

(43) International Publication Date  
10 June 2010 (10.06.2010)

PCT

(10) International Publication Number  
**WO 2010/064804 A2**

## (51) International Patent Classification:

*H04B 7/04* (2006.01) *H04W 52/34* (2009.01)  
*H04L 25/03* (2006.01)

## (21) International Application Number:

PCT/KR2009/006932

## (22) International Filing Date:

24 November 2009 (24.11.2009)

## (25) Filing Language:

English

## (26) Publication Language:

English

## (30) Priority Data:

10-2008-0122741 4 December 2008 (04.12.2008) KR  
10-2009-0081445 31 August 2009 (31.08.2009) KR(71) Applicants (for all designated States except US): **ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE** [KR/KR]; 161, Gajeong-dong, Yuseong-gu, Daejeon 305-350 (KR). **SAMSUNG ELECTRONICS CO., LTD.** [KR/KR]; 416, Maetan-dong, Yeongtong-gu, Suwon-si, Gyeonggi-do 442-742 (KR).

## (72) Inventors; and

(75) Inventors/Applicants (for US only): **SONG, Young Seog** [KR/KR]; 305-602, Songrim-maeul 3-danji Apt., Hagidong, Yuseong-gu, Daejeon 305-759 (KR). **YEH, Choongil** [KR/KR]; 101-502, Mugunghwa Apt.,Wolpyeong-dong, Seo-gu, Daejeon 302-280 (KR). **KWON, Dong Seung** [KR/KR]; 204-1304, Expo Apt., Jeonmin-dong, Yuseong-gu, Daejeon 305-390 (KR). **SEO, Min Sik** [KR/KR]; 816-303, Saemirae Apt., 520-1, Noeun-dong, Yuseong-gu, Daejeon 305-325 (KR). **KIM, Joondoo** [KR/KR]; 309-1103, Hyoseong Whantville Apt., Gongneung 2-dong, Nowon-gu, Seoul 139-853 (KR). **KANG, Jiwon** [KR/KR]; 2409-1101, Lotte Castle Apt., Guwol 2-dong, Namdong-gu, Incheon 405-734 (KR). **LEE, Chungyong** [KR/KR]; 104-1803, Yuwon Apt., Seocho-dong, Seocho-gu, Seoul 137-070 (KR).(74) Agent: **YOU ME PATENT AND LAW FIRM**; Seolim Bldg., 649-10, Yoksam-dong, Kangnam-ku, Seoul 135-080 (KR).

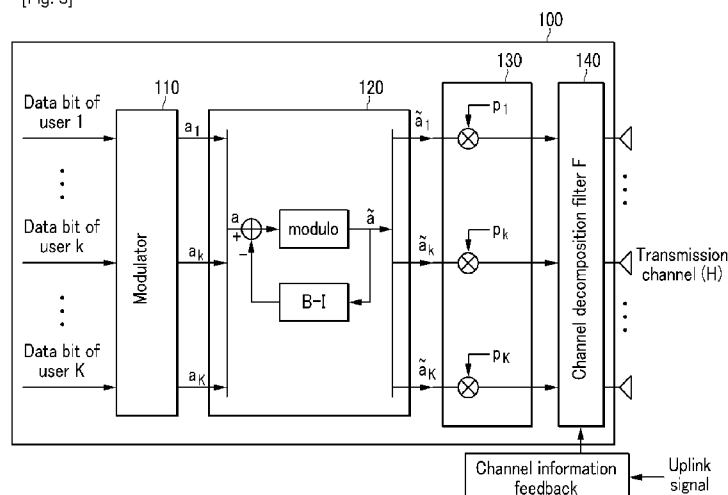
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

[Continued on next page]

(54) Title: TRANSMITTING APPARATUS IN MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM

[Fig. 3]



(57) Abstract: Provided are a transmitting apparatus and a transmitting method in a multiple input multiple output system. A power allocation controller includes a block Tomlinson-Harashima precoder (BTHP) that precodes and outputs data to be transmitted to each user in a nonlinear scheme. The BTHP removes and outputs inference signals from data for each user based on the channel information that is fed back from the users. The data for each user output from the BTHP are allocated with power by the power allocation controller. The power allocation controller calculates power allocation parameters so that receiving minimum distances at receiving ends for each user that receive data through the MIMO antennas are the same, and allocates the calculated parameters to data for each user.



GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

## Description

### Title of Invention: TRANSMITTING APPARATUS IN MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM

#### Technical Field

- [1] The present invention relates to a multiple input multiple output (hereinafter, referred to as "MIMO") system in multiple-user environments, and in particular, to a transmitting apparatus and a transmitting method using a block Tomlinson-Harashima precoder (hereinafter, referred to as "BTHP") to remove interference caused due to multiple users in a multiple input multiple output system.

