SFM SOFTWARE RELEASE

March, 1983

Documentation Update

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This manual documents the 1 March 1983 release of the SFM software.

PREFACE

The March 1983 software release for the Sample-to-Disk (tm) system provides several new SFM commands.

The new EDIT command is used to splice sound files together. You can splice together whole files or short segments created with the EXTRACT command.

There are several new commands for spectral manipulation. You can now smooth, invert, autocorrelate and rescale spectra. You can also zero out regions within a spectrum and compare one spectrum with another. Manipulated spectra can be converted into impulse responses and used as filters.

In addition, there are a few general features that make using the SFM more convenient. We will start with these:

Saving and Recalling Spectral Files

Spectral files can now be saved on and recalled from the Winchester disk. This enhancement saves a great deal of time since each spectrum or manipulated spectrum need not be recalculated.

The current spectral display is now automatically saved in the file .SPECTRU as soon as it appears on the screen. In addition, you can save the current spectral display under another filename with either the SAVE or REPLACE commands. All spectral files in the current catalog are listed at the bottom of the SFM catalog display.

To recall the spectral file stored in .SPECTRU, you use the command RECOVER with no filename. To recall another spectral file, use the command RECOVER <filename>. You will continue to use the OLD command to recall signal files and to use the UNSAVE command to erase either signal or spectral file from the Winchester disk.

The .SPECTRU file is useful for quickly recalling a spectral display after you use the PRINT command. It is also useful when you are going back and forth between the spectral and time domains. When you are performing a series of spectral manipulations, you may wish to save each stage in the process in its own named file.

Using the BREAK Key

Previously you could press the BREAK key to interrupt filter computations or running spectra computations. Now you may press the BREAK key to interrupt the replotting of either signal or spectral files. This feature allows you to enter new commands without waiting for the entire screen to be plotted.

Using the SET SCALE Command

You have been introduced to the SET SCALE command in the main SFM manual. This command can now be used to change the scale of the display to be greater than 1 (the density of a full power sine wave). The ability to indicate a scale greater than 1 is useful because some of the new spectral manipulation commands can result in the computation of a density greater than 1.

Commands Under Development

There are a few commands listed by the MENU command that are still under development and are not documented here. These are MODULATE, CEPSTRUM, and OVERLAY.

SPLICING SOUND FILES

The EDIT command is used to splice sound files together. When this new command is used in conjunction with the EXTRACT command, the possibilities for new timbres are endless. You can splice completely different sounds together. You can interlace segments from one sound file with those of another. Or you can extract a short segment from a file and splice it to itself many times in a repetitive cycle.

The splicing procedure is simple. First prepare the pieces to be spliced together by recording, extracting, or otherwise generating signal files. Store each piece in its own file on the Winchester disk.

Next type the command EDIT. (It doesn't matter what the current file is.) A "Butt Splice" menu will then appear on the screen. You use this menu to built up a <u>splice file list</u>, or a list of the files that you want spliced together in a new file. You type in the name of each file to be inserted and the number of times it should be repeated. You can enter the same filename as many times as you want in the list. A maximum of ten filenames may be entered. When you have finished listing all the filenames, press RETURN instead of entering a filename. Then enter a name for the new spliced file. The files on the list will then be spliced together. The new spliced file will be saved on the Winchester disk under the specified name and will become the new current file.

In the following exercise, you will extract a single waveform cycle from the TRUMPET file. Then you will use the EDIT command to create a new file which consists of the single cycle replicated 500 times. This sort of splicing can be used to stretch out a note to any desired length or to "freeze" a tone.

1. Type

   OLD TRUMPET

2. Press RETURN for display.

3. Type

   DISPLAY 0.033

4. Move the cursor to the zero crossing at 0.033 640 and type

LAB T1

This is the first point in the cycle and will be the first point in the extracted file (Figure 1).

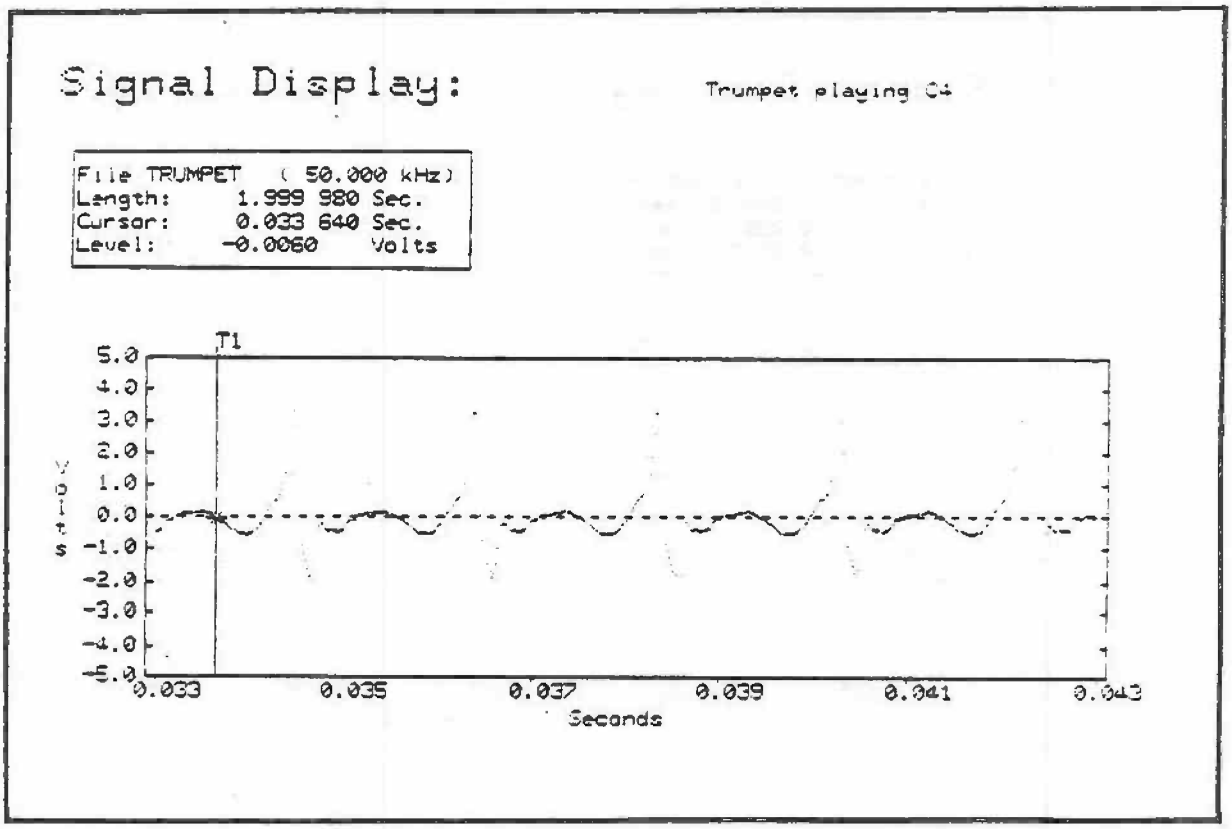

Figure 1

5. Move the cursor to the end of the cycle 0.35 580 and type

LAB T2

This is the last point in the cycle and will be the last point in the extracted file (Figure 2).

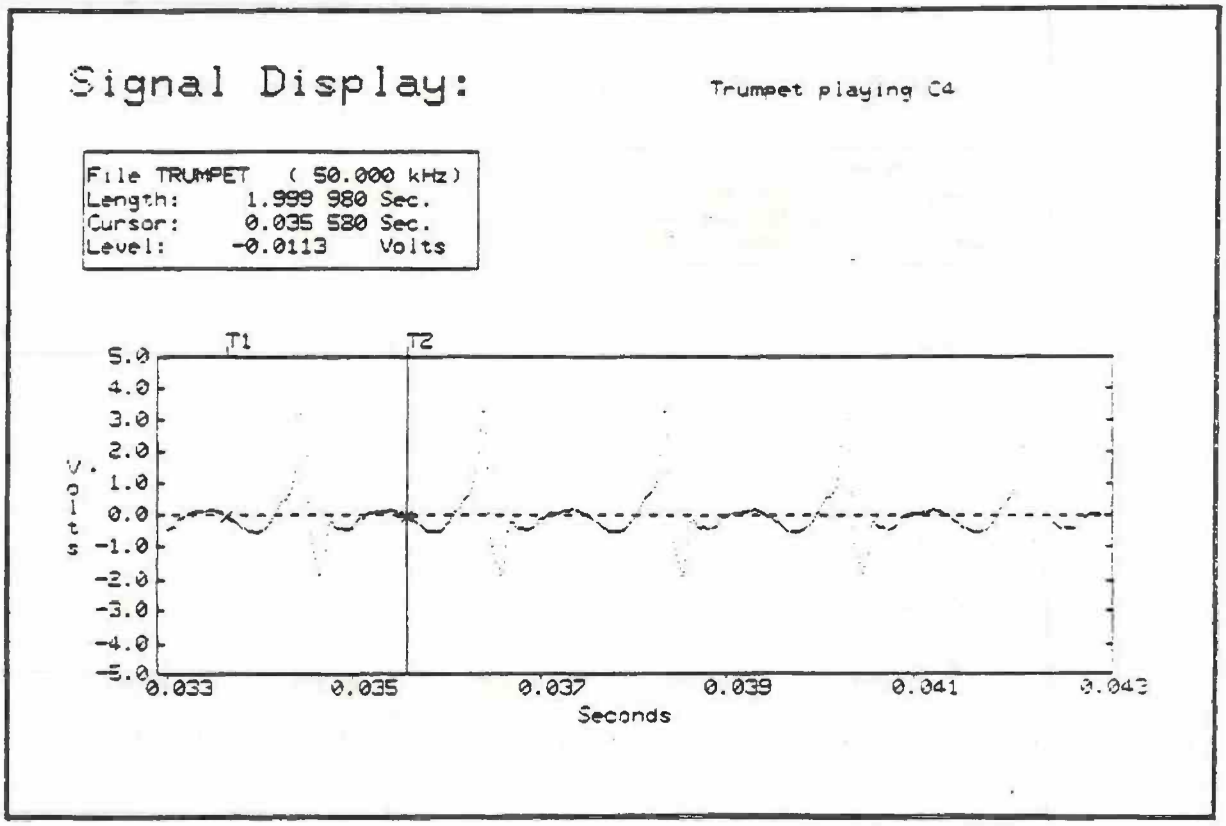

Figure 2

In order to create a clean spliced file with no pops, you want the level of the last sample before a splice as close as possible to the level of the first sample after the splice. Extracted files which begin and end on a zero crossing can be spliced together cleanly.

When there are big gaps in the levels between the samples at the splice points, audible pops will occur in the new spliced file.

