US00RE48371E

(19) **United States**
(12) **Reissued Patent**
**Zhu et al.**

(10) **Patent Number: US RE48,371 E**
(45) **Date of Reissued Patent: Dec. 29, 2020**

(54) **MICROPHONE ARRAY SYSTEM**

(71) Applicant: **LI Creative Technologies, Inc.**, Florham Park, NJ (US)

(72) Inventors: **Manli Zhu**, New City, NY (US); **Qi Li**, New Providence, NJ (US)

(73) Assignee: **VOCALIFE LLC**, Plano, TX (US)

(21) Appl. No.: **16/052,623**

(22) Filed: **Aug. 2, 2018**

**Related U.S. Patent Documents**

Reissue of:

(64) Patent No.: **8,861,756**
Issued: **Oct. 14, 2014**
Appl. No.: **13/049,877**
Filed: **Mar. 16, 2011**

U.S. Applications:

(63) Continuation of application No. 15/293,626, filed on Oct. 14, 2016, now Pat. No. Re. 47,049, which is an application for the reissue of Pat. No. 8,861,756.
(Continued)

(51) **Int. Cl.**
***H04R 25/00*** (2006.01)
***H03G 3/20*** (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ..... ***G01S 3/8055*** (2013.01); ***G01S 3/801*** (2013.01); ***G01S 5/22*** (2013.01); ***H04R 1/406*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. H04R 3/005; H04R 1/406; H04R 2201/401; H04R 2201/403; G01S 3/801; G01S 8/055; G01S 5/22; H04M 3/568
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,315,562 A * 5/1994 Bradley et al. ..... 367/89
5,825,898 A 10/1998 Marash
(Continued)

FOREIGN PATENT DOCUMENTS

EP 1538867 A1 6/2005
KR 20090128221 A 12/2009
(Continued)

OTHER PUBLICATIONS

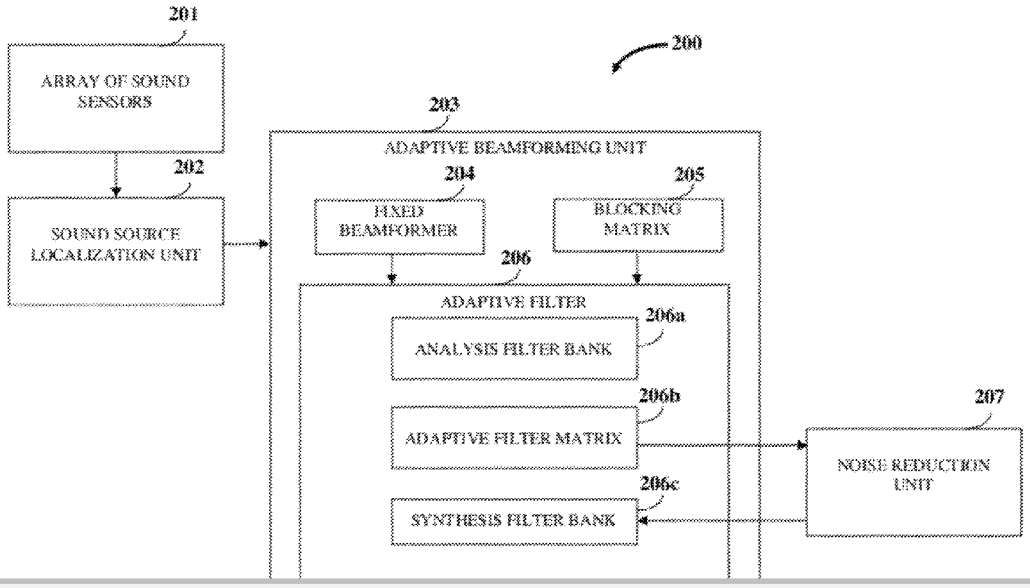
US 9,711,140 B2, 07/2017, Ayrapetian et al. (withdrawn)
(Continued)

*Primary Examiner* — Ovidio Escalante
(74) *Attorney, Agent, or Firm* — Ashok Tankha

(57) **ABSTRACT**

A method and system for enhancing a target sound signal from multiple sound signals is provided. An array of an arbitrary number of sound sensors positioned in an arbitrary configuration receives the sound signals from multiple disparate sources. The sound signals comprise the target sound signal from a target sound source, and ambient noise signals. A sound source localization unit, an adaptive beamforming unit, and a noise reduction unit are in operative communication with the array of sound sensors. The sound source localization unit estimates a spatial location of the target sound signal from the received sound signals. The adaptive beamforming unit performs adaptive beamforming by steering a directivity pattern of the array of sound sensors in a direction of the spatial location of the target sound signal, thereby enhancing the target sound signal and partially suppressing the ambient noise signals, which are further suppressed by the noise reduction unit.

