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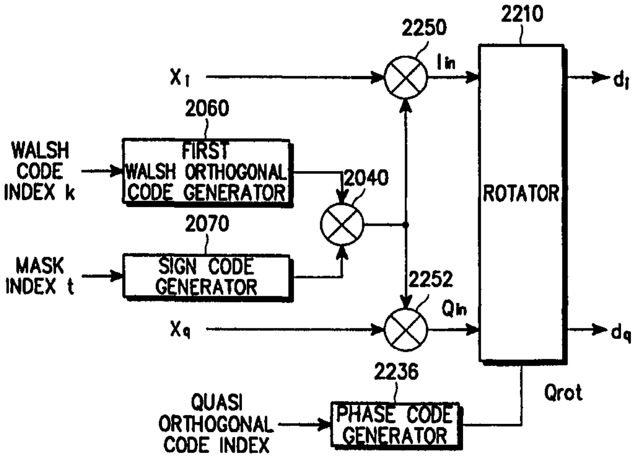

(57) Abstract

A method for generating a complex quasi-orthogonal code for channel spreading in a CDMA communication system is disclosed. The method comprises generating an M-sequences having a length N and a specific sequence having a good full correlation property with the M-sequence; generating a predetermined number of other specific sequences by circularly shifting said specific sequence; generating a predetermined number of other M-sequences by circularly shifting said M-sequence, and column permutating the circularly shifted specific sequences in a same method as a column permutating method for converting the generated M-sequences to Walsh orthogonal codes to generate canditate masks; generating quasi-orthogonal code representatives by operating the canditate masks and the Walsh orthogonal codes having the same length as the mask candidates; and selecting quasi-orthogonal codes out of the generated quasi-orthogonal code representatives and a partial correlation between different quasi-orthogonal codes, and selecting masks pertinent to generating the selected quasi-orthogonal codes.

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METHOD FOR GENERATING COMPLEX QUASI-ORTHOGONAL CODE AND APPARATUS AND METHOD FOR SPREADING CHANNEL DATA USING THE QUASI-ORTHOGONAL CODE IN CDMA COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a spreading device and method for a mobile communication system, and in particular, to a method for generating complex quasi-orthogonal codes and apparatus nd method for spreading channel data using those generated complex quasi-orthogonal codes.

2. Description of the Related Art

In general, a CDMA (Code Division Multiple Access) mobile communication system performs channel separation using orthogonal codes in order to increase channel capacity. For example, a forward link specified by the IS-95/IS-95A standard separates the channels using the orthogonal codes. This channel separation method can also be applied to a reverse link through time alignment. In addition, a UMTS (Universal Mobile Terrestrial System) down link also spread the channels using the orthogonal codes.

FIG. 1 illustrates the IS-95/IS-95A forward link in which channels are separated by orthogonal codes. Referring to FIG. 1, channels are separated by associated orthogonal codes Wi (where i=0 to 63), respectively, which typically are Walsh codes. The IS-95/IS-95A forward link uses convolutional codes having a code rate R=1/2, employs BPSK (Binary Phase Shift Keying) modulation, and has a bandwidth of 1.2288MHz. Accordingly, the number of available channels is 1.2288MHz/(9.6KHz*2)=64. That is, the IS-95/IS-95A forward link can separate channels using 64 Walsh codes.

As stated above, the number of available orthogonal codes depends on the employed modulation method and the minimum data rate. However, in future CDMA mobile communication systems, channels assigned to the users will increase in number in order to improve performance. To this end, future CDMA mobile communication systems will need to increase the channel capacity of traffic channels, pilot channels and control channels.

However, there are a limited number of available orthogonal codes the improved system can use. Therefore, any increase in channel capacity will be restricted due to the limitation on the number of available orthogonal codes. To solve this problem, it is desirable to generate quasi-orthogonal codes, which will have the least interference with the orthogonal codes and a variable data rate.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a method for generating complex quasi-orthogonal codes having the least interference with orthogonal codes in a CDMA communication system using the orthogonal codes.

It is another object of the present invention to provide a method for generating complex quasi-orthogonal codes having a correlation of below $\sqrt{L}$ with orthogonal codes of length L by generating and applying complex quasi-orthogonal codes for QPSK (Phase Shift Keying) modulation.

It is further another object of the present invention to provide a apparatus and method for spreading channel data with the complex quasi-orthogonal code generated using a quasi-orthogonal code mask in a CDMA communication system.

It is still another object of the present invention to provide a apparatus and method for spreading channel data with complex quasi-orthogonal codes generated using a sign and a phase of quasi-orthogonal code in a CDMA communication system.

It is yet another object of the present invention to provide a method for generating quasi-orthogonal codes having the least interference with orthogonal codes thereby to increase a channel capacity in a CDMA communication system using the orthogonal codes.

It is yet another object of the present invention to provide a device and method for generating quasi-orthogonal sequences satisfying all the conditions of quasi-orthogonal codes in a CDMA communication system.

It is yet another object of the present invention to provide a column permutation method for generating quasi-orthogonal sequences satisfying all the conditions of quasi-orthogonal codes in a CDMA communication system.

It is yet another object of the present invention to provide quasi-orthogonal codes which can be expressed as a sign code and a phase code and satisfy conditions of the quasi orthogonal codes in a CDMA communication system.

It is yet another object of the present invention to provide a device and method for spreading and despreading a channel signal using the quasi-orthogonal code expressed as a sign code and a phase code in a CDMA communication system.

It is yet another object of the present invention to provide quasi-orthogonal codes which can be expressed as a specific walsh code used as a sign code and a phase code and satisfy conditions of the quasi-orthogonal codes in a CDMA communication system.

It is yet another object of the present invention to provide a device and method for spreading and despreading a channel signal using a quasi-orthogonal code expressed as a specific walsh code used as a sign code and a phase code in a CDMA communication system.

To achieve the above objects, a method for generating a complex quasi-orthogonal code for channel spreading in a CDMA communication system is provided. The method comprises generating an M-sequence having a length N and a specific sequence having a good full correlation property with the M-sequence; generating a predetermined number of other specific sequences by circularly shifting said specific sequence; generating predetermined number of other M-sequences by circularly shifting said M-sequence, and column permutating the circularly shifted specific sequences in a same method as a column permutation method for converting the generated M-sequences to Walsh orthogonal codes to generate candidate masks; generating quasi-orthogonal code representatives by operating the mask candidates and the Walsh orthogonal codes having the same length as the candidate masks; and selecting quasi-orthogonal code candidates satisfying a partial correlation bound between the Walsh orthogonal codes and the quasi-orthogonal code representatives and a partial correlation between different quasi-orthogonal codes representatives, and selecting masks pertinent to generating the selected quasi-orthogonal codes.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagram illustrating channel separation using orthogonal codes in a CDMA communication system;

FIG. 2 is a diagram illustrating a partial correlation between a Walsh code and a quasi-orthogonal code;

FIG. 3 is a diagram illustrating a matrix Q for quasi-orthogonal code mask candidates used in generating complex quasi-orthogonal codes according to an embodiment of the present invention;

FIG. 4 is a diagram illustrating a matrix Q' for complex quasi-orthogonal code candidates generated by operating mask candidates for quasi-orthogonal codes and Walsh orthogonal codes according to an embodiment of the present invention;

FIG. 5 is a flow diagram illustrating a procedure for generating complex quasi-orthogonal codes according to an embodiment of the present invention;

FIG. 6 is a diagram illustrating channel separation using Walsh orthogonal codes and quasi-orthogonal codes in a CDMA communication system according to an embodiment of the present invention;

FIG. 7 is a block diagram illustrating a channel spreading device which uses complex quasi-orthogonal codes, in a CDMA communication system according to an embodiment of the present invention;

FIG. 8 is a detailed block diagram illustrating the channel spreading and PN masking part of FIG. 7 for complex quasi-orthogonal codes;

FIG. 9 is a diagram comparing the complex expression for numbers and the complex expression for signal transmission in an actual system on a complex plane;

FIG. 10 is a detailed block diagram illustrating the complex quasi-orthogonal code generator of FIG. 7, which generates quasi-orthogonal code masks in numbers;

FIG. 11 is a detailed block diagram illustrating the complex quasi-orthogonal code generator of FIG. 7, which generates quasi-orthogonal code masks in I and Q values;

FIG. 12 is a detailed block diagram illustrating a complex quasi-orthogonal code spreading device in the channel spreading and PN masking part of FIG. 7 according to a first embodiment of the present invention;

FIG. 13 is a detailed block diagram illustrating the rotator of FIG. 12;

FIG. 14 is a detailed block diagram illustrating a complex quasi-orthogonal code spreading device in the channel spreading and PN masking part of FIG. 7 according to a second embodiment of the present invention;

FIG. 15 is a detailed block diagram illustrating the rotator of FIG. 14;

FIG. 16 is a block diagram illustrating a device for despreading signals transmitted from the complex quasi-orthogonal code spreading device of FIG. 12;

FIG. 17 is a detailed block diagram illustrating the rotator of FIG. 16;

FIG. 18 is a block diagram illustrating a device for despreading signals transmitted from the complex quasi-orthogonal code spreading device of FIG. 14;

FIG. 19 is a detailed block diagram illustrating the rotator of FIG. 18;

FIG. 20 is a detailed block diagram illustrating a complex quasi-orthogonal code spreading device in the channel spreading and PN masking part of FIG. 7 according to a third embodiment of the present invention;

FIG. 21 is a detailed block diagram illustrating a complex quasi-orthogonal code spreading device in the channel spreading and PN masking part of FIG. 7 according to a fourth embodiment of the present invention; and

FIG. 22 is a flow diagram illustrating a procedure for generating a column permutation function in the quasi-orthogonal code generation process of FIG. 5 according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

The invention aims to generate quasi-orthogonal codes which have the least interference with orthogonal codes, in order to increase the channel capacity or maximize a capacity of a single cell in a CDMA communication system.

Quasi-orthogonal sequences can be generated from Kasami sequences, Gold sequences and Kerdock sequences. These sequences have a common feature that a sequence can be expressed as the sum of sequences having a good (or high) correlation property between PN sequences (M sequences) and the sequences. For this reason, the above sequences can be used in generating quasi-orthogonal codes. Walsh codes can be obtained by performing column permutation on PN sequences (M sequences). If a sequence comprised of the sum of a certain sequence and PN sequences undergoes column permutation in the same manner as in the column permutation for the PN sequences (M sequences), the column permuted sequence will maintain a good correlation property with the Walsh code. That is, since the two sequences having the good correlation property have equally undergone column permutation, the good correlation property can remain unchanged in terms of the whole length of the sequences. A sequence remaining after exclusion of the PN sequence from the sum of the two sequences can be given as a mask candidate family for a quasi-orthogonal code, which will be described hereafter. When this sequence is given as a mask candidate family for a quasi-orthogonal code, the full correlation property is basically satisfied.

Below, a detailed description will be made of a procedure for generating complex quasi-orthogonal codes using the Kerdock sequences (i.e., Family A sequences) out of the sequences having the above feature.

Complex quasi-orthogonal codes should satisfy the following conditions expressed by Equations (1) to (3).

$$\left|\sum_{t=1}^{N} j^{S_i(t)+2W_k(t)}\right| \le \theta_{\min}(N) \quad \cdots\cdot (1) \qquad \text{<Condition 1>}$$

$$\left|\sum_{t=1}^{N} j^{S_i(t)+S_i'(t)}\right| \le \theta_{\min}(N) \quad \cdots\cdot (2) \qquad \text{<Condition 2>}$$

$$\left|\sum_{t=1+(\frac{N}{M}l)}^{\frac{N}{M}(l+1)} j^{S_i(t)+2W_k(t)}\right| \le \theta_{\min}(\frac{N}{M}) \quad \cdots\cdot (3) \qquad \text{<Condition 3>}$$

In addition, it is preferable that the complex orthogonal codes partially satisfy the following condition expressed by Equation (4).

$$\left|\sum_{t=1+(\frac{N}{M}l)}^{\frac{N}{M}(l+1)} j^{S_i(t)+S_{i'}(t)}\right| \le \theta_{\min}(\frac{N}{M}) \quad \cdots\cdot (4) \qquad \text{<Condition 4>}$$

where $i=0,1,2,\cdots,M-1$, and $j=\sqrt{-1}$.

In Equations (1) to (4), $W_k(t)$ denotes the k-th sequence of a Walsh orthogonal code having length N ($1 \le k \le N$) and $S_i(t)$ denotes an i-th complex quasi-orthogonal code having length N ($1 \le i \le X$), where X denotes the number of quasi-orthogonal codes satisfying Conditions 1 to 3 and partially satisfying Condition 4. Condition 1 expressed by Equation (1) means that the full correlation between the k-th orthogonal code $W_k(t)$ ($1 \le k \le N$, $1 \le t \le N$) and the i-th quasi-orthogonal code $S_i(t)$ ($1 \le i \le X$, $1 \le t \le N$) should not exceed $\theta_{\min}(N)$. Condition 2 expressed by Equation (2) means that the full correlation between an i-th line and an i'-th line of a quasi-orthogonal code should not exceed $\theta_{\min}(N)$. Condition 3 expressed by Equation (3) means that a partial correlation should not exceed $\theta_{\min}(\frac{N}{M})$, when the partial correlation is taken for respective parts $\frac{N}{M}$ obtained by dividing, by M, the length N of a k-th line of an orthogonal code and an i-th line of a quasi-orthogonal code.

Here, Condition 1 of Equation (1) represents the full correlation property of a Walsh orthogonal code and a complex quasi-orthogonal code, and means the minimum correlation value that a complex quasi-orthogonal code can have theoretically as an absolute correlation value with a Walsh orthogonal code, wherein $\theta_{\min}(N)=\sqrt{N}$. Condition 2 of Equation (2) represents a condition for a full correlation property between complex quasi-orthogonal codes. Condition 3 of Equation (3) represents a partial correlation property between a Walsh orthogonal code and a complex quasi-orthogonal code. Condition 4 of Equation (4) represents a partial correlation property between complex quasi-orthogonal codes.

FIG. 2 is a diagram for explaining a method for taking a partial correlation between a complex quasi-orthogonal code and a Walsh orthogonal code, wherein $M=2^a$ $(0 \le a \le \log_2 N)$. During a data service, if the data rate increases, the N/M parts of the orthogonal code are transmitted. The partial correlation satisfies a correlation property at this moment. For example, when N=256, $\theta_{\min}(\frac{N}{M})$ values are shown in Table 1. Condition 4 represents a partial correlation between quasi-orthogonal codes, and correlation property values $\theta_{\min}(\frac{N}{M})$ are identical to those in Condition 3.

Table 1

N=256	M=1	$\theta_{\min}(N)=16$
N=256	M=2	$\theta_{\min}(\frac{N}{M})=8\sqrt{2}$
N=256	M=4	$\theta_{\min}(\frac{N}{M})=8$
N=256	M=8	$\theta_{\min}(\frac{N}{M})=4\sqrt{2}$
N=256	M=16	$\theta_{\min}(\frac{N}{M})=4$
N=256	M=32	$\theta_{\min}(\frac{N}{M})=2\sqrt{2}$
N=256	M=64	$\theta_{\min}(\frac{N}{M})=2$

The results of Table 1 can be generally extended. For example, when N=1024 and M=2, for the partial correlation between an orthogonal code of length 1024 and an orthogonal code of length 256, a full correlation bound $\theta_{mim}(N)$ between an orthogonal code of length 512 and a sequence other than the orthogonal code should be considered. Table 2 shows the relationship between the length N and the minimum correlation value $\theta_{mim}(N)$.

Table 2

N = 2048	$\theta_{\min}(N)=32\sqrt{2}$
N = 1024	$\theta_{\min}(N)=32$
N = 512	$\theta_{\min}(N)=16\sqrt{2}$
N = 256	$\theta_{\min}(N)=16$
N = 128	$\theta_{\min}(N)=8\sqrt{2}$
N = 64	$\theta_{\min}(N)=8$
N = 32	$\theta_{\min}(N)=4\sqrt{2}$

Sequences satisfying Conditions 1 and 2 include Kasami sequences, Gold sequences and Kerdock sequences. That is, all of these sequence families have a good cross correlation property. A full correlation property for the above sequence families is well known.

However, research has not been conducted to provide a sequence satisfying Condition 3. However, it is very important for the IS-95B standard or the future CDMA system supporting the variable data rate to satisfy Condition 3.

The full correlation of the above sequences is 2^{m+1} ($>\sqrt{L}$) for the length $L=2^{2m+1}$ (i.e., the length of odd-numbered exponent of 2). Therefore, the sequences do not have the best correlation for the length $L=2^{2m+1}$. Here, L denotes the length of the sequences.

The present invention provides a device and method for generating sequences expressed in complex numbers so that the correlation becomes $\sqrt{L}$ for the length $L=2^{2m+1}$ and the above conditions are satisfied. In an exemplary embodiment of the present invention, Kerdock sequences are used to generate complex quasi-orthogonal codes.

FIG. 5 illustrates a procedure for generating complex quasi-orthogonal codes for use in a spreading device for a CDMA communication system according to an embodiment of the present invention. Here, a PN sequence is generated from a M-sequence. That is, a Walsh orthogonal code is generated by column permuting the M-sequence.

Referring to FIG. 5, in step 511, an M-sequence and a specific sequence having a good full correlation property with orthogonal code are generated to generate a quasi-orthogonal code. In an embodiment of the present invention, Family A, which represents a Kerdock code set generated from Kerdock codes expressed in numbers, is used to generate complex sequences for the above sequences. At this point, there exists homomorphism, $H: n \rightarrow j^n$, $(j=\sqrt{-1})$, corresponding to a complex number set for multiplication in a number set for modulo-4 (hereinafter, referred to as "mod 4" for short) operation. That is, numbers {0,1,2,3} can be expressed as {1,j,-1,-j} in complex numbers. Therefore, after generation of sequences, the generated sequences will undergo conversion in accordance with the homomorphism.

By using a trace function, a binary M-sequence S(t) can be expressed as:

$$S(t) = tr(A\alpha^t) \cdots\cdots (5)$$

where $tr(a)=a+a^2+a^{2^2}+\cdots+a^{2^{m-1}}$, $a \in GF(2^m)$, $f(x)$ is a primitive polynomial of Galois field $GF(2^m)$, and α is primitive element which is a root of $f(x)$.

Functional values of the above binary formula are 0 and 1, and it is possible to generate a sequence using the trace function in similar manner.

First, in step 511 of FIG. 5, a binary primitive polynomial $f(x)$ of the m-th degree is selected to obtain a quasi-orthogonal code sequence of length 2^m. A characteristic polynomial $g(x)$ having coefficients is generated by applying Hensel Lift to the binary primitive polynomial $f(x)$, as shown in Equation (6).

$$g(x^2) = (-1)^m f(x) f(-x) \quad \text{mod } 4 \cdots\cdots (6)$$

It is possible to construct a Galois ring $GR(4^m)$ using the characteristic polynomial $g(x)$. Further, when β is a root of $g(x)$, $\beta=\alpha$ *mod 2.* Given $I=\{0,1,\beta,\beta^2,\cdots,\beta^{2^m-2}\}$, an element a of a Galois ring $GR(4^m)$ can be expressed as $a=\gamma+2\delta$, $\gamma,\delta\in I$. A trace function, which is a linear function, in the Galois ring is expressed as $T(a) = \sum_{i=0}^{m-1} \gamma^{2^i} + 2\sum_{i=0}^{m-1} \delta^{2^i}$. (See "Sequences with Low Correlation", T. Helleseth and P.V. Kumar)

To obtain a sequence $S(t)$ of length $N=2^m-1$, the above formula is expressed as the following Equation (7), which is a general formula of the Kerdock code, by using β and trace expression.

$$S(t) = T(\gamma\beta^t) + 2T(\delta\beta^t), \quad \gamma,\beta \in \left\{0,1,\beta,\beta^2,\cdots,\beta^{2^m-2}\right\} \cdots\cdots (7)$$

where $2T(\delta\beta^t)$ is equal to a value obtained by doubling a binary M-sequence and then applying a mod 4 operation to it. In the embodiment, this sequence portion will be referred to as a M-sequence. A M-sequence can be calculated by substituting 0 or $\beta^i (0 \le i \le 2^{2^m-2})$ for δ, and inserting 0 in a first column. Therefore, in step 511, sequences $S_i(t)=T(\beta^{t+i})$ of length 2^m-1 where $t=0,1,\cdots,2^m-2$, and M-sequences $2T(\delta\beta^t)$, which are doubled binary M-sequences, are generated for every i $(0 \le i \le 2^{2^m-2})$. This is a process of generating Kerdock codes.

Thereafter, in step 513, the M-sequence is column permuted by performing $\sigma(t) = \sum_{s=0}^{m-1} M(t+s)^{2^{m-1-s}}$ to generate a Walsh code. A column permutation function for the M-sequence is applied to a specific sequence to generate a mask for generating a quasi-orthogonal code. That is, in step 513, when $\alpha=\beta$ mod 2 and $\delta=\beta^\tau$, $m(t) = tr(a^{(t+\tau)})$ and a column permutation function σ is defined as follows (Definition of column permutation for $T(\gamma\beta^t)$ $\gamma \in \{0,1,\beta,\beta^2,\cdots,\beta^{2^m-2}\}$ of Kerdock code):

$$\sigma : \{0,1,2,\cdots,2^m-2\} \rightarrow \{1,2,\cdots,2^m-1\}$$

$$\sigma(t) = \sum_{i=0}^{m-1} m(t+i)2^{m-1-i}$$

It is possible to generate (2^m-1) complex sequences of length 2^m, which simultaneously satisfy Conditions 1 and 2, by inserting "0" at the head of the sequence $T(\gamma\beta^t)$ of length 2^m-1 in Equation (7) and substituting $\beta^i(0 \le i \le 2^{2^m-2})$ for γ. Therefore, when $\gamma = \beta^i$, a sequence for $T(\gamma\beta^t)$ will be expressed as $S_i(t)$ in Equation (8) below. Here, $S_i(t)$ becomes a function of a specific sequence and can be expressed as:

$$K = [S_0(t), S_1(t), \cdots, S_{2^m-2}(t)] \quad \cdots\cdot (8)$$

where $t=*,0,1,2,\cdots,2^m-2$, and $S_i(*)=0$.

Thereafter, in step 515, a matrix Q shown in FIG. 3 is generated using sequences of the completed set K of Equation (8). The matrix has $(2^m-1)*2^m$ rows and 2^m columns. That is, in step 515, by using (2^m-1) sequences $S_i(t) = T(\beta^{t+i})$, $t = 0,1,2,\cdots,2^m-2$ generated in step 511, a definition is given ("0" is inserted at the head of the sequence $S_i(t)$):

$$[d_i(t) | t = 1,2,\cdots,2^m, \quad i = 1,2,\cdots,2^m-1]$$

$$d_i(t) = \begin{cases} 0, & \text{if } t = 1 \\ S_i(t-1), & \text{if } t=2,3,\cdots,2^m \end{cases}$$

Here, it is possible to obtain (2^m-1) sequences of length 2^m, satisfying Conditions 1 and 2, by applying column permutation to the matrix Q in the same manner as used in column permuting the M-sequence to obtain the Walsh code. Therefore, in step 517, $S_i(t)$ of Equation (7) undergoes column permutation in the same method as used in step 513. That is, in step 517, the sequences generated in step 515 are column permuted according to the column permutation function calculated in step 513. Then, in step 517, new sequences are generated as follows (Column Permutation Process):

$$[e_i(t)|t = 1,2,\cdots,2^m,\ \ i = 1,2,\cdots,2^m - 1]$$

$$e_i(t) = \begin{cases} d_i(t), & \text{if } t = 1 \\ d_i(\sigma^{-1}(t-1)+2), & \text{if } t=2,3,\cdots,2^m \end{cases}$$

The sequence $e_i(t)$ generated in step 517 will be referred to as a quasi-orthogonal mask candidate sequence.

Then, in step 519, another quasi-orthogonal mask candidate sequence satisfying Conditions 1 and 2 is generated by combining (i.e., eXclusive-ORing) the above quasi-orthogonal mask candidate sequence and a Walsh code as shown in FIG. 4. That is, in step 519, quasi-orthogonal code representatives are generated using the sequences generated in step 517, as follows (Quasi-orthogonal Code Candidate Generation):

$$[S_{ij}(t)|t = 1,2,\cdots,2^m]$$

$$S_{ij}(t) = e_i(t) + 2W_j(t) \text{ (mod 4)}, \qquad i = 0,1,2,\cdots,2^m - 2,\ \ j = 0,1,\cdots,2^m - 1$$

It is assumed herein that $[W_j(t)|t = 1,2,\cdots,2^m,\ \ j = 0,1,\cdots,2^m - 1]$ means a Walsh sequence which is an orthogonal code, and is represented in symbols of "0" and "1". In the above formula, $e_i(t)$ is $T(\gamma\beta^t)$ of Equation (7), which is column permuted in accordance with the column permutation formula defined in step 513. Therefore, it is possible to obtain $(2^m-1)*2^m$ quasi-orthogonal code candidates by performing step 519.

Thereafter, in step 521, the sequences satisfying Condition 3 are selected from the $(2^m-1)*2^m$ quasi-orthogonal code candidates and then, a used mask candidate for the quasi-orthogonal code is selected as a mask for the quasi-orthogonal code. That is, after the process of step 519, those satisfying Condition 3 are selected from the finally calculated quasi-orthogonal code representatives $S_{ij}(t)$. For selection of the sequences, a every partial correlation for the Walsh codes with quasi-ofrthogonal code candidates is calculated to determine whether Condition 3 is satisfied, and the mask candidate is selected as a mask when a partial correlation is satisfied for every Walsh code.

