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(54) **SYSTEMS AND METHODS FOR REAL OR NEAR REAL TIME WIRELESS COMMUNICATIONS BETWEEN A WIRELESS POWER TRANSMITTER AND A WIRELESS POWER RECEIVER**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

787,412 A 4/1905 Tesla
3,167,775 A 1/1965 Guertler
(Continued)

FOREIGN PATENT DOCUMENTS

CN 203826555 U 9/2014
CN 104090265 A 10/2014
(Continued)

OTHER PUBLICATIONS

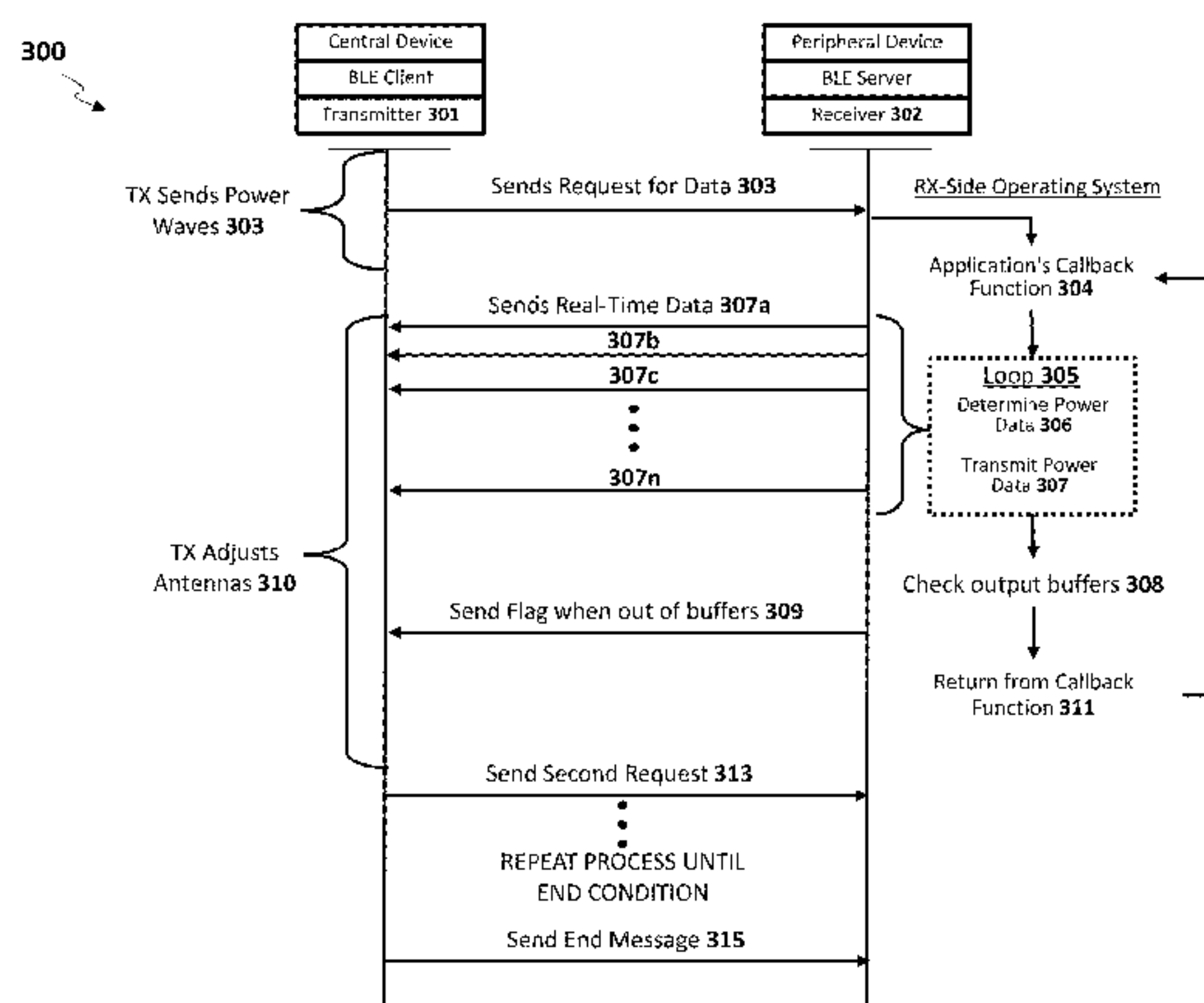
International Search Report dated Sep. 12, 2014 corresponding to International Patent Application No. PCT/US2014/037072, 3 pages.
(Continued)

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(57) **ABSTRACT**

Disclosed herein are systems, methods, and devices using an improved wireless communications component that allows for real time or near-real time data sampling reporting between devices using modified wireless communications protocols (e.g., Bluetooth®, Wi-Fi), and real time or near-real time behavior adjustments by a first device based on the data samples received from a second device. Embodiments disclosed herein comprise devices, such as receivers and transmitters, having communications components that may communicate data samples, such as power values, in real time or near-real time, thereby allowing a first device (e.g., transmitter) to adjust in real time or near-real time operational behavior of the first device's hardware or software (e.g., adjust power waves) based upon the data samples (e.g., power values) received from a second device (e.g., receiver).

19 Claims, 3 Drawing Sheets



Related U.S. Application Data					
(60)	Provisional application No. 62/272,878, filed on Dec. 30, 2015.		7,351,975 B2	4/2008	Brady et al.
			7,359,730 B2	4/2008	Dennis et al.
			7,392,068 B2	6/2008	Dayan
			7,403,803 B2	7/2008	Mickle et al.
			7,443,057 B2	10/2008	Nunally
(51)	Int. Cl. <i>H04W 4/80</i> (2018.01) <i>H02J 50/20</i> (2016.01) <i>H02J 50/80</i> (2016.01)		7,451,839 B2	11/2008	Perlman
			7,463,201 B2	12/2008	Chiang et al.
			7,471,247 B2	12/2008	Saily
			7,535,195 B1	5/2009	Horovitz et al.
			7,614,556 B2	11/2009	Overhultz et al.
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			7,643,312 B2	1/2010	Vanderelli et al.
			7,652,577 B1	1/2010	Madhow et al.
			7,679,576 B2	3/2010	Riedel et al.
			7,702,771 B2	4/2010	Ewing et al.
			7,786,419 B2	8/2010	Hyde et al.
			7,812,771 B2	10/2010	Greene et al.
			7,830,312 B2	11/2010	Choudhury et al.
			7,844,306 B2	11/2010	Shearer et al.
			7,868,482 B2	1/2011	Greene et al.
			7,898,105 B2	3/2011	Greene et al.
			7,904,117 B2	3/2011	Doan et al.
			7,911,386 B1	3/2011	Ito et al.
			7,925,308 B2	4/2011	Greene et al.
			7,948,208 B2	5/2011	Partovi et al.
(56)	References Cited U.S. PATENT DOCUMENTS		8,055,003 B2	11/2011	Mittleman et al.
			8,070,595 B2	12/2011	Alderucci et al.
			8,072,380 B2	12/2011	Crouch
			8,092,301 B2	1/2012	Alderucci et al.
			8,099,140 B2	1/2012	Arai
			8,115,448 B2	2/2012	John
			8,159,090 B2	4/2012	Greene et al.
			8,159,364 B2	4/2012	Zeine
			8,180,286 B2	5/2012	Yamasuge
			8,228,194 B2	7/2012	Mickle
			8,234,509 B2	7/2012	Gioscia et al.
			8,264,101 B2	9/2012	Hyde et al.
			8,264,291 B2	9/2012	Morita
			8,276,325 B2	10/2012	Clifton et al.
			8,278,784 B2	10/2012	Cook et al.
			8,284,101 B2	10/2012	Fusco
			8,310,201 B1	11/2012	Wright
			8,338,991 B2	12/2012	Von Novak et al.
			8,362,745 B2	1/2013	Tinaphong
			8,380,255 B2	2/2013	Shearer et al.
			8,384,600 B2	2/2013	Huang et al.
			7,191,013 B1	3/2013	Miranda et al.
			8,410,953 B2	4/2013	Zeine
			8,411,963 B2	4/2013	Luff
			8,432,062 B2	4/2013	Greene et al.
			8,432,071 B2	4/2013	Huang et al.
			8,446,248 B2	5/2013	Zeine
			8,447,234 B2	5/2013	Cook et al.
			8,451,189 B1	5/2013	Fluhler
			8,452,235 B2	5/2013	Kirby et al.
			8,457,656 B2	6/2013	Perkins et al.
			8,461,817 B2	6/2013	Martin et al.
			8,467,733 B2	6/2013	Leabman
			8,497,601 B2	7/2013	Hall et al.
			8,497,658 B2	7/2013	Von Novak et al.
			8,552,597 B2	8/2013	Song et al.
			8,558,661 B2	10/2013	Zeine
			8,560,026 B2	10/2013	Chanterac
			8,604,746 B2	12/2013	Lee
			8,614,643 B2	12/2013	Leabman
			8,621,245 B2	12/2013	Shearer et al.
			8,626,249 B2	1/2014	Kuusilinnä et al.
			8,629,576 B2	1/2014	Levine
			8,653,966 B2	2/2014	Rao et al.
			8,674,551 B2	3/2014	Low et al.
			8,686,685 B2	4/2014	Moshfeghi
			8,712,355 B2	4/2014	Black et al.
			8,712,485 B2	4/2014	Tam
			8,718,773 B2	5/2014	Wills et al.
			8,729,737 B2	5/2014	Schatz et al.
			8,736,228 B1	5/2014	Freed et al.
			8,760,113 B2	6/2014	Keating
			8,770,482 B2	7/2014	Ackermann et al.
			8,772,960 B2	7/2014	Yoshida

(56)

