VARIATION OF ISO 9613, CONCAWE AND THE JOINT NORDIC METHODS OF PROPAGATION CALCULATION

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1 INTRODUCTION

The implementation of the EU Noise directive and ever more stringent planning requirements are forcing industrial developers to consider noise requirements much more carefully than had usually been the case previously. Plant operators need to consider both the protection of their employees hearing in accordance with the Health and Safety at Work Act and, due to constraints on available land, planned commercial development may be placed close to residential areas, or residential areas placed close to commercial enterprises. This causes plant developers and operators to have to evaluate more extensive and expensive noise control measures to comply with planning and noise nuisance requirements.

To facilitate this design work, great reliance is placed upon computer modelling. As computer-processing power has increased, increasingly sophisticated software has allowed tremendously complex modelling to be undertaken and for the results of this modelling to be presented in an easily understood graphical manor.

Most of these software tools allow a variety of different propagation models to be used, with the selection driven by either local legislation or personal preference of the noise control engineer. However, each of the different propagation models is likely to give a different result for a given geometry, location or atmospheric condition. A significant question facing most noise control engineers at some time is “which is the right answer?”

For large new industrial plants software tools are invaluable. This is especially true where the costs and dis-benefits of noise control need to be assessed for existing plants that operate at the limit of their licence and therefore require retrofitted noise control measures to be evaluated. But, when each dB of attenuation can cost millions of Dollars, Pounds or Euros [(1)], which is the most accurate of the “standard” propagation model to use?

Recent expansion work on an existing industrial plant that was already operating at the maximum level allowed within its operating license conditions enabled a comparison of three of the most widely used methods to be undertaken.

“Real world” measurements were made at various positions and distances from a high sound power noise source. (Because an additional aim of the work was the calibration of a permanent noise monitoring system at the site, to establish transfer functions from this system to local “community receiver locations”, when the plant itself could not be shut down, meant that a very high powered source was required for this work). Predicted noise levels were then calculated for each of the measured locations using the three most popular propagation models, and the calculated levels compared with the measured results.

To ensure adequate acoustic power was available, and so that it could be easily determined at each of the receiver locations that an increase of at least 10 dB was achieved over the background level, the source was switched through an octave band filter set. A number of measurements were made at each location and the results averaged.

2 THE PROPAGATION MODELS

Three propagation models were selected for testing. (1) The ISO 9613-2 “Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation”. (2) The “Joint Nordic Method”, originally published as the “Environmental noise from industrial plants. General prediction method” (Report 32 by the Danish Acoustical Laboratory), which has been progressively revised and is currently presented as the “Nord 2000” method [(2)]. (3) The CONCAWE method titled “The propagation of noise from petroleum and petrochemical complexes to neighboring communities."

2.1 ISO 9613

The ISO 9613 Part 2 presents an implementation of the German VDI 2714 “Outdoor Sound Propagation” and VDI 2720 “Noise Control by Barriers Outdoors” standards. These were initially produced in 1976, with VDI 2714 being updated in 1988 and with VDI 2720 being most recently updated in 1997.

The ISO 9613 combines both of the VDI papers and was approved in 1992 as a “general purpose” standard for outdoor noise propagation. It is empirically based and was created as an easy to use, reliable standard where all of the formulas produced results with smooth curves. It is a ray-tracing method that incorporates all aspects of the propagation for a frequency dependent noise source.

2.2 The Nordic Method

The Nordic method undertakes all calculations based on octave band levels. It also incorporates frequency dependent calculation of ground effect.

The first Nordic method was very similar to the ISO method in that it was based on empirical corrections to the source sound powers. The main difference being the used of proscribed weather conditions that included either down wind or temperature inversion such that a worst case would be calculated.

The 2000 revision of the Nordic Method moves on to use geometric ray theory to calculate diffraction over barriers. The method provides a compromise between what is possible and what is possible within a reasonable calculation time.

Ground absorption is calculated using impedance modeling. The terrain being approximated using segments, each with its own impedance. Barriers are modeled as a peak in the terrain line segments.

The propagation model uses sound rays that follow a curved path simulating downwind propagation. The curvature depends on the speed of sound profiles determined using a semi-analytical approach based on the meteorological conditions. The method is applicable to relatively simple conditions without multiple ground reflections and shadow zones

2.3 The CONCAWE Method

The CONCAWE method was developed especially for the requirements of large industrial facilities, principally for the oil, gas and chemical Industries. It was developed from an earlier OCMA model [(3)] incorporating propagation of noise over long distances across relatively flat terrain (either water or land). It was published in 1981 under the title, "The propagation of noise from petroleum and petrochemical complexes to neighboring communities" and incorporates geometrical spreading, atmospheric absorption, ground effects, meteorological effects and barriers.

This method is the only one of the three considered that includes directly corrections for the influence of wind and the stability of the atmosphere.

3 MEASUREMENTS

These were undertaken at night in stable weather conditions. The noise source was set up and measured at a series of different receiver locations (some 17 different locations, measuring each octave band separately and with a series of broadband measurements), all of which were repeated a number of times to allow a reasonable average measurement to be produced. In total some 460 measurements were analysed as part of this review. Measurements were concurrently made of the source so that any variation in source energy could be corrected.

4 MODELLING

A detailed SoundPLAN model was created of the site and area surrounding the test location. A representative source was created and receiver points set at each of the points that measurements had been made.

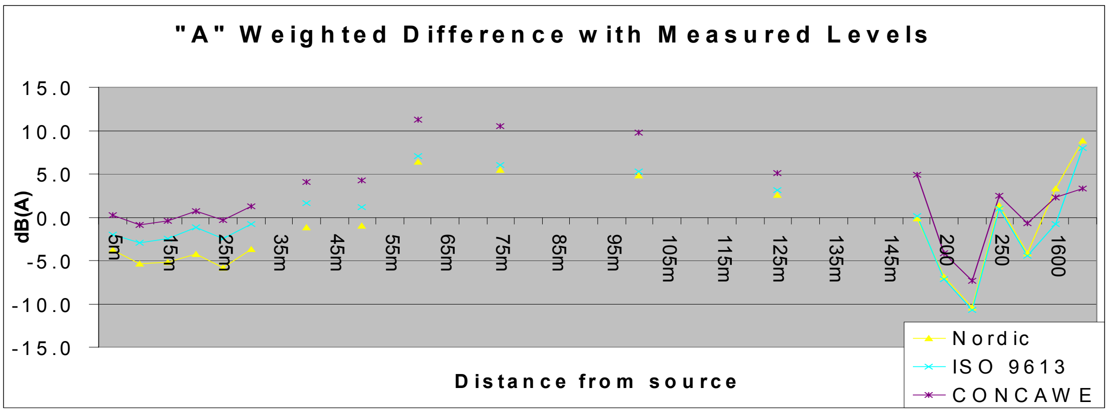
This model was then run using each of the propagation models in turn. Where required for the CONCAWE method, the prevailing weather data was incorporated into the model.

5 DATA ANALYSIS

The noise levels calculated using each of the propagation models, at each of the receiver locations, were then compared with each other and with the averaged measured levels recorded at that location.

The octave band predicted noise levels produced for each propagation model are shown on the graphs attached as figures 2 to 18. Also included on these graphs are the comparable measured levels.

A summary of the “A” weighted broadband differences between each of the predicted results at a location compared to the actual measured level at that location are presented in figure 1 below:



The RMS level difference between each of the predicted levels and the respective measured level has been calculated for each of the overall "A" weighted broadband predictions. These show a surprising overall consistency between the three prediction methods, despite some large individual "differences" which can be seen in both the broadband results shown in figure 1 and particularly in the individual octave band results presented in the other figures.

Prediction Method	Average RMS Difference
Nordic 2000	4.7
ISO 9613	4.0
CONCAWE	5.2

6 CONCLUSIONS

The results presented are preliminary. They are from one set of measurements with simple geometry's. The weather conditions are with the receiver up wind of the source. These are not as required by the Nordic method, which is intended to be used downwind. The method can be used to calculate noise levels in up wind situations but the accuracy of such calculations is lower.

This work has been in no-way exhaustive, but does give a good indication of the variability (or possible levels of "error") that can be anticipated when using these three popular prediction methods.

What is disappointing is that ± 4 dB (A) is a very large average error margin when considering expensive noise control measures.

The level of error calculated for each of the propagation models tested may be overestimated because of the simple geometry involved. The use of a single source does not afford the benefit of integrating the results of predictions from several component sources of the same overall source level, and in the case of the Nordic 2000 method, over an increased number of "terrain segments".

Multi-source models should statistically help to reduce the level of error by bringing the predicted result closer to the +4 dB(A) point, through the logarithmic addition of the component noise levels. This is because the use of logarithmic addition causes the predicted noise levels for sources that are over-predicted to dominate noise levels from sources that are under-predicted. However, it would be a very brave noise control engineer who would assume that the noise propagation prediction will build in a +4 dB(A) error and so design to a level 4 dB(A) above that indicated by the modeling. This does mean that an expensive safety margin is probably being incorporated when using these prediction methods.

From previous experience, it would be considered normal for the Nordic method to calculate noise levels that are approximately 5 dB(A) higher than those predicted using the CONCAWE method because of the assumption of either down wind propagation or temperature inversion conditions that increase the noise level at the receiver. It is often during such conditions that plant managers receive complaints from neighbors saying that it wasn't that noisy yesterday.

The measurements presented here are part of a larger study that includes site scattering through process modules and barrier attenuation. Further results will be published later.

