



(51) International Patent Classification:
H04L 5/00 (2006.01)

(21) International Application Number:
PCT/CN2016/086732

(22) International Filing Date:
22 June 2016 (22.06.2016)

(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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, 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, 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))

(54) Title: UPLINK TRANSMISSION METHODS, ASSIGNMENT METHODS, USER EQUIPMENT, AND BASE STATIONS, USING UNLICENSED SPECTRUM

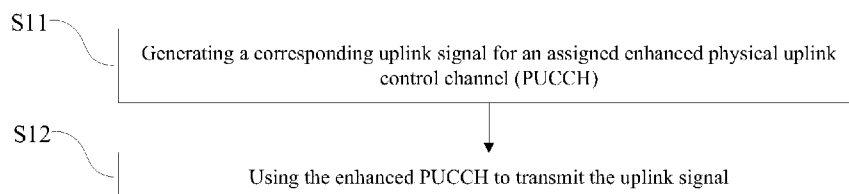


FIG. 2

(57) Abstract: An uplink transmission method using unlicensed spectrum is disclosed. The method includes: generating a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH), where the enhanced PUCCH belongs to the unlicensed spectrum, and corresponds to at least two physical resource blocks (PRBs) in frequency domain at a same time point; and using the enhanced PUCCH to transmit the uplink signal. Resource assignment methods, user equipment, and base stations using the unlicensed spectrum are further disclosed. Thereby, the present disclosure can effectively increase the bandwidth occupied by the PUCCH.



UPLINK TRANSMISSION METHODS, ASSIGNMENT METHODS, USER EQUIPMENT, AND BASE STATIONS, USING UNLICENSED SPECTRUM

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to the field of communications, and more particularly, to uplink transmission methods, assignment methods, user equipment, and base stations, using unlicensed spectrum.

BACKGROUND OF THE DISCLOSURE

[0002] As mobile communications continue to develop and the demand for mobile broadband is rapidly increasing, the scarcity of spectrum resources, especially licensed spectrum resources, has posed an urgent challenge to mobile communications. To meet the increasingly growing demand for data rate, traffic, and bandwidth, and thus to mitigate the current spectrum scarcity crisis, 3GPP has launched a study item on Licensed-Assisted Access (LAA) to unlicensed spectrum.

[0003] LAA is an auxiliary access technology which offloads the cellular traffic in the licensed band to the unlicensed spectrum. By means of the carrier aggregation framework, a licensed carrier may be used by a primary cell (PCell) to carry critical information to maintain the Quality of Service (QoS), while another carrier on the unlicensed band may be opportunistically employed by a secondary cell (SCell) to boost the data rate.

[0004] Typically, a physical uplink control channel (PUCCH) may be used to transmit uplink control information (UCI). The UCI is typically handled by PCell. Thus, as the number of SCells increases, the UCI load on the PCell will also be drastically increased. In view of this, it is proposed to support the PUCCH transmission over the LAA SCells, to reduce the load on the PCell of licensed spectrum and to increase the number of SCells.

[0005] The LTE legacy PUCCH is located at the PRBs around the two edges of the

system bandwidth in frequency domain, and hopping across the two edges between two time-slots, as is shown in FIG. 1. Therefore, the PUCCH only occupies one PRB in one slot, one PRB including 12 continuous subcarriers in the frequency domain. The bandwidth occupied by the PUCCH would be merely 180KHz given that one subcarrier spans 15KHz.

SUMMARY OF THE DISCLOSURE

[0006] A principal technical problem to be addressed by the disclosure is to provide uplink transmission methods, assignment methods, user equipment, and base stations, using unlicensed spectrum, to solve the problem existing in the prior art that in the LAA SCells the PUCCH occupies a small bandwidth.

[0007] To address the above technical problem, one technical solution adopted by the disclosure is to provide an uplink transmission method using unlicensed spectrum, the method comprising: generating a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH), where the enhanced PUCCH belongs to the unlicensed spectrum, and comprises at least two physical resource blocks (PRBs) in frequency domain at a same time point; and using the enhanced PUCCH to transmit the uplink signal.

[0008] The corresponding PRBs in the frequency domain of the enhanced PUCCH may comprise at least one interlaced PRB group. The at least one interlaced PRB group may comprise at least three non-continuous and equally spaced PRBs in the frequency domain.

[0009] The m index of the legacy PUCCH may be mapped to the index of the assigned interlaced PRB group of the enhanced PUCCH.

[0010] The highest and the lowest frequency of the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[0011] The enhanced PUCCH may occupy smaller than one sub-frame whilst not smaller than one symbol in time domain.

[0012] The step of using the enhanced PUCCH to transmit the uplink signal may

comprise: using the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[0013] The step of using the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after the end of the downlink transmission which occupies only a part of the sub-frame may comprise: using the enhanced PUCCH to transmit the uplink signal during an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[0014] The step of using the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after the end of the downlink transmission which occupies only a part of the sub-frame may comprise: using the enhanced PUCCH to transmit the uplink signal during a guard period (GP) in the remaining partial sub-frame.

[0015] The step of using the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after the end of the downlink transmission which occupies only a part of the sub-frame may comprise: using the enhanced PUCCH to transmit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

[0016] The step of using the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after the end of the downlink transmission which occupies only a part of the sub-frame may comprise: transmitting an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value; and using the enhanced PUCCH to transmit the uplink signal right after the uplink reservation signal.

[0017] The length of a corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

[0018] The step of generating the corresponding uplink signal for the assigned enhanced PUCCH may comprise: obtaining a block of complex-valued symbols based on a block of bits to be transmitted, and a reference signal sequence based on

corresponding cyclic shift; mapping the block of complex-valued symbols and the reference signal sequence to resource elements (REs) occupied by the enhanced PUCCH; generating baseband signal using the REs; and modulating and upconverting the baseband signal to the carrier frequency to obtain the uplink signal.

[0019] The enhanced PUCCH may be of a format 3. The step of obtaining the block of complex-valued symbols based on the block of bits to be transmitted, may comprise: scrambling and modulating the block of bits to be transmitted to obtain complex-valued modulation symbols; block-wise spreading the complex-valued modulation symbols in time domain to obtain the block of complex-valued symbols.

[0020] The step of mapping the block of complex-valued symbols and the reference signal sequence to the REs of the enhanced PUCCH may comprise: mapping sequentially the complex-valued symbols in the block to the REs to be assigned the block, in increasing order of first the subcarriers indexes and then the symbols indexes, and mapping sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence, in increasing order of first the subcarriers indexes and then the symbols indexes.

[0021] The REs included in the enhanced PUCCH may comprise at least two symbols in time domain. The step of mapping both the block of complex-valued symbols and the reference signal sequence to the REs included in the enhanced PUCCH may comprise: mapping the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence may belong to at least two PRBs in the frequency domain.

[0022] The step of mapping the block of complex-valued symbols and the reference signal sequence to the REs of the enhanced PUCCH may comprise: mapping part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH that correspond to a same symbol in the time domain.

[0023] The step of mapping the block of complex-valued symbols and the reference

signal sequence to the REs of the enhanced PUCCH may comprise: mapping repeatedly part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH.

[0024] Of the REs in the enhanced PUCCH at least one RE may be set to 0.

[0025] The method may further comprise, before the step of generating the corresponding uplink signal for the enhanced PUCCH: selecting among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

[0026] The step of using the enhanced PUCCH to transmit the uplink signal may comprise: performing a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel may be one corresponding to the entire system bandwidth or to the enhanced PUCCH; when the channel is available, using the enhanced PUCCH to transmit the uplink signal.

[0027] The method may further comprise, before the step of using the enhanced PUCCH to transmit the uplink signal when the detected channel is available: when there is a time interval between after determination the channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, using the detected channel to transmit reservation signal during the time interval to indicate the detected channel is occupied or will be occupied.

[0028] Another technical solution adopted by the disclosure is to provide an assignment method using unlicensed spectrum, the method comprising: assigning an enhanced PUCCH to a user equipment (UE), such that the UE generates a corresponding uplink signal and transmits it over the enhanced PUCCH, wherein the enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource block (PRBs) in frequency domain at a same time point.

[0029] The method may further comprise, before the step of assigning the enhanced PUCCH to the UE: dividing the unlicensed spectrum to multiple interlaced PRBs, where each interlaced PRB may comprise at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups are arranged

alternatively in the frequency domain. The step of assigning the enhanced PUCCH to the UE may comprise: assigning to the UE an enhanced PUCCH which comprises at least one interlaced PRB group in the frequency domain.

[0030] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[0031] The enhanced PUCCH may occupy smaller than one sub-frame whilst not smaller than one symbol in time domain.

[0032] The corresponding transmission period of the enhanced PUCCH may be located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[0033] The corresponding transmission period of the enhanced PUCCH may be located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[0034] The corresponding transmission period of the enhanced PUCCH may be located within a guard period (GP) in the remaining partial sub-frame.

[0035] The corresponding transmission period of the enhanced PUCCH may be initiated right after the downlink transmission with a duration gap no larger than a preset value.

[0036] The length of the corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

[0037] The downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission, and the downlink reservation signal may initiate after an end of the downlink burst transmission.

[0038] Yet another technical solution adopted by the disclosure is to provide a user equipment (UE), comprising a generation module configured to generate a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH), where the enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point; and a transmission module configured to transmit the uplink signal over

the enhanced PUCCH.

[0039] The corresponding PRBs in the frequency domain of the enhanced PUCCH may comprise at least one interlaced PRB group. The at least one interlaced PRB group may comprise at least three non-continuous and equally spaced PRBs in the frequency domain.

[0040] The highest and the lowest frequency of the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[0041] The enhanced PUCCH may occupy smaller than one sub-frame whilst not smaller than one symbol in the time domain.

[0042] The transmission module may be configured to use the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[0043] The transmission module may be configured to use the enhanced PUCCH to transmit the uplink signal during an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[0044] The transmission module may be configured to use the enhanced PUCCH to transmit the uplink signal during a guard period (GP) in the remaining partial sub-frame.

[0045] The transmission module may be configured to use the enhanced PUCCH to transmit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

[0046] The transmission module may be configured to transmit an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value, and use the enhanced PUCCH to transmit the uplink signal right after the uplink reservation signal.

[0047] The length of a corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

[0048] The generation module may comprise: a sequencing unit configured to obtain

a block of complex-valued symbols based on a block of bits to be transmitted and a reference signal sequence based on corresponding cyclic shift; a mapping unit configured to map the block of complex-valued symbols and the reference signal sequence to resource elements (REs) occupied by the enhanced PUCCH; a baseband unit configured to generate baseband signal using the REs; and a modulation unit configured to modulate and upconvert the baseband signal to the carrier frequency to obtain the uplink signal.

[0049] The mapping unit may be configured to map sequentially the complex-valued symbols in the block to the REs to be assigned the block, in increasing order of first the subcarriers indexes and then the symbols indexes, and mapping sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence, in increasing order of first the subcarriers indexes and then the symbols indexes.

[0050] The REs included in the enhanced PUCCH may comprise at least two symbols in time domain. The mapping unit may be configured to map the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence may belong to at least two PRBs in the frequency domain.

[0051] The UE may further comprise a selection module configured to select among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

[0052] The transmission module may comprise an evaluation unit configured to perform a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel may be one corresponding to the entire system bandwidth or to the enhanced PUCCH. The transmission module may transmit the uplink signal using the enhanced PUCCH when the detected channel is available.

[0053] The transmission module may further comprise a reservation unit configured to, when there is a time interval between after determination the channel is evaluated

as available and before a start of the corresponding transmission period of the enhanced PUCCH, use the channel to transmit reservation signal during the time interval to indicate the channel is occupied or will be occupied.

[0054] Still another technical solution adopted by the disclosure is to provide a base station comprising: an assignment module configured to assign an enhanced physical uplink control channel (PUCCH) to a user equipment (UE), such that the UE generates a corresponding uplink signal and transmits it over the enhanced PUCCH, wherein the enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point.

[0055] The base station may further include a division module configured to divide the unlicensed spectrum to multiple interlaced PRBs, where each interlaced PRB may comprise at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups may be arranged alternatively in frequency domain; and an assignment module configured to assign to the UE an enhanced PUCCH which comprises at least one interlaced PRB group in the frequency domain.

[0056] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[0057] The enhanced PUCCH may occupy smaller than one sub-frame whilst not smaller than one symbol in time domain.

[0058] The corresponding transmission period of the enhanced PUCCH may be located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[0059] The corresponding transmission period of the enhanced PUCCH may be located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[0060] The corresponding transmission period of the enhanced PUCCH may be located within a guard period (GP) in the remaining partial sub-frame.

[0061] The corresponding transmission period of the enhanced PUCCH may be initiated right after the downlink transmission with a duration gap no larger than a

preset value.

[0062] The length of the corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

[0063] The downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission, and the downlink reservation signal may initiate after an end of the downlink burst transmission.

[0064] Still another technical solution adopted by the disclosure is to provide a user equipment (UE), comprising a processor and a communication circuit connected to the processor. The processor may be configured to: generate a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH), where the enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point; and use the enhanced PUCCH to transmit the uplink signal via the communication circuit.

[0065] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[0066] The corresponding PRBs in the frequency domain of the enhanced PUCCH may comprise at least one interlaced PRB group. The at least one interlaced PRB group may comprise at least three non-continuous and equally spaced PRBs in the frequency domain.

[0067] The processor may be configured to map the m index of the legacy PUCCH to the index of the assigned interlaced PRB group of the enhanced PUCCH.

[0068] The enhanced PUCCH may occupy smaller than one sub-frame whilst not smaller than one symbol in time domain.

[0069] The processor may be configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[0070] The processor may be configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal during an uplink pilot timeslot (UpPTS)

in the remaining partial sub-frame.

[0071] The processor may be configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal during a guard period (GP) in the remaining partial sub-frame.

[0072] The processor may be configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

[0073] The processor may be configured to transmit via the communication circuit an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value, and use the enhanced PUCCH to transmit via the communication circuit the uplink signal right after the uplink reservation signal.

[0074] The length of a corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

[0075] The processor may be configured to: obtain a block of complex-valued symbols based on a block of bits to be transmitted and a reference signal sequence based on corresponding cyclic shift; map the block of complex-valued symbols and the reference signal sequence to resource elements (REs) occupied by the enhanced PUCCH; generate baseband signal using the REs; and modulate and upconvert the baseband signal to the carrier frequency to obtain the uplink signal.

[0076] The enhanced PUCCH may be of a format 3. The processor may be configured to: scramble and modulate the block of bits to be transmitted to obtain complex-valued modulation symbols; block-wise spread the complex-valued modulation symbols in time domain to obtain the block of complex-valued symbols.

[0077] The processor may be configured to map sequentially the complex-valued symbols in the block to the REs to be assigned the block, in increasing order of first the subcarriers indexes and then the symbols indexes, and mapping sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence, in increasing order of first the subcarriers indexes and then the symbols indexes.

[0078] The REs included in the enhanced PUCCH may comprise at least two symbols in time domain. The processor may be configured to map the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence may belong to at least two PRBs in the frequency domain.

[0079] The processor may be configured to map part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH that correspond to a same symbol in the time domain.

[0080] The processor may be configured to map repeatedly part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH.

[0081] Of the REs in the enhanced PUCCH, at least one RE may be set to 0.

[0082] The processor may be further configured to select among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

[0083] The processor may be configured to: perform through the communication circuit a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel may be one corresponding to the entire system bandwidth or to the enhanced PUCCH; and, when the detected channel is available, use the enhanced PUCCH to transmit the uplink signal.

[0084] The processor may be further configured to, when there is a time interval between after determination the channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, use the channel to transmit reservation signal during the time interval to indicate the channel is occupied or will be occupied.

[0085] Still another technical solution adopted by the disclosure is to provide a base station comprising a processor and a transceiver connected to the processor. The processor may be configured to: assign an enhanced physical uplink control channel

(PUCCH) to a user equipment (UE), such that the UE generates a corresponding uplink signal and transmits it over the enhanced PUCCH, wherein the enhanced PUCCH may belong to unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point.

[0086] The processor may be further configured to: divide the unlicensed spectrum to multiple interlaced PRBs, where each interlaced PRB may comprise at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups may be arranged alternatively in frequency domain; and assign via the transceiver to the UE an enhanced PUCCH which comprises at least one interlaced PRB group in the frequency domain.

[0087] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference no smaller than 80% of the entire system bandwidth.

[0088] The enhanced PUCCH may occupy smaller than one sub-frame whilst not smaller than one symbol in time domain.

[0089] The corresponding transmission period of the enhanced PUCCH may be located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[0090] The corresponding transmission period of the enhanced PUCCH may be located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[0091] The corresponding transmission period of the enhanced PUCCH may be located within a guard period (GP) in the remaining partial sub-frame.

[0092] The corresponding transmission period of the enhanced PUCCH may be initiated right after the downlink transmission with a duration gap no larger than a preset value.

[0093] The length of the corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

[0094] The downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission, and the downlink reservation signal may

initiate after an end of the downlink burst transmission.

