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 power spectrum plot of the frequency components of such an audio signal as a function of time. In this Spectrogram program, digital audio recordings (PCM format) are analyzed to produce a plot of frequency versus time, with harmonic power 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.

Spectrogram provides three basic modes of operation, “Analyze File,” “Scan File,” and “Scan Input.” The Analyze File mode stores the audio signal and spectrogram display bitmap in RAM and allows manipulation of the analysis parameters to achieve the best possible display of the data. The Scan File and Scan Input modes provide real-time spectrum analysis of audio signals of unlimited length, but do not store the audio data for manipulation. To record a wave file through your sound card, use the Scan Input mode with recording enabled.

Spectrogram uses a mathematical Fast Fourier Transform (FFT) to perform the frequency analysis. FFT's are usually specified by the number of input data points used in each calculation which are always powers of two (512, 1024, 2048, etc). The frequency resolution of the spectrogram is always the digital sampling rate of the audio signal divided by the number of FFT data points. The greater the number of FFT data points, the finer the frequency resolution of the spectrogram. The maximum frequency computed by the FFT and the upper frequency limit of the spectrogram will be half the digital sampling rate.

The choice of sampling rate depends entirely on the highest frequencies in the audio signal. The rule of thumb is to use a sampling rate that is twice the highest frequency in the audio signal. That is, if you expect to have no frequency components above 11KHz, then a sampling rate of 22KHz is adequate. If you examine a spectrogram and see that all of the signal is concentrated in lower frequency components at the bottom of the display then it is a good bet that the recording was sampled at too high a rate, wasting a significant amount of memory. By varying the sampling rate and the number of FFT input data points, the frequency resolution and frequency span of the spectrogram can be chosen to best fit the audio signal of interest. Don't fall into the habit of automatically recording everything at a 44 KHz sampling rate. Lower rates often result in much better spectrogram displays.

THE SPECTROGRAM DISPLAY

The spectrogram display reveals the audio signal as a frequency versus time plot with signal amplitude 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.

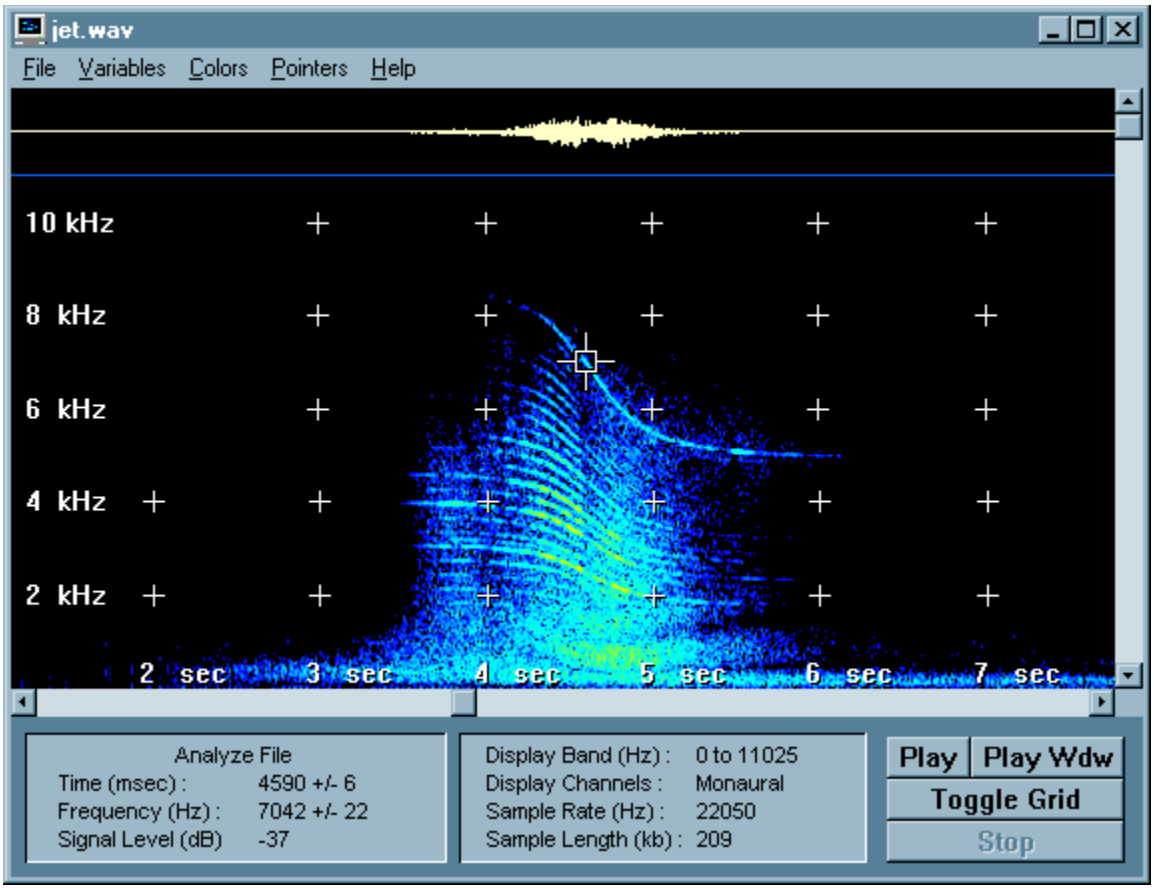
A continuous readout of time (milliseconds), frequency (Hz) and signal power level (dB) at the position of the mouse pointer (cursor) is displayed at the bottom left of the display. A coordinate grid can also be added or removed by clicking the "Toggle Grid" button at the bottom right of the display.

In the Analyze File mode, Spectrogram can play back the audio sample through your 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 width of the spectrogram display is limited only by the display screen. Maximizing the spectrogram window will expand the display horizontally to fill the screen. If the spectrogram width is greater than display width, you can use the horizontal scroll bar at the bottom of the display to position the spectrogram side-to-side.

The height of the spectrogram display is determined by the mode of operation and the size of the FFT chosen for analysis. The Scan File, and Scan Input modes of operation each allow a maximum display height of 256 frequency points. These modes must update the scrolling spectrogram display in real time which limits the maximum allowable display height. The Analyze File mode of operation is used for very detailed frequency analysis and does not require real-time display update. The maximum height of the Analyze File mode is 1024 frequency points. If the spectrogram height is greater than the display height, you can use the vertical scroll bar at the right of the display to position the spectrogram top-to-bottom.

To maximize the Spectrogram window to fill the entire screen, choose the Analyze File mode, select a 1024 point FFT (or greater) and then maximize the Spectrogram window. Only by selecting an FFT of 1024 points or greater will the display fill the entire screen.


jet.wav
File Variables Colors Pointers Help
10 kHz
8 kHz
6 kHz
4 kHz
2 kHz
2 sec
3 sec
4 sec
5 sec
6 sec
7 sec
Analyze File
Time (msec) : 4590 +/- 6
Frequency (Hz) : 7042 +/- 22
Signal Level (dB) -37
Display Band (Hz) : 0 to 11025
Display Channels : Monaural
Sample Rate (Hz) : 22050
Sample Length (kb) : 209
Play
Play Wdw
Toggle Grid
Stop