#### Background Art

- [2] A basic development direction of portable Internet should be focused on faster data communication. Since it is difficult to further improve the portable Internet through a frequency bandwidth that is already nearing semi-saturation, a MIMO mechanism, which increases frequency efficiency using spatial division, will be used as a main mechanism in next-generation mobile communication.
- [3] A mobile communication system using the MIMO mechanism transmits data through independent channels that are formed among MIMO antennas of transmitting and receiving ends, thereby making it possible to obtain a data transmission rate that is higher than a system using a single antenna.
- [4] In the MIMO system, assuming that the transmitting end or the receiving end knows the information of the channels, the interference signals can be removed by a proper detection mechanism or a precoding mechanism.
- [5] The MIMO system can be applied to a cellular system that simultaneously supports multiple users. At this time, since cooperation communication between terminals cannot be generally performed, a base station transmits data to not cause inter-user interference using the precoding mechanism in a downlink.
- [6] In the MIMO system supporting multiple users, the mechanism to remove the inter-user interference depends on a dirty paper coding mechanism. The paper coding mechanism can completely remove the inter-user interference without losing transmittable data, but cannot be realistically implemented due to its complexity. Therefore, as an actual mechanism applied to remove the inter-user interference, a simplified nonlinear mechanism such as the Tomlinson Harashima precoder (THP) or a linear mechanism such as block diagonalization has been used.
- [7] The block diagonalization mechanism is relatively simple and shows good error performance, but has a drawback of a large loss of channel capacity as the number of users that are simultaneously supported increases. However, the THP mechanism has

an advantage in that the loss of channel capacity is small even though the number of users increases, but has a disadvantage in that the system complexity is large and the error performance is degraded when there are a relatively small number of users.

[8] Examples of mechanisms to improve the above-mentioned disadvantages of the block diagonalization or the THP may include a BTHP mechanism to remove the inter-user interference and a maximum likelihood (ML) receiving mechanism designed to be suitable therefore so as to improve the error performance of the THP using the MIMO antennas of the user.

[9] The BTHP mechanism using the ML shows excellent error performance as compared to the existing THP mechanism, but still has a disadvantage in that the error performance is degraded as compared to the block diagonalization mechanism using the ML.

[10] Therefore, a need exists for an additional optimization mechanism in order to further improve the error performance of the BTHP mechanism using the ML.

[11] The above information disclosed in this Background section is only for enhancement of understanding of the background of the invention and therefore it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

## **Disclosure of Invention**

### **Technical Problem**

[12] The present invention has been made in an effort to provide a transmitting apparatus and a transmitting method in a multiple input multiple output system to prevent error performance of a MIMO system using a BTHP mechanism using ML from being degraded as compared to a system using a block diagonalization mechanism using ML.

### **Solution to Problem**

[13] In order to achieve the above objects, a transmitting apparatus in a multiple input multiple output system according to an exemplary embodiment of the present invention includes:

[14] a precoder that precodes data to be transmitted to each user in a nonlinear scheme and outputs the pre-coded data; a power allocation controller that allocates and outputs power to data for each user output from the precoder; and a channel decomposition filter that obtains filter values decomposing the channels of the system in a triangular form, multiplies them by data for each user output from the power allocation controller, and then outputs them to the MIMO antennas, wherein the power allocation controller calculates power allocation parameters so that receiving minimum distances at receiving ends for each user that receives data through the MIMO antennas are the same, and allocates the calculated parameters to data for each user.

- [15] A transmitting method in a multiple input multiple output system according to another exemplary embodiment of the present invention includes:
- [16] precoding data to be transmitted to each user in a nonlinear scheme; allocating and outputting power to each precoded data for each user; and obtaining filter values decomposing the channels of the system in a triangular form, multiplying the obtained filter values by the data for each user allocated with power, and then outputting them to the MIMO antennas, wherein the allocating and outputting the power calculates power allocation parameters so that receiving minimum distances at receiving ends for each user that receives data through the MIMO antennas are the same, and allocates the calculated parameters to data for each user.

### **Advantageous Effects of Invention**

- [17] With the present invention, when the BTHP and ML receiving mechanisms are used in the MIMO system in the multiple-user environments, it similarly controls the error performance of all the users according to power allocated to data for each user, making it possible to improve the average error performance of the system.

