

Case No. IPR2023-1005
Patent No. 9,674,628 B2

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

META PLATFORMS, INC.,
Petitioner,

v.

EIGHT KHZ, LLC,
Patent Owner.

Case IPR2023-01005
Patent 9,674,628 B2

**DECLARATION OF DURAND R. BEGAULT, PH.D.
IN SUPPORT OF PATENT OWNER'S PRELIMINARY RESPONSE**

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I, Durand R. Begault, declare as follows:

I. INTRODUCTION

1. I am currently employed as Director, Audio Forensic Center, a wholly-owned subsidiary of Charles M. Salter Associates, an acoustical consulting firm located in San Francisco, California. I am also currently employed as a research scientist in the Human Systems Integration Division of NASA Ames Research Center, Moffett Field, California.

2. I have been retained as an independent expert consultant in the *inter partes* review (“IPR”) proceeding involving the 9,674,628 Patent by Eight kHz LLC (“8kHz”). I will refer to this patent using common shorthand. I have been asked to consider the arguments raised by the Petition regarding the validity of the ‘628 Patent in this proceeding.

II. QUALIFICATIONS

3. I am the director for Audio Forensic Center, where I perform investigations with regards to acoustics; video and audio evidence recordings; audio patent infringement analysis; acoustic measurement; speech intelligibility and warning signal audibility; human factors and psychoacoustics; musicology and copyright infringement; voice comparison; and recorded gunshot analysis. I also serve as a research scientist for NASA Ames Research Center specializing in psychoacoustics, human factors, multimodal systems, and communications

engineering research, applied to aerospace safety, virtual reality, and speech communications. I obtained my Ph.D. in 1987 from the University of California, San Diego with a focus in Computer Audio, and was made a fellow of the Audio Engineering Society in 2002 “for contributions to understanding of spatial hearing”.

4. For over 30 years I have conducted analyses and testified in cases for attorneys, law enforcement agencies, and corporate internal investigations. I have qualified as an expert in numerous State and U.S. Federal Courts; the United States International Trade Commission (USITC); and courts in Canada and international arbitration panels. I have over 100 publications in the area of acoustics, psychoacoustics and forensic audio, and have testified over 85 times in court or deposition, including in the area of digital audio recording authentication and metadata (e.g., the International Centre for Settlement of Investment Disputes, The World Bank, Washington, D.C.; California Superior Courts; United States District Court). I have served as an adjunct faculty member of the Sound Recording Department at McGill University in Montreal, Canada, and have received a Fellowship Award from the Audio Engineering Society. I have also served on numerous journal review boards, technical committees and Ph.D. dissertation committees in the area of acoustics and audio engineering. Exhibit 2002, attached to the Patent Owner’s Preliminary Response is a true and correct copy of my CV.

III. SUMMARY OF OPINIONS

5. My opinions in this Declaration are based on my review of the ‘628 Patent, its prosecution history before the U.S. Patent and Trademark Office, the IPR Petition concerning this patent, and references cited therein in support of the Petition. I draw upon my experience and knowledge of acoustical engineering, psychoacoustics, signal processing, human-machine interaction, and virtual reality systems.

IV. RELEVANT LEVEL OF ORDINARY SKILL IN THE ART

6. In my opinion, as relates to the ‘628 Patent, a person having ordinary skill in the relevant art (a PHOSITA) would have several years of academic and/or professional experience in a technical field relevant to digital audio signal processing, such as electrical engineering, computer engineering, or computer science; and a familiarity with relevant literature and concepts concerning virtual “3D” audio processing, which were widely available at the time of disclosure.

V. The ‘628 Patent

7. The ‘628 patent describes various scenarios whereby two or more participants in a video enhanced telephone call (“calling parties and called parties”) can more naturally see and hear each other during the call. Within the space defined between users (between one and two meters in independent claim 9 and at least one meter in independent claim 16), various participants can interact in three-

dimensional space. The claims of '628 refer to tracking changes in location and orientation of both called and calling parties relative to one another, with video and spatial audio processing to make these changes conform to what would occur visually and audibly if both parties were interacting within the real world.

8. The changes in location and orientation of called and calling parties described in '628, including that of other sounds in the environment, involves manipulating virtual sound locations (sound localization points, or SLPs) in both elevation as well as azimuth.

VI. GROUND 1 OF THE PETITION: BILLINGHURST AND SCHRÖDER

9. I understand that Petitioner relies on Billingham, Mark, et al. "A wearable spatial conferencing space," Digest of Papers. Second International Symposium on Wearable Computers. IEEE, 1998 ("Billingham") and International Pub. WO 2005/032209 to Ernst Schröder ("Schröder") to allege that these references teach or suggest every limitation of independent claims 9 and 16. I disagree, and for the reasons discussed below, I am of the opinion that Petitioner mischaracterized teachings of Billingham and Schröder, and that a PHOSITA would have seen no rationale for combining these two sources.

