ODEON APPLICATION NOTE – RESTAURANTS

JHR, July 2012

Scope

This is a guide how to calculate the ambient noise level in a space where the noise source is speech from a large number of people gathered and talking to each other in small groups. The field of application includes eating facilities like canteens, bars, and restaurants. Noise at receptions and similar social gatherings where people are standing may also be simulated. The method is not applicable to small spaces, i.e. a minimum of around 50 people should be required for this method.

This application note refers to ODEON version 11 or earlier, Industrial or Combined edition. It cannot be used with the Auditorium edition.

Method

The principle is to model the source as a surface source covering the area with speaking people and at a height just above the heads. The receivers are the points in a grid covering the same area, but at the average ear height. The spectrum and sound power of the source is adjusted in such a way that the Lombard effect is taken into account. This implies that an initial calculation must first be made in order to find the response of the room (the transfer function from the surface source to the receiver grid, using the 50% percentile result). For the final calculation the user must specify the total number of people and the assumed group size. The method is based on a simple prediction model [1] and further described with examples in [2].

Terms and definitions

Ambient noise level

$L_{N,A}$

spatially averaged, A-weighted equivalent sound pressure level.

Vocal effort

characterisation of the sound level emitted by a human speaker; ANSI 3.5 [3] has three levels: normal, raised, loud, and shouted.

Speech spectrum

sound power level in octave bands emitted by a human speaker; varies with the vocal effort, see ANSI 3.5 [3].

Lombard effect

increase in vocal effort due to the ambient noise level. The A-weighted sound power level of speech is assumed to increase by 0.5 dB when the ambient noise level increases by 1 dB (for $L_{N,A} > 45$ dB) [1].

Group size

g

ratio between total number of people and the assumed number of people talking simultaneously; $g = 3.5$ is a typical value found in eating establishments [2].

Room conditions

The room model used for the simulations should include the absorption and the rough geometry of tables and other furniture. However, the absorption represented by the dining people is often of minor importance and can be neglected. In case of an existing room it is recommended to measure the reverberation time (with furniture, table cloths etc. but without people) and adjust the absorption of the materials in the model in order that the calculated reverberation times are as close as possible to the measured ones.

Before you begin you should know the total number of people and decide the group size to be used in the simulations.

Sound source

First step is to introduce into the room model the surfaces to be used as sound sources. This can be one or more horizontal surfaces covering the areas where people are located, typically where there are tables and chairs; the height above the floor level should be set to 1.50 m to represent seated people, and a little higher in the case of standing people . NB: These surfaces shall be transparent, which is done by assigning material no. 0 in the material list.

The sound source is defined as one or more **multi surface sources** and the direction of radiation is set to **Both**. (Don't use the single surface source because that cannot have both directions of radiation). The radiation type is set to **Lambert**.

Choose the assumed vocal effort in Tab. 1 and insert the corresponding **sound power levels in octave bands**. An example is shown in Fig. 1 using the spectrum of raised speech.

Table 1. Speech spectrum in octave bands depending on vocal effort (250 – 8000 Hz values derived from ANSI 3.5). Also given the A-weighted sound power level for one speaker and the valid range of ambient noise level.

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	$L_{W,A,1}$	$L_{N,A}$ range
Normal	*45,0*	*55,0*	65,3	69,0	63,0	55,8	49,8	44,5	68,4	45; 61
Raised	*48,0*	*59,0*	69,5	74,9	71,9	63,8	57,3	48,4	75,5	61; 75
Loud	*52,0*	*63,0*	72,1	79,6	80,2	72,9	65,9	54,8	82,6	75; 91
Shouted	*52,0*	*63,0*	73,1	84,0	89,3	82,4	74,9	64,1	91,0	> 91

