

(51) International Patent Classification:
H04B 7/005 (2006.01)(21) International Application Number:
PCT/US2013/047210(22) International Filing Date:
23 June 2013 (23.06.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/669,587 6 November 2012 (06.11.2012) US(71) Applicant (for all designated States except US): **INTEL CORPORATION** [US/US]; 2200 Mission College Blvd., Santa Clara, California 95054 (US).

(72) Inventors; and

(71) Applicants (for US only): **TEPLITSKY, Moshe** [IL/IL]; Andersan 14, 6910712 Tel-Aviv (IL). **GENOSSAR, Michael** [IL/IL]; 62 Binyamin, 71724 Modiin (IL). **BANIN, Elan** [IL/IL]; Brenner 54A, 43606 Raanana (IL).(74) Agent: **SHICHRUR, Naim**; Shichrur & Co., c/o CPA Global, P.O. Box 52050, Minneapolis, Minnesota 55402 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: APPARATUS, SYSTEM AND METHOD OF DIRECT CURRENT (DC) ESTIMATION OF A WIRELESS COMMUNICATION PACKET

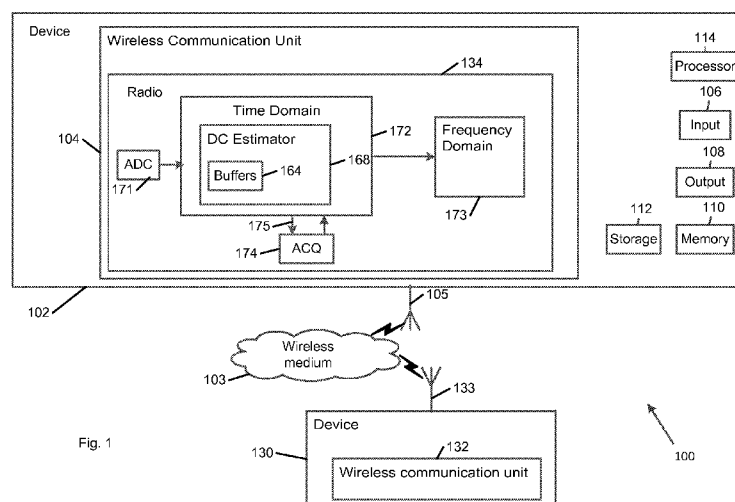


Fig. 1

(57) Abstract: Some demonstrative embodiments include devices, systems and/or methods of Direct Current (DC) estimation. For example, an apparatus may include an estimator to estimate a DC component of a received wireless communication packet based on a first value, a second value and an estimated frequency offset, wherein the first value is based on a first plurality of samples including at least a plurality of samples of a first sequence of a preamble of the wireless communication packet, the second value is based on a second plurality of samples including at least a plurality of samples of a second sequence of the preamble, immediately successive to the first sequence, and the estimated frequency offset corresponds to a frequency offset between the first and second pluralities of samples.

APPARATUS, SYSTEM AND METHOD OF DIRECT CURRENT (DC)
ESTIMATION OF A WIRELESS COMMUNICATION PACKET

5

BACKGROUND

A received wireless communication signal may suffer Direct Current (DC) impairment. The DC impairment may vary based on various parameters, e.g., gain, temperature and the like.

Mitigation of a DC component of a received signal at a relatively high accuracy level may be required, for example, when communicating at relatively high Signal-to-Noise-Ratio (SNR) levels.

One method of mitigating the DC component may include using a notch filter. For example, a High Pass Filter (HPF) may be utilized. However, the HPF may also affect other components of the signal, e.g., by reducing a gain of the components. For example, applying the HPF to a Short training Field (STF) of a preamble of a wireless communication packet may result in degradation of a Channel Estimation (CE) field of the preamble.

BRIEF DESCRIPTION OF THE DRAWINGS

For simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity of presentation. Furthermore, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. The figures are listed below.

Fig. 1 is a schematic block diagram illustration of a system, in accordance with some demonstrative embodiments.

Fig. 2 is a schematic illustration of a preamble of a wireless communication packet, in accordance with some demonstrative embodiments.

Fig. 3 is a schematic illustration of a graph depicting a Direct Current (DC) estimation error versus a timing offset, in accordance with some demonstrative embodiments.

Fig. 4 is a schematic timing illustration of DC estimation, in accordance with some demonstrative embodiments.

Fig. 5 is a schematic illustration of graphs depicting a Packet Error Rate (PER) versus Signal to Noise Ratio (SNR) with respect to three different DC simulation scenarios, in accordance with some demonstrative embodiments.

Fig. 6 is a schematic flow-chart illustration of a method of DC estimation, in accordance

with some demonstrative embodiments.

Fig. 7 is a schematic illustration of a product, in accordance with some demonstrative embodiments.

5

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of some embodiments. However, it will be understood by persons of ordinary skill in the art that some embodiments may be practiced without these specific details. In other instances, well-known methods, procedures, components, units and/or
10 circuits have not been described in detail so as not to obscure the discussion.

Discussions herein utilizing terms such as, for example, “processing”, “computing”, “calculating”, “determining”, “establishing”, “analyzing”, “checking”, or the like, may refer to operation(s) and/or process(es) of a computer, a computing platform, a computing system, or other electronic computing device, that manipulate and/or transform data represented as physical
15 (e.g., electronic) quantities within the computer’s registers and/or memories into other data similarly represented as physical quantities within the computer’s registers and/or memories or other information storage medium that may store instructions to perform operations and/or processes.

The terms “plurality” and “a plurality”, as used herein, include, for example, “multiple” or
20 “two or more”. For example, “a plurality of items” includes two or more items.

References to “one embodiment”, “an embodiment”, “demonstrative embodiment”, “various embodiments” etc., indicate that the embodiment(s) so described may include a particular feature, structure, or characteristic, but not every embodiment necessarily includes the particular feature, structure, or characteristic. Further, repeated use of the phrase “in one
25 embodiment” does not necessarily refer to the same embodiment, although it may.

As used herein, unless otherwise specified the use of the ordinal adjectives “first”, “second”, “third” etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

30 Some embodiments may be used in conjunction with various devices and systems, for example, a Personal Computer (PC), a desktop computer, a mobile computer, a laptop computer, a notebook computer, a tablet computer, a server computer, a handheld computer, a handheld device, a Personal Digital Assistant (PDA) device, a handheld PDA device, an on-board device, an off-board device, a hybrid device, a vehicular device, a non-vehicular device, a mobile or

portable device, a consumer device, a non-mobile or non-portable device, a wireless communication station, a wireless communication device, a wireless Access Point (AP), a wired or wireless router, a wired or wireless modem, a video device, an audio device, an audio-video (A/V) device, a wired or wireless network, a wireless area network, a Wireless Video Area Network (WVAN), a Local Area Network (LAN), a Wireless LAN (WLAN), a Personal Area Network (PAN), a Wireless PAN (WPAN), and the like.

Some embodiments may be used in conjunction with devices and/or networks operating in accordance with existing Wireless-Gigabit-Alliance (WGA or WiGig) specifications (Wireless Gigabit Alliance, Inc WiGig MAC and PHY Specification Version 1.0, April 2010, Final specification) and/or future versions and/or derivatives thereof, devices and/or networks operating in accordance with existing IEEE 802.11 standards (*IEEE 802.11-2012, IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, March 29, 2012*; IEEE802.11 task group ac (TGac) (*"IEEE802.11-09/0308r12 – TGac Channel Model Addendum Document"*); *IEEE 802.11 task group ad (TGad) (IEEE P802.11ad/D1.0 Draft Standard for Information Technology – Telecommunications and Information Exchange Between Systems – Local and Metropolitan Area Networks – Specific Requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications – Amendment 5: Enhancements for Very High Throughput in the 60GHz Band)*, and/or future versions and/or derivatives thereof, devices and/or networks operating in accordance with existing IEEE 802.16 standards (*IEEE-Std 802.16, 2009 Edition, Air Interface for Fixed Broadband Wireless Access Systems*; *IEEE-Std 802.16e, 2005 Edition, Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands*; *amendment to IEEE Std 802.16-2009, developed by Task Group m*) and/or future versions and/or derivatives thereof, devices and/or networks operating in accordance with existing Wireless- WirelessHD™ specifications and/or future versions and/or derivatives thereof, units and/or devices which are part of the above networks, and the like.

Some embodiments may be used in conjunction with one way and/or two-way radio communication systems, cellular radio-telephone communication systems, a mobile phone, a cellular telephone, a wireless telephone, a Personal Communication Systems (PCS) device, a PDA device which incorporates a wireless communication device, a mobile or portable Global Positioning System (GPS) device, a device which incorporates a GPS receiver or transceiver or chip, a device which incorporates an RFID element or chip, a Multiple Input Multiple Output

(MIMO) transceiver or device, a Single Input Multiple Output (SIMO) transceiver or device, a Multiple Input Single Output (MISO) transceiver or device, a device having one or more internal antennas and/or external antennas, Digital Video Broadcast (DVB) devices or systems, multi-standard radio devices or systems, a wired or wireless handheld device, e.g., a Smartphone, a
5 Wireless Application Protocol (WAP) device, or the like.

