Draft quick introduction user guide

Roomsim User Guide

v0.0

03 March 2003

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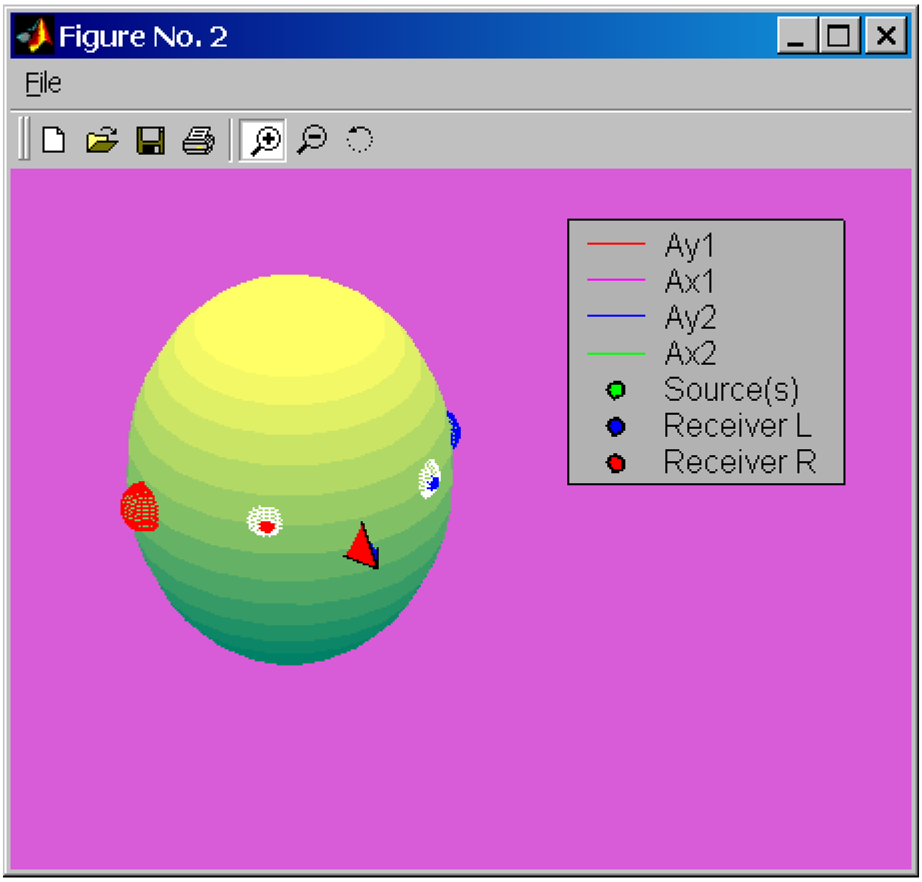


Contents

1 Introduction

What Roomsim is intended to be.
The Roomsim computer program provides a simulation of the acoustics of a simple empty "shoebox" room within which simulated (omni) directional microphones or simulated heads can be placed to allow estimation of the signal received at the sensors/ears from sources placed at locations within the room. It is intended as a tool for providing "sufficiently realistic" impulse responses and reverberant audio signals for either:

A) demonstrating some issues of room acoustics to undergraduate and postgraduate students.
B) the preliminary evaluation of audio processing algorithms prior to more accurate, (and time consuming) experiments.

What Roomsim is not intended to be.
Although care has been taken to produce a program that correctly implements the image source model of "shoebox" room acoustics, the programme is not intended to deliver an accurate simulation of even "shoebox" room acoustics in the real world. It is certainly not an attempt at producing a simulation of enclosure acoustics that would rival the more complex software available for creating architectural acoustic simulations e.g CATT Acoustics (http://www.catt.se). Neither is it intended to be a real time auralisation system e.g. SLAB (http://human-factors.arc.nasa.gov/SLAB).

Roomsim, its gestation and distribution.
The basis for building the Roomsim program is the publication of a Fortran routine by Allen and Berkley (1979) that many researchers have used as the core of their own simulations of "shoebox" room acoustics written in various computer languages. The reason for producing yet another is that the authors believe that a MATLAB implementation will be of use to digital signal processing (DSP) researchers and educators, because of its ease of communicating within what has become the prime DSP algorithm development platform.

The authors (at this time unknown to each other) separately searched for a WindowsPC MATLAB implementation of room acoustics that would satisfy their experimental requirements, but although a couple of candidate programs were found, neither incorporated the majority of features required and copyright issues were unclear. One of the authors (Palomaki) created a program to satisfy the immediate needs of a research project. Following a chance meeting in 2002 at a Binaural Hearing workshop at which results from that project were presented, Campbell was supplied with Palomaki's code and used that as the core of the Roomsim program.

The intention is to release the program for teaching and academic research as free software, under the GNU GPL licence, in the hope that, should it prove useful, its development and improvement will be encouraged. To this end both the MATLAB source m-code files and an executable version, for non-MATLAB installations, will be posted on a few appropriate web sites including the user contributed programs library at MATLAB Central. The existence and location of the code will be more widely disseminated via notices to various special interest groups in signal processing, binaural hearing, speech processing, audio processing and acoustics.

Roomsim features.

The program simulates the geometrical acoustics of a perfect rectangular parallelpiped room volume using the image model to produce an impulse response from each omni directional source to a directional receiver system which may be a single sensor, a sensor pair or a simulated head. The simulation of the head utilises Head Related Transfer Function (HRTF) data actually Head Related Impulse Response (HRIR) data provided from measurements made either on a Kemar mannequin at MIT (http://xenia.media.mit.edu/~kdm/hrtf.html ,Dec 2002), or on real subjects and a Kemar at University of California, Davis (http://interface.cipic.ucdavis.edu ,Dec 2002). The impulse response(s) can then be saved and convolved, within the program, with an audio (*.wav) or MATLAB file (*.mat). The resulting monaural, stereo, or "binaural response" can then be saved as an audio (*.wav) or MATLAB file (*.mat). If saved in *.wav format it can be played using a Windows compatible media player or sound editor.

The following parameters can be configured by the user:

1) Receiver coordinates
2) Receiver type (single sensor, sensor pair, HRTF)
3) Sensor directionality (restricted to "forward looking")
4) Sensor separation for sensor pair
5) HRTF from MIT Kemar or CIPIC subject (Kemar and human subjects)
6) Multiple sources, location specified as polar with origin at Receiver
7) Surface absorption for each of the six surfaces (24 frequency dependent values provided)
8) Air absorption model may be ON or OFF
9) Humidity (modifies air absorption coefficient)
10) Temperature (modifies the speed of sound)
11) Order of reflections
12) Sampling frequency
13) Length of impulse response
14) Smoothing filter (main use is for interpolation in sensor pair case)
15) High-pass filter for reduction of DC bias and low frequency ripple
16) Effect of distance (1/R) may be ON or OFF

The following displays are provided:

i) Plot of surface absorption vs. frequency
ii) 3D display of room, receiver and sources geometry.
iii) Plot of mean reverberation time (RT60) vs frequency
iv) Plot of impulse response(s) colour coded for Left and Right sensor, time or sample number ordinate.
v) Magnitude spectrum corresponding to above impulse response(s) (FFT length selectable), displayed cf. HRTF when MIT or CIPIC data selected..
vi) 2D zoom and rotatable plan view of room, receiver, source(s), surrounding image rooms, and image sources, with source intensity indicated by colour code.
vii) 2½D version of the above plan view with source intensity displayed as stem plot height.
viii) 3D zoom and rotatable view of room, receiver, source(s), surrounding image rooms, and image sources, with source intensity indicated by colour code.

The following file formats are supported:

a) MATLAB *.mat
b) Microsoft Windows PCM *.wav

The following utilities are provided for processing data files:

I) A 4th order high-pass filter for reducing DC offset and low-frequency ripple. Input and output data are presented
II) A 4th order low-pass filter for reducing high-frequency signal content.
III) A convolution operation that accepts both *.mat and *.wav format, and displays the impulse response data, audio file data and convolution result as line graphs, and additionally the latter two as spectrograms.

Roomsim requirements

The program was developed on a medium specification PC (1.5 GHz Intel Pentium4, 500 MB RAM, 30GB HDD, AGP Graphics) running Windows 2000 with MATLAB v 6.5 rev. 13 installed. The executable version does not require a MATLAB installation but may be constrained in its operation, particularly the behaviour of the graphic displays. Reflection orders>4, impulse responses > 10,000 samples and multiple sources will all contribute to imposing a large computational load resulting in slow response especially of the core impulse response calculation and the 2D and 3D graphics. The faster the CPU, memory and disk access the better the response time will be.

Installing Roomsim

Installation for use within MATLAB.

The program may be installed in a directory (folder) called Roomsim created under the users preferred parent directory by moving the **roomsim.zip** file into the parent directory and unzipping the complete contents. MATLAB **work** directory is a reasonable choice of parent. The action of unzipping **roomsim.zip** will create the directory **roomsim** and a subdirectory structure containing the MIT and CIPIC HRTF data sets.

Installation for use outwith MATLAB.

Unzip the executable version **roomsim_exe.zip** to the desired directory (folder). This will create the required subdirectory structure containing, supporting data files for roomsim.exe, the MIT and CIPIC HRTF data sets, and a subdirectory containing some support for manipulating the graphic display windows.

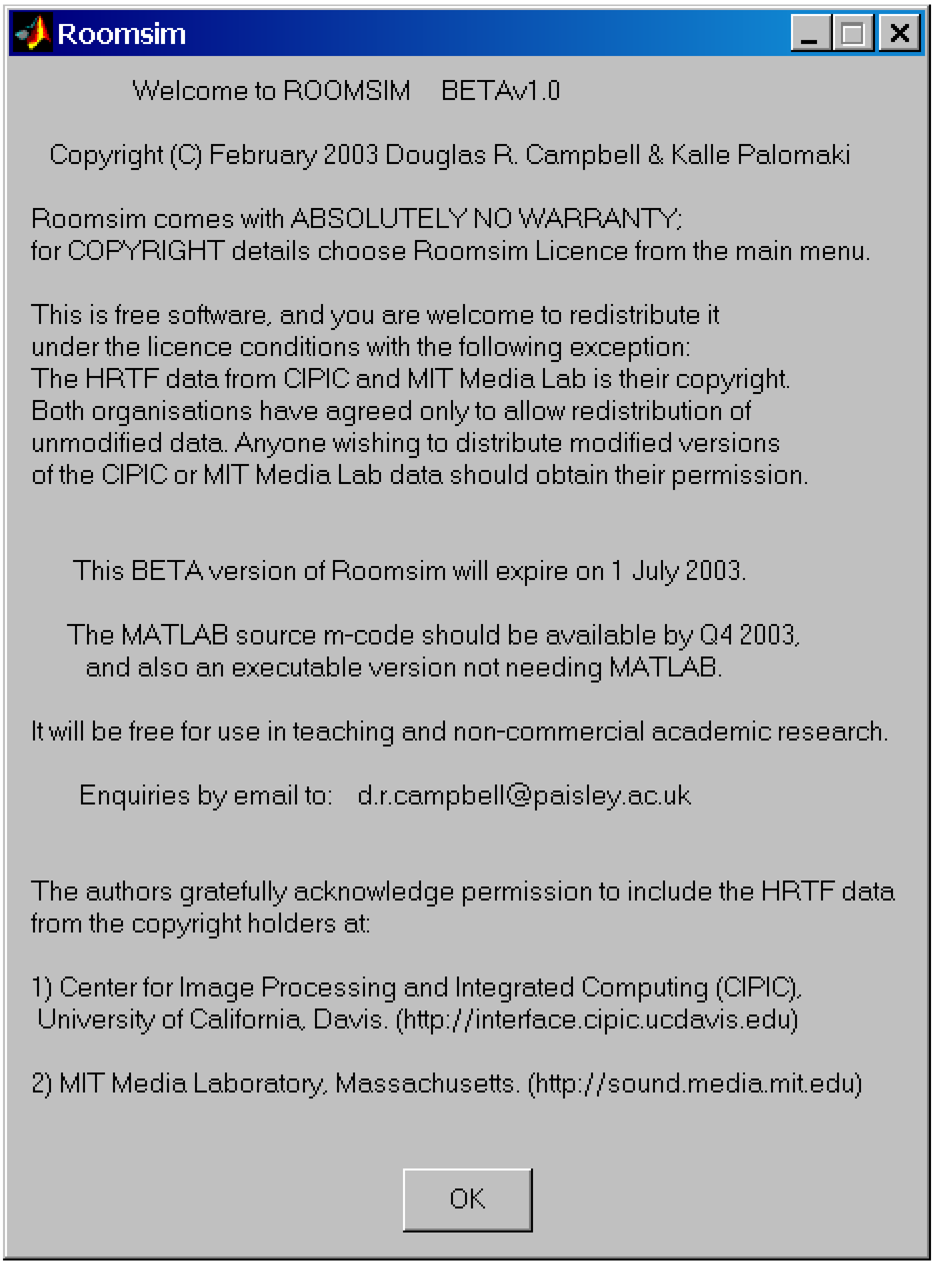
Running Roomsim

A brief guide to operating the program follows. The illustrations are "screen shots" from the program to help familiarise the user.

To run the program within the MATLAB environment make the current directory roomsim and type **roomsim** in the command window. If MATLAB is not available, the executable can be run by double clicking on the **roomsim.exe** icon. A command prompt window will open and display data items from the program that would otherwise appear in the MATLAB command window. In both cases the program will display a Welcome Message and users can then proceed to the Main Menu. During a run of the program a text file **Roomsim.log** will be created in the current directory and various items of data logged (see Appendix B).

2 Brief Operating Guide

Welcome Message



Left Button Click (LBC) on **OK** to proceed to Main Menu

MENU Roomsim: Main Menu

LBC on menu button to choose.

Choice 1: Exit to MATLAB (NB Clears windows)

Choice 2: About Roomsim

Choice 3: Set-up and Run the Room Simulation

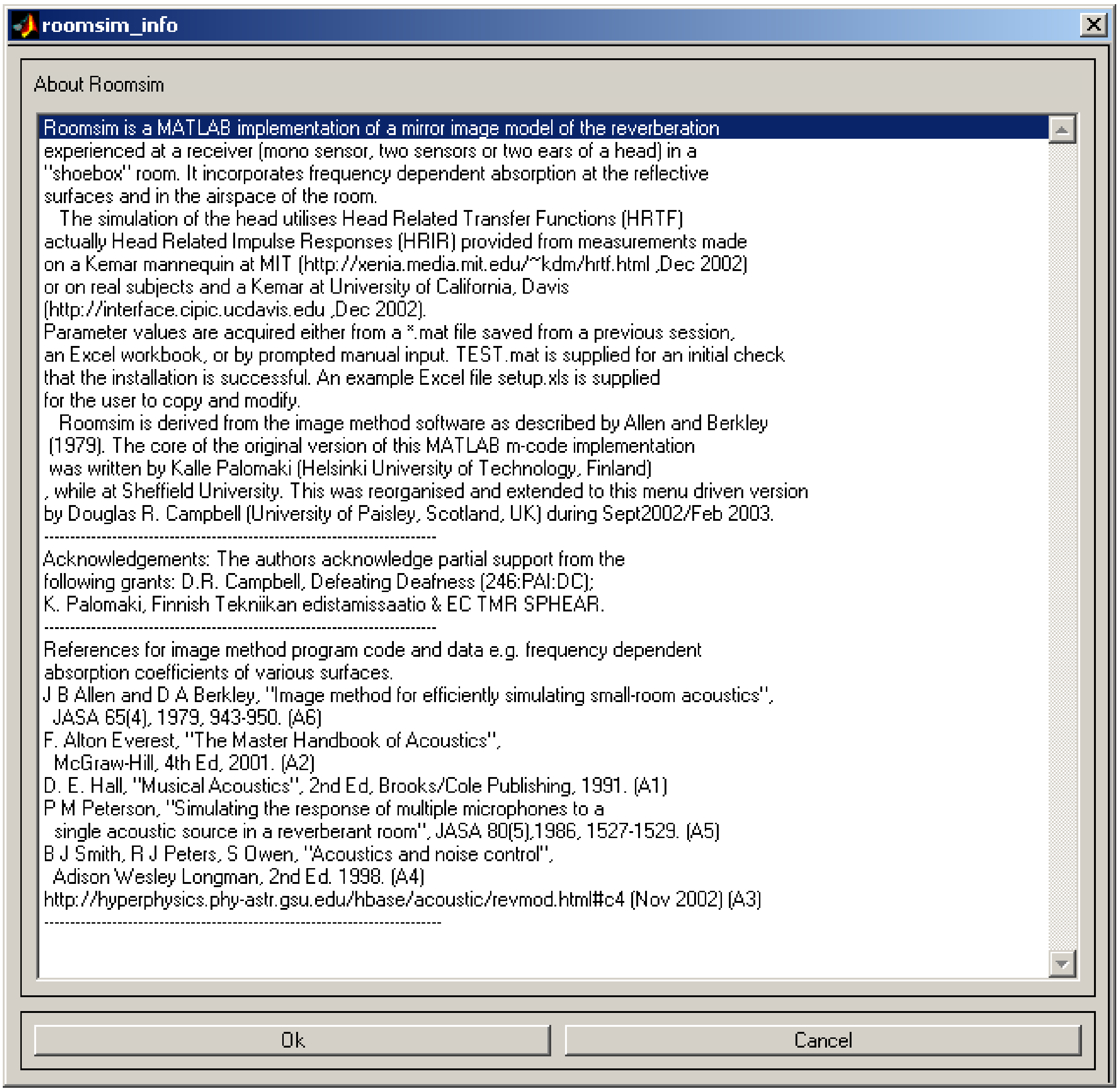
Choice 4: Convolve Impulse Response & Audio Data

Choice 5: Display Options

Choice 6: Utilities

Choice 7: Vacancy – reserved for expansion

About Roomsim: roomsim_info


roomsim_info

About Roomsim

Roomsim is a MATLAB implementation of a mirror image model of the reverberation
experienced at a receiver (mono sensor, two sensors or two ears of a head) in a
"shoebox" room. It incorporates frequency dependent absorption at the reflective
surfaces and in the airspace of the room.
The simulation of the head utilises Head Related Transfer Functions (HRTF)
actually Head Related Impulse Responses (HRIR) provided from measurements made
on a Kemar mannequin at MIT (http://xenia.media.mit.edu/~kdm/hrtf.html ,Dec 2002)
or on real subjects and a Kemar at University of California, Davis
(http://interface.cipic.ucdavis.edu ,Dec 2002).
Parameter values are acquired either from a *.mat file saved from a previous session,
an Excel workbook, or by prompted manual input. TEST.mat is supplied for an initial check
that the installation is successful. An example Excel file setup.xls is supplied
for the user to copy and modify.
Roomsim is derived from the image method software as described by Allen and Berkley
(1979). The core of the original version of this MATLAB m-code implementation
was written by Kalle Palomaki (Helsinki University of Technology, Finland)
, while at Sheffield University. This was reorganised and extended to this menu driven version
by Douglas R. Campbell (University of Paisley, Scotland, UK) during Sept2002/Feb 2003.

