g.tec – medical engineering GmbH
Sierningstrasse 14, A-4521 Schiedlberg
Austria - Europe
Tel.: (43)-7251-22240-0
Fax: (43)-7251-22240-39
office@gtec.at, http://www.gtec.at

SSVEP BCI V2.12.01

g.USBamp and g.MOBIlab+ are biosignal acquisition systems for EEG, ECG, EMG, EOG and other sensors. In this tutorial the usage of the devices for a SSVEP BCI will be shown. For the proper working of the device also g.STIMbox and g.SSVEPbox are necessary. The Simulink Highspeed On-line Processing blockset allows to read in data into Simulink in real-time and to perform the parameter estimation and classification. No additional compilation of the Simulink model is required for the on-line processing.

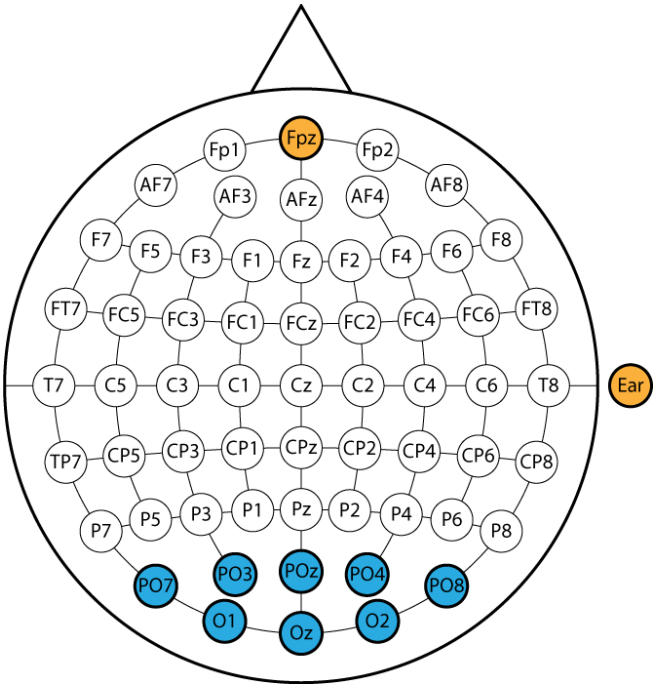
PREPARATION

Before start there are a few important things to check:

- The g.USBamp or g.MOBIlab+ must be connected to the computer and switched on
- g.GAMMAbox must be connected and switched on
- The g.STIMbox and the g.SSVEPbox must be connected to the computer
- Make sure that the COM ports for all devices are set correctly (see gSTIMbox Help).

APPLYING THE ELECTRODES

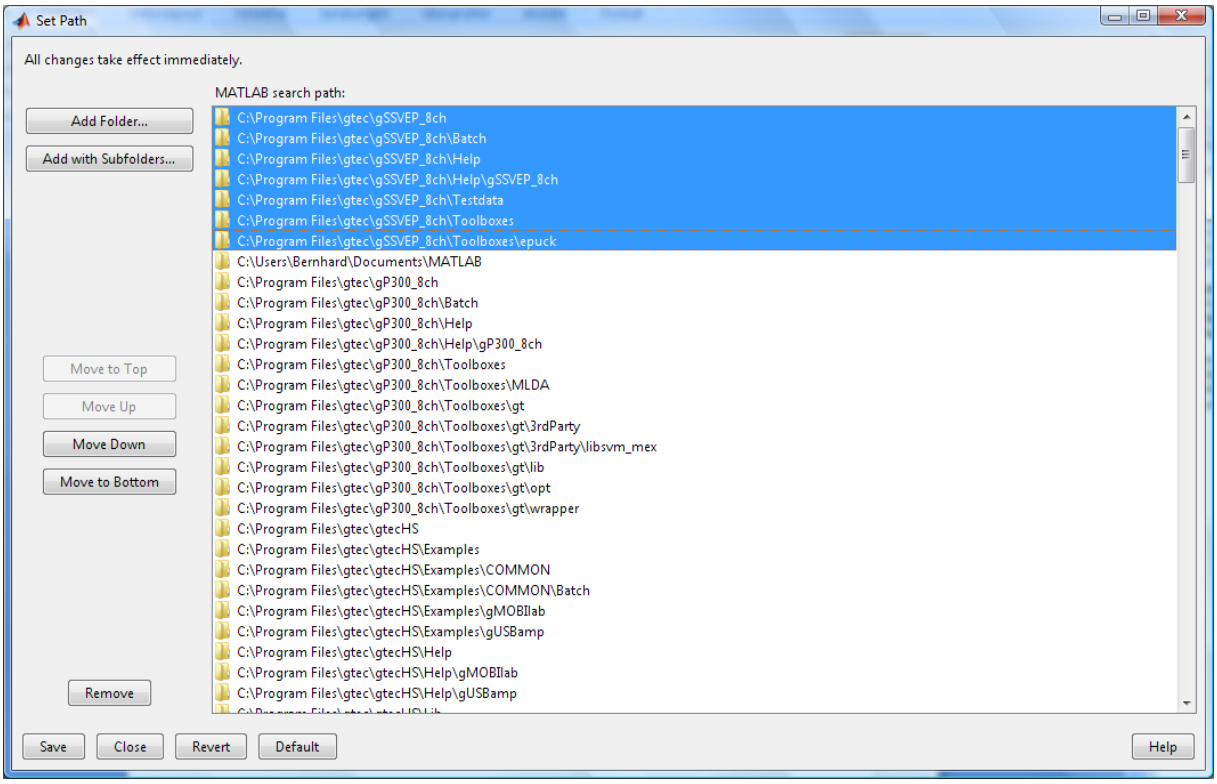
Apply the electrodes to the positions depicted below. Make sure that they are connected to the g.GAMMAbox in the right order. The following figure lists the correct configuration.



Position	Channel number
PO7	1
PO3	2
POz	3
PO4	4
PO8	5
O1	6
Oz	7
O2	8
Fpz	GND
Right Earlobe	Ref

INSTALLATION

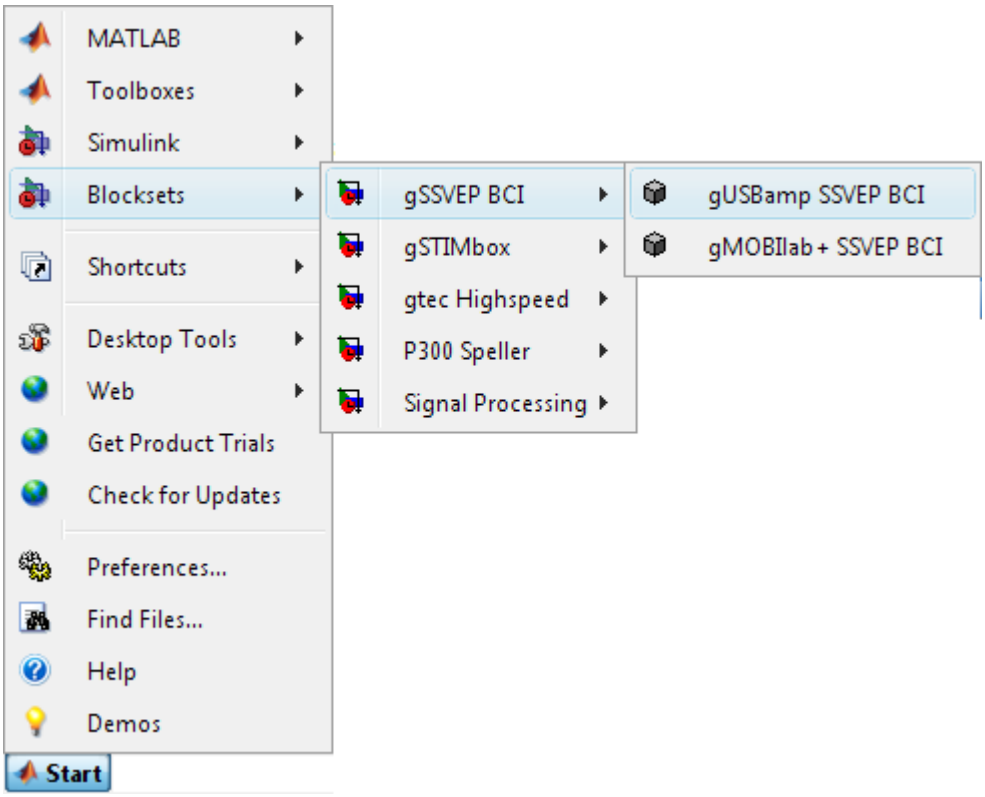
Copy the directory **gSSVEP_8ch** to your local hard disc. You have to manually set the path for MATLAB by selecting **Set Path** in the **File** menu. Click the **Add with Subfolders** button, and select the directory
`Your Installation path:\gSSVEP_8ch\`



Click **Save** and **Close** to finish the path settings.