Some embodiments may be used in conjunction with one or more types of wireless communication signals and/or systems, for example, Radio Frequency (RF), Infra Red (IR), Frequency-Division Multiplexing (FDM), Orthogonal FDM (OFDM), Time-Division Multiplexing (TDM), Time-Division Multiple Access (TDMA), Extended TDMA (E-TDMA),
10 General Packet Radio Service (GPRS), extended GPRS, Code-Division Multiple Access (CDMA), Wideband CDMA (WCDMA), CDMA 2000, single-carrier CDMA, multi-carrier CDMA, Multi-Carrier Modulation (MDM), Discrete Multi-Tone (DMT), Bluetooth®, Global Positioning System (GPS), Wi-Fi, Wi-Max, ZigBee™, Ultra-Wideband (UWB), Global System for Mobile communication (GSM), 2G, 2.5G, 3G, 3.5G, Long Term Evolution (LTE), LTE
15 advanced, Enhanced Data rates for GSM Evolution (EDGE), or the like. Other embodiments may be used in various other devices, systems and/or networks.

The term “wireless device”, as used herein, includes, for example, a device capable of wireless communication, a communication device capable of wireless communication, a communication station capable of wireless communication, a portable or non-portable device
20 capable of wireless communication, or the like. In some demonstrative embodiments, a wireless device may be or may include a peripheral that is integrated with a computer, or a peripheral that is attached to a computer. In some demonstrative embodiments, the term “wireless device” may optionally include a wireless service.

The term “communicating” as used herein with respect to a wireless communication signal
25 includes transmitting the wireless communication signal and/or receiving the wireless communication signal. For example, a wireless communication unit, which is capable of communicating a wireless communication signal, may include a wireless transmitter to transmit the wireless communication signal to at least one other wireless communication unit, and/or a wireless communication receiver to receive the wireless communication signal from at least one
30 other wireless communication unit.

Some demonstrative embodiments may be used in conjunction with suitable limited-range or short-range wireless communication networks, for example, a wireless area network, a “piconet”, a WPAN, a WVAN and the like. Other embodiments may be used in conjunction with any other suitable wireless communication network.

Some demonstrative embodiments may be used in conjunction with a wireless communication network communicating over a frequency band of 60GHz. However, other embodiments may be implemented utilizing any other suitable wireless communication frequency bands, for example, an Extremely High Frequency (EHF) band (the millimeter wave (mmwave) frequency band), e.g., a frequency band within the frequency band of between 30Ghz and 300GHZ, a WLAN frequency band, a WPAN frequency band, a frequency band according to the WGA specification, and the like.

The term “antenna”, as used herein, may include any suitable configuration, structure and/or arrangement of one or more antenna elements, components, units, assemblies and/or arrays. In some embodiments, the antenna may implement transmit and receive functionalities using separate transmit and receive antenna elements. In some embodiments, the antenna may implement transmit and receive functionalities using common and/or integrated transmit/receive elements. The antenna may include, for example, a phased array antenna, a single element antenna, a set of switched beam antennas, and/or the like.

The term “station” (STA), as used herein, may include any logical entity that is a singly addressable instance of a medium access control (MAC) and a physical layer (PHY) interface to a wireless medium (WM).

The phrases “directional multi-gigabit (DMG)” and “directional band” (DBand), as used herein, may relate to a frequency band wherein the Channel starting frequency is above 40 GHz.

The phrases “DMG STA” and “mmWave STA (mSTA)” may relate to a STA having a radio transmitter, which is operating on a channel that is within the DMG band.

Reference is now made to Fig. 1, which schematically illustrates a block diagram of a system 100, in accordance with some demonstrative embodiments.

As shown in Fig. 1, in some demonstrative embodiments, system 100 may include a wireless communication network including one or more wireless communication devices, e.g., wireless communication devices 102 and/or 130, capable of communicating content, data, information and/or signals over a wireless communication medium 103, for example, a radio channel, an IR channel, a RF channel, a Wireless Fidelity (WiFi) channel, and the like. One or more elements of system 100 may optionally be capable of communicating over any suitable wired communication links.

In some demonstrative embodiments, wireless communication devices 102 and/or 130 may include, for example, a PC, a desktop computer, a mobile computer, a laptop computer, a notebook computer, a tablet computer, a server computer, a media center, a mobile internet device, a handheld computer, a handheld device, a storage device, a mass storage device, a USB

mass storage (UMS) device, a hard drive, an optical drive, a flash memory device, a PDA device, a handheld PDA device, an on-board device, an off-board device, a hybrid device (e.g., combining cellular phone functionalities with PDA device functionalities), a consumer device, a vehicular device, a non-vehicular device, a mobile or portable device, a non-mobile or non-portable device, a mobile phone, a cellular telephone, a PCS device, a PDA device which incorporates a wireless communication device, a mobile or portable GPS device, a DVB device, a relatively small computing device, a non-desktop computer, a “Carry Small Live Large” (CSLL) device, an Ultra Mobile Device (UMD), an Ultra Mobile PC (UMPC), a Mobile Internet Device (MID), an “Origami” device or computing device, a device that supports Dynamically Composable Computing (DCC), a context-aware device, a video device, an audio device, an A/V device, a Set-Top-Box (STB), a Blu-ray disc (BD) player, a BD recorder, a Digital Video Disc (DVD) player, a High Definition (HD) DVD player, a DVD recorder, a HD DVD recorder, a Personal Video Recorder (PVR), a broadcast HD receiver, a video source, an audio source, a video sink, an audio sink, a stereo tuner, a broadcast radio receiver, a flat panel display, a Personal Media Player (PMP), a digital video camera (DVC), a digital audio player, a speaker, an audio receiver, an audio amplifier, a gaming device, a data source, a data sink, a Digital Still camera (DSC), a media player, a Smartphone, a television, a music player, or the like.

In some demonstrative embodiments, wireless communication devices 102 and/or 130 may include wireless communication units 104 and/or 132, respectively, to perform wireless communication between wireless communication devices 102 and 130 and/or with one or more other wireless communication devices, e.g., as described below.

Wireless communication devices 102 and/or 130 may also include, for example, one or more of a processor 114, an input unit 106, an output unit 108, a memory unit 110, and a storage unit 112. Wireless communication devices 102 and/or 130 may optionally include other suitable hardware components and/or software components. In some demonstrative embodiments, some or all of the components of one or more of wireless communication devices 102 and/or 130 may be enclosed in a common housing or packaging, and may be interconnected or operably associated using one or more wired or wireless links. In other embodiments, components of one or more of wireless communication devices 102 and/or 130 may be distributed among multiple or separate devices.

Processor 114 includes, for example, a Central Processing Unit (CPU), a Digital Signal Processor (DSP), one or more processor cores, a single-core processor, a dual-core processor, a multiple-core processor, a microprocessor, a host processor, a controller, a plurality of processors or controllers, a chip, a microchip, one or more circuits, circuitry, a logic unit, an

Integrated Circuit (IC), an Application-Specific IC (ASIC), or any other suitable multi-purpose or specific processor or controller. Processor 114 executes instructions, for example, of an Operating System (OS) of wireless communication devices 102 and/or 130 and/or of one or more suitable applications.

5 Input unit 106 includes, for example, a keyboard, a keypad, a mouse, a touch-screen, a touch-pad, a track-ball, a stylus, a microphone, or other suitable pointing device or input device. Output unit 108 includes, for example, a monitor, a screen, a touch-screen, a flat panel display, a Liquid Crystal Display (LCD) display unit, a plasma display unit, one or more audio speakers or earphones, or other suitable output devices.

10 Memory unit 110 includes, for example, a Random Access Memory (RAM), a Read Only Memory (ROM), a Dynamic RAM (DRAM), a Synchronous DRAM (SD-RAM), a flash memory, a volatile memory, a non-volatile memory, a cache memory, a buffer, a short term memory unit, a long term memory unit, or other suitable memory units. Storage unit 112 includes, for example, a hard disk drive, a floppy disk drive, a Compact Disk (CD) drive, a CD-
15 ROM drive, a DVD drive, or other suitable removable or non-removable storage units. Memory unit 110 and/or storage unit 112, for example, may store data processed by wireless communication devices 102 and/or 130.

In some demonstrative embodiments, wireless communication units 104 and 132 may include, or may be associated with, one or more antennas 105 and 133, respectively. Antennas
20 105 and/or 133 may include any type of antennas suitable for transmitting and/or receiving wireless communication signals, blocks, frames, transmission streams, packets, messages and/or data. For example, antennas 105 and/or 133 may include any suitable configuration, structure and/or arrangement of one or more antenna elements, components, units, assemblies and/or arrays. Antennas 105 and/or 133 may include, for example, antennas suitable for directional
25 communication, e.g., using beamforming techniques. For example, antennas 105 and/or 133 may include a phased array antenna, a single element antenna, a set of switched beam antennas, and/or the like. In some embodiments, antennas 105 and/or 133 may implement transmit and receive functionalities using separate transmit and receive antenna elements. In some embodiments, antennas 105 and/or 133 may implement transmit and receive functionalities using
30 common and/or integrated transmit/receive elements.

