Mind the Gap

TMT 2018, November 2018, Cologne, Germany

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Assumptions made are not reflective of the position of any entity other than the author.

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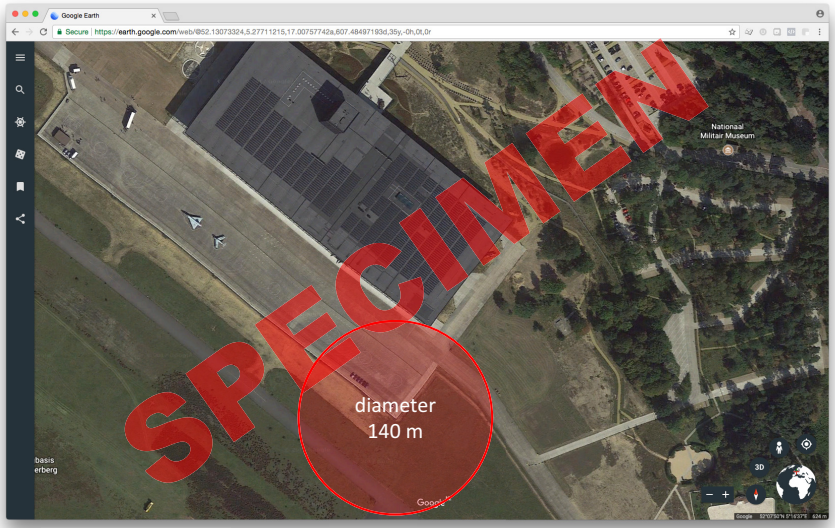
Former Air Force Base "Soesterberg" NL

(Summer 2017)



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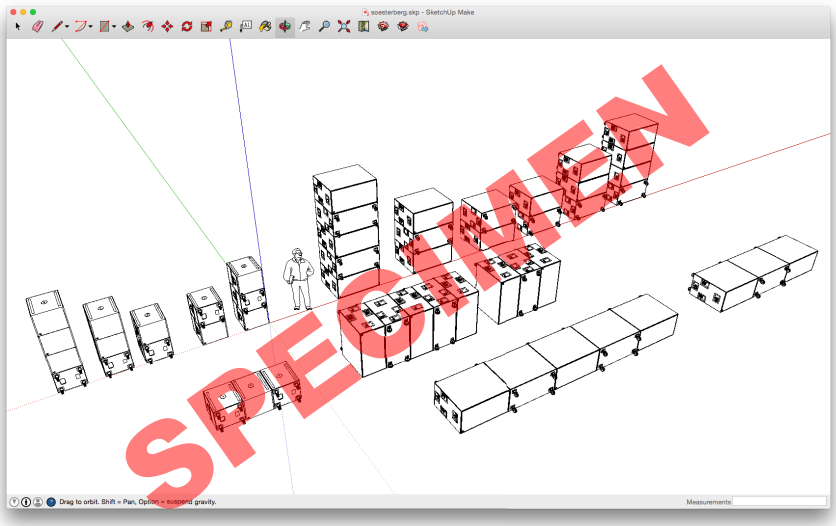
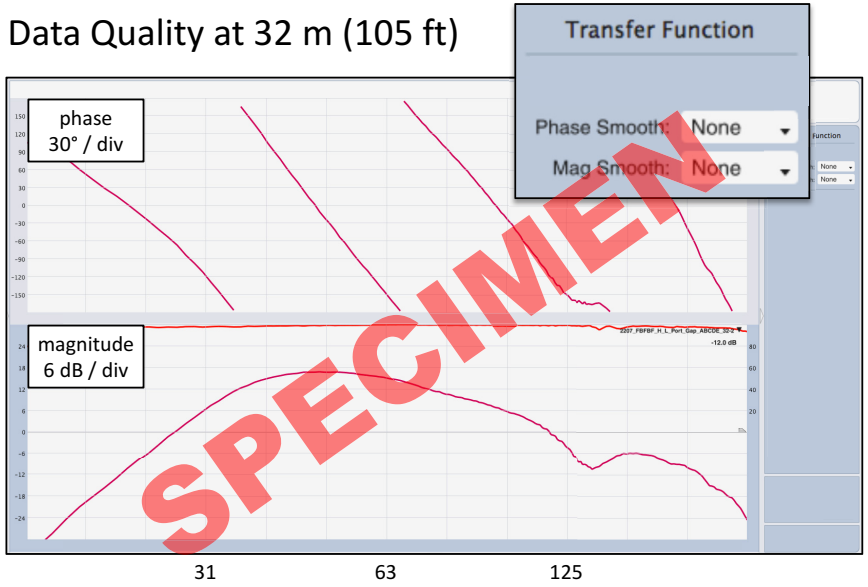


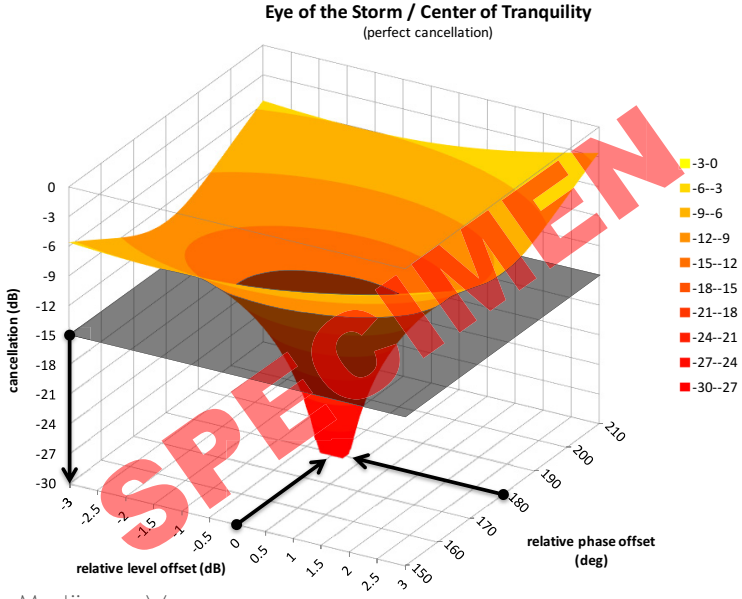
Source: SketchUp 3D Warehouse, models by David M.

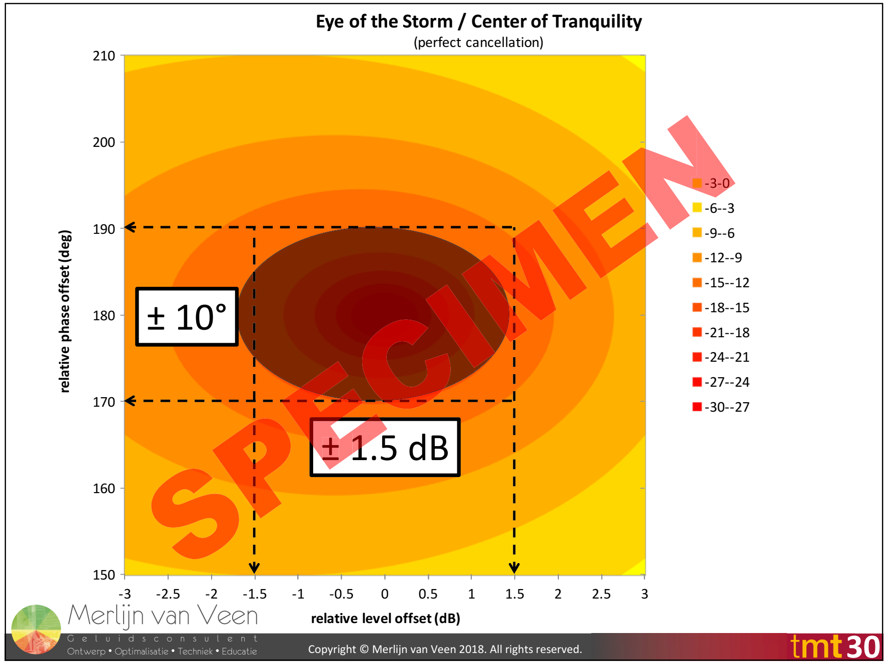
Wind noise reduction

Source: rycote.com

Data Quality at 32 m (105 ft)