THE SCOPE DISPLAY

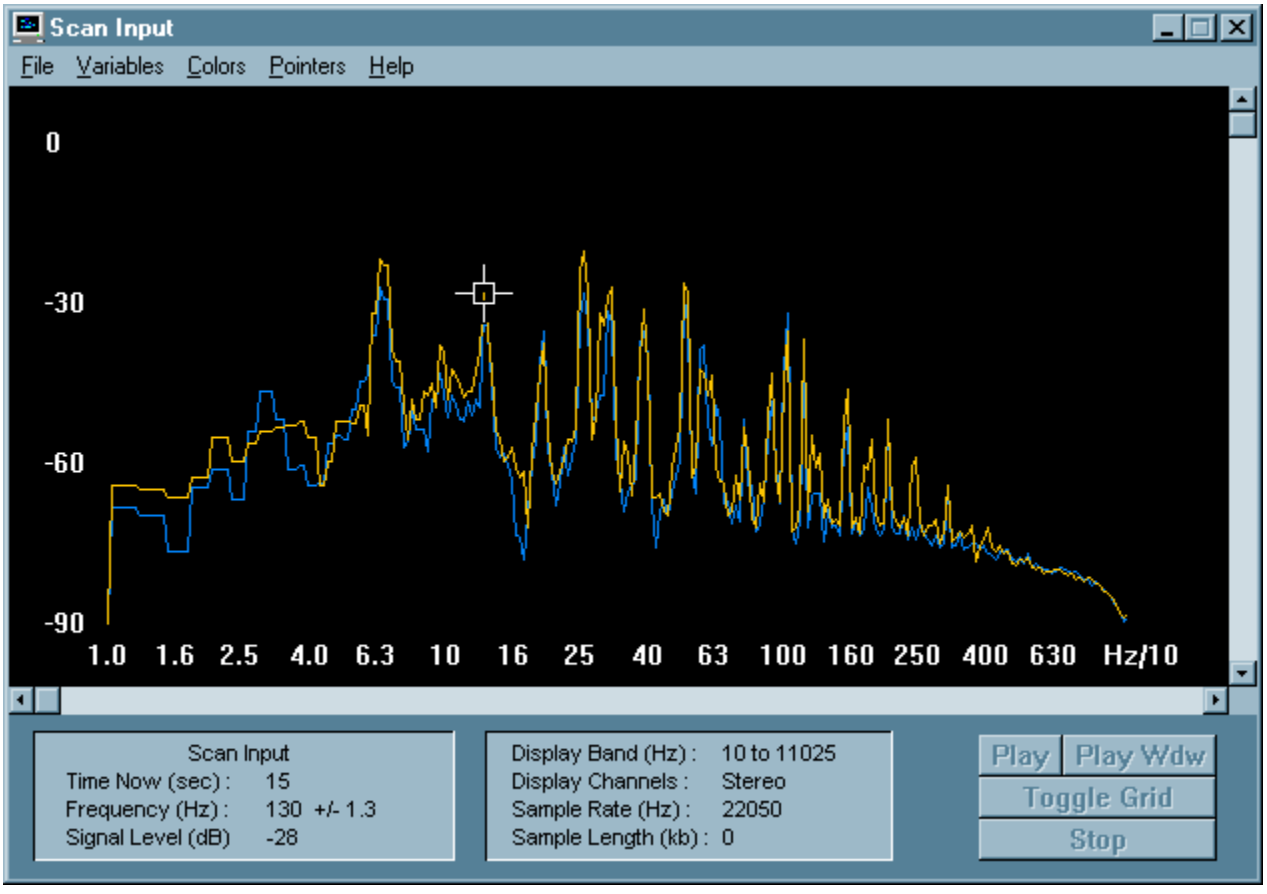
The Scan Input and Scan File modes also provide a spectrum analyzer scope display as an option for viewing the sound spectrum. The scope display can be configured for either dual channel or single channel audio with a wide selection of frequency resolutions and either linear or logarithmic frequency 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 of signal power 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.

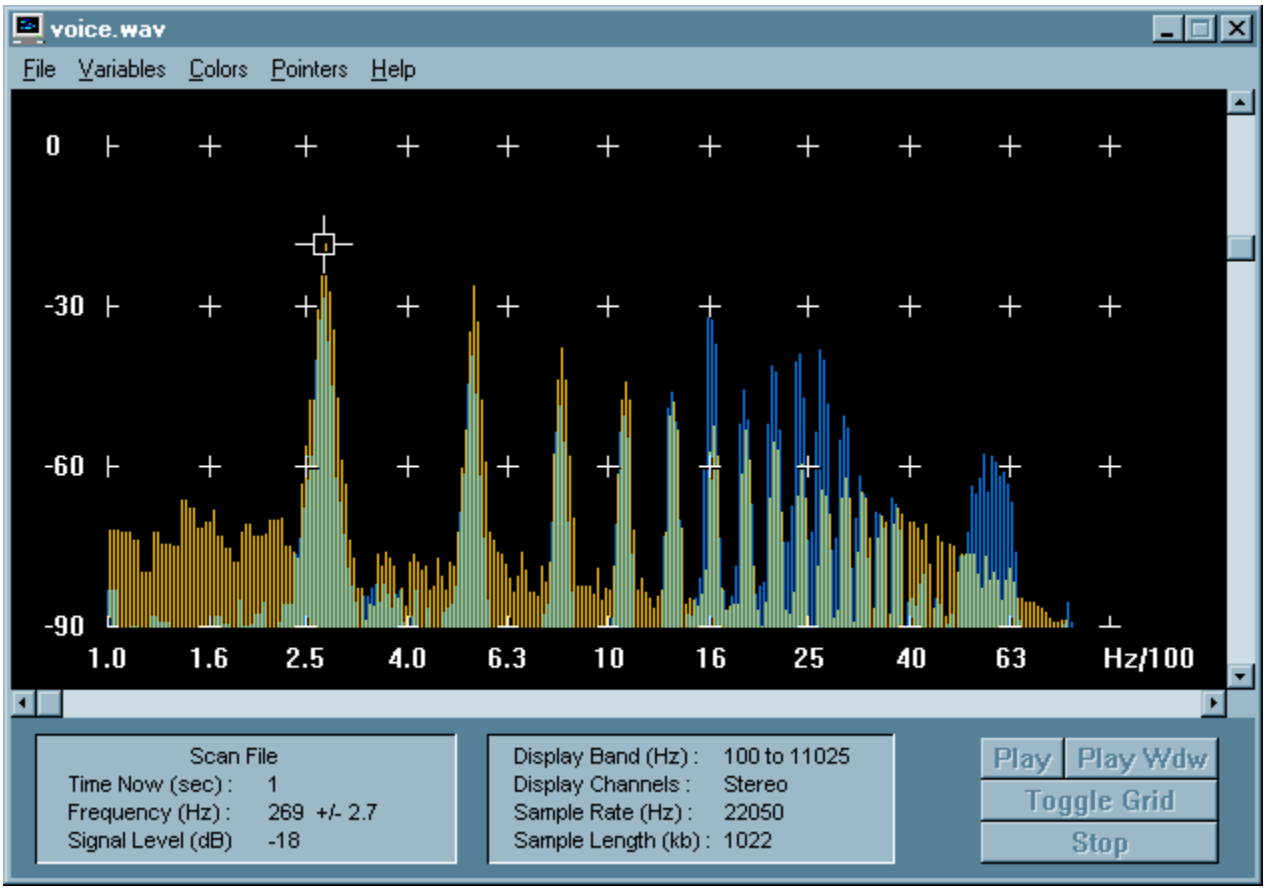
The scope display can be configured as either a histogram bar display where component amplitude is represented at each frequency by a vertical bar, or as a continuous line plot of component amplitude at each frequency.

A continuous readout of time (milliseconds), frequency (Hz) and signal level (dB) at the position of the mouse pointer (cursor) is displayed at the bottom left of the display. A coordinate grid can also be added or removed by clicking the "Toggle Grid" button at the bottom right of the display.

