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(54) Title: RECEIVER AND RECEIVING METHOD FOR DEMULTIPLEXING MULTIPLEXED SIGNALS

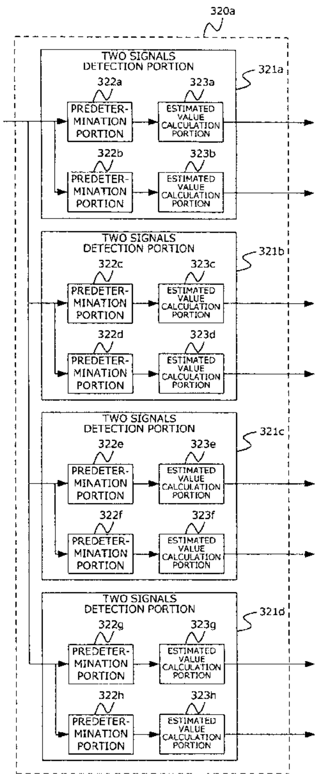

FIG. 3

(57) Abstract: A receiver comprises: means for splitting multiplexed complex baseband signals into a real component and an imaginary component; and means for calculating an estimated signal vector, said means for calculating an estimated signal vector: for one or more of the complex baseband signals, predetermining the real component to be one of possible signal point candidates and calculates an estimated signal value for the real component of another complex baseband signal based on the predetermined signal point candidate(s); and for said one or more of the complex baseband signals, predetermining the imaginary component to be one of possible signal point candidates and calculates an estimated signal value for the imaginary component of said other complex baseband signal based on the predetermined signal point candidate(s).

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RECEIVER AND RECEIVING METHOD FOR DEMULTIPLEXING MULTIPLEXED SIGNALS

[Technical Field]

[0001]

This invention relates to a receiving method and a receiver for demultiplexing multiplexed signals and a communication system comprising such a receiver.

[Background Art]

[0002]

Wide band communication systems for performing communication using very wide bandwidths are drawing attention toward an era of large capacity radio communication. For example, the Ultra Wide Band (UWB) radio transmission is a scheme that performs a wide band radio communication of 500 MHz or more of bandwidth or 20% or more of relative bandwidth. MBOA SIG (Multi-Band OFDM Alliance Special Interest Group) which promotes the UWB determines specifications for the physical layer or the media access layer wherein a multiband OFDM (Orthogonal Frequency Division Multiplexing) scheme is applied. In particular, Non-Patent Document 1 describes that Dual Carrier Modulation (DCM) scheme, which obtains transmission diversity effect by multiplexing a plurality of modulated signals by a precoding matrix or the like and transmitting the multiplexed signals via different frequency bands, is employed in the physical layer.

[0003]

Also, Non-Patent Document 2 discloses that a frequency diversity effect is obtained at the symbol level even when the OFDM is applied by performing code multiplexing using spreading codes.

[0004]

If signals are thus multiplexed at the transmitting end, the multiplexed signals have to be demultiplexed upon signal detection at the receiving end. A representative example of a method for demultiplexing the received signals is a linear detector using a ZF (Zero Forcing) method, an MMSE (Minimum Mean Square Error) method, etc. These methods have an advantage that receiver construction can be simplified because their amounts of operation are small, but have a problem that characteristics degradation occurs due to noise emphasizing or the like upon signal demultiplexing.

[0005]

On the other hand, an MLD (Maximum Likelihood Detection) method is named as the most appropriate method among various signal demultiplexing methods. This method performs signal demultiplexing by determining a distance between a received signal vector and possible signal point vectors for all signal point candidates and determining a signal point with the shortest distance to be an estimated signal vector. This method can realize transmission characteristics extremely superior to that of the above linear detector such as the ZF method or the MMSE method because it compares all possible signal points. However, this method has a problem that it is difficult to implement because the number of the signal point candidates increases exponentially as the modulation level, the number of the transmitting antennas and/or the number of multiplexed signals increase so that the amount of operation becomes enormous.

[Prior Art Documents]

[Non-Patent Documents]

[0006]

[Non-Patent Document 1]

Wimedia Alliance, Inc., "Multiband OFDM Physical Layer Specification", Final Deliverable 1.5, August 2009

[Non-Patent Document 2]

Akira Wakamiya and Kenichi Higuchi, "Spreading Code Sequences Appropriate for Maximum Likelihood Detection in MC-CDMA", Technical Report of the Institute of Electronics, Information and Communication Engineers, RCS2009-48, June 2009

[Non-Patent Document 3]

K. J. Kim, J. Yue, R. A. Iltis, and J. D. Gilson, "A QRD-M/Kalman filter-based detection and channel estimation algorithm for MIMO-OFDM systems", IEEE Transaction on Wireless Communication, vol. 4, no. 2, pp. 710-712, March 2005

[Non-Patent Document 4]

E. Viterbo and J. Boutros, "A Universal Lattice Code Decoder for Fading Channels", IEEE Transaction on Information Theory, vol. 46, no. 2, pp. 710-721, March 2005

[Non-Patent Document 5]

Y. Lomnitz and D. Andelman, "Efficient maximum likelihood detector for MIMO systems with small number of streams", IEEE Electronics Letters, vol. 43, no. 22, 25th October 2007

[Summary of the Invention]

[Problems to be Solved by the Invention]

[0007]

As a method for reducing the amount of operation in the MLD method, Non-Patent Document 3 discloses a QRM-MLD (complexity-reduced MLD with QR decomposition and M-algorithm) method which applies QR decomposition to propagation paths between the transmitter and the receiver to make it orthogonal and then reduces the number of signal candidates in a stepwise manner by using an M algorithm. Also, Non-Patent Document 4 discloses a Sphere Decoding method wherein the signal search range is limited to a sphere centered on a received signal point. These methods intend to reduce the amounts of operation by reducing the numbers of the signal point candidates. Although the reducing effect is significant, they have a problem that their signal demultiplexing characteristics are less than that of the MLD method.

[0008]

Also, Non-Patent Document 5 discloses a technique for realizing a reduced amount of operation by removing a predetermined signal from a received signal for each signal point candidate of the predetermined signal so that the number of the signal points to be searched is reduced. Although the technique allows realizing signal demultiplexing characteristics equivalent to the MLD method, the technique has a problem that the effect of reducing the amount of operation becomes small if the modulation level or the number of transmitting antennas is large.

[0009]

Thus, there is conventionally a problem that simultaneous realization of superior signal demultiplexing characteristics according to the MLD method and the effect of reducing the amount of operation is difficult.

[0010]

The present invention is aimed at realizing signal demultiplexing characteristics equivalent to the MLD method with a reduced amount of operation upon demultiplexing the signals at the receiving end which were multiplexed by a precoding matrix.

[Means for Solving the Problems]

[0011]

In order to solve the above problems, a receiver related to the present invention comprises:

means for splitting multiplexed complex baseband signals into a real component and an imaginary component; and

means for calculating an estimated signal vector, said means for calculating an estimated signal vector:

- for one or more of the complex baseband signals, predetermining the real component to be one of possible signal point candidates and calculates an estimated signal value for the real component of another complex baseband signal based on the predetermined signal point candidate(s); and

- for said one or more of the complex baseband signals, predetermining the imaginary component to be one of possible signal point candidates and calculates an estimated signal value for the imaginary component of said other complex baseband signal based on the predetermined signal point candidate(s).

[0012]

The means for calculating an estimated signal vector may comprise at least one means for detecting two signals and the number of said means for detecting two signals may correspond to a largest possible modulation level.

[0013]

Means for correcting an amount of phase rotation given at propagation path(s) may be provided.

[0014]

Also, a communication system related to the present invention comprises:

a transmitter for multiplexing complex baseband signals, real components and imaginary components of said complex baseband signals being modulated respectively independently, by a precoding matrix so that an amount of phase rotation is a multiple of 90 degrees;

propagation paths wherein the multiplexed signals are transmitted via respective channels orthogonal to each other; and

the above receiver.

[0015]

Also, a receiving method related to the present invention is characterized in that it comprises steps of:

splitting multiplexed complex baseband signals into a real component and an imaginary component;

estimating a signal, wherein:

- for one or more of the complex baseband signals excepting a signal to be estimated, the real component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the real component of said signal to be estimated based on the predetermined signal point candidate(s); and

- for said one or more of the complex baseband signals excepting the signal to be estimated, the imaginary component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the imaginary component of said signal to be estimated based on the predetermined signal point candidate(s); and

determining a signal vector, wherein:

- a most likely estimated signal real component vector is determined among estimated signal real component vectors each constituted by said predetermined real component and said estimated signal value for the real component; and

- a most likely estimated signal imaginary component vector is determined among estimated signal imaginary component vectors each constituted by said predetermined imaginary component and said estimated signal value for the imaginary component.

