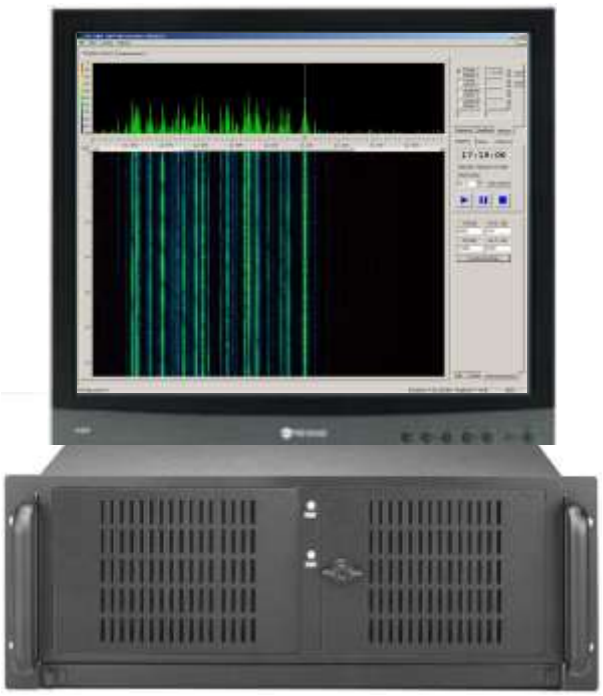
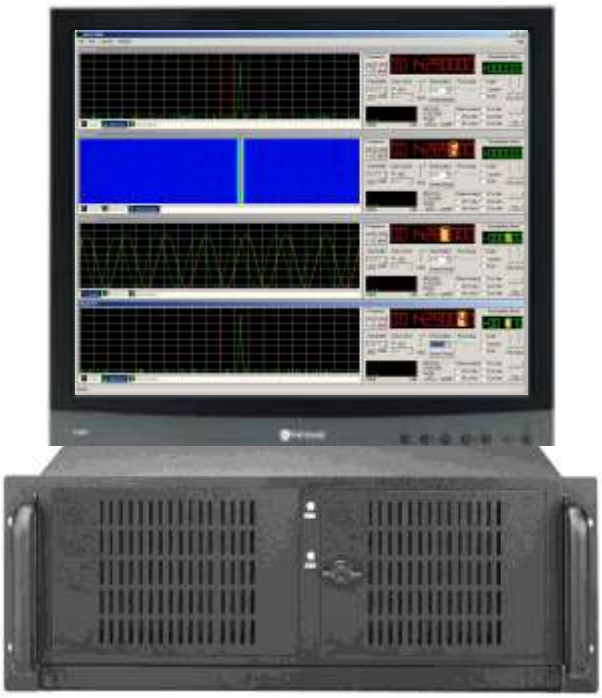
Frequency tuning of SRS-3000/SRM-3000 digital receivers





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CONTENT

INTRODUCTION **3**

ARCHITECTURE OVERVIEW **3**

DOMAIN CONVERSION 3
DIGITAL TUNERS 3

DIGITAL RECEIVER IMPLEMENTATIONS **4**

INPUT SOURCE SELECTOR 5
FREQUENCY EXTENSION FRONT-END TUNER 6

RECEIVER CONFIGURATION **8**

INPUT SOURCE SELECTION 8
HARDWARE CONFIGURATION SETUP 8

FREQUENCY TUNING **11**

TUNING OF THE DIGITAL RECEIVER 11
Continues tuning 11
Tuning around offset 12
TUNING OF THE FRONT-END TUNER 12
Automatic tuning of the front-end tuner 12
Manual tuning of the front-end tuner 12
WIDEBAND SEARCH MODE 13

