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Working with directivities **SP Net info 101**

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This info is mainly addressed to customers with Industry Noise Propagation.

To get started

Point, line and area sources can be assigned with directivity (DI). To attach an existing DI record to an emission, pick the DI from the drop-down list on the index card Values of the emission record, Fig 1. How to prepare records in the DI library, see below.

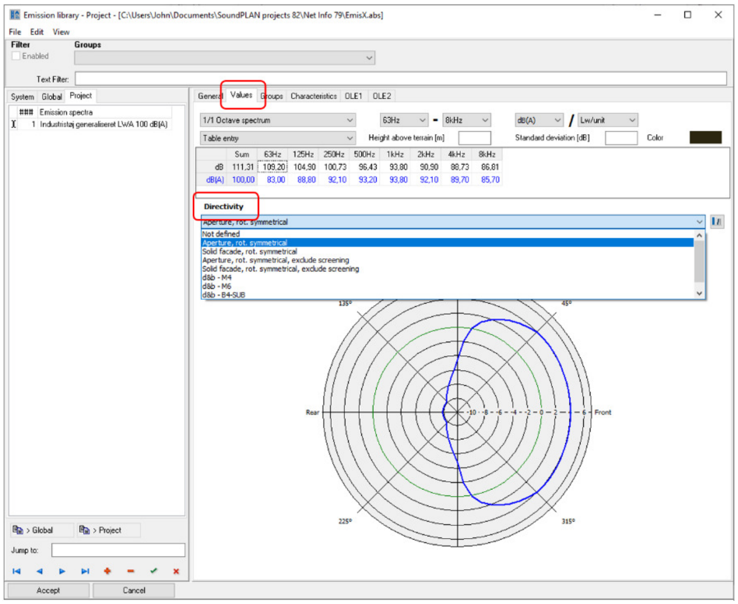


***Fig 1** Emission record attached with a directivity*

For sources with an embedded DI an index card Directivity appears in the source property window, Fig 2. Here the orientation ('zero-direction') of the directivity relevant for this specific source can be adjusted. Default the orientation points along the X-axis (towards the east) and horizontally.

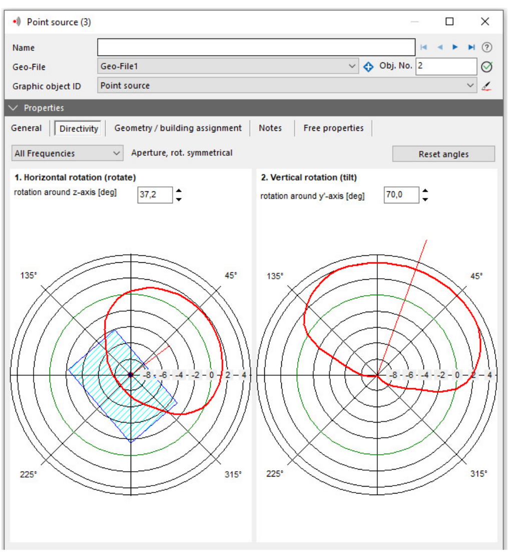


***Fig 2** Source property window, index card Directivity*

The settings shown in Fig 2 refers to the radiation from an opening in a slanted roof of a factory hall. The projection on the XY plane of the normal to the roof plane points towards northeast (37,2°); the slope of the roof is 20°. If you use the object type Building to model the hall, then do like this: First rotate the orientation around the z-axis so the zero-direction points towards northeast (the leftmost diagram shows the footprint of the building which makes it easy to adjust visually to the relevant angle). Next rotate around the (now rotated) Y-axis so the zero-direction coincide with the normal to the roof plane (here 70°). Hint: rotate the diagrams by locating the cursor on them and drag with the right mouse button held down). The cross-section map in Fig 3 shows the result. Hint: If you instead use the object type Industrial building to model the hall, SoundPLAN takes care of the orientation automatically; the difference compared to object type Building is that Industrial buildings can have 'real' complex roof constructions, whereas the slanted roof on the object type Building is nothing but a graphical object (eventually with screening effect depending on the graphics object type of the ridge). However, if you assign a source with DI to a vertical façade of object type Building, SoundPLAN will automatically adjust the zero-direction along a normal to the façade.

