

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

META PLATFORMS, INC.,

Petitioner,

v.

JAWBONE INNOVATIONS, LLC,

Patent Owner.

Patent No. 8,019,091

Filing Date: September 18, 2003

Issue Date: September 13, 2011

Inventor: Gregory C. Burnett and Eric F. Breitfeller

Title: VOICE ACTIVITY DETECTOR (VAD)-BASED
MULTIPLE-MICROPHONE ACOUSTIC NOISE SUPPRESSION

DECLARATION OF AKBAR M. SAYEED, Ph.D.

Case No. IPR2023-01127

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I, Akbar M. Sayeed, declare as follows:

1. I have been asked by counsel for Patent Owner, Jawbone Innovations, LLC (“Jawbone” or “Patent Owner”), to review U.S. Patent No. 8,019,091 (the “’091 Patent”) entitled VOICE ACTIVITY DETECTOR (VAD)-BASED MULTIPLE-MICROPHONE ACOUSTIC NOISE SUPPRESSION and to provide my technical review, analysis, insights, and opinions regarding the ’091 Patent in view of the prior art cited by Petitioner Meta Platforms, Inc. (“Meta” or “Petitioner”). I submit this Declaration in support of Patent Owner’s Response in this IPR proceeding. I have personal knowledge of the matters stated herein and would be competent to testify to them if required.

2. I have been retained on behalf of Jawbone for the above-captioned *inter partes* review proceeding. I understand that the ’091 Patent is currently assigned to Jawbone.

3. I am over 18 years of age. I have personal knowledge of the facts stated in this Declaration and could testify competently if asked to do so.

I. INTRODUCTION

A. Background and Qualifications

4. I have reviewed and am familiar with the specification of the ’091 Patent. I understand the ’091 Patent has been provided as Exhibit 1001. I will cite to the specification using the following format: ’091 Patent at col.:line.

5. My CV is being submitted simultaneously herewith (Ex. 2003).
6. I received my B.S. degree in Electrical and Computer Engineering (ECE) from the University of Wisconsin-Madison in 1991. I received my M.S. and Ph.D. degrees in ECE from the University of Illinois at Urbana-Champaign in 1993 and 1996, respectively. In my undergraduate and graduate studies, I took a variety of courses generally focusing on the areas of signal processing, communication theory, information theory, electromagnetics and antennas, and statistical techniques in signal processing and communications. My Ph.D. dissertation was entitled “Statistical Time-Frequency Analysis” in which I proposed new framework for statistical signal processing using time-frequency representations, mathematical tools that extend the powerful theory of Fourier transforms and Fourier analysis to time-varying signals and systems.
7. I currently work as an Independent Researcher, Engineer and Technical Consultant, and worked as professor of Electrical and Computer Engineering at the University of Wisconsin-Madison from 1997-2021, where I directed the Wireless Communications and Sensing Laboratory until my retirement on August 1, 2021 to pursue a career as an independent researcher and consultant.
8. My current work as an independent researcher and consultant spans STEM (science, technology, engineering & mathematics) fields through the lens of

information science and technology. My STEM skills and experience cover a broad range of areas, including:

- Wireless technologies for sensing, processing, and communication of information (5G/6G/XG), internet of things, and emerging technologies for untapped spectrum (e.g., millimeter-wave, THz).
- Sensing and acquisition of data in new modalities through technological innovation.
- Machine learning and statistical techniques for extracting useful information from data.
- Quantum information science and technology (computing, sensing, and communication) spanning foundational concepts, algorithms, and platforms.
- Conception, design, and development of new information technologies through basic theory, computational modeling, and hybrid software-hardware prototyping and experimentation.

9. I have written/co-written 200+ papers in leading journals and conferences. I am an inventor/co-inventor of 10 patents.

10. After receiving my Ph.D. in 1996, I spent a year at Rice University as a postdoctoral research fellow where I expanded the scope of my research to the growing field of wireless communications that underpins much of mobile cellular

technology. In particular, the propagation channels encountered in mobile cellular communication are inherently time-varying in nature and that provided a natural connection to my Ph.D. research. After spending a year at Rice University, I accepted a position as an Assistant Professor in the ECE Department at the University of Wisconsin-Madison in 1997. I was granted tenure and promoted to Associate Professor in 2003, and was promoted to Professor in 2008.

11. I founded and directed the Wireless Communication and Sensing Laboratory at UW-Madison and engaged in research, teaching, and innovation in the basic science, engineering, and technology of sensing, processing, and communication of information. In particular, I led a team in the conception, design, development, and successful demonstration of a state-of-the-art prototype for multi-beam MIMO (multiple input multiple output) communication at 28 GHz based on the concept of a lens array that I had pioneered.

12. I co-founded and co-led the NSF-sponsored Research Coordination Network (RCN) on millimeter-wave wireless (2016-2019) for bringing together researchers from academia, industry, and government agencies to address critical technical challenges in the area.

13. From 2017-2019 I served as a Program Director in the Electrical, Communications and Cyber Systems (ECCS) Division of the Directorate of Engineering at the National Science Foundation. At the NSF, I managed existing

programs and initiated new research programs involving sensing, processing, and communication of information in all possible physical modalities, architectures, and technologies, including quantum information science and engineering. I actively contributed to three NSF-wide working groups: Electromagnetic Spectrum Management (ESM) working group, and the working groups of two of the 10 NSF Big Ideas: i) Quantum Leap and ii) Harnessing the Data Revolution. In particular, I co-led the team that developed the NSF solicitation for Quantum Leap Challenge Institutes (Feb 2019) in response to the National Quantum Initiative (NQI) Act signed in December 2018.

14. I have a demonstrated history (25 yrs.) of leading an interdisciplinary research and development group at the forefront of foundational and technological innovations in wireless communication and sensing. Physics-based accurate and computationally tractable system modeling has been a key underlying theme in my work, spanning communication & sensor networks, multipath propagation over highly dynamic environments, wideband MIMO systems, mm-wave and THz wireless, and prototype development (hardware & software).

15. My technical background, experience and skills are directly relevant to the subject matter in this case. The modeling, analysis, and processing of information bearing signals and waves, including transmission and reception through antennas and antenna arrays, and propagation over channels, has been an

underlying theme throughout my career. In particular, I have extensive experience in the conception, modeling, development, and analysis of techniques and algorithms for processing and filtering of signals from an array of sensors or antennas, including beamforming, interference and noise suppression, and adaptive filtering methods. While most of my work has focused on electromagnetic signals, the underlying physics and mathematics are very similar to acoustic signals.

II. COMPENSATION

16. My compensation for time worked on this proceeding is not dependent on any issues related to the '091 Patent, the outcome of this proceeding, or the substance of my opinions. My compensation for time worked on this proceeding is at my customary rate of \$200 per hour. I have no financial interest in, or affiliation with, the Patent Owner or any of the real parties in interest.

III. MATERIALS CONSIDERED

17. In providing my technical review, analysis, insights, and opinions, I have considered the '091 Patent and its prosecution history.

18. I have also considered the Petition filed by the Petitioner in this proceeding and the relevant exhibits relied on by Petitioner, including the expert declaration submitted by Richard M. Stern, Ph.D. ("Ex. 1002").

19. I have further considered the transcript of Dr. Stern's deposition. ("Ex. 2004").

20. I have also considered my own experience and knowledge, as discussed above, and described more fully in my CV, in areas including signal processing, electrical engineering, and other related technologies.

IV. LEGAL PRINCIPLES

21. I understand that a patent claim is unpatentable as “obvious” if the subject matter of the claim as a whole would have been obvious to a person of ordinary skill in the art (POSITA) as of the time of the invention at issue.

22. I understand that the use of “the person of ordinary skill” rubric is to prevent one from improperly, in the present day, using hindsight to decide whether a claim is obvious.

23. I understand that the following factors must be evaluated to determine whether the claimed subject matter is obvious: (1) the scope and content of the prior art; (2) the difference or differences, if any, between the scope of the patent claim and the scope of the prior art; and (3) the level of ordinary skill in the art at the time of the invention.

