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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
02 April 2020 (02.04.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/062085 A1

(51) International Patent Classification:
H04W 72/04 (2009.01) *H04W 36/34* (2009.01)

(21) International Application Number:
PCT/CN2018/108458

(22) International Filing Date:
28 September 2018 (28.09.2018)

(25) Filing Language: English

(26) Publication Language: English

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(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, JO, 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,

(54) Title: CARRIER SELECTION FOR BEAM FAILURE RECOVERY

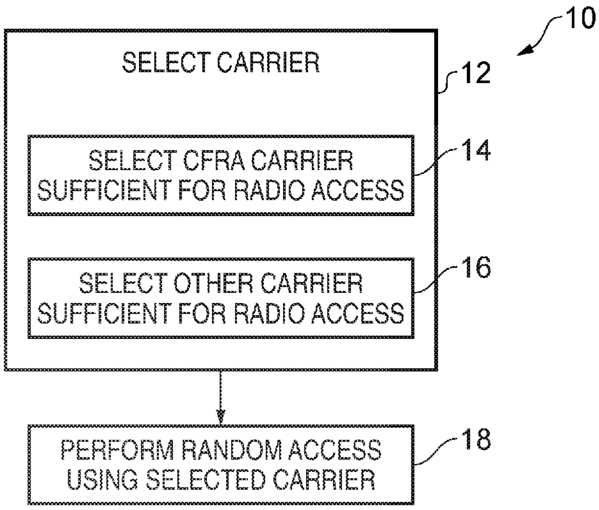

FIG. 1

(57) Abstract: A method comprising: selecting an uplink carrier for use for random access procedure; and using the uplink carrier for random access procedure, wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the ransom access procedure is initiated but not initiated for beam failure recovery.

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MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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

CARRIER SELECTION FOR BEAM FAILURE RECOVERY

TECHNOLOGICAL FIELD

Embodiments of the present disclosure relate to carrier selection for beam failure recovery. Some embodiments relate to controlling selection of supplementary uplink carriers for beam failure recovery.

BACKGROUND

It would be desirable to optimize beam failure recovery. Beam failure recovery uses the standard random access procedure.

The inventors have realized that it is desirable to optimize the random access procedure, and in particular the random access procedure used for beam failure recovery.

Selection of a correct carrier helps optimize the random access procedure, and in particular the random access procedure used for beam failure recovery.

BRIEF SUMMARY

According to various, but not necessarily all, embodiments there is provided a method comprising:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the random access procedure is initiated but not initiated for beam failure recovery.

In some but not necessarily all examples, the first condition compares a measured downlink carrier characteristic against a first threshold, when the first threshold is configured.

In some but not necessarily all examples, the first condition compares the measured downlink carrier characteristic against a different threshold to the first threshold, when the first threshold is not configured.

In some but not necessarily all examples, the second condition compares the measured downlink carrier characteristic against a second threshold, different to the first threshold.

In some but not necessarily all examples, the second condition is independent of the first threshold.

In some but not necessarily all examples, the first condition compares the measured downlink carrier characteristic against the second threshold, different to the first threshold, when the first threshold is not configured.

In some but not necessarily all examples, selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

In some but not necessarily all examples, the method further comprises: using a threshold parameter that at least partially determines the first threshold to determine the first threshold.

In some but not necessarily all examples, the threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold.

In some but not necessarily all examples, the threshold parameter is not configured, assuming the offset to be zero.

In some but not necessarily all examples, the threshold parameter defines the first threshold independently of the second threshold.

In some but not necessarily all examples, the measured downlink carrier characteristic is dependent upon received signal power and/or received signal quality.

In some but not necessarily all examples, the measured carrier characteristic is reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

In some but not necessarily all examples, the first condition depends upon a comparison of a measured downlink carrier characteristic against a first threshold and an additional condition,.

In some but not necessarily all examples, the additional condition depends upon availability of contention free random access resources.

In some but not necessarily all examples, the additional condition depends upon availability of beam failure recovery configuration for currently active bandwidth part.

In some but not necessarily all examples, the first condition depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when there has been configuration of the first threshold, and a different threshold, when there has not been configuration of the first threshold.

In some but not necessarily all examples, the first condition and the second condition provide separate logic paths that each enable selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

In some but not necessarily all examples, an apparatus comprises means for performing or means for causing performance of the method.

According to various, but not necessarily all, embodiments there is provided an apparatus comprising means for:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the ransom access procedure is initiated but not initiated for beam failure recovery.

In some but not necessarily all examples, selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

In some but not necessarily all examples, the apparatus comprises comprising means for using a threshold parameter that at least partially determines the first threshold to determine the first threshold.

In some but not necessarily all examples, the threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold or wherein the threshold parameter defines the first threshold independently of the second threshold.

In some but not necessarily all examples, the apparatus comprises means for selecting a carrier in dependence upon a comparison of a measured downlink carrier characteristic against a first threshold and an additional condition.

In some but not necessarily all examples, the additional condition depends upon availability of contention free random access resources and/or upon availability of beam failure recovery resources for currently active bandwidth part.

In some but not necessarily all examples, the apparatus is configured to select a carrier that is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

In some but not necessarily all examples, the apparatus is configured as mobile equipment or configured as user equipment.

According to various, but not necessarily all, embodiments there is provided 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 to, with the at least one processor, cause the apparatus at least to perform:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,

wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a computer program that, when run on a computer, performs:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a data structure comprising data that defines a threshold parameter specifically used to differentiate a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a comparison of the measured downlink carrier characteristic against a second, different threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold, when configured for beam failure recovery, and a second, different threshold, when not configured for beam failure recovery.

In some but not necessarily all examples, configuration for beam failure recovery configures a threshold parameter that at least partially determines the first threshold. In some but not necessarily all examples the threshold parameter is provided in an information element.

In some but not necessarily all examples the threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold.

In some but not necessarily all examples the threshold parameter defines the first threshold independently of the second threshold

In some but not necessarily all examples, selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold and an additional condition, when configured for beam failure recovery.

In some but not necessarily all examples the additional condition depends upon availability of contention free random access resources.

In some but not necessarily all examples the additional condition depends upon availability of beam failure recovery resources for currently active bandwidth part.

In some but not necessarily all examples the measured carrier characteristic is dependent upon received signal power and/or received signal quality.

In some but not necessarily all examples the measured carrier characteristic is reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

In some but not necessarily all examples the first threshold and the second threshold are for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

In some but not necessarily all examples the method comprises: modifying the measurement in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the selected carrier is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

According to various, but not necessarily all, embodiments there is provided an apparatus comprising means for:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold, when configured for beam failure recovery, and a second, different threshold, when not configured for beam failure recovery.

In some but not necessarily all examples, configuration for beam failure recovery configures a threshold parameter that at least partially determines the first threshold.

In some but not necessarily all examples the threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold.

In some but not necessarily all examples the threshold parameter defines the first threshold independently of the second threshold.

In some but not necessarily all examples, the apparatus comprises means for selecting a carrier in dependence upon a comparison of a measured carrier characteristic against a first threshold and an additional condition, when configured for beam failure recovery.

In some but not necessarily all examples the additional condition depends upon availability of contention free random access resources and/or upon availability of beam failure recovery resources for currently active bandwidth part.

In some but not necessarily all examples, the apparatus is configured to select a carrier that is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

According to various, but not necessarily all, embodiments there is provided 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 to, with the at least one processor, cause the apparatus at least to perform:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold, when configured for beam failure recovery, and a second, different threshold, when not configured for beam failure recovery.

According to various, but not necessarily all, embodiments there is provided an apparatus configured as mobile equipment or configured as user equipment

According to various, but not necessarily all, embodiments there is provided a computer program that, when run on a computer, performs: selecting a carrier for use for random access during beam failure recovery, wherein the selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold, when configured for beam failure recovery, and a second, different threshold, when not configured for beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a data structure comprising data that defines a threshold used
in a comparison with a measured carrier characteristic
to cause selection of a carrier, for random access during recovery from beam failure, that has been assigned a beam failure recovery configuration in preference to a carrier that has not been assigned a beam failure recovery configuration.

According to various, but not necessarily all, embodiments there is provided a method comprising:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access, to be different depending upon which carrier is configured for beam failure recovery.

In some but not necessarily all examples, the method comprises: causing preferential selection of a carrier that been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the method comprises: causing alternative selection of a carrier that has not been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the method comprises: causing modification of a measured carrier characteristic and/or the threshold used in a comparison, for selecting a carrier, in dependence upon which carrier has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the threshold is for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

In some but not necessarily all examples, the method comprises: causing application of a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and
causing application of a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

In some but not necessarily all examples, the method comprises: causing use of a first threshold when SUL has been assigned a beam failure recovery configuration; and causing use of a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the method comprises: causing modification of a measured carrier characteristic used in a comparison, for selecting a carrier, in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

According to various, but not necessarily all, embodiments there is provided an apparatus comprising means for:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access, to be different depending upon which carrier is configured for beam failure recovery.

In some but not necessarily all examples, the apparatus comprises: causing preferential selection of a carrier that been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the apparatus comprises: means for causing alternative selection of a carrier that has not been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the apparatus comprises: means for causing modification of a measured carrier characteristic and/or the threshold used in a comparison, for selecting a carrier, in dependence upon which carrier has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the threshold is for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

In some but not necessarily all examples, the apparatus comprises: means for:
causing application of a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and
causing application of a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

In some but not necessarily all examples, the apparatus comprises: means for:
causing use of a first threshold when SUL has been assigned a beam failure recovery configuration; and

causing use of a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the apparatus comprises: means for: causing modification of a measured carrier characteristic used in a comparison, for selecting a carrier, in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

In some but not necessarily all examples, a network comprises a plurality of network nodes comprising the apparatus as described.

According to various, but not necessarily all, embodiments there is provided a computer program that, when run on a computer, performs:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access, to be different depending upon which carrier is configured for beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein selecting a carrier depends upon a comparison of a measured carrier characteristic against a threshold,
wherein the measured carrier characteristic and/or the threshold are modified in dependence upon if a carrier has been assigned a beam failure recovery configuration.

According to various, but not necessarily all, embodiments there is provided a method comprising:
initiating random access procedure,
selecting a carrier for use in random access procedure, wherein selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold, when performing beam failure recovery, and a second, different threshold, when not performing beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier depends upon whether a carrier is configured to perform beam failure recovery.

In some but not necessarily all examples the method comprises:
preferentially selecting a carrier that been assigned a beam failure recovery configuration and is sufficient for radio access; and
using the carrier for random access by performing random access using the selected carrier. In some but not necessarily all examples the method comprises:
alternatively selecting a carrier that has not been assigned a beam failure recovery configuration and is sufficient for radio access; and
using the carrier for random access by performing contention based random access using the selected carrier.

In some but not necessarily all examples, selecting a carrier for use for random access is dependent upon whether
(i) the carrier has or has not been assigned a beam failure recovery configuration; and
(ii) the carrier is sufficient for radio access.

In some but not necessarily all examples the method comprises:
determining if the carrier has or has not been assigned a beam failure recovery configuration; and

determining if the carrier is sufficient for radio access.

In some but not necessarily all examples the method comprises:
determining the carrier is sufficient for radio access in dependence upon whether one or more measured characteristics of the carrier are sufficient.

In some but not necessarily all examples the method comprises: determining the carrier is sufficient for radio access in dependence upon whether the carrier is in use, and if not in use whether one or more measured characteristics of the carrier are sufficient.

In some but not necessarily all examples, selecting a carrier comprises comparison of a measured carrier characteristic against a threshold.

In some but not necessarily all examples the method comprises: modifying the measured carrier characteristic and/or the threshold used in the comparison in dependence upon which carrier has been assigned a beam failure recovery configuration; and which sufficient carriers are preferred for radio access.

In some but not necessarily all examples the method comprises: determining a carrier is sufficient for radio access in dependence upon whether one or more measured characteristics of the carrier are sufficient or in dependence upon whether the carrier is in use, and if not in use whether one or more measured characteristics of the carrier are sufficient.

In some but not necessarily all examples, the characteristic is dependent upon received signal power and/or received signal quality.

