KILLING SOUND

Means of Controlling Sound in Public Space

Research Paper

Bachelor course on Media Technology
at St. Pölten University of Applied Sciences

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Declaration

- The attached research paper is my own, original work undertaken in partial fulfillment of my degree.

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Abstract

The following thesis deals about the means of controlling sound. Where are the human and technological boundaries to limit the sound in open air considering the various frequency bands? This work goes to the solid rock bottom of how and why we perceive frequencies like we use to.

While the first part focuses on the fundamental elements (creation and destruction) of acoustics, followed by an overview of contemporary technical progress, the emphasis is set on a journey to extraordinary locations where people cherish and enjoy a delightful experience through sound.

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1 Introduction

This work is presumably one the most interesting piece of paper you will ever hear of, or is it not? While you are reading these words, you are simultaneously hearing a voice inside of your head reciting this text. Can you hear whether it is your voice or somebody else's?

This experiment was just to demonstrate how silent sound can be. Even a silent room is not completely silient considering that every single place on earth has different sonority and impulse response. Therefore, depending on which space somebody is located, there is a special sound of silence (e.g. a giant hall, in the mountains, the dark room, or an old dirty Irish pub etcetera).

From an opposite point of view, sound creates the space where the people are.

Like it has always been the case human beings try to control the habitat for their own comfort. This research paper deals with the means of controlling sound in public space. What are the possibilities of keeping sound locally and which ways of futuristic technologies are available to enjoy sound at maximum level within the boundaries of the event and how to kill the noise from inside out.

2 Working with Sound

This chapter focuses on the prerequisites for making a sound and about the origins of listening.

2.1 Creation and Perception of Sound

Many ancient cultures (e.g. Hindus, Mayans, Polynesians, etc.) believe that sound created our universe. Scientifically we cannot prove the theory, that the universe is litterally created by sound.

What we do know is how sound works. Sound is often described as a vibration of a medium within a frequency the human ear is able to recognize. It is used for the transfer of information what is also well known as communication. The figure below describes an ordinary communication flow.

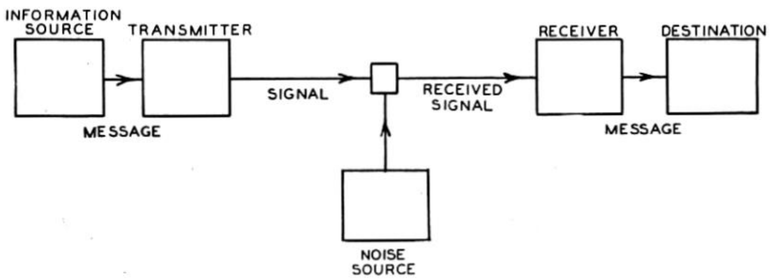

Figure 1. Shannon-Weaver modell of communication.

"The ear is – compared to the eye – not easy to close. Whether we want or not, the ear is automatically part of every perception" (Raffaseder, 2010, translated by author).

That means it is difficult avoid hearing if there is sonic available. The following chapters deal with sonic waves and how to kill or influence them without harming parts of the hearing organ, the precious ear.

2.2 Wavelength

In case of describing a sound in the 21st century, there are two major ways which are part of the fundamentals of acoustics. On the one hand we have frequency, and on the other hand we have the wavelength.

$$\lambda = c/f$$

λ… wavelength Lambda [m]
c… velocity of wave propagation [m/s]
f… frequency [Hz]

The wavelength indicates the position of the zero amplitudes of the algebraic function. Here is a simplified example to show the correlation between Lambda and the frequencies based on the harmonics of a stretched string aka. guitar:

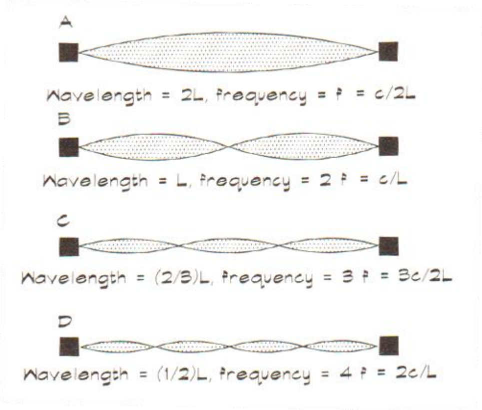

Figure 2. Harmonics of a Streched String.

2.3 Frequency Spectrum (Classification)

In terms of audio our cognitive frequency spectrum, we are designated to hear from 20 Hz to 20 kHz. That equals wavelengths within the range of 2 cm and 20 m. The spectrum of course goes far below and beyond this but it does not need to be considered because of the limited perception of the human ear outside of this range (e.g. radio waves, micro waves, light waves, infrasonic, ultrasonic, radioactive waves, magnetic/electromagnetic waves etc.)

By means of an equalizer it is possible to digitally modify the audible frequency spectrum. A 10-band equalizer subdivides the audible frequency range (20-20000Hz) into ten equal segments. Every segment is assigned with a fader for each frequency band. By the means of a graphical Equalizer it is possible to take out (kill) or boost a specific frequency by moving the designated fader. Other models are also available with eight, twenty-six or thirty-one faders.

