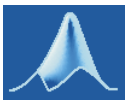
FREQID[1]

a graphical user interface for
frequency domain identification



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[1]This manual describes the FREQID-toolbox version 1.3 for use with MATLAB 5.2, 5.2.1 or 5.3. 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 consists of 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 GUI windows like titles, text on buttons and ordinary string are typeset in a sans serif font. To indicate menu bar (sub)items, the notation item|subitem is used to indicate that subitem can be found under item on the menu bar. Names of files or directories, commands to be typed and editable text in various windows are typeset `in a typewriter font`. Finally, most abbreviations will be typeset IN A SMALL CAPITALS FONT. In this way, the difference between freqid in a title of a GUI window, the command `freqid` to be typed in the MATLAB command window and FREQID as an abbreviation will hopefully be clear.

This manual has been outlined 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] 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.

Including additional frequency domain identification algorithms is discussed in section 5 where some information on how to customize the GUI of FREQID is given.

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 5.x. The current version of FREQID has been tested with MATLAB versions 5.2, 5.2.1 (patched 5.2) and 5.3. FREQID also works with the student version of MATLABversion 5.x, but the size of the frequency domain data and orders of the model to be estimated are limited by the matrix size limitation of the student version of.
- 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 1.5Mb free hard disk space to install the FREQID software, whereas at least 8Mb of free memory would be nice to run MATLAB and play around with FREQID.
- And last, but not least, you will need something like a mouse and a keyboard.

For the software requirements, of course the MATLAB-program 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.

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 What's in the package

The contents of the FREQID toolbox can be divided into two main toolbox components: the FREQID GUI toolbox and the estimation toolboxes. The FREQID GUI toolbox contains the necessary

MATLAB files for the Graphical User Interface of FREQID. The estimation toolboxes contain all the (standalone) MATLAB files for the computation and estimation of models on the basis of frequency domain data. In the current distribution of FREQID, two estimation routines are supported:

1. LSFITS - A multivariable Least Squares curve FITing routine with Schur based weighting functions.

2. INVFREQ - The standard MATLAB SIGNAL-toolbox INVerse FREQuency domain routines based on least squares frequency domain curve fitting.

Additional frequency domain estimation routines can be added easily and one is referred to Section 5.3 on how to customize FREQID for your needs.

Each toolbox component is packed in a ZIP archive (PKZIP'ed or GZIP'ed file) for easy distribution. As the INVFREQ estimation routine already comes with MATLAB, the FREQID distribution will consist of two ZIP archives:

1. `freqid.zip` - ZIP archive of the FREQID GUI toolbox.

2. `lsfits.zip` - ZIP archive of the LSFITS estimation routine.

The next section will explain how to install FREQID by unpacking the ZIP archives.

2.3 Installation

The installation of FREQID has been documented in the `install.txt` file, distributed with FREQID. Installation is easy and is done by hand in three basic steps. First create a couple of directories. Then unpack the ZIP archives in the directories. Finally, edit the MATLAB search path (`matlabpath`), so MATLAB knows where to find your new toolboxes. Below, the two steps are mentioned are discussed in more detail.

1. Create separate directories for each ZIP archive. Preferably, give the directories a similar name as the ZIP archive. Hence, a directory with the name `freqid` for the FREQID GUI toolbox and a `lsfits` directory name for the LSFITS toolbox. Furthermore, as this installation creates MATLAB toolboxes, it wise to create these directories under your own MATLAB-root toolbox directory. On a Windows PC, the two directories would then look like

   ```
   C:\MATLABR11\TOOLBOX\FREQID
   C:\MATLABR11\TOOLBOX\LSFITS
   ```

   where `C:\MATLABR11` reflects the MATLAB-root directory located on drive `C:`, where MATLAB 5.3 has been installed.

2. Unpack (with `pkunzip`) the ZIP archives containing the FREQID GUI toolbox and the estimation toolboxes into their corresponding directories. A shareware version of the `pkunzip.exe` program for a Windows PC is being distributed with FREQID for your convenience. Following the example mentioned above, unpack the `freqid.zip` archive into the directory called `C:\MATLABR11\TOOLBOX\FREQID` and unpack the `lsfits.zip` archive into the directory called `C:\MATLABR11\TOOLBOX\LSFITS`.

3. The last step of the installation involves the modification of the `matlabpath` to include the above mentioned directories in the search path of MATLAB. This can be done easily in three different ways:

   - Using the path browser in MATLAB.
     Type `editpath` in the MATLAB command window to invoke the path browser. Browse for the directories you just created and select Path|Add to path in the menu bar of the path browser. Now close the path browser, and click on yes to save the modified path for future sessions.

