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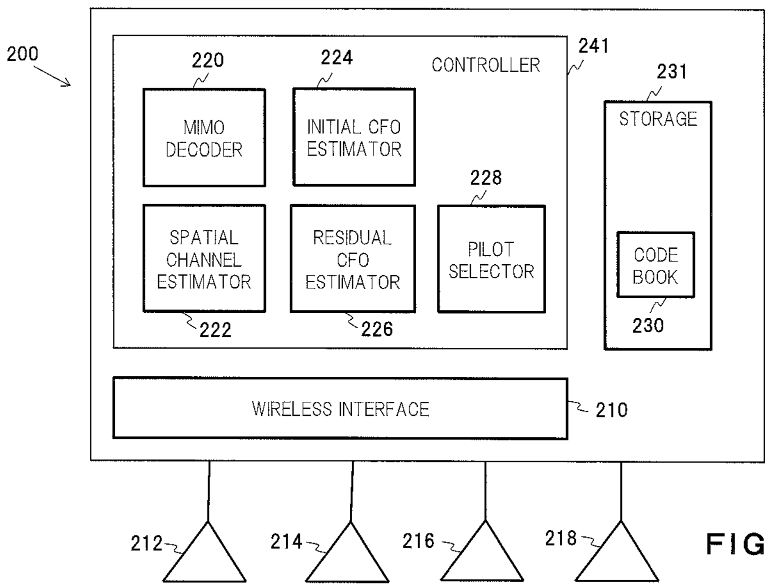

FIG.3

(57) Abstract: According to one embodiment, an integrated circuitry for wireless communication includes a baseband integrated circuitry. The baseband integrated circuitry controls transmission of a first packet via an RF integrated circuitry, the first packet instructing a plurality of wireless communication terminals to execute an initial spatial multiplexing transmission after completing reception of the first packet. The first packet includes first information identifying at least one pilot signal used by each of the plurality of wireless communication terminals in the spatial multiplexing transmission.

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DESCRIPTION

INTEGRATED CIRCUITRY FOR WIRELESS COMMUNICATION, WIRELESS COMMUNICATION TERMINAL AND METHOD

FIELD

Embodiments described herein relates an integrated circuitry for wireless communication, a wireless communication terminal and a wireless communication method.

BACKGROUND

In multiuser uplink communication, multiple users, which are wireless communication terminals, communicate at the same time with an access point. To increase system capacity and facilitate a more efficient scheduling of users, these users can be separated in space (spatial division multiple access, SDMA) rather than be given a separate time slot (time division multiple access, TDMA) or frequency band (frequency division multiple access, FDMA). By employing multiple antennas at the access point and/or terminals, multiple users can transmit one or more data stream simultaneously, which are separated by multiple-input and multiple-output (MIMO) decoding at the access point. One problem is that each user may have a small carrier frequency offset (CFO) due to variations in the local oscillators with respect to the local oscillator of the access point, which needs to be estimated and corrected for at the access point. Here, CFO is the difference of a center frequency between a transmitting side and a receiving side.

In the orthogonal frequency-division multiplexing (OFDM) systems, inter-subcarrier interference occurs, causing deterioration of transmission performance. Thus, in existing wireless LAN (Local Area Network) systems that use the OFDM systems, a known signal for CFO compensation (also known as a training sequence) is included in a preamble added to a frame. In the OFDM systems, the preamble is usually used to estimate the channel and any CFO. Since there are multiple CFOs (one for each terminal), the training sequence in the preamble must be designed accordingly. However, a signal received at an access point includes CFOs, which differs from terminal to terminal. Thus, it is difficult to highly accurately estimate respective CFOs based on signals from each terminal. Also, even in the case where an access point individually estimates a CFO of each terminal in advance and carries out CFO compensation, the CFO still remains due to an accidental error in the estimation. This is also true in the case where a CFO measured for each terminal is notified to each terminal and a process for compensating for the CFO is carried out on the side of the terminal. Such a residual CFO after estimation and compensation will cause phase rotations to the data symbols in the remaining part of the packet.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a wireless network according to an embodiment;

Figure 2 schematically shows that each user has a CFO with respect to a center frequency of an AP;

Figure 3 shows an access point according to an embodiment;

Figure 4 shows a terminal of a wireless network according to an embodiment;

Figure 5 shows a method of wireless communication according to an embodiment;

Figure 6 shows pilot subcarriers in an embodiment;

Figure 7 shows a sounding procedure in an embodiment;

Figure 8 shows schematically construction of a codebook;

Figure 9 shows an example of a sequence in which an access point notifies a codebook index to each terminal;

Figure 10A shows an example of a basic format of a MAC frame;

Figure 10B shows an example of a basic format of a MAC header;

Figure 11 shows an example of an information element;

Figures 12A and 12B show an example of an arrangement of a notification field;

Figures 13A and 13B show an example of a format of a notification field;

Figure 14A and 13B show an example of a format of a notification field;

Figure 15 shows another sounding procedure in an embodiment;

Figure 16 is a flowchart of an operation example of an access point;

Figure 17 is a flowchart of an operation example of a terminal;

Figure 18 shows an example of a hardware configuration of a wireless communication device mounted on an access point;

Figure 19 shows an example of a hardware configuration of a wireless communication device mounted on a terminal;

Figures 20A and 20B are perspective views of wireless terminals;

Figure 21 shows a memory card; and

Figure 22 shows one example of frame exchange in a contention period.

DETAILED DESCRIPTION

According to one embodiment, an integrated circuitry for wireless communication includes a baseband integrated circuitry. The baseband integrated circuitry controls transmission of a first packet via an RF integrated circuitry, the first packet instructing a plurality of wireless communication terminals to execute an initial spatial multiplexing transmission after completing reception of the first packet. The first packet includes first information identifying at least one pilot signal used by each of the plurality of wireless communication terminals in the spatial multiplexing transmission.

Hereinafter, embodiments of the present invention will be described with reference to the drawings. Assume that the entire contents of IEEE Std 802.11™-2012 and IEEE Std 802.11ac™-2013, known as the wireless LAN specification are herein incorporated by reference in the present specification.

Figure 1 shows a wireless network 100 according to an embodiment. The wireless network 100 comprises an access point 110, a first user terminal 150, a second user terminal 160, a third user terminal 170 and a fourth user terminal 180. The access point 110 basically has the same functions as a terminal except having a relay function as well as other functions, and is thus one form of terminal. An access point may also be called as base station. Also, a user terminal may also be alternatively called as terminal, wireless communication terminal, or user.

The access point 110 comprises four antennas 112 114 116 and 118. Each of the user terminals comprises one antenna. The first user terminal 150 comprises a first user antenna 152. The second user terminal 160 comprises a second user antenna 162. The third user terminal 170 comprises a third user antenna 172. The fourth user terminal 180 comprises a fourth user antenna 182.

To increase the system capacity of the network 100 and facilitate a more efficient scheduling of the user terminals, the users are separated in space (spatial division multiple access, SDMA). By employing multiple antennas 112 114 116 and 118 at the access point and/or terminals, multiple users can transmit one or more data stream simultaneously, which are separated by multiple-input and multiple-output (MIMO) decoding at the access point 110. Such a communication scheme may be called uplink MU-MIMO (multiuser multiple-input and multiple-output) transmission herein.

Each user may have a small carrier frequency offset (CFO) due to variations in the local oscillators with respect to the oscillator of the access point. Figure 2 schematically shows that each user has a CFO with respect to a center frequency of an AP. This CFO can be estimated and corrected at the access point 110 for each user. The estimation of the CFO will be described below with reference to Figure 5. It is also possible to notify a CFO estimated at an access point to each terminal and to correct the CFO on a terminal side.

Figure 3 shows functionally an access point 200 according to an embodiment. The access point 200 has four antennas 212 214 216 218; and comprises a controller 241, storage 231 and a wireless interface 210. The controller 241 comprises a MIMO decoder 220, a spatial channel estimator 222, an initial CFO estimator 224, a residual CFO estimator 226 and a pilot selector 228. The storage comprises a codebook 230.

The controller 241 manages and controls the overall behavior of the access point. The controller 241 mainly executes protocol processing related to the MAC layer and the physical layer. The protocol processing is executed in the digital domain. The wireless interface 210 executes analog signal processing and transmits and receives signals via the antennas 212, 214, 216, 218. The analog signal processing includes, for example, processing related to band control, frequency conversion (up-conversion from a baseband to a radio frequency, down-conversion from a radio frequency to a baseband, and the like), and amplification. An AD converter that executes AD conversion and a DA converter that executes DA conversion may be provided in either the controller 241 or the wireless interface 210, or may exist as a separate processor.

The controller 241 corresponds to one form of communication processing device or baseband integrated circuitry that executes processing related to communication with another terminal. The wireless interface 210 corresponds to one form of wireless communicator or RF (Radio Frequency) integrated circuitry that transmits and receives signals via the antennas 212, 214, 216, 218, for example. The integrated circuitry for wireless communication according to the present embodiment may include at least the former of the baseband integrated circuitry (communication processing device) and the RF integrated circuitry.

The spatial channel estimator 222 is operable to estimate spatial channels from sounding signals received by the four antennas.

The MIMO decoder 220 is configured to separate signals received at the antennas from different user data streams, using spatial decoding.

The initial CFO estimator 224 is configured to estimate an initial carrier frequency offset for each user from sounding signals received from the users.

The residual CFO estimator 226 is configured to estimate a residual carrier frequency offset from pilot symbols (which may be called pilot signals) which are transmitted within data packets received by the access point 200.

The codebook 230 stores a plurality subsets of possible pilot symbol(s), and each subset is identified by an index which is referred to as a codebook index. Each subset includes at least one possible pilot symbol, but in the embodiment, each subset includes a plurality of possible pilot symbols. Each subset may be called a codeword or a codebook entry. The codebook 230 includes also indices assigned to the subsets of the possible pilot symbols. Each subset can be identified by its index. The pilot symbols included in each subset may be associated with pilot subcarriers which are arranged at predetermined positions out of a plurality of subcarriers associated with an OFDM symbol.

The pilot selector 228 is configured to select the subset of pilot symbols for use by each user from the codebook 230, based on spatial channel realisations determined by the spatial channel estimator 222.

The elements of the access point 200 may be implemented as computer program modules running on processor or may be implemented as programmed hardware devices or a combination of the two. The storage 231 may be a memory, an SSD (Solid State Drive), or a hard disk, for example. If the buffer is a memory, the memory may be a volatile memory such as a DRAM (Dynamic Random Access Memory), an NAND (inverted AND) memory, or a non-volatile memory such as an MRAM (Magnetic Random Access Memory), for example.

Figure 4 shows functionally a user terminal 300 according to an embodiment. The user terminal 300 comprises an antenna 352, a controller 341, storage 321 and a wireless interface 310. The storage 321 comprises a codebook 320.

The controller 341 manages and controls the overall behavior of the terminal. The controller 341 mainly executes protocol processing related to the MAC layer and the physical layer. The protocol processing is executed in a digital region. The wireless interface 310 executes analog signal processing and transmits and receives signals via the antenna 352. The analog signal processing includes, for example, processing related to band control, frequency conversion (up-conversion from a baseband to a radio frequency, down-conversion from a radio frequency to a baseband, and the like), and amplification. An AD converter that executes AD conversion and a DA converter that executes DA conversion may be provided in either the controller 341 or the wireless interface 310, or may exist as a separate processor.

The controller 341 corresponds to one form of communication processing device or baseband integrated circuitry that executes processing related to communication with an access point. The wireless interface 310 corresponds to one form of wireless communicator or RF (Radio Frequency) integrated circuitry that transmits and receives signals via the antenna 352, for example. The integrated circuitry for wireless communication according to the present embodiment may include at least the former of the baseband integrated circuitry (communication processing device) and the RF integrated circuitry.

The wireless interface 310 allows the user terminal 300 to transmit and receive signals via the antenna 352 as stated above.

The codebook 320 stores the plurality of subsets of possible pilot symbols and indices assigned to the subsets. The codebook 320 may be same as the codebook 230 of the access point.

The user terminal 300 may be implemented as computer program modules running on processor or may be implemented as programmed hardware devices or a combination of the two. The storage 321 may be a memory, an SSD (Solid State Drive), or a hard disk, for example. If the buffer is a memory, the memory may be a volatile memory such as a DRAM (Dynamic Random Access Memory), an NAND (inverted AND) memory, or a non-volatile memory such as an MRAM (Magnetic Random Access Memory), for example.

Figure 5 is a flowchart showing the steps carried out in a wireless communication method according to an embodiment. Figure 5 shows the steps carried out by an access point and a user, for example the access point 200 shown in Figure 3 and the user terminal 300 shown in Figure 4. It will be appreciated that the method is carried out for a network with multiple users such as the network 100 shown in Fig.1. As one example, the network is a wireless LAN (Local Area Network) compliant with IEEE 802.11 standards. Below, such a wireless LAN is presumed, and the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) is therein employed as communication procedure.

In step S402, the access point transmits an announcement 420 to all users (i.e., user 1, 2, 3, 4). The user n (n= 1, 2, 3, or 4) receives the announcement 420 in step S442. In response to the announcement 420, in step S444, the user n sends a sounding signal 422 to the access point. The access point receives the sounding signal 422 in step S404. The announcement 420 instructs the users to transmit the sounding signals. The announcement 420 is a frame based on MAC frame format as described below.

In step S406, the access point estimates the spatial channel associated with the user n and initial CFO of the user n, from the sounding signal 422.

In step S408, the access point uses the estimated spatial channels for all users to select the subset of pilot symbols from a codebook for the user n. In step S410, the access point sends a codebook index 424 corresponding to the selected subset to the user n. The codebook index 424 indicates the pilot symbols selected by the access point for the user n to use. One of the characterized features of the present embodiment relates to a method of notifying a codebook index to a user. This feature will be described later in detail.

The user n receives the codebook index 424 in step S446. In step S448, the user n looks up the pilot symbols in the codebook, based on the codebook index 424. In step S450, the user n transmits a data packet 426 including the pilot symbols to the access point. More specifically, since there are users 1 to 4 (i.e., n=1 to 4), a plurality of users (user 1, 2, 3, and 4) transmits the data packets simultaneously in a space (spatial division multiple access, SDMA): uplink MU-MIMO transmission is implemented.

Here, the data packet 426 includes a physical header (which is called a preamble) and a data field. The pilot symbols can be arranged for pilot subcarriers of each OFDM symbol forming the data field. Here, in the data field, a MAC frame is set as one example. A plurality of types of MAC frame are defined in IEEE 802.11 standards: a data frame, a management frame and a control frame. The data frame is a MAC frame that a type field in a frame control field of a MAC header shows “data”, the management frame is a MAC frame that a type field in a frame control field of a MAC header shows “management”, and the control frame is a MAC frame that a type field in a frame control field of a MAC header shows “control”. Each type may be still classified into a plurality of subtype according to a value of the subtype filed in the frame control field. The details of the type and the subtype will be described later.

The access point receives the data packet 426 in step S412. In step S414, the access point uses the pilot symbols in the data packet 426 to estimate the residual CFO. In step S416, the access point decodes the data in the data packet 426 using the spatial channel estimate and initial CFO estimate from step S406 and the residual CFO estimated in step S414.

More specifically, since there are users 1 to 4 (i.e., n=1 to 4), the access point receives the data packets from a plurality of users (user 1, 2, 3, and 4) simultaneously. The access point uses the pilot symbols in each data packet to estimate the residual CFO for each user. The access point decodes the data included in the data field in each data packet using the spatial channel estimate and initial CFO estimate for each user and the residual CFO estimated for each user.

As described above with reference to Figure 5, the channel and the initial CFO can be estimated using a sounding signal. The effect of the residual CFO is to introduce a phase shift to all data symbols that follow. Here, the data symbols are OFDM symbols forming data (such as MAC frame) in the data field of the data packet as above-stated.

For a single-user OFDM system, the phase shift is:

$$\phi = 2\pi\left(1+\frac{N_{cp}}{N_{sub}}\right)\varepsilon$$

where N_{cp} is the length of the cyclic prefix in the OFDM symbol, N_{sub} is the number of subcarriers and ε is the residual CFO relative to the subcarrier spacing. Here, the phase rotation amount as an effect of the residual CFO (ε) is represented as "ϕ". When the phase rotation amount as an effect of a frequency offset is generally represented, the CFO may be used as "ε" (that is, the total of the initial CFO and the residual CFO) (the same applies hereinafter).

Extending this to an uplink MU-MIMO system with N receive antennas and M single-antenna terminals, the received signal on subcarrier k and antenna n is

$$R_{n,k} = \sum_{m=1}^{M} e^{j\phi_m} H_{n,m,k} X_{m,k} + W_{n,k} + V_{n,k}$$

Where $H_{n,m,k}$, are the channel realisations (or channel coefficients) between the nth antenna and the mth user with respect to the kth subcarrier, $X_{m,k}$ is the data signal transmitted by the mth user on the kth subcarrier, $W_{n,k}$ is intercarrier interference (ICI) caused by the residual CFO and $V_{n,k}$ is the thermal noise. Normally the ICI can be modelled as Gaussian white noise and combined into a single noise term $\tilde{V}_{n,k}$.

The individual phase shifts for M terminals are $\phi_m = 2\pi\left(1+\frac{N_{cp}}{N_{sub}}\right)\varepsilon_m$ and the goal is then to estimate them and compensate for them to avoid a phase rotation of the data symbol and to minimise the ICI.

In a single-user system, where there is only one residual CFO, it is straightforward to use a differential scheme.

In a multiuser system, coherent estimation is more appropriate. One way is to formulate the linear system

$$\begin{pmatrix} R_{1,k_1} \\ \vdots \\ R_{1,k_P} \\ \vdots \\ R_{N,k_P} \end{pmatrix} = \begin{pmatrix} H_{1,1,k_1}X_{1,k_1} & \cdots & H_{1,M,k_1}X_{M,k_1} \\ \vdots & \ddots & \vdots \\ H_{1,1,k_P}X_{1,k_P} & \cdots & H_{1,M,k_P}X_{M,k_P} \\ \vdots & \ddots & \vdots \\ H_{N,1,k_P}X_{1,k_P} & \vdots & H_{N,M,k_P}X_{M,k_P} \end{pmatrix} \begin{pmatrix} e^{j\phi_1} \\ \vdots \\ e^{j\phi_M} \end{pmatrix} + \begin{pmatrix} \tilde{V}_{1,k_1} \\ \vdots \\ \tilde{V}_{1,k_P} \\ \vdots \\ \tilde{V}_{N,k_P} \end{pmatrix}$$

$$\boldsymbol{r} = \boldsymbol{A}\boldsymbol{y} + \widetilde{\boldsymbol{v}}$$

$$\boldsymbol{r} \in \mathbb{C}^{PN\times 1}, \boldsymbol{A} \in \mathbb{C}^{PN\times \mathrm{M}}, \boldsymbol{y} \in \mathbb{C}^{M\times 1}, \widetilde{\boldsymbol{v}} \in \mathbb{C}^{PN\times 1}$$

where $k_1, \ldots, k_P$ are the pilot subcarriers on which known symbols are transmitted:. $\mathbb{C}^{PN\times 1}$ means a matrix of "PN" lines by one column whose elements are complex numbers. $\mathbb{C}^{PN\times \mathrm{M}}$ means a matrix of "PN" lines by "M" columns whose elements are complex numbers. $\mathbb{C}^{M\times 1}$ means a matrix of "M" lines by one column whose elements are complex numbers. The residual CFOs ε_m can now be estimated using, *e.g.*, a maximum-likelihood method; for a simpler implementation, it is also possible to do a least-squares/minimum mean-squared error estimation of the terms $e^{j\phi_m}$.

