
User guide

MAINE 3A

Version 1.5



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1. *MAINE 3A software overview*

1.1. Introduction

MAINE 3A is a simulation software product for predicting the acoustic properties of layered structures containing sound absorbing materials. Featuring a user-friendly graphical interface, MAINE 3A is a highly efficient tool for quickly optimising the sound absorption or insulation properties of multilayer materials.

MAINE 3A models the properties of individual layers (presumed to have infinite lateral dimensions) using a transfer matrix for high performance calculation times [4]. Available media include plates, visco-elastic solids, fluids, porous materials with deformable / non-deformable skeletons, thin resistive layers and perforated plates. The process involves the application of plane wave or diffuse field excitation. Results are presented in narrow bands or octave bands.

MAINE 3A was written by researchers from the Laboratoire d'Acoustique (Acoustics Laboratory) at the Université du Maine (LAUM - UMR CNRS 6613) an institution that enjoys a worldwide reputation for its work on modelling porous sound absorbing materials. (cf. Scientific references). Exploitation of the MAINE 3A code is governed by a "CNRS-Université du Maine" licence. The software source code has been deposited at the Agence de Protection des Programmes (French programme protection agency).

MAINE 3A is a trademark registered at INPI.

1.2. Features

MAINE 3A software allows the computation of:

- impedance, reflection coefficient, absorption coefficient
- transfer impedance
- transmission loss,
- R_w , D_{Lr} , α_w and $D_{L\alpha}$ indicators

of a multilayer material placed between two fluid propagation media or on a rigid wall. Acoustic excitation can be either diffuse field or plane wave of given incidence. Output is function of frequency or incidence angle.

The multilayer material is represented as a stack of propagation media of infinite lateral dimensions, modelled analytically (no mesh) by transfer matrices. Five types of propagation media are available :

- Viscoelastic,
- Gas
- Porous: dual-phase medium with open porosity, with rigid or viscoelastic skeleton
- Resistive screen
- Perforated screen

Porous materials are described by several models [1 to 3, 7 to 14] :

- Empirical model by Delany and Bazley
- Equivalent fluid model by Johnson-Champoux-Allard using 5 parameters: porosity, resistivity, tortuosity, viscous and thermal characteristic lengths,
- Equivalent fluid model by Limp: same equivalent fluid model as above, taking into account the density of the porous material. It uses six parameters : porosity, resistivity, tortuosity, viscous and thermal characteristic lengths, density
- Physical poroelastic model by Biot-Allard: the visco-thermal couplings description is the same as equivalent fluid models above, now taking into account the frame deformation and inter-phase elastic coupling. It uses nine parameters : porosity, resistivity, tortuosity, viscous and thermal characteristic lengths, density, Young modulus, loss factor, Poisson coefficient.

A simplified physical model is also available. It is particularly adapted for fibrous media. Tortuosity is set to 1, and the characteristic lengths are calculated from the porosity and resistivity values.

It is also possible to provide a frequency-dependant Young modulus for the solid phase in the cases of Biot model poroelastic layer and solid viscoelastic layer.

1.3. Demo version

A demonstration version is available to explore the capabilities of the MAINE 3A software featuring pre-calculated validation cases. This version features full graphics interface functionalities but no solver, therefore it cannot perform computations

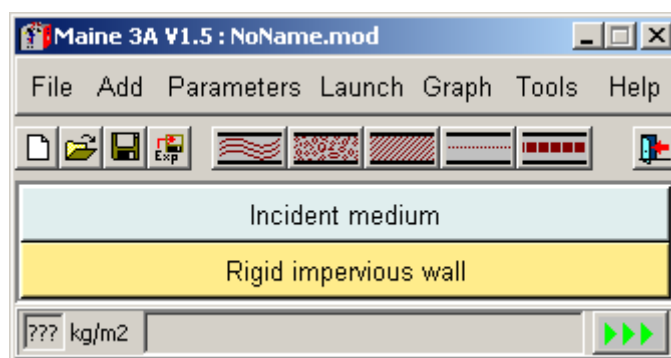
Demonstration configurations can be accessed via the "File / Demos" menu. The corresponding results can be consulted via the "Graph" menu. For some values it is possible to superimpose an experimental results curve using the "File / Reference" menu in the graphics window.

All of the Graphical User Interface features can be browsed and tested, but the results cannot be modified.

2. Using the graphical user interface

2.1. Introduction: calculation steps

MAINE 3A software features a graphics interface which greatly simplifies the calculation process.



Overview of the graphical user interface: menus and buttons

Calculations can be performed by selecting individual menus (or icons from the taskbar) from left to right one after the other:

File

Open an existing or new multilayer medium model, save models, export computing outputs, start demos.

Add

Add a new fluid, porous or solid layer, a resistive screen or a perforated screen. Select the created layer using the left mouse button to access the selected layer's physical characteristics (provided manually or imported from a database).

Parameters

Select angular or frequency dependence for plane waves or a frequency range for diffuse field excitation. Select global indicators computation and the application of spatial windowing if desired. Select the problem type, transmission or absorption on a rigid wall by clicking on the lower layer and changing its type.

Launch

Launch the solver (or click the lower right button in the main screen)

Graph

Graphical display of the results, compare to a reference curve, save the results in a file.

Tools

Access special tools such as precomputation of spatial windowing coefficients, compression of fibrous materials, import, edit or export a database, language selection.

Help

Classical help menu.

2.2. Managing models: the "File" menu

A model features all the input data of a problem, namely:

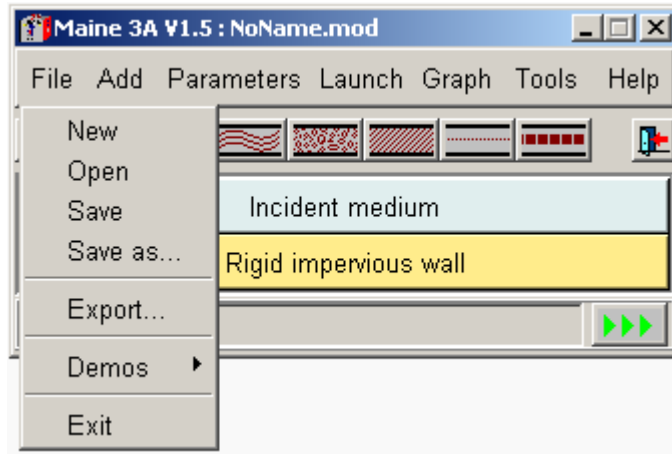
- the multilayer definition including the characteristics of each model,
- the type of excitation,
- the computation options (frequency range, spatial windowing, global indicators, etc.).

Information can be stored in a "model" file with the ".mod" extension. The toolbar features direct buttons for opening, saving and creating new models. Key combination shortcuts can also be used.

Command	Effect
Ctrl + n	New model
Ctrl + o	Open
Ctrl + s	Save

Ctrl + q	Quit
F1	Help

Model management shortcuts



The "File" menu

The "Demos" menu can be used to load a demonstration model featuring precomputed sample calculations (see Demonstration version). Demonstration models must be saved with a different name so that they can be recalculated.

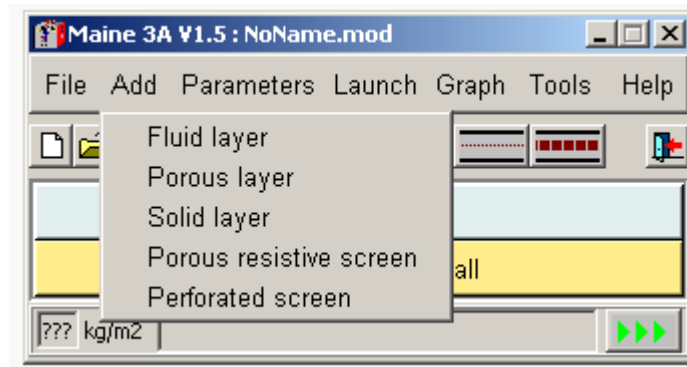
The "Export" menu allows the saving of the multilayer configuration, input data used for the computation, and the obtained results (a computation therefore must have been performed) into a .txt file. See also the key combination shortcuts.

2.3. Creating a layer: the "Add" menu

A layer is defined by its type:

- Fluid layer,
- Porous layer,
- Solid layer,
- Porous resistive screen,
- Perforated screen.

To create a new layer, select the type of layer in the "Add" menu or the corresponding icon in the toolbar. The layer will be added on top of the existing layers



The "Add" menu

Please note that:

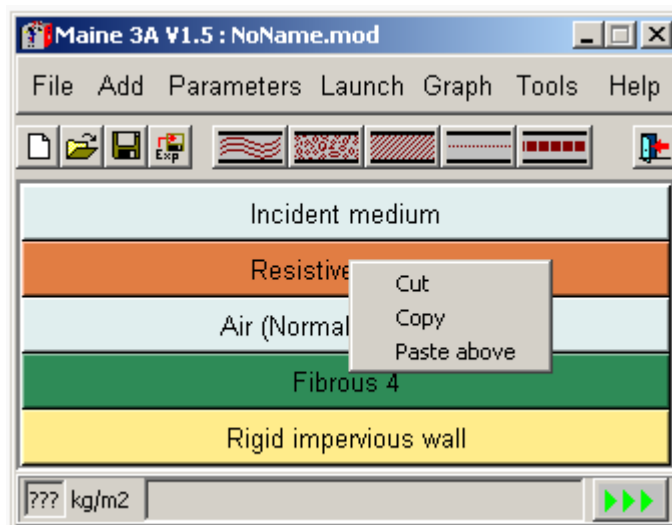
- The thickness of the layer (if available) appears in the status bar while the mouse pointer is over a layer button.
- The surface mass of the multilayer is computed automatically whenever the required data is available (lower left corner frame).