7 REFERENCES:

(1) J. Richards, "Noise design engineering of a large industrial plant – measured equipment noise levels". Proceedings Internoise 2001

(2) J. Kraugh, "Nord 2000. State-of-the-art overview of the New Nordic prediction methods for environmental noise". Proceedings Internoise 2001

(3) Oil Companies Materials Association (OCMA), NWG-1 (Revision 2) "Noise Procedure Specification" March 1980.

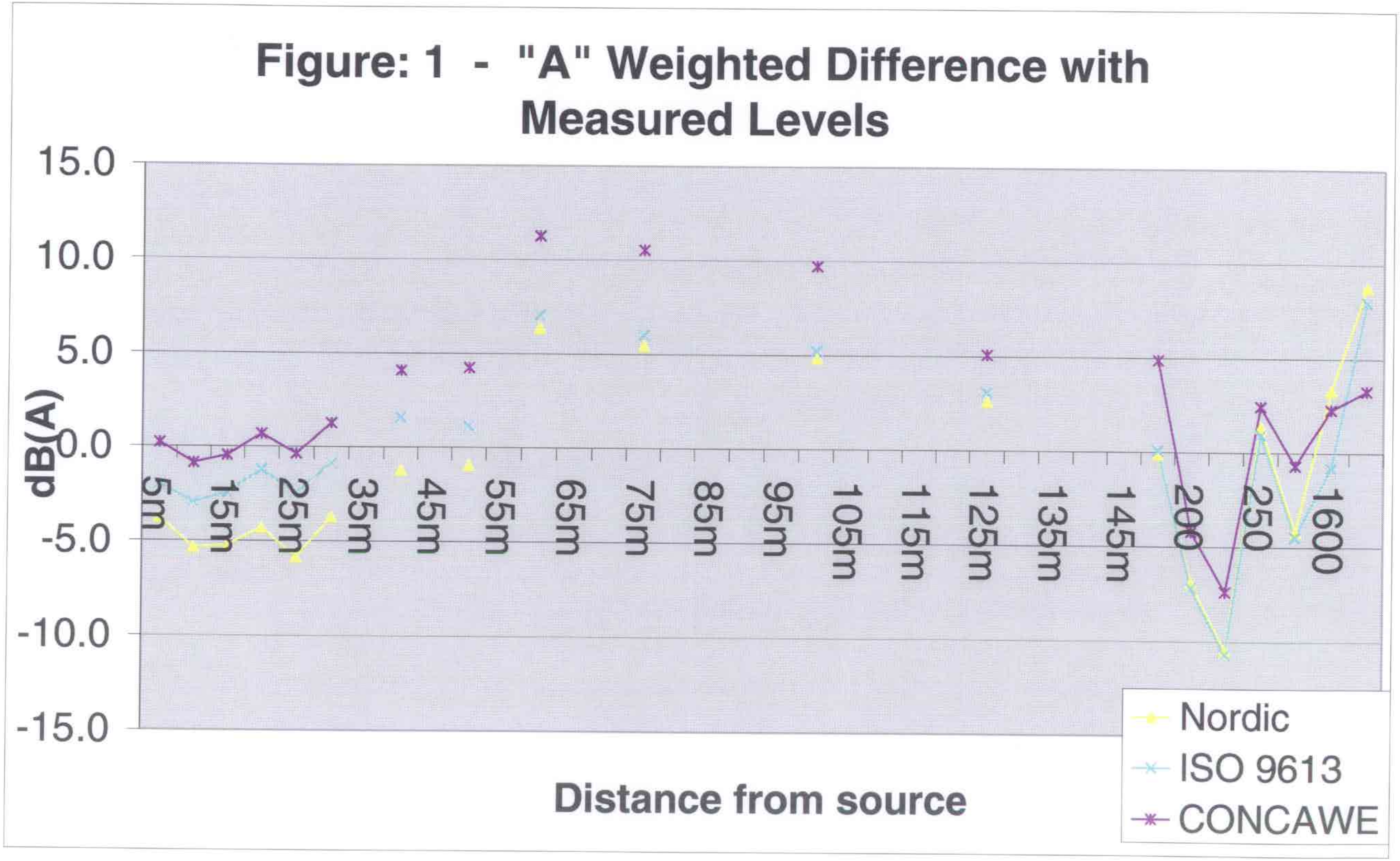


Figure: 1 - "A" Weighted Difference with Measured Levels
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
dB(A)
5m
15m
25m
35m
45m
55m
65m
75m
85m
95m
105m
115m
125m
135m
145m
200
250
1600
Distance from source
Nordic
ISO 9613
CONCAWE

