GNU Radio Companion (GRC) module for openHPSDR Hermes/Metis

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Tom McDermott, N5EG

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Outline

- GNU Radio (GR) and GNU Radio Companion (GRC).

- Integrating HPSDR into GRC.

  - Hermes / Metis with Ethernet Interface.

  - Tested with both Hermes and Metis/Atlas.

- Some applications of GRC and HPSDR.

- Where to find, how to install the software.

  - Notes about GRC version 3.7

- References

GNU Radio and GNU Radio Companion (GRC)

- GNU Radio (GR)

  - Library of DSP modules; some Python, some C++.

  - Graphical display & input, file I/O, soundcard audio I/O, network I/O.

  - Real-time data stream management.

  - Real-time code usually in C++ for performance.

  - Open source. I've run it on Ubuntu 12.04, 12.10, 13.04.

  - Reports of Windows & MAC with the right platform environment. However issues noted on reflector...

- GNU Radio Companion (GRC)

  - GUI front end to GNU Radio.

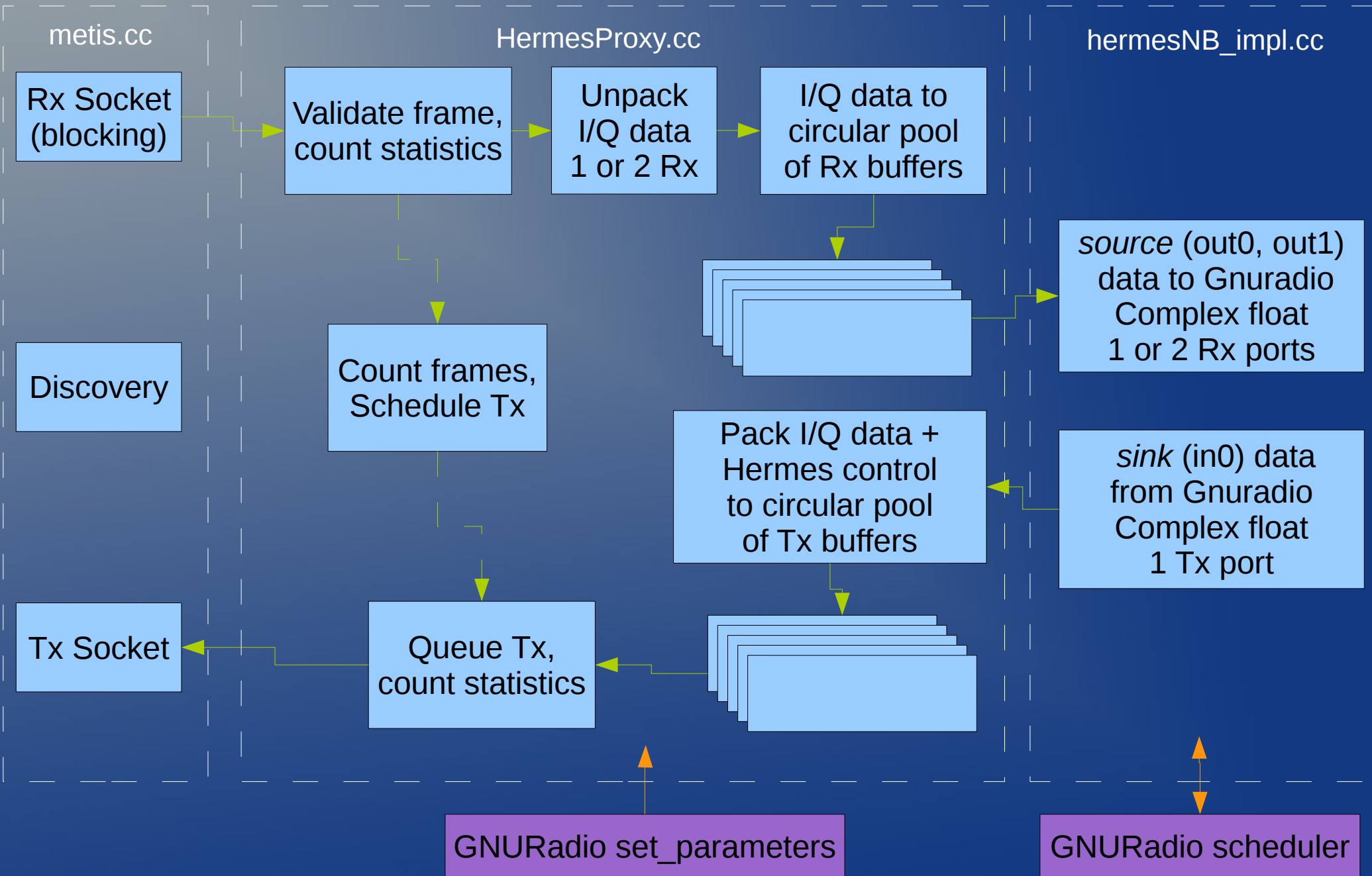 - Create *real-time* DSP implementations via drag-and-drop without writing code.

HPSDR & GRC

- Project to add Ethernet-based HPSDR radios (Hermes & Metis) to GRC.

- Developed as an *out-of-tree module* using the modtool.py generator.

  – Creates skeleton directories, module prototypes, make and cmake files.

  – Minimal 'make file' editing required.

  – Cmake and Make to build & install [hpsdr]/hermesNB.

- All code written in C++. Threaded buffer management, frame parsing, callbacks to set/change parameters.

  – ~ 1k source lines. GCC tool chain, standard Linux sockets & C headers.

- XML file: GUI labels & help text for the module.

Hermes/Metis Software

- Provides connection of Hermes receivers Rx0, Rx1 I/Q data as Gnuradio *source(s) 'out0', 'out1'*.

