Waves on a String B1

Head of Experiment: Timothy Sumner

The following experiment guide is NOT intended to be a step-by-step manual for the experiment but rather provides an overall introduction to the experiment and outlines the important tasks that need to be performed in order to complete the experiment. Additional sources of documentation may need to be researched and consulted during the experiment as well as for the completion of the report. This additional documentation must be cited in the references of the report.

Imperial College London

RISK ASSESSMENT AND STANDARD OPERATING PROCEDURE

1. PERSON CARRYING OUT ASSESSMENT					
Name	Geoff Green	**Position**	Chf Lab Tech	**Date**	15/09/08

2. DESCRIPTION OF ACTIVITY

B1 Waves on a string

3. LOCATION					
Campus	SK	**Building**	Blackett Lab	**Room**	410

4. HAZARD SUMMARY			
Accessibility	X	**Mechanical**	X
Manual Handling	X	**Hazardous Substances**	
Electrical	X	**Other**	X
Lone Working Permitted?	**Yes** ☒ **No** ☐	**Permit-to-Work Required?**	**Yes** ☐ **No** ☒

5. PROCEDURE	PRECAUTIONS
Use of Computer Display	Use of Computer DisplayAvoid prolonged sessions; Take Breaks
Use of 240v Mains Powered Equipment	Isolate Socket using Mains Switch before unplugging or plugging in equipment
Suspended Weights	Wear suitable footwear and avoid suspending weights over walkway
Tensioned wire	Sudden breakage could cause injury to eyes or skin; wear eye protection or avoid close proximity to wire when under high tensions.
Accessibility	All bags/coats to be kept out of aisles and walkways.

6. EMERGENCY ACTIONS

All present must be aware of the available escape routes and follow instructions in the event of an evacuation

B1. The Fundamentals of Acoustics: Waves on a String and Fourier Theory

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Contents

Introduction

You are provided with a sonometer to investigate the properties of waves propagating along a string. At first glance, you may well think that here is pre-19th century physics, utterly understood and completely described in even the most rudimentary textbook. Read on and investigate for yourself!

Overview

Section 1

You find the **velocity** of waves on a string, indirectly from measurements of the resonance frequencies of wires with different tensions and different lengths.

Section 2a

By plucking the string at different positions, you will observe the different **harmonics**, their relative amplitudes, and how these change over time, and how these results compare to those predicted by Fourier theory.

Section 2b

It turns out that the decaying motion of the wire is actually quite complex. Several modes can actually interact under the **real conditions** of the given sonometer. By isolating individual frequencies and using signal-processing techniques, you explore the frequency dependence of the decay constant.

Section 3

The air drag mechanism could be investigated. How far you get with this depends on available time. You are of course encouraged to criticise and maybe modify the model to produce a better quantitative account of a real decay of a vibrating wire.

The amount of work required to complete each section is not equal; to that end, you should try not to become bogged down with the earlier sections. You are encouraged to leave around a week and a half to complete section 2b, which should form the main body of your report.

Section 1

This first part of the experiment involves studying the relationship between the tension of a string, the velocity of travelling waves (actually forming standing, resonant waves) on the string and its length.

Method

You first decide on a sensible fixed wire length (~ 60cm).

For a given suspended mass (which sets the tension) you will drive the wire to resonance, observing the resonance frequency for that particular tension and of wire length. Using a number of different masses, find the fundamental frequency of the string for a number of different string tensions.

Now since $$v = f\lambda$$

where v = velocity of wave, f = frequency, λ = wavelength, find the velocity of the wave for each of the different string tensions.

Plot a graph of velocity against tension. *What can you deduce?*

Now repeat the experiment, this time keeping the tension constant but changing the length of the vibrating string.

Plot a graph of velocity against length. *What can you now deduce?*

Putting both of these together, derive a general relationship between wave velocity, string length and string tension.

Now measure the diameter of the string.

The density of the string is typically 7.9 g cm^{-3}. (It would be well to check that this is true for the string you actually use). Hence find its mass per unit length, μ. Use this information to confirm the equation derived theoretically in Appendix 1.

Note on method. *The driver coil is a small LOUDSPEAKER with a rather low input impedance. Make sure that it is driven from the low output impedance of the audio signal generator you are using. If you do not understand this issue make sure to ask your demonstrator.*

Section 2a

In this part you are going to observe the decay of the oscillation of the wire following a simple pluck. In preparation for the finer details in Section 2b you should examine and note which modes (harmonics) are excited by plucking (see note) at different positions along the wire.

