United States Patent	12388539
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Jones; Daniel John et al.

Method and system for improved acoustic transmission of data

Abstract

The present invention relates to a method for communicating data acoustically. The method includes segmenting the data into a sequence of symbols; encoding each symbol of the sequence into a plurality of tones; and acoustically generating the plurality of tones simultaneously for each symbol in sequence. Each of the plurality of tones for each symbol in the sequence may be at a different frequency.

Inventors: **Jones; Daniel John (London, GB), Nesfield; James Andrew (London, GB)**

Applicant: **SONOS EXPERIENCE LIMITED** (Hayes, GB)

Family ID: **61009064**

Assignee: **Sonos Experience Limited (Hayes, GB)**

Appl. No.: **18/405045**

Filed: **January 05, 2024**

Prior Publication Data

Document Identifier	Publication Date
US 20240333401 A1	Oct. 03, 2024

Foreign Application Priority Data

GB	1721457	Dec. 20, 2017

Related U.S. Application Data

continuation parent-doc US 16956905 US 11870501 WO PCT/GB2018/053733 20181220 child-doc US 18405045

Publication Classification

Int. Cl.: **H04L27/10** (20060101); **H04B11/00** (20060101)

U.S. Cl.:

CPC **H04B11/00** (20130101);

Field of Classification Search

CPC: H04B (11/00); H04L (1/0071)

USPC: 375/275; 375/272; 375/303; 375/307; 375/334; 375/335; 375/260

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
4045616	12/1976	Sloane	N/A	N/A
4048074	12/1976	Bruenemann et al.	N/A	N/A
4088030	12/1977	Iversen et al.	N/A	N/A
4101885	12/1977	Blum	N/A	N/A
4323881	12/1981	Mori	N/A	N/A
4794601	12/1987	Kikuchi	N/A	N/A
6133849	12/1999	McConnell et al.	N/A	N/A
6163803	12/1999	Watanabe	N/A	N/A
6272535	12/2000	Iwamura	N/A	N/A
6532477	12/2002	Tang et al.	N/A	N/A
6711538	12/2003	Omori et al.	N/A	N/A
6766300	12/2003	Laroche	N/A	N/A
6798889	12/2003	Dicker et al.	N/A	N/A
6909999	12/2004	Thomas et al.	N/A	N/A
6996532	12/2005	Thomas	N/A	N/A
7058726	12/2005	Osaku et al.	N/A	N/A
7349668	12/2007	Ilan et al.	N/A	N/A
7379901	12/2007	Philyaw	N/A	N/A
7403743	12/2007	Welch	N/A	N/A
7571014	12/2008	Lambourne et al.	N/A	N/A
7944847	12/2010	Trine et al.	N/A	N/A
8483853	12/2012	Lambourne	N/A	N/A
8494176	12/2012	Suzuki et al.	N/A	N/A
8594340	12/2012	Takara et al.	N/A	N/A
8782530	12/2013	Beringer et al.	N/A	N/A
9118401	12/2014	Nieto et al.	N/A	N/A
9137243	12/2014	Suzuki et al.	N/A	N/A
9237226	12/2015	Frauenthal et al.	N/A	N/A
9270811	12/2015	Atlas	N/A	N/A
9288597	12/2015	Carlsson et al.	N/A	N/A
9344802	12/2015	Suzuki et al.	N/A	N/A
10090003	12/2017	Wang	N/A	N/A
10186251	12/2018	Mohammadi	N/A	N/A
10236006	12/2018	Gurijala et al.	N/A	N/A
10236031	12/2018	Gurijala	N/A	N/A
10498654	12/2018	Shalev et al.	N/A	N/A
11205437	12/2020	Zhang et al.	N/A	N/A
11870501	12/2023	Jones	N/A	H04B 11/00
2002/0054608	12/2001	Wan et al.	N/A	N/A
2002/0107596	12/2001	Thomas et al.	N/A	N/A
2002/0152388	12/2001	Linnartz et al.	N/A	N/A

2002/0184010	12/2001	Eriksson et al.	N/A	N/A
2003/0065918	12/2002	Willey	N/A	N/A
2003/0195745	12/2002	Zinser, Jr. et al.	N/A	N/A
2003/0212549	12/2002	Steentra et al.	N/A	N/A
2004/0002858	12/2003	Attias et al.	N/A	N/A
2004/0081078	12/2003	McKnight et al.	N/A	N/A
2004/0133789	12/2003	Gantman et al.	N/A	N/A
2004/0148166	12/2003	Zheng	N/A	N/A
2004/0264713	12/2003	Grzesek	N/A	N/A
2005/0049732	12/2004	Kanevsky et al.	N/A	N/A
2005/0086602	12/2004	Philyaw et al.	N/A	N/A
2005/0219068	12/2004	Jones et al.	N/A	N/A
2006/0167841	12/2005	Allan et al.	N/A	N/A
2006/0253209	12/2005	Hersbach et al.	N/A	N/A
2006/0287004	12/2005	Fuqua	N/A	N/A
2007/0063027	12/2006	Belfer et al.	N/A	N/A
2007/0121918	12/2006	Tischer	N/A	N/A
2007/0144235	12/2006	Werner et al.	N/A	N/A
2007/0174052	12/2006	Manjunath et al.	N/A	N/A
2007/0192672	12/2006	Bodin et al.	N/A	N/A
2007/0192675	12/2006	Bodin et al.	N/A	N/A
2007/0232257	12/2006	Otani et al.	N/A	N/A
2007/0268162	12/2006	Mss et al.	N/A	N/A
2008/0002882	12/2007	Voloshynovskyy et al.	N/A	N/A
2008/0011825	12/2007	Giordano et al.	N/A	N/A
2008/0027722	12/2007	Haulick et al.	N/A	N/A
2008/0031315	12/2007	Ramirez et al.	N/A	N/A
2008/0059157	12/2007	Fukuda et al.	N/A	N/A
2008/0112885	12/2007	Okunev et al.	N/A	N/A
2008/0144624	12/2007	Marcondes et al.	N/A	N/A
2008/0232603	12/2007	Soulodre	N/A	N/A
2008/0242357	12/2007	White	N/A	N/A
2008/0262928	12/2007	Michaelis	N/A	N/A
2009/0034712	12/2008	Grasley et al.	N/A	N/A
2009/0119110	12/2008	Oh et al.	N/A	N/A
2009/0123002	12/2008	Karthik et al.	N/A	N/A
2009/0141890	12/2008	Steenstra et al.	N/A	N/A
2009/0175257	12/2008	Belmonte et al.	N/A	N/A
2009/0254485	12/2008	Baentsch et al.	N/A	N/A
2010/0030838	12/2009	Atsmon et al.	N/A	N/A
2010/0054275	12/2009	Noonan et al.	N/A	N/A
2010/0064132	12/2009	Ravikiran Sureshbabu	N/A	N/A
2010/0088390	12/2009	Bai et al.	N/A	N/A
2010/0134278	12/2009	Srinivasan et al.	N/A	N/A
2010/0146115	12/2009	Bezos	N/A	N/A
2010/0223138	12/2009	Dragt	N/A	N/A
2010/0260348	12/2009	Bhow et al.	N/A	N/A
2010/0267340	12/2009	Lee	N/A	N/A
2010/0290504	12/2009	Torimoto et al.	N/A	N/A
2010/0290641	12/2009	Steele	N/A	N/A
2011/0173208	12/2010	Vogel	N/A	N/A
2011/0216783	12/2010	Takeuchi et al.	N/A	N/A
2011/0276333	12/2010	Wang et al.	N/A	N/A
2011/0277023	12/2010	Meylemans et al.	N/A	N/A