- Provides connection of Hermes transmitter I/Q data from Gnuradio *sink 'in'*.

- The module is *full duplex*. Tx + Rx simultaneously.

- Takes control inputs from GUI and sends formatted control registers to Hermes/Metis (embedded in data packets).

    – Set frequencies, attenuator, PTT, number of receivers, etc.

- Receives status from Hermes and sets internal variables.

    – ADC Overload, FPGA version. Right now -- not used.

- Limitation: supports only one Hermes/Metis at a time.

Software Block diagram

metis.cc	HermesProxy.cc	hermesNB_impl.cc

Rx Socket (blocking) → **Validate frame, count statistics** → **Unpack I/Q data 1 or 2 Rx** → **I/Q data to circular pool of Rx buffers**

Discovery

Count frames, Schedule Tx

source (out0, out1) data to Gnuradio Complex float 1 or 2 Rx ports

Pack I/Q data + Hermes control to circular pool of Tx buffers

sink (in0) data from Gnuradio Complex float 1 Tx port

Tx Socket ← **Queue Tx, count statistics**

GNURadio set_parameters

**GNURadio scheduler**

Full Duplex

- Hermes hardware is full duplex. The PTT control <u>does not</u> turn the transmitter on or off.

    - PTT toggles a logic control output line. Typically used to switch a T/R relay, key an amplifier, etc.

- The hermesNB software implments:

    - TxPTTMode

        - = 0: Set PTT Off (de-assert)

        - = 1: PTT VOX – if any Tx I/Q symbols in the current frame are non-zero, then assert PTT, else de-assert PTT.

        - = 2: Set PTT On (assert)

    - PTTOnMutesRx = 1: If PTT is On (asserted), then Rx I/Q samples are zeroed out. Mutes the received signals.

    - PTTOffMutesTx = 1: If PTT is Off (not asserted), then Tx I/Q samples are zeroed out. Effectively sets transmitter output to zero.

HPSDR Hermes & Metis/Atlas
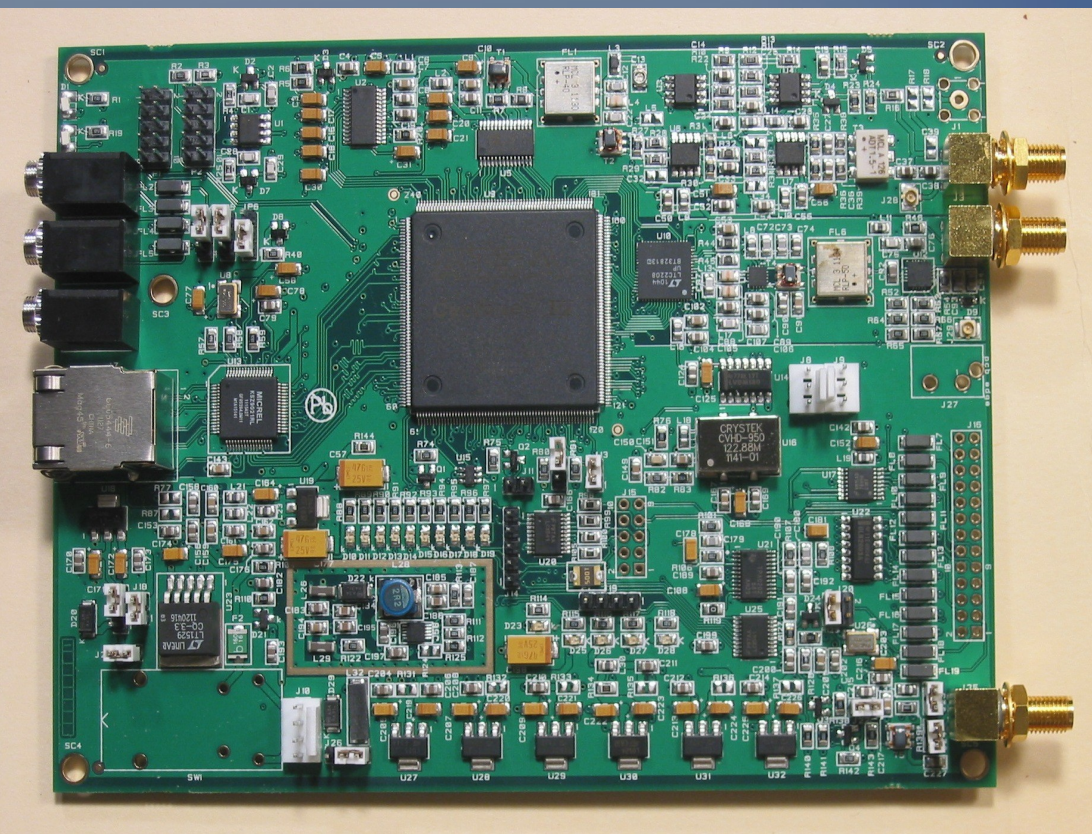
What hermesNB GRC block looks like...