6. Type

   EXTRACT T1 TO T2

7. Press RETURN to display the extracted waveform cycle (Figure 3).

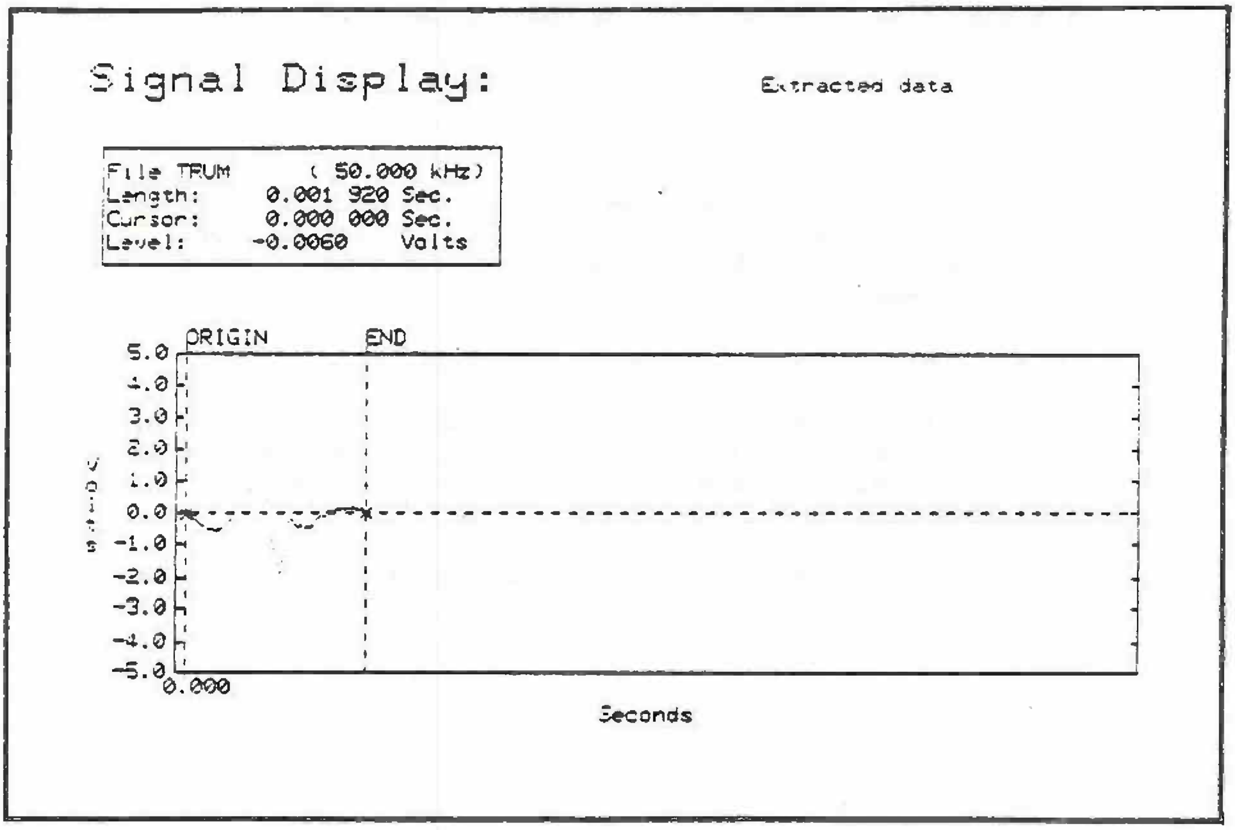

Figure 3

8. Type

9. SAVE TRUM

   to save this extracted segment on the Winchester disk.

10. Type

    EDIT

    This command recalls the "Butt Splice" menu to the screen. You will first specify "File #1:" or the first file to be inserted into the new spliced file.

11. Type

    TRUM

    and press RETURN.

    Then you will specify "Repetitions:" or the number of times the file should be inserted into the new spliced file.

12. Type

    500

    and press RETURN. TRUM will be spliced to itself, or repeated, 500 times. To insert a file into the new spliced file only one time, press 1 or RETURN. Otherwise, you can type in any desired number of repetitions.

    You will next be asked to specify "File #2:"

13. Press RETURN instead of a filename to indicate that you do not wish to splice any more files. (Although your splice file list consists of only one file, up to ten files can be entered into the splice file list.)

    The bottom of the screen will ask you to enter a filename for the new spliced file.

14. Type

    CYCLE

    and press RETURN.

    If you wished to abort the splicing process at this time, you could simply press RETURN without entering a filename. You would then be returned to the file that was current when you entered the EDIT command.

    Since you did enter a filename, however, the splicing process will now begin. The status of the splicing process will appear on the first Repetitions line.

    When splicing is completed, the bottom of screen will display the number of splices (500) and the number of sectors (193) which the file uses on the Winchester disk. Then the Butt Splice menu will be cleared from the screen. CYCLE will become the current file and will be saved on the Winchester disk. The length in seconds (0.969 980) of CYCLE will be displayed on the screen.

15. Press RETURN to display CYCLE (Figure 4). You will note that the splices are undetectable.

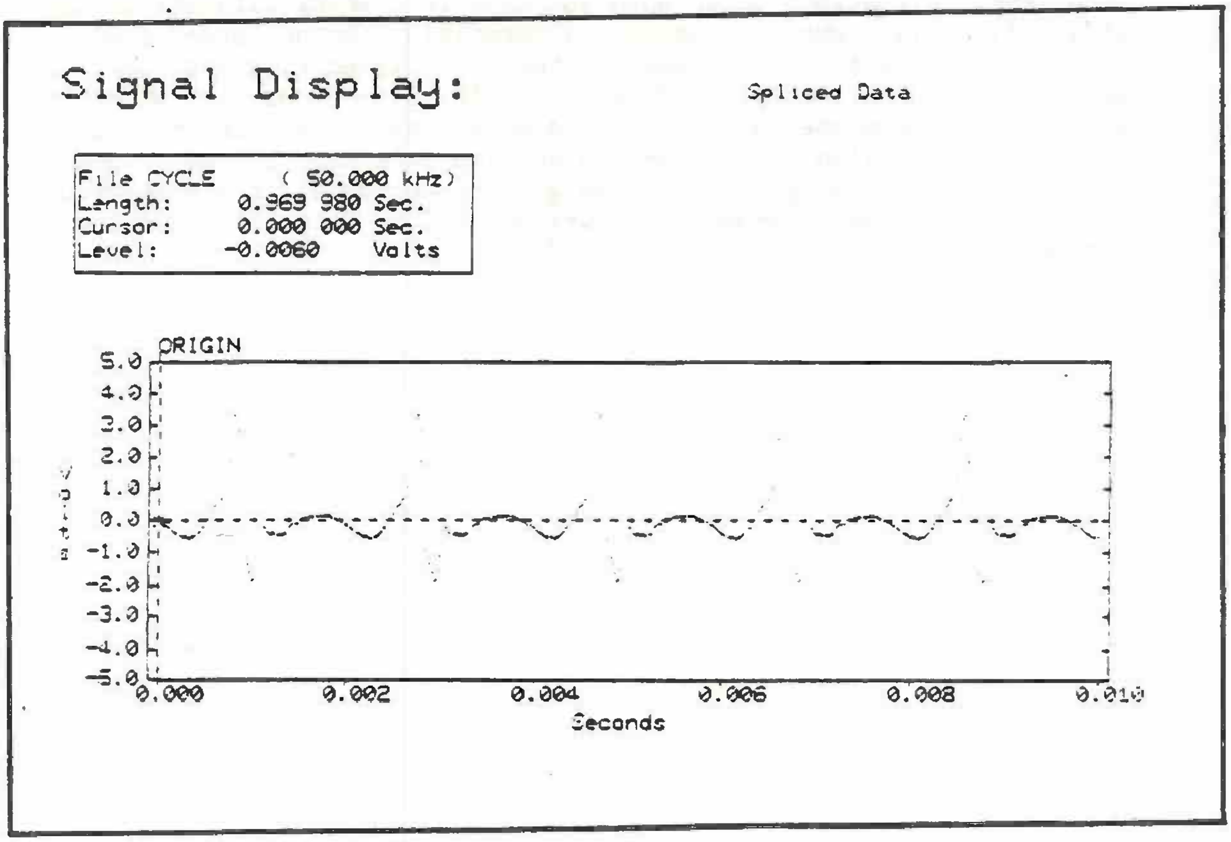

Figure 4

16. Type

    PLAY

    to hear the sound. You should not hear any pops due to the splicing.

EDIT PROGRAM MESSAGES

As you experiment further with the EDIT command, you may run into various error messages. These are well documented on the screen.

One example of an error situation occurs when the spliced file you have specified is too long to fit in the remaining space in the current catalog. In this case, an error message will be displayed briefly at the bottom of the screen. In addition, the splicing program will be aborted and you will be returned to the file that was current when you entered the EDIT command. No information, other than the splice file list, will be lost.

Other error situations occur when you type in a wrong filename in the splice file list, when you specify a repetition factor larger than 65K, or when you specify a name for the new spliced file that is already in use on the splice file list. In these cases, the wrong entries will be erased and you can re-enter the correct information. If you enter a filename for the new spliced file that already appears in the current catalog, you will be given a choice as to whether you wish to change the filename or to write over the file stored on the Winchester disk.

USING THE SPECTRAL MANIPULATION COMMANDS

This chapter describes the new spectral manipulation commands: SMOOTH, IVT (invert), IMPULSE, SCALE, SUBTRACT, and AUTO (autocorrelate), as well as the procedure for zeroing out regions in a spectra. Step-by-step instructions are used to introduce the new spectral commands and demonstrate some powerful applications. Note that these features are primarily designed for research applications by users with some background in spectral analysis.

* * * * * * * * *

In the first experiment, you will smooth (SMOOTH) and invert (IVT) the spectrum of the TRUMPET sound file, convert the resulting spectrum into an impulse response (IMPULSE), and use it as an inverse filter on the TRUMPET file.

Smoothing a Spectrum

The SMOOTH <n> command is used to average adjacent points on the spectral display. <n> is the number of points to be averaged on either side of each FFT point. This command is useful for smoothing out the appearance of a noisy spectrum in order to see the significant frequency components. It is also useful for creating spectral envelopes for filters and inverse filters.

You can repeat the SMOOTH command for further smoothing of a spectrum.

1. Type

   OLD TRUMPET

   to recall the original sound file.

2. Type

SPE .0

This spectrum (Figure 1) will be automatically saved in .SPECTRU.

