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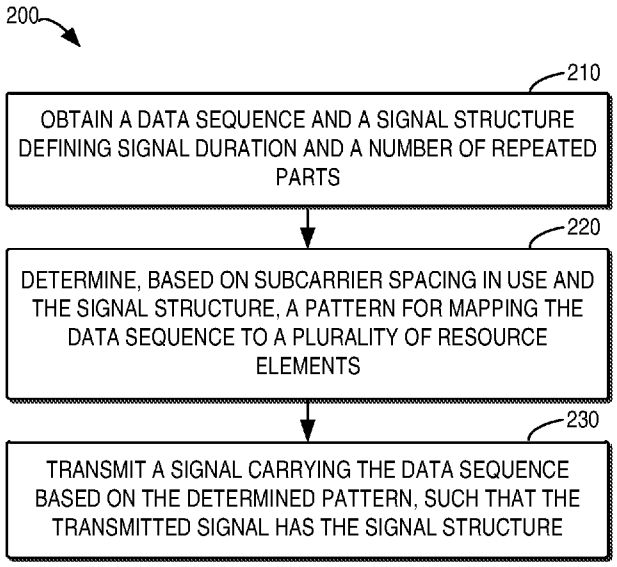


FIG. 2

(57) Abstract: Embodiments of the present disclosure provide methods, devices and computer readable media for communication. In an aspect, a method for communication comprises obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts. The method also comprises determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The method further comprises transmitting a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure. The embodiments of the present disclosure simplify both transmitting operations at a transmitter and receiving operations at a receiver.

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COMMON SIGNAL STRUCTURE FOR MULTIPLE NUMEROLOGIES

FIELD

[0001] Embodiments of the present disclosure generally relate to wireless communication, and in particular, to a common signal structure for multiple numerologies.

BACKGROUND

[0002] Recently, detection of a transmission burst from a network device by a terminal device has been studied. In addition, concerns have been raised on power consumption of the terminal device required for detecting a transmission burst, for example, if the terminal device needs to frequently detect or monitor the physical downlink control channel (PDCCH). The proposals that have been made by contributions regarding these topics include existing New Radio (NR) signals with potential enhancements, a channel such as the PDCCH with potential enhancements, and the 802.11a/802.11ax preamble with potential enhancements. Consensus is not achieved on any of these proposals.

[0003] In the third-generation partnership project (3GPP) radio access network (RAN) 1 #95 meeting, it is agreed that a preamble similar to 802.11a/802.11ax with potential enhancements will be studied as a candidate solution for transmission burst detection in NR on Unlicensed Spectrum (NR-U). For 802.11a/802.11ax, a preamble may be sent by a transmitter before a transmission burst, and a receiver may detect the preamble and get some information of this transmission burst, for example, a length of the transmission burst.

SUMMARY

[0004] In general, example embodiments of the present disclosure provide a solution related to a common signal structure for multiple numerologies.

[0005] In a first aspect, there is provided a method for communication. The method comprises obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts. The method also comprises determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The method further comprises transmitting a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

[0006] In a second aspect, there is provided a method for communication. The method

comprises receiving a signal carrying a data sequence. The method also comprises obtaining a signal structure defining signal duration and a number of repeated parts. The method also comprises determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The method further comprises obtaining the data sequence from the signal based on the determined pattern.

[0007] In a third aspect, there is provided a device. The device comprises at least one processor and at least one memory storing computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the device to obtain a data sequence and a signal structure defining signal duration and a number of repeated parts. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the device to determine, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The at least one memory and the computer program code are further configured to, with the at least one processor, cause the device to transmit a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

[0008] In a fourth aspect, there is provided a device. The device comprises at least one processor and at least one memory storing computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the device to receive a signal carrying a data sequence. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the device to obtain a signal structure defining signal duration and a number of repeated parts. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the device to determine, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The at least one memory and the computer program code are further configured to, with the at least one processor, cause the device to obtain the data sequence from the signal based on the determined pattern.

[0009] In a fifth aspect, there is provided an apparatus for communication. The apparatus comprises means for obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts. The apparatus also comprises means for determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The apparatus further comprises means for transmitting

a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

[0010] In a sixth aspect, there is provided an apparatus for communication. The apparatus comprises means for receiving a signal carrying a data sequence. The apparatus also comprises means for obtaining a signal structure defining signal duration and a number of repeated parts. The apparatus also comprises means for determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. The apparatus further comprises means for obtaining the data sequence from the signal based on the determined pattern.

[0011] In a seventh aspect, there is provided a non-transitory computer readable medium. The computer readable medium comprises program instructions for causing an apparatus to perform the method according to the first aspect.

[0012] In an eighth aspect, there is provided a non-transitory computer readable medium. The computer readable medium comprises program instructions for causing an apparatus to perform the method according to the second aspect.

[0013] It is to be understood that the summary section is not intended to identify key or essential features of embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Through the more detailed description of some embodiments of the present disclosure in the accompanying drawings, the above and other objects, features and advantages of the present disclosure will become more apparent, wherein:

[0015] Fig. 1 is a schematic diagram of a communication environment in which embodiments of the present disclosure can be implemented;

[0016] Fig. 2 shows a flowchart of an example method in accordance with some embodiments of the present disclosure;

[0017] Fig. 3 shows different patterns associated with different subcarrier spacing values for mapping a data sequence to resource elements such that a transmitted signal carrying the data sequence is the same in time domain for the different subcarrier spacing values in accordance with some embodiments of the present disclosure;

[0018] Fig. 4 shows various transmitted or received signals carrying a data sequence associated with different subcarrier spacing values in case that a cyclic prefix is inserted in accordance with some embodiments of the present disclosure;

[0019] Fig. 5 shows that two transmitted signals carrying a data sequence associated with different subcarrier spacing values are the same after linear phase rotation values are applied to the data sequence, in case that a cyclic prefix is inserted in accordance with some embodiments of the present disclosure;

[0020] Fig. 6 shows a flowchart of another example method in accordance with some embodiments of the present disclosure;

[0021] Fig. 7 shows a simulation result of performance of data sequence transmission without a cyclic prefix in accordance with some embodiments of the present disclosure;

[0022] Fig. 8 shows a simulation result of performance of data sequence transmission with a cyclic prefix in accordance with some embodiments of the present disclosure;

[0023] Fig. 9 shows a simulation result of performance of data sequence transmission with a cyclic prefix and a phase rotation in accordance with some embodiments of the present disclosure; and

[0024] Fig. 10 is a simplified block diagram of a device that is suitable for implementing embodiments of the present disclosure.

[0025] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION OF EMBODIMENTS

[0026] Principles of the present disclosure will now be described with reference to some example embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitations as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below.

[0027] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0028] References in the present disclosure to "one embodiment," "an embodiment," "an example embodiment," and the like indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0029] It shall be understood that although the terms "first" and "second" and so on may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

[0030] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "has," "having," "includes" and/or "including," when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0031] The term "circuitry" used herein may refer to one or more or all of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) combinations of hardware circuits and software, such as (as applicable): (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (for example, firmware) for operation, but the software may not be present when it is not needed for operation."

[0032] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0033] As used herein, the term "communication network" refers to a network following any suitable communication standards, such as New Radio (NR), Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT) and so on. In addition, the communication network may also refer to a so called Unlicensed Band Network, Licensed Band Network or MuLTEfire Network, or the like. Furthermore, the communications between a terminal device and a network device in the communication network may be performed according to any suitable generation communication protocols, including, but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the future fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future. Embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will of course also be future type communication technologies and systems with which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned system.

[0034] As used herein, the term "network device" refers to a node in a communication network via which a terminal device accesses the network and receives services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth, depending on the applied terminology and technology.

[0035] The term "terminal device" refers to any end device that may be capable of wireless communication. By way of example rather than limitation, a terminal device may also be

referred to as a communication device, user equipment (UE), a Subscriber Station (SS), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a mobile phone, a cellular phone, a smart phone, voice over IP (VoIP) phones, wireless local loop phones, a tablet, a wearable terminal device, a personal digital assistant (PDA), portable computers, desktop computer, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, vehicle-mounted wireless terminal devices, self-driving cars, wireless endpoints, mobile stations, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), USB dongles, smart devices, wireless customer-premises equipment (CPE), an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms "terminal device," "communication device," "terminal," "user equipment" and "UE" may be used interchangeably.

[0036] Fig. 1 is a schematic diagram of a communication environment 100 in which embodiments of the present disclosure can be implemented. The communication environment 100 may comprise a network device 110, which provides wireless connections for a plurality of terminal devices 120 and 130 within its coverage. The terminal devices 120 and 130 may communicate with the network device 110 via channels such as wireless transmission channels 115 and 125, respectively.

[0037] For transmissions from the network device 110 to the terminal devices 120 and 130, the channels 115 and 125 may be referred to as downlink channels, whereas for transmissions from the terminal devices 120 and 130 to the network device 110, the channels 115 and 125 may alternatively be referred to as uplink channels. Additionally, the terminal devices 120 and 130 may communicate with each other via a device-to-device (D2D) link 135 or communicate with each other or towards the network device 110 via relay type links (not shown in Fig. 1).

[0038] It is to be understood that the number of network devices and the number of terminal devices as shown in Fig. 1 are only for the purpose of illustration without suggesting any limitations. The communication environment 100 may include any suitable number of network devices and any suitable number of terminal devices adapted for implementing

embodiments of the present disclosure. In addition, it would be appreciated that there may be various wireless communications as well as wireline communications (if needed) among these network devices and terminal devices.

[0039] Communications in the communication environment 100 may be implemented according to any proper communication protocol(s), comprising, but not limited to, cellular communication protocols of the first generation (1G), the second generation (2G), the third generation (3G), the fourth generation (4G) and the fifth generation (5G) and on the like, wireless local network communication protocols such as Institute for Electrical and Electronics Engineers (IEEE) 802.11 and the like, and/or any other protocols currently known or to be developed in the future.

[0040] Moreover, the communication may utilize any proper wireless communication technology, comprising but not limited to: Code Divided Multiple Address (CDMA), Frequency Divided Multiple Address (FDMA), Time Divided Multiple Address (TDMA), Frequency Divided Duplexer (FDD), Time Divided Duplexer (TDD), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Divided Multiple Access (OFDMA) and/or any other technologies currently known or to be developed in the future.

[0041] In general, when performing wireless communications with other devices, the network device 110 and the terminal device 120, 130 may transmit a wireless signal based on subcarrier spacing (SCS) in use, which is associated with a type of numerology. For example, if a transmitting device uses two different subcarrier spacing values to transmit a same data sequence, the transmitting device may actually transmit two different signals carrying the same data sequence. In particular, the two signals may be different in signal duration, or the like.

