PolaRxS
Application Manual

Version 2.4.1

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Version 2.4.1
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1 Introduction

1.1 PolaRxS Concept

The PolaRxS is a multi-frequency multi-constellation receiver dedicated to ionospheric monitoring and space weather applications.

The PolaRxS incorporates a state-of-the-art triple-frequency receiver engine and an ultra low noise OXCO frequency reference in a rugged housing. The housing provides a multitude of interfaces including USB and Ethernet.

An intuitive User Graphical Interface is provided for data logging and remote control. Specifically for space weather and ionosphere monitoring applications, the logging tool (RxLogger) supports continuous TEC and scintillation indices logging and monitoring. Available indices include the S4, σ_ϕ, spectral slope and SI indexes for all satellite constellations and frequency bands.

1.2 High-Level Operation Overview

In a typical setup, the receiver generates and outputs 50-Hz phase and amplitude samples for all visible satellites and frequency bands. These samples are logged on a host PC in hourly files using the provided RxLogger graphical interface. At the end of every hour, TEC and scintillation indices are computed for all visible satellites and logged as comma-delimited ASCII records.

1.3 About this Manual

This manual covers the configuration of the PolaRxS receiver and of the RxLogger tool for ionospheric scintillation and TEC monitoring.

Chapter 2 of this document covers the configuration of the RxLogger tool.

Chapter 3 provides details on the **`sbf2ismr`** command line program and on the format of the ISMR output files. ISMR files contain Ionospheric Scintillation Monitoring Records (ISMR) logged every minute for all tracked satellites.

Additional relevant documentation can be found in the following manuals:
- The Firmware User Manual describes the operation principle of the receiver and provides how-to’s to help configuring the receiver in a selected set of applications.
- The Command Line Interface Reference Guide describes the the user command set.
- The SBF Reference Guide describes the Septentrio binary format (SBF).
- The PolaRxS Product Family Hardware Manual contains a description of the PolaRxS connectors and mechanical characteristics.
- The RxControl Manual covers the RxTools software suite, including RxControl and RxLogger.

Chapter 4 provides recommendations applicable when operating the receiver at 100-Hz output rate.

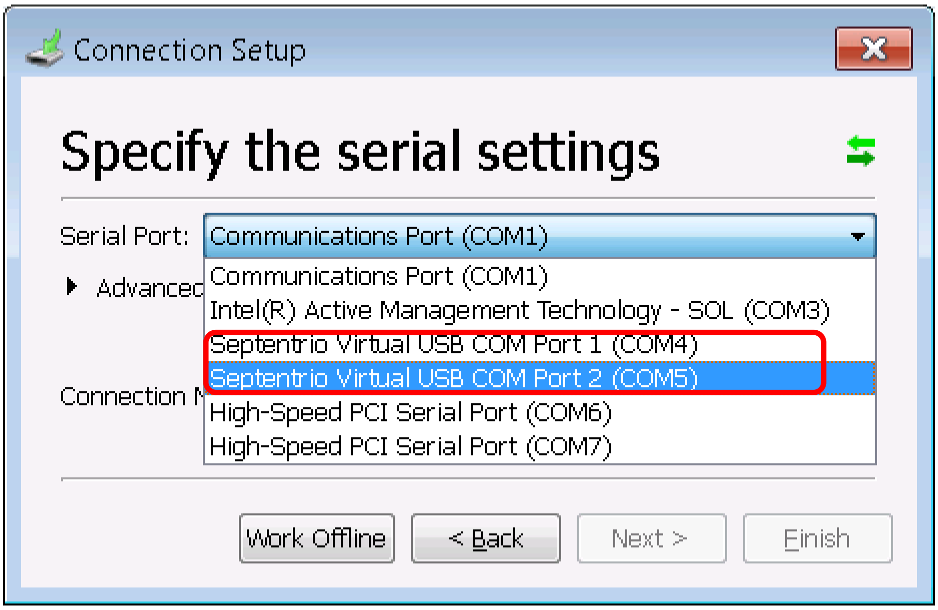
2 Typical RxLogger Configuration

2.1 Connecting To the Receiver

The first time you run RxLogger, you need to create a new connection. The next times, RxLogger will by default reuse the last connection, so that the connection creation must only be done once.

Refer to the RxControl Manual for a complete description of the connection options.

It is recommended to use one of the two Virtual USB COM ports (see below) connections to connect RxLogger to the receiver. A TCP/IP (Ethernet) connection is also possible but, depending on your network topology, may lead to occasional data gaps when logging at high rate. Standard serial ports should not be used because their bandwidth is too low to support the high-rate data required for ionospheric scintillation monitoring.



2.2 Configuring the Receiver

For scintillation monitoring, it is recommended to configure the receiver such that:

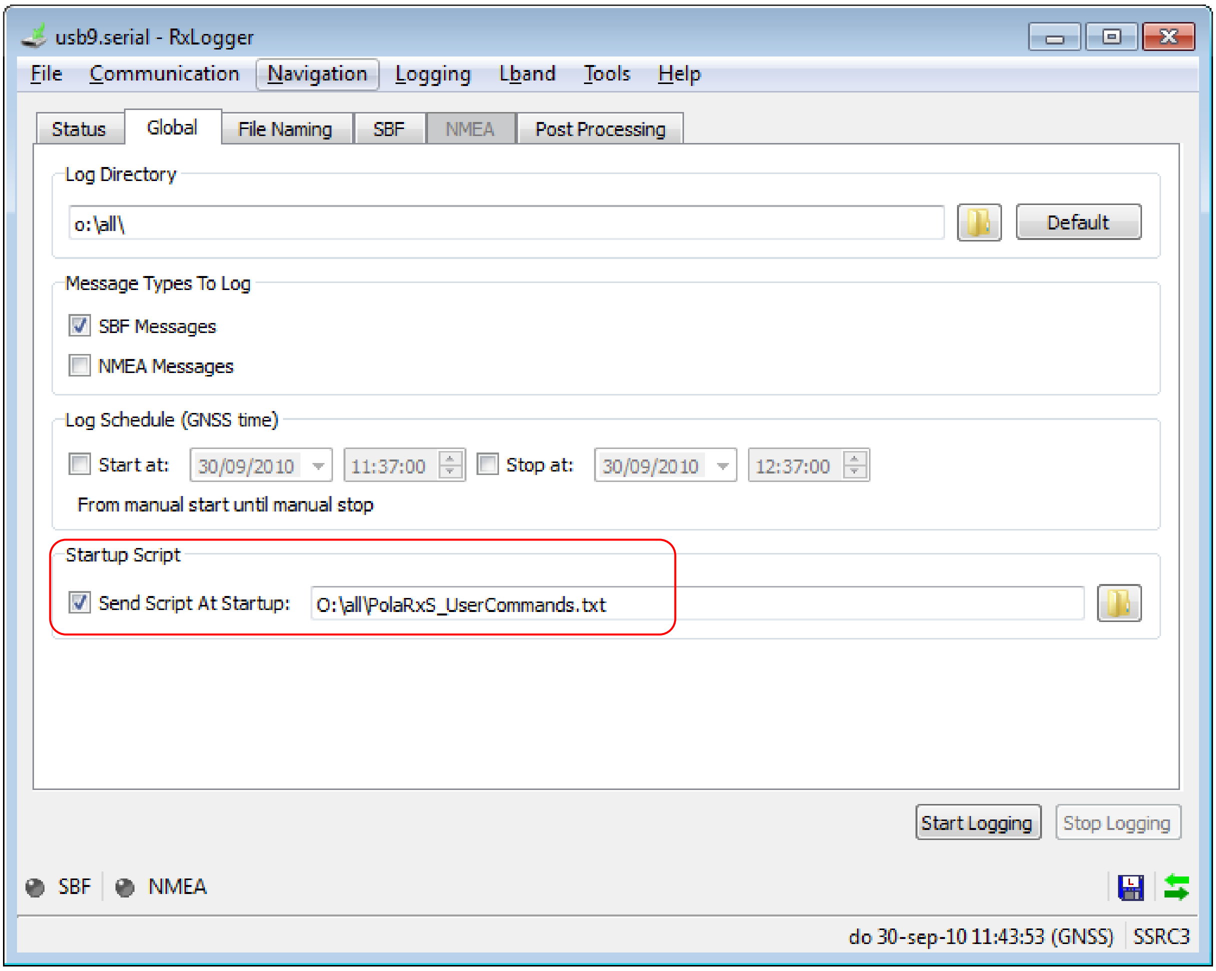
- the frontend automatic gain control (AGC) is turned off;
- the adaptive tracking loop parameters are turned off;
- the C/N0 mask is reduced.

One of the ways to do so is to ask RxLogger to send a “startup script” to the receiver before the logging starts. A startup script is a text file containing a list of user commands, one command per line. It is recommended that the startup script would contain the following lines:

```
setAGCMode,all,frozen
setTrackingLoopParameters,all,,,,,off
setCN0Mask,all,15
```

Please refer to the Command Line Interface Reference Guide for a description of these three commands.

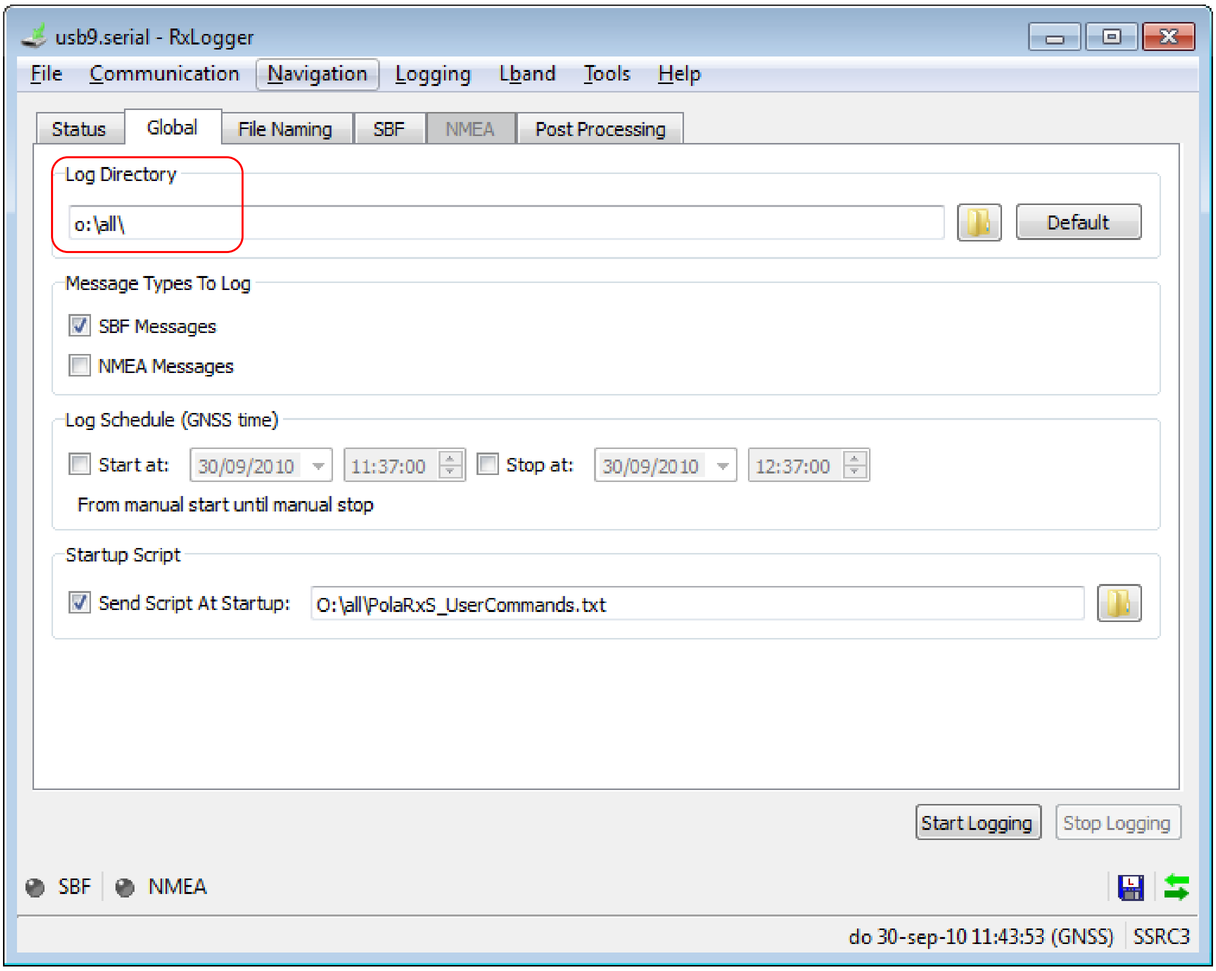
In the main window of RxLogger, select the “Global” tab and enter the location of the startup script as shown below.