START-UP

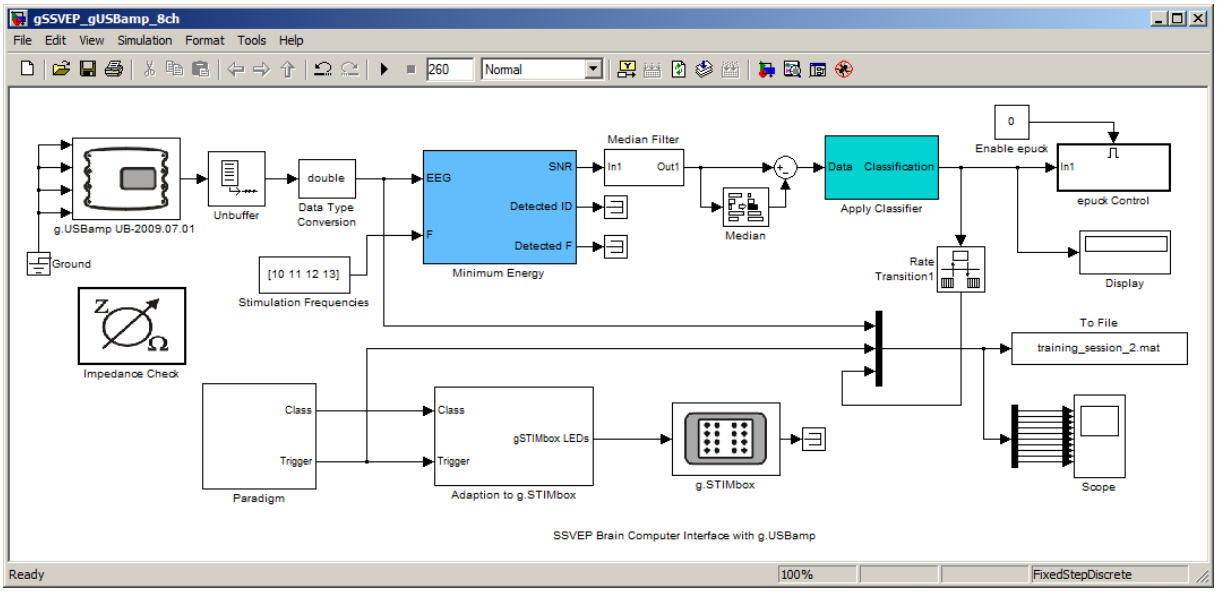
The corresponding Simulink models can be started from the MATLAB **Start** button



or by typing the name of the Simulink model into the MATLAB command line.

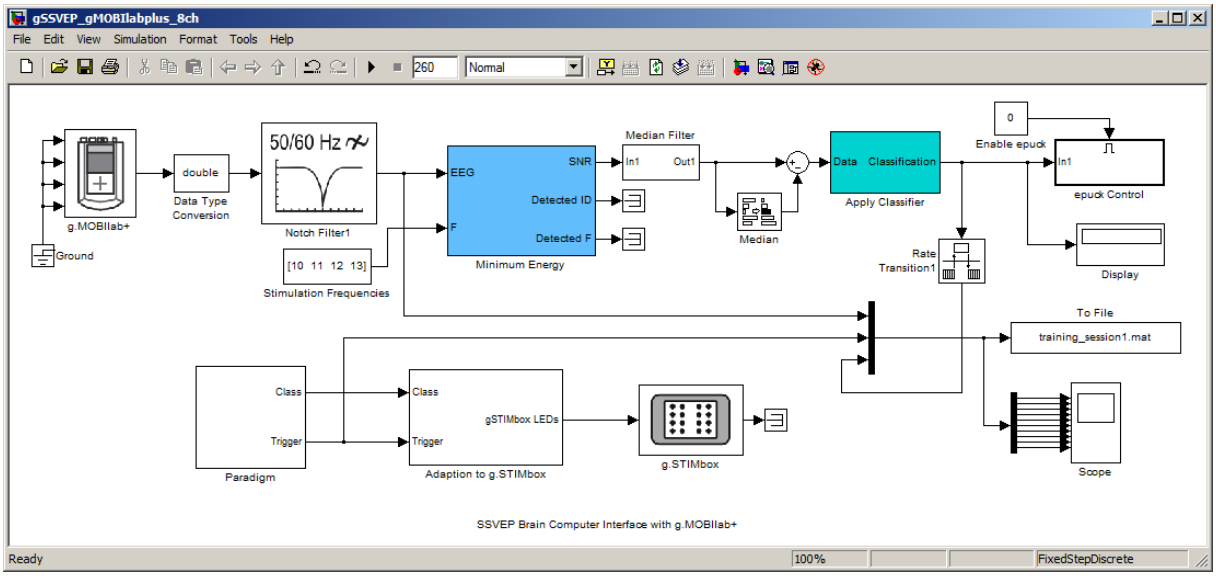
To start the g.USBamp SSVEP model type `gSSVEP_gUSBamp_8ch` into the MATLAB command line.

The following Simulink model opens:



To start the g.MOBIlab+ SSVEP model type `gSSVEP_gMOBIlabplus_8ch` into the MATLAB command line.

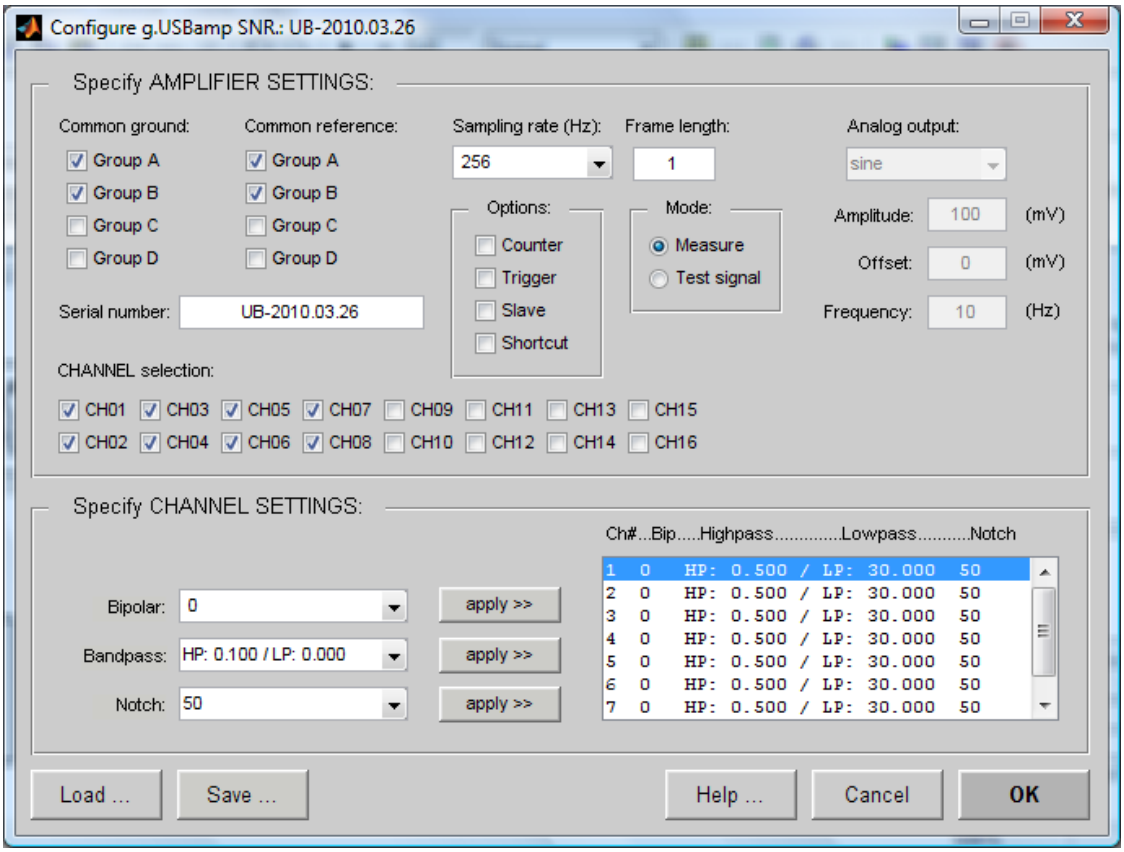
In that case this Simulink model opens:



DRIVER CONFIGURATION

g.USBamp

Double click on the **g.USBamp** block to open the following window:



Enter the serial number of your g.USBamp, select a **Sampling rate** of `256` Hz and a **Frame length** of `1`. Then select channels `CH01-CH08`, set **Common ground** and **Common reference** for **Group A** and **Group B**. Apply a **Bandpass** filter with lower-cut-off frequency of 0.5Hz and upper-cut-off frequency of 30Hz and a 50Hz **Notch** filter.

