

HISTORY OF SPATIAL AUDIO

Prannav Bhalla 307065464

Spatial Audio, DESC9137, Semester 1 2007
Graduate Program in Audio and Acoustics
Faculty of Architecture, Design and Planning, University of Sydney

ABSTRACT

This paper examines the concept of visualizing sound through virtual auditory imaging from the point of view of the history of audio coding. Sophisticated technological advancements and comprehensive coding techniques developed over the last century have enabled us in being to extend the perception of the sound beyond the conventional 2-D space.

The focus of this paper would be a detailed analysis of the milestones leading up to the state of the art. In doing so I shall, apart from documenting the developments thus far, provide for incisive inferences on each of these developments. Consequently, the concept of recreating a visual space through audio shall be detailed.

1. INTRODUCTION

In examining the process of evolution of coding for various formats of sound reproduction, we'd have to consider a timeline that leads up until the current day standard. Spatial Audio is recognized as the most up to date form of sound reproduction. The formats preceding it, each had their novelty and originality when concerned with their purpose. The simplest of ideas like creating a device that, through the principles of simple mechanical transduction, sowed the seeds for further development. [1]

The idea of having the listener immersed into the sound space thereby creating a virtual environment by means of effective manipulation of audio technology has yielded (and continues to) the results that we've come to witness ever since the genesis of developments in the field of audio production and reproduction.

Needless to say that every format is a stepping stone in the pursuit of further enhancing the effectiveness and fidelity of the concept of creating a sound field. Each format has its detractors and supporters for reasons ranging from the absolute technical to others based on a sense of aesthetics. The gradual process of experimentation is the essence in the rapidly developing area of creating a realistic perception of sound through virtual techniques.

1.1. What is Spatial Audio?

In this day and age where the gravity of a concept like spatial audio would be assumed to be status quo, we'd have to look back in time to fully understand the significance of the extent

that the technology has advanced. To reiterate the same, I quote K.K., an anonymous music critic mentioned in 1928 in the July issue of THE GRAMAPHONE: -

“ When I sit in an acoustically perfect hall, (full of people), in the best seat for hearing, and listen to an orchestra, I hear such and such sounds. I want to hear precisely this effect from a recording, if that be possible.”[2]

The categorization of Spatial could be roughly divided into two aspects. One that deals with the “reproduction of an approximation of the original soundfield and the psycho acoustical approach of conveying the essential spatial cues without actually recreating the signal itself”. [3]

Furthermore, the idea of giving a physical dimension to audio, that is a essentially recorded and reproduced through nearly dimensionless sources (eg: transducers etc), further illustrates the intricacies involved in the background of any audio production format, and in particular Spatial Audio.

1.2. The Dawn Of Audio: Development of the sense of space and sound.

To be able to comprehend the vitality of audio imagery and perception it would be worthwhile to note some of the significant events, inventions and concepts of relaying and reproducing sound that have directly/indirectly affected the course of spatial imagery. It was for these simple extrapolations of existing scientific reasoning that has now elevated the science behind audio into a semi-artistic status.

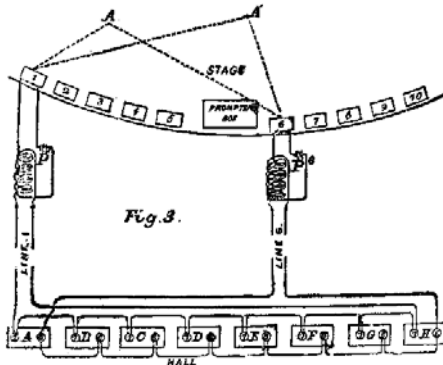
- Alexander Graham Bell inaugurated the telephone on 10th March 1876. The first words ever were “ Mr. Watson, come here. I want you”. This was conversed to his assistant Mr. Watson.

