
gr-satellites Documentation

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gr-satellites is a GNU Radio out-of-tree module with a collection of telemetry decoders for Amateur satellites.

INTRODUCTION

gr-satellites is a [GNU Radio](#) out-of-tree module encompassing a collection of telemetry decoders that supports many different [Amateur satellites](#). This open-source project started in 2015 with the goal of providing telemetry decoders for all the satellites that transmit on the [Amateur radio bands](#).

It supports most popular protocols, such as [AX.25](#), the GOMspace NanoCom U482C and [AX100](#) modems, an important part of the [CCSDS stack](#), the [AO-40](#) protocol used in the [FUNcube](#) satellites, and several ad-hoc protocols used in other satellites.

This out-of-tree module can be used to decode frames transmitted from most Amateur satellites in orbit, performing demodulation, forward error correction, etc. Decoded frames can be saved to a file or displayed in hex format. For some satellites the telemetry format definition is included in gr-satellites, so the decoded telemetry frames can be printed out as human-readable values such as bus voltages and currents. Additionally, some satellites transmit files such as JPEG images. gr-satellites can be used to reassemble these files and even display the images in real-time as they are being received.

gr-satellites can be used as a set of building blocks to implement decoders for other satellites or other groundstation solutions. Some of the low level blocks in gr-satellites are also useful for other kinds of RF communications protocols.

INSTALLATION

There are currently three major ways to install gr-satellites:

- *Building from source*
- *Installing using conda*
- *Using the Ubuntu PPA*

Installing from the Ubuntu PPA is the easiest and recommended way to install gr-satellites in Ubuntu 20.10 and later versions.

Conda is a multi-platform package manager that can be used to install gr-satellites and its dependencies (such as GNU Radio) in a virtual environment that does not clash with the system-wide set up. It is the recommended way to install gr-satellites in Windows and macOS, and also in Linux distributions which do not include GNU Radio 3.8.

It is also possible to build gr-satellites from source, which is easy to do on Linux systems, and perhaps also macOS, but not in Windows.

Finally, there are a number of distributions that provide their own packages for gr-satellites:

- [Arch Linux](#), through the AUR
- [Debian Linux](#) (testing and unstable releases)
- [MacPorts](#)

INSTALLING FROM SOURCE

gr-satellites is a GNU Radio out-of-tree module, and can be installed as such, by building it from source in a system where GNU Radio is already installed. The general steps for installing gr-satellites from source include making sure that all the dependencies are installed and then building and installing the out-of-tree module.

3.1 Dependencies

gr-satellites requires [GNU Radio](#) version at least 3.8. Depending on the GNU Radio version, a different branch of gr-satellites should be used. See the [gr-satellites README](#) for more information about the different branches.

Warning: There are some build dependencies for GNU Radio out-of-tree modules that are not required to run GNU Radio, so some distributions might not install them by default when GNU Radio is installed. The main ones that may cause problems are:

- swig (only for GNU Radio 3.8)
- liborc (in Debian-based distributions `liborc-0.4-dev` is needed)
- libsndfile (only for GNU Radio 3.9 and greater; in Debian-based distributions `libsndfile1-dev` is needed).
- spdlog (only for GNU Radio 3.10 and greater; in Debian-based distributions `libspdlog-dev` is needed).

Additionally, the following Python packages are required:

- [construct](#), at least version 2.9.
- [requests](#)
- [websocket-client](#)

Note: `construct` and `requests` can be installed with [pip](#) by doing

```
$ pip3 install --user --upgrade construct requests
```

Alternatively, `construct` and `requests` can be installed from your distribution's package manager.

3.2 Optional dependencies

To use the realtime image decoders, gr-satellites needs [feh](#)

Note: feh is best installed through your distribution's package manager

The decoders that use Mobitex or Mobitex-NX require the GNU Radio out-of-tree module `gr-tnc_nx`, which can be found in [beesat-sdr](#) (note that the `maint-3.8` branch is the one which supports GNU Radio 3.8).

3.3 Downloading

gr-satellites is developed in the [daniestevez/gr-satellites](#) Github repository. It is recommended that you download the [latest stable release](#). You can also browse the list of [all releases](#) to see older versions and pre-releases.

Users interested in collaborating with testing or developing gr-satellites can clone the git repository and use the main branch. There is more information about the organization in branches in the [README](#).

3.4 Building and installing

gr-satellites can be built and installed using cmake. The following can be run inside the directory containing the gr-satellites sources:

```
$ mkdir build
$ cd build
$ cmake ..
$ make
$ sudo make install
$ sudo ldconfig
```

After running make, you can run the tests by doing `make test` in the `build/` directory.

Note: There are systems where the AO-73 and similar decoders fail to decode correctly if `volk_profile` has not been run ever in the system. This seems to be caused by the Viterbi decoder chosen by Volk by default when there is no `~/.volk/volk_config` file. If problems with these decoders are seen, it is recommended to run `volk_profile` to see if it fixes the problems. Additionally, it is recommended to check if in `~/.volk/volk_config` there is a line that contains `volk_8u_x4_conv_k7_r2_8u_avx2 avx2` and replace both occurrences of `avx2` by either `spiral` or `generic`.

3.5 PYTHONPATH

After installing gr-satellites, it is necessary to ensure that Python is able to locate the gr-satellites Python module. Depending on the configuration of Python and the location where gr-satellites has been installed, it might be necessary to set the PYTHONPATH environment variable.

If Python is not able to locate the gr-satellites module, it will produce an error like this:

```
ModuleNotFoundError: No module named 'satellites'
```

Often, gr-satellites is installed into /usr/local/lib/python3/dist-packages/ or a similar directory, in a subdirectory called satellites. Therefore,

```
$ export PYTHONPATH=/usr/local/lib/python3/dist-packages/
```

can be used to allow Python to find the gr-satellites module. More information about the PYTHONPATH can be found in Python's documentation description of the [PYTHONPATH](#).

Note: A permanent configuration of the PYTHONPATH can be added to a script such as ~/.bashrc or ~/.bash_profile. This applies the correct PYTHONPATH when gr_satellites or gnuradio-companion are run from a bash session. If gnuradio-companion is run directly from the graphical environment, then it is necessary to set the PYTHONPATH in xinitrc or xprofile. See the [Arch Linux documentation on environment variables](#) for more information,

3.6 Downloading sample recordings

The satellite-recordings/ directory is a [git submodule](#) that contains many short sample recordings of different satellites that can be used to test the decoders. From a clone of the gr-satellites git repository, the submodule can be cloned (downloaded) by running

```
$ git submodule update --init
```

inside the gr-satellites/ directory.

Alternatively, it is possible to run

```
$ git clone --recursive https://github.com/daniestevez/gr-satellites
```

when cloning the gr-satellites repository to download both gr-satellites and the satellite-recordings submodule.

The satellite-recordings sample recordings can also be downloaded from its [own git repository](#), which is necessary if gr-satellite has not been installed from the git repository.

INSTALLING USING CONDA

gr-satellites and GNU Radio can also be installed using [conda](#), in Linux, macOS, and Windows. Conda is a multi-platform open-source package management system that can install packages and their dependencies in different virtual environments, independently from the rest of the packets installed in the OS. Using conda is the easiest and recommended way of installing gr-satellites in Windows.

This section shows how to install [miniconda](#), GNU Radio, and gr-satellites from scratch.

More details about installing GNU Radio with conda can be found in the *CondaInstall_* page of the GNU Radio wiki.

4.1 Miniconda

[Miniconda](#) is a minimal installer for conda, so it is the recommended way to get GNU Radio and gr-satellites quickly running in an OS that does not have conda already installed. Miniconda can be installed by downloading and running the installer for the appropriate platform from Miniconda's page. The installer can be run as a regular user. It does not need root access.

After installing Miniconda, its (base) virtual environment will be active by default. This means that (base) will be shown at the beginning of the command line prompt and software will be run from the version installed in the (base) virtual environment (when it is installed), and otherwise from the OS.

Users might prefer to run things from the conda virtual environment only upon request. To disable the activation of the (base) environment by default, we can run

```
$ conda config --set auto_activate_base false
```

When the (base) environment is not enabled by default, we can enter it by running

```
$ conda activate base
```

and exit it by running

```
$ conda deactivate
```

When the (base) environment is activated, the prompt will start by (base). The (base) environment needs to be activated in order to install applications through conda into this environment, and also to run applications that have been previously installed in this environment.

4.2 GNU Radio

To install GNU Radio, the (base) environment (or another conda virtual environment) needs to be activated as described above. Installing GNU Radio and all its dependencies is as simple as doing

```
$ conda install -c conda-forge gnuradio
```

Then GNU Radio may be used normally whenever the virtual environment where it was installed is activated. For instance, it is possible to run

```
$ gnuradio-companion
```

4.3 gr-satellites

gr-satellites needs to be installed into a virtual environment where GNU Radio has been previously installed (the (base) environment, if following the instructions here). To install gr-satellites and its dependencies, we do

```
$ conda install -c conda-forge gnuradio-satellites
```

After installation, the `gr_satellites` command line tool might be run as

```
$ gr_satellites
```

(provided that the virtual environment where it was installed is activated) and blocks from gr-satellites may be used in GNU Radio companion.

It might be convenient to download the *sample recordings* manually.

4.4 Acknowledgments

Thanks to [Ryan Volz](#) and [Petrus Hyvönen](#) for their work in putting together recipes to install gr-satellites and its dependencies through Conda and for helping me make gr-satellites build on Windows.

INSTALLING FROM THE UBUNTU PPA

The [Ubuntu PPA](#) is an easy way to install the latest version of gr-satellites in Ubuntu 20.10 and later.

To use the PPA, it must first be added to the system by doing

```
$ sudo add-apt-repository ppa:daniestevez/gr-satellites  
$ sudo apt-get update
```

Then gr-satellites can be installed by doing

```
$ sudo apt-get install gr-satellites
```


OVERVIEW

gr-satellites can be used in different ways depending on the experience of the user and the desired degree of customization. This section gives an overview of the possibilities.

6.1 Command line tool

The main way of using gr-satellites is through the `gr_satellites` command line tool. This allows users to decode the satellites officially supported by gr-satellites by using a command line tool. Decoding options can be specified as command line parameters. The tool supports processing both RF samples streamed in real-time from an SDR receiver or a conventional radio connected to the computer's soundcard, and recordings in different formats.

The command line tool is the most simple way of using gr-satellites and so it is recommended as the starting point for beginners. The usage of this tool is described in depth in the *gr_satellites command line tool* section.

6.2 Satellite decoder block

The Satellite decoder block gives most of the functionality of the `gr_satellites` command line tool encapsulated as a GNU Radio block.



Fig. 1: Satellite decoder GNU Radio block

It can be included in any kind of *GNU Radio Companion* flowgraphs and it can be used to achieve a greater degree of customization and flexibility than what it is possible with the command line tool.

The input to the Satellite decoder block may be pre-processed freely using GNU Radio blocks. The decoded frames are output as PDUs and can be handled in any manner by the user's flowgraph.

The Satellite decoder block is recommended for users who are already familiar with the command line tool and want a higher degree of customization. Its usage is described in the *Satellite decoder block* section.

6.3 Components

Components are the high level blocks in which gr-satellites is structured. Briefly speaking, the decoding chain is split into different tasks and the `gr_satellites` command line tool and Satellite decoder block perform decoding by selecting and connecting the appropriate components for each of these tasks depending on the satellite selected by the user.

The architecture of components is described in more detail in the [Components](#) section. They can be used as GNU Radio Companion blocks to customize decoders further than what is allowed by the Satellite decoder block. Additionally, they can be useful to build receivers for other RF communication protocols.

Users interesting in learning how the decoding process works or in adding new decoders to gr-satellites should be familiar with components.

6.4 Low level blocks

Finally, gr-satellites has a large number of lower level GNU Radio Companion blocks that may be useful in many different situations. Usage of these low level blocks is recommended only for users already familiar with gr-satellites or GNU Radio.

6.5 Utilities

Besides the `gr_satellites` command line tool and the GNU Radio blocks, gr-satellites also contains a few [Miscellaneous utilities](#) that can be used with some of the satellites.

GR_SATELLITES COMMAND LINE TOOL

The `gr_satellites` command line tool is a complete solution that can decode frames using either real-time RF samples from an SDR or conventional radio, or a recording.

7.1 Basic usage

`gr_satellites` can be run from a terminal after `gr-satellites` has been installed. If run without any arguments, `gr_satellites` will only print some basic information about the arguments it allows.

```
$ gr_satellites
usage: gr_satellites satellite [-h] [--version] [--list_satellites]
                                [--ignore_unknown_args]
                                [--satcfg]
                                (--wavfile WAVFILE | --rawfile RAWFILE | --rawint16 RAWINT16_
→ | --audio [DEVICE] | --udp | --kiss_in KISS_IN)
                                [--samp_rate SAMP_RATE]
                                [--udp_port UDP_PORT] [--iq] [--udp_raw]
                                [--input_gain INPUT_GAIN]
                                [--start_time START_TIME] [--throttle]
                                [--kiss_out KISS_OUT] [--kiss_append]
                                [--kiss_server [PORT]]
                                [--kiss_server_address KISS_SERVER_ADDRESS]
                                [--zmq_pub [ADDRESS]] [--hexdump]
                                [--dump_path DUMP_PATH]
```

7.1.1 Specifying the satellite

The arguments that `gr_satellites` allows depend on the satellite that has been selected. Therefore, to use `gr_satellites` it is always necessary to specify the `satellite` to be used as an argument immediately following `gr_satellites`. There are three different ways to specify the satellite:

- Using the satellite name, such as *FUNCube-1* or *LilacSat-2*. This can be used with any *satellite officially supported by gr-satellites*, and it is the most simple way of specifying a satellite.

```
$ gr_satellites FUNCube-1
```

A satellite may have several different names, known as *alternative names*. For example, FUNCube-1 is both known as AO-73 and FUNCube-1.

- Using the satellite **NORAD ID**. This can be used with any *satellite officially supported by gr-satellites*, and it can be useful when interfacing gr_satellites with other tools that use NORAD IDs to classify satellites.

Below we show gr_satellites running with NORAD ID 39444, which corresponds to FUNcube-1.

```
$ gr_satellites 39444
```

- Using a path to an .yaml SatYAML file. SatYAML files are used by gr-satellites to specify the decoding parameters and configuration corresponding to each different satellite. They are described in more detail in the *SatYAML files* section.

gr-satellites comes bundled with a large number of SatYAML files corresponding to all the officially supported satellites. They can be found in the python/satyaml/ directory.

Specifying the path of a SatYAML file is useful if the user has modified some of the files bundled with gr-satellites or has created their own ones.

```
$ gr_satellites python/satyaml/AO-73.yaml
```

7.1.2 Specifying the input source

Besides specifying the satellite to use for decoding, it is mandatory to specify the input source by using exactly one of the following options:

- `--wavfile` can be used to read a recording in WAV/OGG/FLAC format. This uses libsndfile through the GNU Radio WAV File Source block, so any format supported by libsndfile can be used. The sample rate is obtained from the file header, but it can be overridden using the `--samp_rate` argument if necessary.

By default, the WAV/OGG/FLAC file is interpreted as a one-channel file containing real RF samples. To read a two-channel file containing IQ RF samples, the `--iq` argument needs to be specified.

Note: All the *sample recordings* in the `satellite-recordings/` are real 48kHz WAV files and can be read with the `--wavfile file --samp_rate 48e3` arguments.

For example, this will decode some frames from FUNcube-1:

```
$ gr_satellites FUNcube-1 --wavfile satellite-recordings/ao73.wav
```

- `--rawfile` can be used to read a recording in `complex64` or `float32` format (depending on whether the `--iq` argument is used or not). The sample rate of the recording needs to be specified with the `--samp_rate` argument.

Note: Files in `complex64` format contain a sequence of 32-bit floating point numbers in IEEE 754 format. The sequence alternates between the I (in-phase) and Q (quadrature) components of a stream of IQ samples. This format is used by the GNU Radio File Source and File Sink blocks when their type is set to *complex*.

Files in `float32` format contain a sequence of 32-bit floating point numbers in IEEE 754 format. The sequence contains the elements of a stream of real samples. This format is used by the GNU Radio File Source and File Sink blocks when their type is set to *float*.

- `--rawint16` can be used to read a recording in `int16` format. The file is interpreted as IQ or real data according as to whether the `--iq` argument is used or not. The sample rate of the recording needs to be specified with the `--samp_rate` argument.

Note: Files in `int16` format contain a sequence of 16-bit integers in host endianness. This format is used by GNU Radio File Source and File Sink blocks when their type is set to *short*.

- `--audio` can be used to read samples from the soundcard, using GNU Radio's [Audio Source](#). This can be used to receive audio from a conventional radio by using the soundcard or from another application via a "virtual audio cable".

The sample rate to use needs to be specified with the `--samp_rate` argument. A sample rate of 48000 is typical with audio devices.

Both real samples (by default) and IQ samples (using the `--iq` argument) are supported. IQ samples use two audio channels (stereo).

The `--audio` argument can optionally be followed by the name of the audio device to use. Details about how to specify the device name vary between platform and are described in the [Audio Source](#) documentation. If no device name is entered, the default audio device will be chosen.

- `--udp` can be used to receive RF samples streamed in real-time. The sample rate of the recording needs to be specified with the `--samp_rate` argument.

The streaming format is the same as for the `--rawint16` and both real samples (by default) and IQ samples (using the `--iq` argument) are supported. If the `--udp_raw` is used the format will be the same as for `--rawfile`.

By default, `gr_satellites` will listen on the IP address `::` (all addresses) and the UDP port 7355. A different port can be specified using the parameter `--udp_port`.

Note: [GQRX](#) can stream audio in UDP using this format and UDP port, and a sample rate of 48ksps by following the instructions [here](#). In this case, `gr_satellites` should be run as

```
$ gr_satellites FUNcube-1 --udp --samp_rate 48e3
```

This is recommended as a simple way of interfacing `gr_satellites` with SDR hardware for beginner users.

It is also possible to use the example GNU Radio companion flographs in [gr-frontends](#) to stream samples by UDP from different sources.

For more advanced users, `nc` can also be a very useful tool for streaming.

- `--kiss_in` can be used to process a file containing already decoded frames in KISS format. All the demodulation steps are skipped and only telemetry parsing, file receiving, etc. are done.

This can be useful to view the telemetry stored in files previously decoded with `gr-satellites` or other software.

7.1.3 Getting help

`gr_satellites` prints a detailed description of all the allowed arguments by using the `-h` or `--help` argument. Note that a satellite needs to be specified, since the set of allowed arguments depends on the decoders used by that satellite.

For example, this shows all the options allowed by the FUNcube-1 decoder:

```
$ gr_satellites FUNcube-1 --help
usage: gr_satellites satellite [-h] [--version] [--list_satellites]
                                [--wavfile WAVFILE | --rawfile RAWFILE | --rawint16_
↳ RAWINT16 | --audio [DEVICE] | --udp | --kiss_in KISS_IN)
                                [--samp_rate SAMP_RATE]
```

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```

[--udp_port UDP_PORT] [--iq]
[--input_gain INPUT_GAIN]
[--start_time START_TIME] [--throttle]
[--kiss_out KISS_OUT] [--kiss_append]
[--kiss_server [PORT]]
[--kiss_server_address KISS_SERVER_ADDRESS]
[--zmq_pub [ADDRESS]] [--hexdump]
[--dump_path DUMP_PATH]
[--telemetry_output TELEMETRY_OUTPUT]
[--f_offset F_OFFSET] [--rrc_alpha RRC_ALPHA]
[--disable_fll] [--fll_bw FLL_BW]
[--clk_bw CLK_BW] [--clk_limit CLK_LIMIT]
[--costas_bw COSTAS_BW]
[--manchester_history MANCHESTER_HISTORY]
[--syncword_threshold SYNCWORD_THRESHOLD]
[--verbose_rs]

```

gr-satellites - GNU Radio decoders for Amateur satellites

optional arguments:

```

-h, --help          show this help message and exit
--version           show program's version number and exit
--list_satellites   list supported satellites and exit
--ignore_unknown_args Treat unknown arguments as warning
--satcfg            Use default options from sat.cfg for named satellite

```

input:

```

--wavfile WAVFILE    WAV/OGG/FLAC input file (using libsndfile)
--rawfile RAWFILE    RAW input file (float32 or complex64)
--rawint16 RAWINT16  RAW input file (int16)
--audio [DEVICE]     Soundcard device input
--udp                Use UDP input
--kiss_in KISS_IN     KISS input file
--samp_rate SAMP_RATE
                    Sample rate (Hz)
--udp_port UDP_PORT  UDP input listen port [default='7355']
--iq                 Use IQ input
--input_gain INPUT_GAIN
                    Input gain (can be negative to invert signal) [default=1]
--start_time START_TIME
                    Recording start timestamp
--throttle            Throttle recording input to 1x speed

```

output:

```

--kiss_out KISS_OUT  KISS output file
--kiss_append        Append to KISS output file
--kiss_server [PORT] Enable KISS server [default port=8100]
--kiss_server_address KISS_SERVER_ADDRESS
                    KISS server bind address [default='127.0.0.1']
--zmq_pub [ADDRESS]  Enable ZMQ PUB socket [default address=tcp://127.0.0.1:5555]
--hexdump            Hexdump instead of telemetry parse
--dump_path DUMP_PATH

```

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```

                                Path to dump internal signals

demodulation:
  --f_offset F_OFFSET    Frequency offset (Hz) [default=1500 or 12000]
  --rrc_alpha RRC_ALPHA  RRC roll-off (Hz) [default=0.35]
  --disable_fll          Disable FLL
  --fll_bw FLL_BW        FLL bandwidth (Hz) [default=25]
  --clk_bw CLK_BW        Clock recovery bandwidth (relative to baudrate) [default=0.06]
  --clk_limit CLK_LIMIT  Clock recovery limit (relative to baudrate) [default=0.02]
  --costas_bw COSTAS_BW  Costas loop bandwidth (Hz) [default=50]
  --manchester_history MANCHESTER_HISTORY
                        Manchester recovery history (symbols) [default=32]

deframing:
  --syncword_threshold SYNCWORD_THRESHOLD
                        Syncword bit errors [default=8]
  --verbose_rs           Verbose RS decoder

data sink:
  --telemetry_output TELEMETRY_OUTPUT
                        Telemetry output file [default=stdout]

```

The satellite parameter can be specified using name, NORAD ID or path to YAML file

7.1.4 Output

By default, `gr_satellites` will “do its best” to show the user the output for the decoded frames. If the telemetry format for the satellite is implemented in `gr-satellites`, the telemetry frames will be printed to the standard output in human-readable format. Otherwise, the raw frames will be printed out in hex format to the standard output.

