Using a PC with soundcard as a VLF receiver

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This article describes how to use your PC as a receiver for *narrow-band* signals in the VLF radio spectrum. If you are more interested in the reception of VLF natural radio (which is a *broadband* audio application), there is another document for you.

Overview

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- VFO Control
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Last modified: April 17, 2006.
Note: some links only work if this file is located in the help directory of Spectrum Lab.
If so, you can return here to the main index.
Check for the latest release of Spectrum Lab somewhere at www.qsl.net/dl4yhf .

Basic principle

The PC is used to convert the VLF signal into an audible signal

- Soundcard runs at a sample rate of 44100 or 48000 Hz (see Notes)
- Frequency is converted down to an audio frequency of 650Hz (or similar)
- 650 Hz "Audio IF" is passed through a narrow-band filter (100Hz BW)
- The amplified audio is sent to the soundcard's D/A converter.

Required "hardware"

A PC with at least 266 MHz Pentium II, a soundcard (original Creative Labs Soudblaster 16 has been tested, others work too, but some soundcards don't..)

For a start, just connect some meters of wire as an antenna to the MIC input of the soundcard and try to listen to a local QRM source (like a TV set). If you can get the system (described below) to work, add a simple LC network parallel to the input as VLF preselector. This will also protect your soundcard if you connect a longer piece of wire. In my own tests I have found that the system is very sensitive even with only passive components (including 2 protection diodes on a 200 meter long wire).

Operation of Spectrum Lab

All settings required for a receiver for 17.2kHz are contained in the user profile "SaqRcvr1.usr" which is contained in Spectrum Lab's installation archive (since V1.65).
(Why "SaqRcvr" ? SAQ is the name of Grimeton Radio, a historic radio station in Sweden. More infos are/were available at www.alexander.n.se in Swedish language, very impressive !).

After starting Spectrum Lab, go to the menu "Quick settings"..."User defined

Menus"..."Import". Select the file "SaqRcvr1.usr", "GBRrcvr.usr" or " VlfStns.usr", then click "Ok, Load". This will install a new item in the Quick Settings menu which you can use later to recall these settings.

Note for "old-time users" of Spectrum Lab:

The "SAQrcvr1.usr" file was modified in 2006. It uses the FFT-based filter which didn't exist in earlier versions, making it much easier to operate. The frequency conversion and filtering is now done entirely in the frequency domain (inside the "Filter" runing in FFT mode), so the oscillator / mixer / IIR-filter is not required any longer. You will notive in the component window that the oscillator- and mixer blocks are disabled. This is not an error ! The oscillator + mixer blocks still exist for compatibility reasons, but the preferred way to "shift frequencies" is the FFT-based filter now.