   - Using the FREQID Search Path utility (recommended)
     FREQID comes with an utility to update the path. The utility is called FREQIDSP (FREQID Search Path) and can be invoked in the MATLAB command window by typing `freqidsp`. In order for this MATLAB function to work, copy the `freqidsp.m` file to your working directory and make sure that FREQID GUI and any estimation toolboxes are installed below your working directory or somewhere under the standard MATLAB root directory. Typing `freqidsp` will check your version of FREQID, whether or not any older versions still are installed and updates the MATLAB search path for you.

   - Manual editing of the `pathdef.m` file (not recommended)
     Alternatively, you can directly modify the `matlabpath` by editing the `pathdef.m` file that defines the `matlabpath` when MATLAB is started. Most likely, `pathdef.m` can be found under the `\matlabr11\toolbox\local` directory.

After installation, the directories you have created and unpacked the ZIP archives in will contain the following files. 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. Finally, some files with the extension `.jpg` can be found and constitute the graphic files (buttons and logo) used by FREQID.

2.4 Getting started

If the installation of FREQID has been completed successfully, MATLAB should be (re)started. 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 window depicted in Figure 1 to be displayed on the desktop of your computer.

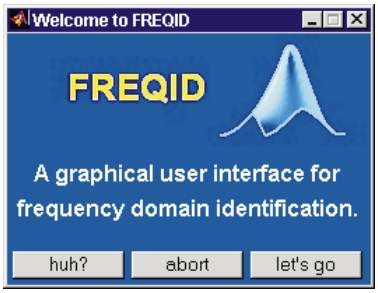

Figure 1: Welcome window of FREQID.

A click on the help-button[3] will yield some more 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 let's go-button, the actual GUI 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 let's go-button, the main window of FREQID depicted in Figure 2 will be opened. 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 of FREQID.
In order to explain the different components present in the main window of FREQID given in Figure 2, the main window will be divided in the following six parts:

[3] huh?

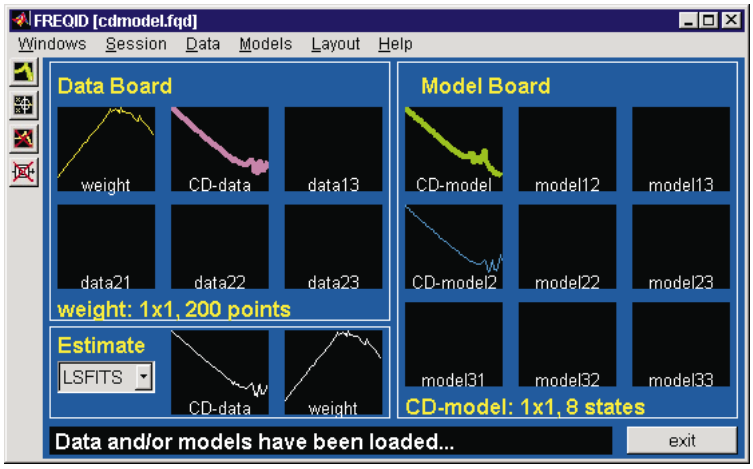

Figure 2: Main window of FREQID

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

2. At the left part of the window one can find the *toolbar*. The toolbar gives access to frequently used functions such as comparing frequency responses, pole/zero plots and deleting data or models. Moving the mouse over the buttons in the toolbar will display the tool tips.

3. At the left top part of the window one can find the Data Board. The Data Board is divided in *data icons* and they are used to store and manipulate frequency domain data and/or weights used for estimating a model. Data can be selected by clicking on a (non empty) data icon. Data can be copied by a drag and drop operation of the icons.

4. The right part of the window covers the Model Board. Similar to the Data Board, the *model icons* are used to store and manipulate models. Models can be selected by clicking on a (non empty) model icon. A model can be copied by a drag and drop operation.

5. The left bottom part of the main window is reserved for Estimation Board. This is used to store the actual estimation data, weighting functions and to start up the different estimation routines. Data and or weighting functions can be copied here from the data board.

6. 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 `cdmodel.fqd` was loaded.

A more detailed discussion of the operation of the GUI of FREQID is done by presenting the functionality of some of the elements mentioned above.

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 Windows on the menu bar allows you to switch between different windows of FREQID, once they are opened. This menu option also allows you to print out a window of FREQID. The Windows|Print menu bar utility is also found in other windows of FREQID and is especially useful to print out frequency domain plots without the 'uicontrols' such as buttons and popup-menu's. Invoking the Windows|Print menu option for the main window of FREQID will just dump the main window onto the local default printer.

