



**19th INTERNATIONAL
CONGRESS ON ACOUSTICS**

2-7 September 2007, MADRID, SPAIN

"Acoustics for the 21st Century"

SOUND TRANSMISSION BETWEEN MUSICIANS IN A SYMPHONY ORCHESTRA ON A CONCERT HALL STAGE

Magne Skålevik,

Brekke&Strand,

www.akutek.info

Motivation

- Mutual hearing in orchestra is essential
- Mutual hearing needs sound transmission
- We need to know what they hear, namely:
 - Direct sound quality (time and frequency)
 - Indirect sound paths quality
 - Effect of Directivity, Height (source-receiver), Sightlines (open sound path), Obstacles
- Measurements with omni-directional source on empty stage cannot alone describe real conditions

Measurement description

Time	January 31, 2007
Place	Oslo Concert Hall, podium
Orchestra	Oslo Philharmonic, 90 musicians, instruments, music stands
Transducers	3.5" speaker, omni-microphone
Software	winMLS 2004
Number of measurements	16
Variables	Source-receiver heights Canopy (with-without) Directionality (source axis direction) Musicians (occupied-empty chairs)

Oslo Philharmonic Orchestra in Oslo Concert Hall

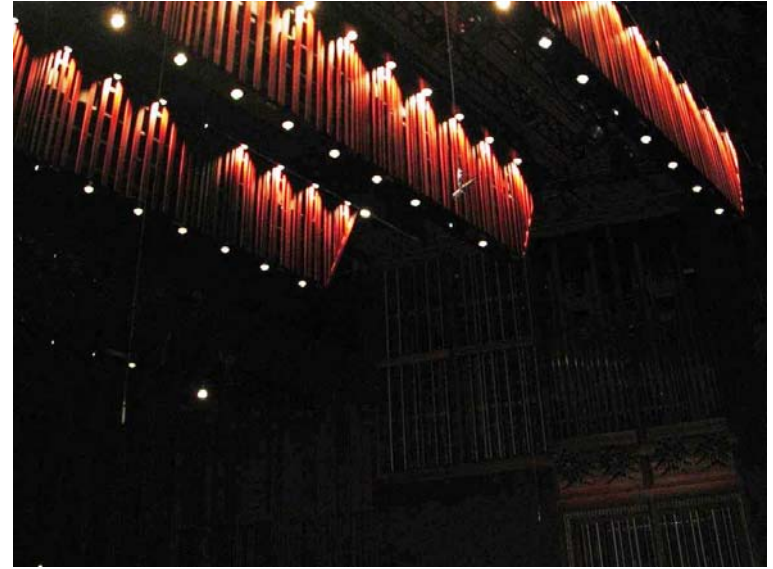


1. Violin to contrabassoon (11m)



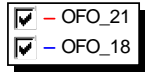
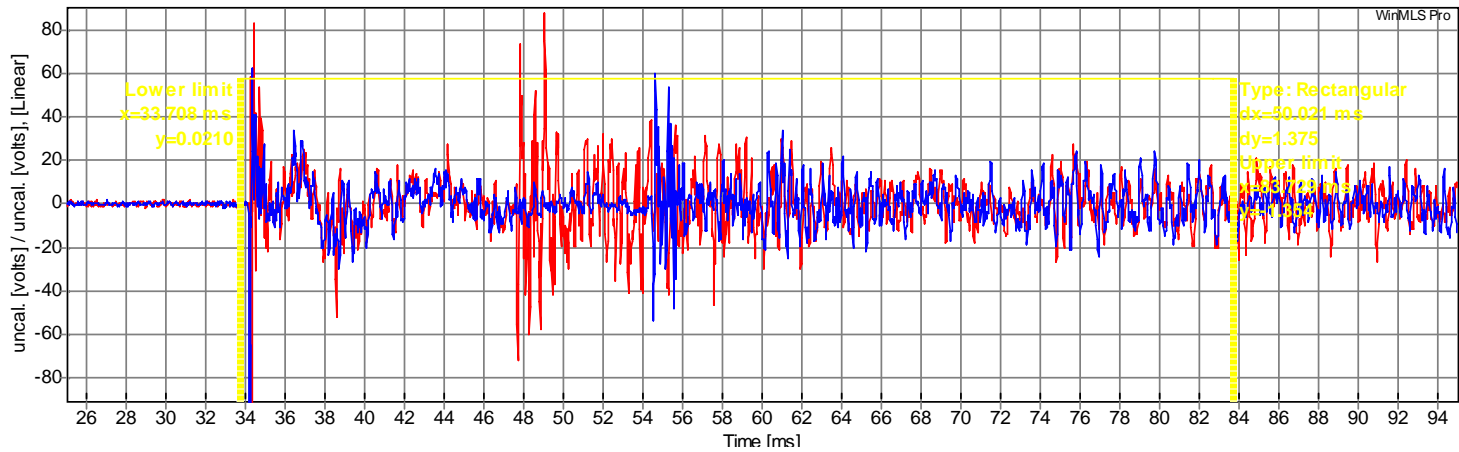
Illustration of source-receiver positions

(Image: <http://www.mti.dmu.ac.uk/~ahugill/manual/seating.html>)