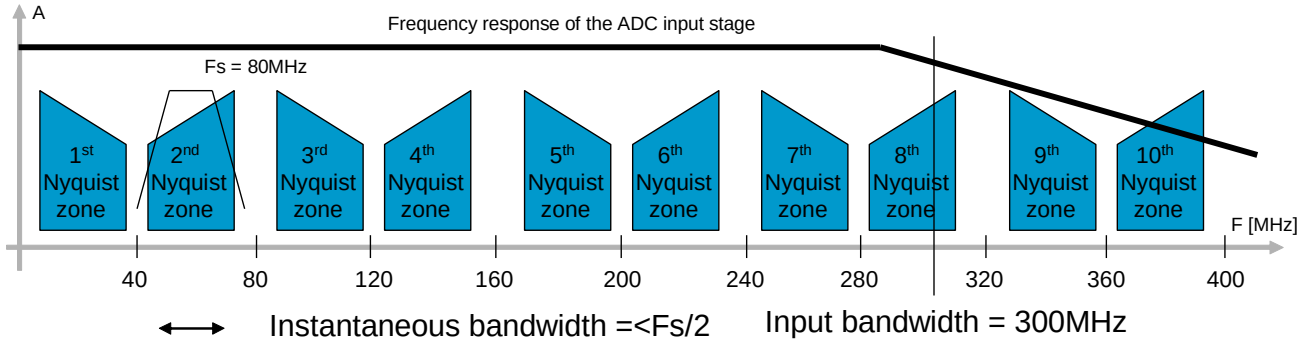
Introduction

Sagax offers two high-performance digital receivers for professional users in the field of signal intelligence and electronic warfare. One of them (SRS-3000) is a wide-band, high-speed scanning receiver, the other (SRM-3000) is a feature-reach, multi-channel monitoring receiver. The digital receivers are based on wide-band analog to digital converters and all of the functionalities are realized in digital domain by digital signal processing algorithms. The basic difference between the scanning and monitoring receivers lays in the band-width of the digital tuners and the demodulation capability.

Architecture overview

Domain conversion

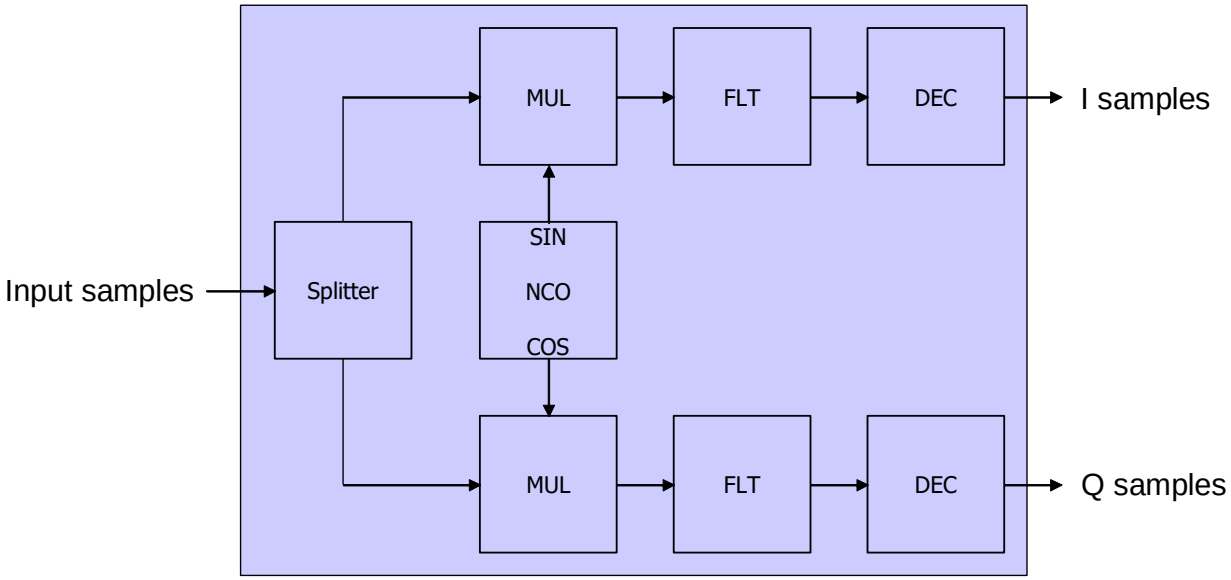
Modern digital receivers based on a wide-band analog to digital domain converters. After the converter the analog signal is represented by digital samples with a given sampling rate and quantization resolution. These two basic parameters determine the instantaneous (Nyquist) bandwidth and instantaneous dynamic range respectively. The input bandwidth of the converter is larger than the instantaneous bandwidth and determined by the input signal coupling and input (sampling and hold) stage of the converter and the width of sampling pulse. The sampled digital data contains all of the signal components from the input bandwidth of the converter but all of them are converted to the base band of the spectrum. To avoid this spectrum overlapping (aliasing) the anti-aliasing filter should be used. This behavior which is called under sampling or down-mixing conversion could be used to digitize frequency components higher than the sampling rate of the converter, but it requires using the proper input band limiting (anti-aliasing) filter.



