WAVEosSCOPE
V 2.1
Brief Introduction

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1   Introduction

The Program WAVEosSCOPE was designed to measure the speed of model aircrafts. It makes use of the Doppler shift of acoustic sound waves, which are emitted by the model aircraft during a pass-by flight.

The program is compressed into a ZIP-archive with the name SCOPE.ZIP. It contains the following files:

- WOS….EXE   - the program executable
- MIG_29_1.WAV   - an example sound file
- PAMPA.WAV   - an other example sound file
- Waveosscope.doc   - this documentation

2   The Theory behind it

2.1 Doppler effect

From the daily experience it is well known to everyone that the sound of a fast car or a flying model airplane changes, if it drives past or flies past an observer. That is caused by the Doppler effect, which changes the sound of each moving object
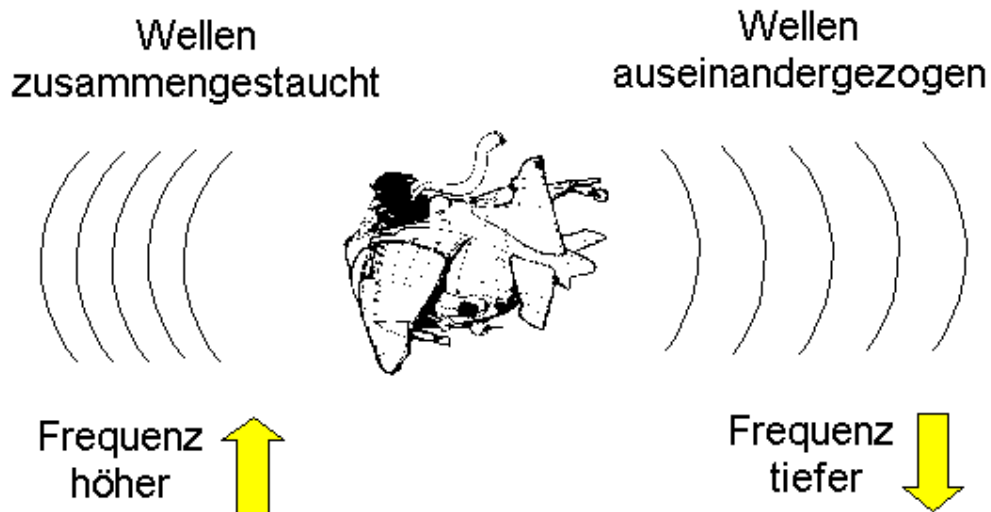

Figure 1 Doppler effect

The Doppler effect is caused by the finite speed of sound in the air. If an acoustic source moves trough the air, then in front of it the acoustic waves are compressed, which leads to a higher sound - behind the acoustic source the waves are stretched, what results in a lower sound frequency. One calls this frequency change Doppler shift.

The Doppler shift can be calculated from
- The speed of the acoustic waves,
- And the speed of the acoustic source and

- The original sound frequency.

Consequently one can calculate the speed of an acoustic source from
- The speed of the acoustic waves in air and
- The Doppler shift.

The speed of the acoustic waves in air is about 1300 km/h at a temperature of 15°C and rises and/or falls somewhat with the air temperature. One can determine the Doppler shift, if one compares the sound frequency of an approaching model airplane with the sound frequency of the same model airplane flying away (speed has to be constant). The difference between the two tones is exactly the double Doppler shift.

WAVEosSCOPE analyzes the frequency change of the sound on a model airplane during a flyby. It is using an FFT (Fast Fourier Transform) to calculate the speed of the model. As a first step, the sound of the model has to be recorded. A practical solution is a Camcorder that records a movie of the bypassing model.
The loudest acoustic source at the airplane is the engine and/or the propeller. This acoustic source must produce a constant sound during the recording. Otherwise the measurement is corrupted. Therefore the measurement must take place during a flyby at constant height and with constant engine performance (full power). Descending before the measuring point (location of the Camcorders) or pulling up past the measuring point would cause the measured speed to be too high a too high, since the engine turns faster when diving than when pulling up. However, such manipulations could be identified during later analysis.

3 Preparation

3.1 Sound recording at the model airport

A camcorder is a suitable device for sound recording at the airfield. The model airplane has to make a flyby at the camcorder position with constant speed, constant rpm (normally that means nothing else then full power and constant altitude.The closer the model passes the camcorder, the better the results. But for safety reasons the distance should not be less then 15 meters.