Acknowledgements: The authors acknowledge partial support from the
following grants: D.R. Campbell, Defeating Deafness (246:PAI:DC);
K. Palomaki, Finnish Tekniikan edistamissaatio & EC TMR SPHEAR.

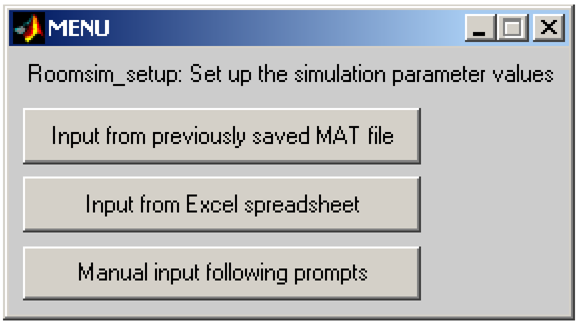
References for image method program code and data e.g. frequency dependent
absorption coefficients of various surfaces.
J B Allen and D A Berkley, "Image method for efficiently simulating small-room acoustics",
JASA 65(4), 1979, 943-950. (A6)
F. Alton Everest, "The Master Handbook of Acoustics",
McGraw-Hill, 4th Ed, 2001. (A2)
D. E. Hall, "Musical Acoustics", 2nd Ed, Brooks/Cole Publishing, 1991. (A1)
P M Peterson, "Simulating the response of multiple microphones to a
single acoustic source in a reverberant room", JASA 80(5),1986, 1527-1529. (A5)
B J Smith, R J Peters, S Owen, "Acoustics and noise control",
Adison Wesley Longman, 2nd Ed. 1998. (A4)
http://hyperphysics.phy-astr.gsu.edu/hbase/acoustic/revmod.html#c4 (Nov 2002) (A3)

Ok Cancel

A summary of:
The programme’s function and features.
Statement of authorship and acknowledgements.
References.

LBC on **Ok** or **Cancel** or mouse left button double-click (LBDC) on the text area will return to the Main menu.

MENU Roomsim_setup

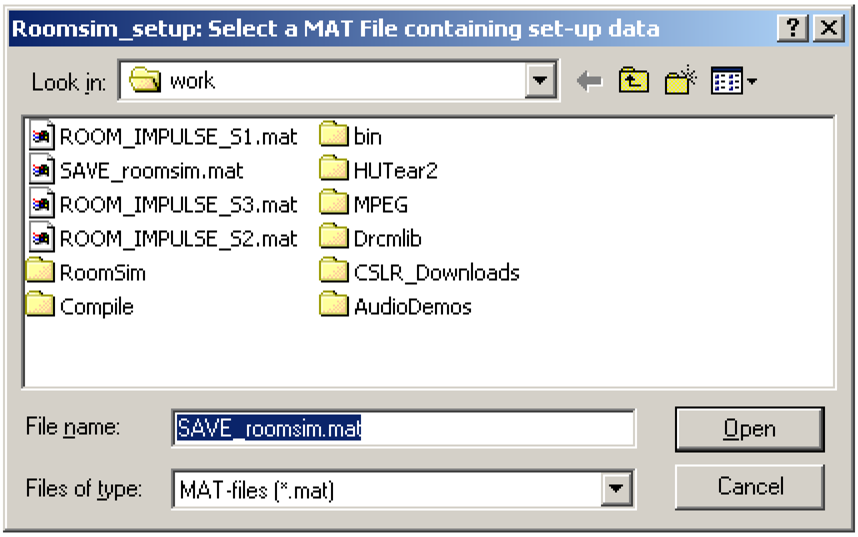


Choice 1: Load previously saved MAT file

Choice 2: Read from Excel spreadsheet

Choice 3: Manual input following prompts

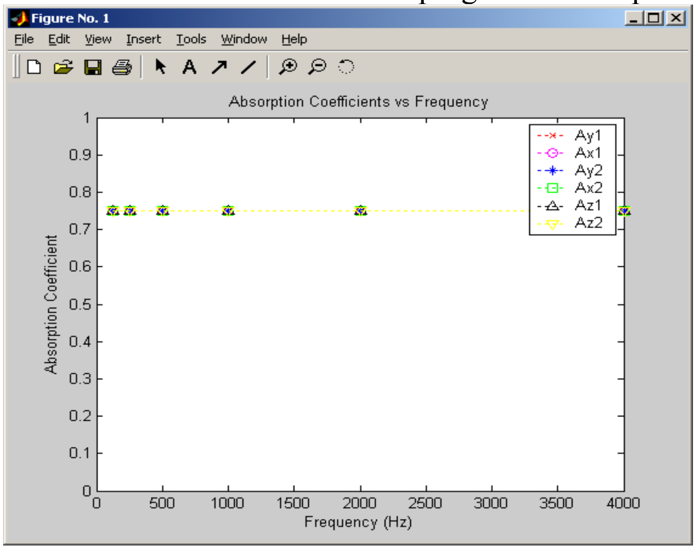
MENU Roomsim_setup Choice **1: Load previously saved MAT file**



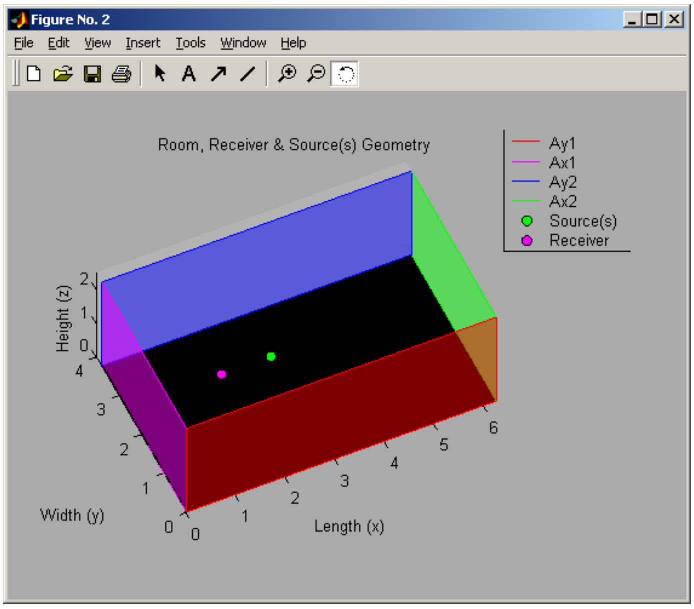
Select an appropriate *.mat file (default is SAVE_roomsim.mat), saved during a previous session, to load the required data for the room acoustic simulation.

Cancel will return the user to the above roomsim_ setup menu.

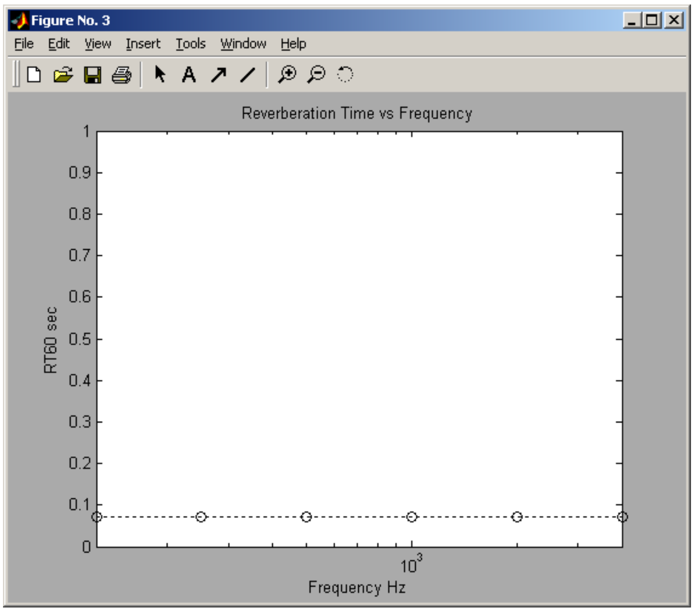
Execution will continue and the programme will produce the following three plots.



Absorption coefficients vs. frequency.



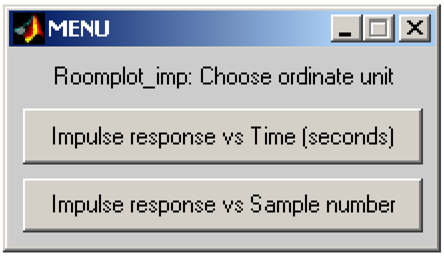
3D visualisation of the room geometry.



RT60 vs. frequency.

The programme then calls a function to compute the room impulse response. Depending on the simulation parameters and computer power <u>this may take some time</u>. If running within MATLAB the command window will indicate "busy" at the extreme bottom left. When the impulse response has been calculated **MENU Roomplot_imp** below will appear.

MENU Roomplot_imp

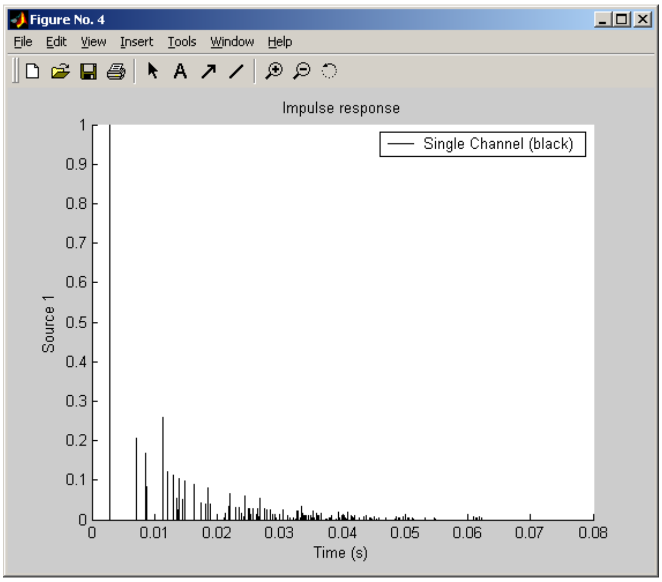


Choice 1: Impulse response vs. Time (seconds)

Displays a plot (shown below) of the computed impulse response(s) between the source(s) and the receiver system with the ordinate axis scaled as time in seconds. The abscissa axis label identifies the source.

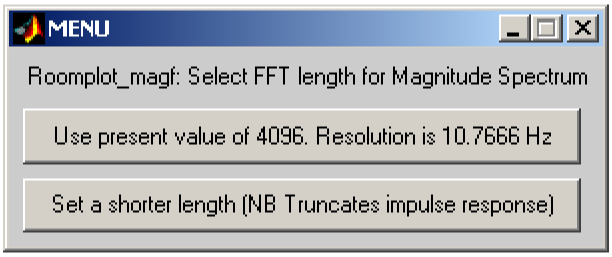
Choice 2: Impulse response vs. Sample number

As Choice 1 but with the ordinate axis scaled as integer Sample number.



The programme continues and the MENU Roomplot_magf below will appear.

MENU Roomplot_magf

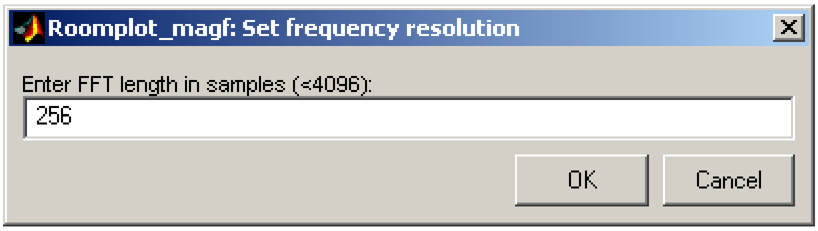


Choice 1: Use present value of **** . Resolution is *** Hz

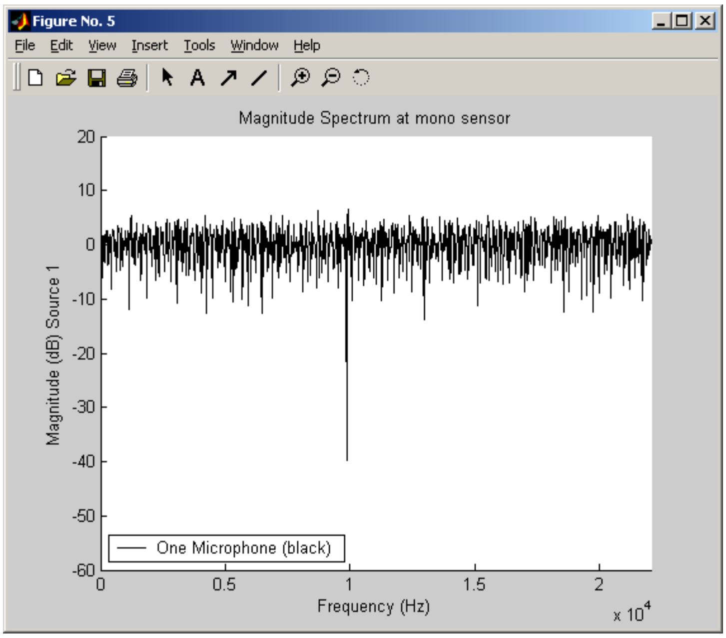
Displays a plot (shown below) of the computed magnitude of the frequency response(s) obtained by applying an FFT to the impulse response data. The ordinate axis is scaled in Hz. The abscissa axis is in dB with a label identifying the source.

Choice 2: Set a shorter length (NB Truncates impulse response)

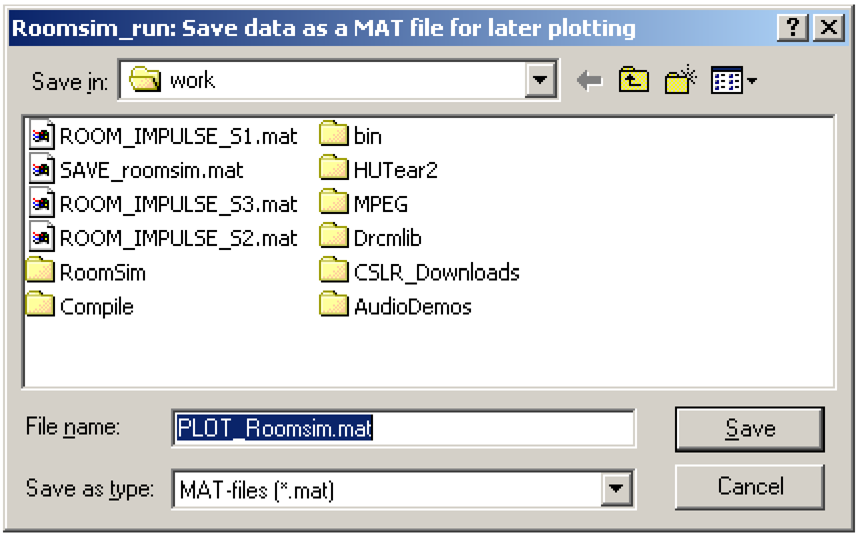
This choice presents a dialogue box prompting for a value that defines the length of FFT to be applied.



Enter the desired FFT length and LBC OK to proceed. The impulse response data used is restricted to the first M non-zero data points where M is the integer power of two number equal to or greater than the supplied value. The magnitude vs. frequency plot(s) is then displayed



A dialogue box then appears offering the option to save the data required to re-plot all the available display formats. The user may select a filename *.mat or accept the default name PLOT_roomsim.mat.

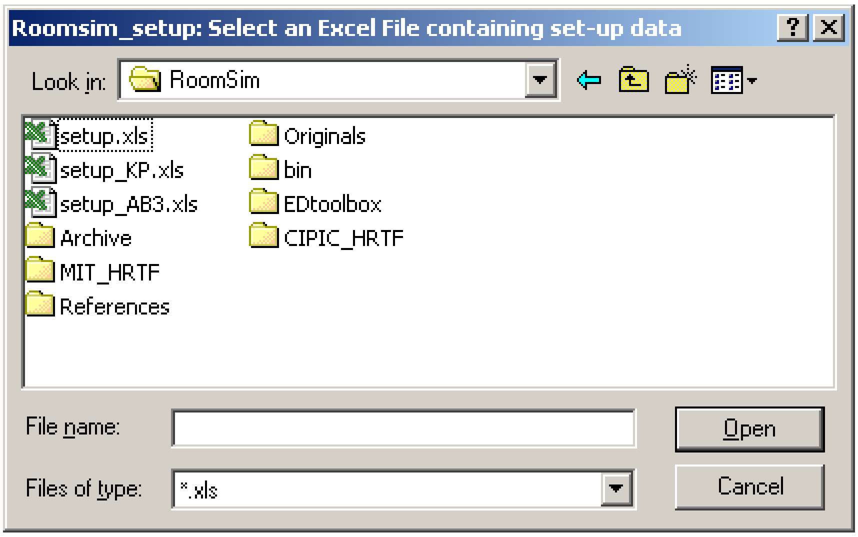


Cancel will proceed without saving any display data.

