Using Spectrum Laboratory (Spec Lab) for Precise Audio Frequency Measurements

Ver 1.15

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NOTE: SpecLab version V2.7 b18 has some problems with fast playback (Analyse audio file, without DSP).

Version V2.7 b12 does not exhibit this problem and should be used.

Spec Lab Reference web site: http://freenet-homepage.de/dl4yhf/speclab/index.htm

Many thanks to Connie, K5CM for "setting me up" with Spec Lab as well as providing feedback ! http://www.k5cm.com/

Features Ref: http://freenet-homepage.de/dl4yhf/speclab/index.htm#features

- SpecLab allows measuring peak frequencies as well as peak amplitudes.
- This peak detecting mode can provide <u>sub-milliHertz</u> <u>accuracy</u> after calibration, if the soundcard in your PC has a crystal oscillator, and has been running for a few hours.
- You may record the audio signal as a .wav file and play it back for further analysis. It is then possible to generate a text file that may be further processed with a spreadsheet software, such as Excel.

Setting SL in default mode (Factory Settings)

Every time SL is started, it sets the previous set-up that existed at turn-off. It's a good idea to start everything from scratch, at least once before setting SL

for frequency measurements. If you want to save your present settings, see the section: Saving / Recalling settings.

Select: Quick Settings, click Restore all "factory" settings.

Note that it does not reset the calibrated sample rates of the sound card.



Preliminary

The Start / Stop Menu



Select: Stop Sound Thread while doing the set-ups.

Select: **Start Sound Thread** when ready to display waterfall and optionally record the results of the analysis in a file (File Export mode).

FFT Settings Ref: http://freenet-homepage.de/dl4yhf/speclab/settings.htm#fft_settings

🔀 Spectrum L	aborato	ry V2.7 b12		
File Start/Stop	Options	Quick Settings	View/Windows	Help
(Freedow Loop	Audio	settings		
Freq Time RDF Min 990.0	FFT se Spectr dis Displa Radio Screen Wave Reado Frequi Refere System Config Volum	ettings rum display settings, pa y colors and font Direction Finder in capture options file settings out cursor setting ency marker sett ence spectrum in settings gure built-in HTTP e control for "Re e control for "Re	ngs art 2 :s s gs ings ? server cord " (audio in) y" (audio out)	996 11111111111111111111111111111111111
- 120 dB -40.0 d	Edit W	/aterfall Color Pa	lette	

Select: Options, FFT settings

ANALYSIS OF A NARROW FREQUENCY SPAN (for precise freq. measurements)

Set *Decimate input (by divisor)* to 16, *FFT input size* to 16384 points Set *FFT Type and center frequency*: *Complex with internal frequency shift* Set *Center frequency (Hz)* to the center of the frequency span to be analyzed

SpecLab Configuration and Display Control	Note: Larger <i>Decimate</i>
TRX Control Memory Filenames Wave Files Markers System Freq-Resp Spectrum (1) Spectrum (2) Spectrum (3) Radio DF FFT Audio VO AD/DA Server FFT properties, frequency resolution FFT Type and center frequency Decimate input by (divisor) 16 Complex with internal frequency shift. 	<i>input</i> values will give a narrower spectrum display and posssibly increase frequency resolution and accuracy.
FFT input size ("length") 16384 C Complex input, separate VQ channels FFT window function Hann Center frequency [Hz] 1000.0 Interfrequency [Hz] Hann Hannn Hann Hann	
✓ use anti-alias filter for decimation □ Sweep [Hz/sec]: 0.0 Effect of FFT settings with fs= 8.00000 kHz: □ Include F.O. calibrator what ?! Width of one FFT-bin: 30.5176 mHz □ FFT Output Equiv. noise bandwidth: 45.7764 mHz FFT Output Max freq range: 0875.00 Hz 1125.00 Hz Type Normal (amplitude only) Overlap from scroll interval: 99.1 % Unit dB (userdefd reference) Internal average 0	Note: Shows the allowed freq span in Complex mode with: - Center frequency = 1000 - FFT input size = 16384 - Decimate input = 16 - Sampling freq. = 8 KHz
Shown: Settings for Analyser 1, channel 1 (L)	4

