

CLAIMS

1. A method of wireless communication, comprising:

modulating uplink control information (UCI) ~~comprising~~ of a plurality of control information types; to generate a plurality of modulated UCI symbols, each modulated UCI symbol carrying UCI of a corresponding one of the control information types;

~~mapping the plurality of modulated UCI symbols to a plurality of resource elements (REs) of a plurality of orthogonal frequency division multiplexing (OFDM) symbols of a physical uplink shared channel (PUSCH) such that the,~~ the mapping comprising, for each of the control information types, distributing the respective modulated UCI symbols of each control information type are distributed according to a predetermined step size among the REs resource elements of one or more corresponding orthogonal frequency division multiplexing (OFDM) symbols of the PUSCH OFDM symbols of the plurality of OFDM symbols based on a step size between adjacent ones of the respective resource elements for each respective OFDM symbol, the step size for the respective OFDM symbol being a function of a number of available resource elements in the respective OFDM symbol and a number of remaining modulated UCI symbols of the respective control information type; and

~~transmitting data in the PUSCH including the UCI,~~ plurality of resource elements to which the modulated UCI symbols were mapped.

2. The method of claim 1,

wherein the UCI includes:

first UCI of a first control information type of the plurality of control information types that comprises a hybrid automatic repeat request acknowledgment (HARQ-ACK),

second UCI of a second control information type of the plurality of control information types that comprises a first portion of control channel state information (CSI), and

third UCI of a third control information type of the plurality of control information types that comprises a second portion of CSI; and,

~~wherein the mapping comprises:~~

~~mapping the HARQ-ACK to a first set of the REs;~~

~~mapping the first portion of CSI to a second set of the REs; and~~

~~mapping the second portion of CSI to a third set of the REs.~~

3. The method of claim 2, wherein ~~two or more of the resources~~ elements of the plurality of resource elements in which the first set of the REs, UCI, the second set of the REs, UCI and the third set of the REs, UCI are mapped are multiplexed in a frequency domain in ~~each one or more~~ of the OFDM symbols.

4. The method of claim 3, wherein the mapping comprises:
~~interleaving two one or more of the REs~~ resource elements in which the first UCI is mapped to one or more of the HARQ ACK, the REs of the first portion of CSI, and the REs of resource elements in which the second portion of CSI, in an OFDM symbol, UCI is mapped and to one or more of the resource elements in which the third UCI is mapped in one or more of the OFDM symbols.

5. The method of claim 2, wherein the ~~mapping comprises:~~
~~mapping the HARQ ACK to one or more OFDM symbols of the PUSCH~~ resource elements to which the first UCI is mapped occur earlier in a time domain than the first portion of CSI ~~resource elements to which the second UCI and the second portion of CSI;~~ or mapping the first portion of CSI to one or more OFDM symbols of the PUSCH earlier in a time domain than the HARQ ACK; third UCI are mapped.

6. The method of claim 2, wherein the ~~mapping comprises:~~
~~mapping the HARQ ACK, resource elements to which the second UCI is mapped occur earlier in the time domain than the resource elements to which the first portion of CSI, and the second portion of CSI to the OFDM symbols of the PUSCH in a predetermined order in a time domain; and~~
~~for each OFDM symbol, evenly distributing modulated symbols of one or more of the HARQ ACK, the first portion of CSI, and the second portion of CSI mapped to the OFDM symbols, in a frequency domain;~~ third UCI is mapped.

7. The method of claim 1,
~~wherein the mapping comprises:~~

~~dividing the modulated UCI symbols into a first partition and a second partition;~~
~~and~~

~~mapping the first partition to REs of a first frequency band and the second partition to REs of a second frequency band; and~~

~~wherein the transmitting comprises transmitting the data including the modulated UCI symbols in the PUSCH using frequency hopping across the first frequency band and the second frequency band.~~

8. ~~The method of claim 1,~~

wherein the PUSCH further comprises a first demodulation reference signal (DMRS) and a second DMRS, and

~~wherein the mapping further comprises:~~

~~dividing the modulated UCI symbols of each control information type into a plurality of groups; and~~

~~mapping each group of the modulated UCI symbols to one or more OFDM symbols starting at an OFDM symbol adjacent to the first DMRS or the second DMRS.~~

98. ~~The method of claim 8, wherein the first DMRS is front-loaded in the PUSCH, and the first DMRS and the second DMRS are separated by one or more OFDM symbols; and~~

~~wherein the mapping further comprises:~~

~~mapping a first group of the UCI symbols to OFDM symbols adjacent to the first DMRS; ———~~

~~mapping a second group of the UCI symbols to OFDM symbols adjacent to and earlier in time than the second DMRS; and~~