There are a few different Equalizers used on various occasions or purposes. In the professional diskjockey sector the frequency band is subdivided in 3 parts, therefore, there are 3 potentiometers called HI, MID and LOW (which regulate the higher, middle and lower frequencies separately). DJanes and DJs all around the world use them for their elementary skills of mixing their tunes.

2.4 Filter

In the digital world electronic filters (or virtual filter simulations) are used to realize what is done by an equalizer in the front end. The most popular filters are high-pass (aka. low-cut), the low-pass (aka. high-cut) or the band-pass filter made out of RC-Elements (electronic components). Referring to quality Q of your band-pass you are able to silence any possible frequency out of your acoustic environment.

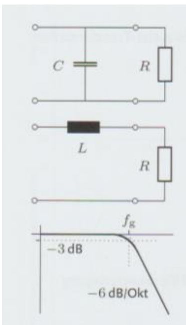

Figure 3. Low-Pass Filter in First-Order Mode (RC&CL) and the corresponding frequency response curve.

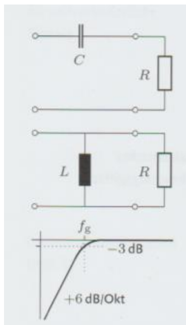

Figure 4. High-Pass Filter in First-Order Mode (RC&RL) and the corresponding frequency response curve.

In the modern world there are hardly any physical constructions which are literally meant to break the wavelengths of sound on purpose. Consequently digital filters are more efficient and dynamic from the economical perspective than real life audio filters.

2.5 Loudspeaker

Loudspeakers are nessesary to reproduce or amplify a sound. Most of them follow the principles of electromagnetism. A membrane is connected to a permanent magnet surrounded by a coil of wire which responds to electric signals. Whether the coil or the ferrite core moves the membrane, it is not doubted that the membrane produces the actual sonic by triggering the air with vibration (back and forth motion).

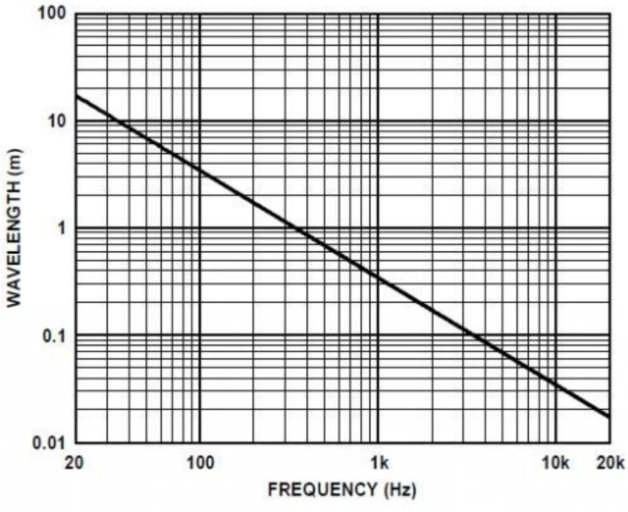

Figure 5. Frequency vs. Wavelength for Sound Waves in Air.

As it shows on *Figure 6* above, our auditory sensation is on a logarithmic diagram and the wavelength gets shorter with higher frequencies.

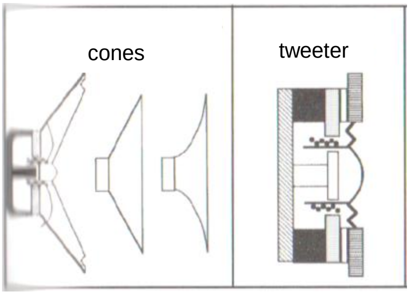

Figure 6. Loudspeaker Types.

Developing simple soundsystems it is quite easy to recreate tweeters (dome loudspeakers). Higher frequencies (HI) have litte oszillation of the air (compared to sub-woofers) and they do not need much energy to move the air.

"Cone loudspeakers are not particularly efficient sound radiators. Typically, they convert between 0.5 an 2% of the electrical energy to sound" (Long, 2006, p. 277).

Lower frequency (LOW) loudspeakers need a more sophisticated open/closed box to create sonic because there is a need to produce longer wavelengths and move more air.

In everyday life we distinguish coil and horn loudspeakers (see chapter 4.3.1 The Horn). Most soundsystems use both speakers and the wave band is separated. The separation is controlled by an electronic driver circuit which is implemented close to appropriate speaker by adequate audio engineers.

There are a few other loudspeakers which differenciate by the means of the vents of the boxing.

2.6 Binaural Beats

Binaural Beats are not beats such as drum patterns we usually use to hear when we listen to our preferred music. The target is to listen to a frequency that is lower than 30 Hz, the frequency of the brainwaves.

Referring to Capter 2.3 it is already known that a human being is not able to hear outside of the audible range. Binaural Beats use mathematical addition respectively the method of subtraction to make this possible. Imagine that the left ear listens to a frequency e.g. 300 Hz and the right ear gets another frequency e.g. 305 Hz. The brain works in the function of an algebraic adder and subtracts:

$$305 \text{ Hz} - 300 \text{ Hz} = 5 \text{ Hz}$$

Altough it is impossible to hear 5 Hz in everday life, simple mathematics are used to trick the the brain into hearing extremely low frequencies. Hence the final emerging question is: *Why should people do this?*

To answer this question there is a need to clarify some basic terms of psychoacoustics. The frequency range of common human brainwaves goes from 0 Hz to 30 Hz and is subdivided in alpha, beta, theta and delta-Waves.

