Transducer Array Calculation (TAC) GUI

Manual

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1. Introduction

The Transducer Array Calculation (TAC) GUI was developed in the context of the 3D Ultrasound Computer Tomography (USCT) project at the Karlsruhe Institute of Technology (KIT). One part of the project is the engeneering of our self-made transducers with means of simulation.
The TAC GUI was created because of the lack of free, credible and easy-to-use tools to calculate and visualize the transducers' directivity pattern and sound field.

This programm enables:

- Configurate:
  - Rectangular Array Transducer Dimensions
  - Single element selection and amplification
  - Variable excitation signal
  - Including of impedance characteristics
- View:
  - Excitation signal in time and frequency domain
  - Frequency-angle diagram
  - Directivity pattern in azimuth, elevation and 3D
  - Spatial sound field on variable planes
  - Pressure on middle axis including end of near field
  - Half-Power beamwidth
- Save:
  - All Figures
  - Configuration of simulated transducer
- Import:
  - Saved Configuration of simulated transducer
  - Measured or simulated impedance characteristics
  - Variable excitation signal
  - Attenuation

This manual is intended to give only a short overview how to use the TAC GUI. For that, not all possibilities are described completely and in detail. In addition to that, the source code is partly commented.

Any kind of usage and improvements of this work are welcome.

2. Directivity pattern calculation – GUI overview

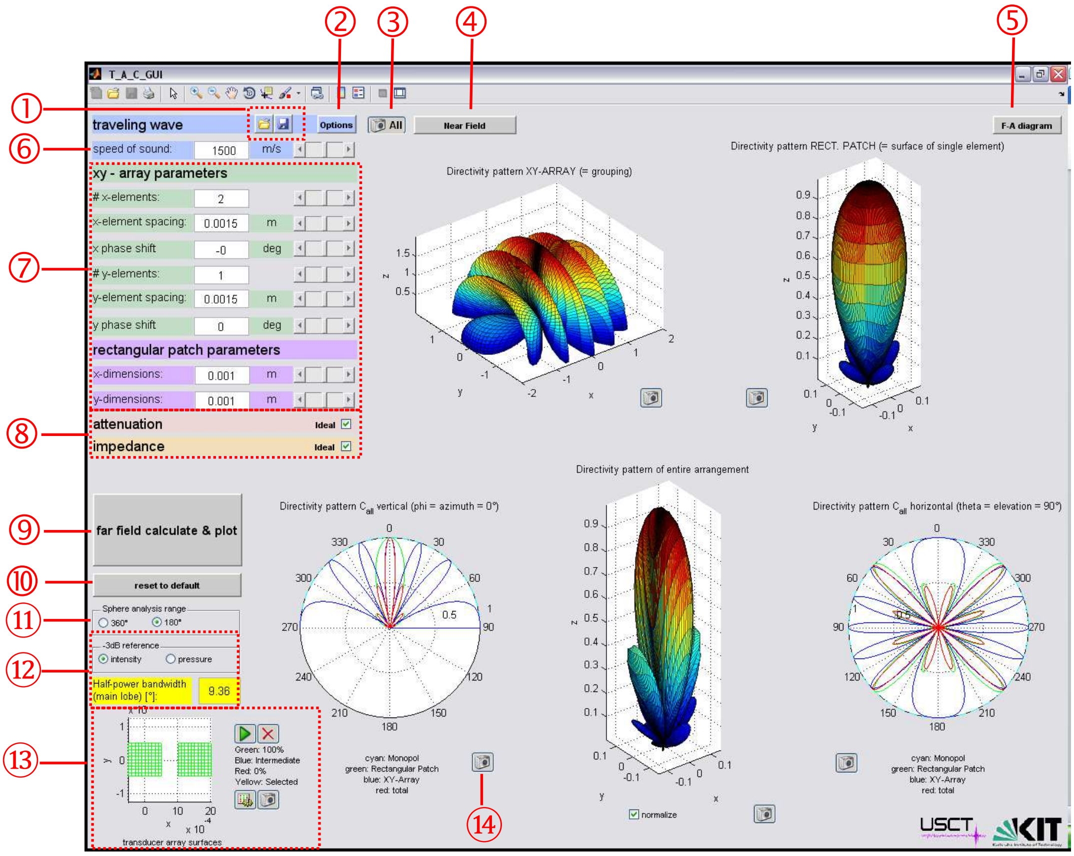


Figure 1. Transducer Array Calculation (TAC) GUI – directivity pattern calculation