The development of the telephone was not only significant for its intrinsic value in the field of communication but can also be looked at in essence as a significant step towards extensive research into the field of electrostatic transduction that has found its way into various forms of research including acoustics. One such example would be of using the principles of electrostatic transduction as a means to producing audio frequency tones that were used in studying the transient response of linear arrays of receiving transducers by Professor Hunt in '47. [4]

The principles of electrostatic transduction have played a significant part in the design and sonic quality of modern day electrostatic loudspeakers as well.

- Before even the mono system was fully developed, experimental work had already with

spatial audio. The first widely noted public demonstration of spatial audio in 1881 when Clement Adler set up series of microphones across the stage of the Paris Opera and fed their outputs to headphones in nearby hotel rooms. Listeners perceived a crude but effective binaural image of decent quality.



A schematic diagram of the setup that Adler implemented. [6]

Adler's attempt, in the days before Marconi had devised a method for relaying wireless audio signals is a commendable effort in that it allowed for people to experience a performance of music without physically being presented. In a sense it provided them with a sense of binaural placement of the auditory source sans the visual to correlate with.

- French engineer Leon Gaumont in 1903 was granted patents for loudspeaker systems to go with his sound on disc talking films, which used one of Berliner's Gramophones. He was the first to suggest placing loudspeakers behind the screen, and carrying them about to follow the images on the screen. [7]

It might be presumptuous to attribute the concept of crediting the thought of following the visual with its corresponding audio to that of modern day spatial audio and its ability to create a sense of directional coherence, but it must be noted that he was on the cusp of suggesting the idea of localizing sound in the presence of a visual aid.

1.3 The Advent of Stereophonic sound

The aforementioned efforts in achieving an appropriate localization of the sound source confirm the basis of stereophonic sound. The principle of stereophonic sound lies in the fact that the listener's perception of the directivity, depth and effective distance of the sound space is achieved by careful manipulation of the sound pressure level of the incoming sound and the difference in phase of the sounds arriving from either the left right. The human ear would achieve localization through the position producing a higher sound pressure level and/or advanced phase level. [8]

Alan Blumlein

The understanding of the above stated principles of sound propagation and conception was arguably never understood better than Alan Blumlein who, through his innovative ideas, redefined the concept of stereophonic sound thus acquiring the patent for Stereo in 1931. His thorough knowledge on the theoretical and practical implications of circuit design and

functioning led his proposal of improvements in the design circuitry for various applications such as High Frequency Electrical Circuits management, Signal Amplifying Systems, Electroacoustic Devices to name a few [9]. For the purpose of this dissertation, we shall focus on one of his contributions which is of utmost relevance. **Improvements in and relating to sound-transmission, sound-recording and sound-reproduction systems.** He claimed that

“Human ability to determine the direction from which sound arrives is due to binaural hearing, the brain being able to detect differences between sounds received by the two ears from the same source and thus to determine angular direction. With two microphones correctly spaced and the two channels entirely separate it is known that this directional effect can also be obtained for example in a studio, but if the channels are not kept separate (for example, by replacing the headphones by two loud speakers) the effect is largely lost. The invention contemplates controlling the sound, emitted for example by such loud speakers, in such a way that the directional effect will be retained.” [10]

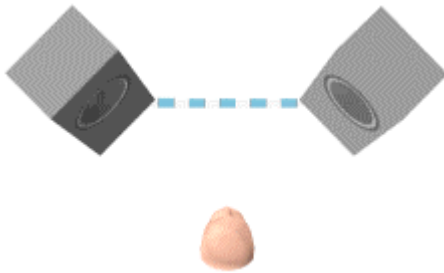
In doing so, he laid the foundation for spatial imaging as far two speakers placed at the left and right with the purpose of creating an image stage between them. [11] However the untimely death of Alan Blumlein in 1942 and the considering that the years just passed immediately before then was a time where there was minimal research done due to the ongoing World War, his patents and research weren't able to materialize beyond the substantial work he had already done.