24. I understand that certain secondary considerations, such as commercial success, skepticism of experts, surprise, and copying, may provide evidence of non-obviousness. I further understand that such considerations are often the most probative and determinative of obviousness or non-obviousness.

25. I understand that a reference “teaches away” when a POSITA, reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the patent’s inventor.

26. I understand that even if a reference does not teach away, its statements regarding preferences for other modes or paths are still relevant to whether a POSITA would combine it with another reference.

27. I understand that a reference must be considered for all that it teaches, including disclosures that diverge and teach away from the invention at hand.

28. I understand that I must construe a claim in accordance with the ordinary and customary meaning of the language of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

V. LEVEL OF SKILL IN THE ART

29. I understand that I should perform my analysis from the viewpoint of a person of ordinary skill in the art. I understand that this hypothetical person of ordinary skill in the art is considered to have the normal skills of a person in a certain technical field. I understand that factors that may be considered in determining the level of ordinary skill in the art include: (1) the education level of the inventor; (2) the types of problems encountered in the art; (3) the prior art solutions to those problems; (4) rapidity with which innovations are made; (5) the sophistication of the technology; and (6) the education level of active workers in the field.

30. In my opinion, a person of ordinary skill in the art would have a bachelor's degree in computer engineering, computer science, electrical engineering, mechanical engineering, or a similar field, and approximately three years of industry or academic experience in a field related to acoustics, speech recognition, speech detection, or signal processing. Work experience can substitute for formal education and additional formal education can substitute for work experience.

VI. THE CLAIMED INVENTION OF THE '091 Patent

31. I have reviewed the '091 Patent, entitled VOICE ACTIVITY DETECTOR (VAD)-BASED MULTIPLE-MICROPHONE ACOUSTIC NOISE SUPPRESSION (Ex. 1001). It issued on September 13, 2011, and was filed on September 18, 2003.

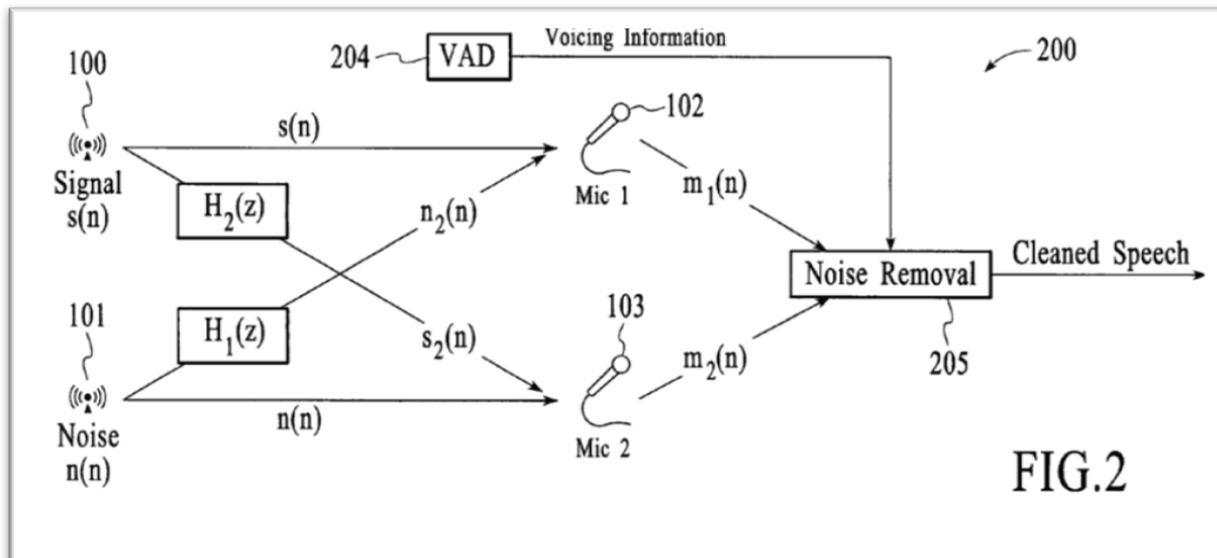
32. The '091 Patent discloses inventions for “acoustic noise suppression in multiple-microphone systems using Voice Activity Detectors (VAD).” '091 Patent, Abstract.

(57)

ABSTRACT

Acoustic noise suppression is provided in multiple-microphone systems using Voice Activity Detectors (VAD). A host system receives acoustic signals via multiple microphones. The system also receives information on the vibration of human tissue associated with human voicing activity via the VAD. In response, the system generates a transfer function representative of the received acoustic signals upon determining that voicing information is absent from the received acoustic signals during at least one specified period of time. The system removes noise from the received acoustic signals using the transfer function, thereby producing a denoised acoustic data stream.

33. In exemplary embodiments, the invention provides systems and methods for detecting and processing a desired signal in the presence of acoustic noise using a noise removal algorithm. '091 Patent at 1:16-18; Fig. 2.



34. According to these exemplary embodiments, the algorithm uses two microphones, a “signal” microphone and a “noise” microphone to capture mostly signal with some noise, and to capture mostly noise with some signal. ’091 Patent at 3:20-38.

FIG. 2 is a block diagram including components of a noise removal algorithm **200** of an embodiment. A single noise source and a direct path to the microphones are assumed. An operational description of the noise removal algorithm **200** of an embodiment is provided using a single signal source **100** and a single noise source **101**, but is not so limited. This algorithm **200** uses two microphones: a “signal” microphone **1** (“MIC1”) and a “noise” microphone **2** (“MIC 2”), but is not so limited. The signal microphone MIC **1** is assumed to capture mostly signal with some noise, while MIC **2** captures mostly noise with some signal. The data from the signal source **100** to MIC **1** is denoted by $s(n)$, where $s(n)$ is a discrete sample of the analog signal from the source **100**. The data from the signal source **100** to MIC **2** is denoted by $s_2(n)$. The data from the noise source **101** to MIC **2** is denoted by $n(n)$. The data from the noise source **101** to MIC **1** is denoted by $n_2(n)$. Similarly, the data from MIC **1** to noise removal element **205** is denoted by $m_1(n)$, and the data from MIC **2** to noise removal element **205** is denoted by $m_2(n)$.

35. In exemplary embodiments, the noise removal element receives a signal from a VAD element, which uses physiological information to determine when a speaker is speaking. The VAD may include, at least, an accelerometer, a skin surface microphone in physical contact with the skin of a user, a human tissue vibration detector, a radio frequency (RF) vibration and/or motion detector/device, an electroglottograph, an ultrasound device, an acoustic microphone used to detect

acoustic frequency signals corresponding to the user's speech directly from the skin of the user, an airflow detector, and a laser vibration detector. '091 Patent at 3:39-50.

The noise removal element **205** also receives a signal from a voice activity detection (VAD) element **204**. The VAD **204** uses physiological information to determine when a speaker is speaking. In various embodiments, the VAD can include at least one of an accelerometer, a skin surface microphone in physical contact with skin of a user, a human tissue vibration detector, a radio frequency (RF) vibration and/or motion detector/device, an electroglottograph, an ultrasound device, an acoustic microphone that is being used to detect acoustic frequency signals that correspond to the user's speech directly from the skin of the user (anywhere on the body), an airflow detector, and a laser vibration detector.

36. In exemplary embodiments, certain transfer functions from the signal source and the noise source to the mics are assumed to be unity. '091 Patent at 3:51-59.

The transfer functions from the signal source **100** to MIC **1** and from the noise source **101** to MIC **2** are assumed to be unity. The transfer function from the signal source **100** to MIC **2** is denoted by $H_2(z)$, and the transfer function from the noise source **101** to MIC **1** is denoted by $H_1(z)$. The assumption of unity transfer functions does not inhibit the generality of this algorithm, as the actual relations between the signal, noise, and microphones are simply ratios and the ratios are redefined in this manner for simplicity.

37. In exemplary embodiments, a conventional two-microphone noise removal system uses information from Mic 2 to attempt to remove noise from Mic 1.

The system thus generates a transfer function that characterizes the received acoustic signals, while the VAD indicates that the user is not talking. '091 Patent at 3:60-4:2.