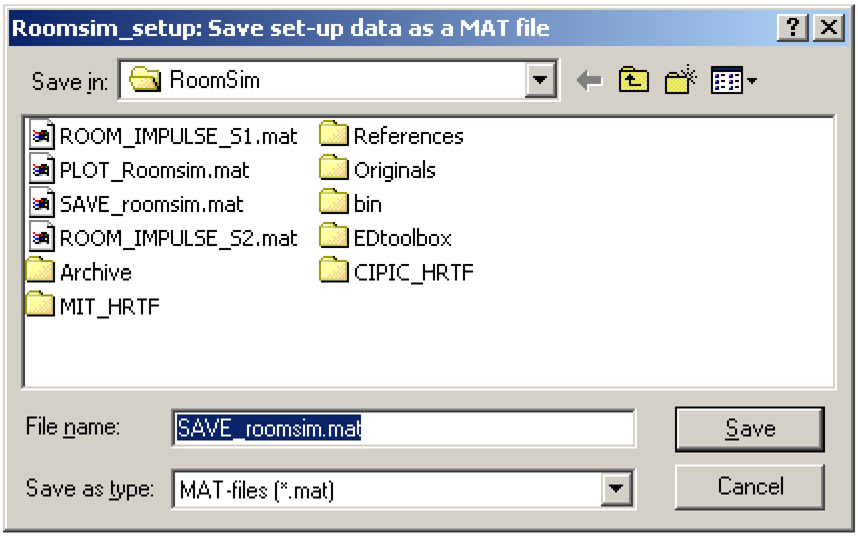
The programme then returns control to the Main Menu.

MENU Roomsim_setup Choice 2: Read from Excel spreadsheet

A dialogue box appears offering the option to read data from an Excel file. The user may select a filename *.xls or accept the default name setup.xls.



A dialogue box then appears offering the option to save all the data required to re-run the simulation. The user may select a filename *.mat or accept the default name SAVE_roomsim.mat. Cancel will return the user to the roomsim_ setup menu



The program then follows the same sequence as described for loading a *.mat file.

The Excel spreadsheet format

Spreadsheet entry is provided as an easy way to generate a text based set-up file to avoid repeated manual prompted entry when running experiments where only a few variables need to be changed e.g. moving a source to several different angles around a receiver.

The format of the spreadsheet is similar to that for the manual prompted entry but is divided by function among several sheets. There are five sheets, with tabs labelled **single values**, **sources**, **sensor dir**, **surface absorption**, and **absorption table**. The yellow coloured filled cells indicate protected areas of a sheet. The white areas may be overtyped with other values without removing the protection (which is not password protected).

The **single values** sheet below
is a list of single data items such as sampling frequency, sensor type etc. A calculator for speed of sound as a function of temperature (and temperature to achieve a desired speed of sound) is included on this sheet.

Parameter	Value (NB Text)	Comment
Fs	16000	% Sampling frequency (Hz)
humidity	50	% Relative humidity of air (%) (Used to calculate air absorption coefficient "m", valid range 20%< h <70%)
TEMP	-42	% Temperature of air (deg C) (Used to calculate speed of sound (m/s))
order	-1	% If -ve then value computed in make_Roomsim is used, else value supplied here is used (limits order of reflections computed)
H_length	-1	%Length of Impulse Response. If -ve then H_length is later set = RT60, else value supplied here is used.
H_filename	H_ROOM_AB3	%Filename for impulse response.
air_F	1	% 0 = no absorption due to air, 1 = air absorption is present.
smooth_F	1	% 0 = no smoothing filter applied, 1= smoothing filter used.
Fc_HP	0	% 0 = no high-pass filter. If scalar value supplied for cut-off frequency then high-pass filter applied.
plot_F2	0	% 0 = no plot, 1 = 2D-plan, shows image rooms on constant z plane.
plot_F3	0	% 0 = no plot, 1 = 3D-plot, rotatable
Lx	3.048	% Room Length
Ly	4.572	% Room Width
Lz	3.81	% Room Height
xp	1.9	% Receiver x co-ordinate
yp	0.38	% Receiver y co-ordinate
zp	2.29	% Receiver z co-ordinate e.g. Typical height above floor of ears of seated human subject
sensor	**one_mic**	% Receiver, copy one of these: **one_mic** **two_mic** **mithrir** **cipicir** NB all strings must be same length for later logical tests.
sensor_space	0.145	% case 'two_mic', Sensor separation (if head it is implicit in the HRIR data)
dir_ch	\	%PC directory change character
ext	.mat	%File extension type= MATLAB data
MIT_root	MIT_HRTF	% Substitute the value for root of MIT Kemar data base in your system
subdir	Kemar\compact	% MIT sub-directory path
filename	hrir_final	% MIT filename for HRIR
S_No	021	% CIPIC subject number, format '&&&' (e.g. '021' Kemar with small pinnae)
CIPIC_root	CIPIC_HRTF	% Substitute the value for root of CIPIC data base in your system
subdir	standard_hrir_database\subject	% CIPIC sub-directory path
filename	hrir_final	% CIPIC filename for HRIR
dist_F	1	% 0 = no distance attenuation applied (ie no 1/R effect), 1= distance attenuation applied
alpha_F	0	% 0 = fixed transparent surfaces for Room Geometry plot, 1 = (surface opacity = reflectivity)

Calculator	
temperature degC	c Speed of sound m/s
20	342.7
-41.9	305

The **sources** sheet below presents a table allowing column entry of radial distance of source from receiver, azimuth of source from receiver, and elevation of source from receiver. Eight source entries are supported in the example file setup.xls but if more than eight are required others may be added by following the instructions on the sheet. The Roomsim software and the Excel table format have been constructed so that the table can be extended to allow users to add sources without requiring any modification to the Roomsim reading process. A calculator is provided for converting receiver and source Cartesian coordinates to the required polar form for Roomsim.

SOURCES	1	2	3	4	5	6	7	8
R_s (m)	3.6							
alpha (deg)	102.49							
beta (deg)	-12.36							

% R_s = Radial distance(s) of source(s) from head (m)
% alpha = Azimuth(s) of sources -180< alpha < 180 (deg) NB +ve is ACW on xy plane
% beta = Elevation(s) of sources -90< beta < 90 (deg).

% To add a source:
1) Clear or change any inappropriate existing values
2) Add the new column (R_s, alpha, beta) immediately to the right of the existing values
3) Save the file.

% To add sources > 8:
1) Unprotect this sheet
2) Add an entry column (R_s, alpha, beta) to right of the existing values list above
3) Unlock the cells just added
4) Protect the sheet
5) Save the file

Calculator	Receiver	Source	Polar	Polar		
x	1.9	1.14	3.596582	R_s	3.6	m
y	0.38	3.81	1.788848	alpha	102.49	deg
z	2.29	1.52	-0.21576	beta	-12.36	deg

The **sensor dir** sheet below presents a table for recording the desired directionality of either a single sensor (e.g. one microphone) receiver or a two sensor (e.g. stereo microphone pair). The entries required for omni directional sensors are listed on the sheet as a reminder.

Directionality (deg)	Single or Left	Right		
min_azim_sensor	-180		Single Sensor	%Minimum azimuth seen by single sensor
max_azim_sensor	180			%Maximum azimuth seen by single sensor
min_elev_sensor	-90			%Minimum elevation seen by single sensor
max_elev_sensor	90			%Maximum elevation seen by single sensor
min_azim_sensor	-180	-180	Two Sensors	%Minimum azimuth seen by sensor
max_azim_sensor	180	180		%Maximum azimuth seen by sensor
min_elev_sensor	-90	-90		%Minimum elevation seen by sensor
max_elev_sensor	90	90		%Maximum elevation seen by sensor

Omnidirectional	Values
min_azim_sensor	-180
max_azim_sensor	180
min_elev_sensor	-90
max_elev_sensor	90

The **surface absorption** sheet below presents a table for entering the absorption coefficients (at the standard octave measurement frequencies) of the ceiling, floor and each wall surface. The values can be entered individually as required or copied and pasted from the supplied list of surface types on the **absorption table** sheet. The calculator for speed of sound as a function of temperature (and temperature to achieve a desired speed of sound) is duplicated on this sheet, for use with a calculator of reverberation time RT60. This is provided to support iterative estimation of reverberation time from the selected room surfaces and sizes, for those who wish to manipulate surface absorption to achieve a desired RT60.

Set the room surface absorptions

F_abs	125	250	500	1000	2000	4000	Standard measurement frequencies (Hz)
Ax1	0.19	0.19	0.19	0.19	0.19	0.19	Absorption of wall in x=0 plane (behind Receiver in plan)
Ax2	0.19	0.19	0.19	0.19	0.19	0.19	Absorption of wall in x=Lx plane (front in plan)
Ay1	0.19	0.19	0.19	0.19	0.19	0.19	Absorption of wall in y=0 plane (right in plan)
Ay2	0.19	0.19	0.19	0.19	0.19	0.19	Absorption of wall in y=Ly plane (left in plan)
Az1	0.51	0.51	0.51	0.51	0.51	0.51	Absorption of floor i.e. z=0 plane
Az2	0.51	0.51	0.51	0.51	0.51	0.51	Absorption of ceiling i.e. z=Lz plane

Data for RT60 Estimator		
humidity %	30	
c m/s	343	
Lx (m)	4	
Ly (m)	4	
Lz (m)	4	
V (m^3)	64.00	
Sxz (m^2)	16.00	
Syz (m^2)	16.00	
Sxy (m^2)	16.00	
S (m^2)	96.00	
Se (m^2)	28.48	
a_bar	0.30	
m_air_bar	8.68379E-05	
Method	**RT60 estimate**	
Norris-Eyring	0.702	RT60=(55.25*V/c)/(4*m*V-S*log(1-a_bar))
Sabine	0.362	Simple, RT60=(55.25*V/c)/Se
Sabine	0.558	Adjusted for high absorption and air, RT60=(55.25*V/c)/(Se*(1+a_bar/2)+4*m*V)

Calculator	
temperature degC	c Speed of sound m/s
20	342.7
-41.9	305

% This table provides the surface absorption data for the room simulation "roomsim".
% You can copy and paste surface absorptions from the required row (columns B to G) to rows 3 to 8 of the surface absorption sheet

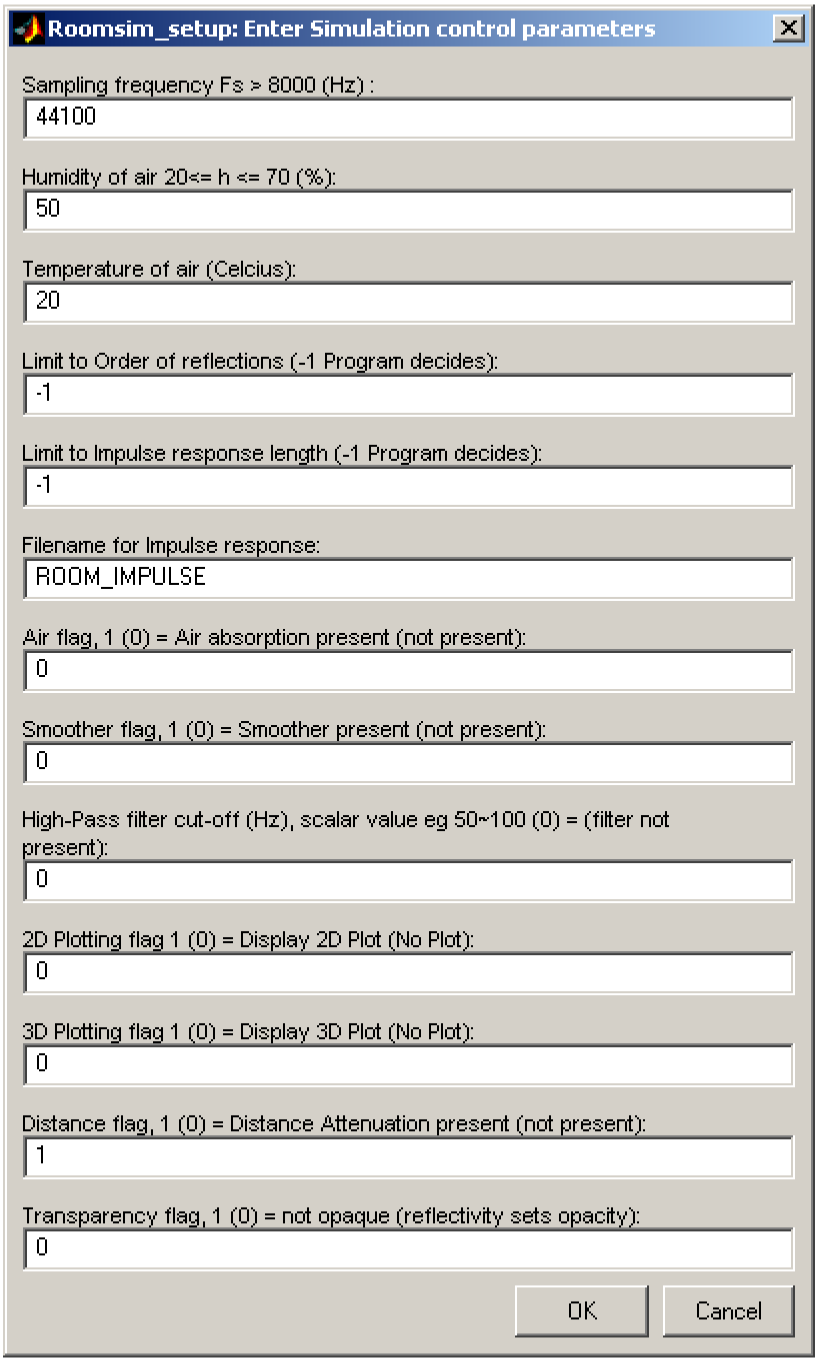
% This table is also read to provide the surface absorption list for the manual data entry option of Roomsim
% To add a surface type: 1) Add an entry to the foot of the Surface absorption data list below 2) Save the file
% DO NOT PLACE ANYTHING ELSE ABOVE OR BELOW THE TABLE as that would disrupt the reading process

% References for data frequency dependent absorption coefficients of various surfaces.
% (A1) D. E. Hall, "Musical Acoustics", 2nd Ed, Brooks/Cole Publishing, 1991. Taken from the list at (A3).
% (A2) F. Alton Everest, "The Master Handbook of Acoustics", McGraw-Hill, 3rd Ed, 1994.
% (A3) http://hyperphysics.phy-astr.gsu.edu/hbase/acoustic/revmod.html#c4 (Nov 2002)
% (A4) B J Smith, R J Peters, S Owen, "Acoustics and noise control", Adison Wesley Longman, 2nd Ed. 1998.

			Surface absorption data				
F_abs	**125**	**250**	**500**	**1000**	**2000**	**4000**	Standard measurement frequencies (Hz)
anechoic	1	1	1	1	1	1	% Simulated Anechoic Chamber i.e. total absorption at all frequencies
quiet_room	0.9	0.9	0.9	0.9	0.9	0.9	% Simulated Quiet Room i.e. High absorption at all frequencies
percent50	0.75	0.75	0.75	0.75	0.75	0.75	% 50% reflectance at all frequencies. Used for testing impulse amplitude calculations.
echoic	0.01	0.01	0.01	0.01	0.01	0.01	%Very echoic room i.e.little absorption at any frequency
acoustic_tile_average	0.1	0.3	0.8	0.85	0.75	0.65	% Average acoustic tile 3/4" thick (Ref A2)
acoustic_tile_rigid	0.2	0.4	0.7	0.8	0.6	0.4	% Acoustic tile rigid mount (Ref A1).
acoustic_tile_suspended	0.5	0.7	0.6	0.7	0.7	0.5	% Acoustic tile suspended mount (Ref A1).
acoustic_plaster	0.1	0.2	0.5	0.6	0.7	0.7	% Acoustical plaster (Ref A1).
plaster_on_lath	0.2	0.15	0.1	0.05	0.04	0.05	% Ordinary plaster on lath (Ref A1).
gypsum_wallboard	0.3	0.1	0.05	0.04	0.07	0.1	% Gypsum wallboard (Ref A1).
plywood	0.6	0.3	0.1	0.1	0.1	0.1	% Plywood sheet, 1/4" on studs (Ref A1).
brick	0.03	0.03	0.03	0.04	0.05	0.07	% Brick (Ref A1).
conc_unpaint	0.4	0.4	0.3	0.3	0.4	0.3	% Concrete unpainted (Ref A1).
conc_paint	0.1	0.05	0.06	0.07	0.1	0.1	% Concrete painted (Ref A1).
conc_poured	0.01	0.01	0.02	0.02	0.02	0.03	% Concrete poured (Ref A1).
vinyl_tile_on_concrete	0.02	0.03	0.03	0.03	0.03	0.02	% Vinyl tile on concrete (Ref A1).
heavy_carpet_on_concrete	0.02	0.06	0.15	0.4	0.6	0.6	% Heavy Carpet on concrete (Ref A1).
heavy_carpet_felt_backing	0.1	0.3	0.4	0.5	0.6	0.7	% Heavy carpet on felt backing (Ref A1).
platform_floor_wooden	0.4	0.3	0.2	0.2	0.15	0.1	% Platform floor wooden (Ref A1).
ordinary_window_glass	0.3	0.2	0.2	0.1	0.07	0.04	% Ordinary window glass (Ref A1).
heavy_plate_glass	0.2	0.06	0.04	0.03	0.02	0.02	% Ordinary window glass (Ref A1).
glazed_wall	0.01	0.01	0.01	0.01	0.01	0.01	% Glazed tiles, polished marble or stone (Ref A4).
draperies_medium_velour	0.07	0.3	0.5	0.7	0.7	0.6	% Draperies medium velour (Ref A1).
water	0.01	0.01	0.01	0.01	0.01	0.01	% eg swimming pool (Ref A4).