### **Brief Description of Drawings**

- [18] FIG. 1 is a schematic block diagram of a MIMO system in general multiple-user environments.
- [19] FIG. 2 is a detailed block diagram of a case where a base station shown in FIG. 1 uses a BTHP mechanism.
- [20] FIG. 3 is a block diagram of a transmitting apparatus in a MIMO system in multiple-user environments according to an embodiment of the present invention.
- [21] FIG. 4 is a diagram showing a system average BER graph according to an embodiment of the present invention in the case where a base station has six transmission antennas and three users each have two receiving antennas.
- [22] FIG. 5 is a diagram showing a system average BER graph according to an embodiment of the present invention in the case where the base station has twenty transmitting antennas and ten users each have two receiving antennas.

### **Mode for the Invention**

- [23] In the following detailed description, only certain exemplary embodiments of the present invention have been shown and described, simply by way of illustration. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention. Accordingly, the drawings and description are to be regarded as illustrative in nature and not restrictive. Like reference numerals designate like elements throughout the specification.
- [24] In the specification, unless explicitly described to the contrary, the word "comprise"

and variations such as "comprises" or "comprising" will be understood to imply the inclusion of stated elements but not the exclusion of any other elements.

- [25] In the specification, a receiving end may designate a receiving station, a mobile terminal (MT), a mobile station (MS), a terminal, a subscriber station (SS), a portable subscriber station (PSS), user equipment (UE), an access terminal (AT), etc., and may include the entire or partial functions of the mobile terminal, the subscriber station, the portable subscriber station, the user equipment, etc.
- [26] In the specification, a transmitting end may designate a base station (BS), an access point (AP), a radio access station (RAS), a node B, a base transceiver station (BTS), a mobile multihop relay (MMR)-BS, etc., and may include the entire or partial functions of the AP, the RAS, the node B, the BTS, the MMR-BS, etc.
- [27] First, a MIMO system in general multiple-user environments will be described.
- [28] FIG. 1 is a schematic block diagram of a MIMO system in general multiple-user environments.
- [29] As shown in FIG. 1, the MIMO system is configured to include a base station 10 having  $N_T$  transmitting antennas and  $K$  users 20-1, ..., 20-k, ..., 20-K each including  $N_{Rk}$  receiving antennas. Herein,  $K$  users means  $K$  receiving ends or mobile stations.
- [30] That is, the base station 10 in the MIMO system transmits data to  $K$  users 20-1, ..., 20-k, ..., 20-K through  $N_T$  transmitting antennas, and  $K$  users 20-1, ..., 20-k, ..., 20-K each demodulate data received through  $N_{Rk}$  receiving antennas and use the demodulated data.
- [31] FIG. 2 is a detailed block diagram of a case where a base station 10 shown in FIG. 1 uses a BTHP mechanism.
- [32] Herein,  $K$  users 20-1, ..., 20-k, ..., 20-K have a different number of receiving antennas but have the same configuration. Therefore, only the configuration of the user  $K$  20-k will be illustrated and described.
- [33] As shown in FIG. 2, the base station 10, which is a transmitting end, modulates data bits to be transmitted to each user (20-1, ..., 20-k, ..., 20-K) into a transmission symbol by using a modulator 11, and then removes interference signals using a BTHP 12 based on channel information that is fed back from each user 20-1, ..., 20-k, ..., 20-K.
- [34] At this time, when removing inter-user interference signals using the BTHP 12 in the MIMO system in the multiple-user environments, a channel decomposition filter 13 obtains a filter  $F$ , which decomposes all the system channels into a triangular form, to be matched with the number of antennas by using a block QR (BQR) mechanism that is a generalized QR mechanism, and multiplies it by the output of the BTHP 12 and transmits it, such that each user 20-1, ..., 20-k, ..., 20-K receives data through a

subchannel existing in a diagonal of the channel matrix without the interference signals.

