FREQID[1]

A graphical user interface for frequency domain identification

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[1]This manual describes the FREQID-toolbox version 1.1 for use with MATLAB 4.2c. MATLAB is a registered trademark of the MathWorks, Inc.

Contents

1 Introduction

1.1 Name of the game

This manual describes the usage of FREQID, a graphical user interface for performing identification on the basis of frequency domain data. FREQID is an abbreviation of FREQuency domain IDentification, which is supposed to cover the main purpose of this software: estimating or identifying models[2] on the basis of frequency domain data. The estimation of a model is done on the basis of curve fitting. In this way, a model is obtained by fitting the frequency response of a model on a given frequency domain measurement.

To simplify the operations involved with the estimation and validation of a model on the basis of frequency domain data, FREQID is equipped with a Graphical User Interface (GUI). The GUI is meant to simplify both the manipulation of frequency domain data, the choice of the weighting functions and the model order selection during the estimation of a model. Furthermore, the GUI enables the user to validate and/or compare various models relatively easily.

1.2 How to read this manual

The purpose of this manual is to focus on the usage the GUI associated to FREQID. As the GUI is designed to be a user friendly interface, most of the information described in this manual, directly follows from the GUI of FREQID. By the clicking the various help-buttons present in FREQID, additional information on a specific windows within FREQID can be displayed. Therefore, this manual will only follow the main line present in the GUI of FREQID and focuses on the various windows that are available in FREQID.

For notational convenience and reasons of clarity, different fonts are used in this manual to indicate different objects. Text in various windows created by MATLAB using the FREQID software like titles, text on buttons and ordinary string are typeset in this font. Names of files or directories, commands to be typed and editable text in various windows are typeset `in this font`. Finally, most abbreviations will be

[2]The models that are referred to in this manual are restricted to be linear, time-invariant and finite dimensional. The models can be multivariable and either discrete or continuous time model representations.

typeset IN THIS FONT. In this way, the difference between freqid in a title, the command `freqid` to be typed and FREQID as an abbreviation will be unambiguous.

The structure of this manual is as follows. In section 2, the installation of FREQID is discussed. If the installation has (already) been completed, one can directly move to section 3. This section contains information on how to start up FREQID and discusses the main window of FREQID. How models can be estimated on the basis of frequency domain data is discussed shortly in section 4.

2 Installation of FREQID

2.1 Requirements

The software of FREQID, including the GUI, is developed in a MATLAB environment. In order to use FREQID, the following hardware is required.

- You will need some computer that is able to run MATLAB, version 4.2c.
- A colour monitor is not required, but is very useful as FREQID tries to distinguish various models and/or data by different colours.
- You need approximately 1Mb free hard disk space to install the FREQID software, whereas at least 8Mb memory would be nice to run MATLAB and play around with FREQID.
- And inevitably last, but not least, you will need something like a mouse and a keyboard.

For the software requirements, of course the MATLAB-program (version 4.2c) must be available to run FREQID. Additionally, the following toolboxes are required to run FREQID properly:

- The standard signal processing toolbox (SIGNAL-toolbox) of MATLAB.
- The standard control systems toolbox (CONTROL-toolbox) of MATLAB.

Without the above toolboxes, the software of FREQID will not run properly. In order to use the least squares estimation method to estimate models on the basis of frequency domain data, no additional software is required. However, in order to use the maximum amplitude estimation method discussed in section 4, the optimization toolbox is required. This toolbox is needed to solve the linear programming problems involved with the maximum amplitude estimation routine.

Additionally, FREQID supports the data and model storage formats that available in the System identification toolbox (IDENT-toolbox) and the μ-analysis and synthesis toolbox (MU-toolbox). However, these toolboxes are not required in order to run FREQID. Finally, it should be noted that FREQID does not use any tools available in the UITOOLS.

2.2 Installation

For the installation of FREQID-software, the following three steps have to be followed.

1. Create two directories on your hard disk, for example called `CFIDENT` and `CFGUI`. As this installation will install a MATLAB-toolbox, it wise to create these two directories under your MATLAB-root toolbox directory. For a PC, the two directories would then look like

   ```
   C:\MATLAB\TOOLBOX\CFIDENT
   C:\MATLAB\TOOLBOX\CFIDENT\CFGUI
   ```

   where `C:\MATLAB` reflects the MATLAB-root directory located on drive `C:`, in which MATLAB has been installed.

2. Now copy all the files that are present in the `CFIDENT` subdirectory on the floppy-disk onto the `CFIDENT` directory on your hard disk. Also copy all the files that are present in the `CFGUI` subdirectory on the floppy-disk onto the `CFGUI` directory on your hard disk.

3. As a last step you will have to modify the `matlabpath` to include the above mentioned directories in the search path of MATLAB. Usually, the `matlabpath` is specified in a file called `matlabrc.m` already located on your hard disk. If you extend the `matlabpath` specified in `matlabrc.m`, make sure that the two directories of FREQID are always specified *after* a path that is pointing to the IDENT- and/or MU-toolbox (if available). In this way, the proper function m-files present in either the IDENT- or MU-toolboxes will be used in FREQID.