In some but not necessarily all examples, the characteristic is reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

In some but not necessarily all examples, the threshold is received in a BFR config IE.

In some but not necessarily all examples, the threshold is for selection between a normal uplink carrier and a supplementary uplink carrier.

In some but not necessarily all examples the method comprises: applying a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and applying a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

In some but not necessarily all examples the method comprises: using a first threshold when SUL has been assigned a beam failure recovery configuration; and using a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the method comprises: using a first threshold for random access for beam failure recovery configuration; and using a second threshold for random access otherwise.

In some but not necessarily all examples the method comprises: modifying the measurement in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the method comprises: preferentially using a current in use carrier if assigned a beam failure recovery configuration.

In some but not necessarily all examples the method comprises: using a current in use carrier if assigned a beam failure recovery configuration.

In some but not necessarily all examples, selecting a carrier for use for random access is a selection from a sub-set of a set of candidates defined by a telecommunications specification, wherein the sub-set are more likely to be available for beam failure recovery.

In some but not necessarily all examples, the carrier is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

In some but not necessarily all examples a carrier is assigned a beam failure recovery configuration by assignment of a preamble for contention free random access.

In some but not necessarily all examples, an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

In some but not necessarily all examples, a carrier is assigned a beam failure recovery configuration by configuring the carrier to perform beam failure recovery.

In some but not necessarily all examples, configuring a carrier to perform beam failure recovery can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and configuring a carrier to perform beam failure recovery cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

In some but not necessarily all examples the method comprises:
configuring a carrier to perform beam failure recovery using the BFR config IE.

According to various, but not necessarily all, embodiments there is provided an apparatus comprising means for:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier depends upon whether a carrier that has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the apparatus comprises: means for:
preferentially selecting a carrier that been assigned a beam failure recovery configuration and is sufficient for radio access; and

using the carrier for random access by performing contention free random access using the selected carrier.

In some but not necessarily all examples the apparatus comprises: means for: alternatively selecting a carrier that has not been assigned a beam failure recovery configuration and is sufficient for radio access; and
using the carrier for random access by performing contention based random access using the selected carrier.

In some but not necessarily all examples, selecting a carrier for use for random access is dependent upon whether
(i) the carrier has or has not been assigned a beam failure recovery configuration; and
(ii) the carrier is sufficient for radio access.

In some but not necessarily all examples the apparatus comprises: means for: determining if the carrier has or has not been assigned a beam failure recovery configuration; and
determining if the carrier is sufficient for radio access.

In some but not necessarily all examples the apparatus comprises: means for determining the carrier is sufficient for radio access in dependence upon whether one or more measured characteristics of the carrier are sufficient.

In some but not necessarily all examples the apparatus comprises: means for determining the carrier is sufficient for radio access in dependence upon whether the carrier is in use, and if not in use whether one or more measured characteristics of the carrier are sufficient.

In some but not necessarily all examples, selecting a carrier comprises comparison of a measured carrier characteristic against a threshold.
In some but not necessarily all examples the apparatus comprises: means for modifying the measured carrier characteristic and/or the threshold used in the comparison in dependence upon which carrier has been assigned a beam failure recovery configuration; and which sufficient carriers are preferred for radio access.

In some but not necessarily all examples the apparatus comprises: means for determining a carrier is sufficient for radio access in dependence upon whether one or more measured characteristics of the carrier are sufficient or in dependence upon whether the carrier is in use, and if not in use whether one or more measured characteristics of the carrier are sufficient.

In some but not necessarily all examples, the characteristic is dependent upon received signal power and/or received signal quality.

In some but not necessarily all examples, the characteristic is reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

In some but not necessarily all examples, the threshold is received in a BFR config IE. In some but not necessarily all examples the threshold is RSRP_ThresholdSSB-SUL.

In some but not necessarily all examples, the threshold is for selection between a normal uplink carrier and a supplementary uplink carrier.

In some but not necessarily all examples the apparatus comprises: means for:
applying a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and
applying a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

In some but not necessarily all examples the apparatus comprises: means for using a first threshold when SUL has been assigned a beam failure recovery configuration; and using a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the apparatus comprises: means for modifying the measurement in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the apparatus comprises: means for preferentially using a current in use carrier if assigned a beam failure recovery configuration.

In some but not necessarily all examples the apparatus comprises: means for using a current in use carrier if assigned a beam failure recovery configuration.

In some but not necessarily all examples, selection of a carrier for use for random access is a selection from a sub-set of a set of candidates defined by a telecommunications specification, wherein the sub-set are more likely to be available for beam failure recovery.

In some but not necessarily all examples, the carrier is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

In some but not necessarily all examples, a carrier is assigned a beam failure recovery configuration by assignment of a preamble for contention free random access.

In some but not necessarily all examples, an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

In some but not necessarily all examples, a carrier is assigned a beam failure recovery configuration by configuring the carrier to perform beam failure recovery.

In some but not necessarily all examples, configuring a carrier to perform beam failure recovery can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and configuring a carrier to perform beam failure recovery cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

In some but not necessarily all examples the apparatus comprises: means for configuring a carrier to perform beam failure recovery using the BFR config IE.

In some but not necessarily all examples the apparatus comprises: means for performing or means for causing performance of the methods described.

According to various, but not necessarily all, embodiments there is provided 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 to, with the at least one processor, cause the apparatus at least to perform:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier depends upon whether a carrier that has been assigned a beam failure recovery configuration.

In some but not necessarily all examples the apparatus is configured as mobile equipment or configured as user equipment.

According to various, but not necessarily all, embodiments there is provided an apparatus comprising means for: selecting a carrier for use for random access during beam failure recovery, wherein the selecting a carrier depends upon whether a usable carrier that has been assigned a beam failure recovery configuration.

According to various, but not necessarily all, embodiments there is provided a network comprising a plurality of network nodes comprising the apparatus as described.

According to various, but not necessarily all, embodiments there is provided a computer program that, when run on a computer, performs: selecting a carrier for use for random access during beam failure recovery, wherein the selecting a carrier depends upon whether a usable carrier that has been assigned a beam failure recovery configuration.

According to various, but not necessarily all, embodiments there is provided a data structure comprising data that defines a threshold used
in a comparison with a measured carrier characteristic
to select a carrier, for random access during recovery from beam failure, that has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the data structure is configured to enable preferential selection of supplementary uplink instead of normal uplink when supplementary uplink has been assigned a beam failure recovery configuration and normal uplink has not been assigned a beam failure recovery configuration and to enable preferential selection of normal uplink instead of supplementary uplink when normal uplink has been assigned a beam failure recovery configuration and supplementary uplink has not been assigned a beam failure recovery configuration.

According to various, but not necessarily all, embodiments there is provided a method comprising:
selecting a carrier for use for random access, wherein selecting a carrier for use for random access is dependent upon whether
(i) the carrier has or has not been assigned a beam failure recovery configuration; and
(ii) the carrier is sufficient for radio access.

In some but not necessarily all examples, the method comprises: preferentially selecting a carrier that been assigned a beam failure recovery configuration and is sufficient for radio access. In some but not necessarily all examples, the method comprises: alternatively assigned to carrier that has not been assigned a beam failure recovery configuration and is sufficient for radio access.

According to various, but not necessarily all, embodiments there is provided a method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access

wherein the selecting a carrier is depends upon whether a carrier configured to perform beam failure recovery.

According to various, but not necessarily all, embodiments there is provided a method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier is biased to favour a carrier that has been assigned a resource for contention free random access.

According to various, but not necessarily all, embodiments there is provided an apparatus comprising means for:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier is biased to favour a carrier that has been assigned a resource for contention free random access.

According to various, but not necessarily all, embodiments there is provided 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 to, with the at least one processor, cause the apparatus at least to perform:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier is biased to favour a carrier that has been assigned a resource for contention free random access.

According to various, but not necessarily all, embodiments there is provided a computer program that, when run on a computer, performs: selecting a carrier for use for random access during beam failure recovery, wherein the selecting a carrier is biased to favour a usable carrier that has been assigned a resource for contention free random access.

According to various, but not necessarily all, embodiments there is provided a data structure comprising data that defines a threshold used
in a comparison with a measured carrier characteristic
to select a carrier, for random access during recovery from beam failure, that has been assigned a resource for contention free random access.

According to various, but not necessarily all, embodiments there is provided examples as claimed in the appended claims.

BRIEF DESCRIPTION

Some example embodiments will now be described with reference to the accompanying drawings in which:
FIG. 1 shows an example embodiment of the subject matter described herein;
FIG. 2 shows another example embodiment of the subject matter described herein;
FIG. 3 shows another example embodiment of the subject matter described herein;
FIG. 4 shows another example embodiment of the subject matter described herein;
FIG. 5 shows another example embodiment of the subject matter described herein;
FIG. 6 shows another example embodiment of the subject matter described herein;
FIG. 7 shows another example embodiment of the subject matter described herein;
FIG. 8 shows another example embodiment of the subject matter described herein;
FIG. 9 shows another example embodiment of the subject matter described herein;
FIG. 10 shows another example embodiment of the subject matter described herein;
FIG. 11 shows another example embodiment of the subject matter described herein;
FIG. 12 shows another example embodiment of the subject matter described herein;

DETAILED DESCRIPTION

FIG 1 illustrates an example of a method 10.

The method 10, at block 12, comprises selecting a carrier for use for random access. The selection of a carrier for use for random access is dependent upon whether:

(i) the carrier has or has not been assigned a contention free random access resource; and
(ii) the carrier is sufficient for radio access.

The method 10, at sub-block 14, preferentially selects a carrier that been assigned a contention free random access resource and is sufficient for radio access and, at block 18, performs contention free random access using the selected carrier.

The method 10, at sub-block 16, alternatively selects a carrier that has not been assigned a contention free random access resource and is sufficient for radio access and, at block 18, performs contention free random access using the selected carrier.

In some but not necessarily all examples, the carrier is sufficient for radio access if a measured characteristic or measured characteristics (e.g. path power loss) of the carrier are sufficient for use.

In some but not necessarily all examples, the carrier is sufficient for radio access if it is already in use or, if not in use, a measured characteristic or measured characteristics (e.g. path power loss) of the carrier are sufficient for use.

In some but not necessarily all examples, the method 10 comprises at block 12, determining if the carrier has or has not been assigned a contention free random access resource and determining if the carrier is sufficient for radio access.

The method 10 may be used to recover from detected beam failure by the performance of random access using the selected carrier. The selecting of a carrier depends upon whether a carrier has been assigned a contention free random access resource. In some examples, the selecting of a carrier is biased to favour a carrier that has been assigned a contention free random access resource.

FIG 2 illustrates an example of a method 20.

The method at block 24 comprises: at block 26, selecting a carrier for use for random access; and at block 28, using the carrier for random access.

In one example, the method 20 comprises, at block 22, initiating random access and at block 24 enabling the random access procedure.

Block 26 (selecting a carrier for random access) and block 28 (using the selected carrier for random access) are performed differently when the random access procedure is initiated for beam failure recovery, and when the ransom access procedure is initiated but not initiated for beam failure recovery.

Consequently, in some examples, the method 20 comprises:
selecting, at block 26, an uplink carrier for use for random access procedure; and using, block 28, the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the ransom access procedure is initiated but not initiated for beam failure recovery.

In some examples, the first condition compares a measured downlink carrier characteristic against a first threshold, when the first threshold is configured.

In some examples, the second condition compares the measured downlink carrier characteristic against a second threshold, different to the first threshold.

In some examples, the first condition compares the measured downlink carrier characteristic against a different threshold to the first threshold, for example the second threshold, when the first threshold is not configured.

Thus, selecting an uplink carrier can depend upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, different threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery

In another example, the method 20 comprises: at block 22 detecting beam failure; and at block 24 recovering from beam failure.

The recovery from beam failure is achieved by:

at sub-block 26, selecting a carrier for use for random access; and
at sub-block 28, using the carrier for random access.

In some examples, selecting a carrier depends upon whether a carrier that has been assigned a resource for contention free random access. For example, selecting a carrier may be biased to favour a carrier that has been assigned a resource for contention free random access

In some examples, selecting a carrier depends upon whether a carrier is configured to perform beam failure recovery. For example, selecting a carrier may be biased to favour a carrier configured to perform beam failure recovery or one with a configured threshold.

