(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 July 2018 (12.07.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/126356 A1

(51) International Patent Classification:
*H04W 72/04* (2009.01)

(21) International Application Number:
PCT/CN2017/070144

(22) International Filing Date:
04 January 2017 (04.01.2017)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **NOKIA TECHNOLOGIES OY** [FI/FI]; Karaportti 3, FI-02610 Espoo (FI).

(71) Applicant *(for LC only)*: **NOKIA TECHNOLOGIES (BEIJING) CO., LTD.** [CN/CN]; Unit 18, Room 1001, Level 10, East Tower, World Financial Center, No. 1 East Third Ring Middle Road, Chaoyang District, Beijing 100020 (CN).

(72) Inventors: **ZHANG, Yi**; Room 132, Building 27, Jia Yun Yuan, Lijun Road, Changping District, Beijing 102218 (CN). **ZHANG, Yuantao**; Room 3502, Bldg. Jia-4, Hepingli Yi Area, Dongcheng District, Beijing 100012 (CN). **MIAO, Deshan**; Room 903, Building 13, Linheli, Tongzhou District, Beijing 101101 (CN). **ENESCU, Mihai**; Riistapolku 4B 30, FI-02120 Espoo (FI).

(74) Agent: **KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Centre, No. 1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

(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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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, SA, 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, ST, 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).

**Declarations under Rule 4.17:**
— *of inventorship (Rule 4.17(iv))*

(54) Title: SOUNDING REFERENCE SIGNAL (SRS) POWER SCALING SCHEME

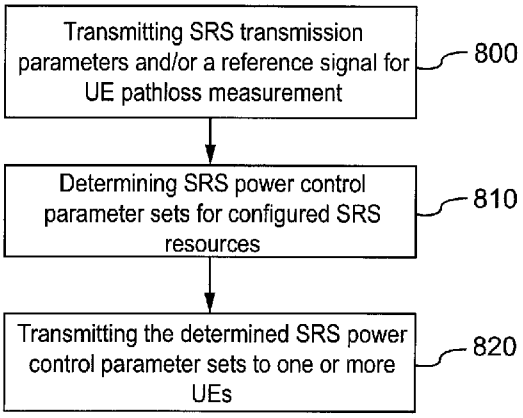



Fig. 8a

(57) Abstract: Systems, methods, apparatuses, and computer program products for sounding reference signal (SRS) power scaling, for example, in 5th generation new radio systems (5 G NR) are provided. One method includes transmitting, by a network node, at least one of SRS transmission parameters and reference signal for user equipment pathloss measurement. The SRS transmission parameters may include comb value and/or SRS pattern. The method may also include determining SRS power control parameter sets for configured SRS resources, and transmitting the determined SRS power control parameter sets to one or more user equipment. The comb value may be used as a scaling factor for the SRS power scaling.

WO 2018/126356 A1

*[Continued on next page]*

**Published:**
— *with international search report (Art. 21(3))*

# SOUNDING REFERENCE SIGNAL (SRS) POWER SCALING SCHEME

BACKGROUND:

**Field:**

**[0001]** Embodiments of the invention generally relate to wireless or mobile communications networks, such as, but not limited to, the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN), Long Term Evolution (LTE) Evolved UTRAN (E-UTRAN), LTE-Advanced (LTE-A), LTE-Advanced Pro, LTE-M, and/or 5G radio access technology or new radio access technology (NR). Some embodiments may generally relate to a sounding reference signal (SRS) power scaling scheme for 5G NR.

**Description of the Related Art:**

**[0002]** Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN) refers to a communications network including base stations, or Node Bs, and for example radio network controllers (RNC). UTRAN allows for connectivity between the user equipment (UE) and the core network. The RNC provides control functionalities for one or more Node Bs. The RNC and its corresponding Node Bs are called the Radio Network Subsystem (RNS). In case of E-UTRAN (enhanced UTRAN), no RNC exists and radio access functionality is provided by an evolved Node B (eNodeB or eNB) or many eNBs. Multiple eNBs are involved for a single UE connection, for example, in case of Coordinated Multipoint Transmission (CoMP) and in dual connectivity.

**[0003]** Long Term Evolution (LTE) or E-UTRAN refers to improvements of the UMTS through improved efficiency and services, lower costs, and use of new spectrum opportunities. In particular, LTE is a 3GPP standard that provides for uplink peak rates of at least, for example, 75 megabits per second (Mbps) per carrier and downlink peak rates of at least, for example, 300 Mbps per carrier. LTE supports scalable carrier bandwidths from 20 MHz down to 1.4 MHz and supports both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD).

**[0004]** As mentioned above, LTE may also improve spectral efficiency in networks, allowing carriers to provide more data and voice services over a given bandwidth. Therefore, LTE is designed to fulfill the needs for high-speed data and media transport in addition to high-capacity voice support. Advantages of LTE include, for example, high throughput, low latency, FDD and TDD support in the same platform, an improved end-user experience, and a simple architecture resulting in low operating costs.

**[0005]** Certain releases of 3GPP LTE (e.g., LTE Rel-10, LTE Rel-11, LTE Rel-12, LTE Rel-13) are targeted towards international mobile telecommunications advanced (IMT-A) systems, referred to herein for convenience simply as LTE-Advanced (LTE-A).

**[0006]** LTE-A is directed toward extending and optimizing the 3GPP LTE radio access technologies. A goal of LTE-A is to provide significantly enhanced services by means of higher data rates and lower latency with reduced cost. LTE-A is a more optimized radio system fulfilling the international telecommunication union-radio (ITU-R) requirements for IMT-Advanced while maintaining backward compatibility. One of the key features of LTE-A, introduced in LTE Rel-10, is carrier aggregation, which allows for increasing the data rates through aggregation of two or more LTE carriers.

**[0007]** 5$^{th}$ generation wireless systems (5G) refers to the new generation of radio systems and network architecture. 5G is expected to provide higher bitrates and coverage than the current LTE systems. Some estimate that 5G will provide bitrates one hundred times higher than LTE offers. 5G is also expected to increase network expandability up to hundreds of thousands of connections. The signal technology of 5G is anticipated to be improved for greater coverage as well as spectral and signaling efficiency. 5G is expected to deliver extreme broadband and ultra-robust, low latency connectivity and massive networking to support the Internet of Things (IoT). With IoT and machine-to-machine (M2M) communication becoming more widespread, there will be a growing need for networks that meet the needs of lower power, low data rate, and long battery life. Narrowband IoT-LTE (NB-IoT) is envisioned to operate on

180/200 kHz channel. The deployment of NB-IoT may be in-band LTE, a guard band to LTE, UMTS or other system as well as stand-alone on a specific carrier.

SUMMARY:

**[0008]** One embodiment is directed to a method of sounding reference signal (SRS) power scaling. The method includes transmitting, by a network node, at least one of sounding reference signal (SRS) transmission parameters and reference signal for user equipment pathloss measurement. The sounding reference signal (SRS) transmission parameters may include at least one of comb value or sounding reference signal (SRS) pattern. The method may further include determining sounding reference signal (SRS) power control parameter sets for configured sounding reference signal (SRS) resources, and transmitting the determined sounding reference signal (SRS) power control parameter sets to at least one user equipment. The comb value may be used as a scaling factor for the sounding reference signal (SRS) power scaling.

**[0009]** Another embodiment is directed to an apparatus, which may include at least one processor and at least one memory including computer program code. The at least one memory and the computer program code configured, with the at least one processor, to cause the apparatus at least to transmit at least one of sounding reference signal (SRS) transmission parameters and reference signal for user equipment pathloss measurement. The sounding reference signal (SRS) transmission parameters may include at least one of comb value or sounding reference signal (SRS) pattern. The at least one memory and the computer program code may be further configured, with the at least one processor, to cause the apparatus at least to determine sounding reference signal (SRS) power control parameter sets for configured sounding reference signal (SRS) resources, and transmit the determined sounding reference signal (SRS) power control parameter sets to at least one user equipment. The comb value may be used as a scaling factor for sounding reference signal (SRS) power scaling.

**[0010]** Another embodiment is directed to an apparatus, which includes transmitting means for transmitting at least one of sounding reference signal (SRS) transmission parameters and reference signal for user equipment pathloss measurement. The sounding

reference signal (SRS) transmission parameters may include at least one of comb value or sounding reference signal (SRS) pattern. The apparatus may further include determining means for determining sounding reference signal (SRS) power control parameter sets for configured sounding reference signal (SRS) resources, and transmitting means for transmitting the determined sounding reference signal (SRS) power control parameter sets to at least one user equipment. The comb value is used as a scaling factor for sounding reference signal (SRS) power scaling.

**[0011]** Another embodiment is directed to a method of sounding reference signal (SRS) power scaling. The method may include receiving, by a user equipment, at least one of sounding reference signal (SRS) transmission parameters and reference signal for pathloss measurement, performing reference signal received power (RSRP) measurement based on the received at least one reference signal and obtaining the reference signal received power (RSRP) and the pathloss measurement, receiving sounding reference signal (SRS) power control parameters for configured sounding reference signal (SRS) resources, and determining transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters.

**[0012]** Another embodiment is directed to an apparatus, which may include at least one processor and at least one memory including computer program code. The at least one memory and the computer program code configured, with the at least one processor, to cause the apparatus at least to receive at least one of sounding reference signal (SRS) transmission parameters and reference signal for pathloss measurement, perform reference signal received power (RSRP) measurement based on the received at least one reference signal and obtain the reference signal received power (RSRP) and the pathloss measurement, receive sounding reference signal (SRS) power control parameters for configured sounding reference signal (SRS) resources, and determine transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters.

**[0013]** Another embodiment is directed to an apparatus, which may include receiving means for receiving at least one of sounding reference signal (SRS) transmission parameters and reference signal for pathloss measurement, performing means for performing reference signal received power (RSRP) measurement based on the received at least one reference signal and obtaining the reference signal received power (RSRP) and the pathloss measurement, receiving means for receiving sounding reference signal (SRS) power control parameters for configured sounding reference signal (SRS) resources, and determining means for determining transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters.

