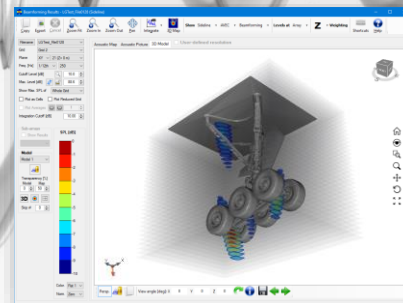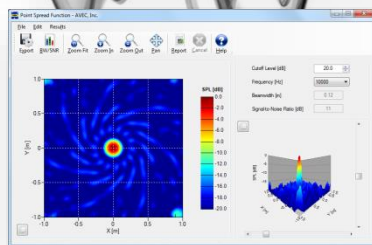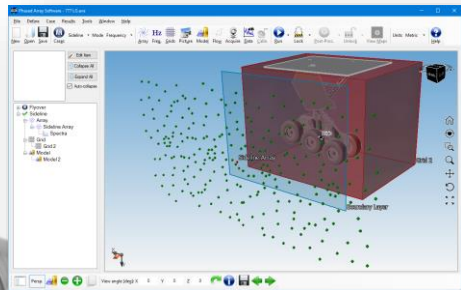# AVEC PHASED ARRAY SOFTWARE V5.0

FAST, SIMPLE, INTUITIVE, HELPFUL

AVEC's Phased Array Software is a complete solution for the design of microphone phased arrays, simulation of array performance, beamforming, deconvolution and analysis of experimental data collected with microphone phased arrays.

Built from the ground up for large-scale wind tunnel testing, our software design philosophy is centered on the user. Being long time developers and users of phased array technologies allowed AVEC to focus on the most important aspects of array processing and analysis. The goal was to give the user a comprehensive environment to perform all tasks involved in phased array testing when hundreds or even thousands of data points are measured.

As a result, our software excels in processing speed, simplicity of setup, and intuitive access to results. It also provides the user with tools that help increase productivity such as exporting data to spreadsheets and automatic report generation. This and several other features allow the user to focus on what matters most: data analysis.

The results shown are courtesy of JAXA (Japan Aerospace Exploration Agency) and part of work done and published by NASA Langley Research Center.

Overview of Main Features

AVEC's software includes modules for all the typical tasks of a large-scale wind tunnel test using microphone phased arrays. Additional functions were added to aid in the data processing and analysis. Some of the features available in the software include:

➢ Fast and easy project setup through an intuitive interface design,

➢ Integrated data acquisition capabilities (optional),

➢ Multi-case analysis (to compare results from different processing options or settings),

➢ Array coordinates transformation (rotation and translation),

➢ Quick raw data review (time histories and spectra),

➢ Disabling of non-working microphones (manually or programmatically),

➢ Processing with a user-defined shading algorithm or microphone weights,

➢ Diagonal removal beamforming,

➢ Multiple-file beamforming and deconvolution (CLEAN-SC, CLEAN, DAMAS),

➢ Integrated spectra and directivity calculation (of single or multiple regions),

➢ Results available in narrowband, 1/24th, 1/12th, and 1/3rd octave bands,

➢ Acoustic maps overlay with pictures, drawings or CAD models,

➢ Automatic export/report generation for multiple files, and

➢ Hundreds of files can be part of a project and be easily batch-processed, integrated or exported.

Most of these and other features are described and explained in more detail in this brochure.
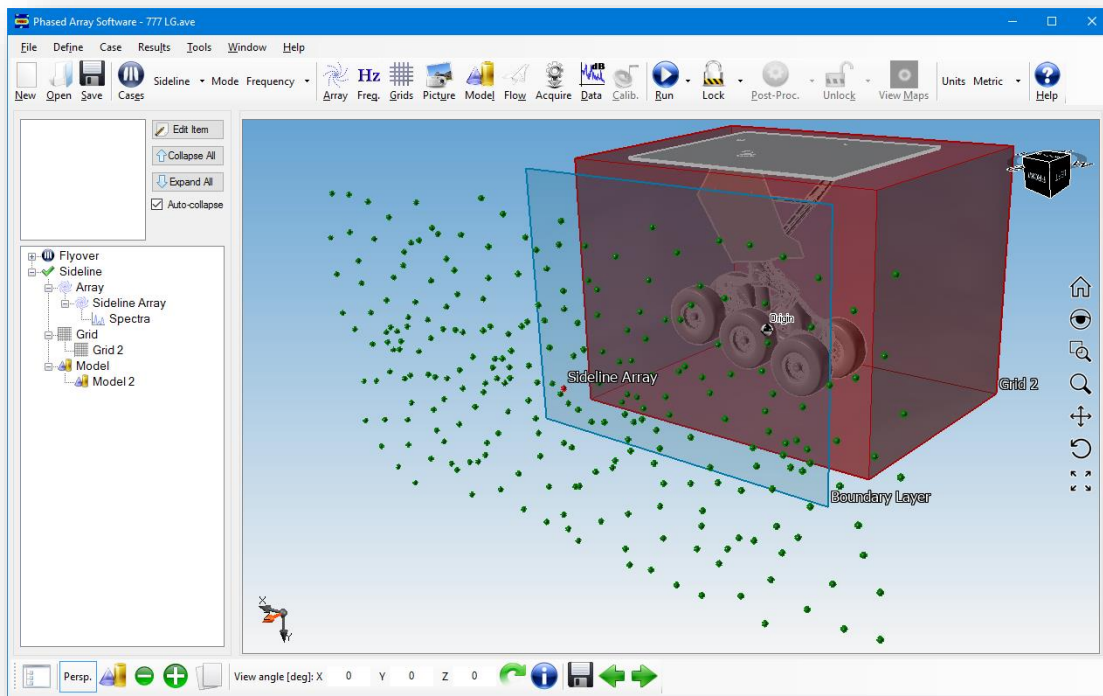
Array Definition Module

The software has several tools that allow defining, manipulating and modifying the arrays to be used for data processing. The array module allows the user to:

➢ Import array coordinates and parameters (weights, sensitivities and channel type) from a text file (easily obtained from a spreadsheet).

