

COMMUNICATION METHOD, TRANSMITTER AND RECEIVER

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to a communication method, a transmitter and a receiver, and more particularly, is applicable to radio communication system such as a portable telephone system or the like.

DESCRIPTION OF THE RELATED ART

In this kind of radio communication system, an area for providing communication service is divided into cells having a desired size and a base station is set as a fixed radio station in the cell. The portable telephone device as a mobile radio station is installed in the cell so that the portable telephone device as a fixed radio station is constituted to be engaged in communication with the base station in the cell in which the portable telephone device is present. At that time, in this kind of radio communication system, the interference problem of an electronic wave is avoided by using a channel of frequency which is different between cells (this is simply referred to as a channel).

By the way, when a different channel is used between

adjacent cells in this manner, the problem of interference can be avoided, but at the same time, there arises a disadvantage in that the usage efficiency of the frequency is reduced. As a consequence, in recent years, the interference problem is avoided by changing the channel which is used in each cell at random for each predetermined timing, and the usage efficiency of the frequency is improved.

By the way, in such radio communication system, the channel is only changed at random so that it is not necessarily possible to avoid that the channel becomes the same between adjacent cells. Thus, it is feared that the timing becomes the same. In the case where the same channel is used, there might arise an interference problem in the same manner as the prior art.

For example, as shown in Fig. 1, in the cell 1A, when the portable telephone device 2A uses the predetermined channel to be engaged in communication with the base station 3A, and the same channel as the cell 1A is used in the adjacent cell 1B so that the portable telephone device 2B is engaged in communication with the base station 3B, it sometimes happens that the sending signal CB which is sent by the portable telephone device 2B reaches the base station 3A. In this case, the sending signal CB which reaches the base station 3A becomes an interference wave

(so-called hindrance wave) with respect to the sending signal CA which is sent to the base station 3A. In this manner, even when an interference wave I is generated to the sending signal CA in this manner, the signal level of the sending signal CA is larger than the interference wave I, and no considerable problem is generated in normal cases. However, in the case where because, for example, the portable telephone device 2A is distant from the base station 3A and the signal level of the sending signal CA becomes smaller than the interference wave I, the base station 3A receives the interference wave I by mistake instead of the sending signal CA from the portable telephone device 2A. As a consequence, the signal series transmitted by the portable telephone device 2B is restored, and the communication content of the other person is leaked with the result that a situation which is not preferable as a radio communication system might arise. For reference, in such a situation, even when the received data is not obtained as the radio communication system, it is desirable that the interference wave I is not demodulated.

SUMMARY OF THE INVENTION

In view of the foregoing, an object of this invention is to provide a communication method which is capable of avoiding restoring the signal series which is sent in other

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communication by mistake even when the same channel is used in the other communication, and is to provide a transmitter and receiver which use the communication method.

The foregoing object and other objects of the invention have been achieved by the provision of a communication method. In the communication method, the orthogonal conversion is performed by multiplying an orthogonal matrix which is different for each communication to signal series which is sent, and the signal series to which the orthogonal conversion is performed is sent by using the predetermined channel. On the receiving side, the signal series before the orthogonal conversion is restored by multiplying the inverse matrix of the orthogonal matrix which is used on the sending side of the communication partner to the received signal series.

With the above arrangement, the signal series is multiplied with the orthogonal matrix which is different for each communication and transmitted, and at a receiving side, the received signal series is multiplied with an inverse matrix of the orthogonal matrix used at a transmitting side of the communication partner, so that the signal series before orthogonal conversion is restored. Therefore, even when another communication is performed and received by using the same channel, since the orthogonal matrix used for the orthogonal conversion differs from one

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communication to another, inverse orthogonal conversion cannot be attained for one communication even if an inverse matrix for another communication is multiplied, thereby signal series sent in another communication being not restored.

The nature, principle and utility of the invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings in which like parts are designated by like reference numerals or characters.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a system structure view explaining that the sending signal which is sent by the other communication becomes an interference wave;

Fig. 2 is a system structural view explaining a principle of the present invention;

Figs. 3A to 3C are signal transition views explaining an operation at the time of receiving a sending signal from the communication partner in a radio communication system to which the present invention is applied;

Figs. 4A to 4C are signal transition views explaining an operation at the time of receiving an interference wave in the radio communication system;

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Fig. 5 is a block view showing a structure of a transmitter provided in the portable telephone set;

Fig. 6 is a block view showing a structure of a receiver provided in the station; and

Fig. 7 is a signal transition view explaining an orthogonal conversion at the time of using the first dimension orthogonal matrix.

DETAILED DESCRIPTION OF THE EMBODIMENT

Preferred embodiments of this invention will be described with reference to the accompanying drawings:

In the beginning, the principle of the present invention will be explained by using Fig. 2. In Fig. 2, reference numerals 5A, 5B denote the portable telephone device respectively. Reference numeral 6A and 6B denote the base station to which the present invention is applied. As shown in Fig. 2, the portable telephone device 5A uses the predetermined channel to be engaged in radio communication with the base station 6A in the cell 1A. At the same time, the same channel is used in the adjacent cell 1B so that the portable telephone device 5B is engaged in radio communication with the base station 6B. At that time, for example, in the portable telephone devices 5A and 5B both QPSK modulation (Quadrature Phase Shift Keying; Four Phase Transition Modulation) is used as a modulation

method of the sent data. The signal series of the modulated sending signal are defined as $x^{(A)}_1, x^{(A)}_2, x^{(A)}_3, \dots \dots x^{(A)}_{k-1}, x^{(A)}_k, x^{(A)}_{k+1}, \dots \dots$ and $x^{(B)}_1, x^{(B)}_2, x^{(B)}_3, \dots \dots x^{(B)}_{k-1}, x^{(B)}_k, x^{(B)}_{k+1}, \dots \dots$

The portable telephone device 2A to which the present invention is applied groups N (N is an integer which is 1 or more) sending signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots \dots$). The grouped sending signal series $x^{(A)}_k, \dots \dots x^{(A)}_{k+N}$ and a predetermined Nth normal orthogonal matrix M_A are multiplied in order as shown in the following equation.