For example, when the length of an orthogonal code is 128, a partial correlation is first calculated for every Walsh code having a partial length of 64 and then it is examined whether the partial correlation exceeds 8. If the partial correlation does not exceed 8, the mask candidate is not selected as a mask. Otherwise, if the condition is satisfied, a partial correlation is calculated again for a partial length 32 with respect to this mask candidate. Thereafter, it is determined whether the partial correlation exceeds $4\sqrt{2}$. If the partial correlation does not exceed $4\sqrt{2}$, the mask candidate is not selected as a mask. Otherwise, if the condition is satisfied, the same operation is performed on the next length. After performing the above operation on the partial lengths of up to 4, the mask candidates which have passed the above conditions are selected as quasi-orthogonal code mask candidates satisfying Conditions 1 to 3.

A detailed description will be now made regarding the procedure for generating quasi-orthogonal code candidate sequences with reference to FIG. 5, by way of example.

Herein, it is assumed that $f(x) = x^3 + x + 1$ is used for the binary primitive polynomial. When the binary primitive polynomial $f(x) = x^3 + x + 1$ undergoes Hensel Lift in accordance with Equation (6), a characteristic polynomial having coefficients becomes $g(x^2) = (-1^3)(x^3 + x + 1)(-x^3 - x + 1)(\mathrm{mod}\ 4)$. This can be rewritten as $g(x) = x^3 + 2x^2 + x + 3$.

Accordingly, in step 511, let the root of $g(x)$ be β to determine specific sequences. That is, $\beta^3 + 2\beta^2 + \beta + 3 = 0$. For convenience, β, β^2, β^3, β^4, β^5, β^6 and β^7 will be first determined, as follows.

$$\beta = \beta$$
$$\beta^2 = \beta^2$$
$$\beta^3 = 2\beta^2 + 3\beta + 1$$
$$\beta^4 = 2\beta^3 + 3\beta^2 + \beta = 2(2\beta^2 + 3\beta + 1) + 3\beta^2 + \beta = 3\beta^2 + 3\beta + 2$$
$$\beta^5 = 3\beta^3 + 3\beta^2 + 2\beta = 3(2\beta^2 + 3\beta + 1) + 3\beta^2 + 2\beta = \beta^2 + 3\beta + 3$$
$$\beta^6 = \beta^3 + 3\beta^2 + 3\beta = (2\beta^2 + 3\beta + 1) + 3\beta^2 + 3\beta = \beta^2 + 2\beta + 1$$
$$\beta^7 = \beta^3 + 2\beta^2 + \beta = (2\beta^2 + 3\beta + 1) + 2\beta^2 + \beta = 1$$

When $\gamma = \beta^0 = 1$, $T(\gamma\beta^t) = T(\beta^t)$ will be determined as follows.

$$\text{for t=0, } T(1) = \sum_{i=0}^{2} \beta^{2^i} = 1+1+1 = 3$$

$$\text{for t=1, } T(\beta) = \sum_{i=0}^{2} \beta^{2^i} = \beta + \beta^2 + \beta^4 = 2$$

$$\text{for t=2, } \mathrm{T}(\beta^2) = \sum_{i=0}^{2} (\beta^{2)2^{i}} = \beta^2 + \beta^4 + \beta^8 = \beta^2 + \beta^4 + \beta = 2$$

$$\text{for t=3, } \mathrm{T}(\beta^3) = \sum_{i=0}^{2} (\beta^{3)2^{i}} = \beta^3 + \beta^6 + \beta^{12} = \beta^3 + \beta^6 + \beta^5 = 1$$

$$\text{for t=4, } \mathrm{T}(\beta^4) = \sum_{i=0}^{2} (\beta^4)^{2^i} = \beta^4 + \beta^8 + \beta^{16} = \beta^4 + \beta + \beta^2 = 2$$

$$\text{for t=5, } \mathrm{T}(\beta^5) = \sum_{i=0}^{2} (\beta^5)^{2^i} = \beta^5 + \beta^{10} + \beta^{20} = \beta^5 + \beta^3 + \beta^6 = 1$$

$$\text{for t=6, } \mathrm{T}(\beta^6) = \sum_{i=0}^{2} (\beta^6)^{2^i} = \beta^6 + \beta^{12} + \beta^{24} = \beta^6 + \beta^5 + \beta^3 = 1$$

In addition, when $\gamma = \beta^1 = \beta$, $T(\gamma\beta^t) = T(\beta^t)$ will be determined as follows. Then, $T(\beta)=T(\beta\beta^0)$ for t=0, $T(\beta^2)=T(\beta\beta^1)$ for t=1, $T(\beta^3)=T(\beta\beta^2)$ for t=2, $T(\beta^4)=T(\beta\beta 3)$ for t=3, $T(\beta^5)=T(\beta\beta^4)$ for t=4, $T(\beta^6)=T(\beta\beta^5)$ for t=5 and $T(\beta^7)=T(\beta\beta^6)$ for t=6, which is equivalent to shifting once the sequences determined when $\gamma = \beta^0 = 1$.

In this manner, a sequence 3221211 and its shifted sequence can be determined. A sequence shifted i times will be referred to as S_i. In addition, it is possible to determine 1001011 as an associated M-sequence.

In step 513, it is possible to calculate a column permutation function for converting an M-sequence to a Walsh code in accordance with a formula $\sigma(t) = \sum_{s=0}^{m-1} m(t+s)2^{m-1-s}$ using the M-sequence 1001011. Here, the formula $\sigma(t)$ is equivalent to grouping the M-sequence by three (3) consecutive terms and converting them to decimal numbers. That is, the first three terms are 100, which can converted to decimal number 4; the second three terms are 001, which can be converted to decimal number 1; the third three terms are 010, which can be converted to decimal number 2; the fourth three terms are 101, which can be converted to decimal number 5; the fifth three terms are 011, which can be converted to decimal number 3; the sixth three terms are 111, which can be converted to decimal number 7; and the seventh three terms are 110, which can be converted to decimal number 6. The following results can be obtained using the formula $\sigma(t) = \sum_{s=0}^{m-1} m(t+s)2^{m-1-s}$.

$$\text{for } t=0,\ \sigma(0) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(0) + 2\times m(1) + m(2) = (100)_2 = 4$$

$$\text{for } t=1,\ \sigma(1) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(1) + 2\times m(2) + m(3) = (001)_2 = 1$$

$$\text{for } t=2,\ \sigma(2) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(2) + 2\times m(3) + m(4) = (010)_2 = 2$$

$$\text{for } t=3,\ \sigma(3) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(3) + 2\times m(4) + m(5) = (101)_2 = 5$$

$$\text{for } t=4,\ \sigma(4) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(4) + 2\times m(5) + m(6) = (011)_2 = 3$$

$$\text{for } t=5,\ \sigma(5) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(5) + 2\times m(6) + m(7) = (111)_2 = 7$$

$$\text{for } t=6,\ \sigma(6) = \sum_{s=0}^{2} m(t+s)2^{2-s} = 4\times m(6) + 2\times m(7) + m(8) = (110)_2 = 6$$

The calculated column permutation functions are shown in Table 3A.

Table 3A

t	Three Consecutive Terms	$\sigma(t)$
0	100	4
1	001	1
2	010	2
3	101	5
4	011	3
5	111	7
6	110	6

In step 515, "0" is added at the head of every sequence determined in step 511. With regard to the expression of $d_i(t)$ in accordance with $S_i(t)$, when i=0, $d_0(t)$ is the sequence $S_0(t)$, at the head of which "0" is added, determined in step 511 for $\gamma = \beta^0 = 1$. That is, when $S_0(0)=3$, $S_0(1)=2$, $S_0(2)=2$, $S_0(3)=1$, $S_0(4)=2$, $S_0(5)=1$ and

$S_0(6)=1$ as determined in step 511, $d_0(t)$ is determined such that $d_0(0)$ representing the foremost bit is always "0" and $d_0(1)$ to $d_0(7)$ are as shown in Table 3B.

Table 3B

$d_0(1) = S_0(1\text{-}1) = S_0(0) = 3$
$d_0(2) = S_0(2\text{-}1) = S_0(1) = 2$
$d_0(3) = S_0(3\text{-}1) = S_0(2) = 2$
$d_0(4) = S_0(4\text{-}1) = S_0(3) = 1$
$d_0(5) = S_0(5\text{-}1) = S_0(4) = 2$
$d_0(6) = S_0(6\text{-}1) = S_0(5) = 1$
$d_0(7) = S_0(7\text{-}1) = S_0(6) = 1$

In addition, when i=1, $d_1(t)$ is the sequence $S_1(t)$, at the head of which "0" is added, determined in step 511 for $\gamma = \beta^1 = \beta$. That is, when $S_1(0)=2$, $S_1(1)=2$, $S_1(2)=1$, $S_1(3)=2$, $S_1(4)=1$, $S_1(5)=1$ and $S_1(6)=3$ as determined in step 511, $d_1(t)$ is determined such that $d_1(0)$ representing the foremost bit is always "0" and $d_1(1)$ to $d_1(7)$ are as shown in Table 3C.

Table 3C

$d_1(1) = S_1(1-1) = S_1(0) = 2$
$d_1(2) = S_1(2-1) = S_1(1) = 2$
$d_1(3) = S_1(3-1) = S_1(2) = 1$
$d_1(4) = S_1(4-1) = S_1(3) = 2$
$d_1(5) = S_1(5-1) = S_1(4) = 1$
$d_1(6) = S_1(6-1) = S_1(5) = 1$
$d_1(7) = S_1(7-1) = S_1(6) = 3$

In step 517, the column shifted sequences are column permutated with the above column permutation functions. First, the column shifted sequences are shown in Table 3D.

Table 3D

c_1	c_2	c_3	c_4	c_5	c_6	c_7
3	2	2	1	2	1	1
1	3	2	2	1	2	1
1	1	3	2	2	1	2
2	1	1	3	2	2	1
1	2	1	1	3	2	2
2	1	2	1	1	3	2
2	2	1	2	1	1	3

In Table 3D, c_i denotes an i-th column. For example, c_1 denotes a first column and c_2 a second column. If column permuted with the column permutation functions determined in step 513, the sequences of Table 3D become as follows.

Table 3E

c_4	c_1	c_2	c_5	c_3	c_7	c_6
1	3	2	2	2	1	1
2	1	3	1	2	1	2
2	1	1	2	3	2	1
3	2	1	2	1	1	2
1	1	2	3	1	2	2

1	2	1	1	2	2	3
2	2	2	1	1	3	1

Therefore, sequences of length 8 shown in Table 3F are generated by adding "0" at the head of every sequence determined by column permuting the column shifted sequences with the column permutation functions. The generated sequences become quasi-orthogonal code mask representatives of length 8.

Table 3F

0	1	3	2	2	2	1	1
0	2	1	3	1	2	1	2
0	2	1	1	2	3	2	1
0	3	2	1	2	1	1	2
0	1	1	2	3	1	2	2
0	1	2	1	1	2	2	3
0	2	2	2	1	1	3	1

The quasi-orthogonal code sequences generated in the process of FIG. 5 are determined by the mask function $e_i(t)$. That is, when the mask function $e_i(t)$ satisfies Conditions 1 to 3, it is possible to obtain (2^m-1) complex orthogonal codes. Therefore, if there exist k masks satisfying Conditions 1 to 3, it is possible to obtain $k \times 2^m$ complex quasi-orthogonal codes. Table 4 shows the number of the complex quasi-orthogonal codes according to the M-sequences. Table 5 shows the mask function $e_i(t)$ for the complex quasi-orthogonal codes determined for m=6. Tables 6 to 8 show the mask function $e_i(t)$ for the complex quasi-orthogonal codes determined for m=7, m=8 and m=9, respectively. Here, 0 denotes 1, 1 denotes j, 2 denotes –1 and 3 denotes –j.

Table 4

m	characteristic polynomial	# of Quasi-orthogonal sequences
6	1002031	4*64
7	10020013	4*128
8	102231321	4*256

Table 5

$$f(X) = 1 + X + X^6, \quad g(X) = 1 + 3X + 2X^3 + X^6$$

e1 :	00131120 22131102 20113122 20331322 11200013 33200031 31222011 31000211
e2 :	03010121 21230121 10301210 10303032 23210323 23212101 30101012 12321012
e3 :	00021311 31112202 33132000 02001113 02223313 11132022 13112220 00203111
e4 :	01032101 12103212 30323212 23212101 01210301 30103230 30101012 01212123

Table 6

$$f(X) = 1 + X + X^7, \quad g(X) = 3 + X + 2X^4 + X^7$$

e1 :	03233010 01031012 32302321 30100323 12320323 32300103 23211012 03231232 30100323 10120103 01031012 21011232 03231232 01033230 32300103 30102101
e2 :	01033230 10300121 12102123 21013010 12320323 03013032 01211030 32300103 03011210 30100323 32302321 23031030 10302303 23213230 21011232 30322123
e3 :	02003331 22021333 13110002 33132000 31332220 33132000 20221113 22021333 02001113 00201333 31330002 33130222 31330002 11312000 02001113 22023111
e4 :	02221113 02001131 33130200 11132000 00203133 22201333 13330002 13110020 11130222 33132022 02003313 02223331 31330020 31110002 00021333 22023133

Table 7

$$f(X) = 1 + X^2 + X^3 + X^4 + X^8$$

$$g(X) = 1 + 2X + 3X^2 + X^3 + 3X^4 + 2X^5 + 2X^6 + X^8$$

e1 :	03101021	23121201	21321021	23123023	03323221	23303001	21103221	23301223
	23123023	03103203	01303023	03101021	23301223	03321003	01121223	03323221
	30232312	32030310	12012312	32032132	30010112	32212110	12230112	32210332
	10210310	12012312	32030310	12010130	10032110	12230112	32212110	12232330
e2 :	00023313	20221333	11132202	31330222	33132220	31112022	00201113	02221311
	20223111	00021131	13110222	33312202	31110200	33130002	20001311	22021113
	11132202	31330222	00023313	20221333	00201113	02221311	33132220	31112022
	31332000	11130020	02001333	22203313	02223133	00203331	13332022	11312220
e3 :	02001311	31330200	02223111	31112000	22023313	11312202	22201113	11130002
	22011131	33132202	22203331	33310002	20221311	31332022	20003111	31110222
	11132220	22203331	33132202	00203313	31110222	02221333	13110200	20221311
	13330222	02223111	31330200	20223133	11130002	00023331	33130020	22023313
e4 :	02011210	12322101	21231210	12320323	32122303	01033230	32120121	23213230
	23033212	10122321	23031030	32302321	12100301	03233010	30320301	03231232
	12322101	21233032	30102101	21231210	01033230	10300121	01031012	32120121
	32300103	23033212	32302321	01213212	21011232	12100301	03231232	12102123

Table 8

$$f(X) = 1 + X^4 + X^9, \quad g(X) = 3 + 2X^2 + 3X^4 + X^9$$

e1 :	03232123	01212321	01032303	21230323	30103032	10301012	32303212	30323010
	21232101	01030121	01210103	03230301	30321232	32301030	10303230	30101210
	30323010	10121030	10301012	12321210	21230323	23210121	01212321	21010301
	30101210	32121012	32301030	12103010	03230301	23032321	01030121	03010323
	30323010	32303212	32123230	12321210	03012101	23210121	01212321	03232123
	30101210	10303230	10123212	12103010	21012123	23032321	01030121	21232101
	21010301	01212321	01032303	03012101	30103032	32123230	10121030	30323010
	03010323	01030121	01210103	21012123	30321232	10123212	32121012	30101210
e2 :	02221333	02003133	33130020	111300023	1112000	31330200	22021131	00021113
	20223133	20001333	33310002	11310020	31332022	31110222	00023331	22023313
	00203313	22201113	13332000	13110200	33132202	11132220	02223111	02001311
	00021113	22021131	31330200	31112000	11130002	33130020	02003133	02221333
	31112000	31330200	22021131	00021113	02221333	02003133	33130020	11130002
	13110200	13332000	22201113	00201131	02001311	02223111	11132220	33132202
	33132202	11132220	02223111	02001311	00201131	22201113	13332000	13110200
	33312220	11312202	20221311	20003111	22203331	22023313	13112022	13330222
e3 :	01212321	03232123	32301030	30321232	32121012	30101210	23210121	21230323
	30101210	10303230	03012101	23210121	21010301	01212321	30321232	10123212
	30103032	10301012	21232101	01030121	03230301	23032321	30323010	10121030
	01210103	03230301	10121030	12101232	10301012	12321210	23212303	21232101
	23212303	21232101	32123230	30103032	32303212	30323010	01210103	03230301
	30323010	10121030	21012123	01210103	03010323	23212303	30103032	10301012
	12103010	32301030	21010301	01212321	03012101	23210121	12323032	32121012
	01032303	03012101	32121012	30101210	32301030	30321232	23030103	21010301
e4 :	00203331	02003111	13110222	11310002	31112022	33312202	22201131	20001311
	33132220	31332000	20221333	22021113	20001311	22201131	33312202	31112022
	11310002	31332000	20221333	00203331	20001311	00023313	11130020	31112022
	22021113	02003111	13110222	33132220	31112022	11130020	00023313	20001311
	22023331	20223111	13112000	11312220	31110200	33310020	00021131	02221311

33130002 31330222 02001333 00201113 02221311 00021131 33310020 31110200 33130002 13112000 20223111 00201113 20003133 00021131 33310020 13332022 22023331 02001333 31330222 11312220 13332022 33310020 00021131 20003133

As described above, when the system runs short of orthogonal codes, it is possible to increase the channel capacity by using the quasi-orthogonal codes generated according to the present invention. In this case, there occurs the least interference with the Walsh orthogonal codes, providing a fixed correlation value. For example, for N=64, the correlation value between a quasi-orthogonal code and a Walsh orthogonal code is either 8 or –8. In addition, for N=256, a partial correlation value is also either 8 or –8 (during the length N=64). This means that it is possible to accurately predict the interference, providing excellent characteristics.

Therefore, as can be appreciated from the foregoing process, to obtain a complex quasi-orthogonal code of length 2^m, a characteristic polynomial f(X) of the m-th degree is initially selected. Thus, to obtain a complex quasi-orthogonal code of length $128=2^7$, a characteristic polynomial of the 7th degree is first selected. At this point, to obtain a sequence of length 128, the characteristic polynomial should be a primitive polynomial (c.f. "Shift Register Sequence", Solomon W. Golomb), and there are 18 primitive polynomials of the 7th degree in total. Table 9 shows mask functions for every complex quasi-orthogonal sequences of length 128 satisfying Conditions 1 to 3 for the 18 primitive polynomials of the 7th degree, respectively. Further, in the Tables below, the results for Condition 4 are shown together. Here, "e1+e2" refers to the partial correlation between a first mask and a second mask, and the numerals on the right side of it represent the lengths of the portions where the first and second masks satisfy Condition 4. For example, in Table 9, "e1+e2 : 64, 128" means that a partial correlation between quasi-orthogonal codes generated respectively with e1 and e2 masks satisfies Condition 4 only for the partial lengths 64 and 128. Similarly, "e1+e3 : 32, 64, 128" means that a partial correlation between quasi-orthogonal codes generated respectively with e1 and e3 masks satisfies Condition 4 only for the partial lengths 32, 64 and 128. Therefore, it can be understood that the partial correlation property becomes better, as the numerals and the kinds of the partial lengths satisfying the partial correlation condition increase more in number. Further, it can be noted from following tables that the partial correlation between the quasi-orthogonal sequences depends on the characteristic polynomials. Therefore, it is preferable to use the characteristic polynomials which generate the quasi-orthogonal codes having a good partial correlation between the quasi-orthogonal sequences.

Table 9

$f(X)=1 + X + X^2 + X^3 + X^5 + X^6 + X^7$

$g(X)=3 + 3X + X^2 + X^3 + 2X^4 + 3X^5 + X^6 + X^7$

```
e1 : 00021311 31112202 00021311 13330020 33130222 02003331 11312000 02003331
     13332202 00023133 31110020 00023133 20223331 33132000 20223331 11310222
e2 : 02113122 33022213 00313302 31222033 20333122 33020031 00311120 13002033
     02111300 33020031 22133302 13002033 02113122 11200031 00313302 13000211
e3 : 03010323 10301012 30321232 23030103 32123230 21232101 23030103 30321232
     21010301 32301030 12321210 01030121 32301030 21010301 23212303 30103032
e4 : 01033032 03011012 21233230 01033032 01213010 21013212 03231030 01213010
     01211232 03233212 03233212 23033010 23213032 03013230 03013230 01031210
         e1 + e2 : 8,16,64,128
         e1 + e3 : 8,16,32,64,128
         e1 + e4 : 16,32,64,128
         e2 + e3 : 4,8,16,64,128
         e2 + e4 : 4,8,32,64,128
         e3 + e4 : 16,32,128
```

In using mask functions for complex quasi-orthogonal sequences of length 128 as shown in Table 9, it is also possible to use e_i+W_k as complex quasi-orthogonal sequence masks instead of the above mask functions e_i. The complex quasi-orthogonal sequences generated by e_i+W_k are equal to the complex quasi-orthogonal sequences generated by e_i. Therefore, the number of the masks which can be actually used, is $128\times128\times128\times128=128^4$ for the respective characteristic polynomials.

In this method, there exist 16 primitive polynomials of the 8th degree; Table 10 below shows mask functions for every complex quasi-orthogonal sequences of length 256 satisfying the three correlation conditions for the 16 primitive polynomials of the 8th degree, respectively. Further, in using mask functions for complex quasi-orthogonal sequences of length 256, it is also possible to use e_i+W_k as complex quasi-orthogonal sequence masks instead of the above mask functions e_i. At this point, the complex quasi-orthogonal sequences generated by e_i+W_k are equal to the complex quasi-orthogonal sequences generated by e_i. Therefore, the number of the masks which can be actually used, is $256\times256\times256\times256=256^4$ for the respective characteristic polynomials.

Table 10

$f(X)=1+X^3+X^5+X^7+X^8$

$$g(X)=1+3X^3+X^5+2X^6+3X^7+X^8$$

```
e1 : 03233212 01211232 32300301 30322321 21011030 23033010 32300301 30322321
     32122101 12322303 21233230 01033032 32122101 12322303 03011012 23211210
     12102321 32302123 23031232 03231030 12102321 32302123 01213010 21013212
     01031210 03013230 12320121 10302101 23213032 21231012 12320121 10302101
e2 : 02332213 13221120 00130211 11023122 22130233 33023100 20332231 31221102
     02330031 13223302 22310211 33203122 00310233 11203100 20330013 31223320
     20112213 13223302 22310211 11021300 22132011 11203100 20330013 13001102
     02332213 31003302 22312033 11023122 22130233 11201322 02110013 31221102
e3 : 03323001 10210130 23123203 30010332 12230332 23121021 32030130 03321223
     12012132 23303221 32212330 03103023 21323023 32210112 01123221 12010310
     01123221 12010310 21323023 32210112 10030112 21321201 30230310 01121003
     32030130 03321223 12230332 23121021 01301021 12232110 21101223 32032312
e4 : 02332213 02112231 11023122 11203100 13223302 31221102 00132033 22130233
     11021300 33023100 02330031 20332231 22312033 22132011 31003302 31223320
     31223320 13221120 00310233 22312033 20332231 20112213 11201322 11021300
     00312011 00132033 31221102 31001120 33021322 11023122 02112231 20110031
         e1 + e2 : 4,16,32,64,128,256
         e1 + e3 : 4,8,32,128,256
         e1 + e4 : 4,256
         e2 + e3 : 4,16,32,64,128,256
         e2 + e4 : 64,256
         e3 + e4 : 4,32,256
```

The mask values in Table 10 are expressed in numbers. Further, the mask values in Tables 27 to 42 are expressed as complex numbers, wherein "0" represents "1", "1" represents "j", "2" represents "-1" and "3" represents "-j". Therefore, it is noted that the complex numbers can be expressed with 1, j, -1 and –j. Actually, however, in an IS-95 CDMA communication system, complex numbers are expressed with "1+j". "–1+1", "-1-j" and "1-j".

FIG. 9 compares the complex expression for numbers on the left and the complex expression for signal transmission in an actual system on the right on a complex plane. To convert mask values into the complex expressions used in the actual system, "1+j" is transmitted for "0", "-1+j" for "1", "-1-j" for "2" and "1-j" for 3. This relationship is equivalent to rotating the complex expression of 1, j, -1 and –j by 45°, and can be obtained by multiplying the complex expression by "1+j". By using the above relationship, the mask values can be converted to the complex expression of "1+j", "-1+1", "-1-j" and "1-j", and they can be divided into a real part I and an imaginary part Q. Tables 11 and 12 below express the mask values of Tables 9 and 10 in hexadecimal values divided into the real part I and the imaginary part Q. In particular, Tables 9 and 10 show the good partial correlation property of Condition 4 for the full lengths 128 and 256, respectively.

