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NOISE CONTROL FOR A BETTER ENVIRONMENT

Directivity of a hemi-dodecahedron sound source.

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ABSTRACT

ISO 16283:2014 Part 1 specifies dodecahedron sound sources but permits the use of a hemi-dodecahedron sound source for airborne sound insulation tests provided that the hemi-dodecahedron sound source is placed flat on the floor of the test room and that the test direction, when testing a separating floor, is upwards i.e. from lower to upper room. This causes compliance issues if the upper room has a greater volume than the lower room, or where there may be structure borne noise resulting from the sound source being in direct contact with the floor.

This paper describes novel directivity tests, which broadly follow Annex A of ISO 16293:2014 Part 1, to investigate the suitability of a hemi-dodec sound source when testing a floor downwards, i.e. from upper to lower room.

The novel tests measure the directivity of a hemi-dodec sound source in two dimensions, with the sound source raised above the floor using a stand.

Keywords: Hemi-dodecahedron, Directivity, Sound Insulation Testing

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1. INTRODUCTION

In Annex A of ISO 16283-1:2014 it states that a hemisphere polyhedron loudspeaker that is mounted directly on the floor can be used although this will preclude vertical measurements where the upper room is the source room. This is a problem because in Annex C2.1 it says that if the rooms are of different volumes, the larger room should be chosen as source room when the standardized level difference is to be evaluated. This effectively means that a sound insulation measurement cannot be made with a hemi-dodecahedron sound source when the upper room is the larger.

2. TESTS AND RESULTS.

2.1 Test 1 - Directivity test in a horizontal plane according to Annex A of ISO 16283-1:2014

This was a 'baseline' test to measure the directivity of the Norsonic Nor 250 hemi-dodecahedron sound source when placed flat on the floor, as described in Annex A. The test was also intended to validate the test arrangement and the test procedure.

For this test, a temporary reflecting plane was constructed in the anechoic chamber using sheets of plywood. The sound source was positioned in the centre of the reflecting plane with a measurement microphone positioned at a height of 0.5 metres at a distance of 1.5 metres from the source centre, as shown in Figure 1. The sound source was rotated manually, in 5 degree steps for a full 360 degree rotation.

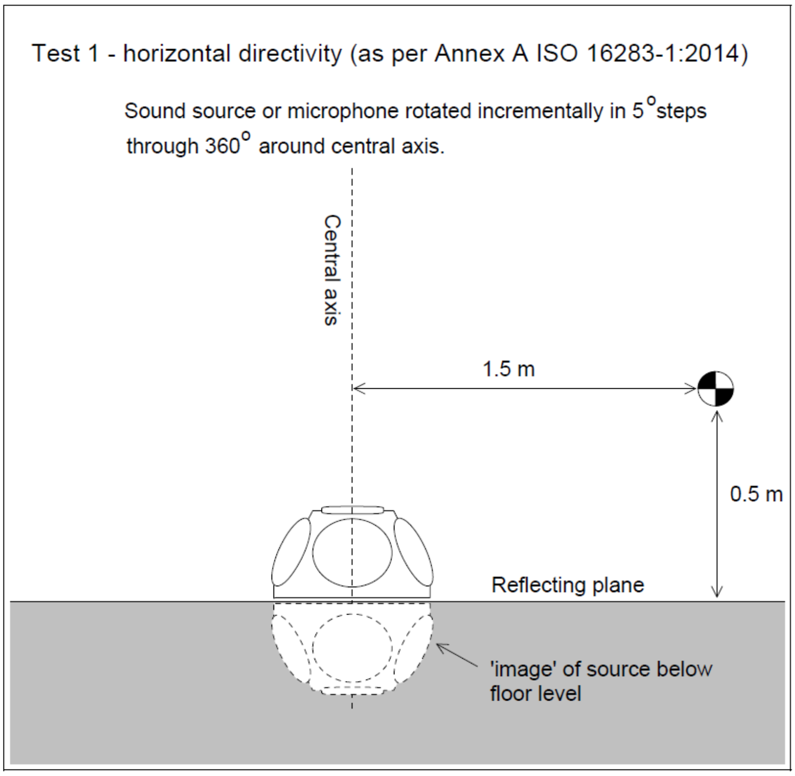

Figure 1 – test arrangement for Test 1.

Following Annex A, section A.2, the energy-averaged level, L_{360} was calculated for the complete 360 degree rotation (72 measurements).

The 'gliding arc' value, $L_{30,i}$ was calculated for each 30 degree angle step, in 5 degree increments and the directivity indices, DI_i calculated using the following formula:

$DI_i = L_{360} - L_{30,i}$

The results of the calculations were compared, graphically, with the directivity criteria stated in Annex A, i.e. +/- 2 dB for the frequency range 100 Hz to 630 Hz, +/- 5 dB for 800 Hz and +/- 8 dB for the frequency range 1000 Hz to 5000 Hz. The convention for the display of sound source directivity is shown in the graph of Figure 2.

