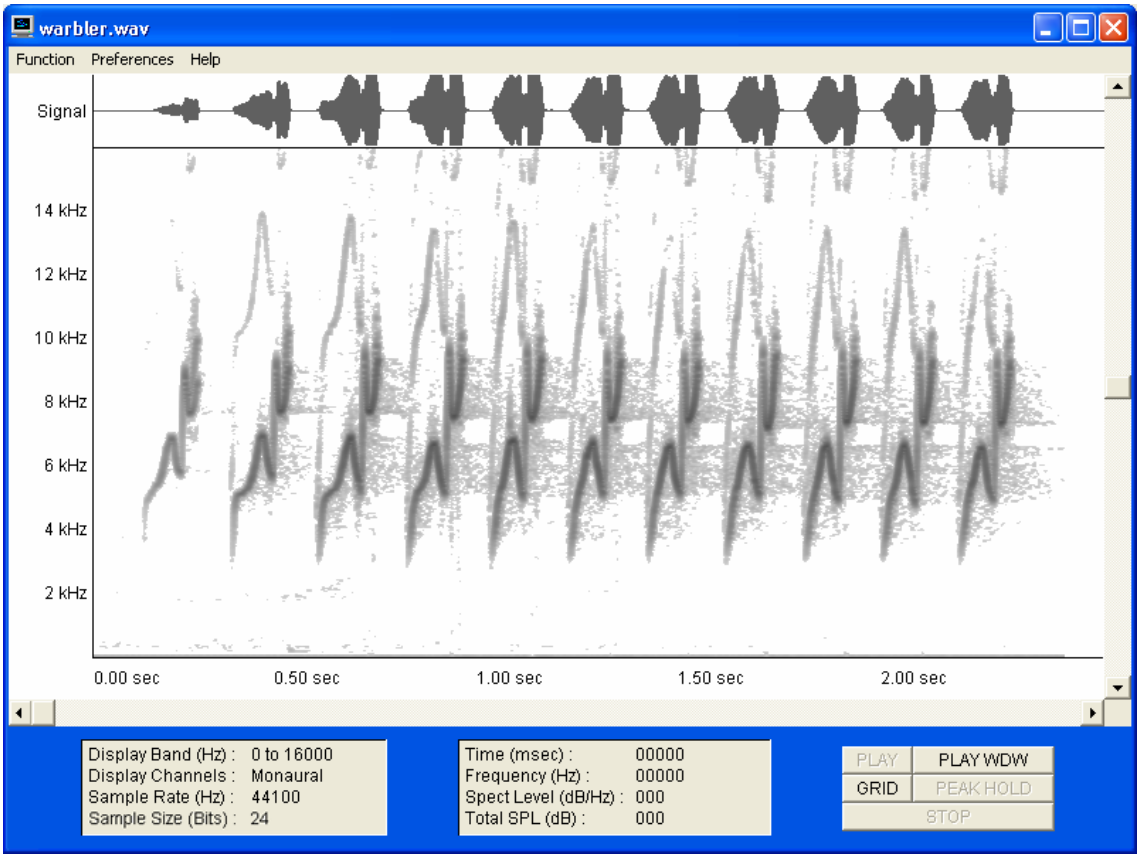
# Spectrogram Version 16
# Operating Instructions




***Audio Spectrum of the Song of the Prothonotary Warbler***

Spectrogram is a product of Visualization Software LLC
www.visualizationsoftware.com

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## PRINCIPLES OF OPERATION

Most ordinary sounds are complex combinations of individual frequency components or harmonics with a wide range of frequency and intensity. A spectrogram is simply a plot of the frequency components of sounds as a function of time. In this Spectrogram program, digital audio from the computer sound card is analyzed to produce a plot of frequency versus time, with the harmonic Spectrum Level at each frequency represented by a variable color scale. These spectrograms reveal the fascinating hidden frequency structure of audio signals and can be used for identifying or classifying particular sounds.

The Spectrogram program provides three basic modes of operation named **Scan Input, Scan File, and Analyze File.**

- **Scan Input** mode analyzes the audio signal from a microphone or other source through the computer sound card and provides a real-time scrolling spectrogram display. When scanning is stopped, as much as the last 60 seconds of audio are captured in memory for detailed analysis and playback. The Scan Input mode of operation is selected by choosing "Function - Scan Input" from the program menu (or with Function Key F1).

  The Scan Input mode is also used for recording of wave files of up to two hours length using the computer sound card. See **Frequency Analysis Parameters - Recording Enable**.

- **Scan File** mode plays and analyzes recorded wave files (PCM format) and provides a real-time scrolling spectrogram display. The Scan File mode is intended for **very long wave files** of greater than one minute in duration. When scanning is stopped, as much as the last 60 seconds of audio are captured in memory for detailed analysis and playback. The Scan File mode of operation is selected by choosing "Function - Scan File" from the program menu (or with Function Key F2).

- **Analyze File** mode is used for spectrum analysis of an entire recorded wave file (PCM format). The entire length of the recording is stored in memory for detailed analysis and playback. The Analyze File mode is intended for use with **relatively short wave files** of less than one minute in duration. Significant memory resources are required since the entire wave file and its spectrogram bitmap must be stored in memory. The Analyze File mode of operation is selected by choosing "Function - Analyze File" from the program menu (or with Function Key F3).

## THE TIME-FREQUENCY UNCERTAINTY PRINCIPLE

The Spectrogram program provides many different controls for setting time and frequency resolution on the spectrum displays. Very high resolutions can be selected; however, there are practical limits to the choices available.

In any process of spectrum analysis, time resolution and frequency resolution are inversely related. Very good time resolution corresponds to poor frequency resolution. Very good frequency resolution corresponds to poor time resolution. The practical result is that choosing very high frequency resolution will mask time details in the audio spectrum. Choosing a proper frequency resolution and corresponding time resolution becomes a tradeoff between the need to observe fine frequency details in the spectrum and the need to observe rapid time variations in the spectrum. The Spectrogram program will automatically select a frequency resolution matching the choice of time resolution. You can override this selection if desired, but this fundamental uncertainty principle will still apply.

## CHOICE OF SAMPLING RATE AND DATA RESOLUTION

Spectrogram provides the capability to select digital sampling rates from 22 kHz to 96 kHz and data resolution of 16 bits or 24 bits. It is important to select the digital sampling rate and data resolution to match the characteristics of the audio data to be recorded or analyzed. Please note that careless use of the highest sampling rate will often degrade both system performance and the amount of detail visible in the spectrogram image.

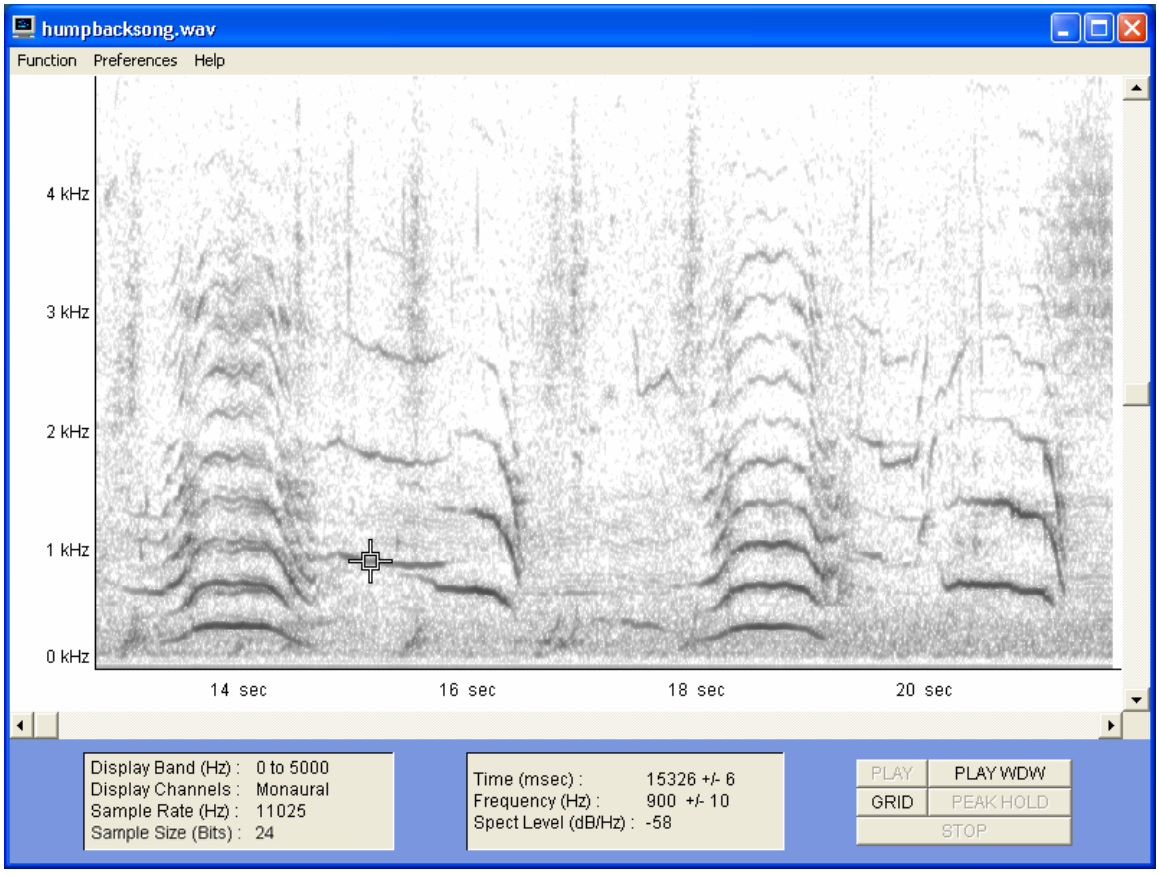
The rule of thumb is that the digital sampling rate should be set at twice the highest frequency expected in the audio signal. For this reason, the 48 kHz sampling rate is the highest that can be recommended for use with a microphone or other ordinary audio source. Even the highest quality professional microphones do not detect frequencies above 24 kHz, so the best choice for digital sampling rate in these circumstances is 48 kHz. The 96 kHz sampling rate can only be recommended if the audio source is a high frequency transducer or other device that can actually detect frequencies above 24 kHz.

24 bit data resolution is the best choice for high fidelity recording and analysis. It provides the highest dynamic range and the most accurate representation of the audio signal. However, using 24 bit data resolution does require a significant amount of memory, which can become a serious consideration in recording of lengthy audio samples. 16 bit data resolution requires less memory and is entirely suitable for recording of voice or biological sounds, which usually do not present the extremes of high and low volume that might be expected when recording music or other highly dynamic sounds.

Also, note that all Windows sound cards do not support 96 kHz sampling rate and 24 bit data resolution. Please check the specifications of your sound card if Spectrogram is not able to open the audio device, or if you see no audio data when attempting to record at this rate and resolution.

## NARROWBAND SPECTROGRAM DISPLAY

The narrowband spectrogram display reveals the audio signal as a frequency versus time plot with spectrum level (dB) at each frequency represented by intensity (or color). The display can be configured for either dual channel or single channel audio with a wide selection of frequency resolutions and either linear or logarithmic frequency scales. In dual channel operation, the spectrogram window is split into left and right halves with separate scrolling spectrograms for the left and right audio channels.




**SINGLE CHANNEL SCROLLING SPECTROGRAM DISPLAY (SCROLL 1 FORMAT)**

A continuous readout of time (milliseconds), frequency (Hz), and spectrum level (dB), at the position of the mouse pointer (cursor) is shown at the bottom of the display. If system calibration has been conducted, a readout of total sound pressure level , SPL (dB), is also shown. See **Sound Pressure Level and Calibration** for calibration procedures and definitions of spectrum level and sound pressure level.

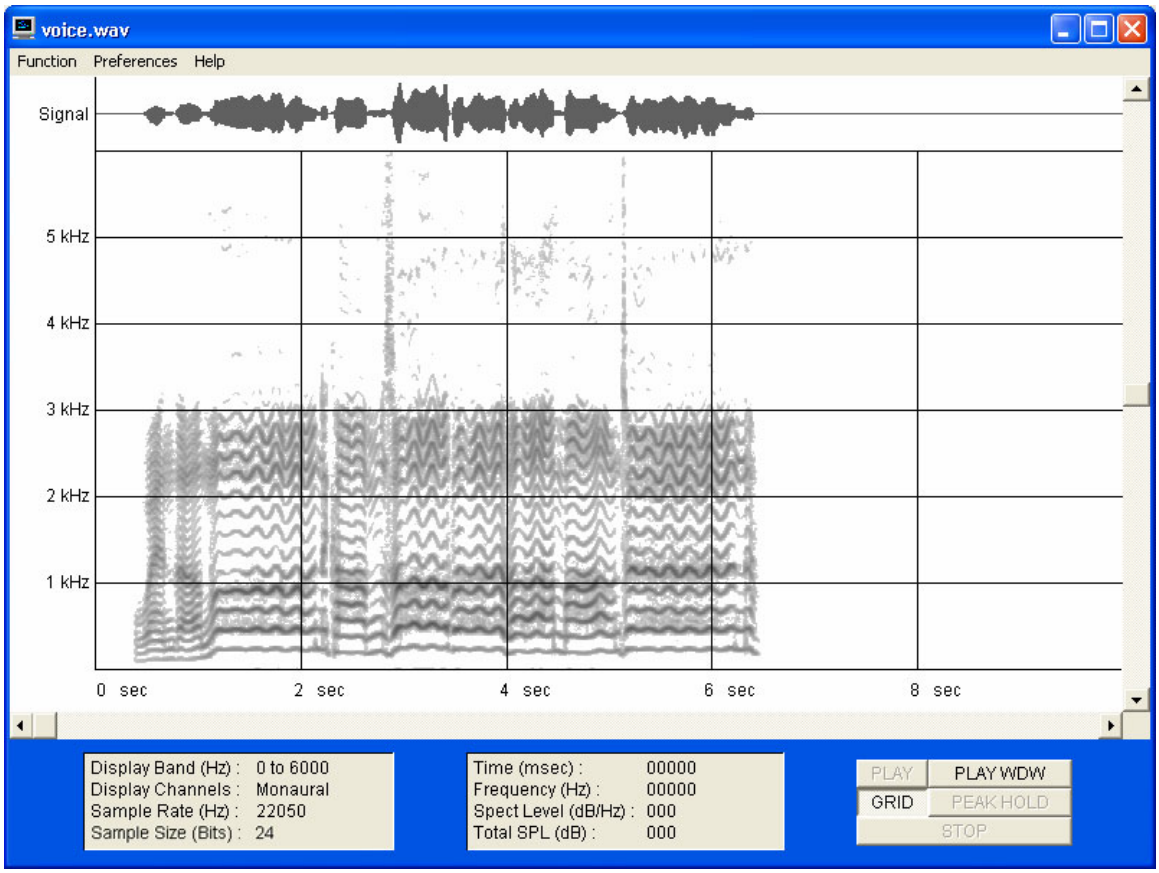
A coordinate grid can also be added or removed by clicking the "GRID" button at the bottom right of the display.

Signal gain or volume on the display can be adjusted using the vertical slider at the right side of the display window.

## NARROWBAND SPECTROGRAM DISPLAY (CONT'D)

Spectrogram can play back the audio sample through the computer sound card when you click the "PLAY" or "PLAYWDW" buttons at the bottom right of the display. PLAYWDW replays only the segment of the spectrogram visible in the display window; whereas, PLAY replays the entire width of the spectrogram.

The height and width of the spectrogram display are limited only by the display screen. Maximizing the spectrogram window will expand the display to fill the screen. The scale of the spectrogram display is automatically adjusted to match the size of the display window. The spectrogram color scale and signal range and gain can be adjusted by use of the Spectrum Color Scale controls. See **Spectrum Color Scale** for more information.

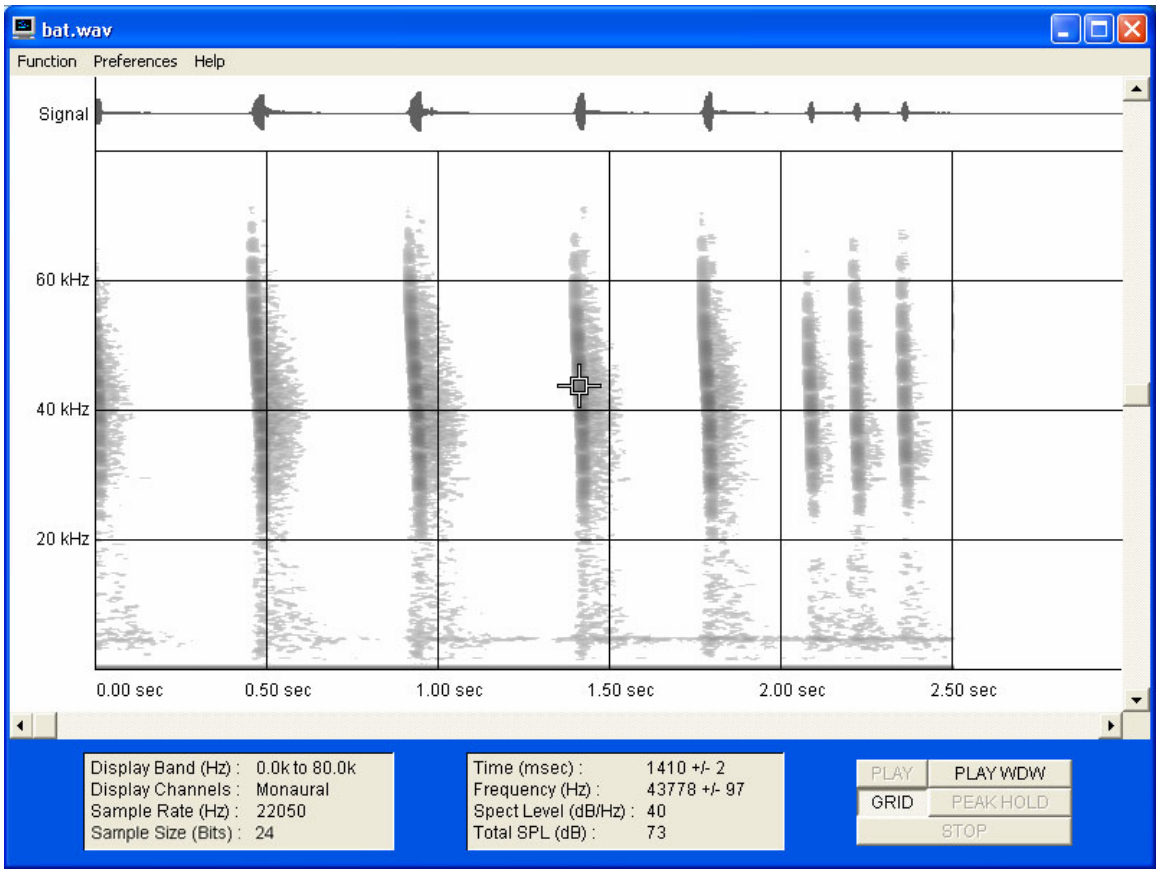



## SINGLE CHANNEL SCROLLING SPECTROGRAM DISPLAY (SCROLL 2 FORMAT)

The Scroll 2 display is an alternative spectrogram format that includes a depiction of the analog audio signal in a strip across the top of the display. All other display controls and adjustments are identical to those of the Scroll 1 format.

