

Problems with the INM: Part 2 – Atmospheric Attenuation

Steven Cooper, John Maung

The Acoustic Group, Sydney, Australia

ABSTRACT

In relation to predicted aircraft noise levels and derivation of the EPNL for aircraft operations by INM, reliance is placed upon attenuation for atmospheric absorption based on distance, temperature and relative humidity. Measurements of military aircraft (helicopters and fixed wing) for the purpose of deriving noise power distance curves to be used in INM have revealed significant anomalies with measured and theoretical results. Standard practice in the US for deriving NPD curves is to utilise measurements in relatively close proximity to the aircraft, extrapolate a 6 dB per doubling of distance and provide standard atmospheric attenuation. Working backwards from field measurements utilising aircraft distances greater than that used for certification assessments has consistently revealed significant discrepancies. Specific testing in the South Australian desert utilising a twin engine military jet on full afterburners to a height of 5,500m above monitoring microphones has revealed the atmospheric attenuation over distance is not a dB per 100 metres linear rate. The basis of deriving atmospheric attenuation from field measurements, rather than laboratory measurements with dimensions significantly less than 100 metres, is explained.

INTRODUCTION

The previous paper identified the need for creating NPD curves for inclusion of helicopter operations on military bases in Australia. Whilst the major validation issue associated with operations near an aerodrome was found to be related to the lateral attenuation, there was difficulty in developing the NPD curves by way of a regression analysis, in that initially the helicopter operations did not utilise distances in excess of 900m for a microphone directly under the flight path.

What became apparent arising from communication with the FAA and members of the SAE 12A Standards Committee (Cooper 2004) was that the procedure in the US for determining the NPD curves was to focus on measurements with a helicopter at 150m above the microphone point and extrapolation of the results by use of the ICAO Annex 16 procedures. Similarly, for aircraft measurements, the curves were generally derived from certification testing, which utilised altitudes of 120m (approach), 650m on takeoff and 600 – 900 m for fly-overs and extrapolation of those results.

Inquiries with US personnel involved in the preparation of such material found that there were no NPD validation exercises in that it was assumed the curves were reasonably accurate.

An interest to persons involved in aircraft noise assessment is that in the US, NEF contours are not placed in the public domain and therefore, not subject to the public scrutiny that noise contour outputs experience in Australia.

As discussed in the next paper, a number of interesting anomalies were found in relation to the derivation of the NPD curves in that for slant distances greater than 300 metres, there is significant difference between the slant distance versus the actual distance at which the aircraft is located when the maximum level is derived for the nominal slant distance reference position.

The NPD derivation utilises nominal distances which are the nearest distance from the microphone to the flight track. This

“slant distance” is the distance the position on the flight profile that is perpendicular to the flight track.

However as shown in Figure 1 the position of the aircraft when the maximum level occurs is not at the slant distance, but a greater distance. The ICAO corrections for certification procedures utilise the actual distance to the aircraft but the NPD data for the microphone position relates to the slant distance.

For the NPD curves derived from certification data the difference between the slant distance and the actual distance is not significant when dealing with the logarithm of the distance.

Prior to undertaking the NPD testing it was necessary to ascertain a method of precise tracking. Previous testing regimes of theodolites, microwave tracking systems and time synchronisation of recording data etc were very costly but obviously more sophisticated than the Civil Aviation Authority photographic method for certification of utilising two poles and a rope with ribbons above a camera to identify the height and position of the aircraft.

By use of a differential GPS tracking (DGPS) system, one can precisely locate the aircraft in half second increments to an accuracy of plus or minus half a metre in each axis, that when GPS time coded with the recorded acoustic signals, permits one to accurately place the aircraft for subsequent analysis.

For previous investigations for helicopters a general concept of excess attenuation was identified. However due to the various noise sources associated with helicopters (main rotors, engine, exhaust and tail rotor) one can get different source contributions/directivities to a receiver location. The spectrum of the helicopter noise passby dramatically changes during an overflight.

In the determination of the NPD curve one needs to extract the atmospheric and distance attenuation components to provide a source level, move the aircraft to a new position and then apply the distance attenuation and atmospheric attenua-

tion for a reference atmosphere of 1013.25 hPa, 25°C and relative humidity of 70%. Theoretically by that method one could validate the NPD curve for any position and any atmospheric conditions.