1. Load or save transducer configuration
2. Options for excitation signal configuration
3. Save all figures
4. Switch to near field (soundfield without approximation) calculation
5. View frequency-angle diagram
6. Speed of sound configuration
7. Transducer geometry configuration
8. Transducer impedance and attenuation configuration
9. Start calculation of directivity patterns („far field calculate & plot“)
10. Reset to default
11. Select sphererical view
12. Half-power bandwidth of the main lobe including reference selection
13. Visualization and Configuration of current transducer elements
14. Save single figure

Calculation of the directivity patterns uses the Rayleigh approximination. Patterns of the xy-array assuming acoustical monopoles in two dimensional grouping are multiplied with the pattern of single element geometry to receive the overall directivity pattern of the transducer.

3. Transducer geometry configuration

In this program, all transducer elements are identically rectangular shaped. Figure *2.7.1* shows the different configuration possibilities.

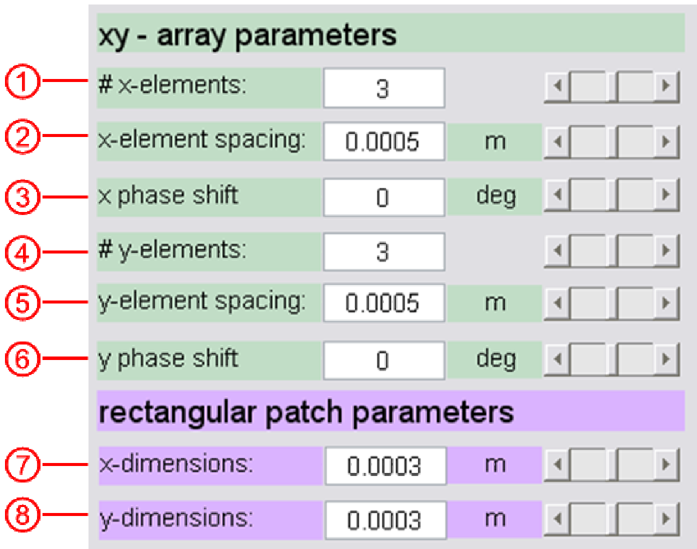


Figure 2. Configuration of the transducer

1. Number of x-elements
2. X-element spacing[1] (*Figure 2.7.2.,* 2)
3. Phase shift of excitation in x-direction
4. Number of y-elements
5. Y-element spacing[1] (*Figure 2.7.2 ,* 3)
6. Phase shift of excitation in y-direction
7. Rectangular patch parameters: x-dimensions (*Figure 2.7.2.,* 1)
8. Rectangular patch parameters: y-dimensions (*Figure 2.7.2.,* 4)

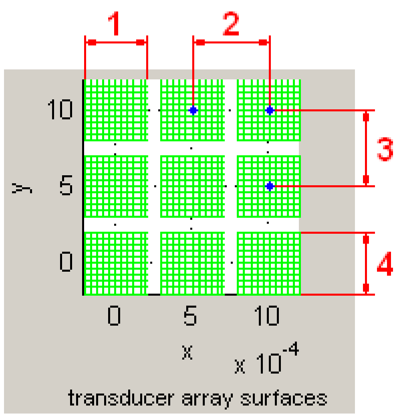


Figure 3. Visualized transducer surface

[1] Pitch of elements: Distance middle of element to middle of next element

4. Including transducers' electrical impedance characteristic

Any ultrasound transducer has a specific electrical impedance characteristic determined by its geometries and materials. A special feature of TAC is to include this measured or simulated characteristics into the directivity pattern and sound field calculation.

If the „ideal“ checkbox is activated, all frequencies will be transmitted equally (100%).

