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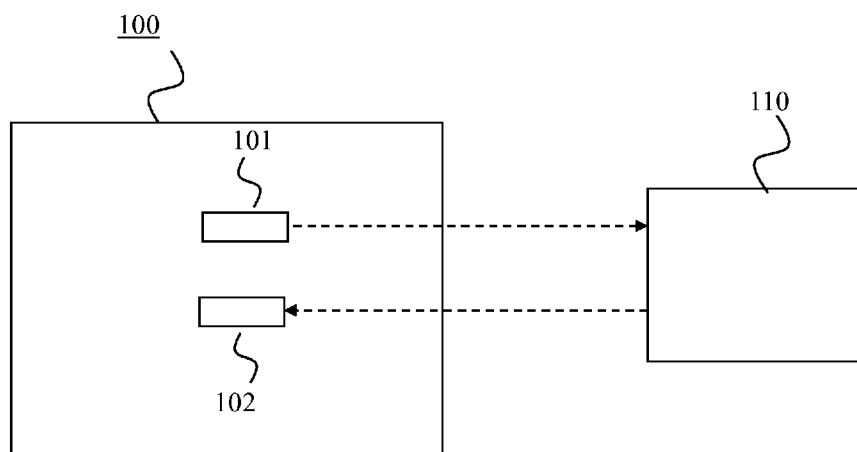


FIG. 1

(57) **Abstract:** A network device for supporting beam power variation measurements is provided. The network device provides information to a User Equipment (UE), indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams. The network device obtains a first measurements report from the UE. A UE for measuring beam power variation is further provided. The UE receives information indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams. Further, the UE performs a measurement for each beam of the determined set of beams, and generates a first measurements report based on the measurements. Then, the UE sends the first measurements report to a network device. A multi-stages measurements method is also described. By measuring a per-beam signal Power Variation Pattern (RPVP), the beam signal quality can be predicted.



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DEVICE AND METHOD FOR MEASURING PERIODIC BEAM QUALITY VARIATION

5 TECHNICAL FIELD

The present disclosure relates to a beam measurement method, in particular, a beam power variation measurement in 5G New Radio (5G-NR). In particular, the disclosure provides a network device and a user equipment (UE), both for supporting beam power variation
10 measurements.

BACKGROUND

Industry automation is one big potential application area of 5G-NR. For such application,
15 high reliability of radio link is required. In industrial environments (e.g. factories), a lot of machines are moving. Since 5G-NR generally applies beamforming, both at 3.5 GHz and millimeter wave frequencies, the radio link will suffer dynamic blockage of beams, due to moving UE and/or moving blockers (objects that block the link) in the environment. Further, radio links will suffer from fading (within beamformed channel), due to moving
20 UE and scatters. The robots in factories can move at a speed around 15 m/s or even faster in the future. Thus, dynamic blockage due to machine movement, when the blocking part has 10 cm diameter, has a duration of around 6.7 ms, which is in general much larger than the Transmission Time Interval (TTI) defined in 5G-NR. Thus, the time granularity is coarse. However, the fading can have much finer granularity, which can be in the order of
25 0.1 ms, which is much smaller than a TTI. Both blockage and fading effects are critical for use cases with small cycle time and high reliability requirements.

Typically, the machines in the factories repeat the same movements periodically, especially in a production line. The machine movement period can range from hundred ms to several
30 seconds. Thus, it is expected that both fading and blockage can happen periodically, and thus can be predicted. Identifying predictable blockage/fading behavior of beam quality would help to enhance link reliability.

The technical problem is how to identify such periodic and predictable blockage/fading behavior, so that it can be used to enhance the radio link.

The current 5G-NR standard (Release 15 etc.) allows Synchronization Signal Block (SSB) and/or Channel State Information Reference Signal (CSI-RS) based measurements. A straightforward implementation would be that a UE measures the Reference Signal Received Power (RSRP) or Reference Signal Received Quality (RSRQ) of a series of SSB/CSI-RS resources that belong to the same beam. Then the UE reports the RSRP/RSRQ per reference signal resource to the Base Station (BS), which performs processing on such measurements and identify periodic behaviors. The drawbacks of such implementation are:

- High overhead: Per SSB/CSI-RS resource report of Rx power is required. However, long period of machine movements (up to seconds) and the need for measuring multiple periods and multiple beams imply high reporting overhead;
- Reference signal density in time: In current 5G-NR standard, the minimum SSB bursts period is 5 ms (with 30 kHz Subcarrier Spacing, SCS), implying measurement resolution of 5 ms in time. The minimum CSI-RS period is 5 slots, i.e. 5 ms with 15 kHz SCS or 1.25 ms with 60 kHz SPS. Such measurement resolution is sufficient for typical blockage measurements (in the order of 6.7 ms) but not sufficient for measuring fading behavior per beam (in the order of 0.1 ms).

Further, current Beam Failure Recovery (BFR) schemes in 5G-NR cannot deal with such dynamic blockage/deep fade. First, it takes a relatively long time to trigger BFR and the BFR report. Second, the periodic blockage could trigger a beam change or BFR frequently. The new beam could also contain blockage interval, which again triggers a further beam change. Thus, the link would become intermittent, i.e. have low reliability.

SUMMARY

In view of the above-mentioned problems and disadvantages, embodiments of the present invention aim to improve conventional beam measurement methods. An objective is in

particular to provide devices and methods for supporting beam power variation measurements.

5 The objective is achieved by the embodiments provided in the enclosed independent claims. Advantageous implementations of the present invention are further defined in the dependent claims.

10 In particular, embodiments of the present invention base on a multi-stages measurement method. By measuring a per-beam signal Power Variation Pattern (RPVP), the beam signal quality can be predicted. Further, tracking of changes of such a variation pattern can adjust the prediction.

15 A first aspect of the invention provides a network device for supporting beam power variation measurements, the network device being configured to: provide information to a UE, indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams; and obtain a first measurements report from the UE.

20 The network device, for example, a base station, may inform the UE of a set of beams (which may also be called “candidate beams”), and configures and requires the UE to capture a RPVP per beam of the determined set of beams. In particular, the network device may send a measurement request, together with configuration parameters, to the UE.

25 In an implementation form of the first aspect, the power variation measurement comprises at least one of a: Synchronization Signal Block, SSB-based measurement, Channel State Information Reference Signal, CSI-RS-based measurement, and Demodulation Reference Signal, DMRS-based measurement.

30 The power variation measurements may thus comprise 3 stages: SSB-based measurements, CSI-RS-based measurements, and DMRS-based measurements.

In an implementation form of the first aspect, the first set of configuration parameters includes at least one of: an indication for performing the power variation measurements based on a resource group, the resources in the resource group associated to each beam to

be measured, at least one threshold to identify blockage/deep fade, and a repetition period of each beam.

5 In particular, the network device configures UE measurements with a set of configuration parameters. The set of configuration parameters may include other optional parameters. In addition, based on the different measurements, the set of configuration parameters may also include other specific parameters.

10 In an implementation form of the first aspect, the network device is configured to: determine a subset of beams based on the received first measurement report; provide information to the UE indicating a second set of configuration parameters for performing a power variation measurement per each beam of the subset of beams; and obtain a second measurements report from the UE.

15 After receiving the first measurement report, the network device may decide whether the UE needs to further perform power variation measurements for further beams with different beam width. In particular, the network device may select a subset of beams based on the first measurement report, and may indicate the UE to perform a 2nd stage measurement.

20 In an implementation form of the first aspect, the network device is configured to indicate the UE to send the first measurements report, wherein the first measurements report includes information about at least one of: at least one of a starting and an ending time of a beam blockage/deep fade interval for one or more beams, signal-to-noise ratio, SNR, value variations in intervals with SNR above a threshold, indices of complementary beams,
25 and a periodic beam selection pattern.

The network device may configure the UE how to report the measurement results. There may be two types of reports. Type 1 report (brief) may include indices of beams with sufficient SNR at least for a certain portion of time. Type 2 report (detailed) may include a
30 report about time domain information of the beam blockage/deep fade, or report about complementary beams. Predictability related indicators can also be reported in Type 2 report.

In an implementation form of the first aspect, the network device is configured to determine the subset of beams based on a quality metric.