## ULTRASOUND SPECTROGRAM DISPLAY

The Ultrasound Spectrogram Display is designed for use with ultrasound detectors such as those used to capture high-frequency vocalizations of bats and communication signals by insects, rodents or other animals. Ultrasound detectors shift these high frequency sounds down into the audible frequency range and save them as Windows wave file recordings. The Ultrasound Spectrogram Display can be used to analyze these recordings and is scaled so that proper measurements of frequency and time can be made directly from the screen. The Ultrasound Spectrogram Display is activated from the Preferences Menu. Choose "Preferences - Analysis Controls - Ultrasound Controls" to activate this display.




## ULTRASOUND SPECTROGRAM DISPLAY

There are three types of ultrasound detector. The "heterodyne" and "frequency division" detectors shift the high frequency sound down into the audible range without any change in the time scale of the recording. The "time expansion" detector records the sound at a very high sampling rate that is then reduced for playback. Thus the time expansion detector produces recordings that are shifted down in frequency and stretched in time. See **Ultrasound Conversion Parameters** for a description of the controls for the Ultrasound display.

## THE SCOPE DISPLAY

The Scan Input and Scan File modes also provide a spectrum analyzer scope display as an option for viewing the sound spectrum. The scope display can be configured for either dual channel or single channel audio with a wide selection of frequency resolutions and either linear or logarithmic frequency scales. In dual channel operation, the left and right channel data can be plotted in different colors, allowing an evaluation of the spectral differences between the two channels.

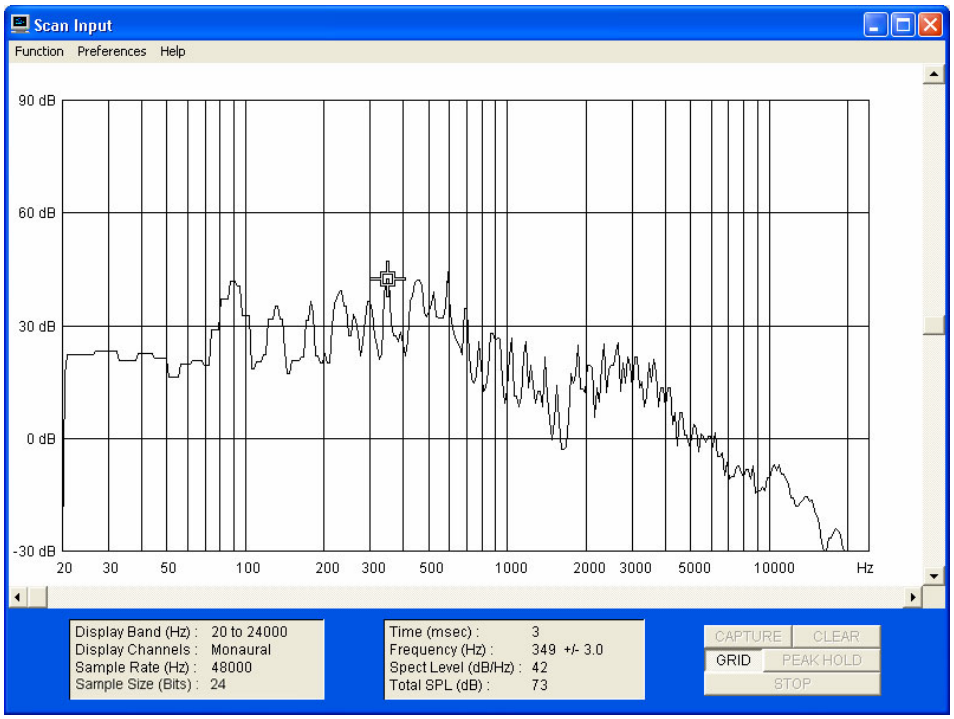
Spectrogram also provides the option of a 1/3 octave scope display in which the spectrum in adjacent frequency bands of one third octave width is displayed in real time. The 1/3 octave display is useful in measurement and calibration of broadband acoustics sources.

The scope display can be configured as either as a continuous plot of component amplitude versus frequency (Scope 1) or a histogram, where component amplitude is represented at each frequency by a vertical bar (Scope 2). A continuous readout of time (milliseconds), frequency (Hz), and spectrum level (dB), at the position of the mouse pointer (cursor) is shown at the bottom of the display. If system calibration has been conducted, readout of total sound pressure level, SPL (dB), is also shown. See **Sound Pressure Level and Calibration** for calibration procedures and definitions of spectrum level and sound pressure level.

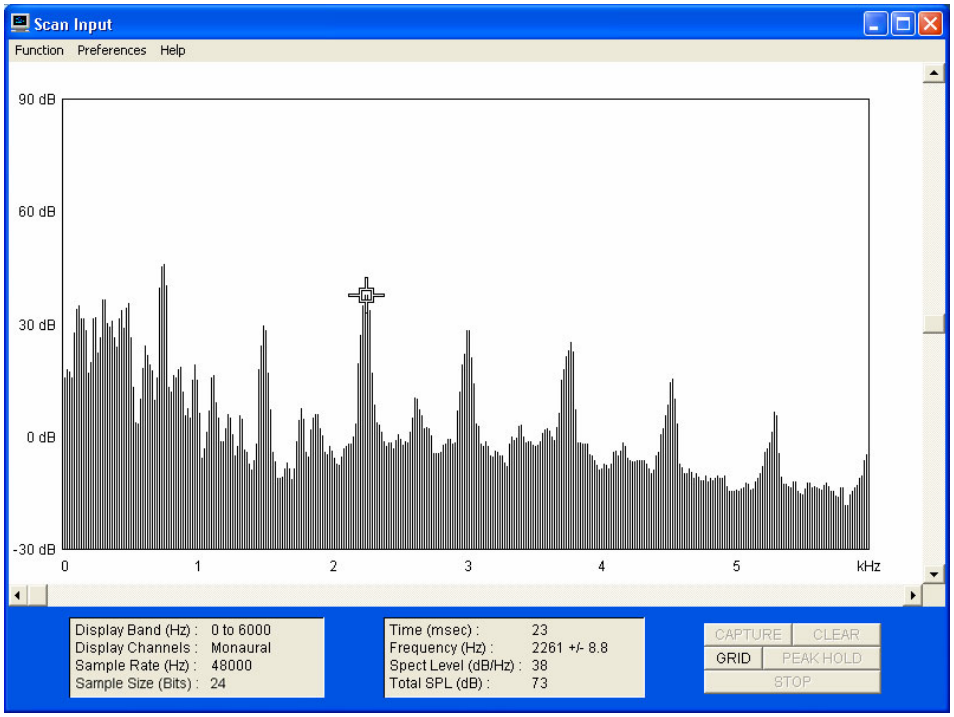
A coordinate grid can also be added or removed by clicking the "GRID" button at the bottom right of the display.

Signal gain on the scope display can be adjusted using the vertical slider at the right side of the display window.

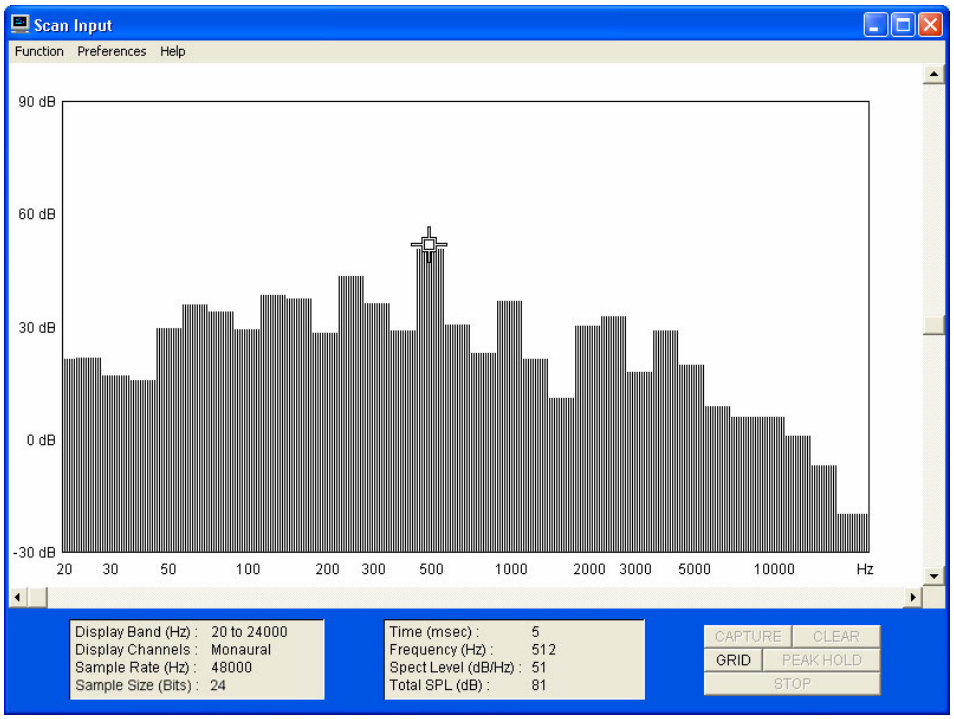
### SPECTRUM ANALYZER SCOPE DISPLAY - SCOPE 1



## SPECTRUM ANALYZER SCOPE DISPLAY - SCOPE 2



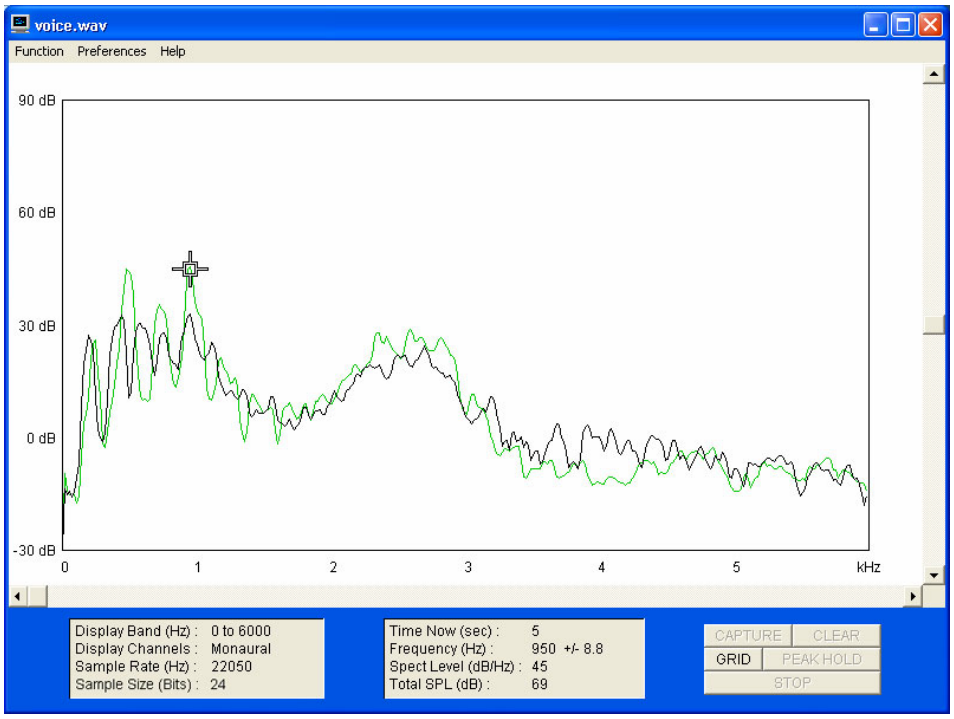

## SPECTRUM ANALYZER SCOPE DISPLAY - 1/3 OCTAVE



## THE SPECTRUM CAPTURE DISPLAY

An instantaneous plot of the signal spectrum can be captured on both the Scope 1 and Scope 2 displays. Click the “Capture” button at the bottom right of the display, and the instantaneous spectrum at that point in time will be indicated by a green line.

This spectrum plot can be used for comparison of the spectra of two different signals. Once captured, this plot will remain on the Scope Displays as other signals are analyzed for comparison. Click the “Clear” button to remove the captured spectrum plot.

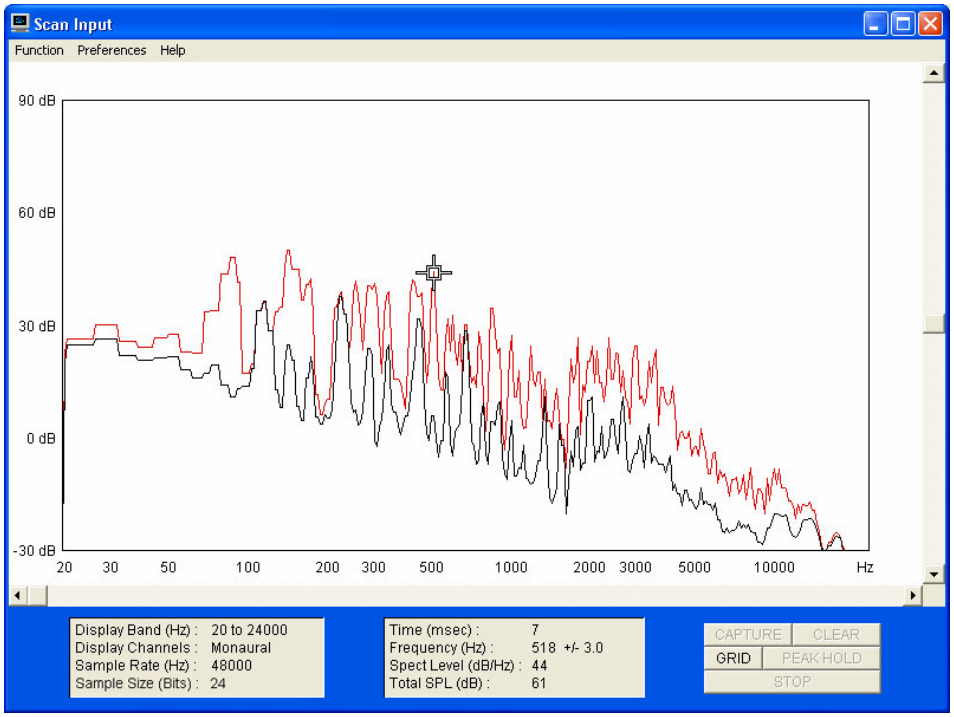



**SPECTRUM CAPTURE DISPLAY**

## PEAK HOLD& SIGNAL DIFFERENCE DISPLAYS

Both the Scope 1 and Scope 2 displays can be configured to include a plot of peak signal. Click the "PEAK HOLD" button at the bottom right of the display window to show the peak signal plot. The peak signal plot can be reset at any time by releasing the PEAK HOLD button. The Peak Hold display is only available for a single channel display (display of mono sampling, or display of either left or right channel from stereo sampling).

The Scope 1 display can also be configured to show the difference between the left and right channel inputs. This display allows precise balancing of the left and right channels across the entire spectrum. The L-R Signal Delta display is only available using stereo sampling. See **Sample and Display Parameters** for more information.