hermesNB block
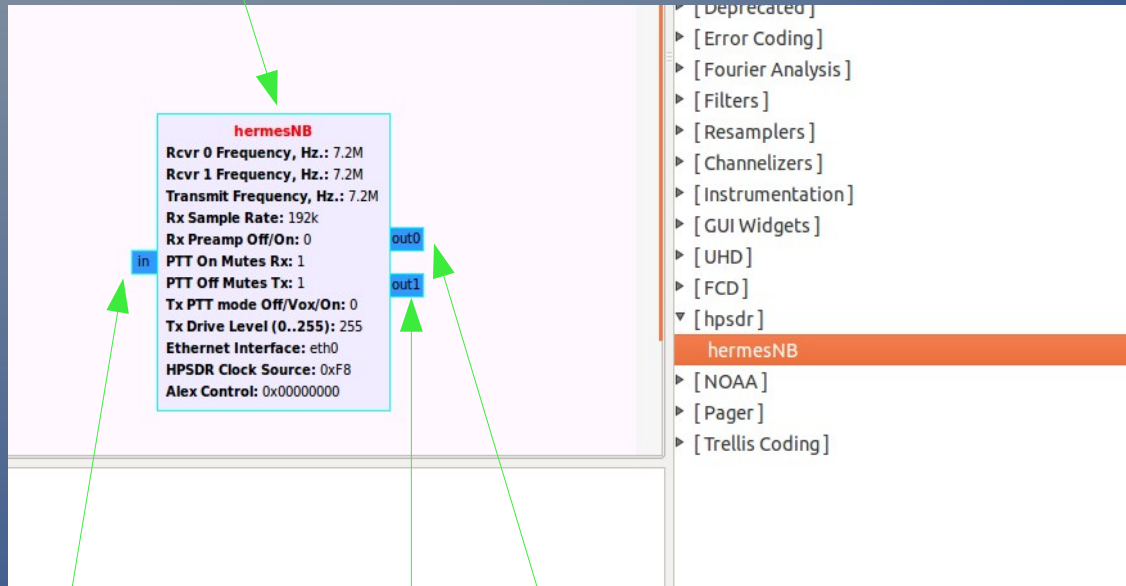
Sink

Sources (1 or 2)

hermesNB
Rcvr 0 Frequency, Hz.: 7.2M
Rcvr 1 Frequency, Hz.: 7.2M
Transmit Frequency, Hz.: 7.2M
Rx Sample Rate: 192k
Rx Preamp Off/On: 0
PTT On Mutes Rx: 1
PTT Off Mutes Tx: 1
Tx PTT mode Off/Vox/On: 0
Tx Drive Level (0..255): 255
Ethernet Interface: eth0
HPSDR Clock Source: 0xF8
Alex Control: 0x00000000

in
out0
out1

▶ [Deprecated]
▶ [Error Coding]
▶ [Fourier Analysis]
▶ [Filters]
▶ [Resamplers]
▶ [Channelizers]
▶ [Instrumentation]
▶ [GUI Widgets]
▶ [UHD]
▶ [FCD]
▼ [hpsdr]
   hermesNB
▶ [NOAA]
▶ [Pager]
▶ [Trellis Coding]

hermesNB Properties
(double click the block)

Properties: hermesNB

Parameters:

ID	hpsdr_hermesNB_0
Rcvr 0 Frequency, Hz.	RxFreq0
Rcvr 1 Frequency, Hz.	RxFreq1
Transmit Frequency, Hz.	TxFreq
Rx Sample Rate	samp_rate
Rx Preamp Off/On	Preamp
PTT On Mutes Rx	PTTRx
PTT Off Mutes Tx	PTTTx
Tx PTT mode Off/Vox/On	PTT
Tx Drive Level (0..255)	TxD
Num Rcvrs (1 or 2)	2
Ethernet Interface	"eth0"
HPSDR Clock Source	"0xF8"
Alex Control	"0x00000000"

Documentation:

This block is the HPSDR Hermes/Metis module.
It supports one or two receivers and one transmitter in the Narrow Band (digital downconversion) mode.
*RxSamp = 48000, 96000, 192000, or 384000
*RxPreamp = 0 (Off), or 1 (On)
*PTTMode = 0 (TxOff), 1 (Vox on Txframe contents), or 2 (TxOn)
*PTTOffMutesTx = 0 (Tx always emits), 1 (Tx IQ is zeroed when PTT is Off)
*PTTOnMutesRx = 0 (Rx always receives), 1 (Rx IQ is zeroed when PTT is On)
*TxDrive = 0..255 (0 is minimum (but not zero) drive, 255 is maximum drive)
Rcvr0 corresponds to out0, Rcvr1 corresponds to out1.
*Interface = the ethernet interface to use.
  Example: "eth0" {including quote marks}.
*Clock Source = HPSDR Clock Selector - 1 byte-> assigned to one register. byte->C1 when C0 = 0. Allows selection of clock and mic sources. Only upper
6 bits are used (lower 2 bits are overwritten by receive sample speed selection. Hermes ignores this register. Default value selects Mercury.
  Example: "0xfc" {including quote marks}
*Alex Control = HPSDR Alex Controls - 4 bytes, each assigned to one register.
MSB->C3, 3rd byte->C4 for C0=0, 2nd byte->C3, LSB->C4 for C0 = 0x12.
  Example: "0x00000000" {including quote marks}
See "HPSDR - USB Data Protocol" document.

Cancel   OK

GRC Applications

- GRC is essentially a *software breadboard*.

    - Real time DSP by dragging, dropping, wiring up processing blocks (not writing code).

    - *Good* for learning, prototyping experimental setups, lab tests, DSP experiments, data capture & analysis, casual operation.

    - *Not good* for building a replacement of PowerSDR or cuSDR. GRC control widgets are rudimentary by comparison.

- Multiple graphical display capabilities.

- Transient generation and capture capability.

- Ethernet Network I/O:

    - Communications with Hermes, plus:

        - UDP & TCP client / server for processed data streams.

        - XMLRPC (SOAP) for start, stop, parameter setting.

Application: High Resolution Frequency Measurement

- Apply frequency standard to external reference input of Hermes.

- Set receiver frequency to precise small offset (~ 1 Hz).

  - FPGA NCO has 32-bit phase accumulator.

- Use narrow LPFilter and high decimation to create low-sample-rate complex output stream.

- Display output as FFT, Time, Constellation.

