FREQUENCY OFFSET ESTIMATION METHOD, STATION, AND ACCESS POINT

[0001] This application claims priority to Chinese Patent Application No. 202010228622.5, filed with the China National Intellectual Property Administration on March 27, 2020 and entitled "FREQUENCY OFFSET ESTIMATION METHOD, STATION, AND ACCESS POINT", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This application relates to the communications field, and more specifically, to a frequency offset estimation method, a station, and an access point.

BACKGROUND

[0003] With development of a wireless local area network technology, an uplink multi-user multiple-input multiple-output (uplink multi-user multiple input multiple output, UL MU-MIMO) technology is introduced. A plurality of stations (station, STA) simultaneously send data to an access point (access point, AP) in uplink, and interference between the stations is eliminated by using a spatial multiplexing technology and orthogonal equalization on an AP side. This effectively improves uplink spectrum resource utilization.

[0004] However, stations have different types and different radio frequency links. Therefore, carrier frequencies used when the stations send data are hardly consistent, that is, frequency synchronization cannot be implemented when the plurality of stations send data to the AP. As a result, when channel estimation is performed on the AP side, it is difficult for channels of the plurality of stations to be orthogonal, and the channels crosstalk with each other. Consequently, precision of channel estimation is greatly reduced. Therefore, how to improve precision of estimating values of frequency offsets for a plurality of stations relative to the AP by the AP in an uplink multi-station channel multiple-input multiple-output scenario becomes an urgent problem to be resolved.

SUMMARY

[0005] This application provides a frequency offset estimation method, a station, and an access point, to improve estimation precision of determining a frequency offset by an access point.

[0006] According to a first aspect, a frequency offset estimation method is provided. The frequency offset estimation method may be performed by an access point AP, or may be performed by a chip or a circuit disposed in the AP. This is not limited in this application.

[0007] The frequency offset estimation method includes the following steps.

[0008] The AP sends first information to a STA. The first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the STA to report the first training field or the second training field, the STA is any one of the at least one STA~~the STA is any one of a plurality of STAs~~, the first subcarrier subset is a subcarrier subset that corresponds to the STA and that is in S preset subcarrier subsets, and M and S are positive integers and are for determining the first training field or a second training field. The AP receives, on the first subcarrier subset, a physical layer protocol data unit PPDU from the STA. The PPDU includes the first training field and the second training field, and the first training field and the second training field are used for determining a value of a frequency offset between the STA and the AP.

[0009] According to the frequency offset estimation method provided in this embodiment of this application, the AP indicates, by using the first information, how the STA generates and reports a frequency offset estimation training field, and the AP determines the value of the frequency offset between the AP and the STA based on at least two received frequency offset estimation training fields, so that estimation precision of determining the frequency offset by the AP can be improved.

[0010] With reference to the first aspect, in some implementations of the first aspect, the first information includes first indication information and second indication information, the first indication information indicates M, and the second indication information is for determining the first subcarrier subset.

[0011] The indication information indicating the quantity of spatial streams corresponding to the at least one STA~~a quantity M of STAs~~ and the indication information indicating the first subcarrier subset may be two different pieces of indication information, and different indication information sending manners are provided, to improve flexibility of the solution.

[0012] With reference to the first aspect, in some implementations of the first aspect, that the AP sends the first information to the STA includes: The AP sends a trigger frame to the STA, where the trigger frame triggers the STA to report the PPDU, the trigger frame carries the first indication information and the second indication information, and the first indication information is a scheduling information field.

[0013] According to the frequency offset estimation method provided in this embodiment of this application, the first information that is sent by the AP and that indicates how the STA generates and reports the frequency offset estimation training field may reuse an existing trigger frame sent by the AP to the STA. In this way, signaling overheads are reduced, and the solution is compatible with an existing procedure, improving compatibility.

[0014] With reference to the first aspect, in some implementations of the first aspect, that the trigger frame carries the first indication information includes: The trigger frame includes a common information field, and the common information field includes the first indication information.

[0015] Further, in a possible implementation in which the trigger frame includes the first indication information, the first indication information is carried in the common information field in the trigger frame. An existing field in the trigger frame is reused to carry the first indication information, so that signaling overheads can be reduced.

[0016] With reference to the first aspect, in some implementations of the first aspect, the first training field or the second training field is determined based on a mapping relationship between the STA and a P matrix element.

[0017] The first training field or the second training field may be determined based on an element that is in a preset P matrix and that corresponds to the STA. A manner of determining the first training field or the second training field based on a known P matrix is provided. Compatibility with an existing solution can be improved without introducing a new matrix.

[0018] With reference to the first aspect, in some implementations of the first aspect, the method further includes: The AP receives a first information matrix on the first subcarrier subset. The first information matrix is determined based on the first training field, channel information, and the value of the frequency offset between the STA and the AP. The AP receives a second information matrix on the first subcarrier subset. The second information matrix is determined based on the second training field, the channel information, and the value of the frequency offset

between the STA and the AP. The value of the frequency offset between the STA and the AP is determined based on the first information matrix and the second information matrix.

[0019] According to the frequency offset estimation method provided in this embodiment of this application, the AP may determine the value of the frequency offset between the STA and the AP based on the information matrix received by the AP on the first subcarrier subset. Because the two information matrices received by the AP on the first subcarrier subset are different due to the value of the frequency offset between the STA and the AP, the value of the frequency offset between the STA and the AP can be accurately determined based on the two received information matrices, thereby improving estimation precision of determining the frequency offset by the AP.

[0020] With reference to the first aspect, in some implementations of the first aspect, the PPDU further includes a channel estimation training field, and the first training field, the second training field, and the channel estimation training field are sequentially arranged or alternately arranged in the PPDU.

[0021] According to the frequency offset estimation method provided in this embodiment of this application, when the STA sends a PPDU to the AP, and the PPDU includes a first training field, a second training field, and a channel estimation training field, there are various arrangement manners of the first training field, the second training field, and the channel estimation training field in the PPDU, and this can improve flexibility of a PPDU structure.

[0022] With reference to the first aspect, in some implementations of the first aspect, that the first training field, the second training field, and the channel estimation training field are alternately arranged in the PPDU includes: The first training field is located after a preamble field and before the channel estimation training field, and the second training field is located after the channel estimation training field and before a data symbol; or the first training field is located after a preamble field and before a first channel estimation training field, and the second training field is located after the first channel estimation training field and before a second channel estimation training field, where the first channel estimation training field and the second channel estimation training field form the channel estimation training field.

[0023] With reference to the first aspect, in some implementations of the first aspect, that the first training field, the second training field, and the channel estimation training field are sequentially arranged in the PPDU includes: The first training field is located after a preamble field and before the second training field, and the second training field is located before the channel

estimation training field; or the first training field is located after the channel estimation training field and before the second training field, and the second training field is located before a data symbol.

[0024] According to the frequency offset estimation method provided in this embodiment of this application, structures of a plurality of different PPDU frame formats are provided, so that flexibility of the solution can be improved.

[0025] With reference to the first aspect, in some implementations of the first aspect, the PPDU further includes an automatic gain control training field, and the automatic gain control training field is used by the AP to adjust receive power for receiving the first training field and/or the second training field on the first subcarrier subset.

[0026] According to the frequency offset estimation method provided in this embodiment of this application, the STA sends the PPDU to the AP, and the automatic gain control training field is newly added to the PPDU. The AP may adjust, based on the automatic gain control training field, receive power for receiving the first training field and/or the second training field on the first subcarrier subset. In this way, the receive power for receiving the first training field and/or the second training field by the AP is adjustable.

[0027] According to a second aspect, a frequency offset estimation method is provided. The frequency offset estimation method may be performed by a STA, or may be performed by a chip or a circuit disposed in the STA. This is not limited in this application.

[0028] The frequency offset estimation method includes the following steps.

[0029] The STA receives first information from the AP, where the first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the STA for reporting the first training field or the second training field. The first subcarrier subset is a subcarrier subset that corresponds to the STA and that is in S preset subcarrier subsets, and M and S are positive integers and are for determining the first training field or the second training field.

[0030] The STA sends a physical layer protocol data unit PPDU to the AP on the first subcarrier subset, where the PPDU includes the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the STA and the AP.

[0031] According to the frequency offset estimation method provided in this embodiment of

this application, the STA determines, based on the received first information, how to generate and report a frequency offset estimation training field, so that the AP can determine the value of the frequency offset between the AP and the STA based on at least two received frequency offset estimation training fields, and estimation precision of determining the frequency offset by the AP can be improved.

[0032] With reference to the second aspect, in some implementations of the second aspect, the first information includes first indication information and second indication information, the first indication information indicates M, and the second indication information is for determining the first subcarrier subset.

[0033] The indication information indicating a quantity M of STAs and the indication information indicating the first subcarrier subset may be two different pieces of indication information, and different indication information sending manners are provided, to improve flexibility of the solution.

[0034] With reference to the second aspect, in some implementations of the second aspect, that the STA receives the first information from the AP includes: The STA receives a trigger frame from the AP, where the trigger frame triggers the STA to report the PPDU, the trigger frame carries the first indication information and the second indication information, and the first indication information is a scheduling information field.

[0035] According to the frequency offset estimation method provided in this embodiment of this application, the first information that is sent by the AP and that indicates how the STA generates and reports the frequency offset estimation training field may reuse an existing trigger frame sent by the AP to the STA. In this way, signaling overheads are reduced, and the solution is compatible with an existing procedure, improving compatibility.

[0036] With reference to the second aspect, in some implementations of the second aspect, that the trigger frame carries the first indication information includes: The trigger frame includes a common information field, and the common information field includes the first indication information.

[0037] Further, in a possible implementation in which the trigger frame includes the first indication information, the first indication information is carried in the common information field in the trigger frame. An existing field in the trigger frame is reused to carry the first indication information, so that signaling overheads can be reduced.

[0038] With reference to the second aspect, in some implementations of the second aspect, the first training field or the second training field is determined based on a mapping relationship between the STA and a P matrix element.

[0039] The first training field or the second training field may be determined based on an element that is in a preset P matrix and that corresponds to the STA. A manner of determining the first training field or the second training field based on a known P matrix is provided. Compatibility with an existing solution can be improved without introducing a new matrix.

[0040] With reference to the second aspect, in some implementations of the second aspect, the PPDU further includes a channel estimation training field, and the first training field, the second training field, and the channel estimation training field are sequentially arranged or alternately arranged in the PPDU.

[0041] According to the frequency offset estimation method provided in this embodiment of this application, the AP may determine the value of the frequency offset between the STA and the AP based on the information matrix received by the AP on the first subcarrier subset. Because the two information matrices received by the AP on the first subcarrier subset are different due to the value of the frequency offset between the STA and the AP, the value of the frequency offset between the STA and the AP can be accurately determined based on the two received information matrices, thereby improving estimation precision of determining the frequency offset by the AP.

[0042] With reference to the second aspect, in some implementations of the second aspect, that the first training field, the second training field, and the channel estimation training field are alternately arranged in the PPDU includes: The first training field is located after a preamble field and before the channel estimation training field, and the second training field is located after the channel estimation training field and before a data symbol; or the first training field is located after a preamble field and before a first channel estimation training field, and the second training field is located after the first channel estimation training field and before a second channel estimation training field, where the first channel estimation training field and the second channel estimation training field form the channel estimation training field.

[0043] With reference to the second aspect, in some implementations of the second aspect, that the first training field, the second training field, and the channel estimation training field are sequentially arranged in the PPDU includes: The first training field is located after a preamble field and before the second training field, and the second training field is located before the channel

estimation training field; or the first training field is located after the channel estimation training field and before the second training field, and the second training field is located before a data symbol.

[0044] According to the frequency offset estimation method provided in this embodiment of this application, structures of a plurality of different PPDU frame formats are provided, and this can improve flexibility of the solution.

[0045] With reference to the second aspect, in some implementations of the second aspect, the PPDU further includes an automatic gain control training field, and the automatic gain control training field is used by the AP to adjust receive power for receiving the first training field and/or the second training field on the first subcarrier subset.

[0046] According to the frequency offset estimation method provided in this embodiment of this application, the STA sends the PPDU to the AP, and the automatic gain control training field is newly added to the PPDU. The AP may adjust, based on the automatic gain control training field, receive power for receiving the first training field and/or the second training field on the first subcarrier subset. In this way, the receive power for receiving the first training field and/or the second training field by the AP is adjustable.

[0047] According to a third aspect, a frequency offset estimation apparatus is provided, where the apparatus is configured to perform the method provided in the first aspect. Specifically, the apparatus may include a module configured to perform any one of the first aspect or the possible implementations of the first aspect.

[0048] According to a fourth aspect, a frequency offset estimation apparatus is provided, where the apparatus is configured to perform the method provided in the second aspect. Specifically, the apparatus may include a module configured to perform any one of the second aspect and the possible implementations of the second aspect.

[0049] According to a fifth aspect, a frequency offset estimation apparatus is provided, including a processor. The processor is coupled to a memory, and may be configured to execute instructions in the memory, to perform the method according to any one of the first aspect and the possible implementations of the first aspect. Optionally, the apparatus further includes the memory. Optionally, the apparatus further includes a communication interface, and the processor is coupled to the communication interface.

[0050] In an implementation, the apparatus is an access point. When the apparatus is an access

point, the communication interface may be a transceiver, or an input/output interface.

[0051] In another implementation, the apparatus is a chip configured in an access point. When the apparatus is a chip configured in an access point, the communication interface may be an input/output interface.

[0052] In another implementation, the apparatus is a chip or a chip system.

[0053] Optionally, the transceiver may be a transceiver circuit. Optionally, the input/output interface may be an input/output circuit.