ANALYSIS OF A WIDE FREQUENCY SPAN

Set **Decimate input (by divisor)** to 1, **FFT input size** to 16384 points or more. Set **FFT Type and center frequency**: **Real FFT starting at 0 Hz**

SpecLab Configuration and Display Control	×
TRX Control Memory Filenames Way	ve Files Markers System Freq-Resp
Spectrum (1) Spectrum (2) Spectrum (3)	Radio DF FFT Audio VO AD/DA Server
FFT properties, frequency resolution Decimate input by (divisor) 1 FFT input size ("length") 16384 FFT window function Hann Image: state of the state of	FFT Type and center frequency Real FFT starting at 0 Hz (no offset) Complex with internal frequency shift. Complex input, separate VQ channels Center frequency [Hz] Sweep [Hz/sec1 : 0.0
Effect of FFT settings with fs= 8.00000 kHz: Width of one FFT-bin: 488.281 mHz Equiv. noise bandwidth: 732.422 mHz Max freq range: -1200.00 Hz 2800.00 Hz Overlap from scroll interval: 85.4 %	FFT Output Type Normal (amplitude only) Unit dB (userdef d reference) internal average 0
	Shown: Settings for Analyser 1, channel 1 (L)
	Apply Close ? Help

NOTE: With 8000 Hz Sampling rate you can display from 0 to 4000 Hz in Real FFT mode,with decimate input = 1 (under FFT tab)

Select OPTIONS, Spectrum display settings, set the Waterfall Scroll Interval

SpecLab Configuration and Display Control	
TRX Control Memory Filenames Wave Files Markers System Freq-Resp Spectrum (1) Spectrum (2) Spectrum (3) Radio DF FFT Audio I/O AD/DA Server Vertical Frequency Axis ✓ Amplitude Grid (dB or %) Show : both / Plot right	
✓ optimum waterfall average multi strip WF, 100 pix/strip both / Plot left ☐ triggered Spectrum more non scrolling WF Maths: both / Plot right ✓ peak detecting cursor peak holding graph, hold time (s): 5 Spectrum Graph only Spectrum Graph only ✓ show spectrum as BARgraph Waterfall Time Grid Channels / Connections Channels / Connections	Select the display type here: - Waterfall, - Spectrum - or both (default)
300 (• ms to sec C minutes automatic (50% overlap) ✓ smooth scroll More spectrum display settings on the next >>	
Shown: Settings for Analyser 1, channel 1 (L) Apply Close ? Help	5

Set up the main SL Display

Ref: http://freenet-homepage.de/dl4yhf/speclab/controls.htm

On the main SL display set the "*Min/Max*" values to the disired width. These values must be within the range reported previously in *FFT Settings*.



On the main SL display click the **bad frequency range (or peak at...)** button. In the window that appears, set ... peak f (995,1005)) where 995 and 1005 are the frequencies over which the peak detection will be active.



Your frequencies must be within the "*Max freq range*" as

Sound Card Audio Settings

Ref: http://freenet-homepage.de/dl4yhf/speclab/settings.htm#audio_settings

On the main SL display, select Options, Audio settings

😹 Spectrum I	aborato	ry V2.7 b12		
File Start/Stop	Options	Quick Settings	View/Windows	He
	Audio	settings		
Freq Time RDF	FFT se	ettings		
Min 990.0 -	Spect	rum display settir	igs	
Max 1010.0	dis Displa	play settings, pa y colors and font	art 2 s	
<u>Offs</u> 0.0	Radio	Direction Finder		
	Screer	n capture options		
Cursor [N]	Reado	out cursor setting	s	
990.2916 Hz	Frequ	ency marker sett	ings	
-0.0000 ?	Refer	ence spectrum	-	
	Syster	m settings		۲
B 1	Config	jure built-in HTTP	server	
CI	Volum	e control for "Red	cord " (audio in)	
	Volum	e control for "Pla	y" (audio out)	
- 120 dB - 40 0 d	Edit W	/aterfall Color Pa	ette	

Cursor modes and set point: Click on the frame of the cursor panel. By default, it is set to: "Simple, two independent cursors". This is the recommended setting.

Set the sound card *Audio Processing Sample Rate (nominal)* to 8000 Hz, or to a higher value... at least 2X the highest frequency to be observed.