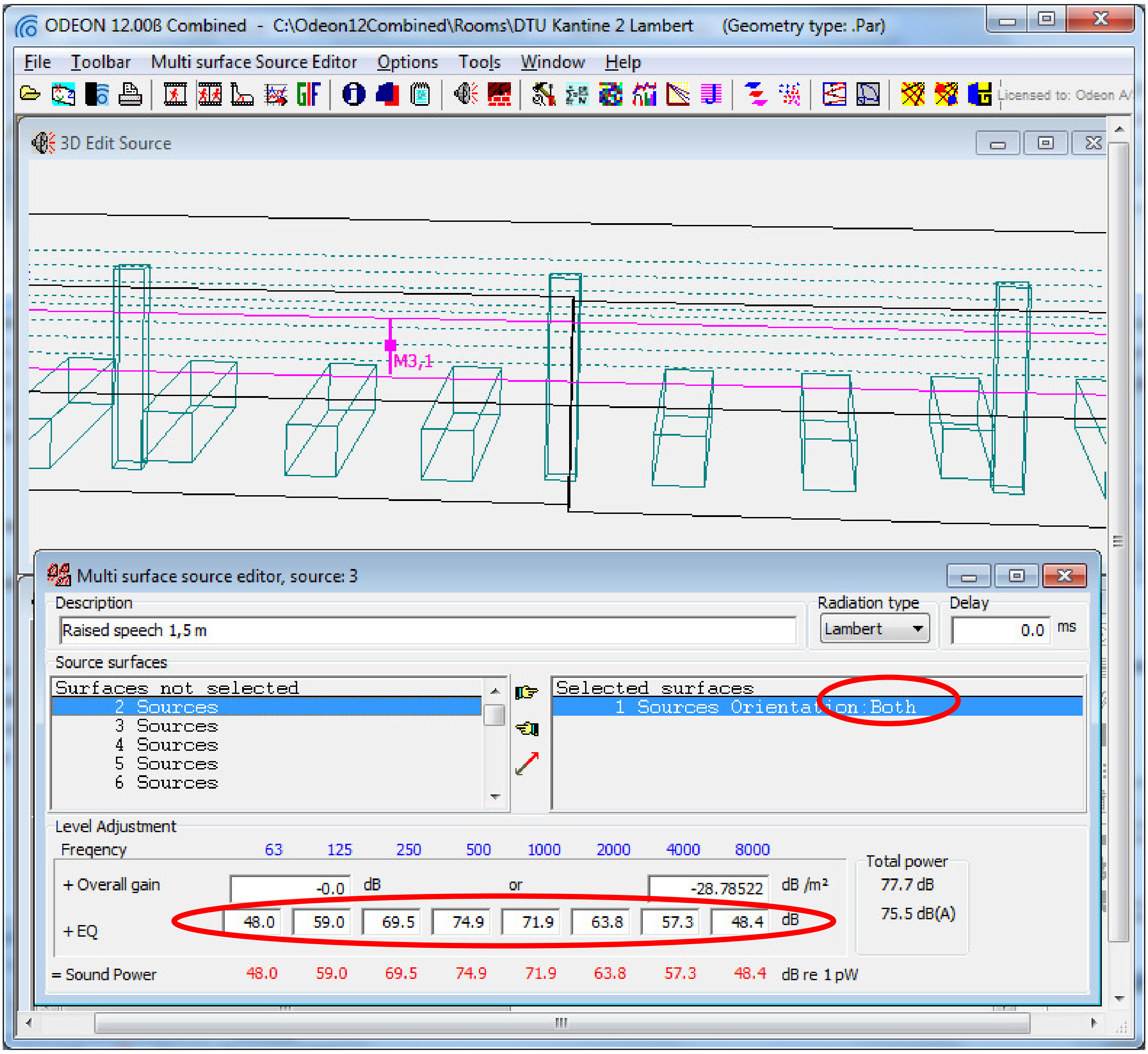

Figure 1. Example of definition the multi surface source for the initial calculation; spectrum as raised speech from Tab. 1, radiation type Lambert, source orientation: Both. Overall gain: 0 dB.

Receiver grid

The receiver grid should cover the same area as the surface source, but the recommended height above the floor level is 0.30 m below the source, i.e. 1.20 m in the case of seated people. In the example shown in Fig. 2 the surface used for the source is also used to define the grid of receivers. In this example the distance between receives in the grid is set to 2.0 m, but in other cases a smaller distance may be appropriate. This parameter is not critical.