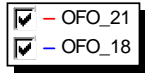
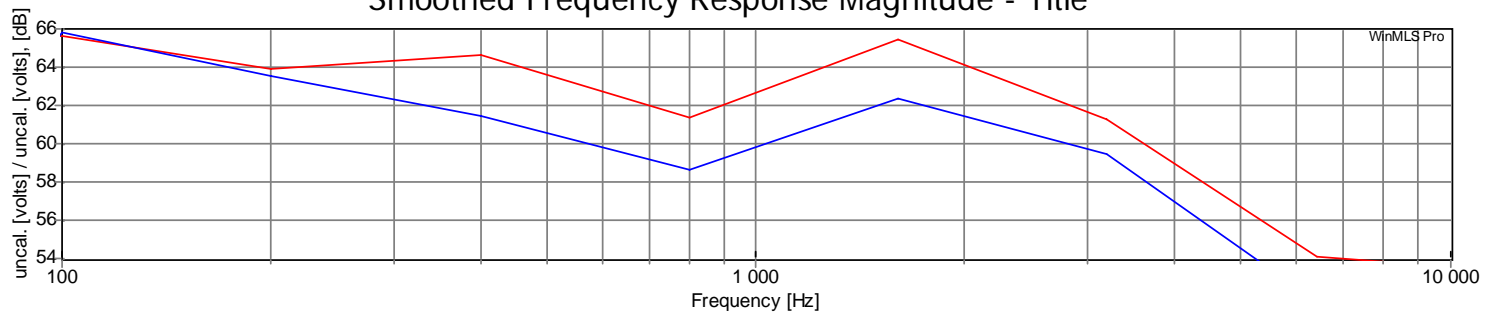


IR and FR (0-50ms)

Time Data - Title



Smoothed Frequency Response Magnitude - Title



Measured - 10:16:38, 31Jan2007 Plotted - 19:58:28, 30Aug 2007
Name: OFO_18 Comment: Comment

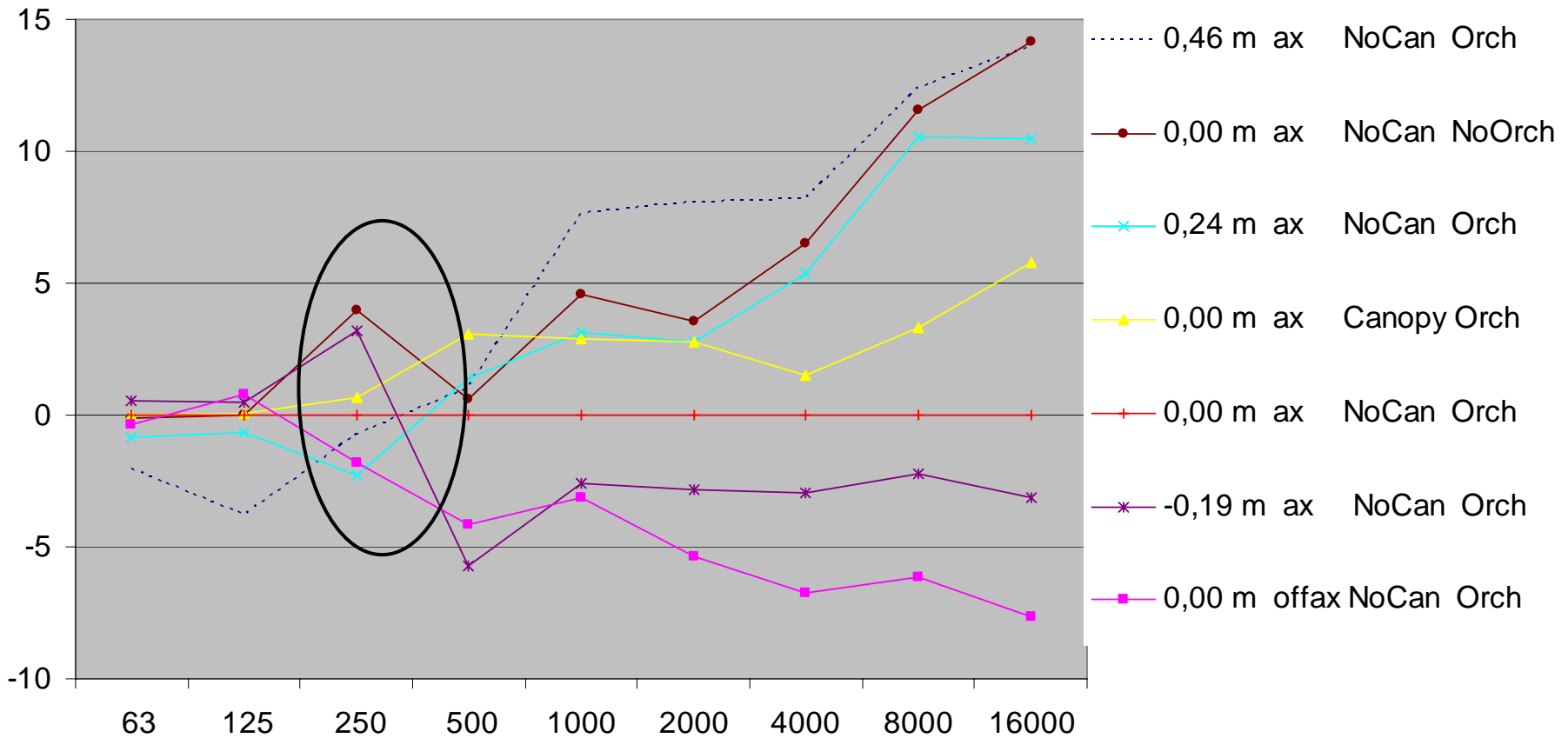
1. Violin to Bassoon, without canopy (blue curve), and with canopy (red)

G50

- Parameter used in this study is G50
- G50 obtained from G and D50 in winMLS
$$G50 = G + 10 \cdot \log(D50)$$
- G50 is hearing-related (50ms merging)
- G50 is detail sensitive
- Tonal information (intonation) is better described with longer \rightarrow 200ms integration