➢ Easily rotate and translate the array to match the test setup.

➢ Independently assign the channel type, weight and sensitivity of each channel in the array.

➢ Implement custom shading algorithms (parameters can be modified within the GUI).

➢ Automatically disable auxiliary channels (e.g. IRIG, synchronization, trigger, etc.) .

➢ Define and use multiple arrays and sub-arrays in a single project.

➢ Visualization of array shading values as a function of frequency for the entire array or individual channels.
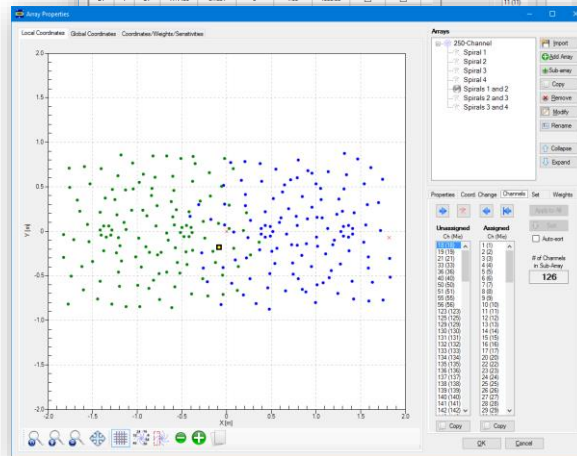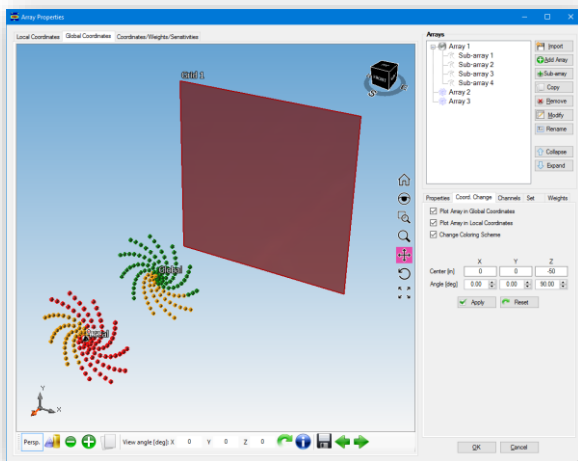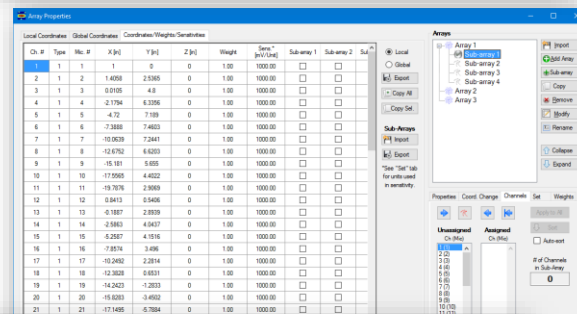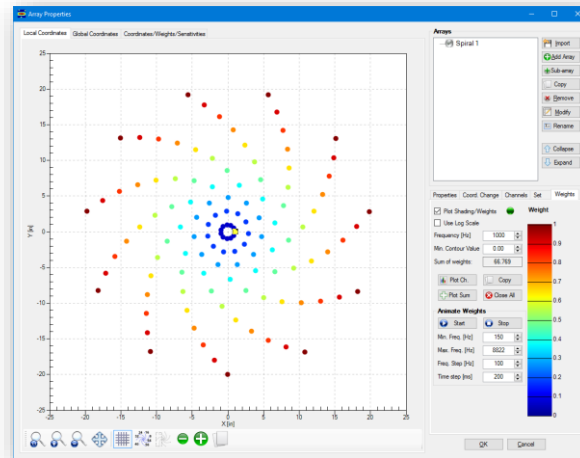
Array Calibration Module

This module obtains calibration matrices from speaker tests conducted in an anechoic chamber. It provides the capability of using multiple speaker tests for different frequency ranges to improve the calibration results. To determine the quality of the calibration data, results are summarized in a plot showing the coherence between microphones and the eigenvalues ratio.

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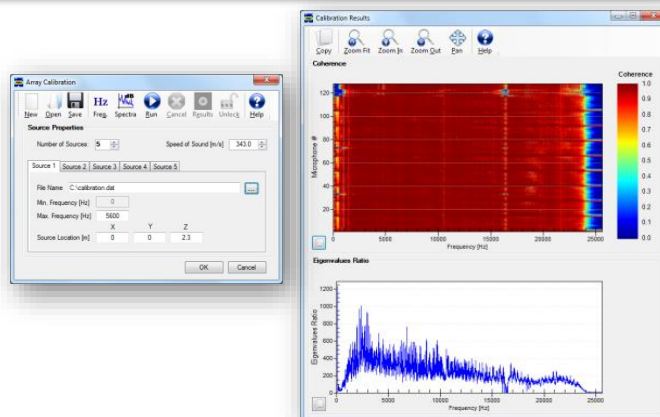
Data Acquisition Module

The data acquisition module (optional) allows control of AVEC's phased array systems or the customer's system within the same user interface. This allows for a more streamlined process without the need to move data files between systems, import/export data to and from AVEC's software, etc. Besides many of the features described below for the raw data analysis module, the data acquisition module also includes:

➢ Multi-channel oscilloscope (time history or spectra).

➢ External triggering and/or synchronization with other AVEC systems or wind tunnel instrumentation (custom hardware required).

➢ Automated data backup to a network location (or any secondary storage location).

