

Claims

[Claim 1] A transmission apparatus for transmitting a block of data over a plurality of transmission channels, the transmission apparatus comprising:

a modulator operable to generate one of a plurality of rotated constellation points in accordance with the block of data to be transmitted, each of the plurality of rotated constellation points having N components; and

a transmitter operable to transmit each component of the generated rotated constellation point over a different one of the plurality of transmission channels, wherein

the plurality of rotated constellation points are obtained by applying an orthogonal transformation to each of a plurality of initial constellation points that has N components,

N is a multiple of four,

the orthogonal transformation has one of (i) an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value, and (ii) a matrix representation obtained by permuting either or both of rows and columns in the N-by-N matrix representation, and

when the N-by-N matrix representation is denoted by R,

$$R = \begin{pmatrix} s_{1,1}a & s_{1,2}b & \cdots & s_{1,N}b \\ s_{2,1}b & s_{2,2}a & & \vdots \\ \vdots & & \ddots & s_{N-1,N}b \\ s_{N,1}b & \cdots & s_{N,N-1}b & s_{N,N}a \end{pmatrix}$$

a and b denote real parameters,

each sign value $s_{i,j}$ satisfies

$$s_{i,j} \in \{-1, +1\}, \text{ and}$$

$$s_{i,i}s_{i,j} = -s_{j,i}s_{j,j} \quad \text{for all } i \neq j, \text{ and}$$

the real parameters a and b satisfy

$$a^2 + (N-1)b^2 = 1.$$

[Claim 2] A reception apparatus for receiving a block of data over a plurality of transmission channels, the reception apparatus comprising:

a receiver operable to receive N component signals over the plurality of transmission channels; and

a demodulator operable to select one of a plurality of rotated constellation points in accordance with the plurality of received N component signals, wherein

the plurality of rotated constellation points are obtained by applying an orthogonal transformation to each of a plurality of initial constellation points that has N components ,

N is a multiple of four, and

the orthogonal transformation has one of (i) an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value, and (ii) a matrix representation obtained by permuting either or both of rows and columns in the N-by-N matrix representation, and

when the N-by-N matrix representation is denoted by R,

$$R = \begin{pmatrix} s_{1,1}a & s_{1,2}b & \cdots & s_{1,N}b \\ s_{2,1}b & s_{2,2}a & & \vdots \\ \vdots & & \ddots & s_{N-1,N}b \\ s_{N,1}b & \cdots & s_{N,N-1}b & s_{N,N}a \end{pmatrix}$$

a and b denote real parameters,

each sign value $s_{i,j}$ satisfies

$$s_{i,j} \in \{-1, +1\}, \text{ and}$$

$$s_{i,i}s_{i,j} = -s_{j,i}s_{j,j} \quad \text{for all } i \neq j, \text{ and}$$

the real parameters a and b satisfy

$$a^2 + (N-1)b^2 = 1.$$

[Claim 3] A transmission method for transmitting a block of data over a plurality of transmission channels, the transmission method comprising the steps of:

generating one of a plurality of rotated constellation points in accordance with the block of data to be transmitted, each of the plurality of rotated constellation points having N components; and

transmitting each component of the generated rotated constellation point over a different one of the plurality of transmission channels, wherein

the plurality of rotated constellation points are obtained by applying an orthogonal transformation to each of a plurality of initial constellation points that has N components,

N is a multiple of four, and

the orthogonal transformation has one of (i) an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value, and (ii) a matrix representation obtained by permuting either or both of rows and columns in the N-by-N matrix representation, and

when the N-by-N matrix representation is denoted by R,

$$R = \begin{pmatrix} s_{1,1}a & s_{1,2}b & \cdots & s_{1,N}b \\ s_{2,1}b & s_{2,2}a & & \vdots \\ \vdots & & \ddots & s_{N-1,N}b \\ s_{N,1}b & \cdots & s_{N,N-1}b & s_{N,N}a \end{pmatrix}$$

a and b denote real parameters,

each sign value $s_{i,j}$ satisfies

$$s_{i,j} \in \{-1, +1\}, \text{ and}$$

$$s_{i,i}s_{i,j} = -s_{j,i}s_{j,j} \quad \text{for all } i \neq j, \text{ and}$$

the real parameters a and b satisfy

$$a^2 + (N-1)b^2 = 1.$$

[Claim 4] A reception method for receiving a block of data over a plurality of transmission channels, the reception method comprising the steps of:

receiving N component signals over the plurality of transmission channels;
and

selecting one of a plurality of rotated constellation points in accordance with the plurality of received N component signals, wherein

the plurality of rotated constellation points are obtained by applying an orthogonal transformation to each of a plurality of initial constellation points that has N components ,

