Application Note

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UTIA Phased Array Analysis Tool

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Revision history

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2			

Contents

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1 Array Analysis Tools

The Array Analysis Tools package consists of three single-purpose GUI applications and one viewer application, all launched from a common launcher application, MainLauncherApp.

1. Array RAW Data Preview and Analysis
   This tool is intended for diagnostics of newly built microphone arrays. It displays microphone-pair data one pair at a time and provides several diagnostic views, including microphone-pair signals, spectrograms, PDM signal statistics, waveform plots, and signal envelopes.
   These views make it possible to identify most common microphone-array hardware problems, such as non-responding microphones, permanent overload, clogged acoustic ports, soldering defects, or other assembly-related faults.
   The tool also supports crosstalk analysis. Since microphones are used as stereo pairs sharing a common output path, the tool helps verify whether each microphone contributes its own data correctly or whether one microphone in the pair is being overdriven by the other. For this analysis, multiple RAW microphone recordings are required, typically recorded while selected microphone acoustic ports are left open and others in the pair are tightly covered.
2. Array Beam Modelling Tool
   The Array Beam Modelling Tool visualizes the directional beam response of a microphone array for a selected array layout, frequency, and related parameters. The tool supports linear array configurations with a defined number of microphones and microphone spacing. It also supports general microphone layouts imported from a CSV file containing the XYZ coordinates of each microphone.
   Beam visualization can be performed as a 2D cross-section of 3D space, or as an isometric 3D visualization.
3. Training Dataset Preparation Tool
   This tool is designed for generating training datasets in the form of logarithmically scaled 2D power spectrogram images.
   The generated output images are automatically sorted into class folders named 0, 1, 2, and so on, making the dataset directly compatible with TensorFlow 2 workflows.
   The tool supports generation of training data for the pre-processing chain based on partial-discharge recordings produced by BUT.
4. Echo Viewer
   The Echo Viewer is a dedicated viewer for displaying data captured by the capture_echo2.elf tool.

2 Main Launcher App

The Main Launcher App provides a top-level launcher window for opening all applications included in the Array Analysis Tools package. It acts as a central entry point from which the user can start individual MATLAB GUI tools or open multiple tools as needed.

2.1 Description

The Launcher is a MATLAB GUI application used to simplify access to several related MATLAB applications from a single unified interface.

The launcher provides buttons for opening the following tools:

- Beam Preview Application
- BUT PD Dataset Generator
- evBoard Array Analyzer Tool
- Echo Viewer

Instead of requiring the user to manually run each application from the MATLAB Command Window, the user can start the Main Launcher App and then select the required tool from the launcher window.

This approach improves usability by grouping all related array-analysis applications into one common starting point and makes the tool package easier to use, especially for users who are not familiar with MATLAB command-line operation.

Figure 1 shows the Launcher Application.

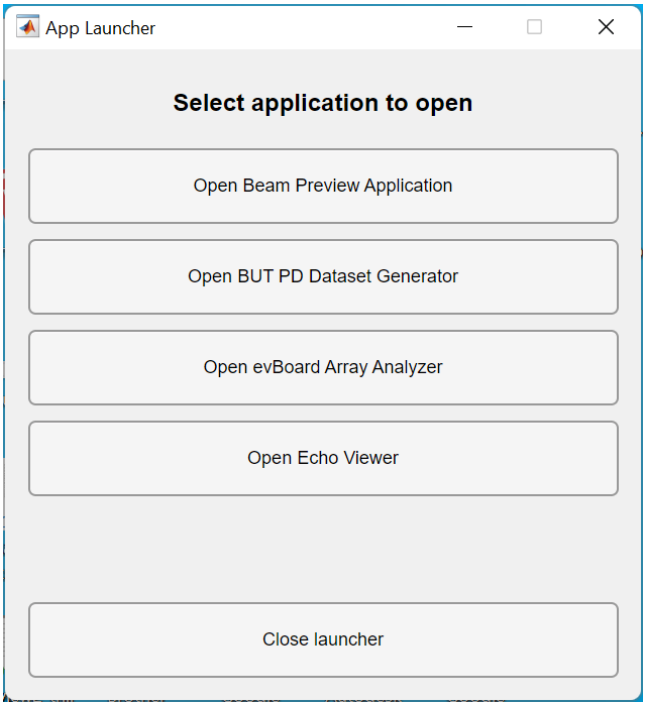

Figure 1: Launcher Application

3 evBoard Array Analyzer

3.1 Description

The evBoard Array Analyzer is a MATLAB GUI application for analyzing microphone recordings captured from an evBoard microphone array.

