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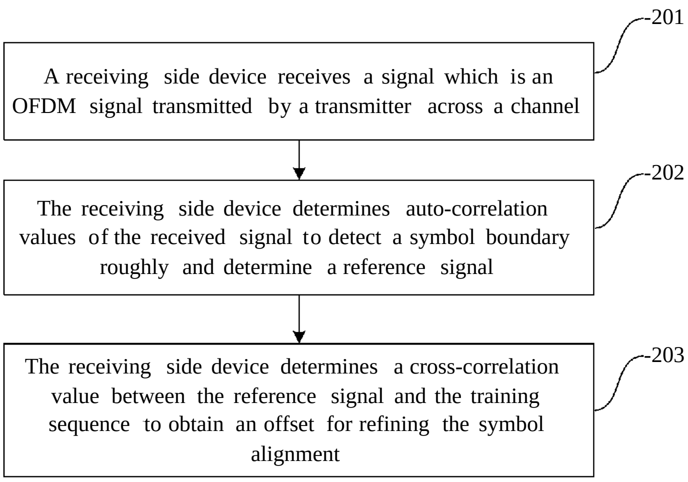

FIG. 2

(57) Abstract: A method and a device for symbol alignment are provided. The method includes: receiving a signal which is an orthogonal frequency division multiplexed (OFDM) signal comprising a preamble having a first number repeated copies of an intact first sequence and an intact second sequence whose values are negative of those of the first sequence ; determining auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal ; and determining a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment. Symbol alignment can be achieved successfully even in the presence of impulse noise (IN) as long as a portion of the received signal corresponding to the second sequence and at least one portion of the received signal corresponding to the first sequence are not severely distorted by IN.

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METHOD AND DEVICE FOR SYMBOL ALIGNMENT IN POWER LINE COMMUNICATION SYSTEM

TECHNICAL FIELD

[0001] The present invention relates to the field of communications technologies, and in particular, to a method and a device for symbol alignment in a power line communication system.

BACKGROUND

[0002] Power line communication (PLC) is a communications technology to transmit data through power lines that are used for electrical power distribution. Typically, electrical power is transmitted over high voltage transmission lines, distributed over medium voltage, and used inside commercial or residential buildings at lower voltages. In the past years power line communication has attracted a lot of attention, since it requires no extra deployment cost.

[0003] Orthogonal frequency division multiplexing (OFDM) transmission technique is adopted by PLC systems such as Homeplug, Ghn and IEEE1901. OFDM systems are robust to frequency selective fading channels when each subcarrier has a bandwidth narrow enough to experience flat fading for such channels. The frame structure of a PLC system can comprise a preamble used for signal detection and synchronization, possibly followed by a sequence of data symbols. To identify the end of the frame without data symbols or the boundary between the preamble and the data symbols in order to decode the data symbols, symbol alignment is done to correctly identify the end of the preamble.

[0004] A lot of existing symbol alignment methods being proposed for wireless communication systems cannot be applied to the PLC systems directly. Recently symbol alignment applicable to power line communication has been proposed.

[0005] In an existing method for symbol alignment in power line communication system, the preamble includes a first section that is a repeated copy of a training sequence with known structure in both time and frequency domains and a second section whose values are the negative of those of the training sequence and symbol alignment is done by exploiting the properties of the preamble that the first section is a replica of the training sequence and the second section is negatively correlated with the training sequence.

[0006] In another existing method for symbol alignment in power line communication system, cross-correlation between received signals and local copy of preamble symbols are used to align OFDM symbols. Then symbol alignment is done by searching for the transition of different patterns of preamble. Similarly, this is also done by exploiting the phase difference of preamble with different patterns in frequency domain.

[0007] However PLC systems may suffer from impulse noise (Impulse Noise, IN), which is caused by switch-on/off or operation of electrical appliances plugged to the power line, because the effects of impulse noise may not be taken into account when performing symbol alignment using existing methods and the preamble distorted by IN may still be used for phase calculation which will lead to symbol alignment error.

SUMMARY

[0008] Embodiments of the present invention provide a method and a device for symbol alignment in power line communication system, which take into account the effects of impulse noise and therefore is more robust to IN.

[0009] According to embodiments of the present invention, a method for symbol alignment includes:

receiving, by a receiving side device, a signal which is an orthogonal frequency division multiplexed (OFDM) signal transmitted by a transmitter across a channel, wherein the OFDM signal comprises a preamble having a first section including a first number repeated copies of an intact first sequence and a second section including an intact second sequence, where the first number is an integer larger than 0, and values of the second sequence is a negative of those of the first sequence;

determining, by the receiving side device, auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal; and

determining, by the receiving side device, a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment.

[0010] In an embodiment, determining, by the receiving side device, the auto-correlation values of the received signal to detect the symbol boundary roughly and determine the reference signal includes:

for case n-1, n-2,. .., 0 where a distance between a center of a first sliding window and a center of a second sliding window is 2K, 3K, ……, (n+l)K respectively, wherein K is the number of samples the first sequence has, n equals the first number, and both the first sliding window and the second sliding window have a length of K: shifting, by the receiving side device, the first sliding window and the second sliding window within the received signal in parallel and determining the auto-correlation value by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the second sliding window; and

determining, by the receiving side device, the symbol boundary and the reference signal based on a minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window.

[0011] In an embodiment, when mK samples are received, the receiving side device starts to determine the auto-correlation values for case n+2-m and determines the auto-correlation values for case n+3-m,. ..,n-l in parallel, wherein m=3,. ..,n+2.

[0012] In an embodiment, when (n+2)K samples are received, the receiving side device starts to determine the auto-correlation values for each of the n cases simultaneously.

[0013] In an embodiment, the shifting, by the receiving side device, of the first sliding window and the second sliding window within the received signal and determining the auto-correlation values by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the second sliding window includes:

determining, by the receiving side device, for each case, the auto-correlation values by determining the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with a first sample of the first sliding window being y_0 for each of the cases and a first sample of the second sliding window being $y_{(n+i)K}$ for case 0, y_{nK} for case 1,……, y_{3k} for case n-2 and y_{2K} for case n-1;

if the auto-correlation values of all cases are greater than or equal to a predetermined threshold, shifting the first sliding window and the second sliding window in parallel by a first step at a time and determining the auto-correlation values for each of the cases until the auto-correlation value for at least one case is less than the predetermined threshold;

continuing to shift the first sliding window and the second sliding window in parallel by a second step at a time for a predetermined range and determining the auto-correlation value for each of the cases and recording the auto-correlation value and the position of the second sliding window corresponding to the auto-correlation value for each of the cases.

[0014] In an embodiment, a size of the first step is determined according to a difference between a current minimum auto-correlation value among the determined auto-correlation values of all cases and the predetermined threshold.

[0015] In an embodiment, a size of the second step is equal to or smaller than the size of the first step.

[0016] In an embodiment, determining, by the receiving side device, the symbol boundary and the reference signal based on a minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window includes:

determining the minimum auto-correlation value among the determined auto-correlation values of all cases;

determining positions of a first sliding window and a second sliding window associated with the minimum auto-correlation value;

determining the symbol boundary based on the position of the second sliding window associated with the minimum auto-correlation value; and

taking a sequence being formed by samples within the first sliding window associated with the minimum auto-correlation value as the reference signal.

[0017] In an embodiment, determining, by the receiving side device, a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment includes:

circularly shifting the reference signal and determining the cross-correlation value between the first sequence and the circularly shifted version of the reference signal for each shifted distance; and

determining the shifted distance with a maximum cross-correlation value among the determined cross-correlation values of all shifted distances as the offset for refining the symbol alignment.

[0018] In an embodiment, determining, by the receiving side device, a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment includes:

obtaining, by the receiving side device, a first frequency signal transformed from the first sequence, and a second frequency signal transformed from the reference signal;

determining, by the receiving side device, for each shifted distance, the cross-correlation value between the first frequency signal and the second frequency signal, wherein the shifted distance is an integer larger than -K/2 but less than K/2, wherein K is a number of samples the first sequence has;

determining, by the receiving side device, a maximum cross-correlation value among the determined cross-correlation values of all shifted distances; and

taking, by the receiving side device, the shifted distance giving the maximum cross-correlation value as the offset for refining the symbol alignment.

[0019] In an embodiment, the predetermined range is less than K.

[0020] In an embodiment, in the determining of the cross-correlation value between the first frequency signal and the second frequency signal, subcarriers between [2, 30] MHz frequency carry more weight than other carriers.

[0021] According to embodiments of the present invention, a device for symbol alignment includes:

a receiving unit, configured to receive a signal which is an orthogonal frequency division multiplexed (OFDM) signal transmitted by a transmitter across a channel, wherein the OFDM signal comprises a preamble having a first section including a first number repeated copies of an intact first sequence and a second section including an intact second sequence, where the first number is an integer larger than 0, and values of the second sequence is a negative of those of the first sequence;

a first aligning unit, configured to determine auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal; and

a second aligning unit, configured to determine a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment.

[0022] In an embodiment, the first aligning unit comprises:

an auto-correlation determining subunit, configured to, for case n-1, n-2,. .., 0, shift a first sliding window and a second sliding window within the received signal in parallel and determine the auto-correlation value by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the first and second sliding window, wherein a distance between a center of the first sliding window and a center of the second sliding window is 2K, 3K, ..., (n+l)K for case n-1, n-2,. .., 0 respectively, wherein K is a number of samples the first sequence has, n equals the first number, and both the first sliding window and the second sliding window have a length of K samples; and

an aligning subunit, configured to determine the symbol boundary and the reference signal based on a minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the first and second sliding window.

[0023] In an embodiment, the auto-correlation determining subunit is configured to, when mK samples are received, start to determine the auto-correlation values for case n+2-m and determine the auto-correlation values for case n+3-m,. ..,n-l, which have already started, in parallel with the case n+2-m, wherein m=3,. ..,n+2.