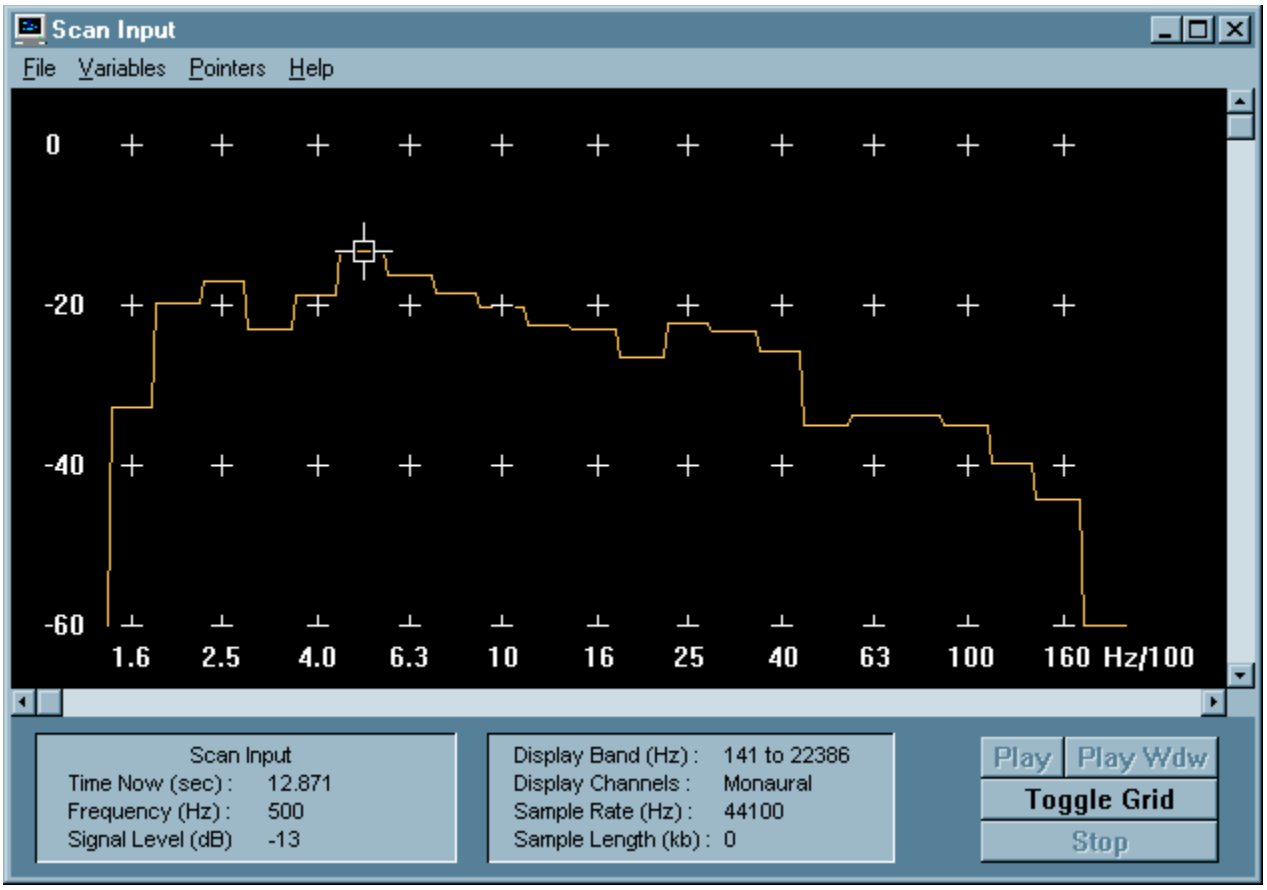
Spectrum Analyzer Scope Display - Line



Spectrum Analyzer Scope Display - Bar



Spectrum Analyzer Scope Display – 1/3 Octave


Scan Input
File Variables Pointers Help
0
-20
-40
-60
1.6 2.5 4.0 6.3 10 16 25 40 63 100 160 Hz/100
Scan Input
Time Now (sec): 12.871
Frequency (Hz): 500
Signal Level (dB) -13
Display Band (Hz): 141 to 22386
Display Channels: Monaural
Sample Rate (Hz): 44100
Sample Length (kb): 0
Play
Play Wdw
Toggle Grid
Stop

LINEAR AND LOG FREQUENCY SCALES

Both the 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 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 high frequency resolution at low frequencies. The result is that use of a log scale requires a much larger FFT in order to achieve the needed frequency resolution. Because of the computational load of a large FFT, scanning of wave files or audio input may run more slowly when using a log frequency scale.

When using a log frequency scale, choose the smallest FFT that gives acceptable frequency resolution on the spectrogram or scope at low frequencies. If the low frequency regions on a log frequency display appear noticeably blocky, increase the low frequency resolution by choosing a larger FFT size.

The 1/3 octave scope display is a special case of a log frequency scale in which the spectrum of signal power in adjacent frequency bands of one third octave width is displayed in real time.

SIGNAL READOUTS

A continuous readout of time (milliseconds), frequency (Hz) and signal power level (dB) at the position of the mouse pointer (cursor) is displayed at the bottom left of the program window. The spectrogram display provides signal level measurements only after analysis or scanning is complete. The scope display can provide signal level measurements during all analysis or scanning.

A coordinate grid can also be added or removed by clicking the "Toggle Grid" button.

The mouse pointer can also be used to measure time and frequency differences on the spectrogram display. 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 left 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) you have the option of adding a fixed reference cross mark 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, you have the option of adding one or two fixed frequency markers 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 “Cursors - Freq Mark” from the main 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

In the Scan Input mode, you can pause the scrolling spectrogram display by clicking the right mouse button while the pointer is over the spectrogram display area. The program will continue to run, but display scrolling will be halted. Display scrolling can be resumed with another click of the right mouse button. This feature allows you to closely examine interesting features on the scrolling spectrogram without the need to stop and restart the program.

Display pause does not operate if Recording Enable “On” or “Trigger” is selected in order not to interfere with the timing of recording start and stop.

TO ADJUST OR FREEZE PARAMETERS

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 Spectrogram 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.

PROGRAM START UP AND INITIALIZATION

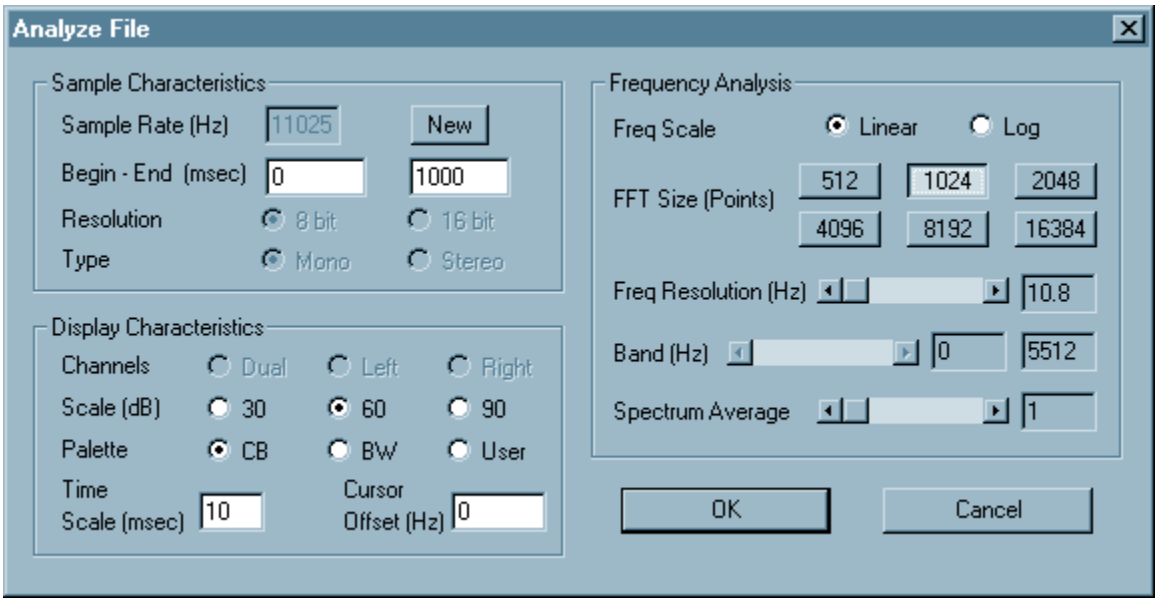
Spectrogram will always start up in the same configuration that was in effect the last time the program was running. Program settings are saved in the "Gram.ini" file in the same directory with Spectrogram.

For example, if you last used the program in the Scan Input mode, the next time you start Spectrogram it will begin in this mode and bring up the Scan Input dialog box for entry of analysis parameters. If variables are frozen, Spectrogram will automatically begin scanning without the need for entry of any analysis parameters.

If you have instructed Windows Explorer to always run Spectrogram when you select a wave file, and you last used Spectrogram in the Analyze File mode, then each time you select a wave file Spectrogram will automatically start and analyze the file you have selected. If variables are frozen, Spectrogram will begin analysis without the need for entry of any analysis parameters.

ANALYZE FILE DIALOG BOX

The Analyze File mode allows you to compute and display a spectrogram from a prerecorded digital audio sample or wave file. Choose "Analyze File" from the File menu (or Function Key F1) 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. Click on any control in the Analyze File dialog box below for a detailed description.



ANALYZE FILE, SAMPLE CHARACTERISTICS

These controls are available from the Analyze File Dialog Box. Choose "File-Analyze File" from the main menu to enter the Analyze File mode and bring up this dialog box.

- Sample Rate Edit Box - You can choose any value of sample rate from 5513 Hz to 44100 Hz. If you have selected a wave file (.wav), the sample rate displayed will be the rate used in the original recording. If you have selected a raw data file, a sample rate of 11025 Hz will be initially assumed, and you should enter the correct value if necessary. In order to enter a sample rate value, first click the "New" button in the Sample Characteristics group. Then enter the new value in the text box and click the "OK" button. Note that entering sample rate here does not result in any change to the data file, but simply changes the sample rate used in calculation, display, and playback of the spectrogram.

- Begin/End Edit Box - You can also choose the beginning and ending location in the selected file (in milliseconds) to be analyzed. Initially, the starting and ending location of the entire file will be displayed. If you make no change here, the entire file will be analyzed. For a very large file, it may be necessary to select a smaller time interval for analysis in order not to exceed available RAM memory.

- Resolution and Type Radio Buttons - You also have a choice of 8 bit or 16 bit data resolution and mono or stereo operation. Pick the value that you know corresponds to the data file you are analyzing. If you are loading a wave file, the correct value will already be shown. If this is a raw data file, 16 bit data and monaural operation will be assumed, but it is up to you to specify the correct value.

ANALYZE FILE, FREQUENCY ANALYSIS

These controls are available from the Analyze File Dialog Box. Choose "File-Analyze File" from the main menu to enter the Analyze File mode and bring up this dialog box.

- Freq Scale Radio Buttons - You have a choice of using either a linear or logarithmic frequency 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 on the display. Experiment with these scales to choose the one best suited to your analysis.

- FFT Size Push Buttons - You can compute a spectrogram using 512, 1024, 2048, 4096, 8192, or 16384 point Fast Fourier Transforms (FFTs). The highest possible frequency resolution of your spectrogram will be the digital sampling rate divided by this FFT size. Use the larger FFTs only for high resolution analysis or with the logarithmic frequency scale. The higher resolution FFTs require more time to compute the spectrogram. For this reason it is sometimes preferable to decrease sampling rate when recording audio data if increased frequency resolution is needed, rather than to use a higher resolution FFT.