The mind vibrates or reverberates constantly in one the aforementioned waves. According to the frequency (Binaural Beat) which is forced to hear, the brain adapts the state of mind.

> "Beta (14-30 Hz): Associated with alertness, concentration and learning, higher levels associated with anxiety, fear and stress.
>
> Alpha (8-13.9 Hz): Associated with relaxation and wellbeing, super learning, light trance and increased seratonin production.
>
> Theta (4-6.9 Hz): Present during REM sleep (dreaming sleep). Associated with increased learning and memory, creativity, deep meditation, hypnogogic imagery and trance. Allows access to the unconscious.
>
> Delta (.1-3.9 Hz): Present during dreamless sleep. Hormones such as prolactin and human groth hormones are released. The deepest phase of sleep." (*EEG, Brain waves Alpha, Beta, Theta, Delta*, 2012, 3:10)

Zero Hertz would be the condition of the so called braindeath (void) or often described colloquially as nirvana.

There are a few other procedures to influence the state of mind, which result in changing the mood. It is quite likely that listening to Isocronic Beats (similar to Binaural Beats), or taking actively part in some kind of a music therapy, by enjoying songs of the preferred genre (vibe), will trigger an immediate affect on the mental and spiritual environment.

Scientific resarchers from all over the world, especially the Middle-East participate in studies where synthetic brainwaves are used to cure epilepsy. In recent years there was a lot of medical and technical progress in the psychoacoustical area which leads to the next chapter.

3 Contemporary Technical Progress

3.1 Phase Shifting

Sinus and Cosinus are shifted 90° against each other. Like this simplified sinus waveform (with the phase of 0°) every other signal can be duplicated, shifted and layered upon the source signal. The result will be an acoustic distortion of the original. Layered sounds appear stronger and more impulsive.

Through phase shifting it is oviously possible to create delays because the shift happens on a timeline. If the delay is larger than 30 ms from the originating signal, the human brain automatically distinguishes this as there are two completely separate streams.

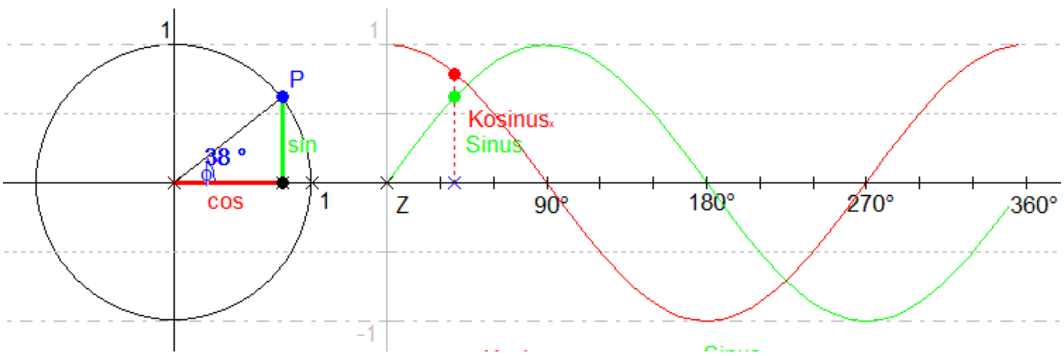

Figure 7. 90° Phase Difference of Sinus and Cosinus.

3.2 Active Noise Cancelling (ANC)

Sometimes it is desired to shift the phase (as explained in *chapter 3.1*) to 180°. This is also known as phase cancelling. Basically antinoise is produced by flipping the phases of the originating signal against each other. This invoked coincidence of killing sound with sound is the core technology used in active noise cancelling.

> “[A]dditional secondary sources are used to cancel noise from the original primary source, has received considerable interest and has shown significant promise. Active noise control (ANC) involves an electroacoustic or electromechanical system that cancels the primary (unwanted) noise based on the principal of superposition; specifically, an antinoise of equal amplitude and opposite phase is generated and combined with the primary noise, thus resulting in the cancellation of both noises.” (Kuo & Morgan, 1995)

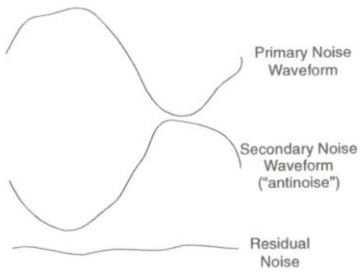

Figure 8. Physical Concept of Active Noise Cancelling.

This technology has already gained enormous popularity at d&b Audiotechnik or the Bose Corporation and many more.

<u>QuietComfort 15 Acoustic Noise Cancelling headphones</u>

The in *Figure 9* shown headphones provide active and passive noise reduction, so they significantly reduce noise. Engineers worked hard to measure sound with microphones from the inside and the outside of your soundsystem environment. Sophisticated electronics, which are inside your headphones, respond with the appropriate antinoise.

Figure 9. Bose Noise Cancelling Headphones.