- Dump to file for long-duration post-processing if desired.

  - Fairly clean with a well-behaved unknown.

  - It looks really messy when listening to WWV + WWVH at the same time & strength.

Visualize + Listen + Save Time-Domain data to file
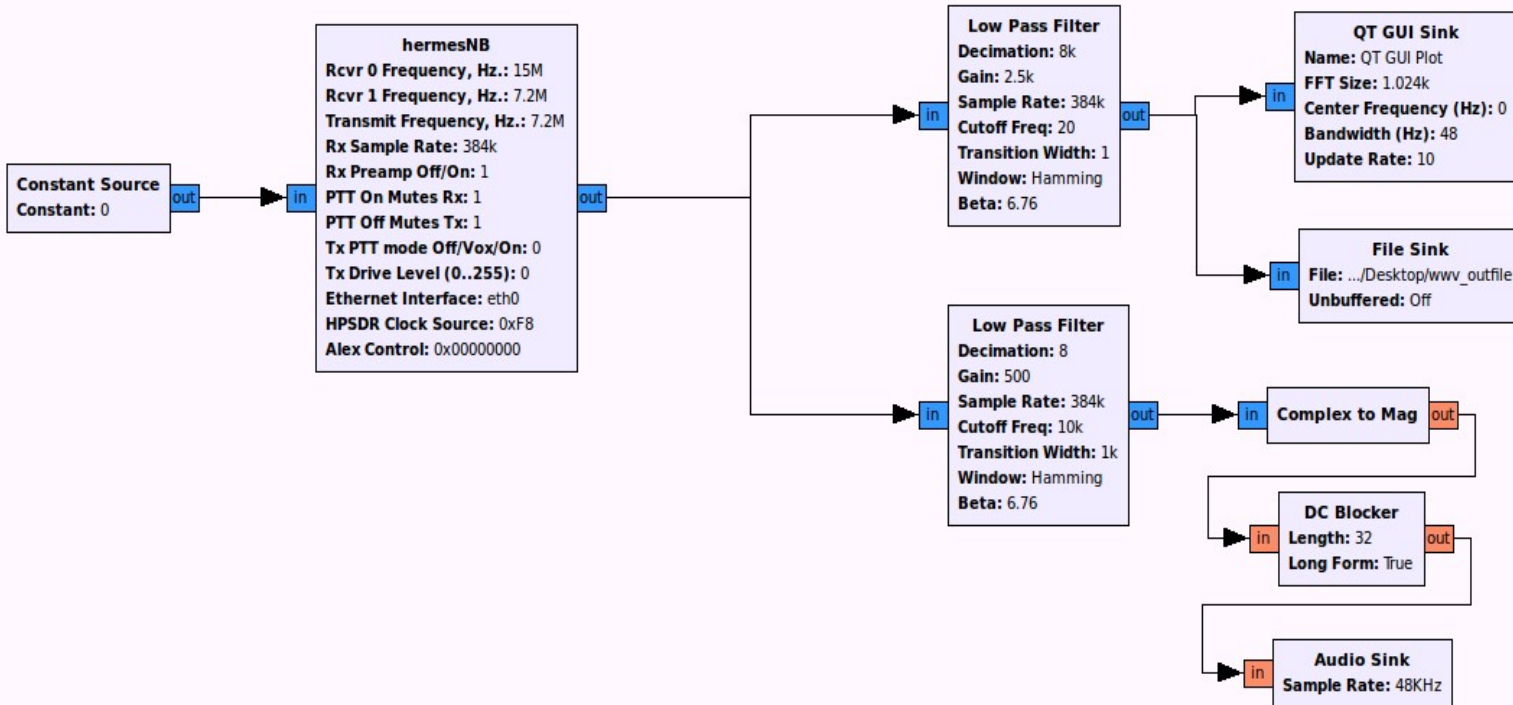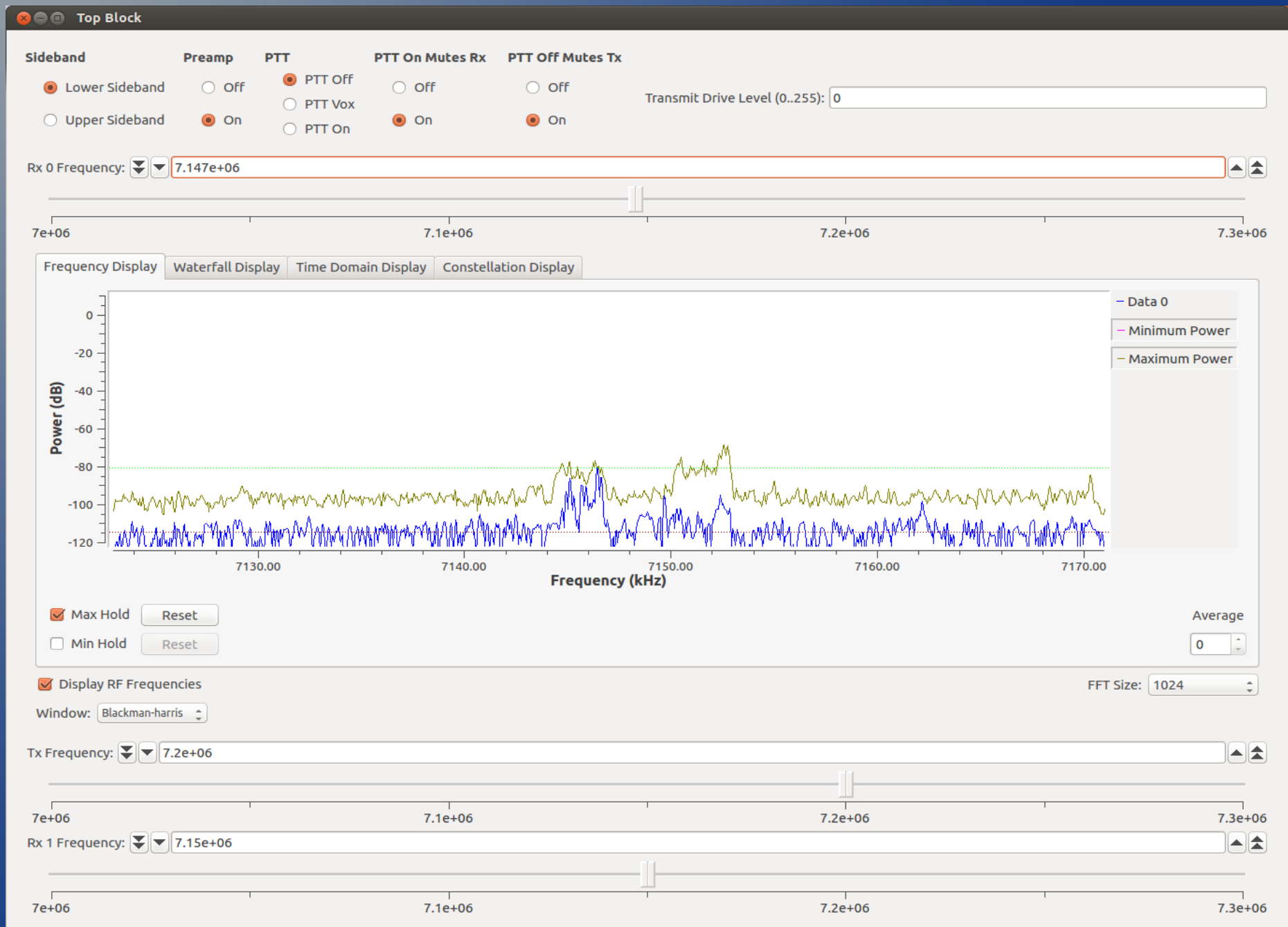
Time & Constellation Views
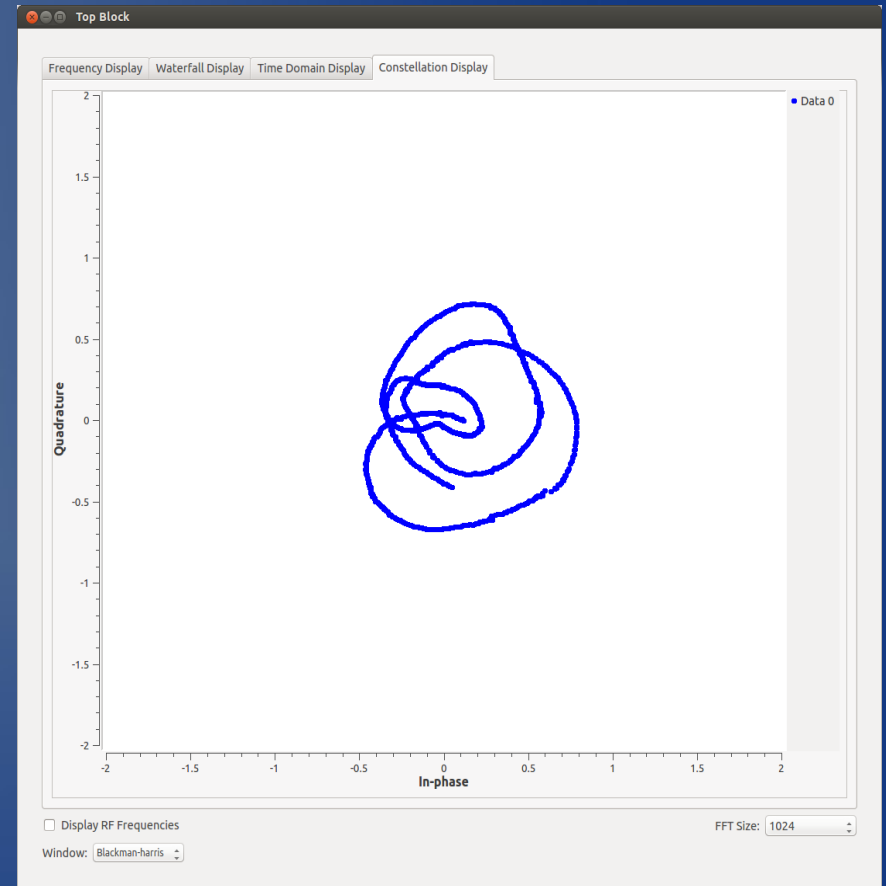