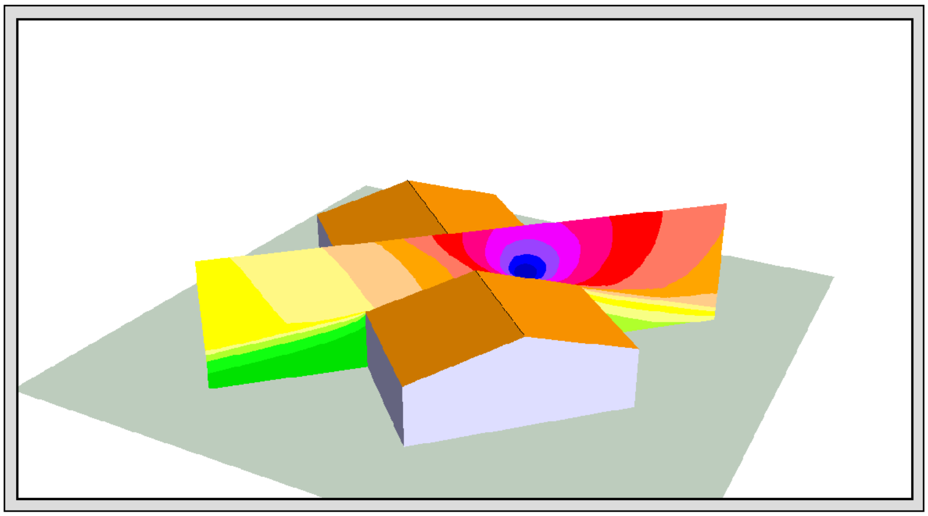


Fig 3 *Cross-section map generated with the settings in Fig 2.*

<u>How to generate a DI record</u>

Click the red + to create a new record. Give the record a name, see Fig 4. On the index card Settings select the type of DI. With horizontal DI's you get the same directivity for all receivers on a vertical plane through source and receiver. The decicive angle is the angle between the zero-direction and the projection of the source-receiver line on the XY plane; on Fig 5 this angle is named Horizontal angle.

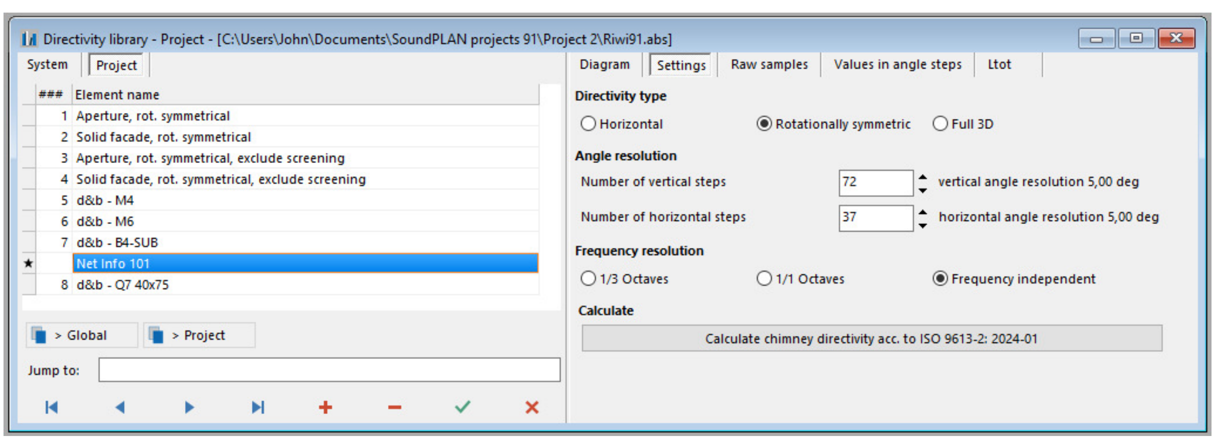


Fig 4 *Generating new DI's.*

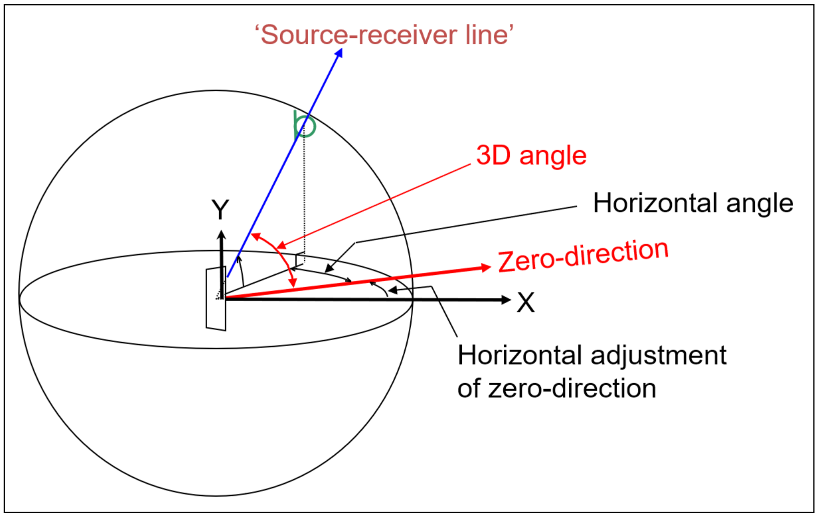


Fig 5 *Definition of DI's.*

Rotationally symmetric DI's are generated by rotating a horizontal DI around the X-axis; the decicive angle is marked '3D angle' on Fig 5. Horizontal and rotationally symmetric DI's are the most relevant directivity types, when dealing with environmeltal industry noise. Full 3D directivy is rarely available when it comes to 'ordinary' industry noise sources, but could very well be relevant, if the source is a loudspeaker.

Once you have decided for a DI type, you should select the angle steps you want to see on the index card 'Values in angle steps' for the final record. Finally select the frequency resolution.

On the index card Raw samples you can generate an input mask that matches the available external data. Click the red + the relevant number of times and fill in your data in the generated table. Or use the wizard to generate the table (which is convenient if the external data are given in equdistant angle steps). All steps in the entire process of creating a horizontal DI is explained in details in the example below. Preparing a rotationally symmetric DI is very similar.

<u>Example</u>

Prerequisites: Sound pressure measurements have been performed at a fixed distance from the source and in angle steps 45° around a source. The results are shown in the table Fig 6.