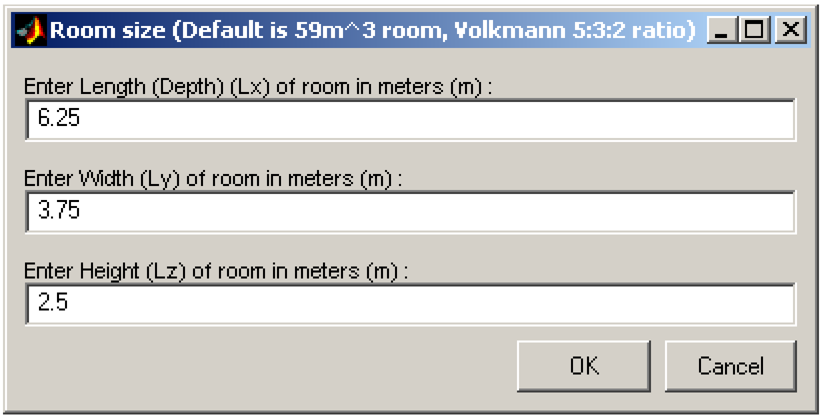
MENU Roomsim_setup Choice 3: Manual input following prompts

The dialogue box below appears with a set of "sensible" default values. The user should modify the values as required. A list of the simulation parameters is available in Appendix A.



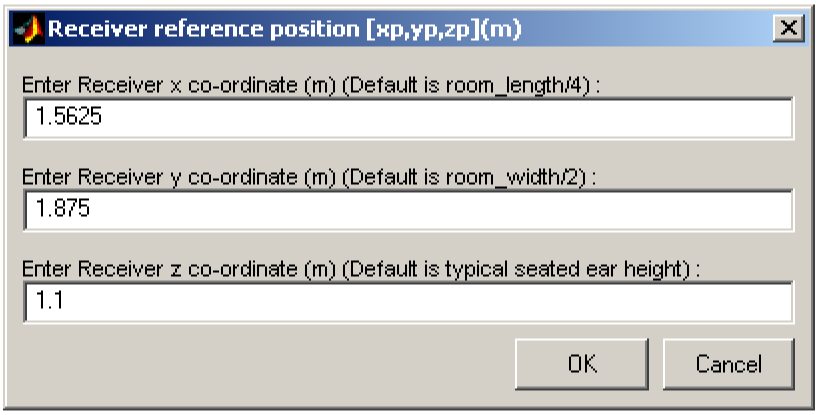
LBC **OK** to continue to next menu. Cancel will redisplay the above dialogue box. NB In addition to the plots described earlier, the 2D plotting flag allows the user to select display of a plan view of the room and surrounding image rooms, receiver position, source(s) position and image source positions with source "strengths" coded either by brightness or by the height of a 3D stem plot. The 3D plotting flag allows selection of a 3D version of the 2D display with sources only coded by brightness.

The dialogue box below appears with a set of default values for a room of ~ 60 m^3. The user should modify the values as required.

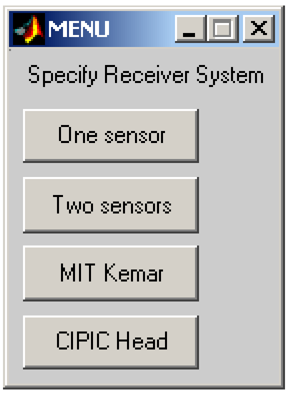


LBC **OK** to continue to next menu. Cancel will redisplay the above dialogue box.

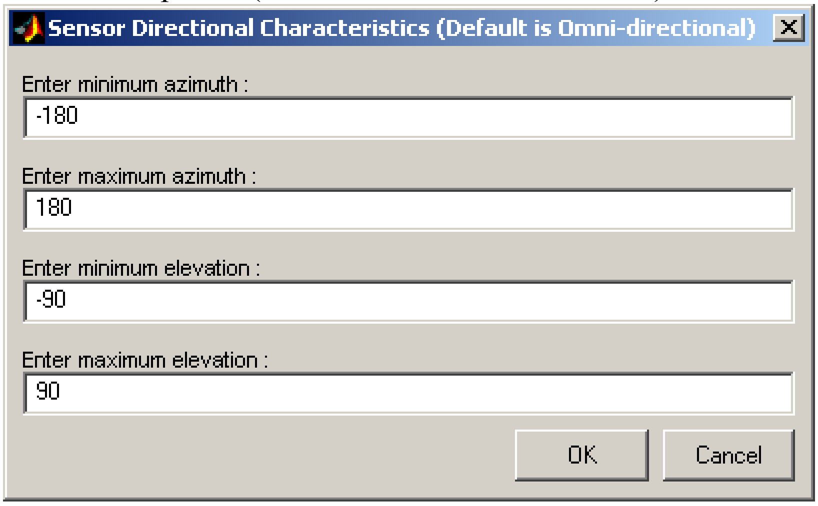
The dialogue box below appears with a set of default values based on room size. The user should modify the values as required.



The menu below appears. The user should choose the receiver system as required.



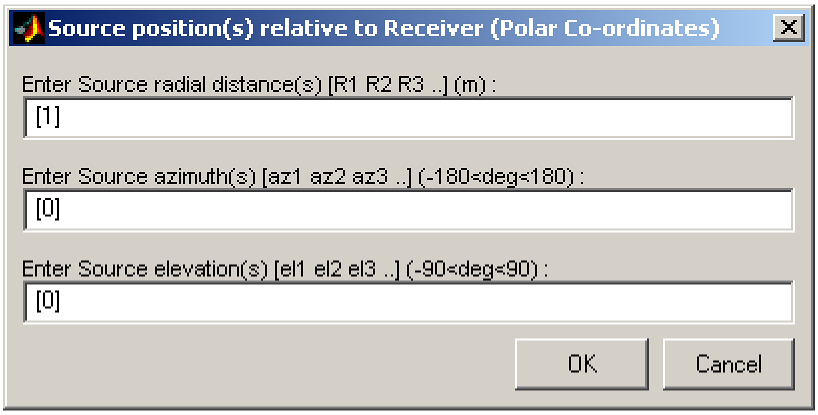
The dialogue box below appears with a set of default values. The user should modify the values as required. (Omni-directional is the default). Azimuth is +ve moving clockwise in the



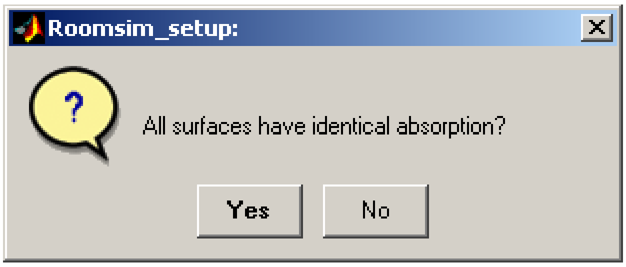
z = 0 plane about the z axis viewed from above and from the x axis 0 datum. Elevation is +ve moving anti-clockwise in the y = 0 plane about the y axis and from the x axis 0 datum.

The dialogue box below appears with a set of default values. The user should modify the values as required. NB Several sources can be entered in MATLAB bracketed row vector format e.g.

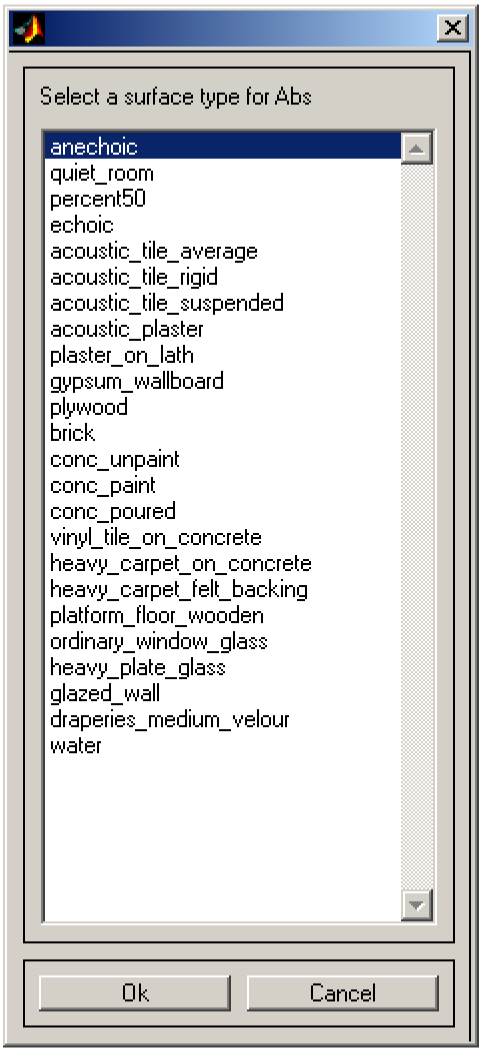
Distances: [1 2 3]
Azimuths: [0 –179 90]
Elevations: [0 –89 45]



The question dialogue box below allows the user to force all surfaces to be of one type or to separately specify them.

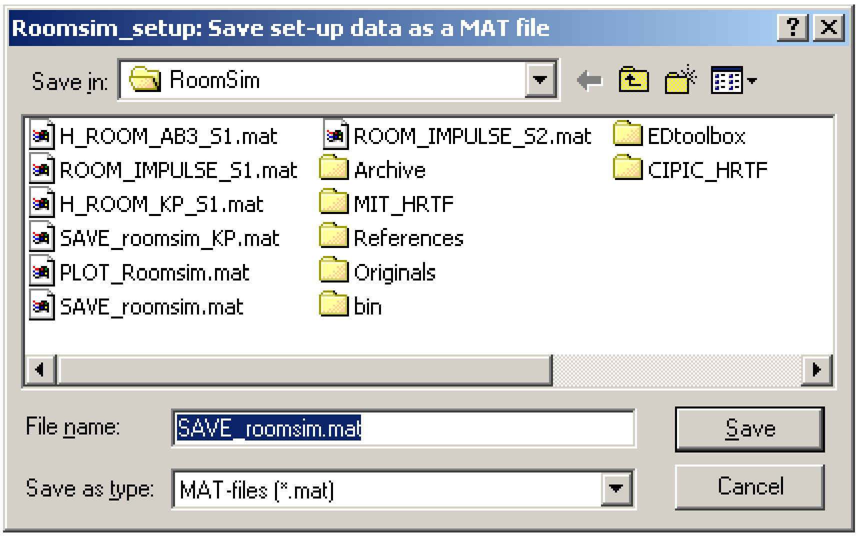


The list dialogue box below allows the user to choose a surface type. This will appear once per surface to be specified if No was answered to the above question.



Selection can be made with LBC on a surface type then LBC on OK, or by LBDC on a surface type.

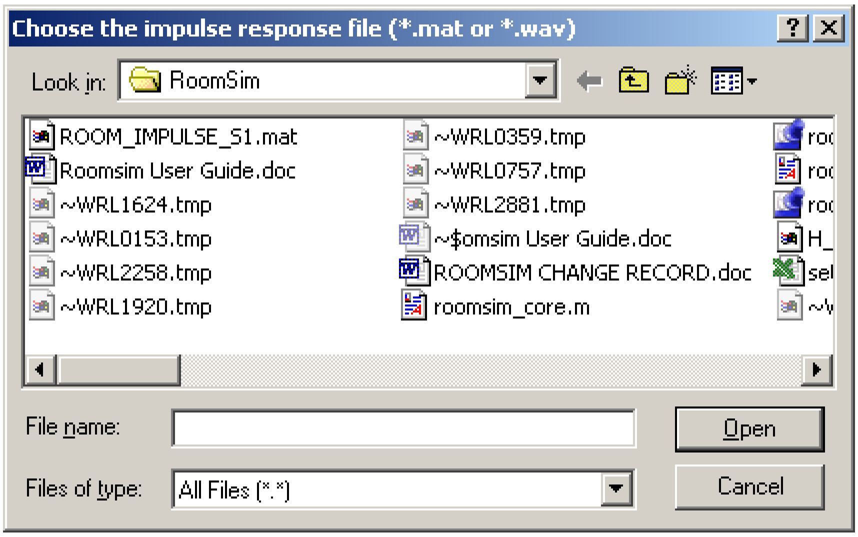
A dialogue box then appears offering the option to save all the data required to re-run the simulation. The user may select a filename *.mat or accept the default name SAVE_roomsim.mat. Cancel will return the user to the roomsim_ setup menu



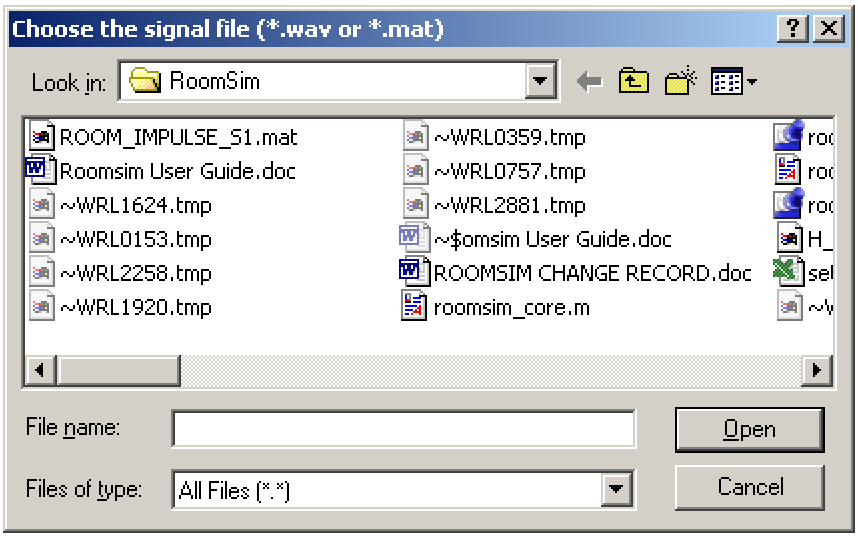
The program then follows the same sequence as described for loading a *.mat file.

Main Menu Choice 4: Convolve Impulse Response & Audio Data

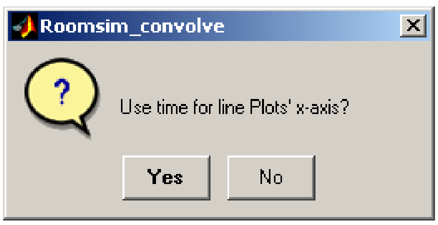
This allows selection of two files to be convolved together and the result saved. Either of the input files may be *.mat or *.wav format and the output may also be either of these formats.



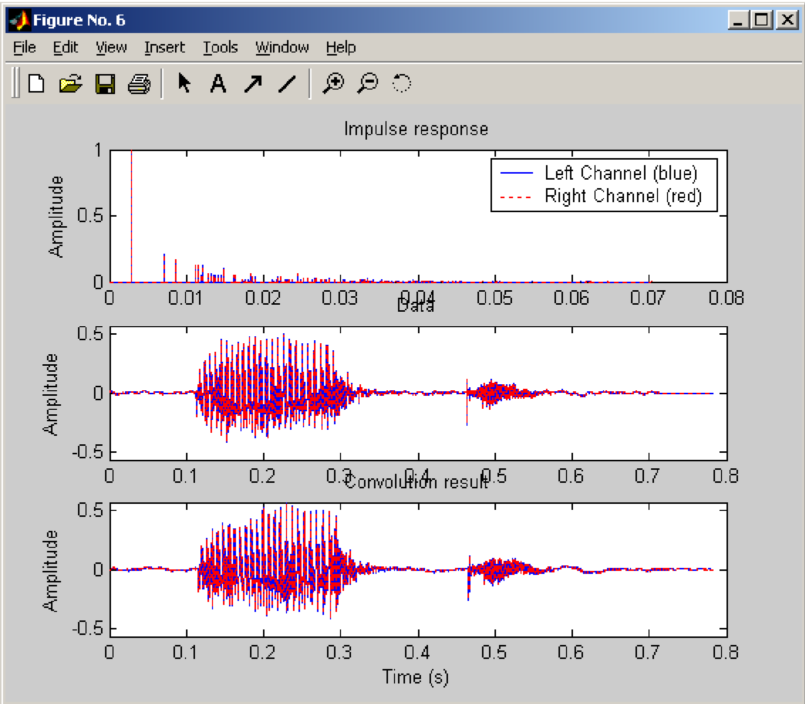
The user selects a previously saved impulse response (either *.mat or *.wav format) and a dialogue box to allow selection of the second file will appear.



