Java-DSP Earth Systems Edition Exercises

These exercises are aimed at creating a basic understanding of using J-DSP/ESE for time series analysis of Earth system signals. Basic working knowledge of PC or MAC systems and MS-Excel is assumed. Throughout the exercise, MS-Excel can be used whenever necessary.

Getting Started with JDSP/ESE:

For using J-DSP/ESE, latest Java runtime engine is required on your computer, which can be downloaded and installed from http://java.com/en/download/manual.jsp. Once the ***Editor Frame*** opens, all the functions of J-DSP/ESE can be seen as buttons in the top and left ***function panels*** of the applet. To use a particular function, just click on the button, move the cursor to an open area in the white ***canvas*** and click once again to create a block. To modify the parameters of the block, double-click to open a ***dialog window*** for the block, set the desired parameters and click *Update*. The *Help* button can be used to open a separate help window that displays help on that particular block. A screenshot of the editor frame, along with ***Signal Generator*** block and its dialog ***window*** are displayed in Figure 1. The other functional blocks of JDSP/ESE will be described as they are introduced in the exercises.

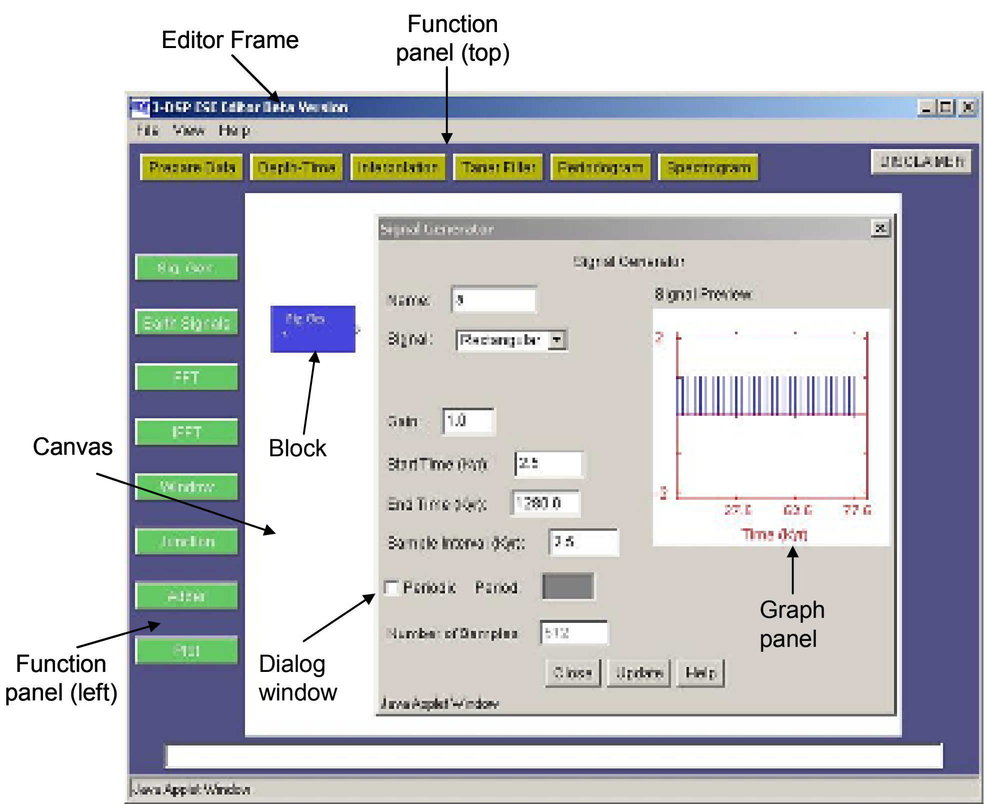

Figure 1: J-DSP/ESE editor frame with the dialog window for *Signal Generator* block.

Part 1: Basics of Spectral Analysis

The objective of this exercise is to perform spectral analysis of three synthetic time series with J-DSP/ESE. These time series are realized at uniform time intervals of Δt=1 Kyr (kiloyears) over a total of N=1024 samples. The three synthetic time series to be created are:

<u>**Series 1:**</u> Single frequency sinusoid signal : $y_n = \cos(2\pi t_n/(20kyr))$, $t_n = n*\Delta t$, n=1,…,N

To create this series, use the ***Signal Generator*** block of J-DSP/ESE, named as "Sig.Gen." in the left panel of the editor frame. In the dialog window of ***Signal Generator***, the signal should be set to *Cosine* (from the pull-down menu), the sample interval should be set to 1 Kyr, start time to 1 Kyr, end time to 1024 Kyr, frequency to 1/20 = 0.05 cycles/Kyr. Note that these values are consistent with the equation of the signal given above.

<u>**Series 2:**</u> Random noise with zero mean and unit variance: z_n, assigned to time values $t_n = n*\Delta t$, n=1,…,N

Using the ***Signal Generator*** block, create random signal with uniform distribution of zero mean and unit variance with start time of 1 Kyr, end time of 1024 Kyr and sample interval of 1 Kyr.

<u>**Series 3:**</u> Combined signal at half amplitude plus noise : $s_n = 0.5*y_n + z_n$

This series is created by combining the signals for the previous two series. The gain in the first ***Signal Generator*** is set to 0.5 and the ***Adder*** is used to add the two signals.

<u>**Exercise 1:**</u> Analyzing the time series

A. Create series 1 using the ***Signal Generator*** and plot the time series with the ***Plot***. Set the X-axis from 1 to 200, for visual convenience. Using *Graph/Value/Stats* display the signal statistics. Pay particular attention to the variance of the time series, which is directly proportional to the power value.

