

WHAT IS CLAIMED IS:

1. A wireless device (16) configured to operate in a cellular communications network (10), comprising:

a radio subsystem (18); and

5 a processing subsystem (20) associated with the radio subsystem (18) configured to:

10 receive, via the radio subsystem (18), a downlink subframe comprising a downlink control channel from the cellular communications network (10), a search space of the wireless device (16) with respect to the downlink control channel comprising one or more sets of downlink control channel physical resources; and

15 estimate one or more large-scale channel properties for an antenna port of interest in a set of downlink control channel physical resources in the search space of the wireless device (16) in the downlink control channel based on a subset of a plurality of reference signals corresponding to antenna ports in the cellular communications network (10) that are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties, the antenna ports that are quasi co-located with the antenna port of interest comprising at least a subset of antenna ports in the same set of downlink control  
20 channel physical resources in the search space of the wireless device (16).

25 2. The wireless device (16) of claim 1 wherein the cellular communications network (10) is a Long Term Evolution, cellular communications network, the downlink control channel is an enhanced Physical Downlink Control Channel, the one or more sets of downlink control channel physical resources are one or more sets of enhanced Physical Downlink Control Channel physical resource block pairs, where each set of enhanced Physical Downlink Control Channel physical resource block pairs includes one or more physical resource block pairs in one or more enhanced Physical Downlink Control Channel regions within the downlink subframe.

30 3. The wireless device (16) of claim 1 or claim 2 wherein the search space of the wireless device (16) includes two or more sets of downlink control channel physical

resources, and the wireless device (16) does not assume that antenna ports in different sets of downlink control channel physical resources are quasi co-located with respect to the one or more large-scale channel properties.

5      4. The wireless device (16) of any one of claims 1-3 wherein the antenna port of interest is a Demodulation Reference Signal, DMRS, port, and the at least a subset of antenna ports in the same set of downlink control channel physical resources in the search space of the wireless device (16) comprise at least one of a group consisting of:  
10 at least one other DMRS port in the same set of downlink control channel physical resources and at least one Reference Signal, RS, port of a type other than DMRS.

~~2. The wireless device (16) of claim 1 wherein the subset of the plurality of reference signals comprise:~~

15 ~~reference signals that are transmitted in different reference signal ports for the same reference signal type in the same physical resource block within the downlink subframe;~~

20 ~~wherein the different reference signal ports for the same reference signal type in the same physical resource block within the downlink subframe correspond to antenna ports that are quasi co-located with respect to the one or more large-scale channel properties.~~

~~3. The wireless device (16) of claim 1 wherein the subset of the plurality of reference signals comprise reference signals that are:~~

25 ~~the same reference signal transmitted in the same reference signal port for the same reference signal type in a different physical resource block within the downlink subframe;~~

30 ~~wherein the reference signal port for the same reference signal type in the different physical resource block within the downlink subframe correspond to antenna ports that are quasi co-located with respect to the one or more large-scale channel properties.~~

4. ~~The wireless device (16) of claim 1 wherein the subset of the plurality of reference signals comprise:~~

~~reference signals that are transmitted in different reference signal ports for different reference signal types in the same physical resource block within the downlink subframe;~~

~~wherein the different reference signal ports for the different reference signal types in the same physical resource block within the downlink subframe correspond to antenna ports that are quasi co-located with respect to the one or more large-scale channel properties.~~

5. ~~The wireless device (16) of claim 1 wherein the subset of the plurality of reference signals comprise:~~

~~reference signals that are transmitted in different reference signal ports for different reference signal types in different physical resource blocks within the downlink subframe;~~

~~wherein the different reference signal ports for the different reference signal types in the different physical resource blocks within the downlink subframe correspond to antenna ports that are quasi co-located with respect to the one or more large-scale channel properties.~~

56. The wireless device (16) of claim 1 wherein the processing subsystem (20) is further configured to receive, via the radio subsystem (18), information from the cellular communications network (10) that is indicative of the antenna ports that are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties.