➢ Support for complex, individual channel gain settings.
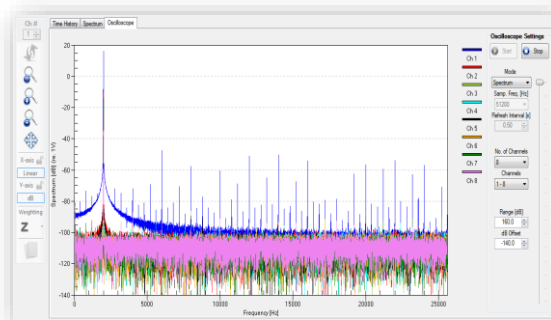
Raw Data Analysis Module

The raw data analysis tools can be used to quickly determine if all channels are working properly during the test. This information can help to determine if some microphones should be discarded during processing, i.e. to avoid "contaminating" the beamforming results. Some of the tools in the raw data analysis module include:

➢ Visualization of the time history or spectrum of each individual microphone. The average spectra of a subset of microphones is also available.

➢ The overall levels of all the microphones in the array can be used to easily find outliers. Also, the overall levels can be obtained for a frequency range defined by the user.

➢ Non-working channels are easily identified in the figures so they can be troubleshot during the test or excluded during data processing.

➢ Microphones can be programmatically disabled based on their overall levels relative to the average value.

➢ Quick raw data review (time histories and spectra) using multiple monitors. In this tool, disabled and non-microphone channels can be easily hidden to facilitate the analysis.

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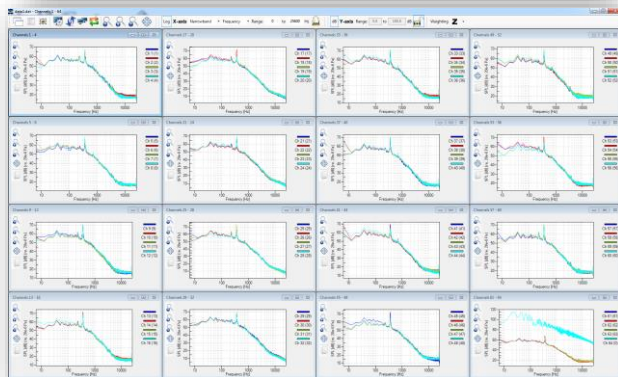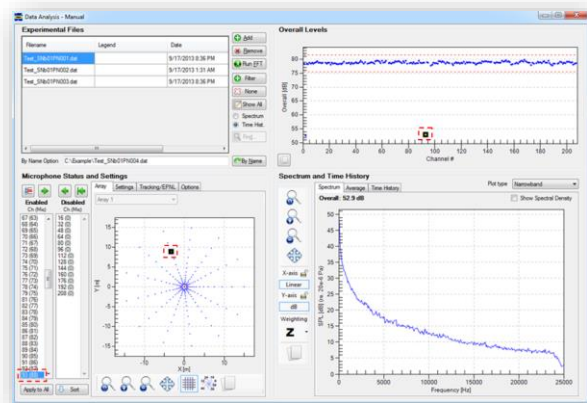
Beamforming Module

AVEC's software offers several beamforming options and features, including:

➢ **Frequency or time-domain beamforming:** different processing options are available depending on the desired type of beamforming. The time domain options include advanced beamforming with diagonal removal.

➢ **Flow Corrections:** Wind tunnel testing is a common application of phased array technologies in which flow corrections should be accounted for. Two flow correction types are available in the software: convection and refraction. The convection corrections are used when the source and observer are immersed in a uniform flow and is typically used in hard wall wind tunnels. The second type of correction available in the software accounts for boundary/shear layer refraction, as in the case of uniform flow with the receiver in a region at rest, i.e. open jet wind tunnel testing. Note that these corrections do not currently account for transmission losses.

➢ Simultaneous processing of files using entire array and multiple sub-arrays.

➢ Different FFT windows (rectangular, Hanning, Hamming, Tukey) and overlap options.

➢ Processing with microphone weights or shading algorithms defined by the user (in a customizable library). The shading algorithm and options for sub-arrays can be defined independently.

➢ Optimized, multi-threaded processing allows results to be obtained quickly during the test.

➢ Hundreds of files can be part of the project and easily batch-processed, and later visualized and integrated.

➢ A script file can be generated to process the files in multiple computers or a LINUX cluster (special license required).
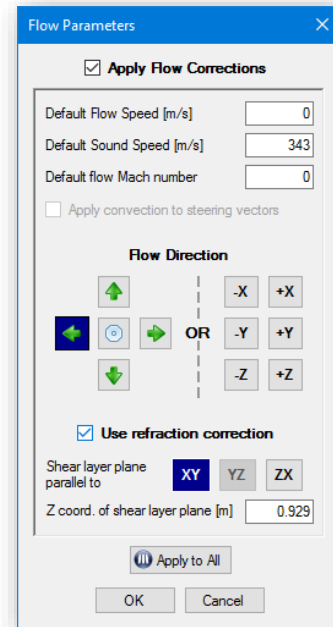
Scanning Grid Module

The scanning grids over which the data will be beamformed can be easily defined using its coordinates relative to the test object. The user can also define the grids using a picture or drawing of the aircraft. The user can then visualize the acoustic maps overlaid on these pictures.

The software also allows rotating the scanning grid independently for each data file to match the test conditions, e.g. the angle of attack of an airfoil or aircraft model.