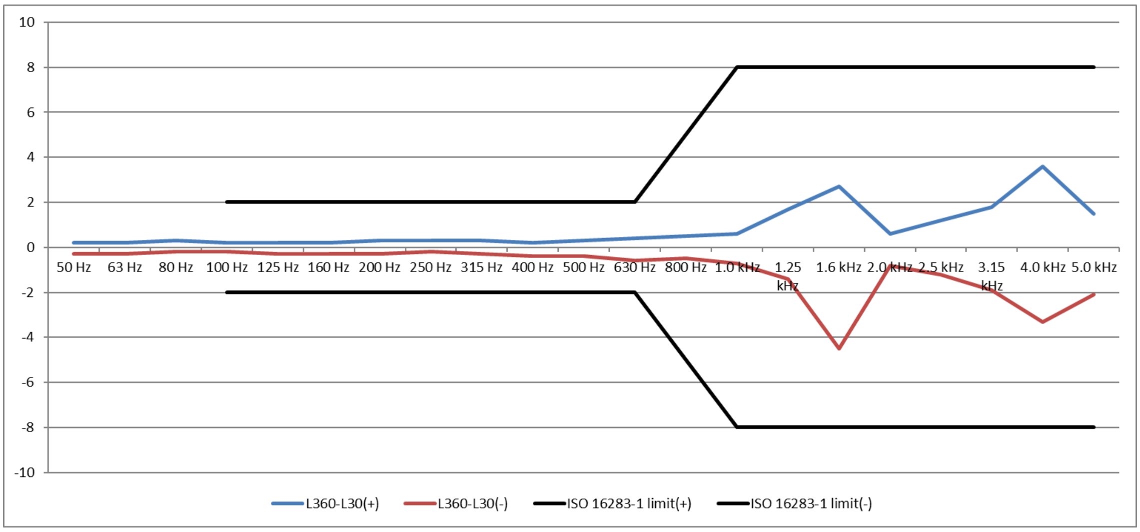

Figure 2 – graph showing Directivity Indices for Test 1 (horizontal plane).

The results of Test 1 show that the directivity of the hemi-dodecahedron sound source is well within the parameters defined in Annex A of ISO 16283-1:2014, in the horizontal plane.

The obvious limitation with this test arrangement is that it is unsuitable for testing from an upper room to a lower room, through a separating floor, for example when the upper room has the greater volume of the pair of rooms. This limitation is clearly stated in Annex A of ISO 16283-1:2014.

For reference, polar plots are included for Test 1, at 100 Hz and at 1.6 kHz. It should be noted, however, that the data points are for each incremental 5-degree measurement and NOT the gliding arc energy-average. The limit values shown in red and green (L360 +2, L360 -2, L360 +8 and L360 -8) are therefore for reference only.

The 'lobed' pattern of Figure 4 shows that each individual driver produces its own directivity pattern at high frequencies, but well within the +/- 8 dB limit values.

