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Digipeater Manual

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1 INTRODUCTION

The implemented system acts as a "Store and forward", it receives messages in UHF (435.310 MHz) and re-transmits these messages in UHF (435.190 MHz) either immediately or at a later time, allowing the messages to be broadcasted when the desired region is in visibility of the spacecraft.

The on-board system normally operates in the "store and forward" mode, receiving messages from a public RX frequency. It will periodically switch to a different non-public RX frequency dedicated to telecommands and wait for messages from the ground station, before reverting to the public store and forward frequency.

With this implementation of a store and forward system, the team provides a tool which takes as an input:

- Callsign / identifier;
- Satellite name;
- Time of re-transmission (can between now and 2 days);
- The message itself.

The system then outputs an audio signal to be given as input to a typical radio capable of operating in SSB. The bandwidth required is small as the uplink runs at 1200 bps. Transmitted messages have an MTU (Maximum Transfer Unit) of 200 bytes, with a limit on how many messages can be stored on-board (in the order of a few hundreds). The satellite will restrict how many messages can be re-transmitted at a given time, with a window of approximately 10 seconds.

At the same time, the tool is able to receive data from the satellite, taking as input the audio channel of the radio. The tool will display any incoming message from other radio amateurs as well as telemetry processed by the On-Board Computer.

Since the software is a modified version of the GreeCube digipeater, the requirements for the radio are:

- Ability to transmit and receive in FM or SSB, at least 1800 Hz of bandwidth;
- A 25W or greater power amplifier for transmission;
- A tracking antenna with a gain of at least 12 dBi.

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2   SIGNAL INFORMATION

The spacecraft uses as transceiver a commercial off-the-shelf radio, the AX100 from GOMSpace. This is a half-duplex UHF transceiver able of operating at two different frequencies and baud rates for transmission and reception. The proposed baud rates are, due to the altitude of the orbit (600 km), 1200 bps in downlink and in uplink. The properties of the encoding and modulations can be found in the table below.

Modulation	GMSK
Baud Rate	1200 up / 1200 down
Frequency Uplink	435'310'000 Hz
Frequency Downlink	435'190'000 Hz
Frame Synchronization	ASM four-byte sync word at the beginning
Length Field	GOLAY encoded (12 bits length + 12 bits parity)
Forward Error Correction	Reed Solomon (223, 255)
Scrambling	CCSDS randomization (Same as G3RUH 9k6 scrambler)
Network Layer	Cubesat Space Protocol

This type of encoding and modulation is not unknown to the radio amateur community as satellites with this transceiver have been received in the past, e.g. by EA4GPZ, who created the gr-satellites module of GNURadio, or using UH7ZO's modem.

3   DIFFICULTIES

There are two main difficulties when communicating with LEDSAT is the frequency set, since the on-board AFC only allows for small frequency errors, within 200-300Hz, so the transmission frequency must be set correctly.

4   MESSAGE FORMAT

The messages send to the satellite are in the format:

$SourceCallsign > *$DestCallsign*, *$SatelliteName*, STORE=*$Time $Message*

An example of the messages could be:

IU0POY > IU0BFO, LEDSAT, STORE=5 This a message relayed by LEDSAT in 5 seconds

The satellite name and the "STORE" parameter are case sensitive.

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5 ARCHITECTURE

The software is divided into three parts (See also Figure 1):

