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FRACTAL

Software System for Verification and Identification of Audio Recording Equipment

User Manual

Version 1.0

February 2021

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1 Introduction

This version of the Fractal software package (hereinafter referred to as the System) solves the problems of verification and identification of audio recording equipment based on individual statistical characteristics of the noise of the equipment.

Audio recording equipment identification describes the situation when there are several phonograms (audio files) with voice recording of the speaker and it is necessary to determine whether these phonograms are created on one audio recording device or on different ones.

Audio recording equipment verification describes the situation when there is a large database of phonograms (audio files) (partially identified, partially not) and it is necessary to sort the phonograms by the proximity of the individual characteristics of the noise of the audio recording equipment for further analysis with possible subsequent identification.

This version of the System is intended for identification and verification of audio recording equipment of mobile communication devices. The use of this version of the System for other audio recording devices (for example, voice recorders) is possible, but less effective.

Usually audio recording equipment (e.g. a smartphone) is identified by the phone number or the individual number of the mobile device. However, the SIM card can be disposed of making such identification impossible.

The System uses another method and **identifies audio recording equipment through the individual characteristics of the background noise equipment itself produces.** As long as the original device is still available it is possible to verify if the message recorded was made using it or not.

The System includes several built-in databases that are used for verification and identification of audio recording equipment. Depending on the closeness of the characteristics of the equipment noise in audio files and phonograms' duration the probability of an error in identifying audio recording equipment can be 0.01% or less.

At the core of the system is the built-in **Noise Characteristics Selection module** for audio recording equipment. This module analyses and highlights ambient noise characteristics, unique for each digital audio recording device.

The basis of the probabilistic identification of audio recording equipment is the graphs of errors of the first and second kind. These error probabilities of the first and second kind are used directly in solving problems of identification and verification of equipment.

This version of the System has three localizations - English, Russian and Ukrainian. At the request of the Customer, the System can be supplemented with any language localization.

1.1 Source Audio Requirements

- Optimal duration: 200 ms and longer
- Minimum duration: 30 ms

- Maximum duration: unlimited
- Audio file formats: .mp3, .ac3, .aac, .ogg, .wma, .aiff, .asf, .au, .flac, .mp2, .avi, .flv, .mp4, .m4a, .wav (at least 44100 Hz and 16 bit)

1.2 Hardware Requirements

- Processor: from 2 GHz
- RAM: at least 4 GB (preferably 8 GB)
- OS: Windows 10 (64 bit).

2 Principles of audio recording equipment identification

Special characteristics of the wavelet analysis distinguish the characteristics of the audio recording equipment between two phonograms. As studies and long-term tests of the System show, these characteristics can be identified automatically as individual characteristics of the noise of audio recording equipment.

When the characteristics are selected, an integral comparison criterion is formed: the distribution of characteristics by fractal scales for each of the two phonograms. The final conclusion regarding audio recording device verification and identification is made based on the proximity of integral criteria.

The System can analyze audio recordings of various durations, lasting from 30 to several hundred milliseconds. The dimensions of the time windows in the analysis are determined adaptively, depending on a number of factors. This allows the System to analyze even time windows ranging from 10 to 30 ms.

The System uses probabilistic characteristics for solving verification and identification problems. All probability characteristics in the form of graphs of errors of the first and second kind were determined using rigorous tests (for various groups of audio recording equipment and phonograms of various duration) based on previously prepared experimental data. These error graphs are automatically used in the System for making verification and identification decisions.

2.1 Main features

1. Verification and identification problems are solved based on the analysis of the proximity of the noise characteristics of the audio recording equipment.

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2. The efficiency of the analysis of phonograms depends on the time duration of the phonograms. It is possible to analyze with a high degree of precision fragments starting from 30 ms.

3 System Installation

3.1 Operating System

The System requires Windows 10 (64 bit version).

3.2 Installation Package

The System installation packages includes the following:

1. The executable file of the system: Fractal_17_2021_01.exe,
2. Files and directories that support the operation of the System,
3. User manual.

3.3 Installation

Follow these steps to install the System:

1. Unzip the package and copy the Fractal's system folder with the entire System kit to your computer's hard drive.
2. Before the first launch of the System it has to be activated on this specific computer. To activate the System, open the folder with Fractal.exe file and run the file Read_Activation_08_2019_FL.exe and send the key to the System Provider.
3. After receiving the activation file File_rdkd.svi from the Provider, copy this file to the folder with Fractal.exe and replace the previous File_rdkd.svi file.
4. Launch the System by running Fractal_17_2021_01.exe file directly or by using the desktop icon.

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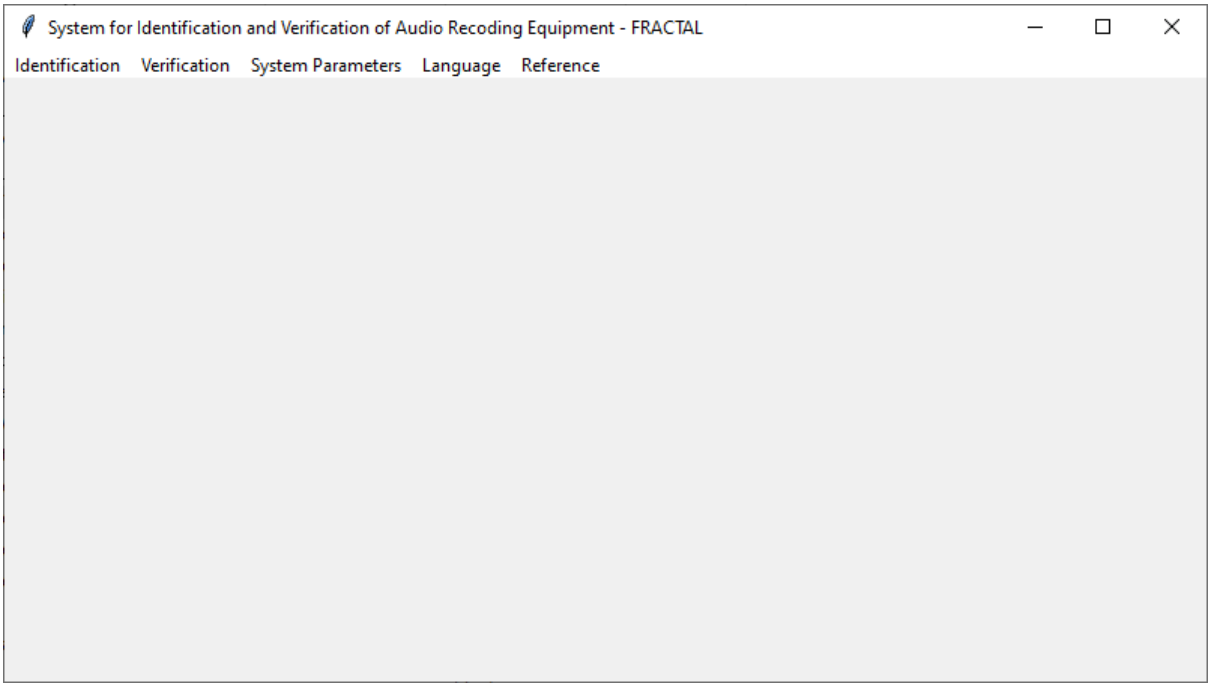

Fig. 1 Fractal System menu window

4 Main Menu

4.1 Identification

Identification menu includes two sections: Identification and Parameters of Equipment.

4.1.1 Identification

This option is for recording all the relevant characteristics of the audio recording equipment used to make a particular phonogram. All characteristics are recorded in designated .svis files in the embedded database.

Note
All data processed during identification is entered into a database directory called Dir_Ident. To use different groups of processed phonograms in the analysis later, copy the Dir_Ident folder to another directory. Then it is safe to delete its content and to accumulate new phonogram characteristics. All characteristics of various files in Dir_Ident have a name identical to the name of the original .wav file and .svis file extension.