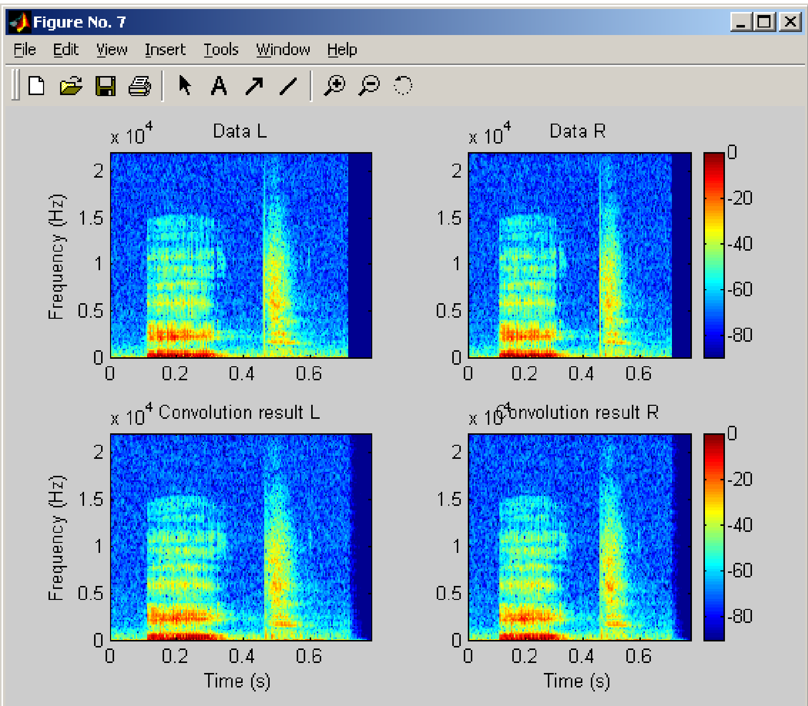
The user selects a previously saved audio data file (either *.mat or *.wav format) and a question dialogue box to allow selection of the ordinate axis units (time or samples) will appear.



A progress bar will appear indicating the convolution calculation is proceeding. When it completes, a time history plot of the two data files contents and the convolved result will appear and a spectrogram display of the original audio data and the convolution result will also appear (the latter may obscure the former so click and drag the top window to reveal the lower one)



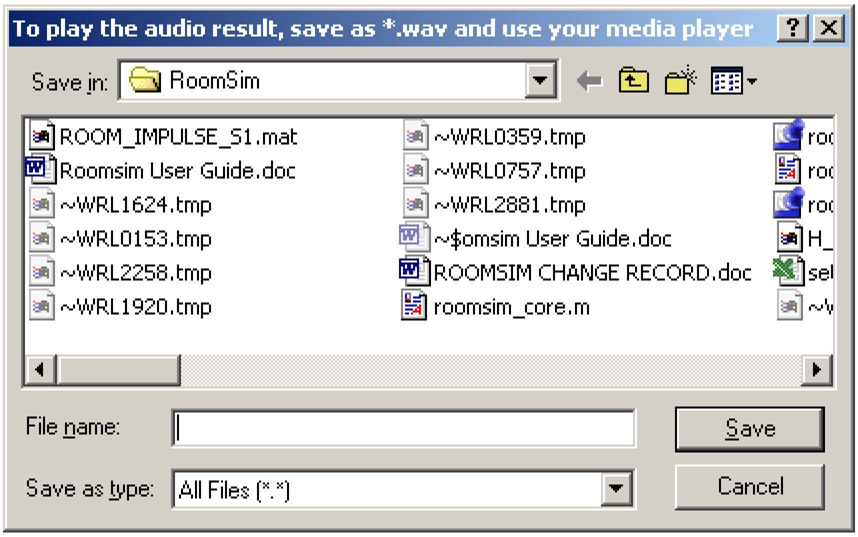
Time Histories



Spectrograms

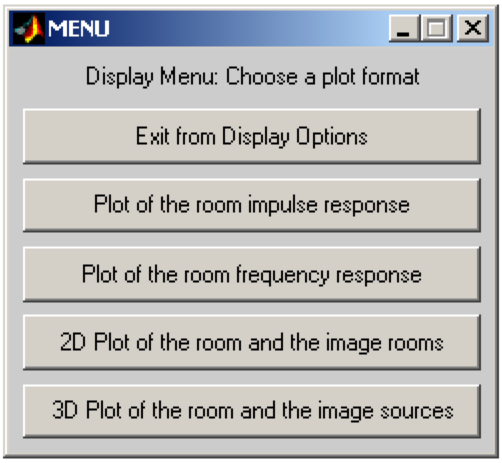
Example sounds are provided as crickets.wav and eight.wav which have been separately convolved with a room response to yield crickets_reverb.wav and eight_reverb.wav.

A file save dialogue box (below) will also appear prompting the saving of the convolution result for audio display. The data can be saved as a stereo *.mat or *.wav file. The latter may be played using an MSwindows compatible media player.



The programme then returns control to the Main Menu.

Main Menu Choice 5: Display menu



The room impulse response and frequency response are as shown previously but here access a *.mat file saved during a previous run. The 2D and 3D plots can be initiated during manual input at Roomsim set-up (or through the Excel set-up file) or using a previously saved plot data file. The appearance of these displays is shown below. The 3D display is very cluttered for most “realistic” scenarios but has some educational value for simple acoustic arrangements.

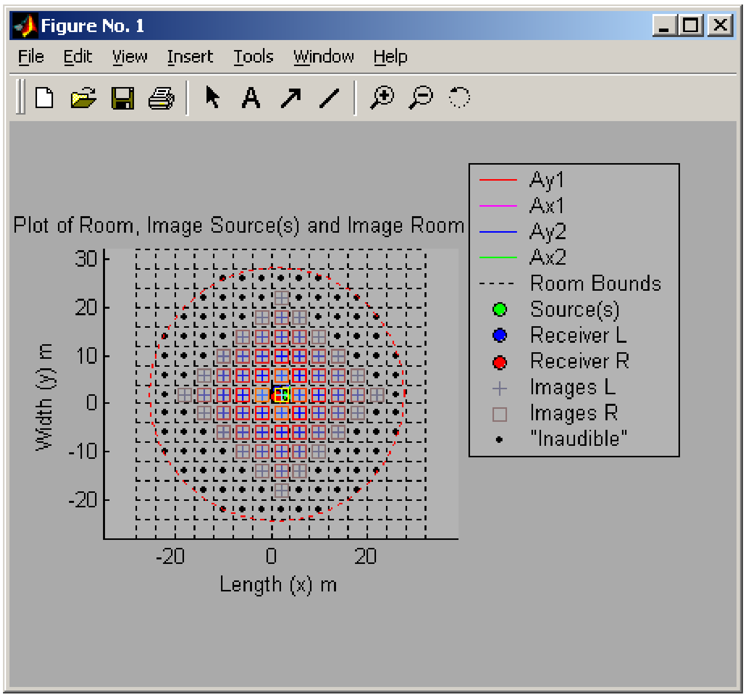


Image rooms and intensity colour coded sources shown in plan view

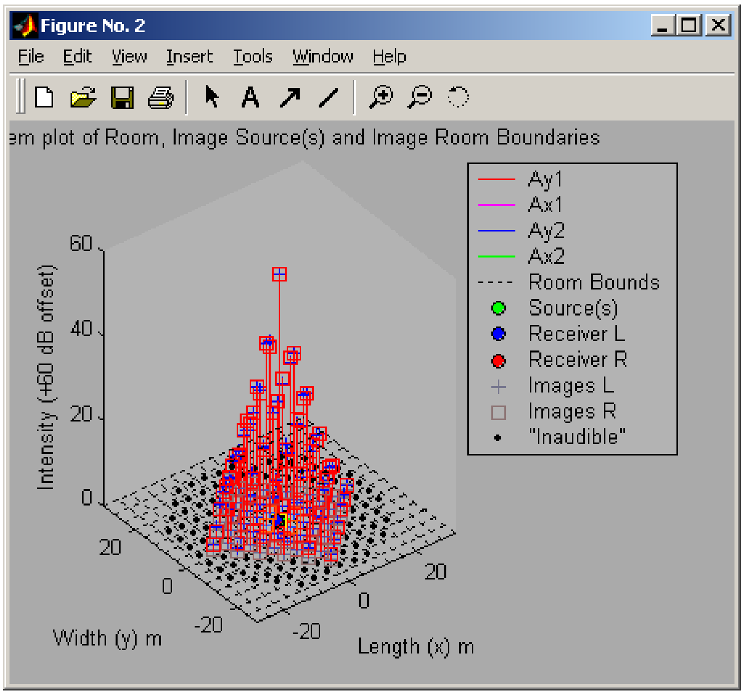
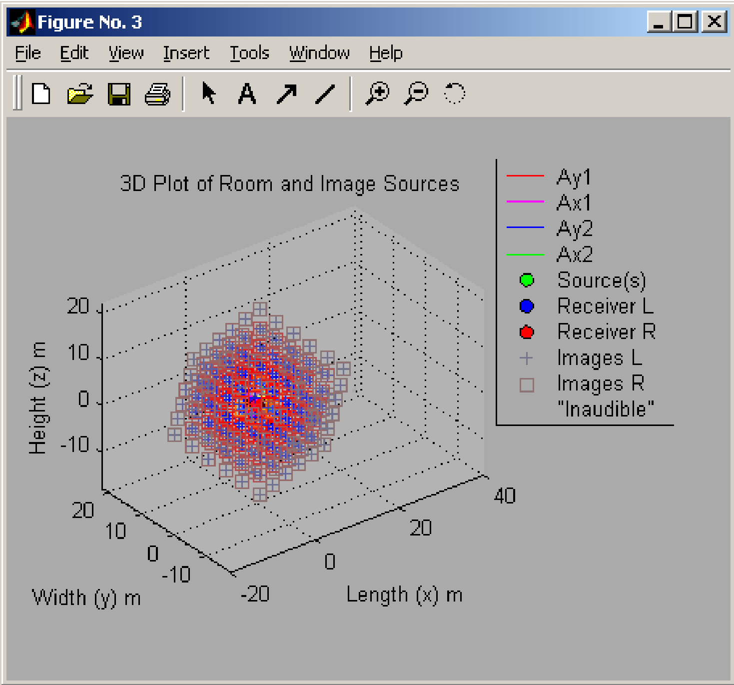


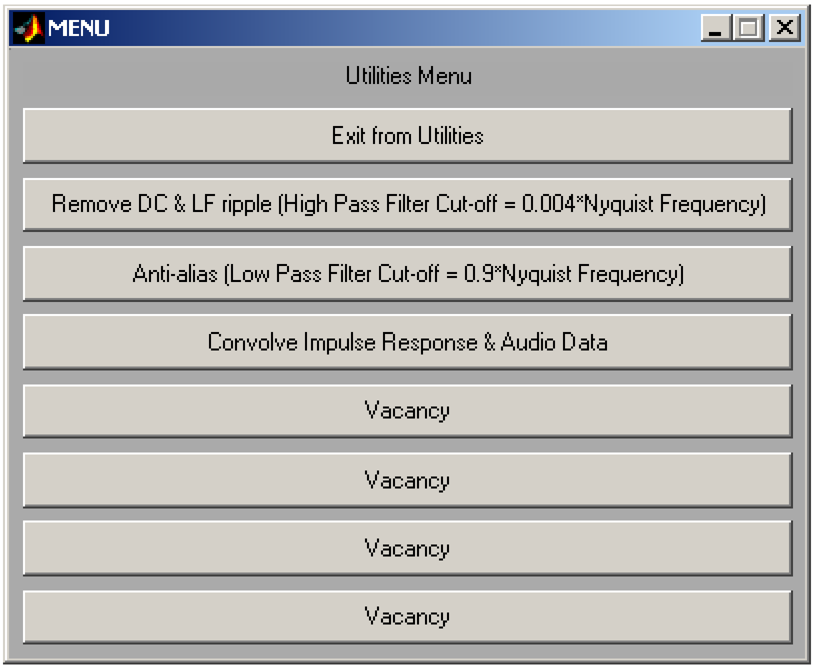
Image rooms and intensity colour plus stem height coded sources shown in 2½D view



Intensity colour coded sources shown in 3D view

The Display Options menu returns control to the Main Menu.

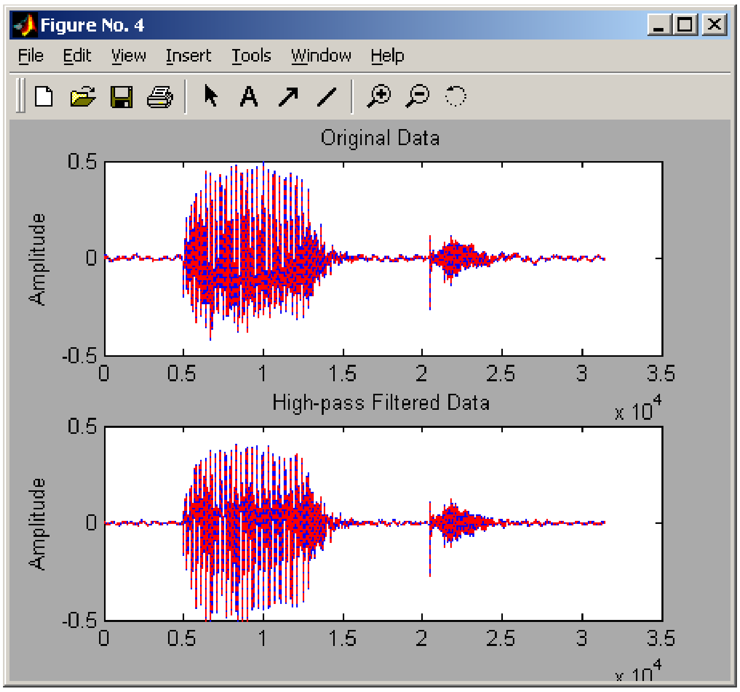
Main Menu Choice 6: Utilities



The three utilities at present installed allow the user to perform operations on previously saved files.

Utilities Menu Choice 1: High-pass filter

The user can select a file to be high-pass filtered to reduce DC bias or low-frequency ripple e.g. generated in the convolution of an impulse response with an audio file. The input file is selected and the filtered result is saved using dialogue boxes as previously shown, and a plot of the input and filtered output file is displayed as shown below.

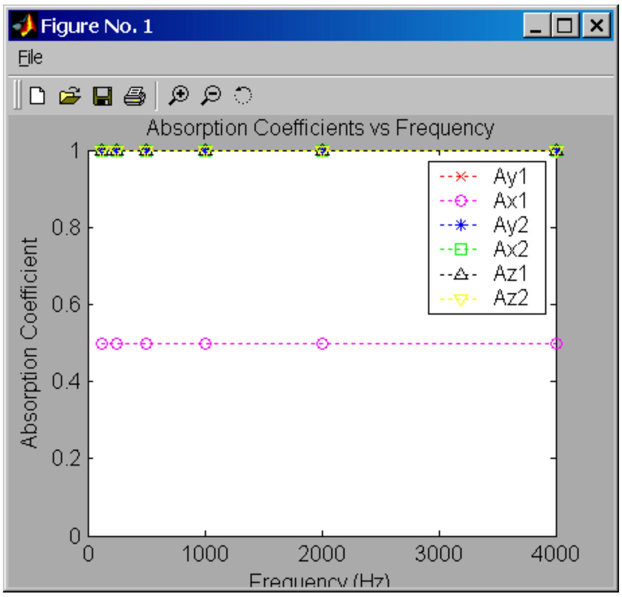


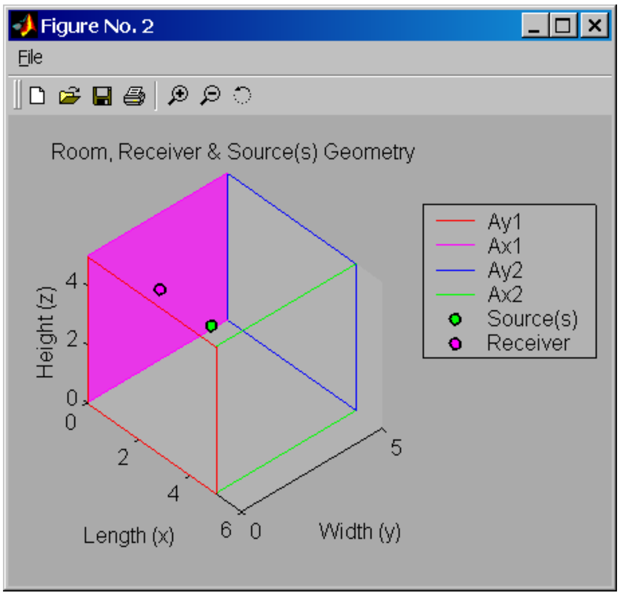
The low-pass filter operation is controlled in the same fashion. The convolution is provided here for convenience and is identical to that available from the Main Menu.

3 Example Materials

3.1 Setup One Wall

The Excel file setup_onewall.xls can be used with Roomsim to demonstrate the simple mirror image case and the effect of placing a microphone close to an acoustic reflector (comb filter effect). The selections made in this data file set up a room in which only one wall has non-zero reflectivity (Fig 1) and this is shown as the colour filled wall on the 3D plot of the room geometry (Fig 2). The graph of impulse response (Fig 4 (Fig 3 not shown)) shows the direct impulse and the reflected impulse at the single sensor allowing for measurement and checking with predicted values (0.5ms delay). The graph of frequency response (Fig5) displays the comb filter effect with notches at the appropriate frequencies (1kHz, 3kHz, 5kHz, etc.). A plan view showing the image source is provided (Fig 6) as is a 3D version (Fig 7) which can be rotated using the figure control palette.