[0054] According to a sixth aspect, a frequency offset estimation apparatus is provided, including a processor. The processor is coupled to a memory, and may be configured to execute instructions in the memory, to perform the method according to any one of the second aspect and the possible implementations of the second aspect. Optionally, the apparatus further includes the memory. Optionally, the apparatus further includes a communication interface, and the processor is coupled to the communication interface.

[0055] In an implementation, the apparatus is a station. When the apparatus is a station, the communication interface may be a transceiver, or an input/output interface.

[0056] In another implementation, the apparatus is a chip configured in a station. When the apparatus is a chip configured in a station, the communication interface may be an input/output interface.

[0057] In another implementation, the apparatus is a chip or a chip system.

[0058] Optionally, the transceiver may be a transceiver circuit. Optionally, the input/output interface may be an input/output circuit.

[0059] According to a seventh aspect, a computer-readable storage medium is provided. The computer-readable storage medium stores a computer program. When the computer program is executed by an apparatus, the apparatus is enabled to implement the method according to any one of the first aspect or the possible implementations of the first aspect.

[0060] According to an eighth aspect, a computer-readable storage medium is provided. The computer-readable storage medium stores a computer program. When the computer program is executed by an apparatus, the apparatus is enabled to perform the method according to any one of the second aspect and the possible implementations of the second aspect.

[0061] According to a ninth aspect, a computer program product including instructions is provided. When the instructions are executed by a computer, an apparatus is enabled to implement

the method provided according to any one of the first aspect or the possible implementations of the first aspect.

[0062] According to a tenth aspect, a computer program product including instructions is provided. When the instructions are executed by a computer, an apparatus is enabled to perform the method according to any one of the second aspect and the possible implementations of the second aspect.

[0063] According to an eleventh aspect, a communication system is provided, including the foregoing access point and station.

BRIEF DESCRIPTION OF DRAWINGS

[0064] FIG. 1 is a schematic diagram of a system in a typical WLAN deployment scenario;

[0065] (a) and (b) in FIG. 2 are schematic diagrams of uplink transmission between an AP and STAs in an MU-MIMO mode according to an embodiment of this application;

[0066] FIG. 3 is a schematic diagram of sending data to an AP by two STAs according to an embodiment of this application.

[0067] FIG. 4 is a schematic diagram of sending data by a single-antenna STA according to an embodiment of this application;

[0068] FIG. 5 is a schematic diagram of orthogonal fields respectively corresponding to a plurality of STAs according to an embodiment of this application;

[0069] FIG. 6 is a schematic flowchart of a frequency offset estimation method according to an embodiment of this application;

[0070] (a) and (b) in FIG. 7 are schematic diagrams of division into subcarrier subsets according to an embodiment of this application;

[0071] FIG. 8 is a schematic diagram of a common information field in a trigger frame according to an embodiment of this application;

[0072] (a) and (b) in FIG. 9 are a schematic diagram of indirectly indicating a subcarrier subset according to an embodiment of this application;

[0073] FIG. 10 is a schematic diagram of determining related information of a frequency offset estimation training field according to an embodiment of this application;

[0074] FIG. 11 is a schematic diagram of a frequency offset estimation training field according

to an embodiment of this application;

[0075] FIG. 12(a) to FIG. 12(e) are schematic diagrams of frame formats of physical frames according to an embodiment of this application;

[0076] FIG. 13 is a scenario to which a frequency offset estimation method according to an embodiment of this application is applicable;

[0077] FIG. 14 is a schematic diagram of physical frames that are sent by a plurality of STAs and that are received by an AP;

[0078] FIG. 15 is a schematic diagram of a frequency offset estimation apparatus 1500 according to this application;

[0079] FIG. 16 is a schematic diagram of a structure of a STA 1600 applicable to an embodiment of this application;

[0080] FIG. 17 is a schematic diagram of a frequency offset estimation apparatus 1700 according to this application; and

[0081] FIG. 18 is a schematic diagram of a structure of an AP 1800 applicable to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0082] The following describes technical solutions of this application with reference to accompanying drawings.

[0083] Embodiments of this application may be applied to a wireless local area network (wireless local area network, WLAN). The WLAN may include one or more basic service sets (basic service set, BSS). Network nodes in the BSS include an AP and a STA. Each BSS may include one AP and a plurality of STAs associated with the AP.

[0084] The AP is referred to as an access point, or may be referred to as a wireless access point, a hotspot, or the like. APs are access points used by user terminals to access wired networks, and are mainly deployed in homes, buildings, and campuses. A typical AP coverage radius ranges from dozens of meters to hundreds of meters. It should be understood that the APs may also be deployed outdoors. An AP is equivalent to a bridge connecting a wired network to a wireless network. Main functions of the AP are to connect clients of the wireless network together and then connect the wireless network to the Ethernet. Currently, standards for the AP that are mainly used are the

Institute of Electrical and Electronics Engineers (institute of electrical and electronics engineers, IEEE) 802.11 series, for example, the 802.11ax or 802.11be standard. The AP may be a device that supports a WLAN standard. For example, the AP may be a terminal device or a network device with a Wireless Fidelity (wireless fidelity, Wi-Fi) chip.

[0085] The STA is referred to as a station. In this application, the STA represents a user terminal, and therefore may be directly referred to as a user terminal or a user in the following. The STA may ~~carry~~a a wireless communication chip, a wireless sensor, or a wireless communication terminal. The STA may be a device supporting a WLAN standard, for example, a mobile phone supporting a Wi-Fi communication function, a tablet computer supporting a Wi-Fi communication function, a set-top box supporting a Wi-Fi communication function, a smart television supporting a Wi-Fi communication function, a smart wearable device supporting a Wi-Fi communication function, or a computer supporting a Wi-Fi communication function.

[0086] FIG. 1 is a schematic diagram of a system in a typical WLAN deployment scenario. The system includes one AP and four STAs. The AP may communicate with a STA #1, a STA #2, a STA #3, and a STA #4. Modes of uplink transmission between the AP and the STA include but are not limited to an orthogonal frequency-division multiple access (orthogonal frequency-division multiple access, OFDMA) mode, a multi-user multiple-input multiple-output (multi-user multiple input multiple output, MU-MIMO) mode, and an OFDMA and MU-MIMO hybrid transmission mode.

[0087] In this application, an example in which an uplink transmission mode between an AP and a plurality of STAs is a MU-MIMO mode is used. A quantity N of antennas of the AP is greater than or equal to a sum M of antennas of all STAs associated with the AP. It should be understood that any STA may include a plurality of antennas. When one STA has two antennas, the STA may be equivalent to two same single-antenna STAs, except that channels from the two STAs to the AP are different. FIG. 2 shows schematic diagrams of uplink transmission between an AP and STAs in an MU-MIMO mode according to an embodiment of this application. In FIG. 2, the AP includes N antennas (an antenna #1 to an antenna #N shown in FIG. 2). A sum of antenna quantities of all STAs is M. h_{NM} in FIG. 2 shows a channel between an antenna M on a STA side and an antenna N on an AP side.

[0088] In this application, a quantity M of spatial streams refers to the sum M of antenna quantities of STAs, and the quantity M of spatial streams corresponding to the STA may be

understood as a sum M of antenna quantities of at least one STA.

[0089] Embodiments of this application are applicable to a system with two spatial streams (spatial streams, ss), and are also applicable to systems with 4, 8, and 16 ss. With development of technologies, the technical solutions provided in embodiments of this application may also be applicable to a system with a larger quantity of spatial streams.

[0090] FIG. 2(a) shows that one STA may include a plurality of antennas. If a frequency difference exists between the STA and the AP, frequency differences existing between the AP and signals sent by the plurality of antennas included in the STA are the same. FIG. 2(b) is an equivalent transformation of FIG. 2(a). To be specific, the STA including a plurality of antennas may be equivalent to a plurality of same single-antenna STAs. It should be understood that this equivalent transformation is merely for easier understanding of the technical solutions provided in this application, and constitutes no limitation on the protection scope of this application. When the STA including a plurality of antennas is equivalent to the plurality of same single-antenna STAs, the sum M of antenna quantities of STAs may be understood as a quantity M of STAs. In other words, when a multi-antenna STA is equivalent to a single-antenna STA, the quantity M of spatial streams corresponding to STAs in embodiments of this application may also be referred to as the quantity M of STAs.

[0091] For ease of understanding embodiments of this application, the following descriptions are provided.

[0092] First, in this application, "indicate" may include "directly indicate" and "indirectly indicate". When a piece of indication information is described as indicating A, the indication information may directly indicate A or indirectly indicate A, but it does not necessarily indicate that the indication information carries A.

[0093] Information indicated by the indication information is referred to as to-be-indicated information. In a specific implementation process, the to-be-indicated information may be indicated in a plurality of manners, for example, but not limited to, a manner of directly indicating the to-be-indicated information. For example, the to-be-indicated information is indicated by using the to-be-indicated information or an index of the to-be-indicated information. The to-be-indicated information may alternatively be indirectly indicated by indicating other information, where there is an association relationship between the other information and the to-be-indicated information. Alternatively, only a part of the to-be-indicated information may be indicated, and the other part

of the to-be-indicated information is known or pre-agreed on. For example, specific information may alternatively be indicated by using an arrangement sequence of a plurality of pieces of information that is pre-agreed on (for example, stipulated in a protocol), to reduce indication overheads to some extent. In addition, a common part of all pieces of information may be further identified and indicated in a unified manner, to reduce indication overheads caused by separately indicating same information.

[0094] Secondly, "first", "second", and various numerical numbers (for example, "#1", and "#2") shown in this application are merely for ease of description, and are used to distinguish between objects, but are not intended to limit the scope of embodiments of this application. For example, the numbers are used for distinguishing between different fields, or distinguishing between different STAs, but are not used for describing a particular order or sequence. It should be understood that the objects described in this way are interchangeable in a proper circumstance, so that a solution other than embodiments of this application can be described.

[0095] Thirdly, in this application, "preset" may include "predefined", for example, defined in protocols. "Predefined" may be implemented by storing corresponding code or a table in a device (for example, the device includes a STA and an AP) in advance, or may be implemented in another manner that may be used to indicate related information. A specific implementation of "predefined" is not limited in this application.

[0096] Fourth, "storage" in embodiments of this application may be stored in one or more memories. The one or more memories may be separately disposed, or may be integrated into an encoder, a decoder, a processor, or a communication apparatus. Alternatively, a part of the one or more memories may be separately disposed, and a part of the one or more memories are integrated into the translator, the processor, or the communication apparatus. A type of the memory may be a storage medium in any form, and this is not limited in this application.

[0097] Fifthly, "protocols" in embodiments of this application may be standard protocols in the communication field, for example, may include a Wi-Fi protocol, a new radio (new radio, NR) protocol, and a related protocol used for a future communication system. This is not limited in this application.

[0098] Sixthly, for ease of understanding, the following briefly describes main parameters in this application.

[0099] h_{ij} indicates a channel between an antenna of a STA #j and an antenna #i on an AP

side, where i and j are positive integers. (In this application, a single-antenna STA is used as an example for description, and a case in which a STA includes a plurality of antennas may be equivalent to single-antenna STAs shown in FIG. 2).

[00100] y_k^l indicates a size of information received on the l^{th} symbol by an antenna #k on the AP side, where k and l are positive integers.

[00101] Δf_q indicates a frequency offset between a STA#q and the AP.

[00102] $e^{j2\pi\Delta f_q * (W-1) * T}$ indicates an angle of phase rotation of a training field sent on a W^{th} symbol relative to a training field sent on a first symbol in the first training field corresponding to the STA#q.

[00103] P_{fix} indicates a matrix P corrected based on a value of a frequency offset between the STA and the AP.

[00104] Specifically, uplink multi-user MIMO mainly depends on multi-antenna orthogonal equalization on the AP side, that is, the AP side obtains air-interface link information by using a training field (for example, channel state information (channel state information, CSI)), to equalize effective payloads of the plurality of stations; and split superimposed information of the plurality of stations, so that the stations are orthogonal to each other and do not affect each other. Therefore, whether the ~~wireless~~ channel state information can be accurately obtained affects orthogonality of a plurality of stations in uplink directly or affects accuracy of obtaining a stream by each station, and may also affect accuracy of precoding performed by an access point during downlink data transmission. A process of obtaining the wireless channel state information may also be referred to as channel estimation.

[00105] However, there are various types of user terminals, and radio frequency links of different user terminals may be different. Therefore, carrier frequencies used by the user terminals to send signals are difficult to be consistent, that is, it is difficult for different user terminals to implement frequency synchronization.

[00106] Firstly, an impact caused by frequency asynchronization of signals sent by a plurality of user terminals on channel estimation on an AP side is briefly described with reference to FIG. 3. FIG. 3 is a schematic diagram of sending data to an AP by two STAs according to an embodiment of this application. Two STAs (a STA #1 and a STA #2 shown in FIG. 3) and one AP are included in FIG. 3, where the STA #1 and the STA #2 may access a network by using the AP. For example,

the STA #1 and the STA #2 may be two mobile phones that support a Wi-Fi communication function, the AP may be a router with a Wi-Fi chip, and the AP is deployed with two antennas (an antenna #1 and an antenna #2 shown in FIG. 3).

[00107] In a possible implementation, there is no frequency difference between the STA #1 and the AP or between the STA #2 and the AP, that is, there is no carrier frequency offset (carrier frequency offset, CFO). In this case, no phase rotation occurs on two orthogonal symbols sent by the STA #1 and the STA #2. The CFO is a frequency offset value for short in the following.