Steps:

1. Click on Identification → Identification.
2. A window for selecting a .wav file for analysis opens:

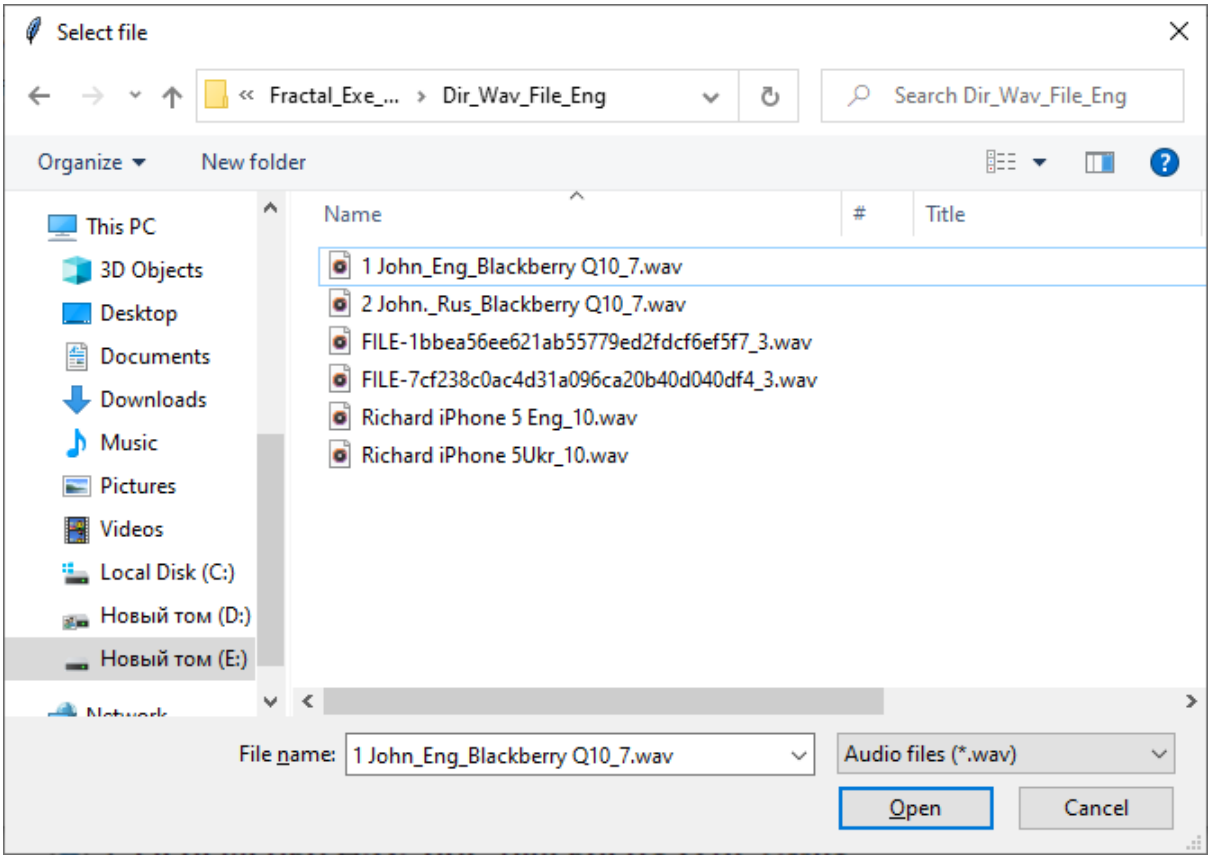

Fig. 2 Window for selecting a file for analysis

3. Select the file and click on Open.
4. Procedure for automatic analysis and data processing starts. All data is entered into the directory - Dir_Ident.

4.1.2 Parameters of Equipment

This menu option initiates audio recording equipment identification process.

Steps:

1. Make sure that files with voice characteristics for the audio files in question are in the Dir_Ident directory.
2. Click on Identification → Parameters of Equipment
3. A window for selecting .svis files with audio recording equipment characteristics opens:

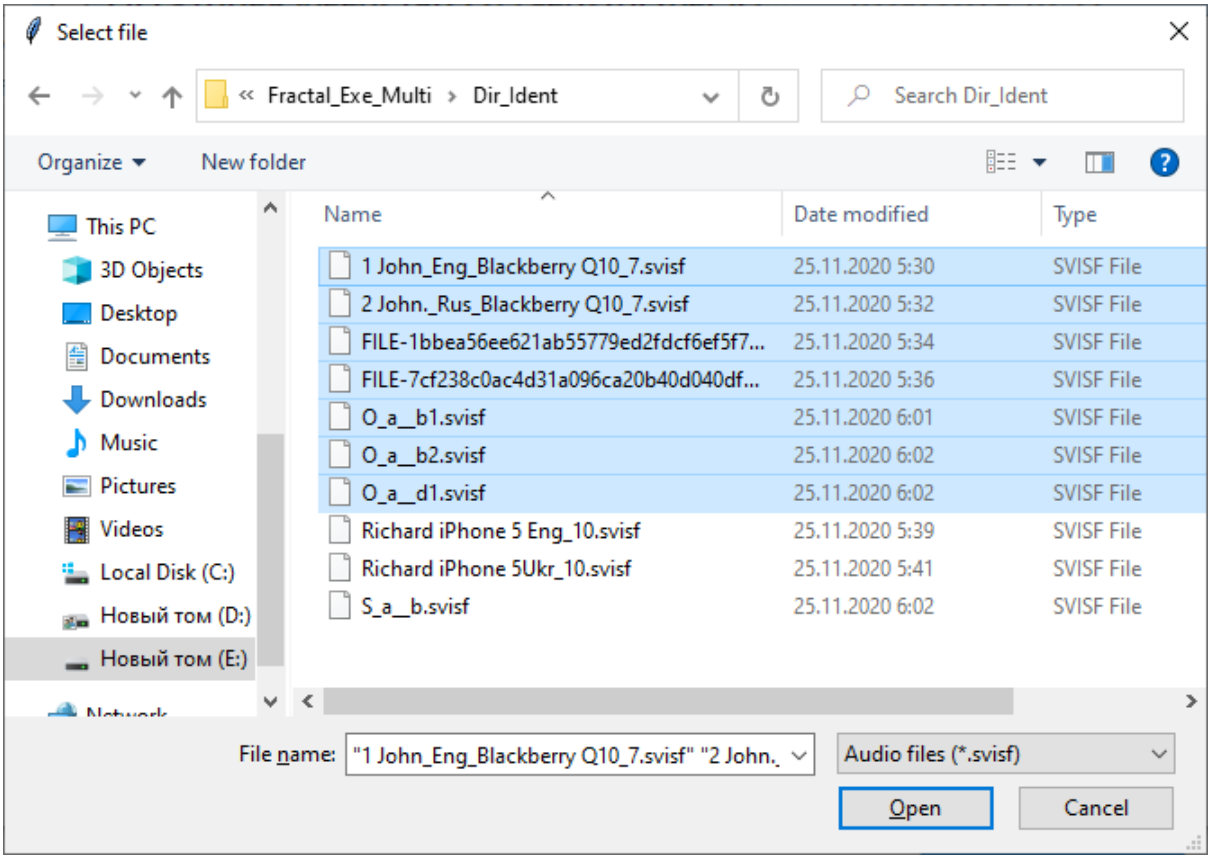

Fig. 3 File selection window for subsequent comparative analysis.

Note
All files for comparative analysis are located only in the Dir_Ident (and copied) directories. it is also possible to use the verification directories - Dir_Verification (see below).

For multiple selection press Ctrl and left-click to select the files for analysis..