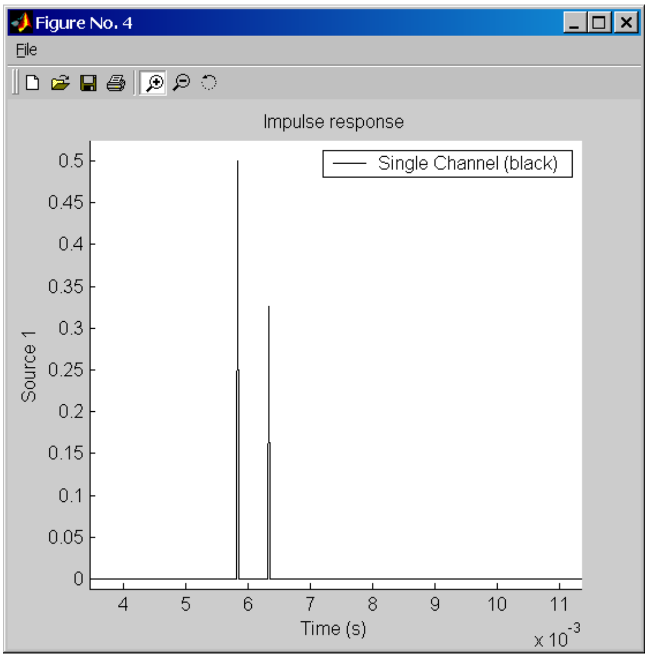


Figure No. 4
File
Impulse response
Single Channel (black)
Source 1
Time (s)
x 10^-3

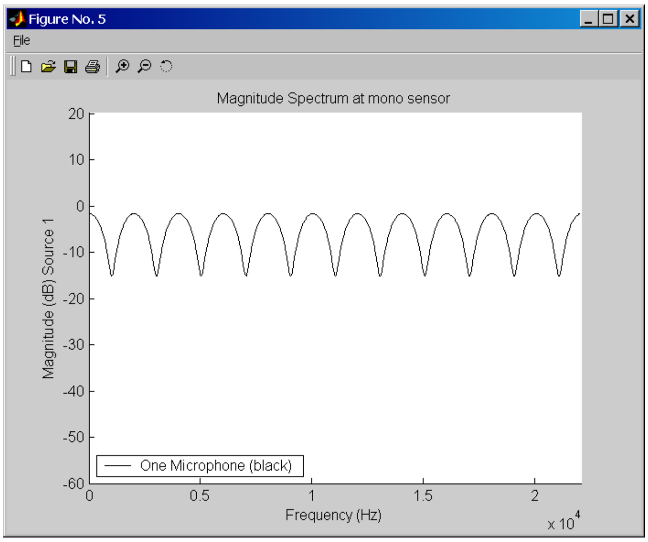


Figure No. 5
File
Magnitude Spectrum at mono sensor
Magnitude (dB) Source 1
One Microphone (black)
Frequency (Hz)
x 10^4

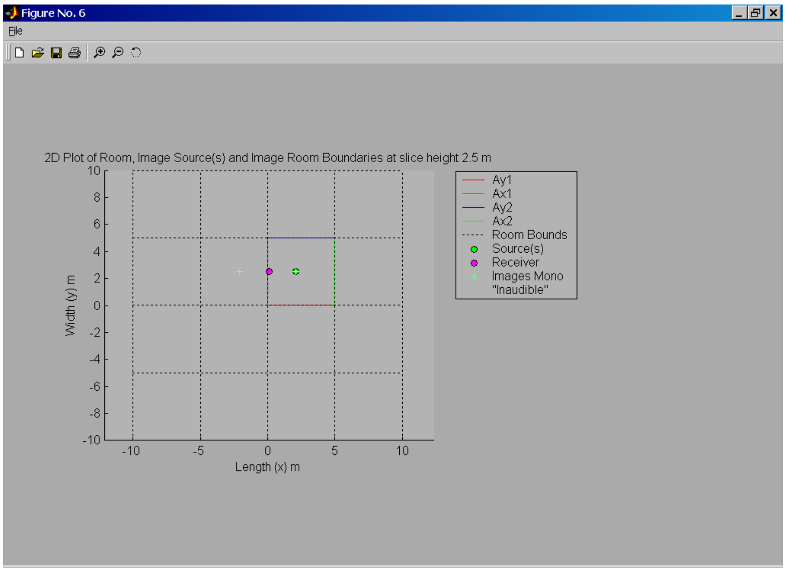
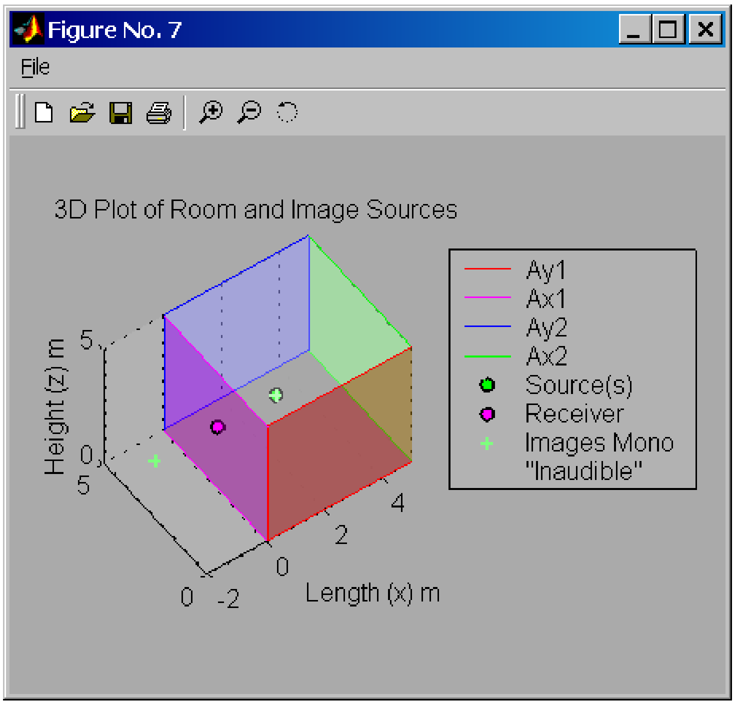
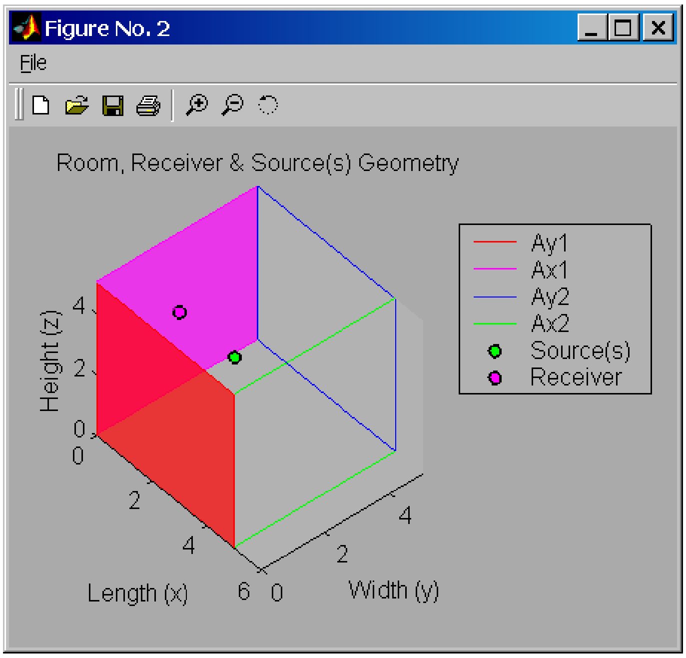


Figure No. 6
File
2D Plot of Room, Image Source(s) and Image Room Boundaries at slice height 2.5 m
Ay1
Ax1
Ay2
Ax2
Room Bounds
Source(s)
Receiver
Images Mono
"Inaudible"
Width (y) m
Length (x) m



3.2 Setup Two Walls

The Excel file setup_twowalls.xls gives an example of the additional complexity from a second reflective wall as shown in Fig 2. The impulse response graph (Fig 4) shows the extra reflections due to the second wall. The effect of the smoothing filter has been included in this simulation and shows up in the ringing on the impulse response and the high frequency roll-off around the Nyquist frequency (Fig 5).The image sources are shown as stem amplitude plots in Fig 6.



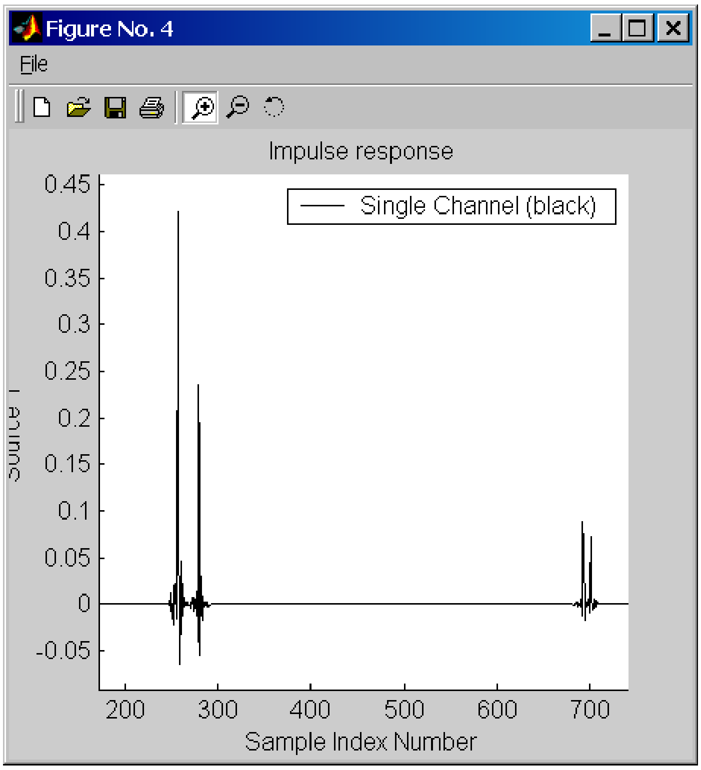


Figure No. 4
File
Impulse response
Single Channel (black)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
200
300
400
500
600
700
Sample Index Number

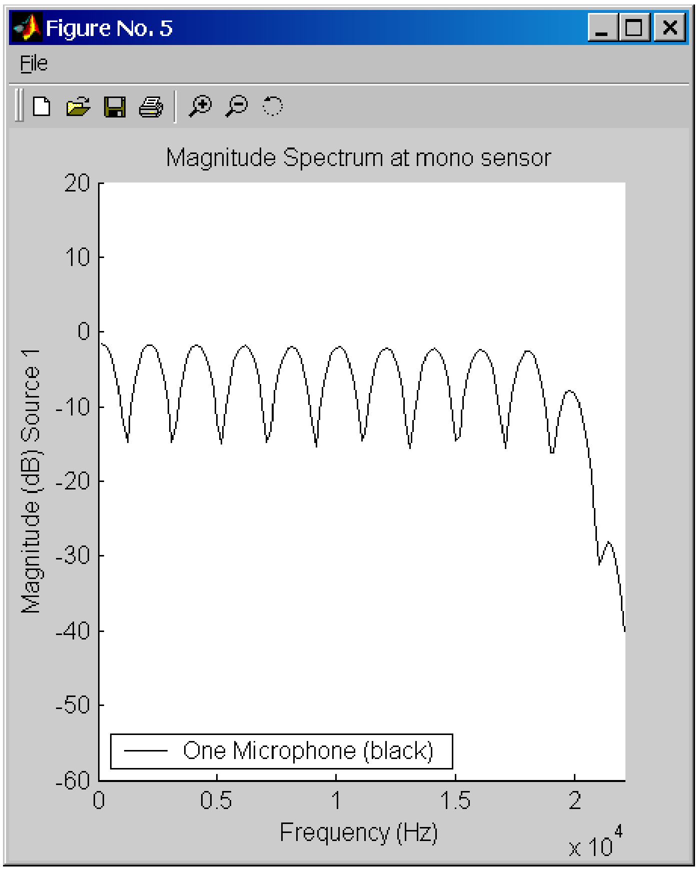
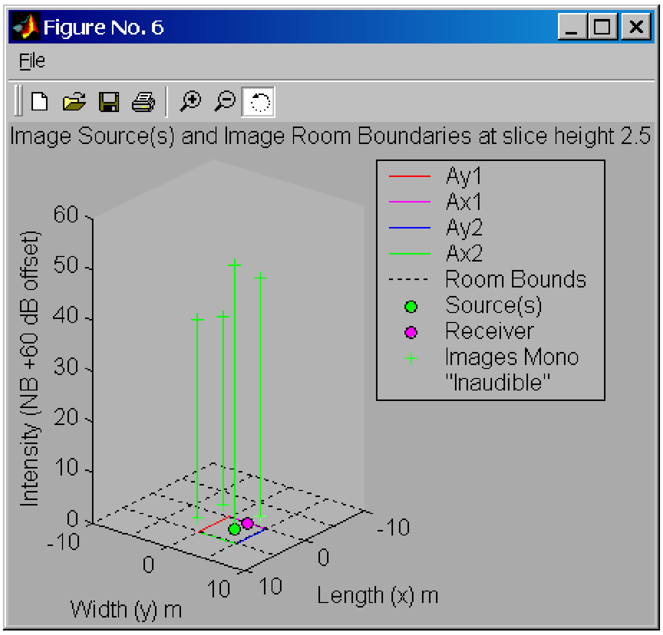
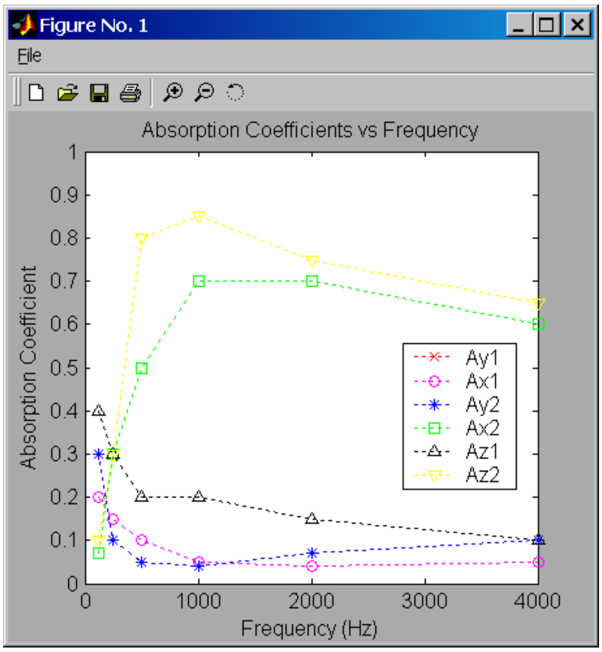


Figure No. 5
File
Magnitude Spectrum at mono sensor
Magnitude (dB) Source 1
20
10
0
-10
-20
-30
-40
-50
-60
One Microphone (black)
0
0.5
1
1.5
2
Frequency (Hz)
x 10^4



3.4 Setup Room

The Excel file setup_room.xls provides for a six surface "shoebox" room with different absorption profiles on five of the surfaces (Fig 1). The source has been given an elevation (Fig 2) and the estimated mean RT60 vs. frequency is shown (Fig 3). The increased complexity of the impulse response is obvious (Fig 4) and the early reflections are clearly identifiable. A zoomed in display of a plan view shows the many images in a constant z slice (Fig 5) and the totality of the simulated images and their relative intensity (brightness) is shown in the 3D view of the room at the centre of an image source cloud that can be zoomed and rotated to reveal its structure.



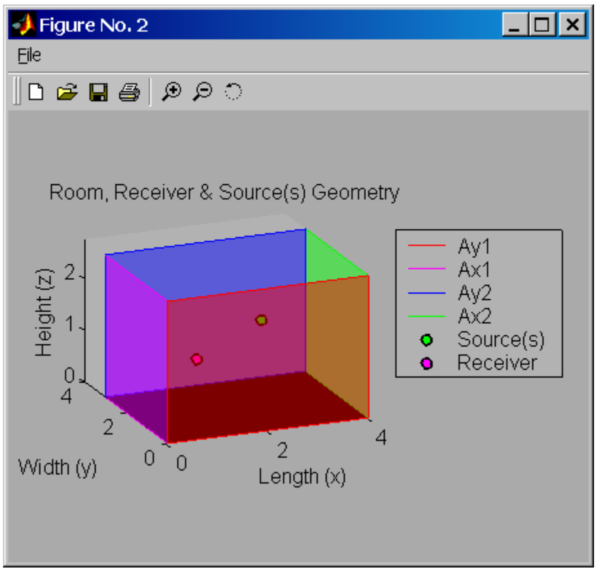


Figure No. 2
File
Room, Receiver & Source(s) Geometry
Ay1
Ax1
Ay2
Ax2
Source(s)
Receiver
Height (z)
Width (y)
Length (x)