Method

For a given plucking position and a sensible wire tension, you should record the decay of the wire oscillation as a time series, using the given record wave recording programme. This programme will also provide a reasonable estimate of the frequency spectrum of the decay. At this stage it is sufficient for you to note just which frequencies are present in the decay, and in what proportion for a sensible range of plucking points. [There would be no harm in saving these recordings as **".wav"** files for later possible analysis. You should also note the general form of the decay in time (from the screen), both in its initial and final stages.]

In principle your observations are perfectly predictable using simple Fourier theory. The static form of the wire, immediately prior to letting go, sets a geometric boundary condition (initial condition) for the ensuing oscillation. Your initial static wire configuration can be decomposed into a Fourier series and the computed amplitudes of the several harmonics should represent the initial amplitudes of the decaying oscillation. Plucking at different positions changes the precise combination of starting amplitudes, and thus the exact composition of harmonics in the ensuing decaying oscillation.

The initial shape of a wire plucked in the centre is given by

$$\psi(x, t=0) = \begin{cases} \dfrac{2hx}{l} \ , & 0 \le x < \dfrac{l}{2} \\ \dfrac{2h}{l}(l-x) \ , & \dfrac{l}{2} \le x \le l \\ 0 & otherwise \end{cases} \qquad (2),$$

where l is the length of the string and h is the vertical height of the pluck. Using equation (2) and the Fourier theory in *Appendix 2*, you should be able to predict the relative intensities of the different frequency components.

Does simple Fourier theory really match experiment even at this qualitative level?

Finally before going on to Section 2B repeat and record one representative "pluck" but with the tensioner loaded as much as you dare (without breaking the wire!) Compare the corresponding overall decays especially in their initial stages. Think about what is actually happening in these "plucking experiments" by observing the actual geometric wire "boundary condition" at the tensioner end.

In the light of this can we honestly expect simple Fourier to reproduce the precise harmonic composition of the decays?

Method notes:

1. Pull the string upwards by a small distance. Place the detector at the central point, Use Matlab to record the output of the detector, using the Matlab function "wavrecord" (see Appendix3).

2. Note that the detector is very similar to an electric guitar "pick-up". The string is made of magnetic alloy and its vibrations induce a voltage in the nearby pick-up coil by the Faraday effect. Does what you see on the screen correspond to the displacement of the wire or its time derivative?

Section 2b

In this part you will undertake a more detailed analysis of the wire oscillation decay. It is strongly suggested that here you pick a single string length, a definite plucking position and initial deflection amplitude and as big a tensioning mass as you dare. The last partially eliminates the interesting but very complex effects observed in Section 2a.

Method

Record a few decays initiated by nominally identical starting conditions (tension, pluck position, pluck amplitude). You record a few such decays to get an idea of variation with the inevitable small differences in your real starting conditions. The .wav files should be imported into MATLAB and you should write a simple programme which**: -**

1. Applies a Hamming window to the data (the time series)
2. Isolates each of the harmonic components in frequency by applying Gaussian windows to the Fourier spectrum, each one centred on a chosen harmonic frequency.
3. Inverts the Gaussian filtered components to get an estimate of the contribution of the each isolated harmonic to the overall decay.
4. Plot log-linear plots of each of these to provide an estimate of the decay constant for each harmonic.

Your aim is to produce a plot of decay constant versus frequency

Method Note: Depending on pluck etc you might want to only use the later part of each decay. The early parts might still be effectively quantitatively beyond analysis. Guidance on the use of MATLAB is found on the Web. You might well want a mini tutorial after reading the notes. Contact the demonstrator.

Analysis

It is probably obvious to you that a simple wave equation cannot possibly describe the motion of the decaying oscillating wire since it does not contain any damping! Questions arise then; what is the dominant damping mechanism? How can this be described mathematically so that the results might be compared with a reasonable theory? There is apparently no simple answer to this but here are a few ideas (and fixes!).