~~mapping a third group of the UCI symbols to OFDM symbols adjacent to and later in time than the second DMRS.~~

9. A method of wireless communication, comprising:

modulating uplink control information (UCI) comprising a plurality of control information types, to generate a plurality of modulated UCI symbols;

mapping the plurality of modulated UCI symbols to a plurality of resource elements of a

physical uplink shared channel (PUSCH) such that the modulated UCI symbols of each control information type are distributed according to a predetermined step size among the resource elements of one or more corresponding orthogonal frequency division multiplexing (OFDM) symbols of the PUSCH, the mapping comprising:

dividing the modulated UCI symbols into a first partition and a second partition,
and
mapping the first partition to resource elements of the plurality of resources elements in a first frequency band and the second partition to resource elements of the plurality of resources elements in a second frequency band; and
transmitting the PUSCH, including the plurality of resource elements to which the modulated UCI symbols were mapped and including resource elements to which data is mapped, using frequency hopping across the first frequency band and the second frequency band.

10. An apparatus comprising:

a communication interface configured for wireless communication; and

a communication circuit configured to:

modulate uplink control information (UCI) comprising of a plurality of control information types; to generate a plurality of modulated UCI symbols, each modulated UCI symbol carrying UCI of a corresponding one of the control information types;

map the plurality of modulated UCI symbols to a plurality of resource elements (REs) of a plurality of orthogonal frequency division multiplexing (OFDM) symbols of a physical uplink shared channel (PUSCH) such that, the mapping comprising, for each of the control information types, distributing the respective modulated UCI symbols of each control information type are distributed according to a predetermined step size among the REs resource elements of one or more corresponding orthogonal frequency division multiplexing (OFDM) symbols of the PUSCH OFDM symbols of the plurality of OFDM symbols based on a step size between adjacent ones of the respective resource elements for each respective OFDM symbol, the step size for the respective OFDM symbol being a function of a number of available resource elements in the respective OFDM symbol and a number of remaining modulated UCI symbols of the respective control information type;
and

transmit ~~data in the PUSCH including the UCI using the communication interface.~~
plurality of resource elements to which the modulated UCI symbols were mapped.

11. The apparatus of claim 10,

wherein the UCI includes:

first UCI of a first control information type of the plurality of control information types
that comprises a hybrid automatic repeat request acknowledgment (HARQ-ACK),

second UCI of a second control information type of the plurality of control information
types that comprises a first portion of ~~control channel~~ state information (CSI), and

third UCI of a third control information type of the plurality of control information types
that comprises a second portion of CSI; and,

wherein

12. The apparatus of claim 11, wherein resources elements of the plurality of resource
elements in which the first UCI, the second UCI and the third UCI are mapped are multiplexed in
a frequency domain in one or more of the OFDM symbols.

13. The apparatus of claim 12, wherein to, map the modulated UCI symbols, the
communication circuit is further configured to:

map the HARQ-ACK to a first set of the REs;

map the first portion of CSI to a second set of the REs; and

map the second portion of CSI to a third set of the REs.

~~12. The apparatus of claim 11, wherein two or more of the first set of the REs, the~~
~~second set of the REs, and the third set of the REs, are multiplexed in a frequency domain in~~
~~each of the OFDM symbols.~~

~~13. The apparatus of claim 12, wherein the communication circuit is further~~
~~configured to:~~

~~interleave two or more of the REs of the HARQ-ACK, the REs of resource elements in~~
~~which the first portion of CSI, and the REs of UCI is mapped to one or more of the resource~~
~~elements in which the second portion of CSI, in an OFDM symbol. UCI is mapped and to one or~~

more of the resource elements in which the third UCI is mapped in one or more of the OFDM symbols.

14. The apparatus of claim 11, wherein the ~~communication circuit is further configured~~ resource elements to:

~~map the HARQ ACK to one or more OFDM symbols of the PUSCH~~ which the first UCI is mapped occur earlier in a time domain than the first portion of CSI and resource elements to which the second portion of CSI; or

~~map the first portion of CSI to one or more OFDM symbols of the PUSCH earlier in a time domain than the HARQ ACK, UCI and the third UCI are mapped.~~

15. The apparatus of claim 11, wherein the ~~communication circuit is further configured~~ resource elements to which the second UCI is mapped occur earlier in the time domain than the resource elements to:

~~map the HARQ ACK, the first portion of CSI, and the second portion of CSI to the OFDM symbols of the PUSCH in a predetermined order in a time domain; and~~