When seeking to verify the results with the field measurements, discrepancies in the larger distances were found, particularly at frequencies above 4,000 Hz. Agreement could not be obtained between the field measurements and the predicted levels by way of the ICAO methodology when we had the full time history in 1/3 octave bands (Figure 2).

Theoretically, by the ICAO assessment procedure, the attenuation for atmosphere is taken in an absorption per 100 metres, which for relatively low distances does not present an issue. However, as one increases the distance from the aircraft to the ground receiver, there is a significant attenuation of such frequencies.

If one seeks to work backwards from the measurement results utilising the attenuation coefficients provided in ICAO Annex 16 to determine an effective sound power level of the aircraft, one finds a dramatic increase in the sound power level which is physically impossible for the aircraft of concern. The helicopters having a nominal sound power level of 150 dB(A) for a 150 metre flyover produced by reverse engineering a sound power level of 400 dB(A) for a 1000 metre flyover.

With this issue highlighted, we took the opportunity during further helicopter testing to incorporate higher flyovers utilising 2000 metres above ground level, utilising the exact same power and flight procedures for the same helicopter at 150 metres. This testing proved that further research was required and to overcome the multiple source issue for a helicopter it was recommended that such investigations be applied to fixed wing aircraft.

As a result of validation of the INM output being raised and there being different database information in subsequent versions of INM, testing was undertaken for verification of the NPD curves for a military twin engine fighter jet.

Testing conducted at a military base in Queensland found difficulty in obtaining suitable monitoring positions to test the larger standard slant distances in view of existing ambient noise levels but preliminary work indicated that again there was disagreement between the INM predictions and field measurements when dealing with slant distances greater than 1,000 metres.

Subsequently, testing was conducted at a military base in South Australia, where the monitoring microphones could be placed up to 10 nautical miles from the departure end of a runway and in low ambient background levels in the order of 23 dB(A). In such ambient levels one was clearly able to measure increases above the ambient background levels from certain aircraft operations.

For the purpose of identifying the source noise emission power level testing was undertaken with the aircraft stationary (on the ground) at full afterburners with microphones at a distance of 200 metres from the aircraft (Figure 3). It was not deemed safe to permit persons to be located towards the rear of the aircraft during such a test. For the maximum level at the rear quarter of the aircraft a sound power level for hemispherical radiation without allowance for ground absorption was 169 dB(A). If we assume ground absorption for a source 2 metres above the ground and a receiver microphone of 1.5 metres above the ground over hard ground with short grass is say 7dB then a nominal sound power level of 176 dB(A) can be used.

For the purpose of investigating the distance attenuation issue an additional operation was added to the NPD testing program, where the aircraft was required to fly along the runway at full military power, then apply after burner and at a point equivalent to the nominal lift off position, take off with full afterburner (for both engines) and continued flying out on a constant power up to a height of 5,500m AGL, at which point the afterburners were switched off. A series of microphones directly under the flight path were used for monitoring purposes (flight profile in Figure 1). Monitoring staff at the ground positions could clearly hear when the afterburners were switched off.

Testing conducted for the aircraft overflight at 150 metres with full afterburners revealed a sound power level 174 dB(A). Reverse engineering the field measurement results with the ICAO attenuation procedures revealed a dramatic increase in the sound power level to 570 dB(A) as shown in Figure 4.

At the time of the measurements, there was no wind at the ground positions and by reason of weather balloon information from the aerodrome meteorological station, there were no winds evident in the profile up to 6,200m AGL.

It is physically impossible for the aircraft to generate the power levels derived from the ICAO methodology. Accordingly, even allowing for temperature gradients normally used in acoustic formula, a significant difference in predicted noise levels could not be explained by the standard formula.

Atmospheric excess attenuation was examined in relation to the operation of a large chemical plant, where the sound power level of 123 dB(A) for the plant had been calculated in accordance with ISO 8297. Regular monitoring over twenty years at residential receivers 1,500-1,800 metres from the centre of the plant consistently provided high frequency contributions much greater than ISO 1693 would suggest.

When faced with the issue of significantly less attenuation than predicted, the original source information upon which the standard formulas and text books utilise for atmospheric attenuation is Harris (1963). The work occurred some time ago where the attenuation/100metres was a theoretical conclusion, not measurements in a laboratory having dimensions in the order of 300 or 400 metres. The attenuation coefficients expressed in terms of attenuation per 100 metres under different temperature and relative humidity were obtained from experimental work utilising a stainless steel spherical chamber of 1.9 metres diameter. This measurement procedure did not have actual measurement data (for the derived distances) to support the attenuation characteristics nominated.