**20 Claims, 34 Drawing Sheets**



**Related U.S. Application Data**

(60) Provisional application No. 61/403,952, filed on Sep. 24, 2010.

(51) **Int. Cl.**

| | |
|---|---|
| ***G01S 3/805*** | (2006.01) |
| ***G01S 3/801*** | (2006.01) |
| ***G01S 5/22*** | (2006.01) |
| ***H04R 1/40*** | (2006.01) |
| ***H04R 3/00*** | (2006.01) |
| *H04M 3/56* | (2006.01) |

(52) **U.S. Cl.**

CPC ..... ***H04R 3/005*** (2013.01); *H04M 3/568* (2013.01); *H04R 2201/401* (2013.01); *H04R 2201/403* (2013.01)

(58) **Field of Classification Search**

USPC ..... 381/300, 57

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 6,198,693 | B1 | 3/2001 | Marash | |
| 6,236,862 | B1 * | 5/2001 | Erten | G01S 3/00 370/342 |
| 7,039,199 | B2 | 5/2006 | Rui | |
| 7,068,801 | B1 | 6/2006 | Stinson et al. | |
| 7,970,151 | B2 | 6/2011 | Oxford et al. | |
| 8,855,295 | B1 | 10/2014 | Chhetri et al. | |
| 8,885,815 | B1 | 11/2014 | Velusamy et al. | |
| 8,953,777 | B1 | 2/2015 | Chhetri | |
| 8,983,057 | B1 | 3/2015 | Deng et al. | |
| 9,116,962 | B1 | 8/2015 | Pance | |
| 9,229,526 | B1 | 1/2016 | Neglur et al. | |
| 9,319,782 | B1 | 4/2016 | Crump et al. | |
| 9,319,783 | B1 | 4/2016 | Barton et al. | |
| 9,332,167 | B1 | 5/2016 | Pance | |
| 9,354,731 | B1 | 5/2016 | Pance et al. | |
| 9,363,616 | B1 | 6/2016 | Chu et al. | |
| 9,373,338 | B1 | 6/2016 | Gopalan et al. | |
| 9,390,723 | B1 | 7/2016 | McDonough, Jr. et al. | |
| 9,423,886 | B1 | 8/2016 | Neglur et al. | |
| 9,431,982 | B1 | 8/2016 | Yang et al. | |
| 9,432,768 | B1 | 8/2016 | O'Neill et al. | |
| 9,432,769 | B1 | 8/2016 | Sundaram et al. | |
| 9,456,276 | B1 | 9/2016 | Chhetri | |
| 9,473,646 | B1 | 10/2016 | Chhetri | |
| 9,516,410 | B1 | 12/2016 | Ayrapetian et al. | |
| 9,521,249 | B1 | 12/2016 | Chhetri | |
| 9,589,575 | B1 | 3/2017 | Ayrapetian et al. | |
| 9,591,404 | B1 | 3/2017 | Chhetri | |
| 9,614,486 | B1 | 4/2017 | Yang et al. | |
| 9,653,060 | B1 | 5/2017 | Hilmes et al. | |
| 9,658,738 | B1 | 5/2017 | Park et al. | |
| 9,659,555 | B1 | 5/2017 | Hilmes et al. | |
| 9,661,438 | B1 | 5/2017 | Yang et al. | |
| 9,677,986 | B1 | 6/2017 | Baldwin et al. | |
| 9,678,559 | B1 | 6/2017 | Devries et al. | |
| 9,689,960 | B1 | 6/2017 | Barton et al. | |
| 9,704,478 | B1 | 7/2017 | Vitaladevuni et al. | |
| 9,734,845 | B1 | 8/2017 | Liu et al. | |
| 9,747,899 | B2 | 8/2017 | Pogue et al. | |
| 9,747,920 | B2 | 8/2017 | Ayrapetian et al. | |
| 9,754,605 | B1 | 9/2017 | Chhetri | |
| 9,767,828 | B1 | 9/2017 | Velusamy et al. | |
| 9,818,425 | B1 | 11/2017 | Ayrapetian et al. | |
| 9,820,036 | B1 | 11/2017 | Tritschler et al. | |
| 9,837,099 | B1 | 12/2017 | Sundaram et al. | |
| 9,918,163 | B1 | 3/2018 | Ayrapetian et al. | |
| 9,940,949 | B1 | 4/2018 | Vitaladevuni et al. | |
| 9,966,059 | B1 | 5/2018 | Ayrapetian et al. | |
| 9,973,849 | B1 | 5/2018 | Zhang et al. | |
| 9,978,387 | B1 | 5/2018 | Pogue et al. | |
| 9,997,151 | B1 | 6/2018 | Ayrapetian et al. | |
| 10,062,372 | B1 | 8/2018 | Barton et al. | |
| 10,109,294 | B1 | 10/2018 | Ayrapetian et al. | |
| 10,147,439 | B1 | 12/2018 | Kristjansson et al. | |
| 10,147,441 | B1 | 12/2018 | Pogue et al. | |
| 10,229,698 | B1 | 3/2019 | Chhetri | |
| 10,237,647 | B1 | 3/2019 | Chhetri | |
| 10,242,695 | B1 | 3/2019 | Velusamy et al. | |
| 10,244,313 | B1 | 3/2019 | O'Neill et al. | |
| 10,304,475 | B1 | 5/2019 | Wang et al. | |
| 2003/0204397 | A1 * | 10/2003 | Amiri et al. | 704/231 |
| 2004/0071284 | A1 | 4/2004 | Abutalebi et al. | |
| 2004/0161121 | A1 * | 8/2004 | Chol et al. | 381/92 |
| 2006/0153360 | A1 | 7/2006 | Kellermann et al. | |
| 2006/0245601 | A1 | 11/2006 | Michaud et al. | |
| 2006/0269080 | A1 | 11/2006 | Oxford et al. | |
| 2007/0055505 | A1 | 3/2007 | Doclo et al. | |
| 2007/0076898 | A1 | 4/2007 | Sarroukh et al. | |
| 2008/0112574 | A1 | 5/2008 | Brennan et al. | |
| 2008/0181430 | A1 | 7/2008 | Zhang et al. | |
| 2008/0232607 | A1 | 9/2008 | Tashev et al. | |
| 2009/0067642 | A1 | 3/2009 | Buck et al. | |
| 2009/0073040 | A1 | 3/2009 | Sugiyama | |
| 2009/0141907 | A1 * | 6/2009 | Kim et al. | 381/71.7 |
| 2009/0279714 | A1 | 11/2009 | Kim et al. | |
| 2009/0304200 | A1 | 12/2009 | Kim et al. | |
| 2010/0150364 | A1 | 6/2010 | Buck et al. | |
| 2012/0327115 | A1 | 12/2012 | Chhetri et al. | |
| 2013/0265276 | A1 | 10/2013 | Obeidat et al. | |
| 2015/0006176 | A1 | 1/2015 | Pogue et al. | |
| 2017/0178662 | A1 | 6/2017 | Ayrapetian et al. | |
| 2018/0130468 | A1 | 5/2018 | Pogue et al. | |
| 2018/0182387 | A1 | 6/2018 | Chua et al. | |