67. The wireless device (16) of claim 56 wherein the information from the cellular communications network (10) is further indicative of one or more physical resource blocks over which the antenna ports are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties.

78. The wireless device (16) of claim 1 wherein the antenna ports that are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties are predefined for the cellular communications network (10).
- 5 | 89. The wireless device (16) of claim 78 wherein one or more physical resource blocks over which the antenna ports are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties are also predefined by the cellular communications network (10).
- 10 | 910. The wireless device (16) of claim 1 wherein the antenna ports that are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties comprise first antenna ports that are predefined for the cellular communications network (10) as being quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties and second  
15 | antenna ports indicated as being quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties via signaling from the cellular communications network (10).
- 20 | 101. The wireless device (16) of claim 910 wherein one or more physical resource blocks over which the first antenna ports are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties are also predefined by the cellular communications network (10).
- 25 | 112. The wireless device (16) of claim 910 wherein one or more physical resource blocks over which the second antenna ports are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties are also indicated to the wireless device (16) via signaling from the cellular communications network (10).
- 30 | 123. The wireless device (16) of claim 1 wherein the cellular communications network (10) is a Long Term Evolution cellular communications network, and the downlink control channel is an enhanced Physical Downlink Control Channel.

1314. The wireless device (16) of claim 1 wherein:

the wireless device (16) does not assume that antenna ports that correspond to reference signals in an enhanced Physical Downlink Control Channel are quasi co-located with respect to large-scale channel properties between antenna ports and between physical resource blocks within a subframe; and

the antenna ports that are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties comprise antenna ports signaled by the cellular communications network (10).

145. The wireless device (16) of claim 1 wherein:

the cellular communications network (10) is a Long Term Evolution cellular communications network;

the downlink control channel is an enhanced Physical Downlink Control Channel; and

the plurality of reference signals comprise a plurality of reference signals transmitted within the enhanced Physical Downlink Control Channel.

~~16. The wireless device (16) of claim 15 wherein:~~

~~the wireless device (16) does not assume that any antenna ports corresponding to Demodulation Reference Signal ports within the enhanced Physical Downlink Control Channel are quasi co-located with respect to long-term channel properties between antenna ports and between physical resource blocks within the downlink subframe; and~~

~~the processing subsystem (20) is further configured to:~~

~~determine whether a downlink control information message transmitted in the enhanced Physical Downlink Control Channel is associated with two or more Demodulation Reference Signal ports;~~

~~wherein, if the downlink control information message is associated with two or more Demodulation Reference Signal ports, the antenna ports that are quasi co-located with respect to the one or more large-scale channel properties comprise antenna ports associated with the downlink control information~~

~~message for physical resource blocks associated with the downlink control information message.~~

17. ~~The wireless device (16) of claim 15 wherein:~~

~~the wireless device (16) does not assume that any antenna ports corresponding to Demodulation Reference Signal ports within the enhanced Physical Downlink Control Channel are quasi co-located with respect to long term channel properties between antenna ports and between physical resource blocks within the downlink subframe; and~~

~~the processing subsystem (20) is further configured to:~~

~~determine whether a downlink control information message transmitted on the enhanced Physical Downlink Channel is associated with two or more physical resource blocks;~~

~~wherein if the downlink control information message is associated with two or more physical resource blocks, the antenna ports that are quasi co-located with respect to the one or more large scale channel properties comprise antenna ports associated with the downlink control information message for physical resource blocks associated with the downlink control information message.~~

18. ~~The wireless device (16) of claim 15 wherein a search space of the wireless device (16) with respect to the enhanced Public Downlink Control Channel includes two or more sets of physical resources, and the antenna ports that are quasi co-located with respect to the one or more large scale channel properties comprise antenna ports within the same set of the two or more sets of physical resources.~~

159. The wireless device (16) of claim 145 wherein a search space of the wireless device (16) with respect to the enhanced PublicPhysical Downlink Control Channel includes two or more sets of physical resources, and the processing subsystem (20) is further configured to:

receive information from the cellular communications network (10) that is indicative of which antenna ports within the two or more sets of physical resources are quasi co-located with respect to the one or more large-scale channel properties.