Whilst an issue for excess atmospheric attenuation was observed in the helicopter testing measurements, those measurements were limited in height and potentially have different source locations. The use of the twin engine military jet on constant power up to 18000 ft permitted the known sound power level from measurements at a distance of 150 metres from the aircraft to be derived. From this source data the excess attenuation could be derived on the assumption that there are no other significant attenuations in this situation.

Utilising the constant sound power source and the curves from field measurements permitted the derivation of NPD curves which were placed in an INM scenario for the actual test flight and provided validation of the measurement results. On plotting that information with respect to the ICAO nominated attenuation characteristics for a temperature of 15°C and relative humidity of 50% indicates that a power

curve can accommodate the field data and provide agreement with the theoretical attenuation co-efficients if limited to small distances (Figure 5). At the greater distances the high frequency attenuation dramatically reduces the influence on the dB(A) value which is then controlled by the mid and low frequency components.

Subsequent to the military jet testing, testing of a new military fourth generation helicopter (not yet in commercial or military operation in Australia) was subsequently carried out at the same base in South Australia for the development of NPD curves and evaluation of typical flight profiles.

The helicopter testing operations could not include slant distances under the aircraft at 5,500m but with a limit of about 1,200m, provided information in terms of distance attenuation under a temperature of 25°C and relative humidity of 20% (Figure 6).

REFERENCES

SAE-A21 Helicopter Noise Working Group, Las Vegas 2004
 ICAO International Standards and Recommended Practices, Environmental Protection Annex 16 to the Convention & International Civil Aviation, Vol 1, Aircraft Noise Third Edition 1997
 ISO 8297:1984 Acoustics – Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment – Engineering method, International Standards Organisation 1984
 ISO 9613-1:1993 Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere, International Standards Organisation, 1993
Integrated Noise Model, US Department of Transportation, Federal Aviation Administration
 Harris C, Absorption of Sound in Air in the Audio-Frequency