Eye of the Storm / Center of Tranquility
(perfect cancellation)
± 10°
± 1.5 dB
relative phase offset (deg)
relative level offset (dB)
-3-0
-6--3
-9--6
-12--9
-15--12
-18--15
-21--18
-24--21
-27--24
-30--27
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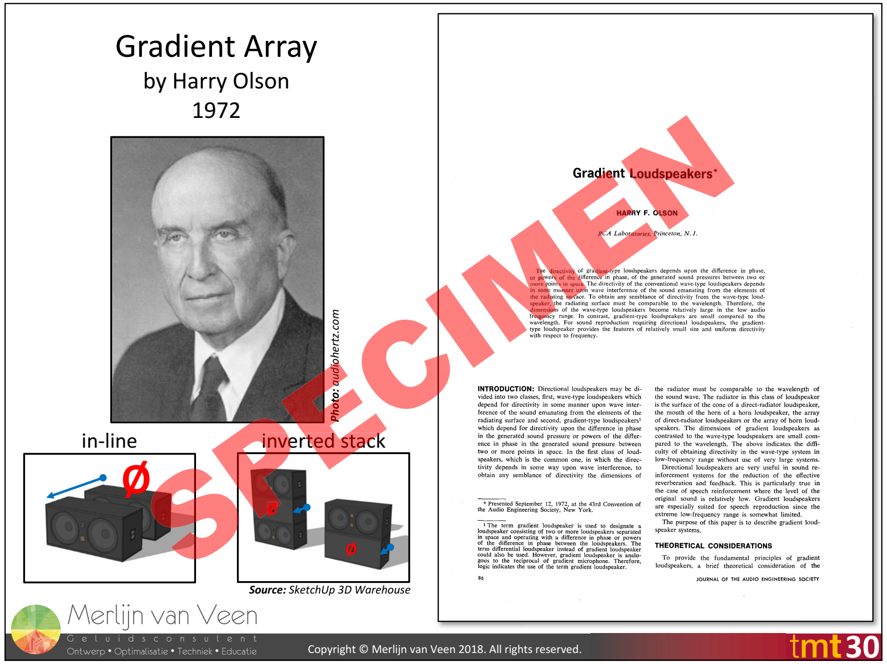
Gradient Array
by Harry Olson
1972
Photo: audiohertz.com
in-line
inverted stack
Source: SketchUp 3D Warehouse
Gradient Loudspeakers*
HARRY F. OLSON
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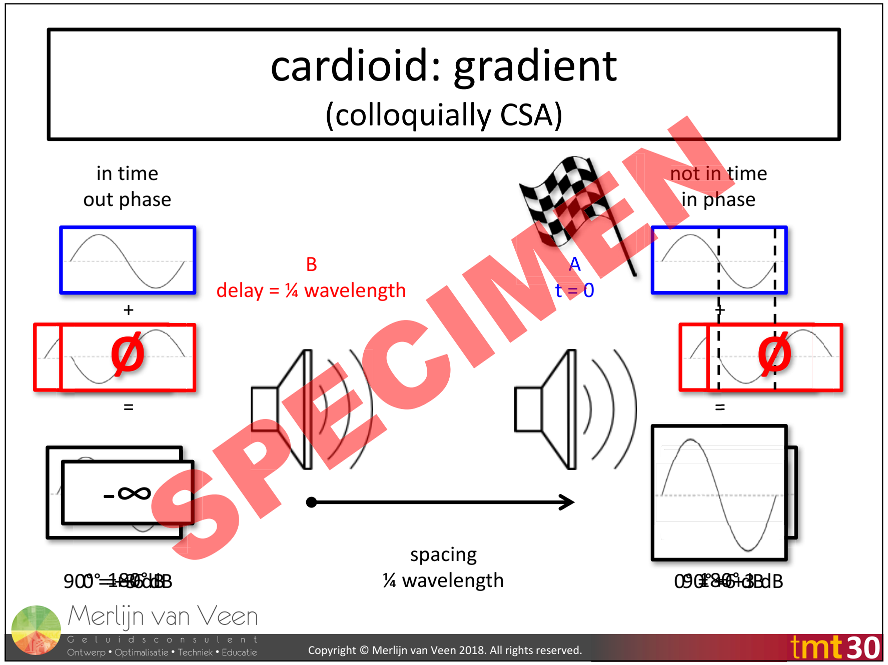
cardioid: gradient
(colloquially CSA)
in time
out phase
not in time
in phase
B
delay = ¼ wavelength
A
t = 0
-∞
spacing
¼ wavelength
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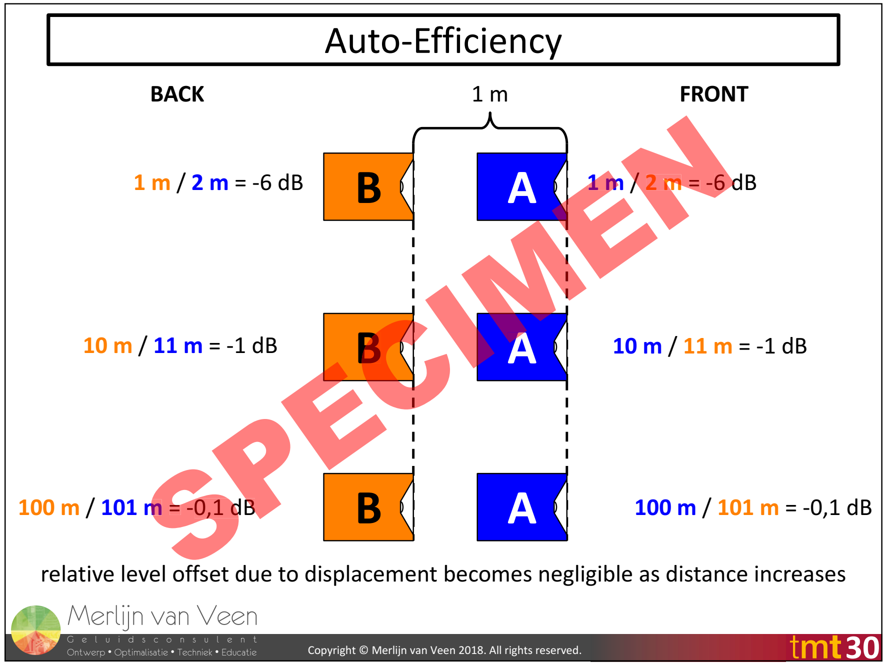
Auto-Efficiency
BACK
1 m
FRONT
1 m / 2 m = -6 dB
1 m / 2 m = -6 dB
10 m / 11 m = -1 dB
10 m / 11 m = -1 dB
100 m / 101 m = -0,1 dB
100 m / 101 m = -0,1 dB
B
A
relative level offset due to displacement becomes negligible as distance increases
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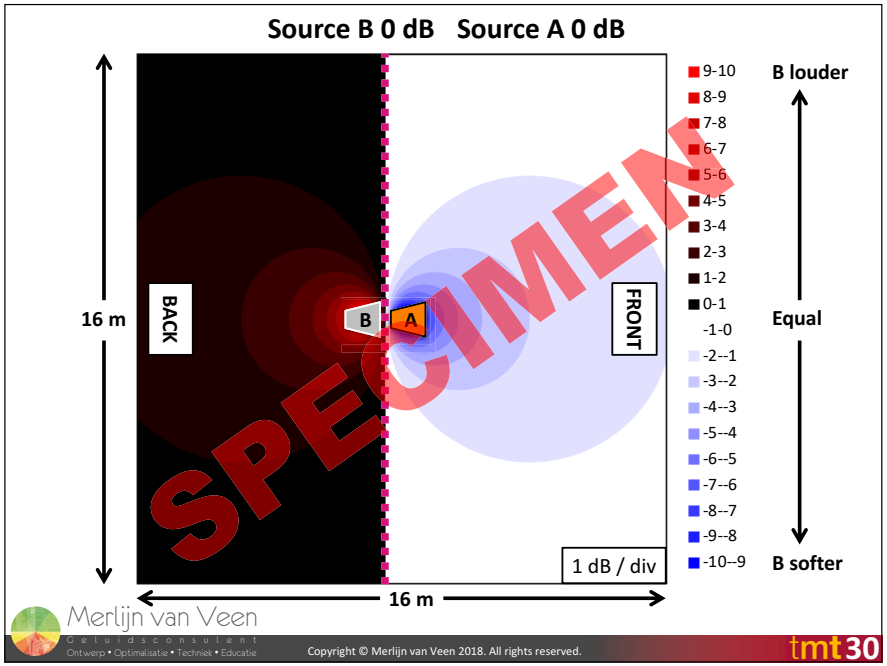
Source B 0 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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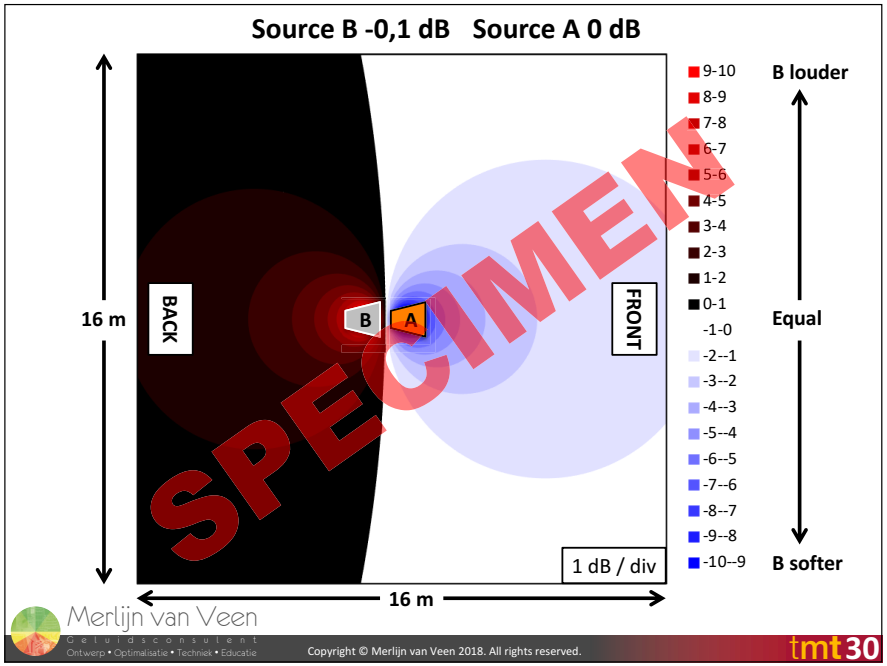
Source B -0,1 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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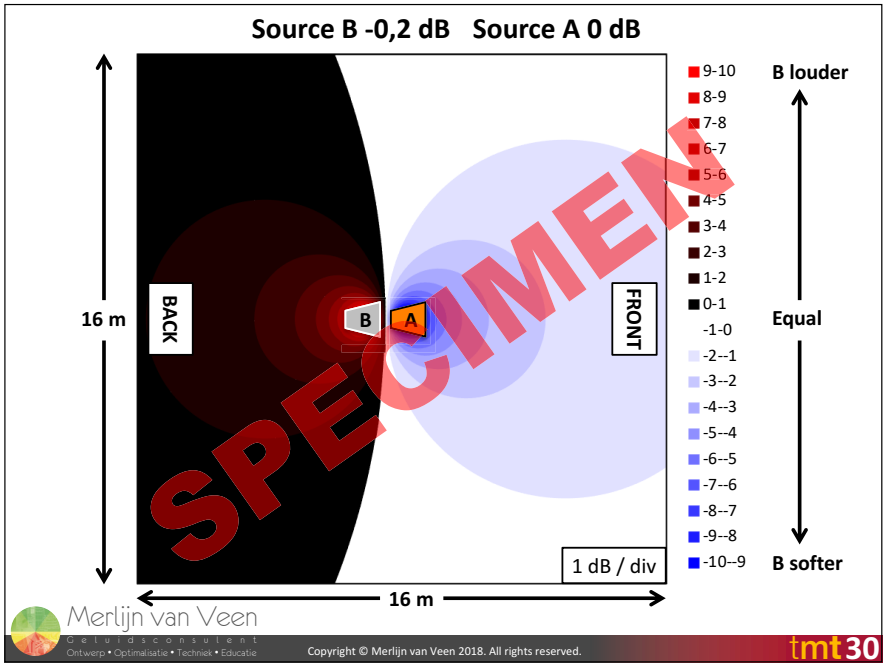
Source B -0,2 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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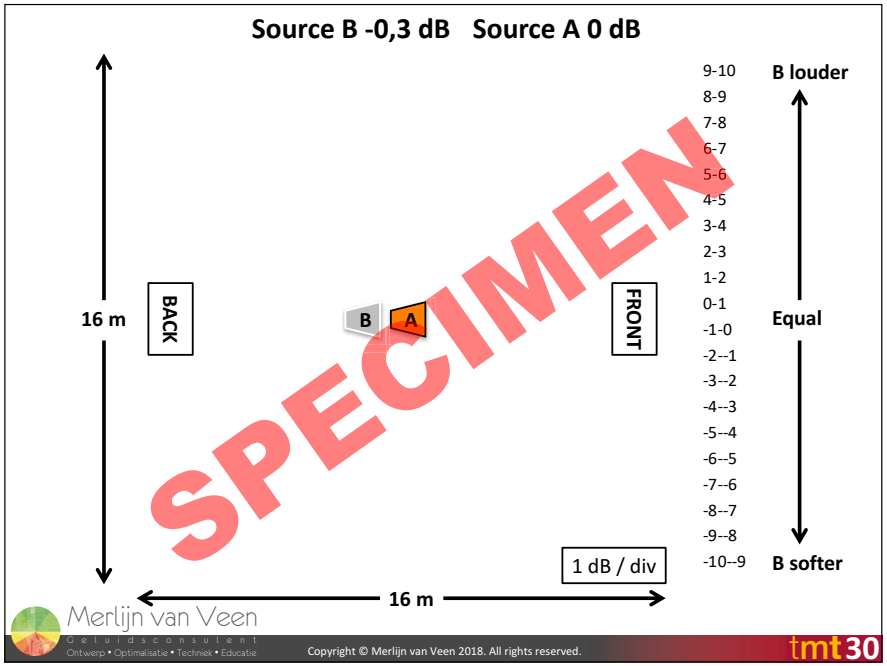
Source B -0,3 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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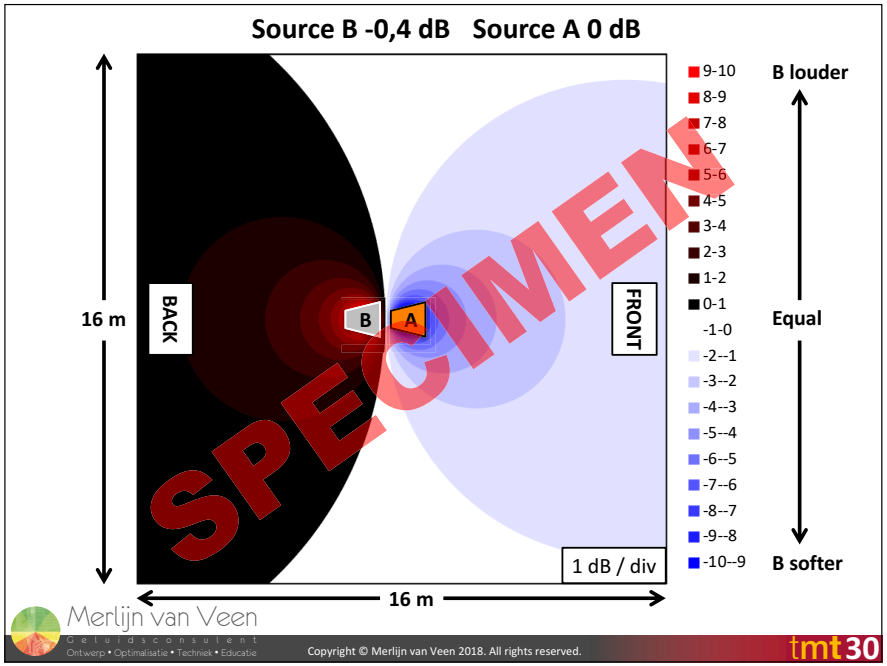
Source B -0,4 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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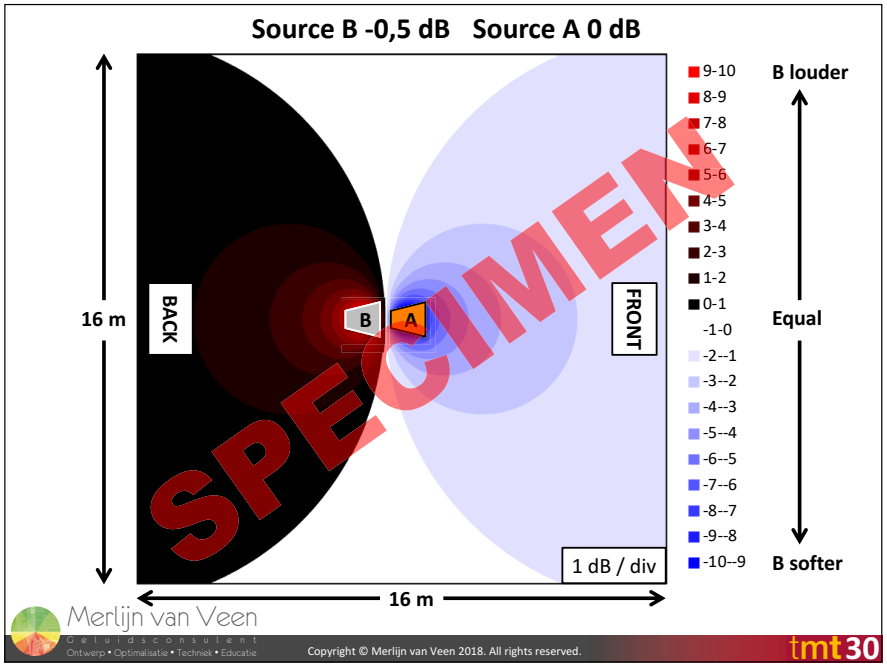
Source B -0,5 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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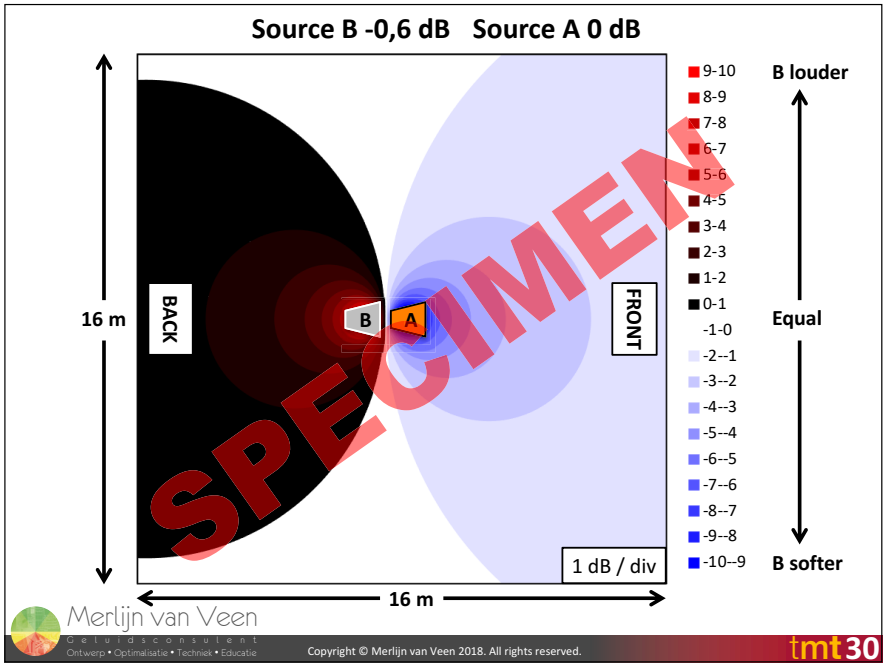
Source B -0,6 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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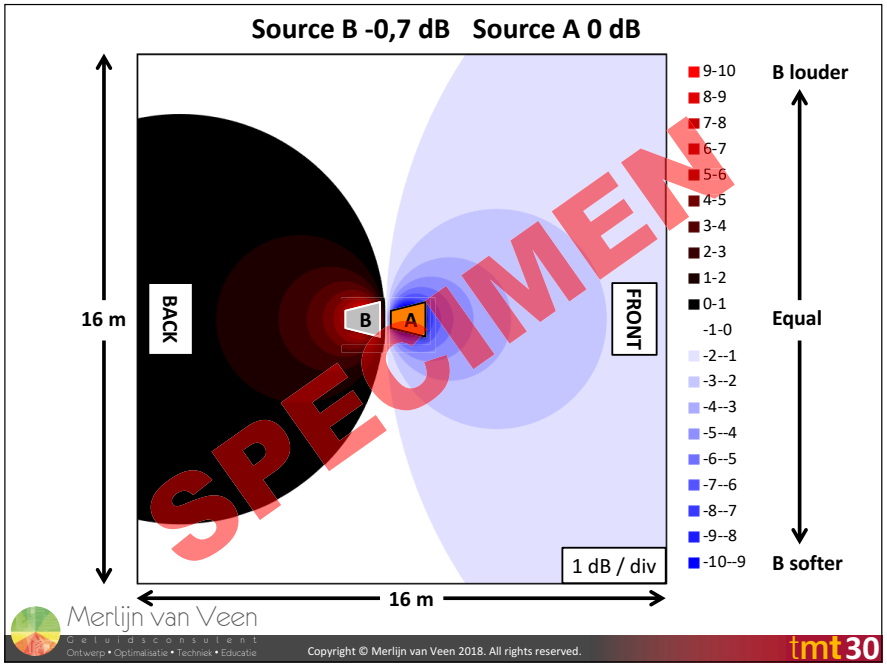
Source B -0,7 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
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1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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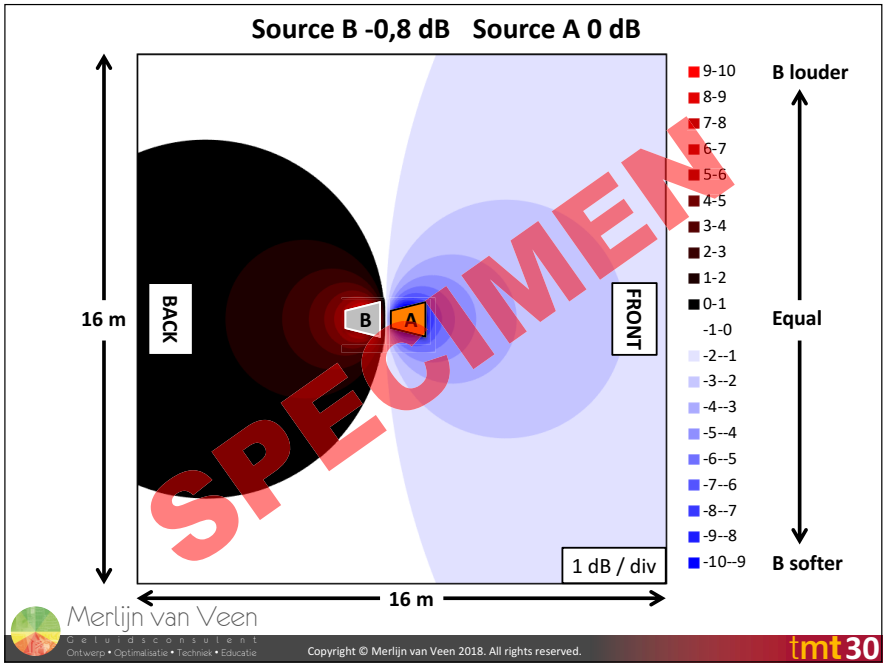
Source B -0,8 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
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6-7
5-6
4-5
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-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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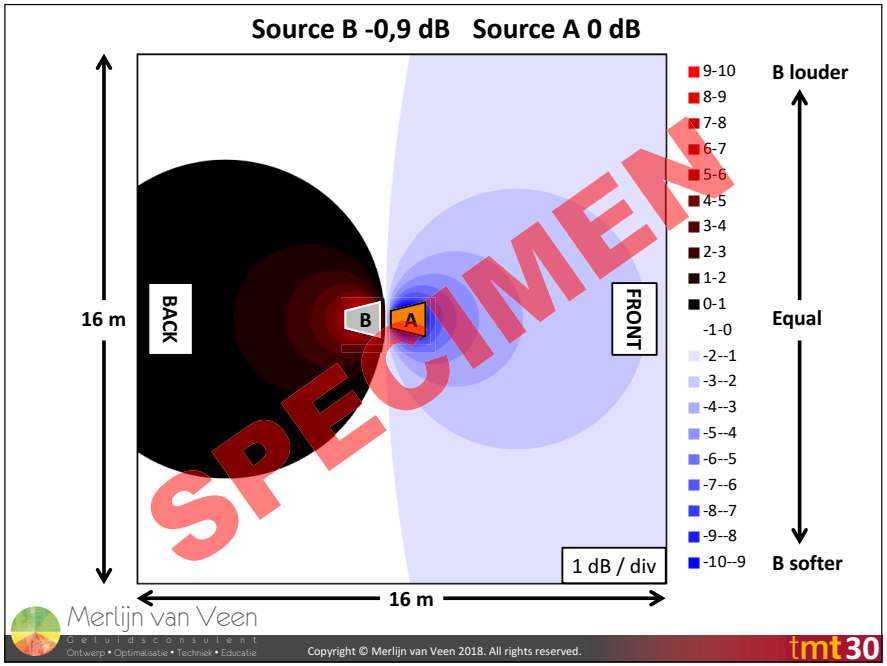
Source B -0,9 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
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6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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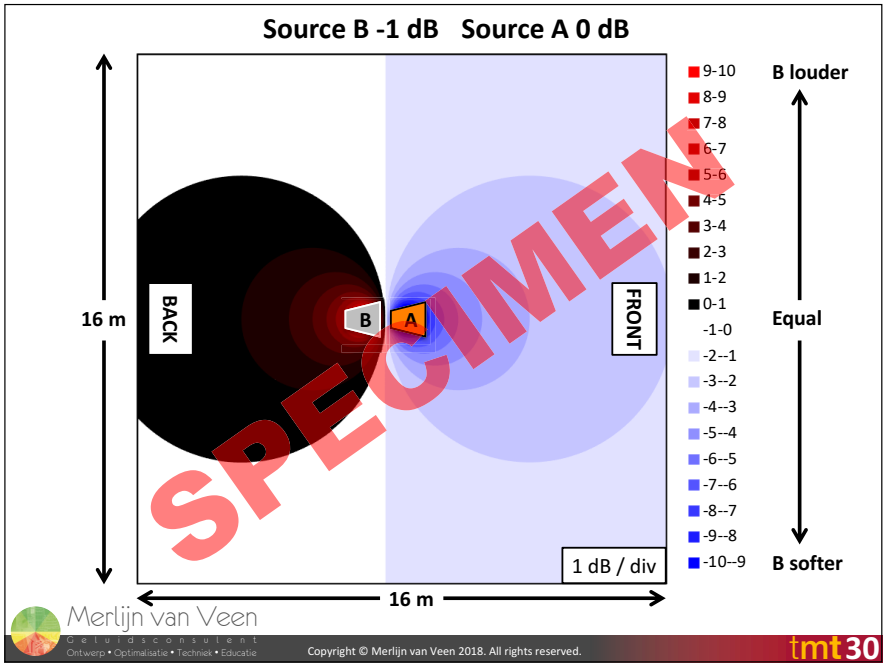
Source B -1 dB Source A 0 dB
16 m
BACK
FRONT
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-8--7
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Equal
B softer
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16 m
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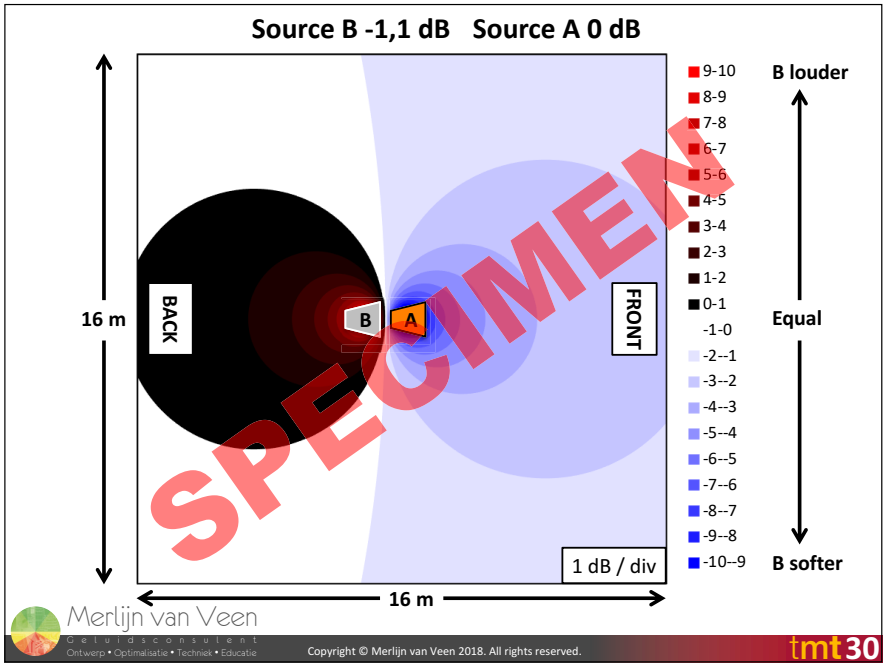
Source B -1,1 dB Source A 0 dB
16 m
BACK
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-6--5
-7--6
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Equal
B softer
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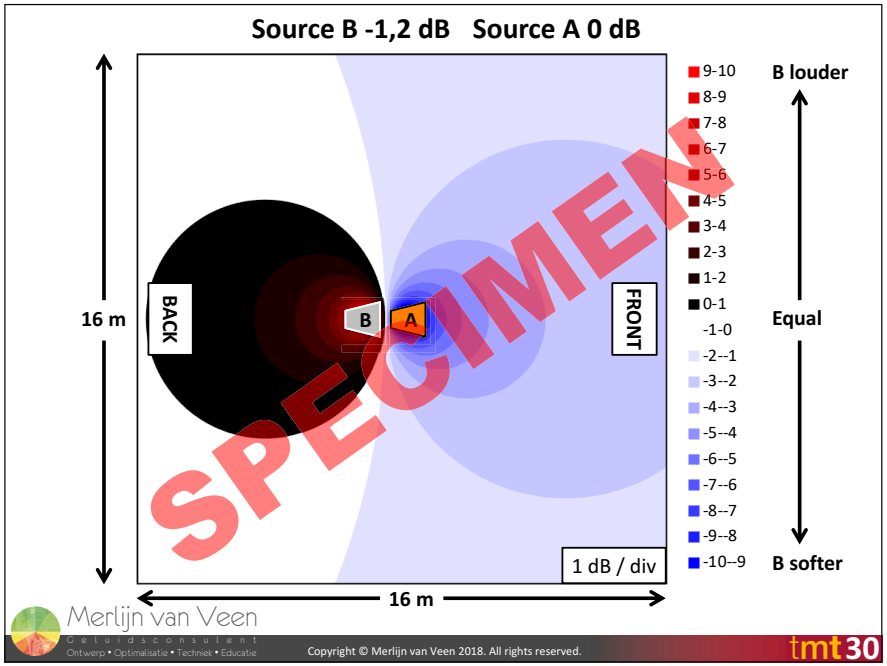
Source B -1,2 dB Source A 0 dB
16 m
BACK
B
A
FRONT
9-10
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3-4
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0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
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B softer
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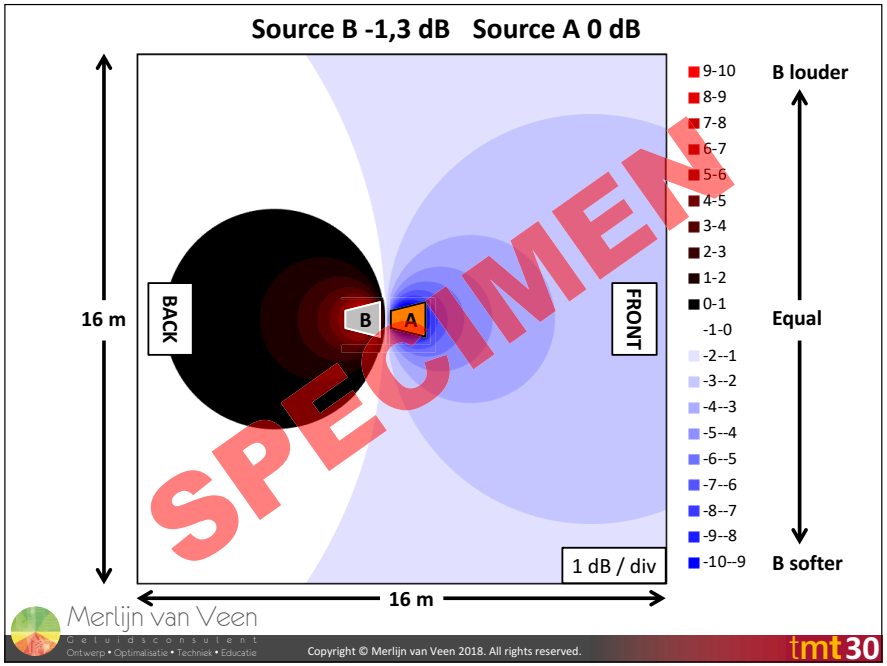
Source B -1,3 dB Source A 0 dB
16 m
BACK
B
A
FRONT
9-10
8-9
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6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
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Equal
B softer
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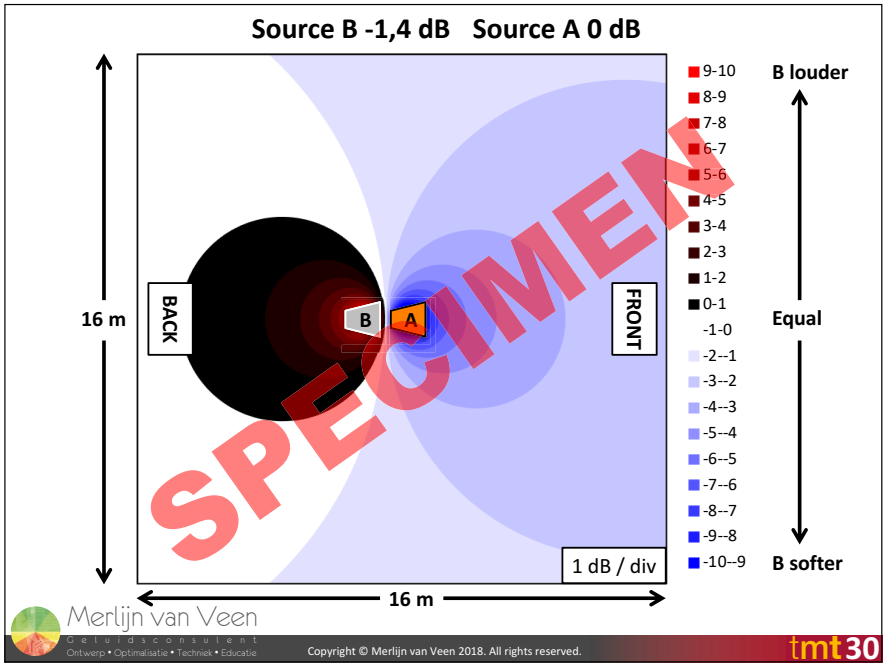
Source B -1,4 dB Source A 0 dB
16 m
BACK
B
A
FRONT
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
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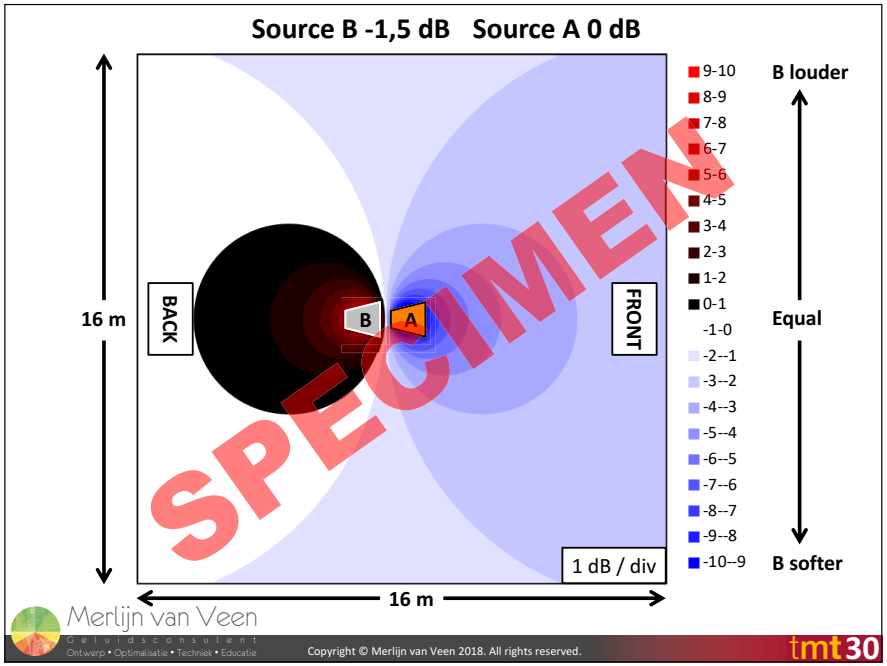
Source B -1,5 dB Source A 0 dB
16 m
BACK
B
A
FRONT
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
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Equal
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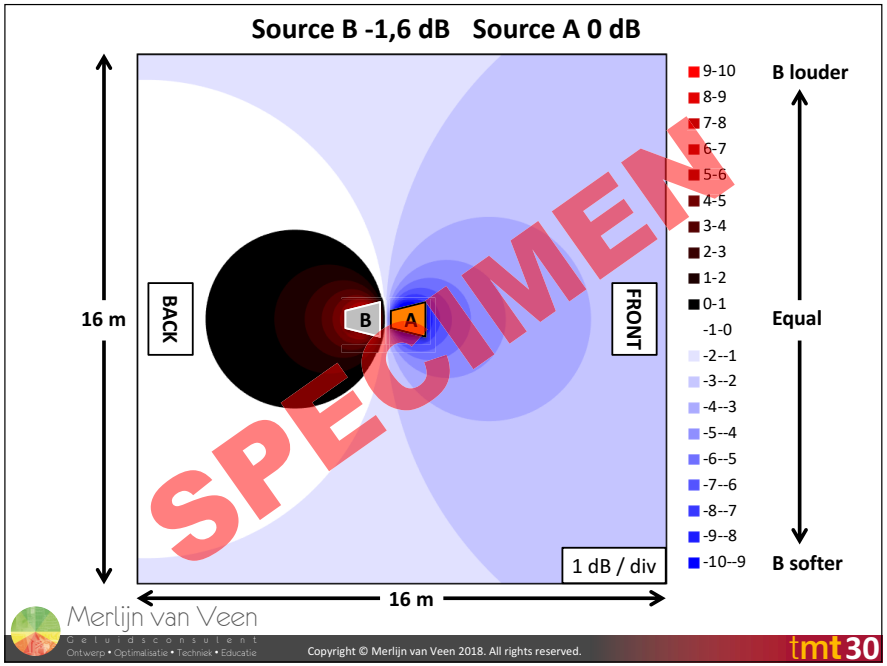
Source B -1,6 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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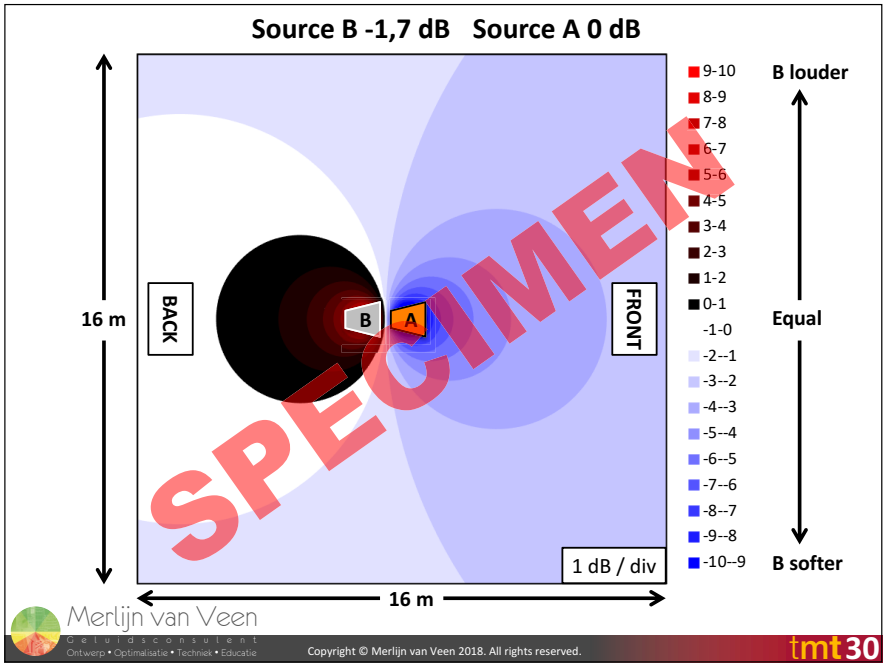
Source B -1,7 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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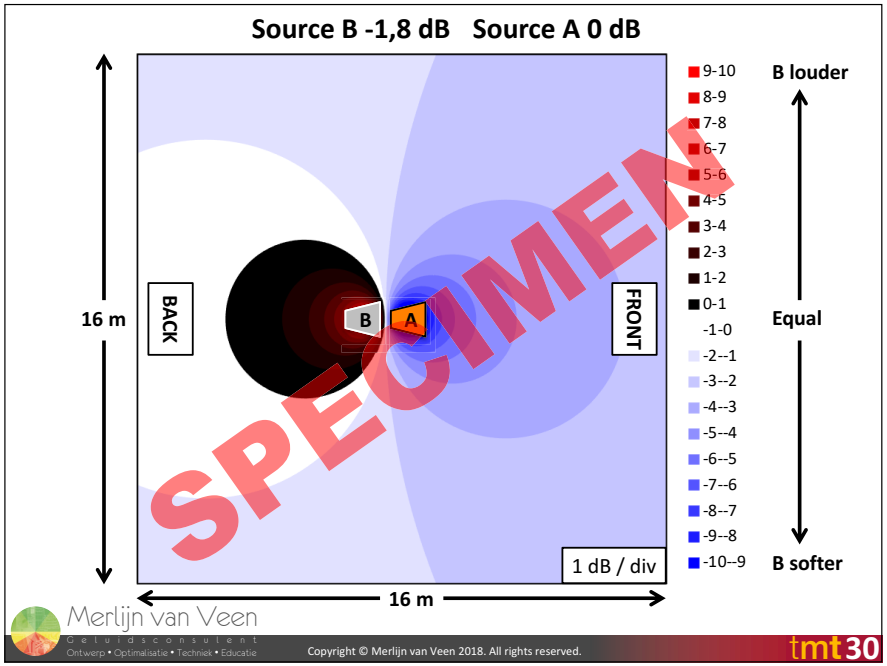
Source B -1,8 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