[0095] Advantages of the disclosure may follow: by using the enhanced PUCCH which comprises at least two PRBs in the frequency domain at a same time point, the bandwidth occupied by the PUCCH can be effectively increased.

BRIEF DESCRIPTION OF THE DRAWINGS

[0096] FIG. 1 is a schematic diagram showing the resource distribution related to existing PUCCH.

[0097] FIG. 2 is a flowchart illustrating a first embodiment of an uplink transmission method using unlicensed spectrum according to the disclosure.

[0098] FIG. 3 is a flowchart illustrating an embodiment of an uplink transmission method using unlicensed spectrum according to the disclosure.

[0099] FIG. 4 is a schematic diagram illustrating the division of interlaced PRB groups in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00100] FIG. 5 is a schematic diagram illustrating the execution of the LBT procedure before the start of the enhanced PUCCH transmission in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00101] FIG. 6 is a schematic diagram illustrating the execution of the LBT procedure with the transmission of reservation signal in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00102] FIG. 7 is a schematic diagram illustrating a second embodiment of an uplink transmission method using unlicensed spectrum according to the disclosure.

[00103] FIG. 8 is a schematic diagram illustrating the enhanced PUCCH transmission during the remaining partial sub-frame without LBT procedure in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00104] FIG. 9 is a schematic diagram illustrating the downlink transmission comprising downlink burst transmission and downlink reservation signal transmission in an uplink transmission method using unlicensed spectrum according to an

embodiment of the disclosure.

[00105] FIG. 10 is a flowchart illustrating a third embodiment of an uplink transmission method using unlicensed spectrum according to the disclosure.

[00106] FIG. 11 is a schematic diagram illustrating the mapping to the enhanced PUCCH when the block of bits to be transmitted is of the format 1/1a/1b in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00107] FIG. 12 is a schematic diagram illustrating the mapping to the enhanced PUCCH when the block of bits to be transmitted is of the format 2/2a/2b in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00108] FIG. 13 is a schematic diagram illustrating the mapping to the enhanced PUCCH when the block of bits to be transmitted is of the format 3 in an uplink transmission method using unlicensed spectrum according to an embodiment of the disclosure.

[00109] FIG. 14 shows the ACK missed detection probabilities for format 1a according to an embodiment of the disclosure.

[00110] FIG. 15 shows the ACK missed detection probabilities for format 1b according to an embodiment of the disclosure.

[00111] FIG. 16 shows a flowchart illustrating a first embodiment of an assignment method using unlicensed spectrum according to the disclosure.

[00112] FIG. 17 shows a flowchart illustrating a second embodiment of an assignment method using unlicensed spectrum according to the disclosure.

[00113] FIG. 18 shows a block diagram of a first embodiment of a user equipment (UE) according to the disclosure.

[00114] FIG. 19 shows a block diagram of an embodiment of a UE according to the disclosure.

[00115] FIG. 20 shows a block diagram of a second embodiment of a UE according to the disclosure.

[00116] FIG. 21 shows a block diagram of a third embodiment of a UE according to

the disclosure.

[00117] FIG. 22 shows a block diagram of a fourth embodiment of a UE according to the disclosure.

[00118] FIG. 23 shows a block diagram of a first embodiment of a base station according to the disclosure.

[00119] FIG. 24 shows a block diagram of a second embodiment of a base station according to the disclosure.

[00120] FIG. 25 shows a block diagram of a third embodiment of a base station according to the disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[00121] Referring to FIG. 2, there is shown a first embodiment of an uplink transmission method using unlicensed spectrum according to the disclosure. The first embodiment uplink transmission method can be implemented on a user equipment (UE). The UE can be stationary or mobile, including, but not limited to, cellular phones, personal digital assistants (PDA), wireless modems, tablet computers, notebook computers, cordless phones, and so forth. The embodiment can comprise the following steps.

[00122] In a first step S11, a corresponding uplink signal may be generated for an assigned enhanced physical uplink control channel (PUCCH).

[00123] The enhanced PUCCH may belong to the unlicensed spectrum, and may correspond to at least two physical resource blocks (PRBs) in the frequency domain at a same time point.

[00124] When the UE is assigned at least two carriers of the unlicensed spectrum, i.e., LAA SCells, if the assigned enhanced PUCCH corresponds to one or more specific LAA SCells, the UE can transmit the enhanced PUCCH over the specific LAA SCell(s); otherwise if the assigned enhanced PUCCH does not correspond to any specific LAA SCells, referring to FIG. 3, in step S10, the UE can autonomously select among assigned LAA SCells one or more LAA SCells for the enhanced PUCCH before generating the corresponding uplink signal, for example, select a clear LAA

SCell having the lowest frequency index to transmit the enhanced PUCCH.

[00125] The corresponding PRBs of the enhanced PUCCH can be continuous or non-continuous in the frequency domain. The different PRBs in the frequency domain of the enhanced PUCCH may carry the same or different contents.

[00126] The enhanced PUCCH can occupy one sub-frame, i.e., two continuous time-slots, the same as the PUCCH in the existing LTE/LTE-A standards, or can occupy smaller than one sub-frame while not smaller than one symbol. When the enhanced PUCCH includes more than one symbol in the time domain, the PRBs of the enhanced PUCCH in different symbols may be the same or different in the frequency domain. Typically, the symbol refers to an SC-FDMA symbol. The number of SC-FDMA symbols in one time-slot may depend on a length of the cyclic prefix (CP). For a conventional CP, each time-slot may comprise seven SC-FDMA symbols, whilst for an extended CP, each time-slot may comprise six SC-FDMA symbols.

[00127] The enhanced PUCCH can be used to transmit at least the uplink control information (UCI), including uplink scheduling request (SR), hybrid automatic repeat request acknowledgment/negative acknowledgment (HARQ ACK/NACK), and channel state information (CSI). The method may proceed to step S12.

[00128] In the following step S12, the enhanced PUCCH is used to transmit the uplink signal.

[00129] The enhanced PUCCH may be used to transmit the uplink signal during the corresponding transmission period of the enhanced PUCCH. A length of the corresponding transmission period of the enhanced PUCCH may be equal to or longer than the time length of the enhanced PUCCH in the time domain. When the length of the corresponding transmission period of the enhanced PUCCH is longer than the time length of the enhanced PUCCH in the time domain, it can adapt to the uncertainty of access to the unlicensed spectrum in order to improve the transmission success probability.

[00130] According to the above embodiment, by using the enhanced PUCCH which comprises at least two PRBs in the frequency domain at the same time point, the

bandwidth occupied by the PUCCH can be effectively increased.

[00131] In one embodiment, the corresponding PRBs of the enhanced PUCCH in the frequency domain may comprise at least one interlaced PRB group. The at least one interlaced PRB group may comprise at least three non-continuous and equally spaced PRBs in the frequency domain. The PRBs of different interlaced PRB groups may be arranged alternatively in the frequency domain. The present embodiment can be combined with any embodiment of the uplink transmission method using unlicensed spectrum according to the disclosure.

[00132] Typically, the base station may divide a part or whole of the system bandwidth belonging to the unlicensed spectrum to multiple interlaced PRB groups, and may further assign an enhanced PUCCH comprising at least one interlaced PRB in the frequency domain to the UE. Often, the base station may divide the entire system bandwidth belonging to the unlicensed spectrum to multiple interlaced PRB groups. The base station can be connected to a core network and perform wireless communications with the UE, thus providing communication coverage for the corresponding geographical area. The base station can include, but not limited to, macro base stations, micro base stations, or pico base stations. In some embodiments, a base station can also be interchangeably referred to as a wireless base station, an access point, a Node B, an evolved Node B (eNodeB or eNB), and so on.

[00133] The corresponding PRBs of the enhanced PUCCH in the frequency domain may comprise one or more complete interlaced PRB groups, or a part of the one or more complete interlaced PRB groups and of other interlaced PRB groups, and may further comprise one or more PRBs in the unlicensed spectrum that do not belong to any interlaced PRB groups.

[00134] As required by the European Telecommunications Standards Institute (ETSI), the maximum power spectral density (PSD) for 5150-5350 MHz is limited to 10 dBm/MHz. Similarly, Federal Communications Commission (FCC) in USA set the peak UE PSD for 5.15-5.725 MHz to 11 dBm/MHz.

[00135] Under the above PSD constraints, given the numbers of the PRBs are the same, the maximum allowed transmission power in the case that the corresponding

PRBs in the frequency domain of the PUCCH comprising at least one interlaced PRB group is typically greater than the maximum allowed transmission power when the PUCCH corresponds to continuous PRBs in the frequency domain.

[00136] For example, referring now to FIG. 4, suppose the system bandwidth spans a total of 20MHz. Removing the guard bands at both ends, the system bandwidth is divided into 100 PRBs $\{\text{PRB}_0, \text{PRB}_1, \dots, \text{PRB}_{99}\}$. The 100 PRBs are categorized into 10 interlaced PRB groups $\{G_0, G_1, \dots, G_9\}$, in the figure each interlaced PRB group is separately drawn for easy viewing, but in fact these interlaced PRB groups belong to a common cell. Each interlaced PRB group may comprise 10 PRBs, and $G_i = \{\text{PRB}_{i+10k}\}_{k=0,1,\dots,9}$. For example, assume the UE is assigned G_0 , i.e., $\{\text{PRB}_0, \text{PRB}_{10}, \dots, \text{PRB}_{90}\}$, then its maximum allowed transmission power would be 20dBm, according to the definition of ETSI. Whilst if the UE is assigned 10 continuous PRBs, such as $\{\text{PRB}_0, \text{PRB}_1, \dots, \text{PRB}_9\}$, then its maximum allowed transmission power would be merely 13dBm.

[00137] The bigger the maximum allowed transmission power, the higher signal power can be used by the UE to transmit uplink signal over the enhanced PUCCH, which can thus ensure a stable transmission of the uplink signal while enabling that other devices can accurately detect the uplink signal when they perform clear channel assessment (CCA).

[00138] In one embodiment, the highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth. The current embodiment can be combined with any embodiment of the uplink transmission method using unlicensed spectrum according to the disclosure.

[00139] As required by ETSI, the occupied channel bandwidth (OCB), which is defined to be the bandwidth containing 99% of signal power, shall be between 80% and 100% of the declared Nominal Channel Bandwidth.

[00140] In the prior art the PUCCH may occupy only 1 PRB, i.e., 180kHz, in one time-slot, the OCB of which, even with respect to the smallest system bandwidth, 1.4MHz, is still less than 20% and thus does not meet the requirements of ETSI. In

contrast, the enhanced PUCCH may comprise at least two PRBs in the frequency domain at a same time point, and the highest and the lowest frequency occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth. For example, referring still to FIG. 3, the corresponding PRBs of the enhanced PUCCH in the frequency domain comprise one of ten interlaced PRB groups, and the corresponding OCB can be as high as 90%.

[00141] In one embodiment, a listen-before-talk (LBT) procedure may be performed before the enhanced PUCCH transmission, namely, performing a clear channel assessment (CCA) on a channel to be detected to determine whether the channel is available. The channel can be one corresponding to the entire system bandwidth, or one corresponding to the enhanced PUCCH. Only when the detected channel is available and the LBT procedure succeeds can the enhanced PUCCH be used to transmit the uplink signal. The current embodiment can be combined with any embodiment of the uplink transmission method using unlicensed spectrum according to the disclosure. In other embodiments, the LBT procedures may not be performed and the enhanced PUCCH will be used directly to transmit uplink signal.

[00142] Referring now to FIG. 5, an LBT procedure is performed within a preset detection period T1 on the channel to be detected. The preset detection period T1 as shown in the figure is ahead of the corresponding transmission period T2 of the enhanced PUCCH, and T1 and T2 do not overlap. When a length of the corresponding transmission period of the enhanced PUCCH is longer than its time length in the time domain, the preset detection period can be earlier than the corresponding transmission period of the enhanced PUCCH and may partially overlap thereto, or the preset detection period may be contained within the corresponding transmission period of the enhanced PUCCH.

[00143] The LBT procedure can be one-shot, namely, the CCA procedure may be performed on the detected channel for only once, thus if the channel is found idle, the LBT procedure succeeds, otherwise if the channel is found occupied, the LBT procedure fails. The LBT procedure can also be configured with a variable contention window. Specifically, a random number may be selected from the

contention window and the CCA procedure may be repeatedly performed on the channel to be detected within the preset detection period, if duration of the channel as idle is not smaller than the time represented by the random number, the LBT procedure succeeds.

[00144] According to the above embodiment, the LBT procedures can be performed before the enhanced PUCCH is used in the LAA SCell to transmit uplink signal, thus the fair coexistence with other transmission nodes (including Wi-Fi equipment and equipment used in LAA networks deployed by different operators) using the same unlicensed spectrum band can be realized. In addition, if the channel corresponding to the enhanced PUCCH is configured as the channel to be detected, it can, compared with taking the entire system bandwidth as the channel to be detected, narrow the channel bandwidth requiring CCA detection, thus enabling that the occupation of the frequency resources outside of the corresponding channel of the enhanced PUCCH will not affect the CCA results, reducing the failure probability of the LBT procedures, and improving the success probability of the enhanced PUCCH transmission.

[00145] Furthermore, when there is a time interval between after determination the channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, the channel can be used to transmit reservation signal during the time interval to indicate the channel is occupied or will be occupied. For example, referring now to FIG. 6, in which the LBT procedure succeeds at time t_1 and the detected channel is evaluated as available. However, the corresponding transmission starting time of the enhanced PUCCH is time t_2 , namely there would be a time interval between times t_1 and t_2 . Thus, the detected channel may be used to transmit reservation signal during the time interval between the times t_1 and t_2 to indicate the detected channel is occupied or will be occupied.

[00146] The corresponding transmission starting time of the enhanced PUCCH may be the start of the corresponding transmission period of the enhanced PUCCH. Certainly, if the length of the corresponding transmission period of the enhanced PUCCH is longer than the time length of the enhanced PUCCH in the time domain, the corresponding transmission starting time of the enhanced PUCCH can be any time

point in its corresponding transmission period. Typically, the corresponding transmission starting time of the enhanced PUCCH may be the start of part or all of the symbols in the corresponding transmission period of the enhanced PUCCH. Confining the corresponding transmission starting time of the enhanced PUCCH to the starting time of the symbols can reduce the workload of the base station detecting the enhanced PUCCH.

[00147] The reservation signal can be used to occupy the detected channel, to avoid the channel being occupied by other equipment before the start of the transmission period which thus may cause the UE to be unable to transmit data or may cause conflicts, thus further improving the success probability of the enhanced PUCCH transmission.

[00148] The second embodiment of the uplink transmission method using the unlicensed spectrum is derived based on the first embodiment uplink transmission method, and further defines that the enhanced PUCCH is used to transmit uplink signal during the remaining partial sub-frame after an end of downlink transmission which occupied only a part of the sub-frame, wherein the enhanced PUCCH may comprise smaller than one sub-frame while not smaller than one symbol in the time domain.

[00149] Typically, the partial sub-frame occupied by the downlink transmission may comprise a downlink pilot timeslot (DwPTS), whilst the remaining partial sub-frame may comprise a guard period (GP) and an uplink pilot timeslot (UpPTS). Lengths of the DwPTS, GP, and the UpPTS can be configured, but the total length would always be equal to one sub-frame, i.e., 1ms.

[00150] The enhanced PUCCH can be used to transmit uplink signal within the UpPTS, see UE1 shown in FIG. 7; or within the GP, see UE2 shown in FIG. 7; or within a combination of the UpPTS and the GP, see UE3 shown in FIG. 7. It can be concluded that, when the enhanced PUCCH comprise a relatively short time period in the time domain, a sub-frame can be time-multiplexed to the enhanced PUCCH transmissions of multiple UEs, see UE1 and UE2 shown in FIG. 7.

[00151] When the UCI transmitted over the enhanced PUCCH is the HARQ

ACK/NACK, it can be a confirmation message to the downlink information transmitted across a specified number of sub-frames before the current sub-frame, or to the downlink information transmitted over the current sub-frame.

[00152] According to the above embodiment, the enhanced PUCCH can be used to transmit uplink signal during the remaining partial sub-frame after the end of the downlink transmission which occupies only a part of the sub-frame, whilst the PUSCH does not support the transmission during partial sub-frame, thus when the UE uses the enhanced PUCCH to transmit uplink data, it needs not to compete with the PUSCH transmissions of the other intra-cell UEs, which thus can improve the success probability of the PUCCH transmission, and a faster and more reliable UCI transmission can be achieved. Furthermore, the PUCCH, when compared to the PUSCH, involves a small amount of data to be transmitted, and the PUCCH transmission using the remaining partial sub-frame can reduce the PRB over-utilization and thus can improve the spectrum efficiency.

[00153] Thus, when combining the current embodiment with that shown in FIG. 5 to further improve the success probability of the PUCCH transmission, more aggressive LBT parameters can be employed, including longer preset detection period and/or contention windows of a smaller size, for example, the LBT procedure may be initiated immediately after the end of the downlink transmission.