Digital tuners

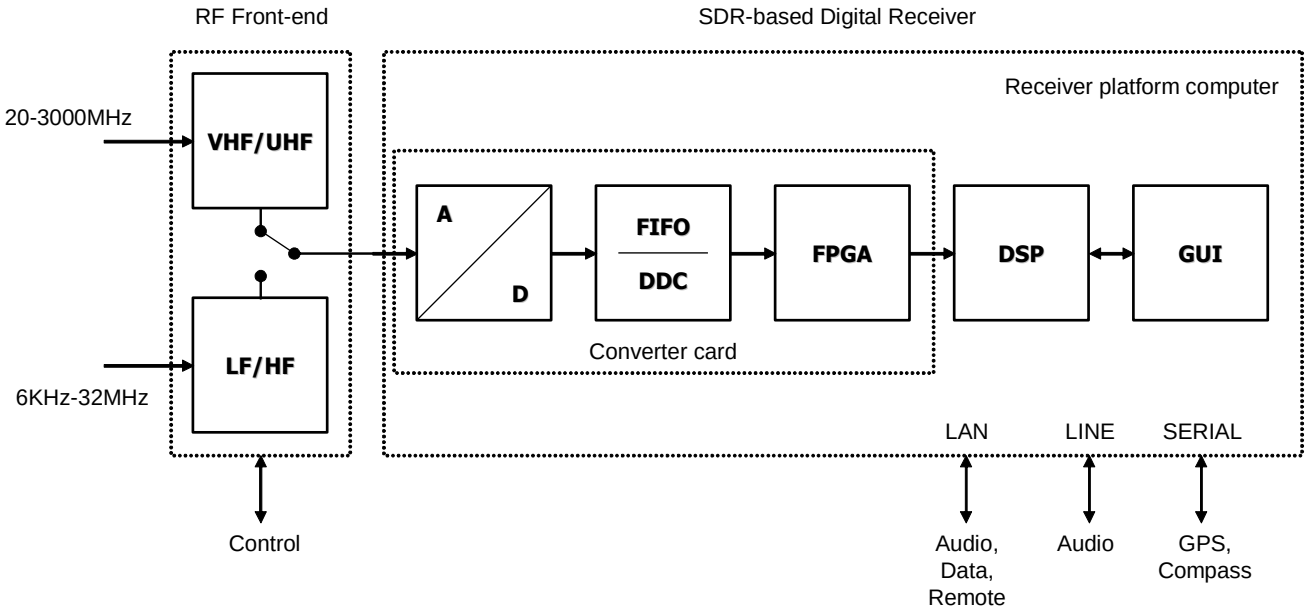
At the output of the analog to digital converter we found digital samples with band-width equal to the half of the sampling frequency. As we described earlier this bandwidth could contains signals anywhere from the input bandwidth of the converters which is actually determined by the input band limiting filter. In the case that not all of the instantaneous bandwidth is required for a given receiver functionality we have to find our wanted signals in the incoming instantaneous bandwidth and filter out it from the other signals

and reduce the sampling frequency to the required minimum for handling this signal. We could use a band-pass filter to filter out the signal too, but it is more efficient to implement low-pass filters in digitally. So first we convert the center frequency of the wanted signal to zero frequency and use low-pass filter to reduce the bandwidth to filter out the unwanted signals. After filtering we can reduce the sampling frequency too to reduce the processing power requirement to the required minimum. This step is called decimation or decimation filtering if we join the filtering and sampling rate reduction together. These signal processing tasks are performed by the digital tuner and finally it presents the digital samples of the wanted signal.