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6-7
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4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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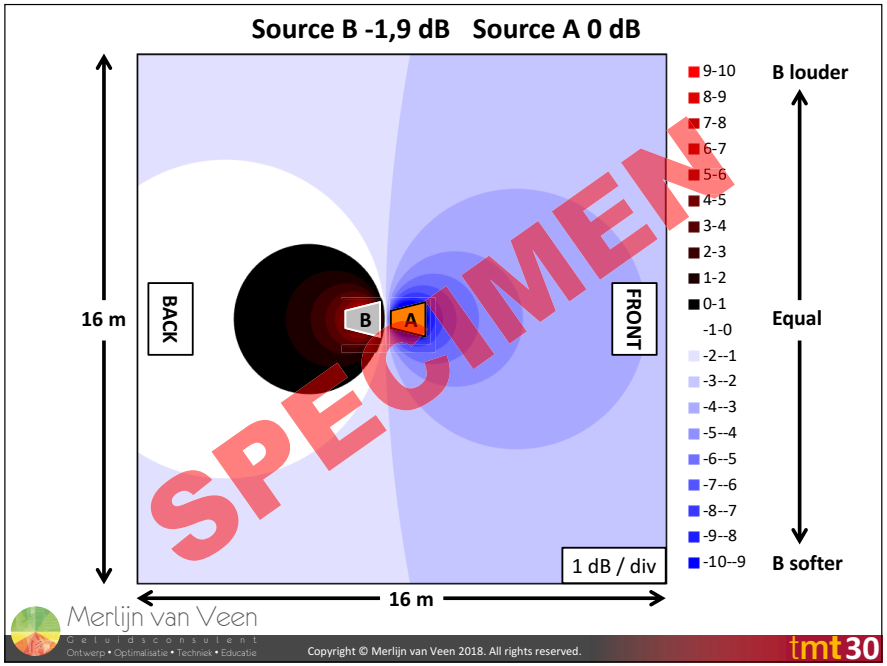
Source B -1,9 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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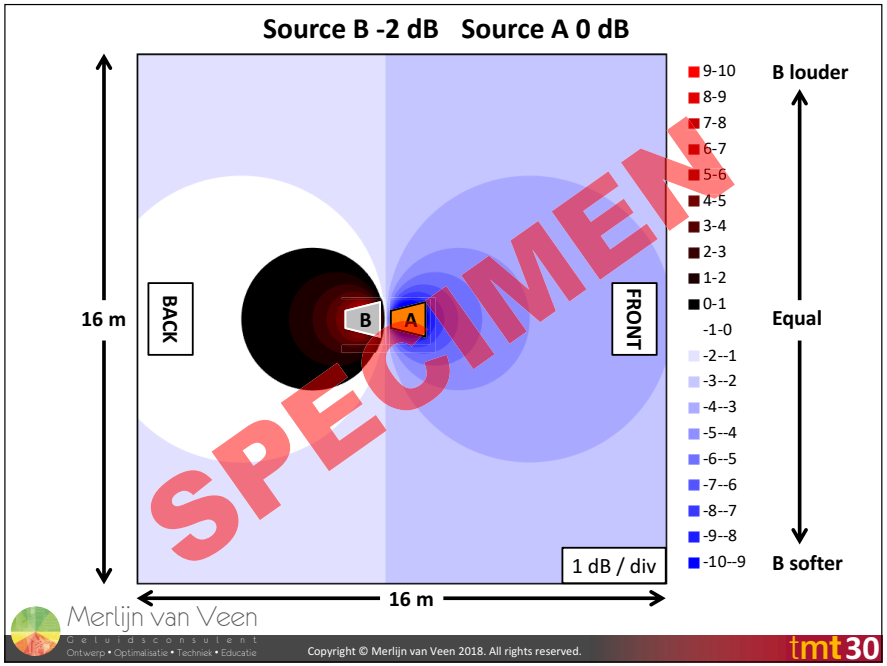
Source B -2 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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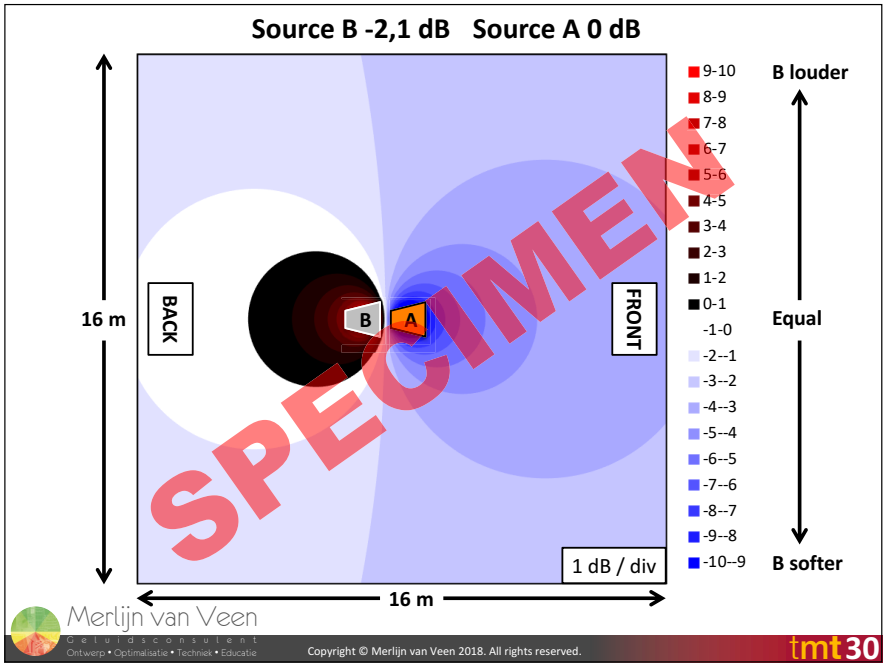
Source B -2,1 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
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6-7
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4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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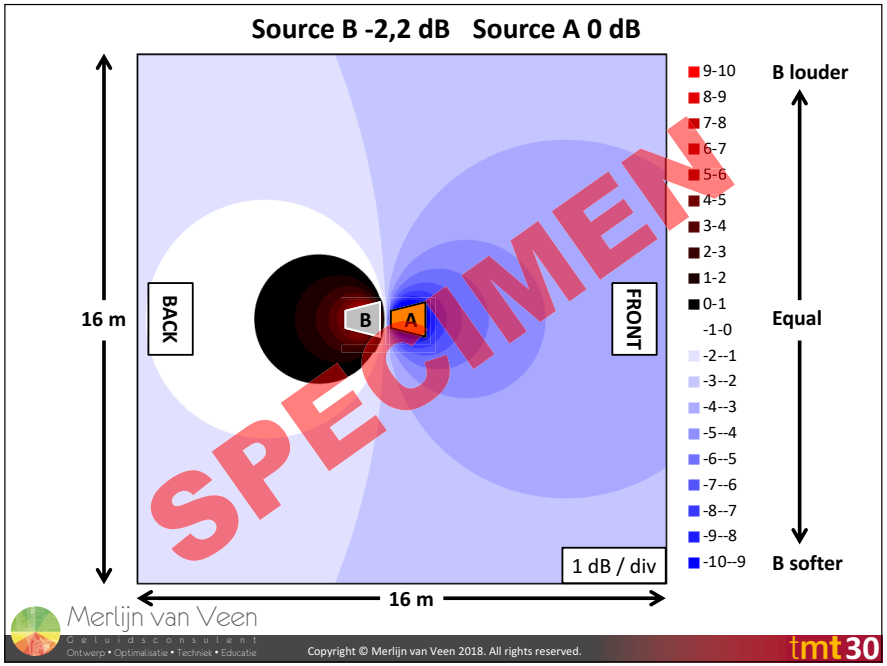
Source B -2,2 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
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4-5
3-4
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1-2
0-1
-1-0
-2--1
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-9--8
-10--9
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Equal
B softer
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16 m
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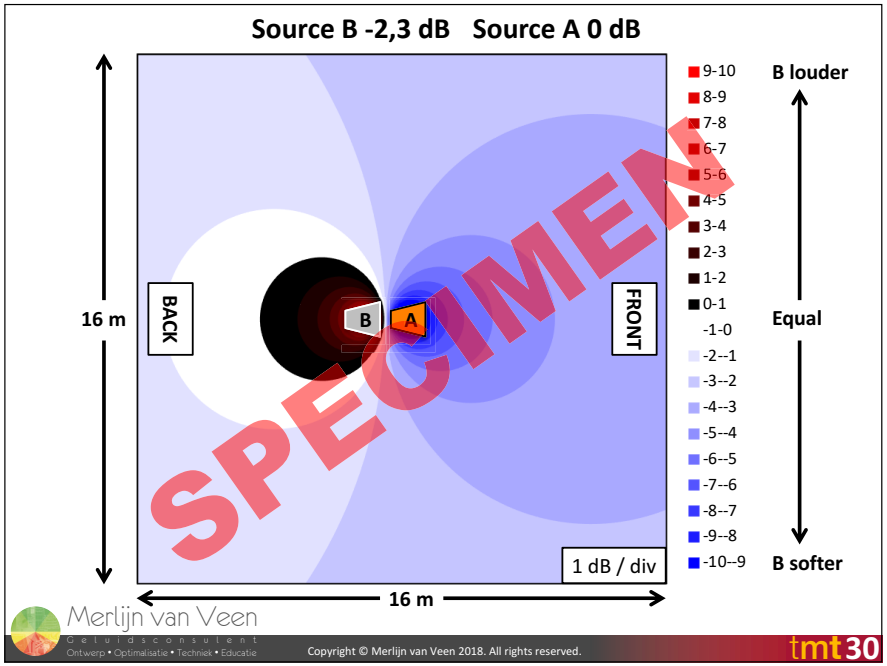
Source B -2,3 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
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6-7
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4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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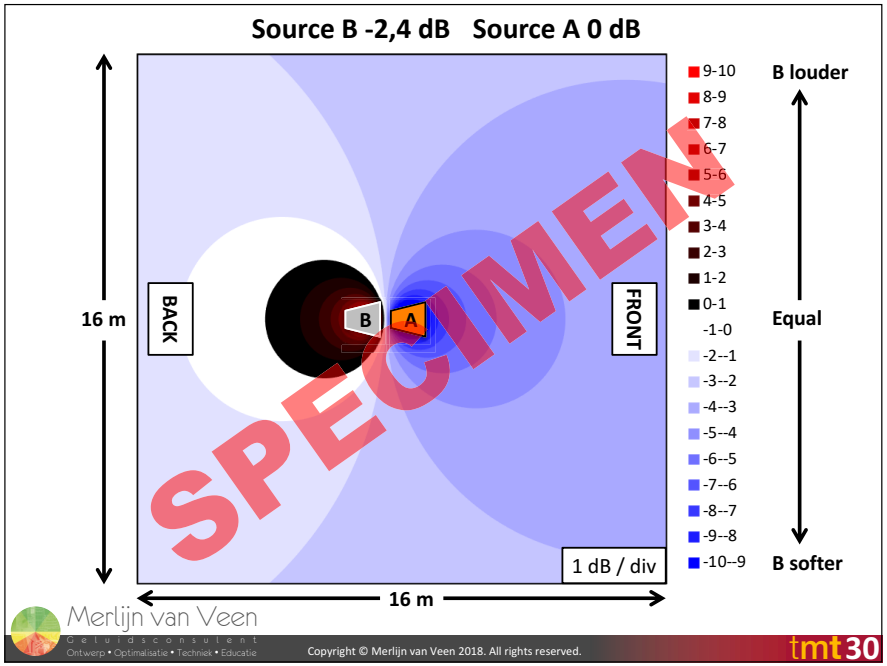
Source B -2,4 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
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5-6
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-1-0
-2--1
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-7--6
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-10--9
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Equal
B softer
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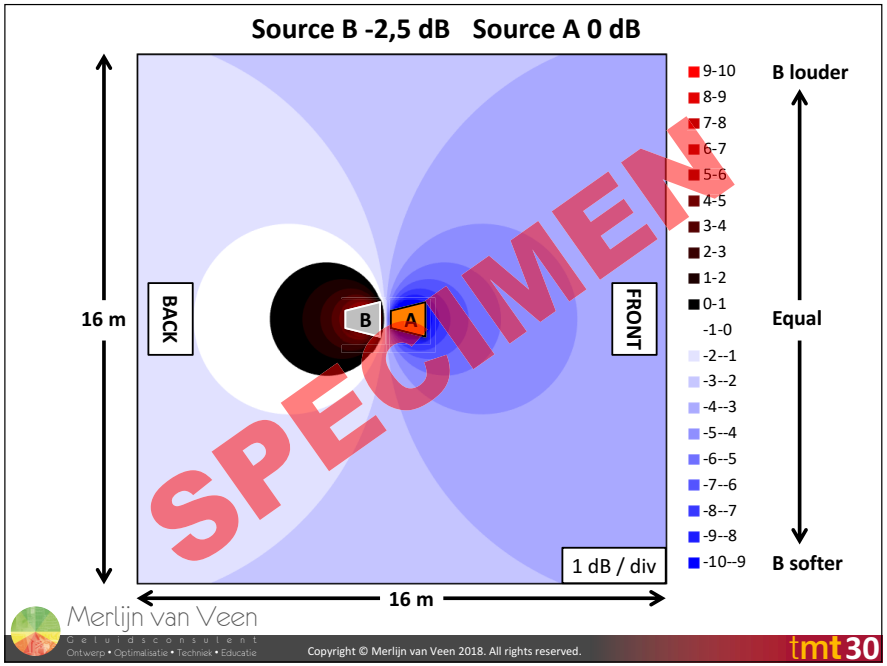
Source B -2,5 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
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-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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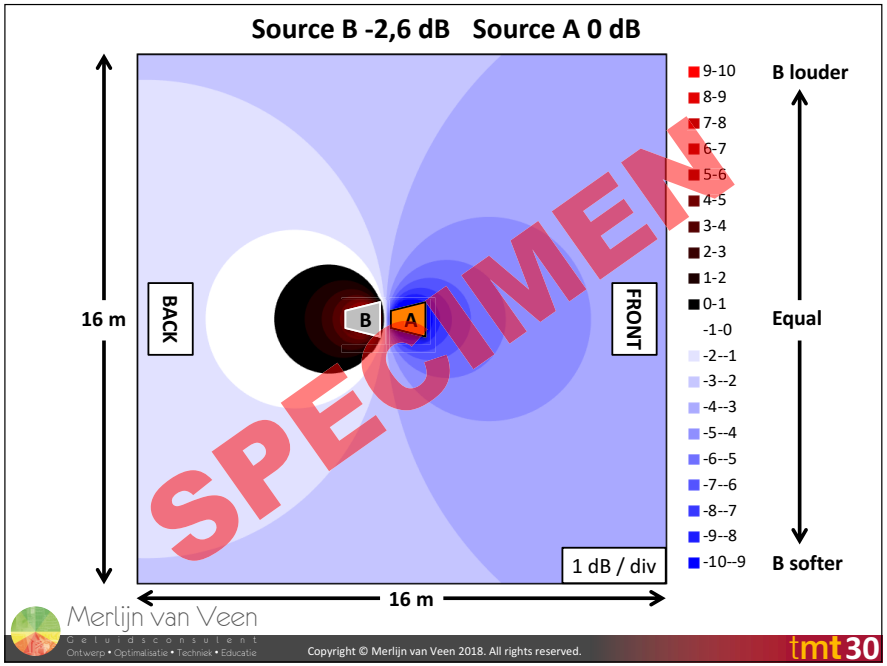
Source B -2,6 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
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-1-0
-2--1
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-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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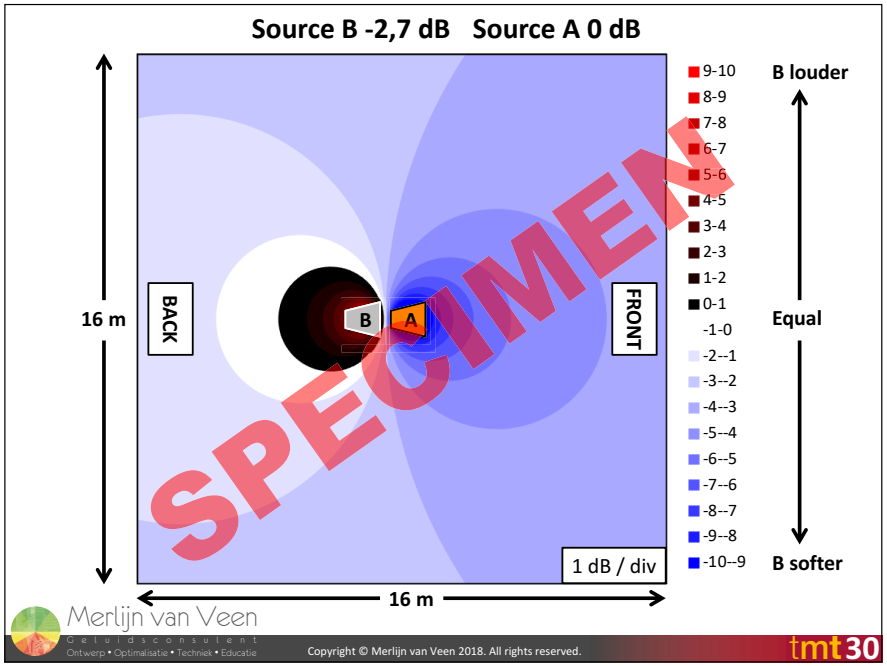
Source B -2,7 dB Source A 0 dB
16 m
BACK
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A
1 dB / div
16 m
9-10
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-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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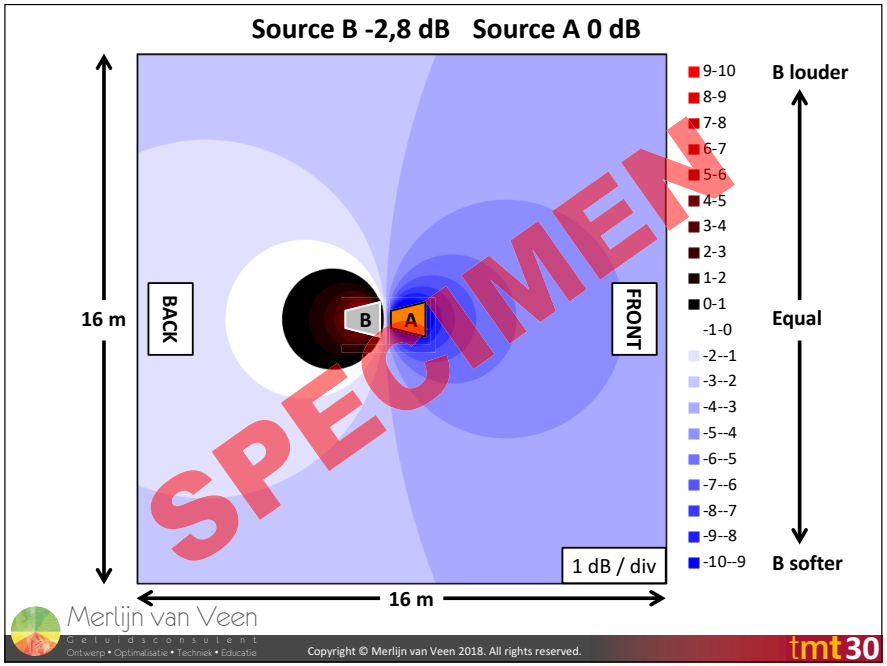
Source B -2,8 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
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-1-0
-2--1
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-5--4
-6--5
-7--6
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-9--8
-10--9
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Equal
B softer
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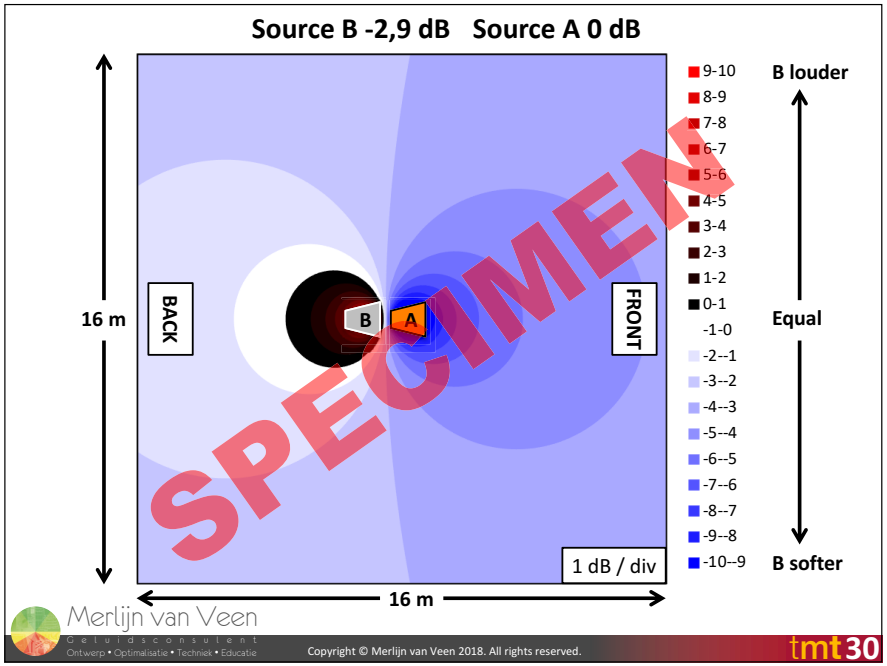
Source B -2,9 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
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-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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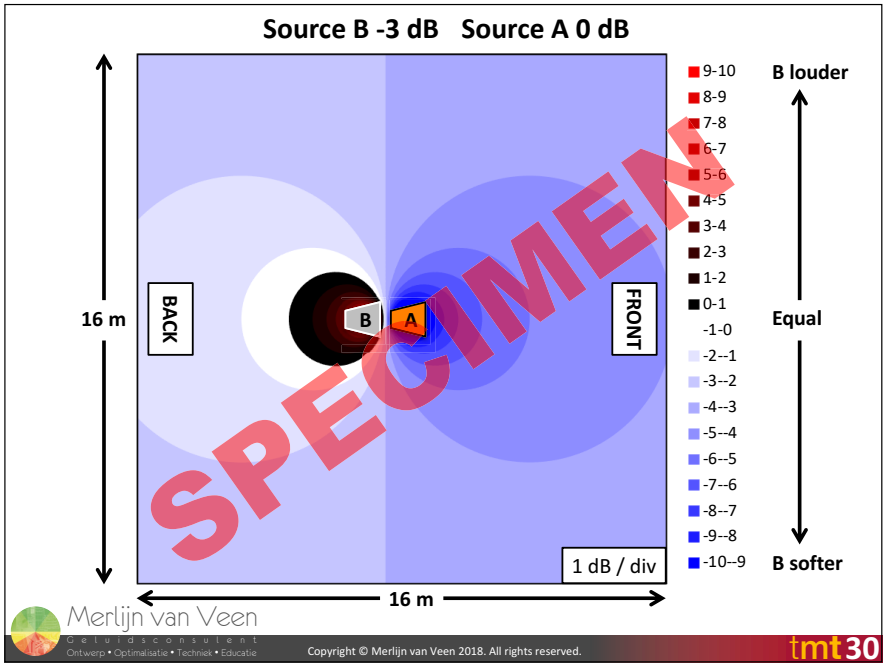
Source B -3 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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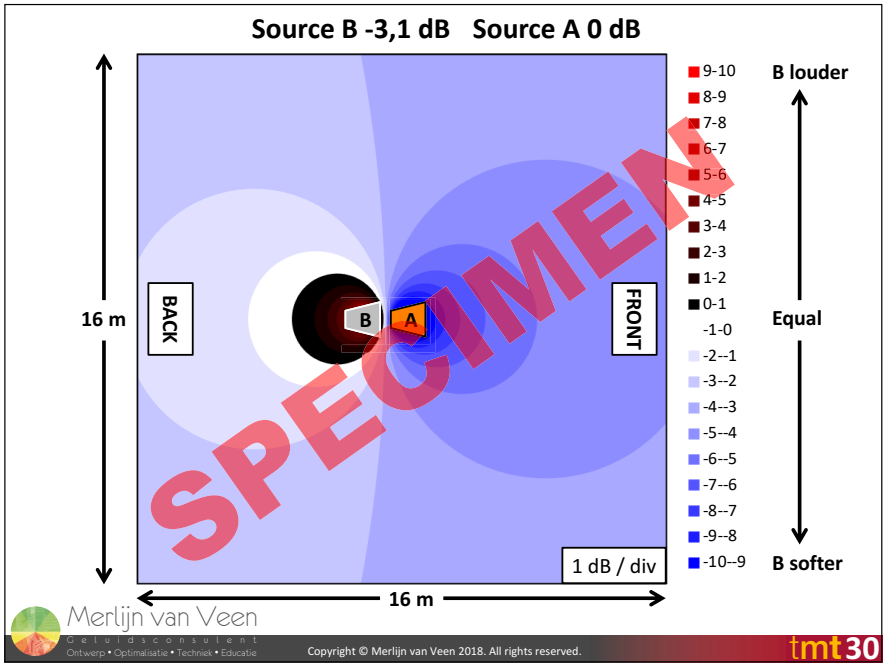
Source B -3,1 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
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4-5
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0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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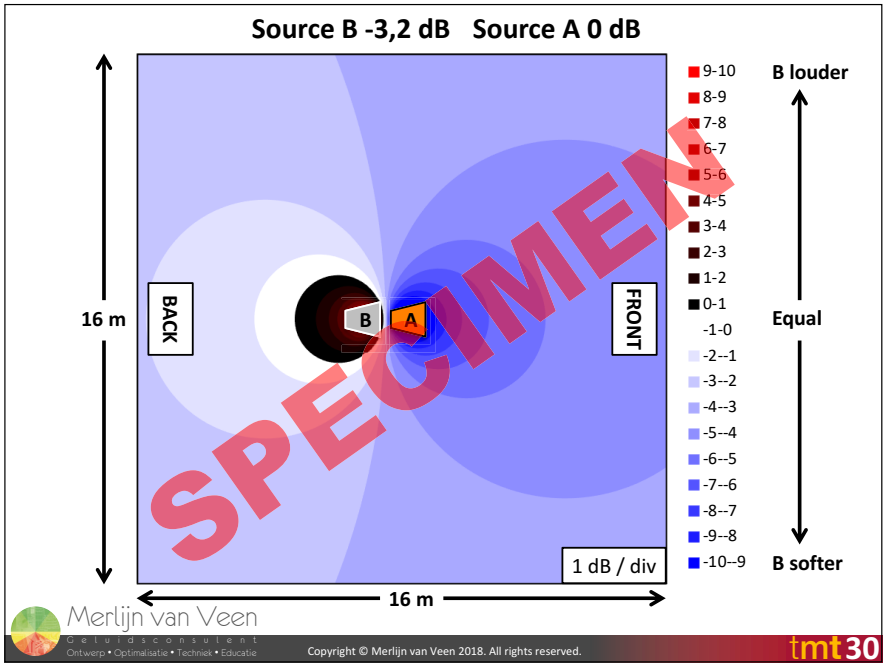
Source B -3,2 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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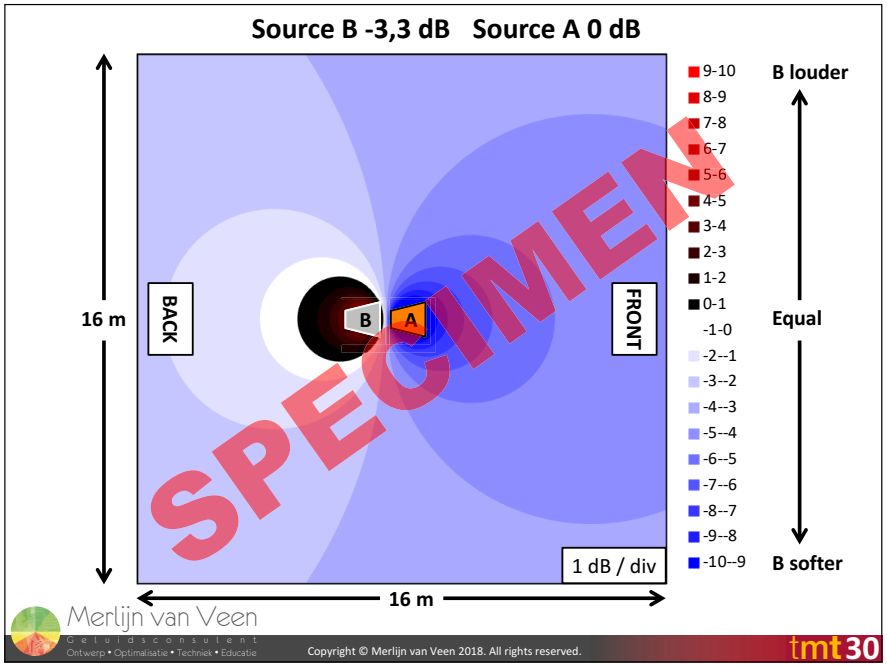
Source B -3,3 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
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1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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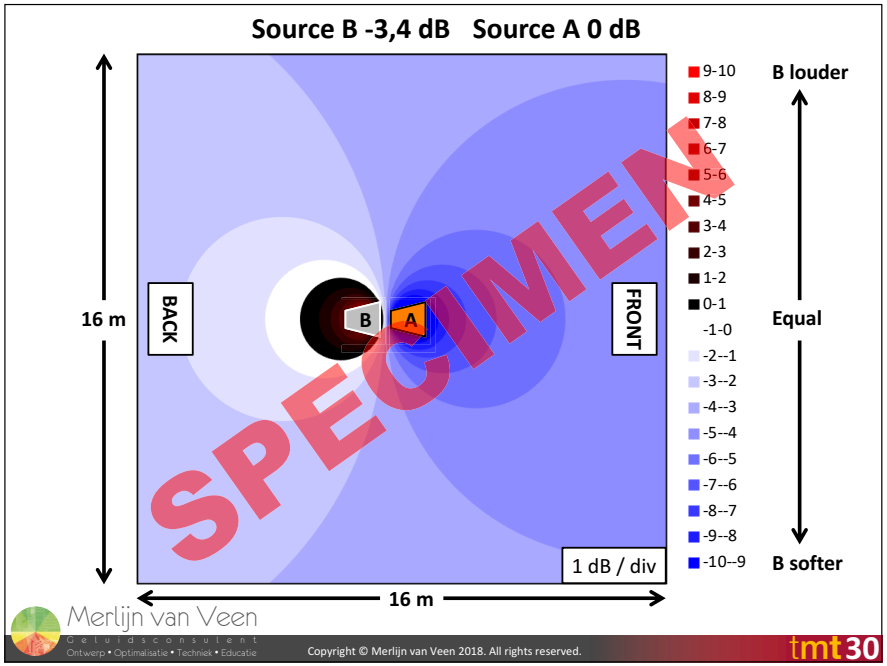
Source B -3,4 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
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5-6
4-5
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-4--3
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-6--5
-7--6
-8--7
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-10--9
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Equal
B softer
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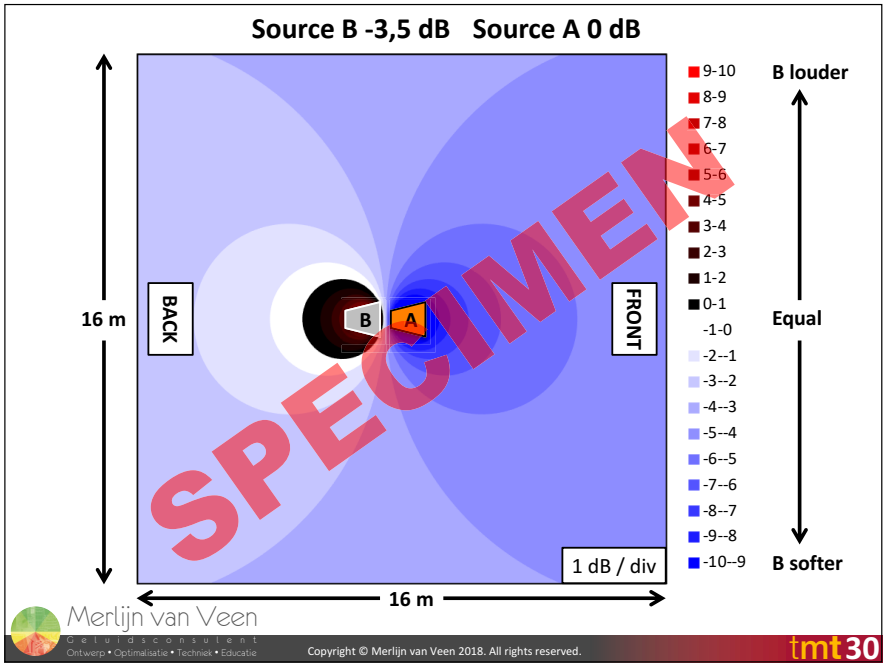
Source B -3,5 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