2.4. Deleting, copying, pasting a layer: context menu

A layer can be cut, copied or pasted by right-clicking on its button.

To copy or suppress a layer, select it using the mouse right button and select the desired option in the contextual menu : cut, copy, paste above.

To paste a previously cut or copied layer above another layer, select the remaining layer by right-clicking it and select the "paste above" action.



Right-clicking on a layer

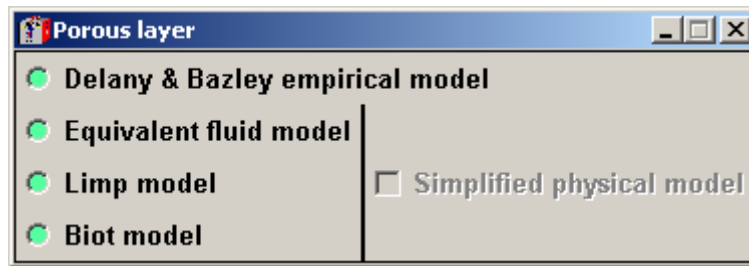
2.5. Input a layer's characteristics: left click

To input layer's characteristics, simply select the desired layer using the left mouse button. A pop-up window will display the different parameters input fields. The same method applies to the initial "Incident medium" and "Transmission medium / Rigid wall " layers.

Notes :

- According to the selected model, only the characteristics available for that model are active. Values are input manually.
- To move from one field to the other, the keyboard shortcut is the "Tab" key.

Some type of layers can be modelled using a variety of models. The desired model must be selected before inputting the parameters of the layer.



Model selection

Available layer types are described in the next section..

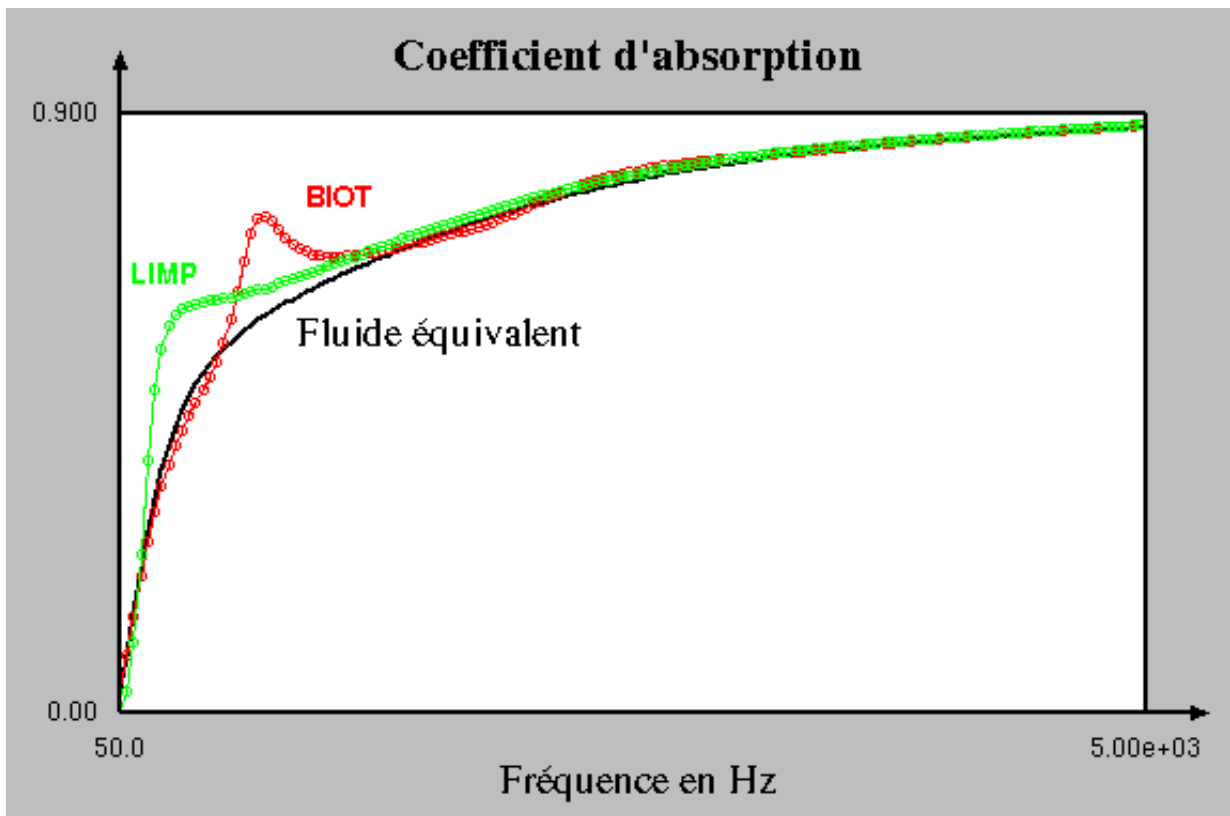
2.5.1. Porous layer

Four models are available:

- Empirical model by Delany and Bazley
- Equivalent fluid model by Johnson-Champoux-Allard using 5 parameters: porosity, resistivity, tortuosity, viscous and thermal characteristic lengths,
- Equivalent fluid model by Limp: same equivalent fluid model as above, taking into account the density of the porous material. It uses six parameters : porosity, resistivity, tortuosity, viscous and thermal characteristic lengths, density
- Physical poroelastic model by Biot-Allard: the visco-thermal couplings description is the same as equivalent fluid models above, now taking into account the frame deformation and inter-phase elastic coupling. It uses nine parameters : porosity, resistivity, tortuosity, viscous and thermal characteristic lengths, density, Young modulus, loss factor, Poisson coefficient.

Notes:

The default physical characteristics (temperature and pressure) of the fluid phase are those of the incident medium (top layer).



Graphical comparison of the three physical models: absorption coefficient of a porous material layer resting against a rigid wall.

Porous layer	
<input type="radio"/> Delany & Bazley empirical model	
<input type="radio"/> Equivalent fluid model	
<input checked="" type="radio"/> Limp model	<input type="checkbox"/> Simplified physical model
<input type="radio"/> Biot model	
Thickness	<input type="text"/> mm
Air flow resistivity	<input type="text"/> N.m ⁻⁴ .s
Porosity	<input type="text"/>
Tortuosity	<input type="text"/>
Viscous characteristic length	<input type="text"/> μ m
Thermal characteristic length	<input type="text"/> μ m
Porous density	<input type="text"/> kg/m ³
Young's modulus	<input type="text"/> Pa <input type="checkbox"/>
Loss factor	<input type="text"/>
Poisson's ratio	<input type="text"/>
Material name	<input type="text" value="Porous layer"/>
Database	<input type="text" value="standard.db"/>
Read material	Save material
Ok	

Porous layer characteristics

In the case of physical models, the frame (solid phase) can be either infinitely rigid (equivalent fluid model) or elastic (Biot-Allard model). In the latter case, it is possible to input a frequency depend Young modulus. Check the box to activate the elastic frame parameters, i.e. Young modulus, loss factor, volumic mass and Poisson ratio.

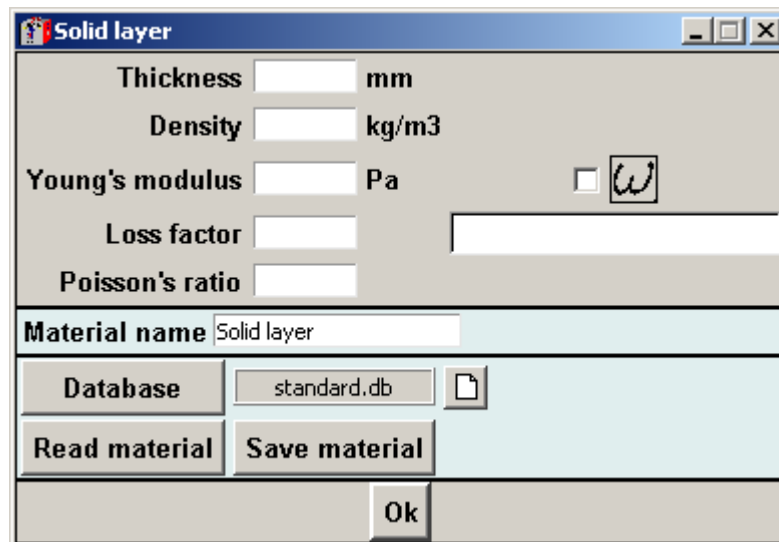
The "simplified physical model" option allows for an automatic computation of the viscous and thermal characteristic lengths based on the values of airflow resistivity and porosity tortuosity, by assuming a tortuosity value of 1. This model is particularly adequate for porous materials.

Note:

Checking the "Simplified physical model" option from an existing set of parameters causes the modification of some of the parameters values. Unchecking the option does not restore the initial values of the parameters.

