

Towards Sonic Urban Morphologies: *A Modeling Nexus (WIP)*

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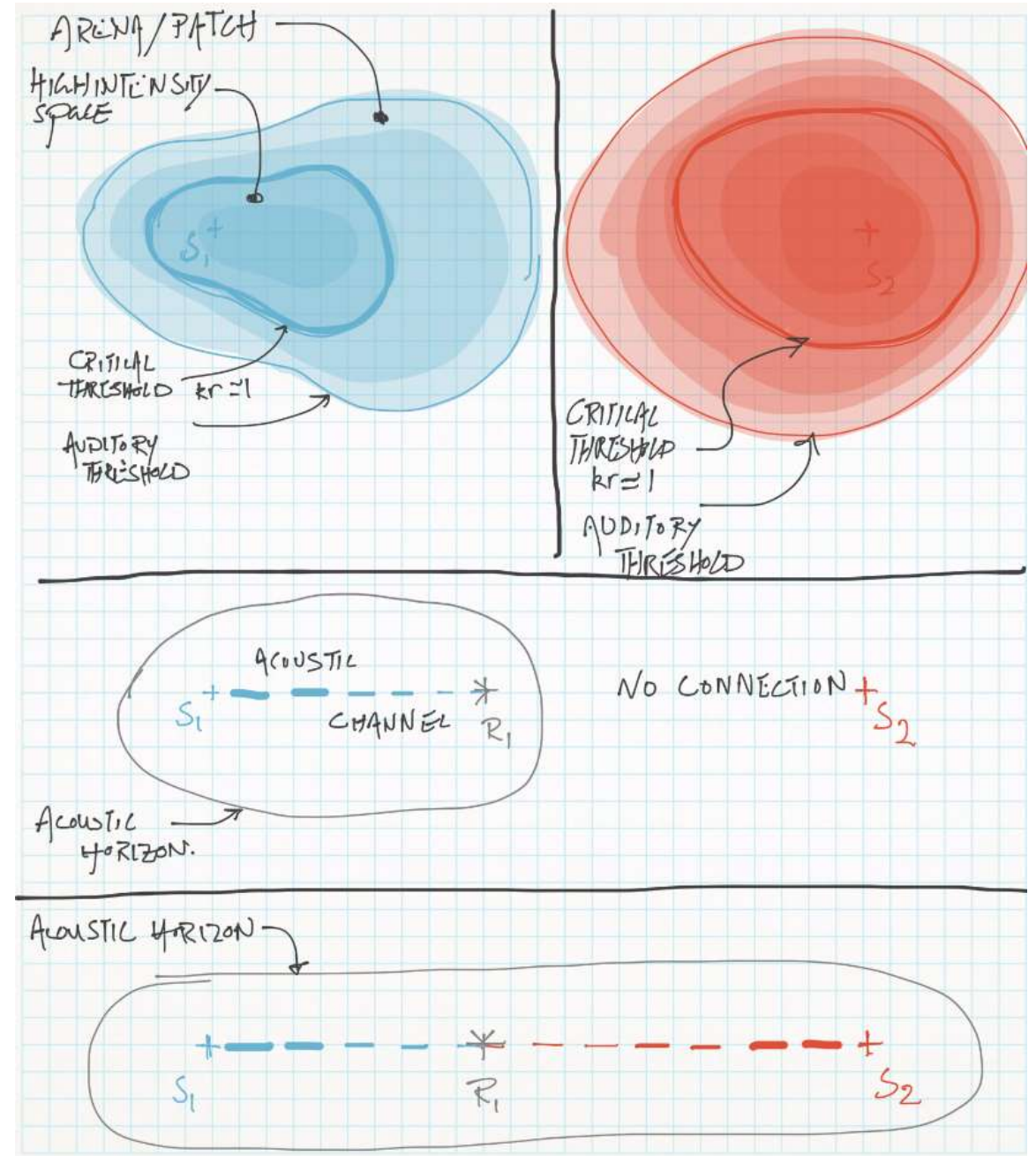


Aural Architecture



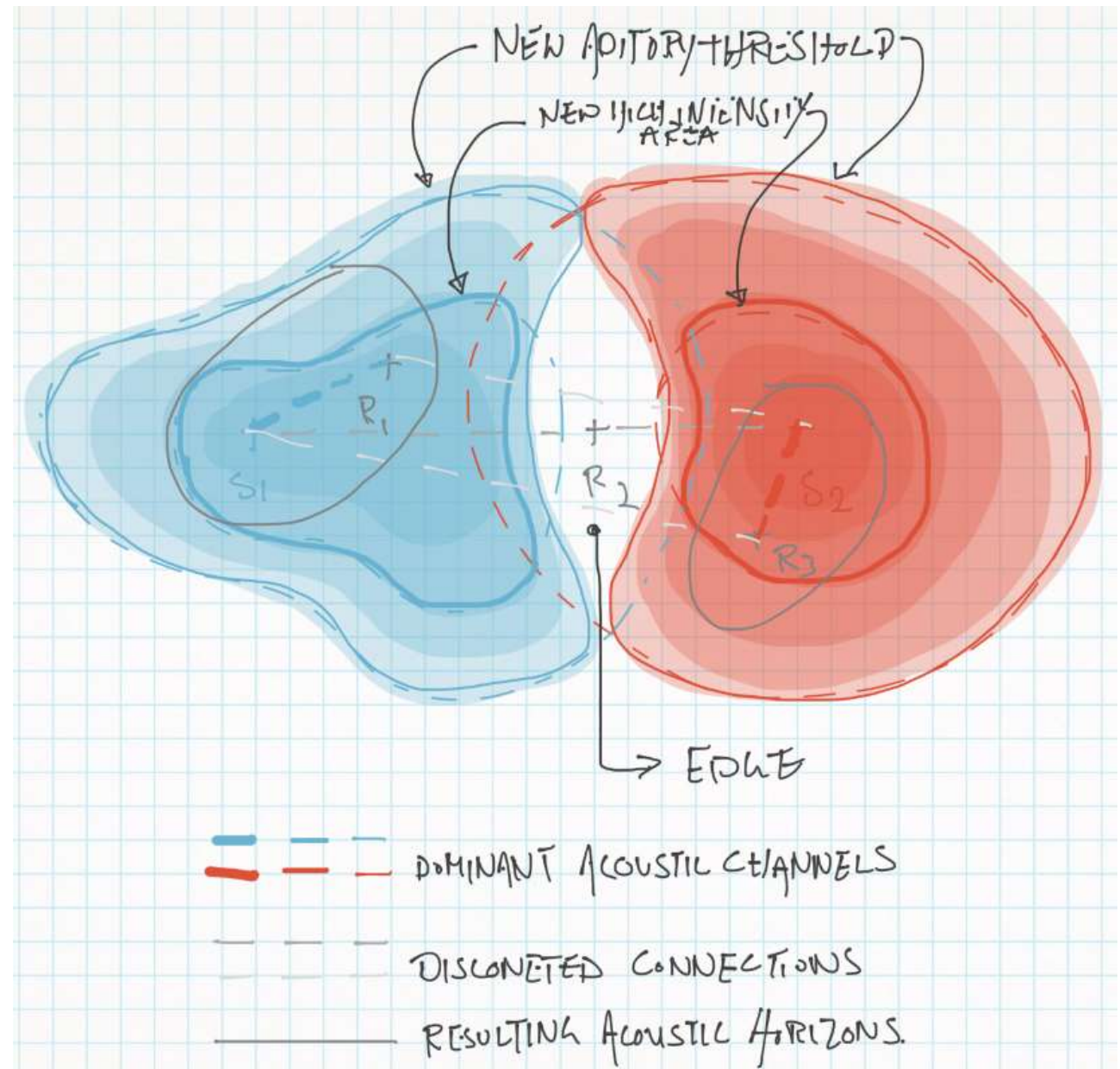
Terminology

- Receiver | Sensor
- Sonic Event | Sound Source | Signal
- Auditory Channel and Acoustic Horizon
- Acoustic Arena | Acoustic Space | Patch
- Edge
- Soundscape Pattern



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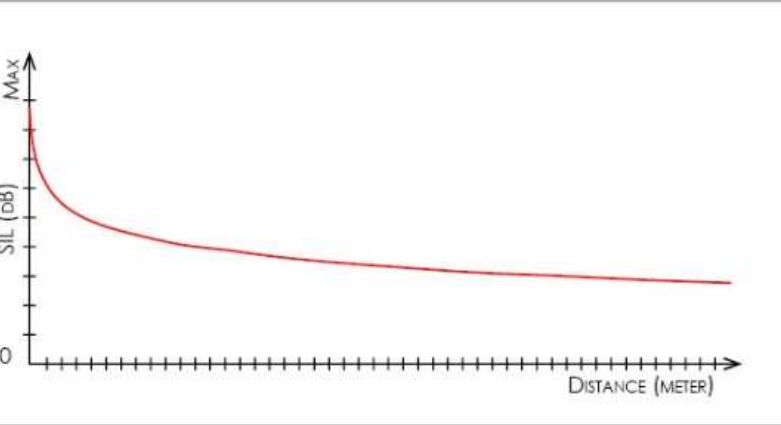


Soundscape & Psychoacoustic Parameters

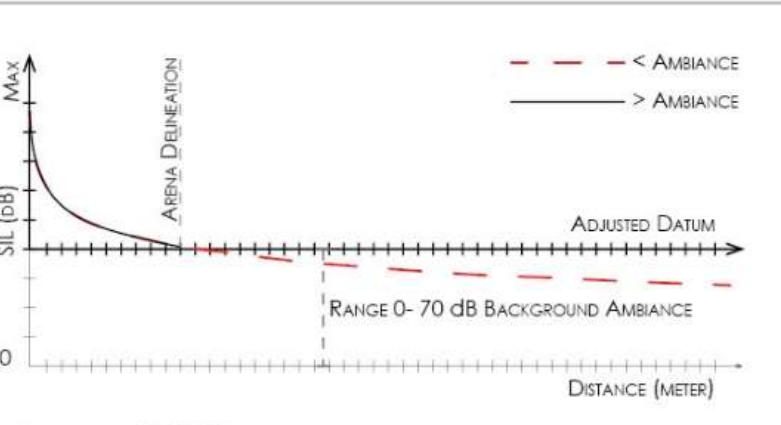


Expected Divergence From Inverse Square Law

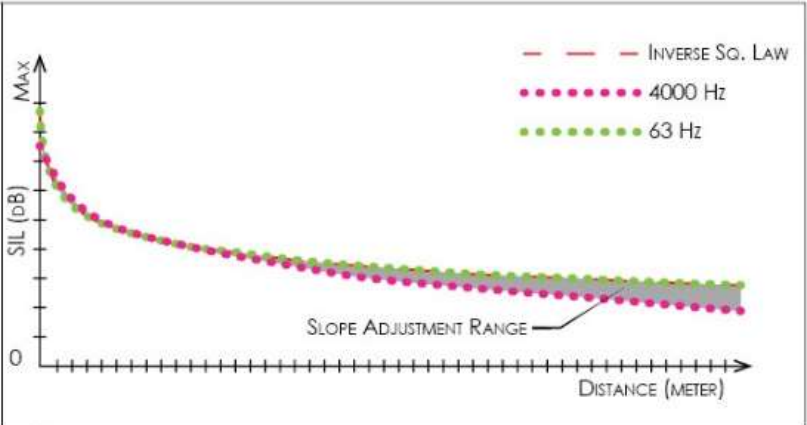
- Acoustic Impedance
- Sound-To-Noise Ratio (SNR) | Ambient Background Sound Level
- Frequency Dependent Attenuation
- Audible threshold



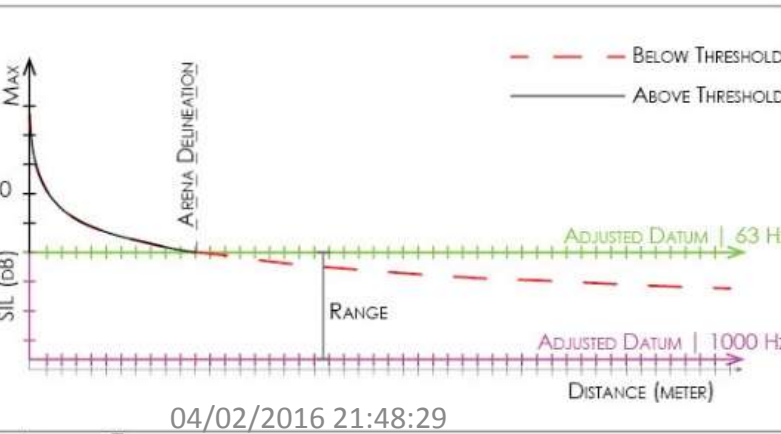
IMPEDANCE AND INVERSE SQUARE LAW



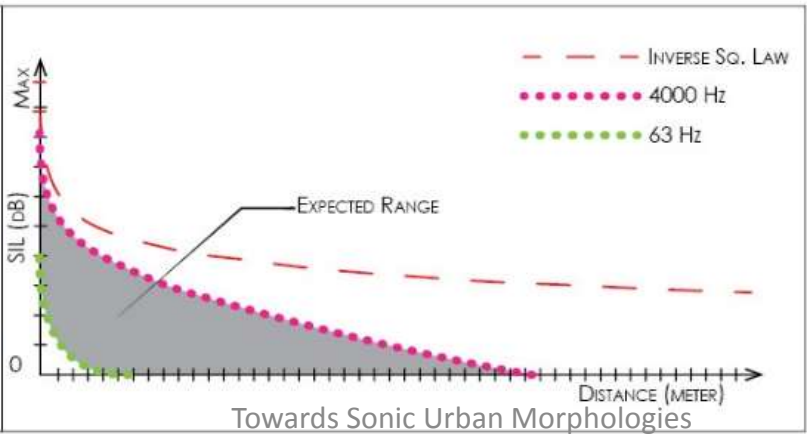
AMBIENCE & SNR



ATTENUATION



AUDIBLE THRESHOLD

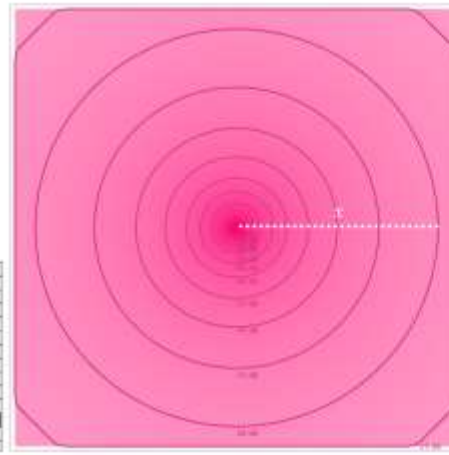
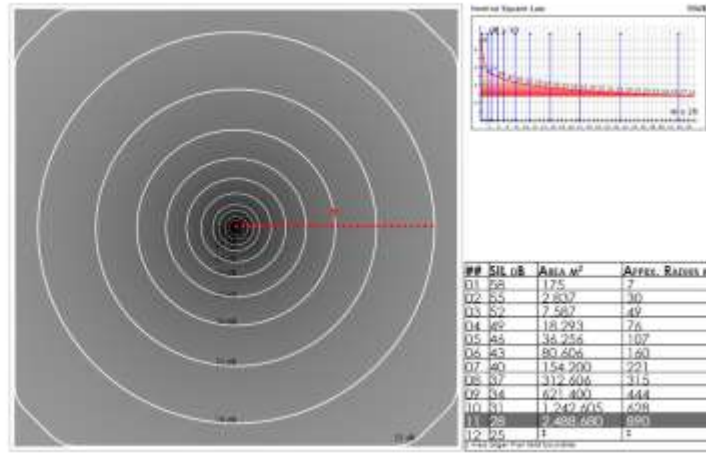


ALL PARAMETERS

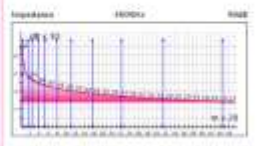
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Towards Sonic Urban Morphologies