- [35] K users 20-1, ..., 20-k, ..., 20-K each obtains the received signals. That is, a MIMO receiver 21 recovers the received signals based on the effective channel information of each user with an ML receiver method and a demodulator 22 demodulates them to generate the transmission data bits, making it possible to obtain excellent error performance.
- [36] The MIMO system according to the BTHP mechanism using the above-mentioned ML can simultaneously obtain a spatial division gain and a diversity gain as compared to the case when the user using the existing THP-based systems does not obtain the spatial diversity gain due to the MIMO antennas.
- [37] However, the MIMO system has disadvantages in that the quality of the channel occupied by each user is different according to the characteristics of the BQR mechanism, and the error performance is still degraded as compared to the block diagonalization method using the ML.
- [38] Therefore, in order to further improve the error performance of the MIMO system according to the BTHP mechanism using the ML, additional optimization mechanisms are needed.
- [39] Hereinafter, a transmitting apparatus in the MIMO system in the multiple-user environments according to an exemplary embodiment of the present invention will be described in detail with reference to the accompanying drawings.
- [40] FIG. 3 is a block diagram of a transmitting apparatus in a MIMO system in multiple-user environments according to an embodiment of the present invention.
- [41] As shown in FIG. 3, a base station 100, which is a transmitting apparatus in a MIMO system according to an exemplary embodiment of the present invention, includes a modulator 110, a precoder 120 that is a BTHP, a power allocation controller 130, and a channel decomposition filter 140.
- [42] The modulator 110 modulates data bits for each user to be transmitted to mobile stations of K users according to predetermined modulation schemes, and outputs them. At this time, the modulator 110 can perform adaptation modulation that selects the modulation scheme according to the channel information that is fed back from the mobile station.
- [43] The precoder 120 precodes data output from the modulator 110, and outputs them. At this time, the precoder 120 removes and outputs the reference signals by the BTHP mechanism based on the channel information that is fed back from the mobile station of the K users for data output from the modulator 110. Herein, the precoder 120 uses the BTHP that is well known to those skilled in the art, and therefore a detailed description of the BTHP will be omitted.

- [44] The power allocation controller 130 allocates power allocation parameters to data for each user output from the precoder 120, and multiplies and outputs the allocated power allocation parameters by data for each user.
- [45] The channel decomposition filter 140 obtains a filter  $F$  that decomposes a system channel into a block triangular form, multiplies it by each data for each user output from the power allocation controller 130, and outputs it to  $N_T$  transmitting antennas. Herein, the channel decomposition filter 140 obtains the filter  $F$  by decomposing the system channel into a block triangular form using the BQR mechanism, which is well known to a person of ordinary skill in the art and therefore a detailed description thereof will be omitted.
- [46] Hereinafter, a scheme in which the power allocation controller 130 calculates the power allocation parameters allocated to data for each user that is output from the precoder 120 will be described.
- [47] First, in the following description, it is assumed that the base station 100, which is a transmitting apparatus, can accurately estimate downlink channel information of users through uplink sounding signals, channel information feedback, etc., received from users that are positioned at service areas.
- [48] For convenience of explanation, it is assumed that each user has the same number (eg.  $N_{Rk}$ ) of receiving antennas, and that the base station 100, which is the transmitting apparatus, uses the same modulation scheme.
- [49] First, all the channel matrices
- $$\mathbf{H} = \begin{bmatrix} \mathbf{H}_1^T & \mathbf{H}_2^T & \cdots & \mathbf{H}_K^T \end{bmatrix}^T$$
- of the system are QR-decomposed according to the following Equation 1.
- [50] [Equation 1]
- [51]  $\mathbf{H}^H = \mathbf{Q}\mathbf{R}$
- [52] Then,  $\mathbf{Q}$  becomes a base vector obtained by sequentially orthogonalizing spaces formed by row vectors of the channel matrices, and  $\mathbf{R}$  is a triangular matrix.
- [53] Next, the base vectors in each vector space are randomly rotated through a unitary matrix  $\mathbf{T}_k$  according to the number of user antennas in order to obtain the gain of the ML mechanism applied to the receiving end. Then, the  $k$ -th precoding matrix of the user is formed as a product of a nulling matrix and a rotating matrix, such as  $\mathbf{F}_k = \mathbf{Q}_k \mathbf{T}_k$ .
- [54] Next, when considering the user power allocation parameters  $P_k$ , the effective channels observed by the BTHP 110 in order to remove inter-user interference become  $P_k \mathbf{H}_k \mathbf{F}_k$ . At this time, a sum of the power amount

$$P_k^2$$

allocated to each user is equal to  $KN_R$ .

- [55] When the symbol vector obtained by modulating data to be transmitted to each user, that is, the symbol vector output from the modulator 110, is

$$\mathbf{a} = \begin{bmatrix} \mathbf{a}_1^T & \mathbf{a}_2^T & \cdots & \mathbf{a}_K^T \end{bmatrix}^T$$

, a signal vector

$$\tilde{\mathbf{a}}_k$$

output from the BTHP 120 for the k-th user is defined by Equation 2.

- [56] [Equation 2]

$$\tilde{\mathbf{a}}_k = \mathbf{a}_k - (p_k \mathbf{H}_k \mathbf{F}_k)^{-1} \sum_{j=1}^{k-1} p_j \mathbf{H}_k \mathbf{F}_j \tilde{\mathbf{a}}_j + \mathbf{d}_k, \quad \tilde{\mathbf{a}}_1 = \mathbf{a}_1$$

- [58] Herein,  $\mathbf{d}_k$  represents a sign vector that is added by a modulo operation.