The application provides a graphical interface for opening RAW microphone data files, displaying microphone-pair analysis, playing selected microphone channels, and evaluating crosstalk measurements across microphone pairs.

The tool is designed for a 32-microphone array organized into 16 microphone pairs, such as MIC pair 1–2, MIC pair 3–4, and so on.

3.2 User Interface Layout

The application interface is shown in Figure 2. It provides the following main controls:

Button	Function
Open File	Opens a single .raw microphone recording file.
Analyze Crosstalk	Selects a folder containing crosstalk measurement .raw files and processes them one by one.
Show	Displays analysis figures for selected microphone pairs.
Play	Plays audio from the first selected microphone pair.

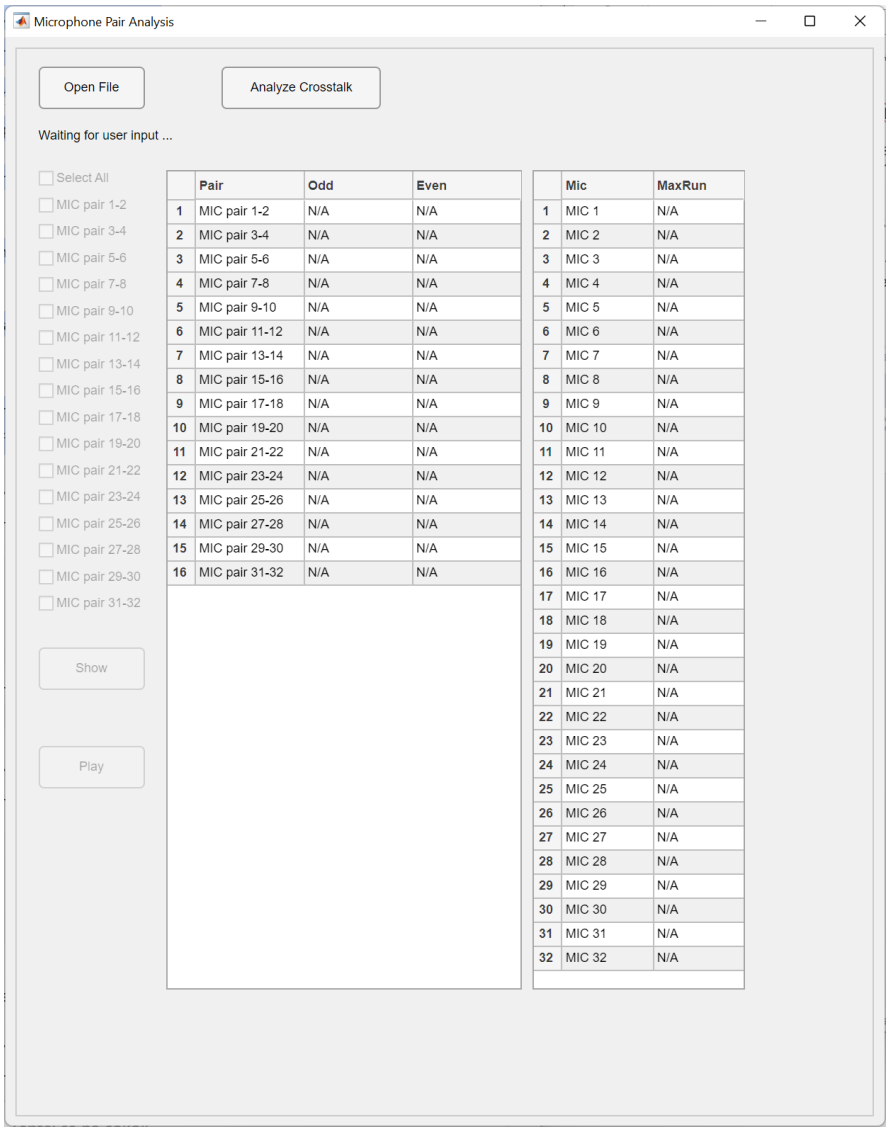

Figure 2: GUI before opening a RAW file.