2.3 Configuring File Names and Directories

You need to specify where to store the raw data from the receiver. Raw data (high-rate phase and amplitude and low-rate support data) are stored in the Septentrio-proprietary SBF format. Raw data files are referred to as “SBF files” in the sequel of this document.

In the main window of RxLogger, select the “Global” tab and make sure that the Log Directory points to the folder where the SBF files must be logged. In the screen shot shown below, we want all data to be stored under `o:\all\`.



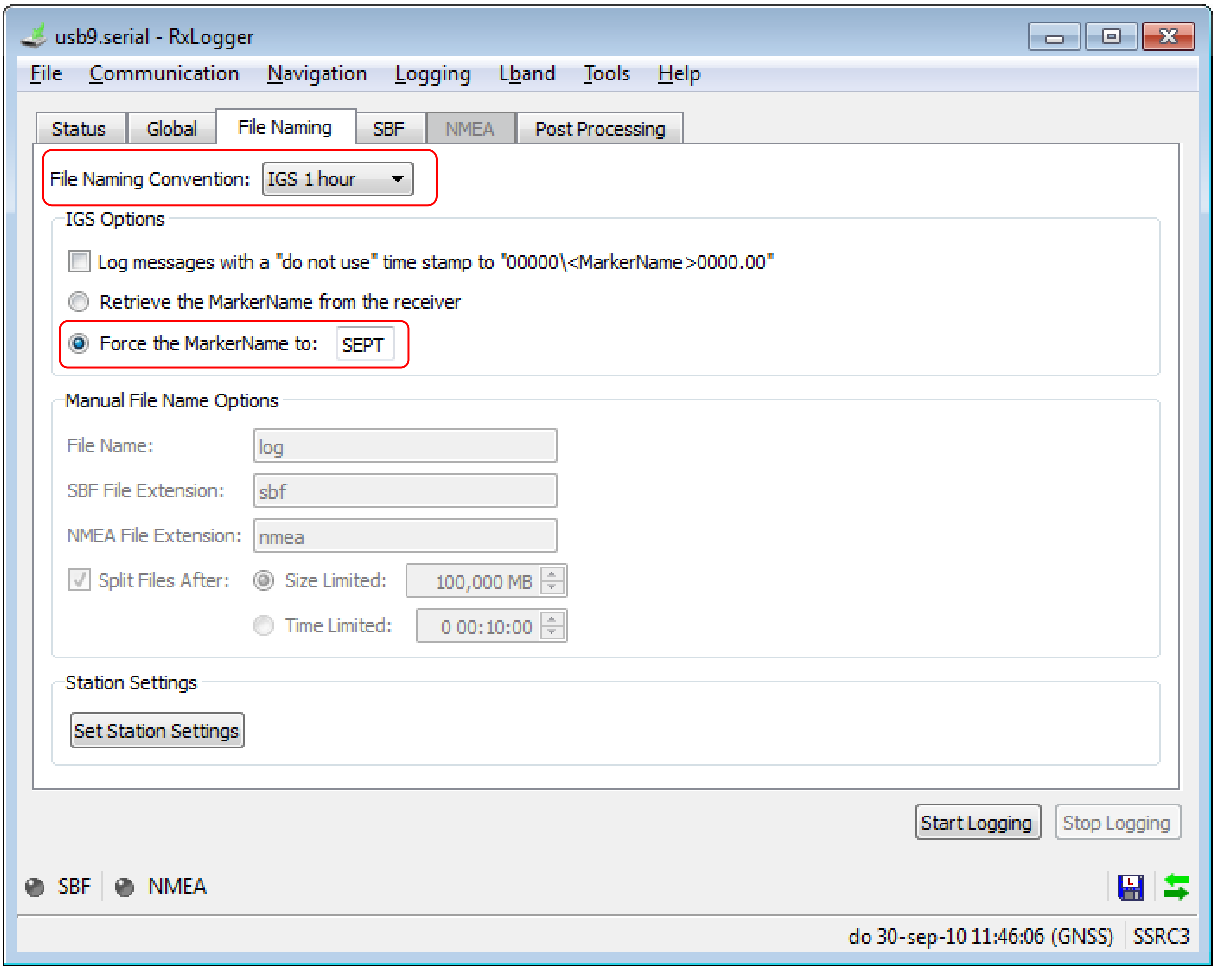
Now select the “File Naming” tab, and set the file naming convention to “IGS 1 hour”: this will cause RxLogger to create hourly SBF files.

Do not use the “IGS 6-hours” or “IGS 24-hours” naming conventions as this could cause SBF file size to exceed 2Gbytes. The **sbf2ismr** tool (see Chapter 3) does not support file sizes larger than 2Gbytes.

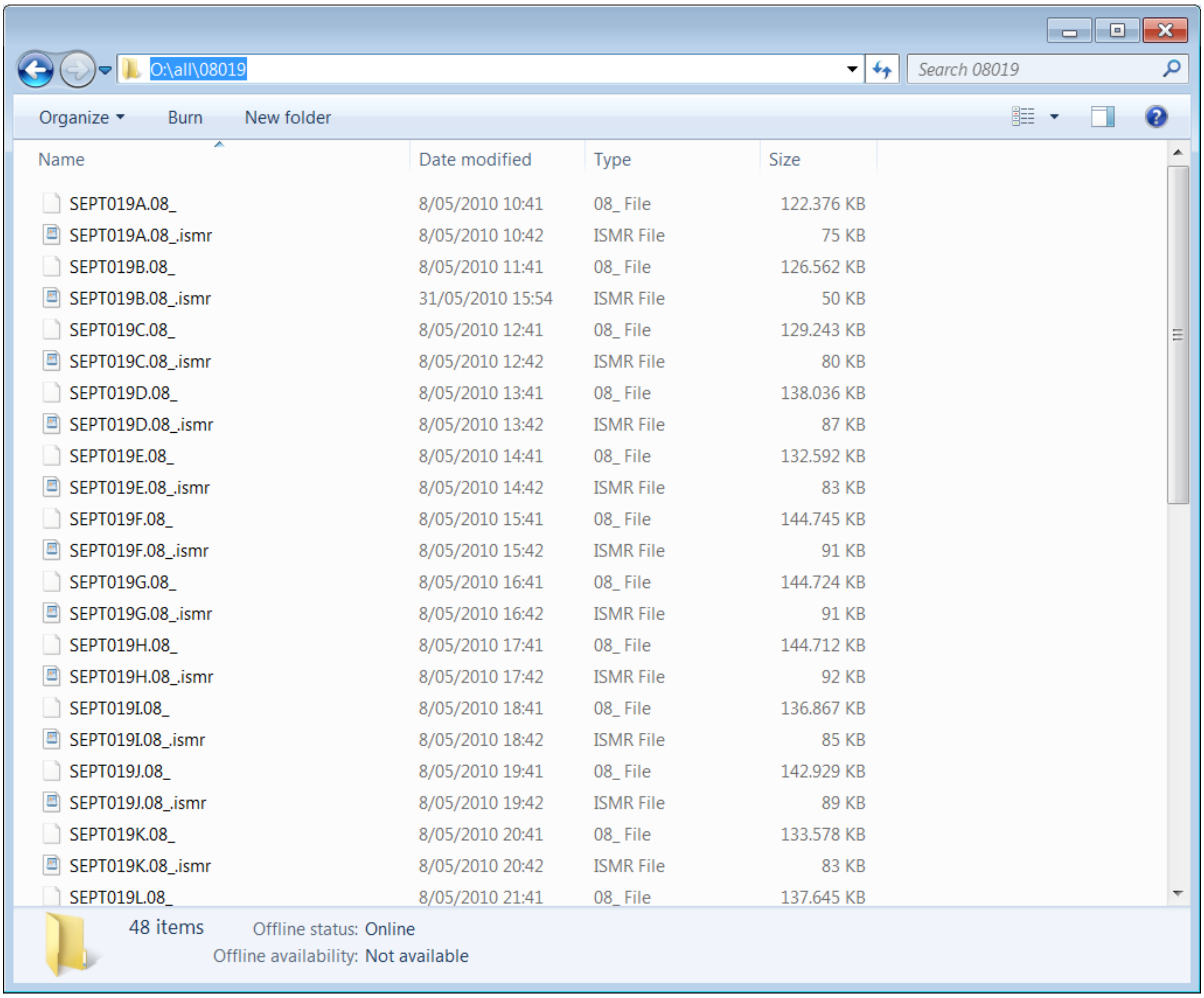
A new directory will be created every day under the directory specified under the “Global” tab, with the name being formed by the concatenation of the two-digit year number and the 3-digit day-of-year. Within each of the daily directories, the hourly SBF files follow the IGS file naming convention:

```
ssssdddf.yy_
|   |  | |
|   |  | |
|   |  | |
|   |  | +---  yy:  two-digit year
|   |  |
|   |  +-----   f:  file sequence character within day
|   |               A:  1st hour 00h-01h; B: 2nd hour 01h-02h; ...
|   |               X: 24th hour 23h-24h
|   |
|   +-------  ddd:  day of the year of first record in file
|
+----------- ssss:  4-character station name designator
```

The “ssss” field (the station name designator) can be freely chosen by the user by checking “Force the MarkerName to:”. In the example shown below, the “ssss” field is set to “SEPT”.



The screen shot below shows an exemplary directory contents corresponding to January 19, 2008. The files with the "`.08_`" extension are SBF files containing the raw data from the receiver. The files with the "`.08_.ismr`" extension are the post-processed files containing the scintillation indices (see later in section 2.5 how to configure the post-processing actions).