In some demonstrative embodiments, wireless communication units 104 and/or 132 include, for example, one or more radios 134, e.g., including one or more wireless transmitters, receivers and/or transceivers able to send and/or receive wireless communication signals, RF signals, frames, blocks, transmission streams, packets, messages, data items, and/or data. For

example, wireless communication units 104 and/or 132 may include or may be implemented as part of a wireless Network Interface Card (NIC), and the like.

In some demonstrative embodiments, wireless communication devices 102 and/or 130 may perform the functionality of DMG stations ("DMG STA"). For example, wireless communication devices 102 and/or 130 may be configured to communicate over the DMG band.

In some demonstrative embodiments, device 102 may include a Direct Current (DC) estimator 168 to estimate a DC component of a wireless communication packet received by device 102.

In some demonstrative embodiments, wireless communication unit 104 may be configured according to an initial DC calibration, e.g., during manufacturing. A DC impairment of wireless communication unit 104 may vary according to various conditions and/or parameters, e.g., gain, temperature, and the like.

In some demonstrative embodiments, DC estimator 168 may be configured to dynamically estimate and/or calibrate the DC impairment of wireless communication unit 104. For example, DC estimator 168 may estimate and/or calibrate the DC impairment of wireless communication unit 104 based on preambles of wireless communication packets received by device 102.

In one example, DC estimator 168 may estimate and/or calibrate the DC impairment of wireless communication unit 104 by estimating the DC component of the preambles, e.g., periodically.

In some demonstrative, DC estimator 168 may be implemented as part of wireless communication unit 104, e.g., as part of radio 134, to estimate the DC component of a wireless communication packet received by wireless communication unit 104, e.g., from wireless communication unit 132. In other embodiments, DC estimator 168 may be implemented as part of any other element of device 102.

In some demonstrative embodiments, radio 134 may include an Analog to Digital Converter (ADC) 171 to convert analog signals of a received wireless communication packet into digital samples to be processed in a time domain 172.

In some demonstrative embodiments, DC estimator 168 may be implemented, for example, to estimate the DC component in time domain 172.

In some demonstrative embodiments, radio 134 may also include an Acquisition (ACQ) unit 174 configured to detect a plurality of sequences of a preamble of the wireless communication packet and to estimate a frequency offset between the sequences, e.g., based on samples 175 received from time domain 172.

In some demonstrative embodiments, time domain 172 may provide calibrated signals,

e.g., DC and/or offset calibrated signals, to be processed by a frequency domain 173.

In some demonstrative embodiments, DC estimator 168 may be configured to estimate a DC component of the received wireless communication packet based on the samples of the preamble of the wireless communication packet, e.g., based on the samples provided by ADC
5 171.

In some demonstrative embodiments, DC estimator 168 may estimate the DC component based on a first value corresponding to at least a first sequence of the preamble, and a second value corresponding to at least a second sequence of the preamble, e.g., as described in detail below.

10 In some demonstrative embodiments, the first value may be based on a first plurality of samples including at least a plurality of samples of the first sequence, and/or the second value may be based on a second plurality of samples including at least a plurality of samples of the second sequence. The second sequence may be immediately successive to the first sequence.

In some demonstrative embodiments, DC estimator 168 may estimate the DC component
15 based on the first and second values and an estimated frequency offset corresponding to a frequency offset between the first and second pluralities of samples, as described in detail below. For example, DC estimator 168 may receive the frequency offset from ACQ unit 174, e.g., as described below.

In some demonstrative embodiments, DC estimator 168 may estimate the DC component
20 based on a predefined section of the preamble, which has an average zero mean value, e.g., as described in detail below.

In some demonstrative embodiments, the first sequence may include a second to last sequence of a Short training Field (STF) of the preamble, and the second sequence may include a last sequence of the STF field, e.g., as described in detail below.

25 Some demonstrative embodiments are described below with reference to DC estimation based on a section of a preamble including a first sequence, e.g., the Golay sequence $G_{A_{128}}$, followed by a second sequence, e.g., the Golay sequence $-G_{A_{128}}$, which is an inverse of the first sequence. However, in other embodiments, the DC estimation may be performed with respect to any other section, e.g., any other section of the wireless communication packet, any section of
30 the preamble of the packet and/or any other section of the STF, including any other Golay sequences and/or any other one or more sequences having an average mean value.

Reference is made to Fig. 2, which schematically illustrates a preamble 200 of a wireless communication packet, in accordance with some demonstrative embodiments. For example, wireless communication unit 104 (Fig. 1) may receive the wireless communication packet

including preamble 200, and DC estimator 168 (Fig. 1) may estimate the DC component of the wireless communication packet based on preamble 200.

As shown in Fig. 2, preamble 200 may include a STF 202 followed by a Channel Estimation (CE) field 204.

5 As shown in Fig. 2, STF 202 may include a plurality of Golay sequences. For example, STF 202 may include a repetition of a first Golay sequence followed by a second Golay sequence, which is an inverse of the first Golay sequence. In one example, as shown in Fig. 2, STF 202 may include a repetition of the Golay sequence Ga_{128} followed by the Golay sequence $-Ga_{128}$, e.g., such that a second to last sequence 206 of STF 202 includes the Golay sequence Ga_{128} , and a last sequence 208 of the STF 202 includes the Golay sequence $-Ga_{128}$.

As shown in Fig. 2, CE field 204 may begin with a sequence 210, which may be immediately successive to sequence 208. For example, sequence 210 may include the Golay sequence $-Gb_{128}$.

15 In some demonstrative embodiments, a beginning portion 220 of sequence 210 may include a plurality of values, which are an inverse, of a respective plurality of values included in a first portion 218 of sequence 208. For example, by definition, a plurality of values at the beginning of the Golay sequence $-Gb_{128}$ may be an inverse of a respective plurality of values at the beginning of the Golay sequence $-Ga_{128}$.

20 In some demonstrative embodiments, the plurality of values of portion 220 may be identical to a respective plurality of values of a beginning portion 212 of sequence 206. For example, by definition, the plurality of values at the beginning of the Golay sequence $-Gb_{128}$ may be identical to a respective plurality of values at the beginning of the Golay sequence Ga_{128} .

25 In one example, sequences 206, 208 and 210 may each include 128 values, and portions 212, 218 and 220 may include the first 64 values of sequences 206, 208 and 210, respectively. In other embodiments, sequences 206, 208 and 210 and/or portions 212, 218 and 220 may include any other number of values.

Referring back to Fig. 1, in some demonstrative embodiments DC estimator 168 may estimate the DC component based on the first plurality of samples including at least a plurality of samples of sequence 206 (Fig. 2), the second plurality of samples including at least a plurality of samples of sequence 208 (Fig. 2), and an estimated frequency offset corresponding to a frequency offset between the first and second pluralities of samples, as described in detail below.

In some demonstrative embodiments, DC estimator 168 may estimate the DC component based on samples corresponding to a section of STF 202 (Fig. 2) including sequences 206 (Fig. 2) and 208 (Fig. 2), which may have an average zero-mean value, e.g., since sequence 208 (Fig.

2) is an inverse of sequence 206 (Fig. 2).

In some demonstrative embodiments, the boundaries of sequence 206 (Fig. 2) and/or sequence 208 (Fig. 2) may be detected based on information received from ACQ unit 174.

In some demonstrative embodiments, ACQ unit 174 may be configured to generate an indication (“detect position”) of a detected beginning of each sequence of STF 202 (Fig. 2). For example, ACQ unit 174 may generate a first detect position indication at a detected beginning of a first Golay sequence of STF 202 (Fig. 2), a second detect position indication at a detected beginning of a second Golay sequence of STF 202 (Fig. 2), and so on, e.g., until generating a detect position indication at a detected beginning of sequence 206 (Fig. 2), and a subsequent detect position indication at a detected beginning of sequence 208 (Fig. 2).

In some demonstrative embodiments, ACQ unit 174 may be configured to generate an indication (“sync position”) of a detected end of STF 202 (Fig. 2).

In some demonstrative embodiments, the detected position indications may be offset from an actual timing of a beginning of sequence 206 (Fig. 2) and/or beginning of sequence 208 (Fig. 2), and/or the sync position indication may be offset from an actual timing of an actual end of STF 202 (Fig. 2), e.g., due to one or more timing offset errors.

Accordingly, a plurality of samples, which are sampled between the detected position indicator corresponding to sequence 206 (Fig. 2), and the sync position indicator corresponding to the end of STF 202 (Fig. 2), may be offset with respect to sequences 206 (Fig. 2) and 208 (Fig. 2).

For example, a negative timing offset error between the detected position indicators and the beginning of the sequences of STF 202 (Fig. 2) may result in the plurality of samples including samples of some values of a sequence immediately preceding sequence 206 (Fig. 2), followed by samples of the values of sequence 206 (Fig. 2), and followed by samples of only some values of sequence 208 (Fig. 2).

Conversely, a positive timing offset error between the detected position indicators and the beginning of the sequences of STF 202 (Fig. 2) may result in the plurality of samples including samples of only some values of sequence 206 (Fig. 2), followed by samples of the values of sequence 208 (Fig. 2), and followed by samples of some values of sequence 210 (Fig. 2).