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4-5
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-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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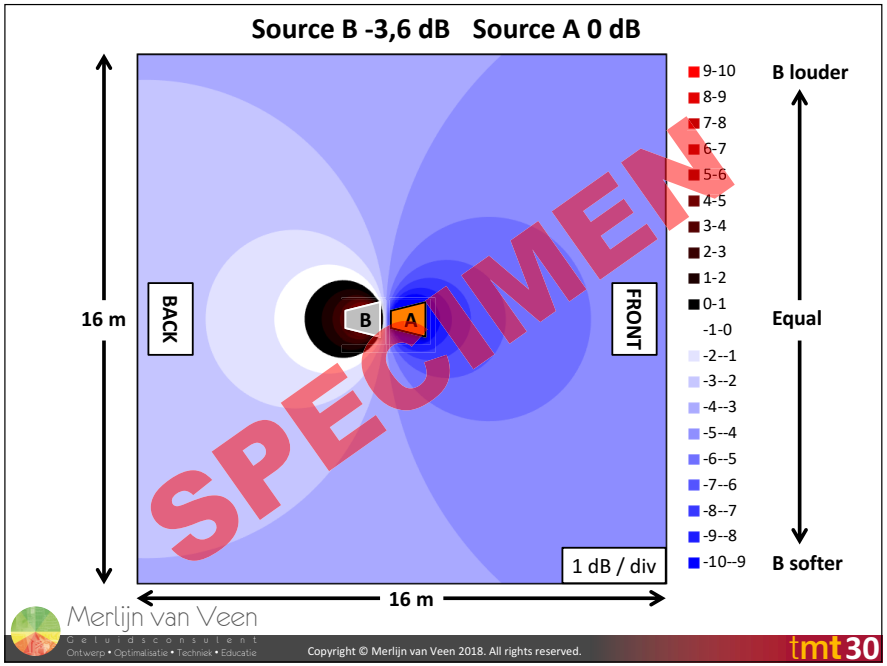
Source B -3,6 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
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-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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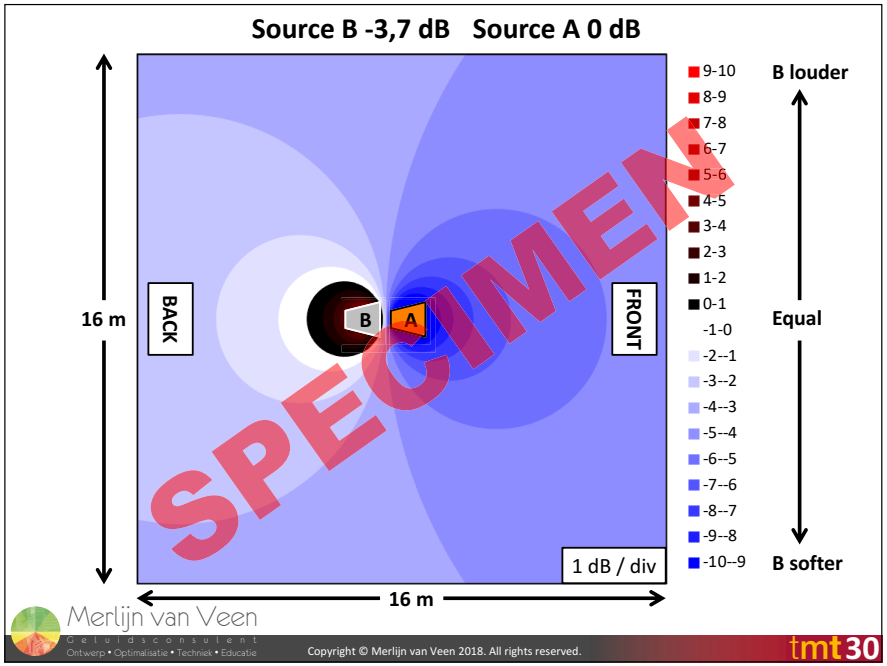
Source B -3,7 dB Source A 0 dB
16 m
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A
1 dB / div
16 m
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-7--6
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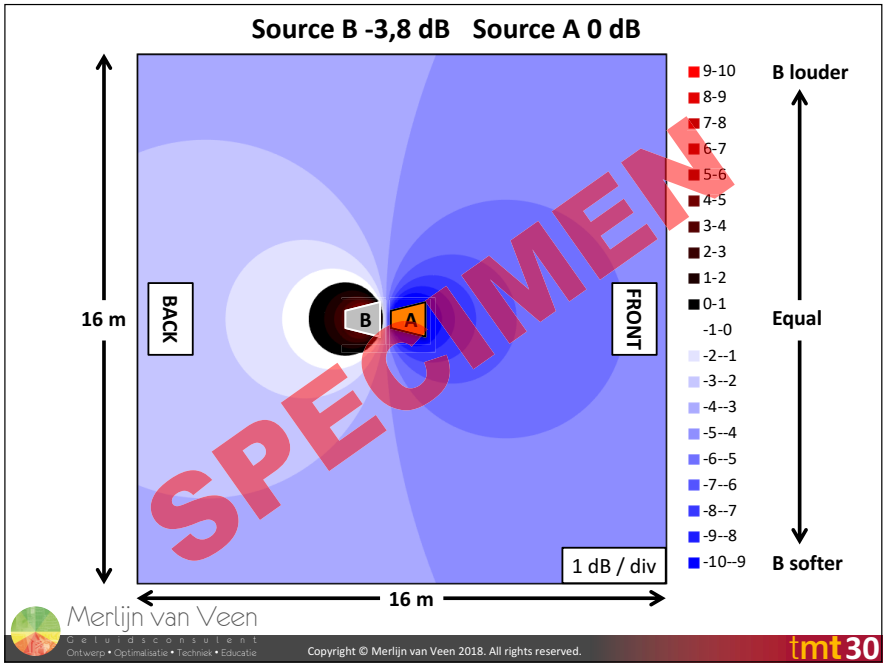
Source B -3,8 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
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-6--5
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-8--7
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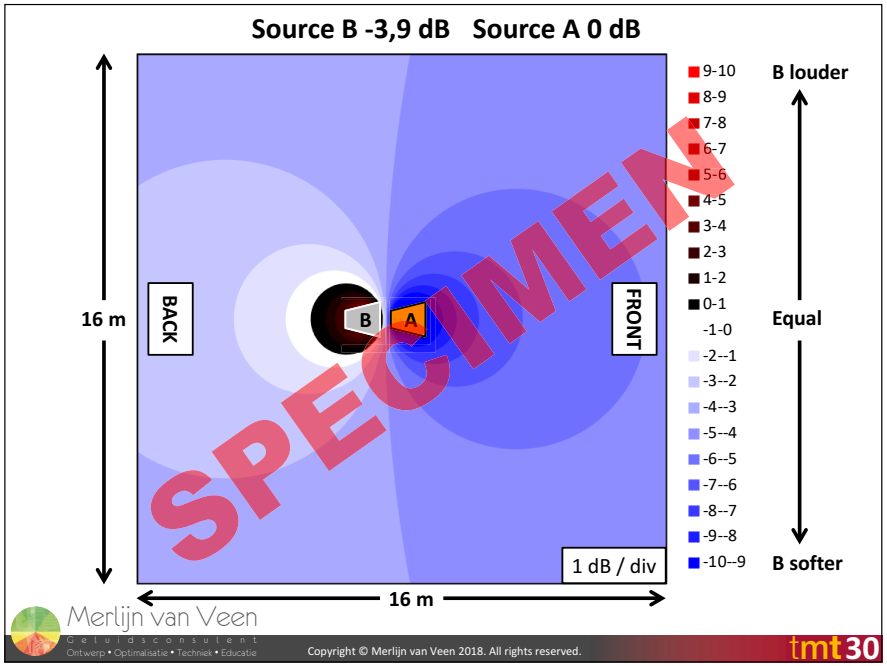
Source B -3,9 dB Source A 0 dB
16 m
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1 dB / div
16 m
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-7--6
-8--7
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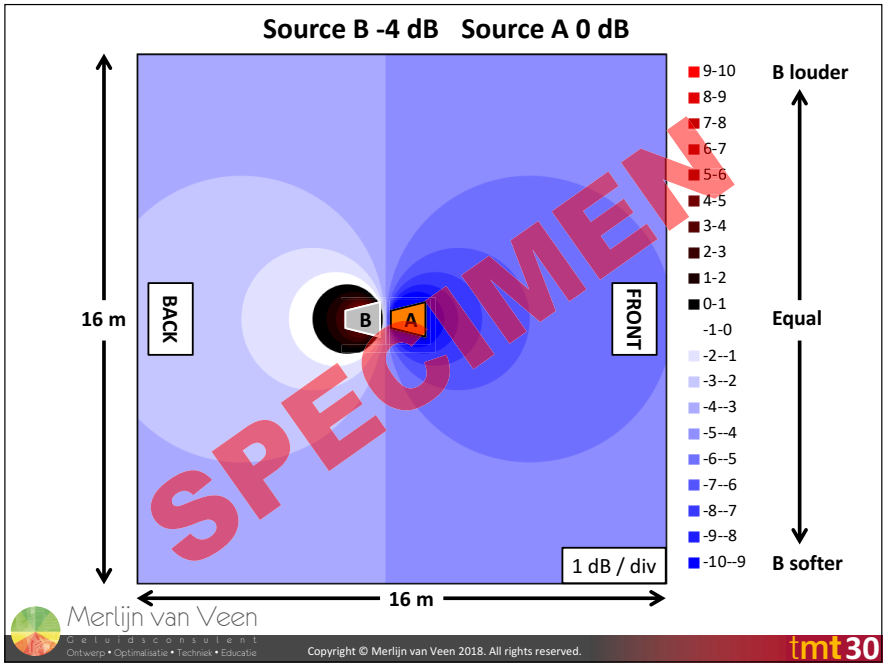
Source B -4 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
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4-5
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0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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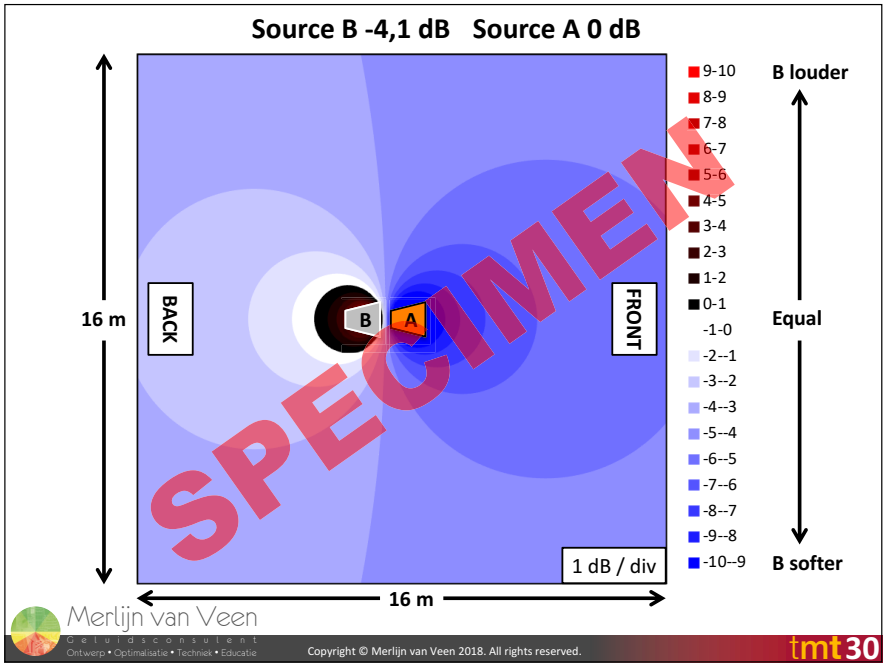
Source B -4,1 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
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-7--6
-8--7
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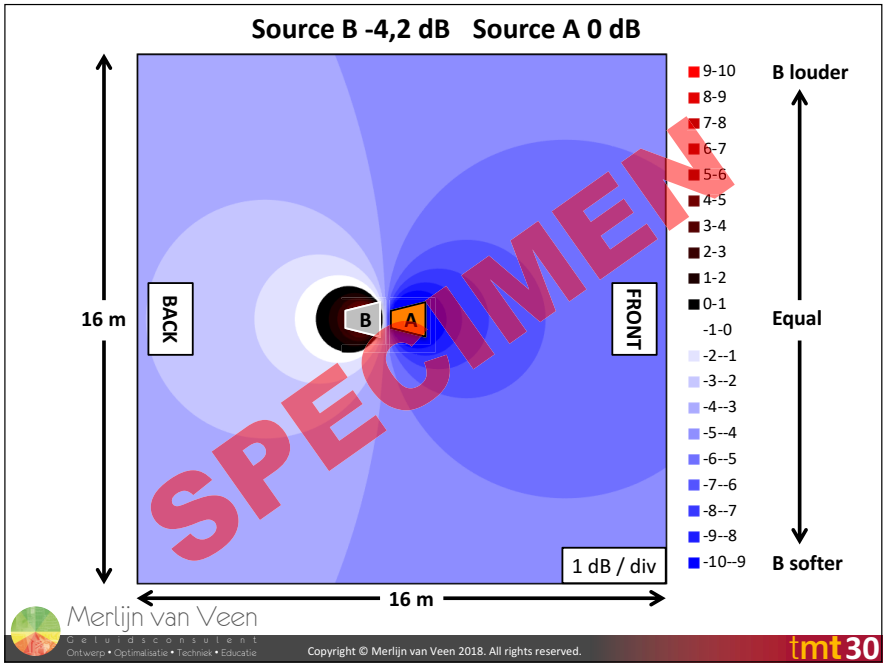
Source B -4,2 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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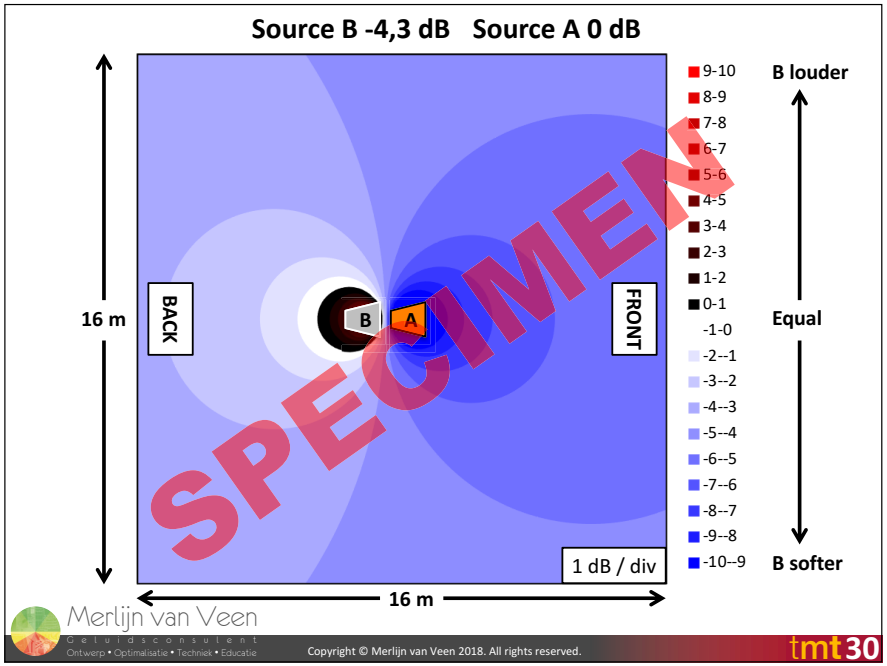
Source B -4,3 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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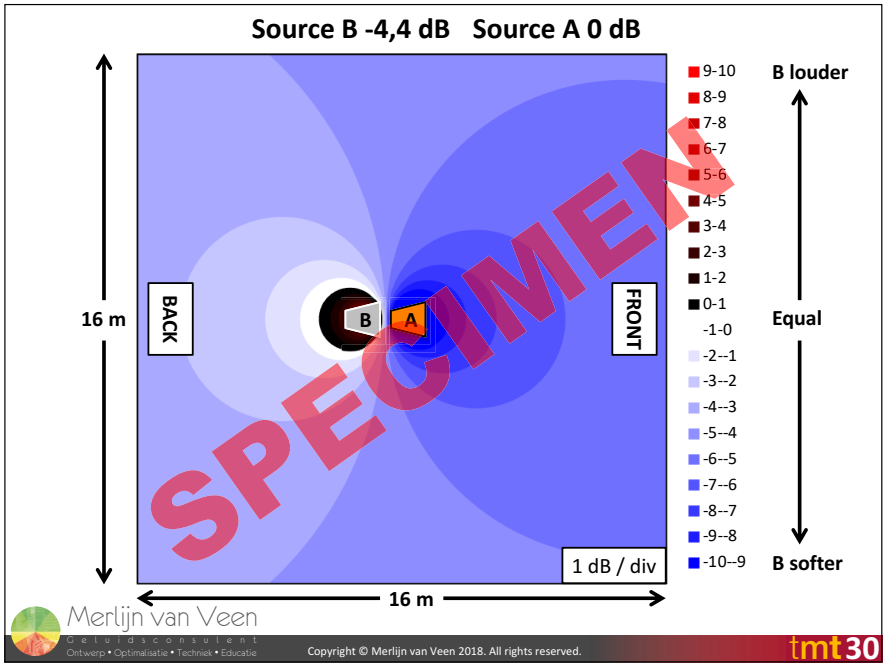
Source B -4,4 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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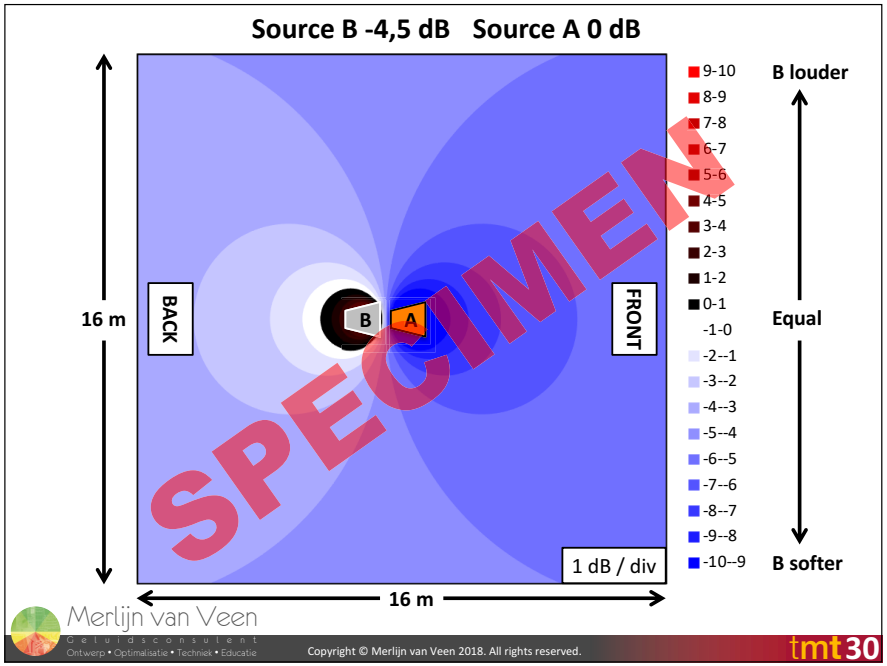
Source B -4,5 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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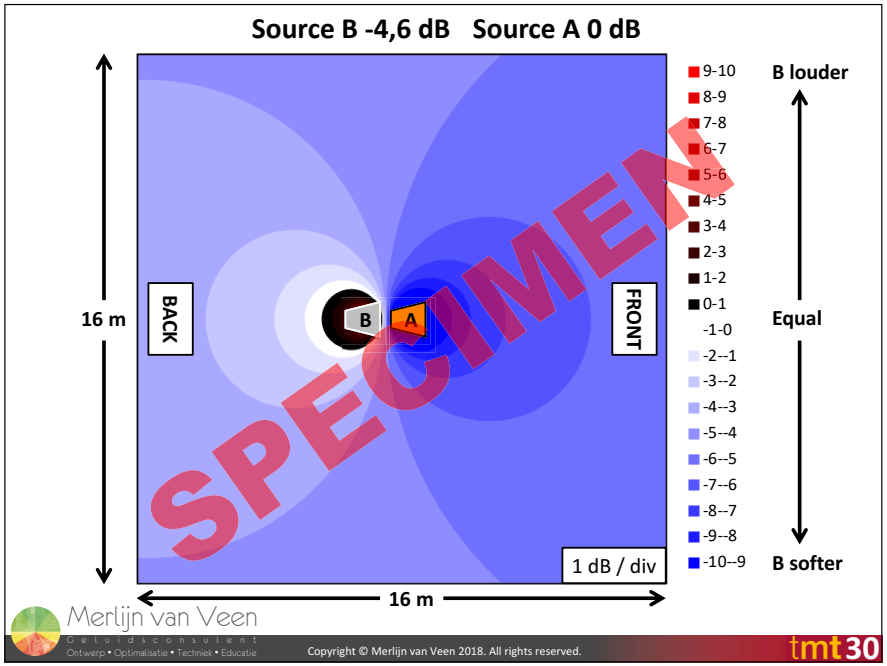
Source B -4,6 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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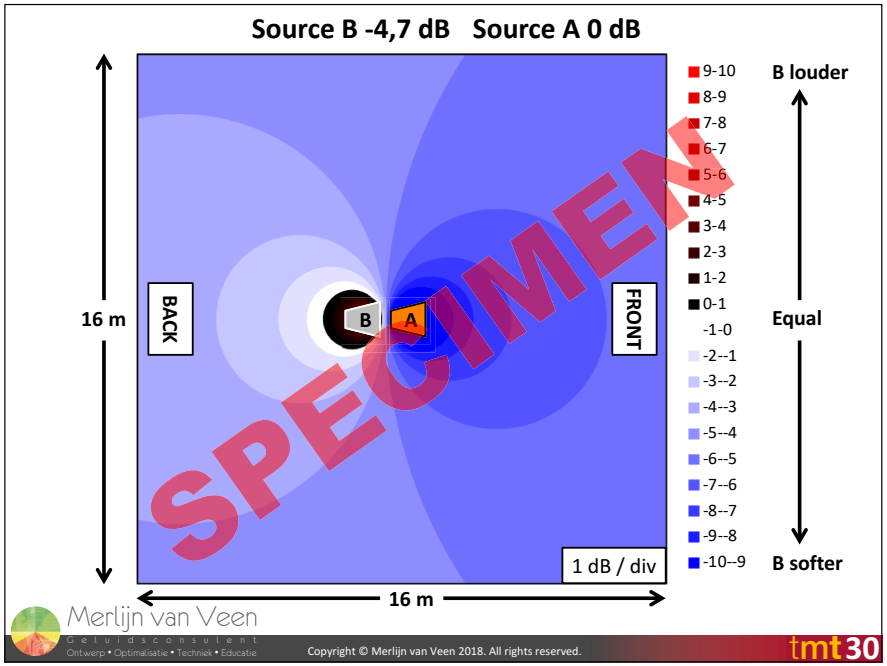
Source B -4,7 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
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B louder
Equal
B softer
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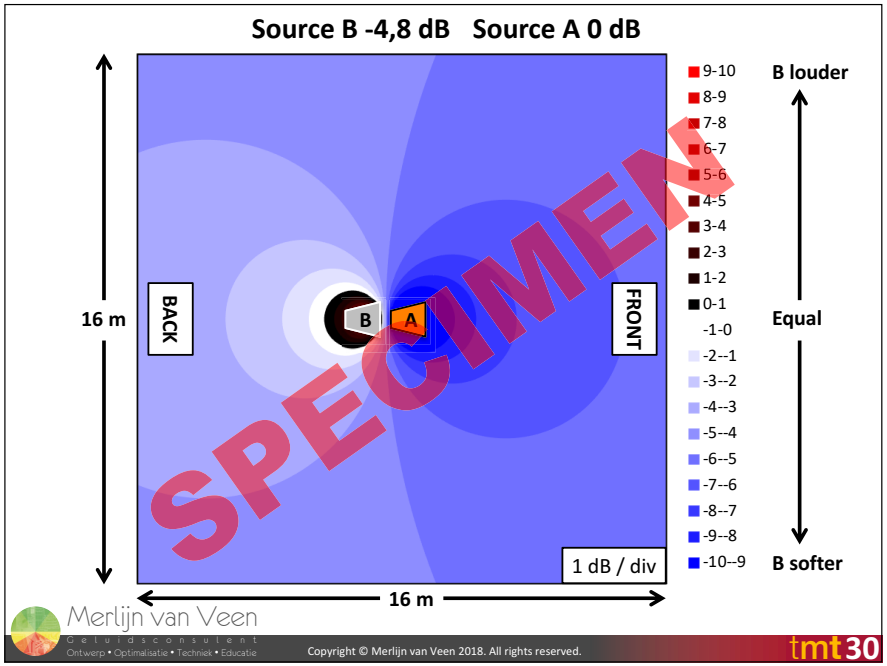
Source B -4,8 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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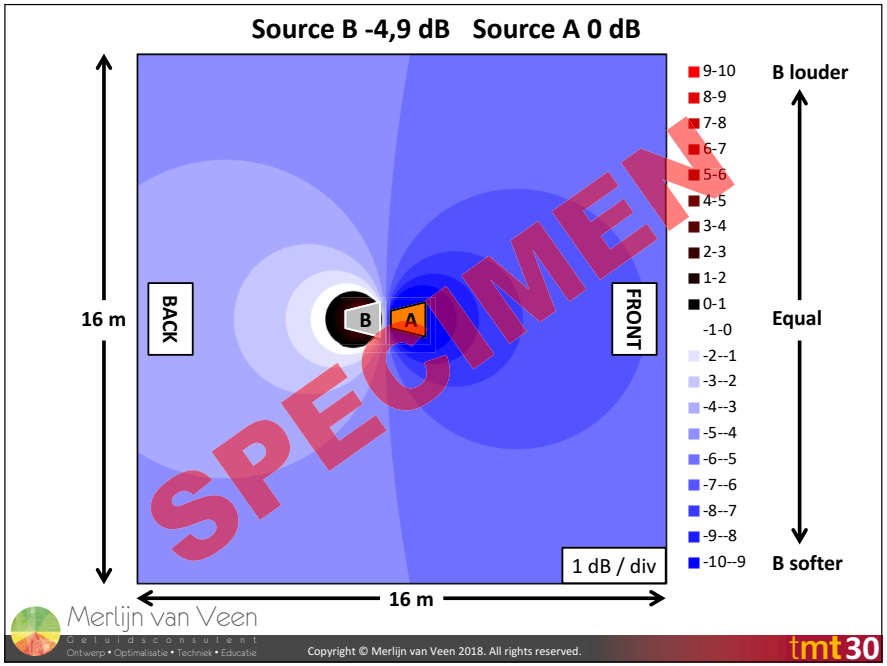
Source B -4,9 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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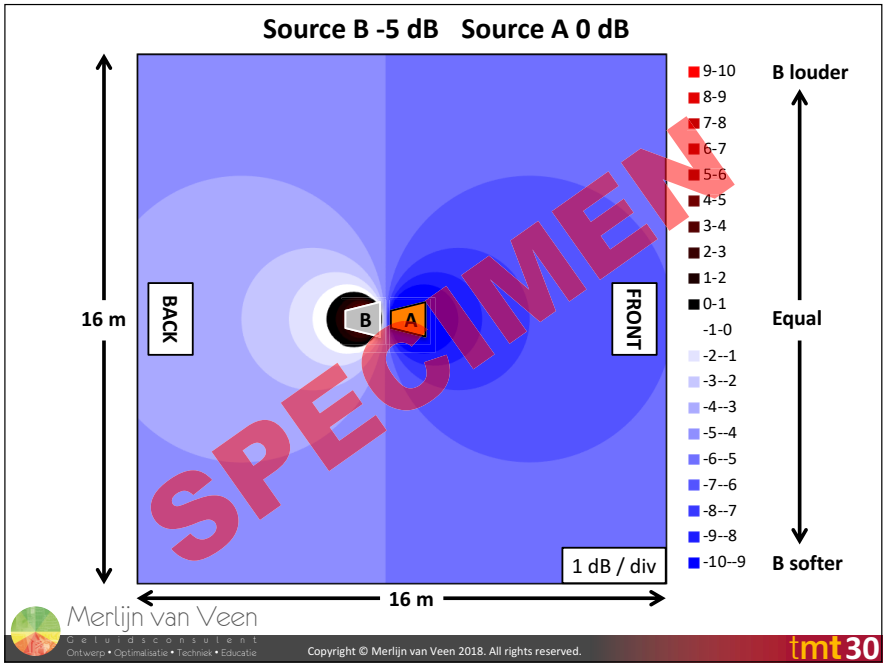
Source B -5 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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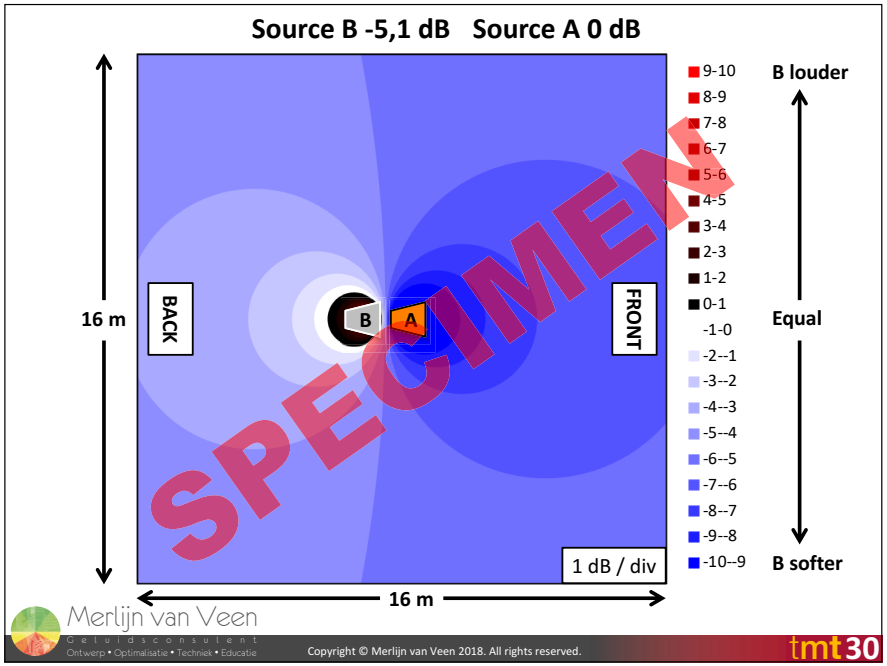
Source B -5,1 dB Source A 0 dB
16 m
BACK
FRONT
B
A
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
1 dB / div
16 m
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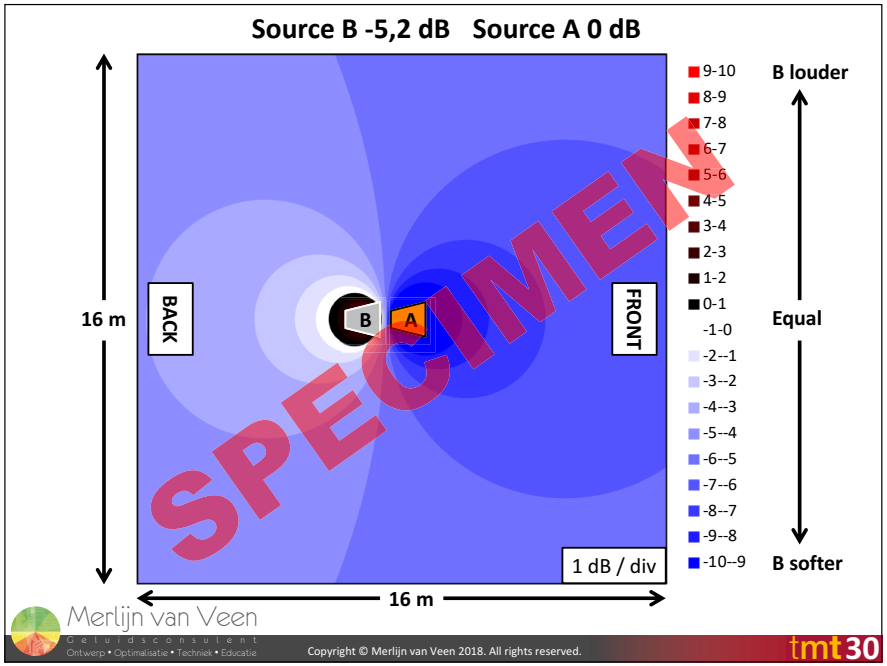
Source B -5,2 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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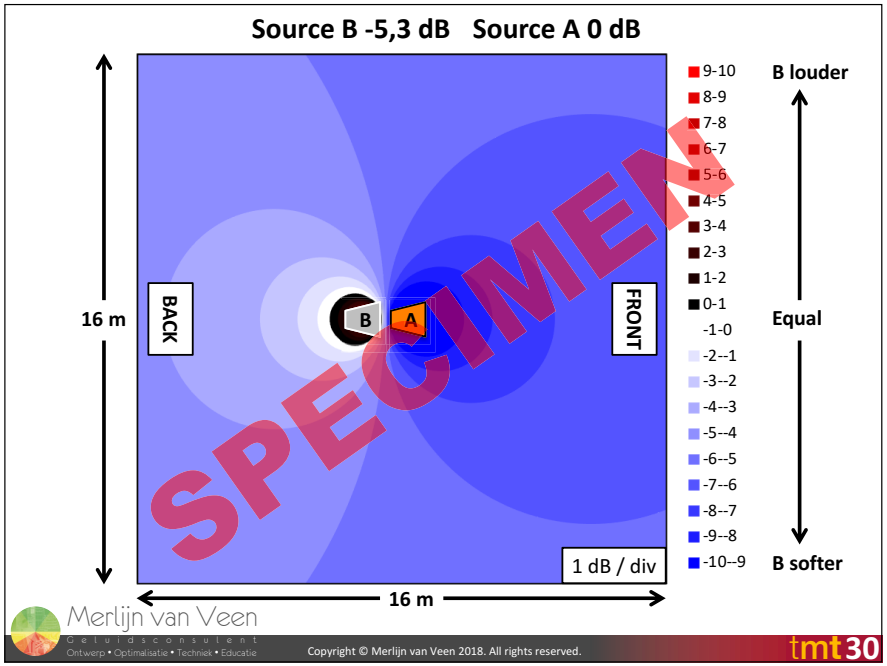
Source B -5,3 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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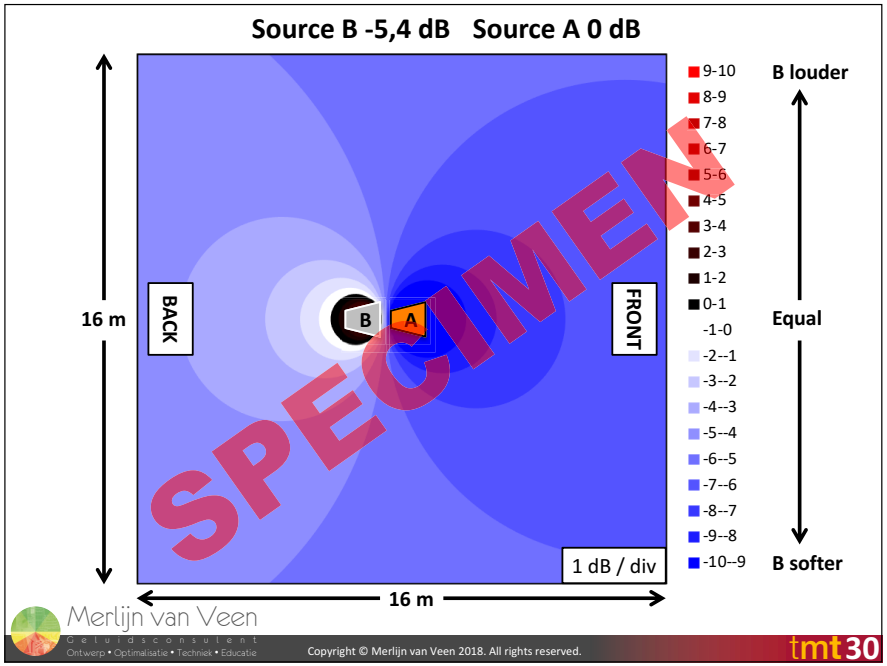
Source B -5,4 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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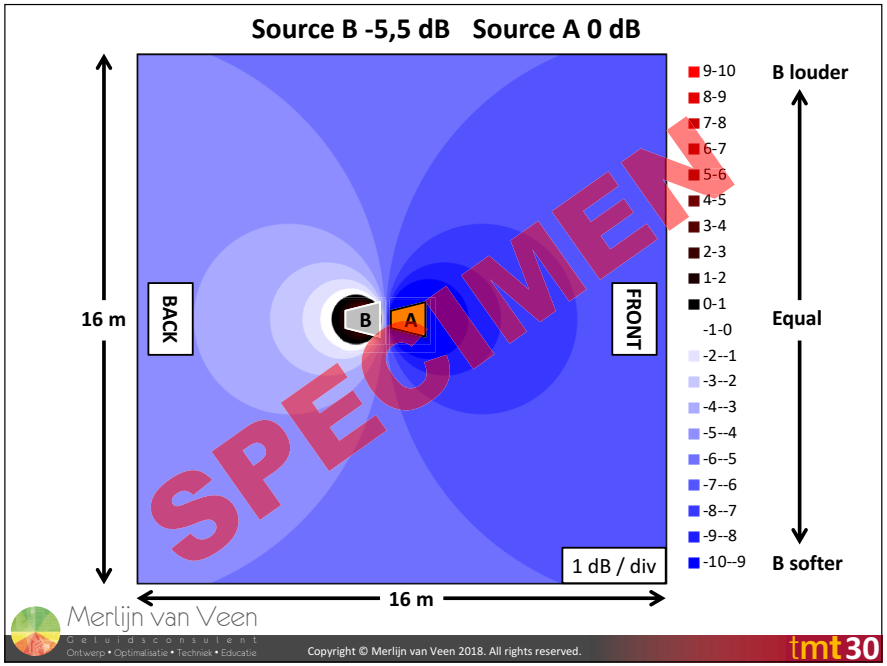
Source B -5,5 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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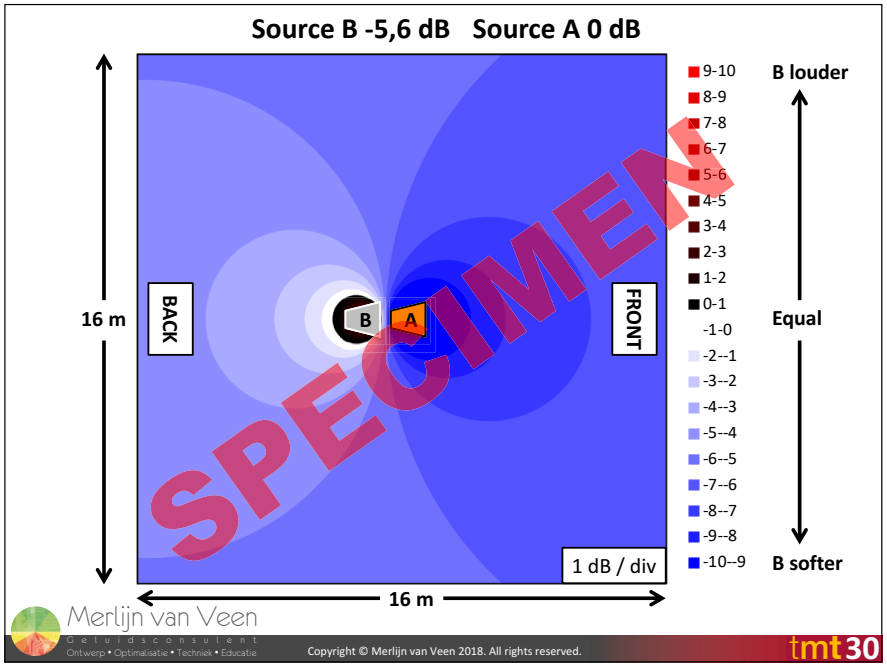
Source B -5,6 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
B louder
Equal
B softer
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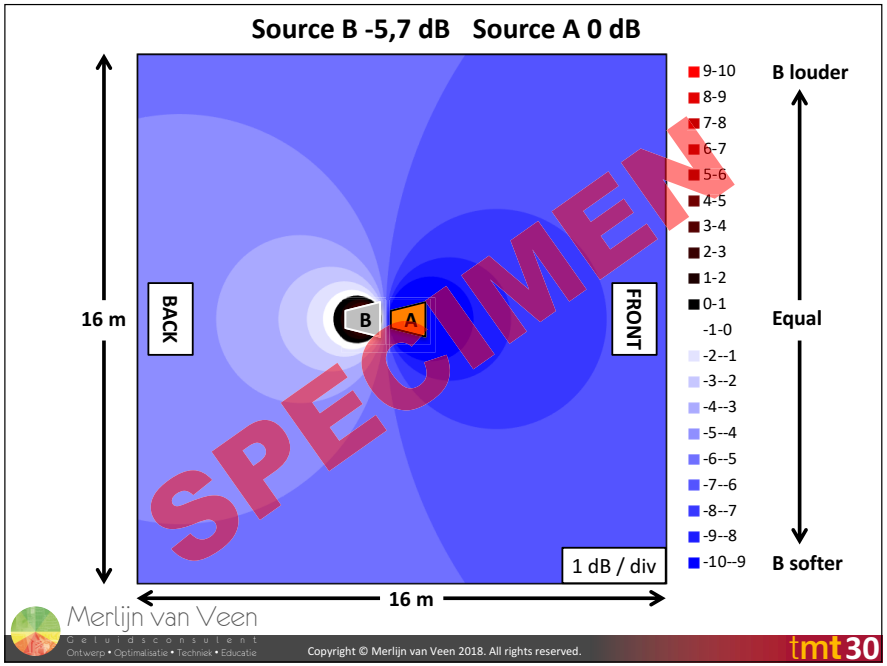
Source B -5,7 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
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Equal
B softer
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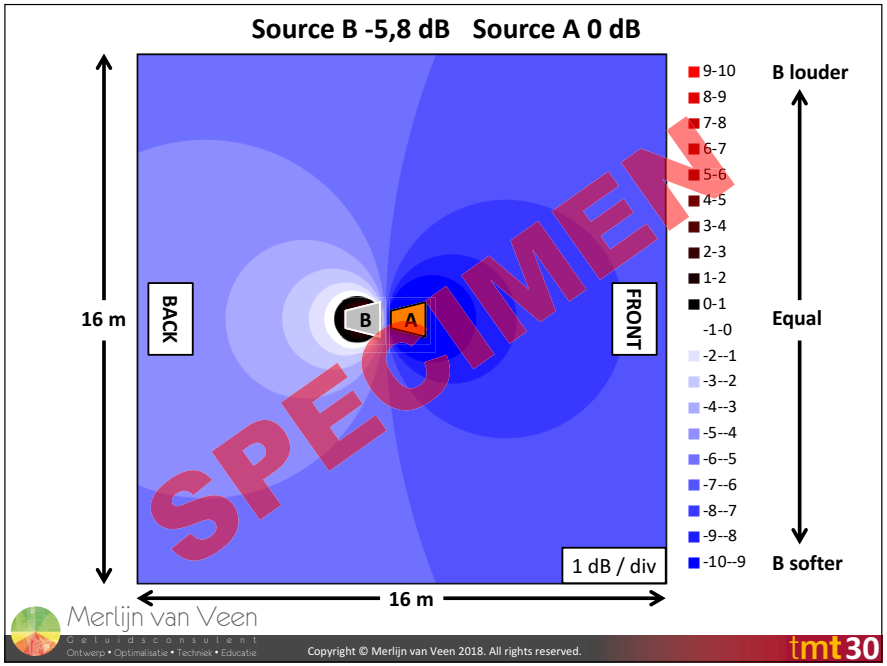
Source B -5,8 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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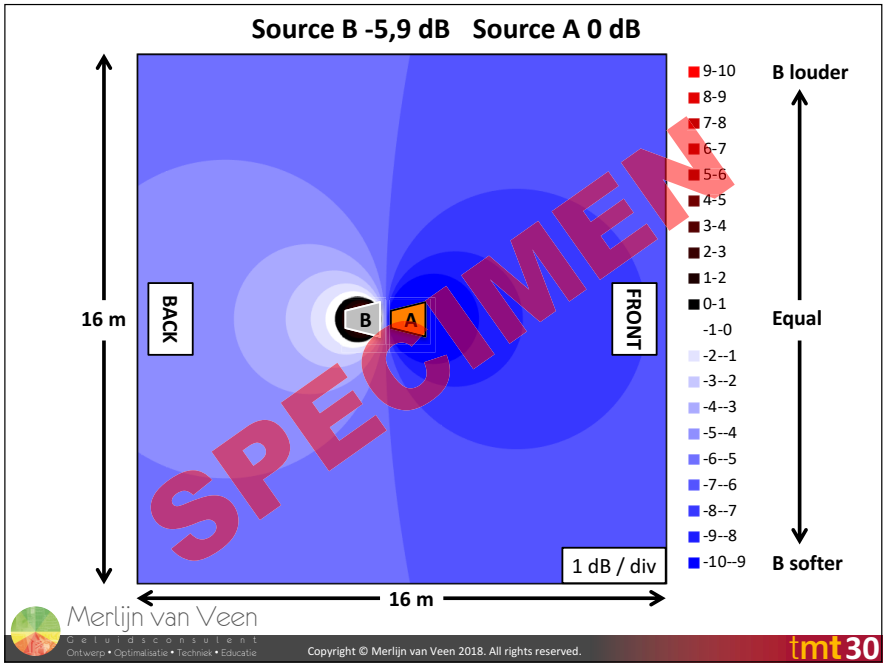
Source B -5,9 dB Source A 0 dB
16 m
BACK
FRONT
B
A
1 dB / div
16 m
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
-1-0
-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7
-9--8
-10--9
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Equal
B softer
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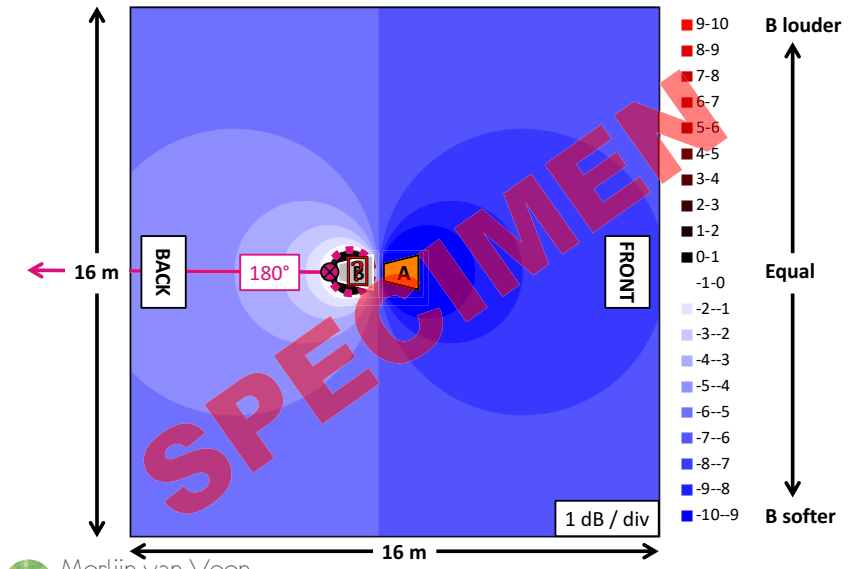
Source B -6 dB Source A 0 dB



