INTERACTIVE INFRASONIC ENVIRONMENT:
A New Type of Sound Installation for Controlling Infrasound

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ABSTRACT

This paper proposes a new type of interactive sound instrument for use with audiences in sound installations and musical performances. The Interactive Infrasonic Environment allows users to perceive and experiment with the vibration and acoustic energy produced by infrasound.

This article begins with a brief overview of infrasound and examines its generation, human perception, areas of application and some odd myths. Infrasound is sound with a frequency lower than 20 hertz (20 cycles per second) – outside the normal limits of human hearing. Nevertheless the human body can perceive such low frequencies via cross-modal senses.

This paper describes three key aspects of infrasonic sound technologies: the artificial generation of infrasound, the human perception of infrasound, and the interactive environment for sound installations and musical performances.

Additionally we illustrate these ideas with related works from the field of sound art and interactive art.

Keywords

sound installation, interactive environment, infrasound, video tracking system.

1. INTRODUCTION

Our idea for building an interactive system that uses infrasound came from the myth of "Demutspfeife" in which a single tone from an organ brings humility to its listeners. The legend says that these big organ pipes are often used in churches to subdue people. While researching the field of infrasound further myths about the affects of infrasound on humans were found. We focused on the possibility for bringing infrasound to audiences in sound installations and musical performances wherein the users could experiment with infrasound on their own bodies. With this project we attempt to increase acoustic awareness by sensitizing people to very low sound frequencies. This sense is still underdeveloped in our culture.

A main problem was just how to generate infrasound. There are only a few possibilities and most of them would be unsuitable for an audience in a sound installation. Due to the fact that sound installations tend to be difficult to perceive and understand for the audience we wanted to create a simple interactive environment that offers a great deal of creative freedom and options for the users.

We could not find many artistic projects relating to the field of infrasound but there have been a number of studies from several areas of study such as medicine, weaponry and noise reduction. There are too many facets to this research and far too much speculation on infrasound to fit within the scope of this paper.

2. INFRASOUND

Infrasound is sound that is lower than 20 cycles per second. This is sound that is just below the lower limit of the human sense of hearing.

Sound range	Frequency	Wave length
Infrasound	1 Hz < f < 20 Hz	1 Hz = 1125 ft = 342,9 m
Hearable sound	20 Hz < f < 16 kHz	20 Hz = 56 ft = 17 m

SMC 2009, July 23-25, Porto, Portugal

2.1. The Generation of Infrasound

Natural sources:	Artificial sources:
- Wind and atmospheric turbulence - Earthquakes and volcanic eruption - Waterfalls and breaking waves - Animals (e.g. whales, elephants, rhinoceros, giraffes, okapi and alligators)	- Air conditioning systems - Wind energy turbines - Gas turbine power stations - Industrial facilities (e.g. compressors, compactors) - Buildings (e.g. skyscrapers, tunnels, bridges) - Vehicles(cars and trucks, trains, ships, planes) - Explosions -Speaker systems - Organ pipe

Table 1. Sources of infrasound

2.2. The Human Perception of Infrasound

Hearing does not abruptly stop below 20 Hz. As careful measurements have shown, with high enough sound pressure the ear can register infrasound down to about 1 Hz. [1] Infrasound perceived as a mixture of auditory and tactile sensation at a high threshold level.

Sense	Perception
- Ear	- Feeling of pressure
- Skin	- Pulsation and vibration
- Viscera	- Resonance vibration
- Sinuses, nares, chest, bowel	- Barometric variation
- Eye	- Vibration

Table 2. The human perception with cross-modal senses

Infrasound especially affects the cavities of the human body though its affect on air pressure. Different pitches and intensities of infrasound can be perceived as changes in pressure and vibration. The effects of very low frequency noises such as infrasound on human beings have been documented in many articles; these include: temporary hearing threshold shifts, changes in blood pressure, changes in heart rate, changes in respiratory rate, balance disturbances, cognition disturbances. [2]

During medical research at the Hellersen Hospital in Lüdenscheid (Germany) the psychosomatic effects of infrasound were tested on people with chronic pain. Six inpatients suffering with chronic pain were exposed to infrasound at 9 Hz for 20 min per day. After one week they concluded that infrasound activates the autonomic nervous system and has positive effects on stress and also has a palliative effect on pain. [3] If the sound pressure of infrasound is higher than 120 dB, negative effects of infrasound appear: headache, breathing problems, changes in heart rate and general stress. Constant pressure (more than 10 minutes) with infrasound at more than 170 dB causes the death of the test animals. [4] Additionally there is an additional impressive effect, which is produced by infrasound. A NASA technical report mentions a resonant frequency for the eyes of 18 Hz (NASA Technical Report 19770013810). In this case the eyeball would begin vibrating which would cause a notable "smearing" of vision. [5] Vic Tany outlines the idea that a standing wave of 19Hz could, under certain conditions, generate sensory phenomena suggestive of a ghost in his paper "The Ghost in the Machine" from 1998.

