UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LG ELECTRONICS, INC.,

Petitioner,

v.

JAWBONE INNOVATIONS, LLC,

Patent Owner.

Patent No. 11,122,357
Filing Date: August 5, 2013
Issue Date: September 14, 2021

Inventor: FORMING VIRTUAL MICROPHONE ARRAYS USING DUAL OMNIDIRECTIONAL MICROPHONE ARRAY (DOMA)

DECLARATION OF AKBAR M. SAYED, Ph.D.

Case No. IPR2023-01134

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1. Petitioner's Combination Does Not Disclose or Render Obvious "wherein the first virtual microphone and the second virtual microphone are distinct virtual directional microphones with substantially similar responses to noise and substantially dissimilar responses to speech" as recited in independent Claims 1 and 15 15

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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. 11,122,357 (the "'357 Patent") entitled FORMING VIRTUAL MICROPHONE ARRAYS USING DUAL OMNIDIRECTIONAL MICROPHONE ARRAY (DOMA), and to provide my technical review, analysis, insights, and opinions regarding the '357 Patent in view of the prior art cited by Petitioner LG Electronics, Inc. ("LG" or "Petitioner"). I submit this declaration in support of Patent Owner's Preliminary 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 '357 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 '357 Patent. I understand the '357 Patent has been provided as Exhibit 1001. I will cite to the specification using the following format: '357 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 look 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 ’357 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 ‘357 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 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

20. 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.

21. 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.

22. 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.

23. 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.

24. 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

25. 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.

26. 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 '357 PATENT

27. I have reviewed the '357 Patent, entitled FORMING VIRTUAL MICROPHONE ARRAYS USING DUAL OMNIDIRECTIONAL MICROPHONE ARRAY (DOMA) (Ex. 1001). It issued on September 14, 2021, and was filed on August 5, 2013.

28. The '357 Patent discloses and claims methods for noise suppression in dual omnidirectional microphone arrays. Unlike "conventional arrays and algorithms which seek to reduce noise by nulling out noise sources," the '357 Patent uses omnidirectional microphone arrays "to form two distinct virtual directional microphones which are configured to have very similar noise responses and very dissimilar speech responses." '357 Patent, Abstract. While "conventional multi-microphone systems attempt to increase the [signal-to-noise ratio] of the user's speech by 'steering' the nulls of the system to the strongest noise sources, [t]his approach is limited in the number of noise sources removed by the number of available nulls." *Id.*, 1:60-62. Counterintuitively, in the '357 Patent, "[t]he only null formed by the DOMA is one used to remove the *speech* of the user from [the second virtual microphone]". *Id.* at 5:15-16 (emphasis added). However, the similarity of the '357 Patent's virtual microphones' noise responses allows them to be cancelled while leaving the speech response intact, "resulting in excellent noise suppression performance and minimal speech removal and distortion." *Id.* at 8:16-18.

29. The '357 Patent discloses a noise suppression apparatus that creates two virtual microphones V_1 and V_2 based on the signals generated by two omnidirectional microphones.

$$V_1(z) = O_1(z)z^{-\gamma} - \beta O_2(z)$$

$$V_2(z) = O_2(z) - z^{-\gamma}\beta O_1(z)$$

Id. at 12:20, 11:7. In these equations, β and γ are defined as follows:

$$\beta = \frac{d_1}{d_2}$$

$$\gamma = \frac{d_2 - d_1}{c} . f_s \text{ (samples)}$$

Id. at 11:10-12. "The distances d_1 and d_2 are the distances from O_1 and O_2 to the speech source," respectively, and "γ is their difference divided by c, the speed of sound, and multiplied by the sampling frequency f_s." *Id.*, 11:19-22.

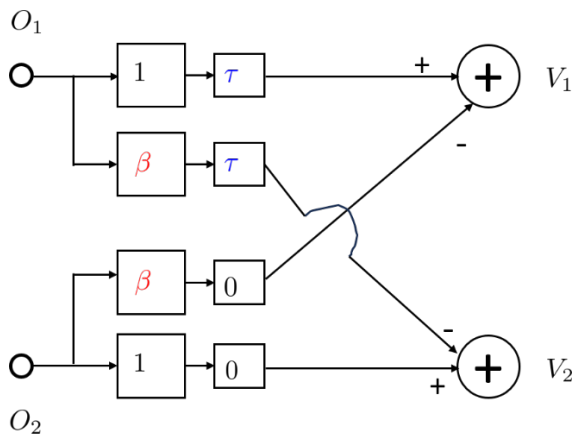
30. In the frequency domain, the equations for V_1 and V_2 are written as follows:

$$V_1(f) = e^{-j2\pi f\tau}O_1(f) - \beta O_2(f)$$

$$V_2(f) = -\beta e^{-j2\pi f\tau}O_1(f) + O_2(f)$$

where $z = e^{j2\pi f}$ and $\tau = \frac{d_2 - d_1}{c}$.