Maybe, but not for sure, air damping is dominant so that "air drag" is the culprit. If so then the damping force would have the form

$$F = -C\left(\frac{\partial y}{\partial t}\right)^2$$

so that the correct full wave equation will read

$$v^2 \frac{\partial^2 y}{\partial t^2} = \frac{\partial^2 y}{\partial x^2} - C\left(\frac{\partial y}{\partial t}\right)^2$$

It looks simple enough but is unfortunately non-linear and there is no relatively simple, pencil and paper method of solution. It could of course be solved numerically but that is really beyond the remit of this experiment. Arguing in the following manner we can make a small displacement approximation. The total air damping will be dominated by the region of oscillation close to the resting string position where the wire velocity is at its maximum. Over this imagined limited region of the motion we could imagine that quadratic damping force is approximately linear in the speed so that we use the approximate form

$$\nu^2 \frac{\partial^2 y}{\partial t^2} = \frac{\partial^2 y}{\partial x^2} - \alpha\left(\frac{\partial y}{\partial t}\right)$$

where α is the decay constant (which depends on frequency!). Now this can be solved, in fact you have already done so – last year in E&M when you considered the skin effect. This equation is the standard approximation used to derive the skin depth of a plain EM wave propagating into a metal. There is no need to re-solve it from scratch but simply adapt either what you know or use, say, R K Wangsness: Electromagnetic Fields (ISBN-471-04103-3) to find an approximate variation of damping constant with frequency to compare with the experiment.

Produce a plot of damping constant versus frequency with a "theoretical" line for comparison. *How good is the comparison?*

Section 3

The basic assumption concerning the air drag mechanism could be investigated. For example a series of very low mass foam sleeves, placed around the wire could be used to deliberately increase the air drag force and so examine if it is indeed the culprit for the bare wire.

APPENDIX 1: Velocity of waves on a string

Consider a string of length L, stretched to a tension T between two fixed points and having a mass per unit length μ. We now induce a small vertical displacement of the string, ensuring that neither the length nor the tension changes appreciably in the following discussion. The tension force drives the string back towards its equilibrium position, setting up a series of oscillations along its length. Rather than attempt to analyse the complex shape the string makes directly, we instead split it into a series of infinitesimally small straight lines, or “elements”. This situation is shown in figure A1.
Resolving forces in the ψ and x directions gives the total force acting on the element

$$\vec{F} = \begin{pmatrix} F_\psi \\ F_x \end{pmatrix} \sim T \begin{pmatrix} \sin(\theta+\delta\theta) - \sin\theta \\ \cos(\theta+\delta\theta) - \cos\theta \end{pmatrix} \quad (A1),$$

where θ is the angle between the line element and the horizontal. As the vertical displacement is small, the angle between the line element and the horizontal will always be small and hence, applying the small angle formula

$$\begin{pmatrix} F_\psi \\ F_x \end{pmatrix} \sim \begin{pmatrix} T\delta\theta \\ 0 \end{pmatrix} \quad (A2).$$

Applying Newton’s Second Law, we obtain

$$\mu\sqrt{\delta x^2 + \delta\psi^2}\,\frac{\partial^2\psi}{\partial t^2} \sim \mu\delta x\,\frac{\partial^2\psi}{\partial t^2} \sim T\delta\theta \quad (A3),$$

where we have made use of the fact that the vertical displacement is small to simplify the left hand side of (A3). Now, from the geometry of the line element, we note that

$$\frac{\delta\psi}{\delta x} = \tan\theta \;\Rightarrow\; \frac{\partial^2\psi}{\partial x^2} = \sec^2\theta\,\frac{\delta\theta}{\delta x} \sim \frac{\delta\theta}{\delta x} \quad (A4),$$

via the small angle approximation. Hence, via substitution into (A3),

$$\frac{\partial^2\psi}{\partial t^2} \sim \frac{1}{v^2}\frac{\partial^2\psi}{\partial x^2} \quad (A5),$$

where $v = \sqrt{\frac{T}{\mu}}$ is the wave velocity, and equation (A5) is the equation describing wave motion of the string.