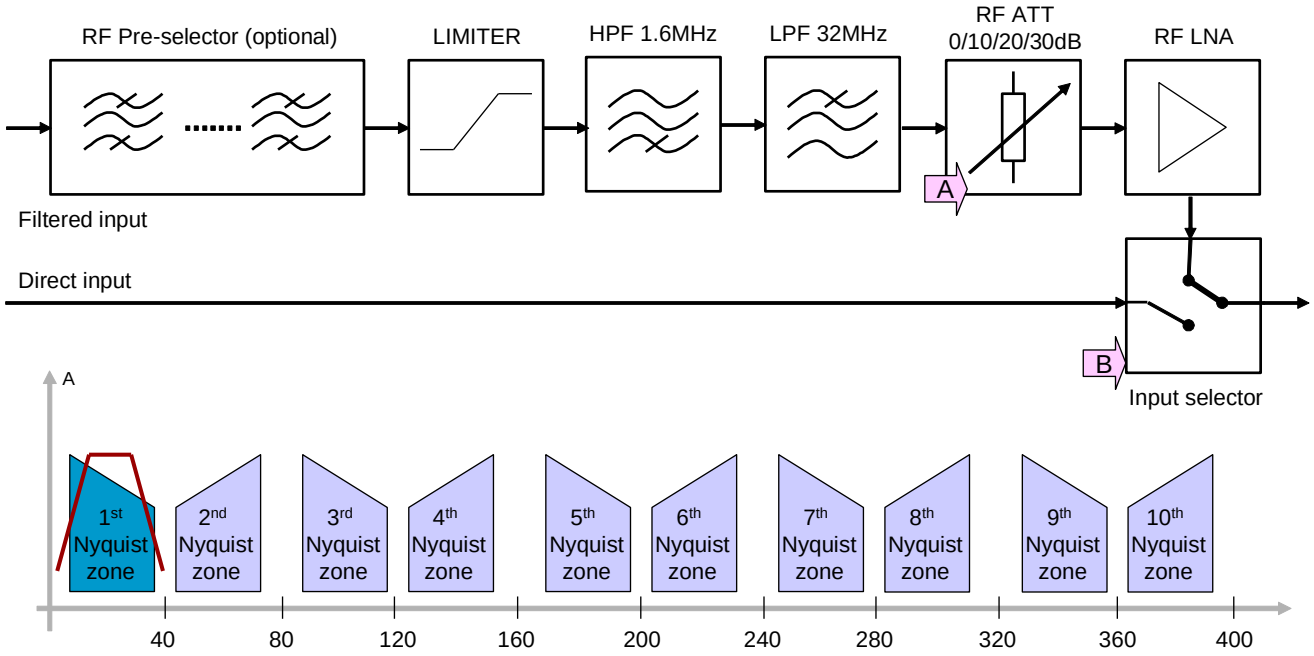
Digital receiver implementations

The basic functionality of the type SRS-3000 scanning receiver is performing a spectrum estimation to present what is going on the spectrum outside in the air. The parameters of that spectrum estimation are the bandwidth of the calculation, the resolution of the spectrum, and timing of the estimation. The type SRS-3000 scanning receiver contains wide-band digital tuners. Its bandwidth could be setup up to the maximum instantaneous bandwidth of the analog to digital converter which is used in the receiver. However using high-resolution spectrum estimation in wide bandwidth has increasing resource requirements, so the bandwidth could be limited down to 1MHz provide more resource to produce higher resolution spectrum estimation. The center frequency of the digital tuner could be tune with 1MHz resolution. In the type SRM-3000 monitoring receiver the basic functionality is to filter out the interested signal and perform de-modulation of the signal to provide the information content. The multi-channel receiver contains more digital tuners to offer receiving capability of multiple signals in the instantaneous bandwidth of the receiver. Type SRM-3000 monitoring receiver is designed to de-modulate medium to narrow band-width signals so it provides 400KHz to 50KHz instantaneous digital IF bandwidth in which the demodulator with its narrow filtering capability could be placed. As this type of receiver could handle narrow-band signals the tuning resolution of the digital tuners is 1Hz.



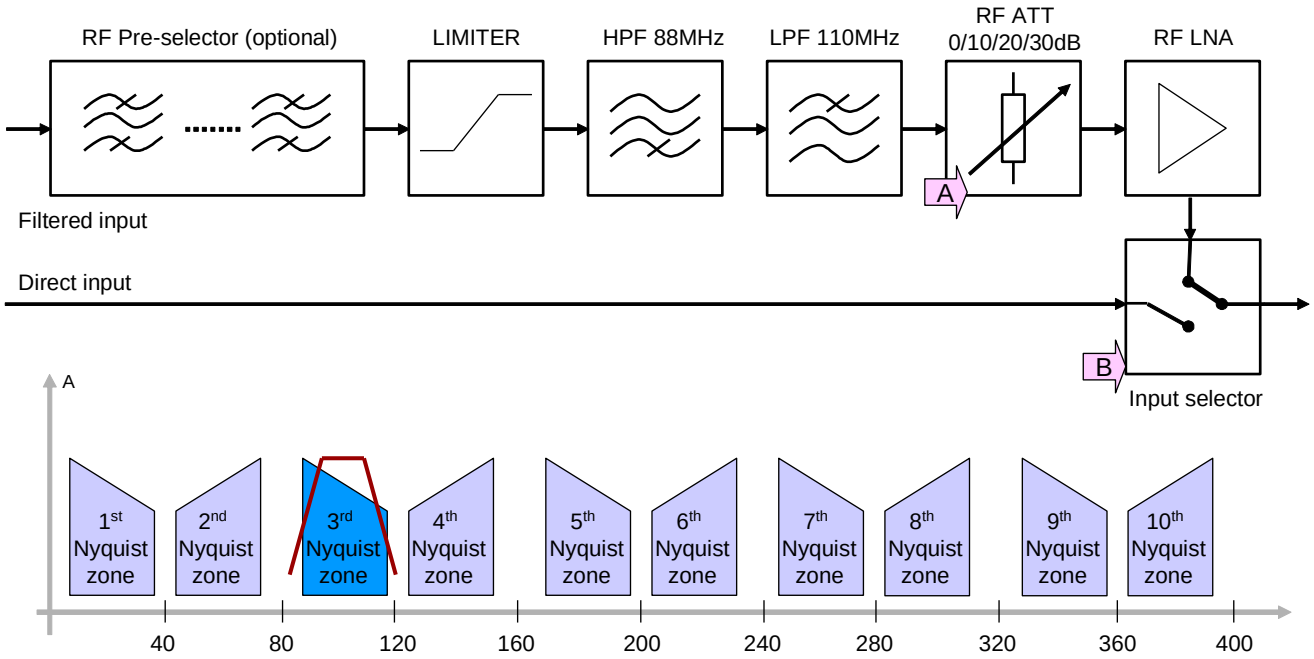
Input source selector

As it is described in the prior section an SDR based digital receiver is based on a wide-band AD converter. The input instantaneous dynamic range of such a state of the art converter is around 80dB and this dynamic range is lying between -80 to 0dBm signal level. So to implement high-sensitivity receiver we have to amplify the real-word signals to that level. This task is covered by the analog RF front-end.