[0042] However, multiple numerologies (such as, SCS 15/30/60 kHz for the frequency range 1 as specified in the 3GPP specifications, and SCS 120/240 kHz for the frequency range 2 as specified in the 3GPP specifications) are supported in a NR system. In case that a preamble is transmitted, if each type of numerology has its own version of preamble, a receiver needs to monitor multiple versions of preamble using multiple Fast Fourier Transform (FFT) sizes simultaneously, which is not possible for a single radio frequency (RF) chain. On the other hand, if all preambles have to be transmitted in a pre-defined numerology, transmitters/receivers need to switch their working numerologies to the pre-defined numerology, which introduces additional delay and complexity. In case that a

data sequence is transmitted, similar issues also exist at both the transmitters and receivers. Therefore, it is beneficial to design a common signal structure which can be transmitted and received regardless of a type of numerology (subcarrier spacing). However, there is no existing solution for providing such a common signal structure for different types of numerology.

[0043] In view of the above, embodiments of the present disclosure provides a solution related to a common signal structure for multiple numerologies. In some embodiments, for transmitting a data sequence, different numerologies may use different comb values in resource elements in frequency domain, and use different numbers of resource elements in time domain, so as to generate signals with a common signal structure in time domain. In some other embodiments, to solve an issue raised by an inserted cyclic prefix, linear phase rotations are applied to elements of the data sequence, which linear phase rotations may vary with an index of a resource element in time domain (also referred to as OFDM symbol-dependent).

[0044] With the embodiments of the present disclosure, both transmitting operations at a transmitter and receiving operations at a receiver are simplified. In particular, transmitters do not need to switch their working numerologies to the pre-defined numerology for performing transmission, and receivers do not need to monitor multiple versions of the data sequence using multiple FFT sizes simultaneously. In the following, some embodiments of the present disclosure will be detailed with reference to Figs. 2-9.

[0045] Fig. 2 shows a flowchart of an example method 200 in accordance with some embodiments of the present disclosure. The method 200 can be implemented at a network device, such as the network device 110 as shown in Fig. 1. Alternatively, the method 200 can also be implemented at a terminal device, such as the terminal devices 120 and 130 as shown in Fig. 1. In other words, the example method 200 may be used for either or both of uplink and downlink transmissions, and may be performed at either or both of a network device and a terminal device in communication with each other. In addition, the example method 200 may also be used for D2D communications between terminal devices. For the purpose of discussion, the method 200 will be described with reference to Fig. 1 and described as being performed by the terminal device 120 without loss of generality.

[0046] At block 210, the terminal device 120 obtains a data sequence for transmitting to the network device 110 or the terminal device 130, for example. In some embodiments, the data

sequence may be a predefined or known sequence including a series of 0 and 1, such as a preamble for performing random access, a preamble before a transmission burst, and various preambles or reference signals as defined in 3GPP specifications. In some other embodiments, elements of the data sequence can be information complex values, which may be modulation symbols generated from data to be transmitted from the terminal device 120 to the network device 110 or the terminal device 130, for example. In some embodiments, the data may include any data that can be transmitted among network devices and terminal devices, including user plane data, control plane data, or the like.

[0047] As described above, in transmitting the data sequence, it is desirable to transmit a signal with a same signal structure regardless of the subcarrier spacing (or the numerology) used by the terminal device 120. For this purpose, at block 210, the terminal device 120 also obtains a signal structure defining signal duration and a number of repeated parts, so that the terminal device 120 may transmit a signal carrying the data sequence based on the signal structure. In particular, the signal transmitted by the terminal device 120 may have the signal duration and the number of repeated parts defined by the signal structure. In some embodiments, the signal structure may be configured and informed to the terminal device 120 by the network device 110. Alternatively, the signal structure may be predefined in the communication environment 100.

[0048] At block 220, the terminal device 120 determines, based on subcarrier spacing in use and the obtained signal structure, a pattern for mapping the data sequence to a plurality of resource elements. In general, before transmitting the data sequence, the terminal device 120 may map the data sequence (that is, its elements) to a plurality of resource elements. In some embodiments, one resource element refers to one subcarrier by one OFDM symbol. Thus, a resource element may be identified by an index of the resource element in frequency domain (for example, an index of the subcarrier) and an index of the resource element in time domain (for example, an index of the OFDM symbol).

[0049] For mapping the data sequence to a plurality of resource elements, the terminal device 120 determines which resource elements the data sequence are mapped to. The pattern for mapping the data sequence to the plurality of resource elements may determine the signal structure of the signal actually transmitted by the terminal device 120. Therefore, in order to transmit a signal with a same signal structure regardless of the subcarrier spacing (or the numerology) in use, the terminal device 120 may employ different patterns associated with different subcarrier spacing values. This is further detailed with reference to an

example as depicted in Fig. 3.

[0050] Fig. 3 shows different patterns 310, 320, and 330 associated with different subcarrier spacing values for mapping a data sequence to resource elements such that a transmitted signal 340 carrying the data sequence is the same in time domain for the different subcarrier spacing values in accordance with some embodiments of the present disclosure. In the example of Fig. 3, it is assumed that a data sequence {a, b, c, d} is transmitted by the terminal device 120 and mapped to the resource elements. Although a data sequence of a particular length (four) is shown herein for example, it is understood that embodiments of the present disclosure may be equally applicable to data sequence of any suitable length. Without loss of generality, a horizontal direction refers to time domain and a vertical direction refers to frequency domain.

[0051] The example pattern 310 is associated with a subcarrier spacing value of 15 kHz, and a resource element 312 is a subcarrier of 15 kHz in frequency domain by about 66.7 microseconds (μs) in time domain. The example pattern 320 is associated with a subcarrier spacing value of 30 kHz, and a resource element 322 is a subcarrier of 30 kHz in frequency domain by about 33.3 μs in time domain. The example pattern 330 is associated with a subcarrier spacing value of 60 kHz, and a resource element 332 is a subcarrier of 60 kHz in frequency domain by about 16.7 μs in time domain.

[0052] As depicted, if the terminal device 120 uses a subcarrier spacing value of 15 kHz, the elements "a," "b," "c," and, "d" of the data sequence are mapped to the resource elements 312, 314, 316, and 318, respectively, and other resource elements are null. If the terminal device 120 uses a subcarrier spacing value of 30 kHz, the element "a" is mapped to two contiguous resource elements in time domain including the resource element 322, the element "b" is mapped to two contiguous resource elements in time domain including the resource element 324, the element "c" is mapped to two contiguous resource elements in time domain including the resource element 326, and the element "d" is mapped to two contiguous resource elements in time domain including the resource element 328. Other resource elements are null.

[0053] If the terminal device 120 uses a subcarrier spacing value of 60 kHz, the element "a" is mapped to four contiguous resource elements in time domain including the resource element 332, the element "b" is mapped to four contiguous resource elements in time domain including the resource element 334, the element "c" is mapped to four contiguous resource elements in time domain including the resource element 336, and the element "d" is mapped

to four contiguous resource elements in time domain including the resource element 338.

[0054] In other words, for a subcarrier spacing value of 15 kHz, a distance (also referred to as a comb value) between the centers of two successive used resources elements is 4 subcarriers in frequency domain, and the data sequence is to be transmitted once in time domain. For a subcarrier spacing value of 30 kHz, a distance between the centers of two successive used resources elements is 2 subcarriers in frequency domain, and the data sequence is to be transmitted twice in time domain. For a subcarrier spacing value of 60 kHz, a distance between the centers of two successive used resources elements is 1 subcarrier in frequency domain, and the data sequence is to be transmitted four times in time domain. In this way, after Inverse Fast Fourier Transform (IFFT), the signals in time domain transmitted by the terminal device 120 using the three numerologies are the same signal 340, which includes four same repeated parts 342, 344, 346, and 348.

[0055] It is understood that the specific patterns 310, 320, 330 and the specific signal structure of the signal 340 as shown in Fig. 1 are only for the purpose of illustration without suggesting any limitations. In other embodiments, the signal 340 may have any suitable signal duration and any suitable number of repeated parts, and thus the patterns 310, 320, 330 may have corresponding comb values in frequency domain and corresponding numbers of resource elements in time domain. In addition, it would be appreciated that the specific values of subcarrier spacing are only examples without any limitations. In other embodiments, the subcarrier spacing in use may be any suitable value.

[0056] Therefore, in determining the mapping pattern, the terminal device 120 may select a predetermined pattern associated with the subcarrier spacing in use for generating the intended signal. In some other embodiments, in determining the mapping pattern, the terminal device 120 may separately determine the comb value in frequency domain and the number of resource elements in time domain. Therefore, the terminal device 120 may determine, based on the subcarrier spacing in use and the defined number of repeated parts of the signal structure, a distance between two successive resource elements in frequency domain for transmitting the signal carrying the data sequence.

[0057] As an example, if the terminal device 120 uses a subcarrier spacing value of 15 kHz, the terminal device 120 may determine the distance as four subcarriers based on the number 4 of the repeated parts and the 15 kHz subcarrier spacing. As another example, if the terminal device 120 uses a subcarrier spacing value of 30 kHz, the terminal device 120 may determine

the distance as two subcarriers based on the number 4 of the repeated parts and the 30 kHz subcarrier spacing. As a further example, if the terminal device 120 uses a subcarrier spacing value of 60 kHz, the terminal device 120 may determine the distance as one subcarrier based on the number 4 of the repeated parts and the 60 kHz subcarrier spacing.

[0058] In time domain, as schematically depicted in Fig. 3, different subcarrier spacing values correspond to different time lengths of one resource element, such as, one OFDM symbol. This means that the terminal device 120 may need to use different numbers of contiguous resource elements in time domain for transmitting the signal 340 with the defined signal duration, in case of different subcarrier spacing values. Accordingly, in some embodiments, in determining the pattern for mapping the data sequence to a plurality of resource elements, the terminal device 120 may determine a time length of each of the plurality of resource elements based on the subcarrier spacing in use. For example, for subcarrier spacing values of 15 kHz, 30 kHz, and 60 kHz, the terminal device 120 determines a time length of 66.7 μs, 33.3 μs, and 16.7 μs, respectively.

[0059] Then, the terminal device 120 may determine, based on the time length and the signal duration of the signal 340, a number of contiguous resource elements in time domain for transmitting the signal. In the example of Fig. 3, it is assumed that the defined signal duration of the signal 340 is 66.7μm. For subcarrier spacing values of 15 kHz (one OFDM symbol of 66.7 μs), 30 kHz (one OFDM symbol of 33.3 μs), and 60 kHz (one OFDM symbol of 16.7 μs), the terminal device 120 determines the number of contiguous resource elements in time domain as one, two, and four, respectively. Through determining the comb value in frequency domain and the number of resource elements in time domain in a separate manner, the terminal device 120 may determine the mapping pattern more flexibly.

[0060] Referring back to Fig. 2, at block 230, with the determined pattern for mapping the data sequence to a plurality of resource elements, the terminal device 120 transmits a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure. As described above, the mapping pattern is determined according to the signal structure, and thus the transmitted signal based on the mapping pattern conforms to the desired signal structure. In this way, even if the terminal device 120 uses different subcarrier spacing values to transmit the data sequence, the transmitted signal carrying the data sequence remains unchanged.