4. Select several .svis files for analysis
5. Click Open.
6. Phonogram Listing window with files characteristics opens:

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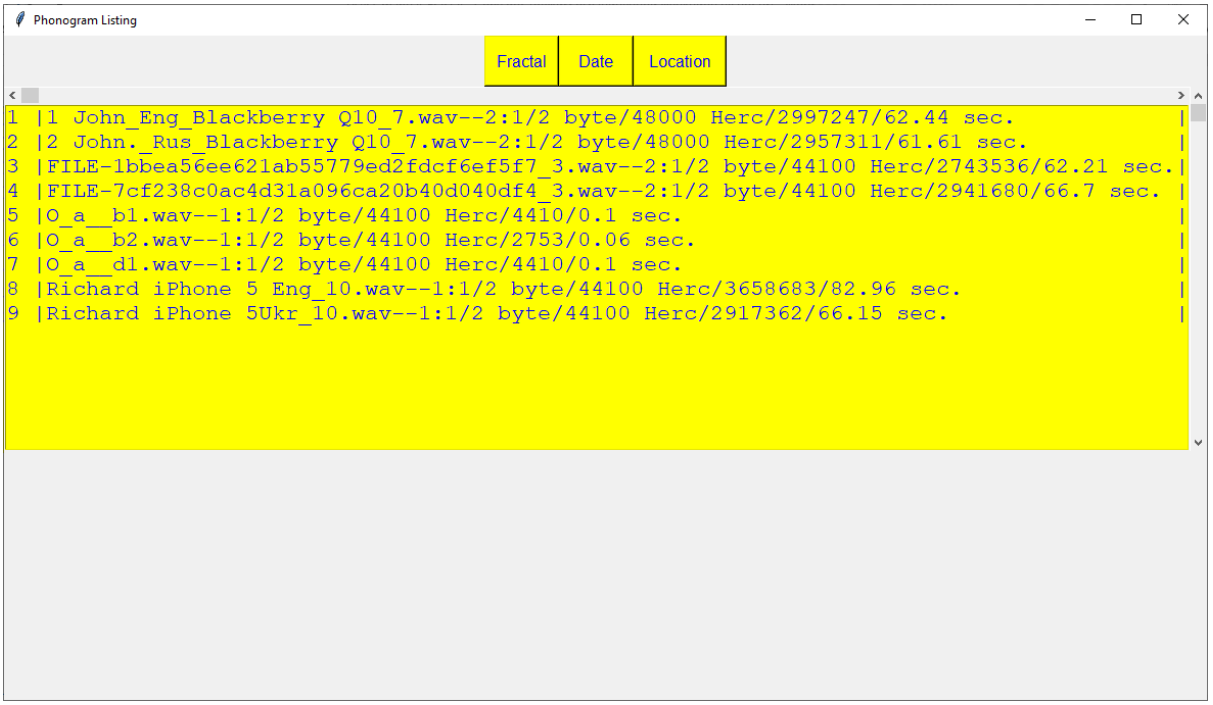

Fig. 4 Window listing the characteristics of files.

Each line includes the following information for the file:

- file name,
- number of channels: selected channel,
- bit capacity (bytes),
- sampling frequency,
- file size (bytes per channel),
- phonogram duration (sec.)

Additionally, during the initial recording of the characteristics, the current date and location are entered. The location is set to “Unknown” by default.

Location and date can be edited later on, and the list can be sorted by the location.

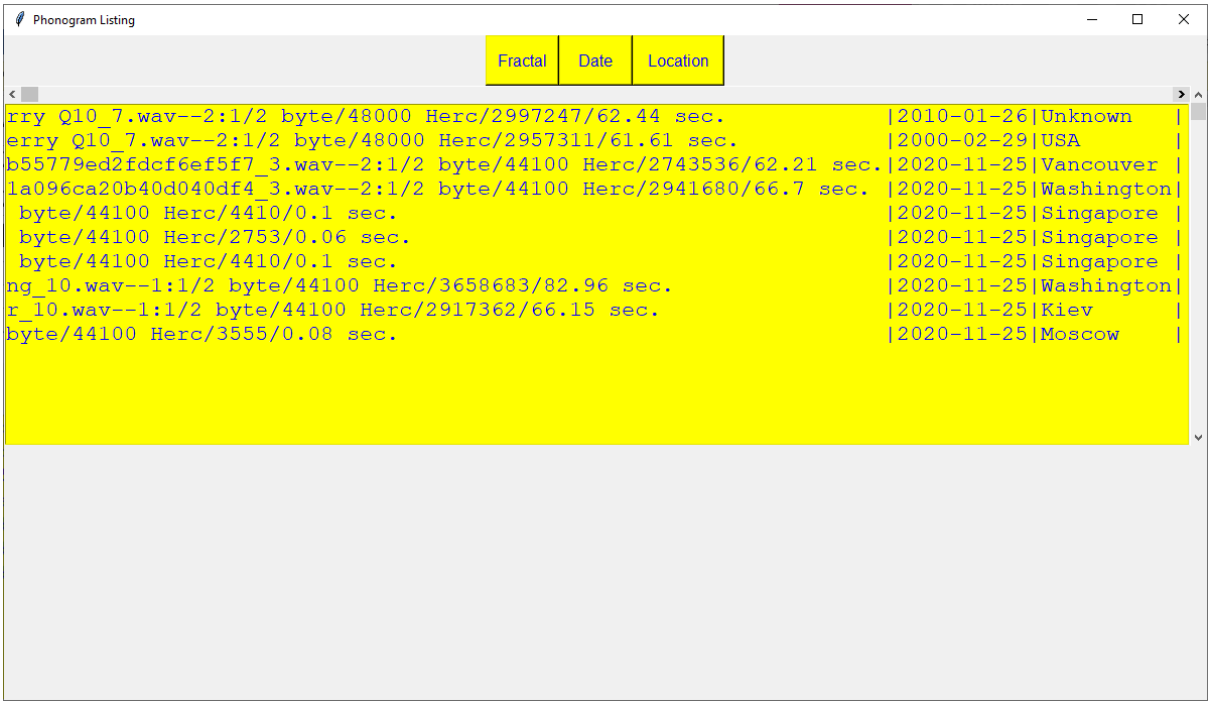

Fig. 5 Date of entry and where the files come from (default)

Phonogram Listing form contains **3 operation buttons**: Fractal, Date and Location.

Fractal is an option for comparative analysis of the distribution of the characteristics of the equipment noise over fractal scales. Whether the audio recording equipment is identical or not is calculated automatically (see Fig. 6)

To save the graphs click on the Save button in the left lower corner of the window.

For the description of the technology for the decision making for the device identification see System Parameters section.

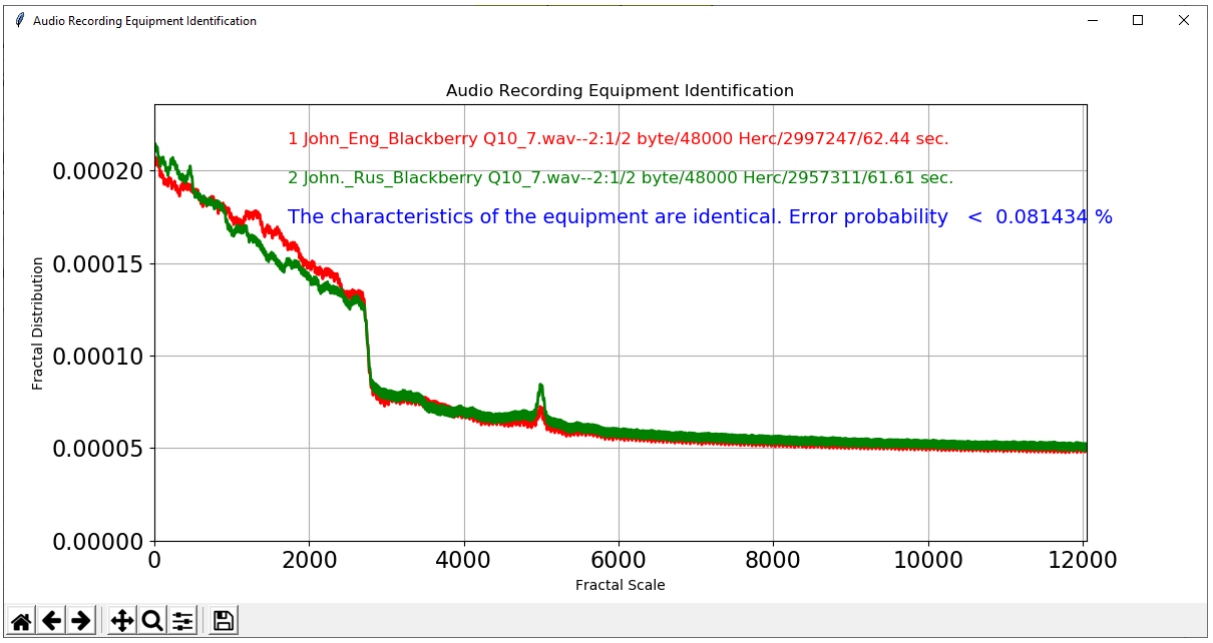

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Fig. 6 Comparative analysis of the distribution by fractal scales.