File decoding, image decoding and other special output options of some particular satellites are enabled by default.

Customization of the output options is described in the [Output options](#) subsection below.

7.1.5 Examples

The `test.sh` script in the `gr-satellites/` directory runs `gr_satellites` on several of the *sample recordings* in `satellite-recordings/`. This script can be used as a series of examples of how to run `gr_satellites`.

7.2 Output options

This subsection explains in detail the different output options that can be used with the `gr_satellites` command line tool. The default behaviour when no options are specified has been described in the *Output* subsection above.

7.2.1 Hex dump

By using the option `--hexdump`, it is possible to make `gr_satellites` print the received frames in hexadecimal format, regardless of whether there is a telemetry decoder available or not. The format used to print the frames is the same as used by the GNU Radio block *Message Debug print_pdu* input.

An example of the use of this option can be seen here:

```
$ gr_satellites FUNcube-1 --wavfile ~/gr-satellites/satellite-recordings/ao73.wav \
--hexdump
* MESSAGE DEBUG PRINT PDU VERBOSE *
O
pdu_length = 256
contents =
0000: 89 00 00 00 00 00 00 00 00 1f cc 00 ce 02 d1 00
0010: 00 07 08 09 09 00 00 05 01 01 00 40 13 2f c8 f2
0020: 5c 8f 34 23 f3 ba 0b 5d 62 74 51 c7 ea fa 69 4a
0030: 9a 9f 00 09 ef a0 1f f4 a7 ea 4a c6 8f 11 40 11
0040: 1e 10 f7 01 3e 20 64 00 d7 8b f8 d7 94 c8 93 a8
0050: 2a da 52 a6 0e 58 0e c8 0f 4e 01 1d 20 5a 00 db
0060: 94 a8 aa 8a 98 13 ac 69 0a a6 a8 10 e6 10 92 0f
0070: b8 01 50 20 64 00 d7 96 a8 c1 8b 48 25 ab a9 ca
0080: ce 9d 10 76 0f c9 10 55 01 3a 20 5a 00 d7 97 29
0090: 08 8c 48 4f a9 6a 5a f2 a4 10 39 0f 7b 0f 86 01
00a0: 49 20 64 00 d7 94 08 d0 8a d8 2a ad 6a 5a 7e b4
00b0: 0e 53 0e 9b 0e b7 01 09 20 5a 00 db 99 a8 f2 8f
00c0: e8 38 af aa 8a c2 9e 0e de 0f 48 0e 31 01 31 20
00d0: 5a 00 ce 9b c8 ff 88 68 1b b2 6a 5a ca a7 0f c3
00e0: 0e 74 0e 58 01 34 20 5a 00 d7 9b 39 1b 97 b8 c5
00f0: b0 2b 3a d6 b5 01 6b 00 6a 02 9e 00 03 20 13 00
*****
```

7.2.2 KISS output

Decoded frames can be saved to a file in [KISS format](#). This is a simple format that serves to delimit frames stored in a file or sent over a serial bus, and it is frequently used to store telemetry frames.

To enable KISS output, the `--kiss_out` parameter followed by the path of the output file should be used. By default `gr_satellites` will overwrite the file if it already exists. To append to the file instead, the option `--kiss_append` can be used in addition to the `--kiss_out` option. Appending can be used to concatenate frames obtained in several decoding runs.

Files in KISS format can be read with `gr_satellites` as indicated above or with other software tools.

Note: KISS files produced with `gr_satellites` use an extension proposed by [Mike Rupprecht](#) to store the reception timestamp of the frames. Before each data frame, a KISS control frame using the control byte `0x09` and storing a timestamp with UNIX timestamp in milliseconds stored as a big-endian 64 bit integer is included in the file.

Some software, including the decoders by Mike Rupprecht, will be able to read and use these timestamps. Other software that processes KISS will ignore the timestamps.

7.2.3 KISS server

A KISS TCP server can be enabled with the `--kiss_server` parameter, optionally followed by the TCP port to listen on (by default port 8100 is used). This allows other applications to connect to `gr_satellites` and receive decoded frames using the KISS protocol.

By default the KISS server will only bind on `127.0.0.1` and listen to requests from localhost only. If access from other computers on the network is needed, the `--kiss_server_address` parameter can be used to specify the address to bind to. For instance, if `--kiss_server_address ''` or `--kiss_server_address 0.0.0.0` is used, the server will bind to `0.0.0.0` and listen to requests from all addresses.

7.2.4 ZMQ PUB socket

Decoded frames can also be sent to other applications by using a [ZeroMQ](#) PUB socket. Several applications can connect to the PUB socket using SUB sockets. The frames are sent using the *ZMQ PUB Message Sink* GNU Radio block, and can be received using the *ZMQ SUB Message Source* GNU Radio block.

The ZMQ PUB socket is enabled using the `--zmq_pub` parameter, optionally followed by the socket endpoint to use. By default, the endpoint `tcp://127.0.0.1:5555` is used. This means that the ZMQ PUB socket will only listen to connections from localhost. If desired, the endpoint `tcp://*:5555` can be used to listen on all addresses.

7.2.5 Telemetry output

For satellites supporting telemetry parsing, `gr_satellites` will default to printing the decoded telemetry values to the standard output. It is possible to write these messages to a file instead by using the `--telemetry_output` parameter followed by the path of the output file.

7.2.6 Dump internal signals

For advanced users and developers, the demodulators used in `gr_satellites` can dump the internal signals used inside the demodulator. This option can be enabled by using the `--dump_path` parameter followed by a path to the directory where the different files are created. It is recommended to use this option with a short recording, to avoid creating very large files. The details of each of these files are best studied in the Python source code of the demodulators (see `python/components/demodulators/`).

The following example show how to use `--dump_path` to plot the symbols with `Numpy` and `Matplotlib` and optimize the decoding parameters for a particular recording. We first run the following to dump to the path `/tmp/fsk` the internal signals produced by decoding a sample recording of AU02.

```
$ mkdir -p /tmp/fsk
$ gr_satellites AU02 --wavfile satellite-recordings/au02.wav \
  --dump_path /tmp/fsk
```

We see that we do not get any decoded packets. Then, we can plot the FSK symbols with the following Python code:

```
import numpy as np
import matplotlib.pyplot as plt

x = np.fromfile('/tmp/fsk/clock_recovery_out.f32', dtype = 'float32')
plt.plot(x, '.')
plt.show()
```

This produces the figure below, which shows that there has been a clock cycle slip mid packet, which prevents correct decoding.

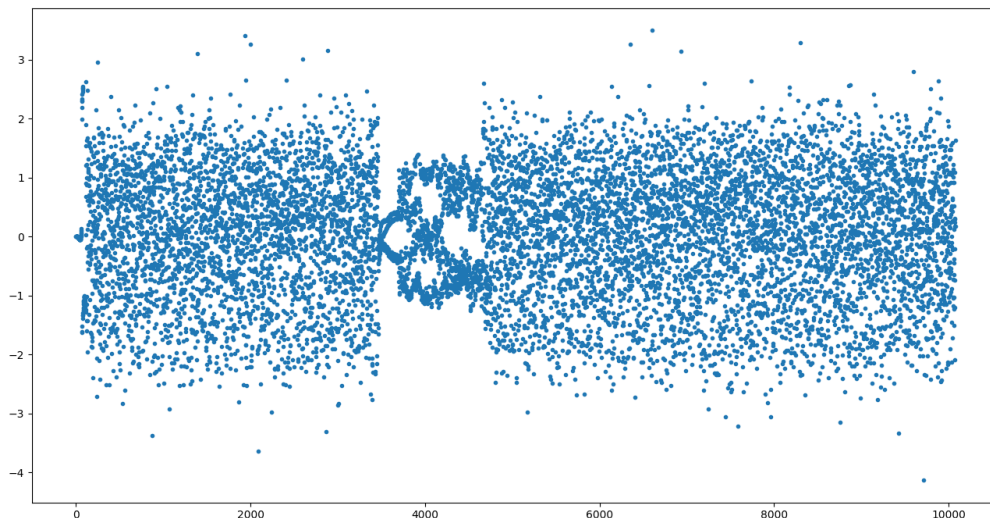


Fig. 1: FSK symbols with default parameters

We can run `gr_satellites` again adding the parameter `--clk_bw 0.1` to increase the clock recovery loop bandwidth. With this parameter we get a successful decode and if we plot the FSK symbols again, we get the figure below, which shows that the clock recovery is working much better than before.

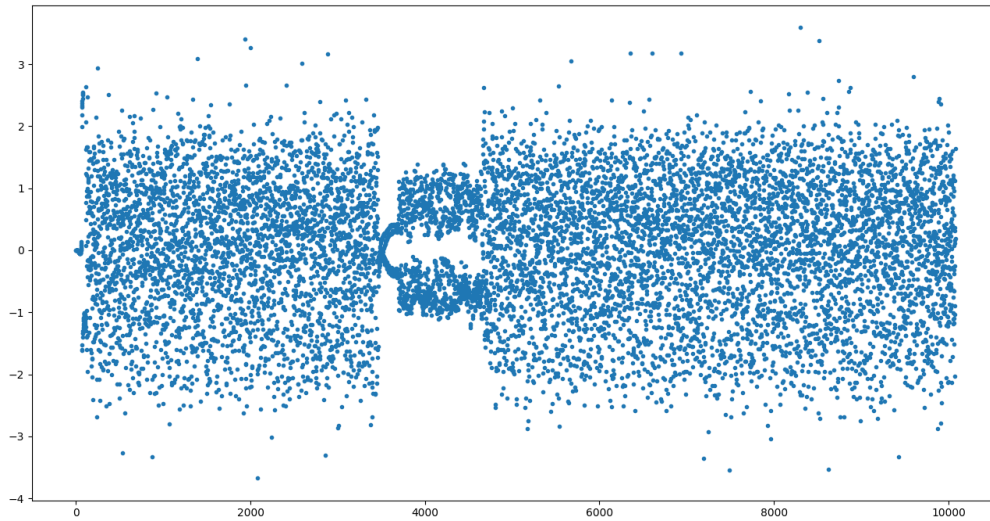


Fig. 2: FSK symbols with non-default parameters

7.3 Telemetry submission

The `gr_satellites` command line tool can be used to submit decoded telemetry to an online database server, such as [SatNOGS DB](#) and these others servers used by certain satellite projects:

- [FUNcube Warehouse](#), which is used by the FUNcube payloads on FUNcube-1, UKube-1, Nayif-1 and JY1Sat.
- [PW-Sat2 Groundstation](#), which is used by PW-Sat2.
- The [BME telemetry server](#), which is used by SMOG-P, ATL-1 and SMOG-1. (This server is deprecated, since it is not used anymore by BME).
- The [BME telemetry server \(WebSocket\)](#), which is used by MRC-100.
- [Harbin Institute of Technology](#), which connects to the telemetry proxy included in `gr-lilacsat` and `gr-dslwp`.
- Any custom server using the SIDS protocol. The [SIDS protocol](#) is an HTTP-based protocol that was first developed by the ESTCube team and later used by the UWE-3 team. It is the basis of the SatNOGS DB server and other telemetry servers.

To enable telemetry submission, it is necessary to edit some parameters in `gr_satellites`'s config file, which is located in `~/.gr_satellites/config.ini`. If this file does not exist, it will be created with a template when `gr_satellites` is first run. The template looks like this:

```
[Groundstation]
callsign =
latitude = 0
longitude = 0
submit_tlm = no

[FUNcube]
site_id =
```

(continues on next page)

(continued from previous page)

```
auth_code =  
  
[PW-Sat2]  
credentials_file =  
  
[BME]  
user =  
password =
```

To enable telemetry submission, the `submit_tlm` parameter must be set to `yes`. Additionally, the receiving stations `callsign` as well as its location (`latitude` and `longitude`) need to be set, since some of the servers need these parameters. Once this is done, telemetry submission to SatNOGS DB will be enabled for all satellites.

To enable telemetry submission to the FUNcube warehouse, it is necessary to fill in the `site_id` and `auth_code`. These can be obtained by [registering in the warehouse](#).

To enable telemetry submission to the PW-Sat2 server, it is necessary to enter the path to the credentials file in the `credentials_file` parameter. This file is a JSON file that is generated and downloaded in the “[Your credentials](#)” section of the server web interface. It is necessary to have an account registered in the server to obtain the credentials file.

To enable telemetry submission to the BME server, it is necessary to [register an account in the BME server](#). The user and password should be entered into the `gr-satellites .ini` file.

The BME server (WebSocket) does not require any registration or additional configuration.

To use the Harbin Institute of Technology proxy to submit telemetry, the proxy needs to be run and started in the local computer before running `gr_satellites`. The command line tool will connect to the correct port where the proxy is listening (this is specified in the SatYAML file of each satellite). All the configuration regarding the station and the operator is done in the proxy itself. When `gr_satellites` starts, it will attempt to connect to the proxy, and print a warning if unable (in which case telemetry submission through the proxy is disabled for this run).

Note: The Harbin Institute of Technology proxy is a Python2 application that uses PyQt4. Users having more modern systems may find useful the PyQt5 version that can be found in the [pyqt5 branch of gr-lilacsat](#). This requires `tornado` version 4.5.3. It will not work with more recent versions of `tornado`.

No special configuration needs to be done to enable submission to custom SIDS servers, since these use the same protocol and configuration as SatNOGS DB.

For some telemetry servers, including SatNOGS DB, the frames are submitted together with a timestamp of reception. This timestamp is taken from the computer’s clock by `gr_satellites` at the moment when it decodes the frame. This means that, in order to use telemetry submission appropriately, the computer’s clock should be set accurately and a live signal rather than a recording should be decoded.

7.4 File and image receiver

Some satellites transmit files (especially image files) by splitting the files into many telemetry packets. The `gr_satellites` decoder supports reassembling and storing these files into a directory. Additionally, image files are automatically displayed in real time as they are being received, using [feh](#).

Currently the satellites that have decoders supporting file reception are ATL-1 and SMOG-P (they transmit RF spectrum data), and the satellites that have decoders supporting image reception are 1KUNS-PF, BY70-1, D-SAT, LilacSat-1, Lucky-7 and Światowid.

For satellites supporting file reception, the `--file_output_path` parameter can be used to set the directory that is used to store received files. The filenames of the received files will be automatically created using metadata or a counter (if no metadata is transmitted). By default, received files are stored in `/tmp/`.

The `--verbose_file_receiver` parameter can be used to enable additional debugging information about the functionality of the file receiver.

7.5 Other topics

This subsection deals with other topics which are relevant to the usage of `gr_satellites`.

7.5.1 Real or IQ input

The `gr_satellites` command line tool supports both real (one-channel) input and IQ input (which consists of two channels: in-phase and quadrature). A detailed description of these two ways to represent a signal is out of the scope of this document. This subsection gives some practical advice regarding the difference between real and IQ input.

By default `gr_satellites` will assume that its input is real. To use IQ input, the `--iq` option must be used.

When using the audio output of either a conventional radio or an SDR software performing SSB or FM demodulation, `gr_satellites` should be used with the real input option. Likewise, recordings produced from this kind of audio output, such as one-channel WAV recordings should also be used with the real input option.

However, most SDR softwares will also have an option to save raw samples to a file. These files are almost always IQ, and can be either a two-channel WAV file or a file in raw format. The IQ input option must be used when using `gr_satellites` to read these files. Additionally, some SDR software may support streaming IQ data by UDP. This can also be used in `gr_satellites` with the IQ input option.

7.5.2 FSK demodulation and IQ input

When using an AFSK or FSK demodulator, the usage of the `--iq` option has an additional effect. Since (A)FSK is a mode based on frequency modulation, it is common to use either a conventional FM radio or an SDR software performing FM demodulation to receive (A)FSK. Audio recordings obtained in this manner are also common. Therefore, when `gr_satellites` is run without the `--iq` signal, it will expect that (A)FSK signals have already been FM-demodulated in this way.

When the `--iq` option is used, `gr_satellites` expects an (A)FSK signal that has not been FM-demodulated, and so it will perform FM-demodulation first. This is the kind of procedure that should be employed with inputs such as raw IQ recordings of an SDR, since the (A)FSK signals present in this kind of recordings have not been FM-demodulated.

Note: The output of the radio or SDR software when running in FM mode to receive an FSK signal is actually an NRZ signal. Therefore, when `gr_satellites` is run without the `--iq` option, it will expect an NRZ signal instead of an FSK signal. When `gr_satellites` is run with the `--iq` option, it will expect an FSK signal.

Similarly, the output of the radio or SDR software when running in FM mode to receive an AFSK signal is actually an audio-frequency FSK signal. Therefore, when `gr_satellites` is run without the `--iq` option, it will expect an audio-frequency FSK signal instead of an AFSK signal. When `gr_satellites` is run with the `--iq` option, it will expect an AFSK signal.

Note that this behaviour is what the user wants in most cases, but it also means that it is not possible to run `gr_satellites` directly on an (A)FSK signal which is represented in intermediate frequency as a real signal.

7.5.3 Frequency offsets for BPSK

A usual way of receiving a BPSK signal is to use either a conventional radio or an SDR software in SSB mode (USB mode, normally) and tune the BPSK signal in the middle of the audio passband. Audio recordings obtained in this manner are also common.

Note: The SSB filter of a conventional radio is often approximately 3kHz wide. For this reason, only BPSK signals with a baudrate of 2400 baud or lower can be received with a conventional SSB radio. For BPSK signals with larger baudrate, an SDR receiver should be used.

The `gr_satellites` command line tool needs to know the frequency at which the BPSK signal is tuned within the audio passband. If necessary, this can be specified with the `--f_offset` parameter, followed by the frequency in Hz. There are the following defaults:

- For signals with a baudrate of 2400 baud or less, a frequency offset of 1500 Hz is used. This follows the common practice of using a regular 3kHz SSB bandwidth and tuning the signal in the middle of the passband.
- For signals with a baudrate larger than 2400, a frequency offset of 12000 Hz is used. The rationale is that, for best results, a passband of 24000 Hz should be used, since this is the largest that fits in a 48kHz audio signal, and the signal should be tuned in the middle of this 24000 Hz passband. This kind of usage is sometimes called “wide SSB mode”.

These settings only apply for a real input. When `gr_satellites` is used with IQ input, the default is to expect the BPSK signal tuned at 0Hz (i.e., at baseband). A different frequency can still be selected with the `--f_offset` parameter.

7.5.4 FSK signal polarity

A conventional FM radio, or even an SDR software running in FM mode might invert the polarity of the output signal, since the polarity is not relevant for audio signals. However, the polarity is relevant when receiving an FSK signal that does not use differential coding.

An input with the inverted polarity will cause decoding to fail. In this case, the input can be inverted again by using the `--input_gain -1` parameter, which has the effect of multiplying the input signal by -1 before it is processed, thus restoring the correct polarity.

7.5.5 Multiple transmitters

Some satellites have multiple transmitters (or different types of signals) declared in their *SatYAML files*. When run for these satellites, the `gr_satellites` command line tool will run decoders for all the transmitters or signal types in parallel. Therefore, it is not necessary or possible to specify the transmitter to use.

In the case when it is necessary to run only the decoder for a single transmitter, the easiest solution is to make a copy of the SatYAML file for that satellite, edit the copy to leave out only the desired transmitter, and then running `gr_satellites` and indicating it to use the modified SatYAML file.

7.5.6 Getting correct timestamps with recordings

One of the difficulties with working with recordings is obtaining correct timestamps for each of the decoded packets. These timestamps are included in KISS files and telemetry submissions to some servers, such as SatNOGS DB. To produced correct timestamps `gr_satellites` will play back the recording at 1x speed and count the clock time elapsed since the beginning of the execution, it will then add that time to a timestamp specified by the user, which should correspond to the start of the recording.

To use this functionality it is necessary to use the `--throttle` parameter to limit playback speed to 1x and use the `--start_time` parameter followed by the timestamp in ISO 8601 format (YYYY-MM-DDTHH:MM:SS) to indicate the start time of the recording.