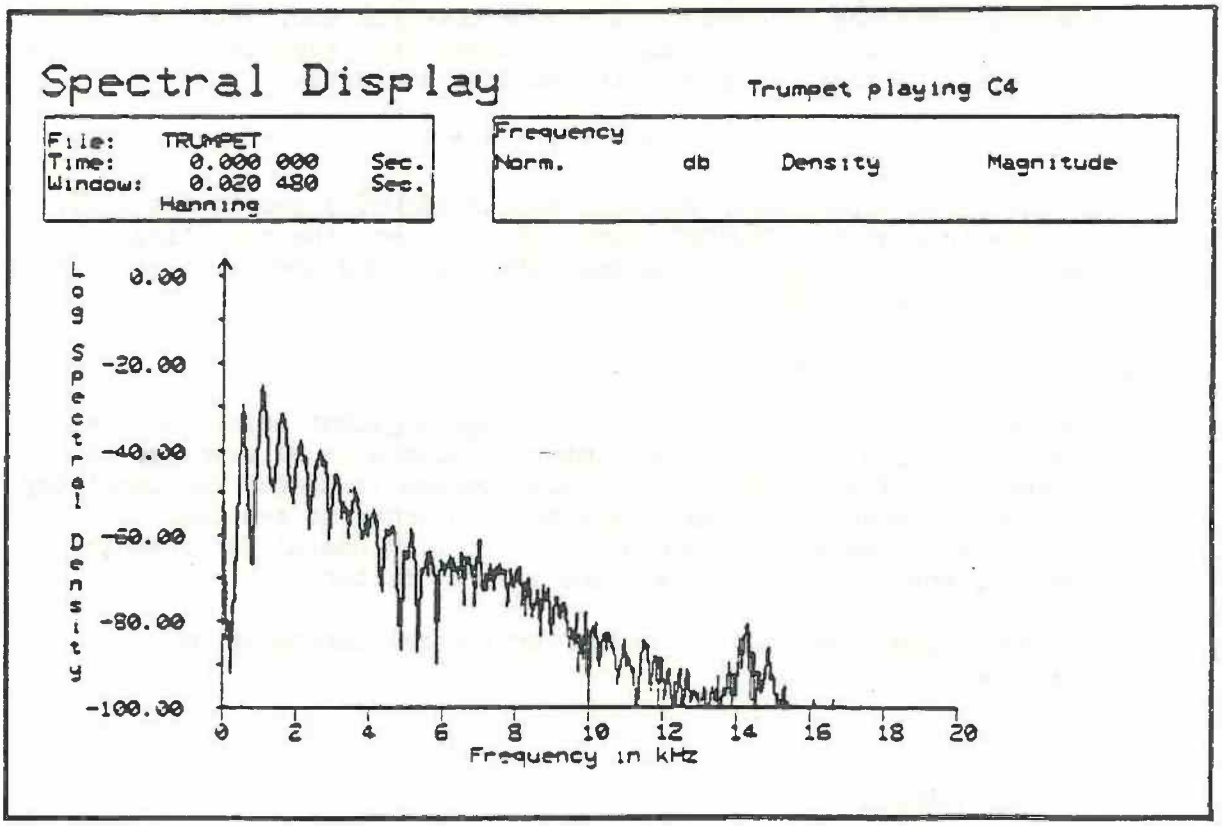

Figure 1

3. Type

SMOOTH 10

The SMOOTH 10 command averages 10 points on either side of each FFT point. There will be a short delay while the computation takes place.

The new spectrum (Figure 2) will be saved in .SPECTRU, replacing the original spectrum.

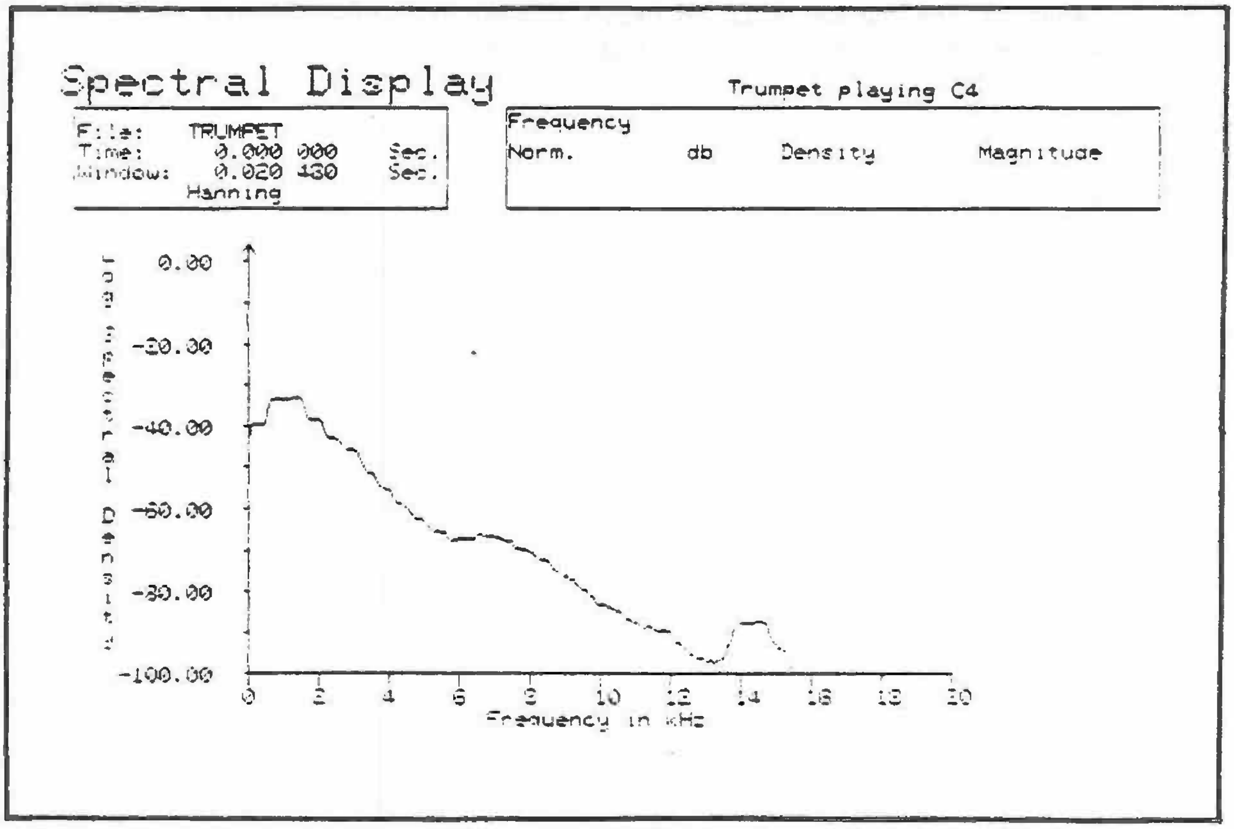

Figure 2

Let's save the smoothed spectrum in its own file.

4. Type

SAVE SM010

The smoothed display is now saved in the current catalog under the filename SM010.

Inverting a Spectrum

Inverted spectra are useful in making "whitening"* filters. You can invert the spectrum around a specified value in dB or around the current cursor location.

The command IVT <n> will invert the spectrum so that points at 0 dB in the original spectrum will appear at <n> dB and points at <n> dB will appear at 0 dB.

The command IVT * will invert the spectrum so that points at the level of the cursor will be repositioned at 0 dB. Points at 0 dB will be repositioned at the original level of the cursor.

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* A "whitening" filter is a filter which, when applied to a signal, flattens out its spectrum to equal the strength of all frequency components. The resultant spectrum resembles white noise, although the filter is not actually adding noise to the signal.

1. Type

   IVT -100

   The smoothed spectrum will be inverted around -100 dB (Figure 3). Points at 0 in the original display will appear at -100 dB; points at -100 dB will appear at 0 dB.

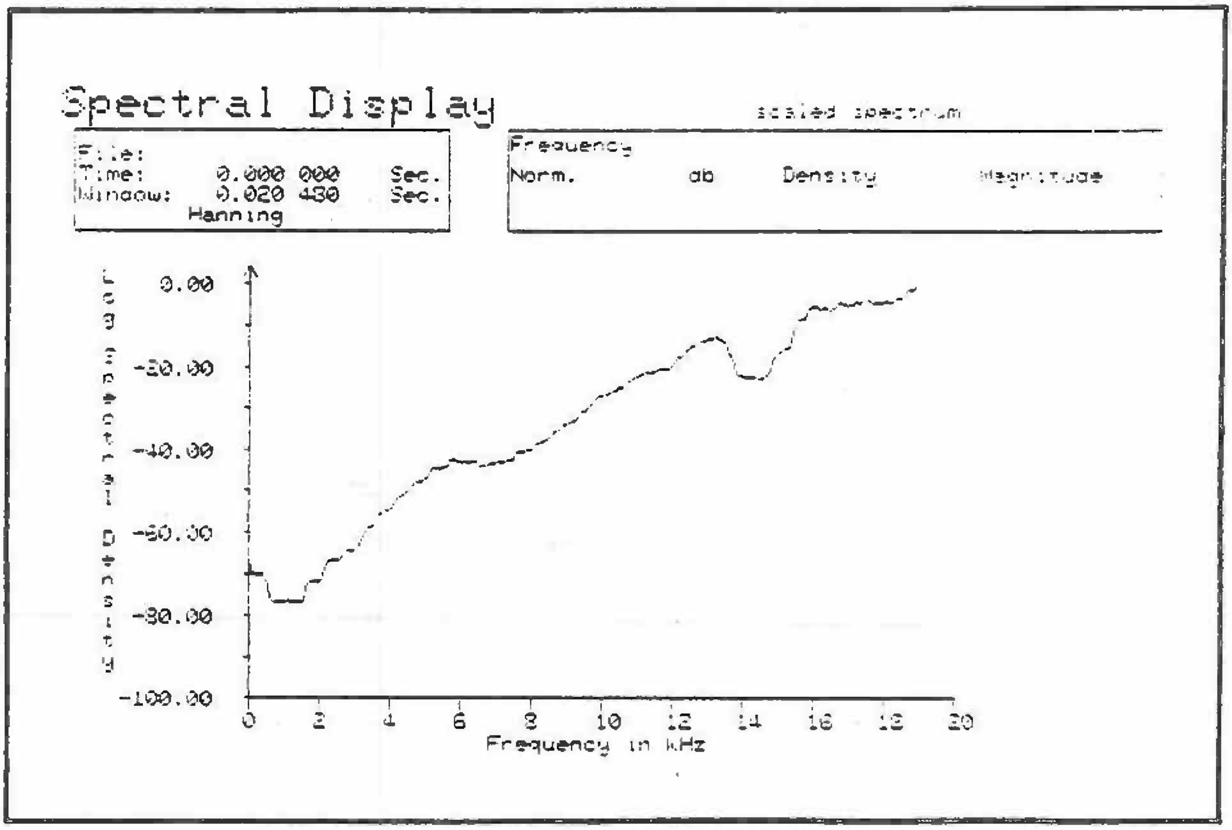

Figure 3

Now let's invert the smoothed spectrum around a cursor location.

2. Type

   RECOVER SMO10

   The smoothed spectrum will be displayed.

