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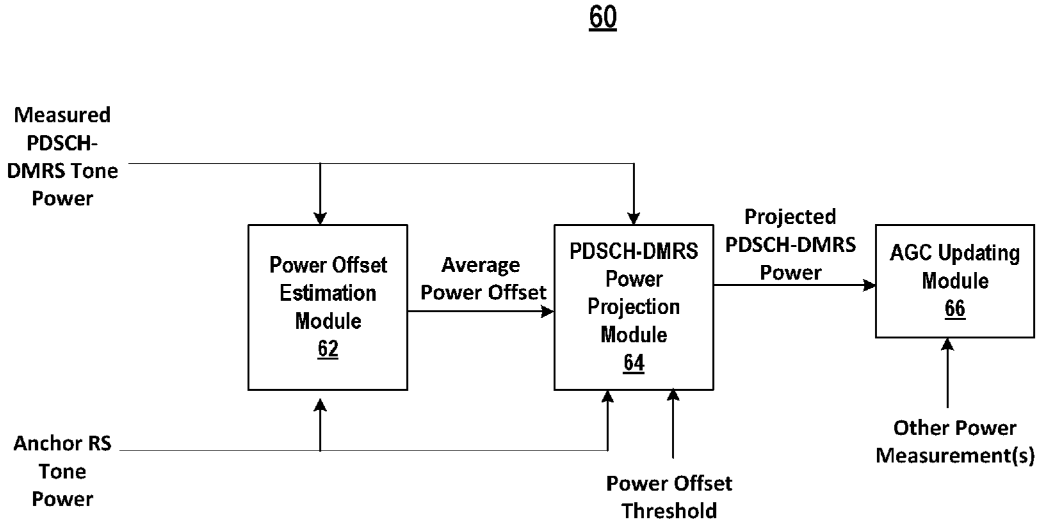

FIG. 6

(57) **Abstract:** Embodiments of apparatuses and methods of power estimation for automatic gain control (AGC) are disclosed. In one example, when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, projected PDSCH-DMRS power may be obtained based on measured anchor reference signal (RS) tone power and a one-shot power offset. The one-shot power offset may indicate power compensation for infrequent PDSCH-DMRS reception at a time point. AGC may be performed based on the projected PDSCH-DMRS power.

[Continued on next page]

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APPARATUS, SYSTEM, AND METHOD OF POWER ESTIMATION FOR AUTOMATIC GAIN CONTROL

BACKGROUND

[0001] Embodiments of the present disclosure relate to apparatuses and methods for wireless communication.

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. In a wireless communication system, a receiver may receive signals from different transmitters at different received power levels and thus may need to perform automatic gain control (AGC) to maintain the baseband signal level within an acceptable range in an attempt to avoid saturation of the receiver circuits and clipping of an analog-to-digital converter (ADC) used to digitize the baseband signal.

SUMMARY

[0003] Embodiments of apparatus, system, and method of power estimation for automatic gain control are disclosed herein.

[0004] In one example, a baseband chip is provided. The baseband chip may include a processor and a storage medium coupled to the processor and storing computer-executable instructions. The computer-executable instructions, when executed by the processor, may cause the processor to when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtain projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and a one-shot power offset. The one-shot power offset may include power compensation for infrequent PDSCH-DMRS reception at a time point. Automatic gain control (AGC) may be performed based on the projected PDSCH-DMRS power.

[0005] In another example, a system is provided. The system may include a radio frequency (RF) chip and a baseband chip. The baseband chip may be configured to: when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtain projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and one-shot power offset. The one-shot power offset may include power compensation for infrequent PDSCH-DMRS reception at a time point. Automatic gain control

(AGC) may be performed based on the projected PDSCH-DMRS power. The AGC may include a digital AGC gain and an analog AGC gain. The baseband chip may be configured to adjust an amplification gain of a digital circuit based on the digital AGC gain; and transmit the analog AGC gain to the RF chip. The RF chip may be configured to adjust an amplification gain of an analog circuit based on the analog AGC gain.

[0006] In still another example, a method of power estimation for AGC is provided. The method may include when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtaining projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and a one-shot power offset, the one-shot power offset may include power compensation for infrequent PDSCH-DMRS reception at a time point; and performing automatic gain control (AGC) based on the projected PDSCH-DMRS power.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate embodiments/implementations of the present disclosure and, together with the description, further serve to explain the principles of the present disclosure and to enable a person skilled in the pertinent art to make and use the present disclosure.

[0008] FIG. 1 illustrates a scenario in which a scheme of power averaging may still cause saturation risk in dynamic resource allocation.

[0009] FIG. 2 illustrates an exemplary wireless network, in which certain aspects of the present disclosure may be implemented.

[0010] FIG. 3 illustrates a block diagram of an exemplary node, according to some implementations of the present disclosure.

[0011] FIG. 4 illustrates a block diagram of an exemplary apparatus including a baseband chip, a radio frequency (RF) chip, and a host chip, according to some implementations of the present disclosure.

[0012] FIGs. 5A and 5B illustrate flow charts of an exemplary method of power estimation for automatic gain control (AGC), according to some implementations of the present disclosure.

[0013] FIG. 6 illustrates a diagram showing an exemplary AGC unit, according to some implementations of the present disclosure.

[0014] FIG. 7 illustrates a diagram showing an exemplary power offset estimation module in an AGC unit, according to some implementations of the present disclosure.

[0015] FIGs. 8A and 8B illustrate diagrams showing portions of an exemplary physical downlink shared channel demodulation reference signal (PDSCH-DMRS) power projection module in an AGC unit, according to some implementations of the present disclosure.

[0016] Embodiments of the present disclosure will be described with reference to the accompanying drawings.

DETAILED DESCRIPTION

[0017] Although specific configurations and arrangements are discussed, it should be understood that this is done for illustrative purposes only. A person skilled in the pertinent art will recognize that other configurations and arrangements can also be used without departing from the spirit and scope of the present disclosure. It will be apparent to a person skilled in the pertinent art that the present disclosure can also be employed in a variety of other applications.

[0018] It is noted that references in the specification to "one embodiment," "an embodiment," "an example embodiment," "some embodiments," "certain embodiments," "other embodiments," "one implementation," "some implementations," "other implementations," "an instance," "some instances," "an example," "some examples," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it would be within the knowledge of a person skilled in the pertinent art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0019] In general, terminology may be understood at least in part from usage in context. For example, the term "one or more" as used herein, depending at least in part upon context, may be used to describe any feature, structure, or characteristic in a singular sense or may be used to describe combinations of features, structures, or characteristics in a plural sense. Similarly, terms, such as "a," "an," or "the," again, may be understood to convey a singular usage or to convey a plural usage, depending at least in part upon context. In addition, the terms "based on" and "according to" may be understood as not necessarily intended to convey an exclusive set of factors and may, instead, allow for the existence of additional factors not necessarily expressly described, again, depending, at least in part, on the context.

[0020] Various aspects of wireless communication systems will now be described with reference to various apparatuses and methods. These apparatuses and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, modules, units, components, circuits, steps, operations, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, firmware, computer software, or any combination thereof. Whether such elements are implemented as hardware, firmware, or software depends upon the particular application and design constraints imposed on the overall system.

[0021] The techniques described herein may be used for various wireless communication networks, such as frequency division multiple access (FDMA) system, orthogonal frequency division multiple access (OFDMA) system, single-carrier frequency division multiple access (SC-FDMA) system, wireless local area network (WLAN) system, and other networks. The terms “network” and “system” are often used interchangeably. A CDMA network may implement a radio access technology (RAT), such as Universal Terrestrial Radio Access (UTRA), evolved UTRA (E-UTRA), CDMA 2000, etc. A TDMA network may implement a RAT, such as the Global System for Mobile Communications (GSM). An OFDMA network may implement a RAT, such as Long-Term Evolution (LTE) or New Radio (NR). A WLAN system may implement a RAT, such as Wi-Fi. The techniques described herein may be used for the wireless networks and RATs mentioned above, as well as other wireless networks and RATs.

[0022] In wireless communication networks, it is crucial to regulate signal strengths at a wireless receiver to maintain suitable signal amplitudes at the analog-to-digital converter (ADC). As such, the desired signal-to-noise ratio (SNR) of the received signals for proper decoding can be acquired. In addition, saturation at the ADC and/or signal clipping may thus be prevented. Due to multi-path fading channels, strong interference, gNodeB (gNB) dynamic resource allocation, etc., however, the received signal strengths may vary and accordingly become unpredictable. To handle a wide dynamic range of input power, various automatic gain control (AGC) algorithms are introduced and implemented in wireless communication systems to continuously monitor the received power. In this way, it can be determined how much gains to be applied to the receiver circuits, e.g., the low noise amplifier (LNA) module at the receiver.

[0023] In some technical solutions, based on recently measured total whole-band power and in-band power, analog and digital gains applied to the receiver circuits can be determined and tuned. More specifically, power measurements may be conducted periodically, and the AGC gains may be modified regularly according to the recently-observed power measurement to track power variations. The major function of the receiver AGC is to provide proper gains so as to optimize the receiver performance during the downlink physical downlink shared channel (PDSCH) reception. For that reason, the physical downlink shared channel demodulation reference signal (PDSCH-DMRS) may be the ideal received signal for the AGC gain adjustment.

[0024] In 5G new radio (NR), however, there is no always-on reference signal, and the PDSCH (physical downlink shared channel) signals can be scheduled dynamically with respect to both the time domain (TD) and the frequency domain (FD). Due to the highly dynamic resource allocation in both the time domain and frequency domain, large power measurement fluctuations may be present. Thus, dynamic power variations may be resulted at the wireless receiver, thereby bringing AGC gain fluctuations and posing more challenges to the AGC tracking. These issues initiate the concepts that the update of AGC gains may also resort to non-PDSCH signals, such as the tracking reference signal (TRS), the synchronization signal block (SSB) signal, or a combination thereof.

[0025] In some other approaches, to reduce saturation risk under the dynamic PDSCH resource allocation, maximum received power in a certain period (e.g., a subframe) is used in the gain control. Alternatively, multiple AGC runs can be performed, and a power average may be adopted to bring down the impact of the dynamic resource allocation.

[0026] FIG. 1 illustrates a scenario in which the scheme of power averaging may still cause saturation risk under the dynamic resource allocation. As described above, in 5G NR, the PDSCH signals can be targeted to different UEs that are separated by beamforming and thus may be scheduled dynamically in both the time and frequency domains. Such dynamic resource allocation may be associated with sudden power variations in both the time and frequency domains. Accordingly, the AGC gain may also fluctuate. To make it worse, the UE may not be aware of the dynamic resource allocation in advance.

[0027] In this averaging AGC algorithm, the AGC gains may be updated according to an average of the latest varying power observations. As shown in the example of FIG. 1, the PDSCH is scheduled at the N^{th} time slot and may become empty at the next $N+1^{th}$ and $N+2^{th}$ time slots. Based on the power averaging scheme, it is apparent that the AGC gain may need to be tuned up due to the partially loaded PDSCH at the N^{th} time slot and the empty $N+1^{th}$ and $N+2^{th}$ time slots. Subsequently, when fully loaded PDSCH is scheduled at the $N+3^{th}$ time slot, the average AGC gain may not be able to react in response to the burst occurrence of power variations. In such a scenario, saturation may occur at the N+3th time slot.