BRIEF DESCRIPTION OF THE DRAWINGS:

**[0014]** For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

**[0015]** Fig. 1 illustrates an example of a procedure of multiple beam SRS transmission for beam management;

**[0016]** Fig. 2a illustrates an example of a frequency division multiplexing (FDM) for multiple beam SRS management;

**[0017]** Fig. 2b illustrates an example of a time division multiplexing (TDM) for multiple beam SRS management;

**[0018]** Fig. 3 illustrates a block diagram depicting an example of the impact of frequency density on SRS transmission power;

**[0019]** Fig. 4 illustrates an example of the high priority for beam management SRS, according to an embodiment;

**[0020]** Fig. 5 illustrates a diagram depicting an example of high priority by better link quality and transmitting on primary sounding resource, according to an embodiment;

**[0021]** Fig. 6 illustrates an example of a signaling diagram, according to one embodiment;

**[0022]** Fig. 7a illustrates a block diagram of an apparatus, according to one embodiment;

**[0023]** Fig. 7b illustrates a block diagram of an apparatus, according to another embodiment;

**[0024]** Fig. 8a illustrates a flow diagram of a method, according to an embodiment; and

**[0025]** Fig. 8b illustrates a flow diagram of a method, according to another embodiment.

DETAILED DESCRIPTION:

**[0026]** It will be readily understood that the components of the invention, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following detailed description of embodiments of systems, methods, apparatuses, and computer program products for sounding reference signal (SRS) power scaling in, for example, 5$^{th}$ generation new radio systems (5G NR), as represented in the attached figures, is not intended to limit the scope of the invention, but is merely representative of some selected embodiments of the invention.

**[0027]** The features, structures, or characteristics of the invention described throughout this specification may be combined in any suitable manner in one or more embodiments. For example, the usage of the phrases "certain embodiments," "some embodiments," or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present invention. Thus, appearances of the phrases "in certain embodiments," "in some embodiments," "in other embodiments," or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

**[0028]** Additionally, if desired, the different functions discussed below may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the described functions may be optional or may be combined. As such, the following description should be considered as merely illustrative of the principles, teachings and embodiments of this invention, and not in limitation thereof.

**[0029]** Certain embodiments described herein relate to 5G wireless systems with support for massive multiple-input and multiple-output (m-MIMO). These systems are characterized by increased antenna number, finer beamforming and higher antenna gain. In particular, some embodiments relate to power scaling for SRS on account of flexible time frequency configuration and precoding/beamforming at both the transmit and/or receive side. In certain embodiments described herein, SRS refers to a reference signal (RS) transmitted by a UE in the uplink (UL) direction and used by an eNB/gNB, for example, to estimate the UL channel quality over a wider bandwidth and/or for UL frequency selective scheduling.

**[0030]** For LTE systems, power control for SRS is linked with that for physical uplink shared channel (PUSCH) by one offset value in principle. In detail, SRS power control is specified according to the following formula:

$$P_{\mathrm{SRS},c}(i) = \min\left\{ P_{\mathrm{CMAX},c}(i),\ P_{\mathrm{SRS_OFFSET},c}(m) + 10\log_{10}(M_{\mathrm{SRS},c}) + P_{\mathrm{O_PUSCH},c}(j) + \alpha_c(j)\cdot PL_c + f_c(i) \right\}$$

where $P_{\mathrm{CMAX},c}(i)$ is the configured maximal allowed transmit power for a specific cell $c$; $M_{\mathrm{SRS},c}(i)$ is the uplink physical resource block (PRB) number for SRS transmission; $P_{\mathrm{O_PUSCH},c}(j)$ is the semi-static nominal power for PUSCH; $PL_c$ is downlink pathloss estimated in the UE for serving cell $c$ in dB; $\alpha_c(j)$ is a cell specific pathloss compensation factor to achieve balance between cell average and cell edge throughput; $f_c(i)$ is the PUSCH close loop power adjustment part for serving cell c; and $P_{\mathrm{SRS_OFFSET},c}(m)$ is the offset value for power adjustment relative to PUSCH power control, which is semi-statically configured by higher layers.

**[0031]** When the total transmit power of the UE for the SRS in an SC-FDMA symbol exceeds $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\mathrm{SRS},c}(i)$ for the serving cell $c$ and the SC-FDMA symbol in subframe $i$ such that the following condition,

$$\sum_{c} w(i) \cdot \hat{P}_{\mathrm{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

,

is satisfied where $\hat{P}_{\mathrm{SRS},c}(i)$ is the linear value of $P_{\mathrm{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of $P_{CMAX}$ in subframe $i$ and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c}(i)$ for serving cell $c$ where $0 < w(i) \le 1$. In this example, $w(i)$ values are the same across serving cells.

**[0032]** 3GPP working groups have agreed to some basic power control principles for NR-PUSCH; however, the power control for other reference signals (RSs) still requires further study. The agreed principles include that, for NR-PUSCH at least targeting enhanced mobile broadband (eMBB), open-loop power control based on pathloss estimate is supported (pathloss is estimated using DL RS for measurement, fractional power control is supported, but which DL RS(s) for measurement is used was left for further study) and closed-loop power control is supported based on network signaling (dynamic UL-power adjustment is considered). However, numerology specific power control (e.g., numerology specific power control parameters), beam specific power control parameters, power control for other RSs and physical channels, power control for grant free PUSCH if supported, and power control per layer (group) were all left for further study.

**[0033]** In view of this need for a power control scheme for other RSs, certain embodiments of the present disclosure provide enhanced SRS power scaling scheme on account of flexible time frequency resource configuration and precoding/beamforming at both transmit and/or receive side for SRS.

**[0034]** 3GPP has agreed that SRS can be configured with different density, e.g., comb levels, in frequency domain. The agreements include that, in NR, SRS can be configurable with respect to density in frequency domain (e.g., comb levels) and/or in time domain (including multi-symbol SRS transmissions); but the specifics of the configurable frequency density for SRS were left for further study. Additionally, the details on how the set of port(s) for SRS can be indicated by the gNodeB (gNB) were also left for further study.

**[0035]** In a LTE system, only the physical resource block (PRB) number is used for determining SRS transmission power and has no relation with SRS pattern in detail.

For 5G NR, the SRS resource configuration is flexible and frequency density, e.g., comb levels, can be variable. This can be considered for a UE to determine SRS transmission power.

**[0036]** 3GPP has also agreed that multiple SRS resources (K>1) can be configured for one UE according to the UE capability. In particular, the agreements include that an NR-SRS resource comprises of a set of resource elements (RE) within a time duration/frequency span and N antenna ports ($N \geq 1$), and a UE can be configured with $K \geq 1$ NR-SRS resources (Consider the maximum value of K to be a UE capability to avoid mandatory support for large values of K). However, the time duration/frequency span was not agreed upon.

**[0037]** With the unified design framework for both orthogonal frequency division multiple access (OFDMA) and single carrier frequency division multiple access (SC-FDMA) waveforms, the multiplexing situation at the UE side becomes more complex, which includes simultaneous transmission for PUCCH, PUSCH and all types of SRS. When multiple SRS resources are configured, different SRS can be transmitted in one OFDM symbol, which are used for different precoding/beamforming, numerology and even multiple functions including downlink/uplink channel state information (CSI) acquisition and beam management. For example, for beam management SRS, SRS may be transmitted from a UE with multiple [analogue] beams where each beam is configured with different resource in frequency domain or time domain. Therefore, these new cases should be considered for SRS power scaling in 5G NR.

**[0038]** When SRS is used for beam management, SRS may be transmitted with 'multiple beams' so that the gNB can decide which beam is the best. Fig. 1 illustrates an example of a procedure of multiple beam SRS transmission for beam management. As illustrated in Fig. 1, at step 1, the UE selects the best beam from DL beamformed RS and, at step 2, the UE sends multiple adjacent beams for accurate beam selection. The gNB may then detect the best beam. There may be two different ways to support multi-beam SRS transmission, frequency division multiplexing (FDM) or time division

multiplexing (TDM). In case of TDM, only a part of SRS can be overlapped with other channel/signal.

**[0039]** Figs. 2a and 2b illustrate an example of a FDM and TDM scheme, respectively, for multiple beam SRS management. For multiple beam SRS transmission, the power scaling scheme needs to be considered to achieve the consistence of channel estimation quality for the sounding link with different beams.

**[0040]** Accordingly, certain embodiments of the present disclosure provide enhanced SRS power scaling schemes, where the granularity for SRS in frequency domain (e.g., Comb), SRS functions, link quality, robustness transmission requirement are considered.

**[0041]** For example, the enhanced SRS power scaling scheme(s) described herein can work well for simultaneous transmission of PUCCH, PUSCH and multiple SRS in m-MIMO system(s) with flexible beamforming.

**[0042]** In certain embodiments, at least the following aspects are addressed: the configurable frequency density, e.g. Comb, is considered for SRS power scaling; the high priority is put on beam management SRS for guaranteeing transmission power; the link quality of beam pair used for SRS transmission is considered for SRS power scaling in case of multiple SRS simultaneous transmission; and transmission robustness and flexibility controlled by gNB are considered for SRS power scaling in case of multiple SRS simultaneous transmission.

**[0043]** As mentioned above, according to current power control mechanism, SRS transmit power is only related with number of PRBs and has no relation with SRS pattern. In 5G NR, the configurable frequency density, e.g. comb, is used for one UE. Thus, according to one embodiment, comb value is introduced into SRS power control scheme. If uniform power spectrum is assumed, SRS transmit power may be linearly increased with RE number per symbol in one PRB. The scaling factor, $2/n_comb$, is imported to eliminate the impact of different frequency density for SRS pattern since the value of comb is assumed 2 for power control scheme in LTE. Fig. 3 illustrates one example of the impact of frequency density on SRS transmission power. SRS transmission power of configuration 1, e.g. comb 2, is 2 times that of configuration 2

and 3, e.g., comb 4. In particular, according to an embodiment, the power control formula is modified as follows:

$$P_{\mathrm{SRS},c}(i)=\min\left\{P_{\mathrm{CMAX},c}(i),\ P_{\mathrm{SRS_OFFSET},c}(m)+10\log_{10}(M_{\mathrm{SRS},c}\times 2/n_comb)+P_{\mathrm{O_PUSCH},c}(j)+\alpha_c(j)\cdot PL_c+f_c(i)\right\}$$

where $P_{\mathrm{CMAX},c}(i)$ is the configured maximal allowed transmit power for a specific cell $c$; $M_{\mathrm{SRS},c}(i)$ is the uplink physical resource block (PRB) number for SRS transmission; $P_{\mathrm{O_PUSCH},c}(j)$ is the semi-static nominal power for PUSCH; $PL_c$ is downlink pathloss estimated in the UE for serving cell $c$ in dB; $\alpha_c(j)$ is a cell specific pathloss compensation factor to achieve balance between cell average and cell edge throughput; $f_c(i)$ is the PUSCH close loop power adjustment part for serving cell c; $P_{\mathrm{SRS_OFFSET},c}(m)$ is the offset value for power adjustment relative to PUSCH power control, which is semi-statically configured by higher layers; and n_comb is the number comb (for example, this value is 2 for LTE systems but may have more possible values in 5G NR).