[00108] For example, data sent by the STA #1 is $X_1 = \left[X_1^1, X_1^2\right] = \begin{bmatrix} 1 & -1 \end{bmatrix}$, and reaches the antenna #1 and the antenna #2 on the AP side through wireless channels~~spatial channels~~ h_{11} and h_{21}. Data sent by the STA #2 is $X_2 = \left[X_2^1, X_2^2\right] = \begin{bmatrix} 1 & 1 \end{bmatrix}$, and reaches the antenna #1 and the antenna #2 on the AP side through wireless channels~~spatial channels~~ h_{12} and h_{22}. Information received by the antenna #1 on the AP side is two superimposed signals from the STAs through wireless channels~~air interface channels~~, and information received by the antenna #2 is two superimposed signals from the STAs through wireless channels~~air interface channels~~. Specifically, information received by the antenna #1 includes y_1^1 and y_1^2, where $y_1^1 = h_{11} + h_{12}$ and $y_1^2 = -h_{11} + h_{12}$. Information received by the antenna #2 includes y_2^1 and y_2^2, where $y_2^1 = h_{21} + h_{22}$ and $y_2^2 = -h_{21} + h_{22}$.

[00109] Specifically, data sent by the STA in embodiments of this application may be understood as a training field corresponding to a long training field (long training field, LTF) sent by the STA on a subcarrier. The data may be understood as a signal or information. The LTF is included in a PPDU sent by the STA to the AP. Using 802.11ax as an example, the LTF may be an HE-LTF. A specific frame format of the PPDU including the HE-LTF may be shown as follows:

L-STF	L-LTF	L-SIG	RL-SIG	HE-SIG-A	HE-SIG-B	HE-STF	HE-LTF	…	HE-LTF	Data	PE

[00110] L-STF represents a non-high throughput short training field (non-High throughput short training field). L-LTF represents a non-high throughput long training field (non-High throughput long training field). L-SIG represents a non-high throughput signal field (non-High throughput signal field). RL-SIG represents a repeated non-high throughput signal field (repetition

non-High throughput signal field). HE-SIG-A represents a high efficiency signal field A (High efficiency signal field A). HE-SIG-B represents a high efficiency signal field B (High efficiency signal field B). HE-STF represents a high efficiency short training field (high-efficiency short training field, HE-STF). HE-LTF represents a high efficiency long training field (high efficiency long training field, HE-STF). Data represents a data field. PE represents a packet extension field (package extension field).

[00111] For another example, 802.11be is used. The LTF may be an EHT-LTF, and a possible format of a PPDU frame including the EHT-LTF may be shown as follows:

L-STF	L-LTF	L-SIG	RL-SIG	U-SIG	EHT-SIG	EHT-STF	EHT-LTF	…	EHT-LTF	Data	PE

[00112] L-STF represents a non-high throughput short training field. L-LTF represents a non-high throughput long training field. L-SIG represents a non-high throughput signal field. RL-SIG represents a repeated non-high throughput signal field. A universal signal field (universal signal field, U-SIG) and an extremely high throughput signal field (extremely High throughput signal field, EHT-SIG) carry signaling for demodulating subsequent data. An extremely high throughput short training field (extremely High throughput short training field, EHT-STF) is used for automatic gain control of a subsequent field. An extremely high throughput long training field (Extremely High throughput long training field, EHT-LTF) is used for channel estimation. Data represents a data field. PE represents a packet extension field.

[00113] The AP side only needs to solve the received information h_{11}, h_{21}, h_{12}, and h_{22} to obtain CSI. The foregoing process may be expressed in a matrix manner for better understanding. Information matrix received by the AP is expressed by the following formula:

$$\begin{bmatrix} y_1^1 & y_1^2 \\ y_2^1 & y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$$

[00114] The AP side knows that the training fields sent by the STA #1 and the STA #2 are $X_1 = [1 \quad -1]$ and $X_2 = [1 \quad 1]$, respectively, and the AP can learn of the matrix $\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$ in the foregoing formula based on the training fields. The matrix is referred to as a matrix P in the current protocol. Therefore, the AP side can obtain a channel matrix simply by performing the following operations on the received information matrix:

$$\begin{bmatrix} y_1^1 & y_1^2 \\ y_2^1 & y_2^2 \end{bmatrix}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}^{-1} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}^{-1} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

[00115] In another possible implementation, the STA #1 and the STA #2 have respective frequency offsets with the AP. For example, the frequency offset of the STA #1 relative to the AP is Δf_1, and the frequency offset of the STA #2 relative to the AP is Δf_2. When the STA #1 and the STA #2 send data on two consecutive orthogonal symbols, there is phase rotation between the data. It is assumed that a cycle of each symbol is T. In this case, a phase of data sent by the STA #1 on the second symbol is rotated by $e^{j2\pi\Delta f_1 T}$ relative to a phase of data sent by the STA #1 on the first symbol. Similarly, a phase of data sent by the STA #2 on the second symbol is rotated by $e^{j2\pi\Delta f_2 T}$ relative to a phase of data sent by the STA #2 on the first symbol. In this case, data sent by the STA #1 is $X_1 = \begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \end{bmatrix}$, and data sent by the STA #2 is $X_2 = \begin{bmatrix} 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}$.

[00116] Information matrix received by the AP is represented by the following formula:

$$\begin{bmatrix} y_1^{3+D} & y_1^{4+D} \\ y_2^{3+D} & y_2^{4+D} \\ y_3^{3+D} & y_3^{4+D} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{31} & h_{32} \end{bmatrix}\begin{bmatrix} 1e^{j2\pi\Delta f_1(D+2)T} & -1e^{j2\pi\Delta f_1(D+3)T} \\ 1e^{j2\pi\Delta f_2(D+2)T} & 1e^{j2\pi\Delta f_2(D+3)T} \end{bmatrix} =$$

$$\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{31} & h_{32} \end{bmatrix}\begin{bmatrix} 1e^{j2\pi\Delta f_1(D+2)T} & 0 \\ 0 & 1e^{j2\pi\Delta f_2(D+3)T} \end{bmatrix}\begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}$$

[00117] For the AP side, the matrix P corresponding to the data sent by the two STAs is still $\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$,,1--1-1-1.. by default. Because the AP side does not know that the STA has a frequency offset relative to the AP, the AP obtains the channel matrix according to an original operation:

$$\begin{bmatrix} y_1^1 & y_1^2 \\ y_2^1 & y_2^2 \end{bmatrix}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}^{-1} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}\begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}^{-1} =$$

$$\frac{1}{2}\begin{bmatrix} h_{11}(1+e^{j\theta_1}) + h_{12}(1-e^{j\theta_2}) & h_{12}(1-e^{j\theta_1}) + h_{11}(1-e^{j\theta_2}) \\ h_{21}(1+e^{j\theta_1}) + h_{22}(1-e^{j\theta_2}) & h_{22}(1-e^{j\theta_1}) + h_{21}(1-e^{j\theta_2}) \end{bmatrix}$$

[00118] It may be found that, in the channel matrix determined by the AP, a channel of one STA of the two STAs is doped with a channel of the other STA, and mutual crosstalk occurs. It can be learned from the foregoing calculation process that this is because a corresponding P_{fix} matrix is non-orthogonal in a case in which a frequency offset exists. In other words, if the AP side can

learn frequency offset information of the STA, the P matrix known by the AP side is compensated or corrected, so that the P matrix is not the foregoing matrix $\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$, but a P_{fix} matrix $\begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}$ in which the frequency offset information is considered. Then, the AP performs inverse calculation based on the matrix P_{fix} to obtain channel information. In this case, the AP can obtain the accurate channel information.

[00119] The foregoing provides detailed description with reference to FIG. 3: When there is a frequency offset between the STA and the AP, the AP cannot accurately obtain channel information between the STA and the AP based on the original matrix P. To obtain accurate channel information, the AP needs to obtain the matrix P_{fix} first. Learning of the value of the frequency offset between the STA and the AP is crucial to obtaining of the matrix P_{fix}. The matrix P_{fix} can be obtained by correcting or compensating the matrix P based on the value of the frequency offset.

[00120] Therefore, embodiments of this application mainly relate to how to learn of a value of a frequency offset between a STA and an AP.

[00121] Optionally, one STA sends two same pieces of data on two symbols. In this way, when information corresponding to the two pieces of data is received on the AP side, a value of a frequency offset between the STA and the AP can be obtained simply by comparing a change of the information corresponding to the two pieces of data on the two symbols.

[00122] For example, FIG. 4 is a schematic diagram of sending data by a single-antenna STA according to an embodiment of this application. The data separately sent by the STA #1 on the two symbols should be $X_1 = \begin{bmatrix} 1 & 1 \end{bmatrix}$. Because the frequency offset between the STA and the AP is Δf_1, it is equivalent to that the data separately sent by the STA #1 on the two symbols is $X_1 = \begin{bmatrix} 1 & 1e^{j2\pi\Delta f_1 T} \end{bmatrix}$. Information matrix corresponding to the data on the two consecutive symbols received by the antenna #1 of the AP is $\begin{bmatrix} y_1^1 & y_1^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{11}e^{j2\pi\Delta f_1 T} \end{bmatrix}$. The AP performs point division ~~or conjugation~~ on the received information matrix to obtain a relative rotation angle $2\pi\Delta f_1 T$ of the two pieces of data, and then calculates the frequency offset Δf_1 between the STA #1 and the AP.

[00123] However, when a plurality of STAs send data in an uplink direction, an information matrix received on an AP side is superimposed data sent by the plurality of STAs, and information cannot be distinguished. Even if each STA sends repeated data on two symbols, because information on the two symbols received on the AP side is the sum of the data of the plurality of STAs, a value of a frequency offset of each STA relative to the AP cannot be accurately estimated in the foregoing point division manner.

[00124] Optionally, it may be considered as that channels of adjacent orthogonal subcarrier blocks are nearly equal within the measured Wi-Fi bandwidth, in other words, the channels are flat channels. Different orthogonal fields are allocated to subcarriers for sending by the STAs, so that the AP side can split channel information of the STAs to obtain an inter-symbol phase rotation angle.

[00125] For example, FIG. 5 is a schematic diagram of orthogonal fields respectively corresponding to a plurality of STAs according to an embodiment of this application. Data sent by a STA #1 on each subcarrier of the first symbol is $X_1 = \left[X_1^1 X_1^2 \quad X_1^3 \quad X_1^4 \right]$; and data sent by a STA #2 on each subcarrier of the first symbol is $X_1 = \left[X_2^1 X_2^2 \quad X_2^3 \quad X_2^4 \right]$. Because an orthogonal field is allocated to a subcarrier for sending by each STA,

$$X_1 (X_2)^T = \sum_{i=1}^{4} X_1^i X_2^i = 0$$

[00126] An antenna #1 is used as an example on the AP side. Information received on subcarriers of the first symbol may be expressed as follows:

$$\begin{aligned} y_1^{1,1} &= h_{11}^1 X_1^1 + h_{12}^1 X_2^1 \\ y_1^{1,2} &= h_{11}^2 X_1^2 + h_{12}^2 X_2^2 \\ y_1^{1,3} &= h_{11}^3 X_1^3 + h_{12}^3 X_2^3 \\ y_1^{1,4} &= h_{11}^4 X_1^4 + h_{12}^4 X_2^4 \end{aligned}$$

[00127] Because the prerequisite is that the channels within the consecutive subcarrier orthogonal blocks are nearly equal, $h_{11}^1 = h_{11}^2 = h_{11}^3 = h_{11}^4 = h_{11}$, and $h_{12}^1 = h_{12}^2 = h_{12}^3 = h_{12}^4 = h_{12}$.

[00128] This method is applied to the orthogonal blocks by analogy. There are 234 effective subcarriers 802.11ax in which consecutive subcarriers need to be flat. When the foregoing prerequisite is met, received signals are orthogonalized. For example, signals from the STA #2 are

orthogonalized, orthogonal summation is performed on signals received by the antenna #1 of the AP side on each subcarrier of the first symbol:

$$\sum_{i=1}^{4} y_i^{1,i} X_1^i = \sum_{i=1}^{4} (h_{11} X_1^i + h_{12} X_2^i) X_1^i = h_{11} \sum_{i=1}^{4} (X_1^i)^2 + h_{12} \sum_{i=1}^{4} X_2^i X_1^i$$

[00129] Because $\sum_{i=1}^{4} X_1^i X_2^i = 0$, $h_{12} \sum_{i=1}^{4} X_2^i X_1^i = 0$. The signals from the STA #2 can be eliminated, and only information from the STA #1 is retained. In other words,

$$\sum_{i=1}^{4} y_i^{1,i} X_1^i = h_{11} \sum_{i=1}^{4} (X_1^i)^2$$

[00130] Similarly, for the second symbol, the AP side may perform the same processing as the foregoing to obtain:

$$\sum_{i=1}^{4} y_i^{2,i} X_1^i = h_{11} e^{j2\pi\Delta f_1 T} \sum_{i=1}^{4} (X_1^i)^2$$

[00131] $2\pi\Delta f_1 T$ may be obtained through calculation on $\sum_{i=1}^{4} y_i^{1,i} X_1^i = h_{11} \sum_{i=1}^{4} (X_1^i)^2$ and $\sum_{i=1}^{4} y_i^{2,i} X_1^i = h_{11} e^{j2\pi\Delta f_1 T} \sum_{i=1}^{4} (X_1^i)^2$.

[00132] However, the foregoing prerequisite that the channels within the orthogonal blocks of the consecutive subcarriers are nearly equal is a harsh condition, and is difficult to meet in practice. As a result, precision of channel estimation by the AP is difficult to be ensured.

[00133] To resolve a disadvantage existing in the foregoing channel estimation, this application provides a frequency offset estimation method. Two repeated frequency offset estimation training fields are sent to the AP, to improve accuracy of frequency offset estimation.

[00134] It should be understood that the method provided in embodiments of this application may be applied to a WLAN communication system, for example, a communication system 100 shown in FIG. 1. The communication system may include at least one AP and a plurality of STAs. Frequency offsets between the plurality of STAs and the AP are inconsistent.