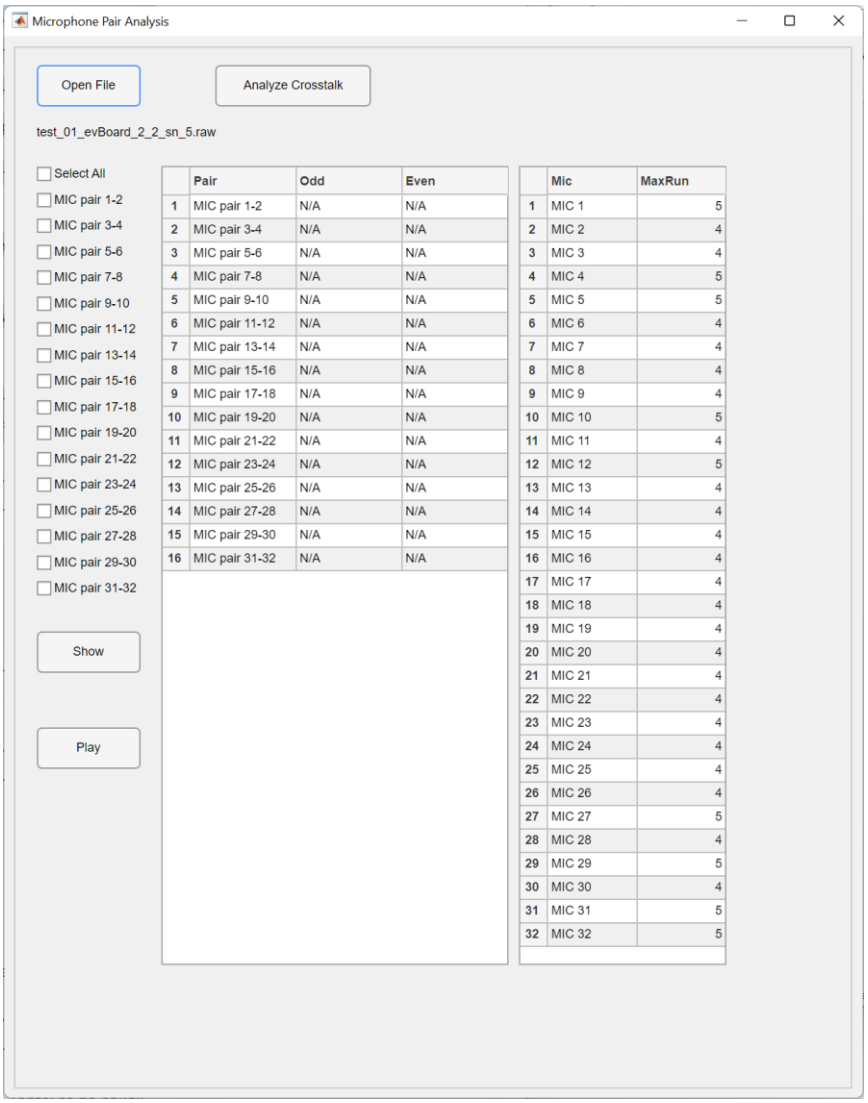

Figure 3: GUI after opening test_01_evBoard_2_2_sn_5.raw

The ‘Show’ and ‘Play’ buttons are initially disabled. They become active only after a valid .raw file is loaded. The same applies to the MIC pair checkboxes.

After a RAW file is opened, as shown in Figure 3, the GUI enables microphone-pair selection together with the ‘Show’ and ‘Play’ buttons. The ‘Play’ button plays the recorded audio waveforms for the left and right channels of the first selected microphone pair.

For the opened RAW file, a second table is also populated. This table shows the maximum run length of the PDM signal for each of the 32 microphones.

Microphone Pair Analysis View

The ‘Show’ button opens a new analysis window for each selected microphone pair, as shown in Figure 4. Each opened window contains six analysis panels.

The displayed panels include:

1. Spectrogram of the odd microphone.
2. Spectrogram of the even microphone.
3. PCM waveform and envelope of the odd microphone.
4. PCM waveform and envelope of the even microphone.
5. Histogram of PDM signal differences.
6. PDM signal bit density for the microphones.