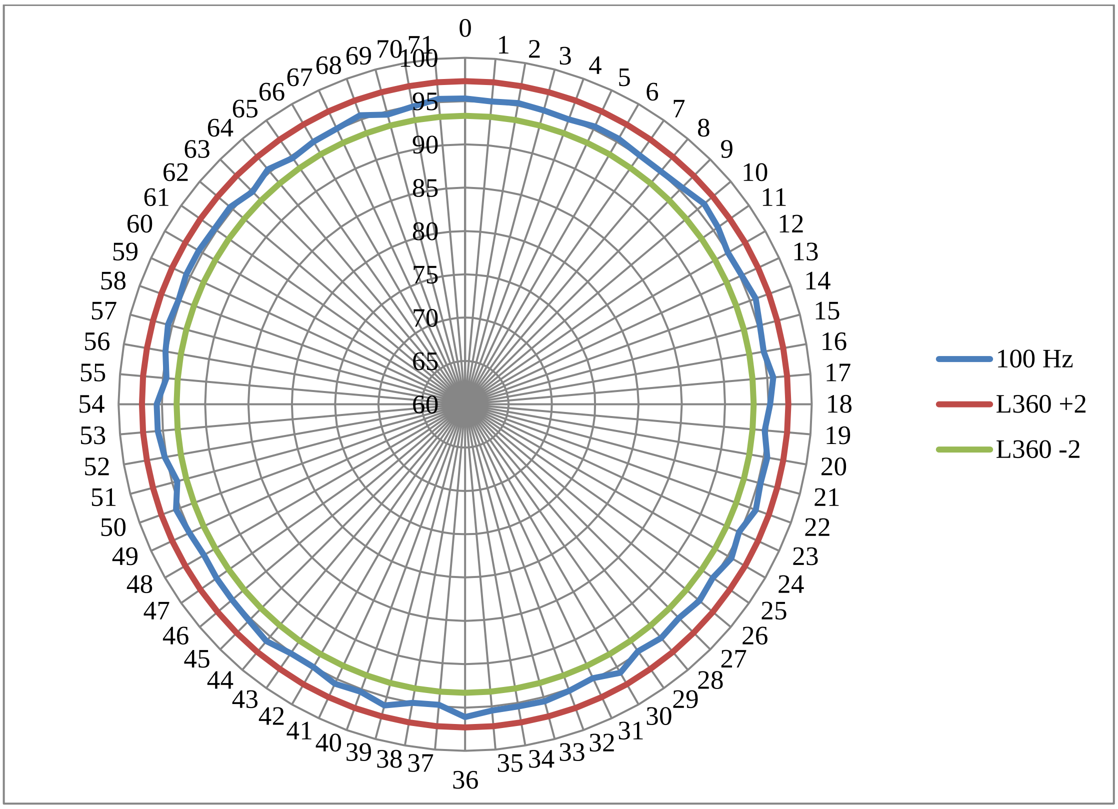

Figure 3 – polar plot for Test 1 at 100 Hz

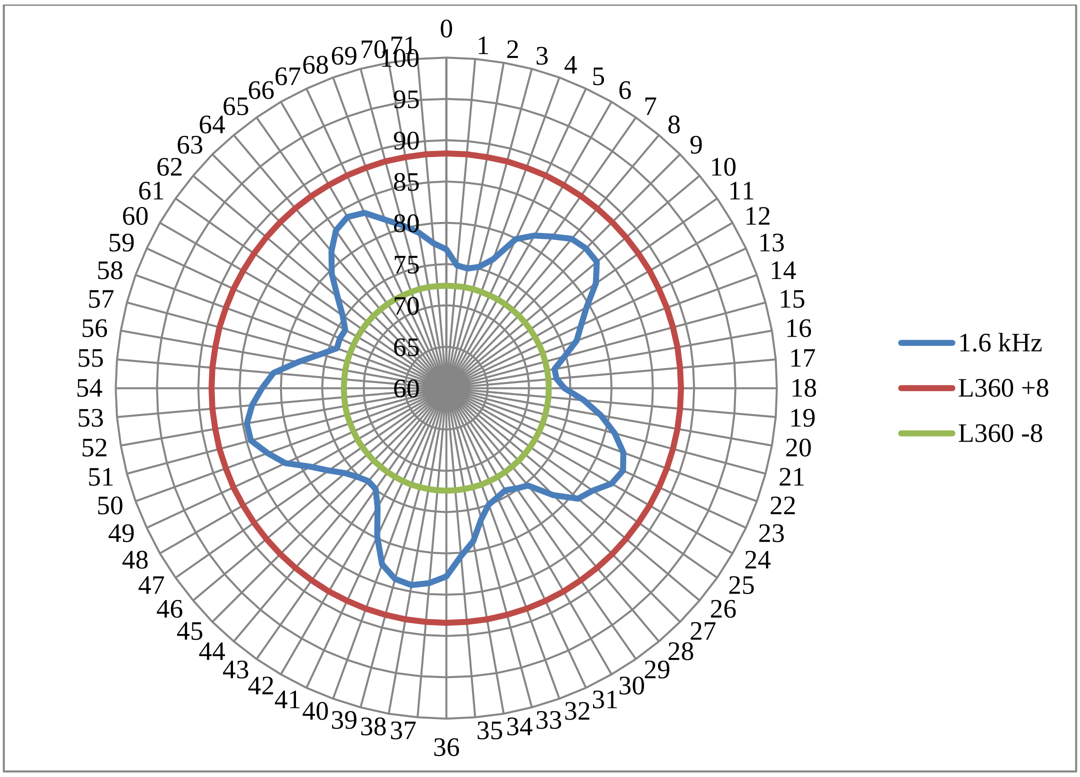

Figure 4 – polar plot for Test 1 at 1.6 kHz.

Having established that the hemi-dodecahedron sound source meets the qualification requirements for directivity in a horizontal plane, as described in A.2 of Annex A of ISO 16283-1:2014, we proceeded to the next test which measured the directivity in a vertical plane.

2.2 Test 2 – Vertical directivity – source on reflecting plane.

This test required a degree of ingenuity from the test team. The test rig involved a semi-circular plastic hoop, 3 metres in diameter, marked at intervals corresponding to 5-degree arcs. The measurement microphone was clamped to the semi-circular hoop and able to slide freely between each position.

The test arrangement for Test 2 is shown, schematically, in Figure 5, noting that only the 30-degree positions are shown for clarity.

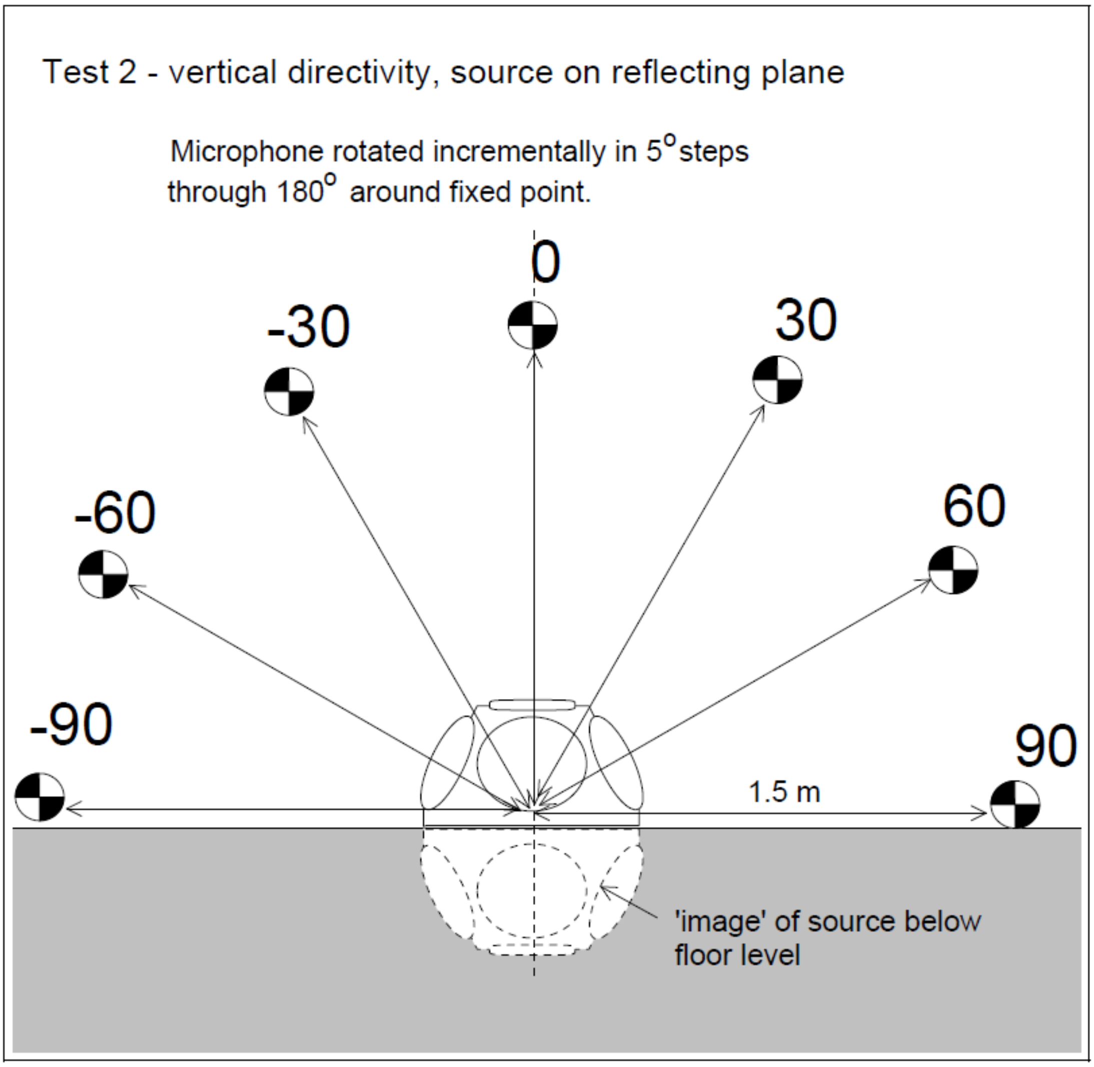

Figure 5 – test arrangement for Test 2.