[00135] A single-antenna STA is used as an example for description in embodiments of this application, that is, one AP is associated with a plurality of single-antenna STAs. When a STA includes a plurality of antennas, frequency offsets between the antennas included in the STA and an antenna of the AP are the same. Therefore, for a manner of calculating channel information between another antenna of the STA and the antenna of the AP, refer to a manner of calculating channel information between an antenna of the STA and the antenna of the AP in embodiments of this application. For a case in which a STA includes a plurality of antennas, details are not described in this application again.

[00136] It should be further understood that the frequency offset estimation method provided in embodiments of this application may be further applied to a scenario of a plurality of APs. For example, the system in the WLAN deployment scenario shown in FIG. 1 further includes another AP. Communication between the another AP and the STA is the same as communication between the AP and the STA shown in FIG. 1. For frequency offset estimation between the another AP and the STA, refer to frequency offset estimation between the AP and the STA shown in FIG. 1. Details are not described in this application.

[00137] In addition, data transmission between the STA and the AP may occur on a full bandwidth (for example, a bandwidth of 20 MHz, including 256 subcarriers). In this embodiment of this application, estimation of a frequency offset between the STA and the AP on one subcarrier is used as an example for description. A manner of estimating a frequency offset between the STA and the AP on another subcarrier is the same. Details are not described again in this application.

[00138] A specific structure of an entity for executing the method provided in embodiments of this application is not specially limited in the following embodiments, provided that a program that records code for the method provided in embodiments of this application can be run to perform communication according to the method provided in embodiments of this application. For example, the method provided in embodiments of this application may be performed by an AP or a STA, or a functional module of the AP or the STA that can invoke and execute the program.

[00139] Without loss of generality, the following describes in detail the frequency offset estimation method provided in embodiments of this application by using interaction between an AP and a STA as an example.

[00140] FIG. 6 is a schematic flowchart of a frequency offset estimation method according to an embodiment of this application. The method is executed by an AP and a STA.

[00141] For ease of understanding, FIG. 6 shows only one STA. In this embodiment of this application, there are actually a plurality of STAs associated with the AP shown in FIG. 6. FIG. 6 does not show all the STAs because steps performed by the plurality of STAs associated with the AP are the same. For specific steps performed by other STAs that are not shown, refer to the STA shown in FIG. 6. Details are not described in the following.

[00142] The frequency offset estimation method includes some or all of the following steps.

[00143] S610: The AP sends first information to the STA.

[00144] The first information indicates a quantity M of spatial streams corresponding to at least

one STA that needs to report a first training field and a second training field, and a first subcarrier subset, to be occupied by the STA that receives the first information, for reporting the first training field or the second training field. The first training field and the second training field are used to estimate a value of a frequency offset between the AP and the STA, and the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the STA.

[00145] The quantity M of spatial streams corresponding to the STA refers to a sum M of antenna quantities included in at least one STA that needs to report a first training field and a second training field. In addition, the embodiment shown in FIG. 6 uses a single-antenna STA as an example (as shown in FIG. 2(b), a multi-antenna STA may be equivalent to a single-antenna STA). In this case, the quantity M of spatial streams corresponding to the STA may also be referred to as a quantity M of STAs, that is, the quantity of spatial streams is equal to the quantity of STAs that need to report a first training field and a second training field. In this case, the quantity of STAs in the following may alternatively be the quantity of spatial streams.

[00146] It should be understood that the first training field and the second training field in embodiments of this application are same training fields, but occupy different locations in a physical layer protocol data unit (physical protocol data unit, PPDU) sent by the STA to the AP, and the first training field and the second training field include same information. Therefore, the following may describe how the STA generates the first training field from a perspective of the first training field. M and S are positive integers, and M and S are for determining the first training field. How to specifically determine the first training field based on M and S is described in the following, and is not described herein.

[00147] The first training field may also be referred to as a frequency offset estimation training field, a long training field (long training field, LTF), an extremely high throughput-LTF (extremely high throughput LTF, EHT-LTF), a frequency offset training field, or the like. A name of a training field used to estimate a value of a frequency offset is not limited in embodiments of this application.

[00148] It should be noted that, to facilitate description of the frequency offset estimation method provided in this embodiment of this application from a perspective of one STA in the embodiment shown in FIG. 6, the foregoing STA is any one of the plurality of STAs associated with the AP.

[00149] For example, the first information may indicate a subcarrier subset that is to be occupied by the plurality of STAs associated with the AP and that is for reporting the first training

field or the second training field.

[00150] Alternatively, for example, the AP may separately send a plurality of pieces of information to the plurality of STAs associated with the AP, where each of the plurality of pieces of information indicates the quantity of STAs that need to report the first training field and the second training field, and a subcarrier subset, to be occupied by the STA that receives the information, for reporting the first training field or the second training field.

[00151] In another implementation, the first information may indicate a quantity of symbols needed by the STA to report the first training field, the quantity of symbols may be used for determining a quantity of dimensions of a matrix P, and the matrix P is for determining the first training field.

[00152] In another possible implementation, the quantity of symbols required by the STA for reporting the first training field may alternatively be determined in a manner predefined in a protocol.

[00153] It should be noted that, in embodiments of this application, a quantity J of symbols, a total quantity S of subcarrier subsets, and a total quantity M of STAs that need to report a frequency offset estimation training field may be mutually derived. In other words, the other parameter can be determined by learning two of the three parameters J, S, and M. A specific determining process may be table lookup or calculation. This is not limited in this application.

[00154] In other words, when the protocol predefines or the AP indicates the quantity of symbols needed by the STA to report the first training field, the foregoing quantity S of subcarrier subsets is not needed to be predefined in the protocol. In this embodiment of this application, an example in which the quantity S of subcarrier subsets is learned of is used for description. A case in which the quantity J of symbols needed for reporting the first training field is learned of is similar to a case in which the quantity S of subcarrier subsets is learned of. A difference lies in that, in the first case, J may be directly indicated without derivation, and in the second case, J is derived from S. Details are not described in this application.

[00155] In embodiments of this application, a subcarrier subset division manner may be predefined in a protocol, or may be negotiated by the STA and the AP, or may be notified by the AP to each STA by using signaling after being determined by the AP, or may be reported to the AP by using signaling after being determined by STAs through negotiation. It should be understood that a manner of dividing all subcarriers to obtain at least one subcarrier subset is not limited in

this embodiment of this application.

[00156] For example, a protocol predefines that all subcarriers (K subcarriers) are divided into S subcarrier subsets, there is no intersection set between the S subcarrier subsets, and subcarriers occupied by each subcarrier subset may be consecutive or inconsecutive, where K is a positive integer, and S is a positive integer.

[00157] For example, if subcarriers in the subcarrier subsets are consecutive, subcarriers included in the foregoing S subcarrier subsets may be as follows.

[00158] A subcarrier subset #1 includes subcarriers {1, 2, 3, ..., K/S}, a subcarrier subset #2 includes subcarriers {K/S + 1, K/S + 2, K/S + 3, ..., 2K/S}, ..., and a subcarrier subset #S includes subcarriers {K – K/S+1, K – K/S+2, K – K/S + 3, ..., K}. Refer to FIG. 7(a). FIG. 7(a) is a schematic diagram of division into subcarrier subsets according to this embodiment of this application.

[00159] For example, if subcarriers in the subcarrier subsets are inconsecutive, subcarriers included in the foregoing S subcarrier subsets may be as follows.

[00160] A subcarrier subset #1 includes subcarriers {1, K/S + 1, 2K/S + 1, ..., K – K/S + 1}, a subcarrier subset #2 includes subcarriers {2, K/S + 2, 2K/S + 2, ..., K – K/S + 2}, ..., and a subcarrier subset #S includes subcarriers {K/S, 2K/S, 2K/S + 3, ..., K}. Refer to FIG. 7(b).

[00161] It should be noted that all subcarriers in this application are all subcarriers under current scheduling, and a quantity of subcarriers under each scheduling may be different.

[00162] For example, all subcarriers under current scheduling include K subcarriers, and all subcarriers scheduled next time are 2K subcarriers. In embodiments of this application, generally, a value of a frequency offset between a STA and an AP in one scheduling procedure is estimated. For a case in which a value of a frequency offset in another scheduling procedure needs to be estimated, refer to the solution for estimating a value of a frequency offset provided in embodiments of this application. In embodiments of this application, frequency offset estimation solutions in different scheduling procedures are not described again.

[00163] In a possible implementation, the first information includes first indication information and second indication information, where the first indication information indicates the quantity M of STAs that need to report the first training field and the second training field, and the second indication information indicates the first subcarrier subset.

[00164] Optionally, the first indication information and the second indication information may

be simultaneously sent to the STA, or the first indication information and the second indication information may be sequentially sent to the STA. A field of sending the first indication information and the second indication information to the STA is not limited in embodiments of this application.

[00165] In a possible implementation, the first information is a trigger frame (trigger frame, TF) specified in an existing protocol or a next-generation standard protocol, and the trigger frame triggers the STA to report the PPDU. In embodiments of this application, a frame format of a trigger frame specified in the 802.11ax protocol is used as an example for description. Q bits may be added to a common information field (common information field) in the trigger frame, where the Q bits indicate the quantity M of STAs that need to report the first training field and the second training field, and Q is a positive integer. In this example, a format of the common information field in the trigger frame is shown in FIG. 8. FIG. 8 is a schematic diagram of a common information field of a trigger frame according to an embodiment of this application.

[00166] It can be learned from FIG. 8 that the trigger frame includes the following fields:

Trigger type (trigger type), uplink length (uplink length, UL length), more trigger frames (more trigger frame, more TF), carrier sense required (carrier sense required, CS required), uplink bandwidth (uplink bandwidth, UL BW), guard interval and long training field type (guard interval and long training field type, GI and LTF type), MU-MIMO long training field type (MU-MIMO LTF mode), number of High Efficiency long training field symbol and mid-amble training field periodicity (number of HE-LTF symbols and mid-amble periodicity), uplink space-time block coding (uplink space time block code, UL STBC), low density parity check code extra symbol segment (low density parity check code extra symbol segment), access point transmit power (AP TX power), uplink packet extension (UL packet extension), uplink spatial reuse (UL spatial reuse), Doppler (Doppler), uplink high-efficiency signal field A2 part reserved (UL HE-SIG-A2 reserved), reserved (reserved), and trigger dependent common information (trigger dependent common information).

[00167] For a specific meaning of each field in the trigger frame in embodiments of this application, refer to specifications in an existing protocol and a next-generation standard protocol, for example, specifications in the 802.11ax or 802.11be standard. Details are not described in this application again. Different from a common information field in a trigger frame specified in an existing protocol and a next-generation standard protocol, in the common information field in the trigger frame in embodiments of this application, first indication information is added between a

reserved bit field in the common information field and a trigger dependent common information field, and the first indication information may occupy at least one bit.

[00168] For example, if a quantity of STAs that need to report the first training field and the second training field is 10, the first indication information only needs to occupy 4 bits.

[00169] In another possible implementation, the first information is a trigger frame specified in an existing protocol or a next-generation standard protocol. The first indication information may be a newly added field in the trigger frame, but is not necessarily limited to a newly added field in a common information field in the trigger frame. In this embodiment of this application, a specific location of the first indication information in the trigger frame is not limited, provided that the first indication information is carried in the trigger frame and sent to the STA associated with the AP.

[00170] In still another possible implementation, the first information is a trigger frame specified in an existing protocol or a next-generation standard protocol, and a reserved field (for example, a reserved field shown in FIG. 8) in the trigger frame may be reused for the first indication information. In this implementation, signaling overheads can be reduced.

[00171] In still another possible implementation, the first information is a trigger frame specified in an existing protocol or a next-generation standard protocol. One part of the first indication information may be obtained by reusing a reserved field in the trigger frame, and the other part is a newly added field in the trigger frame (for example, when the reserved field is not sufficient for carrying the first indication information).

[00172] It should be understood that carrying the first indication information in the trigger frame is merely an example, and does not constitute any limitation on the protection scope of this application. For example, the first indication information may be carried in new signaling between the AP and the STA, and sent to the STA; or the first indication information may be carried in other existing signaling between the AP and the STA, and sent to the STA.

[00173] Embodiments of this application may also be applied to uplink transmission, where the foregoing first information may be a PPDU sent by the STA to the AP, and the first indication information and the second indication information may be carried in a signal (Signal) field in the PPDU sent by the STA to the AP, for example, carried in an HE-SIG or an EHT-SIG field in the PPDU.

[00174] Further, when the first information is a trigger frame specified in an existing protocol or a next-generation standard protocol, a scheduling information field included in the trigger frame

may indicate the first subcarrier subset. In other words, the scheduling information field in the trigger frame may be reused for the foregoing second indication information, to indicate the first subcarrier subset. The following describes in detail how to reuse the scheduling information field to indicate the first subcarrier subset with reference to FIG. 9.

[00175] FIG. 9 is a schematic diagram of indirectly indicating a subcarrier subset according to an embodiment of this application. The trigger frame in (a) in FIG. 9 includes:~~(a) in FIG. 9 includes~~:

[00176] Media Access Control header (MAC header) information, a STA scheduling information sequence, padding (padding), and a frame check sequence (frame check sequence, FCS). The MAC header information includes frame control (frame control), duration (duration), a receiver address (reserve address, RA), transmitter address (transmit address, TA), and common information (common information). The STA scheduling information sequence includes scheduling information (user information) of at least one user, and the scheduling information of the at least one user is arranged in a STA scheduling information field according to a specific sequence. Therefore, each STA may be sequentially mapped to each subcarrier subset according to a sequence of scheduling information, in the trigger frame, corresponding to a plurality of STAs. After all subcarrier subsets are fully arranged, remaining STAs are re-arranged starting from the first subcarrier subset. Final arrangement effect is shown in (b) in FIG. 9. The arrangement process may be expressed as follows.