2.5.2. Solid layer

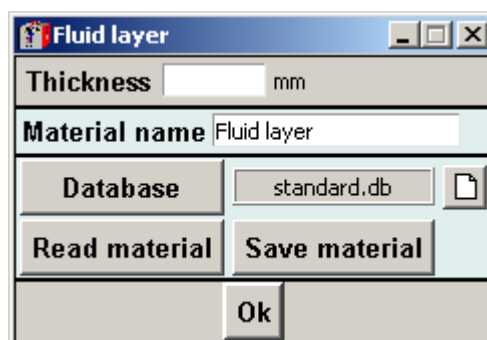
The model is that of an isotropic elastic material. It is possible to input a frequency dependant Young modulus file.



Solid layer characteristics

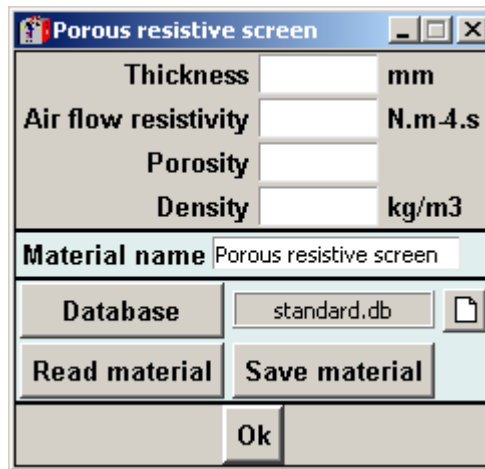
2.5.3. Fluid layer

The model is that of a viscothermic fluid. The temperature and pressure can be accessed through the graphical user interface. The default characteristics are those of the air at 20°C and 101325 Pa.

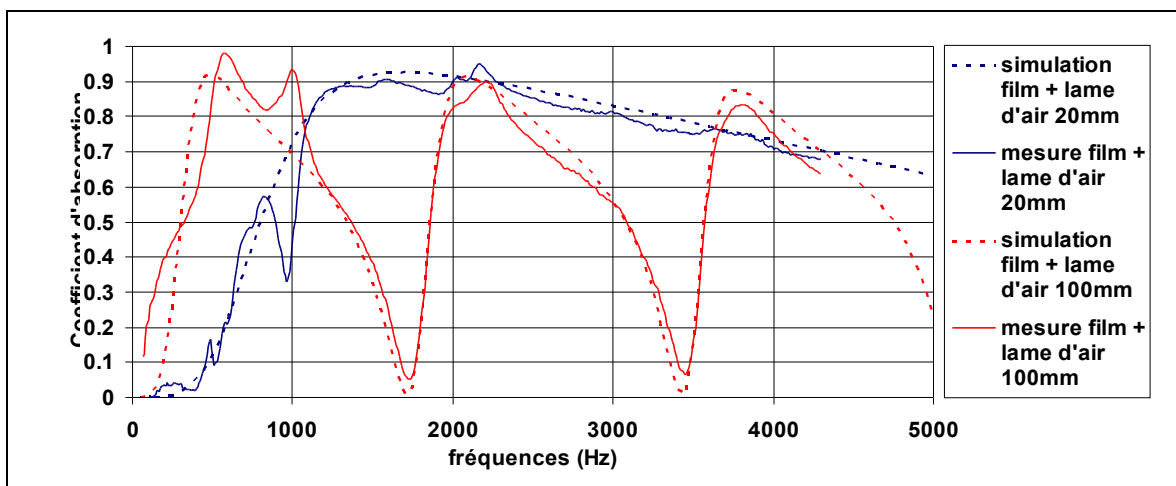


2.5.4. Porous resistive screen

This model is suited for porous resistive screens (thin layers with high resistivity).



Porous resistive screen characteristics



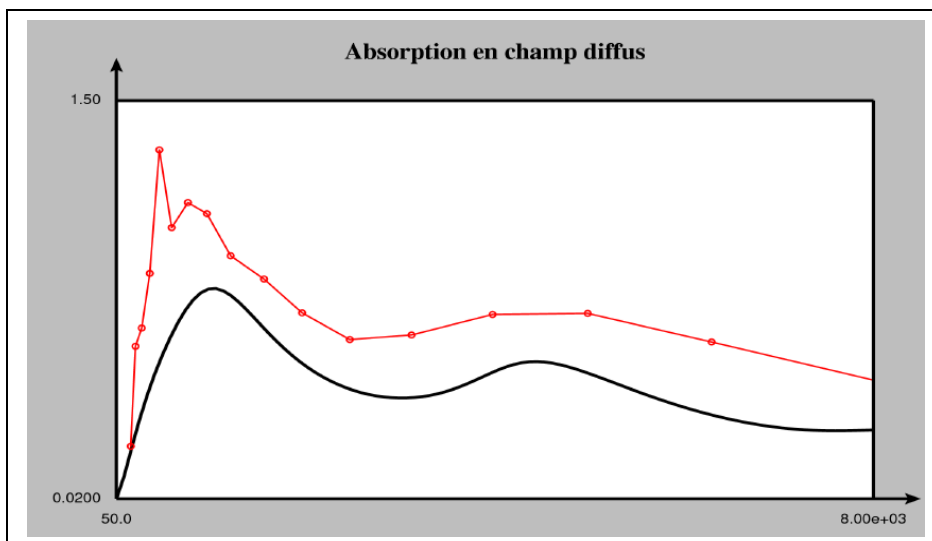
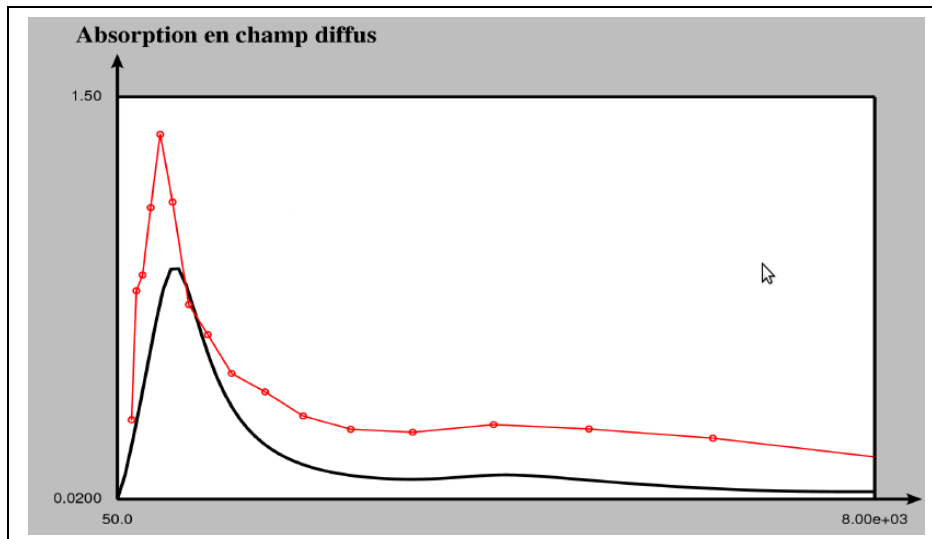
Comparing experimental measurements to simulations: absorption of an air layer behind a resistive screen (— : impedance tube measurements ; ----: normal incidence plane wave simulation)

2.5.5. Perforated screen

The perforated plate model interface window is as shown in the next figure.

Perforated screen	
Thickness	<input type="text"/> mm
Porosity	<input type="text"/>
<input checked="" type="radio"/> Air flow resistivity	<input type="text"/> N.m-4.s
<input checked="" type="radio"/> Hole diameter	<input type="text"/> mm
Porous density	<input type="text"/> kg/m ³
Young's modulus	<input type="text"/> Pa
Loss factor	<input type="text"/>
Poisson's ratio	<input type="text"/>
Material name	Perforated screen
Database	standard.db <input type="button" value="📄"/>
<input type="button" value="Read material"/>	<input type="button" value="Save material"/>
<input type="button" value="Ok"/>	

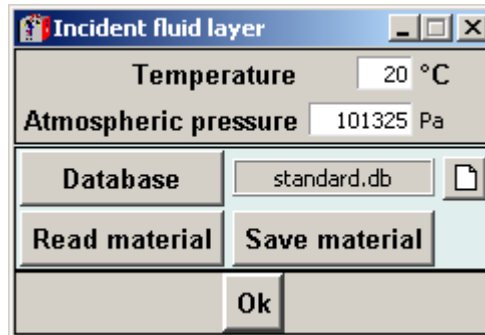
Perforated plate characteristics



Comparing experimental measurements to simulations: absorption of an air layer behind a resistive screen (red: impedance tube measurements ; black : diffuse field absorption simulation)

2.5.6. Top layer: incident fluid layer

The at rest temperature and pressure of the propagation medium can be changed. The default characteristics are those of air at 20°C and 101325 Pa. The characteristics of the top layer are used for all the fluid phases of all the porous materials layers.