References Cited

U.S. PATENT DOCUMENTS

8,823,319 B2	9/2014	Von Novak, III et al.	9,866,279 B2	1/2018	Bell et al.
8,832,646 B1	9/2014	Wendling	9,876,394 B1	1/2018	Leabman
8,854,176 B2	10/2014	Zeine	2001/0027876 A1	10/2001	Tsukamoto et al.
8,860,364 B2	10/2014	Low et al.	2002/0001307 A1	1/2002	Nguyen et al.
8,897,770 B1	11/2014	Frolov et al.	2002/0024471 A1	2/2002	Ishitobi
8,903,456 B2	12/2014	Chu et al.	2002/0028655 A1	3/2002	Rosener et al.
8,917,057 B2	12/2014	Hui	2002/0034958 A1	3/2002	Oberschmidt et al.
8,923,189 B2	12/2014	Leabman	2002/0054330 A1	5/2002	Jinbo et al.
8,928,544 B2	1/2015	Massie et al.	2002/0065052 A1	5/2002	Pande et al.
8,937,408 B2	1/2015	Ganem et al.	2002/0072784 A1	6/2002	Sheppard et al.
8,946,940 B2	2/2015	Kim et al.	2002/0095980 A1	7/2002	Breed et al.
8,963,486 B2	2/2015	Kirby et al.	2002/0103447 A1	8/2002	Terry
8,970,070 B2	3/2015	Sada et al.	2002/0133592 A1	9/2002	Matsuda
8,989,053 B1	3/2015	Skaaksrud et al.	2002/0172223 A1	11/2002	Stilp
9,000,616 B2	4/2015	Greene et al.	2003/0005759 A1	1/2003	Breed et al.
9,001,622 B2	4/2015	Perry	2003/0058187 A1	3/2003	Billiet et al.
9,006,934 B2	4/2015	Kozakai et al.	2003/0076274 A1	4/2003	Phelan et al.
9,021,277 B2	4/2015	Shearer et al.	2003/0179152 A1	9/2003	Watada et al.
9,030,161 B2	5/2015	Lu et al.	2003/0179573 A1	9/2003	Chun
9,059,598 B2	6/2015	Kang et al.	2003/0192053 A1	10/2003	Sheppard et al.
9,059,599 B2	6/2015	Won et al.	2004/0019624 A1	1/2004	Sukegawa
9,077,188 B2	7/2015	Moshfeghi	2004/0020100 A1	2/2004	O'Brian et al.
9,083,595 B2	7/2015	Rakib et al.	2004/0036657 A1	2/2004	Forster et al.
9,088,216 B2	7/2015	Garrity et al.	2004/0066251 A1	4/2004	Eleftheriades et al.
9,124,125 B2	9/2015	Leabman et al.	2004/0107641 A1	6/2004	Walton et al.
9,130,397 B2	9/2015	Leabman et al.	2004/0113543 A1	6/2004	Daniels
9,130,602 B2	9/2015	Cook	2004/0119675 A1	6/2004	Washio et al.
9,142,998 B2	9/2015	Yu et al.	2004/0130425 A1	7/2004	Dayan et al.
9,143,000 B2	9/2015	Leabman et al.	2004/0130442 A1	7/2004	Breed
9,143,010 B2	9/2015	Urano	2004/0142733 A1	7/2004	Parise
9,178,389 B2	11/2015	Hwang	2004/0145342 A1	7/2004	Lyon
9,225,196 B2	12/2015	Huang et al.	2004/0196190 A1	10/2004	Mendolia et al.
9,240,469 B2	1/2016	Sun et al.	2004/0203979 A1	10/2004	Attar et al.
9,242,411 B2	1/2016	Kritchman et al.	2004/0207559 A1	10/2004	Milosavljevic
9,244,500 B2	1/2016	Cain et al.	2004/0218759 A1	11/2004	Yacobi
9,252,628 B2	2/2016	Leabman et al.	2004/0259604 A1	12/2004	Mickle et al.
9,270,344 B2	2/2016	Rosenberg	2004/0263124 A1	12/2004	Wieck et al.
9,282,582 B1	3/2016	Dunsbergen et al.	2005/0007276 A1	1/2005	Barrick et al.
9,294,840 B1	3/2016	Anderson et al.	2005/0030118 A1	2/2005	Wang
9,297,896 B1	3/2016	Andrews	2005/0046584 A1	3/2005	Breed
9,318,898 B2	4/2016	John	2005/0055316 A1	3/2005	Williams
9,368,020 B1	6/2016	Bell et al.	2005/0077872 A1	4/2005	Single
9,401,977 B1	7/2016	Gaw	2005/0093766 A1	5/2005	Turner
9,409,490 B2	8/2016	Kawashima	2005/0116683 A1	6/2005	Cheng
9,419,335 B2	8/2016	Pintos	2005/0117660 A1	6/2005	Vialle et al.
9,438,045 B1	9/2016	Leabman	2005/0134517 A1	6/2005	Gottl
9,438,046 B1	9/2016	Leabman	2005/0171411 A1	8/2005	KenKnight
9,444,283 B2	9/2016	Son et al.	2005/0198673 A1	9/2005	Kit et al.
9,450,449 B1	9/2016	Leabman et al.	2005/0227619 A1	10/2005	Lee et al.
9,461,502 B2	10/2016	Lee et al.	2005/0232469 A1	10/2005	Schofield
9,520,725 B2	12/2016	Masaoka et al.	2005/0237249 A1	10/2005	Nagel
9,520,748 B2	12/2016	Hyde et al.	2005/0237258 A1	10/2005	Abramov et al.
9,522,270 B2	12/2016	Perryman et al.	2005/0282591 A1	12/2005	Shaff
9,537,354 B2	1/2017	Bell et al.	2006/0013335 A1	1/2006	Leabman
9,537,357 B2	1/2017	Leabman	2006/0019712 A1	1/2006	Choi
9,537,358 B2	1/2017	Leabman	2006/0030279 A1	2/2006	Leabman et al.
9,538,382 B2	1/2017	Bell et al.	2006/0033674 A1	2/2006	Essig, Jr. et al.
9,544,640 B2	1/2017	Lau	2006/0071308 A1	4/2006	Tang et al.
9,559,553 B2	1/2017	Bae	2006/0092079 A1	5/2006	de Rochemont
9,564,773 B2	2/2017	Pogorelik et al.	2006/0094425 A1	5/2006	Mickle et al.
9,571,974 B2	2/2017	Choi et al.	2006/0113955 A1	6/2006	Nunally
9,590,317 B2	3/2017	Zimmerman et al.	2006/0119532 A1	6/2006	Yun et al.
9,590,444 B2	3/2017	Walley	2006/0136004 A1	6/2006	Cowan et al.
9,620,996 B2	4/2017	Zeine	2006/0160517 A1	7/2006	Yoon
9,647,328 B2	5/2017	Dobric	2006/0183473 A1	8/2006	Ukon
9,706,137 B2	7/2017	Scanlon et al.	2006/0190063 A1	8/2006	Kanzius
9,711,999 B2	7/2017	Hietala et al.	2006/0192913 A1	8/2006	Shutou et al.
9,723,635 B2	8/2017	Nambord et al.	2006/0199620 A1	9/2006	Greene et al.
9,793,758 B2	10/2017	Leabman	2006/0238365 A1	10/2006	Vecchione et al.
9,793,764 B2	10/2017	Perry	2006/0266564 A1	11/2006	Perlman et al.
9,800,172 B1	10/2017	Leabman	2006/0266917 A1	11/2006	Baldis et al.
9,806,564 B2	10/2017	Leabman	2006/0278706 A1	12/2006	Hatakayama et al.
9,819,230 B2	11/2017	Petras et al.	2006/0284593 A1	12/2006	Nagy et al.
9,825,674 B1	11/2017	Leabman	2006/0287094 A1	12/2006	Mahaffey et al.
9,853,361 B2	12/2017	Chen et al.	2007/0007821 A1	1/2007	Rossetti
			2007/0019693 A1	1/2007	Graham
			2007/0021140 A1	1/2007	Keyes
			2007/0060185 A1	3/2007	Simon et al.
			2007/0070490 A1	3/2007	Tsunoda et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2007/0090997	A1	4/2007	Brown et al.	2009/0280866	A1	11/2009	Lo et al.
2007/0093269	A1	4/2007	Leabman et al.	2009/0281678	A1	11/2009	Wakamatsu
2007/0097653	A1	5/2007	Gilliland et al.	2009/0284082	A1	11/2009	Mohammadian
2007/0103110	A1	5/2007	Sagoo	2009/0284083	A1	11/2009	Karalis et al.
2007/0106894	A1	5/2007	Zhang	2009/0284220	A1	11/2009	Toncich et al.
2007/0109121	A1	5/2007	Cohen	2009/0284227	A1	11/2009	Mohammadian et al.
2007/0139000	A1	6/2007	Kozuma	2009/0284325	A1	11/2009	Rossiter et al.
2007/0149162	A1	6/2007	Greene et al.	2009/0286475	A1	11/2009	Toncich et al.
2007/0164868	A1	7/2007	Deavours et al.	2009/0291634	A1	11/2009	Saarisalo
2007/0173196	A1	7/2007	Gallic	2009/0299175	A1	12/2009	Bernstein et al.
2007/0173214	A1	7/2007	Mickle et al.	2009/0308936	A1	12/2009	Nitzan et al.
2007/0178857	A1	8/2007	Greene et al.	2009/0312046	A1	12/2009	Clevenger et al.
2007/0178945	A1	8/2007	Cook et al.	2009/0315412	A1	12/2009	Yamamoto et al.
2007/0182367	A1	8/2007	Partovi	2009/0322281	A1	12/2009	Kamijo et al.
2007/0191074	A1	8/2007	Harrist et al.	2010/0001683	A1	1/2010	Huang et al.
2007/0191075	A1	8/2007	Greene et al.	2010/0007307	A1	1/2010	Baarman et al.
2007/0197281	A1	8/2007	Stronach	2010/0007569	A1	1/2010	Sim et al.
2007/0210960	A1	9/2007	Rofougaran et al.	2010/0019686	A1	1/2010	Gutierrez, Jr.
2007/0222681	A1	9/2007	Greene et al.	2010/0019908	A1	1/2010	Cho et al.
2007/0257634	A1	11/2007	Leschin et al.	2010/0026605	A1	2/2010	Yang et al.
2007/0273486	A1	11/2007	Shiotsu	2010/0027379	A1	2/2010	Saulnier et al.
2007/0296639	A1	12/2007	Hook et al.	2010/0029383	A1	2/2010	Dai
2007/0298846	A1	12/2007	Greene et al.	2010/0033021	A1	2/2010	Bennett
2008/0014897	A1	1/2008	Cook et al.	2010/0033390	A1	2/2010	Alamouti et al.
2008/0024376	A1	1/2008	Norris et al.	2010/0034238	A1	2/2010	Bennett
2008/0048917	A1	2/2008	Achour et al.	2010/0041453	A1	2/2010	Grimm, Jr.
2008/0062062	A1	3/2008	Borau et al.	2010/0044123	A1	2/2010	Perlman et al.
2008/0062255	A1	3/2008	Gal	2010/0054200	A1	3/2010	Tsai
2008/0067874	A1	3/2008	Tseng	2010/0060534	A1	3/2010	Oodachi
2008/0074324	A1	3/2008	Puzella et al.	2010/0066631	A1	3/2010	Puzella et al.
2008/0089277	A1	4/2008	Aledander et al.	2010/0075607	A1	3/2010	Hosoya
2008/0110263	A1	5/2008	Klessel et al.	2010/0079005	A1	4/2010	Hyde et al.
2008/0113816	A1	5/2008	Mahaffey et al.	2010/0082193	A1	4/2010	Chiappetta
2008/0122297	A1	5/2008	Arai	2010/0087227	A1	4/2010	Francos et al.
2008/0123383	A1	5/2008	Shionoiri	2010/0090524	A1	4/2010	Obayashi
2008/0129536	A1	6/2008	Randall et al.	2010/0090656	A1	4/2010	Shearer et al.
2008/0140278	A1	6/2008	Breed	2010/0109443	A1	5/2010	Cook et al.
2008/0169910	A1	7/2008	Greene et al.	2010/0117926	A1	5/2010	DeJean, II
2008/0197802	A1	8/2008	Onishi	2010/0119234	A1	5/2010	Suematsu et al.
2008/0204342	A1	8/2008	Kharadly	2010/0123618	A1	5/2010	Martin et al.
2008/0204350	A1	8/2008	Tam et al.	2010/0123624	A1	5/2010	Minear et al.
2008/0210762	A1	9/2008	Osada et al.	2010/0127660	A1	5/2010	Cook et al.
2008/0211458	A1	9/2008	Lawther et al.	2010/0142418	A1	6/2010	Nishioka et al.
2008/0233890	A1	9/2008	Baker	2010/0142509	A1	6/2010	Zhu et al.
2008/0248758	A1	10/2008	Schedelbeck et al.	2010/0148723	A1	6/2010	Cook et al.
2008/0248846	A1	10/2008	Stronach et al.	2010/0151808	A1	6/2010	Toncich et al.
2008/0258993	A1	10/2008	Gummalla et al.	2010/0156721	A1	6/2010	Alamouti et al.
2008/0266191	A1	10/2008	Hilgers	2010/0156741	A1	6/2010	Vazquez et al.
2008/0278378	A1	11/2008	Chang et al.	2010/0164296	A1	7/2010	Kurs et al.
2008/0309452	A1	12/2008	Zeine	2010/0164433	A1	7/2010	Janefalker et al.
2009/0002493	A1	1/2009	Kates	2010/0171461	A1	7/2010	Baarman et al.
2009/0019183	A1	1/2009	Wu et al.	2010/0174629	A1	7/2010	Taylor et al.
2009/0036065	A1	2/2009	Siu	2010/0176934	A1	7/2010	Chou et al.
2009/0047998	A1	2/2009	Alberth, Jr.	2010/0181961	A1	7/2010	Novak et al.
2009/0058354	A1	3/2009	Harrison	2010/0181964	A1	7/2010	Huggins et al.
2009/0058361	A1	3/2009	John	2010/0194206	A1	8/2010	Burdo et al.
2009/0058731	A1	3/2009	Geary et al.	2010/0201189	A1	8/2010	Kirby et al.
2009/0067208	A1	3/2009	Martin et al.	2010/0201201	A1	8/2010	Mobarhan et al.
2009/0096412	A1	4/2009	Huang	2010/0201314	A1	8/2010	Toncich et al.
2009/0096413	A1	4/2009	Partovi	2010/0207572	A1	8/2010	Kirby et al.
2009/0102292	A1	4/2009	Cook et al.	2010/0210233	A1	8/2010	Cook et al.
2009/0102296	A1	4/2009	Greene et al.	2010/0213895	A1	8/2010	Keating et al.
2009/0108679	A1	4/2009	Porwal	2010/0214177	A1	8/2010	Parsche
2009/0122847	A1	5/2009	Nysen et al.	2010/0222010	A1	9/2010	Ozaki et al.
2009/0128262	A1	5/2009	Lee et al.	2010/0227570	A1	9/2010	Hendin
2009/0157911	A1	6/2009	Aihara	2010/0231470	A1	9/2010	Lee et al.
2009/0200985	A1	8/2009	Zane et al.	2010/0237709	A1	9/2010	Hall et al.
2009/0206791	A1	8/2009	Jung	2010/0244576	A1	9/2010	Hillan et al.
2009/0207090	A1	8/2009	Pettus et al.	2010/0256831	A1	10/2010	Abramo et al.
2009/0207092	A1	8/2009	Nysen et al.	2010/0259110	A1	10/2010	Kurs et al.
2009/0218884	A1	9/2009	Soar	2010/0259447	A1	10/2010	Crouch
2009/0218891	A1	9/2009	McCollough	2010/0264747	A1	10/2010	Hall et al.
2009/0219903	A1	9/2009	Alamouti et al.	2010/0277003	A1	11/2010	Von Novak et al.
2009/0243397	A1	10/2009	Cook et al.	2010/0277121	A1	11/2010	Hall et al.
2009/0264069	A1	10/2009	Yamasuge	2010/0279606	A1	11/2010	Hillan et al.
				2010/0289341	A1	11/2010	Ozaki et al.
				2010/0295372	A1	11/2010	Hyde et al.
				2010/0308767	A1	12/2010	Rofougaran et al.
				2010/0309079	A1	12/2010	Rofougaran et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2010/0309088 A1	12/2010	Hyvonen et al.		2011/0302078 A1	12/2011	Failing	
2010/0315045 A1 *	12/2010	Zeine	H02J 7/025 320/137	2011/0304216 A1	12/2011	Baarman	
				2011/0304437 A1	12/2011	Beeler	
2010/0316163 A1	12/2010	Forenza et al.		2011/0304521 A1	12/2011	Ando et al.	
2010/0327766 A1	12/2010	Recker et al.		2012/0013196 A1	1/2012	Kim et al.	
2011/0013198 A1	1/2011	Shirley		2012/0013198 A1	1/2012	Uramoto et al.	
2011/0018360 A1	1/2011	Baarman et al.		2012/0013296 A1	1/2012	Heydari et al.	
2011/0028114 A1	2/2011	Kerselaers		2012/0019419 A1	1/2012	Prat et al.	
2011/0031928 A1	2/2011	Soar		2012/0043887 A1	2/2012	Mesibov	
2011/0032149 A1	2/2011	Leabman		2012/0051109 A1	3/2012	Kim et al.	
2011/0032866 A1	2/2011	Leabman		2012/0051294 A1	3/2012	Guillouard	
2011/0034190 A1	2/2011	Leabman		2012/0056486 A1	3/2012	Endo et al.	
2011/0034191 A1	2/2011	Leabman		2012/0056741 A1	3/2012	Zhu et al.	
2011/0043047 A1	2/2011	Karalis et al.		2012/0068906 A1	3/2012	Asher et al.	
2011/0043163 A1	2/2011	Baarman et al.		2012/0074891 A1	3/2012	Anderson et al.	
2011/0043327 A1	2/2011	Baarman et al.		2012/0080957 A1	4/2012	Cooper et al.	
2011/0050166 A1	3/2011	Cook et al.		2012/0086284 A1	4/2012	Capanella et al.	
2011/0055037 A1	3/2011	Hayashigawa et al.		2012/0095617 A1	4/2012	Martin et al.	
2011/0056215 A1	3/2011	Ham		2012/0098350 A1	4/2012	Campanella et al.	
2011/0057607 A1	3/2011	Carobolante		2012/0098485 A1	4/2012	Kang et al.	
2011/0062788 A1	3/2011	Chen et al.		2012/0099675 A1	4/2012	Kitamura et al.	
2011/0074342 A1	3/2011	MacLaughlin		2012/0103562 A1	5/2012	Clayton	
2011/0074349 A1	3/2011	Ghovanloo		2012/0104849 A1	5/2012	Jackson	
2011/0074620 A1	3/2011	Wintermantel		2012/0105252 A1	5/2012	Wang	
2011/0078092 A1	3/2011	Kim et al.		2012/0112532 A1	5/2012	Kesler et al.	
2011/0090126 A1	4/2011	Szini et al.		2012/0119914 A1	5/2012	Uchida	
2011/0109167 A1	5/2011	Park et al.		2012/0126743 A1	5/2012	Rivers, Jr.	
2011/0114401 A1	5/2011	Kanno et al.		2012/0132647 A1	5/2012	Beverly et al.	
2011/0115303 A1	5/2011	Baarman et al.		2012/0133214 A1	5/2012	Yun et al.	
2011/0115432 A1	5/2011	El-Maleh		2012/0146426 A1	6/2012	Sabo	
2011/0115605 A1	5/2011	Dimig et al.		2012/0146576 A1	6/2012	Partovi	
2011/0121660 A1	5/2011	Azancot et al.		2012/0146577 A1	6/2012	Tanabe	
2011/0122018 A1	5/2011	Tarng et al.		2012/0147802 A1	6/2012	Ukita et al.	
2011/0122026 A1	5/2011	DeLaquil et al.		2012/0149307 A1	6/2012	Terada et al.	
2011/0127845 A1	6/2011	Walley et al.		2012/0150670 A1	6/2012	Taylor et al.	
2011/0127952 A1	6/2011	Walley et al.		2012/0153894 A1	6/2012	Widmer et al.	
2011/0133655 A1	6/2011	Recker et al.		2012/0157019 A1	6/2012	Li	
2011/0133691 A1	6/2011	Hautanen		2012/0161531 A1	6/2012	Kim et al.	
2011/0148578 A1	6/2011	Aloi et al.		2012/0161544 A1	6/2012	Kashiwagi et al.	
2011/0151789 A1	6/2011	Viglione et al.		2012/0169276 A1	7/2012	Wang	
2011/0154429 A1	6/2011	Stantchev		2012/0169278 A1	7/2012	Choi	
2011/0156494 A1	6/2011	Mashinsky		2012/0173418 A1	7/2012	Beardsmore et al.	
2011/0156640 A1	6/2011	Moshfeghi		2012/0179004 A1	7/2012	Roesicke et al.	
2011/0163128 A1	7/2011	Taguchi et al.		2012/0181973 A1	7/2012	Lyden	
2011/0175455 A1	7/2011	Hashiguchi		2012/0182427 A1	7/2012	Marshall	
2011/0175461 A1	7/2011	Tinaphong		2012/0187851 A1	8/2012	Huggins et al.	
2011/0181120 A1	7/2011	Liu et al.		2012/0193999 A1	8/2012	Zeine	
2011/0182245 A1	7/2011	Malkamaki et al.		2012/0200399 A1	8/2012	Chae	
2011/0184842 A1	7/2011	Melen		2012/0201153 A1	8/2012	Bharadia et al.	
2011/0188207 A1	8/2011	Won et al.		2012/0201173 A1	8/2012	Jian et al.	
2011/0194543 A1	8/2011	Zhao et al.		2012/0206299 A1	8/2012	Valdes-Garcia	
2011/0195722 A1	8/2011	Walter et al.		2012/0211214 A1	8/2012	Phan	
2011/0199046 A1	8/2011	Tsai et al.		2012/0212072 A1	8/2012	Miyabayashi et al.	
2011/0215086 A1	9/2011	Yeh		2012/0214462 A1	8/2012	Chu et al.	
2011/0217923 A1	9/2011	Ma		2012/0214536 A1	8/2012	Kim et al.	
2011/0220634 A1	9/2011	Yeh		2012/0228392 A1	9/2012	Cameron et al.	
2011/0221389 A1	9/2011	Won et al.		2012/0228956 A1	9/2012	Kamata	
2011/0222272 A1	9/2011	Yeh		2012/0231856 A1	9/2012	Lee et al.	
2011/0243040 A1	10/2011	Khan et al.		2012/0235636 A1	9/2012	Partovi	
2011/0243050 A1	10/2011	Yanover		2012/0242283 A1	9/2012	Kim et al.	
2011/0244913 A1	10/2011	Kim et al.		2012/0248886 A1	10/2012	Kesler et al.	
2011/0248573 A1	10/2011	Kanno et al.		2012/0248888 A1	10/2012	Kesler et al.	
2011/0248575 A1	10/2011	Kim et al.		2012/0248891 A1	10/2012	Drennen	
2011/0249678 A1	10/2011	Bonicatto		2012/0249051 A1	10/2012	Son et al.	
2011/0254377 A1	10/2011	Widmer et al.		2012/0262002 A1	10/2012	Widmer et al.	
2011/0254503 A1	10/2011	Widmer et al.		2012/0265272 A1	10/2012	Judkins	
2011/0259953 A1	10/2011	Baarman et al.		2012/0267900 A1	10/2012	Huffman et al.	
2011/0273977 A1	11/2011	Shapira et al.		2012/0268238 A1	10/2012	Park et al.	
2011/0278941 A1	11/2011	Krishna et al.		2012/0274154 A1	11/2012	DeLuca	
2011/0279226 A1	11/2011	Chen et al.		2012/0280650 A1	11/2012	Kim et al.	
2011/0281535 A1	11/2011	Low et al.		2012/0286582 A1 *	11/2012	Kim	H02J 5/005 307/104
2011/0282415 A1	11/2011	Eckhoff et al.					
2011/0285213 A1	11/2011	Kowalewski		2012/0292993 A1	11/2012	Mettler et al.	
2011/0286374 A1	11/2011	Shin et al.		2012/0293021 A1	11/2012	Teggatz et al.	
2011/0291489 A1	12/2011	Tsai et al.		2012/0293119 A1	11/2012	Park et al.	
				2012/0299389 A1	11/2012	Lee et al.	
				2012/0299540 A1 *	11/2012	Perry	H04B 11/00 320/108
				2012/0299541 A1	11/2012	Perry	