A carrier configured to perform beam failure recovery may have prioritized random access because, for example, it has been assigned a resource for contention free random access, or because it has different, more rapid, power ramping.

In some examples, selecting a carrier depends upon whether a carrier is both configured to perform beam failure recovery and has been assigned a resource for contention free random access.
In some but not necessarily all examples, sub-block 26 comprises preferentially selecting a carrier that has been assigned a beam failure recovery configuration and is sufficient for radio access; and sub-block 28 comprises using the carrier for random access by performing contention free random access using the selected carrier, or alternatively, at sub-block 26, selecting a carrier that has not been assigned a beam failure recovery configuration and is sufficient for radio access; and then at sub-block 28 using the carrier for random access by performing contention based random access using the selected carrier.

In some but not necessarily all examples, block 26 comprises: determining if the carrier has or has not been assigned a beam failure recovery configuration; and determining if the carrier is sufficient for radio access.

In some but not necessarily all examples, selecting a carrier for use for random access is dependent upon whether

(i) the carrier has or has not been assigned a beam failure recovery configuration; and

(ii) the carrier is sufficient for radio access.

In some but not necessarily all examples, the carrier is sufficient for radio access if a measured characteristic or measured characteristics (e.g. path power loss) of the carrier are sufficient for use.

In some but not necessarily all examples, the carrier is sufficient for radio access if it is already in use by the user equipment or, if not in use, a measured characteristic or measured characteristics (e.g. path power loss) of the carrier are sufficient for use. FIG 3 illustrates an example of a method 30 for selecting a carrier that may, for example, be used in in block 12 of the method 10 or block 24 of the method 30.

The method 30 of selecting a carrier comprises, at block 32, a comparison of a measured downlink carrier characteristic 31 against a threshold 33.

In some but not necessarily all examples, the method 30 comprises at block 34, modifying the measured carrier characteristic(s) 31, used in the comparison 32. For example, the modification may be in dependence upon which carrier has been assigned a beam failure recovery configuration; and which sufficient carriers are preferred for radio access.

Additionally or alternatively, the method 30 comprises at block 36, modifying the threshold 33, used in the comparison 32. This modification may be dependent upon whether the random access procedure was initiated by beam failure recovery (first threshold used) or whether the random access procedure was initiated other than by beam failure recovery (different threshold used, e.g. second threshold). When the random access procedure was initiated by beam failure recovery, then this threshold may depend upon beam failure recovery configuration. For example, if beam failure recovery configuration has occurred and the first threshold has been configured, then the first threshold can be used and if beam failure recovery configuration has not occurred and the first threshold has not been configured, then the second threshold can be used.

The comparison can, via the thresholds, be used to favour selection of one sufficient carrier over another.
In some but not necessarily all examples, the carrier is determined to be sufficient for radio access if a measured characteristic or measured characteristics (e.g. path power loss) of the carrier are sufficient for use.

In some but not necessarily all examples, the carrier is determined to be sufficient for radio access if it is already in use or, if not in use, a measured characteristic or measured characteristics (e.g. path power loss) of the carrier are sufficient for use.

In some but not necessarily all examples, a measured characteristic or measured characteristics is/are dependent upon received signal power and/or received signal quality.

In some but not necessarily all examples, a measured characteristic is a reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

In some but not necessarily all examples, the threshold used in the comparison is received from the network, for example via a BFR config IE. For example, the threshold may be or be dependent upon RSRP_ThresholdSSB-SUL.

In some but not necessarily all examples, the threshold used in the comparison is for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL), where the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

The method can select whichever of the normal uplink carrier and the supplementary uplink carrier, has been assigned a beam failure recovery configuration; and is usable. This favors CFRA, which is faster then CBRA and avoids wasting available and usable contention free resources.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery, the modification block 36 comprises:
applying a first offset to the threshold, used in the comparison, when SUL has been assigned a beam failure recovery configuration; and applying a second offset to the

threshold, used in the comparison, when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery, the method 30 comprises: using a first threshold in the comparison 32 when SUL has been assigned a beam failure recovery configuration; and using a second, different, threshold in the comparison 32 when NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery , the method 30 comprises:
modifying 34 the measurement 31, used in the comparison 32, in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery, the method comprises: preferentially using a current in use carrier if it is assigned a beam failure recovery configuration.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery , the method comprises: using a current in use carrier if assigned a beam failure recovery configuration.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery , selecting a carrier for use for random access is a selection from a sub-set of a set of candidates defined by a telecommunications specification, where the candidates of the sub-set are more likely to be available for beam failure recovery.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery, a carrier is assigned a beam failure recovery configuration by assignment of a dedicated preamble for contention free random access. An assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

In some but not necessarily all examples, when using the random access procedure for beam failure recovery , a carrier is assigned a beam failure recovery configuration by configuring the carrier to perform beam failure recovery. Configuring a carrier to perform beam failure recovery can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and configuring a carrier to perform beam failure recovery cannot occur for both an associated uplink normal carrier and uplink supplementary carrier. In some but not necessarily all examples, configuring a carrier to perform beam failure recovery uses the BFR config IE.

The above described methods may be performed by an apparatus 200, for example an apparatus configured as mobile equipment or configured as user equipment.

The apparatus 200 can operate as part of a network 100 comprising a plurality of network nodes 110 comprising the apparatus 200.

The above described methods may be enabled by a computer program that, when run on a computer, performs:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

The above described methods may be enabled by a computer program that, when run on a computer, performs: selecting a carrier for use for random access during beam failure recovery (random access procedure initiated for beam failure recovery), wherein the selecting a carrier is biased to favour a usable carrier that has been assigned a resource for contention free random access.

The above described methods may be enabled by a computer program that, when run on a computer, performs: selecting a carrier for use for random access during beam failure recovery (random access procedure initiated for beam failure recovery), wherein the selecting a carrier depends upon whether a usable carrier has been assigned a beam failure recovery configuration. In some examples, the selecting a carrier is biased to favour a usable carrier that has been assigned a beam failure recovery configuration such as a resource for contention free random access.

The above described methods may be enabled by a data structure that defines a threshold parameter specifically used to differentiate a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a comparison of the measured downlink carrier characteristic against a second, different threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

The above described methods may be enabled by a data structure that defines a threshold parameter specifically used to differentiate a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery and the first threshold is configured, and a comparison of the measured downlink carrier characteristic against a different threshold, when the ransom access procedure is initiated for beam failure recovery and the first threshold is not configured.

In some but not necessarily all examples, the data structure is configured to enable preferential selection of supplementary uplink instead of normal uplink when supplementary uplink has been assigned a beam failure recovery configuration and normal uplink has not been assigned a beam failure recovery configuration and to enable preferential selection of normal uplink instead of supplementary uplink when normal uplink has been assigned a beam failure recovery configuration and supplementary uplink has not been assigned a beam failure recovery configuration.

Fig 4 illustrates an example of a network 100 comprising a plurality of network nodes including terminal nodes 110, access nodes 120 and one or more core nodes 130. The terminal nodes 110 and access nodes 120 communicate with each other. The one or more core nodes 130 communicate with the access nodes 120.

The one or more core nodes 130 may, in some examples, communicate with each other. The one or more access nodes 120 may, in some examples, communicate with each other.

The network 100 may be a cellular network comprising a plurality of cells 122 each served by an access node 120. In this example, the interface between the terminal nodes 110 and an access node 120 defining a cell 122 is a wireless interface 124. The access node 120 is a cellular radio transceiver. The terminal nodes 110 are cellular radio transceivers.

In the example illustrated the cellular network 100 is a third generation Partnership Project (3GPP) network in which the terminal nodes 110 are user equipment (UE) and the access nodes 120 are base stations.

In the particular example illustrated the network 100 is an Evolved Universal Terrestrial Radio Access network (E-UTRAN). The E-UTRAN consists of E-UTRAN NodeBs (eNBs) 120, providing the E-UTRA user plane and control plane (RRC) protocol terminations towards the UE 110. The eNBs 120 are interconnected with each other by means of an X2 interface 126. The eNBs are also connected by means of the S1 interface 128 to the Mobility Management Entity (MME) 130.

3GPP Examples

DEFINITIONS

Bandwidth: Difference between limiting frequencies of a continuous frequency band.

Base station: A base station is an access node. It may be a network element in radio access network responsible for radio transmission and reception in one or more cells to or from the user equipment.

Beam: beam (of the antenna) is the main lobe of the radiation pattern of an antenna array.

BFR: Beam failure Recovery. Beam recovery in case the current serving beams are lost by a UE.

BFR config: the BeamFailureRecoveryConfig IE.

BFR resources: resources used specifically for BFR, for example, a BFR specific threshold or contention free Random Access resources/preambles. BFR configuration configures such resources.

BWP: Bandwidth Part. A subset of the total cell bandwidth of a cell.

BWP IE: Bandwidth Part Information Element. This is used to configure a bandwidth part.

Carrier: modulated waveform, for example a modulated waveform conveying the physical channels

CBRA: Contention Based Random Access

Cell: A 'cell' is the geographical region into which radio coverage of a single base station extends.

CFRA: Contention Free Random Access

CFRA resources: resources such as random access preamble or occasion assigned for CFRA

CSI-RS: channel-state information reference signals

DL: Downlink

FDD: Frequency division duplex. A duplex technique where the traffic in each direction of a two-way telecommunications link is carried on two different carriers frequencies each dedicated to the traffic in one direction.

gNB: gNode B, NR Node B

IE: Information Element. A data structure containing a single or multiple fields.

MAC: Medium Access Control

MAC entity: logical entity that performs MAC.

ME: Mobile Equipment, can for example be a handset.

Network element: A discrete telecommunications entity e.g. apparatus or system, which can be managed over a specific interface

Node B: A logical node responsible for radio transmission / reception in one or more cells to/from the UE. Reference to Node B also includes a reference to the physical entity or entity hosting the logical node, such as a base station.

NR: New Radio (3GPP name for 5G technology)

NUL: Normal Uplink (may be referred also to as Uplink)

PCell: Primary cell. The cell, operating on the primary frequency, in which the UE either performs the initial connection establishment procedure or initiates the connection re-establishment procedure, or the cell indicated as the primary cell in the handover procedure.

physical channel: the carrier that is or will be modulated with information bits of the bursts. A physical channel uses a combination of frequency and time division multiplexing and is defined in terms of a radio frequency channel sequence and a timeslot sequence. In FDD mode, a physical channel is defined by code, frequency and, in the uplink, relative phase (I/Q). In TDD mode, a physical channel is defined by code, frequency, and time-slot

PUCCH: Physical Uplink Control CHannel

PUSCH: Physical Uplink Shared Channel

RACH: Random Access CHannel

radio access network: telecommunications network in which the access to the network (connection between user equipment and network) is implemented over the air interface.

Random Access: media access method by which several transmitters may concurrently access the same portion of the resources. It provides capability of receiving a service from an arbitrary point in its timeline.

Random Access resources: resources such as random access preambles and occasions assigned for random access.

RRC: Radio Resource Control. A group of control functions responsible for the handling of radio resources.

RSRP: Reference Signal Received Power.

SIM: subscriber identity module. Also refers to USIM.

SSB: Synchronization Signal Block

Subcarrier : one of a large number of closely spaced or overlapping orthogonal narrow-bandwidth data signals within an OFDM channel.

SUL: Supplementary Uplink.

TDD: time division duplex. A duplex technique where the traffic in each direction carried on two way telecommunications link is carried on a single carrier radio frequency, in discrete time intervals each dedicated to traffic in one direction.

UE: User equipment, reference to UE can refer to a working combination of ME and SIM or the ME with or without a battery and with or without a SIM.

UL: Uplink.

The following examples relate to the Beam Failure Recovery handling when a UE has been configured with both NUL and SUL for a cell in NR system.

<u>Supplementary Uplink (SUL)</u>

Supplementary Uplink (SUL) was introduced in NR to improve UL coverage for high frequency scenarios. It provides uplink coverage extension.