	Frequency								
Direction	63	125	250	500	1000	2000	4000	8000
0	87,9	97,3	103,1	103,4	99,4	96,8	93,5	90,6
45	86,2	95,5	101,2	104	98,2	95,6	93,1	90,6
90	80,1	89,1	94,1	96,9	97,1	94,3	92,1	91,9
135	83,8	85	88,8	89,4	90,4	88,9	88,2	87,4
180	71,6	82,8	85,6	87,7	90,1	86,7	84,8	83,3
225	83,8	85	88,8	89,4	90,4	88,9	88,2	87,4
270	80,1	89,1	94,1	96,9	97,1	94,3	92,1	91,9
315	86,2	95,5	101,2	104	98,2	95,6	93,1	90,6

Fig 6 *Measurement results.*

To match these external data, settings are selected as shown in Fig 7:

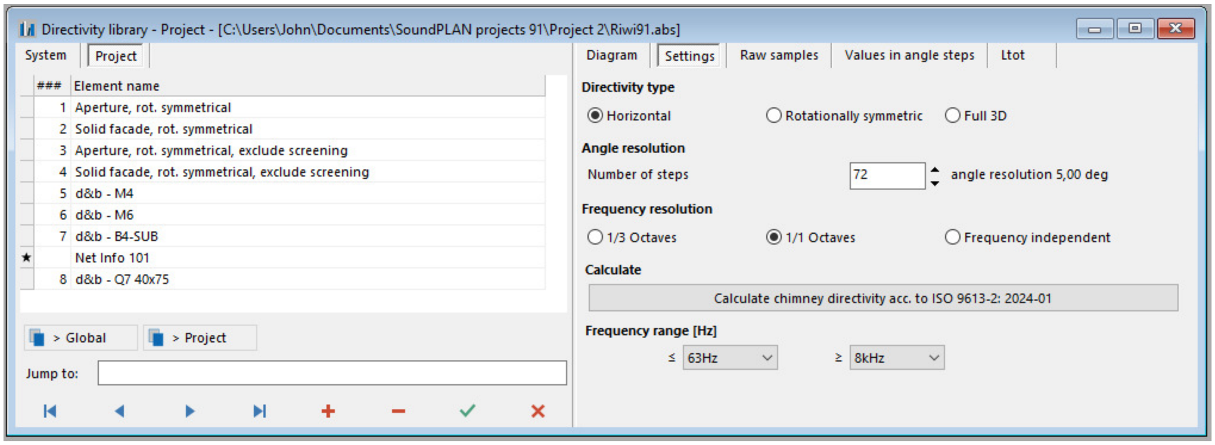


Fig 7 *Settings.*

The input mask is generated with the wizard, see Fig 8; the prepared table can be seen in Fig 9.