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 `cdmodel.fqd` has just been loaded.

The Data and Models options on the menu bar are used to import and delete frequency domain data or models. Data or models that are being imported from a file or the MATLAB workspace are stored on the data or model boards. Deleting data or models will delete all data or models that currently have been selected. For more information on selecting data or models, see Section 3.4.2 and Section 3.5.2. Both the Data and the Menu option have an Example option to illustrate how a data or a model can be imported.

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.

Finally, the Help option will give some more information on FREQID and enables you to toggle the appearance of the tool tips on the toolbar of the main FREQID window.

3.3 The toolbar

On the left hand side of the main FREQID window you will find a toolbar. The toolbar gives access to frequently used functions such as comparing frequency responses, pole/zero plots and deleting data or models. Moving the mouse over the buttons in the toolbar will display the functionality of the buttons in the toolbar by displaying the tool tips. The tool tips can be turned on and off by selecting the Help|Tooltips option on the menu bar.

3.3.1 Predefined buttons

The toolbar of FREQID comes with four predefined buttons. A simple mouse click on one of the buttons will invoke the following actions.


Frequency domain plots
This button will popup an interactive frequency domain window that allows you to evaluate the complex or frequency domain data that is either stored at the Data Board or generated by the models on the Model Board. Only those data and models that have been selected, see also Section 3.4.2 and Section 3.5.2, will be plotted in the frequency domain window.


Pole/zero plots
This button will popup an interactive pole/zero window that allows you to evaluate the location of the poles and zeros of the models stored on the Model Board. Only those models that have been selected, see also Section 3.4.2, will be plotted in the frequency domain window.


Delete selected data
This button will delete all data that has been selected on the Data Board.


Delete selected models
This button will delete all models that has been selected on the Model Board.

3.3.2 Adding your own buttons

Next to these four predefined buttons, additional tools or buttons can be added to the toolbar. FREQID is equipped with a MATLAB function file called `cf_tlbar` that allows you to add buttons to the toolbar of FREQID. More information on customizing and adding items to the FREQID graphical user interface can be found in Section 5.2.

3.4 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 accessible before starting up FREQID, so that it can be imported on the Data Board of FREQID.

The Data Board is divided into *data icons* and they are used to store and manipulate frequency domain data and/or frequency domain weights used for estimating a model. For this purposes, specific actions such data import, export and mouse functions (clicking, drag and drop) are defined within the Data Board. Below is a summary of these possibilities.

3.4.1 Importing 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 Data|Import option on the menu bar, yielding the window depicted in Figure 3.

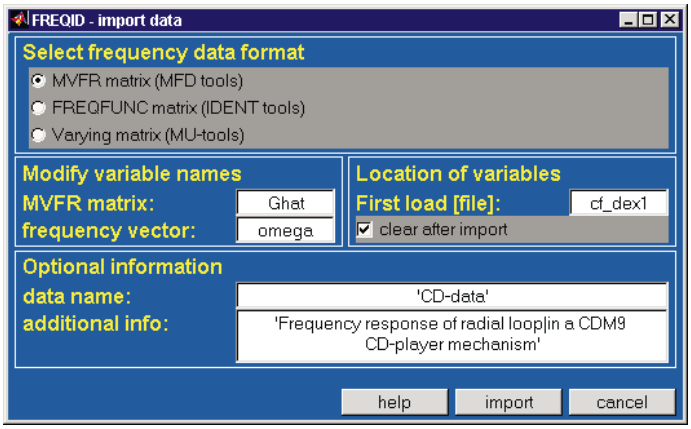

Figure 3: Import data window.

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 corresponding frequency vector (in [rad/s]), 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 after import 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 be cleared from the workspace after import. Furthermore, the name and additional information on the data have been specified.

3.4.2 Mouse actions: select, copy and data editing

Once the data has been loaded successfully, it will appear in one of the icons present in the Data Board by plotting the Bode amplitude plot of the first element of the (multivariable) frequency domain data. Once the data is imported, it can be selected simply by clicking on the corresponding icon in the Data Board. If the data has been selected, the thickness of the line of the Bode plot is increased. An other click on the data icon will again deselect the data.

Data can also be copied to other data icons by a simple drag and drop mouse action. Push the mouse button on the data icon 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 icon 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.

The data and the information on data can also be edited by simple mouse click. By (de)selecting the data, some information is already displayed at the status line of the Data Board. Additionally, clicking on the name of the data in a data icon will open a dialog box that allows the data to be edited or exported.

3.4.3 Editing data

Data on the data board can be edited by clicking on the name of the data in the corresponding data icon. This will yield a dialog box with an edit button that will open the edit data window depicted in Figure 4.