Top layer characteristics

2.5.7. Bottom layer

Two options are available for the bottom layer: transmission medium or rigid impervious wall. This choice will decide which type of problem is processed : transmission or absorption. In the case of a transmission medium, the default temperature and pressure are those of the top layer



Characteristics of the bottom layer

2.5.8. Using the materials database


The characteristics of the layers can also be accessed via a materials database (file extension ".db")

- To create a database, click the "Create database" button.
- To select a database, click on the "Database" button.
- To read the data in a database :
 - Click on the "Read a material" button, a list of materials compatible with the type of layer is displayed.
 - Double click on the desired material to select it.
- To save a material into a database:
 - Fill in the material's name.
 - Click on the "Save material" button. The material will append after the materials already stored in the database. A warning message will display if you are about to overwrite an existing material of the same name within the current database.

MAINE 3A features two default databases: standard.db which contains a set of usual materials of known properties, and demos.db which contains the materials used in the demonstration models. It is possible to modify a database by editing it.

Some special tools allow for easier management of the databases (refer to the Database section of the [tools](#) section).

2.6. Frequency dependant Young's modulus

The Young modulus of solid layers and of porous materials' frame (Biot model), can vary frequency dependant. It is possible to input a frequency dependence for this parameter by checking the box next to the  icon. The user is then prompted to input a filename. The file must conform to the following rules:

- The 3 first lines are ignored. They can be used to comment the file,
- The first column is the ascending frequency,
- The second column is the Young modulus,
- The third column is the loss factor.

Furthermore, during calculations :

- If needed, the values of the Young modulus are interpolated for unavailable intermediate frequencies,
- The value at the lowest available frequency is used for all frequencies below,
- The value at the highest available frequency is used for all frequencies above.

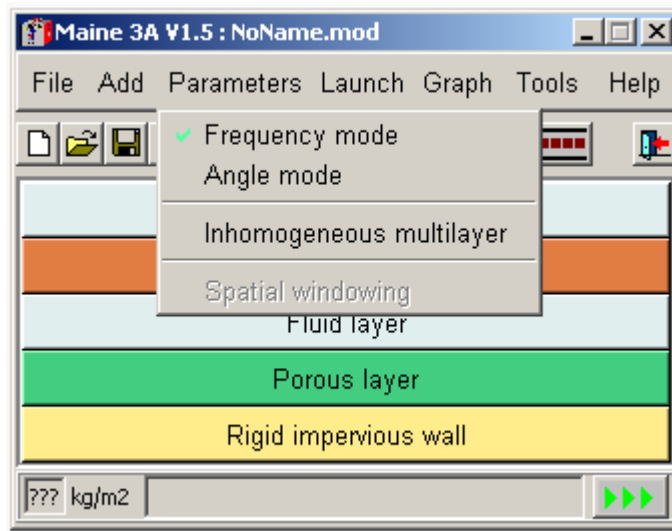
Example of a file:

```
# Used for comments
# Green material
# freq E eta
1000 5e5 0.1
5000 5e7 0.001
```

2.7. Definition of the calculation type: "Parameters" menu

Select the "Parameters" menu to define the type of excitation. The menu allows the user to:

- To perform a frequency-wise calculation,
- To perform an incident angle-wise calculation,
- To set the software to inhomogeneous multilayer configuration,
- To apply a spatial windowing in the case of a transmission calculation.



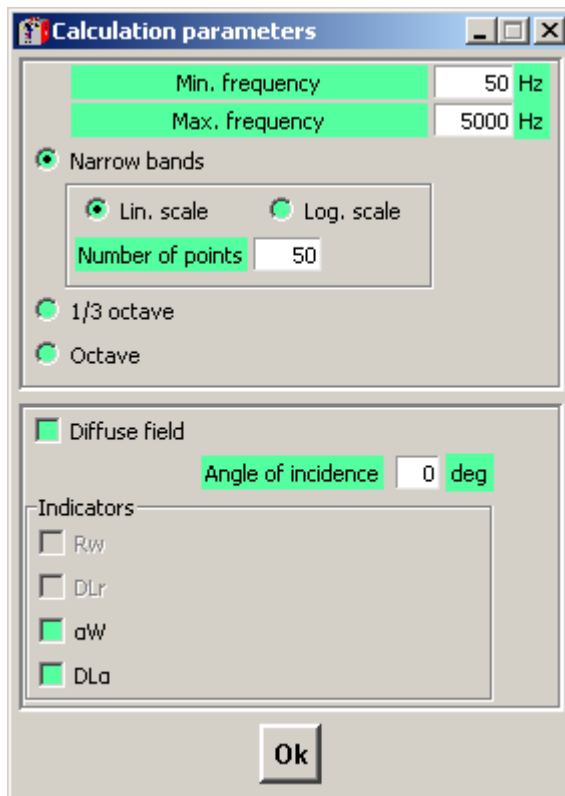
Menu "Paramétrer"

2.7.1. Frequency mode or angle mode

In a frequency-wise calculation, it is possible to select a diffuse field excitation (integration of plane waves) or a plane wave excitation. The frequency-wise calculation can be performed in linear or logarithmic narrow bands, in octave bands or third octave bands. For diffuse field conditions, it is possible to compute two indicators, depending on the multilayer configuration:

- The α_w et D_{La} indicators (if the lower layer is a rigid wall),
- The R_w et D_{Lr} indicators (if the lower layer is a transmission medium).

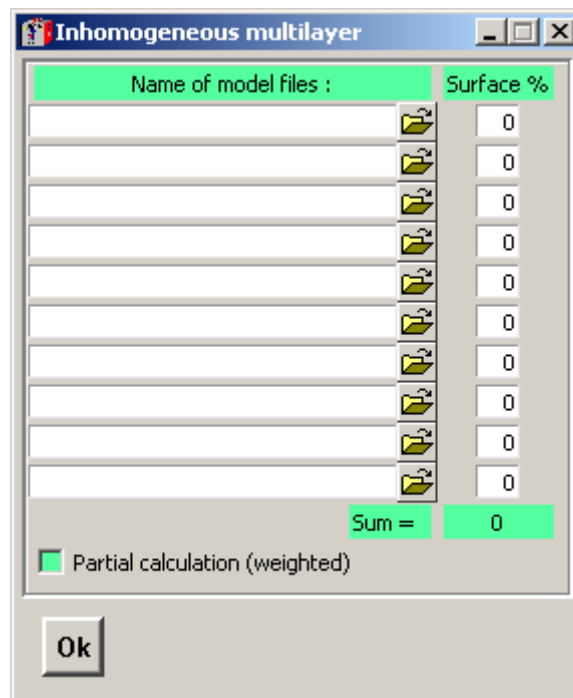
For an incident angle wise calculation, the only input is the frequency for the computation.



Calculation options : frequency-wise, incident angle-wise

2.7.2. Inhomogeneous multilayer

The inhomogeneous multilayer allows the user to create a multilayer material composed of various zones. Each zone is described by a MAINE 3A model file..



Inhomogeneous multilayer configuration

Note: the parameters used for calculation are those contained in the model file associated to the inhomogeneous multilayer (calculation parameters contained in the files of the zones are not taken into account).

Each zone can be weighted by a % of the surface. The sum of all weights must be 100.

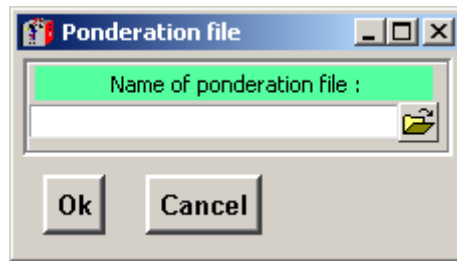
Because the weighting is a post-processing, it is possible to modify the weights of the zones without having to redo the whole calculations. This can be achieved by checking the "partial calculation (weighting)" box. Whenever this is done, the parameters are frozen and the previous results are deleted by default. Therefore it is preferable, when using the "partial calculation" option, to check it before running the first calculation, otherwise it will be needed to re-launch the calculation.