After installation, the CFIDENT directory contains all the stand-alone function m-files, whereas CFGUI directory contains all function m-files associated to the GUI. In these two directories, the following files can be found. Files with extension .m are ASCII-files that denote the function m-files or script files used by FREQID. Files with extension .mat are binary files used for model and/or data storage. Files with extension .fqd are binary files used by FREQID to store complete sessions.

2.3 Getting started

If the installation of FREQID has been completed successfully, MATLAB should be (re)invoked. If MATLAB is running and the matlabpath has been properly set, the command

```
>> freqid
```

typed in the MATLAB command window will start up FREQID. Starting up FREQID will results in the following window. A click on the info-button will yield some more

Fig. 1: Welcome window of FREQID.

information about FREQID. Here you can find what FREQID is all about and who wrote the stuff, especially if you have any comments or bugs to report. A click on the abort-button directly aborts FREQID, if you made an error by typing freqid in the first place. Finally, by a click on the continue-button the main window of FREQID will be opened.

3 The big picture

3.1 The main window

After starting up FREQID by typing the command

```
>> freqid
```

in the MATLAB command window and pressing the continue-button, the main window of FREQID is opened, see for example figure 2. As soon as the main window of FREQID is being opened, (re)typing `freqid` in the MATLAB command window, will directly popup the main window.

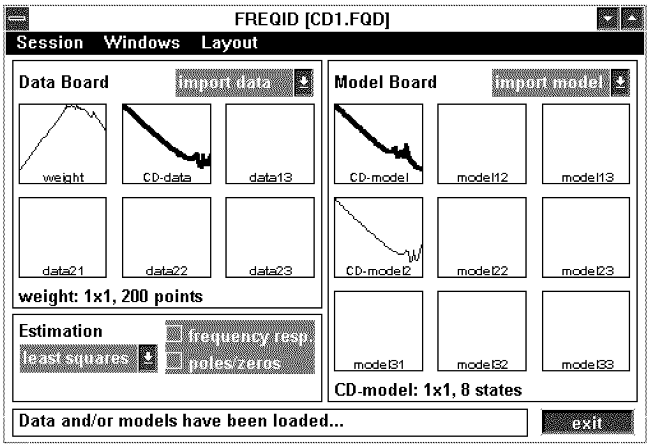

Fig. 2: Main window of FREQID

In order to explain the different components present in the main window of FREQID as depicted in figure 2, the main window will be divided in the following five parts:

1. At the top of the window you will find the menu bar. Via the options on the menu bar you can either load or save session files, access different MATLAB windows and change or save the layout of the FREQID windows.

2. At the left top part of the window one can find the Data Board. This is used to store and manipulate frequency domain data and/or weights used for estimating a model.

3. The right part of the window covers the Model Board. Similar to the Data Board, this is used to store and manipulate models.

4. The left bottom part of the main window is reserved for Estimation (and validation). This is used to estimate, validate and compare different models.

5. Finally, at the bottom of the window you will find the status line. This is used to display all kinds of messages to the user. In figure 2 the user is notified of the fact that Data and/or models have been loaded..., just after the session file `cd1.fqd` was loaded.

A more detailed discussion of the first four elements mentioned above can be found in the following sections. First the menu bar is discussed in section 3.2.

3.2 The menu bar

This section discusses the options that are available on the menu bar of the main window of FREQID, as depicted in figure 2.

The Session option on the menu bar can be used to load, save or merge a complete session via a FREQID-session file (a file having extension `.fqd`). If two session have been merged or if no session was loaded or saved, the title of the main FREQID window remains FREQID [untitled]. Once a session is loaded or saved, the name of the session file is placed between the brackets in the title of main FREQID window. In figure 2 this is illustrated by the fact that the session `cd1.fqd` has just been loaded.

The Windows option on the menu bar allows you to switch between different windows of FREQID, if they are opened.

Finally, the Layout option on the menu bar is used to change and/or save the various colours, position and size of the main FREQID window. Default, the main window has a blue background and starts up in the middle of the screen, having some specific size. By changing and saving the layout specifications, you can modify the appearance of the main FREQID window. As most of the other (sub)windows created by FREQID are related to the main window, these windows will also be affected by the layout specifications.

3.3 The data board

The starting point for estimating models within FREQID is the availability of some frequency domain data that needs to be fitted. This frequency domain data should be accessable before starting up FREQID, so that it can be imported on the Data Board of FREQID, see figure 2.

The Data Board is used to store and manipulate frequency domain data and/or frequency domain weights used for estimating a model. For this purposes, specific mouse actions (clicking, drag and drop) and a data-popup menu are defined within the Data Board. Below is a summary of these possibilities.

3.3.1 import data

The first step in estimating a model on the basis of frequency domain data via FREQID, is to load the data on the Data Board. This data can only be frequency domain data and basically there are two ways to load such data on the Data Board. The first possibility is to load a complete session, as discussed in section 3.2. The second possibility is to use the import data option of the data-popup menu. Invoking the import data option yields the window depicted in figure 3.