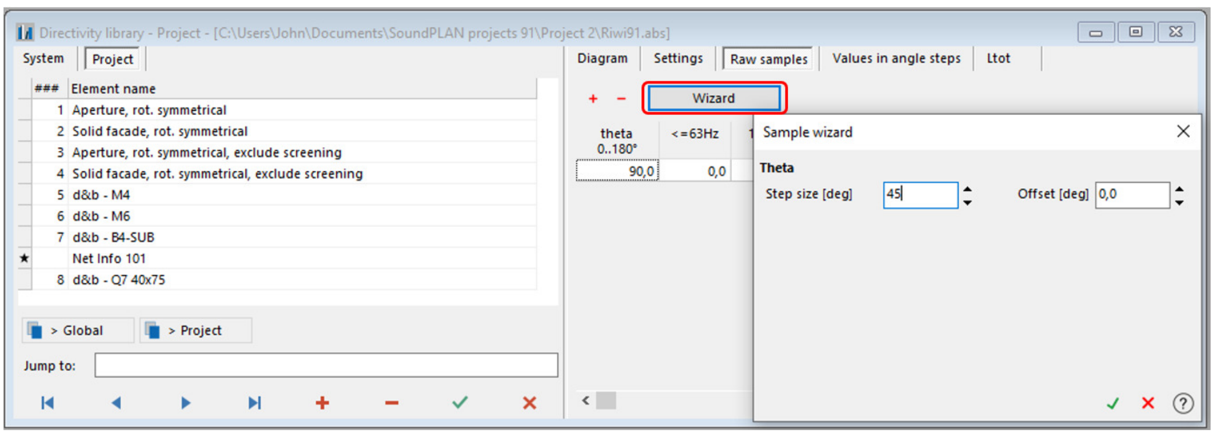


Fig 8 *The input mask is generated.*

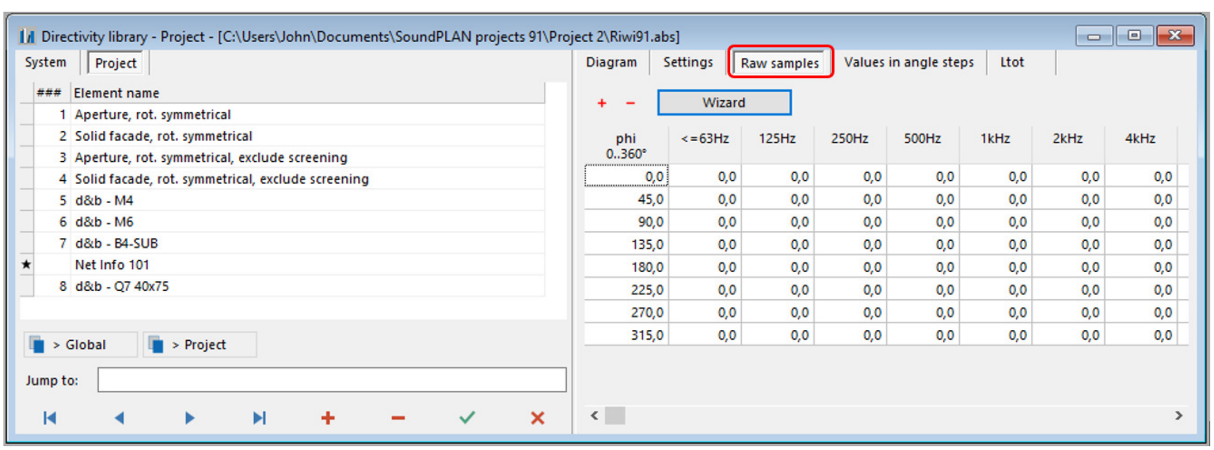
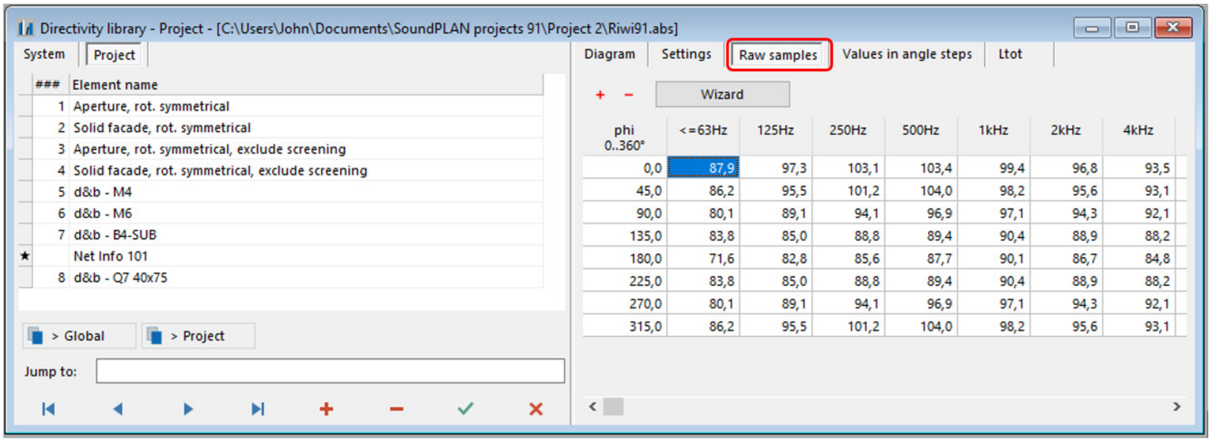


Fig 9 *Table ready for pasting external data.*

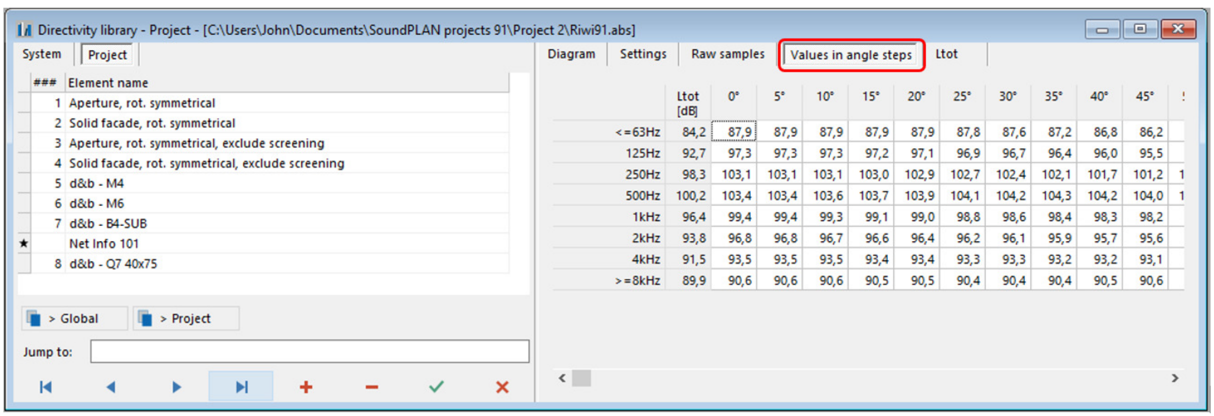
Mark all levels (cell C4 – J11) shown in Fig 6 and take them to the clipboard (ctrl+c); go to the DI library, locate the cursor in the upper left cell (63 Hz, 0°) of the prepared table and paste all data with ctrl+v, Fig 10.



phi 0..360°	<=63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
0,0	87,9	97,3	103,1	103,4	99,4	96,8	93,5
45,0	86,2	95,5	101,2	104,0	98,2	95,6	93,1
90,0	80,1	89,1	94,1	96,9	97,1	94,3	92,1
135,0	83,8	85,0	88,8	89,4	90,4	88,9	88,2
180,0	71,6	82,8	85,6	87,7	90,1	86,7	84,8
225,0	83,8	85,0	88,8	89,4	90,4	88,9	88,2
270,0	80,1	89,1	94,1	96,9	97,1	94,3	92,1
315,0	86,2	95,5	101,2	104,0	98,2	95,6	93,1