2.7.3. Ponderation file

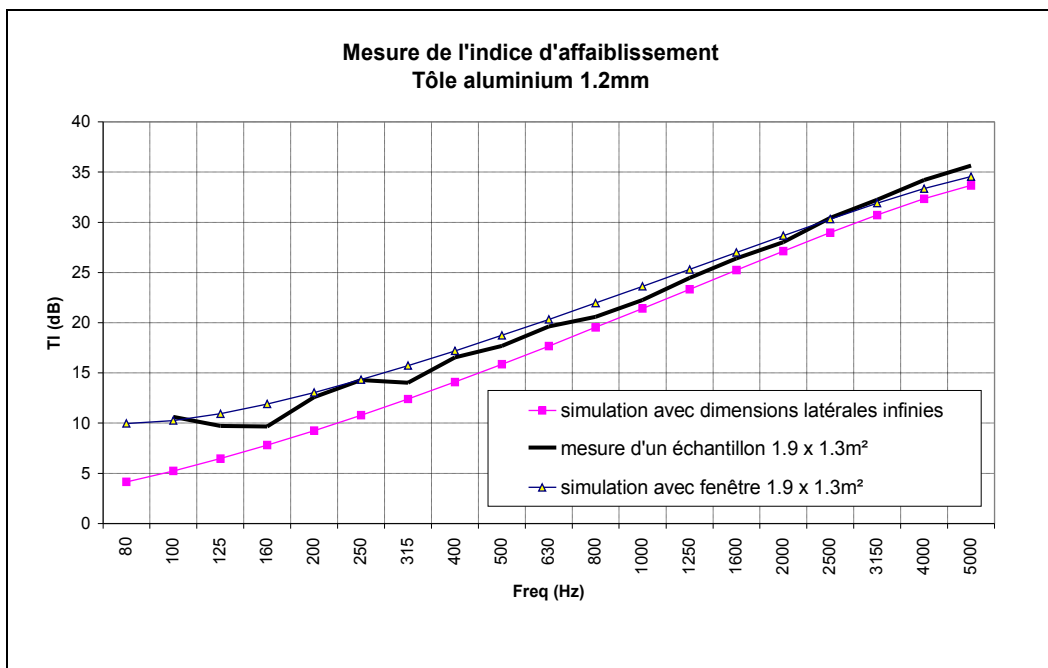
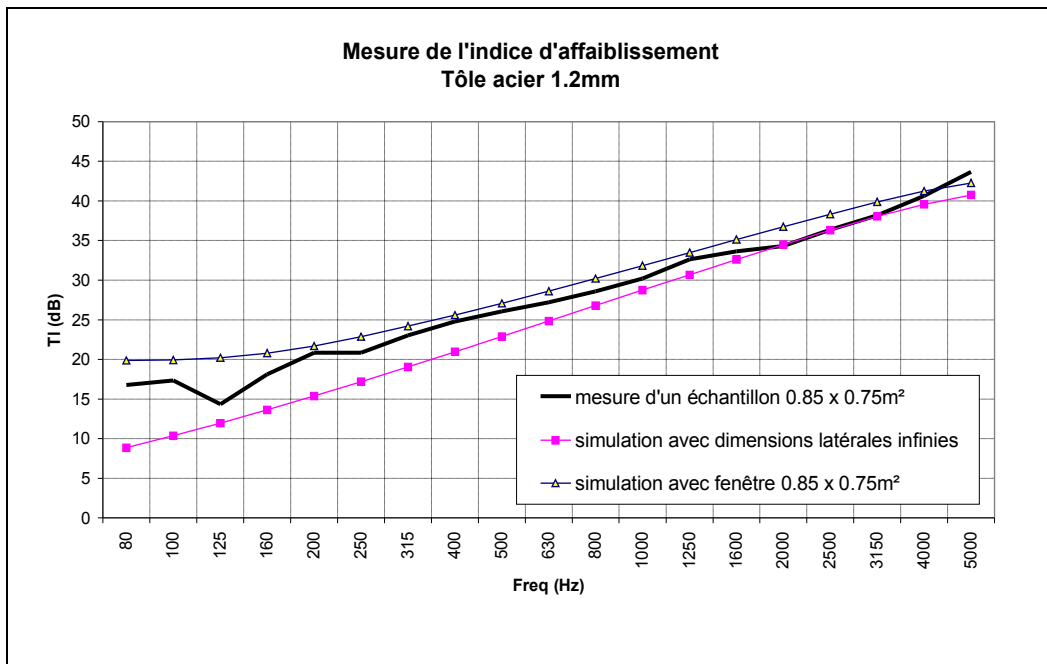
It is possible to add a weighting to a theoretical transmission loss calculation so as to account for experimental setup conditions (panel dimensions) [15,16]. The spatial window depends on the frequency and incidence angle. It is taken into account during the integration of plane waves that compose the diffuse field. This operation requires to pre-compute some coefficients (see the [Tools/Spatial windowing definition](#) menu), then recall these coefficients.

Whenever the Inhomogeneous multilayer option is activated, the same spatial weighting is applied to each zone. The spatial weighting is defined along with the multizone model (see previous chapter).

The spatial window weighting must be adequate to the entire surface of the sample (see [Scientific references](#)).



Calculation options: ponderation file selection.

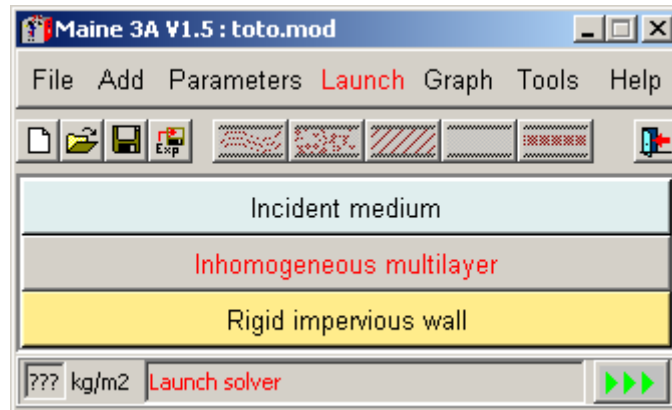


Comparing measurements to simulations: transmission loss of two finite dimensions samples.

2.8. Running the calculation: the "Launch" menu

Launch the calculation by selecting the calculation menu or the green arrow in the lower right corner.

The calculation starts immediately, and the arrow becomes red: the graphical interface is then frozen, and the calculation cannot be interrupted. The calculation time can range from a few seconds to a few minutes, depending on the type of excitation and the number of frequency points.

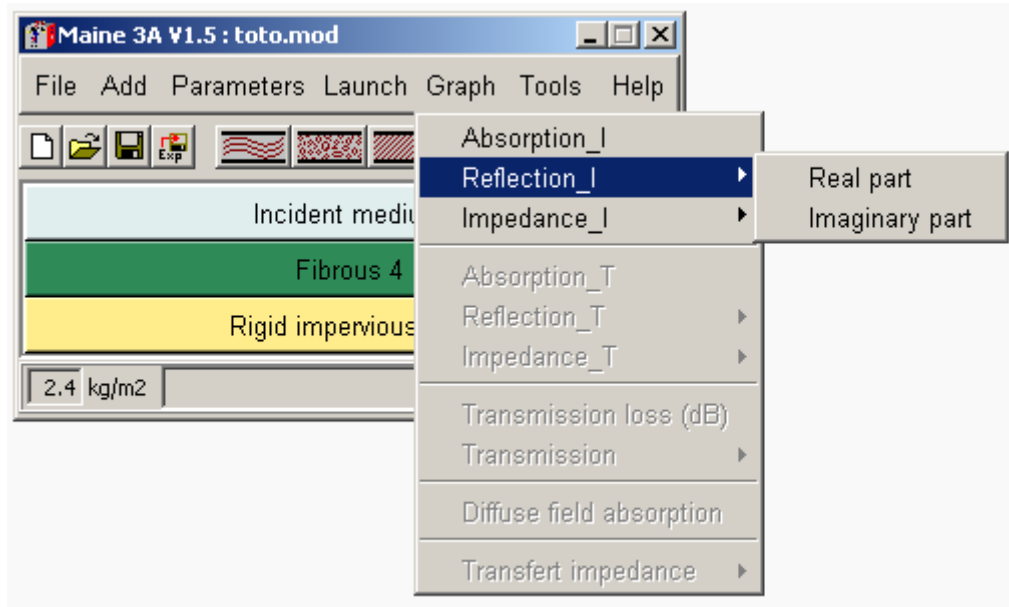


Launch the calculation using the "compute" button or the arrow icon in the lower right corner.

2.9. Display and results management: the "Graph" menu

Depending on the type of calculation, various results can be accessed in the "Graph" menu: absorption coefficient, reflection coefficient, impedance, transmission loss, diffuse field absorption, transfer impedance. Results that are not available with the selected type of calculation will appear in grey.

Whenever the bottom layer is a transmission medium and non-diffuse field excitation is applied, some values will be defined on each side of the layered medium. To distinguish between them the suffix "_I" is used for the incident side and the suffix "_T" is used for the transmission side.



The "Graph" menu

By selecting a result, a graphics window opens to display the corresponding curve. Several graphics windows can be opened at the same time. If the calculations of standard indicators were requested, the values appear in the chart window of the losses by transmission. The text can be moved using the right button of the mouse.

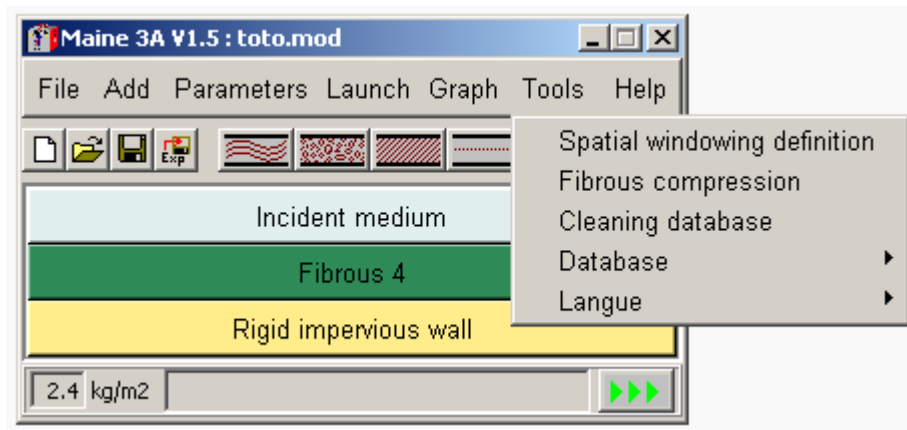
Check the [Graphics](#) section for more details.

2.9.1. Special case: transfer impedance

This option allows to process the case of an impedance calculation which takes into account the displacement of the lower layer [17].