Figure 4. Transducer impedance, ideal

If the „ideal“ checkbox is deactivated, it will be possible to laod a impedance characteristic.

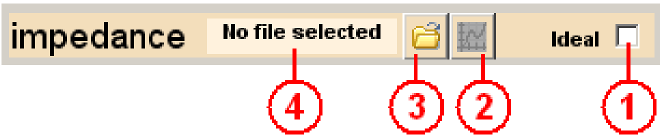
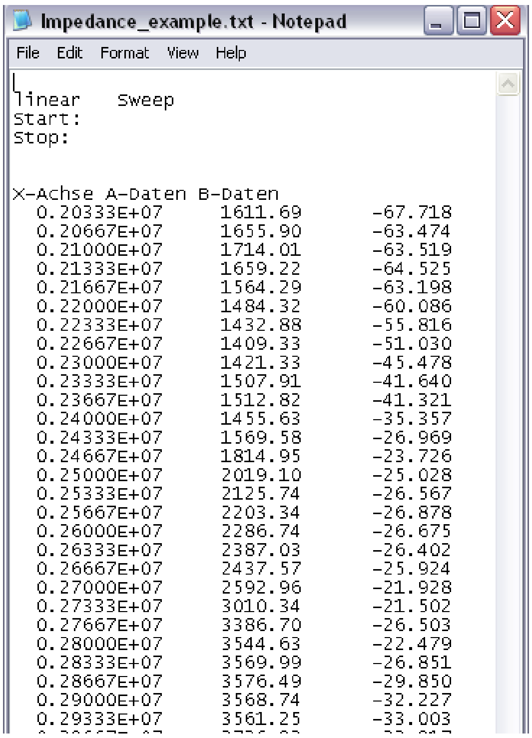


Figure 5. Impedance charachteristic laod menu

1. Checkbox to activate or deactivate the ideal charachteristic
2. Visualize characteristic
3. Open / load impedance characteristic
4. Status

Any arbitrary impedance characteristic hast to be a „.txt“ file fulfilling the following template:



Impedance_example.txt - Notepad

File Edit Format View Help

```
linear    Sweep
Start:
Stop:


X-Achse  A-Daten  B-Daten
  0.20333E+07     1611.69      -67.718
  0.20667E+07     1655.90      -63.474
  0.21000E+07     1714.01      -63.519
  0.21333E+07     1659.22      -64.525
  0.21667E+07     1564.29      -63.198
  0.22000E+07     1484.32      -60.086
  0.22333E+07     1432.88      -55.816
  0.22667E+07     1409.33      -51.030
  0.23000E+07     1421.33      -45.478
  0.23333E+07     1507.91      -41.640
  0.23667E+07     1512.82      -41.321
  0.24000E+07     1455.63      -35.357
  0.24333E+07     1569.58      -26.969
  0.24667E+07     1814.95      -23.726
  0.25000E+07     2019.10      -25.028
  0.25333E+07     2125.74      -26.567
  0.25667E+07     2203.34      -26.878
  0.26000E+07     2286.74      -26.675
  0.26333E+07     2387.03      -26.402
  0.26667E+07     2437.57      -25.924
  0.27000E+07     2592.96      -21.928
  0.27333E+07     3010.34      -21.502
  0.27667E+07     3386.70      -26.503
  0.28000E+07     3544.63      -22.479
  0.28333E+07     3569.99      -26.851
  0.28667E+07     3576.49      -29.850
  0.29000E+07     3568.74      -32.227
  0.29333E+07     3561.25      -33.003
```