[Equation 1]

$$\begin{bmatrix} y^{(A)}_k \\ \vdots \\ y^{(A)}_{k+N} \end{bmatrix} = M_A \begin{bmatrix} x^{(A)}_k \\ \vdots \\ x^{(A)}_{k+N} \end{bmatrix} \quad \dots (1)$$

As a consequence, an orthogonal conversion is added to the sending signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots \dots$) and a resulting sending signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots \dots$) are sent in order.

On the other hand, at the base station 6A which is a receiving side, when a sending signal CA is received from the portable telephone device 5A of the communication partner, N received signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots \dots$)

are grouped, and the grouped received signal series $y^{(A)}_k, \dots \dots y^{(A)}_{k+N}$ are successively multiplied with an inverse matrix M_A^{-1} of the Nth normal orthogonal matrix M_A used on the sending side as shown in the following equation:
[Equation 2]

$$\begin{aligned} \begin{bmatrix} X^{(A)}_k \\ \vdots \\ X^{(A)}_{k+N} \end{bmatrix} &= M_A^{-1} \begin{bmatrix} y^{(A)}_k \\ \vdots \\ y^{(A)}_{k+N} \end{bmatrix} \\ &= M_A^{-1} M_A \begin{bmatrix} X^{(A)}_k \\ \vdots \\ X^{(A)}_{k+N} \end{bmatrix} = \begin{bmatrix} X^{(A)}_k \\ \vdots \\ X^{(A)}_{k+N} \end{bmatrix} \end{aligned} \quad \dots (2)$$

As a consequence, the signal series $X^{(A)}_n$ ($n=1, 2, 3, \dots \dots$) is restored which is equal to the signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots \dots$) before orthogonal conversion.

In the similar manner, at the time of sending data, the portable telephone device 5B groups the N sending signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots \dots$). The grouped sending signal series $x^{(B)}_k, \dots \dots X^{(B)}_{k+N}$ and the predetermined Nth normal orthogonal matrix M_B are multiplied in order for each group as shown in the following equation.

[Equation 3]

$$\begin{bmatrix} y^{(B)}_k \\ \vdots \\ y^{(B)}_{k+N} \end{bmatrix} = M_B \begin{bmatrix} x^{(B)}_k \\ \vdots \\ x^{(B)}_{k+N} \end{bmatrix}$$

... (3)

As a consequence, the orthogonal conversion is added to the sending signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$), and the resulting sending signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) are sent in order. For reference, the Nth normal orthogonal matrix M_B which is used in the portable telephone device 5B and the Nth normal orthogonal matrix M_A which is used in the portable telephone device 5A are matrixes which are completely different from each other.

At the base station 6B which is a receiving side, when the sending signal CB from the portable telephone device 5B of the communication partner is received, the N received receiving signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) are grouped, and the grouped $y^{(B)}_k, \dots, y^{(B)}_{k+N}$ and the inverse matrix M_B^{-1} of the Nth normal orthogonal matrix M_B used at a sending side are multiplied in order for each group as shown in the following equation.

[Equation 4]

$$\begin{aligned}
\begin{bmatrix} X^{(B)}_k \\ \vdots \\ X^{(B)}_{k+N} \end{bmatrix} &= M_B^{-1} \begin{bmatrix} y^{(B)}_k \\ \vdots \\ y^{(B)}_{k+N} \end{bmatrix} \\
&= M_B^{-1} M_B \begin{bmatrix} X^{(B)}_k \\ \vdots \\ X^{(B)}_{k+N} \end{bmatrix} = \begin{bmatrix} X^{(B)}_k \\ \vdots \\ X^{(B)}_{k+N} \end{bmatrix} \\
&\dots (4)
\end{aligned}$$

Consequently, the signal series $X^{(B)}_n$ ($n=1, 2, 3, \dots$) which is equal to the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) before the orthogonal conversion is restored.

By the way, at the base station 6A, only the sending signal CA sent by the portable telephone device 5A reaches, but the sending signal CB sent by the portable telephone device 5B also reaches depending on the situation. In that case, the sending signal CB from the portable telephone device 5B acts as an interference wave I. When the signal level of the sending signal CB is large as compared with the sending signal CA from the portable telephone device 5A, trouble is caused to communication with the portable telephone device 5A. In other words, as the base station 6A, it is not recognized that the signal is a sending signal from either of the portable telephone devices 5A or 5B so that it is feared that the sending signal CB from the

portable telephone device 5B is received by mistake.

In such a case, the base station 6A groups the N received signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) received from the portable telephone device 5B so that the demodulation processing is performed by multiplying the inverse matrix M_A^{-1} to the grouped signal series $y^{(B)}_k, \dots y^{(B)}_{k+N}$ as shown in the following equation as in the normal receiving processing.

[Equation 5]

$$\begin{bmatrix} X^{(A)}_k \\ \vdots \\ X^{(A)}_{k+N} \end{bmatrix} = M_A^{-1} \begin{bmatrix} y^{(B)}_k \\ \vdots \\ y^{(B)}_{k+N} \end{bmatrix} = M_A^{-1} M_B \begin{bmatrix} x^{(B)}_k \\ \vdots \\ x^{(B)}_{k+N} \end{bmatrix} \quad \dots (5)$$

However, as seen from the equation (5), the receiving signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) from the portable telephone device 5B is a result obtained from a multiplication of the orthogonal matrix M_B which is different from the orthogonal matrix M_A so that the diagonal reverse conversion is not obtained even when the inverse matrix M_A^{-1} is multiplied with the result that the original signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) is not restored. In this case, the received signal series becomes a signal series which is the original signal series $x^{(B)}_n$.