5 | ~~1620.~~ The wireless device (16) of claim ~~1519~~ wherein the information from the  
cellular communications network (10) indicates that at least some of the antenna ports  
within the same set of physical resources are quasi co-located with respect to the one or  
more large-scale channel properties,~~and the antenna ports that are quasi co-located and~~  
~~on which the estimate of the one or more large-scale channel properties is based~~  
10 | ~~comprise the antenna ports in the same set of physical resources.~~

~~1721.~~ The wireless device (16) of claim ~~1519~~ wherein the information from the  
cellular communications network (10) indicates that at least some of the antenna ports  
within two or more different sets of physical resources from the two or more sets of  
15 | physical resources are quasi co-located with respect to the one or more large-scale  
channel properties,~~and the antenna ports that are quasi co-located and on which the~~  
~~estimate of the one or more large-scale channel properties is based comprise the~~  
antenna ports in the two or more different sets of physical resources.

20 | ~~1822.~~ The wireless device (16) of claim 1 wherein the one or more large-scale channel  
properties include one or more of a group consisting of: delay spread, Doppler spread,  
Doppler shift, average gain, and average delay.

25 | ~~1923.~~ A method of operation of a wireless device (16) in a cellular communications  
network (10), comprising:

receiving a downlink subframe from the cellular communications network (10),  
the downlink subframe comprising a downlink control channel from the cellular  
communications network (10), a search space of the wireless device (16) with respect  
to the downlink control channel comprising one or more sets of downlink control  
30 | channel physical resources; and

estimating one or more large-scale channel properties for an antenna port of  
interest in a set of downlink control channel physical resources in the search space of

the wireless device (16) ~~in the downlink control channel~~ based on a subset of a plurality of reference signals corresponding to antenna ports in the cellular communications network (10) that are quasi co-located with the antenna port of interest with respect to the one or more large-scale channel properties, the antenna ports that are quasi co-  
5 located with the antenna port of interest comprising at least a subset of antenna ports in  
the same set of downlink control channel physical resources in the search space of the  
wireless device (16).

10 2024. A base station (14) of a cellular communications network (10), comprising:  
a radio subsystem (22); and  
a processing subsystem (24) associated with the radio subsystem (22)  
configured to:

provide, via the radio subsystem (22), a downlink subframe comprising  
a plurality of reference signals corresponding to a plurality of antenna ports  
15 according to one or more predefined rules that define one or more subsets of the  
plurality of antenna ports that must be quasi co-located within a downlink  
control channel of the downlink subframe, the one or more rules comprising a  
rule that at least some antenna ports within the same set of downlink control  
channel physical resources in a configured search space of a wireless device  
20 (16) are to be quasi co-located with respect to one or more large-scale channel  
properties.

~~25. A base station (14) of a cellular communications network (10), comprising:~~  
~~a radio subsystem (22); and~~  
25 ~~a processing subsystem (24) associated with the radio subsystem (22)~~  
~~configured to:~~

~~send, via the radio subsystem (22), information to a wireless device (16)~~  
~~that is indicative of antenna ports that are quasi co-located within a downlink~~  
~~control channel of a subframe of a downlink from the cellular communications~~  
30 ~~network (10).~~

26. ~~The base station (14) of claim 25 wherein the information is explicitly indicative of the antenna ports that are quasi co-located.~~

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27. ~~The base station (14) of claim 25 wherein the information is implicitly indicative of the antenna ports that are quasi co-located.~~

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28. ~~The base station (14) of claim 25 wherein the subframe includes a plurality of sets of resources for the downlink control channel, and the information is indicative of whether antenna ports within the same set of resources are quasi co-located with respect to one or more large scale channel properties.~~

29. ~~The base station (14) of claim 28 wherein the downlink control channel is an enhanced Physical Downlink Control Channel.~~