For each serving cell the network configures at least an initial bandwidth part comprising of at least a downlink bandwidth part and one uplink bandwidth part (if the serving cell is configured with an uplink) or two uplink bandwidth parts (if using supplementary uplink (SUL)). With SUL, the UE is configured with 2 UL carriers for one DL carrier of the same cell, for example, as depicted in FIG 5.

Uplink transmissions on the two ULs are controlled by the network to avoid overlapping PUSCH/PUCCH transmissions in time. Overlapping transmissions on PUSCH are avoided through scheduling while overlapping transmissions on PUCCH are avoided through configuration (PUCCH can only be configured for only one of the 2 ULs of the cell). In addition, initial access is supported in each of the uplink.

The NR operating bands currently include, for SUL:

NR operating band	Uplink (UL) *operating band* BS receive / UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) *operating band* BS transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780MHz	N/A	SUL

Beam Failure Recovery (BFR)

Network controlled mobility applies to UEs in RRC_CONNECTED and is categorized into two types of mobility: cell level mobility and beam level mobility.

Cell Level Mobility requires explicit RRC signalling to be triggered, i.e. handover. The RRC Signalling includes signalling between Source gNB and Target gNB, source gNB and UE (Handover Command), and UE and Target gNB (Handover Complete).

Beam Level Mobility does not require explicit RRC signalling to be triggered. The gNB provides via RRC signalling the UE with measurement configuration. Beam Level Mobility is then dealt with at lower layers by means of physical layer and MAC layer control signalling, and RRC is not required to know which beam is being used at a given point in time.

Beam Failure Recovery (BFR) is introduced in NR to provide UE based fast beam recovery in case the current serving beams are lost.

For beam failure detection, the gNB configures the UE with beam failure detection reference signals and the UE declares beam failure when the number of beam failure instance indications from the physical layer reaches a configured threshold within a configured period.

After beam failure is detected, the UE: triggers beam failure recovery by initiating a Random Access procedure on the PCell and selects a suitable beam to perform beam failure recovery. Upon completion of the Random Access procedure, beam failure recovery is considered complete.

The random access procedure takes two distinct forms: contention-based random access (CBRA) illustrated in FIG 6 and contention-free random access (CFRA) illustrated in FIG 7. Normal DL/UL transmission can take place after the random access procedure. CFRA is a two-step procedure, which is faster than CBRA (4 steps and step and having potential collision risk).

<u>Bandwidth Part (BWP)</u>

Bandwidth Part (BWP) concept is introduced in NR to provide system flexibility and enhanced UE power saving possibilities by being able to adapt the UE operating channel bandwidth dynamically.

With Bandwidth Adaptation (BA), the receive and transmit bandwidth of a UE need not be as large as the bandwidth of the cell and can be adjusted: the width can be ordered to change (e.g. to shrink during period of low activity to save power); the location can move in the frequency domain (e.g. to increase scheduling flexibility); and the subcarrier spacing can be ordered to change (e.g. to allow different services). A subset of the total cell bandwidth of a cell is referred to as a Bandwidth Part (BWP) and BA is achieved by configuring the UE with BWP(s) and telling the UE which of the configured BWPs is currently the active one. The BWP is defined by width (e.g. 10, 20, 40..MHz) and subcarrier spacing (e.g. 15, 60 ...kHz)

BWP Information Element (IE)

The BWP IE is used to configure a bandwidth part

For each serving cell the network configures at least an initial bandwidth part comprising of at least a downlink bandwidth part and one (if the serving cell is configured with an uplink) or two (if using supplementary uplink (SUL)) uplink bandwidth parts. Furthermore, the network may configure additional uplink and downlink bandwidth parts for a serving cell.

The locationAndBandwidth field of the BWP IE defines a frequency domain location and bandwidth of this bandwidth part.

The subcarrierSpacing field of the BWP IE defines a subcarrier spacing to be used in this BWP for all channels and reference signals unless explicitly configured elsewhere. It can, for example, have values 15, 30, or 60 kHz (<6GHz), and 60 or 120 kHz (>6GHz)

The rach-ConfigCommon field of the BWP IE defines a configuration of cell specific random access resources (parameters) which the UE uses for contention based and contention free random access as well as for contention based beam failure recovery in this BWP. The random access resources can include CFRA resources, for example, CFRA (Contention Free Random Access) preambles. CFRA (Contention Free Random Access) preambles for BFR can only be configured on either of the UL or SUL carrier.

The beamFailureRecoveryConfig field (BFR config) of the BWP IE defines how the UE performs Beam Failure Recovery upon detection of a Beam Failure. If supplementaryUplink is present, the field is present (configured on) only in one of the uplink carriers, either UL or SUL.

When performing BFR on the carrier without BFR config, the UE can only use CBRA (Contention Based Random Access).

BeamFailureRecoveryConfig IE

The BeamFailureRecoveryConfig IE is used to configure the UE with RACH resources and candidate beams for beam failure recovery in case of beam failure detection.

The rach-ConfigBFR field defines a configuration of contention free random access occasions for BFR.

The rsrp-ThresholdSSB field defines a threshold used for determining whether a candidate beam may be used by the UE to attempt contention free Random Access to recover from beam failure. It is a threshold for the beam failure recovery;

The candidateBeamRSList field defines a list of reference signals identifying the candidate beams for recovery and the associated RA parameters.

The ra-prioritization field defines parameters which apply for prioritized random access procedure for BFR.

rsrp-ThresholdSSB-SUL: an RSRP threshold for the selection between the NUL carrier and the SUL carrier;

<u>Random Access procedure initialization</u>

According to TS 38.300, s 9.2.6, the random access procedure is initiated as a consequence of any of a number of different events, for instance:

- Initial access from RRC_IDLE;
- RRC Connection Re-establishment procedure;
- Handover;
- DL or UL data arrival during RRC_CONNECTED when UL synchronisation status is "non-synchronised";
- Transition from RRC_INACTIVE;
- To establish time alignment at SCell addition;
- Request for Other SI (see subclause 7.3);

- Beam failure recovery (BFR).

BFR uses a random access procedure for beam failure recovery. The best carrier for this random access procedure needs to be selected. In the examples below this is achieved, for example, by comparing an RSRP of a downlink pathloss reference with a threshold to select SUL or NUL.

Example implementations

When the beam failure recovery is triggered after beam failure detection, it is dependent upon which one of the carriers (NUL or SUL) the BFR config is configured for.

Additional selection logic/prioritization is applied for the UL carrier selection based on which one of the carriers (NUL or SUL) the BFR config is configured for. This can be achieved by either:
1. configuring an offset parameter to the pathloss reference or the configured RSRP threshold to prioritize the carrier for which BFR config (beamFailureRecoveryConfig IE) is configured;
2. configuring a separate RSRP threshold for the case of beam failure recovery to prioritize the carrier for which BFR config (beamFailureRecoveryConfig IE) is configured;.

Applying the prioritization may be conditional and subject to:
- being able to use the CFRA resources (i.e., configured candidate beams with CFRA resources are available);
- having the BFR config on the currently active UL BWP on SUL or NUL.

The example implementations are therefore examples of the method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier depends upon whether a carrier configured to perform beam failure recovery and/or a carrier that has been assigned a beam failure

recovery configuration. In some examples, the selecting a carrier is biased to favour a carrier configured to perform beam failure recovery and/or a carrier that has been assigned a beam failure recovery configuration.

In some but not necessarily all examples, the offset parameter is a new field in the beamFailureRecoveryConfig IE.

In some but not necessarily all examples, the separate RSRP threshold is a new field in the beamFailureRecoveryConfig IE.

The new beamFailureRecoveryConfig IE is therefore a data structure comprising data that defines a threshold used in a comparison with a measured carrier characteristic to select a carrier, for random access during recovery from beam failure, that has been assigned a beam failure recovery configuration. The new data structure enables preferential selection of supplementary uplink instead of normal uplink when supplementary uplink has been assigned a beam failure recovery configuration and normal uplink has not been assigned a beam failure recovery configuration and
enables preferential selection of normal uplink instead of supplementary uplink when normal uplink has been assigned a beam failure recovery configuration and supplementary uplink has not been assigned a beam failure recovery configuration.

A method comprising:
selecting a carrier for use for random access, wherein selecting a carrier for use for random access is dependent upon whether
(i) the carrier has or has not been assigned a beam failure recovery configuration; and
(ii) the carrier is sufficient for radio access.

301. <u>Implementation of *offset_bfr (offset is zero, negative or positive value)*</u>

Referring to FIG 8, the method 60 comprises at block 62 determining if UE has triggered BFR and determining whether BFR config is configured on SUL carrier or NUL carrier. The method 60 comprises at block 64, based on the determining at block 62, prioritizing in the carrier selection the carrier which has been configured with beamFailureRecoveryConfig by an offset value or by applying a dedicated RSRP threshold.

Referring to the example method 70 illustrated in FIG 9, in this example, if UE has triggered BFR (block 71), and BFR config is determined to be configured on SUL carrier (block 72, 73) then :

At block 74A,

If (RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL + offset_bfr),*

the UE shall use the SUL for performing Random Access procedure for beam recovery (block 75A).

Else

the UE shall use NUL for performing Random Access procedure for beam recovery (block 76A).

offset_bfr is a positive value. The offset_bfr may be a new field in the BFR config.

This is beneficial because using an offset value allows the network to configure priority for the SUL carrier with BFR config for beam recovery. With higher offset values UE is more likely selecting the SUL with BFR config.

if UE has triggered BFR (block 71), and BFR config is determined to be configured on SUL carrier (block 72, 73) then :

If UE has triggered BFR (block 71) and BFR config is determined to be configured on NUL carrier (block 72, 73) then:

At block 74B,

If (RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL + offset_bf),*

the UE shall use the SUL for performing Random Access procedure for beam recovery (block 75B)

Else

the UE shall use NUL for performing Random Access procedure for beam recovery (block 76B).

offset_bfr is a negative value. The offset_bfr may be a new field in the BFR config.

This is beneficial because using negative offset value allows the network to configure priority for the NUL carrier with BFR config for beam recovery. With higher negative offset values UE is more likely selecting the NUL with BFR config.

In another implementation example, the offset may be included into a new SUL/NUL selection RSRP threshold (e.g. *rsrp_ThresholdSSB-SUL_bfr.*) as a field in the BFR config. There may be a new threshold for when BFR is configured for SUL and a different new threshold when BFR is configured for NUL. When UE is configured with BFR config, the network may configure UE to apply different threshold *rsrp_ThresholdSSB-SUL_bfr* when running the selection logic for SUL/NUL.

Thus the condition “If (RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL + offset_bfr)”,* in the method 70 becomes “If (RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL_bfr)”.*

2. Implementation of prioritizing active UL BWP

Referring to FIG 10, the method 80 comprises at block 82 determining if UE has triggered BFR and determining whether BFR config is configured on SUL carrier or NUL carrier.

The method 60 comprises at block 84, determining whether BFR config is configured on a current active BWP of the SUL carrier or NUL carrier:

The method 60 comprises at block 64, based on the determining at block 82, 84, prioritizing in the carrier selection the carrier which has been configured with beamFailureRecoveryConfig by an offset value or by applying a dedicated RSRP threshold.

If UE has triggered BFR and BFR config is on current active BWP of NUL carrier:

If (RSRP of the downlink pathloss reference + *offset_bfr* is less than *rsrp-ThresholdSSB-SUL),* the UE shall use the SUL for performing Random Access procedure for beam recovery.

Else

the UE shall use the current active BWP for performing Random Access procedure for beam recovery.

offset_bfr is a positive value. The offset_bfr may be a new field in the BFR config.

In one example if UE has triggered BFR, and BFR config is not on the current active BWP, the configured offset value is not applied but only the *rsrp-ThresholdSSB-SUL* is used.

In one alternative example, a specific rsrp_threshold for selecting SUL is used when random access procedure is triggered due to beam failure recovery: *rsrp_ThresholdSSB-SUL_bfr*. This may be a new field in the BFR config.