Fig 10 *All levels 'imported' into the DI library with few keystrokes.*

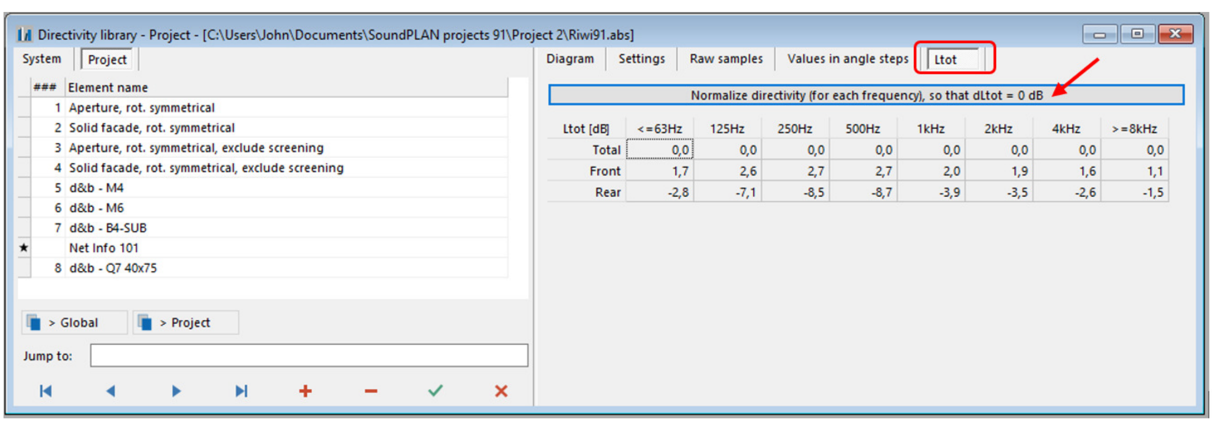
Now check the result in 5° steps on index card Values in angle steps, see Fig 11:



	Ltot [dB]	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°
<=63Hz	84,2	87,9	87,9	87,9	87,9	87,9	87,8	87,6	87,2	86,8	86,2
125Hz	92,7	97,3	97,3	97,3	97,2	97,1	96,9	96,7	96,4	96,0	95,5
250Hz	98,3	103,1	103,1	103,1	103,0	102,9	102,7	102,4	102,1	101,7	101,2
500Hz	100,2	103,4	103,4	103,6	103,7	103,9	104,1	104,2	104,3	104,2	104,0
1kHz	96,4	99,4	99,4	99,3	99,1	99,0	98,8	98,6	98,4	98,3	98,2
2kHz	93,8	96,8	96,8	96,7	96,6	96,4	96,2	96,1	95,9	95,7	95,6
4kHz	91,5	93,5	93,5	93,5	93,4	93,4	93,3	93,3	93,2	93,2	93,1
>=8kHz	89,9	90,6	90,6	90,6	90,5	90,5	90,4	90,4	90,4	90,5	90,6

Fig 11 *Data in fixed angle steps.*

Go to index card Ltot and normalize the results, Fig 12.



Ltot [dB]	<=63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	>=8kHz
Total	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Front	1,7	2,6	2,7	2,7	2,0	1,9	1,6	1,1
Rear	-2,8	-7,1	-8,5	-8,7	-3,9	-3,5	-2,6	-1,5

Fig 12 *Normalized results.*

To obtain directivity values at all angles – and not only towards the original measurment positions (0°, 45°, 90° etc) – the data must be interpolated. On the index card Diagram there are 3 different spline functions to do this (cubic, exponential, Fourier). We have no official recommandation which one to use, so just pick the one you think looks realistic. On the diagram the magenta coloured curve represents the original data and the green curve is the interpolated (and normalized) data, Fig 13.

