

Report Virtual Sound Sources (Lab 2)

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TTT4170 Audio Technology

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Innhold

1	Introduction	1
2	Theory	1
2.1	intensity stereophony	1
3	Measurements	1
3.1	Equipment	1
3.2	stereo vs. dummyhead recording	2
3.3	sound source deviation SPL	2
3.4	sound source deviation Δt	2
4	Calculations	3
4.1	calculation of ϕ_{SPL}	3
4.2	calculation of $\phi_{timedifference}$	5
5	Conclusion	6
6	Appendix	7
6.1	Example calculations	7
6.1.1	time difference for head	7
6.1.2	dummy head diameter	7
6.1.3	intensity stereo	8

Summary

In this laboratory virtual sound sources are handled. Stereo recordings with a xy-stereo microphone pair as well as a recording with a dummy head were made and compared both at loudspeaker and headphone listening. There it can be obtained, that directional hearing is possible with headphones, where the virtual source location can be done easier with the dummy head recording. When using loudspeakers the virtual sound source always has a position between the two loudspeakers. A directional representation of the real sound source is not possible.

In an other listening test the influence of sound pressure level differences as well as time delays were obtained. There it can be found out, that the virtual sound source moves to the louder or earlier sound source. A special thing occurs when at time difference listening test. When the time difference gets too big, the two sound sources are obtained as independent ones, a position of a single sound source is not available any more.

1 Introduction

Hearing is important for our lives. Sound effects like time differences and sound pressure differences let us know the position of a sound source and so avoid us from potential safety risk, e.g. in the car traffic. These differences in SPL, time and spectral behaviour of the signal in the two ears can help to get the right position of the source.

In this laboratory the reproducibility of sound source positions with different recording techniques was obtained. As recording techniques xy-stereophony as well as binaural recording with using a dummy head were used. The laboratory mainly was done by human perceiving of recorded signals over both loudspeakers and headphones.

2 Theory

For obtaining the position of a sound source three different characteristics of a sound signal are processed:

- time difference
this is defined by the difference in time which sound arrives earlier at one ear. This is mainly the difference of the sound propagation of the head size. It can be calculated using following formula:

$$\Delta t = \frac{a \cdot (\phi + \sin(\phi))}{c} \quad (1)$$

where

- a : head radius
 - ϕ : angle of sound source regarding to the head position
 - c : speed of sound
- level difference
this can be obtained easily, when the diameter is smaller than the wavelength λ .
 - spectral behaviour

2.1 intensity stereophony

In this case one signal is recorded and played on both sound sources, but with time difference. The position of the virtual sound source moves then in direction of the earlier sound source. Further information can be found in the lecture notes¹.

3 Measurements

3.1 Equipment

For this laboratory exercise following equipment was used for the measurements:

- 1 Yamaha Mixing Console (Model: 01v)
- 1 HDD-Recorder (Model: SoundDevices 722)
- 2 microphones (Model: Rde NT5)
- 2 loudspeakers (Model: dynaudio acoustics BM6A)
- 1 dummy head (Model: KUBii)

¹P. Svensson, *Lecture Notes on TTT4170*, 2014, chapter hearing

3.2 stereo vs. dummyhead recording

In this task two recordings were made.

1. One recording was made with a stereo microphone pair. As recording technique xy-stereophony was used. A person speaking was walking around the microphone in an aequidistant circle.
2. In an other recording the dummyhead was used. A person walked again around the head and speaked.

After this, the two sound recordings were played over headphones and loudspeakers. Following results can be observed:

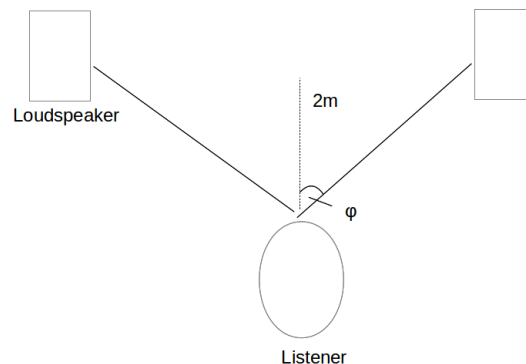
results

As result it can be obtained that the sound source with dummyhead recording can be located better when it is at the sides and a little bit harder from back and especially when the sound source is in the front. This can be obtained when using headphones. The same is when using the microphone recording, but the ability to locate is more difficult.