[0024] In an embodiment, the auto-correlation determining subunit is configured to, when (n+2)K samples are received, start to determine the auto-correlation values for each of the n cases simultaneously.

[0025] In an embodiment, the auto-correlation determining subunit is configured to:

determine, for each case, the auto-correlation values by determining the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with a first sample of the first sliding window being y_0 for each of the cases and a first sample of the second sliding window being $y_{(n+i)K}$ for case 0, y_{nK} for case 1,……, y_{3K} for case n-2 and $\mathbf{y_{2K}}$ for case n-1;

if the auto-correlation values of all cases are greater than or equal to a predetermined threshold, shift the first sliding window and the second sliding window in parallel by a first step at a time and determine the auto-correlation values for each of the cases until the auto-correlation value for at least one case is less than the predetermined threshold; and

continue to shift the first sliding window and the second sliding window in parallel by a second step at a time for a predetermined range and determine the auto-correlation value for each of the cases and recording the auto-correlation value and the position of the second sliding window corresponding to the auto-correlation value for each of the cases.

[0026] In an embodiment, a size of the first step is determined according to a difference between a current minimum auto-correlation value among the determined auto-correlation values of all the cases and the predetermined threshold.

[0027] In an embodiment, a size of the second step is equal to or smaller than the size of the first step.

[0028] In an embodiment, the aligning subunit is further configured to:

determine the minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window;

determine positions of a first sliding window and a second sliding window associated with the minimum auto-correlation value;

determine the symbol boundary based on the position of the second sliding window associated with the minimum auto-correlation value; and

take a sequence being formed by samples within the first sliding window associated with the minimum auto-correlation value as the reference signal.

[0029] In an embodiment, the second aligning unit comprises:

a cross-correlation determining subunit, configured to circularly shift the reference signal and determine the cross-correlation value between the first sequence and the circularly shifted version of the reference signal for each shifted distance; and

an offset determining subunit, configured to determine the shifted distance with a maximum cross-correlation value among the determined cross-correlation values of all shifted distances as the offset for refining the symbol alignment.

[0030] In an embodiment, the second aligning unit further comprises a transforming subunit, configured to obtain a first frequency signal transformed from the first sequence, and a second frequency signal transformed from the reference signal;

the cross-correlation determining subunit is configured to determine, for each shifted distance, the cross-correlation value between the first frequency signal and the second frequency signal, wherein the shifted distance is an integer larger than

-K/2 but less than K/2, wherein K is a number of samples the first sequence has;

the offset determining subunit is configured to determine, a maximum cross-correlation value among the determined cross-correlation values of all shifted distances; and take the shifted distance giving the maximum cross-correlation value as the offset for refining the symbol alignment.

[0031] In an embodiment, the predetermined range is less than K.

[0032] In an embodiment, in the determining of the cross-correlation value between the first frequency signal and the second frequency signal, subcarriers between [2, 30] MHz frequency carry more weight than other carriers.

[0033] In the embodiments of the present invention, a device receiving an OFDM signal performs coarse symbol alignment by determining auto-correlation values of a received signal to detect a symbol boundary roughly and determine a reference signal without or least distorted by IN, then determines the cross-correlation value between the reference signal and the training sequence and obtains an offset that can be used to refine the coarse symbol alignment. Symbol alignment can be achieved successfully even in the presence of IN as long as a portion of the received signal corresponding to the second sequence and at least one portion of the received signal corresponding to the first sequence are not severely distorted by IN.

BRIEF DESCRIPTION OF DRAWINGS

[0034] FIG. 1a is a schematic diagram of a preamble structure and a data symbol according to an embodiment of the present invention;

[0035] FIG 1b is a schematic diagram of a preamble structure and a data symbol of a signal received at a receiving side according to an embodiment of the present invention;

[0036] FIG. 2 is a schematic flow diagram of a method for symbol alignment according to an embodiment of the present invention;

[0037] FIG. 3 is a schematic flow diagram of coarse symbol alignment in a method for symbol alignment according to an embodiment of the present invention;

[0038] FIG. 4 is a schematic diagram showing different cases of determining auto-correlation values for coarse symbol alignment in a method for symbol alignment according to an embodiment of the present invention;

[0039] FIG. 5 is a schematic flow diagram of coarse symbol alignment in a method for symbol alignment according to an embodiment of the present invention;

[0040] FIG. 6 is a schematic flow diagram of fine symbol alignment in a method for symbol alignment according to an embodiment of the present invention;

[0041] FIG. 7 is. a schematic structural diagram of a device for symbol alignment according to an embodiment of the present invention;

[0042] FIG. 8 is a schematic structural diagram of a device for symbol alignment according to another embodiment of the present invention;

[0043] FIG. 9 is a schematic structural diagram of a device for symbol alignment according to still another embodiment of the present invention;

[0044] FIG 10 is a schematic structural diagram of a device for symbol alignment according to still another embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0045] The technical solution of the present invention is hereinafter described in detail with reference to the accompanying drawings. It is evident that the embodiments are only some exemplary embodiments of the present invention, and the present invention is not limited to such embodiments. Other embodiments that those skilled in the art obtain based on embodiments of the present invention also all within the protection scope of the present invention.

[0046] Preamble is usually a sequence transmitted at the head of a data packet. The preamble may be standalone, or followed by one or more data symbols. A preamble followed by a data symbol is taken as an example for illustration in the following; however, embodiments of the present invention are not limited thereto. FIG. 1a shows a schematic structural diagram of a preamble after windowing and overlapping process, according to an embodiment of the present invention. As can be seen from FIG. la, the preamble includes two sections followed by a data symbol, where the first section is a repeated copy of a first sequence SI, i.e. a training sequence, with known structure in both time and frequency domains, and the second section is a second sequence S2, whose values are the negative of those of the training sequence SI. Both SI and S2 have K samples. As shown in FIG. la, in this embodiment, without loss of generality, there are six intact Sis in the first section and one S2 in the second section. In general, the present invention will work for preamble structure composed of any positive integer of intact Sis and one S2.

[0047] At a transmitting side, an orthogonal frequency division multiplexed (OFDM) signal with a preamble having a structure as shown in FIG. 1a is transmitted. The OFDM signal is transmitted across a channel and then, at a receiving side, a signal with a preamble is received. For notation simplicity, as shown in FIG. lb, the portion of the received signal corresponding to Sx (x=l, 2) is denoted as Yx (x=l, 2). Specifically, the portion of the received signal corresponding to the first intact SI is denoted as Y10 and that corresponding to the second SI is denoted as Yll etc. The received signal corresponding to the intact S2 is denoted as Y2. Each sample of the received signal is denoted as y_m. The receiving side device uses the preamble to perform symbol alignment with effects of impulse noises being considered.

[0048] The method for symbol alignment according to the embodiments of the present invention is performed by a receiving side device, which may be any receiver for signals with preamble structure as described above such as Ghn and Homeplug compatible receiver. Besides PLC systems, the method for symbol alignment according to the embodiments of the present invention can also be employed in other systems with frame structure as described above and in FIG 1.

[0049] The method for symbol alignment according to the embodiments of the present invention mainly consists of two stages. In the first stage, coarse symbol alignment is performed by determining the auto-correlation values of the received signal in multiple cases. Symbol boundary is roughly detected when the auto-correlation value reaches the minimum. A portion of the received signal giving the minimal auto-correlation value is then considered as a reference signal. When the preamble is followed by a data symbol, the symbol boundary refers to a boundary between the preamble and the data symbol. When the preamble is standalone without data symbols, the symbol boundary refers to the end of the preamble. In the second stage, coarse symbol alignment can be refined by cross-correlation between the reference signal and the original training sequence.

[0050] FIG. 2 shows a schematic flow diagram of a method for symbol alignment according to an embodiment of the present invention. As shown in FIG. 2, a method for symbol alignment according to this embodiment includes the following steps:

[0051] Step 201: A receiving side device receives a signal which is an OFDM signal transmitted by a transmitter across a channel; the OFDM signal transmitted by the transmitter has a preamble with a structure as shown in FIG. la, and the OFDM signal transmitted across a channel and received by the receiving side device has a preamble with a structure as shown in FIG. lb.

[0052] Step 202: The receiving side device determines auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal.

[0053] In this step, coarse symbol alignment is performed by auto-correlation. Correlation values of different portions of the received signal are determined with each portion having a same length as the training sequence. Symbol boundary is roughly detected when the auto-correlation value reaches minimum. Once coarse symbol alignment succeeds, the two portions of the received signal which give the minimal auto-correlation value are found, where one portion can be determined to correspond to a SI included in the first section of the transmitted OFDM signal and the other one to correspond to a S2 included in the second section of the transmitted OFDM signal according to the known structure of the preamble. Then the portion corresponding to S2 can be used to determine the symbol boundary, while the portion corresponding to SI, which is a clean Yl without or least distorted by impulse noise (IN) can be considered as the reference signal. In this embodiment, the preamble is followed by a data symbol as shown in FIG. la, and the symbol boundary refers to a boundary between the preamble and the data symbol. In an embodiment where the preamble is standalone without data symbols, the symbol boundary refers to the end of the preamble, and accordingly, the end of the preamble is detected roughly.

[0054] Step 203: The receiving side device determines a cross-correlation value between the reference signal and the training sequence to obtain an offset for refining the symbol alignment.

[0055] In this step, through determining the cross-correlation value between the reference signal and the training sequence, an offset is obtained to refine the coarse symbol alignment. After the coarse symbol alignment is refined by the offset, a data packet begins to be processed.

[0056] In this embodiment of the present invention, a receiving side device performs coarse symbol alignment by determining auto-correlation values of a received signal to detect a symbol boundary roughly and determine a reference signal without or least distorted by IN; then the receiving side device determines the cross-correlation value between the reference signal and the training sequence and obtains an offset that can be used to refine the coarse symbol alignment. Symbol alignment can be achieved successfully even in the presence of IN as long as Y2 and at least one Y1 are not severely distorted by IN.