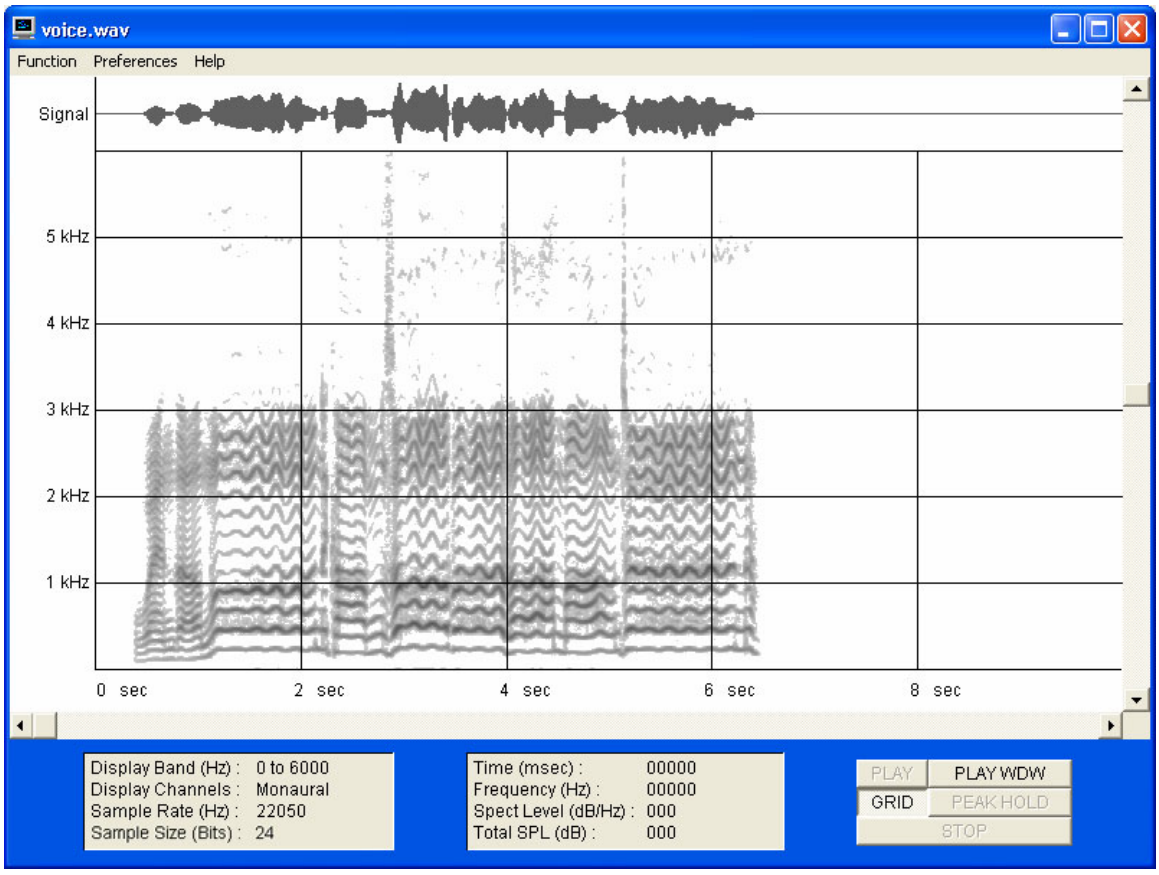

**PEAK HOLD DISPLAY**

## VOLUME CONTROL

Setting the proper signal amplitude or volume is very important to creation of a spectrogram that reveals all of the fine detail of the audio spectrum. A signal that is too weak will show little detail in the spectrum. A signal that is too strong will be clipped at its extremes of amplitude, resulting in distorted sound and a distorted spectrum display.

Use the vertical slider control at the right side of the display to adjust volume so that the signal fills about ¾ of the height of the signal amplitude strip at the top of the Scroll 2 display. This adjustment can be made while analyzing a signal via the microphone or after the spectrogram has been completed. The illustrations below show spectrograms with proper signal amplitude, weak signal amplitude, and clipped signal amplitude.

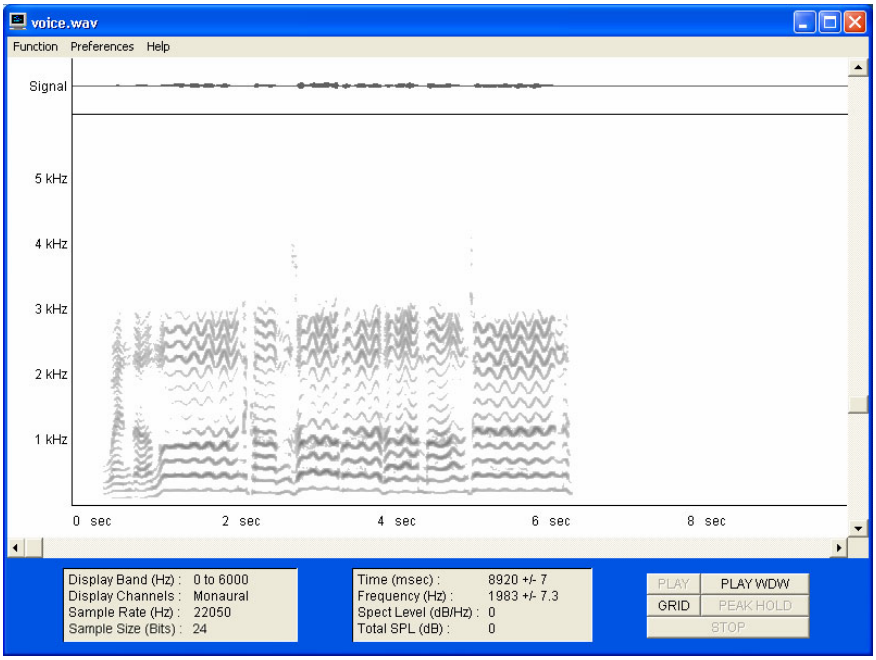
Note that these adjustments are applied to the audio signal AFTER processing by the sound card. If the initial sound card volume setting is extremely high or low, this vertical slider control may not be able to compensate. See the following paragraphs entitled **Sound Card Control for Windows Vista** and **Sound Card Control for Windows XP** for instructions on setting the sound card volume control.



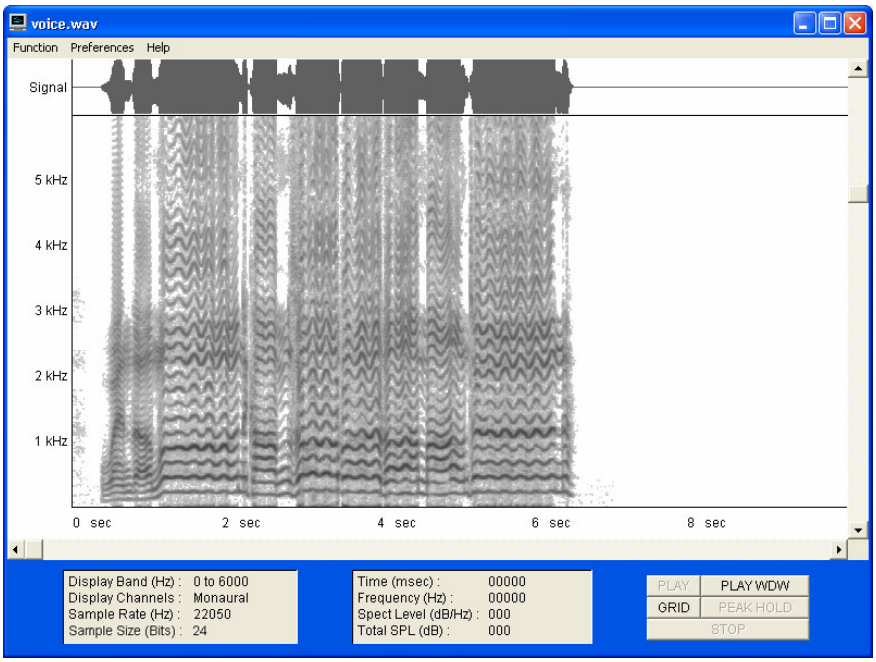

The spectrogram above illustrates the proper setting of signal amplitude or volume.

If you plan to calibrate Spectrogram for sound pressure level measurement, the volume setting should be established prior to running the calibration procedure. To maintain calibration, the volume setting should not be changed after calibration is completed. See **Sound Pressure Level and Calibration** for more information about the calibration procedure and its relationship to volume control

## VOLUME CONTROL (CONT'D)




The spectrogram above illustrates signal amplitude that has been set too low. Details in the spectrogram are lost when the signal amplitude is this low.




The spectrogram above illustrates signal amplitude that has been set at too high a level resulting in clipping of the signal at its amplitude extremes. Clipped signals will result in distortion of both the spectrogram and of wave file recordings made from the spectrogram.

## DISPLAY READOUTS AND ADJUSTMENTS

### SIGNAL READOUTS

A continuous readout of time (milliseconds), frequency (Hz), and spectrum level (dB), at the position of the mouse pointer (cursor) is shown at the bottom of the display. If system calibration has been conducted, a readout of total sound pressure level, SPL (dB), is also shown. See **Sound Pressure Level and Calibration** for calibration procedures and definitions of spectrum level and sound pressure level.

A coordinate grid can also be added or removed by clicking the "GRID" button. The grid can be removed by releasing the GRID button.

The mouse pointer can also be used to measure time and frequency differences on a completed spectrogram display (after scanning has been stopped). Click and hold down the right mouse button to establish a reference point in frequency and time. Then as the mouse is moved, the differences in frequency and time at the mouse position will be displayed at the bottom of the Spectrogram window. Releasing the right mouse button returns the mouse cursor to normal operation.

### DISPLAY MARKERS

In the real-time scanning modes (Scan Input, and Scan File), a fixed reference cross mark can be added to either the scrolling spectrogram display or the scope display. This marker can be useful for identification of amplitude or frequency peaks in the audio signal. Click the left mouse button to set this cross mark at the cursor position on the display.

In addition, one or two fixed frequency markers can be added to the either the scrolling spectrogram display or the scope display. These markers can be useful when using Spectrogram to tune an audio source to a particular frequency. To activate the frequency markers, choose “Preferences - Display Freq Mark - On” from the program menu. Enter the frequency values (Hz) for each marker, and they will then appear on the screen as fixed lines at the chosen frequencies.

### DISPLAY PAUSE

A display pause function is available in the Scan Input mode of operation. Clicking the right mouse button or the keyboard Space Bar will freeze the scrolling spectrogram display. Clicking the right mouse button or keyboard Space Bar again will restart the scrolling spectrogram display.

### PROGRAM START UP AND INITIALIZATION

Spectrogram will always start up in the same configuration that was in effect the last time the program was running. Program settings are saved in the “gram15.ini” file in the same directory with Spectrogram. The saved configuration includes time and frequency resolution, color and display thresholds, and selection of the type of display. You can always return to the default program settings by clicking the “Reset” button on any of the Scan Input, Scan File, or Analyze File dialog boxes.

## DISPLAY AND CONTROL PREFERENCES

The Spectrogram program menu includes selections for display and control preferences as described below. Primarily, these controls determine the methods to be used to select display time resolution and frequency resolution. They affect the type of control panel that will be presented for selection of time and frequency resolution. See **Scan Input Parameter Selection**, **Scan File Parameter Selection, and Analyze File Parameter Selection** for more information.

Spectrogram can record and analyze two channels of audio in either 16 bit or 24 bit PCM format at sampling rates up to 96 kHz (for sound cards that provide this capacity). Spectrogram can also analyze recorded wave files in 32 bit PCM IEEE FLOAT format.

### ANALYSIS CONTROLS

- **Automatic Controls:** When this option is selected, Spectrogram will automatically set display frequency resolution and time resolution based upon your specification of the display frequency bandwidth (High Band Limit and Low Band Limit). This is the easiest way to set up the Spectrogram display for a good presentation of the audio frequency spectrum.

- **Manual Controls:** This option is intended for use by those who require complete control over display frequency resolution and time resolution. It allows designation of digital sampling rate, spectrum analysis FFT size, display frequency resolution, and display time scale. These controls give the most flexibility in setting up the spectrogram display, but also require an engineering knowledge of the parameters of digital spectrum analysis.

- **Ultrasound Controls:** This option is used when analyzing files produced by Ultrasound Detectors. Ultrasound detectors are used to capture high-frequency vocalizations of bats, cetacean echolocation calls, and communication signals by insects, rodents or other animals. Ultrasound detectors shift these high frequency sounds down into the audible frequency range and save them as Windows wave file recordings.

  There are three types of ultrasound detector. The “heterodyne” and “frequency division” detectors shift the high frequency sound down into the audible range without any change in the time scale of the recording . Recordings from these detectors can be analyzed using the “Freq Div” setting.

  The “time expansion” detector records the sound at a very high sampling rate that is then reduced for playback. Thus the time expansion detector produces recordings that are shifted down in frequency and stretched in time. Recordings from a time expansion detector can be analyzed using the “Time Exp” setting.

  The “Freq Scale Multiplier” slider is used to set the frequency scale of the Spectrogram. This multiplication factor corresponds to the reduction in frequency of the ultrasound recording and can range from 1 to 64 for frequency division detectors and from 1 to 32 for time expansion detectors. This factor is applied to the display frequency and time scales so that exact measurements of frequency and time can be made directly from the display.

## DISPLAY POINTERS

Use these menu items to select the type of mouse pointer for the Spectrogram display. The mouse pointer may take the form of a Target Box, a White Cross, or a Black Cross. Select the appropriate mouse pointer based on the type of display (Scroll or Scope) and the selected display colors.

## DISPLAY FREQ MARKERS

Use these menu items to select one or two fixed frequency markers to be added to the either the scrolling spectrogram display or the scope display. These markers can be useful when using Spectrogram to tune an audio source to a particular frequency. Enter the frequency values (Hz) for each marker, and they will then appear on the screen as fixed lines at the chosen frequencies.

## SPL CAL GAIN LOCK

If you have calibrated Spectrogram for measurement of Sound Pressure Level (SPL), the Spectrogram volume control (vertical slider at the right side of the display window) will be locked to prevent inadvertent changes. The SPL Cal Gain Lock can be turned on and off from the Spectrogram display window by choosing "Preferences - SPL Cal Gain Lock - On or Off" from the program menu. Turning the SPL Cal Gain Lock back on at any time will return Spectrogram to its most recent calibrated settings. This allows you to return the program to its calibrated state at any future time without repeating the entire SPL calibration process. See the section entitled **Sound Pressure Level and Calibration** for more information.

## VARIABLES

If you continuously use the same analysis parameters with Spectrogram, then you can choose to freeze these same parameters so that you will not have to enter them each time you analyze or scan a file or audio input. Choose "Variables - Freeze" from the program menu to automatically use the current analysis parameters again and again. Choose "Variables - Adjust" to manually adjust the analysis parameters each time you perform a spectrum analysis.

This setting must be enabled each time you restart the Spectrogram program. Thereafter your processing settings will be remembered each time you begin scanning or analysis.

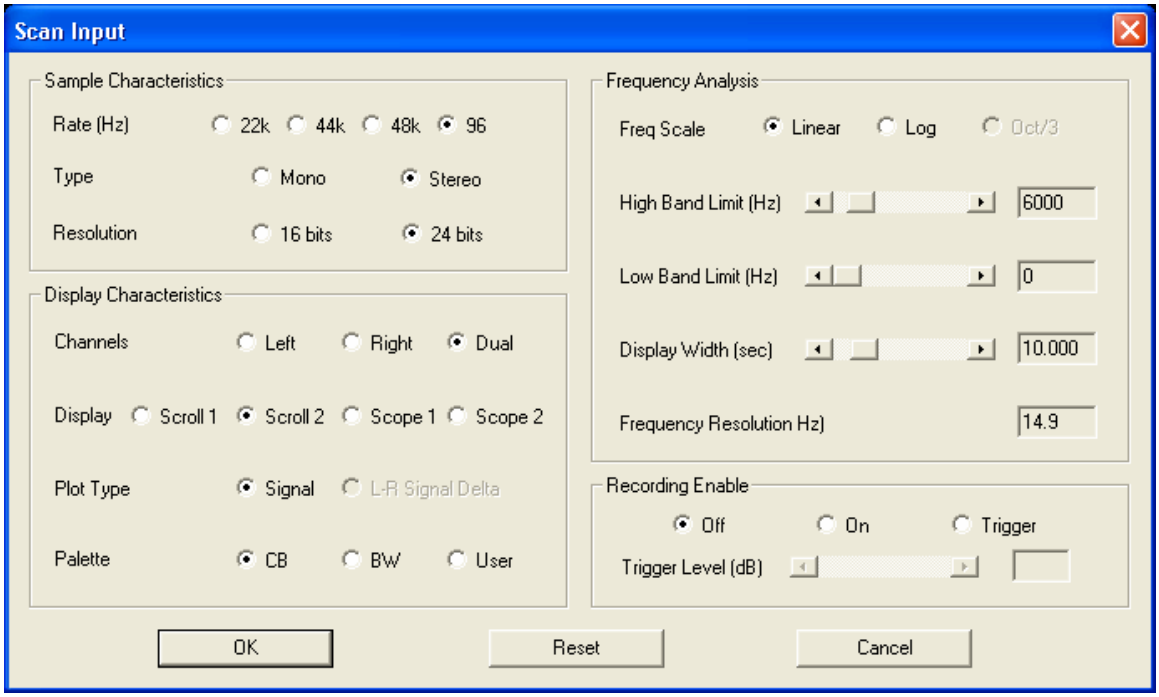
## PARAMETER SELECTION CONTROLS

Spectrogram provides control panels for selection of display parameters and frequency analysis parameters. The control panels for the Scan Input, Scan File, and Analyze File modes of operation are shown below. See the sections on **Sample and Display Parameters** and **Frequency Analysis Parameters** that follow for a description of the individual controls within each panel.

## SCAN INPUT PARAMETER SELECTION

The Scan Input mode allows you to scan the input audio signal from your sound card and display its spectrum in real time using either a scrolling spectrogram display or a spectrum analyzer scope display. Choose "Function - Scan Input" from the program menu (or Function Key F1) to bring up the Scan Input dialog box for selection of scanning parameters.