When listening to the recordings on loudspeakers, locating of the sound source is not possible. The sound source appears always between the two loudspeakers, using the dummyhead recording as well as the microphone recording.

3.3 sound source deviation SPL

In this task the position of the virtual sound source regarding to a sound pressure difference between two speakers is measured. Therefore a person speaking was placed in front of a mono microphone and recorded. The reorded signal was played equally strong on two speakers placed in an angle of 60° . A listener was placed 2 meters in front of the loudspeakers, so that a calculation of the deviation of the virtual sound source from the center between the loudspeakers can easily be calculated with a tan-function. The listening position can be seen in figure 1. It can be obtained



Figur 1: Listening position

that with no amplitude difference the sound source appears exactly in the center between the two loudspeakers. With increasing difference of SPL the virtual sound source moves to the speaker with higher sound pressure level. When the sound pressure difference is high enough, the sound is heard as coming only from one speaker. The measured sound source deviation can be seen in table 1 as well as in figure 2.

3.4 sound source deviation Δt

The position of the virtual sound source should be measured with increasing time delay of one loudspeaker. The measured results can be seen in table 2 as well as in figure 3. Until a certain

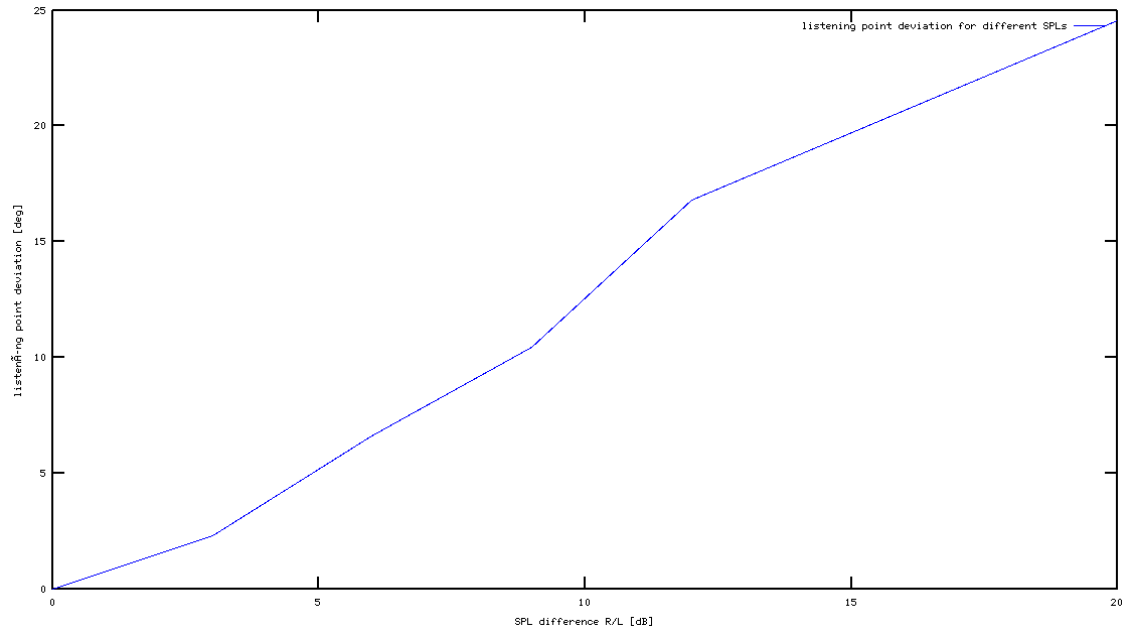


Figure 2: Sound source deviation for different SPLs in degrees

SPL difference <i>dB</i>	deviation from center <i>m</i>	ϕ <i>rad</i>	ϕ $^{\circ}$
0	0	0	0
3	0.08	0.04	2.29
6	0.23	0.116	6.62
9	0.36	0.182	10.43
12	0.57	0.293	16.79
20	0.81	0.429	24.56