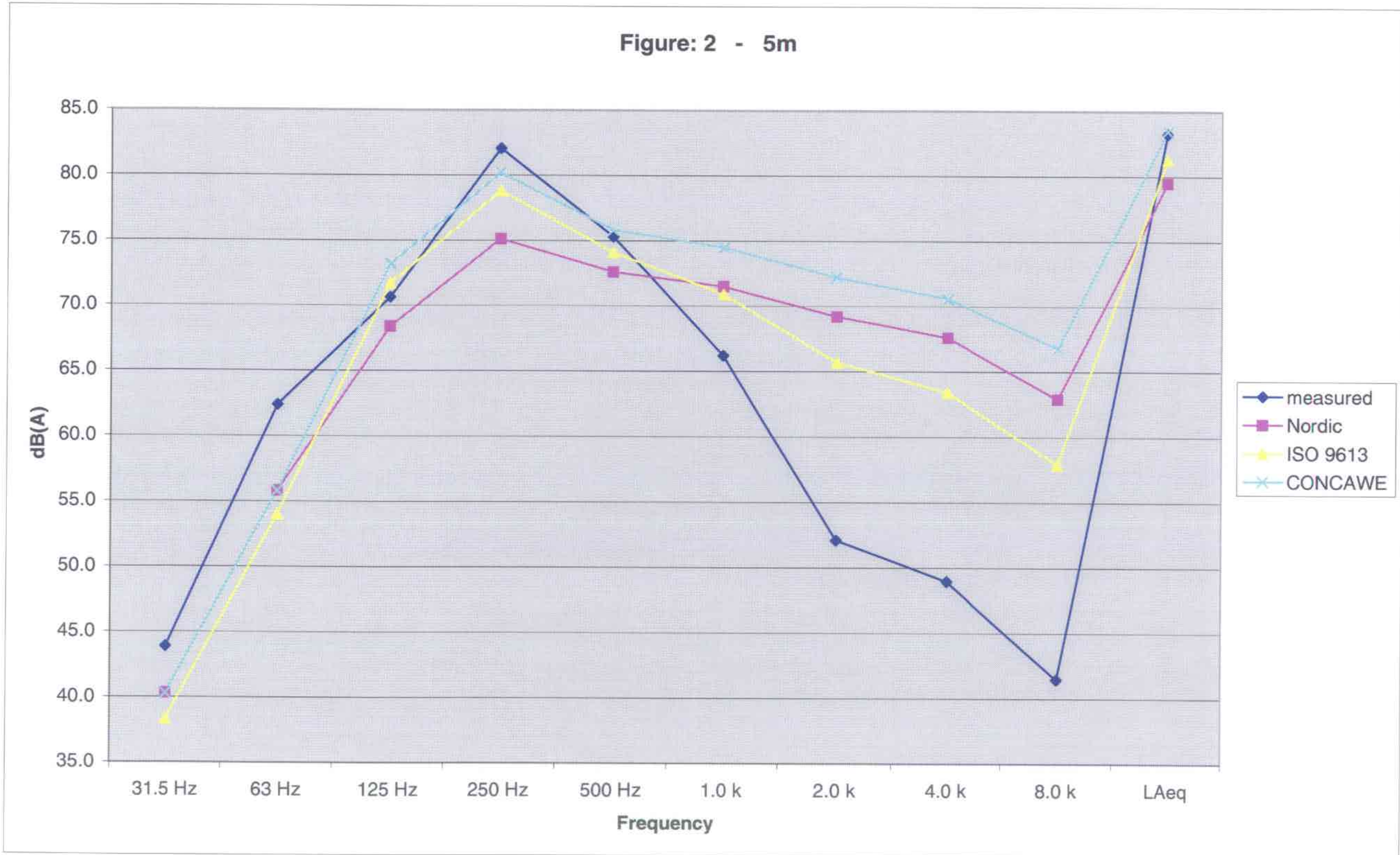


Figure: 2 - 5m
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 3 - 10m

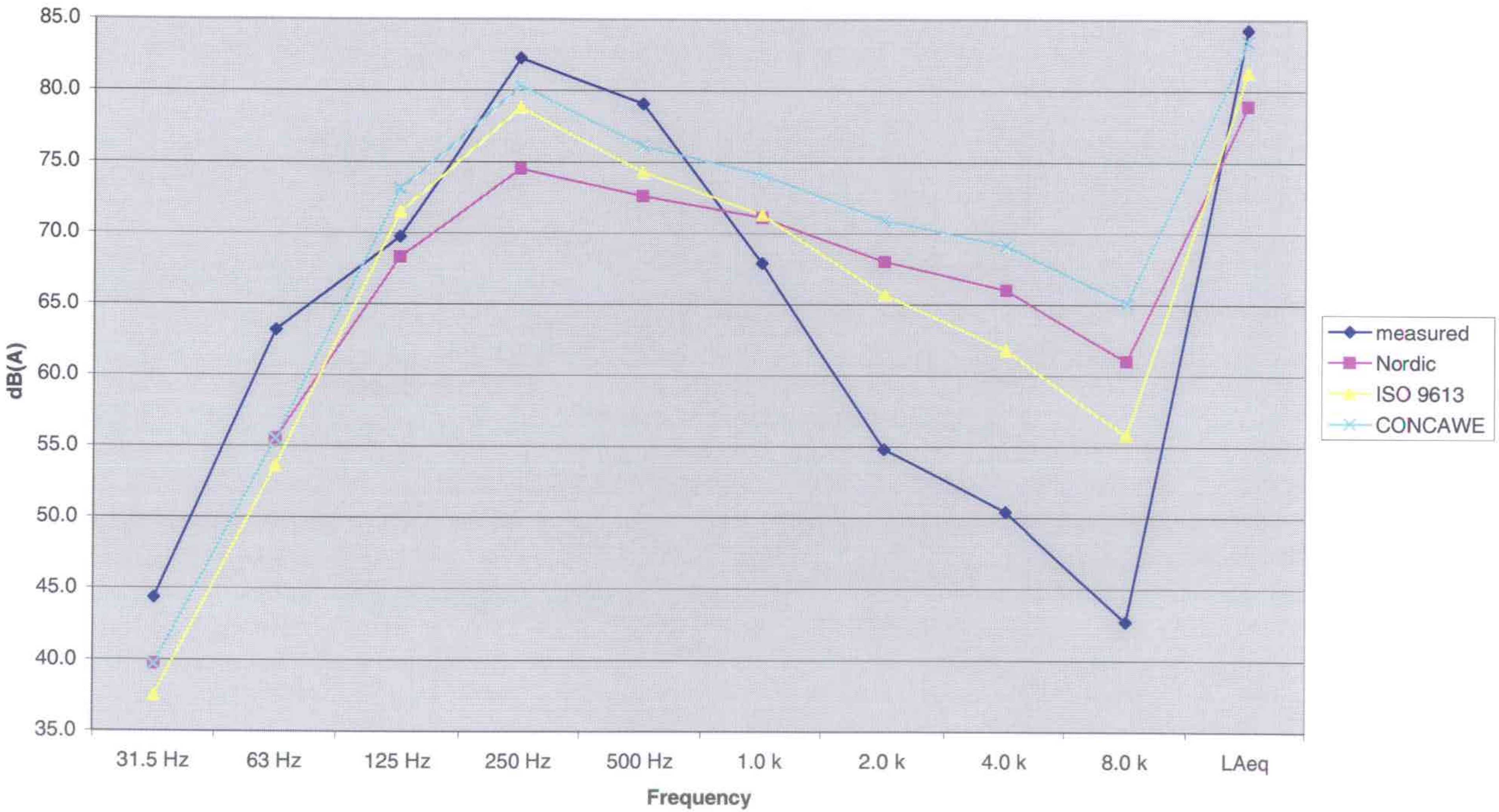

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 4 - 15m

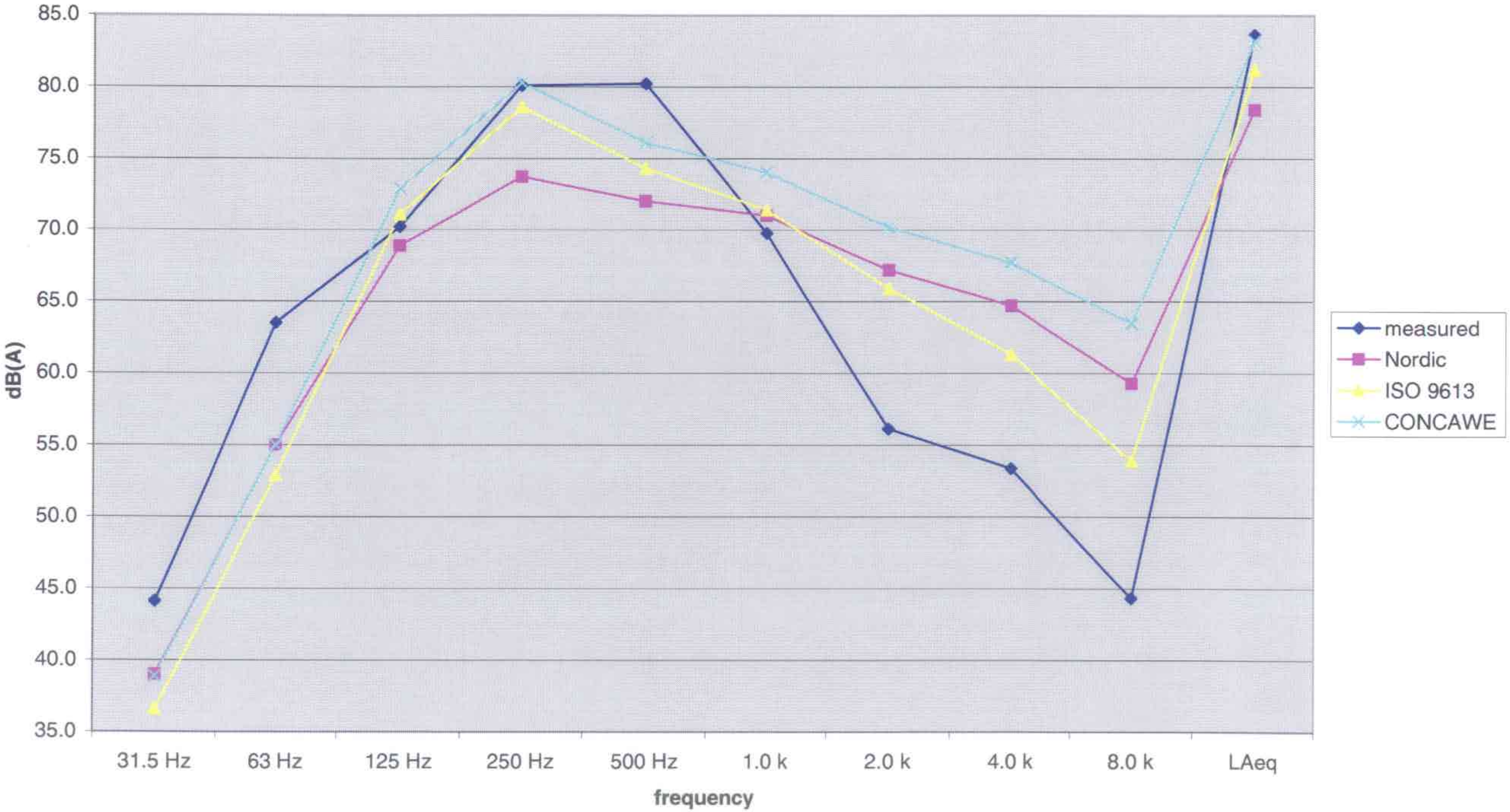

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 5 - 20m