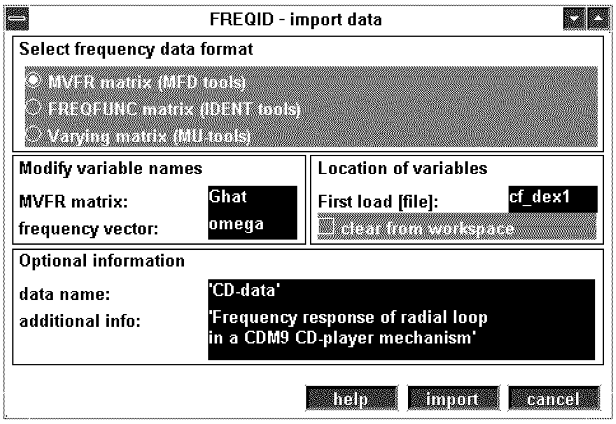

Fig. 3: Import data window.

In order to import the required frequency domain data, the right format has to be selected first. Three data formats are supported:

- MVFR matrix (MFD tools) This is most general supported format. In such a MVFR matrix, a frequency domain measurement (single- or multivariable) is stacked columnwise for each frequency point separately. The frequency vector (in [rad/s]) corresponding to it, must be specified separately. This format is also supported by the Multivariable Frequency Domain Toolbox (MFD tools).

- FREQFUNC matrix (IDENT tools) This is a format to store frequency domain data supported by the System Identification toolbox (IDENT-tools). Such a matrix already contains the corresponding frequency vector.

- Varying matrix (MU tools) This is the format supported by the μ-analysis and synthesis toolbox (MU tools). Such a matrix already contains the frequency vector.

Above formats will be saved and converted to a format used internally by FREQID and is used for editing, estimation and plotting.

Subsequently, the name(s) of the variable(s) associated to the frequency data should be specified under Modify variable names. Default, the variables are assumed to be located in the MATLAB workspace. If not, a file name can be specified under Location of variables. Alternatively, a file can be searched interactively, by clicking on [file] in First load [file]:. The check box clear form workspace can be set on (default) to clear the variables from workspace after importing so as to reduce memory requirements.

Finally, the name of the data and some additional information can be specified under Optional information. Note that the name and info should be placed between quotes, otherwise FREQID tries to load the corresponding variable name from the MATLAB workspace or the file specified.

From figure 3 it can be seen that the file `cf_dex1` will be loaded first (extension `.mat` is added automatically). This file should contain the frequency data `Ghat` and the frequency vector `omega`. These variables will not be cleared from the workspace after import. Furthermore, the name and additional information on the data have been specified.

3.3.2 mouse actions: select, copy and data information

Once the data has been loaded successfully, it will appear in one of the boxes present in the Data Board by plotting the Bode amplitude plot of the first element of the (multivariable) frequency domain data. The second step in order to use the data for estimation and/or manipulation is to *select* the data.

Data can be selected simply by clicking on the corresponding box on the Data Board. If the data has been selected, a fat line will be drawn in the corresponding box, see e.g. the second box in figure 2. An other click on the data will again deselect the data. Only one data box can be selected.

Data can also be copied to other data boxes by a simple drag and drop mouse action. Push the mouse button on the data you like to copy and *hold* it. The mouse cursor will change so as to notify you are in dragging mode. Simply move the cursor to another data box and release the mouse button: the data will be copied. Moving data is possible by first copying the data and deleting the original one afterwards.

Information on data can also be accessed by simple mouse click. By (de)selecting the data, some information is already displayed in at the bottom of the Data Board. Alternatively, clicking on the name of the data present in a data box will display some additional information on the data.

3.3.3 export data

Once data has been selected (see section 3.3.2), it can be exported to the MATLAB workspace or a user specified file. This can be done by invoking the export data option of the data-popup menu. Invoking the export data option yields the window depicted in figure 4.

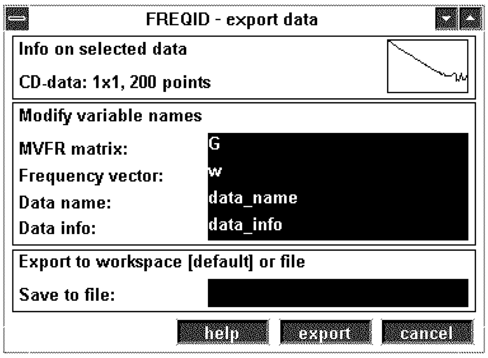

Fig. 4: Export data window.

The selected data can only be exported in the MVFR format (see section 3.3.1) as this is the most general supported format. Additionally, the name of the data and the information can also be saved. The name(s) of the corresponding variable(s) again should be specified under Modify variable names. Default, the variables are assumed to be saved to the MATLAB workspace. If not, a file name can be specified.

3.3.4 edit data

Once data has been selected (see section 3.3.2), it can also be edited. Editing data can be achieved by invoking the edit data option of the data-popup menu. Invoking the edit data option yields the window depicted in figure 5.

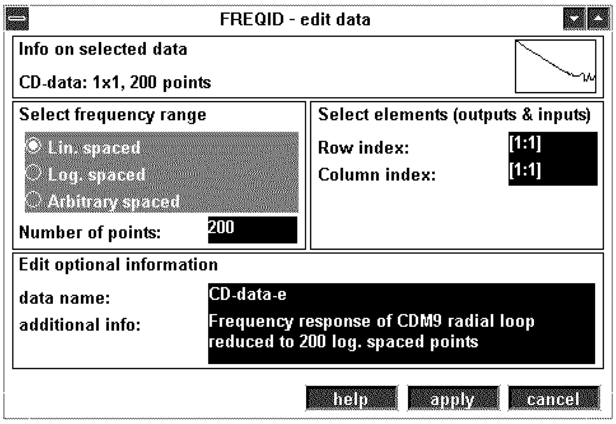

Fig. 5: Edit data window.