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| RS | WO2008041878 | A2 | 4/2008 |
| SG | 2006006935 | A1 | 1/2006 |
| WO | 2008041878 | A2 | 4/2008 |
| WO | WO2008041878 | A2 | 4/2008 |
| WO | 2013155098 | A1 | 10/2013 |
| WO | 2017105998 | A1 | 6/2017 |
| WO | 2018118895 | A2 | 6/2018 |

OTHER PUBLICATIONS

Qi (Peter) Li, "A Portable USB-Based Mirophone Array Device For Robust Speech Recognition", "2009 IEEE International Conference on Acoustics, Speech, and Signal Processing", Apr. 19-24, 2009, Seven pages.

Osamu Hoshuyama, Akihiko Sugiyama, and Akihiro Hirano, A Robust Adaptive Beamformer for Microphone Arrays with a Blocking Matrix Using Constrained Adaptive Filters, IEEE Transactions on Signal Processing, vol. 47, No. 10, Oct. 1999, 8 Pgs.

Cha Zhang, Dinei Florencio, Demba E. Ba, and Zhengyou Zhang, Maximum Likelihood Sound Source Localization and Beamforming for Directional Microphone Arrays in Distributed Meetings, IEEE Transactions on Multimedia, vol. 10, No. 3, Apr. 2008, 11 pages

Afsaneh Asaei, Mohammad Javad Taghizadeh, Marjan Bahrololum, Mohammed Ghanbari, Verified speaker localization utiiizing voicing level in split-bands Signal Processing 89 (2009) 1038-1049, 12 pages.