3. Move the cursor to a frequency of 13281.2500. This point has value in dB of -97.53 (Figure 4).

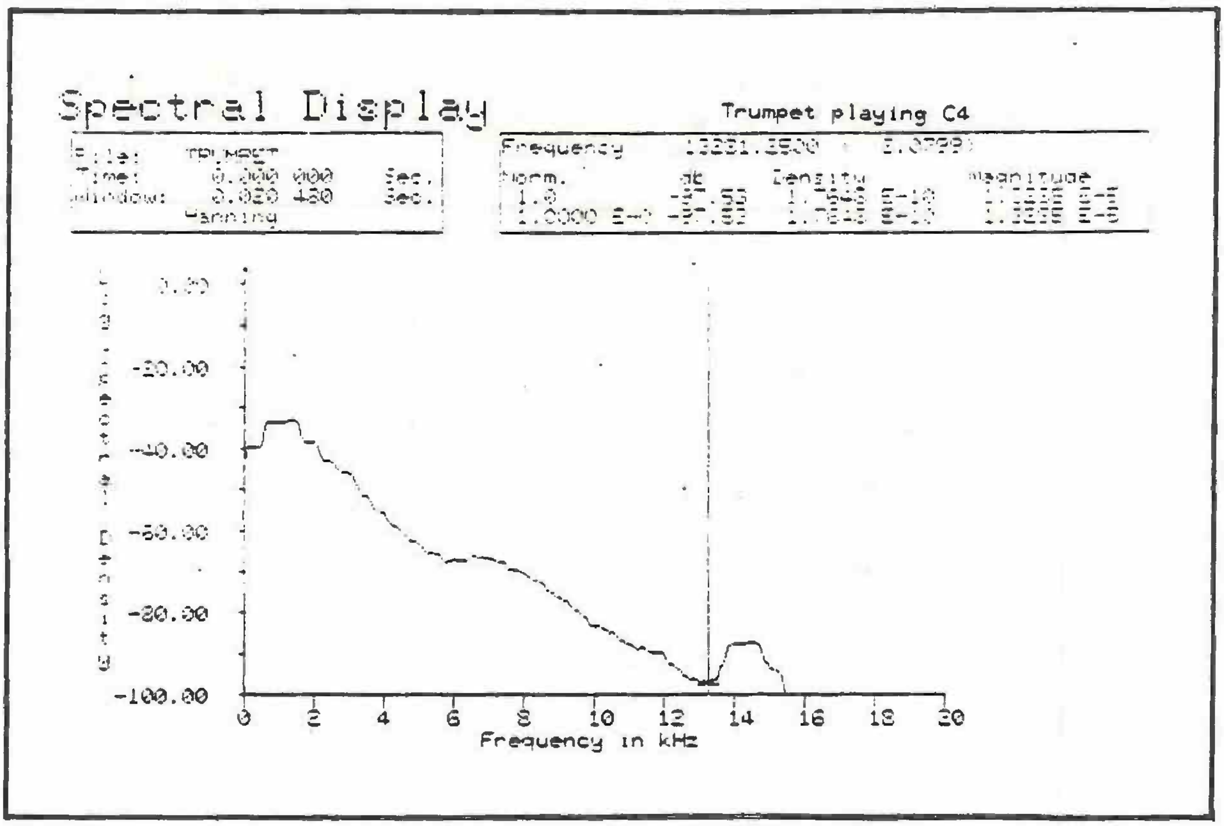

Figure 4

4. Type

IVT *

The spectrum will be inverted so that all points previously at -97.53 dB appear 0 dB (Figure 5).

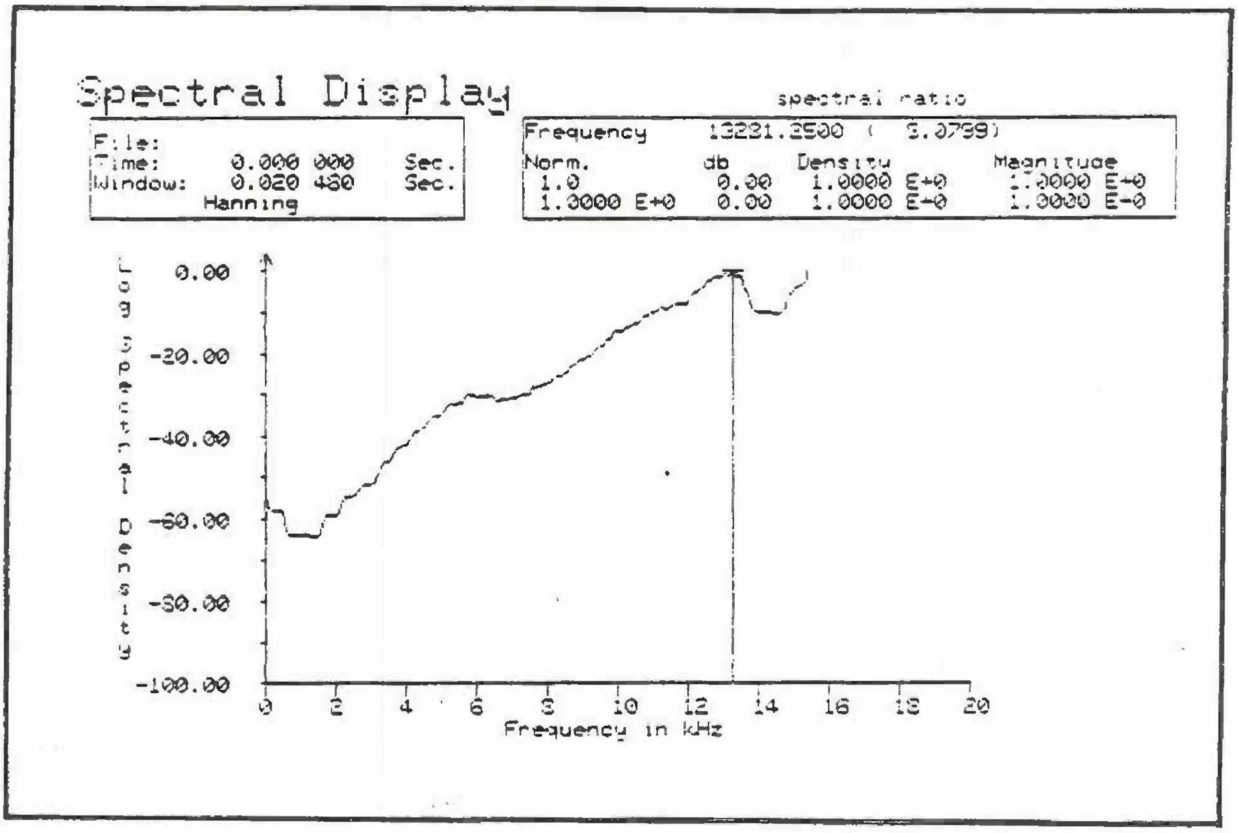

Figure 5

You will note that some of the points in the spectrum now run off the screen and are above 0 dB. Above 0 points can cause overflows during the computation of a filter impulse response from a spectral envelope. Therefore, before you convert this spectrum into an impulse response, you must get rid of these unwanted above 0 points.

Zeroing Out a Region in the Spectrum

Any region in the spectrum can be zeroed out. First place the cursor on the lowest frequency in the region and press the period key on the keypad. Next move the cursor to the highest frequency in the region and press the comma key on the keypad. All points within the region will be set equal to 0 density.

Let's use this technique to remove the irrelevant points from the inverted spectrum.

1. Type

   SET RANGE 25

   to change the horizontal scale so that you will be sure to remove all the points above 0 dB, including any above 20 kHz.

2. Move the cursor to frequency 15039.0613 (Figure 6).

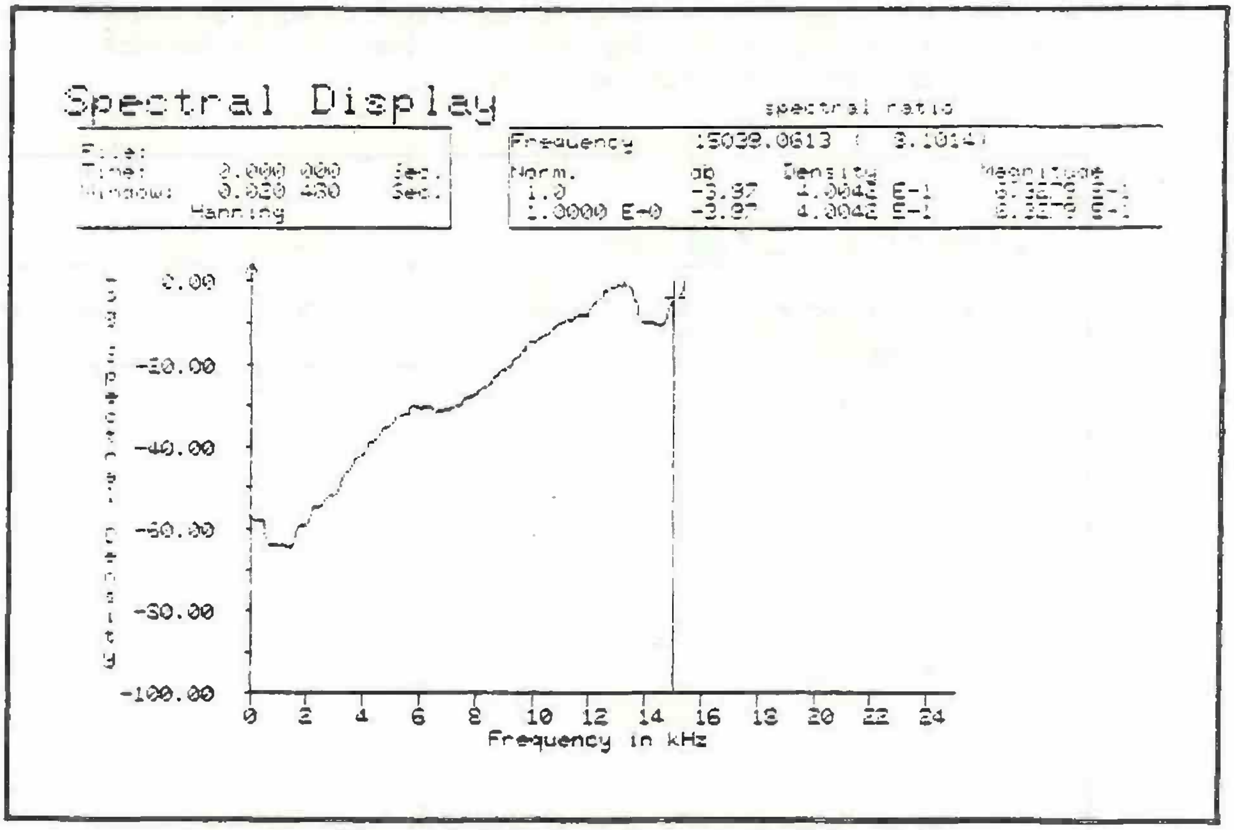

Figure 6

3. Press the period key on the keypad.

4. Move the cursor all the way to the right (beyond 25 kHz) and press the comma key.

   All the points beyond the first cursor position will be removed from the file (Figure 7). You will note that now the highest point in the spectrum occurs at 0 dB.