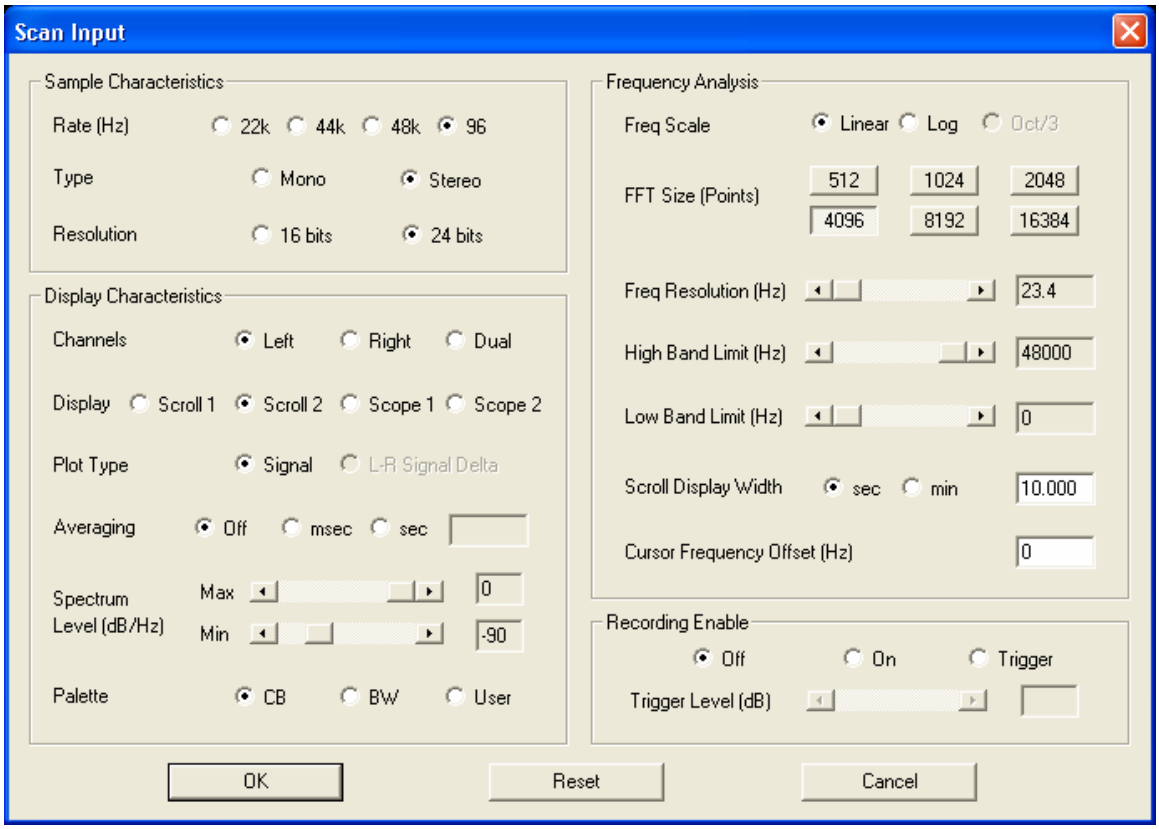
There are two possible configurations of the Scan Input dialog box depending on the **Display and Control Preferences** that you have selected.




## SCAN INPUT - AUTOMATIC CONTROLS

The Scan Input Automatic Controls as shown above are recommended in nearly all situations because of their simplicity. Digital sampling rate and time and frequency resolution are automatically calculated for you, so it is much easier to obtain the right combination of parameters needed for a revealing Spectrogram display. See the sections on **Sample and Display Parameters** and **Frequency Analysis Parameters** that follow for a description of the individual controls available here.

## SCAN INPUT PARAMETER SELECTION (CONT'D)



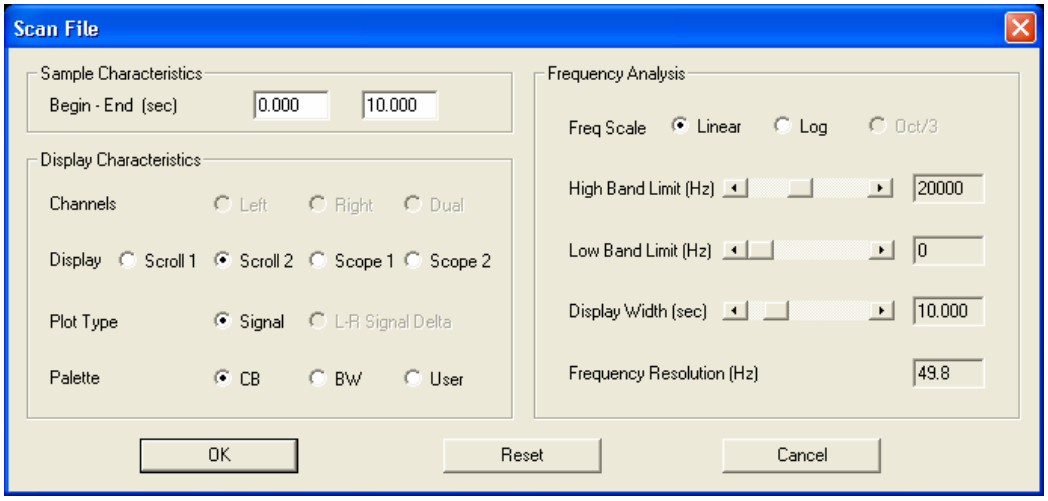

## SCAN INPUT - MANUAL CONTROLS

The Scan Input Manual Controls are provided for those who require complete control over display frequency resolution and time resolution. They allow designation of digital sampling rate, spectrum analysis FFT size, display frequency resolution, and display time scale. These controls give the most flexibility in setting up the spectrogram display, but also require an engineering knowledge of the parameters of digital spectrum analysis. See the sections on **Sample and Display Parameters** and **Frequency Analysis Parameters** that follow for a description of the individual controls available here.

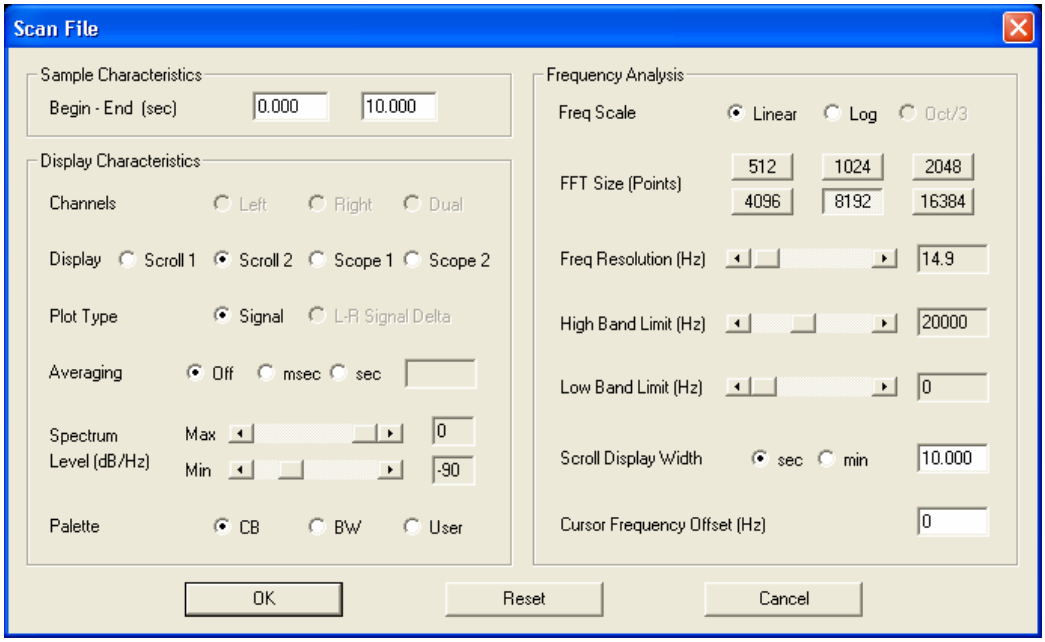
## SCAN FILE PARAMETER SELECTION

The Scan File mode allows you to scan a prerecorded wave file of any length and display its spectrum using either a scrolling spectrogram display or a spectrum analyzer scope display. Choose "Function - Scan File" from the program menu (or Function Key F2) to select a file for scanning. Once a file has been selected, you will be presented with the Scan File dialog box for selection of scanning parameters.

There are two possible configurations of the Scan File dialog box depending on the **Display and Control Preferences** that you have selected.




**SCAN FILE - AUTOMATIC CONTROLS**




**SCAN FILE - MANUAL CONTROLS**

## SCAN FILE PARAMETER SELECTION (CONT'D)

The Scan File Automatic Controls as shown above are recommended in nearly all situations because of their simplicity. Digital sampling rate and time and frequency resolution are automatically calculated for you, so it is much easier to obtain the right combination of parameters needed for a revealing Spectrogram display.

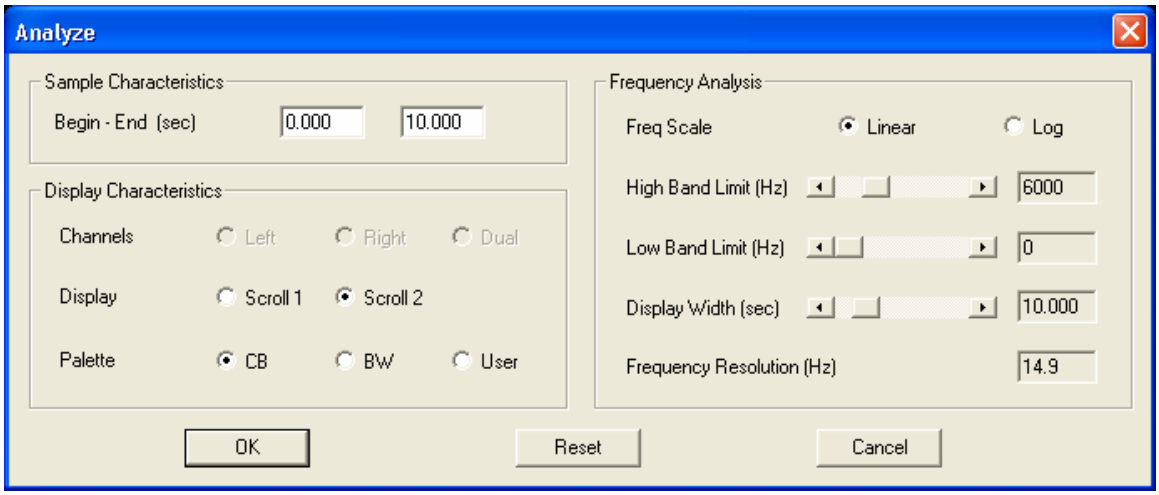
The Scan File Manual Controls are provided for those who require complete control over display frequency resolution and time resolution. They allow designation of spectrum analysis FFT size, display frequency resolution, and display time scale. These controls give the most flexibility in setting up the spectrogram display, but also require an engineering knowledge of the parameters of digital spectrum analysis.

See the sections on **Sample and Display Parameters** and **Frequency Analysis Parameters** that follow for a description of the individual controls available here.

## ANALYZE FILE PARAMETER SELECTION

The Analyze File mode allows you to compute and display a spectrogram from a recorded digital audio sample or wave file. Choose "Function - Analyze File" from the program menu (or Function Key F3) to load a digital audio sample file. Once a file has been selected, you will be presented with the Analyze File dialog box for selection of frequency analysis parameters. To select the default values, just press the OK button. You can also make changes in any of the parameters to customize the analysis.

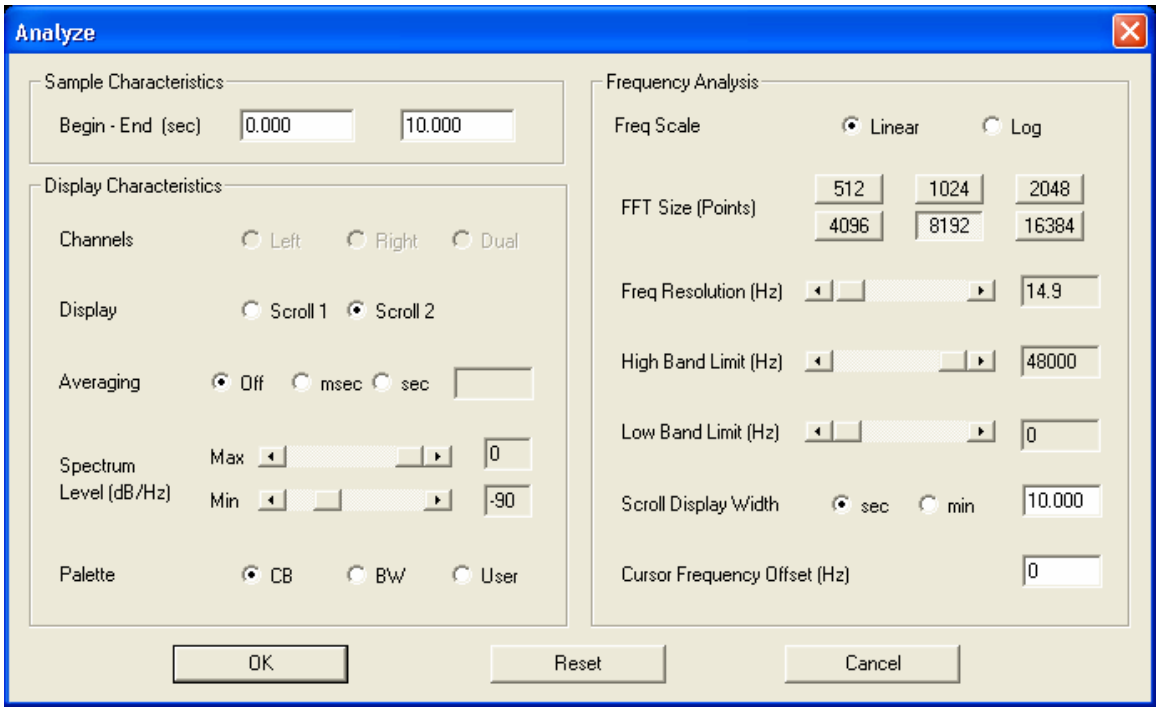
There are three possible configurations of the Analyze File dialog box depending on the **Display and Control Preferences** that you have selected.



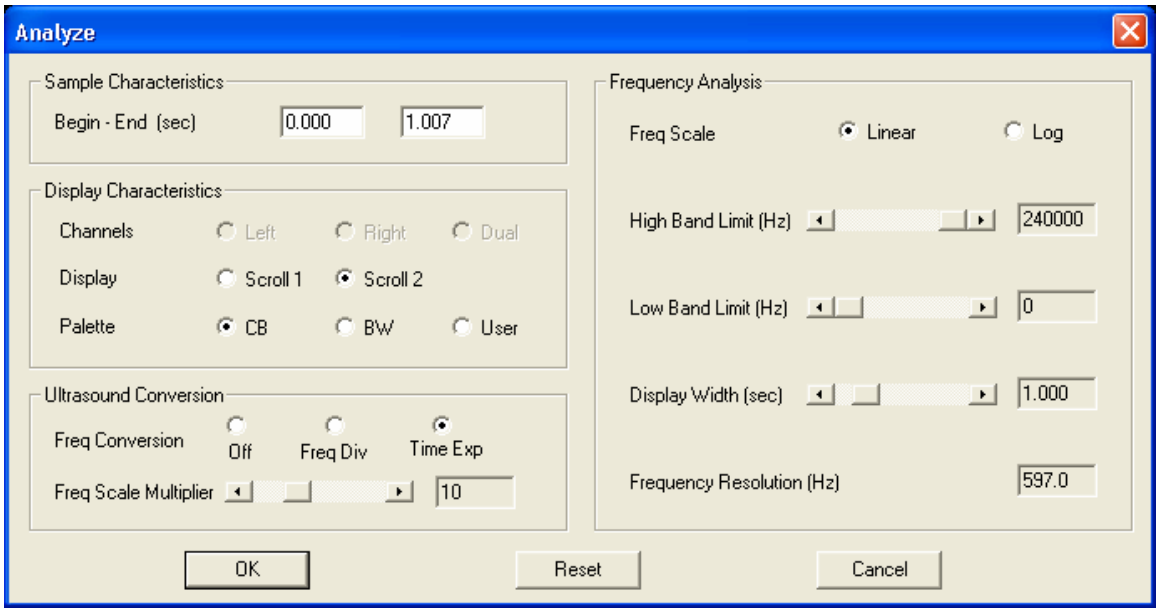

## ANALYZE FILES - AUTOMATIC CONTROLS

The Analyze File Automatic Controls as shown above are recommended in nearly all situations because of their simplicity. Digital sampling rate and time and frequency resolution are automatically calculated for you, so it is much easier to obtain the right combination of parameters needed for a revealing Spectrogram display. See the sections on **Sample and Display Parameters** and **Frequency Analysis Parameters** that follow for a description of the individual controls available here.

## ANALYZE FILE PARAMETER SELECTION (CONT'D)




## ANALYZE FILES - MANUAL CONTROLS




## ANALYZE FILES - ULTRASOUND CONTROLS

## ANALYZE FILE PARAMETER SELECTION (CONT'D)

The Analyze File Manual Controls are provided for those who require complete control over display frequency resolution and time resolution. They allow designation of digital sampling rate, spectrum analysis FFT size, display frequency resolution, and display time scale. These controls give the most flexibility in setting up the spectrogram display, but also require an engineering knowledge of the parameters of digital spectrum analysis. See the sections on **Sample and Display Parameters** and **Frequency Analysis Parameters** that follow for a description of the individual controls available here.

The Analyze File Ultrasound Controls are provided for analysis of recorded files produced by Ultrasound Detectors. Ultrasound detectors are used to capture high-frequency vocalizations of bats and communication signals by insects, rodents or other animals. Ultrasound detectors shift these high frequency sounds down into the audible frequency range and save them as Windows wave file recordings. See the section on **Ultrasound Conversion Parameters** that follow for a description of the individual controls available here.

## SAMPLE AND DISPLAY PARAMETERS

Below are descriptions of the individual controls found on the Scan Input, Scan File, and Analyze File control panels.

- **Sample Rate Control Buttons -** The Scan Input Controls give you the option of selecting a digital sampling rate. Select a value that is at least twice the frequency of the highest frequency components expected in the audio signal. Note that a sampling rate of less than 48 kHz should not be used if you wish to use the program for calibrated sound pressure level (SPL) measurement.

- **Begin/End Edit Box -** The Scan File and Analyze File Controls provide edit boxes for entry of the beginning and ending time (in seconds) of the sample to be analyzed. Initially, the starting and ending locations of the entire file will be displayed. If you make no change here, the entire file will be analyzed.

- **Stereo or Monaural Audio Selection Buttons** - These buttons give you a choice of analyzing audio data as single channel (Monaural) or dual channel (Stereo).

- **Sample Resolution Selection Buttons** - Select 16 bit or 24 bit sample resolution using these buttons.

- **Channels Selection Buttons** - Select left, right, or dual channel operation using these buttons.

- **Display Selection Buttons** - For Scan File and Analyze File, you can choose to display audio data in real time using either a scrolling spectrogram display, or a spectrum analyzer scope display. The spectrogram display consists of a scrolling full-screen frequency vs. time display for either single or dual channels. The scope display consists of real-time amplitude vs. frequency display in typical scope format for either single or dual channels.

  Choosing “Scroll 1” or “Scroll 2” will produce the scrolling spectrogram display. Choosing “Scope 1” will produce a spectrum analyzer scope display in which the spectrum level is represented as a continuous line. Choosing “Scope 2” will produce a spectrum analyzer scope display in which the spectrum level is represented at each frequency by a vertical bar.