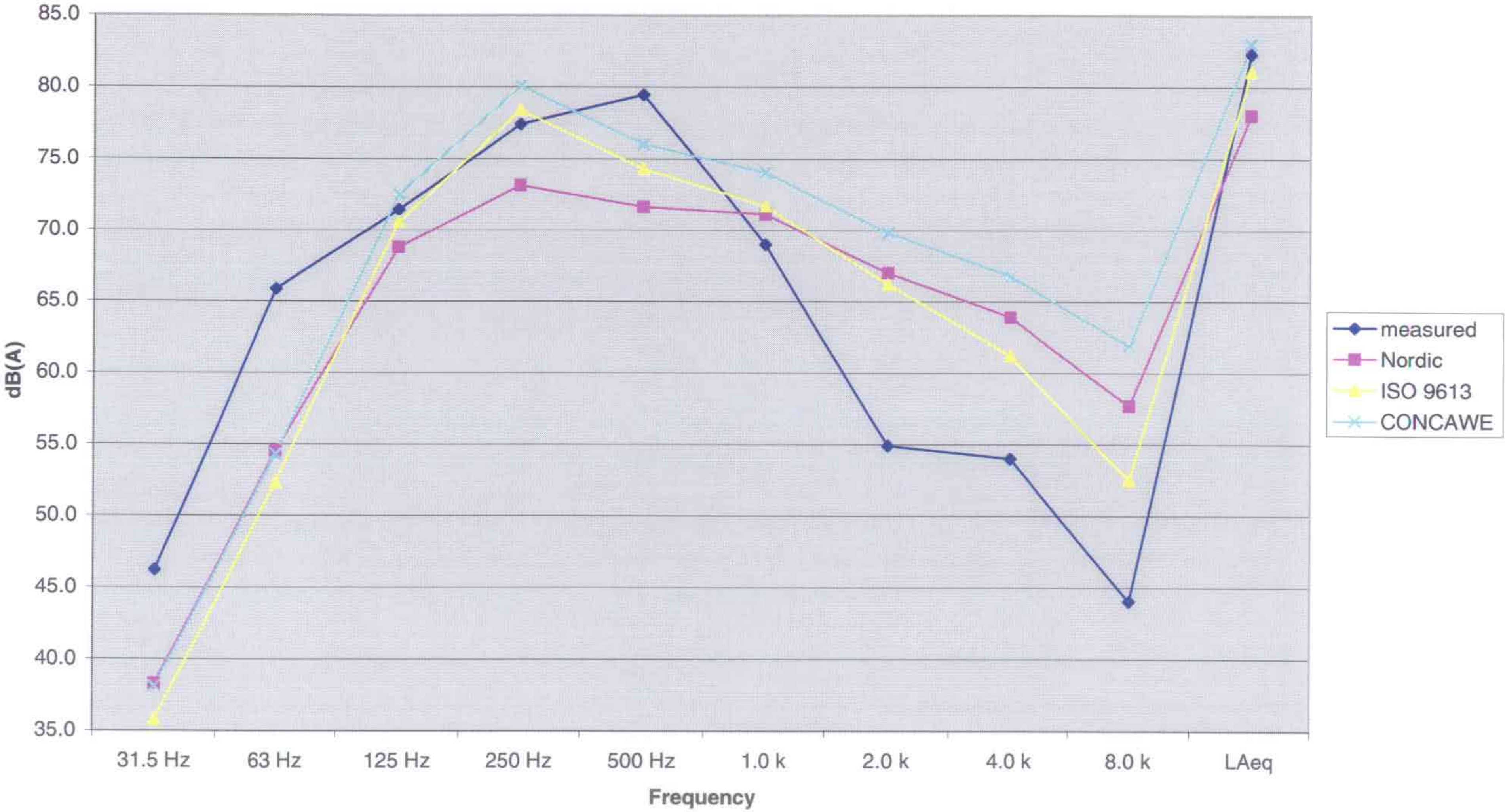

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 6 - 25m

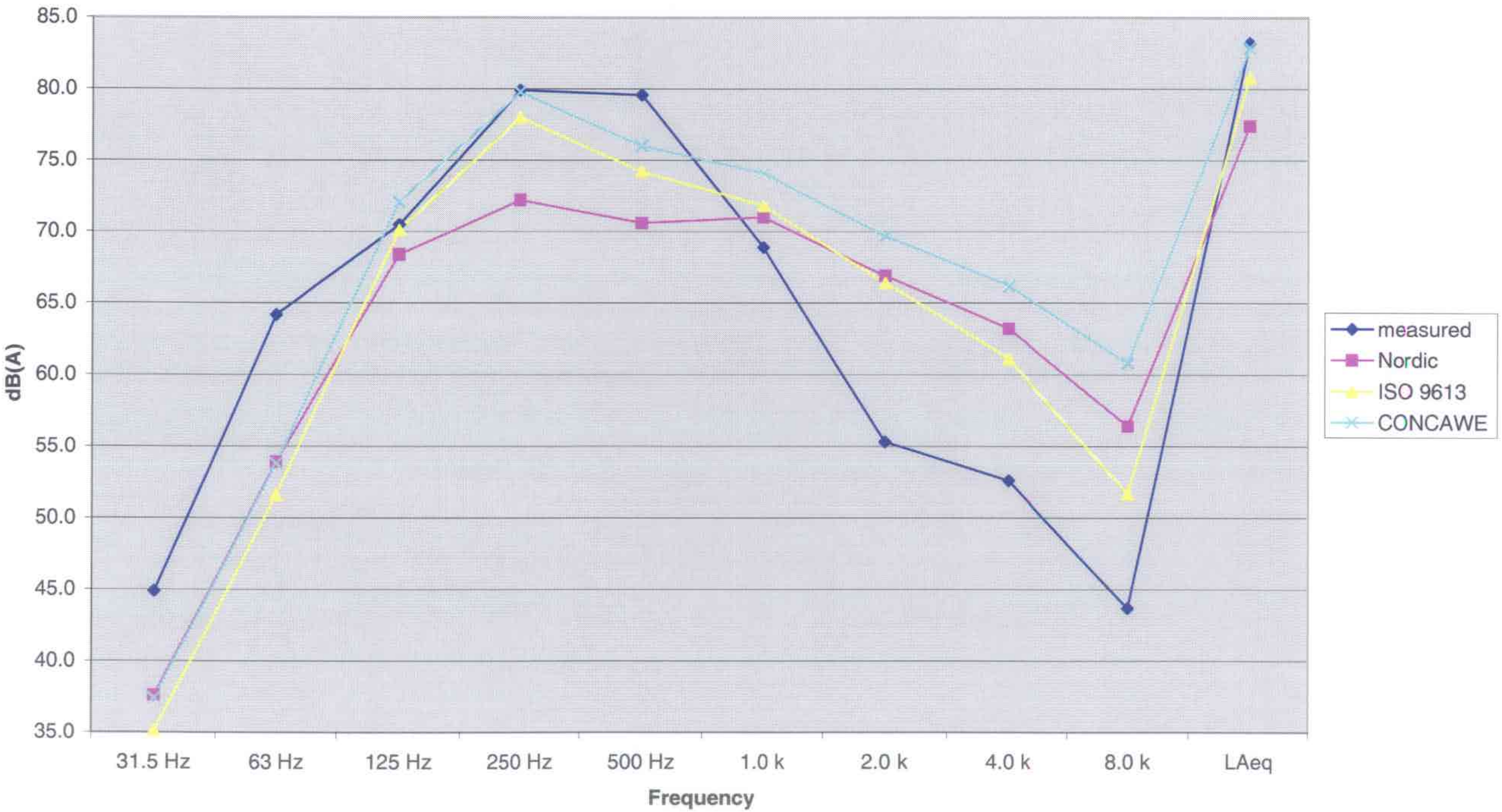

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 7 - 30m

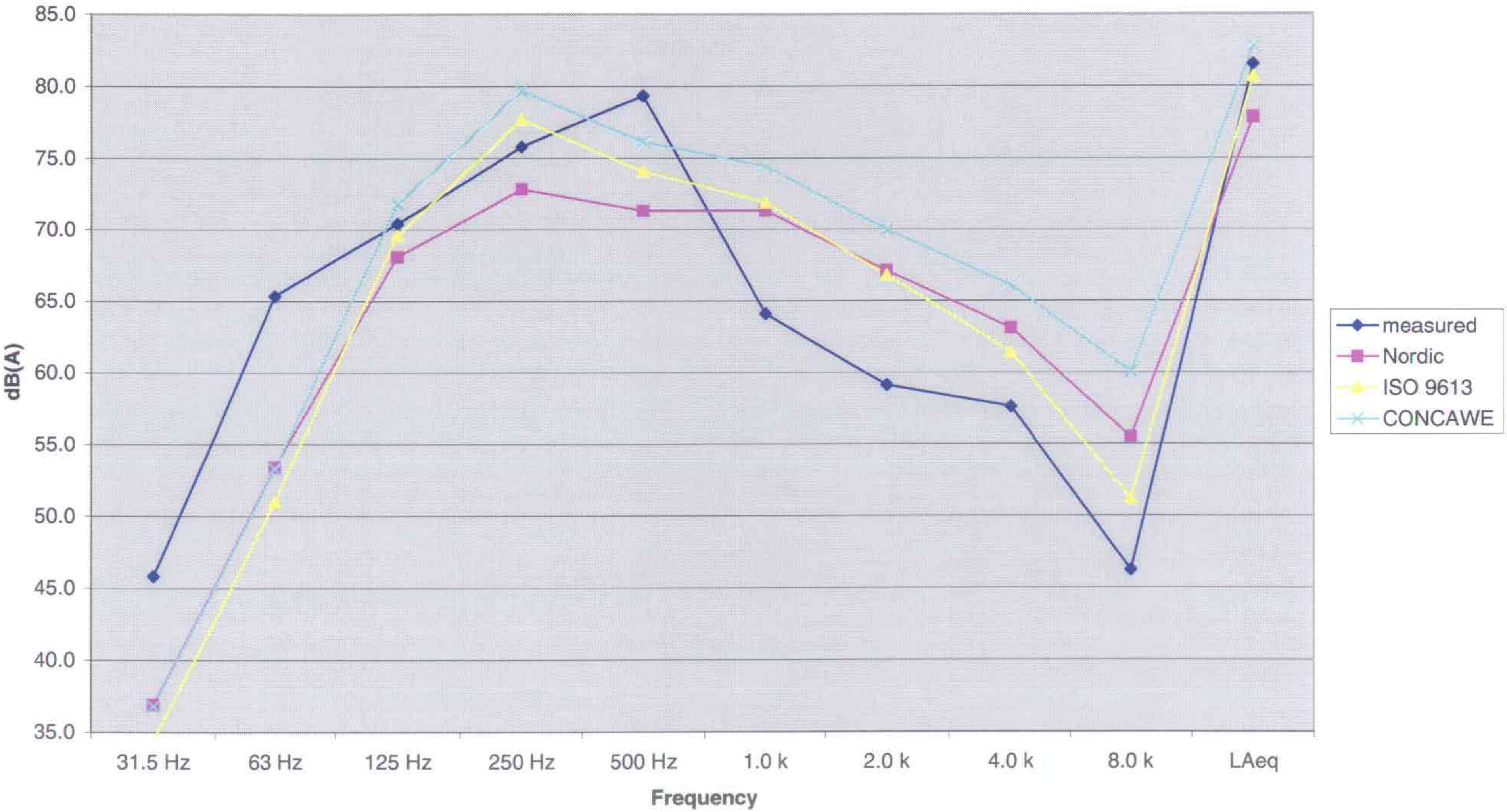

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 8 - 40m

