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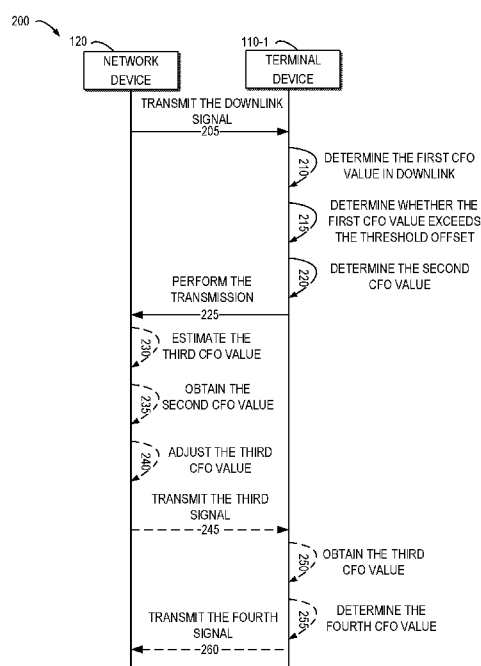


Fig. 2

(57) Abstract: Embodiments of the present disclosure relate to mechanism for compensation of frequency shift. According to embodiments of the present disclosure, if the carrier frequency offset (CFO) value in a first link exceeds a predetermined threshold offset, the first device determines a further CFO value for transmitting a signal in a second link. The second device corrects the determined further CFO value and transmits another signal in the first link to indicate the corrected CFO value. In this way, fast and robust compensation for Doppler shift is achieved in initial access mode and maintain the OFDMA maintains orthogonal.

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## MECHANISM FOR COMPENSATION OF FREQUENCY SHIFT

### FIELD

5 [0001] Embodiments of the present disclosure generally relate to the field of communications and in particular, to a method, device, apparatus and computer readable storage medium for compensating frequency shift in communication systems.

### BACKGROUND

10 [0002] Since resources and infrastructure are limited in remote area, it is very difficult for terrestrial network to provide 5G coverage. The main benefits of introducing Non-Terrestrial Network (NTN) is to enable ubiquitous 5G services to terminal devices by extending connectivity in less densely populated areas with extremely low density of devices and the overall cost of deployment may be much less than providing permanent  
15 infra-structure on the ground. Using the space-borne or air-borne platforms may provide reliable coverage in remote areas, which have a distinct advantage. However, it has also brought some problems in other aspects.

### SUMMARY

20 [0003] Generally, embodiments of the present disclosure relate to a method for compensating frequency shift and the corresponding communication devices.

[0004] In a first aspect, there is provided a device. The device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor,  
25 cause the device to determine, at the device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a further device. The device is also caused to determine whether the first CFO value in the first link from the further device to the device exceeds a threshold offset. The device is further caused to determine a second CFO value in a second link from the device to the further device based on the first CFO  
30 value in first link in response to a determination that the first CFO value in the first link

exceeds the threshold offset. The second CFO value in the second link is greater than the first CFO value in the first link. The device is yet caused to perform transmission from the device to the further device on a carrier compensated with the second CFO value in the second link.

5 [0005] In a second aspect, there is provided a device. The device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the device to transmit, to a further device, a first signal in a first link from the device to the first device with a first carrier frequency offset (CFO) value. The device is also  
10 caused to receive a second signal in a second link from the further device on a carrier compensated with a second CFO value in response to the first CFO value in the first link exceeding a threshold offset. The second CFO value in the second link is greater than the first CFO value in the first link.

[0006] In a third aspect, there is provided a method. The method comprises determining,  
15 at a first device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a second device. The method also comprises determining whether the first CFO value in the first link from the second device to the first device exceeds a threshold offset. The method further comprises in response to a determination that the first CFO value in the first link exceeds the threshold offset, determining a second CFO  
20 value in a second link from the first device to the second device based on the first CFO value in first link. The second CFO value in the second link is greater than the first CFO value in the first link. The method yet comprises performing transmission from the first device to the second device on a carrier compensated with the second CFO value in the second link.

25 [0007] In a fourth aspect, there is provided a method. The method comprises transmitting, to a first device and at a second device, a first signal in a first link from the second device to the first device with a first carrier frequency offset (CFO) value. The method also comprises in response to the first CFO value in the first link exceeding a threshold offset, receiving a second signal in a second link from the first device on a carrier  
30 compensated with a second CFO value. The second CFO value in the second link is greater than the first CFO value in the first link.

[0008] In a fifth aspect, there is provided an apparatus comprising means for determining, at a first device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a second device; means for determining whether the first CFO value in the first link from the second device to the first device exceeds a threshold offset; means for  
5 in response to a determination that the first CFO value in the first link exceeds the threshold offset, determining a second CFO value in a second link from the first device to the second device based on the first CFO value in first link, the second CFO value in the second link being greater than the first CFO value in the first link; and means for performing transmission from the first device to the second device on a carrier compensated with the  
10 second CFO value in the second link.

[0009] In a sixth aspect, there is provided an apparatus comprising means for transmitting, to a first device and at a second device, a first signal in a first link from the second device to the first device with a first carrier frequency offset (CFO) value; and means for in response to the first CFO value in the first link exceeding a threshold offset, receiving a second  
15 signal in a second link from the first device on a carrier compensated with a second CFO value, the second CFO value in the second link being greater than the first CFO value in the first link.

[0010] In a seventh aspect, there is provided a non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method  
20 according to any one of the above third to fourth aspects.

[0011] 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

[0012] Some example embodiments will now be described with reference to the accompanying drawings, where:

[0013] Fig. 1 illustrates a schematic diagram of a communication system according to  
30 embodiments of the present disclosure;

[0014] Fig. 2 illustrates a schematic diagram of interactions among devices according to embodiments of the present disclosure;

[0015] Figs. 3A-3D illustrate comparison of system performances between the conventional technologies and embodiments of the present disclosure;

5 [0016] Fig. 4 illustrates a flow chart of a method implemented at a network device according to embodiments of the present disclosure;

[0017] Fig. 5 illustrates a flow chart of a method implemented at a terminal device according to embodiments of the present disclosure;

10 [0018] Fig. 6 illustrates a schematic diagram of a device according to embodiments of the present disclosure; and

[0019] Fig. 7 shows a block diagram of an example computer readable medium in accordance with some embodiments of the present disclosure.

[0020] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

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## DETAILED DESCRIPTION

[0021] Principle 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  
20 the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below.

[0022] 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  
25 ordinary skills in the art to which this disclosure belongs.

[0023] 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  
30 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.

[0024] It shall be understood that although the terms “first” and “second” etc. 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.

[0025] 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.

[0026] As used in this application, the term “circuitry” 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 (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0027] 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  
5 integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0028] As used herein, the term “communication network” refers to a network following any suitable communication standards, such as Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA),  
10 High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT) and so on. Furthermore, the communications between a user equipment 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,  
15 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  
20 limiting the scope of the present disclosure to only the aforementioned system.

[0029] As used herein, the term “network device” refers to a node in a communication network via which a user equipment 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  
25 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.

[0030] 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  
30 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, 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.

**[0031]** As mentioned above, the NTN has also brought some problems in other aspects. For example, due to relative movements between the terminal device and the network device, Doppler effect may be caused. The Doppler effect (or the Doppler shift) is the change in frequency or wavelength of a wave in relation to an observer who is moving relative to the wave source. In cellular networks, network devices are usually fixed, except a moving platform such as a train. In Non-Terrestrial Networks, the network devices are on satellites and/or High-Altitude Pseudo-Satellite (HAPS). For geostationary systems, the network devices are quasi static with respect to the terminal devices with only small Doppler shift. For HAPS, the network devices moving around or across a theoretical central point but creates small Doppler shift. In the scenario of non-geostationary systems, the satellites move relative to the earth and create higher Doppler shift than geostationary systems.

**[0032]** The Doppler shift depends on the relative satellite/HAPS velocity with respect to the terminal device and the frequency band. In term of Doppler shift, the worst case for NTN systems corresponds to non-geostationary systems, at lowest altitude (i.e. 600 km), where the speed of the satellite embedding transmission equipment is 7.5 km/s. Assuming a worst case where the NTN terminal velocity is 1000 km/h, for LEO in S band (2 GHz), the Doppler Shift in downlink for the whole satellite coverage is up to 48 kHz. For LEO in Ka band (20 GHz), the Doppler Shift in downlink for the whole satellite coverage is up to 480 kHz.