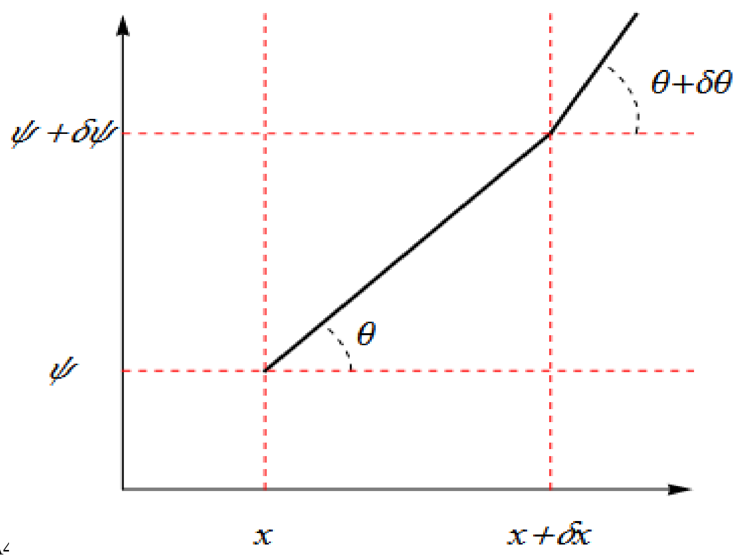


Figure 1: Line element of the string with vertical displacement ψ and horizontal displacement x. θ is the angle between the element and the horizontal axis x. The string is held at constant tension T, and has a mass per unit length μ

APPENDIX 2: Fourier Theory

Even and Odd functions

A function $E(x)$ is even if

$$E(-x) = E(x) \quad (B1)$$

holds true for all real values of x. Similarly, a function $O(x)$ is odd if the property

$$O(-x) = -O(x) \quad (B2)$$

holds. An arbitrary function $f(x)$may be decomposed into a sum of even and odd functions:

$$f(x) = \frac{f(x)}{2} + \frac{f(x)}{2} + \frac{f(-x)}{2} - \frac{f(-x)}{2} \quad (B3)$$

$$= \left[\frac{f(x) + f(-x)}{2}\right] + \left[\frac{f(x) - f(-x)}{2}\right] \quad (B4)$$

$$\equiv E'(x) + O'(x),$$

where $E'(x)$ and $O'(x)$ are even and odd functions respectively. This is easily verified- for example

$$E'(-x) = \left[\frac{f(-x) + f(x)}{2}\right] = \left[\frac{f(x) + f(-x)}{2}\right] = E'(x). \quad (B5)$$

It may also be shown that a sum of even functions is an even function and the sum of odd functions is odd:

$$S(-x) = \sum_n S_n(-x) = \sum_n \pm S_n(x) = \pm S(x), \quad (B6)$$

where the plus sign holds if the functions S_n are even, and the minus sign holds if the S_n are odd. Thus, we may write any function as a sum of even and odd functions. But which even and odd functions should we choose? Fourier analysis gives us a methodical way of finding the correct mixture to properly represent our function.

The Fourier Series

Suppose we choose our S_n to be sinusoidal. Then, for some function $f(t)$ we may write

$$f(t) = a_0 + \sum_{n \neq 0} a_n \cos(n\omega t) + \sum_{n \neq 0} b_n \sin(n\omega t), \quad (B7)$$

where $\omega = 2\pi/T$; T, a_n and b_n are numerical constants; $n \in \mathbb{Z}$; and we have explicitly pulled the $n = 0$ term out of the cosine sum. We now wish to determine the values of the a and b constants. T is nominally defined as the time taken for one period of the sine or cosine function when $n = 1$.

We begin with the a_0 term. Recall that, for $n \neq 0$, the average of the cosine function over one period is given by

$$\langle \cos\left(\frac{2\pi nt}{T}\right)\rangle \equiv \frac{1}{T}\int_0^T \cos\left(\frac{2\pi nt}{T}\right)\, dt = 0, \quad (B8)$$

and similarly for $\langle \sin\left(\frac{2\pi nt}{T}\right)\rangle$. Thus, the average of $f(t)$ is given by

$$\frac{1}{T}\int_0^T f(t)\, dt = \frac{1}{T}\int_0^T \left[a_0 + \sum_{n\neq 0} a_n \cos(n\omega t) + \sum_{n\neq 0} b_n \sin(n\omega t)\right] dt = a_0$$

$$\Rightarrow a_0 = \frac{1}{T}\int_0^T f(t)\, dt. \quad (B9)$$

To calculate the other terms, we use a trick first noted by Fourier himself. Consider the integral

$$\int_0^T \cos(n\omega t)\cos(m\omega t)\, dt$$

$$= \frac{1}{2}\int_0^T [\cos[(n+m)\omega t] + \cos[(n-m)\omega t]]\, dt. \quad (B10)$$