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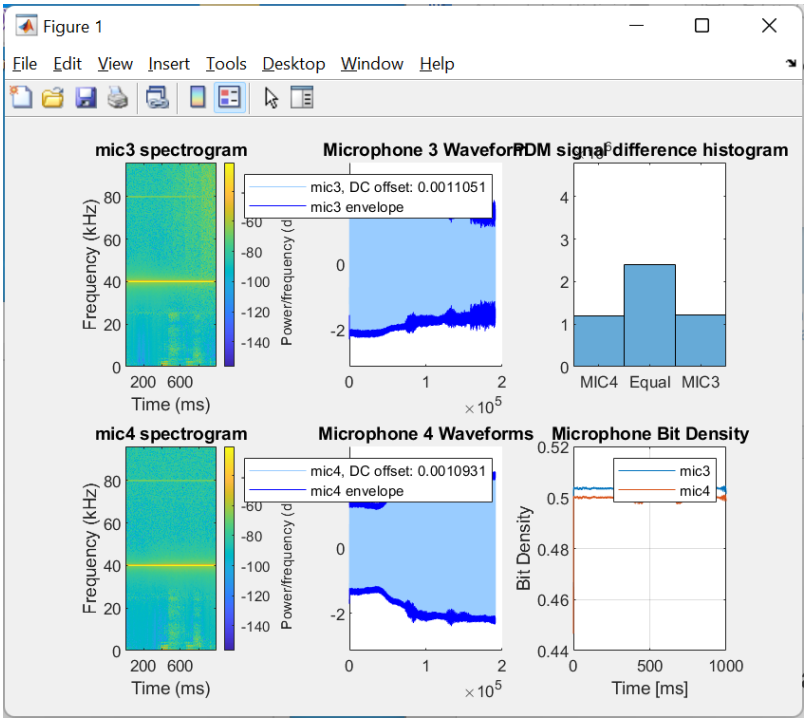

Figure 4: Data panels for microphones 3&4 include spectrograms, waveforms with envelope, PDM signal statistics and PDM signal bit density.

Crosstalk Analysis

The ‘Analyze Crosstalk’ button allows the user to select a folder containing crosstalk measurement files.

The application searches the selected folder for files matching the following pattern:

*mic_*.raw

For each matching file, the application performs the following steps:
1. Loads the RAW microphone data.
2. Extracts the microphone number from the filename using the pattern mic_(number).
3. Determines the corresponding microphone pair.
4. Computes the crosstalk value for the corresponding microphone.
5. Updates the result table with either ‚OK‘ or ‚Failed‘.

A result is considered successful when the microphone signal separation is greater than or equal to 40 dB. Otherwise, the result table displays the rounded separation value in dB.

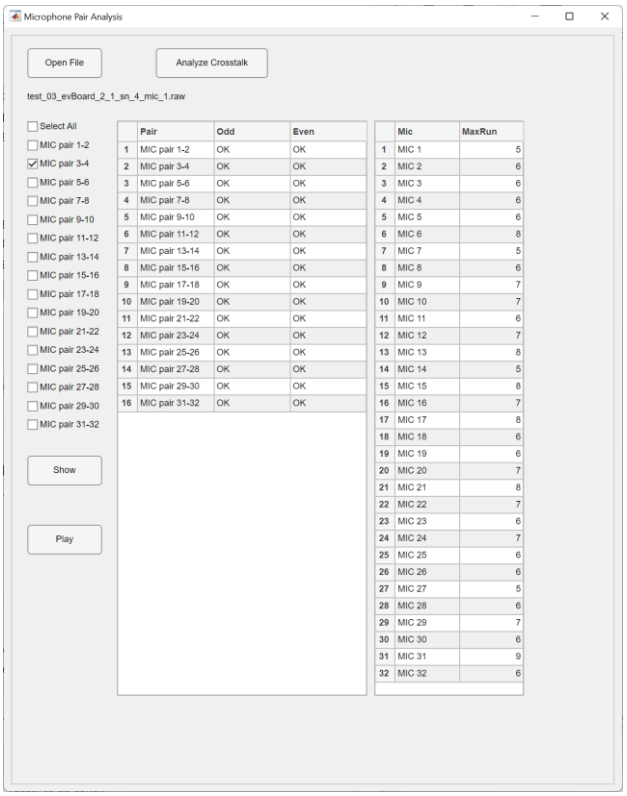

Figure 5: GUI after crosstalk data analysis, showing all microphones passing the test.

4 Beam Preview Application

4.1 Description

The Beam Preview Application is a MATLAB graphical user interface for previewing acoustic beamforming patterns of a microphone array.
The application allows the user to configure acoustic parameters, microphone geometry, beam focus position, preview resolution, and visualization mode. Based on these settings, the tool calculates and displays the normalized beam intensity either as a 2D preview or as a 3D visualization.
The GUI is intended for quick visual inspection of how a microphone array focuses acoustic energy in space.