- The TNC – which receives the bit-flow from GNURadio, syncs to the incoming packets and forwards then to the graphical interface
- GNURadio – which interfaces with the radio to receive the satellite signal
- The Graphical User Interface – which is used to receive and transmit packets
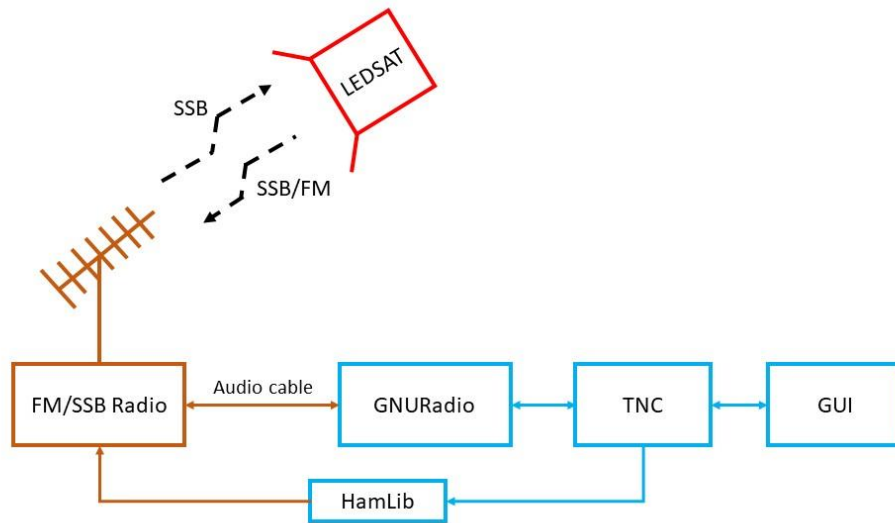- The HamLib library, to interface the TNC with the radio for the PTT.

Figure 1: Architecture of the system (Blue – Software, Orange – Hardware, Red – LEDSAT)

All parts of the software, apart from HamLib, use the same configuration file, located in the GreenCube directory created in the user home folder (*C:\Users\%USERNAME\GreenCube*).

5.1 TNC

The TNC receives the constant bit-flow from GNURadio which comes after the GMSK demodulation. The TNC will look for the sync marker sequence in the packet, extract the GOLAY-encoded packet length and forward this packet to the GUI.

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At the same time, it will receive packets from the GUI and generate the bit sequence to be transmitted by GNURadio.

An example of the TNC output is shown in Figure 2. When the synchronization market is detected, the "Frame Detected" string appears.

```
[30/09 15:47:49.758] ReedSolomon: OK (Corrected 0 bytes)
[30/09 15:47:49.758] Received 137 bytes
[30/09 15:47:49.759] -------FRAME END--------
[30/09 15:47:49.759] CSP Packet to port: 8
[30/09 15:47:49.759] Beacon 01/01 11:56:57.031
[30/09 15:48:03.858] -----FRAME DETECTED-----
[30/09 15:48:04.758] ReedSolomon: OK (Corrected 0 bytes)
[30/09 15:48:04.758] Received 137 bytes
[30/09 15:48:04.759] -------FRAME END--------
[30/09 15:48:04.759] CSP Packet to port: 8
[30/09 15:48:04.760] Beacon 01/01 11:57:12.031
[30/09 15:48:18.858] -----FRAME DETECTED-----
[30/09 15:48:19.758] ReedSolomon: OK (Corrected 0 bytes)
[30/09 15:48:19.758] Received 137 bytes
[30/09 15:48:19.759] -------FRAME END--------
[30/09 15:48:19.760] CSP Packet to port: 8
[30/09 15:48:19.760] Beacon 01/01 11:57:27.031
[30/09 15:48:34.657] -----FRAME DETECTED-----
[30/09 15:48:35.358] ReedSolomon: OK (Corrected 0 bytes)
[30/09 15:48:35.358] Received 112 bytes
[30/09 15:48:35.359] -------FRAME END--------
[30/09 15:48:35.360] CSP Packet to port: 8
[30/09 15:48:35.360] Alt. Beacon 01/01 11:57:42.426
[30/09 15:48:48.858] -----FRAME DETECTED-----
[30/09 15:48:49.758] ReedSolomon: OK (Corrected 0 bytes)
[30/09 15:48:49.758] Received 137 bytes
[30/09 15:48:49.759] -------FRAME END--------
[30/09 15:48:49.759] CSP Packet to port: 8
[30/09 15:48:49.759] Beacon 01/01 11:57:57.031
```

Figure 2: Example TNC output.

5.2 HAMLIB

The HamLib library (https://hamlib.github.io) is used to control the radio. In particular, the TNC will communicate with HamLib to enable and disable the PTT (Push To Talk) of the radio and enable transmission.

Since all radios behave differently between brands and models, the HamLib library provides several interfaces for the PTT button. The user must configure HamLib correctly in order to use the PTT feature, by starting the Rig Control Daemon (*rigctld*) before the TNC.