Now switch to SpecLab's "Circuit" window (Menu "View/Windows...Spectrum Lab Components"). If everything is ok with the soundcard, you should see this window (the component window may looked different in other versions):
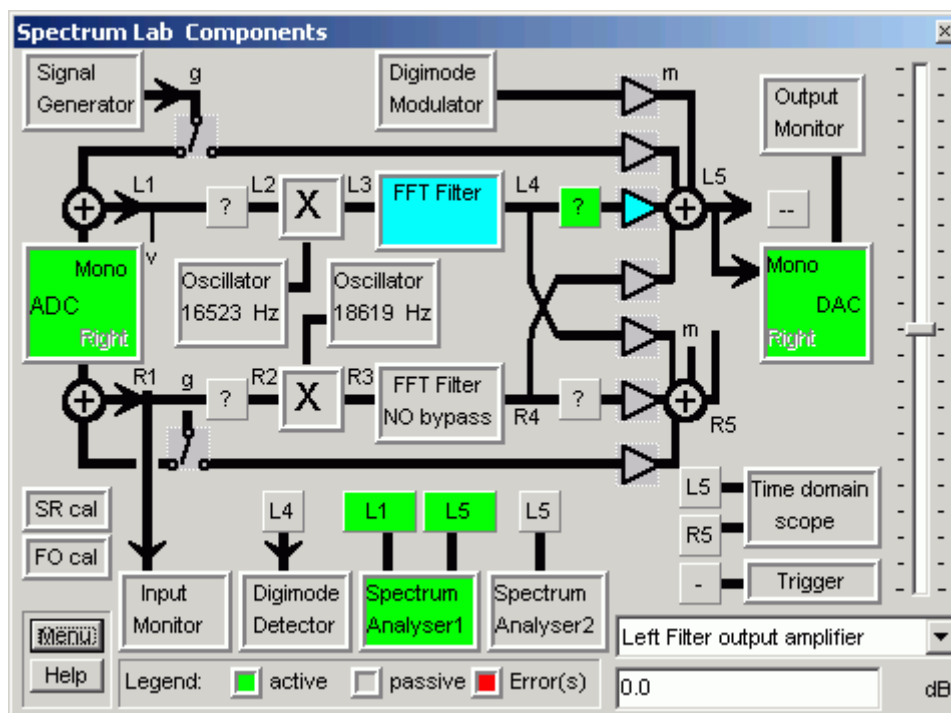
(component window after loading the application "SAQ - Receiver #1")

If one of the function blocks is colored red, the program has detected a malfunction- maybe the PC is too slow (it did work with a 266MHz-P2) or the soundcard is not supported.

Connect a headphone to the soundcard's output. You should hear a weak 650-Hz signal. Otherwise you must find the correct audio settings using the control program for your soundcard (some info is in SpecLab's help system, but SpecLab cannot adjust the audio gain in the soundcard itself).

VFO Control

Note: This was more complicated in older versions. Now everything is done within the FFT-filter; oscillator + mixer are not involved anymore)
To modify the VLF "RX-frequency", move the red "VFO" marker on the frequency scale of the spectrum plot or waterfall display in the main window. Move the mouse across the frequency scale, and hold the left mouse button pressed to move the marker.
Note: The 'connection' of the red frequency marker ("diamond") for the VfO frequency is a programmed feature of the "VLF-Receiver" profile. How this works internally is explained here in the SpecLab manual, but you don't need to know it if you only want to *use* this feature.

Receiver Gain Control

The "SAQ receiver" application uses one of Spectrum Lab's DSP blackboxes as automatic gain control. This is the green square with the questionmark in the circuit diagram. If necessary, the AGC can be configured as explained here. But for most applications the default setting should be ok.

If the audio output is too weak, though the soundcard volume control is at maximum, you can add more gain by software. If you click at the amplifier symbol in the circuit diagram (triangle just right to DSP blackbox), a small dialog opens where you can enter the gain, or connect the gain control to the vertical slider on the left side of the component window shown above.

If you don't hear anything: To verify if a signal is getting in, activate the "Input Monitor" (click..). Increase the "Vmag" value of the oscilloscope until you can see a signal.

If you cannot hear any audio coming out of the soundcard, activate the "Signal Generator" and connect it to the sound output (click on the function block and then start the sine generator). If you still can't hear anything, check the Volume Control from the program "sndvol32.exe" which is part of Windows. To modify the "recording" settings (here: Sound IN), you must change the properties in the "Options" menu of sndvol32. (Sorry, Spectrum Lab cannot find the optimum settings itself. It can not access the soundcard's "Mixer" like other nice programs ;-).