4.2 User Interface Layout

The application controls are divided into four tabs: Basic, Plane/ISO, Array, and Options.

Basic Tab

The ‚Basic‘ tab is used to set the main acoustic and visualization parameters. It allows the user to configure acoustic parameters, define the beam focus point coordinates in 3D space, select the beam type, and choose the display mode.

Plane/ISO Tab

The ‚Plane/ISO' tab defines the 3D preview region for which the beam preview will be computed.
The preview region is defined as a 3D box. The preview plane defines a plane perpendicular to the selected axis and intersecting that axis at a specified position. The beam preview is then computed for the cross-section area produced by the intersection of the preview region box and the preview plane.

This tab also contains section-quality settings. These parameters influence the visual quality and resolution of the preview images. The user should choose an appropriate trade-off between preview quality and computation requirements.

Array Tab

The ‚Array' tab is used to select the microphone array layout.
Two array layout options are supported:

1. A linear array with a defined number of microphones and microphone spacing.
2. A custom array layout loaded from a CSV file containing the array parameters.

Options Tab

The ‚Options' tab contains additional controls that modify the behavior of the application. These options include manual preview update, image export, and view reset.

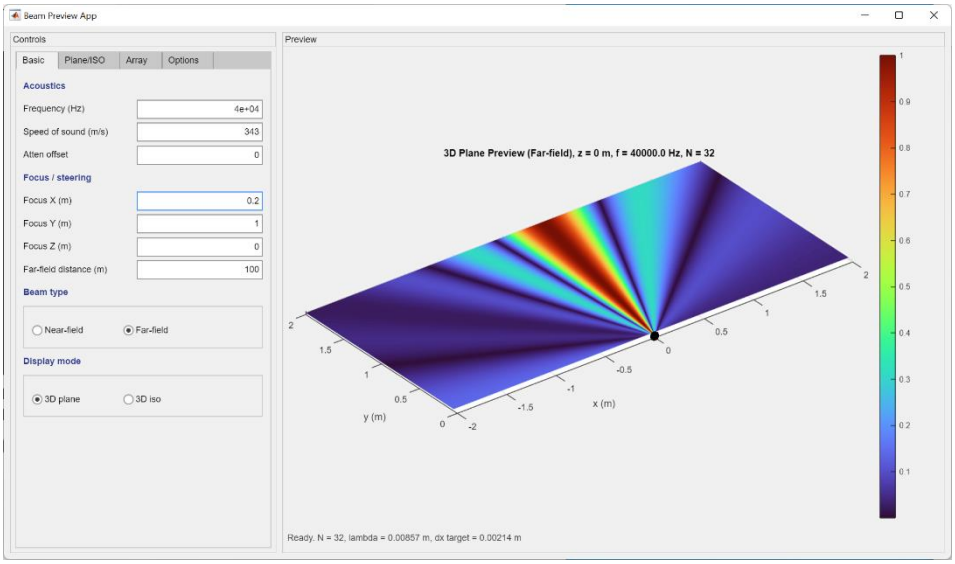

Figure 6: Example beam cross secion.

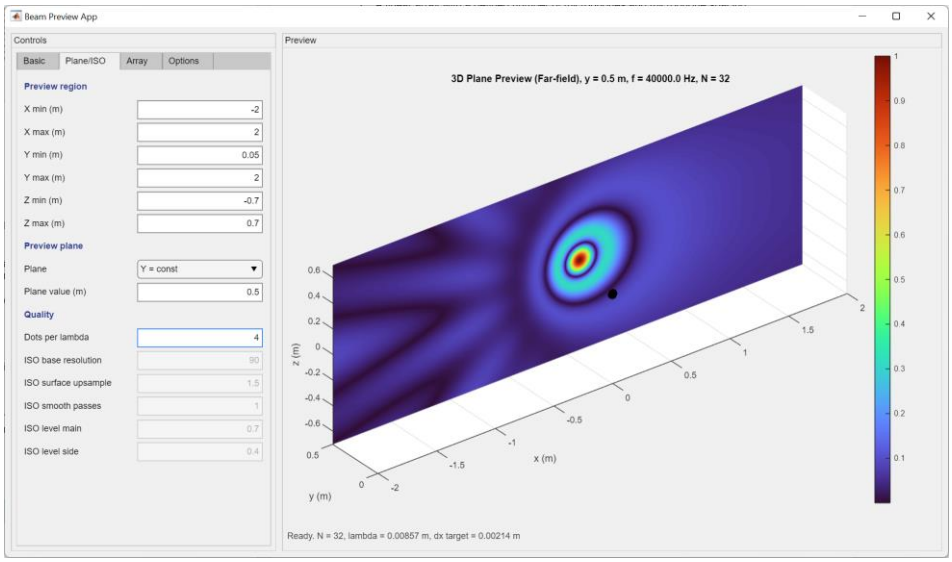

Figure 7: The same beam as in Figure 6, different plane cross section.