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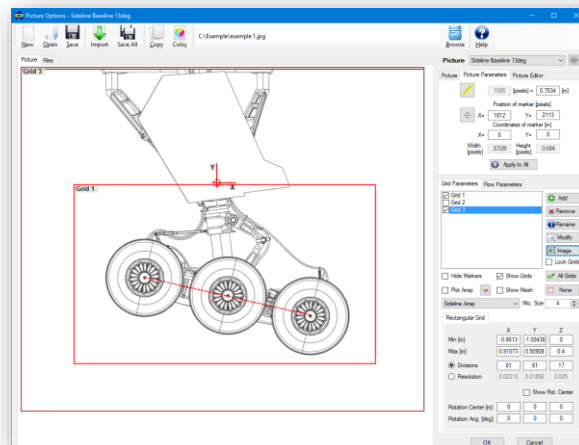
Post-processing Module

The post-processing module includes array deconvolution, point spread functions (PSF) calculation, and data reduction tools. The main features are:

- ➢ CLEAN and DAMAS are implemented with different processing options suggested in the literature.

- ➢ The CLEAN algorithm and the PSFs calculation are parallelized (multi-threaded) to reduce computational time.

- ➢ An innovative approach for DAMAS includes a parallelized version that can be used to reduce computational time while not requiring large amounts of memory.

- ➢ The data reduction tool can be used to speed-up the deconvolution process or to obtain results only for a few desired frequencies. This is a very helpful feature during a test.

- ➢ Several files can be batch-processed with a single click of a button.

- ➢ The results obtained with the entire array and/or multiple sub-arrays can be post-processed.

- ➢ A script file can be generated to post-process the files in multiple computers or a LINUX cluster (special license required).
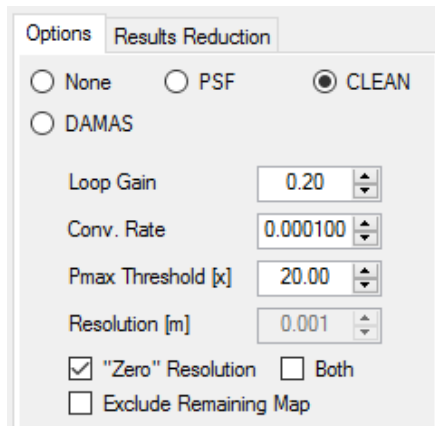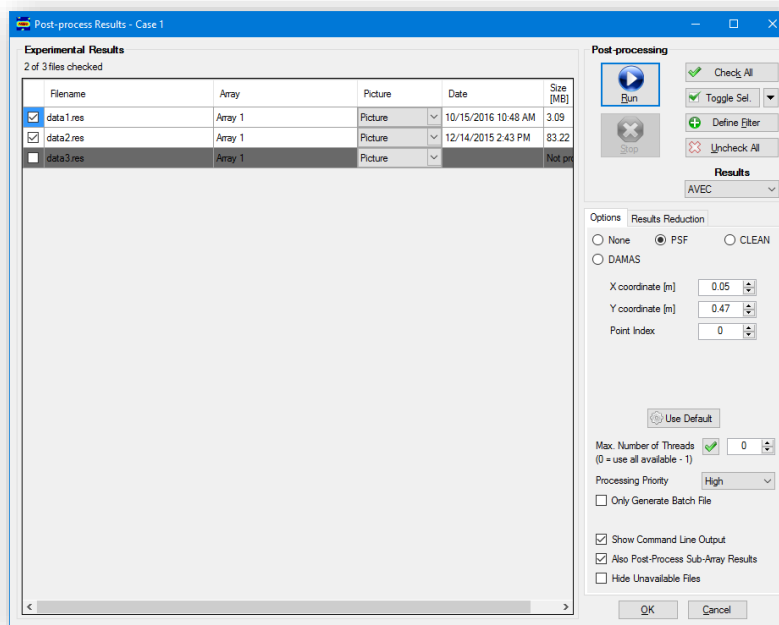

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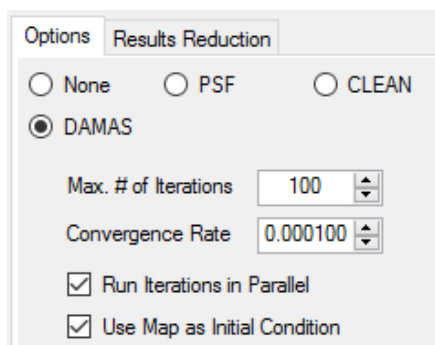
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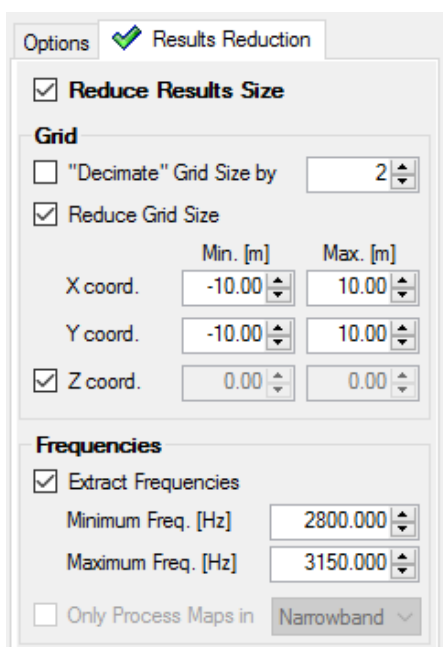
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Visualization of Acoustic Maps

The beamforming results visualization options include:

➢ Acoustic maps (for narrowband or different octave bands) can be visualized as conventional contour plots or overlaid with pictures, drawings or a CAD model.

➢ Multiple pictures and CAD models (e.g. for different test configurations) can be easily defined and assigned to multiple files.

➢ Different contour coloring, transparency, and flooding options available.

➢ The levels can be weighted (Z, A, B, C, D) and also obtained at the array or normalized to a user defined distance.