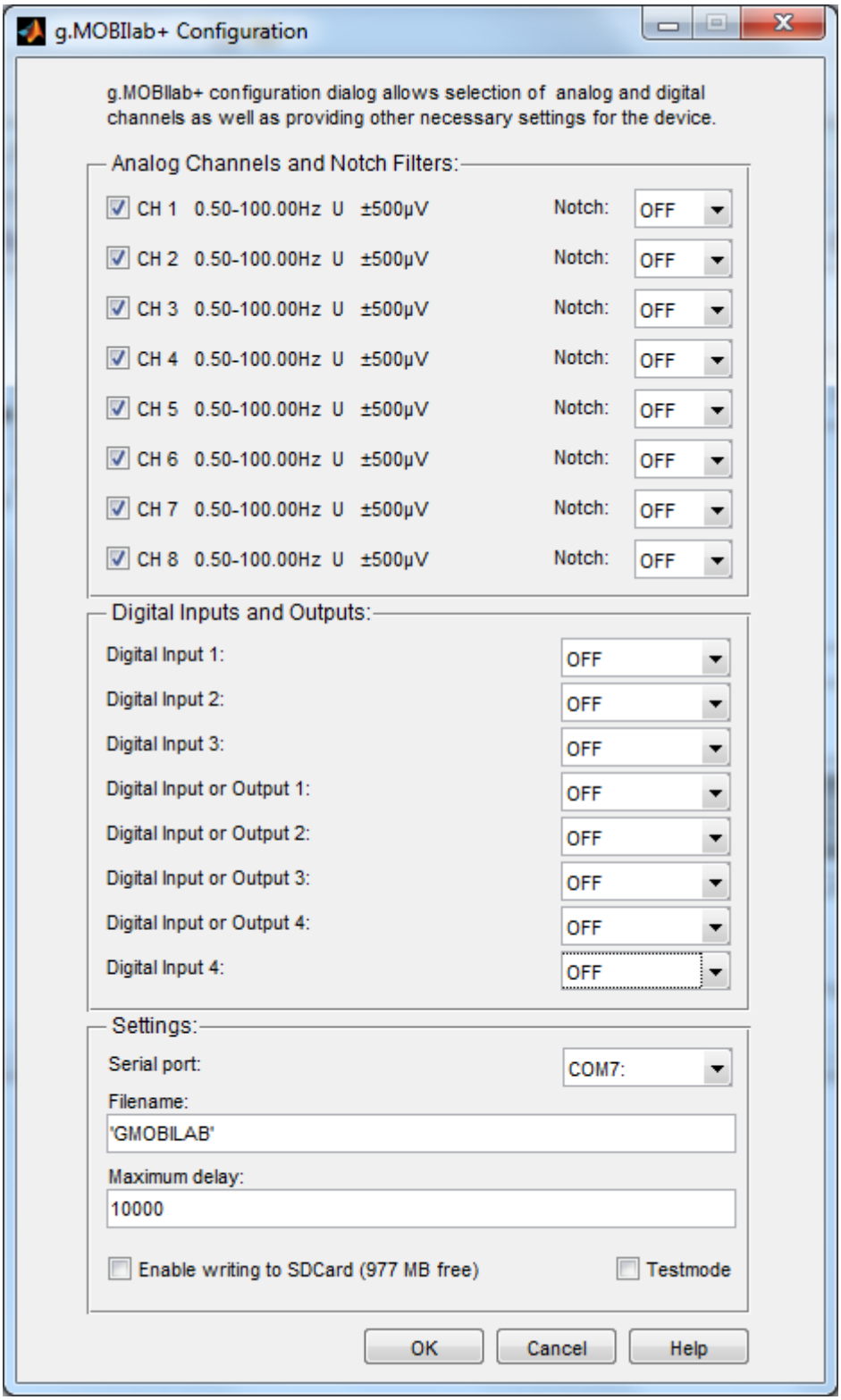
Now g.USBamp is correctly initialized.

Save the settings by clicking on the **Save …** button and enter a filename to store the settings.

Press **OK** to accept the settings and to close the window.

g.MOBIlab+

Double click on the **g.MOBIlab+** block to open the following window:



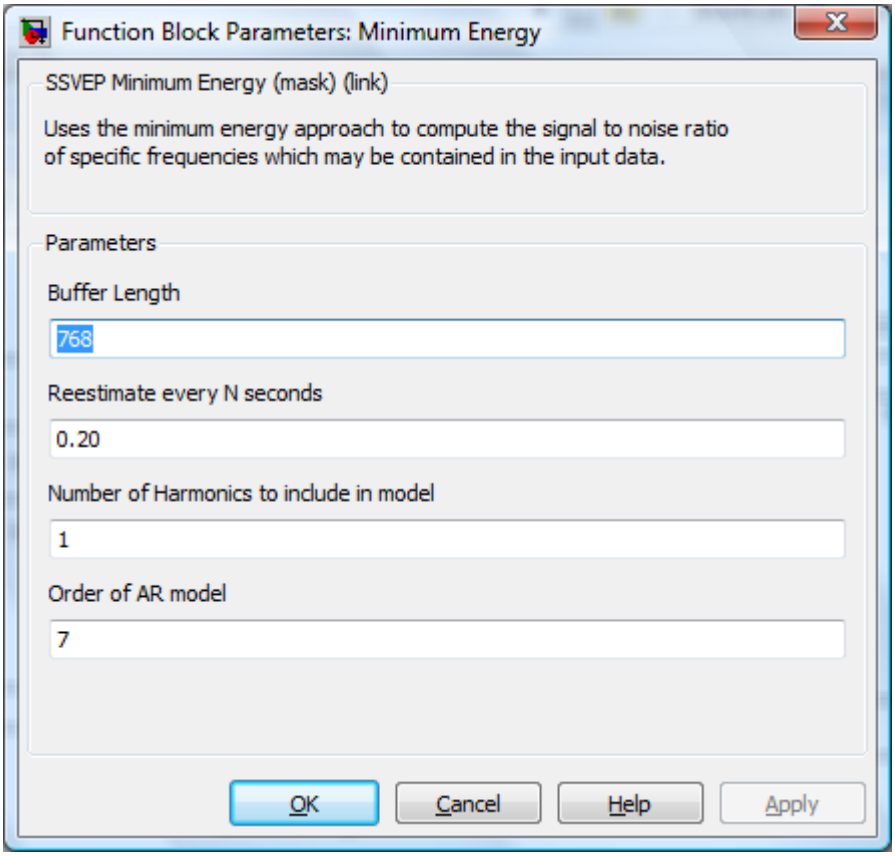
Select **CH 1-8**, set the **Digital Channel 1-8** parameters to `OFF` and select the **COM Port** where your amplifier is connected to the PC.

Press **OK** to accept the settings and to close the window.

MINIMUM ENERGY

The sampling frequency of g.USBamp is 256 Hz. It is connected to an **Unbuffer** block and **Data Type Conversion** block to work with data in double precision format. The data is passed to the **Minimum Energy** block to calculate the signal-to-noise ratio (SNR) for the frequencies, specified in the **Stimulation Frequencies** block, with respect to the base EEG-signal.

A double-click on the **Minimum Energy** block opens the following dialog:



Buffer Length is the number of used samples for estimating the SNR, the minimum is 128 samples. A buffer length between 512 and 1024 samples is recommended.
For the tutorial please enter 768 samples.

Reestimate every N seconds: Time period after which the SNR shall be reestimated, minimum is 0.1 seconds.
Enter 0.2 s, that is a re-estimation rate of 5Hz.

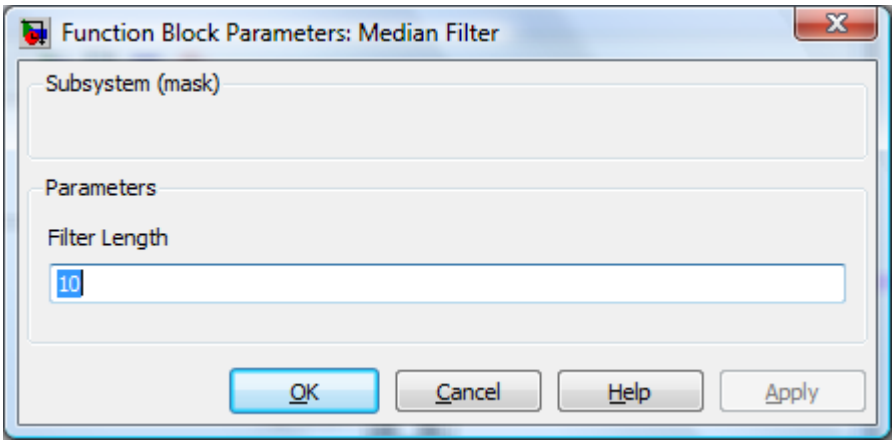
Number of Harmonics to include in model: The number of harmonics the Minimum Energy estimator shall consider when building the signal models for each frequency, minimum is 0. 1, which includes the first order harmonic is used within this tutorial.

Order of AR model: The minimum energy estimator uses the Levinson AR model to estimate the frequency spectrum of the signals. The order of the model is defined through this parameter. Minimum model order is 3. A model order between 5 and 7 is recommended.
Set the **Order of AR model** to 7.

MEDIAN FILTER

The **Moving Median** Filter smoothes the output signal of the **Minimum Energy** block by calculating the median of the data.

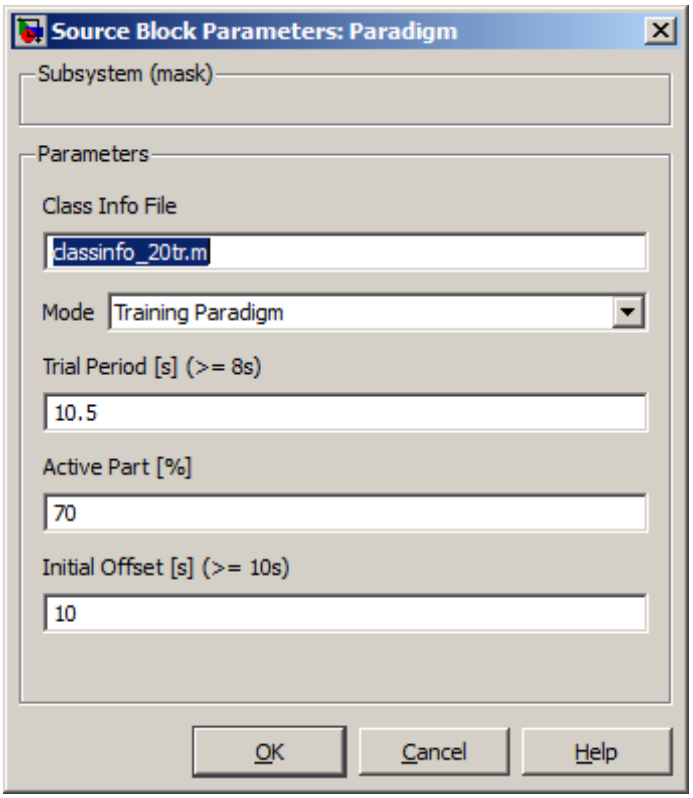
Double click on the **Median Filter** block to open the following window:



Filter Length: The number of samples which are used for calculating the median.
Set the **Filter Length** to `10`.

PARADIGM

Double click on the **Paradigm** block to open the following window:



Class Info File: Set the path of the Class Info File.