31. The configuration of the '357 Patent circuit according to these equations can be shown as follows:



'357 Patent Circuit

In this diagram, the signals from omnidirectional microphones O_1 and O_2 first pass through a gain with a value of β or 1 (i.e., no gain) and then pass through a delay τ or 0 (i.e., no delay). I refer to the four lines of the circuit throughout this declaration as the first, second, third and fourth lines. In this circuit, the first and third lines are summed to form virtual microphone V_1, and the second and fourth lines are summed to form the virtual microphone V_2.

32. The '357 Patent discloses that the apparatus "works very well because the noise (far-field) responses of V_1 and V_2 are very similar while the speech (near-field) responses are very different." *Id.* at 17:21-23.

33. The '357 Patent discloses polar plots depicting similar noise responses which may be cancelled while leaving dissimilar speech responses intact. For instance, Figures 10 and 12 show the linear responses of virtual microphones V_2 and V_1, respectively, to noise from a source at 1 meter:

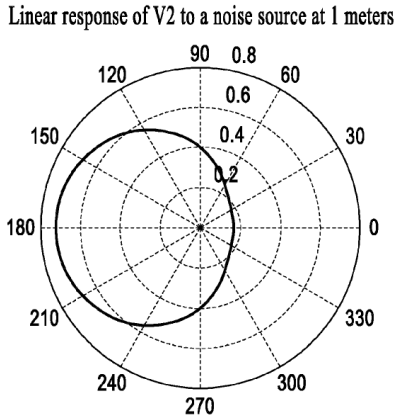


FIG.10

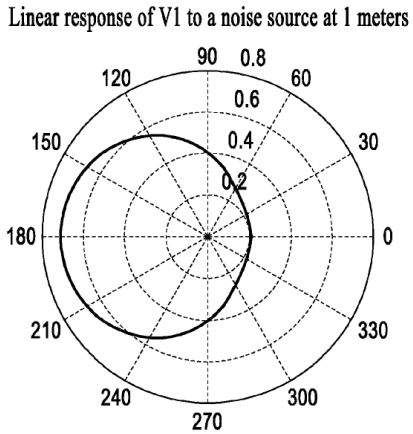


FIG.12

'357 Patent, 11:44-49, 12:44-48, Figs. 10, 12.

34. Figures 9 and 11 show the linear responses of virtual microphones V_2 and V_1, respectively, to speech at a distance of 0.1 meter at an angle of zero degrees:

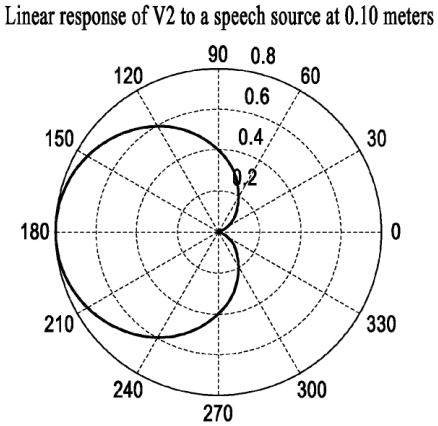


FIG.9

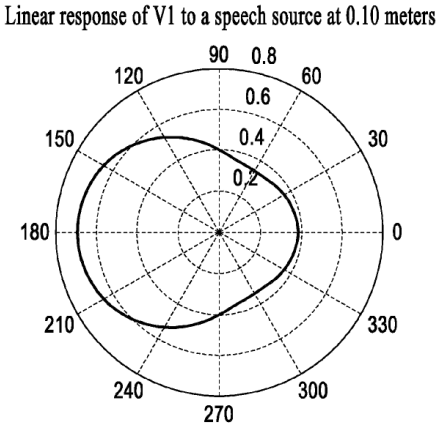


FIG.11

'357 Patent, 11:40-42, 12:39-41, Figs 9,11.

35. Figure 9 shows a null in the linear response of virtual microphone V_2 to speech at zero degrees, "where the speech is typically expected to be located." *Id.*, 11:42-44. As shown in Figure 10, "[t]he linear response of V_2 to noise is devoid of or includes no null, meaning all noise sources are detected." *Id.*, 11:47-49. This configuration ensures that virtual microphone V_2 will detect all of the noise in front

of the user so that it can be removed, which is an advantage over "conventional systems that can have difficulty removing noise in the direction of the mouth of the user." *Id.*, 11:58-60. In addition, "the superior noise suppression made possible using this system more than compensates for the initially poorer SNR," or signal to noise ratio, of the virtual microphones. *Id.*, 13:11-13.