Continuous

Flat 1

Flat 2

Transparency 50

Transparency 0

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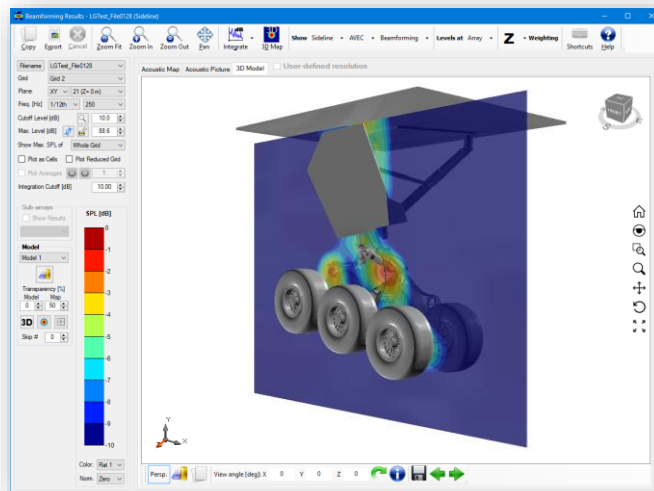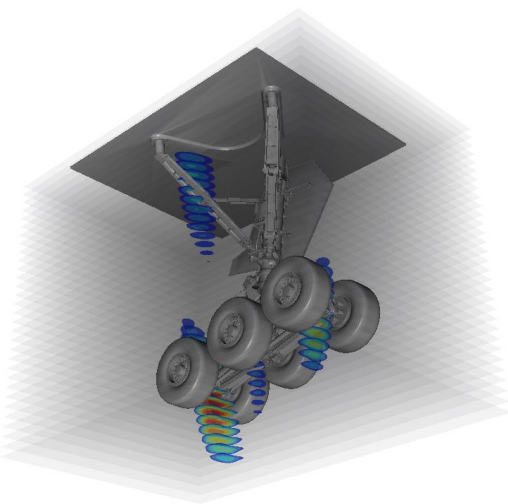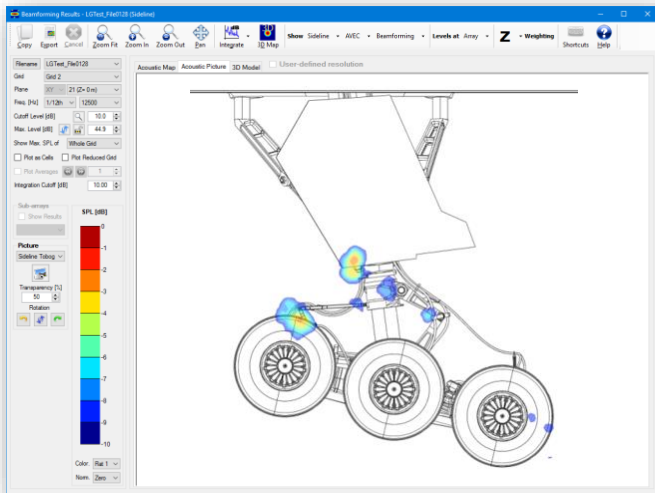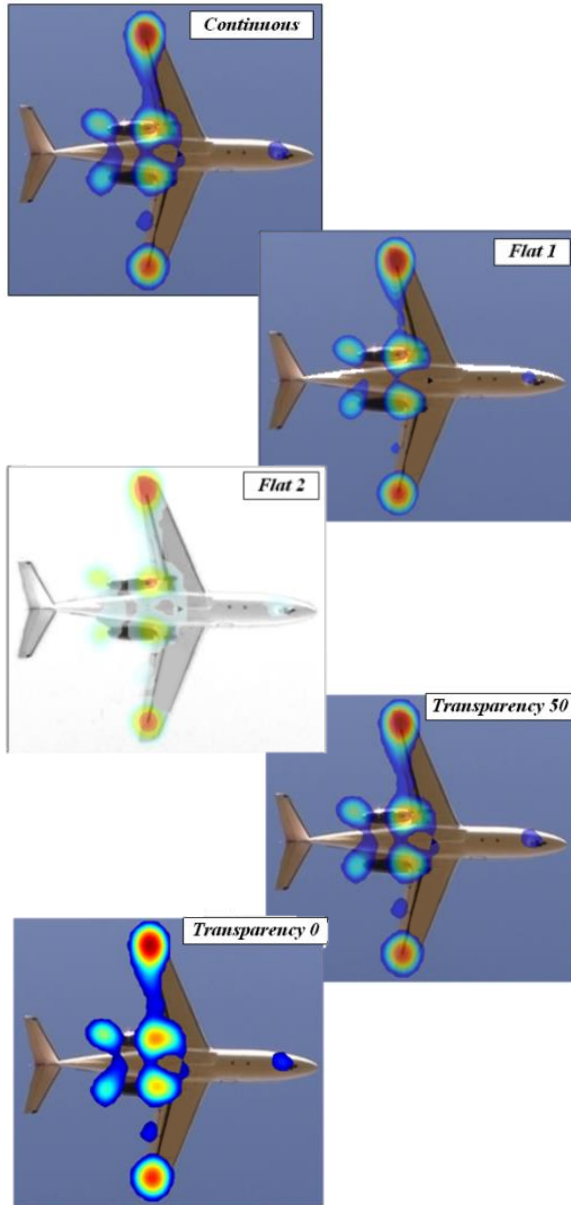
Exporting Results and Generating Reports

AVEC's software has unique features that can be used to automatically export beamforming results for multiple files and frequencies. The features in the export module increase user productivity and allows for more time to be spent analyzing data instead of copying, pasting, and cropping figures. Depending on the selected format, tables indicating the processing parameters and other relevant information are included. The acoustic map parameters and/or customer's logo can be included in every map. The available export formats and some of their features include:

- ➢ **Web Pages (HTML):** a separate web page is generated for each file exported allowing the user to easily visualize and access the acoustic maps and integrated spectra for the beamforming or deconvolution results. An index page is created to easily access the results for each exported file.

- ➢ **Word®:** this option generates professional looking reports including cross-referenced figure captions, table of contents, and table of figures.

