this might affect the network visibility to mobile phones.

10.8 My phone sees the OpenBTS network but fails to register

In my case, this occurred when I had not applied the single daughterboard patch (I am using a single daughterboard). See section 9.4.

10.9 I’ve got a 64Mhz clock and my phones are not registering

Please do get a 52Mhz clock, see section 3.4. My understanding is that it hardly never works with 64 Mhz.

10.10 Where did you buy your cheap clock?

As I said in section 3.4, I got it from Andy Fung who got it from a local Chinese retailer, and unfortunately we don't have any better references for it except the specifications copy-pasted in this document. I'm afraid I can't help you find such a clock, but I'm sure there should be others.

10.11 I've got a RFX 1800 daughterboard but would like to use the 900Mhz band

You don't need to buy another daughterboard: it's possible to flash the hardware.

From RFX1800 to RFX900:

```
$ burn-db-eeprom -B --force -t rfx900
$ burn-db-eeprom -A --force -t rfx900
```

And back:

```
$ burn-db-eeprom -B --force -t rfx1800
$ burn-db-eeprom -A --force -t rfx1800
```

10.12 I've done everything just the same as you but it's not working!

I'm sorry to hear that. Besides getting help from the OpenBTS mailing-list [opef], I would recommend you check:

1. you have applied all software patches (4)
2. switch your phones to manual GSM-only network research
3. the OpenBTS config file uses the Transceiver52M directory (for people using 52Mhz clock)

10.13 smqueue reports an error ”Address already in use”

.

Disable ipv6 on the Linux box and the error should disappear.

10.14 smqueue crashes

smqueue crashes with the following message:

```
cannot find configuration value Log.Alarms.Max
terminate called after throwing an instance of 'ConfigurationTableKeyNotFound'
Aborted
```

The message gives you the answer: add a Log.Alarms.Max entry to smqueue.config (for example, set to 10).

10.15 smqueue complains: ”Failed to read queue from file savedqueue.txt”

.

This is a warning (not a fatal error). Smqueue will still run. Create savedqueue.txt in the ./smqueue directory to remove the warning next times.

10.16 smqueue complains ”sh: asterisk: command not found”

.

Are you running smqueue as root? Usually, it does not find asterisk because the process is not root and can’t access it. Asterisk is typically located in /usr/sbin/asterisk.

11 Acknowledgements

I definetely need to thank Andy Fung for helping me with OpenBTS. Andy helped step by step understand and build the whole system - not to mention he sent me his spare 52Mhz clock. Yes, Andy, you deserve your bottle of wine with French (smelly) cheese whenever you come and see us in France.

I also wish to thank Alexandre Becoulet for installing the 52Mhz clock on the USRP. This was far beyond my skills and he kindly accepted to do it besides his own work.

I would also thank the OpenBTS mailing-list, in particular Sylvain Munaut, Alexander Chemeris, Kurtis Heimerl, Caleb Pal, Ralph Schmid but several other people too who kindly answered my inquiries and keep the mailing-list active.

Finally, thanks to David Maciejak for the nice macro pictures of the USRP, SIM card and reader :)

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