[0061] As indicated above, in some embodiments, the terminal device 120 transmits the data

sequence using a plurality of contiguous resource elements in time domain. That is, the terminal device 120 transmits the data sequence in time domain for a plurality of times. For every transmission, the terminal device 120 may map the data sequence to the determined resource elements in frequency domain (for example, subcarriers), perform IFFT on the mapped data sequence, and then transmit the transformed data sequence in time domain. Transmitting the data sequence for the plurality of times constitutes the desired signal with the intended signal structure.

[0062] In some embodiments, the signal structure may include a cyclic prefix, for example, each resource element in time domain (such as OFDM symbol) in the signal structure may have a respective cyclic prefix. In this event, the transmitted signals using different subcarrier spacing values are not the same, and a signal transmitted using one subcarrier spacing value cannot be correctly received using another subcarrier spacing value without interference. This is further explained with reference to Fig. 4.

[0063] Fig. 4 shows various transmitted or received signals 410, 420, 430, and 440 carrying a data sequence associated with different subcarrier spacing values in case that a cyclic prefix is inserted in accordance with some embodiments of the present disclosure. In particular, Fig. 4 depicts a signal 410 transmitted with a subcarrier spacing value of 15 kHz, a signal 420 received with a subcarrier spacing value of 60 kHz, a signal 430 transmitted with a subcarrier spacing value of 60 kHz, and a signal 440 received with a subcarrier spacing value of 15 kHz.

[0064] As shown, the signals 410 and 440 have only one OFDM symbol (OS) and respective associated cyclic prefixes 412 and 442. In contrast, the signals 420 and 430 each have four OFDM symbols, and thus have four associated cyclic prefixes 422, 424, 426, 428 and 432, 434, 436, 438, respectively. Due to the difference in cyclic prefixes under different subcarrier spacing values, if the signal 410 transmitted with a subcarrier spacing value of 15 kHz is received with a subcarrier spacing value of 60 kHz, the data sequence cannot be correctly extracted from the signal 410. Likewise, if the signal 430 transmitted with a subcarrier spacing value of 60 kHz is received with a subcarrier spacing value of 15 kHz, the data sequence also cannot be correctly extracted from the signal 430. To solve this issue caused by the inserted cyclic prefix, a common signal structure with a cyclic prefix in time domain may be defined for all values of subcarrier spacing, as further detailed in Fig. 5.

[0065] Fig. 5 shows that two transmitted signals 410 and 510 carrying a data sequence associated with different subcarrier spacing values are the same after linear phase rotation

values are applied to the data sequence, in case that a cyclic prefix is inserted in accordance with some embodiments of the present disclosure. In the example of Fig. 5, the signal 410 is normally generated using a subcarrier spacing of 15 kHz and has the common signal structure with a cyclic prefix 412 in time domain.

[0066] If other subcarrier spacing values (such as, 30 or 60 kHz) are in use, proper linear phase rotations are applied to elements of the data sequence in frequency domain for each resource element in time domain (for example, OFDM symbol), in order to make the normally generated signal in time domain is the same as the signal 410 having the common signal structure with a cyclic prefix. The term "linear" means that the applied phase rotation value is linearly changed for different elements of the data sequence. In addition, the linear phase rotations may vary with an index of a resource element in time domain, also referred to as OS-dependent. Correspondingly, in receiving the data sequence using other subcarrier spacing values (such as, 30/60 kHz), the corresponding linear phase rotations in a reverse direction are applied to the received complex values associated with the data sequence for combining.

[0067] Accordingly, in some embodiments, if the terminal device 120 determines that the intended signal structure comprises a cyclic prefix, for each of the contiguous resource elements in time domain for transmitting the signal carrying the data sequence, the terminal device 120 may apply linear phase rotation values to a plurality of elements of the data sequence before mapping the data sequence to the plurality of resource elements, such that the actually transmitted signal has the signal structure. In some embodiments, each of the phase rotation values may be determined based on the desired signal structure, the subcarrier spacing in use, an index of the resource element in frequency domain, an index of the resource element in time domain, or the like, and any combination thereof.

[0068] Fig. 6 shows a flowchart of another example method 600 in accordance with some embodiments of the present disclosure. The method 600 can be implemented at a network device, such as the network device 110 as shown in Fig. 1. Alternatively, the method 600 can also be implemented at a terminal device, such as the terminal devices 120 and 130 as shown in Fig. 1. In other words, the example method 600 may be used for either or both of uplink and downlink transmissions, and may be performed at either or both of a network device and a terminal device in communication with each other. In addition, the example method 600 may also be used for D2D communications between terminal devices. For the purpose of discussion, the method 600 will be described with reference to Fig. 1 and

described as being performed by the network device 110 without loss of generality.

[0069] At block 610, the network device 110 receives a signal carrying a data sequence. In some embodiments, the signal is transmitted by the terminal device 120 according to the method 200 as described with reference to Fig. 2.

[0070] At block 620, the network device 110 obtains a signal structure defining signal duration and a number of repeated parts. In some embodiments, the signal structure may be configured by the network device 110 or another network device. Alternatively, the signal structure may be predefined in the communication environment 100.

[0071] At block 630, the network device 110 determines, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements. In some embodiments, the network device 110 may determines the pattern in an analogous manner to that described with reference to Fig. 2.

[0072] In some embodiments, the network device 110 may determine, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal. In some embodiments, the network device 110 may determine a time length of each of the plurality of resource elements based on the subcarrier spacing. Then, the network device 110 may determine, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

[0073] With the determined pattern, the network device 110 may determine which resource elements the elements of the data sequence are mapped to, according to the subcarrier spacing used by the network device 110. Thus, at block 640, the network device 110 may obtain the data sequence from the signal based on the determined pattern.

[0074] In some embodiments, the network device 110 may determine whether a phase rotation is needed for obtaining the data sequence, based on the signal structure and the subcarrier spacing. For example, if the time length of one resource element based on the subcarrier spacing in use is different from the signal duration of the desired signal structure, the network device 110 may determine that a phase rotation is needed. Alternatively, in case that the common signal structure with a cyclic prefix is determined based on reference subcarrier spacing, the network device 110 may determine that a phase rotation is needed if the subcarrier spacing in use is different from the reference subcarrier spacing.

[0075] If the network device 110 determines that a phase rotation is needed, for each of the

contiguous resource elements in time domain, the network device 110 may apply linear phase rotation values to a plurality of complex values in the received signal in frequency domain associated with a plurality of elements of the data sequence. In this way, the data sequence may be recovered from the received signal even if the signal has a cyclic prefix. In some embodiments, the network device 110 may determine the linear phase rotation values in a similar way to that described with reference to Fig. 2.

[0076] In some embodiments, each of the phase rotation values may be determined based on the signal structure, the subcarrier spacing in use, an index of the resource element in frequency domain, an index of the resource element in time domain, or the like, and any combination thereof.

[0077] The effectiveness and performance of embodiments of the present disclosure have been tested and verified by simulations. In four simulations as described below, it is assumed that for a subcarrier spacing value of 15 kHz, an FFT size is 2048 and a cyclic prefix length is 144 (if a cyclic prefix is inserted). For a subcarrier spacing value of 30 kHz, an FFT size is 1024 and a cyclic prefix length is 72 (if a cyclic prefix is inserted). For a subcarrier spacing value of 60 kHz, an FFT size is 512 and a cyclic prefix length is 36 (if a cyclic prefix is inserted). In addition, a sequence length of a data sequence is 300, that is, the data sequence has 300 elements.

[0078] In a first simulation, it is assumed that a transmitting device employs a subcarrier spacing value of 15 kHz, a receiving device employs a subcarrier spacing value of 60 kHz, and a phase rotation is not applied. In a second simulation, it is assumed that a transmitting device employs a subcarrier spacing value of 60 kHz, a receiving device employs a subcarrier spacing value of 15 kHz, and a phase rotation is not applied. In a third simulation, it is assumed that a transmitting device employs a subcarrier spacing value of 15 kHz, a receiving device employs a subcarrier spacing value of 60 kHz, and a phase rotation is applied. In a fourth simulation, it is assumed that a transmitting device employs a subcarrier spacing value of 60 kHz, a receiving device employs a subcarrier spacing value of 15 kHz, and a phase rotation is applied.

[0079] Specifically, in the first simulation, at a transmitting device using a subcarrier spacing value of 15 kHz, the data sequence (complex value $(a_0, a_1, a_2, \cdots, a_{299})$) is mapped to an interlace whose comb value is 4 and comb offset is 0, that is, $d_{k+0}, d_{k+4}, d_{k+8}, \cdots, d_{k+1196}$, in

frequency domain, where k is a multiple of 4. Other $d_n,\ n \neq k+0, k+4, k+8, \cdots, k+1196$ is set to 0. Then, the resource elements (REs) $(d_0, d_1, d_2, \cdots, d_{2047})$ in frequency domain are converted to a time domain baseband signal $s_0, s_1, s_2, \cdots, s_{2047}$ by IFFT, where

$$s_m = \beta_t \sum_{n=0}^{2047} d_n \exp\left(j2\pi \cdot \frac{nm}{2048} \right)$$

and β_t denotes a transmitting power factor, and other notations are consistent with the 3GPP specifications. Since $d_n,\ n \neq k+0, k+4, k+8, \cdots, k+1196$ is set to 0, it can be obtain that $s_m = s_{m+512} = s_{m+1024} = s_{m+1536}$ for all $0 \leq m \leq 511$. If a cyclic prefix is inserted, the final baseband signal in time domain $\tilde{s}_0, \tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_{2191}$ is set to $\tilde{s}_m = s_{(m-144) \bmod 2048}$, where mod denotes a modulo operation, and other notations are consistent with the 3GPP specifications.

[0080] At a receiving device using a subcarrier spacing value of 60 kHz, if a cyclic prefix is not inserted, the four received OFDM symbols are $(r_0^{(1)}, r_1^{(1)}, r_2^{(1)}, \cdots, r_{511}^{(1)}) = (s_0, s_1, s_2, \cdots, s_{511})$, $(r_0^{(2)}, r_1^{(2)}, r_2^{(2)}, \cdots, r_{511}^{(2)}) = (s_{512}, s_{513}, s_{514}, \cdots, s_{1023})$, $(r_0^{(3)}, r_1^{(3)}, r_2^{(3)}, \cdots, r_{511}^{(3)}) = (s_{1024}, s_{1025}, s_{1026}, \cdots, s_{1535})$, $(r_0^{(4)}, r_1^{(4)}, r_2^{(4)}, \cdots, r_{511}^{(4)}) = (s_{1536}, s_{1537}, s_{1538}, \cdots, s_{2047})$. If a cyclic prefix is inserted, the four received OFDM symbols excluding the cyclic prefixes are $(r_0^{(1)}, r_1^{(1)}, r_2^{(1)}, \cdots, r_{511}^{(1)}) = (\tilde{s}_{36}, \tilde{s}_{37}, \tilde{s}_{38}, \cdots, \tilde{s}_{547})$, $(r_0^{(2)}, r_1^{(2)}, r_2^{(2)}, \cdots, r_{511}^{(2)}) = (\tilde{s}_{584}, \tilde{s}_{585}, \tilde{s}_{586}, \cdots, \tilde{s}_{1095})$, $(r_0^{(3)}, r_1^{(3)}, r_2^{(3)}, \cdots, r_{511}^{(3)}) = (\tilde{s}_{1132}, \tilde{s}_{1133}, \tilde{s}_{1134}, \cdots, \tilde{s}_{1643})$, $(r_0^{(4)}, r_1^{(4)}, r_2^{(4)}, \cdots, r_{511}^{(4)}) = (\tilde{s}_{1680}, \tilde{s}_{1681}, \tilde{s}_{1682}, \cdots, \tilde{s}_{2191})$. Then, the received u-th OFDM symbol is converted to frequency domain REs

$$e_n^{(u)} = \beta_r \sum_{m=0}^{511} r_m^{(u)} \exp\left(-j2\pi \cdot \frac{nm}{512} \right),$$

where β_r denotes a receiving power factor, and other notations are consistent with the 3GPP specifications. The final received data sequence $(b_0, b_1, b_2, \cdots, b_{299})$ is obtained by

$b_i = \sum_{u=1}^{4} e_{k/4+i}^{(u)}$. Theoretically, by choosing a proper transmitting/receiving power factor, it can be obtained that $(a_0, a_1, a_2, \cdots, a_{299}) = (b_0, b_1, b_2, \cdots, b_{299})$ for the case of no cyclic prefixes and no noise.