In conventional two-microphone noise removal systems, the information from MIC 2 is used to attempt to remove noise from MIC 1. However, an (generally unspoken) assumption is that the VAD element 204 is never perfect, and thus the denoising must be performed cautiously, so as not to remove too much of the signal along with the noise. However, if the VAD 204 is assumed to be perfect such that it is equal to zero when there is no speech being produced by the user, and

equal to one when speech is produced, a substantial improvement in the noise removal can be made.

38. In exemplary embodiments, the transfer function can be used to remove environmental noise while the user is speaking, resulting in denoised, clean speech. '091 Patent at 5:13-25.

After calculating $H_1(z)$ and $H_2(z)$, they are used to remove the noise from the signal. If Equation 1 is rewritten as

$$S(z) = M_1(z) - N(z)H_1(z)$$

$$N(z) = M_2(z) - S(z)H_2(z)$$

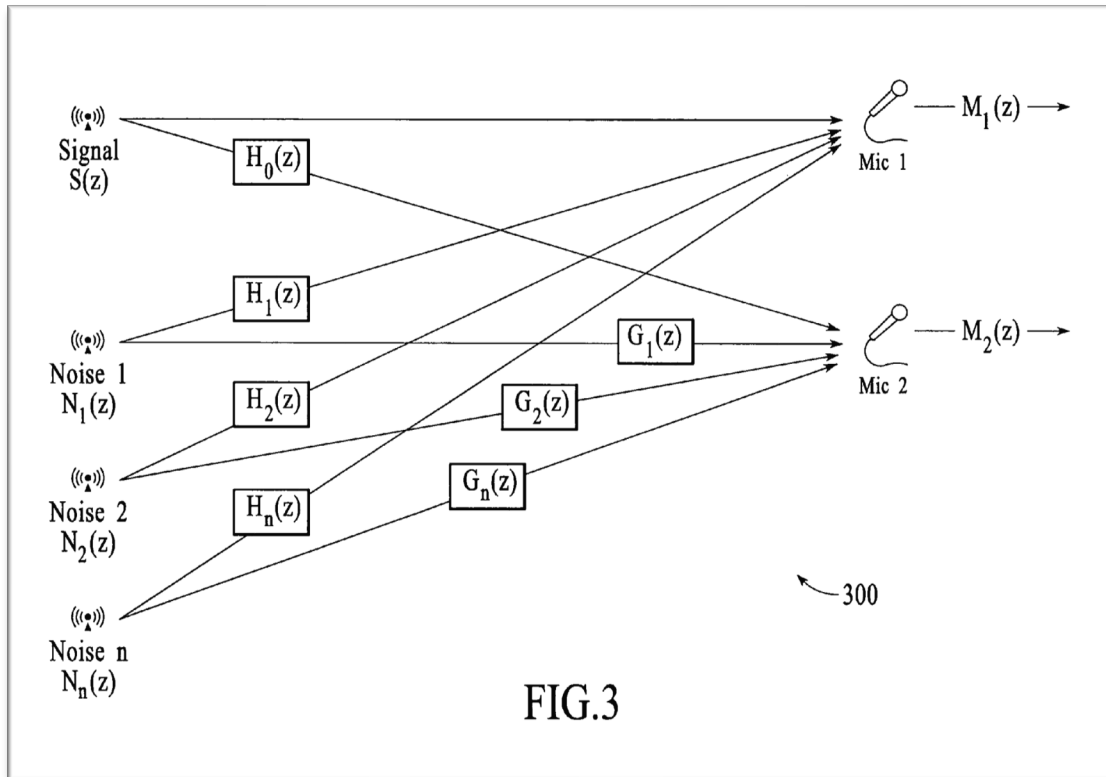
$$S(z) = M_1(z) - [M_2(z) - S(z)H_2(z)]H_1(z)$$

$$S(z)[1 - H_2(z)H_1(z)] = M_1(z) - M_2(z)H_1(z),$$

then $N(z)$ may be substituted as shown to solve for $S(z)$ as

$$S(z) = \frac{M_1(z) - M_2(z)H_1(z)}{1 - H_2(z)H_1(z)}. \quad \text{Eq. 3}$$

39. In exemplary embodiments, the front end components of a noise removal algorithm are generalized to include any number of noise sources. '091 Patent at 5:37-42; Fig. 3.



40. In exemplary embodiments, these noise sources are shown, each with a transfer function, or path, to each microphone. '091 Patent at 5:37-67.

The noise removal algorithm described herein is easily generalized to include any number of noise sources. FIG. 3 is a block diagram including front-end components 300 of a noise removal algorithm of an embodiment, generalized to n distinct noise sources. These distinct noise sources may be reflections or echoes of one another, but are not so limited. There are several noise sources shown, each with a transfer function, or path, to each microphone. The previously named path H_2 has been relabeled as H_0 , so that labeling noise source 2's path to MIC 1 is more convenient. The outputs of each microphone, when transformed to the z domain, are:

$$\begin{aligned} M_1(z) &= S(z) + N_1(z)H_1(z) + N_2(z)H_2(z) + \dots N_n(z)H_n(z) \\ M_2(z) &= S(z)H_0(z) + N_1(z)G_1(z) + N_2(z)G_2(z) + \dots N_n(z)G_n(z) \end{aligned} \quad \text{Eq. 4}$$

When there is no signal (VAD=0), then (suppressing z for clarity)

$$\begin{aligned} M_{1n} &= N_1H_1 + N_2H_2 + \dots N_nH_n \\ M_{2n} &= N_1G_1 + N_2G_2 + \dots N_nG_n. \end{aligned} \quad \text{Eq. 5}$$

A new transfer function can now be defined as

$$\tilde{H}_1 = \frac{M_{1n}}{M_{2n}} = \frac{N_1H_1 + N_2H_2 + \dots N_nH_n}{N_1G_1 + N_2G_2 + \dots N_nG_n}, \quad \text{Eq. 6}$$

where $\tilde{H}_1$ is analogous to $H_1(z)$ above. Thus $\tilde{H}_1$ depends only on the noise sources and their respective transfer functions and can be calculated any time there is no signal being trans-

VII. THE RELEVANT ALLEGED PRIOR ART

A. Ikeda (U.S. Patent No. 5,978,824)

41. I have reviewed U.S. Patent No. 5,978,824 (Ex. 1003, "Ikeda"). Ikeda discloses a noise canceler which "includes a signal-to-noise power ratio estimator." Ex. 1003, Abstract. "The estimator 10 estimates the signal-to-noise [sic] power ratio of the main signal from the mean power of a desired signal contained in the main

signal [sic] and a mean power of a noise signal also contained in the main signal.”

Id. “In addition, the estimator estimates the signal-to-noise power ratio of the reference signal from the mean power of a desired signal contained in the reference signal and the mean power of a noise signal [sic] also contained in the reference signal.” *Id.* Ikeda uses two microphones, a first microphone for a main signal and a second microphone for a reference signal. *Id.*, 4:48-56.

42. Ikeda explains that the adaptive filters of the prior art system are updated when the desired signal component $S(z)$ and the noise component $N(z)$, respectively, are absent or negligible:

[T]he conventional noise canceler updates the coefficient of the adaptive filter 3 and learns the acoustic characteristic of noise in sections where the noise signal $N(z)$ is present and the desired signal component $S(z)$ is absent or negligibly small. Further, the noise canceler updates the coefficient of the adaptive filter 4¹ and learns a Signal distortion correction filter in sections where the desired signal component $S(z)$ is present and the noise component $N(z)$ is absent or negligibly small. It is therefore necessary to detect the above sections where the desired signal component $S(z)$ is absent (or little) and the sections where the noise signal component $N(z)$ is absent (or little) and to command the adaptive filters to perform learning [sic] in such sections from the outside.

¹ Identifier 4 refers to a subtracter. In my opinion, Ikeda is referring to adaptive filter 6 in this passage.

Ex. 1003, 3:32-45.