[0028] In still other approaches, any available reference signal can be readily utilized in the AGC algorithms for the AGC gain updates. These approaches, however, do not consider the received power difference, caused by different beamforming, antenna ports, etc., between various applied reference signals. The real situation is that a network may configure different energy per resource element (EPRE) levels for, e.g., the TRS and SSB, with respect to the PDSCH, based on the radio resource control (RRC) protocol. Moreover, the TRS and SSB transmissions are single-port based (i.e., single polarization), while the PDSCH may use multiple antenna ports and/or two polarizations for multiple inputs multiple outputs (MIMO) transmissions. In 5G NR, gNB may transmit the TRS and SSB with wider gNB Tx beams for the purpose of coverage but transmit the PDSCH with narrower beams for performance improvement. Meanwhile, it may also need special attention that the actual beamforming (BF) gain difference between the wide and narrow beams is unknown to the UE. Even for 4G LTE, there can be a significant BF gain difference between the demodulation reference signal-based (DMRS-based) and the cell-specific reference signal-based (CRS-based) transmissions. In view of the above, the direct use of the non-PDSCH signals as proposed in these technical solutions for updating AGC gain may not be feasible and suitable for the DMRS-based PDSCH reception.

[0029] To address the above and other issues, the present disclosure proposes some technical schemes in which stable AGC tracking can be achieved by effectively and advantageously utilizing available periodic reference signals, such as the TRS and SSB signals in 5G NR or the cell-specific reference signal (CRS) in 4G LTE, as an anchor RS. To achieve this goal, power offsets between the anchor reference signal (RS) and the PDSCH-DMRS may be continuously tracked (or termed “delta tracking” in the present disclosure) to compensate for the infrequent PDSCH reception. The proposed schemes well consider the dynamic resource allocation property of the PDSCH and the significant power variations between the PDSCH and the reference signals to enhance the effectiveness and performance of the AGC tracking.

[0030] In the following, reference will now be made in detail to exemplary embodiments/implementations of the present disclosure, which may be illustrated with reference to the accompanying drawings. It is apparent that the described embodiments/implementations are some but not all of the embodiments/implementations of the present disclosure, and the drawings are only used for illustration purposes but not for limitation.

[0031] FIG. 2 illustrates an exemplary wireless network 200, in which certain aspects of the present disclosure may be implemented. As shown in FIG. 2, wireless network 200 may include a network of nodes, such as a user equipment (UE) 202, an access node 204, and a core network element 206. UE 202 may be any terminal device, such as a mobile phone, a desktop computer, a laptop computer, a tablet, a vehicle computer, a gaming console, a printer, a positioning device, a wearable electronic device, a smart sensor, or any other device capable of receiving, processing, and transmitting information, such as any member of a vehicle to everything (V2X) network, a cluster network, a smart grid node, or an Internet-of-Things (IoT) node. It is understood that UE 202 is illustrated as a mobile phone simply by way of illustration and not by way of limitation.

[0032] Access node 204 may be a device that communicates with UE 202, such as a wireless access point, a base station (BS), a Node B, an enhanced Node B (eNodeB or eNB), a next-generation NodeB (gNodeB or gNB), a cluster master node, or the like. Access node 204 may have a wired connection to UE 202, a wireless connection to UE 202, or any combination thereof. Access node 204 may be connected to UE 202 by multiple connections, and UE 202 may be connected to other access nodes in addition to access node 204. Access node 204 may also be connected to other user equipments. It is understood that access node 204 is illustrated by a radio tower by way of illustration and not by way of limitation.

[0033] Core network element 206 may serve access node 204 and UE 202 to provide core network services. Examples of core network element 206 may include a home subscriber server (HSS), a mobility management entity (MME), a serving gateway (SGW), or a packet data network gateway (PGW). These are examples of core network elements of an evolved packet core (EPC) system, which is a core network for the LTE system. Other core network elements may be used in LTE and in other communication systems. In some implementations, core network element 206 includes an access and mobility management function (AMF) device, a session management function (SMF) device, or a user plane function (UPF) device, of a core network for the NR system. It is understood that core network element 206 is shown as a set of rack-mounted servers by way of illustration and not by way of limitation.

[0034] Core network element 206 may connect with a large network, such as Internet 208, or another Internet Protocol (IP) network, to communicate packet data over any distance. In this way, data from UE 202 may be communicated to other user equipments connected to other access points, including, for example, a computer 210 connected to Internet 208, for example, using a wired connection or a wireless connection, or to a tablet 212 wirelessly connected to Internet 208 via a router 214. Thus, computer 210 and tablet 212 provide additional examples of possible user equipments, and router 214 provides an example of another possible access node.

[0035] A generic example of a rack-mounted server is provided as an illustration of core network element 206. However, there may be multiple elements in the core network including database servers, such as a database 216, and security and authentication servers, such as an authentication server 218. Database 216 may, for example, manage data related to user subscription to network services. A home location register (HLR) is an example of a standardized database of subscriber information for a cellular network. Likewise, authentication server 218 may handle the authentication of users, sessions, and so on. In the NR system, an authentication server function (AUSF) device may be the specific entity to perform user equipment authentication. In some implementations, a single server rack may handle multiple such functions, such that the connections between core network element 206, authentication server 218, and database 216, may be local connections within a single rack.

[0036] Each element in FIG. 2 may be considered a node of wireless network 200. More details regarding the possible implementation of a node are provided by way of example in the description of a node 300 in FIG. 3. Node 300 may be configured as UE 202, access node 204, or core network element 206 in FIG. 2. Similarly, node 300 may also be configured as computer 210, router 214, tablet 212, database 216, or authentication server 218 in FIG. 2. As shown in FIG. 3, node 300 may include a processor 302, a memory 304, and a transceiver 306. These components are shown as connected to one another by a bus, but other connection types are also permitted. When node 300 is UE 202, additional components may also be included, such as a user interface (UI), sensors, and the like. Similarly, node 300 may be implemented as a blade in a server system when node 300 is configured as core network element 206. Other implementations are also possible.

[0037] Transceiver 306 may include any suitable device for sending and/or receiving data. Node 300 may include one or more transceivers, although only one transceiver 306 is shown for simplicity of illustration. An antenna 308 is shown as a possible communication mechanism for node 300. Multiple antennas and/or arrays of antennas may be utilized. Additionally, examples of node 300 may communicate using wired techniques rather than (or in addition to) wireless techniques. For example, access node 204 may communicate wirelessly to UE 202 and may communicate by a wired connection (for example, by optical or coaxial cable) to core network element 206. Other communication hardware, such as a network interface card (NIC), may be included as well.

[0038] As shown in FIG. 3, node 300 may include processor 302. Although only one processor is shown, it is understood that multiple processors can be included. Processor 302 may include microprocessors, microcontroller units (MCUs), digital signal processors (DSPs), application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functions described throughout the present disclosure. Processor 302 may be a hardware structure having one or more processing cores. Processor 302 may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. The software can include computer instructions written in an interpreted language, a compiled language, or machine code. Other techniques for instructing hardware are also permitted under the broad category of software.

[0039] As shown in FIG. 3, node 300 may also include memory 304. Although only one memory is shown, it is understood that multiple memories can be included. Memory 304 can broadly include both memory and storage. For example, memory 304 may include random-access memory (RAM), read-only memory (ROM), static RAM (SRAM), dynamic RAM (DRAM), ferro-electric RAM (FRAM), electrically erasable programmable ROM (EEPROM), CD-ROM or other optical disk storage, hard disk drive (HDD), such as magnetic disk storage or other magnetic storage devices, Flash drive, solid-state drive (SSD), or any other medium that can be used to carry or store desired program code in the form of instructions that can be accessed and executed by processor 302. Broadly, memory 304 may be embodied by any computer-readable medium, such as a non-transitory computer-readable medium.

[0040] Processor 302, memory 304, and transceiver 306 may be implemented in various forms in node 300 for performing wireless communication functions. In some implementations, processor 302, memory 304, and transceiver 306 of node 300 are implemented (e.g., integrated) on one or more SoCs. In one example, processor 302 and memory 304 may be integrated on an application processor (AP) SoC (sometimes known as a “host,” referred to herein as a “host chip”) that manages application processing in an operating system environment, including generating raw data to be transmitted. In another example, processor 302 and memory 304 may be integrated on a baseband processor (BP) SoC (sometimes known as a “modem,” referred to herein as a “baseband chip”) that converts the raw data, e.g., from the host chip, to signals that can be used to modulate the carrier frequency for transmission, and vice versa, which can run a real-time operating system (RTOS). In still another example, processor 302 and transceiver 306 (and memory 304 in some cases) may be integrated on an RF SoC (sometimes known as a “transceiver,” referred to herein as an “RF chip”) that transmits and receives RF signals with antenna 308. It is understood that in some examples, some or all of the host chip, baseband chip, and RF chip may be integrated as a single SoC. For example, a baseband chip and an RF chip may be integrated into a single SoC that manages all the radio functions for cellular communication.

[0041] Any suitable node of wireless network 200, as shown in FIG. 2, which receives signals from another node (e.g., UE 202 that receives signals from access node 204 via the downlink) may implement the schemes of power estimation for AGC provided by the present disclosure, with reference to some implementations shown in FIGs. 4-8B. Compared with the known solutions in the other technical approaches, stable AGC tracking can be achieved by means of considering the dynamic resource allocation of PDSCH in addition to the significant power variations between the PDSCH and the reference signals. Consequently, the proposed power projection can provide well-tuned and more-robust AGC gains.

[0042] FIG. 4 illustrates a block diagram of an exemplary apparatus 400 that may include a baseband chip 402, an RF chip 404, and a host chip 406, according to some implementations of the present disclosure. Apparatus 400 may be implemented as UE 202 of wireless network 200 in FIG. 2. As shown in FIG. 4, apparatus 400 may include baseband chip 402, RF chip 404, host chip 406, and one or more antennas 410. In some implementations, baseband chip 402 may be implemented by processor 302 and memory 304, and RF chip 404 may be implemented by processor 302, memory 304, and transceiver 306, as described above with reference to FIG. 3. In addition to the on-chip memory (also known as “internal memory,” e.g., registers, buffers, or caches) on each chip 402, 404, or 406, apparatus 400 may further include an external memory 408 (e.g., the system memory or main memory) that can be shared by each chip 402, 404, or 406 through the system/main bus. Although each of baseband chip 402, RF chip 404, and host chip 406 is illustrated as a standalone SoC in FIG. 4, it is understood that in some examples, baseband chip 402 and RF chip 404 may be integrated as one SoC; in still some examples, baseband chip 402 and host chip 406 may be integrated as one SoC; in other examples, baseband chip 402, RF chip 404, and host chip 406 may be integrated as one SoC, as described above. The present disclosure does not place limitations thereto.