- Freq Resolution Slider - Adjustment of this slider, in conjunction with selection of the FFT size described above, determines the frequency resolution of the spectrogram. For usual narrow band frequency analysis this control should be set to the minimum (leftmost position) in order to achieve the highest possible frequency resolution. Where broadband analysis is required (such as for observation of speech formants) this control can be adjusted to set a wider analysis bandwidth.

- Freq Band Slider (Linear) - If you have chosen a linear frequency scale, this slider allows you to choose the frequency band to be displayed in the spectrogram. The highest resolution spectrograms may not fit entirely in the display window, which has a maximum height of 1024 points. In this case, the Freq Band Slider allows you to choose which portion of the spectrum to display.

- Freq Band Slider (Log) - If you have chosen a logarithmic frequency scale, then the Freq Band Slider allows you to choose the lower frequency cutoff of the spectrogram. A logarithmic scale will always allow displaying the entire frequency band. However, you may find it useful to eliminate the very low frequencies to reduce clutter or improve the appearance of the spectrogram.

- Spectrum Average - Use this slider to determine the number of sequential spectrum measurements that are averaged together before display on either the scrolling spectrogram display or the scope display. Averaging is particularly useful in recovering weak periodic signals from a noisy background, but is probably not of much interest in analysis of speech or other rapidly varying signals. You can choose averaging of one (no averaging) to 128 spectrum measurements.

ANALYZE FILE, DISPLAY CHARACTERISTICS

These controls are available from the Analyze File Dialog Box. Choose "File-Analyze File" from the main menu to enter the Analyze File mode and bring up this dialog box.

- Channels Radio Buttons - If you are analyzing a stereo wave file, you will be able to select left, right, or dual channel operation using these buttons. This selection will not be available for a monaural wave file.

- Scale Radio Buttons - Here you have a choice of amplitude scales for the scrolling spectrogram display. The 30 dB scale examines a signal range from -30 dB t0 -60 dB. The 60 dB scale examines a signal range from 0 dB to -60 dB. And the 90 dB scale examines a signal range from 0 dB to -90 dB. The 30 dB scale is most useful for strong audio signals; whereas, the 90 dB scale is most useful for very weak audio signals.

- Palette Radio Buttons - The palette radio 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.

- Time Scale Edit Box - Here you can select a time scale in milliseconds that corresponds to the time interval between the calculation of each FFT. To obtain greater time resolution in the spectrogram, choose a smaller value for the time scale. Each vertical line in the spectrogram display represents the output of one FFT calculation. The FFT data input window is stepped sequentially through the data, performing an FFT calculation at each step. The time scale selected determines the length of the step between each FFT and thus the total width of the Spectrogram display. Experiment with this value to pick the time scale which best displays the audio signal of interest.

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

  Cursor offset should be set equal to the zero beat frequency of the radio 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) radio 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.

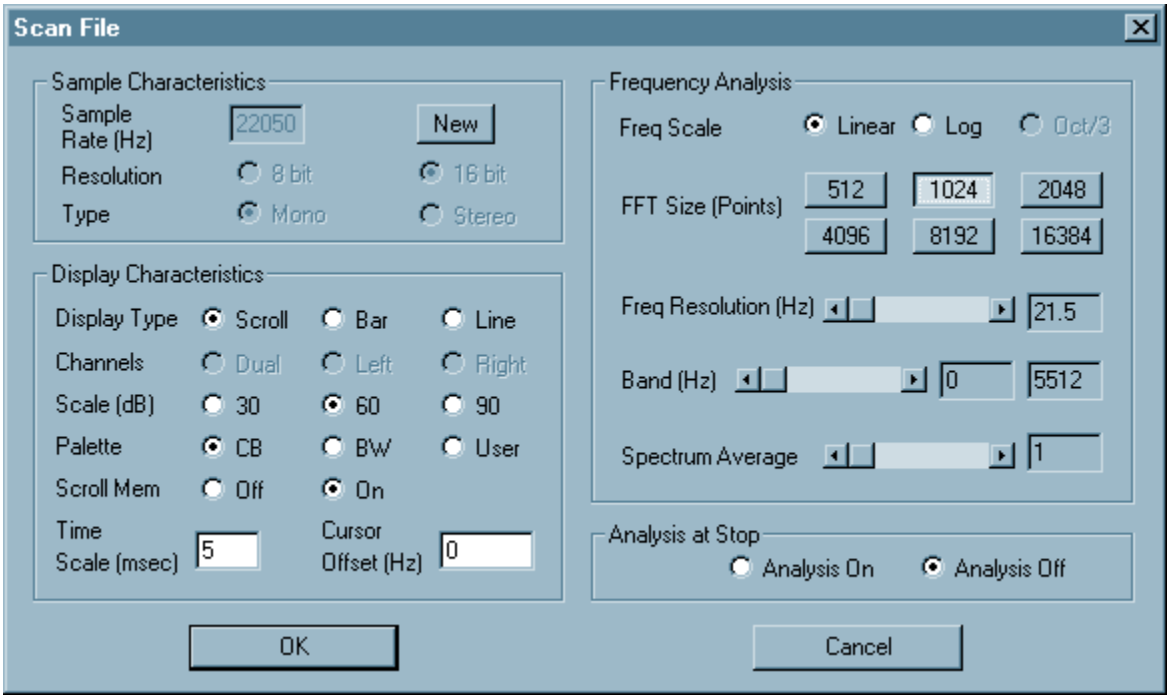
  Positive offset results in: Readout frequency = Cursor Offset + Frequency at cursor
  Negative offset results in: Readout frequency = Cursor Offset - Frequency at cursor

  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.

SCAN FILE DIALOG BOX

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 "Scan File" from the File 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. In this mode, no audio data is saved in RAM for detailed analysis. Click on any control in the Scan File dialog box below for a detailed description.

The purpose of the Scan File mode is to allow the selection of smaller time intervals for analysis from within very large wave files. If a wave file is too large to fit in RAM for detailed analysis, the file can be scanned in real time until the "Stop" button is clicked. A detailed spectrogram analysis can then automatically be calculated at that point. The Scan File dialog box gives you the option to enable or disable this detailed analysis at the scan file stop point. Choose "Analysis On" or "Analysis Off" buttons from the "Analysis at Stop" group box.



SCAN FILE, SAMPLE CHARACTERISTICS

These controls are available from the Scan File Dialog Box. Choose "File-Scan File" from the main menu to enter the Scan File mode and bring up this dialog box.

- Sample Rate Edit Box - You can choose any value of sample rate from 5513 Hz to 44100 Hz. If you have selected a wave file (.wav) for scanning, the sample rate displayed will be the rate used in the original recording. If you have selected a raw data file, a sample rate of 11025 Hz will be initially assumed, and you should enter the correct value if necessary. In order to enter a sample rate value, first click the "New" button in the Sample Characteristics group. Then enter the new value in the text box and click the "OK" button. Note that entering sample rate here does not result in any change to the data file, but simply changes the sample rate used in calculation, display, and playback of the spectrogram.

- Resolution and Type Radio Buttons - You also have a choice of 8 bit or 16 bit data resolution and monaural or stereo operation. Pick the values that you know correspond to the data file you are analyzing. If you are loading a wave file, the correct values will already be shown. If this is a raw data file, 16 bit data and monaural operation will be assumed, but it is up to you to specify the correct value.

SCAN FILE, FREQUENCY ANALYSIS

These controls are available from the Scan File Dialog Box. Choose "File-Scan File" from the main menu to enter the Scan File mode and bring up this dialog box.

- Freq Scale Radio Buttons - You have a choice of using either a linear or logarithmic frequency 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 on the display. 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 of the power spectrum in which the spectrum of signal power 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 Push Buttons - You can compute a spectrogram using 512, 1024, 2048, 4096, 8192, or 16384 point Fast Fourier Transforms (FFTs). The highest possible frequency resolution of your spectrogram will be the digital sampling rate divided by this FFT size. Use the larger FFTs only for high resolution analysis or with the logarithmic frequency scale. The higher resolution FFTs require more time to compute the spectrogram. For this reason it is sometimes preferable to decrease sampling rate when recording audio data if increased frequency resolution is needed, rather than to use a higher resolution FFT.

- Freq Resolution Slider - Adjustment of this slider, in conjunction with selection of the FFT size described above, determines the frequency resolution of the spectrogram. For usual narrow band frequency analysis this control should be set to the minimum (leftmost position) in order to achieve the highest possible frequency resolution. Where broadband analysis is required (such as for observation of speech formants) this control can be adjusted to set a wider analysis bandwidth.

- Freq Band Slider (Linear) - If you have chosen a linear frequency scale, this slider allows you to choose the frequency band to be displayed in the spectrogram. The highest resolution spectrograms may not fit entirely in the display window that has a maximum height of 256 points. In this case, the Freq Band Slider allows you to choose which portion of the spectrum to display.