Table 11

$f(X) = 1 + X^3 + X^5 + X^7 + X^8$ $g(X) = 1 + 3X^3 + X^5 + 2X^6 + 3X^7 + X^8$		
e1	I	277d411bd882411b7dd8e4417dd81bbeeb4e8d28eb4e72d74e14d78db1ebd78d
	Q	7d27e4be82d8e4bed87dbe1bd87d41e44eebd7724eeb288d144e7228ebb17228
e2	I	4ebe27d7e4148d7d41b1d72714e48272beb1d7d8ebe4828d4e41d8d7e4eb727d
	Q	7d72141bd7d8beb1727de4eb2728b1be8d7de414d828b1417d8deb1bd72741b1
e3	I	11b4b411e1bb441edd877822d27777d277d2d27787dd2278441ee1bb4beeee4b
	Q	7822dd8777d2d2774beeee4bbbe11e441e44bbe111b4b411d27777d2227887dd
e4	I	4e7dd7e4b17d28e4d814418dd8eb417272be14d88dbeebd81b287d4e1bd77db1
	Q	7d4e1b287db11bd714d872beebd88dbebe7227ebbe8d2714281bb182d71b4e82

Table 12

$f(X) = 1 + X + X^2 + X^3 + X^5 + X^6 + X^7$ $g(X) = 3 + 3X + X^2 + X^3 + 2X^4 + 3X^5 + X^6 + X^7$		
e1	I	1b7d1b822741d8418d147214b128b1d7
	Q	148d1472d74e284e7d1b821bbed8be27
e2	I	771e117887111e887811e18877e11187
	Q	4bdd2dbbbbd2224b44d2dd4b4b222d44
e3	I	128b1d8474ed841dd148de4748d1b821
	Q	4721b7d1deb8d1b784e27412e284ed8b
e4	I	411be44172d728727d272782b114144e
	Q	1b41be1b288d7228277d7dd8eb4e4e14

The above complex quasi-orthogonal codes can be used for every link in the CDMA system using the Walsh orthogonal codes. When the complex quasi-orthogonal codes are used together with the orthogonal codes, the following three options can be considered.

Option 1

In a system using the Walsh orthogonal codes and providing a service at a variable data rate, it is possible to freely use the complex quasi-orthogonal codes without restriction on the length. Further, it is possible to use every complex quasi-orthogonal code sequences at full length.

Option 2

One of a Walsh orthogonal code group and a complex quasi-orthogonal code group is selected to make two orthogonal sets, and the two groups both can provide a service at the variable data rate.

Option 3

It is possible to use the Walsh orthogonal code group and every complex quasi-orthogonal code group as one group to allow every code group to support the variable data rate. In this case, there may occur a random code characteristic between the complex quasi-orthogonal code groups.

It is preferable to use the complex quasi-orthogonal codes according to the types of application, taking into consideration the above three options. In general, when only the Walsh codes are used, the modulating side exchanges a predetermined orthogonal code number with the demodulating side. Therefore, when the orthogonal codes and the complex quasi-orthogonal codes are used, it is necessary to exchange a predetermined orthogonal code number and a group number (i.e., an index i of the Q' matrix $e_i(t)$ shown in FIG. 4). In this case, the orthogonal code group is defined as a Group 0, and subsequently, the group numbers are redefined up to 2^m-1.

A description will now be made regarding a method for applying the complex quasi-orthogonal code group to a system supporting the variable data rate, like the orthogonal code group. An element of the complex quasi-orthogonal code group are comprised of a Walsh number corresponding to the orthogonal code number and a complex quasi-orthogonal code mask corresponding to the group number. The group number indicates which $e_i(t)$ is selected in FIG. 4. To service the variable data rate using the complex quasi-orthogonal code group, a previously allocated orthogonal code number is used as a Walsh orthogonal code number and then, allocated $e_i(t)$ is added to it every length N. At this point, when signals are expressed with “0” and “1”, addition is performed; when signals are expressed with “1” and “-1”, multiplication is performed.

FIG. 6 illustrates a channel separation method using the Walsh orthogonal codes and the complex quasi-orthogonal codes in an IS-95/IS-95A forward link to extend the channel capacity according to an embodiment of the present invention. FIG. 6 shows an exemplary embodiment where the channels which can be assigned with the Walsh orthogonal codes are used in the same method as in the IS-95 system, and the complex quasi-orthogonal codes are used to expand the channel capacity. However, it is also possible to assign the Walsh orthogonal codes to common channels and assign the remaining Walsh orthogonal codes and the complex quasi-orthogonal codes to traffic channels. Here, the traffic channels refer to dedicated channels. In addition, although FIG. 6 shows an embodiment which uses the complex quasi-orthogonal codes of length 256, the complex quasi-orthogonal codes can be varied in length, when necessary.

In FIG. 6, Walsh orthogonal codes are represented by Wi (where i=0,1,···, 63), and respective channels are separated by previously allocated unique orthogonal codes. Further, in FIG. 6, complex quasi-orthogonal codes are represented by Sj (where j=0,1,···, 255), and are assigned to the traffic channels. As illustrated, an IS-95/IS-95A forward link can separate 64 channels using the Walsh orthogonal codes, and 256 channels, which is 4 times the number of the Walsh orthogonal codes, using the complex quasi-orthogonal codes. Therefore, it is possible to expand the channels five times by using the Walsh orthogonal codes and the complex quasi-orthogonal codes.

FIG. 7 illustrates a transmitter for a mobile communication system, including a spreader which uses Walsh orthogonal code and complex quasi-orthogonal codes according to an embodiment of the present invention. Unlike the IS-95 system, the mobile communication system of FIG. 7 includes a channel transmitter which uses the complex quasi-orthogonal codes for channel spreading codes.

Referring to FIG. 7, a complex signal converter 710 converts an input data bit stream to complex signals and divides the complex signal into a real signal Xi and an imaginary signal Xq. First and second signal converters (or signal mappers) 711 and 713 convert the complex data bit streams Xi and Xq output from the complex signal converter 710, respectively. More specifically, the first signal converter 711 converts the input bit stream Xi by converting a bit "0" to "+1" and a bit "1" to "-1", and demultiplexes the converted signal to a channel spreading and PN masking part 719. The second signal converter 713 converts the input bit stream Xq by converting a bit "0" to "+1" and a bit "1" to "-1", and demultiplexes the converted signal to the channel spreading and PN masking part 719.

A complex quasi-orthogonal code generator 715 receives complex quasi-orthogonal code indexes and Walsh orthogonal code indexes, and generates complex quasi-orthogonal codes QOFi and QOFq. The complex quasi-orthogonal code generator 715 stores therein quasi-orthogonal code masks generated and selected in the process of FIG. 5, and selects a mask according to the complex quasi-orthogonal code index. Further, the complex quasi-orthogonal code generator 715 includes a Walsh orthogonal code generator to generate a Walsh orthogonal code according to the Walsh orthogonal code index. Thereafter, the complex quasi-orthogonal code generator 715 uses the selected quasi-orthogonal code mask and the Walsh orthogonal code to generate complex quasi-orthogonal codes QOFi and QOFq.

A PN code generator 717 generates a real PN code PNi and an imaginary PN code PNq, and applies the generated PN codes to the channel spreading and PN masking part 719. The channel spreading and PN masking part 719 spreads the signals output from the first and second signal converters 711 and 713 by multiplying the output signals by the complex quasi-orthogonal codes QOFi and QOFq and then PN-masks the spread signals by multiplying the spread signals by the real and imaginary PN codes PNi and PNq, thereby generating output signals Yi and Yq. A baseband filter 721 baseband-filters the spread signals Yi and Yq output from the channel spreading and PN masking part 719. A frequency shifter 723 converts the signals output from the baseband filter 721 to an RF (Radio Frequency) signal.

FIG. 8 illustrates the channel spreading and PN masking part 719 of FIG. 7, which performs channel spreading using the complex quasi-orthogonal codes QOFi and QOFq and performs PN masking using the complex PN codes PNi and PNq.

Referring to FIG. 8, a spreader 811 multiplies the complex channel signals Xi and Xq by the complex quasi-orthogonal codes QOFi and QOFq, respectively, to output channel spread signals di and dq. The signals, di+dq, output from the spreader 811, which were spread with the complex quasi-orthogonal codes, become (Xi+jXq)*(QOFi+jQOFq). A complex multiplier 813 multiplies the spread signals di and dq output from the spreader 811 by the PN codes PNi and PNq to output PN masked signals Yi and Yq. The output signals of the complex multiplier 813 become Yi+Yq=(di+dq)*(PNi+jPNq). The complex multiplier 813 performs complex PN masking.

FIGs. 10 and 11 illustrate the complex quasi-orthogonal code generator 715 of FIG. 7 according to different embodiments of the present invention. The complex quasi-orthogonal code generator 715 can be differently constructed according to the structure of the mask. That is, the complex quasi-orthogonal code generator 715 can be differently constructed according to whether the output mask will be generated with values, with I and Q components, or with sign and direction components. FIG. 10 illustrates the complex quasi-orthogonal code generator 715, which generates quasi-orthogonal code masks in values as shown in Table 9, and FIG. 11 illustrates a complex quasi-orthogonal code generator 715, which generates quasi-orthogonal code masks in I and Q values as shown in Table 11.

Referring to FIG. 10, upon receipt of a quasi-orthogonal code index, a quasi-orthogonal mask generator 1000 generates a quasi-orthogonal mask according to the quasi-orthogonal code index. Also, the quasi-orthogonal mask generator 1000 can directly generate a mask using the quasi-orthogonal code index. Further, the quasi-orthogonal mask generator 1000 can store quasi-orthogonal code masks, and selectively outputs a mask corresponding to the received quasi-orthogonal code index. Upon receipt of a Walsh orthogonal code index, a Walsh orthogonal code generator 1010 generates a Walsh orthogonal code corresponding to the Walsh orthogonal code index. At this point, the Walsh orthogonal code is output with the values of “0” and “1”. A multiplier 1031 then multiplies the Walsh orthogonal code output from the Walsh orthogonal code generator 1010 by “2” to express the Walsh orthogonal code in a number, and provides its output to an adder 1033. The adder 1033 then adds the quasi-orthogonal code mask output from the quasi-orthogonal mask generator 1000 and the Walsh orthogonal code output from the multiplier 1031. At this moment, the adder 1033 performs addition on the two input signals, since the two input signals are both signals. A signal converter 1020 receiving the signals output from the adder 1033 converts the quasi-orthogonal code to a complex quasi-orthogonal code, by converting “0” to “1+j”, “1” to “-1+j”, “2” to “-1-j” and “3” to “1-j” and then outputting a real part as a I signal QOFi and an imaginary part as a Q signal QOFq.

Referring to FIG. 11, upon receipt of a quasi-orthogonal code index, an I-component mask generator 1100 and a Q-component mask generator 1105 generate I- and Q-component masks, expressed with “0” and “1”, corresponding to the quasi-orthogonal code index, respectively. The I- and Q-component masks output from the mask generators 1100 and 1105 are applied to adders 1133 and 1135, respectively.

Further, upon receipt of a Walsh orthogonal code index, a Walsh orthogonal code generator 1110 generates a Walsh orthogonal code corresponding to the Walsh orthogonal code index and provides the generated Walsh orthogonal code to the adders 1133 and 1135. As a result, the adders 1133 adds the I-component mask and the Walsh orthogonal code to generate an I-component quasi-orthogonal code, and the adder 1135 adds the Q-component mask and the Walsh orthogonal code to generate a Q-component quasi-orthogonal code. Signal converters 1137 and 1139 convert input signals of "0" to "+1" and input signals of "1" to "-1", and provide the converted signals to the spreader 811.

The quasi-orthogonal sequence masks can be expressed in several ways. First, the quasi-orthogonal sequence masks can be expressed in binary values of 0, 1, 2 and 3 as shown in the above tables. Second, the binary values can be expressed in 1, -1, j and –j by gray mapping. Third, 1, -1, j and –j can be expressed in 1+j, -1-j, -1+j and 1-j by phase shifting 1, -1, j and –j by 45°. Fourth, 1, -1, j and –j can be expressed in sign and phase values of a polar coordinate. Fifth, 1, -1, j and –j can be expressed in only the sign value of the polar coordinate. In addition, 1, -1, j and –j can also be expressed in complex values. Therefore, although the above tables show the values, the same masks can be expressed in various ways according to the above gray mapping rule.

In this complex expression, the complex numbers can be divided into real numbers and imaginary numbers. As an alternative method, polar coordinates are used to express the complex numbers with a coordinate on a Gauss complex plane, wherein the complex numbers are expressed as a phase value between the coordinate and a positive portion of the real number and an absolute value indicating a distance from the origin (0) to the coordinate. At this point, when the quasi-orthogonal sequences are expressed with 1, -1, j and –j, the absolute value is always 1. Further, when the phase is over 180° it is equivalent to the complex number being multiplied by -1. Therefore, it is also possible to express the complex numbers with the phase and sign on the Gauss complex plane as shown in Equation (9) below.

$$a + jb = (sign) \times (\cos(phase) + j\sin(phase)) \quad \cdots\cdots (9)$$

By using Equation (9), the complex number of 1, -1, j and –j can be expressed as follows:

$$1 = (+1) \times (\cos 0° + j \sin 0°)$$
$$-1 = (-1) \times (\cos 0° + j \sin 0°)$$
$$j = (+1) \times (\cos 90° + j \sin 90°)$$
$$-j = (-1) \times (\cos 90° + j \sin 90°)$$

It is noted from the above formula that the complex number of 1, -1, j and –j can be expressed with the sign and phase. Thus, the masks expressed with 0, 1, 2 and 3 in the above tables can be converted to 1, -1, j and –j using gray mapping. With regard to the quasi-orthogonal sequence expressed with 1, -1, j and -j; a sign 1 is expressed with a sign control signal "0" and a phase control signal "0"; a sign -1 is expressed with a sign control signal "1" and a phase control signal "0"; a sign j is expressed with a sign control signal "0" and a phase control signal "1"; a sign -j is expressed with a sign control signal "1" and a phase control signal "1".

In the spreading device for spreading an input signal with the complex quasi-orthogonal sequence, when the complex quasi-orthogonal sequence is expressed in the polar coordinate to spread the input signal, the masks of length 256 show in Table 10 and the masks of length 128 shown in Table 9 can be expressed with the sign and phase values of Tables 13 and 14 below, respectively. Here, the sign value of "0" indicates a positive sign (+) and the sign value of "1" indicates a negative sign (-). Further, the phase control value of "0" indicates the real component and the phase control value of "1" indicates the imaginary component obtained by phase shifting the signal by 90°.

Table 13

<table>
<tr><td colspan="3">$f(X) = 1 + X^3 + X^5 + X^7 + X^8$
$g(X) = 1 + 3X^3 + X^5 + 2X^6 + 3X^7 + X^8$</td></tr>
<tr><td rowspan="2">e1</td><td>Phase</td><td>0101101001011010101001011010010101011010010110101010010110100101
1010010110100101010110100101101010100101101001010101101001011010
1010010110100101010110100101101010100101101001010101101001011010
0101101001011010101001011010010101011010010110101010010110100101</td></tr>
<tr><td>Sign</td><td>0111110100100111111001001011111010000010110110001110010010111110
1101100001111101101111100001101111011000011111010100000111100100
0100111011101011110101110111001001001110111010110010100010001101
0001010001001110011100100010100011101011101100010111001000101000</td></tr>
</table>

e2	Phase	0011001111001100001100111100110000110011110011000011001111001100 0011001111001100001100111100110000110011110011000011001111001100 0011001111001100001100111100110000110011110011000011001111001100 0011001111001100001100111100110000110011110011000011001111001100
	Sign	0111110101110010000101000001101111010111110110001011111010110001 0111001001111110111100100111010110010011100101000101100011011110 1000110101111110111100100000101001101100000101000101100010100000 1 0111110110001101111010110001101111010111001001110100000110110001
e3	Phase	0110100110010110011010011001011010010110011010011001011001101001 1001011001101001100101100110100101101001100101100110100110010110 0110100110010110011010011001011010010110011010011001011001101001 1001011001101001100101100110100101101001100101100110100110010110
	Sign	0111100000100010110111011000011101110111110100101101001001110111 0100101111101110111011100100101110111011111000010001111001000100 0001111001000100101110111110000100010001101101001011010000010001 1101001001110111011101111101001000100010011110001000011111011101
e4	Phase	0011001100110011110011001100110011001100110011000011001100110011 1100110011001100001100110011001100110011001100111100110011001100 1100110011001100001100110011001100110011001100111100110011001100 0011001100110011110011001100110011001100110011000011001100110011
	Sign	0111110101001110000110110010100001111101101100010001101111010111 0001010011011000011100101011111011101011110110001000110110111110 1011111001110010001001111110101110111111010001101001001110001010 0 0010100000011011101100011000001011010111000110110100111010000010

Table 14

$f(X)=1+X+X^2+X^3+X^5+X^6+X^7$ $g(X)=3+3X+X^2+X^3+2X^4+3X^5+X^6+X^7$		
e1	Phase	0000111111110000000011111111000011110000000011111111000000001111 1111000000001111111100000000111100001111111100000000111111110000
	Sign	0001010010001101000101000111001011010111010011100010100001001110 0111110100011011100000100001101110111110110110001011111100010011 1
e2	Phase	0011110011000011001111001100001100111100110000110011110011000011 0011110011000011001111001100001100111100110000110011110011000011
	Sign	0100101111011110100101101101110111011101111010010001000100100101 1 0100010011010010110111010100101101001011001000100010111010100010 0
e3	Phase	0101010110101010101010100101010110101010010101010101010110101010 0101010110101010101010100101010110101010010101010101010110101010
	Sign	0100011100100001101101111101000111011110101110001101000110110111 1000010011100010011101000000100101110001010000100111011011000101 1
e4	Phase	0101101001011010010110100101101001011010010110100101101001011010 0101101001011010010110100101101001011010010110100101101001011010
	Sign	0001101101000000110111111000011011001010001000110101110010001010 00 0010011101111110101111110111011000111010110100111001001110000101 00

FIG. 12 shows the spreader 811of FIG. 8, for spreading input signals using the above masks when expressing the quasi-orthogonal sequences in the polar coordinate. Referring to FIG. 12, multipliers 1250 and 1252 receive the input signals Xi and Xq, respectively. At the same time, a Walsh orthogonal code generator 1232 generates a Walsh orthogonal code corresponding to a Walsh orthogonal code index for channel assignment, and a sign code generator 1234 generates a sign value representing a sign code of a quasi-orthogonal code corresponding to a quasi-orthogonal code index for channel assignemt. A multiplier 1240 then multiplies the Walsh orthogonal code by the sign value, and provides its output to the multipliers 1250 and 1252. The multiplier 1250 multiplies the input signal Xi by the output of the multiplier 1240 to output a signal Iin. The multiplier 1252 multiplies the input signal Xq by the output of the multiplier 1240 to output a signal Qin. The signals Iin and Qin are input to a rotator 1210. A phase code generator 1236 generates a phase value corresponding to the quasi-orthogonal code index and provides the generated phase value to the rotator 1210 as a rotation select signal. The rotator 1210 controls the output phases of the multipliers 1250 and 1252 according to the rotation select signal Qrot output from the phase code generator 1236. For example, the rotator 1210 outputs the input signals Iin+jQin as channel spread signals di and dq, when the phase value representing a phase of the quasi-orthogonal code is 0. However, when the phase value is 1, the rotator 1210 multiplies the input signal Iin+jQin by j to output the signals -Qin+jIin as the channel spread signals di and dq.

The quasi-orthogonal code index input to the sign code generator 1234 has the same value as the quasi-orthogonal code index input to the phase code generator 1236. The sign code generator 1234 is chip synchronized with the phase code generator 1236. Therefore, the sign codes and the phase codes shown in Tables 13 and 14 are output from the sign code generator 1234 and the phase code generator 1236. When the sign code generator 1234 generates a sign code (e.g., e1 sign) for a specific orthogonal code, the phase code generator 1236 also generates a phase code (e.g., e1 phase) corresponding to the generated sign code, wherein the sign code is chip synchronized with the phase code.

FIG. 13 shows the rotator 1210 of FIG. 12. Referring to FIG. 13, the signal Iin is input to a D1 node of a selector 1320 and a D2 node of a selector 1325, and the signal Qin is input to an inverter 1310 and a D1 node of the selector 1325. The inverter 1310 inverts the signal Qin and provides the inverted signal to a D2 node of the selector 1320. At the same time, the phase value Qrot representing the phase of the quasi-orthogonal code is commonly input to each select node SEL of the selectors

1320 and 1325. For example, the selectors 1320 and 1325 select the signals Iin and Qin received at their D1 nodes as the channel spread signals di and dq, respectively, when the phase value is 0. Otherwise, when the phase value is 1, the selectors 1320 and 1325 select the signals -Qin and Iin received at their D2 nodes as the channel spread signals di and dq, respectively.

As shown in Equation (9), the complex number can be expressed with the phase and sign on the Gauss complex plane. Therefore, with regard to the quasi-orthogonal sequence which can be expressed with the complex number of 1, -1, j and –j; 1 is expressed with a sign code of 0 and a phase code of 0; -1 is expressed with a sign code of 1 and a phase code of 0; j is expressed with a sign code of 0 and a phase code of 1; -j is expressed with a sign code of 1 and a phase code of 1. Therefore, by controlling a phase of the channel spread signal using the phase code corresponding to the sign code, after expressing the masks, which can be expressed with the complex number, with the sign code and the phase code and spreading a channel signal by mixing the sign code with the Walsh code, it is possible to obtain the same results of spreading the channel signal using the quasi-orthogonal code.

Although the channel spreader of FIG. 12 first spreads the channel signals using the sign code and the Walsh orthogonal code and then spreads the quasi-orthogonal code by controlling a phase of the spread signal, it is also possible to first control a phase of the signal to be channel spread using the phase code and then spread the phase controlled channel signal using the sign code and the Walsh orthogonal code. That is, it is possible that the rotator 1210 first controls phases of the input signals Xi and Xq according to the phase value Qrot and then, the multipliers 1250 and 1252 spread the phase controlled signals Xi and Xq with the mixed signal of the sign code and the Walsh orthogonal code, output from the multiplier 1240.

In addition, unlike the method shown in FIG. 12, it is also possible to express the complex number of 1, -1, j and -j with only the phase code, excluding the sign code, as shown in Equation (12) below.

$$a + jb = \cos(phase) + j\sin(phase) \quad \cdots\cdots (12)$$

By using Equation (12), the complex number of 1, -1, j and -j can be expressed as follows:

$$
\begin{aligned}
1 &= \cos 0° + j \sin 0° \\
-1 &= \cos 180° + j \sin 180° \\
j &= \cos 90° + j \sin 90° \\
-j &= \cos 270° + j \sin 270°
\end{aligned}
$$

It therefore follows from Equation (12) that the complex number of 1, -1, j and –j can be expressed with only the phase. With regard to the quasi-orthogonal sequence expressed with 1, -1, j and -j; 1, which is phase shifted by 0°, is expressed with a phase code "0"; -1, which is phase shifted by 180°, is expressed with a phase code "2"; j, which is phase shifted by 90°, is expressed with a phase code "1"; -j, which is phase shifted by 270°, is expressed with a phase code "3".

In the spreading device for spreading an input signal with the complex quasi-orthogonal sequence, when the complex quasi-orthogonal sequence is expressed in the polar coordinate to spread the input signal, the masks of length 256 shown in Table 10 and the masks of length 128 shown in Table 9 can be expressed with the phase values of Tables 13 and 14 below, respectively. Here, the phase control value of "0" indicates that the signal to be spread is phase shifted by 0°; the phase control value of "1" indicates that the signal to be spread is phase shifted by 90°; the phase control value of "2" indicates that the signal to be spread is phase shifted by 180°; the phase control value of "3" indicates that the signal to be spread is phase shifted by 270°.

FIG. 14 shows the spreader 811of FIG. 8, for spreading input signals using the above masks when expressing the quasi-orthogonal sequences in the polar coordinate. Referring to FIG. 14, multipliers 1450 and 1452 receive the input signals Xi and Xq, respectively. At the same time, a Walsh orthogonal code generator 1432 generates a Walsh orthogonal code corresponding to a Walsh orthogonal code index for channel assignment, and provides the generated Walsh orthogonal code to the multipliers 1450 and 1452. The multiplier 1450 multiplies the input signal Xi by the Walsh orthogonal code to output a channel spread signal Iin. The multiplier 1452 multiplies the input signal Xq by the Walsh orthogonal code to output a channel spread signal Qin. The signals Iin and Qin are input to a rotator 1410. A phase code generator 1436 generates a phase code Qrot representing a phase of the quasi-orthogonal code corresponding to the quasi-orthogonal code index for channel assignment and provides the generated phase code Qrot to the rotator 1410. The rotator 1410 controls the phases of channel spread signals Iin and Qin according to the phase code Qrot. For example, the rotator 1410 outputs the input signals Iin and jQin as the channel spread signals di and dq when the phase value is 0. When the phase value is 1, the rotator 1410 multiplies the input signals Iin and jQin by j to output the signals -Qin+jIin as the channel spread signals di and dq. When the phase value is 2, the rotator 1410 multiplies the input signals Iin and jQin by -1 to output the signals -Iin-jQin as the channel spread signals di and dq. When the phase value is 3, the rotator 1410 multiplies the input signals Iin and jQin by -j to output the signals Qin-jIin as the channel spread signals di and dq.