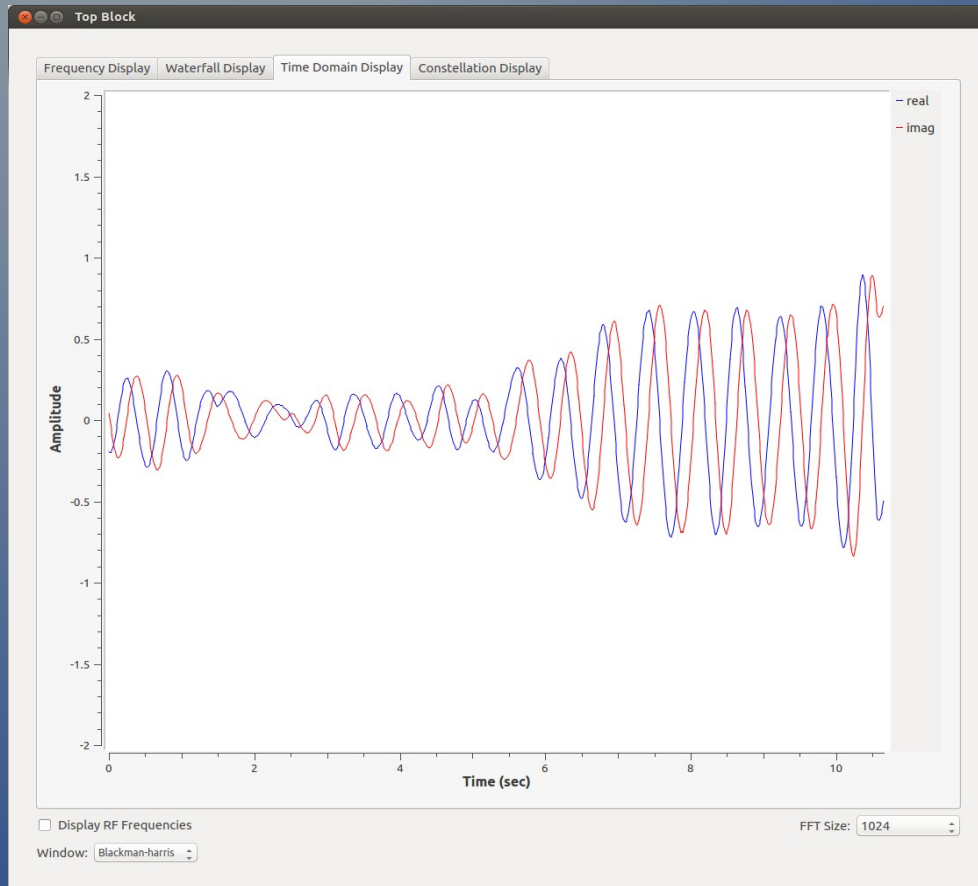
Application: Single-Signal SSB Receiver
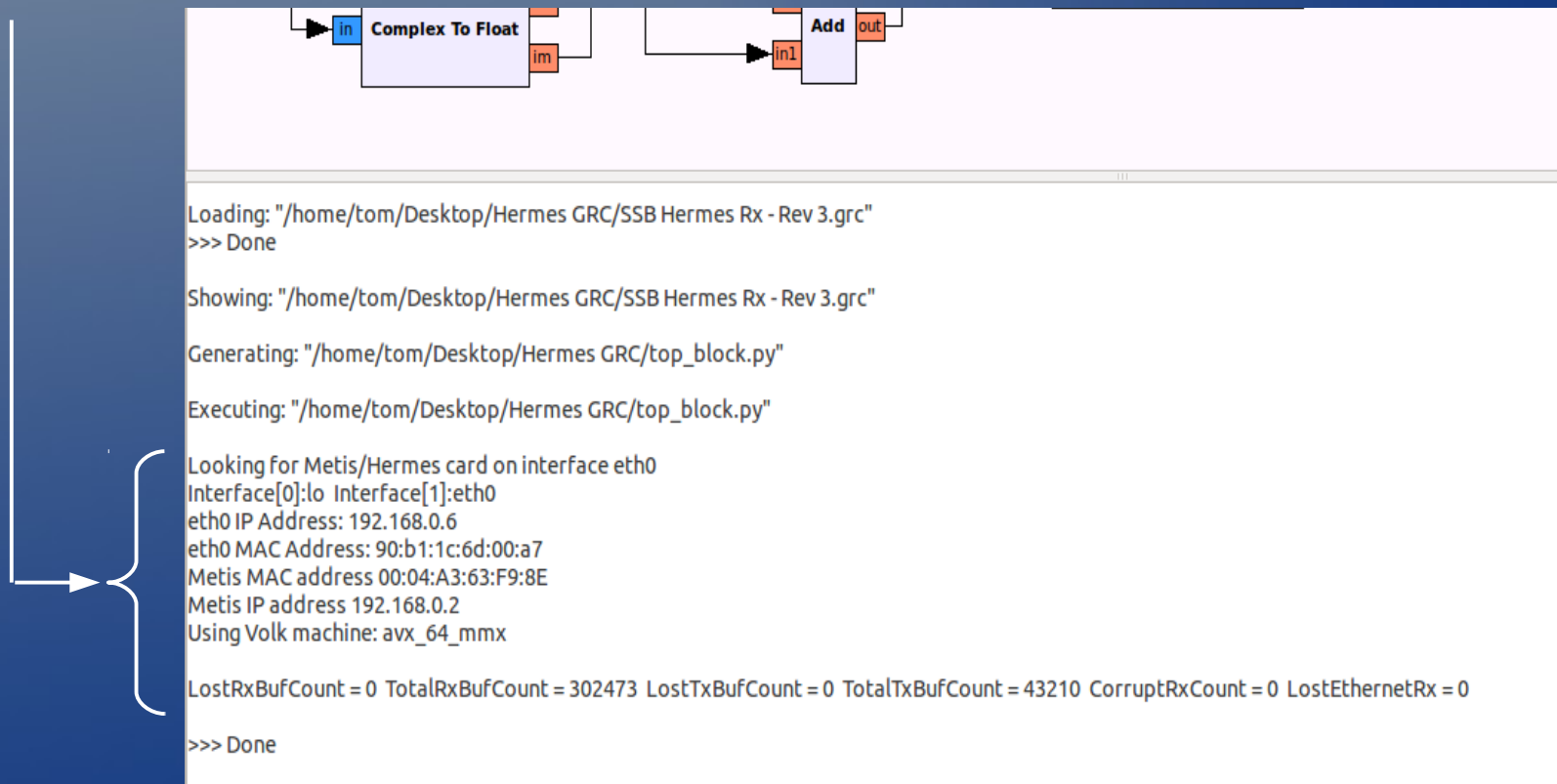## (using phasing method)
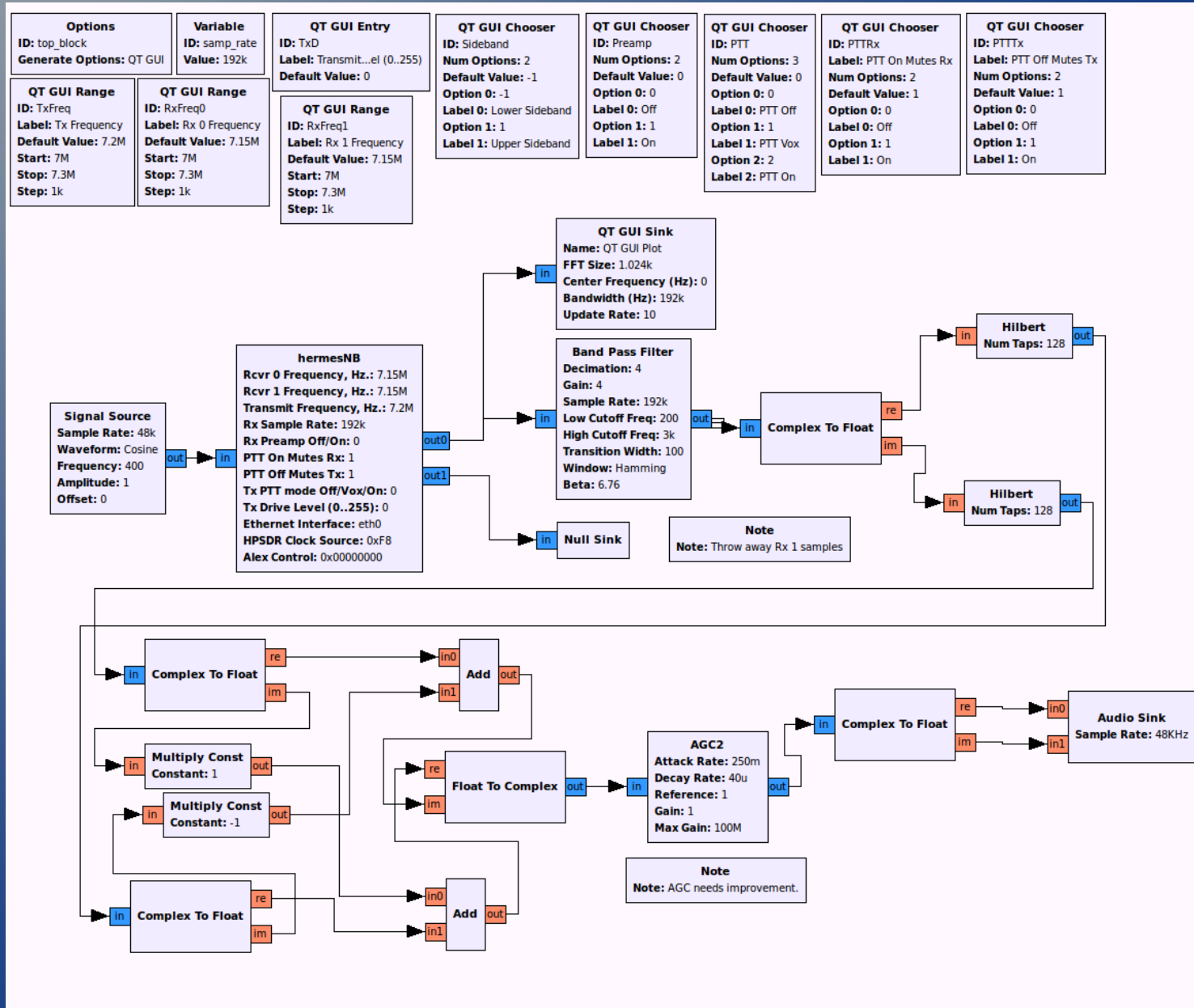
GUI Control Panel