Mode:
The window allows selecting between three modes: (i) `Training Paradigm`, (ii) `Paradigm with feedback` and (iii) `Free running`.

Trial period defines the length of one trial in seconds. It should not be shorter than 8s

Active Part [%] defines the time duration the user has to concentrate on a LED during one single **trial period**. It is specified as percentage of the **trial period**.

Initial Offset defines the length before starting with the first trial in seconds. It should not be set to values less than 10s.

CLASSIFIER GENERATION

The SSVEP Device uses `Linear Discriminant Analysis` for feature classification. To use this signal processing algorithms you have to generate corresponding classifiers first.

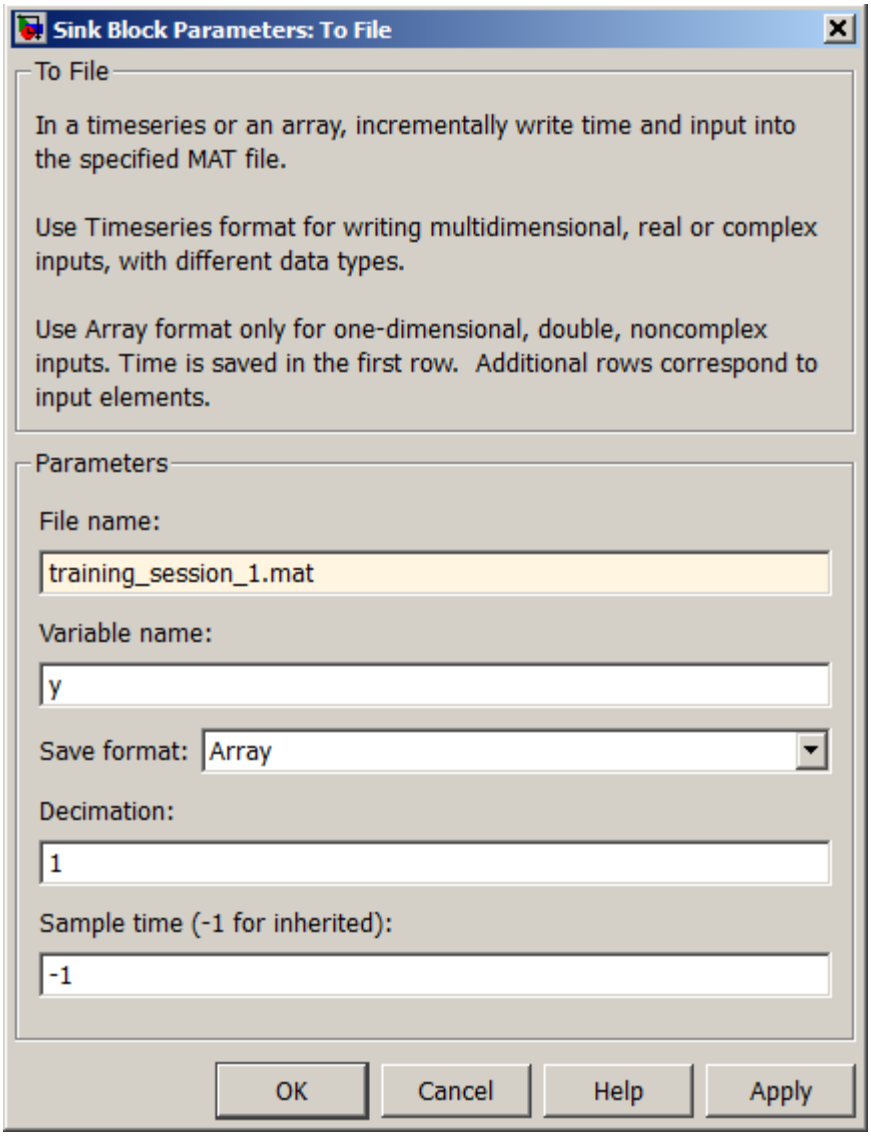
Double click the **Paradigm** block.

Enter `classinfo_20tr.m` as **Filename** and select `Training Paradigm` as **Mode**.

Set the **Trial Period** to `10.5` s, the **Active Part** to `70` % and the Initial Offset to `10` s.

Press **OK** to close the window.

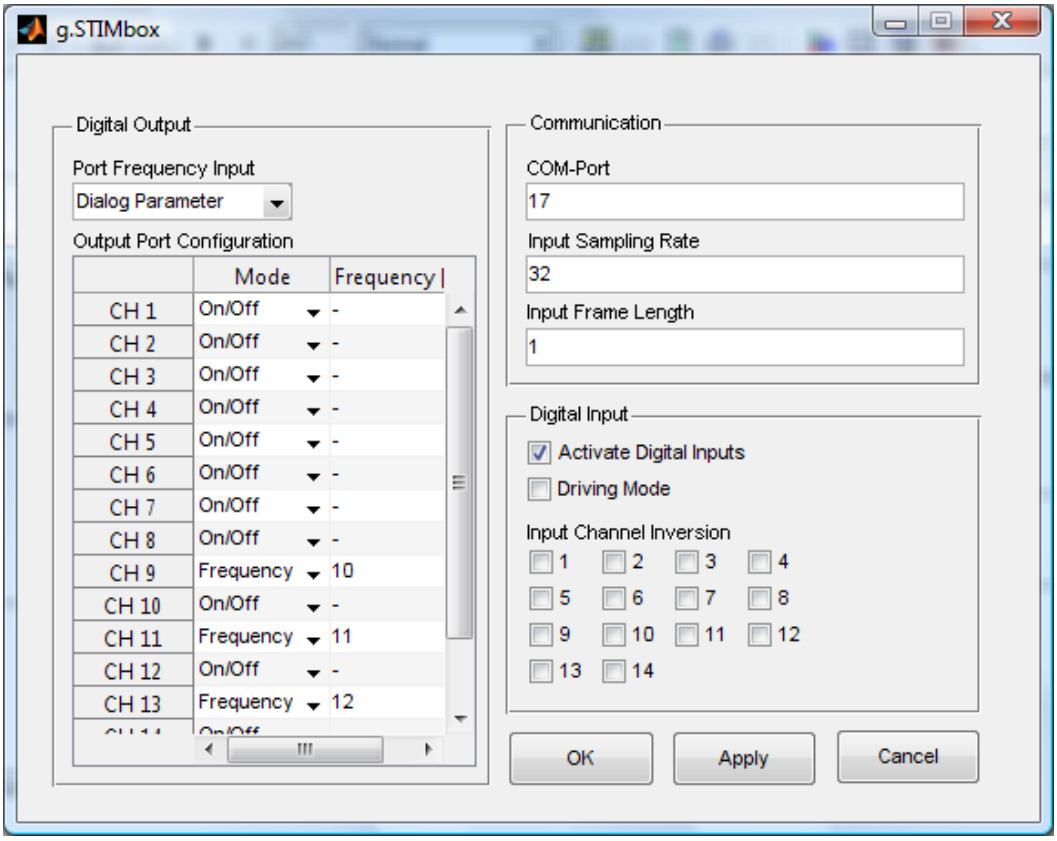
Then double-click onto the **To File** block:



Enter under **Filename** `training_session1.mat` and under **Variable Name** `y`. This stores the data into matrix y.

Press **OK** to close the window.

Double-click on the g.STIMbox **block to set the stimulation frequencies.**



Set the COM Port of the g.STIMbox correctly (see g.STIMbox Help).

Enter an **Input Sampling Rate** of `32` Hz and an **Input Frame Length** of `1`.

Change the Mode of CH 9, CH 11, CH 13, CH 15 to `Frequency` and enter the frequencies `10` Hz, `11` Hz, `12` Hz and `13` Hz (same as in the **Stimulation Frequencies** block).

Press **OK** to close the window.

Start the SSVEP model in the Simulink model menu.

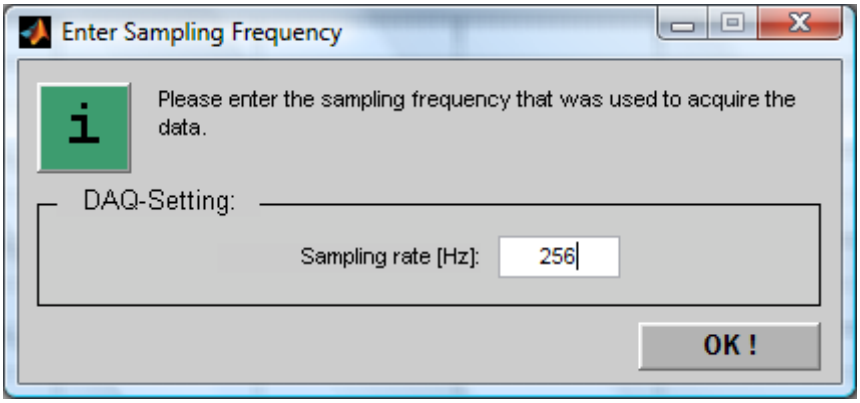
After the **Initial Offset** the LED will start flashing. Look at the left white LED. After the **Trial Period** the next LED will flash (clockwise). The current LED you have to concentrate on is marked with the green LED. Between two trials all green LEDs are lighting and the user has enough time to switch the focus to the next LED.