Figure 6. Impedance file template

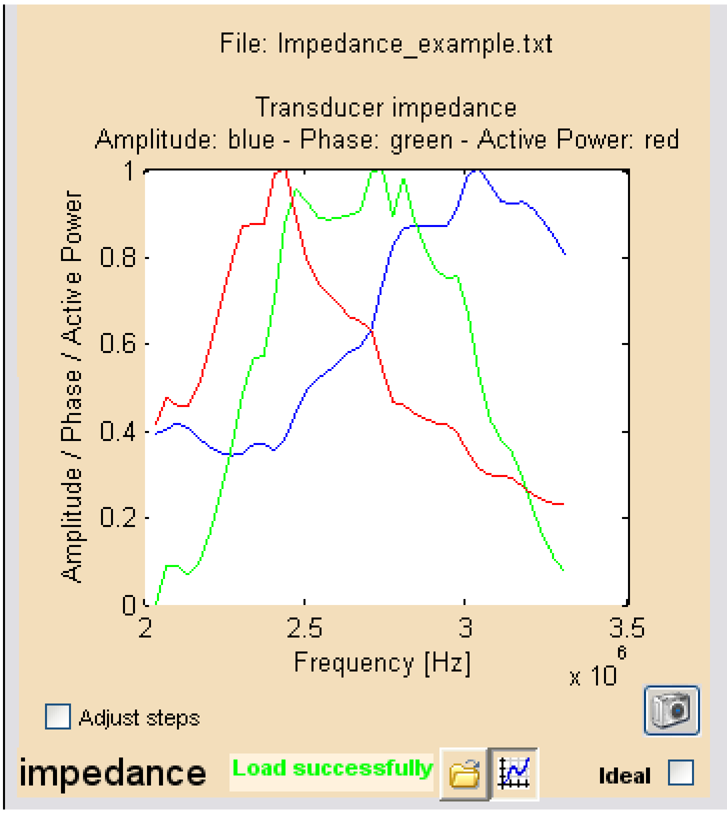


Figure 7. Example impedance characteristics

TAC calculates the active power out of the magnitude and phase information. Corresponding to this maximum normalized characteristic, the excitation signals' frequency dependant amplitudes will be adapted.

By activating the "adjust steps" checkbox, the frequency stepsize of the impedance characteristic will be automatically applied for the excitation signal. Otherwise TAC performances an interpolationof the impedance chracteristics to match the excitation signal frequencies.

5. Single-array-element configuration

In this programm, it is possible to configure the single elements of a transducer array. This is simply done by clicking either on a single element to switch this on or off, or by using the buttons next to the visualized array.

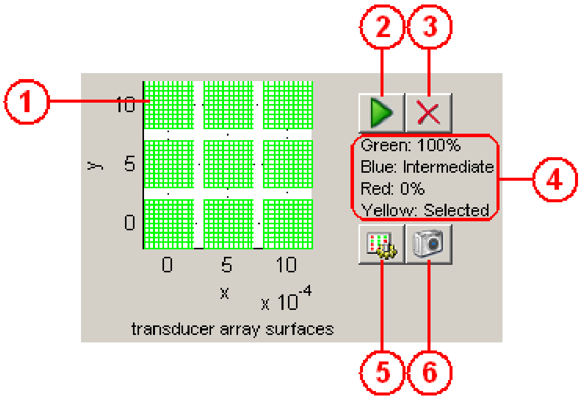


Figure 8. Single-array-element configuration

1. Single element
2. Activate all elements
3. Deactivate all elements
4. Legend
5. Button to activate and deactivate the menu for single element configuration
6. Save element configuration

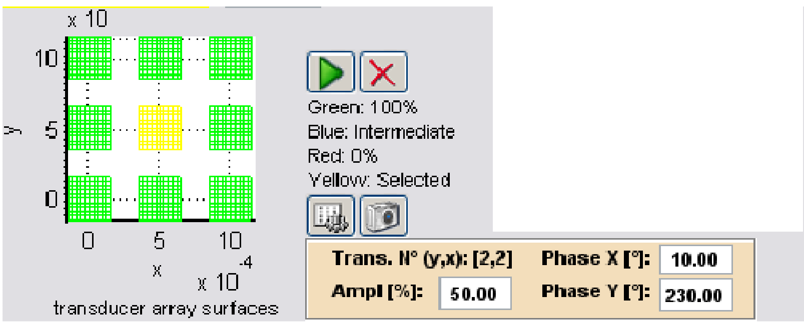


Figure 9. Single element configuration

The receive informations about the elemet amplitude, place the mouse pointer over the visualization.