The instantaneous bandwidth and frequency range of the converters enable us to implement receivers with limited frequency coverage with direct sampling of the antenna signals in that case the RF front-end

should contains only some variable amplification and filtering for selecting the proper Nyquist zone for the operation. On the other hand to extend the frequency range to upper bands we have to use the frequency extension front-end containing heterodyne frequency transforming functionality. The provision for switch between the two front-end and amplification in direct receiver mode is provided by the input selector.
As the input bandwidth of the converters covers some hundred MHz the direct digital receiver implementation technique could be used at upper frequencies too. A direct digital VHF receiver RF front-end stage could be seen on the following figure.

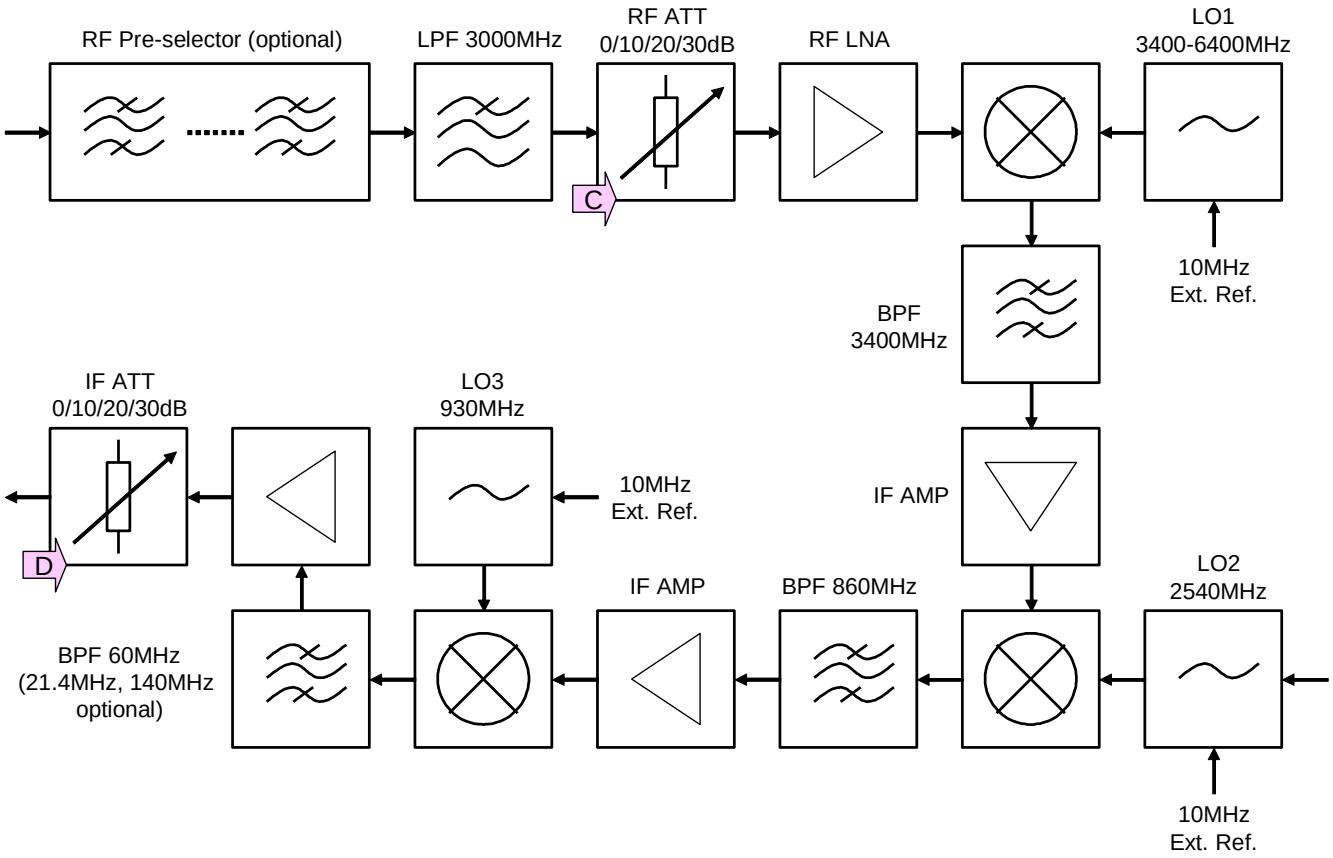


Please refer to the datasheet of your receiver to describe that does your equipment contains input selector or not and what is the frequency band of the filters in the selector. In the case that direct digital reception is required and only the frequency extension front-end tuner is used the input selector is not required and the output of the tuner could be feed directly to the input of the converter.