Acoustic Impedance

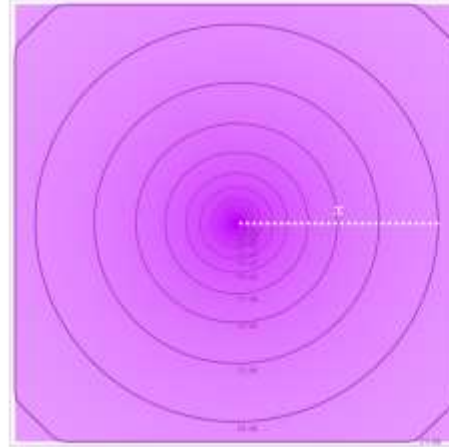


#	SIL dB	AREA M ²	AFFEC. RADIUS M
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	76
05	46	36.256	107
06	43	80.606	160
07	40	154.200	221
08	37	312.606	315
09	34	621.400	444
10	31	1.242.606	608
11	28	2.485.200	800
12	25	4.970.400	1100

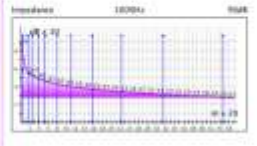


4^k 90 100[%]
 Hz Max dB Factor

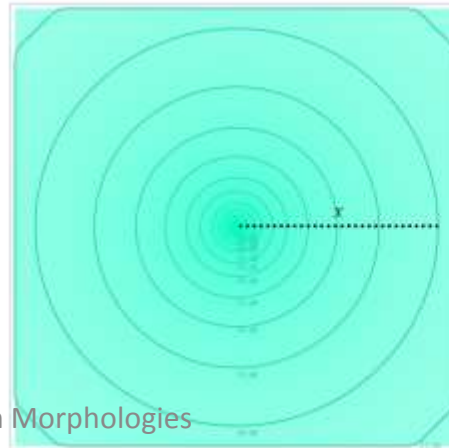
N/A 90 Ref
 Hz Max dB Factor
 Relative SIL dB



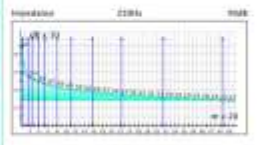
#	SIL dB	AREA M ²	AFFEC. RADIUS M
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	76
05	46	36.256	107
06	43	80.606	160
07	40	154.200	221
08	37	312.606	315
09	34	621.400	444
10	31	1.242.606	608
11	28	2.485.200	800
12	25	4.970.400	1100



1^k 90 100[%]
 Hz Max dB Factor

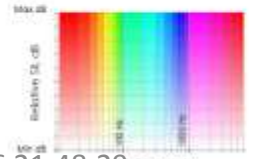


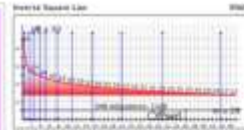
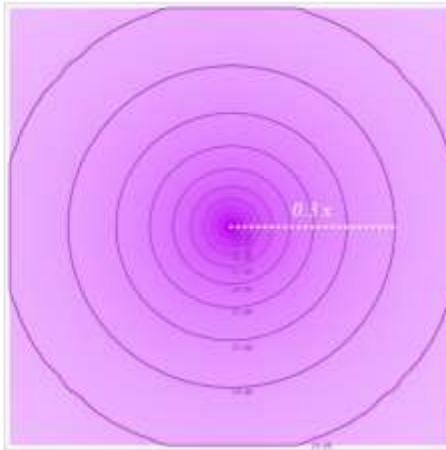
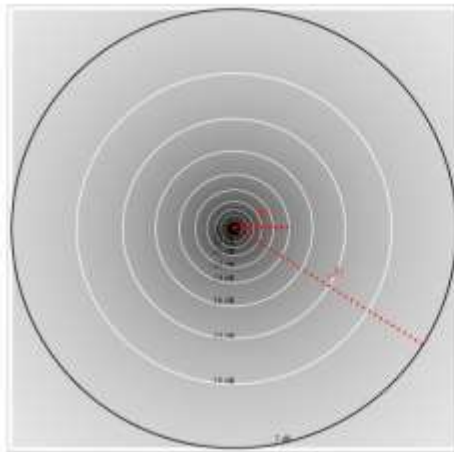
#	SIL dB	AREA M ²	AFFEC. RADIUS M
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	76
05	46	36.256	107
06	43	80.606	160
07	40	154.200	221
08	37	312.606	315
09	34	621.400	444
10	31	1.242.606	608
11	28	2.485.200	800
12	25	4.970.400	1100



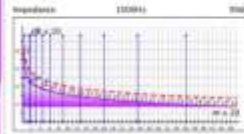
2²⁵ 90 100[%]
 Hz Max dB Factor

2⁰/2⁰ 2^k/2^k 3^{dB}
 Grid Size m Field Size m Isoline Step





#	SIL dB	Area m ²	Approx. Radius m
01	49	17.5	7
02	46	2.837	30
03	43	3.950	35
04	40	10.293	57
05	37	25.056	89
06	34	47.006	122
07	31	99.806	178
08	28	207.006	256
09	25	401.522	360
10	22	813.805	508
11	19	1,432,600	720
12	16	-	-



1^k Hz 90 Max dB 40dB Ambient 30% Factor

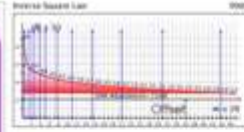
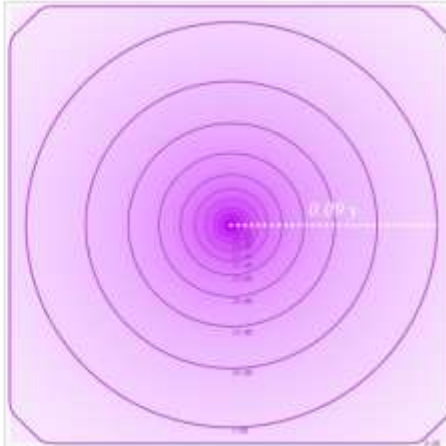
N/A Hz 90 Max dB R^{ref} Factor

Relative SIL dB

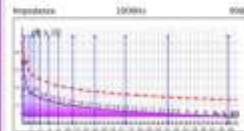
2⁰⁰/_{2⁰⁰} 2^{0k}/_{2^{0k}} 3dB

Grid Size m Field Size m IsoLine Step

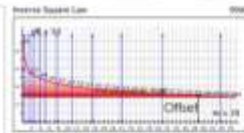
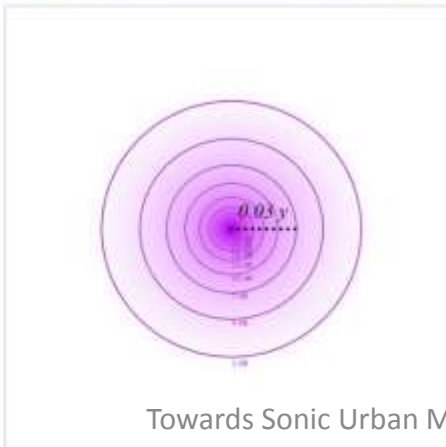
#	SIL dB	Area m ²	Approx. Radius m
01	37	17.488	7.4
02	34	375.006	30.6
03	31	1,029.364	57.2
04	28	2,140.408	85.5
05	25	4,540.576	1,202
06	22	9,348.080	1,724
07	19	18,460.004	2,424
08	16	37,019.960	3,468
09	13	74,080.576	4,920
10	10	148,220.144	6,940
11	7	303,900.384	9,635



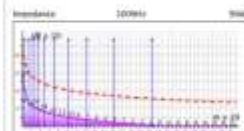
#	SIL dB	Area m ²	Approx. Radius m
01	37	17.5	7
02	34	2.837	30
03	31	7.587	49
04	28	18.293	76
05	25	40.281	116
06	22	80.606	160
07	19	152.399	233
08	16	322.700	320
09	13	655.205	454
10	10	1,298.200	642
11	7	2,586.199	907
12	4	-	-



1^k Hz 90 Max dB 50dB Ambient 9.5% Factor



#	SIL dB	Area m ²	Approx. Radius m
01	28	17.5	7
02	25	2.837	30
03	22	7.587	49
04	19	15.468	70
05	16	29.481	86
06	13	63.006	141
07	10	130.200	203
08	7	256.199	286
09	4	512.200	403
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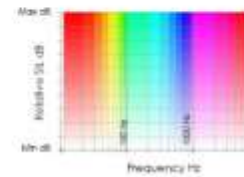


1^k Hz 90 Max dB 60dB Ambient 3% Factor

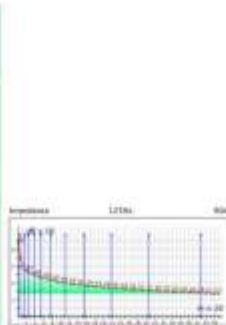
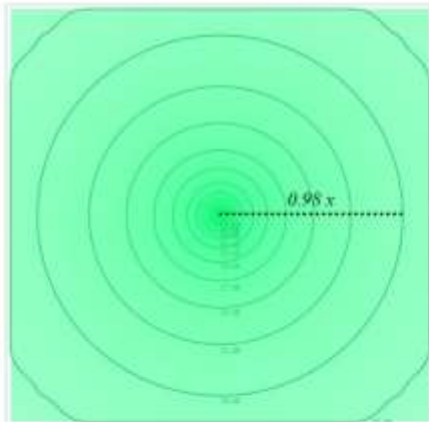
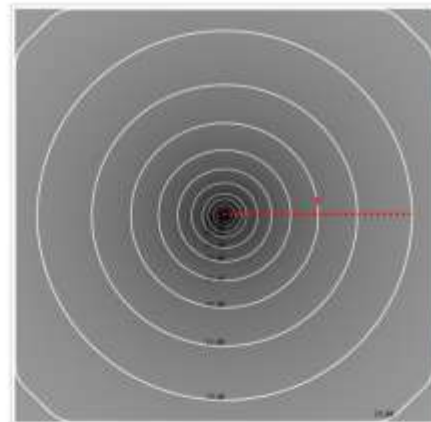
Sound-To-Noise Ratio (SNR)

2⁰/_{2⁰} 2^k/_{2^k} 3dB

Grid Size m Field Size m IsoLine Step

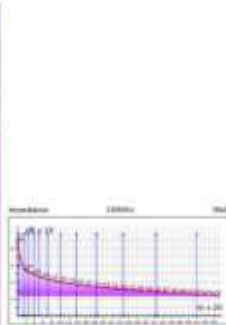
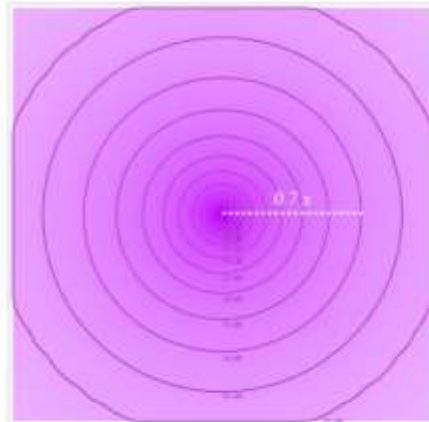


Frequency Dependent Attenuation



#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	74
05	46	36.256	107
06	43	74.281	153
07	40	144.200	221
08	37	300.206	309
09	34	600.600	437
10	31	1.175.000	611
11	28	2.350.000	844
12	25	-	-

125 Hz 90 Max dB 32¹⁰ dB/km 98% Factor



#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	74
05	46	36.256	107
06	43	74.281	153
07	40	144.200	221
08	37	300.606	374
09	34	601.211	517
10	31	1.202.422	717
11	28	2.404.844	1000
12	25	-	-

1^k Hz 90 Max dB 42¹⁰ dB/km 70% Factor

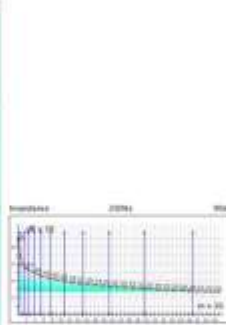
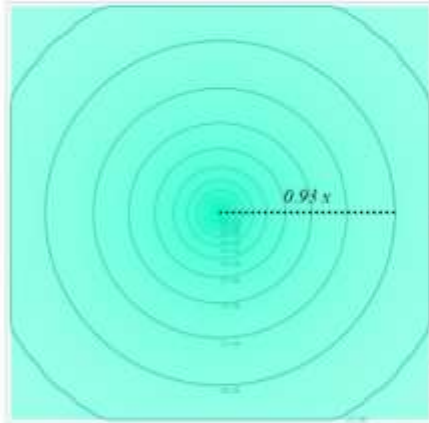
N/A Hz 90 Max dB R^{ref} Factor

Relative SL dB

Grid Size m Field Size m Isoline Step

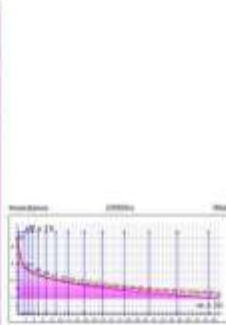
2⁰ / 2⁰ 2^k / 2^k 3 dB

#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	74
05	46	36.256	107
06	43	72.512	150
07	40	145.024	221
08	37	290.048	315
09	34	580.096	444
10	31	1.160.192	608
11	28	2.320.384	832
12	25	-	-



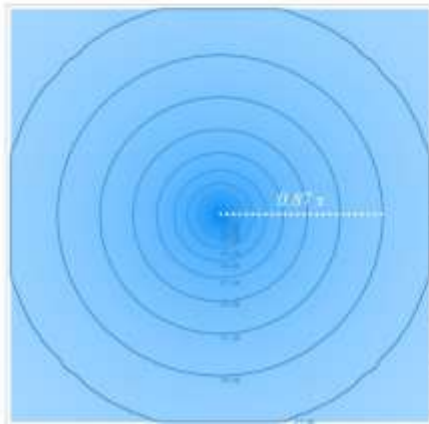
#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	74
05	46	36.256	107
06	43	72.512	153
07	40	145.024	216
08	37	290.048	300
09	34	580.096	428
10	31	1.160.192	591
11	28	2.320.384	817
12	25	-	-

250 Hz 90 Max dB 72¹⁰ dB/km 93% Factor



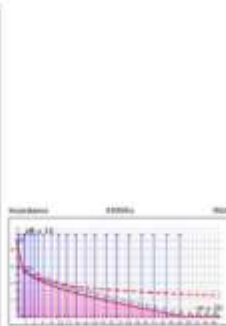
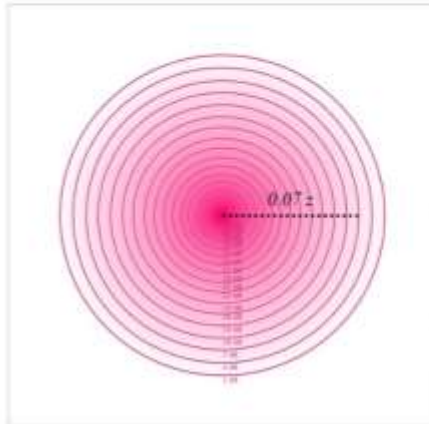
#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.468	70
05	46	36.936	94
06	43	73.872	134
07	40	147.744	176
08	37	295.488	232
09	34	590.976	312
10	31	1.181.952	424
11	28	2.363.904	576
12	25	4.727.808	768
13	22	9.455.616	1024
14	19	18.911.232	1368
15	16	37.822.464	1824
16	13	75.644.928	2432
17	10	151.289.856	3264
18	7	302.579.712	4416
19	4	605.159.424	5888
20	1	1.210.318.848	7968

2^k Hz 90 Max dB 1¹⁰ dB/km 37% Factor



#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	7.587	49
04	49	18.293	74
05	46	36.256	107
06	43	72.512	152
07	40	144.881	214
08	37	289.762	295
09	34	579.524	406
10	31	1.159.048	561
11	28	2.318.096	769
12	25	-	-