(56)

References Cited

U.S. PATENT DOCUMENTS

2012/0299542 A1	11/2012	Perry	2013/0207604 A1	8/2013	Zeine
2012/0300588 A1	11/2012	Perry	2013/0207879 A1	8/2013	Rada et al.
2012/0300592 A1	11/2012	Perry	2013/0210357 A1	8/2013	Qin et al.
2012/0300593 A1	11/2012	Perry	2013/0221757 A1	8/2013	Cho et al.
2012/0306705 A1	12/2012	Sakurai et al.	2013/0222201 A1	8/2013	Ma et al.
2012/0306707 A1	12/2012	Yang et al.	2013/0234530 A1	9/2013	Miyauchi
2012/0306720 A1	12/2012	Tanmi et al.	2013/0234536 A1	9/2013	Chemishkian et al.
2012/0309295 A1	12/2012	Maguire	2013/0234658 A1	9/2013	Endo et al.
2012/0309308 A1	12/2012	Kim et al.	2013/0241306 A1	9/2013	Aber et al.
2012/0309332 A1	12/2012	Liao	2013/0241468 A1	9/2013	Moshfeghi
2012/0313449 A1	12/2012	Kurs	2013/0241474 A1	9/2013	Moshfeghi
2012/0313835 A1	12/2012	Gebretnsae	2013/0249478 A1	9/2013	Hirano
2012/0326660 A1	12/2012	Lu et al.	2013/0249479 A1	9/2013	Partovi
2013/0002550 A1	1/2013	Zalewski	2013/0250102 A1	9/2013	Scanlon et al.
2013/0018439 A1	1/2013	Chow et al.	2013/0254578 A1	9/2013	Huang et al.
2013/0024059 A1	1/2013	Miller et al.	2013/0268782 A1	10/2013	Tam et al.
2013/0026981 A1	1/2013	Van Der Lee	2013/0270923 A1	10/2013	Cook et al.
2013/0026982 A1	1/2013	Rothenbaum	2013/0278209 A1	10/2013	Von Novak
2013/0032589 A1	2/2013	Chung	2013/0285477 A1	10/2013	Lo et al.
2013/0033571 A1	2/2013	Steen	2013/0285606 A1	10/2013	Ben-Shalom et al.
2013/0038124 A1	2/2013	Newdoll et al.	2013/0288600 A1	10/2013	Kuusilinnä et al.
2013/0038402 A1	2/2013	Karalis et al.	2013/0288617 A1	10/2013	Kim et al.
2013/0043738 A1	2/2013	Park et al.	2013/0293423 A1	11/2013	Moshfeghi
2013/0044035 A1	2/2013	Zhuang	2013/0307751 A1	11/2013	Yu-Juin et al.
2013/0049471 A1	2/2013	Oleynik	2013/0310020 A1	11/2013	Kazuhiro
2013/0049475 A1	2/2013	Kim et al.	2013/0311798 A1	11/2013	Sultenfuss
2013/0049484 A1	2/2013	Weissentern et al.	2013/0328417 A1	12/2013	Takeuchi
2013/0057078 A1	3/2013	Lee	2013/0334883 A1	12/2013	Kim et al.
2013/0057205 A1	3/2013	Lee et al.	2013/0339108 A1	12/2013	Ryder et al.
2013/0057210 A1	3/2013	Negaard et al.	2013/0343208 A1	12/2013	Sexton et al.
2013/0057364 A1	3/2013	Kesler et al.	2013/0343251 A1	12/2013	Zhang
2013/0058379 A1	3/2013	Kim et al.	2014/0001846 A1	1/2014	Mosebrook
2013/0063082 A1	3/2013	Lee et al.	2014/0001875 A1	1/2014	Nahidipour
2013/0063143 A1	3/2013	Adalsteinsson et al.	2014/0001876 A1	1/2014	Fujiwara et al.
2013/0069444 A1	3/2013	Waffenschmidt et al.	2014/0006017 A1	1/2014	Sen
2013/0077650 A1	3/2013	Traxler et al.	2014/0008992 A1	1/2014	Leabman
2013/0078918 A1	3/2013	Crowley et al.	2014/0008993 A1	1/2014	Leabman
2013/0082651 A1	4/2013	Park et al.	2014/0009108 A1	1/2014	Leabman
2013/0082653 A1	4/2013	Lee et al.	2014/0009110 A1	1/2014	Lee
2013/0083774 A1	4/2013	Son et al.	2014/0011531 A1	1/2014	Burstrom et al.
2013/0088082 A1	4/2013	Kang et al.	2014/0015336 A1	1/2014	Weber et al.
2013/0088090 A1	4/2013	Wu	2014/0015344 A1	1/2014	Mohamadi
2013/0088192 A1	4/2013	Eaton	2014/0021907 A1	1/2014	Yun et al.
2013/0088331 A1	4/2013	Cho	2014/0021908 A1	1/2014	McCool
2013/0093388 A1	4/2013	Partovi	2014/0035524 A1	2/2014	Zeine
2013/0099389 A1	4/2013	Hong et al.	2014/0035526 A1	2/2014	Tripathi et al.
2013/0099586 A1	4/2013	Kato	2014/0035786 A1	2/2014	Ley
2013/0107023 A1	5/2013	Tanaka et al.	2014/0043248 A1	2/2014	Yeh
2013/0119777 A1	5/2013	Rees	2014/0049422 A1	2/2014	Von Novak et al.
2013/0119929 A1	5/2013	Partovi	2014/0054971 A1	2/2014	Kissin
2013/0120217 A1	5/2013	Ueda et al.	2014/0055098 A1	2/2014	Lee et al.
2013/0132010 A1	5/2013	Winger et al.	2014/0057618 A1	2/2014	Zirwas et al.
2013/0134923 A1	5/2013	Smith	2014/0062395 A1	3/2014	Kwon et al.
2013/0137455 A1	5/2013	Xia	2014/0082435 A1	3/2014	Kitgawa
2013/0141037 A1	6/2013	Jenwatanavet et al.	2014/0086125 A1	3/2014	Polo et al.
2013/0148341 A1	6/2013	Williams	2014/0086592 A1	3/2014	Nakahara et al.
2013/0149975 A1	6/2013	Yu et al.	2014/0091756 A1	4/2014	Ofstein et al.
2013/0154387 A1	6/2013	Lee et al.	2014/0091968 A1	4/2014	Harel et al.
2013/0155748 A1	6/2013	Sundstrom	2014/0103869 A1	4/2014	Radovic
2013/0157729 A1	6/2013	Tabe	2014/0111147 A1	4/2014	Soar
2013/0162335 A1	6/2013	Kim et al.	2014/0113689 A1	4/2014	Lee
2013/0169061 A1	7/2013	Microshnichenko et al.	2014/0117946 A1	5/2014	Muller et al.
2013/0169219 A1	7/2013	Gray	2014/0118140 A1	5/2014	Amis
2013/0169348 A1	7/2013	Shi	2014/0128107 A1	5/2014	An
2013/0171939 A1	7/2013	Tian et al.	2014/0132210 A1	5/2014	Partovi
2013/0175877 A1	7/2013	Abe et al.	2014/0133279 A1	5/2014	Khuri-Yakub
2013/0178253 A1	7/2013	Karaoguz	2014/0139034 A1	5/2014	Sankar et al.
2013/0181881 A1	7/2013	Christie et al.	2014/0139039 A1	5/2014	Cook et al.
2013/0187475 A1	7/2013	Vendik	2014/0139180 A1	5/2014	Kim et al.
2013/0190031 A1 *	7/2013	Persson H04W 24/08 455/517	2014/0141838 A1	5/2014	Cai et al.
2013/0193769 A1	8/2013	Mehta et al.	2014/0142876 A1	5/2014	John et al.
2013/0197320 A1	8/2013	Albert et al.	2014/0143933 A1	5/2014	Low et al.
2013/0200064 A1	8/2013	Alexander	2014/0145879 A1	5/2014	Pan
2013/0207477 A1	8/2013	Nam et al.	2014/0145884 A1	5/2014	Dang et al.
			2014/0152117 A1	6/2014	Sanker
			2014/0159651 A1	6/2014	Von Novak et al.
			2014/0159652 A1	6/2014	Hall et al.
			2014/0159662 A1	6/2014	Furui
			2014/0159667 A1	6/2014	Kim et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2014/0169385	A1	6/2014	Hadani et al.	2015/0042264	A1	2/2015	Leabman et al.
2014/0175893	A1	6/2014	Sengupta et al.	2015/0042265	A1	2/2015	Leabman et al.
2014/0176054	A1	6/2014	Porat et al.	2015/0044977	A1	2/2015	Ramasamy et al.
2014/0176061	A1	6/2014	Cheatham, III et al.	2015/0046526	A1	2/2015	Bush et al.
2014/0177399	A1	6/2014	Teng et al.	2015/0061404	A1	3/2015	Lamenza et al.
2014/0184148	A1	7/2014	Van Der Lee et al.	2015/0076917	A1	3/2015	Leabman et al.
2014/0184155	A1	7/2014	Cha	2015/0076927	A1	3/2015	Leabman et al.
2014/0184163	A1	7/2014	Das et al.	2015/0077036	A1	3/2015	Leabman et al.
2014/0184170	A1	7/2014	Jeong	2015/0077037	A1	3/2015	Leabman et al.
2014/0191568	A1	7/2014	Partovi	2015/0091520	A1	4/2015	Blum et al.
2014/0194092	A1	7/2014	Wanstedt et al.	2015/0091706	A1	4/2015	Chemishkian et al.
2014/0194095	A1	7/2014	Wanstedt et al.	2015/0097663	A1	4/2015	Sloo et al.
2014/0206384	A1	7/2014	Kim et al.	2015/0102681	A1	4/2015	Leabman et al.
2014/0210281	A1	7/2014	Ito et al.	2015/0102764	A1	4/2015	Leabman et al.
2014/0217955	A1	8/2014	Lin	2015/0102769	A1	4/2015	Leabman et al.
2014/0217967	A1	8/2014	Zeine et al.	2015/0102973	A1	4/2015	Hand et al.
2014/0225805	A1	8/2014	Pan et al.	2015/0108848	A1	4/2015	Joehren
2014/0232320	A1	8/2014	Ento July et al.	2015/0109181	A1	4/2015	Hyde et al.
2014/0232610	A1	8/2014	Shigemoto et al.	2015/0115877	A1	4/2015	Aria et al.
2014/0239733	A1	8/2014	Mach et al.	2015/0115878	A1	4/2015	Park
2014/0241231	A1	8/2014	Zeine	2015/0123483	A1	5/2015	Leabman et al.
2014/0245036	A1	8/2014	Oishi	2015/0123496	A1	5/2015	Leabman et al.
2014/0246416	A1	9/2014	White	2015/0128733	A1	5/2015	Taylor et al.
2014/0247152	A1	9/2014	Proud	2015/0130285	A1	5/2015	Leabman et al.
2014/0252813	A1	9/2014	Lee et al.	2015/0130293	A1	5/2015	Hajimiri et al.
2014/0252866	A1	9/2014	Walsh et al.	2015/0148664	A1	5/2015	Stolka et al.
2014/0265725	A1	9/2014	Angle et al.	2015/0155737	A1	6/2015	Mayo
2014/0265727	A1	9/2014	Berte	2015/0155738	A1	6/2015	Leabman et al.
2014/0265943	A1	9/2014	Angle et al.	2015/0162751	A1	6/2015	Leabman et al.
2014/0266025	A1	9/2014	Jakubowski	2015/0162779	A1	6/2015	Lee et al.
2014/0266946	A1	9/2014	Bily et al.	2015/0171513	A1	6/2015	Chen et al.
2014/0273892	A1	9/2014	Nourbakhsh	2015/0171656	A1	6/2015	Leabman et al.
2014/0281655	A1	9/2014	Angle et al.	2015/0171658	A1	6/2015	Manova-Elssibony et al.
2014/0292090	A1	10/2014	Cordeiro et al.	2015/0171931	A1	6/2015	Won et al.
2014/0300452	A1	10/2014	Rofe et al.	2015/0177326	A1	6/2015	Chakraborty et al.
2014/0312706	A1	10/2014	Fiorello et al.	2015/0180133	A1	6/2015	Hunt
2014/0327320	A1	11/2014	Muhs et al.	2015/0181117	A1	6/2015	Park et al.
2014/0327390	A1	11/2014	Park et al.	2015/0187491	A1	7/2015	Yanagawa
2014/0333142	A1	11/2014	Desrosiers	2015/0188352	A1	7/2015	Peek et al.
2014/0346860	A1	11/2014	Aubry et al.	2015/0199665	A1	7/2015	Chu
2014/0354063	A1	12/2014	Leabman et al.	2015/0207333	A1	7/2015	Baarman et al.
2014/0354221	A1	12/2014	Leabman et al.	2015/0207542	A1	7/2015	Zeine
2014/0355718	A1	12/2014	Guan et al.	2015/0222126	A1	8/2015	Leabman et al.
2014/0357309	A1	12/2014	Leabman et al.	2015/0233987	A1	8/2015	Von Novak, III et al.
2014/0368048	A1	12/2014	Leabman	2015/0234144	A1	8/2015	Cameron et al.
2014/0368161	A1	12/2014	Leabman et al.	2015/0236520	A1	8/2015	Baarman
2014/0368405	A1	12/2014	Ek et al.	2015/0244070	A1	8/2015	Cheng et al.
2014/0375139	A1	12/2014	Tsukamoto	2015/0244080	A1	8/2015	Gregoire
2014/0375253	A1	12/2014	Leabman et al.	2015/0244187	A1	8/2015	Horie
2014/0375255	A1	12/2014	Leabman et al.	2015/0244201	A1	8/2015	Chu
2014/0375258	A1	12/2014	Arkhipenkov	2015/0244341	A1	8/2015	Ritter et al.
2014/0375261	A1	12/2014	Manova-Elssibony et al.	2015/0249484	A1	9/2015	Mach et al.
2014/0376646	A1	12/2014	Leabman et al.	2015/0255989	A1	9/2015	Walley et al.
2015/0001949	A1	1/2015	Leabman et al.	2015/0256097	A1	9/2015	Gudan et al.
2015/0002086	A1	1/2015	Matos et al.	2015/0263534	A1	9/2015	Lee et al.
2015/0003207	A1	1/2015	Lee et al.	2015/0263548	A1	9/2015	Cooper
2015/0008980	A1	1/2015	Kim et al.	2015/0270741	A1	9/2015	Leabman et al.
2015/0011160	A1	1/2015	Uurgovan et al.	2015/0280484	A1	10/2015	Radziemski et al.
2015/0015182	A1	1/2015	Brandtman et al.	2015/0288438	A1	10/2015	Maltsev et al.
2015/0015192	A1	1/2015	Leabman	2015/0311585	A1	10/2015	Church et al.
2015/0015194	A1	1/2015	Leabman et al.	2015/0312721	A1	10/2015	Singh
2015/0015195	A1	1/2015	Leabman et al.	2015/0318729	A1	11/2015	Leabman
2015/0021990	A1	1/2015	Myer et al.	2015/0326024	A1	11/2015	Bell et al.
2015/0022008	A1	1/2015	Leabman et al.	2015/0326025	A1	11/2015	Bell et al.
2015/0022009	A1	1/2015	Leabman et al.	2015/0326063	A1	11/2015	Leabman et al.
2015/0022010	A1	1/2015	Leabman et al.	2015/0326068	A1	11/2015	Bell et al.
2015/0023204	A1	1/2015	Wil et al.	2015/0326069	A1	11/2015	Petras et al.
2015/0028688	A1	1/2015	Masaoka	2015/0326070	A1	11/2015	Petras et al.
2015/0028694	A1	1/2015	Leabman et al.	2015/0326072	A1	11/2015	Petras et al.
2015/0028697	A1	1/2015	Leabman et al.	2015/0326142	A1	11/2015	Petras et al.
2015/0028875	A1	1/2015	Irie et al.	2015/0326143	A1	11/2015	Petras et al.
2015/0029397	A1	1/2015	Leabman et al.	2015/0327085	A1	11/2015	Hadani
2015/0035378	A1	2/2015	Calhoun et al.	2015/0333528	A1	11/2015	Leabman
2015/0035715	A1	2/2015	Kim et al.	2015/0333529	A1	11/2015	Leabman
2015/0041459	A1	2/2015	Leabman et al.	2015/0333573	A1	11/2015	Leabman
				2015/0333800	A1	11/2015	Perry et al.
				2015/0340759	A1	11/2015	Bridgelall et al.
				2015/0340903	A1	11/2015	Bell et al.
				2015/0340909	A1	11/2015	Bell et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2015/0340910 A1 11/2015 Petras et al.
 2015/0340911 A1 11/2015 Bell et al.
 2015/0341087 A1 11/2015 Moore et al.
 2015/0349574 A1 12/2015 Leabman
 2015/0358222 A1 12/2015 Berger et al.
 2015/0365137 A1 12/2015 Miller et al.
 2015/0365138 A1 12/2015 Miller et al.
 2016/0005068 A1 1/2016 Im et al.
 2016/0012695 A1 1/2016 Bell et al.
 2016/0013656 A1 1/2016 Bell et al.
 2016/0013677 A1 1/2016 Bell et al.
 2016/0013678 A1 1/2016 Bell et al.
 2016/0013855 A1 1/2016 Campos
 2016/0020636 A1 1/2016 Khlat
 2016/0020647 A1 1/2016 Leabman et al.
 2016/0020649 A1 1/2016 Bell et al.
 2016/0020830 A1 1/2016 Bell et al.
 2016/0042206 A1 2/2016 Pesavento et al.
 2016/0054395 A1 2/2016 Bell et al.
 2016/0054396 A1 2/2016 Bell et al.
 2016/0054440 A1 2/2016 Younis
 2016/0056635 A1 2/2016 Bell
 2016/0056640 A1 2/2016 Mao
 2016/0056669 A1 2/2016 Bell
 2016/0056966 A1 2/2016 Bell
 2016/0065005 A1 3/2016 Won et al.
 2016/0079799 A1 3/2016 Khlat
 2016/0087483 A1 3/2016 Hietala et al.
 2016/0087486 A1 3/2016 Pogorelik et al.
 2016/0094091 A1 3/2016 Shin et al.
 2016/0094092 A1 3/2016 Davlantes et al.
 2016/0099601 A1 4/2016 Leabman et al.
 2016/0099602 A1 4/2016 Leabman et al.
 2016/0099609 A1 4/2016 Leabman et al.
 2016/0099610 A1 4/2016 Leabman et al.
 2016/0099611 A1 4/2016 Leabman et al.
 2016/0099612 A1 4/2016 Leabman et al.
 2016/0099613 A1 4/2016 Leabman et al.
 2016/0099614 A1 4/2016 Leabman et al.
 2016/0099755 A1 4/2016 Leabman et al.
 2016/0099756 A1 4/2016 Leabman et al.
 2016/0099757 A1 4/2016 Leabman et al.
 2016/0099758 A1 4/2016 Leabman et al.
 2016/0100124 A1 4/2016 Leabman et al.
 2016/0100312 A1 4/2016 Bell et al.
 2016/0126752 A1 5/2016 Vuori et al.
 2016/0126776 A1 5/2016 Kim et al.
 2016/0141908 A1 5/2016 Jakl et al.
 2016/0164563 A1 6/2016 Khawand et al.
 2016/0181849 A1 6/2016 Govindaraj
 2016/0181854 A1 6/2016 Leabman
 2016/0181867 A1 6/2016 Daniel et al.
 2016/0181873 A1 6/2016 Mitcheson et al.
 2016/0191121 A1 6/2016 Bell
 2016/0204622 A1 7/2016 Leabman
 2016/0204642 A1 7/2016 Oh
 2016/0238365 A1 8/2016 Wixey et al.
 2016/0240908 A1 8/2016 Strong
 2016/0294225 A1 10/2016 Blum et al.
 2016/0299210 A1 10/2016 Zeine
 2016/0323000 A1 11/2016 Liu et al.
 2016/0336804 A1 11/2016 Son et al.
 2016/0339258 A1 11/2016 Perryman et al.
 2016/0359367 A1 12/2016 Rothschild
 2016/0380464 A1 12/2016 Chin et al.
 2017/0005481 A1 1/2017 Von Novak, III
 2017/0005516 A9 1/2017 Leabman et al.
 2017/0005524 A1 1/2017 Akuzawa et al.
 2017/0005530 A1 1/2017 Zeine et al.
 2017/0025903 A1 1/2017 Song et al.
 2017/0026087 A1 1/2017 Tanabe
 2017/0043675 A1 2/2017 Jones et al.
 2017/0047784 A1 2/2017 Jung et al.
 2017/0077733 A1 3/2017 Jeong et al.
 2017/0077735 A1 3/2017 Leabman