[0057] FIG. 3 shows a schematic flow diagram of coarse symbol alignment in a method for symbol alignment according to an embodiment of the present invention. As shown in FIG. 3, coarse symbol alignment in this embodiment includes the following steps:

[0058] In Step 301, for case n-1, n-2, …, 0 where the distance between the center of a first sliding window and the center of a second sliding window is 2K, 3K, ……, (n+l)K respectively, where K is the number of samples a training sequence has, n is the number of intact Sis in the first section of the preamble of the transmitted OFDM signal and both the first window and the second window have a length of K samples: the receiving side device shifts in parallel the first sliding window and the second sliding window within the received signal and determines the auto-correlation value, i.e. determining the correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the second sliding window.

[0059] FIG. 4 illustrates six cases, i.e. case 0 to case 5, considered in the coarse symbol alignment for auto-correlation determination according to an embodiment of the present invention, with the six cases being distinguished based on the distance between the center of the first sliding window and the center of the second sliding window. In case 0 the distance between the centers of two sliding windows is 7K. In case 1 the distance between the centers of two sliding windows is 6K. In case 2 the distance between the centers of two sliding windows is 5K. In case 3 the distance between the centers of two sliding windows is 4K. In case 4 the distance between the centers of two sliding windows is 3K. And in case 5 the distance between the centers of two sliding windows decreases to 2K.

[0060] The number of cases considered in the coarse symbol alignment is equal to the number of intact Sis included in the first section of the transmitted preamble. In this embodiment, there are six intact Sis in the first section and thus the six cases as shown in FIG. 4 are considered. When the first section of the transmitted preamble includes more or less intact Sis, more or less cases can be considered accordingly. For example, if the first section has three intact Sis, three cases can be considered in the coarse symbol alignment, i.e. case 0 with the distance between the centers of two sliding windows being 4K, case 1 with the distance between the centers of two sliding windows being 3K, and case 2 with the distance between the centers of two sliding windows being 2K.

[0061] The auto-correlation values in each case are individually determined. For example, when six intact Sis are included in the transmitted preamble, six cases as shown in FIG. 4 can be considered. For case 0 and the first sample in the second sliding window being y_m, the auto-correlation value $\rho_{0,m}$ of the first sequence $\{y_{m-7K}, y_{m-7K+1}, \ldots, y_{m-6K-1}\}$ and the second sequence $\{y_m, y_{m+1}, \ldots, y_{m+K-1}\}$ is determined. Once the first sliding window and the second sliding window shift to the next sample and the first sample in the second sliding window becomes y_{m+1}, the auto-correlation value $\rho_{0,m+1}$ of the first sequence $\{y_{m-7K+1}, y_{m-7K+2}, \cdots, y_{m-6K}\}$ and the second sequence $\{y_{m+1}, y_{m+2}, \cdots, y_{m+K}\}$ is determined. More auto-correlation values are determined, with the two windows shifting further. Similarly, the auto-correlation values can be determined for other cases.

[0062] In an embodiment, the auto-correlation determination can start from the last case, i.e. the case n-1, because the distance between the centers of the two sliding windows is the shortest and the least amount of received samples are required for the auto-correlation determination in this case. For example, as shown in FIG. 4, in case 5, which is the last case of the six cases, the distance between the centers of the two sliding windows is 2K, thus 3K samples are required for the auto-correlation determination in this case, and thereby when 3K samples are received the auto-correlation determination can start. While, for case 4, the distance between the centers of two sliding windows is 3K, only 4K samples are required for the auto-correlation determination and thereby when 4K samples are received, the auto-correlation determination can start. And from this moment, the auto-correlation determination can proceed in parallel for case 5 and case 4. In general, when mK samples are received, the auto-correlation for case n+2-m starts and the auto-correlation for case n+3-m,. ..,n-1, which have already started, can be performed in parallel with that for case n+2-m, where m=3,…,n+2.

[0063] In another embodiment of the present invention, the auto-correlation determination under all n cases can start simultaneously when (n+2)K samples which are required for the auto-correlation determination in case 0 are received. For example, when six Sis are included in the preamble, n=6, for the first case, i.e. case 0, 8K samples are required for the auto-correlation determination. With 8K samples, y_0, y_1, …, y_{8K-1}, the auto-correlation determination can start in parallel for all six cases. The autocorrelation can start with the first sample of the first sliding window for all cases at y_0 and the first sample of the second sliding window at y_{7K}, y_{6K}, y_{5K}, y_{4K}, y_{3K}, y_{2K} for case 0, 1, 2, 3, 4, 5, respectively. Then, when the auto-correlation is determined under all six cases with the first sample of the first sliding window being y_0, the two sliding windows shift to the next sample with the first sample of the first sliding window becoming y_1, and the first sample of the second sliding window becoming y_{7K+1}, y_{6K+1}, y_{5K+1}, y_{4K+1}, y_{3K+1}, y_{2K+1} for case 0, 1, 2, 3, 4, 5 respectively and another auto-correlation is obtained. More auto-correlation values for all cases are determined when the two windows shift further to the next samples.

[0064] In Step 302, the receiving side device determines a symbol boundary and a reference signal based on the minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window.

[0065] According to the preamble structure that the values of S2 are the negative of those of SI, for each case, the auto-correlation value achieves minimum when the second sliding window exactly points to the position of Y2. Referring to FIG. 4, for each case, when the first and the second sliding windows shift to the positions of the windows with dotted line, the auto-correlation value achieves the minimum; at this time, the second sliding window exactly points to the position of Y2. Once the position of Y2 is known, coarse symbol alignment is achieved, and a clean Y1 without or least distorted by IN is also found. Specifically, among all the determined auto-correlation values for all the six cases for all positions, the minimum auto-correlation value and the associated positions of the first and second sliding window can be determined. The first sample of the second sliding window associated with the minimum auto-correlation value gives the starting point of Y2 and the samples within the first sliding window associated with the minimum auto-correlation value form the reference signal.

[0066] In this embodiment of the present invention, a receiving side device performs coarse symbol alignment by determining the auto-correlation values of the received signal in different cases, so as to detect a symbol boundary between the preamble and data symbols roughly and determine a reference signal without or least distorted by IN. If Y2 and at least one Y1 are not severely distorted by IN, coarse symbol alignment can be achieved. The effects of IN are effectively taken into account, enhancing the robustness of the coarse symbol alignment to IN. A reference signal without or least distorted by IN is provided, which can be used to improve the correctness and effectiveness of the cross-correlation in the second stage of fine symbol alignment, and to detect IN in other parts of the preamble.

[0067] FIG. 5 shows a schematic flow diagram of coarse symbol alignment in a method for symbol alignment according to an embodiment of the present invention.

[0068] In this embodiment, the auto-correlation values of the received signals are determined for n cases, i.e. from case 0 to case n-l,where n is the number of intact Sis included in the first section of the transmitted preamble, and n is an integer larger than 1. The distance between the center of the first sliding window and the center of the second sliding window is 2K for case n-1, 3K for case n-2, ……, nK for case 1 and (n+l)K for case 0, where K is the number of samples a training sequence has. Both the first window and the second window have a length of K samples.

[0069] As shown in FIG. 5, coarse symbol alignment includes following steps:

[0070] In Step 501, after receiving (n+2)K samples, i.e. y_0, yi, …, $y_{(n+2)K-i}$, for each of the n cases, the receiving side device starts to determine the auto-correlation value, which is the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with the first sample of the first sliding window being y_0 for each case and the first sample of the second sliding window being $y_{(n+i)K}$ for case 0, y_{nK} for case 1,……, y_{3k} for case n-2 and y_{2K} for case n-1.

[0071] In Step 502, if the auto-correlation values of all cases are greater than or equal to a predetermined threshold, the receiving side device continues to shift the first sliding window and the second sliding window in parallel by one first step for each case and determine the auto-correlation value for each case until the auto-correlation value for at least one case is less than the predetermined threshold;

[0072] In this step, if all the auto-correlation values in each case are greater than or equal to the predetermined threshold, the current position of the second sliding window is relatively far from Y2; the receiving side device keeps shifting the two windows and determining the auto-correlation values for each case.

[0073] If no other impairment such as sampling frequency offsets or IN exists, the minimum auto-correlation value mainly depends on the background noise level. With high signal-noise-ratio (SNR), the minimum auto-correlation value can reach -1. While in low SNR case, its magnitude can be much less than 1. To deal with the low SNR case, the predetermined threshold can be set to an appropriate value between 0 and -1.

[0074] The size of the first step by which the two windows are shifted can be varied, to speed up the coarse symbol alignment. In an embodiment, a size of the first step can be determined according to the difference between the current minimum auto-correlation value of all cases and the predetermined threshold. Generally, a large difference between the current minimum auto-correlation value and the predetermined threshold indicates a large distance from the current position of the second sliding window to the position of Y2. Therefore, when the difference is comparatively large, a big step size can be adopted. With the difference decreasing, the step size can be smaller.

[0075] In Step 503, the receiving side device continues to shift the first sliding window and the second sliding window in parallel by one second step at a time for a predetermined range and determine the auto-correlation value for all cases and record the auto-correlation value and position of the second sliding window corresponding to the auto-correlation value for all cases. The second step should be smaller than or equal to the first step and can be set to be one sample as an example.

[0076] Step 503 is done only when the auto-correlation value for at least one case among all the cases is less than the predetermined threshold. When the auto-correlation value for at least one case among all the cases is less than the predetermined threshold, which usually means the current position of the second sliding window is close to Y2, the receiving side device continues to shift the two windows one second step at a time for a predetermined range and determine the auto-correlation values for all cases in order to determine the position of Y2. The predetermined range can be chosen to be less than K such as K/2 etc.