[00177] It is assumed that a total of M STAs (STA #1 to STA #M shown in (b) in FIG. 9) need to send frequency offset estimation training fields to the AP, and all subcarriers scheduled this time are divided into S subcarrier subsets in total. In this case, an i^{th} STA needs to send a frequency offset estimation training field on a (mod(i – 1, S) + 1)th subcarrier subset, where mod indicates a modulo operation. It can be learned from (b) in FIG. 9 that, each of the first mod(i – 1, S) + 1 subcarrier subsets carries $\left\lceil \frac{M}{S} \right\rceil$ STAs. To distinguish the $\left\lceil \frac{M}{S} \right\rceil$ STAs, the STA needs to multiply a P matrix of $\left\lceil \frac{M}{S} \right\rceil$ dimensions when sending a frequency offset estimation training field, and one corresponding frequency offset estimation training field needs $\left\lceil \frac{M}{S} \right\rceil$ symbols. Other subcarrier subsets carry $\left\lceil \frac{M}{S} \right\rceil$ – 1 STAs. To distinguish the $\left\lceil \frac{M}{S} \right\rceil$ – 1 STAs, the STA

needs to multiply a P matrix of $\left\lceil \frac{M}{S} \right\rceil - 1$ dimensions when sending a frequency offset estimation training field, and one corresponding frequency offset estimation training field needs $\left\lceil \frac{M}{S} \right\rceil - 1$ symbols.

[00178] It should be noted that indicating the first subcarrier subset by reusing the scheduling information field shown in FIG. 9 is merely an example, and does not constitute any limitation on the protection scope of this application.

[00179] In a possible implementation, the second indication information is a newly added field in the trigger frame, and indicates a first subcarrier subset, or the second indication information reuses a reserved field in the trigger frame to indicate a first subcarrier subset.

[00180] It should be understood that carrying the second indication information in the trigger frame is merely an example, and does not constitute any limitation on the protection scope of this application. For example, the second indication information may be carried in new signaling between the AP and the STA, and sent to the STA; or the second indication information may be carried in other existing signaling between the AP and the STA, and sent to the STA.

[00181] Further, after receiving the first information, the STA may generate the first training field based on the first information. In other words, the method procedure shown in FIG. 6 further includes S620: The STA generates the first training field.

[00182] First, the STA determines, based on the first indication information (for example, the newly added field in the common information field in the trigger frame), that M STAs under current scheduling need to send the first training field and the second training field to the AP.

[00183] Then, the STA determines, based on the second indication information (for example, a location of the STA in the scheduling information field is STA #i), a first subcarrier subset (for example, a subcarrier subset #j) corresponding to the STA, and may further determine a quantity of symbols needed for sending the first training field and a quantity (M_j) of STAs carried on the first subcarrier subset, and determine a specific sequence number (R_i) of the STA on the first subcarrier subset.

[00184] The quantity M_j of STAs carried on the first subcarrier subset is for determining a dimension of the P-matrix: The P-matrix is a square matrix of M_j. The sequence number of the

STA in all the STAs carried on the first subcarrier subset determines a specific row of the P-matrix by which the STA multiplies, to generate the first training field.

[00185] An example in which the first information is a trigger frame and the second indication information reuses scheduling information in the trigger frame is used, to describe a process in which the STA generates the first training field.

[00186] Step 1:

[00187] The STA determines, based on the predefined quantity S of subcarrier subsets, the quantity M of STAs indicated by the first indication information carried in the trigger frame, and the sequence number i of the STA in the scheduling information field in the trigger frame, related information required for generating the first training field. FIG. 10 is a schematic diagram of determining related information of the first training field according to this embodiment of this application. It can be learned from FIG. 10 that the related information includes the following information:

1. the quantity $\left\lceil \frac{M}{S} \right\rceil$ of symbols needed for sending the first training field;

2. a sequence number j of a first subcarrier subset to be occupied by the STA, where j = mod(i – 1, S) + 1;

3. a quantity of all STAs carried on the first subcarrier subset occupied by the STA, where $M_j = \begin{cases} \left\lceil \frac{M}{S} \right\rceil, & if \quad j \le \text{mod}(M-1,S) \\ \left\lceil \frac{M}{S} \right\rceil - 1, & if \quad j > \text{mod}(M-1,S) \end{cases}$; and

4. a sequence number of the STA in all STAs carried on the occupied first subcarrier subset, where $R_i = \left\lfloor \frac{i-1}{S} \right\rfloor + 1$.

[00188] It should be noted that, in FIG. 10, an example in which the first indication information indicates the quantity M of STAs is used, to describe that the STA generates the first training field. When the first indication information indicates the quantity J of symbols needed by the STA to report the first training field, the STA may determine, based on the quantity J of symbols and the field order i of the STA in the scheduling information field in the trigger frame, related information needed for generating the first training field:

1. the quantity $\left\lceil \frac{M}{S} \right\rceil$ of symbols needed for sending the first training field, where $\left\lceil \frac{M}{S} \right\rceil$ = J;

2. a sequence number j of a first subcarrier subset to be occupied by the STA, where j = mod(i – 1, S) + 1;

3. a quantity of all STAs carried on the first subcarrier subset occupied by the STA, where

$$M_j = \begin{cases} J, & if \quad j \le \text{mod(M-1,S)} \\ J-1, & if \quad j > \text{mod(M-1,S)} \end{cases}, \text{ and}$$

M can be determined by J and S; and

4. a sequence number of the STA in all STAs carried on the occupied first subcarrier subset, where $R_i = \left\lfloor \frac{i-1}{S} \right\rfloor + 1$.

[00189] Step 2:

[00190] Based on the related information obtained in step 1, the STA generates the first training field to be sent to the AP. The first training field sent by the STA on the subcarrier subset #j is shown in FIG. 11. FIG. 11 is a schematic diagram of a type of a first training field according to an embodiment of this application. It can be learned from FIG. 11 that the preset data is multiplied by an R_i th row of the P-matrix of M_j dimensions. Particularly, when $M_j = \left\lceil \frac{M}{S} \right\rceil - 1$, the last symbol of the first training field is a copy of the first symbol of the first training field or a copy of another symbol of the first training field.

[00191] Further, after the STA generates the first training field, in a possible implementation, a preamble field, a channel estimation training field, and a data symbol part may be generated according to specifications in an existing protocol or a next-generation standard protocol. How to generate the preamble field, the channel estimation training field, and the data symbol part is not limited in this application. Generation of the preamble field, the channel estimation training field, and the data symbol part may be completed in a generation manner in an existing protocol or a next-generation standard protocol, or generation may be completed in a generation manner specified in a future protocol.

[00192] After the frequency offset estimation training field, the preamble field, the channel estimation training field, and the data symbol part are generated, the STA may obtain the PPDU to be sent to the AP. In other words, the method procedure shown in FIG. 6 further includes S630: The STA sends the PPDU to the AP.

[00193] In this embodiment of this application, the PPDU needs to include at least two training fields (for example, a first training field and a second training field), and may include more than two training fields (for example, in addition to the first training field and the second training field, the PPDU further includes a third training field, a fourth training field, and the like, where the first training field, the second training field, the third training field, and the fourth training field are the same). The following uses an example in which the PPDU includes two training fields for description. A case in which the PPDU includes more than two training fields is similar to a case in which the PPDU includes two training fields. Details are not described again in this application.

[00194] It should be noted that the physical layer protocol data unit (physical protocol data unit, PPDU) may be understood as an uplink transmission PPDU (uplink trigger-based PPDU, UL TB PPDU) that is specified in a protocol and that is reported by the STA to the AP, or may be referred to as a physical frame for short. A name of the frame that is reported by the STA to the AP and that carries the first training field and the second training field is not limited in embodiments of this application.

[00195] FIG. 12 is a schematic diagram of a structure of a PPDU according to an embodiment of this application.

[00196] In a possible implementation, the first training field, the second training field, and the channel estimation training field are alternately arranged in the PPDU.

[00197] For example, the first training field is located after the preamble field and before the channel estimation training field, and the second training field is located after the channel estimation training field and before the data symbol.

[00198] For example, it can be learned from FIG. 12(a) that there are two foregoing frequency offset estimation training fields (for example, the first training field and the second training field shown in FIG. 12(a)), and the two frequency offset estimation training fields may be separately placed before and after the channel estimation training field.

[00199] For another example, the first training field is located after the preamble field and before the first channel estimation training field, and the second training field is located after the

first channel estimation training field and before the second channel estimation training field, where the first channel estimation training field and the second channel estimation training field form the channel estimation training field.

[00200] For example, it can be learned from FIG. 12(b) that there are two foregoing frequency offset estimation training fields (for example, the first training field and the second training field shown in FIG. 12(a)), and the two frequency offset estimation training fields may be separately placed before and after a part of the channel estimation training field.

[00201] In another possible implementation, the first training field, the second training field, and the channel estimation training field are sequentially arranged in the PPDU.

[00202] For example, the first training field is located after the preamble field and before the second training field, and the second training field is located before the channel estimation training field.

[00203] For example, it can be learned from FIG. 12(c) that there are two foregoing frequency offset estimation training fields (for example, the first training field and the second training field shown in FIG. 12(a)), and the two frequency offset estimation training fields may be placed before the channel estimation training field.

[00204] For another example, the first training field is located after the channel estimation training field and before the second training field, and the second training field is located before the data symbol.

[00205] For example, it can be learned from FIG. 12(d) that there are two foregoing frequency offset estimation training fields (for example, the first training field and the second training field shown in FIG. 12(a)), and the two frequency offset estimation training fields may be separately placed after the channel estimation training field.

[00206] It should be understood that the PPDU formats shown in FIG. 12(a) to FIG. 12(d) are merely examples and do not constitute any limitation on the protection scope of this application. The first training field and the second training field may be arranged in another form in the PPDU, and the PPDU may further include more than two frequency offset estimation training fields. Details are not described herein again. When the format of the PPDU is as in FIG. 12(a), transmission interference is the smallest.

[00207] In addition, the preamble field in the PPDU may further include third indication information, and the third indication information indicates a total quantity M_j of STAs carried

on first subcarrier subset~~the frequency offset estimation training field~~.

[00208] Further, after the AP receives the PPDU, frequency offset estimation may be implemented based on the two frequency offset estimation training fields in the PPDU. In other words, the method procedure shown in FIG. 6 further includes S640: The AP performs frequency offset estimation.

[00209] One subcarrier in the subcarrier subset j is used as an example. If a value of a frequency offset between the STA and the AP is not considered, an information matrix corresponding to the first or second frequency offset estimation training field received by each antenna of the AP may be represented as:

$$\begin{bmatrix} y_1^{sym_1} & y_1^{sym_2} & \cdots & y_1^{sym_{M_j}} \\ y_2^{sym_1} & y_2^{sym_2} & \cdots & y_2^{sym_{M_j}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ y_N^{sym_1} & y_N^{sym_2} & \cdots & y_N^{sym_{M_j}} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M_j} \\ h_{21} & h_{22} & \cdots & h_{2M_j} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ h_{N1} & h_{N2} & \cdots & h_{NM_j} \end{bmatrix} \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1M_j} \\ P_{21} & P_{22} & \cdots & P_{2M_j} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ P_{M1} & P_{M2} & \cdots & P_{MM_j} \end{bmatrix} \quad (1\text{-}1)$$

[00210] Further, the value of the frequency offset between the STA and the AP is considered. It is assumed that values of frequency offsets between M_j STAs and the AP are respectively Δf_1, Δf_2, ..., and Δf_{M_j}. Due to the frequency offset, there is phase rotation accumulation of a frequency offset estimation training field, relative to a frequency offset estimation training field sent on the first symbol, sent on each symbol after the first symbol by each STA in the M_j STAs. Therefore, a phase rotation angle of a frequency offset estimation training field sent on a symbol Q relative to the frequency offset estimation training field sent on the first symbol is $j2\pi\Delta f(Q-1)T$. In this case that the frequency offset exists, a first information matrix corresponding to the first frequency offset estimation training field received by each antenna of the AP may be expressed as:

$$\begin{bmatrix} y_1^{sym_1} & y_1^{sym_2} & \cdots & y_1^{sym_{M_j}} \\ y_2^{sym_1} & y_2^{sym_2} & \cdots & y_2^{sym_{M_j}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ y_N^{sym_1} & y_N^{sym_2} & \cdots & y_N^{sym_{M_j}} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M_j} \\ h_{21} & h_{22} & \cdots & h_{2M_j} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ h_{N1} & h_{N2} & \cdots & h_{NM_j} \end{bmatrix} \begin{bmatrix} P_{11} & P_{12}e^{j2\pi\Delta f_1 T} & \cdots & P_{1Q}e^{j2\pi\Delta f_1(M_j-1)T} \\ P_{21} & P_{22}e^{j2\pi\Delta f_2 T} & \cdots & P_{2Q}e^{j2\pi\Delta f_2(M_j-1)T} \\ \cdot & & \cdot & \cdot \\ \cdot & & \cdot \cdots & \cdot \\ \cdot & & \cdot & \cdot \\ P_{M1} & P_{M2}e^{j2\pi\Delta f_M T} & \cdots & P_{MM_j}e^{j2\pi\Delta f_M(M_j-1)T} \end{bmatrix} \quad (1\text{-}2)$$