Range, JASA 35 (1) pp11 – 17, Jan 1963

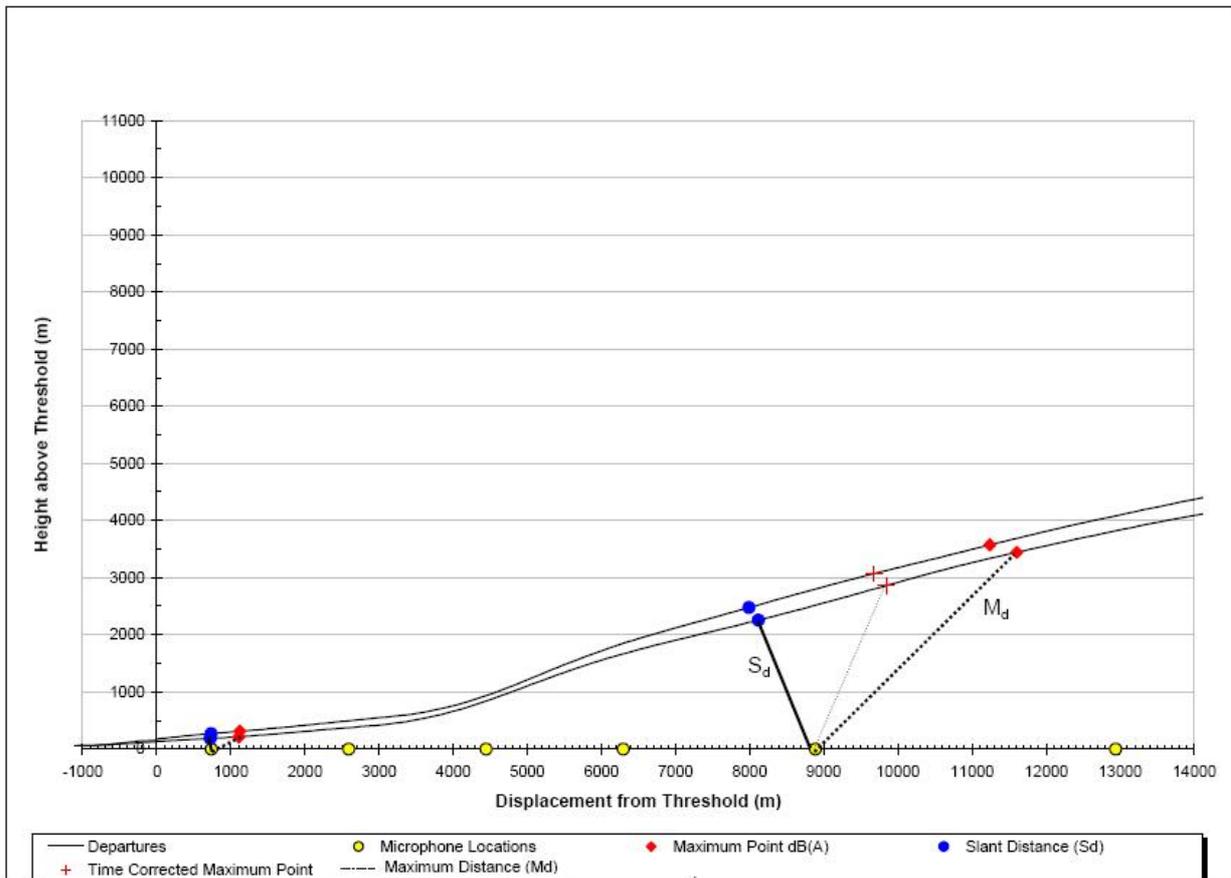


Figure 1. Twin Engine Military Jet – Departure with Afterburners Profile