[0081] In the second simulation, at a transmitting device using a subcarrier spacing value of 60 kHz, the data sequence (complex value $(a_0, a_1, a_2, \cdots, a_{299})$) is mapped to contiguous resources, namely, $d_{k+0}, d_{k+1}, d_{k+2}, \cdots, d_{k+299}$, in frequency domain, where k is the start frequency. Other d_n, $n \neq k+0, k+1, k+2, \cdots, k+299$ is set to 0. Then, the REs $(d_0, d_1, d_2, \cdots, d_{511})$ in frequency domain are converted to time domain baseband signal of an OFDM symbol $s_0, s_1, s_2, \cdots, s_{511}$ by IFFT, where

$$s_m = \beta_t \sum_{n=0}^{511} d_n \exp\left(j2\pi \cdot \frac{nm}{512} \right)$$

and β_t denotes a transmitting power factor, and other notations are consistent with the 3GPP specifications. If a cyclic prefix is inserted, the final baseband signal in time domain of an OFDM symbol $\tilde{s}_0, \tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_{547}$ is set to $\tilde{s}_m = s_{(m-36) \bmod 512}$, where mod denotes a modulo operation, and other notations are consistent with the 3GPP specifications. The final baseband signal in time domain $(s_0, s_1, s_2, \cdots, s_{511})$ or $(\tilde{s}_0, \tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_{547})$ is repeatedly transmitted four times, namely, four OFDM symbols.

[0082] At a receiving device using a subcarrier spacing value of 15 kHz, if a cyclic prefix is not inserted, the received OFDM symbol is $(r_0, r_1, r_2, \cdots, r_{2047}) = (s_0, s_1, s_2, \cdots, s_{511}, s_0, s_1, \cdots, s_{511}, s_0, s_1, \cdots, s_{511}, s_0, s_1, \cdots, s_{511})$. If a cyclic prefix is inserted, the received OFDM symbol excluding cyclic prefix is $(r_0, r_1, r_2, \cdots, r_{2047}) = (\tilde{s}_{144}, \tilde{s}_{145}, \tilde{s}_{146}, \cdots, \tilde{s}_{547}, \tilde{s}_0, \tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_{547}, \tilde{s}_0, \tilde{s}_1, \cdots, \tilde{s}_{547}, \tilde{s}_0, \tilde{s}_1, \cdots, \tilde{s}_{547})$. Then, the received OFDM symbol is converted to frequency domain REs

$$e_n = \beta_r \sum_{m=0}^{2047} r_m \exp\left(-j2\pi \cdot \frac{nm}{2048} \right),$$

where β_r denotes a receiving power factor, and other notations are consistent with the 3GPP

specifications. The final received data sequence $(b_0, b_1, b_2, \cdots, b_{299})$ is obtained by $b_i = e_{4(k+i)}$. Theoretically, by choosing a proper transmitting/receiving power factor, it can be obtained that $(a_0, a_1, a_2, \cdots, a_{299}) = (b_0, b_1, b_2, \cdots, b_{299})$ for the case of no cyclic prefixes and no noise.

[0083] Fig. 7 shows a simulation result of performance (in term of autocorrelation peak) of data sequence transmission without a cyclic prefix in accordance with some embodiments of the present disclosure, where multiple signal-to-noise ratio (SNR) levels are evaluated. In Fig. 7, the horizontal axis refers to OFDM index, the vertical axis refers to Cumulative Distribution Function (CDF), a curve 710 refers to no signal, a curve 720 refers to SNR of -10 dB, a curve 730 refers to SNR of -5 dB, a curve 740 refers to SNR of 0 dB, a curve 750 refers to SNR of 5 dB, a curve 760 refers to SNR of 10 dB, and a curve 770 refers to no noise. It can be observed that the detectability of the data sequence keeps well even for SNR = -10 dB.

[0084] Fig. 8 shows a simulation result of performance (in term of autocorrelation peak) of data sequence transmission with a cyclic prefix in accordance with some embodiments of the present disclosure. In Fig. 8, the horizontal axis refers to OFDM index, the vertical axis refers to CDF, a curve 810 refers to no signal, a curve 820 refers to SNR of -10 dB, a curve 830 refers to SNR of -5 dB, a curve 840 refers to SNR of 0 dB, a curve 850 refers to SNR of 5 dB, a curve 860 refers to SNR of 10 dB, and a curve 870 refers to no noise. It can be observed that the inserted cyclic prefix obviously decreases the detectability of the data sequence. Nevertheless, the detectability of the preamble seems well for SNR above 0 dB.

[0085] As detailed below, different from the first and second simulations, the phase rotation is applied in the third and fourth simulations. In the third simulation, at a transmitting device using a subcarrier spacing value of 15 kHz, it is the same as that described in the first simulation and is not repeated here.

[0086] At a receiving device using a subcarrier spacing value of 60 kHz, the four received OFDM symbols excluding cyclic prefixes are $(r_0^{(1)}, r_1^{(1)}, r_2^{(1)}, \cdots, r_{511}^{(1)}) = (\tilde{s}_{36}, \tilde{s}_{37}, \tilde{s}_{38}, \cdots, \tilde{s}_{547})$, $(r_0^{(2)}, r_1^{(2)}, r_2^{(2)}, \cdots, r_{511}^{(2)}) = (\tilde{s}_{584}, \tilde{s}_{585}, \tilde{s}_{586}, \cdots, \tilde{s}_{1095})$, $(r_0^{(3)}, r_1^{(3)}, r_2^{(3)}, \cdots, r_{511}^{(3)}) = (\tilde{s}_{1132}, \tilde{s}_{1133}, \tilde{s}_{1134}, \cdots, \tilde{s}_{1643})$, $(r_0^{(4)}, r_1^{(4)}, r_2^{(4)}, \cdots, r_{511}^{(4)}) = (\tilde{s}_{1680}, \tilde{s}_{1681}, \tilde{s}_{1682}, \cdots, \tilde{s}_{2191})$. Then, the received u-th OFDM symbol is converted to frequency domain REs

$$e_n^{(u)} = \beta_r \sum_{m=0}^{511} r_m^{(u)} \exp\left(-j2\pi \cdot \frac{nm}{512}\right),$$

where β_r denotes a receiving power factor, and other notations are consistent with the 3GPP specifications. The final received data sequence $(b_0, b_1, b_2, \cdots, b_{299})$ is obtained by $b_i = \sum_{u=1}^{4} e_{k/4+i}^{(u)} \exp\left[j2\pi \frac{36 \cdot (4-u)(k/4+i)}{512}\right]$. Note that a phase rotation is applied on the combination. Theoretically, by choosing a proper transmitting/receiving power factor, it can be obtained that $(a_0, a_1, a_2, \cdots, a_{299}) = (b_0, b_1, b_2, \cdots, b_{299})$ for the case of an inserted cyclic prefix and no noise using the phase rotation.

[0087] In the fourth simulation, at a transmitting device using a subcarrier spacing value of 60 kHz, the data sequence (complex value $(a_0, a_1, a_2, \cdots, a_{299})$) may be mapped to contiguous resource elements in frequency domain, that is, $d_{k+0}, d_{k+1}, d_{k+2}, \cdots, d_{k+299}$, where k is the start frequency. Other d_n, $n \neq k+0, k+1, k+2, \cdots, k+299$ is set to 0. Then, OFDM symbol-dependent linear phase rotations are applied on four OFDM symbols. Specifically, for the u-th OFDM symbol ($1 \leq u \leq 4$), the n-th resource element are $d_n^{(u)} = d_n \exp\left[-j2\pi \frac{36 \cdot (4-u)n}{512}\right]$. The resource element ($d_0^{(u)}, d_1^{(u)}, d_2^{(u)}, \cdots, d_{511}^{(u)}$) in frequency domain is converted to time domain baseband signal of an OFDM symbol $s_0^{(u)}, s_1^{(u)}, s_2^{(u)}, \cdots, s_{511}^{(u)}$ by IFFT, where

$$s_m^{(u)} = \beta_t \sum_{n=0}^{511} d_n^{(u)} \exp\left(j2\pi \cdot \frac{nm}{512}\right),$$

where β_t denotes a transmitting power factor, and other notations are consistent with the 3GPP specifications. The final time domain baseband signal of an OFDM symbol $\tilde{s}_0^{(u)}, \tilde{s}_1^{(u)}, \tilde{s}_2^{(u)}, \cdots, \tilde{s}_{547}^{(u)}$ is set to $\tilde{s}_m^{(u)} = s_{(m-36) \bmod 512}^{(u)}$, where mod denotes a modulo operation, and other notations are consistent with the 3GPP specifications. The final baseband signals in time domain of four OFDM symbols are transmitted consecutively.

[0088] At a receiving device using a subcarrier spacing value of 15 kHz, the received OFDM symbol excluding the cyclic prefix is $(r_0, r_1, r_2, \cdots, r_{2047}) =$

$(\tilde{s}_{144}^{(1)},\tilde{s}_{145}^{(1)},\tilde{s}_{146}^{(1)},\cdots,\tilde{s}_{547}^{(1)},\tilde{s}_{0}^{(2)},\tilde{s}_{1}^{(2)},\tilde{s}_{2}^{(2)},\cdots,\tilde{s}_{547}^{(2)},\tilde{s}_{0}^{(3)},\tilde{s}_{1}^{(3)},\cdots,\tilde{s}_{547}^{(3)},\tilde{s}_{0}^{(4)},\tilde{s}_{1}^{(4)},\cdots,\tilde{s}_{547}^{(4)})$. Then, the received OFDM symbol is converted to frequency domain resource elements

$$e_n = \beta_r \sum_{m=0}^{2047} r_m \exp\left(-j2\pi \cdot \frac{nm}{2048}\right),$$

where β_r denotes a receiving power factor, and other notations are consistent with the 3GPP specifications. The final received data sequence $(b_0,b_1,b_2,\cdots,b_{299})$ is obtained by $b_i = e_{4(k+i)}$. Theoretically, by choosing a proper transmitting/receiving power factor, it can be obtained that $(a_0,a_1,a_2,\cdots,a_{299}) = (b_0,b_1,b_2,\cdots,b_{299})$ for the case of inserted cyclic prefixes and no noise using the phase rotation.