[00211] Second information matrix corresponding to the second frequency offset estimation training field received by the AP in the PPDU format shown in FIG. 12(a) may be expressed as:

$$\begin{bmatrix} y_1^{sym_{1+D+M_j}} & y_1^{sym_{2+D+M_j}} & \cdots & y_1^{sym_{M_j+D+M_j}} \\ y_2^{sym_{1+D+M_j}} & y_2^{sym_{2+D+M_j}} & \cdots & y_2^{sym_{M_j+D+M_j}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ y_N^{sym_{1+D+M_j}} & y_N^{sym_{2+D+M_j}} & \cdots & y_N^{sym_{M_j+D+M_j}} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M_j} \\ h_{21} & h_{22} & \cdots & h_{2M_j} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ h_{N1} & h_{N2} & \cdots & h_{NM_j} \end{bmatrix}$$

$$\begin{bmatrix} e^{j2\pi\Delta f_1(D+M_j)T} & & & \\ & e^{j2\pi\Delta f_2(D+M_j)T} & & \\ & & \cdots & \\ & & & e^{j2\pi\Delta f_{M_j}(D+M_j)T} \end{bmatrix} \begin{bmatrix} P_{11} & P_{12}e^{j2\pi\Delta f_1 T} & \cdots & P_{1Q}e^{j2\pi\Delta f_1(M_j-1)T} \\ P_{21} & P_{22}e^{j2\pi\Delta f_2 T} & \cdots & P_{2Q}e^{j2\pi\Delta f_2(M_j-1)T} \\ \cdot & & \cdot & \cdot \\ \cdot & & \cdot \cdots & \cdot \\ \cdot & & \cdot & \cdot \\ P_{M1} & P_{M2}e^{j2\pi\Delta f_M T} & \cdots & P_{MM_j}e^{j2\pi\Delta f_M(M_j-1)T} \end{bmatrix} \quad (1\text{-}3),$$

where

D is a quantity of symbols of the channel estimation training field. A left multiplication is performed on the second information matrix (that is, formula 1-3) corresponding to the second frequency offset estimation training field, and a result of pseudo-inverse calculation on the first information matrix (that is, formula 1-2) corresponding to the first received frequency offset estimation training field, to obtain:

$$\begin{bmatrix} y_1^{sym_1} & y_1^{sym_2} & \cdots & y_1^{sym_{M_j}} \\ y_2^{sym_1} & y_2^{sym_2} & \cdots & y_2^{sym_{M_j}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ y_N^{sym_1} & y_N^{sym_2} & \cdots & y_N^{sym_{M_j}} \end{bmatrix}^{-1} \begin{bmatrix} y_1^{sym_{1+D+M_j}} & y_1^{sym_{2+D+M_j}} & \cdots & y_1^{sym_{M_j+D+M_j}} \\ y_2^{sym_{1+D+M_j}} & y_2^{sym_{2+D+M_j}} & \cdots & y_2^{sym_{M_j+D+M_j}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & & \cdot \\ y_N^{sym_{1+D+M_j}} & y_N^{sym_{2+D+M_j}} & \cdots & y_N^{sym_{M_j+D+M_j}} \end{bmatrix} = \quad (1\text{-}4)$$

$$\begin{bmatrix} e^{j2\pi\Delta f_1(D+M_j)T} & & & \\ & e^{j2\pi\Delta f_2(D+M_j)T} & & \\ & & \cdots & \\ & & & e^{j2\pi\Delta f_{M_j}(D+M_j)T} \end{bmatrix}$$

[00212] It can be learned from the formula 1-4 that a result obtained by left-multiplying the second information matrix corresponding to the second frequency offset estimation training field with the result obtained through inverse calculation on the first information matrix corresponding to the first frequency offset estimation training field has a standard eigenvalue decomposition

property, and eigenvalues $e^{j2\pi\Delta f_1(D+M_j)T}$, $e^{j2\pi\Delta f_2(D+M_j)T}$, ..., and $e^{j2\pi\Delta f_{M_j}(D+M_j)T}$ are obtained by solving by using eigenvalue decomposition. Values of frequency offsets Δf_1, Δf_2, ..., and Δf_{M_j} between the M_j STAs and the AP are obtained through calculation based on the foregoing eigenvalues.

[00213] A solving process in the case of the PPDU formats shown in FIG. 12(b) to FIG. 12(d) is similar to a solving process of the values of the frequency offsets in the case of the PPDU format shown in FIG. 12(a), and details are not described herein again.

[00214] It should be noted that, in embodiments of this application, that content corresponding to a frequency offset estimation training field received by the AP is referred to as an information matrix is merely an example, and does not constitute any limitation on the protection scope of this application. For example, the content may alternatively be referred to as a signal matrix or frequency offset estimation training field information.

[00215] Further, in embodiments of this application, the PPDU may further include an automatic gain control training field. Generally, the automatic gain control training field may be referred to as a short training field (short training field, STF). For example, in the 802.11ax protocol, in addition to an L-STF and an HE-STF specified in the current protocol, a field similar to the HE-STF is further added, and the newly added field may be referred to as an automatic gain control training field. For another example, in the 802.11be protocol or a future Wi-Fi protocol, in addition to an extremely high throughput -STF (extremely high throughput STF, EHT-STF) specified in a current protocol, a field similar to an EHT-STF is further added, and the newly added field may be referred to as an automatic gain control training field. In embodiments of this application, the automatic gain control training field is used to control a receiver amplifier level when the AP receives a frequency offset estimation training field (for example, the AP is controlled to receive the first training field and/or the second training field). Refer to FIG. 12(e).

[00216] It should be noted that a reason for adding the automatic gain control training field is that a subcarrier occupied by the STA when the STA sends the frequency offset estimation training field is different from another part (for example, the preamble field, the channel estimation training field, and the data symbol). Due to frequency selectivity of a channel, total received signal strength of the AP may change relative to the another part. To enhance receiving performance, the receiver amplifier level needs to be adjusted.

[00217] For example, a target signal strength of the uplink packet after being amplified and adjusted by the AP is X. For another part other than the frequency offset estimation training field, the AP estimates, based on an existing automatic gain control training field, that a signal strength of the another part is Y, so that an amplifier level needs to be adjusted to X/Y when the AP receives the another part; for the frequency offset estimation training field, the AP estimates, based on a newly added automatic gain control training field, that a signal strength of the frequency offset estimation training field part is Z, so that an amplifier level needs to be adjusted to X/Z when the AP receives the frequency offset estimation training field part.

[00218] To facilitate understanding of the frequency offset estimation method provided in embodiments of this application, the following uses a specific example for description.

[00219] It is assumed that the frequency offset estimation method provided in embodiments of this application is applied to the scenario shown in FIG. 13, where one AP is associated with three STAs (a STA #1, a STA #2, and a STA #3 shown in FIG. 13), and each STA is a single-antenna STA.

[00220] Frequency offsets of the three STAs relative to the AP are respectively Δf_1, Δf_2, and Δf_3. The entire frequency band under current scheduling is divided into two subcarrier subsets. In the scenario shown in FIG. 13, the frequency offset estimation method provided in this embodiment of this application includes the following steps.

[00221] Step 1:

[00222] The AP sends a trigger frame to indicate all STAs to prepare to send a PPDU. The trigger frame includes first indication information and scheduling information. The first indication information indicates that there are a total of three STAs that send frequency offset estimation training fields in the scenario shown in FIG. 13. An order of the STAs in a scheduling information field in the trigger frame is the STA #1, the STA #2, and the STA #3.

[00223] Step 2:

[00224] After receiving the trigger frame, the STA #1 constructs frequency offset estimation training fields. The STA #1 learns that one of two frequency offset estimation training fields includes $\left\lceil \frac{M}{S} \right\rceil$ = 2 symbols, and learns that the STA #1 needs to occupy a subcarrier subset #1, there are two STAs (the STA #1 and the STA #3) on the subcarrier subset #1, and the STA #1 is

the first STA in the subcarrier subset #1. Therefore, the first frequency offset estimation training fields sent by the STA #1 on the two symbols are preset data multiplied by two values in the first row in a two-dimensional matrix P $\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$,,1--1-1-1.., that is, multiplied by [1,–1]. In other words, the first frequency offset estimation training field sent on the first symbol is the preset data multiplied by 1, and the first frequency offset estimation training field sent on the second symbol is the preset data multiplied by –1. The first row shown in FIG. 14 is a physical frame sent by the STA #1. FIG. 14 is a schematic diagram of PPDUs that are sent by the plurality of STAs and that are received by the AP.

[00225] After receiving the trigger frame, the STA #3 constructs frequency offset estimation training fields. The STA #3 learns that one of two frequency offset estimation training fields includes two symbols, and learns that the STA #3 needs to occupy the subcarrier subset #1, there are two STAs (the STA #1 and the STA #3) on the subcarrier subset #1, and the STA #3 is the second STA in the subcarrier subset #1. Therefore, the first frequency offset estimation training fields sent by the STA #3 on the two symbols are preset data multiplied by two values in the second row in the two-dimensional matrix P $\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$,,1--1-1-1.., that is, multiplied by [1,1]. In other words, the first frequency offset estimation training field sent on the first symbol is the preset data multiplied by 1, and the first frequency offset estimation training field sent on the second symbol is the preset data multiplied by 1. The ~~second~~ third row in FIG. 14 is a PPDU sent by the STA #3.

[00226] After receiving the trigger frame, the STA #2 constructs frequency offset estimation training fields. The STA #2 learns that one of two frequency offset estimation training fields includes two symbols, and learns that the STA #2 needs to occupy a subcarrier subset #2, there is one STA (the STA #2) in the subcarrier subset #2, and the STA #2 is the first STA in the subcarrier subset #2. Therefore, the first frequency offset estimation training fields sent by the STA #2 on the two symbols are preset data multiplied by a value in the first row in a one-dimensional matrix P $[1]$,,1--1-1-1.., that is, multiplied by [1,1]. In other words, the first frequency offset estimation training field sent on the first symbol is the preset data multiplied by 1, and the first frequency offset estimation training field sent on the second symbol is the preset data multiplied by 1. The ~~third~~ second row in FIG. 14 is a PPDU sent by the STA #~~3~~2.

[00227] Step 3:

[00228] The STA #1, the STA #2, and the STA #3 each send, to the AP, two separately established repeated frequency offset estimation training fields.

[00229] Step 4:

[00230] On the subcarrier subset #1, an information matrix received via an antenna #1 of the AP is a sum of data of the STA #1 passing through a channel ,h-11. and data of the STA #3 passing through a channel h_{13}; information received by an antenna #2 of the AP is a sum of data of the STA #1 passing through a channel ,h-21. and data of the STA #3 passing through a channel h_{23}; information received by an antenna #3 of the AP is a sum of data of the STA #1 passing through a channel ,h-31. and data of the STA #3 passing through a channel ,h-32..

[00231] A frequency offset estimation training field of the STA #1 sent on the second symbol should be -1. However, because each STA has a different frequency offset relative to the AP, -1 becomes -1,e-j2πΔ,f-1.T. due to phase rotation. This applies to frequency offset estimation training fields sent on subsequent symbols. Similarly, a frequency offset estimation training field of the STA #3 sent on the second symbol should be 1. However, due to phase rotation, 1 becomes 1,e-j2πΔ,f-2.T.. This applies to frequency offset estimation training fields sent on subsequent symbols.

[00232] Therefore, a first information matrix corresponding to the first frequency offset estimation training field received by the AP on the subcarrier subset 1 is:

$$\begin{bmatrix} y_1^1 & y_1^3 \\ y_2^1 & y_2^3 \\ y_3^1 & y_3^3 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{13} \\ h_{21} & h_{23} \\ h_{31} & h_{33} \end{bmatrix} \begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}$$

[00233] A second information matrix corresponding to the second frequency offset estimation training field received by the AP on the subcarrier subset 1 is:

$$\begin{bmatrix} y_1^{3+D} & y_1^{5+D} \\ y_2^{3+D} & y_2^{5+D} \\ y_3^{3+D} & y_3^{5+D} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{13} \\ h_{21} & h_{23} \\ h_{31} & h_{33} \end{bmatrix} \begin{bmatrix} 1e^{j2\pi\Delta f_1 (D+2)T} & -1e^{j2\pi\Delta f_1 (D+3)T} \\ 1e^{j2\pi\Delta f_3 (D+2)T} & 1e^{j2\pi\Delta f_3 (D+3)T} \end{bmatrix} =$$

$$\begin{bmatrix} h_{11} & h_{13} \\ h_{21} & h_{23} \\ h_{31} & h_{33} \end{bmatrix} \begin{bmatrix} 1e^{j2\pi\Delta f_1 (D+2)T} & 0 \\ 0 & 1e^{j2\pi\Delta f_3 (D+2)T} \end{bmatrix} \begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_3 T} \end{bmatrix}$$

[00234] The AP performs left multiplication on the second information matrix corresponding to the second frequency offset estimation training field, and a result of pseudo-inverse calculation on the first information matrix corresponding to the first received frequency offset estimation

training field, to obtain a corresponding eigenvalue standard form:

$$\begin{bmatrix} y_1^1 & y_1^3 \\ y_2^1 & y_2^3 \\ y_3^1 & y_3^3 \end{bmatrix}^{-1} \begin{bmatrix} y_1^{3+D} & y_1^{5+D} \\ y_2^{3+D} & y_2^{5+D} \\ y_3^{3+D} & y_3^{5+D} \end{bmatrix} =$$

$$\begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_3 T} \end{bmatrix}^{-1} \begin{bmatrix} 1e^{j2\pi\Delta f_1 (D+2)T} & 0 \\ 0 & 1e^{j2\pi\Delta f_3 (D+2)T} \end{bmatrix} \begin{bmatrix} 1 & -1e^{j2\pi\Delta f_1 T} \\ 1 & 1e^{j2\pi\Delta f_3 T} \end{bmatrix}$$

[00235] Eigenvalues [$e^{j2\pi\Delta f_1 (D+2)T}$, $e^{j2\pi\Delta f_3 (D+2)T}$] can be obtained according to an eigenvalue decomposition theorem, angles for the eigenvalues are calculated, and then the angles are divided by corresponding coefficients to obtain ,Δ,f-1.,Δ,f-2.. and Δf_3.