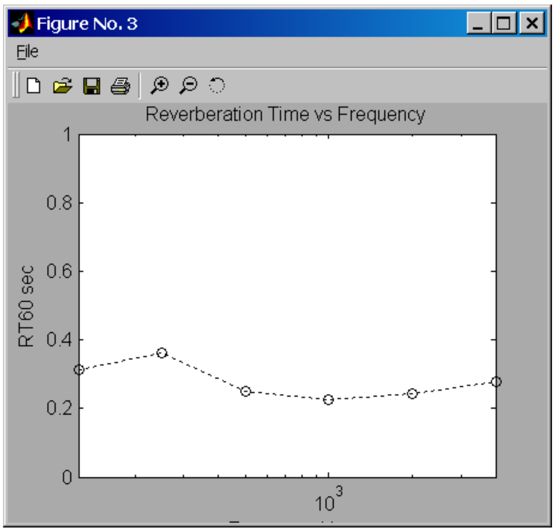


Figure No. 3
File
Reverberation Time vs Frequency
RT60 sec

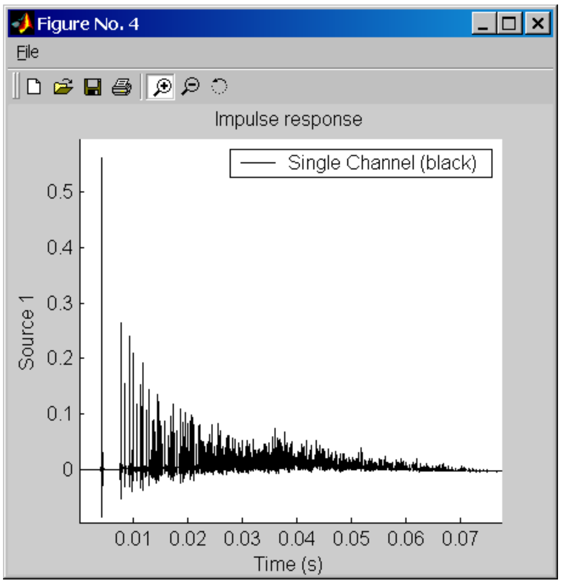
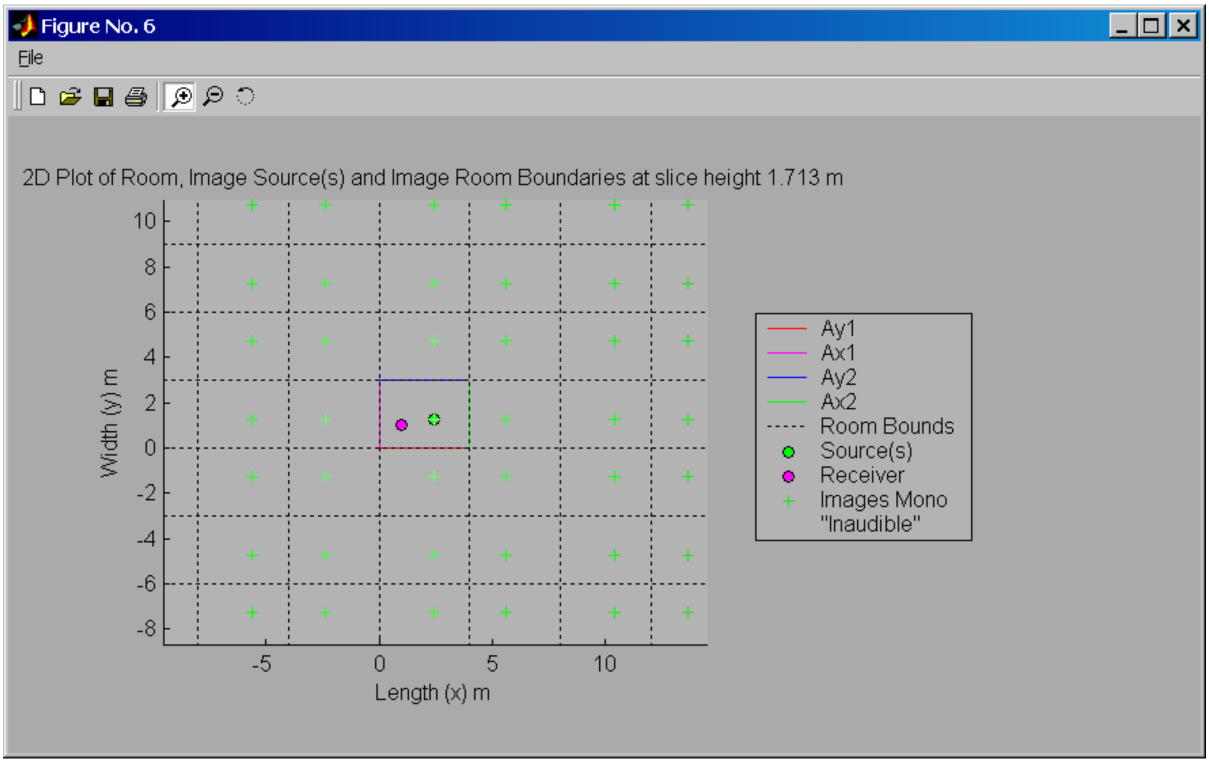
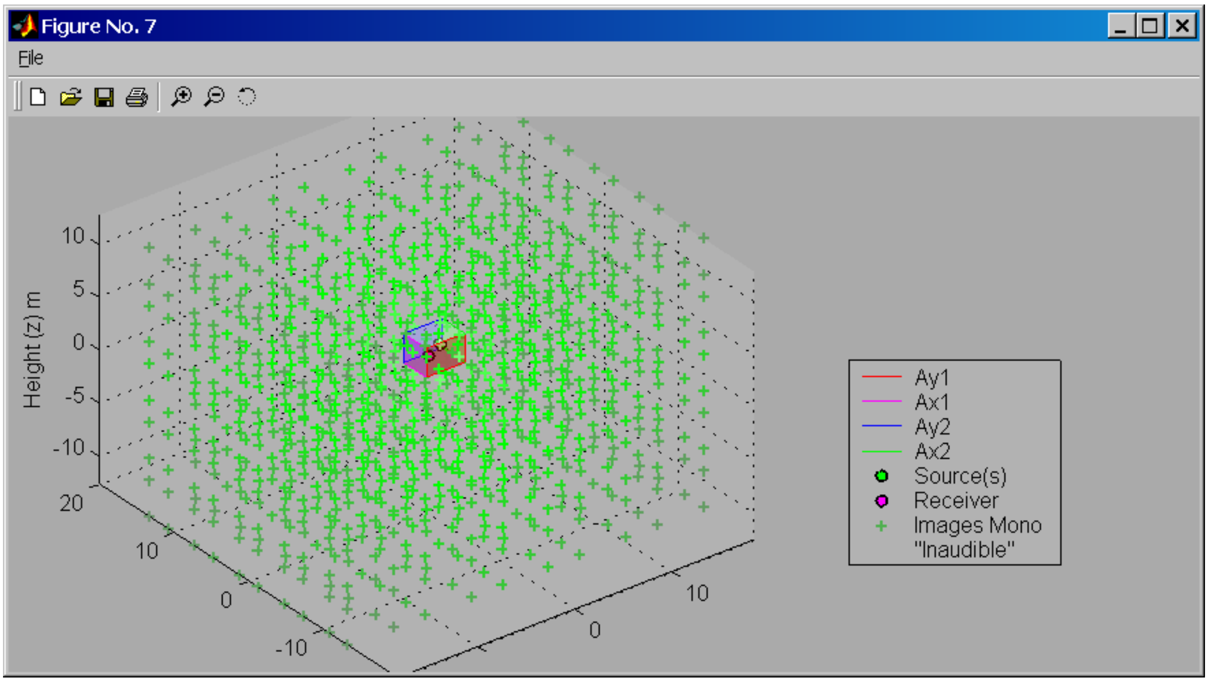


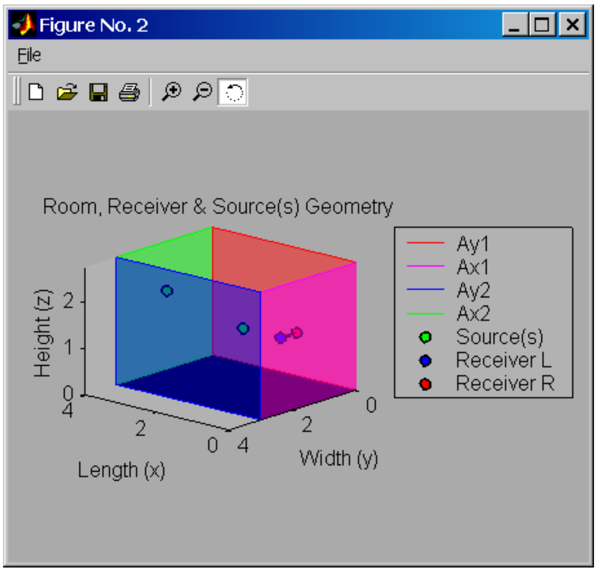
Figure No. 4
File
Impulse response
Single Channel (black)
Source 1
Time (s)

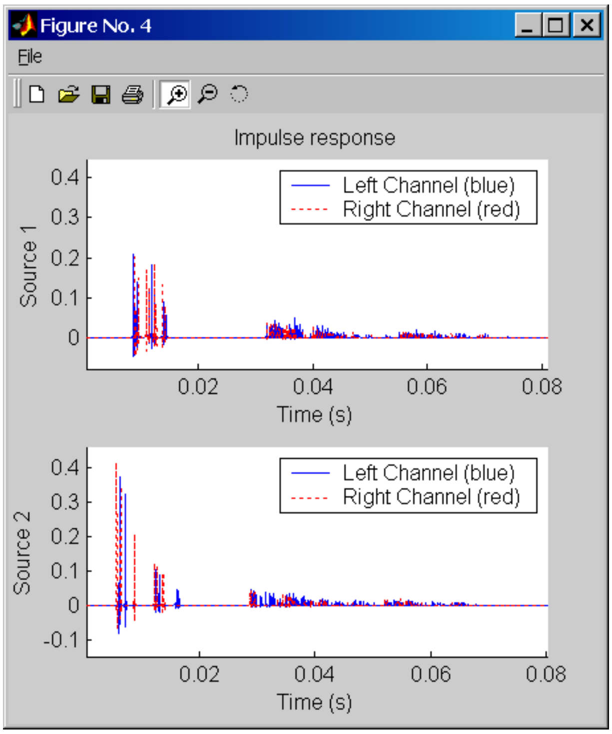




3.4 Setup Two "microphone" and Two source

The Excel file setup_2M_2S.xls constructs a simulation of a "shoebox" room with five of the surfaces having different frequency dependent absorption characteristics as the previous example. Two sensors and two sources are placed in the room (Fig 2) and the sensors are directional (forward looking with x) such that there are areas of overlap in their view of the room and its images. Surface opacity proportional to reflectivity was turned off to allow sensors and sources to be viewed. The effect of the directivity is seen in the (gaps in the) impulse responses (Fig 4) as seen by the sensors. Comb filtering is prominent in the frequency response related to source 2 (Fig 5). The plan view of the room shows the images existing at the slice height of source 1, single crosses (blue) indicate image sources seen by the left sensor and squares (red) those seen by the right sensor. These are superimposed in areas where the sensor views overlap. Image sources not visible to either sensor are shown as dots (black). The 3D view (Fig 6) has been plotted without the “invisible” images for clarity.





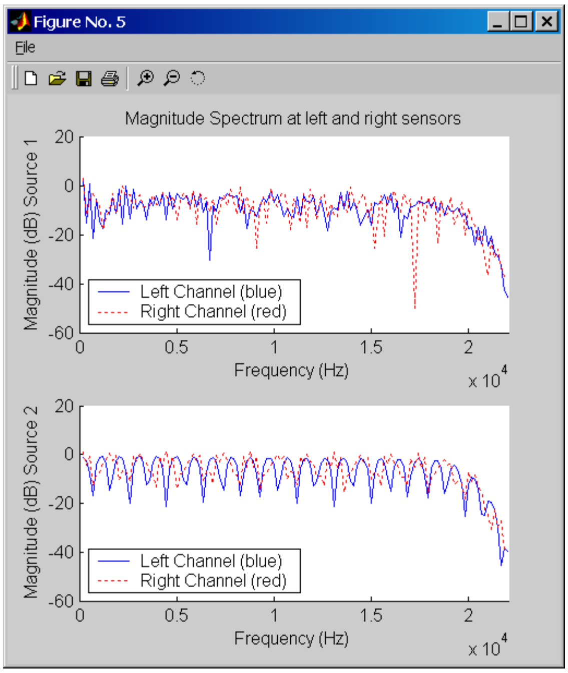


Figure No. 5
File
Magnitude Spectrum at left and right sensors
Magnitude (dB) Source 1
Left Channel (blue)
Right Channel (red)
Frequency (Hz)
x 10^4
Magnitude (dB) Source 2
Left Channel (blue)
Right Channel (red)
Frequency (Hz)
x 10^4

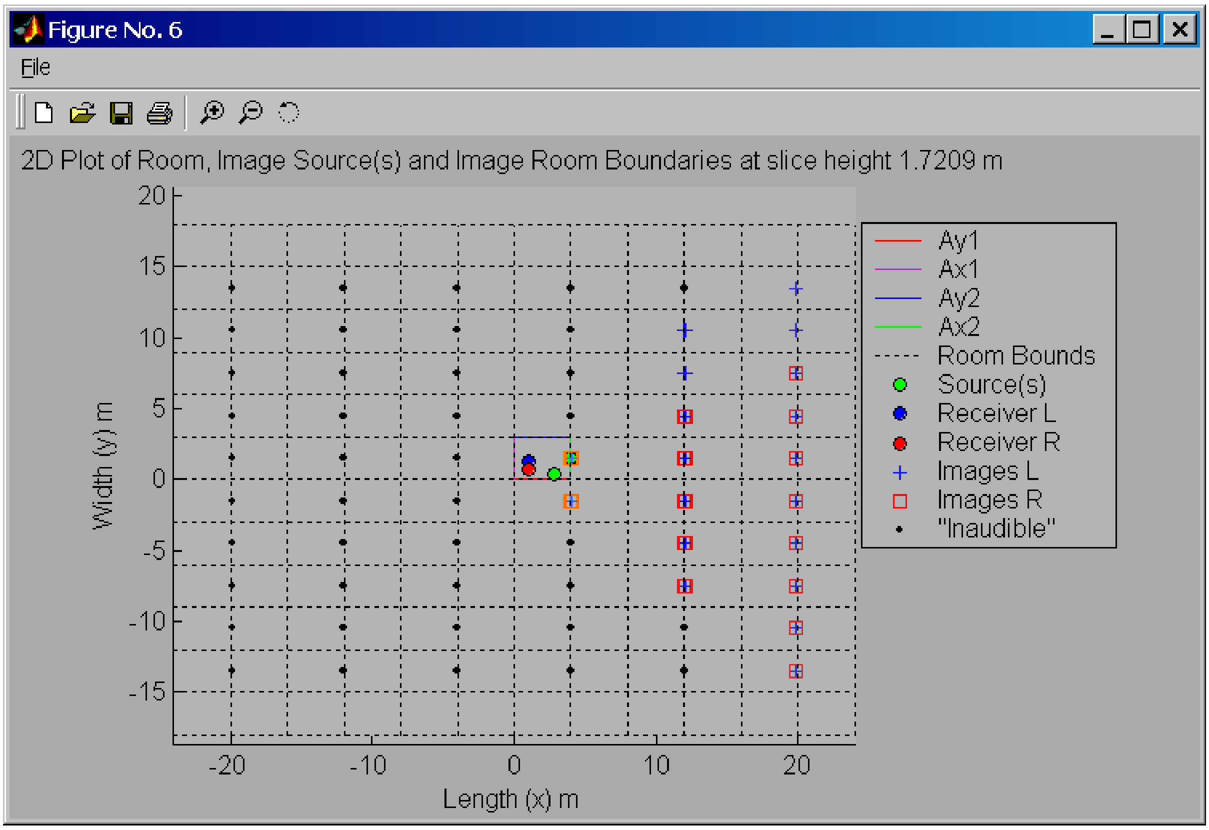
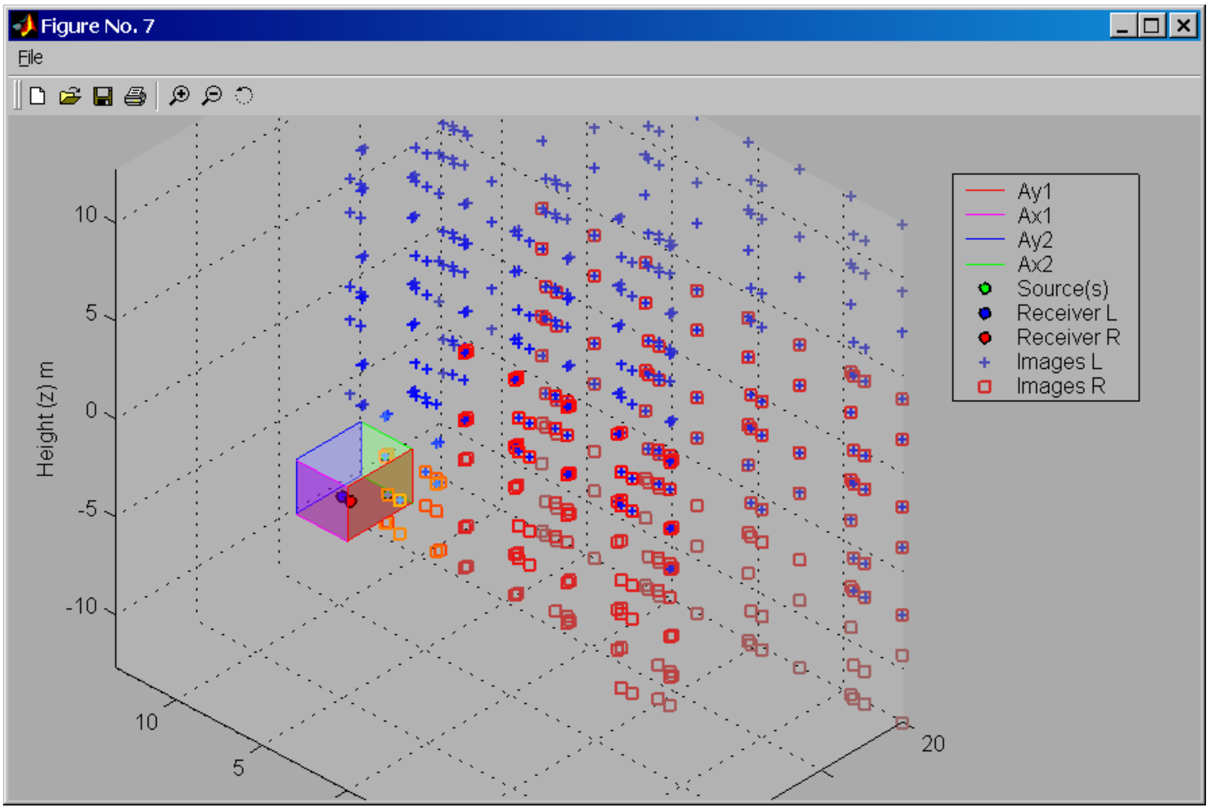


Figure No. 6
File
2D Plot of Room, Image Source(s) and Image Room Boundaries at slice height 1.7209 m
Width (y) m
Length (x) m
Ay1
Ax1
Ay2
Ax2
Room Bounds
Source(s)
Receiver L
Receiver R
Images L
Images R
"Inaudible"



3.5 Setup CIPIC Kemar

The Excel file setup_CIPIC_K.xls utilises the CIPIC Head Related Impulse Response (HRIR) data to provide a virtual head at the receiver position (Fig 2). The impulse response from a source to the two "ears" of the Kemar (Fig 4) is seen to be much more complex than the simple room responses previously viewed. The offset of the source to the left of the Kemar in this case is visible in the time shifts of the left and right impulse response plots and the relative amplitudes of spectral magnitude plot (Fig 5) which also shows the asymmetry in this Kemar HRIR and the effect of the room response on the Kemar HRIR.