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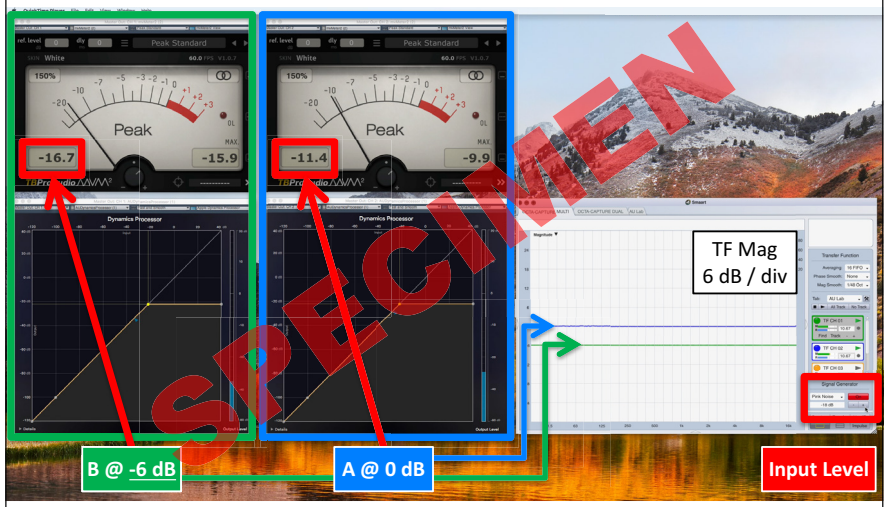
Pattern Implosion