Figure 6 shows pilot subcarriers included in data packet according to an embodiment. The packets 500 shown in Figure 6 are transmitted from users to the access point. In Figure 6, the packet transmitted from one of users is illustrated, but actually the packets are transmitted form the users simultaneously. Each packet 500 includes a preamble 510 and a data portion (or a data field) 520. In this example, the preamble 510 includes a plurality of OFDM symbols and the data portion 520 includes a plurality of OFDM symbols. Each OFDM symbol in the data portion 520 includes pilot subcarriers 525. In Figure 6, one cell corresponds to one subcarrier, and a set of cells in the longitudinal direction at the same clock time correspond to one OFDM symbol. The weights applied to pilot subcarriers 525 (i.e., pilot symbols) are selected from a codebook as one of the subsets of pilot symbols stored therein according to the method described above so that the access point can more accurately determine the residual CFO from the pilot subcarriers 525. The pilot subcarriers 525 may be arranged at predetermined positions according to a system or standards. Alternatively, the access point may determine them.

In an embodiment, the access point sends an indication of a pre-coding vector (i.e., an indication of the set of pilot symbols) selected from a codebook to each of the users. The pre-coding vector specifies a set of weights to be applied to each of the pilot subcarriers 525 to reduce interference between pilots of different users.

In the embodiments, one antenna is assumed per terminal. If at least one of the terminals has more than that and possibly employ beamforming/pre-coding/antenna selection for the data, it is easy to incorporate that in the model. Even in this case, the principle of choosing appropriate pilot symbols (i.e., weights applied to pilot subcarriers 525) for each user does not change. Also note that the number of CFOs is the same regardless of the number of antennas per user since there is only one local oscillator per terminal.

It is clear that the above system matrix $\boldsymbol{A}$, which affects how well the residual CFOs (or the CFOs) can be estimated, depends on the combination of channel coefficients H and pilot symbols x. With conventional fixed pilot symbols, the system matrix $\boldsymbol{A}$ might become ill-conditioned for some channel realisations and hence it is difficult to accurately estimate the residual CFOs (or the CFOs).

On the other hand, if the pilot symbols depend on the channel realisations $H_{n,m,k}$, they can be chosen to form a well-conditioned system matrix. This is possible if the access point knows the uplink channels with the terminals, which is usually done by sounding. Note that this kind of communication between an access point and terminals is already in place due to the uplink multiuser procedure as shown at S402 to S404 in Figure 5.

Figure 7 shows an example of the sounding procedure in an embodiment. The access point AP transmits a non-data (or null data) packet announcement (NDP announcement) 602 to all of the users. The announcement 602 may include identifiers of STAs 1-3 such as AIDs (Association ID) to instruct transmission of the non-data packet. Instead of AIDs, MAC address of STAs 1-3 or other kind of identifiers may be employed. In response to the non-data packet announcement 602, a first user STA1 waits for a short inter frame space (SIFS) period and then transmits a non-data packet 604. This is followed by a second user STA2 waiting for a SIFS period and then transmitting a non-data packet 606. The STA2 may wait for a total of SIFS, NDP length and SIFS after reception completion of NDP announcement 602 and then transmit a non-data packet 606. A third user STA3 then waits for a SIFS period and transmits a non-data packet 608. The STA3 may wait for a total of SIFS, NDP length, SIFS, NDP length and SIFS after reception completion of NDP announcement 602 and then transmit a non-data packet 608.

Once the access point AP has received non-data packets from the users, the access point determines pilot symbols for each of the users to use and also compressed beamforming for each of the users. This information is transmitted to the users as a codebook index and compressed beamforming 610. The codebook index and compressed beamforming 610 includes a codebook index of each user and compressed beamforming information of each user. The reason why the access point AP transmits beamforming information is that in the embodiment of Figure 7, we assume that the users have multiple antennas. Therefore, the access point AP transmits beamforming information to be used by the users when transmitting data to the access point in addition to the codebook index indicating the pilot symbols to be used for residual CFO tracking.

If a linear minimum mean square error (MMSE) estimator is deployed, the error covariance matrix is

$$\boldsymbol{R}_{ee} = \sigma_{\tilde{v}}^2 \left(\boldsymbol{A}^H \boldsymbol{A} + \sigma_{\tilde{v}}^2 \boldsymbol{I}\right)^{-1}$$

$$\boldsymbol{e} = \boldsymbol{y} - \widetilde{\boldsymbol{y}} = \boldsymbol{y} - \left(\boldsymbol{A}^H \boldsymbol{A} + \sigma_{\tilde{v}}^2 \boldsymbol{I}\right)^{-1} \boldsymbol{A}^H \boldsymbol{r}$$

where $\sigma_{\tilde{v}}^2 = E\left\{\left|\tilde{v}_{n,p}\right|^2\right\}$ is the noise variance and $\boldsymbol{I}$ is the $M \times M$ identity matrix. By making the pilot symbols dependent on the channel $H_{n,m,p}$, the above can be minimised.

One technique is to define the objective function as the sum of all errors and then choose the pilot symbols from a codebook; the indices to the codewords (i.e., indices to subsets of the pilot symbols), which tells the terminals which pilot symbols to use, can be signaled with only a few bits, which keeps overhead transmissions to a minimum.

Mathematically this is formulated as

$$\min_{X_{m,p}} \sum_{m=1}^{M} R_{ee}(m,m)$$

$$\text{s.t.}\, X_{m,p} = C_{l_m,p}, \exists l_m \in \{0, \cdots, L-1\}$$

where $C_{l,p}$ is the codebook with L codewords. $R_{ee}(m,m)$ represents a component in mth row and mth column (i.e., diagonal component). “s.t.” represents “subject to” (i.e., constraint condition).

Note that it is also possible to define the objective function in other ways, *e.g.*, to minimise the largest individual error.

$$\min_{\mathrm{X_{m,p}}} \max_{\mathrm{m}} \mathrm{R_{ee}(m,m)}$$

$$\text{s.t.}\, X_{m,p} = C_{l_m,p}, \exists l_m \in \{0, \cdots, L-1\}$$

For a small codebook, the error can be minimised by trying all L^M combinations of codewords. The best choices l_m are the signalled to the terminals, requiring a total of $Mlog_2L$ bits.

One choice of a codebook is based on the Fast Fourier Transform (FFT)

$$C_{p,l} = e^{\frac{j2\pi pl}{L}}$$

$$0 \leq p < P, 0 \leq l < L$$

However it should be noted that there are many other possible choices and that the proposed method works for any codebook. For example a Hadamard matrix codebook could also be used.

Figure 8 shows schematically construction of a codebook. The codebook includes L codewords (L subsets of pilot symbols), which are assigned codebook indices 0 to l-1. Each codeword includes weights (pilot symbols) applied to pilot subcarriers. Each weight is represented by use of a parameter “c” with a subscript schematically. The parameter “c” with a subscript may take a real number or a complex number according to the choice of the codebook. In the example of the above the parameter “c” can take a complex number.

In the example of a sequence shown in Figure 7, the access point transmits the NDP announcement 602, and each terminal (STA or user) transmits an NDP, which is a sounding signal, at intervals of an SIFS time. The SIFS time after completing the reception of an NDP from a terminal that lastly transmitted the NDP, the access point transmits a frame including a codebook index of each terminal etc. In the example of Figure 7, the frame is (codebook index + compressed beamforming) 610, but any frame is possible as long as the frame includes the codebook index. The method of notifying a codebook index is not limited to this, however.

Other methods of notifying a codebook index will now be described.

Figure 9 shows an example of a sequence of the case where an access point transmits a trigger frame for uplink MU-MIMO transmission and each terminal executes MU-MIMO transmission in response to the trigger frame, wherein a codebook index is notified in the trigger frame.

The summary of this sequence is as follows. After deciding that uplink MU-MUMO is to be executed, an access point transmits a trigger frame 1001 (more specifically, a packet in which a preamble is added to the trigger frame) that instructs terminals 1 to 4 to execute uplink MU-MUMO. The terminals 1 to 4 specified in the trigger frame 1001 respectively transmit data frames 1011, 1012, 1013, and 1014 (more specifically, a packet in which a preambles is added to the data frame) a time

"T1" after completing the reception of the trigger frame 1001. This enables the terminals 1 to 4 to transmit data frames in spatial multiplexing. The "T1" is not required to be same value among the terminals 1 to 4. By instructing different transmission timings to each terminal, a case may be that the transmission timings of each terminal are adjusted in order for the access point to receive the data frames from the terminals 1 to 4 simultaneously. A time "T2" after reception completion of the data frames transmitted from the terminals 1 to 4 in spatial multiplexing, the access point transmits an acknowledgment response frame 1002 (more specifically, a packet in which a preamble is added to the acknowledgment response frame) to the terminals 1 to 4. The detail of this sequence will now be described.

After deciding that uplink MU-MUMO transmission is to be executed, the access point determines items needed for uplink MU-MIMO communication. For example, the access point selects terminals that execute uplink MU-MIMO transmission. As a selection method, each terminal may be preliminarily asked whether it has a request for uplink MU-MIMO transmission, and a terminal may be selected out of those terminals having such requests. Or, on the basis of an amount of data for transmission at each terminal, terminals having a larger amount of data may be preferentially selected, or terminals having a similar amount of data may be selected. Also, if the access point has grouped terminals, terminals belonging to a same group may be selected. Also, as a standard for selecting a group, items such as the existence or non-existence of a request for uplink MU-MIMO transmission or the amount of transmission data per terminals belonging to each group may be considered. Or, a terminal or a group may be selected in round-robin fashion, or a terminal or a group may be selected randomly. Or, terminals that have the same or similar amount of data for next transmission, or terminals that have the same or similar data generation cycle (such as terminals whose data generation cycle are within a constant value, or a predetermined number of terminals whose data generation cycles are closer to each other) may be selected. Or, terminals that have the same species (class) of data to be transmitted may be selected. The species (class) may be AC (Access Category) in the cases of being compatible with the QoS, or TID (Traffic ID). Alternatively, a combination of terminals whose spatial correlation is small (interference is small) may be selected on the basis of a spatial channel realisation with each terminal that has obtained in advance. The number of terminals to be selected is equal to or less than the maximum number of available spatial channels (maximum number of streams). If a lower limit of the number of terminals to be selected is defined, a larger number of the terminals than the lower limit may be selected. The above described methods for selecting terminals are mere examples, and a method other than these may be used for selecting terminals. The decision of whether uplink MU-MIMO is to be executed and the selection of terminals may be done before step S402 (transmission of an NDP announcement) of the flowchart in Figure 5, and the processing of the steps subsequent to step S402 may be executed for the selected terminals.

Also, the access point may determine spatial channels used by selected terminals in uplink MU-MIMO transmission on the basis of a plurality of available spatial channels. Each spatial channel has a preliminarily given number, and a spatial channel may be assigned to each terminal by a spatial channel number (stream number). Also, by notifying the spatial channel number to each terminal and making each terminal include the spatial channel number in a packet to be transmitted in uplink transmission, a spatial channel in which each terminal execute transmission may be identified. A symbol pattern including a plurality of symbols may be assigned to each spatial channel number in advance, and the symbols can be set in a preamble of a packet sent from each terminal according to the symbol pattern. By making the symbol patterns orthogonal to each other, the access point may separate signals received from each terminal in uplink MU-MIMO by utilizing these symbol patterns. Also, it is possible to employ a configuration in which channel estimation and initial CFO compensation are executed by utilizing these orthogonal symbol patterns.

Also, in the present embodiment, a pilot symbol is selected from a codebook for each terminal, and the selected pilot symbol is assigned to the terminal. The selected pilot symbol is applied to a pilot subcarrier arranged at a preliminarily defined position out of a plurality of orthogonally arranged subcarriers. Because it is supposed in the present embodiment that a plurality of pilot subcarriers exist, pilot symbols to be selected are also plural. If the number of pilot subcarriers is one, the number of pilot symbols to be selected may be one as well. In order to select a pilot symbol, the above described method may be used. The access point identifies a codebook index that identifies a pilot symbol selected for each terminal. Different pilot symbols may be assigned to different terminals, or a same pilot symbol may be assigned to a plurality of terminals. In the latter case, a same codebook index is identified for each of the plurality of terminals.

Also, the access point may commonly determine a maximum packet length (PPDU (Physical Protocol Data Unit)) sent by terminals. For example, if information including one or both of a TXOP length and a data amount needed for next transmission is obtained from each terminal, then the PPDU length may be determined by utilizing the TXOP length or the data amount (such as a PPDU length) notified from each terminal. For example, the PPDU may be determined on the basis of the largest TXOP or data amount obtained from all terminals.

After determining the items needed for executing uplink MU-MIMO communication, such as terminals to execute the uplink MU-MIMO communication and pilot symbols used by the terminals, then the access point generates a trigger frame 1001. The trigger frame 100 includes information needed to be notified to the terminals for executing uplink MU-MIMO transmission (notification information).

The trigger frame 1001 may be defined on the basis of a format of a conventional MAC frame. Figure 10A shows an example of a basic format of the MAC frame. Not only the trigger frame 1001 but also other frames of the present embodiment are basically based on the frame format like this. This frame format includes fields of an MAC header, a frame body, and a FCS. As shown in Figure 10B, the MAC header includes fields of a Frame Control, a Duration/ID (also simply called Duration), an Address 1, an Address 2, an Address 3, a Sequence Control, a QoS Control, and an HT (High Throughput) control.

It is not necessary for all of these fields to exist, and some of the fields may not exist on the basis of a type of the frame. Also, other fields not shown in Figure 10B may exist. For example, an Address 4 field may further exist. Also, a notification field described below may exist in the MAC header or the frame body field.

The Address 1 field includes a receiver address (RA), the Address 2 field includes a transmitter address (TA), and the Address 3 field includes an BSSID (Basic Service Set Identifier), which is an identifier of a BSS (Basic Service Set) created by an access point (may be a wildcard BSSID, whose bits are all set to one, to specify all BSSIDs), or a TA according to the use of the frame. Here, terminals that communicate with the access point belong to a BSS formed by the access point.

The Frame Control field includes two fields: Type and Subtype. The Type field broadly classifies the frame into a data frame, a management frame, or a control frame, and the subtype field further classifies the frame within each of the broad classification.

The Duration/ID field sets a medium reservation time. When a terminal receives a MAC frame destined for another terminal, then the former terminal virtually determines that the medium is busy from the end of the physical packet including that MAC frame for the length of the medium reservation time. This mechanism of virtually determining the busyness of a medium, or the length for which a medium is virtually determined as busy, is called NAV (Network Allocation Vector). The QoS field is used for executing the QoS control that executes transmissions in consideration of a priority of a frame.

In the management frame, an information element (IE) to which a unique Element ID (IDentifier) is assigned is set in the frame body field. One or more information elements can be set in the frame body field. As shown in Figure 11, the information element includes an Element ID field, a Length field, and an Information field. The information element is identified with the Element ID. The Information field stores the content of information to be notified. The Length field stores length information of the Information field. A notification field described later may be set in the body field of the management frame. In this case, the notification field has a format of the information element.

As a checksum code used for detecting errors of a frame on a receiving side, FCS (Frame Check Sequence) information is set in the FCS field. One example of the FCS information is a CRC (Cyclic Redundancy Code).

Here, notification information notified to a terminal that executes MU-MIMO transmission may be set in a notification field that is newly provided in the MAC header or the frame body field, as shown in Figure 12A. Or, a reserved area in existing fields (fields defined in an existing standard) may be used as a notification field. If a notification field is provided in the frame body field, the notification field may specifically have the format of the information element shown in Figure 11. In this case, a new element ID may be assigned to an information element. Also, as shown in Figure 12B, a notification field may be provided in a preamble (physical header) added to an MAC frame, or a reserved area in existing fields in the physical header may be used as a notification field. As shown in Figure 12B, the physical header may include L-STF, L-LTF, L-SIG, and the like that are fields defined in an existing standard. L-STF, L-LTF, and L-SIG are fields that can be recognized in legacy standards such as IEEE802.11a and that store information such as signal detection, frequency compensation (channel estimation), and transmission rate. A same signal may be set in L-STF, L-LTF, and L-SIG within a preamble (physical header) of a packet transmitted from each terminal in MU-MIMO transmission.

Also, as a subtype of the Frame Control field, a new value may be defined for a trigger frame or a frame including a notification field. A type of the Frame Control field in the trigger frame may be a value representing control, and a value of the subtype may be a value newly defined for the trigger frame. Or, a frame type of the trigger frame may be a value representing management or data. Also, a value of an existing standard may be used for a value of the subtype, instead of newly defining a value. For example, a notification field may be added as an information element to the frame body field of an existing management frame.

The RA (Receiver Address) of the trigger frame 1001 may be, as one example, a broadcast address or a multicast address, and that address may be set in the Address 1 field. Also, the TA (transmitter address) may be the MAC address or the BSSID of the access point.

Figure 13A shows an example of a format of the notification field. The notification field includes a number of terminal information fields (STA Info. fields) in accordance with the number of terminals executing uplink MU-MIMO transmission. If the number of the terminals is four, then four terminal information fields (STA Info. fields) 1 to 4 are set. Information individually notified to each terminal is set in each of the terminal information fields. As one example, an identifier of the selected terminal, information identifying an assigned spatial channel (such as a stream number), a codebook index identifying a subset of selected pilot subcarriers, and the like are set in the terminal information field. The identifier of the terminal may be the MAC address of the terminal, an association ID (AID) assigned by the access point during association, or another ID that is unique between terminals. Other than these, at least one of a data length allowed for transmission, an error-collecting code scheme, and an MCS (Modulation and Coding Scheme) defining a transmission rate of one or both of PHY and MAC may be set. The data length may be common to all terminals, or a unique data length may be allowed for each terminal. The maximum value of the data length (such as PPDU length) may be preliminarily determined by a standard or in a system. In this case, data size is specified within the maximum value. Also, information explicitly instructing uplink MU-MIMO transmission may be included in each terminal information field. A value of the TXOP assigned to each terminal (the TXOP that is to be set in a frame transmitted in uplink transmission) may be set in each terminal information field. Figure 13B shows an example in which an identifier of a terminal, a codebook index, and the like are set in the terminal information field of each terminal. Each terminal may identify the terminal information field in which the identifier of the own terminal is set, and may obtain the information for the own terminal from the identified field. A part of the notification field may be a preamble (physical header) and the rest of the notification field may be set in the MAC header or the frame body field.

Figure 14A shows another example of a format of the notification field. The notification field includes a common information field that notifies common information to each terminal and a number of terminal information fields (STA Info. fields) corresponding the number of terminals. The common information field may include a transmission data size commonly assigned to each terminal. Also, information that explicitly instructs uplink MU-MIMO transmission may be included in the common information field. Also, if the access point manages terminals by grouping them and selects a group that is to execute MU-MIMO transmission, then an identifier of that group (may be a group ID defined in IEEE 802.11ac) may be specified in the common information field. In this case, a terminal is supposed to be notified of an identifier of a group to which the terminal belongs. Here, each terminal may know how many terminal information fields are assigned to the own terminal (user position) from a preliminary notification from the access point. Or, if each terminal is notified, by the access point, of a list of terminals belonging to a group, then the terminal may identify the terminal information field according to the position of the own terminal in the list. Figure 14B shows an example in which a group ID is set in the common information field and a codebook index and the like of each terminal is set in each terminal information field.

A terminal that received the trigger frame 1001 from the access point determines whether the own terminal is specified as a candidate of uplink MU-MIMO in the trigger frame 1001. For example, if the trigger frame has the format shown in Figure 13A or 13B, the terminal checks whether the identifier of the own terminal is set in any of a plurality of the terminal information fields. If the identifier of is set in any of the terminal information fields, the terminal determines that it is specified. In that case, the terminal also extracts information needed for uplink MU-MIMO transmission (in the present embodiment, the information at least includes a codebook index, and may additionally include conditions such as data length (or PPDU length and the like) and MCS) from the terminal information field of the own terminal. According to the extracted information, the terminal generates a frame in which data for uplink transmission is included in a frame body field (more specifically, a packet in which a preamble is added to a data frame). The terminal then transmits the generated frame a time “T1” after completing the reception of the trigger frame 1001.