Within the window depicted in figure 5, the number of frequency domain data points or frequency range can be altered under Select frequency range. Note that decreasing the number of data points may speed up the estimation of a model, without actually loosing the accuracy of the model. This range of frequency points can be either modified to linearly spaced, logarithmically spaced or arbitrary spaced *with respect* to the original number and ordering of frequency points. Logarithmically spaced points will remove mostly high frequency points and thereby removes the high frequency emphasis during least squares curve fitting, in case the original frequency vector was linearly spaced.

Additionally, in case of multivariable frequency domain data, specific inputs and outputs can be selected with the row and column index under Select elements (outputs & inputs). This will reduce the dimension of the frequency domain data (less inputs or outputs) if one is interested in fitting only one specific element.

Finally, the name of the data and the information associated to it can be modified. Default, the edit data operation adds -e to the name of the data to indicate it has been edited.

3.3.5 delete data

Only a finite number of data boxes are available to store frequency domain data or frequency domain weights in order to estimate models. To clear up space on the Data

Board it is also possible to delete data from the Data Board. This can be achieved by invoking the delete data option of the data-popup menu. Selecting the delete data option deletes the *selected* data from the Data Board after an affirmative verification.

3.3.6 example

The last option in the data-popup menu is the example option. This is basically the same as the import data option, but is based on some previously stored frequency domain data and can serve as an example on how to import data in FREQID. In fact, figure 3 reflects the example loaded when invoking the example option.

3.4 Model board

Quite similar to the Data Board discussed in section 3.3, the Model Board has been defined on the main window of FREQID. For reasons of completeness, a summary of the actions possible within the Model Board are listed below.

3.4.1 import model

There are three ways to obtain a model on the Model Board. The first possibility is to load a complete session, as discussed in section 3.2. The second possibility is to estimate a model on the basis of a frequency domain data. This will be discussed in section 4. The last way is to use the import model option of the model-popup menu. Invoking the import model option yields the window depicted in figure 6.

In order to import the required model, the right format has to be selected first. Three model formats are supported:

- State space matrix This is most general supported format. In such a STATE SPACE MATRIX, the state space matrices `A`, `B`, `C` and `D` of a model (single- or multivariable) are stacked in a matrix `S=[A B;C D]`. In order to be able to re-extract the state space, the size of the matrix `A` (state space dimension) must be given by the value `ns` or any integer number.

- THETA matrix. This is a format to store a model supported by the System Identification toolbox. Such a matrix already contains information on the dimension of the state.

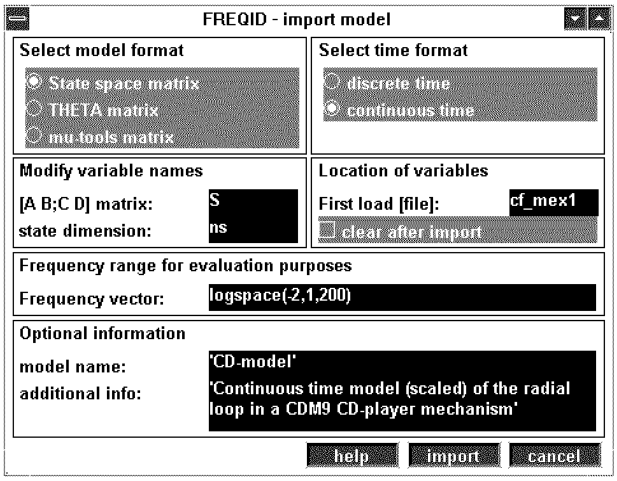

Fig. 6: Import model window.

- mu-tools matrix. This is the format supported by the μ-analysis and synthesis toolbox (MU tools). Such a matrix already contains information on the dimension of the state.

Above formats will be saved and converted to a model representation used internally by FREQID and is used for evaluating frequency reponses, computing poles/zeros and exporting models.

Next, in Select time format the user has to specify whether the model is a discrete or continuous time model. In case of a discrete time model, the sampling time (in [sec]) should be given.

Subsequently, the name(s) of the variable(s) associated to the model should be specified under Modify variable names. Default, the variables are assumed to be located in the MATLAB workspace. If not, a file name can be specified under Location of variables. Alternatively, a file can be searched interactively, by clicking on [file] in First load [file]:. The check box clear from workspace can be set on (default) to clear the variables from workspace after importing so as to reduce memory requirements.

The following property that needs to be specified for a model, is the Frequency range for evaluation purposes. This frequency range is used solely to plot the frequency response of the model in order to evaluate and/or validate the model. This frequency vector (in [rad/s]) must be a *string* that will be evaluated by MATLAB if the frequency response is being plotted in order to reduce memory requirements.

Finally, the name of the model and some additional information can be specified under Optional information. Note that the name and info should be placed between quotes, otherwise FREQID tries to load the corresponding variable name from the MATLAB workspace or the file specified.