7.5.7 Treating unknown args as warning

Using the argument `--ignore_unknown_args` will change the behaviour on unknown arguments to a warning instead of exiting with an error. This can be useful when running in automated scripts and some options may not be available on that satellite. For example the `--f_offset` and `--use_agc`

7.5.8 Using sat.cfg for default arguments

With `--satcfg` the configuration file `~/.gr_satellites/sat.cfg` will be read and arguments added automatically to the command line. Some of these can be overridden with specifying them on the command line again. The format of the file is one row per satellite, first the norad ID then the rest of the row is treated as arguments.

Example:

```
39444 --f_offset 12000
46276 --disable_dc_block --deviation 500 --clk_bw 0.15
35933 --clk_bw 0.3
```


SATELLITE DECODER BLOCK

The Satellite decoder block brings most of the functionality of the `gr_satellites` command line tool in the form of a GNU Radio block. This allows the experienced user to leverage the functionality of the satellite decoders in their own designs or to achieve a greater degree of customization than what is possible with the command line tool.

The input of the Satellite decoder block is a stream of samples, which can be either real or complex, for IQ input (see [Real or IQ input](#)). The output of the block is PDUs with the decoded frames. The figure below shows a very basic use of the Satellite decoder block, where the input is taken from a WAV recording using the Wav File Source block and the output is printed using the Message Debug block. This example can be found in `gr-satellites` in `examples/satellite_decoder/satellite_decoder.grc`.

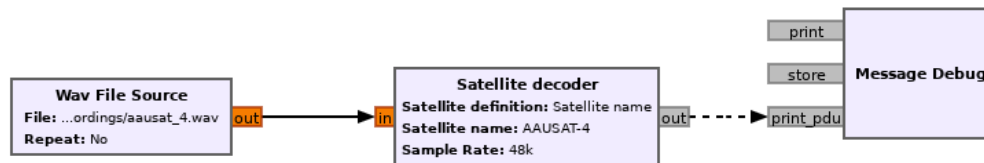


Fig. 1: Usage of Satellite decoder in a flowgraph

The figure below shows the options for the Satellite decoder block. It is possible to specify the satellite to use in the same ways as for the `gr_satellites` command line tool (see [Specifying the satellite](#)). The method to specify the satellite is chosen in the *Satellite definition* dropdown menu. The sample rate needs to be entered in the *Sample Rate* field, and the *IQ input* field selects real or IQ input. The *Command line options* field is described below.

Here are a few ideas of how the Satellite decoder block can be employed by users to build custom decoders which are not possible with the command line tool.

On the input side, it is possible to use all the standard GNU Radio blocks to support a large number of SDR hardware and recording formats. The different channeliser and filter blocks (especially “Frequency Xlating FIR Filter”) can be used to adapt the sample rate and bandwidth of the signal into something useful for the satellite decoder. For example, a wideband SDR might be used to receive the signal of different satellites, performing Doppler correction with `gr-gpredict-doppler`. The signals of these satellites might be channelised with a “Frequency Xlating FIR Filter” blocks and fed into independent Satellite decoder blocks.

On the output side, it is possible to treat the received PDUs freely. This allows classifying and storing them in different ways. Upper layer complex protocols might be completely handled inside the GNU Radio flowgraph, provided there is a suitable implementation of these protocols. Additionally, it is possible to interface the decoder to external tools with default GNU Radio blocks, by using TCP sockets or ZeroMQ.

The image shows a configuration window for the Satellite decoder. It has three tabs: 'General' (selected), 'Advanced', and 'Documentation'. Under the 'General' tab, there are four configuration items:

- Satellite definition:** A dropdown menu showing 'Satellite name'.
- Satellite name:** A text field containing 'AAUSAT-4'.
- Sample Rate:** A text field containing 'samp_rate'.
- IQ input:** A text field containing 'False'.
- Command line options:** A text field containing '""'.

At the bottom right of the window are three buttons: 'Aceptar', 'Cancelar', and 'Aplicar'.

Fig. 2: Options of Satellite decoder

8.1 Command line options

The satellite decoder block allows entering the same kind of command line options supported by the `gr_satellites` command line tool into the *Command line options* parameter of the block. The set of options to use needs to be specified as a Python script. To see the available options, it is possible to use `--help` as the options, just as one would do when using a command line tool. When the flowgraph is run, it will print out the allowable options and stop. In the same manner, if invalid options are specified, when the flowgraph is run it will print the correct usage and stop.

COMPONENTS

Components represent gr-satellite's way of decomposing the decoding process in high-level blocks. The decoding chain is broken into a series of steps which pass their output to the input of the next step. These are the following:

- **Data sources.** These produce the input of the decoding chain, which typically consists of RF signal samples.
- **Demodulators.** These turn RF samples into soft symbols. They filter the signal, recover the transmit clock and carrier if necessary, etc. An example is a BPSK demodulator, which turns RF samples of a BPSK signal into a stream of soft symbols.
- **Deframers.** Deframers implement the lower layer protocols related to frame boundary detection, descrambling, deinterleaving, FEC, error checking with a CRC code, etc. The output of a deframer are PDUs with the frames. Some examples are an AX.25 deframer and a CCSDS concatenated code deframer.
- **Transports.** Transports implement higher layer protocols that might be needed to get to the useful information inside the frames. For example, if frames are fragmented, a transport will handle defragmentation. An example is a KISS transport, whose input are frames that contain bytes of a KISS stream, and its output are the packets contained in that KISS stream, regardless of how they are split between different frames.
- **Data sinks.** Data sinks are the consumers of packets. They might store them, send them to another software, or parse telemetry values.

All the component blocks support *Command line options* in the same way as the satellite decoder block. The set of available options for each component block is different. It is possible to use the "--help" as the options of a particular block in order to print out the available options for that block.

Below, the main component blocks in each category are described.

9.1 Data sources

Data source components can be found under *Satellites > Data sources* in GNU Radio companion. Currently, the only data source is the "KISS File Source" block. This block will read a file in KISS format, and output the frames in the file as PDUs.

The usual operations involving reading RF samples from an SDR or recording can be achieved easily with default GNU Radio blocks, so there are no specific data sources for these. Advanced users can look at the `setup_input()` method of the class `gr_satellites_top_block` in `apps/gr_satellites` to see how the `gr_satellites` command line tools sets up its different inputs using default GNU Radio blocks.

9.2 Demodulators

Demodulator components can be found under *Satellites > Demodulators* in GNU Radio companion. There are currently three demodulator component blocks:

- BPSK demodulator
- FSK demodulator
- AFSK demodulator

They take RF signal samples as input, and output soft symbols, as a stream of `float` normalized with amplitude one. The input can be either real or IQ (complex). See *Real or IQ input* for more information.

The demodulator blocks and their parameters are described below.

9.2.1 BPSK demodulator

The BPSK demodulator expects an input which consists of RF samples of a BPSK signal, and outputs the demodulated BPSK soft symbols. The BPSK signal can optionally be DBPSK or Manchester encoded.

The figure below shows the example flowgraph which can be found in `examples/components/bpsk_demodulator.grc`. This reads a WAV file from *satellite-recordings* which contains some BPSK packets from LilacSat-1 and uses the BPSK demodulator to obtain the symbols. The “Skip Head” and “Head” blocks are used to select a portion of the output, which is then plotted using the “QT GUI Time Sink”.

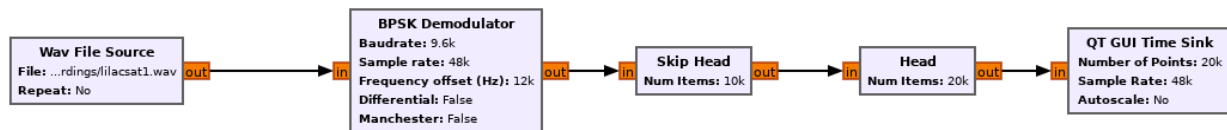


Fig. 1: Usage of BPSK demodulator in a flowgraph

When this example flowgraph is run, it displays the output shown in the figure below. There we can see the start of the BPSK packet. On the left side of the plot we have noise, before the packet starts, then the packet starts, and the clock and carrier recovery take some time to sync. After this, the symbols are demodulated properly. This can be seen because the +1 and -1 symbols are well separated.

The figure below shows the options allowed by the BPSK demodulator block. The *Baudrate* option is used to set the baudrate in symbols per second. The *Sample rate* option specifies the sample rate of the input. The *Frequency offset* specifies at which frequency the BPSK signal is centred (see *Frequency offsets for BPSK*).

The *Differential* option enables differential decoding of DBPSK. For differential decoding, the phase recovery using a Costas loop is disabled and non-coherent demodulation is used.

The *Manchester* option enables Manchester decoding. A Manchester encoded BPSK signal is decoded as if it had twice the baudrate, and then the phase of the Manchester clock is searched in the symbols and the Manchester clock is “wiped-off”, multiplying symbols by the clock and accumulating them by pairs.

The *IQ input* option enables IQ (complex) input.

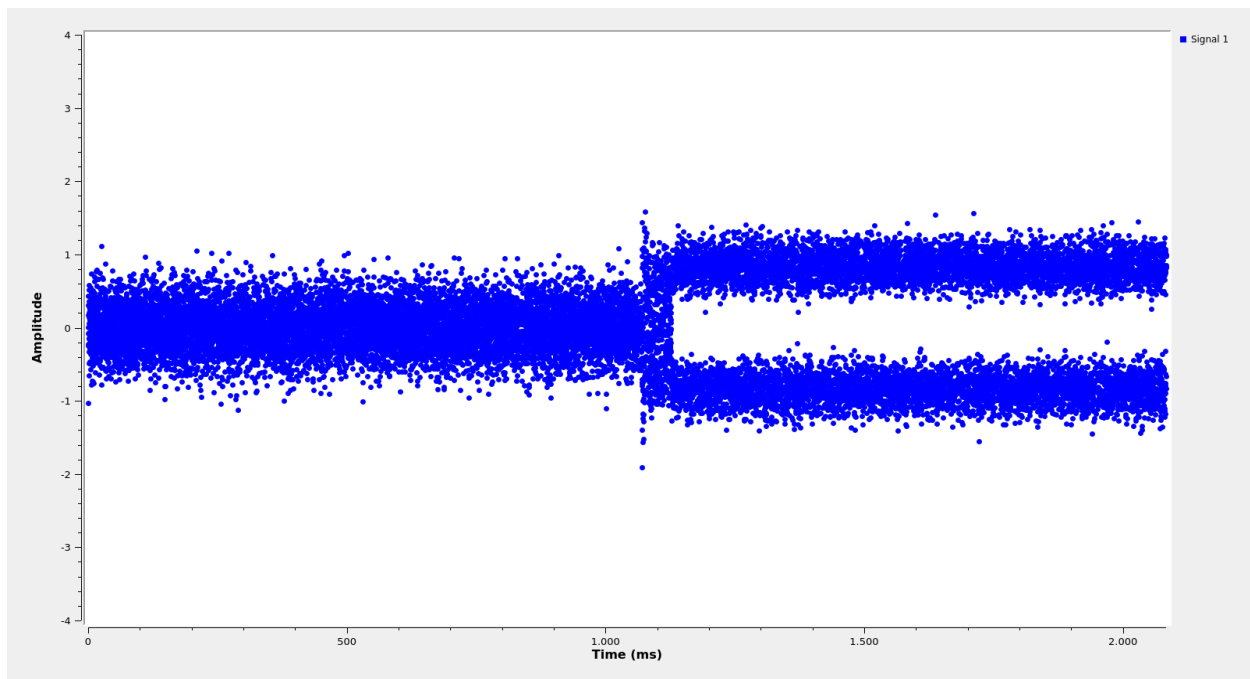


Fig. 2: Output of the BPSK demodulator example flowgraph

General	Advanced	Documentation
Baudrate	9600	
Sample rate	samp_rate	
Frequency offset (Hz)	12000	
Differential	False	
Manchester	False	
IQ input	False	
Command line options	""	

Acceptar Cancelar Aplicar

Fig. 3: Options of BPSK demodulator

9.2.2 FSK demodulator

The FSK demodulator expects an input which consists of RF samples of an FSK signal, and outputs the demodulated FSK soft symbols. Both real and IQ (complex) input are supported, but the semantics are different: with real input, the FSK demodulator expects an FM-demodulated signal; with IQ input, the FSK demodulator expects the signal before FM demodulation (see *FSK demodulation and IQ input*).

The figure below shows the example flowgraph which can be found in `examples/components/fsk_demodulator.grc`. This reads a WAV file from *satellite-recordings* which contains a single FSK packet from AAUSAT-4 and uses the FSK demodulator to obtain the symbols. The output is plotted using the “QT GUI Time Sink”.

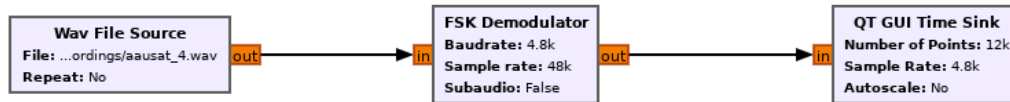


Fig. 4: Usage of FSK demodulator in a flowgraph

When this example flowgraph is run, it displays the output shown in the figure below. There we can see the FSK packet, surrounded by noise on both sides.

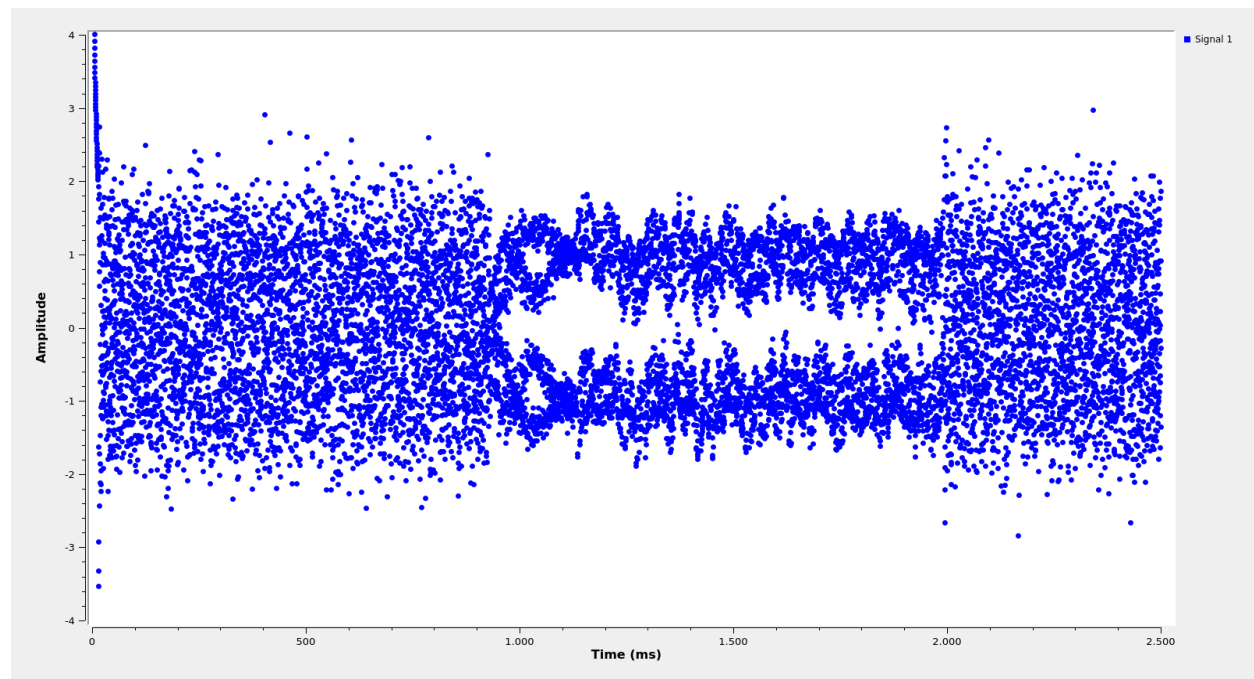


Fig. 5: Output of the FSK demodulator example flowgraph

The figure below shows the options allowed by the FSK demodulator block. The *Baudrate* option is used to set the baudrate in symbols per second. The *Sample rate* option specifies the sample rate of the input. The *IQ input* option enables IQ (complex) input. The signal is expected to be centred at baseband (0Hz) when IQ input is selected. The *Subaudio* option enables subaudio demodulation, which is intended for subaudio telemetry under FM voice and includes an additional lowpass filter to filter out the voice signal.

General	Advanced	Documentation
Baudrate	4800	
Sample rate	samp_rate	
IQ input	False	
Subaudio	False	
Command line options	""	

Fig. 6: Options of FSK demodulator

9.2.3 AFSK demodulator

The AFSK demodulator expects an input which consists of RF samples of an AFSK signal, and outputs the demodulated AFSK soft symbols. Both real and IQ (complex) input are supported, but the semantics are different: with real input, the AFSK demodulator expects an FM-demodulated signal; with IQ input, the AFSK demodulator expects the signal before FM demodulation (see [FSK demodulation and IQ input](#)).

The figure below shows the example flowgraph which can be found in `examples/components/afsk_demodulator.grc`. This reads a WAV file from [satellite-recordings](#) which contains a single AFSK packet from GOMX-1 and uses the AFSK demodulator to obtain the symbols. The “Head” block is used to select a portion of the output, which is then plotted using the “QT GUI Time Sink”.

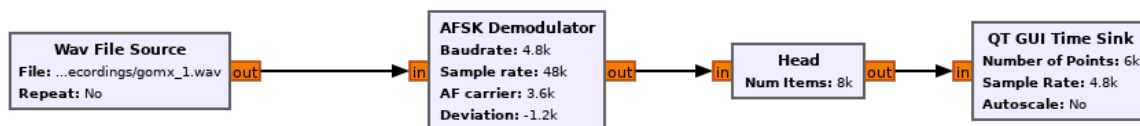


Fig. 7: Usage of AFSK demodulator in a flowgraph

When this example flowgraph is run, it displays the output shown in the figure below. There we can see the AFSK packet, surrounded by noise on both sides.

The figure below shows the options allowed by the AFSK demodulator block. The *Baudrate* option is used to set the baudrate in symbols per second. The *Sample rate* option specifies the sample rate of the input.

The *AF carrier* option specifies the audio frequency in Hz on which the FSK tones are centred. The *Deviation* option specifies the separation in Hz between each of the tones and the AF carrier. If the deviation is positive, the high tone is interpreted as representing the symbol 1, while the low tone is interpreted as representing the symbol 0 (or -1 in bipolar representation). If the deviation is negative, the low tone is interpreted as representing the symbol 1 and the high tone is interpreted as representing the symbol 0.

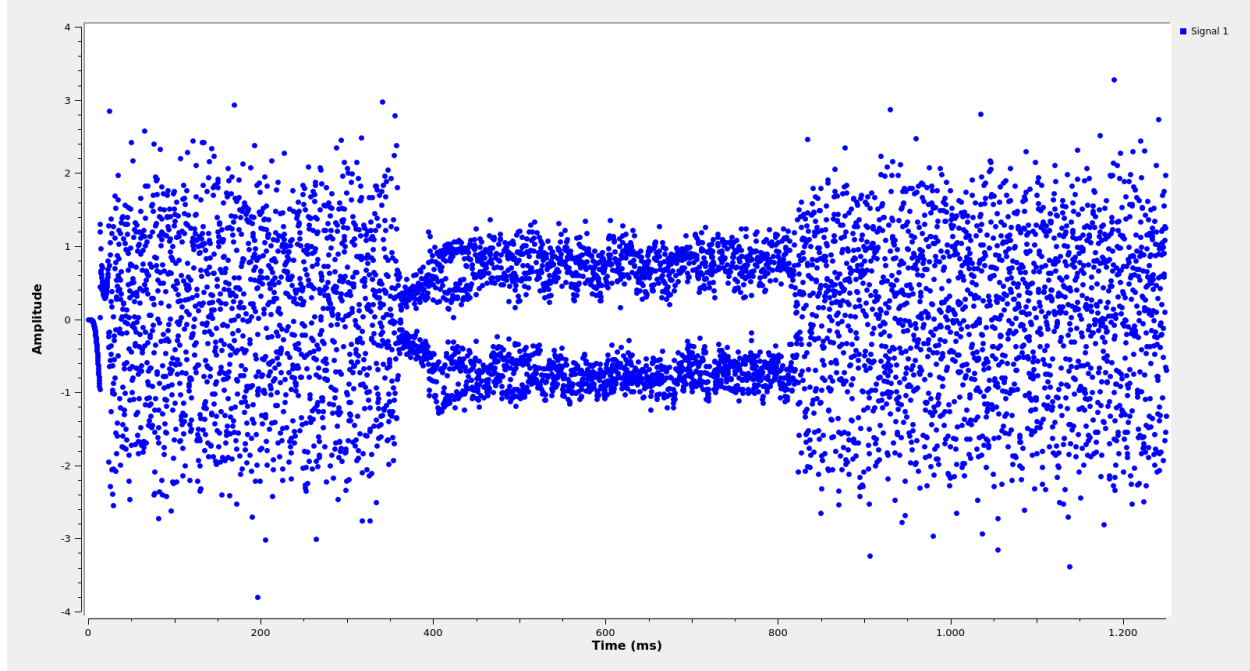


Fig. 8: Output of the AFSK demodulator example flowgraph

In this example, the AF carrier is 3600 Hz and the deviation is -1200 Hz. This means that the tone representing 1 is at 2400 Hz, while the tone representing 0 is at 4800 Hz (the signal is actually 4800 baud GMSK).