In some demonstrative embodiments, the mean value of the plurality of samples corresponding to sequences 206 and 208 (Fig. 2) may depend on the magnitude and direction of the timing offset errors. For example, the mean value of the plurality of values may be different from zero, e.g., if the plurality of samples is offset with respect to sequences 206 and 208 (Fig. 2), for example, if the plurality of samples does not include only pairs of inverse values, which

may “cancel” each other out.

Accordingly, the DC estimation, if based on the mean of the plurality of samples, may have an error, which may depend on the magnitude and direction of the timing offset errors.

Reference is now made to Fig. 3, which schematically illustrates a graph depicting a DC estimation error versus a timing offset, in accordance with some demonstrative embodiments. In one example, the DC estimation error depicted by Fig. 3 may correspond to an error of a DC estimation, which is based on the first and second pluralities of samples corresponding to sequences 206 and 208 (Fig. 2), and the timing offset depicted by Fig. 3 may represent a timing offset of the detected position indicators, e.g., provided by ACQ unit 174 (Fig. 1).

As shown in Fig. 3, a negative timing offset may result in an increased DC estimation error, while a positive timing offset may result in substantially no change in the DC estimation error, e.g., compared to a DC estimation error at a zero timing offset.

In some demonstrative embodiments, the zero timing offset may result in the DC estimation being determined based on the first plurality of samples including only samples of values of sequence 206 (Fig. 2) and the second plurality of samples including only samples of values of sequence 208 (Fig. 2).

In some demonstrative embodiments, the positive time offset may result in the DC estimation being determined based on the first plurality of samples including samples of a portion 214 (Fig. 2) of STF 202 (Fig. 2) and the second plurality of samples including samples of a portion 216 (Fig. 2) of STF 202 (Fig. 2), subsequent to portion 214 (Fig. 2).

In some demonstrative embodiments, the positive timing offset may be assumed to be no longer than a duration of portion 212 (Fig. 2), e.g., no longer than the duration of the 64 first values of the Golay sequence Ga_{128} of sequence 206 (Fig. 2).

Accordingly, portion 214 (Fig. 2) may include one or more consecutive values 230 of an end of portion 212 (Fig. 2), followed by values of sequence 206 (Fig. 2) subsequent to portion 212 (Fig. 2), and followed by one or more consecutive values 232 of a beginning of portion 218 (Fig. 2). Similarly, portion 216 (Fig. 2) may include one or more consecutive values 234 of an end of portion 218 (Fig. 2), followed by values of sequence 208 (Fig. 2) subsequent to portion 218 (Fig. 2), and followed by one or more consecutive values 236 of a beginning of portion 220 (Fig. 2). Values 230, 232, 234 and 236 may include the same number of values.

In some demonstrative embodiments, values 236 (Fig. 2) may include the inverse of values 232 (Fig. 2), e.g., as described above. Accordingly, a section including portions 214 (Fig. 2) and 216 (Fig. 2) may have an average zero-mean value. Therefore, the DC estimation error may not be affected by the positive timing offset, for example, as long as the positive timing offset is no

not greater than the duration of portion 212 (Fig 2).

Referring back to Fig. 1, in some demonstrative embodiments, DC estimator 168 may utilize a predefined positive timing offset, e.g., to increase a probability that the DC estimation is being determined based on the first plurality of samples including samples of portion 214 (Fig. 2) and the second plurality of samples including samples of portion 216 (Fig. 2), e.g., even if the timing offset is negative.

In one example, DC estimator 168 may select the first and second pluralities of samples to be positively offset by a predefined number of samples from the detect position indication. For example, if portion 212 (Fig 2) includes 64 values, as described above, then utilizing a positive offset of 30 samples may enable a timing offset error with a tolerance of $[-30, +33]$ samples.

In some demonstrative embodiments, there may be a frequency offset between portions 214 (Fig 2) and 216 (Fig. 2). This frequency offset may result in a rotation of portion 216 (Fig. 2) relative to portion 214 (Fig. 2).

In some demonstrative embodiments, DC estimator 168 may determine the first value including a mean, denoted m_1 , of the first plurality of samples, e.g., corresponding to portion 214 (Fig. 2), and the second value including a mean, denoted m_2 , of the second plurality of samples, e.g., corresponding to portion 216 (Fig. 2).

In some demonstrative embodiments, DC estimator 168 may determine the DC component of the wireless communication packet based on the mean values m_1 and m_2 , and an estimated frequency offset, denoted θ , between portions 214 and 216 (Fig. 2). The estimated frequency offset θ may be received, for example, from ACQ unit 174 (Fig. 1).

In some demonstrative embodiments, DC estimator 168 may determine the DC component of the wireless communication packet based on a sum of the mean values m_1 and m_2 , a difference between values m_1 and m_2 , and the estimated frequency offset θ , e.g., as described below. In other embodiments, DC estimator 168 may determine the DC component of the wireless communication packet based on any other combination of the mean values m_1 and m_2 , and/or the estimated frequency offset θ .

In some demonstrative embodiments, the mean value m_1 may represent a combination of a DC component, denoted dc , of the wireless communication packet; a mean, denoted dc_s , of the values of the sequence 206 (Fig. 2), e.g., a mean of the Golay sequence Ga_{128} ; and a noise component, denoted v_1 . The mean value m_2 may represent a combination of the DC component dc ; the mean dc_s ; the estimated frequency offset θ , and a noise component, denoted v_2 . For example, the mean values m_1 and m_2 may be represented as follows:

$$m_1 = dc + dc_s + v_1 \quad (1)$$

$$m_2 = dc - dc_s e^{j\theta} + v_2 \quad (2)$$

In some demonstrative embodiments, the DC component of the wireless communication packet may be estimated based on the mean values m_1 and m_2 of Equations 1 and 2. For example, the estimated DC component, denoted dc_{est} , may be estimated by combining and rearranging Equations 1 and 2, e.g., as follows:

$$\begin{aligned} dc_{est} &= \frac{m_1 + m_2 e^{-j\theta}}{1 + e^{-j\theta}} = \frac{e^{-j\frac{\theta}{2}} \left(m_1 e^{+j\frac{\theta}{2}} + m_2 e^{-j\frac{\theta}{2}} \right)}{e^{-j\frac{\theta}{2}} \left(e^{+j\frac{\theta}{2}} + e^{-j\frac{\theta}{2}} \right)} \\ &= \frac{1}{2} \cdot \left[(m_1 + m_2) + j(m_1 - m_2) \tan\left(\frac{\theta}{2}\right) \right] \end{aligned} \quad (3)$$

In some demonstrative embodiments, DC estimator 168 may determine the mean values m_1 and m_2 by calculating the means of the first and second pluralities of samples corresponding to portions 214 and 216 (Fig. 2). DC estimator 168 may also receive the estimated frequency offset θ , e.g., from ACQ unit 174 (Fig. 1).

In some demonstrative embodiments, DC estimator 168 may determine the estimated DC component of the wireless communication packet according to Equation 3. Equation 3 may have low computational complexity, which may require summation operations and a real multiplication operation.

In some demonstrative embodiments, the received wireless communication packet may also be subject to phase noise, which may result in a phase rotation. However, it may be assumed that the estimation of the DC component is not substantially affected by the phase noise, e.g., since the phase noise may be relatively highly correlated over the number of samples included in each of the first and second pluralities of samples, e.g., 128 samples, and/or the mean dc_s may be relatively weak.

In some demonstrative embodiments, DC estimator 168 may utilize a predefined buffering scheme for buffering the first and second values corresponding to the first and second pluralities of samples. The buffering scheme may be configured to reduce delay and/or reduce buffer size, e.g., as described below. In other embodiments, any other buffering scheme may be utilized.

In some demonstrative embodiments, DC estimator 168 may include first and second buffers 169 to buffer first and second mean values, respectively. For example, buffers 169 may include First in First out (FIFO) buffers. In one example, a first buffer 169 may buffer a mean value of a first plurality of samples, including a predefined number of samples, which are sampled upon receiving a detect position indication; and a second buffer 169 may buffer a mean value of a second plurality of samples, including the predefined number of samples, which are

sampled upon an immediately subsequent detect position indication. According to this buffering scheme, the first and second buffers 169 may include the mean values of samples corresponding to two successive most recently sampled sequences of STF 202 (Fig. 2). Accordingly, the first and second buffers 169 may include mean values corresponding to sequences 206 and 208 (Fig. 2), respectively, when the sync position indication is received.

Reference is made to Fig. 4, which schematically illustrates a timing of DC estimation, in accordance with some demonstrative embodiments. In some demonstrative embodiments, one or more elements of system 100 (Fig. 1), e.g., DC estimator 168 (Fig. 1) and/or ACQ unit 174 (Fig. 1), may perform one or more operations according to the timeline of Fig. 4.

In some demonstrative embodiments, one or more operations may be performed with respect to one or more sequences at the beginning of an STF 401 of a received wireless communication packet. For example, STF 401 may have a structure similar to STF 202 (Fig. 2). For example, an Automatic Gain Control (AGC) operation may be performed during an AGC phase 402, e.g., based on a plurality of Golay sequences at the beginning of STF 401.

In some demonstrative embodiments, a detection phase 404 may be performed subsequent to AGC phase 402. For example, ACQ unit 174 (Fig. 1) may detect the beginning of the Golay sequences of STF 401.

