

CLAIMS

1. A method, comprising: in a system in which a communication device searches for ~~unscheduled~~ transmissions of downlink control information for said communication device: selecting a combination of search spaces for ~~unscheduled~~the transmissions of downlink control information for thea communication device by a plurality of transmission techniques: and transmitting an indication of the result of the selected combination to said communication device.

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2. A method according to claim 1, comprising deciding how much search space to assign to ~~unscheduled~~ transmissions of downlink control information for said communication device by one or more of said plurality of transmission techniques relative to ~~unscheduled~~ transmissions of downlink control information for said communication device by one or more others of said plurality of transmission techniques.

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3. A method according to any preceding claim, wherein said selecting comprises selecting a predefined combination from a plurality of predefined combinations.

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4. A method according to claim 3, wherein said plurality of predefined combinations includes a predefined combination according to which no search space is assigned to ~~unscheduled~~ transmissions of downlink control information by one of said plurality of transmission techniques.

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and a second transmission technique involving transmission of one or more cell-specific reference signals.

9. A method according to any preceding claim, wherein said plurality of transmission techniques include: a first transmission technique involving the precoding and transmission of demodulation reference signals together with the precoding and transmission of data symbols defining downlink control information, and the transmission of one or more channel state information reference signals together with the transmission of precoded data symbols defining downlink control information; and a second transmission technique that involves transmission of cell-specific reference signals together with transmission of precoded data symbols defining downlink control information.

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~~10. A method, comprising: in a system in which a communication device searches for unscheduled transmissions of downlink control information messages for said communication device according to a plurality of message formats: selecting a respective set of one or more search spaces for each of said plurality of message formats; and transmitting to said communication device an indication of the result of said selection of respective sets of one or more search spaces.~~

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~~11. A method according to claim 10, wherein a plurality of aggregation levels are used for the transmission of downlink control messages, and a respective search space is predefined for each aggregation level; and wherein the method comprises: selecting a respective set of one or more aggregation levels~~

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~~for each of said plurality of message formats; and transmitting an indication of the selected respective sets of aggregation levels to said communication device.~~

5 ~~12. A method according to claim 10 or claim 11, wherein the plurality of message formats includes first and second message formats providing control information for a transmission according to respective first and second transmission modes; and wherein the selecting takes into account an indication of the~~
 10 ~~respective transmission error probability for the first and second transmission modes.~~

~~13~~10. A method, comprising: in a system in which a radio access network transmits indications of the results of selections of combinations of search spaces for ~~unscheduled~~ transmissions by a plurality of transmission techniques of downlink control information for one or more communication devices:

searching at a first communication device for ~~unscheduled~~ transmissions of downlink control information for said communication device; wherein said searching is performed either: (a) on the basis of a transmitted indication of the result of a selection for said first communication device of a combination of search spaces for ~~unscheduled~~ transmissions by said plurality of transmission techniques of downlink control information; or
 20 (b) in the absence of a transmitted indication of the result of a selection for said first communication device of a combination of search spaces for ~~unscheduled~~ transmissions by said plurality of transmission techniques of downlink control information, on the basis of a default combination of search spaces
 25 for ~~unscheduled~~ transmissions by
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said plurality of transmission techniques of downlink control information for said first communication device.

5 1411. A method, comprising: searching at a first communication device for ~~unscheduled~~-transmissions of downlink control information for said communication device by a plurality of transmission techniques; wherein said searching is performed on the basis of a transmitted indication of the result of a selection of a combination of search spaces for ~~unscheduled~~-transmissions of downlink control information for said first communication device by said plurality of transmission techniques.

15 ~~1512~~. A method according to claim ~~13-10~~ or claim 1411, wherein said transmitted indication indicates how much search space has been assigned to ~~unscheduled~~-transmissions of downlink control information for said first communication device by one or more of said plurality of transmission techniques relative to ~~unscheduled~~-transmissions of downlink control information for said first communication device by one or more others of said plurality of transmission techniques.

25 1613. A method according to any of claims ~~13-10~~ to ~~1512~~, wherein said transmitted indication identifies one of a plurality of predefined combinations.

1714. A method according to claim 1613, wherein said plurality of predefined combinations includes a predefined combination according to which no search space is assigned to

~~unscheduled~~ transmissions of downlink control information by one of said plurality of transmission techniques.

5 ~~1815~~. A method according to any of claims ~~13-10~~ to ~~1714~~, wherein a plurality of aggregation levels are used for the transmission of downlink control information, and a respective search space is predefined for each aggregation level for each transmission technique; and said transmitted indication identifies a respective set of one or more aggregation levels for each of said
10 plurality of transmission techniques.