The passive part of the noise reduction only contains the cosy leather ear cushion, which blocks noise before it enters the ear cup. Additionally Bose renamed the long existing active noise control into their own Acoustic Noise Cancelling® technology, what obviously happened because of internal marketing strategies (bose.at, 2014).

d&b Audiotechnik TI 330 Cardioid Subwoofer Array (CSA)

The TI 330 is an array of cardoid subwoofers. That means there are some woofer chambers in the back end which kill the noise from the front end.

> "In its minimum configuration a CSA setup consists of a stack of three subwoofer cabinets. Due to the directivity of the cabinet arrangement only one subwoofer is needed to compensate the energy of the other two radiating to the front." (d&b datasheet TI330_1.2E.pdf, n.d.)

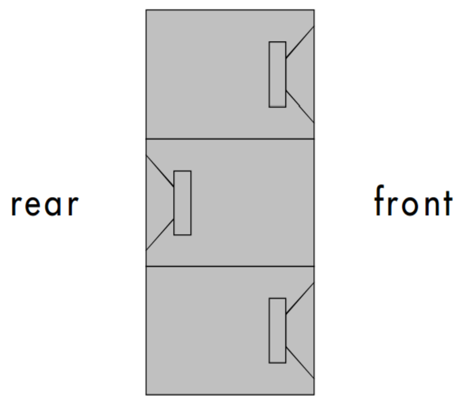

Figure 10. Principle of the Cardoid Subwoofer Array TI330.

3.3 Wave Field Synthesis (WFS)

WFS produce a synthetic wave field made out of an array of loudspeakers. It is the most innovative way to position a sound in a cinema hall or similar places like that kind. The functionality is explained easily. Many small speakers create a large big wave.

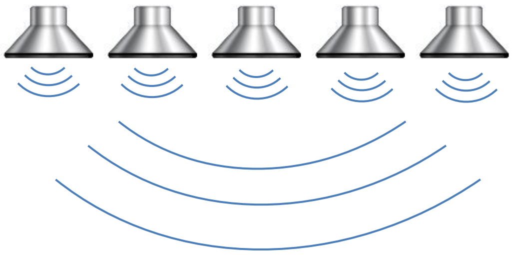

Figure 11. WFS Concept.

As you can see in the Figure above, the WFS is quite deficient in its two-dimensionality because it has issues in focusing the virtual sources inside a three dimensional room and aliasing artefacts (Holdrich & Sontacchi, 2005).

To improve this system additional technology has been developed like the time reversal mirror (TRM).

> "The TRM concept is based on the invariance of the time reversal. Impulse responses (IR) from the focused position to the array-loudspeakers are taken. Afterwards they will be played time reversed. The loudspeaker waves converge in the focus point. The TRM represents a time and space matched filter." (Höldrich & Sontacchi, 2005)

Many theories about WFS are already existing for a long time. Recently the Frauenhofer Institute is developing an encouraging, world-leading cinema and gaming experience called IOSONO which is based on WFS technology.

3.4 Long Range Acoustic Device (LRAD)

LRAD was developed secretly by the United States of America Department of Defense as a military weapon.

“The American-made Long Range Acoustic Device (LRAD) can be used to send verbal warnings over a long distance or emit a beam of pain-inducing tones” (Garvin, 2012).

The LRAD 1000Xi can be used in any weather condition and is even equipped with a MP3 Control Module to broadcast your favourite music during a military mission.

Figure 12. LRAD 1000Xi.

It is possible to transmit directed sonic waves up to 3000 meters and has a maximum beam width of ±15° at 1 kHz (LRAD Corporation, 2014).

“LRAD systems are far superior to bullhorns, which have limited range and poor sound quality” (Garvin, 2012).

Rumors say that the LRAD is less efficient in the lower frequency range, but to download the datasheet there is a need to register at http://www.lradx.com/

3.5 Line Arrays

As the name implies there is an array of soundboxes placed vertically in a line. These lines keep together because of lavishly calculated aluminium/metal constructions and can be staked on the floor or more commonly flown (hanged on suspension elements).

Line arrays produce a directional coherent sound often manufactured for festivals or large-scaled events with broad visitor densities.

Figure 13. Flying Line Arrays (Bananas) at Nova Rock Festival 2014.

Modern soundsystems are relatively complex and use drivers with waveguides for a consequent matching of the array elements.

3.6 Bose Wave Cannon

Common knowledge tells that subwoofers need a large box, so that the big membranes can do their job within the low frequency range. The bigger the better is the motto, when it gets to the point of choice.

Amar Gopal Bose, an electrical engineer, was son of a Bengali physicist and freedom fighter. As things got difficult thanks to the British Empire, Bose's father was forced to escape to USA, where young Amar had the chance to study and to teach at the Massachusetts Institue of Technology. 1964 he founded Bose Corporation and was always ahead of time in modern sound engineering (outlookindia.com, 2013).

At present day Bose has developed a compact subwoofer solution from 25 Hz – 125 Hz called the Bose® Acoustic Wave® Cannon™ System II (AWCS II). This low-frequency device is 3.81 m long, weighs 29 kg and has a woofer with 30 cm (=12 inch) diameter. It performs best when it is when mounted near the floor, solid walls or the roof. Bose's Panaray system digital controller is responsible for the electronic backend of the AWCS II.