Here, the generated frame goes through encoding and modulation processing, and is further processed in DA conversion, band limitation, up-conversion, and the like before being amplified and then transmitted. In the modulation processing, OFDM modulation is used and the data portion of the packet (the above described frame) is made up with a plurality of OFDM symbols. Each OFDM symbol is based on a plurality of subcarriers, and a pilot symbol identified with a codebook index specified in the trigger frame is applied to some of the subcarriers (pilot subcarriers). To all or some of the rest of the subcarriers, a data symbol that maps bits of data to be transmitted and the like in a predetermined modulation scheme, for example, is applied.

In the example shown in Figure 9, the terminals 1 to 4 receive the trigger frame 1001, determine that it is specified, and transmit data frames 1011 to 1014 including data for uplink transmission (more specifically, packets including the data frames) to the access point. Because transmission of each of the data frames is executed the time "T1" after the completion of the reception of the trigger frame 1001 by the terminals 1 to 4, the data frames are simultaneously received at the access point. This enables uplink MU-MIMO transmission. As stated above, the time "T1" is not required to be the same value among the terminals 1 to 4. For example, the access point notifies adjustment amounts of transmission timings of the terminals 1 to 4 from the common "T1" via the terminal information fields, and the terminals 1 to 4 may transmit the data frames at the adjusted transmission timings (this means that "T1" of each terminal is substantially different from each other). Other than the transmission timings, frequencies, powers, or both of them are adjusted among the terminals, and in this case, the access point may specify adjustment amounts of the frequencies, adjustment amounts of the powers, or both of them via the terminal information fields. The data frames 1011, 1012, 1023, and 1014 may include different contents or a same content. Generally, when it is described that a plurality of terminals transmit "X"th frames or that an access point receives a plurality of "X"th frames, the contents of these "X"th frames may be the same or different. X is any number equal to or more than one.

A part of the information described above as being notified in at least one of the terminal information field and the common information field (except the codebook index) may be notified to a terminal before the transmission of the trigger frame. For example, the access point may notify such information when executing an association process with a terminal (this is a procedure needed for making the terminal belong to the BSS of the access point) or at a later timing. In the association process, the access point and a terminal exchange information such as mutual capacities and attributes, for example. At this point, the access point may determine whether the terminal is capable of executing uplink MU-MIMO transmission. Also, the access point may obtain information about a status of a terminal (such as size of data stored in a buffer for uplink transmission) during communication executed before transmitting a trigger frame and manage the status of the terminal.

In the example shown in Figure 9, the packets transmitted by the terminals 1 to 4 have the same length but they are not required to do so. If any of the terminals 1 to 4 does not have data to be transmitted to the access point during MU-MIMO transmission, then the terminal may transmit a frame or packet having a predetermined format, such as a frame not having a frame body field, or may not transmit anything. When the access point receives the frame not having a frame body field or does not receive anything, then the access point may determine that the terminal does not have data for transmission.

Here, as the time “T1” shown in Figure 9, any predefined SIFS time [μs] can be used, for example. The predefined SIFS time may be SIFS time (=16μs) defined in the MAC protocol specification of the IEEE 802.11 wireless LAN as an inter-frame time interval, or a value larger or smaller than the SIFS time. As variation, the value of the time “T1” may be stored in one or both of the common information field and the terminal information field, and the terminals 1 to 4 may obtain the value of the time “T1” from one or both of the common information field and the terminal information field. Furthermore, the time “T1” may be notified in advance in another method, such as using a beacon frame or another management frame.

The access point receives the data frames 1011 to 1014 (more specifically, packets including the data frames) transmitted from the terminals 1 to 4 in MU-MIMO the time “T1” after completing the transmission of the trigger frame. The access point checks whether the data frames 1011 to 1014 are successfully received, and generates the acknowledgment response frame 1002 according to the result of the check. The access point transmits the acknowledgment response frame 1002 a time “T2” after completing the reception of the data frames 1011 to 1014. The time “T2” may be the SISF time or another time (IFS), as long as the time is determined in advance. The value of the time “T2” may be stored in one or both of the common information field and the terminal information field, and the terminals 1 to 4 may obtain the value of the time “T2” from one or both of the common information field and the terminal information field.

As a transmission of the acknowledgment response frame 1002, an ACK frame or a BA (Block ACK) frame may be transmitted to each terminal. The BA frame is used when the data frame transmitted from a terminal in the uplink transmission is an aggregation frame (A-MPDU: A (Aggregated)-Medium access control Protocol Data Unit), for example, and includes information about whether each of a plurality of frames included in the A-MPDU was successful. The access point may transmit the ACK frame or the BA frame for each terminal to the terminals 1 to 4 in MU-MIMO. That is, the acknowledgment response frames may be transmitted in downlink MU-MIMO. Downlink MU-MIMO transmission is defined in IEEE 802.11ac.

Or, a single frame including all of the acknowledgment responses for the terminals 1 to 4 may be transmitted (single-user transmission). As an example of a format in this case, a Multi-TID BA frame defined in the IEEE 802.11 standard may be used. As one example, a BA information field of the Multi-TID BA frame is provided in a number equal to the number of the terminals, and an identifier of each terminal (such as an AID (Association ID) or a part of the AID) is set in a reserved field within a TID information subfield of the each BA information field. In a Block Ack Starting Sequence Control subfield and a Block Ack Bitmap subfield, values may be set as usual on the basis of the data frames 1011 to 1014 for which a transmission acknowledgement response should be replied. The RA (Receiver Address) of the Multi-STA BA frame may be a multicast address of a group to which the terminals 1 to 4 commonly belong or a broadcast address. This enables to notify the BA (Block ACK) to a plurality of terminals in one frame. Also, a new type may be defined for a subtype of the Frame Control field.

Also, when not the BA but the ACK is returned to the terminals 1 to 4, some of the reserved fields within the TID information subfield of each BA information field are used as an identifier of a terminal, and the bits in the rest of the reserved fields are set (to 1). When these bits are set, the Block Ack Starting Sequence Control subfield and the Block Ack Bitmap subfield are omitted (do not exist). This enables to notify ACKs for a plurality of terminals in one frame. The examples described above are one example, and another existing frame may be used or a new frame may be defined instead of using an existing frame.

Although the case where the acknowledgment response frames 1002 are transmitted to the terminals 1 to 4 simultaneously using spatial multiplexing transmission or in a single frame has been described, it is also possible to transmit the BA frames or the ACK frames to the terminals 1 to 4 in a sequential manner. When the frames are sequentially returned, the BA frame may be returned to a first terminal after the completion of the reception of the data frame transmitted in uplink transmission, and for second and later terminals, a process of transmitting a BAR frame from the terminal and receiving a BA frame as a response for the transmission may be repeated. Or, for the second and later terminals, a process of transmitting a BA frame from the access point without transmitting a BAR frame from the terminal and receiving by the terminal an ACK frame as a response for the transmission may be repeated. Which terminal is the first terminal may be notified in the common information field or the terminal information field of the trigger frame 1001, or by using another method. If it is notified in the trigger frame 1001, the notification may be carried out in an implicit manner, such as by indicating that a terminal to which the first terminal information field is assigned is the first terminal. Any method other than these may be used for notifying the information about the first terminal.

After the access point transmits the acknowledgment response frame 1002, uplink MU-MIMO transmission by the terminals 1 to 4 and transmission of an acknowledgment response frame by the access point may be carries out repeatedly. In this case, the terminals 1 to 4 may use a pilot symbol corresponding to a codebook index notified in the trigger frame in the repeated uplink MU-MIMO transmissions.

While the present embodiment represents the case wherein the terminals 1 to 4 execute MU-MIMO transmission to the access point, the uplink transmission may be executed in a communication scheme in which MU-MIMO and OFDMA (Orthogonal Frequency Division Multiple Access) are combined (called OFDMA&MU-MIMO). OFDMA is a communication scheme in which transmissions destined to a plurality of terminals or transmissions originated from a plurality of terminals are executed simultaneously. A plural number ("M") of subcarriers are divided into a plural number of resource units. Each resource unit includes "N" subcarriers (N < M). Each terminal is assigned a resource unit, and transmissions destined to a plurality of terminals or transmissions originated from a plurality of terminals are executed simultaneously on a resource block-basis. In OFDMA&MU-MIMO, on the other hand, each of the plurality of resource units is assigned a plurality of terminals and MU-MIMO transmission is executed in a unit of a resource block. The present embodiment described so far can be applied to the MU-MIMO transmission in a unit of a resource block.

Also, in the sequence shown in Figure 9, a downlink OFDMA scheme may be used when the acknowledgment response frame 1002 is transmitted from the access point to the terminals 1 to 4. That is, ACK frames or BA frames may be simultaneously transmitted to respective terminals in a resource unit assigned to each terminal. In this case, each terminal receives a BA (or ACK) frame in a respective resource unit. Each terminal sets a receive filter so that a signal can be received in a respective resource unit.

Also, in the above described sequence shown in Figure 7, the access point transmits the NDP announcement 602, and each of the terminals receiving the frame 602 sequentially returns an NDP (sounding signal) at intervals of the SIFS time. In this manner, the access point estimates a spatial channel and an initial CFO of each terminal and selects a pilot symbol for each terminal. Another example will now be described in which the access point makes each terminal transmit an NDP in a sequence other than that shown in Figure 7.

Figure 15 shows another sequence in which the access point makes each terminal transmit an NDP. In this sequence, when the access point transmits an NDP announcement 1051, the terminal 1 transmits an NDP 1061 the SIFS time later. On receiving the NDP 1061, the access point transmits a Poll frame 1052 to the terminal 2 the SIFS time later. On receiving the poll frame 1052, the terminal 2 returns an NDP 1062 the SIFS time later. The similar sequence will be repeated afterward. That is, on receiving the NDP 1062 from the terminal 2, the access point transmits a Poll frame 1053 to the terminal 3 the SIFS time later. On receiving the Poll frame 1053, the terminal 3 returns an NDP 1063 the SIFS time later. On receiving the NDP 1063 from the terminal 3, the access point transmits a Poll frame 1054 to the terminal 4. On receiving the Poll frame 1054, the terminal 4 returns an NDP 1064 the SIFS time later.

In the NDP announcement 1051, the terminals 1 to 4 may be specified by setting an identifier of a terminal to which the NDP is transmitted. In this case, fields of a format that is similar or identical to the one shown in Figure 13A may be used for the NDP announcement 1051 and an identifier of a terminal may be set in each of the fields. The terminal whose identifier is set at a predetermined position among the fields, such as in a leading field, may transmits an NDP the time SIFS after receiving the NDP announcement 1051, and the other terminals may wait for receiving a Poll frame destined to the own terminal. The TA of the NDP announcement 1051 may be the access point, and the RA of the NDP announcement 1051 may be a broadcast address or a multicast address of a group to which the terminals 1 to 4 belong. Or, the RA may be the address of any one of the terminals 1 to 4, and the any one of the terminals transmits an NDP the SIFS time after receiving the NDP announcement while the other terminals belonging to the same group as the any one of the terminals may wait for receiving a Poll frame. Similar or identical fields to the ones described here may be used for the NDP announcement 602 transmitted by the access point in the above described sequence shown in Figure 7. A method for making a terminal transmit an NDP is not limited to the methods described here.

In the examples shown in Figure 7 and Figure 15, each terminal transmits a sounding signal such as an NDP. Alternatively, a spatial channel and an initial CFO of each terminal may be estimated in single-user communication separately executed between each terminal and an access point on a CSMA/CA-basis, and the result of this latest estimation may be used to select a pilot symbol of each terminal for executing uplink MU-MIMO. Because this enables to avoid a sounding procedure, the overhead before starting uplink MU-MIMO can be reduced.

Figure 16 is a flowchart of a process executed by an access point wherein a codebook index is notified in a trigger frame for uplink MU-MIMO. Once it has been decided to execute uplink MU-MIMO, the access point selects terminals for which MU-MIMO is executed (S1201) and determines items needed for uplink MU-MIMO communication (S1202). For example, the access point determines spatial channel numbers (stream numbers) for selected terminals, and selects a pilot symbol (pilot signal) for each terminal from a codebook in accordance with the above described methods.

The access point may check spatial channel characteristics and an initial CFO of each terminal by making each terminal transmit a sounding signal such as an NDP in the sequence shown in Figure 7 or 15. The check of spatial channel characteristics and an initial CFO of each terminal may be executed prior to deciding the execution of uplink MU-MIMO, or may be executed after deciding the execution of uplink MU-MIMO for a group of selected terminals. In the former case, if terminals which execute uplink MU-MIMO are not selected yet, then the check may be executed for a terminal capable of executing (and thus possibly executes) uplink MU-MIMO.

On the basis of the items determined in step S1202, the access point generates a trigger frame that instructs the selected terminals (users) to execute uplink MU-MIMO transmission (spatial multiplexing transmission). The access point obtains an access right for a wireless medium according to CSMA/CA and transmits the trigger frame (more specifically, a packet in which a preamble is added to the trigger frame) (S1203). The access right is obtained by executing carrier sensing in a total time of a predetermined time, such as DIFS (Distributed coordination function IterFrame Space), and a randomly determined backoff time. If the result of the carrier sensing is idle, then the access right is obtained. DIFS is one example, and other IFSs such AIFS (Arbitration InterFrame Space) and PIFS (Point coordination function InterFrame

Space) may be used. The trigger frame includes notification information that is needed for uplink MU-MIMO transmission and that is notified to the selected terminals. The notification information includes at least information (codebook index) that specifies a plurality of pilot signals respectively corresponding to a plurality of the selected terminals.

A predetermined time after completing the transmission of the trigger frame, the access point receives, in a simultaneous manner, a data frame (more specifically, a packet in which a preamble is added to the data frame) transmitted from each of the terminals. In other words, the access point receives the frame transmitted from each of the terminals in MU-MIMO transmission (S1204). The data frame may be a single data frame (MPDU (medium access control (MAC) protocol data unit)) or A-MPDU (A (Aggregated)-MPDU) in which a plurality of data frames are connected. Or, the data frame may be A-MSDU (A (Aggregated)-MSDU (MAC service data unit)) in which payload portions of a plurality of data frames are connected. The access point checks the success or failure on the basis of the FCS in the data frame received from each terminal, and generates an acknowledgment response frame in accordance with the check result. The generated acknowledgment response frame is transmitted the SIFS time after completing the reception of the data frames, for example (S1205). In the transmission of the acknowledgment response frame, BA frames or ACK frames respectively corresponding to the terminals may be transmitted simultaneously or sequentially, as described above. Or, as described above, another configuration is possible in which a single frame including the check result for each of the terminals is transmitted as the acknowledgment response frame.

Figure 17 is a flowchart of a process executed by a terminal when the terminal receives a trigger frame for uplink MU-MIMO including the codebook index.

A terminal receives the trigger frame (more specifically, a packet in which a preamble is added to the trigger frame) transmitted from the access point (S1301), and determines whether it is specified as a target terminal of MU-MIMO transmission (S1302). If it is not specified (NO), the frame is discarded and the process ends.

On the other hand, the terminal having received the MU-MIMO transmission (S1302) is specified as the target terminal of the MU-MIMO transmission (S1302), then the terminal reads a codebook index specified for it terminal from an appropriate field, and identifies a pilot symbol (pilot signal) corresponding to the codebook index from the codebook (S1303). Also, the terminal reads other information specified for it due to the necessity of the information for executing MU-MIMO. On the basis of the identified pilot symbol and the read information, the terminal generates a data frame (S1304). At this state, the terminal applies the identified pilot symbol to a pilot subcarrier out of a plurality of subcarriers corresponding to each of a plurality of OFDM symbols constituting the data frame. To the rest of the subcarriers, the terminal applies data symbols such as bits of data to be transmitted.

The terminal transmits the data frame (more specifically, a packet in which a preamble is added to the data frame) a predetermined time after completing the reception of the trigger frame (S1304). As described above, the data frame may be a single data frame (MPDU) or an aggregation frame (A-MPDU). After transmitting the data frame, the SIFS time later, for example, the terminal receives an acknowledgment response frame transmitted from the access point (S1305). In some configurations, when the terminal transmits a single MPDU and the access point cannot receive it, an acknowledgment response frame may not be transmitted. Although in the present case the terminal transmits a data frame, the terminal may transmit a management frame or a control frame.

In the present embodiment described so far, it is supposed that the access point and the terminal respectively have one common codebook. As another example, the access point and the terminal may respectively have a plurality of codebooks. In this case, the access point may notify information that identifies a codebook to be used out of the plurality of codebooks to the terminal in the trigger frame along with a code index. The terminal may identify the codebook on the basis of the information notified in the trigger frame and find a pilot symbol corresponding to the code index from the identified codebook. As a plurality of codebooks, codebooks having different sizes may be provided, and a codebook to be used may be switched between these codebooks according to the number of terminals executing MU-MIMO transmission. For example, a codebook having a larger size may be selected for the larger number of the terminals. This possibly reduces calculation needed for determining a pilot symbol used by each terminal.

Also, although in the present embodiment a pilot symbol used by a terminal is notified via a code index, a value or an abbreviation thereof representing a pilot symbol itself may be notified in the trigger frame. As an example of the abbreviation, when a value of a pilot symbol is represented as a complex number in a format of "$A\varepsilon^{j\theta}$", only "A" and "θ" rather than "$A\varepsilon^{j\theta}$" may be notified.

As described so far, according to the present embodiment, because a pilot symbol is selected for each user and information identifying the selected pilot symbol (codebook index) is notified to the user, a residual CFO of each user can be estimated when frames transmitted from a plurality of users in MU-MIMO transmission are decoded. Also, because the codebook index is notified in a trigger frame for MU-MIMO transmission, a pilot symbol for each user can be selected in consideration of the status of a spatial channel immediately before MU-MIMO transmission. In other words, if the time between the transmission of a pilot symbol to each user and the actual initiation of MU-MIMO transmission becomes longer, the possibility that the pilot symbol does not comply with the current status becomes higher. In the present embodiment, on the other hand, because the codebook index is notified in a trigger frame for MU-MIMO transmission, it is possible to select a pilot symbol in consideration of the current status of the spatial channel for each terminal, enabling the access point to more accurately decode frames.

(Second Embodiment)

FIG. 18 illustrates a hardware configuration example of a wireless communication device provided in an access point which is a base station. This hardware configuration is one example, various changes being applicable to the hardware configuration. Since the operation of the wireless communication device illustrated in FIG. 18 is similar to the wireless communication device described above in FIG. 2, the description below is centered on the differences in hardware configuration and detailed operation explanations have been omitted.

This wireless communication device includes a baseband unit 1111, an RF unit 1121 and one or more antennas 1 to N (N is an integer equal to or larger than 1).

The baseband unit 1111 includes a control circuit (protocol stack) 1112, a transmission processing circuit 1113, a reception processing circuit 1114, DA conversion circuits 1115 and 1116 and AD conversion circuits 1117 and 1118. The RF unit 1121 and the baseband unit 1111 may be collectively configured as IC (Integrated Circuit) chip or may be configured as individual chips.

As one example, the baseband unit 1111 is a baseband LSI or a baseband IC or both of them. Alternatively, the baseband unit 1111 may include an IC 1132 and an IC 1131. At this time, the IC 1132 includes the control circuit 1112, the transmission processing circuit 1113 and the reception processing circuit 1114, while the IC 1131 includes the DA conversion circuits 1115 and 1116 and the AD conversion circuits 1117 and 1118.

The control circuit 1112 corresponds to the communication processing device which controls communication, or a controller which controls communication. At this time, the wireless communicator may include the transmission processing circuit 1113 and the reception processing circuit 1114. The wireless communicator may include the DA conversion circuits 1115 and 1116, and the AD conversion circuits 1117 and 1118 in addition to the transmission processing circuit 1113 and the reception processing circuit 1114. The wireless communicator may include a transmission circuit 1122, a reception circuit 1123 in addition to the transmission processing circuit 1113 and the reception processing circuit 1114, the DA conversion circuits 1115 and 1116, and the AD conversion circuits 1117 and 1118. The integrated circuit or integrated circuitry according to the present embodiment may include a processor that performs all or a part of the processing in the baseband unit 1111, that is, all or a part of the processing in the control circuit 1112, the transmission processing circuit 1113, the reception processing circuit 1114, the DA conversion circuits 1115 and 1116, and the AD conversion circuits 1117 and 1118.