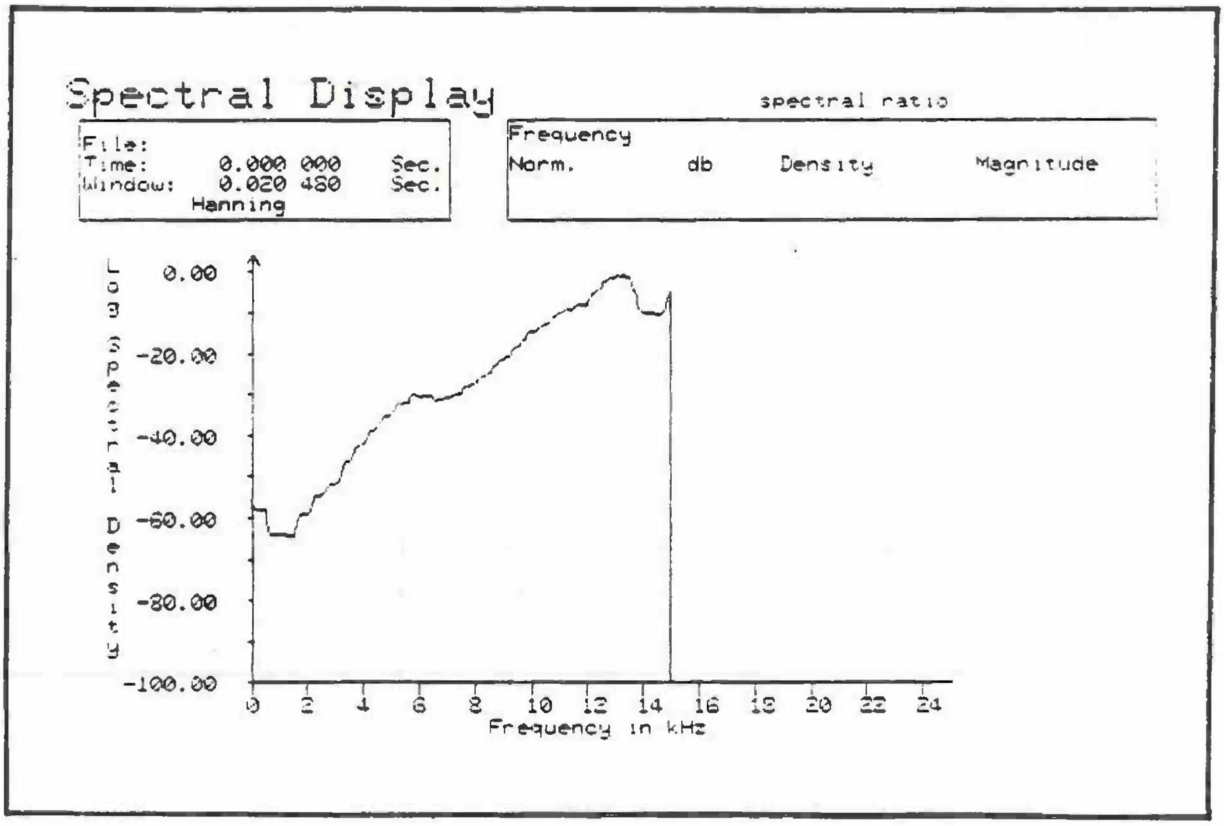

Figure 7

Creating a Filter Impulse Response

The IMPULSE command can now be used to convert this spectrum into an filter impulse response.

1. Type

   IMPULSE

   The screen will say:

   Computing inverse spectrum

and will ask you to select a window shape.

2. Specify 2 for Hamming window.

3. Type

   SET HORIZONTAL .02

   to compress the horizontal scale.

4. Press RETURN.

   The impulse response will be displayed (Figure 8).

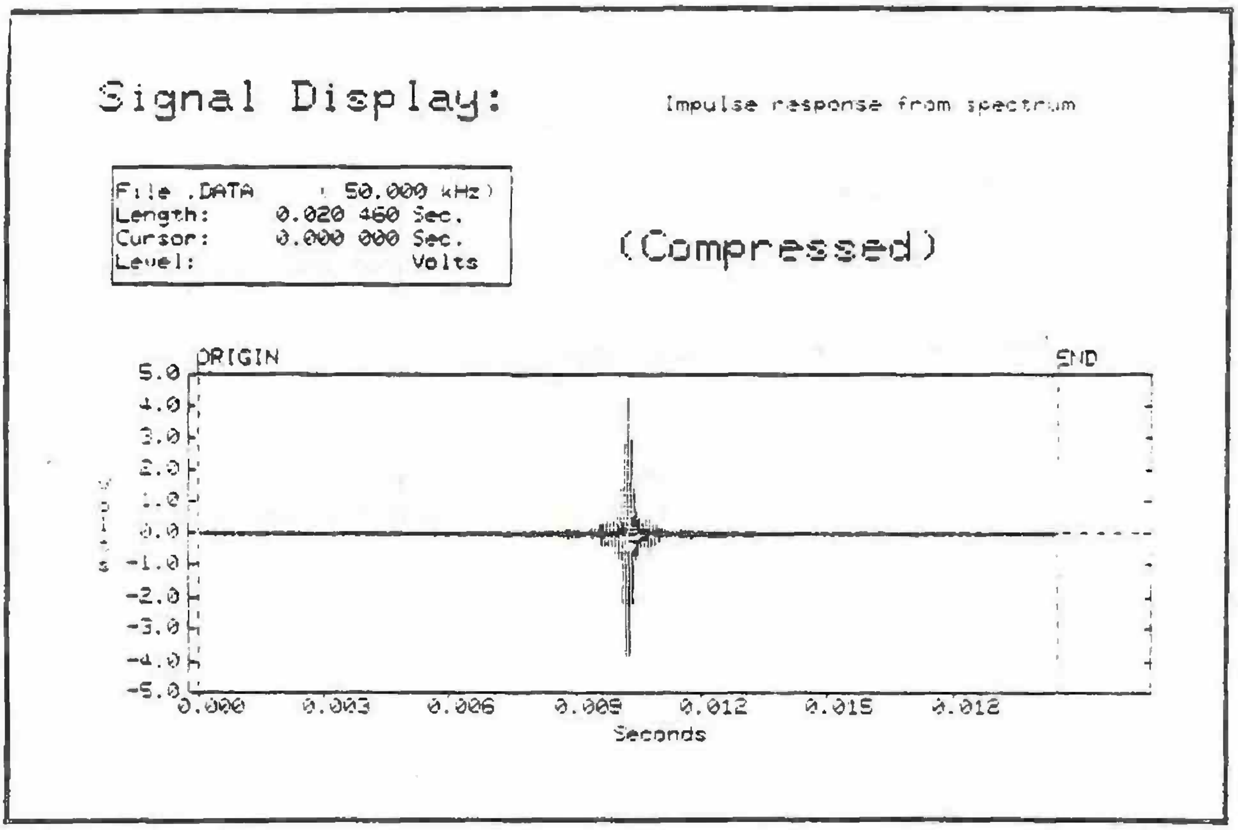

Figure 8

5. Type

   SAVE TRUMINV

   to save the filter impulse response on the Winchester disk.

Using the Inverse Filter

Now you are going to filter the original TRUMPET file with the newly created inverse filter.

Before doing so, you should change the gain factor to increase the amplitude of the filtered waveform.

1. Type

   SET GAIN 24

2. Type

   OLD TRUMPET

   to recall the original signal file.

3. Type

   CONVOLVE TRUMINV

   to filter the TRUMPET file with its smoothed and band-limited inverse.

4. When the filtering is completed, type

   PLAY

   if you wish. You will note that the volume is diminished. Applying an inverse filter tends to reduce the amplitude of the signal.

5. To examine the spectral display, type

SPECTRUM .01024

Use this time value to compensate for the delay caused by the filter. You now have a flat whitened trumpet spectrum (Figure 9).

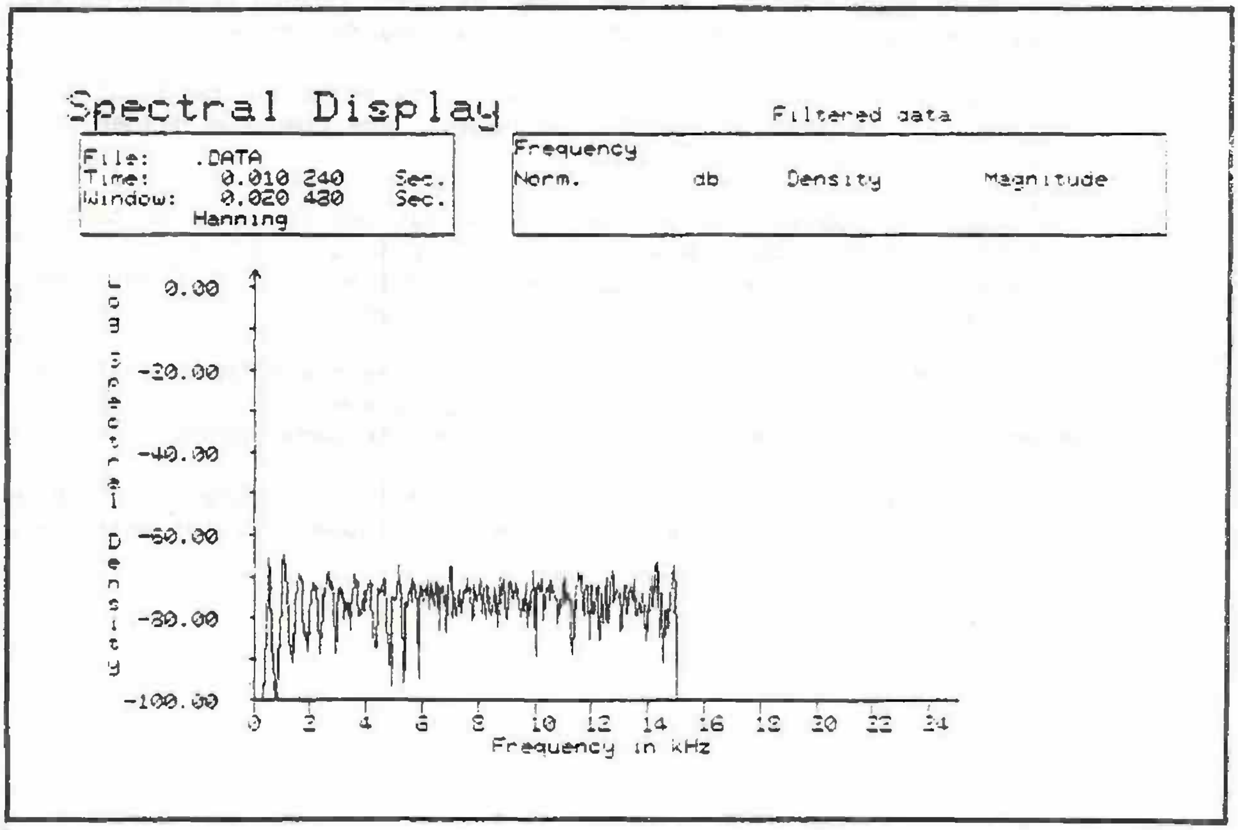

Figure 9

* * * * * * * * *

Now you are going to use the spectral manipulation commands to create a trumpet matching filter which you will convolve with an impulse train to produce a trumpet-like spectrum.

1. Type

RECOVER SM010

so that you start the experiment with the smoothed trumpet spectrum.

Rescaling a Spectrum

If an impulse response is to be computed from a spectrum, the densities of the points within the spectrum must fall within the following range. On the one hand, the point at the peak of the spectrum should have a spectral density of 1 (0 dB) or close to 1. On the other hand, no point in the spectrum should have a spectral density of more than 1. As mentioned earlier, points above 0 dB will cause overflows in the computation of an impulse response.

The density of a spectrum may be adjusted by means of the SCALE command. It is used to rescale, or replot, the spectrum higher or lower within the spectral display.