[Effect of the Invention]

[0016]

The present invention performs signal demultiplexing for a real component and an imaginary component of a received signal respectively independently. The present invention obtains a superior effect of realizing signal demultiplexing characteristics equivalent to the MLD method with a reduced amount of operation by predetermining one or more signals to be one of respective possible signal point candidates and estimating remaining signals after removing respective predetermined signals.

[Brief Description of the Drawings]

[0017]

[Fig. 1]

Fig. 1 is a diagram showing an example of construction for a communication system related to a first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a diagram showing an example of construction for a signal detection portion related to the first embodiment of the present invention.

[Fig. 3]

Fig. 3 is a diagram showing an example of construction for an estimated signal vector calculation portion related to the first embodiment of the present invention.

[Fig. 4]

Fig. 4 is a diagram showing an example of construction for the signal detection portion related to the first embodiment of the present invention.

[Fig. 5]

Fig. 5 is a diagram showing an example of hardware construction for the signal detection portion related to the first embodiment of the present invention.

[Fig. 6]

Fig. 6 is a diagram showing another example of hardware construction for the signal detection portion related to the first embodiment of the present invention.

[Fig. 7]

Fig. 7 is a diagram showing an example of construction for a communication system related to a second embodiment of the present invention.

[Fig. 8]

Fig. 8 is a diagram showing an example of construction for a signal detection portion related to the second embodiment of the present invention.

[Fig. 9]

Fig. 9 is a diagram showing an example of construction for an estimated signal vector calculation portion related to the second embodiment of the present invention.

[Fig. 10]

Fig. 10 is a diagram showing examples of predetermination portions and two signals detection portions related to the second embodiment of the present invention.

[Embodiments for Carrying Out the Invention]

[0018]

Embodiments of receiving methods, receivers and communication systems related to the present invention will be explained below in detail based on the drawings.

[0019]

First Embodiment

Fig. 1 shows an example of construction for a communication system related to a first embodiment of the present invention. Here, it is assumed for facilitating explanation that the number of signals multiplexed by precoding is L=2 and that two radio signals inputted to a precoding portion 100 are modulated respectively using a 16 QAM (Quadrature Amplitude Modulation) scheme. However, the present invention is not limited to this and applicable to any modulation scheme that performs modulation for a real component and an imaginary component respectively independently, such as the QAM.

[0020]

The precoding portion 100 is a device for performing multiplexing of the two modulated signals inputted via signal lines s100a and s100b. The two multiplexed radio signals are outputted from the precoding portion 100 respectively to propagation paths 200a and 200b orthogonal to each other. Note that, in the precoding portion 100, the two radio signals are multiplexed by a precoding matrix wherein an amount of phase rotation is a multiple of 90 degrees. Thus, a communication system related to the present invention comprises: a transmitter for multiplexing complex baseband signals, real components and imaginary components of said complex baseband signals being modulated respectively independently, by a precoding matrix so that an amount of phase rotation is a multiple of 90 degrees; and propagation paths wherein the multiplexed signals are transmitted via respective channels orthogonal to each other.

[0021]

A method described in Non-Patent Document 2 is an example of precoding in the present embodiment. The two radio signals propagated through the propagation paths 200a and 200b are inputted to a signal detection portion 300. The signal detection portion 300 is a device for performing signal demultiplexing on the inputted two radio signals and outputs two demultiplexed signals via signal lines s300a and s300b.

[0022]

Referring to Fig. 2, the signal detection portion 300 related to the first embodiment of the present invention will be explained. The signal detection portion 300 related to the present embodiment comprises a signal splitting portion 310, estimated signal vector calculation portions 320a and 320b and a signal determination portion 330. The signal splitting portion 310 splits the two inputted radio signals into a real component and an imaginary component and outputs signal vectors constituted for respective components toward the estimated signal vector calculation portions 320a and 320b.

[0023]

The estimated signal vector calculation portions 320a and 320b are devices for calculating estimated values with respect to possible signal point candidates (possible component candidates) by using the real and imaginary components of the signals splitted at the signal splitting portion 310. The estimated signal vector calculation portions 320a and 320b output, toward the signal determination portion 330, respective estimated signal component vectors constituted by: a signal component predetermined to be one of possible signal point candidates (possible component candidates); and a signal component estimated by using the same.

[0024]

In the present specification, "to predetermine" a signal, a real component of a signal or an imaginary component of a signal means to select one particular value as a candidate among the values of symbols which the signal can represent and consider in the subsequent processes that the signal represents the candidate value.

[0025]

The signal determination portion 330 outputs, via the signal lines s300a and s300b, likelihoods of the two most likely estimated signal vectors among the inputted plurality of estimated signal vectors. For example, it outputs the likelihood of the single most likely estimated signal real component vector via the signal line s300a and outputs the likelihood of the single most likely estimated signal imaginary component vector via the signal line s300b.

[0026]

Referring to Fig. 3, a construction of the estimated signal vector calculation portion 320a of the first embodiment related to the present invention will be explained. The estimated signal vector calculation portion 320a related to the first embodiment comprises four units of two signals detection portions 321a-321d. The two signals detection portions 321a-321d respectively comprise two units of predetermination portions 322a-322h and two units of estimated value calculation portions 323a-323h. The predetermination portions 322a-322h are devices for predetermining one of the two radio signals inputted to the precoding portion 100 to be respective one of the signal point candidates that the signals can take. The predetermination portions 322a-322h subtract respective vector amounts corresponding to respective predetermined signals (these vector amounts depend on propagation path information corresponding to the signals) from respective inputted signal vectors and output resulting signal vectors toward the estimated value calculation portions 323a-323h.

[0027]

In the present embodiment, it is assumed that the number of signals multiplexed by precoding is L=2 and that each multiplexed signal has a real component and an imaginary component of respectively two bits, i.e. a 16 QAM modulation scheme is applied for maintaining information represented by four signal point candidates. Thus, in the predetermination portions 322a-322h, the number of pairs consisting of a signal to be predetermined and a possible signal point candidate corresponding to the signal is Lx4=8, so the estimated signal vector calculation portion 320a comprises eight units of the predetermination portions 322a-322h. Note that, if a QPSK scheme is applied wherein a real component and an imaginary component respectively hold information of one bit, the number of pairs consisting of a signal to be predetermined and a possible signal point candidate corresponding to the signal is four, so the same effect is obtained by using only two units among the two signals detection portions 321a-321d. Also, the pair consisting of the signal to be predetermined at the predetermination portion 322a-322h and the signal point candidate corresponding to the signal is different for each unit.

[0028]

The estimated value calculation portions 323a-323h are devices for calculating estimated values of a signal which was not predetermined, based on respective predetermined signal point candidates for the signal and respectively inputted signal vectors. The estimated value calculation portions 323a-323h output respective estimated signal vectors each constituted by the signal predetermined at the predetermination portions 322a-322h and the estimated value of the signal calculated at the estimated value calculation portions 323a-323h.

[0029]

Further, Fig. 4 shows an example of construction for the signal detection portion 300 wherein respectively different phase rotations are applied in the propagation paths 200a and 200b shown in Fig. 1. The signal detection portion 300 comprises two units of phase correction portions 340a and 340b at a stage before the signal splitting portion 310 of the signal detection portion 300 shown in Fig. 2. The phase correction portions 340a and 340b multiply the inputted signals by opposite phase rotations of which amounts of phase rotation are respectively equal to those given at the propagation paths 200a and 200b and output the phase-corrected signals toward the signal splitting portion 310. Thus, the phase correction portions 340a and 340b function as means for correcting amounts of phase rotation given at the propagation paths.

[0030]

Next, specific operations will be explained.