[0033] The maximum Doppler shifts in these scenarios are very substantial frequency errors. In addition to the Doppler effects on the service link (referred to as the link between the terminal device and the satellite) mentioned above, the feeder link (referred to as the link between the satellite and the gateway) may also be subject to the Doppler shifts.

5 Depending on the solution, these Doppler shifts may also be visible to the terminal devices.

[0034] In the scenario of the positive/negative Doppler shifts, the downlinks are at frequencies misaligned by the downlink Doppler shift difference and the uplinks are at frequencies further misaligned by the uplink Doppler shift difference. As a result, the orthogonality of orthogonal frequency-division multiple access (OFDMA) may be significantly impacted.

10

[0035] Furthermore, for the NTN system, especially for HAPS or LEO satellite with large Doppler offsets, data transmission signal may suffer from much more significant Doppler effects brought by satellite orbital motion. Therefore, fast and robust Doppler compensation is needed.

15

[0036] The frequency synchronization may be divided into two cases: (1) open loop synchronization with Global Navigation Satellite System (GNSS) and (2) closed loop synchronization on tracking of the frequency of terminal device. In case 1, the Doppler shifts may be calculated if the positions and velocities of the satellite and UE are known. Therefore, prior to initial access, the terminal device can adjust its UL TX frequency when sending Msg1. In case 2, if estimation of Doppler shift prior to the initial access is not possible or still a large residual offset left, closed-loop frequency compensation during random access may be necessary. In addition, even with frequency error pre-compensation in the satellite or terminal device side, remaining Doppler and local oscillator instabilities may still lead to poor system performance. As a consequence, after initial access, the terminal device in connected mode may track of DL frequency shift variations based on variety of reference signals under fading channel.

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[0037] However, conventional technologies do not consider applying to all the terminal devices to deal with the large residual offset in the given beam. Moreover, they lack induction mechanism for the setup of frequency offset robust system if large residual offset exists. It is desired to design a complete mechanism to deal with the NTN Doppler offset in both the initial downlink synchronization mode and the connected mode.

30

[0038] According to embodiments of the present disclosure, if the CFO value in a first link exceeds a predetermined threshold offset, the first device determines a further CFO value for transmitting a signal in a second link. The second device corrects the determined further CFO value and transmits another signal in the first link to indicate the corrected CFO value. In this way, fast and robust compensation for Doppler shift is achieved in initial access mode and maintain the OFDMA maintains orthogonal.

[0039] Fig. 1 illustrates a schematic diagram of a communication system 100 in which embodiments of the present disclosure can be implemented. The communication system 100 comprises the first devices 110 and the second device 120. For the purpose of illustrations, the first devices 110 may be referred to as the terminal device 110 and the second device 120 may be referred to as the network device 120 hereinafter. It should be noted that the first devices and the second devices are interchangeable. For example, the procedures which are described to be implemented at the terminal device may also be able to be implemented at the network device and the procedures which are described to be implemented at the network device may also be able to be implemented at the terminal device.

[0040] The link from the second device 120 to the first devices 110 may be referred to as the “first link” and the link from the first devices 110 to the second device 120 may be referred to as the “second link.” It should be noted that the first link and the second link are interchangeable.

[0041] The communication system 100, which is a part of a communication network, comprises terminal devices 110-1, 110-2, . . . , 110-N (collectively referred to as “terminal device(s) 110” where N is an integer number). The communication system 100 comprises one or more network devices, for example, a network device 120. It should be understood that the communication system 100 may also comprise other elements which are omitted for the purpose of clarity. It is to be understood that the numbers of terminal devices and network devices shown in Fig. 1 are given for the purpose of illustration without suggesting any limitations. The terminal devices 110 and the network device 120 may communicate with each other. Only for the purpose of illustrations, the network device 120 is shown as a satellite. It should be noted that the network device 120 may be on the satellite or on other moving objects.

[0042] It is to be understood that the number of network devices and terminal devices is only for the purpose of illustration without suggesting any limitations. The system 100 may include any suitable number of network devices and terminal devices adapted for implementing embodiments of the present disclosure.

5 [0043] Communications in the communication system 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  
 10 Electronics Engineers (IEEE) 802.11 and the like, and/or any other protocols currently known or to be developed in the future. Moreover, the communication may utilize any proper wireless communication technology, comprising but not limited to: Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Frequency Division Duplex (FDD), Time Division Duplex  
 15 (TDD), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiple (OFDM), Discrete Fourier Transform spread OFDM (DFT-s-OFDM) and/or any other technologies currently known or to be developed in the future.

[0044] Fig. 2 illustrates a schematic diagram of interactions 200 in accordance with embodiments of the present disclosure. The interactions 200 may be implemented at any  
 20 suitable devices. Only for the purpose of illustrations, the interactions 200 are described to be implemented at the terminal device 110-1 and the network device 120.

[0045] The network device 120 transmits 205 a first signal in the first link to the terminal device 110-1. For example, the terminal device 110-1 may detect a synchronization signal block. In some embodiments, the synchronization signal block may also refer to the  
 25 physical broadcast channel (PBCH) block. The network device 120 may transmit a synchronization signal, for example, a primary synchronization signal and/or a secondary synchronization signal.

[0046] The network device 120 and the terminal device 110-1 may be synchronized in time and frequency using the downlink signal during the downlink initial synchronization.  
 30 For example, during DL initial synchronization, with perfect symbol timing, a normalized Doppler offset of  $\varepsilon$  results in a phase rotation of  $2\pi n\varepsilon/N$  in the received signal  $Y(n)$ , given the assumption of NTN channel and regardless of the noise. The correlation

between cyclic prefix (CP) and the corresponding rear part of the OFDM symbol is as below:

$$\sum_{n=0}^{L-1} Y(n) * Y^*(n+N) = \sum_{n=0}^{L-1} |X(n)|^2 e^{j2\pi\epsilon} \Rightarrow \hat{\epsilon} = \frac{1}{2\pi} \arg \left\{ \sum_{n=0}^{L-1} Y(n) * Y^*(n+N) \right\} \quad (1)$$

where N is fast fourier transform (FFT) point, L is CP length,  $X(n)$  is signal in the transmitter.

**[0047]** The terminal device 110-1 determines 210 the first CFO value in the first link based on the first signal in the first link. For example, the estimated Doppler shift is  $\hat{\epsilon}$ ,

so the coarse compensation of FFO could be made in the receiver that  $\overline{Y(n)} = Y(n)e^{-2\pi\hat{\epsilon}n/N}$  and there may be still some residual offset left. After serial to parallel and FFT transition, CFO may be acquired from PSS in frequency domain at the precondition since the accurate symbol timing offset (STO) is acquired.

**[0048]** The terminal device 110-1 determines 215 whether the first CFO value in the first link exceeds a threshold offset. For example, the threshold offset may be 5 ppm. It should be noted that the threshold offset may be any suitable values. In some embodiments, the threshold offset may be determined associated with the performance of the terminal device 110-1.

**[0049]** If the first CFO value in the first link exceeds the threshold offset, the terminal device 110-1 determines 220 the second CFO value in the second link from the terminal device 110-1 to the network device 120 based on the first CFO value. For example, the CFO in the second link may be approximately equivalent to the CFO in the first link since the velocity vectors between the terminal devices and the network devices are the same in a very short time. The second CFO value in the second link is greater than the first CFO value in the first link. In some embodiments, the second CFO value may be as twice as the first CFO value. For example, if the first CFO value is  $f_1$ , the second CFO value may be  $2*f_1$ . In this way, efficiency for compensating Doppler shifts is improved.

**[0050]** The terminal device 110-1 performs 225 the transmission in the second link from the terminal device 110-1 to the network device 120. In some embodiments, the terminal device 110-1 may transmit Msg. 1 to the network device 120. The terminal device 110-1 performs the transmission on the carrier compensated with the second CFO value. For example, the center frequency of the carrier may be  $F_1$  and the second CFO value may be

$2*f_1$ , the terminal device 110-1 may perform the transmission on the frequency  $F_1 + 2*f_1$ . In other embodiments, the terminal device 110-1 may perform the transmission on the frequency  $F_1 - 2*f_1$ .