[00154] Certainly, the LBT procedure may not be performed, and the enhanced PUCCH may be used to transmit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value, e.g., 16 μ s, see UE4 shown in FIG. 8; or an uplink reservation signal may be transmitted by the UE right after the downlink transmission in order to occupy the channel with a duration gap no larger than a preset value between the downlink transmission and the uplink reservation signal, and then the enhanced PUCCH may be used to transmit the uplink signal right after the uplink reservation signal, see UE5 shown in FIG. 8.

[00155] In one embodiment, the length of a corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission, so as to ensure the fair co-existence of the enhanced

PUCCH with other transmission nodes, in the case that more aggressive LBT procedure or no LBT procedure is performed before the transmission of enhanced PUCCH to improve the access probability.

[00156] In one embodiment, the downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission. The downlink reservation signal transmission may initiate right after the end of the downlink burst transmission. The downlink burst is used to transmit downlink data or control signaling, whilst the downlink reservation signal is transmitted by the base station, and used to occupy the channel for the later transmission of the enhanced PUCCH by the UE, such that the UE can have more time to switch from the receiving mode to transmitting mode at the communication circuit, or can have more time to generate the corresponding uplink signal, or to align the enhanced PUCCH transmission to the symbol boundary.

[00157] The current embodiment can be combined with any of the above embodiments. When it is combined with the embodiment as shown in FIG. 8, the enhanced PUCCH may be used to transmit the uplink signal right after the downlink reservation signal transmission with a duration gap no larger than a preset value, see UE6 shown in FIG. 9; or an uplink reservation signal may be transmitted by the UE right after the downlink reservation signal transmission with a duration gap no larger than a preset value, and then the enhanced PUCCH may be used to transmit the uplink signal right after the uplink reservation signal transmission, see UE7 shown in FIG. 9.

[00158] Referring now to FIG. 10, which shows a third embodiment of an uplink transmission method using unlicensed spectrum, which is derived based on the first embodiment uplink transmission method and further defines the step S11. The step S11 in the current embodiment may comprise the following sub-steps.

[00159] In the first sub-step S111, a block of complex-valued symbols may be obtained based on the block of bits to be transmitted, and a reference signal sequence may be derived based on the corresponding cyclic shift.

[00160] To be compatible with the PUCCH in the existing standards, the block of complex-valued symbols and the reference signal sequence can be derived by the

same manner as in the existing standards, see more details in 3GPP (3rd Generation Partnership Project) TS (Technical Specification) 36.211 v13.1.0, which is incorporated herein in its entirety. Certainly, the block of complex-valued symbols and the reference signal sequence can also be derived by other methods, for example, based on the existing standards, some steps may be omitted, added, or modified, or completely differentiated steps may be employed.

[00161] In the next sub-step, the block of complex-valued symbols and the reference signal sequence may be mapped to the resource elements (REs) belonging to the enhanced PUCCH.

[00162] An RE is the smallest resource unit used in the uplink transmission, and corresponds to one subcarrier in the frequency domain and one symbol in the time domain. An RE may be defined by a unique sequence index pair (k, l) , where $k = 0, \dots, N_{RB}^{UL} N_{sc}^{RB} - 1$ is the sequence index of a subcarrier in the frequency domain, while $l = 0, \dots, N_{symb}^{UL} - 1$ is the sequence index of a symbol in the time domain.

Wherein, the N_{RB}^{UL} may represent a total number of the PRBs in the uplink bandwidth; N_{sc}^{RB} may represent a number of subcarriers included in one PRB in the frequency domain, the number is 12 in the existing standards; N_{symb}^{UL} may represent a number of SC-FDMA symbols in one uplink time-slot, and for the conventional CP, $N_{symb}^{UL} = 7$, while for the extended CP, $N_{symb}^{UL} = 6$.

[00163] As with the mapping method in the existing standards, the complex-valued symbols in the block of complex-valued symbols first can be multiplied with an amplitude scaling factor, and then be mapped sequentially to the REs to be assigned the block, in increasing order of first the subcarriers indexes and then the symbols indexes. Likewise, the reference signals in the reference signal sequence may also be multiplied with an amplitude scaling factor, and then be mapped sequentially to the REs to be assigned the reference signal sequence, in increasing order of first the subcarriers indexes and then the symbols indexes. If the enhanced PUCCH strides across two time-slots in the time domain, the mapping may be performed in

increasing order of the following dimensions respectively: first the subcarriers indexes, then the symbols indexes, and finally the time-slots indexes (if necessary). The mapping can also be done using other methods, such as in increasing order of first the symbols indexes and then the subcarriers indexes, or in a jumping manner.

[00164] The REs included in the enhanced PUCCH may all be assigned the block of complex-valued symbols or the reference signal sequence, or there may exist at least one RE set to 0. If the enhanced PUCCH comprises multiple REs set to 0, to satisfy the ESTI's requirements on OCB and PSD, the case in which the REs set 0 are located in the same symbol and in the same PRB should be avoided. Furthermore, even when the case cannot be avoided, i.e., the REs set 0 are located in the same symbol and in the same PRB, the PRBs set 0 should not be present at either end of the bandwidth occupied by the enhanced PUCCH.

[00165] In the enhanced PUCCH the REs assigned the block of complex-valued symbols can correspond to the same or different symbols from the REs assigned the reference signal sequence. When the REs assigned the block of complex-valued symbols correspond to the same symbols as the REs assigned the reference signal sequence, they can correspond to the same or different PRBs in the frequency domain.

[00166] Part or all of the block of complex-valued symbols and part or all of the reference signal sequence can be repeatedly mapped to the REs in the enhanced PUCCH. For example, when the enhanced PUCCH correspond to one sub-frame in the time domain, the block of complex-valued symbols and the reference signal sequence can be derived according to the existing standards, and then be mapped to each PRB in the frequency domain, namely, in a same time-slot, each PRB contained in the enhanced PUCCH will carry exactly the same contents.

[00167] If the corresponding PRBs in the frequency domain of the enhanced PUCCH comprise at least one interlaced PRB group, the m index of the legacy PUCCH, which indicates the PRB location of the legacy PUCCH, may be mapped to the index of the assigned interlaced PRB group of the enhanced PUCCH, for example using the same index value.

[00168] In the next sub-step S113, baseband signal may be generated using the REs.

[00169] To be compatible with the PUCCH of the existing standards, the same methods as in the existing standards can be used to generate the baseband signal; other methods can also be used for the generation of baseband signal.

[00170] In the following sub-step S114, the derived baseband signal may be modulated and upconverted to the carrier frequency to obtain the uplink signal.

[00171] To be compatible with the PUCCH of the existing standards, the same methods as in the existing standards can be used to obtain the uplink signal; other methods can also be used for obtaining the uplink signal.

[00172] According to 3GPP TS36.211 v13.1.0, a total of five PUCCH formats are supported, as is shown in Table 1 below.

[00173] Table 1: Supported PUCCH formats

PUCCH format	Modulation scheme	Number of bits per sub-frame, M_{bit}
1	N/A	N/A
1a	BPSK	1
1b	QPSK	2
2	QPSK	20
2a	QPSK+BPSK	21
2b	QPSK+QPSK	22
3	QPSK	48
4	QPSK	$M_{\text{RB}}^{\text{PUCCH4}} \cdot N_{\text{sc}}^{\text{RB}} \cdot (N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}}) \cdot 2$
5	QPSK	$N_{\text{sc}}^{\text{RB}} \cdot (N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}})$

[00174] Hereinafter, examples will be raised and the accompanying drawings will be referenced to illustrate the generation and mapping of the block of complex-valued symbols and the reference signal sequence in various PUCCH formats in an uplink transmission method according to an embodiment.

[00175] Referring now to FIG. 11, there is shown a schematic diagram illustrating the mapping to the enhanced PUCCH when the block of bits to be transmitted is of the

format 1/1a/1b in an uplink transmission method using unlicensed spectrum according to an embodiment. On the right of the figure is a prior art mapping method, where only one slot0 of a sub-frame is drawn for illustration. Whilst on the left of the figure is the mapping method employed in the enhanced PUCCH according to the current embodiment, the enhanced PUCCH comprises two conventional CP symbols in the time domain, where only three PRBs, including the PRB0, PRB1, and PRB2 are drawn for illustration. Note, the numbers 0, 1, and 2 present in the PRB0, PRB1, and PRB2 represent an ascending order of the frequencies of the corresponding PRBs of the enhanced PUCCH in the frequency domain, but not the indexes across the entire system bandwidth. The PRB0, PRB1, and PRB2 can be continuous or non-continuous in the frequency domain. In the figure each grid represents one RE, grids filled by patterns represent REs to which complex-valued symbols are to be mapped, whilst grids not filled represent REs to which reference signals are to be mapped.

[00176] For the format 1/1a/1b, the block of bits to be transmitted $b(0), \dots, b(M_{\text{bit}} - 1)$ can be modulated according to the solution shown in preceding Table 1 to obtain one complex-valued modulation symbol $d(0)$, which can be scrambled by $S(n_s)$, and block-wise spread with a cyclic shift sequence with a length $N_{\text{seq}}^{\text{PUCCH}} = 12$ in frequency domain $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$, and an orthogonal sequence with a length $N_{\text{seq}}^{\text{PUCCH}} = 4$ in time domain $w_{n_{\text{oc}}}^{(\tilde{p})}(i)$, all of which have been explicitly defined in subclause 5.4.1 of [TS 36.211], resulting in the block of complex-valued symbols defined by the following equation.

$$z(m' \cdot N_{\text{SF}}^{\text{PUCCH}} + m \cdot N_{\text{seq}}^{\text{PUCCH}} + n) = S(n_s) \cdot w_{n_{\text{oc}}}^{(\tilde{p})}(m) \cdot y^{(\tilde{p})}(n)$$

where

$$m = 0, \dots, N_{\text{SF}}^{\text{PUCCH}} - 1$$

$$n = 0, \dots, N_{\text{seq}}^{\text{PUCCH}} - 1$$

$$m' = 0, 1$$

[00177] The mapping method for the block of complex-valued symbols as shown in

the figure is similar as in the existing standards, i.e., the complex-valued symbols in the block may first be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power requirement, and then be mapped sequentially to the REs to be assigned the block of complex-valued symbols, in increasing order of first the subcarrier index and then the symbol index and finally the time-slot index (if necessary). In this embodiment, the REs to be assigned the block of complex-valued symbols may comprise all the REs in the first symbol corresponding to the enhanced PUCCH, thus the above mapping method can be simplified to mapping sequentially the complex-valued symbols in the block to all the REs in the corresponding first symbol in increasing order of the index k for the subcarrier.

[00178] According to the existing standards, the reference signal associated with transmission of PUCCH is demodulation reference signal (DMRS).

[00179] Following the standardized generation procedure for PUCCH DMRS sequence for PUCCH format 1, 1a, 1b, 2, 2a, 2b, and 3, the DMRS sequence is

defined by $r_{\text{PUCCH}}^{(\tilde{p})}(m'N_{\text{RS}}^{\text{PUCCH}}M_{\text{sc}}^{\text{RS}} + mM_{\text{sc}}^{\text{RS}} + n) = \frac{1}{\sqrt{P}} \bar{w}^{(\tilde{p})}(m)z(m)r_{u,v}^{(\alpha_{\tilde{p}})}(n),$

$$m = 0, \dots, N_{\text{RS}}^{\text{PUCCH}} - 1$$

where $n = 0, \dots, M_{\text{sc}}^{\text{RS}} - 1$

$$m' = 0, 1$$

and P is the number of antenna ports used for PUCCH transmission. The sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$, the cyclic shift $\alpha_{\tilde{p}}$, the orthogonal sequence $\bar{w}^{(\tilde{p})}(n)$ and $z(m)$ have been explicitly defined in TS 36.211.

[00180] Differing from the prior art, in this embodiment the enhanced PUCCH has only one symbol, i.e., the second symbol as shown in the figure which will be used to transmit the DMRS. The reference signal sequence, i.e., $\{r(j)\}_{j=0,1,\dots,11}$ may be the first 12 of DMRS sequence $r_{\text{PUCCH}}^{(\tilde{p})}(\cdot)$ generated following the standardized

generation procedure, or defined by $r(n) = \frac{1}{\sqrt{P}} r_{u,v}^{(\alpha_{\tilde{p}})}(n)$, where $n = 0, \dots, M_{\text{sc}}^{\text{RS}} - 1$.

The reference signal sequence can be mapped sequentially and cyclically to the REs

to be assigned the reference signal sequence, in increasing order of first the subcarrier index k , and then the symbol index l , and finally the time-slot index (if necessary).

[00181] It is noteworthy that, for a complete mapping of the block of complex-valued symbols, in a same symbol the enhanced PUCCH may correspond to at least 8 PRBs in the frequency domain. If in the same symbol the enhanced PUCCH correspond to more than 8 PRBs in the frequency domain, part of the block of complex-valued symbols can be repeatedly mapped to the redundant REs to improve the reliability, or the redundant REs can be set to 0.

[00182] Referring now to FIG. 12, there is shown a schematic diagram illustrating the mapping to the enhanced PUCCH when the block of bits to be transmitted is of the format 2/2a/2b in an uplink transmission method using unlicensed spectrum according to an embodiment. On the right of the figure is a prior art mapping method, where only one slot0 of a sub-frame is drawn for illustration. Whilst on the left of the figure is the mapping method employed in the enhanced PUCCH according to the current embodiment, the enhanced PUCCH corresponds to two conventional CP symbols in the time domain, where only three PRBs, including the PRB0, PRB1, and PRB2 are drawn for illustration. Note, the numbers 0, 1, and 2 present in the PRB0, PRB1, and PRB2 represent an ascending order of the frequencies of the corresponding PRBs of the enhanced PUCCH in the frequency domain, but not the indexes for the entire system bandwidth. The PRB0, PRB1, and PRB2 can be continuous or non-continuous in the frequency domain. In the figure each grid represents one RE, grids filled by patterns represent REs to which complex-valued symbols are mapped, whilst grids not filled represent REs to which reference signals are mapped.

[00183] For the format 2/2a/2b, the block of bits to be transmitted $b(0), \dots, b(M_{\text{bit}} - 1)$ can be scrambled and modulated according to the solution shown in the preceding Table 1 to obtain ten complex-valued modulation symbols $d(0), \dots, d(9)$, which can be block-wise spread with a cyclic shift sequence with a length $N_{\text{seq}}^{\text{PUCCH}} = 12$ in

frequency domain $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$, which have been explicitly defined in subclause 5.4.2 of TS 36.211, resulting in the block of complex-valued symbols defined by the following equation.

$$\begin{aligned} z(N_{\text{seq}}^{\text{PUCCH}} \cdot n + i) &= \frac{1}{\sqrt{P}} d(n) \cdot r_{u,v}^{(\alpha_{\tilde{p}})}(i) \\ n &= 0, 1, \dots, 9 \\ i &= 0, 1, \dots, N_{\text{sc}}^{\text{RB}} - 1 \end{aligned}$$

[00184] The mapping method for the block of complex-valued symbols as shown in the figure is similar as in the existing standards, i.e., the complex-valued symbols in the block may first be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power requirement, and then be mapped sequentially to the REs to be assigned the block of complex-valued symbols, in increasing order of first the subcarrier index k and then the symbol index l and finally the time-slot index (if necessary). In this embodiment, the REs to be assigned the block of complex-valued symbols may comprise all the REs in the first symbol corresponding to the enhanced PUCCH, thus the above mapping method can be simplified to mapping sequentially the complex-valued symbols in the block to all the REs in the corresponding first symbol in increasing order of the index k for the subcarrier.

[00185] According to the existing standards, the reference signal associated with transmission of PUCCH is demodulation reference signal (DMRS).

[00186] Following the standardized generation procedure for PUCCH DMRS sequence for PUCCH format 1, 1a, 1b, 2, 2a, 2b, and 3, the DMRS sequence is

$$\text{defined by } r_{\text{PUCCH}}^{(\tilde{p})}(m' N_{\text{RS}}^{\text{PUCCH}} M_{\text{sc}}^{\text{RS}} + m M_{\text{sc}}^{\text{RS}} + n) = \frac{1}{\sqrt{P}} \bar{w}^{(\tilde{p})}(m) z(m) r_{u,v}^{(\alpha_{\tilde{p}})}(n),$$

$$m = 0, \dots, N_{\text{RS}}^{\text{PUCCH}} - 1$$

$$\text{where } n = 0, \dots, M_{\text{sc}}^{\text{RS}} - 1$$

$$m' = 0, 1$$

and P is the number of antenna ports used for PUCCH transmission. The sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$, the cyclic shift $\alpha_{\tilde{p}}$, the orthogonal sequence $\bar{w}^{(\tilde{p})}(n)$ and $z(m)$ have been explicitly defined in TS36.211.

[00187] Note, for the format 2a/2b in the existing standards, part of the corresponding reference signal sequence of the second symbol assigned the DMRS (i.e., the fifth symbol in each slot) is multiplied with a complex-valued modulation symbol $d(10)$, and this part of reference signal sequence is referred to as special reference signal sequence. The reference signal sequence, i.e. $\{r(j)\}_{j=0,1,\dots,23}$, may be the first 24 of DMRS sequence $r_{\text{PUCCH}}^{(\tilde{p})}(\cdot)$ generated following the standardized generation procedure, or defined by $r(mM_{\text{sc}}^{\text{RS}} + n) = \frac{1}{\sqrt{P}} z(m) r_{u,v}^{(\alpha_{\tilde{p}})}(n)$, where $m = 0, 1$, $n = 0, \dots, M_{\text{sc}}^{\text{RS}} - 1$, $z(m)$ equals $d(10)$ for $m = 1$, for all other cases, $z(m) = 1$.