The *IQ input* option enables IQ (complex) input.

9.3 Deframers

Deframer components can be found under *Satellites > Deframers* in GNU Radio companion. There is a large number of deframer component blocks, since many satellites use ad-hoc protocols for framing, so a custom deframer is used for those satellites.

Deframers take soft symbols, produced as the output of one of the demodulator components, and detect frame boundaries, perform as necessary descrambling, deinterleaving, FEC decoding, CRC checking, etc.

Here, the most popular deframers are described. For ad-hoc deframers that are used in few satellites, the reader is referred to the documentation of each of the blocks in GNU Radio companion.

9.3.1 AX.25 deframer

The AX.25 deframer implements the [AX.25](#) protocol. It performs NRZ-I decoding, frame boundary detection, bit destuffing, and CRC-16 checking. Optionally, it can also perform G3RUH descrambling. G3RUH scrambling is typically used for faster baudrates, such as 9k6 FSK packet radio, but not for slower baudrates, such as 1k2 AFSK packet radio.

The figure below shows an example flowgraph of the AX.25 deframer block. This example can be found in `examples/components/ax25_deframer.grc`. The example reads a WAV file from *satellite-recordings* containing 9k6 FSK AX.25 packets from US01, demodulates them with the FSK demodulator block, deframes them with AX.25 deframer, and prints the output with the Message Debug block.

General	Advanced	Documentation
Baudrate	4800	
Sample rate	samp_rate	
AF carrier	3600	
Deviation	-1200	
IQ input	False	
Command line options	""	

Aceptar Cancelar Aplicar

Fig. 9: Options of AFSK demodulator

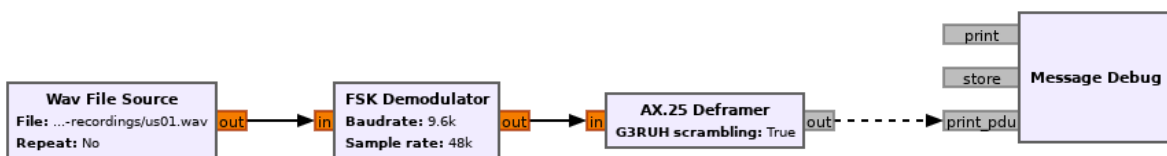


Fig. 10: Usage of AX.25 deframer in a flowgraph

The AX.25 deframer block has a single option that indicates whether G3RUH descrambling should be performed or not.

9.3.2 GOMspace AX100 deframer

The GOMspace AX100 deframer implements two different protocols used by the popular [GOMspace NanoCom AX100](#) transceiver. These two protocols are:

- **ASM+Golay.** This uses a header encoded with a Golay(24,12) code that indicates the packet length. The payload is Reed-Solomon encoded with a (255,223) CCSDS code and scrambled with the CCSDS synchronous scrambler.
- **Reed Solomon.** This uses a G3RUH asynchronous scrambler. The first byte of the packets indicates the length of the payload and is sent unprotected. The packet payload is Reed-Solomon encoded with a (255,223) CCSDS code.

The figure below shows an example flowgraph of the AX100 deframer block running in both modes. This example can be found in `examples/components/ax100_deframer.grc`. For ASM+Golay decoding the example reads a WAV file from [satellite-recordings](#) containing packets from 1KUNS-PF. For Reed Solomon decoding the example reads a WAV file from [satellite-recordings](#) which contains packets from TW-1B. The output frames are printed with Message Debug blocks.

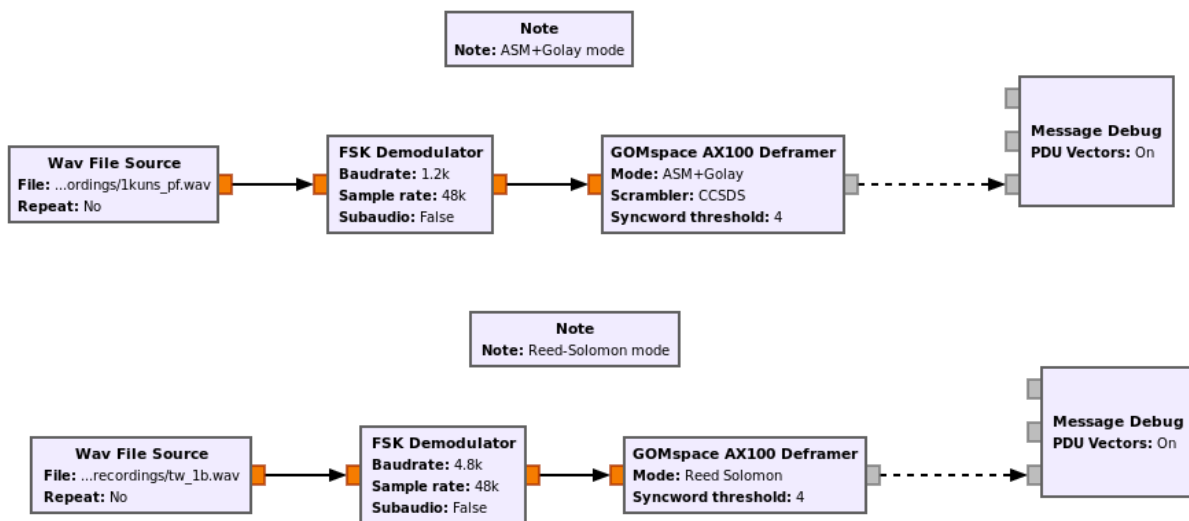


Fig. 11: Usage of AX100 deframer in a flowgraph

In Reed Solomon mode, the AX100 deframer only has two options: the *Mode* option indicates the mode, as described above, and the *Syncword threshold* option specifies how many bit errors are allowed in the detection of the 32 bit syncword. In ASM+Golay mode, the AX100 deframer has an additional option: *Scrambler*, which can be used to enable or disable the CCSDS synchronous scrambler.

9.3.3 GOMspace U482C deframer

The GOMspace U482C deframer implements the protocol used by the GOMspace NanoCom U482C transceiver, which is an older transceiver from GOMspace that is still seen in some satellites.

The protocol used by the U482C is similar to the ASM+Golay mode used by the AX100. The packet payload can be optionally:

- Encoded with the CCSDS $r=1/2$, $k=7$ convolutional encoder
- Scrambled with the CCSDS synchronous scrambler
- Encoded with a CCSDS (255,223) Reed-Solomon code

The packet header has flags that indicate which of these options are in use, in addition to the length field.

The U482C modem uses AFSK with a 4800 baud audio-frequency GMSK waveform.

The figure below shows an example flowgraph of the U482C deframer block. This example can be found in `examples/components/u482c_deframer.grc`. The example reads a WAV file from *satellite-recordings* containing a packet from GOMX-1. The packet is demodulated and deframed, and the output is printed in hex using the Message Debug block.

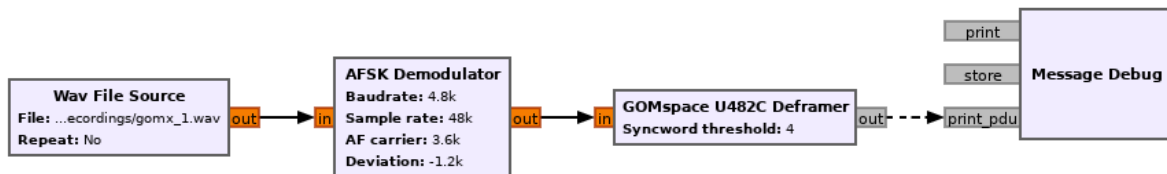


Fig. 12: Usage of U482C deframer in a flowgraph

The U482C deframer has a single option, which indicates the number of bit errors that are allowed in the syncword detection.

9.3.4 AO-40 FEC deframer

The AO-40 FEC deframer implements the protocol designed by Phil Karn KA9Q for the [AO-40 FEC beacon](#). This protocol is currently used in the FUNcube satellites and others.

The FEC is based on CCSDS recommendations and uses a pair of interleaved Reed-Solomon (160,128) codes, the CCSDS synchronous scrambler, the CCSDS $r=1/2$, $k=7$ convolutional code, interleaving and a distributed syncword.

The figure below shows an example flowgraph of the AO-40 FEC deframer block. This example can be found in `examples/components/ao40_fec_deframer.grc`. It reads a WAV file from *satellite-recordings* containing a packet from AO-73 (FUNcube-1). The packet is first BPSK demodulated and then deframed with the AO-40 FEC deframer. The output is printed out using the Message Debug block.

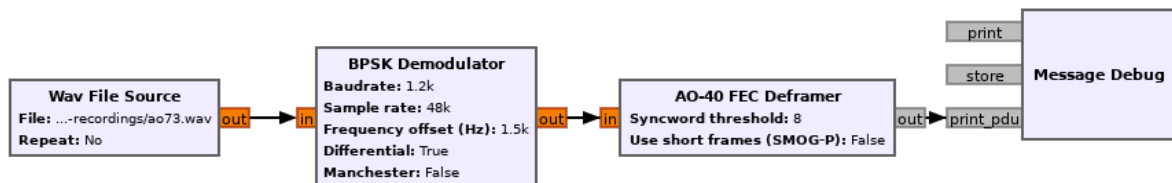


Fig. 13: Usage of AO-40 FEC deframer in a flowgraph

The AO-40 FEC deframer block has two options. The *Syncword threshold* option indicates the number of bit errors to allow in the syncword detection. The *Use short frames* option toggles the usage of short frames. This is a variant of the AO-40 FEC protocol which is based on a single Reed-Solomon codeword and is used by SMOG-P and ATL-1.

9.3.5 CCSDS deframers

The CCSDS Uncoded deframer, CCSDS Concatenated deframer, and CCSDS Reed-Solomon deframer blocks implement some of the CCSDS protocols defined in the TM Synchronization and Channel Coding Blue Book (see the [CCSDS Blue Books](#)).

The CCSDS Uncoded deframer implements uncoded TM frames.

The CCSDS Reed-Solomon deframer implements Reed-Solomon TM frames, which use a Reed-Solomon (255, 223) code (or a shortened version of this code) and the CCSDS synchronous scrambler. There is support for several interleave Reed-Solomon codewords.

The CCSDS Concatenated deframer implements concatenated TM frames, which add an $r=1/2$, $k=7$ convolutional code as an inner coding to the Reed-Solomon frames.

The usage of all three of these deframers is very similar.

The figure below shows an example flowgraph of the CCSDS Concatenated deframer block. This example can be found in `examples/components/ccsds_deframer.grc`. It reads a WAV file from [satellite-recordings](#) containing some packets from BY70-1. These are concatenated TM frames with a frame size of 114 bytes and differential encoding (to solve the BPSK phase ambiguity). The packet is first BPSK demodulated and then deframed. The output is printed using the Message Debug block.

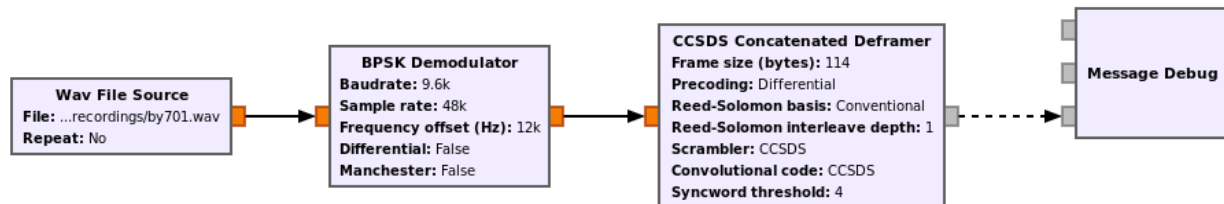


Fig. 14: Usage of CCSDS Concatenated deframer in a flowgraph

The figure below shows the options used by the CCSDS Concatenated deframer. The CCSDS Reed-Solomon deframer block allows exactly the same options, except for the *Convolutional code* option, since all the other options refer to the Reed-Solomon outer code.

The *Frame size* option indicates the size of the frame in bytes (after Reed-Solomon decoding). The *Precoding* option can be used enable a differential decoder before the Reed-Solomon decoder. This is often used to solve the BPSK 180° phase ambiguity. The *Reed-Solomon basis* option can be used to toggle between the conventional and dual basis definitions of the Reed-Solomon code. The CCSDS standard specifies the dual basis, but the conventional basis is frequently used. The *Reed-Solomon interleave depth* option can be used to enable decoding of interleaved Reed-Solomon codewords. The *Scrambler* option can be used to enable or disable the CCSDS synchronous scrambler. The *Syncword threshold* option can be used to choose the number of bit errors that are allowed in the detection of the syncword.

Fig. 15: Options of CCSDS Concatenated deframer

9.4 Transports

Transport components can be found under *Satellites > Transports* in GNU Radio companion. Transports are designed to implement upper layer protocols. They take as input the output of a demodulator, which contains physical layer or link layer frames and process it to obtain upper layer packets. Some of the typical functionalities implemented by these upper layer protocols include fragmentation/defragmentation.

The only transport available so far in gr-satellites is the KISS transport.

9.4.1 KISS transport

The KISS transport implements fragmentation/defragmentation according to the KISS protocol for packet boundary detection. Its input should be PDUs containing the bytes of a KISS stream. The frames are joined and the KISS stream is followed, detecting packet boundaries and extracting the packets. The packets are output as PDUs.

The figure below shows an example flowgraph of the KISS transport, which can be found in `examples/components/kiss_transport.grc`. It is based on the CCSDS Concatenated deframer example described above. BY70-1 sends frames which contain the bytes of a KISS stream, so the KISS transport can be used to extract the packets from this stream. There are two Message Debug blocks that can be enabled or disabled in order to see the input or the output of the KISS transport block.

When the example is run, the frames at the input of the input of the KISS transport look like the one below. We see that there is a single packet embedded into the 114 byte Reed-Solomon frame, using `c0` KISS idle bytes for padding.

```
pdu_length = 114
contents =
0000: c0 b8 64 3d 00 12 00 00 00 00 c8 3a 00 80 00 00
0010: 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32
0020: 32 32 32 32 32 32 32 32 32 32 32 32 32 32 ff c4
```

(continues on next page)

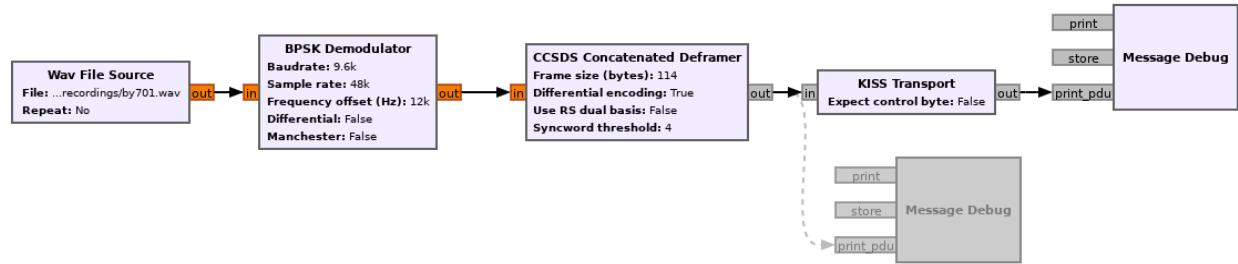


Fig. 16: Usage of KISS transport in a flowgraph

(continued from previous page)

```

0030: 00 1f 00 00 01 05 01 01 01 01 01 01 00 00 00 00
0040: 00 00 00 00 01 02 03 04 05 06 07 08 09 0a 0b ff
0050: 18 21 00 00 db dc 4b f7 07 c0 c0 c0 c0 c0 c0 c0
0060: c0 c0 c0 c0 c0 c0 c0 c0 c0 c0 c0 c0 c0 c0 c0 c0
0070: c0 c0

```

The frames at the output of the KISS transport look like the following. We see that the `c0` KISS idle bytes have been stripped. The KISS transport can also handle the case when a packet is longer than 114 bytes and has been fragmented into several 114 byte frames.

```

pdu_length = 87
contents =
0000: b8 64 3d 00 12 00 00 00 00 c8 3a 00 80 00 00 32
0010: 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32
0020: 32 32 32 32 32 32 32 32 32 32 32 32 32 ff c4 00
0030: 1f 00 00 01 05 01 01 01 01 01 01 01 00 00 00 00
0040: 00 00 00 01 02 03 04 05 06 07 08 09 0a 0b ff 18
0050: 21 00 00 c0 4b f7 07

```

The KISS transport has a single option, called *Expect control byte*. When it is set to `True`, the first byte before the packet payload is interpreted as a control byte according to the KISS protocol. If it is set to `False`, it is assumed that there is no control byte preceeding the packet payload. When using KISS as a means to fragment/defragment upper layer packets it is more common not to use control bytes.

9.5 Data sinks

Data sink components are the final consumers of the PDUs that contain the decoded frames. They can be used for several things, such as printing telemetry values, saving frames to a file, sending frames to an online telemetry database server, and reassembling files and images. The different data sinks available in gr-satellites are described below.

9.5.1 Telemetry parser

The telemetry parser uses `construct` to parse a PDU containing a telemetry frame into the different fields and prints the parsed values to the standard output or a file.

The parser uses *telemetry definitions*, which are either Construct objects (typically a Struct) or any other object supporting the `parse()` method in case more complex parsing behaviour is needed. The list of available telemetry definitions can be seen in `python/telemetry/__index__.py`, or by calling `import satellites.telemetry; help(satellites.telemetry)` in python3.

The figure below shows an example flowgraph of the Telemetry parser block, which can be found in `examples/components/telemetry_paser.grc`. It is based on the U482C example described above. The packets sent by GOMX-1 are deframed and the the Telemetry parser is used to print out the telemetry values to the standard output.

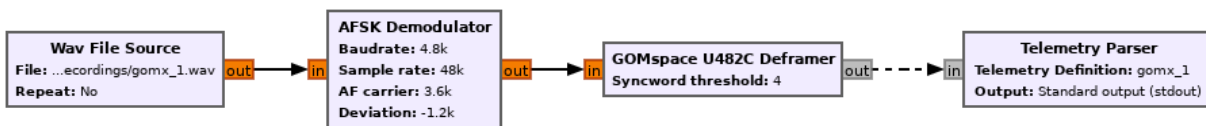


Fig. 17: Usage of Telemetry parser in a flowgraph

The beginning of the ouptut produced by the Telemetry parser block can be seen below.

```

Container:
csp_header = Container:
  priority = 2
  source = 1
  destination = 10
  destination_port = 30
  source_port = 0
  reserved = 0
  hmac = False
  xtea = False
  rdp = False
  crc = False
beacon_time = 2015-03-31 20:57:01
beacon_flags = 121
beacon = Container:
  obc = Container:
    boot_count = 573
    temp = ListContainer:
      -6.0
      -4.0
    panel_temp = ListContainer:
      0.0
      -28.5
      -26.75
      -13.25
      -28.25
      -20.0
  
```

The options used by the Telemetry parser are the following. The *Telemetry definition* option indicates the telemetry definition object, which must be an object in the `satellites.telemetry` module as described above. The *Output* drop down list can be used to select the standard output or a file as the destination for the parser's output. If a file is selected, an additional option to select the file path appears.

9.5.2 Telemetry submit

The telemetry submit block implements *Telemetry submission* to several different online telemetry servers. Its input consists of PDUs with frames, which are then submitted to the selected telemetry server.

This block uses the gr-satellites config file located in `~/.gr_satellites/config.ini` to configure the different options of the telemetry servers, such as the login credentials. See the *information regarding the command line tool* for how to set up this configuration file.

The telemetry submit block has only one option, which is a drop down list that is used to select the telemetry server to use.

9.5.3 Hexdump sink

The hexdump sink prints PDUs in hex to the standard output. It is a wrapper over the Message Debug standard GNU Radio block, so it uses the same output format. This block is used internally by the `gr_satellites` command line tool (see *Hex dump*), and can also be used in custom flowgraphs instead of Message Debug.

9.5.4 KISS file sink

The KISS file sink can be used to store PDUs in a file using the *KISS protocol*. This protocol is a simple format to mark frame boundaries. Files containing frames with the KISS protocol can then be read with the KISS file datasource (see *Data sources*) and with the `gr_satellites` command line tool (see *Specifying the input source*), as well as with external tools.

The KISS file sink block has two options. The *File* option is used to select the path of the output file. The *Append file* option can be used to overwrite or append to the output file.

The KISS files produced by the KISS file sink store timestamps as described in the *KISS output* of the `gr_satellites` command line tool.

9.5.5 KISS server sink

The KISS server sink spawns a TCP server that sends decoded PDUs to connected clients using the *KISS protocol*. A number of tools can act as clients using this protocol.

The KISS file sink block has a *Port* option to specify the TCP port to listen on.

The KISS server sink sends timestamps as described in the *KISS output* of the `gr_satellites` command line tool.

9.5.6 File and Image receivers

The File and Image receiver blocks are used to reassemble files transmitted in chunks, using a variety of different formats. The only difference between the File receiver and the Image receiver is that the Image receiver is able to display image files in realtime using *feh* as they are being received.