Setting the File Export

Ref: http://freenet-homepage.de/dl4yhf/speclab/textexpt.htm

Select: File, Text File Export... Export of calculated data



NOTE: The <u>calculated data</u> may come from: - The sound card ADC

- From a .wav file being analyzed.

The File Contents window shows what data will be put in the exported file.

You may delete some items if required. Here the format for the PeakFreq has been modified to show 4 decimal digits.

Set the min/max frequencies for peakAmpl and PeakFreq.

These values must be within the "*Max freq range*" as reported in *FFT settings*, on page 4. When done, click: *File & Activation*

s	pectrum	Lab - File Exp	oort Format				×
	File Conte	nts Filename 8	Activation Export of FFT results				
	Column S	Separator (ASCI	i) 9 Number of columns: 4	ł			
	Column	Title	Numeric Expression	Format	Flags	Formatted	
	1	Time	time	YYYY-MM-DI	0		
	2	Noise	noise_n(800,1200)	##0.0#	0		
	3	PeakAmpl	peak_a(990,1010)	##0.0#	0		
	4	PeakFreq	peak_f(990,1010)	###0.000#	0		
	Test #1 - Test #2 -	× × <clic< td=""><td>k TEST and watch the result h</td><td>ere></td><td></td><td>></td><td></td></clic<>	k TEST and watch the result h	ere>		>	
	Menu.		<mark>₩</mark> Аррly	X Cancel		<u>7 H</u> elp	1

Setting the File Export... continued

In the field: *Export File #1*: Enter the file name, with a .txt extension, so that it will open with NotePad. Check: *Active*

You may Uncheck the **Use write Interval** box, to obtain a reading each waterfall line written in the above file. The write intervals will then be controlled by the setting under **OPTIONS**, **Spectrum display settings**: in the **Waterfall Scroll Interval**. Slow computers may not be able to follow.

Spectrum Lab	- File Export Format				×
File Contents	Filename & Activation Expo	ort of FFT results			
Export File #1:	29aug07-40m.txt			Active Size:0	
Export File #2:				Active Size:0	
Definition File:	current.edf				
🔲 power-fail	safe				
🔲 Use write i	nterval: 1.0 seconds,	next write at: 14:0	04:01.0	Synchronize !	
Whenever a sp	ectrum has been calculated,	execute these comr	nands:		
					Test
Before writing	a line to the export file, execu	ute these commands	:		
					Test
After writing a	line to the export file, execute	e these commands:			
					Test
<click< td=""><td>TEST and watch the</td><td>result here></td><td></td><td></td><td></td></click<>	TEST and watch the	result here>			
		[1 1 -	
Menu	🔆 Apply	🗸 ок	🗙 Can	cel <u>? H</u> elp	

NOTE: If for example you are running in real mode and logging WWV for many hours, you might set Write interval to 1 minute, but still have the water fall running at a higher rate so you can see what's going on quickly.

Spectrum display settings

The *Waterfall Scroll Interval i*s at the bottom left.

Setting the File Export... continued

Every time a file is played back for further analysis, it appends the new data to the old one.

Clicking on *Menu* below allows deleting the file. Click *Apply* and *OK* when done.

Spectrum L	Lab - File Export Format	×
File Conten	nts Filename & Activation Export of FFT results	
Export File #	#1: 29aug07-40m.txt 🔽 Active Size:0	
Export File #	#2: Active Size:0	
Definition Fi	ile: current.edf	
power-	-fail safe	
🖵 Use wr	rite interval : 1.0 seconds, next write at: 14:04:01.0 Synchronize !	
Whenever	a spectrum has been calculated, execute these commands:	
	a spectrum has been calculated, execute mese commands.	Test
, Before wri	iting a line to the export file, execute these commands:	
		Test
, After writir	ng a line to the export file, execute these commands:	
		Test
<cl< td=""><td>lick TEST and watch the result here></td><td></td></cl<>	lick TEST and watch the result here>	
		1
Menu.	Load definition	
	Save definition	
	Delete "29aug07-40m.txt"	
	Delete T	
	Apply changes & validate	

NOTE: If the soundcard ADC signal is to be analyzed: Select: *Start/Stop, Start Sound Thread*

When done, select: *Start/Stop, Stop Sound Thread*, to end the recording process. The results file is under: C:\spectrum

Analyzing the .wav file

NOTE: It's a good idea to analyze the .wav file, first, before exporting the results to a file. First, set up the main display as in page 6.