From figure 6 it can be seen that the file `cf_mex1` will be loaded first (extension `.mat` is added automatically). This file should contain the state space matrix `S` and the dimension of the state space `ns`. These variables will not be cleared from the workspace after import. The model to be loaded is a continuous time model and will be evaluated at a 200 points logarithmically spaced frequency vector between 10^{-2} and 10 rad/s. Furthermore, the name and additional information on the model have been specified.

3.4.2 mouse actions: select, copy and model information

Once the model has been loaded successfully, it will appear in one of the boxes present in the Model Board by plotting the Bode amplitude plot of the first element of your (multivariable) model, using the Frequency vector for evaluation purposes.

A model can be selected simply by clicking on the corresponding box on the Model Board. If a model has been selected, a fat line will be drawn in the corresponding box, see e.g. the first box in figure 2. An other click on the model will again deselect the model. Only one model box can be selected.

A model can also be copied to other model box by a simple drag and drop mouse action. Push the mouse button on the model you like to copy and *hold* it. The mouse cursor will change so as to notify you are in dragging mode. Simply move the cursor to another model box and release the mouse button: the model will be copied. Moving models is possible by first copying the model and deleting the original one afterwards.

Information on the model can also be accessed by simple mouse click. By (de)selecting the model, some information is already displayed in at the bottom of the Model Board. Alternatively, clicking on the name of the model in one of the model boxes will display some additional information on the model, like stability, the number of states and the dimension (number of inputs and outputs).

3.4.3 export model

Once a model has been selected (see section 3.4.2), it can be exported to the MATLAB workspace or a user specified file. This can be done by invoking the export model option of the model-popup menu. Invoking the export model option yields the window depicted in figure 7.

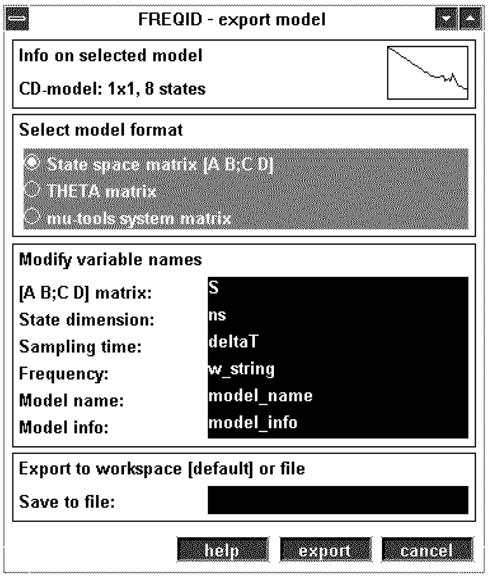

Fig. 7: Export model window.

The selected model can be exported in various formats, see also section 3.4.1. Additionally, the name of the model and the information can also be saved. The name(s) of the corresponding variable(s) again should be specified under Modify variable names. Default, the variables are assumed to be saved to the MATLAB workspace. If not, a file name can be specified.

3.4.4 edit model

Once a model has been selected (see section 3.4.2), it can also be edited. Editing a model can be achieved by invoking the edit model option of the model-popup menu. Invoking the edit model option yields the window depicted in figure 8.

Within the window depicted in figure 8, the frequency range for evaluation purposes can be modified. This frequency range is used solely to plot the frequency response of the model in order to evaluate and/or validate the model. This frequency vector (in

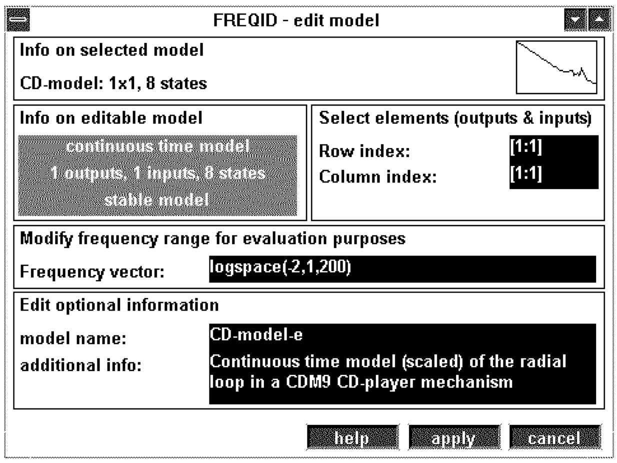

Fig. 8: Edit model window.

[rad/s]) must be a *string* that will be evaluated by MATLAB if the frequency response is being plotted in order to reduce memory requirements.

Additionally, in case of multivariable frequency model, specific inputs and outputs can be selected with the row and column index under Select elements (outputs & inputs). This will reduce the dimension of the model (less inputs or outputs) if one is interested in evaluating only one specific element.

Finally, the name of the model and the information associated to it can be modified. Default, the edit model operation adds -e to the name of the model to indicate it has been edited.

3.4.5 delete model

Only a finite number of model boxes are available to store models on the Model Board. To clear up space on the Model Board it is also possible to delete a model. This can be achieved by invoking the delete model option of the model-popup menu. Selecting the delete model option deletes the *selected* model from the Model Board after an affirmative verification.

3.4.6 example

The last option in the model-popup menu is the example option. This is basically the same as the import model option, but is based on some previously stored frequency domain data and can serve as an example on how to import a model. In fact, figure 6 reflects the example loaded when invoking the example option.