[0051] In some embodiments, the terminal device 110-1 may indicate the network device 120 to adopt the inter-carrier interference (ICI) cancellation. For example, the Msg. 1 may comprise one bit information to indicate to adopt the ICI cancellation. The network device 120 may disuse the ICI cancellation within tolerance. In other embodiments, the terminal device 110-1 may perform the transmission in the second link using the ICI cancellation.

[0052] In some embodiments, the network device 120 may estimate the third CFO value in first link based on the transmission. For example, if the terminal device 110-1 transmits the Msg. 1 to the network device 120, the network device 120 may estimate the third CFO value based on a property of the Msg. 1, for example, sequences of the Msg. 1. The network device 120 may obtain the second CFO value in the second link. The network device 120 may adjust the third CFO value based on the obtained second CFO value in the second link. The uplink frequencies of the terminal devices 110 may be aligned at the network device 120. In this way, the OFDMA orthogonality may be maintained by compensating both the first and second links Doppler shifts.

[0053] The network device 120 may transmit the third signal in the first link. The third signal indicates the adjusted third CFO value. For example, the network device 120 may transmit the Msg. 2 to the terminal device 110-1. The Msg. 2 may comprise one or more bits to indicate the adjusted third CFO value.

[0054] The terminal device 110-1 may obtain the third CFO value from the third signal in the first link. The terminal device 110-1 may determine the fourth CFO value based on the third CFO value. For example, the fourth CFO value in the second link is greater than the third CFO value in the first link. In some embodiments, the fourth CFO value may be as twice as the third CFO value. For example, if the third CFO value is  $f_2$ , the fourth CFO value may be  $2*f_2$ .

[0055] The terminal device 110-1 may transmit the fourth signal in the second link on the further carrier compensated with the fourth CFO value. For example, the center frequency of the further carrier may be  $F_2$  and the fourth CFO value may be  $2*f_2$ , the terminal device 110-1 may transmit the fourth signal with the frequency  $F_2 + 2*f_2$ . In other embodiments, the terminal device 110-1 may transmit the fourth signal with the frequency

$F_2 - 2^*f_2$ . In this way, fast and robust compensation for Doppler shifts in initial access mode is achieved and larger frequency residual offset is resisted.

[0056] Figs. 3A-3D illustrate comparison of system performances between the conventional technologies and embodiments of the present disclosure. As shown in Figs.

3A-3D, all data symbols are mapped onto a pair of two adjacent subcarriers in frequency domain to achieve frequency diversity  $X'(k) = \alpha X(k)$ ,  $X'(k+1) = \beta e^{-j\varphi} X^*(k)$ , where the  $X(k)$  is the signal in the transmitter in frequency domain, the received signal could be demodulated as  $Y''(k) = \frac{1}{\alpha - \beta} [Y'(k) - e^{-j\varphi} Y'^*(k+1)]$ . Flat-fading is used in Figs. 3A-3D.

Moreover,  $\alpha=0.5$ ,  $\beta=-0.5$  and  $\varphi$  could be any angel. Further, the normalized CFO  $\varepsilon$  in Fig. 3A is 0.01, the normalized CFO  $\varepsilon$  in Fig. 3B is 0.1, the normalized CFO  $\varepsilon$  in Fig. 3C is 0.3 and the normalized CFO  $\varepsilon$  in Fig. 3D is 0.5. It can be seen that the system performance of embodiments of the present disclosure is better than the conventional technologies with the increasing of normalized CFO  $\varepsilon$ . In this way, the system is more robust to the residual CFO caused by Doppler offset.

[0057] After succeeding the access procedures, the terminal device 110-1 is in the connected mode. If high Doppler variation rate exists or dramatically channel change occurs, the variety of reference signals signal like demodulation reference signal (DMRS) or channel state information reference signal (CSI-RS) may be used for CFO tracking.

[0058] In addition, the Doppler effects have impacts on the broadband signal: (i) RF central frequency shifting from  $f_c$  to  $f_c[1 + \delta(t)]$ ; (ii) sub-carrier spacing spreading from  $f_s$  to  $f_s[1 + \delta(t)]$ ; (iii) following the sub-carrier spacing spread, the OFDM symbol duration changing from  $T$  to  $T'$ , where  $\delta(t)$  is relative Doppler parameter  $\delta(t) = v'(t)/c$ , the  $v'(t)$  is the velocity vectors onto the line connecting the network device 120 and the terminal devices 110, and  $c$  is radio speed. The sampling starting time of FFT window may drift and give rise to phase rotation, for example, the same CSI-RS mapping RE can be extracted with the number  $N_p$ , the phase offset could be estimated as below:

$$\hat{\phi} = (N / 2m\pi) \arg \left\{ \sum_{k=1}^{N_p/2-1} M(k) M^*(k-m) \right\} \quad (2)$$

where  $m$  is the span between two same CSI-RS. The compensation may be  $\overline{M(k)} = M(k)e^{-j2\pi k\hat{\phi}/N}$ . In the same way, the pilot signal (CSI-RS or DMRS) may also be compensated as  $\overline{P} = Pe^{-j2\pi k\hat{\phi}/N}$ .

[0059] The correction factor  $\kappa$  may be acquired as the average of the utilized corrected

5 pilots signal  $\kappa = \sum_{k=1}^{N_p-1} \overline{P}/N_p$ , and then the fine NTN compensation may be conducted by

$Y(k) = \overline{M(k)}/\kappa$ . The  $\hat{\phi}$  can be feedback in the uplink for the time drift adjustment in the next symbol.

[0060] Fig. 4 illustrates a flow chart of a method 400 in accordance with embodiments of the present disclosure. The method 400 may be implemented at any suitable devices.

10 Only for the purpose of illustrations, the method 400 is described to be implemented at the terminal device 110-1.

[0061] In example embodiments, the terminal device 110-1 may receive the first signal in the first link from the terminal device 110-1. For example, the terminal device 110-1 may detect a synchronization signal block. In some embodiments, the synchronization signal block may also refer to the physical broadcast channel (PBCH) block. The terminal device 110-1 may receive a synchronization signal, for example, a primary synchronization signal and/or a secondary synchronization signal.

[0062] At block 410, the terminal device 110-1 determines the first CFO value in the first link based on the first signal in the first link. For example, the estimated Doppler shift is  $\hat{\varepsilon}$ , so the coarse compensation of FFO could be made in the receiver that

$\overline{Y(n)} = Y(n)e^{-2j\pi n\hat{\varepsilon}/N}$  and there may be still some residual offset left. After serial to parallel and FFT transition, CFO may be acquired from PSS in frequency domain at the precondition since the accurate symbol timing offset (STO) is acquired.

[0063] At block 420, the terminal device 110-1 determines whether the first CFO value in the first link exceeds a threshold offset. For example, the threshold offset may be 5 ppm. It should be noted that the threshold offset may be any suitable values. In some embodiments, the threshold offset may be determined associated with the performance of the terminal device 110-1.

[0064] If the first CFO value in the first link exceeds the threshold offset, the terminal device 110-1 determines, at block 330, the second CFO value in the second link from the

terminal device 110-1 to the network device 120 based on the first CFO value. For example, the CFO in the second link may be approximately equivalent to the CFO in the first link since the velocity vectors between the terminal devices and the network devices are the same in a very short time. The second CFO value in the second link is greater than the first CFO value in the first link. In some embodiments, the second CFO value may be as twice as the first CFO value. For example, if the first CFO value is  $f_l$ , the second CFO value may be  $2*f_l$ . In this way, efficiency for compensating Doppler shifts is improved.

[0065] At block 440, the terminal device 110-1 performs the transmission in the second link from the terminal device 110-1 to the network device 120. In some embodiments, the terminal device 110-1 may transmit Msg. 1 to the network device 120. The terminal device 110-1 performs the transmission on the carrier compensated with the second CFO value. For example, the center frequency of the carrier may be  $F_1$  and the second CFO value may be  $2*f_l$ , the terminal device 110-1 may perform the transmission on the frequency  $F_1 + 2*f_l$ . In other embodiments, the terminal device 110-1 may perform the transmission on the frequency  $F_1 - 2*f_l$ .