~~1916~~. A method according to any of claims ~~13-10~~ to ~~1815~~, wherein said plurality of transmission techniques include: a first transmission technique involving the transmission of one
15 or more reference signals specific to said first communication device; and a second transmission technique that does not involve transmission of one or more reference signals specific to said first communication device.

20 ~~2017~~. A method according to any of claims ~~13-10~~ to ~~1916~~, wherein said plurality of transmission techniques include: a first transmission technique involving the transmission of both one or more reference signals specific to said first communication device and one or more channel-state-information reference
25 signals; and a second transmission technique involving transmission of one or more cell-specific reference signals.

~~21~~18. A method according to any of claims ~~13-10~~ to ~~20~~17, wherein said plurality of transmission techniques include: a first transmission technique involving the precoding and transmission of demodulation reference signals together with the precoding and transmission of data symbols defining downlink control information, and the transmission of one or more channel state information reference signals together with the transmission of precoded data symbols defining downlink control information; and a second transmission technique that involves transmission of cell-specific reference signals together with transmission of precoded data symbols defining downlink control information.

19. The method according to any of claims 1-18, wherein the communication device applies blind decoding in finding the downlink control information intended to said communication device.

~~22. A method, comprising: in a system in which a radio access network transmits unscheduled transmissions of downlink control information messages for a plurality of communication devices according to a plurality of message formats, and in which said radio access network transmits indications of the results of selections for one or more communication devices of respective sets of one or more search spaces for each of said plurality of message formats: searching at a first communication device for unscheduled transmissions of downlink control information for said first communication device; wherein said searching is performed either: (a) on the basis of a transmitted indication of the result of a selection for said first communication device of a respective set of one or more search spaces for each of said plurality of message formats; or (b) in the absence of a transmitted indication of the result of a selection for said first communication device of a respective set of one or more search spaces for each of said plurality of message formats, on~~

~~the basis of a respective default set of one or more search spaces for each of said plurality of message formats.~~

23. ~~A method, comprising: searching at a first communication device for unscheduled transmissions of downlink control information messages for said first communication device according to a plurality of message formats; wherein said searching is performed based on a transmitted indication of the result of a selection of a respective set of one or more search spaces for each of said plurality of message formats.~~

24. ~~A method according to claim 23, wherein a plurality of aggregation levels are used for the transmission of downlink control messages, and a respective search space is predefined for each aggregation level; and wherein the transmitted indication identifies a respective selected set of one or more aggregation levels for each of said plurality of message formats.~~

~~25~~20. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: in a system in which a communication device searches for ~~unscheduled~~ transmissions of downlink control information for said communication device: select a combination of search spaces for ~~unscheduled~~ transmissions of downlink control information for a communication device by a plurality of transmission techniques; and transmitting an indication of the result of the selected combination to said communication device.

2621.An apparatus according to claim 2520, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: decide how much search space to assign to ~~unscheduled~~-transmissions of downlink control information for said communication device by one or more of said plurality of transmission techniques relative to ~~unscheduled~~ transmissions of downlink control information for said communication device by one or more others of said plurality of transmission techniques.

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2722. An apparatus according to claim 25-20 or claim 2621, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: select a predefined combination from a plurality of predefined combinations.

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2823. An apparatus according to claim 2722, wherein said plurality of predefined combinations includes a predefined combination according to which no search space is assigned to ~~unscheduled~~-transmissions of downlink control information by one of said plurality of transmission techniques.

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2924.An apparatus according to any of claims 25-20 to 2823, wherein a plurality of aggregation levels are used for the transmission of downlink control information, and a respective search space is predefined for each aggregation level for each transmission technique; and wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: select a respective set of

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one or more aggregation levels for each of said plurality of transmission techniques; and transmitting an indication of the selected respective sets of aggregation levels to said communication device.

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~~30~~25. An apparatus according to any of claims ~~25—20~~ to ~~29~~24, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: perform said selection at least partly on the basis of one or more of:
10 (a) the size of the load on the cell in which the transmissions are made, and (b) channel state information for the wireless interface with the communication device.

~~31~~26. An apparatus according to any of claims ~~25—20~~ to ~~30~~25, wherein said plurality of transmission techniques include: a
15 first transmission technique involving the transmission of one or more reference signals specific to said communication device; and a second transmission technique that does not involve transmission of one or more reference signals specific to said
20 communication device.

~~32~~27. An apparatus according to any of claims ~~25—20~~ to ~~31~~26, wherein said plurality of transmission techniques include: a
25 first transmission technique involving the transmission of both one or more reference signals specific to said communication device and one or more channel-state-information reference signals; and a second transmission technique involving transmission of one or more cell-specific reference signals.