The camcorder operator makes a movie of the model during the flyby

3.2 Converting the sound into a WAV-file with your PC

Connect the camcorders audio output plug with the PC audio line-in connector. Use the Window audio recorder software to record the sound of the fly-by (10 seconds).

Figure 2 Windows-Audiorecorder

Don't forget to choose "line-in" as record audio source in the audio mixer.
Save the recorded sound as WAV-file. "Telephone-Quality" is good enough.

4   Use of the Program

At the start, the program WAVEosSCOPE shows the following program window:
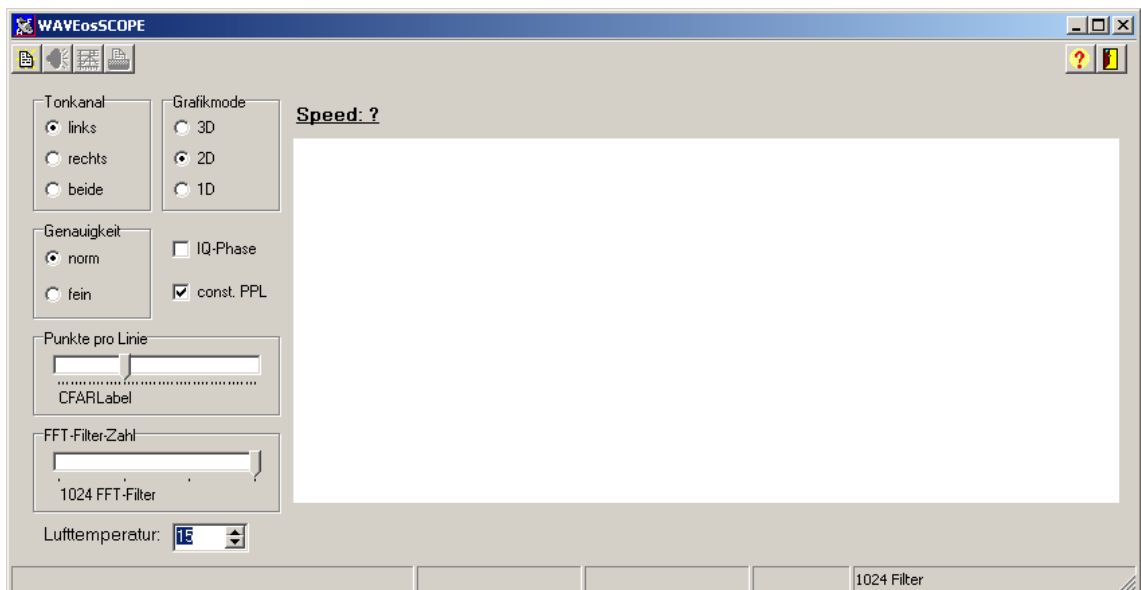

Figure 3 main program window

The icon-list in the upper left corner provides the following functions:

1. load a WAV-file

2. Play the WAV-file

3. Graphic output (make a drawing)

4. Print the program window

5. Program-info

6. End

The functions 2, 3 and 4 are available after a WAV-file was loaded.
The speed of sound depends a little bit on air temperature. The field "Lufttemperatur" in the lower left corner should be used to enter in the air

temperature during the test. Default is 15℃, which is often good enough. But if the temperature during recording was above 25℃ or below 5℃, then the real temperature should be entered.

4.1 Load a WAV-file

The recorded sound file has to be loaded into the program.
At program start the software asks for a WAV-file. But a new WAV-file can be loaded later too.
To load a new WAV-file, one has to click on the "LOAD" icon ("WAV-File laden"). The following file load dialog window will be displayed.
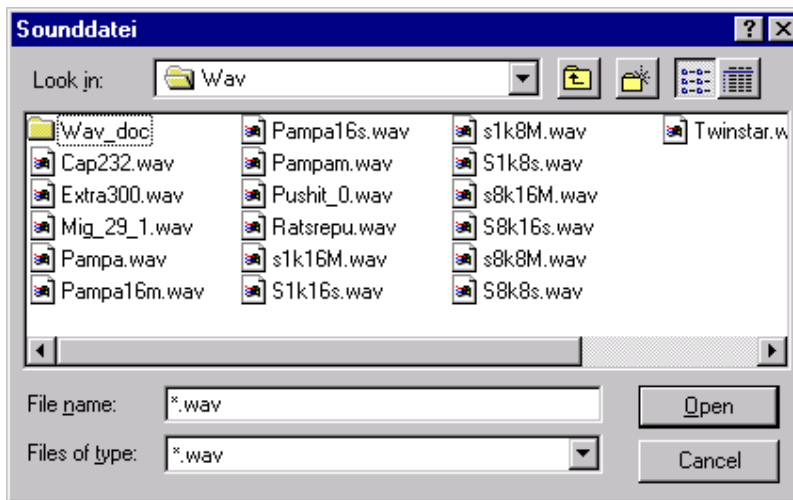