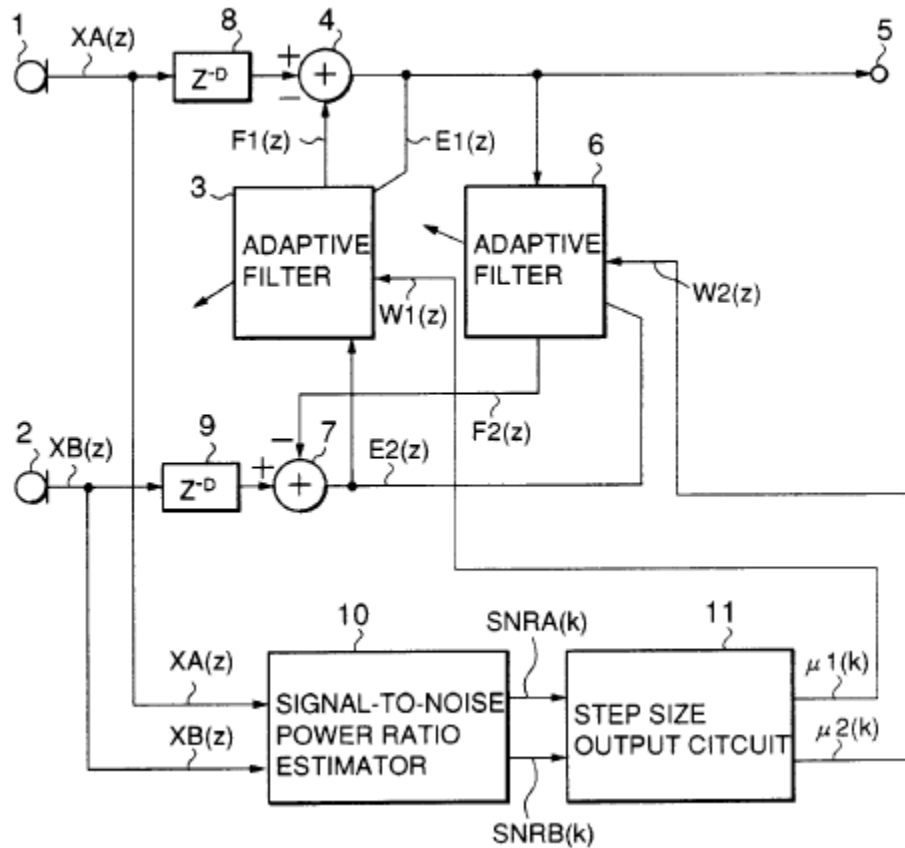
43. Ikeda identifies that the drawback to the prior art conventional system is that:

it is, in many cases, difficult to command the adaptive filters to perform learning *from the outside* in accordance with the level of the desired signal and that of the noise signal, depending on the situation in which the noise canceler is located. With the conventional noise canceler, a sufficient noise canceling ability and a sufficient distortion correction characteristic are not achievable unless adequate learning sections are indicated to each adaptive filter for the learning purpose.

Id., 3:46-54 (emphasis added). Thus, Ikeda contends that prior art which uses “outside” sensors for obtaining information needed to adjust the adaptive filters for adequate noise cancellation is insufficient.

44. To solve this problem, Ikeda discloses that “an object of the present invention to provide a noise canceler capable of achieving a sufficient noise canceling ability and reducing signal distortion *even when adequate learning sections cannot be indicated from the outside.*” *Id.*, 3:57-61(emphasis added). To do so, Ikeda uses a Signal To Noise Power Ratio Estimator. *Id.*, Abstract, 3:62-4:25, 7:18-9:10; Fig. 1.

45. Ikeda includes two microphones. One microphone is intended to capture the desired main signal $X_A(z)$; a second microphone captures the “reference” signal $X_B(z)$. *Id.*, 4:48-5:5; Fig. 1.



Ex. 1003, Fig. 1.

46. $X_A(z)$ includes two components: the desired signal $S(z)$ and the noise $N(z)$. *Id.*, 5:5-38. $X_B(z)$ also contains these two components. *Id.* Ikeda shows these signal components through equations 10 and 11.

$$XA(z)=GA(z)N(z)+HA(z)S(z) \quad \text{Eq. (10)}$$

$$XB(z)=GB(z)N(z)+HB(z)S(z) \quad \text{Eq. (11)}$$

Id., 5:35-39. HA, HB, GA, and GB are acoustic transfer characteristics. *Id.*

47. Ikeda's adaptive filter 3 estimates the noise signal contained in $XA(z)$.

Id. 5:6-9. The adaptive filter 6 estimates the desired signal contained in $XB(z)$. *Id.*

48. Under Ikeda's invention, then, the subtractor 4 removes the noise from the $XA(z)$ signal.

49. The adaptive filters 3 and 6 are updated in steps controlled by Ikeda's signal-to-noise power estimator 10 and step size output circuit 11. *Id.*, 6:19-7:16, 7:17-9:10.

50. The signal-to-noise power estimator 10 returns an estimate of the SNR for both the main signal $XA(z)$ ($SNRA(k)$) and the reference signal $XB(z)$ ($SNRB(k)$). *Id.*, 8:6-12. The step size output circuit 11 then outputs step sizes $u1(k)$ and $u2(k)$, which control the adaptation of filters 3 and 6. *Id.*, 8:13-9:4. In one embodiment, the step sizes are compared to each other and the smaller one is set to 0. *Id.*, 9:4-10.

51. This enables the filters to adapt based on the strength of the desired signal, and without the use of outside sensors. *Id.*, 9:14-18 ("The noise canceler therefore insures rapid convergence and allows a minimum of signal distortion to

occur *without resorting to a command customarily input from the outside* for commanding the learning operation of filters.” (emphasis added).

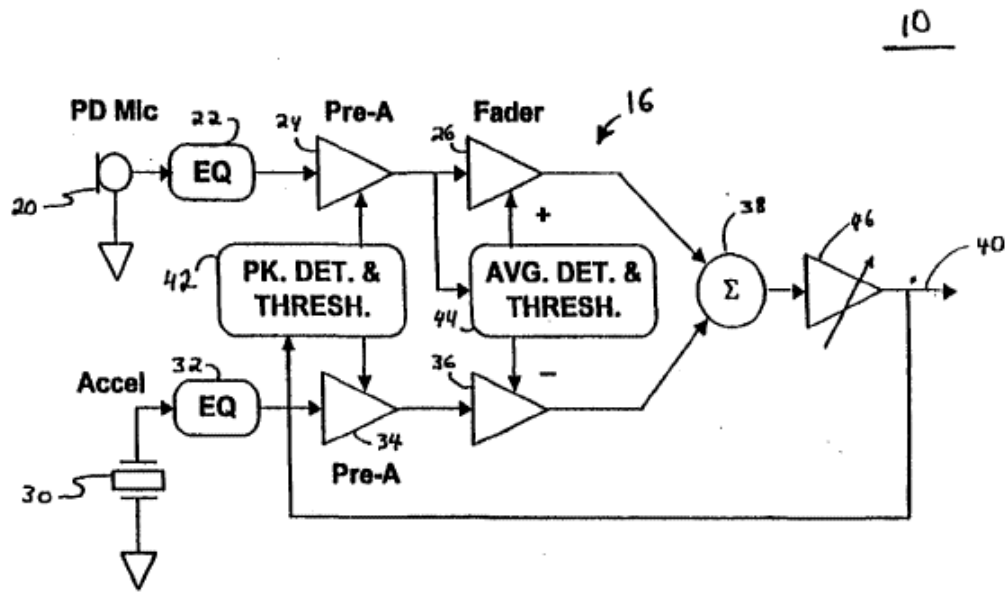
52. Ikeda explains that this use of signal-to-noise ratios, instead of outside sensors, is its main advance over the prior art.

These advantages are derived from a unique configuration in which a relation in size between a desired signal, which is an interference signal for an adaptive filter used to estimate the noise signal of the main signal from the estimated signal-to-noise power ratio of the main signal, and the noise signal to be canceled is determined. This relation is used to control a step size to be fed to the adaptive filter.

Ex. 1003, 9:18-24.