3.5 Estimation and validation

The last part of the main window of FREQID can be used to obtain models by estimation (curve fitting) techniques and to validate models that are present on the Model Board. The estimation of models is postponed to section 4. Validation of models in FREQID is limited to viewing frequency responses (check box frequency resp.) and inspecting the pole/zero locations (check box poles/zeros). Additional validation tools are planned in a future release of FREQID.

By turning the check box frequency resp. on, FREQID will open the frequency response window and computes/plots the frequency response of the *currently selected* data and/or model on the main window. Once the frequency response window is open, (de)selecting data and/or models will toggle the frequency response plot of the data and/or model being (de)selected. The menu bar of the frequency response window can be used to change the plot, axes and toggle zooming, griding, data and models you would like to see. Pushing a >-button in the frequency response window will open another window that enables you to zoom in on one of the elements of a (multivariable) frequency response.

By turning the check box poles/zeros. on, FREQID will open the poles/zeros window and computes/plots the poles and zeros of the *currently selected* model on the main window. Poles are depicted by crosses, whereas zeros are depicted by circles. Once the poles/zeros window is open, (de)selecting models will toggle the poles/zeros plot of the model being (de)selected. The menu bar of the poles/zeros window can be used to change the plot and toggle pole plots, zero plots, griding, zooming and models you would like to see.

4 Obtaining models

4.1 Estimation methods

This section discussed the third possibility next to loading a session (section 3.2) and importing models (section 3.4.1) in order to obtain a model on the Model Board: estimation. Basically, the estimation of a model is done by performing a curve fit on a frequency domain data available on the main window of FREQID. Depending on the parametrization of the model, the curve fitting generally involves a non-linear optimization that needs to be solved. Currently, two different curve fitting routines are implemented within FREQID. These routines are available by invoking the estimation-popup menu present in the main window of FREQID. A short summary of the two methods is listed below.

- least squares

  The least-squares estimation routine implemented is a multivariable extension of the so-called Sanathanan-Koerner iteration (Sanathanan and Koerner, 1963) and aims to minimize the 2-norm of a (weighted) difference between the frequency response of the model and the data. The weighting can be specified for each transfer function separately. The (multivariable) model is parametrized by either a left or right Matrix Fraction Description (MFD), which reduces to a simple numerator/denominator representation for estimating scalar models. For a more detailed discussion on the procedure, one is referred to de Callafon *et al.* (1996).

  There is no guarantee for this iteration to converge, but it seems to work in most situations. Furthermore it is reasonably fast and due to the subsequent affine optimization steps it supports the estimation of relatively high order models.

- max. amplitude

  The maximum amplitude routine implemented has also a strong connection with the so-called Sanathanan-Koerner iteration. However, this procedure aims at minimizing the (weighted) maximum difference between the frequency response of the model and the data, element wise. Again the weighting can be specified for each transfer function separately. The (multivariable) model is parametrized by a combined diagonal left and right Matrix Fraction Description (MFD), which reduces to a simple numerator/denominator representation for estimating scalar models. For a more detailed discussion on the procedure, one is referred to Hakvoort and Van den Hof (1994).

  Again there is no guarantee for this iteration to converge, but it seems to work in most situations. Due to the subsequent affine linear programming problems that need to be solved in each iteration step, it also supports the estimation of relatively high order models.

Due to the strong analogy between the two methods, this manual will focus on the least squares estimation method in order to estimate a model. Similar windows and input variables can be found for the max. amplitude estimation method.

4.2 Least squares estimation

Once a data box has been selected, see section 3.3.2, invoking the least squares option from the estimation-popup menu in the main window of FREQID will present the least squares estimation window on your screen. An overview of this window is depicted in figure 9.

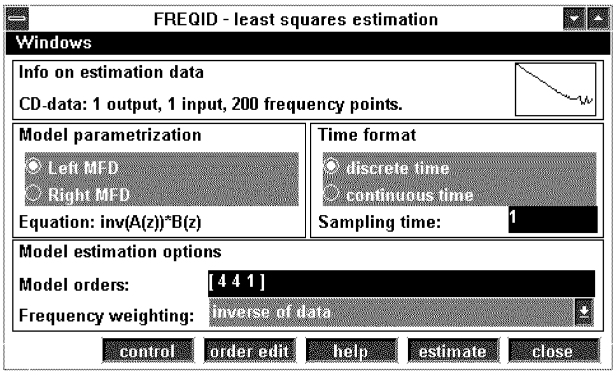

Fig. 9: Least squares estimation window

Before the estimation can be carried out, the user should first characterize the model to be estimated. This includes the parametrization, the number of parameters and the time format (discrete or continuous time). Additionally, a weighting to be used during the estimation (curve fitting) of the model can be specified. These option are discussed in more detail in the following sections.

4.2.1 starting up the estimation

In the least squares estimation algorithm, a multivariable model is parametrized by a Matrix Fraction Description (MFD), using the inverse of a square and monic A-polynomial and a B-polynomial. The MFD can be specified under Model parametrization, see also figure 9. This can be either a left MFD (option left MFD) or a right MFD (right MFD). For the left MFD, the inverse of the monic A-polynomial appears at the output of the model, whereas for the right MFD, the inverse appears at the input. The corresponding equation appears at the bottom of the Model parametrization. For a scalar system, both parametrizations are the same and reflect an ordinairy numerator/denominator parametrization.