The user can specify the address and port of the daemon on the configuration file.

5.3 GNURADIO COMPANION

GNURadio Companion is a graphical interface used often in real time signal processing using Software Defined Radios or audio signals.

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Two scripts are provided – both transmit using SSB demodulation, but one receives using SSB demodulation and the other using FM demodulation. The scripts were tested using GNURadio version 3.7.13.5.

The SSB communication is more reliable, as GNURadio does a good job of filtering out and demodulating the incoming signal correctly, but one can receive via FM if SSB is not available.

5.3.1   SSB Modulation

This script is intended to be used with a radio set in SSB mode. With this mode, GNURadio will send via audio cable (either physical or virtual, depending on the radio) the modulated signal, upshifted by 1600 Hz (the value can be changed from the configuration file). This allows the pure modulated signal to be transmitted as-is. The user must adjust the Doppler compensation to take this into account.

The interface is shown in Figure 3 and is divided in two tabs with the same type of data, for *incoming* and *outgoing* transmissions.

The top plot is the signal in the *time* domain, while the bottom plot is the *waterfall* of the signal.

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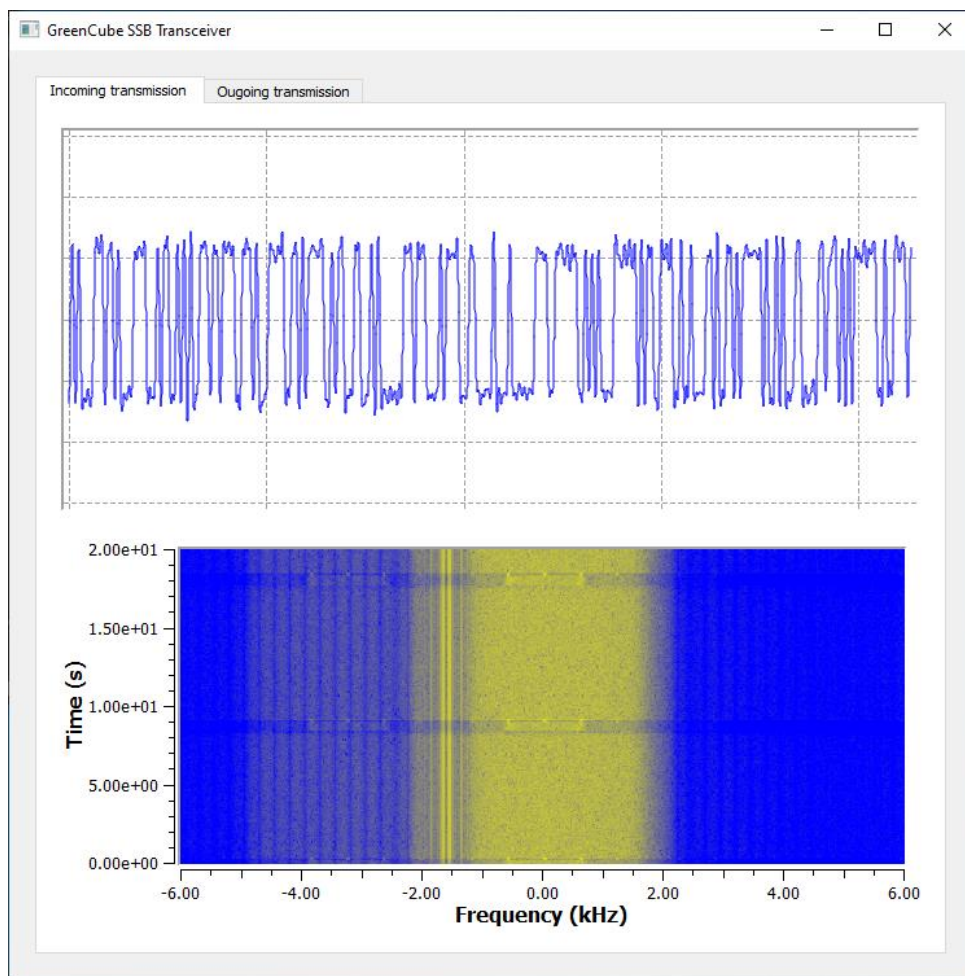Date: June 2023
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Figure 3: The GNURadio SSB script.