(asynchronous compression due to level tampering)



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Video: Merlijn van Veen

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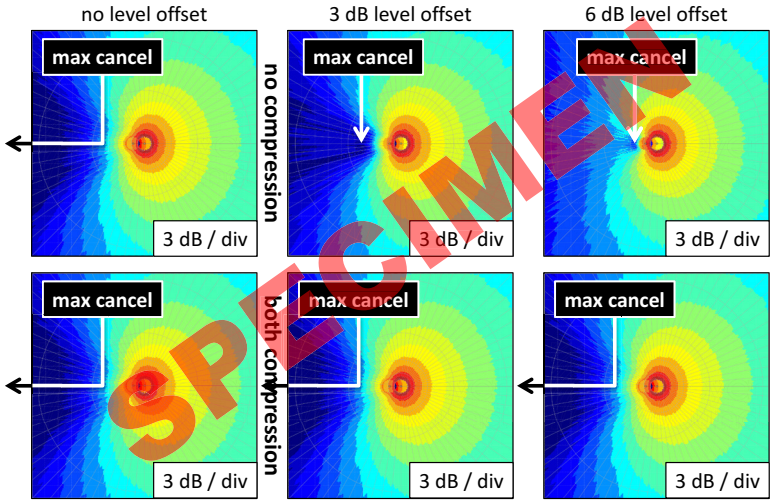
Pattern Implosion

(asynchronous compression due to level tampering)



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***Source:** Meyer Sound MAPP XT*

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Rules of the Game

- Factory Recommended Loudspeaker Presets*
- Only Delay
- Polarity Ø
- No additional processing

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** If applicable*

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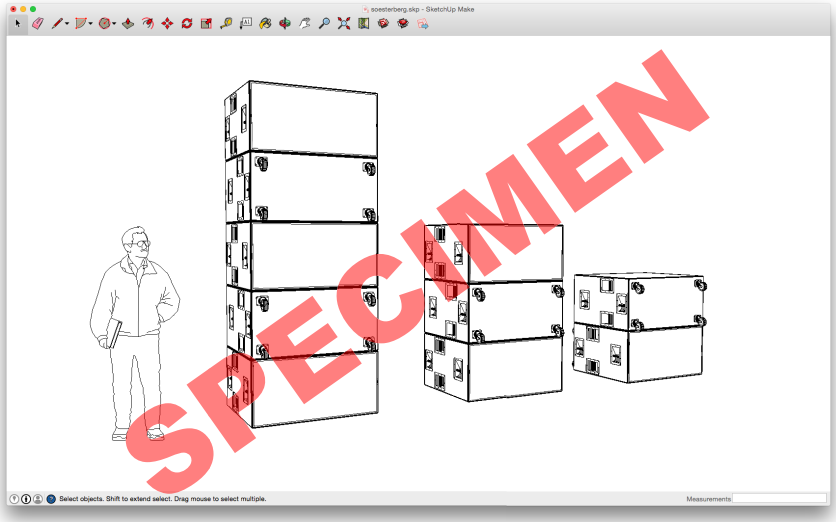
Inverted Stack Gradient - Ratio



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Source: *SketchUp 3D Warehouse, models by David M.*

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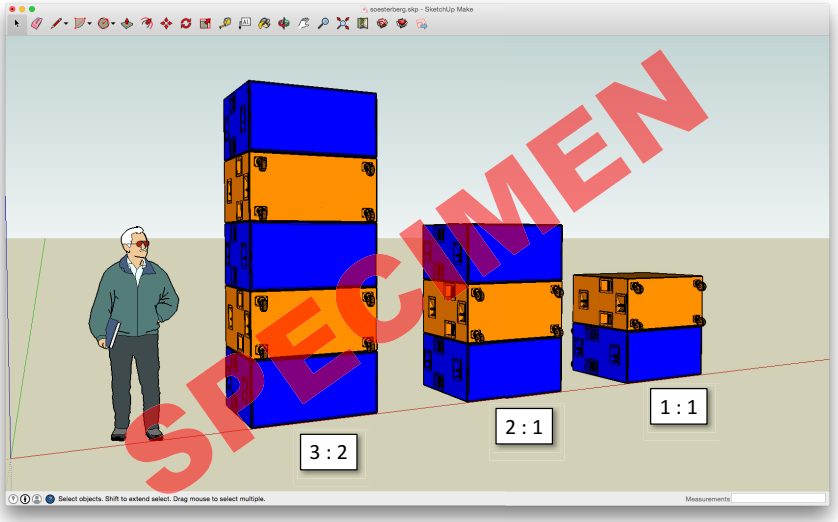
Inverted Stack Gradient - Ratio



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Source: *SketchUp 3D Warehouse, models by David M.*

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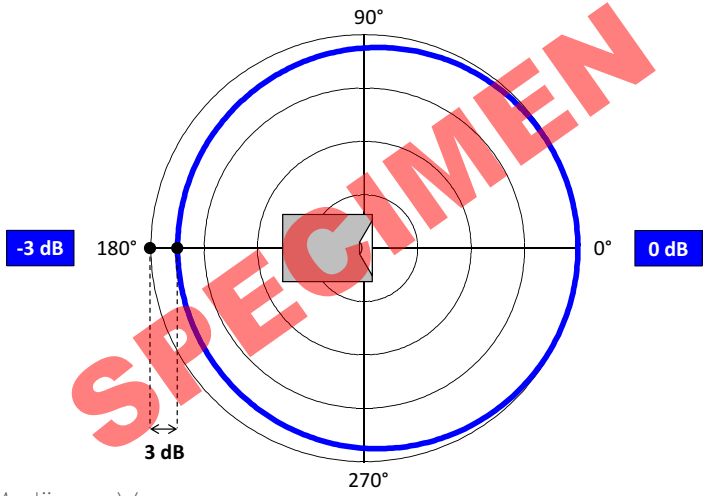
Polar Plot

(6 dB / div)



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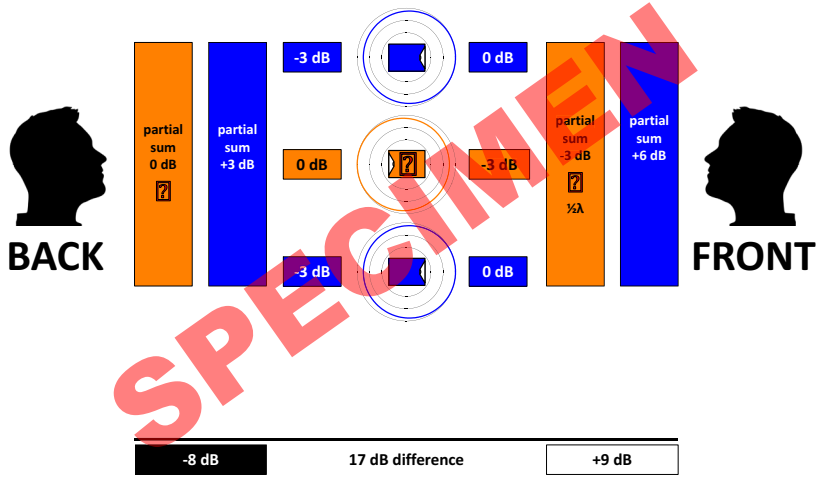
Gradient Inverted Stack – 2 : 1 Ratio



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Gradient Inverted Stack 3 : 2 Ratio

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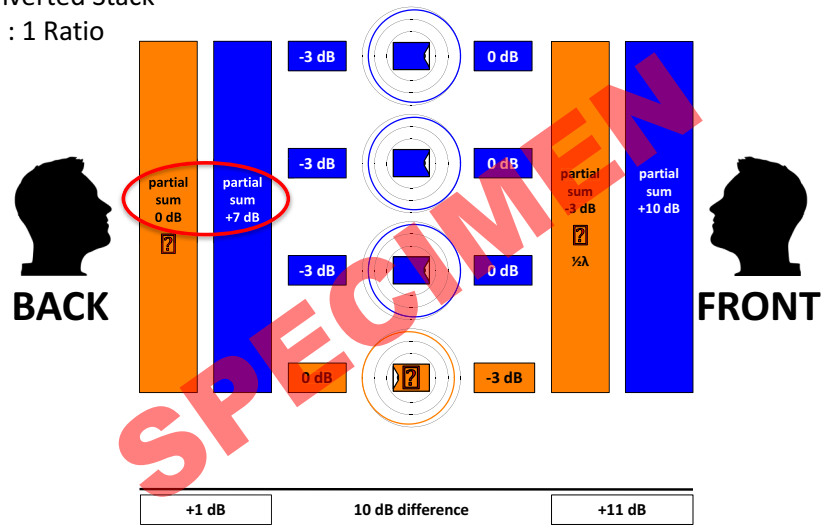
Gradient and End-Fire Inverted Stack 3 : 1 Ratio



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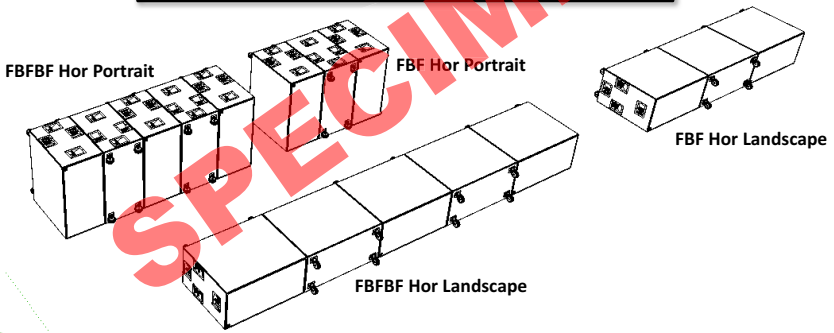
Large Format	B2F @ 32 m (105 ft)		
	31 - 63	63 - 125	Broadband
FBF Hor Portrait	-10 dB	-9 dB	-9 dB
FBF Hor Portrait Gap	-15 dB	-17 dB	-15 dB
FBF Hor Landscape	-10 dB	-12 dB	-10 dB
FBF Hor Landscape Gap	-11 dB	-18 dB	-12 dB
FBFBF Hor Portrait	-7 dB	-4 dB	-5 dB
FBFBF Hor Portrait Gap	-16 dB	-14 dB	-15 dB
FBFBF Hor Landscape	-11 dB	-8 dB	-10 dB
FBFBF Hor Landscape Gap	-14 dB	-14 dB	-13 dB



Source: *SketchUp 3D Warehouse, models by David M.*

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Back-2-Front Difference

Photo: *Merlijn van Veen*

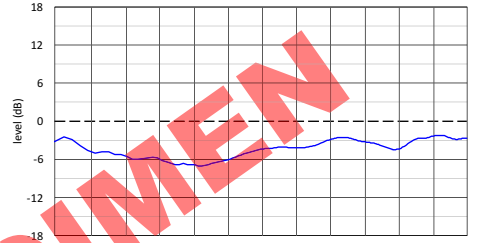
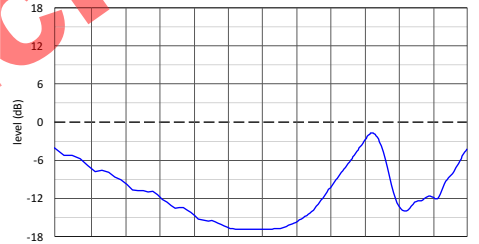


Photo: *Merlijn van Veen*



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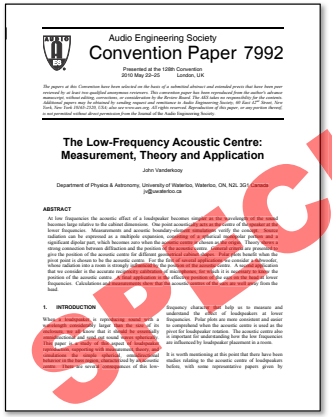
John Vanderkooy

BEng, PhD (McMaster) – Distinguished Professor Emeritus


Audio Engineering Society
Convention Paper 7992

The Low-Frequency Acoustic Centre: Measurement, Theory and Application

John Vanderkooy

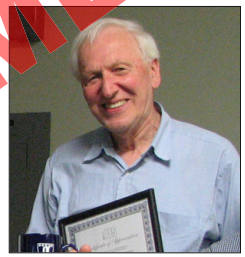


Photo: res.org

2010

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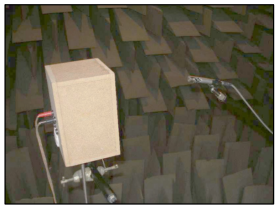
"The Low-Frequency Acoustic Centre: Measurement, Theory and Application"
by John Vanderkooy

Measurements



Analytic proof

$$p(r,t) = \iint [\rho\, \dot{u}_n(r_S, t-R/c) / 4\pi R]\, dS + \iint [e_R \cdot n_S\, (\partial/\partial t + c/R)\, p(r_S, t-R/c) / 4\pi R]\, dS, \quad (1)$$

$$p(r,t) = S(t-r/c)/r - \nabla \cdot \boldsymbol{D}(t-r/c)/r + \Sigma (\partial^2/\partial x_\mu\, \partial x_\psi)\, Q_{\mu\psi}(t-r/c)/r + \cdots \quad (2)$$

$$S(t) = (\rho/4\pi) \iint \dot{u}_n(r_S, t)\, dS \quad (3)$$

$$\boldsymbol{D}(t) = (1/4\pi) \iint [\rho\, r_S\, \dot{u}_n(r_S, t) + n_S\, p(r_S, t)]\, dS \quad (4)$$

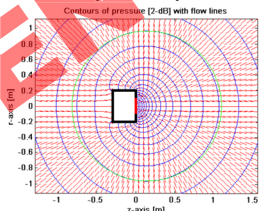
$$Q_{\mu\nu}(t) = (1/8\pi) \iint [\rho\, x_{S\mu}\, x_{S\nu}\, \dot{u}_n(r_S, t) + (x_{S\mu}\, n_\nu + x_{S\nu}\, n_\mu)\, p(r_S, t)]\, dS \quad (5)$$

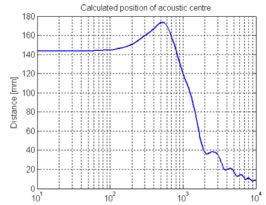
$$0 = \iint [\rho\, (r_S - r_0)\, \dot{u}_n(r_S, t) + n_S\, p(r_S, t)]\, dS. \quad (6)$$

$$\iint r_0\, \dot{u}_n(r_S, t)\, dS = r_0\, \dot{A}(t). \quad (7)$$

$$r_0 = (1/A) \iint [r_S\, \dot{u}_n(r_S) + n_S\, p(r_S)/\rho]\, dS. \quad (8)$$

Numerical computation (i.e. BEM)





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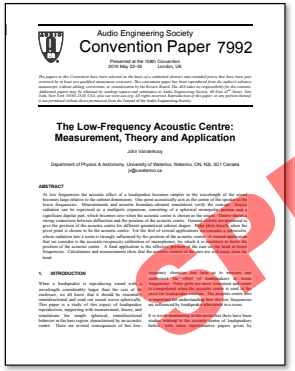
Acoustic Center for LF (Subwoofers)

John Vanderkooy* 2010 | Ambrose Thompson et al. 2010 | Mario Di Cola et al. 2017

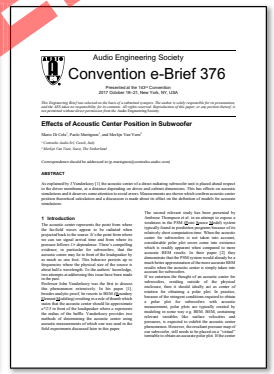

Audio Engineering Society
Convention Paper 7992

The Low-Frequency Acoustic Centre: Measurement, Theory and Application

John Vanderkooy


Audio Engineering Society
Convention Paper

Limitations of Point-Source Sub-woofer array models for Live Sound


Audio Engineering Society
Convention e-Brief 376

Effects of Acoustic Center Position in Subwoofer

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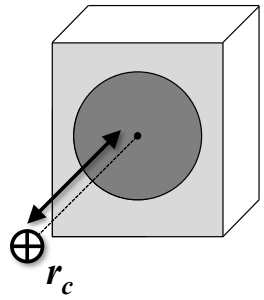
Acoustic Center for LF (Subwoofers)

"The acoustic center represents the point from where the far-field waves appear to emanate when projected back to the source."