($n=1, 2, 3, \dots$) orthogonally converted with another orthogonal matrix consisting of $M_A^{-1}M_B$, so that the signal becomes ostensibly a noise signal, and even when the signal series is QPSK demodulated, the sending data of the portable telephone device 5B is not restored.

In this manner, in the case of the radio communication system to which the present invention is applied, the orthogonal matrix which is different for each communication at the sending side is multiplied with the signal series. On the receiving side, the received signal series is multiplied with the inverse matrix of the orthogonal matrix which is used on the sending side (namely, the communication partner of its own station) so that the original signal series before the orthogonal conversion is restored. As a consequence, even when the same channel is used in the other communication, the restoration of the sent signal series by the other communication is avoided in advance with the result that the leakage of the data sent in the other communication can be avoided in advance.

For reference, there is described here that the leakage problem is avoided when the sending signal CB of the portable telephone device 5B is received by the base station 6A. For the same reason, the leakage problem can be also avoided even when the base station 6B receives the sending signal CA of the portable telephone device 5A.

Here, the orthogonal conversion using the orthogonal matrix and the inverse conversion thereof will be explained by using the signal transition view. In the beginning, the sending signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) of the portable telephone device 5A is QPSK modulated so that the $\pi/4, 3\pi/4, 5\pi/4$ or $7\pi/4$ phase states can be assumed. As a consequence as shown in Fig. 3A, on the complex surface (IQ surface), the phase state is present at a position where the phase state becomes $\pi/4, 3\pi/4, 5\pi/4$ or $7\pi/4$. When such sending signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) is multiplied to the Nth normal orthogonal matrix M_A , the resulting signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$) becomes a random state as shown in Fig. 3B.

On the other hand, at the base station 6A which is a receiving side, this signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$) is received. As described above, when the inverse matrix M_A^{-1} the orthogonal matrix M_A which is used on the sending side is multiplied with this signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$), the resulting signal series $X^{(A)}_n$ ($n=1, 2, 3, \dots$) becomes the same as the original signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) as shown in Fig. 3C so that the resulting signal series is brought back to the position of the phase state comprising $\pi/4, 3\pi/4, 5\pi/4$ or $7\pi/4$ on the complex surface. Consequently, when the signal series $X^{(A)}_n$ ($n=1, 2, 3, \dots$) is subjected to QPSK

demodulation, the sending data from the portable telephone device 5A can be accurately restored.

Furthermore, since the sending signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) of the portable telephone device 5B is also QPSK modulated, $\pi/4, 3\pi/4, 5\pi/4$ or $7\pi/4$ phase state is assumed with the result that the phase is present on the position comprising $\pi/4, 3\pi/4, 5\pi/4$ or $7\pi/4$ on the complex surface as shown in Fig. 4A. When such sending signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) is multiplied with Nth normal orthogonal matrix M_B , the resulting signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) is such that the phase state becomes random as shown in Fig. 4B.

In the case where such signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) is received with the base station 6A which is not the communication partner, the signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) becomes an interference wave for the base station 6A. However, the base station 6A does not recognize that the signal series is either the sending signal from the communication partner or the interference wave, the demodulation processing is performed as in the normal receiving processing. However, even when the inverse matrix M_A^{-1} of the orthogonal matrix M_A is multiplied with this signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$), the inverse matrix M_A^{-1} is not the inverse matrix of the orthogonal matrix M_B which is used at the

sending time. As shown in Fig. 4C, the phase state is not brought back to the original state so that the phase state becomes a random state. Consequently, even when the signal series shown in Fig. 4C is QPSK demodulated, the sending data from the portable telephone device 5B is not restored. Consequently, the leakage of the data sent by the other communication can be avoided, and the generation of the undesirable state as a radio communication system can be avoided.

Here, a concrete structure of the portable telephone device 5A (or 5B) and the base station 6A (or 6B) to which such principle is applied will be explained hereinbelow. In the beginning, the portable telephone device 5A (or 5B) has the transmitter 10 shown in Fig. 5. This transmitter 10 roughly comprises a QPSK modulation circuit 11, an orthogonal conversion part 12, and a sending part 13 so that the sent data S1 supplied via the predetermined noise processing circuit or the like is input to the QPSK modulation circuit 11 in the beginning. The QPSK modulation circuit 11 converts the sent data S1 into a sending signal series S2 of the phase data by performing the QPSK modulation processing on the sent data S1 so that the sending signal series S2 is output to a serial/parallel conversion circuit (S/P) 14 of the orthogonal conversion part 12. For reference, this sending signal

series S2 corresponds to the aforementioned signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) (or $x^{(B)}_n$ ($n=1, 2, 3, \dots$)).

The serial/parallel conversion circuit 14 is a circuit for grouping N groups of the sending signal series S2 so that the sent signal series which is input is N parallel signal by dividing the input signal series S2 into N signals and the resulting parallel signal series ST_1 through ST_N is output to an orthogonal conversion circuit 15.