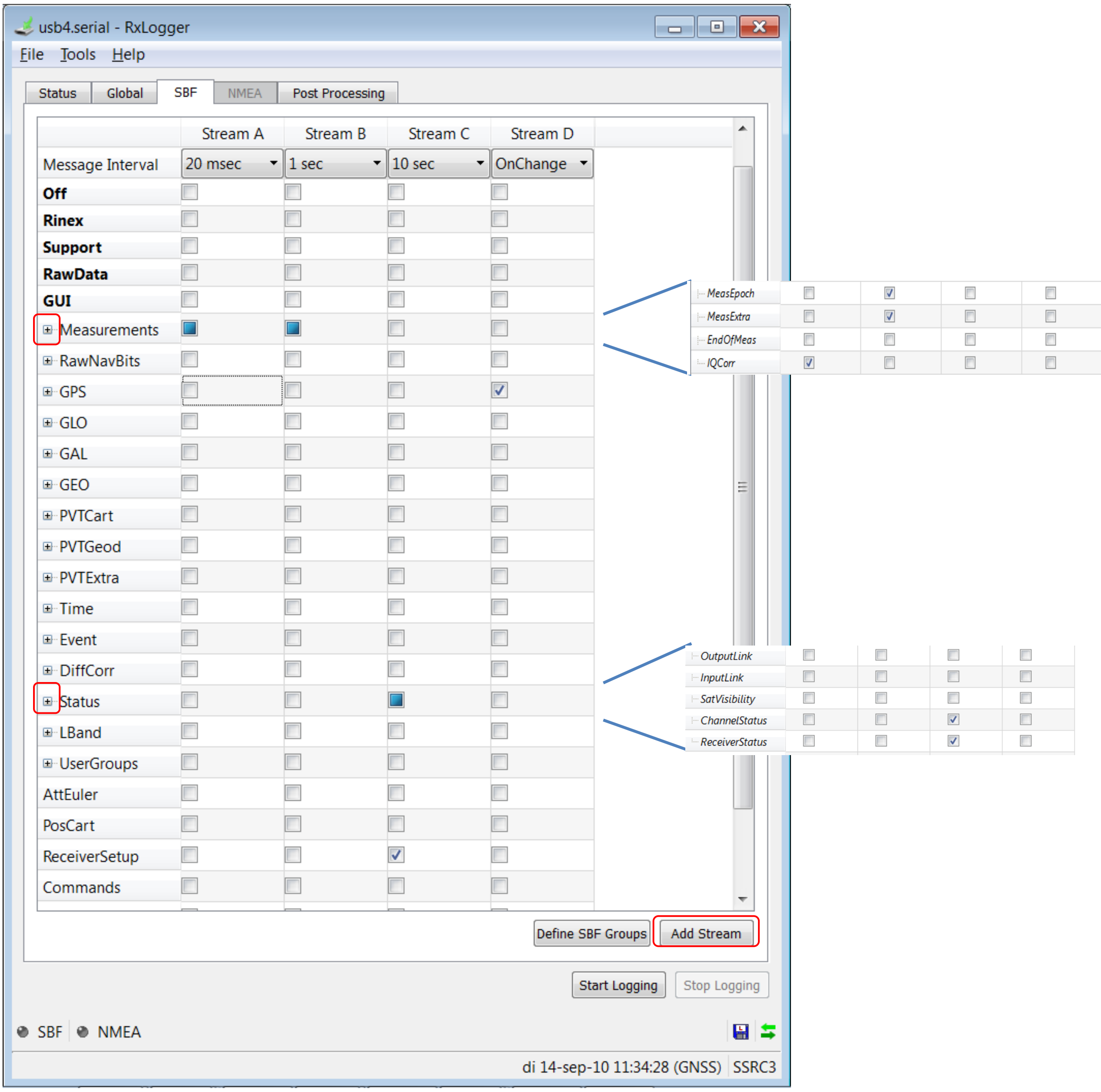
2.4 Configuring the Set of Raw Data to Log

Raw data in the SBF format are arranged in so-called SBF blocks and you need to tell RxLogger which blocks to log and at which interval. This is done under the "SBF" tab of the main window of RxLogger. For ionospheric scintillation and TEC monitoring, the following SBF blocks must be logged:

- At an interval of 20ms (50Hz):
  - IQCorr
- At an interval of 1s (1Hz)[1]:
  - MeasEpoch
  - MeasExtra
- At an interval of 10s:
  - ReceiverStatus
  - ChannelStatus
  - ReceiverSetup
- At an interval of "onchange":
  - GPSNav

Click the "Add Stream" button to add a new column in the window. A column contains all the blocks that need to be logged at a certain interval.

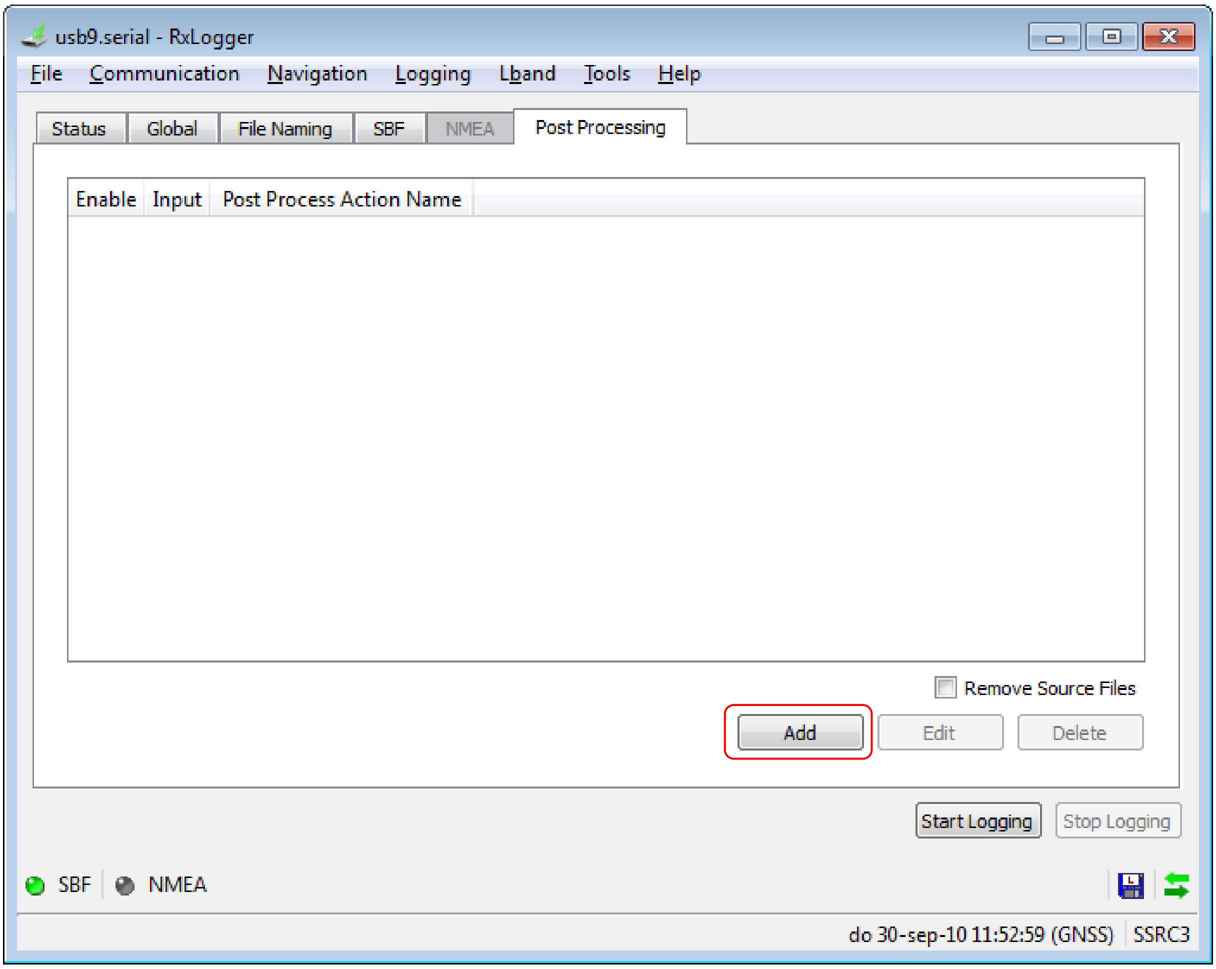
[1] It is not needed to log the MeasEpoch and MeasExtra SBF blocks at 50-Hz. A 1-Hz rate is recommended for these blocks to reduce the CPU burden and minimize the file size.



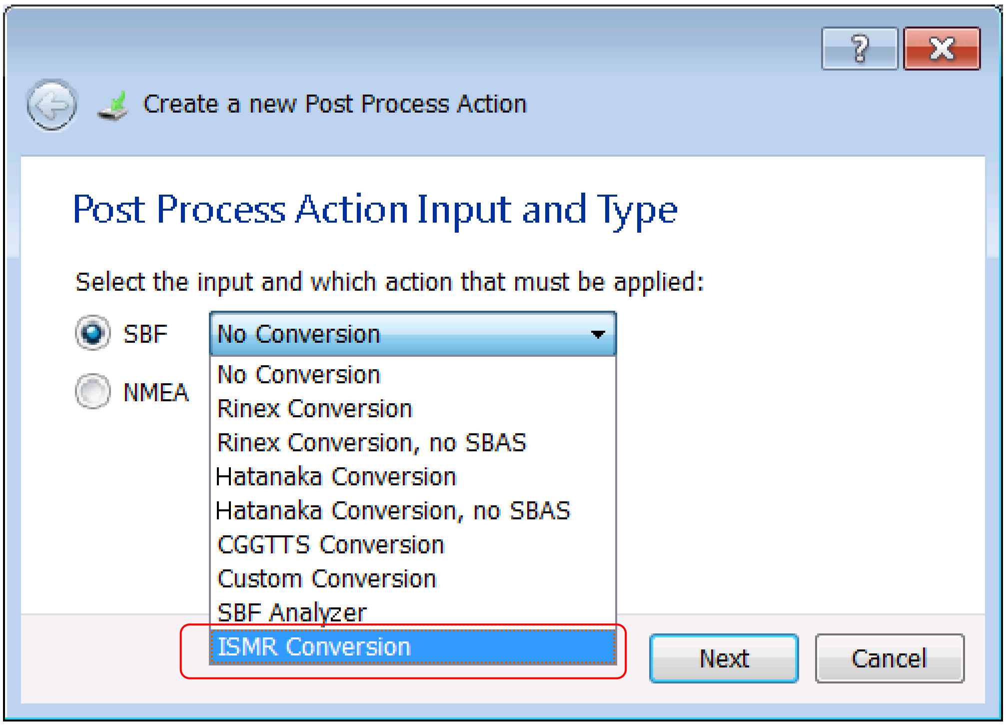
2.5 Configuring the Post Processing Options

The SBF files do not contain the scintillation indices. To compute these indices from the SBF file, you need to use the **`sbf2ismr`** conversion program. RxLogger can automatically call that program at each hour boundary, and let it run over the file collected during the last hour. To do this, you define a post-processing action under the "Post Processing" tab of the main window of RxLogger.