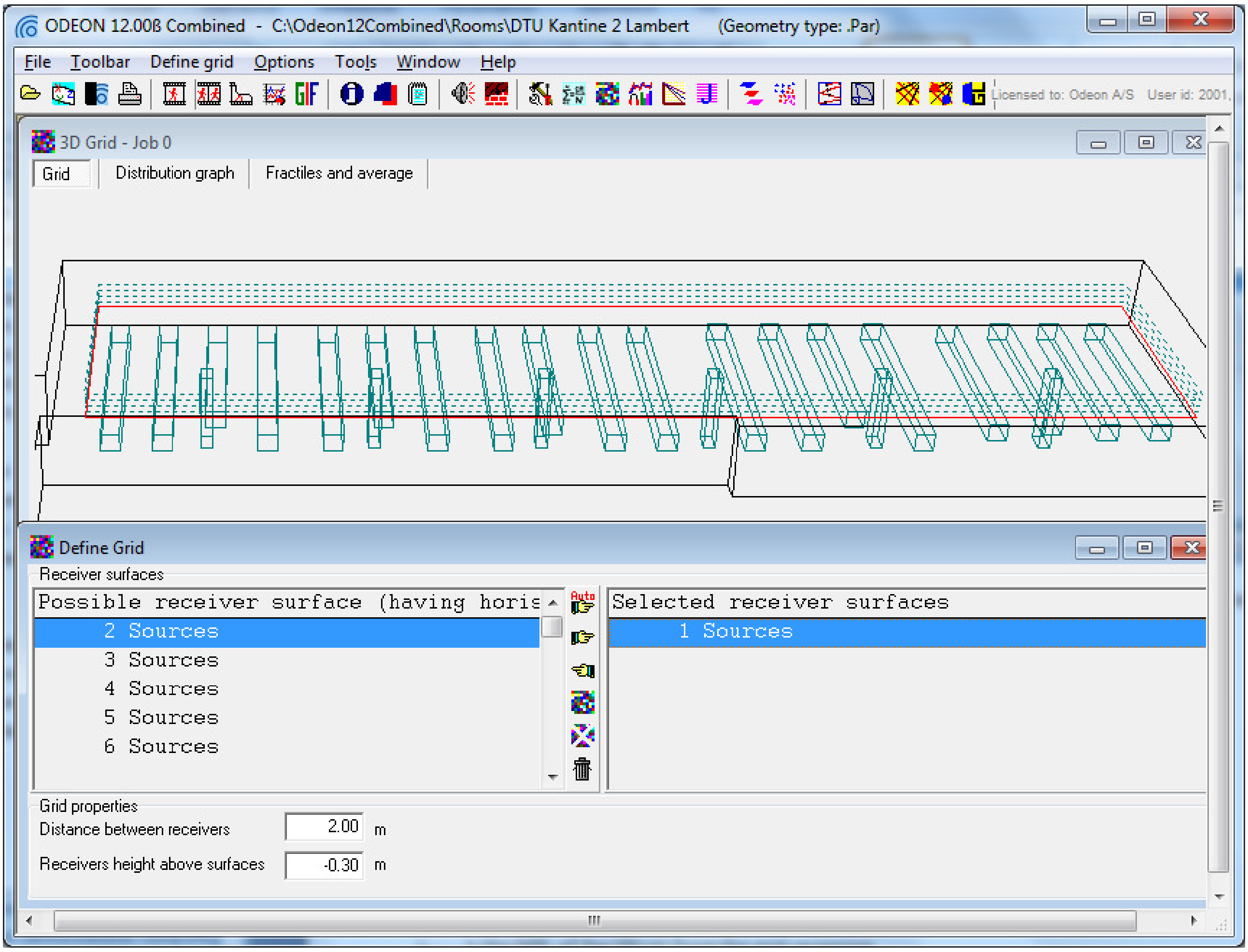

Figure 2. Example of definition of a receiver grid covering all tables in a canteen. The height is 1.20 m above the floor and 0.30 m below the surface source used for the simulation.

Initial calculation

Define a job with the surface source active and tick the grid response. Run the job and look at the grid response, SPL(A). Read the 50% percentile of the SPL(A), see Fig. 3; this is the ambient noise level with the sound power of one speaking person, $L_{N,A,1}$.