A. Billingham

10. Billingham describes the use of a "wearable computer" having an "augmented reality communication space with audio enabled avatars of the remote

collaborators surrounding the user”. Ex. 1010, 1. The paper dates from 1998. The described technology uses “custom developed telephony libraries that incorporate the Microsoft Direct Sound libraries” but does not refer to HRTF processing of sounds in three-dimensional space. *Id.*, 6.

11. Figure 1 shows Figure 4 from the paper, along with an enlargement of the “radar display”. *See id.* Note that the conference participants are at the same elevation, presumably at eye level of the person wearing the system. The “radar display” apparently shows two users within the red viewing angle corresponding to the photo, and two additional users outside of the viewing angle. Such two-dimensional displays of sound sources on the azimuth were already well known by the time of the publication (e.g., Ex. 2003, Begault, D. R. (1995) “Multi-channel spatialization system for audio signals” U.S. patent 5,438,623; described in Begault (2000), p. 187-190). At the time of Billinghamurst’s paper, a PHOSITA familiar with 3D audio applications for teleconferencing was concerned with arranging voices at eye level, as if talking to participants around a conference table. This is confirmed by Kyriakakis (par. 138): “In general, videoconferences were widely known in the relevant time frame to mimic a conference room setting, where participants are seated around a physical conference table and could meet and collaborate face-to-face.”

Figure 1.

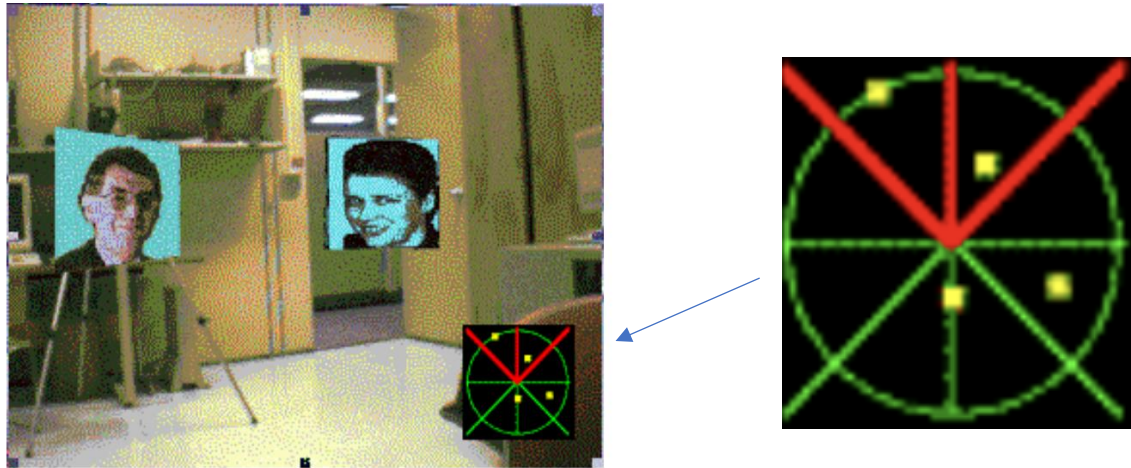


Figure 4.0 The User's View of the Wearable Conferencing Space

12. Claim 9 of the '628 patent states that the sound localization point (SLP) is located at an image location of the calling party, and that the head movements of the called party are tracked with respect to that SLP and corresponding image. The patent gives examples of head movement, "such as changing location, yaw, pitch, or roll", and adjusting the sound of the speaker's voice in response to those movements. ('628 at 31:52-32:2.). "These adjustments change the sound so the sound that the listener hears emulates the sound that the listener would hear if the speaker were physically present at the sound localization point 1850." ('628 at 32:2-5). This teaches that translation of the head positions of either the talker or listener should be compensated for in three-dimensional space that includes not only azimuth, but elevation. These concepts can also be seen in claims 9 and 11:

[b] displaying, during the telephone call and to the called party with a wearable electronic device worn on a head of the called

party, an **image that represents the calling party that is seen** by the called party as being at the SLP that is one meter to two meters away from the called party;