2011/0307787	12/2010	Smith	N/A	N/A
2012/0045994	12/2011	Koh et al.	N/A	N/A
2012/0075083	12/2011	Isaacs	N/A	N/A
2012/0084131	12/2011	Bergel et al.	N/A	N/A
2012/0214416	12/2011	Kent et al.	N/A	N/A
2012/0214544	12/2011	Shivappa et al.	N/A	N/A
2013/0010979	12/2012	Takara et al.	N/A	N/A
2013/0030800	12/2012	Tracey et al.	N/A	N/A
2013/0034243	12/2012	Yermeche et al.	N/A	N/A
2013/0077798	12/2012	Otani et al.	N/A	N/A
2013/0113558	12/2012	Pfaffinger et al.	N/A	N/A
2013/0170647	12/2012	Reilly et al.	N/A	N/A
2013/0216058	12/2012	Furuta et al.	N/A	N/A
2013/0216071	12/2012	Maher et al.	N/A	N/A
2013/0223279	12/2012	Tinnakornsrisuphap et al.	N/A	N/A
2013/0275126	12/2012	Lee	N/A	N/A
2013/0331970	12/2012	Beckhardt et al.	N/A	N/A
2014/0003625	12/2013	Sheen et al.	N/A	N/A
2014/0028818	12/2013	Brockway, III et al.	N/A	N/A
2014/0037107	12/2013	Marino, Jr. et al.	N/A	N/A
2014/0046464	12/2013	Reimann	N/A	N/A
2014/0053281	12/2013	Benoit et al.	N/A	N/A
2014/0074469	12/2013	Zhidkov	N/A	N/A
2014/0108020	12/2013	Sharma et al.	N/A	N/A
2014/0142958	12/2013	Sharma et al.	N/A	N/A
2014/0164629	12/2013	Barth et al.	N/A	N/A
2014/0172141	12/2013	Mangold	N/A	N/A
2014/0172429	12/2013	Butcher et al.	N/A	N/A
2014/0201635	12/2013	Kumar et al.	N/A	N/A
2014/0258110	12/2013	Davis et al.	N/A	N/A
2015/0004935	12/2014	Fu	N/A	N/A
2015/0088495	12/2014	Jeong et al.	N/A	N/A
2015/0141005	12/2014	Suryavanshi et al.	N/A	N/A
2015/0215299	12/2014	Burch et al.	N/A	N/A
2015/0248879	12/2014	Miskimen et al.	N/A	N/A
2015/0271676	12/2014	Shin et al.	N/A	N/A
2015/0349841	12/2014	Mani et al.	N/A	N/A
2015/0371529	12/2014	Dolecki	N/A	N/A
2015/0382198	12/2014	Kashef et al.	N/A	N/A
2016/0007116	12/2015	Holman	N/A	N/A
2016/0021473	12/2015	Riggi et al.	N/A	N/A
2016/0098989	12/2015	Layton et al.	N/A	N/A
2016/0291141	12/2015	Han et al.	N/A	N/A
2016/0309276	12/2015	Ridihalgh et al.	N/A	N/A
2017/0208170	12/2016	Mani et al.	N/A	N/A
2017/0279542	12/2016	Knauer et al.	N/A	N/A
2018/0106897	12/2017	Shouldice et al.	N/A	N/A
2018/0115844	12/2017	Lu et al.	N/A	N/A
2018/0167147	12/2017	Almada et al.	N/A	N/A
2018/0213322	12/2017	Napoli et al.	N/A	N/A
2018/0359560	12/2017	Defraene et al.	N/A	N/A
2019/0035719	12/2018	Daitoku et al.	N/A	N/A
2019/0045301	12/2018	Family et al.	N/A	N/A
2019/0096398	12/2018	Sereshki	N/A	N/A