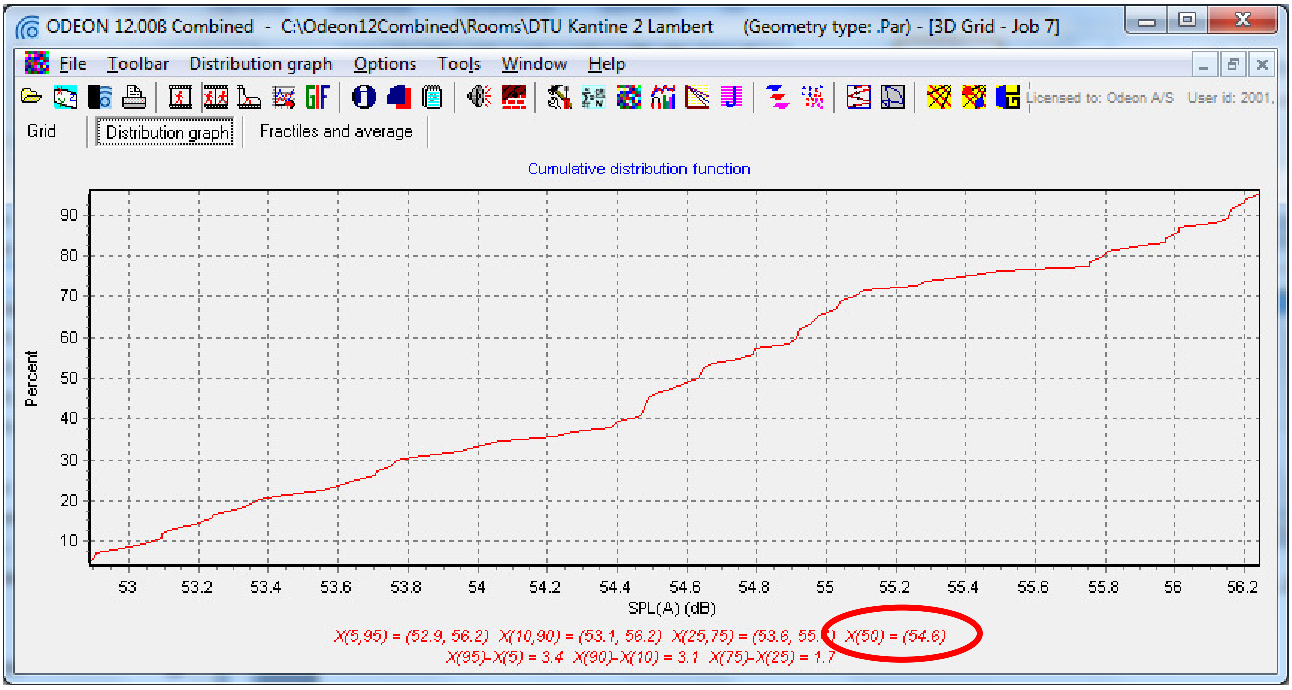

Figure 3. Reading the 50% of the SPL(A) from the grid response after the initial calculation.

Final calculation

Calculate the number of speaking persons N_S:

$$N_S = \frac{N}{g} \tag{1}$$

where N is the total number of persons and g is the assumed group size (typical 3.5).

Calculate the adjustment ΔL from the equation:

$$\Delta L = 81 + 20\log(N_S) + L_{N,A,1} - 2 \cdot L_{W,A,1}\ , \quad (\text{dB}) \tag{2}$$

where $L_{N,A,1}$ is the result from the initial calculation, see Fig. 3, and $L_{W,A,1}$ is the A-weighted sound power level for the chosen vocal effort, see Tab. 1.

Example: N = 530, g = 3.5, $L_{N,A,1}$ = 54.6 dB, $L_{W,A,1}$ = 75.5 dB.

N_S = 530 / 3.5 = 151,

ΔL = 81 + 43.6 + 54.6 – 2*75.5 = 28.2 dB

Insert the calculated adjustment ΔL as overall gain in the source definition, see Fig. 4, and run the job with this source active.