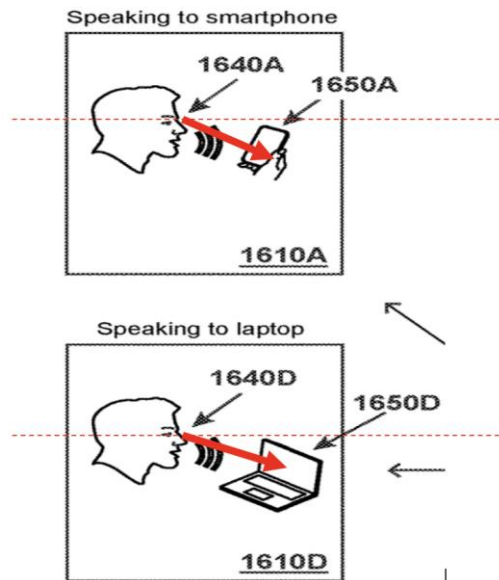
[c] tracking, during the telephone call and with the wearable electronic device, head movements of the called party with respect to the **image that represents the calling party** and that is seen by the called party as being at the SLP; and

[d] **changing, during the telephone call and in response to the head movements of the called party**, the HRTFs processing the voice of the calling party so the voice of the calling party continues to localize to the SLP that is seen by the called party as being the image that represents the calling party that is one meter to two meters away from the called party **while the head of the called party moves with respect to the image that represents the calling party.**

11. The method of claim 9 further comprising: tracking, during the telephone call and with a wearable electronic device worn on a head of the calling party, head movements of the calling party; and **changing, during the telephone call and in response to the head movements of the calling party, the voice of the calling party so the voice of the calling party emulates a sound that the called party would hear if the calling party were physically present at the SLP and talking to the called party.**

13. Figure 2 is an excerpt from Figure 16 of the '628 patent; the red arrow indicates the fact that the SLPs of the receiver (located as displayed in 1650A or 1650D) are located below eye level of the persons talking, shown as the dashed line (1640A, 1640D). In these examples, the SLP of the receiver is at an image located at the end of the solid red arrow.

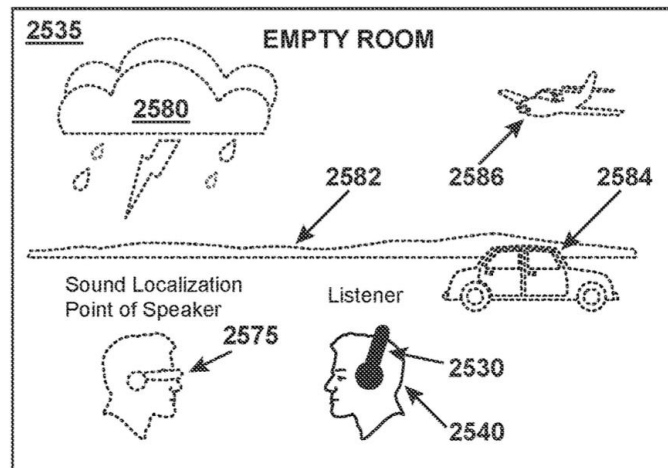
Figure 2.



14. Per the disclosure and claims of '628 discussed above, if either the talker 1640A moved their head in the vertical dimension or if the sound associated with the SLP at 1650A or 1650D moved vertically, adjustments would be made to the sound processing "so the voice of the calling party emulates a sound that the called party would hear if the calling party were physically present at the SLP". This includes not only vertical movement, but also processing based on 6 degree of freedom (DOF) movement (up/down, forward/back, left/right pitch, roll, and yaw; within the space between the calling and called parties). Many other examples are given in '628 that require 6 DOF interaction within three-dimensional space. An example includes the multiple virtual objects in Figure 25 that exist at elevated

locations (lightning, 2580; airplane 2586) relative to the location of the listener 2540 or the talker 2575 (Figure 3).

Figure 3.



15. For all these reasons, it is my opinion that a PHOSITA would understand that the tracked “head movements” in the ‘628 claims include dynamically-changing HRTF processing to account for 6DOF movements of communicating parties in 3-dimensional space.

16. Billingham does not teach a method of interaction within 3-dimensional space that includes an elevation component, or a change in the 6 DOF coordinates of the SLPs for interaction. Furthermore, Billingham does not disclose the use HRTFs as a means of spatializing sound, nor does he disclose an elevation component that would be necessary for 3-dimensional sound reproduction. Instead, the sounds are fixed in elevation and at eye level positions on the azimuth around

the listener. Billinghurst's conference participants cannot move in 3-dimensional space, as suggested by fixed images of the persons shown in the poster boards in Figure 1. Interactivity is limited to movement by the user facing different participants.

17. In a 3D audio display, elevation cues provided by HRTFs are important for distinguishing sounds located on "the cone of confusion" as shown in Figure 5 below. Note that a sound source at position **A** would theoretically produce an identical ITD (interaural time differences) and IID (interaural intensity differences) as a source at position **B** and similarly for sources at positions **x** and **y**. When ITD and IID cues are maximally similar between two locations, such as in the present example, a potential for confusion between the positions exists in the absence of a spatial cue other than ITD and IID. This is called the **cone of confusion** in the literature. The ability to disambiguate sources from above and below in cases where ITD and IID would not supply this information emphasizes the importance of **spectral cues** for vertical localization, caused by the HRTF.