<u>3. Implementation of prioritizing active uplink carrier</u>

In one example:

If UE has triggered BFR and BFR config is on current active UL carrier:

If (RSRP of the downlink pathloss reference + *offset_bfr* is less than *rsrp-ThresholdSSB-SUL),*

the UE shall use the current active uplink carrier for performing Random Access procedure for beam recovery.

Else

If ((BFR config is on non-active UL carrier) and (RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL+ offset_bfr))*:

the UE shall use SUL for BFR.

Else:

the UE shall use NUL for BFR.

<u>In General</u>

In the preceding examples, if UE is not provided the offset parameter (offset_bfr) by higher layer configuration e.g. BFR IE, it shall use the default offset value of X dB (defined in specification). As an example X may e.g. M... -6, -3, 0, 3, 6... N dB.

In another example offset_bfr parameter may be an agreed constant value defined in the specifications (e.g. 3 dB).

In another example, the invention is not limited to SSB based threshold (*rsrp_ThresholdSSB-SUL*) and can work similar manner with rsrp_ThresholdCSIRS-SUL where the pathloss is estimated using CSI-RS signals.

In one example, the *offset_bfr* or *rsrp_ThresholdSSB-SUL_bfr* may be configurable by the network through RRC signalling or via broadcast signalling. In another example the parameters are configured in the BFR config.

<u>ADDITIONAL EXAMPLES</u>

These and other examples disclose a method comprising:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein selecting a carrier depends upon a comparison of a measured carrier characteristic against a first threshold, when configured for beam failure recovery, and a second, different threshold, when not configured for beam failure recovery.

In at least some examples, 'configured for beam failure recovery' means that a BFR threshold parameter has been configured to the UE by the NW, i.e., there may be an option for the network to configured it and not to configure it.

When it is configured, the first threshold, determined at least partially by the BFR threshold parameter, is used. When it is not configured the second threshold is used.

It does not matter in which IE the BFR threshold parameter is provided to the UE but it is, for example, part of either NUL or SUL configuration. UE knows whether it is or whether it is not configured, but it does not need to be taken into account in which IE the BFR parameter is configured.

In some example, the measured carrier characteristic is dependent upon received signal power and/or received signal quality. In the examples that follow, the measured carrier characteristic is reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

The first threshold and the second threshold are for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL). Thus the selected carrier is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

<u>More Examples</u>

In the following examples:

1> if the Serving Cell for the Random Access procedure is configured with *supplementaryUplink*:

    2> if the Random Access procedure was initiated for beam failure recovery

        3> Procedure 1 using condition 1

    2> else

        3> Procedure 2 using condition 2

Procedure 1 is different to procedure 2. It uses a different condition.

In procedure 1, condition 1 is used to control selection between use of SUL or NUL for use for random access.

In procedure 2, condition 2 is used to control selection between use of SUL or NUL for use for random access.

An example of Procedure 1, performed if, at 2>, it is determined to be TRUE that "the Random Access procedure was initiated for beam failure recovery", is:

3> if [condition 1]satisfied

4> select the SUL carrier for performing Random Access procedure;

4> set the *PCMAX* to $P_{CMAX,f,c}$ of the SUL carrier.

3> else

4> select the NUL carrier for performing Random Access procedure;

4> set the *PCMAX* to $P_{CMAX,f,c}$ of the NUL carrier.

An example of Procedure 2, performed if, at 2>, it is determined to be FALSE that "the Random Access procedure was initiated for beam failure recovery", because random access has been initiated but not for beam failure recovery is:

2> if [condition 2]satisfied

3> select the SUL carrier for performing Random Access procedure;

3> set the PCMAX to PCMAX,f,c of the SUL carrier.

	2> else:	
		3> select the NUL carrier for performing Random Access procedure; 3> set the PCMAX to PCMAX,f,c of the NUL carrier.

The method therefore comprises:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the ransom access procedure is initiated but not initiated for beam failure recovery.

Condition 1 and condition 2 are different. Condition 1 and condition 2 use different thresholds.

Both condition 1 and condition 2, depend upon a comparison of a measured downlink carrier characteristic against a threshold. However, different thresholds are used.

The method therefore comprises:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure was initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

In the examples below [condition 1] uses, a least, a comparison of a measured carrier characteristic against a first threshold.

In the examples below [condition 2] uses a comparison of the measured carrier characteristic against a second threshold, different to the first threshold. In the examples below [condition 2] does not use a comparison of the measured carrier characteristic against the first threshold.

The thresholds and/or difference between the thresholds may be controlled by one or more information elements. Thus in some examples, configuration for beam failure recovery configures a threshold parameter that at least partially determines the first threshold. The threshold parameter may be provided in an information element. Thus a data structure can comprise data that defines a threshold parameter specifically used to differentiate a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a comparison of the measured downlink carrier characteristic against a second, different threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

The overall process is therefore:

1> if the Serving Cell for the Random Access procedure is configured with *supplementaryUplink*:

  2> if the Random Access procedure was initiated for beam failure recovery (as specified in subclause 5.1.7):

    3> if [condition 1]satisfied

      4> select the SUL carrier for performing Random Access procedure;

      4> set the *PCMAX* to $P_{CMAX,f,c}$ of the SUL carrier.

    3> else

      4> select the NUL carrier for performing Random Access procedure;

4> set the *PCMAX* to $P_{CMAX,f,c}$ of the NUL carrier.

2> elseif the RSRP of the downlink pathloss reference is less than rsrp-ThresholdSSB-SUL:

3> select the SUL carrier for performing Random Access procedure;

3> set the PCMAX to PCMAX,f,c of the SUL carrier.

2> else:

3> select the NUL carrier for performing Random Access procedure;

3> set the PCMAX to PCMAX,f,c of the NUL carrier.

<u>condition 1</u>

In the examples below [condition 1] uses, a least, a comparison of a measured downlink carrier characteristic against a first threshold.

In these examples, but not necessarily all example, [condition 1] is satisfied either by satisfaction of sub-condition 1 or by satisfaction of sub-condition 2.

Sub-condition 1 is based on a comparison of the measured carrier characteristic against the first threshold. Sub-condition 1 requires that there has been configuration for beam failure recovery. Thus sub-condition 1 requires that there has been configuration for beam failure recovery and that the carrier is sufficient for use based, at least, on the comparison with the first threshold.

The alternative, sub-condition 2 is based on a comparison of the measured carrier characteristic against a different threshold, in these examples the second threshold. Sub-condition 2 requires that there has not been configuration for beam failure recovery. Thus sub-condition 2 requires that there has not been configuration for beam failure recovery and that the carrier is sufficient for use based, at least, on the comparison with a threshold different to the first threshold, for example the second threshold.

There are different requirements for carrier sufficiency for use based, at least, on the comparison of the same measured carrier characteristic against different thresholds. In the following example, a threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold.[condition 1]=

3> if the *offset-BFR* is configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL* + *offset-BFR*; or

3> if the *offset-BFR* is not configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL*:

Thus, when the threshold parameter is not configured, the offset is assumed to be zero.

In the following example, a threshold parameter defines the first threshold independently of the second threshold.

[condition 1]=

3> if the *rsrp-ThresholdSSB-SUL-bfr* is configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL-bfr*; or

3> if the *rsrp-ThresholdSSB-SUL-bfr* is not configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL*:

In the following example, selecting a carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold and an additional condition, when configured for beam failure recovery. The additional condition depends upon availability of contention free random access resources.

[condition 1]=

if the *offset-BFR* is configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL* + *offset-BFR* and if the contention-free Random Access Resources for beam failure recovery request associated with any of the SSBs and/or CSI-RSs have been explicitly provided by RRC; or

3> if the *offset-BFR* is not configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL*:

In the following example, selecting a carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold and an additional condition, when configured for beam failure recovery. The additional condition depends upon availability of beam failure recovery resources for currently active bandwidth part.

[condition 1]=

> if the *offset-BFR* is configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL* + *offset-BFR* if the *beamFailureRecoveryConfig* is available in the currently active UL BWP; or

3> if the *offset-BFR* is not configured and the RSRP of the downlink pathloss reference is less than *rsrp-ThresholdSSB-SUL*:

<u>condition 2</u>

[condition 2] depends upon a comparison of a measured downlink carrier characteristic against a second threshold, different to the first threshold, , when not configured for beam failure recovery.

[condition 2]=

elseif the RSRP of the downlink pathloss reference is less than rsrp-ThresholdSSB-SUL:

In this example, the comparison in sub-condition 2 of condition 1 (RSRP of the downlink pathloss reference is less than rsrp-ThresholdSSB-SUL) in the same as the comparison in condition 2 (RSRP of the downlink pathloss reference is less than rsrp-ThresholdSSB-SUL), however the routes to the same comparison are different.

From the foregoing, it will be understood that condition 1, in sub-condition 1, compares a measured downlink carrier characteristic against a first threshold, when the first threshold is configured. the first threshold may be configured during beam failure recovery configuration.

In the foregoing examples, the condition 1, in sub-condition 2, compares the measured downlink carrier characteristic against a different threshold to the first threshold (e.g. the second threshold), when the first threshold is not configured. The comparison is dependent on the first threshold. This comparison only compares only the measured downlink carrier characteristic against only the second threshold,

In the foregoing examples, condition 2 compares the measured downlink carrier characteristic against the second threshold, different to the first threshold. The comparison is independent of the first threshold. The comparison only compares only the measured downlink carrier characteristic against only the second threshold,

It will be appreciated from the foregoing that the network can control BFR by assignment of the threshold parameter.

The network comprises an apparatus comprising means for performing a method comprising:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access,
to be different depending upon which carrier is configured for beam failure recovery.

The network can cause preferential selection of a carrier that been assigned a beam failure recovery configuration, and cause alternative selection of a carrier that has not been assigned a beam failure recovery configuration.

The network can cause modification of a measured carrier characteristic and/or the threshold used in a comparison, for selecting a carrier, in dependence upon which carrier has been assigned a beam failure recovery configuration.

The threshold is for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL), and the method comprises:
(i) causing application of a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and causing application of a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative, or
(ii) causing use of a first threshold when SUL has been assigned a beam failure recovery configuration; and
causing use of a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

The method can additionally cause modification of a measured carrier characteristic used in a comparison, for selecting a carrier, in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

As previously described, an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

Fig 11 illustrates an example of a controller 50 of an apparatus 200. Implementation of a controller 50 may be as controller circuitry. The controller 50 may be implemented in hardware alone, have certain aspects in software including firmware alone or can be a combination of hardware and software (including firmware).

As illustrated in Fig 11 the controller 50 may be implemented using instructions that enable hardware functionality, for example, by using executable instructions of a computer program 56 in a general-purpose or special-purpose processor 52 that may be stored on a computer readable storage medium (disk, memory etc) to be executed by such a processor 52.

The processor 52 is configured to read from and write to the memory 54. The processor 52 may also comprise an output interface via which data and/or commands are output by the processor 52 and an input interface via which data and/or commands are input to the processor 52.

The memory 54 stores a computer program 56 comprising computer program instructions (computer program code) that controls the operation of the apparatus 200 when loaded into the processor 52. The computer program instructions, of the computer program 56, provide the logic and routines that enables the apparatus to perform the methods illustrated in Figs 1 to 3 and 8 to 10. The processor 52 by reading the memory 54 is able to load and execute the computer program 56.

The apparatus 200 therefore comprises:
at least one processor 52; and
at least one memory 54 including computer program code
the at least one memory 54 and the computer program code configured to, with the at least one processor 52 , cause the apparatus 200 at least to perform:
detecting beam failure; and
recovering from beam failure by
  selecting a carrier for use for random access; and
  using the carrier for random access,
wherein the selecting a carrier depends upon whether a carrier that has been assigned a beam failure recovery configuration.

In some examples, the selecting a carrier is biased to favour a carrier that has been assigned a beam failure recovery configuration.

As illustrated in Fig 12, the computer program 56 may arrive at the apparatus 200 via any suitable delivery mechanism 60. The delivery mechanism 60 may be, for example, a machine readable medium, a computer-readable medium, a non-transitory computer-readable storage medium, a computer program product, a memory device, a record medium such as a Compact Disc Read-Only Memory (CD-ROM) or a Digital Versatile Disc (DVD) or a solid state memory, an article of manufacture that comprises or tangibly embodies the computer program 56. The delivery mechanism may be a signal configured to reliably transfer the computer program 56. The apparatus 200 may propagate or transmit the computer program 56 as a computer data signal.