2019/0348041	12/2018	Cella et al.	N/A	N/A
2020/0029167	12/2019	Bostick et al.	N/A	N/A
2020/0091963	12/2019	Christoph et al.	N/A	N/A
2020/0105128	12/2019	Frank	N/A	N/A
2020/0169327	12/2019	Lin	N/A	H04L 1/0071
2020/0301651	12/2019	Georganti	N/A	N/A
2021/0029452	12/2020	Tsoi et al.	N/A	N/A
2021/0098008	12/2020	Nesfield et al.	N/A	N/A
2022/0059123	12/2021	Sheaffer et al.	N/A	N/A
2022/0322010	12/2021	Seefedlt et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
103259563	12/2012	CN	N/A
105790852	12/2015	CN	N/A
106921650	12/2016	CN	N/A
1612999	12/2005	EP	N/A
1760693	12/2006	EP	N/A
2334111	12/2010	EP	N/A
2916554	12/2014	EP	N/A
3275117	12/2017	EP	N/A
3408936	12/2017	EP	N/A
3526912	12/2018	EP	N/A
2369995	12/2001	GB	N/A
2484140	12/2011	GB	N/A
H1078928	12/1997	JP	N/A
2001320337	12/2000	JP	N/A
2004512765	12/2003	JP	N/A
2004139525	12/2003	JP	N/A
2007121626	12/2006	JP	N/A
2007195105	12/2006	JP	N/A
2008219909	12/2007	JP	N/A
0016497	12/1999	WO	N/A
0115021	12/2000	WO	N/A
0150665	12/2000	WO	N/A
0161987	12/2000	WO	N/A
0163397	12/2000	WO	N/A
0211123	12/2001	WO	N/A
0235747	12/2001	WO	N/A
2004002103	12/2002	WO	N/A
2005006566	12/2004	WO	N/A
2005013047	12/2004	WO	N/A
2008131181	12/2007	WO	N/A
2016094687	12/2015	WO	N/A

OTHER PUBLICATIONS

U.S. Appl. No. 62/519,024, filed Jun. 13, 2017. cited by examiner
Madhavapeddy et al., Context-Aware Computing with Sound, University of Cambridge 2003, pp. 315-332. cited by applicant
Monaghan et al. “A method to enhance the use of interaural time differences for cochlear implants in reverberant environments.”, published Aug. 17, 2016, Journal of the Acoustical Society of America, 140, pp. 1116-1129. Retrieved from the Internet URL: https://asa.scitation.org/doi/10.1121/1.4960572 Year: 2016, 15 pages. cited by applicant
Non-Final Office Action mailed Mar. 25, 2015, issued in connection with U.S. Appl. No. 12/926,470, filed

Nov. 19, 2010, 24 pages. cited by applicant
Non-Final Office Action mailed Mar. 28, 2016, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 26 pages. cited by applicant
Non-Final Office Action mailed Jan. 6, 2017, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 22 pages. cited by applicant
Non-Final Office Action mailed Aug. 9, 2019, issued in connection with U.S. Appl. No. 16/012,167, filed Jun. 19, 2018, 15 pages. cited by applicant
Non-Final Office Action mailed on Oct. 4, 2022, issued in connection with U.S. Appl. No. 16/496,685, filed Sep. 23, 2019, 15 pages. cited by applicant
Non-Final Office Action mailed on Feb. 5, 2014, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 22 pages. cited by applicant
Non-Final Office Action mailed on Jul. 1, 2022, issued in connection with U.S. Appl. No. 16/623,160, filed Dec. 16, 2019, 10 pages. cited by applicant
Non-Final Office Action mailed on Jul. 11, 2022, issued in connection with U.S. Appl. No. 17/660,185, filed Apr. 21, 2022, 20 pages. cited by applicant
Non-Final Office Action mailed on Aug. 12, 2021, issued in connection with U.S. Appl. No. 16/342,060, filed Apr. 15, 2019, 88 pages. cited by applicant
Non-Final Office Action mailed on Oct. 15, 2021, issued in connection with U.S. Appl. No. 16/496,685, filed Sep. 23, 2019, 12 pages. cited by applicant
Non-Final Office Action mailed on May 19, 2023, issued in connection with U.S. Appl. No. 16/956,905, filed Jun. 22, 2020, 20 pages. cited by applicant
Non-Final Office Action mailed on Jul. 21, 2022, issued in connection with U.S. Appl. No. 16/956,905, filed Jun. 22, 2020, 15 pages. cited by applicant
Non-Final Office Action mailed on Sep. 24, 2020, issued in connection with U.S. Appl. No. 16/012,167, filed Jun. 19, 2018, 20 pages. cited by applicant
Non-Final Office Action mailed on Dec. 27, 2021, issued in connection with U.S. Appl. No. 16/956,905, filed Jun. 22, 2020, 12 pages. cited by applicant
Non-Final Office Action mailed on Jan. 29, 2021, issued in connection with U.S. Appl. No. 16/342,060, filed Apr. 15, 2019, 59 pages. cited by applicant
Non-Final Office Action mailed on Feb. 5, 2021, issued in connection with U.S. Appl. No. 16/342,078, filed Apr. 15, 2019, 13 pages. cited by applicant
Non-Final Office Action mailed on Dec. 6, 2023, issued in connection with U.S. Appl. No. 18/140,393, filed Apr. 27, 2023, 15 pages. cited by applicant
Non-Final Office Action mailed on Sep. 7, 2021, issued in connection with U.S. Appl. No. 16/623,160, filed Dec. 16, 2019, 11 pages. cited by applicant
Notice of Allowance mailed Mar. 15, 2018, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 10 pages. cited by applicant
Notice of Allowance mailed Mar. 19, 2021, issued in connection with U.S. Appl. No. 16/012,167, filed Jun. 19, 2018, 9 pages. cited by applicant
Notice of Allowance mailed on Feb. 8, 2023, issued in connection with U.S. Appl. No. 16/623,160, filed Dec. 16, 2019, 10 pages. cited by applicant
Notice of Allowance mailed on Sep. 1, 2023, issued in connection with U.S. Appl. No. 16/956,905, filed Jun. 22, 2020, 8 pages. cited by applicant
Notice of Allowance mailed on Aug. 11, 2022, issued in connection with U.S. Appl. No. 16/342,078, filed Apr. 15, 2019, 15 pages. cited by applicant
Notice of Allowance mailed on Aug. 11, 2023, issued in connection with U.S. Appl. No. 17/883,020, filed Aug. 8, 2022, 21 pages. cited by applicant
Notice of Allowance mailed on Feb. 18, 2022, issued in connection with U.S. Appl. No. 16/564,766, filed Sep. 9, 2019, 8 pages. cited by applicant
Notice of Allowance mailed on Sep. 19, 2023, issued in connection with U.S. Appl. No. 17/460,708, filed Aug. 30, 2021, 10 pages. cited by applicant
Notice of Allowance mailed on Jan. 23, 2024, issued in connection with U.S. Appl. No. 17/460,708, filed Aug. 30, 2021, 9 pages. cited by applicant
Notice of Allowance mailed on Jan. 27, 2023, issued in connection with U.S. Appl. No. 16/496,685, filed