Figure 5. (From Begault, 2000).

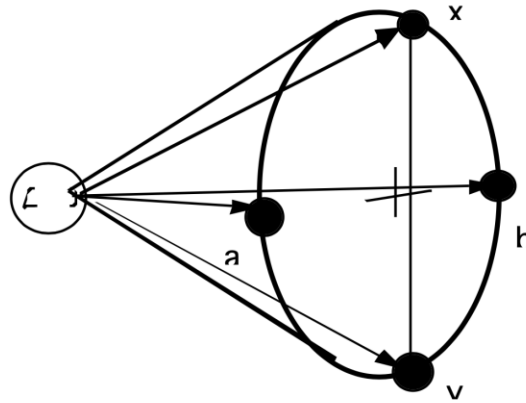


Figure 2.8. The cone of confusion. Identical values of IID and ITD can be calculated for a spherical model of a head at two opposite points anywhere on the surface of the cone (here, **a** and **b** show a front-back ambiguity, and **x** and **y** show an elevation ambiguity).

18. Billinghamurst did not disclose the use of elevation or azimuth cues from HRTFs for three-dimensional audio for at least two reasons: (1) it was beyond technical capabilities of the current system (2) it did not conform to the concept of his paper, exemplified to the “eye level” arrangement of conference participants. Given these restrictions, and in order to support bi-directional communication given technical limits, he restricted his audio to have only 8 bits of dynamic range, i.e., about 48 decibels. “The audio is then spatialized in real time. The audio is implemented utilizing Microsoft’s Direct Sound technology.... for the audio to operate in full duplex mode it has to be captured at a rate of 8 bit 22KHz, resulting in a data rate 172Kb/s.” Ex. 1010, 7.

19. The article Petitioner cites in support of the notion that Microsoft DirectSound implements HRTFs (Ex. 1043) does not mention HRTFs at all, much

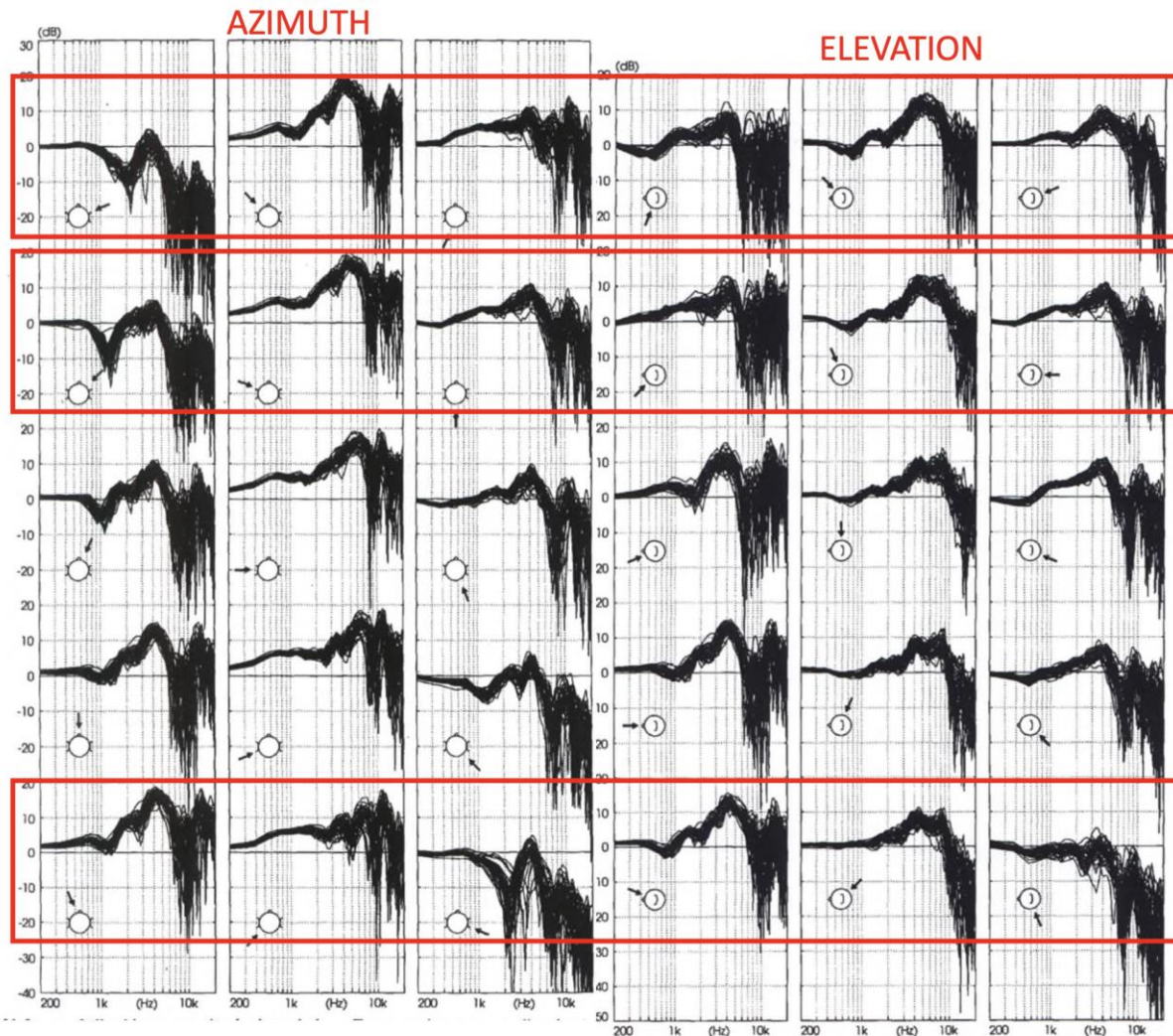
less say that their use in Microsoft DirectSound is mandatory. And based on Billinghurst's limited disclosure of the technical details of its sound system, a PHOSITA would understand that Billinghurst could not have used HRTFs.