In 1933 though, Bell Labs' researchers attempted to widen the 'sweet spot' of stereo by adding a third channel in the centre. This was the first experimentations with LCR configuration. The idea was to increase spatial depth through the presence of a center channel which would create a visual image that would enable the listener to localize and respond to sounds not only on the peripheral axis on the horizontal plane but also on a pseudo 3-D plane.

One of the much-talked about and commonly referenced events in the development of audio format is Fantasound [12]. It was an idea proposed by Walt Disney for the animated classic Fantasia and it was further developed by composer Leopold Stokowski. This was the first feature film presentation to be released in stereophonic sound. It used a four channel optical soundtrack on a separate film synched with the projected film. Since the soundtrack of the film was based upon Classical music, its requisite was to be able to represent the dynamic range of the music, which it successfully achieved.

The reason for Fantasound not being able to cement its place as a widely accepted audio format was the fact that the circumstances that prevailed with a looming threat to war made it implausible for large equipment to be carried across the country. The financial implications also affected its adoption as a standard cinema theatre format because of the fact that the expensiveness of the cost and installation of the system didn't convince the major theatre owners to shut down operation and incur losses for the days that the studio wouldn't function for. Another prime reason was the fact that was the fact that the sheer volume of the equipment implied the requirement of larger spaces, a condition that wasn't well received.

1.3. 1950 – Stereo Age



Stereo set-up [13]

The 1950's was a time of a revival of sorts in the way of technology and the way that popular music was played, produced and heard, so to speak. In 1948, Peter Goldmark of the CBS Laboratories developed the 33-1/3 RPM LP (Long Play). It was to be in the years to come that the LP would become the most popular consumer format. The relevance of the technology pertaining to the stereophonic sound lies in the fact that in 1958, the first stereo two-channel records were introduced by Audio Fidelity and Pye in the U.S.A and Britain respectively. The Westrex 45/45 single groove system provided the flexibility of playing monophonic as well as stereophonic sound by adjusting the way in which the stylus moved. The provision of being compatible with monophonic recording wasn't available in other systems until then. [14]

The fundamental concept behind the Westrex system was that because the vertical and horizontal motion of the stylus dealt with the vector sum and differences between the Left and Right Channel, the issue of compatibility with the pre-existing mono format was accounted for.

On Sep 30th 1952, the Cinerama process was introduced with the release of the film "This Is Cinerama". This system was developed by Fred Waller, it employed 3 synchronized projectors each covering 1/3 of the screen. The Sound System was developed by Hazard E. Reeves, and was based around a synchronised dubber running 7-channel magnetic soundtrack (6 channel one control) 5 screen loudspeakers (Similar to SDDS). The system abandoned in 1963 due to impracticalities of costs and few compatible theatres. [15]

Cinemascope, as a system, was far less complicated than Cinerama, was introduced on Sep 16th, 1953 with the release of the film "The Robe". The system used an anamorphic lens to project a wide image with a single 35-mm projector. The sound system, developed by Ampex, used four magnetic tracks striped onto print, intended for L, C, R plus mono effects. The first off screen voices (ambient sounds) were used in this film. The high quality of cinemascope allowed sound to not be filtered through the academy mono equalisation which was required for the optical tracks of other films at that time. This indeed was a step in the right way for the development of sound.

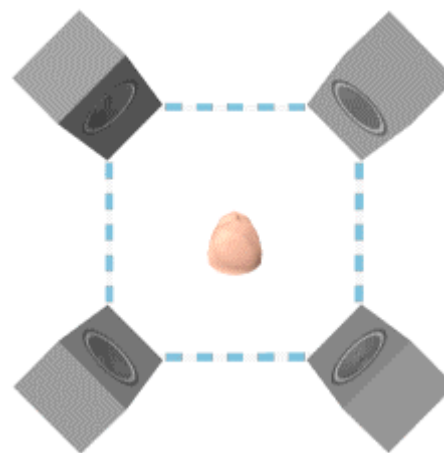
The decade of the 60's saw the development of complementary technology that greatly expanded the use of stereo audio. June 1st 1961, WEFM, the first Stereo Radio Station began its operation in Chicago. Two years later Philips introduced the compact cassette followed by the introduction of the eight track.