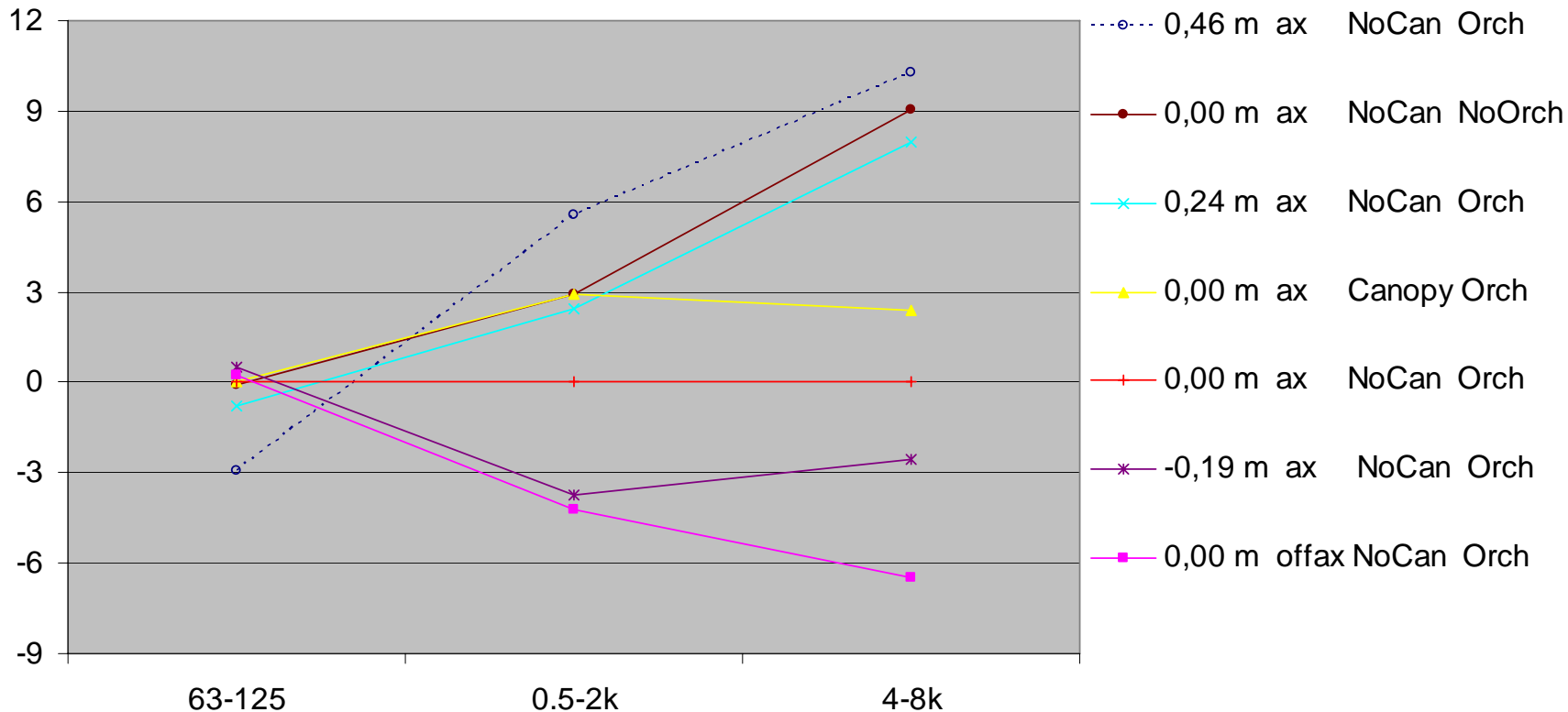
Chaos around 250Hz

- Interference- and wave-related



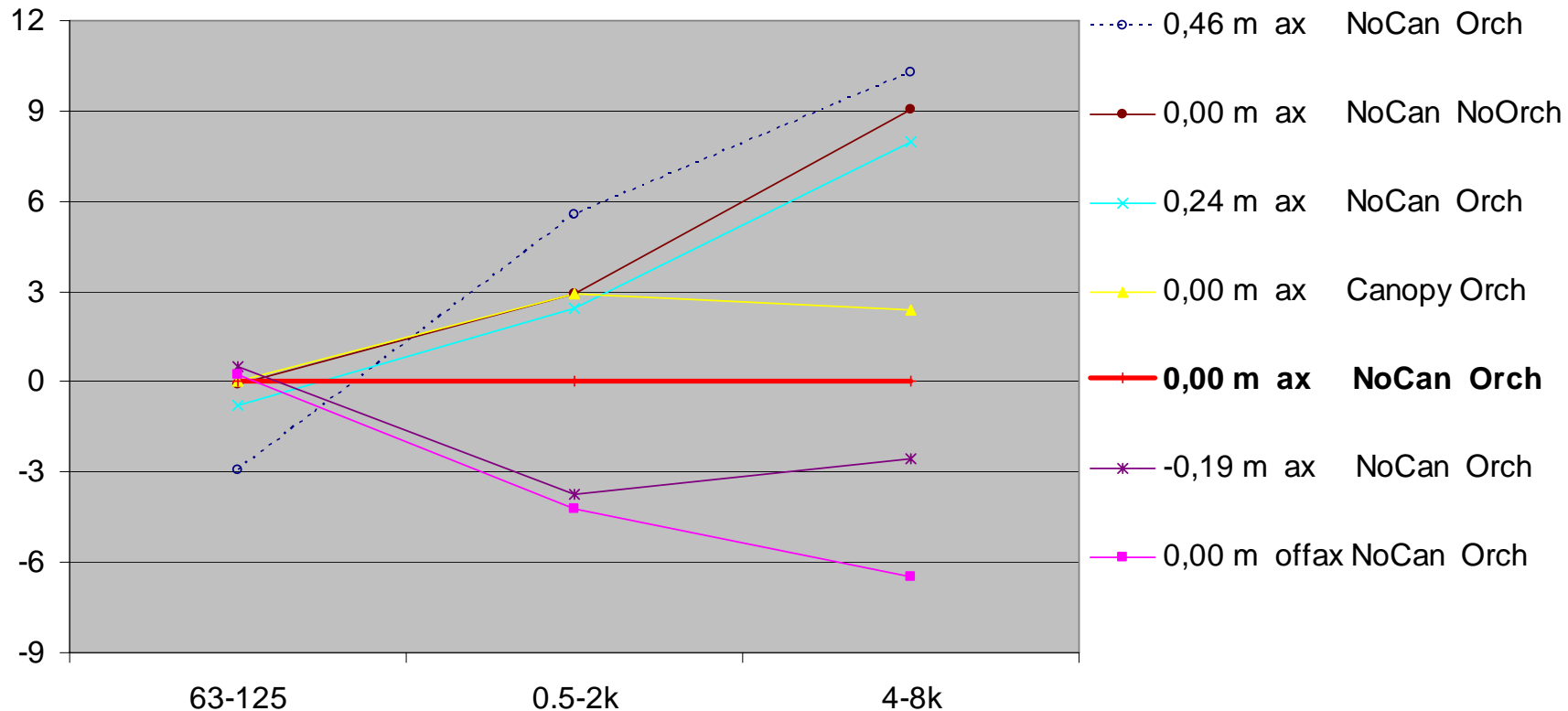
Simplified to 3 bands (250Hz removed)