The IC 1132 may correspond to the communication processing device which controls communication, or a controller which controls communication. At this time, the wireless communicator may include the transmission processing circuit 1113 and the reception processing circuit 1114. The wireless communicator may include the DA conversion circuits 1115 and 1116, and the AD conversion circuits 1117 and 1118 in addition to the transmission processing circuit 1113 and the reception processing circuit 1114.

The control circuit 1112 in the baseband unit 1111 performs processing of MAC layer etc. The function one or more layers above the MAC layer may be included in the control circuit 1112. The control circuit 1112 may include a clock generating unit (i.e., oscillator). The transmission processing circuit 1113 corresponds a part which performs processing of PHY layer. The transmission processing circuit 1113 performs PHY layer processing such as modulation, adding of PHY header, to creates, for example, two kinds of digital baseband signals (hereafter, referred to as a digital I signal and a digital Q signal).

The DA conversion circuits 1115 and 1116 correspond to parts that perform DA conversion. The DA conversion circuits 1115 and 1116 subject signals input from the transmission processing circuit 1113 to the DA conversion. More specifically, the DA converting circuit 1115 converts the digital I signal into an analog I signal, the DA converting circuit 1116 converts the digital Q signal into an analog Q signal. There may be a case that a single-line (single-system) signal is transmitted without the above quadrature modulation. In this case, the number of DA converting circuits may be one.

In addition, in the case where signals in single-line or multiple lines are transmitted after being distributed to a plurality of antennas, DA converting circuits may be provided corresponding to the number of antennas.

The RF unit 1121 is, as one example, an RF analog IC or a high frequency IC or both of them. A transmission circuit 1122 in the RF unit 1121 corresponds to a part that performs processing at the time of transmission at a post-DA conversion stage. The transmission circuit 1122 includes a transmission filter that extracts a signal of a desired band from signals of the frames subjected to DA conversion, a mixer that performs up-conversion of the filtered signal into a radio frequency by the use of a signal of a constant frequency supplied from an oscillator, and a preamplifier (PA) that amplifies the signal after up-conversion, and so on.

A reception circuit 1123 in the RF unit 1121 corresponds to a part that performs processing at the time of reception up to the stage before AD conversion. The reception circuit 1123 includes an LNA (low-noise amplifier) that amplifies a signal received by an antenna, a mixer that down-converts the amplified signal into a baseband by the use of a signal of a constant frequency supplied from an oscillator, and a reception filter that extracts a signal of a desired band from the down-converted signal, and so on. More specifically, the reception circuit 1123 subjects the received signals that is subjected to low-noise amplification by a low noise amplifier (not shown) to quadrature demodulation with carriers of the phase difference between which is 90° to create the I (In-phase) signal being in phase with the received signal and the Q (Quad-phase) signal with a phase delayed by 90° from the I signal. These I signal and Q signal are adjusted in gain and output from the reception circuit 1123.

The AD conversion circuits 1117 and 1118 in the baseband unit 1111 correspond to a part that performs DA conversion. The AD conversion circuits 1117 and 1118 perform AD conversion on an input signal from the reception circuit 1123. More specifically, the AD converting circuit 1117 converts an I signal into a digital I signal, and the AD converting circuit 1118 converts the Q signal into a digital Q signal. There may be a case that the signal in a single-line may be received without involving the quadrature modulation. In this case, the number of the AD converting circuits may be one. In addition, in the case where a plurality of antennas are provided, AD converting circuits corresponding in number to the antennas may be provided. The reception processing circuit 1114 corresponds to a part that performs reception processing of PHY layer. That is, the reception processing circuit 1114 performs processing such as demodulation, decoding and preamble and PHY header analysis on the signal subjected to AD conversion, and passes a processed frame to the control circuit 1112. The control circuit 1112 performs processing of MAC layer etc. on the frame obtained by the reception processing circuit 1114. The control circuit 1112 also performs processing related to MIMO, for example, at least one process or plural processes out of channel estimation, transmission weight calculation and stream separation.

The control circuit 1112 may control the operations of the transmission filter of the transmission circuit 1122 and of the reception filter of the reception circuit 1123 such that, according to the setting of a used channel, a signal of a channel covered by the channel is extracted. Similar control may be performed by the control circuit 1112 giving instructions to another controller which controls the transmission circuit 1122 and the reception circuit 1123.

Here, a switch that switches the antennas 1 to N between any one of the transmission circuit 1122 and the reception circuit 1123 may be disposed in the RF unit 1121. By controlling the switch, at the time of transmission, the antennas 1 to N may be connected to the transmission circuit 1122 and, at the time of reception, the antennas 1 to N may be connected to the reception circuit 1123.

FIG. 19 illustrates a hardware configuration example of a wireless communication device provided in a wireless terminal. This hardware configuration is one example, various changes being applicable to the hardware configuration. Since the operation of the wireless communication device illustrated in FIG. 18 is similar to the wireless communication device described above in FIG. 3, the description below is centered on the differences in hardware configuration and detailed operation explanations have been omitted.

This wireless communication device includes a baseband unit 2111, an RF unit 2121 and one or more antennas 1 to N (N is an integer equal to or larger than 1). The RF unit 2121 and the baseband unit 2111 may be collectively configured as IC (Integrated Circuit) chip or may be configured as individual chips.

The baseband unit 2111 includes a control circuit (protocol stack) 2112, a transmission processing circuit 2113, a reception processing circuit 2114, DA conversion circuits 2115 and 2116 and AD conversion circuits 2117 and 2118.

As one example, the baseband unit 2111 is a baseband LSI or a baseband IC or both of them. Alternatively, the baseband unit 2111 may include an IC 2132 and an IC 2131. At this time, the IC 2132 includes the control circuit 2112, the transmission processing circuit 2113 and the reception processing circuit 2114, while the IC 2131 includes the DA conversion circuits 2115 and 2116 and the AD conversion circuits 2117 and 2118.

The control circuit 2112 corresponds to the communication processing device which controls communication, or a controller which controls communication. At this time, the wireless communicator may include the transmission processing circuit 2113 and the reception processing circuit 2114. The wireless communicator may include the DA conversion circuits 2115 and 2116, and the AD conversion circuits 2117 and 2118 in addition to the transmission processing circuit 2113 and the reception processing circuit 2114. The wireless communicator may include a transmission circuit 2122, a reception circuit 2123 in addition to the transmission processing circuit 2113 and the reception processing circuit 2114, the DA conversion circuits 2115 and 2116, and the AD conversion circuits 2117 and 2118. The integrated circuit or integrated circuitry according to the present embodiment may include a processor that performs all or a part of the processing in the baseband unit 2111, that is, all or a part of the processing in the control circuit 2112, the transmission processing circuit 2113, the reception processing circuit 2114, the DA conversion circuits 2115 and 2116, and the AD conversion circuits 2117 and 2118.

The IC 2132 may correspond to the communication processing device which controls communication, or a controller which controls communication. At this time, the wireless communicator may include the transmission processing circuit 2113 and the reception processing circuit 2114. The wireless communicator may include the DA conversion circuits 2115 and 2116, and the AD conversion circuits 2117 and 2118 in addition to the transmission processing circuit 2113 and the reception processing circuit 2114.

The control circuit 2112 in the baseband unit 2111 performs processing of MAC layer etc. The function of a layer upper than the MAC may be included in the control circuit 2112. The control circuit 2112 may include a clock generating unit (i.e., oscillator). The transmission processing circuit 2113 corresponds to a part which performs processing of PHY layer. The transmission processing circuit 2113 performs PHY layer processing such as modulation, adding of PHY header, to creates, for example, two kinds of digital baseband signals (hereafter, referred to as a digital I signal and a digital Q signal). The DA conversion circuits 2115 and 2116 correspond to parts that perform DA conversion. The DA conversion circuits 2115 and 2116 subject signals input from the transmission processing circuit 2113 to the DA conversion. More specifically, the DA converting circuit 2115 converts the digital I signal into an analog I signal, the DA converting circuit 2116 converts the digital Q signal into an analog Q signal. There may be a case that a single-line (single-system) signal is transmitted without the above quadrature modulation. In this case, the number of DA converting circuits may be one. In addition, in the case where signals in single-line or multiple lines are transmitted after being distributed to a plurality of antennas, DA converting circuits may be provided corresponding to the number of antennas.

The RF unit 2121 is, as one example, an RF analog IC or a high frequency IC or both of them. A transmission circuit 2122 in the RF unit 2121 corresponds to a part that performs processing at the time of transmission at a post-DA conversion stage. The transmission circuit 2122 includes a transmission filter that extracts a signal of a desired band from signals of the frames subjected to DA conversion, a mixer that performs up-conversion of the filtered signal into a radio frequency by the use of a signal of a constant frequency supplied from an oscillator, and a preamplifier (PA) that amplifies the signal after up-conversion, and so on.

A reception circuit 2123 in the RF unit 2121 corresponds to a part that performs processing at the time of reception up to the stage before AD conversion. The reception circuit 2123 includes an LNA (low-noise amplifier) that amplifies a signal received by an antenna, a mixer that down-converts the amplified signal into a baseband by the use of a signal of a constant frequency supplied from an oscillator, and a reception filter that extracts a signal of a desired band from the down-converted signal, and so on. More specifically, the reception circuit 2123 subjects the received signals that is subjected to low-noise amplification by a low noise amplifier (not shown) to quadrature demodulation with carriers of the phase difference between which is 90° to create the I (In-phase) signal being in phase with the received signal and the Q (Quad-phase) signal with a phase delayed by 90° from the I signal. These I signal and Q signal are adjusted in gain and output from the reception circuit 2123.

The AD conversion circuits 2117 and 2118 in the baseband unit 2111 correspond to a part that performs DA conversion. The AD conversion circuits 2117 and 2118 perform AD conversion on an input signal from the reception circuit 2123. More specifically, the AD converting circuit 2117 converts an I signal into a digital I signal, and the AD converting circuit 2118 converts the Q signal into a digital Q signal. There may be a case that the signal in a single-line may be received without involving the quadrature modulation. In this case, the number of the AD converting circuits may be one. In addition, in the case where a plurality of antennas are provided, AD converting circuits corresponding in number to the antennas may be provided. The reception processing circuit 2114 corresponds to a part that performs reception processing of PHY layer. That is, the reception processing circuit 2114 performs processing such as demodulation, decoding and preamble and PHY header analysis on the signal subjected to AD conversion, and passes a processed frame to the control circuit 2112. The control circuit 2112 performs processing of MAC layer etc. on the frame obtained by the reception processing circuit 2114.

The control circuit 2112 may control the operations of the transmission filter of the transmission circuit 2122 and of the reception filter of the reception circuit 2123 such that, according to the setting of a used channel, a signal of a channel covered by the channel is extracted. Similar control may be performed by the control circuit 2112 giving instructions to another controller which controls the transmission circuit 2122 and the reception circuit 2123.

In the case that the terminal provides with a plurality antennas and is compatible with MIMO, the control circuit 2112 also performs processing related to MIMO, for example, at least one process or plural processes out of channel estimation, transmission weight calculation and stream separation.

Here, a switch that switches the antennas 1 to N between any one of the transmission circuit 2122 and the reception circuit 2123 may be disposed in the RF unit 2121. By controlling the switch, at the time of transmission, the antennas 1 to N may be connected to the transmission circuit 2122 and, at the time of reception, the antennas 1 to N may be connected to the reception circuit 2123.

(Third embodiment)

FIG. 20A and FIG. 20B are perspective views of wireless terminal according to the third embodiment. The wireless terminal in FIG. 20A is a notebook PC 301 and the wireless communication device in FIG. 20B is a mobile terminal 321. Each of them corresponds to one form of a terminal (which may indicate a base station). The notebook PC 301 and the mobile terminal 321 are equipped with wireless communication devices 305 and 315, respectively. The wireless communication device provided in a terminal (which may indicate a base station) which has been described above can be used as the wireless communication devices 305 and 315. A wireless terminal carrying a wireless communication device is not limited to notebook PCs and mobile terminals. For example, it can be installed in a TV, a digital camera, a wearable device, a tablet, a smart phone, a gaming device, a network storage device, a monitor, a digital audio player, a web camera, a video camera, a projector, a navigation system, an external adapter, an internal adapter, a set top box, a gateway, a printer server, a mobile access point, a router, an enterprise/service provider access point, a portable device, a handheld device and so on.

Moreover, a wireless communication device installed in a terminal (which may indicate a base station) can also be provided in a memory card. FIG. 21 illustrates an example of a wireless communication device mounted on a memory card. A memory card 331 contains a wireless communication device 355 and a body case 332. The memory card 331 uses the wireless communication device 355 for wireless communication with external devices. Here, in FIG. 21, the description of other installed elements (for example, a memory, and so on) in the memory card 331 is omitted.

(Fourth embodiment)

In the fourth embodiment, a bus, a processor unit and an external interface unit are provided in addition to the configuration of the wireless communication device (i.e., the wireless communication device in the base station, the wireless communication device in the wireless terminal, or both of them) according to any of the first to third embodiments. The processor unit and the external interface unit are connected with an external memory (a buffer) through the bus. A firmware operates the processor unit. Thus, by adopting a configuration in which the firmware is included in the wireless communication device, the functions of the wireless communication device can be easily changed by rewriting the firmware. The processing unit in which the firmware operates may be a processor that performs the process of the communication controlling device or the control unit according to the present embodiment, or may be another processor that performs a process relating to extending or altering the functions of the process of the communication controlling device or the control unit. The processing unit in which the firmware operates may be included in the access point or the wireless terminal according to the present embodiment. Alternatively, the processing unit may be included in the integrated circuit of the wireless communication device installed in the access point, or in the integrated circuit of the wireless communication device installed in the wireless terminal.

(Fifth embodiment)

In the fifth embodiment, a clock generating unit is provided in addition to the configuration of the wireless communication device (i.e., the wireless communication device in the base station, the wireless communication device in the wireless terminal, or both of them) according to any of the first to third embodiments. The clock generating unit generates a clock and outputs the clock from an output terminal to the exterior of the wireless communication device. Thus, by outputting to the exterior the clock generated inside the wireless communication device and operating the host by the clock output to the exterior, it is possible to operate the host and the wireless communication device in a synchronized manner.

(Sixth embodiment)

In the sixth embodiment, a power source unit, a power source controlling unit and a wireless power feeding unit are included in addition to the configuration of the wireless communication device (i.e., the wireless communication device in the base station, the wireless communication device in the wireless terminal, or both of them) according to any of the first to third embodiments. The power supply controlling unit is connected to the power source unit and to the wireless power feeding unit, and performs control to select a power source to be supplied to the wireless communication device. Thus, by adopting a configuration in which the power source is included in the wireless communication device, power consumption reduction operations that control the power source are possible.

(Seventh embodiment)

In the seventh embodiment, a SIM card is added to the configuration of the wireless communication device according to the sixth embodiment. For example, the SIM card is connected with the controller, another unit or both of them in the wireless communication device. Thus, by adopting a configuration in which the SIM card is included in the wireless communication device, authentication processing can be easily performed.

(Eighth embodiment)

In the eighth embodiment, a video image compressing/decompressing unit is added to the configuration of the wireless communication device according to the fourth embodiment. The video image compressing/decompressing unit is connected to the bus. Thus, by adopting a configuration in which the video image compressing/decompressing unit is included in the wireless communication device, transmitting a compressed video image and decompressing a received compressed video image can be easily done.

(Ninth embodiment)

In the ninth embodiment, an LED unit is added to the configuration of the wireless communication device (i.e., the wireless communication device in the base station, the wireless communication device in the wireless terminal, or both of them) according to any of the first to third embodiments. For example, the LED unit is connected to at least one of the controller, another unit or both of them in the wireless communication device. Thus, by adopting a configuration in which the LED unit is included in the wireless communication device, notifying the operation state of the wireless communication device to the user can be easily done.

(Tenth embodiment)

In the tenth embodiment, a vibrator unit is included in addition to the configuration of the wireless communication device (i.e., the wireless communication device in the base station, the wireless communication device in the wireless terminal, or both of them) according to any of the first to third embodiments. For example, the vibrator unit is connected to at least one of the controller, another unit or both of them in the wireless communication device. Thus, by adopting a configuration in which the vibrator unit is included in the wireless communication device, notifying the operation state of the wireless communication device to the user can be easily done.

(Eleventh embodiment)

In a eleventh embodiment, the configuration of the wireless communication device (i.e., the wireless communication device in the base station, the wireless communication device in the wireless terminal, or both of them) includes a display in addition to the configuration of the wireless communication device (the wireless communication device of the terminal (which may indicate the base station) according to any one of the first to third embodiments. The display may be connected to the controller, another unit or both of them in the wireless communication device via a bus (not shown). As seen from the above, the configuration including the display to display the operation state of the wireless communication device on the display allows the operation status of the wireless communication device to be easily notified to a user.

(Twelfth embodiment)

In the present embodiment, [1] the frame type in the wireless communication system, [2] a technique of disconnection between wireless communication devices, [3] an access scheme of a wireless LAN system and [4] a frame interval of a wireless LAN are described.

[1] Frame type in communication system

Generally, as mentioned above, frames treated on a wireless access protocol in a wireless communication system are roughly divided into three types of the data frame, the management frame and the control frame. These types are normally shown in a header part which is commonly provided to frames. As a display method of the frame type, three types may be distinguished in one field or may be distinguished by a combination of two fields.

The management frame is a frame used to manage a physical communication link with a different wireless communication device. For example, there are frames used to perform communication setting with the different wireless communication device or a frame to release communication link (that is, to disconnect the connection), and a frame related to the power save operation in the wireless communication device.

The data frame is a frame to transmit data generated in the wireless communication device to the different wireless communication device after a physical communication link with the different wireless communication device is established. The data is generated in a higher layer of the present embodiment and generated by, for example, a user's operation.

The control frame is a frame used to perform control at the time of transmission and reception (exchange) of the data frame with the different wireless communication device. A response frame transmitted for the acknowledgment in a case where the wireless communication device receives the data frame or the management frame, belongs to the control frame.

These three types of frames are subjected to processing based on the necessity in the physical layer and then transmitted as physical packets via an antenna. Here, in a procedure of connection establishment, a connection request frame and a connection reception frame denote the management frame, and it is possible to use the response frame of the control frame as a confirmation frame with respect to the connection reception frame.

[2] Technique of disconnection between wireless communication devices

For disconnection, there are an explicit technique and an implicit technique. As the explicit technique, a frame to disconnect any one of the connected wireless communication devices is transmitted. This frame is classified into the management frame. The frame for disconnection may be referred to as "release frame" by the meaning of releasing connection, for example. Normally, it is determined that the connection is disconnected at the timing of transmitting the release frame in a wireless communication device on the side to transmit the release frame and at the timing of receiving the release frame in a wireless communication device on the side to receive the release frame. Afterward, it returns to the initial state in a communication phase, for example, a state to search for a wireless communication device of the communicating partner. This is because, at the time of transmitting the frame for disconnection, a physical wireless link may not be secured, for example, the communication distance to the wireless communication device of connection destination is separated and radio signals cannot be received or decoded.

On the other hand, as the implicit technique, it is determined that the connection state is disconnected in a case where frame transmission (transmission of a data frame and management frame or transmission of a response frame with respect to a frame transmitted by the subject device) is not detected from a wireless communication device of the connection partner which has established the connection for a certain period. Such a technique is provided because, in a state where it is determined that the connection is disconnected as mentioned above, a state is considered where the physical wireless link cannot be secured, for example, the communication distance to the wireless communication device of the connection destination is separated and the radio signals cannot be received or decoded. That is, it is because the reception of the release frame cannot be expected.

As a specific example to determine the disconnection of connection in an implicit method, a timer is used. For example, at the time of transmitting a data frame that requests an acknowledgment response frame, a first timer (for example, a retransmission timer for a data frame) that limits the retransmission period of the frame is activated, and, if the acknowledgement response frame to the frame is not received until the expiration of the first timer (that is, until a desired retransmission period passes), retransmission is performed. When the acknowledgment response frame to the frame is received, the first timer is stopped.