Computer program instructions for causing an apparatus to perform at least the following or for performing at least the following: selecting a carrier for use for random access during beam failure recovery, wherein the selecting a carrier depends upon whether a usable carrier that has been assigned a beam failure recovery configuration.

In some example, the selecting a carrier is biased to favour a usable carrier that has been assigned a beam failure recovery configuration.

The computer program instructions may be comprised in a computer program, a non-transitory computer readable medium, a computer program product, a machine readable medium. In some but not necessarily all examples, the computer program instructions may be distributed over more than one computer program.

Although the memory 54 is illustrated as a single component/circuitry it may be implemented as one or more separate components/circuitry some or all of which may be integrated/removable and/or may provide permanent/semi-permanent/ dynamic/cached storage.

Although the processor 52 is illustrated as a single component/circuitry it may be implemented as one or more separate components/circuitry some or all of which may be integrated/removable. The processor 52 may be a single core or multi-core processor.

References to 'computer-readable storage medium', 'computer program product', 'tangibly embodied computer program' etc. or a 'controller', 'computer', 'processor' etc. should be understood to encompass not only computers having different architectures such as single /multi- processor architectures and sequential (Von Neumann)/parallel architectures but also specialized circuits such as field-programmable gate arrays (FPGA), application specific circuits (ASIC), signal processing devices and other processing circuitry. References to computer program, instructions, code etc. should be understood to encompass software for a programmable processor or firmware such as, for example, the programmable content of a hardware device whether instructions for a processor, or configuration settings for a fixed-function device, gate array or programmable logic device etc.

As used in this application, the term 'circuitry' may refer to one or more or all of the following:
(a) hardware-only circuitry implementations (such as implementations in only analog and/or digital circuitry) and
(b) combinations of hardware circuits and software, such as (as applicable):
(i) a combination of analog and/or digital hardware circuit(s) with software/firmware and
(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions and
(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g. firmware) for operation, but the software may not be present when it is not needed for operation.
This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit for a mobile device or a similar integrated circuit in a server, a cellular network device, or other computing or network device.

The blocks illustrated in the Figs 1 to 3 and 8 to 10 may represent steps in a method and/or sections of code in the computer program 56. The illustration of a particular order to the blocks does not necessarily imply that there is a required or preferred order for the blocks and the order and arrangement of the block may be varied. Furthermore, it may be possible for some blocks to be omitted.

It should be appreciated that at least in some example threshold parameters, threshold and offsets are non-zero.

Where a structural feature has been described, it may be replaced by means for performing one or more of the functions of the structural feature whether that function or those functions are explicitly or implicitly described.

Thus the apparatus 200 comprises means for:
detecting beam failure; and
recovering from beam failure by
selecting a carrier for use for random access; and
using the carrier for random access,
wherein the selecting a carrier depends upon whether a carrier that has been assigned a beam failure recovery configuration.

In some examples, the selecting a carrier is biased to favor a carrier that has been assigned a beam failure recovery configuration.

The apparatus 200 may be part of the Internet of Things forming part of a larger, distributed network.

As used here 'module' refers to a unit or apparatus that excludes certain parts/components that would be added by an end manufacturer or a user.

An IE may be encoded in an electromagnetic signal.

The above described examples find application as enabling components of: automotive systems; telecommunication systems; electronic systems including consumer electronic products; distributed computing systems; media systems for generating or rendering media content including audio, visual and audio visual content and mixed, mediated, virtual and/or augmented reality; personal systems including personal health systems or personal fitness systems; navigation systems; user interfaces also known as human machine interfaces; networks including cellular, non-cellular, and optical networks; ad-hoc networks; the internet; the internet of things; virtualized networks; and related software and services.

The term 'comprise' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one Y or may comprise more than one Y. If it is intended to use 'comprise' with an exclusive meaning then it will be made clear in the context by referring to "comprising only one.." or by using "consisting".

In this description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'can' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example', 'can' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example as part of a working combination but does not necessarily have to be used in that other example.

Although embodiments have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the claims.

Features described in the preceding description may be used in combinations other than the combinations explicitly described above

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain embodiments, those features may also be present in other embodiments whether described or not.

The term 'a' or 'the' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising a/the Y indicates that X may comprise only one Y or may comprise more than one Y unless the context clearly indicates the contrary. If it is intended to use 'a' or 'the' with an exclusive meaning then it will be made clear in the context. In some circumstances the use of 'at least one' or 'one or more' may be used to emphasis an inclusive meaning but the absence of these terms should not be taken to infer and exclusive meaning.

The presence of a feature (or combination of features) in a claim is a reference to that feature) or combination of features) itself and also to features that achieve substantially the same technical effect (equivalent features). The equivalent features include, for example, features that are variants and achieve substantially the same result in substantially the same way. The equivalent features include, for example, features that perform substantially the same function, in substantially the same way to achieve substantially the same result.

In this description, reference has been made to various examples using adjectives or adjectival phrases to describe characteristics of the examples. Such a description of a characteristic in relation to an example indicates that the characteristic is present in some examples exactly as described and is present in other examples substantially as described.

The use of the term 'example' or 'for example' or 'can' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example', 'can' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example as part of a working combination but does not necessarily have to be used in that other example

Whilst endeavoring in the foregoing specification to draw attention to those features believed to be of importance it should be understood that the Applicant may seek protection via the claims in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not emphasis has been placed thereon.

WHAT IS CLAIMED IS:

1. A method comprising:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the ransom access procedure is initiated but not initiated for beam failure recovery.

2. A method as claimed in claim 1, wherein the first condition compares a measured downlink carrier characteristic against a first threshold, when the first threshold is configured.

3. A method as claimed in claim 2, wherein the first condition compares the measured downlink carrier characteristic against a different threshold to the first threshold, when the first threshold is not configured.

4. A method as claimed in claim 2 or 3 wherein the second condition compares the measured downlink carrier characteristic against a second threshold, different to the first threshold.

5. A wherein as claimed in claim 4, wherein the second condition is independent of the first threshold.

6. A method as claimed in claim 4 or 5, wherein the first condition compares the measured downlink carrier characteristic against the second threshold, different to the first threshold, when the first threshold is not configured.

7. A method as claimed in any preceding claim wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

8. A method as claimed in any of claims 2 to 7, further comprising: using a threshold parameter, which at least partially determines the first threshold, to determine the first threshold.

9. A method as claimed in claim 8, when dependent upon any of claims 4 to 7, wherein the threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold.

10. A method as claimed in claim 8 or 9, when the threshold parameter is not configured, assuming the offset to be zero.

11. A method as claimed in claim 8, wherein the threshold parameter defines the first threshold independently of the second threshold.

12. A method as claimed in any of claim 2 to 11, wherein the measured downlink carrier characteristic is dependent upon received signal power and/or received signal quality.

13. A method as claimed in any of claims 2 to, 12 wherein the measured carrier characteristic is reference signal received power (RSRP) for selected downlink channel, for example a downlink pathloss reference.

14. A method as claimed in any preceding claim, wherein the first condition depends upon a comparison of a measured downlink carrier characteristic against a first threshold and an additional condition.

15. A method as claimed in claim 14, wherein the additional condition depends upon availability of contention free random access resources.

16. A method as claimed in claim 14 or 15, wherein the additional condition depends upon availability of beam failure recovery configuration for currently active bandwidth part.

17. A method as claimed in any preceding claim, wherein first condition depends upon a comparison of a measured downlink carrier characteristic against a first

threshold, when there has been configuration of the first threshold, and a different threshold, when there has not been configuration of the first threshold.

18. A method as claimed in any of claims 4 to 17, wherein first condition and the second condition provide separate logic paths that each enable selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

19. An apparatus comprising means for performing or means for causing performance of the method of any of claims 1 to 18.

20. An apparatus comprising means for:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a first condition when the random access procedure is initiated for beam failure recovery, and a second condition, different to the first condition, when the ransom access procedure is initiated but not initiated for beam failure recovery.

21. An apparatus as claimed in claim 20, wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

22. An apparatus as claimed in claim 20, comprising means for using a threshold parameter that at least partially determines the first threshold to determine the first threshold.

23. An apparatus as claimed in claim 22, wherein the threshold parameter is an offset to the second threshold that is added to the second threshold to create the first threshold or wherein the threshold parameter defines the first threshold independently of the second threshold.

24. An apparatus as claimed in any of claims 20 to 23, comprising means for selecting a carrier in dependence upon a comparison of a measured downlink carrier characteristic against a first threshold and an additional condition.

25. An apparatus as claimed in claim 24, wherein the additional condition depends upon availability of contention free random access resources and/or upon availability of beam failure recovery resources for currently active bandwidth part.

26. An apparatus as claimed in any of claims 20 to 23, configured to select a carrier that is an uplink normal carrier or uplink supplementary carrier, wherein the supplementary carrier is a borrowed downlink carrier of lower frequency than the uplink normal carrier.

27. 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 to, with the at least one processor, cause the apparatus at least to perform:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

28. An apparatus as claimed in any of claims 20 to 27 configured as mobile equipment or configured as user equipment.

29. A computer program that, when run on a computer, performs:
selecting an uplink carrier for use for random access procedure; and
using the uplink carrier for random access procedure,
wherein selecting an uplink carrier depends upon a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam failure recovery, and a second, threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

30. A data structure comprising data that defines a threshold parameter specifically used to differentiate a comparison of a measured downlink carrier characteristic against a first threshold, when the random access procedure is initiated for beam

failure recovery, and a comparison of the measured downlink carrier characteristic against a second, different threshold, when the ransom access procedure is initiated but not initiated for beam failure recovery.

31. A method comprising:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access, to be different depending upon which carrier is configured for beam failure recovery.

32. A method as claimed in claim 31, comprising:
causing preferential selection of a carrier that been assigned a beam failure recovery configuration.

33. A method as claimed in claim 32, comprising:
causing alternative selection of a carrier that has not been assigned a beam failure recovery configuration.

34. A method as claimed in claim 31, 32 or 33, comprising causing modification of a measured carrier characteristic and/or the threshold used in a comparison, for selecting a carrier, in dependence upon which carrier has been assigned a beam failure recovery configuration.

35. A method as claimed in any of claims 31 to 34, wherein the threshold is for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

36. A method as claimed in claim 35, comprising:
causing application of a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and
causing application of a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

37. A method as claimed in claim 36, comprising causing use of a first threshold when SUL has been assigned a beam failure recovery configuration; and

causing use of a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

38. A method as claimed in claim 35, 36, or 37 comprising causing modification of a measured carrier characteristic used in a comparison, for selecting a carrier, in dependence upon whether SUL or NUL has been assigned a beam failure recovery configuration.

39. A method as claimed in any of claims 35 to 38, wherein an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

40. An apparatus comprising means for:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access, to be different depending upon which carrier is configured for beam failure recovery.

41. An apparatus as claimed in claim 40 comprising means for:
causing preferential selection of a carrier that been assigned a beam failure recovery configuration.

42. An apparatus as claimed in claim 41 comprising means for
causing alternative selection of a carrier that has not been assigned a beam failure recovery configuration.

43. An apparatus as claimed in claim 40, 41, 42 comprising means for causing modification of a measured carrier characteristic and/or the threshold used in a comparison, for selecting a carrier, in dependence upon which carrier has been assigned a beam failure recovery configuration.

44. An apparatus as claimed in any of claims 40 to 43, wherein the threshold is for selection between a normal uplink carrier (NUL) and a supplementary uplink carrier (SUL).

45. An apparatus as claimed in claim 44 comprising means for:
causing application of a first offset to the threshold when SUL has been assigned a beam failure recovery configuration; and
causing application of a second offset to the threshold when NUL has been assigned a beam failure recovery configuration, wherein one of the first and second offsets is positive and the other is negative.

46. An apparatus as claimed in claim 45 comprising means for:
causing use of a first threshold when SUL has been assigned a beam failure recovery configuration; and
causing use of a second, different, threshold when NUL has been assigned a beam failure recovery configuration.