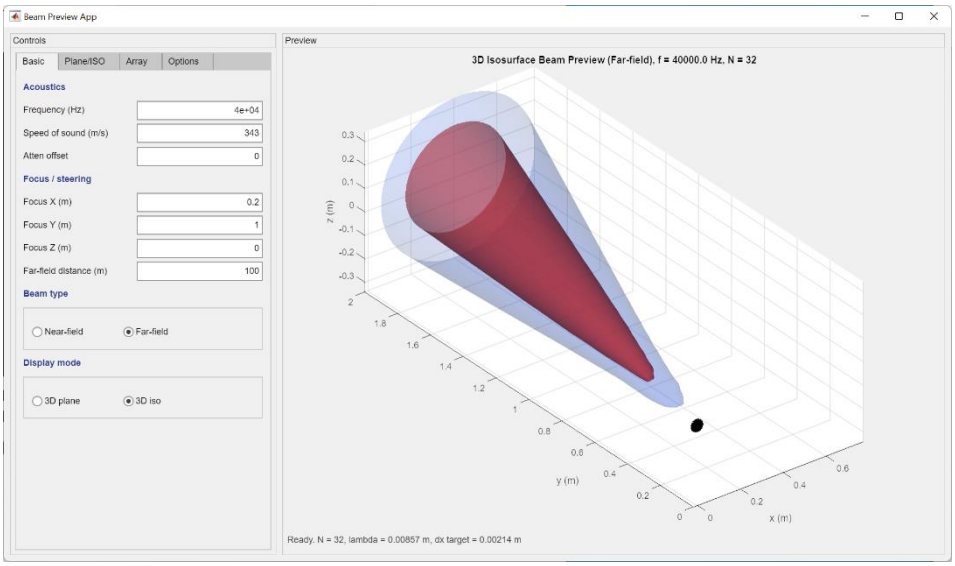

Figure 8: The same beam as in Figure 6 in 3D ISO mode.

For correct parameter configuration, use the tooltip help available for each field by hovering the mouse over the corresponding control.

5 BUT PD Viewer and Dataset Generator

The BUT PD Viewer application provides a graphical interface for loading, previewing, and exporting partial-discharge signal datasets with configurable augmentation parameters.