500 Hz 90 Max dB 18¹⁰ dB/km 87% Factor

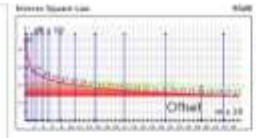
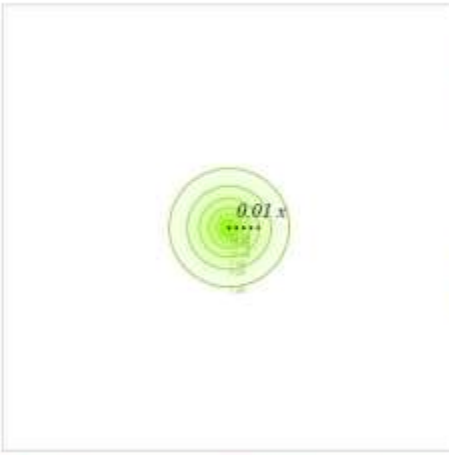
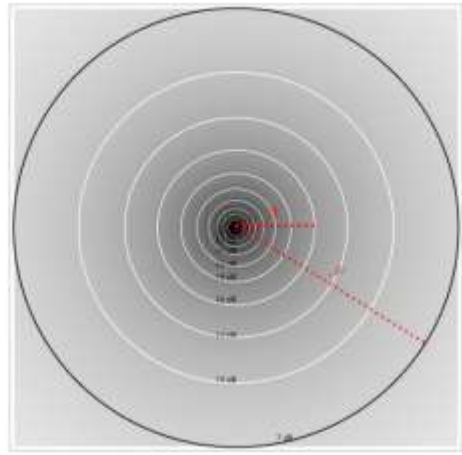


#	SIL dB	Area m²	Approx. Radius m
01	58	1.75	7
02	55	2.837	30
03	52	3.820	36
04	49	10.292	57
05	46	18.293	74
06	43	29.481	96
07	40	47.006	132
08	37	80.606	180
09	34	117.481	252
10	31	170.281	332
11	28	254.281	475
12	25	317.000	518
13	22	415.000	663
14	19	540.200	816
15	16	683.800	966
16	13	859.700	1225
17	10	1.074.600	1581
18	7	1.328.500	2137
19	4	1.531.000	2692
20	1	1.810.100	3528

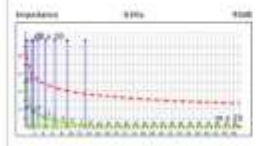
4^k Hz 90 Max dB 2.6¹⁰ dB/km 7% Factor



Audible threshold



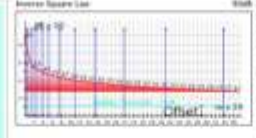
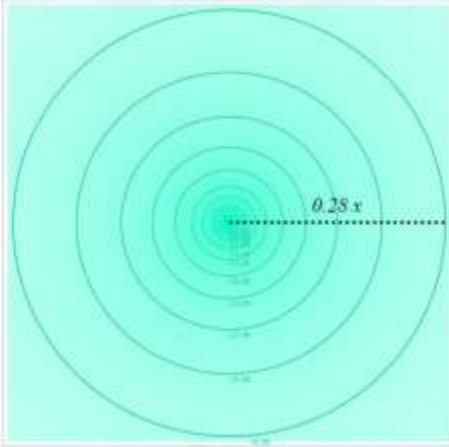
#	SIL dB	Area m²	Approx. Radius m
01	22	175	7
02	19	2.837	30
03	16	3.950	35
04	13	10.293	57
05	10	23.056	82
06	7	53.818	130
07	4	107.800	185
08	1	219.800	264



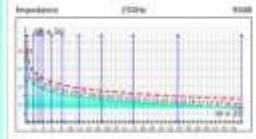
63 Hz 90 Max dB 37 dB Threshold 1.5% Factor

N/A Hz 90 Max dB Ref Factor
2⁰⁰/2⁰⁰ 2^{0k}/2^{0k} 3 dB
 Grid Size m Field Size m Isoline Step

#	SIL dB	Area m²	Approx. Radius m
01	37	17.488	7.4
02	34	395.008	35.4
03	31	1.022.348	57.2
04	28	2.140.638	82.5
05	25	4.540.576	120.2
06	22	9.348.080	172.4
07	19	18.440.904	249.4
08	16	37.819.960	349.9
09	13	76.060.576	492.0
10	10	152.220.124	684.0
11	7	303.500.364	936.0

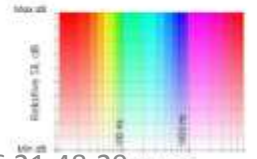


#	SIL dB	Area m²	Approx. Radius m
01	46	175	7
02	43	3.950	35
03	40	10.293	57
04	37	18.293	74
05	34	42.581	116
06	31	83.800	163
07	28	176.606	237
08	25	352.000	338
09	22	712.600	474
10	19	1.431.000	674
11	16	2.862.000	955



250 Hz 90 Max dB 11 dB Threshold 28% Factor

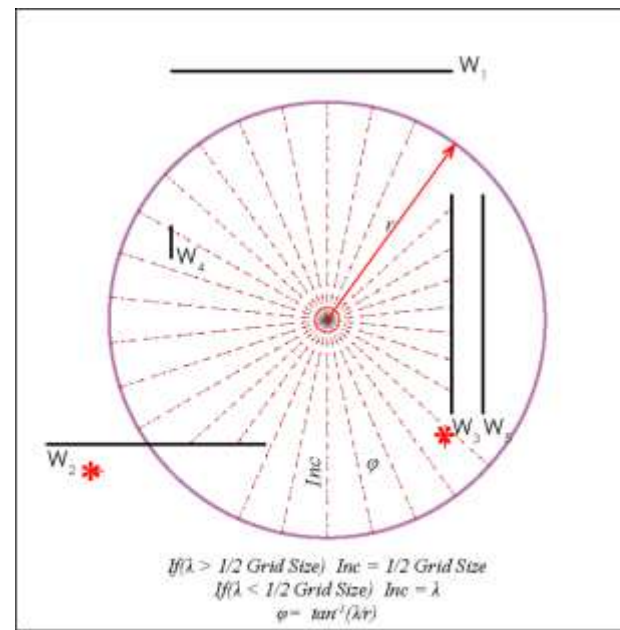
2⁰/2⁰ 2^k/2^k 3 dB
 Grid Size m Field Size m Isoline Step



Geometric Solution



Sonic Event Sphere of Influence



ENVIRONMENT DETECTION

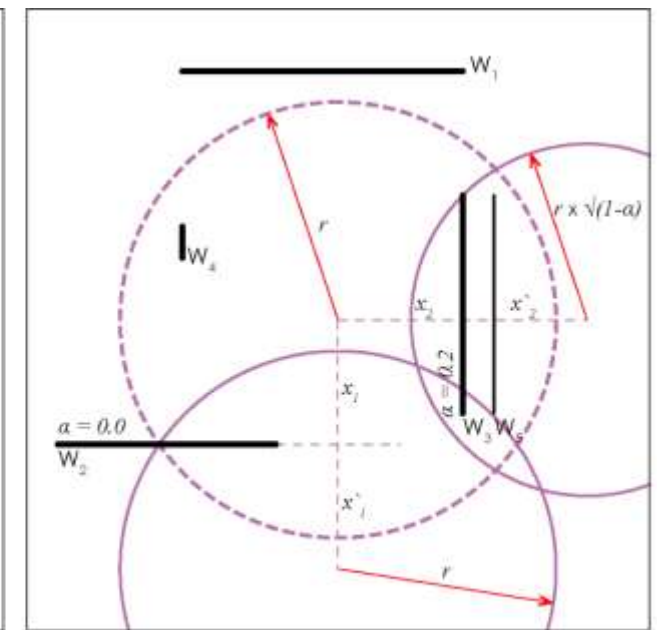
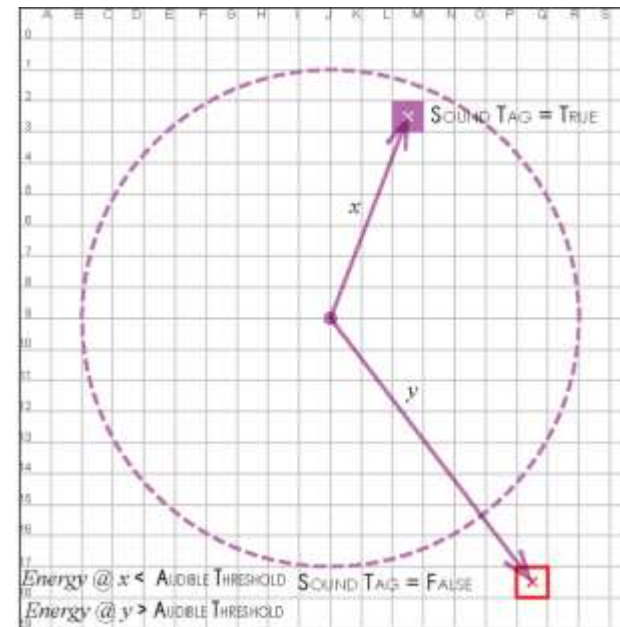
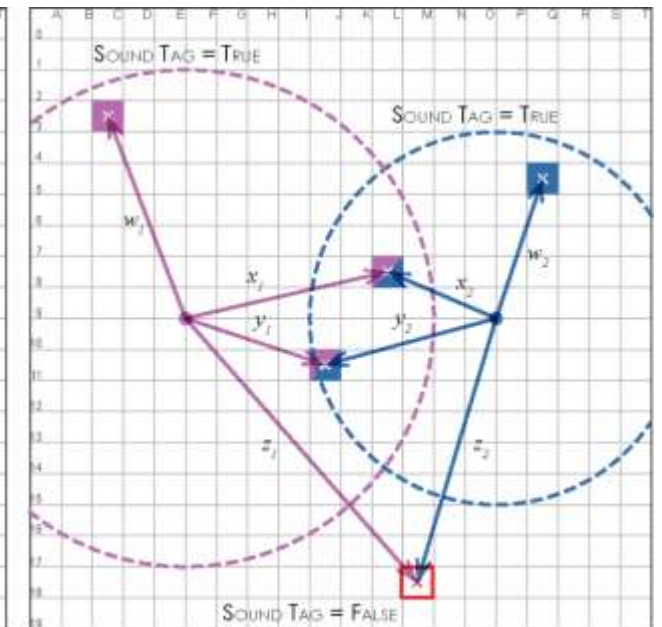


IMAGE SOURCE METHOD



SENSOR ACTUATION



SENSOR DECISION

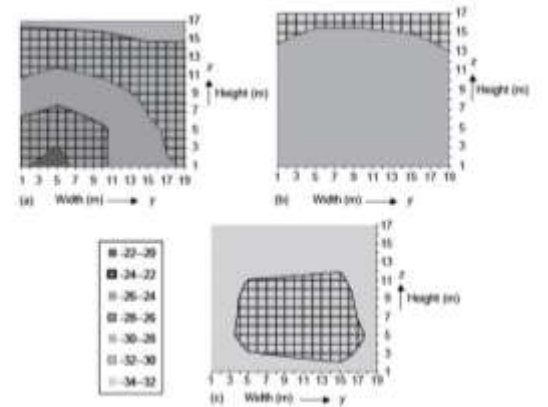
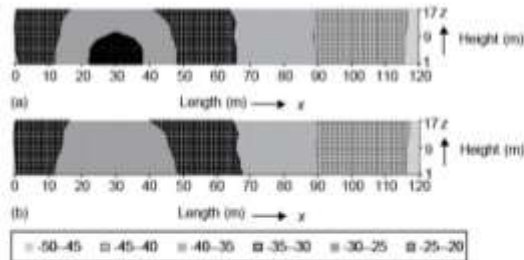
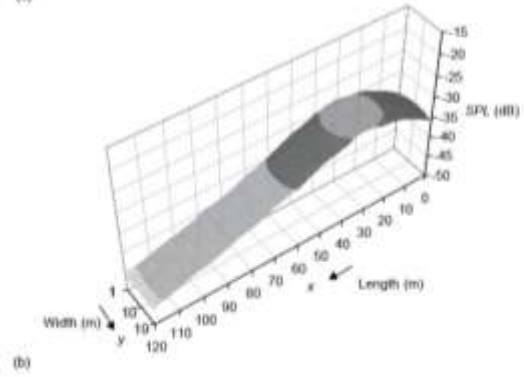
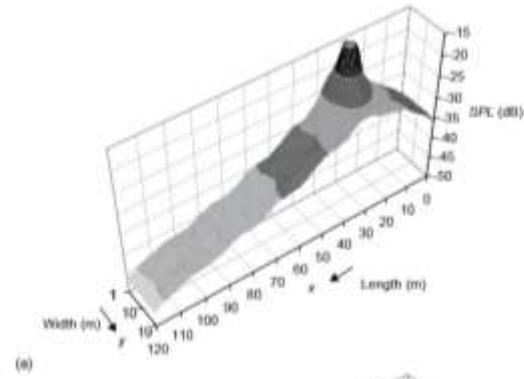
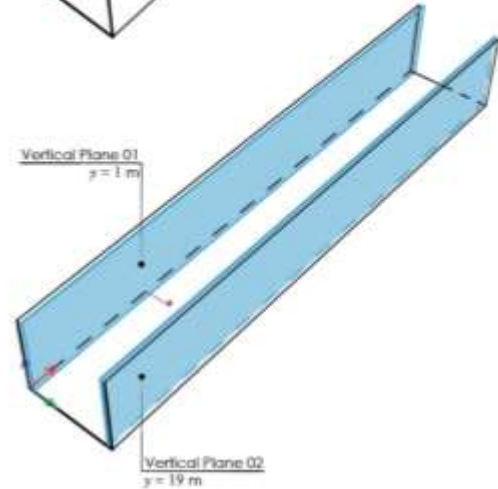
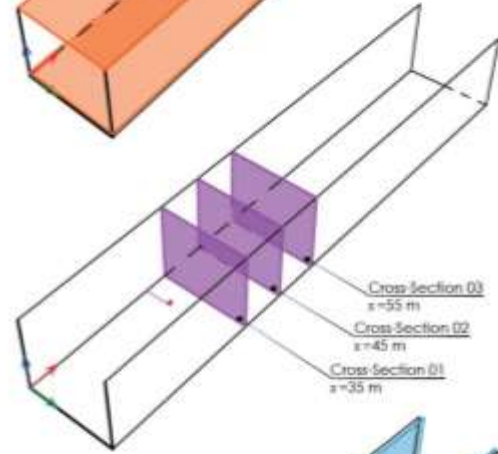
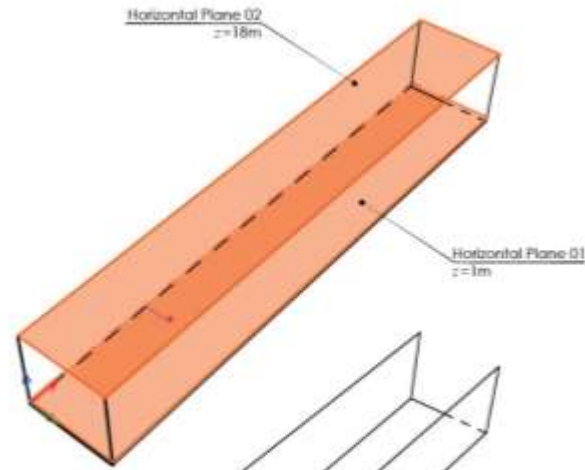
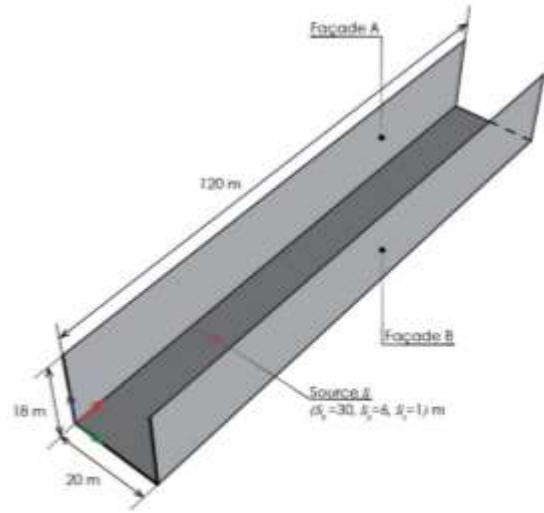
Model Verification