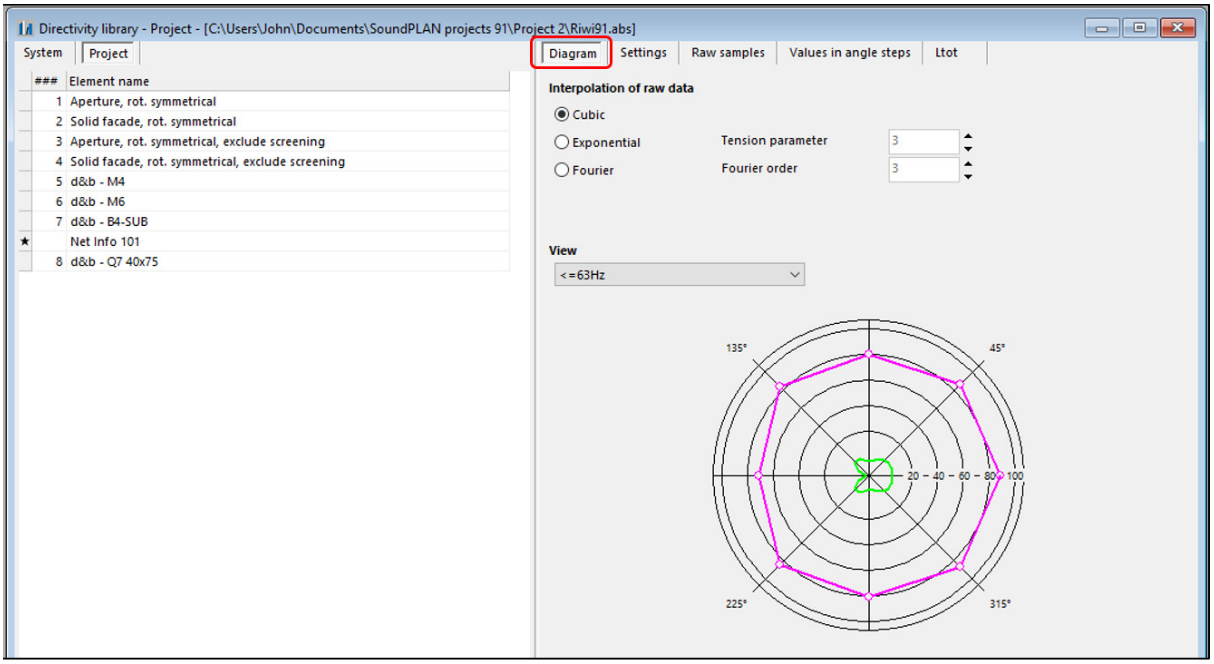


Fig 13 *Diagram showing the original data and the final interpolated and normalized data.*

Going back to index card Values in angle steps gives you the chance to inspect the final directivy corrections, Fig 14.

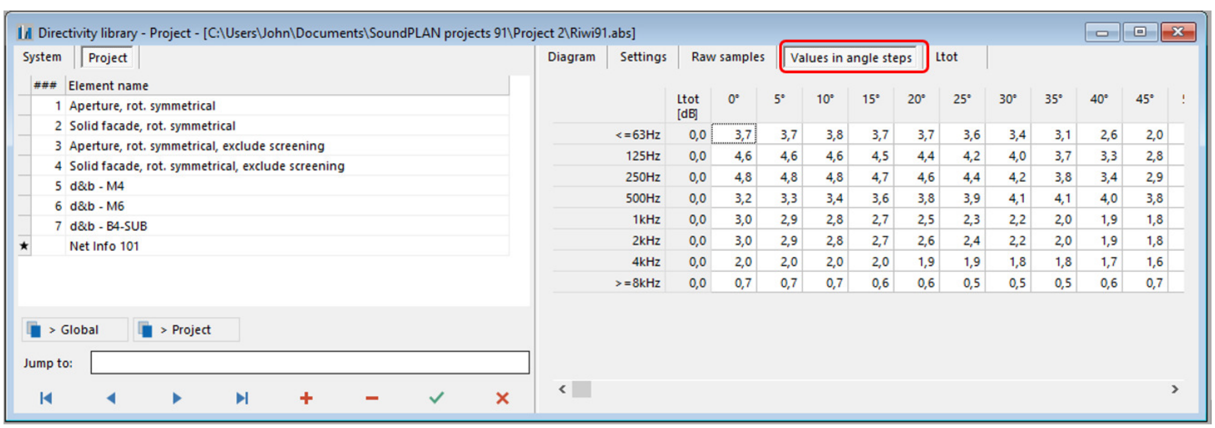


Fig 14 *The final DI values.*

<u>Line and area source with DI</u>

Line and area sources can also be assigned with a directivity. The assignment can be done in different ways as illustrated in Fig 15. Define your choice on the index card Additional in the source property window.