FIG. 15 shows the rotator 1410 of FIG. 14. Referring to FIG. 15, the signal Iin is input to an inverter 1510, a D1 node of a selector 1520 and a D2 node of a selector 1525, and the signal Qin is input to an inverter 1515, a D4 node of the selector 1520 and a D1 node of the selector 1525. The inverter 1510 inverts the input signal Iin and provides the inverted signal to a D3 node of the selector 1520 and a D4 node of the selector 1525. The inverter 1515 inverts the input signal Qin and provides the inverted signal to a D2 node of the selector 1520 and a D3 node of the selector 1525. Further, a phase code Qrot representing a phase of the quasi-orthogonal code is input to the selectors 1520 and 1525. The selectors 1520 and 1525 then control phases of the spread signals Iin and Qin according to the phase code Qrot. For example, the selectors 1520 and 1525 select the signals received at their D1 nodes, when the phase code is 0; the selectors 1520 and 1525 select the signals received at their D2 nodes, when the phase code is 1; the selectors 1520 and 1525 select the signals received at their D3 nodes, when the phase code is 2; the selectors 1520 and 1525 select the signals received at their D4 nodes, when the phase code is 3.

Although the channel spreader of FIG. 14 first spreads the channel signals using the Walsh orthogonal code and then spreads the quasi-orthogonal code by controlling a phase of the spread signal, it is also possible to first control a phase of the signal to be channel spread using the phase code and then spread the phase controlled channel signal using the Walsh orthogonal code. That is, it is possible that the rotator 1410 first controls phases of the input signals Xi and Xq according to the phase code Qrot and then, the multipliers 1450 and 1452 spread the phase controlled signals Xi and Xq with the Walsh orthogonal code.

A despreader for a receiver for receiving the output of the transmitter has a reverse structure of the spreader shown in FIG. 7. Herein, a description will be made of a complex quasi-orthogonal code despreading device in the despreader.

FIG. 16 shows a despreader for a receiver, which corresponds to the complex quasi-orthogonal code spreader of FIG. 12. Referring to FIG. 16, multipliers 1650 and 1652 receive the input signals di and dq, respectively. A Walsh orthogonal code generator 1632 generates a Walsh orthogonal code corresponding to a Walsh orthogonal code index, and a sign code generator 1634 generates a sign code corresponding to a quasi-orthogonal code index. A multiplier 1640 then multiplies the Walsh orthogonal code by the sign code, and provides its output to the multipliers 1650 and 1652. The multiplier 1650 despreads the input signal di with the output of the multiplier 1640 to output a signal Iin. The multiplier 1652 despreads the input signal dq with the output of the multiplier 1640 to output a signal Qin. The signals Iin and Qin are input to a rotator 1610. A phase code generator 1636 generates a phase code corresponding to the quasi-orthogonal code index and provides the generated phase code to the rotator 1610. The rotator 1610 then outputs the input signals Iin and jQin as channel despread signals Xi and Xq, when the phase code is 0. Otherwise, when the phase code is 1, the rotator 1610 multiplies the input signals Iin and jQin by -j to output signals Qin-jIin as the channel despread signals Xi and Xq.

In FIG. 16, it is also possible that the channel despreader first controls phases of the PN despread signals Xi and Xq using the phase code and then despreads the phase controlled signals with a signal obtained by multiplying the Walsh code by the sign code.

FIG. 17 shows the rotator 1610 of FIG. 16. Referring to FIG. 17, the signal Iin is input to a D1 node of a selector 1720 and an inverter 1710, and the signal Qin is input to a D2 node of the selector 1720 and a D1 node of the selector 1725. The inverter 1710 inverts the signal Iin and provides the inverted signal to a D2 node of the selector 1725. At the same time, the phase code Qrot representing the phase of the quasi-orthogonal code is commonly input to the selectors 1720 and 1725. For example, the selectors 1720 and 1725 select the signals received at their D1 nodes, when the phase value is 0. Otherwise, when the phase value is 1, the selectors 1720 and 1725 select the signals received at their D2 nodes.

FIG. 18 shows the despreader for a receiver, which corresponds to the channel spreader of FIG. 14. Referring to FIG. 18, multipliers 1850 and 1852 receive the input signals di and dq, respectively. At the same time, a Walsh orthogonal code generator 1832 generates a Walsh orthogonal code corresponding to a Walsh orthogonal code index for channel assignment, and provides the generated Walsh orthogonal code to the multipliers 1850 and 1852. The multiplier 1850 multiplies the input signal di by the Walsh orthogonal code to output a channel spread signal Iin. The multiplier 1852 multiplies the input signal dq by the Walsh orthogonal code to output a channel spread signal Qin. The signals Iin and Qin are input to a rotator 1810. A phase code generator 1836 generates a phase code Qrot representing a phase of the quasi-orthogonal code corresponding to the quasi-orthogonal code index for channel assignment and provides the generated phase code Qrot to the rotator 1810. The rotator 1810 controls the phases of channel spread signals Iin and Qin according to the phase code Qrot. For example, the rotator 1810 outputs the input signals Iin and jQin as the channel despread signals Xi and Xq when the phase code is 0. When the phase code is 1, the rotator 1810 multiplies the input signals Iin and jQin by j to output the signals -Qin+jIin as the channel despread signals Xi and Xq. When the phase code is 2, the rotator 1810 multiplies the input signals Iin and jQin by -1 to output the signals -Iin-jQin as the channel despread signals Xi and Xq. When the phase code is 3, the rotator 1810 multiplies the input signals Iin and jQin by -j to output the signals Qin-jIin as the channel despread signals Xi and Xq.

FIG. 19 shows the rotator 1810 of FIG. 18. Referring to FIG. 19, the signal Iin is input to an inverter 1910, a D1 node of a selector 1920 and a D4 node of a selector 1925, and the signal Qin is input to an inverter 1915, a D2 node of the selector 1920 and a D1 node of the selector 1925. The inverter 1910 inverts the input signal Iin and provides the inverted signal to a D3 node of the selector 1920 and a D2 node of the selector 1925. The inverter 1915 inverts the input signal Qin and provides the inverted signal to a D4 node of the selector 1920 and a D3 node of the selector 1925. Further, a phase code Qrot representing a phase of the quasi-orthogonal code is input to the selectors 1920 and 1925. The selectors 1920 and 1925 then control phases of the spread signals Iin and Qin according to the phase code Qrot. For example, the selectors 1920 and 1925 select the signals received at their D1 nodes, when the phase code is 0; the selectors 1920 and 1925 select the signals received at their D2 nodes, when the phase code is 1; the selectors 1920 and 1925 select the signals received at their D3 nodes, when the phase code is 2; the selectors 1920 and 1925 select the signals received at their D4 nodes, when the phase code is 3.

Although the channel spreader of FIG. 18 first despreads the channel signals using the Walsh orthogonal code and then spreads the quasi-orthogonal code by controlling a phase of the despread signal, it is also possible to first control a phase of the signal to be channel despread using the phase code and then despread the phase controlled channel signal using the Walsh orthogonal code.

When spreading is performed using the sign and phase as described above, a spreading device can be implemented using another method. A method according to an embodiment of the present invention generates a complex quasi-orthogonal code mask, and converts the generated quasi-orthogonal code mask into the polar coordinate to generate the sign code and the phase code, wherein the phase code is expressed as a specific Walsh orthogonal code of the corresponding length. That is, in the complex quasi-orthogonal code masks shown in Tables 13 and 14, the values of the phase codes become a specific Walsh orthogonal code. Therefore, when spreading and despreading the channel signals using the methods of FIGS. 12 and 16, the sequence for the phase is actually equal to the sequence of the Walsh orthogonal code. That is, when using the complex quasi-orthogonal code masks of length 256, a phase sequence for a mask e1 is a sequence of a 213th Walsh orthogonal code; a phase sequence for a mask e2 is a sequence of a 10th Walsh orthogonal code; a phase sequence for a mask e3 is a sequence of a 111th Walsh orthogonal code; and a phase sequence for a mask e4 is a sequence of a 242nd Walsh orthogonal code.

Therefore, for channel spreading, it is possible to use a spreading device of FIG. 20, wherein a sequence for the phase is changed to a sequence of the Walsh orthogonal code. A Walsh orthogonal code generator mentioned below can either store all the Walsh orthogonal codes in a memory to read a Walsh orthogonal code corresponding to the Walsh orthogonal code index from the memory, or generate a Walsh orthogonal code using a specific device for generating the Walsh orthogonal code.

Referring to FIG. 20, multipliers 2050 and 2052 receive the input signals Xi and Xq, respectively. At the same time, a first Walsh orthogonal code generator 2060 generates a k-th Walsh orthogonal code corresponding to a Walsh orthogonal code index k for the channel assignment, and a sign code generator 2070 generates a sign code corresponding to a t-th quasi-orthogonal code index t. Here, the sign code generator 2070 can either store the sign codes of Table 13 in a memory to read a sign code corresponding to the mask index, or use a separate device for generating the sign code. A multiplier 2040 then multiplies the Walsh orthogonal code by the sign code, and provides its output to the multipliers 2250 and 2252. The multiplier 2250 multiplies the input I-component signal Xi by the output of the multiplier 2040 to output a signal Iin. The multiplier 2252 multiplies the input Q-component signal Xq by the output of the multiplier 2040 to output a signal Qin. The signals Iin and Qin are input to a rotator 2210. A second Walsh orthogonal code generator 2236 generates a Walsh orthogonal code corresponding to the mask index k and provides the generated Walsh orthogonal code to the rotator 2210. When the sign codes and the phase codes of length 256 shown in Table 13 are used for the sign code and the Walsh orthogonal code, a 213th Walsh orthogonal code sequence is output for the Walsh orthogonal code index t=1; a 10th Walsh orthogonal code sequence is output for the Walsh orthogonal code index t=2; a 111th Walsh orthogonal code sequence is output for the Walsh orthogonal code index t=3; a 243rd Walsh orthogonal code sequence is output for the Walsh orthogonal code index t=4. The rotator 2010 rotates the input signals according to the Walsh orthogonal code sequence values. The rotator 2210 has the structure shown in FIG. 13.

Unlike the channel despreader of FIG. 16, the channel despreader of FIG. 20 uses the Walsh orthogonal code sequence instead of the phase code, thereby reducing the hardware complexity. That is, when using the Walsh orthogonal code, it is possible to use the Walsh orthogonal code generator included in the channel spreader and despreader. Therefore, memory is not required for storing the phase codes nor is a device for generating the phase codes, thus reducing the hardware complexity.

In the spreader for spreading the input signal with the complex quasi-orthogonal code, when the complex quasi-orthogonal code is expressed in the polar coordinate to spread the input signal, it is possible to use the sign code of length 256 and the sign code of length 128 shown in Tables 15 and 16, respectively, wherein “0” denotes the positive sign (+) and “1” denotes the negative sign (-).

Table 15

e1	Sign	0111110100100111111001001011111010000010110110001110010010111110 1101100001111101101111100001101111011000011111010100000111100100 0100111011101011110101110111001001001110111010110010100010001101 0001010001001110011100100010100011101011101100010111001000101000
e2	Sign	0111110101110010000101000001101111010111110110001011111010110001 0111001001111101111001001110101100100111001010001011000110111110 1000110101111101111001000000101001101100000101000101100010100001 0111110110001101111010110001101111010111001001110100000110110001
e3	Sign	0111100000100010110111011000011101110111110100101101001001110111 0100101111101110111011100100101110111011111000010001111001000100 0001111001000100101110111110000100010001101101001011010000010001 1101001001110111011101111101001000100010011110001000011111011101
e4	Sign	0111110101001110000110110010100001111101101100010001101111010111 0001010011011000011100101011111011101011110110001000110110111110 1011111001110010001001111110101110111110100011010010011100010100 0010100000011011101100011000001011010111000110110100111010000010

Table 16

e1	Sign	0001010010001101000101000111001011010111010011100010100001001110 0111110100011011100000100001101110111110110110001011111000100111
e2	Sign	0100101111011101001011011011101110111011110100100010001001001011 0100010011010010110111010100101101001011001000100010110101000100
e3	Sign	0100011100100001101101111101000111011110101110001101000110110111 1000010011100010011101000000100101110001010000100111011011000101 1
e4	Sign	0001101101000000110111111000011011001010001000110101110010001010 00 0010011101111110101111101110110001110101101001110010011100001010 0

In addition, the rotator 2210 of FIG. 20 operates with a clock having a very high rate, such as a chip rate, where the clock rate of the input signal is equal to an output rate of the Walsh orthogonal code.

FIG. 21 shows a modified despreader in which the position of a rotator 2110 is change. Since the rotator 2110 receives data symbols, the clock rate for the input signal of the rotator 2110 should be equal to the symbol rate. Now, a description will be made of a method for reducing the clock rate of the input signal of the rotator by changing the position of the rotator.

Referring to FIG. 21, the rotator 2110 receives input signals Xi and Xq at a clock rate, and at the same time, a Walsh orthogonal code generator 2165 generates a Walsh orthogonal code corresponding to an input mask index t. That is, when using the sign code and the phase code of length 256 shown in Table 13, the Walsh orthogonal code generator 2165 generates a 213th Walsh orthogonal code sequence for a Walsh orthogonal code index t=1, a 10th Walsh orthogonal code sequence for a Walsh orthogonal code index t=2, a 111th Walsh orthogonal code sequence for a Walsh orthogonal code index t=3, and a 242nd Walsh orthogonal code sequence for a Walsh orthogonal code index t=4. The Walsh orthogonal code sequences generated from the Walsh orthogonal code generator 2165 are input to the rotator 2110, which operates in the same manner as described with reference to FIG. 16. The rotator 2110 provides the output signals Iin and Qin to multipliers 2150 and 2152. At the same time, a Walsh orthogonal code generator 2160 generates a k-th Walsh orthogonal code corresponding to an input Walsh orthogonal code index k and provides the generated Walsh orthogonal code to a multiplier 2140. Further, a sign code generator 2170 generates a t-th sign code corresponding an input quasi-orthogonal code index t and provides the generated sign code to the multiplier 2140. Here, the sign code generator 2170 can either store the sign codes of Table 13 to read a sign code corresponding to the mask index t when necessary, or use a separate device for generating a sign code. The multiplier 2140 multiplies the Walsh orthogonal code by the sign code and provides its output to the multipliers 2150 and 2152. The multiplier 2150 multiplies the input signal Iin by the signal output from the multiplier 2140 and the multiplier 2152 multiplies the input signal Qin by the signal output from the multiplier 2140.

Herein, the rotators 2210 and 2110 of FIGS. 20 and 21 have the same structure as the rotator 1610 of FIG. 16.

A quasi-orthogonal code mask function having a good property for Condition 4 could be determined using the column permutation function $\sigma(t)=\sum_{i=0}^{m-1} m(t+i)2^{m-1-i}$ calculated in step 513 of FIG. 5. The above column permutation function converts the M-sequence to the Walsh orthogonal code, and there are several types of column permutation functions. Therefore, it is possible to use the different column permutation functions other than the above column permutation function. By using a proper column permutation function, it is possible to determine quasi-orthogonal code mask functions satisfying Condition 4. In an embodiment described below, there is provided a method for generating the above quasi-orthogonal code mask sequence using the different column permutation function. In the embodiment, the column permutation function is generated using a trace orthogonal basis on the Galois field GF(2^m).

First, the trace orthogonal basis is {bi | 0≤i≤m-1} of GF(2^m), satisfying Equation (10) below.

[Equation 10]

$Tr(b_i b_j)=0 \quad i \neq j$

$Tr(b_i b_j)=0 \quad i=j$

A column permutation function $\sigma^{-1}(t)$ can be generated using the trace orthogonal basis in accordance with Equation (11) below:

[Equation 11]

$$\sigma^{-1}(t)=\log_{\alpha}(c_0b_0+c_1b_1+\cdots+c_{m-1}b_{m-1})$$
$$t=c_{m-1}2^{m-1}+c_{m-2}2^{m-2}+\cdots+c_0$$

In the above orthogonal code generation method, the different orthogonal code mask function can be obtained by changing the column permutation function. In particular, when using the column permutation function generated from the trace orthogonal basis, it is possible to generate different masks. Further, several pairs of the generated quasi-orthogonal code mask functions can be selected to fully satisfy Conditions 1 to 4 for the quasi-orthogonal codes. In the embodiment below, a description will be made of a procedure for determining quasi-orthogonal code pairs completely satisfying Conditions 1 to 4 by using the trace orthogonal basis.

In this embodiment, a procedure for generating quasi-orthogonal code sequences which fully satisfy Conditions 1 to 4 is equal to the steps 511, 515, 517 and 519 of FIG. 5 for generating the quasi-orthogonal masks. Further, the trace orthogonal basis method is used in the step 513 for generating a column permutation function. Therefore, a description will be made focusing on the step for generating the column permutation function.

Here, a description will be made of an operation of generating column permutation functions using the trace orthogonal basis method in the process of generating the quasi-orthogonal code masks satisfying Conditions 1 to 4. It will be assumed herein that the embodiment generates a quasi-orthogonal code mask of length $2^7=128$. Further, it is assumed that a Galois generator polynomial for determining the quasi-orthogonal code mask is $f(x)=x^7+x^6+x^5+x^3+x^2+x+1$, trace orthogonal bases $\{\alpha^2, \alpha^{92}, \alpha^{16}, \alpha, \alpha^{80}, \alpha^5, \alpha^{88}\}$ (where α is a root of the generator polynomial f(x)) are used, and a set of the bases is referred to as an orthogonal basis set. In this case, a change in the sequence of the trace orthogonal bases will vary a partial correlation of the quasi-orthogonal mask. Therefore, the sequence of the trace orthogonal bases is used as specified above.

First, a column permutation function for the code length 128 can be calculated using Equation (11). More specifically, the column permutation function can be calculated by expressing the numbers 1 to 127 in an expansion $c_{m-1}2^{m-1} + c_{m-2}2^{m-2} + \cdots$

$+ c_0$, and taking finite logarithms for Galois finite elements calculated by permuting 2^i with the corresponding trace orthogonal basis b_i. For this, the numbers 1 to 127 can be expressed in the decimal expansion $c_{m-1}2^{m-1} + c_{m-2}\, 2^{m-2} + \cdots + c_0$, as follows:

$(1)_{10} = (0000001)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 0\times2^2 + 0\times2^1 + 1\times2^0$
$(2)_{10} = (0000010)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$
$(3)_{10} = (0000011)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0$
$(4)_{10} = (0000100)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$
$(5)_{10} = (0000101)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 1\times2^0$
$(6)_{10} = (0000000)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 1\times2^2 + 1\times2^1 + 0\times2^0$
$(7)_{10} = (0000111)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 0\times2^3 + 1\times2^2 + 1\times2^1 + 1\times2^0$
$(8)_{10} = (0001000)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 1\times2^3 + 0\times2^2 + 0\times2^1 + 0\times2^0$
$(9)_{10} = (0001001)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 1\times2^3 + 0\times2^2 + 0\times2^1 + 1\times2^0$
$(10)_{10} = (0001010)_2 = 0\times2^6 + 0\times2^5 + 0\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$

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$(116)_{10} = (1110100)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$
$(117)_{10} = (1110101)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 1\times2^0$
$(118)_{10} = (1110110)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 0\times2^3 + 1\times2^2 + 1\times2^1 + 0\times2^0$
$(119)_{10} = (1110111)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 0\times2^3 + 1\times2^2 + 1\times2^1 + 1\times2^0$
$(120)_{10} = (1111000)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 0\times2^2 + 0\times2^1 + 0\times2^0$
$(121)_{10} = (1111001)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 0\times2^2 + 0\times2^1 + 1\times2^0$
$(122)_{10} = (1111010)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$
$(123)_{10} = (1111011)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0$
$(124)_{10} = (1111100)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$
$(125)_{10} = (1111101)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 1\times2^2 + 0\times2^1 + 1\times2^0$
$(126)_{10} = (1111110)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 1\times2^2 + 1\times2^1 + 0\times2^0$
$(127)_{10} = (1111111)_2 = 1\times2^6 + 1\times2^5 + 1\times2^4 + 1\times2^3 + 1\times2^2 + 1\times2^1 + 1\times2^0$

By permuting 2^i with the corresponding trace orthogonal bases b_i (i.e., permuting 2^0 with α^2, 2^1 with α^{92}, 2^2 with α^{16}, 2^3 with α, 2^4 with α^{80}, 2^5 with α^5, and 2^6 with α^{88}), the Galois finite element sequences are generated as follows:

$(0000001)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 0\times\alpha^{16} + 0\times\alpha^{92} + 1\times\alpha^2 = \alpha^2$
$(0000010)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 0\times\alpha^{16} + 1\times\alpha^{92} + 0\times\alpha^2 = \alpha^{92}$
$(0000011)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 0\times\alpha^{16} + 1\times\alpha^{92} + 1\times\alpha^2 = \alpha^{81}$
$(0000100)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 0\times\alpha^{92} + 0\times\alpha^2 = \alpha^{16}$
$(0000101)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 0\times\alpha^{92} + 1\times\alpha^2 = \alpha^{42}$
$(0000110)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 1\times\alpha^{92} + 0\times\alpha^2 = \alpha^{84}$
$(0000111)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 1\times\alpha^{92} + 1\times\alpha^2 = \alpha^{60}$
$(0001000)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 0\times\alpha^{92} + 0\times\alpha^2 = \alpha$
$(0001001)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 0\times\alpha^{92} + 1\times\alpha^2 = \alpha^{56}$
$(0001010)_2 \rightarrow 0\times\alpha^{88} + 0\times\alpha^5 + 0\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 1\times\alpha^{92} + 0\times\alpha^2 = \alpha^{65}$

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$(1110100)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 0\times\alpha^{92} + 0\times\alpha^{2} = \alpha^{41}$
$(1110101)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 0\times\alpha^{92} + 1\times\alpha^{2} = \alpha^{44}$
$(1110110)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 1\times\alpha^{92} + 0\times\alpha^{2} = \alpha^{33}$
$(1110111)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 0\times\alpha + 1\times\alpha^{16} + 1\times\alpha^{92} + 1\times\alpha^{2} = \alpha^{55}$
$(1111000)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 0\times\alpha^{92} + 0\times\alpha^{2} = \alpha^{70}$
$(1111001)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 0\times\alpha^{92} + 1\times\alpha^{2} = \alpha^{78}$
$(1111010)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 1\times\alpha^{92} + 0\times\alpha^{2} = \alpha^{39}$
$(1111011)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 0\times\alpha^{16} + 1\times\alpha^{92} + 1\times\alpha^{2} = \alpha^{118}$
$(1111100)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 1\times\alpha^{16} + 0\times\alpha^{92} + 0\times\alpha^{2} = \alpha^{15}$
$(1111101)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 1\times\alpha^{16} + 0\times\alpha^{92} + 1\times\alpha^{2} = \alpha^{122}$
$(1111110)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 1\times\alpha^{16} + 1\times\alpha^{92} + 0\times\alpha^{2} = \alpha^{110}$
$(1111111)_2 \rightarrow 1\times\alpha^{88} + 1\times\alpha^{5} + 1\times\alpha^{80} + 1\times\alpha + 1\times\alpha^{16} + 1\times\alpha^{92} + 1\times\alpha^{2} = \alpha^{0}$

By taking logarithms having the calculated Galois element sequences as bases α which are Galois elements (i.e., enumerating exponents of the respective element sequences), it is possible to calculate the column permutation function for the code length 128.

Therefore, the column permutation function $\sigma^{-1}(t)$ can be calculated as follows, in accordance with Equation (11):

2 92 81 16 42 84 60 1 56 65 29 82 30 22 9 80
86 51 8 107 76 46 67 91 125 19 21 63 48 104 113 5
90 106 73 53 121 95 6 94 124 75 74 100 14 24 98 52
20 66 93 116 109 34 111 120 18 45 123 87 126 57 3 88
117 54 101 89 103 50 13 102 38 32 37 4 112 7 99 12
69 40 36 105 47 85 23 49 77 43 31 72 62 79 97 26
71 11 27 83 17 108 64 10 61 68 114 59 119 115 28 25
96 35 58 41 44 33 55 70 78 39 118 15 122 110 0

By applying the above column permutation function $\sigma^{-1}(t)$ to the step 513 of FIG. 5, it is possible to calculate the quasi-orthogonal code mask completely satisfying Condition 4, as follows:

Table 17

$$f(X) = 1 + X + X^2 + X^3 + X^5 + X^6 + X^7$$

$$g(X) = 3 + 3X + X^2 + X^3 + 2X^4 + 3X^5 + X^6 + X^7$$

```
e1 : 03323221 32212110 10030332 03323221 10030332 03323221 21101003 10030332
     10030332 03323221 21101003 10030332 21101003 10030332 32212110 21101003
e2 : 03230301 12103010 10303230 23212303 21232101 12323032 32301030 23032321
     32301030 23032321 03010323 30101210 32121012 01030121 03230301 12103010
e3 : 02113122 22133302 20333122 00313302 31222033 33020031 13002033 11200031
     20113100 22311102 02333100 00131102 31000233 11020013 13220233 33200013
```

FIG. 22 shows a procedure for generating the column permutation function. Referring to FIG. 22, when the bases b_i are input in step 513a, the column permutation function $\sigma^{-1}(t)$ is generated in accordance with Equation (11) in step 513b. Thereafter, the step 515 is performed using the calculated $\sigma^{-1}(t)$, and the succeeding process is performed in the same method.

Such a column permutation function can also be generated from the bases satisfying Equation (10) using the same process as stated above, even for the lengths 256 and 512. Further, it is also possible to generate quasi-orthogonal code masks completely satisfying Condition 4.