Street Canyon



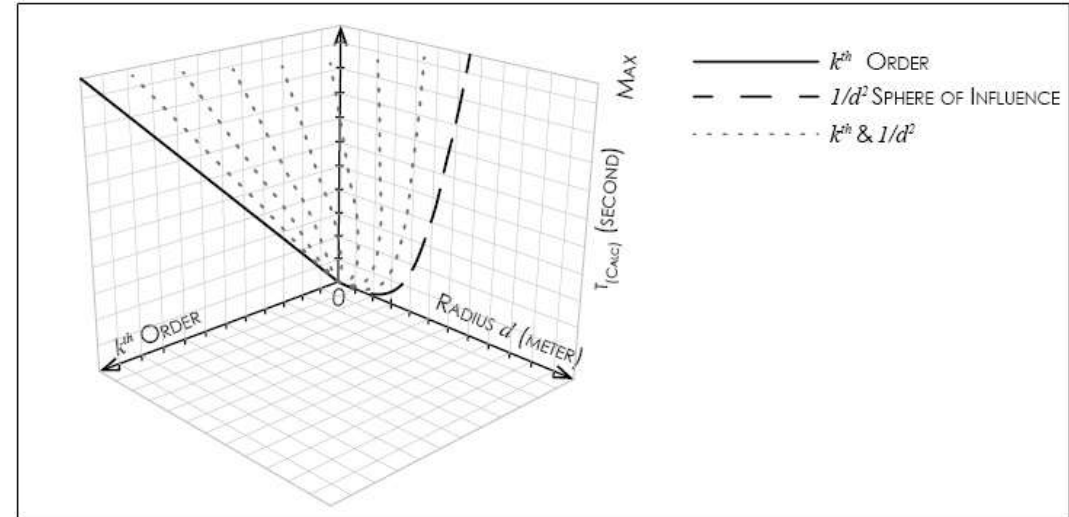
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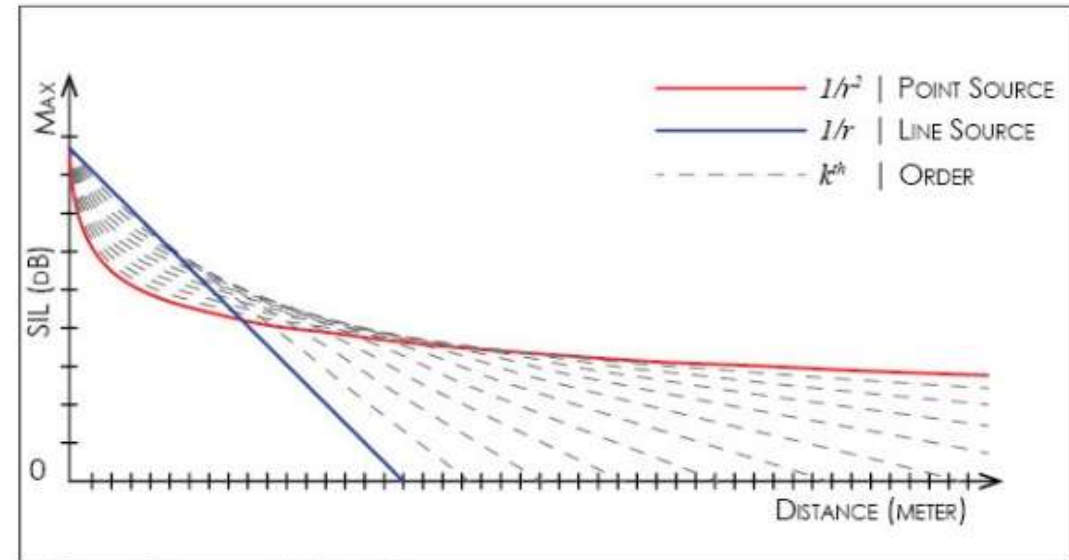
Towards Sonic Urban Morphologies

Expected Increase in Computation time & Divergence From Inverse Square Law

- Acoustic Impedance
- Sound-To-Noise Ratio (SNR) | Ambient Background Sound Level
- Frequency Dependent Attenuation
- Audible threshold
- Image Source order to the k^{th} order
- Façade Absorption Coefficient ($\alpha = 0$ to 1)

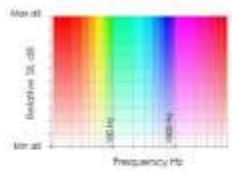
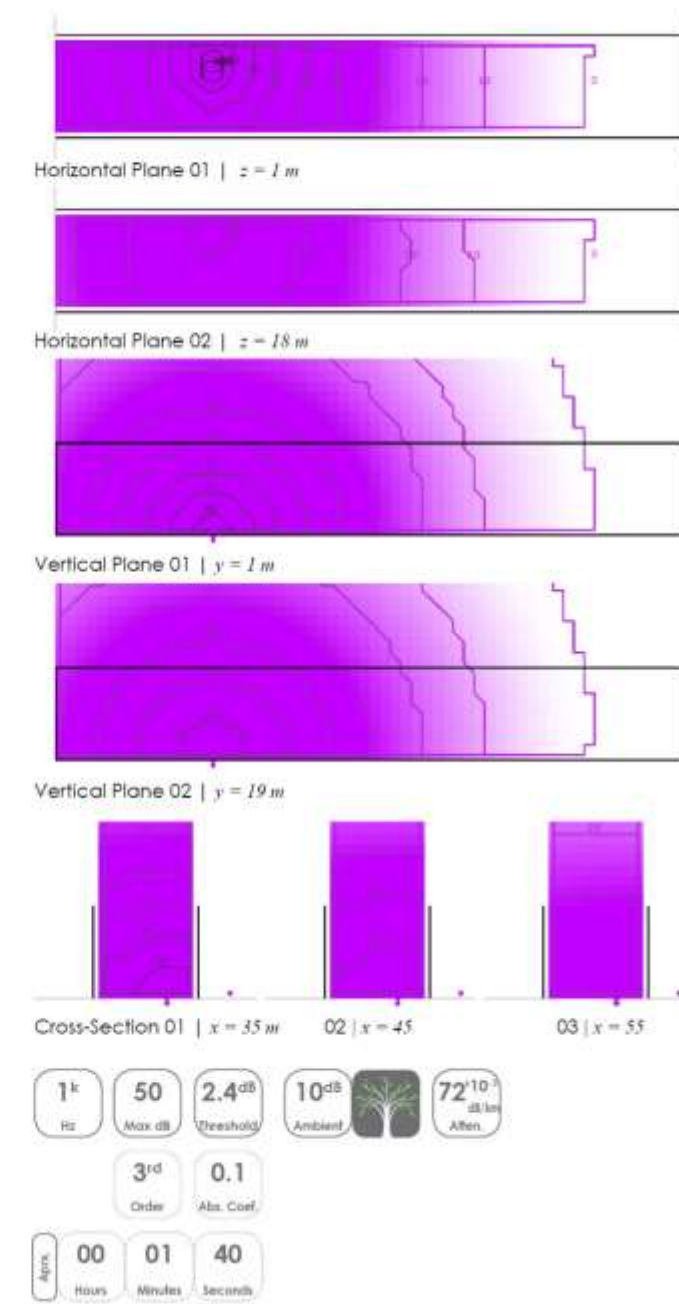
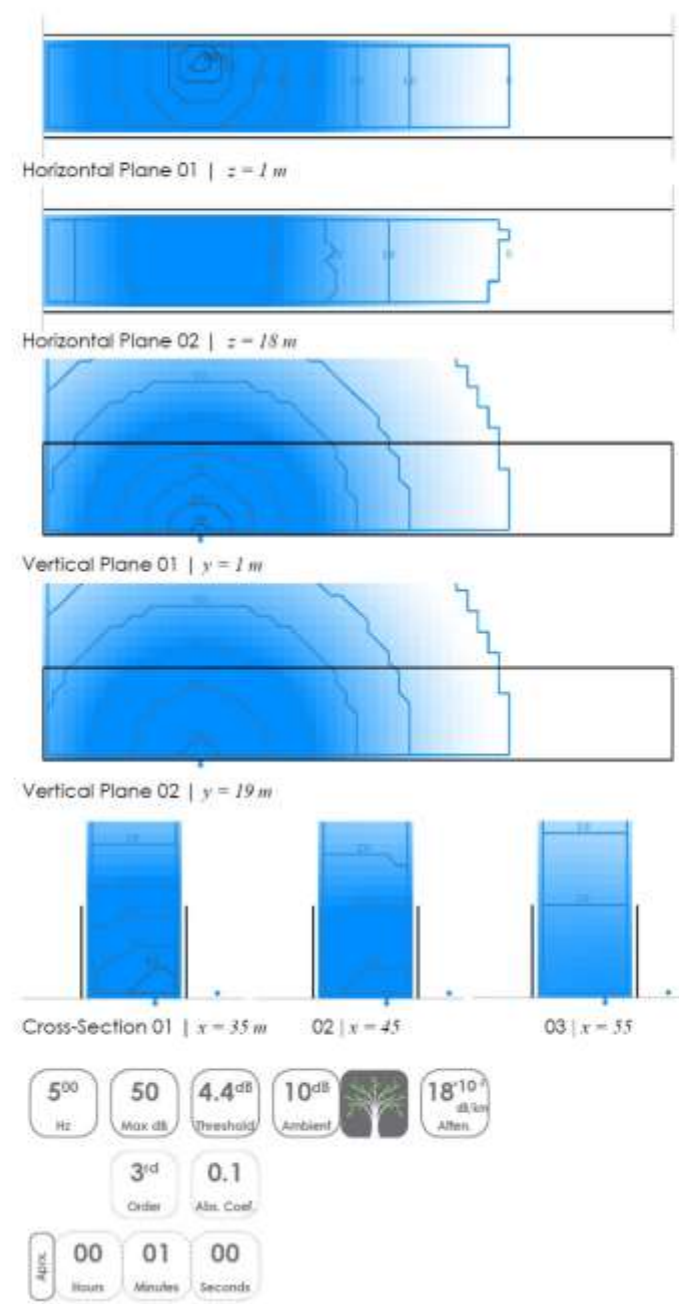
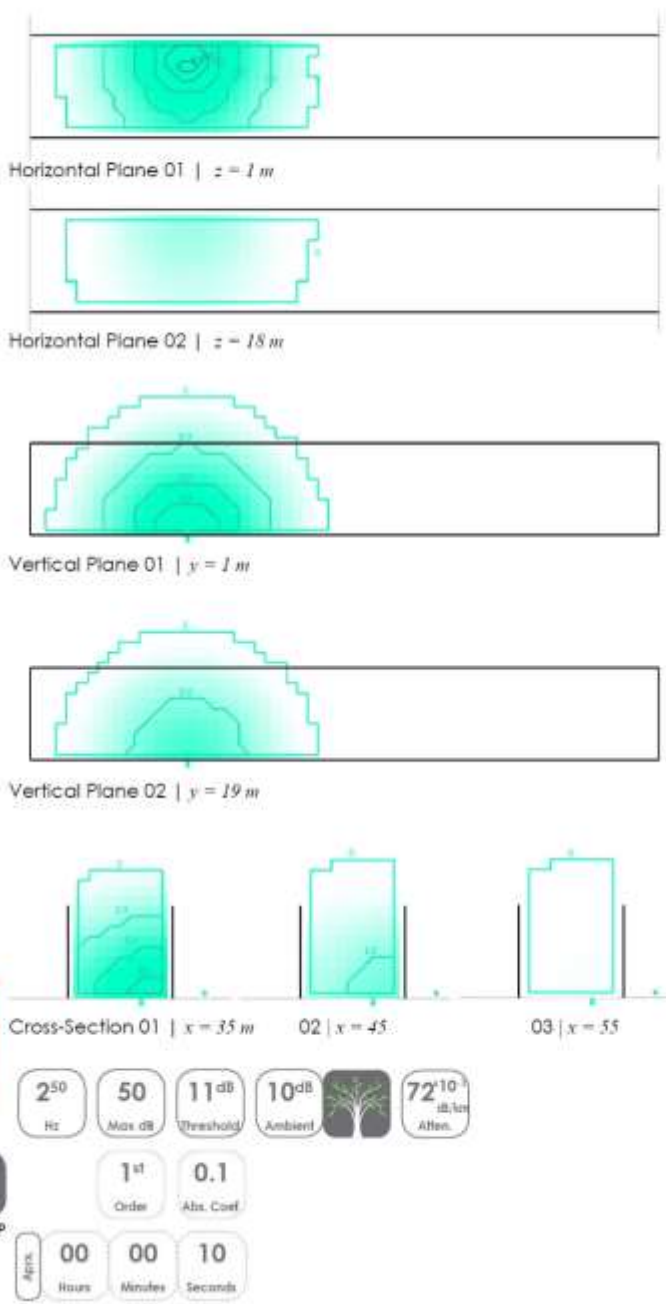


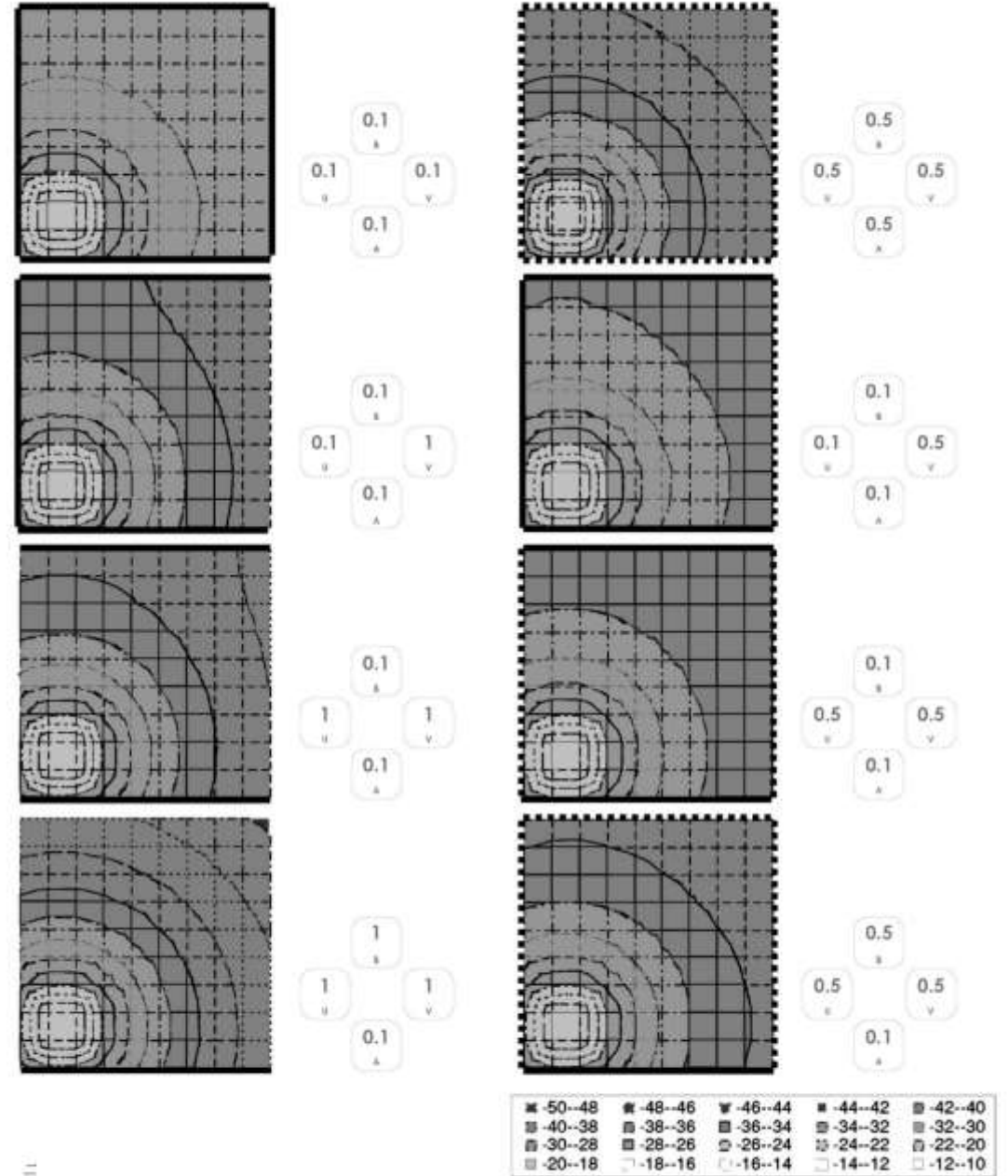
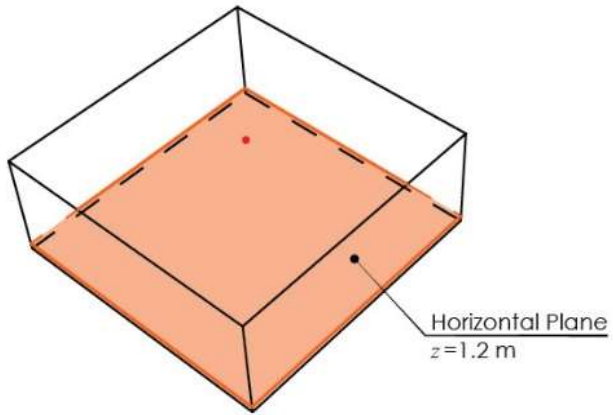
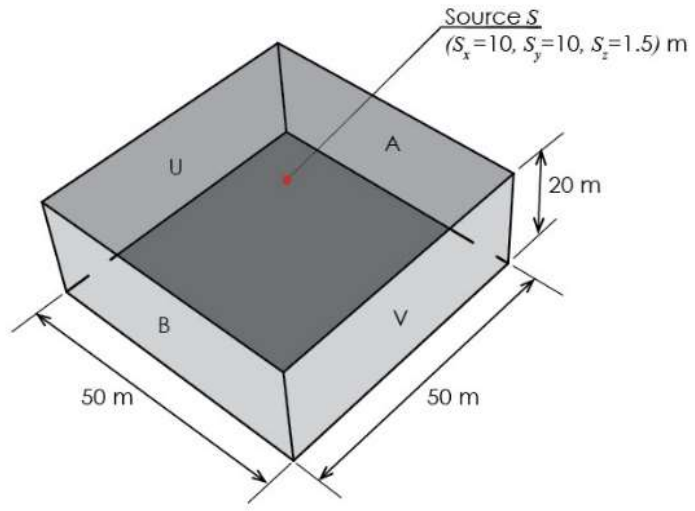
COMPUTATION TIME