The orthogonal conversion circuit 15 is a circuit for adding an orthogonal conversion to the sending signal series by using a predetermined Nth normal orthogonal matrix. The parallel signal series ST_1 through ST_N are defined as one group and Nth normal orthogonal matrix is multiplied in order, and each group of signal series ST_1 through ST_N are subjected to an orthogonal conversion. At that time, the orthogonal conversion circuit 15 searches for a matrix which is completely different from the Nth normal orthogonal matrix which is used in the other communication, and the matrix is not used for the orthogonal conversion, and a matrix which is selected at random from the Nth normal orthogonal matrixes which are present in plurality. This is because when an attempt is made to search for a matrix which is completely different from the Nth normal orthogonal matrix which is used in the

other communication, it is necessary to inspect a matrix which is used in the other communication with the result that the selection processing of the orthogonal matrix for the processing becomes complicated. As a consequence, this orthogonal conversion circuit 15 obtains a matrix ostensibly different from the matrix which is used in the other communication by selecting at random a matrix out of the Nth normal orthogonal matrixes which are present in plurality so that the matrix selection processing is simplified.

Here, a method for selecting the Nth normal orthogonal matrix will be concretely explained. In the orthogonal conversion circuit 15, for example N Nth Walsh vectors are prepared as the Nth diagonal vector whose vector components comprise two values. The orthogonal conversion circuit 15 gives a random phase rotation to this Nth Walsh vector respectively so that the Nth random normal orthogonal matrix is generated by combining the random phase rotation. In other words, as shown in the following equation,
[Equation 6]

$$M = \frac{1}{\sqrt{N}} \begin{bmatrix} e^{jZ_1} & W_1^T \\ e^{jZ_2} & W_2^T \\ \vdots & \vdots \\ e^{jZ_N} & W_N^T \end{bmatrix}$$

... (6)

a random phase rotation is given to the Walsh vectors $W_1, W_2, \dots, W_N$ by multiplying random phase rotation components $e^{jz_1}, e^{jz_2}, \dots, e^{jz_N}$ (here Z_1 through Z_N denote phase rotation angles) to N th Walsh vectors $W_1, W_2, \dots, W_N$. Then, $1/\sqrt{N}$ is multiplied so that a random N th normal orthogonal matrix M is generated. However, in the equation (6), $W_1^T, W_2^T, \dots, W_N^T$ is what is vector placed so as to have a vector component in a line direction of the Walsh vectors $W_1, W_2, \dots, W_N$ having vector component in the row direction.

By using such selection method, the orthogonal conversion circuit 15 selects the N th normal orthogonal matrix and multiplies it to the parallel signal series ST_1 through ST_N so that the orthogonal conversion is added to the signal series ST_1 through ST_N . The resulting parallel signal series ST_1' through ST_N' are output to a parallel/serial conversion circuit (P/S) 16.

The parallel/serial conversion circuit 16 is a circuit

for collecting grouped sending signal series into one group by converting a parallel signal into a serial signal so that the parallel signal series ST_1' through ST_n' which are input are converted into a serial signal series $S3$, which is output to a reverse Fourier conversion circuit (IFFT) 17 at the sending part 13. For reference, this signal series $S3$ corresponds to the aforementioned signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$) or $y^{(B)}_n$ ($n=1, 2, 3, \dots$).

The reverse Fourier conversion circuit 17 dissipates and overlaps the signal series $S3$ with a plurality of multiple carriers having a different frequencies by adding a reverse Fourier conversion to the signal series $S3$. Then the resulting sending signal $S4$ is output to a high frequency circuit 18. The high frequency circuit 18 converts this sending signal $S4$ into a predetermined channel of sending signal $S5$ in frequency. At the same time, after the sending signal $S5$ is amplified to a predetermined power, the sending signal is sent via an antenna 19. For reference, the high frequency circuit 18 changes at random the channel of the sending signal $S5$ for each of the predetermined timing (so-called frequency hopping is performed). As a consequence, the usage efficiency of the frequency is improved while avoiding the situation that the channel becomes the same as the other communication.

In contrast, the base station 6A (or 6B) has a receiver 20 as shown in Fig. 6. This receiver 20 roughly comprises a receiving part 21, an orthogonal conversion part 22, and a QPSK demodulation circuit 29. The signal S10 received via the antenna 23 is input to a high frequency circuit 24 of the receiving part 21. The high frequency circuit 24 amplifies the sending signal S10 to a predetermined power, and at the same time, the received signal S10 is converted into a received signal S11 of a base band, and the received signal is output to the Fourier conversion circuit (FFT) 25. The Fourier conversion circuit 25 extracts a signal series S12 which is dissipated and overlapped with the a plurality of multiple carriers by adding the Fourier conversion to the receiving signal S11 and the extracted signal is output to a serial/parallel conversion circuit (S/P) 26 of the diagonal reverse conversion part 22. For reference, this signal series S12 corresponds to the aforementioned signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$) (or $y^{(B)}_n$ ($n=1, 2, 3, \dots$)).

The serial/parallel conversion circuit 26 is a circuit for dividing the signal series S12 into groups comprising N signal series, and the circuit converts the signal series into N parallel data by dividing input signal series S12 into groups comprising N signal series and the resulting parallel signal series SR_1 through SR_N are output to a

diagonal reverse conversion circuit 27.

The diagonal reverse conversion circuit 27 is a circuit for performing diagonal reverse conversion by using an inverse matrix of Nth normal orthogonal matrix which is used by the orthogonal conversion circuit 15 of the communication partner. The diagonal reverse conversion circuit adds the diagonal reverse conversion for each group with respect to the signal series SR_1 through SR_N by multiplying the inverse matrix in order by defining the input parallel signal series SR_1 through SR_N as one group. The resulting signal series SR_1' through SR_N' is output to a parallel/serial conversion circuit (P/S) 28. For reference, the diagonal reverse conversion circuit 27 recognizes Nth normal orthogonal matrix which is used on the sending side by receiving processing or the like of the control signal, for example, at the time of the start of the communication.