2.10. Additional functions: the "Tools" menu

The "Tools" menu gives access to additional functions.

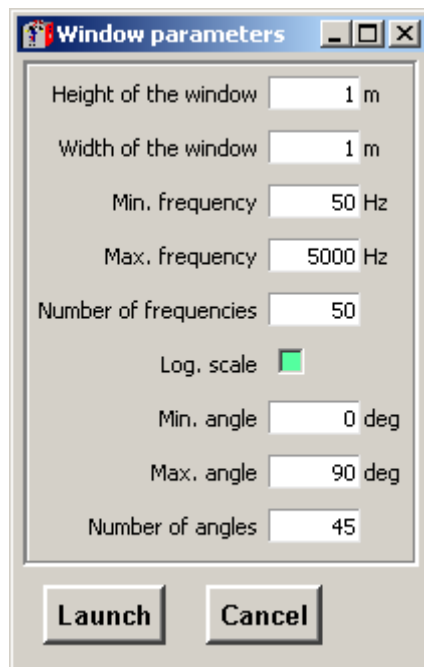


The "Tools" menu

2.10.1. The "Spatial windowing definition » menu

It is possible to account for experimental conditions (finite sample dimensions) by weighting a theoretical calculation [15,16]. The spatial window depends on the frequency and incidence angle. By clicking the "Start" button, the weighting coefficients are calculated (the operation can take some time) and stored into .bin file. This file can be used for any later calculation through the [Parameters/Spatial windowing](#) menu.

The minimum and maximum frequencies are fixed by the user. It is required that they overlap the frequency range used for simulations. The incidence angles must cover the 0° - 90° range. The number of frequency points and angle points are given as an indication for a correct use of the tool. During a transmission loss calculation with spatial window weighting, the values of the weighting coefficients are interpolated. Reducing the number of angles and/or frequencies reduces the file calculation time, but might alter the quality of the final result.

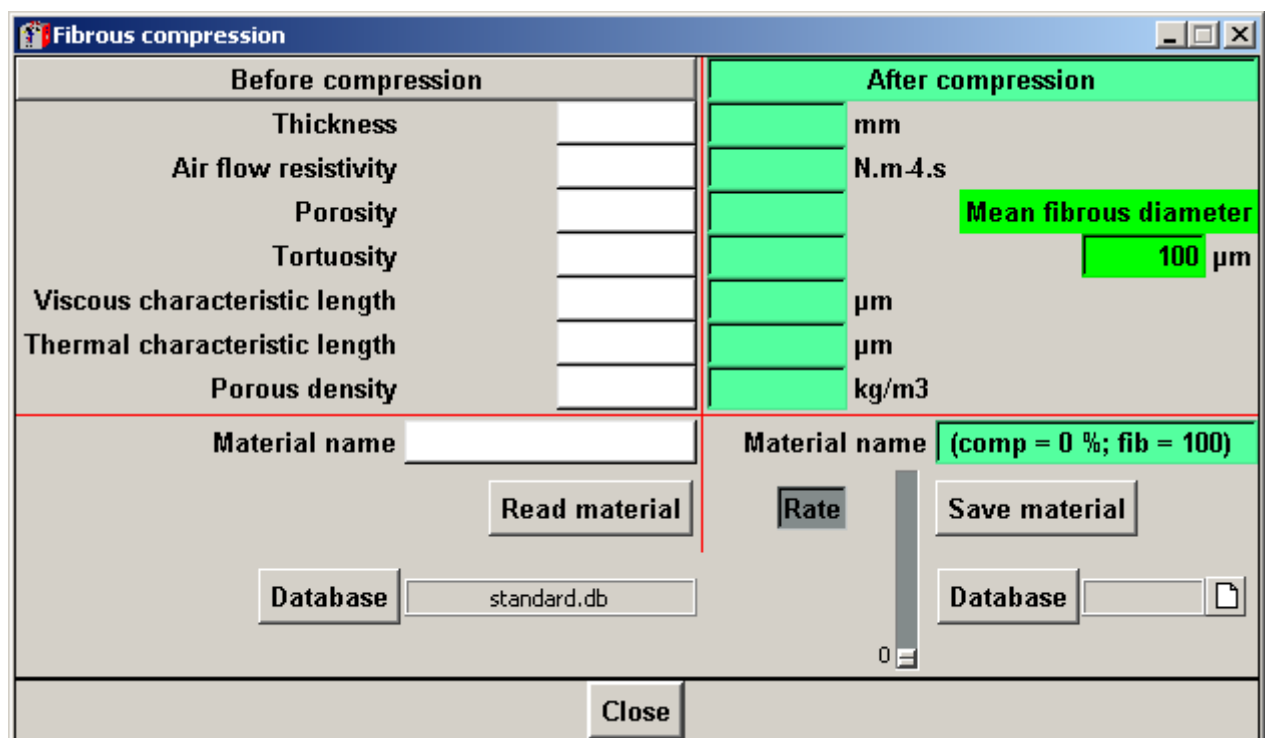


Spatial windowing parameters

2.10.2. The "Fibrous compression" menu

This feature allows to simulate the effect of compression on a fibrous material's acoustic parameters, depending on the average diameter of the fibers (see [scientific references](#)). The compression is applied depending on the material's thickness [5, 6].

1. In the left frame, select the material to be compressed among the database,
2. Input the average diameter of the fibers,
3. Select the compression ratio using the cursor,
4. Save the new material into a database.



Tools for fibrous materials compression

2.10.3. The "Database cleanup" menu

This menu allows the user to select a database to delete materials.

2.10.4. Database import/export : the "Database" menu

This menu allows the user to import or export a database into a file that can be opened by most table editors. It is possible to select the desired decimal separator.

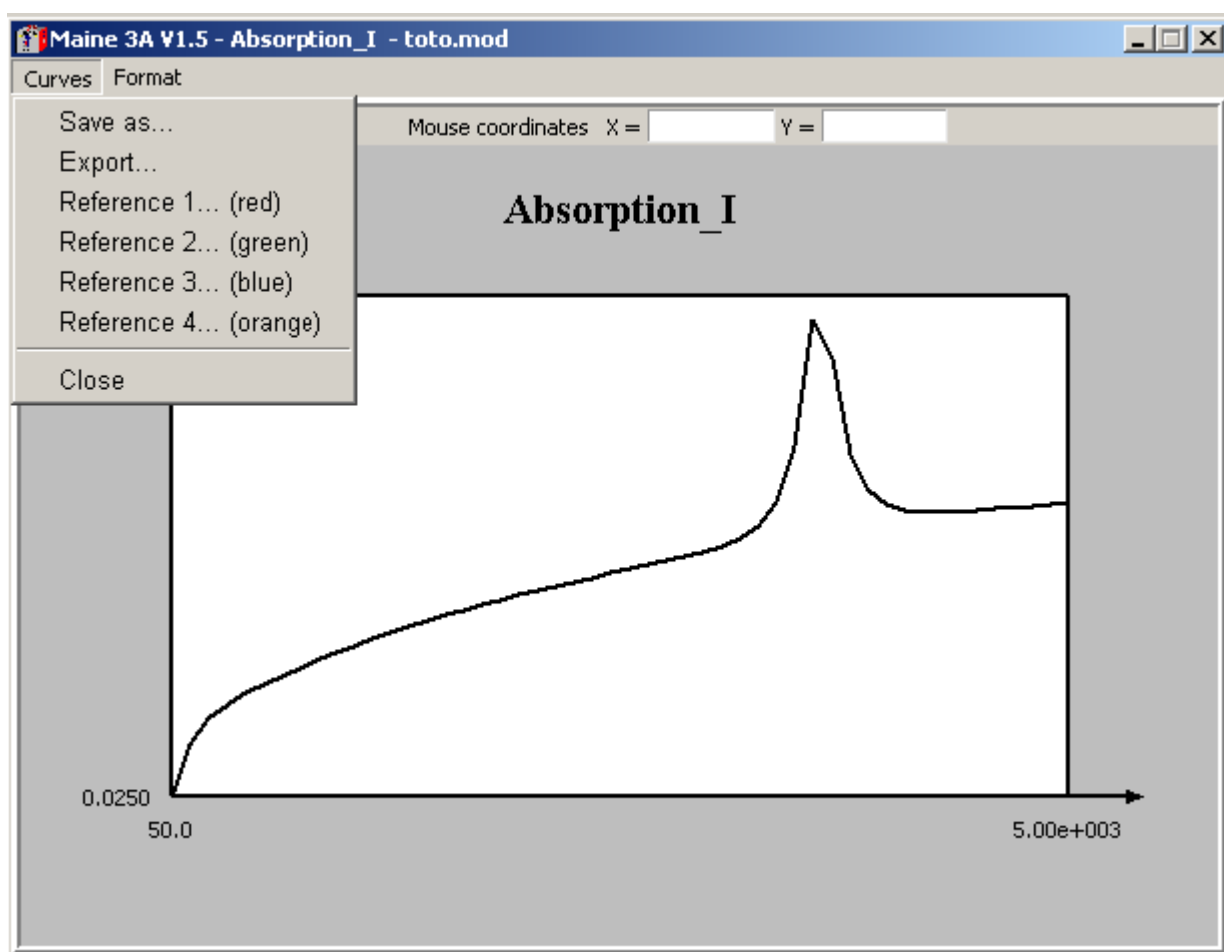
2.10.5. Language selection: the "Language" menu

This menu allows the user to modify the language used by MAINE 3A. The only languages available are French and English. Please contact us if you wish to volunteer for additional translations.