- [59] When the output vector

$$\tilde{\mathbf{a}}$$

of the BTHP 120 that is defined depending on Equation 2 is multiplied by the channel decomposition filter F, which passes through the channel, each user receives signals in a form of which all the inter-user interferences are removed and can use the ML receiving mechanism based on the information of the corresponding effective channel  $P_k H_k F_k$ .

- [60] The signal vector received at the receiving end depends on Equation 3.

- [61] [Equation 3]

$$\begin{aligned} \mathbf{r}_k &= \sum_{j=1}^k p_j \mathbf{H}_k \mathbf{F}_j \tilde{\mathbf{a}}_j + \mathbf{n}_k \\ &= p_k \mathbf{H}_k \mathbf{F}_k \left( \mathbf{a}_k - (p_k \mathbf{H}_k \mathbf{F}_k)^{-1} \sum_{j=1}^{k-1} p_j \mathbf{H}_k \mathbf{F}_j \tilde{\mathbf{a}}_j + \mathbf{d}_k \right) - \sum_{j=1}^{k-1} p_j \mathbf{H}_k \mathbf{F}_j \tilde{\mathbf{a}}_j + \mathbf{n}_k \\ &= p_k \mathbf{H}_k \mathbf{F}_k (\mathbf{a}_k + \mathbf{d}_k) + \mathbf{n}_k \end{aligned}$$

- [63] Herein,  $\mathbf{n}_k$  represents a noise vector at a user k side.

- [64] Assuming a sufficiently high signal-to-noise ratio, it can be assumed that the influence  $\mathbf{d}_k$  of the modulo operation can be completely removed in Equation 3. Therefore, it can be estimated that each user observes independent MIMO channels. At this time, the bit error rates (BERs) for the given effective channels  $P_k H_k F_k$  is approximated depending on Equation 4.

- [65] [Equation 4]

[66]

$$P_{e|p_k \mathbf{H}_k \mathbf{F}_k} \approx \text{NeQ} \left( \frac{d_{\min,k}}{2\sqrt{N_0/2}} \right)$$

[67]

Herein, Ne is an average value of the number of nearest symbols, and

$$d_{\min,k} = \min_{\mathbf{a}_1, \mathbf{a}_2 \in S, \mathbf{a}_1 \neq \mathbf{a}_2} \left\| p_k \mathbf{H}_k \mathbf{F}_k (\mathbf{a}_1 - \mathbf{a}_2) \right\|$$

is a minimum receive distance.

[68]

Assuming that the same amount of data is transmitted to all users, the average BER performance of the system may be represented by the arithmetic mean of each user BER, and is defined by the geometric mean of each user BER as represented in Equation 5.

[69]

[Equation 5]

[70]

$$\frac{1}{K} \sum_{k=1}^K P_{e|p_k \mathbf{H}_k \mathbf{F}_k} \geq \left( \prod_{k=1}^K P_{e|p_k \mathbf{H}_k \mathbf{F}_k} \right)^{\frac{1}{K}}$$

[71]

Herein, an equal sign is established when BERs of all users are the same.

[72]

In Equation 4, since Ne is constant and Qfunction is a monolithic function for  $d_{\min,k}$ , power is allocated so that the receiving minimum distances of each user are the same as in Equation 6, thereby making it possible to maximize the error performance of the system.

[73]

[Equation 6]

[74]

$$\min_{\mathbf{a}_1, \mathbf{a}_2 \in S, \mathbf{a}_1 \neq \mathbf{a}_2} \left\| p_1 \mathbf{H}_1 \mathbf{F}_1 (\mathbf{a}_1 - \mathbf{a}_2) \right\| = \dots = \min_{\mathbf{a}_1, \mathbf{a}_2 \in S, \mathbf{a}_1 \neq \mathbf{a}_2} \left\| p_K \mathbf{H}_K \mathbf{F}_K (\mathbf{a}_1 - \mathbf{a}_2) \right\|$$

[75]

However, it is very complex to determine the power allocation parameter  $P_k$  satisfying Equation 6. This is because distances for all possible sets of two different transmission symbol vectors should be calculated in order to determine the receiving minimum distances of each user.

[76]

Therefore, in order to substantially determine the power allocation parameter, approximate values of the receiving minimum distances are used.