[0066] In some embodiments, the terminal device 110-1 may indicate the network device 120 to adopt the inter-carrier interference (ICI) cancellation. For example, the Msg. 1 may comprise one bit information to indicate to adopt the ICI cancellation. The network device 120 may disuse the ICI cancellation within tolerance. In other embodiments, the terminal device 110-1 may perform the transmission in the second link using the ICI cancellation.

[0067] In other embodiments, the terminal device 110-1 may obtain the third CFO value from the third signal in the first link. The terminal device 110-1 may determine the fourth CFO value based on the third CFO value. For example, the fourth CFO value in the second link is greater than the third CFO value in the first link. In some embodiments, the fourth CFO value may be as twice as the third CFO value. For example, if the third CFO value is  $f_2$ , the fourth CFO value may be  $2*f_2$ . The terminal device 110-1 may transmit the fourth signal in the second link on the further carrier compensated with the fourth CFO value. For example, the center frequency of the further carrier may be  $F_2$  and the fourth CFO value may be  $2*f_2$ , the terminal device 110-1 may transmit the fourth signal with the frequency  $F_2 + 2*f_2$ . In other embodiments, the terminal device 110-1 may transmit the fourth signal with the frequency  $F_2 - 2*f_2$ . In this way, fast and robust compensation for

Doppler shifts in initial access mode is achieved and larger frequency residual offset is resisted.

[0068] Fig. 5 illustrates a flow chart of a 500 in accordance with embodiments of the present disclosure. The method 400 may be implemented at any suitable devices. Only  
 5 for the purpose of illustrations, the method 500 is described to be implemented at the network device 120.

[0069] At block 510, the network device 120 transmits the first signal in the first link with the first CFO value. For example, the network device 120 may transmit a synchronization signal, for example, a primary synchronization signal and/or a secondary synchronization  
 10 signal.

[0070] At block 520, the network device 120 receives the second signal in the second link from the terminal device 110-1 to the network device 120. In some embodiments, the network device 120 may receive Msg. 1 from the terminal device 110-1. The network device 120 may receive the second signal on the carrier compensated with the second CFO  
 15 value. For example, the center frequency of the carrier may be  $F_1$  and the second CFO value may be  $2*f_l$ , the second signal may be received on the frequency  $F_1 + 2*f_l$ . In other embodiments, the second signal may be received on the frequency  $F_1 - 2*f_l$ .

[0071] In some embodiments, the second signal in the second link may indicate the network device 120 to adopt the inter-carrier interference (ICI) cancellation. For example,  
 20 the Msg. 1 may comprise one bit information to indicate to adopt the ICI cancellation. The network device 120 may disuse the ICI cancellation within tolerance.

[0072] In some embodiments, at block 530, the network device 120 may determine the third CFO value in first link based on the transmission. For example, if the terminal device 110-1 transmits the Msg. 1 to the network device 120, the network device 120 may  
 25 estimate the third CFO value based on a property of the Msg. 1, for example, sequences of the Msg. 1. The network device 120 may obtain the second CFO value in the second link.

[0073] In an example embodiment, at block 540, the network device 120 may adjust the third CFO value based on the obtained second CFO value in the second link. The uplink frequencies of the terminal devices 110 may be aligned at the network device 120. In this  
 30 way, the OFDMA orthogonality may be maintained by compensating both the first and second links Doppler shifts.

[0074] In some embodiments, at block 550, the network device 120 may transmit the third signal in the first link to the terminal device 110-1. The third signal may indicate the

adjusted third CFO value. For example, the network device 120 may transmit the Msg. 2 to the terminal device 110-1. The Msg. 2 may comprise one or more bits to indicate the adjusted third CFO value.

[0075] In some embodiment, the network device 120 may receive the fourth signal in the second link on the further carrier compensated with the fourth CFO value. For example, the center frequency of the further carrier may be  $F_2$  and the fourth CFO value may be  $2*f_2$ , the fourth signal may be received on the frequency  $F_2 + 2*f_2$ . In other embodiments, the fourth signal may be received on the frequency  $F_2 - 2*f_2$ .

[0076] In some embodiments, an apparatus for performing the method 400 (for example, the controlling network device 120) may comprise respective means for performing the corresponding steps in the method 400. These means may be implemented in any suitable manners. For example, it can be implemented by circuitry or software modules.

[0077] In some embodiments, the apparatus comprises: means for determining, at a first device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a second device; means for determining whether the first CFO value in the first link from the second device to the first device exceeds a threshold offset; means for in response to a determination that the first CFO value in the first link exceeds the threshold offset, determining a second CFO value in a second link from the first device to the second device based on the first CFO value in first link, the second CFO value in the second link being greater than the first CFO value in the first link; and means for performing transmission from the first device to the second device on a carrier compensated with the second CFO value in the second link.

[0078] In some embodiments, the means for determining the second CFO value in the second link comprises: means for determining the second CFO value in the second link to be as twice as the first CFO value in the first link.

[0079] In some embodiments, the means for performing transmission from the first device to the second device comprises: means for transmitting a second signal in the second link indicating the second device to perform inter-carrier interference cancellation.

[0080] In some embodiments, the means for performing transmission from the first device to the second device comprises: means for performing the transmission using inter-carrier interference cancellation.

[0081] In some embodiments, the apparatus further comprises: means for receiving a third signal in the first link from the second device, the third signal in the first link indicating a

third CFO value in the first link which is adjusted based on the second CFO value in the second link; means for determining a fourth CFO value in the second link based on the third CFO value in the first link, the fourth CFO value in the second link being greater than the third CFO value in the first link; and means for transmitting a fourth signal to the second device on a further carrier compensated with the fourth CFO value in the first link.

[0082] In some embodiments, the first device is a terminal device, the second device is a network device, the first link is a downlink and the second link is an uplink.

[0083] In some embodiments, an apparatus for performing the method 500 (for example, the network device 120) may comprise respective means for performing the corresponding steps in the method 500. These means may be implemented in any suitable manners. For example, it can be implemented by circuitry or software modules.

[0084] In some embodiments, the apparatus comprises: means for transmitting, to a first device and at a second device, a first signal in a first link from the second device to the first device with a first carrier frequency offset (CFO) value; and means for in response to the first CFO value in the first link exceeding a threshold offset, receiving a second signal in a second link from the first device on a carrier compensated with a second CFO value, the second CFO value in the second link being greater than the first CFO value in the first link.

[0085] In some embodiments, the second CFO value in the second link is as twice as the first CFO value in the first link.

[0086] In some embodiments, the means for receiving the second signal from the first device comprises: means for receiving the second signal indicating the second device to perform inter-carrier interference cancellation.

[0087] In some embodiments, the apparatus further comprises: means for determining a third CFO value in the first link based on the received second signal; and means for adjusting the third CFO value in the first link based on the second CFO value in the second link.

[0088] In some embodiments, the apparatus further comprises: means for transmitting a third signal in the first link to the first device indicating the third CFO value in the first link; and means for receiving a fourth signal in the second link from the first device on a further carrier compensated with the fourth CFO value in the second link.

[0089] In some embodiments, the first device is a terminal device, the second device is a network device, the first link is a downlink and the second link is an uplink.

[0090] Fig. 6 is a simplified block diagram of a device 600 that is suitable for implementing embodiments of the present disclosure. The device 600 may be provided to implement the communication device, for example the network device 120 or the terminal devices 110 as shown in Fig. 1. As shown, the device 600 includes one or more processors 610, one or more memories 620 coupled to the processor 610, and one or more communication module (for example, transmitters and/or receivers (TX/RX)) 640 coupled to the processor 610.

[0091] The communication module 640 is for bidirectional communications. The communication module 640 has at least one antenna to facilitate communication. The communication interface may represent any interface that is necessary for communication with other network elements.

[0092] The processor 610 may be of any type suitable to the local technical network and may include one or more of the following: general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. The device 600 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.

[0093] The memory 620 may include one or more non-volatile memories and one or more volatile memories. Examples of the non-volatile memories include, but are not limited to, a Read Only Memory (ROM) 624, an electrically programmable read only memory (EPROM), a flash memory, a hard disk, a compact disc (CD), a digital video disk (DVD), and other magnetic storage and/or optical storage. Examples of the volatile memories include, but are not limited to, a random access memory (RAM) 622 and other volatile memories that will not last in the power-down duration.