VII. THE ALLEGED PRIOR ART

A. Brandstein

36. I have reviewed Microphone Arrays: Signal Processing Techniques and Applications, (Ex. 1003, "Brandstein") (Ex. 1003). Brandstein is a collection of papers discussing topics in microphone arrays. Ex. 1003 at 5. Brandstein purports to have been published in 2001. *Id.* at 4.

37. Petitioner primarily relies on the paper "Robust Adaptive Beamforming" as reproduced in Brandstein as Chapter 5. As discussed in detail *infra* Section IX.A.1, the Griffiths-Jim beamformer (GJBF) described in that paper operates by attenuating noise while passing speech through a top path and by attenuating speech while passing noise through a bottom path. Brandstein's GJBF achieves noise suppression by using a multiple input canceller ("MC") to subtract certain components of the noise signal from a top path that already has an attenuated noise response. This is fundamentally different than the invention of the '357 Patent, which operates using a first virtual mic pass through capture ***both*** speech and noise

in combination with a second virtual microphone that has a **substantially similar** response to noise, such that the noise may be cancelled.

B. Gannot

38. I have reviewed Signal Enhancement Using Beamforming and Nonstationarity with Applications to Speech by Sharon Gannot, David Burshtein, and Ehud Weinstein (Ex. 1004, "Gannot"). Gannot is a paper purportedly published in August 2001. Gannot discusses a "sensor array located in an enclosure, where arbitrary transfer functions (TFs) relate the source signal and the sensors." Ex. 1004 at 1614, Abstract.

VIII. CLAIM CONSTRUCTION

39. 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 '357 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 '357 Patent's disclosure and prosecution history.

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

A. GROUND 1: The Combination of Brandstein in view of Gannot Does Not Render Obvious Claims 1-20

40. In my opinion, the combination of Brandstein and Gannot does not render claims 1-20 of the '357 Patent obvious.

1. Petitioner's Combination Does Not Disclose or Render Obvious "wherein the first virtual microphone and the second virtual microphone are distinct virtual directional microphones with substantially similar responses to noise and substantially dissimilar responses to speech" as recited in independent Claims 1 and 15.

41. The Petition argues that Brandstein discloses this limitation, and does not otherwise argue that it is inherent or obvious in view of Gannot. I disagree that Brandstein discloses "wherein the first virtual microphone and the second virtual microphone are distinct virtual directional microphones ***with substantially similar responses to noise***."

42. Unlike the invention of the '357 Patent which contemplates a first virtual microphone that captures both speech and noise, the top branch of the GJBF discussed in the cited portions of Brandstein captures speech while suppressing as much noise as possible, while the bottom branch captures as much noise as possible while suppressing speech. Brandstein states that for the top path "[t]he [fixed beamformer] is designed to form a beam in the look direction so that the target signal is passed through ***and all other signals are attenuated***" while for the bottom path "the [blocking matrix] forms a null in the look direction so that the target signal is suppressed ***and all other signals are passed through***." Ex. 1003 at 88 (emphasis added). In other words, the fixed beamformer (top path) passes speech through (the target signal) **and attenuates noise**, while the blocking matrix (bottom path)

suppresses speech **and passes noise through**. Brandstein's design is therefore consistent with the type of "conventional arrays and algorithms, which seek to reduce noise by nulling out noise sources" that the '357 Patent itself distinguishes. Ex. 1001 at 5:10-11. Brandstein's implementation is very different than the invention of the '357 patent, in which the first virtual microphone passes through ***both*** speech and noise, such that another virtual response with a "substantially similar" noise response may be used to cancel noise while preserving speech. A POSITA would understand that a virtual microphone that attenuates noise does not have a "substantially similar" noise response to one that passes noise through.

43. I understand that Petitioner and Dr. Stern argue that "[t]he two virtual microphones also have similar responses to noise so that in the final subtraction output the noise cancels out," citing to Dr. Stern's declaration at ¶95. I disagree. The ultimate result of cancelling noise in "the final output of an example Griffiths-Jim beamformer" does not disclose (or even suggest) that the noise responses of a first and second virtual microphone must be substantially similar. A POSITA would not leap to any such conclusion, particularly given that the cited portions of Brandstein teach a contrary means of noise suppression. The Petition's obviousness analysis is based on a hindsight reverse engineering of the noise suppression device of the '357 Patent. Brandstein states that it uses a "multiple input canceller" ("MC") which

"generate[s] replicas of components correlated with the interferences" that are "subtracted from a delayed output signal [] of the fixed beamformer" based on which "the target signal is enhanced and undesirable signals such as ambient noise and interferences are suppressed." Ex. 1003 at 88-89. In other words, **instead of** using virtual microphones with substantially similar noise responses, Brandstein's GJBF attempts to isolate speech in the top path as much as possible, then uses the MC to subtract only those noise components of the bottom path that are "correlated with the interferences."