Frequency extension front-end tuner

Modern analog to digital converters offer wide instantaneous and input bandwidth, but it is not enough to cover all of the frequency interested in real-word operations. In that case we have to use the frequency extension front-end tuner to convert radiated frequency to the digitally process able frequency range using analog signal processing components and methods. This kind of tuners based on the well-known analog processing components like filters, amplifiers, mixers, oscillators. The signal bandwidth is not limited and it provides bandwidth near to the instantaneous bandwidth of the digital back-end receivers to use implement receivers functions in digital domain. The front-end should contain the gain control functionality too to extend the dynamic range of the receiver. This extended dynamic range is called gain-controlled dynamic range of the receiver and it is not equal with the instantaneous dynamic range which is determined by the analog to digital converter of the digital receiver. One of the main parameters of the front-end tuner is its input radio frequency (RF) range and its output intermediate frequency (IF) which should be processed by the digital tuner. To process the tuned frequency of the front-end tuner we have to

tune the digital tuner of the digital receiver to the output intermediate frequency of the front-end tuner. Both SRS-3000 scanning and SRM-3000 monitoring receiver have capability to tune the frequency extension front-end tuner directly to provide the receiver frequency directly on the frequency display of the receiver. However, the digital receivers are prepared to handle external front-end tuners without control capability with different IF frequencies.
Typical 20-3000MHz VHF/UHF RF front-end tuner is described in the following figure.

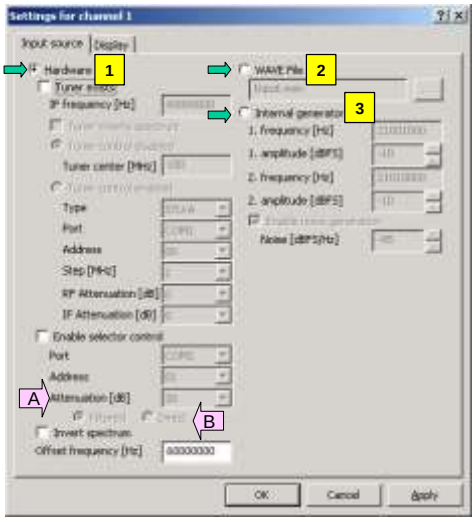


Receiver configuration

Input source selection

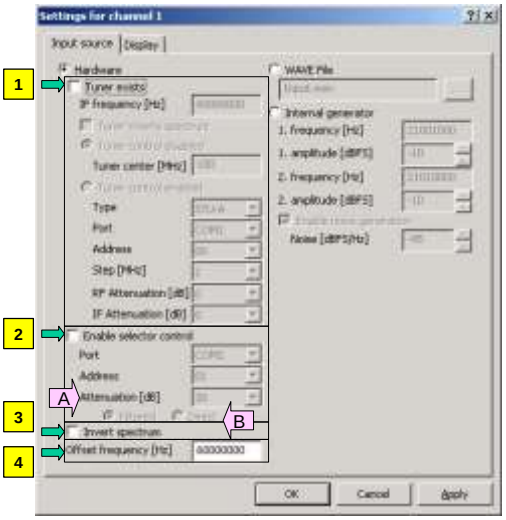
First we have to describe, what is the input signal source of the receiver we are using. The channel setting panel which could be seen below provides the functionality for that. On that panel we could choice between the input sources of the receiver which as follows:
-hardware 1
-recorded file 2
-internal generator 3

In the hardware mode we use the samples from the converter card installed in the receiver. That is essential, so we have no options to setup the converter, but we have to describe the hardware connected to the converter.
The recorded file could be pre-stored data file containing the input signal samples. This functionality is provided for off-line data analysis.
The internal generator is used for generating well-known signals without hardware and recorded files. This generated signals could be used for debugging and demonstrations.

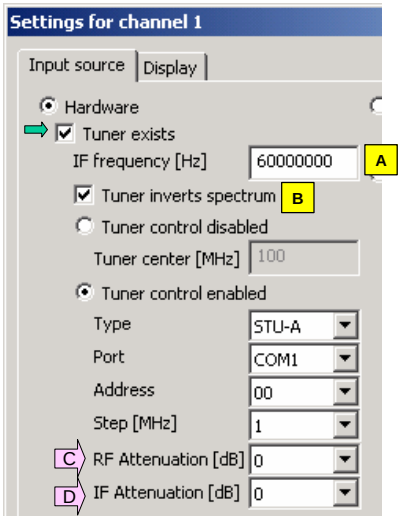


Hardware configuration setup

After we select hardware input we have three switches and one parameter to describe the analog signal processing components and their properties. We have to answer the following question to setup the receiver. Please consult with the datasheet of your equipment to determine of your exact configuration.
-Do we have a front-end tuner in the system or not? 1
-Do we use an input selector in the system or not? 2
-Do we like to invert the processed spectrum or not? 3
-What is the offset frequency used by the tuner control element. 4