The quality metric is defined for a beam selection.

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In an implementation form of the first aspect, the quality metric is defined to reflect the average SNR or a signal-to-interference-and-noise ratio, SINR in intervals with SNR or SINR above the threshold.

- 10 Definition of a quality metric reflects the SNR and the time portion (within the observation time duration) in which the beam is not blocked/has no deep fade.

- In an implementation form of the first aspect, the network device is configured to determine the subset of beams by selecting at least one of: beams with the highest quality metrics,
15 beams that are complementary to each other and with the highest quality metrics, beams fulfilling a percentage of time portion where the SNR or SINR value is above the threshold.

- Based on the defined quality metric, beam down selection can be performed. There are different options to select the subset of beams, and a combination of those options is also
20 possible.

- In an implementation form of the first aspect, the network device is configured to receive a report from the UE indicating that no periodic power variation in the determined set of beams is identified.

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After the measurement, the UE can report that no periodicity is identified. Then the system can fall back to a traditional mode (without beam power variation measurement).

- A second aspect of the invention provides a UE, for measuring beam power variation, the
30 UE being configured to: receive information indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams; perform a measurement for each beam of the determined set of beams; generate a first measurements report based on the measurements; and send the first measurements report to a network device.

The UE may be a factory equipment, or an industrial robot. The information received by the UE from the network device may be a measurement request signaled by the network device, and the UE may perform the beam measurement based on the configuration parameters obtained from the network device. After the measurement, a measurement report may be generated and may be sent to the network device.

In an implementation form of the second aspect, the power variation measurement comprises at least one of a: Synchronization Signal Block, SSB-based measurement, Channel State Information Reference Signal, CSI-RS-based measurement, and Demodulation Reference Signal, DMRS-based measurement.

The measurements may comprise 3 stages: SSB-based measurements, CSI-RS-based measurements, and DMRS-based measurements.

In an implementation form of the second aspect, the first set of configuration parameters includes at least one of: an indication for performing the power variation measurements based on a resource group, the resources in the resource group associated to each beam to be measured, at least one threshold to identify blockage/deep fade, and a repetition period of each beam.

The set of configuration parameters may further include other optional parameters. In addition, based on the different measurements, the set of configuration parameters may also include other specific parameters.

In an implementation form of the second aspect, the UE is configured to perform a SSB-based measurement and/or a CSI-RS-based measurement in a normal mode and/or a training mode.

SSB-based measurements and CSI-RS-based measurements can be performed both under a normal mode and a training mode.

In an implementation form of the second aspect, a density of the resources in training mode is higher than a density of the resources in normal mode.

For example, when the UE performs SSB-based measurements in training mode, the density of SSB can be increased up to 4 SSB's per subframe.

- 5 In an implementation form of the second aspect, the training mode is scheduled by the network device, or the training mode is triggered by the UE.

The training mode can be triggered by the UE. In particular, the UE may send a request on the super-dense SSB mode to trigger the training mode.

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In an implementation form of the second aspect, the UE is configured to perform the SSB-based measurement in the training mode, wherein each SSB in a subset of SSBs consists of a Primary Synchronization Signal, PSS, and a Secondary Synchronization signal, SSS.

- 15 For saving overhead, an option would be that a subset of SSB's only contain a PSS field and a SSS field, i.e. without the Physical Broadcast Channel (PBCH). Other fields of an SSB is omitted and the corresponding resources may be released for other usages, e.g. data.

- 20 In an implementation form of the second aspect, the UE is configured to receive information from the network device, indicating a second set of configuration parameters for performing a power variation measurement per each beam of the subset of beams; perform a measurement per each beam of the subset of beams; generate a second measurements report; and send the second measurements report to the network device.

- 25 After receiving the first measurement report, the network device may decide whether the UE needs to further perform the power variation measurements for further beams with different beam width. In particular, the network device may select a subset of beams based on the first measurement report, and may indicate the UE to perform a 2nd stage measurements by providing the UE a second measurement request. The UE may further
30 perform the beam measurement based on the second set of configuration parameters obtained from the network device and feedback the second measurements report to the network device.

In an implementation form of the second aspect, the UE is configured to receive an indication from the network device indicating the UE to send the first measurements report, wherein the first measurements report includes information about at least one of: at least one of a starting and an ending time of a beam blockage/deep fade interval for one or more
5 beams, signal-to-noise ratio, SNR, value variations in intervals with SNR above a threshold, complementary beam indices, a periodic beam selection pattern; and generate the first measurements report according to the indication.

The network device may indicate the UE how to report the measurement results. There
10 may be two types of reports. Type 1 report (brief) may include indices of beams with sufficient SNR at least for a certain portion of time. Type 2 report (detailed) may include report about time domain information of the beam blockage/deep fade, or report about complementary beams. Predictability related indicators can also be reported in Type 2 report.

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In an implementation form of the second aspect, the UE is configured to send a report to the network device indicating that no periodic power variation in the determined set of beams is identified.

20 After the measurement, if the UE identifies that no periodicity exists and reports to the network device, the system can fall back to a traditional mode (without beam power variation measurement).

A third aspect of the present invention provides a method for supporting beam power
25 variation measurements, the method comprising: providing information to a user equipment, UE, indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams; obtaining a first measurements report from the UE.

30 The method of the third aspect and its implementation forms provide the same advantages and effects as described above for the wireless transmitting device of the first aspect and its respective implementation forms.

A fourth aspect of the present invention provides a method for supporting beam power variation measurements, the method comprising: receiving information indicating a first set of configuration parameters for performing a power variation pattern measurement per each beam of a determined set of beams; performing a measurement for each beam of the
5 determined set of beams; generating a first measurements report based on the measurements; and sending the first measurements report to a network device.

The method of the fourth aspect and its implementation forms provide the same advantages and effects as described above for the wireless receiving device of the second aspect and
10 its respective implementation forms.

A fifth aspect of the present invention provides a computer program product, the computer program product includes computer program code, and when the computer program code is run by a processor, the processor can execute the method according to any one of the
15 first aspect or the possible implementations of the first aspect, or any one of the second aspect or the possible implementations of the second aspect.

It has to be noted that all devices, elements, units and means described in the present application could be implemented in the software or hardware elements or any kind of
20 combination thereof. All steps which are performed by the various entities described in the present application as well as the functionalities described to be performed by the various entities are intended to mean that the respective entity is adapted to or configured to perform the respective steps and functionalities. Even if, in the following description of specific embodiments, a specific functionality or step to be performed by external entities
25 is not reflected in the description of a specific detailed element of that entity which performs that specific step or functionality, it should be clear for a skilled person that these methods and functionalities can be implemented in respective software or hardware elements, or any kind of combination thereof.

30 BRIEF DESCRIPTION OF DRAWINGS

The above described aspects and implementation forms of the present invention will be explained in the following description of specific embodiments in relation to the enclosed drawings, in which

FIG. 1 shows a network device according to an embodiment of the invention.

FIG. 2 shows an overview of the 3 stages of RPVP measurements according to an
5 embodiment of the present invention.

FIG. 3 shows an illustration of the SSB-based measurements according to an embodiment
of the present invention.

10 FIG. 4 shows an illustration of the CSI-RS-based measurements according to an
embodiment of the present invention.

FIG. 5 shows an illustration of the training mode of the CSI-RS-based measurements
according to an embodiment of the present invention.

15 FIG. 6 shows an illustration of the DMRS-based measurements according to an
embodiment of the present invention.

FIG. 7 shows an illustration of a quality metric according to an embodiment of the present
20 invention.

FIG. 8 shows a user equipment according to an embodiment of the invention.

FIG. 9 shows a schematic block flowchart of a method for supporting beam power variation
25 measurements according to an embodiment of the present invention.

FIG. 10 shows a schematic block flowchart of a method for measuring beam power
variation according to an embodiment of the present invention.

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DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 shows a network device 100 according to an embodiment of the invention. In
particular, the network device 100 is configured to provide information 101 to a UE 110.

The network device 100 is further configured to indicate a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams, and obtain a first measurements report 101 from the UE 110.

- 5 The network device 100 may be a base station, or an access point. The network device 100 communicates with the UE 110 through a radio link.