[0089] Fig. 9 shows a simulation result of performance (in term of autocorrelation peak) of data sequence transmission with a cyclic prefix and a phase rotation in accordance with some embodiments of the present disclosure, where multiple SNR levels are evaluated. In Fig. 9, the horizontal axis refers to OFDM index, the vertical axis refers to CDF, a curve 910 refers to no signal, a curve 920 refers to SNR of -10 dB, a curve 930 refers to SNR of -5 dB, a curve 940 refers to SNR of 0 dB, a curve 950 refers to SNR of 5 dB, a curve 960 refers to SNR of 10 dB, and a curve 970 refers to no noise. It can be observed that the detectability of the preamble is nearly equal to that shown in Fig. 7. This means that the issue caused by an inserted cyclic prefix can be solved using the OFDM symbol-dependent phase rotation.

[0090] In some embodiments, an apparatus for performing the method 200 (for example, the network device 110 and the terminal devices 120, 130) may comprise respective means for performing the corresponding steps in the method 200. These means may be implemented in any suitable manners. For example, it can be implemented by circuitry or software modules or a combination thereof.

[0091] In some embodiments, the apparatus comprises: means for obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts; means for determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and means for transmitting a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

[0092] In some embodiments, the means for determining the pattern comprises: means for

determining, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal.

[0093] In some embodiments, the means for determining the pattern comprises: means for determining a time length of each of the plurality of resource elements based on the subcarrier spacing; and means for determining, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

[0094] In some embodiments, the apparatus further comprises: means for in response to determining that the signal structure comprises a cyclic prefix, for each of the contiguous resource elements in time domain, applying linear phase rotation values to a plurality of elements of the data sequence before mapping the data sequence to the plurality of resource elements, such that the signal has the signal structure.

[0095] In some embodiments, each of the phase rotation values is determined based on at least one of: the signal structure; the subcarrier spacing; an index of the resource element in frequency domain; and an index of the resource element in time domain.

[0096] In some embodiments, the signal structure is configured by a network device or is predefined.

[0097] In some embodiments, an apparatus for performing the method 600 (for example, the network device 110 and the terminal devices 120, 130) may comprise respective means for performing the corresponding steps in the method 600. These means may be implemented in any suitable manners. For example, it can be implemented by circuitry or software modules or a combination thereof.

[0098] In some embodiments, the apparatus comprises: means for receiving a signal carrying a data sequence; means for obtaining a signal structure defining signal duration and a number of repeated parts; means for determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and means for obtaining the data sequence from the signal based on the determined pattern.

[0099] In some embodiments, the means for determining the pattern comprises: means for determining, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal.

[00100] In some embodiments, the means for determining the pattern comprises: means for determining a time length of each of the plurality of resource elements based on the subcarrier

spacing; and means for determining, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

[00101] In some embodiments, the apparatus further comprises: means for determining whether a phase rotation is needed for obtaining the data sequence, based on the signal structure and the subcarrier spacing; and means for in response to determining that a phase rotation is needed, for each of the contiguous resource elements in time domain, applying linear phase rotation values to a plurality of complex values in the signal in frequency domain associated with a plurality of elements of the data sequence.

[00102] In some embodiments, each of the phase rotation values is determined based on at least one of: the signal structure; the subcarrier spacing; an index of the resource element in frequency domain; and an index of the resource element in time domain.

[00103] In some embodiments, the signal structure is configured by a network device or is predefined.

[00104] Fig. 10 is a simplified block diagram of a device 1000 that is suitable for implementing embodiments of the present disclosure. The device 1000 can be considered as a further example embodiment of the network device 110 and the terminal devices 120, 130 as shown in Fig. 1. Accordingly, the device 1000 can be implemented at or as at least a part of the network device 110 or the terminal device 120, 130.

[00105] As shown, the device 1000 includes a processor 1010, a memory 1020 coupled to the processor 1010, a suitable transmitter (TX) and receiver (RX) 1040 coupled to the processor 1010, and a communication interface coupled to the TX/RX 1040. The memory 1020 stores at least a part of a program 1030. The TX/RX 1040 is for bidirectional communications. The TX/RX 1040 has at least one antenna to facilitate communication. The communication interface may represent any interface that is necessary for communication with other network elements, such as X2 interface for bidirectional communications between eNBs, S1 interface for communication between a Mobility Management Entity (MME)/Serving Gateway (S-GW) and the eNB, Un interface for communication between the eNB and a relay node (RN), or Uu interface for communication between the eNB and a terminal device.

[00106] The program 1030 is assumed to include program instructions that, when executed by the associated processor 1010, enable the device 1000 to operate in accordance with the embodiments of the present disclosure, as discussed herein with reference to Figs. 1 to 9. The embodiments herein may be implemented by computer software executable by the

processor 1010 of the device 1000, or by hardware, or by a combination of software and hardware. The processor 1010 may be configured to implement various embodiments of the present disclosure. Furthermore, a combination of the processor 1010 and memory 1020 may form processing means 1050 adapted to implement various embodiments of the present disclosure.

[00107] The memory 1020 may be of any type suitable to the local technical network and may be implemented using any suitable data storage technology, such as a non-transitory computer readable storage medium, semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, as non-limiting examples. While only one memory 1020 is shown in the device 1000, there may be several physically distinct memory modules in the device 1000. The processor 1010 may be of any type suitable to the local technical network, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. The device 1000 may have multiple processors, such as an application specific integrated circuit chip that is slaved in time to a clock which synchronizes the main processor.

[00108] The components included in the apparatuses and/or devices of the present disclosure may be implemented in various manners, including software, hardware, firmware, or any combination thereof. In one embodiment, one or more units may be implemented using software and/or firmware, for example, machine-executable instructions stored on the storage medium. In addition to or instead of machine-executable instructions, parts or all of the units in the apparatuses and/or devices may be implemented, at least in part, by one or more hardware logic components. For example, and without limitation, illustrative types of hardware logic components that can be used include Field-programmable Gate Arrays (FPGAs), Application-specific Integrated Circuits (ASICs), Application-specific Standard Products (ASSPs), System-on-a-chip systems (SOCs), Complex Programmable Logic Devices (CPLDs), and the like.

[00109] Generally, various embodiments of the present disclosure may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device. While various aspects of embodiments of the present disclosure are

illustrated and described as block diagrams, flowcharts, or using some other pictorial representation, it will be appreciated that the blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[00110] The present disclosure also provides at least one computer program product tangibly stored on a non-transitory computer readable storage medium. The computer program product includes computer-executable instructions, such as those included in program modules, being executed in a device on a target real or virtual processor, to carry out the process or method as described above with reference to any of Figs. 2 and 6. Generally, program modules include routines, programs, libraries, objects, classes, components, data structures, or the like that perform particular tasks or implement particular abstract data types. The functionality of the program modules may be combined or split between program modules as desired in various embodiments. Machine-executable instructions for program modules may be executed within a local or distributed device. In a distributed device, program modules may be located in both local and remote storage media.

[00111] Program code for carrying out methods of the present disclosure may be written in any combination of one or more programming languages. These program codes may be provided to a processor or controller of a general purpose computer, special purpose computer, or other programmable data processing apparatus, such that the program codes, when executed by the processor or controller, cause the functions/operations specified in the flowcharts and/or block diagrams to be implemented. The program code may execute entirely on a machine, partly on the machine, as a stand-alone software package, partly on the machine and partly on a remote machine or entirely on the remote machine or server.

[00112] The above program code may be embodied on a machine readable medium, which may be any tangible medium that may contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device. The machine readable medium may be a machine readable signal medium or a machine readable storage medium. A machine readable medium may include but not limited to an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the machine readable storage medium would include an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM),

an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[00113] For the purpose of the present disclosure as described herein above, it should be noted that,

- method steps likely to be implemented as software code portions and being run using a processor at a network element or terminal (as examples of devices, apparatuses and/or modules thereof, or as examples of entities including apparatuses and/or modules therefore), are software code independent and can be specified using any known or future developed programming language as long as the functionality defined by the method steps is preserved;

- generally, any method step is suitable to be implemented as software or by hardware without changing the idea of the invention in terms of the functionality implemented;

- method steps and/or devices, units or means likely to be implemented as hardware components at the above-defined apparatuses, or any module(s) thereof, (e.g., devices carrying out the functions of the apparatuses according to the embodiments as described above, eNode-B etc. as described above) are hardware independent and can be implemented using any known or future developed hardware technology or any hybrids of these, such as MOS (Metal Oxide Semiconductor), CMOS (Complementary MOS), BiMOS (Bipolar MOS), BiCMOS (Bipolar CMOS), ECL (Emitter Coupled Logic), TTL (Transistor-Transistor Logic), etc., using for example ASIC (Application Specific IC (Integrated Circuit)) components, FPGA (Field-programmable Gate Arrays) components, CPLD (Complex Programmable Logic Device) components or DSP (Digital Signal Processor) components;

- devices, units or means (e.g. the above-defined apparatuses, or any one of their respective means) can be implemented as individual devices, units or means, but this does not exclude that they are implemented in a distributed fashion throughout the system, as long as the functionality of the device, unit or means is preserved;

- an apparatus may be represented by a semiconductor chip, a chipset, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of an apparatus or module, instead of being hardware implemented, be implemented as software in a (software) module such as a computer program or a computer program product comprising executable software code portions for execution/being run on a processor;

- a device may be regarded as an apparatus or as an assembly of more than one apparatus, whether functionally in cooperation with each other or functionally independently of each other but in a same device housing, for example.

[00114] It is noted that the embodiments and examples described above are provided for illustrative purposes only and are in no way intended that the present disclosure is restricted thereto. Rather, it is the intention that all variations and modifications be included which fall within the spirit and scope of the appended claims.

[00115] Further, while operations are depicted in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Likewise, while several specific embodiment details are contained in the above discussions, these should not be construed as limitations on the scope of the present disclosure, but rather as descriptions of features that may be specific to particular embodiments. Certain features that are described in the context of separate embodiments may also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment may also be implemented in multiple embodiments separately or in any suitable sub-combination.

[00116] Although the present disclosure has been described in language specific to structural features and/or methodological acts, it is to be understood that the present disclosure defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

WHAT IS CLAIMED IS:

1. A method for communication, comprising:

obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts;

determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

transmitting a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

2. The method of claim 1, wherein determining the pattern comprises:

determining, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal.

3. The method of claim 1, wherein determining the pattern comprises:

determining a time length of each of the plurality of resource elements based on the subcarrier spacing; and

determining, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

4. The method of claim 3, further comprising:

in response to determining that the signal structure comprises a cyclic prefix, for each of the contiguous resource elements in time domain, applying linear phase rotation values to a plurality of elements of the data sequence before mapping the data sequence to the plurality of resource elements, such that the signal has the signal structure.