- **Plot Type Selection Buttons** - The Plot Type Selection buttons allow selection of two possible types of signal plot when either the Scope 1 or Scope 2 displays have been selected.

  The Signal plot shows the spectrum level of left, right, or dual audio channels. The peak signal can also be displayed by clicking the “PEAK HOLD” button at the bottom right of the Spectrogram display window. The Peak Hold plot is only available for a single channel display (display of mono sampling, or display of either left or right channel from stereo sampling).

  The L-R Signal Delta plot shows the spectrum level difference between the left channel and the right channel. This display allows precise balancing of the left and right channels across the entire spectrum. The L-R Signal Delta plot is only available using stereo sampling.

- **Averaging Edit Box -** Here you can select a time span in milliseconds or seconds over which the spectrum data will be averaged before being displayed. This time averaging is useful to reduce the jumpiness of the scope display or to detect weak signals using the spectrogram display.

  For the scope display, choose an averaging value of about 200 msec to smooth the Scope 1 or Scope 2 displays. For normal operation of the scrolling display, choose 0 msec (or Averaging Off) to give the most dynamic representation of the audio spectrum. For the special case of weak signal detection, you can choose an averaging time of many seconds to reveal very weak long duration signals in the noise.

- **Spectrum Level Slider Controls** - The Scan Input, Scan File, and Analyze File Manual Controls provide horizontal sliders that allow you to set the upper and lower limits of the color scale used with the scrolling spectrogram display. This is useful, for example, if the signal is very weak or very noisy. For a very weak signal, the upper limit of the color scale can be reduced, resulting in stronger colors on the display. If the signal is very noisy, the lower limit of the color scale can be increased, resulting in less clutter on the display.

  It is also possible to adjust these color scale limits while the display is scrolling. Choose "Function - Spectrum Color Scale" from the Spectrogram menu (or Function Key F7) to bring up the Spectrum Color dialog box that contains an identical set of amplitude slider controls. These controls allow experimentation with the color scale limits while viewing the active signal on the scrolling spectrogram display.

  The Spectrum Level Slider Controls also affect the upper and lower amplitude limits of the spectrum analyzer scope display. The amplitude limits can be adjusted to the values that give an optimum plot of signal level versus frequency.

- **Palette Selection Buttons** - The palette Selection buttons allow you to select one of three color palettes. The "CB" button selects color on black background. The "BW" button selects black on a white background. The "User" button selects a user-defined color palette that has been previously specified using the Color Palette Controls. See **Spectrum Color Scale** for more information on modification of the display colors.

## FREQUENCY ANALYSIS PARAMETERS

- **Freq Scale Selection Buttons** - Here you have a choice of either a linear or logarithmic scale for computing a spectrogram. A linear scale spaces frequency components equally across the entire spectrum, while a logarithmic scale expands the low frequency region of the spectrogram and compresses the high frequency region. Experiment with these scales to choose the one best suited to your analysis.

  If you have selected a spectrum analyzer scope display type, you will also be able to choose a 1/3 Octave display in which the spectrum level in adjacent frequency bands of one third octave width is displayed in real time. The 1/3 octave display is useful in measurement and calibration of broadband acoustics sources.

- **FFT Size Selection Buttons** - The Scan Input and Scan File Manual Controls allow selection of the Fast Fourier Transform (FFT) size to be used in spectrum analysis. The Automatic Controls make this selection automatically based on the requested frequency band limits.

- **Frequency Resolution Slider Control** - This slider control adjusts the value of the frequency resolution on the display. In the automatic modes of operation, frequency resolution will be initially assigned based upon the chosen Low Band Limit, High Band Limit, and Scroll Display Width. You can manually override the automatically assigned frequency resolution if necessary. However, it will not be possible in practice to simultaneously achieve both high frequency resolution and high time resolution.

- **Low Band Limit and High Band Limit Slider Controls** - These slider controls allow selection of the low frequency and high frequency limits of the display. Required frequency resolution on the display is determined by these limits. For smaller frequency resolution on the display, choose a narrower frequency band for analysis.

- **Scroll Display Width Edit Box** - Here you can select the width of the scrolling spectrogram display in seconds or minutes. To obtain greater time resolution in the spectrogram, choose a smaller value for the display width. Select a large value for the scroll display width if you need to slow down the scrolling rate for any reason (extremely slow CW Selection reception, for example).

  Selection of time resolution cannot be made independently of frequency resolution. See the discussion of the **Time-Frequency Uncertainty Principle**. In the automatic modes of operation, the frequency resolution will be automatically updated to an optimum value each time you make a change in the display width. You can override the automatic frequency resolution selection, but it will not be possible in practice to simultaneously achieve both high frequency resolution and high time resolution.

## FREQUENCY ANALYSIS PARAMETERS (CONT'D)

- **Cursor Frequency Offset -** Cursor offset is useful when scanning or analyzing signals that have been frequency translated. For example, the audio output signals from an SSB Selection receiver can be read as true Selection frequency by placing the cursor on the displayed signal.

  Cursor offset should be set equal to the zero beat frequency of the Selection i.e. the difference between RF frequency and audio frequency. Both positive and negative offsets are allowed. Positive offset should be used with USB (Upper SideBand) and negative offset with LSB (Lower SideBand) Selection settings. However, a negative offset value does not work as one might first expect because the audio from an LSB receiver is spectrally reversed with respect to the antenna signal.

  Positive offset results in: Readout frequency = Cursor Offset + Frequency at cursor
  Negative offset results in: Readout frequency = Cursor Offset - Frequency at cursor

  Please note that the spectral display itself will not be altered in any way by the cursor offset setting. Only the cursor frequency readout at the lower left of the display window is affected. The grid marks, if used, always represent physical audio frequency, regardless of the cursor offset setting. For analysis of natural sounds that have not been frequency translated, Cursor Offset should remain at zero.

- **Recording Enable** provided with the Scan Input Controls allows you to turn recording on and off while you are scanning audio input. If you select Recording Enable "On," you will be prompted for a file name. Then while scanning you can click the "Save" and "Stop Save" buttons to turn recording on and off. Note that it may take a few seconds before recording can be started again after you have turned recording off. However each time you restart recording, the new data segment is added to the end of the wave file you have specified. This feature allows you to record interesting events without the need to record continuously for long periods.

  If you select Recording Enable "Trigger," then recording will be automatically start and continue when the input spectrum level is greater than a dB level set by the "Trigger Level" slider. Experiment with the trigger level to determine the best setting for your circumstances.

  Using the Recording Enable function allows you to record audio files of up to two hours length with the Spectrogram program.

  Please note that use of the Recording Enable feature requires that your hard drive be continuously powered. Some computers can operate in power saving mode in which the hard drive power is turned off if the drive is not accessed for a fixed amount of time (usually 10 to 20 minutes). If you attempt to Quick Save after the hard drive power has been turned off, the time delay required to turn the drive on and bring it up to operating speed will disrupt the timing of the Spectrogram program and introduce this delay into data display and recording. If you intend to record after an extended period of scanning, then you may need to disable your computer's power saving mode so that the hard drive will remain continuously powered.

## ULTRASOUND CONVERSION PARAMETERS

These controls are activated from the Preferences Menu. Choose "Preferences - Analysis Controls - Ultrasound Controls." These controls are then available only in the Analyze File mode of operation. Choose "Function - Analyze File" from the program menu (or Function Key F3) to enter the Analyze File mode.

**Ultrasound Freq Conversion and Freq Scale Multiplier** - These controls are used when analyzing files recorded with Ultrasound Detectors. Set Ultrasound Freq Conversion to "Off" for standard Windows wave files such as recordings made with an ordinary microphone and sound card, or recordings of music.

Ultrasound detectors are used to capture high-frequency vocalizations of bats, and communication signals by insects, rodents or other animals. Ultrasound detectors shift these high frequency sounds down into the audible frequency range and save them as Windows wave file recordings.

There are three types of ultrasound detector. The "heterodyne" and "frequency division" detectors shift the high frequency sound down into the audible range without any change in the time scale of the recording . Recordings from these detectors can be analyzed using the "Freq Div" setting.

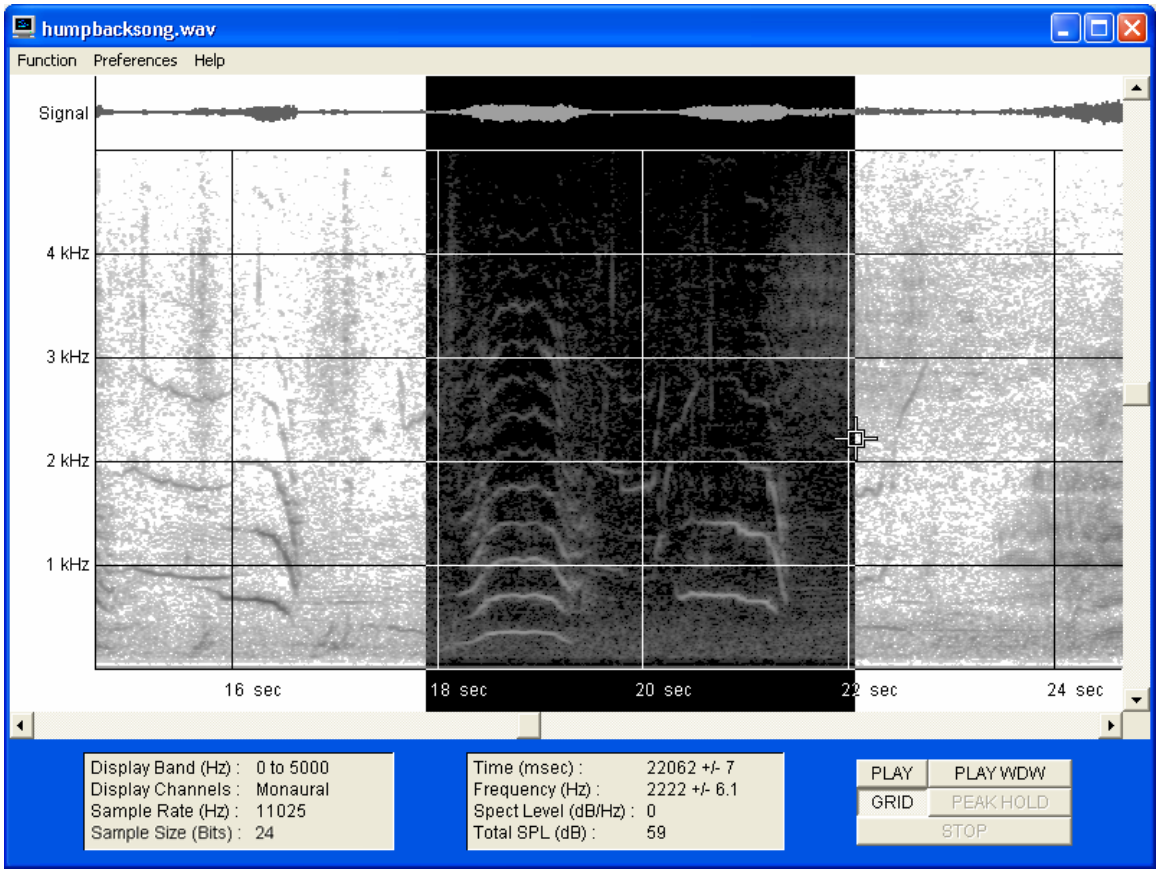
The "time expansion" detector records the sound at a very high sampling rate that is then reduced for playback. Thus the time expansion detector produces recordings that are shifted down in frequency and stretched in time. Recordings from a time expansion detector can be analyzed using the "Time Exp" setting.

The "Freq Scale Multiplier" slider is used to set the frequency scale of the Spectrogram. This multiplication factor corresponds to the reduction in frequency of the ultrasound recording and can range from 1 to 64 for frequency division detectors and from 1 to 32 for time expansion detectors. This factor is applied to the display frequency and time scales so that exact measurements of frequency and time can be made directly from the display.

## MODIFYING SPECTROGRAMS

Once you have computed a spectrogram, you may want to make changes to its length, vertical or horizontal scale, threshold or color to improve the frequency analysis. Choose "Function - Change Parameters" from the program menu (or Function Key F5) to bring up the Modify Analysis Parameters dialog box. The parameters that can be changed here are those that were used to define the original spectrogram. Enter the desired changes and click “OK” to redraw the spectrogram. You can return to the original unmodified spectrogram by choosing “Function - Restore Parameters” from the program menu (or Function Key F6). The program provides six levels of undo for Restore Parameters.

Frequently you will want to select a portion of the spectrogram for modification rather than the entire length. You can drag select this section from the spectrogram display. Position the mouse pointer at the desired starting point, press the left mouse button and drag the mouse to the desired ending point and then release the mouse button. The spectrogram will then be automatically redrawn, filling the display window with the segment you have selected.



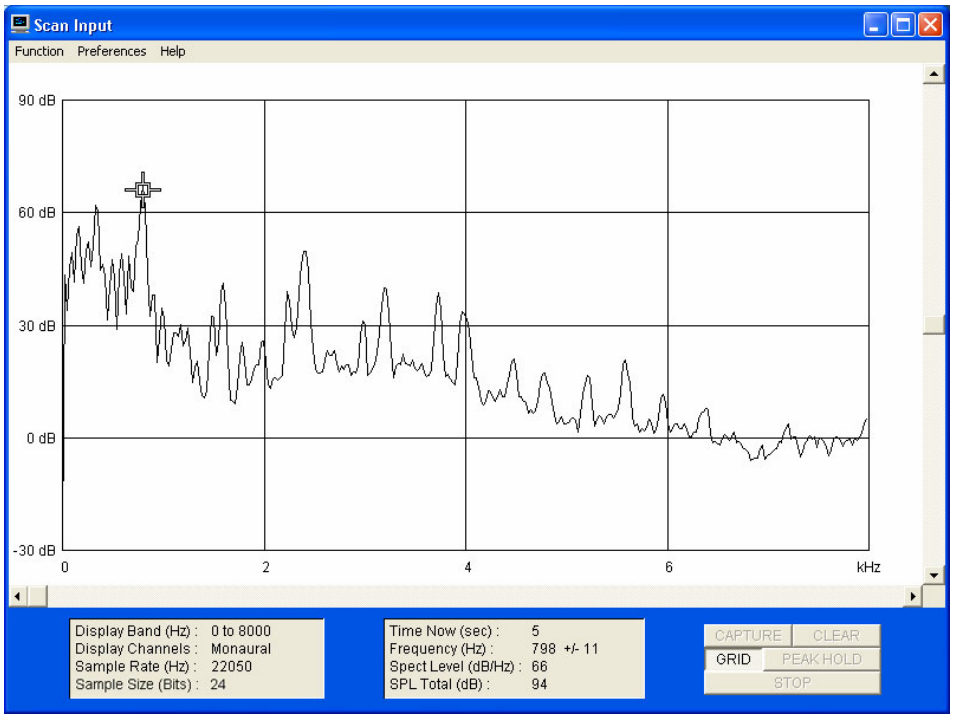

You can return to your starting spectrogram prior to any modification by choosing "Function - Restore Parameters” from the program menu (or Function Key F6). The program provides six levels of undo for Restore Parameters.

The modified spectrogram can be saved as a wave file recording by choosing “Function - Save Wave” from the program menu.

## SINGLE SPECTRUM PLOT

Spectrogram provides the ability to plot the spectrum at a single point in time selected from the scrolling spectrogram display. After creating a spectrogram, select a point in time by moving the display cursor to a feature of interest. A single left-button mouse click at this point will produce an instantaneous spectrum plot using the Scope Display. This plot can then be saved as an image or sent directly to your printer.

You can return to the original spectrogram plot by choosing "Function - Restore Parameters" from the program menu (or Function Key F6).



## SAVING AUDIO OR IMAGE FILES AND PRINTING

### SAVING AUDIO FILES

Spectrogram can save audio data files in Windows wave format. To save an audio file of less than 60 seconds length, select “Function - Save Wave” from the program menu after creating a Spectrogram. To record a wave file of longer than 60 seconds, use the procedure described under **Frequency Analysis Parameters - Recording Enable**.

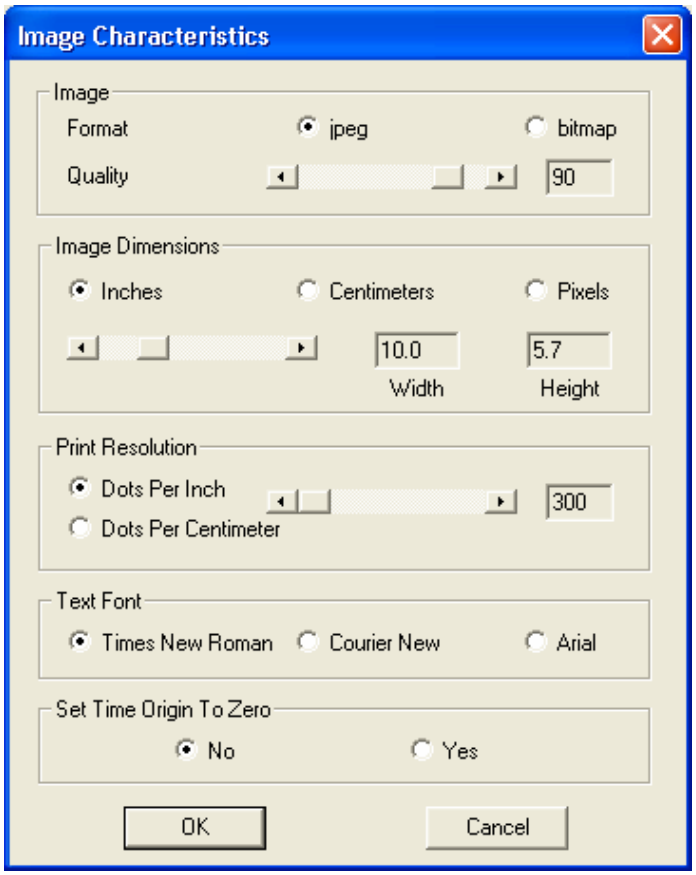
You can select a small area from a larger wave file to be saved by using the selection procedure described under **Modifying Spectrograms**.