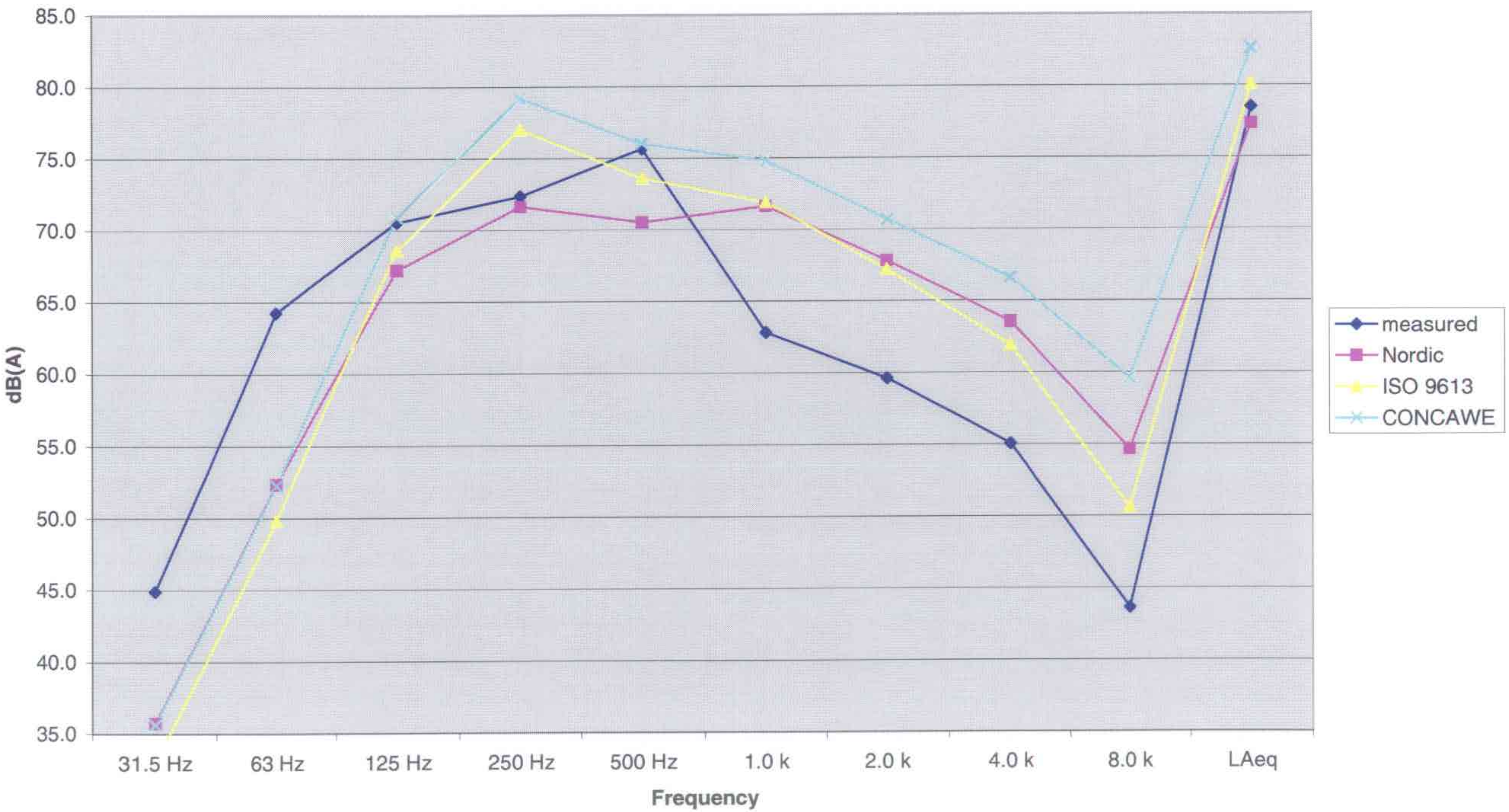

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 9 - 50m

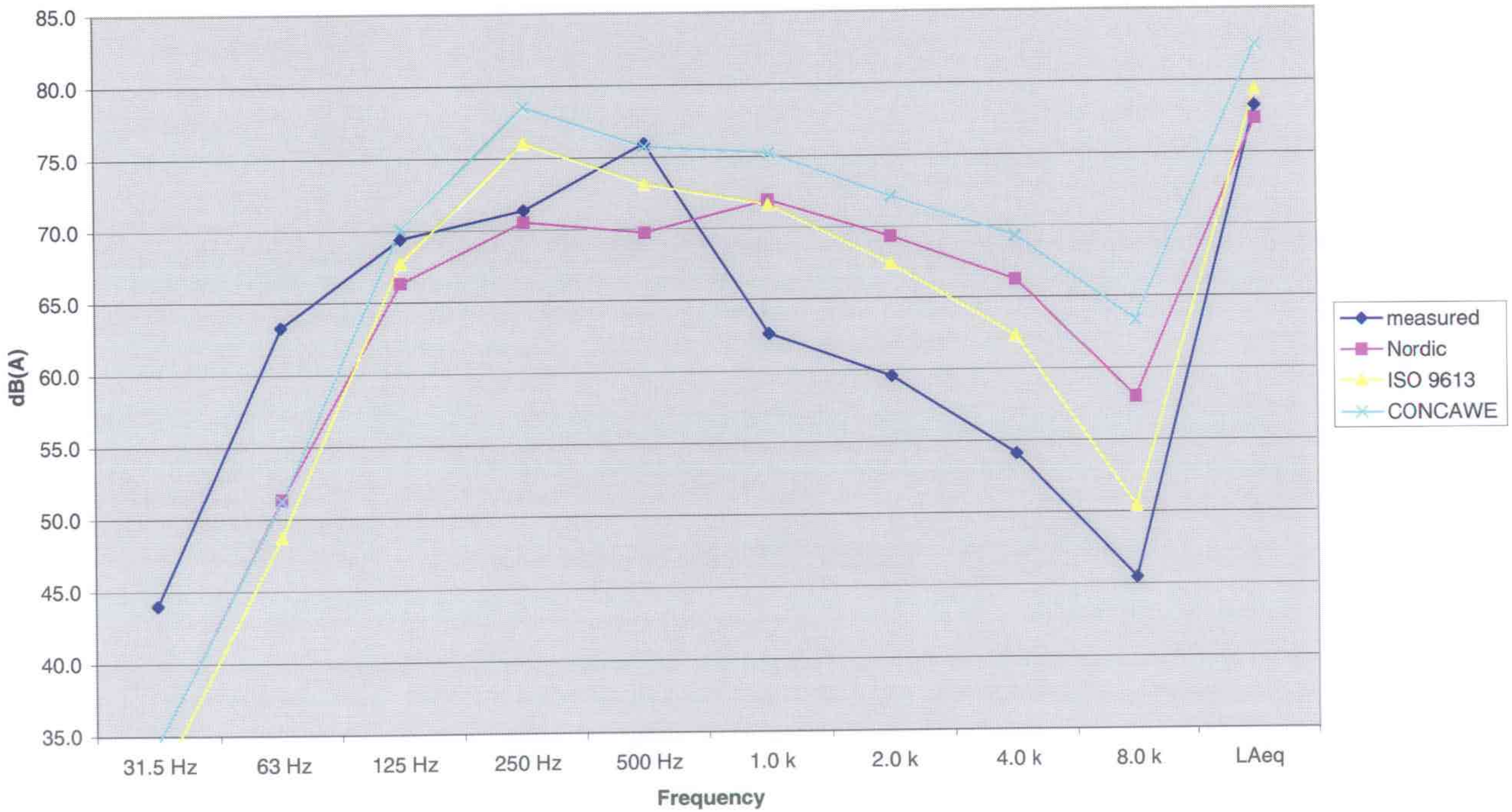

85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
dB(A)
31.5 Hz
63 Hz
125 Hz
250 Hz
500 Hz
1.0 k
2.0 k
4.0 k
8.0 k
LAeq
Frequency
measured
Nordic
ISO 9613
CONCAWE