Date button is for editing the phonogram date when necessary. To open the calendar, select the entry and press the Time button. Then select the correct date and click OK to save it (see Fig.7).

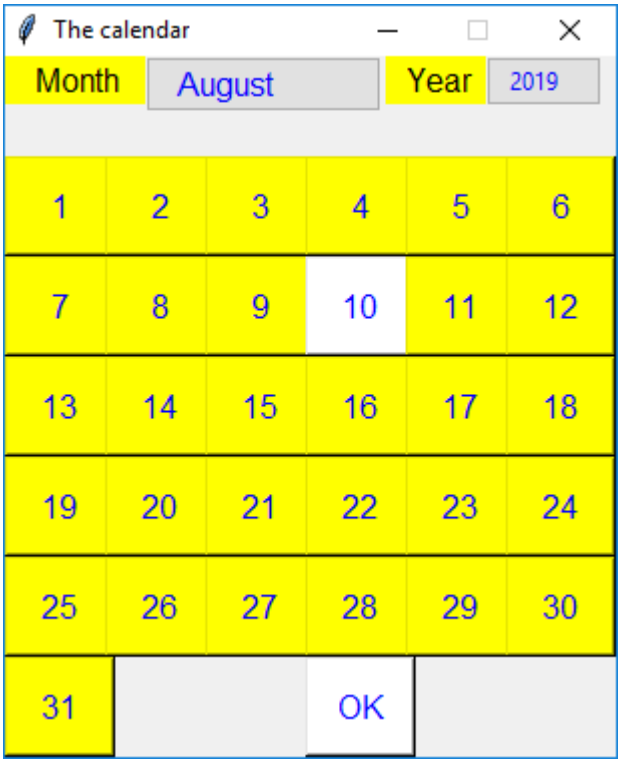


Fig. 7. Editing the soundtrack date.

Location button is for editing the place of receipt of the phonogram. To access the Phonogram reference (location) window, select the phonogram in the Phonogram Listing window and press the Location button. Choose the correct location, then click on the Select button to save it.

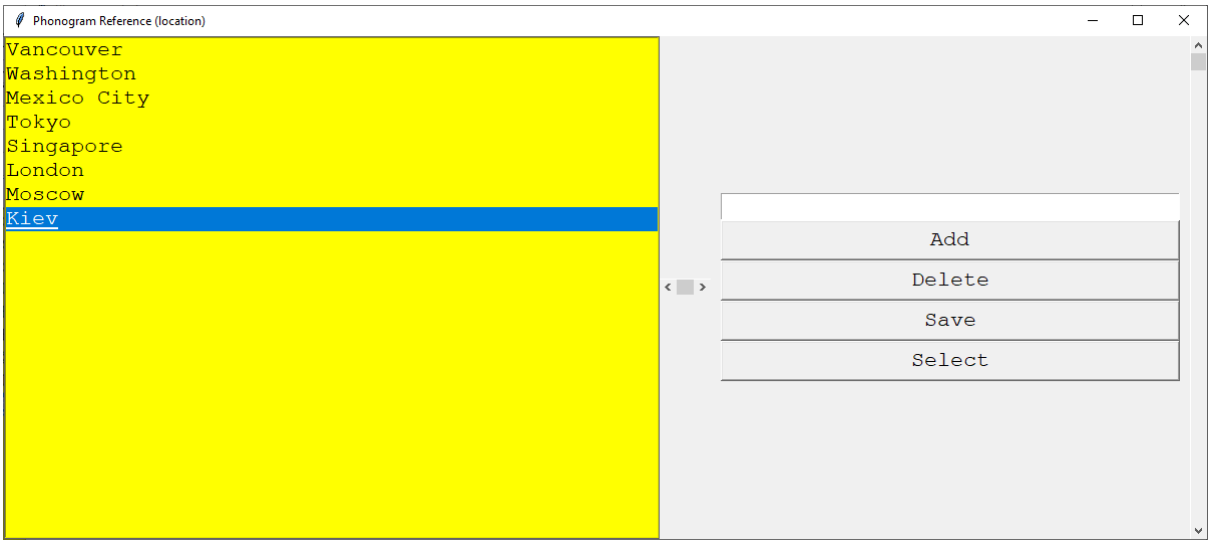


Fig. 8 Phonogram reference (location)

The reference is editable.

The location references can be edited. You can add to the directory any entries in any language and it is also possible to delete any entries.

Note
When filters are turned on at the place of localization of phonograms, filtering collisions are possible (see Verification section). This may happen when places of receipt are different.

4.2 Verification

This option is for sorting phonograms by the proximity of the noise characteristics of the equipment and for further analysis of the sorting listing.

Verification includes two sections: Verification and Verification Listing.

4.2.1 Verification

This section allows the processing and recording of noise characteristics of equipment from a specific directory with audio files. The entire set of files of the selected directory is processed.

Steps:

1. Click on Verification → Verification.

2. A window for selecting a directory with .wav files opens

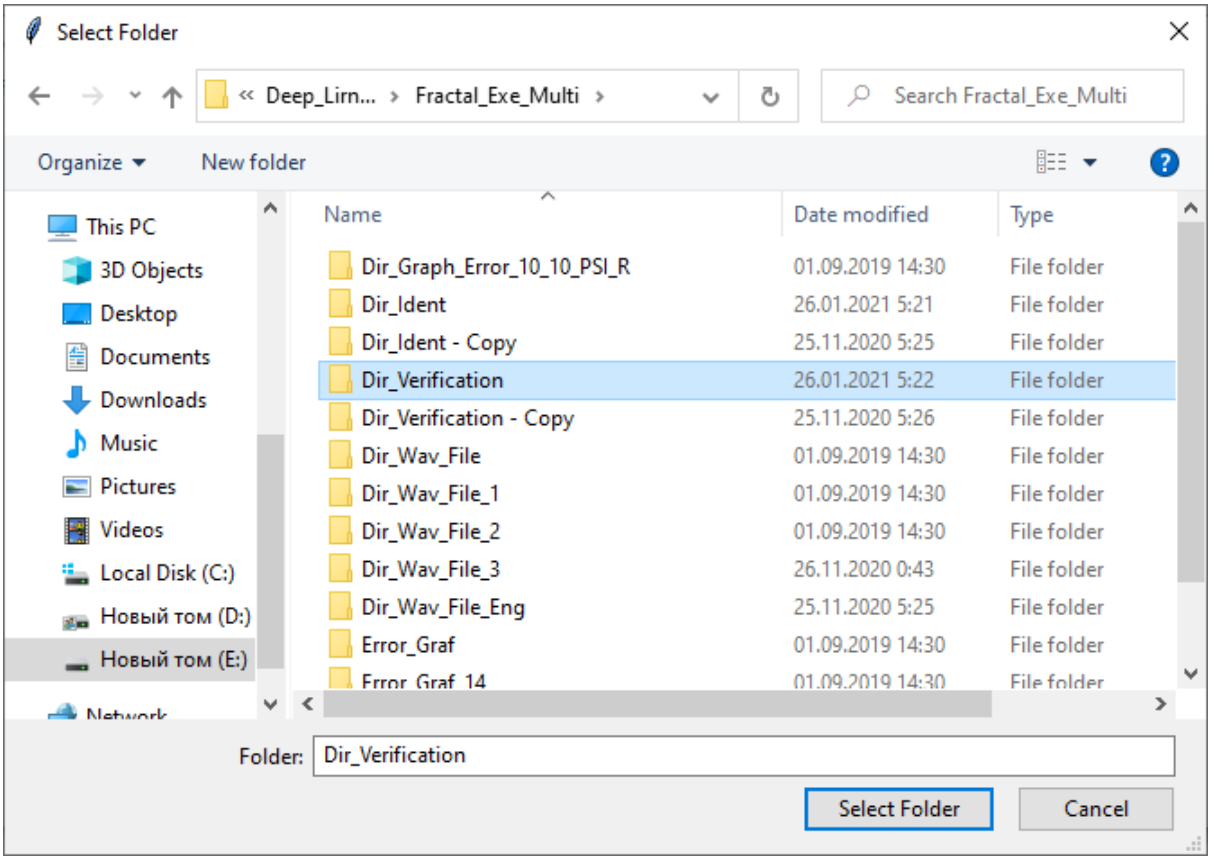


Fig. 9 Selecting the file directory for verification

3. Select the directory, the file analysis process follows automatically.

Note
If there is a large number of files, this process can take a lot of time. 60 sec. file takes about 2-3 minutes to process on a computer with a processor with a clock frequency of 3 GHz. It is better to select a directory with the appropriate number of files. Records for verification can be added in stages from different directories.

All analysis files are written to a common directory - Dir_Verification.

To create several directories with different verification options, copy the Dir_Verification directory after each analysis session. Then it is possible to use different directories when sorting speakers.

4.2.2 Verification Listing

This menu option initializes sorting the phonograms by the proximity of the individual characteristics of the equipment noise.

Steps:

1. Click on Verification → Verification Listing in the main menu.
2. A window for selecting a directory for analysis and sorting opens

3. Select the directory that contains files with the results of the analysis for identification and verification (file extensions: .svidf, .svif, .svisf, .svid). For example, Dir_Verification, Dir_Ident or various copies of these directories.
4. Verification Listing window with files available for sorting opens:

Fig. 10 Verification Listing directory of files for sorting

The parameters of each record are the same as parameters of records in the Identification section.

This Verification Listing form contains **6 operation buttons.**

Sorting operation button sorts phonograms by the proximity of the integrated noise characteristics of the audio recording equipment (see Fig.11). To sort the files, first select the record relative to which the sorting should be done, then click on the Sorting button.

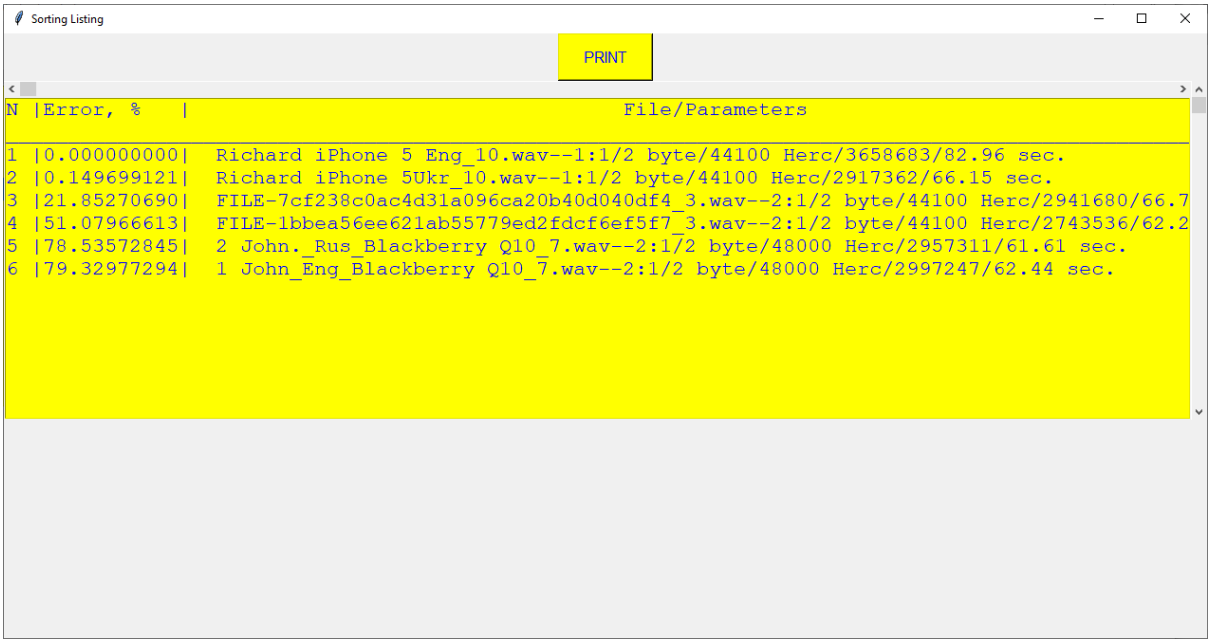


Fig. 11 Sorting Listing window

The second column in the Sorting Listing window is the probability of a mistake of the first kind when comparing two phonograms. Sorting is carried out by this value. This value depends on the duration of the phonogram, and a number of other factors. The system automatically makes decisions on these parameters. A detailed description of the technology in the System Parameters section.

Sorting Listing Fields:

N - index number

Error,% - the probability value of the error of the first kind in percent. Using this value, records are sorted by the proximity of the characteristics of the voices.

File / Parameters - file name, number of channels, bit depth (bytes), sampling frequency, file size (bytes per channel), duration (sec.).

Date - date of the phonogram recording

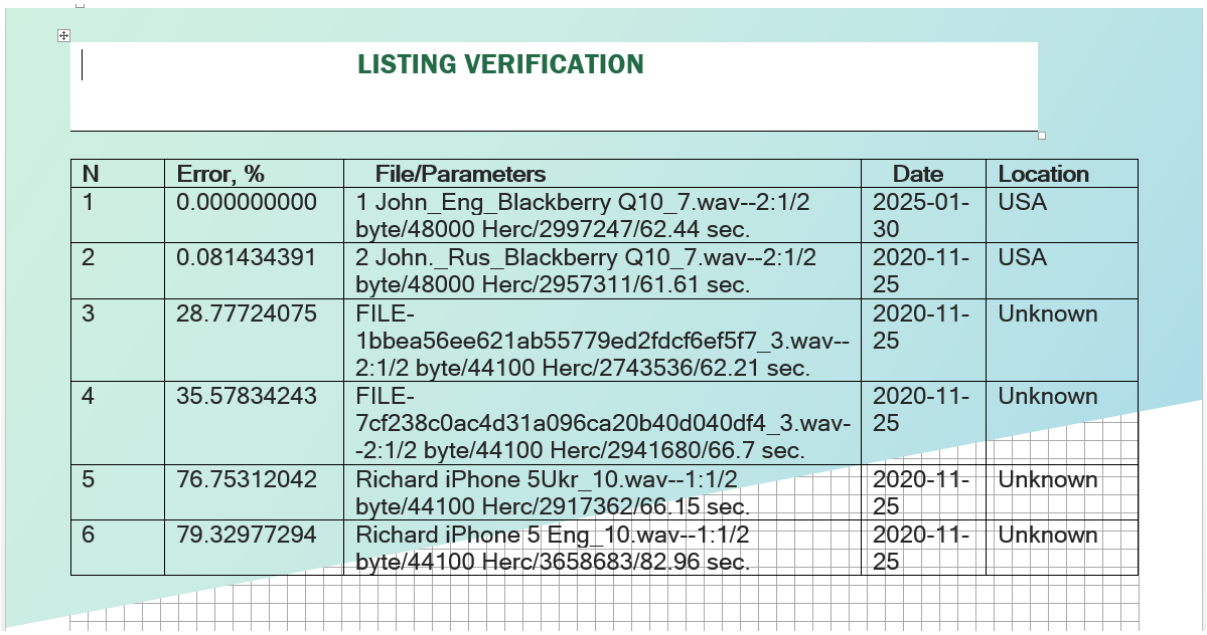
Location - the place of receipt of the phonogram.