[77]

As is generally known, when the channels are given, the receiving minimum distances have singular values for the channel matrices as a lower boundary. Therefore, results such as Equation 6 can be obtained by the power allocation mechanism

depending on Equation 7.

[78] [Equation 7]

[79]

$$p_1 \lambda_{\min}(\mathbf{H}_1 \mathbf{F}_1) = \cdots = p_K \lambda_{\min}(\mathbf{H}_K \mathbf{F}_K)$$

[80] In addition to the above-mentioned singular value, the receiving minimum distances are approximated by the geometric mean of singular values of the given channel matrices, which are equal to  $N_R$  square root of determinants of the channel matrices.

[81] Using the determinants of the channel matrices can simplify the calculation since there is no need to perform the singular value decomposition (SVD) for the channel matrices in order to obtain the singular values of the channel matrices.

[82] In this way, the results as represented in Equation 6 can be likewise obtained by the power allocation mechanism depending on Equation 8.

[83] [Equation 8]

[84]

$$p_1 \sqrt[N_R]{\det(\mathbf{H}_1 \mathbf{F}_1)} = \cdots = p_K \sqrt[N_R]{\det(\mathbf{H}_K \mathbf{F}_K)}$$

[85] Therefore, the power allocation controller 130 calculates the power allocation parameters  $P_k$ , which are each allocated to data for each user output from the precoder 120, to have the values for making the receiving minimum distances of each user same as represented in Equation 6, respectively, and allocates them to data for each user, thereby making it possible to maximize the error performance of the MIMO system according to the embodiment of the present invention.

[86] In detail, the power allocation controller 130 can be implemented to allocate the power allocation parameters to data for each user so that all values obtained by multiplying the singular values of the channel matrices for each user by the power allocation parameters allocated to each user are the same as represented in Equation 7.

[87] To this end, the power allocation controller 130 obtains the singular values of the channel matrix for each user and calculates the power allocation parameters so that the values obtained by multiplying the singular values for each user by the power allocation parameters to be allocated to each user are the same.

[88] Therefore, the power allocation controller 130 allocates the power allocation parameters satisfied with Equation 7 to data for each user, multiplies them by data for each user, and outputs them to the channel decomposition filter 140.

[89] In this way, the same effect as Equation 6 is generated, such that the error performance of the MIMO system according to an exemplary embodiment of the present invention can be maximized.

- [90] As another method, the power allocation controller 130 can be implemented to allocate the power allocation parameters to data for each user so that all the values obtained by multiplying the  $N_R$  square root of determinants of the channel matrices for each user by the power allocation parameters allocated to each user are the same as represented in Equation 8.
- [91] To this end, the power allocation controller 130 obtains the determinants of the channel matrices for each user and the  $N_R$  square root of the obtained determinants and then calculates the power allocation parameter so that all the values obtained by multiplying the  $N_R$  square root of the obtained determinants for each user by the power allocation parameters to be allocated to each user are the same.
- [92] Therefore, the power allocation controller 130 allocates the power allocation parameters as represented in Equation 8 to data for each user, multiplies them by data for each user, and outputs them to the channel decomposition filter 140.
- [93] In this way, the same effect as Equation 6 is generated, such that the error performance of the MIMO system according to an exemplary embodiment of the present invention can be maximized.
- [94] In addition to this, when there are schemes that enables the power allocation controller 130 in the base station 100 to easily obtain the values so that the receiving minimum distances of each user are the same, the power allocation parameters each corresponding to data for each user according to the corresponding schemes can be calculated and allocated.
- [95] Hereinafter, the performance of the transmitting apparatus in the MIMO system according to an exemplary embodiment of the present invention will be described with reference to FIGs. 4 and 5.
- [96] In order to compare and evaluate the performance of the transmitting apparatus according to an exemplary embodiment of the present invention with the performance of the transmitting apparatus according to the related art, a simulation was performed while changing the number of antennas and the number of users.
- [97] First, FIG. 4 shows the comparison results of the average BER performance of multiple users in the MIMO system according to the embodiment of the present invention with the block diagonalization scheme and the BTHP scheme to which power is not allocated according to the related art when a total number of transmitting antennas is 6, the number of users is 3, and the number of antennas of each user is 2.
- [98] In the following description, the horizontal axis represents the signal-to-noise ratio and the vertical axis represents the average BER of the system.
- [99] Each of the power allocation scheme 1 (scheme1) and the power allocation scheme 2 (scheme2) uses a mechanism of using the singular values of the channel matrices in Equation 7 and the mechanism of using the determinants of the channel matrices in

Equation 8.