When $n \neq m$ the integral is zero via equation *(B8)*. However, when $n = m$ the second term in *(B10)* is unity and hence integrates to $T/2$. The first term is zero as before. Hence, we may combine both cases to obtain

$$\int_0^T \cos(n\omega t)\cos(m\omega t)\, dt = \frac{T}{2}\delta_n^m, \quad (B11)$$

where

$$\delta_n^m = \begin{cases} 0 \; if \; n \neq m \\ 1 \; if \; n = m \end{cases}$$

is the Kronecker delta. Similarly,

$$\int_0^T \sin(n\omega t)\cos(m\omega t)\;\; dt = \frac{1}{2}\int_0^T \sin[(n+m)\omega t] \; + \sin[(n-m)\omega t]\;\; dt$$

$$= 0. \quad (B12)$$

Hence

$$\int_0^T \cos(m\omega t) \times f(t) dt = \frac{T}{2}\sum_{n\neq 0} a_n \delta_n^m = \frac{T}{2} a_m \, . \quad (B13)$$

Following the same methodology, we can obtain a similar result for the sine coefficients. We can therefore summarize the proof above for any Fourier coefficient:

$$\boxed{\begin{aligned} a_n &= \begin{cases} \dfrac{1}{T}\displaystyle\int_0^T f(t)\; dt \;\; if \; n = 0 \\ \dfrac{2}{T}\displaystyle\int_0^T \cos(n\omega t) \times f(t)\; dt \; otherwise \end{cases} \\ b_n &= \frac{2}{T}\int_0^T \sin(n\omega t) \times f(t)\;\; dt. \end{aligned}}$$

APPENDIX 3: Instructions on recording the waveform as a computer sound file

Initially, ensure that the detector is in the correct location, and that it is wired into the back of the soundcard.

Do not use one of the trolley digital scope to record the oscillation because they are limited in sampling time/ maximum number of samples

By far the easiest method of recording is to use the MATLAB installed on the computers provided function. There is a built-in function

Signal = wavrecord(n,fs); where n is the number of samples and fs is the sampling frequency (in sec). Typically you should use fs = 44 KHz and record for about 4-5 seconds.

At the end of the recording, the array, 'Signal' contains the time series measured from the decaying oscillation.

Typically you would

1. Start the recording
2. Pluck the string within say 0.5s
    A. This way you are guaranteed to capture the beginning of the decay

A general introduction to the use of Matlab is on the 3rd year laboratory website and we include some more information below for convenience.

Andrew Earis/Richard Thompson
October 1999
modified by Chris Guy, April 2006
Tim Sumner, Sept 2013

Getting Started with MATLAB

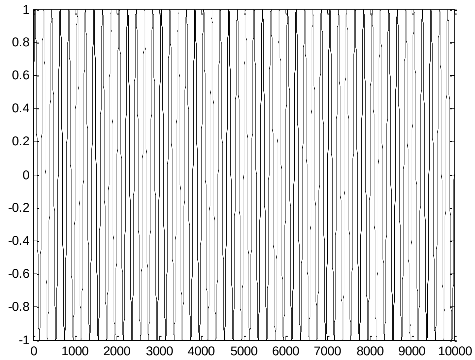
These notes are intended primarily as an aid to analysing the B1 experiment data but can be used as an aide-memoire, should you decide to get yourself more functional with Matlab. Experience shows that once you have mastered a few (..very few) basic issues such as the four environment windows and the basic syntax for scripting then you will become skilled quite quickly. The help files are very comprehensive. The library of functions is huge.

You might be interested to know that Matlab has become the linqua franca of engineering schools and engineering textbooks (>600 have been written, it is said). Proficiency in Matlab is thus something for your CV, as well as your soul.