Following Annex A, section A.2, the energy-averaged level, L_{180} was calculated for a 170 degree rotation (34 measurements).

To complete a full 180 degree arc would have required the measurement microphone to be in contact with the floor, whch was clearly impracticable, so the measurements commenced at +85 degrees and finished at -85 degrees, so the microphone was approximately 150 mm above the floor.

The 'gliding arc' value, $L_{30,i}$ was calculated for each 30 degree angle step, in 5 degree increments and the directivity indices, DI_i calculated using the following formula:

$$DI_i = L_{180} - L_{30,i}$$

The results of the calculations were compared, graphically, with the directivity criteria stated in Annex A, i.e. +/- 2 dB for the frequency range 100 Hz to 630 Hz, +/- 5 dB for 800 Hz and +/- 8 dB for the frequency range 1000 Hz to 5000 Hz. The convention for display of sound source directivity is shown in the graph of Figure 6.

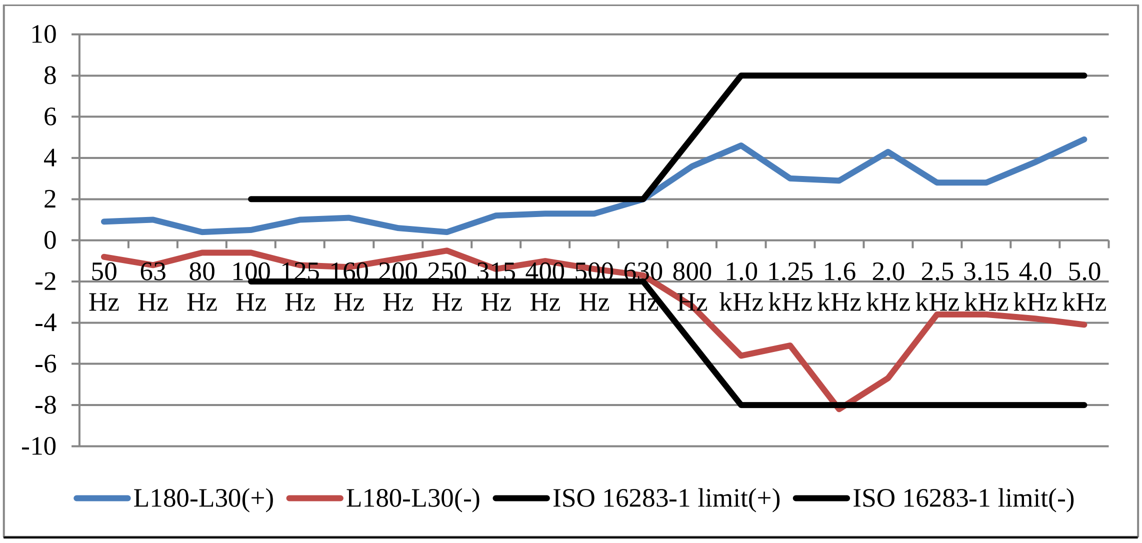

Figure 6 – graph showing directivity indices for Test 2

The results of Test 2 show that the directivity of the hemi-dodecahedron sound source is just within the parameters defined in Annex A of ISO 16283-1:2014, in the vertical plane.

For reference, polar plots are included for Test 2, at 100 Hz and at 1.6 kHz. It should be noted, however, that the data points are for each incremental 5-degree measurement and NOT the gliding arc energy-average. The limit values shown in red and green (L180 +2, L180 -2, L180 +8 and L180 -8) are therefore for reference only.

The asymmetrical 'lobed' pattern of Figure 8 is the result of the directivity of the individual drivers at high frequencies. The polar pattern shows a low value at +75 degrees and at + 80 degrees, which could be a phase cancellation effect, being close to the floor. Note that the effect is exaggerated in the polar plots as the data points are the actual 5-degree measurement values and NOT the gliding arc values.