5. The method of claim 4, wherein each of the phase rotation values is determined based on at least one of:

the signal structure;

the subcarrier spacing;

an index of the resource element in frequency domain; and

an index of the resource element in time domain.

6. The method of claim 1, wherein the signal structure is configured by a network device or is predefined.

7. A method for communication, comprising:

receiving a signal carrying a data sequence;

obtaining a signal structure defining signal duration and a number of repeated parts;

determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

obtaining the data sequence from the signal based on the determined pattern.

8. The method of claim 7, wherein determining the pattern comprises:

determining, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal.

9. The method of claim 7, wherein determining the pattern comprises:

determining a time length of each of the plurality of resource elements based on the subcarrier spacing; and

determining, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

10. The method of claim 9, further comprising:

determining whether a phase rotation is needed for obtaining the data sequence, based on the signal structure and the subcarrier spacing; and

in response to determining that a phase rotation is needed, for each of the contiguous resource elements in time domain, applying linear phase rotation values to a plurality of complex values in the signal in frequency domain associated with a plurality of elements of the data sequence.

11. The method of claim 10, wherein each of the phase rotation values is determined based on at least one of:

the signal structure;

the subcarrier spacing;

an index of the resource element in frequency domain; and

an index of the resource element in time domain.

12. The method of claim 7, wherein the signal structure is configured by a network device or is predefined.

13. A device, comprising:

at least one processor; and

at least one memory storing computer program code;

the at least one memory and the computer program code configured to, with the at least one processor, cause the device to:

obtain a data sequence and a signal structure defining signal duration and a number of repeated parts;

determine, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

transmit a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

14. The device of claim 13, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the device to:

determine, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal.

15. The device of claim 13, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the device to:

determine a time length of each of the plurality of resource elements based on the subcarrier spacing; and

determine, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

16. The device of claim 15, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the device to:

in response to determining that the signal structure comprises a cyclic prefix, for each of the contiguous resource elements in time domain, apply linear phase rotation values to a

plurality of elements of the data sequence before mapping the data sequence to the plurality of resource elements, such that the signal has the signal structure.

17. The device of claim 16, wherein each of the phase rotation values is determined based on at least one of:

the signal structure;

the subcarrier spacing;

an index of the resource element in frequency domain; and

an index of the resource element in time domain.

18. The device of claim 13, wherein the signal structure is configured by a network device or is predefined.

19. A device, comprising:

at least one processor; and

at least one memory storing computer program code;

the at least one memory and the computer program code configured to, with the at least one processor, cause the device to:

receive a signal carrying a data sequence;

obtain a signal structure defining signal duration and a number of repeated parts;

determine, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

obtain the data sequence from the signal based on the determined pattern.

20. The device of claim 19, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the device to:

determine, based on the subcarrier spacing and the number of repeated parts, a distance between two successive resource elements in frequency domain for transmitting the signal.

21. The device of claim 19, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the device to:

determine a time length of each of the plurality of resource elements based on the

subcarrier spacing; and

determine, based on the time length and the signal duration, a number of contiguous resource elements in time domain for transmitting the signal.

22. The device of claim 21, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the device to:

determine whether a phase rotation is needed for obtaining the data sequence, based on the signal structure and the subcarrier spacing; and

in response to determining that a phase rotation is needed, for each of the contiguous resource elements in time domain, apply linear phase rotation values to a plurality of complex values in the signal in frequency domain associated with a plurality of elements of the data sequence.

23. The device of claim 22, wherein each of the phase rotation values is determined based on at least one of:

the signal structure;

the subcarrier spacing;

an index of the resource element in frequency domain; and

an index of the resource element in time domain.

24. The device of claim 19, wherein the signal structure is configured by a network device or is predefined.

25. An apparatus for communication, comprising:

means for obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts;

means for determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

means for transmitting a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

26. An apparatus for communication, comprising:

means for receiving a signal carrying a data sequence;

means for obtaining a signal structure defining signal duration and a number of

repeated parts;

means for determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

means for obtaining the data sequence from the signal based on the determined pattern.

27. A non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the following:

obtaining a data sequence and a signal structure defining signal duration and a number of repeated parts;

determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

transmitting a signal carrying the data sequence based on the determined pattern, such that the transmitted signal has the signal structure.

28. A non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the following:

receiving a signal carrying a data sequence;

obtaining a signal structure defining signal duration and a number of repeated parts;

determining, based on subcarrier spacing in use and the signal structure, a pattern for mapping the data sequence to a plurality of resource elements; and

obtaining the data sequence from the signal based on the determined pattern.

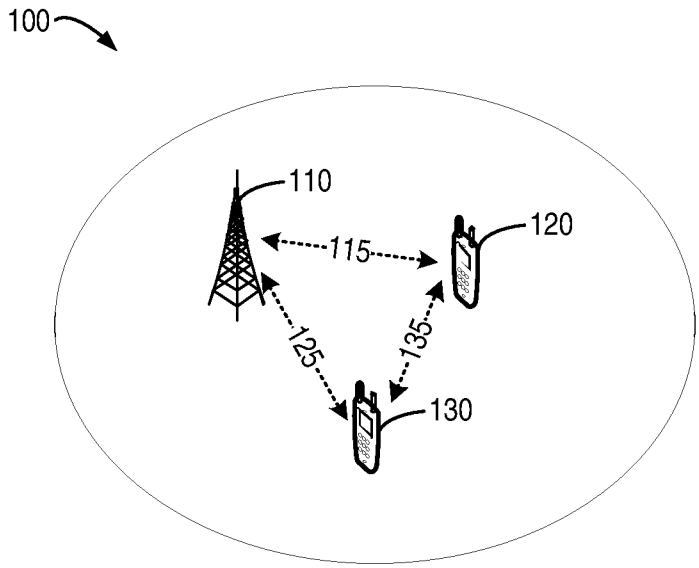


FIG. 1

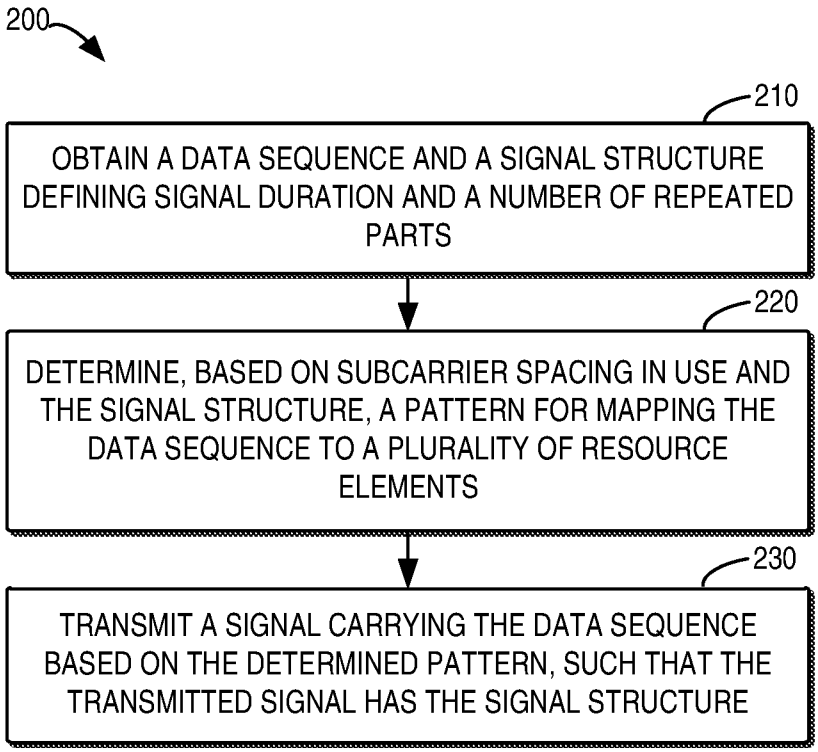

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OBTAIN A DATA SEQUENCE AND A SIGNAL STRUCTURE DEFINING SIGNAL DURATION AND A NUMBER OF REPEATED PARTS
220
DETERMINE, BASED ON SUBCARRIER SPACING IN USE AND THE SIGNAL STRUCTURE, A PATTERN FOR MAPPING THE DATA SEQUENCE TO A PLURALITY OF RESOURCE ELEMENTS
230
TRANSMIT A SIGNAL CARRYING THE DATA SEQUENCE BASED ON THE DETERMINED PATTERN, SUCH THAT THE TRANSMITTED SIGNAL HAS THE SIGNAL STRUCTURE