The SCALE <n> command can be used to rescale the spectrum so that each point in the spectrum will be moved up or down by <n> dB. If you wish to scale a spectrum up, use a negative value. If you wish to scale a spectrum down, use a positive value.

The SCALE * command can be used to rescale the spectrum so that the point at which the cursor is located will be moved to 0 dB. All other points in the spectrum will be moved the same amount.

In the following exercise, you will use the SCALE * command to scale the density of the spectrum up in order to create a filter with the maximum amount of gain.

1. Move the cursor over to the peak in the display (to the point with a frequency of 1367.1975) (Figure 10).

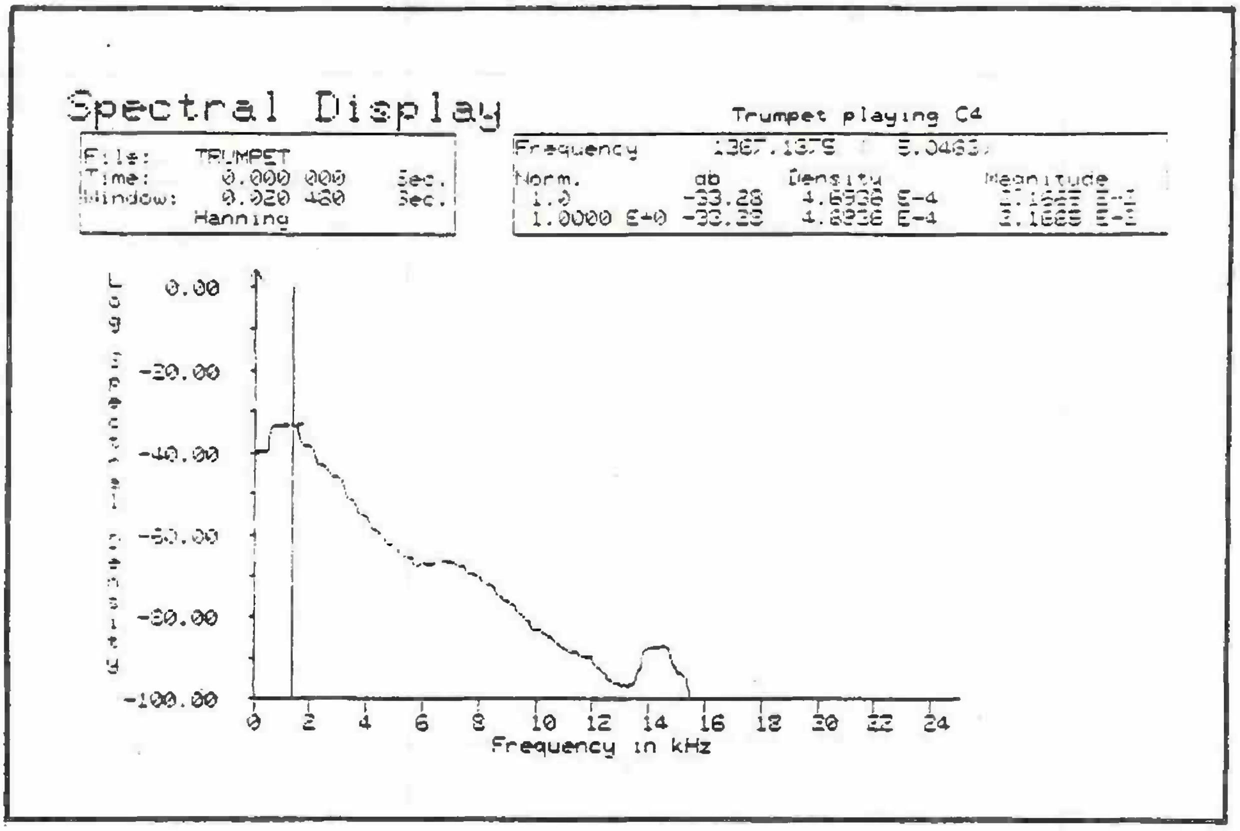

Figure 10

2. Type

SCALE * This replots the spectrum so that the point with the cursor is now located at 0 dB (Figure 11).

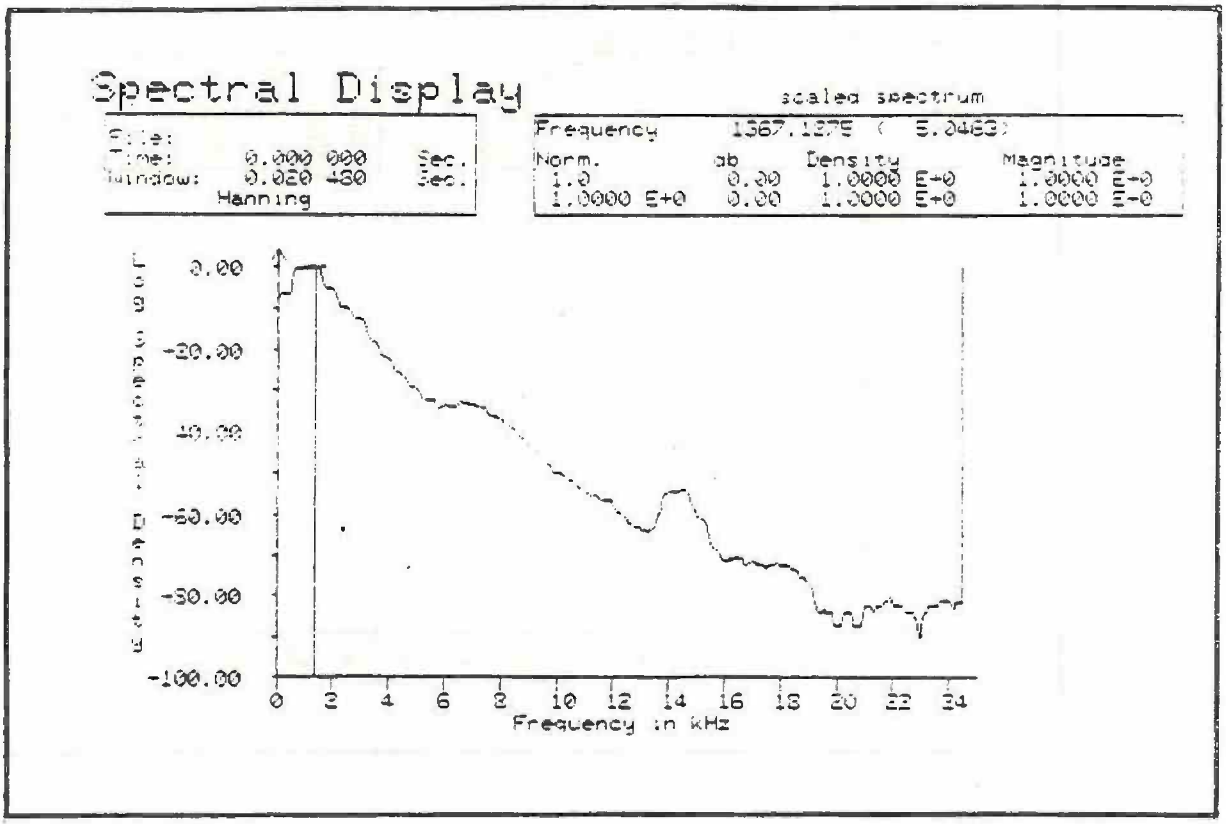

Figure 11

3. Type

IMPULSE

to convert the smoothed, rescaled spectrum into an impulse response.

4. Type

2

to select a Hamming window.

5. Press RETURN to display the impulse response (Figure 12).

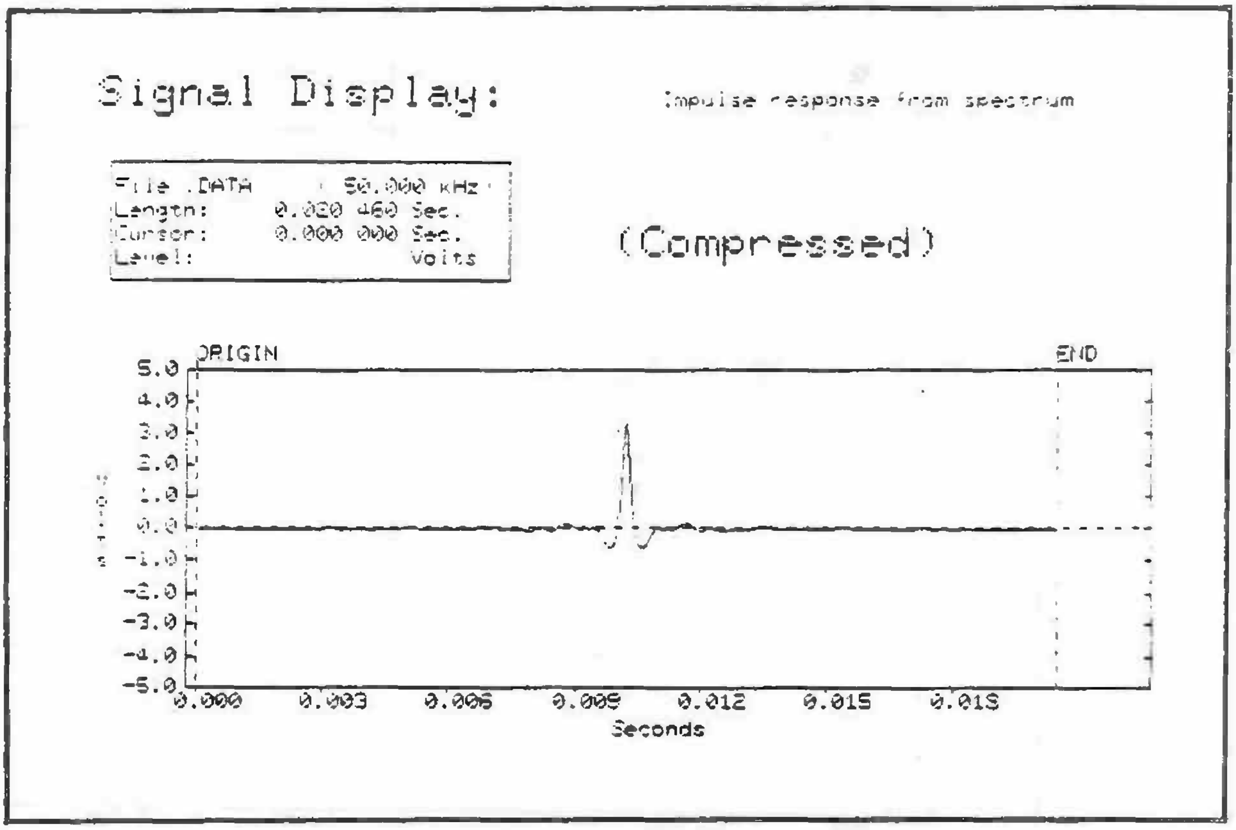

Figure 12

6. Type

   SAVE TRUMMAT

   to save the trumpet matching impulse response on the Winchester disk.

7. Now generate an impulse train (for details see pages 87-95 in the main SFM manual).

   a. Type

      CREATE 20

b. Type

ADD IMPULSE

c. Press RETURN to see the signal display (Figure 13).