20. In line with a PHOSITA's understanding of digital audio processing, Billinghurst's 8-bit audio using a 22 KHz sample rate is incapable of any meaningful spatial audio rendering because of it could not represent the magnitude of spectral changes effected by HRTF filters. Figure 6 (adapted from Ex. 2004, Moller, 1995, Figure 13 and 14) shows the measured dynamic range of HRTF filters, with the dynamic range of 8 bits overlayed as red rectangles. These are measurements for multiple persons at the left ear, for different azimuths and elevations as shown by the arrows at the bottom left of each graph.

21. Figure 6 shows that, for even a single source input at maximum input volume, there would not be sufficient dynamic range to capture the dynamic range of the black line vertical excursions representing the "peaks and "troughs" of HRTF filtering. In a practical application with multiple participants, the usable dynamic range would reduce even further (the vertical extent of the rectangles would decrease). This restriction of the 8-bit dynamic range (and the high frequency cut-off at 11 KHz of the 22 KHz sample rate, which eliminates additional cues) would cause Billinghurst's system to be unusable for successfully conveying 3D audio cues for spatial hearing. This is why practical implementations of 3D audio require at

least a 16-bit dynamic range, equivalent to 96 decibels, and why customized sound cards would have been required that exceed the technical limits taught by Billinghamurst.

Figure 6.



B. Schröder

22. Schröder's invention relates to methods for mitigating inside-the-head localization when wearing headphones. A solution is proposed whereby head

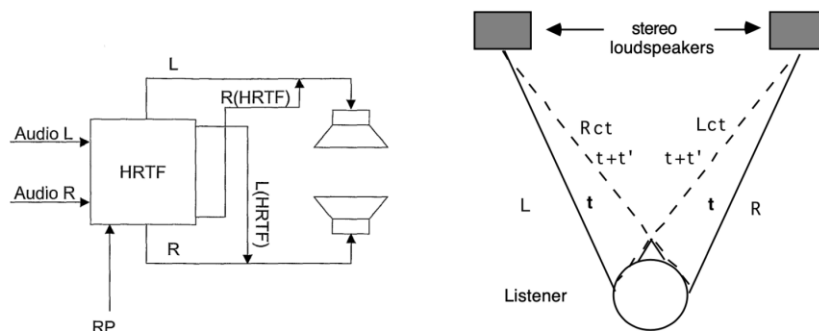
tracking and “trunk” tracking is used to “detect the rotational movements of the head and are used to keep the position of a virtual sound source outside the head.” Ex. 1012, 2:6-10. To do this, a method using HRTF filtering is used to keep headphone-produced sound at the same position on average that would be experienced if one were listening to stereo loudspeakers outside of the head. *Id.*, 2:24-28. To do this, head- and trunk-tracking is used to keep the stereo image location produced by two loudspeakers independent of movement of the listener, subject to override based on certain movements of the listener as I discuss more below. The loudspeakers’ positions are simulated with a pair of HRTF filters, and an additional pair of HRTF filters are used in the manner of well-known “cross-talk filtering” (Figure 15; ref. Begault (2000), Figure 5.13, p. 177).