FIG. 2

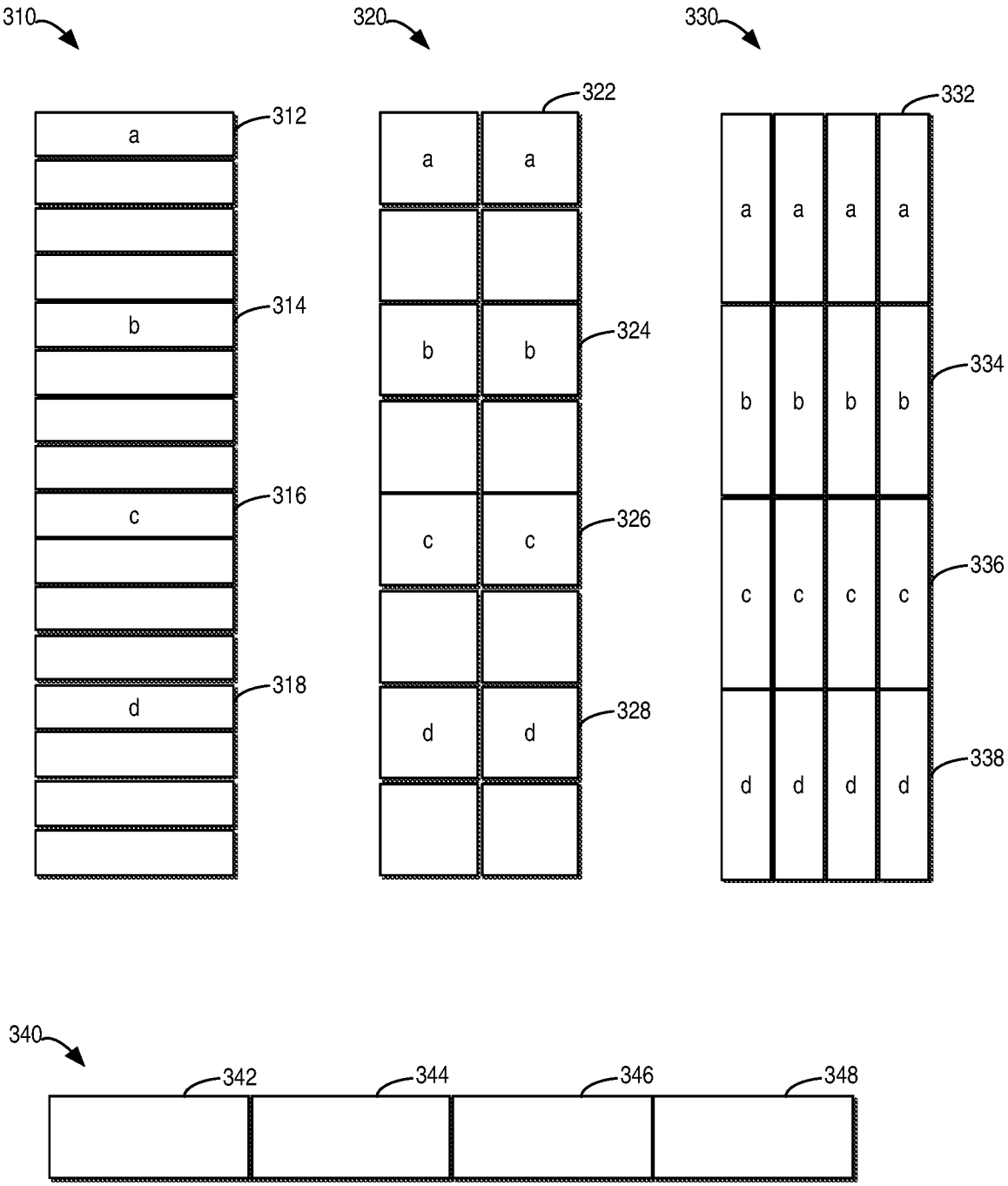

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FIG. 3

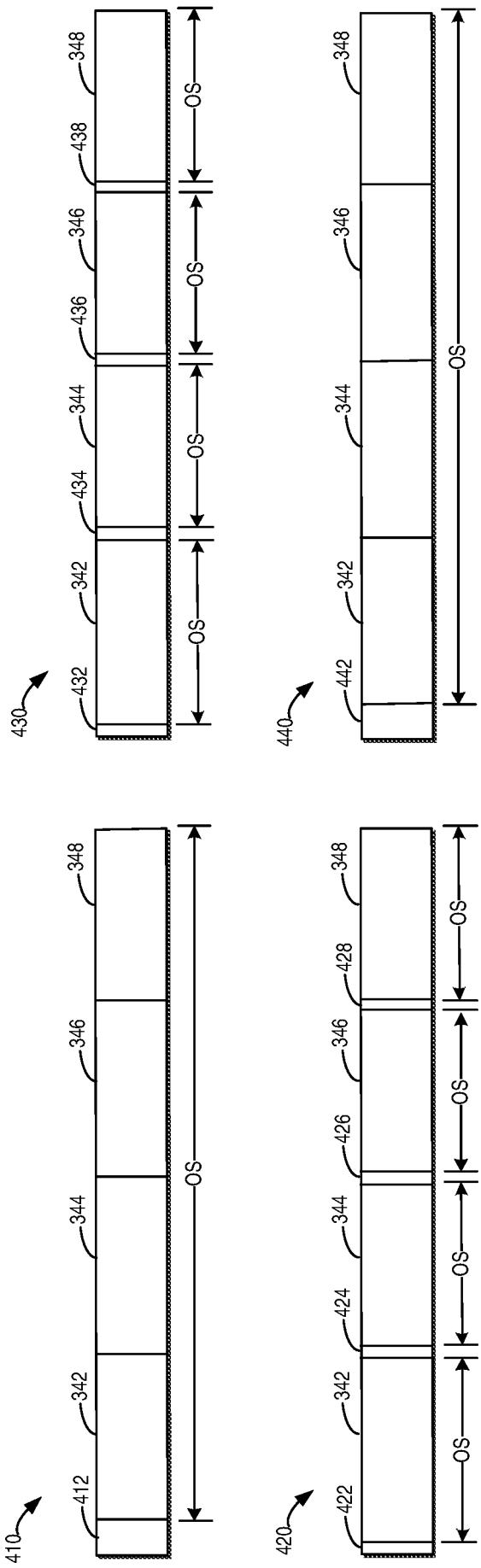

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OS

FIG. 4

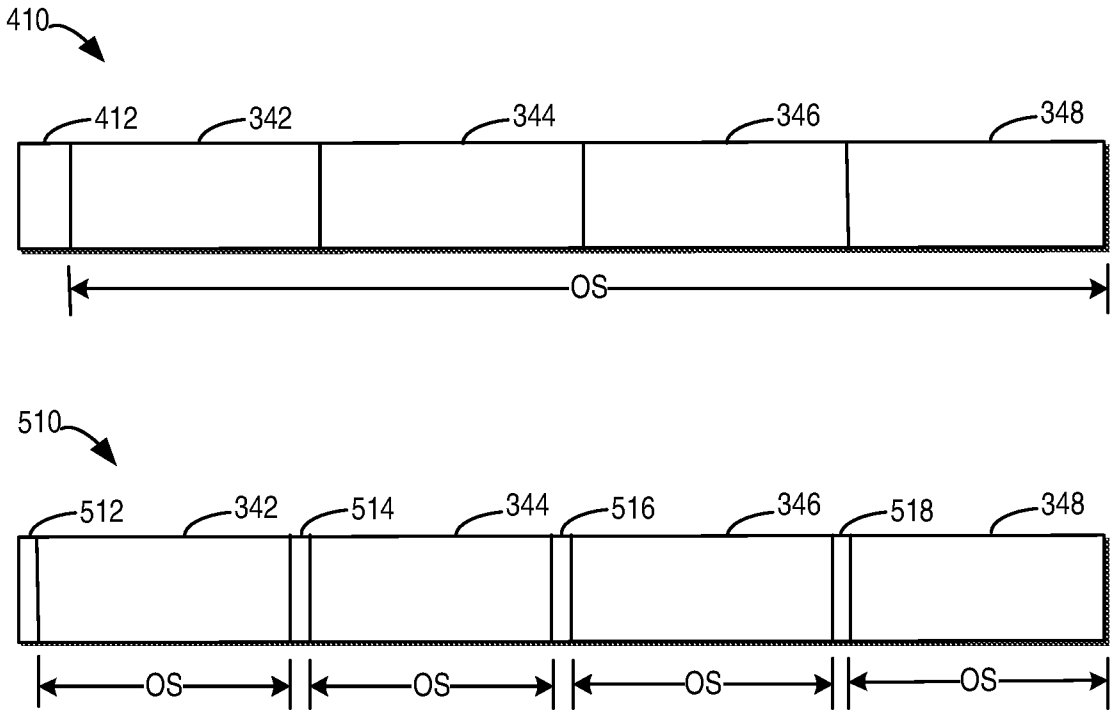

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FIG. 5

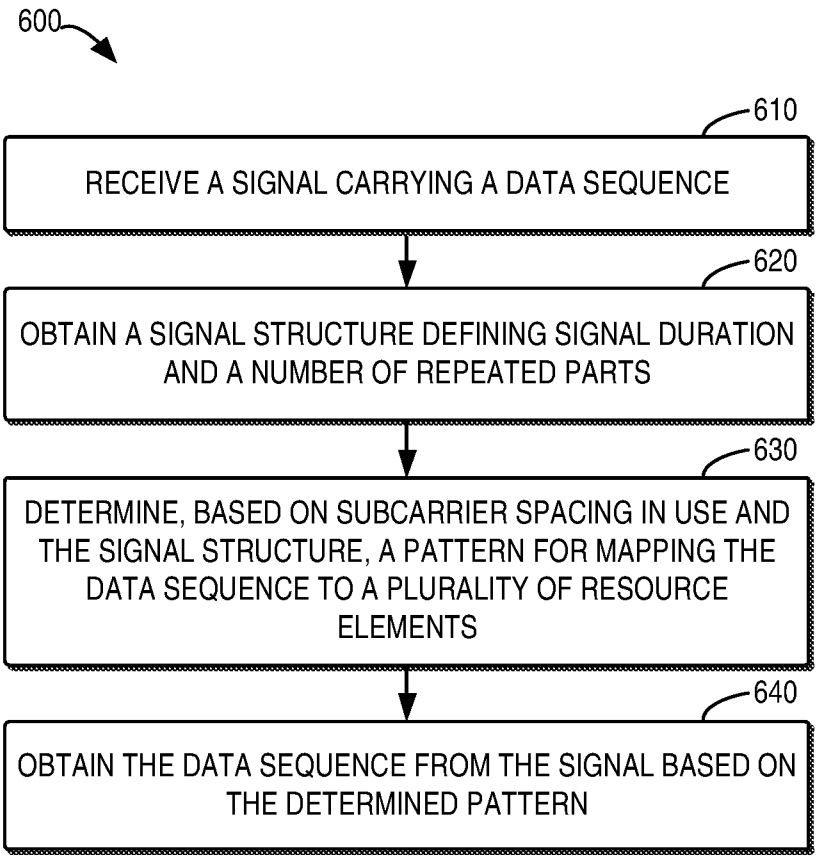

600
610
RECEIVE A SIGNAL CARRYING A DATA SEQUENCE
620
OBTAIN A SIGNAL STRUCTURE DEFINING SIGNAL DURATION AND A NUMBER OF REPEATED PARTS
630
DETERMINE, BASED ON SUBCARRIER SPACING IN USE AND THE SIGNAL STRUCTURE, A PATTERN FOR MAPPING THE DATA SEQUENCE TO A PLURALITY OF RESOURCE ELEMENTS
640
OBTAIN THE DATA SEQUENCE FROM THE SIGNAL BASED ON THE DETERMINED PATTERN

FIG. 6

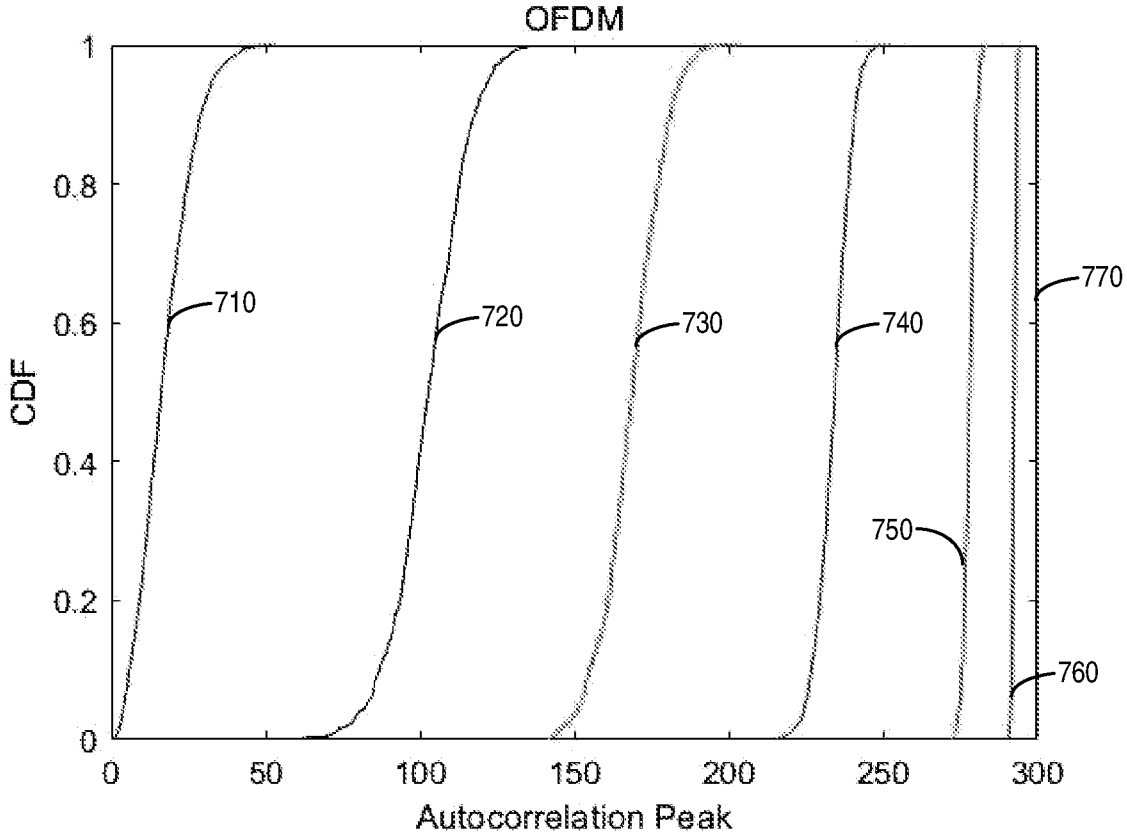

OFDM
CDF
Autocorrelation Peak
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200
250
300
710
720
730
740
750
760
770