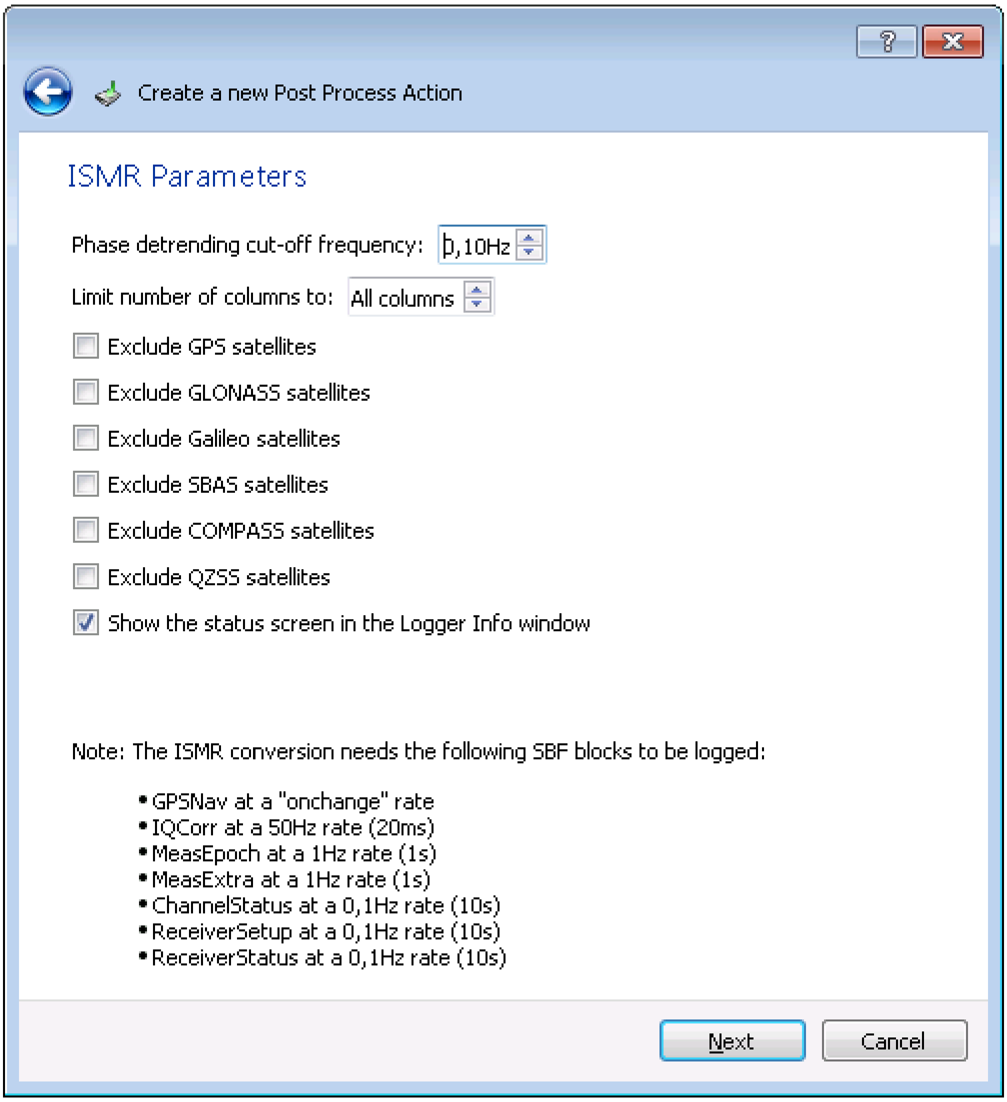
Refer to Chapter 3 for a detailed description of the **`sbf2ismr`** conversion program.



Click the "Add" button to add a post-processing action. The following window appears, where you need to select SBF ISMR Conversion.



Click "Next" to see the ISMR conversion options.

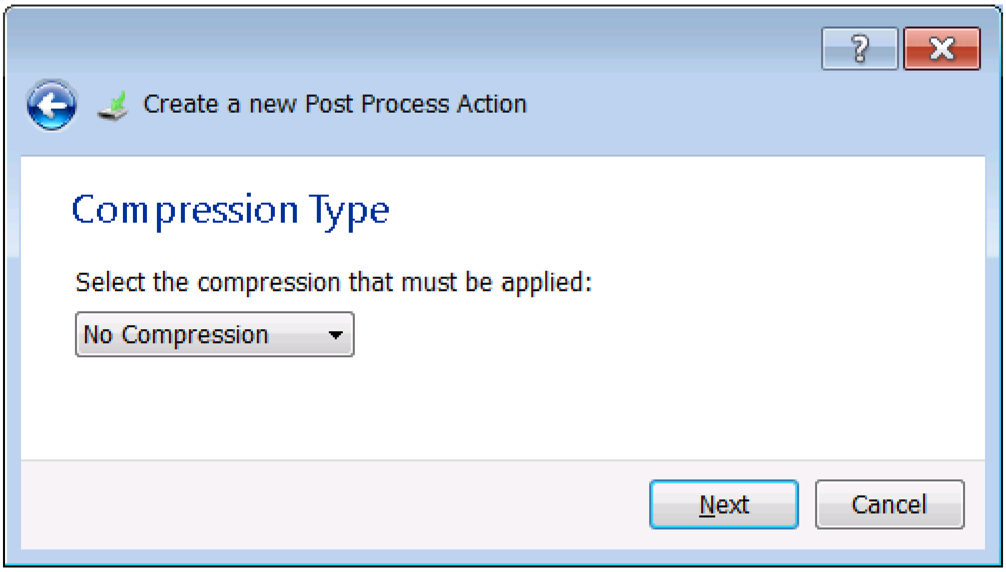


Select the phase detrending cut-off frequency as desired (default is 0.10Hz).

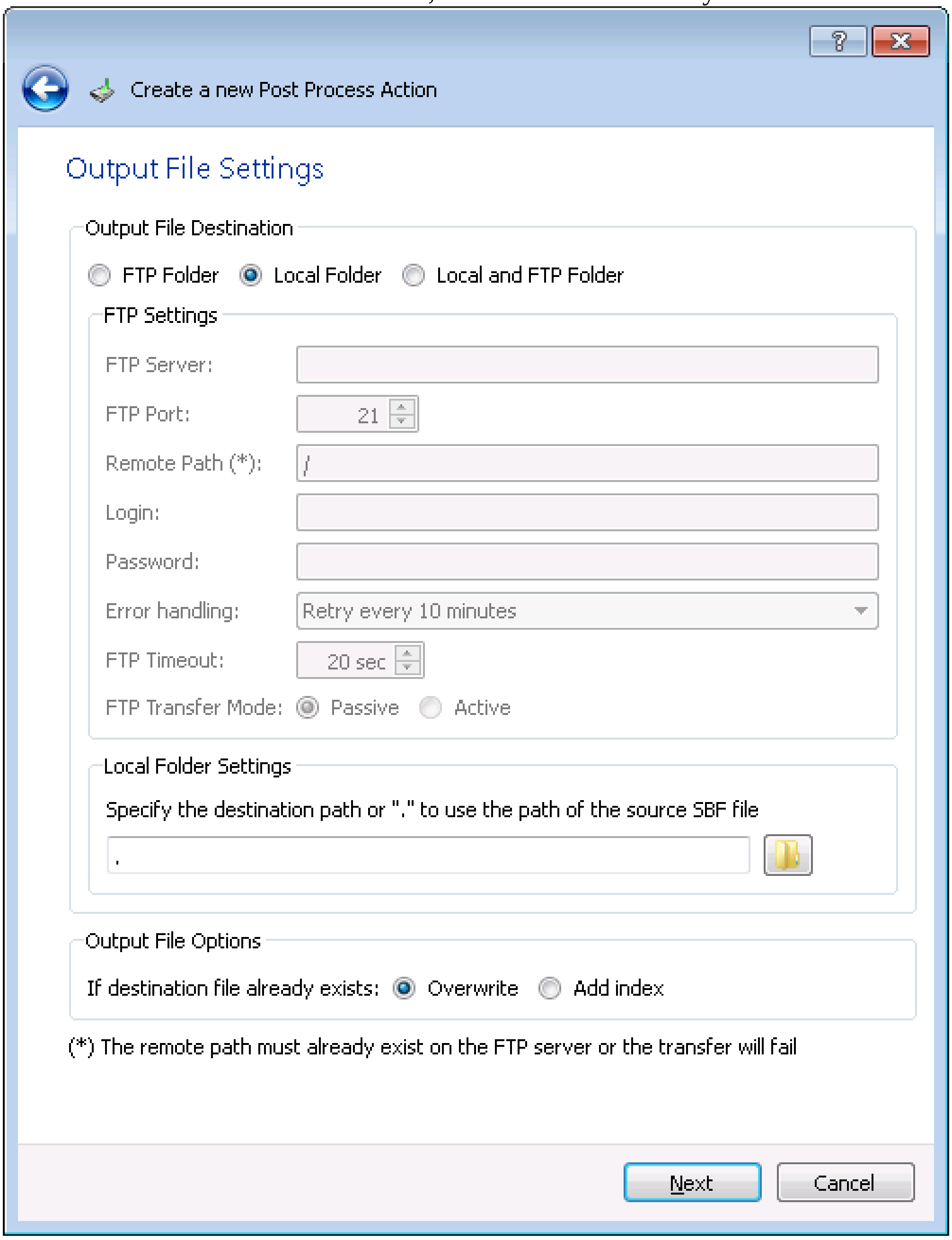
You may want to reduce the number of columns in the ISMR file, for example if you are only interested in single-frequency indices. Refer to section 3.1.3 for details.

It is also possible to exclude one or more constellations from the ISMR file, even if data from satellites from these constellations are available in the SBF file.

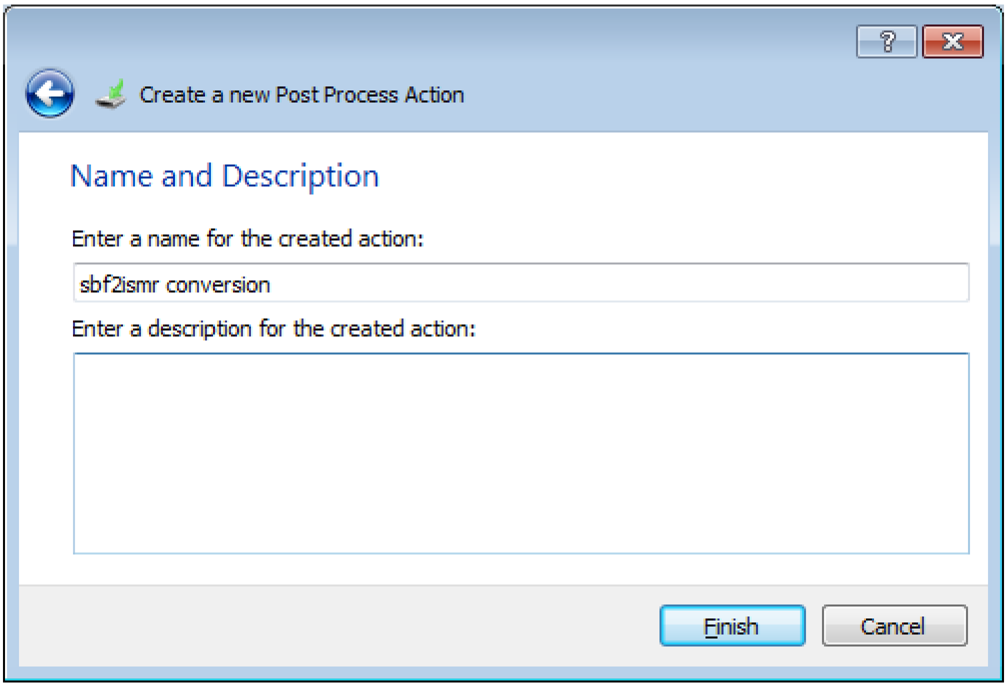
Click "Next" to go to the "Compression Type" window, where you can select which compression to apply to the ISMR file. As these files are typically small (<200kbytes), it is typical not to apply any compression.