- 63-125Hz, 0.5-2kHz, 4-8kHz



Reference (0dB) measurement

0.00 m	ax	NoCan	Orch
--------	----	-------	------



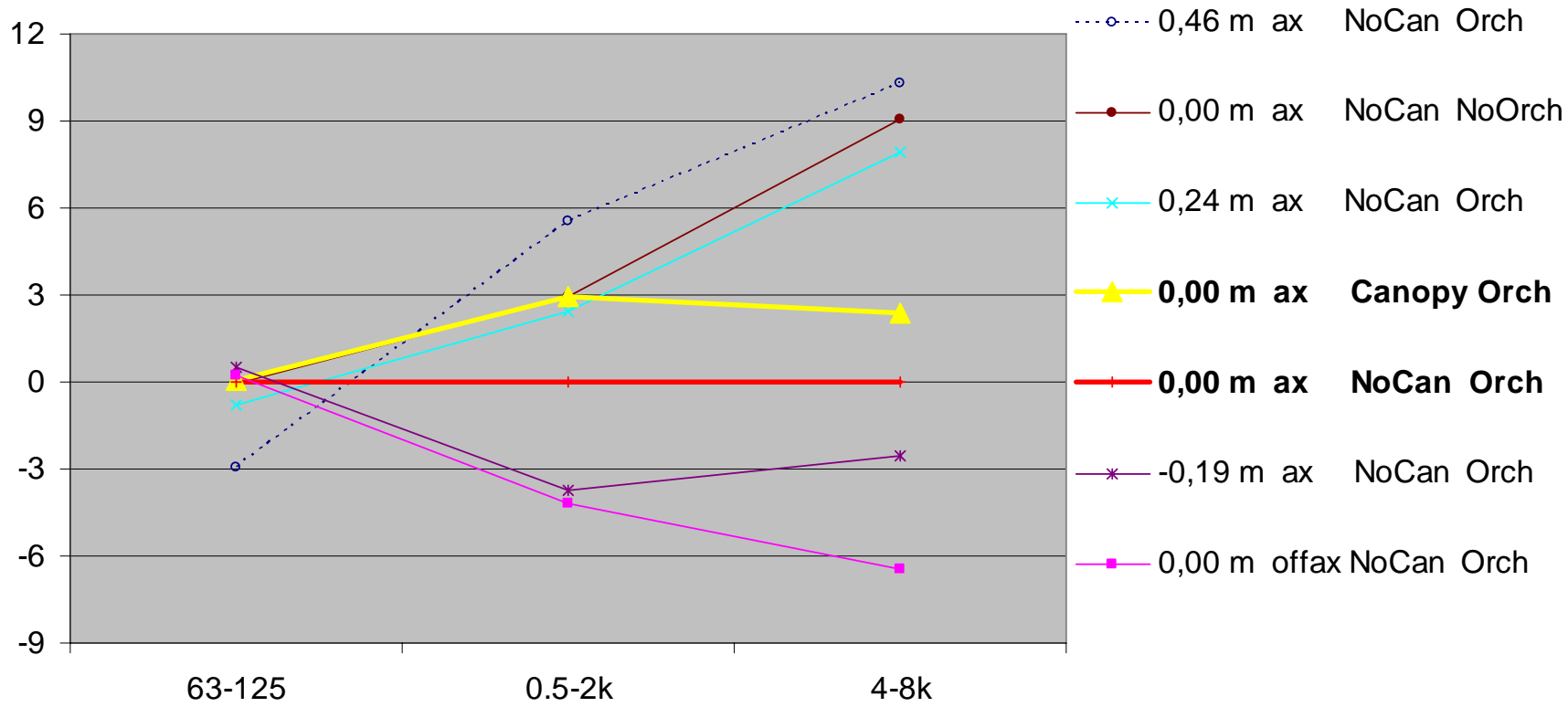
Reference (0dB) measurement

0.00 m	ax	NoCan	Orch
Path height	Path along source axis	No canopy	Orchestra present