The parallel/serial conversion circuit 28 is a circuit for collecting received signal series which is grouped into one group by converting the parallel signal into a serial signal. The input parallel signal series SR_1' through SR_N' are converted into a serial signal series S13. And this signal series S13 is output to a QPSK modulation circuit 29. For reference, this signal series S13 corresponds to the aforementioned signal series $X^{(A)}_n$ ($n=1, 2, 3, \dots$) (or $X^{(B)}_n$ ($n=1, 2, 3, \dots$)). The QPSK modulation circuit 29

restores the received data S14 from the signal series S13 which is phase data by performing a predetermined demodulation processing such as, for example, diagonal delay wave detection to the QPSK modulated signal series S13. In this manner, the received data S14 which is the same as the sent data S1 on the sending side is restored on the receiving side.

For reference, bi-direction communication is performed between the portable telephone device 5A (or 5B) and the base station 6A (or 6B) so that the portable telephone device 5A (or 5B) is provided with a receiver which is approximately the same as the aforementioned receiver 20. In the similar manner, the base station 6A (or 6B) is provided with a transmitter which is approximately similar to the aforementioned transmitter 10.

In the aforementioned structure, in the case of this radio communication system, the orthogonal conversion is applied to the signal series by multiplying the Nth normal orthogonal matrix which is different for each communication to the signal series which is QPSK modulated at the time of sending the signal, and the orthogonally converted signal series is sent. On the other hand, on the receiving side, the diagonal reverse conversion is applied to the signal series by multiplying the inverse matrix of the Nth normal orthogonal matrix which is used on the sending side of the

communication partner to the signal series which has been received and the signal series which is subjected to the reverse conversion is subjected to QPSK demodulation. For example, in the portable telephone device 5A which is shown in Fig. 2, the signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) is subjected to the orthogonal conversion by multiplying the Nth normal orthogonal matrix M_A to the signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) to be sent so that the signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$) which is subjected to the orthogonal conversion is sent. Furthermore, in the portable telephone device 5B, the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) is subjected to the orthogonal conversion by multiplying the Nth normal orthogonal matrix M_B which is different from the orthogonal matrix M_A to the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) to be sent with the result that the signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$) which is subjected to the orthogonal conversion is sent.

By the way, in the case where the base station 6A receives the sending signal CA from the portable telephone device 5A which is a communication partner, the inverse matrix M_A^{-1} of the orthogonal conversion M_A is multiplied to the received signal series $y^{(A)}_n$ ($n=1, 2, 3, \dots$) with the result that the original signal series $x^{(A)}_n$ ($n=1, 2, 3, \dots$) can be accurately restored and the sent data sent by the portable telephone device 5A with QPSK

demodulation can be accurately restored.

On the other hand, in the case where the base station 6A receives the sending signal CB from the portable telephone device 5B, the original signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) is not restored even when the inverse matrix M_A^{-1} is multiplied to the received signal series $y^{(B)}_n$ ($n=1, 2, 3, \dots$), because the inverse matrix M_A^{-1} is not an inverse matrix of the orthogonal matrix M_B which is used on the sending side. In this case, when the inverse matrix M_A^{-1} is multiplied, the matrix comprising $M_A^{-1}M_B$ to the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) is multiplied so that the signal series becomes random and looks ostensibly like a noise signal with the result that the original sent data is not restored even when the QPSK demodulation is performed temporarily.

In this manner, this radio communication system multiplies the orthogonal matrix which is different for each communication to the signal series on the sending side and sends it, while the system multiplies the inverse matrix of the orthogonal matrix which is used at the sending side of the communication partner to the received signal series on the receiving side and the original signal series is restored with the result that the same channel is used in the other communication. Even when the signal series is received, the orthogonal matrix which is used at

the sending time is different from the other communication so that the diagonal reverse conversion is not realized by multiplying the inverse matrix, and the signal series which is sent in the other communication is not restored. As a consequence, the leakage of the sent data which is sent in the other communication can be avoided in advance.

Furthermore, in the case of the radio communication system, a completely different Nth normal orthogonal matrix is not selected by examining the Nth normal orthogonal matrix which is used in the other communication at the time of selecting the Nth normal orthogonal matrix in the orthogonal conversion circuit 15. In actuality, the matrix which is different from the matrix which is used in the other communication is selected by selecting the orthogonal matrix at random out of the Nth normal orthogonal matrixes which are present in plurality. Consequently, a process of examining the matrix which is used in the other communication becomes unnecessary so that a selection processing of the orthogonal matrix can be simplified. Also, depending on the situation, an orthogonal matrix to be used is assigned to each base station in advance, and the terminal station may select the orthogonal matrix to be used in accordance with the base station with which the communication is performed.

Furthermore, in the case of the radio communication

system, a plurality of orthogonal matrixes are not prepared in advance at the time of selecting the orthogonal matrix. In actuality, N Nth Walsh vectors are prepared in advance, and random phase rotation is given to the Walsh vectors $W_1, W_2, \dots \dots W_N$ so that Nth normal orthogonal matrix is obtained by combining the Walsh vectors $W_1, W_2, \dots \dots W_N$. Consequently, the calculation part for calculating the normal orthogonal matrix is constituted with addition and subtraction processing, and at the same time, a memory for memorizing a plurality of orthogonal matrixes becomes unnecessary and the normal orthogonal matrix can be calculated with a simple structure.

For reference, Nth normal orthogonal matrix which is calculated by using the Walsh vector is shown here as a reference. For example, when $N=1$ is set, and random rotation angles which are selected by the portable telephone devices 5A and 5B are set to Z_A and Z_B , the Walsh vector becomes '1' at the time of $N=1$ with the result that the normal orthogonal matrixes M_A and M_B generated in the portable telephone device 5A and 5B are shown in the following equation.