### SAVING IMAGE FILES

Spectrogram gives you the ability to save professional quality spectrum images with a choice of image size (inches or pixels), image density (dots per inch), and proportionally sized text fonts.

Choose "Function - Save Screen Image" from the program menu. Then choose to save either the visible section of the display by choosing "Window Image," or the entire display including area outside the display window by choosing "Entire Image."

The Image Characteristics dialog box shown below will give you a choice of image parameters.



- The "Format" buttons allow saving either a Windows bitmap file, or a jpeg image file of the spectrogram or spectrum plot.

- You also must select an image quality for jpeg files. The higher the selected image quality, the lower the amount of image file compression and the larger the image file size.

- Image Dimensions are selectable in inches, centimeters, or pixels up to a maximum width of 12000 pixels.

- Print resolution is selectable in dots per inch or dots per centimeter with a range from 300 DPI to 1200 DPI. Print resolution can only be defined when the jpeg image format has been selected since Windows bitmaps do not contain print resolution information.

- The text font to be used for the time and frequency axis labels can be selected to be Times New Roman, Courier New, or Arial. The font will be sized appropriately for the image dimensions that have been specified.

- The "Set Time Origin To Zero" selection allows you to either set the time origin of saved spectrogram image to zero, or to leave the time origin unchanged and identical to that appearing on the screen.

You will be requested to enter an appropriate file name once Image Characteristics are defined. Then Spectrogram will proceed to enlarge the displayed spectrogram or spectrum plot image to your specifications. Start with a maximized Spectrogram display window before saving very large images.

**PRINTING FROM SPECTROGRAM DISPLAY**

With a graphics capable printer attached to your computer, you can print the spectrogram display by choosing "Function - Print Window" from the program menu. You will be presented with the Print dialog box for selection of a printer and printer properties. Click "Properties" to change paper orientation or other print characteristics.

When printing a spectrogram, it may be best to choose the black on white color palette (BW) for the spectrogram. Otherwise the printer will use a very large amount of black ink filling in the black background on the printed image.

**PRINTING FROM THE SCOPE DISPLAY**

You can also print the scope display from the Scan File and Scan Input modes with a graphics capable printer. Stop the display at the desired point and then choose "Function - Print Window" from the program menu. When printing, it may be best to choose the black on white color palette (BW) for the scope display. Otherwise the printer will use a very large amount of black ink filling in the black background on the printed image.

## BATCH FILE PROCESSING

Spectrogram can be used to automatically analyze a large group of wave files, saving a bitmap or jpeg image of the spectrogram of each file in sequence.

First, collect all of the batch files into a single file directory on your hard drive. All files to be processed in a batch should have the same digital sampling rate and number of channels. Then, analyze one file of the batch to establish processing and display parameters (upper and lower frequency limits, time scale, color scale, etc.).

Then choose "Function - Analyze File Batch" from the program menu (or Function Key F4) to bring up a file dialog box for selecting the batch files. Select all files by clicking in the dialog box and typing "Control - A" or by dragging a box around the desired files using the mouse.

You will have a choice of image parameters as described under **Saving Audio and Image Files or Prints**. All images will be saved in a directory named "images" contained within the file directory of the batch files.

Batch file processing will only work with a single channel spectrogram display (monaural wave file or the individual left or right channel of a stereo wave file).

## DATA LOGGING

**SPECTRUM LOG** - Spectrogram provides an automatic data logging capability for researchers who wish to record frequency and the spectrum level of audio data. This capability is provided with any stopped single channel spectrogram display or single channel scope display.

- **Scrolling Spectrogram Display - Full Spectrum**

To save the frequency and spectrum level of every point in a single channel spectrogram, choose "Function - Log Spectrum" from the Spectrogram menu. Data are saved in a text file that records comma delimited spectrum level values versus frequency in sequential rows, where each row represents a time increment. The time of occurrence of each row is recorded in the first column of each row. The frequency value of the measurement in each column is recorded in the first row of the file. Commas delimit all values within a row. Rows are delimited by carriage return and line feed.

- **Scrolling Spectrogram Display - Single Spectrum**

To save the sound spectrum at a single point in time from a spectrogram, first create a Single Spectrum Plot by clicking the left mouse button once at the point of interest on the spectrogram. Then choose "Function - Log Spectrum." Data are saved in a text file that records spectrum level measurements versus frequency for one point in time.

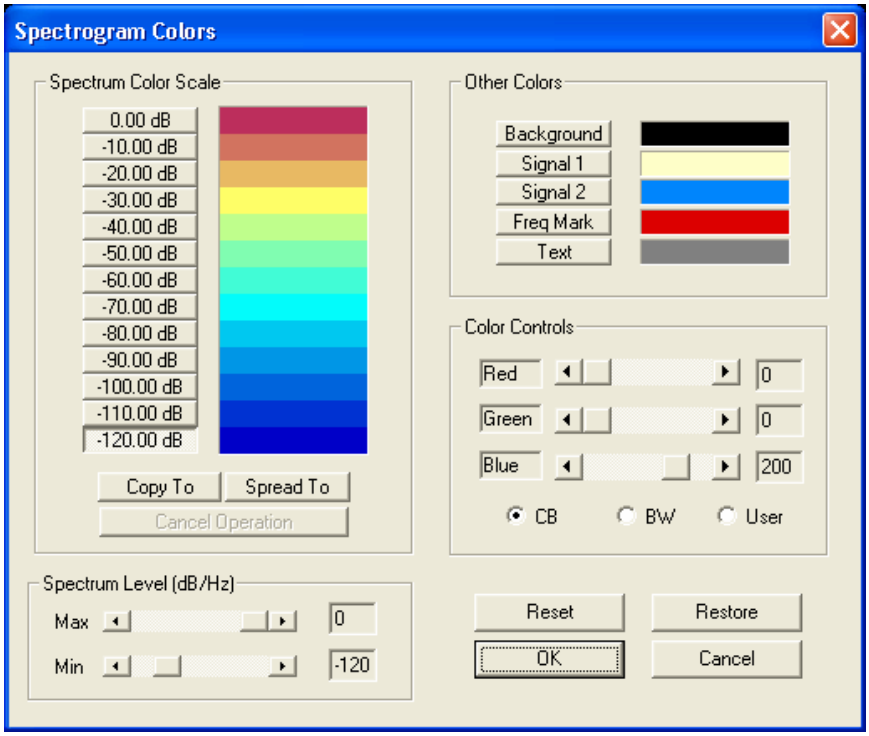
- **Spectrum Analyzer Scope Display**

Stop scanning, and choose "Function - Log Spectrum." Data are saved in a text file that records the time, frequency, and spectrum level at one point in time.

**POINT LOG -** Spectrogram also provides a point log function that saves the time, frequency, and spectrum level of points selected by the mouse from the Spectrogram display. After analyzing a file, choose "Function - Log Points" and select a file name for the point log file. Then select points with the mouse from the spectrogram display. Clicking each point using the left mouse button will save time, frequency, and spectrum level to an ASCII text file. **Caution -** When using the point log with either the Scroll 1 or Scroll 2 displays, turn the **coordinate grid off**. The program reads the spectrum level at each point from color on the display. The coordinate grid will interfere with this measurement.

## SPECTRUM COLOR SCALE

Spectrogram allows you to use either fixed or user-defined color palettes for both the scrolling spectrogram display and the scope display. Choose "Function - Spectrum Color Scale" from the Spectrogram menu (or Function Key F7) to bring up the Spectrogram Colors dialog box. This control allows selection of colors at each of 12 steps corresponding to increasing spectrum level. Intermediate colors are interpolated between each of the 12 selected color steps.




- Colors assigned to spectrum level on the scrolling spectrogram are defined by the "Spectrum Color Scale" buttons. Colors assigned to other display elements (background, markers, text) are defined by the "Other Colors" buttons. Select a color to be modified by pressing the button to its left. Then modify that color using the Red-Blue-Green sliders in the "Color Controls" section.

- The "CB" and "BW" buttons select fixed color-on-black and black-on-white color palettes, respectively. If you make any changes to these fixed palettes, the modified palette will be stored as your User Palette and can then be used for any spectrogram display. Selecting the "User" button will recall your modified palette.

## SPECTRUM COLOR SCALE (CONT'D)

- A color can be copied from one position to another by first selecting the starting color button, then selecting "Copy To," and then selecting the color button at the location where the copy is to be applied.

  A smooth transition, or color spread, between two colors can be created by first selecting the starting color button, then selecting "Spread To," and then selecting the color button at the end of the desired color transition.

  To cancel the copy color or spread color operation, click the "Cancel Operation" button.

- The "Spectrum Level" horizontal slider controls allow you to set the upper and lower decibel limits of the color scale used with the scrolling spectrogram display. This is useful, for example, if the signal is very weak or very noisy. For a very weak signal, the upper limit of the color scale can be reduced, resulting in stronger colors on the display. If the signal is very noisy, the lower limit of the color scale can be increased, resulting in less clutter on the display. Experiment with the Spectrum Level sliders to obtain the best display for the signal of interest.

  The Spectrum Level sliders also affect the upper and lower amplitude limits of the spectrum analyzer scope display. The amplitude limits can be adjusted to the values that give an optimum plot of signal level versus frequency.

- The "Reset" button erases any changes that you have made to the color palette and the min/max dB settings and restores them to the settings that existed before the Spectrogram Colors dialog box was opened.

- The "Restore button returns the color palette and min/max dB settings to the default settings for the particular display format in use (Scroll or Scope).

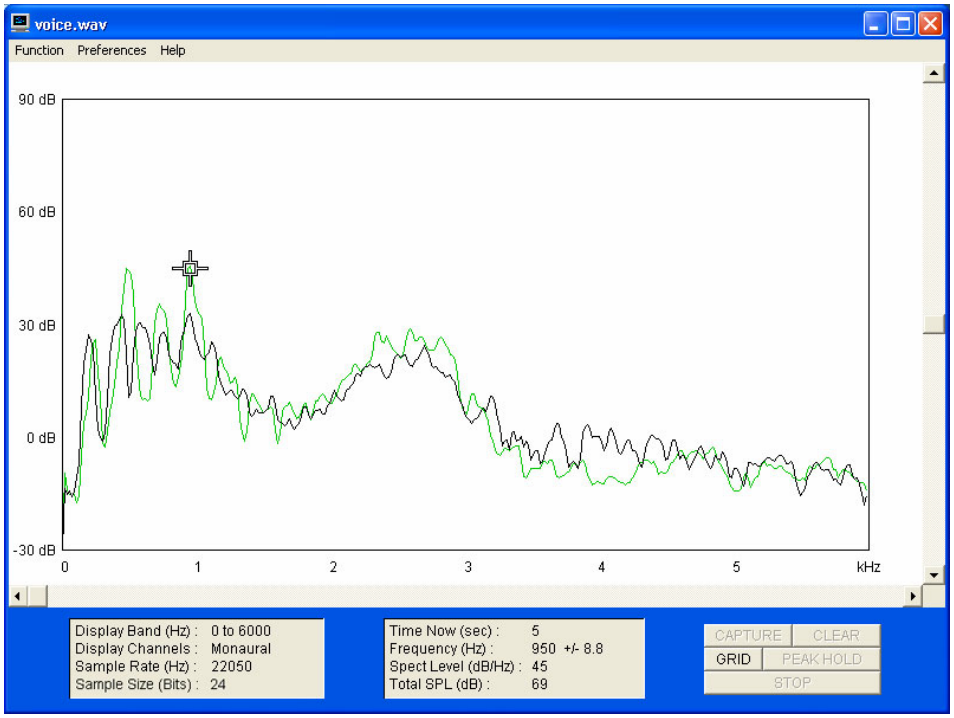
- The "Cancel" button erases any that you have made to the color palette and min/max dB settings, and closes the Spectrogram Colors dialog box.

- The "OK" button applies the palette selections and min/max dB settings that you have made to the display format in use (Scroll or Scope).

## LINEAR AND LOGARITHMIC FREQUENCY SCALES

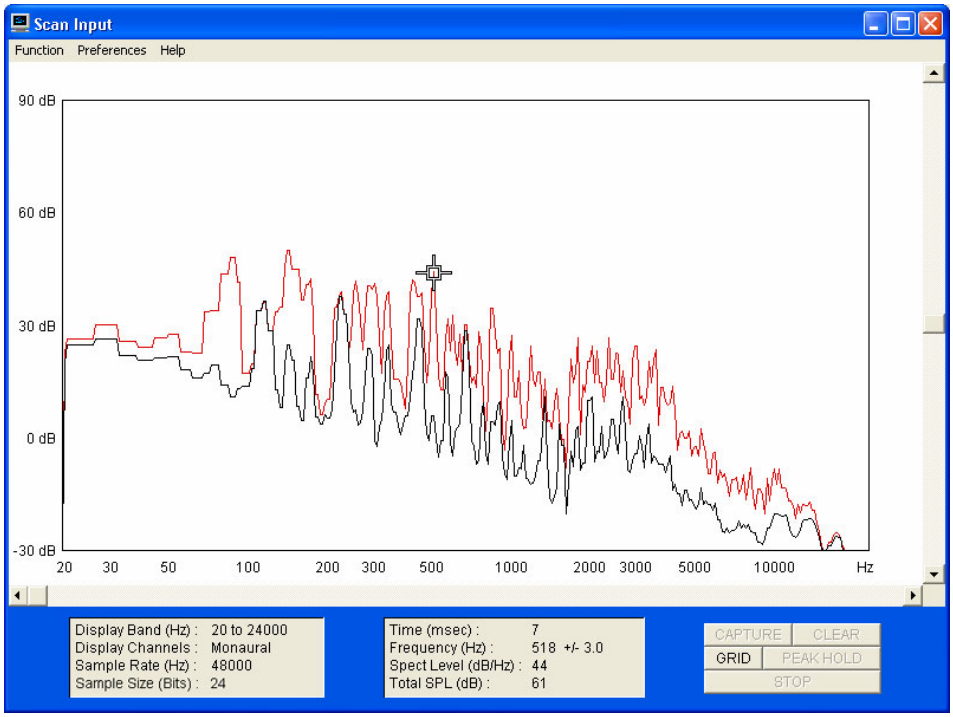
Both the scrolling spectrogram display and the scope display have the option of displaying data with either a linear or a logarithmic frequency scale. The linear scale divides the frequency axis into equal intervals of frequency, where the logarithmic scale divides the frequency axis into equal intervals of the logarithm of frequency. The log frequency scale gives more prominence to low frequencies by expanding the display space for low frequencies at the expense of high frequencies. The 1/3 octave scope display is a special case of a log frequency scale display in which the spectrum level in adjacent frequency bands of one-third octave width is plotted.

The linear scale is less of a computational load since its frequency resolution is constant over the entire frequency band. However, the log scale requires very fine frequency resolution at low frequencies. Because of the additional computational load, scanning of wave files or audio input may run more slowly when using a log frequency scale.




**LINEAR FREQUENCY SCALE**

## LINEAR AND LOGARITHMIC FREQUENCY SCALES (CONT'D)




**LOGARITHMIC FREQUENCY SCALE**

## SOUND PRESSURE LEVEL AND CALIBRATION

**SPL calibration is not necessary** if you are only interested in creating spectrogram images showing the relative strengths of harmonic elements of the spectrum. The relative differences between harmonic elements on the display will be correct without calibration. However, the following calibration procedure is required if you wish to make absolute decibel measurements of SPL and Spectrum Level.

**Definition of SPL -** Total Sound Pressure Level (SPL) of an audio signal is defined as the ratio between actual sound pressure and a fixed reference pressure measured in decibels. The reference pressure is usually the threshold of hearing, which has been internationally defined as 20 micropascals (or 0.0002 dyne /cm$^2$). SPL in decibels is then defined as

$$\mathbf{SPL = 20 \log (\rho/\rho_{ref})}$$

where $\rho$ is the actual sound pressure and $\rho_{ref}$ is the reference sound pressure.

The Spectrogram program decomposes SPL into its frequency components. Each frequency component has an amplitude, or Spectrum Level, defined in units of decibels (dB) in a one Hz band. All Spectrogram displays use Spectrum Level as the decibel measure of amplitude across the audio frequency band. Total SPL is, in effect, the area under the curve of Spectrum Level versus frequency.

**Calibration Sampling Rate** - SPL calibration is applied across the entire audio frequency band, which requires that a digital sampling rate of 48 k Hz be used. Spectrogram may be operated a lower sampling rates, however calibration will only be approximate when the digital sampling rate is less than 48 kHz. A digital sampling rate of 48 kHz is automatically selected if you use the Automatic Controls described in **Scan Input - Parameter Selection.**

**Calibration Procedures -** Because the electrical characteristics of every microphone, preamplifier, and sound card are different, a calibration procedure is required to establish the absolute accuracy of Sound Pressure Level and Spectrum Level measurements.

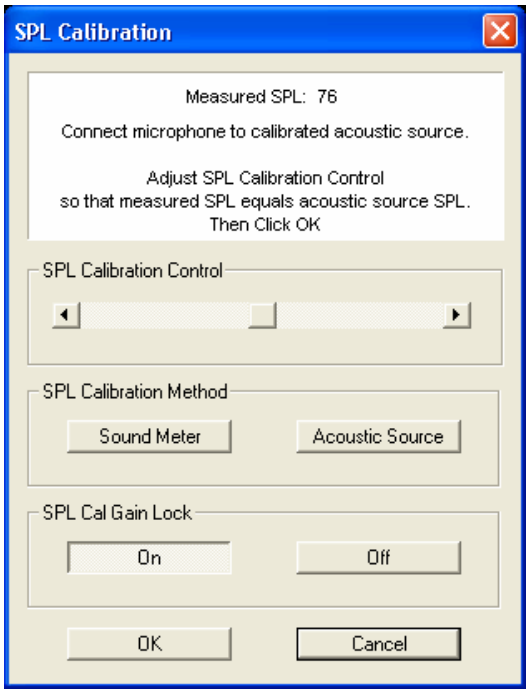
First, you must adjust the external sound source so that the loudest expected sounds do not cause signal clipping. Run Spectrogram in the Scan Input mode, Scroll 2 display. Move the vertical slider control at the right side of the Spectrogram display so that the loudest expected sound fills about ¾ of the height of the signal amplitude strip at the top of the display.