- What is the amplitude of the cycling (half of maximum-to-minimum) value?
- What is the period of cycling?
  - The period of cycling can be found by using the *cross-hair cursor* and values displayed for the time series in ***Plot***. Alternatively MS-Excel can be also used. Note that the values displayed in ***Plot*** can be directly copy-pasted into MS-Excel for further analysis.

The next step is to find the power spectrum of the time series using ***Periodogram***. Set the periodogram type as *Sample Spectrum*, and the window should be set as *Rectangular*. Another ***Plot*** can be connected to the ***Periodogram*** to visualize the spectrum. Restriction of X axis form 0 to 0.2 cycles/Kyr can be made for convenience.

- What is the frequency of the spectral peak?
  - The peak value can be found in the statistics displayed in ***Plot*** and the corresponding frequency can be inferred from the series values. Note that the peak will occur at two frequencies because the spectrum is displayed from 0 to f_s

and not 0 to f_{nyq}, where $f_{nyq} = f_s/2$. Hence, the spectrum will be symmetric about the center and always the first half of the spectrum alone must be taken into consideration.

- How does the frequency relate to the cycle period?
- How does the power relate to the cycle amplitude[1]?
  - The variance can be calculated by summing the spectral values around the neighborhood of the spectral peak (in the first half of the spectrum), and dividing the sum by N/2.

B. Create series 3 in J-DSP/ESE and plot the series and view it from 1 to 200, using manual axis settings. Use the ***Periodogram*** to compute the power spectrum and estimate the signal power (variance in the neighborhood of spectral peak) and noise power. Noise power is the difference between the total power and the signal power. Signal to noise ratio is the ratio of the signal power to the noise power[2].

- Contrast the variance of the signal in series 1 with that of series 2.
- Calculate the signal to noise ratio mathematically and compare it with the estimated value.

PART 2: Earth's orbital parameters and "Milankovitch cycles"

Earth Signals contains the the Laskar solution of the Earth's orbital parameters for the past 3.5 million years. The *orbital eccentricity*, *obliquity* (or tilt) and *precession* series are given in 1 kyr intervals. A summary series, *Standardized ETP* that combines standardized versions of these three parameters is provided for spectral analysis. Classic Milankovitch curves for 30º and 65º North summer insolation (*Summer insol.* 30*N* and *Summer insol.* 65*N*) obtained using the Laskar solution are also provided.

<u>Exercise 1:</u> The orbital parameters

A. Plot out the most recent 3.5 million years of the three series, *orbital eccentricity*, *obliquity* and *precession*, using ***Plot***.

- Indicate the approximate periodicity for each series.

B. Use the ***Periodogram*** to perform spectral analysis of the *Standardized ETP* and ***Plot*** the spectrum from 0 to 0.1 cycles/Kyr.

- Identify the periods of major spectral peaks and the originating parameter.

<u>Exercise 2:</u> Milankovitch cycles

A. Plot out the most recent 3.5 million years of summer insolation at 30º N and 65º N.

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[1] The spectral power is given as "variance/Δf" where the sampling frequency is $\Delta f = 1/(N*\Delta t)$ with $N*\Delta t$ the length of the time series in Kyr. For this exercise, $\Delta f = 1/(1024*1\text{ Kyr}) = 0.0009765625$ cycles/Kyr.
[2] Note that sometimes we use power and variance interchangeably because they are directly proportional. For example, when computing signal to noise ratios, the variance can be directly used.

- Which series has higher average insolation during the summer and why?

B. Using ***Periodogram*** perform spectral analysis on these two insolation series and plot the output spectra over frequency ranging from 0 to 0.1 cycles/Kyr.

- Identify the periods of major spectral peaks and the originating parameter.
- What is the main difference between the spectra of these two insolation series?

PART 3: Analysis of Milankovitch cycles in the Triassic Lockatong Formation

The *Lockatong* series in ***Earth Signals*** contains the depth facies rank series for the Lockatong Formation constructed by the Newark Basin Drilling Project. It was obtained by coring through the formation at the "Nursery" location in New Jersey and facies analysis of core material at regular intervals. The numbers indicate relative lake depth at the depositional site, where 0=exposed, and higher numbers indicate increasing water depths.

Exercise 1: Analyzing the Lockatong Formation composite cycles

A. Plot out the depth rank series as a function of core depth (feet). Plot the first 800 feet.

- Label Van Houten, short modulating and McLaughlin cycles and indicate their approx. thicknesses. MS-Excel can be used to plot the series and calculate thicknesses.

B. Use ***Prepare Data*** to remove the linear trend of the *Lockatong* series compute the spectrum using ***Periodogram***. Smooth the periodogram output over 2 points and display the spectrum using ***Plot***. Restrict the frequency scale from 0 to 0.1 cycles/ft. Take the spectrum data to MS-Excel and plot the data in MS-Excel also.

- Identify the frequencies of the major spectral peaks; what thicknesses to these correspond to?
- Which ones correspond to the “Van Houten”, “short modulating” and “McLaughlin” cycles?

C. It is thought that the McLaughlin cycle is an expression of the Earth's long (405-kyr) eccentricity cycle. This allows a conversion of the spectrum frequency scale from spatial (cycles/feet) to time dimensions (cycles/kyr). Find the conversion factor SR by assigning 405-kyr to the McLaughlin cycle thickness indicated in the spectrum.

- Use SR to convert the other major peaks to periodicity in Kyr.
- According to SR, how long is the entire depth rank series?

References

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