B. Puthuff (International Patent App. Pub. No. WO2000/021194)

53. I have reviewed International Patent Application Pub. No. WO2000/021194 (Ex. 1004, “Puthuff”). Puthuff describes a “pickup system (10) [that] utilizes both sound pressure disturbances sensed by a microphone (20) and bone conduction sensed by a vibration sensor (30) such as an accelerometer, velocity sensor or displacement sensor to pick up and faithfully transmit a talker’s voice despite acoustically noisy ambient environments.” Ex. 1004, Abstract. Puthuff’s system “senses the microphone signal amplitude” and adjusts the system gain and balance to “smoothly fade in the microphone signal and fade out the vibration sensor signal as ambient noise increases.” *Id.*



Ex. 1004, Fig. 1.

54. Puthuff's output signal 40 therefore contains a mix of both acoustic and non-acoustic signals. *Id.*, 9:1-11:5; Fig. 2.

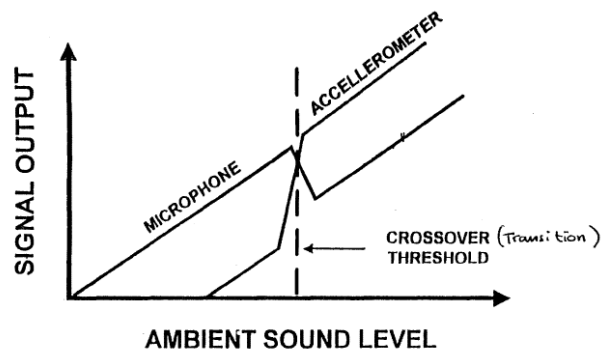


Fig. 2

Ex. 1004, Fig. 2.

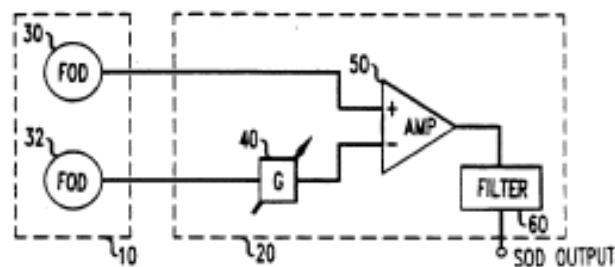
C. Alcivar (U.S. Patent No. 3,746,789)

55. I have reviewed U.S. Patent No. 3,746,789 (Ex. 1005) (“Alcivar”). Alcivar is directed to a voice-activated transmit switch for divers. Alcivar, 1:5-20. Alcivar uses a “tissue-conduction microphone 54 to generate a transmitter keying signal.” *Id.* 4:65-67. The tissue-conduction microphone must be placed against the skin of the user, preferably near the larynx. *Id.*, 4:67-5:15. The microphone is further isolated from outside noises by layers of noise-reducing fabric. *Id.* 5:16-5:31.

D. Bartlett (U.S. Patent No. 5,473,684)

56. I have reviewed U.S. Patent No. 5,473,684 (Ex. 1006, “Barlett”). Bartlett discloses a “Noise-Canceling Differential Microphone Assembly.” Ex. 1006, Title. Bartlett is directed to “an improved SOD [second order differential] microphone that overcomes the deficiencies of the prior art by responding to the speaker’s voice like a FOD [first order differential] microphone (i.e., with respect to the dependence of voice response on distance from the speaker’s lips) but responding to the far field noise like a SOD microphone.” *Id.*, 2:14-19.

FIG. 1



57. Bartlett's SOD microphone receives signals from two first order differential microphones and then combines them together to form a directional microphone signal. *Id.*, 2:33-3:5.

58. Bartlett further reduces noise with an adaptive filter. *Id.*, 6:56-7:3. Bartlett detects when speech is present when the amplitude of the microphone output is above a predetermined threshold. *Id.*, 7:3-17.

E. Hussain

59. I have reviewed *A New Metric For Selecting Sub-Band Processing in Adaptive Speech Enhancement Systems*, by Amir Hussain, Douglas R. Campbell, and Thomas J. Moir. (Ex. 1007, "Hussain"). Hussain discusses a "multi-microphone adaptive speech enhancement system employing diverse sub-band processing." Hussain, at 2611.

F. Sasaki (U.S. Patent No. 5,471,538)

60. I have reviewed U.S. Patent No. 5,471,538 (Ex. 1008, "Sasaki"). Sasaki discusses a dual microphone system. Ex. 1008, Abstract. Sasaki's system includes a "first microphone for picking up a desired sound and a second microphone with directionality in which sensitivity is low to the desired sound arrival direction." *Id.* The signal from "the second microphone is supplied to a subtracting circuit through an adaptive filter." *Id.* "The subtracting circuit subtracts an output signal of the adaptive filter from the sound signal coming from the first microphone."

VIII. CLAIM CONSTRUCTION

61. I understand that Petitioner claims to have applied the plain and ordinary meaning of the claims terms as they would have been understood by a POSITA, consistent with the '091 Patent's disclosure and prosecution history. For my analysis, I have considered each claim term and applied its plain and ordinary meaning consistent with the '091 Patent's disclosure and prosecution history.

IX. PETITIONER'S COMBINATIONS DO NOT RENDER ANY CLAIM OBVIOUS

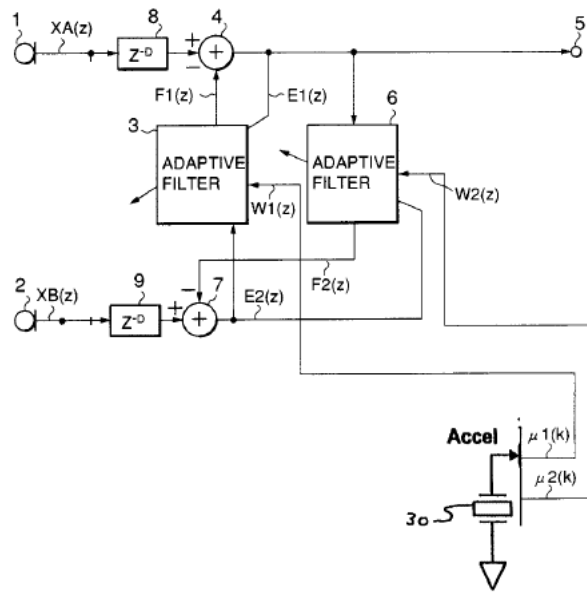
A. GROUND 1: Ikeda in View of Puthuff Does Not Render Obvious Claims 1-8, 11-14, 16, and 18-20

62. In my opinion, combination of Ikeda and Puthuff does not render claims 1-8, 11-14, 16, and 18-20 of the '091 Patent obvious.

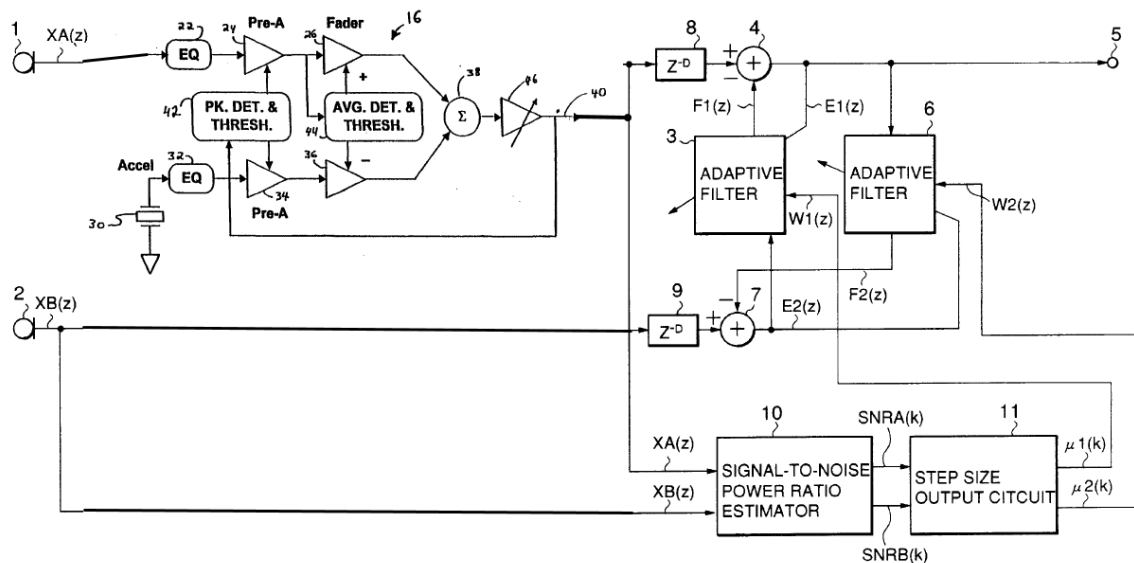
1. Proposed Ikeda/Puthuff Combinations

63. Petitioner and Dr. Stern suggest two different combinations of Ikeda and Puthuff. Pet., 30-36.

64. In one, Puthuff's accelerometer replaces Ikeda's signal-to-noise power ratio estimator and step size output circuit. Pet., 32-34. The modified Ikeda Figure 1 below illustrates this proposed combination.