[00188] The reference signal sequence may be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power requirement, and then the first 12 of the reference signal sequence $\{r(j)\}_{j=0,1,\dots,11}$ may be mapped sequentially and cyclically to the REs to be assigned the reference signal sequence, in increasing order of the subcarrier index k , the last 12 of the reference signal sequence $\{r(j)\}_{j=12,13,\dots,23}$, i.e. the special reference signal sequence, may be mapped sequentially to the REs corresponding to the PRB1 and the first symbol as shown in the figure in increasing order of the subcarrier index k . In other embodiments, the special reference signal sequence can also be mapped to the REs corresponding to other PRBs and/or other symbols.

[00189] It is noteworthy that, for a complete mapping of the block of complex-valued symbols, in a same symbol the enhanced PUCCH may correspond to at least 10 or 11 PRBs in the frequency domain. If in the same symbol the enhanced PUCCH correspond to more than 11 PRBs in the frequency domain, part of the block of complex-valued symbols can be repeatedly mapped to the redundant REs to improve the reliability, or the redundant REs can be set to 0.

[00190] Referring now to FIG. 13, there is shown a schematic diagram illustrating the mapping to the enhanced PUCCH when the block of bits to be transmitted is of the

format 3 in an uplink transmission method using unlicensed spectrum according to an embodiment. In the figure only 3 PRBs, including the PRB0, PRB1, and PRB 2 in the frequency domain, are drawn. Note, the numbers 0, 1, and 2 present in the PRB0, PRB1, and PRB2 represent merely an ascending order of the frequencies of the corresponding PRBs of the enhanced PUCCH in the frequency domain, but not the indexes for the entire system bandwidth. The PRB0, PRB1, and PRB2 can be continuous or non-continuous in the frequency domain. In the figure each grid may represent one RE, grids filled with 0 may represent REs to be set to 0, grids filled by patterns may represent REs to be mapped with the complex-valued symbols, whilst grids not filled may represent REs to be mapped with the reference signals.

[00191] For the format 3, the block of bits to be transmitted $b(0), \dots, b(M_{\text{bit}} - 1)$ can certainly be processed according to the existing standards, i.e., it may be scrambled, modulated, block-wise spread in time domain, cyclic shifted, and transform precoded, to obtain the block of complex-valued symbols, and then be mapped to the REs in the enhanced PUCCH by the same mapping rules as shown in FIG. 11.

[00192] When multiplexing multiple UEs with PUCCH format 3 in the same RB, the channel response of each RE within this PRB should be ensured to be similar when decoded at the base station. However, such assumption does not hold for the proposed enhanced PUCCH format 3. Thus, the enhanced PUCCH of the format 3 derived by the above method cannot enable code-division multiplexing.

[00193] To enable the code-division multiplexing for different UEs, for format 3, the block of bits to be transmitted $b(0), \dots, b(M_{\text{bit}} - 1)$ may first be scrambled and then modulated according to the solution shown in Table 1, to obtain the complex-valued modulation symbols $d(0), \dots, d(M_{\text{symb}} - 1)$, wherein $M_{\text{symb}} = 2N_{\text{sc}}^{\text{RB}} = 24$. And then the orthogonal sequence $w_{n_{\text{oc},0}}^{(\bar{p})}(i)$ and $w_{n_{\text{oc},1}}^{(\bar{p})}(i)$ may be used for block-wise spread in time domain of the complex-valued modulation symbols $d(0), \dots, d(M_{\text{symb}} - 1)$ to gain the block of complex-valued symbols $\{z(i)\}, i = 0, 1, \dots, (N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}})N_{\text{sc}}^{\text{RB}} - 1$, wherein:

$$z(n \cdot N_{sc}^{RB} + k) = \begin{cases} w_{n_{oc,0}}^{(\bar{n})}(\bar{n}) \cdot e^{j\pi \lfloor n_{cs}^{cell}(n_s, l) / 64 \rfloor / 2} \cdot d(k) & n < N_{SF,0}^{PUCCH} \\ w_{n_{oc,1}}^{(\bar{n})}(\bar{n}) \cdot e^{j\pi \lfloor n_{cs}^{cell}(n_s, l) / 64 \rfloor / 2} \cdot d(N_{sc}^{RB} + k) & \text{otherwise} \end{cases}$$

$$\bar{n} = n \bmod N_{SF,0}^{PUCCH}$$

$$n = 0, \dots, N_{SF,0}^{PUCCH} + N_{SF,1}^{PUCCH} - 1$$

$$k = 0, 1, \dots, N_{sc}^{RB} - 1$$

where $N_{SF,0}^{PUCCH} = N_{SF,1}^{PUCCH} = 5$ for both slots in a sub-frame using normal PUCCH format 3 and $n_s \bmod 2$, $N_{SF,0}^{PUCCH} = 5$, $N_{SF,1}^{PUCCH} = 4$ holds for the first and the second slot, respectively, in a sub-frame using shortened PUCCH format 3. The orthogonal sequences $w_{n_{oc,0}}^{(\bar{n})}(i)$ and $w_{n_{oc,1}}^{(\bar{n})}(i)$ are given by Table 5.4.2A-1 in TS36.211 v13.1.0. And $n_{cs}^{cell}(n_s, l)$ is the cyclic shift value.

[00194] Since the block of complex-valued symbols $\{z(i)\}, i = 0, 1, \dots, (N_{SF,0}^{PUCCH} + N_{SF,1}^{PUCCH})N_{sc}^{RB} - 1$ is arranged according to the sequence of first the frequency domain and then the time domain, it cannot be mapped in increasing order of first the subcarrier index k and then the symbol index l and finally the slot index (if necessary), as in the format 1/1a/1b or 2/2a/2b. As shown in the figure, the REs to be assigned the block of complex-valued symbols are all the REs corresponding to the first symbol in the enhanced PUCCH. The complex-valued symbols in the block may be first multiplied with an amplitude scaling factor β_{PUCCH} in order to conform to the transmit power requirement, and the complex-valued symbols corresponding to the same complex-valued modulation symbol will be mapped sequentially to the REs belonging to the same PRB in increasing order of the subcarrier index, and different complex-valued modulation symbols will be arranged in the frequency domain according to the sequence of $d(0), \dots, d(M_{symb} - 1)$. One PRB in the frequency domain can accommodate the complex-valued symbols for two complex-valued modulation symbols, and the remaining REs will be set to 0, which in the figure includes the 6th and the 12th RE. According to the above principle, it can be known that the complex-valued symbol $z(n \cdot N_{sc}^{RB} + k)$ will be mapped to the

$(6k + \bar{n} + 1)$ RE among all the REs in the first symbol belonging to the enhanced PUCCH in increasing order of the subcarrier index.

[00195] See relevant description of 1/1a/1b referenced to FIG. 11 for details of the generation and mapping of the reference signal sequence.

[00196] It is noteworthy that, for a complete mapping of the block of complex-valued symbols, in a same symbol the enhanced PUCCH may correspond to at least 12 PRBs in the frequency domain. If in the same symbol the enhanced PUCCH correspond to more than 12 PRBs in the frequency domain, part of the block of complex-valued symbols can be repeatedly mapped to the redundant REs to improve the reliability, or the redundant REs can be set to be 0.

[00197] For the format 4, one can refer to TS36.211 5.4.2B to generate the block of complex-valued symbols, refer to TS36.211 5.5 to generate the reference signal sequence, and perform mapping according to the rules described in the corresponding format 1/1a/1b of FIG. 11. Note, the length of the block of complex-valued symbols of the format 4 is not fixed, and it will vary with the bandwidth occupied by the PUCCH format 4. For example, a conventional PUCCH format 4, which occupies one RB and uses the conventional CP, may have a block of complex-valued symbols with a length 144, thus for an enhanced PUCCH, which comprises two symbols in the time domain, and all the REs within one symbol may be assigned the block of complex-valued symbols, whilst all the REs within the other symbol may be assigned the reference signal sequence, in a same symbol the enhanced PUCCH may correspond to at least 12 PRB in the frequency domain.

[00198] For the format 5, one can refer to TS36.211 5.4.2C to generate the block of complex-valued symbols, refer to TS36.211 5.5 to generate the reference signal sequence, and perform mapping according to the rules described in the corresponding format 1/1a/1b of FIG. 11.

[00199] Note, the generation and mapping of the block of complex-valued symbols and the reference signal sequence for the enhanced PUCCH and the various PUCCH formats are for illustration purposes only. In other embodiments, the enhanced

PUCCH can be different, and the generation and mapping methods of the block of complex-valued symbols and the reference signal sequence can also be different.

[00200] The computer simulation results are provided below to evaluate the performance of the proposed enhanced PUCCH, wherein the PUCCH format is 1a/1b, and the enhanced PUCCH comprises an interlaced PRB group having 10 PRBs in the frequency domain, and comprises two symbols in the time domain, where all the REs corresponding to one symbol are assigned the block of complex-valued symbols, whilst all the REs corresponding to the other symbol are assigned the reference signal sequence. The simulation parameters and performance requirements defined in TS36.104 are summarized in Table 2.

[00201] Table 2: Simulation parameters

	Format 1a	Format 1b
Bandwidth	20MHz	20MHz
Propagation conditions and correlation matrix	EPA 5 Low	EPA 5 Low
Number of TX antennas	1	1
Number of RX antennas	2	2
TS36.104 requirement	ACK missed detection probability shall not exceed 1% at SNR -5.1dB	ACK missed detection probability shall not exceed 1% at SNR -4.6dB

[00202] FIG. 14 and FIG. 15 show the ACK missed detection probabilities for format 1a and 1b respectively. For both formats, the proposed enhanced PUCCH can outperform the legacy structure, and has about 2dB or 1.4dB margin gain compared to the standard requirement in TS36.104 respectively.

[00203] FIG. 16 is a flowchart illustrating an assignment method using unlicensed spectrum according to an embodiment. The method can be implemented on a base station. The base station can be connected to a core network and perform wireless communications with the UE, thus providing communication coverage for the

corresponding geographical area. The base station can include, but not limited to, macro base stations, micro base stations, or pico base stations. In some embodiments, a base station can also be interchangeably referred to as a wireless base station, an access point, a Node B, an evolved Node B (eNodeB or eNB), and so on. The embodiment can comprise the following steps.

[00204] In the first step S21, an enhanced physical uplink control channel is assigned to a user equipment (UE).

[00205] The base station may assign through a control signaling the enhanced PUCCH to the UE, wherein the enhanced PUCCH may belong to the unlicensed spectrum, and may comprise at least two physical resource blocks (PRBs) in the frequency domain at a same time point. The corresponding PRBs of the enhanced PUCCH can be continuous or non-continuous in the frequency domain. The UE can generate corresponding uplink signal and use the enhanced PUCCH to transmit the uplink signal.

[00206] The enhanced PUCCH can occupy one sub-frame, i.e., two continuous time-slots, the same as the PUCCH in the existing LTE/LTE-A standards, or can occupy smaller than one sub-frame while not smaller than one symbol. When the enhanced PUCCH includes more than one symbol in the time domain, the PRBs of the enhanced PUCCH in different symbols may be the same or different in the frequency domain. Typically, the symbol is referred to as SC-FDMA symbol. The number of SC-FDMA symbols in one time-slot may depend on a length of the cyclic prefix (CP). For a conventional CP, each time-slot may comprise seven SC-FDMA symbols, whilst for an extended CP, each time-slot may comprise six SC-FDMA symbols.

[00207] According to the above embodiment, by using the enhanced PUCCH which comprise at least two PRBs in the frequency domain at the same time point, the bandwidth occupied by the PUCCH can be effectively increased.

[00208] FIG. 17 illustrates a second embodiment of the assignment method using unlicensed spectrum, which is based on the first embodiment of the assignment method and further comprises the following step before the step S21.

[00209] In a previous step S20, the unlicensed spectrum is divided into multiple interlaced PRB groups.

[00210] The base station may divide part or all of the system bandwidth belonging to the unlicensed spectrum to multiple interlaced PRBs, where each interlaced PRB may comprise at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups may be arranged alternatively in frequency domain. Often, the base station may divide the entire system bandwidth belonging to the unlicensed spectrum to multiple interlaced PRB groups.

[00211] In the following step S21, the base station may assign to the UE an enhanced PUCCH comprising one interlaced PRB group in the frequency domain. The corresponding PRBs of the enhanced PUCCH in the frequency domain may comprise one or more complete interlaced PRB groups, or a part of the one or more complete interlaced PRB groups and of other interlaced PRB groups, and may further comprise one or more PRBs in the unlicensed spectrum that do not belong to any interlaced PRB groups.

[00212] Under the above PSD constraints, given the numbers of the PRBs are the same, the maximum allowed transmission power in the case that the corresponding PRBs of the PUCCH in the frequency domain comprise at least one interlaced PRB group is typically greater than the maximum allowed transmission power when the PUCCH corresponds to continuous PRBs in the frequency domain. Referring to FIG. 4 and the relevant description, the bigger the maximum allowed transmission power, the higher signal power can be used by the UE to transmit uplink signal over the enhanced PUCCH, which can thus ensure a stable transmission of the uplink signal meanwhile enabling that other devices can accurately detect the uplink signal when they perform the clear channel assessment (CCA).

[00213] In one embodiment, the highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth, in order to satisfy the ETSI's requirements on OCB. The present embodiment can be combined with any embodiment of the assignment method using the unlicensed spectrum according to the disclosure.

[00214] In one embodiment, the enhanced PUCCH may comprise less than one sub-frame in the time domain, and its transmission period is located within the remaining partial sub-frame after an end of the downlink transmission which occupies only a part of the sub-frame. The present embodiment can be combined with any embodiment of the assignment method using the unlicensed spectrum according to the disclosure.

[00215] Typically, the partial sub-frame occupied by the downlink transmission may comprise a downlink pilot timeslot (DwPTS), whilst the remaining partial sub-frame may comprise a guard period (GP) and an uplink pilot timeslot (UpPTS). Lengths of the DwPTS, GP, and the UpPTS can be configured, but the total length would always be equal to one sub-frame, i.e., 1ms.

[00216] Referring to FIG. 7, the corresponding transmission period of the enhanced PUCCH can be within the UpPTS, the GP, or a combination of the UpPTS and the GP. The length of the corresponding transmission period of the enhanced PUCCH may be longer than or equal to the time length of the enhanced PUCCH in the time domain.

[00217] In one embodiment, the corresponding transmission period of the enhanced PUCCH may be initiated right after the downlink transmission with a duration gap no larger than a preset value, e.g., 16 μ s.

[00218] In one embodiment, the length of the corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission, so as to ensure the fair co-existence of the enhanced PUCCH with other transmission nodes, in the case that more aggressive LBT procedure or no LBT procedure is performed before the transmission of enhanced PUCCH to improve the access probability.

[00219] In one embodiment, the downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission. The downlink reservation signal transmission may initiate right after the end of the downlink burst transmission. The downlink burst is used to transmit downlink data or control signaling, whilst the downlink reservation signal is transmitted by the base station, and used to occupy the channel for the later transmission of the enhanced PUCCH by

the UE, such that the UE can have more time to switch from the receiving mode to transmitting mode at the communication circuit, or can have more time to generate the corresponding uplink signal, or to align the enhanced PUCCH transmission to the symbol boundary.

[00220] Referring now to FIG. 18, a user equipment (UE) according an embodiment may comprise a generation module 11 and a transmission module 12.

[00221] The generation module 11 may be configured to generate a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH). The enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point.

[00222] The transmission module 12 may be configured to transmit the uplink signal over the enhanced PUCCH.

[00223] The various modules of the current embodiment UE may be configured to execute the corresponding steps of the first embodiment uplink transmission method, as shown in FIG. 2, see FIG. 2 and relevant description for details.

[00224] According to the above embodiment, by using the enhanced PUCCH which comprises at least two PRBs in the frequency domain at the same time point, the bandwidth occupied by the PUCCH can be effectively increased.

[00225] The corresponding PRBs in the frequency domain of the enhanced PUCCH may comprise at least one interlaced PRB group. The at least one interlaced PRB group may comprise at least three non-continuous and equally spaced PRBs in the frequency domain.

[00226] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth, to satisfy the ETSI's requirements on OCB.

[00227] The enhanced PUCCH may occupy smaller than one sub-frame while not smaller than one symbol in time domain.

[00228] The transmission module 12 may be configured to use the enhanced PUCCH to transmit the uplink signal during the remaining partial sub-frame after an end of the downlink transmission which occupies only a part of the sub-frame.

[00229] Typically, the partial sub-frame occupied by the downlink transmission may comprise a downlink pilot timeslot (DwPTS), whilst the remaining partial sub-frame may comprise a guard period (GP) and an uplink pilot timeslot (UpPTS). Lengths of the DwPTS, GP, and the UpPTS can be configured, but the total length would always be equal to one sub-frame, i.e., 1ms.