Modifying the Filter characteristics

Depending on the bandwidth of the signal you are looking for, you may want to use different audio filter characteristics. A 50 Hz filter is often a good choice for medium-speed morse transmissions, while 500 Hz may be better for digital transmissions like RTTY and PSK. There is a number of "pre-configured" filters which you can load from disk files, but you can also create your own filters:

The very old way (before Spectrum Lab V1.7)
        Click on the "Filter" block and switch to the tab "IIR-Design 2". Load one of the "650-Hz-filter" designs which are part of the installation archive. The default "SAQ"-filter is a 4-stage IIR filter, each stage is a second order IIR-filter used as a bandpass. The gain, center frequency and bandwidth of each stage can be set individually. Modify a parameter in the filter designer table, then click "Calculate" to make the change effective. You may customize the filter for your own requirements, change the bandwidth, center frequencies or the number of stages used. But it's not easy to spread the poles to get exactly the frequency response you want, so you should use the "IIR-Designer 3" mentioned below, or jump right to the FFT-based filter which is the preferred method since SpecLab V2.6 .
The second method (a bit easier, since Spectrum Lab V1.7, tnx M0BMU):
        Click on the "Filter" block and switch to the tab "IIR-Design 3". Enter a filter center frequency and bandwidth of your own, then click "Apply". More information about the types of narrow-band audio filters can be found here. You can also control the audio filter's center frequency from a small slider on the frequency axis of the waterfall, quite like the VFO control.
The third method (much easier, since Spectrum Lab V2.6): Use the FFT-based filter !
        Much easier to use than the "classic" FIR- and IIR-based filters is the FFT-based filter. There is an extra control tab for it in the filter control window. Select "bandpass" characteristics, the desired center frequency, and the filter bandwidth. An FFT size of 2048 or 4096 (within the filter !) is ok for this application. You can do even more with this filter: Let it do the downconversion too ! The function of the FFT-based filter is explained here .
        If you don't want to learn how all this works internally, but simply use it instead, load the preconfigured application "SAQrcvr1.usr" from the "Quick Settings" menu. It was modified in 2006 so it uses the FFT-based filter for "downconversion" and for narrow-band filtering at the same time. Move the red "diamond" on the main frequency scale with the mouse to tune this receiver to any frequency you like (not just 17.2 kHz for which the receiver was originally

designed).

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Frequency list of some VLF stations

The file "VlfStns.usr" has the frequency markers set to some VLF transmitters which can/could be heard in Europe. This makes identifying them on the waterfall display easier.

Some of these stations are:

Frequency (Hz)	Callsign	Station	Country	Mode, Remarks
11905, 12500, 12649, 12695, 13281, 14881, 15625 (!)	?	RSDN-20 ("Alpha") navigation system. See notes below table.	RUS	Pulses ("beep,beep") all heard in Dec. 2003
15100	?	?	?	
15625	--	Your neighbour's TV		Continuous line sync signal, emitted by flyback transformer
15980	GBR	Navy Rugby	G	RTTY (MSK) 100 Bd heard in March 2003 went QRT in 2003 (*)
16300	VTX1	Navy Vijayanarayanam	IND	CW, rare
16400	JXN	Navy Novik	NOR	RTTY (MSK) 200 Bd heard in March 2003
16800	?			RTTY
17000	VTX2	Navy Vijayanarayanam	IND	CW, rare
17200	SAQ	Grimeton	S	CW, historical transmitter (Alexanderson alternator) 1-2 times per year
18100	RDL,..	Navy Krasnodar + ..	RUS	RTTY (multi-tone FSK?) heard in March 2003
18200	VTX3	Navy Vijayanarayanam	IND	CW, RTTY, rare
18300	HWU	Navy Le Blanc	F	RTTY (MSK) 200 Bd heard in March 2003
19000	GBZ(?)	Navy Criggion (?)	G	RTTY (MSK) not heard in 2003 yet
19200	?	?	?	RTTY (MSK) heard in March 2003
				RTTY (MSK) 200 Bd

19600	GBZ(?)	Navy Criggion (?)	G	heard in March 2003
20270 (+/-)	ICV(?)	Navy Tavolara, Sardinia	I	RTTY (MSK) heard in March 2003
20900	HWU	Navy Le Blanc	F	RTTY (MSK) heard in March 2003
21100	RDL	Navy, Krasnodar et al	RUS	RTTY (MSK) heard in March 2003
22100	?	Navy Anthorn	G	RTTY (MSK) heard in March 2003
23400	DHO38	Navy Ramsloh	D	RTTY (MSK) heard in March 2003

A complete list of VLF stations can be found Renato's VLF Open Lab site, see links at the end of this document. Or scan the net for Klaus Betke's LF pages.