[Equation 7]

$$M_A = e^{jZ_A}, \quad M_B = e^{jZ_B} \quad \dots (7)$$

For reference, when the normal orthogonal matrixes M_A and M_B are used, it means that the signal series having a phase state which is set to $\pi/4$, $3\pi/4$, $5\pi/4$ or $7\pi/4$ on the complex surface is rotated in a predetermined direction by phase rotation angles ZA and ZB . Incidentally, in this case, when the base station 6A receives the sending signal from the portable telephone device 5B which is the other communication, the matrix which is shown in the following equation is multiplied to the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$).

[Equation 8]

$$M_A^{-1} M_B = e^{j(ZB-ZA)}$$

... (8)

It can be seen that when the phase rotation angles ZA and ZB are different, the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) which is sent in the other communication is not restored.

Furthermore, the $N=2$ is set, and random phase rotation angles which are selected by the portable telephone devices 5A and 5B are set to $ZA1$, $ZA2$, $ZB1$ and $ZB2$ respectively. A vector shown in the following equation is used as the line displacement vectors W_1^T and W_2^T of the second Walsh vectors

W_1 and W_2 .

[Equation 9]

$$W_1^T = (1, 1), \quad W_2^T = (1, -1) \quad \dots (9)$$

Then, the normal orthogonal matrixes M_A and M_B which are generated in the portable telephone devices 5A and 5B are shown in the following equation.

[Equation 10]

$$\left\{ \begin{array}{l} M_A = \frac{1}{\sqrt{2}} \begin{bmatrix} e^{jZ_{A1}} & 0 \\ 0 & e^{jZ_{A2}} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \\ M_B = \frac{1}{\sqrt{2}} \begin{bmatrix} e^{jZ_{B1}} & 0 \\ 0 & e^{jZ_{B2}} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \end{array} \right. \quad \dots (10)$$

Incidentally, in this case, when the base station 6A receives the sending signal from the portable telephone device 5B which is the other communication, the state is obtained that the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) is multiplied with the matrix shown in the following equation.

[Equation 11]

$$M_A^{-1} M_B$$

$$= \frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} e^{-jZA1} & 0 \\ 0 & e^{-jZA2} \end{bmatrix} \begin{bmatrix} e^{jZB1} & 0 \\ 0 & e^{jZB2} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$= \frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} e^{j(ZB1-ZA1)} & 0 \\ 0 & e^{j(ZB2-ZA2)} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$= \frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} e^{j(ZB1-ZA1)} & e^{j(ZB1-ZA1)} \\ e^{j(ZB2-ZA2)} & -e^{j(ZB2-ZA2)} \end{bmatrix}$$

$$= \frac{1}{2} \begin{bmatrix} e^{j(ZB1-ZA1)} + e^{j(ZB2-ZA2)} & e^{j(ZB1-ZA1)} - e^{j(ZB2-ZA2)} \\ e^{j(ZB1-ZA1)} - e^{j(ZB2-ZA2)} & e^{j(ZB2-ZA2)} + e^{j(ZB2-ZA2)} \end{bmatrix}$$

... (11)

It can be seen that when the phase rotation angles ZA1 and ZB1 and the phase rotation angles ZA2 and ZB2 are different from each other, the signal series $x^{(B)}_n$ ($n=1, 2, 3, \dots$) which is sent in the other communication is not restored.

Thus, in the aforementioned structure, the sending side multiplies and sends the orthogonal matrix which is different from each other for each communication to the signal matrix, and the receiving side restores the original signal series before the orthogonal conversion by

multiplying the inverse matrix of the orthogonal matrix used by the sending side of the communication partner to the received signal series with the result that the same channel is used in the other communication. Even when the same channel is received, the mistaken restoration of the signal series which is sent in the other communication can be avoided in advance, and the leakage of the sent data which is sent in the other communication can be avoided in advance.

Incidentally, in the aforementioned embodiment, there is described a case in which N Nth Walsh vectors are prepared at the time of selecting the orthogonal matrix, respective random phase rotation is given to the Walsh vector, and the Walsh vector to which the phase rotation is given is combined thereby generating more random orthogonal matrix. However, the present invention is not limited thereto. The same advantage as described above can be obtained by generating more random orthogonal matrix by arranging each vector component of the predetermined orthogonal matrix at random.

Furthermore, in the aforementioned embodiment, there is described a case in which normalized orthogonal matrix is used as the orthogonal matrix. However, the present invention is not limited thereto. An arbitrary orthogonal matrix which is not normalized may be used. In summary,

the same advantage as described above can be obtained by using any orthogonal matrix when the signal series is subjected to the orthogonal conversion by using the orthogonal matrix at the time of sending data.

Furthermore, in the aforementioned embodiment, there is described a case in which QPSK modulation is used as the modulation method for the sent data. However, the present invention is not limited thereto. Other modulation method such as BPSK modulation (Binary Phase Shift Keying), 16 QAM modulation (16 Quadrature Amplitude Modulation) may be used.

Furthermore, in the aforementioned embodiment, there is described a case in which the present invention is applied to a radio communication system of the communication method such that the signal series is dissipated to a plurality of multiple carriers and is overlapped to send the resulting sending signal to the predetermined channel by converting the frequency, and at the same time, the channel of the sending signal is changed at random for each predetermined timing. However, the present invention is not limited thereto. The present invention may be applied to the radio communication system of the other communication. In summary, when there is a possibility that the so-called same channel interference is generated in which the same channel is used to perform at least two or more communications so that two or more

communication electronic waves interfere with each other.