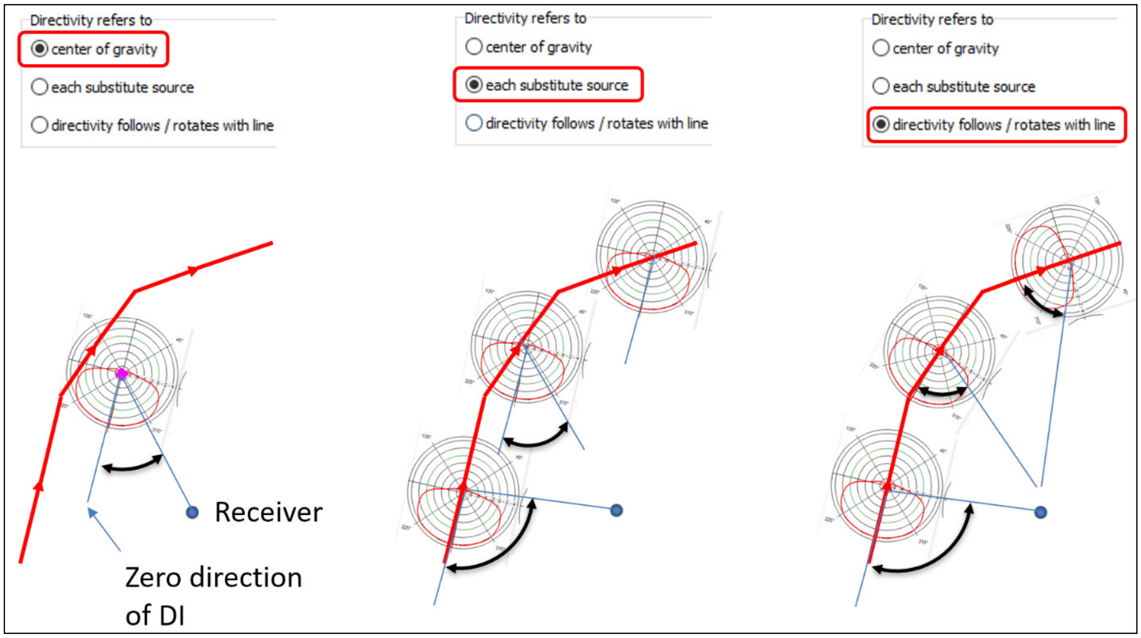


Fig 15 *Three ways to assign DI to line sources.*

If you want the program to assign the same DI to all calculation segments of the line source, then pick 'center of gravity'. The decisive angle will be the angle between the zero direction of the DI and the line from receiver to center of gravity of the source.

Or you can ask the program to pick a DI for each segment ('calculation source'/ 'substitute sources') individually. Here the zero direction of the DI is fixed.

From Ver 8.2 on there is a third possibility: The zero direction of the DI can change with the orientation of the line. This is relevant for example if you use the line source object type to model a moving point source.

<u>Special hint for Danish customers</u>

According to Danish guidelines (Miljøstyrelsens vejl. 5/1993, section 2.7.4) the radiation from an aperture in a baffle/facade or from a solid facade can be modeled using the DI's shown in Fig 16 and 17, respectively.

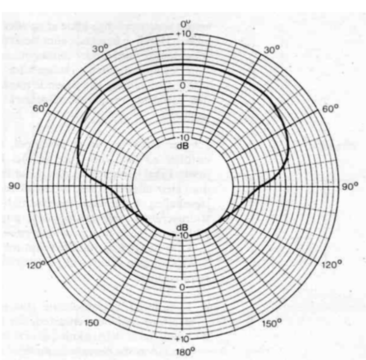


Fig 16 *DI for an aperture*

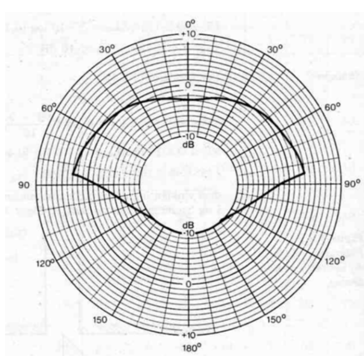


Fig 17 *DI for a solid facade*

The decisive angle is the 3D solid angle (see Fig 5) between the normal to the area and the source-receiver line. This is an obvious case for using rotationally symmetric DI's. The Danish system DI library in SoundPLAN includes those two records. Fig 18 shows the one for apertures.

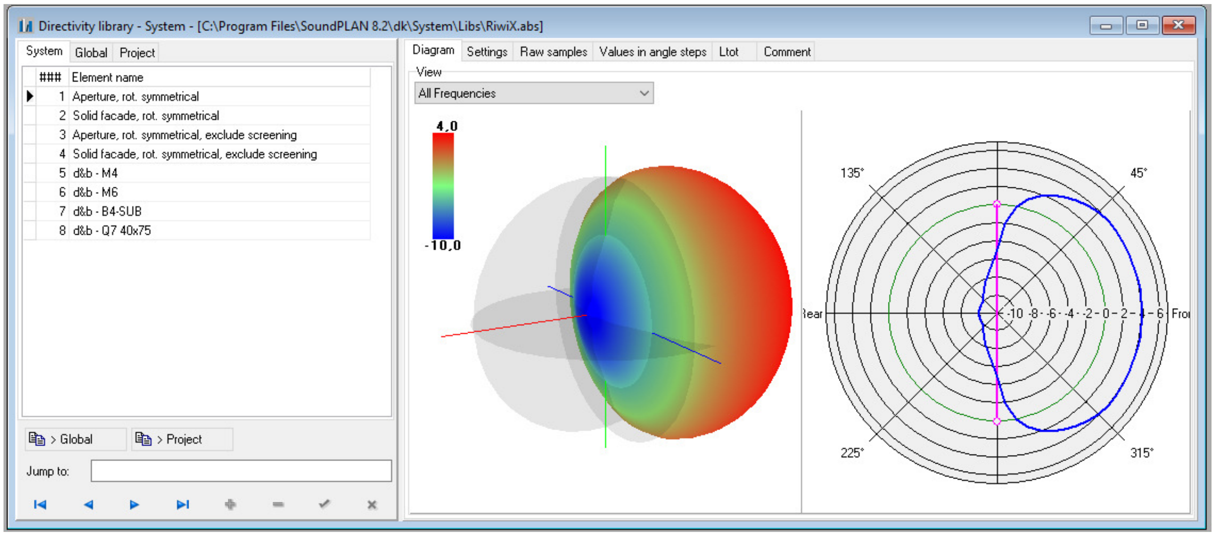


***Fig 18** DI for openings*

These directivities are coarse approximations but nevertheless mandatory in certain types of projects in Denmark ('Miljømåling – ekstern støj').