Ref: http://freenet-homepage.de/dl4yhf/speclab/wavfiles.htm

Used to analyze a .wav file. Finds the peak amplitudes, frequencies etc. You may setup a result file: set the *File Export* mode as in previous pages. On the main SL display, select *File, Audio Files, Analyse audio file (without DSP)* or: (*with DSP*) to play back the file in real time, observe the spectrogram and listen to it.

😹 Spectrum Laboratory V	2.7 b12
File Start/Stop Options Quic	k Settings View/Windows Help
Directories Load Settings	
Screen Capture Periodic Actions Scheduled Actions Conditional Actions	0 992 Hz 994
Image viewer Convert loaded image to Text file export	
Audio Files Waterfall Color Palette Spectrum Reference Curve	Audio file settings Analyse audio file (without DSP) Analyse and play file (with DSP)
Exit - 120 dB -40.0 dB	Stop file analysis Save input as audio file Save decimated I/Q-samples Save output in audio file

NOTE: Playback with DSP mode:

While the file is being analyzed: Activate the Spectrum Analyzer and audio out by selecting: *Start/Stop*, Enable: *Spectrum Analyzer #1,* Enable: *Audio Output to DAC* Then stop analysis and restart it.

Select the file to be analyzed:

Analyse Input fro	m audio file (*.WAV,	DAT,TXT,JAS,AUD)		? 🗙
<u>R</u> egarder dans :	🗀 29aout07		# *	
29aug07-40m.wa	v wav			
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Fichiers de <u>t</u> ype :	Wave files (*.wav)		• A	nnuler
				<u>A</u> ide

Analyzing the .wav file... cont'd

Set *FFT to 16384 points* and *decimate = 16* for your file. (These are starting values). If the file comes from another computer: set the actual *File sample rate* required to make a 100 Hz calibration file (from that other computer) play back at 100 Hz, for example. Set *Speed: slow, smooth scroll.*

Click OK. This starts the file processing.





The main SL display indicates current progress and the end of processing. The results file will be under: c:\spectrum

Calibration of the Soundcard Sample Rate

Ref: http://freenet-homepage.de/dl4yhf/speclab/frqcalib.htm

Your computer should be well warmed up. At least two hours is recommended. On the main SL display, select **Options, Audio settings.** Select the sound card **Audio Processing Sample Rate (nominal)** to be calibrated. **Apply**

Feed a reference signal to the sound card input of precisely known reference frequency.

(Such as WWV 100 Hz tone, with the receiver in AM mode)

Select: *File, Text File Export... Export of calculated data.* Set the min/max frequencies to read the *peak_f* (peak frequency).

SpecLab Configuration and	Display Contro				×
TRX Control Memory	Filenames Wa	ave Files 🌡 Marke	rs Svs	tem Freq-Resp	1
Spectrum (1) Spectrum (2)	Spectrum (3)	Radio DF FFT	Audio I	/0 AD/DA Server	
Audio Input Device	-Audio Processi	ing		- 1	
-1 (use default WAVE inp	Sample Rate (n	ominal) 44100	SF	Calibrator 🤶	
1 drivers found	Input sample ra	te divisor 1	- c	orrect Frequency	
Chn other sources >>	Input decin	nation by A/D serve	r	10000	
Audio Output Device	🔲 use anti-al	ias filter, length 2	5 C	Displayed Freqcy	K.
-1 (use default WAVE ou 💌	Sample Rate Ca	libration [Hz]		10000.0008	
1 drivers found	Nominal (Calibrated	<u>^</u>	Calibrate	
Chn other destinations >>	8000	8000.000			
16 V bits/sample	22050	22050.0965		Deiff Calibertan	
Stereo Processing	44100	44100.1852	_	Drift Calibrator	
VQ input adjustment	48000	48000 000	~		
	~	Shown: Settings	for Analyse	er 1, channel 1 (L)	
			_		
	~	🗸 Apply	Close	<u>?</u> Help	
Spectrum Lab - File Export	Format			2	
Speccium cub The Export	. I WITHING C				XII
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Set **FFT Settings** as in page 3. For sampling rates above 8000 Hz, I used **Decimate input (by divisor)** to 64, **FFT input size** to 32768 points Set SL display as in page 5. Use a wider frequency window at the beginning and zoom in until the span is ~ 4 Hz

In *File Export Format*, click: *Test#1* to read the frequency. Copy that frequency in the *Displayed Frequency* box above.