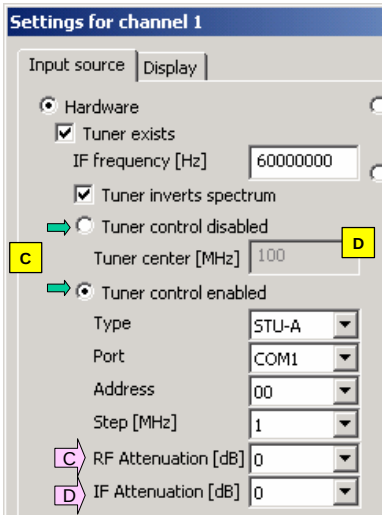


2 The selector control setup we have to give the port and address of the selector panel. The two parameters of the selector panel is that the attenuator value and the selected input. Please refer to your receiver configuration description to determine that you receiver contains such a device or not. Generally this component is build into receivers with HF reception capability and filtered input with band limited to 1.5-32MHz is used for direct reception of the HF signals.
3 The invert spectrum switch is used to change the sidebands of the calculated IF spectrum on the display. This switch is effects only the IF spectrum display and do not effect the spectrum inversion behavior of the front-end tuner which has separate control to set up.
4 The offset frequency could be described here. This offset will be used as a tuning aid capability of the frequency control and it is used separately and differently as the IF frequency of the front-end tuner.
1 In the case we have frequency extension front-end tuner in the system we have to setup some other parameters too.

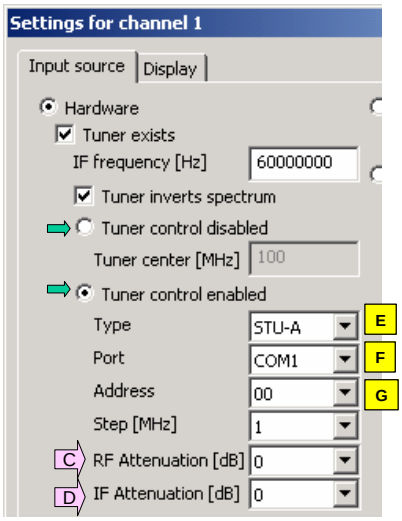


First we have to describe the output IF frequency of the tuner. A Its default value is 60MHz as this is the center of the 2nd Nyquist band with 80MHz sampling rate, but it could be overwritten to any other frequency.

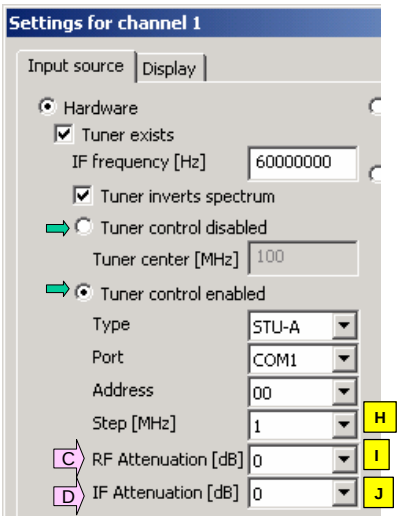
After that we have to describe that the used tuner invert the spectrum or not. B In other ways does it use up- or down conversion scheme. If the tuner do not invert spectrum, then increasing the RF frequency the output IF frequency also increase. If the tuner do invert spectrum, then increasing the RF frequency the output IF frequency decrease. This information is required to determine where to tune the digital tuner relative to the IF for given receiving frequency.
When we work with front-end tuner we have two options. Do we control the tuner or not. C The type SRS/SRM receivers are able to control limited number of tuners.
When we have no possibility to control the tuner, we have to give the RF frequency of the front-end tuner which is converted to a nominal IF frequency. D This frequency description is required to calculate and display the actual reception frequency on the display of the receiver.



When we have a controllable tuner we have to give the type E, the control port F and the address G of the tuner which is used.

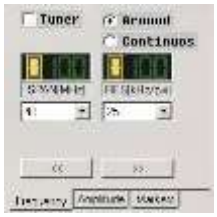


The next parameter is the frequency step. Between the step values the digital tuner is used to tune to the wanted reception frequency. The last two parameters are the value of the RF and IF attenuators.



Frequency tuning

The tuning capabilities of the receivers were designed to employ all of the possibilities offered by the implementation structure. On the control panel of the SRS-3000/SRSM-3000 scanning/monitoring receiver we found two frequency displays. One of them always contains the frequency of the front-end tuner with 1MHz resolution, the other contains the frequency of the digital tuner. The scanning receiver contains a wide-band digital tuner, so its frequency display has 1MHz resolution too. The monitoring receiver contains narrow-band digital tuner so its frequency display has 1Hz resolution.