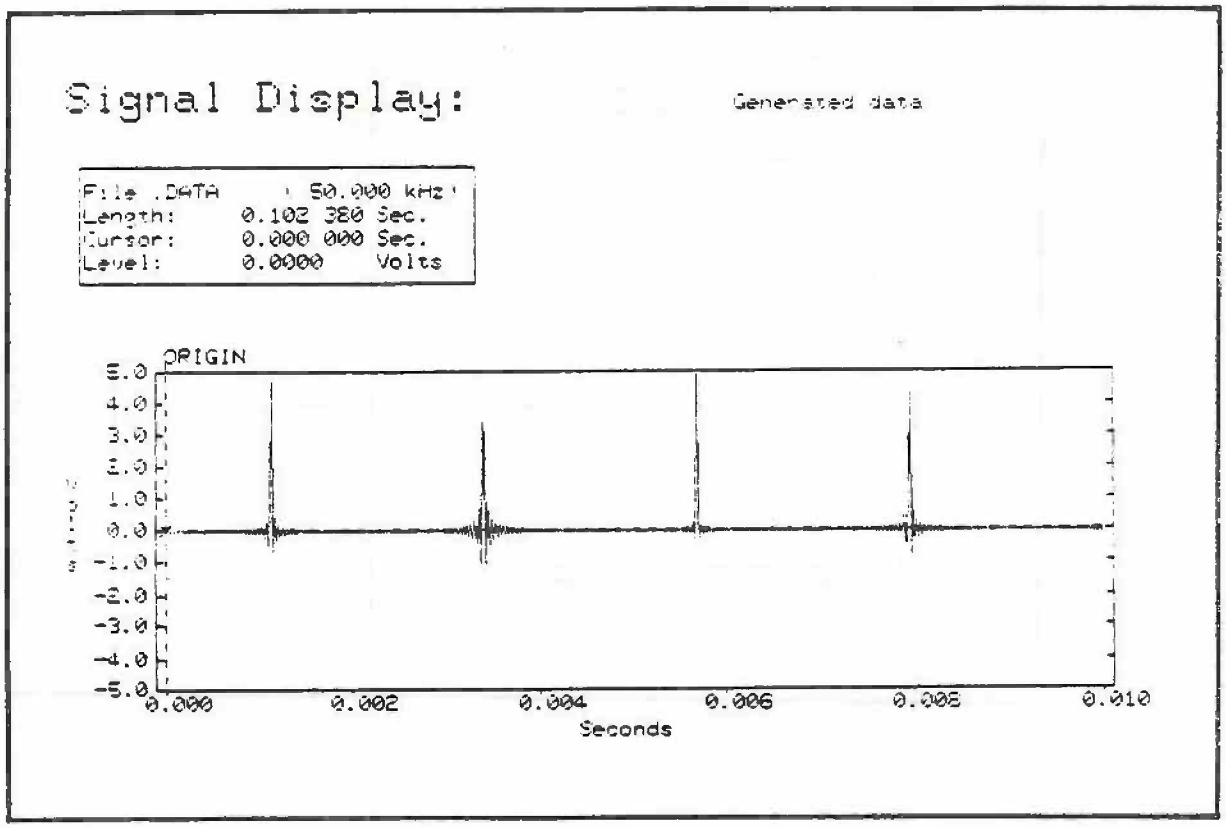

Figure 13

d. Type

SAVE WHITE

to save the file, if desired.

e. Type

SPECTRUM

to see the white spectrum (Figure 14).

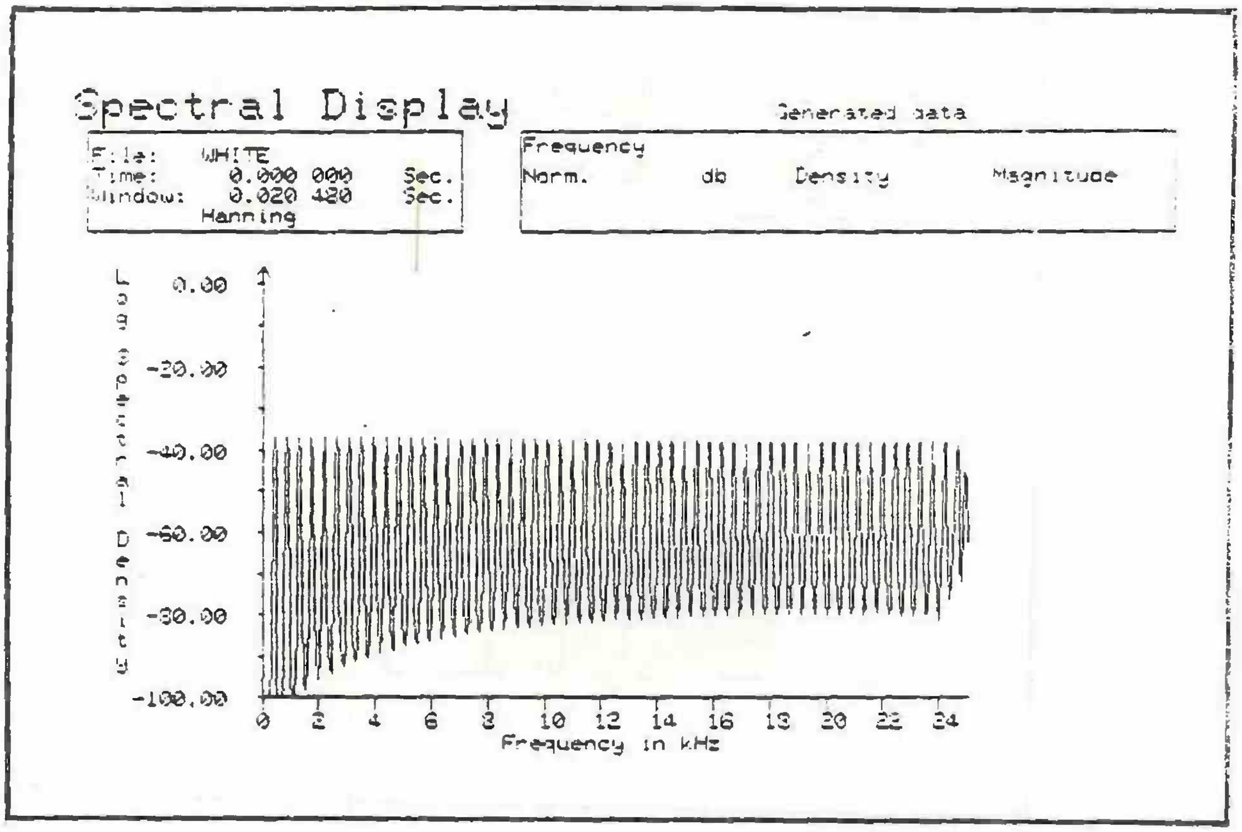

Figure 14

Now convolve the white noise file with the trumpet filter.

8. First type

SET GAIN 0

to reset the gain factor to zero.

9. Type

CONVOLVE TRUMMAT

10. When filtering is completed, type

SPE .02

to see the resultant spectrum (Figure 15).

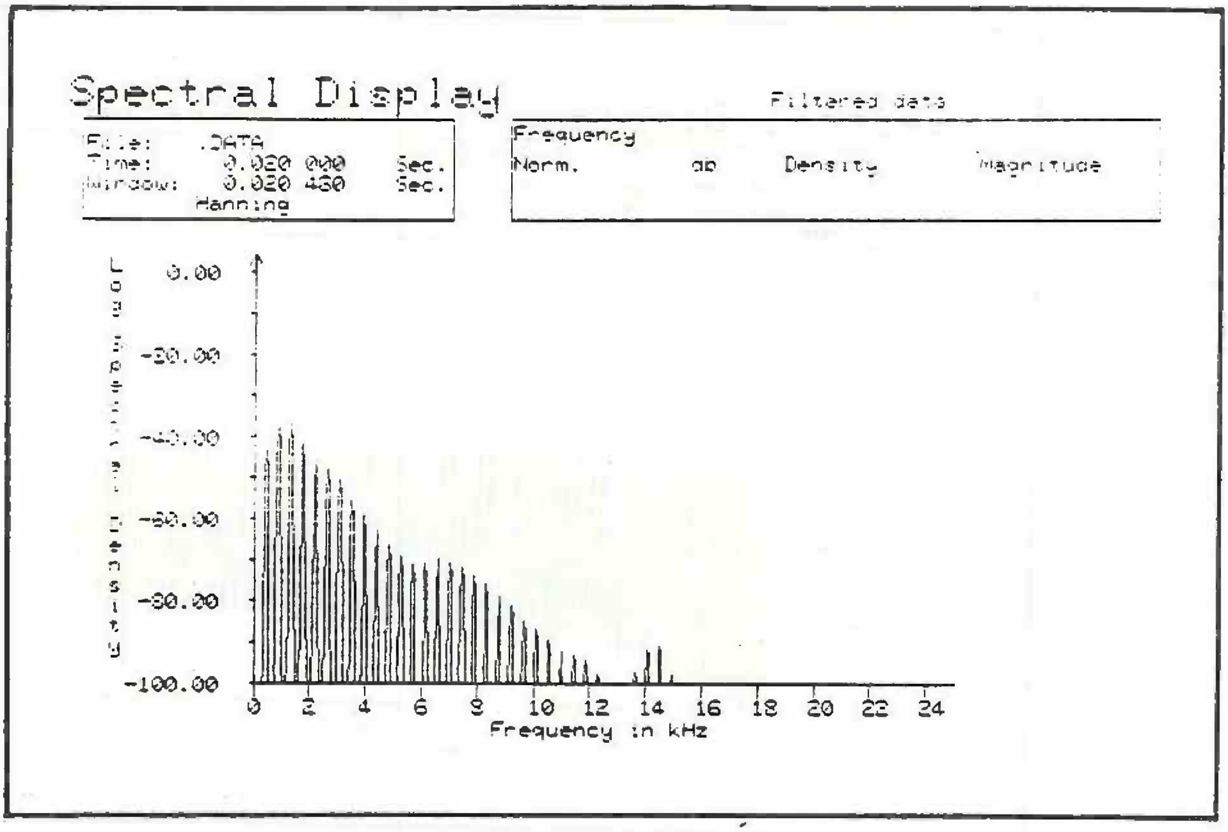

Figure 15

You can see that it resembles the original trumpet spectrum. However, since the pitch is different from the original file (the default A-440 was used for the impulse train), and since it lacks dynamics and pitch variation, the sound will not be very trumpet-like.

* * * * * * * * *

In this exercise, you will compare the spectrum at time 0 in the TRUMPET file with the spectrum at time .5 in the same file.

Comparing Spectra

The command SUBTRACT <filename> will "subtract" the specified spectral file from the current spectrum. This is a subtraction on a logarithmic scale. Each point in the resulting display will actually represent the ratio of the spectral density of the point in the current spectrum to the spectral density of the same point in the named spectrum. The FFT lengths in both spectra must be identical. If 0 is in the denominator of the ratio at any point, the resulting spectral density will be zeroed out at that point.

This procedure is most useful and effective when comparing smoothed spectra.

1. Type

    OLD TRUMPET

    to recall the original sound file.

2. Type

    SPE .5

3. Type

SMOOTH 10

to smooth the spectrum (Figure 16).