[0094] A computer program 630 includes computer executable instructions that are executed by the associated processor 610. The program 630 may be stored in the ROM 624. The processor 610 may perform any suitable actions and processing by loading the program 630 into the RAM 622.

[0095] The embodiments of the present disclosure may be implemented by means of the program 630 so that the device 600 may perform any process of the disclosure as discussed with reference to Figs. 2 to 5. The embodiments of the present disclosure may also be implemented by hardware or by a combination of software and hardware.

[0096] In some embodiments, the program 630 may be tangibly contained in a computer readable medium which may be included in the device 600 (such as in the memory 620) or other storage devices that are accessible by the device 600. The device 600 may load the program 630 from the computer readable medium to the RAM 622 for execution. The computer readable medium may include any types of tangible non-volatile storage, such as ROM, EPROM, a flash memory, a hard disk, CD, DVD, and the like. Fig. 7 shows an example of the computer readable medium 700 in form of CD or DVD. The computer readable medium has the program 630 stored thereon.

[0097] 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 representations, it is to be understood that the block, apparatus, system, technique or method 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.

[0098] 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 methods 400 and 600 as described above with reference to Figs. 2-5. 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.

[0099] 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.

5 [00100] In the context of the present disclosure, the computer program codes or related data may be carried by any suitable carrier to enable the device, apparatus or processor to perform various processes and operations as described above. Examples of the carrier include a signal, computer readable medium, and the like.

10 [00101] The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer 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 computer readable storage medium would include an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access  
15 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.

20 [00102] 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 implementation details are contained in the above discussions, these should not be construed as limitations on the scope of the  
25 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.

30 [00103] Although the present disclosure has been described in languages 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 device comprising:

at least one processor; and

at least one memory including computer program codes;

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

          determine, at the device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a further device;

          determine whether the first CFO value in the first link from the further device to  
10       the device exceeds a threshold offset;

          in response to a determination that the first CFO value in the first link exceeds the threshold offset, determine a second CFO value in a second link from the device to the further device based on the first CFO value in first link, the second CFO value in the second link being greater than the first CFO value in the first link; and

15       perform transmission from the device to the further device on a carrier compensated with the second CFO value in the second link.

2. The device of claim 1, wherein the device is caused to determine the second CFO value in the second link by:

20       determining the second CFO value in the second link to be as twice as the first CFO value in the first link.

3. The device of claim 1, wherein the device is caused to perform transmission from the device to the further device by:

25       transmitting a second signal in the second link indicating the further device to perform inter-carrier interference cancellation.

4. The device of claim 1, wherein the device is caused to perform transmission from the first to the further device by:

30       performing the transmission using inter-carrier interference cancellation.

5. The device of claim 1, wherein the device is further caused to:

receive a third signal in the first link from the further device, the third signal in the first link indicating a third CFO value in the first link which is adjusted based on the second CFO value in the second link;

5 determine a fourth CFO value in the second link based on the third CFO value in the first link, the fourth CFO value in the second link being greater than the third CFO value in the first link; and

transmit a fourth signal to the further device on a further carrier compensated with the fourth CFO value in the first link.

10 6. The device of claim 1, wherein the device is a terminal device, the further device is a network device, the first link is a downlink and the second link is an uplink.

7. A device comprising:

at least one processor; and

15 at least one memory including computer program codes;

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

transmit, to a further device, a first signal in a first link from the device to the further device with a first carrier frequency offset (CFO) value; and

20 in response to the first CFO value in the first link exceeding a threshold offset, receive a second signal in a second link from the further device on a carrier compensated with a second CFO value, the second CFO value in the second link being greater than the first CFO value in the first link.

25 8. The device of claim 7, wherein the second CFO value in the second link is as twice as the first CFO value in the first link.

9. The device of claim 7, wherein the device is caused to receive the second signal from the further device by:

30 receiving the second signal indicating the device to perform inter-carrier interference cancellation.

10. The device of claim 7, wherein the device is further caused to:

determine a third CFO value in the first link based on the received second signal;  
and

adjust the third CFO value in the first link based on the second CFO value in the second link.

5

11. The device of claim 10, wherein the device is further caused to:

transmit a third signal in the first link to the further device indicating the third CFO value in the first link; and

receive a fourth signal in the second link from the further device on a further carrier  
10 compensated with the fourth CFO value in the second link.

12. The device of claim 7, wherein the device is a network device, the further device is a terminal device, the first link is a downlink and the second link is an uplink.

15

13. A method comprising:

determining, at a first device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a second device;

determining whether the first CFO value in the first link from the second device to the first device exceeds a threshold offset;

20

in response to a determination that the first CFO value in the first link exceeds the threshold offset, determining a second CFO value in a second link from the first device to the second device based on the first CFO value in first link, the second CFO value in the second link being greater than the first CFO value in the first link; and

performing transmission from the first device to the second device on a carrier  
25 compensated with the second CFO value in the second link.

14. The method of claim 13, wherein determining the second CFO value in the second link comprises:

determining the second CFO value in the second link to be as twice as the first CFO  
30 value in the first link.

15. The method of claim 13, wherein performing transmission from the first device to the second device comprises:

transmitting a second signal in the second link indicating the second device to perform inter-carrier interference cancellation.

16. The method of claim 13, wherein performing transmission from the first device  
5 to the second device comprises:  
performing the transmission using inter-carrier interference cancellation.

17. The method of claim 13, further comprising:  
receiving a third signal in the first link from the second device, the third signal in  
10 the first link indicating a third CFO value in the first link which is adjusted based on the  
second CFO value in the second link;  
determining a fourth CFO value in the second link based on the third CFO value in  
the first link, the fourth CFO value in the second link being greater than the third CFO  
value in the first link; and  
15 transmitting a fourth signal to the second device on a further carrier compensated  
with the fourth CFO value in the first link.

18. The method of claim 13, wherein the first device is a terminal device, the second  
device is a network device, the first link is a downlink and the second link is an uplink.  
20

19. A method comprising:  
transmitting, to a first device and at a second device, a first signal in a first link from  
the second device to the first device with a first carrier frequency offset (CFO) value; and  
in response to the first CFO value in the first link exceeding a threshold offset,  
25 receiving a second signal in a second link from the first device on a carrier compensated  
with a second CFO value, the second CFO value in the second link being greater than the  
first CFO value in the first link.

20. The method of claim 19, wherein the second CFO value in the second link is as  
30 twice as the first CFO value in the first link.

21. The method of claim 19, wherein receiving the second signal from the first  
device comprises:

receiving the second signal indicating the second device to perform inter-carrier interference cancellation.

22. The method of claim 19, further comprising:

5 determining a third CFO value in the first link based on the received second signal;  
and  
adjusting the third CFO value in the first link based on the second CFO value in the second link.

10 23. The method of claim 22, further comprising:

transmitting a third signal in the first link to the first device indicating the third CFO value in the first link; and

receiving a fourth signal in the second link from the first device on a further carrier compensated with the fourth CFO value in the second link.

15 24. The method of claim 19, wherein the first device is a terminal device, the second device is a network device, the first link is a downlink and the second link is an uplink.

25. An apparatus comprising:

20 means for determining, at a first device, a first carrier frequency offset (CFO) value in a first link based on a first signal received from a second device;

means for determining whether the first CFO value in the first link from the second device to the first device exceeds a threshold offset;

25 means for in response to a determination that the first CFO value in the first link exceeds the threshold offset, determining a second CFO value in a second link from the first device to the second device based on the first CFO value in first link, the second CFO value in the second link being greater than the first CFO value in the first link; and

means for performing transmission from the first device to the second device on a carrier compensated with the second CFO value in the second link.

30 26. An apparatus comprising:

means for transmitting, to a first device and at a second device, a first signal in a first link from the second device to the first device with a first carrier frequency offset (CFO) value; and

means for in response to the first CFO value in the first link exceeding a threshold offset, receiving a second signal in a second link from the first device on a carrier compensated with a second CFO value, the second CFO value in the second link being greater than the first CFO value in the first link.