- Freq Band Slider (Log) - If you have chosen a logarithmic frequency scale, then the Freq Band Slider allows you to choose the lower frequency cutoff of the spectrogram. A logarithmic scale will always allow displaying the entire frequency band. However, you may find it useful to eliminate the very low frequencies to reduce clutter or improve the appearance of the spectrogram.

- Spectrum Average - Use this slider to determine the number of sequential spectrum measurements that are averaged together before display on either the scrolling spectrogram display or the scope display. Averaging is particularly useful in recovering weak periodic signals from a noisy background, but is probably not of much interest in analysis of speech or other rapidly varying signals. You can choose averaging of one (no averaging) to 128 spectrum measurements. In general, the scope display needs averaging of at least four spectrum measurements to produce a stable display.

SCAN FILE, DISPLAY CHARACTERISTICS

These controls are available from the Scan File Dialog Box. Choose "File-Scan File" from the main menu to enter the Scan File mode and bring up this dialog box.

- Display Type Radio Buttons - While scanning, you can choose to display wave file data in real time using either a scrolling spectrogram display, or a spectrum analyzer scope display. The spectrogram display consists of a scrolling 256 point frequency vs. time spectrum 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 with 256 frequency points.

  Choosing "Scroll" will produce the scrolling spectrogram display. Choosing "Bar" will produce a spectrum analyzer scope display in which component power is represented at each frequency by a vertical bar. Choosing "Line" will produce a spectrum analyzer scope display in which component power is represented as a continuous line plot.

- Channels Radio Buttons - If you are scanning a stereo file, you will be able to select dual, left, or right channel operation using these buttons. This selection will not be available for a monaural sample.

- Scale Radio Buttons - Here you have a choice of amplitude scales for the scrolling spectrogram display and the scope display. The 30 dB scale examines a signal range from -30 dB to -60 dB. The 60 dB scale examines a signal range from 0 dB to -60 dB. And the 90 dB scale examines a signal range from 0 dB to -90 dB. The 30 dB scale is most useful for strong audio signals; whereas, the 90 dB scale is most useful for very weak audio signals.

- Palette Radio Buttons - The palette radio 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.

- Scroll Memory Radio Buttons - When scanning, you can choose to retain the scrolling spectrogram image in memory. This will prevent other overlapping windows from disrupting the scrolling display, and will also allow saving or printing window images when scrolling is stopped. There is a small speed penalty in saving the spectrogram image to memory at each update. Scroll Memory "Off" should be selected if the maximum possible scrolling speed is required.

- Time Scale Edit Box - Here you can select a time scale in milliseconds that corresponds to the time interval between the calculation of each FFT. To obtain greater time resolution in the spectrogram, choose a smaller value for the time scale. Each vertical line in the spectrogram display represents the output of one FFT calculation. The FFT data input window is stepped sequentially through the data, performing an FFT calculation at each step. The time scale selected determines the length of the step between each FFT and thus the total width of the Spectrogram display. Experiment with this value to pick the time scale which best displays the audio signal of interest.

  Selecting a value of zero for time scale allows your computer to run without any restriction on display scrolling rate. The time scale of the display will then be determined by the speed with which your computer can complete each FFT calculation and scroll the display. Use a zero value for time scale when you need the very fastest scrolling rate.

  Select a value greater than zero for the time scale if you need to slow down the spectrogram scrolling rate for any reason (extremely slow CW radio reception, for example). Choosing a time scale of 200 msec, for example, will slow the display horizontal scrolling rate to 5 lines per second.

- Cursor Offset Edit Box - Cursor offset is useful when scanning or analyzing signals that have been frequency translated. For example, the audio output signals from an SSB radio receiver can be read as true radio

frequency by placing the cursor on the displayed signal.

Cursor offset should be set equal to the zero beat frequency of the radio 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) radio 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.

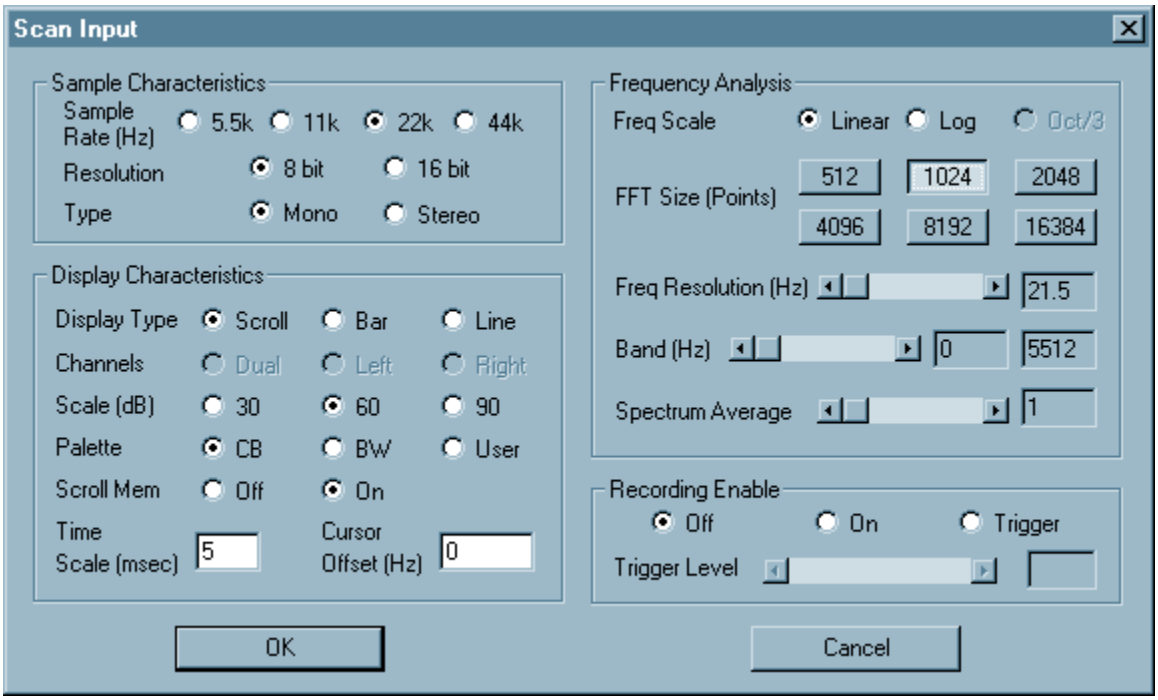
SCAN FILE, ANALYSIS AT STOP

These controls are available from the Scan File Dialog Box. Choose "File-Scan File" from the main menu to enter the Scan File mode and bring up this dialog box.

- Analysis On and Off Radio Buttons - These buttons give you the option to enable or disable detailed analysis (using the Analyze File Mode) at the point at which scanning of a large wave file is stopped. This feature allows you to scan a large wave file for features of interest, stop scanning at that point and perform a detailed spectrum analysis. Choose "Analysis On" or "Analysis Off" buttons from the "Analysis at Stop" group box to enable or disable this automatic feature.

SCAN INPUT DIALOG BOX

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 "Scan Input" from the File menu (or Function Key F3) to bring up the Scan Input dialog box for selection of scanning parameters. Click on any control in the Scan Input dialog box below for a detailed description.



SCAN INPUT, SAMPLE CHARACTERISTICS

These controls are available from the Scan Input Dialog Box. Choose "File-Scan Input" from the main menu to enter the Scan Input mode and bring up this dialog box.

- Sample Rate Radio Buttons - These buttons give you a choice of sampling rates of 5.5K, 11K, 22k, and 44k samples per second for scanning of audio input. Use the lowest sampling rates possible, taking into account that the sampling rate should be at least twice the frequency of the highest frequency component in the audio sample. Lower sampling rates can be used for Spectrograms with linear frequency scales. Logarithmic frequency scales will require higher sampling rates.

- Resolution and Type Radio Buttons - You also have a choice of 8 bit or 16 bit data resolution and monaural or stereo scanning. 16 bit data resolution should be used for all high resolution spectrograms. Monaural scanning is also recommended where memory is limited.

SCAN INPUT, FREQUENCY ANALYSIS

These controls are available from the Scan Input Dialog Box. Choose "File-Scan Input" from the main menu to enter the Scan Input mode and bring up this dialog box.

- Freq Scale Radio Buttons - You have a choice of using either a linear or logarithmic frequency 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 of the power spectrum in which the spectrum of signal power 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 Push Buttons - You can compute a spectrogram using 512, 1024, 2048, 4096, 8192, or 16384 point Fast Fourier Transforms (FFTs). The highest possible frequency resolution of your spectrogram will be the digital sampling rate divided by this FFT size. Use the larger FFTs only for high resolution analysis or with the logarithmic frequency scale. The higher resolution FFTs require more time to compute the spectrogram. For this reason it is sometimes preferable to decrease sampling rate when recording audio data if increased frequency resolution is needed, rather than to use a higher resolution FFT.