23. Whereas the original use of cross-talk filtering was to make loudspeakers simulate headphone listening by cancelling the cross talk signal, Schröder proposes a “mirror image” of the same concept of by adding cross-talk back into the signal from the opposite channel. In other words, for a headphone user, Schröder simulates what occurs with stereo loudspeakers, where both ears hear both loudspeakers.

24. Figure 7 (left) shows Schröder’s cross-talk filtering, and Figure 7 (right) shows cross talk filtering as described in Begault (2000) p. 175, based on the concept originally proposed by Atal and Schroeder (Ex. 2005, “Apparent Sound Source

Translator,” U.S. Patent 3,236,949, 1966). Cross-talk cancellation considered a symmetrically placed listener and two loudspeakers. In Figure 7 (right), the cross-talk signal paths describe how the left speaker will be heard at the right ear by way of the path Rct, and the right speaker at the left ear via path Lct. The direct signals will have an overall time delay t and the cross-talk signals will have an overall time delay $t + t'$. Using cross-talk cancellation techniques, one can eliminate the Lct path by mixing a 180-degree phase-inverted and t' -delayed version of the Lct signal along with the L signal, and similarly for Rct. (Ex. 1036, Begault. 2000, p. 175). Schröder’s circuit from Figure 15 of the patent application (Figure 7, left) is the same application of the cross-talk filtering, without the use phase inversion to cancel out the cross-talk signal.

Figure 7.



25. The cross-talk filtering shown in Figure 7 (left) is not a necessary or sensible condition for the simulation of virtual sounds sources at SLPs in ‘628,

particularly for headphone delivery¹. In fact, Schröder's cross-talk filtering only serves (purportedly) to externalize a specific loudspeaker simulation, and would in fact be viewed by a PHOSITA as **unnecessary and degradative** to the normal means of simulating virtual sound source positions using 3D audio. All of the existing literature at the time of Schröder's disclosure would have not used cross-talk filtering, and instead used techniques of HRTF filtering as summarized in Begault (2000), with a single binaural HRTF pair used to simulate a SLP.

26. In the absence of visual cues, such as a "talking head", externalization of headphone sound was known to be optimized by the use of reverberation, and not cross-talk filtering as described by Schröder (Begault, 2000). There is no scientific study that supports Schröder's contention that sound would be externalized using his described cross-talk filtering technique. Finally, Billinghamhurst has the advantage of sound externalization due to the phenomenon of **visual capture**, where the localization of sound will be biased by visual localization. In other words, a PHOSITA would realize that a user of Billinghamhurst's system would naturally localize talkers to their visual positions as shown in Figure 1, and not go to Schröder to learn about a problem of stereo imagery heard inside of the head.

¹ The '628 patent does disclose the use of cross talk **cancellation** for loudspeaker playback of 3D sound but does not cross talk filtering to **add** a cross talk signal.

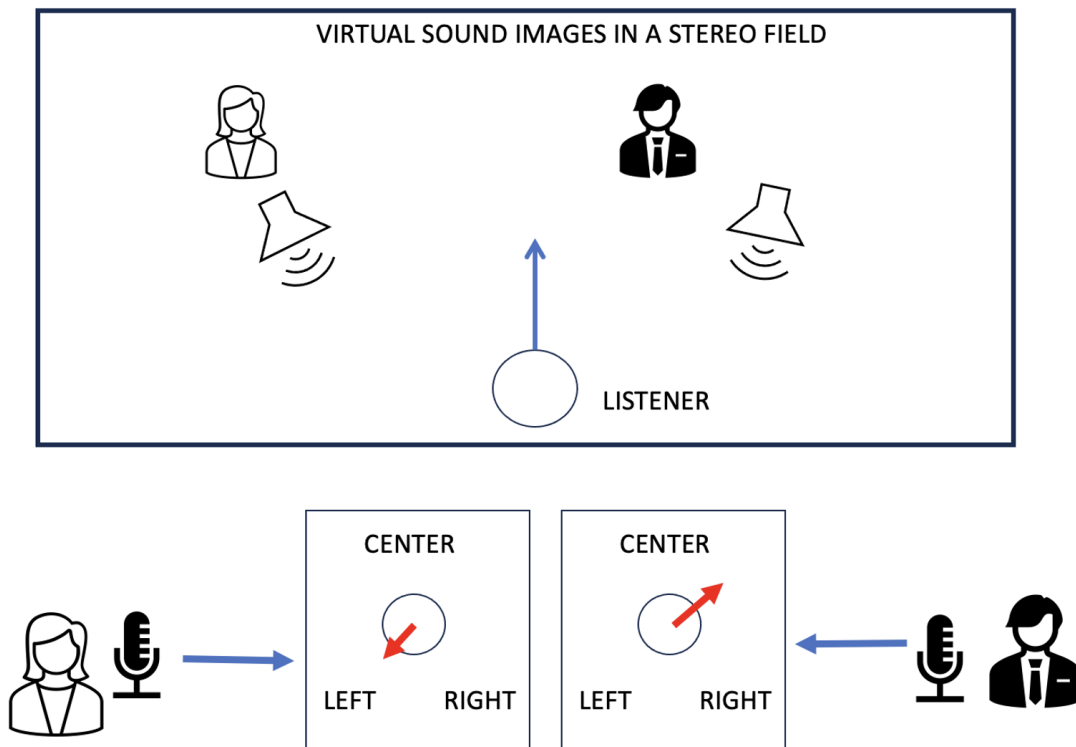
27. Kyriakakis (Ex. 1003, ¶¶100-106) claims that it would have been obvious for a PHOSITA to combine Billinghurst's non-HRTF based conferencing system with the use of HRTFs proposed by Schröder. I disagree for the following reasons:

28. Schröder teaches a method to maintain a virtual image at a fixed, **constant** position using HRTFs, by simulating the virtual image **produced by stereo loudspeakers** independent of head position. Ex. 1012, 3:1-12. This contrasts the use of HRTFs in a spatial auditory display, where the position of simulated sound sources can potentially move to any location in three-dimensional space relative to a listener, even when the head of the listener is fixed. In other words, Schröder teaches a method of creating a stable SLP independent of movement of the listener. The '628 patent, in contrast, teaches the use of dynamically-changing listener and SLP locations in three-dimensional space. These are mutually exclusive goals.

29. Schröder does not consider the use of sound source elevation. Schröder is concerned with a method to "process the signal which is coming from the signal source and is reproduced on the headphones such that the reproduction on the headphones corresponds to the **reproduction of the same signal on a stereo loudspeaker arrangement**". *Id.*, 2:33-37. Stereo loudspeaker reproduction involves virtual imagery that is restricted on the stereo plane between the loudspeakers, as shown in Figure 8, below. In stereophony, virtual sound locations are primarily

formed through amplitude panning (relative level between left and right channels). Schröder therefore teaches a method to maintain a pre-designed arrangement of stereo loudspeaker imagery over headphones; not to create dynamically-changing virtual images in a three-dimensional world. For this reason, a PHOSITA would not have viewed Schröder's stereophonic reproduction solution as relevant or related to Billingham's teleconferencing system, and would not have been motivated to combine the technologies literally or conceptually to arrive at the approach claimed in the '628 patent.

Figure 8.



30. In '628, claims 9 and 11 establish that the SLPs of virtual images remain fixed according to their location in 3-dimensional space and with reference to the user. There is no 'averaging' of spatial positions of virtual sources to the user. Contrasting this, Schröder not only wishes to establish a fixed SLP independent of movement, but also to make "a method which is used to perceive aural events as having a constant spatial direction on average". *Id.*, 6:4-6. "**Averaging**" the positions of aural events independent of head movement would be contrary to the technique of **dynamically** changing spatial position of a SLP relative to a listener, as taught in '628: Schröder, p. 5 par. 4-8 states:

It is therefore desirable to specify a method which is used to perceive aural events as having a constant spatial direction **on average**, i.e. **as coming from one preferred direction on average** in virtually stationary fashion, even when the listener is moving

31. Schröder also proposes a "change in preferred direction" of his virtual image, for instance, "a change in the position of the listener which is for a longer time or is relatively infrequent results in the direction from which the aural event appears to come **being matched to the new preferred direction.**" *Id.*, 6:36-7:3. This is contrary to the location of dynamically changing sounds in a virtual world where a "change in preferred direction" cannot be made arbitrarily simply to match the externalization image of a pair of loudspeakers. Again, Schröder's "preferred direction" is pertinent to his overall goal to maintain an illusion of stereophonic

loudspeaker reproduction over headphones. A PHOSITA would have understood this goal is distinct from the simulation of dynamically-changing virtual sound sources in three dimensional space. This further strengthens my opinion that a PHOSITA would not have viewed Schröder's stereophonic reproduction solution as relevant or related to Billinghurst's teleconferencing system, and therefore would not have been motivated to combine Billinghurst with Schröder to arrive at the approach claimed in the '628 patent.

VII. GROUND 3 OF THE PETITION: BILLINGHURST AND BALLAS

32. I understand that Petitioner relies on Billinghurst and U.S. Patent Publication No. 2003/0059070 to James A. Ballas ("Ballas") to allege that these references teach or suggest every limitation of independent claims 9 and 16. I understand petitioner considers "Ballas and Billinghurst to be structurally and functionally similar". I disagree for the reasons discussed below for Ballas and above for Billinghurst. I am of the opinion that a PHOSITA would have seen no rationale for combining these two sources.