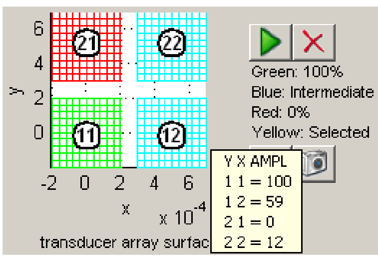


Abbildung 10. Receive amplitude informations

6. Excitation signal options

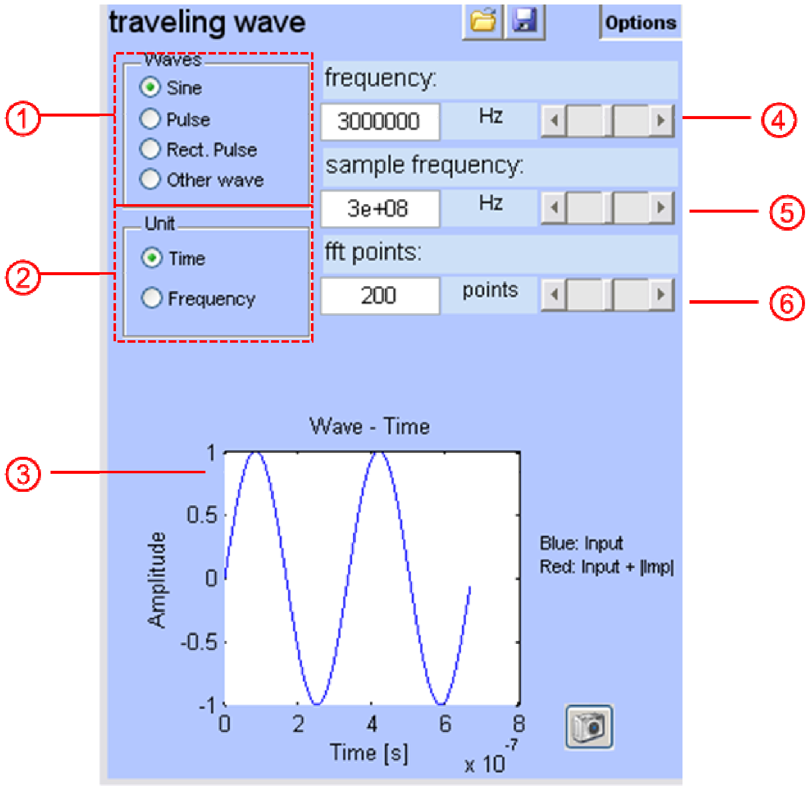


Figure 11. Excitation signal options

1. Selection of the excitation signal wave form
2. Selection of figure domain (time or frequency)
3. Figure of current signal
4. Modify signal frequency
5. Modify sample frequency
6. Modify fft points

6.1. Excitation signal including impedance characteristics

If an impedance characteristic is loaded, the excitation pulse shape will be new calculated including the frequency influence of the impedance characteristic.