Notes on certain VLF stations:

ALPHA beacons
> Read this chapter with the description of an experiment which can be done with SpecLab, a small loop antenna, and this old Russian navigation system which still existed in 2006.

GBR
> Though GBR went QRT in 2003, you may find an old transmission from this station in morse code in your music archive ! For example, when Mike Oldfield recorded "Tubular Bells" in 1972 and 1973 at The Manor studio, some of the recording equipment was not shielded enough so the CW transmission from GBR was recorded on the master tape - possibly without the audio engineer's knowledge. You can see these these morse code transmissions in the spectrogram or make them audible again (play directly from CD or from a WAVE file, but do not try this with lossy MP3 files).

ALPHA beacon experiments

ALPHA is a Russion navigation system in the VLF band which you can receive with a simple loop antenna (at least in Europe). Some ALPHA frequencies are listed here . With a system of two orthogonal loop antennas and a stereo soundcard, the transmission cycle can be analysed with a preconfigured setup which is contained in Spectrum Lab's installation archive : Load the application "AlphaTrg.usr" and see what happens on the screen (most likely, you will need to adjust the 'contrast' and 'brightness' controls for the waterfall because the input level from your VLF antenna will be different). What the "Triggered ALPHA-Beacon Monitor" does is:

1. Wait for the begin of a new ALHA transmission cycle.
   For this purpose, the spectrogram runs in 'triggered SWEEP mode'. The trigger is connected to a pulse generator which fires once every 3.594 seconds (- or is it 3.6 seconds as mentioned somewhere on the net ?).
2. Draw one spectrogram screen and then stop, adding the new spectra to the previously recorded ones : Every line of the waterfall screen has its own average-buffer.
3. Back to step 1 to wait for the next cycle

If everything works ok, the noise-reducing effect of the averaging may look like this (left screenshot without, right screenshot with 10-fold averaging) :
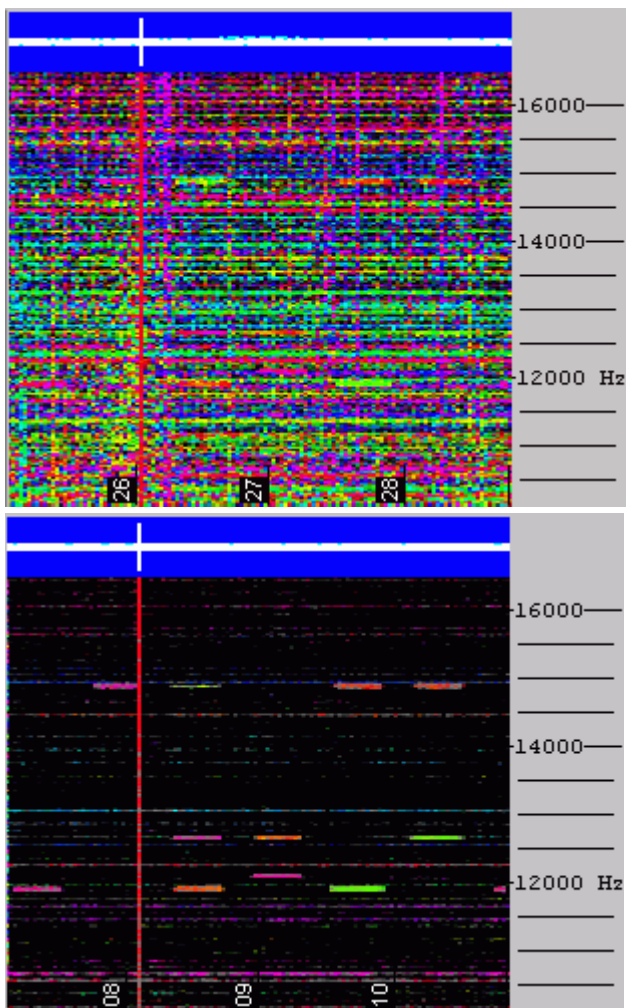
The pretrigger was set to 1 second for this test, so the trigger pulse is visible on the blue amplitude bar. The VLF RDF antenna was deliberately placed in a noisy environment (indoors), so the ALPHA pulses were barely audible in the noise. The waterfall 'contrast' was set to a high value; the same settings were used for both screenshots.