Clicking "Next" brings you to the "Output File Destination" window, where you can configure an automatic FTP of the freshly created ISMR file to a remote FTP server. Just click next to simply leave the ISMR files at their default location, i.e. in the same directory as the raw SBF files.



Finally, you are offered to choose a name for the post-process action and to add some textual details. The name that you type here is for information purpose only.

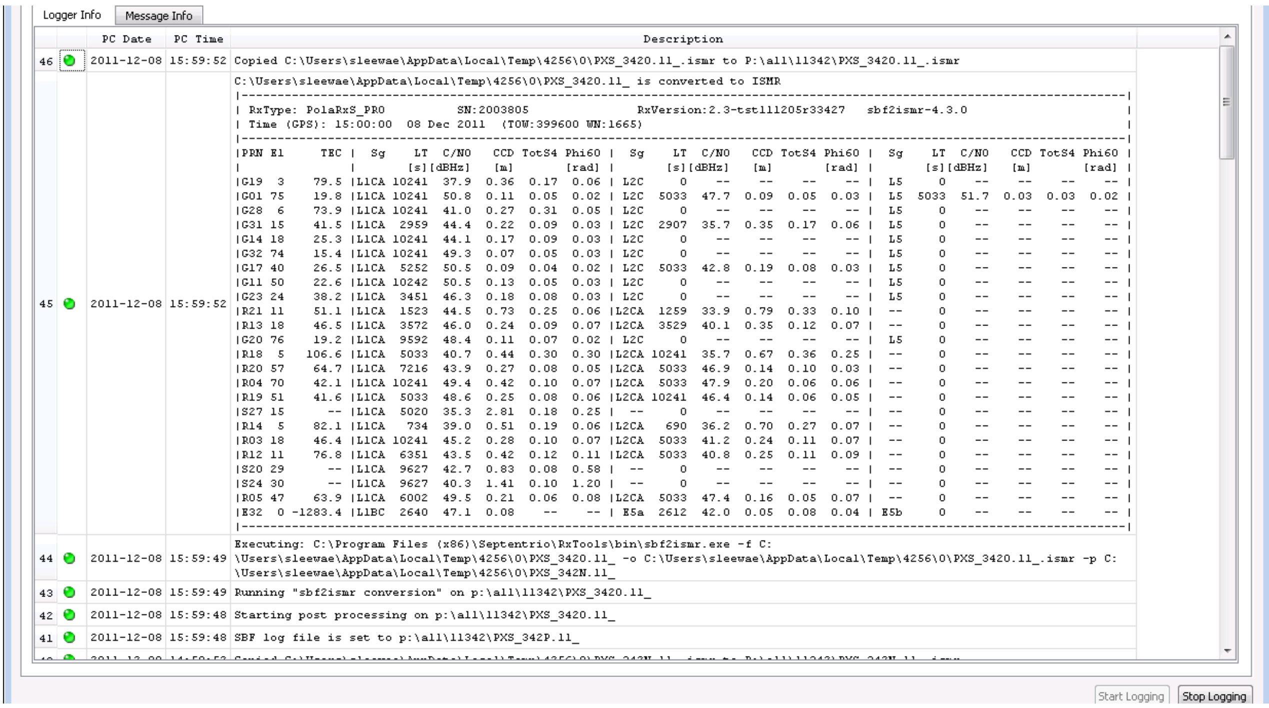


Click “Finish” and you will see the “sbf2ismr conversion” action appearing in the list of post processing actions.

You may now click “Start Logging” to start logging.

2.6 Controlling the Logging and ISMR Status

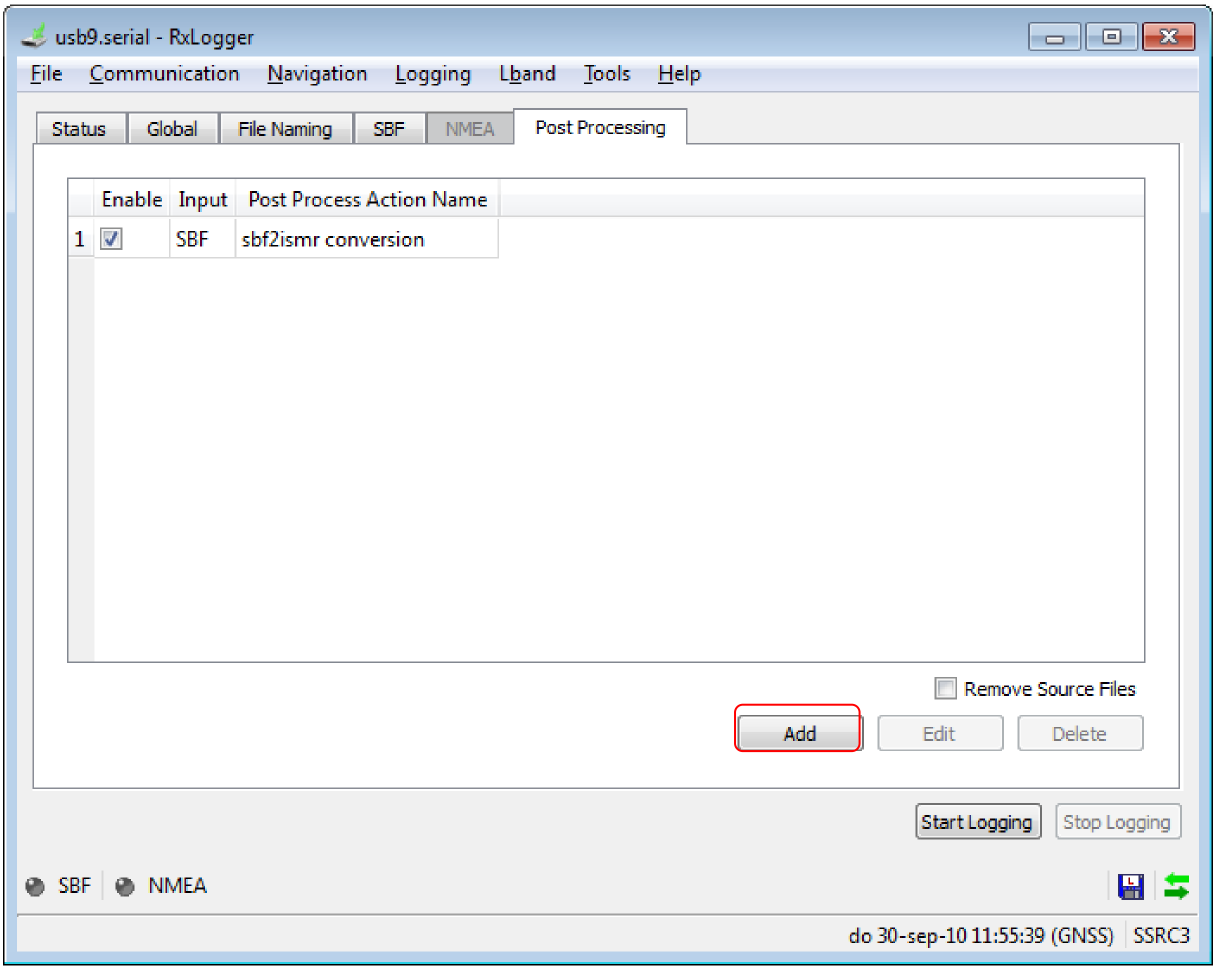
Under the “Status” tab of the main window of RxLogger, you can follow the progress of the logging and post-processing and get a hourly snapshot of the ISMR indices.



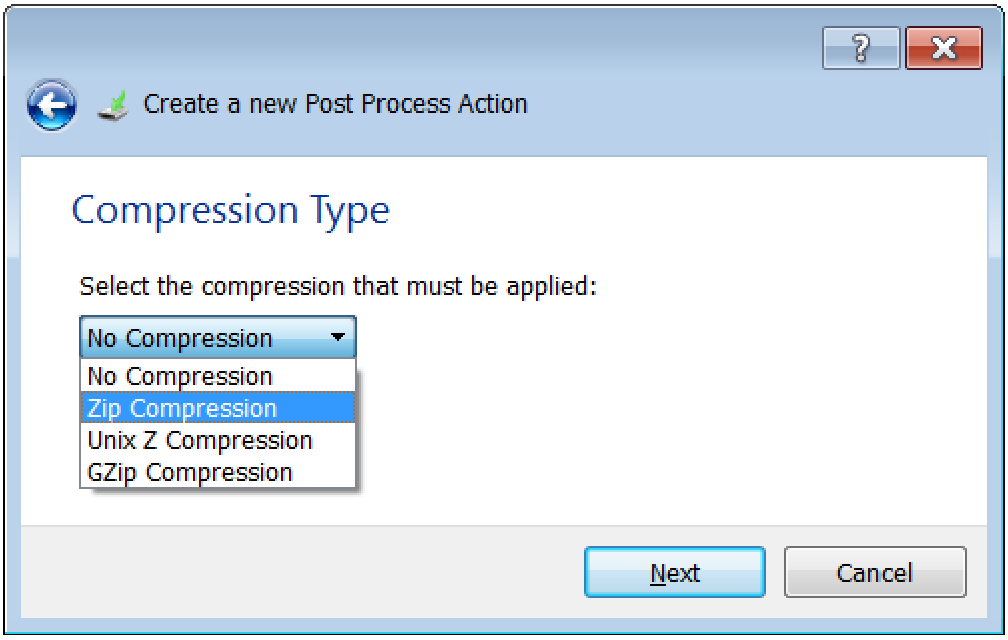
At any time, logging can be stopped by clicking “Stop Logging”.