On the other hand, when the acknowledgment response frame is not received and the first timer expires, for example, a management frame to confirm whether a wireless communication device of a connection partner is still present (in a communication range) (in other words, whether a wireless link is secured) is transmitted, and, at the same time, a second timer (for example, a retransmission timer for the management frame) to limit the retransmission period of the frame is activated. Similarly to the first timer, even in the second timer, retransmission is performed if an acknowledgment response frame to the frame is not received until the second timer expires, and it is determined that the connection is disconnected when the second timer expires.

Alternatively, a third timer is activated when a frame is received from a wireless communication device of the connection partner, the third timer is stopped every time the frame is newly received from the wireless communication device of the connection partner, and it is activated from the initial value again. When the third timer expires, similarly to the above, a management frame to confirm whether the wireless communication device of the connection party is still present (in a communication range) (in other words, whether a wireless link is secured) is transmitted, and, at the same time, a second timer (for example, a retransmission timer for the management frame) to limit the retransmission period of the frame is activated. Even in this case, retransmission is performed if an acknowledgment response frame to the frame is not received until the second timer expires, and it is determined that the connection is disconnected when the second timer expires. The latter management frame to confirm whether the wireless communication device of the connection partner is still present may differ from the management frame in the former case. Moreover, regarding the timer to limit the retransmission of the management frame in the latter case, although the same one as that in the former case is used as the second timer, a different timer may be used.

[3] Access scheme of wireless LAN system

For example, there is a wireless LAN system with an assumption of communication or competition with a plurality of wireless communication devices. CSMA/CA is set as the basis of an access scheme in the IEEE802.11 (including an extension standard or the like) wireless LAN. In a scheme in which transmission by a certain wireless communication device is grasped and transmission is performed after a fixed time from the transmission end, simultaneous transmission is performed in the plurality of wireless communication devices that grasp the transmission by the wireless communication device, and, as a result, radio signals collide and frame transmission fails. By grasping the transmission by the certain wireless communication device and waiting for a random time from the transmission end, transmission by the plurality of wireless communication devices that grasp the transmission by the wireless communication device stochastically disperses. Therefore, if the number of wireless communication devices in which the earliest time in a random time is subtracted is one, frame transmission by the wireless communication device succeeds and it is possible to prevent frame collision. Since the acquisition of the transmission right based on the random value becomes impartial between the plurality of wireless communication devices, it can say that a scheme adopting Carrier Avoidance is a suitable scheme to share a radio medium between the plurality of wireless communication devices.

[4] Frame interval of wireless LAN

The frame interval of the IEEE802.11 wireless LAN is described. There are six types of frame intervals used in the IEEE802.11 wireless LAN, such as distributed coordination function interframe space (DIFS), arbitration interframe space (AIFS), point coordination function interframe space (PIFS), short interframe space (SIFS), extended interframe space (EIFS) and reduced interframe space (RIFS).

The definition of the frame interval is defined as a continuous period that should confirm and open the carrier sensing idle before transmission in the IEEE802.11 wireless LAN, and a strict period from a previous frame is not discussed. Therefore, the definition is followed in the explanation of the IEEE802.11 wireless LAN system. In the IEEE802.11 wireless LAN, a waiting time at the time of random access based on CSMA/CA is assumed to be the sum of a fixed time and a random time, and it can say that such a definition is made to clarify the fixed time.

DIFS and AIFS are frame intervals used when trying the frame exchange start in a contention period that competes with other wireless communication devices on the basis of CSMA/CA. DIFS is used in a case where the right of priority according to the traffic type is not distinguished, AIFS is used in a case where the right of priority by traffic identifier (TID) is provided.

Since operation is similar between DIFS and AIFS, AIFS is chiefly used to give an explanation below. In the IEEE802.11 wireless LAN, access control including the start of frame exchange in the MAC layer is performed. In addition, in a case where QoS (Quality of Service) is supported when data is transferred from a higher layer, the traffic type is notified together with the data, and the data is classified for the priority at the time of access on the basis of the traffic type. The class at the time of this access is referred to as "access category (AC)". Therefore, the value of AIFS is provided every access category.

PIFS denotes a frame interval to enable access which is more preferential than other competing wireless communication devices, and the period is shorter than the values of DIFS and AIFS. SIFS denotes a frame interval which can be used in a case where frame exchange continues in a burst manner at the time of transmission of a control frame of a response system or after the access right is acquired once. EIFS denotes a frame interval caused when frame reception fails.

RIFS denotes a frame interval which can be used in a case where a plurality of frames are consecutively transmitted to the same wireless communication device in a burst manner after the access right is acquired once, and a response frame from a wireless communication device of the transmission partner is not requested while RIFS is used.

Here, FIG. 22 illustrates one example of frame exchange in a competitive period based on the random access in the IEEE802.11 wireless LAN.

When a transmission request of a data frame (W_DATA1) is generated in a certain wireless communication device, a case is assumed where it is recognized that a medium is busy (busy medium) as a result of carrier sensing. In this case, AIFS of a fixed time is set from the time point at which the carrier sensing becomes idle, and, when a random time (random backoff) is set afterward, data frame W_DATA1 is transmitted to the communicating partner.

The random time is acquired by multiplying a slot time by a pseudorandom integer led from uniform distribution between contention windows (CW) given by integers from 0. Here, what multiplies CW by the slot time is referred to as "CW time width". The initial value of CW is given by CWmin, and the value of CW is increased up to CWmax every retransmission. Similarly to AIFS, both CWmin and CWmax have values every access category. In a wireless communication device of transmission destination of W_DATA1, when reception of the data frame succeeds, a response frame (W_ACK1) is transmitted after SIFS from the reception end time point. If it is within a transmission burst time limit when W_ACK1 is received, the wireless communication device that transmits W_DATA1 can transmit the next frame (for example, W_DATA2) after SIFS.

Although AIFS, DIFS, PIFS and EIFS are functions between SIFS and the slot-time, SIFS and the slot time are defined every physical layer. Moreover, although parameters to which the value of each access category such as AIGS, CWmin and CWmax is set can be set every communication group (which is a basic service set (BSS) in the IEEE802.11 wireless LAN), the default values are defined.

For example, in the definition of 802.11ac, with an assumption that SIFS is 16 μs and the slot time is 9 μs, and thereby PIFS is 25 μs, DIFS is 34 μs, the default value of the frame interval of an access category of BACKGROUND (AC_BK) in AIFS is 79 μs, the default value of the frame interval of BEST EFFORT (AC_BE) is 43 μs, the default value of the frame interval between VIDEO(AC_VI) and VOICE(AC_VO) is 34 μs, and the default values of CWmin and CWmax are 31 and 1023 in AC_BK and AC_BE, 15 and 31 in AC_VI and 7 and 15 in AC_VO. Here, EIFS denotes the sum of SIFS, DIFS, and the time length of a response frame transmitted at the lowest mandatory physical rate.

The terms used in each embodiment should be interpreted broadly. For example, the term “processor” may encompass a general purpose processor, a central processor (CPU), a microprocessor, a digital signal processor (DSP), a controller, a microcontroller, a state machine, and so on. According to circumstances, a “processor” may refer to an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), and a programmable logic device (PLD), etc. The term “processor” may refer to a combination of processing devices such as a plurality of microprocessors, a combination of a DSP and a microprocessor, one or more microprocessors in conjunction with a DSP core.

As another example, the term “memory” may encompass any electronic component which can store electronic information. The “memory” may refer to various types of media such as random access memory (RAM), read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read only memory (EPROM), electrically erasable PROM (EEPROM), non-volatile random access memory (NVRAM), flash memory, magnetic or optical data storage, which are readable by a processor. It can be said that the memory electronically communicates with a processor if the processor read and/or write information for the memory. The memory may be integrated to a processor and also in this case, it can be said that the memory electronically communication with the processor. The term “circuitry” may refer to not only electric circuits or a system of circuits used in a device but also a single electric circuit or a part of the single electric circuit.

In each embodiment, a frame may indicate not only one called a frame in IEEE802.11 standards but also one called a packet such as Null Data Packet.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

CLAIMS

1. An integrated circuitry for wireless communication, comprising:

a baseband integrated circuitry to control transmission of a first packet via an RF integrated circuitry, the first packet instructing a plurality of wireless communication terminals to execute an initial spatial multiplexing transmission after completing reception of the first packet, wherein

the first packet includes first information identifying at least one pilot signal to be used by each of the plurality of wireless communication terminals in the spatial multiplexing transmission.

2. The integrated circuitry for wireless communication according to claim 1, wherein

the first information includes an identifier identifying a subset of the at least one pilot signal.

3. The integrated circuitry for wireless communication according to claim 2, wherein

the baseband integrated circuitry selects the at least one pilot signal from a codebook, and

the identifier identifying the subset of the at least one pilot signal includes an index assigned to the subset of the at least one pilot signal in the codebook.

4. The integrated circuitry for wireless communication according to any one of claims 1 to 3, wherein

the first information in the first packet comprises an identifier of each of the plurality of wireless communication terminals.

5. The integrated circuitry for wireless communication according to any one of claims 1 to 4, wherein

the first packet includes a group identifier to identify a group including the plurality of wireless communication terminals,

the first packet includes a plurality of first fields respectively associated with the plurality of wireless communication terminals, and the first information is set in each of the plurality of first fields respectively corresponding to the plurality of wireless communication terminals.

6. The integrated circuitry for wireless communication according to any one of claims 1 to 5, wherein

the first packet includes a preamble and a data portion, and

the first information is included in at least one the preamble and the data portion.

7. The integrated circuitry for wireless communication according to claim 6, wherein

the data portion includes an MAC frame, and

the first information is included in either a header or a frame body field of the MAC frame.

8. The integrated circuitry for wireless communication according to any one of claims 1 to 7, wherein

the at least one pilot signal is applied to at least one subcarrier arranged at a predetermined position out of a plurality of subcarriers associated with an OFDM symbol.

9. The integrated circuitry for wireless communication according to any one of claims 1 to 8, wherein

the at least one pilot signal includes a plurality of pilot signals.

10. The integrated circuitry for wireless communication according to any one of claims 1 to 7, wherein

the baseband integrated circuitry compensates for a residual carrier frequency offset of each wireless communication terminal by using the pilot signal for each wireless communication terminal received in the spatial multiplex transmission.

11. The integrated circuitry for wireless communication according to any one of claims 1 to 10, wherein

the baseband integrated circuitry controls communication in accordance with IEEE 802.11 standard.

12. The integrated circuitry for wireless communication according to any one of claims 1 to 11, wherein

the integrated circuitry for wireless communication further comprises the RF integrated circuitry,

the baseband integrated circuitry DA-converts the first packet, and

the RF integrated circuitry up-converts the DA-converted first packet to a radio frequency.

13. The integrated circuitry for wireless communication according to any one of claims 1 to 12, wherein

the baseband integrated circuitry and the RF integrated circuitry are configured in one integrated circuitry.

14. A wireless communication terminal, comprising:

at least one antenna;

a wireless communicator connected to the at least one antenna, to transmit and receive a packet;

a controller to control transmission of a first packet via the wireless communicator, the first packet instructing a plurality of other wireless communication terminals to execute initial spatial multiplexing transmission after completing reception of the first packet, wherein

the first packet includes first information identifying at least one pilot signal to be used by each of the plurality of other wireless communication terminals in the spatial multiplexing transmission.

15. A wireless communication method performed by a wireless communication terminal, comprising:

transmitting a first packet instructing a plurality of other wireless communication terminals to execute initial spatial multiplexing transmission after completing reception of the first packet, wherein

the first packet includes first information identifying at least one pilot signal to be used by each of the plurality of other wireless communication terminals in the spatial multiplexing transmission.

16. An integrated circuitry for wireless communication, comprising:

a baseband integrated circuitry to receive a first packet via an RF integrated circuitry, the first packet instructing a plurality of wireless communication terminals to execute spatial multiplexing transmission, wherein

the first packet includes first information identifying at least one pilot signal used by each of the plurality of wireless communication terminals in the spatial multiplexing transmission,

the baseband integrated circuitry identifies the pilot signal it is instructed to use by the first information and transmits a second packet including the pilot signal after completing reception of the first packet via the RF integrated circuitry, and

the second packet is transmitted in spatial multiplexing along with another second packet transmitted from another wireless communication terminal among the plurality of wireless communication terminals.

17. The integrated circuitry for wireless communication according to claim 16, wherein

the first information includes an identifier to identify a subset of the at least one pilot signal, and

the baseband integrated circuitry identifies the at least one pilot signal on the basis of the identifier.

18. The integrated circuitry for wireless communication according to claim 17, wherein

the identifier to identify the subset of the at least one pilot signal is an index assigned to the subset in a codebook, and

the baseband integrated circuitry identifies the at least one pilot signal on the basis of the codebook and the index.

19. The integrated circuitry for wireless communication according to any one of claims 16 to 18, wherein

the first packet includes identifiers of the plurality of wireless communication terminals in association with the first information, and

the baseband integrated circuitry identifies the pilot signal on the basis of the first information associated with the identifier of an own device.

20. The integrated circuitry for wireless communication according to any one of claims 16 to 19, wherein

the first packet includes a group identifier to identify a group including the plurality of wireless communication terminals,

the first packet includes a plurality of first fields respectively associated with the plurality of wireless communication terminals in accordance with the group identifier,

the first information is set in each of the plurality of first fields respectively corresponding to the plurality of wireless communication terminals, and

the baseband integrated circuitry identifies the first field associated with an own device when the own device belongs to the group represented with the group identifier and identifies the at least one pilot signal on the basis of the first information set in the identified first field.

21. The integrated circuitry for wireless communication according to any one of claims 16 to 20, wherein

the at least one pilot signal is applied to at least one subcarrier arranged at a predetermined position out of a plurality of subcarriers associated with an OFDM symbol.

22. The integrated circuitry for wireless communication according to any one of claims 16 to 21, wherein

the at least one pilot signal includes a plurality of pilot signals.

23. The integrated circuitry for wireless communication according to any one of claims 16 to 22, wherein

the baseband integrated circuitry controls communication in accordance with IEEE 802.11 standard.

24. The integrated circuitry for wireless communication according to any one of claims 16 to 23, wherein

the integrated circuitry for wireless communication further comprises the RF integrated circuitry,

the RF integrated circuitry down-converts the first packet to a baseband frequency, the baseband integrated circuitry AD-converts the down-converted first packet,

the baseband integrated circuitry DA-converts the second packet, and

the RF integrated circuitry up-converts the DA-converted second packet to a radio frequency.

25. The integrated circuitry for wireless communication according to any one of claims 16 to 22, wherein

the baseband integrated circuitry and the RF integrated circuitry are configured in one integrated circuitry.

26. A wireless communication terminal, comprising:

at least one antenna;

a wireless communicator connected to the at least one antenna, to transmit and receive a packet;

a baseband integrated circuitry to receive a first packet via the wireless communicator, the first packet instructing a plurality of wireless communication terminals to execute spatial multiplexing transmission, wherein

the first packet includes first information identifying at least one pilot signal to be used by each of the plurality of wireless communication terminals in the spatial multiplexing transmission.

the baseband integrated circuitry identifies the pilot signal it is instructed to use by the first information and transmits a second packet including the pilot signal after completing reception of the first packet via the wireless communicator, and

the second packet is transmitted in spatial multiplexing along with another second packet transmitted from another wireless communication terminal among the plurality of wireless communication terminals.

27. A wireless communication method performed by a wireless communication terminal, comprising:

receiving a first packet instructing a plurality of wireless communication terminals to execute spatial multiplexing transmission, wherein the first packet includes first information identifying at least one pilot signal that is to be used by each of the plurality of wireless communication terminals in the spatial multiplexing transmission;

identifying the pilot signal the wireless communication terminal is instructed to use by the first information; and transmitting a second packet including the pilot signal after completing reception of the first packet;

wherein the second packet is transmitted in spatial multiplexing along with another second packet transmitted from another wireless communication terminal among the plurality of wireless communication terminals.

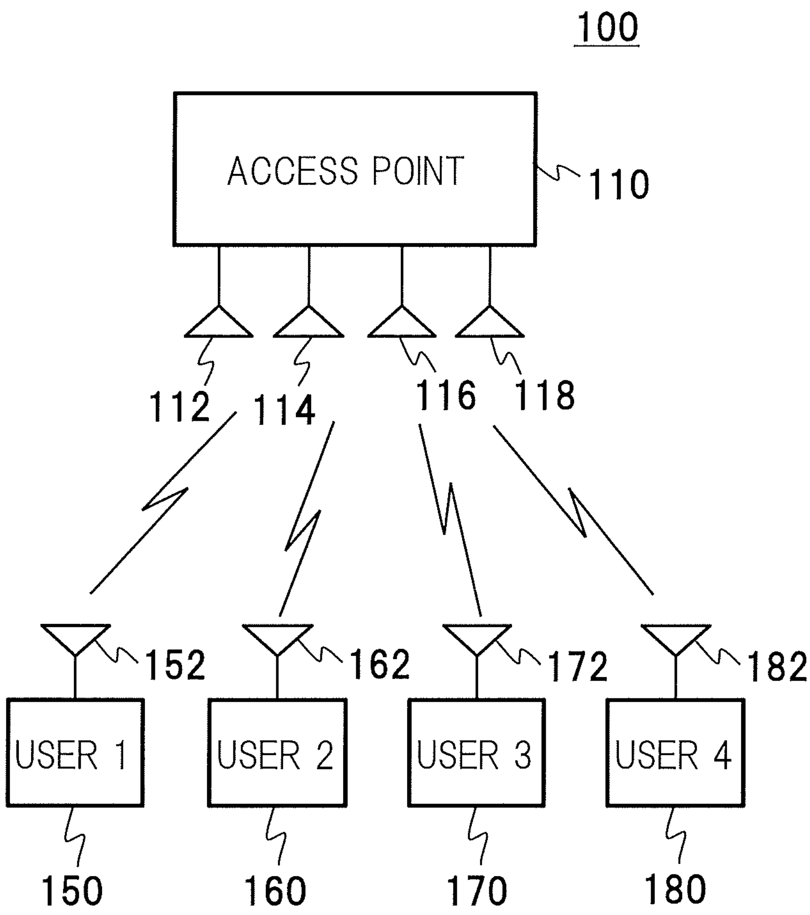
100
ACCESS POINT
110
112
114
116
118
152
162
172
182
USER 1
USER 2
USER 3
USER 4
150
160
170
180