Sep. 23, 2019, 7 pages. cited by applicant
Notice of Allowance mailed on Mar. 29, 2022, issued in connection with U.S. Appl. No. 16/342,060, filed Apr. 15, 2019, 24 pages. cited by applicant
Notice of Allowance mailed on Apr. 5, 2022, issued in connection with U.S. Appl. No. 16/956,905, filed Jun. 22, 2020, 9 pages. cited by applicant
Notice of Allowance mailed on Feb. 7, 2023, issued in connection with U.S. Appl. No. 16/342,078, filed Apr. 15, 2019, 12 pages. cited by applicant
Soriente et al., “HAPADEP: Human-Assisted Pure Audio Device Pairing” Computer Science Department, University of California Irvine, 12 pages. [Retrieved Online] URLhttps://www.researchgate.net/publication/220905534_HAPADEP_Human-assisted_pure_audio_device_pairing. cited by applicant
Tarr, E.W. “Processing perceptually important temporal and spectral characteristics of speech”, 2013, Available from ProQuest Dissertations and Theses Professional. Retrieved from https://dialog.proquest.com/professional/docview/1647737151?accountid=131444, 200 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Examination Report mailed on Oct. 8, 2021, issued in connection with United Kingdom Application No. GB2113511.6, 7 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Examination Report mailed on Jun. 11, 2021, issued in connection with United Kingdom Application No. GB1716909.5, 5 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Examination Report mailed on Feb. 2, 2021, issued in connection with United Kingdom Application No. GB1715134.1, 5 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Examination Report mailed on Oct. 29, 2021, issued in connection with United Kingdom Application No. GB1709583.7, 3 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Office Action mailed on May 10, 2022, issued in connection with United Kingdom Application No. GB2202914.4, 5 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Office Action mailed on Jan. 22, 2021, issued in connection with United Kingdom Application No. GB1906696.8, 2 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Office Action mailed on Mar. 24, 2022, issued in connection with United Kingdom Application No. GB2202914.4, 3 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Office Action mailed on Jan. 28, 2022, issued in connection with United Kingdom Application No. GB2113511.6, 3 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Office Action mailed on Feb. 9, 2022, issued in connection with United Kingdom Application No. GB2117607.8, 3 pages. cited by applicant
United Kingdom Patent Office, United Kingdom Search Report mailed on Sep. 22, 2021, issued in connection with United Kingdom Application No. GB2109212.7, 5 pages. cited by applicant
Wang, Avery Li-Chun. An Industrial-Strength Audio Search Algorithm. Oct. 27, 2003, 7 pages. [online]. [retrieved on May 12, 2020] Retrieved from the Internet URL: https://www.researchgate.net/publication/220723446_An_Industrial_Strength_Audio_Search_Algorithm. cited by applicant
Advisory Action mailed on Mar. 1, 2022, issued in connection with U.S. Appl. No. 16/342,078, filed Apr. 15, 2019, 3 pages. cited by applicant
Advisory Action mailed on Aug. 19, 2022, issued in connection with U.S. Appl. No. 16/496,685, filed Sep. 23, 2019, 3 pages. cited by applicant
Bourguet et al. “A Robust Audio Feature Extraction Algorithm for Music Identification,” AES Convention 129; Nov. 4, 2010, 7 pages. cited by applicant
C. Beaugeant and H. Taddei, “Quality and computation load reduction achieved by applying smart transcoding between CELP speech codecs,” 2007, 2007 15th European Signal Processing Conference, pp. 1372-1376. cited by applicant
European Patent Office, Decision to Refuse mailed on Nov. 13, 2019, issued in connection with European Patent Application No. 11773522.5, 52 pages. cited by applicant
European Patent Office, European EPC Article 94.3 mailed on Oct. 8, 2021, issued in connection with European Application No. 17790809.2, 9 pages. cited by applicant
European Patent Office, European EPC Article 94.3 mailed on Dec. 10, 2021, issued in connection with European Application No. 18845403.7, 41 pages. cited by applicant