for previous flowgraph

GRC Console Window

- Console window can be written by the Hermes/Metis software.

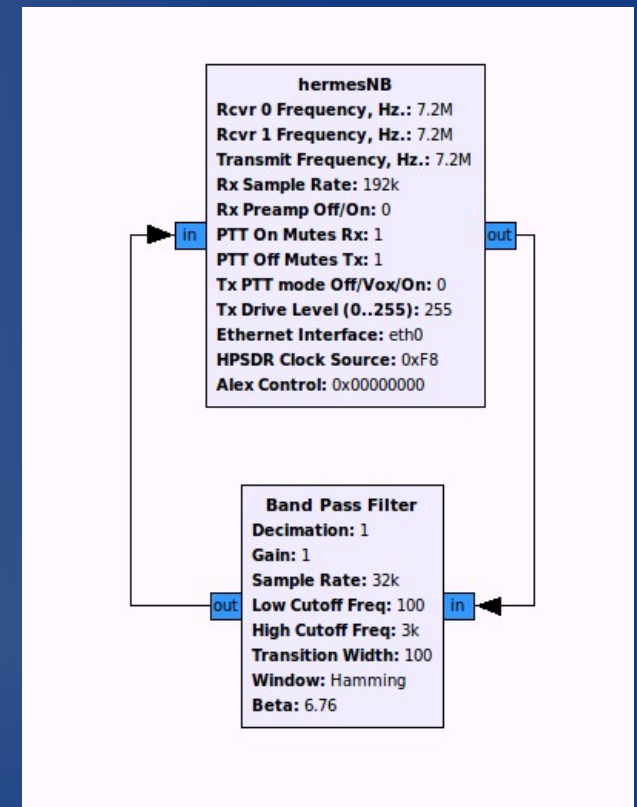- Currently used for status, addresses, interfaces, packet counts, error messages.