33. Ballas describes, in a very general way, a spatial audio display for a user using "at least one pair of speakers near a user's temple for generating spatialized audio signals". Ex. 1008, 18:3-4. Except for the use of speakers mounted as described, Ballas's 2003 publication offers nothing novel regarding what was known regarding 3D audio processing at the time. The publication describes head

tracking and HRTF filters that are updated in response to listener orientation, a concept that was first demonstrated in the 1980s (*See* Ex. 1036, Begault 2000). Even the concept of using speakers was known at the time as “nearphones”: loudspeakers near the ears, mounted in a headrest, motorcycle helmet, etc. Once a transducer is no longer in direct proximity to the ear canal, it is essentially a loudspeaker, as Ballas describes in reference to loudspeakers on either side of a personal computer, a “typical multimedia configuration comes as close to binaural sound as can be expected from free field speakers”. *Id.*, 3:17-19.

34. A PHOSITA would immediately determine that Ballas’ publication offers nothing from a technical standpoint for HRTF filtering or rendering of 3D audio. In paragraph 24, he states without further elaboration that his “computer system 102 is an “off the shelf commercially available system”.

35. Furthermore, a PHOSITA would be immediately concerned with the obvious cross-talk that would occur between the two external loudspeakers, and the lack of a solution to the problem in Ballas. Without a traditional headphone design that uses a circumaural (around the outer ear) or supra-aural (on the outer ear) cup and earpad, or without an insert headphone (e.g., “earbuds”), the sound from each transducer cannot reach the ear canal by a direct, isolated path. This contradicts the normal teachings for implementing 3D audio, where the signal is processed for each ear in isolation by a binaural HRTF pair (Ex. 1036, Begault, 2000). In Ballas’s

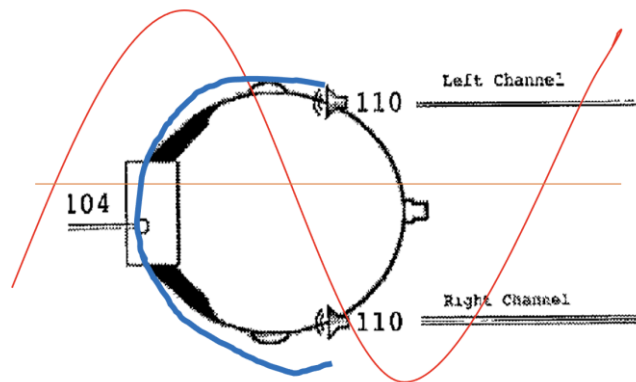
system (Figure 9) the sound from each external transducer meant for one ear will “bleed through” (diffract) around the head to reach the opposite ear, so as to be audible at the opposite ear; and increasingly so as wavelengths become larger than the head². Lower sound frequencies would lack any significant inter-channel isolation.

36. Figure 9 is an annotation of Figure 2 of Ballas, that shows in red a superimposed wavelength that is larger than the head. Sound would also diffract around the head (the blue line shows a simple example) from both the front and the rear of each transducer. Note that Ballas’ transducers are not oriented directionally opposite to the ear canal, but instead at a 90 degree orientation to the ear. Small transducers as shown in Ballas’ Figure 3 will emit a significant level of sound in all directions (omnidirectionally). Such cross-talk would act as a significant distortion to any provided HRTF cues, and therefore significantly affect the ability to create spatial imagery. Ballas does not recognize or address how to eliminate this obvious cross talk problem, despite the fact that it was addressed by Atal and Schroeder (1966) and many others since then. (Obviously, Ballas’ inadvertent crosstalk is also

² As frequency goes down, its wavelength increases (wavelength = velocity / frequency). At a certain point, an obstacle to the wavelength appears small. A typical head only shadows frequencies above ~1.5 KHz.

unlike Schröder, who purposely used cross talk in an attempt to create externalized imagery from stereo loudspeaker imagery).

Figure 9.



37. Given that Billingham never mentions HRTFs in an application to teleconferencing, and the technical description of Ballas that relies on unnamed “off the shelf” products and ignores the obvious problem of interchannel cross talk for loudspeaker reproduction of 3D sound, a PHOSITA would in my opinion not look at these two technologies and be motivated to combine them in any way. There are simply too many basic technical deficiencies and unspecified details in Ballas’s system for a PHOSITA to have considered it a viable candidate for improving Billingham’s spatialized audio to arrive at the approach claimed in the ‘628 patent.

VIII. CONCLUSION

38. I declare that all statements made herein of my knowledge are true, that all statements made on information and belief are believed to be true, and that these

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statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code. I reserve the right to modify my opinions as additional information becomes available to me.

Dated: October 11, 2023

By: 