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~~3328.~~ An apparatus according to any of claims ~~25-20~~ to ~~3227~~, wherein said plurality of transmission techniques include: a first transmission technique involving the precoding and transmission of demodulation reference signals together with the precoding and transmission of data symbols defining downlink control information, and the transmission of one or more channel state information reference signals together with the transmission of precoded data symbols defining downlink control information; and a second transmission technique that involves transmission of cell-specific reference signals together with transmission of precoded data symbols defining downlink control information.

~~34. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: in a system in which a communication device searches for unscheduled transmissions of downlink control information messages for said communication device according to a plurality of message formats: select a respective set of one or more search spaces for each of said plurality of message formats; and transmitting to said communication device an indication of the result of said selection of respective sets of one or more search spaces.~~

~~35. An apparatus according to claim 34, wherein a plurality of aggregation levels are used for the transmission of downlink control messages, and a respective search space is predefined for each aggregation level; and wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: select a respective set of~~

~~one or more aggregation levels for each of said plurality of message formats; and transmit an indication of the selected respective sets of aggregation levels to said communication device.~~

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~~36. An apparatus according to claim 34 or claim 35, wherein the plurality of message formats includes first and second message formats providing control information for a transmission according to respective first and second transmission modes; and wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: perform said selection taking into account an indication of the respective transmission error probability for the first and second transmission modes.~~

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~~37~~29. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: in a system in which a radio access network transmits indications of the results of selections of combinations of search spaces for ~~unscheduled~~ transmissions by a plurality of transmission techniques of downlink control information for one or more communication devices: search at a first communication device for ~~unscheduled~~ transmissions of downlink control information for said communication device; wherein said searching is performed either: (a) on the basis of a transmitted indication of the result of a selection for said first communication device of a combination of search spaces for ~~unscheduled~~ transmissions by said plurality of transmission techniques of downlink control information; or (b) in the absence of a transmitted indication of the result

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of a selection for said first communication device of a combination of search spaces for ~~unscheduled~~-transmissions by said plurality of transmission techniques of downlink control information, on the basis of a default combination of search spaces for ~~unscheduled~~-transmissions by said plurality of transmission techniques of downlink control information for said first communication device.

3830. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: search at a first communication device for ~~unscheduled~~-transmissions of downlink control information for said communication device by a plurality of transmission techniques; wherein said searching is performed on the basis of a transmitted indication of the result of a selection of a combination of search spaces for ~~unscheduled~~-transmissions of downlink control information for said first communication device by said plurality of transmission techniques.

3931. An apparatus according to claim ~~37-29~~ or claim 3830, wherein said transmitted indication indicates how much search space has been assigned to ~~unscheduled~~-transmissions of downlink control information for said first communication device by one or more of said plurality of transmission techniques relative to ~~unscheduled~~-transmissions of downlink control information for said first communication device by one or more others of said plurality of transmission techniques.

4032. An apparatus according to any of claims 37-29 to 3931, wherein said transmitted indication identifies one of a plurality of predefined combinations.

5 4133. An apparatus according to claim 4032, wherein said plurality of predefined combinations includes a predefined combination according to which no search space is assigned to ~~un-~~
~~scheduled~~ transmissions of downlink control information by one of said plurality of transmission techniques.

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4234. An apparatus according to any of claims 37-29 to 1733, wherein a plurality of aggregation levels are used for the transmission of downlink control information, and a respective search space is predefined for each aggregation level for each
15 transmission technique; and said transmitted indication identifies a respective set of one or more aggregation levels for each of said plurality of transmission techniques.

4335. An apparatus according to any of claims 37-29 to 4234,
20 wherein said plurality of transmission techniques include: a first transmission technique involving the transmission of one or more reference signals specific to said first communication device; and a second transmission technique that does not involve transmission of one or more reference signals specific to
25 said first communication device.

4436. An apparatus according to any of claims 37-29 to 4335, wherein said plurality of transmission techniques include:

a first transmission technique involving the transmission of both one or more reference signals specific to said first communication device and one or more channel-state-information reference signals; and a second transmission technique involving transmission of one or more cell-specific reference signals.

4537. An apparatus according to any of claims 37-29 to 4436, wherein said plurality of transmission techniques include: a first transmission technique involving the precoding and transmission of demodulation reference signals together with the precoding and transmission of data symbols defining downlink control information, and the transmission of one or more channel state information reference signals together with the transmission of precoded data symbols defining downlink control information; and a second transmission technique that involves transmission of cell-specific reference signals together with transmission of precoded data symbols defining downlink control information.

38. The apparatus according to any of claims 20 to 37, wherein the communication device applies blind decoding in finding the downlink control information intended to said communication device.