[0077] In Step 504, the receiving side device determines the minimum auto-correlation value among all the auto-correlation values determined for all cases in the predetermined shift range, determines the positions of the first sliding window and the second sliding window associated with the minimum auto-correlation value, determines the symbol boundary based on the position of the second sliding window associated with the minimum auto-correlation value, and takes a sequence, which is formed by samples within the first sliding window associated with the minimum auto-correlation value, as the reference signal.

[0078] In this step, the minimum auto-correlation value among all the determined auto-correlation values for all the cases in the predetermined shift range is determined and then the positions of the two sliding windows associated with the minimum auto-correlation value can be determined. The last sample of the second sliding window can be considered as the symbol boundary and the sequence which is formed by samples within the first sliding window is taken as the reference signal. For example, if the minimum auto-correlation value is given when the first sliding window stops at Y12 as shown in case 2 of FIG. 4, then Y12 is recorded as the reference signal for future use.

[0079] In this embodiment of the present invention, a receiving side device determines auto-correlation values of the received signal in different cases; if all the auto-correlation values are greater than or equal to a predetermined threshold, the receiving side device shifts the first and the second sliding window in parallel by one first step for each case and determines the auto-correlation value, which is the correlation value of the samples of the received signal within the first sliding window and the samples of the received signal within the second sliding window for each case until an auto-correlation value for a case among all the cases is less than the predetermined threshold; then the receiving side device continues shifting the two windows and determining the auto-correlation values for a predetermined range for each case to search for the minimum auto-correlation value among all cases; and after determining the minimum auto-correlation value, the receiving side device determines the symbol boundary and the reference signal without or least distorted by IN according to the position of the two sliding windows associated with the minimum auto-correlation value. If Y2 and at least one Y1 are not severely distorted by IN, coarse symbol alignment can be achieved. The effects of IN are effectively taken into account during the coarse symbol alignment, enhancing the robustness to IN. A reference signal without or least distorted by IN is found, which can be used to improve the correctness and effectiveness of the cross-correlation in the second stage of fine symbol alignment, and to detect IN in other parts of the preamble. The receiving side device continues to search for a minimum auto-correlation value in a predetermined range after any one of all the cases reaches the predetermined threshold, which allows the coarse symbol alignment to deal with low SNR case without causing performance degradation to high SNR case.

[0080] In a method for symbol alignment according to an embodiment of the present invention, fine symbol alignment is done by circularly shifting the reference signal and determining the cross-correlation value between the original training sequence SI and the circularly shifted version of the reference signal for each shifted distance. When the cross-correlation value reaches its maximum, the corresponding shifted distance is then the offset that coarse symbol alignment needs to be adjusted by for refinement.

[0081] A method for determining the cross-correlation in frequency domain is described in the following; however, other methods can also be adopted to determine the cross-correlation either in time domain or frequency domain.

[0082] Without loss of generality the reference signal is denoted as $\{y_m\ \mathbf{y_{m+}i}, \ldots, y_{m+K}\mathbf{-i}\}$. Details are as follows:

[0083] I) The reference signal $\{y_m,\ \mathbf{y_m}\mathbf{+i},\ \cdots,\ y_{m+K}\mathbf{-i}\}$ in time domain is transformed to frequency domain as $\{Y_m, Y_{m+}i, \ldots, Y_{m+K-i}\}$-

[0084] When the original SI sequence in frequency domain denoted as $\{X_m, X_{m+}i, \ldots, X_{m+K-i}\}$ is in perfect alignment with the reference signal, then

$$Y_m = H_m X_m + N_m \qquad \text{(Eq. J)}$$

with H_m being the channel frequency response and N_m being the background noise.

[0085] II) Determine $Y_{m+1} Y_m^*$, where "*" denotes the complex conjugate operation, and /^denotes the complex conjugate of Y_m.

[0086] Assuming $H_m = H_{m+1}$, which is a reasonable assumption since the channel frequency response of adjacent subcarriers can be almost equivalent, then

$$Y_{m+1}Y_m^* = \|H_m\|^2 X_{m+1}X_m^* + O(N_m) \qquad \text{(Eq. 2)}$$

whose phase depends on sequence SI but independent of the channel. Here $0(N_m)$ represents all the terms relevant to noise.

[0087] III) With misalignment by an offset τ, compared to Eq.l, there would be a phase rotation in frequency domain.

$$Y_m = H_m X_m e^{-iM \quad K} + N_m \qquad \text{(Eq. 3)}$$

$$Y_{m+1}Y_m^* = \|H_m\|^2 X_{m+1}X_m^* e^{-i2\pi\tau/K} + O(N_m) \qquad \text{(Eq. 4)}$$

[0088] IV) Determine the cross-correlation between sequence $Y_{m+1}Y_m^{*}$ and $\chi_{m+1}\chi_m^*$. It is defined that

$$T \triangleq \sum_{m\in C} Y_{m+1}Y_m^*(X_{m+1}X_m^*)^* = e^{-i2\pi\tau/K}\sum_{m\in C}\|H_m\|^2\|X_{m+1}X_m^*\|^2 + O(N_m)$$

(Eq. 5)

where C can be a subset of subcarriers with sufficiently high SNR. With perfect coarse symbol alignment, $r = 0$, and *real(T)* reaches maximum.

[0089] V) It is defined that

$$\mathrm{R} \triangleq e^{i2\pi\alpha/K}\mathrm{T} \,. \qquad \text{(Eq. 6)}$$

[0090] When $a = \tau$, real*(R)* reaches maximum. Therefore by searching over different a, the offset a giving the maximum of real*(R)* is then taken as the offset τ' that coarse symbol alignment needs to be adjusted by.

$$\tau' = \arg\max_{\alpha} real(R) \qquad \text{(Eq. 7)}$$

[0091] Once *J* is computed, for each search over α, only one complex multiplier is involved in the determination of *R*, which is convenient for hardware implementation.

[0092] FIG. 6 shows a schematic flow diagram of fine symbol alignment in a method for symbol alignment according to an embodiment of the present invention. As shown is FIG. 6, fine symbol alignment in this embodiment includes the following steps:

[0093] Step 601, the reference signal $\{y_m, y_{m+1}, \cdots, y_{m+K-1}\}$ in time domain is transformed to frequency domain as $\{Y_m, Y_{m+1}, \ldots, Y_{m+K-1}\}$. The original SI sequence in time domain is transformed to frequency domain denoted as $\{X_m, X_{m+1}, \ldots, X_{m+K-1}\}$-

[0094] Step 602, for each shifted distance α, where α can be an integer larger than -K/2 but less than K/2, the receiving side device determines a cross-correlation value between the reference signal in frequency domain and the original SI sequence in frequency domain by using:

$$R \triangleq e^{i 2\pi\alpha IK} T$$

$$T \triangleq \sum_{m \in C} Y_{m+1} Y_m^* (X_{m+1} X_m^*)^*$$

where C can be a subset of subcarriers with high SNR.

[0095] Under low SNR (time domain) situations, this step offers the flexibility to select only the subcarriers with high SNR (frequency domain) to improve the accuracy in determining the cross-correlation value. The subcarrier selection depends on prior information of channel and transmitted power distribution among subcarriers. For example, for power line communications systems such as Ghn and Homeplug, the transmit power spectral density (PSD) limit allowed in the frequency band between 2 and 30 MHz is much higher than that allowed in the frequency band above 30MHz, then SNR of subcarriers between [2, 30] MHz frequency is generally better than other subcarriers and these subcarriers thus may carry more weight than other carriers in determining the cross-correlation value.

[0096] If the reference signal is shifted circularly a distance of α in time domain, it is rotated by -UnaIKm frequency domain. The effect of circular shift on the cross-correlation can be reflected by the effect of a phase change introduced by α on the cross-correlation. Therefore, the cross-correlation value can be determined for each shifted distance α in the frequency domain without actually circularly shifting the reference signal, which has the advantages of low complexity and thus facilitate the hardware implementation.

[0097] Step 603, the receiving side device determines a maximum cross-correlation value among the determined cross-correlation values of all shifted distances and takes a value of α which gives the maximum cross-correlation value among the determined cross-correlation values as an offset for refining the symbol alignment.

[0098] In this embodiment, the cross-correlation value between the circularly shifted version of the reference signal and the original training sequence SI is determined; the shifted distance which gives the maximum cross-correlation value is then taken as the offset that coarse symbol alignment needs to be adjusted by. Only one complex multiplier is involved in the determination of one cross-correlation value, so can be implemented conveniently in hardware with low complexity. Moreover, the solution of this embodiment is also resilient to low SNR (time domain) situations by allowing one to choose only the subcarriers with high SNR (frequency domain) for calculation.

[0099] FIG. 7 shows a schematic structural diagram of a device for symbol alignment according to an embodiment of the present invention. The device for symbol alignment according to this embodiment may be used to implement the method for symbol alignment provided by the embodiments of the present invention. The device for symbol alignment includes a receiving unit 701, a first aligning unit 702 and a second aligning unit 703.

[0100] The receiving unit 701 is configured to receive a signal which is an OFDM signal transmitted by a transmitter across a channel; where the OFDM signal transmitted by the transmitter has a preamble with a structure as shown in FIG. la, and the OFDM signal transmitted across the channel and received by the receiving unit has a preamble with a structure as shown in FIG. lb.

[0101] The first aligning unit 702 is configured to determine auto-correlation values of the received signal to detect a symbol boundary roughly, i.e. to perform coarse symbol alignment, and determine a reference signal.

[0102] The second aligning unit 703 is configured to determine a cross-correlation value between the reference signal and the training sequence to obtain an offset for refining the symbol alignment.

[0103] In this embodiment of the present invention, a device for symbol alignment performs coarse symbol alignment by determining auto-correlation values of a received signal to detect a symbol boundary roughly and determine a reference signal without or least distorted by IN; then the device for symbol alignment determines the cross-correlation value between the reference signal and the training sequence and obtains an offset that can be used to refine the coarse symbol alignment. Symbol alignment can be achieved successfully even in the presence of IN as long as Y2 and at least one Y1 are not severely distorted by IN.