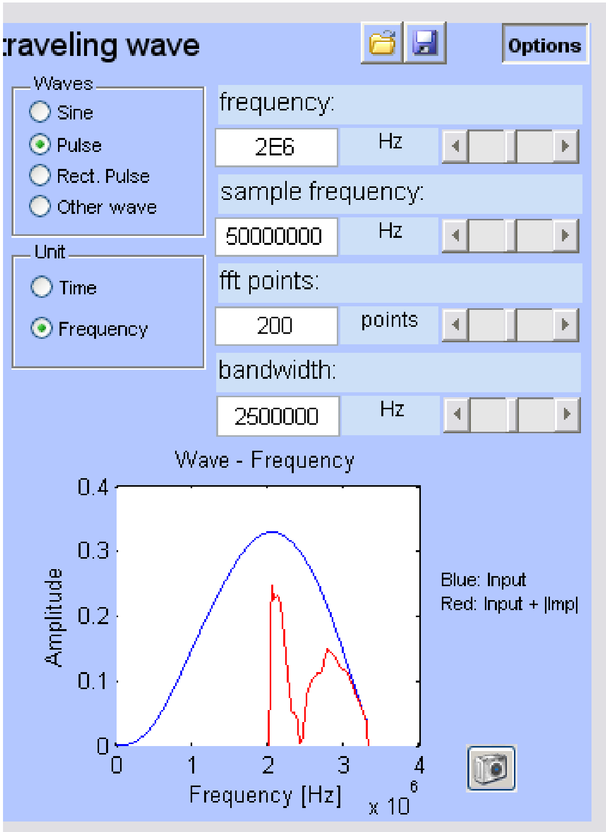


Figure 12. Excitation signal including impedance characteristics

6.2. Excitation signal rectangular time basis switch

The time basis of a rectangular excitation signal can be changed by a right mouse click on ①

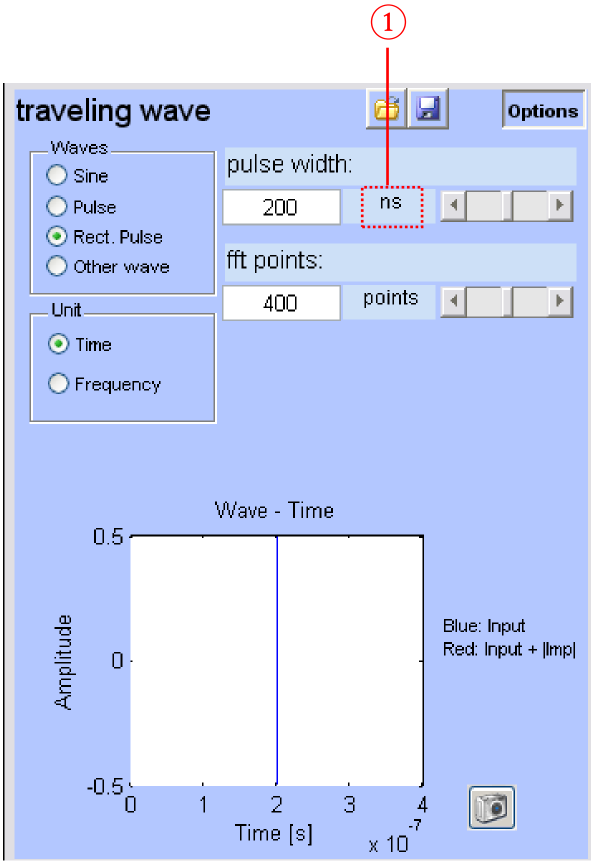


Figure 13. Time basis switch

6.3. Excitation signal: loading a signal

It is possible to load any arbitrary signal.

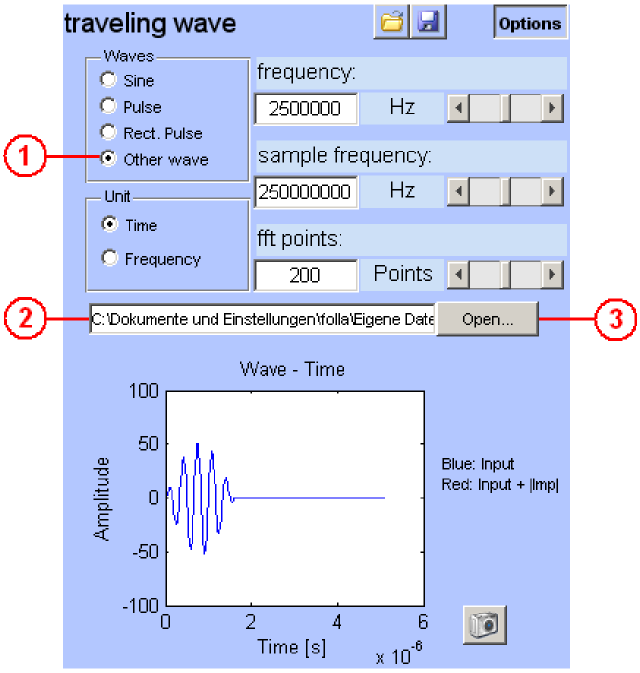


Figure 14. Load other waveform

1. Select „other wave"
2. File path
3. Open-button

Therefore, a „.mat" file must have the following structure:

```
823                         signal = open(aux_string);
K>> signal

signal =

        matchedFilter_AScan: [64x1 double]
     matchedFilter_SampFreq: 10000000

K>>
```

Figure 15. Structure of signal files

„matchedFilter_AScan" contains all informations of the signal in time domain. „matchedFilter_SampFreq" delivers the sample frequency information.