The calibration concept is then to simultaneously measure the total SPL of a test signal using the Spectrogram program and a calibrated hand-held sound level meter. The Spectrogram SPL reading is adjusted to match the reading from the sound level meter. Thereafter, SPL readings by the Spectrogram program will be accurate to within the measurement tolerance of the sound level meter.

An alternative calibration method is provided for use with a precision laboratory microphone and matching calibrated acoustic source. In this method, the microphone is inserted into the calibrated acoustic source, and the Spectrogram SPL reading is adjusted to match the known SPL of the acoustic source. Thereafter, SPL readings by the Spectrogram program will be accurate to within the SPL tolerance of the calibrated acoustic source.

## SOUND PRESSURE LEVEL AND CALIBRATION (CONT'D)

Choose "Function - Total SPL Calibration - Calibrate" from the program menu to begin the calibration process. This will bring up the Calibration Control as shown below.




Select "Sound Meter" as the SPL Calibration Method. The computer will then generate a tone at 1000 Hz that will be played through the computer's speakers. Note that this technique requires that your sound card be capable of full duplex operation (meaning that it is able to record and play sounds simultaneously), and that your computer be equipped with external speakers capable of producing a reasonably loud sound. Adjust the speaker volume control to the point that the hand-held sound meter reads 65 dB or greater SPL using either the A or C band setting. Then hold your microphone and the sound level meter together in front of the computer speakers, and move the SPL Calibration Control to match the Measured SPL reading by Spectrogram with the reading from the sound level meter. Click the OK button when the two readings are stable and equal.

To use the alternative calibration method, select "Acoustic Source" as the SPL calibration method. Then insert the precision microphone into the calibrated acoustic source, and move the SPL Calibration Control until the Measured SPL reading by Spectrogram equals the known dB SPL of the acoustic source.

Once calibration is complete, the Spectrogram volume control (vertical slider at right side of display) should not be moved. SPL calibration should be repeated if it becomes necessary to move the Spectrogram volume control. To lock the Spectrogram volume control to prevent inadvertent changes, click the SPL Cal Gain Lock "On" button.

**Please Note:** The SPL Cal Gain Lock only prevents inadvertent changes to the Spectrogram internal volume control and does not lock the external Windows volume control settings or preamplifier gain (if you use a preamplifier). Once calibration is completed, care should be taken not to change either the external Windows volume control settings or preamplifier gain settings.

The SPL Cal Gain Lock can also be turned on and off from the Spectrogram display window by choosing "Preferences - SPL Cal Gain Lock - On or Off" from the program menu. Turning the SPL Cal Gain Lock back on at any time will return Spectrogram to its most recent calibrated settings. This allows you to return the program to its calibrated state at any future time without repeating the entire SPL calibration process.

The SPL calibration settings will be saved within the Spectrogram initialization file (gram15.ini) and applied again each time you restart the Spectrogram program. If you have not changed the external Windows volume control settings or preamplifier gain (if you use a preamplifier), then it is not necessary to repeat calibration upon restarting the Spectrogram program.

You can completely remove SPL calibration at any time by choosing "Function - Freq Response Calibration - Clear" from the main program menu. Once cleared, the entire calibration procedure described above must be run again if SPL calibration becomes necessary.

**Please Note:** In general, Spectrogram will measure a higher SPL than will be measured using a sound level meter and either the A or C band. Spectrogram measures the SPL in the entire frequency band; whereas, a sound level meter excludes both high and low frequencies. Even the sound level meter C "wide" band attenuates frequencies below 100 Hz and above 5000 Hz. The sound level meter can be used to calibrate Spectrogram only because the signal used for calibration is a 1000 Hz tone and includes no other high or low frequencies. In this special case, Spectrogram and the sound level meter will measure the same value. However, for most real-world sound measurements, Spectrogram will measure the complete SPL and show a higher value than a sound level meter which attenuates low and high frequencies.

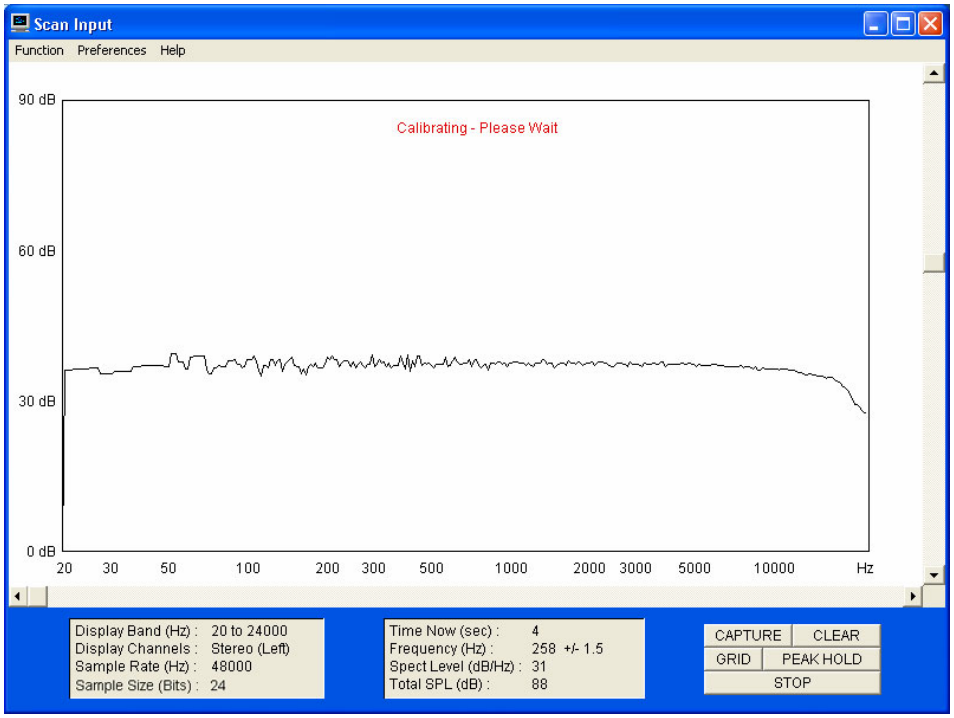
## FREQUENCY RESPONSE CALIBRATION

Spectrogram provides the capability for automatic frequency response calibration using broadband noise. The concept is to measure the spectrum level of a white broadband noise source connected to the line or microphone inputs of the sound card and to use this curve as a correction to the frequency response of the sound card electronics. When this correction is applied, the plot of spectrum level versus frequency of broadband noise will be "flat" as seen on the display. This calibration procedure will eliminate any frequency response roll off associated with the sound card electronics.

**Frequency response calibration is not necessary** for most uses of Spectrogram. The frequency response of most consumer grade sound cards and microphones is fairly uniform across the audio frequency band of interest. However, when using Spectrogram in a laboratory or research environment, calibration is recommended to ensure a uniform frequency response through the sound card and microphone from 20 Hz to 24000 Hz.

**Calibration Sampling Rate** - Calibration is applied across the audio frequency band from 0 to 24 kHz, which requires that a digital sampling rate of 48 k Hz be used. Spectrogram may be operated a lower sampling rates, however calibration will only be approximate when the digital sampling rate is less than 48 kHz. A digital sampling rate of 48 kHz is automatically selected if you use the Automatic Controls described in **Scan Input - Parameter Selection.**

**Calibration Procedures -** To calibrate Spectrogram frequency response, connect a broadband white noise source to the appropriate input of the sound card. Choose "Function - Freq Response Calibration - Calibrate" from the program menu to begin the calibration process. The program will then take about 20 seconds to measure and store the spectrum of this noise and create a correction curve. This correction will be subsequently applied to all spectrum analysis. The correction curve will be stored as a part of the gram.ini file when you exit Spectrogram and will be reinstated each time you restart the program. You can eliminate frequency response calibration at any time by choosing "Function - Freq Response Calibration - Clear" from the main program menu



## FREQUENCY RESPONSE CALIBRATION (CONT'D)

**Sound Card Limitations -** For accurate spectrum level measurement, the microphone, preamplifier, and computer sound card must have a usable frequency response to 20 kHz. An initial frequency response that drops off to zero above 10 kHz may not be correctable with this procedure. Consider the use of an external high-quality preamplifier and digitizer to replace the internal sound card if necessary.

**Frequency Response Calibration of Recordings -** Any subsequent playback and spectrum analysis of a wave file originally recorded with the calibrated Spectrogram program will also be properly calibrated, provided that the same hardware configuration (microphone, preamplifier, and sound card) is used for both recording and playback, and that the Cal Gain Lock remains in effect.

## CALIBRATION STATUS

You can check the current status of Spectrogram sound pressure level calibration and frequency response calibration at any time by choosing "Function - Calibration Status" from the program menu. The status of calibration and the dates of the most recent calibration procedures will then be presented. This is a quick way to determine if calibration is currently in effect for spectrum analysis and display.

## RELATIVE VS. ABSOLUTE SPECTRUM LEVEL MEASURES

The spectrum level (dB) measures shown by Spectrogram can either be relative or absolute measurements. If **Sound Pressure Level Calibration** has not been conducted, all measures will be relative to a maximum spectrum level value of zero dB. The spectrum level scales on the Scope 1 and Scope 2 plots will show a maximum value of zero dB and a minimum value of -120 dB. The spectrum level color scales used on the Scroll 1 and Scroll 2 displays as well as the spectrum level readouts at the bottom of the display will all use this relative scale. This will allow frequency components of the spectrum to be compared with one another and will be the method most often used where it is not necessary to know the absolute values of spectrum level or sound pressure level referenced to international standards.

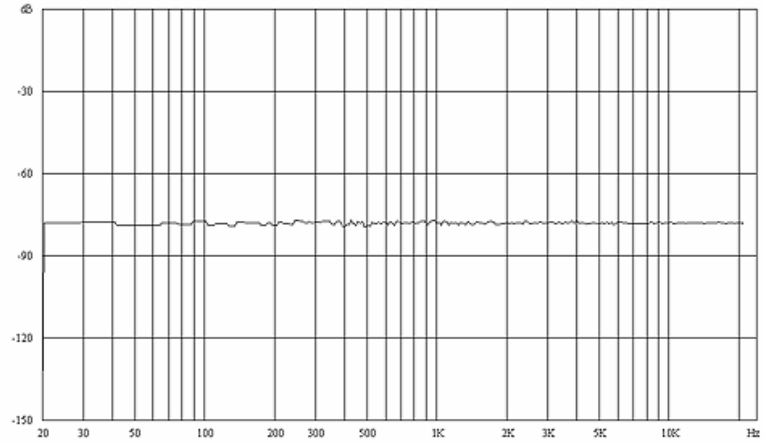
Once the **Sound Pressure Level Calibration** procedure has been conducted, all spectrum level measures will be referenced to a pressure of 20 micropascals (or 0.0002 dyne /$cm^2$) as defined by international standard. This will result in a spectrum level scale with a maximum value of 90 dB and a minimum value of -30 dB. This absolute scale will be used on all displays and all readouts. Additionally, the value of total sound pressure level, SPL (dB), at the position of the mouse cursor will also be shown in the readout area at the bottom of the Spectrogram display. **Sound Pressure Level Calibration** is required only where it is necessary to know the absolute values of spectrum level or sound pressure level referenced to international standards.

## USE OF WHITE AND PINK NOISE

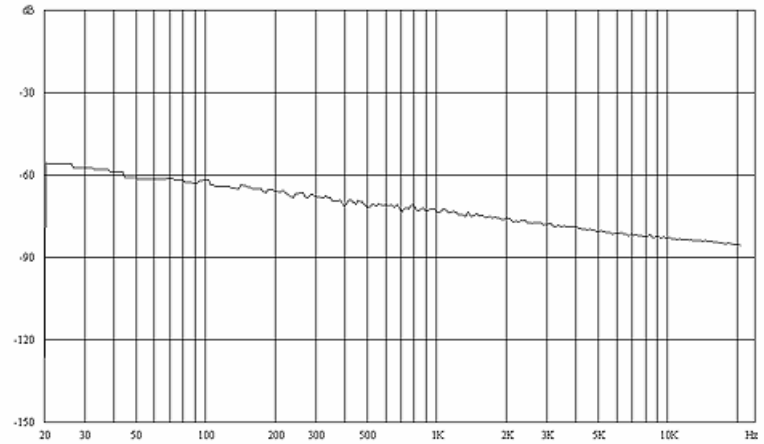
White and pink noise sources are often used in measurement of the acoustic characteristics of microphones, recording equipment, or of the recording studio itself. Ideal white or pink noise is introduced externally, and the resulting frequency response is analyzed to show deviation from ideal performance. It is important to understand how the Spectrogram program measures the audio spectrum in order to make use of white or pink noise sources for these purposes.

White noise is defined as having equal energy per Hz across the entire frequency band. Pink noise is defined as having equal energy per octave across the entire frequency band. Mathematically, pink noise decreases in energy per Hz by 3DB per octave. This decrease is perfectly matched by the increasing octave width with frequency, resulting in equal energy per octave.

Using the Linear or Log frequency scales in Spectrogram results in calculation of the decibel sound pressure level in a constant 1 Hz bandwidth across all frequencies. The resulting white and pink noise plots in this mode of operation are as shown below.

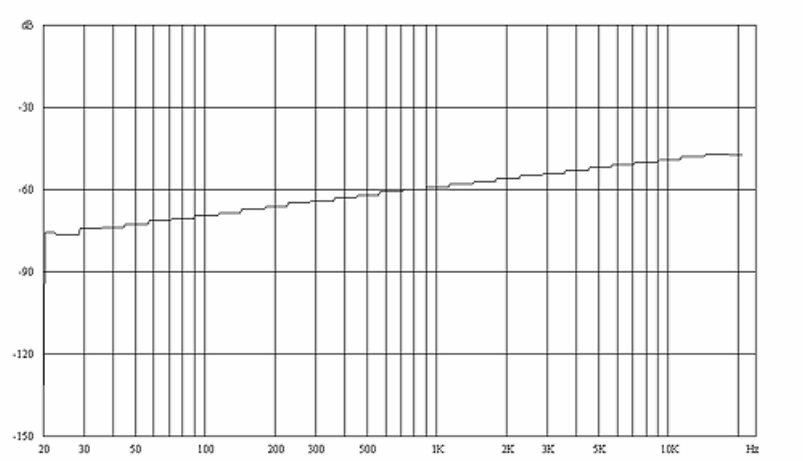



White Noise – Log Frequency Scale
Sound Pressure Level in a 1 Hz Band

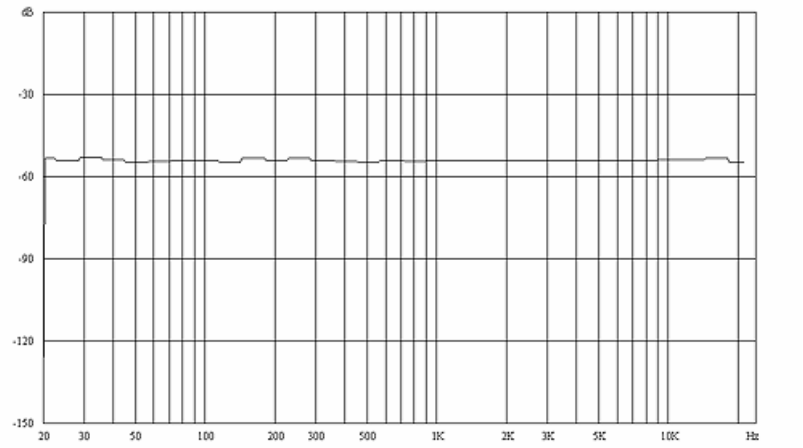



Pink Noise – Log Frequency Scale
Sound Pressure Level in a 1 Hz Band

Using the Oct/3 frequency scale results in calculation of the decibel sound pressure level in a constant 1/3 octave bandwidth across all frequencies. The resulting white and pink noise plots in this mode of operation are as shown below.




White Noise – 1/3 Oct Frequency Scale
Sound Pressure Level in 1/3 Octave Bands




Pink Noise – 1/3 Oct Frequency Scale
Sound Pressure Level in 1/3 Octave Bands

In summary, using the Linear and Log frequency scales in Spectrogram results in measurement of sound pressure level in a constant 1 Hz band. Using the Oct/3 frequency scale results in measurement of sound pressure level in a constant 1/3 Octave band. The white noise spectrum will be flat when using the Linear and Log frequency scales, and sloped when using the Oct/3 frequency scale. The pink noise spectrum will be sloped when using the Linear and Log frequency scales, and flat when using the Oct/3 frequency scale.

## MULTIMEDIA COMMANDS

Spectrogram provides a Command Line interface that can be used by other programs to start and control spectrum analysis of audio input or of recorded wave files. This interface can be used with the Windows Command Prompt or with any multimedia application that can issue commands via the Windows Command Line. The form of commands that will be accepted by Spectrogram is program path and file name followed by command line parameters separated by spaces

**Path Mode MinFreq MaxFreq TimeSpan FilePath**

The command line parameters are defined as follows:

Path: Full path and file name for the spectrogram program
(example c:\Program Files\Visualization Software\Spectrogram 15\gram15.exe)

Display Mode: 1 = Analyze File, Scroll 1 Type Display
2 = Analyze File, Scroll 2 Type Display
3 = Scan File, Scroll 1 Type Display
4 = Scan File, Scroll 2 Type Display
5 = Scan File, Scope Scope 1 Display
6 = Scan File, Scope Scope 2 Display
7 = Scan Input, Scroll 1 Type Display
8 = Scan Input, Scroll 2 Type Display
9 = Scan Input, Scope Scope 1 Display
10 = Scan Input, Scope Scope 2 Display

MinFreq: Minimum frequency in Hz (cycles per second)

MaxFreq: Maximum frequency in Hz (cycles per second)

TimeSpan: Time span of the scrolling display in seconds

FilePath: Full path and file name for the wave file to be analyzed (if required)

**Audio Scanning From the Command Prompt**

For example, to launch Spectrogram and show a scrolling spectrogram display of audio input from the sound card, the following command could be issued from the Windows Command Prompt

"c:\Program Files\Visualization Software\Spectrogram 15\gram15.exe" 7 0 10000 4

This command will start a scrolling display (Scroll 1 format) showing a frequency range from 0 to 10000 Hz with a display time span of 4 seconds.