**[0044]** In LTE systems, discrete fourier transform spread (DFT-S-OFDM) is used for uplink on account of low peak to average power ratio (PAPR) requirement. SRS will be dropped if it is transmitted simultaneously with PUSCH/PUCCH at the last OFDM symbol. For 5G NR, both cyclic prefix (CP)-OFDM and DFT-S-OFDM based waveforms are mandatory for UEs. It is agreed that the common framework is used to design RS for both CP-OFDM and DFT-S-OFDM based waveforms. Therefore, SRS may be simultaneously transmitted with PUSCH/PUCCH in one OFDM symbol. When transmission power for a UE exceeds the maximum power, the power scaling is used.

**[0045]** For SRS with CSI acquisition, it has lower priority relative to PUCCH/PUSCH because it is just used for obtaining uplink or downlink CSI for data transmission in later subframes. Type 0 and 1 SRS are defined in LTE specification for periodic and aperiodic SRS, respectively. For 5G NR, a new function of beam management SRS is being introduced. For beam management SRS, SRS may be transmitted from a UE with multiple [analogue] beams where each beam is configured with difference resource in frequency domain or time domain. SRS for beam management will be triggered to transmit when the link quality with selected beam pair is not good, e.g., in case of beam recovery/reselection. If there is no restriction for the

time instance of beam management SRS transmission, beam management SRS may be transmitted with PUSCH/PUCCH/other SRS in one OFDM symbol in some special cases, such as: 1) UE initialized SRS transmission for beam management; 2) Semi-persistent scheduling for PUSCH; 3) High layer configured periodic SRS; 4) PUCCH transmission with fixed time relation with PUSCH. If scaling is used for beam management SRS in case of simultaneous transmission with other uplink channel and/or signal, it will have impact on the beam recovery/reselection results. This is not desirable from the view of later PUSCH/PUCCH transmission. Therefore, according to an embodiment, higher priority is placed on beam management SRS transmission and its transmission power is guaranteed. That means PUCCH/PUSCH/type 0 or 1 SRS will be scaled or dropped if they are transmitted with beam management SRS in one OFDM symbol. Fig. 4 illustrates an example of the high priority for beam management SRS, according to an embodiment. In detail, the priority on transmit power allocation may be applied according to: Beam management SRS > PUCCH > PUSCH > Type 1/0 SRS. Furthermore, when the power scaling for beam management SRS is necessary, the same transmit (Tx) power may be configured for each of SRS beams even when only part of the SRS beam(s) is simultaneous transmitted with PUCCH/PUSCH, etc.

**[0046]** In one embodiment, multiple SRS resources can be configured with different beamforming/precoding, even with different numerology. According to an embodiment, when multiple SRS are transmitted in one OFDM symbol and the transmit power of UE exceeds maximum power, the power scaling scheme described herein may be used. In an embodiment, type 1 SRS, e.g., aperiodic SRS, has high priority than type 0, e.g., periodic SRS, since aperiodic SRS is triggered by the gNb and its related measurement is required urgently. Thus, transmit power for type 1 SRS can be guaranteed when it is transmitted simultaneously with type 0 SRS.

**[0047]** For the same type SRS transmitted simultaneously, the principle for power scaling needs specification. Since the offset value relative to linked PUSCH has been used for only guaranteeing required channel estimation performance in SRS power control, power scaling on SRS will be harmful to channel estimation quality. To achieve the accuracy of channel estimation, guaranteed SRS transmission power is

needed. Thus, an embodiment places high priority on guaranteeing SRS transmit power for the link with better quality because a better link may have higher probability for scheduling data transmission. Fig. 5 illustrates a diagram depicting an example of high priority by better link quality and transmitting on primary sounding resource, according to an embodiment. On account of different beamforming/precoding used for SRS resources, link quality in the long term can be reflected by reference signal received power (RSRP). That means SRS on the linked beam pair with larger RSRP can be guaranteed with high priority for the transmit power. This is depicted as case 1 in Fig. 5. Since a UE will report RSRP of the linked beam pair to the gNB, there is a common understanding between UE and gNB on the priority for guaranteeing SRS transmit power. For SRS simultaneously transmitted with the same beam pair, the equal power scaling factor may be used because of the same link quality.

**[0048]** To guarantee the robust transmission for later data transmission and some flexibility in variable network load conditions, in one embodiment, the gNB may have the capability to control the priority on guaranteeing transmit power in case of SRS power scaling. Signalling may be needed to indicate the priority for power allocation of multiple SRS. In one embodiment, one SRS resource can be configured by the gNB as primary sounding resource. On this primary resource, the SRS transmit power is guaranteed to the best. This is depicted as case 2 in Fig. 5. In another embodiment, the gNB may indicate the muted sounding resource with high priority. Better channel estimate quality can be guaranteed for other sounding links by muting SRS on this configured sounding resource with high muting priority. This may be especially useful for the case of multi-shot sounding where CSI is obtained by multiple shots and sounding in other shots can be a complement. Using these two alternatives, SRS with desired beam pair, numerology by gNb can be guaranteed for transmit power. Thus, for the related link, the channel estimation quality is accurate and later data transmission can be robust.

**[0049]** Summarizing the above, certain embodiments of the present disclosure are directed to introducing comb value into SRS power control scheme as scaling factor; placing high priority on guaranteeing transmit power for beam management SRS

relative to PUCCH/ PUSCH/type 1/0 SRS in case of power scaling; in case of multiple same type SRS transmission in the same OFDM symbol, guaranteeing SRS transmit power with high priority on the beam pair with larger RSRP, guaranteeing SRS transmit power with high priority on primary sounding resource configured by gNB, and muting SRS on the configured sounding resource with high muting priority to guarantee channel estimation quality of other links; and when the power scaling for SRS is necessary, the same Tx power will be configured for each of SRS beams even when only part of the SRS beam(s) is simultaneous transmitted with PUCCH/PUSCH, etc.

**[0050]** Fig. 6 illustrates an example of a signaling diagram, according to one embodiment. In the example of Fig. 6, a gNB sends SRS transmission parameters and related signalling for SRS power control. A UE performs RSRP measurement and sets transmit power according to the gNB's indication. If the UE transmits SRS simultaneously with other channel/signal and the UE's total transmit power exceeds maximum transmit power, $P_{\mathrm{CMAX,c}}$, the power scaling scheme may be used according to a pre-defined priority. More specifically, as illustrated in Fig. 6, at 1, the gNB transmits SRS transmission parameters that may include comb value, SRS pattern, etc. At 2, the gNB may also send reference signal(s), such as a beam reference signal (BRS) or Channel State Information Reference Signal (CSI-RS), for UE pathloss measurement. The UE, at 3, performs RSRP measurement based on the received reference signal (e.g., BRS or CSI-RS) and obtains the RSRP and pathloss. At 4, the gNB may determine SRS power control parameter sets for configured SRS resources, including P0, $\alpha$, fc, and offset value relative to linked PUSCH, and sends these parameters to the UE, for example, via high layer and/or physical signaling.

**[0051]** The UE, at 5, may determine the transmit power for each SRS resource based on the gNb's signalling, pathloss measurement results, and the SRS transmission parameter, e.g. comb, according to the following formula (Formula 1):

$$P_{\mathrm{SRS,c}}(i) = \min\left\{ P_{\mathrm{CMAX,c}}(i),\ P_{\mathrm{SRS_OFFSET,c}}(m) + 10\log_{10}(M_{\mathrm{SRS,c}} \times 2 / n_comb) + P_{\mathrm{O_PUSCH,c}}(j) + \alpha_c(j) \cdot PL_c + f_c(i) \right\}$$

where $P_{\mathrm{CMAX,c}}(i)$ is the configured maximal allowed transmit power for a specific cell $c$;

$M_{SRS,c}(i)$ is the uplink physical resource block (PRB) number for SRS transmission; $P_{O_PUSCH,c}(j)$ is the semi-static nominal power for PUSCH; $PL_c$ is downlink pathloss estimated in the UE for serving cell $c$ in dB; $\alpha_c(j)$ is a cell specific pathloss compensation factor to achieve balance between cell average and cell edge throughput; $f_c(i)$ is the PUSCH close loop power adjustment part for serving cell c; $P_{SRS_OFFSET,c}(m)$ is the offset value for power adjustment relative to PUSCH power control, which is semi-statically configured by higher layers; and n_comb is the number comb (for example, this value is 2 for LTE systems but may have more possible values in 5G NR).

**[0052]** If SRS are transmitted with other uplink channel/signal and the UE's transmission power exceeds maximum transmission power, at 6, power scaling may be used according to a pre-defined priority as follows:

A. If SRS is beam management SRS and it is transmitted simultaneously with PUCCH/PUSCH/type 1/0 SRS, keep the SRS transmit power determined at step 5 and/or the same Tx power may be configured for each of SRS beams even when only part of the SRS beam(s) is simultaneously transmitted with PUCCH/PUSCH, etc.;

B. If SRS is not beam management SRS and it is transmitted simultaneously with PUCCH/PUSCH, SRS is transmitted with remaining power except for PUCCH/PUSCH transmit power;

C. If type 1 SRS is transmitted simultaneously with type 0 SRS, type 1 SRS is transmitted with power determined at step 5 and type 0 SRS is transmitted with remaining power;

D. If SRS is transmitted simultaneously with other same type SRS,

   i. If primary sounding resource is configured by gNB, SRS on primary sounding resource is transmitted with power determined at step 5;

   ii. Mute SRS on sounding resource(s) with high muting priority if configured by gNB;

iii. For the beam pair with larger RSRP, the SRS with this beam pair is transmitted with power determined at step 5. For the beam pair with smaller RSRP, the SRS with this beam pair is transmitted with remaining power;

iv. If the same beam pair is used, equal power scaling is used for multiple SRS.

**[0053]** Fig. 7a illustrates an example of an apparatus 10 according to an embodiment. In an embodiment, apparatus 10 may be a node, host, or server in a communications network or serving such a network. For example, apparatus 10 may be a base station, a node B, an evolved node B, 5G node B or access point, next generation node B (NG-NB), gNB, WLAN access point, mobility management entity (MME), or subscription server associated with a radio access network, such as a GSM network, LTE network or 5G radio access technology. It should be noted that one of ordinary skill in the art would understand that apparatus 10 may include components or features not shown in Fig. 7a.

**[0054]** As illustrated in Fig. 7a, apparatus 10 may include a processor 12 for processing information and executing instructions or operations. Processor 12 may be any type of general or specific purpose processor. While a single processor 12 is shown in Fig. 7a, multiple processors may be utilized according to other embodiments. In fact, processor 12 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples.

**[0055]** Processor 12 may perform functions associated with the operation of apparatus 10 which may include, for example, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 10, including processes related to management of communication resources.

