CLAIMS

1. A precoding method for generating, from a plurality of baseband signals, a plurality of precoded signals that are transmitted in the same frequency bandwidth at the same time, the precoding method comprising the steps of:

selecting one matrix from among 2N matrices F[i], wherein i = 0, 1, 2, …, 2N-2, 2N-1, by hopping between the matrices, the 2N matrices F[i] defining a precoding process that is performed on the plurality of baseband signals;

multiplying "u" by a first baseband signal s1 generated from a first set of bits, multiplying "v" by a second baseband signal s2 generated from a second set of bits, "u" and "v" denoting real numbers different from each other; and

generating a first precoded signal z1 and a second precoded signal z2 by performing a precoding process, which corresponds to a matrix selected from among the 2N matrices F[i], on a signal obtained by multiplying "u" by the first baseband signal s1 and a signal obtained by multiplying "v" by the second baseband signal s2,

the first precoded signal z1 and the second precoded signal z2 satisfying $(z1, z2)^T = F[i]\,(u \times s1, v \times s2)^T$,

for i = 0, 1, 2, …, N-2, N-1, the 2N matrices F[i] being expressed as:

Math 1

Equation 279

$$F[i]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j\theta_{11}(i)} & \alpha\times e^{j(\theta_{11}(i)+\lambda)} \\ \alpha\times e^{j\theta_{21}(i)} & e^{j(\theta_{21}(i)+\lambda+\pi)} \end{pmatrix}$$

for i = N, N+1, N+2, …, 2N-2, 2N-1, the 2N matrices F[i] being expressed as:

Math 2

Equation 280

$$F[i]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix}\alpha\times e^{j\theta_{11}(i)} & e^{j(\theta_{11}(i)+\lambda)}\\ e^{j\theta_{21}(i)} & \alpha\times e^{j(\theta_{21}(i)+\lambda+\pi)}\end{pmatrix}$$

λ representing an arbitrary angle, α representing a positive real number excluding 1, $\theta_{11}(i)$ and $\theta_{21}(i)$ satisfying:

Math 3

Condition #57

$$e^{j(\theta_{11}(x)-\theta_{21}(x))}\neq e^{j(\theta_{11}(y)-\theta_{21}(y))} \quad \text{for } \forall x, \forall y\ (x\neq y; x, y=0,1,2,\cdots,N-2,N-1)$$

and

Math 4

Condition #62

$$e^{j(\theta_{11}(x)-\theta_{21}(x))}\neq e^{j(\theta_{11}(y)-\theta_{21}(y))} \quad \text{for } \forall x, \forall y\ (x\neq y; x, y=N,N+1,N+2,\cdots,2N-2,2N-1)$$

each of the 2N matrices being selected at least once in a predetermined time period.

2. A precoding apparatus for generating, from a plurality of baseband signals, a plurality of precoded signals that are transmitted in the same frequency bandwidth at the same time, the precoding apparatus comprising:

a weighting information generating unit selecting one matrix from among 2N matrices F[i], wherein i = 0, 1, 2, ..., 2N-2, 2N-1, by hopping between the matrices, the 2N matrices F[i] defining a precoding process that is performed on the plurality of baseband signals;

a power changing unit multiplying "u" by a first baseband signal s1 generated from a first set of bits, multiplying "v" by a second baseband signal s2 generated from a second set of bits, "u" and "v" denoting real numbers different from each other; and

a weighting unit generating a first precoded signal z1 and a second precoded signal z2 by performing a precoding process, which corresponds to a matrix selected

from among the 2N matrices F[i], on a signal obtained by multiplying "u" by the first baseband signal s1 and a signal obtained by multiplying "v" by the second baseband signal s2,

the first precoded signal z1 and the second precoded signal z2 satisfying $(z1, z2)^T = F[i]\,(u \times s1, v \times s2)^T$,

for i = 0, 1, 2, …, N-2, N-1, the 2N matrices F[i] being expressed as:

Math 5

Equation 279

$$F[i]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j\theta_{11}(i)} & \alpha\times e^{j(\theta_{11}(i)+\lambda)} \\ \alpha\times e^{j\theta_{21}(i)} & e^{j(\theta_{21}(i)+\lambda+\pi)} \end{pmatrix}$$

for i = N, N+1, N+2, …, 2N-2, 2N-1, the 2N matrices F[i] being expressed as:

Math 6

Equation 280

$$F[i]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} \alpha\times e^{j\theta_{11}(i)} & e^{j(\theta_{11}(i)+\lambda)} \\ e^{j\theta_{21}(i)} & \alpha\times e^{j(\theta_{21}(i)+\lambda+\pi)} \end{pmatrix}$$

λ representing an arbitrary angle, α representing a positive real number excluding 1, $\theta_{11}(i)$ and $\theta_{21}(i)$ satisfying:

Math 7

Condition #57

$$e^{j(\theta_{11}(x)-\theta_{21}(x))} \neq e^{j(\theta_{11}(y)-\theta_{21}(y))} \quad \text{for } \forall x, \forall y\ (x \neq y; x, y = 0,1,2,\cdots,N-2,N-1)$$

and

Math 8

Condition #62

$$e^{j(\theta_{11}(x)-\theta_{21}(x))} \neq e^{j(\theta_{11}(y)-\theta_{21}(y))} \quad \text{for } \forall x, \forall y\ (x \neq y; x, y = N,N+1,N+2,\cdots,2N-2,2N-1)$$

each of the 2N matrices being selected at least once in a predetermined time period.

CLAIMS

1. A transmission method comprising:

selecting one matrix from among N matrices F[i] for each of a plurality of slots by hopping between the N matrices, wherein N is an integer 9 and index i indicates an integer no less than 0 and no more than 8, the N matrices F[i] defining a precoding process that is performed on a plurality of modulated signals;

generating a first transmission signal z1 and a second transmission signal z2 for each of the plurality of slots by performing a precoding process, which corresponds to the matrix selected from among the N matrices F[i], on a first modulated signal s1 generated from a first set of bits and a second modulated signal s2 generated from a second set of bits; and

transmitting the first transmission signal z1 and the second transmission signal z2 from a first antenna and a second antenna, respectively, at a same time and by using a same frequency,

the first transmission signal z1 and the second transmission signal z2 satisfying $(z1, z2)^T = F[i]\,(s1, s2)^T$, and

the N matrices F[i] being expressed by the following equations:

$$F[i=0]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j0} & e^{j\pi} \end{pmatrix},$$

$$F[i=1]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{2}{9}\pi} & e^{j\left(\frac{2}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=2]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{4}{9}\pi} & e^{j\left(\frac{4}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=3]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{6}{9}\pi} & e^{j\left(\frac{6}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=4]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{8}{9}\pi} & e^{j\left(\frac{8}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=5]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{10}{9}\pi} & e^{j\left(\frac{10}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=6]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{12}{9}\pi} & e^{j\left(\frac{12}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=7]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{14}{9}\pi} & e^{j\left(\frac{14}{9}\pi+\pi\right)} \end{pmatrix}, \text{ and}$$

$$F[i=8]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{16}{9}\pi} & e^{j\left(\frac{16}{9}\pi+\pi\right)} \end{pmatrix},$$

wherein α is a positive real number.

2. A transmission apparatus comprising:

a weighting information generating unit selecting one matrix from among N matrices F[i] for each of a plurality of slots by hopping between the N matrices, wherein N is an integer 9 and index i indicates an integer no less than 0 and no more than 8, the N matrices F[i] defining a precoding process that is performed on a plurality of modulated signals;

a weighting unit generating a first transmission signal z1 and a second transmission signal z2 for each of the plurality of slots by performing a precoding process, which corresponds to the matrix selected from among the N matrices F[i], on a first modulated signal s1 generated from a first set of bits and a second modulated signal s2 generated from a second set of bits; and

a transmission unit transmitting the first transmission signal z1 and the second transmission signal z2 from a first antenna and a second antenna, respectively, at a same time and by using a same frequency,

the first transmission signal z1 and the second transmission signal z2 satisfying $(z1, z2)^T = F[i] (s1, s2)^T$, and

the N matrices F[i] being expressed by the following equations:

$$F[i=0]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j0} & e^{j\pi} \end{pmatrix},$$

$$F[i=1]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{2}{9}\pi} & e^{j\left(\frac{2}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=2]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{4}{9}\pi} & e^{j\left(\frac{4}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=3]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{6}{9}\pi} & e^{j\left(\frac{6}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=4]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{8}{9}\pi} & e^{j\left(\frac{8}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=5]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{10}{9}\pi} & e^{j\left(\frac{10}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=6]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{12}{9}\pi} & e^{j\left(\frac{12}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=7]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{14}{9}\pi} & e^{j\left(\frac{14}{9}\pi+\pi\right)} \end{pmatrix}, \text{ and}$$

$$F[i=8]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{16}{9}\pi} & e^{j\left(\frac{16}{9}\pi+\pi\right)} \end{pmatrix},$$

wherein α is a positive real number.