2.3. The Areas of Application for Infrasound

Infrasound is currently being utilized in various fields. A relatively new discipline is the medical use of infrasound therapy. It is useful in treating chronic pain and arteriosclerosis wherein vibrating medical devices are attached to the body.

Interest in atmospheric infrasound peaked during the Cold War, as it is one of several ways to detect, locate, and classify nuclear explosions at very great distances. At present the Comprehensive Test Ban Treaty requires a more sophisticated global sensor network to monitor compliance. [6]

A global network of infrasonic detectors has been installed to observe the atmosphere. The intention is the early detection of meteorites, tornados, earthquakes and volcanic eruptions. In the 1970s, the National Oceanic and Atmospheric Administration began a study of atmospheric infrasound to determine whether it could be used to improve warning capabilities for severe weather events such as tornadoes. [7] They found that many thunderstorms radiated infrasound, which could be detected by observatories more than thousand miles away.

2.4. Infrasound Myths

The most bizarre myth about infrasound is the *brown note*. As the name implies, it is assumed that this is an infrasound frequency, which causes humans to lose control of their bowels. There is no scientific evidence that such an infrasound note exists.

Another legend is about infrasound weapons. Some infrasound review articles mention the fact that several countries have investigated this possibility. Such an infrasound weapon would be a huge installation that could generate high-pressure low frequencies, which would cause anxiety, internal injuries and death to humans.

Finally there is the myth of "Demutspfeife" that was mentioned earlier. It is a single organ pipe and part of a church organ, which brings humility to its listeners. Our Interactive Infrasonic Environment project strongly references this idea, but we do not intend to bring any negative effects of infrasound. We propose a strictly positive application of infrasound and low sound frequencies.

3. INTERACTIVE INFRASONIC ENVIRONMENT

As there are so many fascinating aspects and also a few strange myths concerning infrasound, we started to develop an infrasonic installation in early 2007.

The goal of the project was to make infrasound approachable for everyone. We attempted to build an installation where the audience can experiment with the perception of infrasound regardless whether it creates a positive or negative effect in their bodies. For this reason we soon realized that an important part of the installation would be a multiple-user interface through which all users can interact simultaneously and in real time.

The Interactive Infrasonic Environment is the first interactive instrument that allows users to generate infrasound while moving around the space. It is an installation that overlaps auditory and tactile stimuli to increase the level of acoustic awareness.

3.1. The Organ Pipe

The installation hardware is based on a 19 ft wooden organ pipe placed in the center of the environment. The pitch of the pipe can be tuned with an adjuster at the end of the organ pipe. The wavelength of the pipe is modified to the characters and sizes of the room in which the installation is located. Adjustments are needed to get satisfying resonates from the specific architecture of the room. The organ pipe can generate sound frequencies down to 15 Hz, going beyond the limits of human hearing.

Figure 1. Dimensions and tone pitch of the organ pipe

3.2. Sound Generation

The sound of the pipe is produced via the vibration of air in the same way as a flute. The airflow is driven over an open aperture and against a sharp lip called a labium. The airflow begins fluttering and creates high and low pressure waves within the pipe's air column. The low sound wave generated has a frequency between 15 Hz and 17 Hz. As described earlier the tuning of the organ pipe depends on the size of the room. The vibration energies of infrasound are transmitted to the human body and the architectural space enhances the natural resonance of both. The source of a sound in an interactive computer based instrument is not some abstract or concrete concept, or even the algorithm(s) that have been written; it is the gesture of the performer, the excitation moment - it is fundamentally about that nature of excitation. [8]

3.3. Video Tracking System

Interaction with an instrument that uses video tracking is a particular case in point, for the nature of engagement is abstract, and as such is based not so much on the physical relationship of the self to the physical space that houses the instrument or interactive installation. [9] The project uses a video camera situated high on a wall, which continuously observes the surroundings of the organ pipe, tracking the position and movement of the users. The software is programmed in Max/MSP and uses the Cyclops object to receive and analyze video input. The program rasterizes the video input and analyses the grayscales of predetermined zones. The users interact by moving around and changing their positions. These actions directly control the wind machine, which is fluently controlling the airflow and thus the volume and pitch of the organ pipe.