- ➢ **PowerPoint®:** this format allows the maps to be exported to slides (1, 2, or 4 per slide) on a user-defined template.

- ➢ **Images (JPEG):** the results for each file can be exported to individual folders. Folders and files are automatically named and created.

- ➢ **ASCII:** this option can be used to export the maps to a text file in a format compatible with Tecplot®.

- ➢ **Rich-Text Format (RTF):** this option is useful when Microsoft Office® is not available.
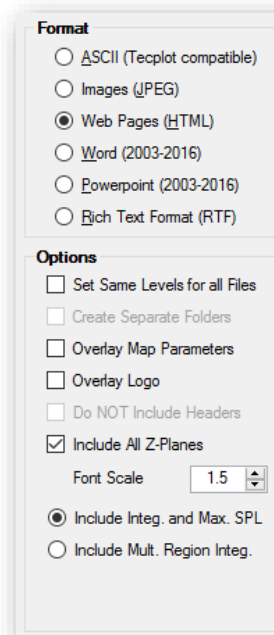

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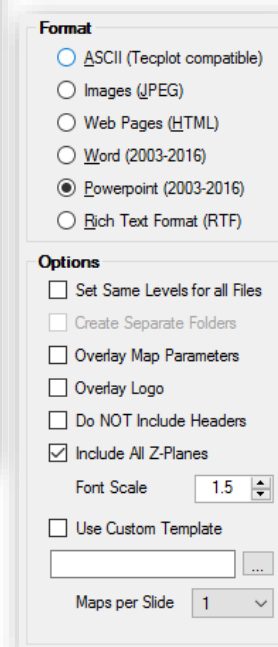
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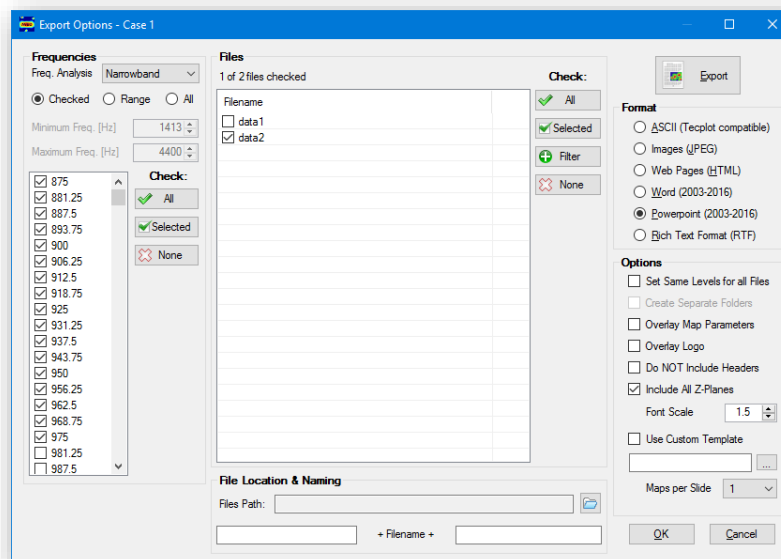
Integration Module

An easy-to-use array integration module has been implemented to quantify the noise from particular regions on the acoustic maps. The features in this module include:

➢ Spectra calculation from normalized integration or maximum SPL "extraction".

➢ The integration can be calculated for single (or multiple) rectangular or quadrilateral regions.

➢ These regions can be defined by "clicking" on the acoustic maps, using the region coordinates, or importing an ASCII file.

➢ Multiple results can be exported to ASCII files, or copied/pasted into a spreadsheet.

➢ The levels can be weighted (Z, A, B, C, or D) and shown as spectral density.

➢ The features in this window allow results for different cases, files, regions, processing codes (e.g. AVEC or customer's, if applicable), deconvolution, and maximum SPL vs. integration to be compared.

➢ Automated or customizable colors, lines, and markers based on plot type.

➢ Beamforming results for sub-arrays can be used to plot the directivity of an integration region.

Case 1 - Freq [Hz]	File 1 - Region 1, Case 1 - SPL [dB] (re. 20e-6 Pa)	File 1 - Region 2, Case 1 - SPL [dB] (re. 20e-6 Pa)	Case 2 - Freq [Hz]	File 1 - Region 1, Case 2 - SPL [dB] (re. 20e-6 Pa)	File 1 - Region 2, Case 2 - SPL [dB] (re. 20e-6 Pa)
Overall	55.4	55.4	Overall	51.3	51.3
1000	51.5	51.5	1600	49.1	49.1
1250	49.0	49.0	2000	45.6	45.6
1600	48.8	48.8	2500	38.0	38.0
2000	44.1	44.1	3150	37.2	37.2
2500	37.7	37.7	4000	37.1	37.1
3150	36.6	36.6			
4000	36.3	36.3			
5000	38.1	38.1			