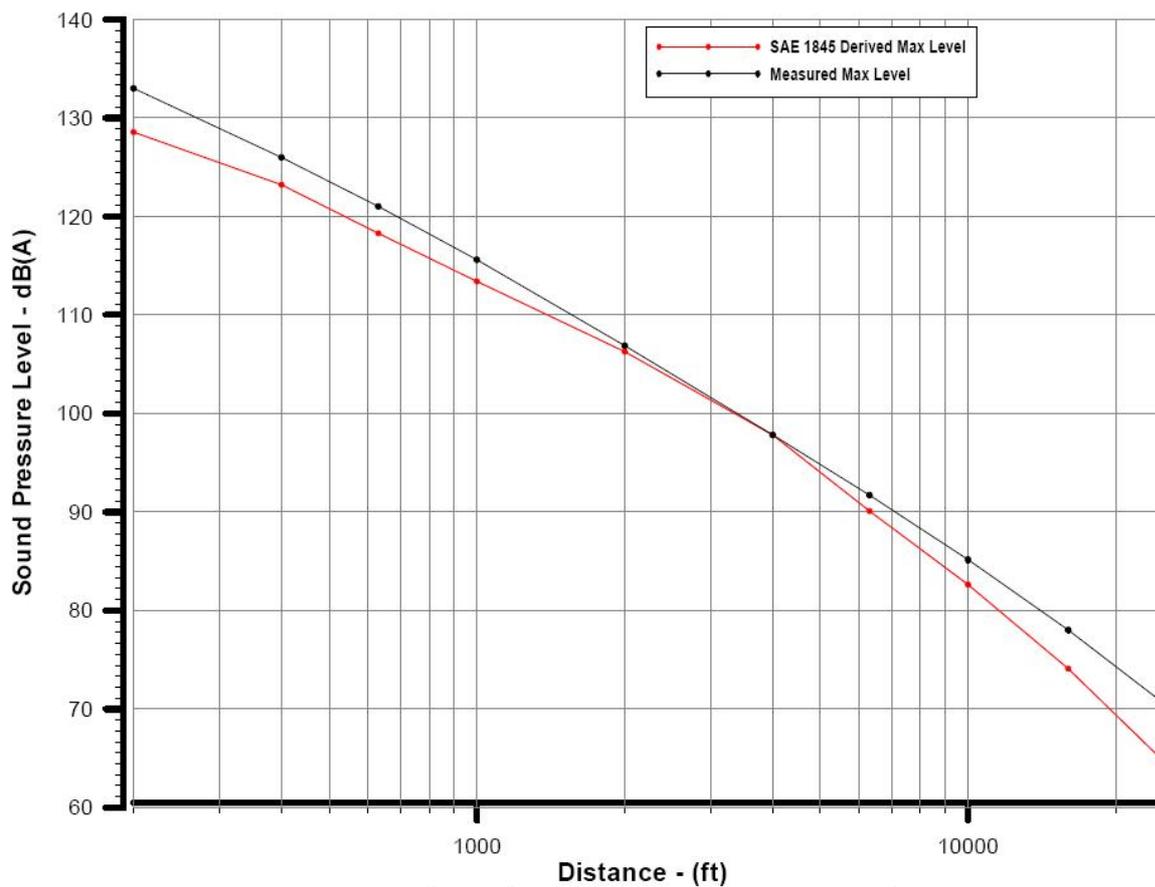


Figure 2. Twin Engine Military Jet – NPD Max Level

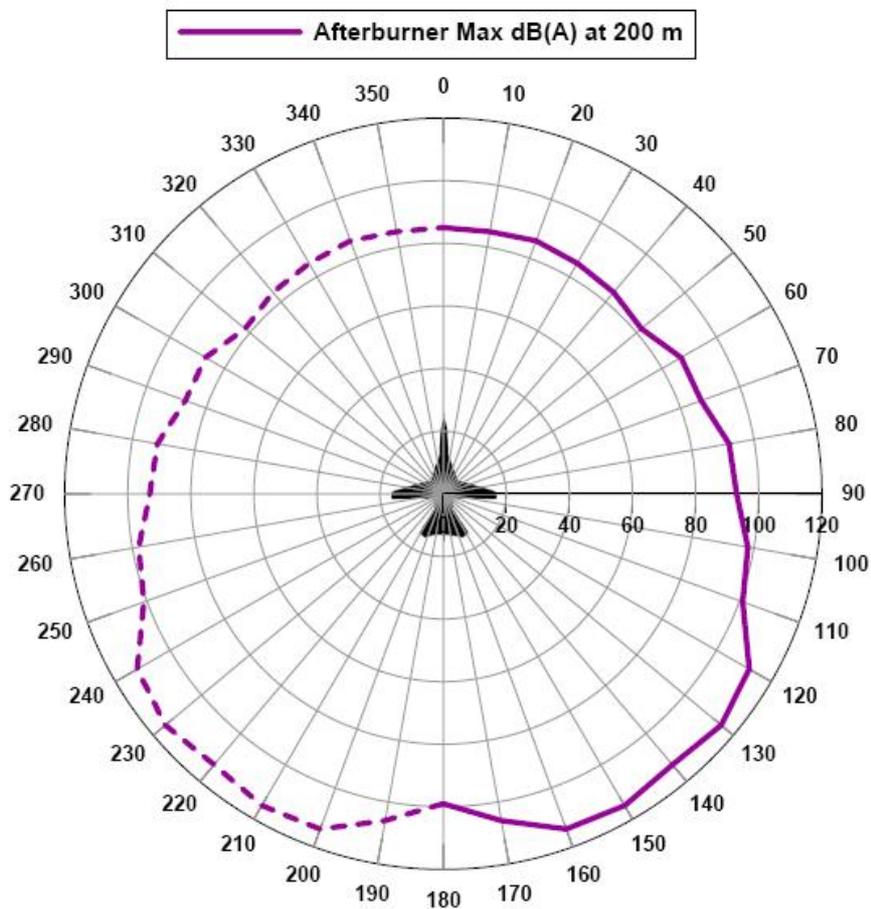