65. In the second, Petitioner places Puthuff's Fig. 1 system (except for the PD microphone) directly into Ikeda's Fig. 1 system. Pet., 34-36. The Figure below illustrates the second Ikeda/Puthuff combination.



2. A POSITA Would Not Modify Ikeda to Include Puthuff's Outside Sensor in Place of Ikeda's Signal-to-Noise Power Ratio Estimator and Step Size Output Circuit

(a) A POSITA Would Not Modify Ikeda to Include an Outside Sensor Because Ikeda's Invention Is Designed to Obviate the Need for One

66. In my opinion, a POSITA would not modify Ikeda to include Puthuff's accelerometer in place of Ikeda's signal-to-noise power ratio estimator and step size output circuit because that replacement would defeat the objective and inventive concept behind Ikeda.

67. The stated objective of Ikeda is "to provide a noise canceler capable of achieving a sufficient noise canceling ability and reducing signal distortion even when adequate learning sections *cannot be indicated from the outside*." Ex. 1003, 3:56-61 (emphasis added).

68. As Ikeda explains, prior art "conventional" noise cancelers rely on a command from the outside, such as from a separate sensor. *Id.*, 3:32-55. However, depending on where the canceler is located, "it is, in many cases difficult to command the adaptive filters to perform learning from the outside in accordance with the level of the desired signal and that of the noise signal." *Id.*, 3:46-50. Ikeda therefore seeks to provide a noise canceler that does not require or use a signal from the outside.

69. A POSITA would understand that Puthuff's sensor is the same type of sensor that Ikeda seeks to avoid. As a sensor other than the physical acoustic microphones, Puthuff is an "outside" sensor.² Thus, any signal received from a Puthuff sensor would be a command from the outside. Moreover, Puthuff's sensor would, just like the outside sensor in Ikeda, be unable to command the filters to "perform learning . . . in accordance with the level of the desired signal and that of the noise signal." Instead, Puthuff's sensor could only command the filters based on vibrations, not on signal levels. In other words, Puthuff's sensor has no way to determine that the vibrations it senses indicate intelligible speech in the acoustic signals or that the level of the desired signal exceeds the level of the noise signal.

70. As I describe above, to achieve its objective, Ikeda discloses a circuit that does not include or need an outside sensor. Instead, by using its signal-to-noise estimator and step-size circuit, Ikeda succeeds in providing a noise canceler that does not require or use a command from an outside sensor. Ex. 1003, 9:11-18 ("The noise canceler therefore insures rapid convergence and allows a minimum of signal distortion to occur without resorting to a command customarily input from the outside for commanding the learning operation of filters.").

² I agree with Petitioner that Ikeda uses "outside" to refer to a "sensor other than the physical microphones." Pet., 21.

71. Ikeda is clear that its advance over the prior art lies in its “unique configuration in which a relation in size between a desired signal, which is an interference signal for an adaptive filter used to estimate the noise signal of the main signal from the estimated signal-to-noise power ratio of the main signal, and the noise signal to be canceled is determined. This relation is used to control a step size to be fed to the adaptive filter. This is also true with an adaptive filter for estimating the desired signal of the reference signal from the estimated signal-to-noise power ratio of the reference signal; the noise signal is an interference signal, while the desired signal is a signal to be canceled.” *Id.*, 9:18-29.

72. A POSITA, reading Ikeda, would therefore understand that Ikeda’s goal is to avoid using outside sensors, and that its advance over the prior art is achieving that goal through its unique configuration, which includes the signal-to-noise estimator and step-size circuit.

73. I note that Dr. Stern agrees with me as to Ikeda’s goal. Ex. 2004, 26:11-27:24. I agree with Dr. Stern’s statement that “that’s the invention.” *Id.*, 26:21-27:13.

74. Despite the above, Dr. Stern and Petitioner state that a POSITA would replace the signal-to-noise estimator and step-size circuit with Puthuff’s accelerometer. I disagree.

75. A POSITA, reading Ikeda, would not seek to roll back Ikeda's advance over the prior art. Ikeda is clear that outside signals should be avoided because they do not provide satisfactory results in certain situations. Ikeda, 3:46-55.

76. Further, in my opinion, a POSITA would be discouraged from incorporating an outside sensor into Ikeda. As discussed above, Ikeda notes the difficulty of commanding adaptive filters from the outside and disparages their use in favor of its circuit. A POSITA would be led away from the outside sensor and towards using the acoustic signals as Ikeda does.

77. I further disagree with Petitioner's and Dr. Stern's suggested motivations to replace Ikeda's signal-to-noise estimator and step size circuit with Puthuff's accelerometer.

78. The first suggested motivation is "Ikeda and Puthuff address the same problem—accurately detecting voice activity in noisy environments." Pet., 32. I disagree that Puthuff is directed toward "detecting voice activity." Instead, Puthuff, as I explain above, is directed toward providing an output signal that approximates the user's voice.

79. The second suggested motivation is "Ikeda discloses the need for accurately determining periods when a desired signal (e.g., voicing activity) is present and periods when a desired signal is absent for an adaptive noise canceler to function optimally." Pet., 32. "[A] POSITA would have been motivated to look to

other VAD methods” and “Puthuff further teaches that its vibration sensor reduces false triggering in noisy environments.” *Id.*, 33. I disagree. I have seen no evidence that including Puthuff’s sensor would reduce “false triggering” compared to Ikeda’s circuit. A POSITA would understand that Puthuff’s discussion of false triggering is in relation to a single microphone system, and not Ikeda’s dual microphone system.

80. The third suggested motivation is “a POSITA would have been motivated to use an accelerometer sensor in Ikeda’s system as an inexpensive, easy-to-find component for detecting voice activity.” Pet., 33. While I agree that accelerometers were known, it does not follow that a POSITA would have been motivated to include one in Ikeda, especially in view of Ikeda’s many statements against using one.

81. The fourth suggested motivation is merely that accelerometers were known. I agree they were known, but not that such knowledge provides any motivation to combine.

82. The fifth motivation is “Puthuff expressly teaches that its vibration sensor is useful for ‘dual microphone’ systems.” Pet., 34 (citing Ex. 1004, 6:11-23). However, Puthuff there discusses its actual invention – the generation of a voice signal from a single acoustic microphone and a bone conduction sensor (“two modalities of sound transfer”)—not a signal for use in noise cancellation as in the

'091 Patent or Ikeda. Indeed, the discussion of “dual microphone” systems is with respect to “dual microphone *directional* pickup systems.”