It is the point from where we can see:

- pressure follows *1/r* dependence (inverse-square-law)
- signal arrival time



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Acoustic Center for LF (Subwoofers)

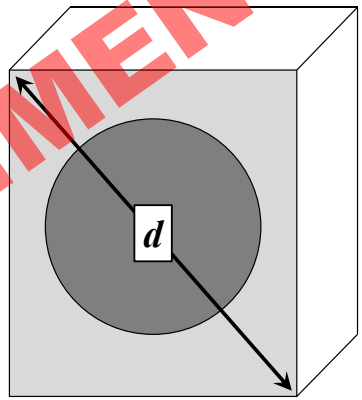
The phenomenon is observed

when

$$f \leq \frac{sound\ speed}{2d}$$

or

$$d \leq \tfrac{1}{2}\lambda$$



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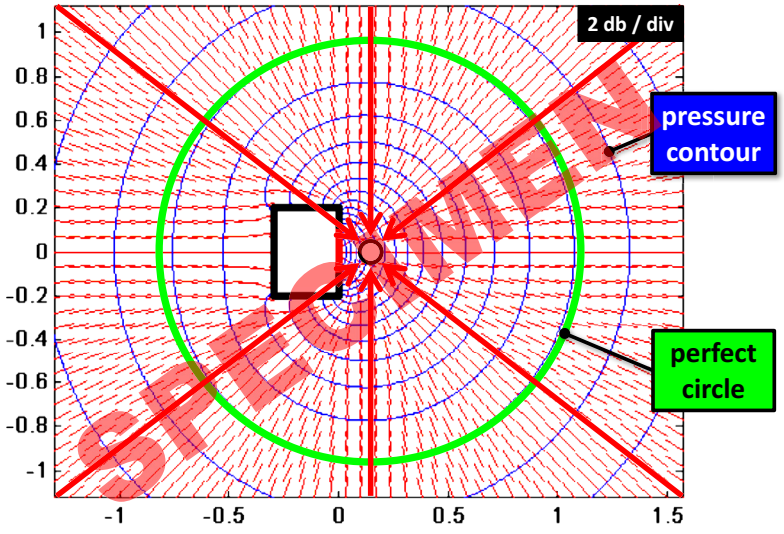
Pressure contours with flow lines



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"The Low-Frequency Acoustic Centre: Measurement, Theory and Application" by John Vanderkooy

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Common live sound subwoofers* are virtually omnidirectional

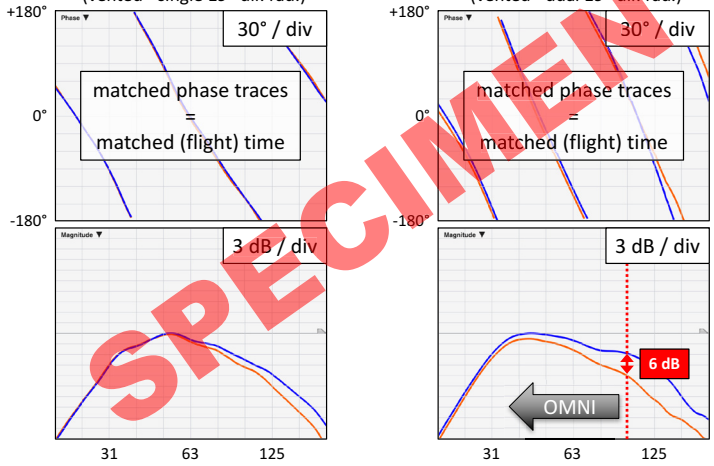
(equitemporal = equidistant)

small format

(vented - single 19" dir. rad.)

large format

(vented - dual 19" dir. rad.)



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* *Purpose-built cardioid subwoofers excluded*

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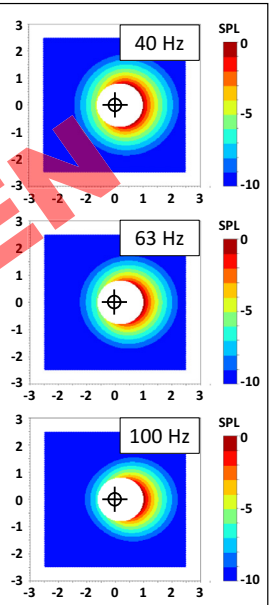
Near-Field-Scanner (NFS)

by Klippel

Photo: *Klippel.de*



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Data by Mario Di Cola, Contralto Audio, Italy

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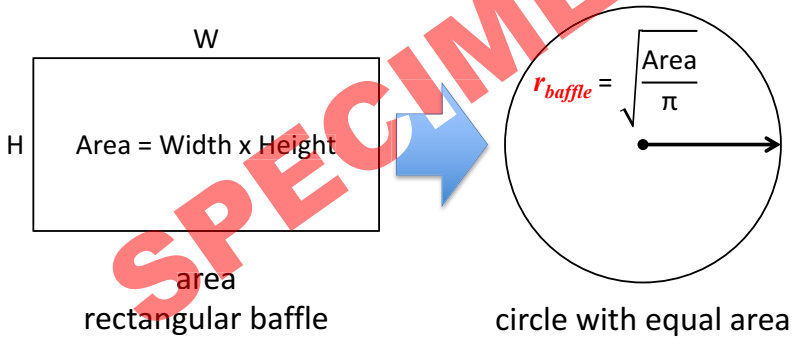
Acoustic Center for LF (Subwoofers)

Limits: $\frac{1}{2} r_{baffle} < r_c < r_{baffle}$

Rule of thumb: $r_c \approx \frac{2}{3} r_{baffle}$



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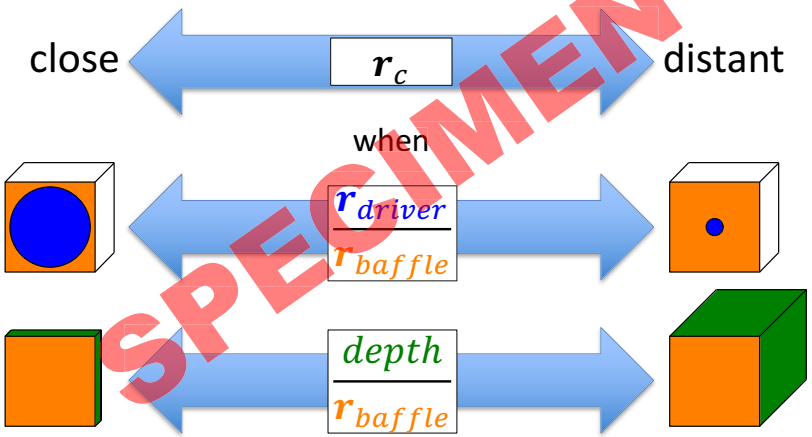
Acoustic Center for LF (Subwoofers)



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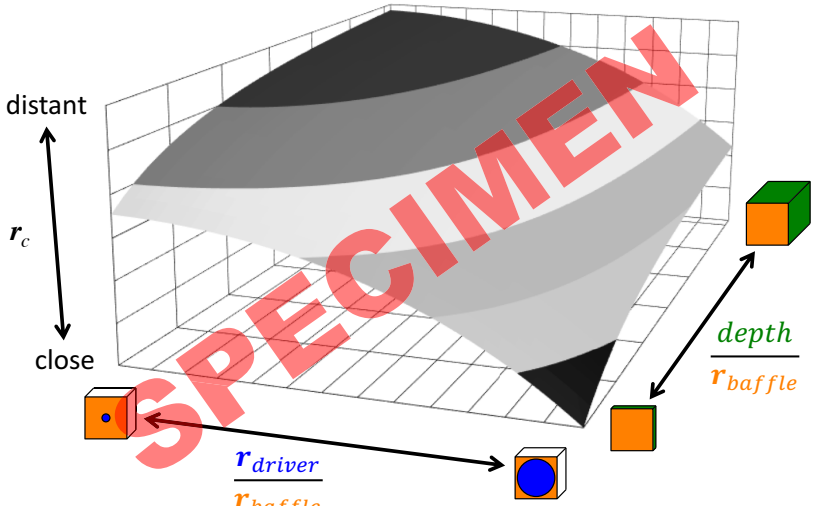
Acoustic Center for LF (Subwoofers)



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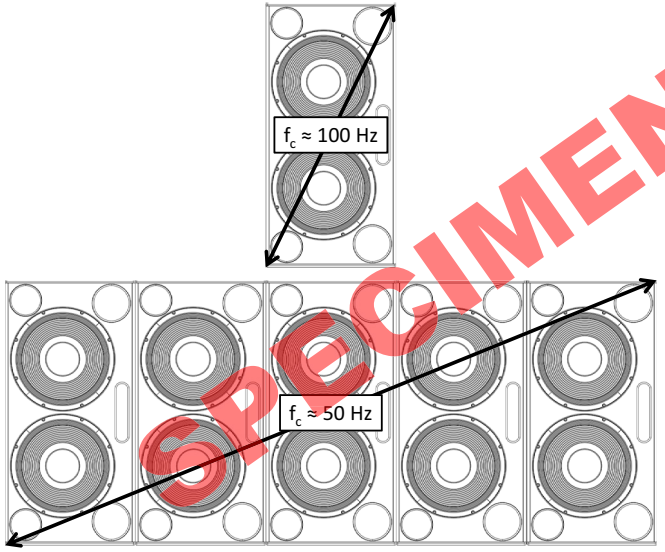
difference in r_{driver} to r_{baffle} ratio



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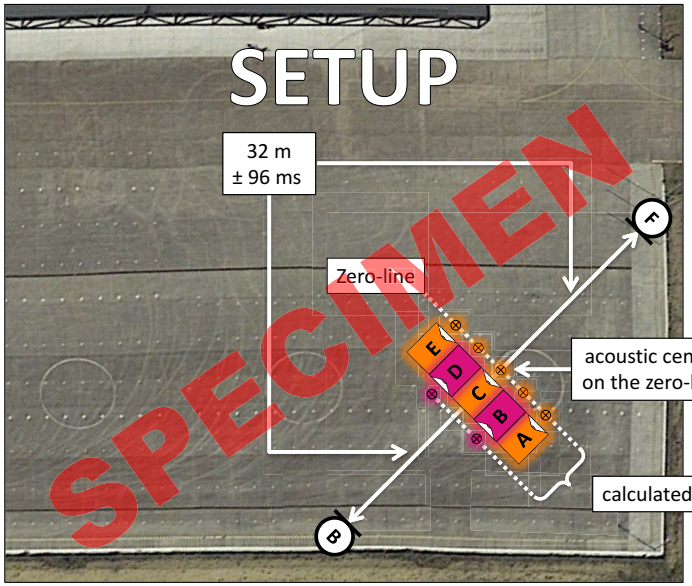
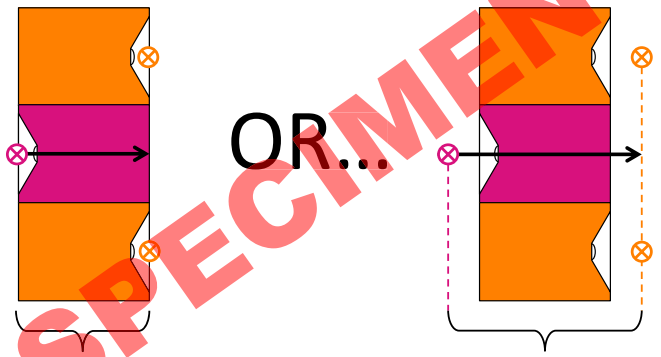


Loudspeakers and microphones not to scale

"fudge" factor

(timing of inverted stack gradient)



Δt = ¼ λ = enclosure depth
(physical displacement)

Δt = ¼ λ = depth + (2 x acc. center)

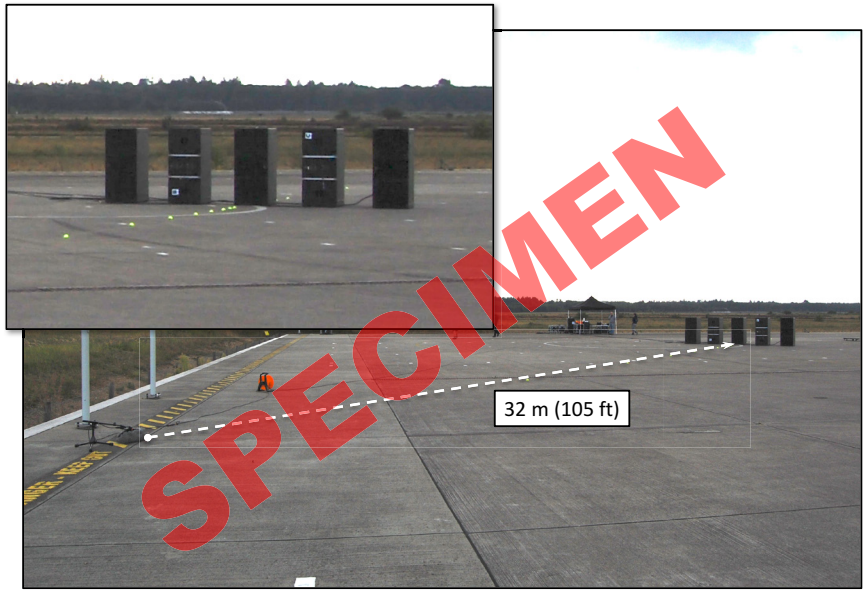
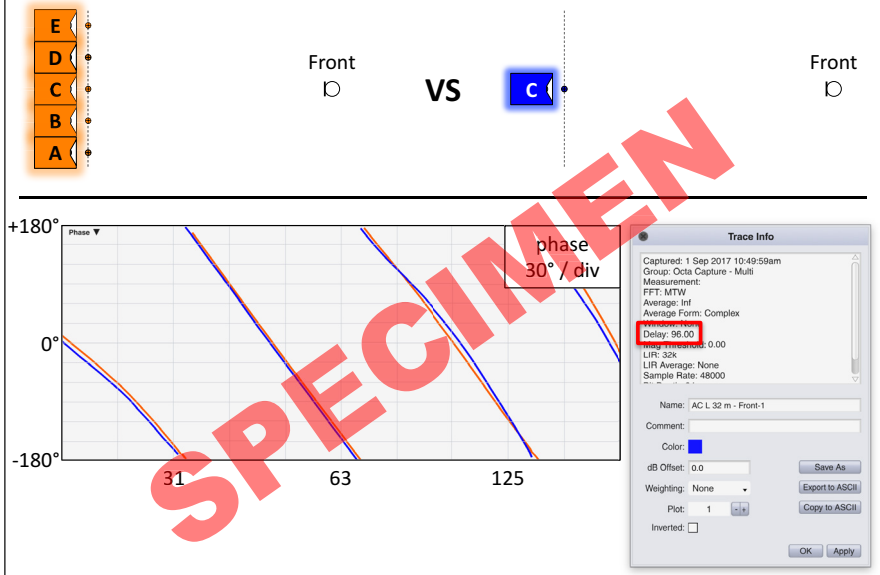


Photo: *Merlijn van Veen*



Data Processing

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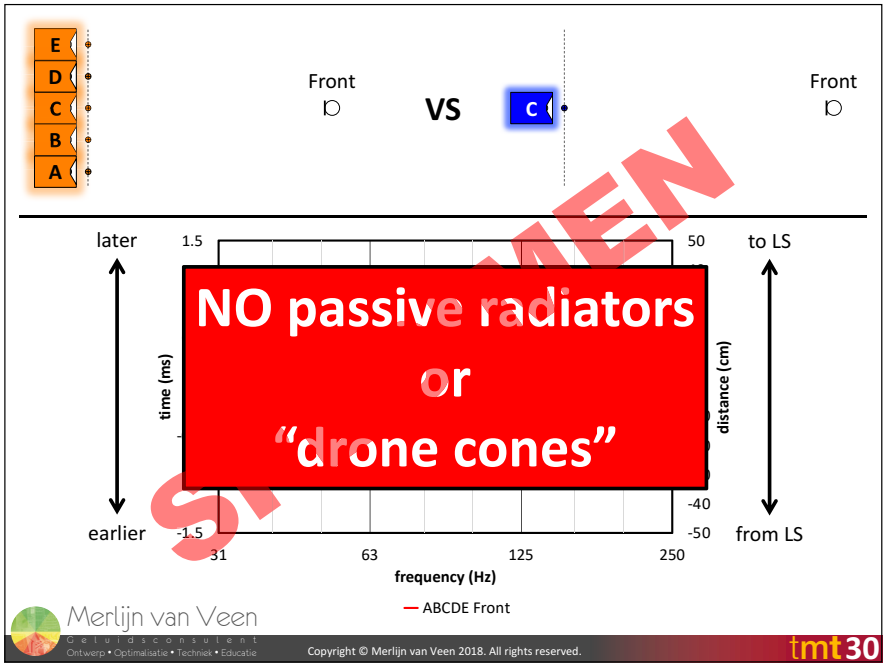

NO passive radiators or "drone cones"

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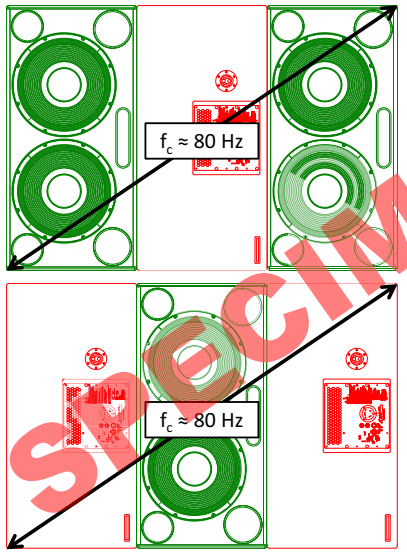
difference in r_{driver} to r_{baffle} ratio



Front view

$$\frac{r_{driver} \times\sqrt{2}}{r_{baffle} \times\sqrt{3}} = 82\%$$

r_c = less distant

Rear view

$$\frac{r_{driver}}{r_{baffle} \times\sqrt{3}} = 58\%$$

r_c = more distant

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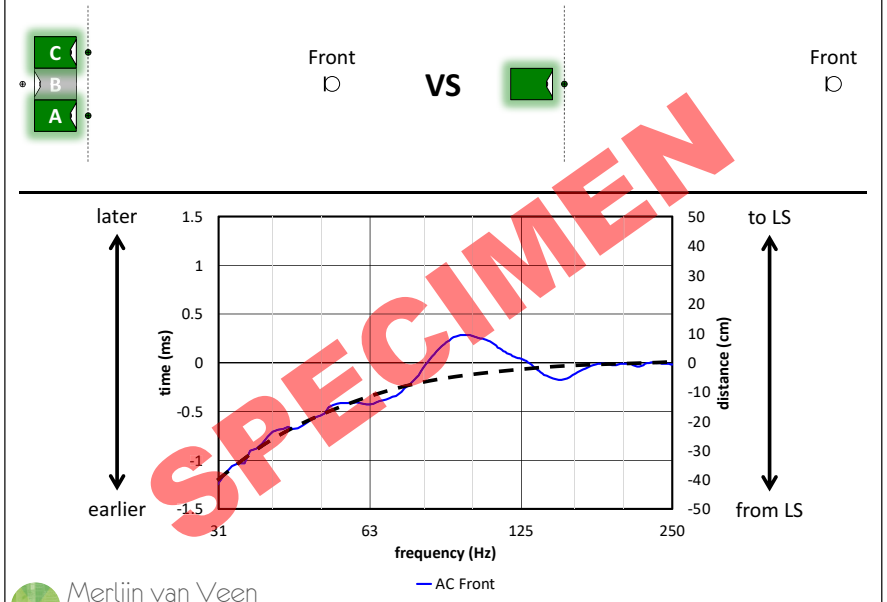

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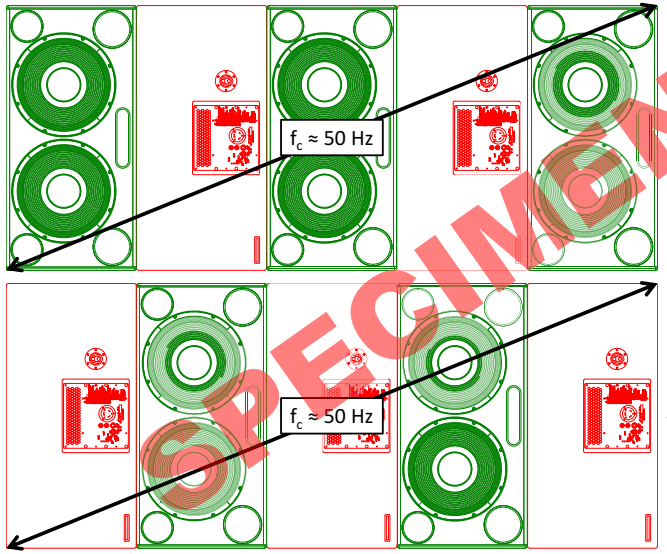
difference in r_{driver} to r_{baffle} ratio



Front view

$$\frac{r_{driver}\ x\sqrt{3}}{r_{baffle}\ x\sqrt{5}} = 77\%$$

r_c = less distant

Rear view

$$\frac{r_{driver}\ x\sqrt{2}}{r_{baffle}\ x\sqrt{5}} = 63\%$$

r_c = more distant

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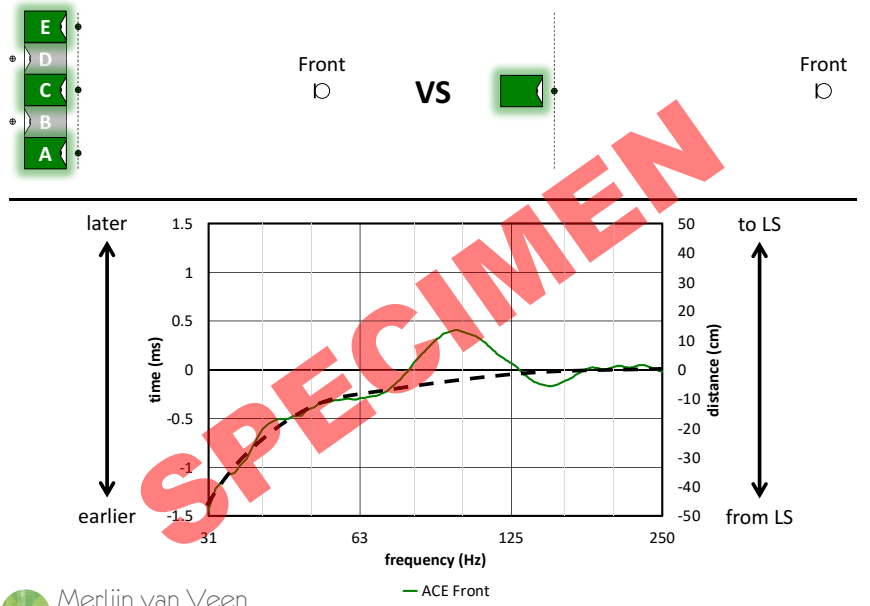