A signal vector $\mathbf{y}$ is outputted from the precoding portion 100 and inputted to the signal detection portion 300 via the propagation paths 200a and 200b. The signal detection portion 300 receives this signal vector $\mathbf{y}$. The signal vector $\mathbf{y}$ is a complex vector having a dimension equal to the number of multiplexed signals (L=2 in the present embodiment) and is represented by the following equation using an equivalent channel matrix $\mathbf{H}$ (constituted by the precoding matrix $\boldsymbol{\phi}$ of the precoding portion 100 and a transfer function matrix Δ of the propagation paths 200a and 200b), a modulated signal vector $\mathbf{z}$ (constituted by modulated signals inputted to the precoding portion 100) and a noise vector $\boldsymbol{\eta}$ (added at an inputting end of the signal detection portion 300):

$$
\begin{aligned}
\mathbf{y} &= \Delta\boldsymbol{\phi}\mathbf{z} + \boldsymbol{\eta} \\
&= \mathbf{H}\mathbf{z} + \boldsymbol{\eta} \\
&= [\boldsymbol{h}_1 \quad \boldsymbol{h}_2]\begin{bmatrix} z_1 \\ z_2 \end{bmatrix} + \boldsymbol{\eta} \qquad (1)
\end{aligned}
$$

wherein z_1 and z_2 are complex baseband signals. The signal vector $\mathbf{y}$ inputted to the signal detection portion 300 is inputted to the signal splitting portion 310, possibly after its amount of phase rotation is corrected. The signal splitting portion 310 splits the signal vector $\mathbf{y}$ into a real component and an imaginary component and inputs the signal vectors reconstructed for respective components to the estimated signal vector calculation portions 320a and 320b. Thus, the signal splitting portion 310 functions as means for splitting multiplexed complex baseband signals into a real component and an imaginary component. Also, a receiving method related to the present invention comprises a step of splitting multiplexed complex baseband signals into a real component and an imaginary component.

[0031]

Here, it is assumed that a vector constituted by the real component of the signal vector $\mathbf{y}$ (real component vector) is inputted to the estimated signal vector calculation portion 320a. First, the predetermination portions 322a-322h predetermines the real component of one of the signals (z_1 or z_2) to be one of possible signal point candidates. A 16 QAM scheme is applied as a modulation scheme for the signal $\mathbf{z}$ in the present embodiment, so there are four values of possible signal point candidates (e.g. -3, -1, 1, 3) for the signals z_1 and z_2 respectively. In the following, as an example, it is assumed that the predetermination portion 322a predetermines the signal z_2 to be -3 which is one of the possible signal point candidates. If a real component corresponding to the predetermined signal $\hat{z}_2$ and the equivalent channel vector $\boldsymbol{h}_2$ is subtracted from the real component of the signal vector $\mathbf{y}$, the following equation is obtained:

$$\begin{aligned}\mathrm{Re}(\mathbf{y} - \boldsymbol{h}_2\hat{z}_2) &= \mathrm{Re}(\mathbf{Hz} - \boldsymbol{h}_2\hat{z}_2 + \boldsymbol{\eta}) \\ &= \mathrm{Re}\{\boldsymbol{h}_1 z_1 + \boldsymbol{h}_2(z_2 - \hat{z}_2) + \boldsymbol{\eta}\} \qquad (2)\end{aligned}$$

wherein Re(·) represents a real component. If it is assumed that the signal $\hat{z}_2$ predetermined to be -3 is equal to the signal z_2 inputted from any of s100a or s100b, the right hand side of the Equation (2) includes only the first term (signal z_1 component) and the third term (the noise component). Based on this, the estimated value calculation portion 323a calculates an estimated value z_1' for the real component of the signal z_1 using the following Equation (3) and outputs an estimated signal vector $\mathbf{z}' = [z_1' \quad \hat{z}_2]$ constituted by the signal $\hat{z}_2$ predetermined at the predetermination portion 322a and the estimated value z_1' calculated at the estimated value calculation portion 323a:

$$\begin{aligned}z_1' &= \mathrm{Re}\{\boldsymbol{h}_1^H(\boldsymbol{y} - \boldsymbol{h}_2\hat{z}_2)\}/\|\boldsymbol{h}_1\|^2 \\ &= \mathrm{Re}\{\boldsymbol{h}_1^H(\boldsymbol{h}_1 z_1 + \boldsymbol{h}_2(z_2 - \hat{z}_2) + \boldsymbol{\eta})\}/\|\boldsymbol{h}_1\|^2 \qquad (3)\end{aligned}$$

wherein $\boldsymbol{h}_1^H$ represents an Hermitian transpose of $\boldsymbol{h}_1$.

[0032]

Thus, the predetermination portion 322a predetermines the signal z_2 to be -3. Similarly, the predetermination portions 322b-322h also predetermine the signal z_1 or z_2 to be one of the possible signal point candidates. For example, the predetermination portion 322b predetermines the signal z_1 to be -3 and the predetermination portions 322c and 322d predetermine the signals z_2 and z_1 respectively to be -1. The estimated value calculation portions 323b-323h calculates respective estimated values of the other signal using the predetermined signals.

[0033]

Thus, each of the estimated signal vector calculation portions 320a and 320b functions as means for calculating an estimated signal vector, said means for calculating an estimated signal vector:

- for one or more of the complex baseband signals, predetermining the real component to be one of possible signal point candidates and calculates an estimated signal value for the real component of another complex baseband signal based on the predetermined signal point candidate(s); and

- for said one or more of the complex baseband signals, predetermining the imaginary component to be one of possible signal point candidates and calculates an estimated signal value for the imaginary component of said other complex baseband signal based on the predetermined signal point candidate(s).

[0034]

Also, a receiving method related to the present invention comprises a step of estimating a signal, wherein:

- for one or more of the complex baseband signals excepting a signal to be estimated, the real component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the real component of said signal to be estimated based on the predetermined signal point candidate(s); and

- for said one or more of the complex baseband signals excepting the signal to be estimated, the imaginary component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the imaginary component of said signal to be estimated based on the predetermined signal point candidate(s).

[0035]

In the present embodiment, eight estimated signal vectors for each estimated signal vector calculation portion (sixteen estimated signal vectors in total) are outputted. Each estimated signal vector is identified by whether it corresponds to the real component vector or the imaginary component vector (two patterns), which of the two signals is a signal to be estimated (in other words, which is predetermined) (two patterns) and which signal point candidate the predetermined signal is predetermined to be (four patterns).

[0036]

The signal determination portion 330: determines the estimated signal vector, among all the estimated signal vectors calculated at the estimated signal vector calculation portion 320a, having the shortest distance from the real component vector inputted to the signal detection portion 300 (i.e. determines the most likely estimated signal vector); calculates likelihood for the determined estimated signal vector; and outputs the calculated likelihood to the signal line s300a. Similarly, regarding the imaginary component of the signal vector $\mathbf{y}$, the estimated signal vector calculation portion 320b calculates the estimated signal vectors, the signal determination portion 330 determines the estimated signal vector having the shortest distance from the imaginary component vector inputted to the signal detection portion 300, the signal determination portion 330 calculates likelihood for the determined estimated signal vector, and the signal determination portion 330 outputs the calculated likelihood to the signal line s330b.

[0037]

Thus, a receiving method related to the present invention comprises a step of determining a signal vector, wherein:

- a most likely estimated signal real component vector is determined among estimated signal real component vectors each constituted by said predetermined real component and said estimated signal value for the real component; and

- a most likely estimated signal imaginary component vector is determined among estimated signal imaginary component vectors each constituted by said predetermined imaginary component and said estimated signal value for the imaginary component.

[0038]

Thus, in the present embodiment, signal demultiplexing is performed for the real component and the imaginary component of the received signal respectively independently. In particular, in the signal demultiplexing, one signal predetermined to be one of the possible signal point candidates is used for calculating the estimated value of the other signal (signal to be estimated) so that the amount of operation can be reduced whereas demultiplexing characteristics equivalent to the MLD method is realized. Also, in the example of construction for the estimated signal vector calculation portion 320a shown in Fig. 3, providing as many two signals detection portions as correspond to the largest possible modulation level and using all or a portion of the two signals detection portions in response to a modulation level allow a single system to process various modulation levels. In other words, the means for calculating an estimated signal vector may comprise as many means for detecting two signals as correspond to a largest possible modulation level.

[0039]

Examples of hardware construction for the signal detection portion 300 related to the first embodiment are shown in Figs. 5 and 6. In the example of Fig. 5, the functions of the signal detection portion 300 (more specifically, the functions of the signal splitting portion 310, the estimated signal vector calculation portions 320a and 320b, the signal determination portion 330, the predetermination portions 322a-322h, the estimated value calculation portions 323a-323h and the phase correction portions 340a and 340b) are realized by the processing circuit 300x. In other words, the receiver comprises the processing circuit 300x for correcting the amounts of phase rotation given at the propagation paths, splitting the signal wherein a plurality of complex baseband signals are multiplexed into the real and imaginary components, and calculating the estimated signal vectors (more specifically, predetermining the real component to be one of possible signal point candidates and calculates an estimated signal value for the real component of another complex baseband signal based on the predetermined signal point candidate, and predetermining the imaginary component to be one of possible signal point candidates and calculates an estimated signal value for the imaginary component of said other complex baseband signal based on the predetermined signal point candidate). The processing circuit 300x may be dedicated hardware or a CPU (Central Processing Unit; also referred to as a processing device, an operation device, a microprocessor, a microcomputer, a processor or a DSP) executing a program stored in a memory.