[0104] FIG. 8 shows a schematic structural diagram of a device for symbol alignment according to an embodiment of the present invention. The device for symbol alignment shown in FIG. 8 may be used to implement the method for symbol alignment provided by the embodiments of the present invention. The device for symbol alignment according to this embodiment is different from the device for symbol alignment as shown in FIG. 7 in that the first aligning unit 702 specifically includes an auto-correlation determining subunit 7021 and an aligning subunit 7022, and the second aligning unit 703 specifically includes a cross-correlation determining subunit 7031 and an offset determining subunit 7032.

[0105] The auto-correlation determining subunit 7021 is configured to, for case n-1, n-2,. .., 0, shift a first sliding window and a second sliding window within the received signal in parallel and determine the auto-correlation value by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the second sliding window, wherein a distance between a center of the first sliding window and a center of the second sliding window is 2K, 3K, ……, (n+l)K for case n-1, n-2,. .., 0 respectively, wherein K is a number of samples the first sequence has, n equals the number of intact Sis included in the first section of the preamble and both the first sliding window and the second sliding window have a length of K samples.

[0106] The aligning subunit 7022 is configured to determine the symbol boundary and the reference signal based on a minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window.

[0107] The cross-correlation determining subunit 7031 is configured to: circularly shift the reference signal and determine the cross-correlation value between the first sequence and the circularly shifted version of the reference signal for each shifted distance.

[0108] The offset determining subunit 7032 is configured to determine the shifted distance with a maximum cross-correlation value among the determined cross-correlation values of all shifted distances as the offset for refining the symbol alignment.

[0109] In an embodiment, the determining of the auto-correlation values may start from the last case in which the least amount of samples are required. The auto-correlation determining subunit 7021 is further configured to, when mK samples are received, start to determine the auto-correlation values for case n+2-m and determine the auto-correlation values for case n+2-m, n+3-m,. ..,n-l in parallel, wherein m=3,. ..,n+2. For details, please refer to descriptions of the method for symbol alignment.

[0110] In an embodiment, the determining of the auto-correlation values under all n cases can start simultaneously when (n+2)K samples which are required for the auto-correlation determination in case 0 are received. The auto-correlation determining subunit 7021 is further configured to, when (n+2)K samples are received, start to determine the auto-correlation values for each of the n cases. For details, please refer to descriptions of the method for symbol alignment.

[0111] In an embodiment, the auto-correlation determining subunit 7021 is specifically configured to: determine, for each case, the auto-correlation values by determining the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with the first sample of the first sliding window being y_0 for each of the cases and the first sample of the second sliding window being $y_{(\eta+\ddot{\imath})K}$ for case 0, y_{n_K} for case 1,......, y_{3k} for case n-2 and y_{2K} for case n-1; if the auto-correlation values of all cases are greater than or equal to a predetermined threshold, shift the first sliding window and the second sliding window in parallel by a first step at a time and determine the auto-correlation values for each of the cases until the auto-correlation value for at least one case is less than the predetermined threshold; and continue to shift the first sliding window and the second sliding window in parallel by a second step at a time for a predetermined range and determine the auto-correlation value for each of the cases , recording the auto-correlation value and the position of the second sliding window corresponding to the auto-correlation value for each of the cases.

[0112] The predetermined threshold may be set to an appropriate value larger than -1 and less than 0. The predetermined range may be chosen to be less than K, preferably K/2. For details, please refer to descriptions of the method for symbol alignment.

[0113] The size of the first step may be determined according to a difference between a current minimum auto-correlation value among the determined auto-correlation values of all the cases and the predetermined threshold. The size of the second step should be smaller than or equal to that of the first step and may be set to one sample as an example. For details, please refer to the description of the method embodiments, which will not be repeated herein.

[0114] In an embodiment, the aligning subunit 7022 is specifically configured to: determine the minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window; determine positions of a first sliding window and a second sliding window associated with the minimum auto-correlation value; determine the symbol boundary based on the position of the second sliding window associated with the minimum auto-correlation value; and take a sequence being formed by samples within the first sliding window associated with the minimum auto-correlation value as the reference signal.

[0115] FIG. 9 shows a schematic structural diagram of a device for symbol alignment according to an embodiment of the present invention. In this embodiment, the second aligning unit 703 further includes a transforming subunit 7033, configured to obtain a first frequency signal transformed from the first sequence, and obtain a second frequency signal transformed from the reference signal. The cross-correlation determining subunit 7031 is specifically configured to determine, for each shifted distance, the cross-correlation value between the first frequency signal and the second frequency signal, wherein the shifted distance is an integer larger than -K/2 but less than K/2, wherein K is a number of samples the first sequence has. The offset determining subunit 7032 is specifically configured to determine, a maximum cross-correlation value among the determined cross-correlation values of all shifted distances and take the shifted distance giving the maximum cross-correlation value as the offset for refining the symbol alignment. In an embodiment, when determining the cross-correlation value between the first frequency signal and the second frequency signal, subcarriers between [2, 30] MHz frequency may carry more weight than other carriers. For details, please refer to the description of the method embodiments, which will not be repeated herein.

[0116] FIG. 10 shows a schematic structural diagram of a device for symbol alignment according to an embodiment of the present invention. In this embodiment, the device for symbol alignment may include a receiver 1010, a memory 1030 and a processor 1020 which is coupled with the receiving module 1010 and the memory 1030 respectively. Certainly, the device for symbol alignment may further include general parts, such as an input-output device etc, which are not limited here in the embodiment of the present invention.

[0117] The memory 1030 stores a series of program codes, and the processor 1020 is configured to call the program codes stored in the memory 83 to execute following operations:

receiving, via the receiver 1010, a signal which is an orthogonal frequency division multiplexed (OFDM) signal transmitted by a transmitter across a channel, wherein the OFDM signal comprises a preamble having a first section including a first number of intact first sequences and a second section including a second number of intact second sequences, where the first number is an integer larger than 0, the second number is an integer larger than 0, and the values of the second sequence is a negative of those of the first sequence;

determining, auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal; and determining, a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment.

[0118] The device for symbol alignment shown in FIG. 10 may be used to implement the method for symbol alignment provided by the above embodiments of the present invention. For details, please refer to the description of the method embodiments, which will not be repeated herein.

[0119] The device for symbol alignment according to the embodiments of the present invention may be any devices receiving an OFDM signal including a preamble having a structure as mentioned above, such as Ghn or Homeplug compatible receiver, or may also be a separate apparatus that can be integrated into these devices.

[0120] Persons of ordinary skill in the art may understand that all or part of the steps in the above method embodiments may be implemented by a program instructing relevant hardware. The program may be stored in a computer readable storage medium. When the program is executed, the foregoing steps in the method embodiments are performed. The aforementioned storage medium includes any medium capable of storing program codes, such as a ROM, a RAM, a magnetic disk, or an optical disk.

[0121] Persons skilled in the art may also understand that an accompanying drawing is only a schematic view of an optional embodiment, the unit or the flow in the accompanying drawing is not necessary for implementing the present invention.

[0122] Persons skilled in the art may also understand that units in the devices of the embodiments may distribute in the devices of the embodiments according to the descriptions of the embodiments, or locate in one or more devices other than the present embodiments via performing corresponding changes. The units in the aforementioned embodiments may be combined into one unit, or further be divided into a plurality of sub-units.

[0123] Finally, it should be noted that the foregoing embodiments are merely intended for describing the technical solutions of the present invention other than limiting the present invention. Although the present invention is described in detail with reference to the foregoing embodiments, a person of ordinary skill in the art should understand that he may still make modifications to the technical solutions described in the foregoing embodiments, or make equivalent replacements to some technical features thereof; however these modifications or replacements will not cause the essence of corresponding technical solutions to depart from the scope of the technical solutions of the embodiments of the present invention.

CLAIMS

1. A method for symbol alignment, comprising:

receiving, by a receiving side device, a signal which is an orthogonal frequency division multiplexed (OFDM) signal transmitted by a transmitter across a channel, wherein the OFDM signal comprises a preamble having a first section including a first number repeated copies of an intact first sequence and a second section including an intact second sequence, where the first number is an integer larger than 0, and values of the second sequence is a negative of those of the first sequence;

determining, by the receiving side device, auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal;

determining, by the receiving side device, a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment.

2. The method according to claim 1, wherein determining, by the receiving side device, the auto-correlation values of the received signal to detect the symbol boundary roughly and determine the reference signal comprises:

for case n-1, n-2,. .., 0 where a distance between a center of a first sliding window and a center of a second sliding window is 2K, 3K, ..., (n+l)K respectively, wherein K is the number of samples the first sequence has, n equals the first number, and both the first sliding window and the second sliding window have a length of K samples: shifting, by the receiving side device, the first sliding window and the second sliding window within the received signal in parallel and determining the auto-correlation value by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the second sliding window; and

determining, by the receiving side device, the symbol boundary and the reference signal based on a minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window.

3. The method according to claim 2, wherein when mK samples are received, the receiving side device starts to determine the auto-correlation values for case n+2-m and determines the auto-correlation values for case n+3-m,. ..,n-l in parallel, wherein m=3,. ..,n+2.

4. The method according to claim 2, wherein when (n+2)K samples are received, the receiving side device starts to determine the auto-correlation values for each of the n cases simultaneously.