[0043] In the uplink (not shown), host chip 406 may generate raw data and send the data to baseband chip 402 for encoding, modulation, mapping, etc. An interface unit of baseband chip 402 may be configured to receive the data from host chip 406. Baseband chip 402 may also be configured to access the raw data generated by host chip 406 and stored in external memory 408, for example, using the direct memory access (DMA). Baseband chip 402 may first encode (e.g., by source coding and/or channel coding) the raw data and modulate the coded data using any suitable modulation techniques, such as multi-phase shift keying (MPSK) modulation or quadrature amplitude modulation (QAM). Baseband chip 402 may perform any other functions, such as symbol or layer mapping, to convert the raw data into a signal that can be used to modulate the carrier frequency for transmission. In the uplink, baseband chip 402 may send the modulated signal to RF chip 404 via the interface unit, e.g., an interface 412 shown in FIG. 4. RF chip 404 may convert the modulated signal in the digital format into analog signals, i.e., RF signals, and perform any suitable front-end RF functions, such as filtering, digital pre-distortion, up-conversion, or sample-rate conversion. Antenna 410 (e.g., an antenna array) may transmit the RF signals provided by transmitter TX of RF chip 404.

[0044] On the other hand, in the downlink, antenna 410 may receive RF signals from an access node or other wireless device in the network. The RF signals may be passed to a receiver of RF chip 404. RF chip 404 may perform any suitable front-end RF functions, such as filtering, IQ imbalance compensation, down-conversion, or sample-rate conversion, and convert the RF signals (e.g., transmission) into low-frequency digital signals (baseband signals) that can be processed by baseband chip 402.

[0045] In some implementations, RF chip 404 may include a radio frequency front end (RF FE), i.e., an “analog front end.” So-called “RF FE” is a generic term for the circuitry between, e.g., antenna 410 and an analog-to-digital converter (ADC). In some implementations, the RF FE may include at least one low-noise amplifier (LNA) configured to amplify a received signal to a sufficient level, without significantly degrading its signal-to-noise ratio (SNR), and the amplified signal can be used for subsequent processing. It is apparent that thus a gain may be required in advance for the LNA to amplify the received signal. The RF FE may also include at least one mixer configured for converting an RF signal to an intermedia frequency (IF) signal. The IF signal may be fed to a trans-impedance amplifier (TIA) which is a current-to-voltage converter. For a similar reason, the TIA may also require a current-to-voltage gain, based on a feedback resistance, in advance.

[0046] As shown in FIG. 4, the RF FE may further include an analog baseband (ABB) block (e.g., an ABB circuit) configured to support communication in various bandwidths. The ABB block may include a lowpass filter and a programming-gain amplifier and may amplify the signals with minimal degradation or distortion. Similarly, the ABB block may also require a gain for the amplification. RF chip 404 may further include an ADC configured to convert a stream of symbols (a.k.a. samples, e.g., orthogonal frequency-division multiplexing symbols) in an analog form (e.g., radio signals) to a digital form (e.g., digital signals).

[0047] In some implementations, RF chip 404 may include any suitable elements that are configured to process the digital signals outputted by ADC, such as elements configured for filtering, up-conversion, or sample-rate conversion. For ease of illustration and description, these elements may be denoted as a generic receiver (RX) chain in FIG. 4. It can also be understood that RF chip 404 in FIG. 4 may not show every detail and may be used only as an exemplary illustration instead of a limitation.

[0048] As shown in FIG. 4, apparatus 400 may include one or more interfaces, for example, interface 412 between RF chip 404 and baseband chip 402. In some aspects, interface 412 may be configured to transmit digital signals from RF chip 404 to baseband chip 402 in the downlink. For example, interface 412 may be configured to transmit signals from a wideband power detector (WBPD) of RF chip 404. The WBPD in FIG. 4 may be a passive electronic device configured to measure time-domain wideband power. In other aspects, interface 412 may also be configured to transmit the modulated signal from baseband chip 402 to RF chip 404 in the uplink.

[0049] In the downlink, as illustrated in FIG. 4, baseband chip 402 may demodulate the baseband signals through a demodulating circuit (not shown) and decode the demodulated signals through a decoding circuit (not shown) to extract raw data that can be processed by host chip 406. The raw data provided by baseband chip 402 may be sent to host chip 406 directly or stored in system memory 408. Baseband chip 402 may perform additional functions, such as de-mapping, channel estimation, descrambling, etc.

[0050] Baseband chip 402 may include one or more elements configured to perform the proposed power estimation schemes for AGC, according to some implementations of the present disclosure. Through this manner, stable AGC tracking can be achieved by effectively and advantageously utilizing available periodic reference signals, such as the TRS and SSB signals in 5G NR or CRS in 4G LTE, as the anchor RS. Further, the power offsets between the anchor RS and the PDSCH-DMRS may be continuously and systematically tracked to compensate for the infrequent PDSCH reception. The proposed schemes consider the dynamic resource allocation of the PDSCH in addition to the significant power variations between the PDSCH and the reference signals, thereby enhancing the effectiveness and performance of the AGC tracking. Consequently, the provided AGC can capture the coming of maximum power. Compared to the other known solutions, the present disclosure can provide stable AGC tracking and reduce saturation risk.

[0051] To achieve these goals, in the downlink, baseband chip 402 may further include an AGC unit 60, a narrowband reference signal (NB-RS) power estimation module 4022, and a wideband reference signal (WB-RS) power estimation module 4024, as depicted in FIG. 4. NB-RS power estimation module 4022 may be configured to supply power estimation based on narrowband reference signals to AGC unit 60. In one example, the power estimation of narrowband reference signals may include power estimations/measurements based on the SSB signals. In the present disclosure, the estimated power based on the SSB signals may be termed “SSB power” and used interchangeably with this term. In the downlink, narrowband reference signals (NB-RS) are received, and these signals may be processed to obtain signal strength estimations/measurements in NB-RS power estimation module 4022. Accordingly, the RS tone power estimations/measurements in the frequency domain may be acquired.

[0052] On the other hand, WB-RS power estimation module 4024 may be configured to provide power estimation based on wideband reference signals, e.g., power estimation based on the TRS (or the CRS in 4G LTE), to AGC unit 60. In the present disclosure, the estimated power based on the TRS (or the CRS) may be termed “TRS power” (or “CRS power”) and used interchangeably with this term. The received reference signals in the time domain may be converted, by a Fast Fourier transform module FFT, as shown in FIG. 4, into frequency-domain signals. Further, the frequency-domain baseband signals may be processed in a baseband processing (BBP) block that may include a digital variable gain amplifier (DVGA), and the processed signals may be used to obtain wideband reference signal power estimation (e.g., the TRS power) in WB-RS power estimation module 4024.

[0053] In accordance with the scope of the present disclosure, AGC unit 60 may be coupled with NB-RS power estimation module 4022 and WB-RS power estimation module 4024 and may be configured to receive, e.g., the SSB power and the TRS power. In some examples, AGC unit 60 may be further connected with an internal memory 4026. Internal memory 4026 in baseband chip 402 may provide local storage or local buffering of data for reuse purposes.

[0054] In some examples, baseband chip 402 may further include other power estimation modules, such as an in-band received signal strength indicator (IB-RSSI) estimation module. In other implementations, these power estimation modules may be included internally in AGC unit 60, while in FIG. 4, these modules are shown separately from AGC unit 60. Further, in some implementations, these power estimation modules may provide power information to and shared by another functional unit, other than AGC unit 60, in baseband chip 402.

[0055] The NB-RS power estimation (e.g., the SSB power) and the WB-RS power estimation (e.g., the TRS power) can be fed to AGC unit 60, respectively. AGC unit 60 may process these power estimations (or aided by other power estimations) to calculate at least one analog AGC gain and at least one digital AGC gain. The analog AGC gains can provide proper gain settings in an RF domain to prevent saturation and/or signal clipping as well as to fully exploit the signal dynamic range at the ADC to minimize the quantization noise effect. In FIG. 4, the at least one analog gain may be fed back in an outer loop. Through an RF gain mapping module in RF chip 404, suitable analog AGC gains may be obtained and respectively supplied to the LNA, the TIA, the ABB block, etc., respectively, and any other suitable components in RF chip 404. Meanwhile, digital gain control may be calculated in baseband chip 402 and provided to a baseband amplifier circuit (e.g., the DVGA of FIG. 4), based on the digital AGC gains, in a digital domain. In FIG. 4, the at least one digital gain may be provided in an inner loop. Through such manners, the bit-width in baseband chip 402 may be fully utilized so as to maximize a signal-to-quantization-noise ratio (SQNR) and reduce saturation risk.

[0056] It can be understood that AGC unit 60 in FIG.4 can be implemented as hardware, firmware, software, or any combination thereof, depending upon the particular application and design constraints imposed on the overall system. In some implementations, AGC unit 60 may be embodied by memory 304 and processor 302, as shown in FIG. 3. Processor 302 can be a baseband processor. Memory 304 may include local memory 4026 in FIG. 4 and may be configured to store instructions regarding functions according to some implementations of the present disclosure. When being implemented in software, the functions may be stored on or encoded as instructions or codes on a non-transitory computer-readable medium. Computer-readable media may include computer storage media. Storage media may be any available media that can be accessed by a computing device, such as node 300 in FIG. 3. By way of example, and not limitation, such computer-readable media can include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, HDD, such as magnetic disk storage or other magnetic storage devices, Flash drive, SSD, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a processing system, such as a mobile device or a computer. Disk and disc, as used herein, includes CD, laser disc, optical disc, digital video disc (DVD), and floppy disk 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.

[0057] In still some implementations, AGC unit 60 may be implemented, in part, in hardware. In other words, at least a portion of the functions can be embodied by a hardware implementation using a physical device or an electronic circuit. The hardware implementation is usually faster in operation and may include, e.g., application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), programmable logic devices (PLDs), or the like.

[0058] Although they are not shown in FIG. 4, baseband chip 402 may further include other functional units configured to perform other functions. For example, baseband chip 402 may further include a routine channel estimation circuit. The channel estimation circuit may include, e.g., a filter, a noise estimation circuit, etc., and may be configured to receive reference signals for channel estimation. AGC unit 60 can be compatible with this routine baseband circuit and may share at least a portion of components with each other.

[0059] FIGs. 5A and 5B illustrate flow charts of an exemplary method 500 of power estimation for AGC, according to some implementations of the present disclosure. When there are no "valid" PDSCH-DMRS power measurements/estimations, method 500 may be accordingly performed to obtain projected PDSCH-DMRS power for AGC. The term "valid" PDSCH-DMRS power estimation may be used to describe a scenario where there is a downlink PDSCH assigned for the UE, and the PDSCH-DMRS power estimation for AGC is reliable. One opposite example of an unreliable DMRS power estimation may occur when an allocated PDSCH reference block number is too small compared to a system bandwidth while an experienced fading channel is highly frequency-selective.

[0060] As shown in FIG. 5A, method 500 may start at 502, and a new AGC run may be initiated. Subsequently, at 504, it may be determined whether measured PDSCH-DMRS tone power is available. The PDSCH-DMRS tone power may be estimated according to a PDSCH-DMRS that was received at a time slot (time point). As described above, the major function of the receiver AGC is to provide the proper gains, either a digital AGC gain or an analog AGC gain, to optimize the receiver performance during the downlink physical downlink shared channel

(PDSCH) reception. For this reason, the PDSCH-DMRS may be an ideal signal for the AGC gain calculation. Consequently, whether the measured PDSCH-DMRS tone power is available may be determined at 504. In a scenario where the measured PDSCH-DMRS tone power is available, method 500 may proceed to 506, a beginning point of a scenario – Case A, as shown in FIG. 5B.