**[0056]** Apparatus 10 may further include or be coupled to a memory 14 (internal or external), which may be coupled to processor 12, for storing information and

instructions that may be executed by processor 12. Memory 14 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. For example, memory 14 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, hard disk drive (HDD), or any other type of non-transitory machine or computer readable media. The instructions stored in memory 14 may include program instructions or computer program code that, when executed by processor 12, enable the apparatus 10 to perform tasks as described herein.

**[0057]** In some embodiments, apparatus 10 may also include or be coupled to one or more antennas 15 for transmitting and receiving signals and/or data to and from apparatus 10. Apparatus 10 may further include or be coupled to a transceiver 18 configured to transmit and receive information. The transceiver 18 may include, for example, a plurality of radio interfaces that may be coupled to the antenna(s) 15. The radio interfaces may correspond to a plurality of radio access technologies including one or more of GSM, NB-IoT, LTE, 5G, WLAN, Bluetooth, BT-LE, NFC, radio frequency identifier (RFID), ultrawideband (UWB), and the like. The radio interface may include components, such as filters, converters (for example, digital-to-analog converters and the like), mappers, a Fast Fourier Transform (FFT) module, and the like, to generate symbols for a transmission via one or more downlinks and to receive symbols (for example, via an uplink). As such, transceiver 18 may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) 15 and demodulate information received via the antenna(s) 15 for further processing by other elements of apparatus 10. In other embodiments, transceiver 18 may be capable of transmitting and receiving signals or data directly.

**[0058]** In an embodiment, memory 14 may store software modules that provide functionality when executed by processor 12. The modules may include, for example, an operating system that provides operating system functionality for apparatus 10. The

memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 10. The components of apparatus 10 may be implemented in hardware, or as any suitable combination of hardware and software.

**[0059]** In one embodiment, apparatus 10 may be a network node or server, such as a base station, node B, eNB, 5G node B or access point (AP), gNB, WLAN AP, or next generation node B (NG-NB), for example. According to certain embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to perform the functions associated with embodiments described herein. For example, in an embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to transmit SRS transmission parameters and/or a reference signal (e.g., BRS) for user equipment pathloss measurement. In one embodiment, the SRS transmission parameters may include a comb value and/or SRS pattern. In an embodiment, the reference signal for user equipment pathloss measurement may include a beam reference signal (BRS).

**[0060]** According to certain embodiments, apparatus 10 may be further controlled by memory 14 and processor 12 to determine SRS power control parameter sets for configured SRS resources, and to transmit the determined SRS power control parameter sets to one or more UEs. In an embodiment, the comb value transmitted as a part of the SRS transmission parameters may be used as a scaling factor to perform the SRS power scaling.

**[0061]** In one embodiment, the SRS power control parameter sets may include P0, $\alpha$, fc, and/or offset value relative to linked PUSCH. According to an embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to transmit the determined SRS power control parameter sets to the UE(s) by higher layer and/or physical signaling.

**[0062]** In an embodiment, when the SRS is beam management SRS, apparatus 10 may be controlled by memory 14 and processor 12 to guarantee the transmit power of the SRS. According to an embodiment, when SRS power scaling becomes necessary, apparatus 10 may be controlled by memory 14 and processor 12 to configure a same

transmit power for each SRS beam even when only a part of the SRS beams are transmitted simultaneously with PUCCH/PUSCH. In certain embodiments, when multiple SRSs are transmitted in one orthogonal frequency division multiplexing (OFDM) symbol, apparatus 10 may be controlled by memory 14 and processor 12 to guarantee a high priority of transmit power for the one of the multiple SRSs that has a largest RSRP. According to an embodiment, apparatus 10 may be further controlled by memory 14 and processor 12 to configure one or more of the SRS resources as a primary sounding resource to guarantee transmit power for SRS power scaling. In some embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to mute SRS on at least one of the configured SRS resources with high muting priority in order to guarantee channel estimation quality of other links.

**[0063]** Fig. 7b illustrates an example of an apparatus 20 according to another embodiment. In an embodiment, apparatus 20 may be a node or element in a communications network or associated with such a network, such as a UE, mobile equipment (ME), mobile station, mobile device, stationary device, IoT device, or other device. As described herein, UE may alternatively be referred to as, for example, a mobile station, mobile equipment, mobile unit, mobile device, user device, subscriber station, wireless terminal, tablet, smart phone, IoT device or NB-IoT device, or the like. As one example, Apparatus 20 may be implemented in, for instance, a wireless handheld device, a wireless plug-in accessory, or the like.

**[0064]** In some example embodiments, apparatus 20 may include one or more processors, one or more computer-readable storage medium (for example, memory, storage, and the like), one or more radio access components (for example, a modem, a transceiver, and the like), and/or a user interface. In some embodiments, apparatus 20 may be configured to operate using one or more radio access technologies, such as GSM, NB-IoT, LTE, LTE-A, 5G, WLAN, WiFi, Bluetooth, NFC, and any other radio access technologies. It should be noted that one of ordinary skill in the art would understand that apparatus 20 may include components or features not shown in Fig. 7b.

**[0065]** As illustrated in Fig. 7b, apparatus 20 may include or be coupled to a processor 22 for processing information and executing instructions or operations.

Processor 22 may be any type of general or specific purpose processor. While a single processor 22 is shown in Fig. 7b, multiple processors may be utilized according to other embodiments. In fact, processor 22 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples.

**[0066]** Processor 22 may perform functions associated with the operation of apparatus 20 including, without limitation, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 20, including processes related to management of communication resources.

**[0067]** Apparatus 20 may further include or be coupled to a memory 24 (internal or external), which may be coupled to processor 22, for storing information and instructions that may be executed by processor 22. Memory 24 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. For example, memory 24 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, or any other type of non-transitory machine or computer readable media. The instructions stored in memory 24 may include program instructions or computer program code that, when executed by processor 22, enable the apparatus 20 to perform tasks as described herein.

**[0068]** In some embodiments, apparatus 20 may also include or be coupled to one or more antennas 25 for receiving a downlink signal and for transmitting via an uplink from apparatus 20. Apparatus 20 may further include a transceiver 28 configured to transmit and receive information. The transceiver 28 may also include a radio interface (e.g., a modem) coupled to the antenna 25. The radio interface may correspond to a

plurality of radio access technologies including one or more of GSM, NB-IoT, LTE, LTE-A, 5G, WLAN, Bluetooth, BT-LE, NFC, RFID, UWB, and the like. The radio interface may include other components, such as filters, converters (for example, digital-to-analog converters and the like), symbol demappers, signal shaping components, an Inverse Fast Fourier Transform (IFFT) module, and the like, to process symbols, such as OFDMA symbols, carried by a downlink or an uplink.

**[0069]** For instance, transceiver 28 may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) 25 and demodulate information received via the antenna(s) 25 for further processing by other elements of apparatus 20. In other embodiments, transceiver 28 may be capable of transmitting and receiving signals or data directly. Apparatus 20 may further include a user interface, such as a graphical user interface or touchscreen.

**[0070]** In an embodiment, memory 24 stores software modules that provide functionality when executed by processor 22. The modules may include, for example, an operating system that provides operating system functionality for apparatus 20. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 20. The components of apparatus 20 may be implemented in hardware, or as any suitable combination of hardware and software.

**[0071]** According to one embodiment, apparatus 20 may be a UE, mobile device, mobile station, ME, IoT device and/or NB-IoT device, for example. According to certain embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to perform the functions associated with embodiments described herein. According to an embodiment, apparatus 20 may be controlled by memory 24 and processor 22 to receive SRS transmission parameters and/or reference signal(s) for pathloss measurement. The SRS transmission parameters may include, for example, a comb value and/or SRS pattern. In one embodiment, apparatus 20 may be further controlled by memory 24 and processor 22 to perform RSRP measurement based on the received reference signal(s) and obtain the RSRP and the pathloss measurement. According to some embodiments, apparatus 20 may also be controlled by memory 24 and processor

22 to receive SRS power control parameters for configured SRS resources, and to determine transmit power for each of the SRS resources based on the pathloss measurement and the SRS power control parameters. According to an embodiment, apparatus 20 may be further controlled by memory 24 and processor 22 to use the comb value received as part of the SRS transmission parameters as a scaling factor for SRS power scaling.

**[0072]** According to an embodiment, apparatus 20 may be controlled by memory 24 and processor 22 to determine the transmit power for each of the SRS resources based on the pathloss measurement and the SRS power control parameters according to the following formula (Formula 1):

$$P_{\mathrm{SRS,c}}(i)=\min\left\{P_{\mathrm{CMAX,c}}(i),\ P_{\mathrm{SRS_OFFSET,c}}(m)+10\log_{10}(M_{\mathrm{SRS,c}}\times 2/n_comb)+P_{\mathrm{O_PUSCH,c}}(j)+\alpha_c(j)\cdot PL_c+f_c(i)\right\}$$

**[0073]** In some embodiments, when SRS are transmitted with other uplink channel(s) or signals and the transmission power of apparatus 20 exceeds a maximum transmission power, apparatus 20 may be controlled by memory 24 and processor 22 to use power scaling according to a pre-defined priority. For example, in an embodiment, the pre-defined priority may include: when SRS is a beam management SRS, apparatus 20 may be controlled to transmit the SRS with high priority to guarantee its transmit power and the same transmit power is configured for each SRS beam even when only part of the SRS beam(s) is simultaneously transmitted with PUCCH/PUSCH if power scaling is used; when SRS is transmitted simultaneously with physical uplink control channel (PUCCH)/physical uplink shared channel (PUSCH), SRS may be transmitted with remaining power except for PUCCH/PUSCH transmit power; when type 1 SRS is transmitted simultaneously with type 0 SRS, type 1 SRS may be transmitted with high priority to guarantee its transmit power and type 0 SRS is transmitted with the remaining power; when SRS is transmitted simultaneously with other same type sounding reference signal (SRS)— if primary sounding resource is configured by a gNB, SRS on primary sounding resource may be transmitted with high priority to guarantee its transmit power; mute SRS on sounding resource(s) with high muting priority if configured by the gNB; for a beam pair with larger RSRP, the SRS with that

beam pair may be transmitted with high priority to guarantee its transmit power, and for a beam pair with smaller RSRP, the SRS with the beam pair may be transmitted with the remaining power; if the same beam pair is used, equal power scaling may be used for multiple RSRP.

**[0074]** Fig. 8a illustrates an example flow diagram of a method according to one embodiment. In certain embodiments, the method of Fig. 8a may be performed by a network node, such as a base station, node B, eNB, 5G node B or access point (AP), gNB, WLAN AP, or next generation node B (NG-NB), for example. As illustrated in Fig. 8a, the method may include, at 800, transmitting SRS transmission parameters and/or a reference signal for UE pathloss measurement. In one embodiment, the SRS transmission parameters may include a comb value and/or SRS pattern. In an embodiment, the reference signal for the user equipment pathloss measurement may include a beam reference signal (BRS).