Sorting listings can be saved in an editable MS Word document template. Click the PRINT button to print or save the sorting listing. The document is saved in the directory - Report.

IMPORTANT In most cases, the value of the error during verification cannot serve as a measure of the probability of the error of identification of audio equipment in the sorting list to make a decision. If a sorting list contains several thousand or even several hundred records, the number of similar characteristics of voices can be significant.

To automate the decision making in case of audio equipment verification a decision threshold for the magnitude of the error is used. However, this threshold in most cases will be subjective.

If necessary, sorting listings can be remembered in an editable Word document template. Option - PRINT. (Fig. 12)



LISTING VERIFICATION

N	Error, %	File/Parameters	Date	Location
1	0.000000000	1 John_Eng_Blackberry Q10_7.wav--2:1/2 byte/48000 Herc/2997247/62.44 sec.	2025-01-30	USA
2	0.081434391	2 John._Rus_Blackberry Q10_7.wav--2:1/2 byte/48000 Herc/2957311/61.61 sec.	2020-11-25	USA
3	28.77724075	FILE-1bbea56ee621ab55779ed2fdcf6ef5f7_3.wav--2:1/2 byte/44100 Herc/2743536/62.21 sec.	2020-11-25	Unknown
4	35.57834243	FILE-7cf238c0ac4d31a096ca20b40d040df4_3.wav--2:1/2 byte/44100 Herc/2941680/66.7 sec.	2020-11-25	Unknown
5	76.75312042	Richard iPhone 5Ukr_10.wav--1:1/2 byte/44100 Herc/2917362/66.15 sec.	2020-11-25	Unknown
6	79.32977294	Richard iPhone 5 Eng_10.wav--1:1/2 byte/44100 Herc/3658683/82.96 sec.	2020-11-25	Unknown

Fig. 12. Printing Verification Listing

Date and **Location** operational buttons are the same as corresponding buttons in the Identification section.

Filter by Date option is for preliminary filtering before sorting phonograms by time.

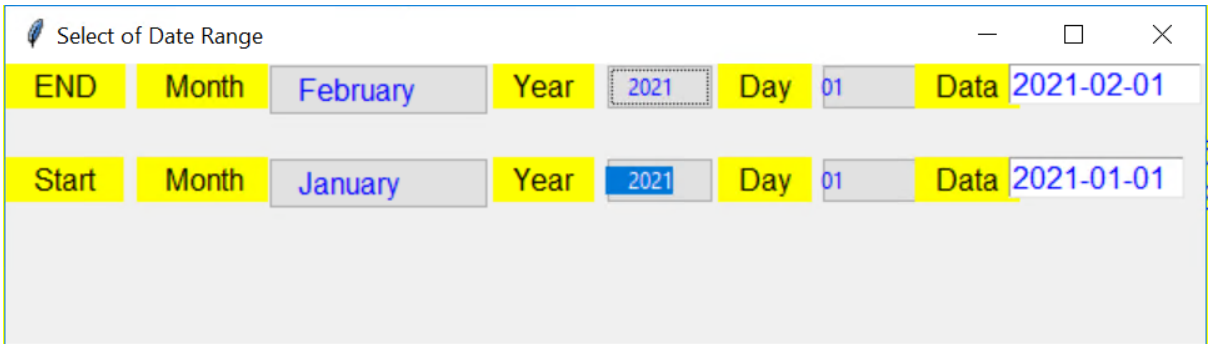


Fig. 13 Filtering phonograms by time

Filter by Location option is for preliminary filtering by the place of receipt of phonograms. To filter the records select the place of receipt, then click on Select apply the filter (see Fig. 14).

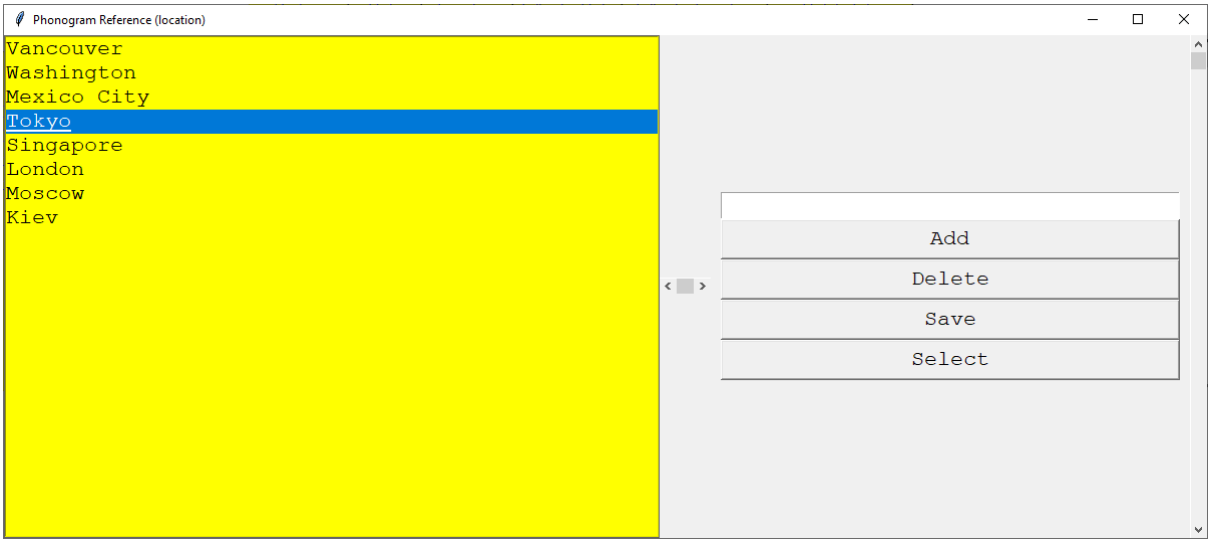


Fig. 14 Filtering by the place of receipt of phonograms

Delete File button is for deleting files with identification and verification parameters from the corresponding directories. Files in the identification and verification directories are part of the built-in relational database. Removing them directly (with the Windows options) can lead to a violation of the integrity of the system.

To properly delete the files manually using Windows File Explorer, delete all three files with the same name and three different extensions (.svif, .svisf, .svidf).

4.3 System Parameters

System Parameters menu Includes three sections: System Parameters, Phonogram Reference (location), Error Plots.

4.3.1 System Parameters

Steps:

1. To open System Parameters, click on System Parameters → System Parameters in the main menu.
2. Parameters Window opens.

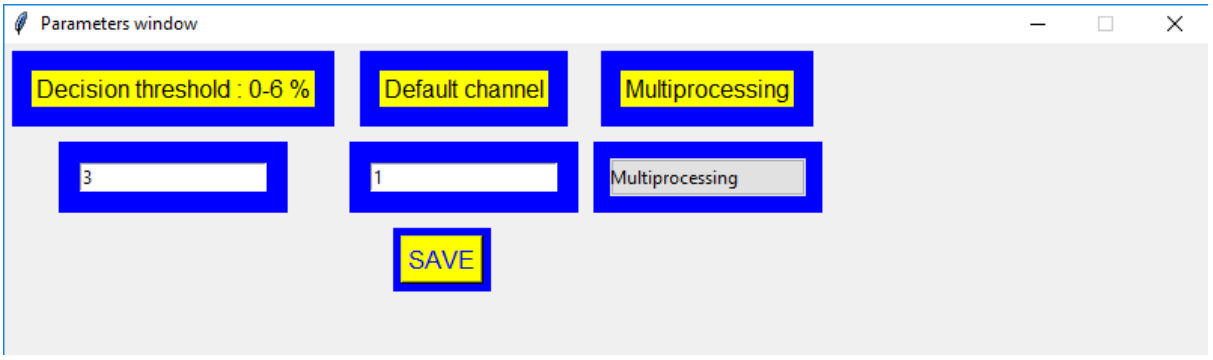


Fig. 15 System Parameters window

System Parameters form sets three important system parameters: Decision Threshold for identification, Default Channel and Multiprocessing.

3. Make the changes to the System parameters.
4. Click on the Save button.

4.3.1.1 Decision Threshold

To better understand how the Decision Threshold operates, refer to the example below.