- [100] In this case, the BTHP mechanism using the power allocation mechanism for each user according to an exemplary embodiment of the present invention shows excellent performance at a high signal-to-noise ratio as compared to the BTHP mechanism not using the power allocation mechanism for each user.
- [101] The block diagonalization mechanism according to the related art shows excellent performance at a low signal-to-noise ratio as compared to the BTHP mechanism using the power allocation mechanism for each user according to an exemplary embodiment of the present invention.
- [102] However, as is generally known, the block diagonalization mechanism has a problem of a larger loss of channel capacity as compared with the BTHP mechanism.
- [103] FIG. 5 shows the comparison results of the average BER performance of multiple users in the MIMO system according to the embodiment of the present invention with the block diagonalization scheme, and the BTHP scheme to which power is not allocated according to the related art when the total number of transmitting antennas is 20, the number of users is 10, and the number of antennas of each user is 2.
- [104] In this case, the BTHP mechanism using the power allocation mechanism for each user according to an exemplary embodiment of the present invention shows excellent performance at a high signal-to-noise ratio as compared to the BTHP mechanism not using the power allocation mechanism for each user, and also shows excellent performance at most signal-to-noise ratios as compared to the block diagonalization mechanism according to the related art.
- [105] Unlike FIG. 4, FIG. 5 shows that the performance of the power allocation schemes 1 and 2 have a significant differences. The scheme 1 has excellent performance but is relatively complicated in a process of calculating the parameters. On the other hand, the scheme 2 is simple in a process of calculating the parameters but has relatively poor characteristics in terms of performance.
- [106] While this invention has been described in connection with what is presently considered to be practical exemplary embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

## Claims

- [Claim 1] A transmitting apparatus in a multiple input multiple output system, comprising:  
a precoder that precodes data to be transmitted to each user in a nonlinear scheme and outputs the pre-coded data;  
a power allocation controller that allocates and outputs power to data for each user output from the precoder; and  
a channel decomposition filter that obtains filter values decomposing the channels of the system in a triangular form, multiplies them by data for each user output from the power allocation controller, and then outputs them to the MIMO antennas,  
wherein the power allocation controller calculates power allocation parameters so that receiving minimum distances at receiving ends for each user that receives data through the MIMO antennas, are the same, and allocates the calculated parameters to data for each user.
- [Claim 2] The transmitting apparatus of claim 1, wherein  
the power allocation controller multiplies power allocation parameters by data for each user output from the precoder and outputs them to a channel decomposition filter.
- [Claim 3] The transmitting apparatus of claim 1, wherein  
the power allocation controller calculates all the power allocation parameters so that all singular values of channel matrices determined for each user are the same; and allocates the calculated parameters.
- [Claim 4] The transmitting apparatus of claim 3, wherein  
the power allocation controller calculates the power allocation parameters so that the all values obtained by multiplying the singular values of the channel matrices for each user by the power allocation parameters allocated to data for each user are the same.
- [Claim 5] The transmitting apparatus of claim 1, wherein  
the power allocation controller calculates the power allocation parameters so that all specific square roots of determinants of the channel matrices for each user are the same and allocates the calculated parameters, the specific square root being a square root based on the number of receiving antennas for each user.
- [Claim 6] The transmitting apparatus of claim 5, wherein  
the power allocation controller calculates the power allocation parameters so that all the values obtained by multiplying the specific

square roots of determinants of the channel matrices for each user by the power allocation parameters allocated to data for each user are the same.

[Claim 7] The transmitting apparatus of claim 1, wherein the precoder is a block Tomlinson-Harashima precoder (BTHP) that removes and outputs interference signals from data for each user based on channel information that is fed back from the users.

[Claim 8] The transmitting apparatus of claim 7, further comprising a modulator that modulates the data for each user according to the channel information that is fed back from the users, and outputs them to the precoder.

[Claim 9] A method for transmitting data for each user in a multiple input multiple output system, comprising:  
precoding data to be transmitted to each user in a nonlinear scheme;  
allocating and outputting power to each precoded data for each user;  
and  
obtaining filter values decomposing the channels of the system in a triangular form, and multiplying the obtained filter values by the data for each user allocated with power, and then outputting them to the MIMO antennas,  
wherein the allocating and outputting the power calculates power allocation parameters so that receiving minimum distances at receiving ends for each user that receives data through the MIMO antennas are the same, and allocates the calculated parameters to data for each user.

[Claim 10] The transmitting method of claim 9, wherein the allocating and outputting the power includes:  
obtaining singular values of channel matrices for each user;  
obtaining power allocation parameters for each user so that all values obtained by multiplying the power allocation parameters for each user by the singular values for each user are the same; and  
multiplying and outputting the power allocation parameters obtained for each user by data for each user.