In some demonstrative embodiments, DC estimator 168 (Fig. 1) may calculate a first mean value 408 and a second mean value 410 of samples corresponding to a pair of first and second subsequent sequences of STF 401, and may store the mean values 408 and 410 in a pair of registers 412 and 414, e.g., as described above.

In some demonstrative embodiments, registers 412 and 414 may include the mean values m_1 and m_2 corresponding to sequences 206 and 208 (Fig. 2), e.g., upon completion of a synchronization phase 406.

In some demonstrative embodiments, a Frequency Offset Estimation (FOE) 409 may be performed, e.g., by ACQ unit 174 (Fig. 1), to estimate the frequency offset based on STF 401.

In some demonstrative embodiments, DC estimation 416 may be performed based on the mean values m_1 and m_2 stored by registers 412 and 414, when the sync position indication is received. For example, DC estimator 168 (Fig. 1) may estimate the DC component of the wireless communication packet according to Equation 3.

Fig. 5 is a schematic illustration of three graphs depicting a Packet Error Rate (PER) versus Signal to Noise Ratio (SNR) with respect to three DC simulation scenarios, in accordance with some demonstrative embodiments.

For example, a first graph 502 may correspond to a DC of -100 decibels relative to the

carrier (dBc), a second graph 504 may correspond to a DC of -10dBc without timing offset and without applying a timing shift to the samples, and a third graph 506 may correspond to a DC of -10dBc with a random timing offset and with a timing shift of 30 samples, e.g., as described above.

5 As shown in Fig. 5, there may be negligible differences between graphs 502, 504 and 506. This similarity between graphs 502, 504 and 506 may indicate that a relatively high level of accuracy, e.g., less than -30dBc, may be achieved with respect to the estimation of the DC component, e.g., as described above.

10 As also shown in Fig. 5, applying the timing offset of 30 samples may successfully mitigate preamble timing location errors.

Reference is made to Fig. 6, which schematically illustrates a method of DC estimation, in accordance with some demonstrative embodiments. In some embodiments, one or more of the operations of the method of Fig. 6 may be performed by a wireless communication system e.g., system 100 (Fig. 1); a wireless communication device, e.g., devices 102 and/or 130 (Fig. 1); a
15 wireless communication unit, e.g., wireless communication units 104 and/or 132 (Fig. 1); and/or a DC estimator, e.g., DC estimator 168 (Fig. 1).

As indicated at block 602, the method may include determining a first value based on a first plurality of samples including at least a plurality of samples of a first sequence of a preamble of a wireless communication packet. For example, DC estimator 168 (Fig. 1) may
20 determine the mean value m_1 based on a first plurality of samples corresponding to sequence 206 (Fig. 2), e.g., as described above.

As indicated at block 604, the method may include determining a second value based on a second plurality of samples including at least a plurality of samples of a second sequence, immediately successive to the first sequence. For example, DC estimator 168 (Fig. 1) may
25 determine the mean value m_2 based on a second plurality of samples corresponding to sequence 208 (Fig. 2), e.g., as described above.

As indicated at block 606, the method may include offsetting the first and second pluralities of samples with respect to a detected beginning of the first and second sequences. For example, DC estimator 168 (Fig. 1) may offset the first and second pluralities of samples with
30 respect to a detected beginning of sequences 206 and 208 (Fig. 1), for example, such that the first and second pluralities of samples include samples of portions 214 and 216 (Fig. 2), e.g., as described above.

As indicated at block 608, the method may include estimating a frequency offset between the first and second sequences. For example, ACQ unit 174 (Fig. 1) may estimate the frequency

offset θ , e.g., as described above.

As indicated at block 610, the method may include estimating a DC component corresponding to the wireless communication signal based on the first and second values and the estimated frequency offset. For example, DC estimator 168 may estimate the DC component of the received wireless communication signal based on the mean values m_1 and m_2 and the frequency offset θ , for example, according to Equation 3, e.g., as described above.

Reference is made to Fig. 7, which schematically illustrates a product of manufacture 700, in accordance with some demonstrative embodiments. Product 700 may include a non-transitory machine-readable storage medium 702 to store logic 704, which may be used, for example, to perform at least part of the functionality of device 102 (Fig. 1), device 130 (Fig. 1), wireless communication unit 104 (Fig. 1), wireless communication unit 132 (Fig. 1), DC estimator 168 (Fig. 1), and/or to perform one or more operations of the method of Fig. 6. The phrase “non-transitory machine-readable medium” is directed to include all computer-readable media, with the sole exception being a transitory propagating signal.

In some demonstrative embodiments, product 700 and/or machine-readable storage medium 702 may include one or more types of computer-readable storage media capable of storing data, including volatile memory, non-volatile memory, removable or non-removable memory, erasable or non-erasable memory, writeable or re-writable memory, and the like. For example, machine-readable storage medium 702 may include, RAM, DRAM, Double-Data-Rate DRAM (DDR-DRAM), SDRAM, static RAM (SRAM), ROM, programmable ROM (PROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), Compact Disk ROM (CD-ROM), Compact Disk Recordable (CD-R), Compact Disk Rewritable (CD-RW), flash memory (e.g., NOR or NAND flash memory), content addressable memory (CAM), polymer memory, phase-change memory, ferroelectric memory, silicon-oxide-nitride-oxide-silicon (SONOS) memory, a disk, a floppy disk, a hard drive, an optical disk, a magnetic disk, a card, a magnetic card, an optical card, a tape, a cassette, and the like. The computer-readable storage media may include any suitable media involved with downloading or transferring a computer program from a remote computer to a requesting computer carried by data signals embodied in a carrier wave or other propagation medium through a communication link, e.g., a modem, radio or network connection.

In some demonstrative embodiments, logic 704 may include instructions, data, and/or code, which, if executed by a machine, may cause the machine to perform a method, process and/or operations as described herein. The machine may include, for example, any suitable processing platform, computing platform, computing device, processing device, computing

system, processing system, computer, processor, or the like, and may be implemented using any suitable combination of hardware, software, firmware, and the like.

In some demonstrative embodiments, logic 704 may include, or may be implemented as, software, a software module, an application, a program, a subroutine, instructions, an instruction set, computing code, words, values, symbols, and the like. The instructions may include any suitable type of code, such as source code, compiled code, interpreted code, executable code, static code, dynamic code, and the like. The instructions may be implemented according to a predefined computer language, manner or syntax, for instructing a processor to perform a certain function. The instructions may be implemented using any suitable high-level, low-level, object-oriented, visual, compiled and/or interpreted programming language, such as C, C++, Java, BASIC, Matlab, Pascal, Visual BASIC, assembly language, machine code, and the like.

Functions, operations, components and/or features described herein with reference to one or more embodiments, may be combined with, or may be utilized in combination with, one or more other functions, operations, components and/or features described herein with reference to one or more other embodiments, or vice versa.

While certain features have been illustrated and described herein, many variations, modifications, substitutions, changes, additions, improvements and equivalents may occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS

What is claimed is:

1. An apparatus comprising:
a direct current (DC) estimator to estimate a DC component of a received wireless
5 communication packet based on a first value, a second value and an estimated frequency offset,
wherein the first value is based on a first plurality of samples including at least a plurality of
samples of a first sequence of a preamble of said wireless communication packet, the second
value is based on a second plurality of samples including at least a plurality of samples of a
second sequence of the preamble, immediately successive to said first sequence, and the
10 estimated frequency offset corresponds to a frequency offset between said first and second
pluralities of samples.
2. The apparatus of claim 1, wherein said first value includes a mean of said first plurality
of samples, and wherein said second value includes a mean of said second plurality of samples.
3. The apparatus of claim 1 or 2, wherein said DC estimator is to estimate said DC
15 component based on a sum of said first and second values, a difference between said first and
second values, and said estimated frequency offset.
4. The apparatus of any one of claims 1-3, wherein said second sequence is an inverse of
said first sequence.
5. The apparatus of any one of claims 1-4, wherein said first plurality of samples is
20 positively offset from a detected beginning of said first sequence, and wherein said second
plurality of samples is positively offset from a detected beginning of said second sequence.
6. The apparatus of any one of claims 1-5, wherein said first plurality of samples includes
samples of a first plurality of values of said first sequence and samples of a second plurality of
values of said second sequence, and wherein said second plurality of samples includes samples
25 of a third plurality of values of said second sequence and samples of a fourth plurality of values
of a third sequence of said preamble, immediately successive to said second sequence.
7. The apparatus of claim 6, wherein said fourth plurality of values includes an inverse of
said second plurality of values.

8. The apparatus of any one of claims 1-7, wherein the first and second sequences include Golay sequences.

9. The apparatus of claim 8, wherein said first sequence includes the Golay sequence Ga_{128} , and wherein the second sequence includes the Golay sequence $-Ga_{128}$.

5 10. The apparatus of any one of claims 1-9, wherein the first sequence includes a second to last sequence of a Short training Field (STF) of said preamble, and wherein the second sequence includes a last sequence of the STF field.

11. A system comprising:

10 a wireless communication device including the apparatus of any one of claims 1-10, said wireless communication device including:

one or more antennas to receive said wireless communication packet; and
said DC estimator to estimate said DC component of the wireless communication packet.