**[0075]** According to certain embodiments, the method may also include, at 810, determining SRS power control parameter sets for configured SRS resources, and, at 820, transmitting the determined SRS power control parameter sets to one or more UEs. In one embodiment, the SRS power control parameter sets may include P0, $\alpha$, fc, and/or offset value relative to linked PUSCH. According to an embodiment, the determined SRS power control parameter sets may be transmitted to the UE(s) by higher layer and/or physical signaling.

**[0076]** Fig. 8b illustrates an example flow diagram of a method according to one embodiment. In certain embodiments, the method of Fig. 8b may be performed by a device, such as UE, mobile device, mobile station, mobile equipment, smartphone, and/or IoT device, for example. As illustrated in Fig. 8b, the method may include, at 850, receiving SRS transmission parameters and/or reference signal(s) for pathloss measurement. The SRS transmission parameters may include, for example, a comb value and/or SRS pattern. In one embodiment, the method may also include, at 860, performing RSRP measurement based on the received reference signal(s) and obtaining the RSRP and the pathloss measurement. According to some embodiments, the method may further include, at 870, receiving SRS power control parameters for configured

SRS resources, and, at 880, determining the transmit power for each of the SRS resources based on the pathloss measurement and the SRS power control parameters.

**[0077]** According to an embodiment, the transmit power for each of the SRS resources based on the pathloss measurement and the SRS power control parameters may be determined according to the following formula (Formula 1):

$$P_{\mathrm{SRS},c}(i) = \min\left\{ P_{\mathrm{CMAX},c}(i),\ P_{\mathrm{SRS_OFFSET},c}(m) + 10\log_{10}(M_{\mathrm{SRS},c} \times 2 / n_comb) + P_{\mathrm{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + f_c(i) \right\}$$

**[0078]** In some embodiments, when SRS are transmitted with other uplink channel(s) or signals and the transmission power of apparatus 20 exceeds a maximum transmission power, the method may include using power scaling according to a pre-defined priority as outlined above.

**[0079]** It is noted that, while embodiments of the invention discussed in the foregoing refer to implementations in 5G or NR, other embodiments of the invention are also applicable in other radio access technologies, such as LTE, or any other future radio access network.

**[0080]** In view of the above, embodiments of the invention provide several technical improvements and/or advantages. For example, certain embodiments are able to provide accurate power control for SRS with different transmission patters, such as different frequency density. In addition, certain embodiments are able to guarantee the reliability and accuracy for beam recover/reselection, to provide good channel estimation quality for the link with better channel quality, and to provide good channel estimation quality for the link with high priority according to a gNB's requirement. As such, embodiments of the invention can improve performance and throughput of network nodes including, for example, base stations/eNBs and UEs. Accordingly, the use of embodiments of the invention result in improved functioning of communications networks and their nodes.

**[0081]** In some embodiments, the functionality of any of the methods, processes, signaling diagrams, or flow charts described herein may be implemented by software and/or computer program code or portions of code stored in memory or other computer readable or tangible media, and executed by a processor.

**[0082]** In certain embodiments, an apparatus may be included or be associated with at least one software application, module, unit or entity configured as arithmetic operation(s), or as a program or portions of it (including an added or updated software routine), executed by at least one operation processor. Programs, also called program products or computer programs, including software routines, applets and macros, may be stored in any apparatus-readable data storage medium and include program instructions to perform particular tasks.

**[0083]** A computer program product may comprise one or more computer-executable components which, when the program is run, are configured to carry out embodiments. The one or more computer-executable components may be at least one software code or portions of it. Modifications and configurations required for implementing functionality of an embodiment may be performed as routine(s), which may be implemented as added or updated software routine(s). Software routine(s) may be downloaded into the apparatus.

**[0084]** Software or a computer program code or portions of it may be in a source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers. The computer readable medium or computer readable storage medium may be a non-transitory medium.

**[0085]** In other embodiments, the functionality may be performed by hardware, for example through the use of an application specific integrated circuit (ASIC), a programmable gate array (PGA), a field programmable gate array (FPGA), or any other combination of hardware and software. In yet another embodiment, the functionality may be implemented as a signal, a non-tangible means that can be carried by an electromagnetic signal downloaded from the Internet or other network.

**[0086]** According to an embodiment, an apparatus, such as a node, device, or a corresponding component, may be configured as a computer or a microprocessor, such as single-chip computer element, or as a chipset, including at least a memory for providing storage capacity used for arithmetic operation and an operation processor for executing the arithmetic operation.

**[0087]** One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. In order to determine the metes and bounds of the invention, therefore, reference should be made to the appended claims.

**WHAT IS CLAIMED IS:**

1. A method of sounding reference signal (SRS) power scaling, the method comprising:

transmitting, by a network node, at least one of sounding reference signal (SRS) transmission parameters and reference signal for user equipment pathloss measurement,

wherein the sounding reference signal (SRS) transmission parameters comprise at least one of comb value or sounding reference signal (SRS) pattern;

determining sounding reference signal (SRS) power control parameter sets for configured sounding reference signal (SRS) resources; and

transmitting the determined sounding reference signal (SRS) power control parameter sets to at least one user equipment,

wherein the comb value is used as a scaling factor for the sounding reference signal (SRS) power scaling.

2. The method according to claim 1, wherein,

when the sounding reference signal (SRS) is beam management SRS, guaranteeing its transmit power; and

when power scaling becomes necessary, guaranteeing a same transmit power for each SRS beam even when only a part of SRS beams are simultaneously transmitted with physical uplink control channel (PUCCH)/physical uplink shared channel (PUSCH).

3. The method according to claims 1 or 2, the method further comprising configuring at least one of the sounding reference signal (SRS) resources as a primary sounding resource to guarantee transmit power for the sounding reference signal (SRS) power scaling.

4. The method according to any one of claims 1-3, further comprising muting sounding reference signal (SRS) on at least one of the configured sounding reference signal (SRS) resources with high muting priority to guarantee channel estimation quality of other links.

5. The method according to any one of claims 1-4, wherein, when multiple sounding reference signals are transmitted in one orthogonal frequency division multiplexing (OFDM) symbol, guaranteeing high priority of transmit power for the one of the multiple sounding reference signals with a largest reference signal received power (RSRP).

6. An apparatus, comprising:

at least one processor; and

at least one memory including computer program code,

the at least one memory and the computer program code configured, with the at least one processor, to cause the apparatus at least to

transmit at least one of sounding reference signal (SRS) transmission parameters and reference signal for user equipment pathloss measurement,

wherein the sounding reference signal (SRS) transmission parameters comprise at least one of comb value or sounding reference signal (SRS) pattern;

determine sounding reference signal (SRS) power control parameter sets for configured sounding reference signal (SRS) resources; and

transmit the determined sounding reference signal (SRS) power control parameter sets to at least one user equipment,

wherein the comb value is used as a scaling factor for sounding reference signal (SRS) power scaling.

7. The apparatus according to claim 6, wherein:

when the sounding reference signal (SRS) is beam management SRS, the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to guarantee transmit power of the sounding reference signal (SRS); and

when power scaling becomes necessary, the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to guarantee a same transmit power for each SRS beam even when

only a part of SRS beams are simultaneously transmitted with physical uplink control channel (PUCCH)/physical uplink shared channel (PUSCH).

8. The apparatus according to claims 6 or 7, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to configure at least one of the sounding reference signal (SRS) resources as a primary sounding resource to guarantee transmit power for the sounding reference signal (SRS) power scaling.

9. The apparatus according to any one of claims 6-8, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to mute sounding reference signal (SRS) on at least one of the configured sounding reference signal (SRS) resources with high muting priority to guarantee channel estimation quality of other links.

10. The apparatus according to any one of claims 6-9, wherein, when multiple sounding reference signals are transmitted in one orthogonal frequency division multiplexing (OFDM) symbol, the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to guarantee high priority of transmit power for the one of the multiple sounding reference signals with a largest reference signal received power (RSRP).

11. An apparatus, comprising:

transmitting means for transmitting at least one of sounding reference signal (SRS) transmission parameters and reference signal for user equipment pathloss measurement,

wherein the sounding reference signal (SRS) transmission parameters comprise at least one of comb value or sounding reference signal (SRS) pattern;

determining means for determining sounding reference signal (SRS) power control parameter sets for configured sounding reference signal (SRS) resources; and

transmitting means for transmitting the determined sounding reference signal

(SRS) power control parameter sets to at least one user equipment,

wherein the comb value is used as a scaling factor for sounding reference signal (SRS) power scaling.

12. A method of sounding reference signal (SRS) power scaling, the method comprising:

receiving, by a user equipment, at least one of sounding reference signal (SRS) transmission parameters and reference signal for pathloss measurement;

performing reference signal received power (RSRP) measurement based on the received at least one reference signal and obtaining the reference signal received power (RSRP) and the pathloss measurement;

receiving sounding reference signal (SRS) power control parameters for configured sounding reference signal (SRS) resources; and

determining transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters.

13. The method according to claim 12, wherein the sounding reference signal (SRS) transmission parameters comprise at least one of a comb value or sounding reference signal (SRS) pattern, and the method further comprises using the comb value as a scaling factor for the sounding reference signal (SRS) power scaling.

14. The method according to claim 13, wherein the determining comprises determining transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters according to the following formula:

$$P_{\mathrm{SRS},c}(i) = \min\left\{ P_{\mathrm{CMAX},c}(i),\ P_{\mathrm{SRS_OFFSET},c}(m) + 10\log_{10}(M_{\mathrm{SRS},c} \times 2 / n_comb) + P_{\mathrm{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + f_c(i) \right\}$$

.

15. The method according to any one of claims 12-14, wherein, when sounding reference signal (SRS) are transmitted with other uplink channel(s) or signals and transmission

power of the user equipment exceeds a maximum transmission power, using power scaling according to a pre-defined priority.

16. The method according to claim 15, wherein the pre-defined priority comprises:

when sounding reference signal (SRS) is beam management sounding reference signal (SRS), the sounding reference signal (SRS) is transmitted with high priority to guarantee its transmit power and a same transmit power is configured for each SRS beam even when only part of the SRS beams are simultaneously transmitted with physical uplink control channel (PUCCH)/physical uplink shared channel (PUSCH).

17. The method according to claim 15, wherein the pre-defined priority further comprises:

when sounding reference signal (SRS) is transmitted simultaneously with physical uplink control channel (PUCCH)/physical uplink shared channel (PUSCH), the sounding reference signal (SRS) is transmitted with remaining power except for PUCCH/PUSCH transmit power.