FIG.1

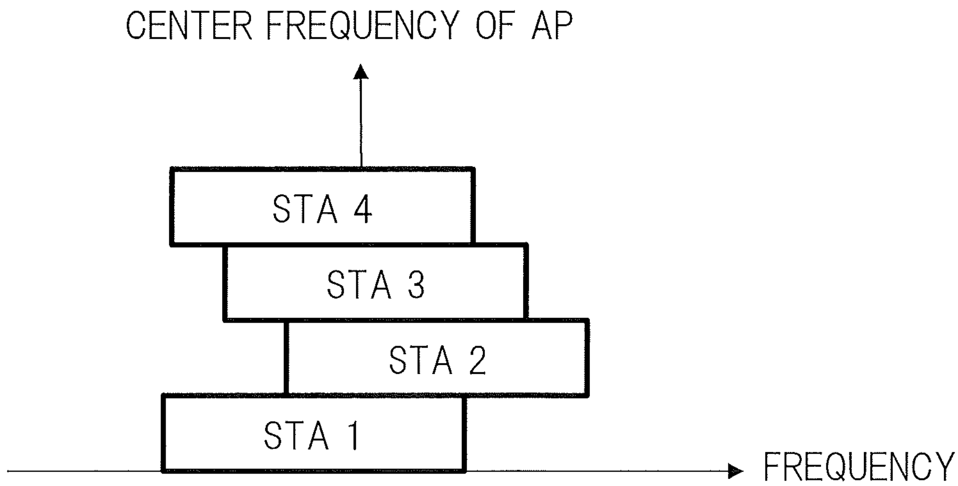
CENTER FREQUENCY OF AP
STA 4
STA 3
STA 2
STA 1
FREQUENCY

FIG.2

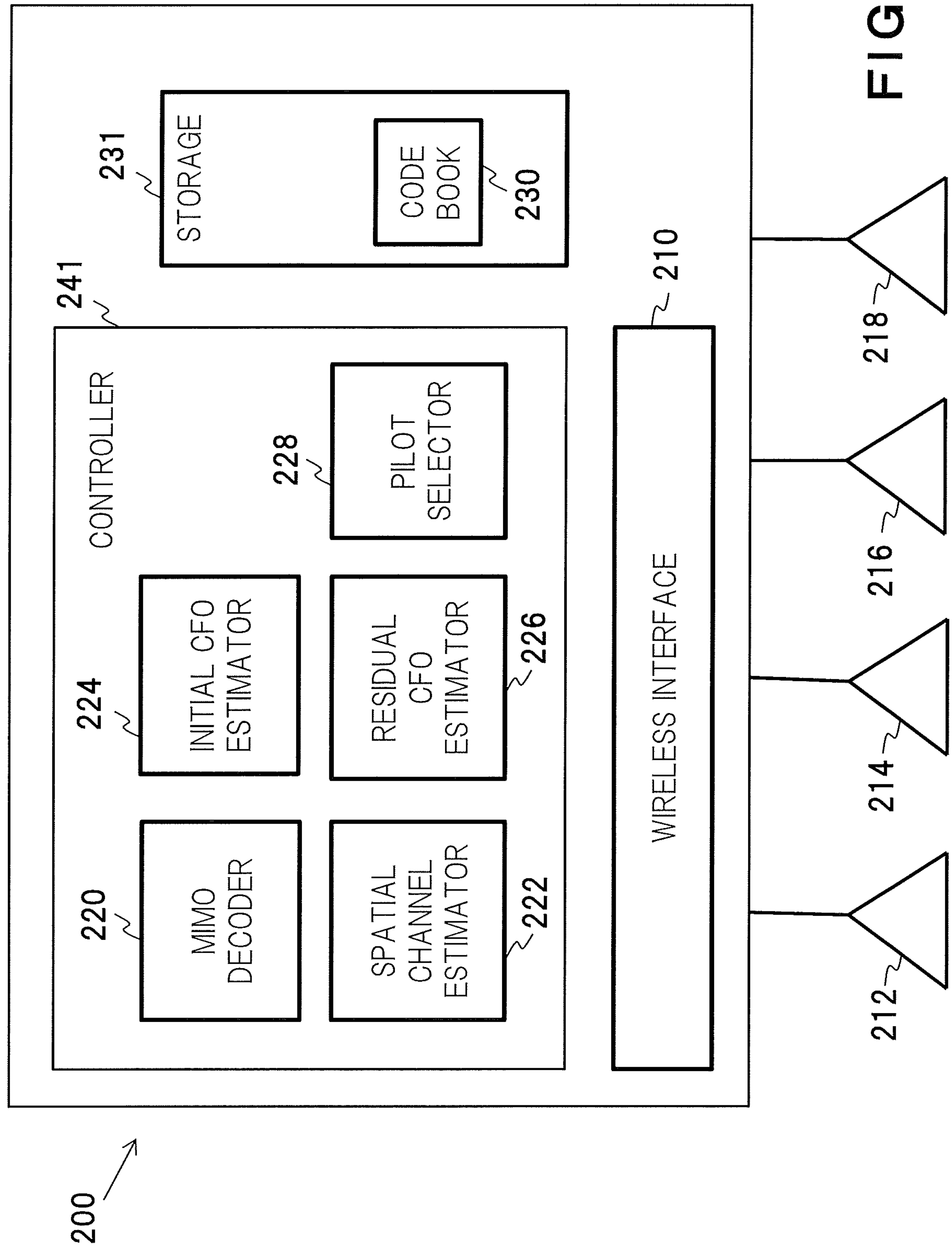
200
CONTROLLER
241
MIMO DECODER
220
SPATIAL CHANNEL ESTIMATOR
222
INITIAL CFO ESTIMATOR
224
RESIDUAL CFO ESTIMATOR
226
PILOT SELECTOR
228
STORAGE
231
CODE BOOK
230
WIRELESS INTERFACE
210
212
214
216
218

FIG.3

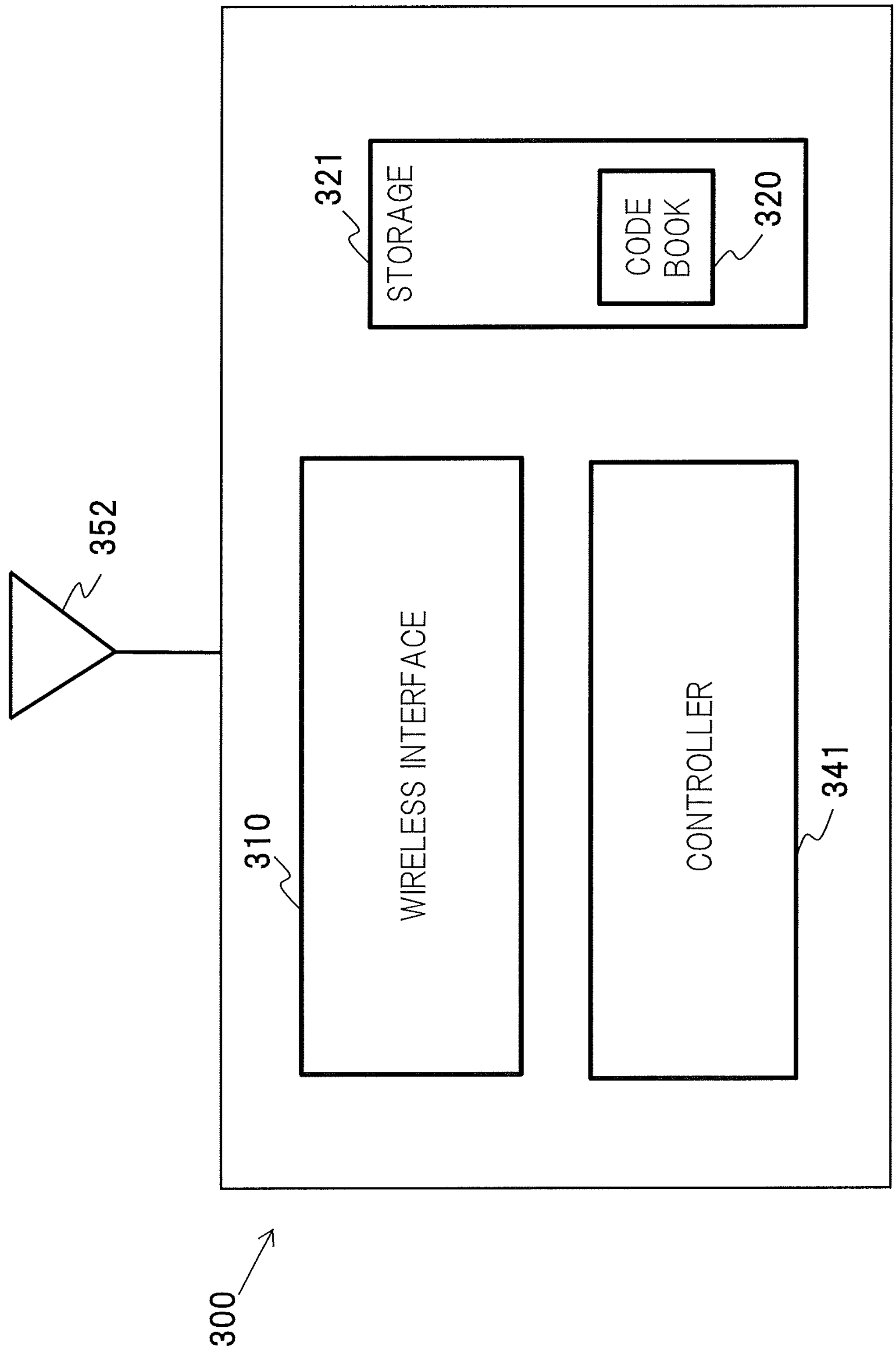
STORAGE
321
CODE
BOOK
320
352
WIRELESS INTERFACE
310
CONTROLLER
341
300

FIG.4

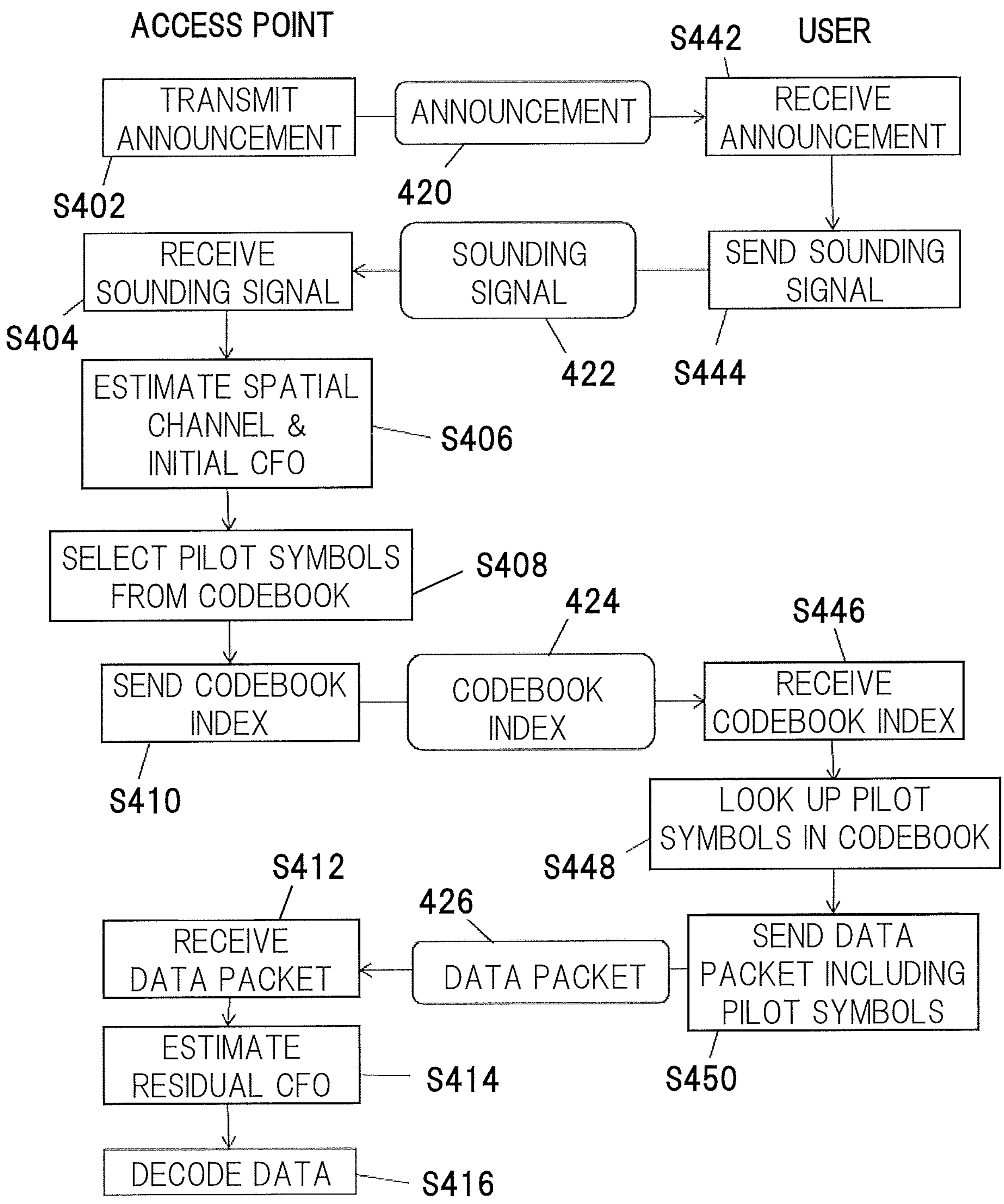
ACCESS POINT
USER
TRANSMIT ANNOUNCEMENT
S402
ANNOUNCEMENT
420
S442
RECEIVE ANNOUNCEMENT
RECEIVE SOUNDING SIGNAL
S404
SOUNDING SIGNAL
422
SEND SOUNDING SIGNAL
S444
ESTIMATE SPATIAL CHANNEL & INITIAL CFO
S406
SELECT PILOT SYMBOLS FROM CODEBOOK
S408
SEND CODEBOOK INDEX
S410
CODEBOOK INDEX
424
RECEIVE CODEBOOK INDEX
S446
LOOK UP PILOT SYMBOLS IN CODEBOOK
S448
RECEIVE DATA PACKET
S412
DATA PACKET
426
SEND DATA PACKET INCLUDING PILOT SYMBOLS
S450
ESTIMATE RESIDUAL CFO
S414
DECODE DATA
S416

FIG.5

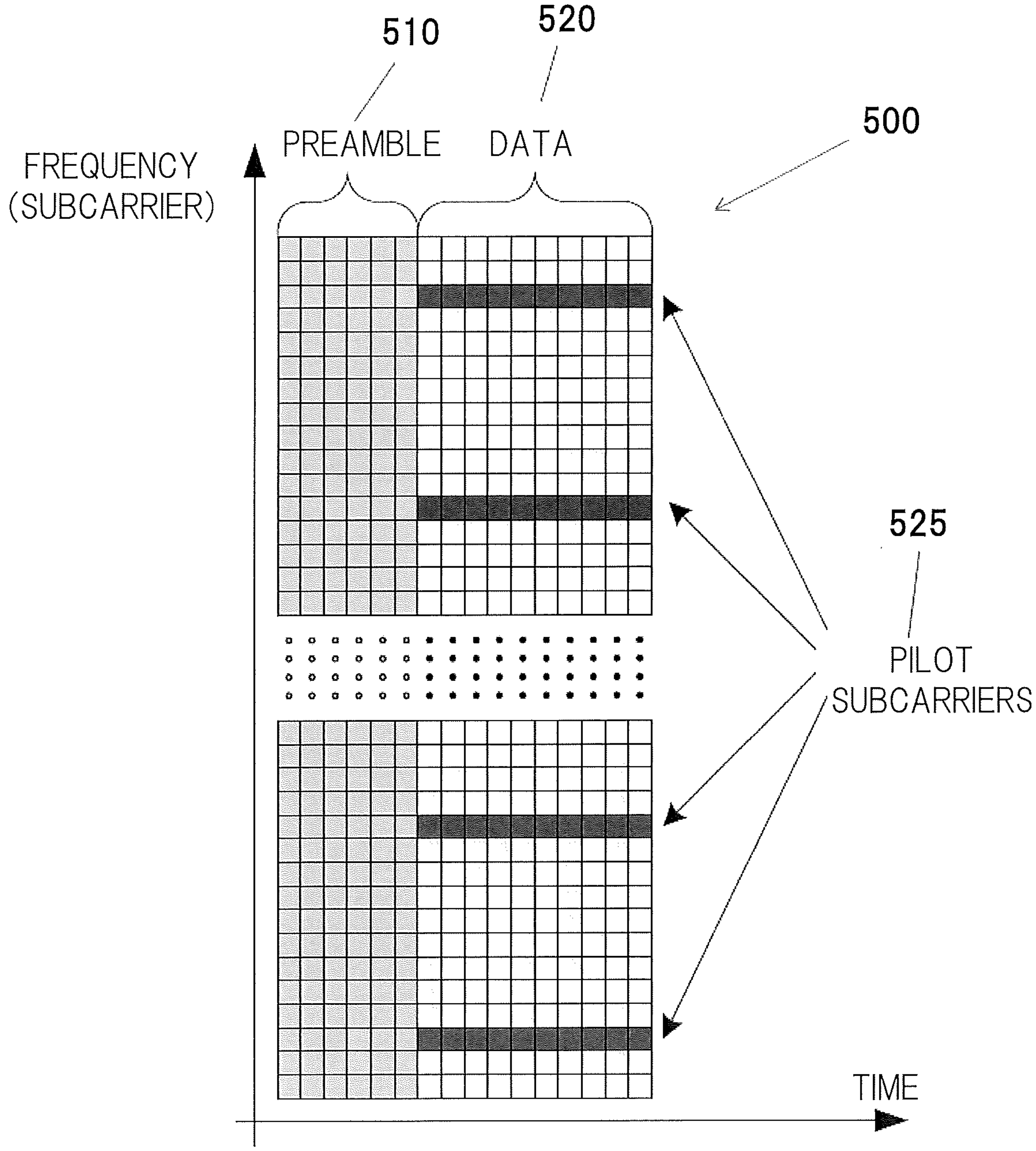
510
520
500
PREAMBLE
DATA
FREQUENCY
(SUBCARRIER)
525
PILOT
SUBCARRIERS
TIME

FIG.6

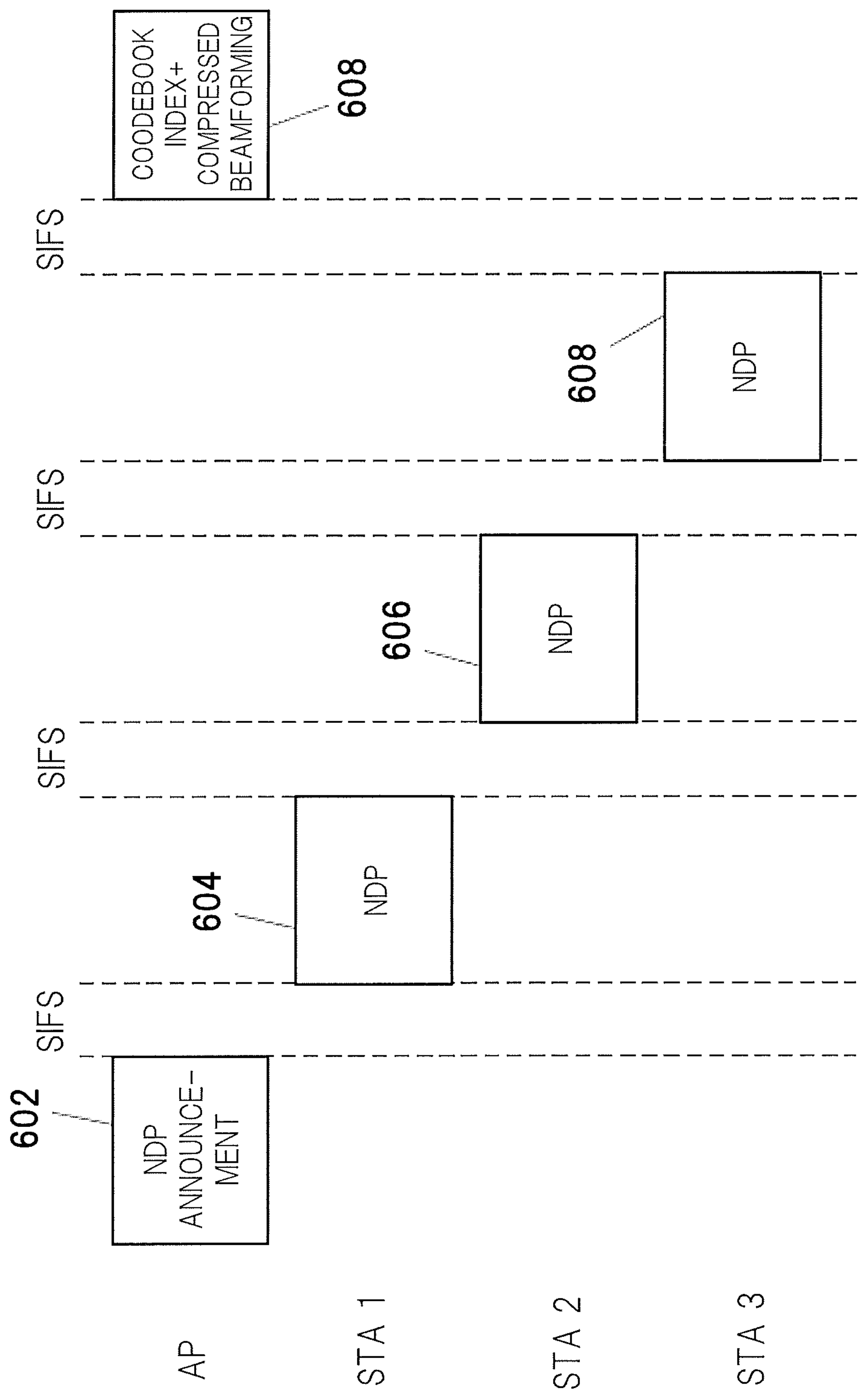
AP
STA 1
STA 2
STA 3
NDP ANNOUNCE-MENT
602
SIFS
NDP
604
SIFS
NDP
606
SIFS
NDP
608
SIFS
COODEBOOK INDEX+ COMPRESSED BEAMFORMING
608