Enter the reference frequency in the *Correct Frequency* Box.

Calibrate when done. Apply

In *File Export Format*, click: *Test#1* to read the frequency. Repeat calibration if req'd.

Repeat this calibration at the other sampling speeds that you will use.

Spectrum Lab remembers the calibration for every sample rate.

Saving / Recalling settings

Ref: http://freenet-homepage.de/dl4yhf/speclab/usermenu.htm

Quick Settings	View/Windows	Help	
Radio Equipment Tests			۲
Slow Morse Reception ("QRSS")		۲	
Predefined d	ligimodes		
Other amateur radio modes		۲	
Image-cancelling DC receiver (separate I/Q)		۲	
Colour Direction Finder		۲	
Natural radio; animal voices		۲	
Restore all "f	factory" settings		
1 10 0			
Load & Crea	te user defined e	ntries	
15734 Hz, 8	te user defined e Hz Span	ntries	
15734 Hz, 8 My Menu #2	te user defined e Hz Span	ntries	
15734 Hz, 8 My Menu #2 My Menu #3	te user denned e Hz Span	ntries	
Load & Crea 15734 Hz, 8 My Menu #2 My Menu #3 My Menu #4	te user denned e Hz Span	ntnes	
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Select: Quick Settings, Load and Create user defined entries...

Saving your settings:



Recall your settings:

Click *Import* to load your settings. SL accepts a file with .usr extension.

GENERAL NOTES

From Connie K5CM...

Increasing FFT/Decimate values may help resolution.

For example I always increase the values to the point SL will no longer read the file then back down one step.

Also it helps to record a longer file as SL will not play a file that does not have at least enough bytes to give the first FFT reading.

This is important if your trying to use high FFT/Decimate values.

Also during calibration I increase the values to at least 32k/64. SL has one of the best interpolation routines I have seen, but sometimes there is no replacement for pure resolution, especially when analyzing something besides a pure sine wave.

I don't know if it's a bug or my computer is not big/fast enough, but I have trouble getting FFT=65536 to work.

Also there is a bug that causes the ruler to become uncalibrated.

It's not obvious when it happens so it's a good idea to restart SL before a calibration or a FMT.

It usually happens after moving the ruler, or making a lot of on screen changes to span size.

Decrease/eliminate the sound card error when measuring simultaneous carriers

If you are in ground wave range of the station your trying to measure or perhaps a two simultaneous frequency FMT, then the sound card error become problematic. I use the SSB position and a reference signal set a few Hertz from the signal to measure. Even though the SSB receiver is not disciplined by GPS it's drift for the signal is the same as its drift for the reference marker.

For example last Sunday when I measured Marvin's 80 meter signal I set my marker to 3565210 Hz and use the following Spectrum Lab Expression to record the frequency to the file: peak_f(1007,1010)-peak_f(999,1001)+3565210
The marker was between 999 and 1001, and the signal was between 1007 and 1010. Sound card error is of little concern as the difference in the two frequencies was only 8 Hertz. Over 100 times better than the real sound card error at 1000 Hertz.

Calibrating the Sound Card

Its a good idea to calibrate the sound card at all sampling rates that will be used.

The help files mention using the 15625 Hz TV line sync signal.

This frequency applies to 50 Hz countries !

In Canada and US, it is: 15734.2657343 Hz.

It is easy to pick up the radiated signal from a CRT type TV set...(LCD's won't work), tuned to analog channels.

I used a 30 turn coil on a ferrite stick. Place it on top of the set, half way from the rear and parallel to the front.

I found that the signal frequency differs from station to station.

Large TV networks had the best accuracy.

With care and a stable sound card oscillator, you could expect a few ppm accuracy. That's +/- 0.01 Hz at 10 KHz.

See Message #267 on FMT-nuts.