- Freq Resolution Slider - Adjustment of this slider, in conjunction with selection of the FFT size described above, determines the frequency resolution of the spectrogram. For usual narrow band frequency analysis this control should be set to the minimum (leftmost position) in order to achieve the highest possible frequency resolution. Where broadband analysis is required (such as for observation of speech formants) this control can be adjusted to set a wider analysis bandwidth.

- Freq Band Slider (Linear) - If you have chosen a linear frequency scale, this slider allows you to choose the frequency band to be displayed in the spectrogram. The highest resolution spectrograms may not fit entirely in the display window, which has a maximum height of 256 points. In this case, the Freq Band Slider allows you to choose which portion of the spectrum to display.

- Freq Band Slider (Log) - If you have chosen a logarithmic frequency scale, then the Freq Band Slider allows you to choose the lower frequency cutoff of the spectrogram. A logarithmic scale will always allow displaying the entire frequency band. However, you may find it useful to eliminate the very low frequencies to reduce clutter or improve the appearance of the spectrogram.

- Spectrum Average - Use this slider to determine the number of sequential spectrum measurements that are averaged together before display on either the scrolling spectrogram display or the scope display. Averaging is particularly useful in recovering weak periodic signals from a noisy background, but is probably not of much interest in analysis of speech or other rapidly varying signals. You can choose averaging of one (no averaging) to 128 spectrum measurements. In general, the scope display needs averaging of at least four spectrum measurements to produce a stable display.

SCAN INPUT, DISPLAY CHARACTERISTICS

These controls are available from the Scan Input Dialog Box. Choose "File-Scan Input" from the main menu to enter the Scan Input mode and bring up this dialog box.

- Display Type Radio Buttons - While scanning, you can choose to display wave file data in real time using either a scrolling spectrogram display, or a spectrum analyzer scope display. The spectrogram display consists of a scrolling 256 point frequency vs. time spectrum 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 with 256 frequency points.

  Choosing "Scroll" will produce the scrolling spectrogram display. Choosing "Bar" will produce a spectrum analyzer scope display in which component power is represented at each frequency by a vertical bar. Choosing "Line" will produce a spectrum analyzer scope display in which component power is represented as a continuous line plot.

- Channels Radio Buttons - If you are scanning a stereo file, you will be able to select dual, left, or right channel operation using these buttons. This selection will not be available for a monaural sample.

- Scale Radio Buttons - Here you have a choice of amplitude scales for the scrolling spectrogram display and the scope display. The 30 dB scale examines a signal range from -30 dB to -60 dB. The 60 dB scale examines a signal range from 0 dB to -60 dB. And the 90 dB scale examines a signal range from 0 dB to -90 dB. The 30 dB scale is most useful for strong audio signals; whereas, the 90 dB scale is most useful for very weak audio signals.

- Palette Radio Buttons - The palette radio 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.

- Scroll Memory Radio Buttons - When scanning, you can choose to retain the scrolling spectrogram image in memory. This will prevent other overlapping windows from disrupting the scrolling display, and will also allow saving or printing window images when scrolling is stopped. There is a small speed penalty in saving the spectrogram image to memory at each update. Scroll Memory "Off" should be selected if the maximum possible scrolling speed is required.

- Time Scale Edit Box - Here you can select a time scale in milliseconds that corresponds to the time interval between the calculation of each FFT. To obtain greater time resolution in the spectrogram, choose a smaller value for the time scale. Each vertical line in the spectrogram display represents the output of one FFT calculation. The FFT data input window is stepped sequentially through the data, performing an FFT calculation at each step. The time scale selected determines the length of the step between each FFT and thus the total width of the Spectrogram display. Experiment with this value to pick the time scale which best displays the audio signal of interest.

  Selecting a value of zero for time scale allows your computer to run without any restriction on display scrolling rate. The time scale of the display will then be determined by the speed with which your computer can complete each FFT calculation and scroll the display. Use a zero value for time scale when you need the very fastest scrolling rate.

  Select a value greater than zero for the time scale if you need to slow down the spectrogram scrolling rate for any reason (extremely slow CW radio reception, for example). Choosing a time scale of 200 msec, for example, will slow the display horizontal scrolling rate to 5 lines per second.

- Cursor Offset Edit Box - Cursor offset is useful when scanning or analyzing signals that have been frequency translated. For example, the audio output signals from an SSB radio receiver can be read as true radio

frequency by placing the cursor on the displayed signal.

Cursor offset should be set equal to the zero beat frequency of the radio 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) radio 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.

SCAN INPUT, RECORDING ENABLE

These controls are available from the Scan Input Dialog Box. Choose "File-Scan Input" from the main menu to enter the Scan Input mode and bring up this dialog box.

- Recording Enable 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 signal level is greater than a level set by the "Trigger Level" slider. Experiment with the trigger level to determine the best setting for your circumstances.

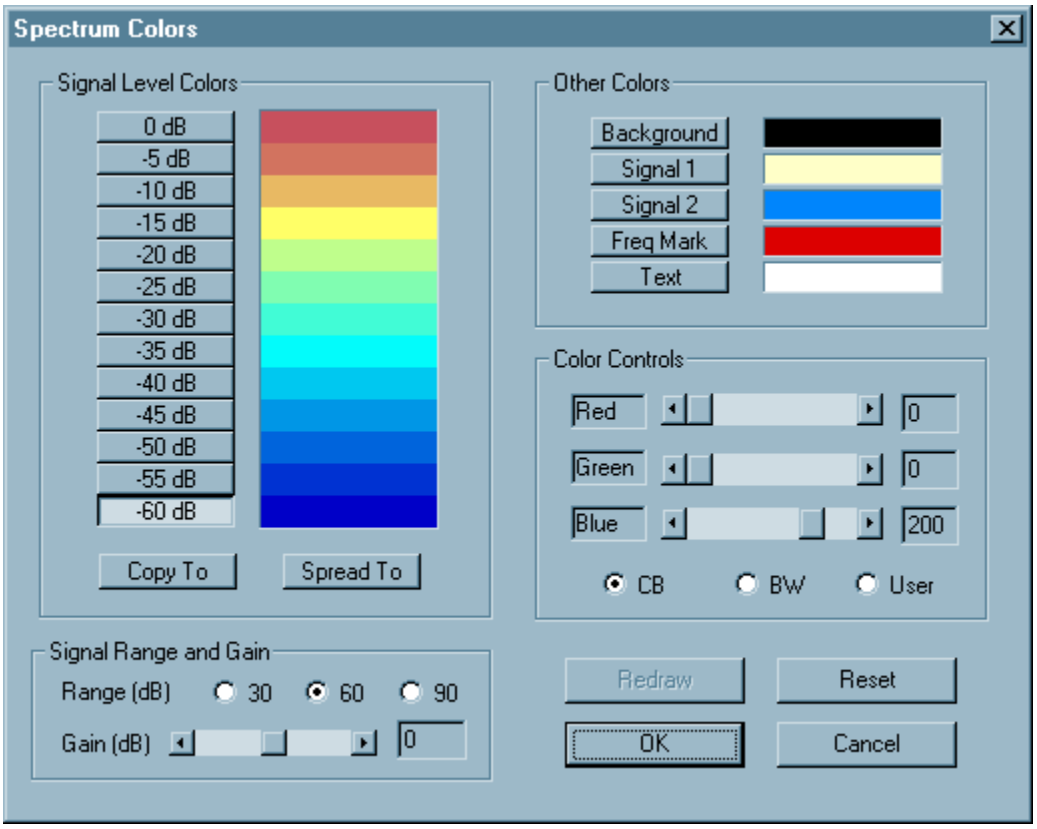
- Please note that use of the Recording Enable feature requires that your hard drive be continuously powered. Some computers can operate in power saving mode in which the hard drive power is turned off if the drive is not accessed for a fixed amount of time (usually 10 to 20 minutes). If you attempt 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 must disable your computer's power saving mode so that the hard drive will remain continuously powered.

COLOR CONTROLS

Spectrogram allows you to use either fixed or user-defined color palettes for both the scrolling spectrogram display and the scope display. Choose "File - Color Palette - Scroll Display" from the Spectrogram menu (or Function Key F4) to bring up the Spectrum Colors dialog box for modifying colors of the scrolling spectrogram display. A similar Scope Colors dialog box is available for modification of the colors of the scope display by choosing "File - Color Palette - Scope Display" (or Function Key F5).

The Scope Colors dialog box allows selection of colors at each of 12 steps corresponding to increasing signal power level. Spectrogram uses 240 colors to draw the scrolling display on the screen. Intermediate colors are interpolated between each of the 12 color steps defined by the Scope Colors dialog box.

It is best to experiment with the color palette modifications while Spectrogram is running the Scan Input mode using the scrolling spectrogram display. Then you can immediately see the effect of each change in color palette or change in signal range and gain that can be made here.



- Colors assigned to each signal level on the scrolling spectrogram are defined by the "Signal Level Colors" 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 it's left. Then you can 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.

- You can copy a color 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.

  You can create a smooth transition, or color spread, between two colors 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.