It is noted that machine movements are mostly periodic (repeated) and (quasi-) deterministic, allowing at least a subset of beam blockage/fading cases to be predicted.

- 10 Usually, the periodic movement pattern is stable until a partial or complete reconfiguration of the production line. Correspondingly, the per-beam signal RPVP within each period is expected to be quasi unchanged.

- Therefore, by measuring such periodic beam RPVP, the beam signal quality can be
15 predicted. Further, tracking of the change of such variation pattern is needed to adjust the prediction.

- To be specific, the RPVP measurements may comprise 3 stages: SSB-based measurements, CSI-RS-based measurements, and DMRS-based measurements. FIG. 2 illustrates and
20 summaries these 3 stages. These multi-stages measurements will be explained in details in the following paragraphs.

- Optionally, the first set of configuration parameters sent by the network device 100 may include an indication for performing the power variation measurements based on a resource
25 group, the resources in the resource group associated to each beam to be measured, at least one threshold to identify blockage/deep fade, and a repetition period of each beam.

- In addition, based on the different measurements, the set of configuration parameters may also include other specific parameters.

30

Optionally, after receiving the first measurement report, the network device 101 may be further configured to determine a subset of beams based on the received first measurement report 102. The network device 101 may further provide information to the UE 110 indicating a second set of configuration parameters for performing a power variation

measurement per each beam of the subset of beams, and obtain a second measurements report from the UE 110.

The second measurement request is used to indicate the UE to perform at least one 2nd stage measurement. It should be noted that, the 2nd stage measurement may be any one of SSB-based measurement, CSI-RS-based measurement, and DMRS-based measurement. For example, the network device may indicate the UE to perform a SSB-based measurement first, then indicate the UE to perform a CSI-RS-based measurement. In another implementation, the network device may indicate the UE to perform SSB-based measurements two or three times in succession. Based on the measurements report, the network device may decide to perform all three types of the measurements. In particular, 2nd stage measurements may be performed based on down-selected beams in the 1st stage, i.e. a smaller subset of beams are to be measured. Similarly, 3rd stage measurements may be performed based on further down-selected beams in the 2nd stage. It should be noted that the above mentioned three measurements may be performed multiple times, and may be performed in different orders. This is not limited in the present invention.

The prediction of RPVP can help to enhance the radio link reliability. One example is that if multiple beams are used for transmission, different blockage/fading behaviors of different beams can be exploited to increase diversity and thus, link reliability. There may exist “Complementary Beams” meaning that among such beams not all beams will suffer from blockage/deep fade at the same time.

The following describes the details of the multi-stages measurements according to embodiments of the present invention.

SSB-based Measurements:

SSB-based measurements can be performed both under a normal mode and a training mode.

In normal mode, the network device may use SSB burst sets for RPVP measurement. The time resolution is denoted as T_{ss} (SSB burst set period) and is larger than 5 ms.

There are two configuration options:

Configuration #1: Only use SSB burst sets for measurement. The same beam sweeping pattern is applied within each SSB burst set (e.g. Beam 1...8, break, 1...8, break ...). A further option is to have beam repetition already within one SSB burst set (e.g. Beam 1...4,
 5 1...4, break, 1...4, 1...4, break, ...). For this configuration, the network device should signal UE the SSB resources belonging to the same beam.

Configuration #2: Use further RS (e.g. CSI-RS) jointly with SSB for measurement, in order to increase measurement time resolution. An example is shown in FIG. 3. Further,
 10 simultaneous multiple antenna ports per CSI-RS symbol can be added on top for measuring more beams. For this configuration, the network device should signal to UE the SSB and CSI-RS resources belonging to the same beam.

In training mode, the density of SSB can be increased up to 4 SSB's per subframe. For
 15 saving overhead, an optional would be that a subset of SSB's only contain PSS and SSS, i.e. without PBCH. Other fields of a conventional SSB is omitted and the corresponding resources are released for other usages, e.g. data. The network device should signal UE the periodicity of SSB of each beam, in terms of the number of SSB.

20 The training mode can be triggered by the UE. The UE may send a request on the super-dense SSB mode.

For SSB-based measurements, the network device may configure UE measurements with the following parameters:

- 25 - Indication for RPVP measurements per beam,
- Resource (and RS) groups associated to each beam to be measured,
- Threshold(s) to identify blockage/deep fade,
 in addition, with optional parameters:
- Different Thresholds for blockage and deep fade,
- 30 - Start of observation: Indicate the first SSB burst set,
- Duration of observation (to extract long time behavior),
- Number of re-occurrence (of blockage/fading) within observation duration to determine periodic events.

Further, the network device may configure UE reports with the following options:

- Rough report: Beams with sufficient SNR at least during a part of the cycle time, and their Rx power indicator (RSRP, RSRQ etc.),
- Detailed report about blockage/deep fade.

5

CSI-RS based Measurements:

Optionally, based on the down-selected beams in the stage 1 measurement (e.g. SSB-based-measurement), a smaller subset of beams may be measured. As illustrated in FIG. 4, the network device can repeat the same beam sweep (over the CSI-RS symbols) for every N CSI-RS period ($N = 1, 2, 3 \dots$). Thus, there is a tradeoff between the number of beams that can be measured and the time resolution.

The mapping between beams and CSI-RS should be signaled to UE's, e.g. the resource index of first CSI-RS of each beam and the sampling period of measurement (in terms of CSI-RS period).

Simultaneous multi-beam via multiple antenna ports can be applied on top to increase the number of beams that can be measured.

20

The minimum CSI-RS period (T_{CSI} , e.g. $1 \times T_{\text{CSI}} = 5$ slots) in current 5G-NR standard (Release 15) is sufficient for measuring dynamic blockage effect, but not sufficient for deep fade measurement. Thus, a training mode with Super Dense CSI-RS can be configured for detailed RPVP measurements of each (down-selected) beam. The training mode can be configured on periodic basis or by the trigger of event (e.g. reconfiguration of product line). In case of on periodic basis, the BS signals UE a duration of the training mode in terms of number of slots; and a period of each training mode + normal operation.

Optionally, the training mode can be triggered by the UE, which sends a request on super-dense CSI-RS.

In the training mode, the CSI-RS has very small periodicity ($T_{\text{CSI}} = 0, 1$, or 2 OFDM symbols). Further, each CSI-RS occurrence can have more than 4 OFDM symbols (i.e. 4 is the maximum number in current 5G-NR standard).

For CSI-RS-based measurements, the BS may configure UE measurements with the following parameters:

- Indication for RPVP measurements per beam using CSI-RS,
 - 5 - Mode of CSI-RS Measurement: training mode or normal mode,
 - CSI-RS resource group associated to each beam to be measured,
 - Repetition period of each beam (i.e. sampling period of the measurement),
 - Threshold to identify blockage/deep fade.
- 10 Additionally, the BS may further configure optional parameters:
- Different Thresholds for blockage and deep fade,
 - Start of observation: Indicate the first CSI-RS,
 - Duration of observation/training,
 - Number of event re-occurrence to determine periodic behavior.

15

Further, the network device may configure UE reports with the following options:

- Rough report: Beams with sufficient SNR at least during a part of the cycle time, and their Rx power indicator (RSRP, RSRQ etc.),
- Detailed report about blockage/deep fade.

20

DMRS based Measurements:

DMRS is used for tracking deep fade/blockages within the allocated resources of a UE. The advantage of DMRS is that it can provide sufficient density. According to current 5G-NR standard, there can be at maximum 1 DMRS occasion every 3 OFDM symbols. Thus, the DMRS density in time can be chosen properly for measuring minimum width of deep fades. Current standard assumes that DMRS of the same antenna port should have the same beam during each slot. However, multiple beams can be multiplexed in the following manner:

- 30 - Time Division Multiplexing (TDM) of different (analog) beams of the same antenna port, as example #1 shown in FIG. 6. For data demodulation, the UE only uses the DMRS corresponding to the same beam as the data,
- Sequential RPVP measurement of each beam, as example #2 shown in FIG. 6.

In both above cases, additional signaling is required.

The restriction of DMRS is that it is only available when data is transmitted. Thus, it is only available in limited frequency and time resources. Based on DMRS-based
5 measurements, super-dense CSI-RS may be triggered for more detailed measurements.