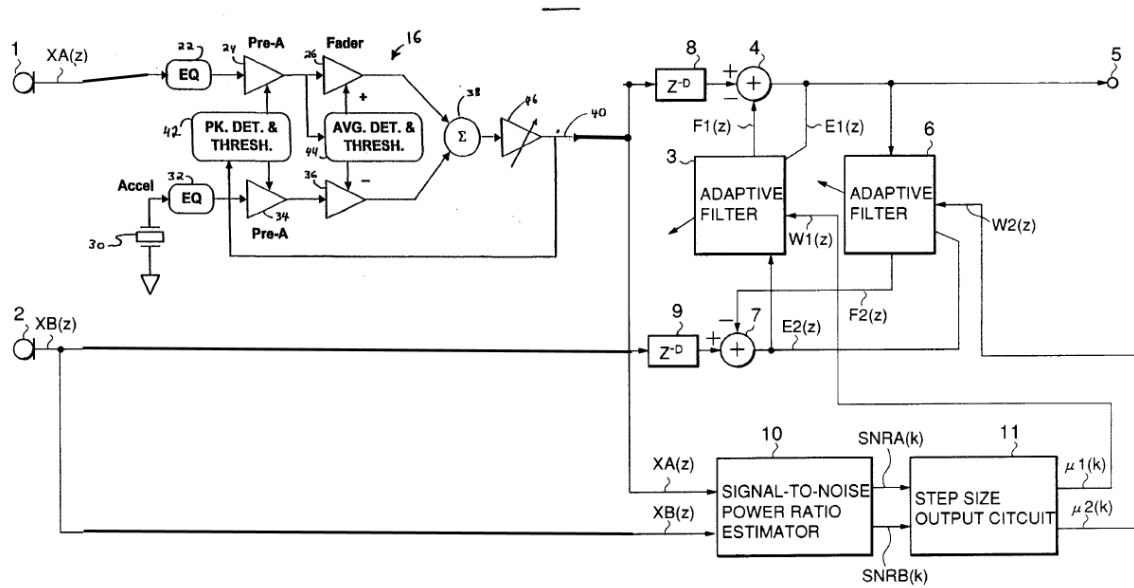
83. In sum, I disagree that any of Petitioner’s suggested motivations, or all of them together, would actually motivate a POSITA to include Puthuff’s accelerometer in Ikeda as in the first Ikeda/Puthuff combination.

84. It is therefore my opinion, that the first Ikeda/Puthuff combination does not render any claims obvious.

3. The Second Ikeda/Puthuff Combination—Using Puthuff’s Output Signal as the Input to Ikeda’s System—Does Not Render Obvious Any Claims

85. As I explain above, the second Ikeda/Puthuff combination would incorporate Puthuff’s Fig. 1 system into Ikeda’s Figure 1 system. Pet., 34-36. Dr. Stern explained that this combination would incorporate the entire body of Puthuff Fig. 1, minus the PD microphone, into Ikeda’s Figure 1 system. Ex. 2004, 38:12-18.

86. For convenience, I will reproduce the combined system here.



87. The second Ikeda/Puthuff combination would have the signal-to-noise power ratio estimator receiving the “amplified, faded” signal from the microphone after it is “combined with the signal from the accelerometer 30 at the adder circuit 38.” Pet., 34-35. In other words, Ikeda’s main signal would be composed of the faded-in and faded-out microphone and accelerometer signals, signal 40 in Puthuff.

88. Puthuff explains that signal 40 is composed of the acoustic and accelerometer signals as a function of ambient sound. Ex. 1004, 7:6-9; Fig. 2.

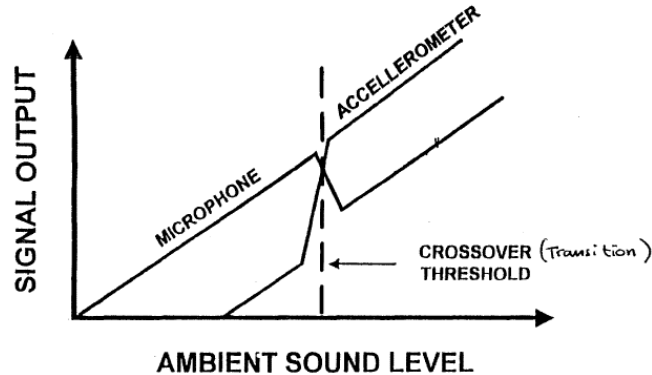


Fig. 2

89. In my opinion, a POSITA would not make this combination because it would not work for its intended purpose of denoising.

90. Further, even if a POSITA would make it, it does not teach the elements of all of the claims.

(a) A POSITA Would Not Make the Second Ikeda/Puthuff Combination

91. 12As I explain above, Ikeda discourages the use of outside sensors. A POSITA would be discouraged from making the second Puthuff/Ikeda combination for the same reasons.

92. A POSITA would be similarly discouraged because the combination would not effectively cancel noise.

Petitioner proposes no modifications to the Ikeda circuit. As I explain above, Ikeda assumes that its input signals are composed of: i) acoustic noise $N(z)$ and

ii) acoustic signal $S(z)$. Ex. 1003, 5:31-37. This is explicitly shown in Ikeda's Equations 10 and 11.

$$XA(z) = GA(z)N(z) + HA(z)S(z) \quad \text{Eq. (10)}$$

$$XB(z) = GB(z)N(z) + HB(z)S(z) \quad \text{Eq. (11)}$$

Id., 5:31-38.

93. Ikeda uses these equations to denoise with calculated transfer functions $W1(z)$ and $W2(z)$.

The above equations give $E1(z)$ and $E2(z)$, as follows:

$$E1(z) = [1 / \{1 - W1(z)W2(z)\}] \{HA(z) - W1(z)HB(z)\}S(z) + [1 / \{1 - W1(z)W2(z)\}] \{GA(z) - W1(z)GB(z)\}N(z) \quad \text{Eq. (12)}$$

$$E2(z) = [1 / \{1 - W1(z)W2(z)\}] \{HB(z) - W1(z)HA(z)\}S(z) + [1 / \{1 - W1(z)W2(z)\}] \{GB(z) - W1(z)GA(z)\}N(z) \quad \text{Eq. (13)}$$

Id., 5:39-50. As Ikeda sums up:

Therefore, if the following equations are satisfied:

$$W1(z) = GA(z)/GB(z) \quad \text{Eq. (14)}$$

$$W2(z) = HB(z)/HA(z) \quad \text{Eq. (15)}$$

then, there hold:

$$E1(z) = S(z) \quad \text{Eq. (16)}$$

$$E2(z) = N(z) \quad \text{Eq. (17)}$$

Ikeda, 5:51-61.

94. But in the proposed Ikeda/Puthuff system, $X_A(z)$ includes *additional* inputs: the noise received from the accelerometer and the signal received from the accelerometer. $X_B(z)$ remains the same.

95. $X_A(z)$ and $X_B(z)$ would thus be representative of two different environments. $X_B(z)$ would be representative of a pure acoustic environment, while $X_A(z)$ would represent a combined acoustic and accelerometer environment.

96. Because of this, the adaptive filter that is updated according to $X_B(z)$ will not account for the noise or signal received from the accelerometer.

97. Ikeda's subtracter 4 will thus be operating on two incompatible signals and its result will be unpredictable, and likely result in distortion of the desired speech signal.

98. Consider the case where $X_A(z)$ is composed mostly or entirely of accelerometer signals. The $N(z)$ acoustic noise component would be close to 0. However, the subtracter would still subtract out a full $N(z)$ as received at the reference microphone and as part of $X_B(z)$. This subtraction would distort the desired signal in $X_A(z)$.

99. In my opinion, therefore, a POSITA would not be motivated to make an Ikeda/Puthuff device that improperly cancels noise and actually worsens the output signal.

(b) The Second Ikeda/Puthuff Combination Does Not Disclose or Render Obvious Generating Transfer Functions in Response to a Determination that Voicing Activity Is Absent from or Present in the Acoustic Signals, as Required by Claims 11 and 18

100. The second Ikeda/Puthuff combination does not disclose or render obvious generating either transfer function in response to a determination that voicing activity is absent or present for a period of time, as required by Claims 11 and 18.

101. In the combination, the Ikeda SNR and Step Size units operate on the Puthuff acoustic/accelerometer signal as $XA(z)$.

102. When the input to Ikeda (Puthuff's signal 40) is composed mostly or entirely of accelerometer signals, which occurs with high environmental noise (Ex. 1004, 5:13-16), the Ikeda circuit will act unpredictably. The SNR estimator will show a high SNR for $XA(z)$, and a low SNR for $XB(z)$, resulting in small step sizes for both u_1 and u_2 . Ex. 1003, 8:36-44, 8:58-63. Due to the mixed modalities of the two signals, there is no way to determine whether u_1 or u_2 will be larger, and thus which filter, if any, will be updated. In any event, the calculation of the transfer function will not be based on a determination that voicing activity is absent or present from the *acoustic* signals. Indeed, because the Ikeda circuit does not receive

the acoustic signals from microphone 1, it cannot make any determination as to what is in those signals.