[00230] The transmission module 12 can also be used to transmit uplink signal over the enhanced PUCCH during the uplink pilot timeslot (UpPTS) in the remaining partial sub-frame, or during the guard period (GP) in the remaining partial sub-frame, or in a combination of the UpPTS and GP.

[00231] The transmission module 12 can also be configured to use the enhanced PUCCH to transmit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

[00232] The transmission module 12 can also be configured to transmit an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value, and use the enhanced PUCCH to transmit the uplink signal right after the uplink reservation signal.

[00233] In one embodiment, the length of a corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission, so as to ensure the fair co-existence of the enhanced PUCCH with other transmission nodes, in the case that more aggressive LBT procedure or no LBT procedure is performed before the transmission of enhanced PUCCH to improve the access probability.

[00234] Referring now to FIG. 19, in one embodiment, the UE may further comprise a selection module 13. The selection module 13 may be configured to select among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

[00235] Referring now to FIG. 20, there is shown a second embodiment of a UE according to the disclosure, which is based on the first embodiment UE and where the generation module 11 comprises a sequencing unit 111, a mapping unit 112, a baseband unit 113, and a modulation unit 114.

[00236] The sequencing unit 111 may be configured to obtain a block of complex-valued symbols based on a block of bits to be transmitted, and obtain a reference signal sequence based on corresponding cyclic shift.

[00237] The mapping unit 112 may be configured to map the block of complex-valued symbols and the reference signal sequence to the resource elements (REs) belonging to the enhanced PUCCH.

[00238] The baseband unit 113 may be configured to generate baseband signal using the REs.

[00239] The modulation unit 114 may be configured to modulate and upconvert the derived baseband signal to the carrier frequency to obtain the uplink signal.

[00240] The various modules of the current embodiment UE may be configured to execute the corresponding steps of the third embodiment uplink transmission method, as shown in FIG. 10, see FIG. 10 and the relevant description for details.

[00241] The mapping unit 112 may be configured to map sequentially the complex-valued symbols in the block to the REs to be assigned the block, in increasing order of first the subcarriers indexes and then the symbols indexes, and map sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence, in increasing order of first the subcarriers indexes and then the symbols indexes.

[00242] The REs included in the enhanced PUCCH may comprise at least two symbols in time domain. The mapping unit 112 may be configured to map the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence may belong to at least two PRBs in the frequency domain.

[00243] Referring now to FIG. 21, there is shown a third embodiment of a UE according to the disclosure, which is based on the first embodiment UE and where the transmission module 12 includes an evaluation unit 121, a transmission unit 122, and a reservation unit 123.

[00244] The evaluation unit 121 may be configured to perform a clear channel

assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel may be one corresponding to the entire system bandwidth or to the enhanced PUCCH.

[00245] The transmission unit 122 may be configured to transmit the uplink signal over the enhanced PUCCH when the detected channel is available.

[00246] The reservation unit 123 may be configured to, when there is a time interval between after determination the channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, use the detected channel to transmit reservation signal during the time interval to indicate the detected channel is occupied or will be occupied.

[00247] The various modules of the current embodiment UE may be configured to execute the corresponding steps of an embodiment uplink transmission method, as shown in FIG. 6, see FIG. 6 and the relevant description for details.

[00248] According to the above embodiment, the LBT procedures can be performed before the enhanced PUCCH is used in the LAA SCell to transmit uplink signal, thus the fair coexistence with other transmission nodes (including Wi-Fi equipment and equipment used in LAA networks deployed by different operators) using the same unlicensed spectrum band can be realized. In addition, if the channel corresponding to the enhanced PUCCH is configured as the channel to be detected, it can, compared with taking the entire system bandwidth as the channel to be detected, narrow the channel bandwidth requiring CCA detection, thus enabling that the occupation of the frequency resources outside of the corresponding channel of the enhanced PUCCH will not affect the CCA results, reducing the failure probability of the LBT procedures, and improving the success probability of the enhanced PUCCH transmission.

[00249] Referring now to FIG. 22, there is shown a block diagram of a fourth embodiment of a UE according to the disclosure. The UE includes a processor 110 and a communication circuit 120 connected to processor 110 via a bus.

[00250] The communication circuit 120 may be configured to transmit and receive data. It is an interface through which the UE communicates with other communication equipment.

[00251] The processor 110 can control operations of the UE, it can also be referred to as a central processing unit (CPU). The processor 110 can be an integrated circuit chip with signal processing capabilities. The processor 110 may also be a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic devices, discrete gates, transistor logic devices, or discrete hardware components. The general purpose processor can be a microprocessor or any conventional processor.

[00252] The UE may further include a memory storage (not shown) used to store the commands and data necessary for operations of the processor 110. The memory storage can also store the data received by the communication circuit 120.

[00253] The processor 110 may be configured to: generate a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH). The enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in the frequency domain at a same time point; and transmit via the communication circuit 120 the uplink signal over the enhanced PUCCH.

[00254] The highest and the lowest frequency of the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[00255] The corresponding PRBs of the enhanced PUCCH in the frequency domain may comprise at least one interlaced PRB group. The at least one interlaced PRB group may comprise at least three non-continuous and equally spaced PRBs in the frequency domain. In one embodiment, the processor 110 may be configured to map the m index of the legacy PUCCH, which indicates the PRB location of the legacy PUCCH, to the index of the assigned interlaced PRB group of the enhanced PUCCH.

[00256] The enhanced PUCCH may occupy smaller than one sub-frame while not smaller than one symbol in time domain.

[00257] The processor 110 may be configured to use the enhanced PUCCH to transmit via the communication circuit 120 the uplink signal during the remaining

partial sub-frame after an end of the downlink transmission which occupies only a part of the sub-frame.

[00258] The processor 110 may be configured to use the enhanced PUCCH to transmit via the communication circuit 120 the uplink signal during an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[00259] The processor 110 may be configured to use the enhanced PUCCH to transmit via the communication circuit 120 the uplink signal during a guard period (GP) in the remaining partial sub-frame.

[00260] The processor 110 may be configured to use the enhanced PUCCH to transmit via the communication circuit 120 the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

[00261] The processor 110 may be configured to transmit via the communication circuit 120 an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value, and use the enhanced PUCCH to transmit via the communication circuit 120 the uplink signal right after the uplink reservation signal.

[00262] The length of a corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission, so as to ensure the fair co-existence of the enhanced PUCCH with other transmission nodes, in the case that more aggressive LBT procedure or no LBT procedure is performed before the transmission of enhanced PUCCH to improve the access probability.

[00263] The processor 110 may be configured to: obtain a block of complex-valued symbols based on a block of bits to be transmitted and a reference signal sequence based on corresponding cyclic shift; map the block of complex-valued symbols and the reference signal sequence to resource elements (REs) occupied by the enhanced PUCCH; generate baseband signal using the REs; and modulate and upconvert the baseband signal to the carrier frequency to obtain the uplink signal.

[00264] The enhanced PUCCH may be of a format 3. The processor 110 may be configured to: scramble and modulate the block of bits to be transmitted to obtain

complex-valued modulation symbols; block-wise spread the complex-valued modulation symbols in time domain to obtain the block of complex-valued symbols.

[00265] The processor 110 may be configured to map sequentially the complex-valued symbols in the block to the REs to be assigned the block, in increasing order of first the subcarriers indexes and then the symbols indexes, and mapping sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence, in increasing order of first the subcarriers indexes and then the symbols indexes.

[00266] The REs included in the enhanced PUCCH may comprise at least two symbols in time domain. The processor 110 may be configured to map the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence may belong to at least two PRBs in the frequency domain.

[00267] The processor 110 may be configured to map part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH that correspond to a same symbol in the time domain.

[00268] The processor 110 may be configured to map repeatedly part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH.

[00269] Of the REs in the enhanced PUCCH at least one RE may be set to 0.

[00270] The processor 110 may be further configured to select among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

[00271] The processor 110 may be configured to: perform through the communication circuit 120 a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel may be one corresponding to the entire system bandwidth or to the enhanced PUCCH; and, when the detected channel is available, use the enhanced PUCCH to transmit the uplink signal via the communication circuit 120.

[00272] The processor 110 may be configured to, when there is a time interval between after determination the channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, use the detected channel to transmit reservation signal during the time interval to indicate the channel is occupied or will be occupied.

[00273] Referring now to FIG. 23, which illustrate a first embodiment of a base station according to the disclosure, comprising an assignment module 21 configured to assign an enhanced physical uplink control channel to a user equipment (UE), such that the UE generates a corresponding uplink signal and transmits it over the enhanced PUCCH, wherein the enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point.

[00274] The various modules of the current embodiment base station may be configured to execute the corresponding steps of the first embodiment assignment method, as shown in FIG. 16, see FIG. 16 and the relevant description for details.

[00275] According to the above embodiment, by using the enhanced PUCCH which comprises at least two PRBs in the frequency domain at the same time point, the bandwidth occupied by the PUCCH can be effectively increased.

[00276] Referring now to FIG. 24, which illustrates a second embodiment of a base station, which is based on the first embodiment base station and further comprises a division module 22.

[00277] The division module 22 may be configured to divide the unlicensed spectrum to multiple interlaced PRBs, where each interlaced PRB may comprise at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups may be arranged alternatively in frequency domain. The assignment module 21 may be configured to assign to the UE an enhanced PUCCH which comprises at least one interlaced PRB group in the frequency domain.

[00278] The various modules of the current embodiment base station may be configured to execute the corresponding steps of the second embodiment assignment method, as shown in FIG. 17; see FIG. 17 and the relevant description for details.

[00279] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth, to satisfy the ETSI's requirements on OCB.

[00280] Further, the enhanced PUCCH may comprise less than one sub-frame in the time domain, and its transmission period may be located within the remaining partial sub-frame after an end of the downlink transmission which occupies only a part of the sub-frame.

[00281] Typically, the partial sub-frame occupied by the downlink transmission may comprise a downlink pilot timeslot (DwPTS), whilst the remaining partial sub-frame may comprise a guard period (GP) and an uplink pilot timeslot (UpPTS). Lengths of the DwPTS, GP, and the UpPTS can be configured, but the total length would always be equal to one sub-frame, i.e., 1ms.

[00282] Referring to FIG. 7, the corresponding transmission period of the enhanced PUCCH can be within the UpPTS, the GP, or within a combination of the UpPTS and the GP. The length of the corresponding transmission period of the enhanced PUCCH may be longer than or equal to the time length of the enhanced PUCCH in the time domain.

[00283] In one embodiment, the corresponding transmission period of the enhanced PUCCH may be initiated right after the downlink transmission with a duration gap no larger than a preset value.

[00284] In one embodiment, the length of the corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission, so as to ensure the fair co-existence of the enhanced PUCCH with other transmission nodes, in the case that more aggressive LBT procedure or no LBT procedure is performed before the transmission of enhanced PUCCH to improve the access probability.

[00285] In one embodiment, the downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission. The downlink reservation signal transmission may initiate after the end of the downlink burst transmission. The downlink burst transmission is used to transmit downlink data or

control signaling, whilst the downlink reservation signal is transmitted by the base station, and used to occupy the channel for the later transmission of the enhanced PUCCH by the UE, such that the UE can have more time to switch from the receiving mode to transmitting mode at the communication circuit, or can have more time to generate the corresponding uplink signal, or to align the enhanced PUCCH transmission to the symbol boundary.

[00286] Referring now to FIG. 25, a third embodiment of a base station may comprise a processor 210 and a transceiver 220. The processor may be connected to the transceiver 220 via a bus.

[00287] The transceiver 220 may be configured to transmit and receive data, which is an interface through which the base station communicates with other communication equipment.

[00288] The processor 210 can control operations of the base station, it can also be referred to as a central processing unit (CPU). The processor 210 can be an integrated circuit chip with signal processing capabilities. The processor 210 may also be a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic devices, discrete gates, transistor logic devices, or discrete hardware components. The general purpose processor can be a microprocessor or any conventional processor.

[00289] The base station may further comprise a memory storage (not shown) used to store the commands and data necessary for operations of the processor 210. The memory storage can also store the data received by the transceiver 220.

[00290] The processor 210 may be configured to assign through the transceiver 220 an enhanced physical uplink control channel to a user equipment (UE), such that the UE can generate a corresponding uplink signal and transmit it over the enhanced PUCCH, wherein the enhanced PUCCH may belong to the unlicensed spectrum and comprise at least two physical resource blocks (PRBs) in frequency domain at a same time point.

[00291] The processor 210 may be further configured to: divide the unlicensed

spectrum to multiple interlaced PRBs, where each interlaced PRB may comprise at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups may be arranged alternatively in frequency domain; and assign via the transceiver 220 the UE an enhanced PUCCH which comprises at least one interlaced PRB group in the frequency domain.

[00292] The highest and the lowest frequency in the frequency domain occupied by the enhanced PUCCH may have a difference not smaller than 80% of the entire system bandwidth.

[00293] The enhanced PUCCH may occupy smaller than one sub-frame while not smaller than one symbol in time domain.

[00294] The corresponding transmission period of the enhanced PUCCH may be located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

[00295] The corresponding transmission period of the enhanced PUCCH may be located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

[00296] The corresponding transmission period of the enhanced PUCCH may be located within a guard period (GP) in the remaining partial sub-frame.

[00297] The corresponding transmission period of the enhanced PUCCH may be initiated right after the downlink transmission with a duration gap no larger than a preset value.

[00298] The length of the corresponding transmission period of the enhanced PUCCH may be counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission, so as to ensure the fair co-existence of the enhanced PUCCH with other transmission nodes, in the case that more aggressive LBT procedure or no LBT procedure is performed before the transmission of enhanced PUCCH to improve the access probability.

[00299] In one embodiment, the downlink transmission may comprise downlink burst transmission and downlink reservation signal transmission. The downlink reservation signal transmission may initiate right after the end of the downlink burst transmission. The downlink burst is used to transmit downlink data or control

signaling, whilst the downlink reservation signal is transmitted by the base station, and used to occupy the channel for the later transmission of the enhanced PUCCH by the UE, such that the UE can have more time to switch from the receiving mode to transmitting mode at the communication circuit, or can have more time to generate the corresponding uplink signal, or to align the enhanced PUCCH transmission to the symbol boundary.

[00300] It should be appreciated that the disclosed UEs, base stations, and methods can also be implemented in other forms. Rather, the base stations and UEs described are merely illustrative, for example, the division of modules or units is only a division based on logic functions, thus in actual implementations there may be other division manners, for example, multiple units or components may be combined or integrated onto another system, or some features may be ignored or not executed. In addition, the displayed or discussed mutual couplings, direct couplings, or communication connections may be achieved through some interfaces, devices, or units, and may be achieved electrically, mechanically or in other forms.

[00301] The separated units as described may or may not be physically separated. Components displayed as units may or may not be physical units, and may reside at one location or may be distributed to multiple networked units. Part or all of the units may be selected, according to actual requirements, to achieve the objectives of the embodiments.

[00302] In addition, various functional units in the disclosure may be integrated into one processing unit, and may be present as various physically separated units, and two or more units may be integrated into one unit. The integrated units may be implemented by hardware, and may also be implemented as software functional units.

[00303] If the integrated units are implemented as software functional units and sold or used as standalone products, they can be stored in a computer readable storage medium. On the basis of such an understanding, the substantial technical solution, or the part which contributes to the prior art, or all or part of the technical solution, of the disclosure, may be embodied as software products. The computer software products can be stored in a storage medium and can include multiple instructions

enabling a computing device (for example, a personal computer, a server, a network device, etc.) or a processor to execute all or part of the steps of the methods as described in various embodiments of the disclosure. The storage medium may include all kinds of medium that can store program codes such as, for example, a USB flash disk, a mobile hard drive, a read-only memory (ROM), a random access memory (RAM), a magnetic disk, or an optical disk.

[00304] The above description is merely some exemplary embodiments of the disclosure, but is not limiting the scope of the disclosure. Any equivalent structures or flow transformations made to the disclosure, or any direct or indirect applications of the disclosure on other related fields, shall all be covered within the protection of the disclosure.

CLAIMS

1. An uplink transmission method using unlicensed spectrum, comprising:
generating a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH), wherein the enhanced PUCCH belongs to the unlicensed spectrum, and occupies at least two physical resource blocks (PRBs) in frequency domain at a same time point; and
using the enhanced PUCCH to transmit the uplink signal.
2. The method according to claim 1, wherein the PRBs included in the frequency domain of the enhanced PUCCH comprises at least one interlaced PRB group, wherein the at least one interlaced PRB group comprises at least three non-continuous and equally spaced PRBs in the frequency domain.
3. The method according to claim 2, wherein the m index of the legacy PUCCH is mapped to the index of the assigned interlaced PRB group of the enhanced PUCCH.
4. The method according to claim 1, wherein a highest and a lowest frequency in the frequency domain occupied by the enhanced PUCCH has a difference not smaller than 80% of entire system bandwidth.
5. The method according to claim 1, wherein the enhanced PUCCH occupies smaller than one sub-frame and no smaller than one symbol in time domain.
6. The method according to claim 5, wherein the step of using the enhanced PUCCH to transmit the uplink signal comprises:
using the enhanced PUCCH to transmit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.
7. The method according to claim 6, wherein the step of using the enhanced PUCCH to transmit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame comprises:
using the enhanced PUCCH to transmit the uplink signal during an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

8. The method according to claim 6, wherein the step of using the enhanced PUCCH to transmit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame comprises:

using the enhanced PUCCH to transmit the uplink signal during guard period (GP) in the remaining partial sub-frame.