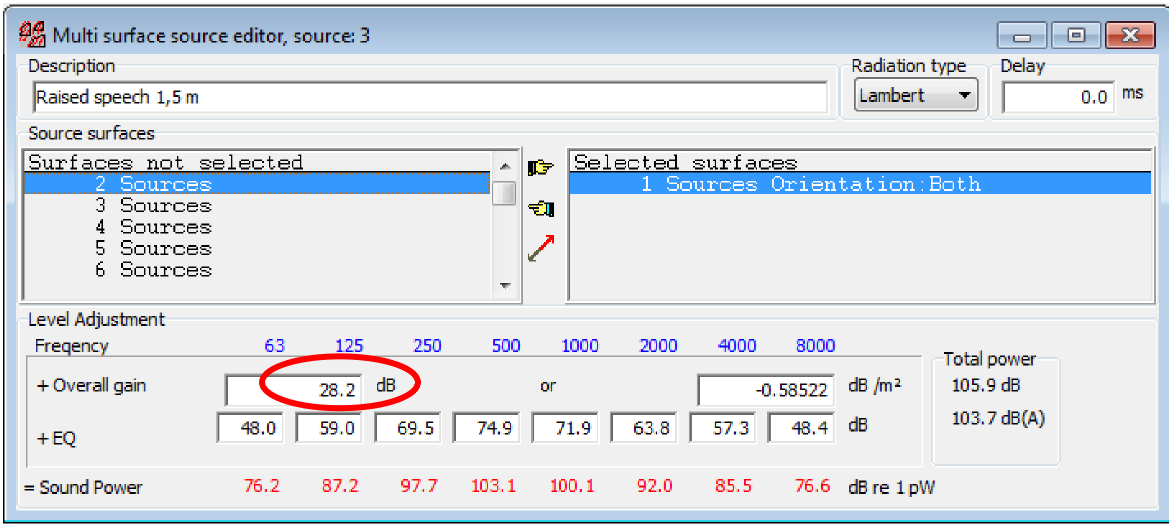

Figure 4. Insertion of the overall gain ΔL in the source definition for the final calculation.

Results

The ambient noise level found as a result of the new calculation is no surprise; it must be:

$$L_{N,A} = L_{N,A,1} + \Delta L \,, \ \text{(dB)} \tag{3}$$

So, in the example above we get $L_{N,A}$ = 54.6 + 28.2 = 82.8 dB. The Octave band levels of the SPL can also be displayed as shown in Fig. 5.

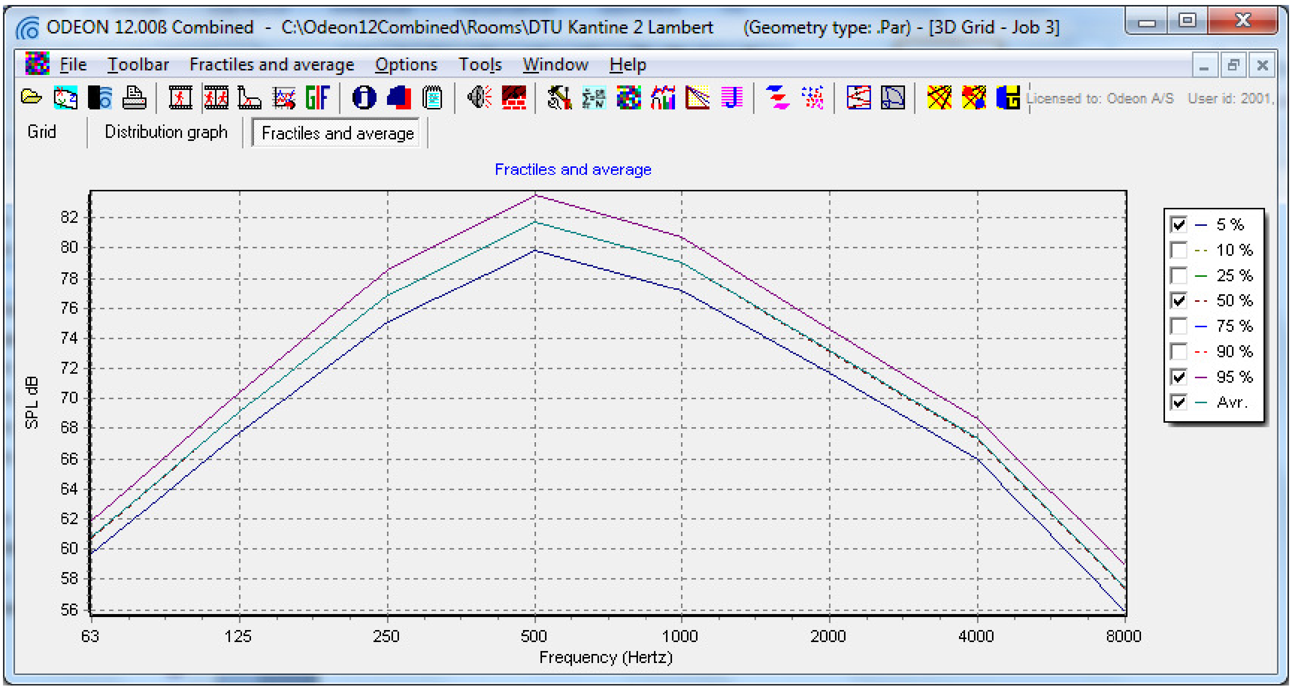

Figure 5. Octave band levels as results of the grid response calculation using the source setting as in Fig. 4.