POINT SOURCE | LINE SOURCE

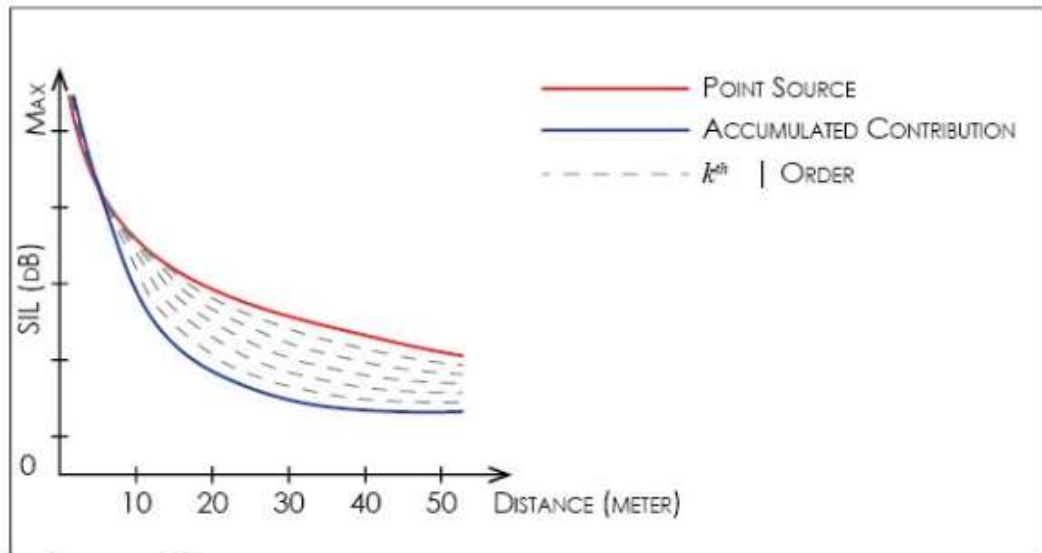
Street Canyon



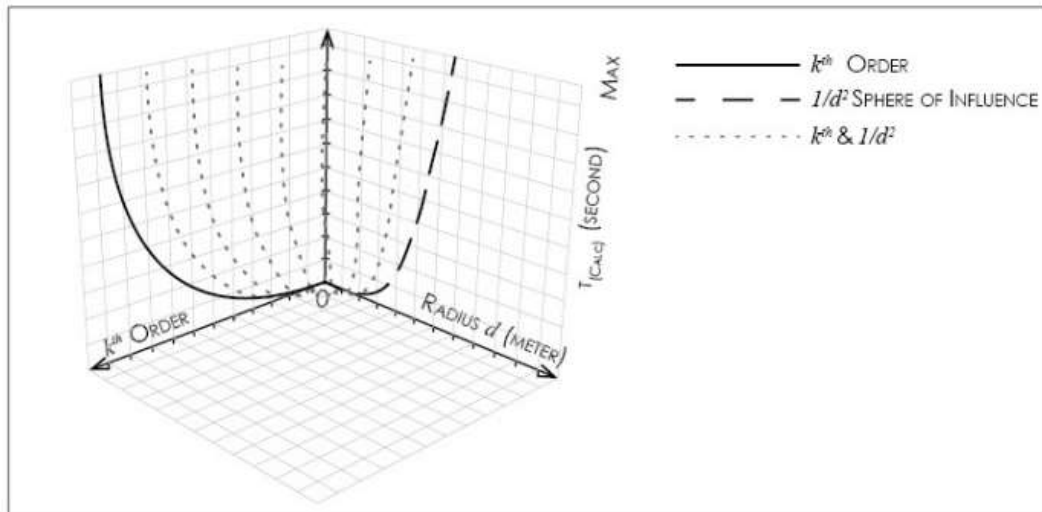


Expected Increase in Computation time & Divergence From Inverse Square Law

- Acoustic Impedance
- Sound-To-Noise Ratio (SNR) | Ambient Background Sound Level
- Frequency Dependent Attenuation
- Audible threshold
- Image Source order to the k^{th} order
- Façade Absorption Coefficient ($\alpha = 0$ to 1)



ENERGY DISTRIBUTION

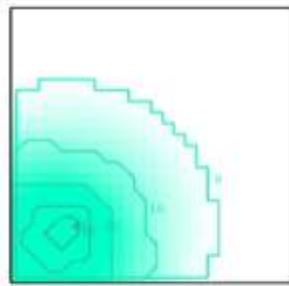


COMPUTATION TIME

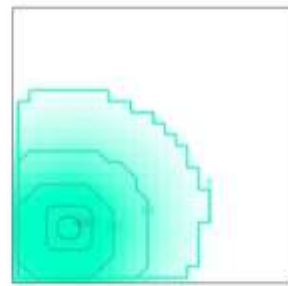
Urban Square



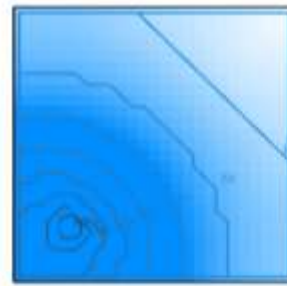
04/02/2016 21:48:29



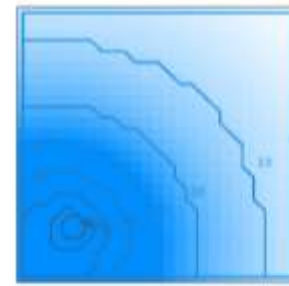
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 U V
 0.1
 A



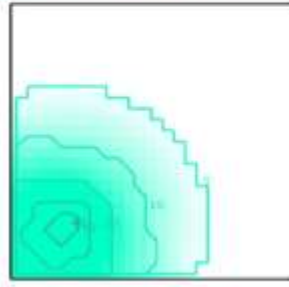
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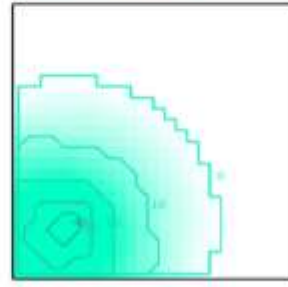
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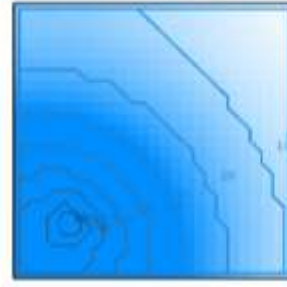
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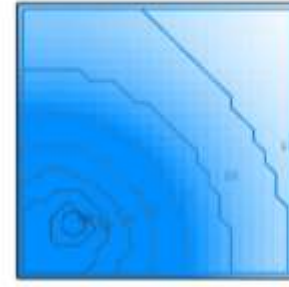
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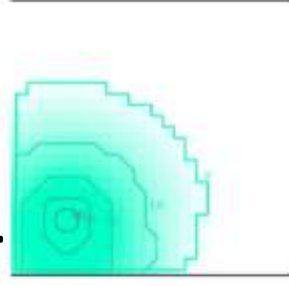
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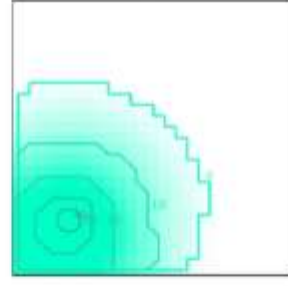
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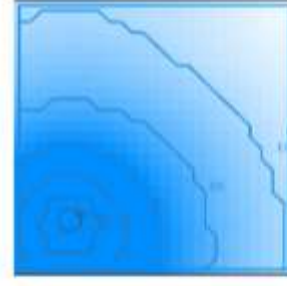
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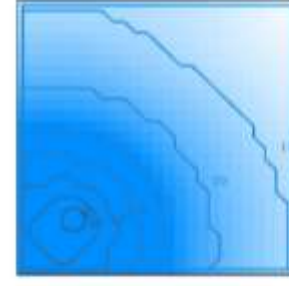
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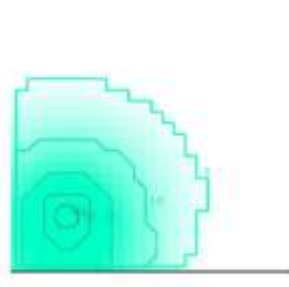
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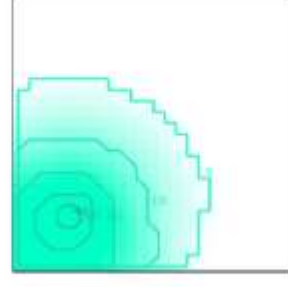
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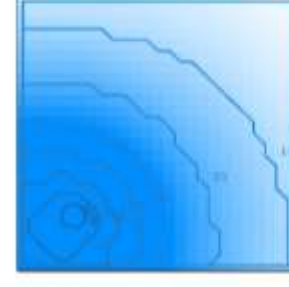
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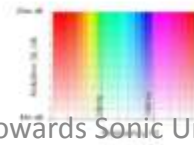


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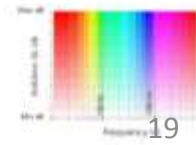


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 A

2nd Order 50 Max dB 72¹⁰ dBA Leq 11dB (Trenschlo) 10^{dB} Ambient 2/2 Grid Size m 1.70/1.30 Felt Size m 10^{dB} Isokw Step



5th Order 50 Max dB 18¹⁰ dBA Leq 4.4dB (Trenschlo) 10^{dB} Ambient 2/2 Grid Size m 1.70/1.30 Felt Size m 10^{dB} Isokw Step

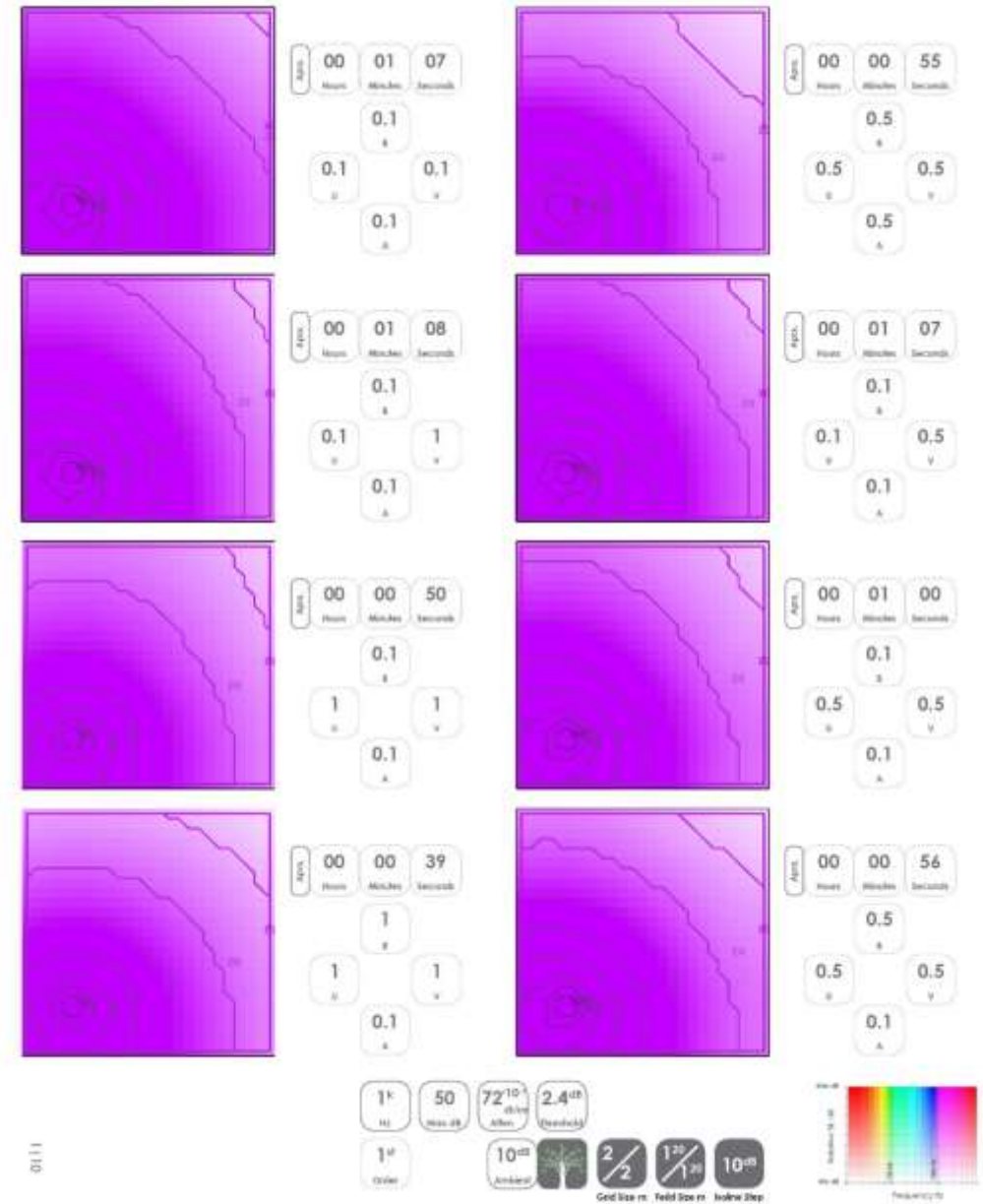
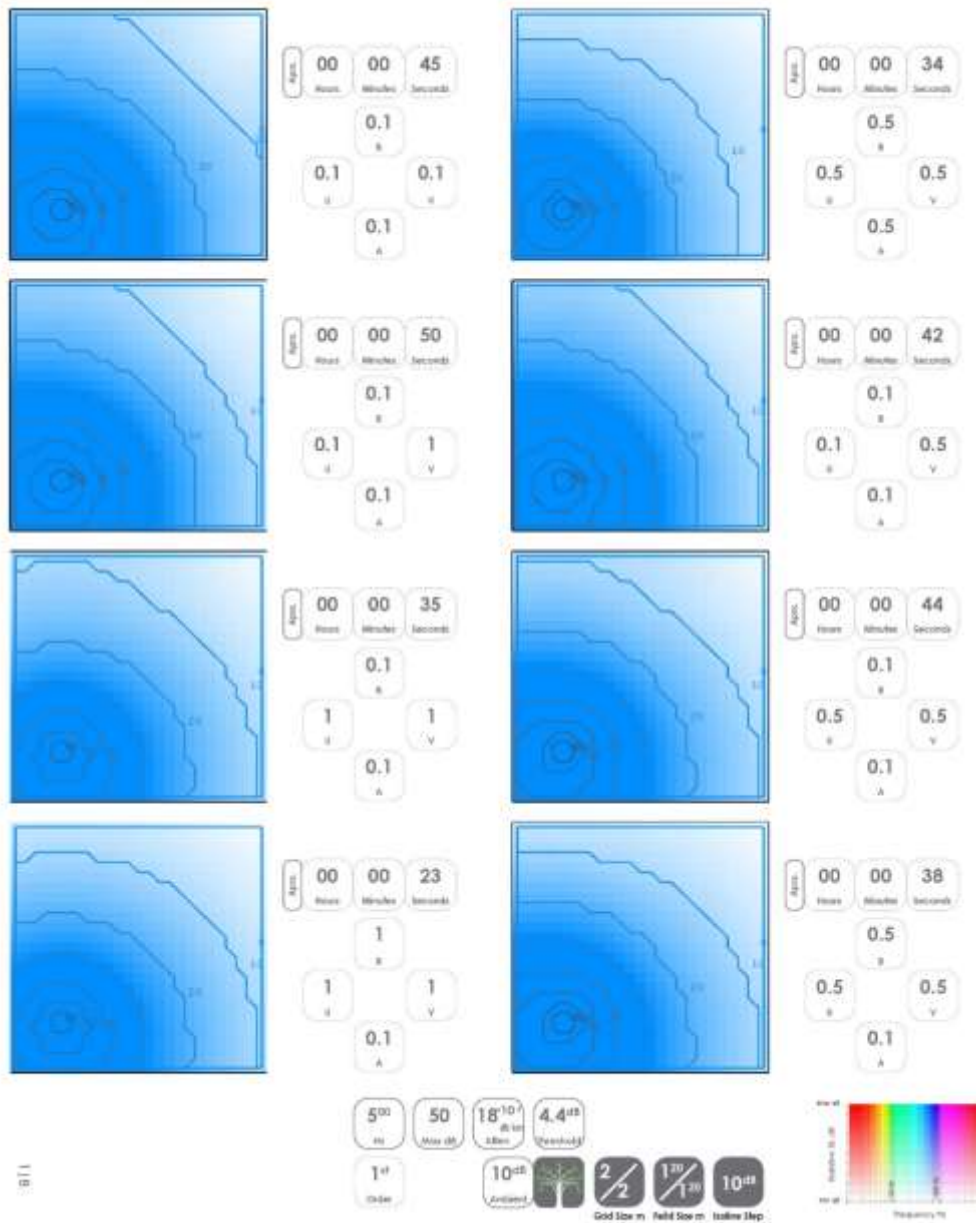