[00236] On the subcarrier subset #2, information received by the antenna #1 of the AP is data of the STA #2 passing through a channel ,h-13., and information received by the antenna #2 of the AP is data of the STA #2 passing through a channel ,h-23.. A frequency offset between the STA #2 and the AP is considered, and first information matrix corresponding to the first frequency offset estimation training field received by the AP on the subcarrier subset #2 is:

$$\begin{bmatrix} y_1^1 & y_1^2 \\ y_2^1 & y_2^2 \\ y_3^1 & y_3^2 \end{bmatrix} = \begin{bmatrix} h_{12} \\ h_{22} \\ h_{32} \end{bmatrix} \begin{bmatrix} 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}$$

[00237] A second information matrix corresponding to the second frequency offset estimation training field received by the AP on the subcarrier subset 2 is:

$$\begin{bmatrix} y_1^{3+D} & y_1^{4+D} \\ y_2^{3+D} & y_2^{4+D} \\ y_3^{3+D} & y_3^{4+D} \end{bmatrix} = \begin{bmatrix} h_{12} \\ h_{22} \\ h_{32} \end{bmatrix} \begin{bmatrix} 1e^{j2\pi\Delta f_2 (D+2)T} & 1e^{j2\pi\Delta f_2 (D+3)T} \end{bmatrix} =$$

$$\begin{bmatrix} h_{12} \\ h_{22} \\ h_{32} \end{bmatrix} e^{j2\pi\Delta f_2 (D+2)T} \begin{bmatrix} 1 & 1e^{j2\pi\Delta f_2 T} \end{bmatrix}$$

[00238] The AP obtains quotients of coefficients at a same location in the second information matrix corresponding to the received second frequency offset estimation training field and the first information matrix corresponding to the first frequency offset estimation training field, to obtain:

$$\begin{bmatrix} y_1^{3+D} & y_1^{4+D} \\ y_2^{3+D} & y_2^{4+D} \\ y_3^{3+D} & y_3^{4+D} \end{bmatrix} ./ \begin{bmatrix} y_1^1 & y_1^2 \\ y_2^1 & y_2^2 \\ y_3^1 & y_3^2 \end{bmatrix} = \begin{bmatrix} e^{j2\pi\Delta f_2 (D+2)T} & e^{j2\pi\Delta f_2 (D+2)T} \\ e^{j2\pi\Delta f_2 (D+2)T} & e^{j2\pi\Delta f_2 (D+2)T} \\ e^{j2\pi\Delta f_2 (D+2)T} & e^{j2\pi\Delta f_2 (D+2)T} \end{bmatrix}$$

[00239] $e^{j2\pi\Delta f_2 (D+2)T}$ can be obtained, and an angle of this complex number is obtained, and

divided by a corresponding coefficient, to obtain Δf_2.

[00240] In addition, Δf_2 can also be obtained by left-multiplying the second information matrix corresponding to the second frequency offset estimation training field with a result of pseudo-inverse calculation on the first information matrix corresponding to the first frequency offset estimation training field. A calculation manner is as follows.

[00241] During calculation, the second column of the first information matrix corresponding to the first received frequency offset estimation training field and the second column of the second information matrix corresponding to the second received frequency offset estimation training field need to be ignored. In other words, left multiplication is performed on the first column of the second information matrix corresponding to the second frequency offset estimation training field with a result of pseudo-inverse calculation on the first column of the first information matrix corresponding to the first frequency offset estimation training field, to obtain:

$$\begin{bmatrix} y_1^1 \\ y_2^1 \\ y_3^1 \end{bmatrix}^{-1} \begin{bmatrix} y_1^{3+D} \\ y_2^{3+D} \\ y_3^{3+D} \end{bmatrix} = e^{j2\pi\Delta f_2(D+2)T}$$

[00242] $e^{j2\pi\Delta f_2(D+2)T}$ can be obtained, and an angle of this complex number is obtained, and divided by a corresponding coefficient, to obtain Δf_2.

[00243] It should be understood that the AP and the STA in the foregoing method embodiments may perform a part or all of the steps in the embodiments. These steps or operations are merely examples. Embodiments of this application may further include performing other operations or variations of various operations.

[00244] It should be further understood that, in embodiments of this application, unless otherwise stated or there is a logic conflict, terms and/or descriptions between different embodiments are consistent and may be mutually referenced, and technical features in different embodiments may be combined based on an internal logical relationship thereof, to form a new embodiment.

[00245] It should be further understood that sequence numbers of the foregoing processes do not mean execution sequences in the foregoing method embodiments. The execution sequences of the processes should be determined based on functions and internal logic of the processes, and should not be construed as any limitation on the implementation processes of embodiments of this

application.

[00246] The foregoing describes in detail the frequency offset estimation method provided in embodiments of this application with reference to FIG. 6. The following describes in detail frequency offset estimation apparatuses provided in embodiments of this application with reference to FIG. 15 to FIG. 18.

[00247] FIG. 15 is a schematic diagram of a frequency offset estimation apparatus 1500 according to this application. As shown in FIG. 15, the apparatus 1500 includes a receiving unit 1510 and a sending unit 1520.

[00248] The receiving unit 1510 is configured to receive first information from an access point AP, where the first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the station for reporting the first training field or the second training field.

[00249] The station is any one of a plurality of stations that communicate with the access point, the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the station, and M and S are positive integers and are for determining the first training field or the second training field.

[00250] The sending unit 1520 is configured to send a physical layer protocol data unit PPDU to the AP on the first subcarrier subset, where the PPDU includes the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the station and the AP.

[00251] The apparatus 1500 completely corresponds to the STA in the method embodiments. The apparatus 1500 may be the STA in the method embodiments, or a chip or a functional module inside the STA in the method embodiments. Corresponding units of the apparatus 1500 are configured to perform corresponding steps performed by the STA in the method embodiment shown in FIG. 6.

[00252] The receiving unit 1510 in the apparatus 1500 performs the step of receiving by the STA in the method embodiment, for example, performs step S610 of receiving the first information in FIG. 6.

[00253] The sending unit 1520 performs the step of sending by the STA in the method embodiment, for example, performs step S630 of sending a PPDU to the AP in FIG. 6.

[00254] The apparatus 1500 may further include a processing unit. The processing unit

performs steps implemented or processed inside the STA in the method embodiment, for example, performs step S620 of generating the first training field in FIG. 6.

[00255] The sending unit 1520 and the receiving unit 1510 may form a transceiver unit that has both a receiving function and a sending function. The processing unit may be a processor. The sending unit 1520 may be a transmitter, and the receiving unit 1510 may be a receiver. The receiver and the transmitter may be integrated to constitute a transceiver.

[00256] FIG. 16 is a schematic diagram of a structure of a STA 1600 applicable to an embodiment of this application. The STA 1600 may be applied to the system shown in FIG. 1. For ease of description, FIG. 16 shows only main components of the STA. As shown in FIG. 16, the STA 1600 includes a processor, a memory, a control circuit, an antenna, and an input/output apparatus (corresponding to the sending unit 1520 and the receiving unit 1530 shown in FIG. 15). The processor is configured to control the antenna and the input/output apparatus to send and receive a signal, the memory is configured to store a computer program, and the processor is configured to invoke and run the computer program from the memory, to perform a corresponding procedure and/or operation performed by the STA in the frequency offset estimation method provided in this application. Details are not described herein.

[00257] A person skilled in the art may understand that, for ease of description, FIG. 16 shows only one memory and one processor. There may be a plurality of processors and memories in an actual STA. The memory may also be referred to as a storage medium, a storage device, or the like. This is not limited in embodiments of this application.

[00258] FIG. 17 is a schematic diagram of a frequency offset estimation apparatus 1700 according to this application. As shown in FIG. 17, the apparatus 1700 includes a receiving unit 1710 and a sending unit 1720.

[00259] The sending unit 1720 is configured to send first information to a station STA, where the first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the STA for reporting the first training field or the second training field.

[00260] the STA is any one of the at least one STA~~The STA is any one of a plurality of STAs~~ that communicate with the apparatus 1700~~access point~~, the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the STA, and M and S are positive integers and are for determining the first training field or the second training field.

[00261] The quantity M of spatial streams corresponding to the STA refers to a sum M of antenna quantities included in at least one STA that needs to report a first training field and a second training field. In addition, embodiments of this application use a single-antenna STA as an example (as shown in FIG. 2(b), a multi-antenna STA may be equivalent to a single-antenna STA). In this case, the quantity M of spatial streams corresponding to the STA may also be referred to as a quantity M of STAs, that is, the quantity of spatial streams is equal to the quantity of STAs that need to report a first training field and a second training field.

[00262] In addition, when embodiments of this application are also applied to uplink transmission, the first information may be a PPDU sent by a STA to an AP. First indication information indicating a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and second indication information indicating a first subcarrier subset to be occupied by the STA for reporting the first training field or the second training field that are included in the first information may be carried in a signal field of the PPDU sent by the STA to the AP, for example, carried in an HE-SIG or EHT-SIG field in the PPDU.

[00263] The receiving unit 1710 is configured to receive a physical layer protocol data unit PPDU from the STA on the first subcarrier subset, where the PPDU includes the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the STA and the access point.

[00264] The apparatus 1700 completely corresponds to the AP in the method embodiments. The apparatus 1700 may be the AP in the method embodiments, or a chip or a functional module inside the AP in the method embodiments. Corresponding units of the apparatus 1700 are configured to perform corresponding steps performed by the AP in the method embodiment shown in FIG. 6.

[00265] The receiving unit 1710 in the apparatus 1700 performs the receiving step of the AP in the method embodiment, for example, performs step S620 of receiving a ~~PDU~~ PPDU sent by the STA in FIG. 6.

[00266] The ~~receiving~~ sending unit 1720 in the apparatus 1700 performs the step of sending by the AP in the method embodiment, for example, performs step S610 of sending the first information to the STA in FIG. 6.

[00267] The apparatus 1700 may further include a processing unit. The processing unit performs steps implemented or processed inside the AP in the method embodiment, for example,

performs step S640 of performing frequency offset estimation in FIG. 6.

[00268] The receiving unit 1710 and the sending unit 1720 may form a transceiver unit that has both receiving and sending functions. The processing unit may be a processor. The sending unit 1720 may be a transmitter. The receiving unit 1710 may be a receiver. The receiver and the transmitter may be integrated to constitute a transceiver.

[00269] FIG. 18 is a schematic diagram of a structure of an AP 1800 applicable to an embodiment of this application. The AP 1800 may be configured to implement functions of the AP in the foregoing frequency offset estimation method. FIG. 18 may be a schematic diagram of a structure of the AP.

[00270] The AP includes a part 1810 and a part 1820. The part 1810 is mainly configured to send and receive a radio frequency signal and perform conversion between the radio frequency signal and a baseband signal. The part 1820 is mainly configured to perform baseband processing, control a location management component, and the like. The part 1810 may usually be referred to as a transceiver unit, a transceiver machine, a transceiver circuit, a transceiver, or the like. The part 1820 is usually a control center of the location management component, may usually be referred to as a processing unit, and is configured to control the location management component to perform a processing operation on an AP side in the foregoing method embodiment.

[00271] The transceiver unit in the part 1810 may also be referred to as a transceiver machine, a transceiver, or the like. The transceiver unit includes an antenna and a radio frequency unit. The radio frequency unit is mainly configured to perform radio frequency processing. Optionally, a component that is in the part 1810 and that is configured to implement a receiving function may be considered as a receiving unit, and a component that is in the part 1810 and that is configured to implement a sending function may be considered as a sending unit. In other words, the part 1810 includes the receiving unit and the sending unit. The receiving unit may also be referred to as a receiver machine, a receiver, a receiver circuit, or the like. The sending unit may be referred to as a transmitter machine, a transmitter, a transmitter circuit, or the like.

[00272] The part 1820 may include one or more boards, and each board may include one or more processors and one or more memories. The processor is configured to read and execute a program in the memory, to implement a baseband processing function and control the location management component. If there are a plurality of boards, the boards may be interconnected to enhance a processing capability. In an optional implementation, a plurality of boards may share

one or more processors, a plurality of boards may share one or more memories, or a plurality of boards may simultaneously share one or more processors.

[00273] It should be understood that FIG. 18 is merely an example instead of a limitation. The AP including the transceiver unit and the processing unit may not depend on the structure shown in FIG. 18.

[00274] It should further be understood that the AP 1800 shown in FIG. 18 can implement functions of the AP in the method embodiment in FIG. 6. Operations and/or functions of the units in the AP 1800 are respectively used to implement corresponding procedures performed by the AP in the method embodiment of this application. To avoid repetition, detailed descriptions are appropriately omitted herein. A structure of the AP shown in FIG. 18 is merely a possible form, and should not constitute any limitation on this embodiment of this application. This application does not exclude a possibility that an AP structure of another form may appear in the future.

[00275] An embodiment of this application further provides a communication system. The communication system includes the foregoing STA and AP.

[00276] This application further provides a computer-readable storage medium. The computer-readable storage medium stores instructions. When the instructions are run on a computer, the computer is enabled to perform the steps performed by the STA in the method shown in FIG. 6.

[00277] This application further provides a computer-readable storage medium. The computer-readable storage medium stores instructions. When the instructions are run on a computer, the computer is enabled to perform the steps performed by the AP in the method shown in FIG. 6.

[00278] This application further provides a computer program product including instructions. When the computer program product is run on a computer, the computer is enabled to perform the steps performed by the STA in the method shown in FIG. 6.

[00279] This application further provides a computer program product including instructions. When the computer program product is run on a computer, the computer is enabled to perform the steps performed by the AP in the method shown in FIG. 6.