FIG. 7

$$
\begin{array}{l}
\text{INDEX } 0 \\
\text{INDEX } 1 \\
\text{INDEX } 2 \\
\vdots \\
\text{INDEX } I-1
\end{array}
\begin{bmatrix}
c_{00} & c_{01} & c_{02} & c_{03} \\
c_{10} & c_{11} & c_{12} & c_{13} \\
c_{20} & c_{21} & c_{22} & c_{23} \\
 & \vdots & & \\
c_{(I-1)0} & c_{(I-1)1} & c_{(I-1)2} & c_{(I-1)3}
\end{bmatrix}
$$

FIG.8

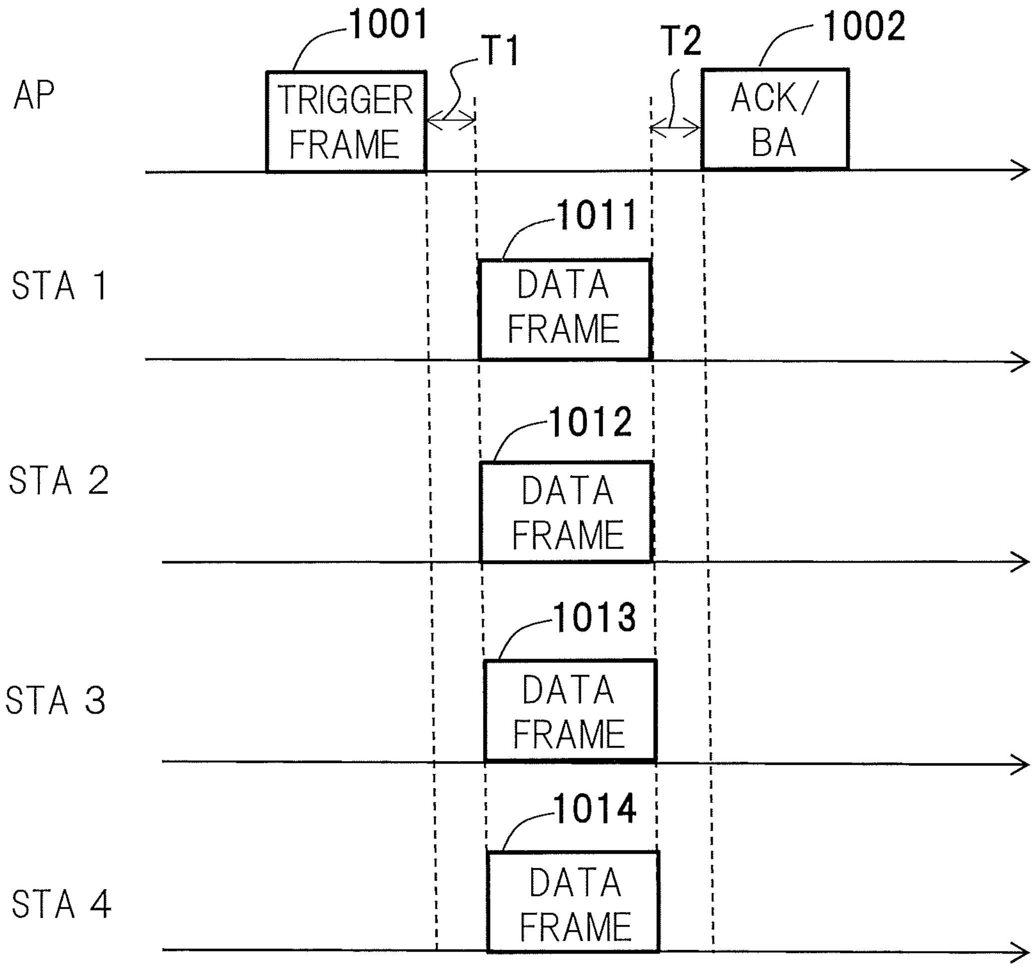
1001
T1
T2
1002
AP
TRIGGER FRAME
ACK/ BA
1011
STA 1
DATA FRAME
1012
STA 2
DATA FRAME
1013
STA 3
DATA FRAME
1014
STA 4
DATA FRAME

FIG.9

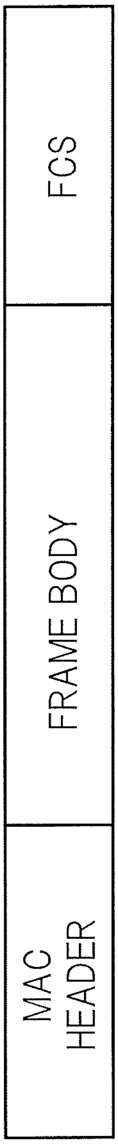

FIG.10A

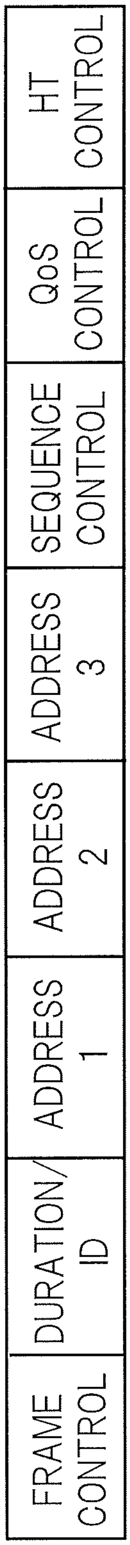

FIG.10B

ELEMENT ID	LENGTH	INFORMATION

FIG.11

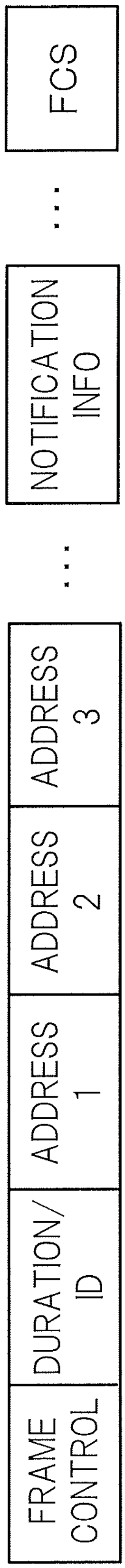

FIG.12A

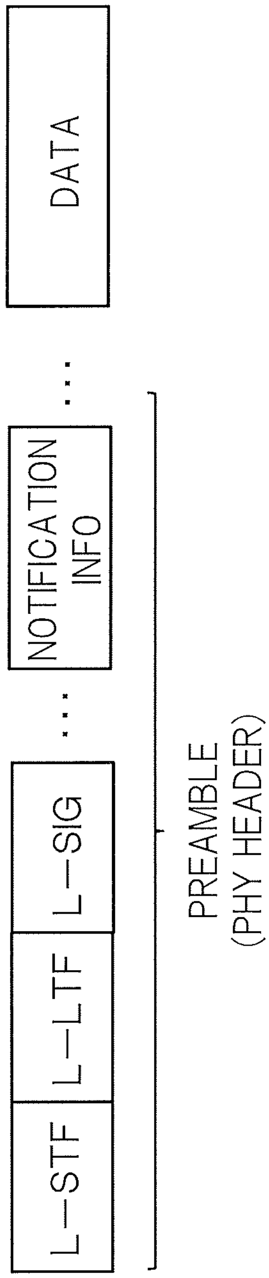

FIG.12B

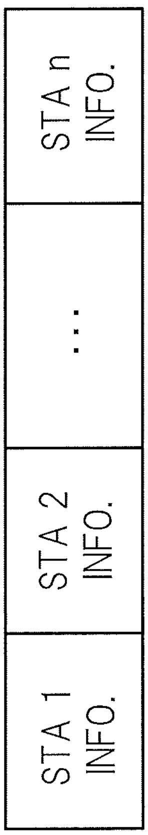

FIG.13A

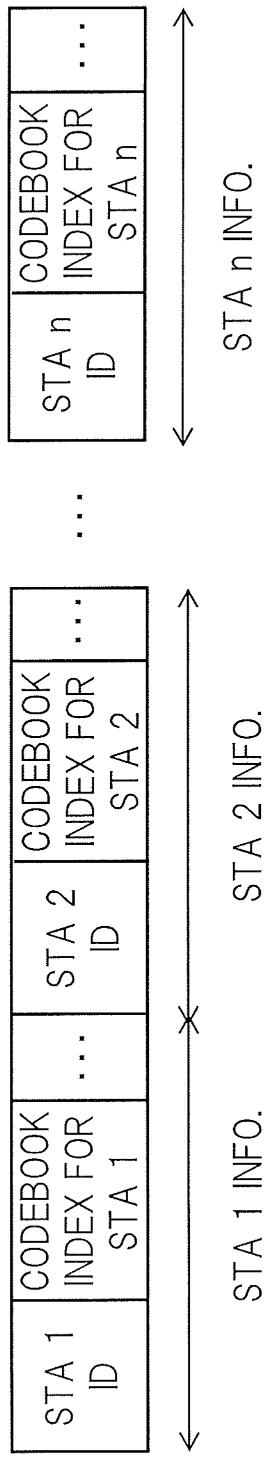

FIG.13B

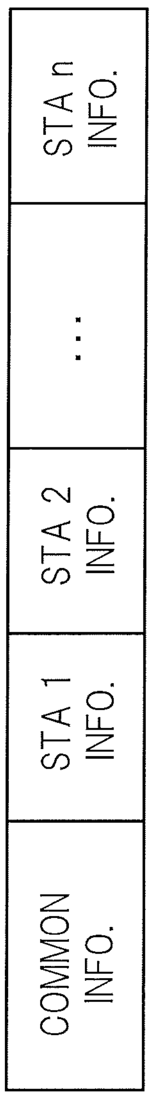

FIG.14A

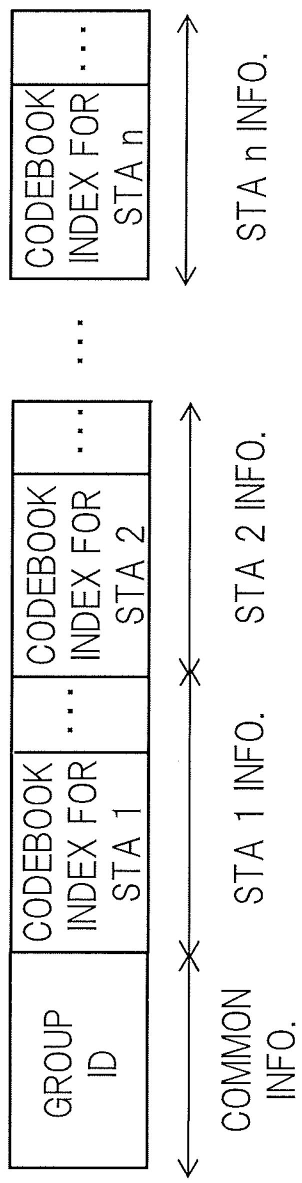

FIG.14B

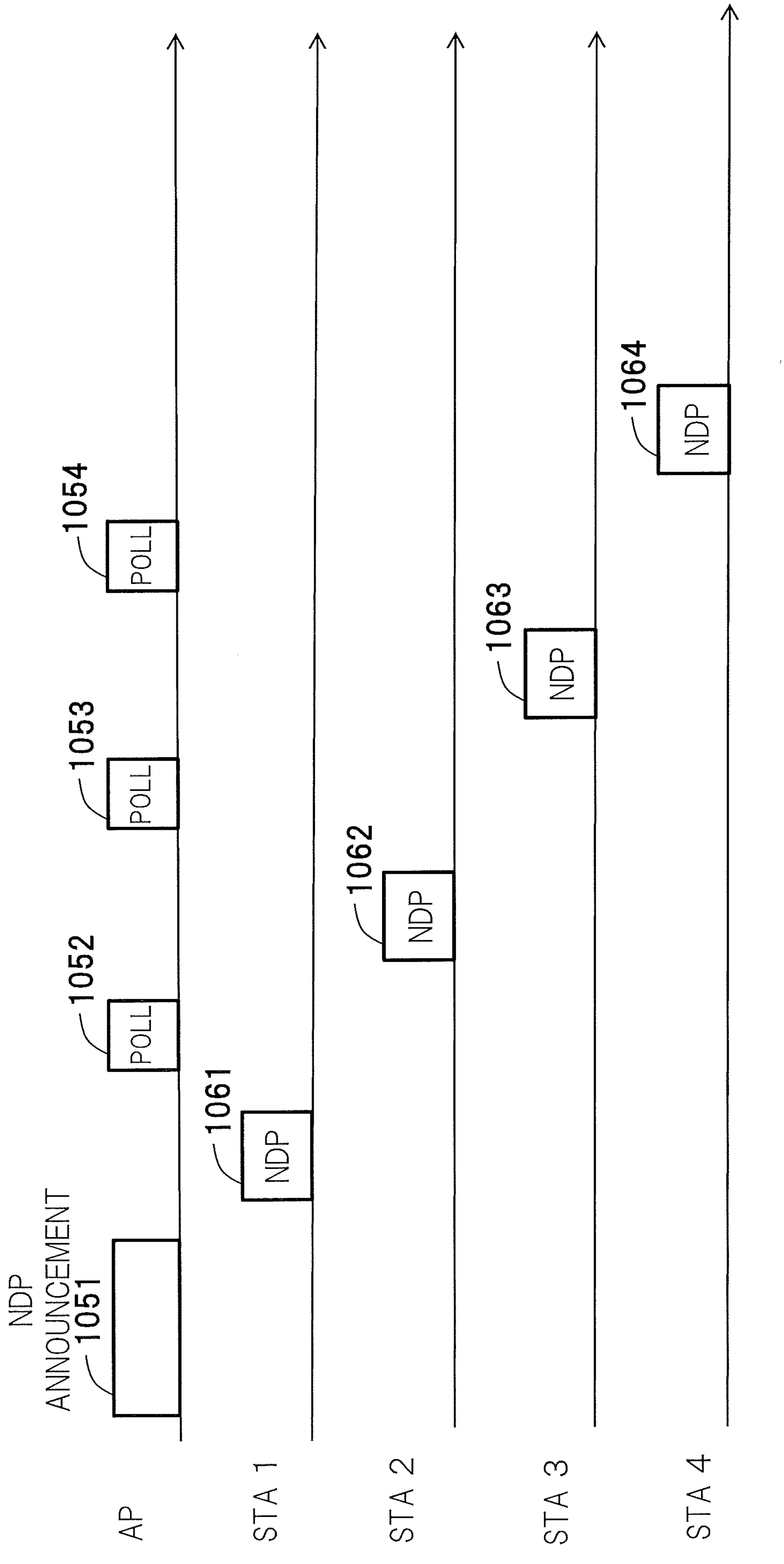
NDP ANNOUNCEMENT
1051
1052
POLL
1053
POLL
1054
POLL
1061
NDP
1062
NDP
1063
NDP
1064
NDP
AP
STA 1
STA 2
STA 3
STA 4

FIG.15

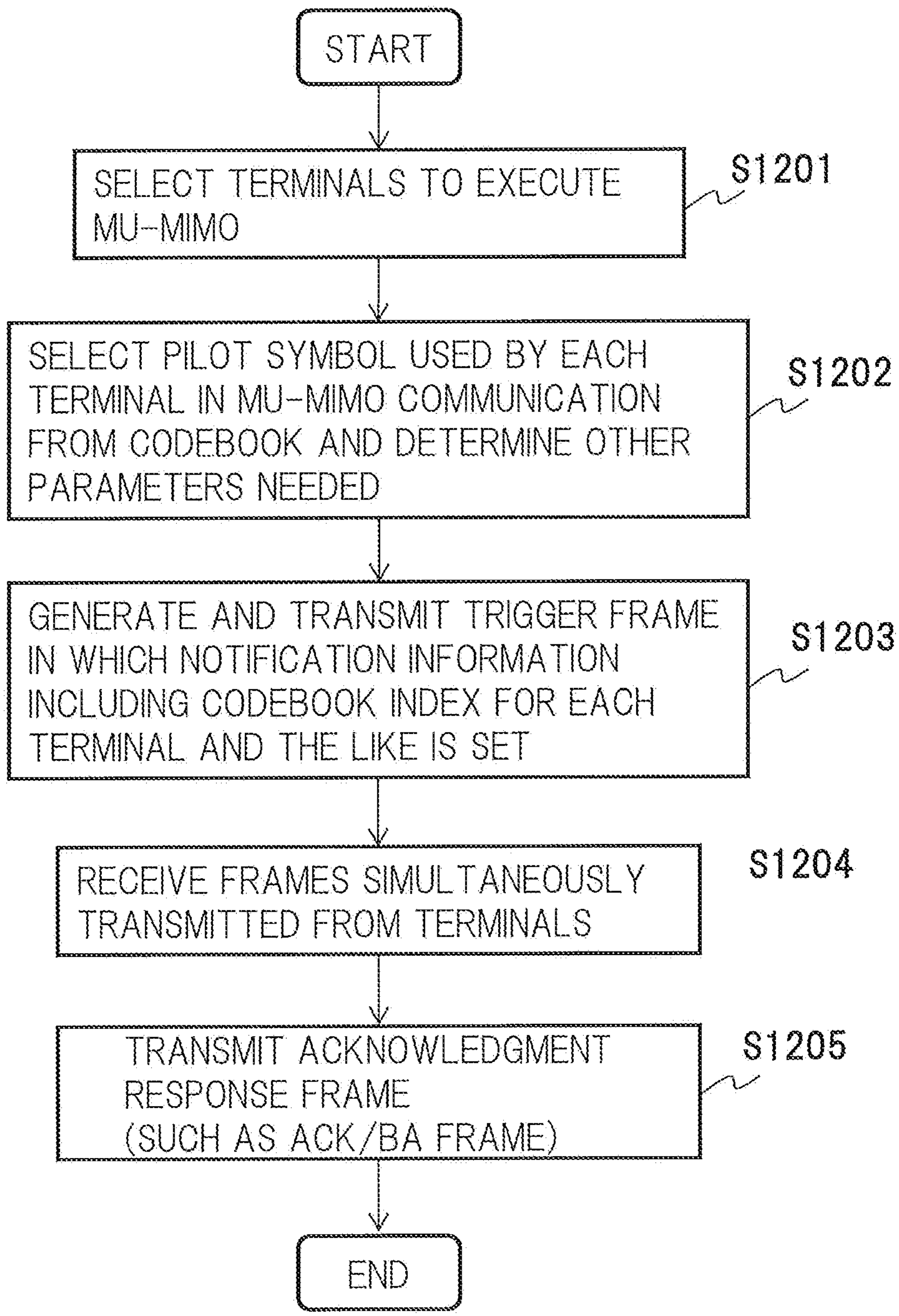
START
SELECT TERMINALS TO EXECUTE MU-MIMO
S1201
SELECT PILOT SYMBOL USED BY EACH TERMINAL IN MU-MIMO COMMUNICATION FROM CODEBOOK AND DETERMINE OTHER PARAMETERS NEEDED
S1202
GENERATE AND TRANSMIT TRIGGER FRAME IN WHICH NOTIFICATION INFORMATION INCLUDING CODEBOOK INDEX FOR EACH TERMINAL AND THE LIKE IS SET
S1203
RECEIVE FRAMES SIMULTANEOUSLY TRANSMITTED FROM TERMINALS
S1204
TRANSMIT ACKNOWLEDGMENT RESPONSE FRAME (SUCH AS ACK/BA FRAME)
S1205
END