"The low-frequency device shall be a lightweight double barrel enclosure that uses two waveguides as the acoustic vehice […] made out of custom-extruded polyvinyl chloride pipe." (pro.bose.com, 2003)

When talking about PVC pipes as material, there is one almost undestroyable thing what has always been used for controlling sound, which leads to the next chapter, a solid architectural structure.

4 Architectural Structures to Control Sound

4.1 The Boundary Wall

> "The arts of music, drama, and public disclosure have both influenced and been influenced by the acoustics and architecture of their presentation environments. It is theorized that African music and dance evolved a highly complex rhythmic character rather than the melodic line of early European music due, in part, to its being performed outdoors." (Long, 2006)

To fall within a definition of arts, it creates the space it occupies. Considering active limitation of the space, the most common way to mute an existing sound is with big solid walls.

"One part of the sonic energy is not reflected on the surface but rather gets absorbed by the second medium." (Raffaseder, 2010, p. 92)

There are a lot of other efficient materials used for occasions determined on the surface of your absorber wall.

Surface Type	*Absoption Rate*					
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4kHz
Brick	0.03	0.03	0.03	0.04	0.04	0.07
Concrete (unplastered)	0.01	0.01	0.02	0.02	0.02	0.03
Plain Glass	0.3	0.2	0.2	0.1	0.07	0.04
Carpet	0.05	0.08	0.2	0.3	0.35	0.4
Curtain	0.05	0.1	0.25	0.3	0.4	0.5

Table 1. Freqeuncy Dependent Absorption Rates

4.2 Constructions throughout History

The following chapter shows examples of the development of historical constructions especially made for an extraordinary listening experience from the cradle of humanity over the Golden Age to our present daylife.

4.2.1 Stonehenge

Stonehenge is an ancient megalithic sight in Wiltshire (England) and serves as an astrological observatory; a pre-historical calendar; a spiritual gathering place; and reminds common people of a sundial clock-face.

It is made out of stones positioned in two big concentric circles, something that looks like a giant horseshoe and various other smaller rocks. The whole construction is secured by a surrounding ditch.

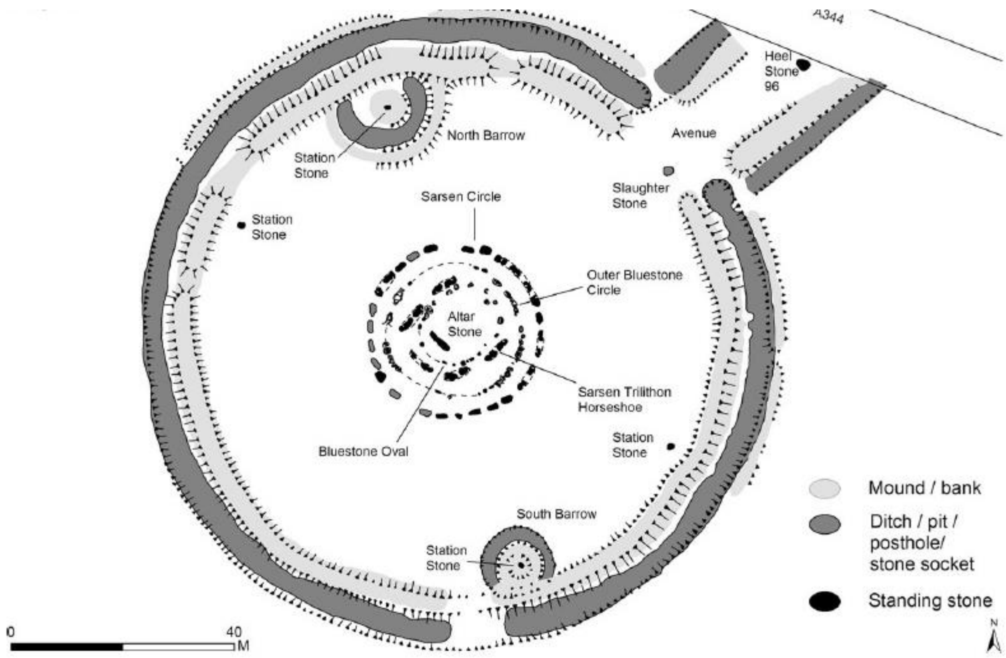

Figure 14. Layout of Stonehenge.

The outer circle of Stonehenge is made out of sarsen stone followed by an outer bluestone circle. The setting of large trilithons in the center (pillars with lintels on the top) is positioned in the form of a horseshoe and is looking towards the avenue. At summer or winter solisitance the sunrise comes from the directon of the avenue. These two days were still celebrated there by English druids and other earth religions.

> "Given that there is no proof there are some spaces between the sones, I naturally assumed sound would rapidly disappear up to the heavens, but actually, some sound stays bouncing around horizontally among the stones. However, the acoustic is subtler than that of a booming school hall because the reflections are quieter; you have to listen carefully to notice the difference. Nevertheless, their reflections would have been helpful during rituals." (Cox, 2014, p. 82ff)

Dr. Rupert Till, a music technology professor at Huddersfield University (UK), enforced an archaeoacoustic study in Stonehenge along with Dr. Bruno Fazenda, who is an acoustic expert. They exposed that Stonehenge is a surprisingly good place for speeches even if people stand behind some of the inner stones (Cox, 2014).