- Signal Range and Gain controls can be used to modify the spectrum level and appearance of the spectrum on the display. The 30 dB range examines a signal range from -30 dB t0 -60 dB. The 60 dB range examines a signal range from 0 dB to -60 dB. And the 90 dB range examines a signal range from 0 dB to -90 dB. The 30 dB scale is most useful for strong audio signals; whereas, the 90 dB scale is most useful for very weak audio signals. The “Gain” slider can be used to amplify or reduce the spectrum level on the display and shift the color scale seen on the display accordingly. Experiment with Signal Range and Gain as well as palette color assignments to obtain the best combination for the signal of interest. It is best to experiment with Range and Gain modifications while Spectrogram is running the Scan Input mode using the scrolling spectrogram display. Then you can immediately see the effect of each change that can be made here.

- If Spectrogram is operating in the “Analyze File” mode, the changes which you make to the color palette or to Signal Range and Gain may not be immediately visible on the display. The “Redraw” button is used to redraw the spectrogram with the new palette and range and gain selections. The Redraw button is only active in the Analyze File mode.

- The “Reset” button erases any changes in the User palette that you have made, and restores the colors to those that existed when the Spectrum Colors dialog box was last opened. The “Cancel” button erases any changes in the User palette that you have made, and closes the Spectrum Colors dialog box.

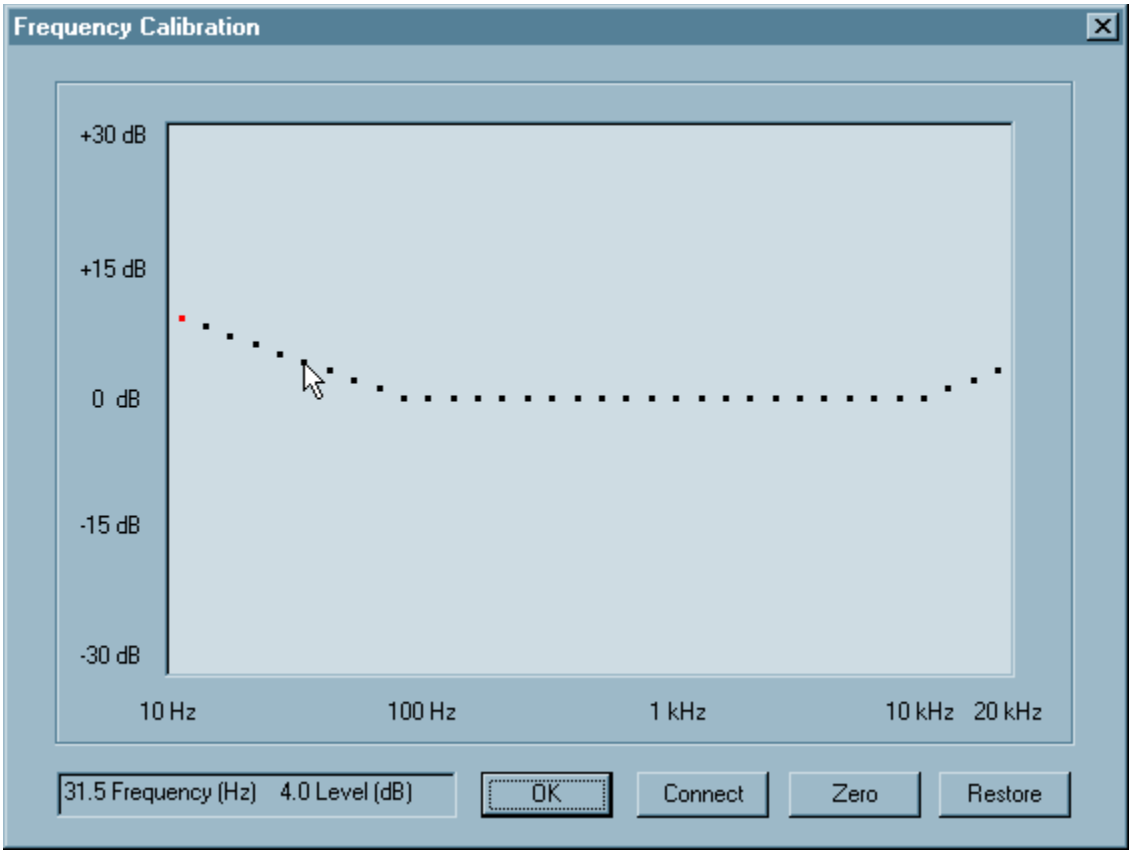
- The “OK” button applies the palette selections that you have made to the scrolling spectrogram display.

DISPLAY CALIBRATION

Many interacting factors will affect the absolute power level of frequency components shown on the display. While the relative power levels of frequency components to each other will always be correct, the gain of your sound card and the combination of frequency analysis parameters selected will affect absolute measurement. There are two methods available to calibrate the Spectrogram display as described below. Both of these methods affect the signal level on the display, but do not modify the audio signal itself.

Signal gain on the display can be adjusted using the "Gain" control available in conjunction with the Color Controls or, in the case of the spectrum analyzer scope display, can be adjusted using the vertical slider on the right edge of the scope window. These gain controls will increase or decrease signal gain by a constant factor across the entire frequency band.

Calibration at individual frequency points across the band can be accomplished by choosing "File - Freq Calibration" from the Spectrogram menu to bring up the Frequency Calibration dialog box which is illustrated below.



- Each point on the frequency calibration plot can be moved with the mouse to establish a calibration curve for your particular equipment. A readout of frequency and calibration level is given at the bottom left of the dialog box. Setting all values to zero will result in no frequency calibration being applied to the display. The "Zero" button can be used to set all points to zero.

- Any two points on the curve can be connected with a straight-line segment. Select any two points with the

mouse, and these points will be colored red. Then press the “Connect” button to fill in points between the two selected.

- The “Restore” button erases all changes you have made to the frequency calibration curve and returns every point to its value when the Frequency Calibration dialog box was last opened.

- The “OK” button applies the modified frequency calibration curve to all future Spectrogram calculations.

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 "Parameters - Change" from the File Menu 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.

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 dialog box will then appear with the starting and ending locations filled according to your selection.

You can return to your starting spectrogram prior to any modification by choosing "Parameters - Restore" from the File menu. The starting spectrogram display is established the first time you choose "Parameters - Change" after analyzing a new data file or recording a new sample. You can return to the starting spectrogram again and again until you analyze a new data file or record a new sample. Note that this function is not available if you have only 8MB of RAM memory.

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 using the "Analyze File" mode, select a point in time by moving the display cursor to a feature of interest. Then perform a single left-button mouse click at that point. A plot of the spectrum at that point in time will then be calculated and displayed using the Spectrum Analyzer Scope. 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 "Parameters - Restore" from the File menu.

SPECTROGRAM PLAYBACK

If you have a windows compatible sound card installed, you will also be able to play back the spectrogram by clicking the 'Play' or 'Play Wdw' buttons. The Play button plays back the entire length of the .wav file, while the Play Wdw button plays back only that portion of the spectrogram that is visible in the Spectrogram Window.

SIMULTANEOUS OPERATION

You can run the Spectrogram program multiple times simultaneously in order to compare different sound samples with each other. However, only one program at a time can access the sound card. This means that only one program at a time can record, playback, or scan audio data.

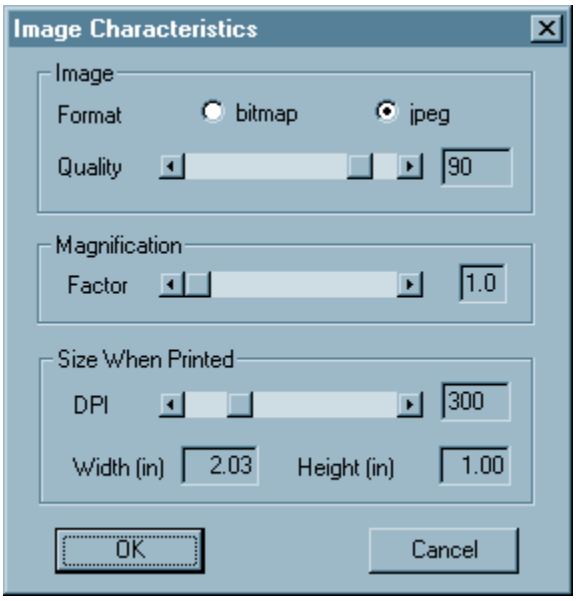
SAVING AUDIO AND IMAGE FILES

You can save a .wav file of the digital audio of your spectrogram by choosing "Save Wave" from the File Menu. The displayed area of the spectrogram will then be saved as a standard Windows wave file in PCM format.

You can also save a jpeg image or bitmap of the Spectrogram Window by choosing "Save Image" from the File Menu. You can 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 save feature is available only for single channel spectrograms.

Note that if you wish to save scrolling spectrogram images created in the “Scan Input” or “Scan File” modes of operation, then you must be operating with Scroll Memory turned on.

Once you have chosen to save an image, the Image Characteristics dialog box shown below will allow you a choice of image parameters.