47. A method as claimed in any of claims 44 to 46, wherein an assignment of a preamble for contention free random access can occur only on one of an associated uplink normal carrier and uplink supplementary carrier and assignment of preambles for contention free random access cannot occur for both an associated uplink normal carrier and uplink supplementary carrier.

48. A network comprising a plurality of network nodes comprising the apparatus as claimed in any of claims 38 to 43.

49. A computer program that, when run on a computer, performs:
determining which carrier is configured for beam failure recovery; and
controlling a threshold, used in selection of a carrier for use for random access, to be different depending upon which carrier is configured for beam failure recovery.

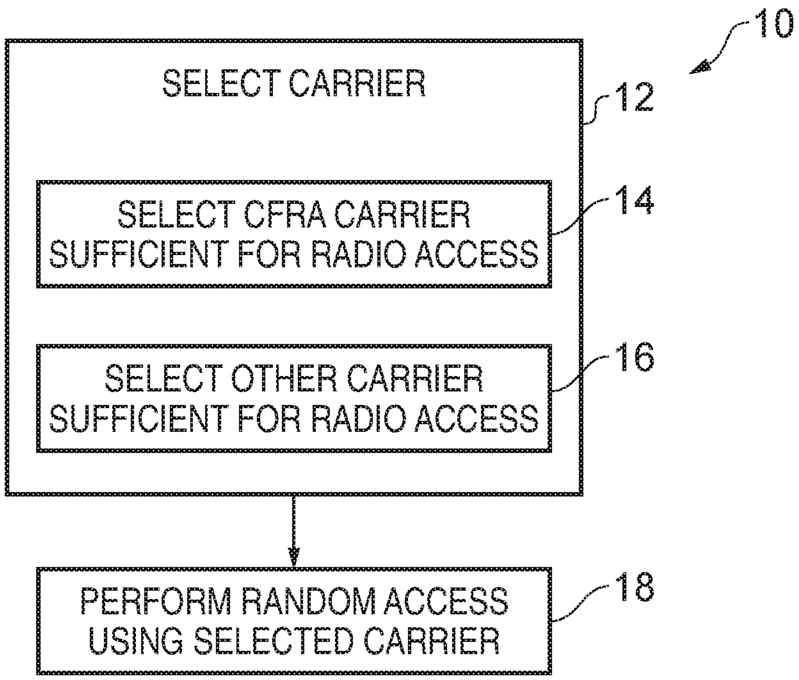

10
SELECT CARRIER
12
SELECT CFRA CARRIER SUFFICIENT FOR RADIO ACCESS
14
SELECT OTHER CARRIER SUFFICIENT FOR RADIO ACCESS
16
PERFORM RANDOM ACCESS USING SELECTED CARRIER
18

FIG. 1

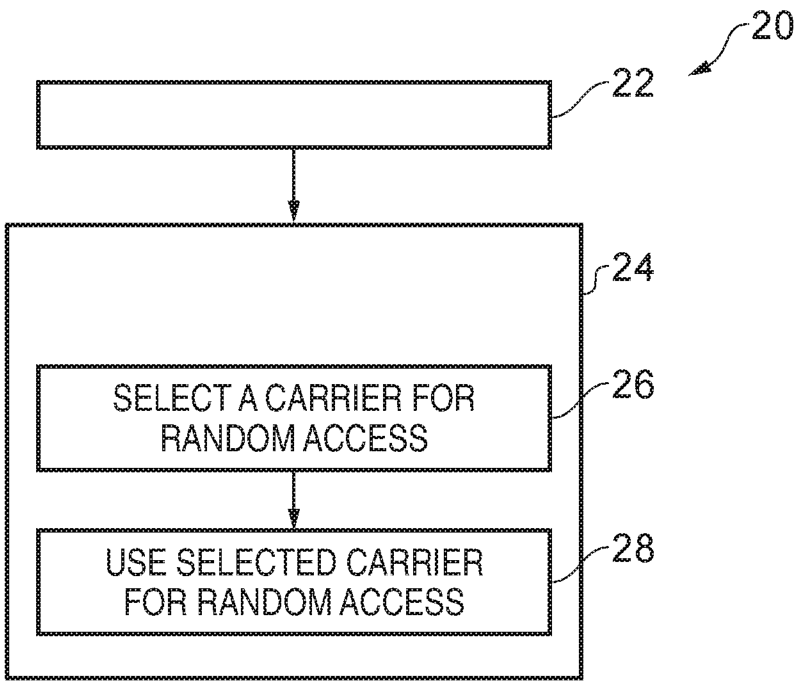

20
22
24
SELECT A CARRIER FOR RANDOM ACCESS
26
USE SELECTED CARRIER FOR RANDOM ACCESS
28

FIG. 2

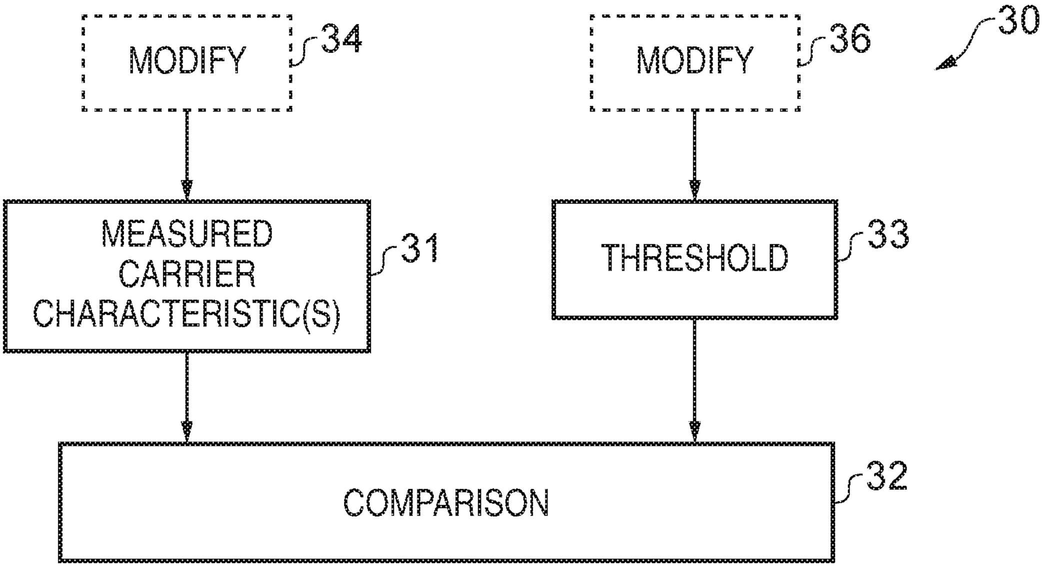
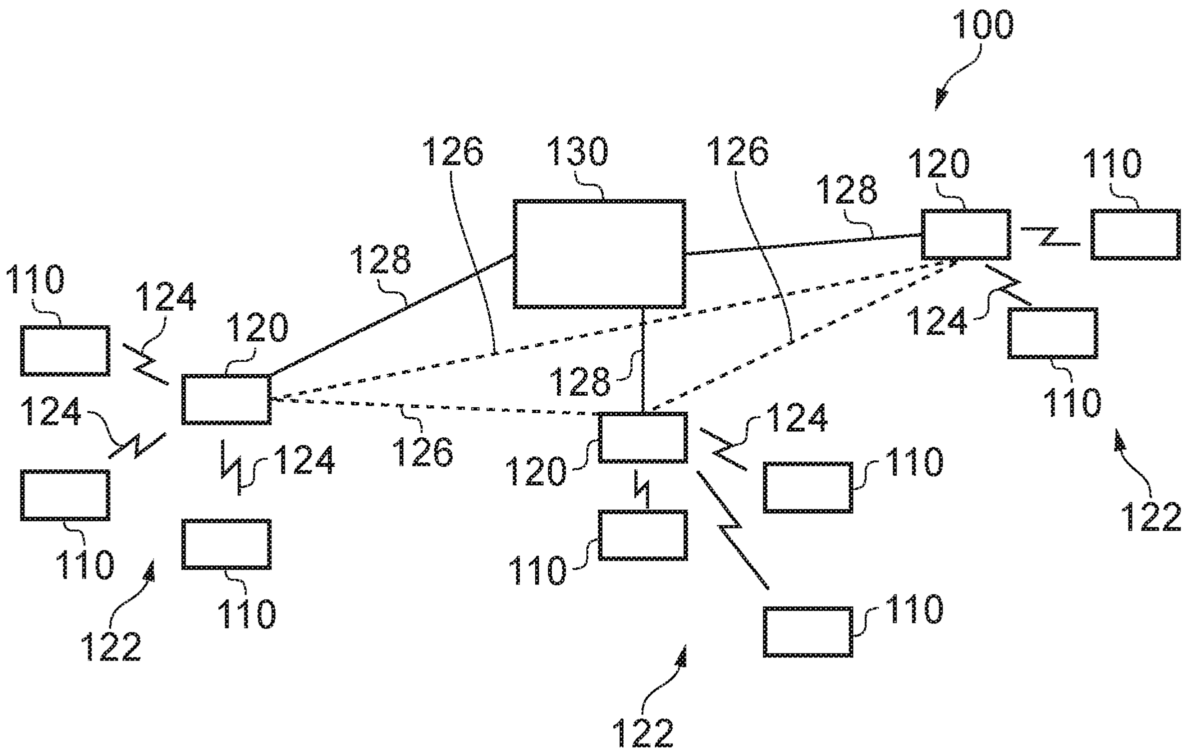

MODIFY
34
MODIFY
36
30
MEASURED CARRIER CHARACTERISTIC(S)
31
THRESHOLD
33
COMPARISON
32

FIG. 3


100
126
130
126
128
120
110
128
110
124
120
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128
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126
124
120
124
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110
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122
110
122