Acceptance of the cassette as a high fidelity medium was aided in 1969 with the advent of the Dolby B-type noise reduction system.

Despite the fact that these developments were made in the stereo era, the human and ear and its perception to observe sound in three dimensions couldn't be achieved effectively enough. In fact there, were a significant number of detractors of the format, some of whom preferred monophonic sound to it. It is believed that Stanley Kubrick, one of the most acclaimed moviemakers in Hollywood decidedly shot all of his movies in mono. Apart from the aesthetic choice made by people of prominence within the industry, as mentioned earlier, stereo sound was on the right track at best, as far as spatial imaging was concerned. The sheer necessity to expand on the existing L-R in order to widen the physical range of the sound space could be assumed as the key reason to the emergence of other multi-track formats.

1.4. Quad Age

Quad, which is a prefix meaning 4, as a concept began as a series of test recordings produced and demonstrated by Robert Berkovitz at Acoustic Research Corporation. The idea behind it was to simply show what happens when rear stereo added to front stereo. The front centre was ignored and two rear channels, which could be roughly equated to the surround channels we have nowadays, were added. According to their anticipation, the listener would be placed more realistically *into* the sound space rather than merely observing and realising the experience of the soundstage as was the case with stereo sound.



Quad set-up [13]

The problem now faced was that the engineers who were pushing the 2 channels through various mediums were suddenly confronted by the problem of trying to add two more channels. The proposed system included discrete tape systems, a discrete multiplexed LP and a discrete quad FM system, Quadcast. But the matrix system designed to extract 4 channels from two channels finally gained the vote.

Although a very novel idea as far as serving the purpose of realistic sound imaging is concerned, the Quad was widely discredited as a viable format due to the fact that there were too many variances in the encoding process. The inconsistency within the format was the main cause for its disappearance from the market. To further elaborate upon the short longevity of the

Quad format, we shall have to detail the process of sub-formats emerging.

CD-4

A discrete Quad system created by JVC, the CD-4 was encoded with a sum and difference of the signals on the standard stereo grooves of the vinyl. The drawback was the fact that it limited the high frequency content to 15kHz. [16]

Stereo Quadraphonic (SQ)

This was a concept based on matrixing four channels into two and was developed by Peter Scheiber. It was devised for vinyl as well, just like the CD-4 with the difference being that it provided for a better high frequency response. In fact it provided the full 20-20kHz response as far as relaying a signal was concerned.

Quadraphonic Stereo- QS

Very similar in the concept as the SQ, the only differences begin that it was developed an independent engineer. It provided for a much better quadraphonic image than the SQ because of the fact that the diagonal speaker separation (in level) was much better than that of the SQ

The existence of three formats within one was itself a cause for concern as far as creating confusion in the minds of the average consumer. Added to that the fact that various major players in the industry were divided between each of these formats caused a corporate war between companies like Atlantic, ABC and CBS who adopted either one of these formats.

Also, from a technical standpoint, the signal-to-noise ratio and channel separation in the quad format were considered to be much less effective as compared to stereo.

Another factor that could've spelt the demise of the Quad format was the fact that radio stations that were the prime source of broadcasting music weren't too impressed with the format. With stereo being fairly new and the requirement that Quad would propose as far as equipment required to decode the signal was concerned, it was a matter of time before the disapproval of the format was confirmed.

As mentioned earlier, Quadraphonic sound was a step in the right direction. With the advent of advanced signal processing and encoding and the dawn of the digital domain, the future of audio and the precision with which a sound stage could be created was already on its way.

1.5. Dawn Of Digital Audio

While quadraphonic sound was getting all the attention in the 70s, the principles of Digital Audio were finding their grounding in the world of audio formatting.

As with most technologies, the establishment of this lay greatly in the establishment of other related technologies; The transistor, this replaced the vacuum tubes, the further development of digital integrated circuits, affordable high precision analog/digital/analog converters, storage media, etc.