Tabell 1: SPL deviation

point is reached, the virtual sound source moves to the speaker which sends the sound first. When the time difference between the two speakers is too big (50ms, 100ms), the two loudspeakers seem as two independent sound sources. In the table the position of the first sound signal occurring is listed for these time delays.

4 Calculations

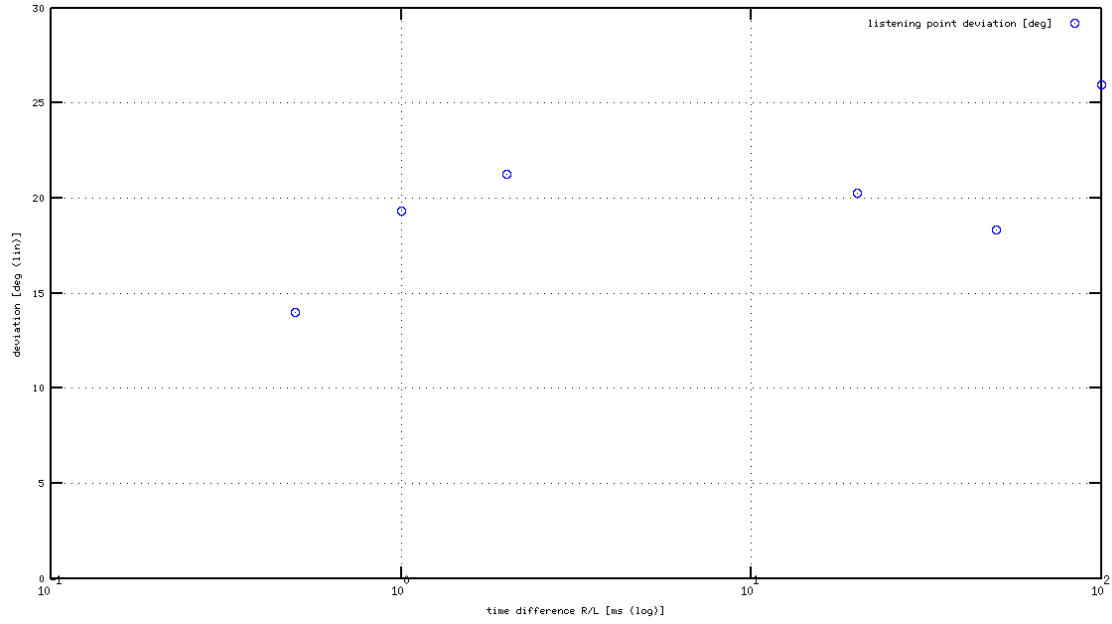
4.1 calculation of ϕ_{SPL}

$$\phi_{rad_{3dB}} = \tan\left(\frac{0.08m}{2m}\right) = 0.04$$

$$\phi_{deg_{3dB}} = \phi_{rad_{3dB}} \cdot \frac{180^{\circ}}{\pi} = 2.29^{\circ}$$

$$\phi_{rad_{6dB}} = \tan\left(\frac{0.23m}{2m}\right) = 0.116$$

$$\phi_{deg_{6dB}} = \phi_{rad_{6dB}} \cdot \frac{180^{\circ}}{\pi} = 6.62^{\circ}$$



Figur 3: Sound source deviation for different time differences in ms

time difference <i>ms</i>	deviation from center <i>m</i>	ϕ <i>rad</i>	ϕ $^{\circ}$
0	0	0	0
0.5	0.28	0.245	14.02
1	0.65	0.337	19.31
2	0.71	0.371	21.24
20	0.68	0.354	20.27
50	0.62	0.320	18.35
100	0.85	0.453	25.93