2.7 Compressing the Raw SBF files

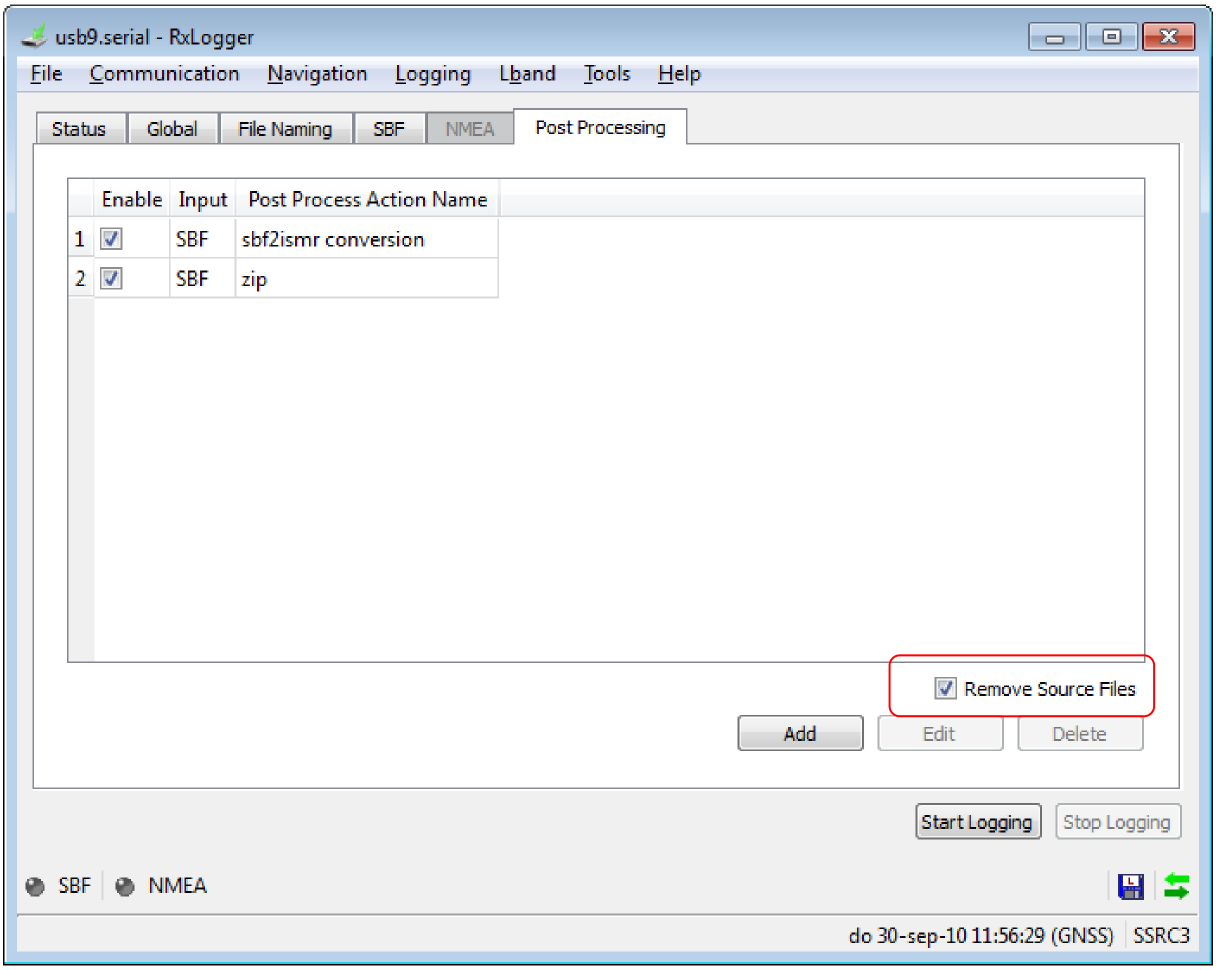
The hourly SBF files are typically very large. RxLogger can automatically compress these files. To do this, you define another post-processing action under the “Post Processing” tab of the main window of RxLogger.



Click the “Add” button to add a new post-processing action. In the Post Process Action Input and Type window, just click “Next” as there is no conversion to apply, but only a compression.



You can now select the compression program to use. Click “Next” to enter the “Output File Destination” window, where you typically click “Next” again. You can now enter a textual description of this new post-processing action and click “Finish”.



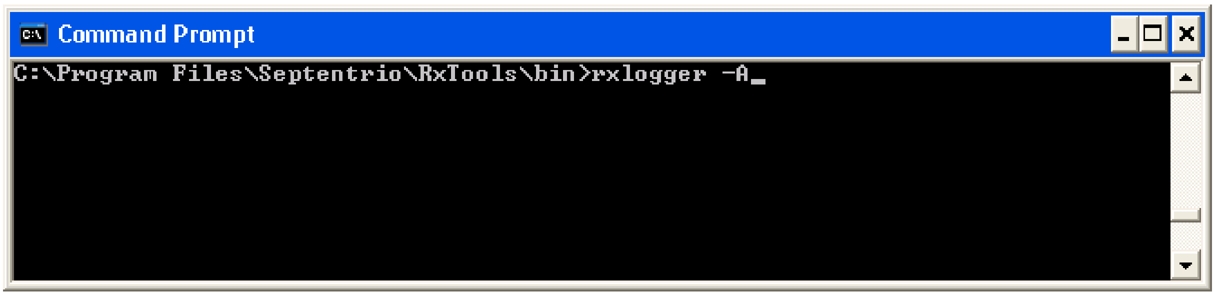
Make sure to check the “Remove Source Files” box, in order to delete the original (non compressed) SBF file.

2.8 Exiting and Restarting RxLogger

When exiting and restarting RxLogger, all the user settings are maintained (they are stored in the file `.septentrio/rxlogger.conf` under the user's home directory), so that the configuration steps described above only need to be executed once.

2.9 Starting RxLogger from the Command Line

It is possible to launch rxlogger from the command line, as shown below under Windows XP.



Rxlogger starts in the configuration as stored in the `rxlogger.conf` file. The `-A` command line option causes RxLogger to immediately start logging without any user interaction.
The command "`rxlogger -A`" can be included in a boot script on the host PC to automatically start RxLogger at each boot.

3 sbf2ismr Program

The **sfb2ismr** program converts a binary SBF file containing 50- or 100-Hz raw correlation and phase data into an ASCII ISMR file containing ionospheric scintillation and TEC indices. In addition, **sbf2ismr** can also produce an ASCII file containing the unprocessed 50- or 100-Hz raw correlations and phase data.

sbf2ismr is a command line tool. Both a Windows and a Linux version are provided. Typically, **sbf2ismr** is automatically started from RxLogger at the end of every hourly file, but it can also be manually called at any time to get an instant overview of the scintillation indices, or to reprocess the raw high-rate data.

The maximum SBF file size supported by **sbf2ismr** is 2Gbytes.

The output ISMR file contains comma-delimited ASCII records for all satellites in view and for every minute. An exemplary set of records is shown below:

```
1462,540300, 11,00000074, 27,15,48.2, 0.029, 0.000, 0.017, 0.023, 0.028, 0.028, 0.028,  2.397, 0.071, 18.811, 0.042, 18.830, 0.044, 18.782, 0.055, 19.934, 0.033, 3581,0, 3578,37.5,  0.8
1462,540300, 10,00000074,232,29,48.2, 0.049, 0.030, 0.026, 0.032, 0.036, 0.036, 0.036, -3.606, 0.066, 13.851,-0.031, 14.099,-0.026, 14.384,-0.021, 14.061,-0.032, 4210,0, 4202,37.6,  1.5
1462,540300, 23,00000074,232,68,48.2, 0.039, 0.007, 0.023, 0.029, 0.033, 0.033, 0.034, -5.799, 0.073,  7.283, 0.004,  5.559,-0.003,  7.273, 0.013,  5.864,-0.006,11894,0,11888,37.6,  1.3
1462,540300, 17,00000074,152,15,48.2, 0.039, 0.006, 0.020, 0.026, 0.030, 0.030, 0.031, -1.774, 0.056, 18.259, 0.010, 19.839, 0.014, 19.230, 0.006, 19.458, 0.006,22381,0,22376,37.7,  1.1
1462,540300,  1,00000074,344,23,48.2, 0.030, 0.000, 0.018, 0.024, 0.029, 0.029, 0.029, -2.851, 0.061, 16.669,-0.041, 17.002,-0.032, 16.412,-0.035, 17.973,-0.036, 3761,0, 3752,37.5,  0.9
1462,540300,  2,00000074, 17,45,48.2, 0.041, 0.012, 0.019, 0.025, 0.030, 0.030, 0.030, -1.537, 0.168, 10.215,-0.019, 10.976,-0.024, 10.329,-0.014, 10.548,-0.021, 2981,0, 2977,37.6,  1.1
1462,540300, 15,00000074, 85,37,48.2, 0.029, 0.000, 0.017, 0.023, 0.028, 0.029, 0.029, -4.356, 0.062,  9.643, 0.008, 10.691, 0.002, 10.748,-0.002, 11.128, 0.007,29080,0,29072,37.7,  0.9
1462,540300, 24,00000074,170,47,48.2, 0.029, 0.000, 0.016, 0.022, 0.028, 0.028, 0.028, -5.024, 0.053,  8.872, 0.012,  8.882, 0.023,  9.082, 0.023,  9.253, 0.024,17000,0,16994,37.7,  0.8
1462,540300,  8,00000074,308,16,48.2, 0.031, 0.000, 0.017, 0.023, 0.029, 0.029, 0.029, -1.904, 0.054, 17.773,-0.001, 19.134,-0.002, 17.611, 0.006, 18.916, 0.002,10137,0,10130,37.6,  0.9
1462,540360, 11,00000074, 27,15,48.0, 0.028, 0.000, 0.016, 0.022, 0.028, 0.029, 0.030,  2.446, 0.048, 18.906, 0.060, 18.744, 0.038, 19.020, 0.052, 18.954, 0.049, 3641,0, 3638,37.6,  0.8
1462,540360, 10,00000074,232,30,48.0, 0.045, 0.022, 0.019, 0.024, 0.030, 0.031, 0.031, -3.654, 0.047, 14.184,-0.022, 13.899,-0.027, 13.575,-0.021, 14.460,-0.017, 4270,0, 4262,37.6,  1.4
1462,540360, 23,00000074,231,68,48.0, 0.039, 0.000, 0.018, 0.023, 0.029, 0.031, 0.031, -5.799, 0.074,  6.616, 0.005,  7.006, 0.003,  6.473, 0.005,  8.339, 0.010,11954,0,11948,37.7,  1.2
1462,540360, 17,00000074,152,15,48.0, 0.037, 0.000, 0.017, 0.022, 0.028, 0.030, 0.030, -1.734, 0.073, 17.887, 0.019, 19.591, 0.008, 19.468, 0.007, 18.697, 0.012,22441,0,22436,37.7,  1.0
1462,540360,  1,00000074,344,23,48.0, 0.030, 0.000, 0.017, 0.022, 0.029, 0.030, 0.030, -2.863, 0.055, 15.289,-0.029, 15.365,-0.043, 15.641,-0.035, 15.774,-0.034, 3821,0, 3812,37.6,  0.8
1462,540360,  2,00000074, 17,45,48.0, 0.042, 0.014, 0.019, 0.024, 0.030, 0.032, 0.032, -1.521, 0.059,  9.843,-0.012,  8.758,-0.018,  9.605,-0.017,  9.615,-0.015, 3041,0, 3037,37.6,  1.2
1462,540360, 15,00000074, 85,37,48.0, 0.029, 0.000, 0.016, 0.022, 0.028, 0.029, 0.030, -4.354, 0.052, 11.167, 0.007, 11.852,-0.000, 12.414, 0.010, 10.929, 0.006,29140,0,29132,37.7,  0.8
1462,540360, 24,00000074,170,46,48.0, 0.030, 0.000, 0.017, 0.022, 0.028, 0.029, 0.030, -5.017, 0.062, 10.205, 0.017,  9.482, 0.025,  8.596, 0.017,  9.205, 0.026,17060,0,17054,37.7,  0.9
1462,540360,  8,00000074,309,16,48.0, 0.032, 0.000, 0.018, 0.022, 0.028, 0.030, 0.030, -1.926, 0.069, 17.764, 0.004, 18.354, 0.001, 17.802, 0.002, 19.268, 0.002,10197,0,10190,37.6,  0.9
```