~~46. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: in a system in which a radio access network transmits unscheduled transmissions of downlink control information messages for a plurality of communication devices according to a plurality of message formats, and in which said radio access network transmits indications of the results of selections for one or more communication devices of respective sets of one or more search spaces for each of said plurality of message formats.~~

~~search at a first communication device for unscheduled transmissions of downlink control information for said first communication device; wherein said searching is performed either:~~
5 ~~(a) on the basis of a transmitted indication of the result of a selection for said first communication device of a respective set of one or more search spaces for each of said plurality of message formats; or (b) in the absence of a transmitted indication of the result of a selection for said first communication device of a respective set of one or more search spaces for~~
10 ~~each of said plurality of message formats, on the basis of a respective default set of one or more search spaces for each of said plurality of message formats.~~

47. ~~An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: search at a first communication device for unscheduled transmissions of downlink control information messages for~~
15 ~~said first communication device according to a plurality of message formats: wherein said searching is performed based on a transmitted indication of the result of a selection of a respective set of one or more search spaces for each of said plurality of message formats.~~

48. ~~A method according to claim 47, wherein a plurality of aggregation levels are used for the transmission of downlink control messages, and a respective search space is predefined for each aggregation level; and wherein the transmitted indication identifies a respective selected set of one or more aggregation~~
25 ~~levels for each of said plurality of message formats.~~

4939. A computer program product comprising program code means which when loaded into a computer controls the computer to: in a system in which a communication device searches for ~~unscheduled~~ transmissions of downlink control information for said communication device: select a combination of search spaces for ~~unscheduled~~ transmissions of downlink control information for a communication device by a plurality of transmission techniques: and transmitting an indication of the result of the selected combination to said communication device.

~~50. A computer program product comprising program code means which when loaded into a computer controls the computer to: in a system in which a communication device searches for unscheduled transmissions of downlink control information messages for said communication device according to a plurality of message formats: select a respective set of one or more search spaces for each of said plurality of message formats; and transmitting to said communication device an indication of the result of said selection of respective sets of one or more search spaces.~~

~~51~~40. A computer program product comprising program code means which when loaded into a computer controls the computer to: in a system in which a radio access network transmits indications of the results of selections of combinations of search spaces for ~~unscheduled~~ transmissions by a plurality of transmission techniques of downlink control information for one or more communication devices: search at a first communication device for ~~unscheduled~~ transmissions of downlink

control information for said communication device; wherein said searching is performed either: (a) on the basis of a transmitted indication of the result of a selection for said first communication device of a combination of search spaces for ~~un-~~
5 ~~scheduled~~-transmissions by said plurality of transmission techniques of downlink control information; or (b) in the absence of a transmitted indication of the result of a selection for said first communication device of a combination of search spaces for ~~unscheduled~~-transmissions by said plurality of
10 transmission techniques of downlink control information, on the basis of a default combination of search spaces for ~~unscheduled~~ transmissions by said plurality of transmission techniques of downlink control information for said first communication device.

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~~5241~~.A computer program product comprising program code means which when loaded into a computer controls the computer to: search at a first communication device for ~~unscheduled~~-transmissions of downlink control information for said communication
20 device by a plurality of transmission techniques; wherein said searching is performed on the basis of a transmitted indication of the result of a selection of a combination of search spaces for ~~unscheduled~~-transmissions of downlink control information for said first communication device by said plurality of trans-
25 mission techniques.

~~53. A computer program product comprising program code means which when loaded into a computer controls the computer to: in a system in which a radio access network transmits unscheduled
30 transmission of downlink control information messages for a plurality of communication devices according to a~~

~~plurality of message formats, and in which said radio access network transmits indications of the results of selections for one or more communication devices of respective sets of one or more search spaces for each of said plurality of message formats: search at a first communication device for unscheduled transmission of downlink control information for said first communication device; wherein said searching is performed either: (a) on the basis of a transmitted indication of the result of a selection for said first communication device of a respective set of one or more search spaces for each of said plurality of message formats; or (b) in the absence of a transmitted indication of the result of a selection for said first communication device of a respective set of one or more search spaces for each of said plurality of message formats, on the basis of a respective default set of one or more search spaces for each of said plurality of message formats.~~

~~54. A computer program product comprising program code means which when loaded into a computer controls the computer to: search at a first communication device for unscheduled transmission of downlink control information messages for said first communication device according to a plurality of message formats: wherein said searching is performed based on a transmitted indication of the result of a selection of a respective set of one or more search spaces for each of said plurality of message formats.~~

42. The computer program product according to any of claims 39 to 41, wherein the communication device applies blind decoding in finding the downlink control information intended to said communication device.