For DMRS-based measurements, the BS may configure UE measurements with the following parameters:

- Indication for RPVP measurements per beam using DMRS,
- 10 - Number of beams to be measured,
- Mapping of beams to DMRS resources within each observation duration (including the multiplexing of beams within/across observation durations),
- Repetition period of each beam (i.e. sampling period of the measurement),
- Threshold to identify blockage/deep fade,
- 15 - Start of observation: Indicate the first DMRS,
- Duration of observation,
- Number of event re-occurrence to determine periodic behavior.

Further, the BS may configure UE reports with the following options:

- 20 - Rough report: Beams with sufficient SNR at least during a part of cycle time, and their Rx power indicator (RSRP, RSRQ etc.),
- Detailed report about blockage/deep fade.

Optionally, the network device 100 may further configured to indicate the UE 101 to send
25 the first measurements report, wherein the first measurements report includes information about at least one of: a starting/ending time of each beam blockage/deep fade interval for each beam, signal-to-noise ratio, SNR, value variations in intervals with SNR above a threshold, indices of complementary beams, and a periodic beam selection pattern.

- 30 The detailed report of the beam quality evolution can have the following options:
 - Report the starting time, duration/ending time of each beam blockage/deepfade interval for each measured beam, including: the period of each beam blockage/deep fade (optional); blockage/deep fade is determined based on one/more thresholds

signaled by BS; and if multiple thresholds are existing: Each beam blockage/deep fade interval is mapped to a threshold index;

- Further report the SNR value variations in the intervals with SNR above threshold (optional), including: option 1 - Interval-wise SNR report; option 2 - [Quantized SNR value, time duration];
- Report complementary beam (resource group) indices;
- Report periodic beam selection pattern: [starting time, duration#1, selected beam#1], [duration#2, selected beam#2], etc.

10 In addition, the network device 100 may be configured to determine the subset of beams based on a quality metric.

To be specific, the quality metric may be defined to reflect the average SNR or a signal-to-interference-and-noise ratio, SINR in intervals with SNR or SINR above the threshold.

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Definition of a quality metric reflects the SNR and a time portion (within the observation time duration) in which the beam is not blocked/has no deep fade. For example, the quality metric may be defined to be equal to SNR*Time portion defined above. For another example, the quality metric may be defined as percentage of time where SNR is above the threshold. FIG. 7 shows an illustration of a quality metric according to an embodiment of the present invention.

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Based on the defined quality metric, beam down selection can be performed. In particular, the network device 100 is configured to determine the subset of beams by selecting at least one of: beams with the highest quality metrics, beams that are complementary to each other and with the highest quality metrics, beams fulfilling a percentage of time portion where the SNR or SINR value is above the threshold.

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It should be noted that there are different options to select the subset of beams, and a combination of those options is also possible. For instance, the network device may inform the UE about a percentage of time portion where the SNR should be above a threshold, so that only beams fulfilling this percentage will be reported.

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Certainly, it is also possible that the UE identifies no periodic power variation in the determined set of beams. Therefore, the network device 100 may also be configured to receive a report from the UE indicating that no periodic power variation in the determined set of beams is identified. Consequently, any traditional beam measurement method can be used. In such case, the network device 110 may provide additional information to the UE 110, indicating the UE 110 to measure a RSRP or RSRQ of a series of resources that belong to each beam; and obtain a third measurements report from the UE 110.

FIG. 8 shows a UE 110 according to an embodiment of the invention. The UE is configured to support beam power variation measurement in 5G. The UE 110 of FIG. 8 is particularly the UE 110 of FIG. 1. The network device 100 shown in FIG. 8 may be the one shown in FIG. 1. The UE 110 may be a factory equipment, or an industrial robots, etc.

The UE 110 may be configured to operate inversely to the network device 100 of FIG. 1. In particular, the UE 110 is configured to: receive information 101 indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams; perform a measurement for each beam of the determined set of beams; generate a first measurements report 102 based on the measurements; and send the first measurements report 102 to a network device 100.

In particular, the information 101 may include a measurement request signaled by the network device 100. The UE 110 may perform the beam measurement based on the configuration parameters obtained from the network device 100. After the measurement, a measurement report may be generated and sent to the network device 100.

The power variation measurement is the same as described in the previous embodiments, i.e. comprising 3 stages: SSB-based measurements, CSI-RS-based measurements, and DMRS-based measurements.

The configuration parameters received by the UE 110 is the same configuration parameters sent by the network device 100 according to the previous embodiments.

Optionally, the UE 110 may be configured to perform a SSB-based measurement and/or a CSI-RS-based measurement in a normal mode and/or a training mode.

Optionally, a density of the resources in training mode is higher than a density of the resources in normal mode. For example, when the UE performs SSB-based measurements in training mode, the density of SSB can be increased up to 4 SSB's per subframe.

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Optionally, the training mode may be scheduled by the network device 100, or the training mode is triggered by the UE 110. In particular, the UE 110 may send a request on the super-dense SSB mode to trigger the training mode.

- 10 The UE may be further configured to perform the SSB-based measurement in the training mode, wherein each SSB in a subset of SSBs consists of a Primary Synchronization Signal, PSS, and a Secondary Synchronization signal, SSS. For saving overhead, an optional would be that a subset of SSB's only contain a PSS field and a SSS field, i.e. without the PBCH. Other fields of an SSB is omitted and the corresponding resources may be released
15 for other usages, e.g. data.

- Optionally, the UE 110 is further configured to receive information from the network device 100, indicating a second set of configuration parameters for performing a power variation measurement per each beam of the subset of beams; perform a measurement per
20 each beam of the subset of beams; generate a second measurements report; and send the second measurements report to the network device 100. In particular, the subset of beams is determined by the network device 100 based on the first measurement report. Optionally, the UE 110 may be instructed by a measurement request sent by the network device 100, to perform a 2nd stage measurements based on the second set of configuration parameters
25 obtained from the network device 100. The UE 110 may feedback the second measurements report to the network device 100.

- Optionally, the UE 110 is further configured to receive an indication from the network device indicating the UE to send the first measurements report, wherein the first
30 measurements report includes information about at least one of: at least one of a starting and an ending time of a beam blockage/deep fade interval for one or more beams, signal-to-noise ratio, SNR, value variations in intervals with SNR above a threshold, complementary beam indices, a periodic beam selection pattern; and generate the first measurements report according to the indication.

The indication received by the UE 110 for indicating how to report the measurement results is the same indication sent by the network device 100 according to the previous embodiments.

5

After the measurement, if the UE identifies that no periodicity exists and reports to the network device, the UE may be configured to send a report to the network device indicating that no periodic power variation in the determined set of beams is identified. In this way, the system can fall back to a traditional mode (without beam power variation measurement).

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FIG. 9 shows a method 900 for supporting beam power variation measurements according to an embodiment of the present invention. In particular, the method 900 is performed by a network device. The method 900 comprises: a step 901 of providing information to a user equipment, UE, indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams; and a step 902 of obtaining a first measurements report from the UE.

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FIG. 10 shows a method 1000 for supporting beam power variation measurements according to an embodiment of the present invention. In particular, the method 1000 is performed by a user equipment. The method comprises: a step 1001 of receiving information indicating a first set of configuration parameters for performing a power variation pattern measurement per each beam of a determined set of beams; a step 1002 of performing a measurement for each beam of the determined set of beams; a step 1003 of generating a first measurements report based on the measurements; and a step 1004 of sending the first measurements report to a network device.

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Basically, the present invention comprises three components:

1. Configuration of UE measurements to capture the RPVP per beam, comprising:
 - Signalling of network device to require UE to perform of RPVP measurement per beam;
 - Configuration of observation duration and occurrence repetition number of blockage/deep fade to identify periodic behaviour;

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- Definition of quality metric (e.g. non-blocked/fade percentage) of each beam as down selection criteria for beam selection.
2. Configuration of SSB's, CSI-RS's, and DMRS for multi-stage measurements, comprising:
- Combined usage of SSB and CSI-RS for RPVP measurement as the 1st stage. One option is the training mode with super-dense SSB;
 - Configuration of CSI-RS for RPVP measurement as 2nd stage, comprising: configuration of a training mode with super-dense CSI-RS, and a normal mode; and configuration of beam multiplexing and beam resource sets.
 - Configuration of Demodulation Reference Signal (DMRS) for RPVP measurement as the 3rd stage, comprising configuration of beam multiplexing pattern of DMRS incl. sampling period for measuring each beam and the number of observation durations that contain different beam sets.
3. Configuration of UE report of the RPVP measurements, comprising:
- Type 1 report (brief): Indexes of beams with sufficient SNR at least for a certain portion of time;
 - Type 2 report (detailed): Report about time domain information of the beam blockage/deep fade, or report about complementary beams. Predictability related indicators can also be reported.