Secondly the Time format should be specified to indicate if the model to be estimated is going to be a discrete or continuous time model. In case of a discrete time model, the sampling time (in [sec]) needs to be specified. The corresponding sampling frequency (in [rad/s]) should be at least twice as large as the maximum frequency of the data selected for estimation purposes. If you like to estimate a model with a smaller larger sampling time, you need to discarge high frequency points by the editting the data, see section 3.3.4.

To complete the characterization of the model to be estimated, the number of parameters of the model need to be specified in the field characterized by Model orders:. For a discrete time model, respectively the number of parameters in the monic A-polynomial, the number of parameters in the B-polynomial and the number of starting zero entries (delays) in the B-polynomial can be specified. Default this is set to `[4 4 1]` for a left MFD and `[4 ; 4 ; 1]` for a right MFD. For a continuous time model, respectively the number of parameters in the monic A-polynomial, the number of parameters in the B-polynomial and the number of trailing zero entries (roots at 0) in the A-polynomial can be specified. For additional help on specifying the number of parametrizations to be estimated, one can use the order edit-button, see section 4.2.3.

Finally, the weighting to be used during the estimation (curve fitting) of the model can be specified. default, the weighting is chosen to be the inverse of the data, so as to minimize a relative error instead of an absolute error. Additional choises include none (unit weighting to minimize an unweighted, absolute error) or advanced. The advanced weighting option enables you to load and/or modify frequency domain weightings relatively easily. One is referred to section 4.2.5 for a more detailed discussion on the usage of advanced weightings.

If all the options specified above are specified, a click on the estimate button will start up the minimization. Progress on the iteration to fit the frequency response is displayed in MATLAB command window. Some options associated to the Sanathanan-Koerner iteration can be accessed by a click on the control-button, see also section 4.2.4.

4.2.2 importing an estimated model

If the minimization is finished, the least squares estimation modifies in the window depicted in figure 10.

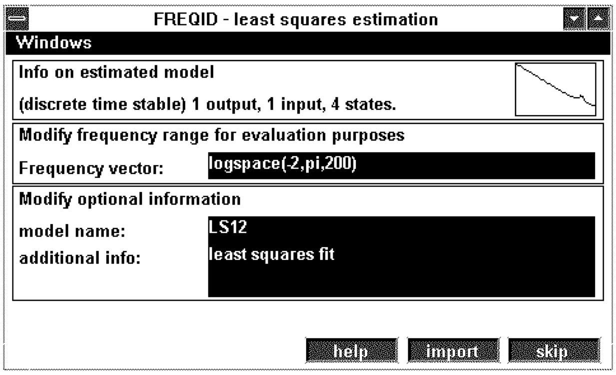

Fig. 10: Least squares estimation window after estimation

The least squares estimation window after estimation presents some information on the model being estimated and plots a small frequency plot for a quick reference. If the minimization has been completed sucssesfully, you can import the model on the Model Board of FREQID by a simple click on the import-button. If you are not satisfied with the model, clicking the skip-button does not import the model.

Before importing the model, you can modify the options associated to the frequency range for evaluation purposes, the name of the model and the additonal information on the model. The default values for these options are depicted in figure 10.

4.2.3 order edit

To facilitate the specification of the number of parameters to be estimated, the least squares estimation window is equipped with an order editor for the MFD parametrization. By a click on the order edit-button, the order editor for MFD parametrization window is opened, see figure 11.

The meaning of the integers to specify the number of parameters to be estimated is made clear and changing the integer values will directly update the corresponding A- and B-polynomial, see also figure 11. A click on the apply-button will update the number of parameters to be estimated in the least squares estimation window.

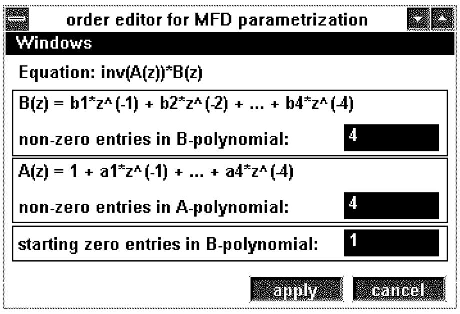

Fig. 11: Order editor for MFD parametrization

4.2.4 iteration control

For controlling parameters associated to the iteration using during minimization, the least squares estimation window is equipped with a control-button. A click on the control-button will open the window depicted in figure 12.

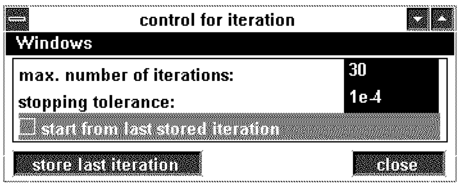

Fig. 12: Control for iteration

The control for iteration window depicted in figure 12 can be used to set up the maximum number of iterations and the tolerance for the iteration to stop. The default values are depicted in figure 12 and the window should be left open if you like to use different values during the iteration.

Additionally, the control for iteration can be used to start from a previously estimated model. The store last iteration-button enables you you store the last computed model (or better: the updated weighting associated to the last computed model via the Sanathanan-Koerner iteration). To start the iteration from this point, the check box start from last iteration must be set on. This option might be helpfull if you like to estimate a high order model for which the iteration does not converge directly. Starting with a low order model, storing the result and invoking the high order estimate from this low order model may improve both the convergence of the iteration and the resulting estimate.