Figure 4 load a wave file

One has to choose the right file and to click on "Open". This window will be closed, and in the main window will be displayed the result of the first analysis.
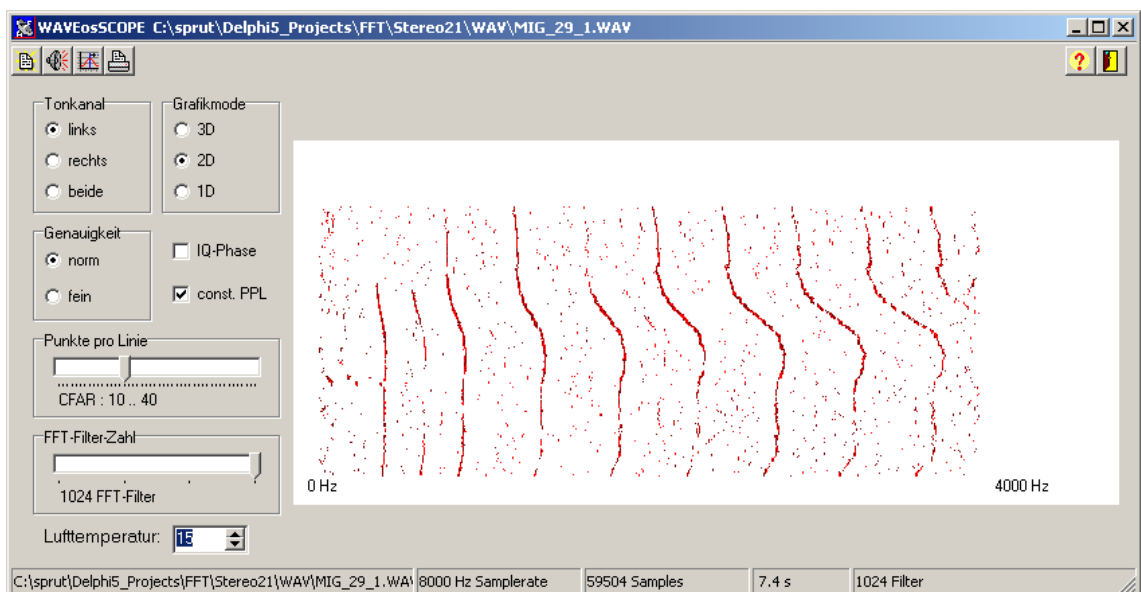

Figure 5 picture with standard resolution

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The S-shaped lines are the result of the Doppler shift during the fly by of the model.
At the bottom of the window, the parameters of the sound-file and the resolution of the analysis (1024 filter) are displayed.

4.2 Options

At the left side of the program window several selections and can be made and parameters can be changed.

Tonkanal: (sound channel select)
The typical sound-file is a stereo file. One can choose to use the left channel ("links") (red color), right channel ("rechts") (green color) or both ("beide").
The use of both channels in parallel is very useful, if the recording was made with two microphones at large interspace, and the model has passed both microphones one after the other.

Grafikmode: (graphic mode)
The frequency spectrum of the sound can be displayed as 3-dimensional waterfall diagram ("3D"), 2-dimensional ("2D") like on the figure above or 1-dimensional ("1D"). For speed measurement the 2-dimensional mode is the best.

Genauigkeit: (precision)
The frequency spectrum can be calculated with good precision ("norm") or with very good precision ("fein"). The influence on speed measurement is small. The good precision ("norm") is normally good enough.

IQ-Phase: (I/Q-phase)
With this option activated the display shows the phase of the signal as color. I did this just for fun. It does not have great practical value

Const. PPL: (constant number of points per line)
This switch controls the graphical display. Especially, the visibility of the S-shaped lines can be influenced.
If this switch is activated, then the software tries to keep the number of color dots in each line of the graphic display constant. This is like a post-FFT gain control with a threshold.
The ruler "Punkte pro Linie" (Points per line) controls the number of dots per line. The default (10 … 40) shows normally good results.

If the switch is deactivated, then a simple threshold function is used for the graphical display. The threshold value is then controlled by the ruler "Punkte pro Linie".