Scott Matthew Griebel, A Microphone Array System for Speech Source Localization, Denoising and Dereverberation, Thesis, The Division of Engineering and Applied Sciences,Harvard University,Cambridge,Massachusetts, Apr. 2002 163 pages.

Cha Zhang, Dinei Florencio, Demba E. Ba, Zhengyou Zhang, Maximum Likelihood Sound Source Localization and Beamform-

(56) **References Cited**

OTHER PUBLICATIONS

Michael Brandstein, Darren Ward Microphone Arrays,Signal Processing Techniques and Applications Springer-Verlag,Berlin,Heidelberg,New York in 2001, 401 pages.
Qi (Peter) Li, Manli Zhu, and Wei Li, "A Portable USB-Based Mirophone Array Device For Robust Speech Recognition", "2009 IEEE International Conference on Acoustics, Speech, and Signal Processing", Apr. 19-24, 2009, 7 pages.
Ivan J. Tashev, Sound Capture and Processing Practical Approaches, 2009 Wiley Publisher, 196 pages.
Manli Zhu, Qi (Peter) Li, Joshua J. Hajicek Circular and Linear Microphone Arrays for Robust Speech Recognition and Conference Phone, ICASSP 2009 Thursday, Apr. 23, 2009, 1 page.
Harry L. Van Trees Arrays and Spatial Filters, Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, John Wiley & Sons, Inc., 73 pages.
Introducing First Low-cost, Light-weight, and Portable USB Array Microphone for Consumer Market, Li Creative Technologies, Inc., Feb. 2. 2010, 1 page.
Crispmic USB-Based Microphone Array for Laptops and PCs LI Creative Technologies, Inc. 2 pages.
Matthias Wolfel and John McDonough Distant Speech Recognition A John Wiley and Sons, Ltd. Publication, 2009, 592 pages.
Darpa 172 Phase I Selections from the 07.2 Solicitation, 69 pages.
Doh H. Johnson and Dan E. Dudgeon Array Signal Processing: Concepts and Techniques, 1993 Prentice Hall Signal Processing Series, 554 pages.
Group Videoconferencing Systems: Video Made Easy HD5000 Series, Multimedia Workgroup Conferencing System, Installation & Setup Guide, 70 pages.
Andrea DA-350 Microphone Performance, 1 page.
VCON—Solutions—Videoconferencing—Group Video Products MediaConnect 9000 Sep. 21, 2003-Feb. 8, 2004, 1 page.
DA-350 Hands Free Linear Array Microphone, 1 page.
DA-350 Auto Array Feb. 25, 2006-Jun. 29, 2016, 1 page.
VCON Group Videoconferencing Systems HD4000 Software-only Multimedia Videoconferencing Version 3.5, 50 pages.
MediaConnect 9000 A workgroup conferencing system for medium and large room environments, 1 page.
VCON Group Videoconferencing Systems HD5000 Series Rollabout and Compact Systems Installation & Setup Guide, 74 pages.
Baruch Berdugo, Miriam A. Doron, Judith Rosenhouse, Haim Azhari On direction finding of an emitting source from time delays 33 pages.
EchoStop, Digital Noise Reduction Technology, 1 page.
VCON—Hardware Addons—Introducing VoiceFinder, Sep. 23, 2003-Feb. 25, 2004, 2 pages.
Digital Super Directional Array (DSDA® 2.0) Far-Field Microphone Technology, 1 page.
Harry L. Van Trees Optimum Array Processing, Part IV of Detection, Estimation, and Modulation Theory A John Wiley & Sons, Inc., Publication, 192 pages.
Charles H. Knapp and G. Clifford Carter The Generalized Correlation Method for Estimation of Time Delay IEEE transactions on acoustics, speech, and signal processing, Vol, ASSP-24, No. 4, Aug. 1976, 8 pages.
PureAudio 2.0 Noise Reduction Algorithm, 1 page.
Andrea's Technologies Overview Oct. 21, 2001-Sep. 11, 2011, 4 pages.
VCON—Hardware Addons—VoiceFinder Sep. 23, 2003-Feb. 8, 2004, 1 page.
Joseph Marash DSDA, Andrea Electronics Corporation Technology, 4 pages.
Joseph Hector Dibiase, A High-Accuracy, Low-Latency Technique for Talker Localization in Reverberant Environments Using Microphone Arrays, Thesis, Division of Engineering at Brown University, Providence, Rhode Island, May 2000, 122 pages.
Qi Li, Manli Zhu, Wei Li A portable USB-based microphone array device for robustn speech recognition IEEE International Conference on Acoustics, Speech and Signal Processing, Apr. 19-24, 2009, 2 pages.
Qi (Peter) Li, Manli Zhu, and Wei Li A Portable Usb-Based Mirophone Array Device For Robust Speech Recognition IEEE International Conference on Acoustics, Speech and Signal Processing Proceedings, Apr. 19-24, 2009, 7 pages.
John Mcdonough, Kenichi Kumatani, Matthias Wolfel,Tobias Gehrig,Emilian Stoimenov, Uwe Mayer, Stefan Schacht, and Dietrich Klakow To Separate Speech! A System for Recognizing Simultaneous Speech, Jun. 2007, 13 pages.
Dmitry N. Zotkin , Ramani Duraiswami Accelerated Speech Source Localization via a Hierarchical Search of Steered Response Power University of Maryland,MD,USA , 20 pages.
Jacek Dmochowski, Jacob Benesty, Sofiane Affes Direction of Arrival Estimation Using the Parameterized Spatial Correlation Matrix, IEEE Transaction on Audio, Speech, and Language Processing, vol. 15, No. 4, May 2007.