5.4 GRAPHICAL USER INTERFACE

The user interface is used to generate messages for the satellite and to interpret incoming packets.

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Figure 4: The Graphical User Interface.

The main "Digipeater" tab shows a history of the transmitted and received packets and allows the operator to write a message to send to the satellite. The operator selects LEDSAT in the satellite name list, then writes the message in the "Content" field and the complete message automatically fills up. The complete message is shown in the "Message" field, with the callsign of the sender, the intended receiver and the LEDSAT relay. To send the message, the operator presses the "Send" button. One can edit the "Message" field directly.

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To access the "store" feature, which stores the packet on-board for later re-transmission, the operator must change the "Re-TX delay" parameter to a number greater than 0. This specifies the re-transmission delay in seconds, for a maximum of 172'800 seconds of delay (two days).

The operator can also modify the "Message" but must be careful to keep the correct format, or the TNC will throw an error. Total message length cannot be over 180 characters.

The "Telemetry" tab shows a real-time view of the telemetry packets that are received. In particular, the "Digipeater Status" will show if the digipeater is active on the spacecraft. If the message states "Digipeater ready!" then the digipeater can be used – wait for at least one beacon packet to get this information from the satellite.
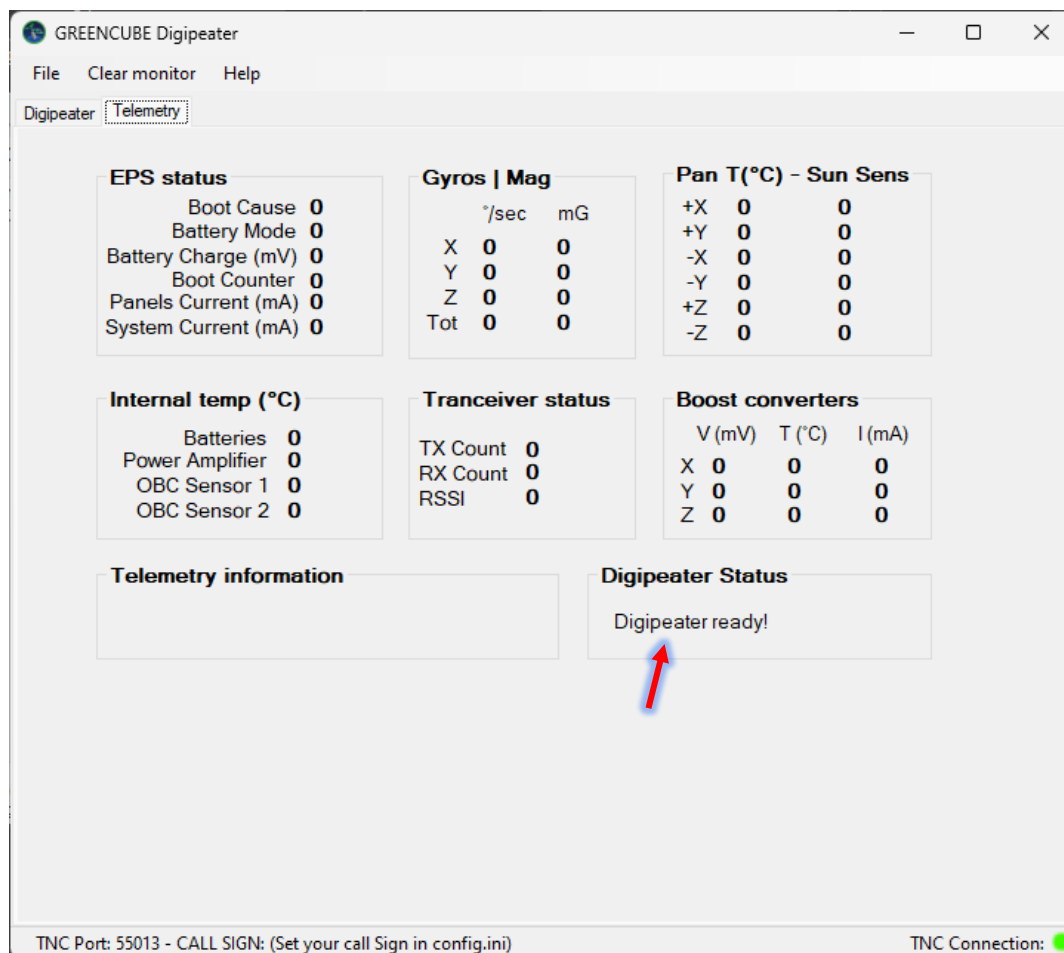