Tables 18 and 19 below shows quasi-orthogonal code masks of lengths 256 and 512, respectively, which are generated from the bases shown below and completely satisfy Condition 4.

Table 18

$$f(X) = 1 + X + X^3 + X^5 + X^8$$

$$g(X) = 1 + 3X + 2X^2 + X^3 + 3X^5 + X^8$$

```
e1 : 02330031 00312011 22130233 02330031 02112231 22312033 22312033 20330013
     22312033 02112231 20330013 22312033 22130233 20112213 20112213 00312011
     11201322 31001120 31001120 33023100 11023122 13001102 31223320 11023122
     13001102 11023122 11023122 31223320 13223302 33023100 11201322 13223302
e2 : 01031012 12102123 01033230 12100301 12100301 23211012 12102123 23213230
     23213230 12102123 23211012 12100301 30322123 23211012 30320301 23213230
     32122303 21011232 10302303 03231232 21013010 10302303 03233010 32122303
     10300121 21011232 32120121 03231232 03231232 10302303 21011232 32122303
e3 : 01121223 10210310 21323203 12230112 30230130 21101003 10032110 23121201
     21103221 30232312 23123023 10030332 10212132 01123001 12232330 21321021
     23301223 32030310 21321021 12232330 30232312 21103221 32212110 01301201
     21101003 30230130 01303023 32210332 32032132 23303001 12230112 21323203
```

Table 19

$$f(X) = 1 + X^4 + X^9$$

$$g(X) = 3 + 2X^2 + 3X^4 + X^8$$

```
e1 : 03103203 32032132 32032132 21321021 10210310 03103203 03103203 32032132
     10210310 03103203 03103203 32032132 21321021 10210310 10210310 03103203
     10210310 03103203 03103203 32032132 21321021 10210310 10210310 03103203
     21321021 10210310 10210310 03103203 32032132 21321021 21321021 10210310
     12012312 23123023 23123023 30230130 01301201 12012312 12012312 23123023
     01301201 12012312 12012312 23123023 30230130 01301201 01301201 12012312
     01301201 12012312 12012312 23123023 30230130 01301201 01301201 12012312
     30230130 01301201 01301201 12012312 23123023 30230130 30230130 01301201
e2 : 00131102 13002033 13222011 00311120 00133320 13000211 13220233 00313302
     13000211 22311102 00313302 31002011 31220211 00131102 22133302 13222011
     13222011 00311120 22313320 31220211 31002011 22131120 00133320 13000211
     22131120 13220233 13000211 22311102 22133302 13222011 13002033 22313320
     00133320 13000211 31002011 22131120 22313320 31220211 13222011 00311120
     31220211 00131102 00311120 31000233 31222033 00133320 00313302 31002011
     13220233 00313302 00133320 13000211 13222011 00311120 00131102 13002033
     00311120 31000233 13002033 22313320 22131120 13220233 31222033 00133320
e3 : 03230301 01030121 23032321 03010323 10303230 12103010 30101210 10123212
     23210121 21010301 21230323 01212321 12101232 10301012 10121030 30103032
     23032321 03010323 03230301 01030121 12323032 32301030 32121012 30321232
     03012101 23030103 01032303 03232123 10121030 30103032 12101232 10301012
     12101232 32123230 32303212 30103032 23210121 03232123 03012101 01212321
     32121012 12103010 30101210 32301030 21012123 01030121 23032321 21232101
     10121030 12321210 30323010 10301012 03012101 01212321 23210121 03232123
     30101210 32301030 32121012 12103010 01210103 03010323 03230301 23212303
```

As stated above, the complex number of 1, -1, j and -j can be expressed using the sign and phase. In Tables 18 and 19, and other tables for the complex quasi-orthogonal code masks, the masks expressed with 0, 1, 2 and 3 can be converted to 1, -1, j and -j, by gray mapping. In addition, with regard to the quasi-orthogonal code sequences which can be expressed with 1, -1, j and –j, "1" can be expressed with a sign code "0" and a phase code "0"; "-1" can be expressed with a sign code "1" and a phase code "0"; "j" can be expressed with a sign code "0" and a phase code "1"; and "-j" can be expressed with a sign code "1" and a phase code "1".

In the spreading device for spreading an input signal with the complex quasi-orthogonal sequence, when the complex quasi-orthogonal sequence is expressed in the polar coordinate to spread the input signal, the masks of lengths 128, 256 and 512 can be expressed with the sign and phase values of Tables 20A, 21A and 22A below, respectively. Here, the sign value of "0" indicates a positive sign (+) and the sign value of "1" indicates a negative sign (-). Further, the phase control value of "0" indicates the real component and the phase control value of "1" indicates the imaginary component obtained by phase shifting the signal by 90°.

Table 20A below shows the values determined by converting the quasi-orthogonal code masks of length 128, shown in Table 17, satisfying Conditions 1 to 4 to the sign and phase values of the polar coordinate.

Table 20A

e1	Sign	0111111011101000000101110111111100001011101111111010000000100010111 00010111011111110100000001000101111000000010001011111110100010000001
	Phase	0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001
e2	Sign	0111010001001000000101110111011011011100001111011111100010110111 10 1110001011011110010001111000010011010001000100100111010001001000
	Phase	0101010110101010101010100101010101010101101010101010101001010101 1010101001010101010101011010101010101010010101010101010110101010
e3	Sign	0100101111011101101110110010110110111011110100100100101100100010 1000100011100001011110000000100011000011100010001011101111100001
	Phase	0011110000111100001111000011110011000011110000111100001111000011 0011110000111100001111000011110011000011110000111100001111000011

Table 21A below shows the values determined by converting the quasi-orthogonal code masks of length 128, shown in Table 18, satisfying Conditions 1 to 4 to the sign and phase values of the polar coordinate.

Table 21A

e1	Sign	0111001000101000110101110111001001001110111010111110101110110001 1110101101001110101100011110101111010111100011011000110100101000 0010011110000010100000101101100000011011010000011011111000011011 0100000100011011000110111011111100111110111011000001001110111101
	Phase	0011001100110011001100110011001100110011001100110011001100110011 0011001100110011001100110011001100110011001100110011001100110011 1100110011001100110011001100110011001100110011001100110011001100 1100110011001100110011001100110011001100110011001100110011001100
e2	Sign	0001000101001011000111100100010001000100111000010100101111101110 1110111001001011111000010100010010111011111000011011010011101110 1101110110000111001011010111011110001000001011010111100011011101 0010001010000111110100100111011101110111001011011000011111011101
	Phase	0101101010100101010110101010010110100101010110101010010101011010 0101101010100101010110101010010110100101010110101010010101011010 1010010101011010101001010101101001011010101001010101101010100101 1010010101011010101001010101101001011010101001010101101010100101
e3	Sign	0001011100100100101111010111000110110010100000001000110001101010 0 1000111010111101110110110001011100101011000110000111111010110010 1110011111010100101100100111111010111101100011101110100000100100 1000000110110010001010111110011111101101111110100001110001101111 01

	Phase	0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001

Table 22A below shows the values determined by converting the quasi-orthogonal code masks of length 128, shown in Table 19, satisfying Conditions 1 to 4 to the sign and phase values of the polar coordinate.

Table 22A

e1	Sign	0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100 0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100
	Phase	0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001 1001011001101001011010011001011001101001100101101001011001101001 0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001 0110100110010110100101100110100110010110011010010110100110010110 0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001
e2	Sign	0001000101001011011110000010001000011110010001000111011100101101 0100010011100001001011011000100010110100000100011101110101111000 0111100000100010111011101011010010001000110100100001111001000100 1101001001110111010001001110000111011101011110000100101111101110 0001111001000100100010001101001011101110101101000111100000100010 1011010000010001001000101000011110111011000111100010110110001000 0111011100101101000111100100010001111000001000100001000101001011 0010001010000111010010111110111011010010011101111011101100011110
	Phase	0011110011000011110000110011110000111100110000111100001100111100 1100001100111100001111001100001111000011001111000011110011000011 1100001100111100001111001100001111000011001111000011110011000011 0011110011000011110000110011110000111100110000111100001100111100 0011110011000011110000110011110000111100110000111100001100111100 1100001100111100001111001100001111000011001111000011110011000011 1100001100111100001111001100001111000011001111000011110011000011 0011110011000011110000110011110000111100110000111100001100111100

e3	Sign	0111010000001001011011110010001110010111001001000100001000011101 1110001010000100101101110010111001000111001000010001001010001011 1101111001000111011101000001001001111011111100010110100011011011 1 0100100011010001000111010111101100010010100010110100011100100001 0100011111011110111011011000101111100010011110110100100000101110 1101000101001000100001001110001010001011000100101101111010111000 0001001001110100101110000010000101001000001011101110001001111011 1000010011100010110100010100100000100001010001110111010011101101
	Phase	0101010101010101010101010101010101101010101010101010101010101010 0101010101010101010101010101010101101010101010101010101010101010 0101010101010101010101010101010101101010101010101010101010101010 0101010101010101010101010101010101101010101010101010101010101010 1010101010101010101010101010101010010101010101010101010101010101 1010101010101010101010101010101010010101010101010101010101010101 1010101010101010101010101010101010010101010101010101010101010101 1010101010101010101010101010101010010101010101010101010101010101

The phase values shown in Tables 20A, 21A and 22A are specific Walsh orthogonal code values of the corresponding lengths. That is, for the quasi-orthogonal code masks of length 128 shown in Table 20A, the phase value for e1 is equal to that of the 127th Walsh orthogonal code, the phase value for e2 is equal to that of the 89th Walsh orthogonal code, and the phase value for e3 is equal to that of the 38th Walsh orthogonal code, wherein the Walsh orthogonal numbers are 0 to 127. In addition, for the quasi-orthogonal code masks of length 256 shown in Table 21A, the phase value for e1 is equal to that of the 130th Walsh orthogonal code, the phase value for e2 is equal to that of the 173rd Walsh orthogonal code, and the phase value for e3 is equal to that of the 47th Walsh orthogonal code, wherein the Walsh orthogonal numbers are 0 to 255. Further, for the quasi-orthogonal code masks of length 512 shown in Table 22A, the phase value for e1 is equal to that of the 511st Walsh orthogonal code, the phase value for e2 is equal to that of the 222nd Walsh orthogonal code, and the phase value for e3 is equal to that of the 289th Walsh orthogonal code, wherein the Walsh orthogonal numbers are 0 to 511.

When using the quasi-orthogonal codes for channel spreading and despreading, it is also possible to store only the sign values of Tables 20B, 21B and 22B below in the channel spreader and despreader, and generate the phase values using the Walsh orthogonal code generator.

Table 20B

e1	Sign	0111111011101000000101110111111100001011101111111010000000100010111 0001011101111111010000001000101111000000100010111111010001000000 1

	Phase	127th Walsh
e2	Sign	0111010001001000001011101110110110111000011110111110001011011110 1110001011011110010001111000010011010001000100100111010001001000
	Phase	89th Walsh
e3	Sign	0100101111011101101110110010110110111011110100100100101100100010 1000100011100001011110000000100011000011100010001011101111100001
	Phase	38th Walsh

Table 21B

e1	Sign	0111001000101000110101110111001001001110111010111110101110110001 1110101101001110101100011110101111010111100011011000110100101000 00100111100000010100000101101100000011011010000011011111000011011 01000001000110110001101110111111001111101110110000010011101111101
	Phase	130th Walsh
e2	Sign	0001000101001011000111100100010001000100111000010100101111101110 1110111001001011111000010100010010111011111000011011010011101110 1101110110000111001011010111011110001000001011010111100011011101 0010001010000111110100100111011101110111001011011000011111011101
	Phase	173rd Walsh
e3	Sign	00010111001001001011110101110001101100101000000010001100011010100 1000111010111101110110110001011100101011000110000111111010110010 1110011111010100101100100111111010111101100011101110100000100100 10000001101100100010101111110011111011011111010000111000110111101
	Phase	47th Walsh

Table 22B

e1	Sign	0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100 0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100
	Phase	511th Walsh
e2	Sign	0001000101001011011110000010001000011110010001000111011100101101 0100010011100001001011011000100010110100000100011101110101111000 0111100000100010111011101011010010001000110100100001111001000100 1101001001110111010001001110000111011101011110000100101111101110 0001111001000100100010001101001011101110101101000111100000100010 1011010000010001001000101000011110111011000111100010110110001000 0111011100101101000111100100010001111000001000100001000101001011 0010001010000111010010111110111011010010011101111011101100011110
	Phase	222nd Walsh

e3	Sign	0111010000010010110111100100011100101110010010001000010000011101 1110001010000100101101110010111001000111001000010001001010001011 1101111001000111011101000001001001111011111000101101000110110111 0100100011010001000111010111101100010010100010110100011100100001 0100011111011110111011011000101111100010011110110100100000101110 1101000101001000100001001110001010001011000100101101111010111000 0001001001110100101110000010000101001000000101110111000100111011 1000010011100010110100010100100000100001010001110111010011101101
	Phase	289th Walsh

Therefore, it is possible to generate three types of quasi-orthogonal codes which can be used in the channel spreader and despreader according to an embodiment of the present invention. That is, in the embodiment, it is possible to generate the quasi-orthogonal code masks completely satisfying Conditions 1 to 4 by using the trace orthogonal basis method described with reference to FIGS. 5 and 22. The quasi-orthogonal code masks generated according to the procedure of FIGS. 5 and 22 are complex masks shown in Tables 17 and 19.

First, when performing channel spreading and despreading using the quasi-orthogonal code masks of Tables 17 to 19, the spreading code generator can have the structure of FIG. 10 or 11. In the channel spreading and despreading device having the spreading code generator of FIG. 10 or 11, the spreading code generator generates the quasi-orthogonal codes for channel spreading by adding the quasi-orthogonal code masks assigned as shown in Tables 17 to 19 and the Walsh orthogonal codes. Here, the quasi-orthogonal code mask generator in the spreading code generator can be so designed as to store the masks of Tables 17 to 19 in a table and selectively output the quasi-orthogonal code mask according to the assigned mask index.

Second, the complex quasi-orthogonal code masks of Tables 17 to 19 can be expressed in the sign code and phase code of the polar coordinate as shown in Tables 20A to 22A. When performing channel spreading and despreading using the quasi-orthogonal code masks of Tables 20A to 22A, the channel spreader can be designed as shown in FIGS. 12 and 14, and the channel despreader can be designed as shown in FIGS. 16 and 18. The channel spreading and despreading device first multiples the designated Walsh orthogonal code by the sign code, and then spreads the input I and Q channel signals by the multiplied signal. Thereafter, channel spread signals are generated by rotating the spread signals using the phase code. Further, in addition to the above channel spreading method, it is also possible to first control a phase of an input signal using the phase code, and then spread the phase controlled input signal using the combined signal of the sign code and the Walsh orthogonal code. The channel despreading operation is also performed in the same procedure.

In the channel spreading and despreading device, the sign code generator and the phase code generator can be designed to store the masks of Tables 20A to 22A in a table and selectively outputs the quasi-orthogonal code mask according to the assigned mask index. At this point, the same mask index t should be used to select the sign code and the phase code. Alternatively, for the sign code generator and the phase code generator can be implemented by designing the separate devices for generating the sign code and phase code of Tables 20A to 22A.

Third, the phase codes shown in Tables 20A to 22A have the type of the specific Walsh orthogonal codes. Therefore, in the masks shown in Tables 20A to 22A, the phase codes are the specific Walsh orthogonal codes of the corresponding length. When performing channel spreading and despreading, the channel spreading and despreading devices of FIGS. 21 and 22 can be design to have the sign codes of Tables 20B to 22B and use the existing Walsh orthogonal codes for the phase codes. The channel spreading and despreading device first multiplies the designated Walsh orthogonal code by the sign code, and then spreads the input I and Q channel signals with the multiplied signals. Thereafter, the channel spread signals are generated by controlling the phase of the spread signals using the assigned second Walsh orthogonal code. In addition, it is possible to use a different channel spreading method. This method first controls a phase of the input signal using the second Walsh orthogonal code, and then spreads the phase controlled input signal using the combined signal of the sign code and the Walsh orthogonal code. The channel despreading operation is also performed in the same procedure.

In the channel spreading and despreading device, the sign code generator stores the masks of Tables 20B to 22B in a table, and the second Walsh orthogonal code generator can be implemented by a device or a table for generating specific Walsh orthogonal codes for controlling the phase. Therefore, the sign code generator and the second Walsh orthogonal code generator can be so designed as to generate the sign code and the second Walsh orthogonal code corresponding to the mask index assigned for channel spreading. At this point, the same mask index t should be used to select the sign code and the second Walsh orthogonal code. Alternatively, the sign code generator and the second Walsh orthogonal code generator can be implemented by designing the separate devices for generating the sign code and phase code of Tables 20B to 22B.

As described above, the embodiment of the present invention can generate complex quasi-orthogonal codes having the least interference with the orthogonal codes. In addition, it is possible to increase the channel capacity without restriction on the number of the orthogonal codes by using the complex quasi-orthogonal codes in a mobile communication system which performs channel separation using the orthogonal codes.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

CLAIMS:

1. A method for generating a complex quasi-orthogonal code for channel spreading in a CDMA (Code Division Multiple Access) communication system, comprising the steps of:

generating an M-sequence having a length N and a specific sequence having a correlation property with the M-sequence that exceeds a threshhold;

generating a predetermined number of other specific sequences by circularly shifting said specific sequence;

generating a predetermined number of other M-sequences by circularly shifting said M-sequence, and column permutating the circularly shifted specific sequences in a same method as a column permutation method for converting the generated M-sequences to Walsh orthogonal codes to generate candidate masks;

generating quasi-orthogonal code representatives by operating on the candidate masks and the Walsh orthogonal codes having the same length as the mask candidates; and

selecting quasi-orthogonal code candidates satisfying a partial correlation between the Walsh orthogonal codes out of the generated quasi-orthogonal code representatives and a partial correlation between different quasi-orthogonal codes, and selecting masks pertinent to generating the selected quasi-orthogonal codes.

2. The method as claimed in claim 1, wherein the mask candidate generating step comprises the steps of:

selecting one of trace orthogonal basis sets given by a generator polynomial for generating the M-sequence;

expressing each length 1, 2,..., N-1 for the specific length N in a binary expression of $C_{m-1}2^{m-1}+C_{m-2}2^{m-2}+\ldots+C_0 2^0$ (where $C_{m-1},C_{m-2},\ldots,C_0$ are 0 or 1);

permuting 2^{m-1}, 2^{m-2},..., 2^0 with the selected trace orthogonal set, and generating element sequences of a Galois field, each having the length N-1 and being expressed as an exponent of a root α of the generator polynomial;

generating a column permutation function by taking a logarithm having α as a basis for each element of the generated element sequence; and

generating the mask candidates by column permuting the specific sequences with the generated column permutation function.

3. The method as claimed in claim 2, wherein the specific sequence is a Kerdock sequence.

4. The method as claimed in claim 3, wherein the step of circularly shifting the specific sequence comprises the step of inserting zero (0) before the shifted specific sequences.

5. The method as claimed in claim 3, wherein the mask selecting step comprises the steps of:

(a) selecting a mask for generating the quasi orthogonal code candidate as the complex quasi orthogonal code mask, when a correlation value for respective parts of a length N/M, where N is the whole length of the complex quasi orthogonal code candidate and the Walsh orthogonal code, does not exceed $\sqrt{\frac{N}{M}}$; and

(b) selecting and storing a mask for generating the quasi orthogonal code candidate as the complex quasi orthogonal code mask, when a correlation value for respective parts of a length N/M, where N is the whole length of a complex quasi orthogonal code candidate generated with the mask selected in step (a) and another complex quasi orthogonal code, does not exceed $\sqrt{\frac{N}{M}}$.

6. The method as claimed in claim 3, wherein for N=128, the generated mask candidates are as follows:

$$f(X) = 1 + X + X^2 + X^3 + X^5 + X^6 + X^7$$

$$g(X) = 3 + 3X + X^2 + X^3 + 2X^4 + 3X^5 + X^6 + X^7$$

```
e1 : 03323221 32212110 10030332 03323221 10030332 03323221 21101003 10030332
     10030332 03323221 21101003 10030332 21101003 10030332 32212110 21101003
e2 : 03230301 12103010 10303230 23212303 21232101 12323032 32301030 23032321
     32301030 23032321 03010323 30101210 32121012 01030121 03230301 12103010
e3 : 02113122 22133302 20333122 00313302 31222033 33020031 13002033 11200031
     20113100 22311102 02333100 00131102 31000233 11020013 13220233 33200013
```

7. The method as claimed in claim 3, wherein for N=256, the generated mask candidates are as follows:

$$f(X) = 1 + X + X^3 + X^5 + X^8$$

$$g(X)=1+3X+2X^2+X^3+3X^5+X^8$$

```
e1 : 02330031 00312011 22130233 02330031 02112231 22312033 22312033 20330013
     22312033 02112231 20330013 22312033 22130233 20112213 20112213 00312011
     11201322 31001120 31001120 33023100 11023122 13001102 31223320 11023122
     13001102 11023122 11023122 31223320 13223302 33023100 11201322 13223302
e2 : 01031012 12102123 01033230 12100301 12100301 23211012 12102123 23213230
     23213230 12102123 23211012 12100301 30322123 23211012 30320301 23213230
     32122303 21011232 10302303 03231232 21013010 10302303 03233010 32122303
     10300121 21011232 32120121 03231232 03231232 10302303 21011232 32122303
e3 : 01121223 10210310 21323203 12230112 30230130 21101003 10032110 23121201
     21103221 30232312 23123023 10030332 10212132 01123001 12232330 21321021
     23301223 32030310 21321021 12232330 30232312 21103221 32212110 01301201
     21101003 30230130 01303023 32210332 32032132 23303001 12230112 21323203
```

8. The method as claimed in claim 3, wherein for N=512, the generated mask candidates are as follows:

$$f(X)=1+X^4+X^9$$

$$g(X)=3+2X^2+3X^4+X^8$$

```
e1 : 03103203 32032132 32032132 21321021 10210310 03103203 03103203 32032132
     10210310 03103203 03103203 32032132 21321021 10210310 10210310 03103203
     10210310 03103203 03103203 32032132 21321021 10210310 10210310 03103203
     21321021 10210310 10210310 03103203 32032132 21321021 21321021 10210310
     12012312 23123023 23123023 30230130 01301201 12012312 12012312 23123023
     01301201 12012312 12012312 23123023 30230130 01301201 01301201 12012312
     01301201 12012312 12012312 23123023 30230130 01301201 01301201 12012312
     30230130 01301201 01301201 12012312 23123023 30230130 30230130 01301201
e2 : 00131102 13002033 13222011 00311120 00133320 13000211 13220233 00313302
     13000211 22311102 00313302 31002011 31220211 00131102 22133302 13222011
     13222011 00311120 22313320 31220211 31002011 22131120 00133320 13000211
     22131120 13220233 13000211 22311102 22133302 13222011 13002033 22313320
     00133320 13000211 31002011 22131120 22313320 31220211 13222011 00311120
     31220211 00131102 00311120 31000233 31222033 00133320 00313302 31002011
     13220233 00313302 00133320 13000211 13222011 00311120 00131102 13002033
     00311120 31000233 13002033 22313320 22131120 13220233 31222033 00133320
e3 : 03230301 01030121 23032321 03010323 10303230 12103010 30101210 10123212
     23210121 21010301 21230323 01212321 12101232 10301012 10121030 30103032
     23032321 03010323 03230301 01030121 12323032 32301030 32121012 30321232
     03012101 23030103 01032303 03232123 10121030 30103032 12101232 10301012
     12101232 32123230 32303212 30103032 23210121 03232123 03012101 01212321
     32121012 12103010 30101210 32301030 21012123 01030121 23032321 21232101
     10121030 12321210 30323010 10301012 03012101 01212321 23210121 03232123
     30101210 32301030 32121012 12103010 01210103 03010323 03230301 23212303
```

9. The method as claimed in claim 6, wherein the masks generated for N=128 are converted to sign and phase values in a polar coordinate as follows:

$f(X) = 1 + X + X^2 + X^3 + X^5 + X^6 + X^7$ $g(X) = 3 + 3X + X^2 + X^3 + 2X^4 + 3X^5 + X^6 + X^7$		
e1	Sign	0111111011101000000101110111111000010111011111101000000100010111 00010111011111101000000100010111110000001000101111110100010000001
	Phase	0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001
e2	Sign	011101000100100000010111011101101101110000111101111110001011011110 1110001011011110010001111000010011010001000100100111010001001000
	Phase	0101010110101010101010100101010101010101101010101010101001010101 1010101001010101010101011010101010101010010101010101010110101010
e3	Sign	0100101111011101101110110010110110111011110100100100101100100010 10001000111000010111100000001000110000111000100010111011111100001
	Phase	0011110000111100001111000011110011000011110000111100001111000011 0011110000111100001111000011110011000011110000111100001111000011

10. The method as claimed in claim 7, wherein the masks generated for N=256 are converted to sign and phase values in a polar coordinate as follows:

$f(X) = 1 + X + X^3 + X^5 + X^8$ $g(X) = 1 + 3X + 2X^2 + X^3 + 3X^5 + X^8$		
e1	Sign	0111001000101000110101110111001001001110111010111110101110110001 1110101101001110101100011110101111010111100011011000110100101000 0010011110000010100000101101100000011011010000011011111000011011 01000001000110110001101110111111001111101110110000010011101111101
	Phase	0011001100110011001100110011001100110011001100110011001100110011 0011001100110011001100110011001100110011001100110011001100110011 1100110011001100110011001100110011001100110011001100110011001100 1100110011001100110011001100110011001100110011001100110011001100
e2	Sign	0001000101001011000111100100010001000100111000010100101111101110 11101110010010111110000101000100101110111111000011011010011101110 11011101100001110010110101110111100010000001011010111100011011101 0010001010000111110100100111011101110111001011011000011111011101
	Phase	0101101010100101010110101010010110100101010110101010010101011010 0101101010100101010110101010010110100101010110101010010101011010 1010010101011010101001010101101001011010101001010101101010100101 1010010101011010101001010101101001011010101001010101101010100101
e3	Sign	00010111001001001011110101110001101100101000000010001100011010100 1000111010111101110110110001011100101011000110000111111010110010 1110011111010100101100100111111010111101100011101110100000100100 1000000110110010001010111110011111011011111010000111000110111101
	Phase	0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001

11. The method as claimed in claim 8, wherein the masks generated for

N=512 are converted to sign and phase values in a polar coordinate as follows:

$f(X)=1+X^4+X^9$ $g(X)=3+2X^2+3X^4+X^8$		
e1	Sign	0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100 0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100
	Phase	0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001 1001011001101001011010011001011001101001100101101001011001101001 0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001 0110100110010110100101100110100110010110011010010110100110010110 0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001
e2	Sign	0001000101001011011110000010001000011110010001000111011100101101 01000100111000010010110110001000101101000001000111011110101111000 01111000000100010111011101011010010001000110100100001111001000100 1101001001110111010001001110000111011101011110000100101111101110 0001111001000100100010001101001011101110101101000111100000100010 10110100000010001001000101000011110111011000111100010110110001000 0111011100101101000111100100010001111000001000100001000101001011 0010001010000111010010111110111011010010011101111011101100011110
	Phase	0011110011000011110000110011110000111100110000111100001100111100 1100001100111100001111001100001111000011001111000011110011000011 1100001100111100001111001100001111000011001111000011110011000011 0011110011000011110000110011110000111100110000111100001100111100 0011110011000011110000110011110000111100110000111100001100111100 1100001100111100001111001100001111000011001111000011110011000011 1100001100111100001111001100001111000011001111000011110011000011 0011110011000011110000110011110000111100110000111100001100111100
e3	Sign	01110100000010010110111100100011100101110010010001000010000011101 1110001010000100101101110010111001000111001000010001001010001011 1101111001000111011101000001001001111011111000101101000110110111 0100100011010001000111010111101100010010100010110100011100100001 0100011111011110111011011000101111100010011110110100100000101110 1101000101001000100001001110001010001011000100101101111010111000 0001001001110100101110000010000101001000001011101110001001111011 1000010011100010110100010100100000100001010001110111010011101101

	Phase	0101010101010101010101010101010110101010101010101010101010101010 0101010101010101010101010101010110101010101010101010101010101010 0101010101010101010101010101010110101010101010101010101010101010 0101010101010101010101010101010110101010101010101010101010101010 1010101010101010101010101010101001010101010101010101010101010101 1010101010101010101010101010101001010101010101010101010101010101 1010101010101010101010101010101001010101010101010101010101010101 1010101010101010101010101010101001010101010101010101010101010101

12. A channel spreading device in a CDMA communication system, comprising:

a Walsh orthogonal code generator for generating a Walsh orthogonal code corresponding to a Walsh orthogonal code index for an assigned channel;

a sign code generator for storing sign codes shown in a table below, and generating a sign code corresponding to a mask index ei (where i=1,2,3) for the assigned channel;

a phase code generator for storing phase codes shown in the table below, and generating a phase code corresponding to a mask index ei (where i=1,2,3) for the assigned channel;

spreaders for spreading input signals with a spreading code generated by mixing the Walsh orthogonal code and the sign code; and

a rotator for controlling phases of signals output from the spreaders according to the phase code to generate channel spread signals:

$f(X) = 1 + X + X^2 + X^3 + X^5 + X^6 + X^7$ $g(X) = 3 + 3X + X^2 + X^3 + 2X^4 + 3X^5 + X^6 + X^7$		
e1	Sign	0111111011101000000101110111111000010111011111101000000100010111 0001011101111110100000010001011110000001000101111110100010000001
	Phase	0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001
e2	Sign	0111010001001000001011101110110110111000011110111110001011011110 1110001011011110010001111000010011010001000100100111010001001000
	Phase	0101010110101010101010100101010101010101101010101010101001010101 1010101001010101010101011010101010101010010101010101010110101010
e3	Sign	0100101111011101101110110010110110111011110100100100101100100010 1000100011100001011110000001000110000111000100010111011111100001
	Phase	0011110000111100001111000011110011000011110000111100001111000011 0011110000111100001111000011110011000011110000111100001111000011

13. A channel spreading device in a CDMA communication system, comprising:

a Walsh orthogonal code generator for generating a Walsh orthogonal code corresponding to a Walsh orthogonal code index for an assigned channel;

a sign code generator for storing sign codes shown in a table below, and generating a sign code corresponding to a mask index ei (where i=1,2,3) for the assigned channel;

a phase code generator for storing phase codes shown in the table below, and generating a phase code corresponding to a mask index ei (where i=1,2,3) for the assigned channel;

spreaders for spreading input signals with a spreading code generated by mixing the Walsh orthogonal code and the sign code; and

a rotator for controlling phases of signals output from the spreaders according to the phase code to generate channel spread signals:

$f(X)=1+X+X^3+X^5+X^8$ $g(X)=1+3X+2X^2+X^3+3X^5+X^8$		
e1	Sign	0111001000101000110101110111001001001110111010111110101110110001 1110101101001110101100011110101111010111100011011000110100101000 0010011110000010100000101101100000011011010000011011111000011011 0100000100011011000110111011111100111110111011000001001110111101
	Phase	0011001100110011001100110011001100110011001100110011001100110011 0011001100110011001100110011001100110011001100110011001100110011 1100110011001100110011001100110011001100110011001100110011001100 1100110011001100110011001100110011001100110011001100110011001100
e2	Sign	0001000101001011000111100100010001000100111000010100101111101110 1110111001001011111000010100010010111011111000011011010011101110 1101110110000111001011010111011110001000001011010111100011011101 0010001010000111110100100111011101110111001011011000011111011101
	Phase	0101101010100101010110101010010110100101010110101010010101011010 0101101010100101010110101010010110100101010110101010010101011010 1010010101011010101001010101101001011010101001010101101010100101 1010010101011010101001010101101001011010101001010101101010100101
e3	Sign	0001011100100100101111010111000110110010100000010001100011010100 1000111010111101110110110001011100101011000110000111111010110010 1110011111010100101100100111111010111101100011101110100000100100 1000000110110010001010111110011111011011111010000111000110111101
	Phase	0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001 0110100110010110011010011001011010010110011010011001011001101001

14. A channel spreading device in a CDMA communication system, comprising:

a Walsh orthogonal code generator for generating a Walsh orthogonal code corresponding to a Walsh orthogonal code index for an assigned channel;

a sign code generator for storing sign codes shown in a table below, and generating a sign code corresponding to a mask index ei (where i=1,2,3) for the assigned channel;

a phase code generator for storing phase codes shown in the table below, and generating a phase code corresponding to a mask index ei (where i=1,2,3) for the assigned channel;

spreaders for spreading input signals with a spreading code generated by mixing the Walsh orthogonal code and the sign code; and

a rotator for controlling phases of signals output from the spreaders according to the phase code to generate channel spread signals:

$f(X)=1+X^4+X^9$ $g(X)=3+2X^2+3X^4+X^8$		
e1	Sign	0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100 0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100
	Phase	0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001 1001011001101001011010011001011001101001100101101001011001101001 0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001 0110100110010110100101100110100110010110011010010110100110010110 0110100110010110100101100110100110010110011010010110100110010110 1001011001101001011010011001011001101001100101101001011001101001
e2	Sign	0001000101001011011110000010001000011110010001000111011100101101 0100010011100001001011011000100010110100000100011101110101111000 0111100000100010111011101011010010001000110100100001111001000100 1101001001110111010001001110000111011101011110000100101111101110 0001111001000100100010001101001011101110101101000111100000100010 1011010000010001001000101000011110111011000111100010110110001000 0111011100101101000111100100010001111000001000100001000101001011 0010001010000111010010111110111011010010011101111011101100011110

	Phase	0011110011000011110000110011110000111100110000111100001100111100 1100001100111100001111001100001111000011001111000011110011000011 1100001100111100001111001100001111000011001111000011110011000011 0011110011000011110000110011110000111100110000111100001100111100 0011110011000011110000110011110000111100110000111100001100111100 1100001100111100001111001100001111000011001111000011110011000011 1100001100111100001111001100001111000011001111000011110011000011 0011110011000011110000110011110000111100110000111100001100111100
e3	Sign	0111010000010010110111100100011100101110010010001000010000011101 1110001010000100101101110010111001000111001000010001001010001011 1101111001000111011101000001001001111011111000101101000110110111 0100100011010001000111010111101100010010100010110100011100100001 0100011111011110111011011000101111100010011110110100100000101110 1101000101001000100001001110001010001011000100101101111010111000 0001001001110100101110000010000101001000001011101110001001111011 1000010011100010110100010100100000100001010001110111010011101101
	Phase	0101010101010101010101010101010110101010101010101010101010101010 0101010101010101010101010101010110101010101010101010101010101010 0101010101010101010101010101010110101010101010101010101010101010 0101010101010101010101010101010110101010101010101010101010101010 1010101010101010101010101010101001010101010101010101010101010101 1010101010101010101010101010101001010101010101010101010101010101 1010101010101010101010101010101001010101010101010101010101010101 1010101010101010101010101010101001010101010101010101010101010101

15. A channel spreading device in a CDMA communication system, comprising:

a first Walsh orthogonal code generator for generating a first Walsh orthogonal code corresponding to a Walsh orthogonal code index for an assigned channel;

a sign code generator for generating a sign code corresponding to a mask index for the assigned channel;

a phase code generator for generating a second Walsh orthogonal code corresponding to a mask index for the assigned channel, the second Walsh orthogonal code controlling a phase of a channel spread signal;

a spreader for spreading input signals with a spreading code generated by mixing the first Walsh orthogonal code and the sign code; and

a rotator for controlling phases of the spread signals according to the second Walsh orthogonal code.

16. The channel spreading device as claimed in claim 15, wherein for the spreading code of length 128, the sign code generator includes a sign code table shown below, and the second Walsh orthogonal code generator uses a 127th Walsh

orthogonal code for a phase value for an e1 sign code, a 89th Walsh orthogonal code for a phase value for an e2 sign code, and a 38th Walsh orthogonal code for a phase value for an e3 sign code:

e1 Sign	0111111011101000000101110111111000010111011111101000000100010111 0001011101111110100000010001011110000001000101111110100010000001
e2 Sign	0111010001001000000101110111011011011100001111011111000101101110 1110001011011110010001111000010011010001000100100111010001001000
e3 Sign	0100101111011101101110110010110110111011110100100100101100100010 1000100011100001011110000000100011000011100010001011101111100001

17. The channel spreading device as claimed in claim 15, wherein for the spreading code of length 256, the sign code generator includes a sign code table shown below, and the second Walsh orthogonal code generator uses a 130th Walsh orthogonal code for a phase value for an e1 sign code, a 173rd Walsh orthogonal code for a phase value for an e2 sign code, and a 47th Walsh orthogonal code for a phase value for an e3 sign code:

e1	Sign	0111001000101000110101110111001001001110111010111110101110110001 1110101101001110101100011110101111010111100011011000110100101000 0010011110000010100000101101100000011011010000011011111000011011 0100000100011011000110111011111001111101110110000010011101111101
e2	Sign	0001000101001011000111100100010001000100111000010100101111101110 1110111001001011110000101000100101110111110000110110100111011110 1101110110000111001011010111011110001000001011010111100011011101 0010001010000111110100100111011101110111001011011000011111011101
e3	Sign	0001011100100100101111010111000110110010100000010001100011010100 1000111010111101110110110001011100101011000110000111111010110010 1110011111010100101100100111111010111101100011101110100000100100 1000000110110010001010111110011111011011111010000111000110111101

18. The channel spreading device as claimed in claim 15, wherein for the spreading code of length 512, the sign code generator includes a sign code table shown below, and the second Walsh orthogonal code generator uses a 511st Walsh orthogonal code for a phase value for an e1 sign code, a 222nd Walsh orthogonal code for a phase value for an e2 sign code, and a 289th Walsh orthogonal code for a phase value for an e3 sign code:

e1	Sign	0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100 0100110111011011110110111011001000100100010011010100110111011011 0010010001001101010011011101101110110010001001000010010001001101 0010010001001101010011011101101110110010001001000010010001001101 1011001000100100001001000100110111011011101100101011001000100100
e2	Sign	0001000101001011011110000010001000011110010001000111011100101101 0100010011100001001011011000100010110100000100011101110101111000 0111100000100010111011101011010010001000110100100001111001000100 1101001001110111010001001110000111011101011110000100101111101110 0001111001000100100010001101001011101110101101000111100000100010 1011010000010001001000101000011110111011000111100010110110001000 0111011100101101000111100100010001111000001000100001000101001011 0010001010000111010010111110111011010010011101111011101100011110
e3	Sign	0111010000010010110111100100011100101110010010001000010000011101 1110001010000100101101110010111001000111001000010001001010001011 1101111001000111011101000001001001111011111000101101000110110111 0100100011010001000111010111101100010010100010110100011100100001 0100011111011111011101101100010111110001001111011010010000101110 1101000101001000100001001110001010001011000100101101111010111000 0001001001110100101110000010000101001000000101110111000100111011 1000010011100010110100010100100000100001010001110111010011101101

19. The channel spreading device in a CDMA communication system, comprising:

a first Walsh orthogonal code generator for generating a first Walsh orthogonal code corresponding to a Walsh orthogonal code index for an assigned channel;

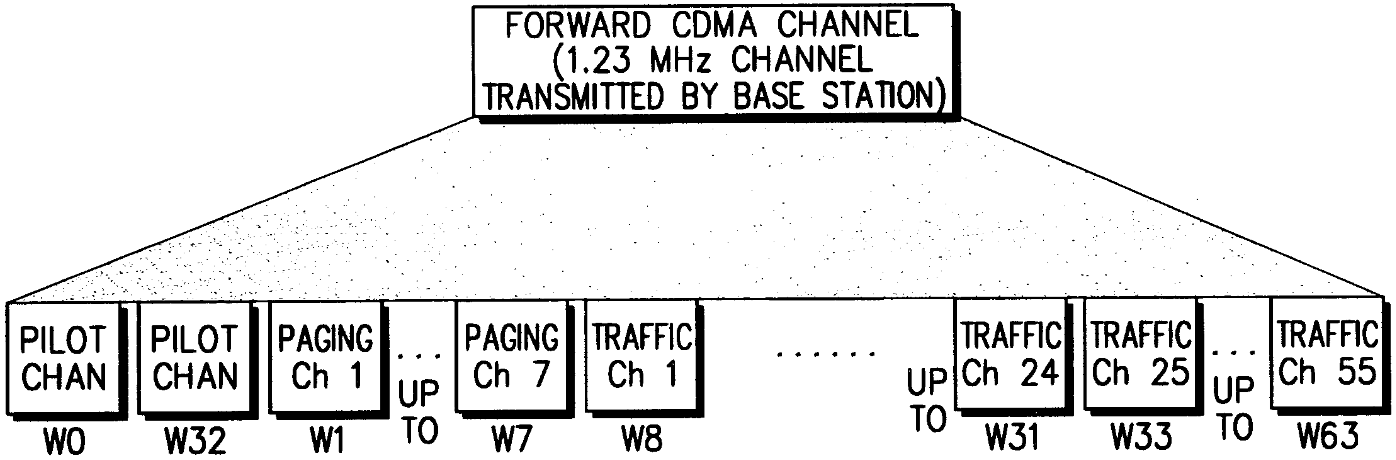
a sign code generator for generating a sign code corresponding to a mask index for the assigned channel;

a phase code generator for generating a second Walsh orthogonal code corresponding to a mask index for the assigned channel, the second Walsh orthogonal code controlling a phase of a channel spread signal;

a rotator for controlling phases of input signals according to the second Walsh orthogonal code; and

a spreader for spreading the phase controlled signals with a spreading code generated by mixing the first Walsh orthogonal code and the sign code.

FIG. 1


FORWARD CDMA CHANNEL
(1.23 MHz CHANNEL
TRANSMITTED BY BASE STATION)
PILOT CHAN
W0
PILOT CHAN
W32
PAGING Ch 1
W1
...
UP TO
PAGING Ch 7
W7
TRAFFIC Ch 1
W8
......
UP TO
TRAFFIC Ch 24
W31
TRAFFIC Ch 25
W33
...
UP TO
TRAFFIC Ch 55
W63

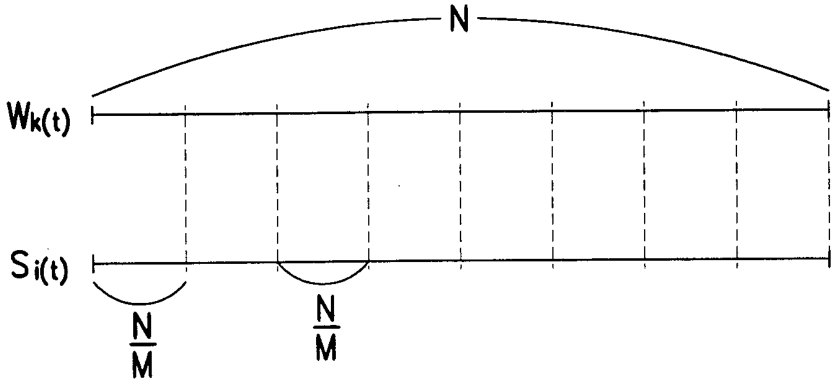


FIG. 2

$$Q=\begin{bmatrix}
0 & 0\quad 0\quad 0\quad 0\quad 0\cdots 0\quad 0 \\
0 & S_0(t) \\
0 & S_0(t+1) \\
\vdots & \vdots \\
0 & S_0(t+2^m-2) \\
0 & S_1(t) \\
0 & S_1(t+1) \\
\vdots & \vdots \\
0 & S_1(t+2^m-2) \\
0 & S_2(t) \\
0 & S_2(t+1) \\
\vdots & \vdots \\
0 & S_{2^m-1}(t) \\
0 & S_{2^m-1}(t+1) \\
\vdots & \vdots \\
0 & S_{2^m-1}(t+2^m-2)
\end{bmatrix}$$

FIG. 3

$$Q' = \begin{array}{cc} \overbrace{\quad\quad\quad}^{2^{2m}} & \\ \left[\begin{array}{c} W \\ e_0 + W \\ e_1 + W \\ \vdots \\ e_{2^m-1} + W \end{array}\right] & 2^m \text{ X } 2^m \end{array}$$

FIG. 4

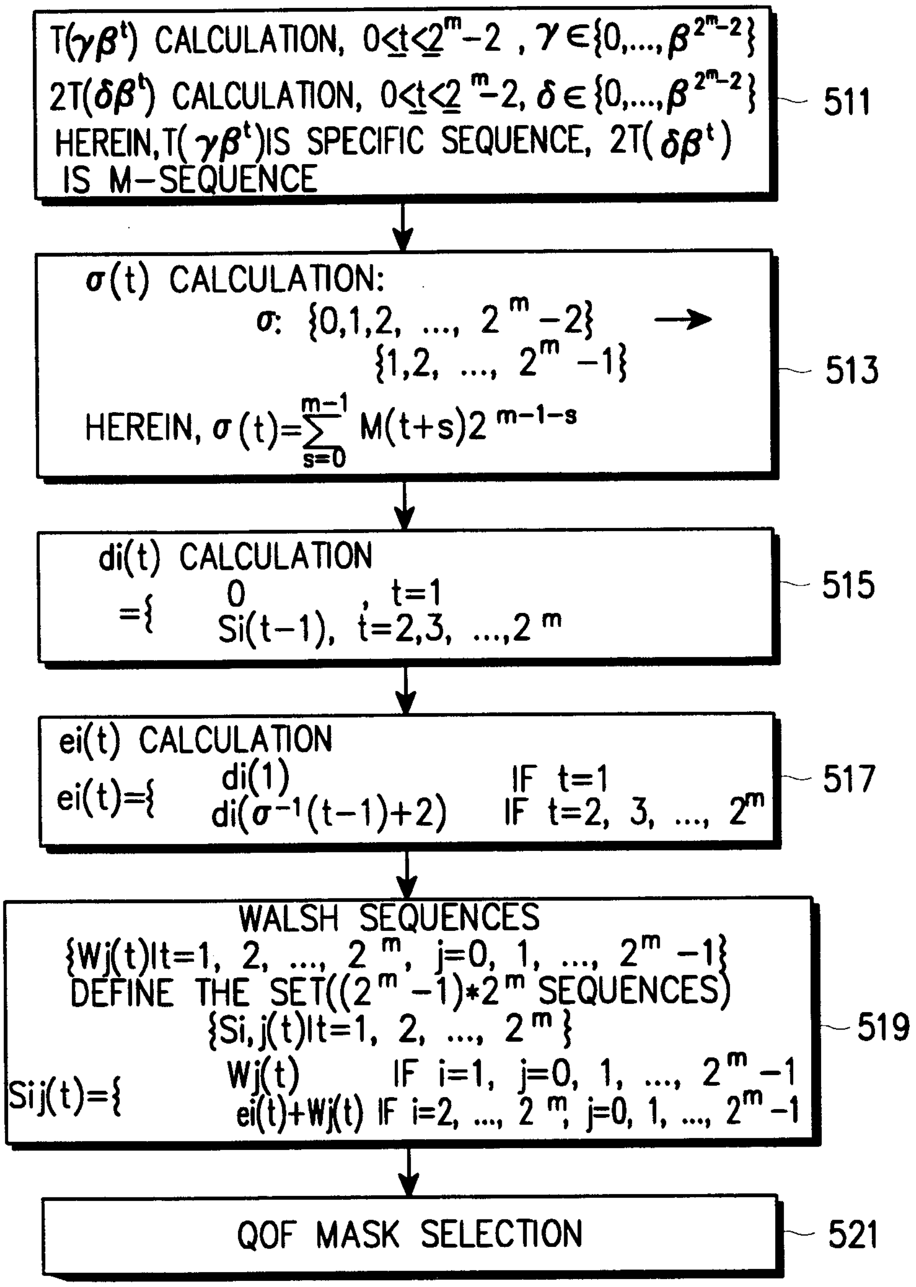

T(γβ^t) CALCULATION, 0≤t≤2^m−2 , γ∈{0,...,β^(2^m−2)}
2T(δβ^t) CALCULATION, 0≤t≤2^m−2, δ∈{0,...,β^(2^m−2)}
HEREIN, T(γβ^t) IS SPECIFIC SEQUENCE, 2T(δβ^t) IS M-SEQUENCE
511
σ(t) CALCULATION:
σ: {0,1,2, ..., 2^m−2} → {1,2, ..., 2^m−1}
HEREIN, σ(t)=Σ_{s=0}^{m−1} M(t+s)2^(m−1−s)
513
di(t) CALCULATION
={ 0 , t=1
Si(t−1), t=2,3, ...,2^m
515
ei(t) CALCULATION
ei(t)={ di(1) IF t=1
di(σ^−1(t−1)+2) IF t=2, 3, ..., 2^m
517
WALSH SEQUENCES
{Wj(t)|t=1, 2, ..., 2^m, j=0, 1, ..., 2^m−1}
DEFINE THE SET((2^m−1)*2^m SEQUENCES)
{Si,j(t)|t=1, 2, ..., 2^m}
Sij(t)={ Wj(t) IF i=1, j=0, 1, ..., 2^m−1
ei(t)+Wj(t) IF i=2, ..., 2^m, j=0, 1, ..., 2^m−1
519
QOF MASK SELECTION
521