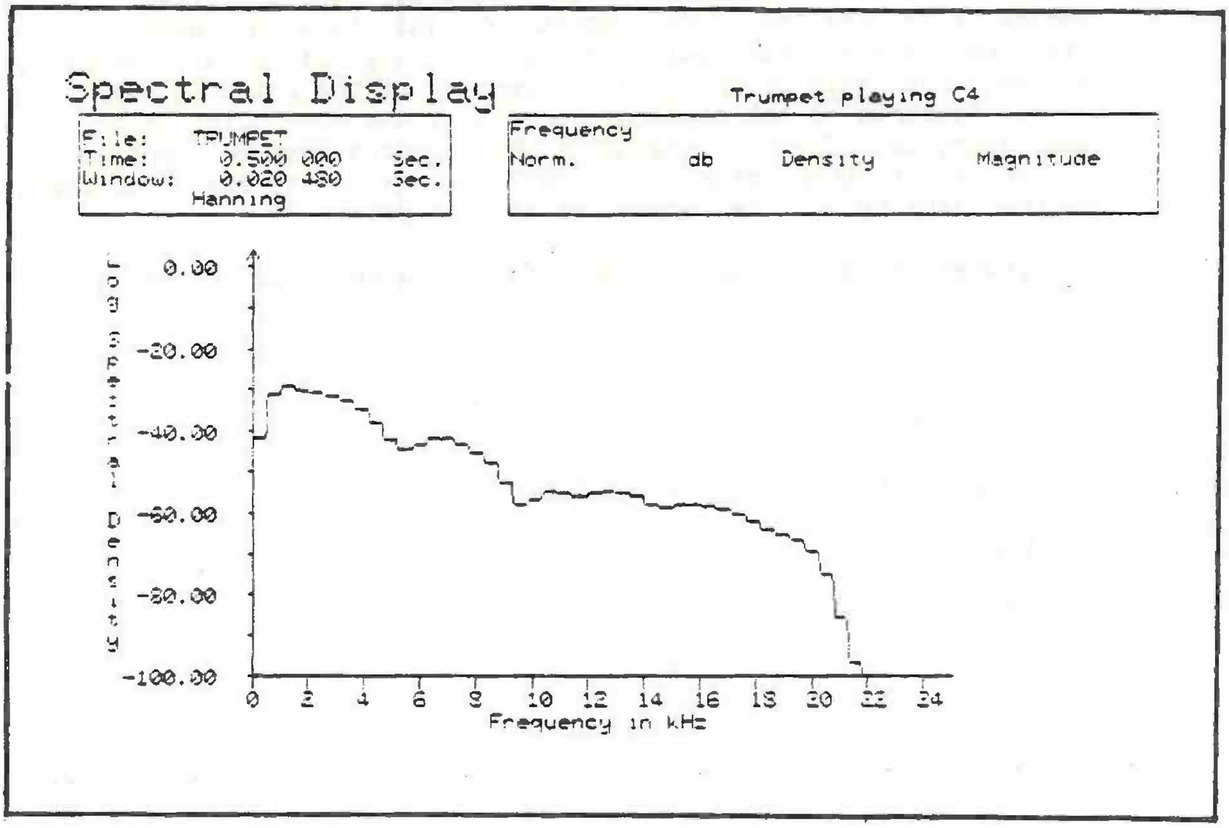

Figure 16

4. Type

SUBTRACT SM010

This subtracts the smoothed spectrum at time value 0 from the current spectrum (Figure 17).

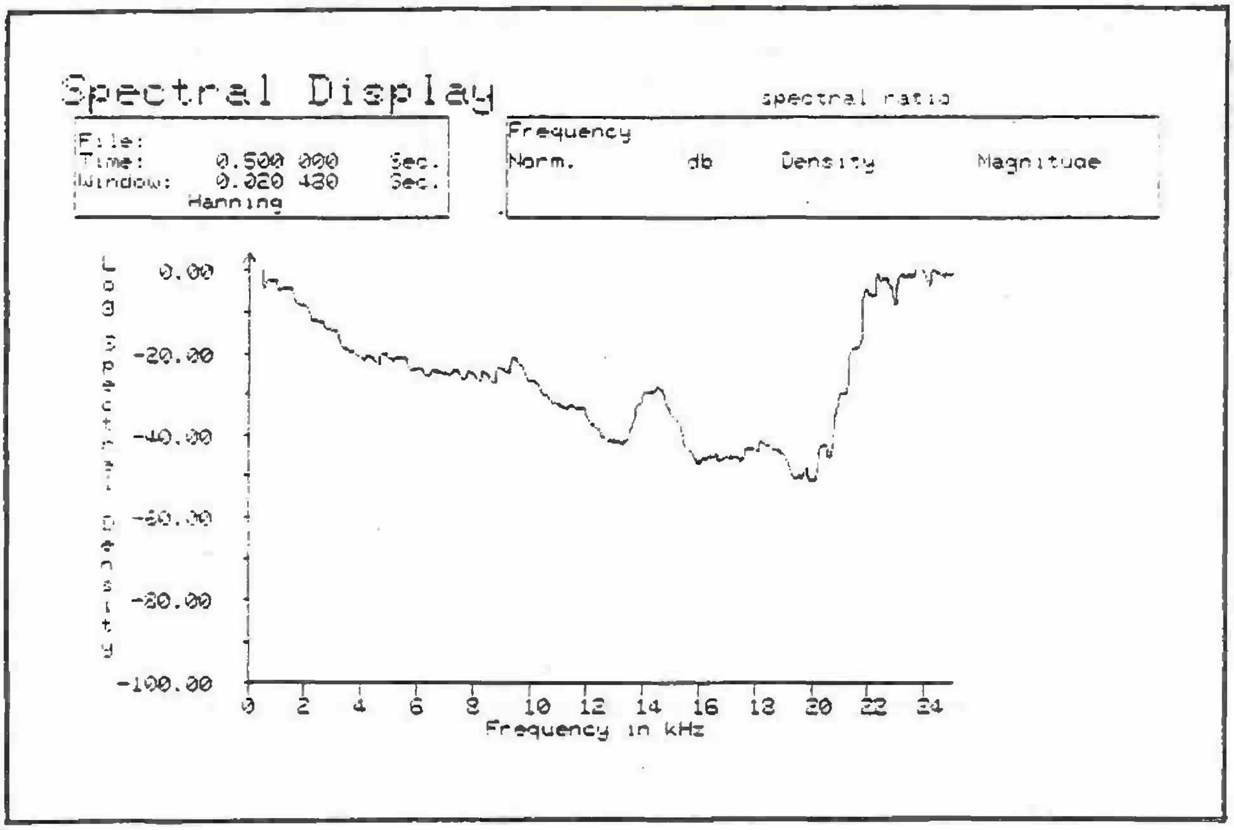

Figure 17

* * * * * * * * *

In this final exercise, you will compute the autocorrelation function of the spectrum at time 0 in the TRUMPET file.

Autocorrelating a Spectrum

Autocorrelation is a useful technique for studying the periodicity of functions. It is widely used in the statistical analysis of waveforms. The AUTO command without a filename will compute the autocorrelation function corresponding to the displayed spectrum. The AUTO <filename> command will recall the named spectral file from the Winchester disk and compute its autocorrelation function. In either case, the result is a new .DATA signal file stored on the disk.

1. Type

   OLD TRUMPET

   to recall the trumpet signal file.

2. Type

   SPE .0

3. Type

   AUTO

   This command initiates the computation of the autocorrelation function of the current spectrum.

4. Type

   SET HOR .01

   to change the horizontal scale from the compressed range used earlier.

5. Press RETURN.

The autocorrelation will be displayed (Figure 18).

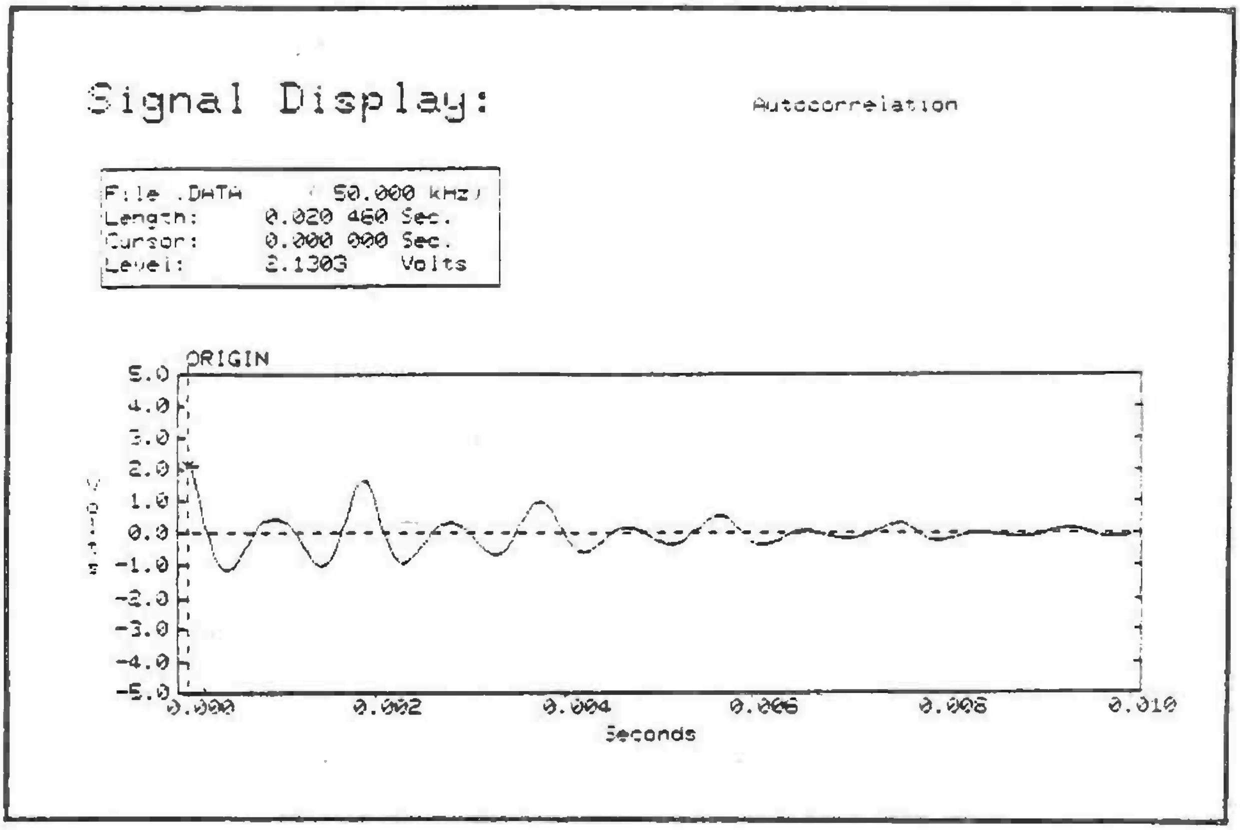

Figure 18

The peak at 0 time corresponds to the peak that occurs in the middle of the window when the impulse response is calculated (Figure 8).

ADDITIONAL NOTES