These receiver blocks use *FileReceiver definitions*, which are classes derived from `FileReceiver`. The list of available definitions can be seen in `python/filereceiver/__index__.py`, or by calling `import satellites.filereceiver; help(satellites.filereceiver)` in python3. Classes used by the Image receiver must be derived from `ImageReceiver`.

The figure below shows an example flowgraph of the Image receiver block, which can be found in `examples/components/image_receiver.grc`. The example reads a WAV file from *satellite-recordings* containing an image transfer from LilacSat-1. The WAV file is played back in real time using the Throttle block. The Satellite decoder block

is used to demodulate and deframe the packets. Since these packets contain a KISS stream, the KISS transport is used to obtain the image packets. These are sent into the Image receiver block, which will print some information to the standard output and when the beginning of the image is received, will launch feh to display the image.

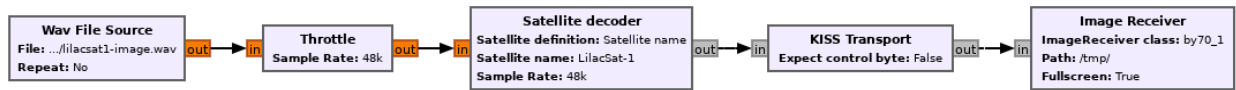


Fig. 18: Usage of Image receiver in a flowgraph

The figure below shows the options of the Image receiver block. The option *ImageReceiver class* indicates the definition to use for reassembling the image (which is implemented by a class derived from `ImageReceiver`). The *Path* option specifies the path of the directory where received files are saved to. The names of the files depend on metadata in the image packets. The *Verbose* option enables printing information to the standard output, such as the frames being received. The *Display* option enables the use of feh to display the image. The *Fullscreen* option is used to run feh in fullscreen.

General	Advanced	Documentation
ImageReceiver class	by70_1	
Path	/tmp/	
Verbose	True	
Display	True	
Fullscreen	True	
Command line options	""	

Acceptar
Cancelar
Aplicar

Fig. 19: Options of Image receiver

The options of the File receiver block are the same as those of the Image receiver block, except for the *Display* and *Fullscreen* options, which are specific to image reception.

9.5.7 Codec2 UDP sink

The Codec2 UDP sink is used internally by the `gr_satellites` command line tool when decoding LilacSat-1. The LilacSat-1 decoder supports outputting Codec2 digital voice frames by UDP. These frames can then be fed into the Codec2 command line decoder.

The Codec2 frames are 7 bytes long, and each is sent in a different UDP packet to ensure minimum latency.

The Codec2 UDP sink has two options, which indicate the IP and port to send the frames to. By default, address `127.0.0.1` and port `7000` are used.

The Codec2 frames can be decoded and played in real time by the Codec2 decoder as shown here.

```
$ nc -lu 7000 | c2dec 1300 - - | play -t raw -r 8000 -e signed-integer -b 16 -c 1 -
```

The `c2dec` command line decoder can be obtained by building from source the [codec2 library](#)

SATYAML FILES

SatYAML files are used by gr-satellites to describe the properties of each specific satellite, such as what kind of protocols and telemetry formats it uses. They are [YAML](#) files and are based around the concept of components. Using SatYAML files, the `gr_satellites` command line tool and the Satellite decoder block can figure out which components to put together to decode a particular satellite.

SatYAML files are stored in the `python/satyaml` directory. Below we show the SatYAML file `1KUNS-PF.yml` to give an overall idea of the format of these files.

```
name: 1KUNS-PF
alternative_names:
norad: 43466
data:
  &tlm Telemetry:
    telemetry: sat_1kuns_pf
  &image JPEG Images:
    image: sat_1kuns_pf
transmitters:
  1k2 FSK downlink:
    frequency: 437.300e+6
    modulation: FSK
    baudrate: 1200
    framing: AX100 ASM+Golay
    data:
      - *tlm
      - *image
  9k6 FSK downlink:
    frequency: 437.300e+6
    modulation: FSK
    baudrate: 9600
    framing: AX100 ASM+Golay
    data:
      - *tlm
      - *image
```

First we can see some fields that give basic information about the satellite. The `name` field indicates the main name of the satellite, which is used by `gr_satellites` and the Satellite decoder block when calling up the satellite by name. There is an optional list of `alternative_names` which can also be used to call up the satellite by name. The `norad` field gives the NORAD ID of the satellite and it is used when calling up the satellite by NORAD ID.

Additional telemetry servers used for this satellite can be specified with the `telemetry_servers` field (see `python/satyaml/PW-Sat2.yml` for an example).

The `data` section indicates the different kinds of data transmissions that the satellite makes, and gives the decoders for them. The following can be used:

- `telemetry`, which specifies a telemetry decoder giving out the telemetry definition (see *Telemetry parser*)
- `file` or `image`, which specify a file receiver or image receiver giving out the `FileReceiver` or `ImageReceiver` class (see *File and Image receivers*)
- `decoder`, which specifies a custom decoder from `satellites.components.datasinks`. This is used for more complex decoders not covered by the above.
- `unknown`, which specifies that the data format is not known, so hex dump should be used to show the data to the user

The `transmitters` section lists the different transmitters used by the satellite, their properties, and ties them to the entries in the `data` section according to which data is sent by each of the transmitters. A transmitter is understood as a specific combination of a frequency, modulation and coding.

Each transmitter has a name (such as `1k2_FSK_downlink`) which is currently used only for documentation purposes, a `frequency`, which gives the downlink frequency in Hz (currently used only for documentation), a `modulation`, that specifies the demodulator component to use, a `baudrate`, in symbols per second, a `framing`, that specifies the deframer to use, and a list of `data` that has entries referring to the items in the `data` section.

The modulations allowed in the `modulation` field are the following:

- `AFSK`, for which the *AFSK demodulator* is used
- `FSK`, for which the *FSK demodulator* with `Subaudio` set to `False` is used
- `FSK_subaudio`, for which the *FSK demodulator* with `Subaudio` set to `True` is used
- `BPSK`. Coherent BPSK, for which the *BPSK demodulator* with `Differential` and `Manchester` set to `False` is used
- `BPSK_Manchester`. Coherent Manchester-encoded BPSK, for which the *BPSK demodulator* with `Differential` set to `False` and `Manchester` set to `True` is used
- `DBPSK`. Differentially-encoded BPSK, for which the *BPSK demodulator* with `Differential` set to `True` and `Manchester` set to `False` is used to perform non-coherent demodulation
- `DBPSK_Manchester`. Differentially-encoded and Manchester-encoded BPSK, for which the *BPSK demodulator* with `Differential` and `Manchester` set to `True` is used to perform non-coherent demodulation

The `AFSK` modulation also needs the `deviation` and `af_carrier` fields that indicate the AFSK tone frequencies in Hz, as in the AFSK demodulator. Optionally, it is possible to indicate the deviation of the FM modulation using the `fm_deviation` field. By default, an FM deviation of 3 kHz is assumed.

The framings allowed in the `framing` field are the following:

- `AX.25`, *AX.25* with no scrambling (see *AX.25 deframer*)
- `AX.25_G3RUH`, *AX.25* with G3RUH scrambling (see *AX.25 deframer*)
- `AX100_ASM+Golay`, GOMspace NanoCom AX100 in ASM+Golay mode (see *GOMspace AX100 deframer*)
- `AX100_Reed Solomon`, GOMspace NanoCom AX100 in Reed-Solomon mode (see *GOMspace AX100 deframer*)
- `U482C`, the GOMspace NanoCom U482C (see *GOMspace U482C deframer*)
- `AO-40_FEC`, the AO-40 FEC protocol (see *AO-40 FEC deframer*)
- `AO-40_FEC_short`, AO-40 FEC protocol with short frames, as used by SMOG-P and ATL-1
- `AO-40_FEC_CRC-16-ARC`, the AO-40 FEC protocol with an CRC-16 ARC, as used by SMOG-1

- **AO-40** FEC CRC-16-ARC short, AO-40 FEC protocol with short frames and a CRC-16 ARC, as used by SMOG-1
- CCSDS Uncoded, uncoded CCSDS codewords (see [CCSDS deframers](#))
- CCSDS Reed-Solomon, CCSDS Reed-Solomon TM codewords (see [CCSDS deframers](#))
- CCSDS Concatenated, CCSDS Concatenated TM codewords (see [CCSDS deframers](#))
- 3CAT-1, custom framing used by 3CAT-1. This uses a CC1101 chip with PN9 scrambler and a (255,223) Reed-Solomon code for the payload
- Astrocast FX.25 NRZ-I, custom framing used by Astrocast 0.1. This is a somewhat non compliant [FX.25](#) variant.
- Astrocast FX.25 NRZ, custom framing used by Astrocast 0.1. This is a somewhat non compliant [FX.25](#) variant that is identical to the FX.25 NRZ-I mode except that NRZ is used instead of NRZ-I.
- **AO-40** uncoded, uncoded AO-40 beacon. It uses 512 byte frames and a CRC-16
- TT-64, custom framing used by QB50 AT03, which uses a Reed-Solomon (64,48) code and CRC16-ARC
- ESEO, custom framing used by ESEO. It uses a custom protocol vaguely similar to AX.25 with some form of G3RUH scrambling and a (255,239) Reed-Solomon code
- Lucky-7, custom framing used by Lucky-7, which uses a SiLabs Si4463 transceiver with a PN9 scrambler and a CRC-16
- Reaktor Hello World, custom framing used by Reaktor Hello World. It uses a Texas Instruments CC1125 transceiver with a PN9 scrambler and a CRC-16.
- Light-1, custom framing used by Light-1 and BlueWalker 3. It is the same as the Reaktor Hello World framing, but uses a different syncword.
- S-NET, custom framing used by S-NET, which uses BCH FEC and interleaving
- SALSAT, custom framing used by SALSAT. It is like S-NET, but without the bugs in the CRC implementation.
- Swiatowid, custom framing used by Swiatowid for image transmission, which includes a (58,48) Reed-Solomon code and a CRC-16CCITT.
- NuSat, custom framing used by NuSat with a (64, 60) Reed-Solomon code and a CRC-8
- K2SAT, custom framing used by K2SAT for image transmission. This uses the CCSDS $r=1/2$, $k=7$ convolutional code and the IESS-308 (V.35) asynchronous scrambler.
- LilacSat-1, low latency decoder for LilacSat-1 codec2 digital voice and image data. This uses the CCSDS $r=1/2$, $k=7$ convolutional code and interleaved telemetry and Codec2 digital voice
- AAUSAT-4, custom framing used by AAUSAT-4, which is similar to the CCSDS Concatenated coding
- NGHam, [NGHam](#) protocol
- NGHam no Reed Solomon, [NGHam](#) protocol without Reed-Solomon, as used by FloripaSat-1
- SMOG-P RA, Repeat-Accumulate FEC as used by SMOG-P and ATL-1
- SMOG-1 RA, Repeat-Accumulate FEC as used by SMOG-1. The difference with SMOG-P RA is a longer 48 bit syncword (instead of 16 bit) and the inclusion of a CRC-16 ARC to check frame integrity.
- MRC-100 RA, Repeat-Accumulate FEC as used by SMOG-1. The difference with SMOG-P RA is a 32-bit syncword, a smaller frame size, and the inclusion of a CRC-16-CCITT-FALSE in the second and third byte to check frame integrity.
- SMOG-P Signalling, custom signalling frames as used by SMOG-P and ATL-1

- **SMOG-1 Signalling**, custom signalling frames as used by SMOG-1. The difference with SMOG-P Signalling is the addition of a different PRBS to mark transitions to TX mode.
- **OPS-SAT**, custom framing used by OPS-SAT, which consists of AX.25 frames with CCSDS Reed-Solomon codewords as payload
- **UA01**, non-AX.25 compliant framing used by QB50 UA01, which is like regular AX.25 but with two layers of NRZ-I encoding
- **Mobitex**, the Mobitex protocol, used by the D-STAR ONE satellites and some Russian whose communications payload has also been built by German Orbital Systems
- **Mobitex-NX**, the Mobitex-NX protocol, used by the BEESAT and TECHNOSAT satellites from TU Berlin
- **FOSSATSAT**, a custom protocol used by FOSSASAT
- **AISTECHSAT-2**, a custom CCSDS-like protocol used by AISTECHSAT-2
- **AALTO-1**, custom framing used by AALTO-1. It uses a Texas Instruments CC1125 transceiver with a PN9 scrambler and a CRC-16 CCITT (as in AX.25)
- **Grizu-263A**, custom framing used by Grizu-263A. It uses a Semtech SX1268 with a PN9 scrambler and CRC-16.
- **IDEASSat**, custom framing used by IDEASSat. It uses NRZI encoding, an 1N8 UART-like encoding with MSB-bit-ordering, and HDLC 0x7e flags to mark the frame boundaries.
- **YUSAT**, custom framing used by YUSAT-1. It is like AX.25 but without bit stuffing, LSB byte endianness, and NRZ-I.
- **AX5043**, FEC framing used by the AX5043 transceiver IC. This uses a convolutional code, a 4x4 interleaver, and HDLC framing with the CRC16-USB.
- **USP**, the [Unified SPUTNIX Protocol](#), which is based on CCSDS concatenate frames with custom synchronization and a PLS based on DVB-S2.
- **DIY-1**, the custom framing used by DIY-1, which uses an RFM22 chip transceiver.
- **BINAR-1**, the custom framing used by the BINAR-1 satellite.
- **Endurosat**, the custom framing used by the Endurosat modem.
- **SanoSat**, the custom framing used by SanoSat-1.
- **FORESAIL-1**, the custom framing used by FORESAIL-1. It is the same as the AX-100 ASM mode, but the ASM used is the CCSDS ASM 0x1ACFFC1D.
- **HSU-SAT1**, the custom framing used by HSU-SAT1.
- **GEOSCAN**, the custom framing used by GEOSCAN-EDELVEIS.
- **SPINO**, the custom framing used by the SPINO payload on INSPIRE-Sat7.

Some framings, such as the CCSDS protocols need the additional field `frame_size` to indicate the frame size.

The CCSDS framings need several additional fields to specify the details of the CCSDS protocol. These are:

- **precoding:** `differential` should be used to specify differential precoding. If it is not specified, differential precoding will not be used.
- **RS basis:** should have the value `conventional` or `dual` to specify the Reed-Solomon basis. This field is mandatory.
- **RS interleaving:** should be used to specify interleaved Reed-Solomon codewords. It defaults to 1 (i.e., no interleaving) if not specified.
- **scrambler:** should have the value `CCSDS` or `none`. This field is optional and defaults to `CCSDS` if not specified.

- `convolutional`: should have one of the following values: `CCSDS`, `NASA-DSN`, `CCSDS uninverted`, `NASA-DSN uninverted`. This field is optional and defaults to `CCSDS` if not specified.

The AX100 ASM+Golay mode also supports the `scrambler` field, with the possible values `CCSDS` and `none`. The default is `CCSDS`, but the value `none` can be used in case the scrambler needs to be disabled (which is a rarely used feature).

The following example shows how transports are indicated in SatYAML files.

```
name: KS-1Q
norad: 41845
data:
  &tlm Telemetry:
    telemetry: csp
transports:
  &kiss KISS:
    protocol: KISS KS-1Q
    data:
      - *tlm
transmitters:
  20k FSK downlink:
    frequency: 436.500e+6
    modulation: FSK
    baudrate: 20000
    framing: CCSDS Concatenated dual
    frame size: 223
    transports:
      - *kiss
```

Instead of specifying a `data` entry in the transmitter, a `transports` entry is used instead. Transports are defined in a section above. They have a name, used for documentation purposes, a `protocol`, and a list of `data` entries to tie them with the appropriate data decoders.

The allowable transport protocols are the following:

- KISS, KISS protocol with a control byte (see *KISS transport*)
- KISS no control byte, KISS protocol with no control byte (see *KISS transport*)
- KISS KS-1Q, KISS variant used by KS-1Q, which includes a header before the KISS bytes

LOW LEVEL BLOCKS

Low level blocks are the custom blocks offered by gr-satellites to implement the required functionality that is not available in the standard GNU Radio blocks. There are many different low level blocks, and some of them date back to the first versions of gr-satellites and have become somewhat outdated. A complete description of the low level blocks is outside the scope of the documentation for this version of gr-satellites.

It is likely that low level blocks will be classified and documented better in the future, perhaps deprecating some of the most outdated old blocks.

For the mean time, the user interested in learning how the different low level blocks can be used can explore which low level blocks are used by the components, by looking at the Python sources inside `python/components/`.

MISCELLANEOUS UTILITIES

Some small utilities are included in `gr-satellites`. These are described below.

12.1 JY1SAT SSDV decoder

The JY1SAT SSDV decoder `jy1sat_ssdv.py` can be used to extract and decode SSDV images transmitted by [JY1SAT](#). To use the decoder, an [ssdv fork](#) supporting the JY1SAT SSDV frame format needs to be installed. The decoder operates over a KISS file containing JY1SAT frames. The KISS file can be produced with the `--kiss_out` option of `gr_satellites` and might contain information for one or several images collected over one or several passes.

The decoder is run as

```
$ jy1sat_ssdv.py frames.kiss /tmp/output
```

This will create files `/tmp/output_n.ssdv` with the extracted SSDV frames and `/tmp/output_n.jpg` with the decoded JPEG image data, where `n` is the number of the image.

12.2 SMOG-P spectrum plot

The SMOG-P spectrum plot tool `smog_p_spectrum.py` can be used to plot spectrum data files transmitted by [SMOG-P](#) and [ATL-1](#). These files are produced by the [file receiver component](#). The `smog_p_spectrum.py` script can be run by using the name of the spectrum data file as argument. For instance,

```
$ smog_p_spectrum.py spectrum_start_824000000_step_24000_rbw_6_measid_312
```

This will create an image `spectrum_312.png` in the same directory as the spectrum file (here 312 is the ID of the measurement, and is contained at the end of the spectrum file name).

SUPPORTED SATELLITES

This is a list of all the satellites supported by gr-satellites. The list is auto-generated by reading the SatYAML files and using the script docs/generate_supported_satellites.py.

1KUNS-PF

NORAD ID: 43466

Transmitters:

- **1k2 FSK downlink** (437.300 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (437.300 MHz): FSK modulation with AX100 ASM+Golay framing

3CAT-1

NORAD ID: 43728

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with 3CAT-1 framing

3CAT-2

NORAD ID: 41732

Transmitters:

- **9k6 BPSK downlink** (145.970 MHz): BPSK modulation with AX.25 framing

AALTO-1

NORAD ID: 42775

Transmitters:

- **9k6 FSK AX.25 downlink** (437.216 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK CC1125 downlink** (437.216 MHz): FSK modulation with AALTO-1 framing

AAUSAT-4

NORAD ID: 41460

Transmitters:

- **2k4 FSK downlink** (437.425 MHz): FSK modulation with AAUSAT-4 framing
- **9k6 FSK downlink** (437.425 MHz): FSK modulation with AAUSAT-4 framing

ACRUX-1

NORAD ID: 44369

Transmitters:

- **9k6 FSK downlink** (437.200 MHz): FSK modulation with AX.25 G3RUH framing

AHMAT-1

Alternative names: RS41S

NORAD ID: 99142

Transmitters:

- **1k2 AFSK downlink** (437.050 MHz): AFSK modulation with AX.25 framing

AISAT

NORAD ID: 40054

Transmitters:

- **4k8 AFSK downlink** (437.250 MHz): AFSK modulation with U482C framing

AISTECHSAT-2

NORAD ID: 43768

Transmitters:

- **1k2 FSK custom CCSDS downlink** (436.600 MHz): FSK modulation with AISTECHSAT-2 framing
- **1k2 FSK AX100 downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK custom CCSDS downlink** (436.600 MHz): FSK modulation with AISTECHSAT-2 framing
- **4k8 FSK AX100 downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK custom CCSDS downlink** (436.600 MHz): FSK modulation with AISTECHSAT-2 framing
- **9k6 FSK AX100 downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing

AISTECHSAT-3

NORAD ID: 44103

Transmitters:

- **4k8 FSK downlink** (436.730 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (436.730 MHz): FSK modulation with AX100 ASM+Golay framing

al-Farabi-2

Alternative names: UN1GWA

NORAD ID: 43805

Transmitters:

- **4k8 FSK downlink** (436.500 MHz): FSK modulation with AX.25 G3RUH framing

ALFACRUX

NORAD ID: 52160

Transmitters:

- **4k8 FSK downlink** (437.100 MHz): FSK modulation with AX100 ASM+Golay framing

AMGU-1

Alternative names: AMURSAT

NORAD ID: 44394

Transmitters:

- **4k8 FSK downlink** (436.250 MHz): FSK modulation with Mobitex framing

AmicalSat

NORAD ID: 46287

Transmitters:

- **1k2 AFSK telemetry downlink** (436.100 MHz): AFSK modulation with AX.25 framing

AO-27

Alternative names: EYESAT-1, AO27

NORAD ID: 22825

Transmitters:

- **1k2 AFSK telemetry downlink** (436.795 MHz): AFSK modulation with AX.25 framing

AO-40

NORAD ID: 26609

Transmitters:

- **400baud uncoded BPSK beacon** (2400.200 MHz): DBPSK Manchester modulation with AO-40 uncoded framing
- **400baud FEC BPSK beacon** (2400.200 MHz): DBPSK Manchester modulation with AO-40 FEC framing