In summary, embodiments of the present invention achieve multiple benefits. Advantages are summarized as:

1. Based on measurement results about predictable dynamic blockage and deep fade, network device can use at least the following transmission techniques to enhance the link reliability:
- Optimized scheduling of beams and time resource based on predicted blockage/deep fade. One example is to mainly schedule the LOS beam (which has highest SNR). But when blockage/deep fade predicted, an alternative beam (e.g. a "complementary beam") is scheduled,

- Optimized multi-beam transmission: Use complementary beams simultaneously to enhance diversity. When one beam is blocked, or in deep fade, the link still remains functioning,
 - Predictive coding and modulation adaptation, based on SNR variation prediction.
- 5
2. Reduced reporting overhead of the RPVP measurement results.

A person of ordinary skill in the art may be aware that, in combination with the examples described in the embodiments disclosed in this specification, units and algorithm steps may be implemented by electronic hardware or a combination of computer software and electronic hardware. Whether the functions are performed by hardware or software depends on particular applications and design constraint conditions of the technical solutions. A person skilled in the art may use different methods to implement the described functions for each particular application, but it should not be considered that the implementation goes beyond the scope of the present invention.

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It may be clearly understood by a person skilled in the art that, for the purpose of convenient and brief description, for a detailed working process of the foregoing system, apparatus, and unit, reference may be made to a corresponding process in the foregoing method embodiments, and details are not described herein again.

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In the several embodiments provided in this application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described apparatus embodiment is merely an example. For example, the apparatus disclosed by the embodiments may comprise a plurality of units or components. These units or components may be physically separate, may be located in one position, may be combined or integrated into another system, or may be integrated into one processing unit.

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When the functions are implemented in the form of a software functional unit and sold or used as an independent product, the functions may be stored in a computer-readable storage medium. Based on such an understanding, the technical solutions of the present invention essentially, or the part contributing to the prior art, or some of the technical solutions may be implemented in a form of a software product. The software product is stored in a storage

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medium, and includes several instructions for instructing a computer device (which may be a personal computer, a server, or a network device) to perform all or some of the steps of the methods described in the embodiments of the present invention. The foregoing storage medium includes: any medium that can store program code, such as a USB flash
5 drive, a removable hard disk, a read-only memory (ROM, Read-Only Memory), a random access memory (RAM, Random Access Memory), a magnetic disk, or an optical disc.

Embodiments of the present invention have been described in conjunction with various embodiments as examples as well as implementations. However, other variations can be
10 understood and effected by those persons skilled in the art and practicing the claimed invention, from the studies of the drawings, this disclosure and the independent claims. In the claims as well as in the description the word “comprising” does not exclude other elements or steps and the indefinite article “a” or “an” does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the
15 claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

Claims

1. Network device (100) for supporting beam power variation measurements, the network device (100) being configured to:
 - 5 provide information (101) to a user equipment (110), UE, indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams;
obtain a first measurements report (102) from the UE (110).
- 10 2. Network device (100) according to claim 1, wherein the power variation measurement comprises at least one of a:
 - Synchronization Signal Block, SSB-based measurement,
 - Channel State Information Reference Signal, CSI-RS-based measurement
 - Demodulation Reference Signal, DMRS-based measurement.
- 15 3. Network device (100) according to claim 2, wherein the first set of configuration parameters includes at least one of:
 - an indication for performing the power variation measurements based on a resource group,
 - 20 - the resources in the resource group associated to each beam to be measured,
 - at least one threshold to identify blockage/deep fade,
 - a repetition period of each beam.
- 25 4. Network device (100) according to one of the claims 1 to 3, configured to determine a subset of beams based on the received first measurement report; provide information to the UE (110) indicating a second set of configuration parameters for performing a power variation measurement per each beam of the subset of beams; and
obtain a second measurements report from the UE (110).
- 30 5. Network device (100) according to one of the claims 1 to 4, configured to indicate the UE (110) to send the first measurements report (102), wherein the first measurements report (102) includes information about at least one of:

- at least one of a starting and an ending time of a beam blockage/deep fade interval for one or more beams,
 - signal-to-noise ratio, SNR, value variations in intervals with SNR above a threshold,
 - 5 - indices of complementary beams,
 - a periodic beam selection pattern.
6. Network device (100) according to claim 4 or 5, configured to determine the subset of beams based on a quality metric.
- 10 7. Network device (100) according to claim 6, wherein the quality metric is defined to reflect the average SNR or a signal-to-interference-and-noise ratio, SINR in intervals with SNR or SINR above the threshold.
- 15 8. Network device (100) according to claim 6 or 7, configured to determine the subset of beams by selecting at least one of:
- beams with the highest quality metrics,
 - beams that are complementary to each other and with the highest quality metrics,
 - 20 - beams fulfilling a percentage of time portion where the SNR or SINR value is above the threshold.
9. Network device (100) according to one of the claims 1 to 8, configured to receive a report from the UE (110) indicating that no periodic power variation in
- 25 the determined set of beams is identified.
10. User equipment (110), UE, for measuring beam power variation, the UE (110) being configured to:
- receive information (101) indicating a first set of configuration parameters for
 - 30 performing a power variation measurement per each beam of a determined set of beams;
 - perform a measurement for each beam of the determined set of beams;
 - generate a first measurements report (102) based on the measurements; and
 - send the first measurements report (102) to a network device (100).

11. UE (110) according to claim 10, wherein
the power variation measurement comprises at least one of a:
- Synchronization Signal Block, SSB-based measurement,
 - Channel State Information Reference Signal, CSI-RS-based measurement
 - 5 - Demodulation Reference Signal, DMRS-based measurement.
12. UE (110) according to one of the claims 9 to 11, wherein
the first set of configuration parameters includes at least one of:
- an indication for performing the power variation measurements based on a
10 resource group,
 - the resources in the resource group associated to each beam to be measured,
 - at least one threshold to identify blockage/deep fade,
 - a repetition period of each beam.
13. UE (110) according to claim 11, configured to
perform a SSB-based measurement and/or a CSI-RS-based measurement in a
normal mode and/or a training mode.
14. UE (110) according to claim 13, wherein
20 a density of the resources in training mode is higher than a density of the
resources in normal mode.
15. UE (110) according to claim 13 or 14, wherein
the training mode is scheduled by the network device (100), or
25 the training mode is triggered by the UE (110).
16. UE (110) according to one of the claims 13 to 15, configured to
perform the SSB-based measurement in the training mode, wherein each SSB in a
subset of SSBs consists of a Primary Synchronization Signal, PSS, and a Secondary
30 Synchronization signal, SSS.
17. UE (110) according to one of the claims 10 to 16, configured to

receive information from the network device (100), indicating a second set of configuration parameters for performing a power variation measurement per each beam of the subset of beams;

perform a measurement per each beam of the subset of beams;

5 generate a second measurements report; and

send the second measurements report to the network device (100).

18. UE (100) according to one of the claims 10 to 17, configured to receive an indication from the network device (100) indicating the UE to send the first measurements report, wherein the first measurements report (102) includes information about at least one of:

- at least one of a starting and an ending time of a beam blockage/deep fade interval for one or more beams,

15 - signal-to-noise ratio, SNR, value variations in intervals with SNR above a threshold,

- complementary beam indices,

- a periodic beam selection pattern; and

generate the first measurements report (102) according to the indication.

20 19. UE (100) according to one of the claims 10 to 18, configured to send a report to the network device (100) indicating that no periodic power variation in the determined set of beams is identified.