[0040]

If the processing circuit 300x is dedicated hardware, the processing circuit 300x corresponds to e.g. a single circuit, a combined circuit, a programmed processor, a parallel-programmed processor, an ASIC, an FPGA or any combination thereof. The functions of the signal splitting portion 310, the estimated signal vector calculation portion 320 and 320b, the signal determination portion 330, the predetermination portions 322a-322h, the estimated value calculation portions 323a-323h and the phase correction portions 340a and 340b may be realized by respectively different processing circuits or the functions of the signal determination portion 330 may be realized together by the processing circuit 300x.

[0041]

In the example of Fig. 6, the processing circuit is a CPU (processor 300y). In this case, the functions of the signal detection portion 300 (more specifically, the functions of the signal splitting portion 310, the estimated signal vector calculation portions 320a and 320b, the signal determination portion 330, the predetermination portions 322a-322h, the estimated value calculation portions 323a-323h and the phase correction portions 340a and 340b) are realized by software, firmware, or a combination of software and firmware. The software and firmware are described as a program and stored in a memory 300z. The processing circuit (processor 300y) realizes the functions of the portions by reading and executing the program stored in the memory 300z. In other words, the receiver comprises the memory 300z for storing a program which results in executing steps of:

splitting multiplexed complex baseband signals into a real component and an imaginary component; estimating a signal (more specifically, for one or more of the complex baseband signals excepting a signal to be estimated, the real component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the real component of said signal to be estimated based on the predetermined signal point candidate(s), and, for said one or more of the complex baseband signals excepting the signal to be estimated, the imaginary component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the imaginary component of said signal to be estimated based on the predetermined signal point candidate(s)); and determining a signal vector, (more specifically, a most likely estimated signal real component vector is determined among estimated signal real component vectors each constituted by said predetermined real component and said estimated signal value for the real component, and, a most likely estimated signal imaginary component vector is determined among estimated signal imaginary component vectors each constituted by said predetermined imaginary component and said estimated signal value for the imaginary component), when the program is executed by the processing circuit (processor 300y). Also, the program can be viewed as a program for making a computer execute the steps or methods of the signal detection portion 300 (more specifically, the signal splitting portion 310, the estimated signal vector calculation portions 320a and 320b, the signal determination portion 330, the predetermination portions 322a-322h, the estimated value calculation portions 323a-323h and the phase correction portions 340a and 340b). Here, the memory 300z corresponds to, for example, a non-volatile or volatile semiconductor memory (such as RAM, ROM, flash memory, EPROM and EEPROM), a magnetic disk, a flexible disk, an optical disk, a compact disc, a minidisc, a DVD, etc.

[0042]

Note that, regarding the functions of the signal detection portion 300 (more specifically, the signal splitting portion 310, the estimated signal vector calculation portions 320a and 320b, the signal determination portion 330, the predetermination portions 322a-322h, the estimated value calculation portions 323a-323h and the phase correction portions 340a and 340b), a portion thereof may be realized by dedicated hardware and another portion thereof may be realized by software or firmware. For example, the functions of the estimated signal vector calculation portions 320a and 320b may be realized by the processing circuit as the dedicated hardware and the function of the signal determination portion 330 may be realized by the processing circuit which reads and executes the program stored in the memory.

[0043]

Thus, the processing circuit can realize the above functions by hardware, software, firmware or a combination thereof.

[0044]

Second Embodiment

In the first embodiment, the number of the signals multiplexed at the precoding portion 100 by the precoding matrix is L=2. In contrast, in the present embodiment, a case is explained wherein the number L of the multiplexed signals is equal to or more than 2 and wherein the amount of operation can be reduced. Although a case of L=3 is explained here for facilitating explanation, the present invention is not limited to this and the number L of the multiplexed signals may be any integer equal to or more than 2. Also, it is assumed that three radio signals inputted to the precoding portion 100 are modulated in accordance with a QPSK (Quadrature Phase Shift Keying) scheme. However, the present invention is not limited to this and applicable to any modulation scheme that performs modulation for a real component and an imaginary component respectively independently, such as the QAM.

[0045]

Fig. 7 shows an example of construction for the communication system related to the second embodiment of the present invention. In the example of construction for the communication system of the first embodiment shown in Fig. 1, the number of the signal lines s100a and s100b, the number of signals inputted to / outputted from the precoding portion 100 and the signal detection portion 300, and the number of the propagation paths 200a and 200b are L=2. However, these numbers will be L=3 in the present embodiment.

[0046]

Referring to Fig. 8, the signal detection portion 300 related to the second embodiment of the present invention will be explained. In the example of construction for the signal detection portion in the first embodiment shown in Fig. 2, the number of signal inputted to the signal splitting portion 310 and the number of signals outputted from the signal determination portion 330 (i.e. the number of the signal lines s300a and s300b) are L=2. However, these numbers will be L=3 in the present embodiment.

[0047]

Referring to Fig. 9, the construction of the estimated signal vector calculation portion 320a related to the second embodiment of the present invention will be explained. The estimated signal vector calculation portion 320a in the second embodiment comprises six units of first stage predetermination portion 322a-322f and six units of two signals detection portions 321a-321f. Note that, if the number L of the signals to be multiplexed by precoding is three or more (L=3 in the present embodiment), L-2 stages of predetermination portion groups are provided (a single stage in Fig. 9) before the two signals detection portions 321a-321f and each stage of predetermination portion group predetermines a real component or an imaginary component of respectively different signal.

[0048]

Referring to Fig. 10, constructions for the first stage predetermination portion 322a and the two signals detection portion 321a related to the second embodiment of the present invention will be explained. The two signals detection portion 321a in the second embodiment comprises two units of the second stage predetermination portion 322g and 322h and two units of the estimated value calculation portion 323a and 323b in a manner similar to the first embodiment shown in Fig. 3. The two signals detection portion 321a outputs estimated signal vectors respectively constituted by a first signal predetermined to be one of the possible signal point candidates at the first stage predetermination portion 322a, a second signal predetermined to be one of the possible signal point candidates at the second stage predetermination portion 322g or 322h within the two signals detection portion 321a and a third signal (i.e. the remaining signal) estimated at the estimated value calculation portion 323a or 323b by using the first and second signals.

[0049]

Next, specific operations will be explained.

The signal vector $\mathbf{y}$ is outputted from the precoding portion 100 and inputted to the signal detection portion 300 via the propagation paths 200a-200c. The signal detection portion 300 receives this signal vector $\mathbf{y}$. The signal vector $\mathbf{y}$ is a complex vector having a dimension equal to the number of multiplexed signals (L=3 in the present embodiment) and is represented by the following equation using an equivalent channel matrix $\mathbf{H}$ (constituted by the precoding matrix $\boldsymbol{\phi}$ of the precoding portion 100 and a transfer function matrix Δ of the propagation paths 200a-200c), a modulated signal vector $\mathbf{z}$ (constituted by modulated signals inputted to the precoding portion 100) and a noise vector η (added at an inputting end of the signal detection portion 300):

$$\begin{aligned}\mathbf{y} &= \Delta\boldsymbol{\phi}\mathbf{z} + \boldsymbol{\eta} \\ &= \mathbf{H}\mathbf{z} + \boldsymbol{\eta} \\ &= [\boldsymbol{h}_1 \quad \boldsymbol{h}_2 \quad \boldsymbol{h}_3]\begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} + \boldsymbol{\eta} \end{aligned} \tag{4}$$

wherein z_1-z_3 are complex baseband signals. The signal vector $\mathbf{y}$ inputted to the signal detection portion 300 is first inputted to the signal splitting portion 310. The signal splitting portion 310 splits the signal vector $\mathbf{y}$ into a real component and an imaginary component and inputs the signal vectors reconstructed for respective components to the estimated signal vector calculation portions 320a and 320b.