In the COMMAND WINDOW Type:-

```
>> tt=1:10000;
>> sig=sin(2*pi*tt/200);
>> figure(1);
>> plot(tt,sig(tt));
```

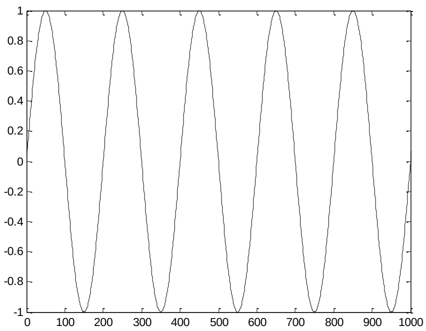
The figure(1) window now contains>>>>>>>>>>>>



Now type :-

```
>> xlim([0 1000]);
```

this allows you crudely to rescale figures
& zoom in on important bits

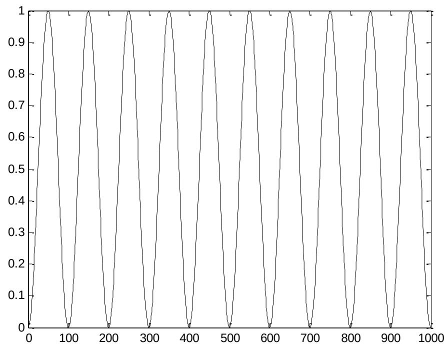


Now type

```
>>abs=sig.*sig;
```

Element by element multiplication(= scalar product) uses the operator, .*

```
>> figure(2)
>> plot(abs)
>> xlim([0 1000]);
```



Labelling Figures

You can label plots in a script or after the event, in the command window, with eg
title (' sinewave'); xlabel(' Time in ms.'); ylabel('Amplitude')

All Matlab plots paste straight into MS Word.

Creating Scripts

- *M-Files are typed and edited in the Editor*

- *You can simply cut and paste your commands and put them into the editor(NB you must remove the chevrons and have the commands in the right sequence!!)*

- *You save the script with a name eg "simple_sine"*

- *Now in the command window type* simple_sine*;* *and the whole set of instructions run*

NB if you make any changes to the script you must "save" before running.

- *Matlab has most of the programming constructs just like C ,*

for - end
while – end
if – end
x =input(' the next value') + *lots more*

- *The power of MATLAB derives from the huge library of functions you can use in your scripts . Using MATLAB efficiently eventually means being aware of what is possible from the* HELP FILES.

Here are a couple of further, more complex, examples that illustrate

- *Using Fourier transforms the fft*
- *Importing /saving files*
- *A few functions specific to image processing*

Fourier in 1D

I shall do it as a script from the beginning

1. *Import a data time series; it is the ECG of a patient.*

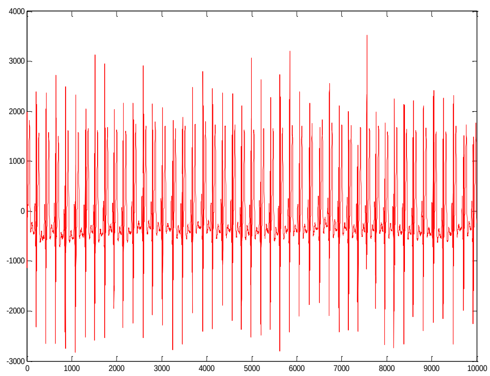
fl=input('filename');
load(fl) ; %………….*this is a binary .MAT file extracted and saved from a much larger hospital file with a non-standard format using* fseek, fread

2. *Find out how big the file is*

sz=size(fl);
N=sz(2);
t=1:N;

3. *plot the imported data – in red*

figure (1);
plot(t , fl(t),'r');



4. *Now get the Fourier transform*

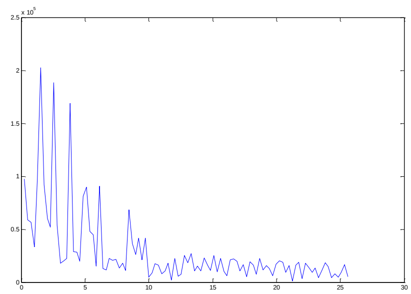
spect=fft(fl,N); N pt FFT

5. *Set up an appropriate frequency scale*

freq = t*256 / (5*N) ; % *here the sampling rate is 256Hz*

6. *Plot the absolute value of spectrum estimate*

figure(2);
plot(freq, abs(spect(t)),'b');



Now save srcipt as *ftsine_simp*

And then, in command window type
>> ftsine_simp

That is it, apart from issues such as ***windowing*** *(Hanning etc) and* ***averaging*** *the spectral samples to reduce variance.*

If you want to save the spectrum, type

>> save spect

*This saves a part of your work space. Just typing "*save*", saves the entire workspace . No harm in this as long as memory is not an issue.*