5. The method according to claim 4, wherein the shifting, by the receiving side device, of the first sliding window and the second sliding window within the received signal and determining the auto-correlation values by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the second sliding window comprises:

determining, by the receiving side device, for each case, the auto-correlation values by determining the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with a first sample of the first sliding window being y_0 for each of the cases and a first sample of the second sliding window being $y_{(n+i)K}$ for case 0, y_{nK} for case 1,......, y_{3K} for case n-2 and y_{2K} for case n-1;

if the auto-correlation values of all cases are greater than or equal to a predetermined threshold, shifting the first sliding window and the second sliding window in parallel by a first step at a time and determining the auto-correlation values for each of the cases until the auto-correlation value for at least one case is less than the predetermined threshold;

continuing to shift the first sliding window and the second sliding window in parallel by a second step at a time for a predetermined range and determining the auto-correlation value for each of the cases and recording the auto-correlation value and the position of the second sliding window corresponding to the auto-correlation value for each of the cases.

6. A device for symbol alignment, comprising:

a receiving unit, configured to receive a signal which is an orthogonal frequency division multiplexed (OFDM) signal transmitted by a transmitter across a channel, wherein the OFDM signal comprises a preamble having a first section including a first number repeated copies of an intact first sequence and a second section including an intact second sequence, where the first number is an integer larger than 0, and values of the second sequence is a negative of those of the first sequence;

a first aligning unit, configured to determine auto-correlation values of the received signal to detect a symbol boundary roughly and determine a reference signal;

a second aligning unit, configured to determine a cross-correlation value between the reference signal and the first sequence to obtain an offset for refining the symbol alignment.

7. The device according to claim 6, wherein the first aligning unit comprises:

an auto-correlation determining subunit, configured to, for case n-1, n-2,. .., 0, shift a first sliding window and a second sliding window within the received signal in parallel and determine the auto-correlation value by determining a correlation value of samples of the received signal within the first sliding window and samples of the received signals within the second sliding window for each position of the first and second sliding window, wherein a distance between a center of the first sliding window and a center of the second sliding window is 2K, 3K, ..., (n+l)K for case n-1, n-2,. .., 0 respectively, wherein K is a number of samples the first sequence has, n equals the first number, and both the first sliding window and the second sliding window have a length of K samples; and

an aligning subunit, configured to determine the symbol boundary and the reference signal based on a minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the first and second sliding window.

8. The device according to claim 7, wherein the auto-correlation determining subunit is configured to, when mK samples are received, start to determine the auto-correlation values for case n+2-m and determine the auto-correlation values for case n+3-m,. ..,n-l, which have already started, in parallel with the case n+2-m,

wherein m=3, …,n+2.

9. The device according to claim 7, wherein the auto-correlation determining subunit is configured to, when (n+2)K samples are received, start to determine the auto-correlation values for each of the n cases simultaneously.

10. The device according to claim 9, wherein the auto-correlation determining subunit is configured to:

determine, for each case, the auto-correlation values by determining the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with a first sample of the first sliding window being y_0 for each of the cases and a first sample of the second sliding window being $y_{(n+i)K}$ for case 0, y_{nK} for case 1,……, y_{3K} for case n-2 and $\mathbf{y}_{2K}$ for case n-1;

if the auto-correlation values of all cases are greater than or equal to a predetermined threshold, shift the first sliding window and the second sliding window in parallel by a first step at a time and determine the auto-correlation values for each of the cases until the auto-correlation value for at least one case is less than the predetermined threshold; and

continue to shift the first sliding window and the second sliding window in parallel by a second step at a time for a predetermined range and determine the auto-correlation value for each of the cases and recording the auto-correlation value and the position of the second sliding window corresponding to the auto-correlation value for each of the cases.

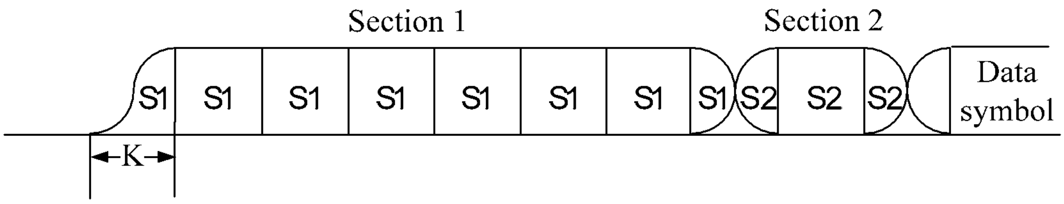

FIG. 1a

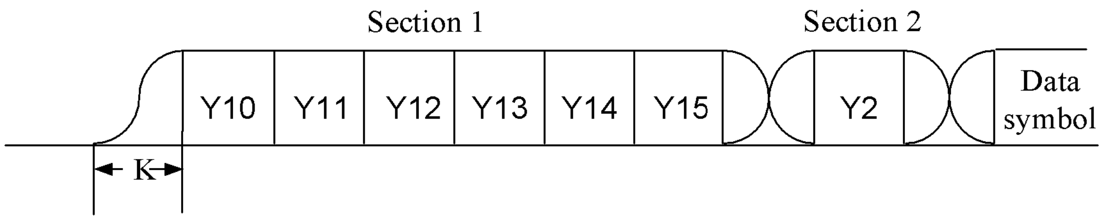

FIG. 1b

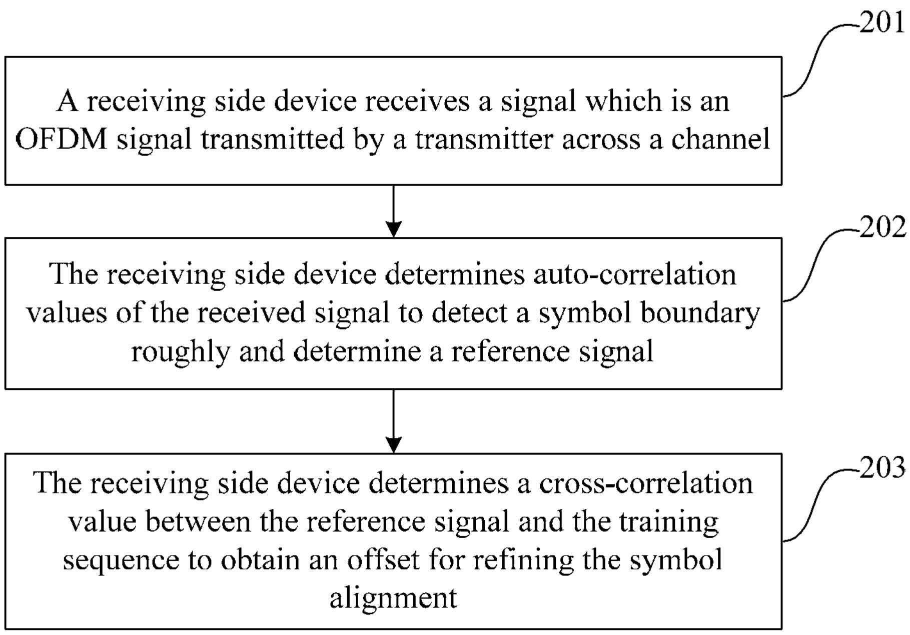

FIG. 2

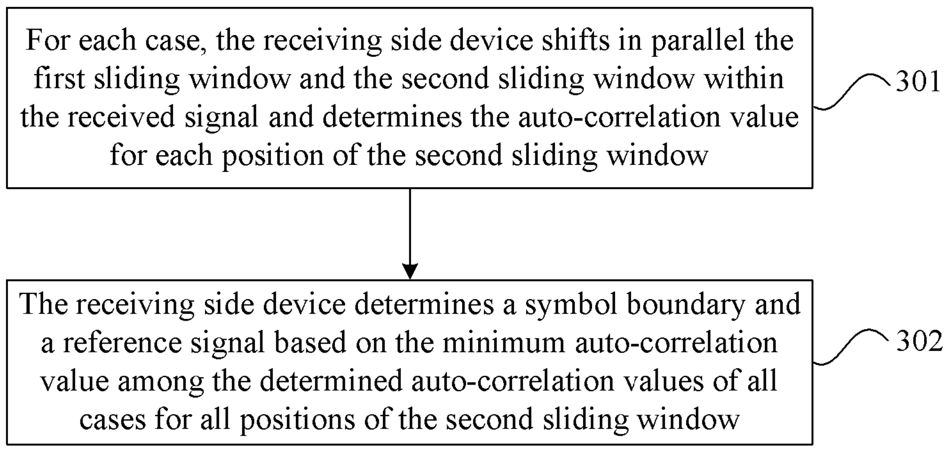
For each case, the receiving side device shifts in parallel the first sliding window and the second sliding window within the received signal and determines the auto-correlation value for each position of the second sliding window
301
The receiving side device determines a symbol boundary and a reference signal based on the minimum auto-correlation value among the determined auto-correlation values of all cases for all positions of the second sliding window
302