9. The method according to claim 6, wherein the step of using the enhanced PUCCH to transmit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame comprises:

using the enhanced PUCCH to transmit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

10. The method according to claim 6, wherein the step of using the enhanced PUCCH to transmit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame comprises:

transmitting an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value; and

using the enhanced PUCCH to transmit the uplink signal right after the uplink reservation signal.

11. The method according to claim 6, wherein the length of a corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

12. The method according to claim 1, wherein the step of generating the uplink signal for the assigned enhanced PUCCH comprises:

obtaining a block of complex-valued symbols based on block of bits to be transmitted, and obtaining a reference signal sequence based on corresponding cyclic shift;

mapping the block of complex-valued symbols and the reference signal sequence to resource elements (REs) occupied by the enhanced PUCCH;

generating baseband signal using the REs; and

modulating and upconverting the baseband signal to carrier frequency to obtain the uplink signal.

13. The method according to claim 12, wherein the enhanced PUCCH is of a format 3; and the step of obtaining the block of complex-valued symbols based on the block of bits to be transmitted comprises:

scrambling and modulating the block of bits to be transmitted to obtain complex-valued modulation symbols; and

block-wise spreading the complex-valued modulation symbols in time domain to obtain the block of complex-valued symbols.

14. The method according to claim 12, wherein the step of mapping the block of complex-valued symbols and the reference signal sequence to resource elements (REs) in the enhanced PUCCH comprises:

mapping sequentially the complex-valued symbols in the block to the REs to be assigned the block of complex-valued symbols in increasing order of first subcarriers indexes and then symbols indexes, and mapping sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence in increasing order of first the subcarrier indexes and then the symbol indexes.

15. The method according to claim 12, wherein the REs in the enhanced PUCCH comprises at least two symbols in the time domain; and the step of mapping the block of complex-valued symbols and the reference signal sequence to resource elements (REs) in the enhanced PUCCH comprises:

mapping the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in the time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence belong to at least two PRBs in the frequency domain.

16. The method according to claim 12, wherein the step of mapping the block of complex-valued symbols and the reference signal sequence to resource elements (REs) in the enhanced PUCCH comprises:

mapping part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH that correspond to a same symbol in the time domain.

17. The method according to claim 12, wherein the step of mapping the block of complex-valued symbols and the reference signal sequence to resource elements (REs) in the enhanced PUCCH comprises:

mapping repeatedly part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH.

18. The method according to claim 12, wherein of the REs in the enhanced PUCCH, at least one RE is set to 0.

19. The method according to claim 1, further comprising, before the step of generating the corresponding uplink signal for the enhanced PUCCH:

selecting among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

20. The method according to claim 1, wherein the step of using the enhanced PUCCH to transmit the uplink signal comprises:

performing a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel is one corresponding to the entire system bandwidth or to the enhanced PUCCH; and

using the enhanced PUCCH to transmit the uplink signal when the detected channel is available.

21. The method according to claim 20, further comprising, before the step of using the enhanced PUCCH to transmit the uplink signal:

when there is a time interval between after determination the detected channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, using the detected channel to transmit reservation signal during the time interval to indicate the detected channel is occupied or will be occupied.

22. An assignment method using unlicensed spectrum, comprising:

assigning an enhanced physical uplink control channel (PUCCH) to a user equipment (UE), such that the UE generates a corresponding uplink signal for the enhanced PUCCH and uses the enhanced PUCCH to transmit the uplink signal,

wherein the enhanced PUCCH belongs to unlicensed spectrum and comprises at least two physical resource blocks (PRBs) in frequency domain at a same time point.

23. The method according to claim 22, further comprising, before the step of assigning the enhanced PUCCH to the UE:

dividing the unlicensed spectrum to a plurality of interlaced PRB groups, where each interlaced PRB group comprises at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups are arranged alternatively in frequency domain; and

the step of assigning the enhanced PUCCH to the UE comprises:

assigning the enhanced PUCCH comprising at least one such interlaced PRB group in the frequency domain to the UE.

24. The method according to claim 22, wherein a highest and a lowest frequency in the frequency domain occupied by the enhanced PUCCH has a difference not smaller than 80% of entire system bandwidth.

25. The method according to claim 22, wherein the enhanced PUCCH occupies smaller than one sub-frame and not smaller than one symbol in time domain.

26. The method according to claim 25, wherein a corresponding transmission period of the enhanced PUCCH is located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

27. The method according to claim 26, wherein the corresponding transmission period of the enhanced PUCCH is located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

28. The method according to claim 26, wherein the corresponding transmission period of the enhanced PUCCH is located within a guard period (GP) in the remaining partial sub-frame.

29. The method according to claim 26, wherein the corresponding transmission period of the enhanced PUCCH is initiated right after the downlink transmission with a duration gap no larger than a preset value.

30. The method according to claim 26, wherein the length of the corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

31. The method according to any one of claims 26-30, wherein the downlink transmission comprises downlink burst transmission and downlink reservation signal transmission, and the downlink reservation signal transmission initiates after an end of the downlink burst transmission.

32. A user equipment (UE), comprising:

a generation module configured to generate an uplink signal for an assigned enhanced physical uplink control channel (PUCCH), wherein the enhanced PUCCH belongs to unlicensed spectrum and comprises at least two physical resource blocks (PRBs) in frequency domain; and

a transmission module configured to transmit the uplink signal over the enhanced PUCCH.

33. The UE according to claim 32, wherein the PRBs included in the frequency domain of the enhanced PUCCH comprise at least one interlaced PRB group, wherein the at least one interlaced PRB group comprises at least three non-continuous and equally spaced PRBs in the frequency domain.

34. The UE according to claim 32, wherein a highest and a lowest frequency of the frequency domain occupied by the enhanced PUCCH has a difference not smaller than 80% of entire system bandwidth.

35. The UE according to claim 32, wherein the enhanced PUCCH occupies smaller than one sub-frame and not smaller than one symbol in time domain.

36. The UE according to claim 35, wherein the transmission module is configured to use the enhanced PUCCH to transmit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

37. The UE according to claim 36, wherein the transmission module is configured to use the enhanced PUCCH to transmit the uplink signal during an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

38. The UE according to claim 36, wherein the transmission module is configured to use the enhanced PUCCH to transmit the uplink signal during guard period (GP) in the remaining partial sub-frame.

39. The UE according to claim 36, wherein the transmission module is configured to use the enhanced PUCCH to transmit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

40. The UE according to claim 36, wherein the transmission module is configured to transmit an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value, and use the enhanced PUCCH to transmit the uplink signal right after the uplink reservation signal.

41. The UE according to claim 36, wherein the length of a corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

42. The UE according to claim 32, wherein the generation module comprises:
a sequencing unit configured to obtain a block of complex-valued symbols based on a block of bits to be transmitted, and obtain a reference signal sequence based on corresponding cyclic shift;

a mapping unit configured to map the block of complex-valued symbols and the reference signal sequence to resource elements (REs) in the enhanced PUCCH;

a baseband unit configured to generate baseband signal using the REs; and

a modulation unit configured to modulate and upconvert the baseband signal to carrier frequency to obtain the uplink signal.

43. The UE according to claim 42, wherein the mapping unit is configured to map sequentially the complex-valued symbols in the block to the REs to be assigned the block of complex-valued symbols in increasing order of first subcarriers indexes and then symbol indexes, and map sequentially the reference signals in the reference signal sequence to the REs to be assigned the reference signal sequence in increasing order of first the subcarriers indexes and then the symbols indexes.

44. The UE according to claim 42, wherein the REs in the enhanced PUCCH comprises at least two symbols in the time domain; and the mapping unit is

configured to map the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in the time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence belong to at least two PRBs in the frequency domain.

45. The UE according to claim 32, further comprising:

a selection module configured to select among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

46. The UE according to claim 32, wherein the transmission module comprises:

an evaluation unit configured to perform a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel is one corresponding to the entire system bandwidth or to the enhanced PUCCH; and

a transmission unit configured to use the enhanced PUCCH to transmit the uplink signal when the detected channel is available.

47. The UE according to claim 46, wherein the transmission module further comprises:

a reservation unit configured to, when there is a time interval between after determination the detected channel is evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, use the detected channel to transmit reservation signal during the time interval to indicate the detected channel is occupied or will be occupied.

48. A base station, comprising:

an assignment module configured to assign an enhanced physical uplink control channel (PUCCH) to a user equipment (UE), such that the UE generates a corresponding uplink signal for the enhanced PUCCH and uses the enhanced PUCCH to transmit the uplink signal, wherein the enhanced PUCCH belongs to unlicensed spectrum and comprises at least two physical resource blocks in frequency domain at a same time point.

49. The base station according to claim 48, further comprising:
a division module configured to divide the unlicensed spectrum to a plurality of interlaced PRB groups, where each interlaced PRB group comprises at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups are arranged alternatively in frequency domain; and
the assignment module is configured to assign an enhanced PUCCH comprising at least one such interlaced PRB group in the frequency domain to the UE.

50. The base station according to claim 48, wherein a highest and a lowest frequency of the frequency domain occupied by the enhanced PUCCH has a difference not smaller than 80% of entire system bandwidth.

51. The base station according to claim 48, wherein the enhanced PUCCH occupies smaller than one sub-frame and not smaller than one symbol in time domain.

52. The base station according to claim 51, wherein a corresponding transmission period of the enhanced PUCCH is located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

53. The base station according to claim 52, wherein the corresponding transmission period of the enhanced PUCCH is located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

54. The base station according to claim 52, wherein the corresponding transmission period of the enhanced PUCCH is located within a guard period (GP) in the remaining partial sub-frame.

55. The base station according to claim 52, wherein the corresponding transmission period of the enhanced PUCCH is initiated right after the downlink transmission with a duration gap no larger than a preset value.

56. The base station according to claim 52, wherein the length of the corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

57. The base station according to any one of claims 52-56, wherein the downlink transmission comprises downlink burst transmission and downlink

reservation signal transmission, and the downlink reservation signal transmission initiates after an end of the downlink burst transmission.

58. A user equipment (UE), comprising a processor and a communication circuit connected to the processor; wherein the processor is configured to:

generate a corresponding uplink signal for an assigned enhanced physical uplink control channel (PUCCH), wherein the enhanced PUCCH belongs to unlicensed spectrum and comprises at least two physical resource blocks (PRBs) in frequency domain at a same time point; and transmit via the communication circuit the uplink signal over the enhanced PUCCH.

59. The UE according to claim 58, wherein a highest and a lowest frequency of the frequency domain occupied by the enhanced PUCCH has a difference not smaller than 80% of entire system bandwidth.

60. The UE according to claim 58, wherein the PRBs included in the frequency domain of the enhanced PUCCH comprises at least one interlaced PRB group, wherein the at least one interlaced PRB group comprises at least three non-continuous and equally spaced PRBs in the frequency domain.

61. The UE according to claim 60, wherein the processor is configured to map the m index of the legacy PUCCH to the index of the assigned interlaced PRB group of the enhanced PUCCH.

62. The UE according to claim 58, wherein the enhanced PUCCH occupies smaller than one sub-frame and not smaller than one symbol in time domain.

63. The UE according to claim 62, wherein the processor is configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal during a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

64. The UE according to claim 63, wherein the processor is configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal during an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

65. The UE according to claim 63, wherein the processor is configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal during a guard period (GP) in the remaining partial sub-frame.

66. The UE according to claim 63, wherein the processor is configured to use the enhanced PUCCH to transmit via the communication circuit the uplink signal right after the downlink transmission with a duration gap no larger than a preset value.

67. The UE according to claim 63, wherein the processor is configured to transmit via the communication circuit an uplink reservation signal right after the downlink transmission with a duration gap no larger than a preset value, and use the enhanced PUCCH to transmit via the communication circuit the uplink signal right after the uplink reservation signal.

68. The UE according to claim 63, wherein the length of a corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

69. The UE according to claim 58, wherein the processor is configured to:
obtain a block of complex-valued symbols based on a block of bits to be transmitted and a reference signal sequence based on corresponding cyclic shift; map the block of complex-valued symbols and the reference signal sequence to resource elements (REs) occupied by the enhanced PUCCH; generate baseband signal using the REs; and modulate and upconvert the baseband signal to carrier frequency to obtain the uplink signal.

70. The UE according to claim 69, wherein the enhanced PUCCH is of a format 3; and the processor is configured to:

scramble and modulate the block of bits to be transmitted to obtain complex-valued modulation symbols; block-wise spread the complex-valued modulation symbols in time domain to obtain the block of complex-valued symbols.

71. The UE according to claim 69, wherein the processor is configured to map sequentially the complex-valued symbols in the block to the REs to be assigned the block of complex-valued symbols in increasing order of first subcarrier indexes and then symbols indexes, and map sequentially the reference signals in the reference

signal sequence to the REs to be assigned the reference signal sequence in increasing order of first the subcarriers indexes and then the symbols indexes.

72. The UE according to claim 69, wherein the REs in the enhanced PUCCH comprises at least two symbols in the time domain; and the processor is configured to map the block of complex-valued symbols and the reference signal sequence to the REs in the enhanced PUCCH that correspond to different symbols in the time domain, respectively, wherein the REs to be assigned the block of complex-valued symbols and the reference signal sequence belong to at least two PRBs in the frequency domain.

73. The UE according to claim 69, wherein the processor is configured to map part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH that correspond to a same symbol in the time domain.

74. The UE according to claim 69, wherein the processor is configured to map repeatedly part or all of the block of complex-valued symbols and part or all of the reference signal sequence to the REs in the enhanced PUCCH.

75. The UE according to claim 69, wherein of the REs in the enhanced PUCCH, at least one RE is set to 0.

76. The UE according to claim 58, wherein the processor is further configured to:

select among a plurality of assigned carriers of the unlicensed spectrum at least one carrier for the enhanced PUCCH.

77. The UE according to claim 58, wherein the processor is configured to:
perform through the communication circuit a clear channel assessment (CCA) on a channel to be detected to determine whether the detected channel is available, wherein the detected channel is one corresponding to the entire system bandwidth or to the enhanced PUCCH; and, when the detected channel is available, use the enhanced PUCCH to transmit the uplink signal.

78. The UE according to claim 77, wherein the processor is further configured to, when there is a time interval between after determination the detected channel is

evaluated as available and before a start of the corresponding transmission period of the enhanced PUCCH, use the detected channel to transmit reservation signal during the time interval to indicate the detected channel is occupied or will be occupied.

79. A base station, comprising a processor and a transceiver connected to the processor; wherein the processor is configured to assigning an enhanced physical uplink control channel (PUCCH) to a user equipment (UE), such that the UE generates a corresponding uplink signal for the enhanced PUCCH and uses the enhanced PUCCH to transmit the uplink signal, wherein the enhanced PUCCH belongs to the unlicensed spectrum and comprises at least two physical resource blocks in frequency domain at a same time point.

80. The base station according to claim 79, wherein the processor is further configured to:

divide the unlicensed spectrum to a plurality of interlaced PRB group, wherein each interlaced PRB group comprises at least three non-continuous and equally spaced PRBs, and the PRBs of different interlaced PRB groups are arranged alternatively in frequency domain; and assign through the transceiver to the UE an enhanced PUCCH which comprises at least one interlaced PRB group in the frequency domain.

81. The base station according to claim 79, wherein a highest and a lowest frequency of the frequency domain occupied by the enhanced PUCCH has a difference not smaller than 80% of entire system bandwidth.

82. The base station according to claim 79, wherein the enhanced PUCCH occupies smaller than one sub-frame and not smaller than one symbol in time domain.

83. The base station according to claim 82, wherein a corresponding transmission period of the enhanced PUCCH is located within a remaining partial sub-frame after an end of downlink transmission which occupies only a part of the sub-frame.

84. The base station according to claim 83, wherein the corresponding transmission period of the enhanced PUCCH is located within an uplink pilot timeslot (UpPTS) in the remaining partial sub-frame.

85. The base station according to claim 83, wherein the corresponding transmission period of the enhanced PUCCH is located within a guard period (GP) in the remaining partial sub-frame.

86. The base station according to claim 83, wherein the corresponding transmission period of the enhanced PUCCH is initiated right after the downlink transmission with a duration gap no larger than a preset value.

87. The base station according to claim 83, wherein the length of the corresponding transmission period of the enhanced PUCCH is counted into the maximum channel occupancy time (MCOT) of the prior downlink transmission.

88. The base station according to any one of claims 83-87, wherein the downlink transmission comprises downlink burst transmission and downlink reservation signal transmission, and the downlink reservation signal transmission initiates after an end of the downlink burst transmission.