2017/0077736 A1 3/2017 Leabman
 2017/0077764 A1 3/2017 Bell et al.
 2017/0077765 A1 3/2017 Bell et al.
 2017/0077995 A1 3/2017 Leabman
 2017/0085120 A1 3/2017 Leabman et al.
 2017/0085437 A1 3/2017 Condeixa et al.
 2017/0092115 A1 3/2017 Sloo et al.
 2017/0110887 A1 4/2017 Bell et al.
 2017/0110914 A1 4/2017 Bell
 2017/0134686 A9 5/2017 Leabman
 2017/0163076 A1 6/2017 Park et al.
 2017/0168595 A1 6/2017 Sakaguchi et al.
 2017/0179763 A9 6/2017 Leabman
 2018/0040929 A1 2/2018 Chappelle

FOREIGN PATENT DOCUMENTS

DE 2000216655 U1 2/2002
 EP 1028482 A2 8/2000
 EP 1081506 A1 3/2001
 EP 2397973 A1 6/2010
 EP 2346136 A1 7/2011
 EP 2545635 9/2011
 GB 2404497 A 2/2005
 JP 2006157586 A 6/2006
 JP 2007043432 A 2/2007
 JP 2008167017 A 7/2008
 JP 2015128349 A 7/2015
 KR 20060061776 A 6/2006
 KR 20070044302 A 4/2007
 KR 100755144 B1 9/2007
 KR 20110132059 A 12/2011
 KR 20110135540 A1 12/2011
 KR 20120009843 A 2/2012
 KR 20120108759 A 10/2012
 KR 1020130026977 A 3/2013
 WO 9952173 A2 10/1999
 WO WO 200111716 A1 2/2001
 WO 2004077550 A1 9/2004
 WO 2003091943 A1 11/2006
 WO WO 2006122783 11/2006
 WO 2008156571 A2 12/2008
 WO 2010022181 A1 2/2010
 WO WO 2010039246 A1 4/2010
 WO WO 2010138994 A1 12/2010
 WO 2011112022 A2 9/2011
 WO WO 2012177283 A1 12/2012
 WO 2013035190 A1 3/2013
 WO WO 2013031988 A1 3/2013
 WO WO 2013038074 A2 3/2013
 WO WO 2013042399 A1 3/2013
 WO WO 2013052950 A1 4/2013
 WO WO 2013105920 A2 7/2013
 WO WO 2014075103 A1 5/2014
 WO WO 2014132258 A1 9/2014
 WO WO 2014182788 A2 11/2014
 WO WO 2014182788 A3 11/2014
 WO WO 2014197472 A1 12/2014
 WO WO 2014209587 A1 12/2014
 WO WO 2015038773 A1 3/2015
 WO WO 2015097809 A1 7/2015
 WO WO 2015161323 A1 10/2015
 WO WO 2016024869 A1 2/2016
 WO WO 2016048512 A1 3/2016
 WO WO 2016187357 A1 11/2016

OTHER PUBLICATIONS

International Search Report dated Sep. 15, 2015 corresponding to International Patent Application No. PCT/US2014/037170, 4 pages.
 International Search Report dated Oct. 16, 2014 corresponding to International Patent Application No. PCT/US2014/041546, 4 pages.
 International Search Report dated Oct. 13, 2014 corresponding to International Patent Application No. PCT/US2014/041534, 4 pages.
 International Search Report and Written Opinion of the International Searching Authority dated Nov. 12, 2014 corresponding to International Patent Application No. PCT/US2014/046956, 10 pages.

(56)

References Cited

OTHER PUBLICATIONS

Energous Corp., Written Opinion, PCT/US2014/037170 , dated Sep. 15, 2014, 7 pgs.
 Energous Corp., IPRP, PCT/US2014/037170, Nov. 10, 2015, 8 pgs.
 Energous Corp., Written Opinion, PCT/US2014/041534, dated Oct. 13, 2014, 6 pgs.
 Energous Corp., IPRP, PCT/US2014/041534, Dec. 29, 2015, 7 pgs.
 Energous Corp., IPRP, PCT/US2014/046956, Jan. 19, 2016, 7 pgs.
 Energous Corp., Written Opinion, PCT/US2014/037072, dated Sep. 12, 2014, 5 pgs.
 Energous Corp., IPRP, PCT/US2014/037072, Nov. 10, 2015, 6 pgs.
 Energous Corp., ISRWO, PCT/US2014/068568, Mar. 20, 2015, 10 pgs.
 Energous Corp., IPRP, PCT/US2014/068568, Jun. 14, 2016, 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/055195, Dec. 22, 2014, 11 pgs.
 Energous Corp., IPRP, PCT/US2014/055195, Mar. 22, 2016, 9 pgs.
 Energous Corp., ISRWO, PCT/US2015/067291, Mar. 4, 2016, 10 pgs.
 Energous Corp., IPRP, PCT/US2015/067291, Jul. 4, 2017, 4 pgs.
 Energous Corp., ISRWO, PCT/US2015/067242, Mar. 16, 2016, 9 pgs.
 Energous Corp., IPRP, PCT/US2015/067242, Jun. 27, 2017, 7 pgs.
 Energous Corp., ISRWO, PCT/US2015/067243, Mar. 10, 2016, 11 pgs.
 Energous Corp., IPRP, PCT/US2015/067243, Jun. 27, 2017, 7 pgs.
 Energous Corp., ISRWO, PCT/US2014/037109, Apr. 8, 2016, 12 pgs.
 Energous Corp., IPRP, PCT/US2014/037109, Apr. 12, 2016, 9 pgs.
 Energous Corp., ISRWO, PCT/US2015/067275, Mar. 3, 2016, 8 pgs.
 Energous Corp., IPRP, PCT/US2015/067275, Jul. 4, 2017, 7 pgs.
 Energous Corp., ISRWO, PCT/US2015/067245, Mar. 17, 2016, 8 pgs.
 Energous Corp., IPRP, PCT/US2015/067245, Jun. 27, 2017, 7 pgs.
 Energous Corp., ISRWO, PCT/US2014/041546, Oct. 16, 2014, 12 pgs.
 Energous Corp., IPRP, PCT/US2014/041546, Dec. 29, 2015, 9 pgs.
 Energous Corp., ISRWO, PCT/US2015/67250, Mar. 30, 2016, 11 pgs.
 Energous Corp., IPRP, PCT/US2015/67250, Mar. 30, 2016, 10 pgs.
 Energous Corp., ISRWO, PCT/US2015/067325, Mar. 10, 2016, 9 pgs.
 Energous Corp., IPRP, PCT/US2015/067325, Jul. 4, 2017, 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/040697, Oct. 10, 2014, 12 pgs.
 Energous Corp., IPRP, PCT/US2014/040697, Dec. 8, 2015, 9 pgs.
 Energous Corp., ISRWO, PCT/US2014/040705, Sep. 23, 2014, 8 pgs.
 Energous Corp., IPRP, PCT/US2014/040705, Dec. 8, 2015, 6 pgs.
 Energous Corp., ISRWO, PCT/US2015/067249, Mar. 29, 2016, 8 pgs.
 Energous Corp., IPRP, PCT/US2015/067249, Jun. 27, 2017, 7 pgs.
 Energous Corp., ISRWO, PCT/US2015/067246, May 11, 2016, 18 pgs.
 Energous Corp., IPRP, PCT/US2015/067246, Jun. 27, 2017, 9 pgs.
 Energous Corp., ISRWO, PCT/US2014/059317, Feb. 24, 2015, 13 pgs.
 Energous Corp., IPRP, PCT/US2014/059317, Apr. 12, 2016, 10 pgs.
 Energous Corp., ISRWO, PCT/US2014/049669, Nov. 13, 2014, 10 pgs.
 Energous Corp., IPRP, PCT/US2014/049669, Feb. 9, 2016, 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/041323, Oct. 1, 2014, 10 pgs.
 Energous Corp., IPRP, PCT/US2014/041323, Dec. 22, 2015, 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/048002, Nov. 13, 2014, 11 pgs.
 Energous Corp., IPRP, PCT/US2014/048002, Feb. 12, 2015 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/062682, Feb. 12, 2015, 10 pgs.