Invoking **sbf2ismr** with the `-h` option prints the help screen, including the definition of all the fields (or columns) in a record:

```
sbf2ismr is a utility to convert the data in a SBF file into ASCII ionospheric scintillation
monitoring records.  The SBF file needs to contain the following SBF blocks at at least
the specified interval:
    IQCorr,         20ms
    MeasEpoch,      1s
    MeasExtra,      1s
    ReceiverStatus, 10s
    ChannelStatus,  10s
    ReceiverSetup,  10s
    GPSNav,         OnChange

Command line options:

sbf2ismr -f InputFile [-o ISMRFile][-p PreviousFile][-x Systems][-c DetFreq]
                      [-n NoCols][-S][-r RawFile][-b StartEpoch][-e EndEpoch]
                      [-V][-h]

  -f InputFile :  (mandatory) Name of the input SBF file.
  -o ISMRFile :   Name of the output file containing the ISMR records (see
                  format below).
                  This argument is optional.  If not provided, the output file
                  name is the same as the input file name, with the extension
                  .ismr being added.See below the format of the ISMR file.
  -p PrevFile :   Name of the previous input file, i.e. name of the SBF file
                  logged just before input_file.  The last epochs of the
                  previous file are used to initialize the detrending filters.
                  If there is no previous file, skip this option or use NA as
                  PrevFile.
  -x Systems      Exclude one or more satellite systems from the observation
                  file. Systems may be G (GPS), R (Glonass), E (Galileo),
                  S (SBAS), C (Compass), J (QZSS) or any combination thereof.  For
                  instance -xERSCJ produces a GPS-only observation file.
  -c DetFreq :    Cutoff frequency of the carrier phase detrending filter
                  (6th order high pass butterworth).  Units of Hz. Valid values
                   range from 0.01 to 1.0 Hz, default 0.1Hz.
  -n NoCols :     Only output the first NoCols in the output file (see column
                  format below).
  -S :            Do not generate the ISMR file, but still print the status
                  screen.
  -r RawFile :    Name of the "raw file" containing the raw data
                  (carrier phase and correlations) in ASCII format.  This
```

```
                  argument is optional.  If not provided, the raw file is
                  not created. See below the format of the raw file.
  -b StartEpoch   Time of first epoch to parse from the SBF file (in GPS time
                  scale). Format: yyyy-mm-dd_hh:mm:ss.
  -e EndEpoch     Time of last epoch to parse from the SBF file (in GPS time
                  scale). Format: yyyy-mm-dd_hh:mm:ss.
  -V :            Display the version of sbf2ismr.
  -h :            Display this help screen.


Format of the ISMR file:
  Note: "Sig1" means L1CA for GPS/GLONASS/SBAS/QZSS, L1BC for GALILEO or B1 for COMPASS.
        "Sig2" means L2C for GPS/GLONASS/QZSS, E5a for GALILEO or B2 for COMPASS.
        "Sig3" means L5 for GPS/QZSS or E5b for GALILEO.

Col  1: WN, GPS Week Number
Col  2: TOW, GPS Time of Week (seconds)
Col  3: SVID
Col  4: Value of the RxState field of the ReceiverStatus SBF block
Col  5: Azimuth (degrees)
Col  6: Elevation (degrees)
Col  7: Average Sig1 C/N0 over the last minute (dB-Hz)
Col  8: Total S4 on Sig1 (dimensionless)
Col  9: Correction to total S4 on Sig1 (thermal noise component only) (dimensionless)
Col 10: Phi01 on Sig1,  1-second phase sigma (radians)
Col 11: Phi03 on Sig1,  3-second phase sigma (radians)
Col 12: Phi10 on Sig1, 10-second phase sigma (radians)
Col 13: Phi30 on Sig1, 30-second phase sigma (radians)
Col 14: Phi60 on Sig1, 60-second phase sigma (radians)
Col 15: AvgCCD on Sig1, average of code/carrier divergence (meters)
Col 16: SigmaCCD on Sig1, standard deviation of code/carrier divergence (meters)
Col 17: TEC at TOW - 45 seconds (TECU)
Col 18: dTEC from TOW - 60s to TOW - 45s (TECU)
Col 19: TEC at TOW - 30 seconds (TECU)
Col 20: dTEC from TOW - 45s to TOW - 30s (TECU)
Col 21: TEC at TOW - 15 seconds (TECU)
Col 22: dTEC from TOW - 30s to TOW - 15s (TECU)
Col 23: TEC at TOW (TECU)
Col 24: dTEC from TOW - 15s to TOW (TECU)
Col 25: Sig1 lock time (seconds)
Col 26: sbf2ismr version number
Col 27: Lock time on the second frequency used for the TEC computation (seconds)
Col 28: Averaged C/N0 of second frequency used for the TEC computation (dB-Hz)
Col 29: SI Index on Sig1: (10*log10(Pmax)-10*log10(Pmin))/(10*log10(Pmax)+10*log10(Pmin)) (dimensionless)
Col 30: SI Index on Sig1, numerator only: 10*log10(Pmax)-10*log10(Pmin) (dB)
Col 31: p on Sig1, spectral slope of detrended phase in the 0.1 to 25Hz range (dimensionless)
Col 32: Average Sig2 C/N0 over the last minute (dB-Hz)
Col 33: Total S4 on Sig2 (dimensionless)
Col 34: Correction to total S4 on Sig2 (thermal noise component only) (dimensionless)
Col 35: Phi01 on Sig2,  1-second phase sigma (radians)
Col 36: Phi03 on Sig2,  3-second phase sigma (radians)
Col 37: Phi10 on Sig2, 10-second phase sigma (radians)
Col 38: Phi30 on Sig2, 30-second phase sigma (radians)
Col 39: Phi60 on Sig2, 60-second phase sigma (radians)
Col 40: AvgCCD on Sig2, average of code/carrier divergence (meters)
Col 41: SigmaCCD on Sig2, standard deviation of code/carrier divergence (meters)
Col 42: Sig2 lock time (seconds)
Col 43: SI Index on Sig2 (dimensionless)
Col 44: SI Index on Sig2, numerator only (dB)
Col 45: p on Sig2, phase spectral slope in the 0.1 to 25Hz range (dimensionless)
Col 46: Average Sig3 C/N0 over the last minute (dB-Hz)
Col 47: Total S4 on Sig3 (dimensionless)
Col 48: Correction to total S4 on Sig3 (thermal noise component only) (dimensionless)
Col 49: Phi01 on Sig3,  1-second phase sigma (radians)
Col 50: Phi03 on Sig3,  3-second phase sigma (radians)
Col 51: Phi10 on Sig3, 10-second phase sigma (radians)
Col 52: Phi30 on Sig3, 30-second phase sigma (radians)
Col 53: Phi60 on Sig3, 60-second phase sigma (radians)
Col 54: AvgCCD on Sig3, average of code/carrier divergence (meters)
Col 55: SigmaCCD on Sig3, standard deviation of code/carrier divergence (meters)
Col 56: Sig3 lock time (seconds)
Col 57: SI Index on Sig3 (dimensionless)
Col 58: SI Index on Sig3, numerator only (dB)
Col 59: p on Sig3, phase spectral slope in the 0.1 to 25Hz range (dimensionless)
Col 60: T on Sig1, phase power spectral density at 1 Hz (rad^2/Hz)
Col 61: T on Sig2, phase power spectral density at 1 Hz (rad^2/Hz)
Col 62: T on Sig3, phase power spectral density at 1 Hz (rad^2/Hz)


Format of the raw ASCII file (option -r):

Col  1: TOW, GPS Time of Week (seconds)
Col  2: SVID
Col  3: Signal type:  0=GPS_L1CA,  3=GPS_L2C,  4=GPS_L5,
                      8=GLO_L1CA, 11=GLO_L2CA,
                     17=GAL_L1BC, 20=GAL_E5a, 21=GAL_E5b, 22=GAL_AltBOC,
                     24=GEO_L1CA,
                      6=QZS_L1CA,  7=QZS_L2C, 26=QZS_L5,
                     28=CMP_B1,   29=CMP_B2
Col  4: Carrier phase (cycles)
Col  5: I correlation (dimensionless)
Col  6: Q correlation (dimensionless)
```

3.1 ISMR Record Details

3.1.1 Time Tag

The first two columns contain the week number and time-of-week. The time scale is GPS time, even for non-GPS satellite records.

3.1.2 Supported Satellites

ISMR records are generated every minute for all satellites tracked by the receiver.

The SVID column identifies the satellite. The range of possible values for SVID is as follows:

1 - 37 : PRN number of a GPS satellite
38 - 61 : Slot number of a GLONASS satellite, with an offset of 37
71 - 102 : PRN number of a GALILEO satellite, with an offset of 70
120 - 140 : PRN number of an SBAS satellite
141 - 172 : PRN number of a COMPASS/BEIDOU satellite, with an offset of 140
181 - 187 : PRN number of a QZSS satellite, with an offset of 180

The value “62” is used for GLONASS satellites of which the slot number is not known.

3.1.3 Number of Columns

By default, the ISMR file contains 62 columns, i.e. 62 values for each satellite every minute.

It is possible to specify the number of columns to include in the ISMR file by using the `-n` option of **`sbf2ismr`**. For example, a user only interested in the satellite azimuth and elevation (columns 5 and 6) could use the option `-n6` to skip all columns after the 6th one.

3.1.4 Not Applicable Values

Not applicable columns or fields of which the value is unknown contain the “nan” string (not-a-number). For example, all columns referring to L2 or L5 are set to “nan” for EGNOS satellites.

3.1.5 S4 index

The total S4 (columns 8, 33 and 47) is the standard deviation of the 50-Hz raw signal power normalized to the average signal power over the last minute.

The S4 correction (columns 9, 34 and 48) accounts for the thermal noise contribution in the total S4.

A corrected S4 (i.e. without the thermal noise contribution) can be computed as follows:

$$X = S4_{total}^2 - S4_{correction}^2$$

$$S4_{corrected} = \begin{cases} \sqrt{X} if\ X > 0 \\ 0\ if\ X \leq 0 \end{cases}$$

3.1.6 Phi*xx* Indexes

The Phi*xx* indexes (columns 10 to 14, 35 to 39 and 49 to 53) contain the standard deviation, in radians, of the 50-Hz detrended carrier phase averaged over intervals of 1, 3, 10, 30 and 60 seconds. More specifically:

- Phi01 is the average of the 60 standard deviations computed over 1-s intervals during the last minute.
- Phi03 is the average of the 20 standard deviations computed over 3-s intervals during the last minute.
- Phi10 is the average of the 6 standard deviations computed over 10-s intervals during the last minute.
- Phi30 is the average of the 2 standard deviations computed over 30-s intervals during the last minute.
- Phi60 is the standard deviation computed over the whole last minute.

The phase detrending is done by filtering the raw 50-Hz carrier phase measurements by a 6th order Butterworth high-pass filter. The cutoff frequency of that filter is user selectable with the `-c` option of **`sbf2ismr`**.

It takes four minutes after initial satellite acquisition for the detrending filter to converge. During that time, no ISMR record is generated.

3.1.7 Code-Phase Divergence

Columns 15-16, 40-41and 54-55 report the average value and the standard deviation of the difference between the pseudorange and the carrier phase measurements over the last minute.

3.1.8 TEC

TEC and dTEC values (both in TECU unit) are provide in columns 17-24.

TEC values are reported every 15 seconds (there are 4 TEC columns per ISMR record) and are based on the pseudorange measurements only. dTEC values report the change of TEC over the four 15-s intervals during the last minute. dTEC is computed from the carrier phase measurements only, and hence is much more accurate than TEC.