Within the window depicted in Figure 4, 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

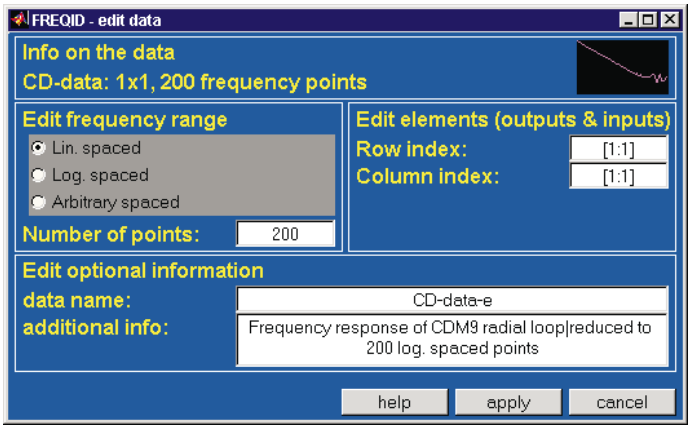

Figure 4: Edit data window.

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, `-e` is added to the name of the data to indicate it has been edited.

3.4.4 Exporting data

Data on the data board can be exported by clicking on the name of the data in the corresponding data icon. This will yield a dialog box with an export button that will open the export data window depicted in Figure 5.

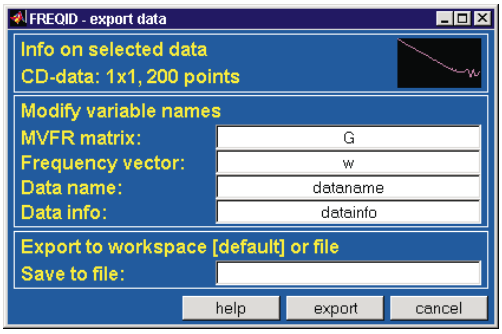

Figure 5: Export data window.

The data can only be exported in the MVFR format (see Section 3.4.1) 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) should be specified under Modify variable names. Default, the variables are assumed to be saved to the MATLAB workspace (memory used by MATLAB). If not, the name of a MATLAB `.mat` file can be specified.

3.4.5 Deleting data

Only a finite number of data icons 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.

Deleting data is fairly straightforward. First, (de)select all the data that you would like to have removed from the Data Board, see also Section 3.4.2. Then click on the delete selected data button on the toolbar or choose the Data|Delete on the menu bar. A dialog window will popup to confirm your delete. Note that once the data has been deleted it cannot be recovered. Hence, it is recommended to save your data (and models) in a session, see Section 3.2, before deleting.

3.5 Model board

The Model Board is used to store and validate models estimated on the basis of the frequency domain data. Quite similar to the Data Board discussed in Section 3.4, the Model Board has been equipped with *model icons* that store the actual models. Specific actions such model import, export and mouse functions (clicking, drag and drop) can be used to maniplate the models on the Model Board. For reasons of completeness, a summary of these possibilities within the Model Board are listed below.

3.5.1 Importing models

Basically, there are three possibilities to store a model under a model icon on the Model Board. The first possibility is to load a FREQID session, as previously discussed in Section 3.2. The second possibility is to actually estimate a model on the basis of a frequency domain data, which is discussed in Section 4. The last possibility is to use the Models|Import option on the menu bar, yielding 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 and in this format 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.

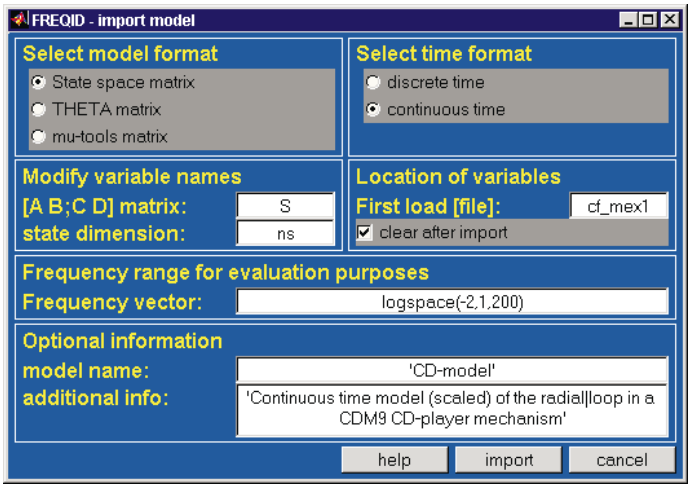

Figure 6: Import model window.