FFT-Filter-Zahl: (number of FFT-filters)
The FFT splits the sound in narrow frequency band by a lot of frequency filters. Every dot in a line of the display represents one FFT-filter. The number of filters can be changed by the ruler "FFT-Filter-Zahl" from 128 filters up to 1024 filters.

A high filter number delivers a sharper picture but requires more processing time. On modern Computers always 1024 filters should be used.

4.3 Speed Measurement

In the graphic window, select one S-shaped line that has good readability and is as much on the right side as possible.
Use the mouse to click with the left mouse button on a point of the upper part of the line, (Do it precisely) and with the right mouse button on a point of the lower part of the line.
The points will be marked by the program with a green and a red vertical line.
The software calculates the aircraft speed based on the frequency shift between the both selected points. The result is displayed above the graphic display in kilometers per hour. Behind the result will be displayed the tolerance of the measurement.
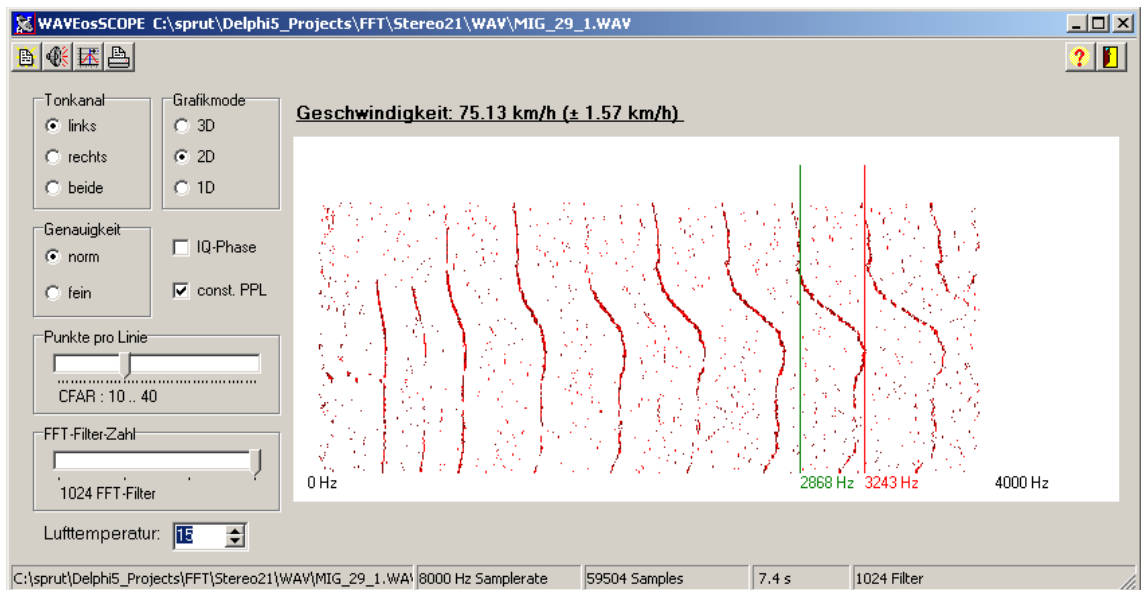

Figure 6 speed measurement

4.4 Additional Steps

An ideal flyby begins at the lower edge of diagram with a vertical line. In the picture center it swivels to the left. Finally it is again running straight up to the upper end of the picture. The lower line part is the approach, the swivel is the flyby and the upper line part the fly away. Fluctuations in the upper and lower line parts suggest an uneven flight. In the figure above one recognizes at the lower edge of diagram that the lines are coming a little bit from the left. The sound frequency was increased just at the beginning of the recording. That is probably the time, at which the model pilot increased the engine speed to maximum. One must ignore such a fluctuation during the evaluation.

One can see in the diagram several S-shaped lines with increasing distances from the left to the right and with ever more strongly shaped. That is normally the frequency of the engine or the propeller and integer multiple of this

frequency. With a direct driven propeller, the propeller frequency is an integer multiple of the engine frequency, therefore engine and propeller frequencies look identical and cover each other.

A fast engine turns at around 15000 RPM (loaded). This corresponds to a frequency of 250 cycles per second. A directly driven two-blade propeller produces a sound of 500 cycles per second. Most engines (and propellers) run at lower RPM and produce lower basic frequencies. Consequently an analysis of the frequencies up to 2000 cycles per second or 4000 cycles per second is completely sufficient. WAVEosSCOPE always analyzes up to the half sample frequency of the WAV file. Therefore a sample frequency of 8000 Hz is completely sufficient during the recording with the Windows audio recorder (telephone quality).