12. The system of claim 11, wherein said wireless communication device comprises first
15 and second registers to store said first and second values.

13. The system of claim 11 or 12, wherein said wireless communication device comprises an Acquisition (ACQ) unit to estimate said frequency offset, and to detect a beginning of said first and second sequences.

14. A method comprising:

20 estimating a direct current (DC) component of a received wireless communication packet based on a first value, a second value and an estimated frequency offset, wherein the first value is based on a first plurality of samples including at least a plurality of samples of a first sequence of a preamble of said wireless communication packet, the second value is based on a second plurality of samples including at least a plurality of samples of a second sequence of the
25 preamble, immediately successive to said first sequence, and the estimated frequency offset corresponding to a frequency offset between said first and second pluralities of samples.

15. The method of claim 14, wherein said first value includes a mean of said first plurality of samples, and wherein said second value includes a mean of said second plurality of samples.

16. The method of claim 14 or 15 comprising estimating said DC component based on a sum of said first and second values, a difference between said first and second values, and said estimated frequency offset.

17. The method of any one of claims 14-16 comprising positively offsetting said first plurality of samples from a detected beginning of said first sequence, and positively offsetting said second plurality of samples from a detected beginning of said second sequence.

18. The method of any one of claims 14-17, wherein said first plurality of samples includes samples of a first plurality of values of said first sequence and samples of a second plurality of values of said second sequence, and wherein said second plurality of samples includes samples of a third plurality of values of said second sequence and samples of a fourth plurality of values of a third sequence of said preamble, immediately successive to said second sequence.

19. The method of any one of claims 14-18, wherein the first sequence includes a second to last sequence of a Short training Field (STF) of said preamble, and wherein the second sequence includes a last sequence of the STF field.

20. A product including a non-transitory storage medium having stored thereon instructions that, when executed by a machine, result in the method of any one of claims 14-19.

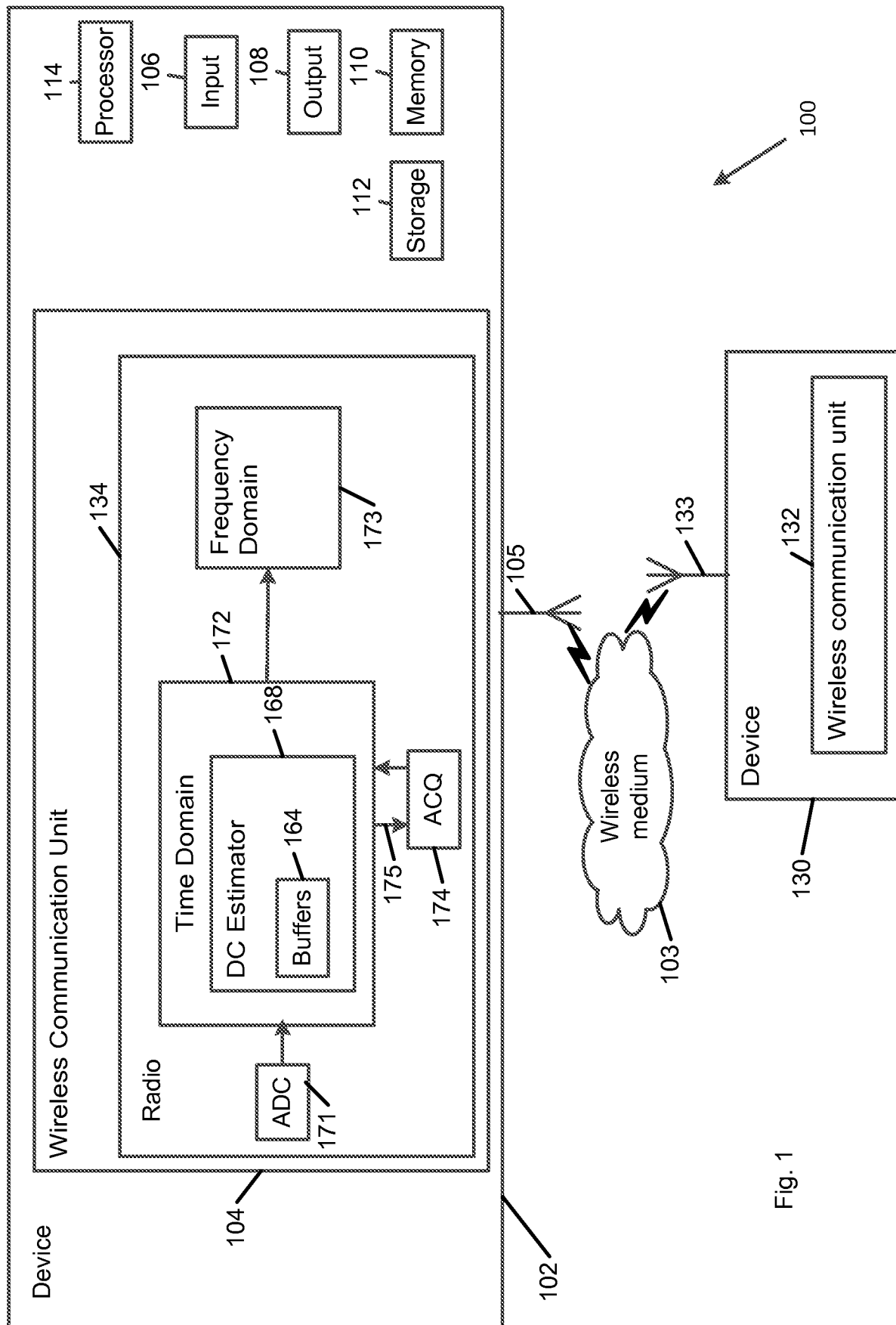
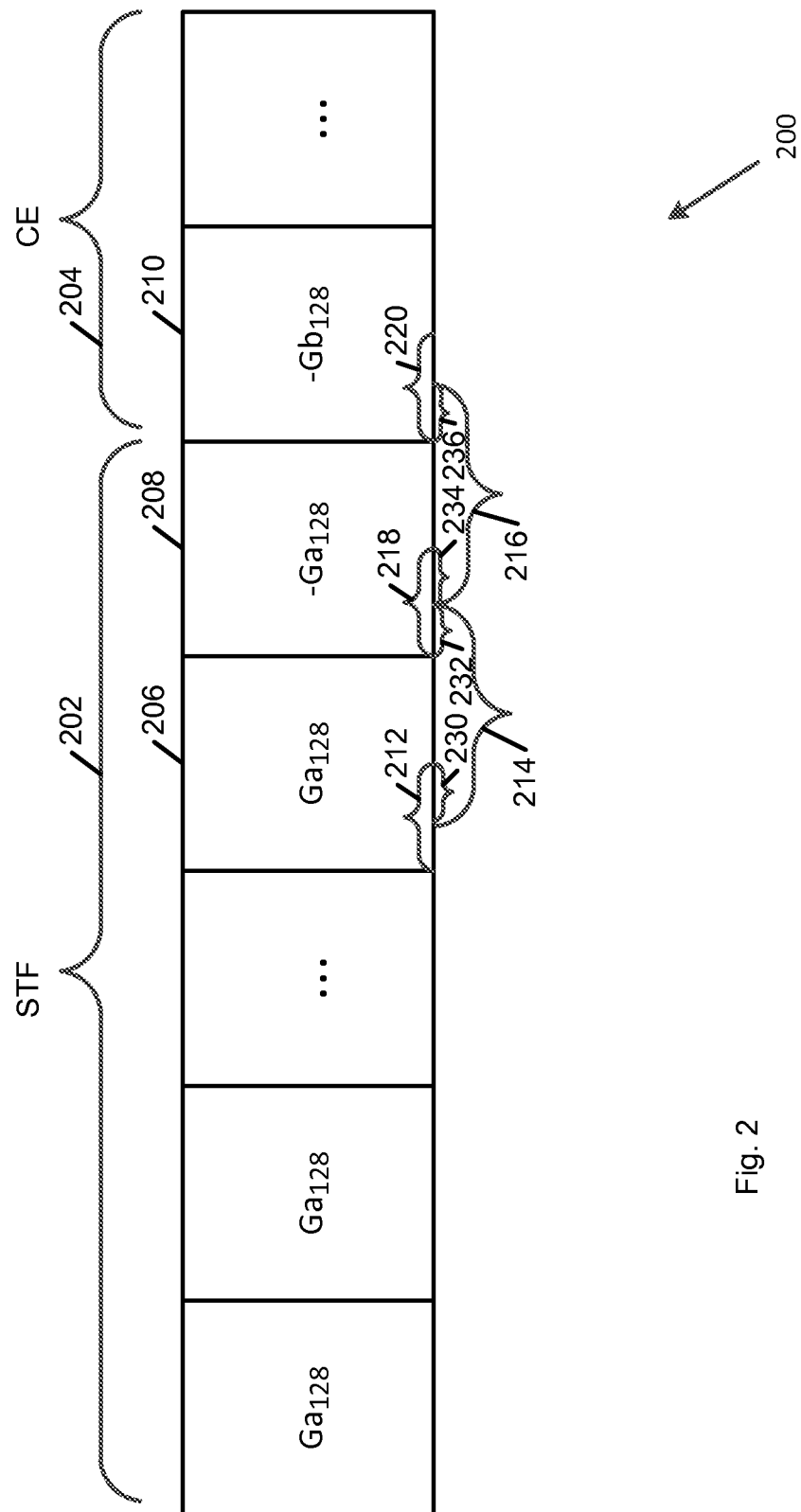