FIG. 3

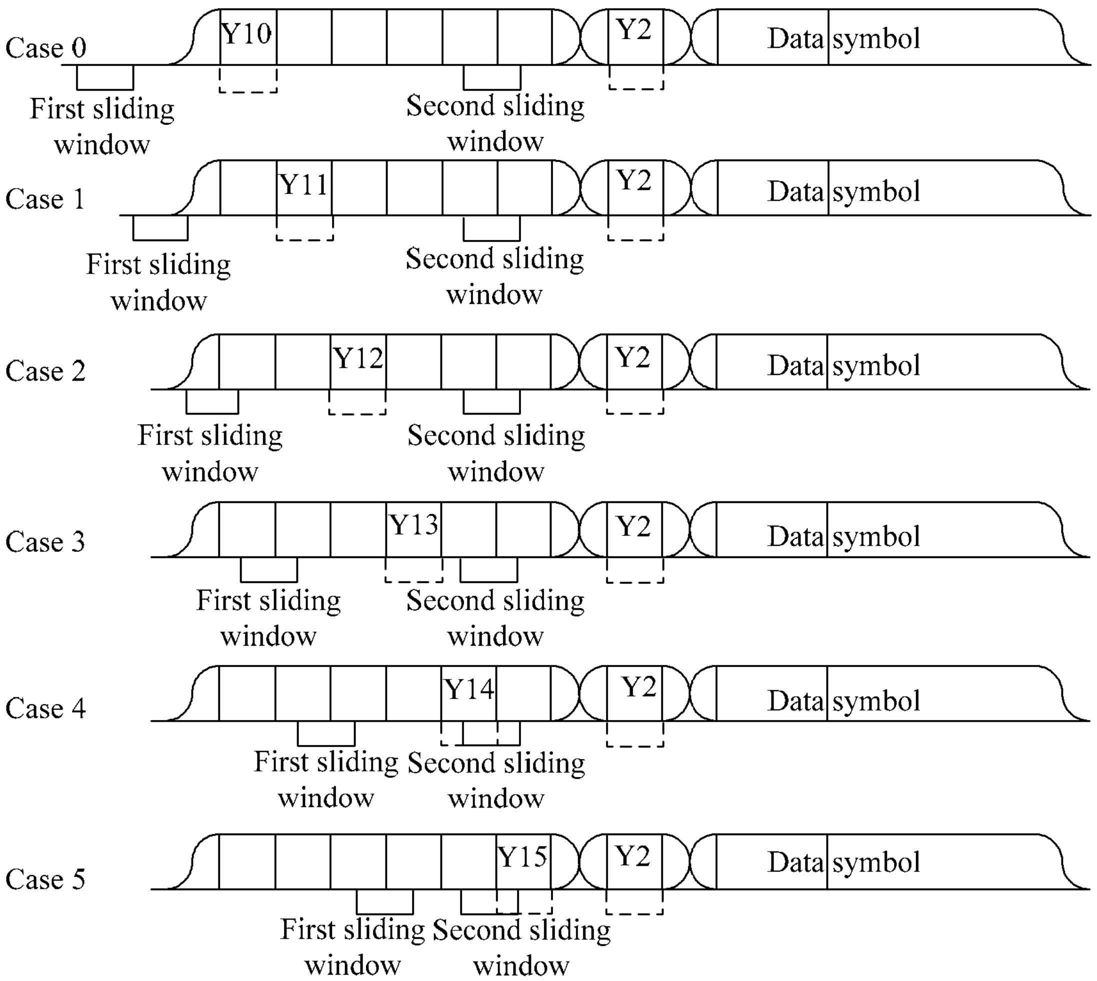
Case 0
Y10
Y2
Data symbol
First sliding window
Second sliding window
Case 1
Y11
Y2
Data symbol
First sliding window
Second sliding window
Case 2
Y12
Y2
Data symbol
First sliding window
Second sliding window
Case 3
Y13
Y2
Data symbol
First sliding window
Second sliding window
Case 4
Y14
Y2
Data symbol
First sliding window
Second sliding window
Case 5
Y15
Y2
Data symbol
First sliding window
Second sliding window

FIG. 4

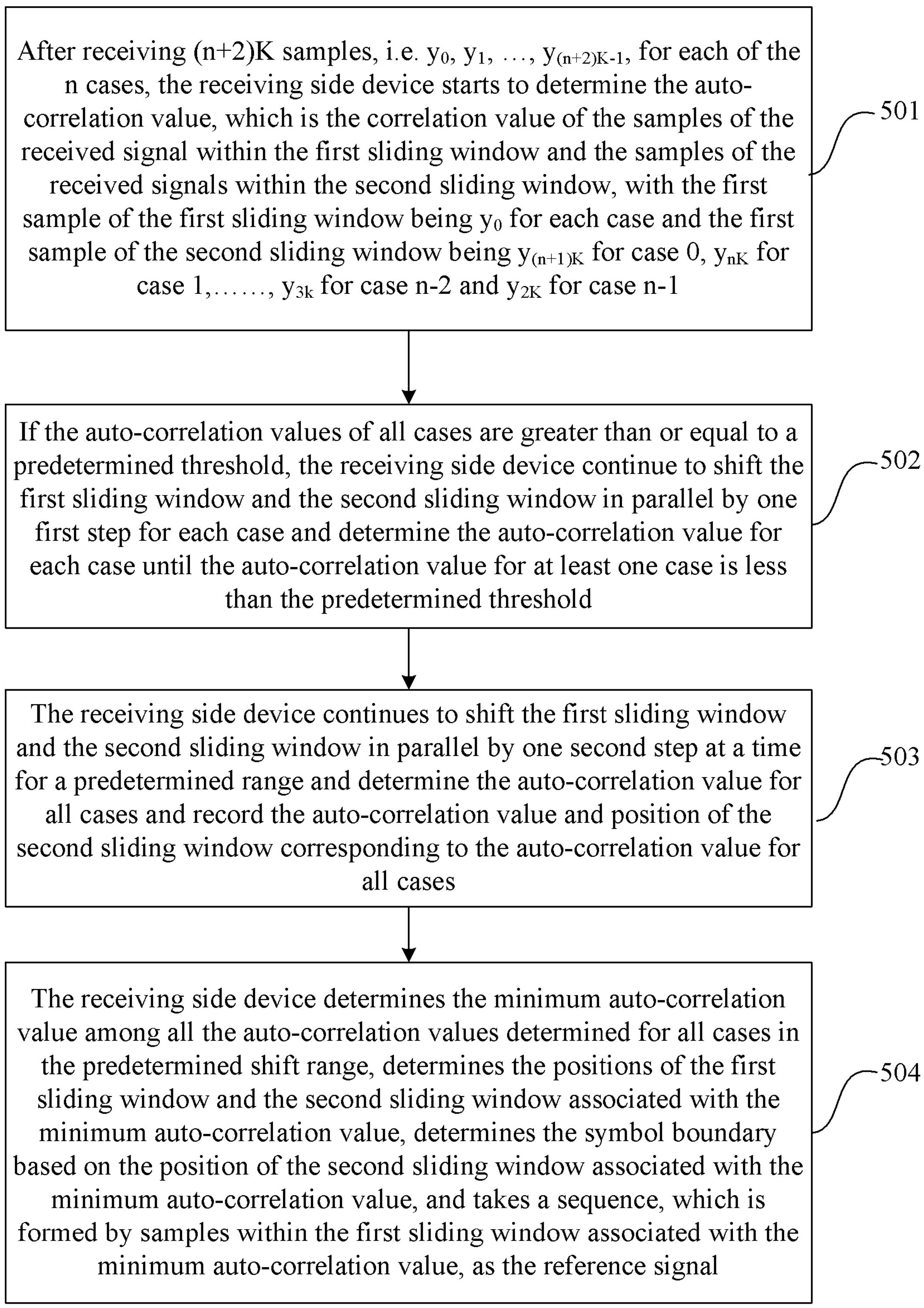
After receiving (n+2)K samples, i.e. y_0, y_1, …, $y_{(n+2)K-1}$, for each of the n cases, the receiving side device starts to determine the auto-correlation value, which is the correlation value of the samples of the received signal within the first sliding window and the samples of the received signals within the second sliding window, with the first sample of the first sliding window being y_0 for each case and the first sample of the second sliding window being $y_{(n+1)K}$ for case 0, y_{nK} for case 1,……, y_{3k} for case n-2 and y_{2K} for case n-1
501
If the auto-correlation values of all cases are greater than or equal to a predetermined threshold, the receiving side device continue to shift the first sliding window and the second sliding window in parallel by one first step for each case and determine the auto-correlation value for each case until the auto-correlation value for at least one case is less than the predetermined threshold
502
The receiving side device continues to shift the first sliding window and the second sliding window in parallel by one second step at a time for a predetermined range and determine the auto-correlation value for all cases and record the auto-correlation value and position of the second sliding window corresponding to the auto-correlation value for all cases
503
The receiving side device determines the minimum auto-correlation value among all the auto-correlation values determined for all cases in the predetermined shift range, determines the positions of the first sliding window and the second sliding window associated with the minimum auto-correlation value, determines the symbol boundary based on the position of the second sliding window associated with the minimum auto-correlation value, and takes a sequence, which is formed by samples within the first sliding window associated with the minimum auto-correlation value, as the reference signal
504

FIG. 5

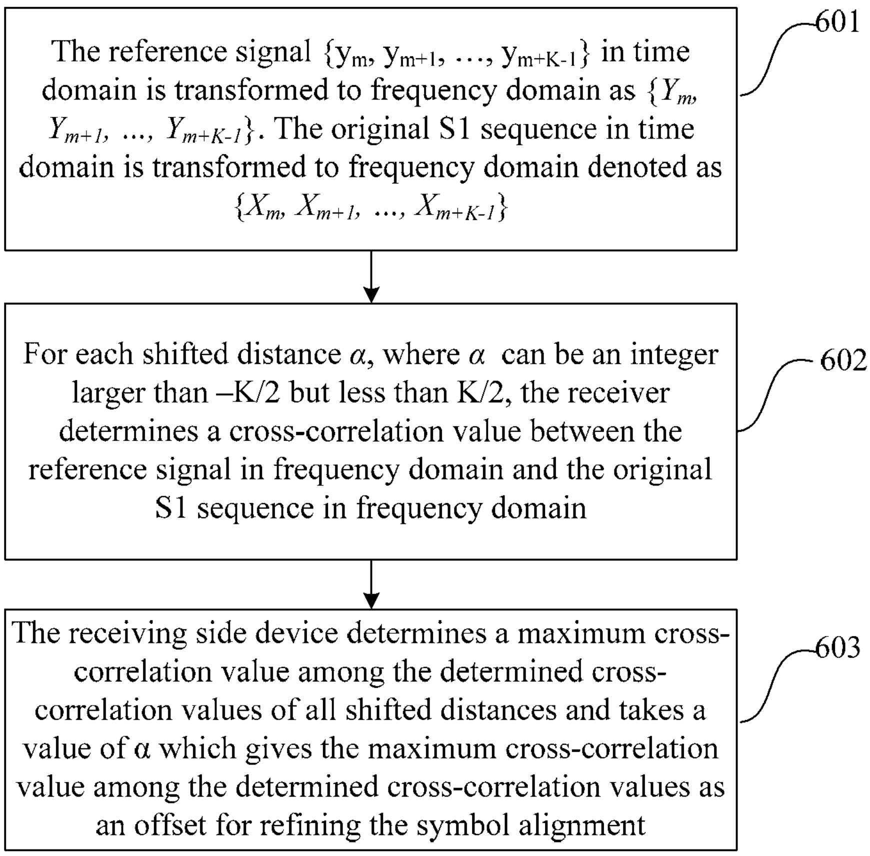
The reference signal $\{y_m, y_{m+1}, \ldots, y_{m+K-1}\}$ in time domain is transformed to frequency domain as $\{Y_m, Y_{m+1}, \ldots, Y_{m+K-1}\}$. The original S1 sequence in time domain is transformed to frequency domain denoted as $\{X_m, X_{m+1}, \ldots, X_{m+K-1}\}$
601
For each shifted distance α, where α can be an integer larger than –K/2 but less than K/2, the receiver determines a cross-correlation value between the reference signal in frequency domain and the original S1 sequence in frequency domain
602
The receiving side device determines a maximum cross-correlation value among the determined cross-correlation values of all shifted distances and takes a value of α which gives the maximum cross-correlation value among the determined cross-correlation values as an offset for refining the symbol alignment
603