5.1 User Interface Layout

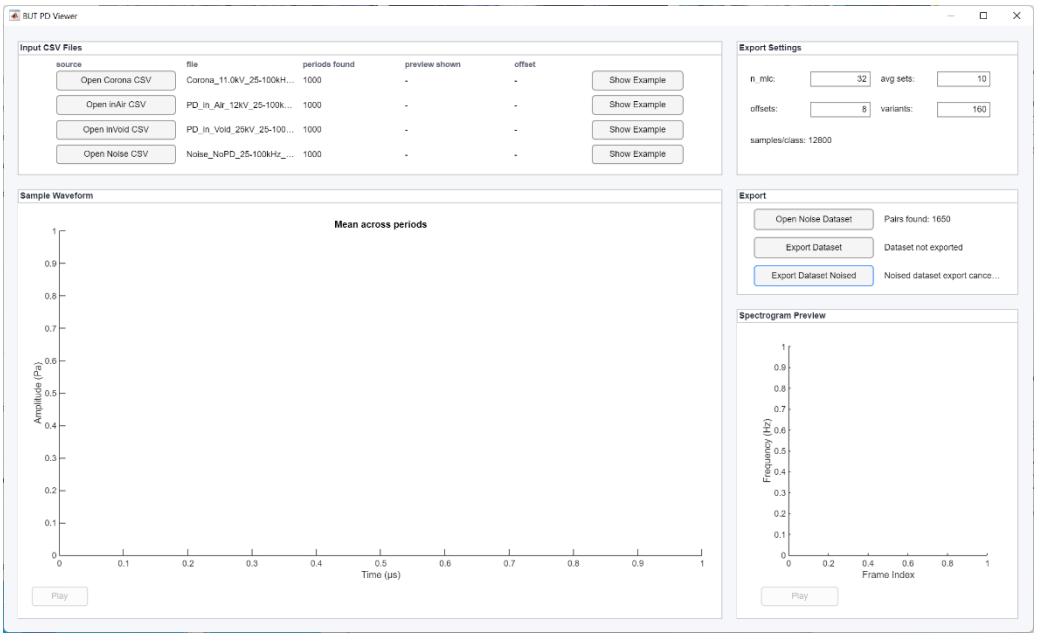

Figure 9: BUT PD Viewer & Dataset Generator GUI

The interface is divided into several functional panels:

1. The Input CSV Files panel is used to load measured signal periods from CSV files. Four input classes are supported: Corona, in-air discharge, in-void discharge, and noise. After a CSV file is loaded, the application shows the file name, the number of detected periods, the currently previewed sample, and the random offset used for spectrogram generation. The Show Example button displays either one selected period or the correlation based average waveform, depending on the n_mic setting.
2. The Export Settings panel defines how dataset samples are generated. The n_mic value sets how many randomly selected periods are correlation-aligned and averaged before export. The avg sets parameter controls how many independent random averages are generated. The offsets field sets the number of random pulse positions inside the spectrogram window, while variants sets the number of power or noise variants. The samples/class value provides a live estimate of the number of generated samples per output class.
3. The Export panel contains controls for loading a background noise spectrogram dataset and exporting generated datasets. Export Dataset creates samples using the loaded CSV noise data. Export Dataset Noised creates samples by mixing pulse spectrograms with measured background noise spectrograms.
4. The Sample Waveform panel displays the currently selected or averaged time-domain waveform. The Play button plays the displayed signal through the PC audio output. For pulse classes, the pulse is played once in the middle of a short silent window. For noise, a longer randomly assembled noise signal is used for playback.
5. The Spectrogram Preview panel displays the spectrogram generated from the current preview signal. Its Play button plays the corresponding time-domain signal used to create the spectrogram, including mixed noise when available.

5.2 Application Workflow

1. Load the CSV files for the required signal classes using the buttons in the Input CSV Files panel. Each CSV file must contain one signal period per row, with 125 samples per period.
2. Load the noise CSV file if the standard dataset export or noisy preview generation is required.
3. Optionally load the background noise dataset using Open Noise Dataset. This is required for Export Dataset Noised.
4. Set the generation parameters in the Export Settings panel:
   n_mic: number of periods used for random averaging,
   avg sets: number of independent random averaged signals,
   offsets: number of random pulse positions,
   variants: number of generated power/noise variants.
5. Use Show Example to preview individual classes. The app randomly selects the requested number of periods, aligns them using cross-correlation, averages them, and displays the resulting waveform and spectrogram.
6. Use the Play buttons to listen to either the displayed waveform or the signal used for the spectrogram preview.
7. Export the dataset using one of the export buttons. The output is organized into train and valid folders with four classes:
   0: noise only,
   1: corona,
   2: in-air discharge,
   3: in-void discharge.
8. When Export Dataset Noised is used, one more GUI window appears for each class where it can be selected random gain range be the definition the low and high bounds for each class.

6 Echo Viewer

The ‘Echo Viewer‘ is a dedicated tool available in the application launcher for analyzing data captured by the ‚capture_echo2‘ application. It provides the following visualization and analysis features:

- Displays the captured signal waveform.
- Shows the bit density of the captured signal.
- Displays the bandpass-filtered version of the captured signal for easier analysis.

This tool is intended for inspecting and evaluating captured echo signals, helping users assess signal quality and characteristics.

7 Installation Instructions

To install the tool, unpack the archive provided with this document. Open the `BeamTools_installer` folder and run the `BeamTools_web.exe` installer.

The installer requires an internet connection to download the MATLAB Runtime package if it is not already installed on the system.

The `array_data` folder contains the recorded array RAW data file `test_01_evBoard_2_1_sn_4.raw`, which can be used to test the array analyzer.

The folder `array_04_crosstalk` contains RAW crosstalk measurement files that can be used for crosstalk evaluation.

8 Notes and Current Limitations

- CSV coordinates are assumed to be in millimeters and are converted to meters.
- Large preview resolutions and ISO resolutions can slow down the GUI.