103. Accordingly, the second combination does not render Claims 11 or 18 obvious.

(c) The Second Ikeda/Puthuff Combination Does Not Disclose or Render Obvious “generating a voice activity detection (VAD) signal using the voice activity signal,” as Required by Claim 1

104. Petitioner appears to rely solely on the first Puthuff combination for this element. Pet., 41-43.

105. I agree that the second Puthuff combination does not disclose or render obvious this element. The only VAD signal identified for this combination is the step size generated from the step size output circuit. Pet., 41-43.

106. However, Claim 1 requires “generating a voice activity detection (VAD) signal *using the voice activity signal.*” The voice activity signal must “include[] information on vibration of human tissue associated with human voicing activity of a user.” ’091 Patent, cl. 1. No such signal is input into Ikeda’s signal to noise power ratio estimator or step size output circuit.

107. Accordingly, the second combination does not render claim 1 obvious.

**B. GROUND 2: Ikeda in View of Alcivar Does Not Render
Obvious Claims 1-8, 11-14, 16, and 18-20**

108. Petitioner further argues that Ikeda combined with Alcivar would render claims 1-8, 11-14, 16, and 18-20 obvious. I disagree.

1. The Ikeda/Alcivar Combination

109. Petitioner here proposes a combination similar to its first Ikeda/Puthuff combination. In this combination, “Alcivar’s tissue-conduction microphone and VAD” would replace Ikeda’s signal-to-noise power ratio estimator and “optionally” step size output circuit. Pet., 49-50.

110. Dr. Stern explained at his deposition that the combination would replace boxes 10 and 11 of Ikeda Figure 1 with components 54, 56, 58, 60, 62, and 68 (and possibly 72 and 74) of Figure 1 of Alcivar. Ex. 2004, 48:7-19.

111. Dr. Stern further explained that the resulting system would have two microphones placed as in Ikeda. *Id.*, 49:23-50:9. Ikeda explains that its invention is for use in a microphone or handset. Ex. 1003, 1:4-9. A POSITA would understand that Ikeda’s main microphone would be placed near the user’s mouth to effectively pick up speech and minimize noise, while the reference microphone would be placed further from the mouth.

112. Alcivar, as explained above, requires that its throat microphone be placed preferably in the vicinity of the larynx but can also be on the chest cavity. Ex.

1005, 4:66-5:8. Dr. Stern confirmed that in the proposed combination, the Alcivar microphone would be in contact with the user's throat. Ex. 2004, 50:10-14.

113. Alcivar explains that its microphone must be insulated from outside sounds by a layer of sound absorbing material. Ex. 1005, 5:21-31; Ex. 2004, 44:19-45:11.

114. Finally, the Alcivar microphone would be connected to the Ikeda system through a wire. Ex. 2004, 50:10-24.

2. A POSITA Would Not Modify Ikeda to Include Alcivar's Throat Microphone and Other Components

115. In my opinion, a POSITA would not modify Ikeda to make the proposed Ikeda/Alcivar combination.

116. As discussed above with respect to the first Ikeda/Puthuff combination, a POSITA would not be motivated to add an outside sensor to Ikeda. For the same reasons discussed there, a POSITA would not be motivated to include Alcivar's separate outside sensor and components to Ikeda.

117. Moreover, a POSITA would not make the device because it would not be useful in the applications Petitioner proposes. Dr. Stern indicates that the combination would be used in "noisy restaurant[s]," "train station[s]," "airport[s], just talking to a cell phone on the street." Ex. 2004, 51:24-52:7.

118. A POSITA would recognize that the “high noise environments” to which Petitioner refers (restaurants, train stations, airports, etc.) do not present the same problem that Alcivar is intended to overcome. Alcivar is intended to deal with the extremely high *near-field noise* that occurs in a diving environment. As Alcivar explains, the diving environment presents loud breathing and gas flow noises that can trigger the microphone within the diver’s mask. Ex. 1005, 1:5-20; 4:44-59. In contrast, a POSITA would know that the noise in, e.g., a restaurant is generally in the far-field and can be easily countered by Ikeda’s unmodified invention.

119. Petitioner raises four suggested motivations to combine. Pet., 50-51.

120. The first suggested motivation is “Ikeda and Alcivar address the same problem—accurately detecting voicing activity in noisy environments.” Pet., 50. Even if true, the mere existence of both references does not motivate a POSITA to combine them.

121. The second suggested motivation is that a “POSITA would have been motivated to use a tissue-conduction microphone or other vibration sensor, as disclosed in Alcivar, instead of Ikeda’s method of detecting voicing activity because, as Alcivar explains, tissue-conduction microphones can ‘discriminate against unwanted noises . . . without having to resort to more elaborate signal processing techniques.’” Pet., 50. I disagree. As discussed above, Ikeda provides a system that can discriminate against unwanted noises.

122. I further disagree that a “POSITA would have understood that a tissue-conduction microphone (e.g., vibration-based) VAD would be a cheaper, simpler option than Ikeda’s acoustic microphone-based VAD for determining periods when voicing activity is present.” Pet., 50. Petitioner and Dr. Stern provide no evidence that including the extra sensor and components of Alcivar is somehow cheaper than Ikeda’s circuit. Indeed, Petitioner proposes that all of Ikeda’s processing is done within a processor. Pet., 17-19. Thus, Ikeda’s signal-to-noise power estimation and step size output circuits would provide no additional cost. To the contrary, a POSITA would recognize that Alcivar’s throat microphone, insulating material, and wire would require substantial additional costs for each device.

123. The third suggested motivation is “a POSITA would have used Alcivar’s vibration-based VAD with Ikeda’s system to detect voice activity because Alcivar’s doing so would improve the accuracy of Ikeda’s system in high-noise environments.” Pet., 51. I disagree. Petitioner provides no evidence that Alcivar is any more accurate than Ikeda in any environment.

124. Moreover, as discussed above, Alcivar’s sensor does not provide any benefit in the high-noise environments to which Petitioner refers. Instead, Alcivar is designed to counter large amounts of near-field noise.

125. Finally, Petitioner states that “the use of vibration sensors to detect voicing activity was well known.” Pet., 51. But this would not motivate a POSITA

to include a new sensor into Ikeda, particularly in view of Ikeda's statements discouraging such outside sensors.

126. Accordingly, in my opinion, a POSITA would not be motivated to make the Ikeda/Alcivar combination.

C. GROUND 3: Ikeda, Puthuff or Alcivar, and Hussain Do Not Render Obvious Claims 3, 9, and 15

127. Ground 3 relies on Grounds 1 or 2 and adds Hussain to meet elements of dependent Claims 3, 9, and 15. Pet., 56. Petitioner does not argue that Hussain remedies the deficiencies of Grounds 1 and 2. Accordingly, in my opinion, no claims are obvious under Ground 3.

D. GROUND 4: Ikeda, Puthuff or Alcivar, and Sasaki Do Not Render Obvious Claims 10 and 17

128. Ground 4 relies on Grounds 1 or 2 and adds Sasaki to meet elements of dependent Claims 10 and 17. Pet., 64. Petitioner does not argue that Sasaki remedies the deficiencies of Grounds 1 and 2. Accordingly, in my opinion, no claims are obvious under Ground 4.

E. GROUND 5: The Grounds 1-4 References and Bartlett Do Not Render Obvious Any Claims

129. Ground 5 relies on Grounds 1-4 and adds Bartlett to meet the processor limitations. Pet., 67. Petitioner does not argue that Bartless remedies the deficiencies of Grounds 1 and 2. Accordingly, in my opinion, no claims are obvious under Ground 5.

X. CONCLUSION

130. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the 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.

Executed this 12th day of April 2024

Respectfully submitted,

A handwritten signature in black ink, appearing to read 'Akbar M Sayeed', with a horizontal line underneath the signature.

Akbar M Sayeed