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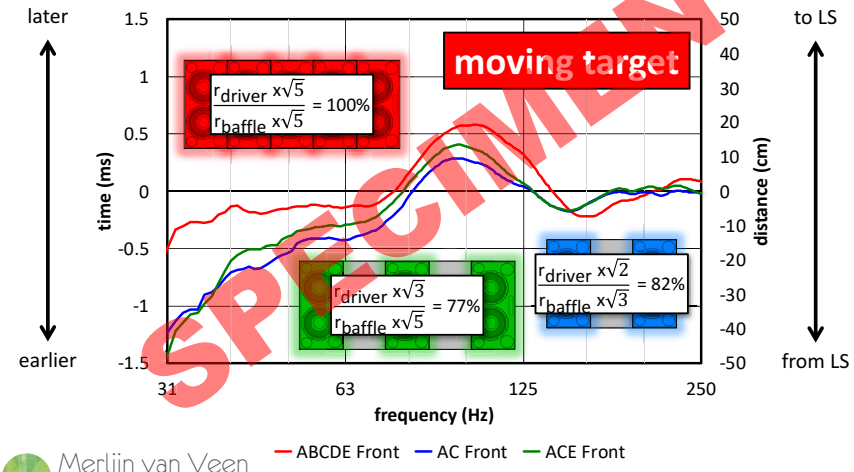
Acoustic Center starts to wander

(**front** re. single loudspeaker)



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Acoustic Center for LF (Subwoofers)

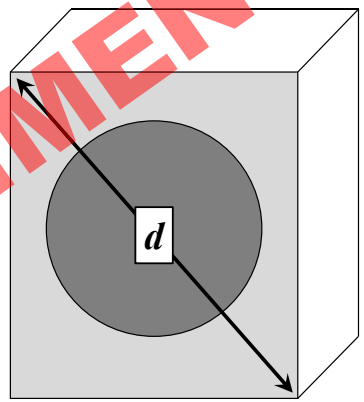
The phenomenon is observed

when

$$f \leq \frac{sound\ speed}{2d}$$

or

$$d \leq \tfrac{1}{2}\lambda$$



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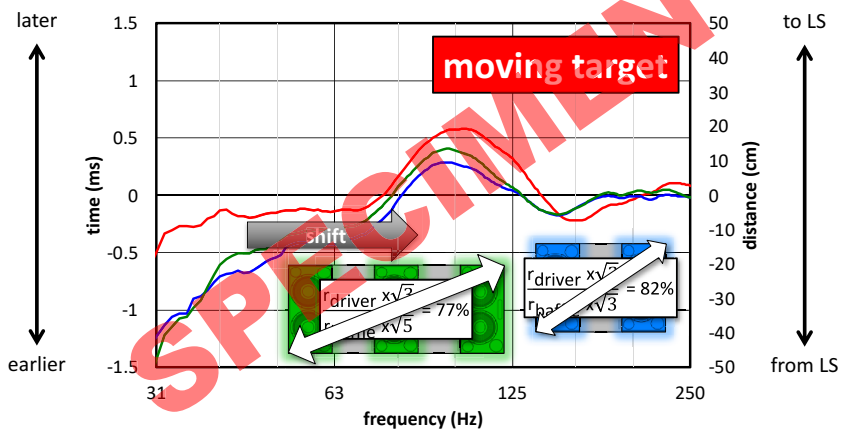
Acoustic Center starts to wander

(**front** re. single loudspeaker)



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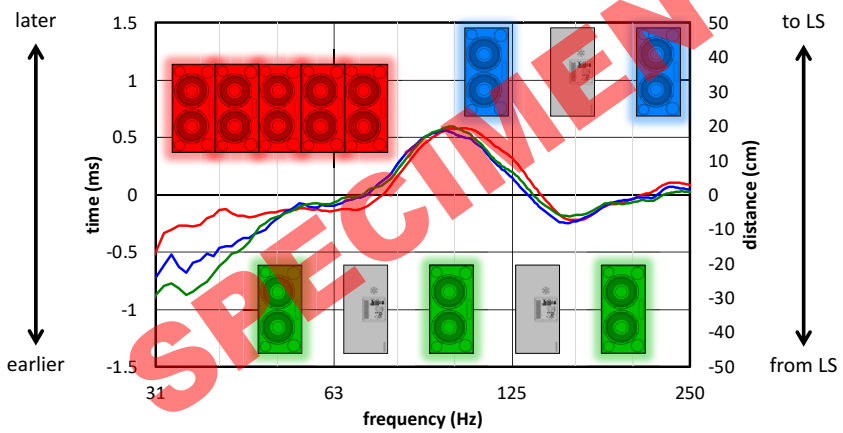
(**front** re. single loudspeaker)



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Acoustic Center starts to wander

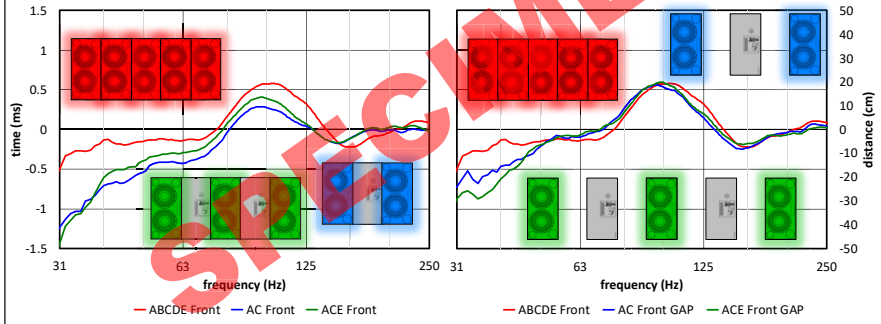
(**front** re. single loudspeaker)

WITHOUT GAPS

r_c not stationary

WITH GAPS

r_c virtually stationary



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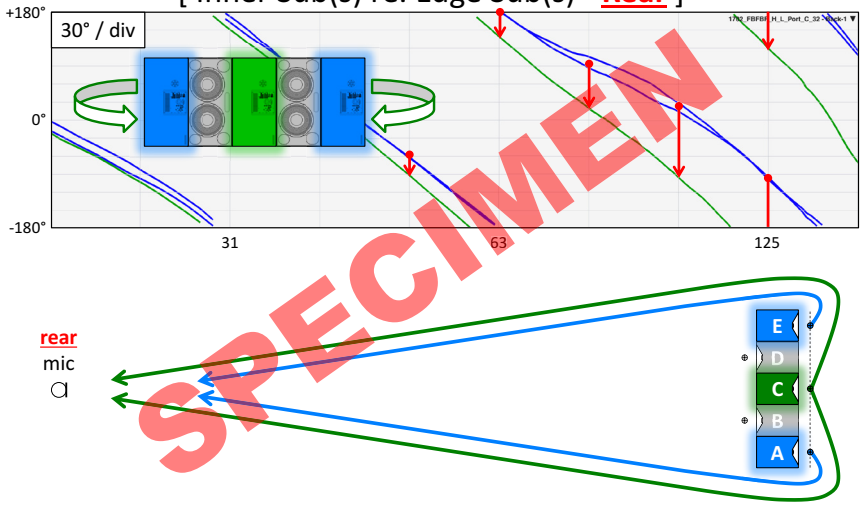
Detours (wrap-around time)

[Inner Sub(s) re. Edge Sub(s) - **Rear**]



Not to scale

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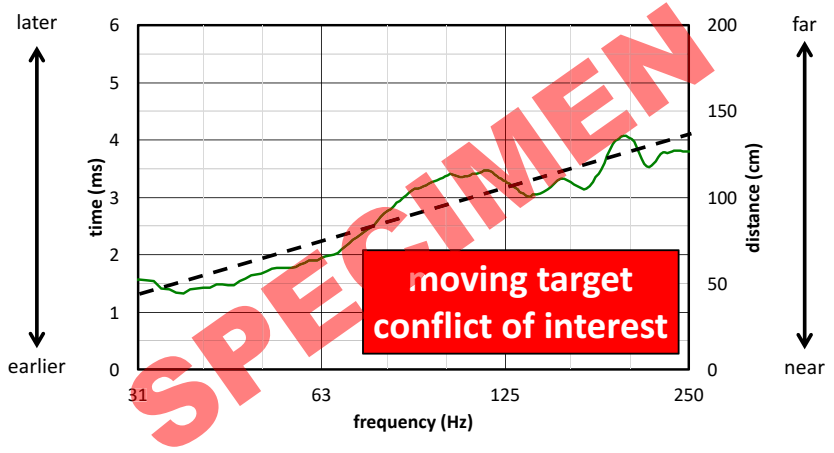
Detours (wrap-around time)

[Inner Sub(s) re. Edge Sub(s) - **Rear**]



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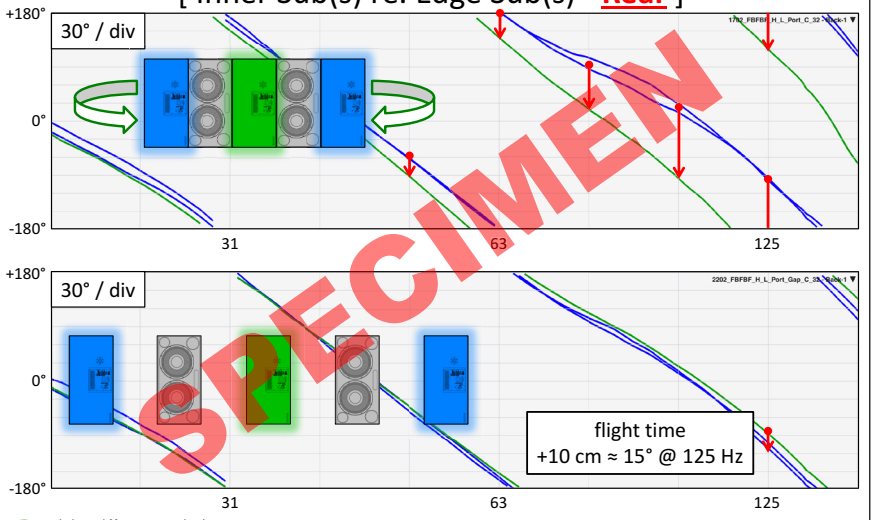
Detours (wrap-around time)

[Inner Sub(s) re. Edge Sub(s) - **Rear**]



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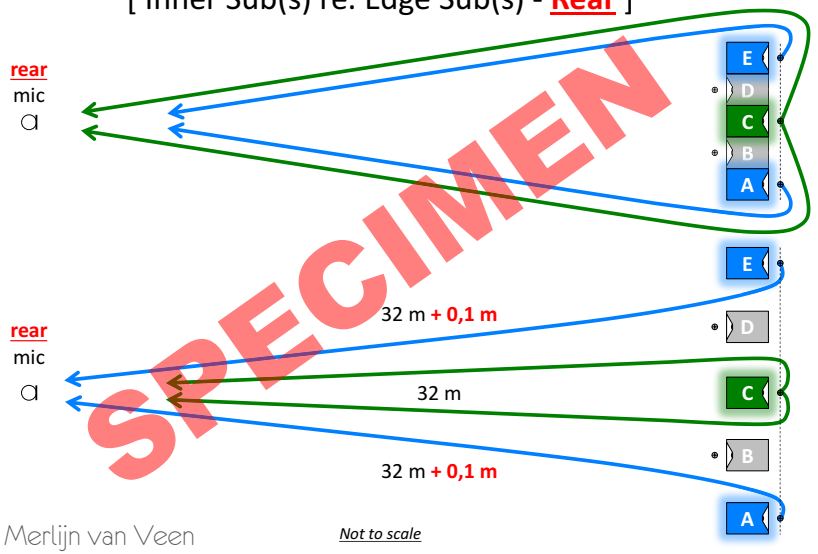
Detours (wrap-around time)

[Inner Sub(s) re. Edge Sub(s) - **Rear**]



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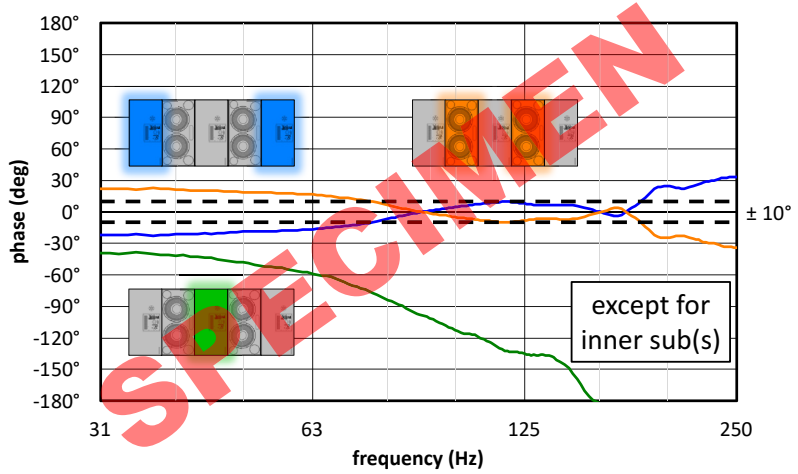
Timing

(**Rear** - **pre** Polarity Inversion)



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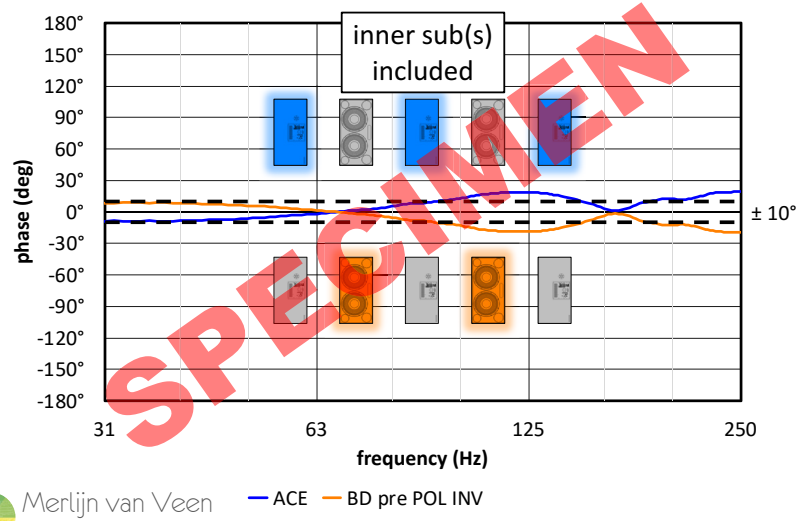
Timing

(**Rear** - **pre** Polarity Inversion)



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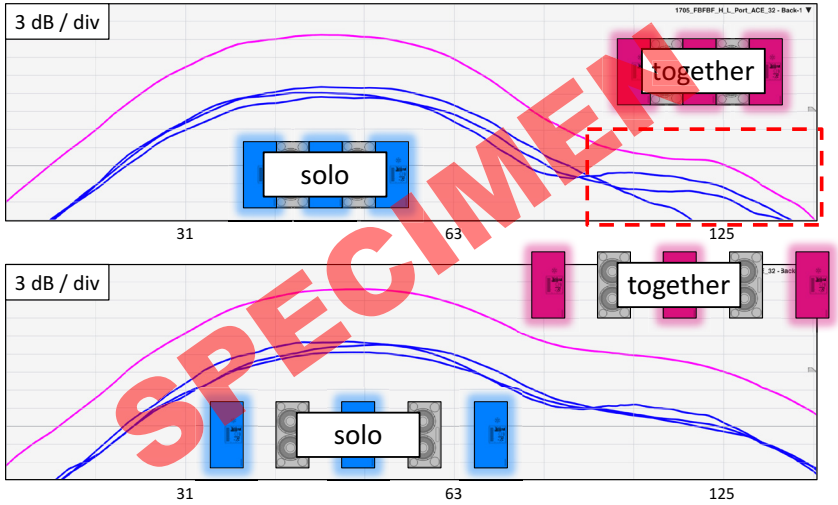
Level

(**Rear**)



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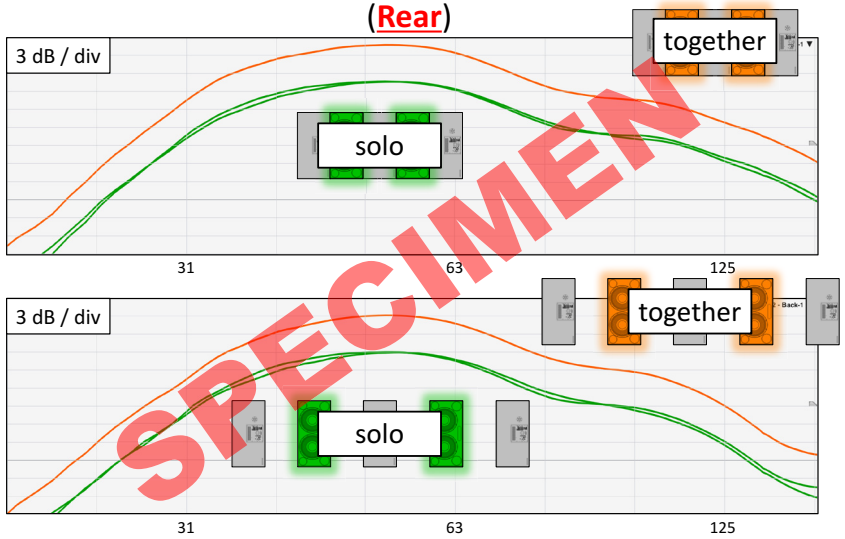
Level

(**Rear**)



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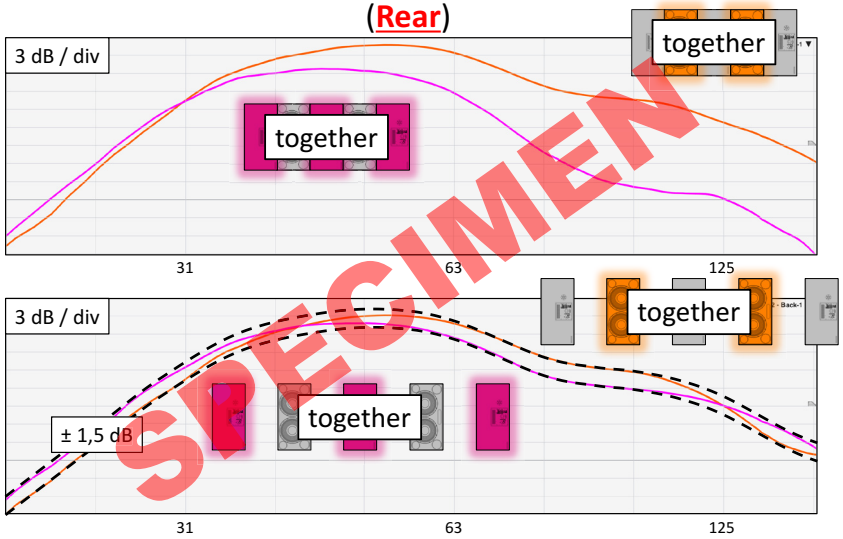
Level

(**Rear**)



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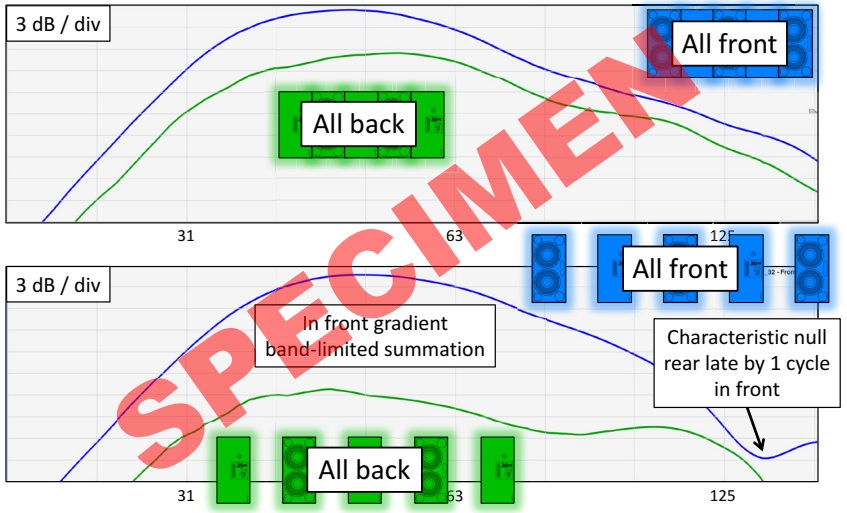
Front-2-Back Difference



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Conclusion

Without Gaps

- acoustic center not stationary
  - array configuration dependent
  - frequency dependent
- (physical) detours in opposite direction (wrap-around time)
  - inner sources take longer than edge sources
  - frequency dependent
- level variance due to diffraction
  - frequency dependent
- hard to predict (PSM falls short)
- every array configuration requires custom preset

With Gaps

- acoustic center virtually stationary
  - array configuration independent
- no (physical) detours
  - inner- and edge-sources arrive in time*
- matched levels (little to no diffrac.)
  - provided front- and rear-facing sources have the appropriate ratio to complement polar plot
- no pattern implosion
- predictable
- modular & scalable
  - one preset suffices

** Flight time not taken into account*

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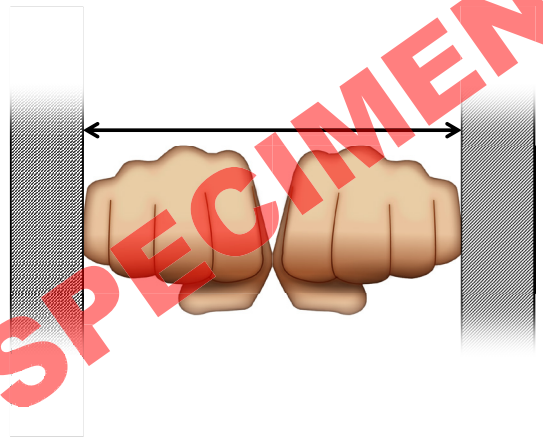
Two Fists

(minimum spacing - experimentally determined)



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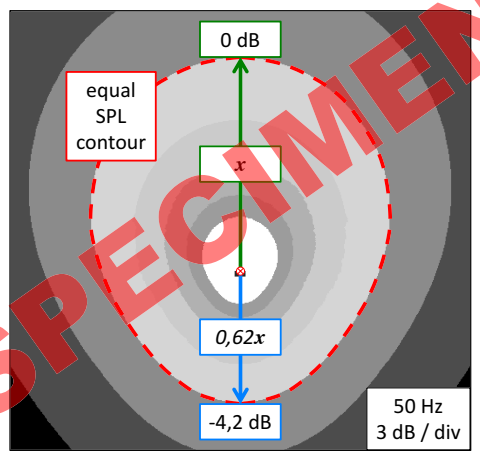
Food for thought…

(Vented enclosure - Dual 18” Direct Radiators)



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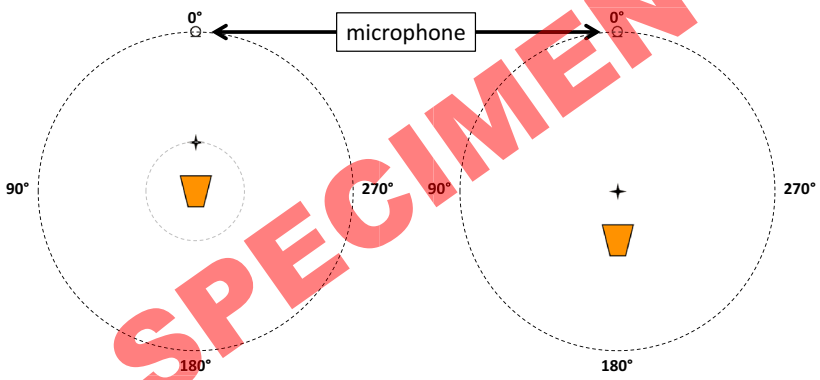
Polar plots for Subwoofers

(Center of Rotation During Measurement)



e.g. Center Of Gravity **or…** **Acoustic Center**

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Thank you!

Credits

Companies

- Audio Electronics Mattijsen
- Heijmans
- National Military Museum
- Sound & Light Import

People

- Timo Beckman
- Tom de Haas
- Dico ter Maten
- Vince van Seggelen
- Lieven Verzele

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