There are many other "Henges" similar to this one, spread all over the United Kingdom and a few other countries which probably could have an equivalent purpose.

Circulating rumors in the wind mention that young and innocent virgins were sacrificed during specific events to worship a higher form of life but this is another story that goes beyond acoustics (Owen, 2009).

4.2.2 Amphitheaters

Amphietheaters also known as Greek theaters were first established in ancient Greek.

> "[…] it became apparent that concentric circles brought the greatest number of people close to the central area. Since the human voice is directional and intelligibility decreases as the listener moves off axis, seating arrangements were defined by the vocal polar pattern and developed naturally, as people sought locations yielding the best audibility. This led to the construction of earthen stone steps, arranging the audience into a semicircle in front of the speaker. The need to improve circulation and permance evolved in time to the construction of dedicated amphietheaters on hillsides based on the same vocal patterns." (Long, 2006, p. 1)

In the following era the Roman and the late Hellenistic theater constructions pursued the steepy, sloped 2:1 seating structure but limited the seating arc to 180° and added some features to flood the floor for mocking sea battles etc. (Long, 2006, p. 4).

Often times the architect of these imposing architecture gets forgotten, like it is the case for the Roman theater in Aspendos, Turkey.

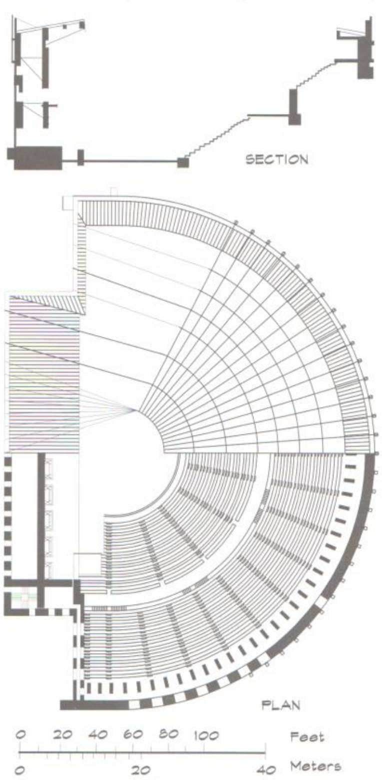

Figure 15. Roman Theater in Aspendos.

4.2.3 Sydney Opera House

The abovementioned opera house is located in Sydney (Austrialia) and is designed by Jørn Utson, an often awarded Danish architect. Its outrageous acoustic characteristics were significantly developed and improved by a moderate team of engineers such as Peter Hall (opera expert), Ben Schlange (stage consultant), Wilhelm Jordan (acoustic consultant) and many more.

> "[…] wooden panelling and cathedral-like ambience, the world-renowned Concert Hall is Sydney Opera House's most prestigious and majestic space. The largest of all Sydney Opera House interior venues, it delivers outstanding acoustics derived from its high vaulted ceiling and white birch timber and brush box panelling.
>
> Extraordinary venues call for incredible performances, which is why the elegant Concert Hall is a natural home to the Sydney Symphony, Australian Chamber Orchestra and Sydney Philharmonia Choirs. But this is not simply

a classical performance space – its unrivalled sound quality has also drawn some of the world's most distinctive voices, ranging from Janet Jackson and Bat for Lashes to Kanye West and The Cure. It's also a prime location for screenings, spoken-word performances and large-scale events, the Sydney Festival being just one example." (sydneyoperahouse.com, 2014)

Queen Elisabeth II, Queen of Australia, successfully opened it in 1973 and it serves as the town's landmark, as UNESCO world cultural heritage and obviously as an opera hall (sydneyoperahouse.com, 2014).

4.3 Radiation Behaviour

Considering the sonic source as an instrument, the radiation behavior can be completely different by the means of the choice.

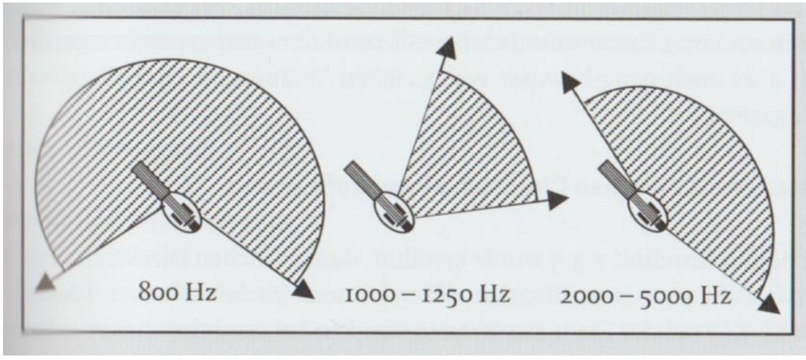

Figure 16. Radiation Behaviour of a Violin.

The directionality can be in fact influenced by simple architectural structures made out of common materials.

"There are relatively few construction materials that are utilized, and knowledge of transmission loss theory is most helpful in properly applying them. The most common materials are concrete, concrete masonry units (rmu), stucco, gypsum plaster, gypboard, and wood or metal sheets in any combination. The structural supports are wood or metal studs for walls, and concrete, steel, or wood-joist systems for floors." (Long, 2006)

4.3.1 The Horn

The horn increases the impedance of the acoustic source and also shows an efficient directional effect with more pressure because of the so called *side walls*.