**File Analysis From the Command Prompt**

To launch Spectrogram and conduct a file analysis, the following command could be issued from the Windows Command Prompt

"c:\Program Files\Visualization Software\Spectrogram 15\gram15.exe" 1 0 10000 4
"c:\wave\soundfile.wav"

This command will analyze the file named c:\wave\soundfile.wav, producing a spectrogram (Scroll 1 format) with a frequency range of 0 to 10000 Hz and a display time span of four seconds.

**Audio Scanning From Within Microsoft Power Point**

Real-time spectrum analysis can be embedded in Microsoft PowerPoint presentations using the Windows Command Line. This can be done by creating a button on the PowerPoint slide that, when clicked, issues the required Command Line instructions to the Spectrogram program.

To create this button in PowerPoint, choose "Slide Show - Action Buttons" from the PowerPoint menu to insert the button image on the current slide. Then use a right mouse button click on the button image and select "Action Settings." Within the Action Settings control box, choose "Run Program" and insert the Spectrogram commands in the text box provided.

"c:\Program Files\Visualization Software\Spectrogram 15\gram15.exe" 7 0 10000 4

This command will start a scrolling display (Scroll 1 format) showing a frequency range from 0 to 10000 Hz with a display time span of 4 seconds. The Spectrogram window will open within the PowerPoint slide. Spectrogram will operate normally and provide all of its usual controls. When you are ready to proceed to the next PowerPoint slide, close Spectrogram by clicking the "Close" button in the upper right hand corner of the Spectrogram window.

**File Analysis From Within Microsoft Power Point**

Spectrum analysis of wave files can be embedded in Microsoft PowerPoint presentations using the Windows Command Line. This can be done by creating a button on the Power Point Slide that, when clicked, issues the required Command Line instructions to the Spectrogram program.

To create this button in PowerPoint, choose "Slide Show - Action Buttons" from the PowerPoint menu to insert the button image on the current slide. Then use a right mouse button click on the button image and select "Action Settings." Within the Action Settings control box, choose "Run Program" and insert the Spectrogram commands in the text box provided.

"c:\Program Files\Visualization Software\Spectrogram 15\gram15.exe" 1 0 10000 4
"c:\wave\soundfile.wav"

This command will analyze the file named c:\wave\soundfile.wav, producing a spectrogram (Scroll 1 format) with a frequency range of 0 to 10000 Hz and a display time span of four seconds. The Spectrogram window will open within the PowerPoint slide. Spectrogram will operate normally and provide all of its usual controls. When you are ready to proceed to the next PowerPoint slide, close Spectrogram by clicking the "Close" button in the upper right hand corner of the Spectrogram window.

## SYSTEM REQUIREMENTS & INSTALLATION

Spectrogram requires Windows 2000, or Windows XP.

Spectrogram runs best with a 1.6 gHz or faster processor and a fast graphics card.

Spectrogram runs best with 1gigabyte or more of RAM memory.

Spectrogram requires 16 or 24 bit color. Spectrogram will not operate with only 8 bit (256) color.

Spectrogram processes PCM format digital audio data such as .wav sound files but cannot convert compressed audio data.

In order to record and play back sound samples, you will need a Windows compatible sound card installed. However, a sound card is not necessary in order to analyze and display audio spectrograms.

To install Spectrogram, run the setup program (gram15_setup.exe). The program can then be started by clicking its desktop icon. If an earlier version of Spectrogram is installed on your computer, you may be asked if you wish to delete it. In this case, answer "yes" and run the setup program a second time to complete installation of the latest version.

## MEMORY USAGE

Spectrogram can require an enormous amount of memory, particularly for high resolution, two channel spectrograms using 24 bit display color. If you ever see the warning "Not Enough Memory," your computer cannot allocate the memory needed for the entire display bitmap.

Solutions to such memory shortages are:

1. Reduce screen size to a maximum of 1024 x 768. This will reduce the memory required for the scrolling spectrogram display window.

2. Reduce the Spectrogram display window size to less than full screen dimensions.

3. Run Spectrogram in monaural rather than stereo mode. A single channel spectrogram requires one half the display bitmap memory of a two-channel spectrogram.

4. Use a digital sampling rate of no more than 48 kHz. Consider reducing the digital sampling rate to 22kH if the high frequency content of the audio signal is expected to be below 11 kHz.

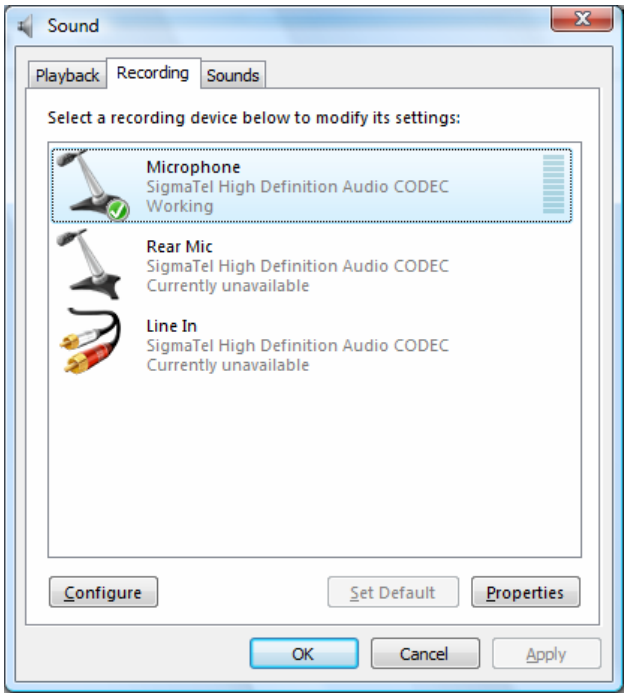
5. Reduce the data resolution for digital sampling from 24 bits to 16 bits.

6. Use the "Scan File" mode of operation rather than the "Analyze File" mode for examination of recorded wave files.

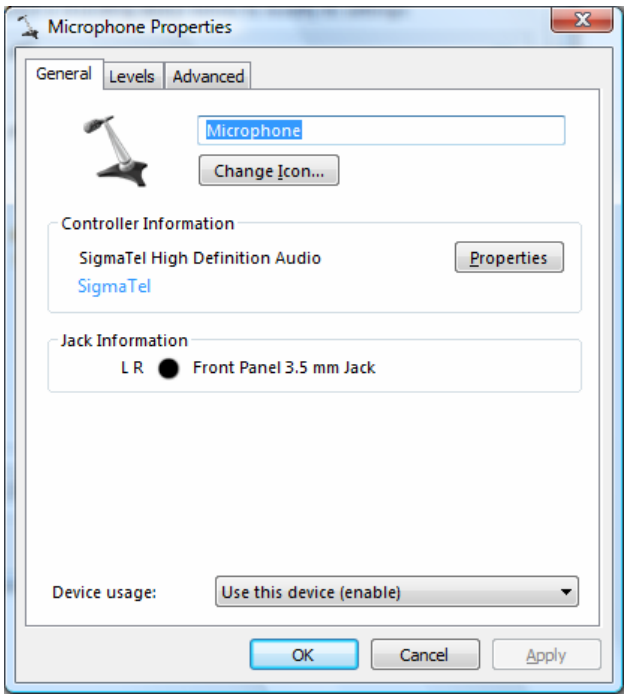
## SOUND CARD CONTROL FOR WINDOWS VISTA

First, connect a microphone to the proper input signal jack on the sound card. Sound cards may have several input/output jacks such as microphone input, line/auxiliary input, speaker output, digital input/output. Check the sound card instructions to be certain that the microphone is properly connected to the microphone input jack. On many sound cards, the microphone input jack is color coded red or pink.

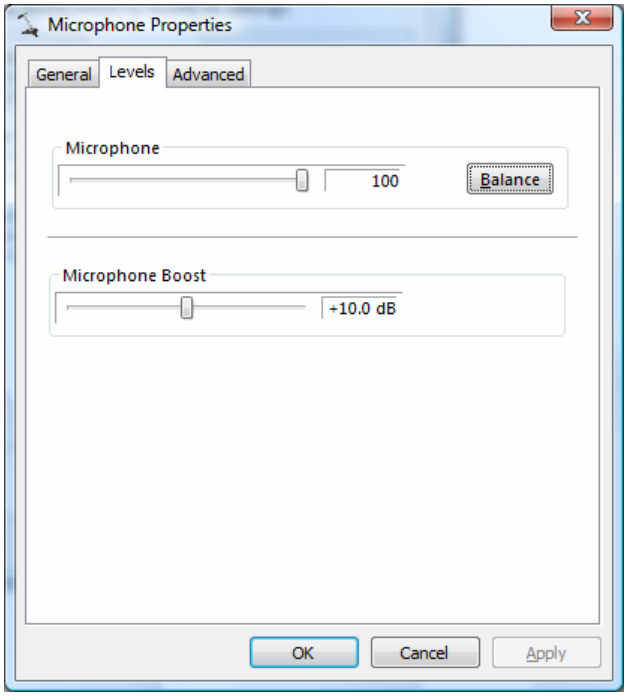
Next, go to the Windows Control Panel and select "Sound." This will bring up the Sound control panel shown below for activating the microphone and setting the microphone input volume.




Click the "Recording" tab, select "Microphone" (by blue highlighting), and then click the "Properties" button at the lower right. This will bring up the Microphone Properties control panel as shown below.




Click the "General" tab in Microphone Properties. Make sure that "Device Usage" at the bottom of this panel indicates "Use this device (enable)." If it does not, use the Device Usage drop-down list to select this option.

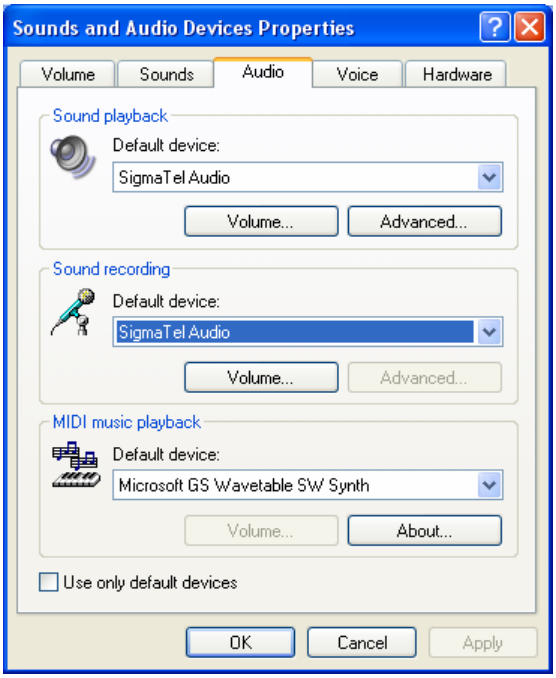



Click the "Levels" tab in Microphone Properties. Set the Microphone level to a value from 75 to 100, and set the Microphone Boost to a value from +10 to +20 dB. Then close the Microphone Properties and Sound control panels.

**SOUND CARD CONTROL FOR WINDOWS XP**

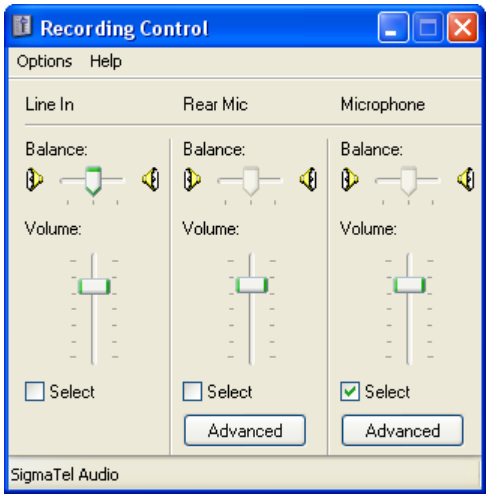
First, connect a microphone to the proper input signal jack on the sound card. Sound cards may have several input/output jacks such as microphone input, line/auxiliary input, speaker output, digital input/output. Check the sound card instructions to be certain that the microphone is properly connected to the microphone input jack. On many sound cards, the microphone input jack is color coded red or pink.

Next, go to the Windows Control Panel and select "Sounds and Audio Devices." This will bring up the Sound and Audio Devices Properties control panel shown below for activating the microphone and setting the microphone input volume. Click the "Audio" tab under Sound and Audio Device Properties.




The "Default Device" under both Sound Playback and Sound Recording should show the name of the sound card that you wish to use. If it does not, select the desired sound card name from the drop-down lists under Sound Playback and Sound Recording.

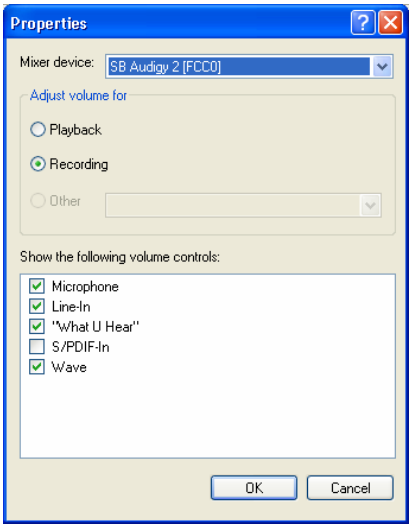
Next, click the “Volume” button under Sound Recording. This will bring up the Recording Control panel as shown below.




Place a check mark in the “Select” box under microphone, and set the Microphone volume slider at about the 75% position as shown.

Often, the microphone selection will have an “Advanced” button that allows boosting the microphone signal level. If this button is present, click it and active the 20dB microphone boost. This will provide the strongest possible signal and will enhance the visible detail on the scrolling voiceprint display. It may be necessary to check the “Options - Advanced Controls” menu item of the Recording Control in order for the Advanced button to be present.

If you do not see the Microphone input in the Recording Control, click “Options - Properties” to bring up the Properties dialog box. Then mark Microphone under “Show the Following Volume Controls” to make the microphone available as an option in the Recording Control



## SOLUTIONS TO SOME COMMON PROBLEMS

Below are recommended solutions for several of the most common problems experienced by new users.

- **Program does not does not properly read and save audio files.**

  This can happen if you do not have user privileges for writing files to the hard drive. Windows Vista users can usually solve this problem by setting the proper privilege level. Use Windows Explorer to go to the Spectrogram installation directory (usually "c:\Program Files\Visualization Software\Spectrogram15." Right click on the "gram15" application file, choose "Properties", and set the "Privilege Level" to "Run this program as an administrator."

- **Program does not accept Line Input, or program does not accept Microphone Input.**

  If an audio source is connected to either the Line Input or Microphone Input, and the Scan Input display does not show the presence of any audio signal, then the sound card has probably not been correctly configured to accept the intended input source. The Line In or Microphone input must be properly enabled in the Windows Record Control. See the instructions under **Sound Card Control** for Windows Vista or Windows XP.

- **Program accepts Microphone Input, but the spectrum display shows a very weak signal.**

  If the microphone signal is very weak, first try increasing the volume by raising the vertical slider control at the right side of the display window. See the instructions under **Volume Control.**

  Also, try enabling microphone boost in the Windows Record Control. See the instructions under **Sound Card Control** for Windows Vista or Windows XP.

- **Stereo signals are not properly displayed. Either both channels of the audio signal are identical, or only one channel is displayed.**

  Many sound cards do not accept stereo signals using the Microphone input jack, resulting in these symptoms. Instead, use the Line-In sound card input jack for real-time analysis of stereo signals.

- **The scrolling spectrogram display does not scroll smoothly in the Scan Input or Scan File mode of operation.**

  Slow or jumpy scrolling can usually be improved by reducing memory usage. See **Memory Usage** for more information. Also note that scrolling speed will be reduced when using very high frequency resolution. This is the expected effect of the longer processing time required.

- **The scrolling spectrogram display is saturated with noise or "snow".**

  First try reducing the signal volume using the vertical slider control at the right side of the display window. See **Volume Control** for more information.

  A noisy display can also be corrected by changing the color scale. Choose "Function - Spectrum Color Scale" from the program menu (or Function Key F7) to bring up the Spectrogram Colors dialog box. See **Spectrum Color Scale** for more information.

## PROBLEM REPORTING & PROGRAM UPDATES

Programs can only be improved if users provide feedback to the author. I can be reached via the Internet for you to report any bugs or to provide comments or feedback. I encourage anyone with a question or suggestion to contact Richard Horne at r.horne@visualizationsoftware.com.

The Spectrogram Program is updated periodically to add features and fix bugs reported by users. The latest Spectrogram update can always be downloaded from http://www.visualizationsoftware.com/gram.html.

## DISCLAIMER

The Spectrogram program is a product of Visualization Software LLC by Richard Horne and is intended for general audio spectrum visualization purposes only. No warranty is expressed or implied regarding the use or the results of the use of Spectrogram in terms of correctness, accuracy, reliability, currency, fitness for a particular purpose, or otherwise.

Comments, questions, or problem reports are always welcome and should be sent to r.horne@visualizationsoftware.com.

## CREDITS

The following persons or organizations have contributed to the capabilities of the Spectrogram program.

Internally, this software makes use of copyrighted techniques for audio spectrum analysis. The internal procedures four1( ), correll( ), and realft( ) are based on routines in Numerical Recipes: The Art of Scientific Computing, published by Cambridge University Press, and are used by permission of the author.

JPEG compression code was developed by the Independent JPEG Group and distributed from http://www.ijg.org/ as the IJG JPEG library.