FIG. 6

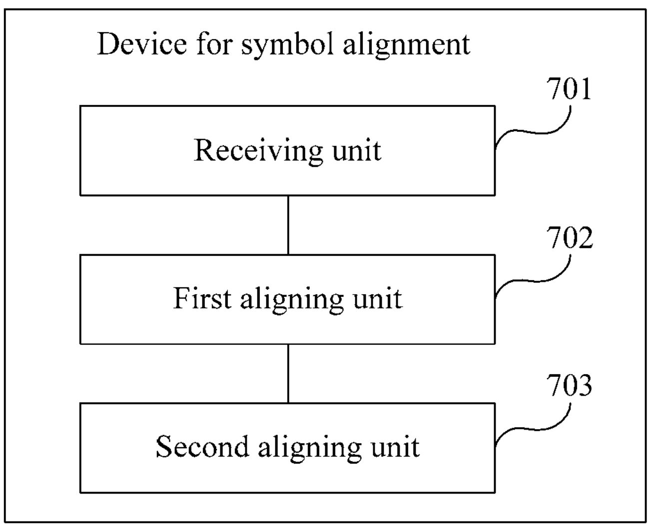
Device for symbol alignment
701
Receiving unit
702
First aligning unit
703
Second aligning unit

FIG. 7

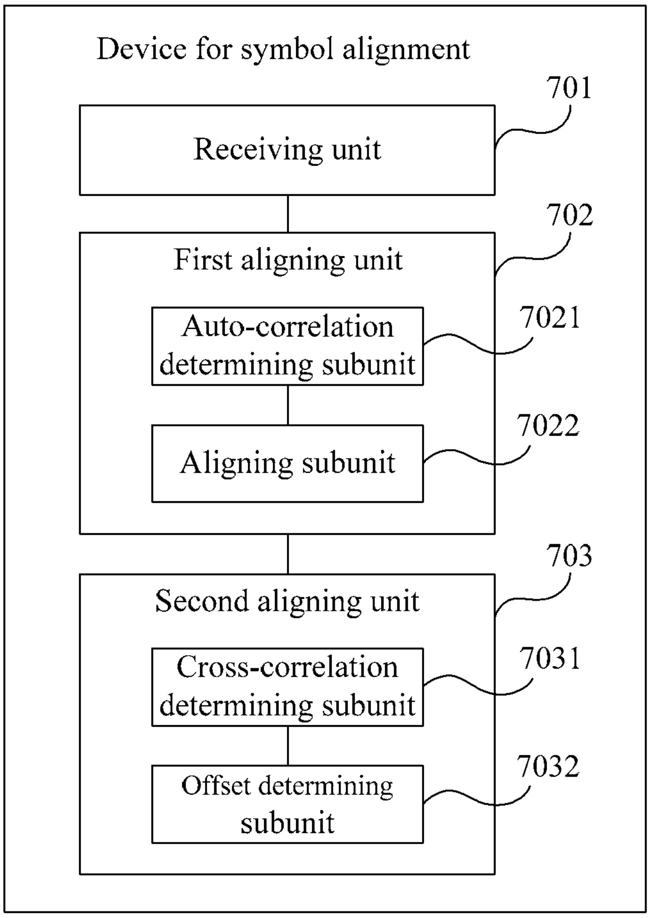
Device for symbol alignment
Receiving unit
701
First aligning unit
702
Auto-correlation determining subunit
7021
Aligning subunit
7022
Second aligning unit
703
Cross-correlation determining subunit
7031
Offset determining subunit
7032

FIG. 8

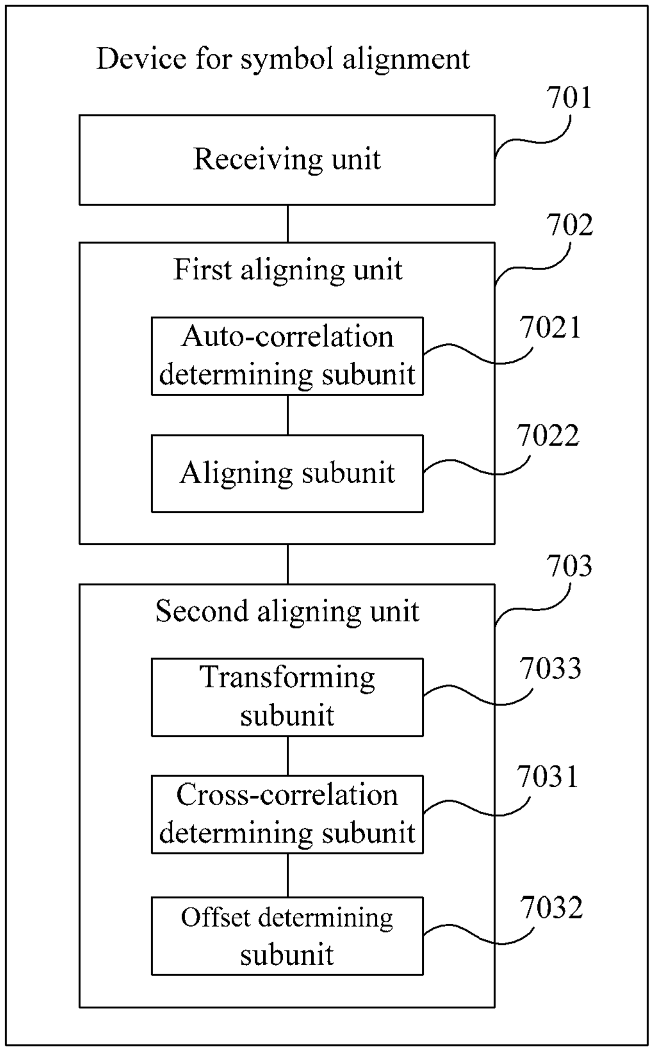
Device for symbol alignment
701
Receiving unit
702
First aligning unit
Auto-correlation determining subunit
7021
Aligning subunit
7022
703
Second aligning unit
Transforming subunit
7033
Cross-correlation determining subunit
7031
Offset determining subunit
7032

FIG. 9

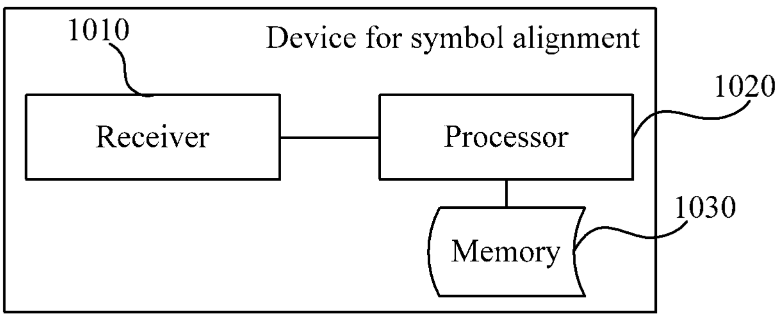
1010
Device for symbol alignment
Receiver
Processor
1020
Memory
1030

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/098443

A. CLASSIFICATION OF SUBJECT MATTER

H04J 3/06(2006.01)i; H04L 27/26(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04J3/06

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)

CNTXT;CNABS;CNKI;VEN: 同步，前同步码¾, 笫g一，第二，g f 关，互相关，粗，ffl, ft, 重复，复制，周期，负，OFDM, 参考信号，synchroniz+, preamble, correlation, first, second, reference, negative, cop

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 101651648 A (CONEXANT SYSTEMS INC.) 17 February 2010 (2010-02-17) description, page 5, paragraphs 2 to 5	1-10
A	CN 101409584 A (NXP B.V.) 15 April 2009 (2009-04-15) the whole document	1-10
A	CN 1799238 A (INTEL CORP.) 05 July 2006 (2006-07-05) the whole document	1-10
A	US 8588052 B1 (SCHELSTRAETE SIGURD) 19 November 2013 (2013-11-19) the whole document	1-10

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

* Special categories of cited documents:

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 September 2016	**18 September 2016**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/098443

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	101651648	A	17 February 2010	US	2010040043	Al	18 February 2010
				CN	101651648	B	25 December 2013
				US	8446894	B2	21 May 2013
CN	101409584	A	15 April 2009	WO	2009047732	A3	06 August 2009
				WO	2009047732	A2	16 April 2009
CN	1799238	A	05 M y 2006	EP	1609283	Al	28 December 2005
				CN	100576834	C	30 December 2009
				AU	2003269739	Al	18 October 2004
				US	7251282	B2	31 July 2007
				US	2004190560	Al	30 September 2004
				WO	2004086708	Al	07 October 2004
US	8588052	Bl	19 November 2013	None			