- 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 responses, 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 seconds) 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 after import 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 MATLAB command that will be evaluated by MATLAB once the frequency response is being computed.

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 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.

3.5.2 Mouse actions: select, copy and model editing

The mouse actions on the Model Board are similar to the ones defined on the Data Board. Once a model has been imported on the Model Board successfully, it will appear in one of the icons present in the Model Board by plotting the Bode amplitude plot of the first element of the (multivariable) model. Once the model is imported, it can be selected simply by clicking on the corresponding icon in the Model Board. If the model has been selected, the thickness of the line of the Bode plot is increased. An other click on the model icon will again deselect the model.

A model can also be copied to other model icons by a simple drag and drop mouse action. Push the mouse button on the model icon 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 icon and release the mouse button: the model will be copied. Moving model is possible by first copying the model and deleting the original one afterwards.

The model and any information on the model can also be edited by simple mouse click. By (de)selecting the model, some information is already displayed at the status line of the Model Board. Additionally, clicking on the name of the model in a model icon will open a dialog box that allows the model to be edited or exported.

3.5.3 Editing a model

Models on the model board can be edited by clicking on the name of the model in the corresponding model icon. This will yield a dialog box with an edit button that will open the edit model window depicted in Figure 7.

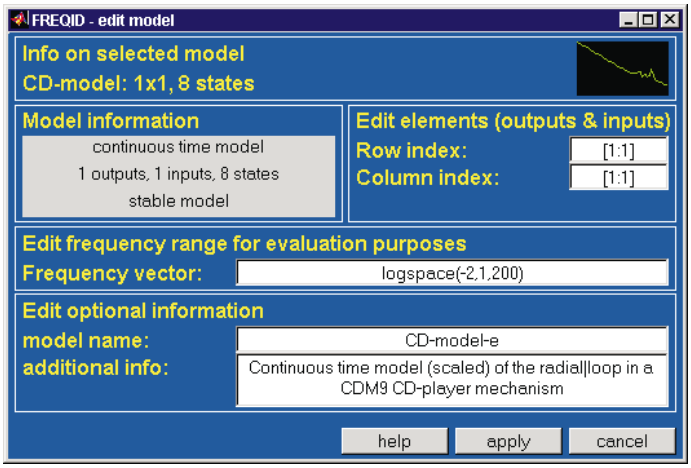

Figure 7: Edit model window.

Within the window depicted in Figure 7, 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 [rad/s]) must be a MATLAB command that will be evaluated by MATLAB once the frequency response is being computed.

Additionally, in the case of a multivariable 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, `-e` is added to the name of the model to indicate it has been edited.

3.5.4 Exporting a model

Data on the data board can be exported by clicking on the name of the data in the corresponding data icon. This will yield a dialog box with an export button that will open the export data window depicted in Figure 8.

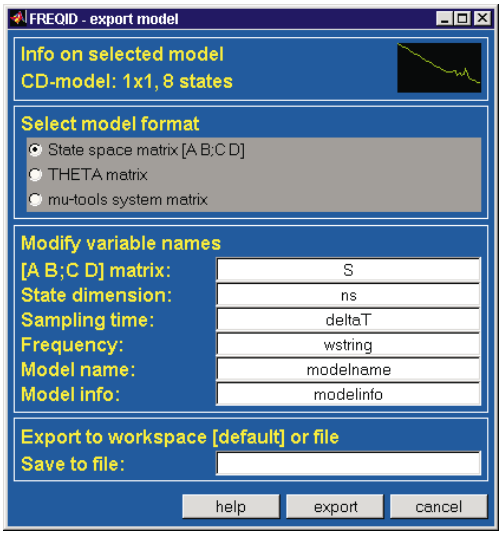

Figure 8: Export model window.

The selected model can be exported in various formats, see also Section 3.5.1. 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, the name of a MATLAB `.mat` file can be specified.

3.5.5 Deleting models

Only a finite number of model icons are available on the Model Board to store models for evaluation purposes. To clear up space on the Model Board it is also possible to delete models from the Model Board.

Deleting models is fairly straightforward. First, (de)select all the models that you would like to have removed from the Model Board, see also Section 3.5.2. Then click on the delete selected models button on the toolbar or choose the Data|Delete on the menu bar. A dialog window will popup to confirm your delete. Note that once models have been deleted, they cannot be recovered. Hence, it is recommended to save your models (and data) in a session, see Section 3.2, before deleting.

3.6 Estimation board

An important interface of the main window of FREQID is the Estimation Board that is used to store the frequency domain data and weighting functions to be used for estimation purposes. The icons in the Estimation Board can be filled with data by simply copying data from the Data Board onto the estimation icons.