Energous Corp., IPRP, PCT/US2014/062682, May 3, 2016, 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/049666, Nov. 10, 2014, 7 pgs.
 Energous Corp., IPRP, PCT/US2014/049666, Feb. 9, 2016, 5 pgs.
 Energous Corp., ISRWO, PCT/US2014/046961, Nov. 24, 2014, 16 pgs.
 Energous Corp., IPRP, PCT/US2014/046961, Jan. 19, 2016, 8 pgs.
 Energous Corp., ISRWO, PCT/US2015/067279, Mar. 11, 2015, 13 pgs.
 Energous Corp., IPRP, PCT/US2015/067279, Jul. 4, 2017, 7 pgs.
 Energous Corp., ISRWO, PCT/US2014/041342, Jan. 27, 2015, 10 pgs.
 Energous Corp., IPRP, PCT/US2014/041342, Dec. 15, 2015, 8 pgs.
 Energous Corp., ISRWO, PCT/US2014/046941, Nov. 6, 2014, 11 pgs.
 Energous Corp., IPRP, PCT/US2014/046941, Jan. 19, 2016, 9 pgs.
 Energous Corp., ISRWO, PCT/US2014/062661, Jan. 27, 2015, 12 pgs.
 Energous Corp., IPRP, PCT/US2014/062661, May 3, 2016, 10 pgs.
 Energous Corp., ISRWO, PCT/US2014/059871, Jan. 23, 2015, 12 pgs.
 Energous Corp., IPRP, PCT/US2014/059871, Apr. 12, 2016, 9 pgs.
 Energous Corp., ISRWO, PCT/US2014/045102, Oct. 28, 2014, 14 pgs.
 Energous Corp., IPRP, PCT/US2014/045102, Jan. 12, 2016, 11 pgs.
 Energous Corp., ISRWO, PCT/US2014/059340, Jan. 15, 2015, 13 pgs.
 Energous Corp., IPRP, PCT/US2014/059340, Apr. 12, 2016, 11 pgs.
 Energous Corp., ISRWO, PCT/US2015/067282, Jul. 5, 2016, 7 pgs.
 Energous Corp., IPRP, PCT/US2015/067282, Jul. 4, 2017, 6 pgs.
 Energous Corp., ISRWO, PCT/US2014/041558, Oct. 10, 2014, 8 pgs.
 Energous Corp., IPRP, PCT/US2014/041558, Dec. 29, 2015, 6 pgs.
 Energous Corp., ISRWO, PCT/US2014/045119, Oct. 13, 2014, 11 pgs.
 Energous Corp., IPRP, PCT/US2014/045119, Jan. 12, 2016, 9 pgs.
 Energous Corp., ISRWO PCT/US2014/045237, Oct. 13, 2014, 16 pgs.
 Energous Corp., IPRP , PCT/US2014/045237, Jan. 12, 2016, 12 pgs.
 Energous Corp., ISRWO , PCT/US2014/054897, Feb. 17, 2015, 10 pgs.
 Energous Corp., IPRP, PCT/US2014/054897, Mar. 15, 2016, 8 pgs.
 Energous Corp., ISRWO , PCT/US2015/067334, Mar. 3, 2016, 6 pgs.
 Energous Corp., IPRP , PCT/US2015/067334, Jul. 4, 2017, 5 pgs.
 Energous Corp., ISRWO , PCT/US2014/047963, Nov. 7, 2014, 13 pgs.
 Energous Corp., IPRP , PCT/US2014/047963, Jan. 26, 2016, 10 pgs.
 Energous Corp., ISRWO , PCT/US2014/054891, Dec. 18, 2014, 12 pgs.
 Energous Corp., IPRP , PCT/US2014/054891, Mar. 15, 2016, 10 pgs.
 Energous Corp., ISRWO , PCT/US2014/054953, Dec. 4, 2014, 7 pgs.
 Energous Corp., IPRP, PCT/US2014/054953, Mar. 22, 2016, 5 pgs.
 Energous Corp., ISRWO , PCT/US2015/067294, Mar. 29 2016, 7 pgs.
 Energous Corp., IPRP , PCT/US2015/067294, Jul. 4, 2017, 6 pgs.
 Energous Corp., ISRWO , PCT/US2014/062672 Jan. 26, 2015, 11 pgs.
 Energous Corp., IPRP, PCT/US2014/062672 May 10, 2016, 8 pgs.
 Energous Corp., ISRWO , PCT/US2014/044810 Oct. 21, 2014, 12 pgs.
 Energous Corp., IPRP, PCT/US2014/044810, Jan. 5, 2016, 10 pgs.
 Energous Corp., ISRWO , PCT/US2015/067271, Mar. 11, 2016, 6 pgs.
 Energous Corp., IPRP , PCT/US2015/067271, Jul. 4, 2017, 5 pgs.
 Energous Corp., ISRWO , PCT/US2014/040648, Oct. 10, 2014, 11 pgs.
 Energous Corp., IPRP , PCT/US2014/040648, Dec. 8, 2015, 8 pgs.

(56)

References Cited

OTHER PUBLICATIONS

Energous Corp., ISRWO, PCT/US2014/049673, Nov. 18, 2014, 10 pgs.

Energous Corp., IPRP, PCT/US2014/049673, Feb. 9, 2016, 6 pgs.

Energous Corp., ISRWO, PCT/US2014/068282, Mar. 19, 2015, 13 pgs.

Energous Corp., IPRP, PCT/US2014/068282, Jun. 7, 2016, 10 pgs.

Energous Corp., ISRWO, PCT/US2014/068586, Mar. 20, 2015, 11 pgs.

Energous Corp., IPRP, PCT/US2014/068586, Jun. 14, 2016, 8 pgs.

Energous Corp., ISRWO, PCT/US2016/068504, Mar. 30, 2017, 8 pgs.

Energous Corp., ISRWO, PCT/US2016/068495, Mar. 30, 2017, 9 pgs.

Energous Corp., ISRWO, PCT/US2015/067287, Feb. 2, 2016, 8 pgs.

Energous Corp., IPRP, PCT/US2015/067287, Jul. 4, 2017, 6 pgs.

Energous Corp., ISRWO, PCT/US2016/068551, Mar. 17, 2017, 8 pgs.

Energous Corp., ISRWO, PCT/US2016/068498, May 17, 2017, 8 pgs.

Energous Corp., ISRWO, PCT/US2016/068993, Mar. 13, 2017, 12 pgs.

Energous Corp., ISRWO, PCT/US2016/068565, Mar. 8, 2017, 11 pgs.

Energous Corp., ISRWO, PCT/US2016/068987, May 8, 2017, 10 pgs.

Energous Corp., ISRWO, PCT/US2016/069316, Mar. 16, 2017, 15 pgs.

Supplementary European Search Report, EP Patent Application No. EP14818136-5, dated Jul. 21, 2016, 9 pgs.

European Search Report, EP Patent Application No. EP16189052.0, dated Jan. 31, 2017, 11 pgs.

European Search Report, EP Patent Application No. EP16189319-3, dated Feb. 1, 2017, 9 pgs.

European Search Report, EP Patent Application No. EP14822971, dated Feb. 1, 2017, 9 pgs.

European Search Report, EP Patent Application No. EP16189987, dated Feb. 1, 2017, 8 pgs.

European Search Report, EP Patent Application No. 16196205.5, dated Mar. 28, 2017, 7 pgs.

European Search Report, EP Patent Application No. 16189300, dated Feb. 28, 2017, 4 pgs.

European Search Report, EP Patent Application No. 16189988.5, dated Mar. 10, 2017, 4 pgs.

European Search Report, EP Patent Application No. 16189982.8, dated Jan. 27, 2017, 9 pgs.

European Search Report, EP Patent Application No. 16189974, dated Mar. 2, 2017, 5 pgs.

European Search Report, EP Patent Application No. 16193743, dated Feb. 2, 2017, 5 pgs.

European Search Report, EP Patent Application No. 14868901.1, dated Jul. 7, 2017, 5 pgs.

L.H. Hsieh et al. Development of a Retrodirective Wireless Microwave Power Transmission System, IEEE, 2003 pp. 393-396.

B.D. Van Veen et al., Beamforming: A Versatile Approach to Spatial Filtering, IEEE, ASSP Magazine, Apr. 1988, pp. 4-24.

Leabman, Adaptive Band-partitioning for Interference Cancellation in Communication System, Thesis Massachusetts Institute of Technology, Feb. 1997, pp. 1-70.

Panda, SIW based Slot Array Antenna and Power Management Circuit for Wireless Energy Harvesting Applications, IEEE APSURSI, Jul. 2012, 2 pgs.

Singh, Wireless Power Transfer Using Metamaterial Bonded Microstrip Antenna for Smart Grid WSN: In Fourth International Conference on Advances in Computing and Communications (ICACC), Aug. 27-29, 2014, Abstract 299.

T. Gill et al. "A System for Change Detection and Human Recognition in Voxel Space using the Microsoft Kinect Sensor," 2011 IEEE Applied Imagery Pattern Recognition Workshop. 8 pgs.

J. Han et al. Enhanced Computer Vision with Microsoft Kinect Sensor: A Review, IEEE Transactions on Cybernetics vol. 43, No. 5. pp. 1318-1334, Oct. 3, 2013.

Zhai, "A Practical wireless charging system based on ultra-wideband retro-reflective beamforming" 2010 IEEE Antennas and Propagation Society International Symposium, Toronto, ON 2010, pp. 1-4.

Mao: BeamStar: An Edge-Based Approach to Routing in Wireless Sensors Networks, IEEE Transactions on Mobile Computing, IEEE Service Center, Los Alamitos, CA US, vol. 6, No. 11, Nov. 1, 2007, 13 pgs.

Smolders—Institute of Electrical 1-15 and Electronics Engineers: "Broadband microstrip array antennas" Digest of the Antennas and Propagation Society International Symposium. Seattle, WA Jun. 19-24 1994. Abstract 3 pgs.

Paolo Nenzi et al; "U-Helix: On-chip short conical antenna", 2013 7th European Conference on Antennas and Propagation (EUCAP), ISBN:978-1-4673-2187-7, IEEE, Apr. 8, 2013, 5 pgs.

Adamiuk G et al; "Compact, Dual-Polarized UWB-Antenna, Embedded in a Dielectric" IEEE Transactions on Antenna and Propagation, IEEE Service Center, Piscataway, NJ, US vol. 56, No. 2, ISSN: 0018-926X, abstract; Figure 1, Feb. 1, 2010, 8 pgs.

Mascarenas et al.; "Experimental Studies of Using Wireless Energy Transmission for Powering Embedded Sensor Nodes." Nov. 28, 2009, Journal of Sound and Vibration, pp. 2421-2433.

Li et al. High-Efficiency Switching-Mode Charger System Design Considerations with Dynamic Power Path Management Mar./Apr. 2012 Issue, 8 pgs.

Energous Corp., ISRWO, PCT/US2016/069313, dated Nov. 13, 2017, 10 pgs.

Energous Corp., IPRP, PCT/US2016/069313, dated Jul. 3, 2018, 7 pgs.

Energous Corp., IPRP, PCT/US2016/068504, dated Jun. 26, 2018, 5 pgs.

Energous Corp., IPRP, PCT/US2016/068495, dated Jun. 26, 2018, 7 pgs.

Energous Corp., IPRP, PCT/US2016/068551, dated Jun. 26, 2018, 6 pgs.

Energous Corp., IPRP, PCT/US2016/068498, dated Jun. 26, 2018, 6 pgs.

Energous Corp., IPRP, PCT/US2016/068993, dated Jul. 3, 2018, 10 pgs.

Energous Corp., IPRP, PCT/US2016/068565, dated Jun. 26, 2018, 9 pgs.

Energous Corp., IPRP, PCT/US2016/068987, dated Jul. 3, 2018, 7 pgs.

Energous Corp., IPRP, PCT/US2016/069316, dated Jul. 3, 2018, 12 pgs.

Energous Corp., ISRWO, PCT/US2018/012806, dated Mar. 23, 2018, 9 pgs.

Energous Corp., ISRWO, PCT/US2017/046800, dated Sep. 11, 2017, 13 pgs.

Energous Corp., ISRWO, PCT/US2017/065886, dated Apr. 6, 2018, 13 pgs.

Order Granting Reexamination Request Control No. 90013793, dated Aug. 31, 2016, 23 pgs.

Ossia Inc. vs Energous Corp., PGR2016-00023-Institution Decision, dated Nov. 29, 2016, 29 pgs.

Ossia Inc. vs Energous Corp., PGR2016-00024-Institution Decision, dated Nov. 29, 2016, 50 pgs.

Ossia Inc. vs Energous Corp., PGR2016-00024-Judgment-Adverse, dated Jan. 20, 2017, 3 pgs.

ReExam Ordered Control No. 90013793, dated Feb. 2, 2017, 8 pgs.

Ossia Inc. vs Energous Corp., Declaration of Stephen B. Heppe in Support of Petition for Post-Grant Review of U.S. Pat. No. 9,124,125, PGR2016-00024, dated May 31, 2016, 122 pgs.

Ossia Inc. vs Energous Corp., Petition for Post-Grant Review of U.S. Pat. No. 9,124,125, dated May 31, 2016, 92 pgs.

Ossia Inc. vs Energous Corp., Patent Owner Preliminary Response, dated Sep. 8, 2016, 95 pgs.

Ossia Inc. vs Energous Corp., Petition for Post Grant Review of U.S. Pat. No. 9,124,125, dated May 31, 2016, 86 pgs.

(56)

References Cited

OTHER PUBLICATIONS

Ossia Inc. vs Energous Corp., Declaration of Stephen B. Hepe in Support of Petition for Post-Grant Review of U.S. Pat. No. 9,124,125, PGR2016-00023, dated May 31, 2016, 144 pgs.

European Search Report. EP15876036, dated May 3, 2018, 8 pgs.

Supplemental European Search Report. EP15874273.4, dated, May 11, 2018, 7 pgs.

Supplemental European Search Report. EP15876033.0, dated Jun. 13, 2018, 10 pgs.

Supplemental European Search Report. EP15876043.9, dated Aug. 8, 2018, 9 pgs.

* cited by examiner

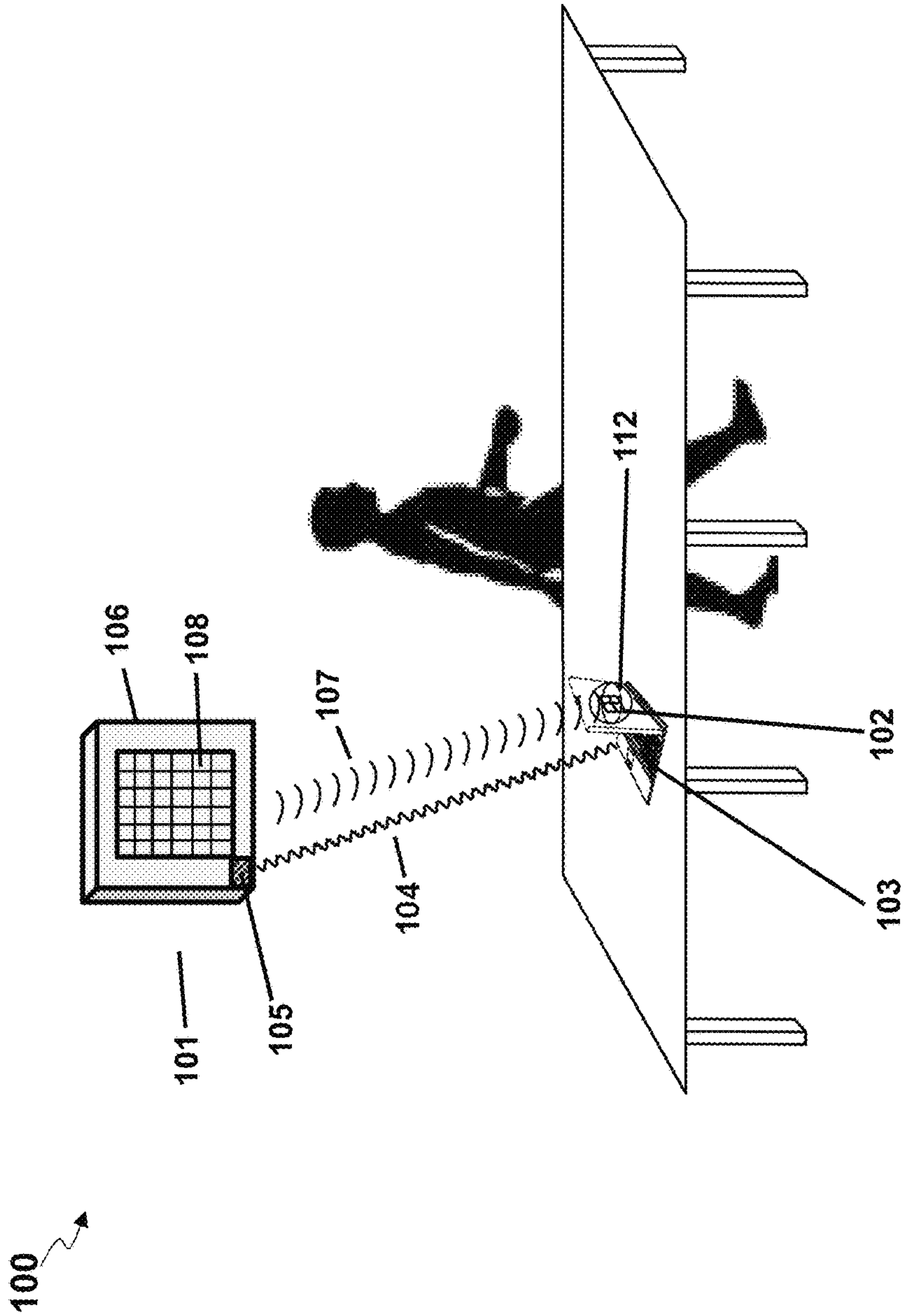
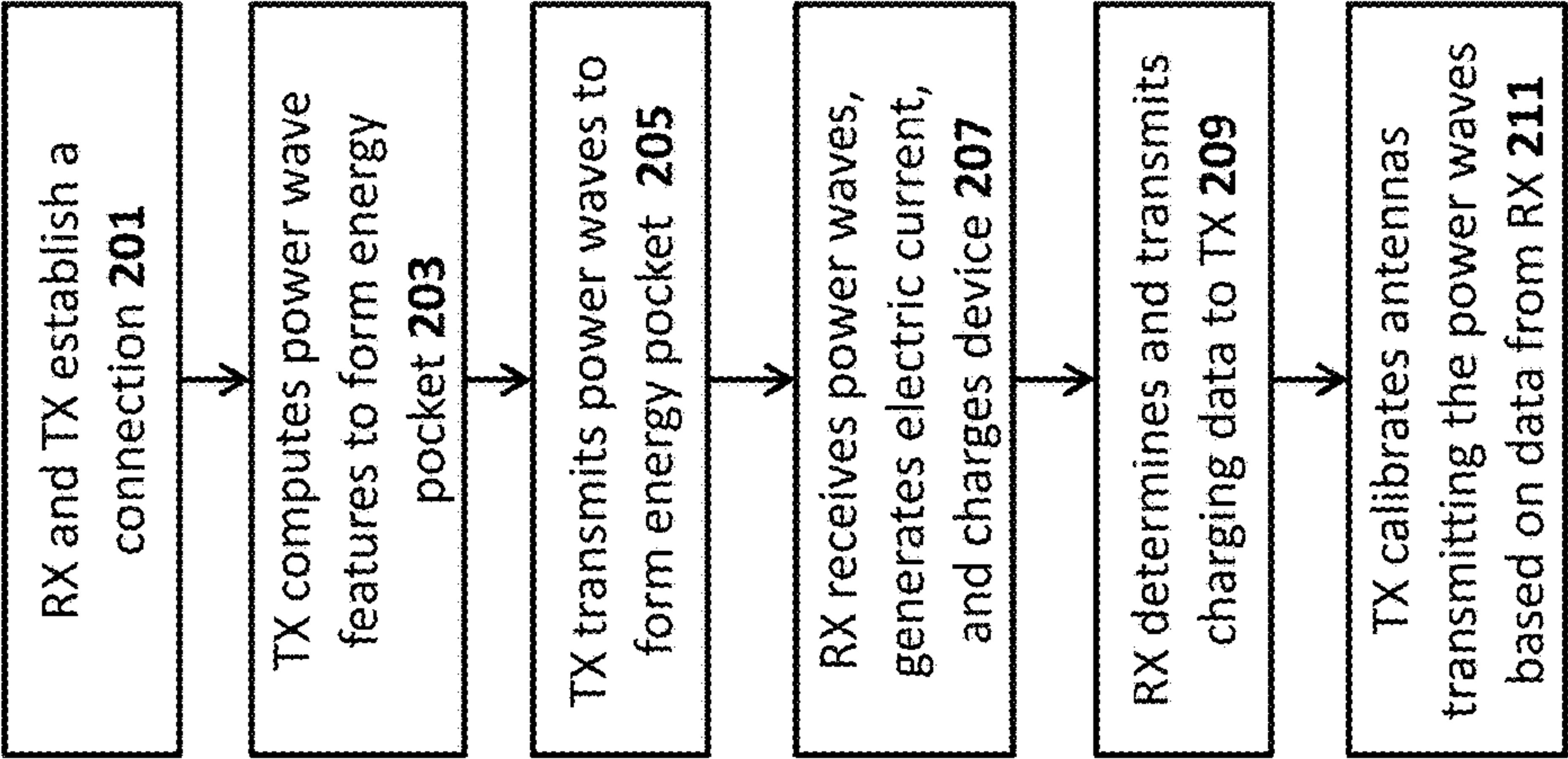