European Patent Office, European EPC Article 94.3 mailed on Oct. 12, 2021, issued in connection with European Application No. 17795004.5, 8 pages. cited by applicant
European Patent Office, European EPC Article 94.3 mailed on Oct. 25, 2022, issued in connection with European Application No. 20153173.8, 5 pages. cited by applicant
European Patent Office, European EPC Article 94.3 mailed on Oct. 28, 2021, issued in connection with European Application No. 18752180.2, 7 pages. cited by applicant
European Patent Office, European EPC Article 94.3 mailed on Jul. 6, 2022, issued in connection with European Application No. 20153173.8, 4 pages. cited by applicant
European Patent Office, European Extended Search Report mailed on May 27, 2024, issued in connection with European Application No. 24155085.4, 9 pages. cited by applicant
European Patent Office, European Extended Search Report mailed on Aug. 31, 2020, issued in connection with European Application No. 20153173.8, 8 pages. cited by applicant
European Patent Office, Summons to Attend Oral Proceedings mailed on Jul. 13, 2023, issued in connection with European Application No. 18752180.2, 6 pages. cited by applicant
European Patent Office, Summons to Attend Oral Proceedings mailed on Mar. 15, 2019, issued in connection with European Application No. 11773522.5-1217, 10 pages. cited by applicant
European Patent Office, Summons to Attend Oral Proceedings mailed on Mar. 19, 2024, issued in connection with European Application No. 20153173.8, 9 pages. cited by applicant
Final Office Action mailed Oct. 16, 2014, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 22 pages. cited by applicant
Final Office Action mailed Aug. 17, 2017, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 22 pages. cited by applicant
Final Office Action mailed Nov. 30, 2015, issued in connection with U.S. Appl. No. 12/926,470, filed Nov. 19, 2010, 25 pages. cited by applicant
Final Office Action mailed on Nov. 1, 2022, issued in connection with U.S. Appl. No. 16/623,160, filed Dec. 16, 2019, 10 pages. cited by applicant
Final Office Action mailed on May 10, 2022, issued in connection with U.S. Appl. No. 16/496,685, filed Sep. 23, 2019, 15 pages. cited by applicant
Final Office Action mailed on Nov. 15, 2022, issued in connection with U.S. Appl. No. 16/956,905, filed Jun. 22, 2020, 16 pages. cited by applicant
Final Office Action mailed on Mar. 18, 2022, issued in connection with U.S. Appl. No. 16/623,160, filed Dec. 16, 2019, 14 pages. cited by applicant
Final Office Action mailed on Apr. 20, 2020, issued in connection with U.S. Appl. No. 16/012,167, filed Jun. 19, 2018, 21 pages. cited by applicant
Gerasimov et al. “Things That Talk: Using sound for device-to-device and device-to-human communication”, Feb. 2000 IBM Systems Journal 39(3.4): 530-546, 18 pages. [Retrieved Online] URlhttps://www.researchgate.net/publication/224101904_Things_that_talk_Using_sound_for_device-to-device_and_device-to-human_communication. cited by applicant
Glover et al. “Real-time detection of musical onsets with linear prediction and sinusoidal modeling.”, 2011 EURASIP Journal on Advances in Signal Processing 2011, 68, Retrieved from the Internet URL: https://doi.org/10.1186/1687-6180-2011-68, Sep. 20, 2011, 13 pages. cited by applicant
Gomez et al: “Distant talking robust speech recognition using late reflection components of room impulse response”, Acoustics, Speech and Signal Processing, 2008. ICASSP 2008. IEEE International Conference on, IEEE, Piscataway, NJ, USA, Mar. 31, 2008, XP031251618, ISBN: 978-1-4244-1483-3, pp. 4581-4584. cited by applicant
Gomez et al., “Robust Speech Recognition in Reverberant Environment by Optimizing Multi-band Spectral Subtraction”, 2013 IEEE International Conference on Acoustics, Speech and Signal Processing ICASSP, Jan. 1, 2008, 6 pages. cited by applicant
Goodrich et al., Using Audio inn Secure Device Pairing, International Journal of Security and Networks, vol. 4, No. 1.2, Jan. 1, 2009, p. 57, Inderscience Enterprises Ltd., 12 pages. cited by applicant
International Bureau, International Preliminary Report on Patentability and Written Opinion, mailed on Apr. 16, 2019, issued in connection with International Application No. PCT/GB2017/053112, filed on Oct. 13, 2017, 12 pages. cited by applicant
International Bureau, International Preliminary Report on Patentability and Written Opinion, mailed on

Apr. 16, 2019, issued in connection with International Application No. PCT/GB2017/053113, filed on Oct. 13, 2017, 8 pages. cited by applicant
International Bureau, International Preliminary Report on Patentability and Written Opinion, mailed on Dec. 17, 2019, issued in connection with International Application No. PCT/GB2018/051645, filed on Jun. 14, 2018, 7 pages. cited by applicant
International Bureau, International Preliminary Report on Patentability and Written Opinion, mailed on Mar. 19, 2019, issued in connection with International Application No. PCT/GB2017/052787, filed on Sep. 19, 2017, 7 pages. cited by applicant
International Bureau, International Preliminary Report on Patentability and Written Opinion, mailed on Jun. 23, 2020, issued in connection with International Application No. PCT/GB2018/053733, filed on Dec. 20, 2018, 7 pages. cited by applicant
International Bureau, International Preliminary Report on Patentability and Written Opinion, mailed on Sep. 24, 2019, issued in connection with International Application No. PCT/GB2018/050779, filed on Mar. 23, 2018, 6 pages. cited by applicant
International Bureau, International Search Report and Written Opinion mailed on Apr. 11, 2019, issued in connection with International Application No. PCT/GB2018/053733, filed on Dec. 20, 2018, 10 pages. cited by applicant
International Bureau, International Search Report and Written Opinion mailed on Sep. 21, 2022, issued in connection with International Application No. PCT/US2022/072465, filed on May 20, 2022, 32 pages. cited by applicant
International Bureau, International Search Report and Written Opinion mailed on Oct. 4, 2018, issued in connection with International Application No. PCT/GB2018/051645, filed on Jun. 14, 2018, 14 pages. cited by applicant
International Searching Authority, International Search Report and Written Opinion mailed on Jan. 5, 2022, issued in connection with International Application No. PCT/US2021/048380, filed on Aug. 31, 2021, 15 pages. cited by applicant
International Searching Authority, International Search Report and Written Opinion mailed on Mar. 13, 2018, issued in connection with International Application No. PCT/GB2017/053112, filed on Oct. 13, 2017, 18 pages. cited by applicant
International Searching Authority, International Search Report and Written Opinion mailed on Nov. 29, 2017, in connection with International Application No. PCT/GB2017/052787, 10 pages. cited by applicant
International Searching Authority, International Search Report and Written Opinion mailed on Nov. 30, 2011, in connection with International Application No. PCT/GB2011/051862, 6 pages. cited by applicant
International Searching Authority, International Search Report mailed on Jan. 18, 2018, issued in connection with International Application No. PCT/GB2017/053113, filed on Oct. 17, 2017, 11 pages. cited by applicant
International Searching Authority, International Search Report mailed on Jun. 19, 2018, issued in connection with International Application No. PCT/GB2018/050779, filed on Mar. 23, 2018, 8 pages. cited by applicant
Japanese Patent Office, Office Action dated Jun. 23, 2015, issued in connection with JP Application No. 2013-530801, 8 pages. cited by applicant
Japanese Patent Office, Office Action dated Apr. 4, 2017, issued in connection with JP Application No. 2013-530801, 8 pages. cited by applicant
Japanese Patent Office, Office Action dated Jul. 5, 2016, issued in connection with JP Application No. 2013-530801, 8 pages. cited by applicant
Lopes et al. “Acoustic Modems for Ubiquitous Computing”, IEEE Pervasive Computing, Mobile and Ubiquitous Systems. vol. 2, No. 3 Jul.-Sep. 2003, pp. 62-71. [Retrieved Online] URL https://www.researchgate.net/publication/3436996_Acoustic_modems_for_ubiquitous_computing. cited by applicant
Madhavapeddy, Anil. Audio Networking for Ubiquitous Computing, Oct. 24, 2003, 11 pages. cited by applicant
Madhavapeddy et al., Audio Networking: The Forgotten Wireless Technology, IEEE CS and IEEE ComSoc, Pervasive Computing, Jul.-Sep. 2005, pp. 55-60. cited by applicant