3. A reception method comprising:

acquiring one or more reception signals each obtained by receiving a first transmission signal and a second transmission signal respectively transmitted from a first antenna and a second antenna at a same time and by using a same frequency, the first transmission signal and the second transmission signal being generated through predetermined generation processing; and

generating reception data by performing demodulation processing on the acquired reception signals,

the predetermined generation processing involving:

selecting one matrix from among N matrices F[i] for each of a plurality of slots by hopping between the N matrices, wherein N is an integer 9 and index i indicates an integer no less than 0 and no more than 8, the N matrices F[i] defining a precoding process that is performed on a plurality of modulated signals; and

generating a first transmission signal z1 and a second signal z2 for each of the plurality of slots by performing a precoding process, which corresponds to the matrix selected from among the N matrices F[i], on a first modulated signal s1 generated from a first set of bits and a second modulated signal s2 generated from a second set of bits,

the first transmission signal z1 and the second transmission signal z2 satisfying $(z1, z2)^T = F[i] (s1, s2)^T$, and

the N matrices F[i] being expressed by the following equations:

$$F[i=0]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j0} & e^{j\pi} \end{pmatrix},$$

$$F[i=1]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{2}{9}\pi} & e^{j\left(\frac{2}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=2]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{4}{9}\pi} & e^{j\left(\frac{4}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=3]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{6}{9}\pi} & e^{j\left(\frac{6}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=4]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{8}{9}\pi} & e^{j\left(\frac{8}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=5]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{10}{9}\pi} & e^{j\left(\frac{10}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=6]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{12}{9}\pi} & e^{j\left(\frac{12}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=7]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{14}{9}\pi} & e^{j\left(\frac{14}{9}\pi+\pi\right)} \end{pmatrix}, \text{ and}$$

$$F[i=8]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{16}{9}\pi} & e^{j\left(\frac{16}{9}\pi+\pi\right)} \end{pmatrix},$$

wherein α is a positive real number.

4. A reception apparatus comprising:

an acquiring unit acquiring one or more reception signals each obtained by receiving a first transmission signal and a second transmission signal respectively transmitted from a first antenna and a second antenna at a same time and by using a same frequency, the first transmission signal and the second transmission signal being generated through predetermined generation processing; and

a generating unit generating reception data by performing demodulation processing on the acquired reception signals,

the predetermined generation processing involving:

selecting one matrix from among N matrices F[i] for each of a plurality of slots by hopping between the N matrices, wherein N is an integer 9 and index i indicates an integer no less than 0 and no more than 8, the N matrices F[i] defining a precoding process that is performed on a plurality of modulated signals; and

generating a first transmission signal z1 and a second signal z2 for each of the plurality of slots by performing a precoding process, which corresponds to the matrix selected from among the N matrices F[i], on a first modulated signal s1 generated from a first set of bits and a second modulated signal s2 generated from a second set of bits,

the first transmission signal z1 and the second transmission signal z2 satisfying $(z1, z2)^T = F[i]\,(s1, s2)^T$, and

the N matrices F[i] being expressed by the following equations:

$$F[i=0]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j0} & e^{j\pi} \end{pmatrix},$$

$$F[i=1]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{2}{9}\pi} & e^{j\left(\frac{2}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=2]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{4}{9}\pi} & e^{j\left(\frac{4}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=3]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{6}{9}\pi} & e^{j\left(\frac{6}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=4]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{8}{9}\pi} & e^{j\left(\frac{8}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=5]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{10}{9}\pi} & e^{j\left(\frac{10}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=6]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{12}{9}\pi} & e^{j\left(\frac{12}{9}\pi+\pi\right)} \end{pmatrix},$$

$$F[i=7]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{14}{9}\pi} & e^{j\left(\frac{14}{9}\pi+\pi\right)} \end{pmatrix}, \text{ and}$$

$$F[i=8]=\frac{1}{\sqrt{\alpha^2+1}}\begin{pmatrix} e^{j0} & \alpha\times e^{j0} \\ \alpha\times e^{j\frac{16}{9}\pi} & e^{j\left(\frac{16}{9}\pi+\pi\right)} \end{pmatrix},$$

wherein α is a positive real number.