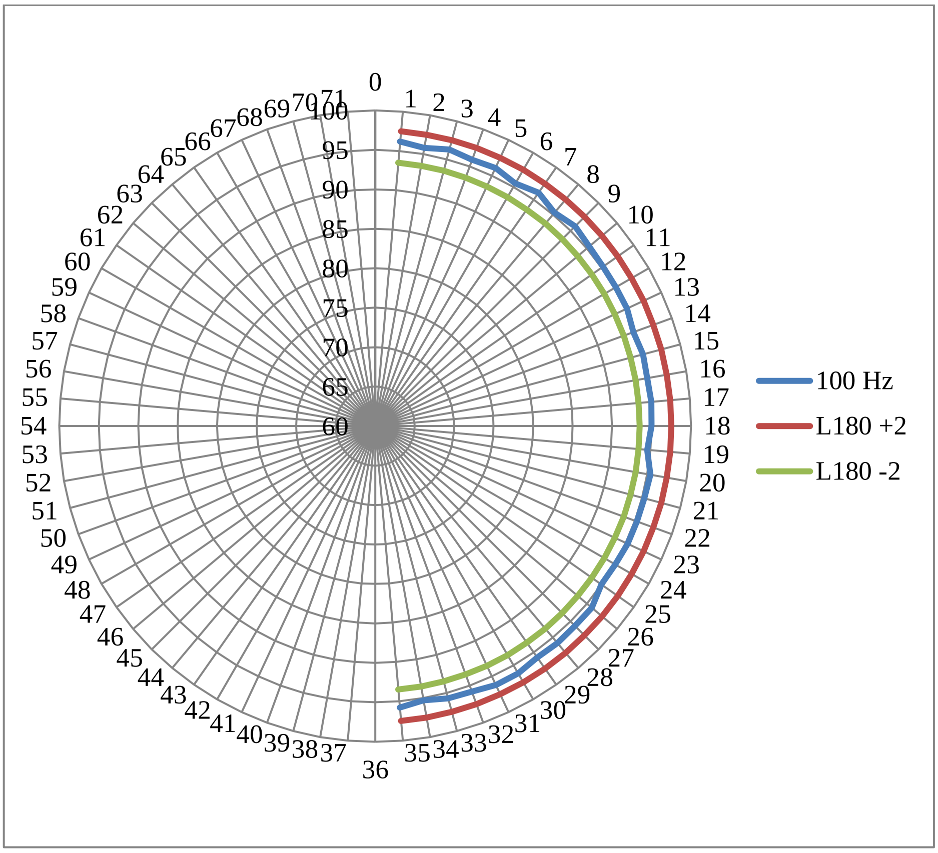

Figure 7 - polar plot for Test 2 at 100 Hz

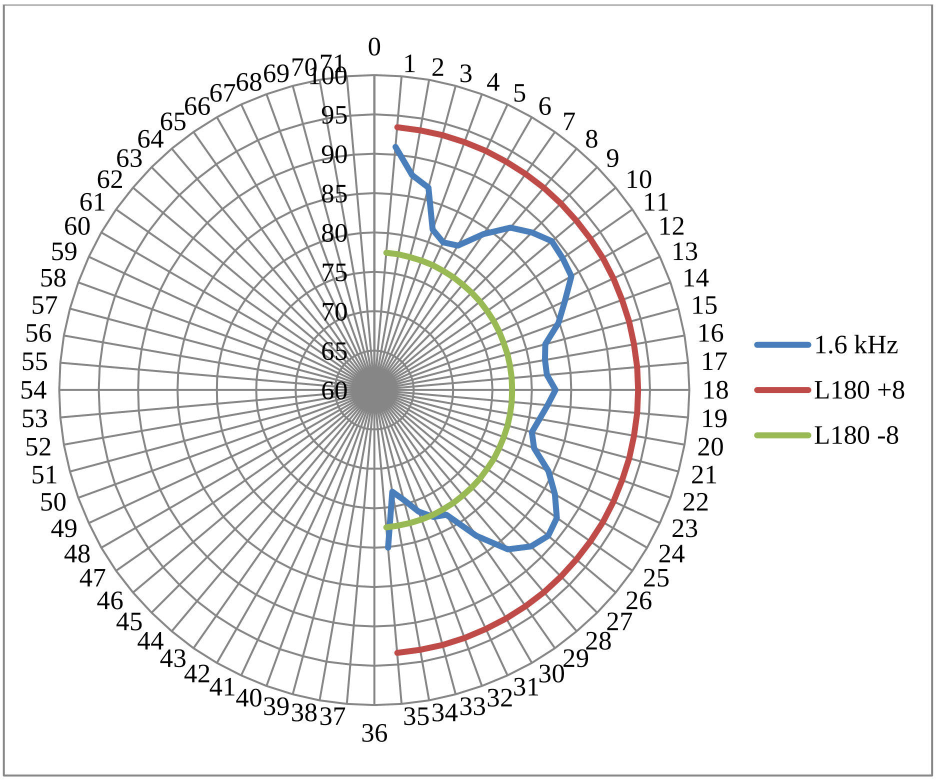

Figure 8 – polar plot for Test 2 at 1.6 kHz

2.3 Test 3 – Vertical directivity – source on 500 mm stand.

Having established that the hemi-dodecahedron sound source also meets the qualification requirements for directivity in a vertical plane, as described in A.2 of Annex A of ISO 16283-1:2014, we proceeded to the next test which measured the directivity *below* the plane of the sound source (the ‘dark’ side).

This involved repeating test 2 but with the sound source raised on a stand so as to be 500. mm above the reflecting plane and measurements over a 220-degree arc.

The test arrangement for Test 3 is shown in the schematic of Figure 9, noting that only the 30-degree positions are shown for clarity.

Following Annex A, section A.2, the energy-averaged level, L_{220} was calculated for a 210 degree rotation (42 measurements). For practical reasons, the measurements commenced at +105 degrees and finished at -105 degrees, so the microphone was approximately 150 mm above the floor.

The ‘gliding arc’ value, $L_{30,i}$ was calculated for each 30 degree angle step, in 5 degree increments and the directivity indices, DI_i calculated using the following formula:

$$DI_i = L_{220} - L_{30,i}$$

The results of the calculations were compared, graphically, with the directivity criteria stated in Annex A, i.e. +/- 2 dB for the frequency range 100 Hz to 630 Hz, +/- 5 dB for 800 Hz and +/- 8 dB for the frequency range 1000 Hz to 5000 Hz. The convention for display of sound source directivity is shown in the graph of Figure 10.