FIG. 1



200 ↗

FIG. 2

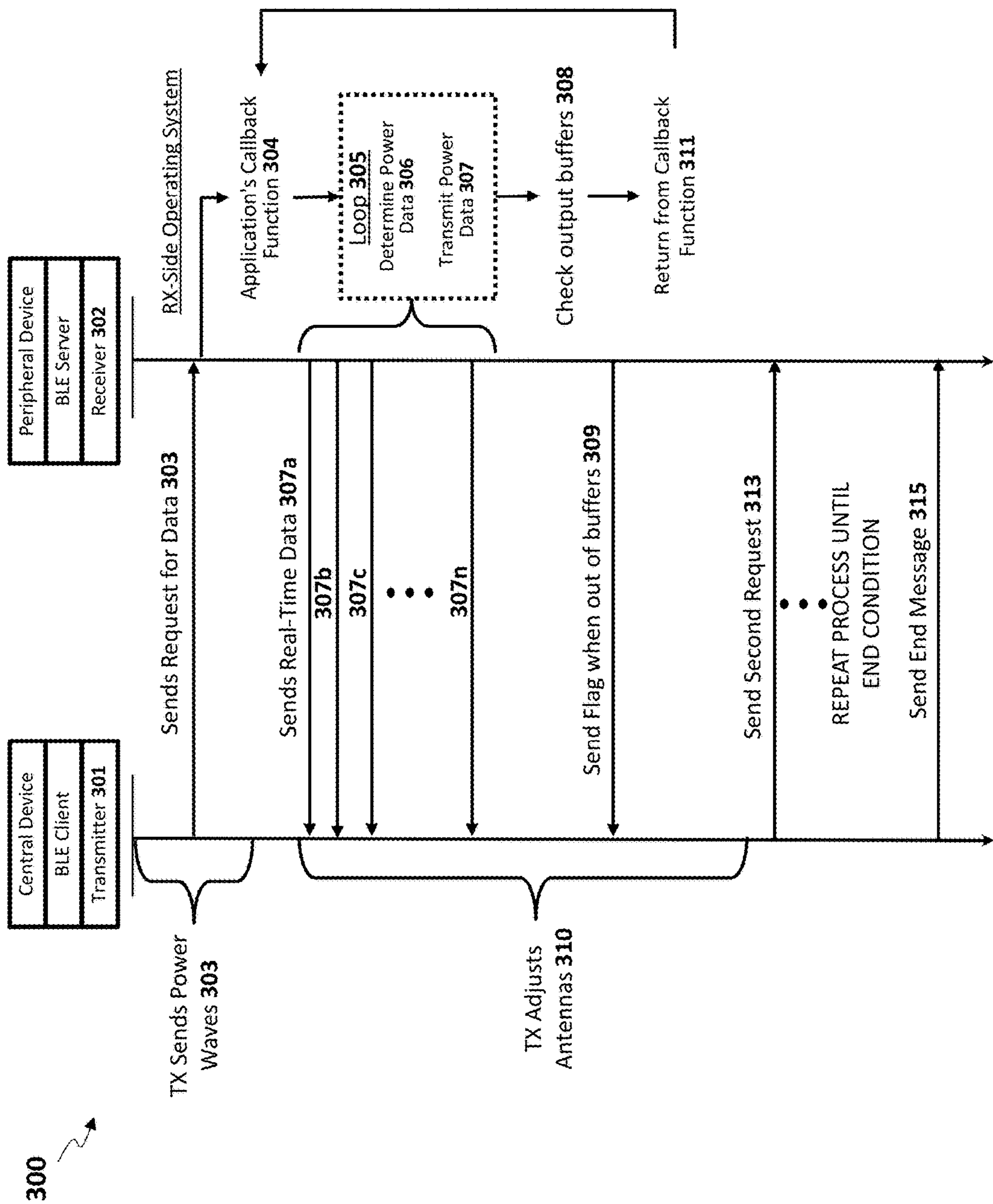


FIG. 3

**SYSTEMS AND METHODS FOR REAL OR
NEAR REAL TIME WIRELESS
COMMUNICATIONS BETWEEN A
WIRELESS POWER TRANSMITTER AND A
WIRELESS POWER RECEIVER**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This non-provisional application claims the benefit of U.S. Provisional Patent Application Ser. No. 62/272,878, entitled "Systems And Methods For Real Time Or Near Real Time Wireless Communications Between Electronic Devices," filed Dec. 30, 2015, which is incorporated by reference in its entirety.

This application is a continuation-in-part of U.S. patent application Ser. No. 14/856,219, entitled "Systems And Methods For Tracking Movement Of Receivers In A Transmission Field," filed Sep. 16, 2015, which is incorporated by reference in its entirety.

TECHNICAL FIELD

This application generally relates wireless communications between electronic devices, with exemplary applications in wireless power systems.

BACKGROUND

There are many use cases for lightweight, low-energy wireless communications protocols, such as Bluetooth®, where the devices need to communicate in real time or near-real time. But often the demands for high rate communications between devices exceeds the capabilities of such wireless communications protocols, as they can often operate too slowly for real-time or near-real time communications.

In wireless charging, it would be beneficial for transmitters and receivers to communicate using low-energy wireless protocols, but it would also be beneficial if the transmitters and receivers could communicate in real time or near-real time. So messages instructing the transmitter how to formulate power waves must be received from the receiver with minimal lag time. However, Bluetooth® was not designed for such rapid communications. Bluetooth® requires senders and receivers to "take turns" responding or not responding, which is prohibitive to achieving or simulating real time or near real time communications. For example, a Bluetooth® client would normally send a request for a data item from a peripheral device and then waits until some data item is received or the Bluetooth® client determines that no response is going to be received.

Furthermore, even if there is a way to increase the rate at which a device could transmit data through a communications protocol, there are often limitations on the hardware responsible for the communications protocol. For example, communications components, such as Bluetooth® chipsets or a Wi-Fi network interface card (NIC), often comprise memory buffers configured to store protocol-specific messages containing the data intended to be transferred between devices. These buffers may be configured to fill and empty according to a predetermined data flow between the devices, according to the particular protocol. In such examples, the buffers may not be capable of allowing for one device or another to continuously transmit data without interruption, outside the normal operational patterns of the protocols. As such, the hardware and firmware of the devices may be

limited in their respective communications rates, such that real time or near-real time data transfers are impractical if not impossible with existing lightweight wireless communications protocols.

What is needed is a means for reducing the overhead requirements on devices communicating via a low-energy or other lightweight communications protocol, such as Bluetooth®. What is needed is a means for adjusting or otherwise modifying the data flow between communications components (e.g., Bluetooth® chipsets, Wi-Fi NICs) over conventional communication protocols that would allow data packets or messages to be transmitted from one device to another in real time or near-real time. What is needed is a mechanism through which the limitation of memory buffers filling up and thereby preventing further communication can be removed.

SUMMARY

Disclosed herein are systems and methods intended to address the shortcomings in the art and may provide additional or alternative advantages as well. Embodiments disclosed herein comprise devices, such as receivers and transmitters, having communications components that may communicate data samples, such as power values, in real time or near-real time, thereby allowing a first device (e.g., transmitter) to adjust in real time or near-real time operational behavior of the first device's hardware or software (e.g., adjust power waves) based upon the data samples (e.g., power values) received from a second device (e.g., receiver).

In an embodiment, a communications component of a first device comprises a processor configured to generate a first request for a data sample associated with a functional routine executed by a second device; and continuously and consecutively receive one or more data samples from the second device; and upon receiving from the second device at least one data signal comprising a flag bit: transmit a second request for a data sample associated with the functional routine executed by the second device.

In another embodiment, a communications component of a first device comprises: one or more memories configured to store one or more data messages containing data samples prior to transmission to a second device; and a processor configured to: continuously and consecutively generate the one or more data messages containing the one or more data samples; and upon determining that each of the one or more memories are filled with one or more messages, transmit at least one data message containing an indicator that the one or more memories are full.

In another embodiment, a method comprises transmitting, by a communications component of a first device, to a second device a first request for one or more data samples associated with a functional routine of the second device; continuously and consecutively receiving, by the communications component of the first device, from the second device one or more data signals containing a data sample; and upon receiving from the receiver at least one data signal comprising a flag bit: transmitting, by the communications component of the first device, a second request for one or more data samples associated with the functional routine of the second device, the second request configured to cause the second device to reset one or more buffers of the communications component of the second device.

In yet another embodiment, a method comprises continuously and consecutively transmitting, by a communications component of a first device, to a second device one or more data samples generated from a functional routine executed

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by the first device; transmitting, by the communications component of the first device, to the second device at least one message comprising a flag bit upon determining that a set of one or more buffers of the communications component of the second device is unavailable; and resetting, by the

In another embodiment, a method for wireless power transmission comprises continuously and consecutively receiving, by a communications component of a transmitter, one or more power messages from a receiver, each respective power message containing at least one power value associated with one or more power waves generated by the transmitter; upon receiving each consecutive power message, determining, by a processor of the transmitter, whether to adjust a characteristic of the one or more power waves based upon the at least one power value of the power message; and upon receiving at least one power message comprising a flag bit, transmitting, by the communications component of the transmitter, to the receiver a second request requesting the one or more power values.

In yet another embodiment, a transmitter device comprises a communications component configured to continuously and consecutively receive one or more power messages from a receiver, each respective power message containing at least one power value associated with or a measurement of one or more power waves generated by the transmitter, and the one or more power messages received via a communications signal independent of the one or more power waves; and a processor configured to: determine whether to adjust a characteristic of the one or more power waves based upon the at least one power value of each consecutive power message; and instruct the communications component to transmit to the receiver a request requesting the one or more power values associated with the one or more power waves, upon receiving at least one power message comprising a flag bit. The flag bit can be configured to instruct or otherwise trigger the transmitter to transmit a second request for one or more power values. In some embodiments, the flag bit received from the receiver can indicate that the receiver has no available output buffers or otherwise requests the transmitter to send the second request for the one or more power values.

In another embodiment, a method for wireless power transmission comprises receiving, by a communications component of a receiver, from a transmitter a first request for one or more power values associated with one or more power waves; continuously and consecutively transmitting, by the communications component of the receiver, one or more power messages containing a power value associated with the one or more power waves; and upon determining that a set of one or more buffers of the communications component of the receiver is unavailable: transmitting, by the communications component of the receiver, at least one message containing an indicator bit indicating that the set of one or more buffers are full or otherwise no another buffer is unavailable for transmission; and resetting, by the communications component of the receiver, at least one buffer memory in the set of one or more buffers of the communications component upon receiving a second request for one or more power values from the transmitter. In some embodiments, the communications component of the receiver may return from a transmission loop of continuously and consecutively transmitting power messages in order to allow or to otherwise cause the output buffers of the receiver to be reset.

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In yet another embodiment, a wireless charging receiver device comprises a communications component comprising: a set of one or more buffer memories configured to store one or more power messages containing one or more power values; and a processor configured to continuously and consecutively transmit to a transmitter the one or more power messages until determining that the set of one or more buffer memories are filled, and upon determining that the set of one or more buffer memories are filled, transmit an indicator bit or flag to the transmitter and reset the set of one or more buffer memories in the receiver; and a processor configured to continuously and consecutively determine a power value associated with one or more power waves for each consecutive power message generated by the communication component of the receiver device.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed. Although some of the features and benefits of the current invention has been described in the context of wireless charging, it should be understood that the invention can be used in the context of any communication link, wired or wireless, where efficient and low power transmission of data is needed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings constitute a part of this specification and illustrate several possible embodiments. The present disclosure can be better understood by referring to the following figures. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the disclosure.

FIG. 1 shows components of a wireless power transmission system, according to an exemplary embodiment.

FIG. 2 shows steps of wireless power transmission, according to an exemplary method embodiment.

FIG. 3 shows the logical data flow for communications over a Bluetooth® communications signal, between a transmitter and a receiver, during a wireless power transmission process, according to an exemplary embodiment.

DETAILED DESCRIPTION

Reference will now be made to exemplary embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation on the scope of potential embodiments is intended. Other embodiments may be used and/or other changes may be made without departing from the spirit or scope of the present disclosure. The illustrative embodiments described in the Detailed Description are not meant to be limiting upon the subject matter presented herein.

Exemplary System and Method of Wireless Charging System

FIG. 1 shows components of a wireless power transmission system **100**, according to an exemplary embodiment. The exemplary system **100** may comprise a transmitter **101** and a receiver **102** coupled to an electronic device **103**. The transmitter **101** and receiver **102** may exchange information related to power waves, including information regarding the location of the receiver **102** within a transmission field and the amount of power being received by the receiver **102**, and other forms of administrative information, through a communication signal **104**. Based on the information gathered over communications signal **104**, the transmitter **101** may generate and transmit one or more power waves **107** to the

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receiver 102, or some location proximate to the receiver 102, allowing the receiver 102 to gather energy from the power waves 107 and convert the energy into electrical current to power the electronic device 103.

A transmitter 101 may comprise an antenna array 106 having one or more antennas that may transmit power waves 107 into a transmission field, which may be a two or three-dimensional space where the transmitter 101 may provide power waves 107 to one or more receivers 102. In some instances, the transmitter 101 may generate and transmit power waves 107 having waveform characteristics (e.g., frequency, amplitude, trajectory, phase) that cause the power waves 107 to converge at a predetermined location in the transmission field to form constructive or destructive interference patterns. When enough power waves 107 accumulate constructively at a particular location, the resulting constructive interference pattern may form a pocket of energy 112. And when enough power waves accumulate destructively at a particular location, the resulting destructive interference pattern may form a null space in the transmission field. The targeted receiver 102 may comprise various circuitry configured to capture energy from a pocket of energy 112 and then convert the energy into usable power for the electronic device 103.