5

27. A computer readable medium storing instructions thereon, the instructions, when executed by at least one processing unit of a machine, causing the machine to perform the method according to any one of claims 13-18.

10

28. A computer readable medium storing instructions thereon, the instructions, when executed by at least one processing unit of a machine, causing the machine to perform the method according to any one of claims 19-24.

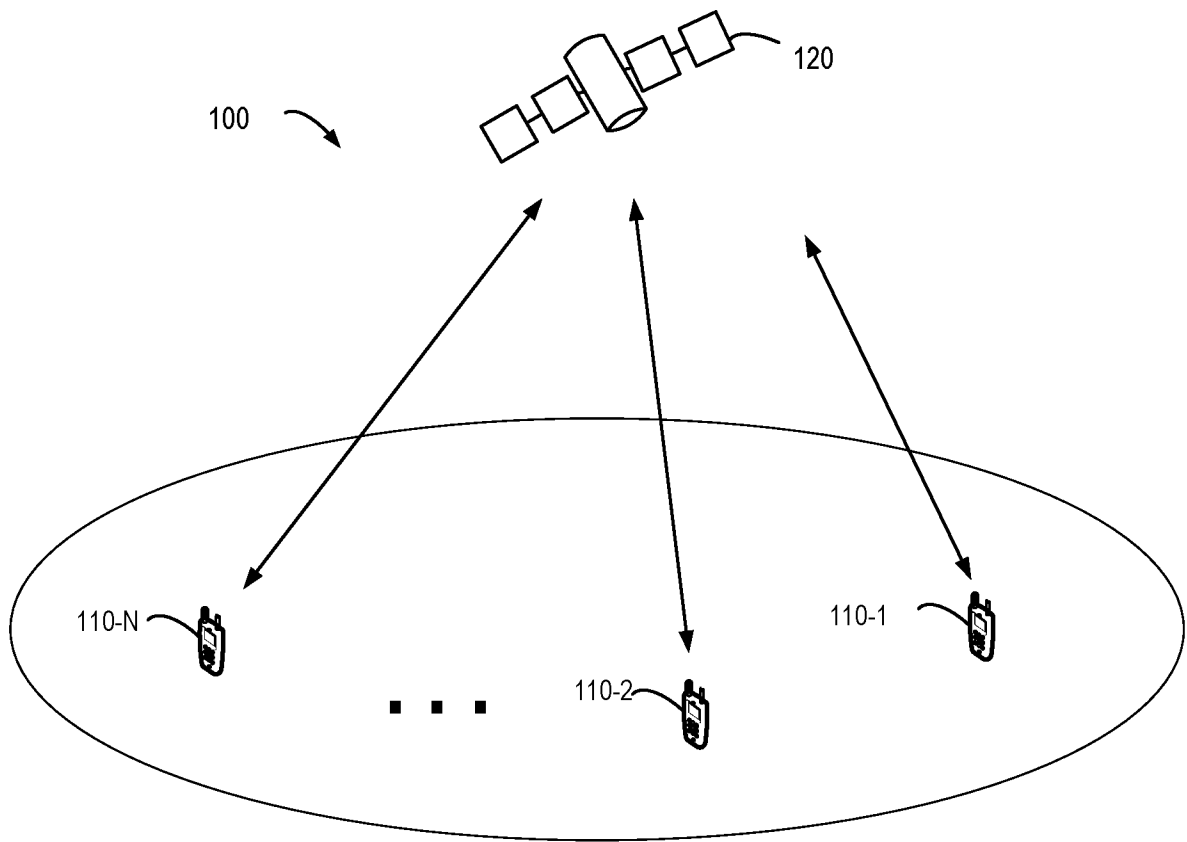


Fig. 1

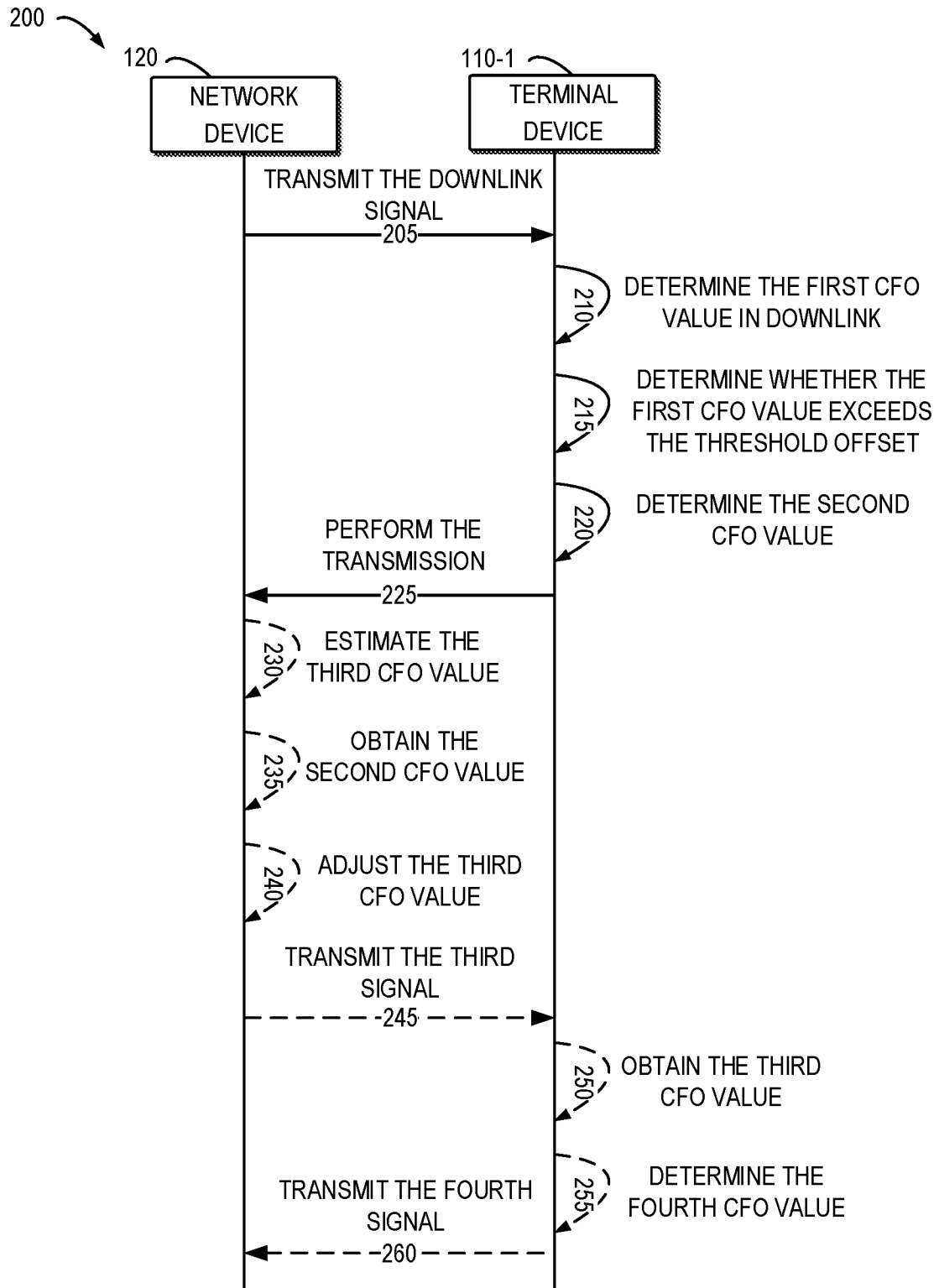


Fig.2

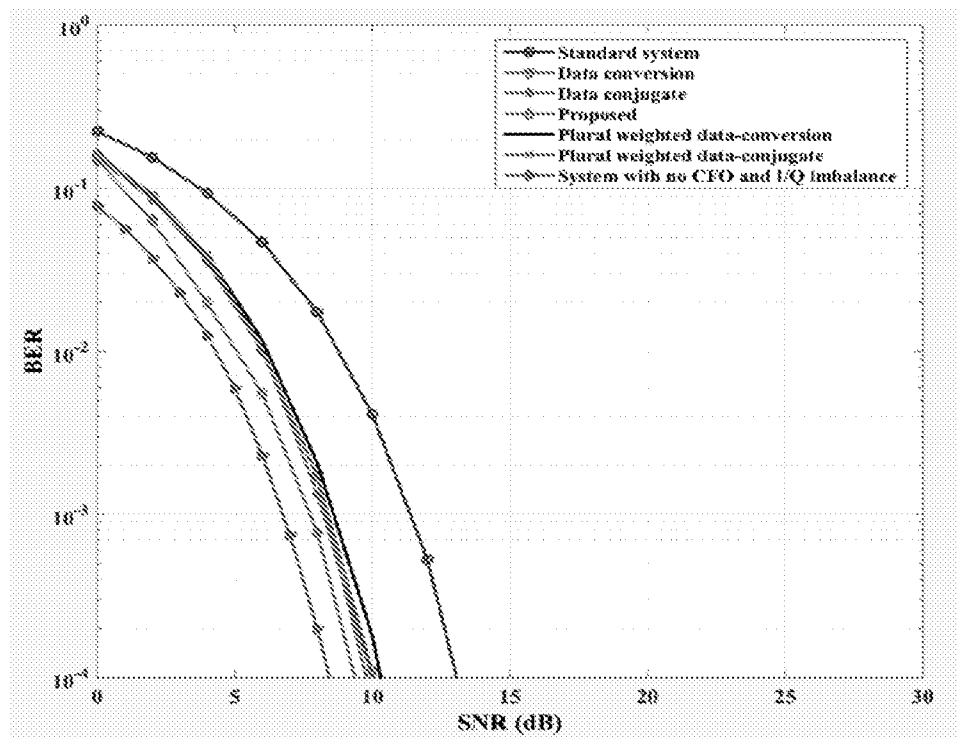


Fig.3A

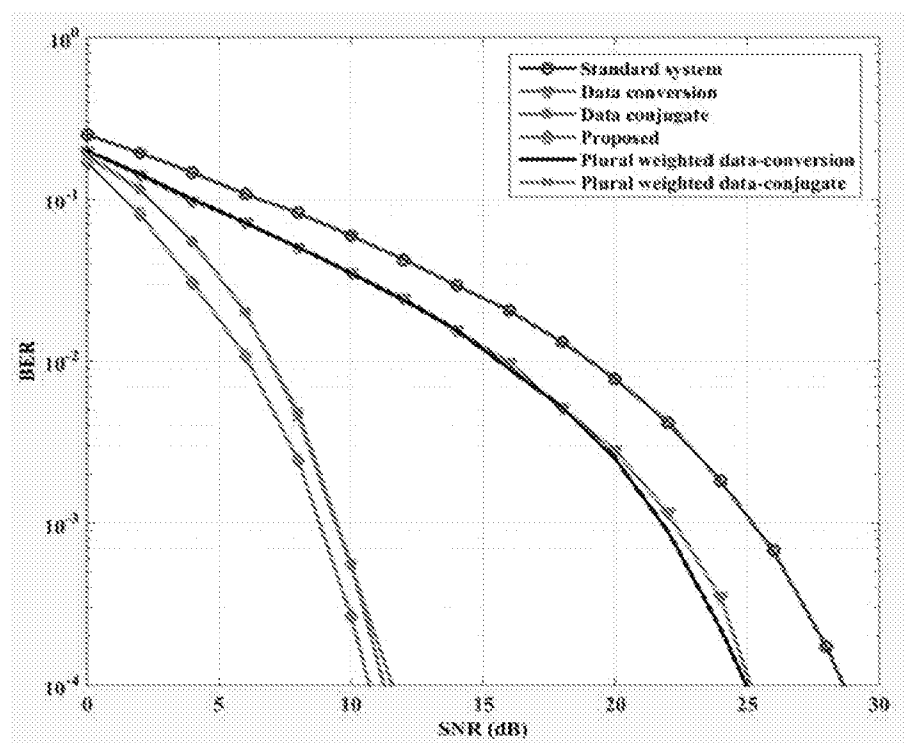


Fig.3B

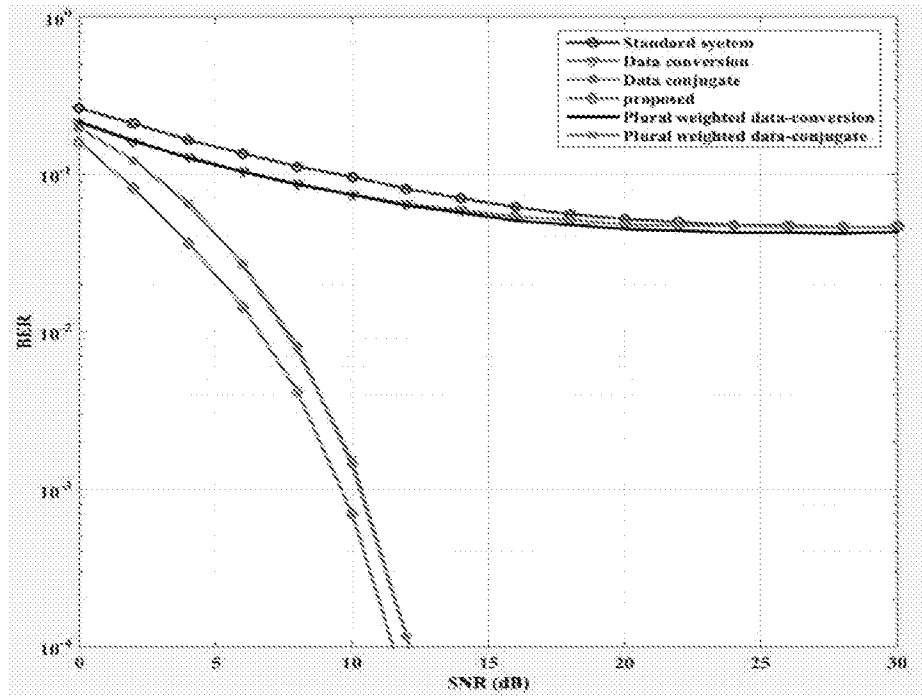


Fig.3C

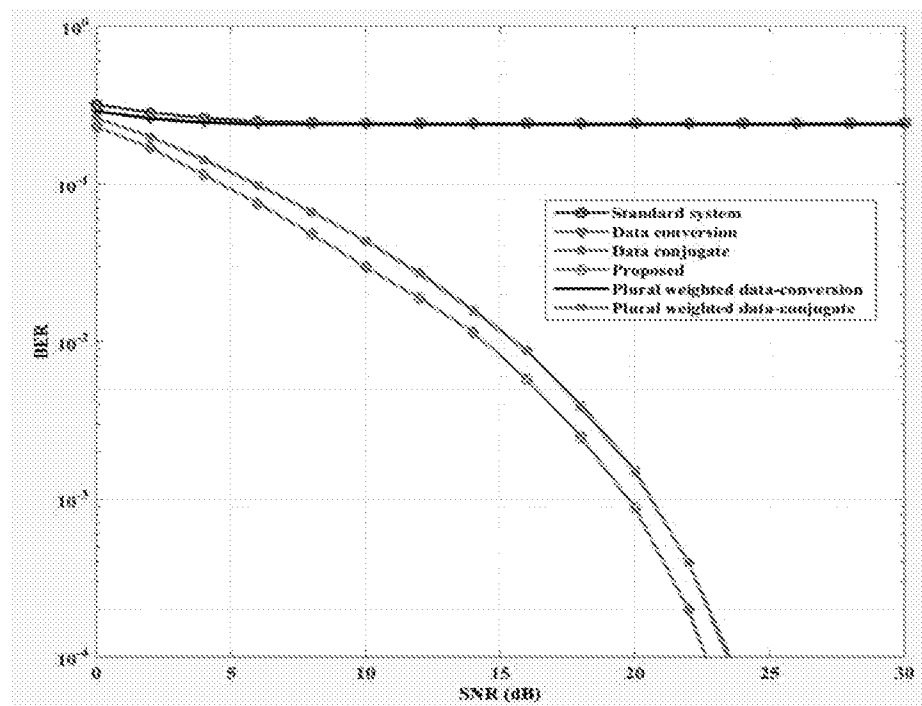


Fig.3D

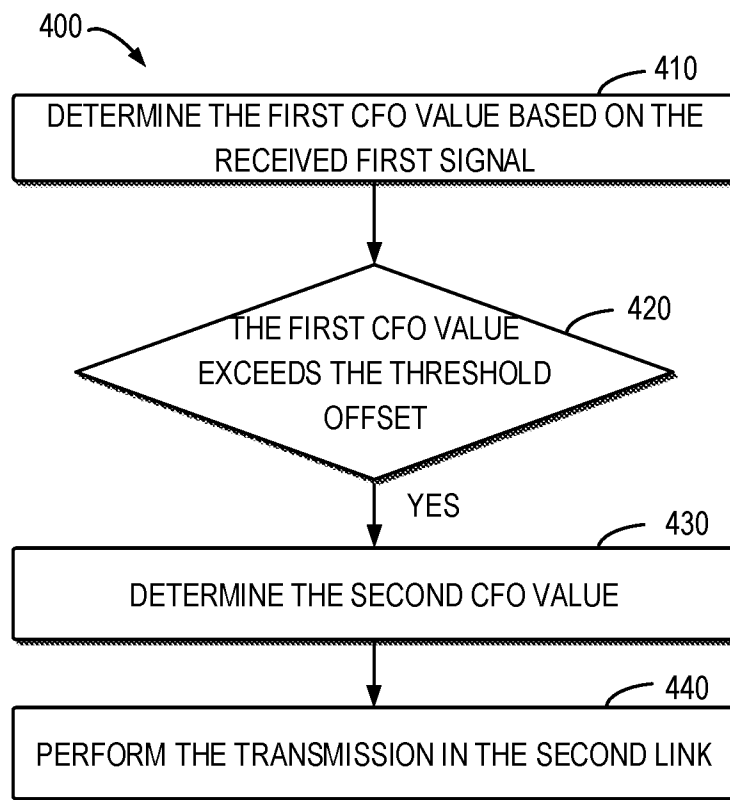


Fig. 4

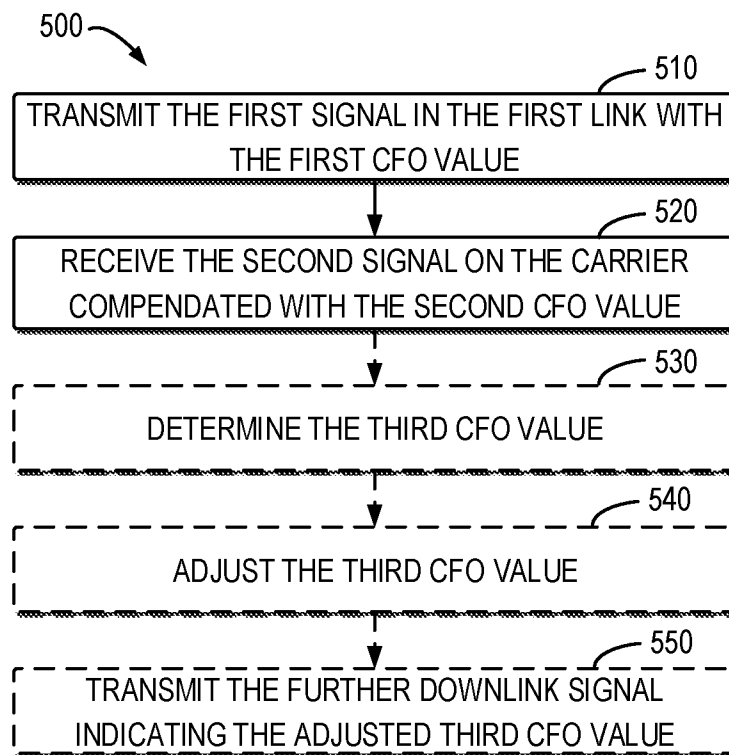


Fig. 5

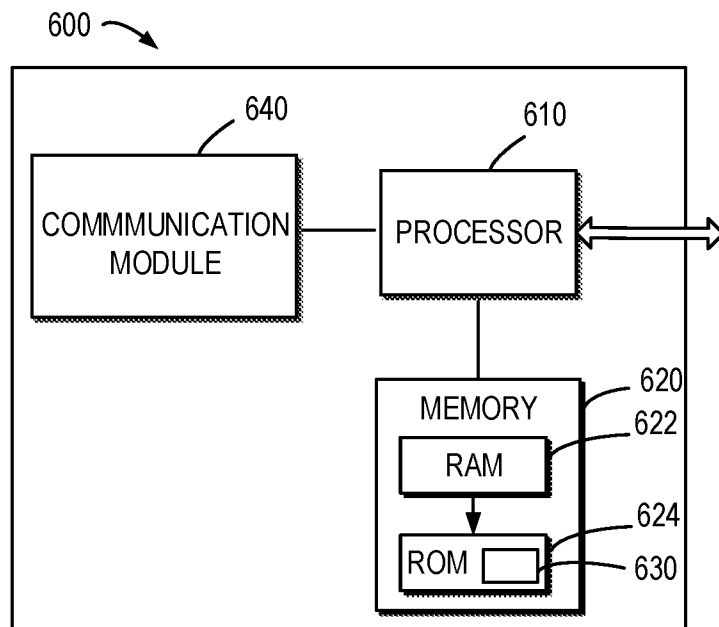


Fig. 6

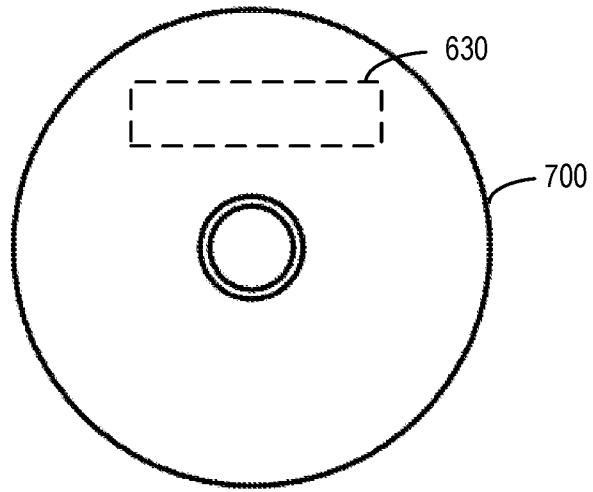


Fig. 7

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2019/085086

**A. CLASSIFICATION OF SUBJECT MATTER**

H04W 56/00(2009.01)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)

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)

CNKI,CNPAT,WPI,EPODOC,3GPP:doppler, frequency, offset, shift, drift, remaining, residual, left, additional, compensat+, carrier, threshold, NTN, non-terrestrial network,