Figure: 10 - 60m

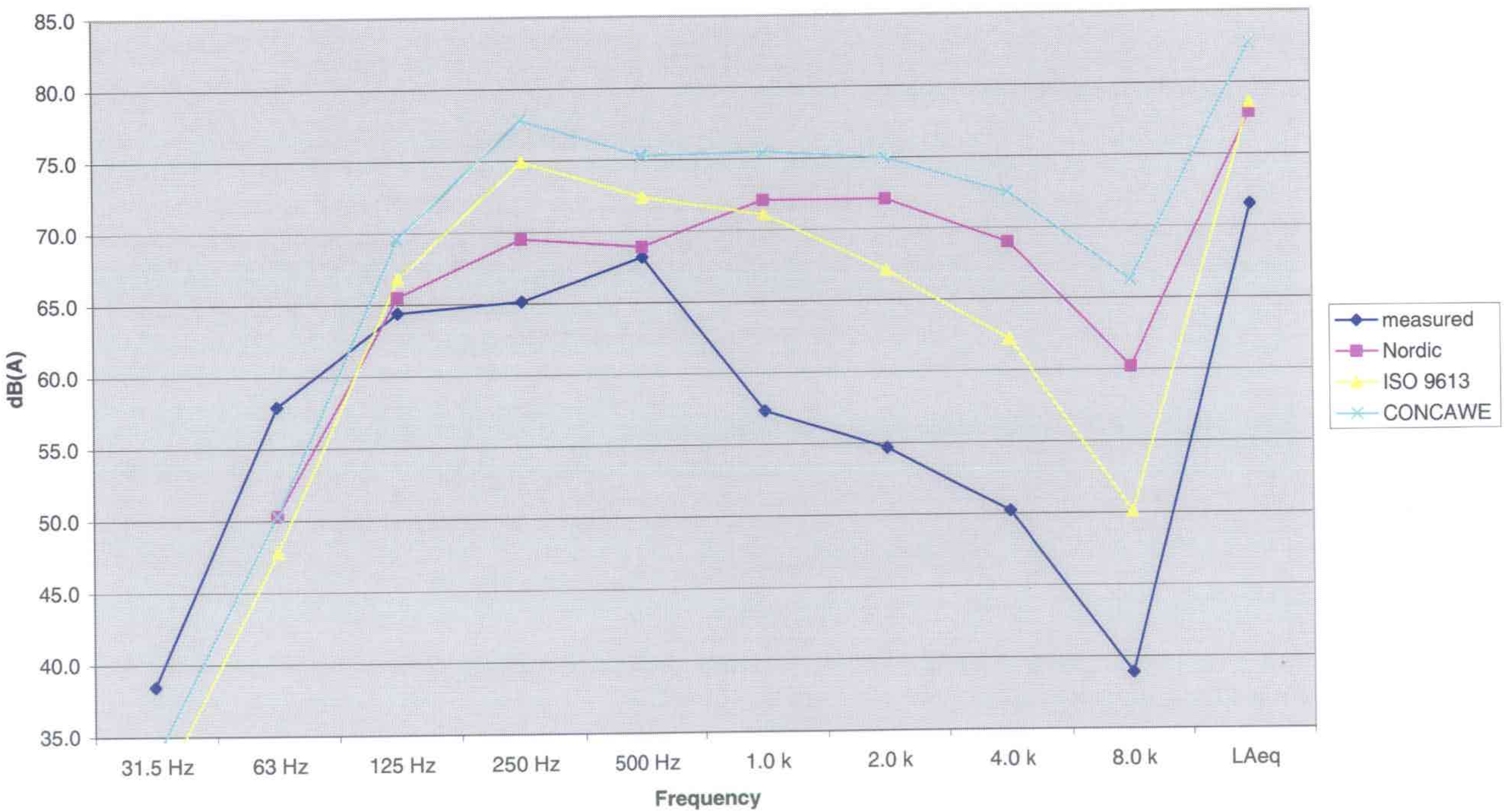


Figure: 11 - 75m

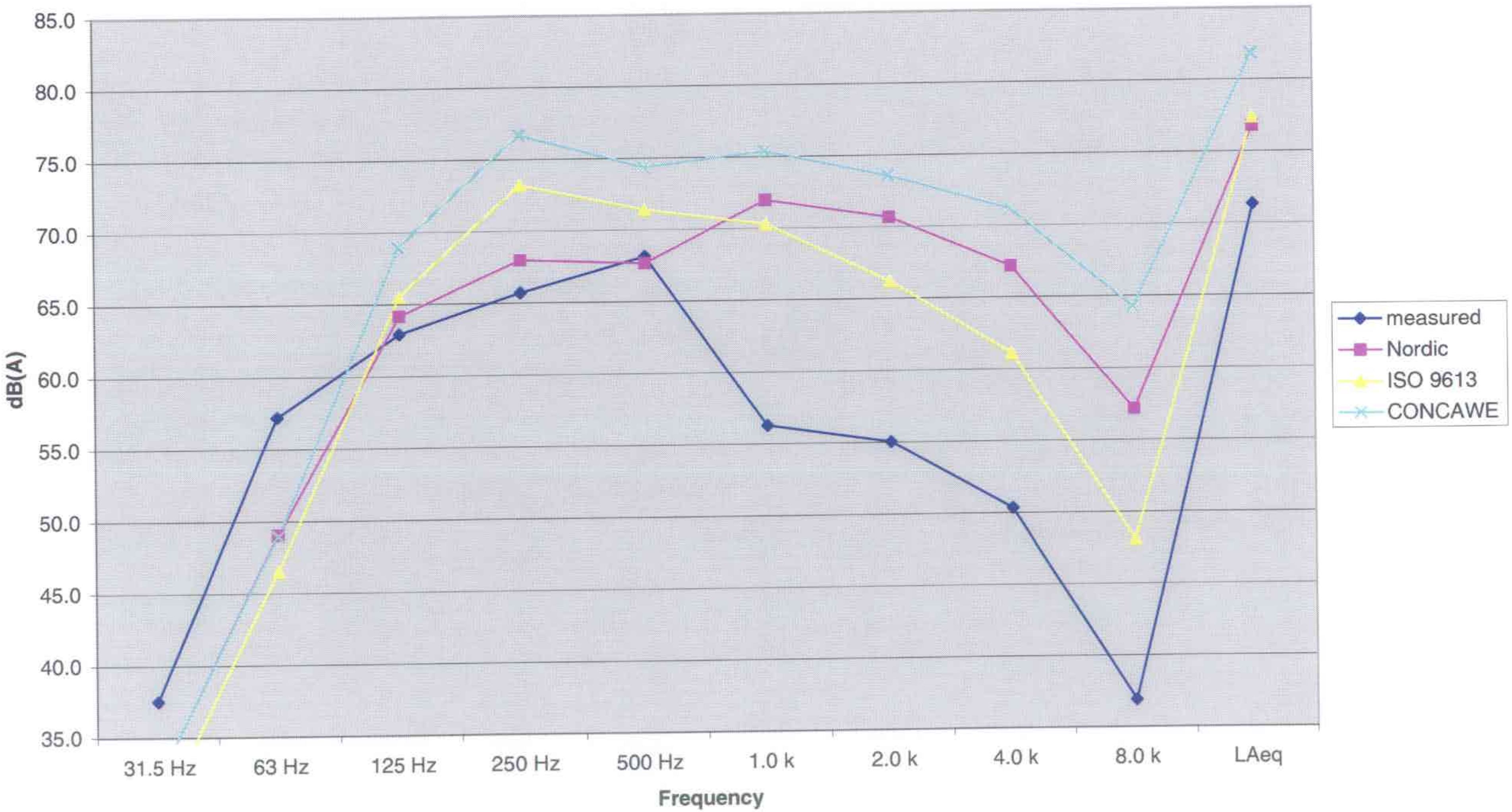


Figure: 12 - 100m

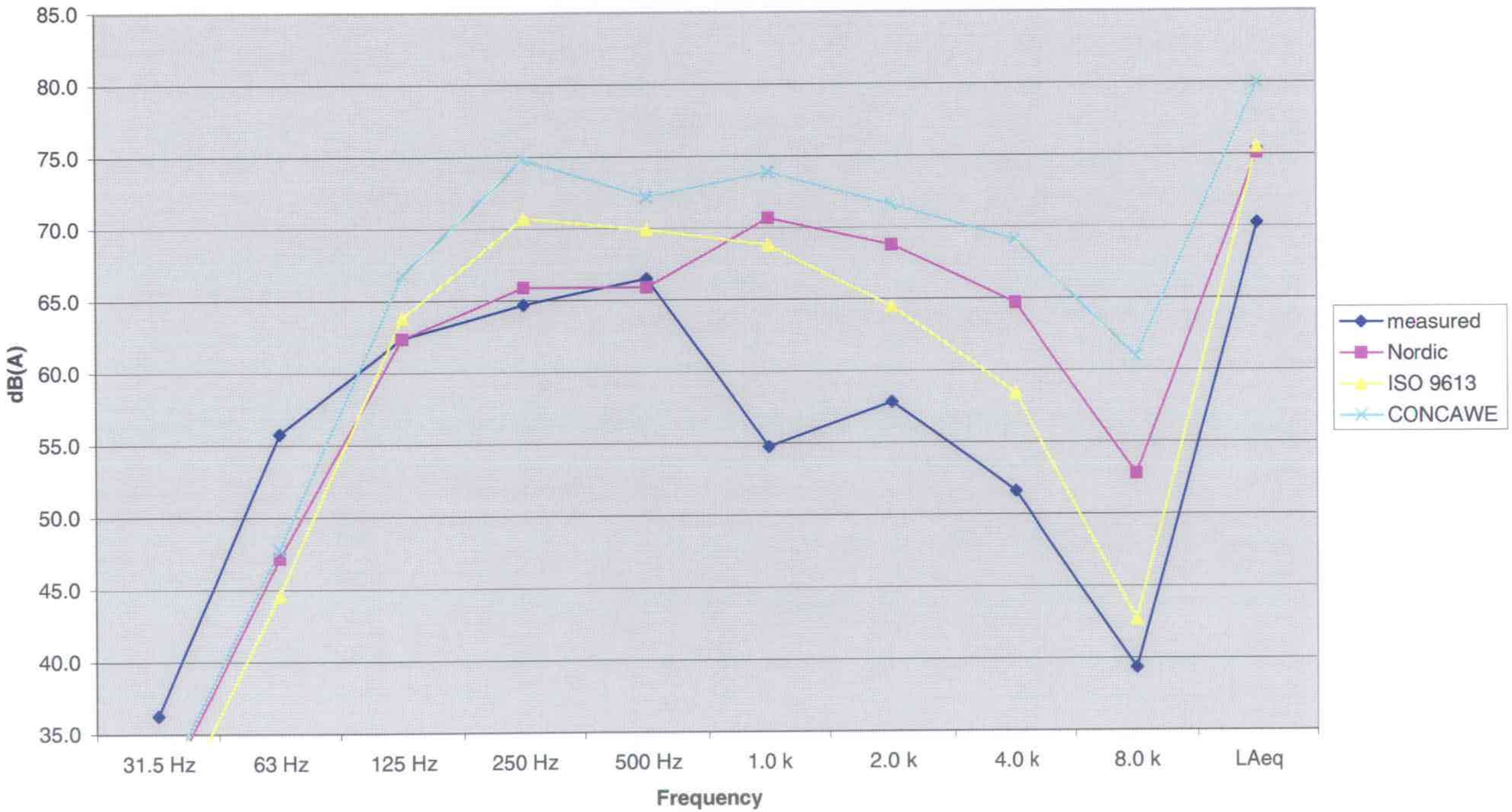


Figure: 13 - 125m

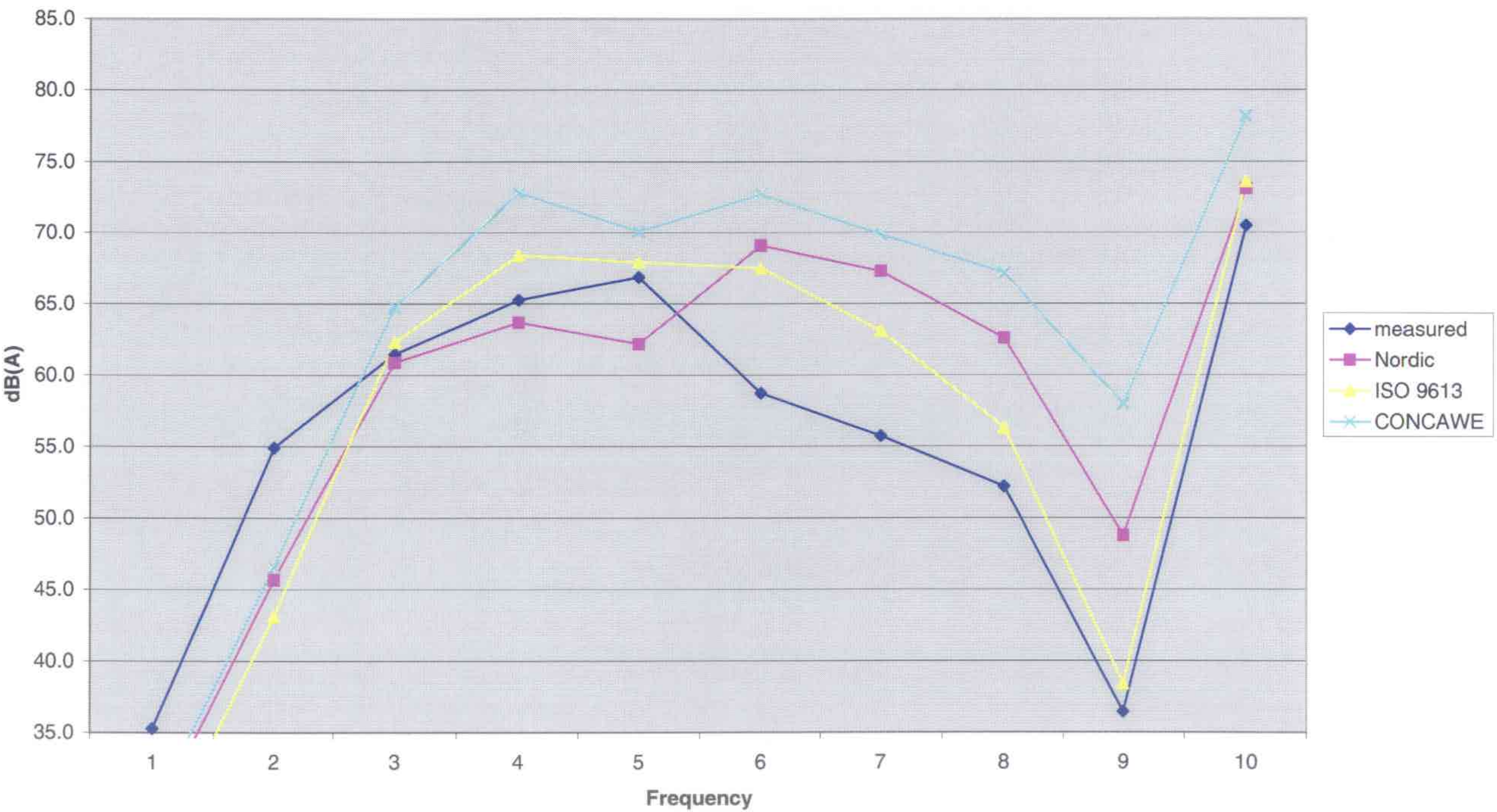