AO-73

Alternative names: FUNcube-1

NORAD ID: 39444

Transmitters:

- **1k2 BPSK downlink** (145.935 MHz): DBPSK modulation with AO-40 FEC framing

ARCCUBE-1

Alternative names: RS25S

NORAD ID: 57205

Transmitters:

- **1k2 FSK downlink** (437.600 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.600 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.600 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.600 MHz): FSK modulation with USP framing

ARMADILLO

NORAD ID: 44352

Transmitters:

- **19k2 FSK downlink** (437.525 MHz): FSK modulation with AX.25 G3RUH framing

ASTROBIO

Alternative names: ABCS, ASTROBIOCUBESAT

NORAD ID: 53107

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

Astrocast 0.1

NORAD ID: 43798

Transmitters:

- **1k2 FSK FX.25 NRZ-I downlink** (437.175 MHz): FSK modulation with Astrocast FX.25 NRZ-I framing
- **1k2 FSK FX.25 NRZ downlink** (437.175 MHz): FSK modulation with Astrocast FX.25 NRZ framing
- **9k6 FSK downlink** (437.175 MHz): FSK modulation with CCSDS Reed-Solomon framing

Astrocast 0.2

Alternative names: HB9GSF

NORAD ID: 44083

Transmitters:

- **9k6 FSK downlink** (437.175 MHz): FSK modulation with AX.25 G3RUH framing
- **1k2 FSK FX.25 NRZ-I downlink** (437.175 MHz): FSK modulation with Astrocast FX.25 NRZ-I framing
- **1k2 FSK FX.25 NRZ downlink** (437.175 MHz): FSK modulation with Astrocast FX.25 NRZ framing

AT03

Alternative names: Pegasus, QB50 AT03

NORAD ID: 42784

Transmitters:

- **9k6 FSK downlink** (436.670 MHz): FSK modulation with TT-64 framing

ATHENOXAT-1

NORAD ID: 41168

Transmitters:

- **4k8 AFSK downlink** (437.485 MHz): AFSK modulation with U482C framing

ATL-1

Alternative names: MO-106

NORAD ID: 44830

Transmitters:

- **1k25 FSK long concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC framing
- **1k25 FSK short concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC short framing
- **1k25 FSK long RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing
- **1k25 FSK short RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing
- **1k25 FSK signalling** (437.175 MHz): FSK modulation with SMOG-P Signalling framing
- **2k5 FSK long concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC framing
- **2k5 FSK short concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC short framing
- **2k5 FSK long RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing
- **2k5 FSK short RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing
- **5k FSK long concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC framing
- **5k FSK short concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC short framing
- **5k FSK long RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing

- **5k FSK short RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing
- **12k5 FSK long concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC framing
- **12k5 FSK short concatenated FEC** (437.175 MHz): FSK modulation with AO-40 FEC short framing
- **12k5 FSK long RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing
- **12k5 FSK short RA FEC** (437.175 MHz): FSK modulation with SMOG-P RA framing

ATLANTIS

Alternative names: US02 ON02US

NORAD ID: 42737

Transmitters:

- **9k6 FSK downlink** (436.388 MHz): FSK modulation with AX.25 G3RUH framing

AU02

Alternative names: QB50 AU02, UNSW-EC0

NORAD ID: 42723

Transmitters:

- **4k8 AFSK downlink** (436.525 MHz): AFSK modulation with U482C framing

AU03

Alternative names: QB50 AU03, i-INSPIRE II

NORAD ID: 42731

Transmitters:

- **4k8 AFSK downlink** (436.330 MHz): AFSK modulation with U482C framing

AzaadiSAT

NORAD ID: 99355

Transmitters:

- **1k2 FSK downlink** (437.400 MHz): FSK modulation with AX.25 framing

AZAADISAT-2

NORAD ID: 55563

Transmitters:

- **1k2 FSK downlink** (437.275 MHz): FSK modulation with AX.25 framing

AztechSat-1

NORAD ID: 45258

Transmitters:

- **9k6 FSK downlink** (437.300 MHz): FSK modulation with AX100 ASM+Golay framing

BCCSAT 1

NORAD ID: 48041

Transmitters:

- **4k8 FSK downlink** (435.635 MHz): FSK modulation with AX.25 G3RUH framing

BDSat

NORAD ID: 52175

Transmitters:

- **9k6 FSK downlink** (436.025 MHz): FSK modulation with AX.25 G3RUH framing

BDSat-2

NORAD ID: 55098

Transmitters:

- **9k6 FSK downlink** (436.025 MHz): FSK modulation with AX.25 G3RUH framing

BEESAT-1

NORAD ID: 35933

Transmitters:

- **4k8 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing
- **9k6 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing

BEESAT-2

NORAD ID: 39136

Transmitters:

- **4k8 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing

BEESAT-4

NORAD ID: 41619

Transmitters:

- **4k8 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing

BEESAT-9

NORAD ID: 44412

Transmitters:

- **4k8 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing

BINAR-1

NORAD ID: 49272

Transmitters:

- **1k2 FSK downlink** (435.810 MHz): FSK modulation with BINAR-1 framing
- **9k6 FSK downlink** (435.810 MHz): FSK modulation with BINAR-1 framing
- **1k2 FSK AX.25 downlink** (435.810 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK AX.25 downlink** (435.810 MHz): FSK modulation with AX.25 G3RUH framing

BISONSAT

Alternative names: N7SKC

NORAD ID: 40968

Transmitters:

- **9k6 FSK downlink** (437.375 MHz): FSK modulation with AX.25 G3RUH framing

BlueWalker 3

NORAD ID: 53807

Transmitters:

- **2k4 FSK downlink** (437.500 MHz): FSK modulation with Light-1 framing

BOBCAT-1

NORAD ID: 46922

Transmitters:

- **100k FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **75k FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **57k6 FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **38k4 FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **19k2 FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing
- **1k2 FSK downlink** (436.600 MHz): FSK modulation with AX100 ASM+Golay framing

BRICSat-2

Alternative names: USNA-P1, USNAP1, NO-103

NORAD ID: 44355

Transmitters:

- **1k2 AFSK downlink** (145.825 MHz): AFSK modulation with AX.25 framing
- **9k6 FSK downlink** (437.600 MHz): FSK modulation with AX.25 G3RUH framing

BUGSAT-1

Alternative names: TITA

NORAD ID: 40014

Transmitters:

- **9k6 FSK downlink** (437.445 MHz): FSK modulation with AX.25 G3RUH framing

BY02

Alternative names: BY70-2

NORAD ID: 45857

Transmitters:

- **9k6 BPSK downlink** (436.200 MHz): BPSK modulation with LilacSat-1 framing

BY03

Alternative names: BY70-3

NORAD ID: 46839

Transmitters:

- **9k6 BPSK downlink** (437.600 MHz): BPSK modulation with AX.25 G3RUH framing

BY70-1

NORAD ID: 41909

Transmitters:

- **9k6 BPSK downlink** (436.200 MHz): BPSK modulation with CCSDS Concatenated framing

CA03

Alternative names: QB50 CA03, ExAlta-1

NORAD ID: 42734

Transmitters:

- **4k8 FSK downlink** (436.705 MHz): FSK modulation with AX100 Reed Solomon framing
- **9k6 FSK downlink** (436.705 MHz): FSK modulation with AX100 Reed Solomon framing

CAPE-3

NORAD ID: 47309

Transmitters:

- **1k2 AFSK AX.25 downlink** (437.325 MHz): AFSK modulation with AX.25 framing
- **1k2 FSK AX5043 downlink** (437.325 MHz): FSK modulation with AX5043 framing

CAS-4A

NORAD ID: 42761

Transmitters:

- **4k8 FSK downlink** (145.836 MHz): FSK modulation with AX.25 G3RUH framing

CAS-4B

NORAD ID: 42759

Transmitters:

- **4k8 FSK downlink** (145.893 MHz): FSK modulation with AX.25 G3RUH framing

CAS-5A

Alternative names: CAMSAT

NORAD ID: 54684

Transmitters:

- **4k8 FSK downlink** (435.650 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink** (435.650 MHz): FSK modulation with AX.25 G3RUH framing

CAS-6

Alternative names: TIANQIN-1

NORAD ID: 44881

Transmitters:

- **9k6 FSK downlink** (145.890 MHz): FSK modulation with AX.25 G3RUH framing

CELESTA

Alternative names: ROBUSTA-1D

NORAD ID: 53111

Transmitters:

- **2k4 FSK downlink** (436.500 MHz): FSK modulation with AX.25 framing
- **9k6 FSK downlink** (436.500 MHz): FSK modulation with AX.25 framing
- **1k2 AFSK downlink** (436.500 MHz): AFSK modulation with AX.25 framing

CHOMPTT

NORAD ID: 43855

Transmitters:

- **9k6 FSK downlink** (437.560 MHz): FSK modulation with AX.25 G3RUH framing
- **1k2 AFSK downlink** (437.560 MHz): AFSK modulation with AX.25 framing

CIRBE

NORAD ID: 56188

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing
- **19k2 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing

CLARKSAT-1

NORAD ID: 58613

Transmitters:

- **4k8 G3RUH FSK downlink** (435.130 MHz): FSK modulation with AX.25 G3RUH framing

COLUMBIA

Alternative names: US04, ON04US

NORAD ID: 42702

Transmitters:

- **9k6 FSK downlink** (437.055 MHz): FSK modulation with AX.25 G3RUH framing

CSIM-FD

NORAD ID: 43793

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing

CTIM

NORAD ID: 52950

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing

CUAVA-1

NORAD ID: 49275

Transmitters:

- **9k6 FSK downlink** (437.075 MHz): BPSK modulation with AX.25 G3RUH framing

CUBE-L

NORAD ID: 47448

Transmitters:

- **9k6 FSK downlink** (400.575 MHz): FSK modulation with AX100 ASM+Golay framing

CubeBel-1

Alternative names: BSUSat-1

NORAD ID: 43666

Transmitters:

- **9k6 FSK downlink** (436.990 MHz): FSK modulation with AX.25 G3RUH framing

CubeBel-2

NORAD ID: 57175

Transmitters:

- **9k6 FSK downlink** (436.990 MHz): FSK modulation with AX.25 G3RUH framing

CUBEBUG-2

Alternative names: LO-74

NORAD ID: 39440

Transmitters:

- **9k6 FSK downlink** (437.445 MHz): FSK modulation with AX.25 G3RUH framing

CubeSX-HSE

NORAD ID: 47952

Transmitters:

- **1k2 FSK downlink** (435.650 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.650 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.650 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.650 MHz): FSK modulation with USP framing

CUBESX-HSE-2

Alternative names: SXC3-213, HSE-AIS, RS21S

NORAD ID: 53383

Transmitters:

- **1k2 FSK downlink** (435.570 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.570 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.570 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.570 MHz): FSK modulation with USP framing

CUBESX-HSE-3

Alternative names: RS42S

NORAD ID: 57178

Transmitters:

- **1k2 FSK downlink** (436.570 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (436.570 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (436.570 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (436.570 MHz): FSK modulation with USP framing

CubeSX-Sirius-HSE

NORAD ID: 47951

Transmitters:

- **1k2 FSK downlink** (437.050 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.050 MHz): FSK modulation with USP framing

- **4k8 FSK downlink** (437.050 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.050 MHz): FSK modulation with USP framing

CUTE

NORAD ID: 49263

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing

CYCLOPS

Alternative names: SXC3-2110, VOENMEH, RS29S

NORAD ID: 53373

Transmitters:

- **1k2 FSK USP downlink** (436.050 MHz): FSK modulation with USP framing
- **2k4 FSK USP downlink** (436.050 MHz): FSK modulation with USP framing
- **4k8 FSK USP downlink** (436.050 MHz): FSK modulation with USP framing
- **9k6 FSK USP downlink** (436.050 MHz): FSK modulation with USP framing

CZ02

Alternative names: QB50 CZ0, VZLUSAT-1

NORAD ID: 42790

Transmitters:

- **4k8 AFSK downlink** (437.240 MHz): AFSK modulation with U482C framing

D-SAT

NORAD ID: 42794

Transmitters:

- **4k8 AFSK downlink** (437.505 MHz): AFSK modulation with U482C framing

D-STAR ONE iSat

NORAD ID: 43879

Transmitters:

- **4k8 FSK downlink** (435.700 MHz): FSK modulation with Mobitex framing

D-STAR ONE LightSat

NORAD ID: 44393

Transmitters:

- **4k8 FSK downlink** (435.700 MHz): FSK modulation with Mobitex framing

D-STAR ONE Sparrow

NORAD ID: 43881

Transmitters:

- **4k8 FSK downlink** (435.700 MHz): FSK modulation with Mobitex framing

DEKART

NORAD ID: 46493

Transmitters:

- **4k8 FSK downlink** (437.000 MHz): FSK modulation with Mobitex framing

DELFI-C3

Alternative names: DO64

NORAD ID: 32789

Transmitters:

- **1k2 BPSK downlink** (145.867 MHz): BPSK modulation with AX.25 framing

DELFI-n3xt

NORAD ID: 39428

Transmitters:

- **2k4 BPSK downlink** (145.870 MHz): BPSK modulation with AX.25 framing

DELFI-PQ

NORAD ID: 51074

Transmitters:

- **1k2 FSK downlink** (436.650 MHz): FSK modulation with AX.25 G3RUH framing

Delphini-1

NORAD ID: 44030

Transmitters:

- **4k8 FSK downlink** (437.500 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (437.500 MHz): FSK modulation with AX100 ASM+Golay framing

DHABISAT

Alternative names: MYSat-2

NORAD ID: 49016

Transmitters:

- **1k2 BPSK downlink** (436.908 MHz): BPSK modulation with AX.25 G3RUH framing
- **2k4 BPSK downlink** (436.908 MHz): BPSK modulation with AX.25 G3RUH framing
- **4k8 BPSK downlink** (436.908 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.908 MHz): BPSK modulation with AX.25 G3RUH framing

DIY-1

NORAD ID: 47963

Transmitters:

- **500 baud FSK downlink** (437.125 MHz): FSK modulation with DIY-1 framing

DUCHIFAT-3

NORAD ID: 44854

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

E-ST@R-II

NORAD ID: 41459

Transmitters:

- **1k2 AFSK downlink** (437.485 MHz): AFSK modulation with AX.25 framing

Eaglet-I

NORAD ID: 43790

Transmitters:

- **1k2 BPSK downlink** (435.200 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink** (435.800 MHz): FSK modulation with AX.25 G3RUH framing

ECAMSAT

NORAD ID: 43019

Transmitters:

- **1k2 AFSK downlink** (437.095 MHz): AFSK modulation with AX.25 framing

EIRSAT-1

NORAD ID: 58472

Transmitters:

- **9k6 GMSK convolutional downlink** (437.100 MHz): FSK modulation with CCSDS Concatenated framing
- **9k6 GMSK downlink** (437.100 MHz): FSK modulation with CCSDS Reed-Solomon framing

ELFIN-A

Alternative names: WJ2XNX

NORAD ID: 43617

Transmitters:

- **19k2 FSK downlink** (437.450 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink** (437.450 MHz): FSK modulation with AX.25 G3RUH framing

ELFIN-B

Alternative names: ELFIN-STAR, WJ2XOX

NORAD ID: 43616

Transmitters:

- **19k2 FSK downlink** (437.475 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink** (437.475 MHz): FSK modulation with AX.25 G3RUH framing

ENDUROSAT ONE

Alternative names: ENDUROSAT AD

NORAD ID: 43551

Transmitters:

- **9k6 FSK downlink** (437.050 MHz): FSK modulation with AX.25 G3RUH framing

ENSO

Alternative names: ROBUSTA 1E

NORAD ID: 58470

Transmitters:

- **2k4 FSK downlink** (436.500 MHz): FSK modulation with AX.25 framing

EntrySat

NORAD ID: 44429

Transmitters:

- **9k6 BPSK downlink** (436.950 MHz): BPSK modulation with AX.25 G3RUH framing

ESEO

Alternative names: FUNcube-4

NORAD ID: 43792

Transmitters:

- **9k6 FSK downlink** (437.000 MHz): FSK modulation with ESEO framing
- **4k8 FSK downlink** (437.000 MHz): FSK modulation with ESEO framing

EXOCUBE-2

Alternative names: CP12

NORAD ID: 47319

Transmitters:

- **9k6 FSK downlink** (437.150 MHz): FSK modulation with AX.25 G3RUH framing

EXP-1

NORAD ID: 37855

Transmitters:

- **1k2 FSK telemetry downlink** (437.493 MHz): FSK modulation with AX.25 framing

FACSAT-1

NORAD ID: 43721

Transmitters:

- **9k6 FSK downlink** (437.350 MHz): FSK modulation with AX100 ASM+Golay framing

FALCONSAT-3

NORAD ID: 30776

Transmitters:

- **9k6 FSK downlink** (435.103 MHz): FSK modulation with AX.25 G3RUH framing

FIREBIRD 3

NORAD ID: 40377

Transmitters:

- **19k2 FSK downlink** (437.397 MHz): FSK modulation with AX.25 G3RUH framing

FIREBIRD 4

NORAD ID: 40378

Transmitters:

- **19k2 FSK downlink** (437.220 MHz): FSK modulation with AX.25 G3RUH framing

FloripaSat-1

NORAD ID: 44885

Transmitters:

- **1k2 FSK beacon** (145.900 MHz): FSK modulation with NGHam no Reed Solomon framing

- **2k4 FSK downlink** (436.100 MHz): FSK modulation with NGHAm no Reed Solomon framing

FMN-1

Alternative names: FengMaNiu-1

NORAD ID: 43192

Transmitters:

- **9k6 BPSK downlink** (435.350 MHz): BPSK modulation with AX.25 G3RUH framing

FORESAIL-1

NORAD ID: 52766

Transmitters:

- **19k2 FSK downlink** (437.125 MHz): FSK modulation with FORESAIL-1 framing
- **9k6 FSK downlink** (437.125 MHz): FSK modulation with FORESAIL-1 framing

FOSSASAT-1B

NORAD ID: 99504

Transmitters:

- **9k6 FSK downlink** (436.980 MHz): FSK modulation with FOSSASAT framing

FOSSASAT-2

NORAD ID: 99505

Transmitters:

- **9k6 FSK downlink** (436.900 MHz): FSK modulation with FOSSASAT framing

GALASSIA

NORAD ID: 41170

Transmitters:

- **4k8 AFSK downlink** (436.400 MHz): AFSK modulation with U482C framing

GALASSIA-2

NORAD ID: 57486

Transmitters:

- **1k2 FSK downlink** (436.400 MHz): FSK modulation with AX100 ASM+Golay framing

GASPACS

NORAD ID: 51439

Transmitters:

- **9k6 FSK AX.25 downlink** (437.365 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK Endurosat downlink** (437.365 MHz): FSK modulation with Endurosat framing

GEOSCAN-EDELVEIS

Alternative names: RS20S, GEOSCAN

NORAD ID: 53385

Transmitters:

- **9k6 FSK downlink** (436.200 MHz): FSK modulation with GEOSCAN framing

GO-32

Alternative names: TECHSAT-1B

NORAD ID: 25397

Transmitters:

- **9k6 FSK downlink A** (435.325 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink B** (435.225 MHz): FSK modulation with AX.25 G3RUH framing

GOMX-1

NORAD ID: 39430

Transmitters:

- **4k8 AFSK downlink** (437.250 MHz): AFSK modulation with U482C framing

GOMX-3

NORAD ID: 40949

Transmitters:

- **19k2 FSK downlink** (437.250 MHz): FSK modulation with AX100 Reed Solomon framing

GR01

Alternative names: QB50 GR01, DUTHSat

NORAD ID: 42724

Transmitters:

- **1k2 BPSK downlink** (436.420 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.420 MHz): BPSK modulation with AX.25 G3RUH framing

GRBAlpha

NORAD ID: 47959

Transmitters:

- **9k6 FSK downlink** (437.025 MHz): FSK modulation with AX.25 G3RUH framing

GRENCUBE

NORAD ID: 53106

Transmitters:

- **300 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing
- **600 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing
- **1k2 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing
- **2k4 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing

GRIFEX

NORAD ID: 40379

Transmitters:

- **9k6 FSK downlink** (437.481 MHz): FSK modulation with AX.25 G3RUH framing

Grizu-263A

NORAD ID: 51025

Transmitters:

- **2k4 FSK downlink** (435.675 MHz): FSK modulation with Grizu-263A framing

GT-1

NORAD ID: 51510

Transmitters:

- **9k6 FSK downlink** (437.175 MHz): FSK modulation with AX.25 G3RUH framing

Hayasat

NORAD ID: 99032

Transmitters:

- **9k6 FSK downlink** (437.020 MHz): FSK modulation with AX.25 G3RUH framing

HSKSAT

NORAD ID: 55182

Transmitters:

- **9k6 FSK downlink** (437.275 MHz): FSK modulation with AX.25 G3RUH framing

HSU-SAT1

NORAD ID: 53462

Transmitters:

- **1k2 AFSK downlink** (437.280 MHz): AFSK modulation with HSU-SAT1 framing

HUMSAT-D

NORAD ID: 39433

Transmitters:

- **1k2 AFSK telemetry downlink** (437.325 MHz): AFSK modulation with U482C framing

IDEASSat

NORAD ID: 47458

Transmitters:

- **9k6 FSK downlink** (437.345 MHz): FSK modulation with IDEASSat framing

IL01

Alternative names: QB50 IL01, DUCHIFAT-2, Hoopoe

NORAD ID: 42718

Transmitters:

- **9k6 BPSK downlink** (437.740 MHz): BPSK modulation with AX.25 G3RUH framing

INNOSAT-2

NORAD ID: 43738

Transmitters:

- **4k8 FSK downlink** (437.450 MHz): FSK modulation with AX100 ASM+Golay framing

INS-1C

NORAD ID: 43116

Transmitters:

- **1k2 FSK downlink** (435.080 MHz): FSK modulation with AX.25 framing

INS-2B

NORAD ID: 54365

Transmitters:

- **1k2 FSK downlink** (435.080 MHz): FSK modulation with AX.25 framing

INS-2TD

NORAD ID: 51658

Transmitters:

- **1k2 FSK downlink** (435.080 MHz): FSK modulation with AX.25 framing

INSPIRE-SAT 7

NORAD ID: 56211

Transmitters:

- **9k6 BPSK downlink** (437.410 MHz): BPSK modulation with AX.25 G3RUH framing
- **2k4 2FSK SPINO payload** (435.200 MHz): FSK modulation with SPINO framing
- **9k6 2FSK SPINO payload** (435.200 MHz): FSK modulation with SPINO framing

INSPIRESat-1

NORAD ID: 51657

Transmitters:

- **9k6 FSK downlink** (437.500 MHz): FSK modulation with AX.25 G3RUH framing

ION SCV-003

NORAD ID: 48912

Transmitters:

- **1k2 FSK downlink** (437.515 MHz): FSK modulation with AX100 ASM+Golay framing

ION-MK01

Alternative names: ION mk01, ION SVC Lucas

NORAD ID: 46274

Transmitters:

- **1k2 FSK downlink** (437.515 MHz): FSK modulation with AX100 ASM+Golay framing

IRAZU

Alternative names: Irazú

NORAD ID: 43468

Transmitters:

- **9k6 FSK downlink** (436.500 MHz): FSK modulation with AX.25 G3RUH framing

IRIS

Alternative names: ManitobaSat-1

NORAD ID: 99073

Transmitters:

- **9k6 AX.25 FSK downlink** (436.250 MHz): FSK modulation with AX.25 G3RUH framing

- **9k6 FSK downlink** (436.250 MHz): FSK modulation with AX100 ASM+Golay framing

IRIS-A

NORAD ID: 51044

Transmitters:

- **9k6 FSK downlink** (436.915 MHz): FSK modulation with AX.25 G3RUH framing

IRIS-C

NORAD ID: 56221

Transmitters:

- **1k2 BPSK downlink** (436.915 MHz): BPSK modulation with AX.25 G3RUH framing
- **2k4 BPSK downlink** (436.915 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.915 MHz): BPSK modulation with AX.25 G3RUH framing

IRVINE-01

NORAD ID: 43693

Transmitters:

- **9k6 FSK downlink** (437.800 MHz): FSK modulation with AX.25 G3RUH framing

ISOI

Alternative names: SXC3-219, MEDEX, RS19S

NORAD ID: 53381

Transmitters:

- **1k2 FSK downlink** (437.650 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.650 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.650 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.650 MHz): FSK modulation with USP framing

IT-SPINS

NORAD ID: 49017

Transmitters:

- **19k2 FSK downlink** (437.405 MHz): FSK modulation with AX.25 G3RUH framing

ITASAT 1

NORAD ID: 43786

Transmitters:

- **1k2 BPSK downlink** (145.860 MHz): BPSK modulation with AX.25 framing

JAGSAT-1

NORAD ID: 53771

Transmitters:

- **9k6 FSK downlink** (437.365 MHz): FSK modulation with Endurosat framing

JAISAT-1

NORAD ID: 44419

Transmitters:

- **4k8 FSK downlink** (435.700 MHz): FSK modulation with Mobitex framing

JY1-Sat

Alternative names: FUNcube-6, JO-97

NORAD ID: 43803

Transmitters:

- **1k2 BPSK downlink** (145.840 MHz): DBPSK modulation with AO-40 FEC framing

KAFASAT

NORAD ID: 58317

Transmitters:

- **1k2 FSK downlink** (435.835 MHz): FSK modulation with AX.25 G3RUH framing

KAI-1

Alternative names: KNRTU-KAI, KNITU-KAI, RS26S

NORAD ID: 53378

Transmitters:

- **1k2 AFSK downlink** (435.665 MHz): AFSK modulation with AX.25 framing
- **1k2 USP FSK downlink** (435.665 MHz): FSK modulation with USP framing
- **2k4 USP FSK downlink** (435.665 MHz): FSK modulation with USP framing
- **4k8 USP FSK downlink** (435.665 MHz): FSK modulation with USP framing
- **9k6 USP FSK downlink** (435.665 MHz): FSK modulation with USP framing

KAIDUN-1

NORAD ID: 41915

Transmitters:

- **1k2 BPSK downlink** (437.600 MHz): BPSK modulation with AX.25 G3RUH framing

KAITUO-1B

NORAD ID: 40912

Transmitters:

- **9k6 FSK downlink** (145.475 MHz): FSK modulation with AX.25 G3RUH framing

KILICSAT

NORAD ID: 56181

Transmitters:

- **9k6 FSK downlink** (436.900 MHz): FSK modulation with AX.25 G3RUH framing

KR01

Alternative names: QB50 KR01, LINK

NORAD ID: 42714

Transmitters:

- **1k2 BPSK downlink** (436.030 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.030 MHz): BPSK modulation with AX.25 G3RUH framing

KrakSat

Alternative names: SR9KRA

NORAD ID: 44427

Transmitters:

- **9k6 FSK downlink** (435.500 MHz): FSK modulation with AX.25 G3RUH framing

KS-1Q

NORAD ID: 41845

Transmitters:

- **20k FSK downlink** (436.500 MHz): FSK modulation with CCSDS Concatenated framing

KSU CubeSat

NORAD ID: 47954

Transmitters:

- **4k8 FSK downlink** (437.130 MHz): FSK modulation with AX.25 G3RUH framing

KUZBASS-300

Alternative names: SXC3-218, KUZSTU, RS34S

NORAD ID: 53375

Transmitters:

- **1k2 FSK downlink** (437.700 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.700 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.700 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.700 MHz): FSK modulation with USP framing
- **19k2 FSK downlink** (437.700 MHz): FSK modulation with USP framing

KUZGTU-1

Alternative names: RS47S

NORAD ID: 57217

Transmitters:

- **1k2 FSK downlink** (437.100 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.100 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.100 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.100 MHz): FSK modulation with USP framing

LEDSAT

NORAD ID: 49069

Transmitters:

- **1k2 FSK downlink** (435.190 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (435.190 MHz): FSK modulation with AX100 ASM+Golay framing

Light-1

NORAD ID: 51509

Transmitters:

- **2k4 FSK downlink** (437.710 MHz): FSK modulation with Light-1 framing

LightSail-2

Alternative names: WM9XPA, LightSail-B

NORAD ID: 44420

Transmitters:

- **9k6 FSK downlink** (437.025 MHz): FSK modulation with AX.25 G3RUH framing

LilacSat-1

Alternative names: CN02, QB50 CN02, LO-90

NORAD ID: 42725

Transmitters:

- **9k6 BPSK downlink** (436.510 MHz): BPSK modulation with LilacSat-1 framing

LilacSat-2

NORAD ID: 40908

Transmitters:

- **9k6 BPSK downlink** (437.200 MHz): BPSK modulation with CCSDS Concatenated framing
- **4k8 FSK downlink** (437.225 MHz): FSK modulation with CCSDS Concatenated framing
- **300baud subaudio downlink** (437.200 MHz): FSK subaudio modulation with CCSDS Reed-Solomon framing

LITUANICASAT-2

NORAD ID: 42768

Transmitters:

- **9k6 FSK downlink** (437.265 MHz): FSK modulation with AX.25 G3RUH framing

Lucky-7

NORAD ID: 44406

Transmitters:

- **4k8 FSK downlink** (437.525 MHz): FSK modulation with Lucky-7 framing

LUME-1

NORAD ID: 43908

Transmitters:

- **4k8 FSK downlink** (437.060 MHz): FSK modulation with AX100 ASM+Golay framing

Luojia-1

NORAD ID: 43485

Transmitters:

- **4k8 FSK downlink** (437.250 MHz): FSK modulation with AX100 ASM+Golay framing

M6P

NORAD ID: 44109

Transmitters:

- **9k6 FSK downlink** (437.265 MHz): FSK modulation with AX.25 G3RUH framing

MARIO

NORAD ID: 55123

Transmitters:

- **9k6 FSK downlink** (437.485 MHz): FSK modulation with AX.25 G3RUH framing

MCUBED-2

NORAD ID: 39469

Transmitters:

- **9k6 FSK downlink** (437.480 MHz): FSK modulation with AX.25 G3RUH framing

MEZNSAT

NORAD ID: 46489

Transmitters:

- **1k2 BPSK downlink** (436.600 MHz): BPSK modulation with AX.25 G3RUH framing
- **2k4 BPSK downlink** (436.600 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.600 MHz): BPSK modulation with AX.25 G3RUH framing

MIET-AIS

Alternative names: SXC3-214, RS28S

NORAD ID: 53377

Transmitters:

- **1k2 FSK downlink** (437.900 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.900 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.900 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.900 MHz): FSK modulation with USP framing

MIMAN

NORAD ID: 52900

Transmitters:

- **2k4 FSK downlink** (436.500 MHz): FSK modulation with AX100 ASM+Golay framing

MINXSS

NORAD ID: 41474

Transmitters:

- **9k6 FSK downlink** (437.345 MHz): FSK modulation with AX.25 G3RUH framing

MinXSS 2

NORAD ID: 43758

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing
- **19k2 FSK downlink** (437.250 MHz): FSK modulation with AX.25 G3RUH framing

MIR-SAT1

NORAD ID: 48868

Transmitters:

- **9k6 FSK downlink** (436.925 MHz): FSK modulation with AX.25 G3RUH framing

MiTEE-1

NORAD ID: 47314

Transmitters:

- **9k6 FSK downlink** (437.800 MHz): FSK modulation with AX.25 G3RUH framing

MONITOR-1

Alternative names: SXC3-212, MGU, RS32S

NORAD ID: 53374

Transmitters:

- **1k2 FSK downlink** (437.550 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.550 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.550 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.550 MHz): FSK modulation with USP framing

MONITOR-2

Alternative names: RS39S

NORAD ID: 57174

Transmitters:

- **1k2 FSK downlink** (435.860 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.860 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.860 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.860 MHz): FSK modulation with USP framing

MONITOR-3

Alternative names: RS58S

NORAD ID: 57180

Transmitters:

- **1k2 FSK downlink** (435.290 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.290 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.290 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.290 MHz): FSK modulation with USP framing

MONITOR-4

Alternative names: RS57S

NORAD ID: 57182

Transmitters:

- **1k2 FSK downlink** (436.080 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (436.080 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (436.080 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (436.080 MHz): FSK modulation with USP framing

MRC-100

NORAD ID: 56993

Transmitters:

- **1k25 FSK** (436.720 MHz): FSK modulation with MRC-100 RA framing
- **2k5 FSK** (436.720 MHz): FSK modulation with MRC-100 RA framing
- **5k FSK** (436.720 MHz): FSK modulation with MRC-100 RA framing
- **12k5 FSK** (436.720 MHz): FSK modulation with MRC-100 RA framing

MTCUBE-2

Alternative names: ROBUSTA-1F

NORAD ID: 53109

Transmitters:

- **2k4 FSK downlink** (436.750 MHz): FSK modulation with AX.25 framing
- **9k6 FSK downlink** (436.750 MHz): FSK modulation with AX.25 framing
- **1k2 AFSK downlink** (436.750 MHz): AFSK modulation with AX.25 framing

MYSAT 1

NORAD ID: 44045

Transmitters:

- **1k2 BPSK downlink** (435.775 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (435.775 MHz): BPSK modulation with AX.25 G3RUH framing

NanosatC-BR1

NORAD ID: 40024

Transmitters:

- **1k2 BPSK downlink** (145.865 MHz): BPSK modulation with AX.25 framing

NanosatC-BR2

NORAD ID: 47950

Transmitters:

- **1k2 BPSK downlink** (145.865 MHz): BPSK modulation with AX.25 framing
- **4k8 BPSK downlink** (145.865 MHz): BPSK modulation with AX.25 framing

NANOZOND-1

NORAD ID: 57190

Transmitters:

- **1k2 FSK downlink** (437.000 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.000 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.000 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.000 MHz): FSK modulation with USP framing

Nayif-1

Alternative names: FUNcube-5, EO-88

NORAD ID: 42017

Transmitters:

- **1k2 BPSK downlink** (145.940 MHz): DBPSK modulation with AO-40 FEC framing

NETSAT 1

NORAD ID: 46506

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

NETSAT 2

NORAD ID: 46507

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

NETSAT 3

NORAD ID: 46505

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

NETSAT 4

NORAD ID: 46504

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

NEUDOSE

NORAD ID: 56315

Transmitters:

- **9k6 FSK AX.25 downlink** (436.050 MHz): FSK modulation with AX.25 framing

NEUTRON-1

NORAD ID: 46923

Transmitters:

- **1k2 BPSK downlink** (435.300 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (435.300 MHz): BPSK modulation with AX.25 G3RUH framing

NEXUS

Alternative names: JS1WAV, FO-99, Fuji-OSCAR 99

NORAD ID: 43937

Transmitters:

- **1k2 AFSK downlink** (435.900 MHz): AFSK modulation with AX.25 framing
- **9k6 FSK downlink** (435.900 MHz): FSK modulation with AX.25 G3RUH framing

NO-84

Alternative names: PSAT, ParkinsonSAT

NORAD ID: 40654

Transmitters:

- **1k2 AFSK downlink** (145.825 MHz): AFSK modulation with AX.25 framing

NODES 1

NORAD ID: 41478

Transmitters:

- **1k2 AFSK downlink** (437.100 MHz): AFSK modulation with AX.25 framing
- **19k2 FSK downlink** (2401.200 MHz): FSK modulation with AX.25 G3RUH framing

NODES 2

NORAD ID: 41477

Transmitters:

- **1k2 AFSK downlink** (437.100 MHz): AFSK modulation with AX.25 framing
- **19k2 FSK downlink** (2401.200 MHz): FSK modulation with AX.25 G3RUH framing

NORBI

NORAD ID: 46494

Transmitters:

- **9k6 FSK downlink** (436.700 MHz): FSK modulation with AX.25 G3RUH framing

NSIGHT-1

Alternative names: AZ02 ON02AZ

NORAD ID: 42726

Transmitters:

- **9k6 FSK downlink** (435.900 MHz): FSK modulation with AX.25 G3RUH framing

NuSat 1

Alternative names: ÑuSat 1

NORAD ID: 41557

Transmitters:

- **40k FSK downlink** (436.445 MHz): FSK modulation with NuSat framing

NUTSat

NORAD ID: 55124

Transmitters:

- **9k6 FSK downlink** (436.850 MHz): FSK modulation with AX.25 framing
- **1k2 AFSK downlink** (436.850 MHz): AFSK modulation with AX.25 framing

O/OREOS

Alternative names: USA 219

NORAD ID: 37224

Transmitters:

- **1k2 AFSK downlink** (437.305 MHz): AFSK modulation with AX.25 framing

OPS-SAT

NORAD ID: 44878

Transmitters:

- **9k6 FSK downlink** (437.200 MHz): FSK modulation with OPS-SAT framing

OrbiCraft-Zorkiy

NORAD ID: 47960

Transmitters:

- **1k2 FSK downlink** (437.850 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.850 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.850 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.850 MHz): FSK modulation with USP framing

OreSat0

NORAD ID: 52017

Transmitters:

- **9k6 FSK downlink** (436.500 MHz): FSK modulation with AX.25 G3RUH framing

PAINANI-1

NORAD ID: 44365

Transmitters:

- **9k6 FSK downlink** (437.475 MHz): FSK modulation with AX.25 G3RUH framing

PEARL-1C

NORAD ID: 58342

Transmitters:

- **9k6 FSK downlink** (435.310 MHz): FSK modulation with AX.25 G3RUH framing

PEARL-1H

NORAD ID: 58265

Transmitters:

- **9k6 FSK downlink** (435.390 MHz): FSK modulation with AX.25 G3RUH framing

PHOENIX

Alternative names: TW01, ON01TW

NORAD ID: 42706

Transmitters:

- **9k6 FSK downlink** (436.915 MHz): FSK modulation with AX.25 G3RUH framing

PHONESAT 2.4

NORAD ID: 39381

Transmitters:

- **1k2 AFSK downlink** (437.425 MHz): AFSK modulation with AX.25 framing

PicSat

NORAD ID: 43132

Transmitters:

- **1k2 BPSK downlink** (435.525 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (435.525 MHz): BPSK modulation with AX.25 G3RUH framing

PLANETUM-1

NORAD ID: 52738

Transmitters:

- **9k6 FSK downlink** (436.680 MHz): FSK modulation with AX.25 G3RUH framing

PlantSat

NORAD ID: 52188

Transmitters:

- **4k8 FSK downlink** (437.240 MHz): FSK modulation with AX100 ASM+Golay framing

POLYTAN-1

NORAD ID: 40042

Transmitters:

- **1k2 AFSK downlink** (437.675 MHz): AFSK modulation with AX.25 framing
- **9k6 FSK downlink** (437.676 MHz): FSK modulation with AX.25 G3RUH framing

PW-Sat2

NORAD ID: 43814

Transmitters:

- **1k2 BPSK downlink** (435.275 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (435.275 MHz): BPSK modulation with AX.25 G3RUH framing

QARMAN

NORAD ID: 45257

Transmitters:

- **9k6 FSK downlink** (437.350 MHz): FSK modulation with AX.25 G3RUH framing

QBEE

Alternative names: SE01, ON01SE

NORAD ID: 42708

Transmitters:

- **9k6 FSK downlink** (435.800 MHz): FSK modulation with AX.25 G3RUH framing

QMR-KWT

NORAD ID: 48943

Transmitters:

- **9k6 FSK downlink** (436.500 MHz): FSK modulation with AX.25 G3RUH framing

QO-100

Alternative names: Es'hail 2

NORAD ID: 43700

Transmitters:

- **400baud uncoded BPSK beacon** (10489.750 MHz): DBPSK Manchester modulation with AO-40 uncoded framing
- **400baud FEC BPSK beacon** (10489.750 MHz): DBPSK Manchester modulation with AO-40 FEC framing

Quetzal-1

NORAD ID: 45598

Transmitters:

- **4k8 FSK downlink** (437.200 MHz): FSK modulation with AX.25 G3RUH framing

RAMSAT

NORAD ID: 48850

Transmitters:

- **9k6 FSK downlink** (436.300 MHz): FSK modulation with AX.25 G3RUH framing

RANDEV

NORAD ID: 52898

Transmitters:

- **1k2 BPSK downlink** (436.029 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.029 MHz): BPSK modulation with AX.25 G3RUH framing

Reaktor Hello World

NORAD ID: 43743

Transmitters:

- **9k6 FSK downlink** (437.775 MHz): FSK modulation with Reaktor Hello World framing

RESHUCUBE

Alternative names: SXC3-2111, SIBSU, SIBGU, RS8S

NORAD ID: 53382

Transmitters:

- **1k2 FSK downlink** (435.380 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.380 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.380 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.380 MHz): FSK modulation with USP framing

ROBUSTA-1B

NORAD ID: 42792

Transmitters:

- **1k2 AFSK downlink** (437.325 MHz): AFSK modulation with AX.25 framing

ROSEYCUBESAT-1

NORAD ID: 56212

Transmitters:

- **1k2 BPSK downlink** (436.825 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (436.825 MHz): BPSK modulation with AX.25 G3RUH framing

S-NET A

Alternative names: DP0TBB

NORAD ID: 43188

Transmitters:

- **1k2 AFSK downlink** (435.950 MHz): AFSK modulation with S-NET framing

S-NET B

Alternative names: DP0TBC

NORAD ID: 43187

Transmitters:

- **1k2 AFSK downlink** (435.950 MHz): AFSK modulation with S-NET framing

S-NET C

Alternative names: DP0TBD

NORAD ID: 43189

Transmitters:

- **1k2 AFSK downlink** (435.950 MHz): AFSK modulation with S-NET framing

S-NET D

Alternative names: DP0TBE

NORAD ID: 43186

Transmitters:

- **1k2 AFSK downlink** (435.950 MHz): AFSK modulation with S-NET framing

SALSAT

NORAD ID: 46495

Transmitters:

- **1k2 AFSK downlink** (435.950 MHz): AFSK modulation with SALSAT framing

SanoSat-1

NORAD ID: 51031

Transmitters:

- **500baud FSK downlink** (436.235 MHz): FSK modulation with SanoSat framing

SCOOB-II

NORAD ID: 99057

Transmitters:

- **9k6 FSK downlink** (437.500 MHz): FSK modulation with AX.25 G3RUH framing

SelfieSat

NORAD ID: 53951

Transmitters:

- **9k6 FSK downlink** (437.500 MHz): FSK modulation with AX.25 G3RUH framing

Shaonian Xing

Alternative names: MXSat-1

NORAD ID: 43199

Transmitters:

- **9k6 BPSK downlink** (436.375 MHz): BPSK modulation with AX.25 G3RUH framing

Sharjahsat-1

NORAD ID: 55104

Transmitters:

- **9k6 FSK downlink** (437.325 MHz): FSK modulation with AX.25 G3RUH framing

SIMBA

Alternative names: WildTrackCube-SIMBA

NORAD ID: 47941

Transmitters:

- **1k2 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing
- **9k6 FSK downlink** (435.310 MHz): FSK modulation with AX100 ASM+Golay framing

SIREN

Alternative names: SXC3-217, RS30S

NORAD ID: 53384

Transmitters:

- **1k2 FSK downlink** (437.750 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.750 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.750 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.750 MHz): FSK modulation with USP framing

SiriusSat-1

Alternative names: RS13S

NORAD ID: 43595

Transmitters:

- **4k8 FSK downlink** (435.570 MHz): FSK modulation with AX.25 G3RUH framing

SiriusSat-2

Alternative names: RS14S

NORAD ID: 43596

Transmitters:

- **4k8 FSK downlink** (435.670 MHz): FSK modulation with AX.25 G3RUH framing

SKCUBE

NORAD ID: 42789

Transmitters:

- **9k6 FSK downlink** (437.100 MHz): FSK modulation with AX.25 G3RUH framing

SKOLTECH-B1

Alternative names: R0AJU-1

NORAD ID: 53379

Transmitters:

- **1k2 FSK downlink** (435.000 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.000 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.000 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.000 MHz): FSK modulation with USP framing

SKOLTECH-B2

Alternative names: R0AJU-1

NORAD ID: 53380

Transmitters:

- **1k2 FSK downlink** (435.000 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.000 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.000 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.000 MHz): FSK modulation with USP framing

SMOG-1

NORAD ID: 47964

Transmitters:

- **1k25 FSK long concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC framing
- **1k25 FSK short concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC short framing
- **1k25 FSK long RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **1k25 FSK short RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **1k25 FSK signalling** (437.345 MHz): FSK modulation with SMOG-1 Signalling framing
- **2k5 FSK long concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC framing
- **2k5 FSK short concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC short framing
- **2k5 FSK long RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **2k5 FSK short RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **5k FSK long concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC framing
- **5k FSK short concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC short framing
- **5k FSK long RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **5k FSK short RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **12k5 FSK long concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC framing
- **12k5 FSK short concatenated FEC** (437.345 MHz): FSK modulation with AO-40 FEC CRC-16-ARC short framing
- **12k5 FSK long RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing
- **12k5 FSK short RA FEC** (437.345 MHz): FSK modulation with SMOG-1 RA framing

SMOG-P

Alternative names: MO-105

NORAD ID: 44832

Transmitters:

- **1k25 FSK long concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC framing
- **1k25 FSK short concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC short framing
- **1k25 FSK long RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **1k25 FSK short RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **1k25 FSK signalling** (437.150 MHz): FSK modulation with SMOG-P Signalling framing
- **2k5 FSK long concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC framing
- **2k5 FSK short concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC short framing
- **2k5 FSK long RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **2k5 FSK short RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **5k FSK long concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC framing
- **5k FSK short concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC short framing
- **5k FSK long RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **5k FSK short RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **12k5 FSK long concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC framing
- **12k5 FSK short concatenated FEC** (437.150 MHz): FSK modulation with AO-40 FEC short framing
- **12k5 FSK long RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing
- **12k5 FSK short RA FEC** (437.150 MHz): FSK modulation with SMOG-P RA framing

SNIPE-1

Alternative names: SNIPE-A, KASI-SAT-A

NORAD ID: 56749

Transmitters:

- **4k8 FSK downlink** (435.450 MHz): FSK modulation with AX100 ASM+Golay framing

SNIPE-2

Alternative names: SNIPE-B, KASI-SAT-B

NORAD ID: 56745

Transmitters:

- **4k8 FSK downlink** (436.000 MHz): FSK modulation with AX100 ASM+Golay framing

SNIPE-3

Alternative names: SNIPE-C, KASI-SAT-C

NORAD ID: 56746

Transmitters:

- **4k8 FSK downlink** (436.950 MHz): FSK modulation with AX100 ASM+Golay framing

SNIPE-4

Alternative names: SNIPE-D, KASI-SAT-D

NORAD ID: 56744

Transmitters:

- **4k8 FSK downlink** (437.800 MHz): FSK modulation with AX100 ASM+Golay framing

SNUGLITE

Alternative names: DS0DH

NORAD ID: 43784

Transmitters:

- **9k6 FSK downlink** (437.275 MHz): FSK modulation with AX.25 G3RUH framing

SNUGLITE-II

NORAD ID: 52899

Transmitters:

- **9k6 FSK downlink** (437.490 MHz): FSK modulation with AX.25 G3RUH framing

SOAR

NORAD ID: 48851

Transmitters:

- **4k8 FSK downlink** (401.725 MHz): FSK modulation with AX100 ASM+Golay framing

SOKRAT

NORAD ID: 44404

Transmitters:

- **4k8 FSK downlink** (436.000 MHz): FSK modulation with Mobitex framing

SOMP 2b

NORAD ID: 47445

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

SpeiSat

Alternative names: Spei Satelles

NORAD ID: 56991

Transmitters:

- **9k6 FSK downlink** (437.500 MHz): FSK modulation with AX.25 G3RUH framing

SPOC

NORAD ID: 46921

Transmitters:

- **9k6 FSK downlink** (437.350 MHz): FSK modulation with AX.25 G3RUH framing

SpooQy-1

NORAD ID: 44332

Transmitters:

- **9k6 FSK downlink** (436.200 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK downlink** (436.200 MHz): FSK modulation with AX100 ASM+Golay framing

SS-1

NORAD ID: 55181

Transmitters:

- **1k2 AFSK downlink** (145.825 MHz): AFSK modulation with AX.25 framing

SSS-2B

NORAD ID: 56184

Transmitters:

- **9k6 FSK downlink** (435.800 MHz): FSK modulation with AX.25 G3RUH framing

Star Vibe

NORAD ID: 55009

Transmitters:

- **9k6 FSK downlink** (437.025 MHz): FSK modulation with AX.25 G3RUH framing

STECCO

NORAD ID: 47962

Transmitters:

- **9k6 FSK downlink** (435.800 MHz): FSK modulation with AX.25 G3RUH framing

STEP-CUBELAB-II

NORAD ID: 52897

Transmitters:

- **9k6 FSK downlink** (437.485 MHz): FSK modulation with AX.25 G3RUH framing

STRAND-1

Alternative names: STRaND-1

NORAD ID: 39090

Transmitters:

- **9k6 FSK downlink** (437.568 MHz): FSK modulation with AX.25 G3RUH framing

STRATOSAT-TK1

Alternative names: RS52S

NORAD ID: 57167

Transmitters:

- **9k6 FSK downlink** (435.870 MHz): FSK modulation with GEOSCAN framing

SUCHAI-2

NORAD ID: 52192

Transmitters:

- **9k6 FSK downlink** (437.230 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK downlink** (437.230 MHz): FSK modulation with AX100 ASM+Golay framing
- **1k2 FSK downlink** (437.230 MHz): FSK modulation with AX100 ASM+Golay framing

SUCHAI-3

NORAD ID: 52191

Transmitters:

- **9k6 FSK downlink** (437.250 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK downlink** (437.250 MHz): FSK modulation with AX100 ASM+Golay framing
- **1k2 FSK downlink** (437.250 MHz): FSK modulation with AX100 ASM+Golay framing

Suomi 100

NORAD ID: 43804

Transmitters:

- **9k6 FSK downlink** (437.775 MHz): FSK modulation with AX100 ASM+Golay framing

SVYATOBOR-1

Alternative names: RS60S

NORAD ID: 57187

Transmitters:

- **1k2 FSK downlink** (437.875 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.875 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.875 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.875 MHz): FSK modulation with USP framing

SwampSat-2

NORAD ID: 45115

Transmitters:

- **9k6 FSK downlink** (436.350 MHz): FSK modulation with AX.25 G3RUH framing

Swiatowid

NORAD ID: 44426

Transmitters:

- **1k2 AFSK telemetry downlink** (435.500 MHz): AFSK modulation with AX.25 framing
- **9k6 FSK image downlink** (435.500 MHz): FSK modulation with Swiatowid framing

SWSU-55-5

Alternative names: RS3S, SWGU-9, YuZGU-55-9

NORAD ID: 53308

Transmitters:

- **1k2 AFSK downlink** (437.087 MHz): AFSK modulation with AX.25 framing

SWSU-55-6

Alternative names: RS4S, SWGU-10, YuZGU-55-10

NORAD ID: 53321

Transmitters:

- **1k2 AFSK downlink** (437.087 MHz): AFSK modulation with AX.25 framing

SWSU-55-7

Alternative names: RS5S, SWGU-11, YuZGU-55-11

NORAD ID: 53310

Transmitters:

- **1k2 AFSK downlink** (437.087 MHz): AFSK modulation with AX.25 framing

SWSU-55-8

Alternative names: RS6S, SWGU-12, YuZGU-55-12

NORAD ID: 53311

Transmitters:

- **1k2 AFSK downlink** (437.087 MHz): AFSK modulation with AX.25 framing

Tanusha-3

Alternative names: Tanusha-SWSU-3 (RS-8), RS8S

NORAD ID: 43597

Transmitters:

- **9k6 FSK downlink** (437.050 MHz): FSK modulation with AX.25 G3RUH framing
- **1k2 AFSK downlink** (437.050 MHz): AFSK modulation with AX.25 framing

TARGET

NORAD ID: 51440

Transmitters:

- **9k6 FSK downlink** (437.285 MHz): FSK modulation with AX.25 G3RUH framing

Taurus-1

NORAD ID: 44530

Transmitters:

- **9k6 BPSK downlink** (435.840 MHz): BPSK modulation with LilacSat-1 framing

TAUSAT-1

NORAD ID: 47926

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TBEX-A

NORAD ID: 44356

Transmitters:

- **9k6 FSK downlink** (437.485 MHz): FSK modulation with AX.25 G3RUH framing

TBEX-B

NORAD ID: 44359

Transmitters:

- **9k6 FSK downlink** (437.535 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink 2** (437.485 MHz): FSK modulation with AX.25 G3RUH framing

TECHNOSAT

NORAD ID: 42829

Transmitters:

- **4k8 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing

TEVEL-1

Alternative names: T1OFK

NORAD ID: 51013

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-2

Alternative names: T2YRC

NORAD ID: 51069

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-3

Alternative names: T3TYB

NORAD ID: 50988

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-4

Alternative names: T4ATA

NORAD ID: 51063

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-5

Alternative names: T5SNG

NORAD ID: 50998

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-6

Alternative names: T6NZR

NORAD ID: 50999

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-7

Alternative names: T7ADM

NORAD ID: 51062

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TEVEL-8

Alternative names: T8GBS

NORAD ID: 50989

Transmitters:

- **9k6 BPSK downlink** (436.400 MHz): BPSK modulation with AX.25 G3RUH framing

TIGRISAT

NORAD ID: 40043

Transmitters:

- **9k6 FSK downlink** (435.000 MHz): FSK modulation with AX.25 G3RUH framing

TRISAT

NORAD ID: 46280

Transmitters:

- **9766 baud FSK downlink** (435.612 MHz): FSK modulation with CCSDS Concatenated framing

TRISAT-R

NORAD ID: 53108

Transmitters:

- **1k baud FSK downlink** (435.612 MHz): FSK modulation with CCSDS Concatenated framing
- **2k baud FSK downlink** (435.612 MHz): FSK modulation with CCSDS Concatenated framing
- **3k baud FSK downlink** (435.612 MHz): FSK modulation with CCSDS Concatenated framing
- **5k baud FSK downlink** (435.612 MHz): FSK modulation with CCSDS Concatenated framing

TSIOLKOVSKY-RYAZAN-1

Alternative names: RS9S

NORAD ID: 53312

Transmitters:

- **1k2 AFSK downlink** (437.025 MHz): AFSK modulation with AX.25 framing

TSIOLKOVSKY-RYAZAN-2

Alternative names: RS12S

NORAD ID: 53313

Transmitters:

- **1k2 AFSK downlink** (437.012 MHz): AFSK modulation with AX.25 framing

TSURU

NORAD ID: 47927

Transmitters:

- **4k8 FSK downlink** (437.375 MHz): FSK modulation with AX.25 G3RUH framing

TTU-100

Alternative names: Hamarik

NORAD ID: 46312

Transmitters:

- **9k6 FSK downlink** (435.450 MHz): FSK modulation with AX.25 G3RUH framing

TUBIN

NORAD ID: 48900

Transmitters:

- **4k8 FSK downlink** (435.950 MHz): FSK modulation with Mobitex-NX framing

TUMnanoSAT

NORAD ID: 53464

Transmitters:

- **9k6 FSK downlink** (436.680 MHz): FSK modulation with AX.25 G3RUH framing

TW-1A

NORAD ID: 40928

Transmitters:

- **4k8 FSK downlink** (435.645 MHz): FSK modulation with AX100 Reed Solomon framing

TW-1B

NORAD ID: 40927

Transmitters:

- **4k8 FSK downlink** (437.645 MHz): FSK modulation with AX100 Reed Solomon framing

TW-1C

NORAD ID: 40926

Transmitters:

- **4k8 FSK downlink** (435.645 MHz): FSK modulation with AX100 Reed Solomon framing

TY 4-01

NORAD ID: 43669

Transmitters:

- **9k6 FSK downlink** (435.925 MHz): FSK modulation with AX100 ASM+Golay framing

TY-2

NORAD ID: 43155

Transmitters:

- **9k6 FSK downlink** (435.350 MHz): FSK modulation with AX100 ASM+Golay framing

TY-6

NORAD ID: 43158

Transmitters:

- **9k6 FSK downlink** (436.100 MHz): FSK modulation with AX100 ASM+Golay framing

UA01

Alternative names: PolyITAN 2-SAU, QB50 UA01

NORAD ID: 42732

Transmitters:

- **9k6 FSK downlink** (436.600 MHz): BPSK modulation with UA01 framing

UBAKUSAT

NORAD ID: 43467

Transmitters:

- **9k6 FSK downlink** (437.325 MHz): FSK modulation with AX.25 G3RUH framing

UCLSAT

NORAD ID: 42765

Transmitters:

- **9k6 FSK downlink** (435.975 MHz): FSK modulation with AX.25 G3RUH framing

UKube-1

Alternative names: FUNcube-2

NORAD ID: 40074

Transmitters:

- **1k2 BPSK downlink** (145.840 MHz): DBPSK modulation with AO-40 FEC framing

UmKA-1

NORAD ID: 57172

Transmitters:

- **1k2 FSK USP downlink** (437.625 MHz): FSK modulation with USP framing
- **2k4 FSK USP downlink** (437.625 MHz): FSK modulation with USP framing
- **4k8 FSK USP downlink** (437.625 MHz): FSK modulation with USP framing
- **9k6 FSK USP downlink** (437.625 MHz): FSK modulation with USP framing
- **1k2 FSK downlink** (437.625 MHz): FSK modulation with AX.25 G3RUH framing
- **2k4 FSK downlink** (437.625 MHz): FSK modulation with AX.25 G3RUH framing
- **4k8 FSK downlink** (437.625 MHz): FSK modulation with AX.25 G3RUH framing
- **9k6 FSK downlink** (437.625 MHz): FSK modulation with AX.25 G3RUH framing

UNISAT-6

NORAD ID: 40012

Transmitters:

- **9k6 FSK downlink** (437.421 MHz): FSK modulation with AX.25 G3RUH framing

UNISAT-7

NORAD ID: 47945

Transmitters:

- **9k6 FSK downlink** (437.425 MHz): FSK modulation with AX.25 G3RUH framing

UPMSat 2

NORAD ID: 46276

Transmitters:

- **1k2 FSK telemetry downlink** (437.405 MHz): FSK modulation with AX.25 framing

URSA MAIOR

Alternative names: IT02

NORAD ID: 42776

Transmitters:

- **9k6 FSK downlink** (435.950 MHz): FSK modulation with AX.25 G3RUH framing

US01

Alternative names: Challenger, QB50 US01, QBUS 1

NORAD ID: 42721

Transmitters:

- **9k6 FSK downlink** (437.505 MHz): FSK modulation with AX.25 G3RUH framing

UTMN

Alternative names: SXC3-216, RS23S

NORAD ID: 53376

Transmitters:

- **1k2 FSK downlink** (435.670 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.670 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.670 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.670 MHz): FSK modulation with USP framing

UTMN-2

Alternative names: RS27S

NORAD ID: 57203

Transmitters:

- **1k2 FSK downlink** (435.485 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (435.485 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (435.485 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (435.485 MHz): FSK modulation with USP framing

UVSQ-SAT

NORAD ID: 47438

Transmitters:

- **1k2 BPSK downlink** (437.020 MHz): BPSK modulation with AX.25 G3RUH framing
- **9k6 BPSK downlink** (437.020 MHz): BPSK modulation with AX.25 G3RUH framing

UWE-3

NORAD ID: 39446

Transmitters:

- **1k2 AFSK downlink** (437.385 MHz): AFSK modulation with AX.25 framing
- **9k6 FSK downlink** (437.384 MHz): FSK modulation with AX.25 G3RUH framing

UWE-4

Alternative names: DP0UWH

NORAD ID: 43880

Transmitters:

- **9k6 FSK downlink** (435.600 MHz): FSK modulation with AX.25 G3RUH framing

VELOX-AM

NORAD ID: 57482

Transmitters:

- **4k8 FSK downlink** (437.125 MHz): FSK modulation with AX100 ASM+Golay framing

VERONIKA

NORAD ID: 58261

Transmitters:

- **9k6 FSK downlink** (436.680 MHz): FSK modulation with AX.25 G3RUH framing

VIZARD

Alternative names: SXC3-215, RS33S

NORAD ID: 53386

Transmitters:

- **1k2 FSK downlink** (437.800 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.800 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.800 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.800 MHz): FSK modulation with USP framing

VIZARD-METEO

Alternative names: RS38S

NORAD ID: 57189

Transmitters:

- **1k2 FSK downlink** (437.825 MHz): FSK modulation with USP framing
- **2k4 FSK downlink** (437.825 MHz): FSK modulation with USP framing
- **4k8 FSK downlink** (437.825 MHz): FSK modulation with USP framing
- **9k6 FSK downlink** (437.825 MHz): FSK modulation with USP framing

VZLUSAT-2

NORAD ID: 51085

Transmitters:

- **9k6 FSK downlink** (437.325 MHz): FSK modulation with AX100 ASM+Golay framing
- **4k8 FSK downlink** (437.325 MHz): FSK modulation with AX100 ASM+Golay framing

X-CUBESAT

Alternative names: FR01, ON01FR

NORAD ID: 42707

Transmitters:

- **9k6 FSK downlink** (437.020 MHz): FSK modulation with AX.25 G3RUH framing
- **1k2 AFSK downlink** (437.020 MHz): AFSK modulation with AX.25 framing

XW-2A

Alternative names: CAS-3A

NORAD ID: 40903

Transmitters:

- **9k6 FSK downlink** (145.640 MHz): FSK modulation with AX.25 G3RUH framing

XW-2B

Alternative names: CAS-3B

NORAD ID: 40911

Transmitters:

- **9k6 FSK downlink** (145.705 MHz): FSK modulation with AX.25 G3RUH framing

XW-2C

Alternative names: CAS-3C

NORAD ID: 40906

Transmitters:

- **19k2 FSK downlink** (145.770 MHz): FSK modulation with AX.25 G3RUH framing

XW-2D

Alternative names: CAS-3D

NORAD ID: 40907

Transmitters:

- **9k6 FSK downlink** (145.835 MHz): FSK modulation with AX.25 G3RUH framing

XW-2E

Alternative names: CAS-3E

NORAD ID: 40909

Transmitters:

- **9k6 FSK downlink** (145.890 MHz): FSK modulation with AX.25 G3RUH framing

XW-2F

Alternative names: CAS-3F

NORAD ID: 40910

Transmitters:

- **9k6 FSK downlink** (145.955 MHz): FSK modulation with AX.25 G3RUH framing

XW-3

Alternative names: CAS-9

NORAD ID: 50466

Transmitters:

- **4k8 FSK downlink** (435.725 MHz): FSK modulation with AX.25 G3RUH framing

YUSAT-1

NORAD ID: 47439

Transmitters:

- **9k6 FSK downlink** (436.250 MHz): FSK modulation with YUSAT framing

ZACUBE-1

Alternative names: South Africa CubeSat-1, TshepisoSat, ZA003

NORAD ID: 39417

Transmitters:

- **9k6 FSK downlink** (437.356 MHz): FSK modulation with AX.25 G3RUH framing

Zhou Enlai

NORAD ID: 43156

Transmitters:

- **9k6 BPSK downlink** (436.420 MHz): BPSK modulation with AX.25 G3RUH framing

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