18. The method according to claim15, wherein the pre-defined priority further comprises:

when type 1 sounding reference signal (SRS) is transmitted simultaneously with type 0 sounding reference signal (SRS), type 1 sounding reference signal (SRS) is transmitted with high priority to guarantee its transmit power and type 0 sounding reference signal (SRS) is transmitted with remaining power.

19. The method according to claim 15, wherein the pre-defined priority further comprises:

when sounding reference signal (SRS) is transmitted simultaneously with other same type sounding reference signal (SRS),

if primary sounding resource is configured by a gNB, sounding reference signal (SRS) on primary sounding resource is transmitted with high priority to

guarantee its transmit power;

muting sounding reference signal (SRS) on sounding resource(s) with high muting priority if configured by the gNB;

for a beam pair with larger reference signal received power (RSRP), the sounding reference signal (SRS) with the beam pair is transmitted with high priority to guarantee its transmit power, and for a beam pair with smaller reference signal received power (RSRP), the sounding reference signal (SRS) with the beam pair is transmitted with remaining power;

if the same beam pair is used, equal power scaling is used for multiple SRS.

20. An apparatus, comprising:

at least one processor; and

at least one memory including computer program code,

the at least one memory and the computer program code configured, with the at least one processor, to cause the apparatus at least to

receive at least one of sounding reference signal (SRS) transmission parameters and reference signal for pathloss measurement;

perform reference signal received power (RSRP) measurement based on the received at least one reference signal and obtain the reference signal received power (RSRP) and the pathloss measurement;

receive sounding reference signal (SRS) power control parameters for configured sounding reference signal (SRS) resources; and

determine transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters.

21. The apparatus according to claim 20, wherein the sounding reference signal (SRS) transmission parameters comprise at least one of a comb value or sounding reference signal (SRS) pattern, and wherein the at least one memory and the computer program

code are configured, with the at least one processor, to cause the apparatus at least to use the comb value as a scaling factor for sounding reference signal (SRS) power scaling.

22. The apparatus according to claim 21, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to determine the transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters according to the following formula:

$$P_{\mathrm{SRS},c}(i)=\min\left\{P_{\mathrm{CMAX},c}(i),\ P_{\mathrm{SRS_OFFSET},c}(m)+10\log_{10}(M_{\mathrm{SRS},c}\times 2/n_comb)+P_{\mathrm{O_PUSCH},c}(j)+\alpha_c(j)\cdot PL_c+f_c(i)\right\}$$

.

23. The apparatus according to any one of claims 20-22, wherein, when sounding reference signal (SRS) are transmitted with other uplink channel(s) or signals and transmission power of the apparatus exceeds a maximum transmission power, the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to use power scaling according to a pre-defined priority.

24. The apparatus according to claim 23, wherein the pre-defined priority comprises:

when sounding reference signal (SRS) is beam management sounding reference signal (SRS), the sounding reference signal (SRS) is transmitted with high priority to guarantee its transmit power and a same transmit power is configured for each SRS beam even when only part of the SRS beams are simultaneously transmitted with PUCCH/PUSCH.

25. The apparatus according to claim 23, wherein the pre-defined priority further comprises:

when sounding reference signal (SRS) is transmitted simultaneously with physical uplink control channel (PUCCH)/physical uplink shared channel (PUSCH), the sounding reference signal (SRS) is transmitted with remaining power except for

PUCCH/PUSCH transmit power.

26. The apparatus according to claim 23, wherein the pre-defined priority further comprises:

when type 1 sounding reference signal (SRS) is transmitted simultaneously with type 0 sounding reference signal (SRS), type 1 sounding reference signal (SRS) is transmitted with high priority to guarantee its transmit power and type 0 sounding reference signal (SRS) is transmitted with remaining power.

27. The apparatus according to claim 23, wherein the pre-defined priority further comprises:

when sounding reference signal (SRS) is transmitted simultaneously with other same type sounding reference signal (SRS),

if primary sounding resource is configured by a gNB, sounding reference signal (SRS) on primary sounding resource is transmitted with high priority to guarantee its transmit power;

muting sounding reference signal (SRS) on sounding resource(s) with high muting priority if configured by the gNB;

for a beam pair with larger reference signal received power (RSRP), the sounding reference signal (SRS) with the beam pair is transmitted with high priority to guarantee its transmit power, and for a beam pair with smaller reference signal received power (RSRP), the sounding reference signal (SRS) with the beam pair is transmitted with remaining power;

if the same beam pair is used, equal power scaling is used for multiple SRS.

28. An apparatus, comprising:

receiving means for receiving at least one of sounding reference signal (SRS) transmission parameters and reference signal for pathloss measurement;

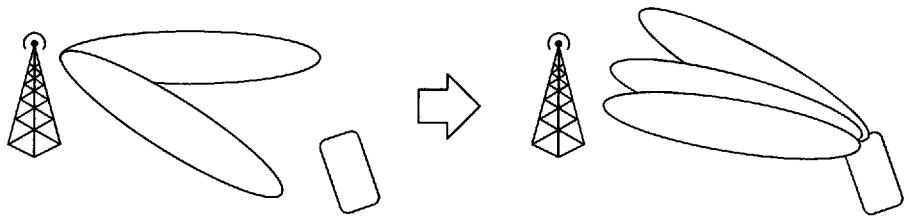
performing means for performing reference signal received power (RSRP)

measurement based on the received at least one reference signal and obtaining the reference signal received power (RSRP) and the pathloss measurement;

receiving means for receiving sounding reference signal (SRS) power control parameters for configured sounding reference signal (SRS) resources; and

determining means for determining transmit power for each of the sounding reference signal (SRS) resources based on the pathloss measurement and the sounding reference signal (SRS) power control parameters.

29. A computer program, embodied on a non-transitory computer readable medium, the computer program configured to control a processor to perform a method according to any one of claims 1-5 or 12-19.



Step 1: UE selects best beam roughly from DL beamformed RS

Step 2: UE sends multiple adjacent beams for accurate beam selection
→ step 3: gNB detect the best beam

Fig. 1

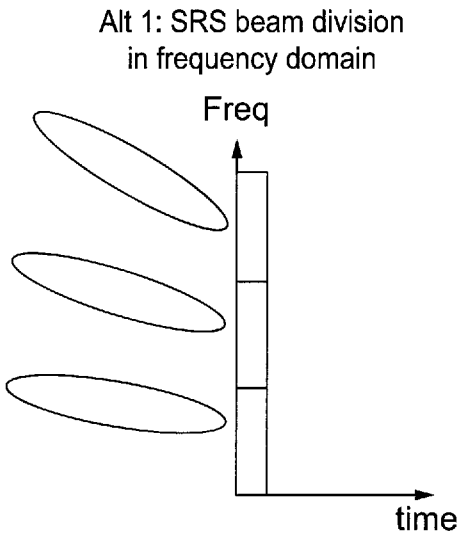



Fig. 2a

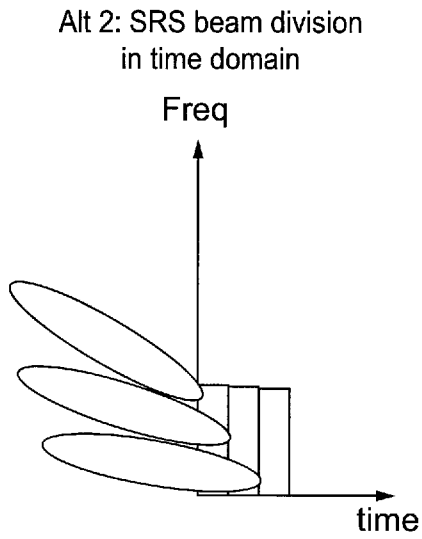



Fig. 2b

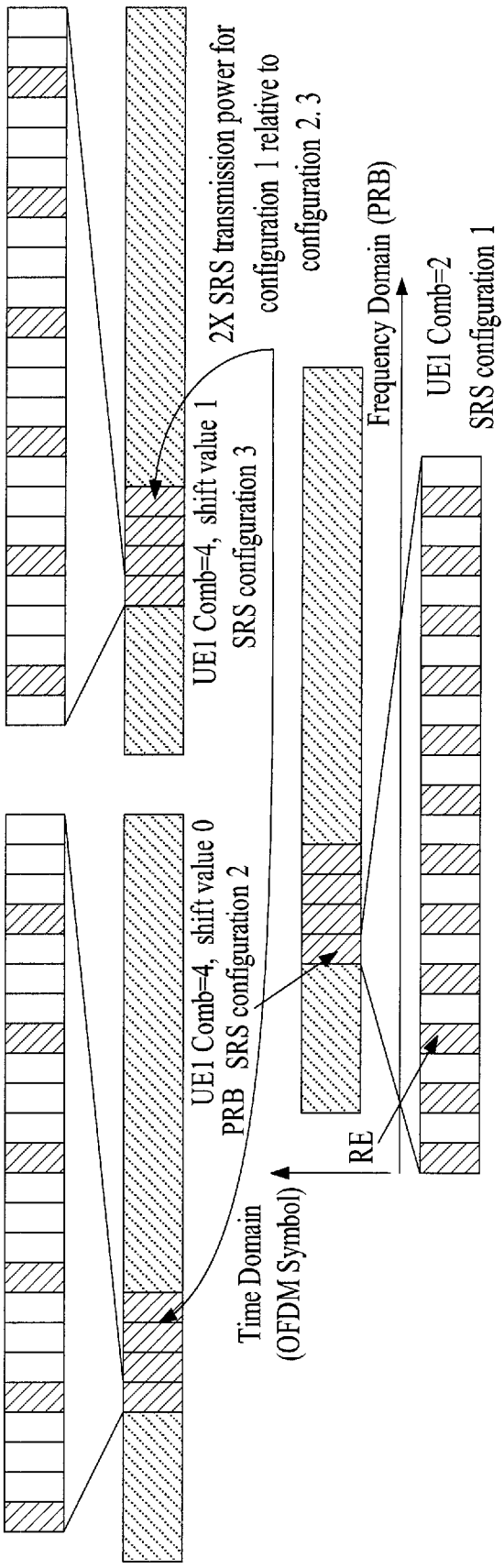

2X SRS transmission power for configuration 1 relative to configuration 2. 3
UE1 Comb=4, shift value 1
SRS configuration 3
UE1 Comb=4, shift value 0
PRB SRS configuration 2
Frequency Domain (PRB)
UE1 Comb=2
SRS configuration 1
RE
Time Domain
(OFDM Symbol)