The transmitter 101 may comprise a communications component 105 that may effectuate wired and/or wireless communications to and from one or more receivers 102 of the system 100. In some embodiments, a communications component 105 may be an embedded component of the transmitter 101; and, in some embodiments, the communications component 105 may be attached to the transmitter 101 through any wired or wireless communications medium. In some instances, an attached communications component 105 may be shared among a plurality of transmitters 101, such that each of the transmitters 101 coupled to the communications component 105 may use the data received within a communications signal 104, by the communications component 105. The transmitter communications component 105 may comprise electromechanical components (e.g., processor, antenna) that allow the communications component 105 to communicate various types of data with corresponding receiver communications components (not shown) of one or more receivers 102. The transmitter communications component 105 may be configured to exchange communications signals 104 with the receiver communications component based on one or more wired or wireless communications protocols. Non-limiting examples of such protocols may include: Bluetooth®, Wireless Fidelity (Wi-Fi), Near-Field Communications (NFC), ZigBee, and others. It should be appreciated that the communications component 105 is not limited to radio-frequency based technologies, but may include radar, infrared, and sonic devices (e.g., ultrasound) for sonic triangulation, and may be used for determining the location, or other aspects, of a receiver 102.

The data contained within the communications signals 104 may be used by the transmitter 101 and/or the receiver 102 to determine how the transmitter 101 should generate and transmit, safe and effective power waves 107, from which the receiver 102 may capture energy and convert it to usable alternating current (AC) or direct current (DC) electricity, or other forms of energy. Using the communications signal 104, the transmitter 101 and receiver 102 may exchange data that may be used for various functions of the transmitter 101, such as: identifying receivers 102 within the transmission field; determining whether electronic devices 103 or users are authorized to receive power waves 107; determining safe and effective waveform characteristics for

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power waves 107; and honing or optimization of the placement of pockets of energy 112 in the transmission field with respect to the receivers 102, among other possible functions.

Similarly, a receiver communications component, which may be integrated into a receiver 102 or electrical device 103 as shown in FIG. 1, may use a communications signal 104 to communicate operational data with the communications component 105 of the transmitter 101, where such operational data may be used for various functions of the transmitter 101 or receiver 102, such as: alerting a transmitter 101 that the receiver 102 has entered, or is about to enter, into the transmission field of the transmitter 101; providing information about the user or the electronic device 103 being charged by the receiver 103, such as authentication data or a system profile; indicating the effectiveness of the power waves 107 or pocket of energy 112 in providing power to the receiver 102, such as a power level conversion or reception indicator; and providing updated transmission parameters for the transmitter 101 to use to adjust the power waves 107 to form more effective pockets of energy 112 or null spaces (not shown), among other types of useful data. Moreover, the communications component 105 of the transmitter 101 and the receiver communication component may communicate different types of data (e.g., authentication data, heat-mapping data, transmission parameters) containing various types of information, message, and data points; non-limiting examples of possible information, messages, and data points may include: a transmitter identifier (transmitter ID), a receiver identifier (receiver ID), a Bluetooth® unique identifier (Bluetooth ID), a beacon message, a device identifier (device ID) for an electronic device 103, a user identifier (user ID), the battery level for the electronic device 103, the receiver's 102 location in the transmission field, and the electronic device's 103 location in the transmission field, among a number of other possible types of information, messages, and/or data points.

The antenna array 106 may be a set of one or more antennas 108 configured to transmit power waves 107 into the transmission field of the transmitter 101. Integrated circuits (not shown) of the transmitter 101, such as a controller circuit and/or waveform generator, may control the behavior of the antennas 108. For example, based on the information received from the receiver 102 via the communications signal 104, a controller circuit may determine a set of waveform characteristics (e.g., amplitude, frequency, trajectory, phase) for generating power waves 107 that would effectively provide power to the receiver 102 and electronic device 103. The controller circuit may also identify a subset of antennas 108 from the antenna array 106 that would be effective in transmitting the power waves 107. As another example, a waveform generator circuit of the transmitter 101 coupled to the controller may convert energy and generate the power waves 107 having the waveform characteristics identified by the controller, and then provide the power waves 107 to the antenna array 106 for transmission.

In some implementations, an antenna 108 of the antenna array 106 may transmit power waves 107 having a set of characteristics that cause the power waves 107 to arrive at a given location within a transmission field and constructively or destructively accumulate as needed. For instance, when forming a pocket of energy 112, the antennas 108 of the antenna array 106 may transmit power waves 107 that intersect at a given location (usually at or nearby a detected receiver 102), and due to the respective characteristics of each of the power waves 107 generated by each respective antenna 108, the intersecting power waves 107 form a constructive interference pattern having enough energy to

create a useful pocket of energy **112** from which the receiver **102** may collect energy and generate electric power. It should be appreciated that, although the exemplary system **100** describes radio-frequency based power waves **107**, additional or alternative transmitter antennas, antenna arrays, and/or wave-based technologies may be used (e.g., ultrasonic, infrared, magnetic resonance) to wirelessly transmit power from the transmitter **101** to the receiver **102**.

Receivers **102** may be used for powering or charging an associated electronic device **102** coupled to or integrated with one or more receivers **102**. A receiver **102** may comprise one or more antennas (not shown) that may receive power waves **107** originating from one or more transmitters **101**. In some implementations, the receiver **102** may receive power waves **107** transmitted directly from a transmitter **101**; and, in some implementations, the receiver **102** may capture energy from the constructive interference pattern defining a pocket of energy **112** and formed from power waves **107**. The pocket of energy **112** may be a three-dimensional field of energy resulting from the convergence of power waves **107** at a location in the transmission field.

The receiver **102** may comprise circuitry (not shown) configured to capture energy from a pocket of energy **112** or power waves **107**, and then convert that energy into electricity usable by the electronic device **103**. Non-limiting examples of such circuits may include a controller-processor integrated circuit, an amplifier, a rectifier, and a voltage conditioner, among others. After the power waves **107** are received and/or energy is gathered from a pocket of energy **112**, the receiver's **102** circuitry (e.g., integrated circuits, amplifiers, rectifiers, voltage conditioner) may convert the energy of the power waves **107** (e.g., radio frequency electromagnetic radiation) to electric power (i.e., electricity), which may be stored into a battery (not shown) or used by an electronic device **103**.

As previously mentioned, a receiver **102** or an electronic device **103** may comprise a receiver-side communications component (not shown) configured to communicate various types of data with the transmitter **101** in real-time or near real-time, through a communications signal **104** generated by the receiver-side communications component. The data may include location indicators for the receiver **102** and/or electronic device **103**, and a power status of the device **103**, status information for the receiver **102**, status information for the electronic device **103**, status information for the power waves **107**, and/or status information for the pockets of energy **112**. In other words, the receiver **102** may provide real time or near-real time data to the transmitter **101**, via the communications signal **104**, regarding the current operation of the system **100**, including: the present location the receiver **102** or the device **103**, the amount of energy received by the receiver **102**, and the amount of power received and/or used by the electronic device **103**, among other possible data points containing other types of information.

As mentioned, in some implementations, the receiver **102** may be integrated into the electronic device **103**, such that, for all practical purposes, the receiver **102** and electronic device **103** may be understood to be a single unit or product; but, in some embodiments, the receiver **102** may be permanently or detachably coupled to the electronic device **103** at some point after production of the receiver **102** and electronic device **103**. It should be appreciated that the receiver **102** may be configured to use the communications component of the electronic device **103**, and/or the receiver **102** may comprise a communications component that is independent of the electronic device **103**.

An electronic device **103** coupled to a receiver **102** may be any electronic device **103** that requires continuous power, or that draws stored power from a battery (not shown). The receiver **102** may be permanently integrated into the electronic device **103**, or the receiver **102** may be permanently or detachably coupled to the electronic device **103**. Non-limiting examples of electronic devices **103** may include laptops, mobile phones, smartphones, tablets, music players, toys, batteries, flashlights, lamps, electronic watches, cameras, gaming consoles, appliances, GPS devices, and wearable devices or so-called "wearables" (e.g., fitness bracelets, pedometers, smart watch), among other types of electrical devices **121**.

FIG. 2 shows steps of wireless power transmission, according to an exemplary method **200** embodiment. The exemplary method **200** comprises steps **201**, **203**, **205**, **207**, **209**, and **211**. However, it should be appreciated that other embodiments may include additional or alternative steps, or may omit one or more steps of the exemplary method **200** shown in FIG. 2, but may nevertheless fall within the scope of this disclosure.

In a first step **201**, a transmitter (TX) and receiver (RX) establish a connection or otherwise associates with one another according to a particular wireless communication protocol. Transmitters and receivers may communicate operational data containing various operational data values and/or operational instructions using a communications signal, according to a wireless communication protocol capable of transmitting data between communications components of electrical devices (e.g., Bluetooth®, Bluetooth Low Energy (BLE), Wi-Fi, NFC, ZigBee®). Some protocols require devices to associate with one another in order to conduct various protocol-specific handshakes, authentication protocols, and other potential administrative data exchanges. For example, to communicate using a Wi-Fi based communications signal, the transmitter may function as a wireless access point requiring the receiver to be authenticated, both the transmitter and receiver may need to be authenticated to a standalone wireless access point.

As another example, in embodiments implementing Bluetooth®, or Bluetooth® variants, a Bluetooth-enabled communications component of a transmitter may scan for receivers indirectly broadcasting advertisement signals, or the transmitter may receive an advertisement signal from the transmitter. The advertisement signal may announce the receiver's presence to the transmitter, and may trigger an association between the transmitter and the receiver. As described herein, in some embodiments, the advertisement signal may communicate information that may be used by various devices (e.g., transmitters, client devices, sever computers, other receivers) to execute and manage pocket-forming procedures. Information contained within the advertisement signal may include a device identifier (e.g., MAC address, IP address, UUID), the voltage of electrical energy received, client device power consumption, and other types of data related to power transmission. The transmitter may use the advertisement signal to identify the receiver and, in some cases, locate the receiver in a two or three-dimensional space. Once the transmitter identifies the receiver, the transmitter may establish the Bluetooth connection thereby associating the transmitter with the receiver and allowing the transmitter and receiver to communicate operational data via communications signals.

In a next step **203**, the transmitter may use the advertisement signal to determine a set of characteristics for power waves that would effectively establish a pocket of energy at or near the receiver. Non-limiting examples of features of

power waves may include phase, gain, amplitude, power level, frequency, and trajectory, among others. The transmitter may use information contained in the receiver's advertisement signal and subsequent communications signals in order to gather the data needed to determine the effective waveform characteristics for producing and transmitting power waves.

In a next step **205**, after the transmitter determines the appropriate waveform characteristics for the power waves, the transmitter may begin generating and transmitting power waves. As the power waves are transmitted, their respective characteristics may cause them to converge at a predetermined location in a transmission field, resulting in a constructive interference pattern that forms a pocket of energy at or near the location of the receiver. An antenna of the receiver may capture or otherwise receive energy from the energy field resulting from the constructive interference pattern that defines the pocket of energy.

In a next step **207**, the receiver may capture or otherwise receive the electrical energy directly from the power waves or from a pocket of energy defined by a constructive interference pattern resulting from the constructive accumulation of converging power waves. As previously mentioned, the receiver may comprise circuitry configured to convert the energy captured from the constructive interference patterns into electrical current that may power an electrical device coupled to receiver, such as a laptop computer, smartphone, battery, toy, or other electronic device. In some embodiments, an AC/DC converter may convert the electrical energy from AC-current into DC-current, or from DC-current into AC-current. In embodiments where the circuitry of the receiver generates AC-current from the power waves, the receiver may comprise a rectifier circuit that may rectify the AC-current in order to provide usable DC-current to the electronic device coupled to the receiver.

In a next step **209**, the receiver may generate operational data containing information indicating the effectiveness of the power waves or pocket of energy. This operational data may then be communicated to the transmitter through the communications signal, using a particular wireless protocol (e.g., Bluetooth®, Wi-Fi, ZigBee, NFC, RFID). When generating the operational data, the receiver may identify and/or process data points and other information useful for instructing the transmitter on generating and transmitting, or otherwise adjusting, the power waves. Non-limiting examples of data points and other types of information that may be included in the operational data or may be used to generate the operational data, may include: the quality of the power waves, the quality of the battery charge or quality of the power reception, the location or motion of the receiver, the power levels (e.g., amount of voltage) received and converted by the receiver, and/or the amount of power used by the electronic device. As an example, the receiver may determine how much energy the antenna of the receiver is receiving from the power waves or pocket energy, how much energy the receiver is converting into electric power, the amount of electric power the receiver is providing to the electronic device, and/or the power consumption or requirements of the electronic device, among others.

In operation, as the transmitter continuously transmits the power waves, the receiver may be continuously generating and transmitting operational data containing information related to the effectiveness of the power waves, and providing this data via the communications signal to the transmitter in real time or near-real time. The operational data may inform the transmitter how to generate and transmit, or otherwise adjust, the power waves to provide effective or

improved wireless-charging service to the receiver. The communications signals may be transmitted and received independent from the power waves, using a wireless protocol capable of communicating operational data between the transmitter and receiver, including BLE, NFC, Wi-Fi, and the like.

In a next step **211**, the transmitter may calibrate or otherwise adjust the characteristics of the power waves and/or the antennas transmitting the power waves, so that the antennas transmit power waves having a more effective set of waveform characteristics (e.g., trajectory, frequency, phase, gain, amplitude). In some embodiments, a processor of the transmitter may automatically determine more effective features for generating and transmitting the power waves based on the operational data received from the receiver via the communications signal.

FIG. 3 shows the logical data flow for communications over a Bluetooth® communications signal, between a transmitter **301** and a receiver **302**, during a wireless power transmission process **300**, according to an exemplary embodiment. In the exemplary embodiment, the transmitter **301** and receiver **302** may comprise improved communications components, which may expand upon the features and capabilities of conventional hardware and software components used to send and receive a communications signal, such as a Bluetooth® processor and antenna. The improved communications components may be configured to send and receive real time or near-real time operational data that may be used by the transmitter **301** for power wave generation and transmission, thereby allowing the transmitter **301** to adjust the antennas and power waves in real time or near-real time. The improved communications components may be configured to communicate the operational data through communications signals using known communications protocols, such as Bluetooth®. However, the communication components may be configured to communicate the operational data through conventional protocols in a way that conventional communications components were previously incapable, and which were regularly discouraged by the art, to accomplish results that were previously believed to be impossible. The improved communications components permit the receiver **302** to transmit the operational data via the communications signals in real time or near-real time to the transmitter **301**, thereby allowing the transmitter **301** to adjust the power waves in real time or near-real time accordingly.

As previously mentioned, the transmitter **301** and receiver **302** may communicate operational data that informs the transmitter **301** how to generate safe and effective power waves. The transmitter **301** may periodically or continuously adjust the antennas to produce power waves differently, based upon the operational data received back from the transmitter **302**. It is desirable for the transmitter **301** to be able to minimize the amount of energy that is transmitted in the proximity of a person through further adjustments, to minimize the time needed to adjust the power waves when a person is in power wave transmission path, and to adjust the power waves to maintain the most effective and/or efficient power waves possible. These goals can be better addressed when the transmitter **301** and receiver **302** are communicating real time or near-real time operational data, to allow for real time or near-real time transmit antenna adjustments. To facilitate real time or near-real time transmit antenna adjustments, the transmitter **301** needs to receive operational power data from the receiver **302** in real time or near-real time. Conventional communications components are ordinarily limited with regards to allowing the receiver

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to **302** to determine and report operational data to the transmitter **301** fast enough for the transmitter **301** to adjust the antennas in real time or near-real time. The exemplary embodiment shown in FIG. 3 addresses such limitations by allowing the communications component of the receiver **302** to transmit real time or near-real time operational power data to the transmitter **301**.

It should be appreciated that the exemplary embodiment described in FIG. 3 is not limited to practice in wireless power transmission processes. One having skill in the art would appreciate that any number of alternative embodiments may exist where a first device (e.g., transmitter **301**) and a second device (e.g., receiver **302**) communicate wirelessly, and where the first device polls or otherwise requests the second device to report data in real time or near-real time so that the first device may likewise adjust operations in real time or near-real time.