20. Method (900) for supporting beam power variation measurements, the method comprising:

providing (901) information to a user equipment, UE, indicating a first set of configuration parameters for performing a power variation measurement per each beam of a determined set of beams;

obtaining (902) a first measurements report from the UE.

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21. Method (1000) for measuring beam power variation, the method comprising:

receiving (1001) information indicating a first set of configuration parameters for performing a power variation pattern measurement per each beam of a determined set of beams;

performing (1002) a measurement for each beam of the determined set of beams;
generating (1003) a first measurements report based on the measurements; and
sending (1004) the first measurements report to a network device.

- 5 22. Computer program product comprising a program code for carrying out, when implemented on a processor, the method according to claim 20 or 21.

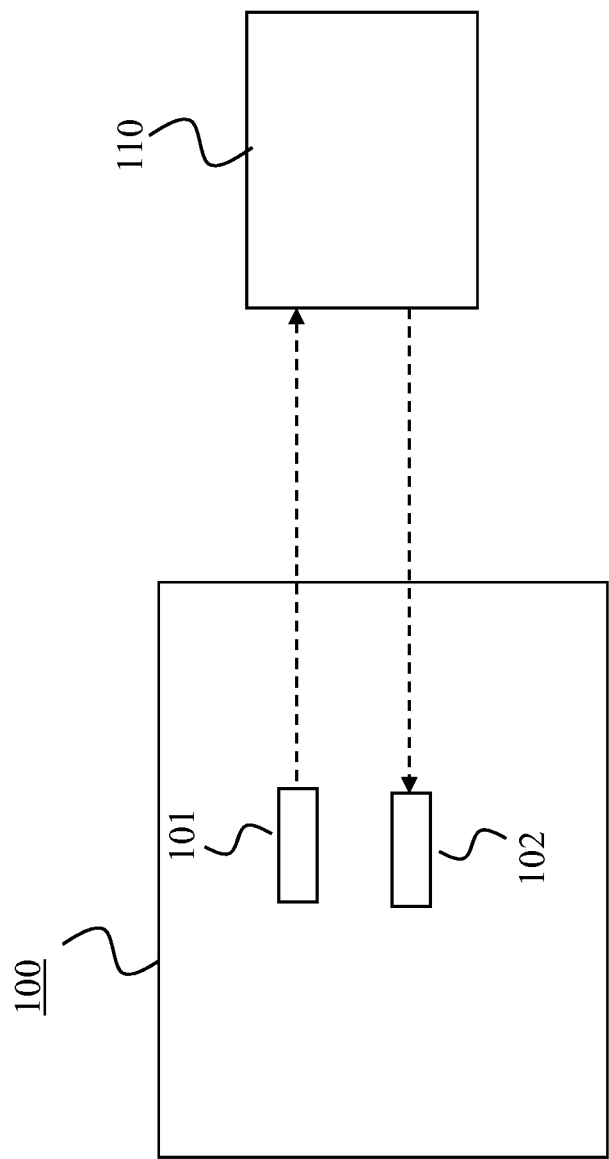


FIG. 1

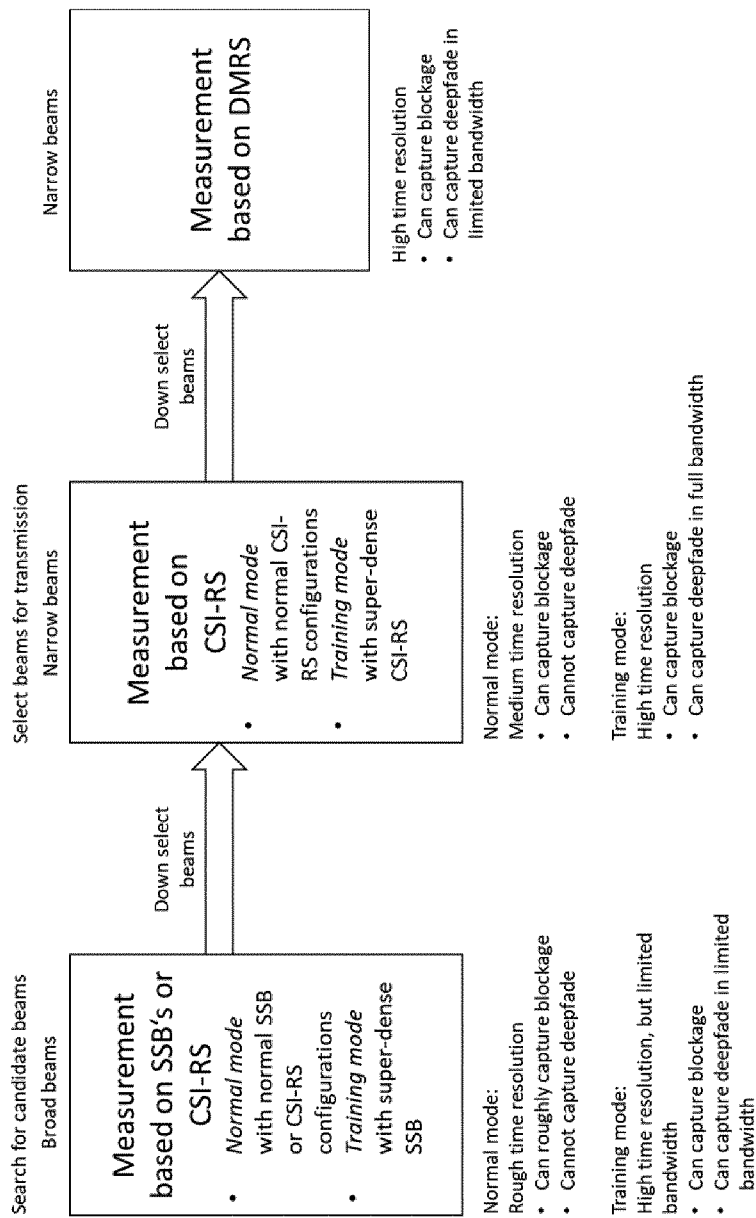


FIG. 2

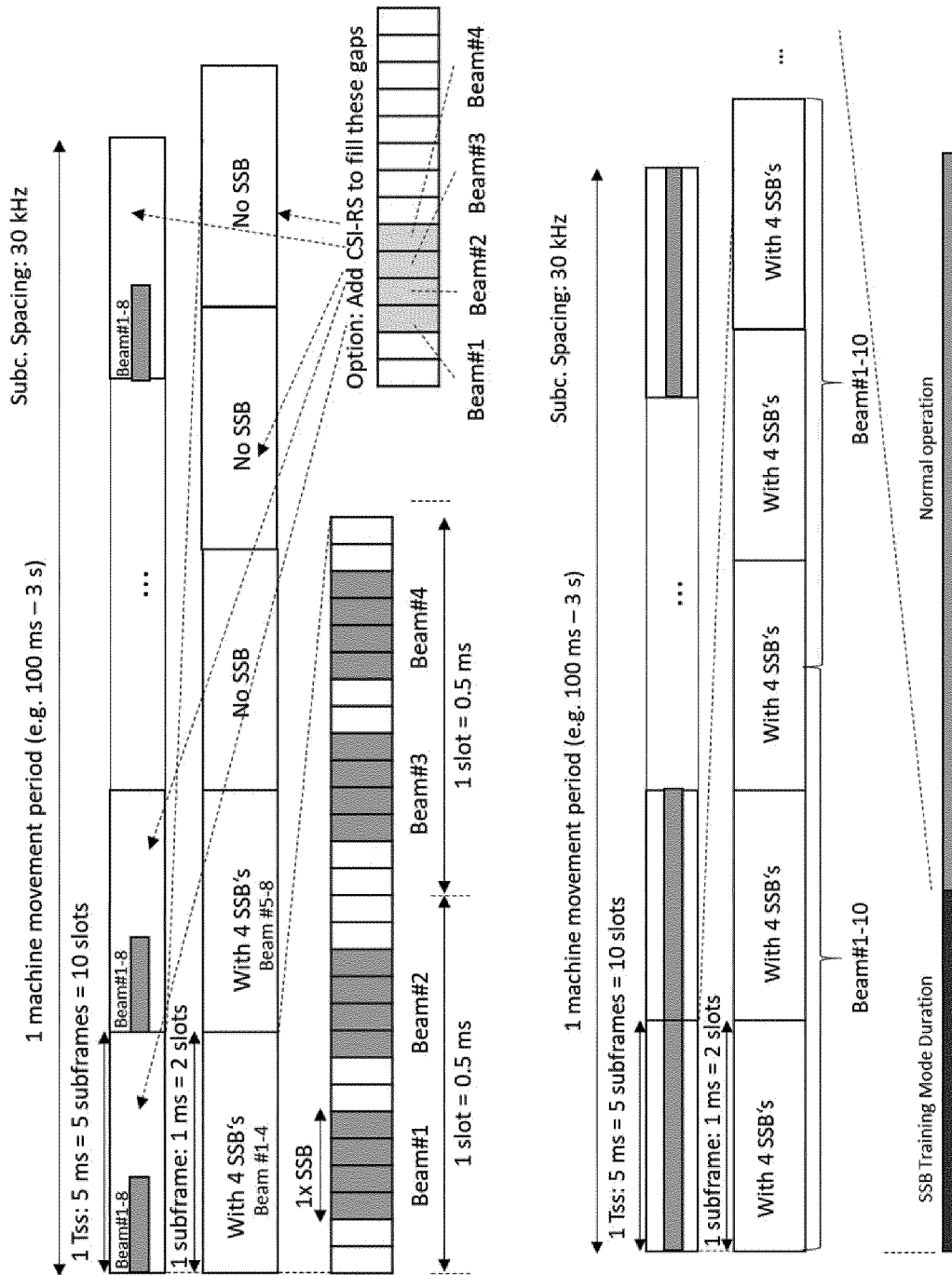


FIG. 3

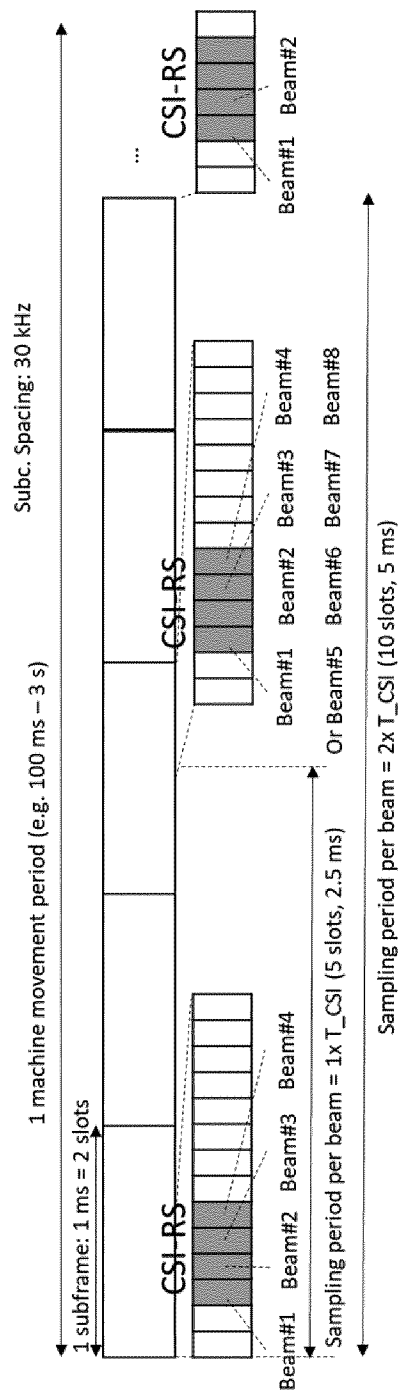


FIG. 4

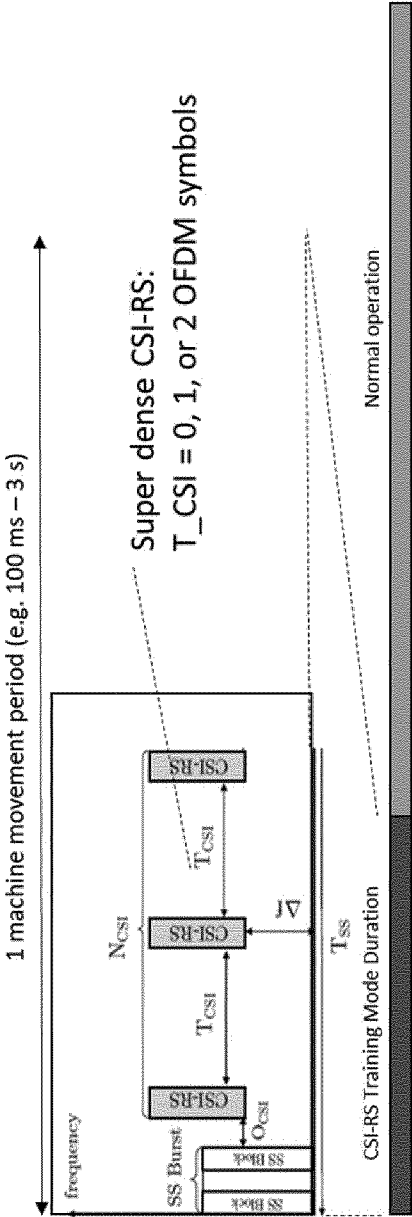


FIG. 5

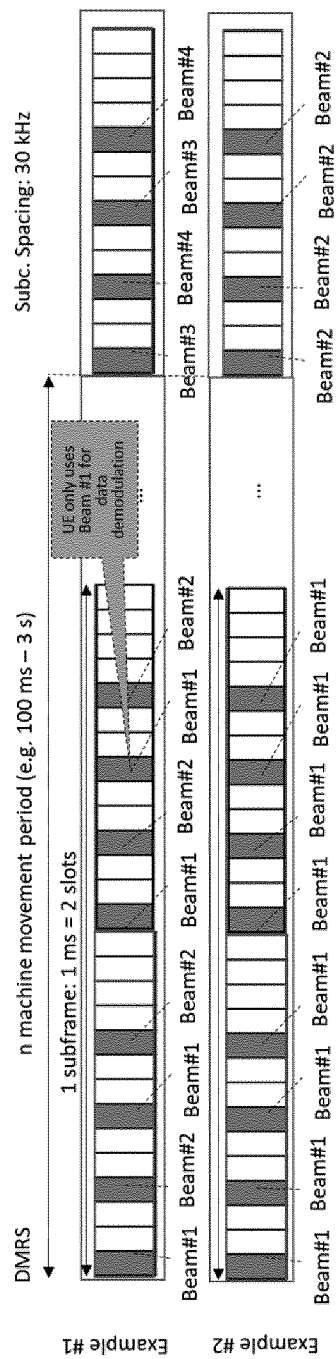


FIG. 6

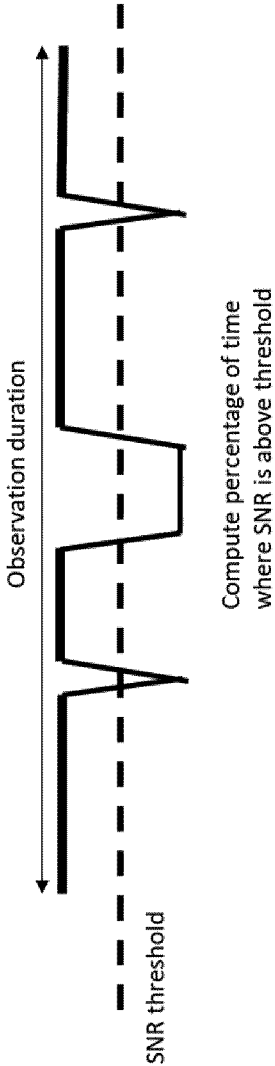


FIG. 7

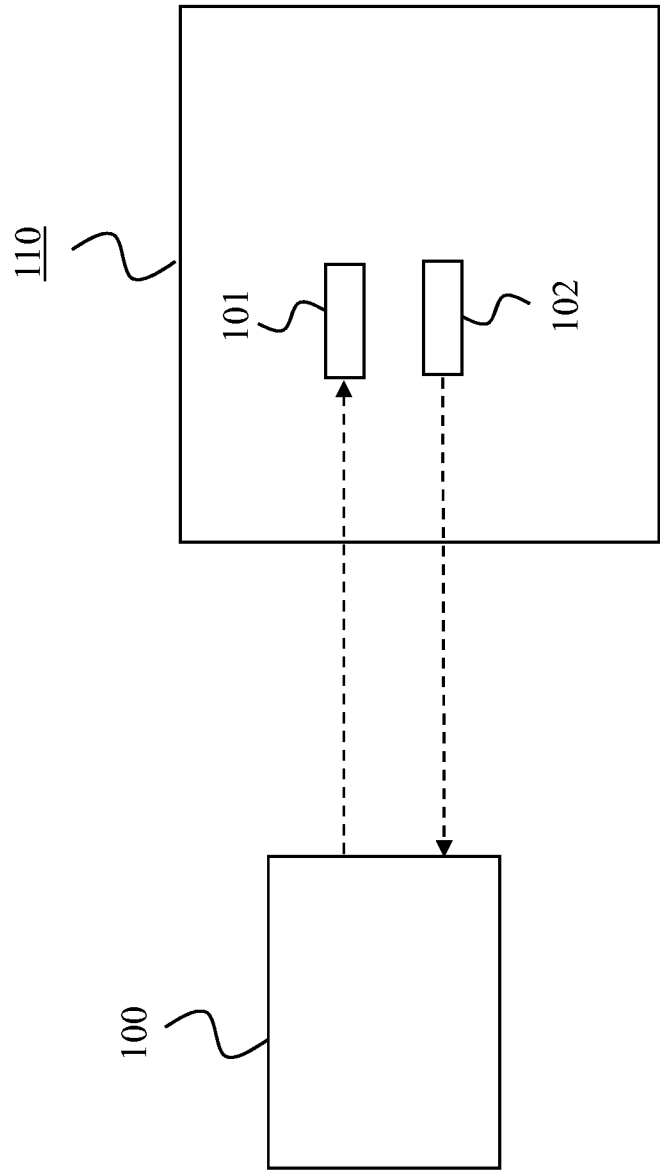


FIG. 8

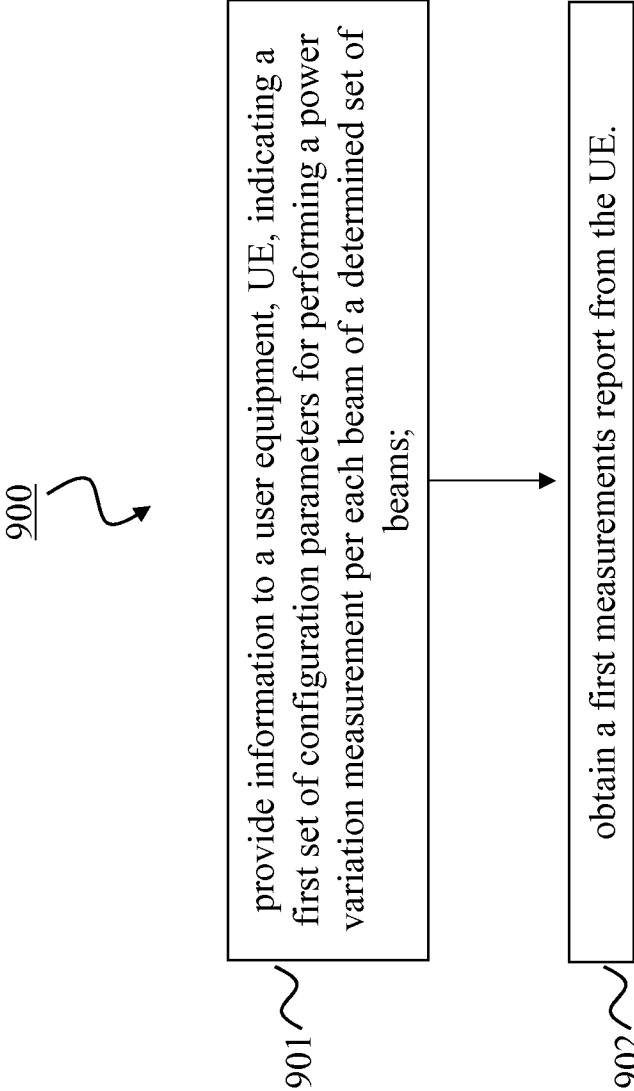


FIG. 9

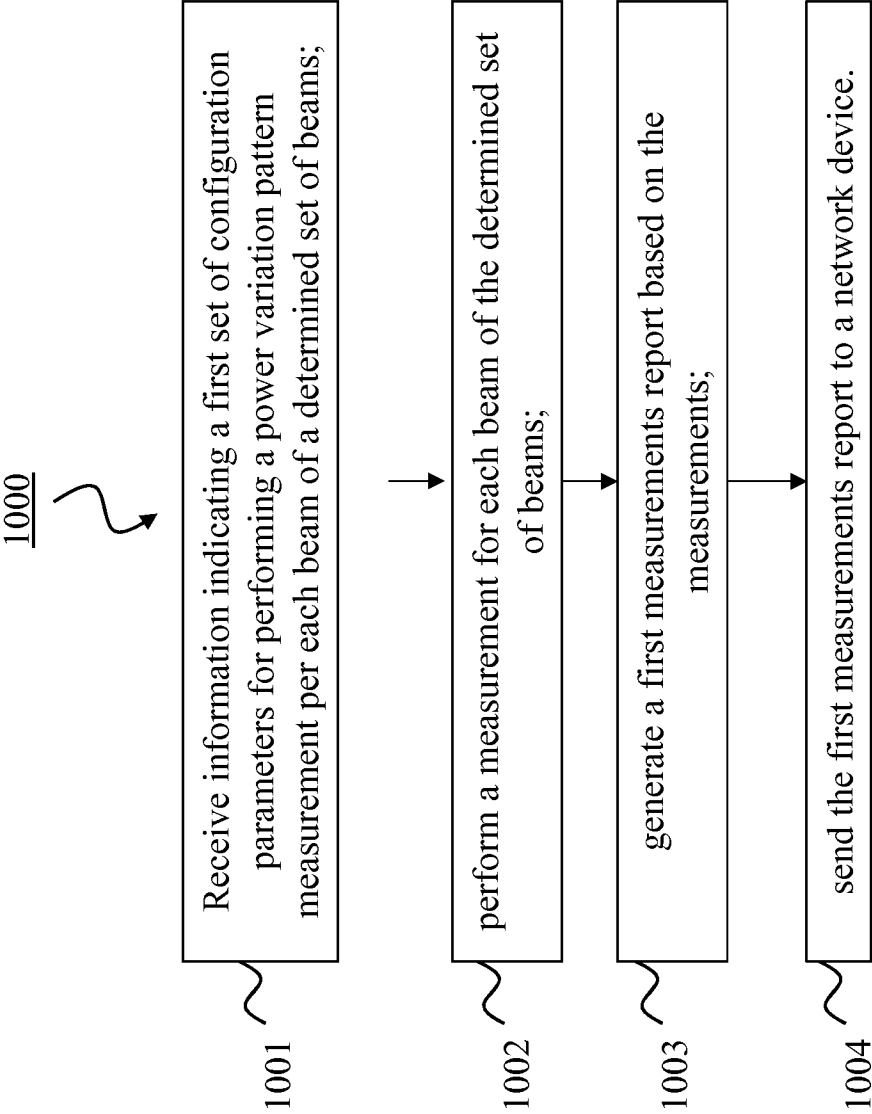


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/067072

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/06 H04B7/08
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/150013 A1 (ZHANG WEI [US] ET AL) 16 May 2019 (2019-05-16) paragraph [0089] - paragraph [0097] paragraph [0104] - paragraph [0107] paragraph [0125] - paragraph [0135] -----	1-22
A	WO 2010/039246 A1 (SEARETE LLC [US]; HYDE RODERICK A [US] ET AL.) 8 April 2010 (2010-04-08) page 2, line 17 - page 4, line 5 page 32, line 13 - page 35, line 5 page 41, line 11 - page 42, line 2 figures 1, 7 ----- -/--	1-22



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

25 February 2020

Date of mailing of the international search report

04/03/2020

Name and mailing address of the ISA/

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Spinnler, Florian

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/067072

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/067072

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