Fig. 3

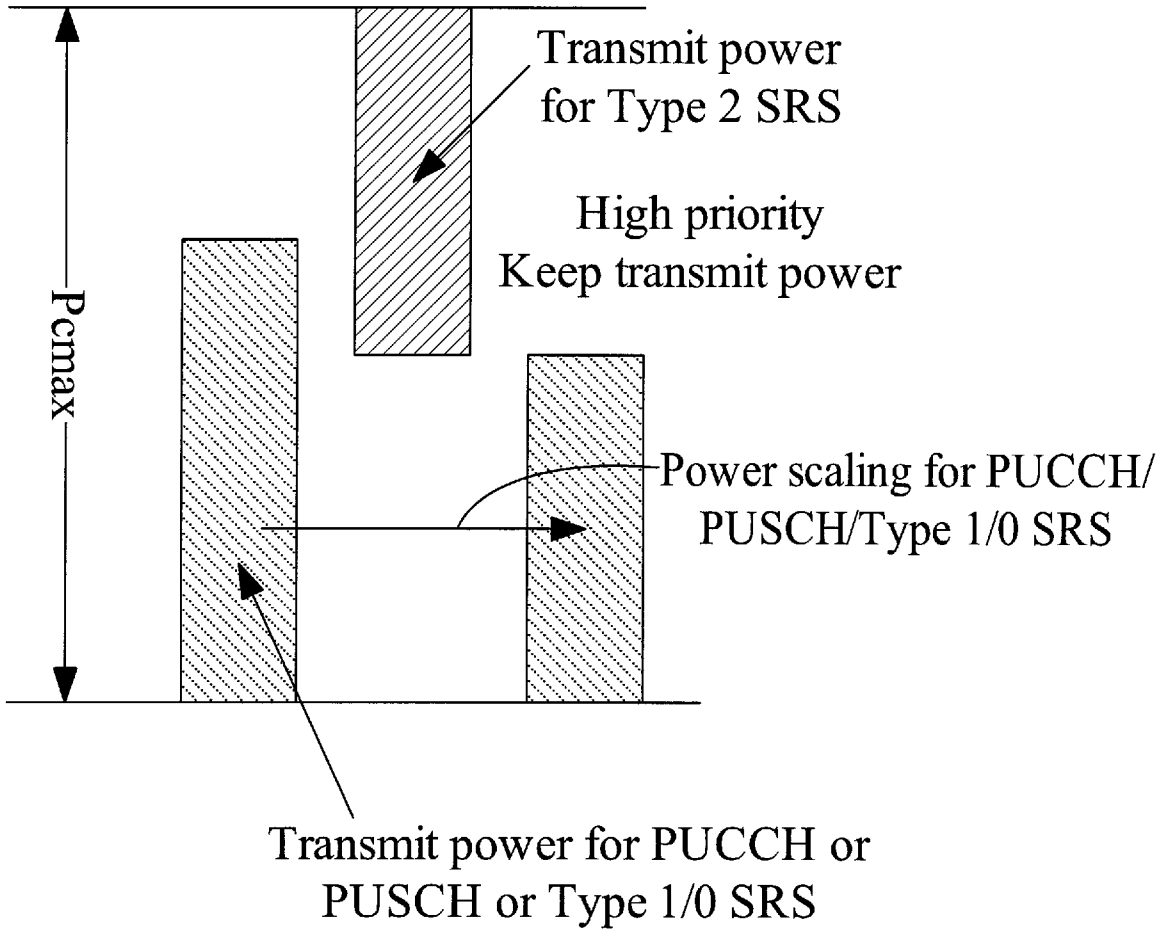

Transmit power
for Type 2 SRS
High priority
Keep transmit power
Pcmax
Power scaling for PUCCH/
PUSCH/Type 1/0 SRS
Transmit power for PUCCH or
PUSCH or Type 1/0 SRS

Fig. 4

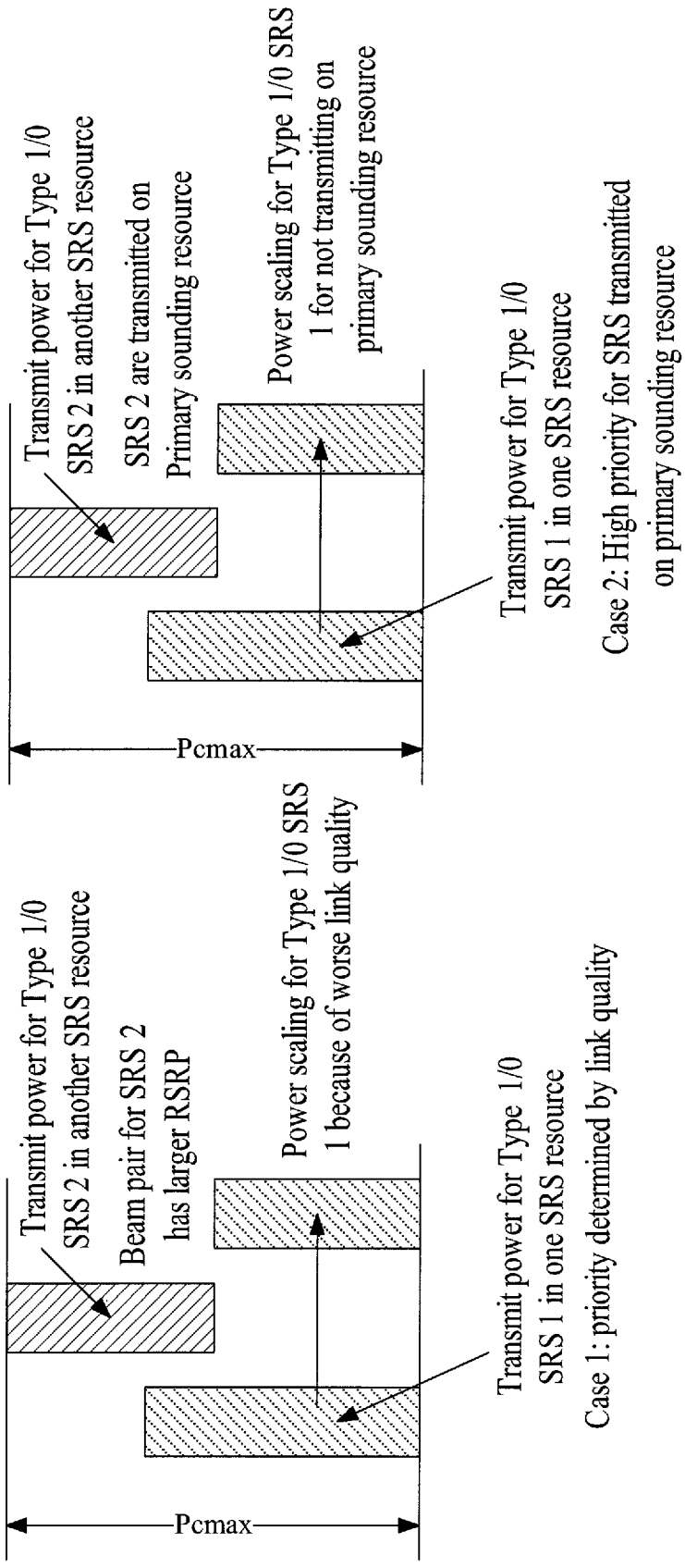

Transmit power for Type 1/0
SRS 2 in another SRS resource
Beam pair for SRS 2
has larger RSRP
Power scaling for Type 1/0 SRS
1 because of worse link quality
Transmit power for Type 1/0
SRS 1 in one SRS resource
Pcmax
Case 1: priority determined by link quality
Transmit power for Type 1/0
SRS 2 in another SRS resource
SRS 2 are transmitted on
Primary sounding resource
Power scaling for Type 1/0 SRS
1 for not transmitting on
primary sounding resource
Transmit power for Type 1/0
SRS 1 in one SRS resource
Pcmax
Case 2: High priority for SRS transmitted
on primary sounding resource

Fig. 5

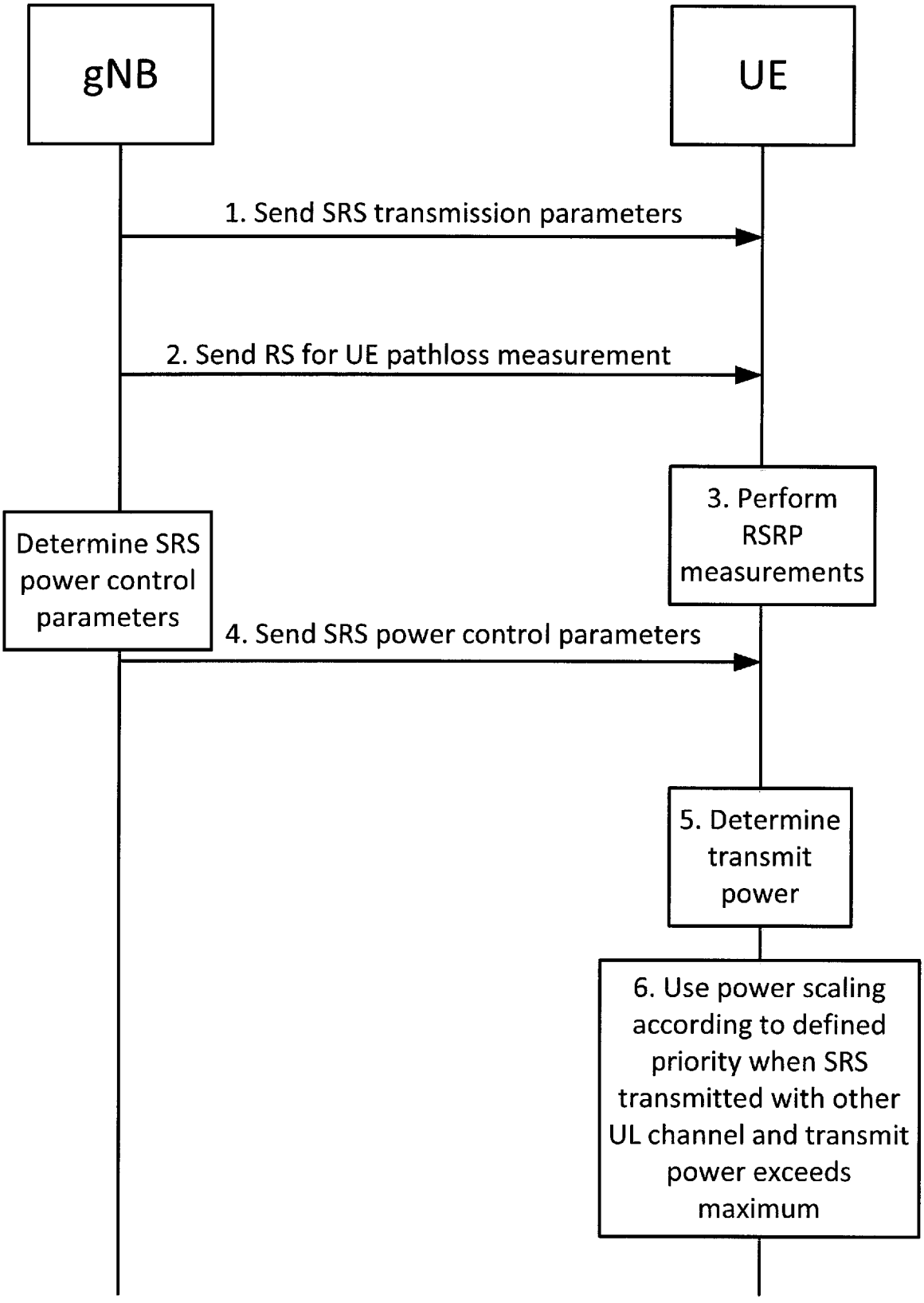

gNB
UE
1. Send SRS transmission parameters
2. Send RS for UE pathloss measurement
3. Perform RSRP measurements
Determine SRS power control parameters
4. Send SRS power control parameters
5. Determine transmit power
6. Use power scaling according to defined priority when SRS transmitted with other UL channel and transmit power exceeds maximum