All levels are G50 in dB

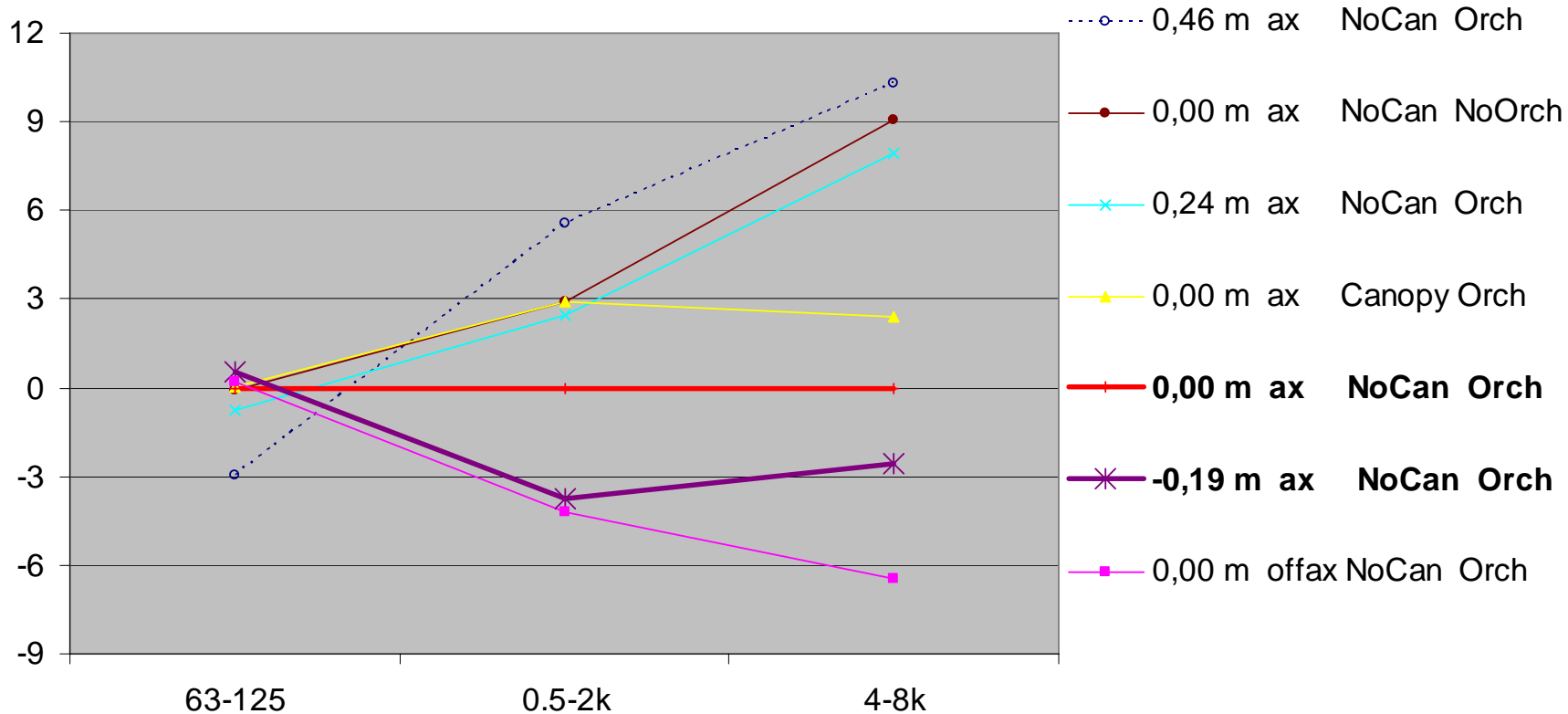
Canopy effect

3dB boost, $f > 400\text{Hz}$



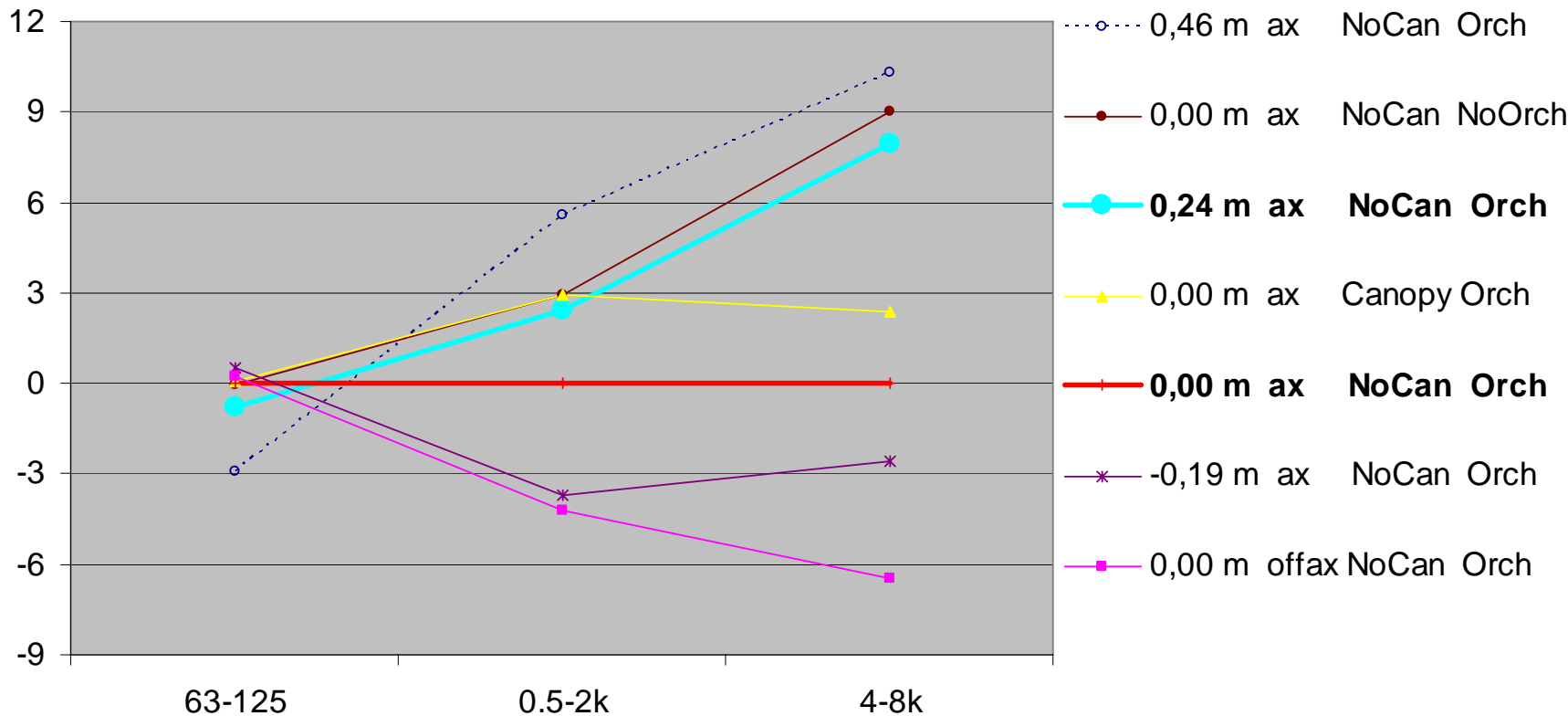
19 cm lower source-receiver path

$\div 3\text{dB}$ for $f > 400\text{Hz}$



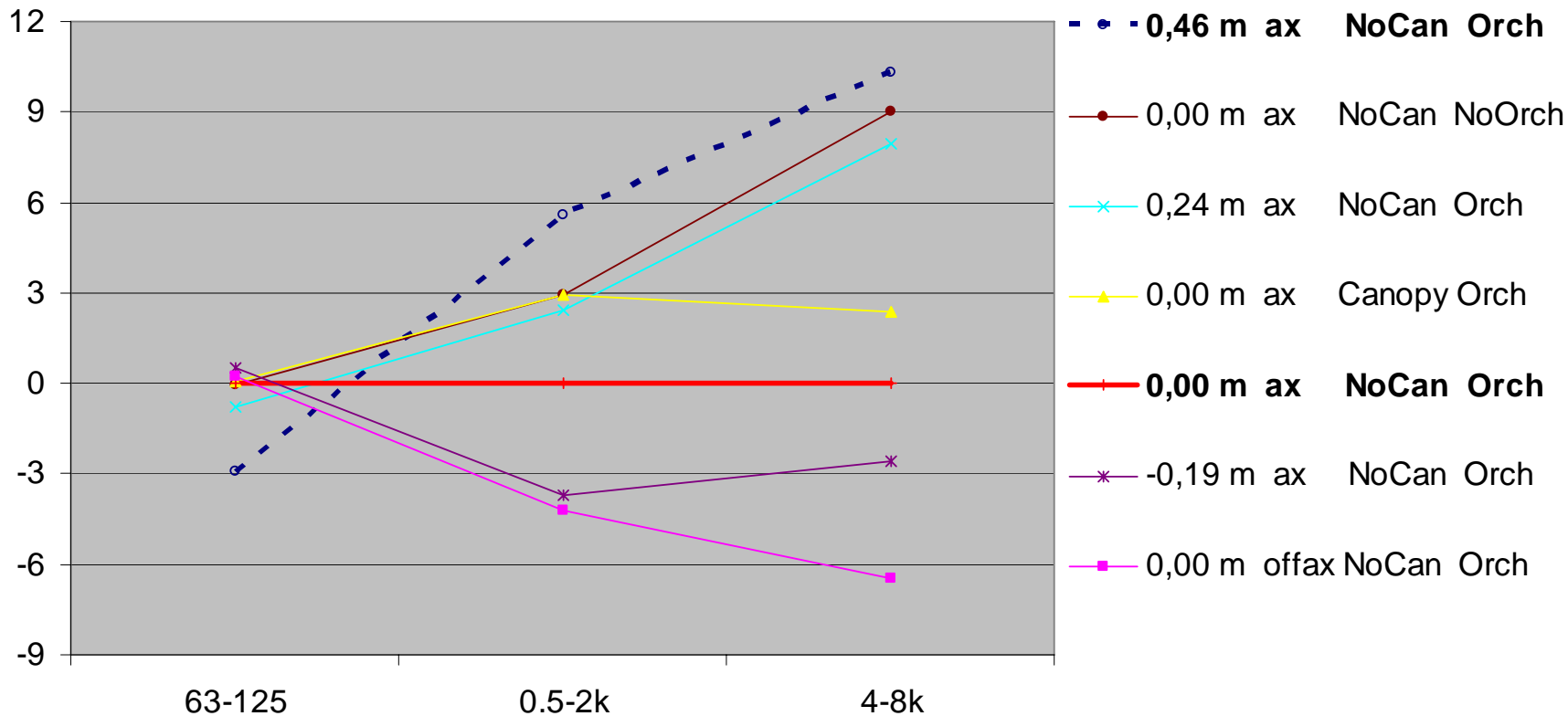
24cm higher source-receiver path

÷1 in low, +3 in mid, +8 in high



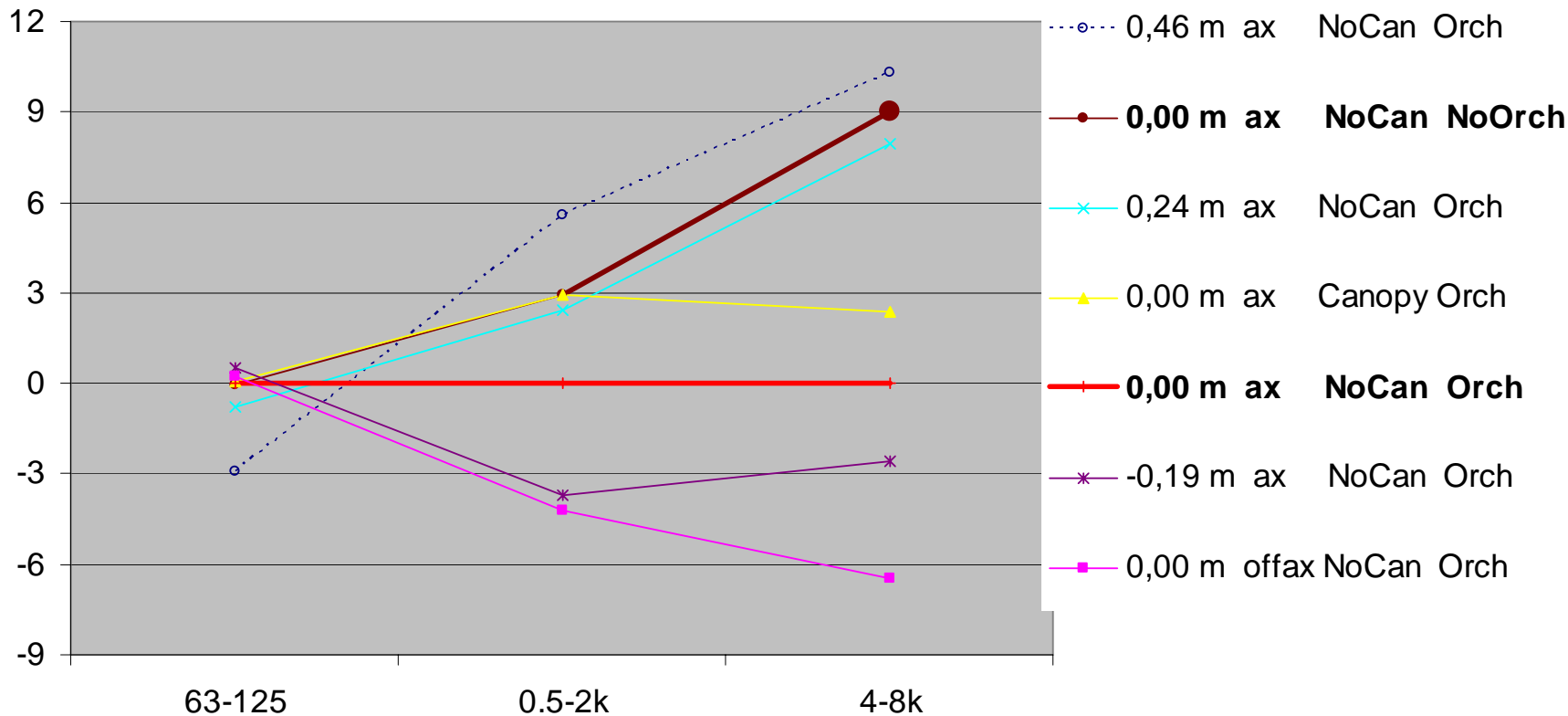
46cm higher source-receiver path

÷3 weaker bass!, +6 in mid, +10 in high



Musicians missing

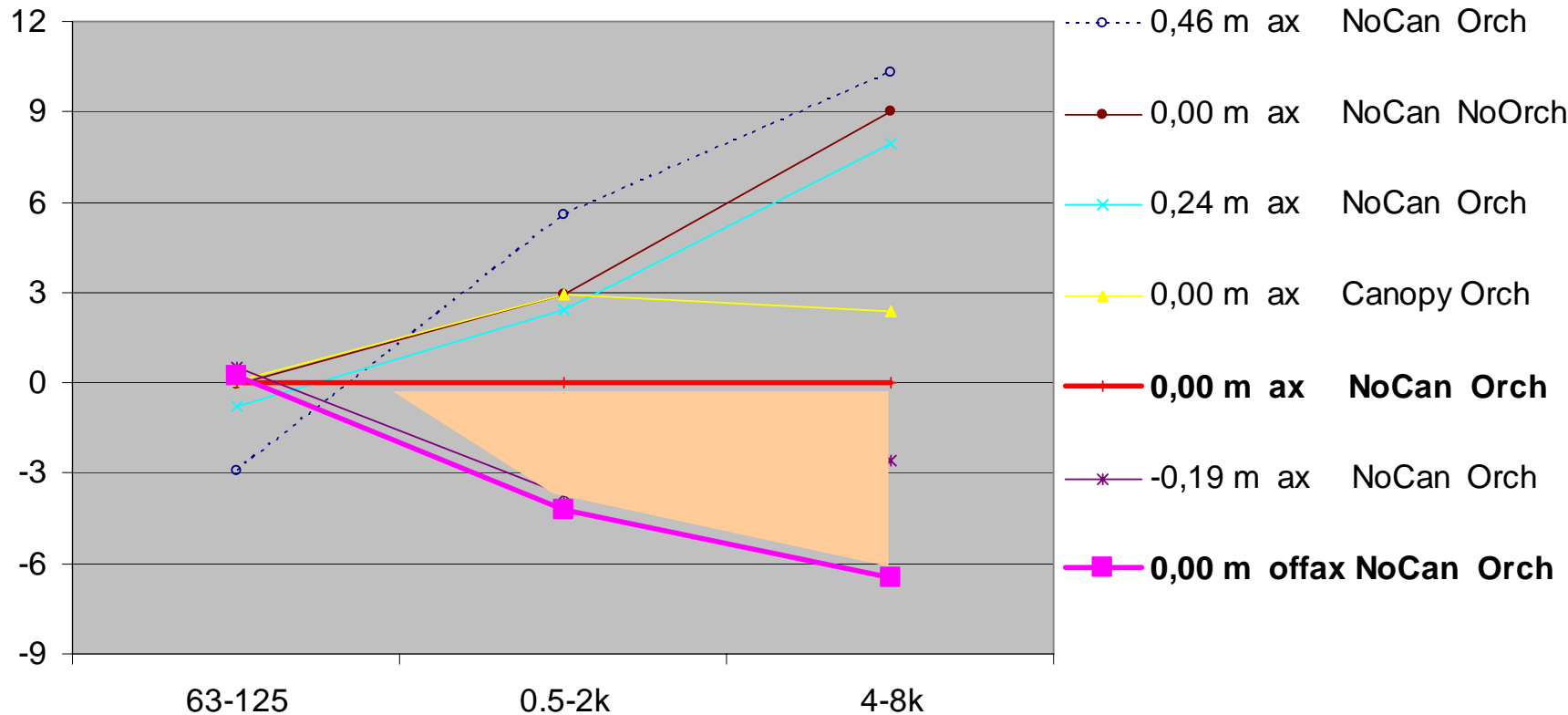