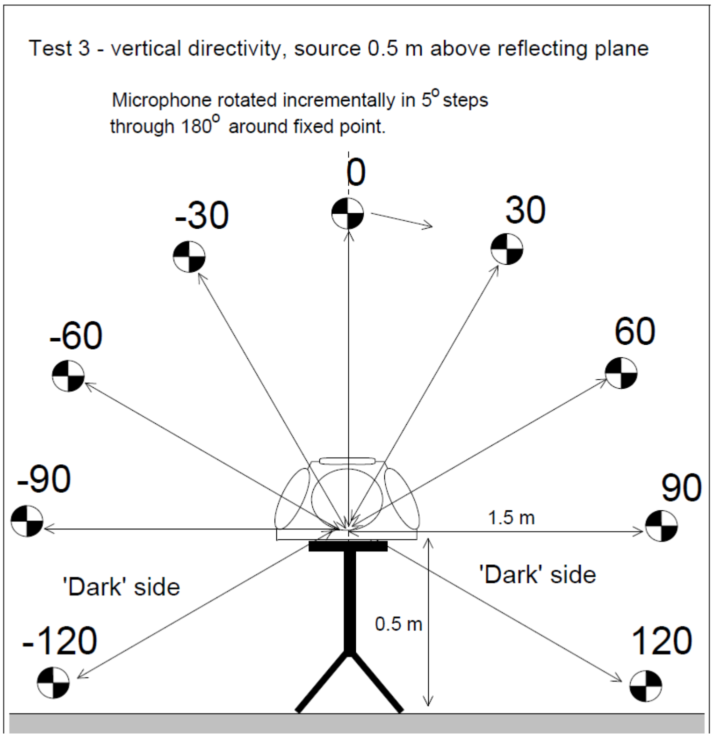

Figure 9 – test arrangement for Test 3.

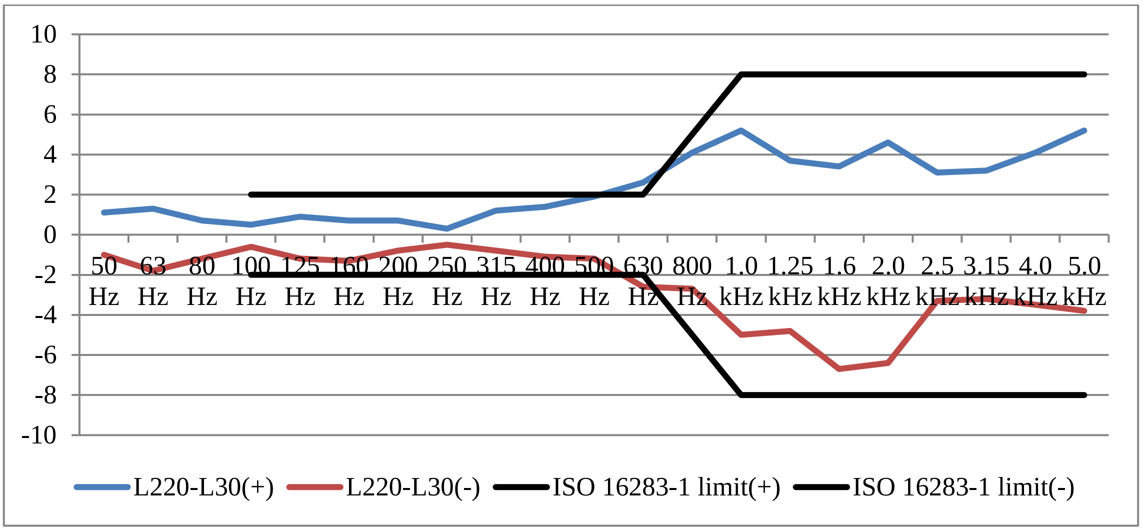

Figure 10 – graph showing directivity indices for Test 3.

The results of Test 3 show that the directivity of the hemi-dodecahedron sound source is just outside the parameters defined in Annex A of ISO 16283-1:2014, in the vertical plane, in the 630 Hz frequency band. The DI at 630 Hz exceeds the +/- 2 dB limits by +0.6 dB and -0.5 dB. However, we calculated an uncertainty budget for the measurements which was a total of ±0.7 dB and these values fall within the measurement uncertainty.

For reference, polar plots are included for Test 3, at 100 Hz and at 1.6 kHz. It should be noted, however, that the data points are for each incremental 5-degree measurement and NOT the gliding arc energy-average. The limit values shown in red and green (L220 +2, L220 -2, L220 +8 and L220 -8) are therefore for reference only.