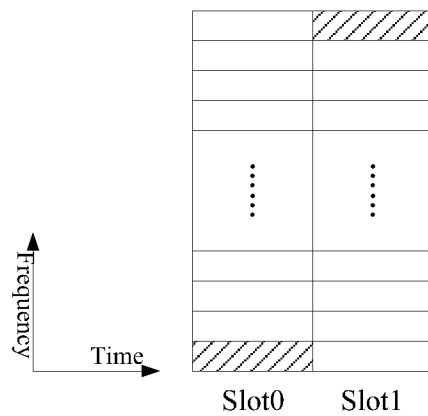


FIG. 1

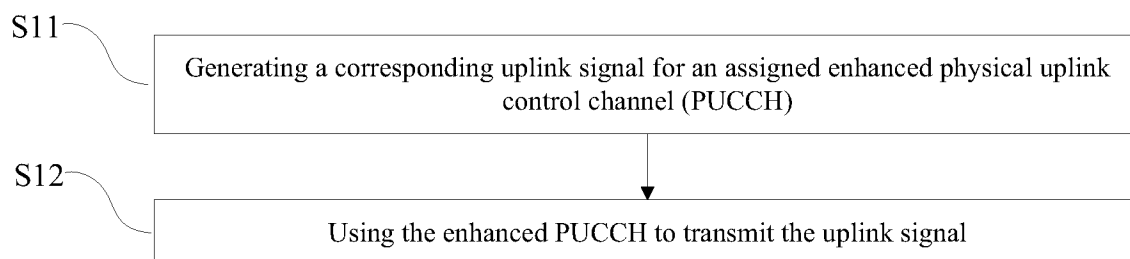


FIG. 2

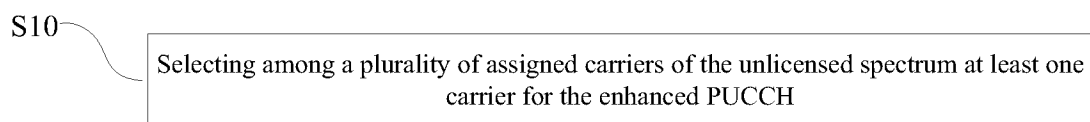


FIG. 3

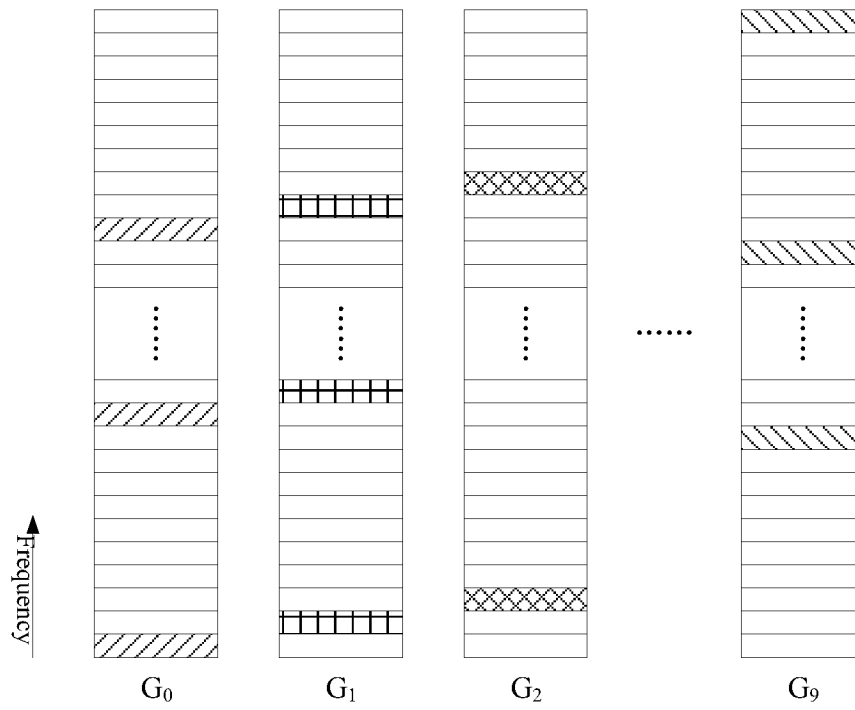


FIG. 4

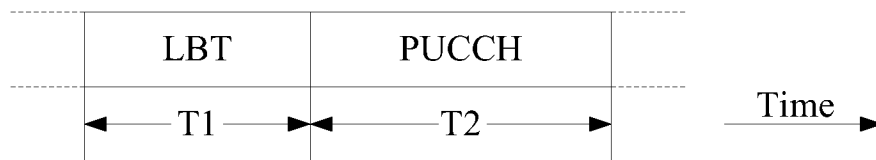


FIG. 5

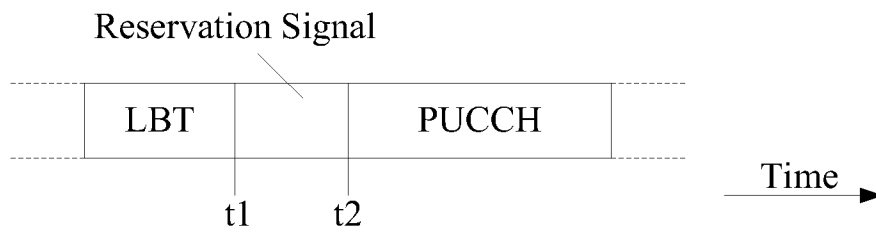


FIG. 6

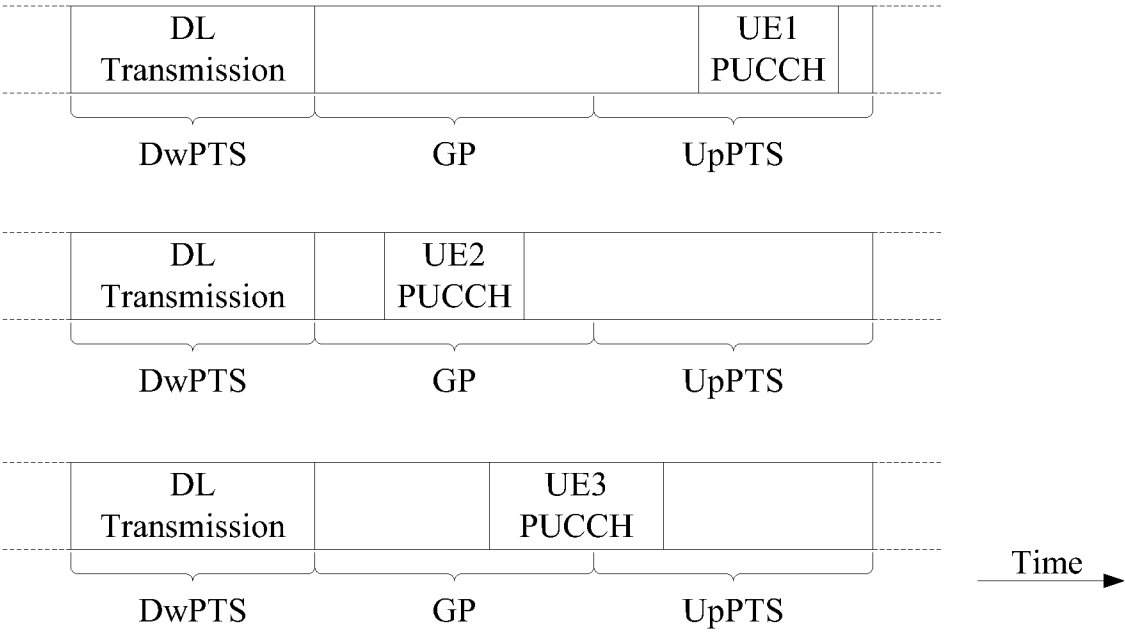


FIG. 7

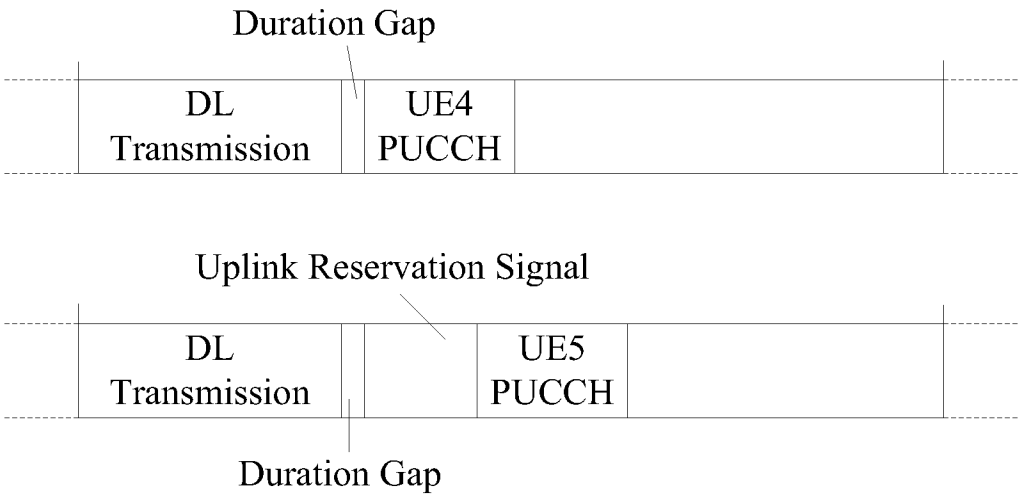


FIG. 8

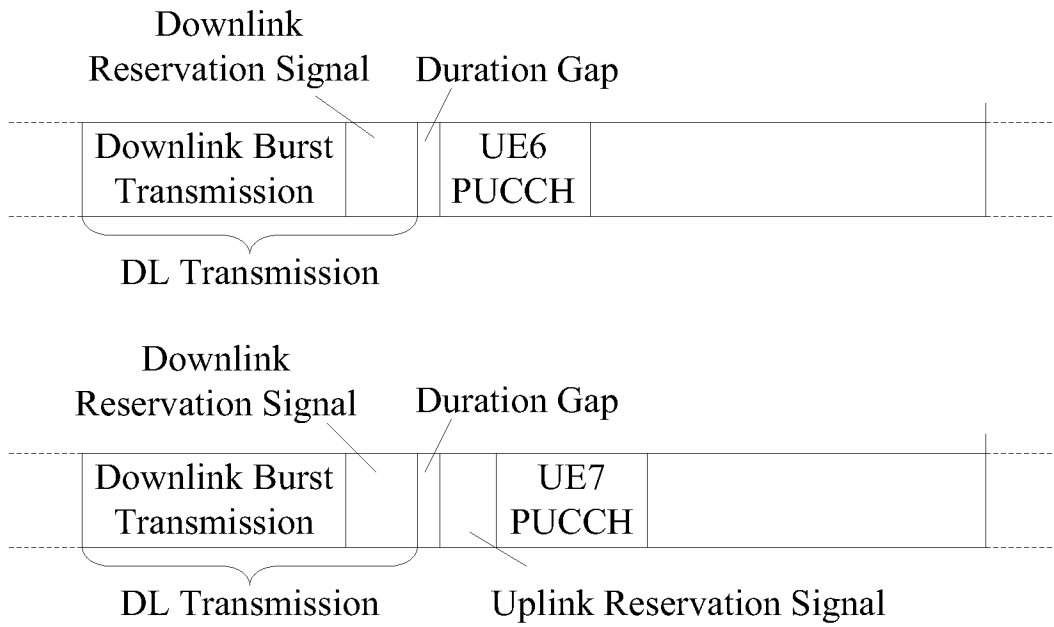


FIG. 9

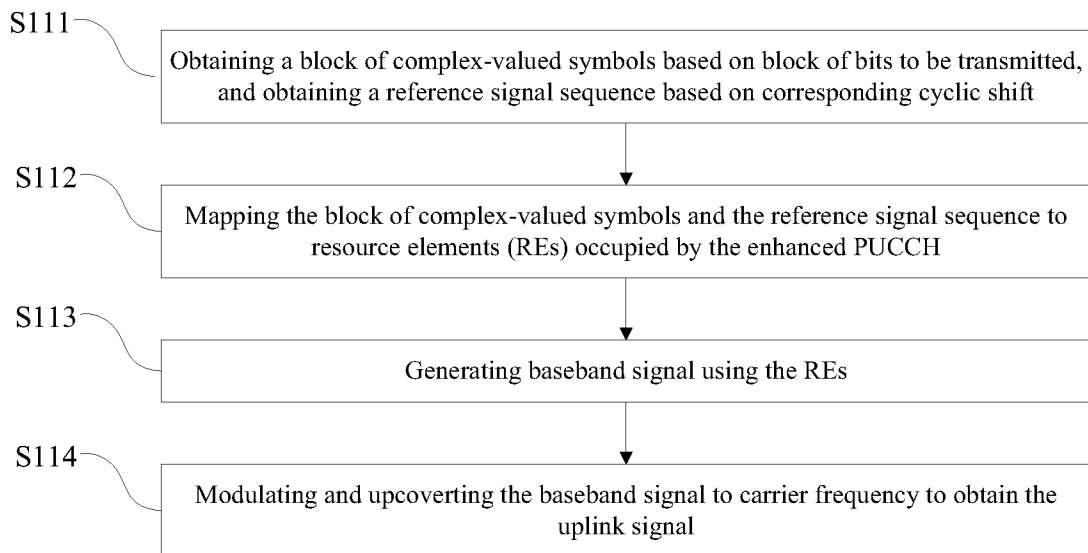


FIG. 10

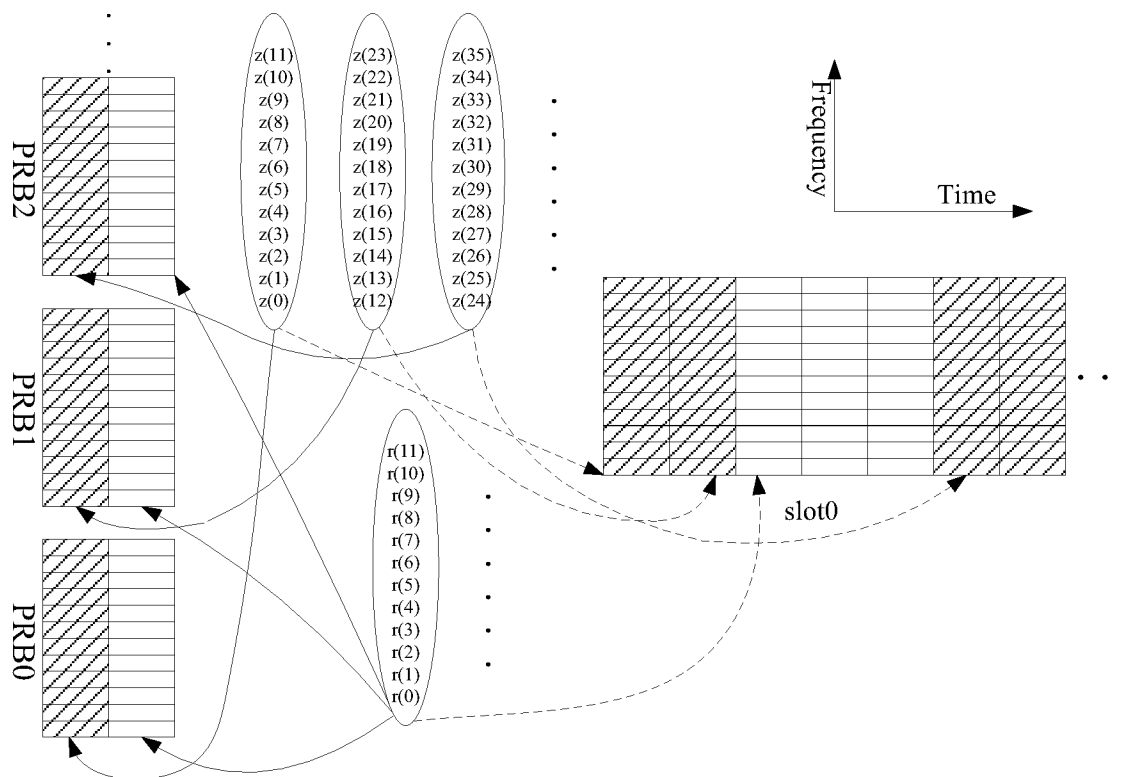


FIG. 11

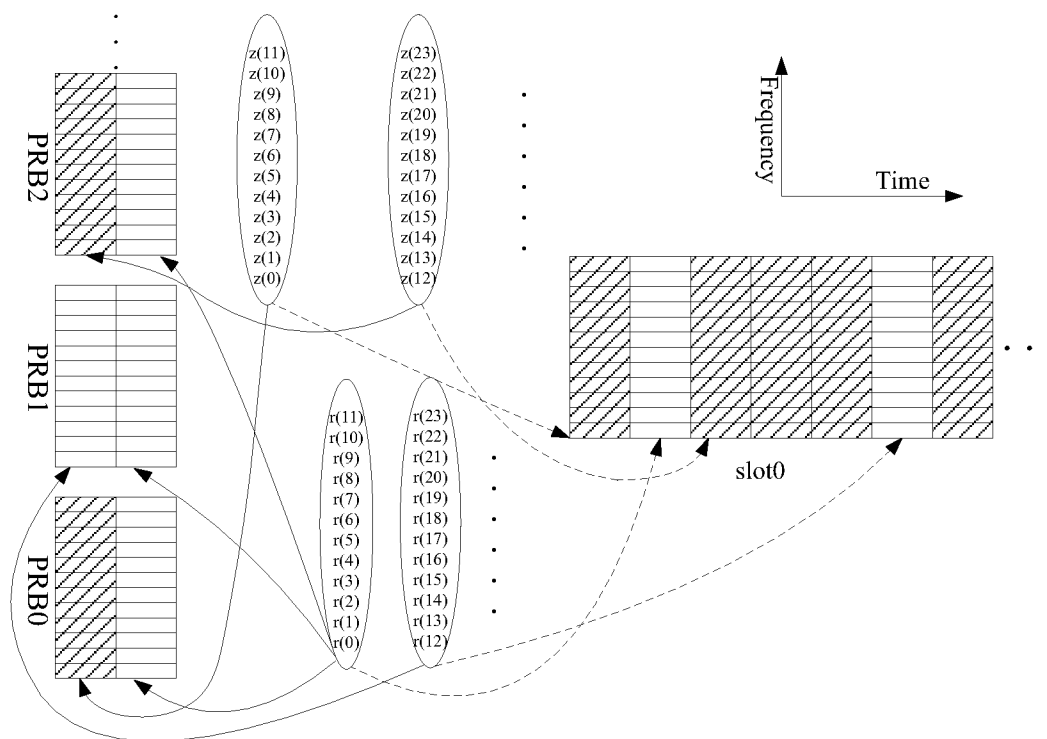


FIG. 12

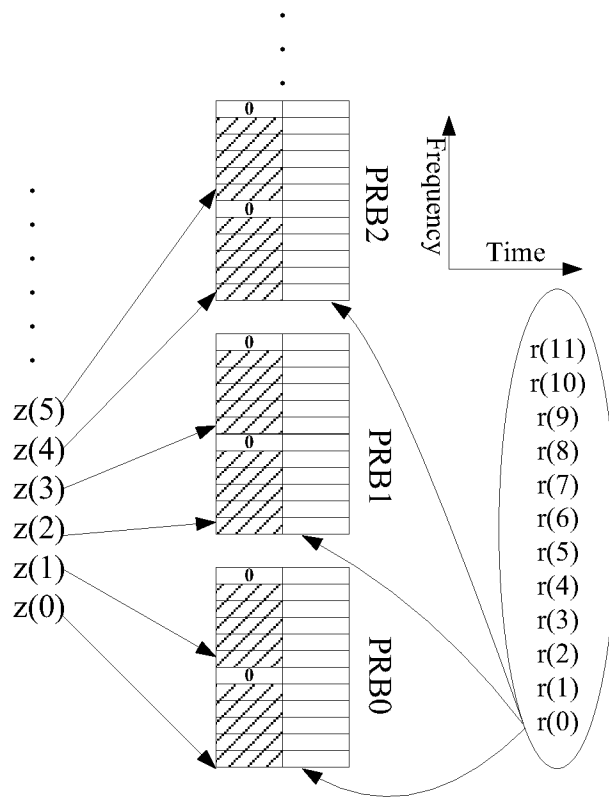


FIG. 13

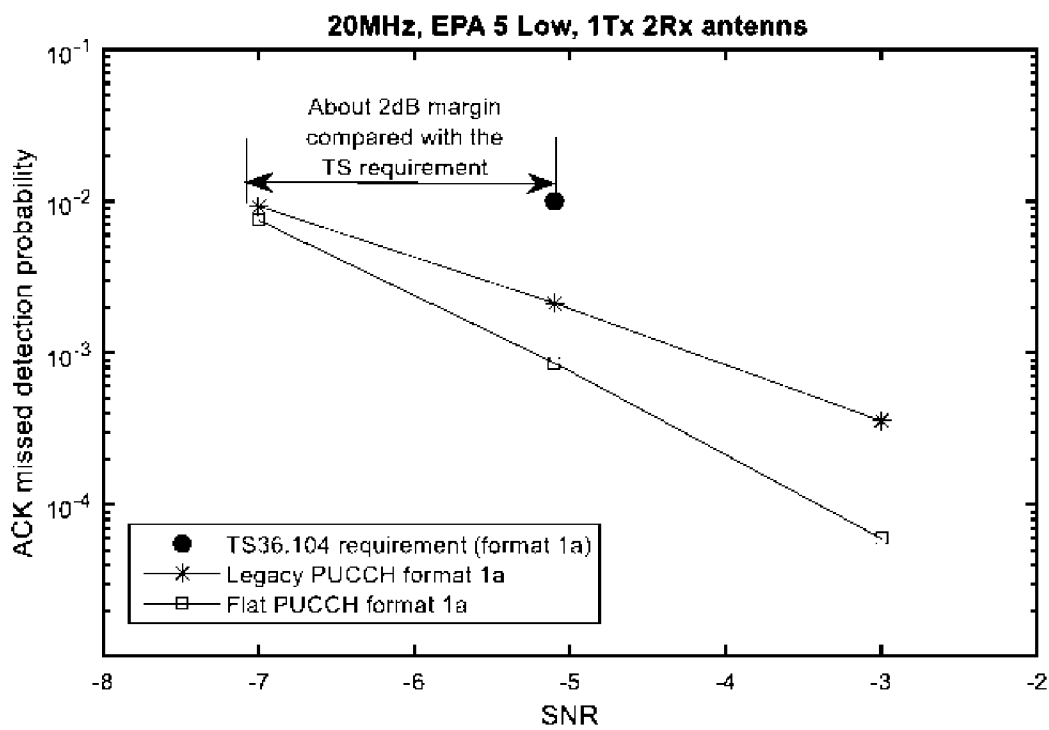


FIG. 14

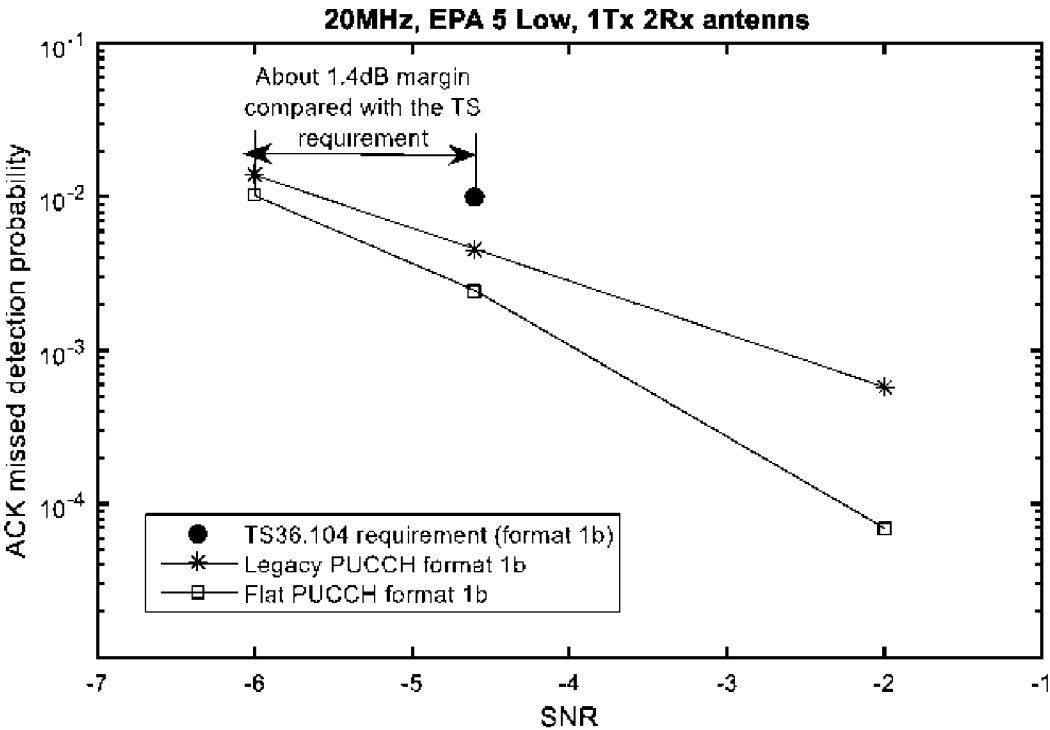


FIG. 15

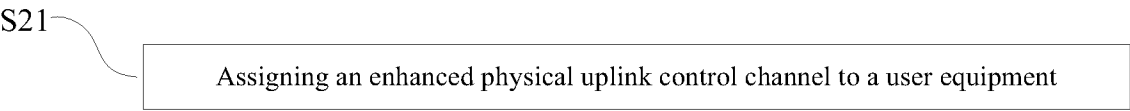


FIG. 16

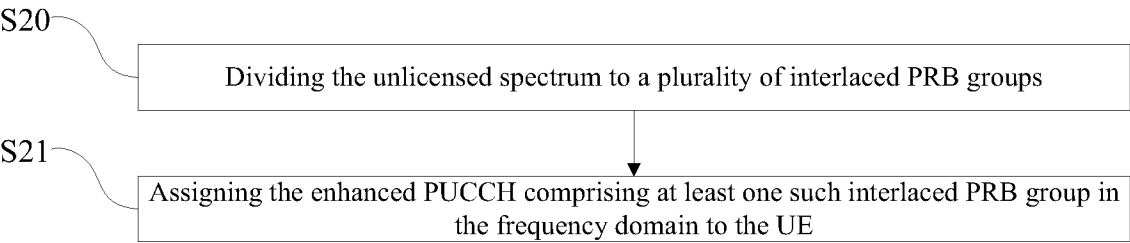


FIG. 17

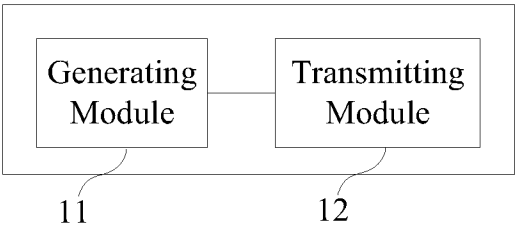


FIG. 18

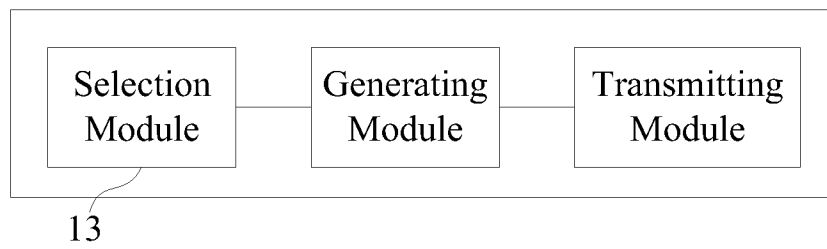


FIG. 19

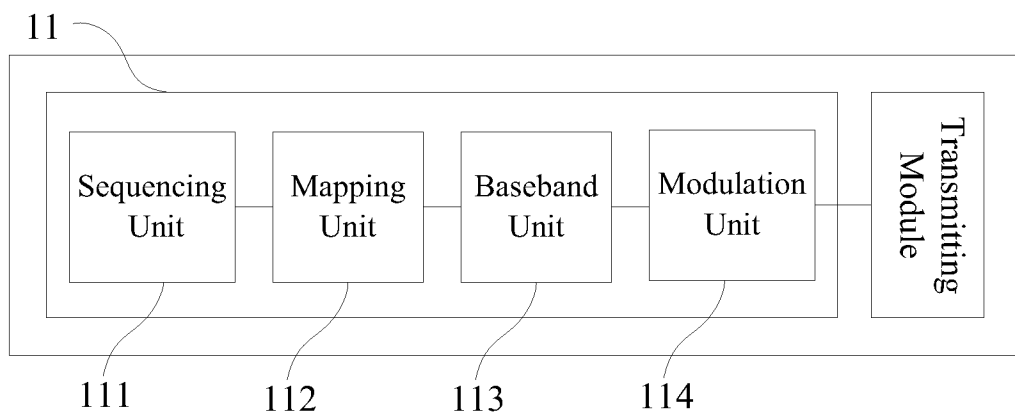


FIG. 20

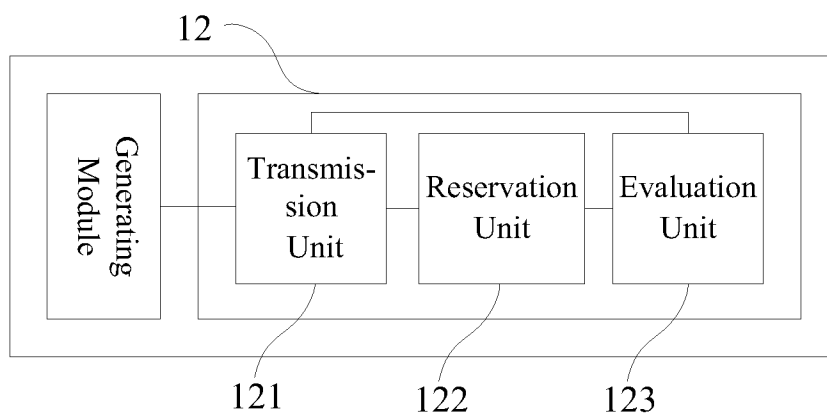


FIG. 21

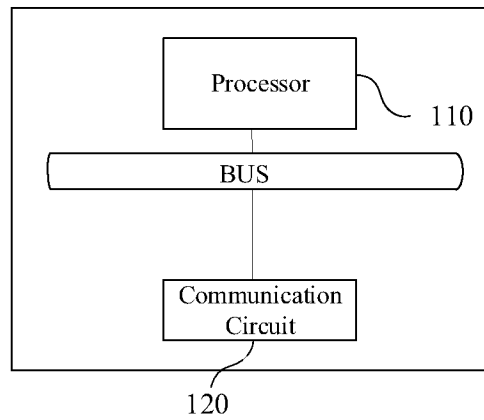


FIG. 22

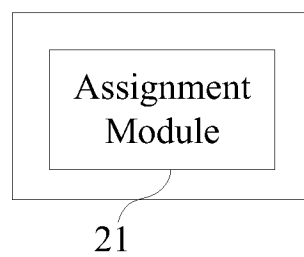


FIG. 23

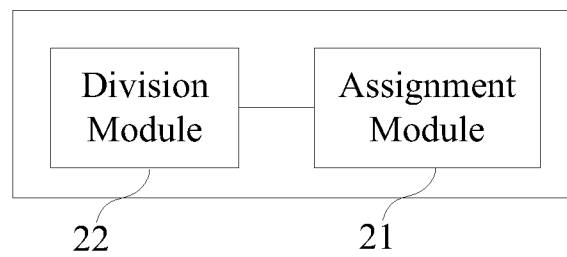


FIG. 24

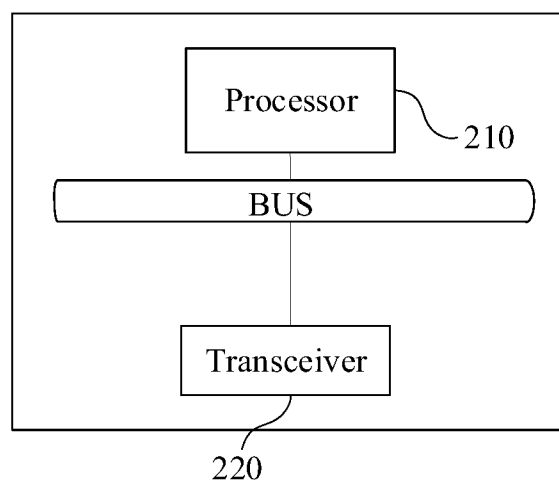


FIG. 25

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/086732**A. CLASSIFICATION OF SUBJECT MATTER**

H04L 5/00(2006.01)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)