Once these were in place, this lead audio engineers to explore DSP. Thomas Stockham experimented with a Hewlett-Packard data recorder. His demonstration of this digital

recording at the Nov 1976 AES convention at New York, gained instant approval. A few years later he produced the first digital recording at the Santa Fe Opera.

In 1970, the first commercial digital product was released, the Lexicon Delta-T101 Delay Line, designed by Francis Lee. In 1975 the first digital reverb unit the EMT was released.

In 1982 the audio world was revolutionised by the advent of the CD. It had a profound influence on the audio engineering community, as it tried to eliminate the traditional problems of flutter, wow, speed errors, clicks, pops, noise and distortion. [18]

From Edison's first foil cylinders, audio recording technology had been based on converting sound waves in the air into a physical transcription or magnetic pattern analogous to the waveform of the original sounds. With digital recording, however, the amplitude of the original waveform is sampled at regular intervals (tens of thousands of times per second), and numeric values are assigned to those samples, which in turn are transmitted or stored as binary code. On playback, the values of the samples are used to reconstruct the original waveform.

In the case of the Compact Disc, the sample rate is 44.1 kHz, while the resolution of each sample is 16 bits. The digital code of sampled sound is stored on disc as a series of non-reflective "pits" in an otherwise reflective surface (the "land"), and is read by a laser pickup. Able to store at least 74 minutes of uninterrupted high-fidelity sound, and free of the surface noise which can mar LP playback, the CD also offers random access to conveniently take listeners directly to any track. The format first caught the attention of classical music lovers, then grew rapidly to become the dominant release format within its first decade on the market.

The rise of the CD coincided with growing interest in home computing, and CD-ROM formats for personal computers were first introduced in 1986. By the mid-1990s, computers were finally powerful enough to begin taking advantage of CD-ROM's multimedia capabilities, and parties both in and out of the music industry began looking for ways to add graphics, text and video to music CDs. The RIAA engineering committee helped record labels understand the pros and cons of various proposed technologies, and ultimately developed a specification for Enhanced CD. But incompatibilities in the way computers handled playback of the discs ultimately undermined efforts to get the format off the ground.

1.6. The Present

It might be noted that, through the course of this dissertation, leading upto this point, the analysis has been subjected to the Quad era. No further elaboration on multi-channel surround has been attempted. The reason for the omission is the fact that I believe that the connection between spatiality and the design of audio format has been thoroughly outlined so as to give the reader an accurate idea of spatial imaging. Furthermore, the vast resource of data available on multi-channel surround places an objective analysis on the topic beyond the scope of this research paper.

Having said that, the sheer significance of the format in the present day situation warrants a brief mention about its impact on present day consumerism.

There are two ways to look at the present day scenario spatial coding and imaging has come up by leaps and bounds ever since the inception of the multi-channel surround sound format. As mentioned in the beginning of this dissertation, the concept of spatial audio is to impose a sound stage upon the listener. In doing so, the existing 5.1 formats have given way remotely, to the SDDS 7.1 setup that further emphasizes the

spatial characteristics of the format. Tomlinson Holman's 10.2 arrangement to improve spatiality in music is another advancement on the verge of further detailing. [16]

Despite the emergence of the multi-channel surround format, stereo still manages to hold a prominent spot in the consumer market. With the advent of CD's, MPEG formats and this being a standard for broadcast over media such as the internet; provides for a further cause to refine the existing stereo format.

2. CONCLUSION

In regard to this report and through the course of detailed research, the conclusion that one can draw upon is that spatial imaging is not a consequence of the development of various audio formats, in the sense that perception of a sound space in a manner that is most in conjunction with how the human senses perceive an impulse, of any kind, and replicating it through any means possible remains the criteria.

To sum up, it is of scant relevance as to what a certain number of speakers can do apart from their immediate purpose of being able to provide the listener with a well-defined perspective that is closest to the image of the sound in reality.

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