4.2.5 advanced weighting

Next to default weighting (inverse of data) and a unit weighting (none), the least squares estimation enables you to use a more advanced weighting. The weighting used in the least squares estimation can be any frequency dependent data weighting, having the same size as the frequency data used for estimation and is applied *elementwise* in case of multivariable frequency domain data.

By selecting the advanced option in the least squares estimation window, the weighting window depicted in figure 13 will be opened.

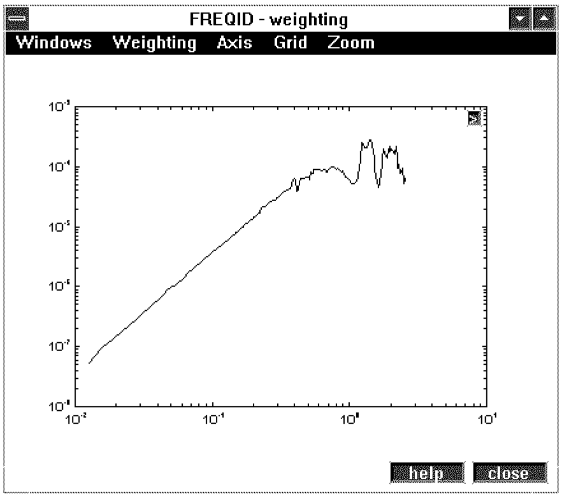

Fig. 13: Weighting window for estimation

The weighting window will start up with the *default* weighting: inverse of data, so as to minimize relative errors during curve fitting. The menu bar of the weighting window can be used to import and export weightings *via* the Model Board of FREQID. Additionally one can change the plot, axes and toggle zooming and griding.

Pushing a >-button in the weighting window will open another window that enables you to zoom in on one of the elements of a (multivariable) frequency domain weighting and allows you to *edit* this element. A snap shot of the is window is depicted in figure 14

The vertical dashed-dotted lines in figure 14 are used to select the frequency range to be editted for this element. These lines can be moved by a simple drag and drop mouse action. The different options on the menu bar of window depicted in figure 14 can be used to modify the weight. In this way, the frequency range between the two

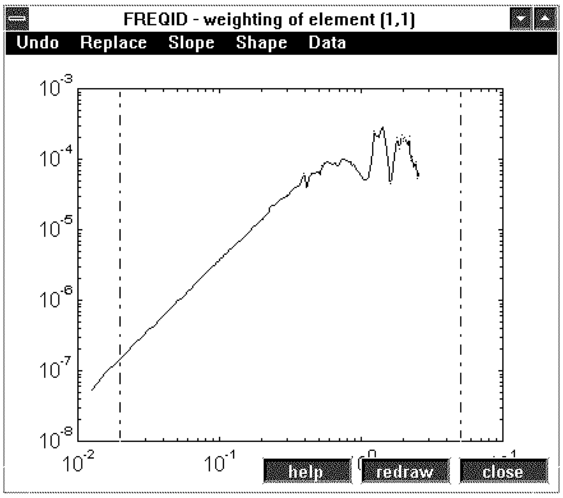

Fig. 14: Editable weighting per element

vertical dash-dotted lines can be inverted and smoothend (Replace) or integrated and differentiated (Slope), etc. One is referred to the different options on the menu bar, where the Undo option can be used to restore the previous weighting.

Additionally, the weighting between the two vertical dash-dotted lines can also be modified by a drag and drop mouse action. The shape of the weighting caused by this dag and drop action can be influenced by the different options available under the Shape option on the menu bar.

Finally, the correspondig element of the data on which the current weight is going to be applied can also be ploted in the window depicted in figure 14. For that purpose, use the Data option on the menu bar. Once the data has been plotted, it can be moved up and down by a drag and drop mouse action. In this way, the data can be used as a reference to edit the weighting.

4.3 Maximum amplitude estimation

The implemented maximum amplitude estimation routine has also a strong connection with the so-called Sanathanan-Koerner iteration. However, in each step of the iteration, the (weighted) maximum difference between the frequency response of the model and the data for each element is being minimized. Again the weighting can be specified for each element separately. The (multivariable) model is parametrized by a combined diagonal left and right Matrix Fraction Description (MFD), which reduces to a simple numerator/denominator representation for estimating scalar models. Although there is no guarantee for this iteration to converge, it seems to work in most situations. Due to the strong analogy with the computations involved with the least-squares estimation, one is referred to windows discussed in section 4.2. FInally it should be noted that the maximum amplitude estimation routine can be invoked only, if the MATLAB optimization-toolbox has been installed succesfully, see section 2.1.

5 Remarks and suggestions

Any feedback by remarks, suggestions or bug reports are a prerequisite to develop reliable and user friendly software. If you have any bugs to report or have any other suggestions to improve FREQID, please consult the corresponding author. An email address can be found in the info on FREQID window that is presented if you click the info-button in the window depicted in figure 1.

6 Acknowledgements

As a final remark, the authors would like to thank David Molenaar for his contribution in testing the FREQID-software and setting up the main line of this manual.

7 References

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