As described above, according to the present invention, the orthogonal matrix which is different for each communication is multiplied to the signal series and sent, and the receiving side restores the signal series before the orthogonal conversion by multiplying the inverse matrix of the orthogonal matrix which is used on the sending side of the communication partner to the received signal series. As a consequence, the other communication is performed by using the same channel so that even when the signal series is received the diagonal reverse conversion is not realized even by multiplying the inverse matrix to the signal series because the orthogonal matrix which is used in the orthogonal conversion is different from the other communication, and the signal series which is used in the other communication is not restored. By doing so, even when the same channel is used in the other communication, it is possible to avoid in advance mistaken the restoration of the signal series which is sent in the other communication.

While there has been described in connection with the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be aimed, therefore, to cover in the appended claims all such changes and modifications as fall

within the true spirit and scope of the invention.



WHAT IS CLAIMED IS:

1. A transmitting method for performing an orthogonal conversion on a desired information and transmitting it, wherein
said orthogonal conversion is different depending on the situation.
2. The transmitting method according to claim 1, wherein
said orthogonal conversion is performed by multiplying orthogonal matrix.
3. The transmitting method according to claim 1, wherein
said orthogonal conversion divides a predetermined number of said desired information into groups, and said orthogonal conversion is performed for each group.
4. The transmitting method according to claim 3, wherein
said orthogonal conversion is performed by multiplying orthogonal matrix.
5. The transmitting method according to claim 2, wherein
said orthogonal matrix can be obtained by selecting at random out of a plurality of orthogonal matrixes.
6. The transmitting method according to claim 4, wherein

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said orthogonal matrix can be obtained by selecting at random out of a plurality of orthogonal matrixes.

7. The transmitting method according to claim 2, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.

8. The transmitting method according to claim 4, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.

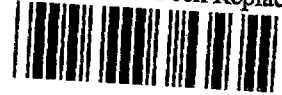
9. The transmitting method according to claim 8, wherein said diagonal vector is Walsh vector.

10. The transmitting method according to claim 2, wherein said orthogonal matrix can be obtained by rearranging each vector component of a predetermined orthogonal matrix at random.

11. The transmitting method according to claim 4, wherein said orthogonal matrix can be obtained by rearranging each vector component of a predetermined orthogonal matrix at random.

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12. A receiving method for performing on the receiving signal an inverse conversion to the orthogonal conversion which is applied at a time of transmission and receiving it, wherein

said orthogonal conversion is different depending on the situation.

13. The receiving method according to claim 12, wherein said orthogonal conversion is performed by multiplying orthogonal matrix.

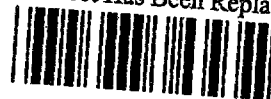
14. The receiving method according to claim 12, wherein said orthogonal conversion divides a predetermined number of said desired information into groups, and said orthogonal conversion is performed for each group.

15. The receiving method according to claim 14, wherein said orthogonal conversion is performed by multiplying orthogonal matrix.

16. The receiving method according to claim 13, wherein said orthogonal matrix can be obtained by selecting at random out of a plurality of orthogonal matrixes.

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17. The receiving method according to claim 15, wherein said orthogonal matrix can be obtained by selecting at random out of a plurality of orthogonal matrixes.
18. The receiving method according to claim 13, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.
19. The receiving method according to claim 15, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.
20. The receiving method according to claim 19, wherein said diagonal vector is Walsh vector.
21. The receiving method according to claim 13, wherein said orthogonal matrix can be obtained by rearranging each vector component of a predetermined orthogonal matrix at random.
22. The transmitting method according to claim 15, wherein said orthogonal matrix can be obtained by rearranging each vector component of a predetermined orthogonal matrix

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at random.

23. A transmitter for performing an orthogonal conversion on a desired information and transmitting it, comprising:

orthogonal converting means for performing the orthogonal conversion on a desired information; and

transmitting means for transmitting the output of said orthogonal converting means, wherein

said orthogonal conversion is different depending on the situation.

24. The transmitter according to claim 23, wherein

said orthogonal conversion is performed by multiplying orthogonal matrix.

25. The transmitter according to claim 23, wherein

said orthogonal conversion divides a predetermined number of said desired information into groups, and said orthogonal conversion is performed for each group.

26. The transmitter according to claim 25, wherein

said orthogonal conversion is performed by multiplying orthogonal matrix.

27. The transmitter according to claim 24, wherein

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39

said orthogonal matrix can be obtained by selecting at random out of a plurality of orthogonal matrixes.

28. The transmitter according to claim 26, wherein said orthogonal matrix can be obtained by selecting at random out of a plurality of orthogonal matrixes.

29. The transmitter according to claim 24, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.

30. The transmitter according to claim 26, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.

31. The transmitter according to claim 30, wherein said diagonal vector is Walsh vector.

32. The transmitter according to claim 24, wherein said orthogonal matrix can be obtained by rearranging each vector component of a predetermined orthogonal matrix at random.

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33. The transmitter according to claim 26, wherein
said orthogonal matrix can be obtained by rearranging
each vector component of a predetermined orthogonal matrix
at random.

34. A receiver for performing on the receiving signal an
inverse conversion to the orthogonal conversion which is
applied at a time of transmission and receiving it,
comprising:

receiving means for receiving a signal; and

inverse converting means for performing on the output
of said receiving means an inverse orthogonal conversion to
the conversion at a time of transmission, wherein

said orthogonal conversion is different depending on
the situation.

35. The receiver according to claim 34, wherein
said orthogonal conversion is performed by multiplying
orthogonal matrix.

36. The receiver according to claim 34, wherein
said orthogonal conversion divides a predetermined
number of said desired information into groups, and said
orthogonal conversion is performed for each group.