Figure 5: The Telemetry tab on the GUI

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5.5 CONFIGURATION FILE

The configuration for all three software is stored in a *config.ini* file in the user home directory (*C:\Users\%USERNAME%\GreenCube*) created automatically at first run of the TNC.

The keys are structured as shown in Table 1.

Table 1: Configuration file config.ini.

Key	Default	Comment
[modem]		
GR_ReceivePort	53010	GNURadio-TNC UDP port (localhost)
GR_TransmitPort	53011	TNC-GNURadio UDP port (localhost)
[KISS]		
KISS_Port	53012	TNC-GUI TCP port (localhost)
[radio]		
CallFrom	NOCALL	Your callsign
PreambleLength	50	
PostambleLennght	50	
[gnuradio]		
AudioCard_RX_DeviceName	empty	The audio device name for receiving the satellite
AudioCard_RX_SampleRate	48000	
AudioCard_TX_DeviceName	empty	The audio device name for transmissions to the satellite
AudioCard_TX_SampleRate	48000	
SSB_mode	LSB	Kind of SSB modulation
SSB_RX_offset	1600	Offset of the received signal in SSB
SSB_TX_offset	1600	Offset of the transmitted signal in SSB
[rigctld]		
Address	127.0.0.1	Network Address of the machine running rigctld. If the line is commented rigctld is not used.
Port	4532	Network port of rigtld
PTT_ON_Command	T 1	Rigtcltd command to switch on PTT
PTT_OFF_Command	T 0	Rigtcltd command to switch off PTT

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KeyUpDelay	200	Delay after pressing the PTT before transmitting data
KeyDownDelay	500	Delay after the transmission before turning off the PTT

6 STEP-BY-STEP SETUP GUIDE

6.1 DOWNLOAD AND INSTALL GNURADIO

The software has been tested with GNURadio version 3.7.13.5, which can be downloaded from http://www.gcndevelopment.com/gnuradio/index.htm

After installation, launch GNURadio Companion by searching its name on the start menu. Beware to not launch the GNURadio Command Prompt, which is named similarly with the same icon but does not provide a graphical interface.
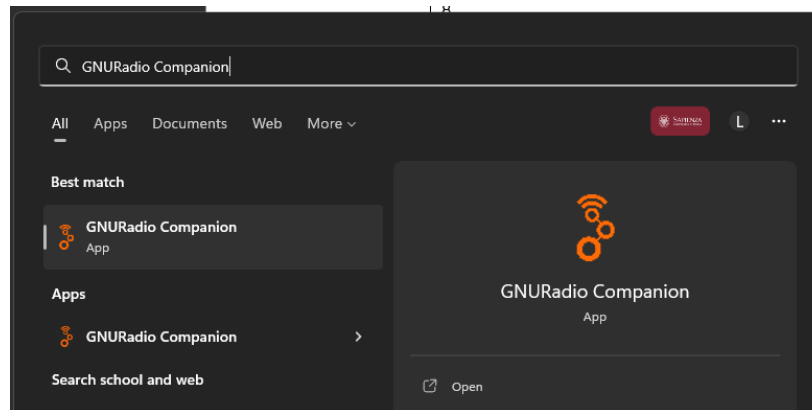

Figure 6: How to start GNURadio Companion.

6.2 VERIFY SETTINGS FILE

Run and close the TNC once (using *DigipeaterTNC.exe*) to generate the default *config.ini* file in C:/Users/%USERNAME%/GreenCube/.