Consider a graph of errors of the first and second kind with a duration of phonograms of 10 to 20 seconds. The intersection point of the error graphs is 5.09% (see Fig. 16).

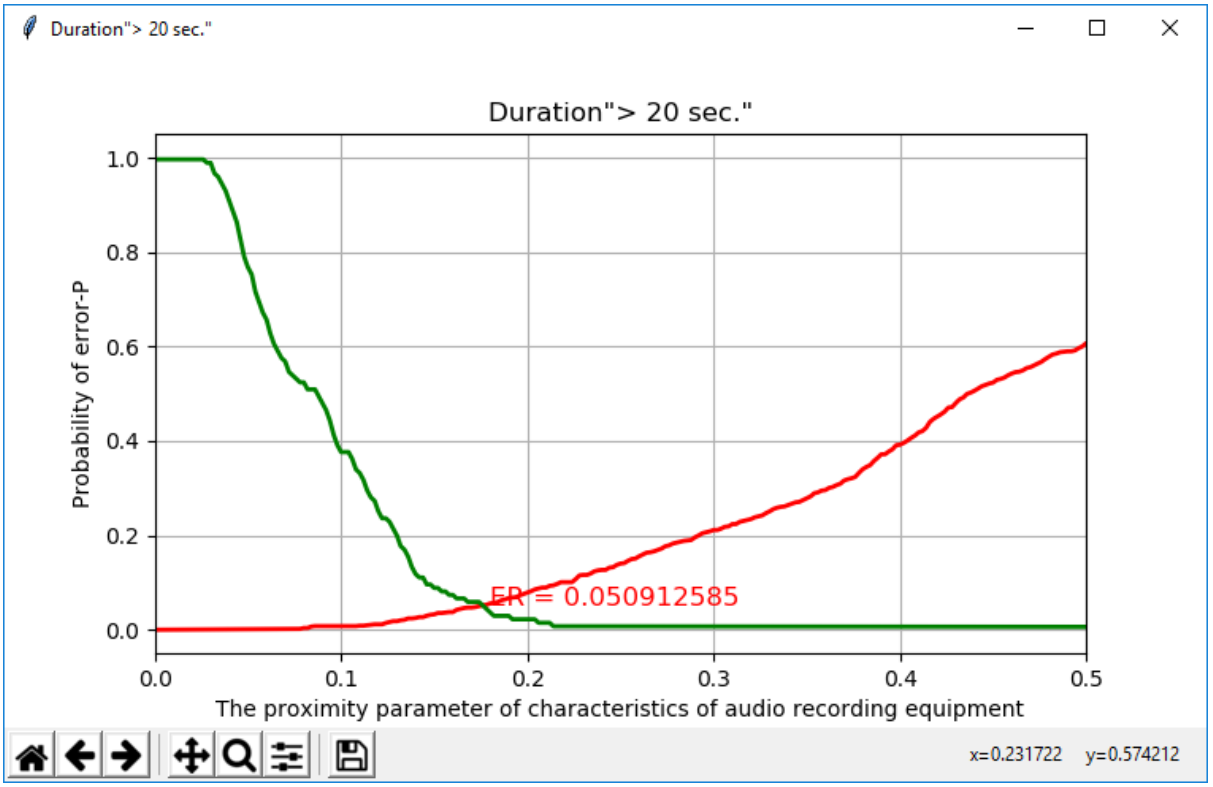


Fig. 16 Graph of errors of the first and second kind

The System provides four types of decisions:

1. **Characteristics of the noise of the equipment are identical.** When the proximity of the parameters of the integral characteristics of the noise of the audio recording equipment for two recordings of equivalent probability, the value of which is less than the decision threshold (and less than the point of intersection of the error graphs), for example 1% (0.01). All probabilities for the first grade are determined from the graph of type I errors (red graph).

2. **The noise characteristics of the equipment may be close.** This decision for two audio recordings is made when the proximity of their characteristics is more than the decision threshold, but less than the intersection point of the error graphs. For example, the error

value is 3% (0.03). All probabilities are determined from the graph of the first kind errors (red graph).

3. **The noise characteristics of the equipment may vary.** This decision for two audio recordings is made when the proximity of their characteristics is more than the decision threshold, but less than the intersection point of the error graphs. All probabilities are determined from the graph of the second type errors (green graph).

4. **The noise characteristics of the equipment are different.** This decision for two audio recordings is made when the proximity of their characteristics is less than the decision threshold. All probabilities are determined from the graph of the second type errors (green graph).

Thus, the identification of the parameters of the noise characteristics of the audio equipment of the two phonograms and their differences depends on the subjectively accepted value: the decision threshold. The subjectivity of setting the threshold value is due to the physical nature of the identification problem.

The preliminary recommended threshold value is 3% (0.03).

Recommended threshold values based on the duration of the phonograms:

- Over 20 seconds - 3% (0.03)
- From 10 to 20 seconds - 4% (0.04)
- From 3 to 10 seconds - 5% (0.05)
- From 1 to 3 seconds - 6% (0.06)
- Less than 1 second - 6% (0.06)

If the length of the phonograms is different, it is recommended to set the threshold for decision-making by the length of the phonogram with minimum duration.

The second value of probability - the point of intersection of graphs - is a more objective factor in decision making, because it is based on extensive testing of hundred thousands of phonograms in the specifically prepared data sets.

4.3.1.2 Default Channel

When analyzing phonograms, one recording channel is analyzed. If there are several recording channels, it is necessary to indicate which recording channel will be analyzed by default.

IMPORTANT If there are multiple audio channels, it is necessary to analyze all the channels. Each audio recording channel contains an individual characteristic of audio recording equipment. The characteristics of the audio channels of the same mobile communication device can vary significantly. This is why identification through different channels can produce different results.

Testing on large databases shows that if there is positive identification through at least one audio recording channel, it is possible to decide on the identity of mobile communication devices which were used for recording.

When analyzing several audio recording channels of the same phonogram, it is necessary to give different file names for each channel, because the data is entered into the database of equipment characteristics based on a file name. Another option is to accumulate phonogram processing data on various channels in different folders.

4.3.1.3 Multiprocessing

If there is a multi-core processor, the system will use parallel processing to carry out the calculations by default.

However, in some cases this may not be the best choice. If there is not enough RAM for the operation of several processors or if during verification there are few files and their duration is too small, the speed-up of calculations due to multiprocessing will be negligible and in some cases even negative.

To cancel multiprocessing, select the Single Processor option and click on the Save button to apply the changes.

4.3.2 Phonogram Reference (location)

To add new locations or delete locations from the list of available options for phonogram editing:

1. Click on System Parameters → Phonogram Reference (location).
2. Phonogram Reference (location) window opens:

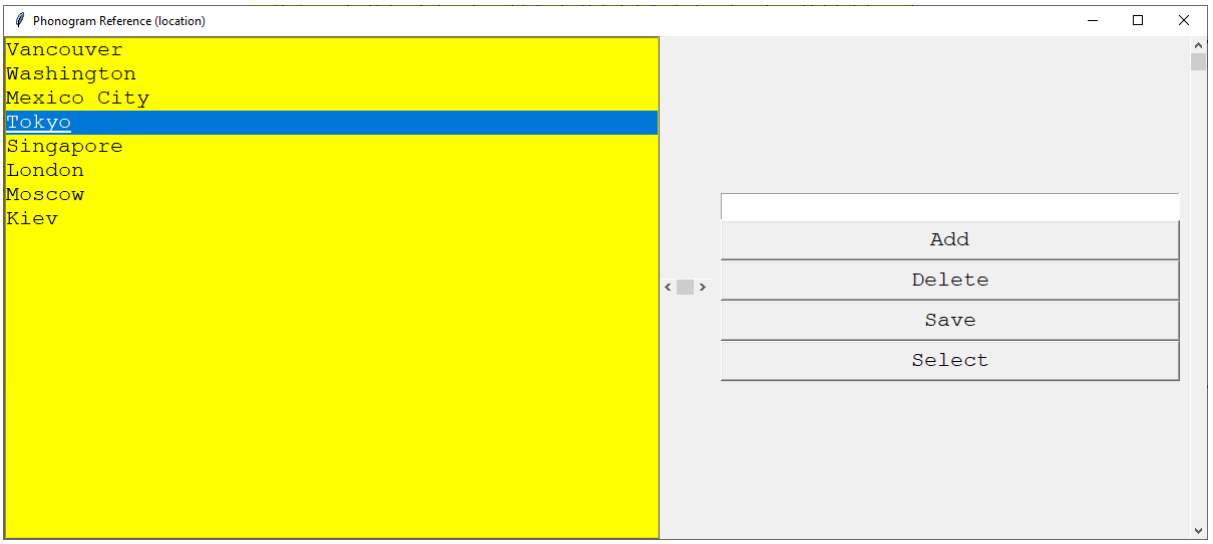


Fig. 17 Phonogram Reference - Location

3. To delete the location select it from the list and click on the Delete button.
4. To add the location type in the white space and click on the Add button.
5. Click on the Save button to apply the changes.