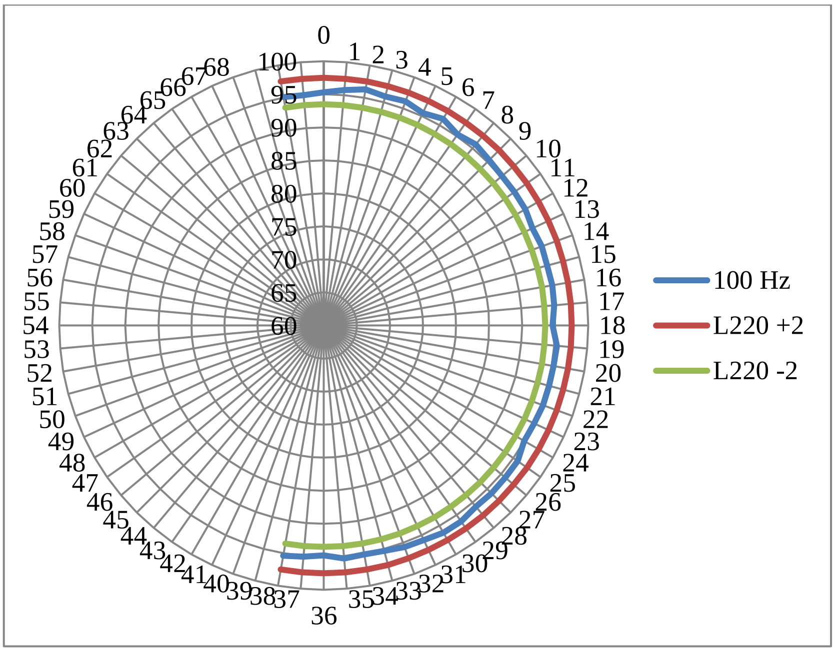

Figure 11 – polar plot for Test 3 at 100 Hz

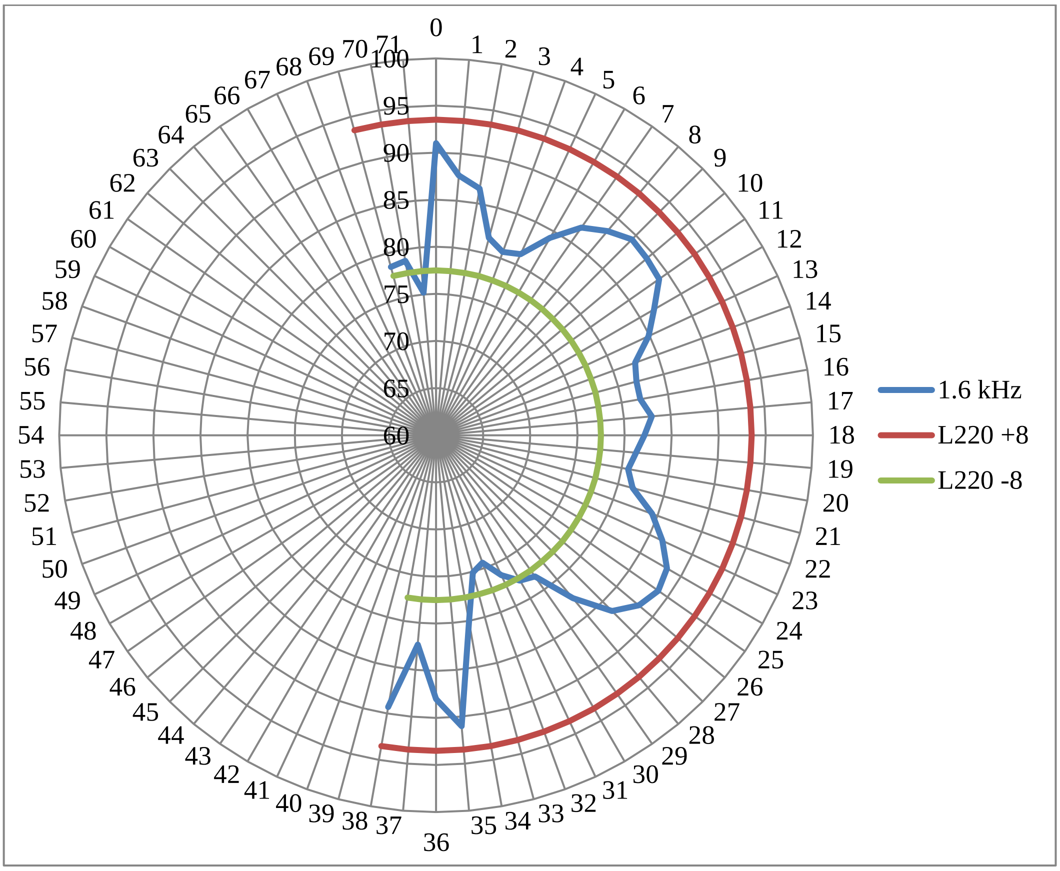

Figure 12 – polar plot for Test 3 at 1.6 kHz

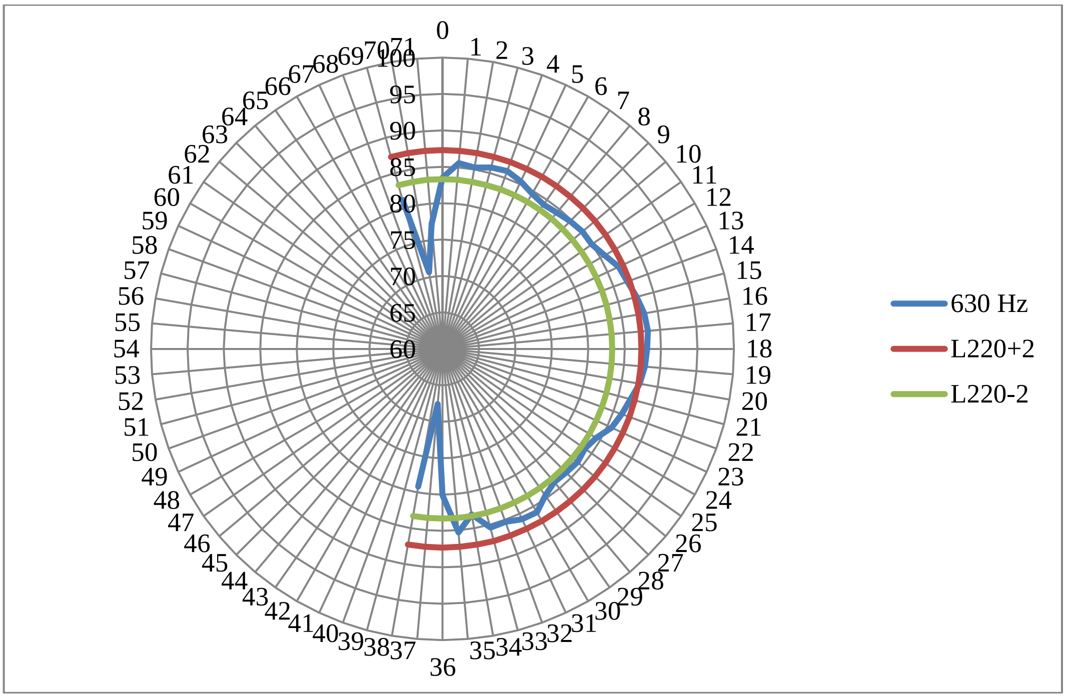

Figure 13 – polar plot for Test 3 at 630 Hz

The polar plot for the 630 Hz band, Figure 13, shows that the anomalous measurements were close to the room boundary and probably due to phase interference effects.

As noted in the previous tests, however, the polar plot displays the individual measurements at each 5-degree arc and NOT the gliding arc value over 30 degrees.