*table borders and coloring were added after pasting the results in a spreadsheet
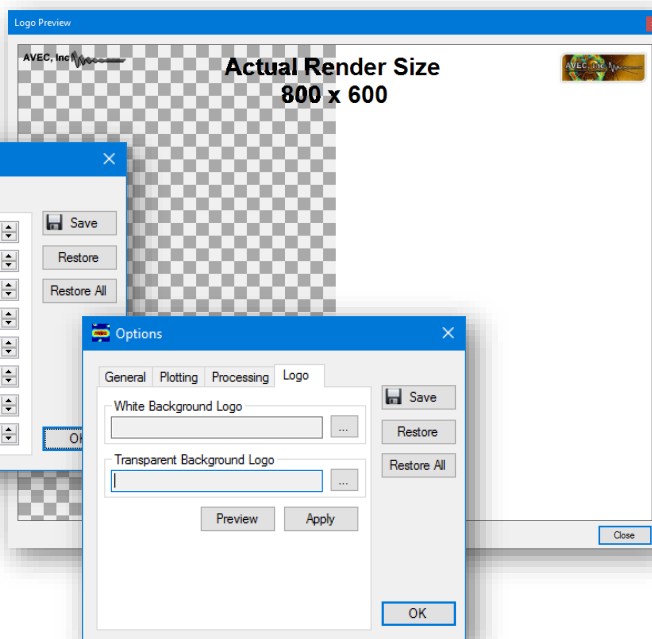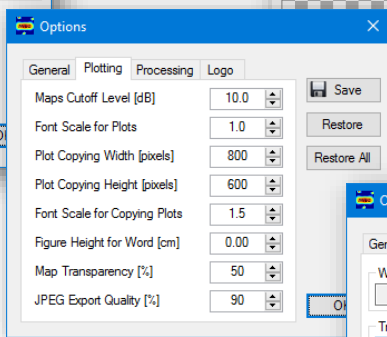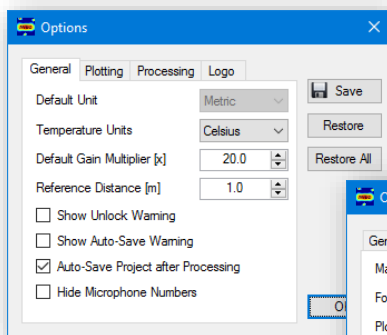
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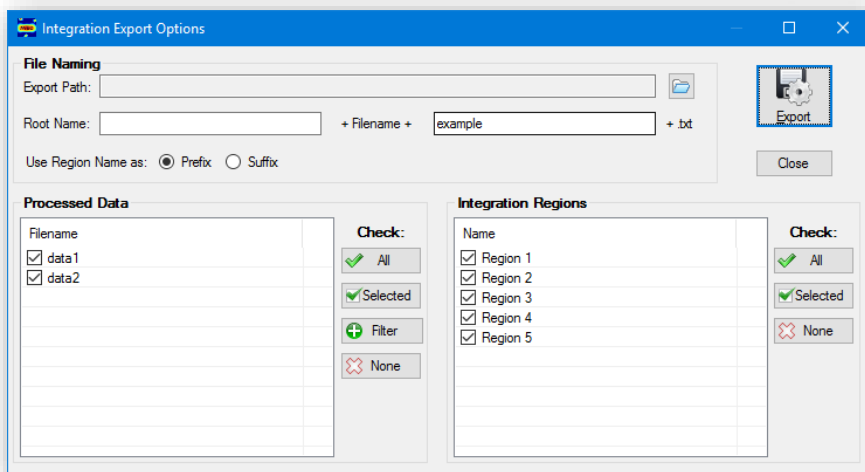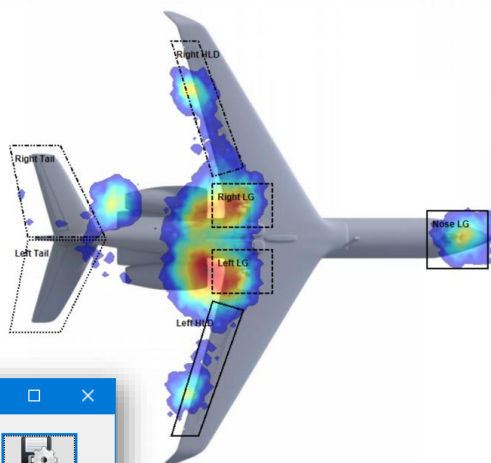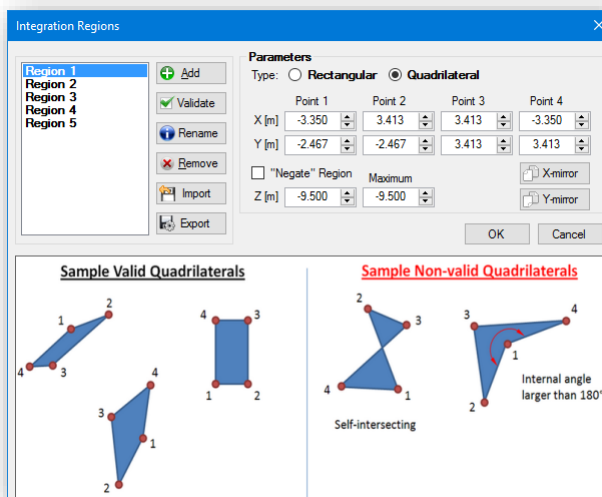
Documentation and Other Features

Other software features include:

➤ Projects and results can be easily moved to other computers for analysis (without needing the raw data files).

➤ Comprehensive user manual, help files, and list of available shortcuts.

➤ Keyboard shortcuts significantly speed-up data navigation (optional custom USB keypad also available).

➤ All plots in the software, as well as spectral data, can be easily copied and pasted into a different application (e.g. spreadsheet or word processor).

➤ A filter tool can be used to quickly select multiple files for processing, integration, or export.

➤ Several software settings and options can be easily changed. This includes options to define and preview custom logos to be used in the exported maps.