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37. The receiver according to claim 36, wherein
said orthogonal conversion is performed by multiplying
orthogonal matrix.

38. The receiver according to claim 35, wherein
said orthogonal matrix can be obtained by selecting at
random out of a plurality of orthogonal matrixes.

39. The receiver according to claim 37, wherein
said orthogonal matrix can be obtained by selecting at
random out of a plurality of orthogonal matrixes.

40. The receiver according to claim 35, wherein
said orthogonal matrix can be obtained by combining a
predetermined diagonal vector and a random phase rotation
processing.

41. The receiver according to claim 37, wherein
said orthogonal matrix can be obtained by combining a
predetermined diagonal vector and a random phase rotation
processing.

42. The receiver according to claim 41, wherein
said diagonal vector is Walsh vector.

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43. The receiver according to claim 35, wherein
said orthogonal matrix can be obtained by rearranging
each vector component of a predetermined orthogonal matrix
at random.

44. The transmitter according to claim 37, wherein
said orthogonal matrix can be obtained by rearranging
each vector component of a predetermined orthogonal matrix
at random.

45. A transmitting method for performing an orthogonal
conversion on a desired information and transmitting it,
comprising the steps of:

applying the first modulation to a desired
information;

performing the orthogonal conversion which is
different depending on the situation on the information;

applying the second modulation to the information; and
transmitting the information.

46. The transmitting method according to claim 45, wherein
said second modulation is a multiple carrier
modulation.

47. The transmitting method according to claim 46, wherein

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said first modulation is a phase modulation.

48. The transmitting method according to claim 45, wherein said second modulation is a modulation for obtaining the CDMA method.
49. The transmitting method according to claim 46, wherein said orthogonal conversion is performed by multiplying orthogonal matrix.
50. The transmitting method according to claim 48, wherein said orthogonal conversion is performed by multiplying orthogonal matrix.
51. The transmitting method according to claim 49, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.
52. The transmitting method according to claim 51, wherein said diagonal vector is Walsh vector.
53. A receiving method for performing on a receiving signal an inverse conversion to the orthogonal conversion which is applied at a time of transmission and receiving it,

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comprising the steps of:

receiving a signal;

applying to the signal the second demodulation for demodulating the second modulation applied at a time of transmission;

performing on the signal an inverse conversion to the orthogonal conversion which is applied at a time of transmission and which is different depending on the situation; and

applying to the signal the first demodulation for demodulating the first modulation applied at a time of transmission.

54. The receiving method according to claim 53, wherein said second modulation is a multiple carrier modulation.

55. The receiving method according to claim 54, wherein said first modulation is a phase modulation.

56. The receiving method according to claim 53, wherein said second modulation is a modulation for obtaining the CDMA method.

57. The receiving method according to claim 54, wherein

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said orthogonal conversion is performed by multiplying orthogonal matrix.

58. The receiving method according to claim 56, wherein said orthogonal conversion is performed by multiplying orthogonal matrix.

59. The receiving method according to claim 57, wherein said orthogonal matrix can be obtained by combining a predetermined diagonal vector and a random phase rotation processing.

60. The receiving method according to claim 59, wherein said diagonal vector is Walsh vector.

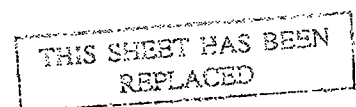
61. A transmitter for performing an orthogonal conversion on a desired information and transmitting it, comprising:

first modulating means for applying the first modulation to a desired information;

orthogonal converting means for performing on the information the orthogonal conversion which is different depending on the situation;

second modulating means for applying the second modulation to the information; and

transmitting means for transmitting the information.





62. The transmitter according to claim 61, wherein
said second modulation is a multiple carrier
modulation.
63. The transmitter according to claim 62, wherein
said first modulation is a phase modulation.
64. The transmitter according to claim 61, wherein
said second modulation is a modulation for obtaining
the CDMA method.
65. The transmitter according to claim 62, wherein
said orthogonal conversion is performed by multiplying
orthogonal matrix.
66. The transmitter according to claim 64, wherein
said orthogonal conversion is performed by multiplying
orthogonal matrix.
67. The transmitter according to claim 65, wherein
said orthogonal matrix can be obtained by combining a
predetermined diagonal vector and a random phase rotation
processing.

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68. The transmitter according to claim 67, wherein
said diagonal vector is Walsh vector.

69. A receiver for performing on a receiving signal an
inverse conversion to the orthogonal conversion which is
applied at a time of transmission and receiving it,
comprising:

receiving means for receiving a signal;

second demodulating means for applying to the output
of said receiving means the second demodulation for
demodulating the second modulation applied at a time of
transmission;

orthogonal converting means for performing on the
output of said second demodulating means an inverse
conversion to the orthogonal conversion which is applied at
a time of transmission and which is different depending on
the situation; and

first demodulating means for applying to the output of
said orthogonal converting means the first demodulation for
demodulating the first modulation applied at a time of
transmission.

70. The receiver according to claim 69, wherein
said second modulation is a multiple carrier
modulation.

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71. The receiver according to claim 70, wherein
said first modulation is a phase modulation.
72. The receiver according to claim 69, wherein
said second modulation is a modulation for obtaining
the CDMA method.
73. The receiver according to claim 70, wherein
said orthogonal conversion is performed by multiplying
orthogonal matrix.
74. The receiver according to claim 72, wherein
said orthogonal conversion is performed by multiplying
orthogonal matrix.
75. The receiver according to claim 73, wherein
said orthogonal matrix can be obtained by combining a
predetermined diagonal vector and a random phase rotation
processing.
76. The receiver according to claim 75, wherein
said diagonal vector is Walsh vector.

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