Fig. 6

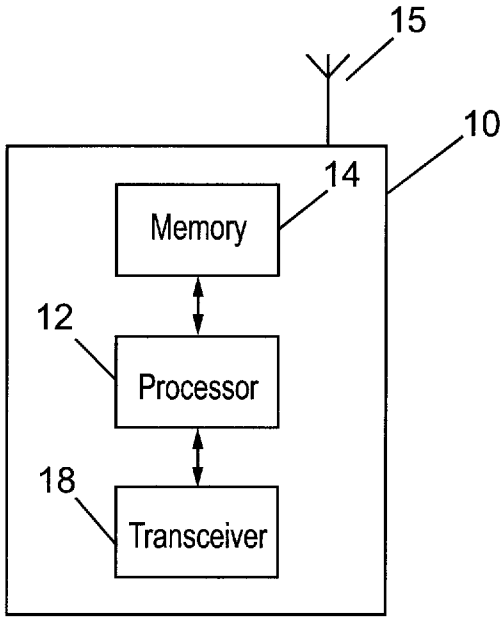

15
10
14
Memory
12
Processor
18
Transceiver

Fig. 7a

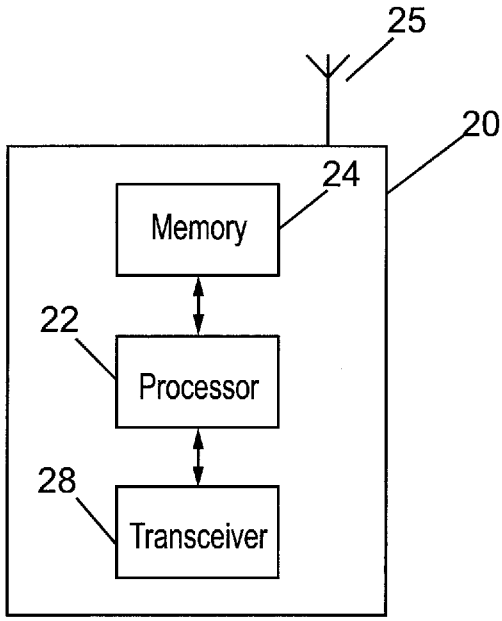

25
20
24
Memory
22
Processor
28
Transceiver

Fig. 7b

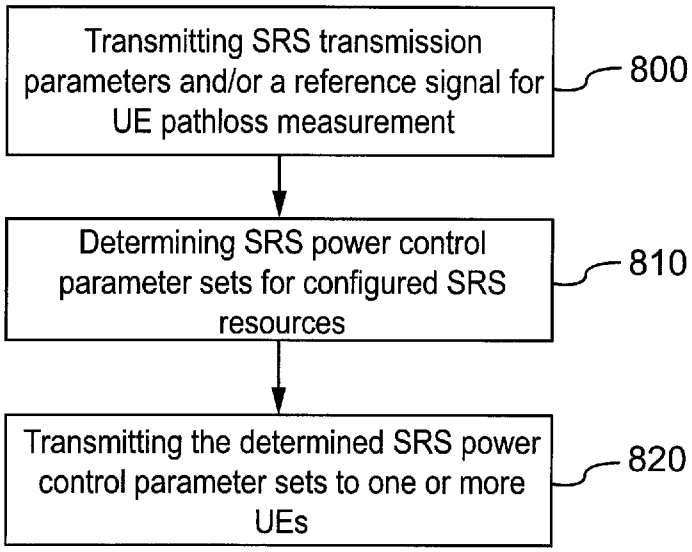

Transmitting SRS transmission parameters and/or a reference signal for UE pathloss measurement
800
Determining SRS power control parameter sets for configured SRS resources
810
Transmitting the determined SRS power control parameter sets to one or more UEs
820

Fig. 8a

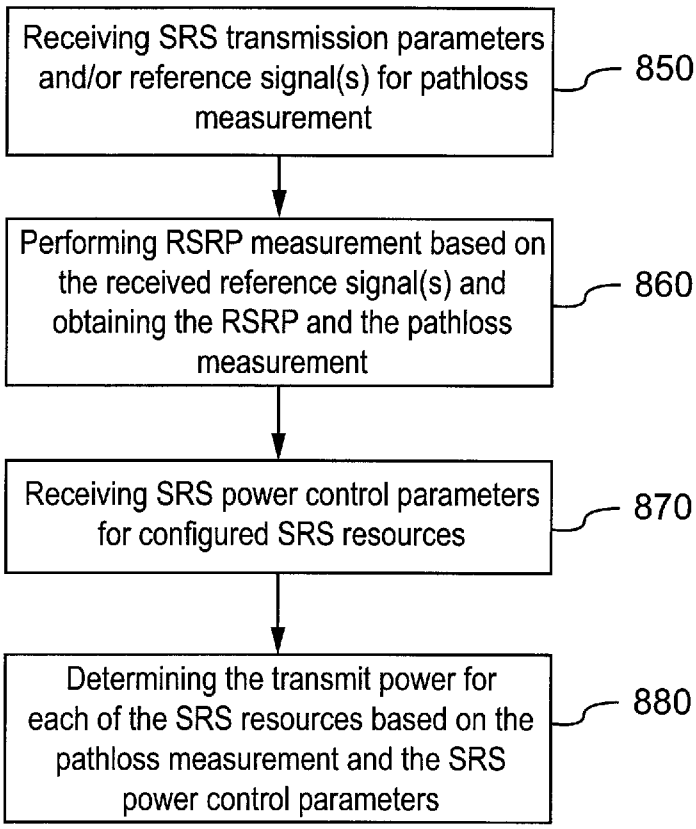

Receiving SRS transmission parameters and/or reference signal(s) for pathloss measurement
850
Performing RSRP measurement based on the received reference signal(s) and obtaining the RSRP and the pathloss measurement
860
Receiving SRS power control parameters for configured SRS resources
870
Determining the transmit power for each of the SRS resources based on the pathloss measurement and the SRS power control parameters
880

Fig. 8b

# INTERNATIONAL SEARCH REPORT

International application No.
**PCT/CN2017/070144**

## A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)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)

H04W; H04L; H04Q

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

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

CNPAT, WPI, EPODOC, ISI, IEEE, 3GPP, CNKI:sounding reference signal, SRS, power, control, scal+, parameter, comb, path loss, PUCCH, PUSCH, period, number, value, select+

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2014119321 A1 (FUJITSU LIMITED) 01 May 2014 (2014-05-01)<br>description, paragraphs [0067]-[0072], [0083]-[0104], table 4 | 12, 15-20, 23-29 |
| Y | US 2014119321 A1 (FUJITSU LIMITED) 01 May 2014 (2014-05-01)<br>description, paragraphs [0067]-[0072], [0083]-[0104], table 4 | 1-11, 13-14, 21-22 |
| Y | US 2016219534 A1 (ZTE CORPORATION) 28 July 2016 (2016-07-28)<br>description, paragraphs [0014]-[0022], [0056]-[0058] | 1-11, 13-14, 21-22 |
| A | CN 103096449 A (ZTE CORPORATION) 08 May 2013 (2013-05-08)<br>the whole document | 1-29 |
| A | CN 102427608 A (CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY) 25 April 2012 (2012-04-25)<br>the whole document | 1-29 |
| A | CN 103312484 A (ZTE CORPORATION) 18 September 2013 (2013-09-18)<br>the whole document | 1-29 |
| A | FUJITSU. "Discussion on SRS Power Control."<br>*3GPP TSG RAN WG1 Meeting #70, R1-123302.*, 17 August 2012 (2012-08-17),<br>the whole document | 1-29 |

☐ 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 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 | Date of mailing of the international search report |
|---|---|
| **31 August 2017** | **30 September 2017** |

| Name and mailing address of the ISA/CN | Authorized officer |
|---|---|
| **STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA**<br>**6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088**<br>**China** | **CHEN,Jing** |
| Facsimile No. **(86-10)62019451** | Telephone No. **(86-10)62413337** |

**INTERNATIONAL SEARCH REPORT**
**Information on patent family members**

International application No.
**PCT/CN2017/070144**

| Patent document cited in search report | | | Publication date (day/month/year) | Patent family member(s) | | | Publication date (day/month/year) |
|---|---|---|---|---|---|---|---|
| US | 2014119321 | A1 | 01 May 2014 | KR | 20140034278 | A | 19 March 2014 |
| | | | | CN | 103535096 | A | 22 January 2014 |
| | | | | WO | 2013010307 | A1 | 24 January 2013 |
| | | | | EP | 2733999 | A1 | 21 May 2014 |
| | | | | JP | 2014521258 | A | 25 August 2014 |
| US | 2016219534 | A1 | 28 July 2016 | CN | 104518845 | A | 15 April 2015 |
| | | | | JP | 2016535471 | A | 10 November 2016 |
| | | | | KR | 20160048907 | A | 04 May 2016 |
| | | | | EP | 3038281 | A1 | 29 June 2016 |
| | | | | WO | 2014180391 | A1 | 13 November 2014 |
| | | | | RU | 2620586 | C1 | 29 May 2017 |
| CN | 103096449 | A | 08 May 2013 | WO | 2013064107 | A1 | 10 May 2013 |
| CN | 102427608 | A | 25 April 2012 | WO | 2013082948 | A1 | 13 June 2013 |
| CN | 103312484 | A | 18 September 2013 | WO | 2013135205 | A1 | 19 September 2013 |