RETSPL for tones in sound field for 135° and 180° azimuth

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Introduction

Sound field audiometry is often performed with the loudspeakers placed at incidence angles (azimuths) of 0, 45 or 90 degrees relative to the direction faced by the subject. RETSPL (Reference Equivalent Threshold Sound Pressure Level) values for these incidence angles are available in the audiometer standards; see for example ANSI S3.6(2004), Table 9.

However, some investigators have expressed interest in performing sound field audiometry for other azimuths, specifically 135 and 180 degrees. This paper describes the derivation of RETSPL values for these azimuths.

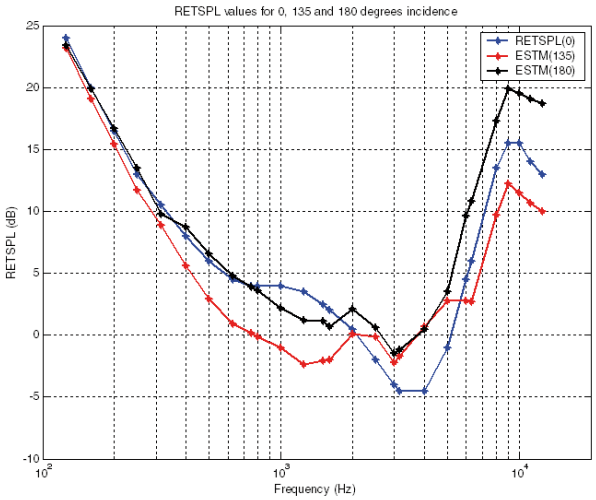
Method

We will make the assumption that the sensation level (the individually perceived level) is *proportional* to the measured sound pressure level at the eardrum.

With this assumption, we can maintain a constant sensation level by keeping the eardrum SPL constant – for example while the azimuth is being varied. In order to keep a constant eardrum SPL – for example corresponding to the threshold level - we can adjust the loudspeaker output while the azimuth is being varied. We hereby vary the free-field SPL, which will exist in the sound booth, without the subject present. As the free-field SPL must be varied to maintain the threshold eardrum SPL, the RETSPL value must also vary with azimuth (please refer to the definition of RETSPL).

Summarizing the above, we can compute RETSPL values for any azimuth, provided that:

- The RETSPL value is known for at least one azimuth (for example, 0 degrees incidence)
- The variation in eardrum SPL with azimuth is known (for a fixed loudspeaker output)



Comparison of RETSPL values for 0, 135 and 180 degress incidence.

Mathematically, we have:

$RETSPL(\theta) = RETSPL(0) - dSPL(\theta)$ (Eq. 1)
where

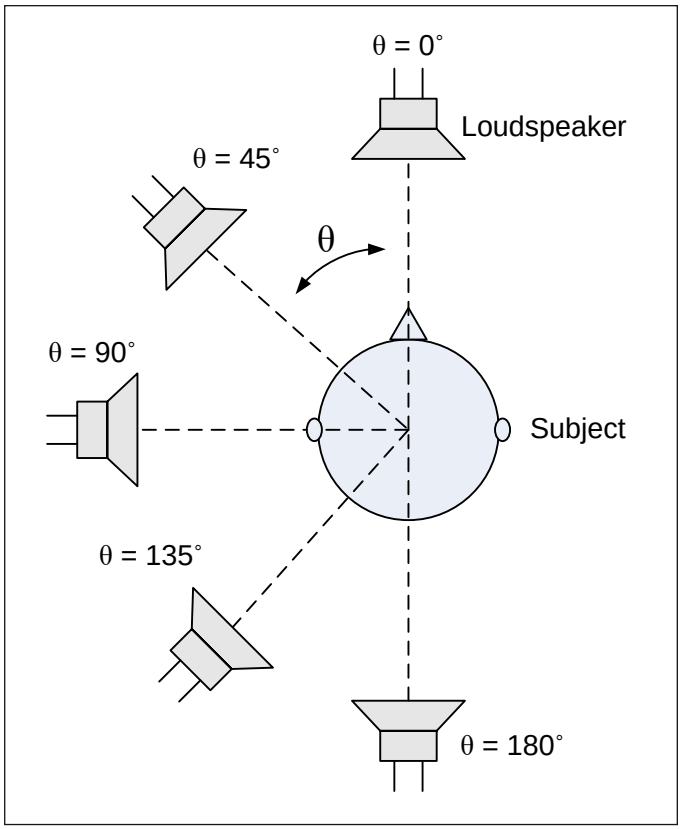
- $RETSPL(\theta)$ is the RETSPL for incidence angle θ
- $RETSPL(0)$ is the RETSPL for frontal incidence
- $dSPL(\theta)$ is the change in eardrum SPL when the incidence angle is changed from 0 to θ.

As mentioned earlier, RETSPL (0) may be found in the audiometer standard.

Shaw (1974) and Shaw & Vaillancourt (1985) presented data to transform free-field sound pressure levels into eardrum sound pressure levels, for a large range of azimuths and frequencies. The transformation values represent the change in eardrum SPL when the incidence angle is changed from 0 to θ, i.e. the value of $dSPL(\theta)$ above.

Derivation of RETSPL values for 135° and 180°

To confirm the validity of the presented method, the RETSPL values for 45° and 90° azimuth were derived using (Eq. 1) above, and the results were compared to the table values listed in the ANSI S3.6 standard. The derived values were very close to the values stated in the ANSI standard for 45° and 90° azimuth.



Position of loudspeakers and subject in audiometry test booth.

Finally, the RETSPL values for 135° and 180° were derived using the same method. The results are shown in the table below.

Frequency (Hz):	ANSI RETSPL(dB) 0°	Derived RETSPL(dB) 135°	Derived RETSPL(dB) 180°
125	24.0	23.2	23.4
160	20.0	19.1	19.9
200	16.5	15.4	16.7
250	13.0	11.7	13.5
315	10.5	8.9	9.8
400	8.0	5.6	8.7
500	6.0	2.9	6.6
630	4.5	0.9	4.8
750	4.0	0.2	3.9
800	4.0	-0.1	3.6
1000	4.0	-1.0	2.2
1250	3.5	-2.4	1.2
1500	2.5	-2.1	1.1
1600	2.0	-2.0	0.7
2000	0.5	0.1	2.1
2500	-2.0	-0.1	0.6
3000	-4.0	-2.2	-1.5
3150	-4.5	-1.7	-1.2
4000	-4.5	0.7	0.5
5000	-1.0	2.8	3.5
6000	4.5	2.8	9.6
6300	6.0	2.7	10.8
8000	13.5	9.7	17.3
9000	15.5	12.2	19.9
10000	15.5	11.5	19.5
11200	14.0	10.7	19.1
12500	13.0	10.0	18.7

References

ANSI S3.6 (2004). Specification for audiometers. Acoustical Society of America.

Shaw, E.A.G. (1974). Transformation of sound pressure from the free field to the eardrum in the horizontal plane. JASA, Vol. 56, pages 1848-1861.

Shaw, E.A.G. and Vaillancourt, M.M. Transformation of sound-pressure level from the free field to the eardrum presented in numerical form. JASA, Vol 78(3), Sept. 1985, pages 1120-1123.

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