Tabell 2: time deviation

$$\phi_{rad_{9dB}} = \tan\left(\frac{0.36m}{2m}\right) = 0.182$$

$$\phi_{deg_{9dB}} = \phi_{rad_{9dB}} \cdot \frac{180^\circ}{\pi} = 10.43^\circ$$

$$\phi_{rad_{12dB}} = \tan\left(\frac{0.57m}{2m}\right) = 0.293$$

$$\phi_{deg_{12dB}} = \phi_{rad_{12dB}} \cdot \frac{180^\circ}{\pi} = 16.79^\circ$$

$$\phi_{rad_{20dB}} = \tan\left(\frac{0.08m}{2m}\right) = 0.429$$

$$\phi_{deg_{20dB}} = \phi_{rad_{20dB}} \cdot \frac{180^\circ}{\pi} = 24.56^\circ$$

4.2 calculation of $\phi_{timedifference}$

$$\phi_{rad_{0.5ms}} = \tan\left(\frac{0.28m}{2m}\right) = 0.245$$

$$\phi_{deg_{0.5ms}} = \phi_{rad_{0.5ms}} \cdot \frac{180^\circ}{\pi} = 14.02^\circ$$

$$\phi_{rad_{1ms}} = \tan\left(\frac{0.65m}{2m}\right) = 0.337$$

$$\phi_{deg_{1ms}} = \phi_{rad_{1ms}} \cdot \frac{180^\circ}{\pi} = 19.31^\circ$$

$$\phi_{rad_{2ms}} = \tan\left(\frac{0.71m}{2m}\right) = 0.371$$

$$\phi_{deg_{2ms}} = \phi_{rad_{2ms}} \cdot \frac{180^\circ}{\pi} = 21.24^\circ$$

$$\phi_{rad_{20ms}} = \tan\left(\frac{0.68m}{2m}\right) = 0.354$$

$$\phi_{deg_{20ms}} = \phi_{rad_{20ms}} \cdot \frac{180^\circ}{\pi} = 20.27^\circ$$

$$\phi_{rad_{50ms}} = \tan\left(\frac{0.62m}{2m}\right) = 0.320$$

$$\phi_{deg_{50ms}} = \phi_{rad_{50ms}} \cdot \frac{180^\circ}{\pi} = 18.35^\circ$$

$$\phi_{rad_{100ms}} = \tan\left(\frac{0.85m}{2m}\right) = 0.453$$

$$\phi_{deg_{100ms}} = \phi_{rad_{100ms}} \cdot \frac{180^\circ}{\pi} = 25.93^\circ$$

5 Conclusion

This laboratory exercise was about the subject of virtual sound sources. Recordings with different recording techniques (xy-stereophony, binaural recording) were made. Differences in perceiving the sound played with headphones as well as with loudspeakers were obtained. The main observations were:

- headphone reproduction
 - the position of the virtual sound source can be reconstructed with both recording techniques, but better with binaural recording
- loudspeaker reproduction
 - at loudspeaker reproduction the virtual sound source appears always between the two loudspeakers, and not at the possible recording position
 - when level difference gets to big, the sound source appears at the louder loudspeaker
 - when time difference gets to big, the two loudspeaker signals appear as two independent signals.

6 Appendix

6.1 Example calculations

6.1.1 time difference for head

For this example a head with a radius of 8cm is assumed. The sound speed is assumed as $c = 343 \frac{m}{s}$. The time difference can be calculated using formula 1. For an angle of $\phi = 90^\circ$ it can be calculated as.

$$\Delta t = \frac{0.08m \cdot (90^\circ + \sin(90^\circ))}{343 \frac{m}{s}} = 599.6 \mu s$$

The time differences for this head with $0^\circ \leq \phi \leq 90^\circ$ can be seen in figure 4.