How does it work ?

Because the ALPHA-beeps will always appear on the same screen positions, the average-buffers will slowly fill up with each new scan. The noise (if randomly distributed) will seem to get weaker with each new scan. For example, if there was a random 1-millivolt "beep" in one sweep, it will appear like a 0.1 mV signal after ten sweeps are averaged. After 1000 averages, 1 mV will be divided down to 1 uV. Ok, what else can you do with this ?

Of course, this principle can be used for all kinds of weak but periodic tone signals - for example, for EME-testing purposes (Earth-Moon-Earth). If say 100 VHF-pings were sent to the moon and the echo received with a small yagi antenna, it may be possible to see the echo on the 'averaged synchronized spectrogram' even if a lot of dB's were missing to copy the signal by ear (- will be tested at the local amateur radio station as soon as time permits).

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Notes

Phantom signals when using 48kHz sample rate

(December 1, 2001)

Be careful when using 48000 samples per second. Most modern audio cards really support this sample rate which is nice to receive signals up to 24 kHz. Some cards don't and you'll get an error message when you try to use this sample rate. In this case, buy another audio card or stick to 44100 samples per second which is a widely used standard sampling rate. Other cards like the onboard "ESS AudioDrive" in the author's notebook play dirty tricks when you use 48000 samples per second, here one example:

Phantom signals appeared on the waterfall, a signal on 20.7 kHz also appeared (a bit weaker) on 16.8 and 12.9 kHz !

(go figure: 48kHz-44.1kHz = 3.9kHz ; 20.7kHz - 3.9kHz = 16.8kHz ; 20.7 kHz - 2*3.9 kHz = 12.9 kHz) It seems that some cards don't really sample the analog input at 48000 samples per second, instead they sample at 44100 samples per second and 'duplicate' a part of the samples.. what a lousy trick !

Even higher sampling rates

(December 2002 and May 2004)

There are now some expensive soundcards on the market which support true 96kHz sampling rate. If you have one of these cards, try to set the sampling rate to 96000 samples/second. With some luck, you may be able to receive VLF stations up to 40..44 kHz (to receive 48kHz is not possible because of the soundcard's anti-aliasing filter). Note: I once bought Creative Lab's "Extigy" card because it said "supports 96 kHz sampling" on the box, only to find out that the A/D converter in fact only runs at 48 kHz. I later tried the Audigy 2 ZS, and got it working after some struggle with unwanted audio bypass from the "Line-In" to "Line-Out" .

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User feedback is welcome. It is the most effective way to make the program better. Please send mail to dl4yhf (at) qsl (dot) net - robots keep off ;-)

If you have optimized the settings to reveive other VLF stations let me know. I will post it somewhere on my website so others can also use them. Because Spectrum Lab is still under construction, some of the functions described above may be slightly different now, but the basic principle remains the same.

If you are interested in VLF reception, check these sites...

- Radio Waves below 22kHz by Renato Romero, IK1QFK and other members of the VLF Open Lab community
- SV1XV's World below 535 kHz by Costas, SV1XV
- Science.Netfold.com is a new amateur science site initiated by Phil Beastal, started in April 2002
- for ULF / ELF reception, consider using an external A/D converter (with "DC"-coupling) connected to the serial port.

Good luck !

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