For GPS, the TEC is based on the L2-P and L1-P pseudoranges (and not on the L1-C/A pseudorange). Thanks to this fact, it is not necessary to compensate for the satellite-dependent C/A-to-P biases. The TEC is compensated for the tau_GD bias as transmitted by the GPS satellites.

For GLONASS, the TEC is based on the L1-C/A and L2-C/A pseudoranges without further bias compensation.

For Galileo, the TEC is based on the L1BC and E5a pseudoranges without further bias compensation.

For Compass/Beidou, the TEC is based on the B1 and B2 pseudoranges without further bias compensation.

For QZSS, the TEC is based on the L1-C/A and L2C pseudoranges without further bias compensation.

Note that, by default, the receiver does not apply any code smoothing, resulting in a noise on the TEC value of a few TECUs. To reduce the noise on the TEC values, code smoothing can be enabled using the “**`setSmoothingInterval`**” command. This remark does not apply to dTEC, which is computed on the basis of carrier phase measurements.

3.1.9 Scintillation Index

The SI index (columns 29, 43 and 57) is computed as follows:

$$SI = \frac{10\log(Pmax) - 10\log(Pmin)}{10\log(Pmax) + 10\log(Pmin)}$$

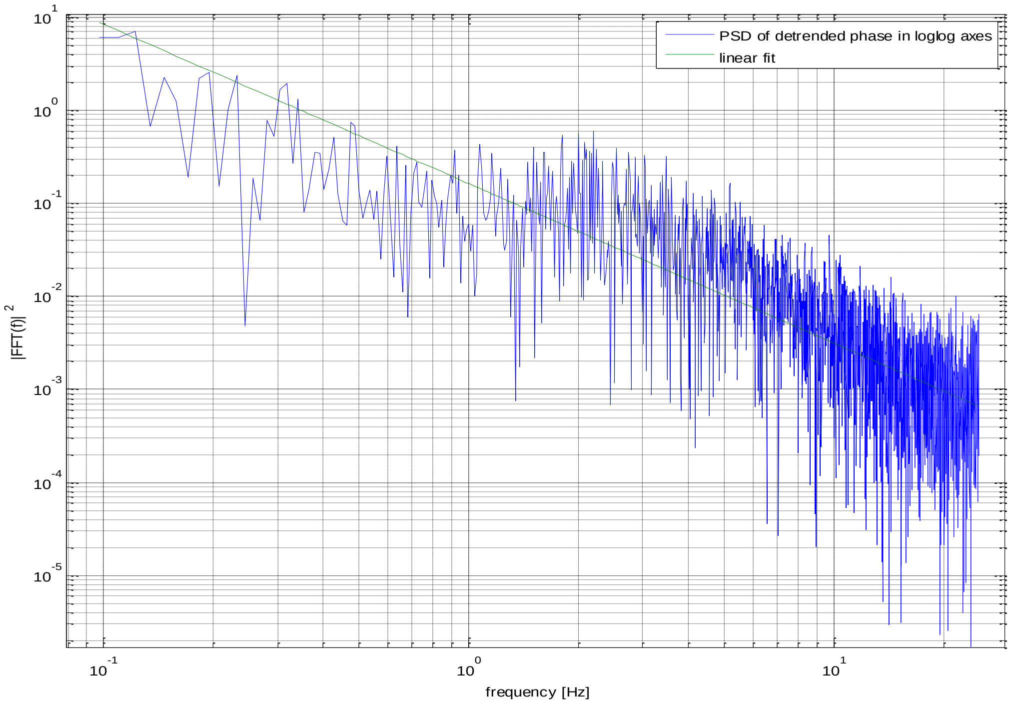
Where Pmax is conventionally defined as the power amplitude of the third peak down from the maximum excursion over the 3000 samples in the last minute, and Pmin is the power amplitude of the third level up from the minimum excursion.

Columns 30, 44 and 58 provide a modified scintillation index where only the numerator is computed (it is expressed in dB).

3.1.10 Spectral Slope and Strength

Columns 31, 45 and 59 provide the opposite of the slope (often noted "*p*") of the phase PSD in log-log axes, where the PSD is obtained by computing the FFT of the 3000 detrended phase samples in the last minute. The slope is computed by fitting a linear polynomial to the PSD over the 0.1 to 25Hz frequency range.

The figure below illustrates the way the slope is computed. In the example depicted, *p* is about 1.7.



Next to the spectral slope, the spectral strength (often noted "*T*") is provided in columns 60 to 62. The spectral strength is the detrended phase power spectral density at 1.0Hz, i.e. the intercept of the linear polynomial described above.

3.2 Monitoring the Current Scintillation Status with sbf2ismr

Invoking **sbf2ismr** with the `–S` option produces a "status screen" output, which is handy to check the current status of the receiver and the level of the major scintillation indices. When using the `–S` option, no ISMR file is created, only a status screen is produced.

```
C:\sbf2ismr -S
|-------------------------------------------------------------------------------------------------------------------------------|
| RxType: PolaRxS_PRO          SN:2003886               RxVersion:2.3-tst111205r33427   sbf2ismr-4.6.0x                          |
| Time (GPS): 09:00:00  05 Jan 2012  (TOW:378000 WN:1669)                                                                       |
|-------------------------------------------------------------------------------------------------------------------------------|
|PRN El     TEC | Sig    LT  C/N0   CCD TotS4 Phi60 | Sig    LT  C/N0   CCD TotS4 Phi60 | Sig    LT  C/N0   CCD TotS4 Phi60 |
|   [deg] [TECU]|       [s][dBHz]   [m]       [rad] |       [s][dBHz]   [m]       [rad] |       [s][dBHz]   [m]       [rad] |
|S24  7      -- |L1CA 11320  36.3  2.67  0.19  1.34 |  --    --    --    --    --    -- |  --    --    --    --    --    -- |
|G20 61    22.6 |L1CA 13829  49.8  0.08  0.06  0.03 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|G23 50    25.2 |L1CA 11793  50.8  0.06  0.05  0.02 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|G31 16    32.8 |L1CA 18480  42.1  0.34  0.26  0.05 | L2C 18910  39.5  0.25  0.13  0.04 |  L5    --    --    --    --    -- |
|G13 35    28.9 |L1CA  6297  48.4  0.15  0.10  0.03 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|G16 20    39.5 |L1CA  4075  42.3  0.28  0.16  0.03 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|G32 53    19.6 |L1CA 17439  50.7  0.09  0.08  0.03 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|R11 72    66.9 |L1CA  7058  49.1  0.13  0.06  0.03 |L2CA  6966  42.2  0.21  0.09  0.04 |  --    --    --    --    --    -- |
|G07 18    12.2 |L1CA  2426  42.8  0.16  0.13  0.04 | L2C  2415  36.8  0.38  0.20  0.06 |  L5    --    --    --    --    -- |
|G11 38    31.0 |L1CA 17724  48.3  0.07  0.10  0.03 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|G30 22    31.7 |L1CA  6491  44.3  0.13  0.07  0.03 | L2C    --    --    --    --    -- |  L5    --    --    --    --    -- |
|S20 42      -- |L1CA 65534  43.0  0.58  0.07  0.56 |  --    --    --    --    --    -- |  --    --    --    --    --    -- |
|R01 28    71.9 |L1CA  5624  45.0  0.22  0.22  0.08 |L2CA  4894  35.8  0.47  0.23  0.09 |  --    --    --    --    --    -- |
|R08 42    39.2 |L1CA 16188  49.1  0.17  0.07  0.11 |L2CA 14929  46.8  0.17  0.07  0.08 |  --    --    --    --    --    -- |
|S38 23      -- |L1CA 65534  44.5  0.80  0.06  0.45 |  --    --    --    --    --    -- |  --    --    --    --    --    -- |
|R23 13    76.5 |L1CA 13454  44.2  0.27  0.15  0.08 |L2CA 13475  40.3  0.31  0.23  0.08 |  --    --    --    --    --    -- |
|R12 22    75.8 |L1CA  2787  47.7  0.23  0.08  0.11 |L2CA  2546  42.7  0.21  0.08  0.09 |  --    --    --    --    --    -- |
|R07 13    73.5 |L1CA 25367  42.7  0.43  0.17  0.10 |L2CA 20359  42.4  0.27  0.10  0.08 |  --    --    --    --    --    -- |
|S33 32      -- |L1CA 20553  42.3  0.83  0.08  0.50 |  --    --    --    --    --    -- |  --    --    --    --    --    -- |
|R10 38    80.4 |L1CA 12821  48.9  0.19  0.07  0.04 |L2CA 12758  41.5  0.31  0.10  0.04 |  --    --    --    --    --    -- |
|G01 59    22.7 |L1CA 15012  50.5  0.09  0.08  0.03 | L2C 14593  47.8  0.15  0.06  0.02 |  L5 14593  53.5  0.15  0.05  0.02 |
|R24 16    60.5 |L1CA  7164  44.1  0.41  0.11  0.07 |L2CA  7164  42.4  0.35  0.22  0.06 |  --    --    --    --    --    -- |
|E31 -- -1242.7 |L1BC 12346  46.9  0.10    --    -- | E5a 12346  46.8  0.08  0.05  0.16 | E5b    --    --    --    --    -- |
|-------------------------------------------------------------------------------------------------------------------------------|
```

3.3 Parsing the Raw Data

With the `–r` option, in addition to the ISMR file, **sbf2ismr** produces an ASCII comma-delimited file containing the raw phase and correlation values. The format of this file is described in **sbf2ismr**'s help screen (see the screen dump at the beginning of this chapter).

For example, to extract raw data from the SBF file `test1.sbf`, use the following command:

C:**sbf2ismr –f test1.sbf –r out_ascii.txt**

The output file (`out_ascii.txt` in the example above) contains records such as the ones shown below:

```
183601.00,101,20,98042793.214,119,11
183601.00,13,0,120929967.314,-305,-2
183601.00,2,0,120488916.249,258,-5
183601.00,8,0,108470409.601,-890,0
183601.00,10,0,107547455.595,806,0
183601.00,4,0,133013504.780,-165,7
183601.00,7,0,108677898.257,-836,-13
183601.00,7,3,84684077.234,266,5
183601.00,26,0,118815821.740,-323,-2
183601.00,5,0,110675377.978,727,-27
```

...

4 100-Hz Output Rate

As described in the previous chapters, ionospheric monitoring typically involves sampling I&Q correlation and carrier phase data at a 50-Hz rate. However, the PolaRxS also supports 100-Hz rate for advanced research.

When operating at 100-Hz output rate, we recommend the following:

- To prevent overloading the receiver's CPU, the only SBF block that should be output at 100 Hz is the `IQCorr` block. That block contains the I&Q correlation values and the carrier phase modulo 65.536 cycles. To be able to reconstruct the full carrier phase at 100 Hz (i.e. to fix the 65.536-cycle ambiguity), it is sufficient to log the `MeasEpoch` SBF block at a lower rate, e.g. 1Hz.

  As of version 5.0.0, the **`sfb2ismr`** program, with the `–r` option, can be used to recover full carrier phase and correlation values from a SBF file containing 100-Hz `IQCorr` blocks and 1-Hz `MeasEpoch` blocks. See section 3.3 for details.

- To avoid data gaps, it is recommended to use the receiver's USB connection when operating at 100-Hz. Depending on the Ethernet network topology, streaming 100-Hz data over a TCP/IP connection may be unreliable.