Fig. 1



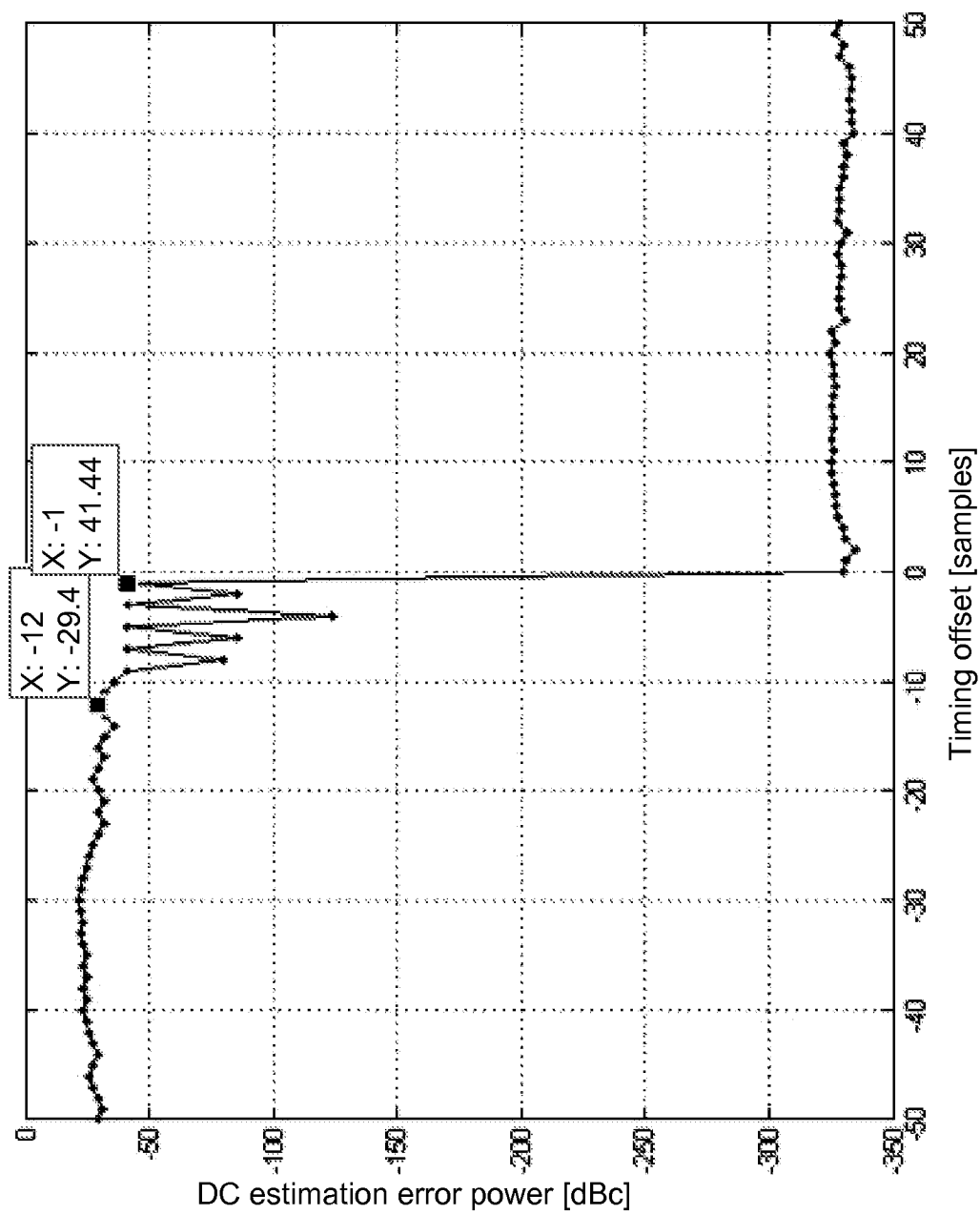


Fig. 3



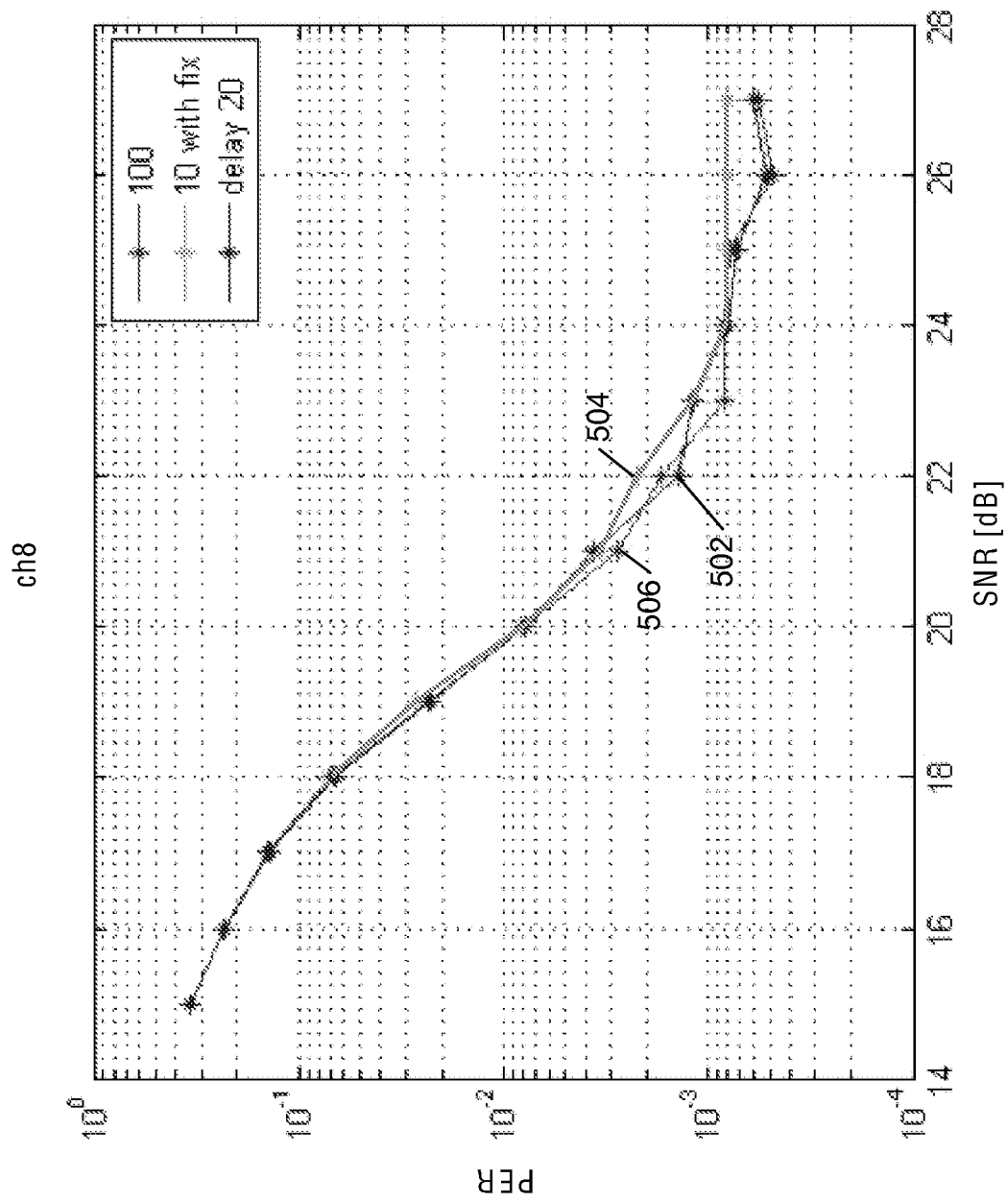


Fig. 5

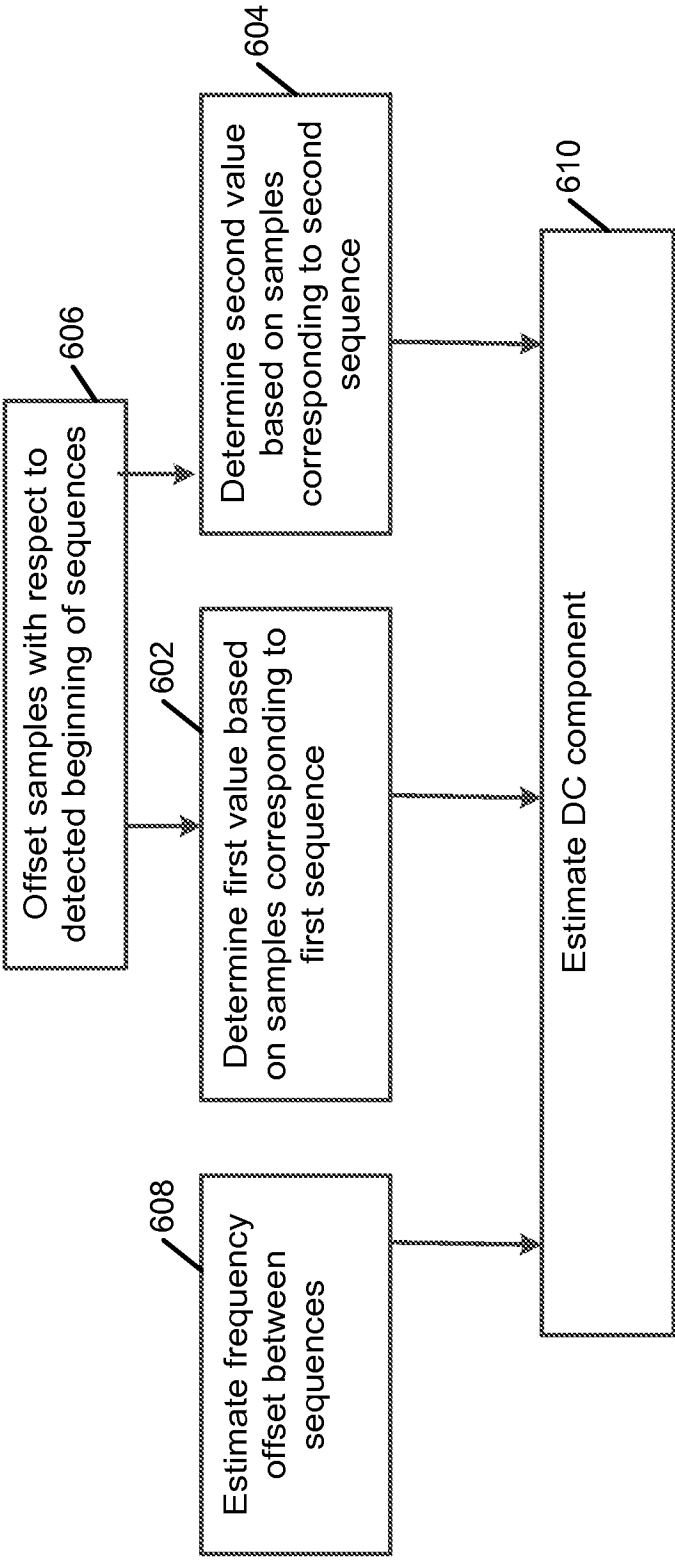


Fig. 6

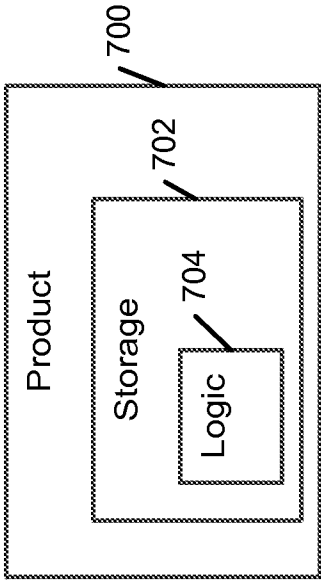


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/047210**A. CLASSIFICATION OF SUBJECT MATTER****H04B 7/005(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B 7/005; H04W 24/00; H04L 25/06; H04L 7/02; H04B 1/06; H04W 72/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: direct current (DC) estimator, DC impairment, communication packet, frequency offset, mitigation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009-0285334 A1 (NEIL BIRKETT et al.) 19 November 2009 See paras. 12-17, 28-35; claim 1; and figs. 3-4.	1-3, 14-16
A	US 2011-0122852 A1 (ZHI-ZHONG YU et al.) 26 May 2011 See paras. 149, 183, 219-222; claim 1; and figs. 13, 35.	1-3, 14-16
A	US 2010-0316175 A1 (CHAOHUANG ZENG et al.) 16 December 2010 See paras. 29-33, 42; claim 15; and figs. 5-6.	1-3, 14-16
A	US 2007-0190957 A1 (DANIEL F. FILIPOVIC) 16 August 2007 See paras. 52, 55-57; claim 1; and figs. 5-6.	1-3, 14-16
A	KR 10-0270310 B1 (KOREA TELECOMMUNICATION) 16 October 2000 See pp. 2-3; claim 1; and figs. 1-3.	1-3, 14-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 October 2013 (15.10.2013)

Date of mailing of the international search report

15 October 2013 (15.10.2013)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City,
302-701, Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

KANG Hee Gok

Telephone No. +82-42-481-8264



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2013/047210**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 7, 9, 12
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
The claims 7, 9 and 12 do not comply with PCT Article 6 because they are referring to unsearchable claims 6, 8 and 11 respectively.
3. ☒ Claims Nos.: 4-6, 8, 10-11, 13, 17-20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/047210

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009-0285334 A1	19/11/2009	CN 1998213 A	11/07/2007
		CN 1998213 B	29/09/2010
		CN 1998213 C0	11/07/2007
		EP 1665708 A1	07/06/2006
		EP 1665708 A4	10/12/2008
		JP 04675323 B2	20/04/2011
		JP 2007-505525 A	08/03/2007
		KR 10-1078570 B1	01/11/2011
		KR 10-2007-0008508 A	17/01/2007
		US 2005-0058227 A1	17/03/2005
		US 7567631 B2	28/07/2009
		US 8085879 B2	27/12/2011
		WO 2005-027453 A1	24/03/2005
US 2011-0122852 A1	26/05/2011	AU 2008-298613 A1	19/03/2009
		AU 2009-292127 A1	18/03/2010
		CA 2696297 A1	19/03/2009