[0050]

Here, it is assumed that a vector constituted by the real component of the signal vector $\mathbf{y}$ (real component vector) is inputted to the estimated signal vector calculation portion 320a. First, the first stage predetermination portions 322a-322f predetermine a real component of one of the signal $\mathbf{z}$ (z_1, z_2 or z_3) to be one of the possible signal point candidates. A QPSK scheme is applied as a modulation scheme for the signal $\mathbf{z}$ in the present embodiment, so there are two values of possible signal point candidates for the signals z_1-z_3 respectively (e.g. -1 or 1). In the following, it is assumed that the first stage predetermination portion 322a predetermines the signal z_2 to be -1 which is one of the possible signal point candidates and that the second stage predetermination portion 322g within the two signals detection portion 321a predetermines the signal z_3 to be -1 which is one of the possible signal point candidates. If a real component corresponding to the predetermined signals $\hat{z}_2$ and $\hat{z}_3$ and the equivalent channel vectors $\boldsymbol{h}_2$ and $\boldsymbol{h}_3$ is subtracted from the real component of the signal vector $\mathbf{y}$, the following equation is obtained.

$$\begin{aligned}\mathrm{Re}(\mathbf{y}-\boldsymbol{h}_2\hat{z}_2-\boldsymbol{h}_3\hat{z}_3) &= \mathrm{Re}(\mathbf{Hz}-\boldsymbol{h}_2\hat{z}_2-\boldsymbol{h}_3\hat{z}_3+\boldsymbol{\eta}) \\ &= \mathrm{Re}\{\boldsymbol{h}_1 z_1+\boldsymbol{h}_2(z_2-\hat{z}_2)+\boldsymbol{h}_3(z_3-\hat{z}_3)+\boldsymbol{\eta}\} \qquad (5)\end{aligned}$$

If it is assumed here that the signals $\hat{z}_2$ and $\hat{z}_3$ predetermined respectively to be -1 are equal to the signals z_2 and z_3 inputted from any of s100a-s100c, the right hand side of the Equation (5) includes only the first term (signal z_1 component) and the fourth term (the noise component). Based on this, the estimated value calculation portion 323a within the two signals detection portion 321a calculates an estimated value z_1' for the real component of the signal z_1 using the following Equation (6) and outputs an estimated signal vector $\mathbf{z}' = [z_1' \quad \hat{z}_2 \quad \hat{z}_3]$ constituted by the signal $\hat{z}_2$ predetermined at the first stage predetermination portion 322a, the signal $\hat{z}_3$ predetermined at the second stage predetermination portion 322g within the two signals detection portion 321a and the estimated value z_1' calculated at the estimated value calculation portion 323a within the two signals detection portion 321a:

$$\begin{aligned}\mathbf{z}_1' &= \mathrm{Re}\{\boldsymbol{h}_1^H(\boldsymbol{y}-\boldsymbol{h}_2\hat{z}_2-\boldsymbol{h}_3\hat{z}_3)\}/\|\boldsymbol{h}_1\|^2 \\ &= \mathrm{Re}\{\boldsymbol{h}_1^H(\boldsymbol{h}_1 z_1+\boldsymbol{h}_2(z_2-\hat{z}_2)+\boldsymbol{h}_3(z_3-\hat{z}_3)+\boldsymbol{\eta})\}/\|\boldsymbol{h}_1\|^2 \qquad (6)\end{aligned}$$

[0051]

Thus, the first stage predetermination portion 322a predetermines the signal z_2 to be -1. Also, the second stage predetermination portion 322g predetermines the signal z_3 to be -1. Similarly, the second stage predetermination portion 322h predetermines the signal z_3 to be 1. Then, the estimated value calculation portion 323a calculates an estimated value z_1' of the signal z_1 with respect to predetermined $(\hat{z}_2,\hat{z}_3)=(-1,-1)$ and the estimated value calculation portion 323b calculates another estimated value z_1' of the signal z_1 with respect to predetermined $(\hat{z}_2,\hat{z}_3)=(-1,1)$.

[0052]

Similarly, the first stage predetermination portions 322b-322f and the two signals detection portions 321b-321f calculate estimated values for all signals and signal point candidates and output the estimated signal vectors. For example, the first stage predetermination portion 322b predetermines the signal z_2 to be 1 and the two signals detection portion 321b calculates estimated values z_1' for the signal z_1 with respect to predetermined $(\hat{z}_2,\hat{z}_3)=(1,-1)$ and $(\hat{z}_2,\hat{z}_3)=(1,1)$. The first stage predetermination portion 322c predetermines the signal z_3 to be -1 and the two signals detection portion 321c calculates estimated values z_2' for the signal z_2 with respect to predetermined $(\hat{z}_3,\hat{z}_1)=(-1,-1)$ and $(\hat{z}_3,\hat{z}_1)=(-1,1)$. The first stage predetermination portion 322d predetermines the signal z_3 to be 1 and the two signals detection portion 321d calculates estimated values z_2' for the signal z_2 with respect to predetermined $(\hat{z}_3,\hat{z}_1)=(1,-1)$ and $(\hat{z}_3,\hat{z}_1)=(1,1)$. The first stage predetermination portion 322e predetermines the signal z_1 to be -1 and the two signals detection portion 321e calculates estimated values z_3' for the signal z_3 with respect to predetermined $(\hat{z}_1,\hat{z}_2)=(-1,-1)$ and $(\hat{z}_1,\hat{z}_2)=(-1,1)$. The first stage predetermination portion 322f predetermines the signal z_1 to be 1 and the two signals detection portion 321f calculates estimated values z_3' for the signal z_3 with respect to predetermined $(\hat{z}_1,\hat{z}_2)=(1,-1)$ and $(\hat{z}_1,\hat{z}_2)=(1,1)$.

[0053]

In the present embodiment, twelve estimated signal vectors for each estimated signal vector calculation portion (twenty-four estimated signal vectors in total) are outputted. Each estimated signal vector is identified by whether it corresponds to the real component vector or the imaginary component vector (two patterns), which of the three signals is a signal to be estimated (in other words, which two among the three signals are predetermined) (three patterns) and which signal point candidates the predetermined signals are predetermined to be (two patterns for two signals; four patterns in total).

[0054]

The signal determination portion 330: determines the estimated signal vector, among all estimated signal vectors calculated at the estimated signal vector calculation portion 320a, having the shortest distance from the real component vector (i.e. determines the most likely estimated signal vector); calculates likelihood for the determined estimated signal vector; and outputs the calculated likelihood to the signal lines s300a-s300c.

Similarly, regarding the imaginary component of the signal vector $\mathbf{y}$, the estimated signal vector calculation portion 320b calculates the estimated signal vectors, the signal determination portion 330 determines the estimated signal vector having the shortest distance from the imaginary component vector, the signal determination portion 330 calculates likelihood for the determined estimated signal vector, and the signal determination portion 330 outputs the calculated likelihood to the signal lines s300a-s300c.

[0055]

Thus, in the present embodiment, signal demultiplexing is performed for the real component and the imaginary component of the received signal respectively independently in a case wherein three or more signals are multiplexed by precoding. In particular, in the signal demultiplexing, a pair constituted by a plurality of signal points predetermined to be respective one of possible signal point candidates is used for calculating the estimated value of the signal to be estimated so that the amount of operation can be reduced whereas demultiplexing characteristics equivalent to the MLD method is realized. Also, in the example of construction for the estimated signal vector calculation portion 320a shown in Fig. 9, providing as many two signals detection portions as correspond to the largest possible modulation level and using all or a portion of the two signals detection portions in response to a modulation level allow a single system to process various modulation levels.

[0056]

Hardware construction of the signal detection portion related to the second embodiment can be realized as shown in Fig. 5 or 6 in a manner similar to the first embodiment.

[0057]

Thus, the present invention has been explained based on the embodiments. Needless to say, various modifications are possible for combinations of the components or the processes of these embodiments.

CLAIMS

[Claim 1]

A receiver characterized in that it comprises:

means for splitting multiplexed complex baseband signals into a real component and an imaginary component; and

means for calculating an estimated signal vector, said means for calculating an estimated signal vector:

- for one or more of the complex baseband signals, predetermining the real component to be one of possible signal point candidates and calculates an estimated signal value for the real component of another complex baseband signal based on the predetermined signal point candidate(s); and

- for said one or more of the complex baseband signals, predetermining the imaginary component to be one of possible signal point candidates and calculates an estimated signal value for the imaginary component of said other complex baseband signal based on the predetermined signal point candidate(s).

[Claim 2]

The receiver of Claim 1, characterized in that the means for calculating an estimated signal vector comprises at least one means for detecting two signals, a number of said means for detecting two signals corresponding to a largest possible modulation level.

[Claim 3]

The receiver of Claim 1, characterized in that it comprises means for correcting an amount of phase rotation given at propagation path(s).