CLASSIFIER CALCULATION

1. Enter `gbsanalyze` on the MATLAB command line to start **g.BSanalyze**.

2. Select **Load Data** from the g.BSanalyze **File** menu and load the acquired data file `training_session1.mat`.

3. Enter a Sampling Rate of `256` Hz.

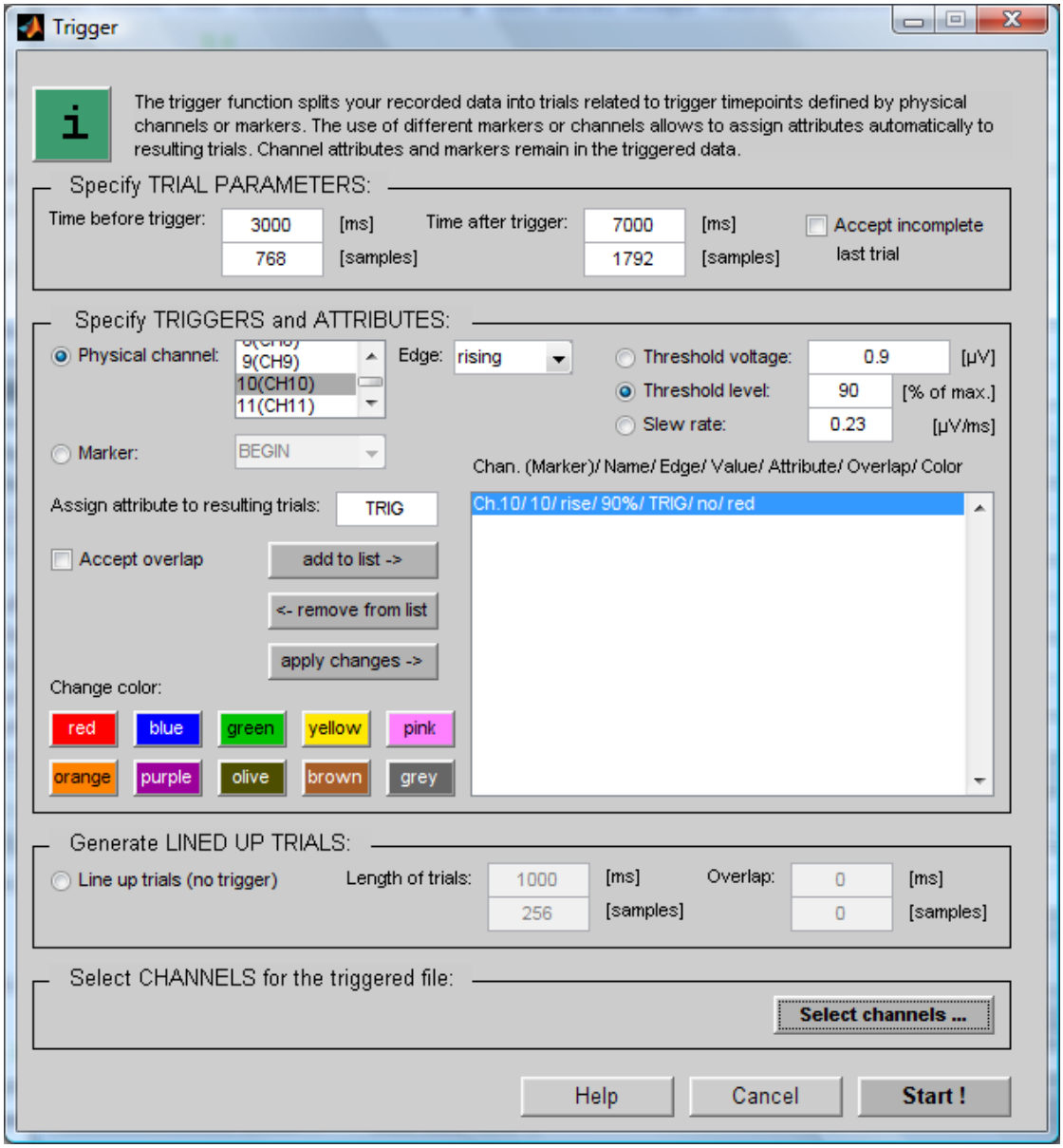


4. The first channel is a time step signal, channel 2 to 9 are the EEG-signals, channel 10 is the trigger signal and channel 11 shows the current classification result (`Paradigm with Feedback`).

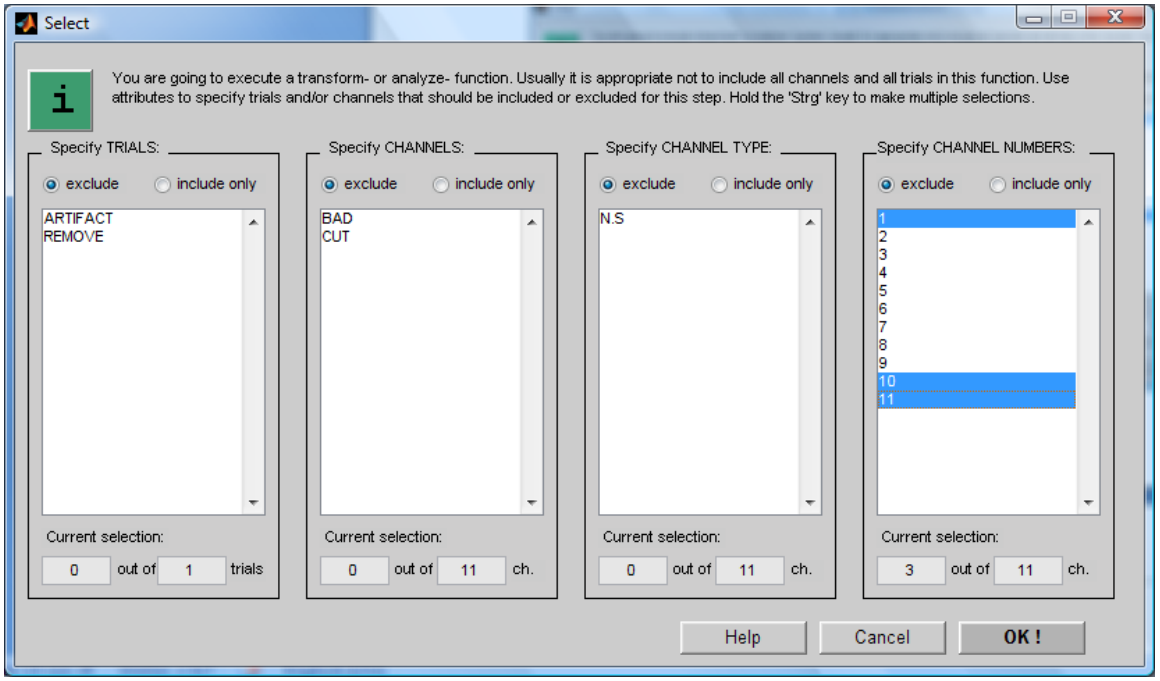
Trigger Data

5. To split the data-set into equal trials open the **Trigger** window under the **Transform** menu.

6. Set the **Time before trigger** to `3000` ms and the **Time after trigger** to `7000` ms. Select channel `10` as **Physical channel** for triggering and set the **Threshold level** to `90` % of maximum.
   Select e.g. the name `TRIG` in **Assign attribute to resulting trials** and press **button add to list ->**.



7. Press **Select channels …** and exclude CH 1, CH 10 and CH 11.



8. Press **Start!** to perform the triggering.

   The process results in 20 trials with a length of 10000ms each.

Load Class Information

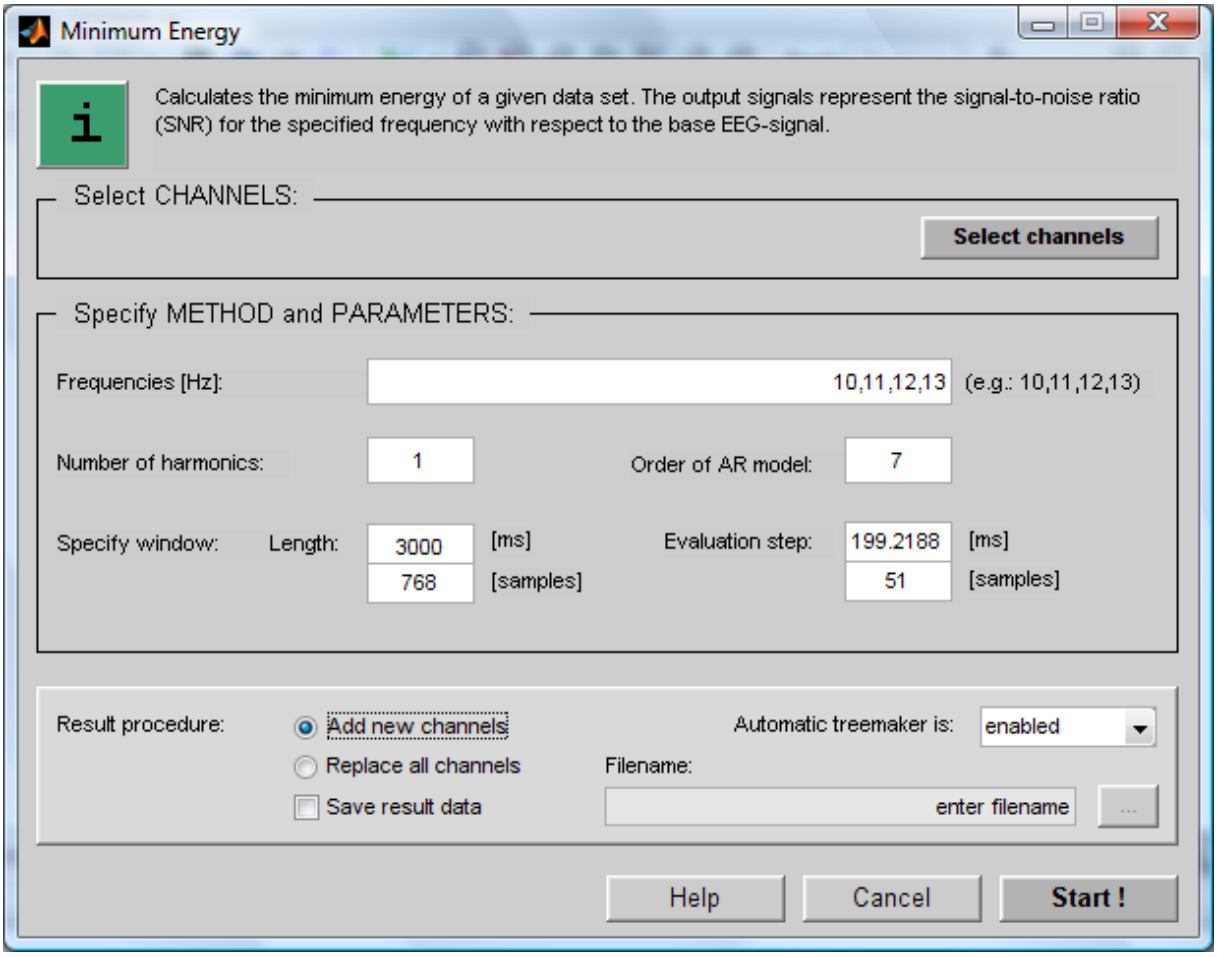
9. To assign class information to the 20 trials open **Load Class Information** of the **File** menu in the Data Editor. Click on the **Browse…** button and select the file `classinfo_20tr.m` from the following directory:

   `Your Installation path:\gSSVEP_8ch\`

10. Change the names of the attributes e.g. to 10Hz, 11Hz, 12Hz, 13Hz. Click **OK!**

Parameter Extraction - Minimum energy

11. Open the **Minimum Energy** window from the **Parameter_Extraction** menu.



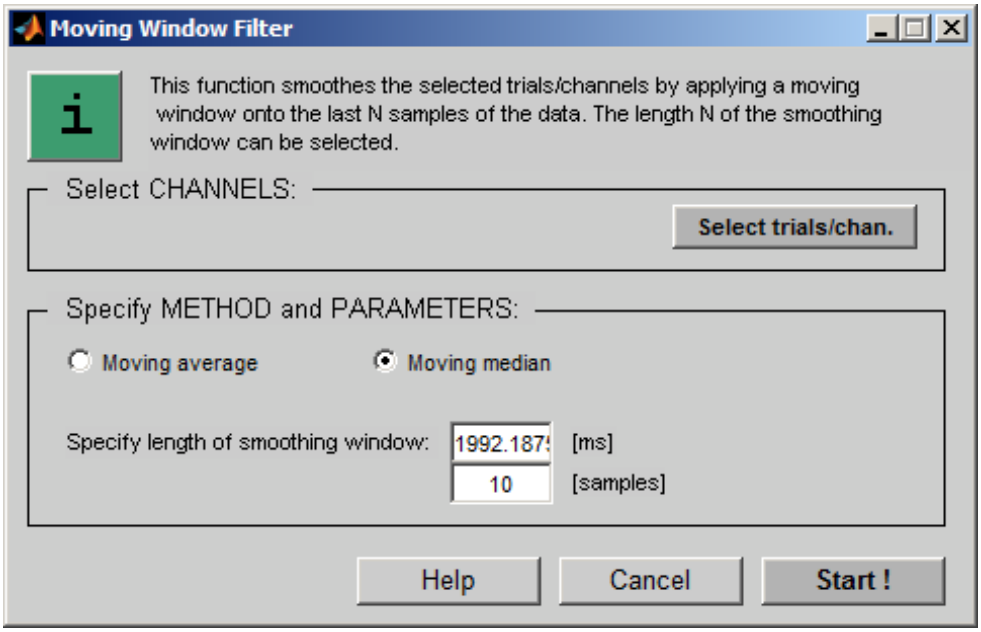
12. Press **Select channels** and **Select all ->>**.

    Enter the **Frequencies** `10,11,12,13` Hz. Set the **Number of harmonics** to 1 and the **Order of AR model** to 7.
    The **window length** is `3000` ms and the **Evaluation step** is `200` ms.
    Select **Add new channels** to add the calculated channels to the data channels in the Data Editor.

13. Press **Start!** to perform the calculation.

Parameter Smoothing – Moving Window Filter

14. Open **Moving Window Filter** window from **Pre-Processing** menu



15. Select **Moving median**

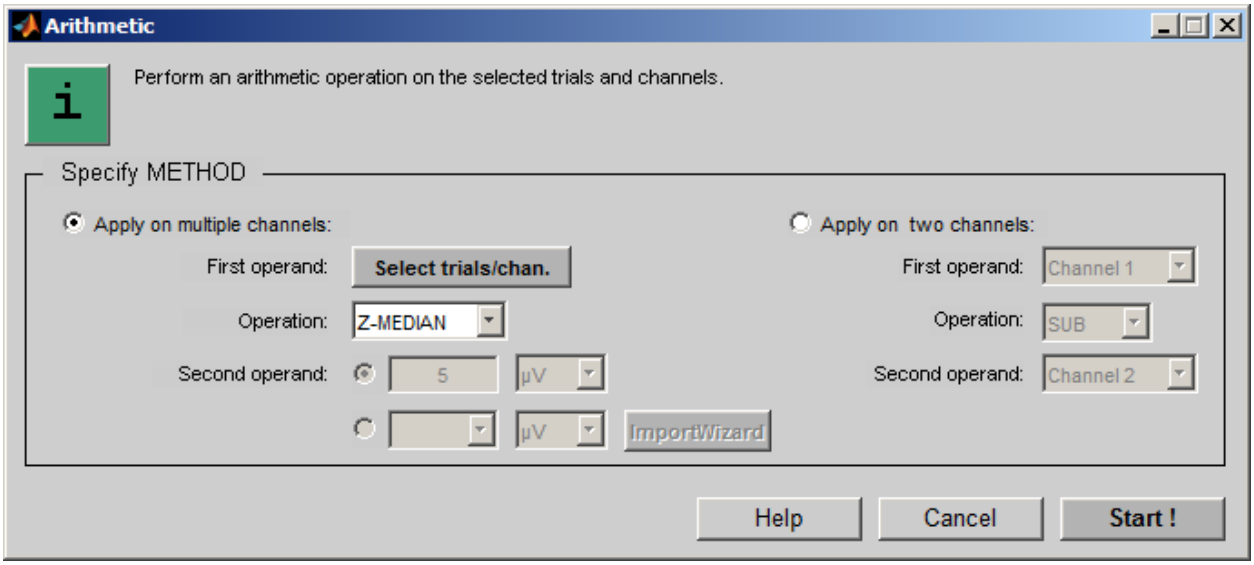
16. **Specify length of smoothing window** 10 Samples.

17. Click on **Select trials/chan,** select channels `9, 10, 11` and `12` to be smoothed only and confirm the settings with the **OK** button.

18. Press **Start** to smooth the data.

Baseline Correction

19. Open **Arithmetic** window from **Transform** menu



20. Select `Apply on multiple channels` for **Specify Method** and set **Operation** to `Z-Median` for subtracting the median of all channels from each sample.

21. Click on **Select trials/chan,** select channels `9, 10, 11` and `12` to be baseline corrected only and confirm the settings with the **OK** button.