[00280] This application further provides a chip, including a processor. The processor is configured to read a computer program stored in a memory and run the computer program, to perform a corresponding operation and/or process performed by the STA in the frequency offset estimation method provided in this application. Optionally, the chip further includes a memory. The memory and the processor are connected to the memory by using a circuit or a wire. The

processor is configured to read and execute the computer program in the memory. Further, optionally, the chip includes a communication interface, and the processor is connected to the communication interface. The communication interface is configured to receive data and/or information that needs to be processed, and the processor obtains the data and/or information from the communication interface, and processes the data and/or information. The communication interface may be an input/output interface, an interface circuit, an output circuit, an input circuit, a pin, a related circuit, or the like in the chip. The processor may alternatively be embodied as a processing circuit or a logic circuit.

[00281] This application further provides a chip, including a processor. The processor is configured to read a computer program stored in a memory and run the computer program, to perform a corresponding operation and/or process performed by the AP in the frequency offset estimation method provided in this application. Optionally, the chip further includes a memory. The memory and the processor are connected to the memory by using a circuit or a wire. The processor is configured to read and execute the computer program in the memory. Further, optionally, the chip includes a communication interface, and the processor is connected to the communication interface. The communication interface is configured to receive data and/or information that needs to be processed, and the processor obtains the data and/or information from the communication interface, and processes the data and/or information. The communication interface may be an input/output interface, an interface circuit, an output circuit, an input circuit, a pin, a related circuit, or the like in the chip. The processor may alternatively be embodied as a processing circuit or a logic circuit. It should be understood that, the foregoing chip may be alternatively replaced with a chip system, and details are not described herein. In this application, the terms "include", "have", and any other variants mean to cover the non-exclusive inclusion, for example, a process, method, system, product, or device that includes a list of steps or units is not necessarily limited to those steps or units that are clearly listed, but may include other steps or units not expressly listed or inherent to such a process, method, product, or device.

[00282] A person of ordinary skill in the art may be aware that, in combination with the examples described in embodiments disclosed in this specification, units and algorithm steps may be implemented by electronic hardware or a combination of computer software and electronic hardware. Whether the functions are performed by hardware or software depends on a particular application and a design constraint condition of the technical solutions. A person skilled in the art

may use different methods to implement the described functions for each particular application, but it should not be considered that the implementation goes beyond the scope of this application.

[00283] It may be clearly understood by a person skilled in the art that, for the purpose of convenient and brief description, for a detailed working process of the foregoing system, apparatus, and unit, refer to a corresponding process in the foregoing method embodiments. Details are not described herein again.

[00284] In the several embodiments provided in this application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described apparatus embodiments are merely examples. For example, the unit division is merely logical function division and may be other division in actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented by using some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic, mechanical, or other forms.

[00285] The units described as separate parts may or may not be physically separate, and parts displayed as units may or may not be physical units, may be located in one position, or may be distributed on a plurality of network units. Some or all of the units may be selected based on actual requirements to achieve the objectives of the solutions of the embodiments.

[00286] In addition, function units in embodiments of this application may be integrated into one processing unit, or each of the units may exist alone physically, or two or more units may be integrated into one unit.

[00287] When the functions are implemented in the form of a software functional unit and sold or used as an independent product, the functions may be stored in a computer-readable storage medium. Based on such an understanding, the technical solutions of this application essentially, or the part contributing to the conventional technology, or some of the technical solutions may be implemented in a form of a software product. The computer software product is stored in a storage medium, and includes several instructions for instructing a computer device (which may be a personal computer, a server, a network device, or the like) to perform all or some of the steps of the methods described in the embodiments of this application. The foregoing storage medium includes any medium that can store program code, such as a USB flash drive, a removable hard

disk, a read-only memory (read-only memory, ROM), a random access memory (random access memory, RAM), a magnetic disk, or an optical disc.

[00288] In addition, the term "and/or" in this application describes only an association relationship between associated objects and represents that three relationships may exist. For example, A and/or B may represent the following three cases: Only A exists, both A and B exist, and only B exists. In addition, the character "/" in this specification generally indicates an "or" relationship between the associated objects. The term "at least one" in this application may represent "one" and "two or more". For example, at least one of A, B, and C may indicate the following seven cases: Only A exists, only B exists, only C exists, both A and B exist, both A and C exist, both C and B exist, and A, B, and C exist. In addition, the term "left-multiply/right-multiply … by" in this application describes a calculation manner used between matrices. For example, a matrix BA is obtained by left-multiplying a matrix A by a matrix B, and a matrix AB is obtained by right-multiplying the matrix A by the B matrix. The term "left-multiply/right-multiply … to" in this application describes a calculation manner between matrices. For example, the matrix AB is obtained by left-multiplying the matrix A to matrix B, and the matrix BA obtained by right-multiplying the matrix A to the matrix B.

[00289] The foregoing descriptions are merely specific implementations of this application, but are not intended to limit the protection scope of this application. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

CLAIMS

What is claimed is:

1. A frequency offset estimation method, applied to an access point AP communicating with a plurality of stations STAs, comprising:

sending, by the AP, first information to a STA, wherein the first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the STA for reporting the first training field or the second training field, wherein

the STA is any one of the at least one STA~~the STA is any one of the plurality of STAs~~, the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the STA, and M and S are positive integers and are for determining the first training field or the second training field; and

receiving, by the AP on the first subcarrier subset, a physical layer protocol data unit PPDU from the STA, wherein the PPDU comprises the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the STA and the AP.

2. The method according to claim 1, wherein the first information comprises:

first indication information and second indication information, wherein the first indication information indicates M, and the second indication information is for determining the first subcarrier subset.

3. The method according to claim 2, wherein the sending, by the AP, the first information to the STA comprises:

sending, by the AP, a trigger frame to the STA, wherein the trigger frame triggers the STA to report the PPDU, the trigger frame carries the first indication information and the second indication information, and the first indication information is a scheduling information field.

4. The method according to claim 3, wherein that the trigger frame carries the first indication information comprises:

the trigger frame comprises a common information field, and the common information field comprises the first indication information.

5. The method according to any one of claims 1 to 4, wherein the first training field or the

second training field is determined based on a mapping relationship between the STA and a P matrix element.

6. The method according to any one of claims 1 to 5, wherein the method further comprises:

receiving, by the AP, a first information matrix on the first subcarrier subset, wherein the first information matrix is determined based on the first training field, channel information, and the value of the frequency offset between the STA and the AP; and

receiving, by the AP, a second information matrix on the first subcarrier subset, wherein the second information matrix is determined based on the second training field, the channel information, and the value of the frequency offset between the STA and the AP, wherein

the value of the frequency offset between the STA and the AP is determined based on the first information matrix and the second information matrix.

7. The method according to any one of claims 1 to 6, wherein the PPDU further comprises a channel estimation training field, and the first training field, the second training field, and the channel estimation training field are sequentially arranged or alternately arranged in the PPDU.

8. The method according to any one of claims 1 to 7, wherein the PPDU further comprises an automatic gain control training field, and the automatic gain control training field is used by the AP to adjust receive power for receiving the first training field and/or the second training field on the first subcarrier subset.

9. A frequency offset estimation method, applied to any one STA of a plurality of stations STAs communicating with an access point AP, comprising:

receiving, by the STA, first information from the AP, wherein the first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the STA for reporting the first training field or the second training field, wherein

the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the STA, and M and S are positive integers and are for determining the first training field or the second training field; and

sending, by the STA, a physical layer protocol data unit PPDU to the AP on the first subcarrier subset, wherein the PPDU comprises the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the STA and the AP.

10. The method according to claim 9, wherein the first information comprises:

first indication information and second indication information, wherein the first indication information indicates M, and the second indication information is for determining the first subcarrier subset.

11. The method according to claim 10, wherein the receiving, by the STA, first information from the AP comprises:

receiving, by the STA, a trigger frame from the AP, wherein the trigger frame triggers the STA to report the PPDU, the trigger frame carries the first indication information and the second indication information, and the first indication information is a scheduling information field.

12. The method according to claim 11, wherein that the trigger frame carries the first indication information comprises:

the trigger frame comprises a common information field, and the common information field comprises the first indication information.

13. The method according to any one of claims 9 to 12, wherein the first training field or the second training field is determined based on a mapping relationship between the STA and a P matrix element.

14. The method according to any one of claims 9 to 13, wherein the PPDU further comprises a channel estimation training field, and the first training field, the second training field, and the channel estimation training field are sequentially arranged or alternately arranged in the PPDU.

15. The method according to any one of claims 9 to 14, wherein the PPDU further comprises an automatic gain control training field, and the automatic gain control training field is used by the AP to adjust receive power for receiving the first training field and/or the second training field on the first subcarrier subset.

16. An access point, comprising:

a sending unit, configured to send first information to a station STA, wherein the first information indicates a quantity M of spatial streams corresponding to at least one STA that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the STA for reporting the first training field or the second training field, wherein

the STA is any one of the at least one STA~~the STA is any one of a plurality of STAs~~ that communicate with the access point, the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the STA, and M and S are positive integers and

are for determining the first training field or the second training field; and

a receiving unit, configured to receive a physical layer protocol data unit PPDU from the STA on the first subcarrier subset, wherein the PPDU comprises the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the STA and the access point.

~~17. The access point according to claim 16, wherein the first information comprises:~~

~~first indication information and second indication information, wherein the first indication information indicates M, and the second indication information is for determining the first subcarrier subset.~~

~~18. The access point according to claim 17, wherein that the sending unit sends the first information to the STA comprises:~~

~~sending, by the sending unit, a trigger frame to the STA, wherein the trigger frame triggers the STA to report the PPDU, the trigger frame carries the first indication information and the second indication information, and the first indication information is a scheduling information field.~~

~~19. The access point according to claim 18, wherein that the trigger frame carries the first indication information comprises:~~

~~the trigger frame comprises a common information field, and the common information field comprises the first indication information.~~

~~20. The access point according to any one of claims 16 to 19, wherein the first training field or the second training field is determined based on a mapping relationship between the STA and a P matrix element.~~

~~21. The access point according to any one of claims 16 to 20, wherein the receiving unit is further configured to receive a first information matrix on the first subcarrier subset, wherein the first information matrix is determined based on the first training field, channel information, and the value of the frequency offset between the STA and the access point; and~~

~~the receiving unit is further configured to receive a second information matrix on the first subcarrier subset, wherein the second information matrix is determined based on the second training field, the channel information, and the value of the frequency offset between the STA and the access point, wherein~~

~~the value of the frequency offset between the STA and the access point is determined based~~

~~on the first information matrix and the second information matrix.~~

~~22. The access point according to any one of claims 16 to 21, wherein the PPDU further comprises a channel estimation training field, and the first training field, the second training field, and the channel estimation training field are sequentially arranged or alternately arranged in the PPDU.~~

~~23. The access point according to any one of claims 16 to 22, wherein the PPDU further comprises an automatic gain control training field, and the automatic gain control training field is used by the access point to adjust receive power for receiving the first training field and/or the second training field on the first subcarrier subset.~~

~~24~~17. A station, comprising:

a receiving unit, configured to receive first information from an access point AP, wherein the first information indicates a quantity M of spatial streams corresponding to the station that needs to report a first training field and a second training field, and a first subcarrier subset to be occupied by the station for reporting the first training field or the second training field, wherein

the station is any one of a plurality of stations that communicate with the access point, the first subcarrier subset is a subcarrier subset that is in S preset subcarrier subsets and that corresponds to the station, and M and S are positive integers and are for determining the first training field or the second training field; and

a sending unit, configured to send a physical layer protocol data unit PPDU to the AP on the first subcarrier subset, wherein the PPDU comprises the first training field and the second training field, and the first training field and the second training field are for determining a value of a frequency offset between the station and the AP.

~~25. The station according to claim 24, wherein the first information comprises:~~

~~first indication information and second indication information, wherein the first indication information indicates M, and the second indication information is for determining the first subcarrier subset.~~

~~26. The station according to claim 25, wherein that the receiving unit receives the first information from the AP comprises:~~

~~the receiving unit receives a trigger frame from the AP, wherein the trigger frame triggers the station to report the PPDU, the trigger frame carries the first indication information and the second indication information, and the first indication information is a scheduling information field.~~

~~27. The station according to claim 26, wherein that the trigger frame carries the first indication information comprises:~~

~~the trigger frame comprises a common information field, and the common information field comprises the first indication information.~~

~~28. The station according to any one of claims 24 to 27, wherein the first training field or the second training field is determined based on a mapping relationship between the station and a P matrix element.~~

~~29. The station according to any one of claims 24 to 28, wherein the PPDU further comprises a channel estimation training field, and the first training field, the second training field, and the channel estimation training field are sequentially arranged or alternately arranged in the PPDU.~~

~~30. The station according to any one of claims 24 to 29, wherein the PPDU further comprises an automatic gain control training field, and the automatic gain control training field is used by the AP to adjust receive power for receiving the first training field and/or the second training field on the first subcarrier subset.~~

~~31~~18. A communication apparatus, comprising:

the memory, configured to store a computer program; and

a processor, configured to execute the computer program stored in the memory, so that the communication apparatus performs the method according to any one of claims 1 to 8, or the communication apparatus performs the method according to any one of claims 9 to 15.

~~32~~19. A computer-readable storage medium, wherein the computer-readable storage medium is configured to store a computer program, and the computer program comprises instructions for implementing the method according to any one of claims 1 to 8, or comprises instructions for implementing the method according to any one of claims 9 to 15.

~~33. A computer program product, comprising computer program code, wherein when the computer program code is run on a computer, the computer implements the method according to any one of claims 1 to 8, or the computer implements the method according to any one of claims 9 to 15.~~

~~34. A chip, comprising one or more processing circuits, wherein the one or more processing circuits are configured to implement the method according to any one of claims 1 to 8 or implement the method according to any one of claims 9 to 15.~~

~~35~~20. An apparatus, configured to implement the method according to any one of claims 1 to 8 or implement the method according to any one of claims 9 to 15.

~~36. A communication system, comprising the access point according to any one of claims 16 to 23 and the station according to any one of claims 24 to 30.~~