Primary Examiner: Phu; Phuong

Attorney, Agent or Firm: Nixon & Vanderhye, P.C.

Background/Summary

(1) This application is a continuation of U.S. application Ser. No. 16/956,905, filed Jun. 22, 2020, which is the U.S. national phase of International Application No. PCT/GB2018/053733 filed 20 Dec. 2018, which designated the U.S. and claims priority to GB Patent Application No. 1721457.8 filed 20 Dec. 2017, the entire contents of each of which are hereby incorporated by reference.

FIELD OF INVENTION

(1) The present invention is in the field of data communication. More particularly, but not exclusively, the present invention relates to a method and system for acoustic transmission of data.

BACKGROUND

(2) There are a number of solutions to communicating data wirelessly over a short range to and from devices using radio frequencies. The most typical of these is WiFi. Other examples include Bluetooth and Zigbee.

(3) An alternative solution for a short range data communication uses a “transmitting” speaker and “receiving” microphone to send encoded data acoustically over-the-air.

(4) Such an alternative may provide various advantages over radio frequency-based systems. For example, speakers and microphones are cheaper and more prevalent within consumer electronic devices, and acoustic transmission is limited to “hearing” distance.

(5) There exist several over-the-air acoustic communications systems. A popular scheme amongst over-the-air acoustic communications systems is to use Frequency Shift Keying as the modulation scheme, in which digital information is transmitted by modulating the frequency of a carrier signal to convey 2 or more integer levels (M-ary fixed keying, where M is the distinct number of levels).

(6) One such acoustic communication system is described in US Patent Publication No. US2012/084131A1, DATA COMMUNICATION SYSTEM. This system, invented by Patrick Bergel and Anthony Steed, involves the transmission of data using an audio signal transmitted from a speaker and received by a microphone where the data, such as a shortcode, is encoded into a sequence of tones within the audio signal.

(7) Acoustic communication systems using Frequency Shift Keying such as the above system can have a good level of robustness but are limited in terms of their throughput. The data rate is linearly proportional to the number of tones available (the alphabet size), divided by the duration of each tone. This is robust and simple in complexity, but is spectrally inefficient.

(8) Radio frequency data communication systems may use phase- and amplitude-shift keying to ensure high throughput. However, both these systems are not viable for over-the-air data transmission in most situations, as reflections and amplitude changes in real-world acoustic environments renders them extremely susceptible to noise.

(9) There is a desire for a system which provides improved throughput in acoustic data communication systems.

(10) It is an object of the present invention to provide a method and system for improved acoustic data transmission which overcomes the disadvantages of the prior art, or at least provides a useful alternative.

SUMMARY OF INVENTION

(11) According to a first aspect of the invention there is provided a method for communicating data acoustically, including: a) Segmenting the data into a sequence of symbols; b) Encoding each symbol of the sequence into a plurality of tones; and c) Acoustically generating the plurality of tones simultaneously for each symbol in sequence; wherein each of the plurality of tones for each symbol in the sequence are at a different frequency.

(12) Other aspects of the invention are described within the claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:
(2) FIG. **1**: shows block diagram illustrating a data communication system in accordance with an embodiment of the invention; and
(3) FIG. **2**: shows a flow diagram illustrating a data communication method in accordance with an embodiment of the invention.
DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS
(4) The present invention provides an improved method and system for acoustically communicating data.
(5) The inventors have discovered that throughput can be increased significantly in a tone-based acoustic communication system by segmenting the data into symbols and transmitting K tones simultaneously for each symbol where the tones are selected from an alphabet of size M. In this way, a single note comprising multiple tones can encode symbols of size log.sub.2 (M choose K) bits compared to a single tone note which encodes a symbol into only log.sub.2 (M) bits. The inventors have discovered that this method of increasing data density is significantly less susceptible to noise in typical acoustic environments compared to PSK and ASK at a given number of bits per symbol.
(6) In FIG. **1**, an acoustic data communication system **100** in accordance with an embodiment of the invention is shown.
(7) The system **100** may include a transmitting apparatus **101** comprising an encoding processor **102** and a speaker **103**.
(8) The encoding processor **102** may be configured for segmenting data into a sequence of symbols and for encoding each symbol of the sequence into a plurality of tones. Each symbol may be encoded such that each of the plurality of tones are different. Each symbol may be encoded into K tones. The data may be segmented into symbols corresponding to B bits of the data. B may be log 2 (M choose K) where M is the size of the alphabet for the tones. The alphabet of tones may be spread evenly over a frequency spectrum or may be spread in ways to improve transmission.
(9) The processor **102** and/or speaker **103** may be configured for acoustically transmitting the plurality of tones simultaneously for each symbol in sequence. For example, the processor **102** may be configured for summing the plurality of tones into a single note or chord for generation at the speaker **103**. Alternatively, the speaker **103** may include a plurality of cones and each cone may generate a tone.
(10) The system **100** may include a receiving apparatus **104** comprising a decoding processor **105** and a microphone **106**.
(11) The microphone **106** may be configured for receiving an audio signal which originates at the speaker **103**.
(12) The decoding processor **105** may be configured for decoding the audio signal into a sequence of notes (or chords), for identifying a plurality of tones within each note, for decoding the plurality of tones for each note into a symbol to form a sequence of symbols, and for reconstituting data from the sequence of symbols.
(13) It will also be appreciated by those skilled in the art that the above embodiments of the invention may be deployed on different apparatuses and in differing architectures. For example, the encoding processor **102** and speaker **103** may exist within different devices and the audio signal to be generated may be transmitted from the encoding processor **102** (e.g. the processor **102** may be located at a server) to the speaker **103** (e.g. via a network, or via a broadcast system) for acoustic generation (for example, the speaker **103** may be within a television or other audio or audio/visual device). Furthermore, the microphone **106** and decoding processor **105** may exist within different devices. For example, the microphone **106** may transmit the audio signal, or a representation thereof, to a decoding processor **105** in the cloud.
(14) The functionality of the apparatuses **101** and **104** and/or processors **102** and **105** may be implemented, at least in part, by computer software stored on an intangible computer-readable medium.
(15) Referring to FIG. **2**, a method **200** for communicating data acoustically will be described.
(16) The data may be comprised of a payload and error correction. In some embodiment, the data may

