THE EFFECTIVENESS OF THE ISO 9614 F4 INDICATOR TO PREDICT UNCERTAINTY IN INTENSITY MEASUREMENTS

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Introduction

The ISO F_4 indicator given in ISO 9614 Part 1 ("Determination of sound power levels of noise sources using the sound intensity technique," 1996 edition) is evaluated as a method to assess uncertainty in intensity measurements due to under-sampling.

The F_4 indicator provides an estimate of the spatial variance in the intensity over the measurement surface and is given by $F_4 = \frac{1}{\overline{I_n}}\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(I_{ni}-\overline{I_n}\right)^2}$ where $\overline{I_n} = \frac{1}{N}\sum_{i=1}^{N} I_{ni}$ and I_{ni} is the measured normal intensity at the i^{th} measurement point. F_4 can be used to estimate the uncertainty in the measurement (i.e., the 95 percent confidence limits) due to sampling,

$95\%CL = 10Log_{10}\left(1 \pm \frac{2F_4}{\sqrt{N}}\right)$ where N is the number of measurement points. There are three measurement grades defined by ISO 9614: *precision, engineering, and survey.* When the number of measurement points exceeds CF_4 then ISO Criterion 2 is satisfied and the measurement will achieve a precision defined by the frequency and grade specific multiplier: C.

In this paper the predicted[1] and actual number of measurement points required to attain *precision* grade (shown in Figure 1) will be compared to assess the effectiveness of F_4 and Criterion 2.

Measured Data

The sound intensity radiated by a double leaf construction (1.52x1.55 m) separating a 350 cubic meter reverberation chamber and a hemi-anechoic chamber was measured in accordance with ISO 9614 Part 1 using a phase matched PP probe with a microphone spacing of 12 mm. The measurement surface consisted of 11 rows and 13 columns each 100 mm o.c. The probe was positioned between 120 and 130 mm from the surface and the integration time was 32 s.

Intensity data were collected at all 143 points. The total intensity and all field indicators were then computed. Systematically, the number of points used in each intensity computation were reduced by taking a subset of the data for the original 143 points. Seven grids each with fewer sample points were constructed and are listed in Table 1.

Figure 1 and Table 1 show that there is a maximum 0.2 dB change in the estimated radiated intensity as a result of reducing the number of measurement points from 143 to 78. This indicates that the 11x13 grid had adequately sampled the surface and that may be used as a reference to assess the effect of reducing the number of measurement points

Figure 1 and Table 1 indicate that when nine points are used (3x3 grid) the deviation of the intensity estimate exceeds the confidence interval allowed for *precision* grade.

The predicted results of Criterion 2 ($N \geq CF_4$) shown in Table 1 indicate that twenty points (4x5 grid) would be the smallest number to give an estimate of intensity within the acceptable precision limits; nine points (3x3 grid) would be insufficient. This is in good agreement with the measured results of Figure 1 and Table 1.

Conclusion

The ISO 9614 F_4 indicator appears to be a very useful and accurate method for calculating the uncertainty in the measured intensity due to under-sampling.

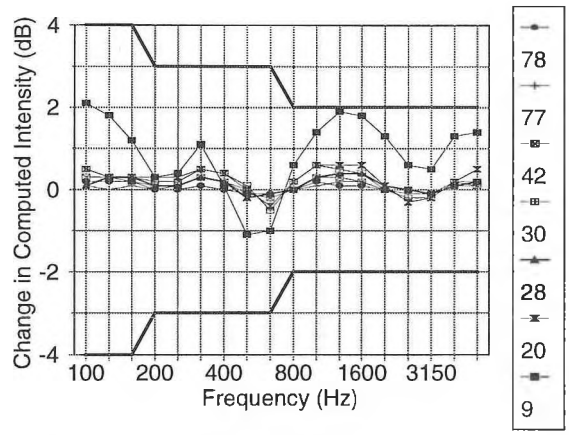

Figure 1: Change in the intensity estimate for various numbers of points used in the measurement grid relative to the full 143 point grid. Uncertainty limits (95% confidence limits) for precision measurements are shown by the solid lines.

[1] Trevor R.T. Nightingale, Valtteri Hongisto, "Investigation of the relationship between the ISO F_4 indicator and the precision of sound intensity measurements made using the point-by-point technique of ISO 9614 Part1," Report MTC 500-1358, 1996, Johns Manville, Littleton, Colorado USA.

Number of points	Rows Sampled	Columns Sampled	CF_4; Criterion 2 Pass/Fail	Maximum 95% confidence limits (dB)	Maximum Deviation re: 11x13 grid (dB); within *precision* limits
143	1 — 11	1 — 13	15; Pass	0.4	n/a ; n/a
78	1, 3, 5, 7, 9, 11	1 — 13	10; Pass	0.4	0.2; Pass
77	1 — 11	1, 3, 5, 7, 9, 11, 13	19; Pass	0.5	0.3; Pass
42	1, 3, 5, 7, 9, 11	1, 3, 5, 7, 9, 11, 13	11; Pass	0.6	0.3; Pass
30	1, 3, 5, 7, 9, 11	1, 4, 7, 10, 13	12; Pass	0.7	0.6; Pass
28	1, 4, 7, 10	1, 3, 5, 7, 9, 11, 13	17; Pass	0.8	0.4; Pass
20	1, 4, 7, 10	1, 4, 7, 10, 13	20; Pass	1.0	0.6; Pass
9	1, 6, 11	1, 7, 13	12; Fail	1.2	2.1; Fail

Table 1: The F_4 indicator correctly predicts when errors due to undersampling cause a deviation in the measured result to exceed the allowable limit for precision grade measurements. This is shown by the predicted number of points (CF_4) to be less than the measured for the 3x3 grid precisely where the measured deviation exceeded the limits for precision measurements.