Towards Sonic Urban Morphologies

Urban Square



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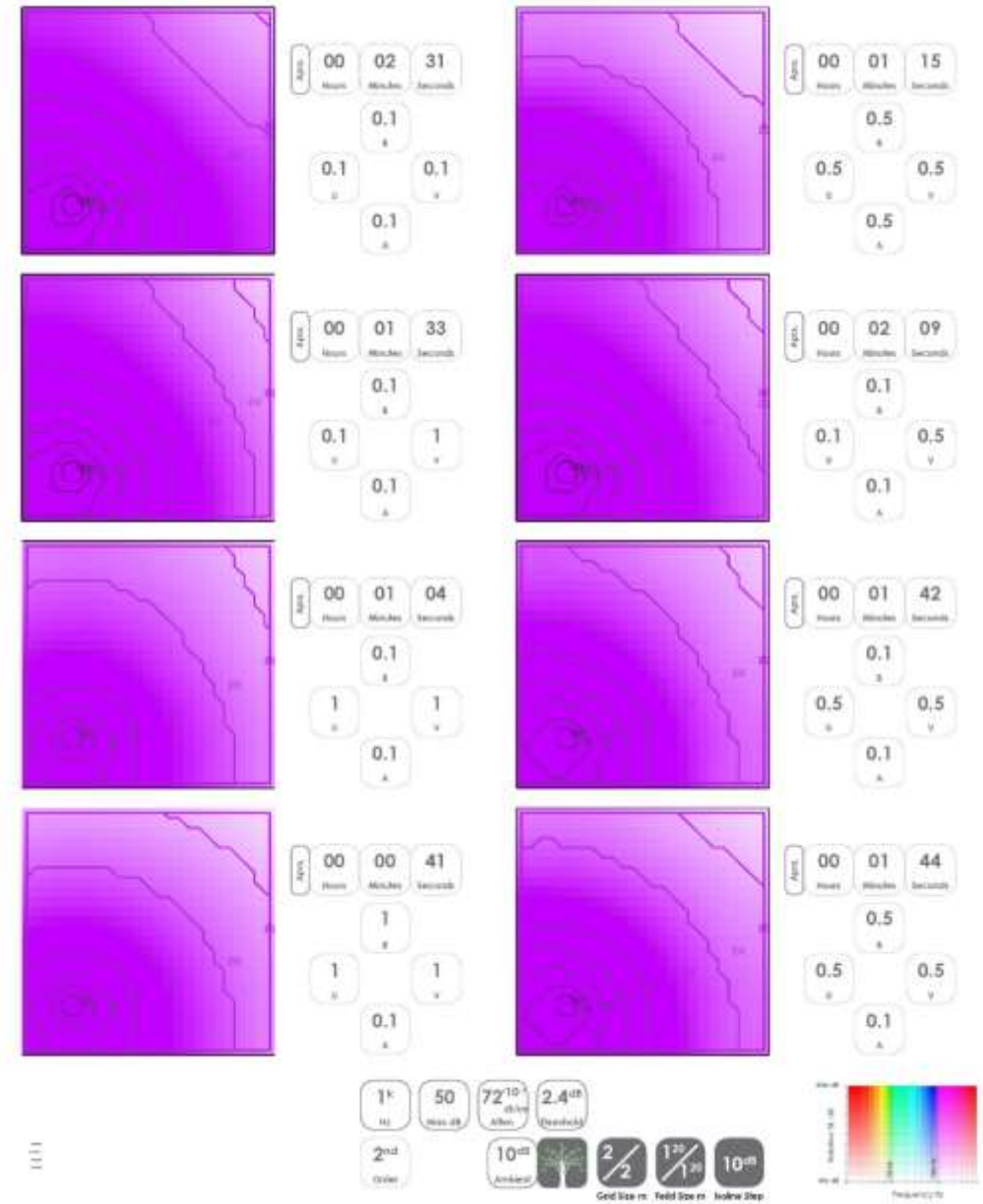
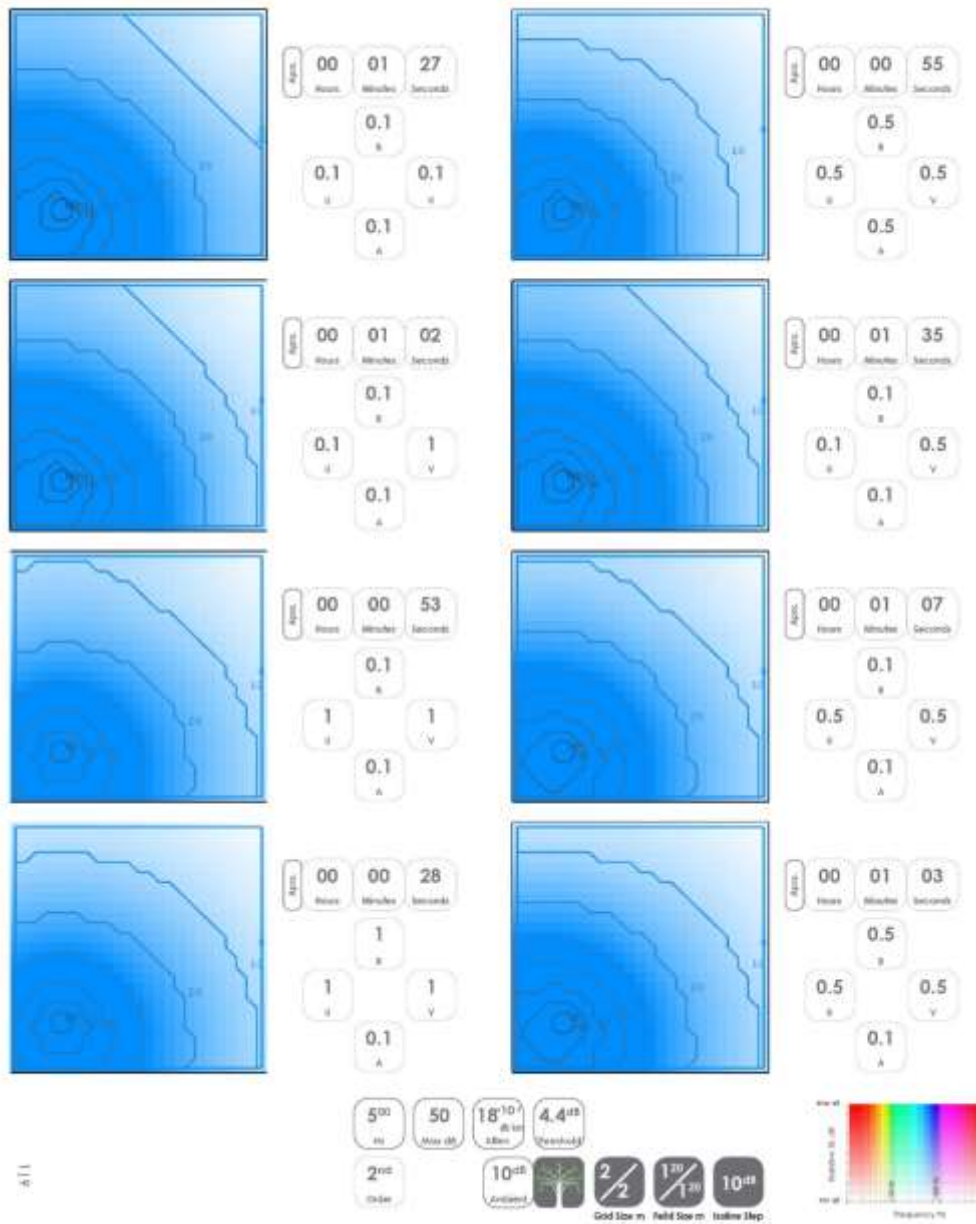


Towards Sonic Urban Morphologies

Urban Square



04/02/2016 21:48:29

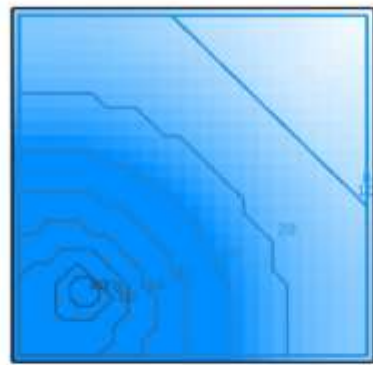


Towards Sonic Urban Morphologies

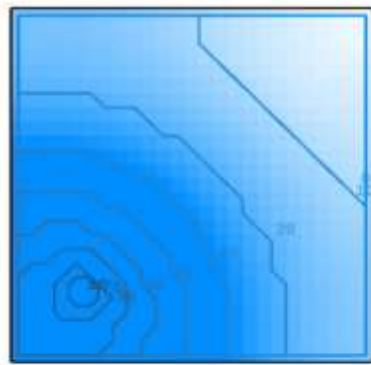
Urban Square



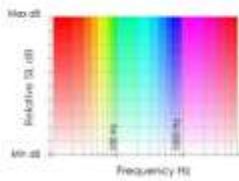
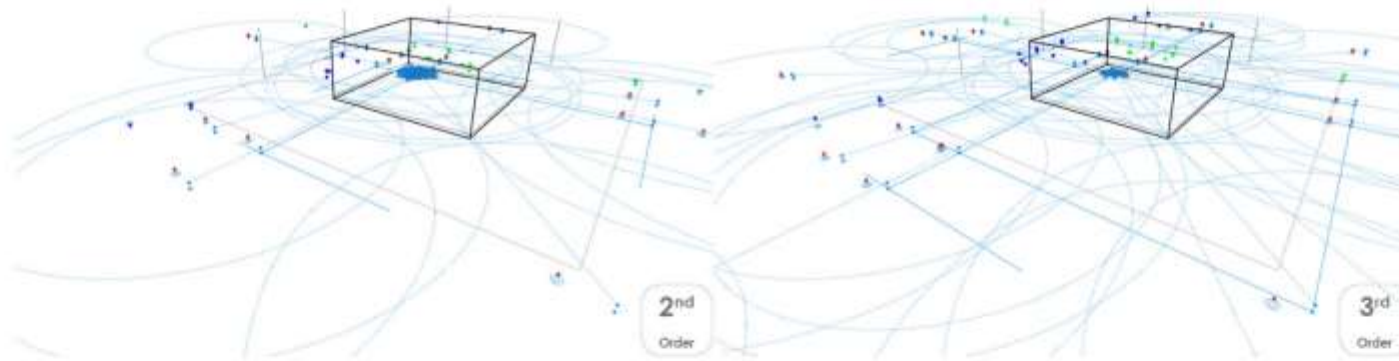
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Approx. 00 01 27
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 u
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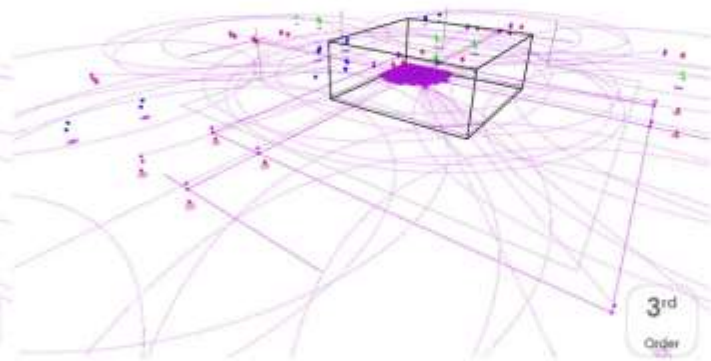
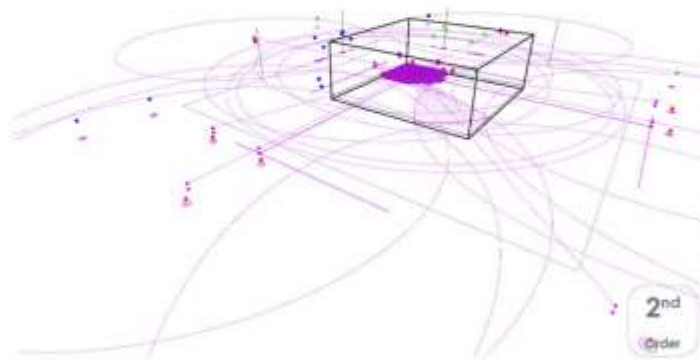
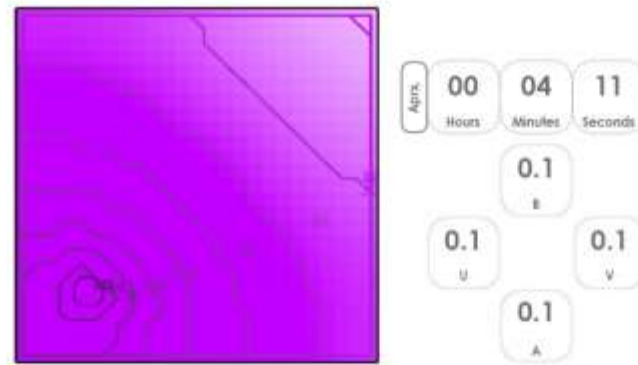
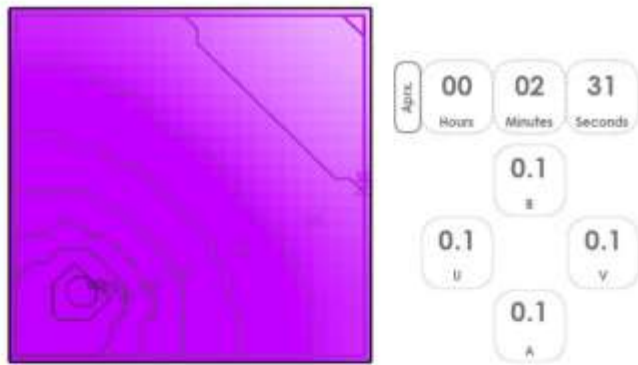
Approx. 00 03 02
 Hours Minutes Seconds
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 A