Figure 3. Twin Engine Military Jet Polar Plot

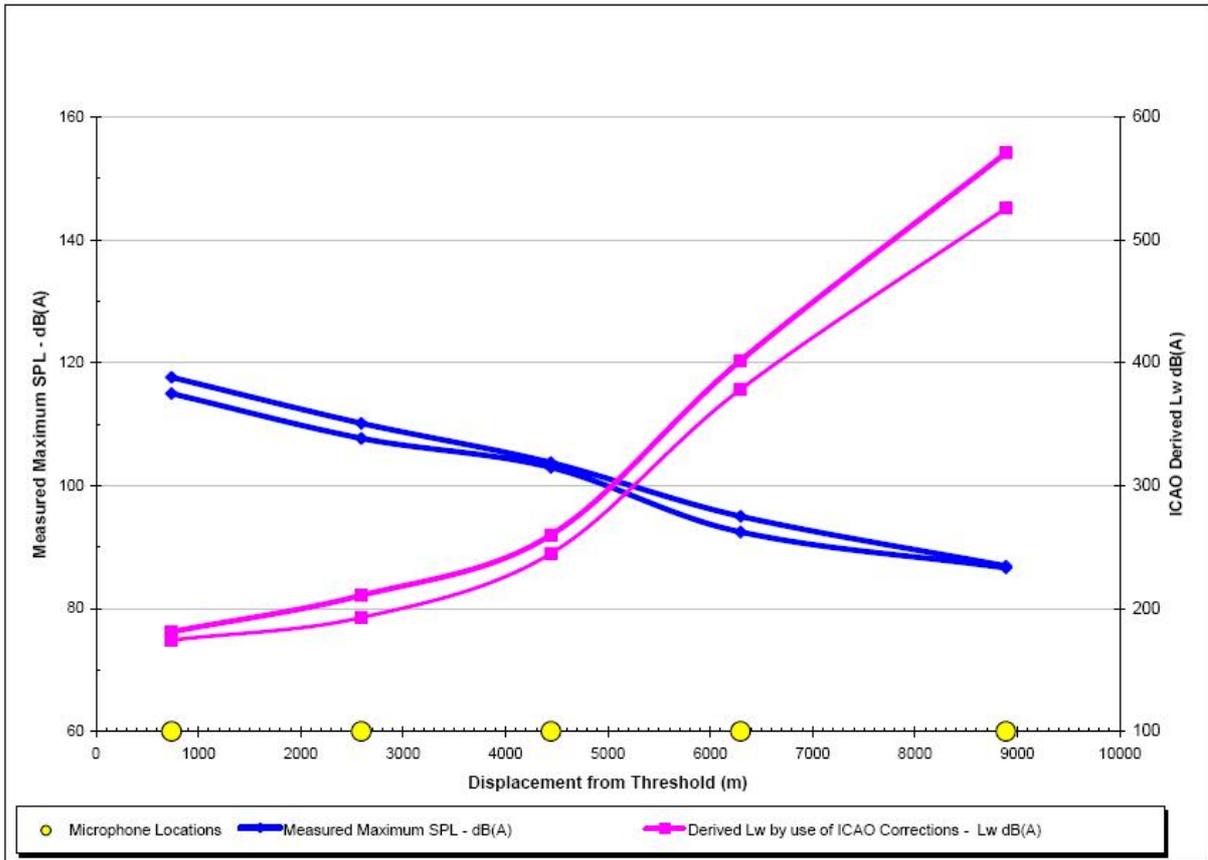


Figure 4. Twin Engine Military Jet – Departure with Afterburners