It should be noted that once data is copied onto the estimation or weighting icons, it is is treated separately from the data on the Data Board. For example, the estimation and weighting data cannot be selected for viewing or deleting purposes. The data on the estimation and weighting icons are merely used as a storage location for the data used in the frequency domain identification of models in FREQID.

The different estimation routines that are supported in the current distribution of FREQID can be found under the estimation popup menu located in the Estimation Board. The estimation popup menu can be modified to include additional estimation routines. More information on this item and how to customize FREQID can be found in Section 5.3.

4 Obtaining models

4.1 Estimation methods

The estimation of models in FREQID is done by fitting a (linear time invariant) model on the frequency data loaded on the Estimation Board of the main FREQID window. There is a wide variety of methods available for fitting frequency domain data. Methods can be based on interpolation algorithms, curve fitting algorithms or realization and subspace algorithms. Depending on the nature and the computational implementation of the frequency domain identification algorithm, optimality properties, optimization parameters, frequency dependent weighting functions and/or the estimation of multivariable models can be taken into account.

In the current distribution of FREQID, only estimation routines based on curve fitting with a least

squares criterion have been implemented. These estimation routines are widely used and FREQID provides a user friendly interface to these estimation routines. However, in future distributions of FREQID the implementation of additional estimation routines is planned. Alternative curve fitting routines, using a maximum amplitude criterion (Hakvoort and Van den Hof 1994) or powerful frequency domain subspace methods (McKelvey *et al.* 1996) are expected to be implemented in a future version. One is referred to Section 5.3 on how to include additional estimation routines.

Depending on the parametrization of the model, a curve fitting generally involves a non-linear optimization that needs to be solved. An interface to the optimization and estimation routines supported by FREQID can be found by invoking the estimation-popup menu present in the Estimation Board of FREQID. A short summary of the two least squares estimation routines is listed below.

- The first least squares curve fitting routine that is supported by FREQID is called INVFREQ (INVerse FREQuency response computation) which provides an interface to the standard MATLAB functions `invfreqz` and `invfreqs`. These functions can be found in the MATLAB SIGNAL-toolbox (Smith *et al.* 1998) and provide a utility for the least squares curve fitting of SISO (Single Input Single Output) models that aims at minimizing a (weighted) 2-norm between the data and the frequency response of the model.

- The second least-squares estimation routine implemented in FREQID is called LSFITS (Least Squares curve FITing with Schur weighting) and is a multivariable extension of the so-called Sanathanan-Koerner iteration (Sanathanan and Koerner 1963). The multivariable weighting can be specified for each transfer function separately using a Schur product. 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).

With the curve fitting procedures, there is no guarantee for the iteration or optimization routines to converge in case poles are estimated in the (multivariable) model. However, the curve fitting routines work in most situations and they are reasonably fast.

To illustrate the operation of the FREQID GUI, this manual will describe the GUI associated to the LSFITS least squares estimation method. A similar GUI is found for the INVFREQ estimation method supported by FREQID.

4.2 LSFITS estimation

Once a data box has been copied onto the estimation data board, invoking the LSFITS option from the estimation-popup menu will present the LSFITS estimation window on your screen. An overview of this window is depicted in Figure 9.

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

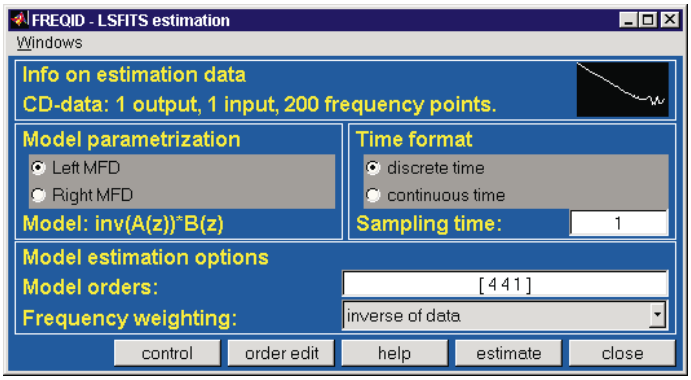

Figure 9: LSFITS estimation window

(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 section.

4.2.1 Starting up the estimation

Parametrization

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 $A^{-1}(z)B(z)$ (option left MFD) or a right MFD $B(z)A^{-1}(z)$ (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. Referring to Figure 9, the corresponding equation appears at the bottom of the Model parametrization. For a scalar system, both parametrizations are the same and reflect an ordinary numerator/denominator parametrization.