include a header. The header may include a length related to the transmission (e.g. for the entire data or the payload). The length may be the number of symbols transmitted.
(17) In step **201**, the data is segmented into a sequence of symbols (e.g. at transmitting apparatus **101** by encoding processor **102**). The data may be segmented by first treating the data as a stream of bits. The segment size (B) in bits may be determined by:
B=log.sub.2(M choose K)
M is the size of the alphabet of the tones at different frequencies spanning an audio spectrum and K is the number of tones per note or chord.
(18) The audio spectrum may be wholly or, at least partially, audible to human beings (e.g. within 20 Hz to 20 kHz), and/or may be wholly, or at least partially, ultrasonic (e.g. above 20 kHz). In one embodiment, the audio spectrum is near-ultrasonic (18 kHz to 20 kHz).
(19) In step **202**, each symbol in the sequence may be mapped to a set of tones (e.g. at transmitting apparatus **101** by encoding processor **102**) Each set may comprise K tones. The tones may be selected from the alphabet of M tones. Preferably each tone within a set is a different tone selected from the alphabet. The symbol may be mapped to the set of tones via bijective mapping. In one embodiment, a hash-table from symbol to tone set may be used to encode the symbol (a second hash-table may map the set of tones to symbol to decode a detected set of tones). One disadvantage of using hashtables is that because the hash-table must cover all possible selections of tones for the set, as M and/or K increases, the memory requirements may become prohibitively large. Therefore, it may be desirable if a more efficient bijective mapping schema could be used. One embodiment, which addresses this desire, uses a combinatorial number system (combinadics) method to map symbols to tone sets and detected tone sets to symbols.
(20) In the combinadics method, each symbol (as an integer) can be translated into a K-value combinatorial representation (e.g. a set of K tones selected from the alphabet of M tones). Furthermore, each set of K tones can be translated back into a symbol (as an integer).
(21) In step **203**, the set of tones may be generated acoustically simultaneously for each symbol in the sequence (e.g. at the transmitting apparatus **101**). This may be performed by summing all the tones in the set into an audio signal and transmitting the audio signal via a speaker **103**. The audio signal may include a preamble. The preamble may assist in triggering listening or decoding at a receiving apparatus (e.g. **104**). The preamble may be comprised of a sequence of single or summed tones.
(22) In step **204**, the audio signal may be received by a microphone (e.g. **106** at receiving apparatus **104**).
(23) In step **205**, the audio signal may be decoded (e.g. via decoding processor **105**) into a sequence of notes. Decoding of the audio signal may be triggered by detection first of a preamble.
(24) Each note may comprise a set of tones and the set of tones may be detected within each node (e.g. by decoding processor) in step **206**. The tones may be detected by computing a series of FFT frames for the audio signal corresponding to a note length and detecting the K most significant peaks in the series of FFT frames. In other embodiments, other methods may be used to detect prominent tones.
(25) The set of detected tones can then be mapped to a symbol (e.g. via a hash-table or via the combinadics method described above) in step **207**.
(26) In step **208**, the symbols can be combined to form data. For example, the symbols may be a stream of bits that is segmented into bytes to reflect the original data transmitted.
(27) At one or more of the steps **205** to **208**, error correction may be applied to correct errors created during acoustic transmission from the speaker (e.g. **103**) to the microphone (e.g. **106**). For example, forward error correction (such as Reed-Solomon) may form a part of the data and may be used to correct errors in the data.
(28) Embodiments of the present invention will be further described below:
(29) Symbols, Lexical Mappings and the Combinatorial Number System (Combinadics)
(30) In monophonic M-ary FSK, each symbol can represent M different values, so can store at most log.sub.2M bits of data. Within multi-tone FSK, with a chord size of K and an alphabet size of M, the number of combinatoric selections is M choose K:
(31) $M! / (K!(M - K)!)$
(32) Thus, for an 6-bit (64-level) alphabet and a chord size K of 4, the total number of combinations is calculated as follows:
(33) $64! / (4!60!) = 635,376$
(34) Each symbol should be expressible in binary. The log.sub.2 of this value is taken to deduce the