[Claim 4]

A communication system comprising:

a transmitter for multiplexing complex baseband signals, real components and imaginary components of said complex baseband signals being modulated respectively independently, by a precoding matrix so that an amount of phase rotation is a multiple of 90 degrees;

propagation paths wherein the multiplexed signals are transmitted via respective channels orthogonal to each other; and

the receiver of Claim 1.

[Claim 5]

A receiving method, characterized in that it comprises steps of:

splitting multiplexed complex baseband signals into a real component and an imaginary component;

estimating a signal, wherein:

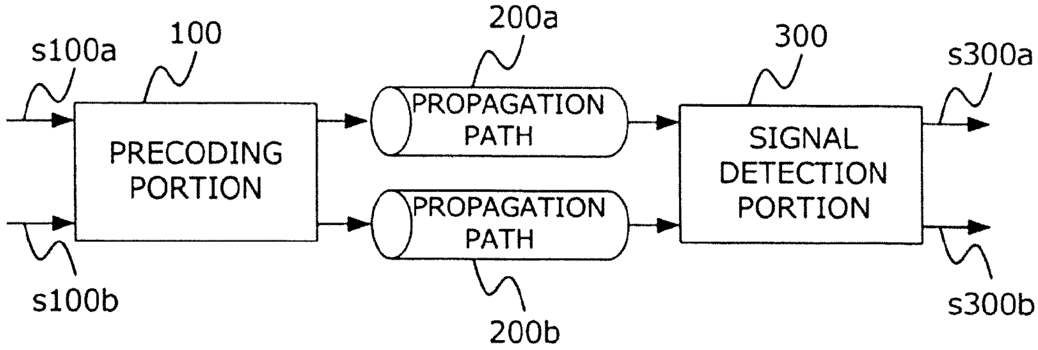
- for one or more of the complex baseband signals excepting a signal to be estimated, the real component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the real component of said signal to be estimated based on the predetermined signal point candidate(s); and

- for said one or more of the complex baseband signals excepting the signal to be estimated, the imaginary component is predetermined to be one of possible signal point candidates and an estimated signal value is calculated for the imaginary component of said signal to be estimated based on the predetermined signal point candidate(s); and

determining a signal vector, wherein:

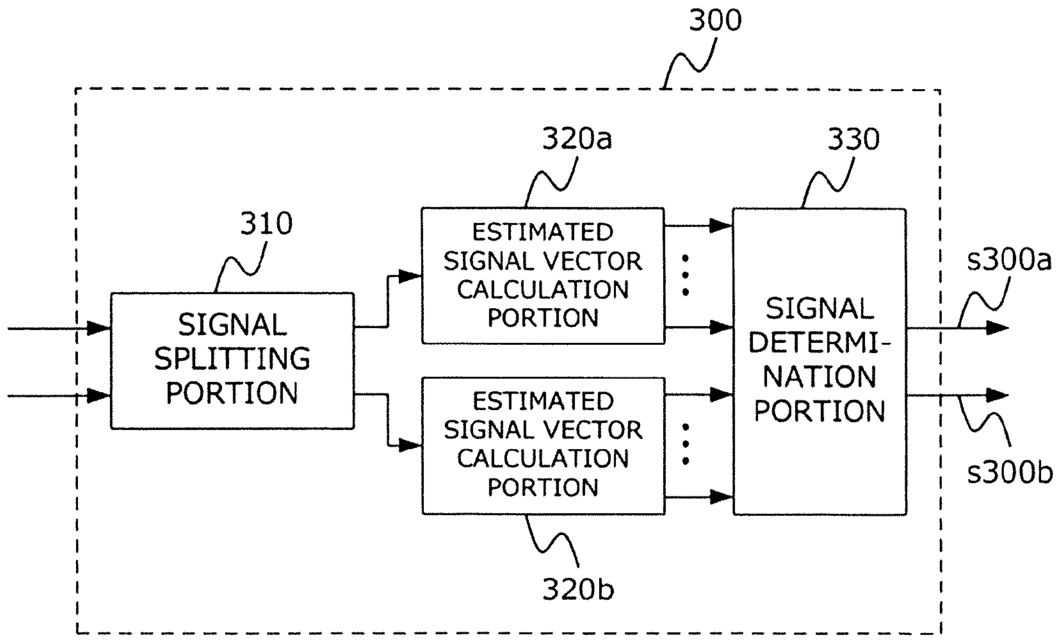
- a most likely estimated signal real component vector is determined among estimated signal real component vectors each constituted by said predetermined real component and said estimated signal value for the real component; and

- a most likely estimated signal imaginary component vector is determined among estimated signal imaginary component vectors each constituted by said predetermined imaginary component and said estimated signal value for the imaginary component.



s100a
100
200a
300
s300a
PRECODING PORTION
PROPAGATION PATH
PROPAGATION PATH
SIGNAL DETECTION PORTION
s100b
200b
s300b

FIG. 1



300
320a
330
310
ESTIMATED SIGNAL VECTOR CALCULATION PORTION
SIGNAL SPLITTING PORTION
SIGNAL DETERMI-NATION PORTION
s300a
ESTIMATED SIGNAL VECTOR CALCULATION PORTION
s300b
320b

FIG. 2

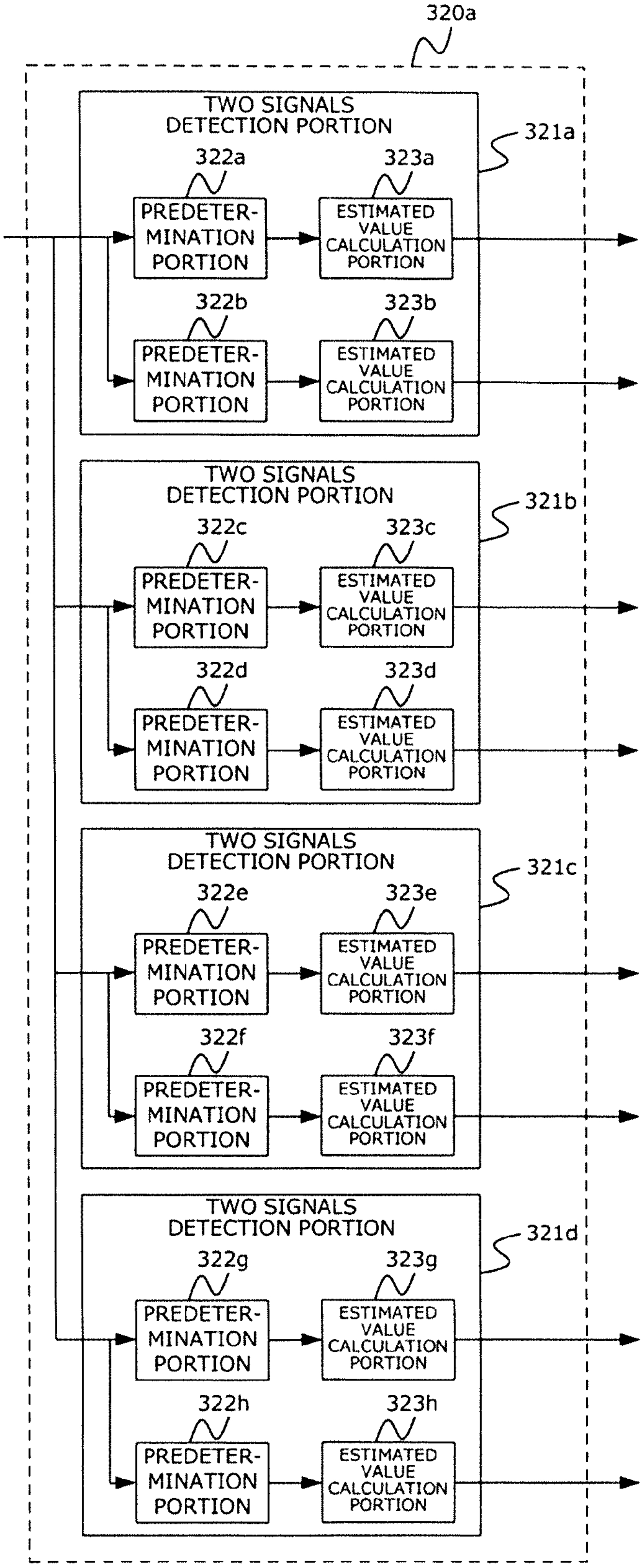

320a
TWO SIGNALS DETECTION PORTION
321a
322a
323a
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
322b
323b
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
TWO SIGNALS DETECTION PORTION
321b
322c
323c
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
322d
323d
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
TWO SIGNALS DETECTION PORTION
321c
322e
323e
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
322f
323f
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
TWO SIGNALS DETECTION PORTION
321d
322g
323g
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION
322h
323h
PREDETER-MINATION PORTION
ESTIMATED VALUE CALCULATION PORTION