> "The use of horn undoubtedly originated with the cupping of the hands around the mouth to increase projected level. The Greeks applied the same idea when they attached conical horns to their theatrical masks to amplifiy the actors' voices." (Long, 2006, p. 228)

4.3.2 The Cube

Inside a cube, or more practically a three dimentional room, a sound wave travels spherically as usual (if it is not pre-limited in radiation type by the source), therefore, the sound gets reflected on the walls by the law of refraction also known as Snell's Law: $v_{2*}\sin(\alpha_1) = v_{1*}\sin(\alpha_2)$

Q…Source
H…Receiver

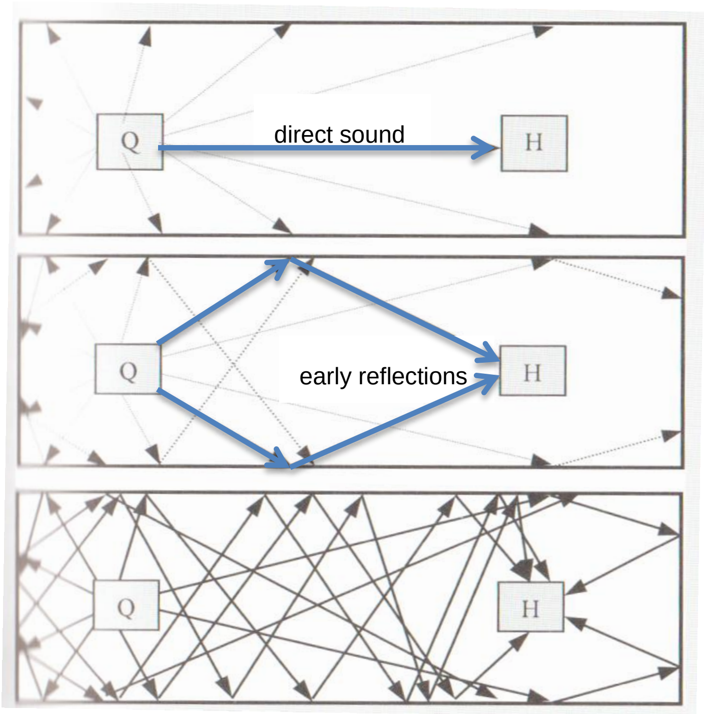

Figure 17. Impulse Response Inside a Room.

4.3.3 The Pillar

A pillar is a vertical construction to support the roof of any building. Often times it is not used for underpinning purposes but rather as gate to somewhere or just to demonstrate swag and power, e.g. the Brandenburg Gate in Berlin, Germany.

From the viewpoint of acoustics the physical effect of diffraction comes into action. Depending on the diameter of the given obstacle, the sonic wave decides wheter it reflects or diffracts around the pillar. The diameter is substancial parameter when a sound gets blocked or not.

The lower the frequency (=high waveslength), the better is the bending property. High-frequent vibes (=short wavelengths) get reflected easily, unless the pillar has specific transmission or absorption characteristics like is shown in *Table 1*.

For example if someone is sitting behind a pillar in a church, the orchestra cannot be seen but heared. The music sounds hollow beause the higher-frequent fractions get filtered (=high-cut) physically (Raffaseder, 2010, p. 94).

> “The phenomenon of the diffraction is also responsible that waves, which meet an opening, which is smaller than her wavelength, do not get reproduced radially behind the object again. If the opening is, greater than the wavelength, then it finds out very well for a radial spreading. This peculiarity of the wave propagation is the reason that deep frequencies can spread better around corners.” (Raffaseder, 2010, p. 95, transladed by author)

Events (e.g. going to chuch on Sunday or dancing in a discotheque on a Friday night) are the pillars of socializing, which leads to the final topic of this paper. The upcoming chapter contains a few basic approaches for viable public event solutions.

5 Viable Public Event Solutions

At a small or medium-sized event there is always the issue with the disorderly conduct of the neighbouring residents. Professional organisers always need to have respect for those who love to party, and for those who don’t.

5.1 Silent Disco

The expression disco is short for discotheque and comes from the Greek word discos, which is a simple disc. Nowadays our understanding of disco, as a library for vinyls and compact discs, switched to a gastronomic facility where music can be enjoyed by ordinary people.

The concept of Silent Disco is straightforward. There is a diskjockey playing some music without loudspeakers, so the original partylocation stays quiet. Every participant gets a set of wireless headphones. The only proper way to listen to the live audio entertainment at this special event is through this device. This results to a paradoxical silent discotheque.

Depending on the largeness of the party there are seperate floors with different kinds of sound. Appearently there is a function on the received earphone, where the party people use to switch the audio streams like a radio channel. Each stream represents a disco floor. Therefore, it is possible to listen to the preferred music whererver the person is located even if he/she is in the restroom or outside of the silenced discotheque. Another convenient function is that members of the audience can individually regulate their volume according to the sensibility of hearing.