➤ Licensing model using encrypted USB key allows the installation of the software on several PCs without requiring complex activation procedures.
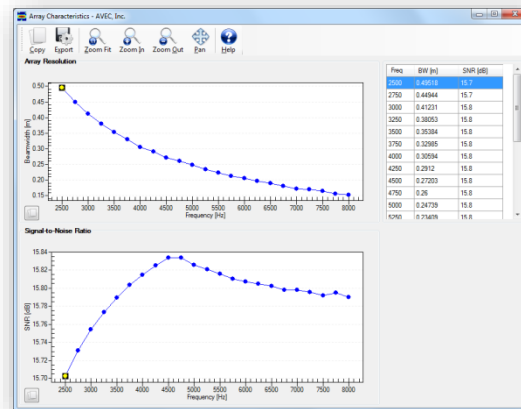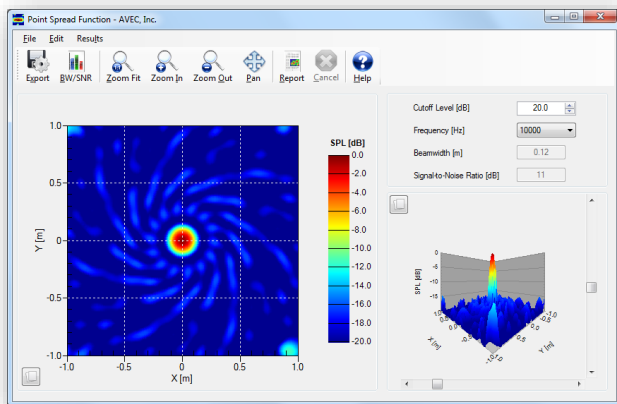
Array Design Module

The phased array Design Module is a powerful tool to design and test different array patterns. This module can generate predefined patterns (rectangular, spiral, star, and random) or import an array from an ASCII file.

Once an array pattern is defined, the simulation settings can be defined in accordance with the actual working conditions of the array. In this way, the results are more representative of the testing conditions in terms of grid resolution, area to be scanned and distance to the source.
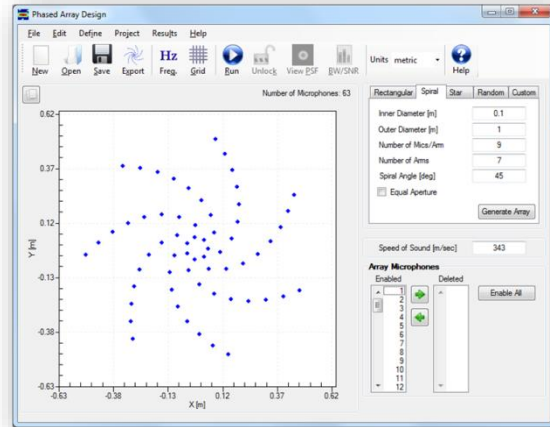
In addition to a beamforming map at each frequency, the simulation results provide the user with valuable information about the design: array signal-to-noise ratio (SNR) and array resolution (beamwidth). These results are also summarized in a simple SNR or resolution vs. frequency plot.

Also, this module is a helpful tool to learn about phased arrays. The design module can help the user understand the effects of array pattern, number of microphones, overall dimensions, etc. on the beamforming results.

Array Simulation Module

The Simulation Module extends the capabilities of the Design Module. This module is intended to provide an environment to test an array under simulated working conditions. This includes multiple sources, sources with different relative levels and spectrums, beamforming in 3D grids, Diagonal Removal (DR) beamforming, etc. The simulation module is also a very useful tool for understanding array results and learning about phased arrays.

This module has been designed with the same layout as the Data Processing module to help the user in the transition from array simulation to processing actual experimental data.
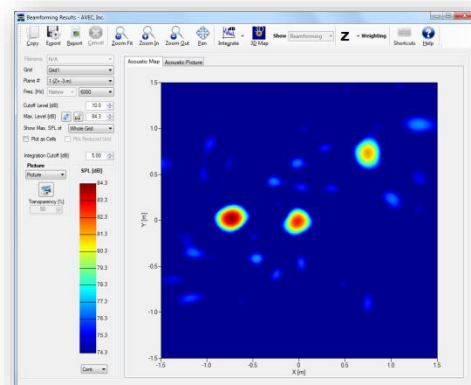
Custom Software Solutions

In addition to our commercial software, AVEC offers custom solutions to fit the customer's needs, including:

➢ Integration with the customer's data acquisition system.

➢ Custom file formats (raw data, weather, etc.).

➢ Integration of the user interface with the client's beamforming/post-processing codes.

➢ Implementation of additional export formats, processing, or visualization techniques.

Please do not hesitate to contact us about any special requirements.

Services and Other Products

Other services and products from AVEC include:

➢ On-site software training.

➢ Test support, data processing, and data analysis services.

➢ Customized turn-key phased array systems, including: microphones, cabling, signal conditioning, and data acquisition system.

➢ Phased array software for flight tests.
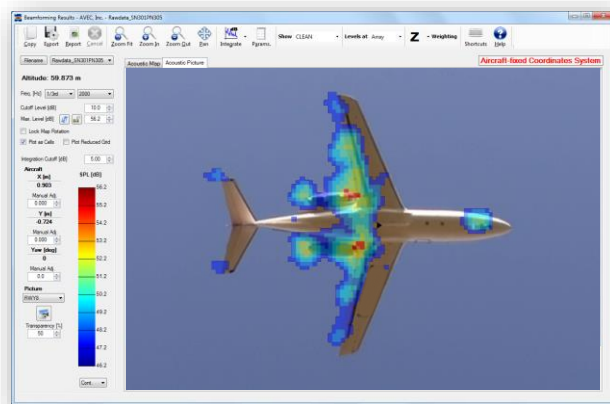
117-microphone phased array
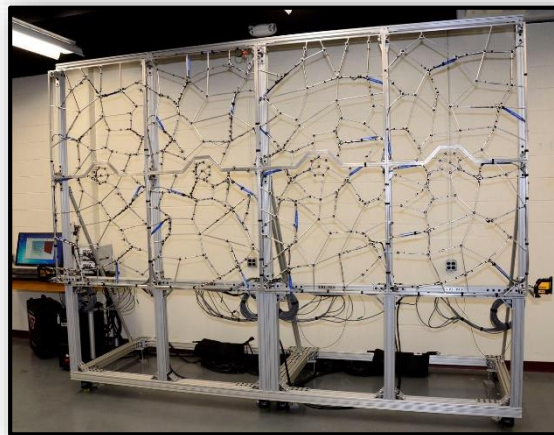
251-microphone phased array

Contact Information

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