44. I understand that Petitioner and Dr. Stern argue that "[t]he different responses to the target signal and similar responses to noise are evident from Figure 5.2, which shows the directivity pattern for the final output of an example Griffiths-Jim beamformer:"

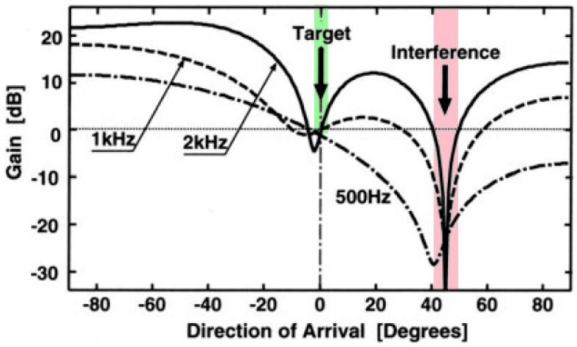


Fig. 5.2. Example directivity pattern of the Griffiths-Jim beamformer.

Pet. at 27-28. Petitioner and Dr. Stern further argue that "[t]he deep null reflects that subtracting the two virtual microphones' outputs cancels the interference, which

confirms that the virtual microphones' responses to the interference are similar." Dr. Stern's declaration at ¶97, Pet. at 28-29. But Figure 5.2 does not support Petitioner's assertions. Figure 5.2 shows the ***overall*** directivity of an exemplary GJBF at three different frequencies (i.e. the combination of both the top and bottom path, with the bottom path also including processing by the "multiple input canceler"), not the directivity of either virtual microphone. That directivity merely has an area of significantly reduced gain in the direction of an interference (i.e. a noise source). This reflects the overall result of the system in attenuating noise; a POSITA would not understand this figure to disclose anything about the comparative responses to noise of the top or bottom path within that system (which are not even depicted in the figure). In any case, as discussed above, Brandstein contemplates this result based on subtracting elements of noise (generated by a multiple input canceller by taking "replicas of components correlated with the interferences") from an FBF signal that already has as little noise as possible, **not** based on any "substantially similar" noise response.

45. Brandstein's Figure 5.3, which actually depicts the directivity of the cited GJBF's top and bottom path unlike Figure 5.2, further shows that their responses to noise are not substantially similar. I have highlighted the noise response of each plot in green. A POSITA would plainly understand that these responses are not substantially similar.

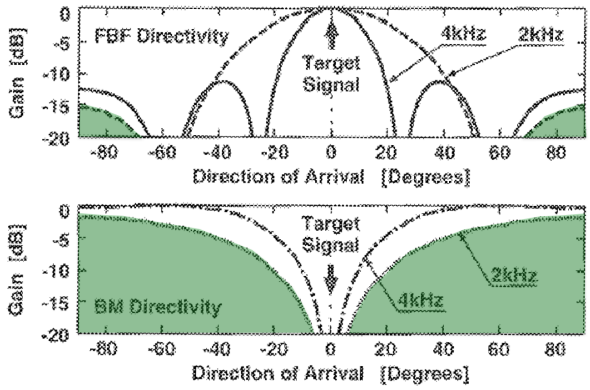


Fig. 5.3. Directivity pattern of a fixed beamformer (FBF) and a blocking matrix (BM).

I therefore conclude that Brandstein does not disclose or render obvious "wherein the first virtual microphone and the second virtual microphone are distinct virtual directional microphones ***with substantially similar responses to noise***." In fact, the discussion in Chapter 5 of Branstein provides only a high-level review of the Griffiths-Jim beamformer (GJBF), listed on page 91 of Ex 1003 (Brandstein), primarily in the context of at addressing the "robustness problem" in the GJBF arising from "target-signal leakage". As Chapter 5 does not disclose equations for the GJBF discussed in section 5.2, Fig. 5.3 would provide a POSITA's *only* understanding of the actual noise responses of its FBF and BM outside of the above-cited disclosure that noise is attenuated in its FBF and not in its BM. This would further support a POSITA's understanding that the top and bottom branches of Brandstein's GJBF do not have substantially similar responses to noise.

X. CONCLUSION

46. 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 12st day of October, 2023

Respectfully submitted,

Akbar M Sayeed

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