N is a multiple of four, and

the orthogonal transformation has one of (i) an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value, and (ii) a matrix representation obtained by permuting either or both of rows and columns in the N-by-N matrix representation, and

when the N-by-N matrix representation is denoted by R,

$$R = \begin{pmatrix} s_{1,1}a & s_{1,2}b & \cdots & s_{1,N}b \\ s_{2,1}b & s_{2,2}a & & \vdots \\ \vdots & & \ddots & s_{N-1,N}b \\ s_{N,1}b & \cdots & s_{N,N-1}b & s_{N,N}a \end{pmatrix}$$

a and b denote real parameters,

each sign value $s_{i,j}$ satisfies

$$s_{i,j} \in \{-1, +1\}, \text{ and}$$

$$s_{i,i}s_{i,j} = -s_{j,i}s_{j,j} \quad \text{for all } i \neq j, \text{ and}$$

the real parameters a and b satisfy

$$a^2 + (N-1)b^2 = 1.$$

[Claim 5] A generation method for generating an N-dimensional rotated constellation for a digital modulation scheme in a data communication system, the generation method comprising the steps of:

receiving a plurality of vectors of an N-dimensional vector space; and

obtaining constellation points of the N-dimensional rotated constellation by applying an orthogonal transformation to the plurality of vectors received, wherein

the orthogonal transformation is adapted for increasing a minimum number of different values in components of any two distinct N-dimensional rotated constellation points relative to a minimum number of different values in components of any two distinct vectors received, and

the orthogonal transformation has one of (i) an N-by-N matrix representation, N being a multiple of four, with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value, and (ii) a matrix representation obtained by permuting either or both of rows and columns in the N-by-N matrix representation, and

when the N-by-N matrix representation is denoted by R,

$$R = \begin{pmatrix} s_{1,1}a & s_{1,2}b & \cdots & s_{1,N}b \\ s_{2,1}b & s_{2,2}a & & \vdots \\ \vdots & & \ddots & s_{N-1,N}b \\ s_{N,1}b & \cdots & s_{N,N-1}b & s_{N,N}a \end{pmatrix}$$

a and b denote real parameters,

each sign value $s_{i,j}$ satisfies

$$s_{i,j} \in \{-1, +1\}, \text{ and}$$

$$s_{i,i}s_{i,j} = -s_{j,i}s_{j,j} \quad \text{for all } i \neq j, \text{ and}$$

the real parameters a and b satisfy

$$a^2 + (N-1)b^2 = 1.$$

Claims

[Claim 1]

A transmission apparatus for transmitting a block of data over a plurality of transmission channels, the transmission apparatus comprising:
 a modulator operable to select one of a plurality of constellation points in accordance with the block of data to be transmitted, each of the plurality of constellation points having a plurality of components; and
 a transmitter operable to transmit each component of the selected constellation point over a different one of the plurality of transmission channels, wherein
 the plurality of constellation points are defined by positions thereof within an N-dimensional space, the positions being obtained by applying an orthogonal transformation to a subset of

$$\mathbb{Z}^N$$

, which is an N-dimensional integer lattice,
 N is a multiple of four, and
 the orthogonal transformation has an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value.

[Claim 2]

The transmission apparatus according to claim 1, wherein instead of the N-by-N matrix representation, the orthogonal transformation has a matrix representation obtained by permuting rows and/or columns in the N-by-N matrix representation.

[Claim 3]

The transmission apparatus according to claim 1, further comprising a mapper operable to map each component of the selected constellation point to the corresponding one of the plurality of transmission channels over which the component is to be transmitted, such that fading of each of the plurality of transmission channels is uncorrelated with fading of any other one of the plurality of transmission channels.

[Claim 4]

The transmission apparatus according to claim 1, wherein the transmitter is adapted for transmitting each component of the selected constellation point over a different one of a plurality of time slots, frequencies, transmitter antennas, or combinations thereof.

[Claim 5]

The transmission apparatus according to claim 1, wherein

- the plurality of transmission channels comprise a plurality of different carriers in an orthogonal frequency-division multiplexing scheme.
- [Claim 6] The transmission apparatus according to claim 1, wherein the plurality of transmission channels comprise a plurality of different symbols in an orthogonal frequency-division multiplexing scheme.
- [Claim 7] A reception apparatus for receiving a block of data over a plurality of transmission channels, the reception apparatus comprising:
 a receiver operable to receive a plurality of component signals over the plurality of transmission channels; and
 a demodulator operable to select one of a plurality of constellation points in accordance with the plurality of received component signals, wherein
 the plurality of constellation points are defined by positions thereof within an N-dimensional space, the positions being obtained by applying an orthogonal transformation to a subset of
- $$\mathbb{Z}^N$$
- , which is an N-dimensional integer lattice,
 N is a multiple of four, and
 the orthogonal transformation has an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value.
- [Claim 8] The reception apparatus according to claim 7, wherein instead of the N-by-N matrix representation, the orthogonal transformation has a matrix representation obtained by permuting rows and/or columns in the N-by-N matrix representation.
- [Claim 9] The reception apparatus according to claim 7, wherein the plurality of transmission channels comprise a plurality of different carriers in an orthogonal frequency-division multiplexing scheme.
- [Claim 10] The reception apparatus according to claim 7, wherein the plurality of transmission channels comprise a plurality of different symbols in an orthogonal frequency-division multiplexing scheme.
- [Claim 11] A transmission method for transmitting a block of data over a plurality of transmission channels, the transmission method comprising the steps of:
 selecting one of a plurality of constellation points in accordance with