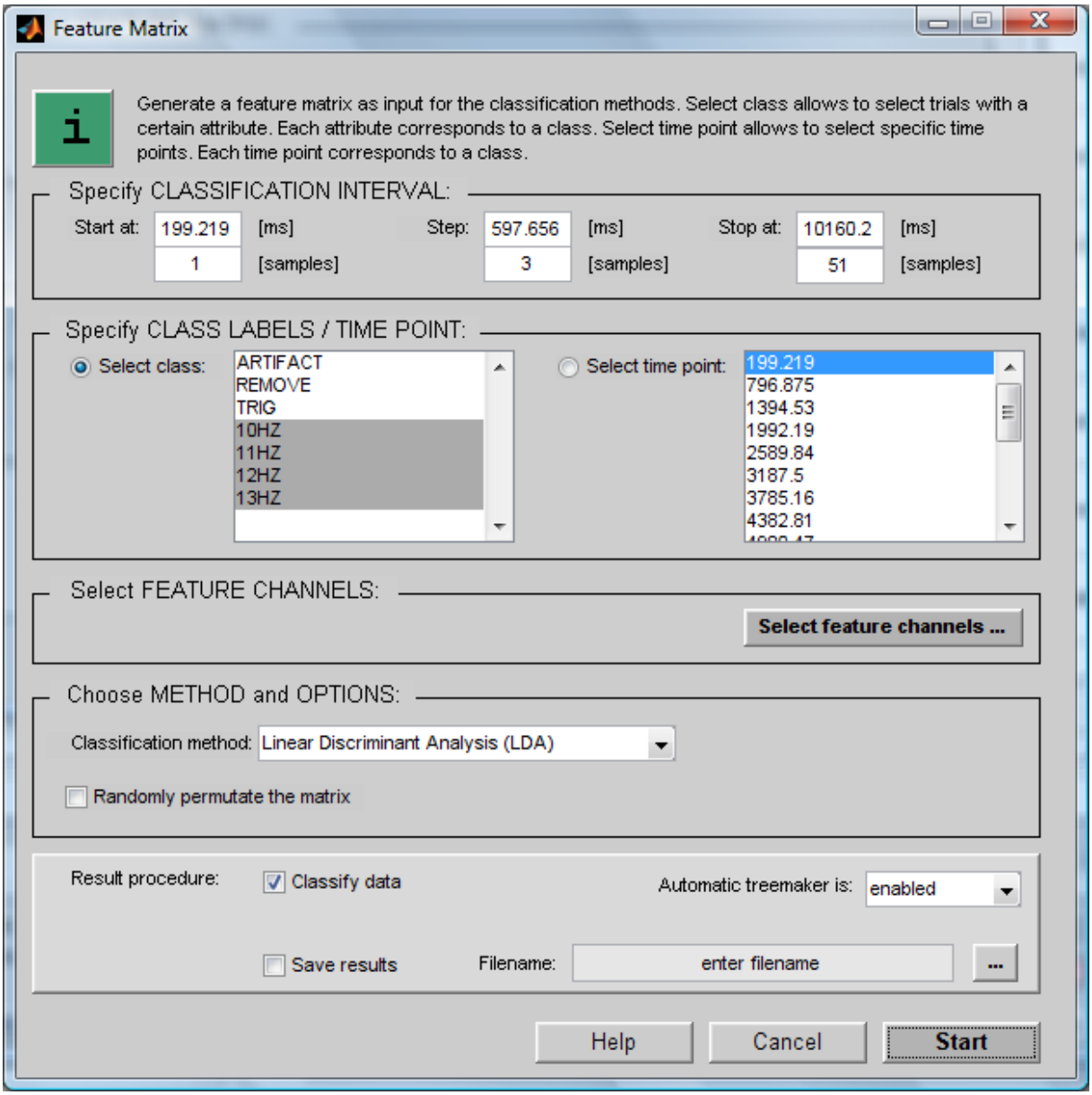
Classification

22. To classify the data open the **Feature Matrix** from the **Classification** menu.

23. Set the **Start at** time to `0` ms (the first sample will be chosen), the **Step size** to `500` ms and **Stop at** to `51` samples (`10160.2` ms). Select classes `10Hz, 11Hz, 12Hz, 13Hz`.

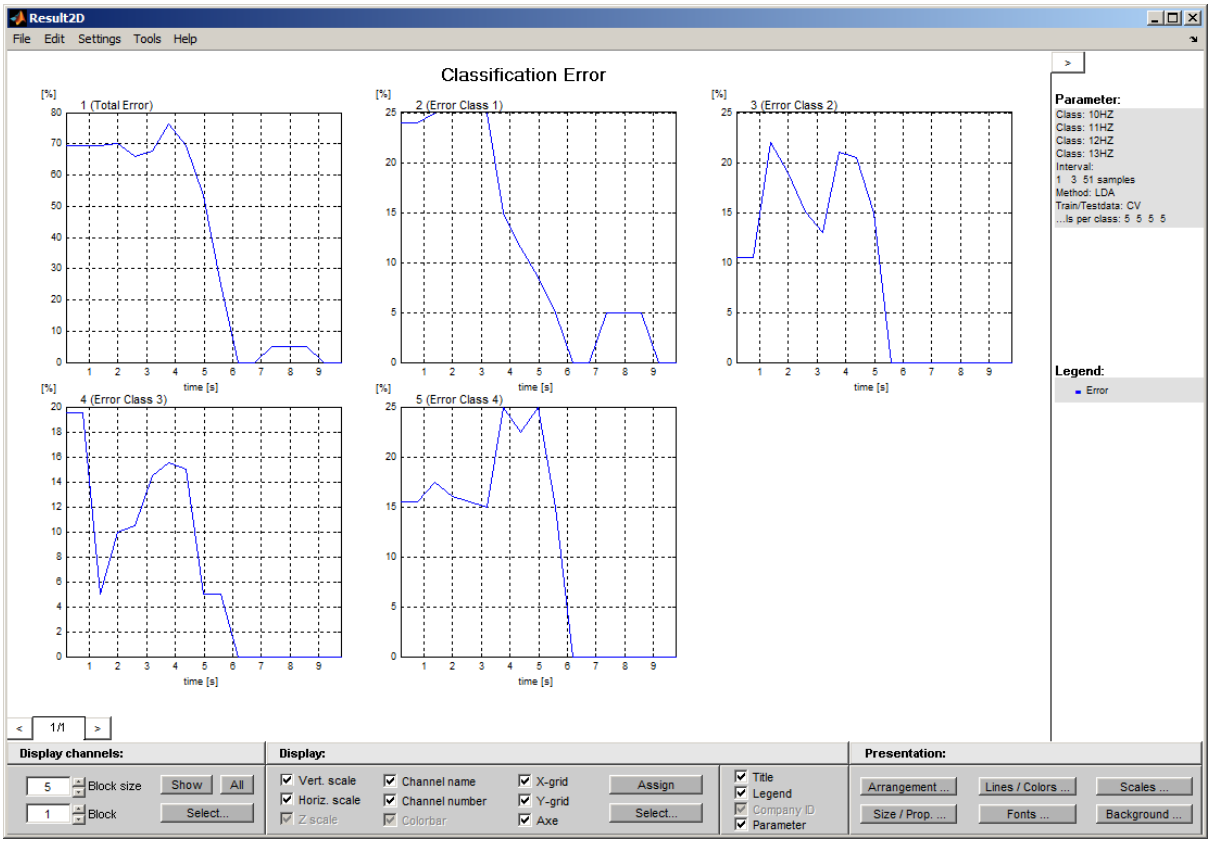
24. Click on **Select feature channels** and select only channels 9 to 12 for the classification.

25. Select `Linear Discriminant Analysis` (LDA) as **Classification method**.



26. Press **Start** to create the feature matrix and to open the **Linear Classifier** window.

27. Perform the classification with a `Linear Discriminant Analysis (LDA)` and with a `10 x 10 cross-validation` by pressing again **Start**. The 10 x 10 cross-validation mixes the testing and training data.
    gResult2D opens automatically with the classification result. The y-axis shows the classification error in %.
    For the Online Classification it is recommended to select a timepoint where the classification error is 0%. In the following figure (…\Testdata\training_testsubj1.mat) you would chose a timepoint between 6-6.5.



28. Close the Result2D, **Linear Classifier** and **Feature Matrix** window and repeat steps 14-19 but now select in the **Linear Classifier** window as **Training / test-sets** `Train 100% - Test 100%` and save the results in

    `Your Installation path:\gSSVEP_8ch\train_lda_session1.mat`

OPTIONAL: CLASSIFIER CALCULATION WITH BATCH

Steps 5-20 can be also performed automatically with a batch.
Note: You have to use the same parameters as used within this tutorial.

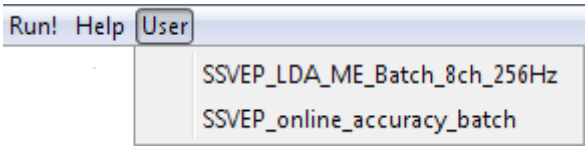
1. Enter `gbsanalyze` in the MATLAB command line to start **g.BSanalyze**.

2. Load the acquired data file `training_session1.mat` (Sampling frequency `256Hz`).

3. Select **Appearance Settings** from the **Options** menu and set the **USER DIRECTORY** to

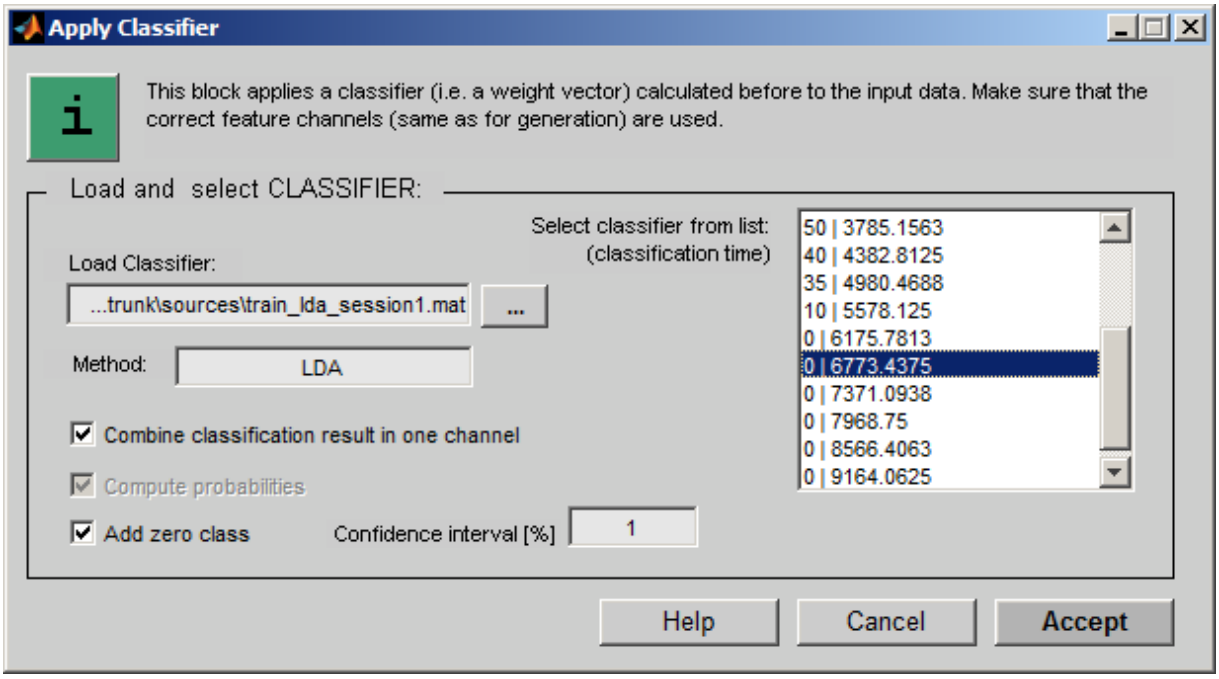
   `Your Installation path:\gSSVEP_8ch\Batch`

4. Go to the **User** menu in g.BSanalyze and select the batch for classifier calculation (`SSVEP_LDA_ME_Batch_8ch_256Hz`).



ONLINE CLASSIFICATION

Double click on the **Apply Classifier** block to load the classifier.