Equivalent to 24cm elevated path



Directivity effect

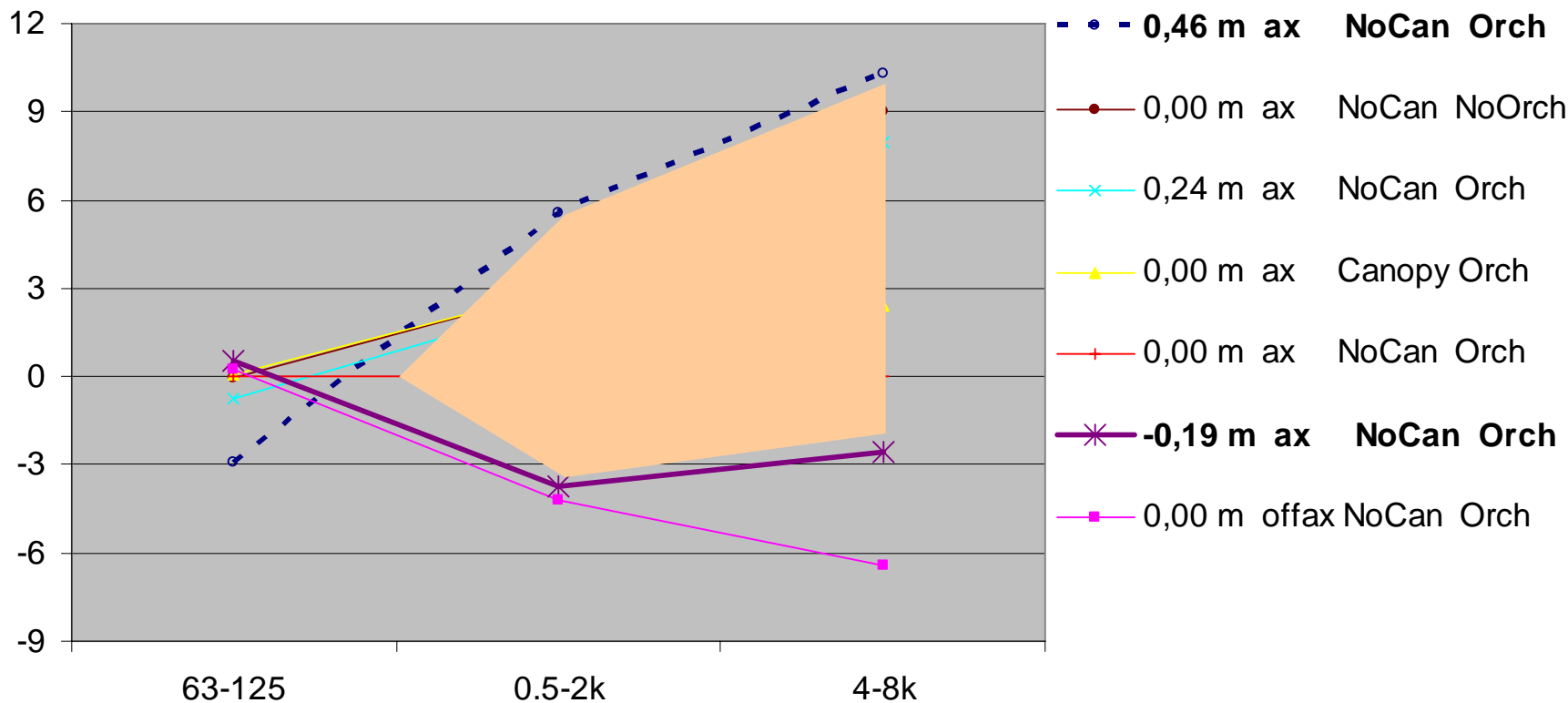
0dB, 4dB and 6dB at normal path (diagram)

0dB, 6dB and 14dB at free path (+46cm)



Obstacle effect

Variation: 9dB in mid, 13dB in high



Path height sensitivity

63-125Hz	$\div 6\text{dB/m}$
500-2000Hz	$+15\text{dB/m}$
4000-8000Hz	$+20\text{dB/m}$

Conclusions

- Obstacle effect significant at $f > 400\text{Hz}$
 - > [Canopy](#) can compensate if it reflects $f > 400\text{Hz}$
- Canopy support underestimated on empty stage
- Directivity more prominent with free paths
- Elevated source/receiver -> less bass
- Research, predictions and measurements in [Stage Acoustics](#) should take the orchestra obstacle effect into account
- “Randomness” from obstacles and directivity
 - 9dB in 0.5-2kHz, and 13dB in 4-8kHz

Further work, further questions

- Radiation from musical instruments
 - Dynamic aspects, analysis
 - Is the direct sound path preferred?
 - Or are multiple paths preferred?
- In terms of remedies
 - Orchestra raisers to provide direct paths?
 - Stage environment providing multiple paths?
- “Randomness” in directivity and obstacles
 - Is it equalized (averaged) by ensemble effect?
- Significance of integration limit ->200ms



**19th INTERNATIONAL
CONGRESS ON ACOUSTICS**

2-7 September 2007, MADRID, SPAIN

"Acoustics for the 21st Century"

Thank you!

- Full paper:
http://www.akutek.info/Papers/MS_Sound_Transmission.pdf
- Acoustics, research, papers, more:
www.akutek.info
- ICA homepage: <http://www.icacommission.org/>