H04L; H04W; 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, CNKI, WPI, EPODOC, 3GPP: user equipment, UE, base station, interlace, uplink, PUCCH, physical uplink control channel, transmit+, unlicensed, unauthorized, spectrum

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016057298 A1 (QUALCOMM INCORPORATED) 14 April 2016 (2016-04-14) description, paragraphs [0100]-[0106], figures 1-4	1-88
A	CN 105636206 A (SHANGHAI LANGBO COMMUNICATION TECHNOLOGY COMPANY LIMITED) 01 June 2016 (2016-06-01) the whole document	1-88
A	CN 104901775 A (SHANGHAI LANGBO COMMUNICATION TECHNOLOGY COMPANY LIMITED) 09 September 2015 (2015-09-09) the whole document	1-88
A	WO 2016039681 A1 (TELEFONAKTIEBOLAGET L M ERICSSON) 17 March 2016 (2016-03-17) the whole document	1-88



Further documents are listed in the continuation of Box C.



See patent family annex.

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“E” earlier application or patent but published on or after the international filing date

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“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

15 February 2017

Date of mailing of the international search report

08 March 2017

Name and mailing address of the ISA/CN

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Telephone No. (86-10)62413203

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2016/086732

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2016057298	A1	14 April 2016	US	2016100407	A1	07 April 2016
CN	105636206	A	01 June 2016	None			
CN	104901775	A	09 September 2015	WO	2015135456	A1	17 September 2015
				US	2016374084	A1	22 December 2016
WO	2016039681	A1	17 March 2016	None			