FIG. 5

FIG. 6

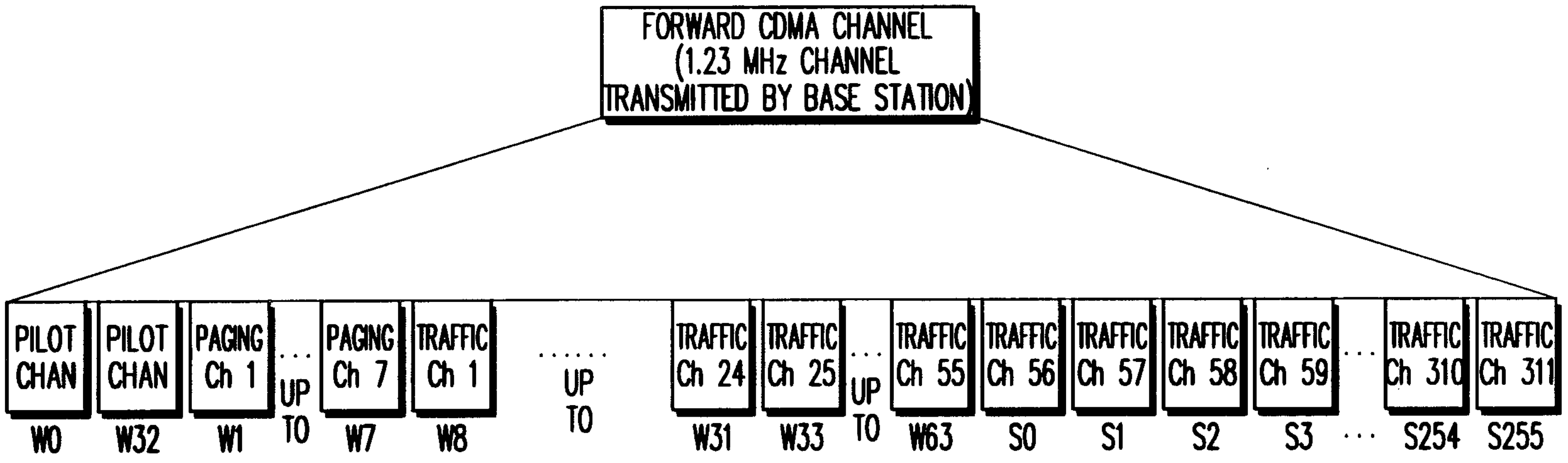

FORWARD CDMA CHANNEL
(1.23 MHz CHANNEL
TRANSMITTED BY BASE STATION)
PILOT CHAN
W0
PILOT CHAN
W32
PAGING Ch 1
W1
...
UP TO
PAGING Ch 7
W7
TRAFFIC Ch 1
W8
......
UP TO
TRAFFIC Ch 24
W31
TRAFFIC Ch 25
W33
...
UP TO
TRAFFIC Ch 55
W63
TRAFFIC Ch 56
S0
TRAFFIC Ch 57
S1
TRAFFIC Ch 58
S2
TRAFFIC Ch 59
S3
...
TRAFFIC Ch 310
S254
TRAFFIC Ch 311
S255

FIG. 7

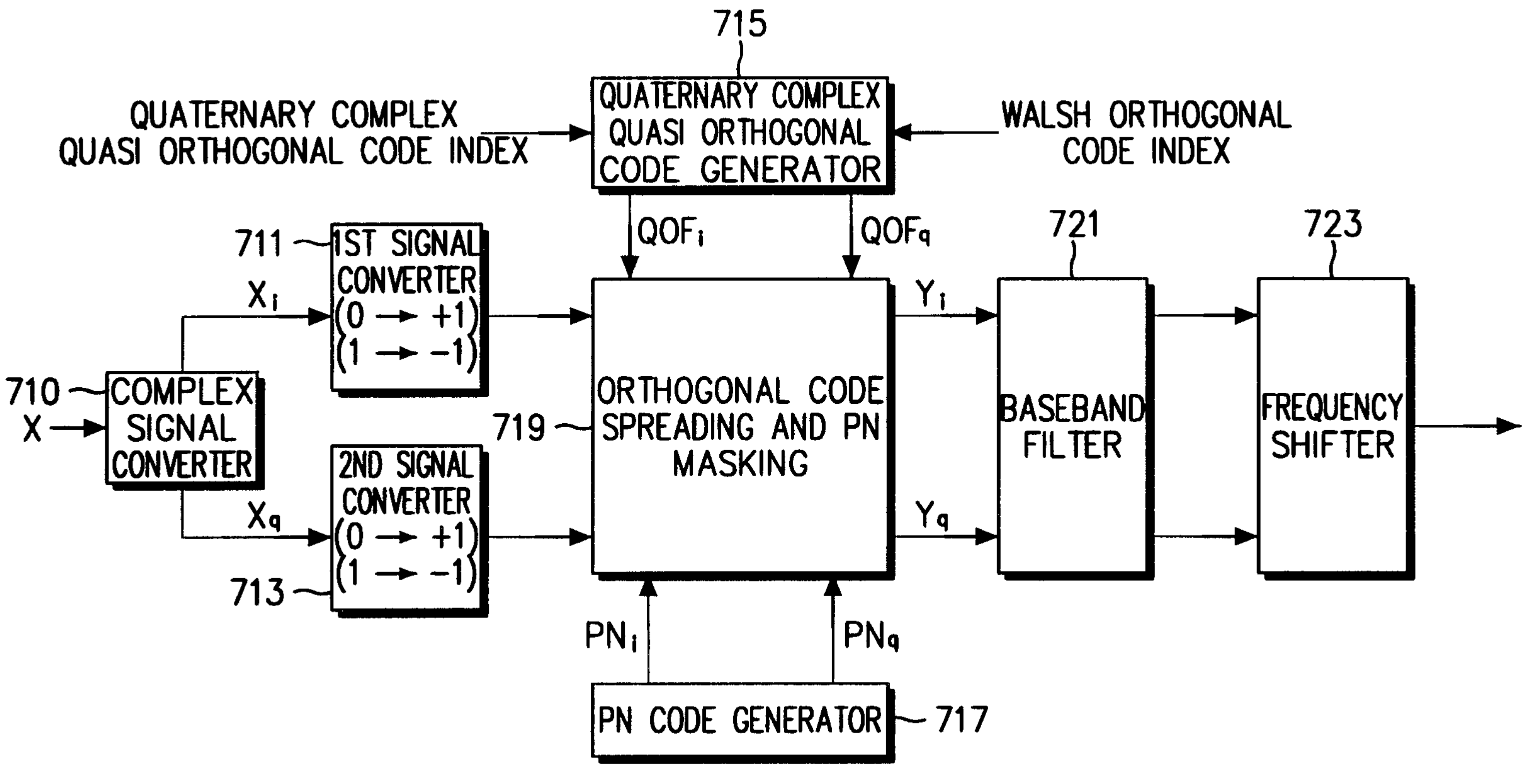

715
QUATERNARY COMPLEX QUASI ORTHOGONAL CODE INDEX
QUATERNARY COMPLEX QUASI ORTHOGONAL CODE GENERATOR
WALSH ORTHOGONAL CODE INDEX
QOF$_i$
QOF$_q$
711
1ST SIGNAL CONVERTER (0 → +1) (1 → −1)
X$_i$
710
X
COMPLEX SIGNAL CONVERTER
X$_q$
2ND SIGNAL CONVERTER (0 → +1) (1 → −1)
713
719
ORTHOGONAL CODE SPREADING AND PN MASKING
Y$_i$
Y$_q$
PN$_i$
PN$_q$
PN CODE GENERATOR
717
721
BASEBAND FILTER
723
FREQUENCY SHIFTER

FIG. 8

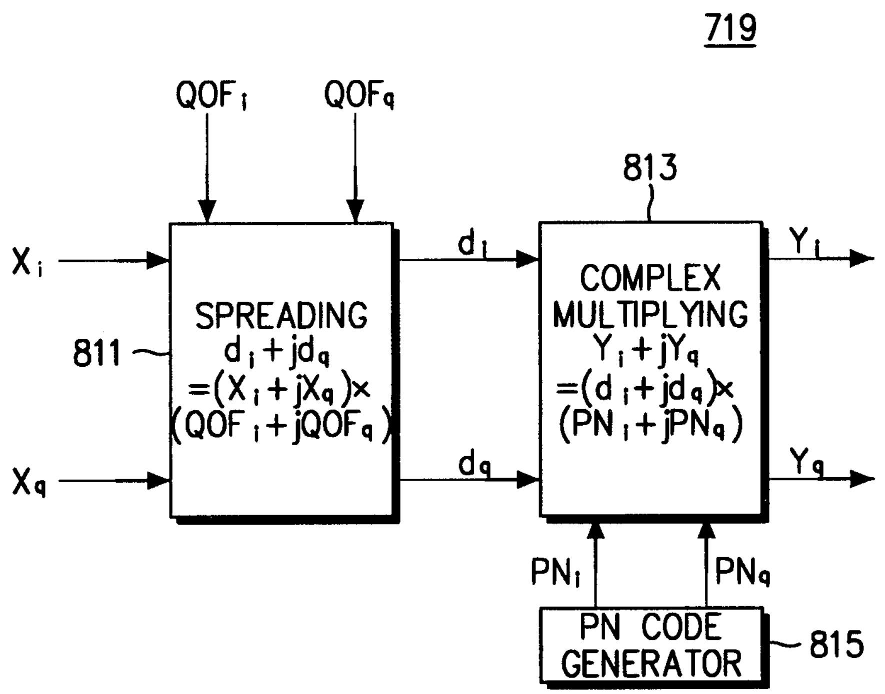

719
QOFi
QOFq
Xi
Xq
811
SPREADING
di+jdq
=(Xi+jXq)×
(QOFi+jQOFq)
di
dq
813
COMPLEX
MULTIPLYING
Yi+jYq
=(di+jdq)×
(PNi+jPNq)
Yi
Yq
PNi
PNq
PN CODE
GENERATOR
815

FIG. 9

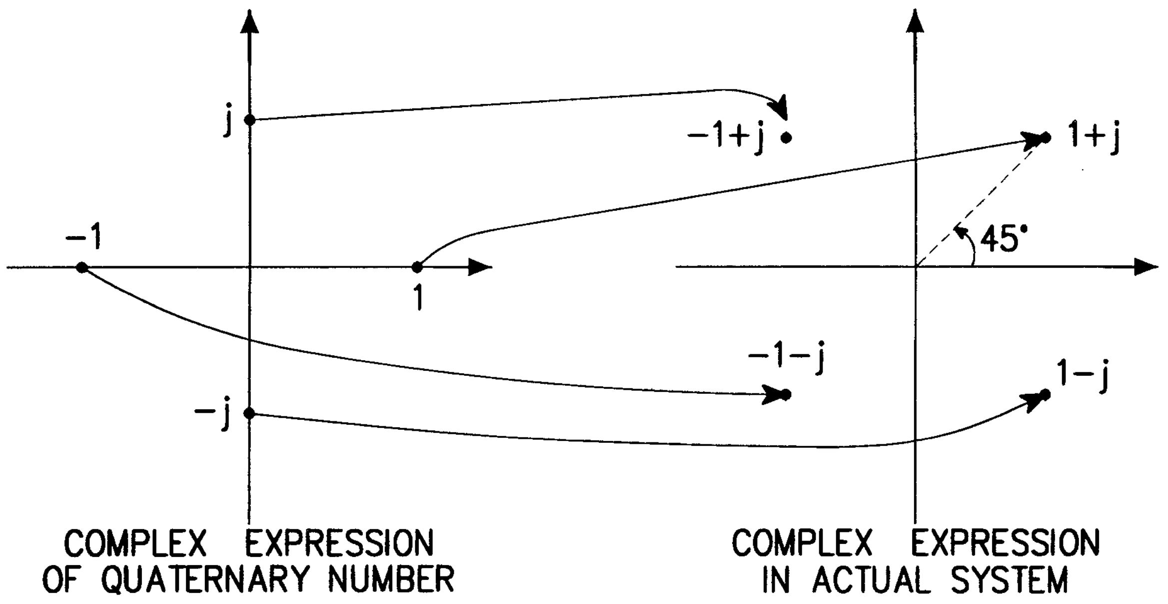

j
−1
1
−j
−1+j
1+j
45°
−1−j
1−j
COMPLEX EXPRESSION OF QUATERNARY NUMBER
COMPLEX EXPRESSION IN ACTUAL SYSTEM

FIG. 10

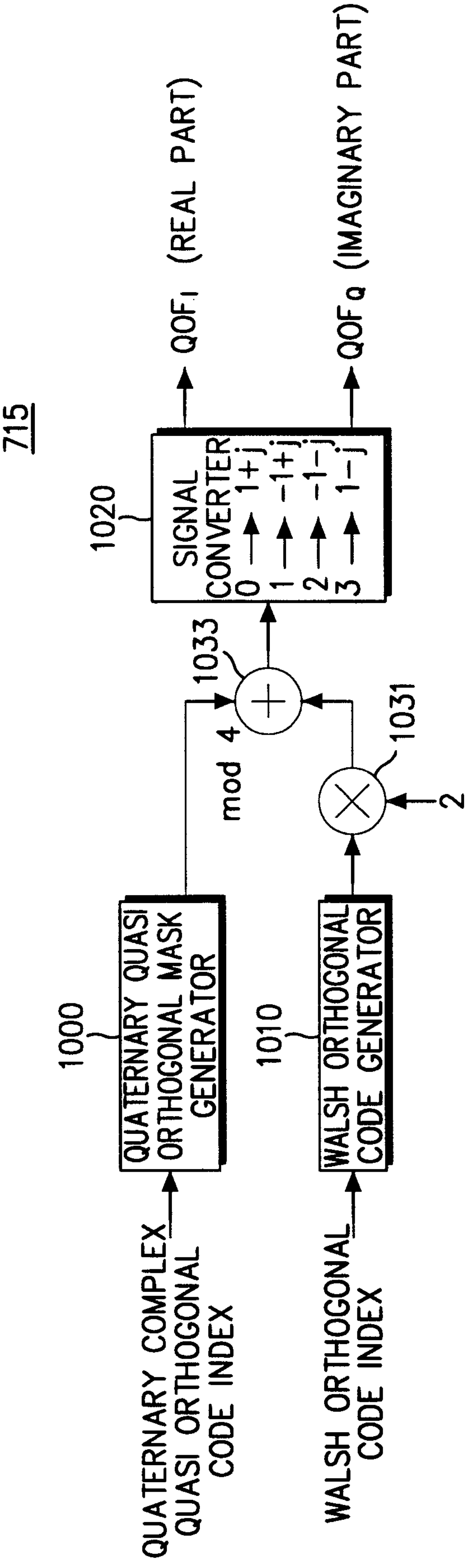
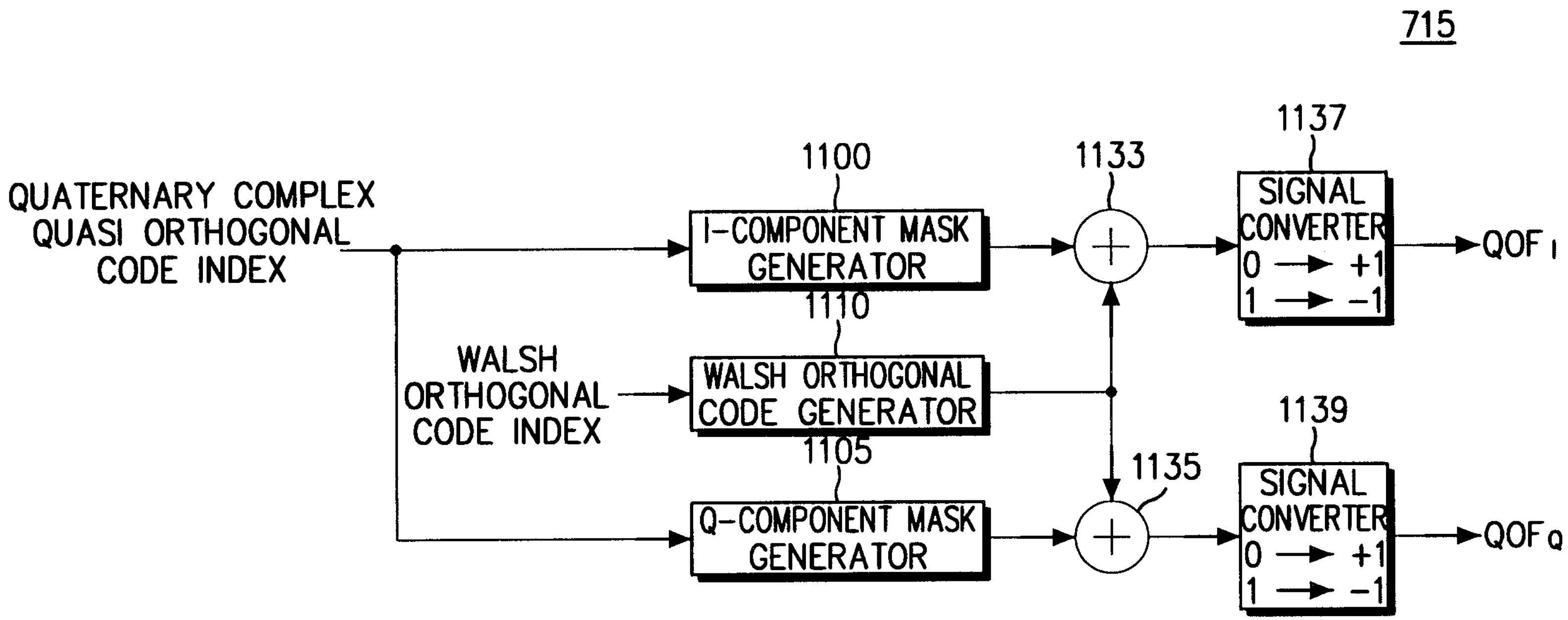

715
QUATERNARY COMPLEX QUASI ORTHOGONAL CODE INDEX
1000
QUATERNARY QUASI ORTHOGONAL MASK GENERATOR
WALSH ORTHOGONAL CODE INDEX
1010
WALSH ORTHOGONAL CODE GENERATOR
1031
2
mod 4
1033
1020
SIGNAL CONVERTER
0 → 1+j
1 → −1+j
2 → −1−j
3 → 1−j
QOF_I (REAL PART)
QOF_Q (IMAGINARY PART)

FIG. 11


715
QUATERNARY COMPLEX QUASI ORTHOGONAL CODE INDEX
WALSH ORTHOGONAL CODE INDEX
1100
I-COMPONENT MASK GENERATOR
1110
WALSH ORTHOGONAL CODE GENERATOR
1105
Q-COMPONENT MASK GENERATOR
1133
1135
1137
SIGNAL CONVERTER
0 → +1
1 → -1
1139
SIGNAL CONVERTER
0 → +1
1 → -1
QOF I
QOF Q

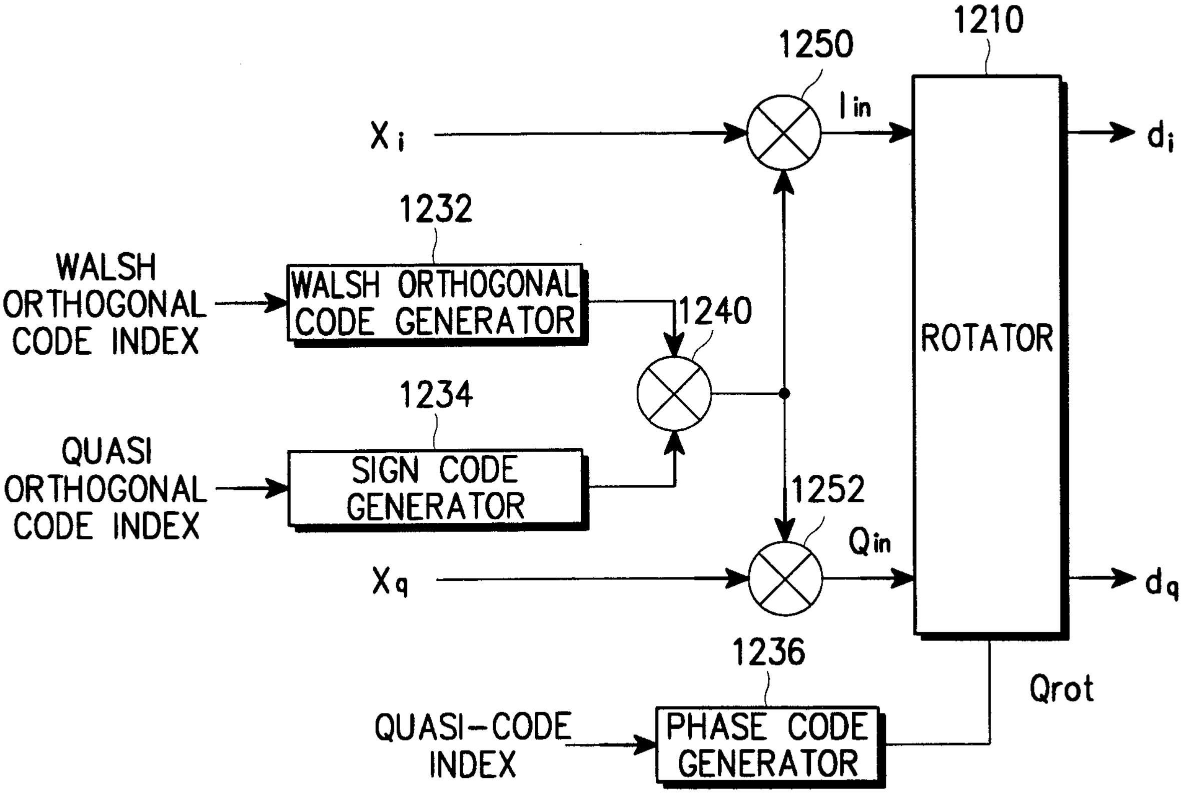

1210
1250
X_i
I_{in}
d_i
1232
WALSH ORTHOGONAL CODE INDEX
WALSH ORTHOGONAL CODE GENERATOR
1240
ROTATOR
1234
QUASI ORTHOGONAL CODE INDEX
SIGN CODE GENERATOR
1252
Q_{in}
X_q
d_q
1236
Qrot
QUASI-CODE INDEX
PHASE CODE GENERATOR

FIG. 12

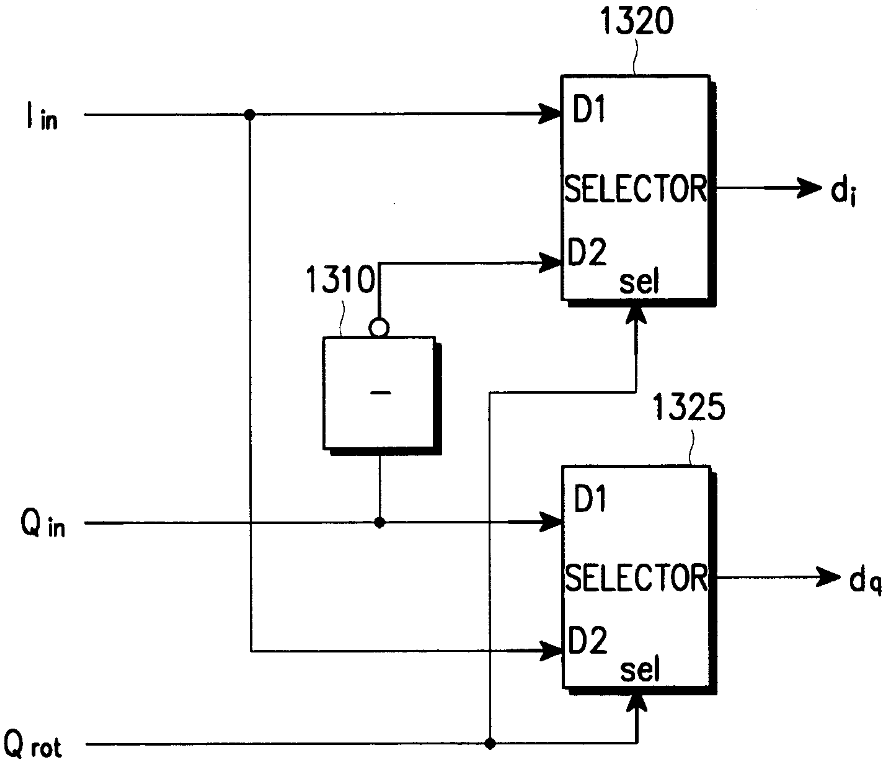

1320
I in
D1
SELECTOR
d_i
D2
sel
1310
–
1325
Q in
D1
SELECTOR
d_q
D2
sel
Q rot

FIG. 13

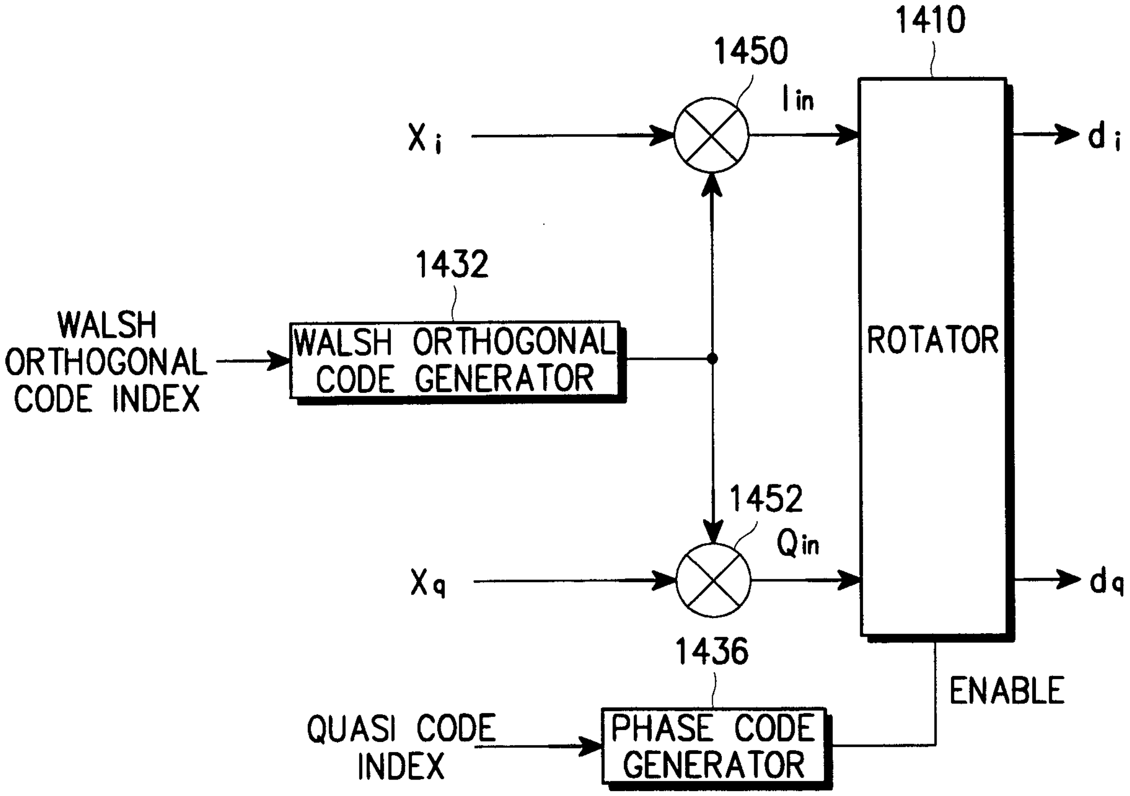

1410
1450
I_{in}
X_i
d_i
1432
WALSH ORTHOGONAL CODE INDEX
WALSH ORTHOGONAL CODE GENERATOR
ROTATOR
1452
Q_{in}
X_q
d_q
1436
ENABLE
QUASI CODE INDEX
PHASE CODE GENERATOR