Test 3 therefore shows that the directivity qualification requirements have been achieved, when taking account of measurement uncertainty.

3. USING A HEMI-DODECAHEDRON TO TEST DOWNWARDS.

Test 1, 2 and 3 have established that the hemi-dodecahedron sound source complies with the directivity requirements of ISO 16283-1:2014, Annex A, in a horizontal plane for a complete 360-degree arc and in a vertical plane, for a 220-degree arc, when raised 500 mm above the reflecting plane. It follows that the hemi-dodecahedron sound source can be considered to be omnidirectional when mounted 500 mm above the reflecting plane.

This paper now supposes that the hemi-dodecahedron sound source is turned through 90 degrees so that its flat base is vertical, as shown in Figure 14.

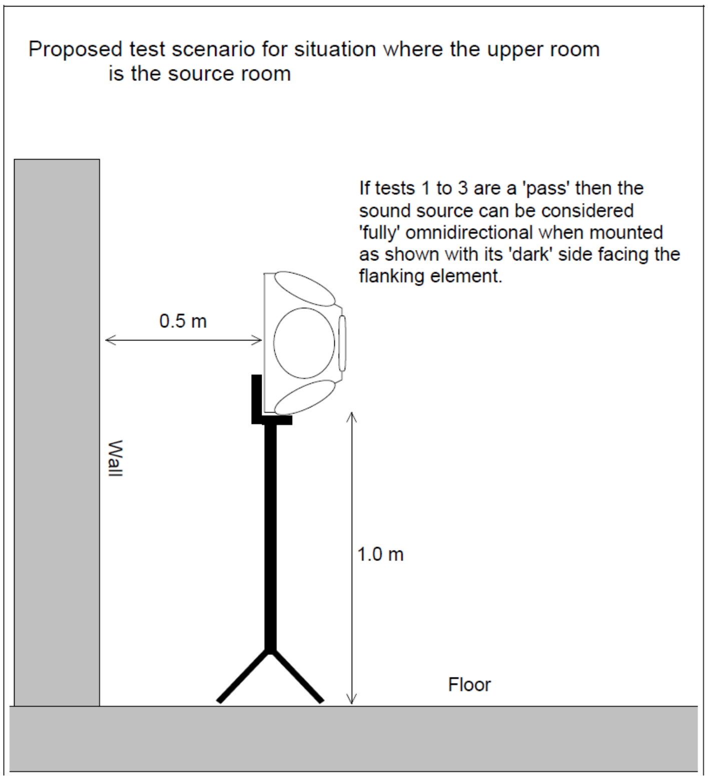

Figure 14 - proposed mounting arrangement for sound source.

This is easy to do using a hook screwed to the base of the sound source which fits into the hollow centre tube of a typical loudspeaker stand (after removing the plastic cap). The co-author of this paper adopted exactly this test arrangement for many successful tests through separating floors, from the upper room to the lower room.

Provided the sound source is mounted at least 1.0 metres above floor level and is 0.5 metres from the nearest wall, the test arrangement is fully compliant with ISO 16283-:2014, Section 7.2.2.

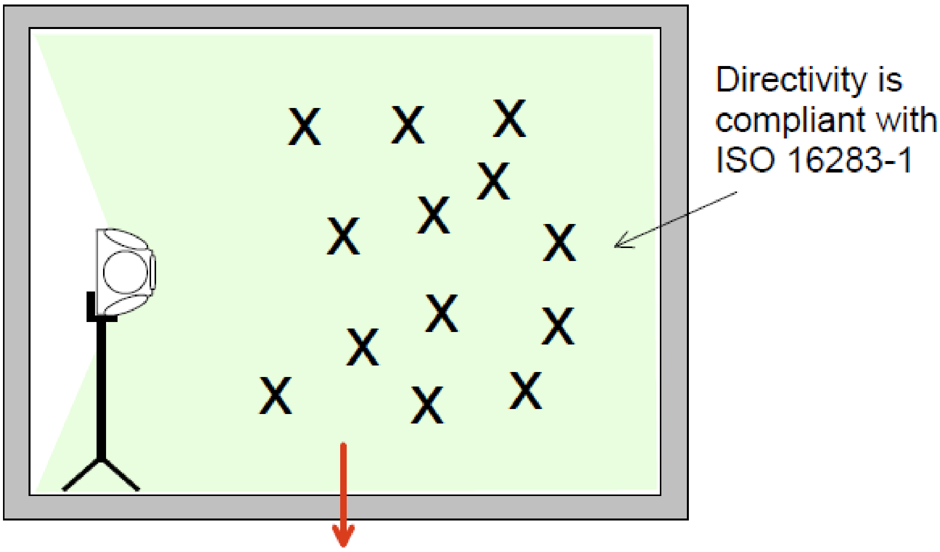

Figure 15 - A sketch of a typical test arrangement, with sample microphone positions.

4. ADVANTAGES OF USING A HEMI-DODECAHERDON, COMPARED TO A DODECAHEDRON.

A hemi-dodecahedron is smaller, lighter, easier to carry and is cheaper to buy. These are important considerations, especially in the UK where testers can be 'one-man bands' and where sound insulation testing is a very competitive market.

The ability to use a hemi-dodecahedron, for all types of sound tests, will help with the adoption of ISO 16283, Parts 1 and 2, in the UK, where there is some resistance to the adoption of the new Standards, partly due to the cost of buying a new dodecahedron sound source.

5. CONCLUSIONS

The tests described in this paper have demonstrated that it is possible to meet the directivity criteria of ISO 16283-1:2014 (Annex A) using a hemi-dodecahedron sound source.

Using a novel test arrangement, which requires that the sound source is turned through 90 degrees and mounted on a stand, enables testing to be carried out from an upper room to a lower room, where the ISO Standard specifically precludes the use of a hemi-dodecahedron for this type of test.

6. ACKNOWLEDGEMENTS

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