Tuning of the digital receiver

In the case we have no front-end tuner we have no possibility to tune the frequency of the front-end tuner, so the color of this display is shaded and the check box for the front-end tuner is disabled. On the other display we could tune the digital receiver in two ways which could be selected by the radio buttons above the display.

Continues tuning

When continuous is selected we can tune the digital receiver to any frequency between 0-3000MHz with 1Hz resolution and the program automatically calculates the required digital tuner frequency based on the

sampling rate and Nyquist zones. E.g. if the tune to 103.3MHz this frequency is lying in the 3rd Nyquist zone between 80-120MHz with a 80MHz sampling rate, so the digital tuner is tuned to 103.3-80=23.3MHz.

Tuning around offset

When around offset is selected we could tune the frequency display between -500MHz and +500MHz. IN this case the offset frequency given in the settings is used to determine the wanted reception frequency and we could tune the digital receiver minus and plus from that frequency. After determining the wanted reception frequency the receiver program determines the required frequency of the digital tuner. Using the above example if the offset is set to 60MHz and we want to receive at 103.3MHz we have to tune to +43.3MHz. Please note that this offset frequency is not equal with the IF frequency of the front-end tuner, and the offset is mainly used in the case when front-end tuner is not exists in the system and the digital receiver is used in direct digital receiver mode of operation.

Tuning of the front-end tuner

Automatic tuning of the front-end tuner

If the tuner control is enabled, the frequency display of the digital tuner (the right one) contains the receiver frequency including the front-end tuner frequency extension with its IF value too. So we have no deals with the tuning of the front-end tuner, just setup a frequency and the receiver GUI program calculates the required front-end tuner settings to take into account the IF frequency and the frequency step value of the front-end tuner.
During the frequency tuning of the receiver we can use the around offset and continues mode too, but the frequency settings is valid for the complete receiver chain including the RF front-end tuner and IF digital tuner. The frequency display of the front-end tuner contains the actual value of the frequency, but it is in disabled status and its value is for your information only.

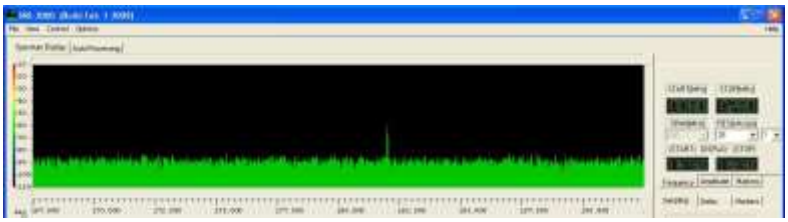
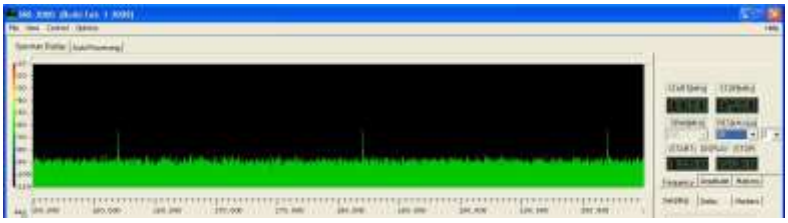
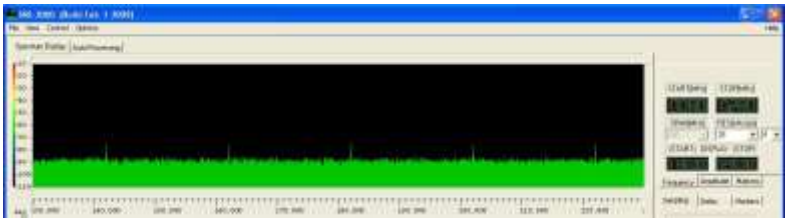
Manual tuning of the front-end tuner

The automatic tuner frequency control could be deactivated to switch on the tuner switch box above the tuner frequency display. In this case the front-end tuner is controlled separately by this display and the right side display controls only the digital tuner of the receiver as described earlier.
Please note that in this case the tuning of the digital tuner is independent from the tuning of the front-end tuner and we have to tune the digital tuner to the output IF frequency of the RF front-end tuner for proper reception. The around offset functionality could be used too.

Wideband search mode

In the SRS-3000 scanning receiver wide-band search mode is provided. In this mode of operation the scanning is performed using the front-end tuner in wider range than the bandwidth of the digital tuner. The frequency setting display looks like to following.

The user is able to set up the scanning frequency band by give the START and STOP frequency in MHz and the resolution for the spectrum estimation. Part of the spectrum is displayed on the 1000 pixel wide spectrum display.



In this mode large number of spectrum points could be generated while the start and stop frequency is not limited and could cover the whole reception range of the receiver. To see larger frequency band on the display decimation by 2 and 4 is possible to reduce the points and zoom out of the display.