2/2 Grid Size m, 1²⁰/1²⁰ Field Size m, 10 dB IsoLine Step, 5⁰⁰ Hz, 50 Max dB, 18^{10⁻³} dB/km Atten., 4.4 dB Threshold

10 dB Ambient, 2/2 Grid Size m, 1²⁰/1²⁰ Field Size m, 10 dB IsoLine Step

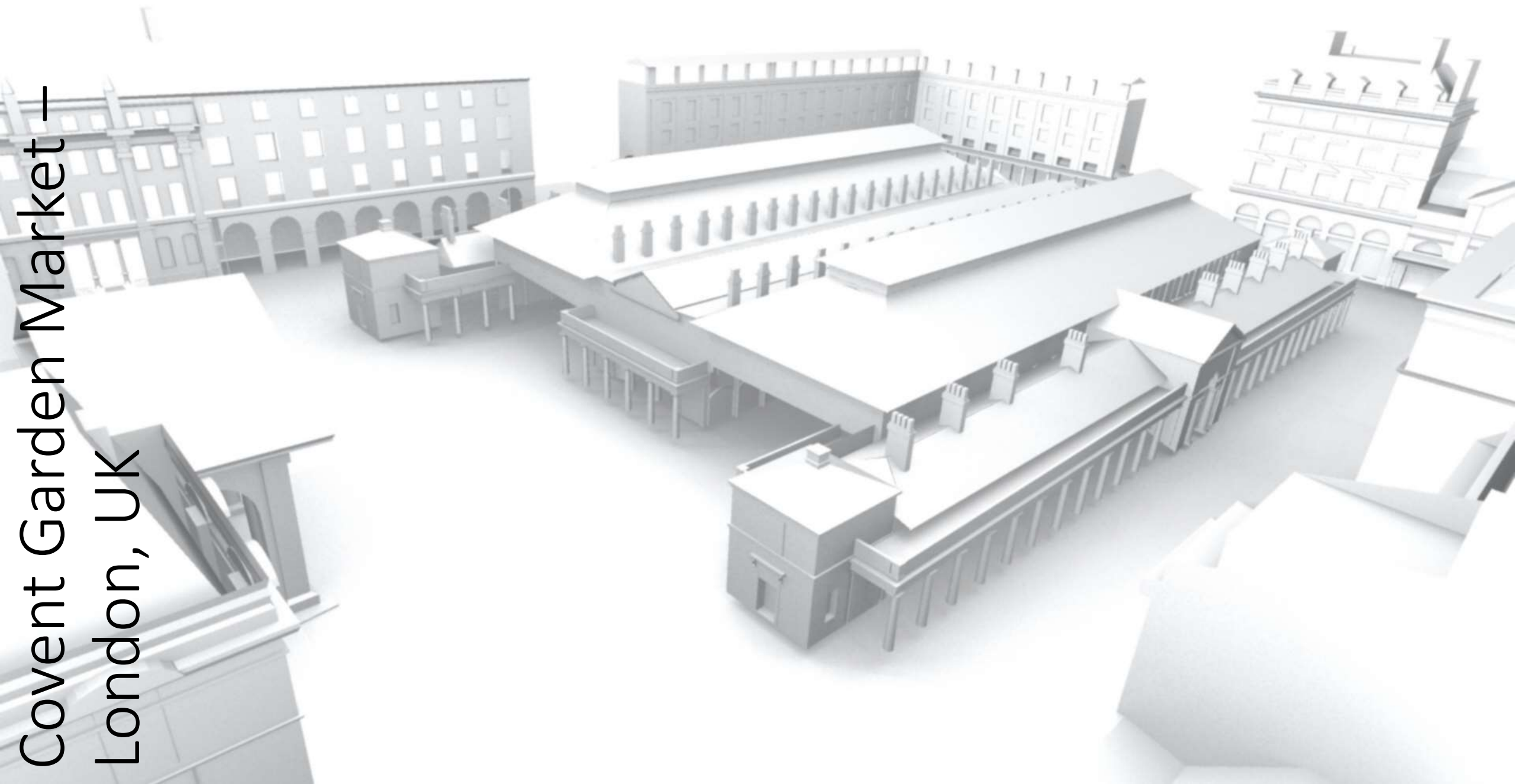
Towards Sonic Urban Morphologies



Concept Validation



Covent Garden Market –
London, UK





音乐

The music of the guqin is a traditional Chinese instrument. It is a plucked zither with seven strings. The guqin is often used to play classical Chinese music. It is a symbol of the Chinese literati and is often associated with the Confucian ideal of the scholar. The guqin is also used in modern Chinese music. It is a beautiful and expressive instrument.



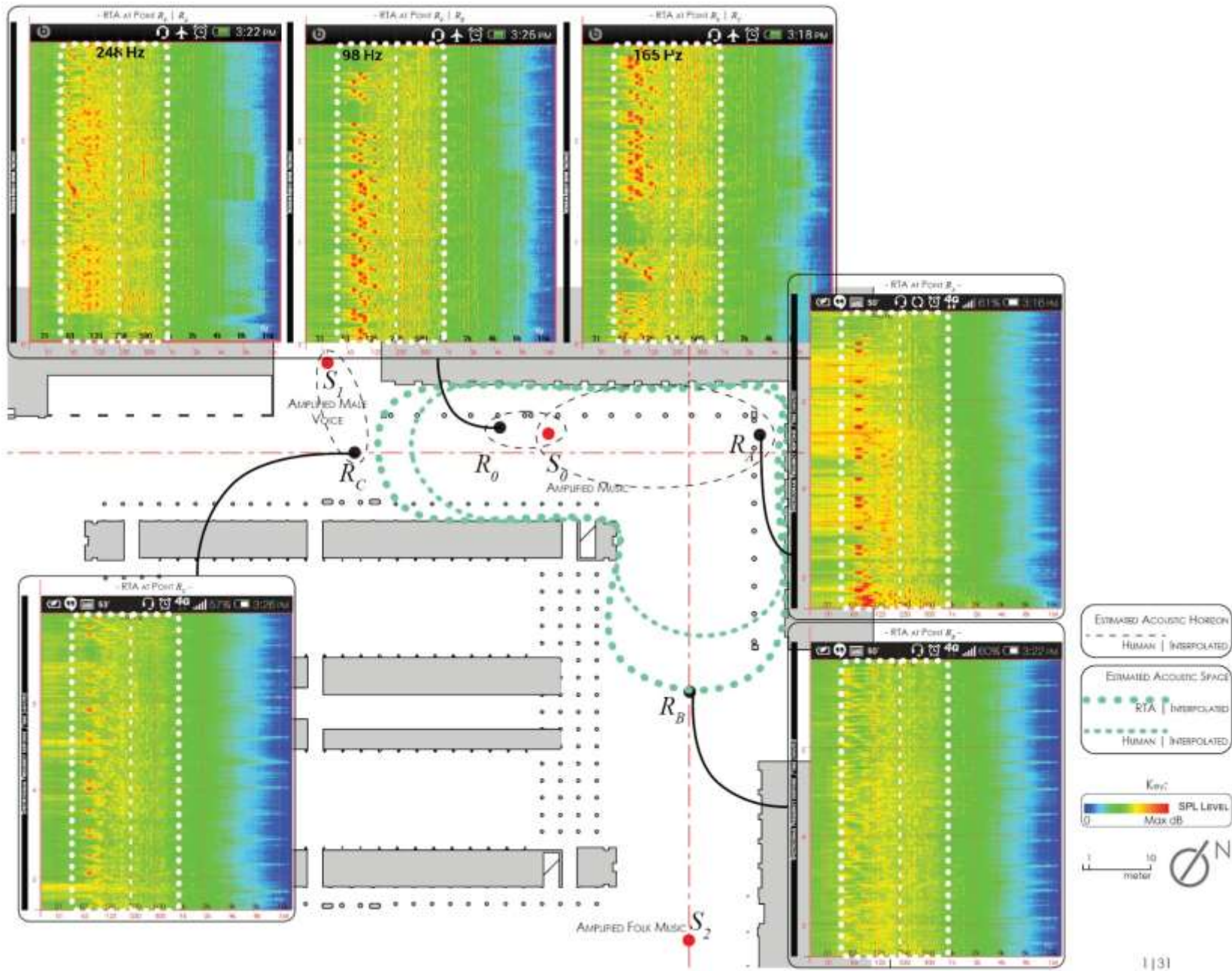
Real-Time Analysis (RTA)



RTA Analysis



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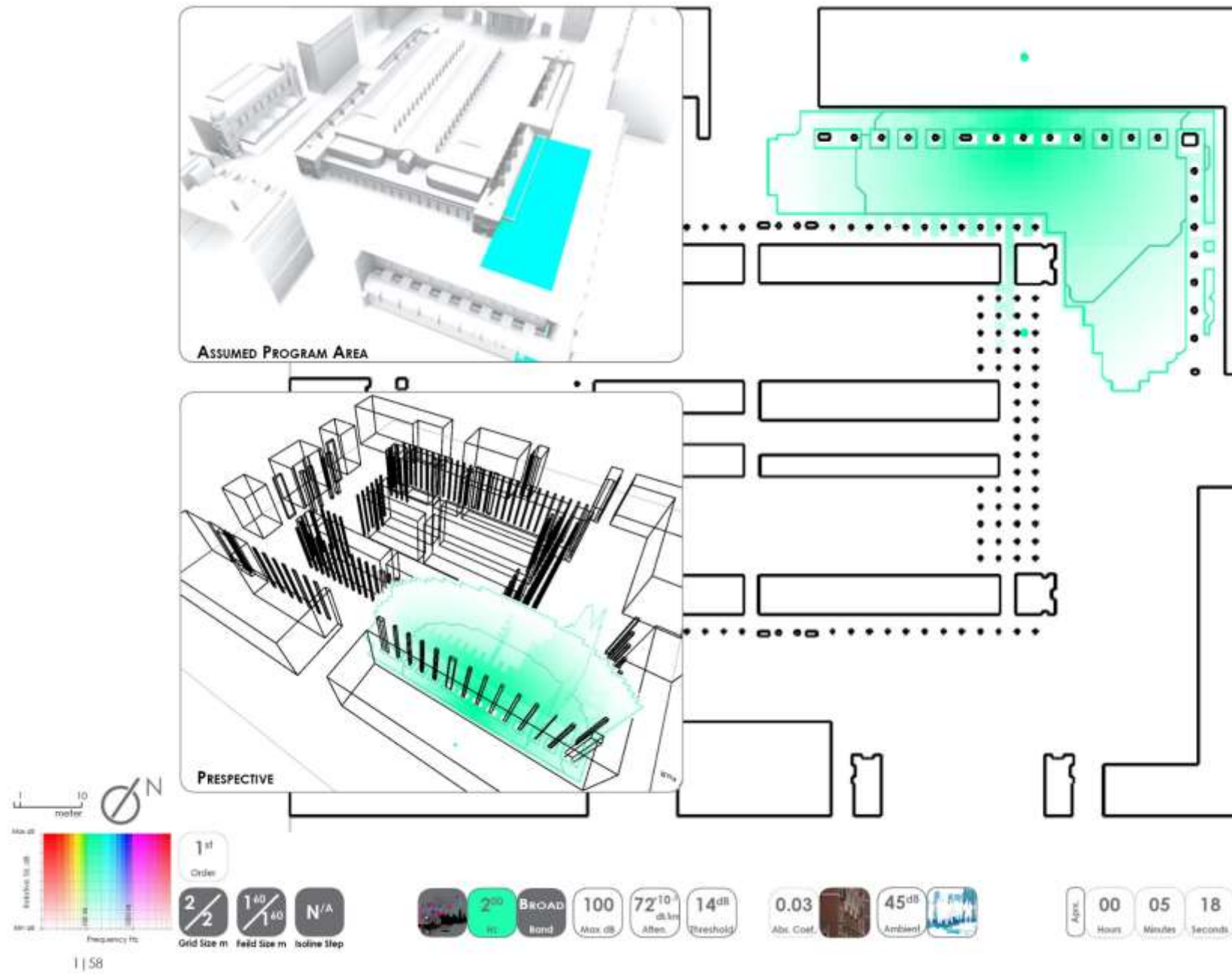