FIG. 14

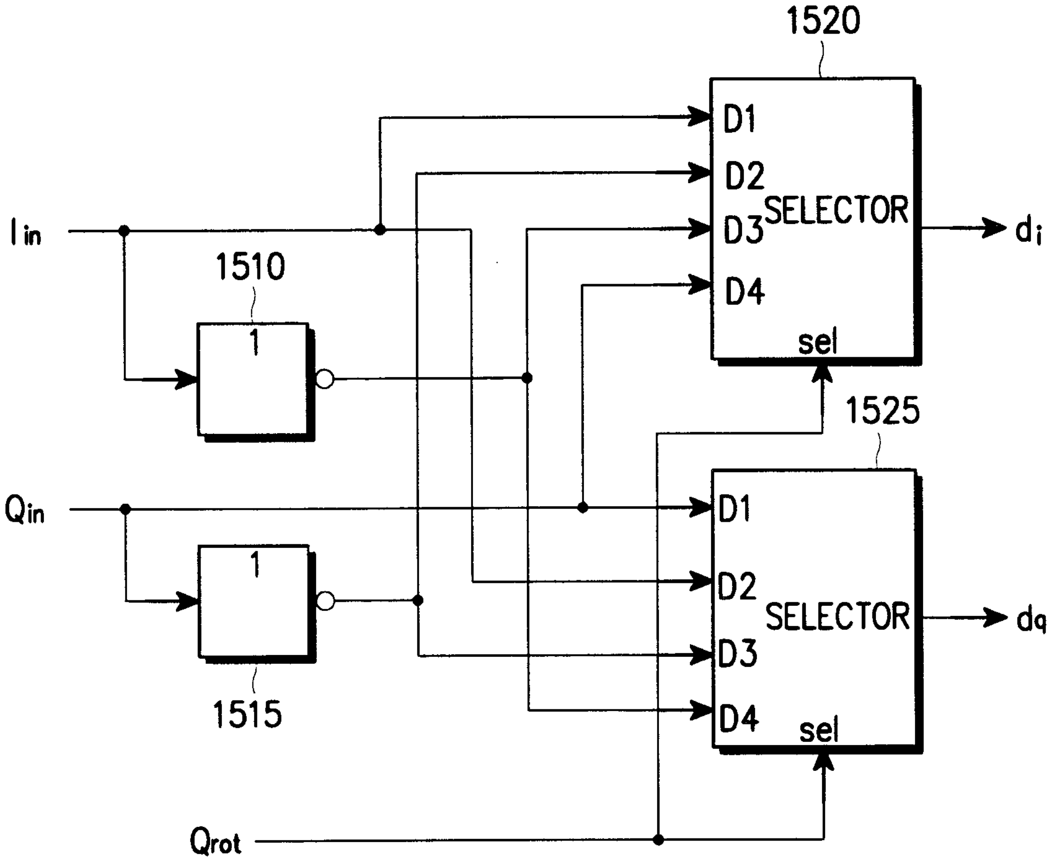

1520
D1
D2
D3
D4
SELECTOR
sel
d_i
I_{in}
1510
1
1525
Q_{in}
1
D1
D2
D3
D4
SELECTOR
sel
d_q
1515
Q_{rot}

FIG. 15

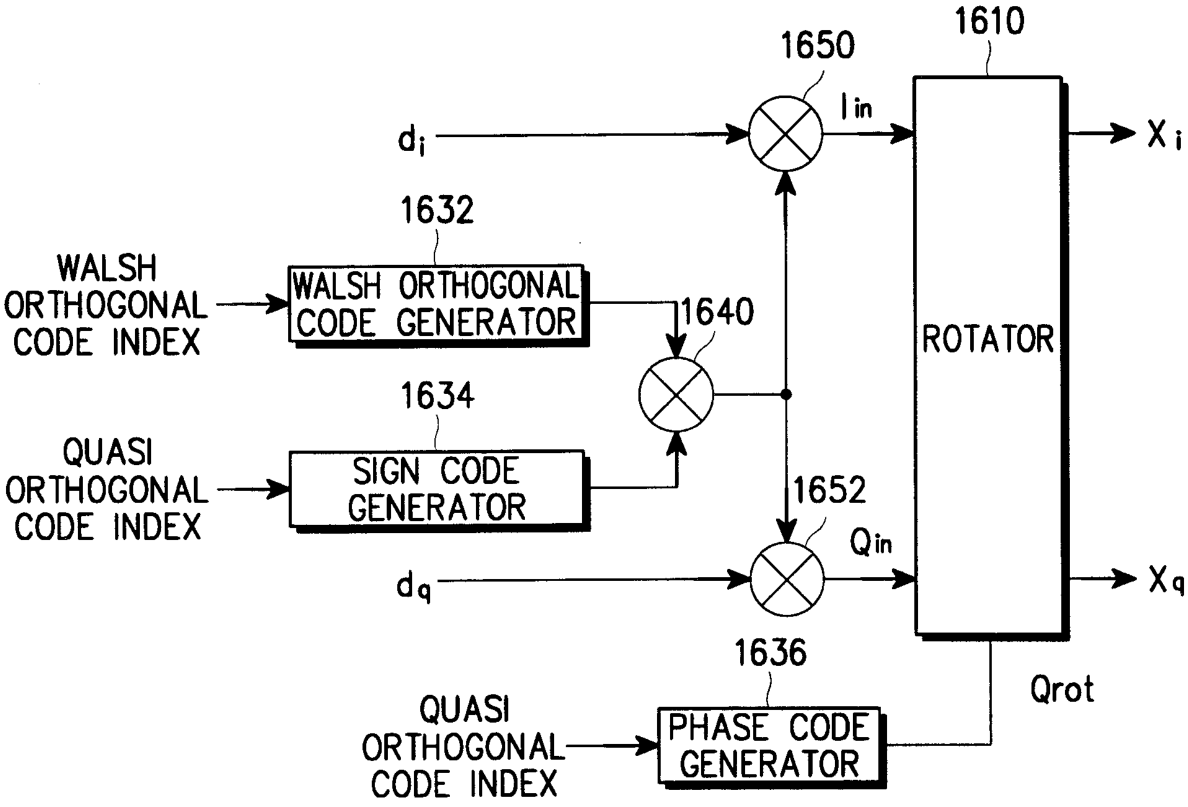

1610
1650
I_{in}
d_i
X_i
1632
WALSH ORTHOGONAL CODE INDEX
WALSH ORTHOGONAL CODE GENERATOR
1640
ROTATOR
1634
QUASI ORTHOGONAL CODE INDEX
SIGN CODE GENERATOR
1652
Q_{in}
d_q
X_q
1636
Qrot
QUASI ORTHOGONAL CODE INDEX
PHASE CODE GENERATOR

FIG. 16

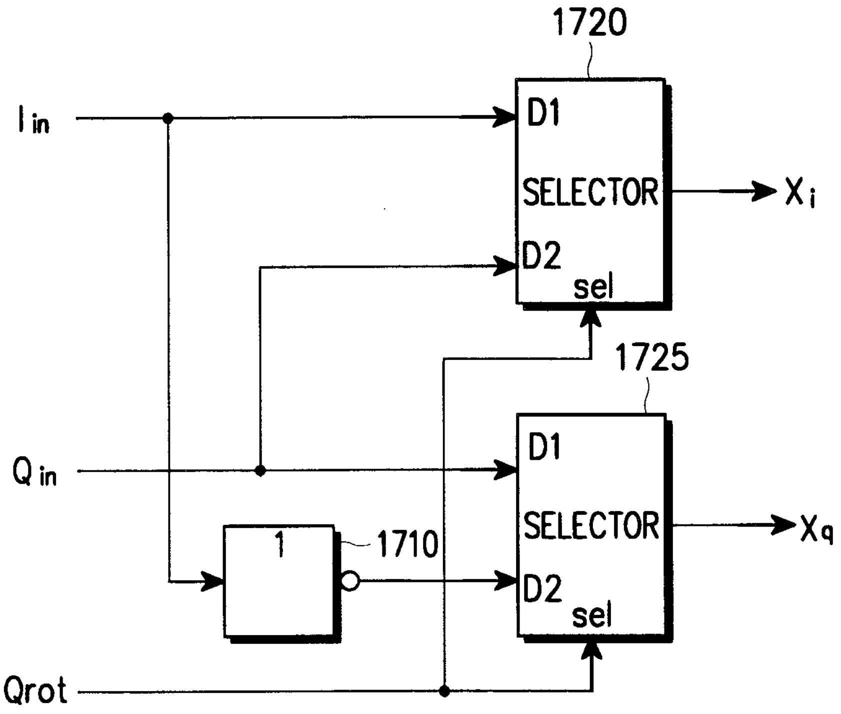

1720
I in
D1
SELECTOR
D2
sel
Xi
1725
Q in
D1
SELECTOR
1
1710
D2
sel
Xq
Qrot

FIG. 17

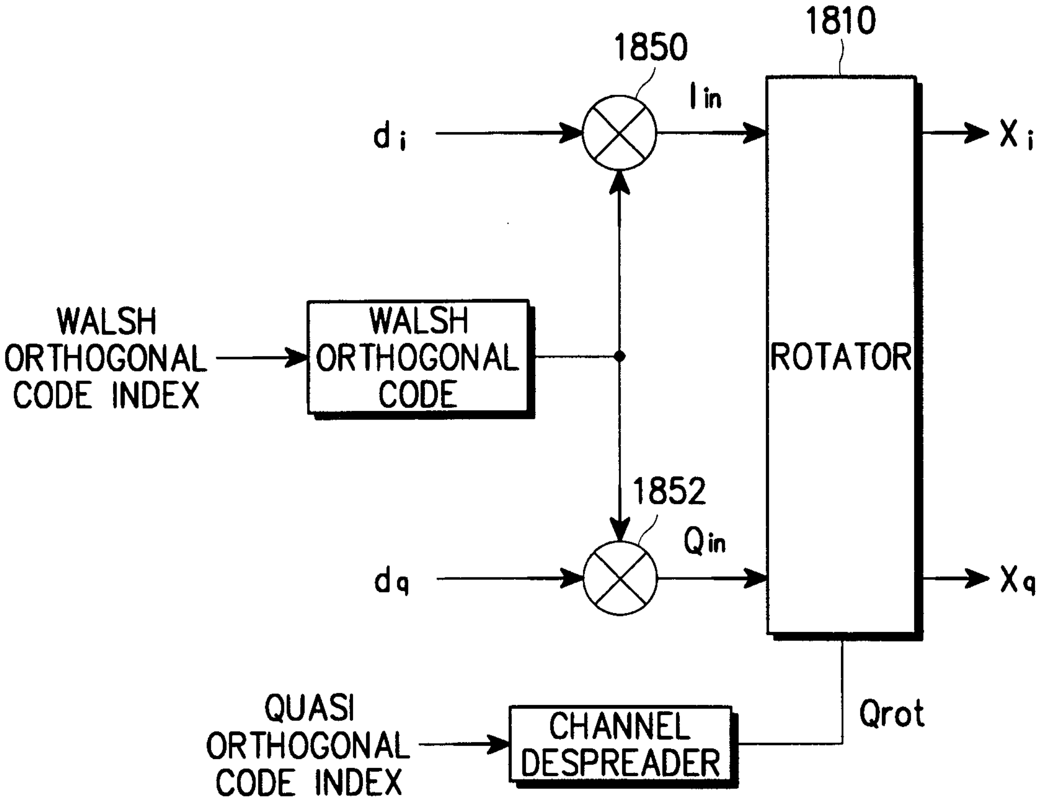

1810
1850
I_{in}
d_i
X_i
WALSH ORTHOGONAL CODE INDEX
WALSH ORTHOGONAL CODE
ROTATOR
1852
Q_{in}
d_q
X_q
QUASI ORTHOGONAL CODE INDEX
CHANNEL DESPREADER
Qrot

FIG. 18

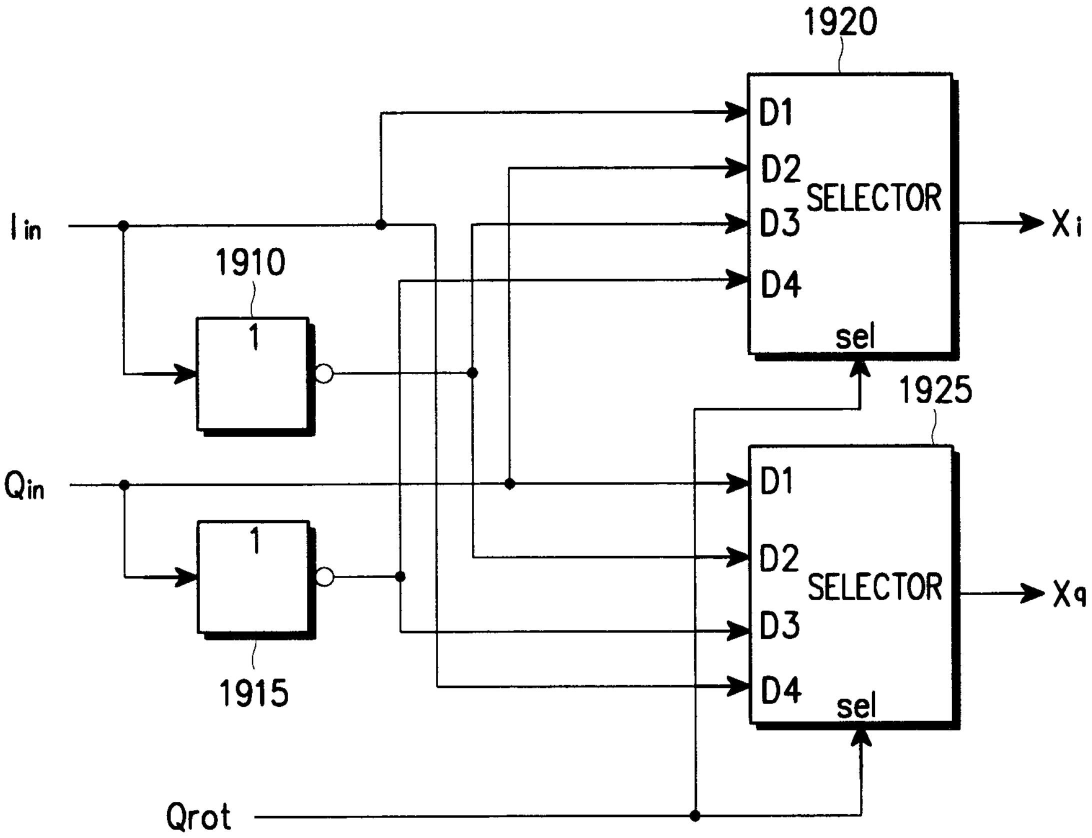

1920
D1
D2
D3
D4
SELECTOR
sel
Xi
Iin
1910
1
Qin
1
1915
1925
D1
D2
D3
D4
SELECTOR
sel
Xq
Qrot

FIG. 19

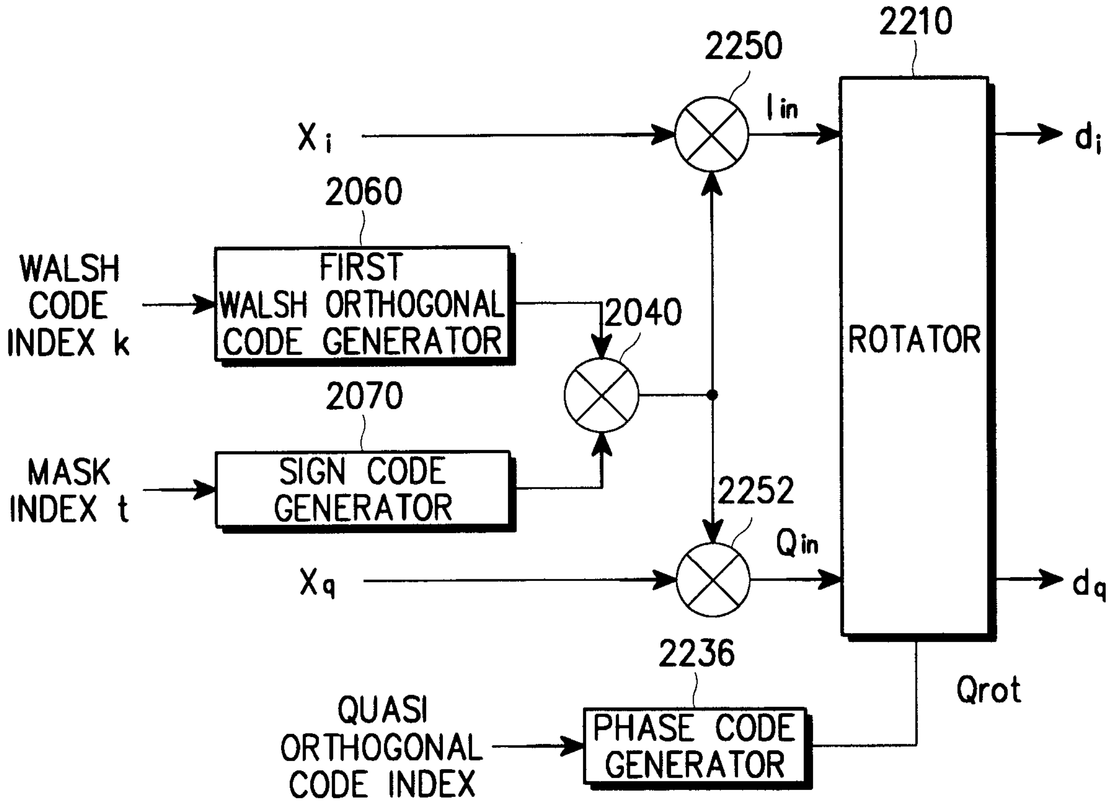

2210
2250
X_i
I_{in}
d_i
2060
WALSH CODE INDEX k
FIRST WALSH ORTHOGONAL CODE GENERATOR
2040
ROTATOR
2070
MASK INDEX t
SIGN CODE GENERATOR
2252
Q_{in}
X_q
d_q
2236
Qrot
QUASI ORTHOGONAL CODE INDEX
PHASE CODE GENERATOR

FIG. 20

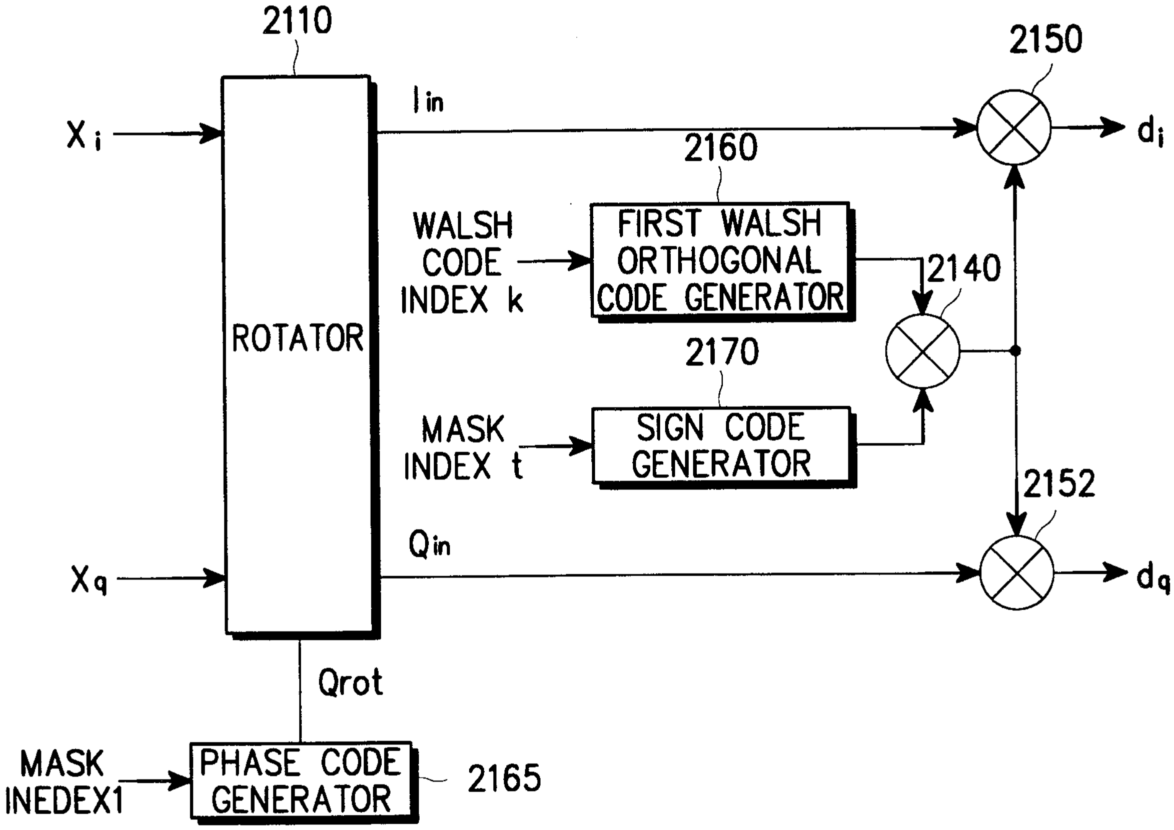

2110
2150
Xi
Iin
di
2160
WALSH CODE INDEX k
FIRST WALSH ORTHOGONAL CODE GENERATOR
2140
ROTATOR
2170
MASK INDEX t
SIGN CODE GENERATOR
2152
Xq
Qin
dq
Qrot
MASK INEDEX1
PHASE CODE GENERATOR
2165

FIG. 21

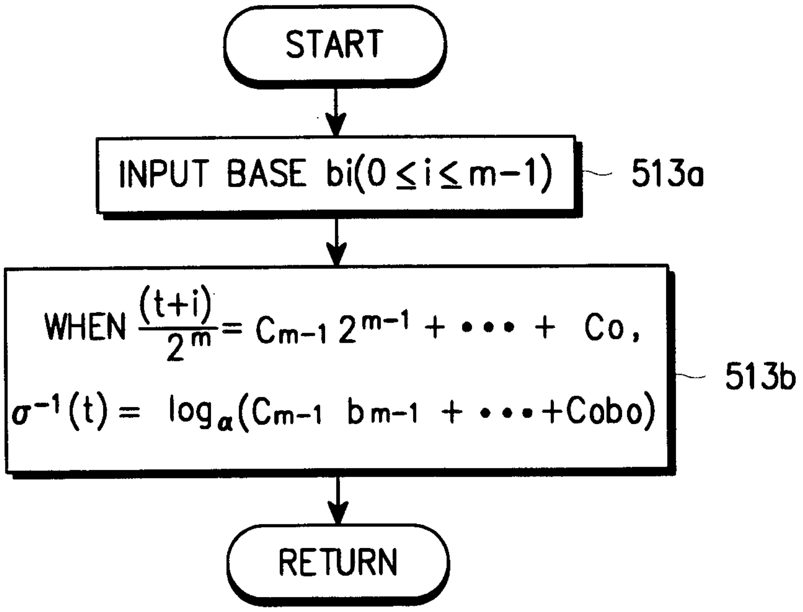

START
INPUT BASE bi(0 ≤ i ≤ m−1)
513a
WHEN $\frac{(t+i)}{2^m} = C_{m-1} 2^{m-1} + \cdots + C_0$,
$\sigma^{-1}(t) = \log_\alpha(C_{m-1} b_{m-1} + \cdots + C_0 b_0)$
513b
RETURN

FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR00/00014

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04B 1/69

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

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)
IPC7 H04M 7/00 13/00, H04B 1/69 7/216

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5519736 21 May 1996 (NEC Co.) see summary of the invention and claim 1	1
Y	US 5416797 16 May 1995 (Qualcomm Inc.) see summary of the inventio	1
P	US 55920591 6 July 1999 (Oki Electric Industry Co., Ltd.) see summary of the invention	1

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevence; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 17 APRIL 2000 (17.04.2000)	Date of mailing of the international search report 25 APRIL 2000 (25.04.2000)
Name and mailing address of the ISA/KR Korean Industrial Property Office Government Complex-Taejon, Dunsan-dong, So-ku, Taejon Metropolitan City 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer JEONG, Jae Woo Telephone No. 82-42-481-5718