Time format

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 seconds) needs to be specified. The corresponding sampling frequency (inverse of sampling time) should be at least twice as large as the maximum frequency (in Hertz) of the data selected for estimation purposes. If you like to estimate a model with a larger sampling time, you need to eliminate data at high frequency points by the editing the data, see Section 3.4.3.

Model order and parameters

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.

Weighting

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 choices include none, advanced or weighting data. Choosing the weighting to be none results in a unit weighting to minimize an unweighted, absolute curve fit error. Choosing the weighting to be advanced enables you to edit a frequency domain weighting relatively easily. One is referred to Section 4.2.5 for a more detailed discussion on the usage of advanced weightings. Finally, the weighting data option uses the weighting data on the Estimation Board as a weighting during the curve fitting process.

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 (multivariable) 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

Once the minimization is finished, the LSFITS estimation window modifies in the window depicted in Figure 10.

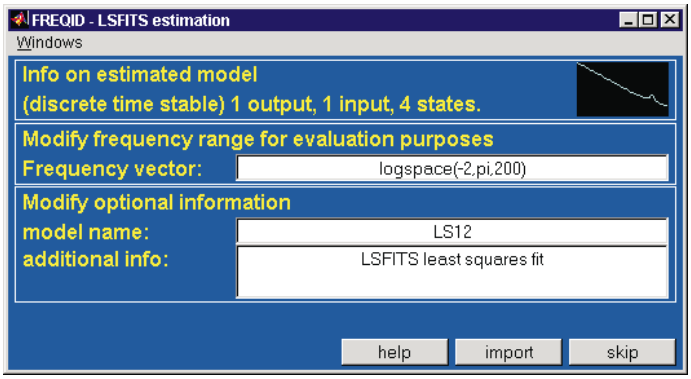

Figure 10: LSFITS estimation window after estimation

The LSFITS 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 successfully, 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 additional information on the model. The default values for these options are depicted in Figure 10.

4.2.3 Help on order edit

To facilitate the specification of the number of parameters to be estimated, the LSFITS 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.

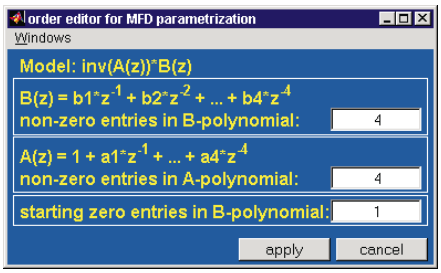

Figure 11: Order editor for MFD parametrization in LSFITS estimation

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 LSFITS estimation window.

4.2.4 Controlling the iteration

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

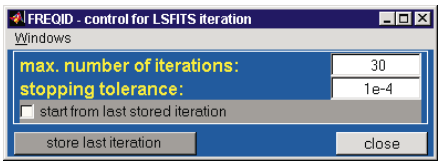

Figure 12: Control for iteration

The control for LSFITS 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 LSFITS iteration window can be used to start from a previously estimated model. The store last iteration-button enables you you store the last computed model (actually: 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 helpful 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.

It should be noted that the control for LSFITS iteration window should not be closed in order to use different optimization parameters. Once the window is closed, the default values for the maximum number of iterations and the tolerance for the iteration are used.

4.2.5 Making an advanced weighting

The LSFITS estimation routine enables you to use and edit an 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 LSFITS estimation window, the weighting window depicted in Figure 13 will be opened. the weighting window can also be opened independently from the LSFITS estimation window by clicking on the name of the weighting data on the Estimation Board and selecting the edit button in the dialog box.

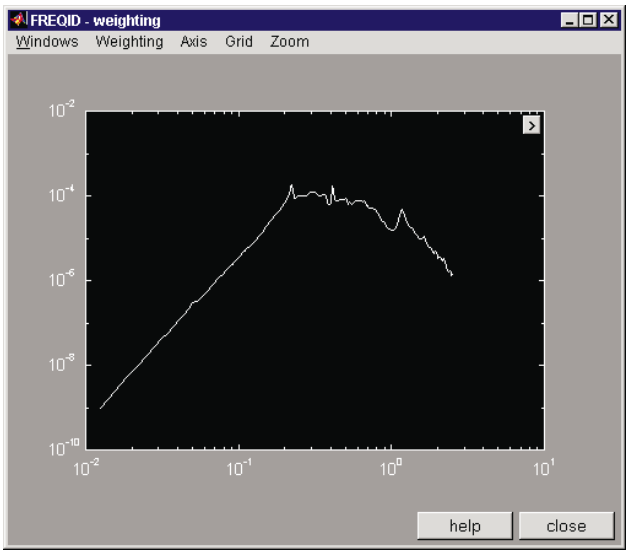

Figure 13: Weighting window for estimation

In case weighting data was uploaded onto the Estimation Board, the weighting data will display

the weighting data. If no weighting data was present on the Estimation Board, the inverse of the estimation data is used as a starting point for the specification of an advanced weighting. Additionally, the menu bar of the weighting window can be used to import and export weightings *via* the weighting data icon on the Estimation Board of FREQID. The menu bar of the weighting window also allow you to change the axis and toggle zooming and the grid.