FIG. 4

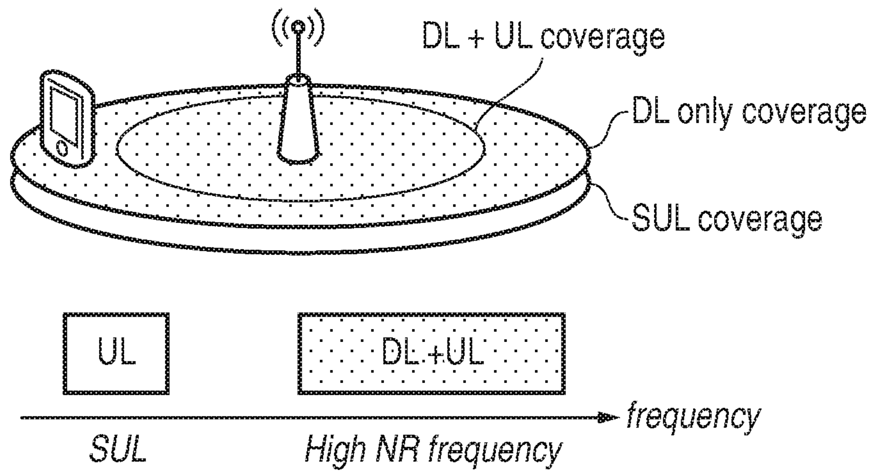

FIG. 5

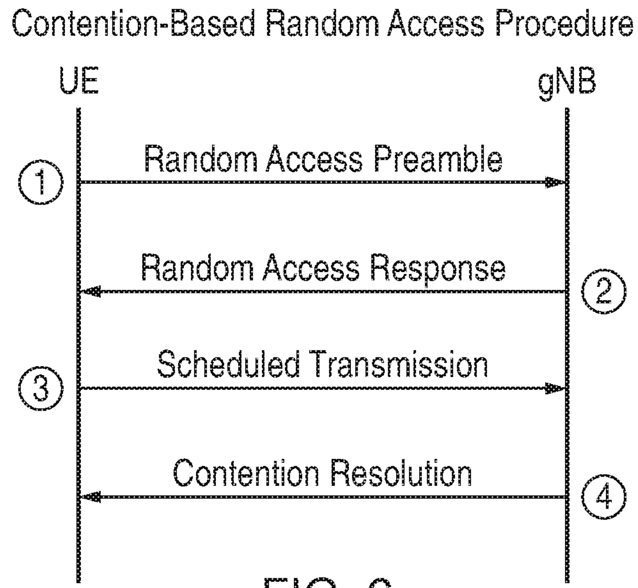

FIG. 6

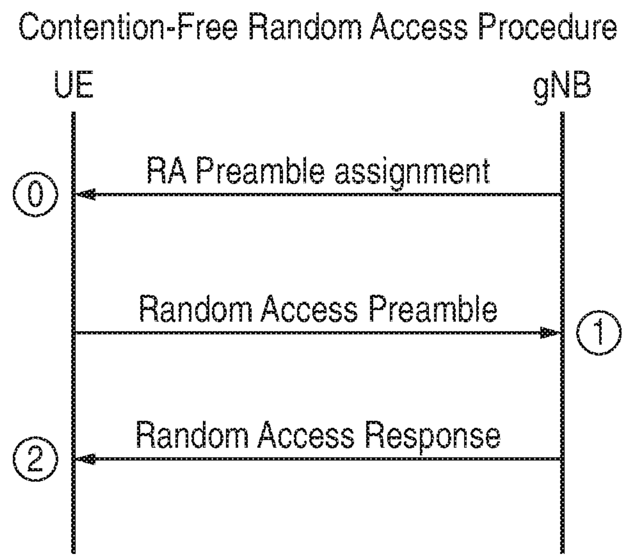

FIG. 7

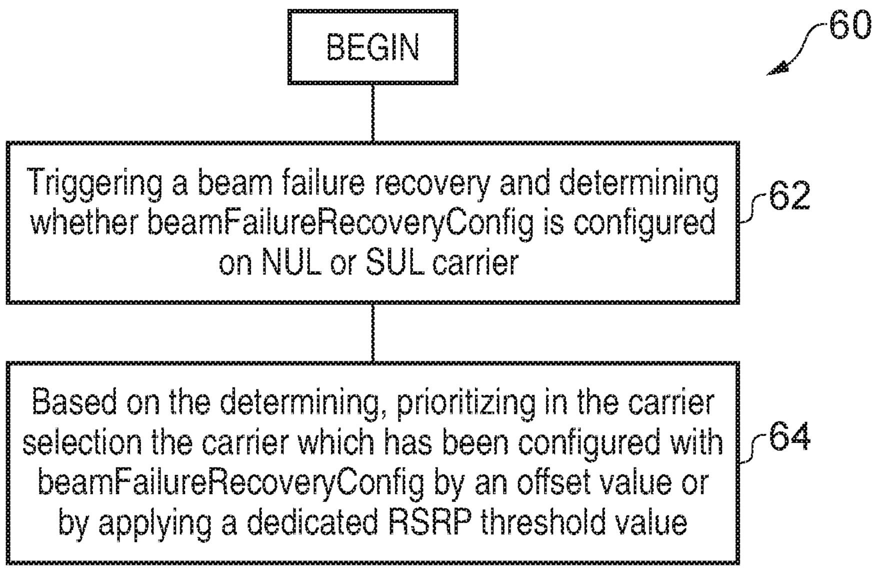
60
BEGIN
Triggering a beam failure recovery and determining whether beamFailureRecoveryConfig is configured on NUL or SUL carrier
62
Based on the determining, prioritizing in the carrier selection the carrier which has been configured with beamFailureRecoveryConfig by an offset value or by applying a dedicated RSRP threshold value
64

FIG. 8

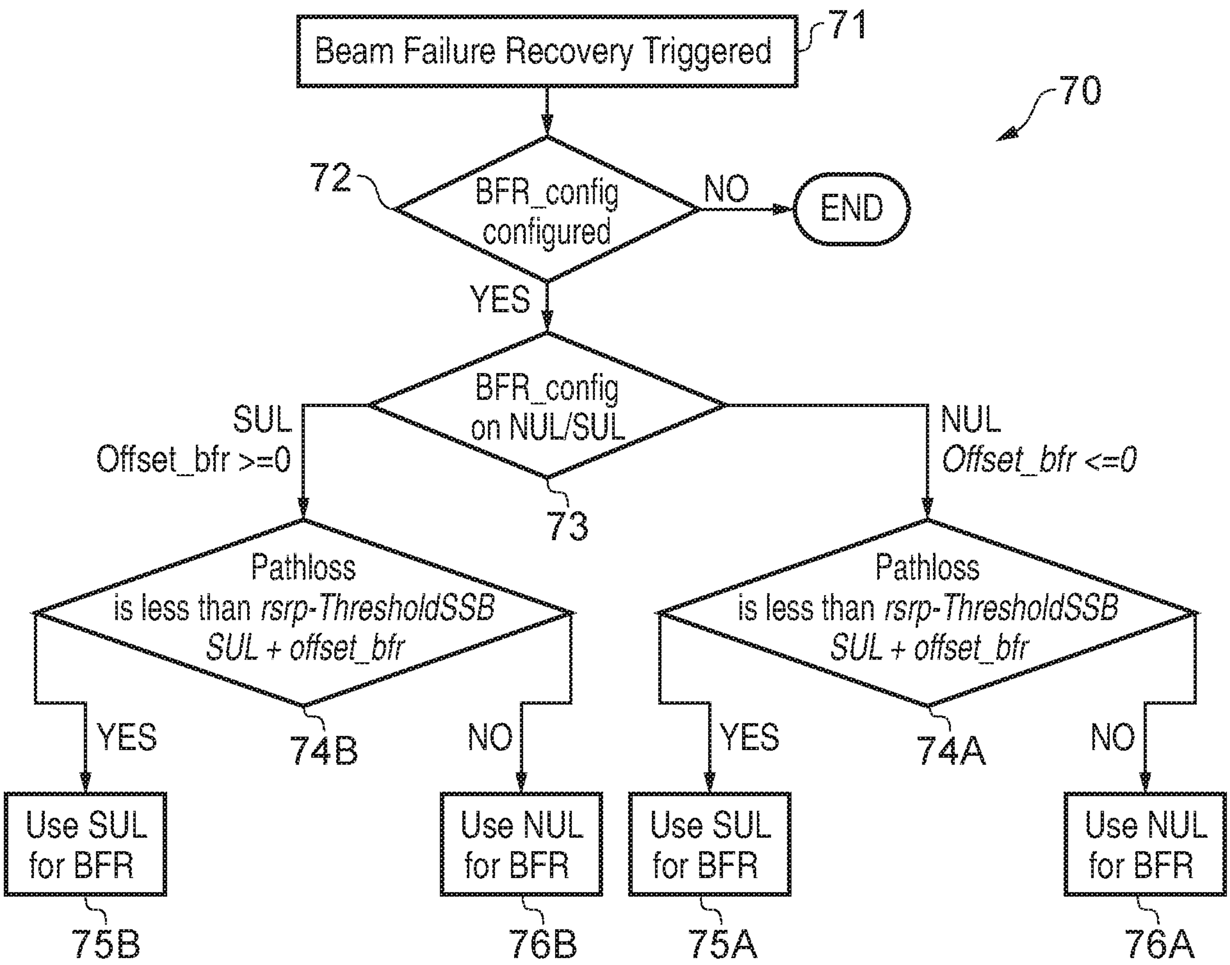
Beam Failure Recovery Triggered
71
70
72
BFR_config configured
NO
END
YES
BFR_config on NUL/SUL
SUL
Offset_bfr >=0
NUL
Offset_bfr <=0
73
Pathloss is less than rsrp-ThresholdSSB SUL + offset_bfr
Pathloss is less than rsrp-ThresholdSSB SUL + offset_bfr
YES
74B
NO
YES
74A
NO
Use SUL for BFR
Use NUL for BFR
Use SUL for BFR
Use NUL for BFR
75B
76B
75A
76A

FIG. 9

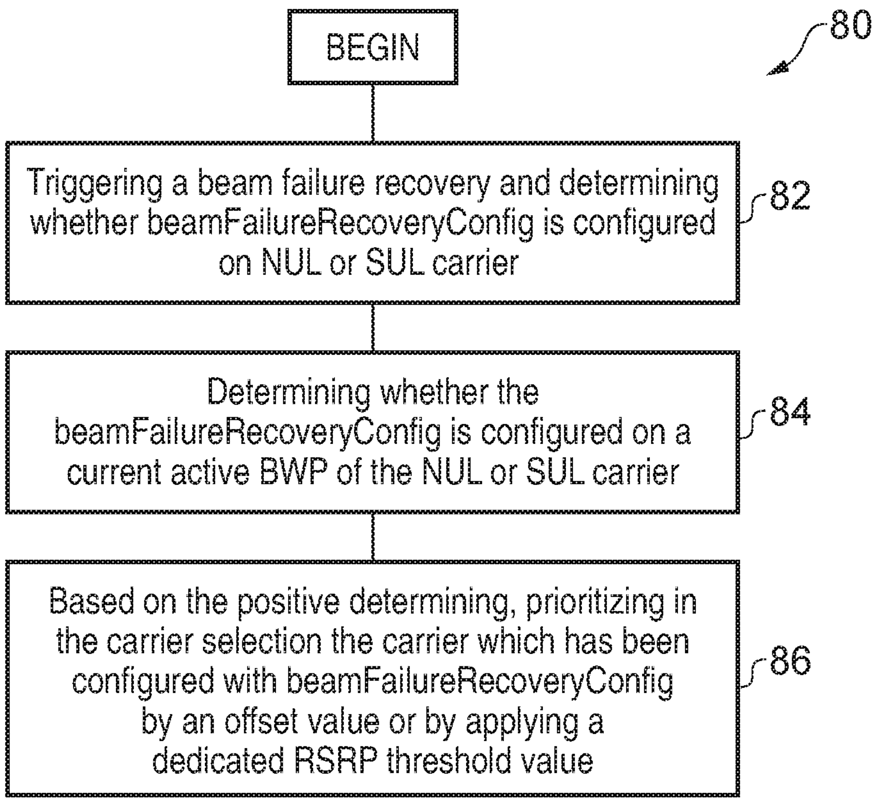

FIG. 10

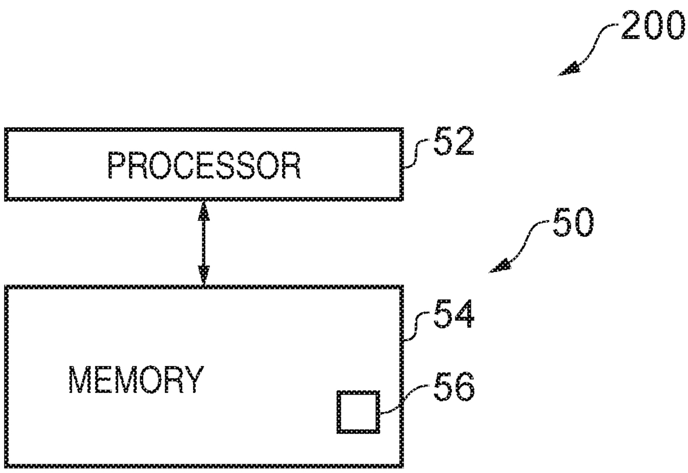

FIG. 11

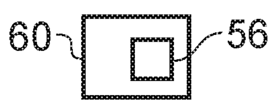

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/108458

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)i; H04W 36/34(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; H04B; 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, CNKI, 3GPP: beam+, failure, recovery, BFR, random, access, uplink, carrier+, initiat+, condition, threshold

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CATT. "RSRP thresholds naming clean-up in MAC" *3GPP TSG-RAN WG2#102 R2-1806997,* 25 May 2018 (2018-05-25), sections 5.1, 5.17	1-49
A	WO 2018129300 A1 (IDAC HOLDINGS, INC.) 12 July 2018 (2018-07-12) the whole document	1-49
A	WO 2018148552 A1 (QUALCOMM INCORPORATED) 16 August 2018 (2018-08-16) the whole document	1-49

☐ 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
14 June 2019	**28 June 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**GUO,Haibo**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961730**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/108458

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2018129300	A1	12 July 2018	None			
WO	2018148552	A1	16 August 2018	US	2018234960	A1	16 August 2018
				TW	201830903	A	16 August 2018