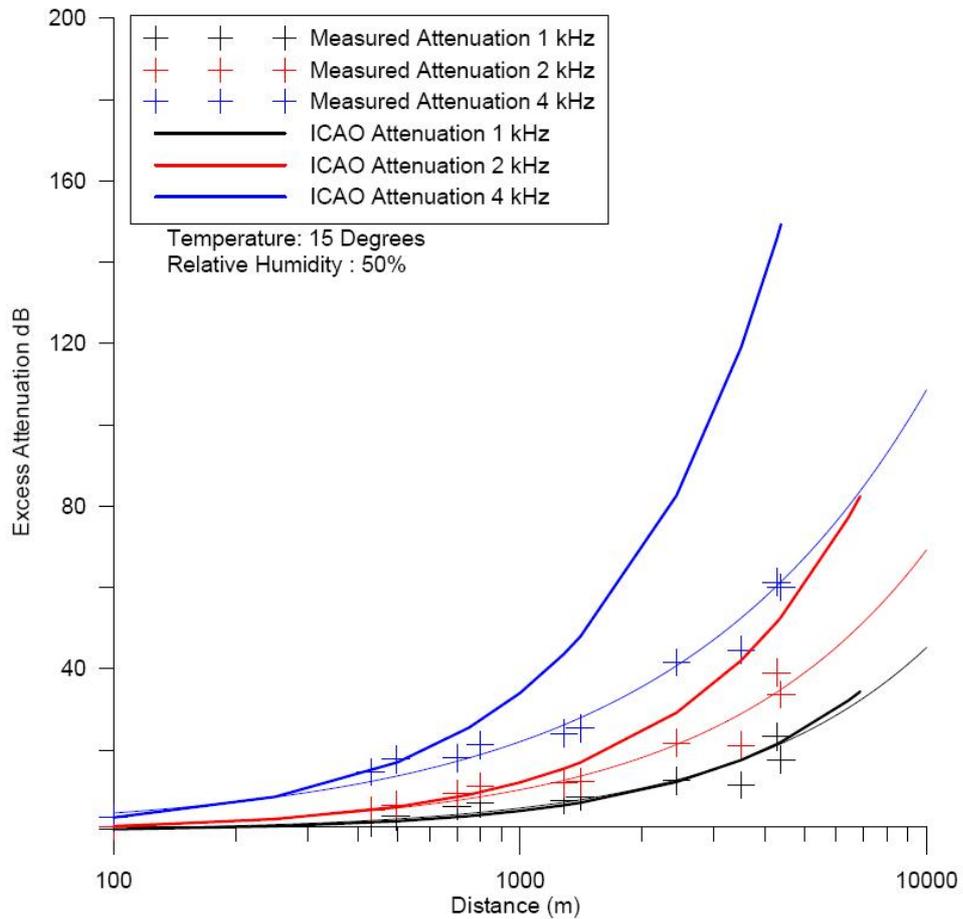


Figure 5. Twin Engine Jet – Excess Attenuation

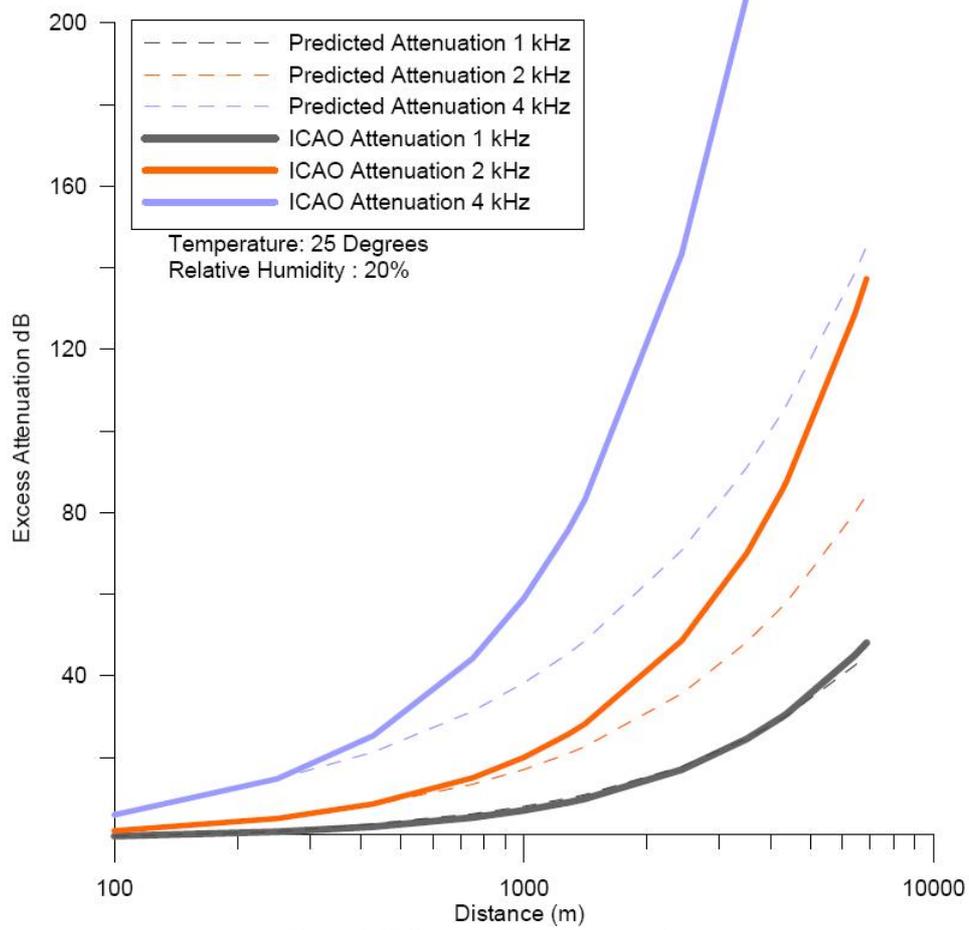


Figure 6. Helicopter – Excess Attenuation