4.3.3 Error Plots

Error Plots menu option shows error graphs for the following time ranges:

- < 3 sec.
- >= 3 < 10 sec.
- >= 10 < 20 sec.
- >= 20 sec.

To view the error graphs:

1. Click on System Parameters → Error Plots
2. List_Fono window opens.
3. Select the time range from the list and click on the Save button.

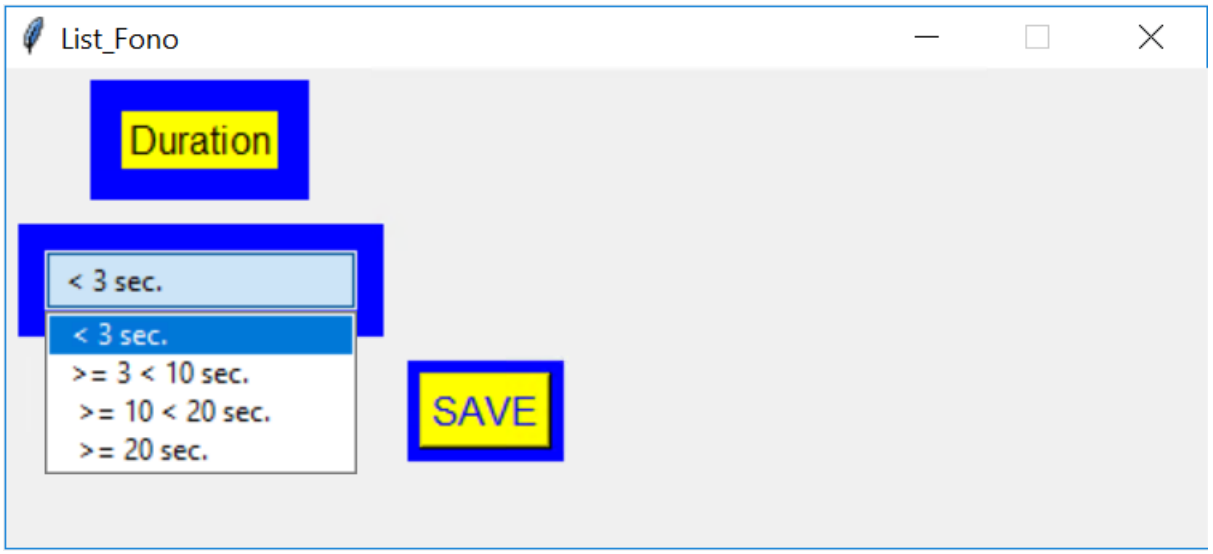


Fig. 18 Graphs of errors

4. The error graph for the selected time range opens in a new window.
5. To save the graph click on the Save icon at the bottom of the graph window (see Fig. 19):

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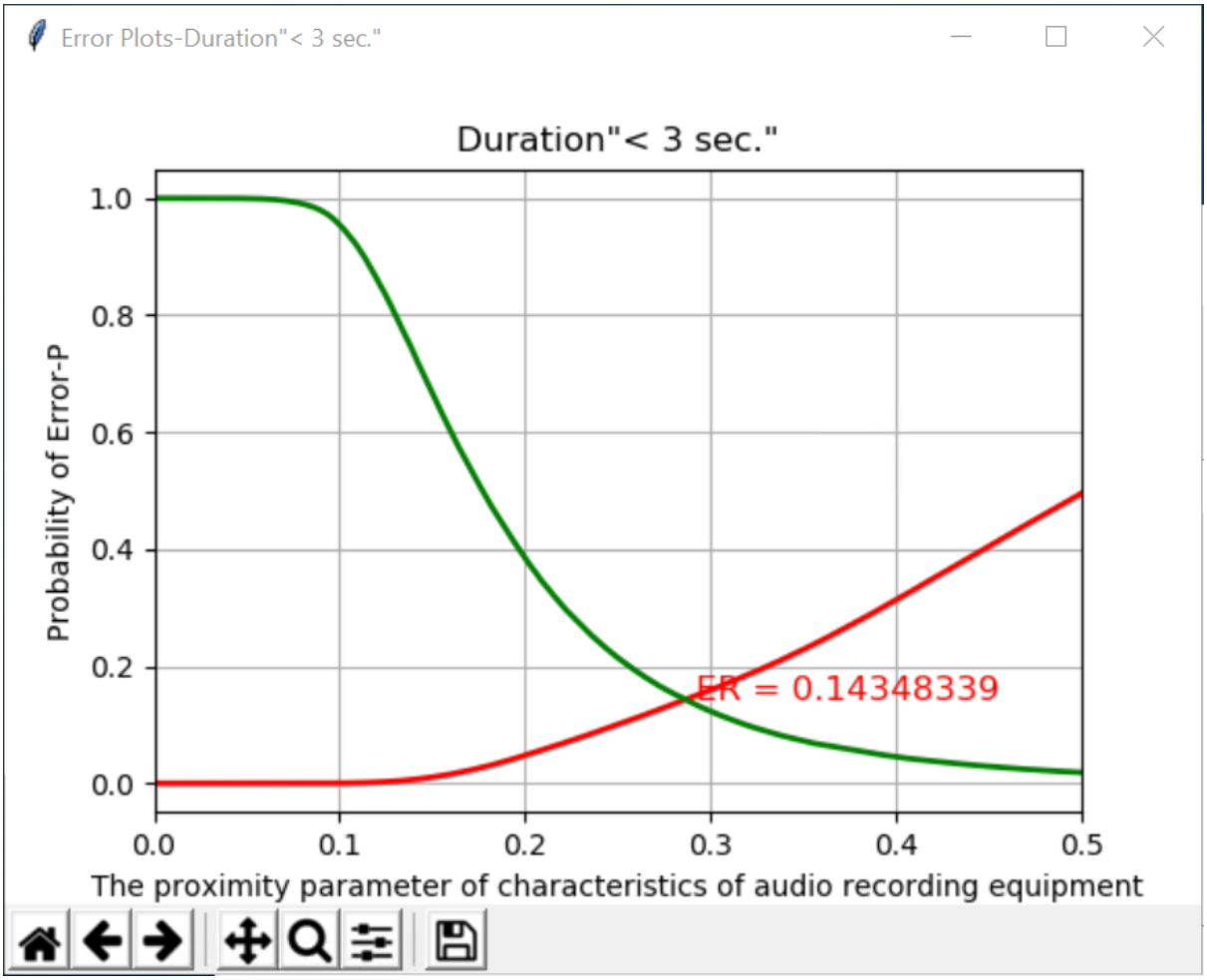

.Fig. 19 Error Plots - Duration < 3 sec.

4.4 Language

This menu option changes the language localization of the system.

Current version of the system provides three localizations: English, Russian, and Ukrainian. All the graphs and forms are displayed in one of these three languages.

At the request of the Customer, any localization of the system can be added.

To select the localization:

1. Click on Language in the main menu.
2. Click on one of the languages in the list.

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5 Publications

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