FIG. 3

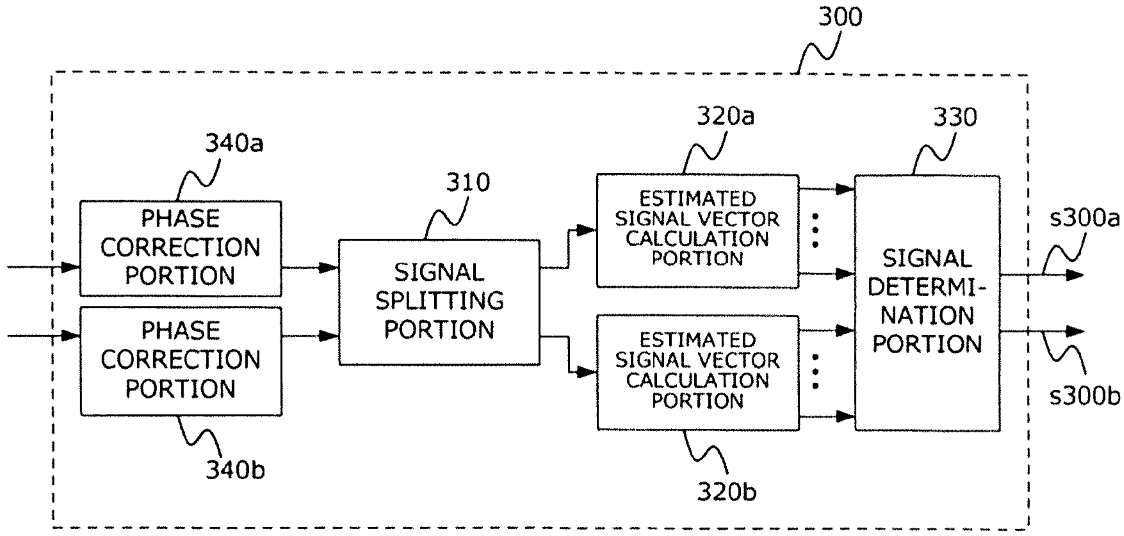

300
340a
PHASE CORRECTION PORTION
PHASE CORRECTION PORTION
340b
310
SIGNAL SPLITTING PORTION
320a
ESTIMATED SIGNAL VECTOR CALCULATION PORTION
ESTIMATED SIGNAL VECTOR CALCULATION PORTION
320b
330
SIGNAL DETERMI-NATION PORTION
s300a
s300b

FIG. 4

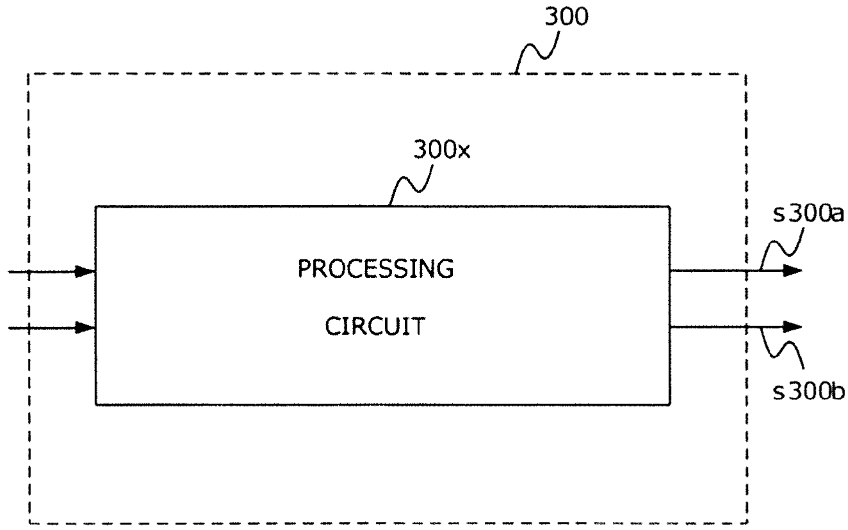

300
300x
PROCESSING CIRCUIT
s300a
s300b

FIG. 5

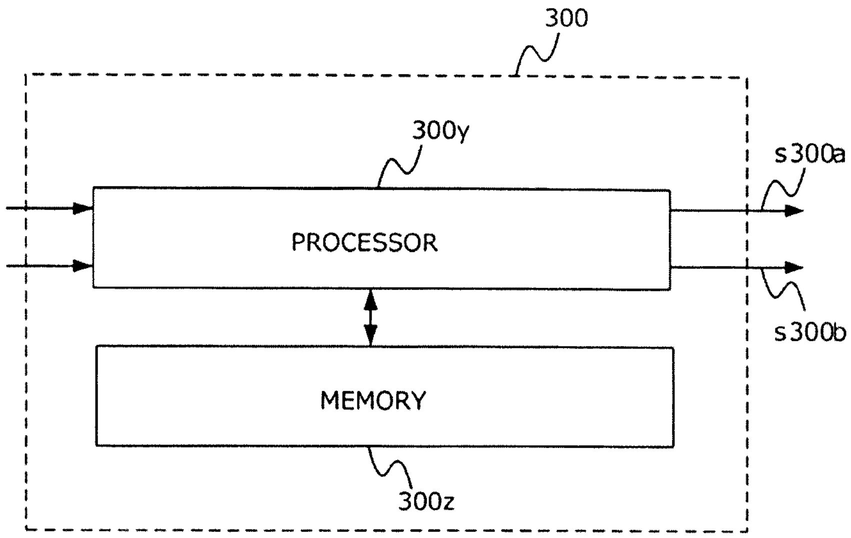

300
300y
s300a
PROCESSOR
s300b
MEMORY
300z

FIG. 6

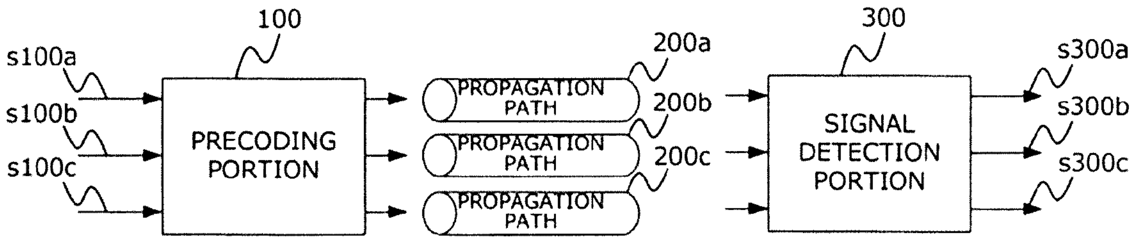

100
300
s100a
200a
s300a
s100b
200b
s300b
s100c
200c
s300c
PRECODING PORTION
PROPAGATION PATH
PROPAGATION PATH
PROPAGATION PATH
SIGNAL DETECTION PORTION

FIG. 7

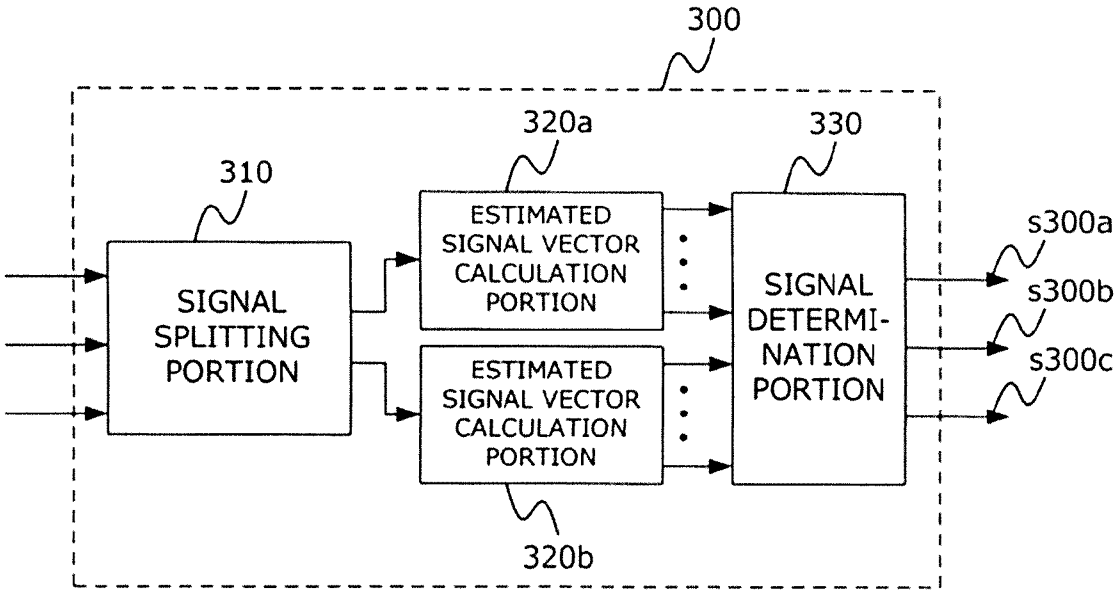

300
310
320a
330
SIGNAL
SPLITTING
PORTION
ESTIMATED
SIGNAL VECTOR
CALCULATION
PORTION
ESTIMATED
SIGNAL VECTOR
CALCULATION
PORTION
SIGNAL
DETERMI-
NATION
PORTION
s300a
s300b
s300c
320b