Load Classifier: Select the *.mat file which contains the classifier results. If you followed the tutorial it should be saved under:

`Your Installation path:\gSSVEP_8ch\train_lda_session1.mat`

Select classifier from list: Select the classifier which should be used for the online classification. The left value is the classification error and the right value the time point the error was observed.

Enable **Combine classification result in one channel** to compute the probability that a sample belongs to a specific class. The class with the highest probability is selected on the output of the **Apply Classifier** block.

Enable **Add zero class** and set the **Confidence interval [%]** to `1.` This activates the rejection of any sample for which no class can be assigned with an uncertainty of less than 1%.

Double click the **Paradigm** block.

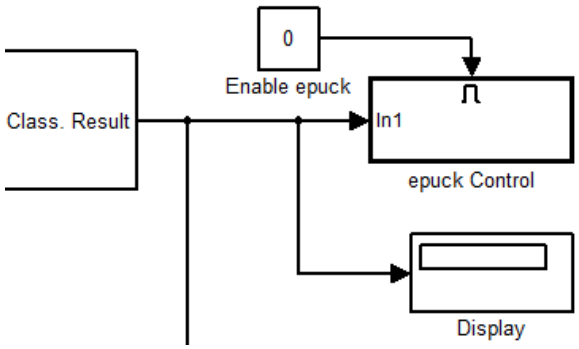
Select `Paradigm with feedback` as **Mode.** This mode allows to calculate the accuracy of the online classification.

Set the **Trial Period** to `10.5` s, the **Active Part** to `70`% and the Initial Offset to `10` s.

Press **OK** to close the window.

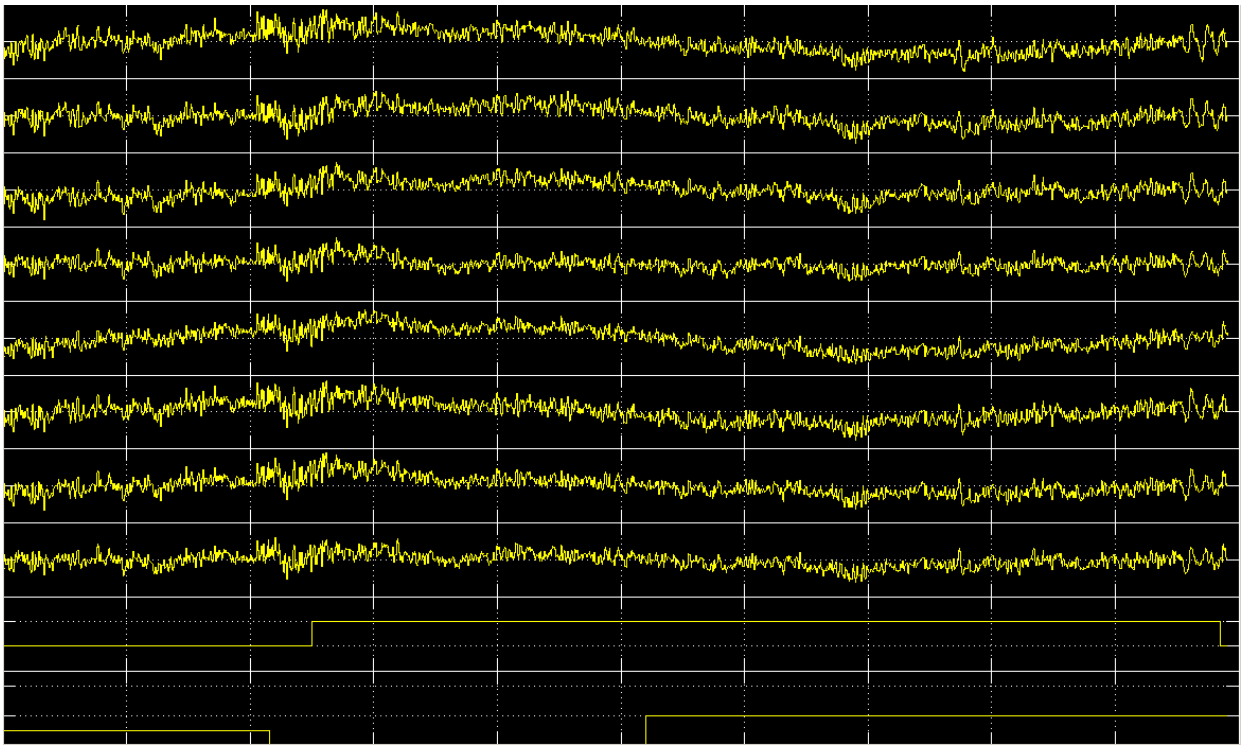
Enter into the **To File** block `fb_session1.mat` and **Start** the Simulink model.
The task for the subject remains the same as with Training Paradigm.
If you would choose `Free running` the white LEDs would flash all the time and you will get a continuous online classification result (can be seen in the **Display** block or as movement of the robot) but you are not able to calculate the accuracy with g.BSanalyze.

To control the **epuck,** set the constant of the **Enable epuck** block to `1`.



DATA STORAGE AND VISUALIZATION

Double-click onto the **Scope** block to investigate the signals:



The channels 1-8 show the EEG data. The 9th channel displays the **trigger signal**, if it is high you have to concentrate on a LED and the 10th channel indicates the **classification result** 1 – 4 (10Hz, 11Hz, 12Hz and 13Hz.) or 0 in case no class could be assigned.

The **To File** block stores these 10 channels plus the automatically stored time stamp of each sample (see documentation of **Simulink To File** .block for further details)

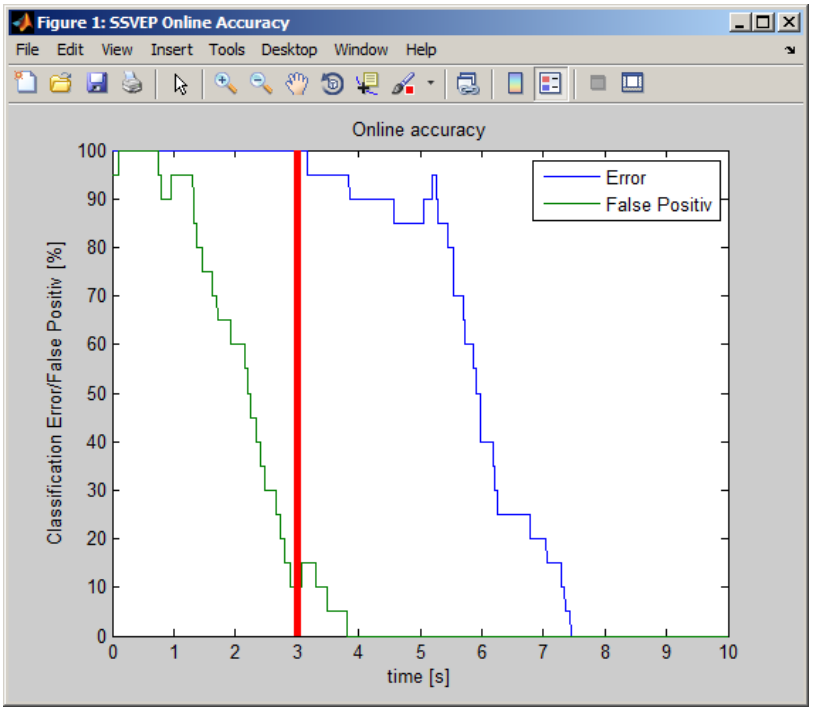
OFF-LINE PROCESSING

Type into the MATLAB command window `gbsanalyze` to start the Data Editor. Load the data file acquired during the `Paradigm with feedback` (fb_session1.mat) trial to calculate the accuracy of the online classification.

If your user directory is not already set, select **Appearance Settings** from the **Options** menu and set the **USER DIRECTORY** to

```
Your Installation path:\gP300_8ch\Batch
```

Go to the **User** menu in g.BSanalyze and select the batch `SSVEP_online_accuracy_batch.`



The x-axis specifies the time and the y-axis shows the classification error (blue line) and the false positive classifications (green line) in %. A sample is considered to be false positive classified if the assigned class is greater than 0 and not equal to the class expected for each trial. The red line marks the trigger, the LEDs start to flash. Before the trigger the classification result should be 0 and after the Trigger the error should be reduced significantly. The buffer length of 3s selected for the **Minimum Energy** and the **Moving Median** block of 2s causes an average delay of about 3s before the user action can be detected. In the shown example the break between two trials was selected to be 3s which is equal to the pre trigger time and the average interval required to detect that the user is not looking anymore at the previous LED. This is the main reason for the false positive classifications prior to the trigger.

SUMMARY

The new Simulink Highspeed On-line Processing blocks **g.USBamp** and **g.MOBIlab+** allows setting up a SSVEP Brain Computer Interface.
The parameter extraction is independent from the paradigm and the classifier, so it can be replaced by other algorithms. Also different classification methods can be used (Linear Discriminant Analysis, Support Vector Machine…).

To perform the tutorial the following components are required:

g.USBamp or **g.MOBIlab+** biosignal acquisition device
Simulink Highspeed On-line Processing blocks for g.USBamp or g.MOBIlab+
g.RTanalyze
g.BSanalyze off-line processing toolbox
g.STIMbox
g.SSVEPbox
g.GAMMAbox
EEG electrodes and an EEG cap
PC or notebook with USB connector or Bluetooth
MATLAB and Simulink Release 2012a


g.tec
GUGER
TECHNOLOGIES
contact information
g.tec medical engineering GmbH
Sierningstrasse 14
4521 Schiedlberg
Austria
tel. +43 7251 22240
fax. +43 7251 22240 39
web: www.gtec.at
e-mail: office@gtec.at