2.11. Graphics

All graphics windows share the same structure. They feature two menus: "Curves" and "Format".

2.11.1. The "Curves" menu

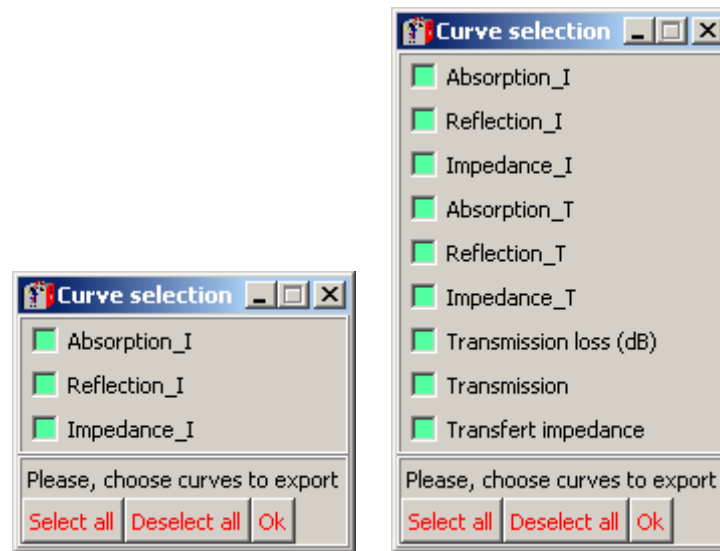


The "Curves" menu

The "Curves" menu gives access to various functionalities:

- [Save as] Saves the values into a .txt extension text file, compatible with most table editors. A

pop-up window allows the user to select the results that will be stored into the file.

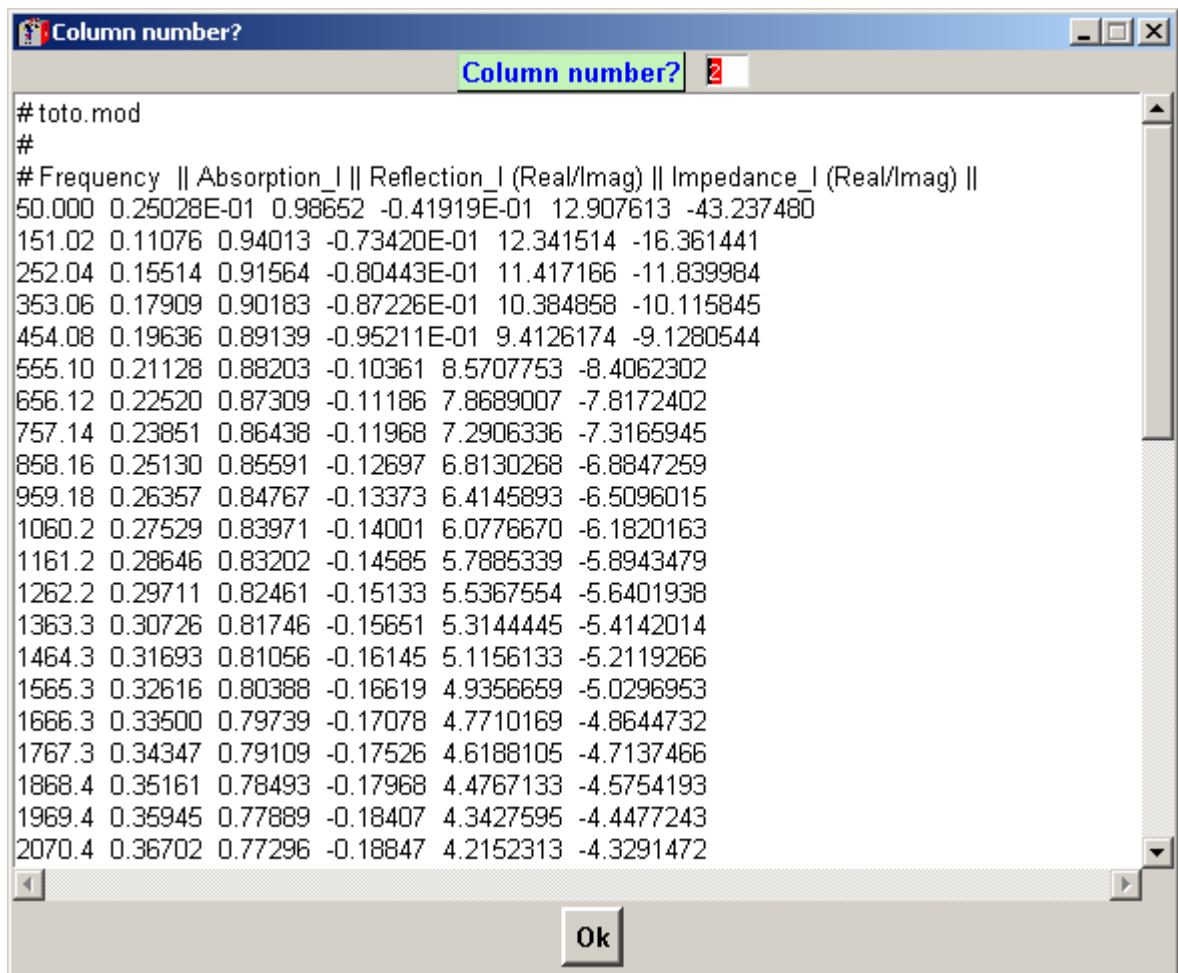


The two windows allowing the selection of the curves.

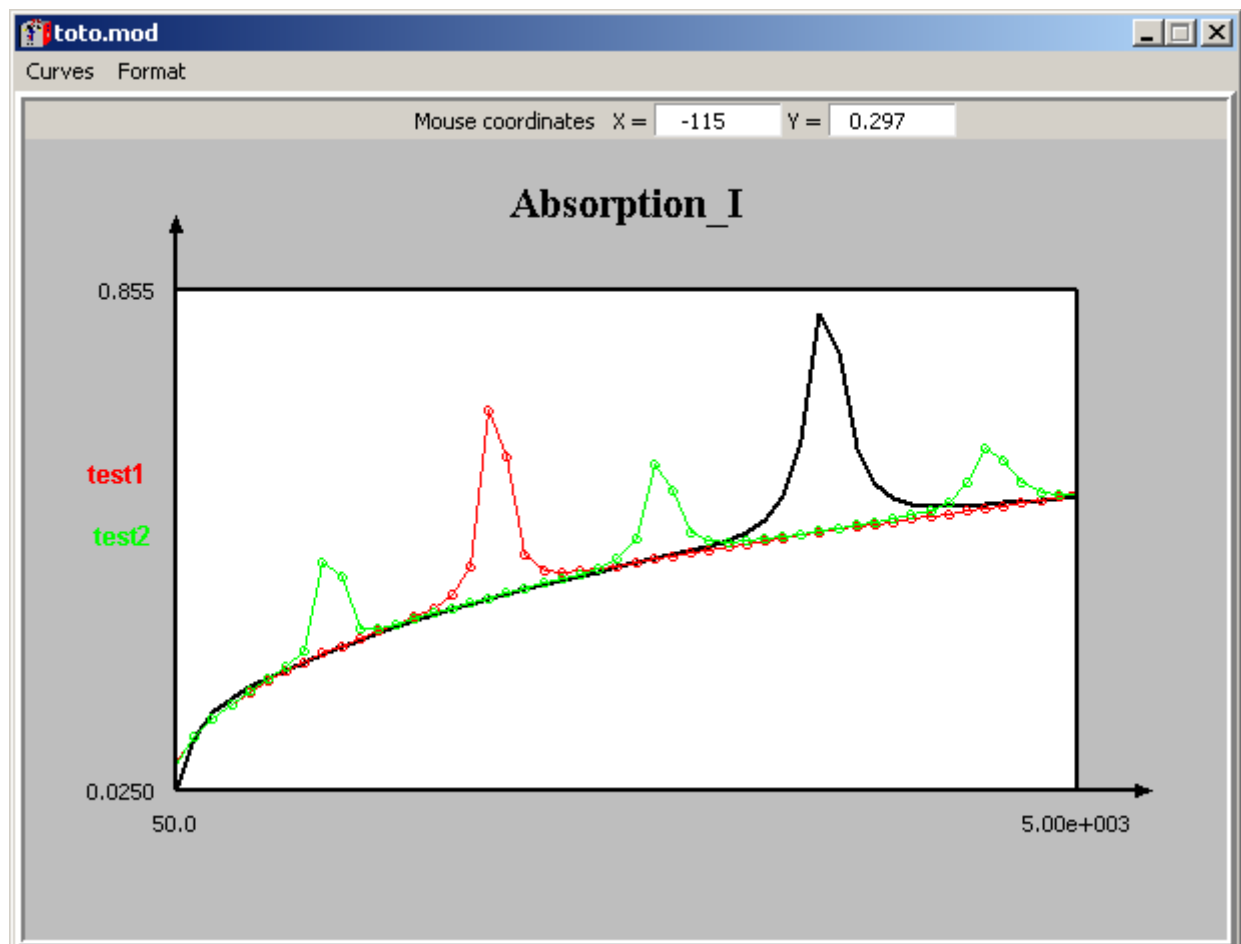
- [Export] Exports the graph in .eps extension Postscript format,
- [Reference] allows the display of up to 4 reference curves. The data for the reference curves must be stored in a file either using either the same formatting as MAINE 3A exports (text file with three lines of comments, frequencies in the first column, data in the next columns) or a more flexible format (indefinite number of lines starting with #, then frequencies in the first column and data in the next columns).