7. Saving Figures

If the „photograph" button is pushed, either a single figure or all figures will be saved.
All pictures are saved in the "Graficos" – folder and is provided with its specific name and date of creation.

e.g.

```
„…\Graficos\110920\11.26.44\..."
     |      |      |    |
     |      |      |    specific name of figure
     |      |      time
     |      date
     folder
```

8. Frequency-Angle diagram

Clicking on the "F-A diagram" button opens the frequency vs. angle vs. amplitude diagram of the calculated directivity pattern. The more frequencies simulated, the more meaningful will be this image.

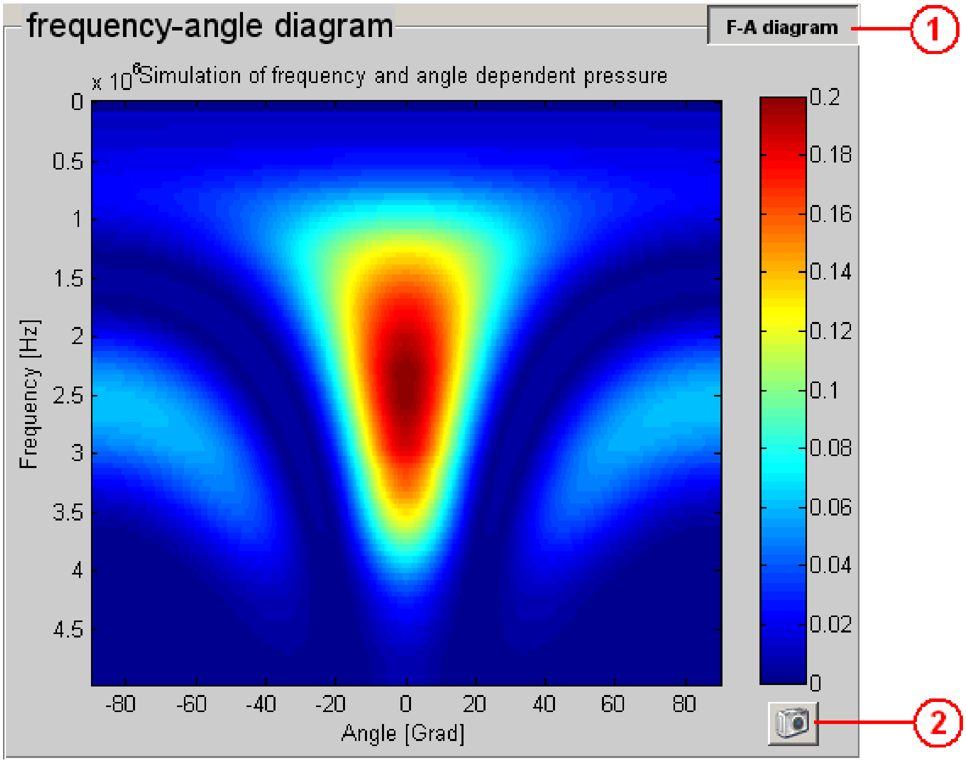


Figure 16. F-A diagram of arbitray transducer with pulse excitation

1. Open / close F-A diagram
2. Save figure

9. Near field calculation

Here, near field calculation means calculation of the sound field without any approximations. [1]