		CA 2732960 A1	25/02/2010
		CA 2735471 A1	18/03/2010
		CA 2802955 A1	19/03/2009
		CA 2803074 A1	19/03/2009
		CN 101816157 A	25/08/2010
		CN 102119514 A	06/07/2011
		CN 102124710 A	13/07/2011
		CN 102150404 A	10/08/2011
		CN 102187631 A	14/09/2011
		CN 102651681 A	29/08/2012
		CN 102664847 A	12/09/2012
		CN 102684863 A	19/09/2012
		CN 102685763 A	19/09/2012
		EP 2204027 A2	07/07/2010
		EP 2209272 A1	21/07/2010
		EP 2209273 A1	21/07/2010
		EP 2209274 A1	21/07/2010
		EP 2230808 A1	22/09/2010
		EP 2329629 A1	08/06/2011
		EP 2329629 B1	17/04/2013
		EP 2338259 A1	29/06/2011
		EP 2342878 A1	13/07/2011
		EP 2342878 B1	19/06/2013
		EP 2342879 A1	13/07/2011
		EP 2342879 B1	10/04/2013
		EP 2544422 A2	09/01/2013
		EP 2544422 A3	15/05/2013
		EP 2608473 A2	26/06/2013
		JP 2010-539817 A	16/12/2010
		JP 2012-500561 A	05/01/2012
		JP 2012-500562 A	05/01/2012
		JP 2012-500579 A	05/01/2012

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/047210

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		JP 2012-502582 A	26/01/2012
		KR 10-1100015 B1	29/12/2011
		KR 10-1100952 B1	29/12/2011
		KR 10-1114063 B1	23/04/2012
		KR 10-1114105 B1	15/05/2012
		KR 10-1114132 B1	10/04/2012
		KR 10-1258488 B1	26/04/2013
		KR 10-1266071 B1	21/05/2013
		KR 10-1266075 B1	21/05/2013
		KR 10-1267406 B1	04/06/2013
		KR 10-2011-0044323 A	28/04/2011
		TW 200931850 A	16/07/2009
		TW 201010315 A	01/03/2010
		TW 201010353 A	01/03/2010
		TW 201010477 A	01/03/2010
		TW 201012110 A	16/03/2010
		TW 201108680 A	01/03/2011
		US 2011-0077017 A1	31/03/2011
		US 2011-0134809 A1	09/06/2011
		US 2011-0149778 A1	23/06/2011
		US 2011-0170482 A1	14/07/2011
		US 2011-0267968 A1	03/11/2011
		US 8374156 B2	12/02/2013
		WO 2009-036389 A2	19/03/2009
		WO 2009-036389 A3	30/07/2009
		WO 2010-021634 A1	25/02/2010
		WO 2010-021635 A1	25/02/2010
		WO 2010-021637 A1	25/02/2010
		WO 2010-021947 A1	25/02/2010
US 2010-0316175 A1	16/12/2010	US 7751520 B1	06/07/2010
		US 8270528 B2	18/09/2012
US 2007-0190957 A1	16/08/2007	AT 365394 T	15/07/2007
		AU 2003-231116 A1	10/11/2003
		CA 2483511 A1	06/11/2003
		DE 60314509 D1	02/08/2007
		DE 60314509 T2	28/02/2008
		EP 1500184 A1	26/01/2005
		EP 1500184 B1	20/06/2007
		ES 2287473 T3	16/12/2007
		HK 1074538 A1	14/09/2007
		JP 2005-524272 A	11/08/2005
		RU 2004134587 A	10/06/2005
		RU 2322753 C2	20/04/2008
		US 2003-0203728 A1	30/10/2003
		US 7212797 B2	01/05/2007
		US 7844239 B2	30/11/2010
		WO 03-092152 A1	06/11/2003

Information on patent family members

PCT/US2013/047210

Form PCT/ISA/210 (patent family annex) (July 2009)