Specific Details for the B1 experiment

Windowing

Just taking a length of data N pts long is effectively the same thing as an infinite stretch of data multiplied by a "top hat" W(t)

$W(t) = 1 \quad 0<t<N$

$W(t) = 0$ everywhere else

The fft is really equivalent to a Fourier series on an imagined infinite stretch of data that is periodic with a period N. The ends of each "period" at t=0 and t=N obviously have discontinuities which actually do affect the spectrum estimate. There many fixes for this, each one is a data "window" which tapers at the ends and so eliminates the discontinuities. A simple and widely used window is called a Hamming window (after a quite famous signal processor) it has the form

```
W(t)=0.5*(1-cos(2*pi*t/N));
```

So a standard way of doing the Fourier transform is

```
spect=abs(fft((sigt-mean(sigt)).*han,N));
```

notice that here the mean has been removed since nearly always DC (zero frequency is not of interest). In more sophisticated analyses "trends" both linear and quadratic might be deemed to be in need of removal.

NB. Not everybody likes Hamming since it actually reduces the importance of data quite a distance away from the ends 0 & N.

Applying a Gaussian filter to the spectrum

You want to isolate just one particular harmonic from the total decay

First get the Fourier transform

```
spect=(fft((sigt-mean(sigt)).*han,N));
```

now apply the filter centred on f = f_o with a width ,"del"

```
f=1:N/2;
fscal=N/sample_rate;  % ..this necessary to get the correct
frequency scale
fs=fo*fscal;
dels=delt*fscal;
arg=exp(-2*(f-fs).*(f-fs)/(dels^2)); %……this creates the gaussian
```

```
This has to be applied to both "positive" and "negative"
frequencies ( pos  (<N/2) , neg (N/2+1 -> N) so we write
```

```
    args(f)=arg(f);
    args(N-f+1)=arg(f);

v2=args.*spect;  %  this applies the filter to  the spectrum
xx=real(ifft(v2,N)); %…….This gets you back to real time eg ideally
                       the decay of just the selected harmonic
```

Importing / Processing standard format files eg An Image

Matlab has functions dedicated to reading standard file formats for text, spreadsheet, scientific, image and audio files. They all have a similar syntax :- here is an example

xy= imread(' C:\matlab\work\Katanga.jpg','jpg') *(here an image file in jpeg format)*

[If your data file is not in standard format you can usually read it using the lower level functions

fseek , fread ***as long as*** *you know the basic file structure including the length of the* **Header** *]*

An M-file script to import an image file , low pass filter it and plot result.

%............simple image filtering with fourier

xy=imread('c:\matlab\bin\katanga.jpg','jpg'); %…………*import the image from a folder*

```
sz=size(xy);
N=min(sz(1:2));
matim=zeros(N,N);
matim(1:N,1:N)=(xy(1:N,1:N));    %………………Ask!!!
figure(1);
imagesc(xy);                  %………………………………..plot original image
figure(10);
imagesc(matim);
colormap(gray)                %……………………………..plot it again but now in greyscale
filter=zeros(N,N);            %……………………….. guassian filter centred on origin of K space
delph=input( '% of fft to retain');     % …….input  ~ % . of K space to retain ~width of guassian
[x,y]= meshgrid(1:N);
rr=((x-N/2).^2+(y-N/2).^2);         % ………………………create 2D guassian filter
rr=rr/((N/2)*(N/2));                  %……….think about exp raised to a  very large number!!!
filter=exp(-(rr*1e4/delph^2));
figure(2);
imagesc(filter)                        %……………………………plot the filter
 ft=fftshift(fft2(matim,N,N));     % …………   do 2D fft  and shift its origin to centre of array
 figure(3);
 imagesc(abs(ft))                    %………………………plot the 2D ft of greyscale image
  imagesc(abs(ft),[0 2e5]);
   ftfilt=ft.*filter;                    %        …………..filter 2D ft
      figure(4);
      imagesc(abs(ftfilt),[ 0 2e5]);%…………plot the filtered 2D ftt
      colormap(jet);
      figure(5);
         filt=ifft2(ftfilt,N,N); %……………..bring real space image back by inverse  2D fft
          colormap(gray);
      imagesc(abs(filt));     %……………… plot  filtered greyscale image
      colormap(gray);
```

functions for you to find out about

imagesc, meshgrid, colormap, fftshift, zeros

Good Matlabing!

Chris Guy Sept 2005