~~for each OFDM symbol, evenly distribute modulated symbols of one or more of the HARQ ACK, the first portion of CSI, and the second portion of CSI mapped to the OFDM symbols, in a frequency domain; which the third UCI is mapped.~~

16. The apparatus of claim 10, wherein the ~~communication circuit is further configured to:~~

~~divide the modulated UCI symbols into a first partition and a second partition; and~~

~~map the first partition to REs of a first frequency band and the second partition to REs of a second frequency band; and~~

~~transmit the data including the modulated UCI symbols in the PUSCH using frequency hopping across the first frequency band and the second frequency band.~~

17. ~~The apparatus of claim 10,~~

~~wherein the PUSCH further comprises a first demodulation reference signal (DMRS) and a second DMRS, and~~

wherein the communication circuit is further configured to:
 divide the modulated UCI symbols of each control information type into a plurality of groups; and
 map each group of the modulated UCI symbols to one or more OFDM symbols starting at an OFDM symbol adjacent to the first DMRS or the second DMRS.

~~18~~¹⁷. The apparatus of claim ~~17~~¹⁶, wherein the first DMRS is front-loaded in the PUSCH, ~~and~~ the first DMRS and the second DMRS are separated by one or more OFDM symbols; and

~~wherein~~ the communication circuit is further configured to:

map a first group of the UCI symbols to OFDM symbols adjacent to the first DMRS; ———

map a second group of the UCI symbols to OFDM symbols adjacent to and earlier in time than the second DMRS; and

map a third group of the UCI symbols to OFDM symbols adjacent to and later in time than the second DMRS.

~~19. — A wireless communication — 18. —~~ An apparatus comprising:

~~means a communication interface configured for wireless communication; and~~
~~a communication circuit configured to:~~

modulating uplink control information (UCI) comprising a plurality of control information types, to generate a plurality of modulated UCI symbols;

~~means for mapping~~map the plurality of modulated UCI symbols to a plurality of resource elements (REs) of a physical uplink shared channel (PUSCH) such that the modulated UCI symbols of each control information type are distributed according to a predetermined step size among the REs of one or more corresponding orthogonal frequency division multiplexing (OFDM) symbols of the PUSCH; and

~~means for transmitting data in the PUSCH including the UCI.~~

~~20. — The wireless communication apparatus of claim 19,~~

wherein the UCI comprises a hybrid automatic repeat request acknowledgment (HARQ-ACK), a first portion of control state information (CSI), and a second portion of CSI; and

wherein the means for mapping is configured to:

- map the HARQ-ACK to a first set of the REs;
- map the first portion of CSI to a second set of the REs; and
- map the second portion of CSI to a third set of the REs.

21.—The wireless communication apparatus of claim 20, wherein two or more of the first set of the REs, the second set of the REs, and the third set of the REs, are multiplexed in a frequency domain in each of the OFDM symbols.

22.—The wireless communication apparatus of claim 21, wherein the means for mapping is configured to:

interleave two or more of the REs of the HARQ-ACK, the REs of the first portion of CSI, and the REs of the second portion of CSI, in an OFDM symbol.

23.—The wireless communication apparatus of claim 20, wherein the means for mapping is configured to:

map the HARQ-ACK to one or more OFDM symbols of the PUSCH earlier in a time domain than the first portion of CSI and the second portion of CSI; or

map the first portion of CSI to one or more OFDM symbols of the PUSCH earlier in a time domain than the HARQ-ACK.

24.—The wireless communication apparatus of claim 20, wherein the means for mapping is configured to:

map the HARQ-ACK, the first portion of CSI, and the second portion of CSI to the OFDM symbols of the PUSCH in a predetermined order in a time domain; and

for each OFDM symbol, evenly distribute modulated symbols of one or more of the HARQ-ACK, the first portion of CSI, and the second portion of CSI mapped to the OFDM symbols, in a frequency domain.

25. — The wireless communication apparatus of claim 19,
 wherein the means for mapping is configured to:
 divide the modulated UCI symbols into a first partition and a second partition;
 and
 map the first partition to REs of a first frequency band and the second partition to
 REs of a second frequency band; and
 wherein the means for transmitting is configured to transmit the data including the
 modulated UCI symbols in the PUSCH using frequency hopping across the first frequency band
 and the second frequency band.

26. — The wireless communication apparatus of claim 19,
 wherein the PUSCH further comprises a first demodulation reference signal (DMRS) and
 a second DMRS, and
 wherein the mapping further comprises:
 dividing the modulated UCI symbols of each control information type into a plurality of
 groups; and
 mapping each group of the modulated UCI symbols to one or more OFDM symbols
 starting at an OFDM symbol adjacent to the first DMRS or the second DMRS.