[0061] Method 500 continues to FIG. 5B. When the measured PDSCH-DMRS tone power is available, method 500 may proceed to 508 and 510. At 508 and 510 in FIG. 5, an average power offset may be estimated at a power offset estimation module 62 (shown in FIG. 6) in AGC unit 60. Power offset estimation module 62 may obtain the measured PDSCH-DMRS tone power and anchor RS tone power as inputs and estimate the average power offset. The anchor RS tone power may include the latest anchor RS tone power measured/estimated at an instant time point or stored anchor RS tone power that was measured/estimated at a previous time point. In one example, the stored anchor RS tone power may be stored in and supplied by internal memory 4026 in baseband chip 402.

[0062] To obtain the above-mentioned anchor RS tone power, a periodic reference signal may be selected as an anchor reference signal (RS). TABLE 1 summarizes the anchor RS selected in different states in 5G NR. In some implementations, when the periodic TRS is configured for the UE, the TRS may be selected as the anchor RS in a CONNECTED state. Otherwise, the serving SSB may be used. On the other hand, in an IDLE state, considering that the TRS is not available, the serving SSB may be used instead. Although the SSB is narrowband and may have more dynamics, the SNR requirement for an IDLE state is much lower than for a CONNECTED state. Therefore, there may be more tolerance room for the SSB power variation, which may also relax the AGC requirement.

TABLE 1

Generation	CONNECTED State	IDLE State
5G NR	(When TRS is configured) TRS (When TRS is not configured) SSB	SSB

[0063] Although the above description discusses the anchor RS in 5G NR, it can be understood that the present disclosure may also be implemented in 4G LTE, and a reference signal in 4G LTE may be selected as the anchor RS. For example, for DMRS-based transmission models, the CRS may be selected as the anchor RS.

[0064] The main goal of AGC unit 60 is to provide a reasonable signal-to-noise ratio (SNR) for the PDSCH reception. At power offset estimation module 62, a composite power offset between the PDSCH-DMRS and the anchor RS may be calculated. It is observed that this power offset is relatively semi-static. That is, the power offset varies slowly. Therefore, a reliable power estimation may be provided based on this power offset.

[0065] FIG. 7 illustrates a diagram showing an exemplary power offset estimation module 62 in AGC unit 60, according to some implementations of the present disclosure. At 508, a one-shot power offset may be updated based on the measured PDSCH-DMRS tone power and the anchor RS tone power. The anchor RS tone power may include at least one of the latest anchor RS tone power measured/estimated at an instant time point or stored anchor RS tone power that was measured/estimated at a previous time point. The stored anchor RS tone power may be stored in and supplied by internal memory 4026 in baseband chip 402. In one example, the anchor RS tone power may include an average of the measured anchor RS tone power and the stored anchor RS tone power.

[0066] The one-shot power offset $offset\_dB\_os$ may be expressed as:

$$offset\_dB\_os = dmrs\_dBm - anchor\_dBm \tag{1},$$

where $dmrs\_dBm$ denotes the measured PDSCH-DMRS tone power in dBm, $anchor\_dBm$ denotes the anchor RS tone power in dBm, and “-” denotes a subtraction operator. In FIG. 7, Equation (1) may be performed by a subtraction block 622 in power offset estimation module 62.

[0067] The term “one-shot” may be used to describe that the one-shot power offset is calculated accordingly on the tone power received at instant time slots. The one-shot power offset may indicate the tone power difference based on the PDSCH-DMRS and the anchor RS. When the measured PDSCH-DMRS tone power is unavailable, the one-shot power offset may be used to compensate for measured anchor RS tone power to project the PDSCH-DMRS power.

[0068] The term “dBm” may represent an absolute RS tone power that is mapped to a receiving antenna port by considering factors from a front end to baseband chip 402. In some implementations, the PDSCH-DMRS and certain anchor RS tone power levels distributing over multiple antenna ports may be obtained by an average over logical antenna ports that are frequency-division multiplexing (FDM) ports or time-division multiplexing (TDM) ports and/or by a summation over multiple antenna ports that are code division multiplexing (CDM) ports.

[0069] In some implementations, at 510 in FIG. 5B, the one-shot power offset may be averaged, through an averaging block 624 in power offset estimation module 62 of FIG. 7, over multiple AGC runs to enhance accuracy. In one example, an auto-regressive (AR) filtering may be applied to obtain the average power offset $offset\_dB[n]$ as follows:

$$offset\_dB[n] = offset\_dB[n-1] + \alpha * (offset\_dB\_os - offset\_dB[n-1]) \quad (2),$$

where $offset\_dB\_os$ denotes the one-shot power offset obtained from Equation (1) above, $offset\_dB[n-1]$ denotes the average power offset based on the previous AGC run with n denoting its index, α denotes an AR filter coefficient, and "*" denotes a multiplication operator. In some examples, α may include a number between $\frac{1}{16} \sim \frac{1}{32}$.

[0070] Based on Equation (2) of the AR filtering, the average power offset of the current n^th AGC run may be the sum of the first portion of the one-shot power offset and the second portion of the average power offset of the previous (n-1)^th AGC run. The first portion weight may be equal to the AR filter coefficient α, while the second portion weight may be equal to (1- α).

[0071] At 512 in FIG. 5B, the average power offset obtained through power offset estimation module 62 may be fed to a PDSCH-DMRS power projection module 64 and compared with a power offset threshold. When the measured PDSCH-DMRS tone power is available, and the average power offset is larger than the power offset threshold, the measured PDSCH-DMRS tone power is reliable. Therefore, it may be regarded as the projected PDSCH-DMRS power (at 514) and may be directly fed to an AGC updating module 66 (at 518) for the calculation of the AGC gains. The power offset threshold may be a configurable parameter. By default, it may be set as 0 dB.

[0072] By contrast, although the measured PDSCH-DMRS tone power is available, while the average power offset is less than or equal to the power offset threshold, the measured PDSCH-DMRS power may be not reliable. Generally speaking, PDSCH power is larger than anchor RS power. Therefore, instead, the anchor RS tone power may be used and determined as the projected PDSCH-DMRS power (at 516) and may be fed to AGC updating module 66 to calculate the AGC gains. As described above, the anchor RS tone power may include the latest anchor RS tone power measured/estimated at an instant time point or the stored RS tone power that was previously measured/estimated at a previous time point.

[0073] FIG. 8A illustrates a diagram showing a portion structure 642 of an exemplary PDSCH-DMRS projection module 64 in AGC unit 60, according to some implementations of the present disclosure. Portion structure 642 may be configured to perform the operations in Case A in FIG. 5B, including 512, 514, and 516. In some implementations, portion structure 642 may include a multiplexer 82. A selector of multiplexer 82 may be determined on a comparison of the average power offset and the power offset threshold, and based on the selector, it may be determined whether the measured PDSCH-DMRS tone power or the anchor RS tone power is the projected PDSCH-DMRS power, as described above.

[0074] Returning to 504 in FIG. 5A, on the other hand, when the measured PDSCH-DMRS tone power is unavailable, it may be determined whether the measured anchor RS tone power is available at 520. At 522, in Case B, when the measured PDSCH-DMRS tone power is not available while the measured anchor RS tone power is, projected PDSCH-DMRS power $proj\_dmrs\_dBm$ may be derived according to:

$$proj\_dmrs\_dBm = anchor\_dBm + \max\left(offset\_dB[n], offset\_thrd\_dB\right) \quad (3),$$

where $anchor\_dBm$ denotes the measured anchor RS power, $offset\_dB[n]$ denotes the average power offset of the nth AGC run, $offset\_thrd\_dB$ denotes the power offset threshold, and max() denotes a maximum function configured to select a larger value from its parameters.

[0075] The measured anchor RS tone power may be acquired according to the anchor RS that was received at an instant time slot. One of the main goals according to the present disclosure is to provide stable AGC tracking that can be achieved by effectively and advantageously utilizing available periodic reference signals, such as the TRS and SSB signals in 5G NR or the cell-specific reference signal (CRS) in 4G LTE, as the anchor RS.

[0076] By default, the power offset threshold may be configured to be 0 dB. In this way, the max operation can ensure that, at least, the measured anchor RS power is directly used for the gain control, instead of a compensated anchor RS power that is lower by a negative average power offset $offset\_dB[n]$. One example of this corner case is that anchor RS is transmitted by one antenna port over a horizontal polarization, while PDSCH is transmitted with two antenna ports over both polarizations. The vertical polarization may experience a reduced gain due to channel fading.

[0077] The operations of Case B at 522 in FIG. 5A may be performed by a portion structure 644 of an exemplary PDSCH-DMRS projection module 64 in AGC unit 60, shown in FIG. 8B. As shown in FIG. 8B, the larger value of the average power offset and the power offset threshold may be selected at a maximum operator 84 in FIG. 8B and may be combined with the measured anchor RS tone power at an adder 86. Consequently, the projected PDSCH-DMRS power according to Case B in FIG. 5A can be obtained for the calculation of the AGC gains.

[0078] In a corner case where none of the measured PDSCH-DMRS power and the measured anchor RS tone power, at an instant time point, is available, the projected PDSCH-DMRS power may not be updated. In some examples, at 524, a previously projected PDSCH-DMRS power may be used for the AGC gain estimation. For example, the lastly-projected PDSCH-

DMRS power may be used.

[0079] At 518, after the projected PDSCH-DMRS power is obtained, it may be used in combination with other available power measurements (either in the time or frequency domains) to update the AGC gains. Meanwhile, the next AGC run may be started, and thus method 500 may return to the starting point at 502, and at least a portion of the above-mentioned operations may be repeated.

[0080] The known approaches update the AGC gains based on the currently received signal powers, with certain averaging and hysteresis mechanisms to enhance AGC loop robustness. That is, what is observed in the current time slot may be directly fed to an AGC loop. As described, the power variations experienced by different signals are not taken into account, resulting in non-optimal gain settings for the PDSCH reception.

[0081] By contrast, the proposed schemes can always maintain and produce a projected PDSCH-DMRS tone power for the gain control. To handle infrequent PDSCH reception, an available periodic RS may be selected as the anchor RS. By continuously tracking the power offset between the anchor RS and the PDSCH-DMRS, it can project the latest PDSCH-DMRS power level for the AGC. In particular, power variations between various reference signals are carefully considered, and a robust gain setting can thus be provided for the PDSCH reception. The semi-static power offset between the anchor RS and the PDSCH-DMRS may be continuously tracked.

[0082] In some implementations, a baseband chip is provided. The baseband chip may include a processor and a storage medium coupled to the processor and storing computer - executable instructions. The computer-executable instructions, when executed by the processor, may cause the processor to when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtain projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and a one-shot power offset. The one-shot power offset may include power compensation for infrequent PDSCH-DMRS reception at a time point. Automatic gain control (AGC) may be performed based on the projected PDSCH-DMRS power.