Changing the vocal effort

If the octave band levels of the ambient noise are important, it is necessary to make sure that the applied speech spectrum is as correct as possible, i.e. the ambient noise level should be within the range specified for the applied vocal effort in Tab. 1.

In the example above this is not fulfilled (the valid range for raised voice is 61 – 75 dB, but the result is $L_{N,A}$ = 82.8 dB). So, the loud voice spectrum would be the correct choice in this case, and we should go back to the initial calculation and repeat the rest of the procedure with the new source spectrum. However, this will have only negligible effect on the A-weighted ambient noise level.

Acoustical capacity

The most important parameter for the ambient noise level is the number of people present. As suggested in [4] the acoustical properties of restaurants and similar places can be characterised by the acoustical capacity, defined as the number of people in the facility that is expected to create an ambient noise level of 71 dB or a quality of verbal communication on the borderline between 'sufficient' and 'insufficient'. The relationship is displayed in the graph in Fig. 6.

The acoustical capacity of the modelled space can be found from the following equation:

$$N_{\max} = N \cdot 10^{(71-L_{N,A})/20} \tag{4}$$

where N is the number of people assumed for the calculation of the ambient noise level $L_{N,A}$. In the example above we have $N_{\max} = 530 \cdot 10^{(71-82.8)/20} = 136$. Thus, the number of people is about four times the acoustical capacity, and the conditions are between 'insufficient' and 'very bad'.

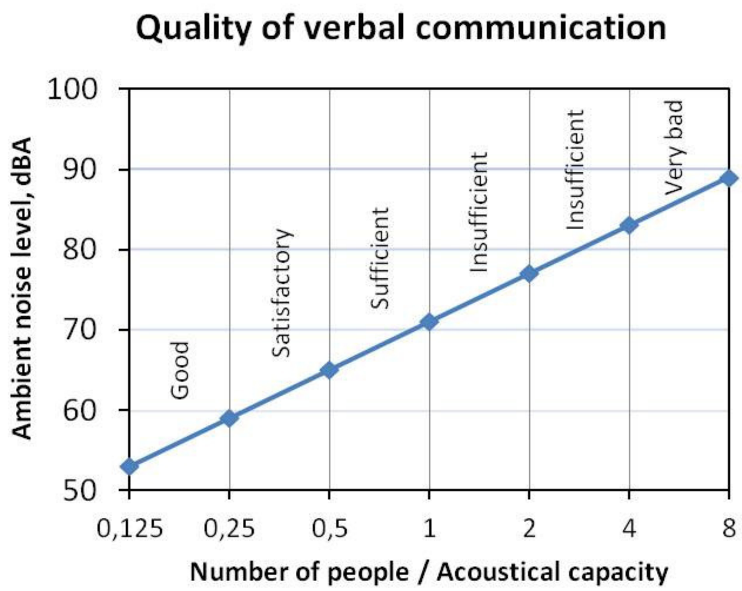

Figure 6. The relation between ambient noise level and the number of people relative to the acoustical capacity. The expected quality of verbal communication is also indicated. (After [4]).

References

1. J.H. Rindel, “Verbal communication and noise in eating establishments”, *Applied Acoustics* **71**, 1156-1161, (2010).
2. J.H. Rindel, C.L. Christensen, A.C. Gade: “Dynamic sound source for simulating the Lombard effect in room acoustic modeling software”. Proceedings of Inter-Noise 2012, New York, USA, (2012).
3. ANSI 3.5-1997. *American National Standard – Methods for Calculation of the Speech Intelligibility Index*, (1997).
4. J.H. Rindel: “Acoustical capacity as a means of noise control in eating establishments”. Proceedings of BNAM 2012, Odense, Denmark, (2012).