1131

One Sonic Event



04/02/2016 21:48:29

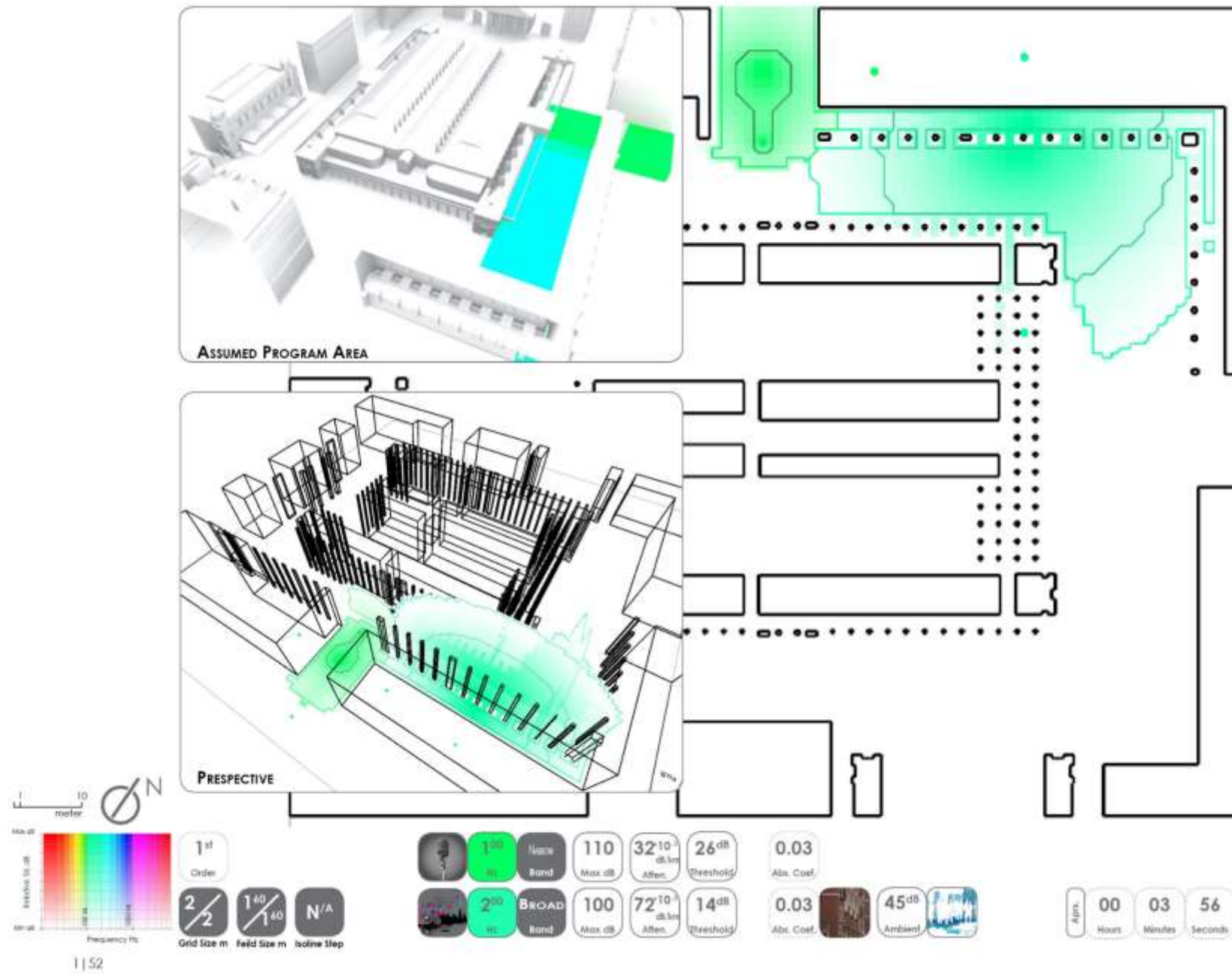


Towards Sonic Urban Morphologies

One Auxiliary Event

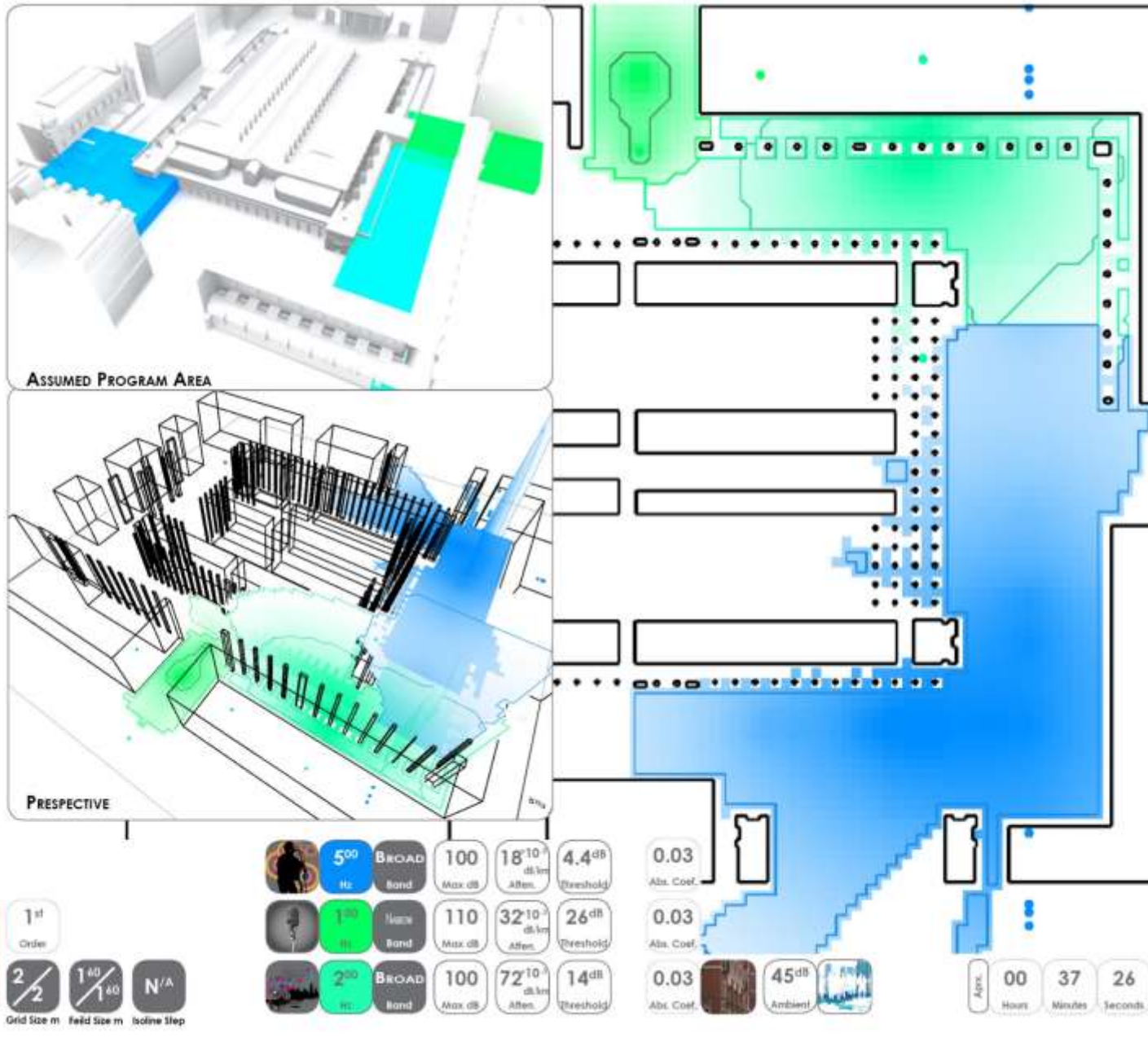


04/02/2016 21:48:29



Towards Sonic Urban Morphologies

Two Auxiliary Events



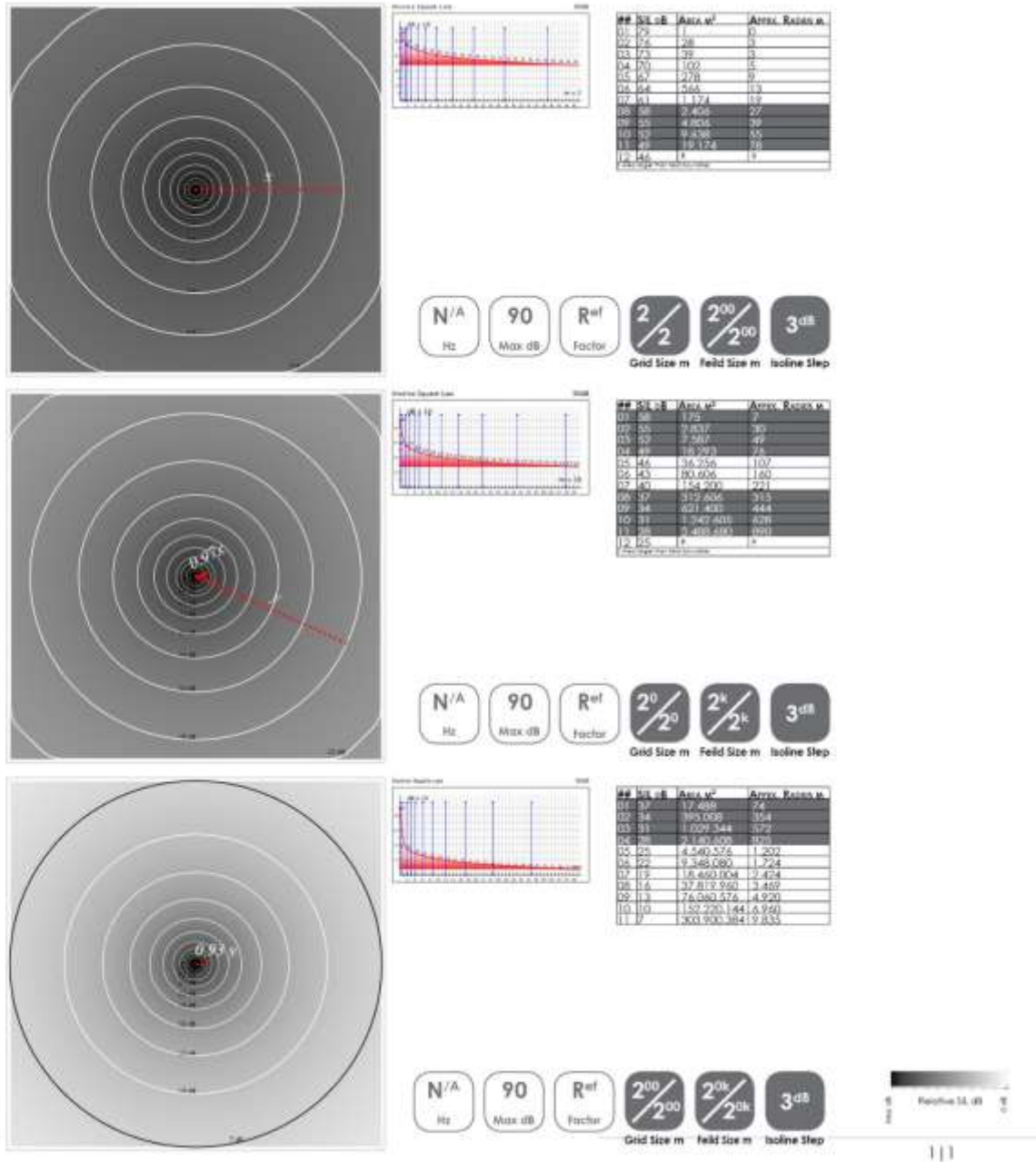
Limitations | Future Work



Grid Resolution



04/02/2016 21:48:29

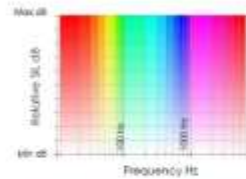


Towards Sonic Urban Morphologies

Computation Time



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500 Hz
50 Max dB
5th Order
0.1 Abs. Coef.
00 Hours
17 Minutes
02 Seconds

Horizontal Plane 01 | $z = 1 m$

Horizontal Plane 02 | $z = 18 m$

Vertical Plane 01 | $y = 1 m$

Vertical Plane 02 | $y = 19 m$

Cross-Section 01 | $x = 35 m$

02 | $x = 45$

03 | $x = 55$

Horizontal Plane 01 | $z = 1 m$

Horizontal Plane 02 | $z = 18 m$

Vertical Plane 01 | $y = 1 m$

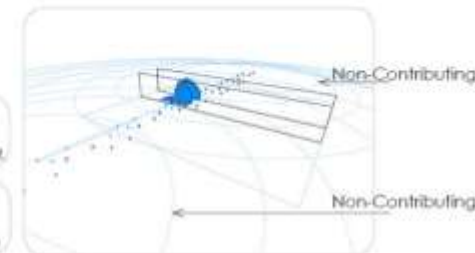
Vertical Plane 02 | $y = 19 m$

Cross-Section 01 | $x = 35 m$

02 | $x = 45$

03 | $x = 55$

500 Hz
50 Max dB
6th Order
0.1 Abs. Coef.
00 Hours
19 Minutes
46 Seconds

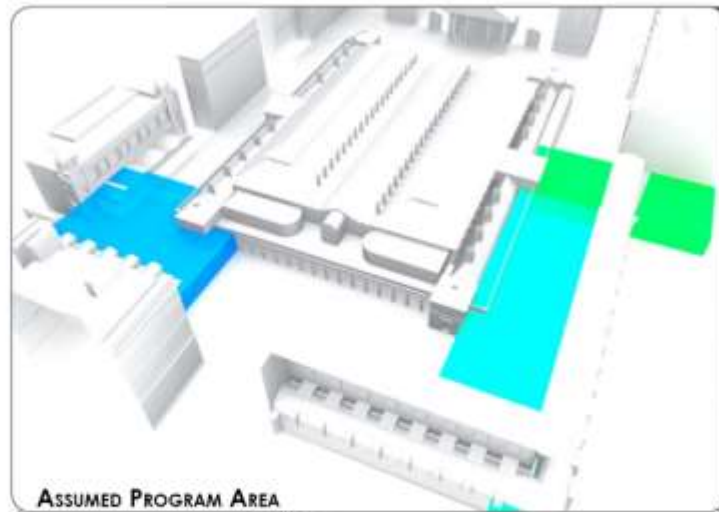


Towards Sonic Urban Morphologies

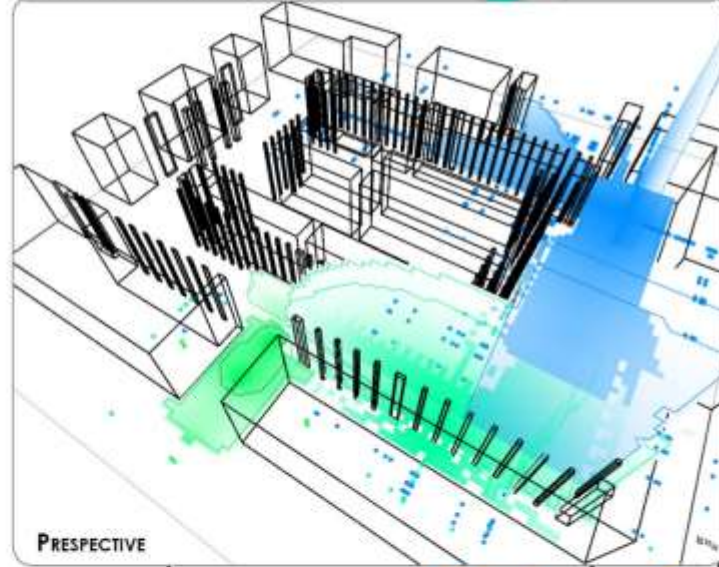
Urban Morphology



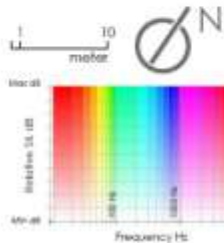
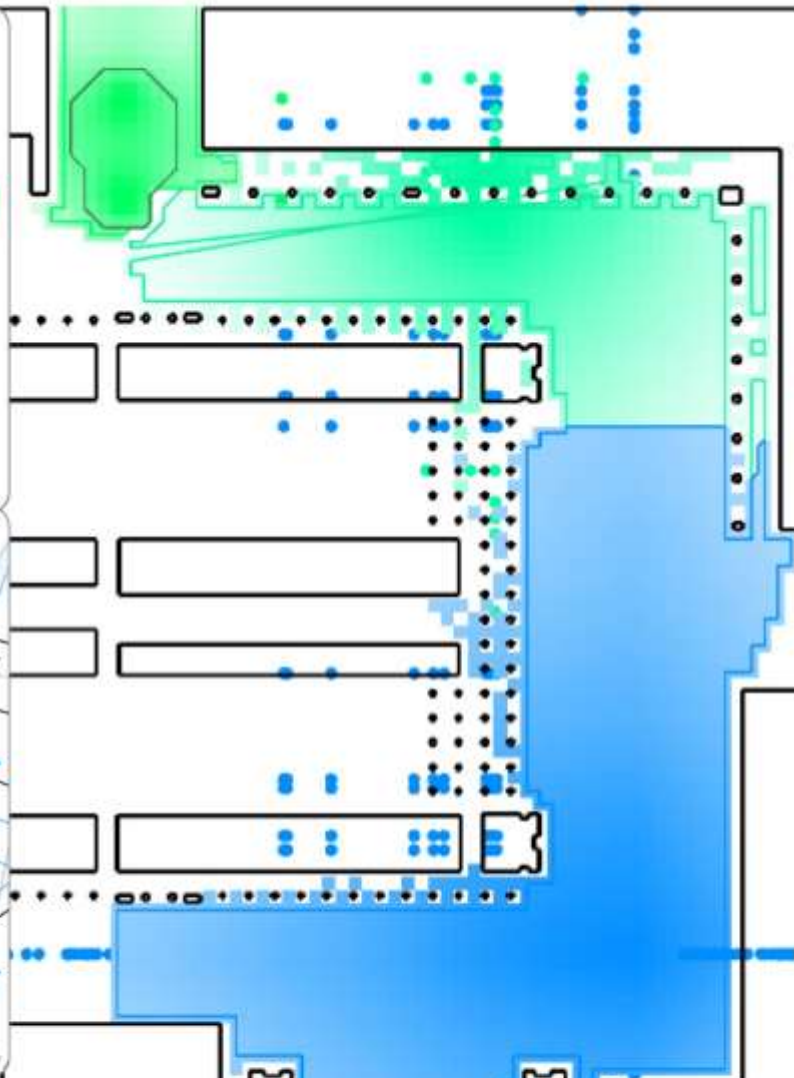
04/02/2016 21:48:29



ASSUMED PROGRAM AREA



PERSPECTIVE



2nd Order
 2/2 Grid Size m
 1.60/1.60 Field Size m
 N/A IsoLine Step

	500 Hz	BROAD BAND	100 Max dB	18 ^{10⁻¹} dB/km Affert.	4.4 dB Threshold	0.03 Abs. Coef.
	100 Hz	NARROW BAND	110 Max dB	32 ^{10⁻¹} dB/km Affert.	26 dB Threshold	0.03 Abs. Coef.
	200 Hz	BROAD BAND	100 Max dB	72 ^{10⁻¹} dB/km Affert.	14 dB Threshold	0.03 Abs. Coef.

45 dB Ambient

Approx. 00 Hours 45 Minutes 31 Seconds

Towards Sonic Urban Morphologies