- The “Format” buttons give you a choice of saving either a Windows bitmap file, or a jpeg image file of the spectrogram.
- For jpeg image files, you also must select an image quality. The higher the image quality chosen, the lower the image file compression.
- Image magnification is provided as an option where the bitmap or jpeg image is to be printed or displayed in another application. Often an image printed at a high value of dots per inch will appear much smaller than on your computer screen. Use the “Size When Printed” controls to predict the final printed size of your image as determined by magnification and the dots per inch of your printer.

PRINTING

PRINTING FROM SPECTROGRAM DISPLAY

With a graphics capable printer attached to your computer, you can print the spectrogram display from the Analyze File mode by choosing “File - Print Window” from the main 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.

You can also print a spectrogram from the Scan File or Scan Input modes provided that you have been operating with Scroll Memory turned on.

When printing a spectrogram to a black and white printer, 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 “File - Print Window” from the main menu. When printing to a black and white printer, 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.

DATA LOGGING

Spectrogram provides an automatic data logging capability for researchers who wish to record frequency and harmonic power levels from audio data. This capability is provided only in the “Analyze File” mode for single channel spectrograms.

FULL SPECTRUM

To save the frequency, and power level of every point in a single channel spectrogram, choose "File - Log Data” from the Spectrogram menu. Data is saved in a text file that records FFT output point number, frequency, and power level for the entire width of the spectrogram. The log file for the entire spectrogram can be enormously large, so it is best to drag select a smaller segment of interest on the spectrogram before saving a full spectrum log.

SINGLE SPECTRUM

To save the power 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 “File - Log Data.” Data is saved in a text file that records that records the time, FFT output point number, frequency, and power level at one point in time.

SYSTEM REQUIREMENTS & INSTALLATION

Spectrogram requires Windows 95, Windows 98, or Windows NT 4.0. Spectrogram does not run properly under Win 3.1 or Win 32s.

Spectrogram runs best with 32MB or more of RAM memory. You can run Spectrogram with only 8MB of RAM. However, not all functions for modifying the Spectrogram display will be available.

Spectrogram is designed for use with 256 colors. Use of more that 256 colors is not recommended because of the speed penalty incurred in real-time display update.

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 just copy gram.exe, gram.hlp, and gram.cnt to any convenient directory on your hard drive. You may then also create a shortcut to gram.exe for display on your desktop. Each time the Spectrogram program is closed, it will save an initialization file (gram.ini) containing analysis and display settings to be used the next time the program is run.

LIMITATIONS

If you are using less than 32 MB of RAM and you encounter a severe slowing of the program or lengthy disk activity, the program requires more RAM than you have available and Windows is attempting to use the hard drive as virtual memory. The only solution to this problem is to analyze only small sound samples of short duration, or to install more RAM.

Spectrogram runs best on systems using 256 colors. Because the program must update the screen many times a second, the large bitmaps of true color screens will slow Spectrogram significantly. Using 256 colors will reduce annoying flickering of your mouse pointer or cursor during analysis or scanning. Also, not all of the palette controls are available with more than 256 colors. So use 256 colors for the best performance in running Spectrogram.

If you are using a colorful screen background bitmap, Spectrogram can change the background to odd looking colors while running. This isn't a bug. Spectrogram must take control of all bitmap color assignments in order to produce its own display. Your background will be restored when Spectrogram is closed.

Any other programs running simultaneously can interfere with Spectrogram, particularly programs that access the hard drive while Spectrogram is scanning a file or recording to disk. For best performance, shut down these other programs.

Don't expect to be able to scan wave files direct from a CD ROM drive. Instead, copy any wave files to be scanned to your hard drive. You can analyze any file from a CD ROM drive. However, real-time scanning puts a heavy load on your computer and doesn't leave much time for data transfer from disk. CD ROM drives are just not fast enough yet. Of course, CD music disks can be scanned by connecting the audio output of your CD player to the input of your sound card and using the "Scan Input" function.

Likewise, don't expect to be able to scan wave files direct from a floppy disk, or to record direct to a floppy disk. You can analyze any file from a floppy disk, but real-time scanning or recording is not possible using floppy disks.

Please note that use of Save Enable during Scan Input 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 run Quick Save after an extended period of scanning, then you must disable your computer’s power saving mode so that the hard drive will remain continuously powered.

Please don't automatically record everything at 44kHz. Lower sampling rates are often a better choice to produce high resolution spectrograms.

MEMORY USAGE

Spectrogram can require an enormous amount of memory, particularly for high resolution, two channel spectrograms using 24 bit display color. For example, a 30 second, two channel spectrogram, computed using a 2048 point FFT and a 5 msec time scale, will require 36 mbytes just for a 24 bit color bitmap. If you ever see the warning "Not Enough Display Memory," your computer cannot allocate the memory needed for the entire display bitmap.

Solutions to such memory shortages are:

1. Use 8 bit (256 color) display color instead of 24 bit display color when running Spectrogram to reduce display bitmap memory by two thirds.

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

3. Increase the spectrogram frequency and time scales in order to reduce the size of the needed display bitmap.

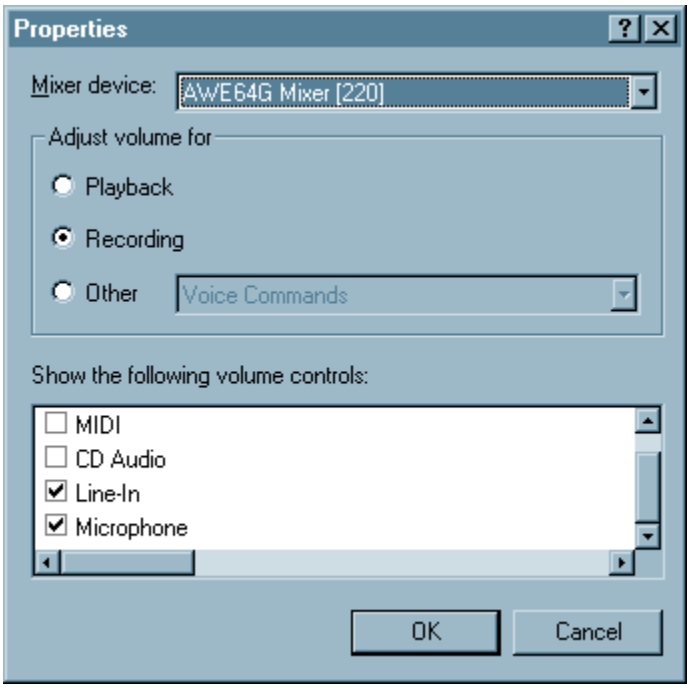
4. Reduce the spectrogram time span.

Use of 256 colors also has the advantage of improving the performance of real-time scanning and recording of wave files or audio input from your sound card.

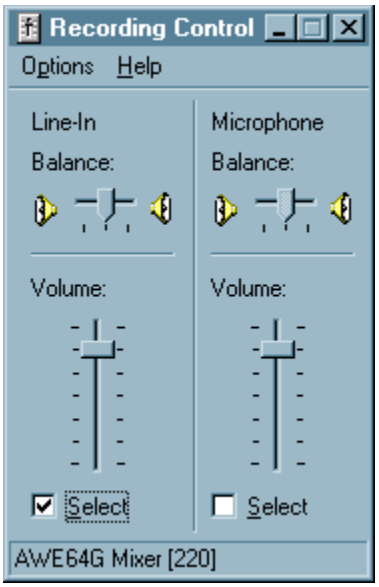
SOUND CARD INITIALIZATION

First, connect an audio data source to the signal input jack of your sound card. Either Line-In or Microphone inputs may be used depending on the signal level expected. It is always best to turn off your computer before making these connections.

Then you must instruct your Windows sound card to process audio signals. Windows 95 provides a separate Volume Control program for this purpose. Choose "File - Volume Control" from the Spectrogram menu (or Function Key F6). This will start the Volume Control program. Then choose "Options - Properties" from the recording control menu. Then mark the "Recording" button, and under "Show the following volume controls" choose "Line-In," and "Microphone."



Now when you click "OK" you will see a Recording Control allowing you to adjust the volume for Line-In and Microphone recording. Select either Line-In or Microphone inputs here depending on the audio source that you intend to use. It is best not to choose both inputs simultaneously, but to choose one or the other depending on the audio source.



Occasionally this Recording Control will also have an active menu item “Options – Advanced Controls.” If this menu item is available it should also be selected. This selection will make available an “Advanced” button on the Recording Control for turning Automatic Gain Control (AGC) on or off. AGC is often useful to keep the recording level automatically within the correct range.

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 rshorne@mnsinc.com.

The Spectrogram Program is updated periodically to add features and fix bugs reported by users. You can always download the latest Spectrogram update from http://www.monumental.com/rshorne/gram.html.

CREDITS

The following persons or organizations have provided free software via the Internet that has greatly contributed to the capabilities of the Spectrogram program.

The original FFT code was contributed by Philip Van Baren.

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