FIG. 7

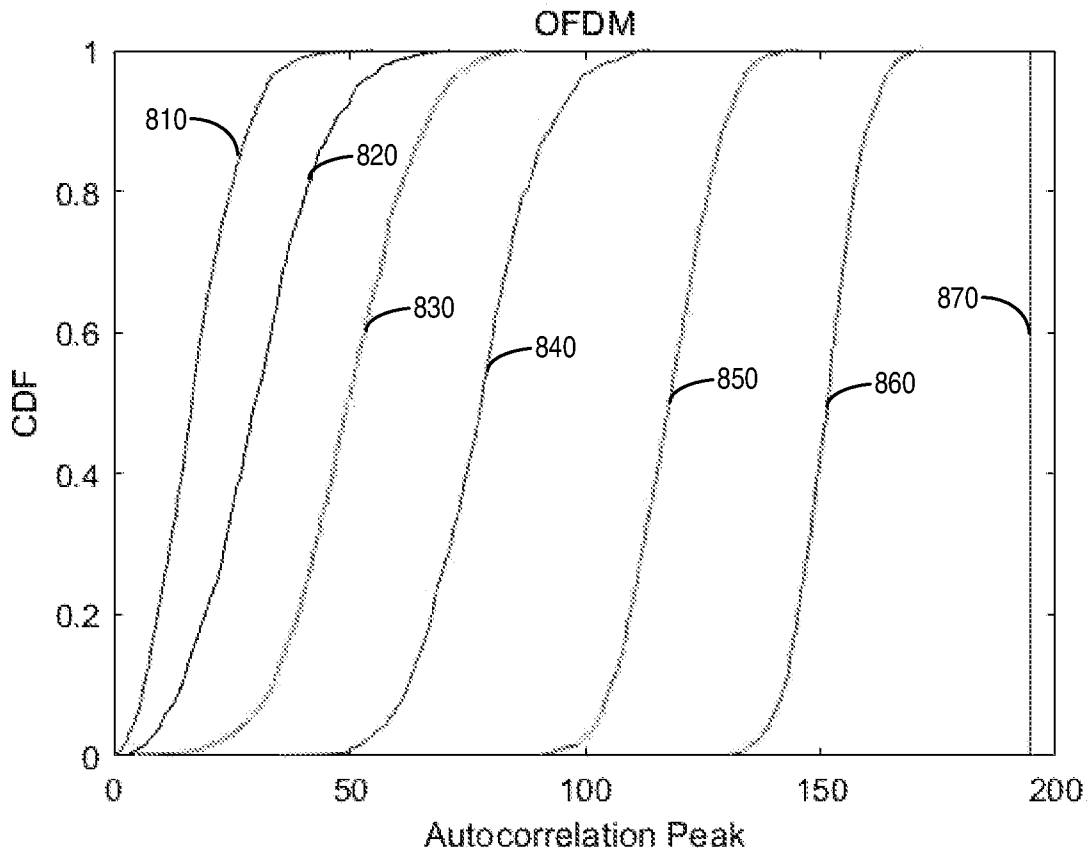

OFDM
CDF
Autocorrelation Peak
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200
810
820
830
840
850
860
870

FIG. 8

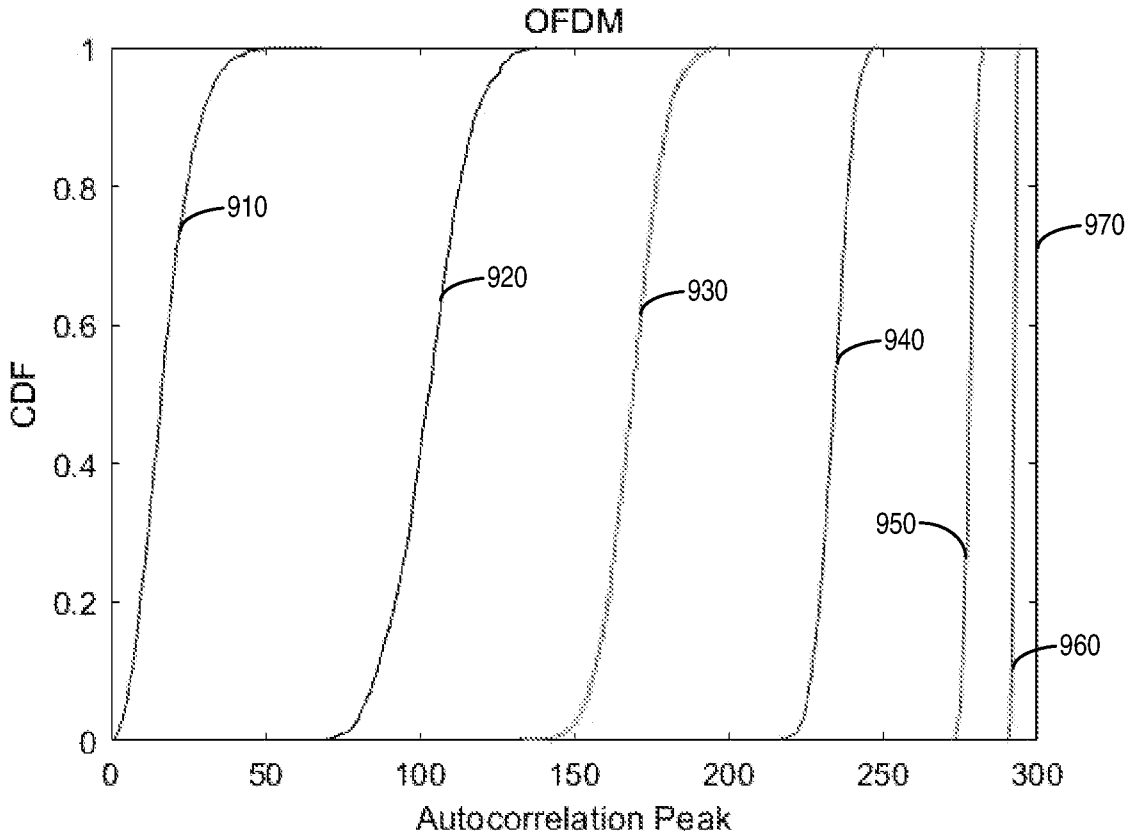

OFDM
CDF
Autocorrelation Peak
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200
250
300
910
920
930
940
950
960
970

FIG. 9

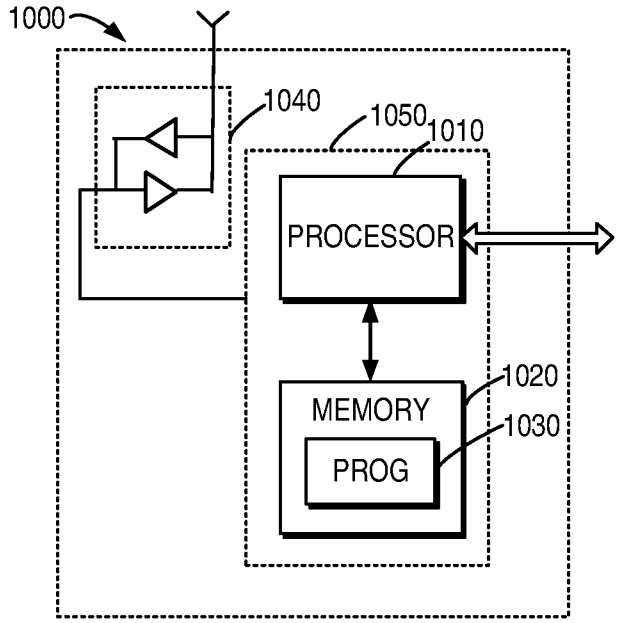


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/071381

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: signal w structure, subcarrier w spacing, transmit,resource, element, frequency w domain, time w domain, signal w duration, mapping, phase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 107483166 A (LONGBO COMMUNICATION TECHNICAL CO., LTD.) 15 December 2017 (2017-12-15) description, paragraphs [11]-[16] and [247]-[256], figures 1, 2, 8 and 9	1-28
A	CN 108023703 A (HUAWEI TECHNOLOGIES CO., LTD.) 11 May 2018 (2018-05-11) the whole document	1-28
A	CN 107801247 A (LONGBO COMMUNICATION TECHNICAL CO., LTD.) 13 March 2018 (2018-03-13) the whole document	1-28
A	CN 108012329 A (HUAWEI TECHNOLOGIES CO., LTD.) 08 May 2018 (2018-05-08) the whole document	1-28
A	CN 108347293 A (HUAWEI TECHNOLOGIES CO., LTD.) 31 July 2018 (2018-07-31) the whole document	1-28
A	WO 2017096131 A1 (IDAC HOLDINGS, INC.) 08 June 2017 (2017-06-08) the whole document	1-28

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2019	**26 September 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**GUO,Jing**
Facsimile No. **(86-10)62019451**	Telephone No. **86-（10）-53961671**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2019/071381

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 107483166 A	15 December 2017	None	
CN 108023703 A	11 May 2018	WO 2018082678 A1	11 May 2018
CN 107801247 A	13 March 2018	None	
CN 108012329 A	08 May 2018	CN 109245876 A	18 January 2019
		WO 2019062779 A1	04 April 2019
CN 108347293 A	31 July 2018	CN 109257147 A	22 January 2019
		WO 2018137605 A1	02 August 2018
WO 2017096131 A1	08 June 2017	EP 3384649 A1	10 October 2018
		CN 108370359 A	03 August 2018
		KR 20180100046 A	06 September 2018
		JP 2019503607 A	07 February 2019
		US 2018367355 A1	20 December 2018