It is important to realize how these directivities are meant to be used. The directivity is minus 10 dB at direction towards the rear for both the aperture and the solid facade. These minus 10 dB are meant to replace the screening of the baffle/facade itself when seen from receivers behind the building. To fulfil the above-mentioned guidelines the building with the opening/façade must be taken out of the model and replaced by an emission with the relevant DI. However, the building most likely causes screening and reflections from other sources in the model and therefore cannot be ignored. Consequently, the only way to fulfil the guidelines is to add the result of two calculations, one calculation with the building and all other sources in the model but without the source in question; and another calculation where the building with aperture/facade is taken out of the model and replaced by the source in question including the DI. This approach would be rather painful when working with noise mapping software.

Below we outline a series of 'emergency exits' to deal with this challenge. When choosing between these 'exits' you must consider if the calculation result in front of the building or on the backside is most important/critical relative to noise limits. If you keep the building in the model, there is no way to fulfil the guidelines in the entire area. An aperture and the DI on Fig 16 are used as example, but similar arguments are valid for a solid facade. We assume the sound power LwA of the source has been worked out as described in the guidelines. All approaches keep the building in the model.

1) Create a free (= not attached) source with emission LwA (without DI) close in front of the aperture/facade. In this case the program will include a reflection from the building which will increase the level for most receivers in front of the building with up to 3 dB (if reflection loss of the building = 0 and source very close to the facade). In front of the aperture the guidelines expect an addition of 4 dB, see Fig 16, due to the radiation through the aperture. This means that this solution will underestimate the level in a wide area [–60°; +60°] in front of the aperture by up to 1 dB, and in the rest of the area in front of the building the level will be overestimated by up to 5 dB. On the backside of the building the calculated level

will most likely be (heavily) underestimated since most realistic buildings will produce much more screening than 10 dB, if the source is close to the building.

2) Attach a source with emission LwA (without DI) to the façade of the building. Attaching the source will cause the program to ignore reflections from the façade and instead increase LwA with the parameter DΩ-Wall. DΩ-Wall is default 3 dB but can be adjusted manually to 4 dB to match the DI for apertures in a wide area (approx. [–45°; +45°]) in front of the building. However, in the rest of the area in front of the building the level will be overestimated, and on the backside of the building the issue is (almost) the same as with 1).

3) Attach the source with assigned DI from Fig 16 to the building and set DΩ-Wall = 0 dB. This solution actually fulfils the guidelines in front of the building, but on the backside the levels will be subject to both the screening calculated by the program and the minus 10 dB from the DI leading to a massive underestimation of the level.

4) To avoid the 10 dB 'screening' from the DI in case 3) we have included in our Danish system library a modified version of the two official DI's. The directivity towards the backside of the building is here set = 0, see directivity record #3 and 4. For comparison the DI for openings with and without the 'screening' backwards are shown in Fig 19. Note the scale, otherwise you might misinterpret the figure. This is a pragmatic workaround in models where the calculation result in front of the building is more important than on the backside. In addition, this solution will in most cases give a calculation result behind the building that comes closer to reality, because the screening by the building in general is much bigger than those 10 dB prescribed by the guidelines.

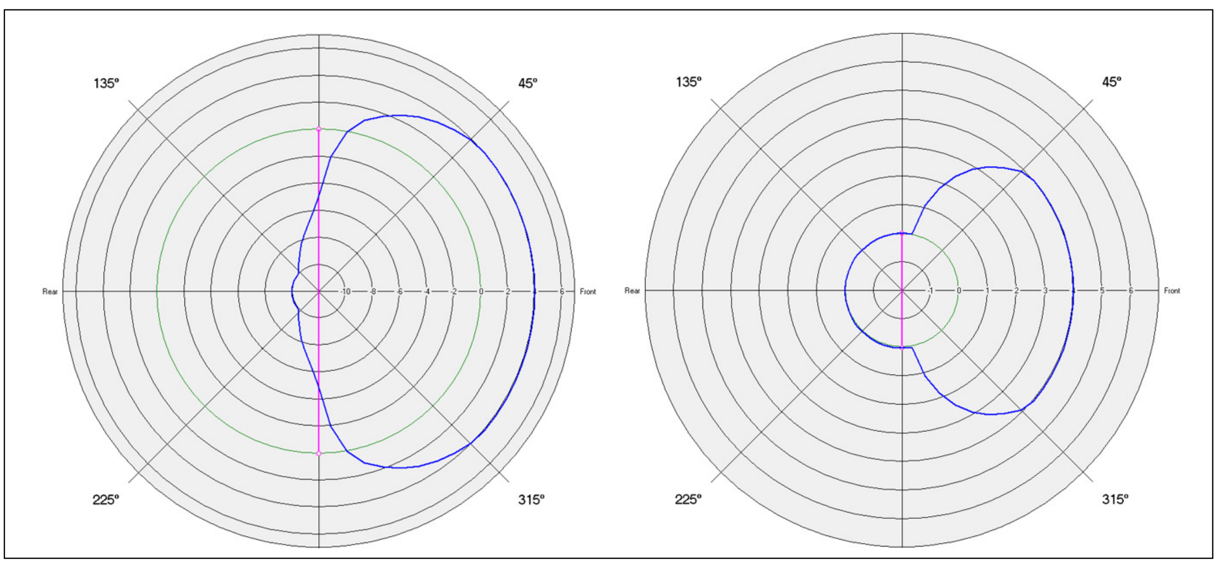


Fig 19 *Directivity for openings, left the official DI, right the same but modified to 0 dB towards the backside*