Figure: 14 - 150m

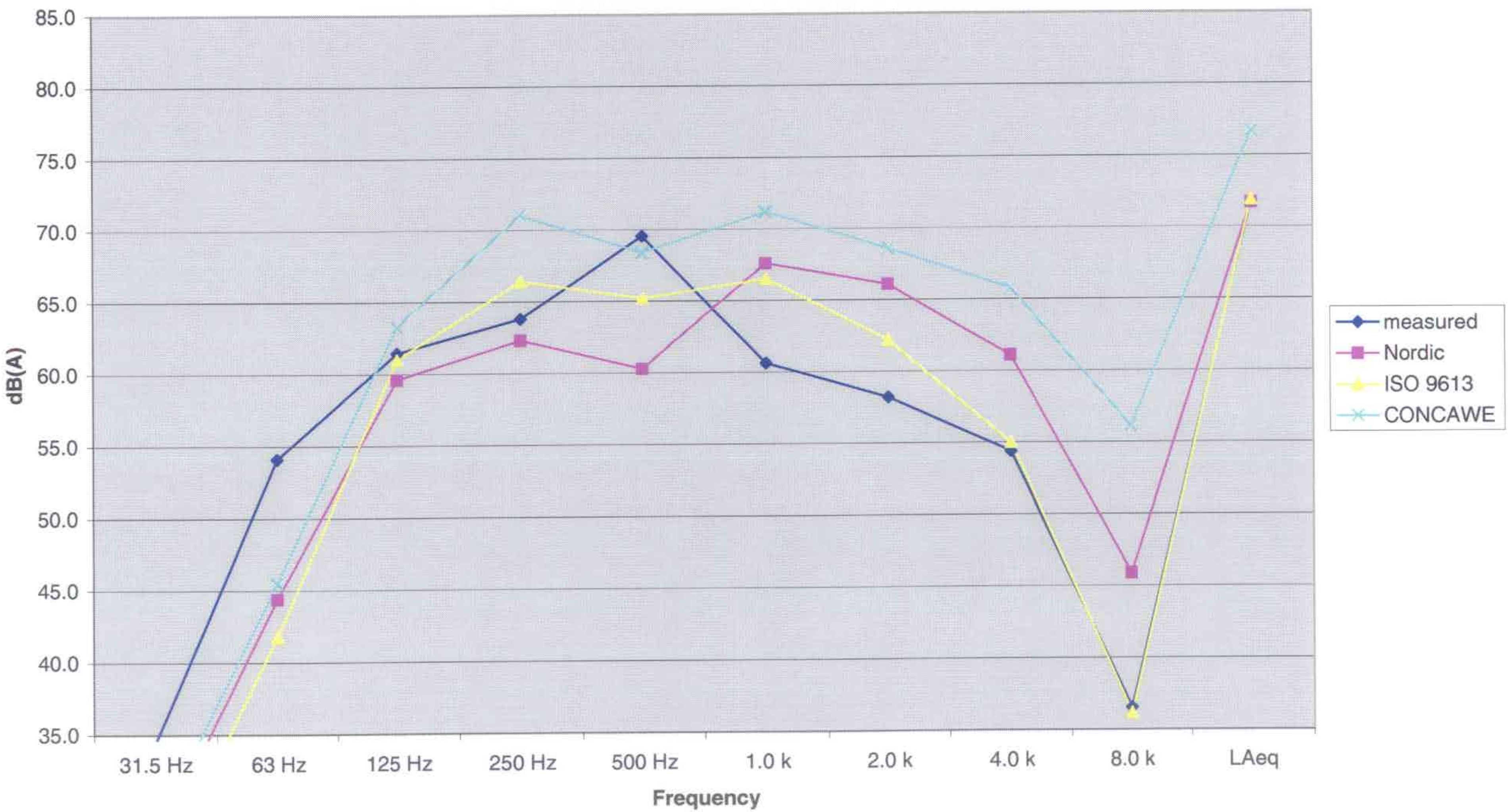


Figure: 15 - 200m

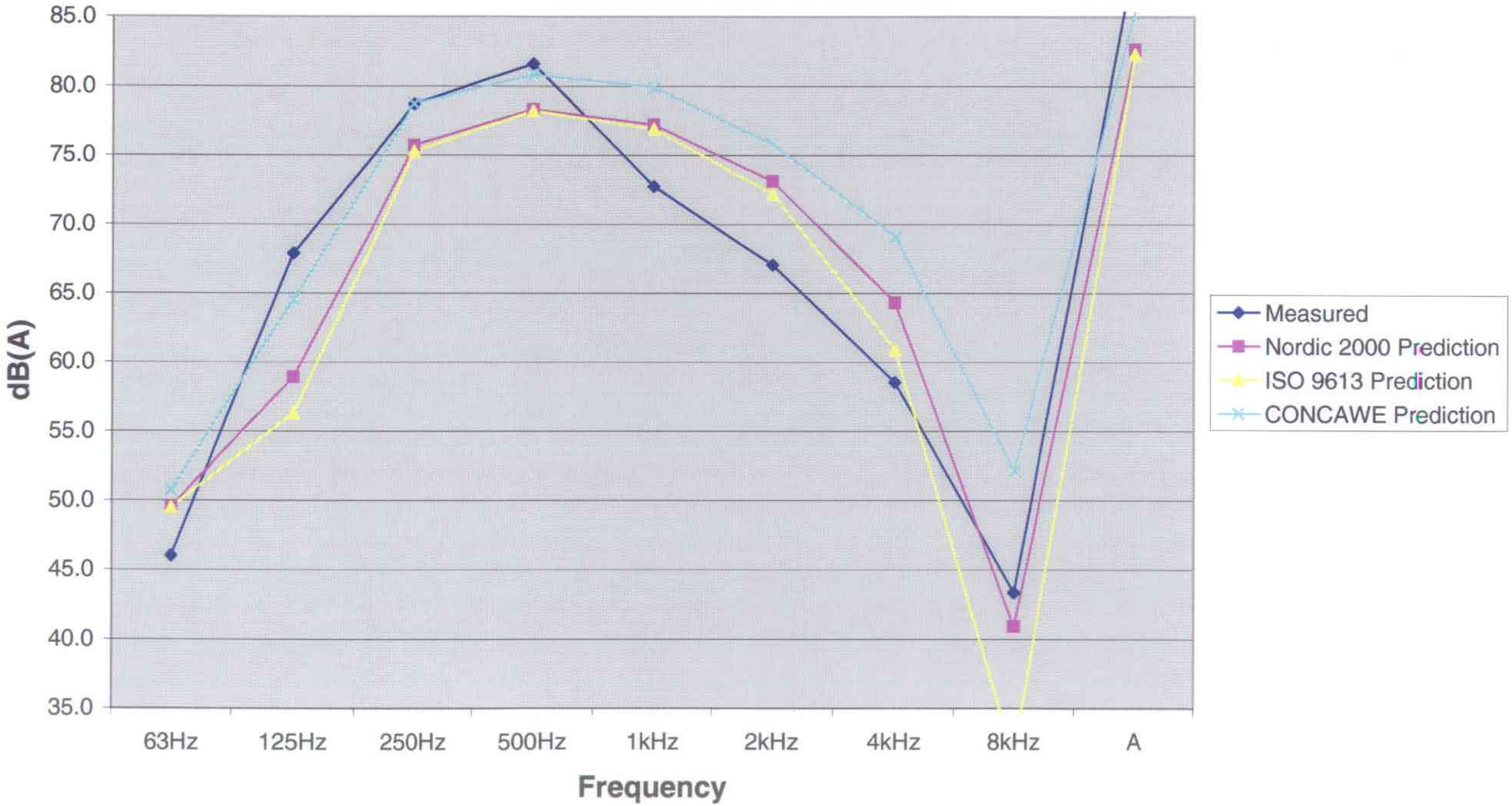
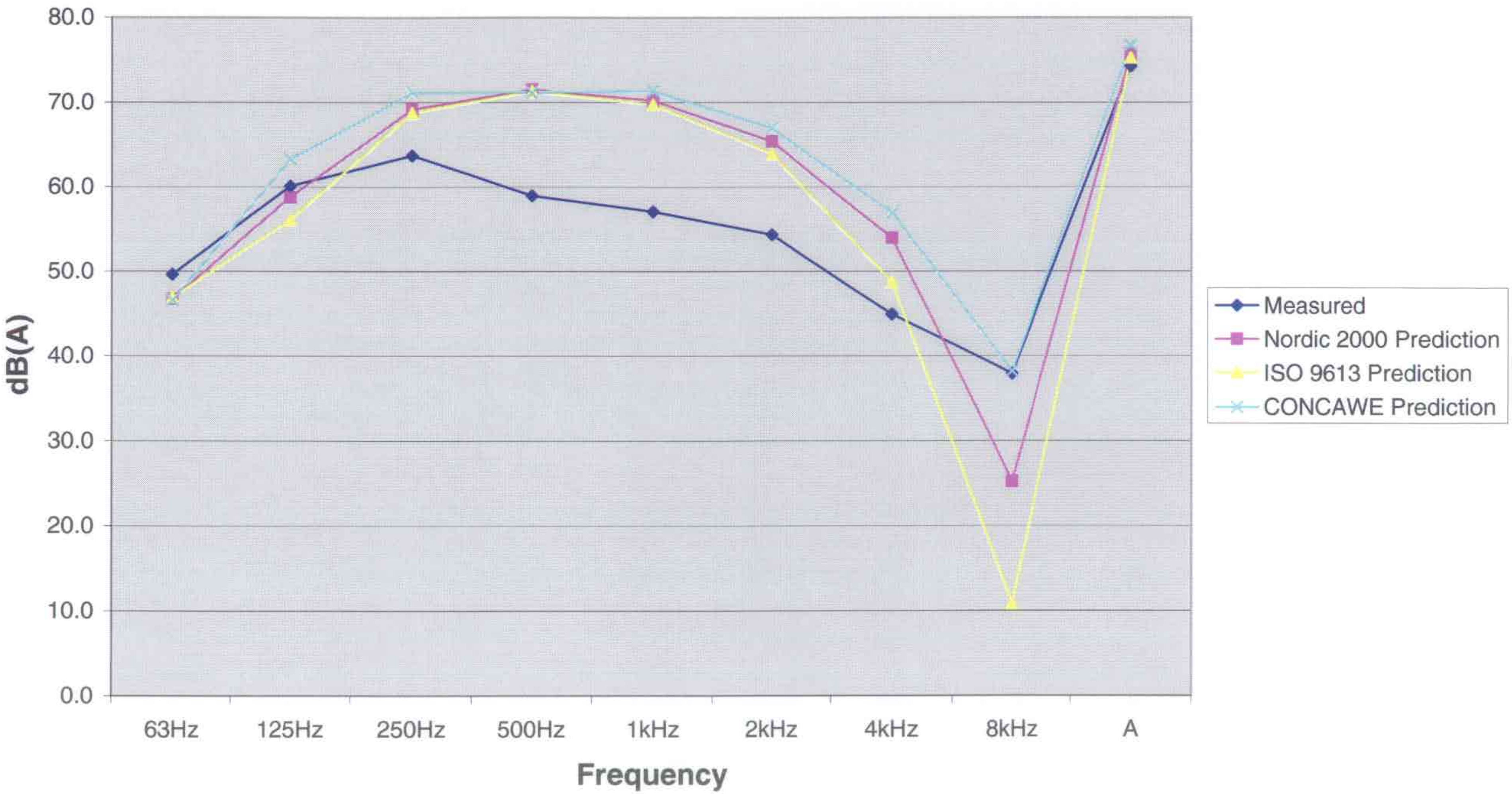


Figure: 16 - 250m



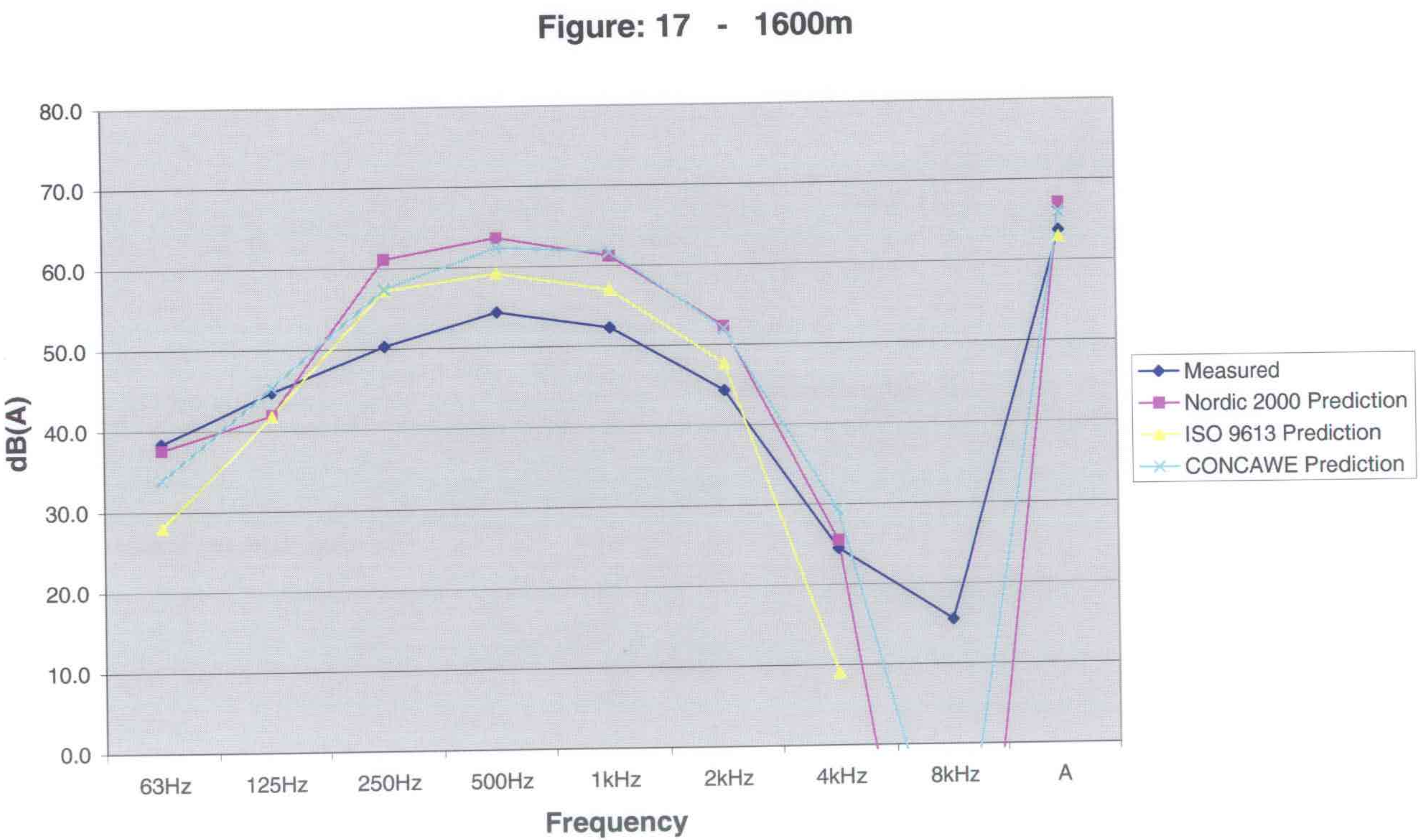


Figure: 17 - 1600m
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
dB(A)
63Hz
125Hz
250Hz
500Hz
1kHz
2kHz
4kHz
8kHz
A
Frequency
Measured
Nordic 2000 Prediction
ISO 9613 Prediction
CONCAWE Prediction

Figure: 18 - 2000m