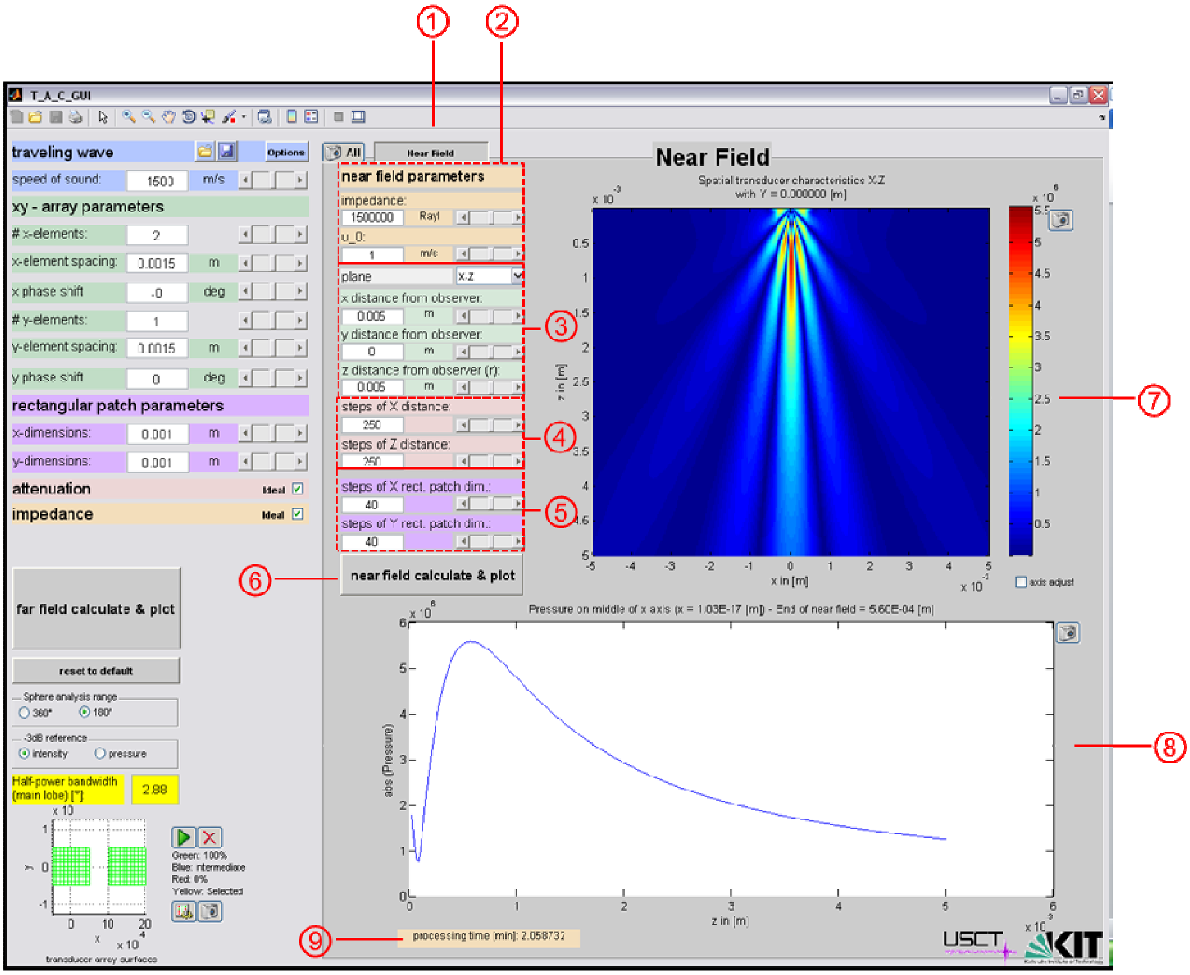


Figure 17. TAC Near field interface

1. Open „Near field“ calculation interface
2. Near field medium and displacement velocity configuration
3. Dimensions of calculation plane
4. Resolution of the image figure
5. Discretization of the transducer elements
6. Start near field calculation
7. Calculated figure
8. Calculate pressure characteristic on middle axis of calculated plane
9. Processing time of the last calculation

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[1] *Ocheltree, K.B.; Frizzel, L.A., "Sound field calculation for rectangular sources," Ultrasonics, Ferroelectrics and Frequency Control, IEEE Transactions on , vol.36, no.2, pp.242-248, Mar 1989.*