the block of data to be transmitted, each of the plurality of constellation points having a plurality of components; and
 transmitting each component of the selected constellation point over a different one of the plurality of transmission channels, wherein
 the plurality of constellation points are defined by positions thereof within an N-dimensional space, the positions being obtained by applying an orthogonal transformation to a subset of

$$\mathbb{Z}^N$$

, which is an N-dimensional integer lattice,

N is a multiple of four, and

the orthogonal transformation has an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value.

- [Claim 12] The transmission method according to claim 11, wherein instead of the N-by-N matrix representation, the orthogonal transformation has a matrix representation obtained by permuting rows and/or columns in the N-by-N matrix representation.
- [Claim 13] The transmission method according to claim 11, further comprising the step of
 mapping each component of the selected constellation point to the corresponding one of the plurality of transmission channels over which the component is to be transmitted, such that fading of each of the plurality of transmission channels is uncorrelated with fading of any other one of the plurality of transmission channels.
- [Claim 14] The transmission method according to claim 11, wherein the plurality of transmission channels comprise a plurality of different carriers in an orthogonal frequency-division multiplexing scheme.
- [Claim 15] The transmission method according to claim 11, wherein the plurality of transmission channels comprise a plurality of different symbols in an orthogonal frequency-division multiplexing scheme.
- [Claim 16] A reception method for receiving a block of data over a plurality of transmission channels, the reception method comprising the steps of:
 receiving a plurality of component signals over the plurality of transmission channels; and
 selecting one of a plurality of constellation points in accordance with

the plurality of received component signals, wherein the plurality of constellation points are defined by positions thereof within an N-dimensional space, the positions being obtained by applying an orthogonal transformation to a subset of

$$\mathbb{Z}^N$$

, which is an N-dimensional integer lattice,

N is a multiple of four, and

the orthogonal transformation has an N-by-N matrix representation with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements not on the main diagonal equal to a non-zero second value.

- [Claim 17] The reception method according to claim 16, wherein instead of the N-by-N matrix representation, the orthogonal transformation has a matrix representation obtained by permuting rows and/or columns in the N-by-N matrix representation.
- [Claim 18] The reception method according to claim 16, wherein the plurality of transmission channels comprise a plurality of different carriers in an orthogonal frequency-division multiplexing scheme.
- [Claim 19] The reception method according to claim 16, wherein the plurality of transmission channels comprise a plurality of different symbols in an orthogonal frequency-division multiplexing scheme.
- [Claim 20] A generation method for generating a multi-dimensional constellation for a digital modulation scheme in a data communication system, the generation method comprising the steps of:
 receiving a plurality of vectors of a multi-dimensional vector space;
 and
 obtaining constellation points of the multi-dimensional constellation by applying an orthogonal transformation to the plurality of vectors received, wherein
 the orthogonal transformation is adapted for increasing a minimum number of different values in components of any two distinct multi-dimensional constellation points relative to a minimum number of different values in components of any two distinct vectors received, and the orthogonal transformation has an N-by-N matrix representation, N being a multiple of four, with absolute values of all elements on a main diagonal equal to a first value, and with absolute values of all elements

not on the main diagonal equal to a non-zero second value.

[Claim 21]

The generation method according to claim 20, wherein instead of the N-by-N matrix representation, the orthogonal transformation has a matrix representation obtained by permuting rows and/or columns in the N-by-N matrix representation.

[Claim 22]

The generation method according to claim 20, further comprising the steps of:

selecting a rotation factor r as a real number between 0 and 1;

calculating the first value, a , by evaluating an expression

$$a = \sqrt{1 - \frac{r(N-1)}{N}}$$

; calculating the second value, b , by evaluating an expression

$$b = \sqrt{\frac{r}{N}}$$

; and

determining the orthogonal transformation by selecting a sign value $s_{i,j}$ for each element (i, j) of a matrix representation

$$R = \begin{pmatrix} s_{1,1}a & s_{1,2}b & \cdots & s_{1,N}b \\ s_{2,1}b & s_{2,2}a & & \vdots \\ \vdots & & \ddots & s_{N-1,N}b \\ s_{N,1}b & \cdots & s_{N,N-1}b & s_{N,N}a \end{pmatrix}$$

, such that the matrix representation is orthogonal.

[Claim 23]

The generation method according to claim 22, wherein the selected rotation factor r maximizes the minimum number of different values in the components of any two distinct multi-dimensional constellation points.

[Claim 24]

The generation method according to claim 20, wherein

the plurality of vectors received represent a subset of

$$\mathbb{Z}^N$$

, which is an N-dimensional integer lattice.