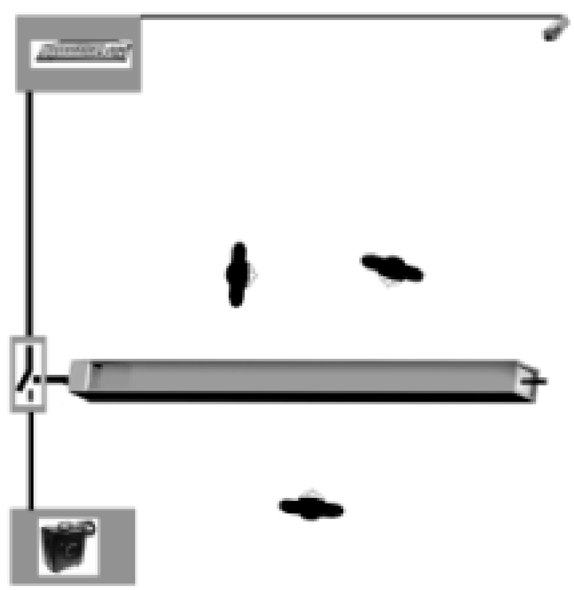

Figure 2. Schematic view of the Interactive Infrasonic Environment

3.4. Experiments with Test Subjects

During the first testing phase we explored the sensations in the Interactive Infrasonic Environment with the help of ten participants. We performed separate individual experiments by using an exposure chamber. A single experiment consisted of three 5 min exposure periods and after each period a 15 min post exposure period, including a short interview of the test subject. The test was performed with a continuous tone at a frequency of 15 Hz and three different sound intensities: low, middle and high. The goal of these experiments was to establish the connection between the Interactive Infrasonic Environment and psychoacoustic human perception. The experiments showed that the low sound frequencies produced feelings of pressure, pulsation and vibration on cross-modal senses for all test persons. It was surprising that the threshold where the test persons started to feel uncomfortable varied from person to person. For two subjects the feeling of discomfort started at the second level of intensity and for five subjects it started at the highest level. For the other subjects (3) there were no uncomfortable feelings experienced during the entire test period. Physical contact with the vibrating organ pipe was enjoyable for all test participants.

3.5. Present and Future Work

To date the Interactive Infrasonic Environment installation has been shown at several exhibitions. The feedback from the audience and the curators confirmed our intention to continue with and further expand this infrasonic project.

Figure 3. Interactive Infrasonic Environment, Sound Characters exhibition, Innsbruck, 2009

We are currently working on and researching a musical performance using the Interactive Infrasonic Environment. We use infrasound to conduct a choir and likewise the members of the choir can control the infrasound through the installation. The first live performance was staged in May 2009 in Linz (Austria), the European Cultural Capital at the time. The members of a women's ensemble improvised to the accompaniment of the Interactive Infrasonic Environment. With certain sequences of movements, members of the choir could steer the tones produced by the organ pipe. The tones generated by the organ pipe in turn provided the impetus for tonal variations in the choir's singing.

Figure 4. Improvisation Concert for Choir and Organ Pipe, Linz, 2009

4. RELATED WORKS

There have been a several studies and projects concerning infrasound in the field of media art. We want to highlight a few of the projects that inspired our vision of an interactive infrasonic installation. The last example refers to our video tracking system, which is a basis to a certain extent on the milestone of the interactive sound installation.

4.1. IIT

The Infrasonic Transmission Tube was designed and constructed by Laton, a research lab and record label based in Vienna. The prototype sound system was able to generate infrasound frequencies from 1 Hz to 20 Hz. They used the Infrasonic Transmission Tube for their realization of their self-titled "Infrasonic Music". The project was shown at the Ars Electronica Festival in 1996.

4.2. Live Room

Mark Bain developed the Live Room in 1998. It was a project that used small acoustic-intensifying machines, which were attached directly to the structure of a room. The installation incorporated the architecture by running impulsive energy throughout, creating sound and vibration in direct relation to the building and the dimensions of the space. With this work, I was interested in

TRANSDUCING ARCHITECTURE, driving the space with external influences of a vibro-kinetic nature. [10] Bain was able to effectively tune a space by delivering the resonant frequency to its different parts. The Live Room also generated infrasonic sound, which brought strangeness to this project related to the production and injection of these unique low frequencies.

4.3. Very Nervous System

In 1982 the Canadian Artist David Rokeby started to develop his Very Nervous System, an interactive sound environment with a real time motion tracking system. Video cameras observed the users action and a computer analyzed the data and responds acoustically to the input. It was the intention to design a space in which the movements of one's body create sound. David Rokeby was interested in creating a complex relationship between the user's body and the system. "Because the computer is purely logical, the language of interaction should strive to be intuitive. Because the computer removes you from your body, the body should be strongly engaged. Because the computer's activity takes place on the tiny playing fields of integrated circuits, the encounter with the computer should take place in human-scaled physical space. Because the computer is objective and disinterested, the experience should be intimate." [11] In the early days of interactive art, the interaction with the Very Nervous System was very novel because the interface was invisible. The system was used in performances, exhibitions and additionally in music therapy applications.

5. CONCLUSION

In summary, this paper provides a brief overview of infrasound, its generation, perception, areas of application and myths. We noted that there is a need to sensitize people to allow them to better register infrasound and that our project intends to increase acoustic awareness; this is still an underdeveloped sense in our culture.

This paper presented a new type of interactive sound instrument that allows users to experiment with the vibration and acoustic energies produced by infrasound.

The challenge for this project was to construct a sound generator, which produces perceptible infrasound. As a final remark we would like to say that there is still much work to do in order to fully implement all of our ideas, especially those involving live musical performances.

6. REFERENCES

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