* cited by examiner

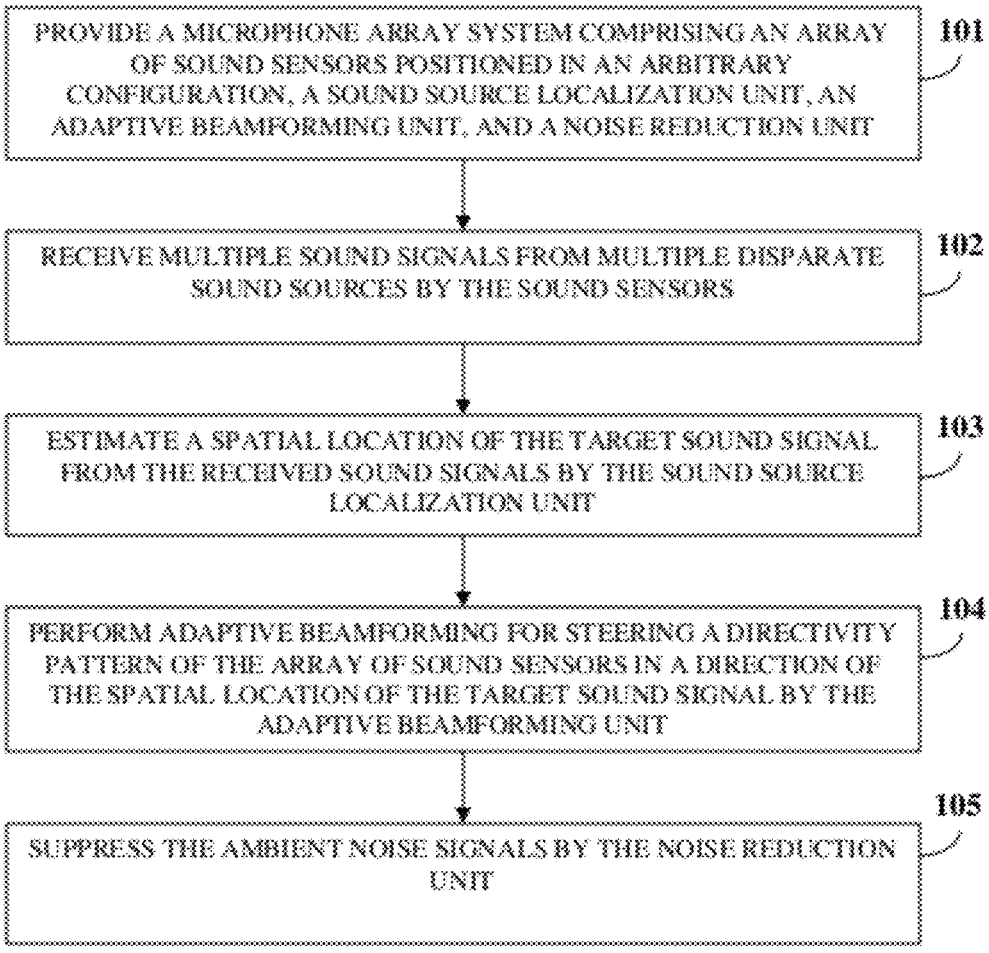



FIG. 1

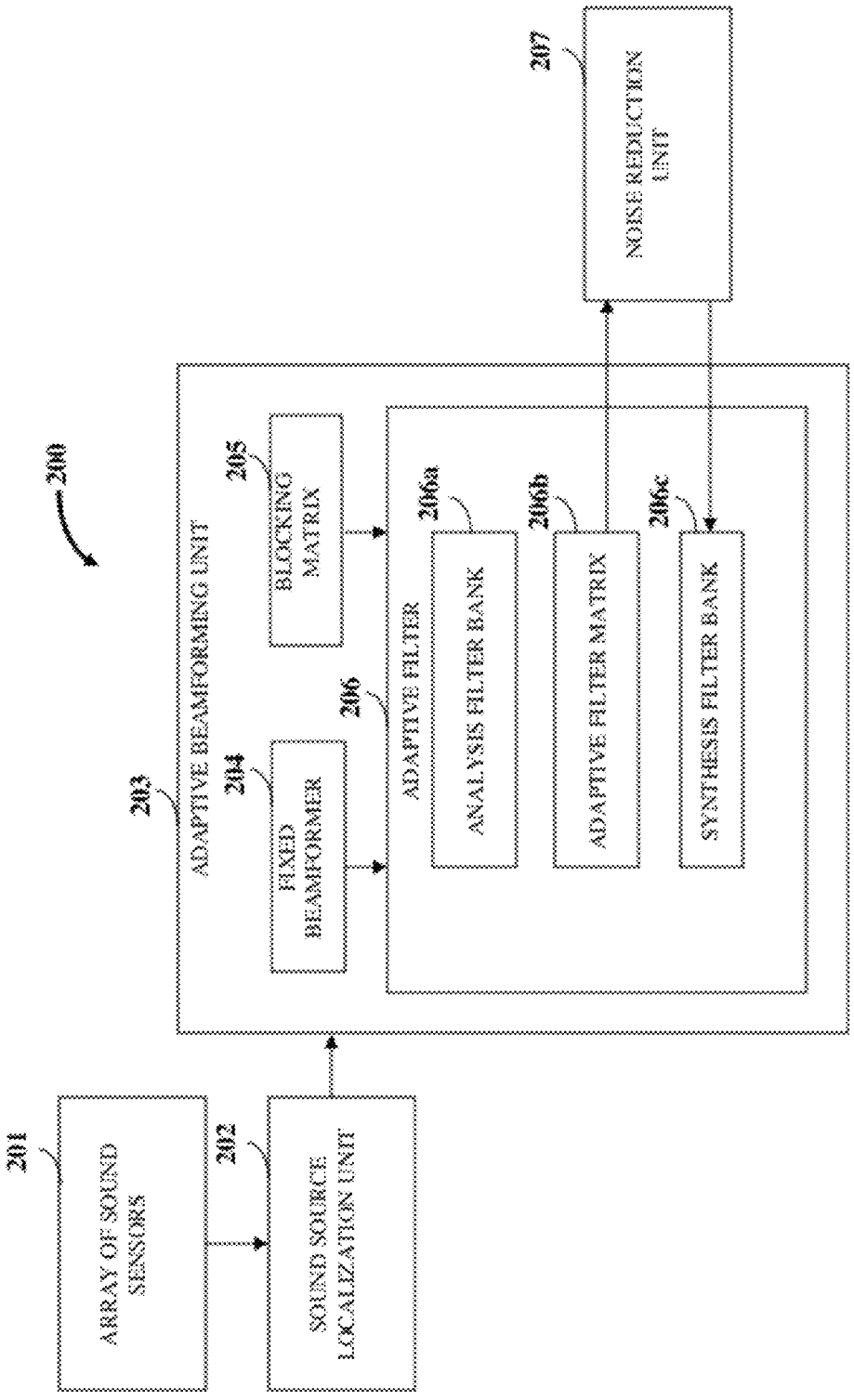



FIG. 2

DOCKET ALARM

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

**LAW FIRMS**
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

**FINANCIAL INSTITUTIONS**
Litigation and bankruptcy checks for companies and debtors.

**E-DISCOVERY AND LEGAL VENDORS**
Sync your system to PACER to automate legal marketing.