In a first step **303**, a transmitter **301** may transmit power waves to a receiver **302** and may also transmit a request for the receiver **302** to report back power data or other operational data. The devices **301**, **302** may comprise communications components configured to communicate the power data via a communications signal using a wireless communications protocol, such as Bluetooth®. In some cases, before transmitting the power waves, the transmitter **301** may be associated with the receiver **302** according to the operational rules of the communications protocol. Before, during, or after transmitting the power waves, the transmitter **301** may transmit a request for the receiver **302** to report the power data or other operational data. In some implementations, this request may instruct, or may otherwise trigger, the receiver **302** to execute an operating system function, software application, or other software or firmware routine that generates and reports back power data indicating the effectiveness of the power waves.

In a next step **304**, when the receiver **302** receives from the transmitter **301** the power waves and/or the Bluetooth® message requesting the power data, the receiver **302** may execute a software “callback” function for continuously determining the power data and transmitting the power data to the transmitter **301**.

In a next step **305**, upon executing or triggering the callback function, the receiver **302** enters into a recurring loop during which, among other possible actions, the callback function of the receiver **302** may determine in a next step **306** the power data based on the power waves received from the transmitter **301**, and then in a following step **307** may transmit the power data to the transmitter **301**. This power data may be determined by hardware devices that measure the voltage and current from the receiver antenna array, and report the voltage and current, or their resultant power product to the receiver’s processor. In addition, before returning to the beginning of the loop, the communications component of the receiver **302** determines, in a subsequent step **308**, whether there are any available output buffers for transmitting additional outbound messages to the transmitter **301**.

In a next step **306**, the callback function of the receiver **302** may determine one or more types of power level data based on efficacy of the power waves captured or otherwise received by the receiver **302**. Non-limiting examples of power data may include the amount of RF energy received or otherwise captured by the antennas of the receiver **302**, the amount of RF energy the receiver is converting or has converted to AC or DC, and how much power is required by an electronic device or battery coupled to the receiver **302**, charge level of the battery of the device, among other types

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of power data. Further explanation and examples of how such power level data may be determined and transmitted to the transmitter **301** can be found in U.S. patent application Ser. No. 14/856,219, entitled “Systems And Methods For Tracking Movement Of Receivers In A Transmission Field,” filed Sep. 16, 2015, which is incorporated by reference in its entirety. The callback function of the receiver **302** may determine power data for a given moment or continuously for a certain time period. As the receiver **302** determines the power data at a given instant, the receiver **302** may then populate one or more output buffers of the communications component with the power data determined for the given instant. The output buffers may be a volatile memory component of the communications component of the receiver **302** that may store wireless messages prepared by the receiver **302**. In some implementations, the output buffers may function as a first-in-first-out (FIFO) memory that temporarily stores wireless messages to be transmitted to the communications component of the transmitter **301**, such that the output buffers operate as a queue for wireless messages containing the power data as the power data is generated.

In a next step **307**, after determining the power level for a given instant or time period, the receiver **302** may transmit to the transmitter **301** the power data recently stored into the output buffers. In some cases, the wireless messages containing the power data may be transmitted as the power data is generated, which provides for faster response times for the transmitter **301** to adjust the antennas. In some cases, the wireless messages may be placed into an output buffer and may be transmitted when the output buffer is filled. This may slow the process **300** slightly, but may be useful for providing more information to the transmitter **301**. As seen shown in FIG. 3, the communications component of the receiver **302** may transmit a power data to the transmitter **301** each interval through the loop **305**, and thus the receiver may continuously determine power value data and then transmit to the transmitter **301** consecutive power messages **307a-n** containing each consecutive power value determination.

In a next step **308**, after each respective power message is transmitted **307a-n** to the transmitter via the communications signal, a processor of the communications component of the receiver or the processor of the receiver may determine whether the output buffers of the communications component are filled or used. A communications component of the receiver may comprise a predetermined number of output buffers and/or a predetermined output buffer size, where an output buffer may be a volatile memory location that temporarily stores messages to be outputted and/or messages that were recently outputted. The communications component may determine the number of available output buffers and/or the number of buffers currently occupied, which is ordinarily zero or otherwise very few at the beginning of the process **300**. As each successive power message is generated and transmitted, the output buffers are filled, which could eventually prohibit generation and transmission of additional power messages to the transmitter because ultimately no output buffer would be available.

When output buffers are not filled or are otherwise available, the loop **305** continues, back to previous step **306**, to determine one or more power values.

During execution of the loop **305**, the transmitter **301** may perform a set of steps **310**, in which the transmitter adjusts the antennas transmitting the power waves based upon the power value data received in the successive power messages. In some implementations, the transmitter **301** may determine whether to adjust the power waves to more

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accurately converge and form constructive interference at or near the receiver 302, when the power levels reported back from the receiver 302 fail to satisfy a power level threshold. The power level threshold may be predetermined and stored in memory of the transmitter 301 or may be received as a power value from the receiver, acting on behalf of an electronic device coupled to the receiver 302. The power waves may converge at the location due to the waveform characteristics used to generate and transmit the power waves, and in some cases, due to which antennas are used to transmit the one or more power waves. In order to adjust and better transmit the power waves, the transmitter 301 may use the power values received from the receiver 302 to identify whether the adjustments are needed, and then to determine which characteristics should be adjusted. For example, the receiver may report that too much power is being received, and thus the receiver may determine that a lower amplitude, or fewer power waves are needed.

It should be noted that such adjustments of the antennas in real time or near-real time would not be feasible using conventional communications components, such as Bluetooth® chips and related firmware, because such conventional devices are unable to continuously and consecutively transmit data messages to the receiver as the data messages are being produced. In addition, the conventional communications components would not be capable of overcoming the limitations of the output buffers. Although it is contrary to conventional wisdom, communications components may be configured to execute loop 305, which may bypass conventional handshakes and/or other overhead processes associated with the particular wireless protocol and/or incorporate a mechanism to reset the buffers when they are determined to be filled, thereby permitting the receiver 302 to generate and transmit to the transmitter 301 power messages containing power data at nearly the same instant the power data is produced.

In a next step 309, after determining that the output buffers are filled, the communications component of the receiver may transmit a power message containing an indicator or flag bit to the transmitter 301. The power message containing the flag bit may or may not contain power value data or other operational data, or may only contain the flag bit. The flag bit may indicate that the buffers of the receiver are filled, or may otherwise instruct the transmitter to transmit a new request for power values. One having skill in the art would appreciate that rather than just one flag bit, one or more bits may be used to indicate that buffers are filled or unavailable, or to otherwise trigger the transmitter 301 to transmit a new request for power values. One or more flag or indicator bits may also be transmitted between the transmitter 301 and receiver 302 to trigger other behaviors, such as requesting that the transmitter 301 stop transmitter power waves, or instructing the receiver 302 to reset the output buffers of the receiver communications component. It should be appreciated that the terms “flag bit,” “flag bits,” “indicator bit,” and “indicator bits” are used interchangeably herein, and may comprise one or more binary data bits configured to instruct or otherwise trigger hardware and/or software behavior by the device intended to receive the one or more binary data bits.

In a next step 311, the communications component of the receiver 302 may reset the memory address of the memory buffers or may purge the data stored in the memory buffers, or otherwise make the buffers again available to output messages from receiver to transmitter, and may then return to a ready state for the call back function, as in previous step 304.

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In a next step 313, when the transmitter 301 receives the indicator or flag bit from receiver 302, the transmitter may automatically transmit a new request for power data and/or other operational data. The process 300 may then repeat until the receiver no longer requires power waves from the transmitter 301 or there is some other break in the wireless association of the devices.

The process 300 may continue to repeat until an ending condition is detected or is otherwise identified by the transmitter 301. One skilled in the art may recognize that there may be any number of ending conditions that may be recognized by either the transmitter or the receiver. However, for ease of description in the exemplary embodiment, the transmitter 301 may be configured to stop the power transmission process 300 for the receiver 302 when the transmitter 301 receives a signal from the receiver 302 indicating that the receiver 302 no longer needs power or when the receiver 302 is physically moved beyond the range of the power waves or the communications signals of transmitter 301.

As another example, a receiver 302 may send a message, indicator or flag bit, or some other signal to the transmitter 301 requesting the end of power transmission. In this example, the receiver 302 may automatically determine that no further power is required, or a user may operate a software application that instructs the receiver 302 to transmit an end-request. As another example, the transmitter 301 may decide to end power transmission when the receiver 301 or user has exceeded an authorized amount of energy, or an application monitoring operations of a wireless power transmission system comprising the transmitter 301 may instruct the transmitter 301 to end the power transmission process 300.

In a next step 315, after the transmitter 301 determines to stop transmitter power waves due to an end condition, the transmitter 301 may then send through the communications signal a special message with a flag bit or other indicator bit that signals to receiver 302 to stop sending power data messages to transmitter 301. In some implementations, the receiver 302 may cease operations, and in some implementations, the receiver 302 application or software module may return from the callback function to ready state, as in previous step 311.

The foregoing method descriptions and the process flow diagrams are provided merely as illustrative examples and are not intended to require or imply that the steps of the various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the steps in the foregoing embodiments may be performed in any order. Words such as “then,” “next,” and the like, are not intended to limit the order of the steps; these words are simply used to guide the reader through the description of the methods. Although process flow diagrams may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination may correspond to a return of the function to the calling function or the main function.

The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, mod-

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ules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

Embodiments implemented in computer software may be implemented in software, firmware, middleware, microcode, hardware description languages, or any combination thereof. A code segment or machine-executable instructions may represent a procedure, a function, a subprogram, a program, a routine, a subroutine, a module, a software package, a class, or any combination of instructions, data structures, or program statements. A code segment may be coupled to another code segment or a hardware circuit by passing and/or receiving information, data, arguments, parameters, or memory contents. Information, arguments, parameters, data, etc. may be passed, forwarded, or transmitted via any suitable means including memory sharing, message passing, token passing, network transmission, etc.

The actual software code or specialized control hardware used to implement these systems and methods is not limiting of the invention. Thus, the operation and behavior of the systems and methods were described without reference to the specific software code being understood that software and control hardware can be designed to implement the systems and methods based on the description herein.

When implemented in software, the functions may be stored as one or more instructions or code on a non-transitory computer-readable or processor-readable storage medium. The steps of a method or algorithm disclosed herein may be embodied in a processor-executable software module, which may reside on a computer-readable or processor-readable storage medium. A non-transitory computer-readable or processor-readable media includes both computer storage media and tangible storage media that facilitate transfer of a computer program from one place to another. A non-transitory processor-readable storage media may be any available media that may be accessed by a computer. By way of example, and not limitation, such non-transitory processor-readable media may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other tangible storage medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer or processor. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory processor-readable medium and/or computer-readable medium, which may be incorporated into a computer program product.

What is claimed is:

1. A method for wireless power transmission comprising: receiving, by an antenna of a receiver, a plurality of radio frequency (RF) power waves from a transmitter that constructively interfere at a location of the receiver; receiving, by a communications component of the receiver and using a pre-existing wireless protocol that

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includes handshakes, from the transmitter a first request for one or more power values associated with reception of the plurality of RF power waves at the receiver;

in response to the first request and without requiring an additional request for power values from the transmitter, continuously and consecutively executing respective iterations of a loop executed at the receiver, each respective iteration of the loop bypassing the handshakes and other overhead processes associated with the pre-existing wireless protocol, and each respective iteration of the loop including:

measuring one or more power values associated with reception of the plurality of RF power waves received at the receiver during the respective iteration of the loop;

transmitting a respective power message to the transmitter, wherein the respective power message contains at least the measured one or more power values; and

proceeding to a next respective iteration of the loop in accordance with a determination that one or more buffers of the communications component that are configured to store the plurality of power messages are not full;

receiving, by the antenna of the receiver, a plurality of adjusted RF power waves from the transmitter, wherein the plurality of adjusted RF power waves are adjusted by the transmitter in accordance with the one or more power values in the plurality of power messages;

in accordance with determining that the one or more buffers of the communications component of the receiver are full:

transmitting, by the communications component of the receiver and using the pre-existing wireless protocol, an indicator bit indicating that the one or more buffers are full; and

upon receiving, from the transmitter, a second request for one or more power values associated with reception of RF power waves at the receiver:

resetting, by the communications component of the receiver, at least one buffer of the one or more buffers of the communications component.

2. The method according to claim 1, wherein the indicator bit is configured to instruct the transmitter to transmit the second request for the one or more power values associated with the reception of the RF power waves.

3. The method according to claim 1, further comprising: receiving, by an antenna of the receiver, the plurality of RF power waves from the transmitter; and converting, by the receiver, the plurality of RF power waves to electrical power.

4. The method according to claim 3, further comprising continuously and consecutively determining, by the receiver, power values associated with an amount of energy received from the plurality of RF power waves.

5. The method according to claim 4, further comprising continuously and consecutively determining, by the receiver, power values indicating an amount of energy converted to electrical power from the plurality of RF power waves.

6. The method according to claim 1, wherein, during a respective iteration of the loop, the method further comprises:

after measuring the one or more power values, generating, by the communications component of the receiver, the

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respective power message containing the one or more power values associated with reception of the plurality of RF power waves.

7. The method according to claim 1, wherein, during a respective iteration of the loop, the method further comprises:

after transmitting the respective power message to the transmitter, storing, by the communications component of the receiver, the respective power message containing the one or more power values into at least one output buffer memory of the one or more buffers of the communications component of the receiver.

8. The method according to claim 1, wherein, during a respective iteration of the loop, the method further comprises:

after transmitting the respective power message to the transmitter, determining whether the one or more buffers are full.

9. The method according to claim 1, wherein resetting the at least one buffer further comprises deleting one or more power messages in the at least one buffer memory.

10. The method according to claim 1, wherein resetting the at least one buffer further comprises restarting an address counter for the one or more buffers.

11. The method according to claim 1, wherein the communications component of the receiver is configured to communicate with a communications component of the transmitter over a communications signal independent of the plurality of RF power waves.

12. The method according to claim 1, wherein the communications component of the receiver comprises one or more chips configured to communicate using a lightweight wireless communications protocol.

13. A receiver device comprising:

one or more antennas;

a communications component; and

a processor configured to execute computer-readable instructions for:

receiving, by the one or more antennas, a plurality of radio frequency (RF) power waves from a transmitter that constructively interfere at a location of the receiver device;

receiving, by the communications component using a pre-existing wireless protocol that includes handshakes, from the transmitter a first request for one or more power values associated with reception of the plurality of RF power waves at the receiver device; in response to the first request and without requiring an additional request for power values from the transmitter, continuously and consecutively executing respective iterations of a loop executed at the receiver device, each respective iteration of the loop bypassing the handshakes and other overhead processes associated with a pre-existing wireless protocol, and each respective iteration of the loop including:

measuring one or more power values associated with reception of the plurality of RF power waves

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received at the receiver device during the respective iteration of the loop;

transmitting a respective power message to the transmitter, wherein the respective power message contains at least the measured one or more power values; and

proceeding to a next respective iteration of the loop in accordance with a determination that one or more buffers of the communications component that are configured to store the plurality of power messages are not full;

receiving, by the antenna of the receiver, a plurality of adjusted RF power waves from the transmitter, wherein the plurality of adjusted RF power waves are adjusted by the transmitter in accordance with the one or more power values in the plurality of power messages;

in accordance with determining that the one or more buffers of the communications component are full: transmitting, by the communications component and using the pre-existing wireless protocol, an indicator bit indicating that the one or more buffers are full; and

upon receiving, from the transmitter, a second request for one or more power values associated with reception of RF power waves at the receiver device:

resetting, by the communications component, at least one buffer of the one or more buffers of the communications component.

14. The receiver device according to claim 13, wherein the indicator bit is configured to instruct the transmitter to transmit a second request for the one or more power values associated with the reception of the RF power waves.

15. The receiver device according to claim 13, further comprising:

at least one circuit configured to convert the plurality of RF power waves to electrical power.

16. The receiver device according to claim 15, wherein the processor of the receiver is further configured to determine at least one power value based upon an amount of energy captured from the plurality of RF power waves.

17. The receiver device according to claim 15, wherein the processor of the receiver is further configured to determine at least one power value based upon an amount of energy converted to electrical power from the plurality of RF power waves.

18. The receiver device according to claim 13, wherein the communications component of the receiver is configured to communicate with a communications component of the transmitter over a communications signal independent of the plurality of RF power waves.

19. The receiver device according to claim 13, wherein the communications component of the receiver comprises one or more chips configured to communicate using a lightweight wireless communications protocol.

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