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                 | Relevant to claim No. |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | MEDIATEK INC. "Doppler compensation in initial access procedure in NR-NTN"<br>3GPP TSG RAN WG1 Meeting #96bis R1-1904644, 29 March 2019 (2019-03-29),<br>section 3 | 1-28                  |
| X         | ERICSSON. "Frequency compensation in NTN"<br>3GPP TSG-RAN WG1 Meeting #95 Tdoc R1-1813362, 03 November 2018 (2018-11-03),<br>sections 2, 3                         | 1-28                  |
| A         | US 6377802 B1 (AIRCELL, INC.) 23 April 2002 (2002-04-23)<br>the whole document                                                                                     | 1-28                  |
| A         | WO 2015143252 A1 (HUGHES NETWORK SYSTEMS, LLC) 24 September 2015<br>(2015-09-24)<br>the whole document                                                             | 1-28                  |
| A         | CN 106411494 A (CHONGQING UNIVERSITY et al.) 15 February 2017 (2017-02-15)<br>the whole document                                                                   | 1-28                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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

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

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

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"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

19 December 2019

Date of mailing of the international search report

31 December 2019

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**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/CN2019/085086**

| Patent document<br>cited in search report |            |    | Publication date<br>(day/month/year) | Patent family member(s) |                 | Publication date<br>(day/month/year) |
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| WO                                        | 2015143252 | A1 | 24 September 2015                    | CA                      | 2970923 A1      | 24 September 2015                    |
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|                                           |            |    |                                      | US                      | 2015270890 A1   | 24 September 2015                    |
| CN                                        | 106411494  | A  | 15 February 2017                     | None                    |                 |                                      |