> “In the last years a new phenomenon has come forward on international music scene: Silent Disco. Started in 2002 by Netherlands 433fm.com DJs as a form of entertainment for people queueing up at the entrance of croved events, the show became more and more popular in the Netherlands and in other European countries such as Germany, France, Switzerland, Great Britain, Spain and more recent in Italy. In 2003, this kind of show involved up to 29,000 people, and in 2004 it reached 78,000.” *(Belgiojoso, 2014)*

The only downside of the concept is that the audience cannot feel the embracing bass and sub-bass frequencies, which are a substancial key part of 21st century music.

Silent discos do not stay silent because the visitors do binge drinking. Drunken human beings often show rude behavior and use to dance excessively and sing along loudly with the running tune.

5.2 Zeltfest

A tent *(das Zelt)* has the properties of a reversed horn. It can be used to guide the noise from a large surface area to a relatively small spot, which ususally is the center of the ceiling.

Many events take place in tents such as the annual festivities of the local fire brigade, which is one of the most popular ways to celebrate in small or medium-sized Austrian villages. Christian Käfer, an event engineer and active firefighter of the Feuerwehr Makersdorf-Markt gets to the bottom of some frequently asked questions in an expert interview.

Why do local fire brigades often or at least most of the time use big tents for their festivities?

> "I think the major reason for doing so is cost and time efficiency. Since these festivities are put together by volunteers in civil service, it has to be cheap in the first place. Furthermore they are often held right in front of the fire brigade headquarters or in the very core of the town, so the installation and teardown also has to be fast." (C. Käfer, personal communication, July 01, 2014)

Do these tents have any affect on sound levels in the surrounding areas and are there any complaints about too high volume levels?

> "The tents swallow a lot of the sound. Keeping people dry is why they put it there in the first place. The levels outside the tent can still get very high and there are also some complaints, but in general, people have a sympathetic understanding for the loudness for three days a year because it is voluntary civil service." (C. Käfer, personal communication, July 01, 2014)

Which soundsystems are used at such festivities and are there any other efforts in sound cancelling than using a tent?

> “As there are mostly coverbands playing there, it is not easy to answer. The musicians bring their own sound systems and also their own equipment. You can see everything from small 2.1 compact systems to very large powerful horn-systems and even line array solutions depending on the size of the tent. There is also not paid much other effort in additional sound cancelling. Firstly, because as I said before there is some kind of awareness in small towns that it gets a little bit louder those three days in a year, and secondly the costs for it would not be affordable in relation to the eventually subsequent complaints.” (C. Käfer, personal communication, July 01, 2014)

Obviously the acoustics do not play such a major role at such events itself, but luckily it weakens the noise for the surrounding neighbourhood.

There are some other temporary tent solutions in the stage construction sector like in *Figure 13* but these events do not count as traditional “Zeltfest” anymore.

5.3 Membrane Constructions

Nowadays professional viable tents are made out of pneumatic and tensile membrane structures and are not only for a temporary purpose.

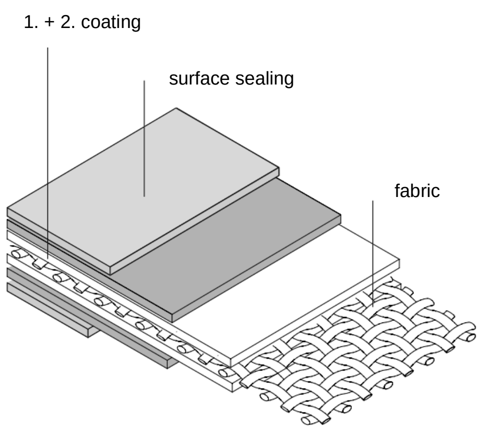

Figure 18. Illustration of a Layered Textile Membrane Structure; a Double-Sided PVC Laminated Polyesterfabric.

Mechanical characteristics of the membrane constructions were determined by the used material, the specific weight and its breaking/tearing attributes.

Material	Spezifisches Gewicht [g/m³]	Bruchfestigkeit [N/mm²]	Bruch-dehnung [%]	Reißlänge [km]
Baumwolle	1,5 - 1,54	350 - 700	6 - 15	48,0
Polyamid 6.6 (Nylon®)	1,14	bis 1000	15 - 20	89,0
Aramide (Kevlar®, Twaron®)	1,45	bis 2700	2 - 4	190,0
Polyesterfasern (Trevira®, Dacron®, Diolen®)	1,38 - 1,41	1000 - 1300	10 - 18	94,0
Glasfasern	2,55	bis 3500	2 -3,5	140,0
Polytetrafluortethylen (Teflon®, Hostaflon®)	2,1 - 2,3	160 - 380	13 - 32	16,8
Kohlenstofffasern	1,7 - 2,0	2000 - 3000	< 1	153,0

Table 2. Overview About Common Materials Used for Textile Membrane Structures.

6 Conclusion

In the end the research question could not be properly answered the way it was thought. From the perspective of psychoacoustic we know we can trick the brain into hearing something the human being does not use to hear.

Technologically it has always been easier to keep a digital workflow, than building sophisticated constructions to physically break the sonic waves. It is possible to recreate any sound, but it is never possible to feel the original atmosphere of a location without actually being there.

In general, there is no perfect solution to kill a sound because there is always another road which leads to Rome.

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Appendix