6.2.1 SSB settings

Change the *SSB_Mode* parameter with either "USB" (Upper Side Band) or "LSB" (Lower Side Band) depending on the radio mode of operation. If necessary, adjust the frequency offset using *SSB_TX_Offset* and *SSB_RX_OFFSET* to adjust where the GFSK signal lies in the sideband.

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6.2.2   Audio Card settings

The sampling rate of the audio card must be set appropriately to match the sound device, using *AudioCard_RX_SampleRate* and *AudioCard_TX_SampleRate* for the microphone and the speakers respectively. Typical audio rates are 48kHz and 44.1kHz. The values can be found in the device properties on Windows sound settings. An incorrect sampling rate will distort the input and output signals.

By default, GNURadio will use the Windows' preferred audio device. If using a particular sound device which is not selected by GNURadio by default, you can specify its name with the *AudioCard_RX_DeviceName* and *AudioCard_TX_DeviceName* variables.

6.2.3   Digipeater settings

Change your callsign with the *CallFrom* setting. Change Satellite name from GreenCube to LEDSAT.

6.3   RUN GNURADIO COMPANION AND THE SSB SCRIPT

Load either the RX_SSB_TX_SSB or the RX_FM_TX_SSB script using File -> Open and then run the script by pressing the "Execute" button in the middle of the toolbar, as indicated by the red arrow in Figure 7.
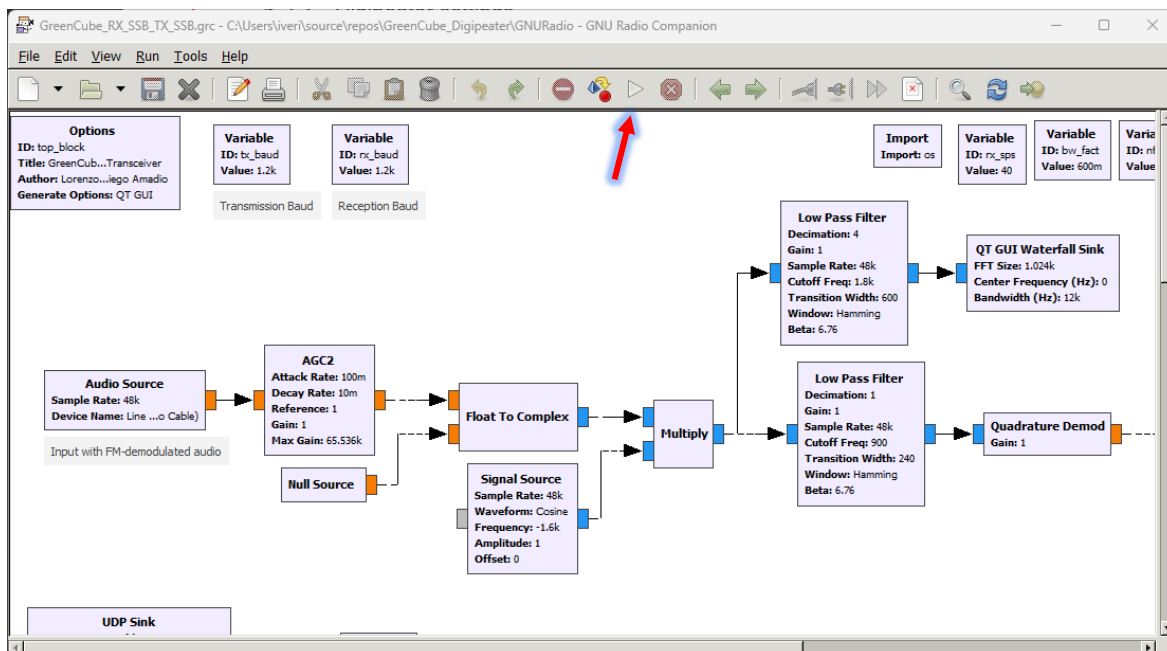

Figure 7: The GNURadio interface.

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6.4   START HAMLIB

Start HamLib and connect it to the radio, if necessary.

6.5   RUN THE TNC

Execute the TNC program by starting the *DigipeaterTNC.exe* file.

6.6   RUN THE GRAPHICAL USER INTERFACE

Execute the GUI program by starting the *DigipeaterGUI.exe* file.