Gnuradio Flowgraph Loops

- Gnuradio does not permit loops around blocks in a flowgraph.

  - They are however allowed within a single block (e.g. PLL).

- hermesNB input and outputs are in the same one block.

  - Cannot connect output → block(s) → input.

- Limits utility of Hermes audio amplifier: cannot produce sound from received signal (forms loop). Therefore code to use it removed.

  - Use audio sink (soundcard) instead.

- Currently a limitation of hermesNB.

  - To fix would require hermesNB sink and source to be separate blocks.

  - Common control would need to be an invisible shared block.

hermesNB
Rcvr 0 Frequency, Hz.: 7.2M
Rcvr 1 Frequency, Hz.: 7.2M
Transmit Frequency, Hz.: 7.2M
Rx Sample Rate: 192k
Rx Preamp Off/On: 0
PTT On Mutes Rx: 1
PTT Off Mutes Tx: 1
Tx PTT mode Off/Vox/On: 0
Tx Drive Level (0..255): 255
Ethernet Interface: eth0
HPSDR Clock Source: 0xF8
Alex Control: 0x00000000

Band Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 32k
Low Cutoff Freq: 100
High Cutoff Freq: 3k
Transition Width: 100
Window: Hamming
Beta: 6.76

Flowgraph loop not allowed

How to Install the Software

1. Install Gnuradio by building from source.

   - Use 'wget' script from gnuradio.org Installation Guide webpage. Instructions also on TAPR SVN.

     • By default - Installs 3.6.5.1

     • Instructions on TAPR SVN on how to install 3.7.latest

   - This loads dependencies and tools needed for both Gnuradio and Hermes/Metis.

2. Download Hermes/Metis source from TAPR SVN.

   - Two branches: GRC3.6 and GRC3.7. Pick the one that matches your Gnuradio install.

3. Build the Hermes/Metis software tree and install.

   - Document is on TAPR SVN. It's easy.

Notes on Gnuradio 3.7

- Gnuradio/GRC latest released Version 3.7

    - <u>Breaking changes</u> to versions 3.6.x and prior.

    - <u>Requires</u> manual removal of previous version before installing 3.7

    - <u>Requires</u> different Hermes/Metis source code and different demo applications.

    - A few GR install & config bugs.

        - Ver 3.7.1 fixed some Cmake problems
        - New Cmake issues found, fix scheduled for 3.7.2

    - Some add-ons are not (yet) 3.7 compatible.

    - Some hardware not yet ported to 3.7

- GRC3.6 is stable, GRC3.7 is rapidly evolving.

Where to find Hermes/Metis modules.

- TAPR SVN: http://svn.tapr.org/repos_sdr_hpsdr/trunk/N5EG

- Two branches: GRC3.6 and GRC3.7

  - Hermes/Metis source code and demo applications for Gnuradio 3.6 and for Gnuradio 3.7.

- Script to remove GNU Radio (before installing 3.7): Gnuradio_remove

- Hermes/Metis build instructions (same for both versions).

- Instructions for installing Gnuradio 3.6.5.1 or Gnuradio 3.7.latest: Building and installing gnuradio.pdf

N5EG/	3103
GRC3.6/	3103
gr-hpsdr/	3058
grc_applications/	3059
Building and installing gnuradio.pdf	3103
Gnuradio_remove	3093
How to build Gnuradio Hermes-Metis.pdf	3060
README.TXT	3062
Using Gnuradio Hermes-Metis block.pdf	3061
GRC3.7/	3101

N5EG/	3101	11h 28
GRC3.6/	3093	39d 2
GRC3.7/	3101	11h 28
gr-hpsdr/	3100	11h 39
grc-applications/	3089	42d 1
Gnuradio_remove	3090	42d 1
How to build Gnuradio Hermes-Metis.pdf	3084	42d 1
README.TXT	3086	42d 1
Upgrading to GRC3.7.pdf	3091	42d 1
Using Gnuradio Hermes-Metis block.pdf	3085	42d 1

GNU Radio Bugfixes

- GNU Radio development team has been very responsive to problem reports.

- GNU Radio Issue Tracker:

  – gnuradio.org/redmine/projects/gnuradio/issues

- Pushing out fixes to git repository as repaired.

  – gnuradio.org/redmine/projects/gnuradio/repository

- Periodic fix collection pushed into a dot release.

Other Radios

- Gnuradio interfaces also available for:

    - RTL2832 based USB DVB-T Receiver

    - Funcube Dongle

    - Ettus Research products

    - SDRstick

        - Both hermesNB 384k-compatible and native 1.25M / 1.92M protocol modes

- Possible to port other radios that have USB or Ethernet interfaces with integrated IQ data, control, and status.

    - Ask around at DCC...

References

- This presentation:

  - www.tapr.org/~n5eg

- GNU Radio main page:

  - gnuradio.org

- TAPR Subversion (SVN) GRC HPSDR code repository

  - svn.tapr.org/repos_sdr_hpsdr/trunk/N5EG

- Discuss-gnuradio mail list archive

  - http://lists.gnu.org/archive/html/discuss-gnuradio/

- I've not tested, but ….

  - Michael Dickens: installing GNU Radio 3.7.1 using MacPorts

    - lists.gnu.org/archive/html/discuss-gnuradio/2013-08/msg00534.html

  - Christophe Devine: installing GNU Radio 3.6.4.1 on Windows x64

    - lists.gnu.org/archive/html/discuss-gnuradio/2013-08/msg00286.html

- Special thanks to John Petrich, W7FU for comments, suggestions, demos, and Atlas/Metis system to verify operation.