27. — The wireless communication apparatus of claim 26,
 wherein the first DMRS is front loaded in the PUSCH, and the first DMRS and the
 second DMRS are separated by one or more OFDM symbols; and
 wherein the mapping further comprises:
 — mapping a first group of the UCI symbols to OFDM symbols adjacent to the first
 DMRS; —
 mapping a second group of the UCI symbols to OFDM symbols adjacent to and
 earlier in time than the second DMRS; and
 — mapping a third group of the UCI symbols to OFDM symbols adjacent to and
 later in time than the second DMRS.

28. ~~A computer-readable storage medium comprising executable code to cause a computer to:~~

~~modulate uplink control information (UCI) comprising a plurality of control information types, to generate a plurality of modulated UCI symbols;~~

~~map the plurality of modulated UCI symbols to a plurality of resource elements (REs) of a physical uplink shared channel (PUSCH) such that the modulated UCI symbols of each control information type are distributed according to a predetermined step size among the REs of one or more corresponding orthogonal frequency division multiplexing (OFDM) symbols of the PUSCH; and, wherein to map the modulated UCI symbols, the communication circuit is configured to:~~

~~transmit data in the PUSCH including the UCI using a communication interface.~~

29. ~~The computer-readable storage medium of claim 28,~~
~~wherein the UCI comprises a hybrid automatic repeat request acknowledgment (HARQ-ACK), a first portion of control state information (CSI), and a second portion of CSI; and~~
~~wherein the computer-readable storage medium further comprising executable code to cause the computer to:~~

~~map the HARQ-ACK to a first set of the REs;~~

~~map the first portion of CSI to a second set of the REs; and~~

~~map the second portion of CSI to a third set of the REs.~~

30. ~~The computer-readable storage medium of claim 29, wherein two or more of the first set of the REs, the second set of the REs, and the third set of the REs, are multiplexed in a frequency domain in each of the OFDM symbols.~~

31. ~~The computer-readable storage medium of claim 30, further comprising executable code to cause the computer to:~~

~~interleave two or more of the REs of the HARQ-ACK, the REs of the first portion of CSI, and the REs of the second portion of CSI, in an OFDM symbol.~~

32.—~~The computer readable storage medium of claim 29, further comprising executable code to cause the computer to:~~

~~map the HARQ ACK to one or more OFDM symbols of the PUSCH earlier in a time domain than the first portion of CSI and the second portion of CSI; or~~

~~map the first portion of CSI to one or more OFDM symbols of the PUSCH earlier in a time domain than the HARQ ACK.~~

33.—~~The computer readable storage medium of claim 29, further comprising executable code to cause the computer to:~~

~~map the HARQ ACK, the first portion of CSI, and the second portion of CSI to the OFDM symbols of the PUSCH in a predetermined order in a time domain; and~~

~~for each OFDM symbol, evenly distribute modulated symbols of one or more of the HARQ ACK, the first portion of CSI, and the second portion of CSI mapped to the OFDM symbols, in a frequency domain.~~

34.—~~The computer readable storage medium of claim 28, further comprising executable code to cause the computer to:~~

~~divide the modulated UCI symbols into a first partition and a second partition; and~~

~~map the first partition to REs of resource elements of the plurality of resources elements in a first frequency band and the second partition to REs of a resource elements of the plurality of resources elements in a second frequency band; and~~

~~transmit the data—transmit the PUSCH, including the plurality of resource elements to which the modulated UCI symbols were mapped and including the modulated UCI symbols in the PUSCH—resource elements to which data is mapped, using frequency hopping across the first frequency band and the second frequency band.~~

35.—~~The computer readable storage medium of claim 28,~~

~~wherein the PUSCH further comprises a first demodulation reference signal (DMRS) and a second DMRS, and~~

~~wherein the computer-readable storage medium further comprises executable code to cause the computer to:~~

~~divide the modulated UCI symbols of each control information type into a plurality of groups; and~~

~~map each group of the modulated UCI symbols to one or more OFDM symbols starting at an OFDM symbol adjacent to the first DMRS or the second DMRS.~~

36.—The computer-readable storage medium of claim 35,

~~wherein the first DMRS is front loaded in the PUSCH, and the first DMRS and the second DMRS are separated by one or more OFDM symbols; and~~

~~wherein the computer-readable storage medium further comprises executable code to cause the computer to:~~

~~—— map a first group of the UCI symbols to OFDM symbols adjacent to the first DMRS;——~~

~~map a second group of the UCI symbols to OFDM symbols adjacent to and earlier in time than the second DMRS; and~~

~~—— map a third group of the UCI symbols to OFDM symbols adjacent to and later in time than the second DMRS.~~