[0083] In some implementations, the executed computer-executable instructions may further cause the processor to when determining that the measured PDSCH-DMRS tone power is available, calculate the one-shot power offset based on the measured PDSCH-DMRS tone power and anchor RS tone power. The anchor RS tone power may include at least one of the measured anchor RS tone power or previously-measured anchor RS tone power.

[0084] In some implementations, the executed computer-executable instructions may further cause the processor to calculate a difference between the measured PDSCH-DMRS tone power and the anchor RS tone power as the one-shot power offset; and calculate an average power offset based on the one-shot power offset.

[0085] In some implementations, the executed computer-executable instructions may further cause the processor to calculate the average power offset based on a first portion of the one-shot power offset and a second portion of a previous average power offset. The previous average power offset may be calculated based on previously-measured PDSCH-DMRS tone power.

[0086] In some implementations, the executed computer-executable instructions may further cause the processor to in response to determining that the average power offset is greater than a power offset threshold, determine the measured PDSCH-DMRS tone power as the projected PDSCH-DMRS power.

[0087] In some implementations, the executed computer-executable instructions may further cause the processor to in response to determining that the average power offset is less than or equal to the power offset threshold, determine the anchor RS tone power as the projected PDSCH-DMRS power.

[0088] In some implementations, the power offset threshold may be a configurable parameter.

[0089] In some implementations, the measured anchor RS tone power may be estimated based on an anchor reference signal (RS). The anchor RS may include at least one of a tracking reference signal (TRS), a synchronization signal block (SSB) signal, or a cell-specific reference signal.

[0090] In some implementations, in 5G New Radio (NR): in a CONNECTED state, the anchor RS may include the TRS; and in an IDLE state, the anchor RS may include the SSB.

[0091] In some implementations, the executed computer-executable instructions may further cause the processor to when determining that the measured PDSCH-DMRS tone power is unavailable and the measured anchor RS tone power is unavailable, determine previously-projected PDSCH-DMRS power as the projected PDSCH-DMRS power.

[0092] In some implementations, the AGC may include a digital AGC gain and an analog AGC gain. The baseband chip may be configured to adjust an amplification gain of a digital circuit based on the digital AGC gain. A radio frequency (RF) chip may be configured to adjust an amplification gain of an analog circuit based on the analog AGC gain.

[0093] In some implementations, a system is provided. The system may include a radio frequency (RF) chip and a baseband chip. The baseband chip may be configured to: when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtain projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and one-shot power offset. The one-shot power offset may include power compensation for infrequent PDSCH-DMRS reception at a time point. Automatic gain control (AGC) may be performed based on the projected PDSCH-DMRS power. The AGC may include a digital AGC gain and an analog AGC gain. The baseband chip may be configured to adjust an amplification gain of a digital circuit based on the digital AGC gain; and transmit the analog AGC gain to the RF chip. The RF chip may be configured to adjust an amplification gain of an analog circuit based on the analog AGC gain.

[0094] In some implementations, a method of power estimation for AGC is provided. The method may include when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtaining projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and a one-shot power offset, the one-shot power offset may include power compensation for infrequent PDSCH-DMRS reception at a time point; and performing automatic gain control (AGC) based on the projected PDSCH-DMRS power.

[0095] In some implementations, the method may further include when determining that the measured PDSCH-DMRS tone power is available, calculating the one-shot power offset based on the measured PDSCH-DMRS tone power and anchor RS tone power. The anchor RS tone power may include at least one of the measured anchor RS tone power or previously-measured anchor RS tone power.

[0096] In some implementations, calculating the one-shot power offset may include calculating a difference between the measured PDSCH-DMRS tone power and the anchor RS tone power as the one-shot power offset. The method may further include calculating an average power offset based on the one-shot power offset.

[0097] In some implementations, calculating the average power offset may include calculating the average power offset based on a first portion of the one-shot power offset and a second portion of a previous average power offset. The previous average power offset may be calculated based on previously-measured PDSCH-DMRS tone power.

[0098] In some implementations, the method may further include in response to determining that the average power offset is greater than a power offset threshold, determining the measured PDSCH-DMRS tone power as the projected PDSCH-DMRS power.

[0099] In some implementations, the method may further include in response to determining that the average power offset is less than or equal to the power offset threshold, determining the anchor RS tone power as the projected PDSCH-DMRS power.

[0100] In some implementations, the measured anchor RS tone power may be obtained based on an anchor reference signal (RS). The anchor RS may include at least one of a tracking reference signal (TRS), a synchronization signal block (SSB) signal, or a cell-specific reference signal.

[0101] In some implementations, the method may further include when determining that the measured PDSCH-DMRS tone power is unavailable and the measured anchor RS tone power is unavailable, determining previously-projected PDSCH-DMRS power as the projected PDSCH-DMRS power.

[0102] The foregoing description of the specific embodiments/implementations will so reveal the general nature of the present disclosure that others can, by applying knowledge within the skill of the art, readily modify and/or adapt for various applications such specific embodiments/implementations, without undue experimentation, without departing from the general concept of the present disclosure. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments/implementations, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for description and not for limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance.

[0103] Embodiments/implementations of the present disclosure have been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed.

[0104] The Summary and Abstract sections may set forth one or more but not all exemplary embodiments/implementations of the present disclosure as contemplated by the inventor(s), and thus, are not intended to limit the present disclosure and the appended claims in any way.

[0105] Various functional blocks, modules, and steps are disclosed above. The particular arrangements provided are illustrative and without limitation. Accordingly, the functional blocks, modules, and steps may be re-ordered or combined in diverse ways than in the examples provided above. Likewise, certain embodiments/implementations include only a subset of the functional blocks, modules, and steps, and any such subset is permitted.

[0106] The breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments/implementations, but should be defined only in accordance with the following claims and their equivalents.

WHAT IS CLAIMED IS:

1. A baseband chip, comprising:

a processor; and

a storage medium coupled to the processor and storing computer-executable instructions that, when executed by the processor, cause the processor to:

when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtain projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and a one-shot power offset, the one-shot power offset comprising power compensation for infrequent PDSCH-DMRS reception at a time point; and

perform automatic gain control (AGC) based on the projected PDSCH-DMRS power.

2. The baseband chip of claim 1, wherein the executed computer-executable instructions further cause the processor to:

when determining that the measured PDSCH-DMRS tone power is available, calculate the one-shot power offset based on the measured PDSCH-DMRS tone power and anchor RS tone power, the anchor RS tone power comprising at least one of the measured anchor RS tone power or previously-measured anchor RS tone power.

3. The baseband chip of claim 2, wherein the executed computer-executable instructions further cause the processor to:

calculate a difference between the measured PDSCH-DMRS tone power and the anchor RS tone power as the one-shot power offset; and

calculate an average power offset based on the one-shot power offset.

4. The baseband chip of claim 3, wherein the executed computer-executable instructions further cause the processor to:

calculate the average power offset based on a first portion of the one-shot power offset and a second portion of a previous average power offset, the previous average power offset being calculated based on previously-measured PDSCH-DMRS tone power.

5. The baseband chip of claim 3, wherein the executed computer-executable instructions further cause the processor to:

in response to determining that the average power offset is greater than a power offset threshold, determine the measured PDSCH-DMRS tone power as the projected PDSCH-DMRS power.

6. The baseband chip of claim 5, wherein the executed computer-executable instructions further cause the processor to:

in response to determining that the average power offset is less than or equal to the power offset threshold, determine the anchor RS tone power as the projected PDSCH-DMRS power.

7. The baseband chip of claim 5, wherein:

the power offset threshold is a configurable parameter.

8. The baseband chip of claim 1, wherein:

the measured anchor RS tone power is obtained based on an anchor reference signal (RS); and

the anchor RS comprises at least one of a tracking reference signal (TRS), a synchronization signal block (SSB) signal, or a cell-specific reference signal.

9. The baseband chip of claim 8, wherein in 5G New Radio (NR):

in a CONNECTED state, the anchor RS comprises the TRS; and

in an IDLE state, the anchor RS comprises the SSB.

10. The baseband chip of claim 1, wherein the executed computer-executable instructions further cause the processor to:

when determining that the measured PDSCH-DMRS tone power is unavailable and the measured anchor RS tone power is unavailable, determine previously-projected PDSCH-DMRS power as the projected PDSCH-DMRS power.

11. The baseband chip of claim 1, wherein:

the AGC comprises a digital AGC gain and an analog AGC gain;

the baseband chip is configured to adjust an amplification gain of a digital circuit based on the digital AGC gain; and

a radio frequency (RF) chip is configured to adjust an amplification gain of an analog circuit based on the analog AGC gain.

12. A system, comprising:

a radio frequency (RF) chip; and

a baseband chip configured to:

when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtain projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and one-shot power offset, the one-shot power offset comprising power compensation for infrequent PDSCH-DMRS reception at a time point;

perform automatic gain control (AGC) based on the projected PDSCH-DMRS power, the AGC comprising a digital AGC gain and an analog AGC gain;

adjust an amplification gain of a digital circuit based on the digital AGC gain; and

transmit the analog AGC gain to the RF chip,

wherein the RF chip is configured to adjust an amplification gain of an analog circuit based on the analog AGC gain.

13. A method of power estimation for AGC, comprising:

when determining that measured physical downlink shared channel demodulation reference signal (PDSCH-DMRS) tone power is unavailable, obtaining projected PDSCH-DMRS power based on measured anchor reference signal (RS) tone power and a one-shot power offset, the one-shot power offset comprising power compensation for infrequent PDSCH-DMRS reception at a time point; and

performing automatic gain control (AGC) based on the projected PDSCH-DMRS power.

14. The method of claim 13, further comprising:

when determining that the measured PDSCH-DMRS tone power is available, calculating the one-shot power offset based on the measured PDSCH-DMRS tone power and anchor RS tone power, the anchor RS tone power comprising at least one of the measured anchor RS tone power or previously-measured anchor RS tone power.

15. The method of claim 14, wherein:

calculating the one-shot power offset comprises calculating a difference between the measured PDSCH-DMRS tone power and the anchor RS tone power as the one-shot power offset; and

the method further comprises calculating an average power offset based on the one-shot power offset.

16. The method of claim 15, wherein:

calculating the average power offset comprises calculating the average power offset based on a first portion of the one-shot power offset and a second portion of a previous average power offset, the previous average power offset being calculated based on previously-measured PDSCH-DMRS tone power.

17. The method of claim 15, further comprising:

in response to determining that the average power offset is greater than a power offset threshold, determining the measured PDSCH-DMRS tone power as the projected PDSCH-DMRS power.

18. The method of claim 17, further comprising:

in response to determining that the average power offset is less than or equal to the power offset threshold, determining the anchor RS tone power as the projected PDSCH-DMRS power.

19. The method of claim 13, wherein:

the measured anchor RS tone power is obtained based on an anchor reference signal (RS); and

the anchor RS comprises at least one of a tracking reference signal (TRS), a synchronization signal block (SSB) signal, or a cell-specific reference signal.

20. The method of claim 13, further comprising:

when determining that the measured PDSCH-DMRS tone power is unavailable and the measured anchor RS tone power is unavailable, determining previously-projected PDSCH-DMRS power as the projected PDSCH-DMRS power.