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.

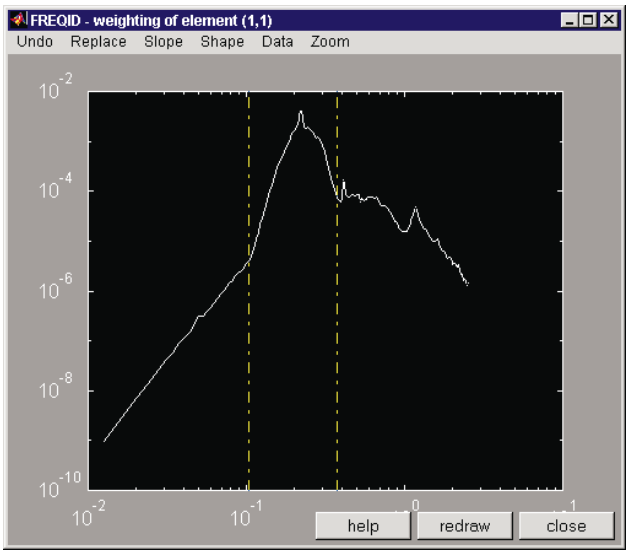

Figure 14: Editable weighting per element

The vertical dashed-dotted lines in Figure 14 are used to select the frequency range to be edited 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 vertical dash-dotted lines can be inverted and smoothed (Replace menu bar option) or integrated and differentiated (Slope menu bar option). 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 drag and drop action can be influenced by the different options available under the Shape option on the menu bar. One is referred to the different options on the menu bar, where the Undo option can be used to restore the previous weighting.

Finally, the corresponding element of the estimation data on which the current weight is going to be applied can also be plotted 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.

5 Customizing FREQID

5.1 Changing colors and layout

The layout (size and position) and the color of the FREQID windows can be changed and saved for future sessions of FREQID. Layout can be changed within the GUI of FREQID by invoking the Layout menu bar option in the main FREQID window. Under this menu bar you will the option to change the colors of the main window and all the data and model icons. The colors will also be used in most of the other windows in FREQID. Choosing the Layout|Save menu bar option will allow you to save the colors, position or both (layout) in a file called `cf_perfs.mat`. Every time FREQID starts up it will look for `cf_perfs.mat` along the `matlabpath` to reload your settings. You can delete the `cf_prefs.mat` file to return to the default settings.

5.2 Modifying the toolbar

Next to the four predefined buttons on the toolbar of FREQID discussed in Section 3.3, additional tools or buttons can be added to the toolbar. FREQID is equipped with a MATLAB function file called `cf_tlbar` that allows you to add buttons to the toolbar of FREQID.

In order to invoke `cf_tlbar` you need a picture or graphic file of your button (both an "up" and "down" button). FREQID comes with two standard empty up and down button in JPEG format. They can be found under `buttnup.jpg` and `buttndnw.jpg` in the main FREQID installation directory. You can copy them and edit them for your own toolbar design purposes. Type `help cf_tlbar` for more information.

5.3 Adding additional estimation routines

FREQID is basically distributed as open source code and the GUI of FREQID can be interfaced with additional estimation routines other than the INVFREQ and LSFITS that are currently implemented. To simplify the process of adding estimation routines, the following suggestions are given here.

- Edit and FREQID function `cf_e_pp.m` to modify the estimation popup menu in the Estimation Board of FREQID.
- Edit and update the FREQID function `freqidsp.m` to include a new estimation routine in the MATLAB search path for FREQID.
- Use the FREQID GUI functions associated to the LSFITS or the INVFREQ estimation routines as a template for including your estimation routine. The GUI for the LSFITS routine can be found in the `cf_ls_*.m` files. The GUI for the INVFREQ routine can be found in the `cf_if_*.m` files.

- Copy your GUI development in the main FREQID directory. The stand alone files for your estimation routine should be placed under a separate directory to distinguish the stand alone files with the GUI of FREQID.

For more info, one is also referred to the `contents.m` file located in the main FREQID directory.

6 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 author. An email address can be found on the front page of this manual or under the Help|About menu bar option under the main window of FREQID. Have fun with FREQID!

References

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