Whenever a file is selected a dialog box displays a preview of the file and allows the user to select the column's number containing the desired data.

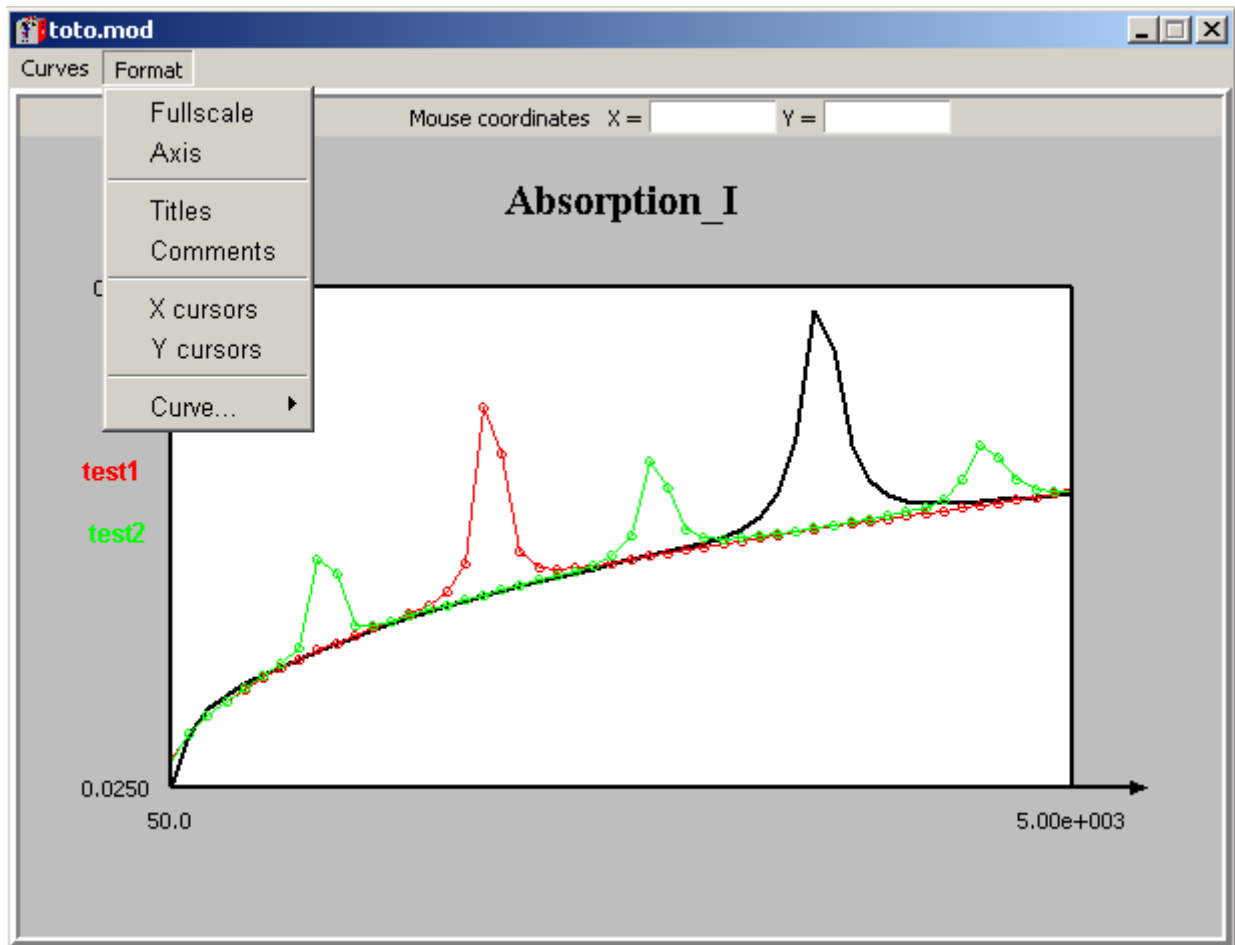
The software automatically detects the decimal separator (dot or comma). The curve is then traced with a color, and a label with the filename is displayed. It is possible to move the label using the mouse right-click, or delete the label by double right-clicking it.



Reference file preview window



2.11.2. The "Format" menu



The "Format" menu

The "Format" menu allows the user to:

- autoscale (full scale option) or manually scale (scale option) the graph and grid
- select the main curve's type (curve option). The reference curves are not configurable.

It is also possible to add:

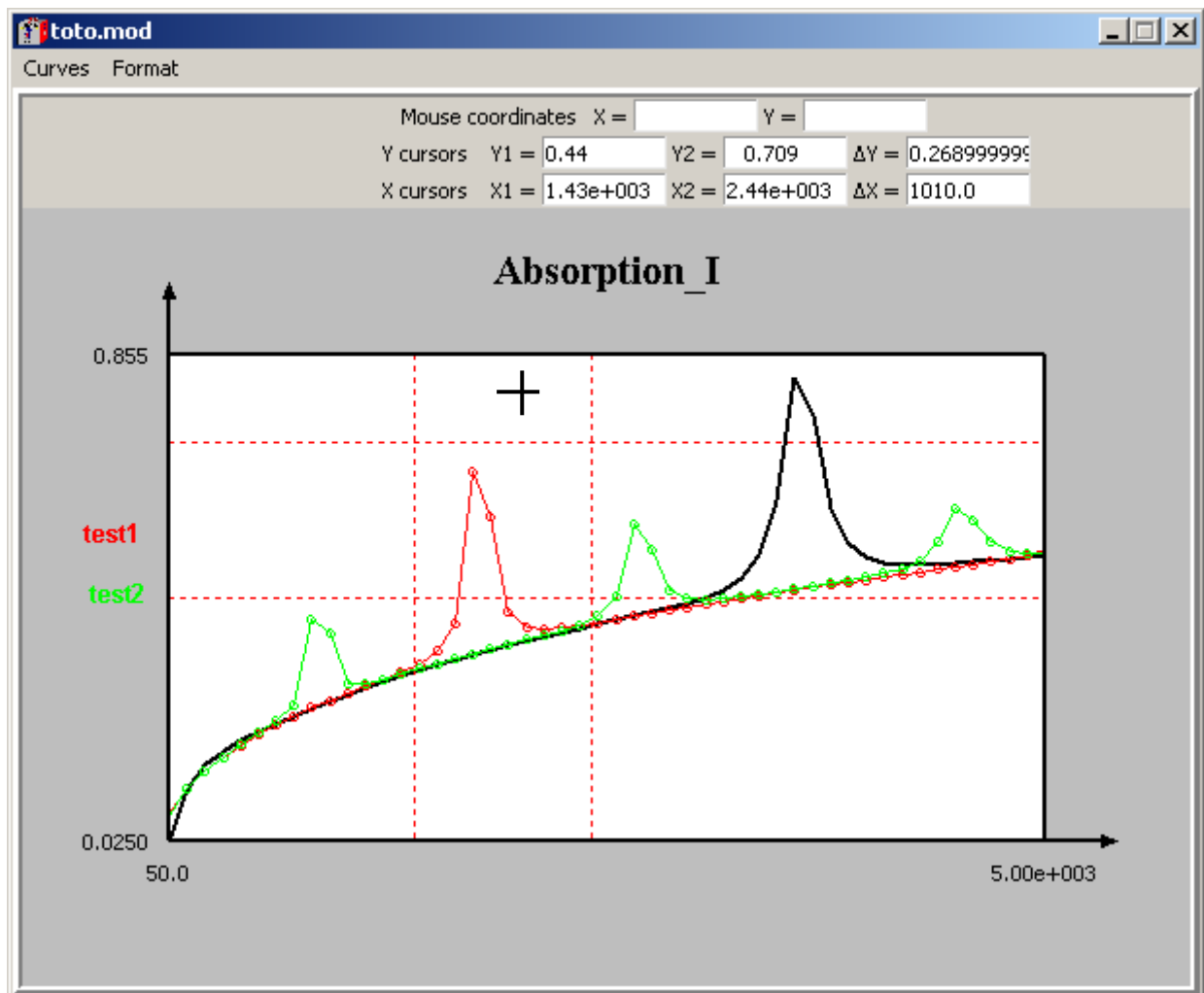
- titles,
- comments,
- two vertical marks and two horizontal marks. Their coordinates display in the graph header.

All these elements can be moved or deleted by using the mouse. See the summary table below.

Command	Effect
Right-click	Move object
Double right-click	Delete object
Ctrl + click	Zoom
Double click	Full scale

Curves manipulation

By placing the mouse pointer over the graphic zone, its coordinates display in the upper band: this feature allows for an easy check of the curve's values. Exact values are available by saving the curve and editing the corresponding .txt file.



Curve example

The curves are automatically refreshed when a new calculation is performed.

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