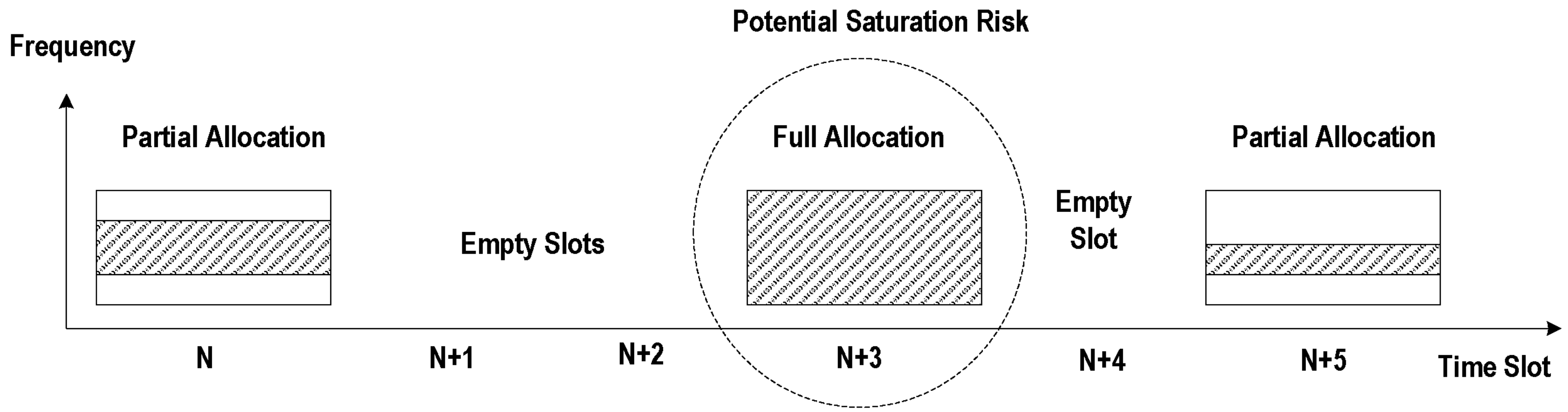
Potential Saturation Risk
Frequency
Partial Allocation
Full Allocation
Partial Allocation
Empty Slots
Empty Slot
N
N+1
N+2
N+3
N+4
N+5
Time Slot

FIG. 1

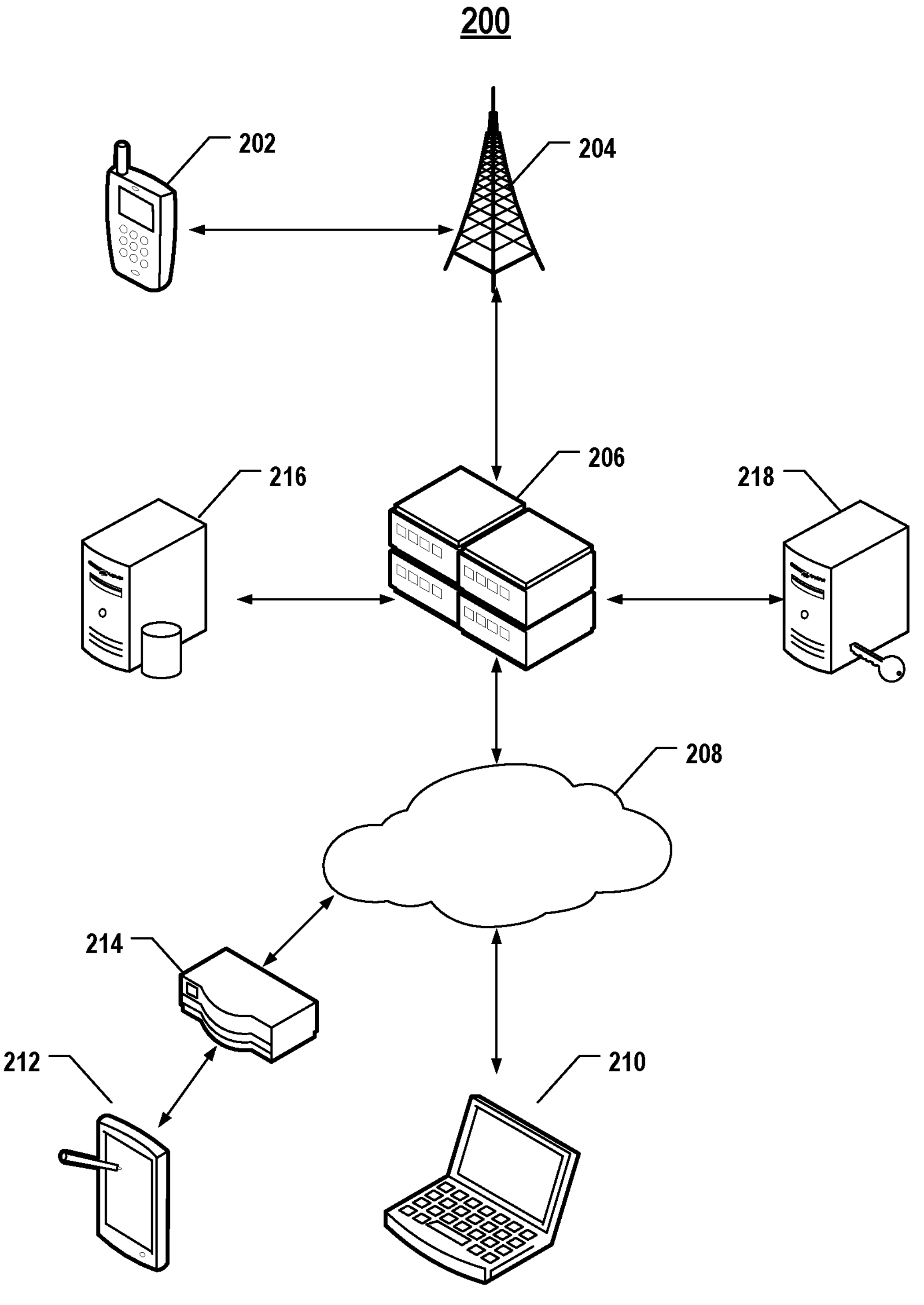

FIG. 2

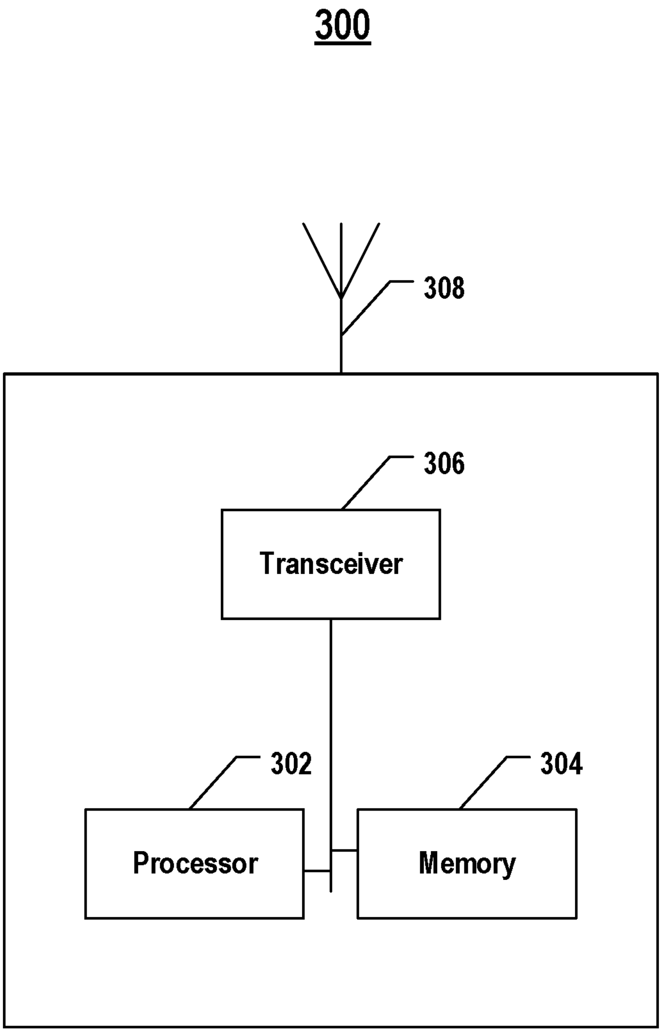

FIG. 3

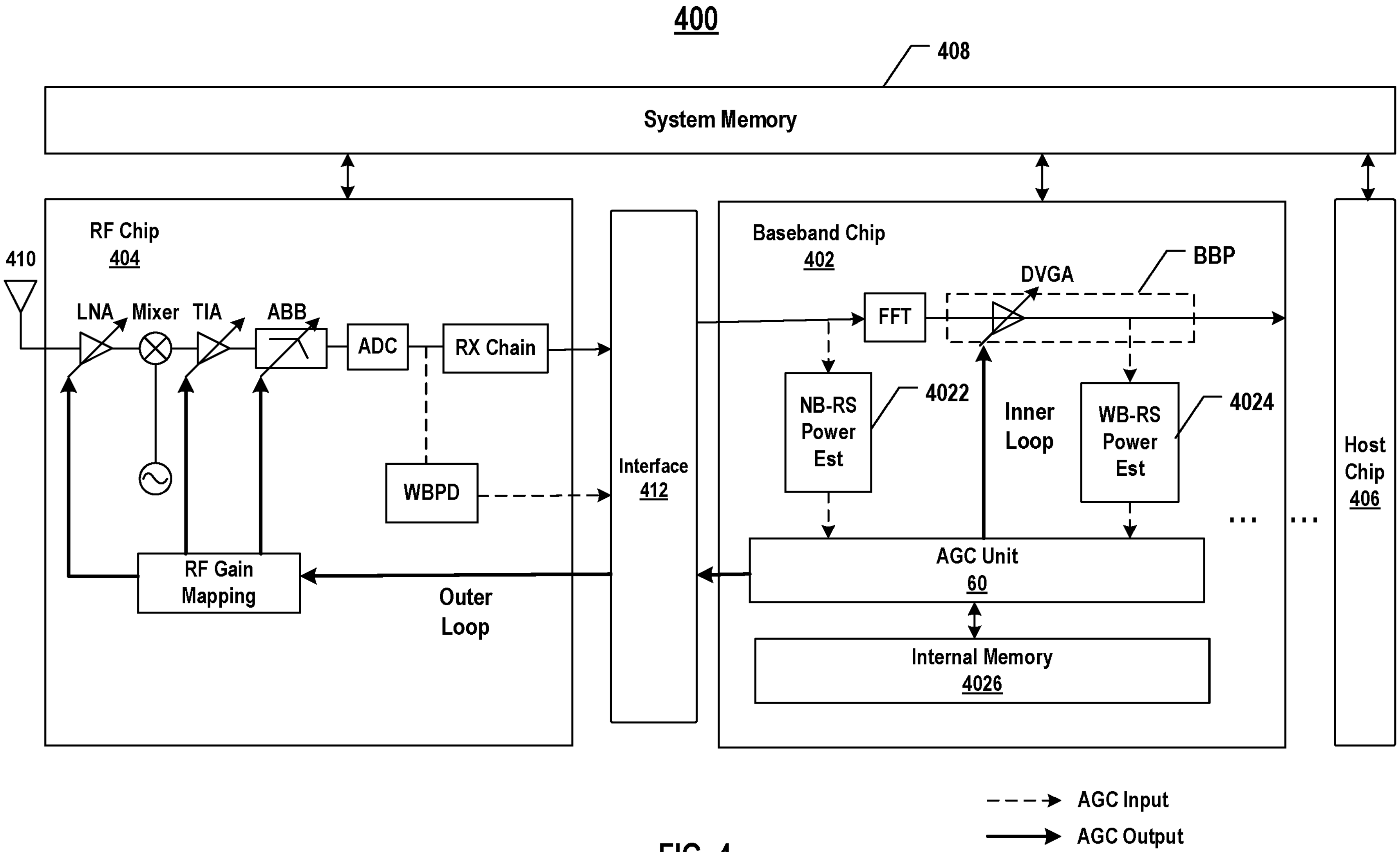
400
408
System Memory
RF Chip
404
410
LNA
Mixer
TIA
ABB
ADC
RX Chain
WBPD
RF Gain
Mapping
Outer
Loop
Interface
412
Baseband Chip
402
FFT
DVGA
BBP
NB-RS
Power
Est
4022
Inner
Loop
WB-RS
Power
Est
4024
AGC Unit
60
Internal Memory
4026
Host
Chip
406
AGC Input
AGC Output