FIG. 8

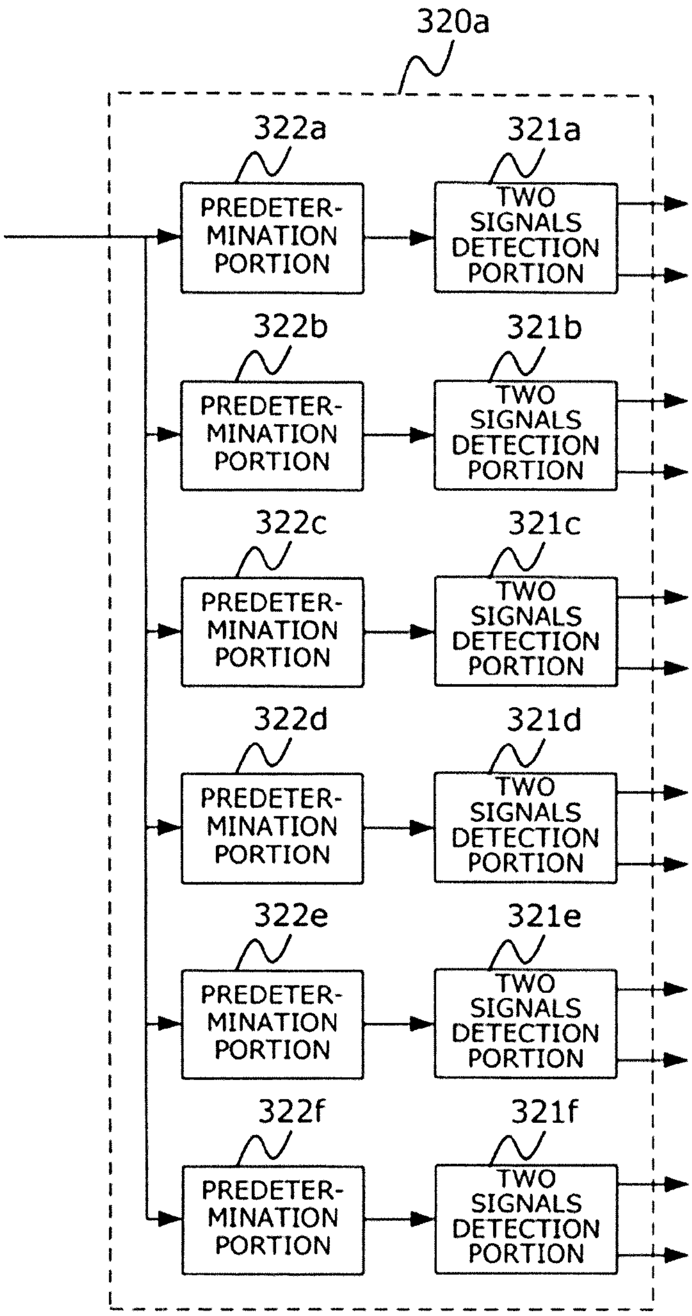

320a
322a
321a
PREDETER-MINATION PORTION
TWO SIGNALS DETECTION PORTION
322b
321b
PREDETER-MINATION PORTION
TWO SIGNALS DETECTION PORTION
322c
321c
PREDETER-MINATION PORTION
TWO SIGNALS DETECTION PORTION
322d
321d
PREDETER-MINATION PORTION
TWO SIGNALS DETECTION PORTION
322e
321e
PREDETER-MINATION PORTION
TWO SIGNALS DETECTION PORTION
322f
321f
PREDETER-MINATION PORTION
TWO SIGNALS DETECTION PORTION

FIG. 9

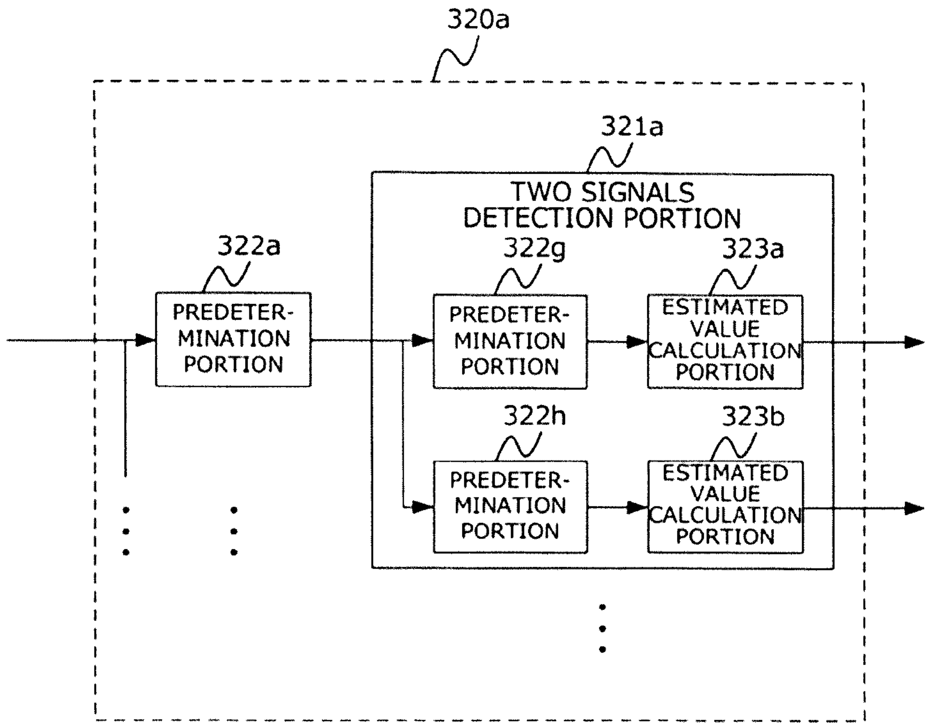

320a
321a
TWO SIGNALS
DETECTION PORTION
322a
PREDETER-
MINATION
PORTION
322g
PREDETER-
MINATION
PORTION
323a
ESTIMATED
VALUE
CALCULATION
PORTION
322h
PREDETER-
MINATION
PORTION
323b
ESTIMATED
VALUE
CALCULATION
PORTION

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/063611

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00 H04B1/7163 H04B7/06 H04L1/00 H04L27/26
H04L27/38
ADD. H04L25/03 H04L25/06

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

B. FIELDS SEARCHED

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

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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/089121 A1 (KOO JI HUN [KR] ET AL) 11 April 2013 (2013-04-11) paragraph [0042] - paragraph [0043] paragraph [0064] - paragraph [0075] figure 3	1-5
X	US 2008/310556 A1 (LEE JOO-HYUN [KR] ET AL) 18 December 2008 (2008-12-18) paragraph [0035] paragraph [0065] - paragraph [0089] figure 3	1-5
X	WO 2008/025402 A1 (SONY DEUTSCHLAND GMBH [DE]; STIRLING-GALLACHER RICHARD [DE]) 6 March 2008 (2008-03-06) page 11, line 22 - page 13, line 30 figure 3	1-5
	-/--	

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

[X] See patent family annex.

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

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

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

"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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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 February 2016	16/02/2016

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	Colzi, Enrico

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/310695 A1 (SAWAI RYO [JP]) 17 December 2009 (2009-12-17) paragraph [0065] -----	1-5

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2015/063611

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2009310695 A1	17-12-2009	JP 4561880 B2 JP 2009302771 A US 2009310695 A1	13-10-2010 24-12-2009 17-12-2009