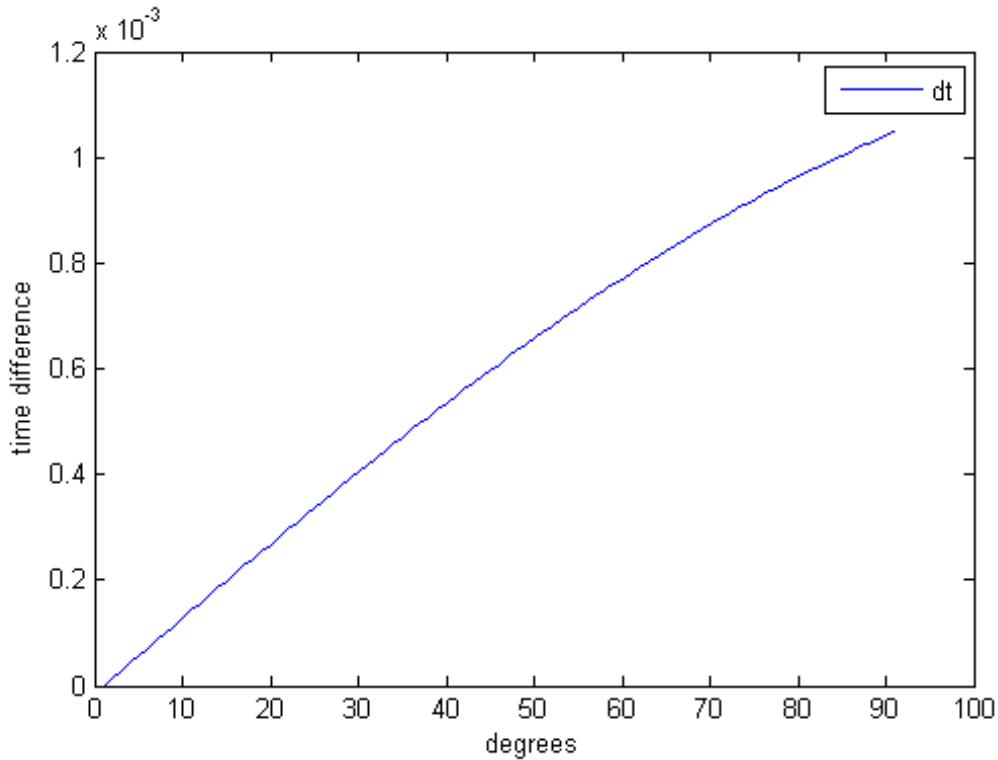


Figure 4: Time differences for sound signal at two ears

6.1.2 dummy head diameter

In this case two impulse cases for the two ear signals are given. The incidence angle is given as $\phi = 30^\circ$. The time difference between the two signals can be obtained by getting the initial peak signals of the two signals.

$$\Delta t = x_2 - x_1 = 25ms - 13ms = 12ms$$

With using formula 1, the diameter can be calculated with

$$d = 2a = \frac{2 \cdot \Delta t \cdot c}{\phi + \sin(\phi)} = 8.04cm$$

6.1.3 intensity stereo

A single loudspeaker is assumed for this calculation. The listener appears at an angle of $\phi = 30^\circ$, the two ears have a distance of 25cm. The time difference between the two signals can be calculated using equation 1:

$$\Delta t = \frac{0.25 \cdot (30^\circ + \sin(30^\circ))}{343 \frac{m}{s}} = 746 \mu s$$

In a further step, two loudspeakers for the two ears can be assumed. The amplitude difference can be described as $S_L = X \cdot S_R$. The sound pressure can then be described as

$$p_L = (S_L + e^{-jk\Delta r} S_R) \frac{e^{-jk r_0}}{r_0} \quad (2)$$

as well as

$$p_R = (e^{-jk\Delta r} S_L + S_R) \frac{e^{-jk r_0}}{r_0} \quad (3)$$

This equations can be found in the lecture notes².

²P. Svensson, *Lecture Notes on TTT4170*, 2014, chapter sound reproduction