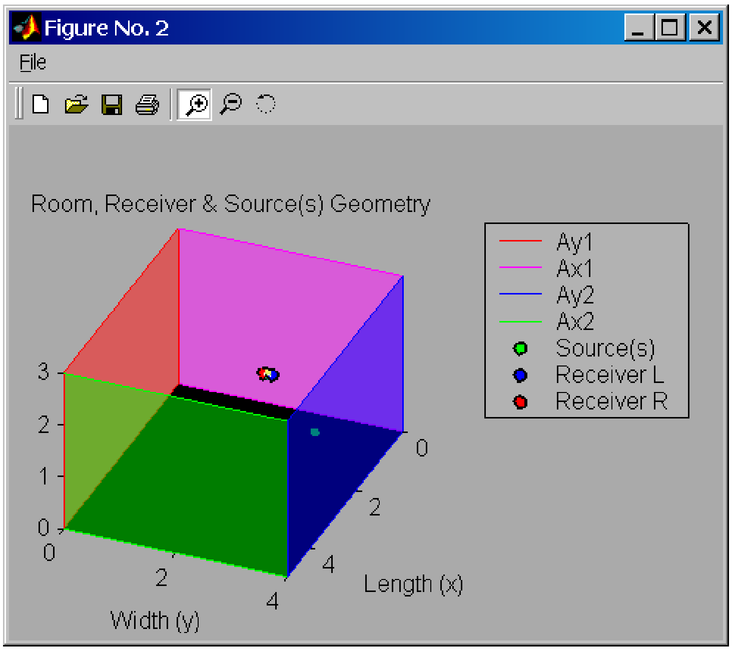


Figure No. 2
File
Room, Receiver & Source(s) Geometry
Ay1
Ax1
Ay2
Ax2
Source(s)
Receiver L
Receiver R
Length (x)
Width (y)

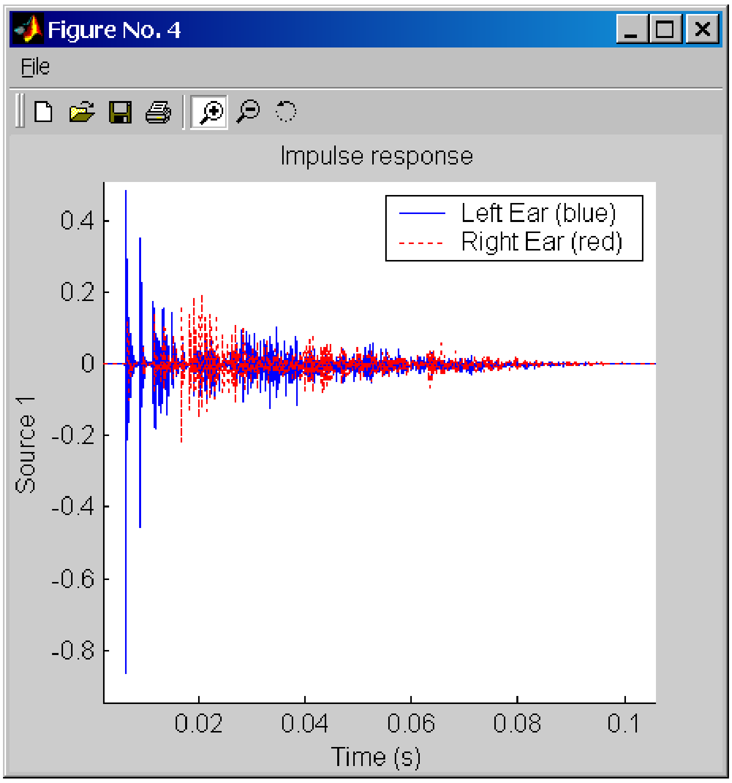


Figure No. 4
File
Impulse response
Left Ear (blue)
Right Ear (red)
Source 1
Time (s)

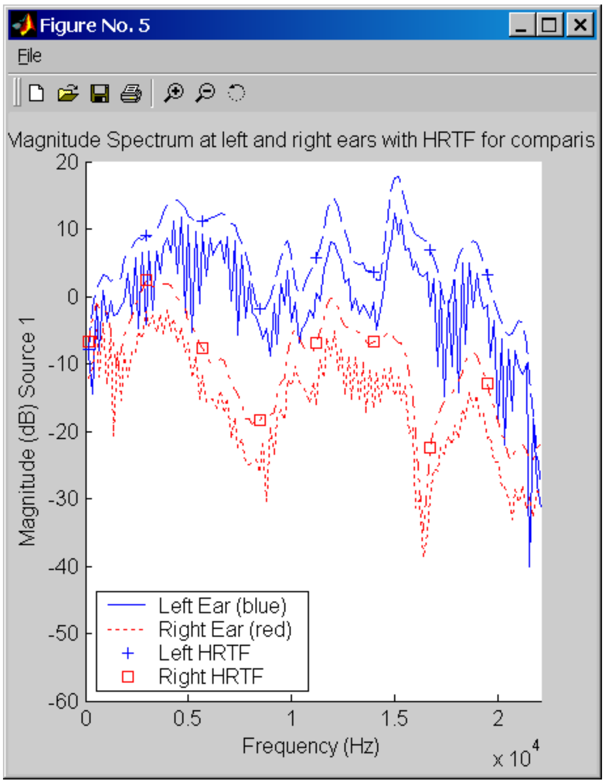
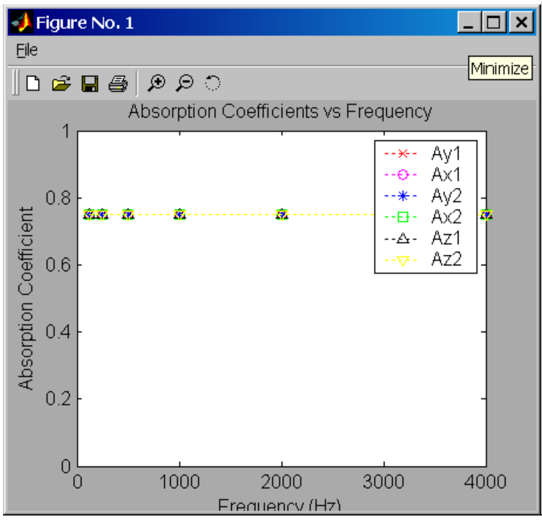
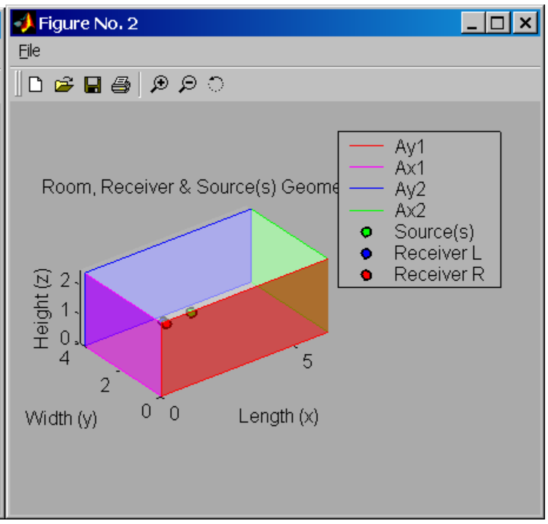
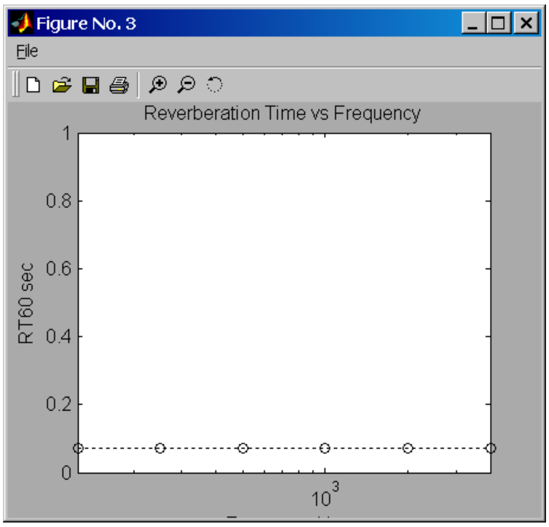


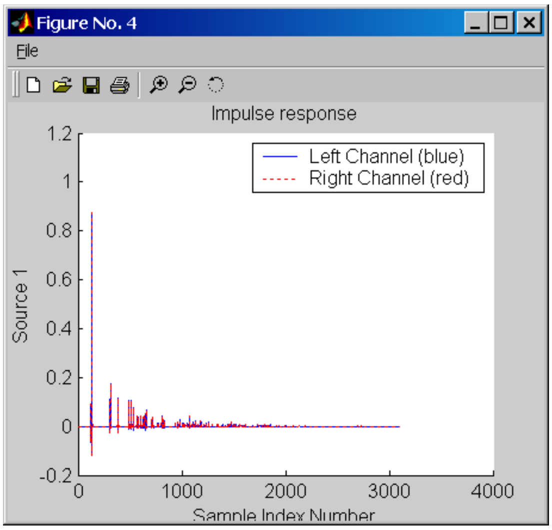
Figure No. 5
File
Magnitude Spectrum at left and right ears with HRTF for comparis
Magnitude (dB) Source 1
20
10
0
-10
-20
-30
-40
-50
-60
0
0.5
1
1.5
2
Frequency (Hz)
x 10^4
Left Ear (blue)
Right Ear (red)
Left HRTF
Right HRTF

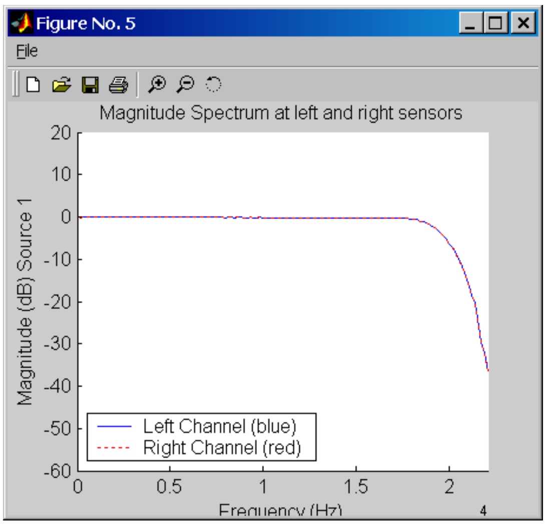
4 Results of running TEST_roomsim.mat

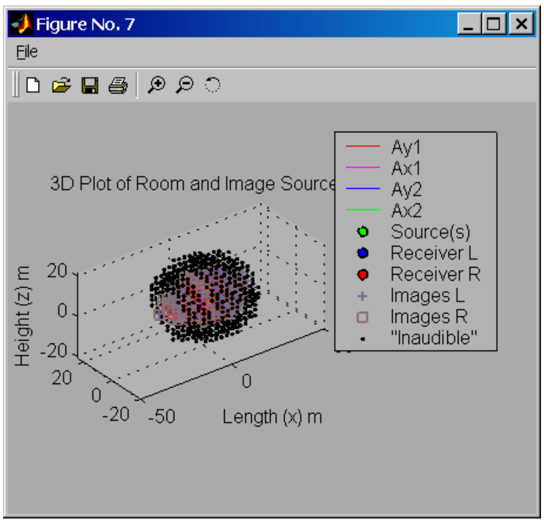












Appendix A **Simulation parameters**.

The simulation parameters are:

Fs, the sampling frequency (Hz).
humidity, of the air in the room. A formula (valid for 20<= h <= 70) is used to compute the absorption m of the air volume (%).
temperature, of the air in the room. This is used to compute the speed of sound in the room (m/s)
order, a scalar when entered manually, converted to a column vector containing the order of reflections to be calculated for each dimension x,y,z. (If –1 the programme will attempt to calculate a reasonable value).
H_length, maximum required length of room impulse response(s). (If –1 the programme will attempt to calculate a reasonable value).
H_filename, a string identifier naming the file to which the final impulse responses H will be saved, one per source labelled name_S1, name_S2 etc.
air_F, logical Flag value 0 or 1, false = no absorption due to air, true = air absorption is present.
smooth_F, logical Flag value 0 or 1, false = no smoothing filter applied to weight intersample impulses, true = smoothing filter used (See ref. A5)
Fc_HP, scalar, the cut-off frequency of the high-pass filter applied to attenuate DC, 0 = no High-pass filter (Ref. A6 used 100 Hz)
plot_F2, logical Flag value 0 or 1. Set this to plot the geometry of receiver, source(s), image sources & image rooms, false= no plot, true= 2D-plan showing image rooms on constant z plane.
plot_F3, logical Flag value 0 or 1. Set for a rotatable 3D-plot using the MATLAB controls.
dist_F, logical Flag value 0 or 1. Set to enable 1/R distance attenuation effect.
alpha_F, logical Flag value 0 or 1. The transparency flag, set to enable display of room surface opacity proportional to reflectivity.
room_size(**Lx,Ly,Lz**), scalar values that are formed into a column vector containing the length x width y and height z of the room in metres.
receiver(**xp,yp,zp**), scalar values that are formed into a column vector containing the RH Cartesian coordinates locating the receiver system reference point in metres.
(NB no facility to set an angle for the Head capital plane i.e. it is aligned with the x axis).

sensor, text string value identifying receiver system, one of: One sensor ('one_mic'), Two sensors (two_mic'), MIT Kemar ('mithrir'), CIPIC Head ('cipicir').

sensor_dir a vector supporting a simple sensor directionality for One Sensor and Two Sensor receiver systems. The vector contains,

min_azim_sensor, a scalar, minimum azimuth (deg) viewable by the sensor

max_azim_sensor, a scalar, maximum azimuth (deg) viewable by the sensor

min_elev_sensor, a scalar, minimum elevation (deg) viewable by the sensor

max_elev_sensor, a scalar, maximum elevation (deg) viewable by the sensor

NB. Omni is -180,180,-90,90.

sensor_space, a scalar, sensor separation for the two_sensor case (if MIT or CIPIC it is implicit in the HRIR data)

S_No, text value, CIPIC subject number format '&&&' (e.g. '021' is Kemar with small pinnae)

R_s, a scalar (or row vector) of radial distance(s) (m) between receiver and each source. NB a check is later performed to ensure that all sources are inside the room.

alpha, a scalar (or row vector) of azimuth(s), -180< alpha < 180 (deg), used to set the source location(s) relative to receiver. NB 0 deg has a source located in the xz plane , +ve deg rotates Anti-CW on the xy plane viewed in plan.

beta, a scalar (or row vector) of elevations(s), -90< beta < 90 (deg), used to set the source location(s) relative to receiver. NB 0 deg has a source located in the xy plane, +ve deg rotates upwards.

A, a matrix of Sabine energy surface absorption coefficients for the "shoebox" enclosure containing (in columns) **Ax1, Ax2, Ay1, Ay2, Az1, Az2**, all being column vectors of frequency dependent absorption coefficients at the six standard octave measurement frequencies (125 Hz to 4 kHz).

x1, y1 and z1 refer to the surfaces lying in the x=0, y=0 and z=0 planes respectively, while x2, y2 and z2 refer to the surfaces lying in the x=Lx, y=Ly and z=Lz planes respectively.

Thus x1 & x2, y1 & y2, z1 & z2 are opposing surfaces eg. z1 refers to the floor and z2 the ceiling.

Appendix B Contents of Runsim.log

03-Mar-2003 00:37:59

Roomsim_setup: Setup parameters have been saved to D:\MATLAB6p5\work\RoomSim\
SAVE_roomsim.mat

Speed of sound c = 343 m/s

Reverberation Times
At frequency = 125 Hz RT60 = 0.05402 s
At frequency = 250 Hz RT60 = 0.05402 s
At frequency = 500 Hz RT60 = 0.05402 s
At frequency = 1000 Hz RT60 = 0.05402 s
At frequency = 2000 Hz RT60 = 0.05402 s
At frequency = 4000 Hz RT60 = 0.05402 s

Estimate of Room break frequencies (uses mean of above RT60's),
F1 = 69 Hz. Lowest room mode, i.e. below F1 no resonant support for sound in room
Between F1 and F2 room modes dominate
F2 = 39 Hz. Approximate cutoff (crossover) frequency
Between F2 and F3 diffraction and diffusion dominate
F3 = 157 Hz. Above F3 specular reflections and ray acoustics are valid

Estimated number of reflections = 6

order_x = 2
order_y = 2
order_z = 2

Sensor = one_mic
min_azim_sensor = -180.00 deg
max_azim_sensor = 180.00 deg
min_elev_sensor = -90.00 deg
max_elev_sensor = 90.00 deg

Number of Images = 2

Roomsim_run: Plot data has been saved to D:\MATLAB6p5\work\RoomSim\
PLOT_Roomsim.mat

03-Mar-2003 00:38:28