FIG. 4

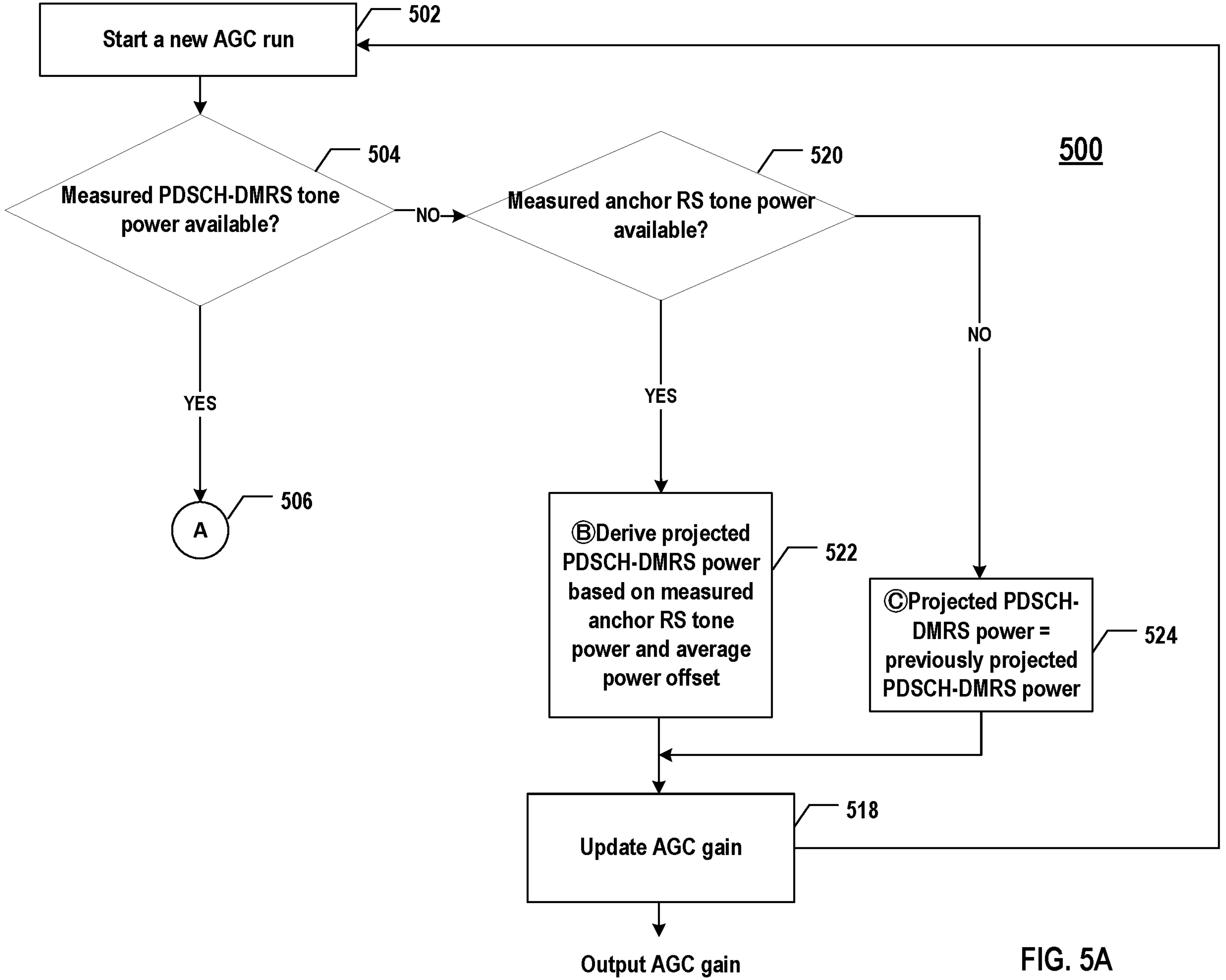
500
Start a new AGC run
502
Measured PDSCH-DMRS tone power available?
504
NO
YES
A
506
Measured anchor RS tone power available?
520
YES
NO
ⒷDerive projected PDSCH-DMRS power based on measured anchor RS tone power and average power offset
522
ⒸProjected PDSCH-DMRS power = previously projected PDSCH-DMRS power
524
Update AGC gain
518
Output AGC gain

FIG. 5A

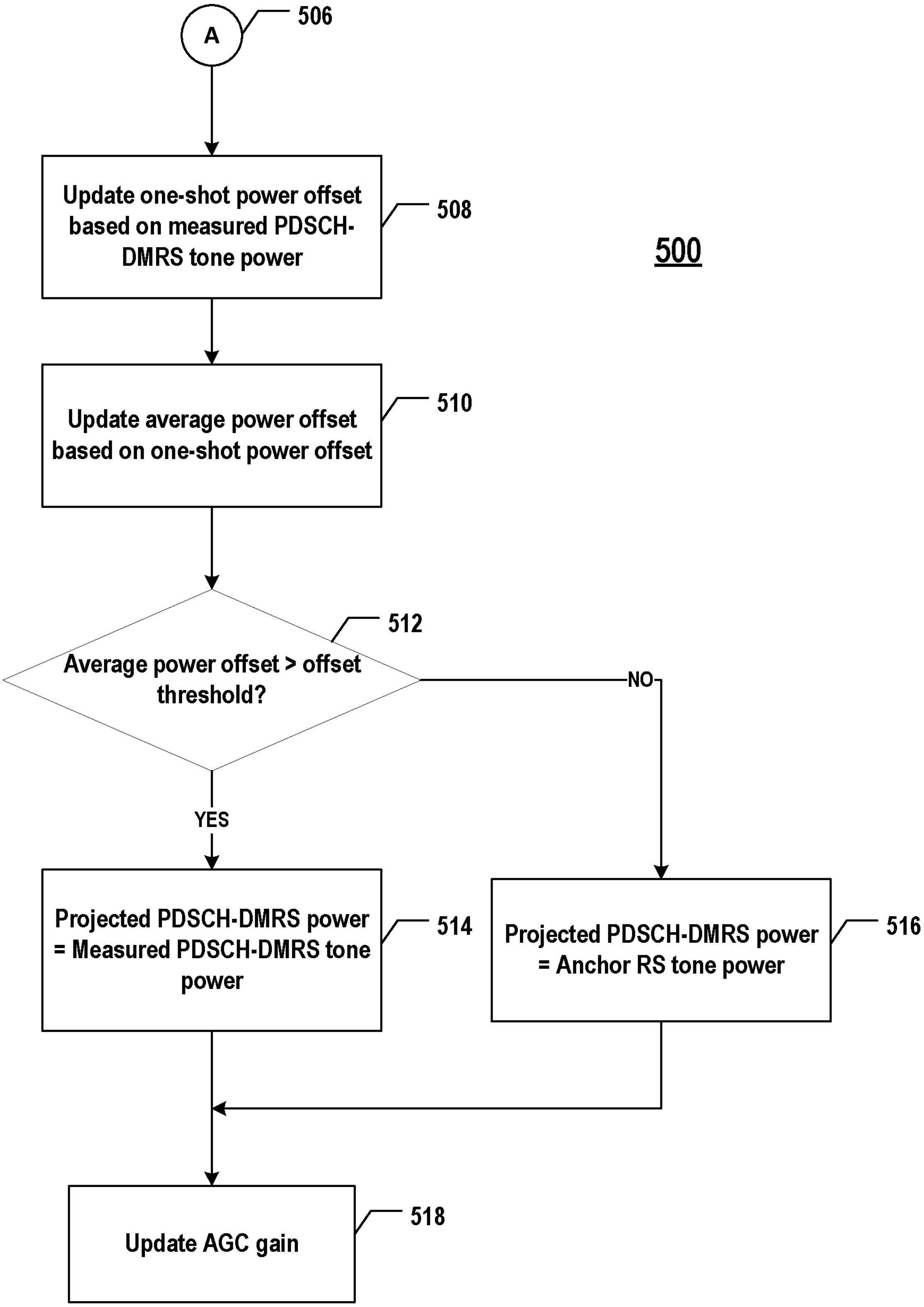
A
506
Update one-shot power offset based on measured PDSCH-DMRS tone power
508
500
Update average power offset based on one-shot power offset
510
512
Average power offset > offset threshold?
NO
YES
Projected PDSCH-DMRS power = Measured PDSCH-DMRS tone power
514
Projected PDSCH-DMRS power = Anchor RS tone power
516
Update AGC gain
518