FIG.16

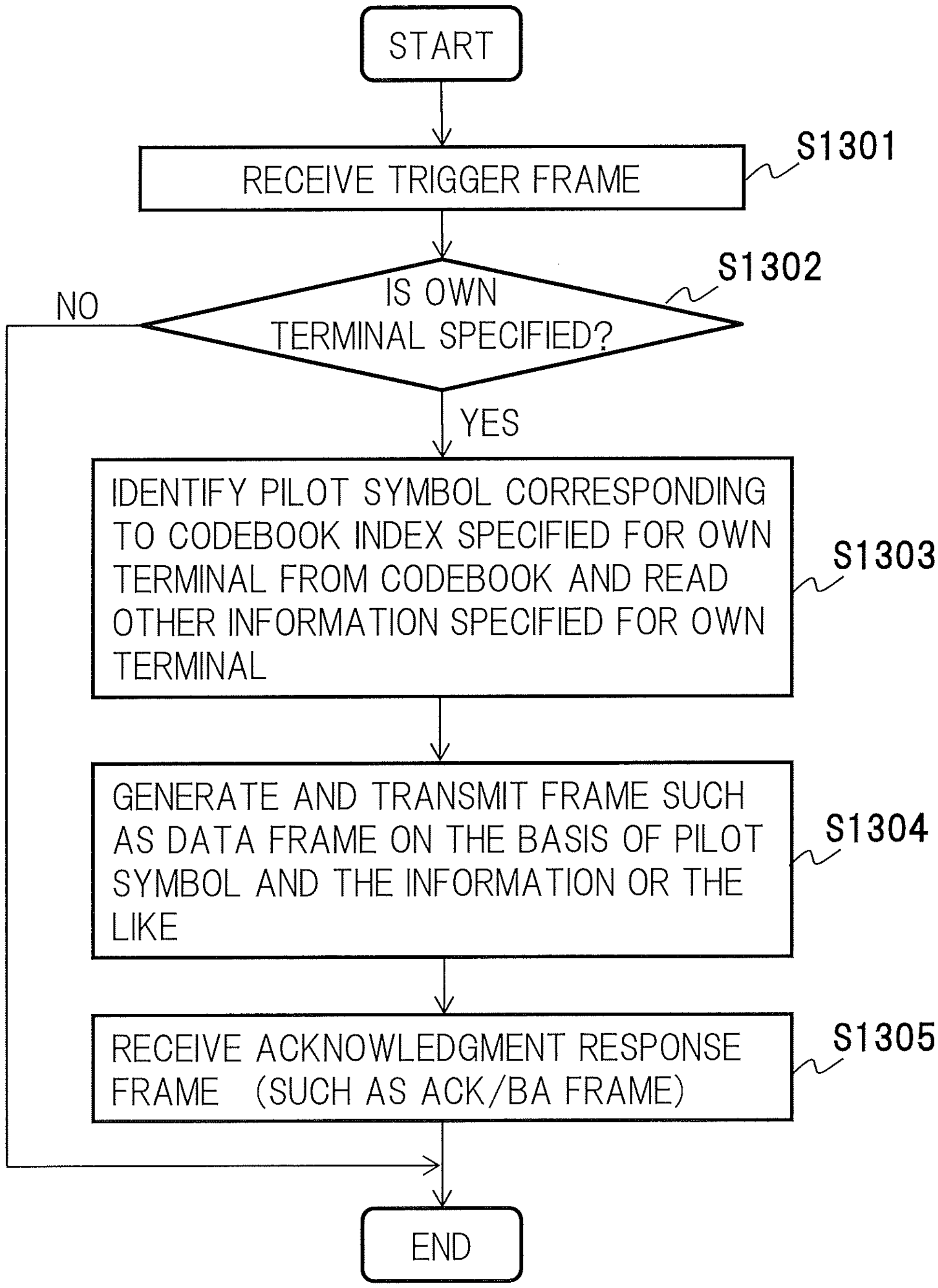
START
RECEIVE TRIGGER FRAME
S1301
IS OWN TERMINAL SPECIFIED?
S1302
NO
YES
IDENTIFY PILOT SYMBOL CORRESPONDING TO CODEBOOK INDEX SPECIFIED FOR OWN TERMINAL FROM CODEBOOK AND READ OTHER INFORMATION SPECIFIED FOR OWN TERMINAL
S1303
GENERATE AND TRANSMIT FRAME SUCH AS DATA FRAME ON THE BASIS OF PILOT SYMBOL AND THE INFORMATION OR THE LIKE
S1304
RECEIVE ACKNOWLEDGMENT RESPONSE FRAME (SUCH AS ACK/BA FRAME)
S1305
END

FIG.17

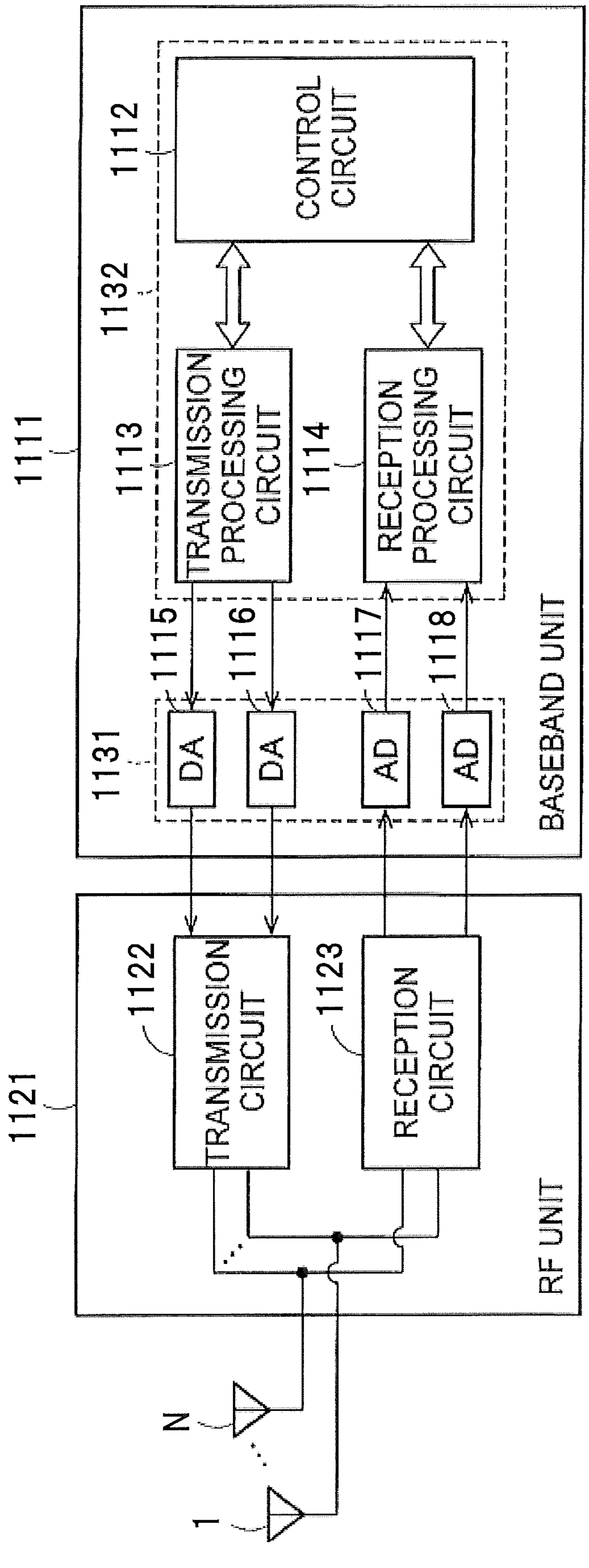
1111
1112
CONTROL CIRCUIT
1132
1113
TRANSMISSION PROCESSING CIRCUIT
1114
RECEPTION PROCESSING CIRCUIT
1115
1116
1117
1118
1131
DA
DA
AD
AD
BASEBAND UNIT
1121
1122
TRANSMISSION CIRCUIT
1123
RECEPTION CIRCUIT
RF UNIT
N
1

FIG.18

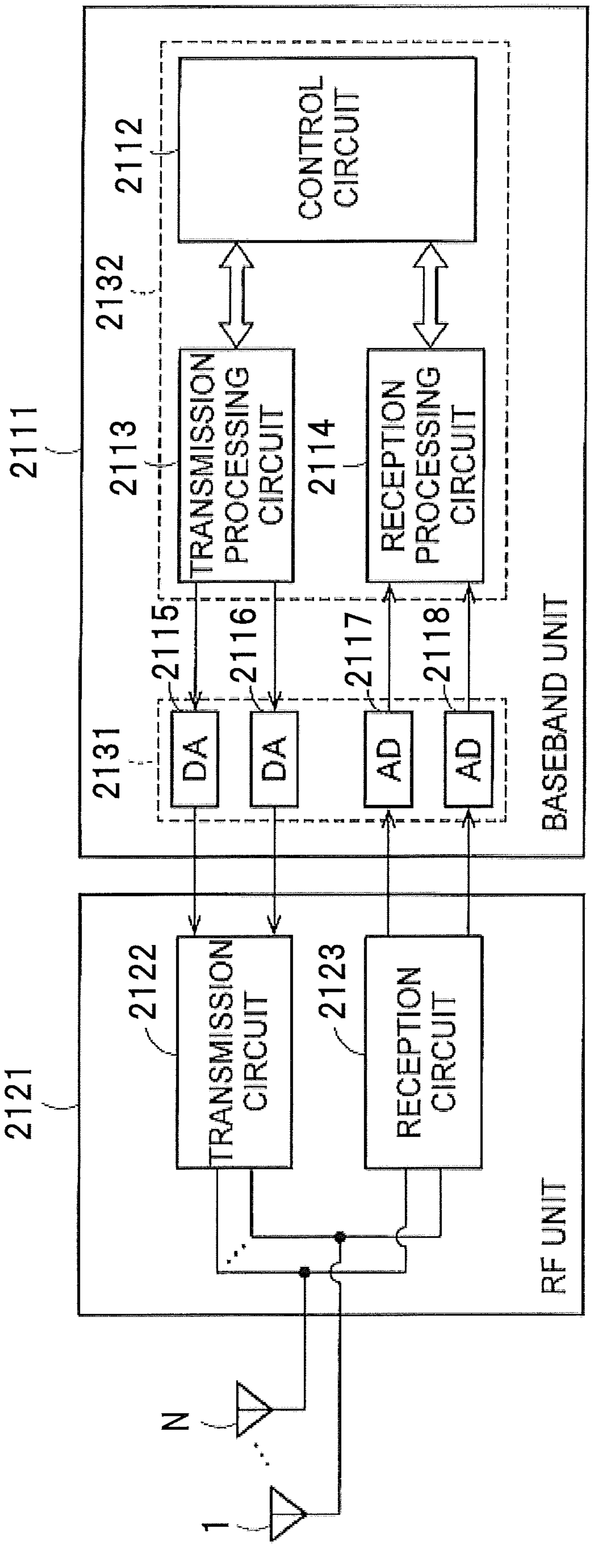
2111
2112
CONTROL CIRCUIT
2132
2113
TRANSMISSION PROCESSING CIRCUIT
2114
RECEPTION PROCESSING CIRCUIT
2115
2116
2117
2118
2131
DA
DA
AD
AD
BASEBAND UNIT
2121
2122
TRANSMISSION CIRCUIT
2123
RECEPTION CIRCUIT
RF UNIT
N
1

FIG.19

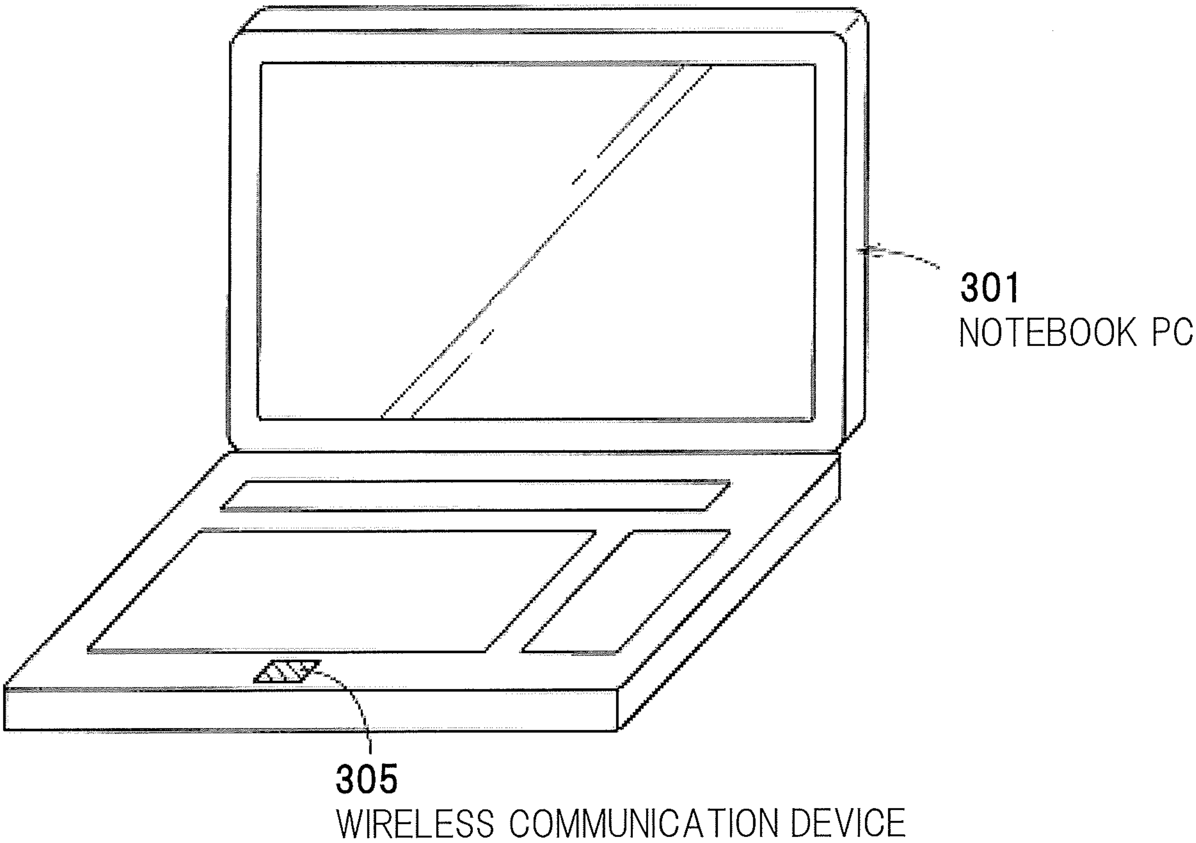

FIG.20A

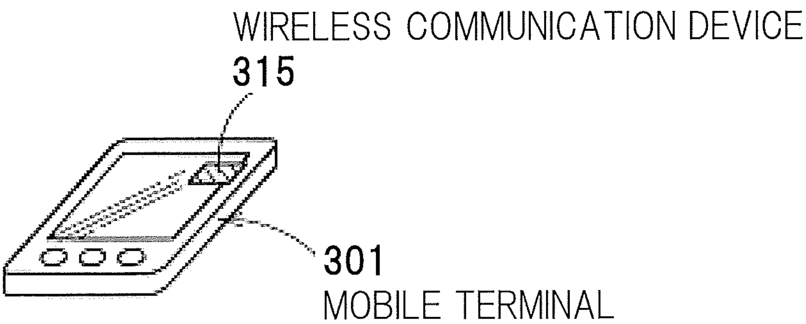

FIG.20B

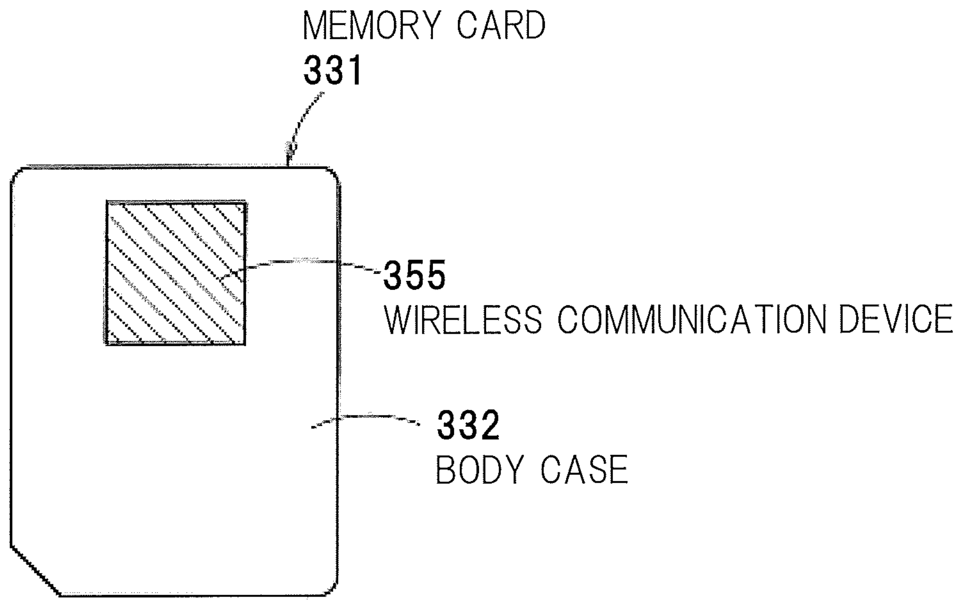
MEMORY CARD
331
355
WIRELESS COMMUNICATION DEVICE
332
BODY CASE

FIG.21

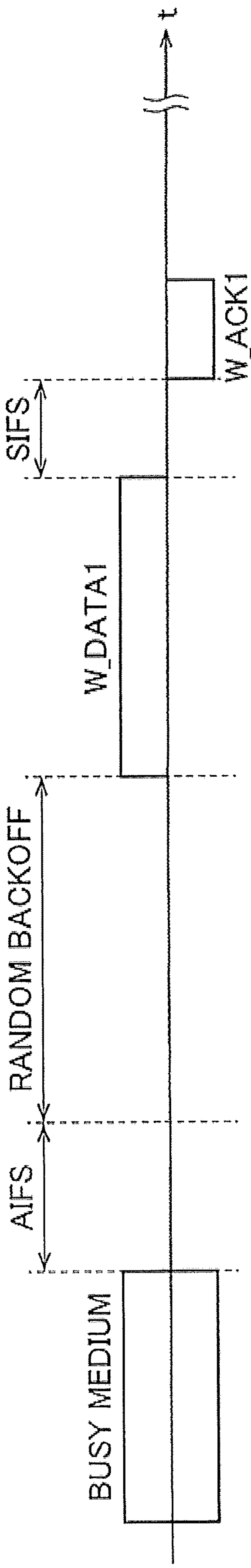

FIG.22

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2015/052422

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/04 H04L5/00 H04L27/26 H04W72/12
ADD. H04L27/00 H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B H04L H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GAMIER C ET AL: "Performance of an OFDM-SDMA based system in a time-varying multi-path channel", IEEE 54TH VEHICULAR TECHNOLOGY CONFERENCE. VTC FALL 2001. PROCEEDINGS 7-11 OCT. 2001 ATLANTIC CITY, NJ, USA; [IEEE VEHICULAR TECHNOLGY CONFERENCE], IEEE, IEEE 54TH VEHICULAR TECHNOLOGY CONFERENCE. VTC FALL 2001. PROCEEDINGS (CAT. NO.01CH37211) IEEE P, vol. 3, 7 October 2001 (2001-10-07), pages 1686-1690, XP010562251, DOI: 10.1109/VTC.2001.956487 ISBN: 978-0-7803-7005-0	1,8,9, 14-16, 21,22, 26,27
Y	section IV (specifically IV. B); page 1688	2-7, 10-13, 17-20, 23-25

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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Date of the actual completion of the international search	Date of mailing of the international search report
30 March 2016	06/04/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Vucic, Jelena

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