number of combinations that can be expressed, which is in this case 2.sup.19. The spectral efficiency is thus improved from 6-bit per symbol to 19-bit per symbol.
(35) Combinadics
(36) To translate between K-note chords and symbols within the potential range, a bijective mapping must be created between the two, allowing a lexographic index A to be derived from a combination {X.sub.1, X.sub.2, . . . X.sub.K} and vice-versa.
(37) A naive approach to mapping would work by: generating all possible combinations, and storing a pair of hashtables from A<->{X.sub.1, X.sub.2, . . . X.sub.K}
(38) Example for M=4, K=3
(39)
0 - {0, 1, 2}1 - {0, 1, 3}2 - {0, 1, 4}3 - {0, 2, 3}4 - {0, 2, 4}5 - {0, 3, 4}6 - {1, 2, 3}7 - {1, 2, 4}8 - {1, 3, 4}9 - {2, 3, 4}
(40) As the combinatoric possibilities increase, such as in the above example, the memory requirements become prohibitively large. Thus, an approach is needed that is efficient in memory and CPU.
(41) Mapping from Data to Combinadics to Multi-Lone FSK
(42) To therefore take a stream of bytes and map it to a multi-tone FSK signal, the process is as follows: segment the stream of bytes into B-bit symbols, where 2.sup.B is the maximum number of binary values expressible within the current combinatoric space (e.g. M choose K) translate each symbol into its K-value combinatorial representation synthesize the chord by summing the K tones contained within the combination
(43) In one embodiment, a transmission “frame” or packet may be ordered as follows: 1. Preamble/wakeup symbols (F) 2. Payload symbols (P) 3. Forward error-correction symbols (E) FF PPPPPPPP EEEEEEEE
(44) At decoding, a receiving may: decode each of the constituent tones using an FFT segment the input into notes, each containing a number of FFT frames equal to the entire expected duration of the note use a statistical process to derive what seem to be the K most prominent tones within each note translate the K tones into a numerical symbol using the combinatorial number system process described above concatenate the symbols to the entire length of the payload (and FEC segment) re-segment into bytes and finally, apply the FEC algorithm to correct any mis-heard tones
(45) In another embodiment, the FEC algorithm may be applied before re-segmentation into bytes.
(46) A potential advantage of some embodiments of the present invention is that data throughput for acoustic data communication systems can be significantly increased (bringing throughput closer to the Shannon limit for the channel) in typical acoustic environments by improved spectral efficiency. Greater efficiency results in faster transmission of smaller payloads, and enables transmission of larger payloads which previously may have been prohibitively slow for many applications.
(47) While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of applicant's general inventive concept.

Claims

1. A device, comprising: one or more processors; and a non-transitory computer-readable medium storing instructions that, when executed by the one or more processors, cause the device to: segment data into a sequence of symbols, each of the symbols having a preset number of bits; determine for each symbol of the sequence of symbols three or more tones based on a mapping between symbols and sets of tones selected from tones spread evenly over a frequency spectrum, wherein the mapping includes a mapping between the symbols and a multi-tone Frequency Shift Keying (FSK) signal including three or more tones; and generate an audio signal based on the determined tones for each symbol of the sequence of symbols.
2. The device of claim 1, wherein each of the three or more tones for each symbol in the sequence of symbols is at a different frequency.
3. The device of claim 1, wherein the mapping comprises a bijective mapping.

4. The device of claim 1, further comprising: a speaker, wherein the non-transitory computer-readable medium storing instructions that, when executed by the one or more processors, further cause the device to: transmit, via the speaker, the generated audio signal.
5. The device of claim 4, wherein transmit, via the speaker, the generated audio signal comprises: for each symbol in the sequence of symbols, cause, via the speaker, simultaneous playback of the three or more tones determined for the respective symbol.
6. The device of claim 1, wherein generate an audio signal based on the three or more tones comprises: generate a packet for a first set of symbols of the sequence of symbols, wherein the packet comprises a payload comprising the determined three or more tones.
7. The device of claim 6, wherein the non-transitory computer-readable medium storing instructions that, when executed by the one or more processors, further cause the device to: transmit, to a speaker, the packet for the first set of symbols of the sequence of symbols.
8. A non-transitory, computer-readable medium storing instructions that, when executed by one or more processors, cause a device to: segment data into a sequence of symbols, each of the symbols having a preset number of bits; determine for each symbol of the sequence of symbols three or more tones based on a mapping between symbols and sets of tones selected from tones spread evenly over a frequency spectrum, wherein the mapping includes a mapping between the symbols and a multi-tone Frequency Shift Keying (FSK) signal including three or more tones; and generate an audio signal based on the determined tones for each symbol of the sequence of symbols.
9. The non-transitory, computer-readable medium of claim 8, wherein each of the three or more tones for each symbol in the sequence of symbols is at a different frequency.
10. The non-transitory, computer-readable medium of claim 8, wherein the mapping comprises a bijective mapping.
11. The non-transitory, computer-readable medium of claim 8, further comprising instructions, that when executed by the one or more processors, cause the device to: transmit, via a speaker, the generated audio signal.
12. The non-transitory, computer-readable medium of claim 11, wherein transmit, via the speaker, the generated audio signal comprises: for each symbol in the sequence of symbols, cause, via the speaker, simultaneous playback of the three or more tones determined for the respective symbol.
13. The non-transitory, computer-readable medium of claim 8, wherein generate an audio signal based on the three or more tones comprises: generate a packet for a first set of symbols of the sequence of symbols, wherein the packet comprises a payload comprising the determined three or more tones.
14. The non-transitory, computer-readable medium of claim 13, further comprising instructions that, when executed by the one or more processors, further cause the device to: transmit, to a speaker, the packet for the first set of symbols of the sequence of symbols.
15. A method, comprising: segmenting data into a sequence of symbols, each of the symbols having a preset number of bits; determining for each symbol of the sequence of symbols three or more tones based on a mapping between symbols and sets of tones selected from tones spread evenly over a frequency spectrum, wherein the mapping includes a mapping between the symbols and a multi-tone Frequency Shift Keying (FSK) signal including three or more tones; and generating an audio signal based on the determined tones for each symbol of the sequence of symbols.
16. The method of claim 15, wherein each of the three or more tones for each symbol in the sequence of symbols is at a different frequency.
17. The method of claim 15, wherein the mapping comprises a bijective mapping.
18. The method of claim 15, further comprising: causing, via a speaker, simultaneous playback of the three or more tones determined for the respective symbol for each symbol in the sequence of symbols.
19. The method of claim 15, wherein generating an audio signal based on the three or more tones comprises: generating a packet for a first set of symbols of the sequence of symbols, wherein the packet comprises a payload comprising the determined three or more tones.
20. The method of claim 19, further comprising: transmitting, to a speaker, the packet for the first set of symbols of the sequence of symbols.