FIG. 5B

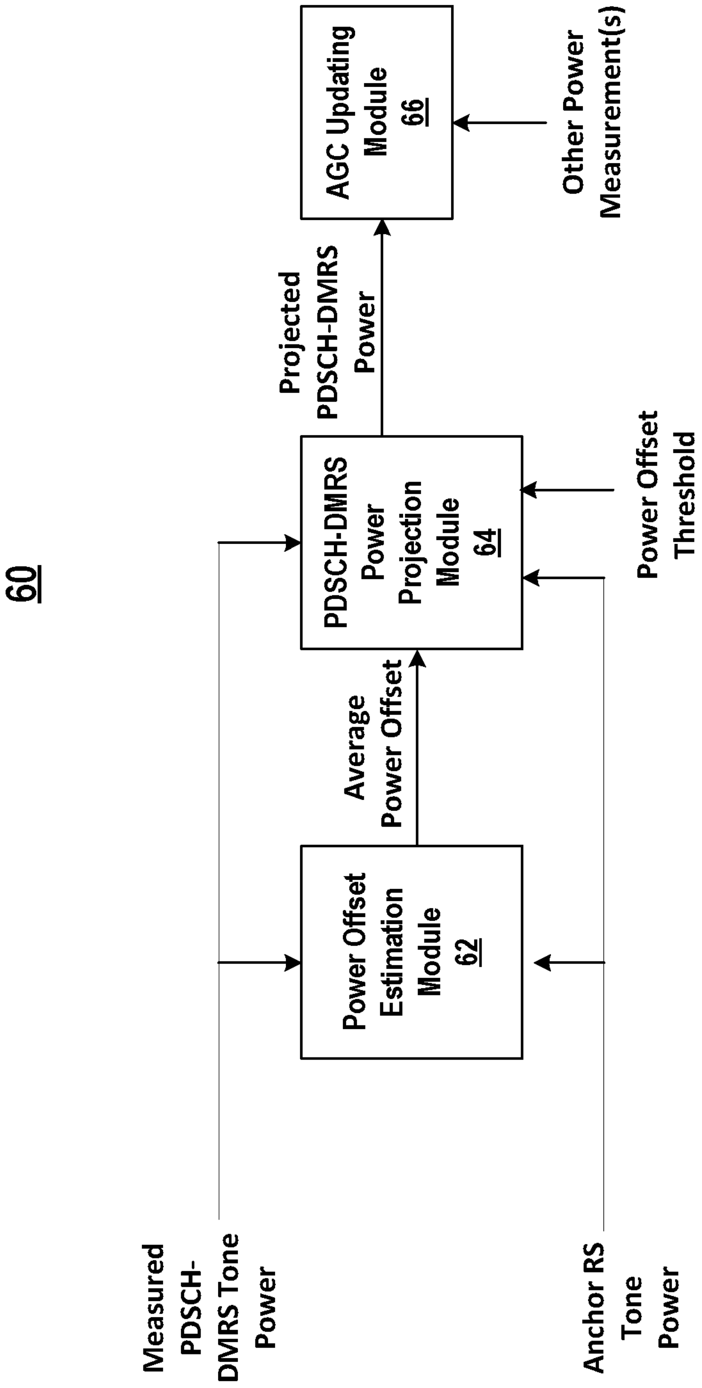
60
Measured PDSCH-DMRS Tone Power
Anchor RS Tone Power
Power Offset Estimation Module 62
Average Power Offset
PDSCH-DMRS Power Projection Module 64
Power Offset Threshold
Projected PDSCH-DMRS Power
AGC Updating Module 66
Other Power Measurement(s)

FIG. 6

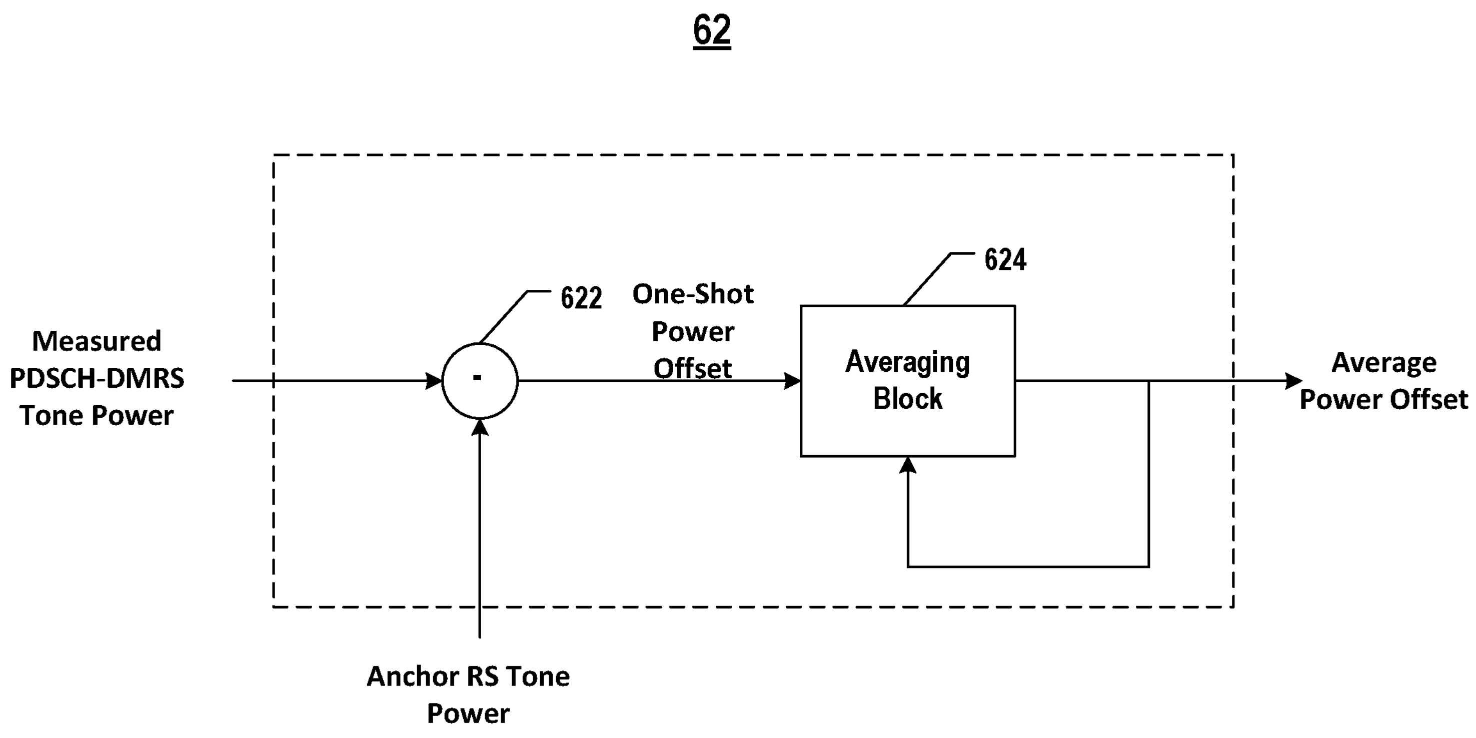
62
Measured
PDSCH-DMRS
Tone Power
622
-
One-Shot
Power
Offset
624
Averaging
Block
Average
Power Offset
Anchor RS Tone
Power

FIG. 7

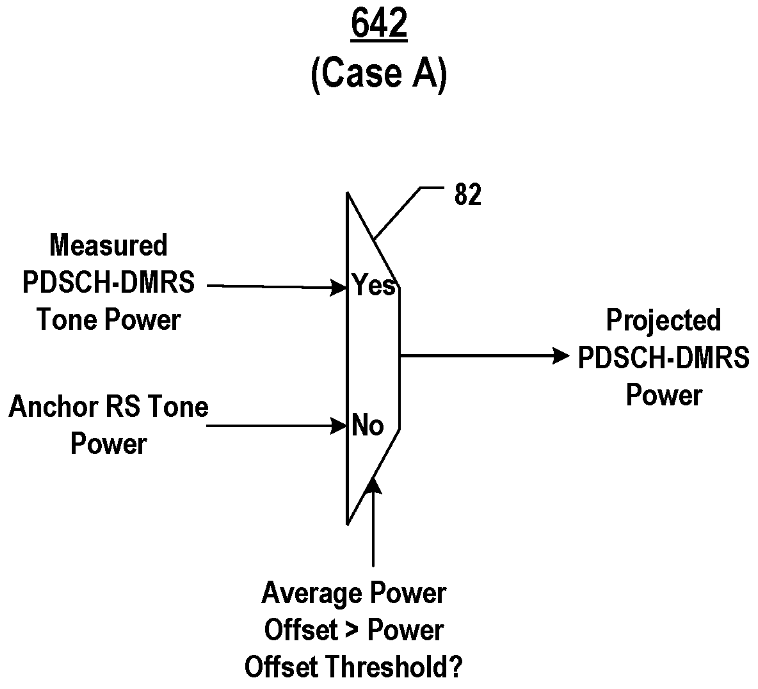
642
(Case A)
82
Measured PDSCH-DMRS Tone Power
Yes
Anchor RS Tone Power
No
Projected PDSCH-DMRS Power
Average Power Offset > Power Offset Threshold?

FIG. 8A

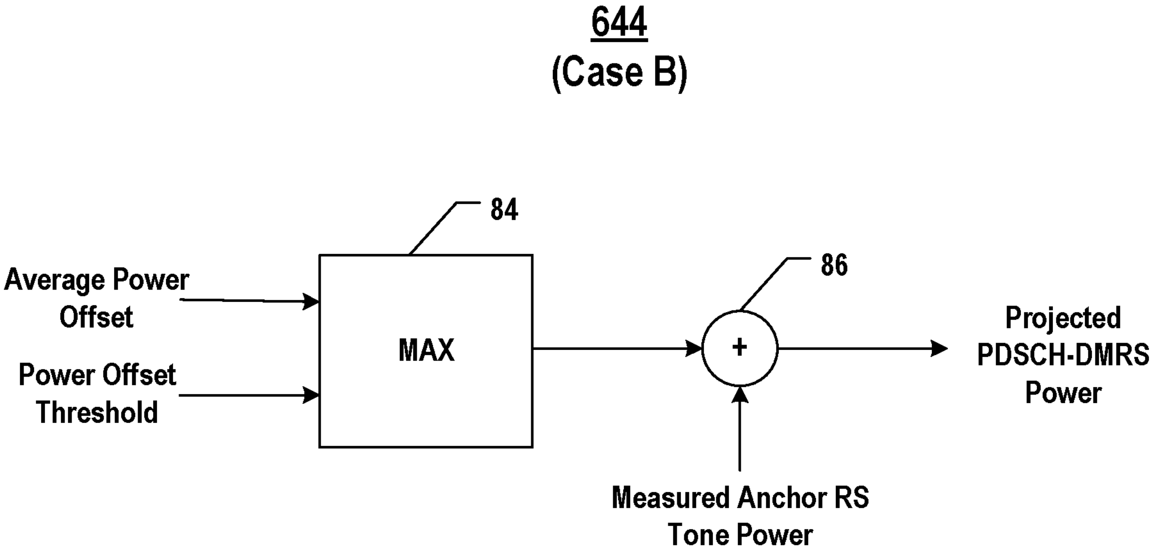
644
(Case B)
84
86
Average Power Offset
Power Offset Threshold
MAX
+
Projected PDSCH-DMRS Power
Measured Anchor RS Tone Power

FIG. 8B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 23/11860

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. H04W 48/12, H04L 1/00, H04B 1/12, H04W 72/23, H04W 52/52 (2023.01)
ADD. H04W 72/04 (2023.01)

CPC - INV. H04W 48/12, H04B 1/12, H04W 72/23, H04W 72/231, H04W 72/232, H04W 52/52, H04L 5/0048
ADD. H04W 72/04

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)
See Search History document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2021/0037484 A1 (Zhou et al.) 04 February 2021 (04.02.2021) entire document, especially para: [0063], [0163], [0186], [0313], [0359]	1-20
A	US 2022/0052808 A1 (SAMSUNG ELECTRONICS CO LTD) 17 February 2022 (17.02.2022) entire document	1-20
A	US 2022/0116949 A1 (QUALCOMM Incorporated) 14 April 2022 (14.04.2022) entire document	1-20
A	US 2013/0301428 A1 (WENG et al.) 14 November 2013 (14.11.2013) entire document	1-20

☐ 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
"D" document cited by the applicant in the international application
"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 another 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 20 April 2023	Date of mailing of the international search report MAY 03 2023
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300