[Claim 11] The transmitting method of claim 9, wherein the allocating and outputting the power includes:  
obtaining determinants of channel matrices for each user;  
obtaining a specific square root of determinants for each user, the specific square root being a square root based on the number of receiving antennas for each user;

obtaining power allocation parameters for each user so that all values obtained by multiplying the specific square roots of determinants for each user by the power allocation parameters for each user are the same; and

multiplying and outputting the power allocation variable obtained for each user by the data for each user.

[Claim 12]

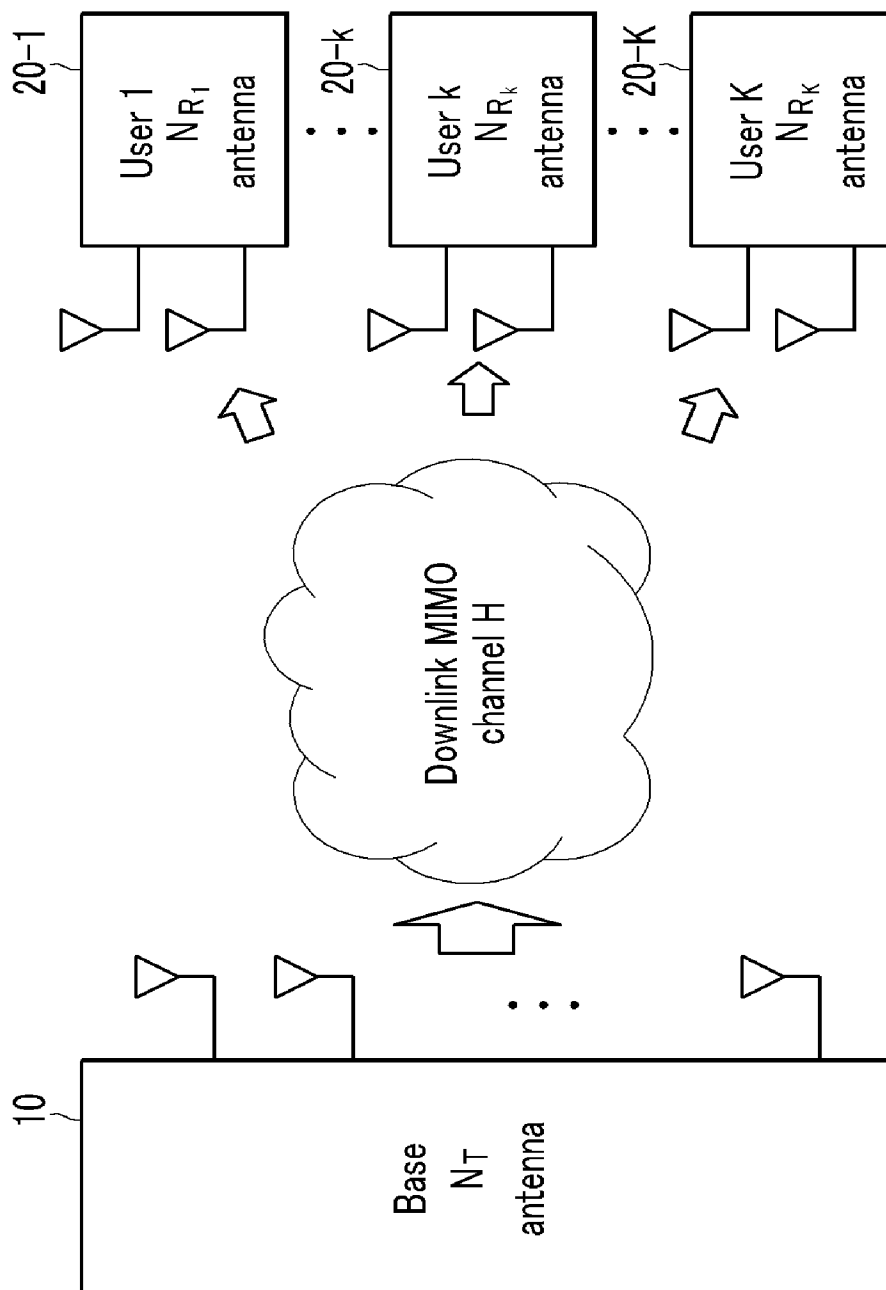
The transmitting method of claim 9, wherein:

the precoding performs the precoding using a block Tomlinson-Harashima precoder (BTHP) scheme that removes and outputs interference signals from data for each user block based on channel information that is fed back from the users.

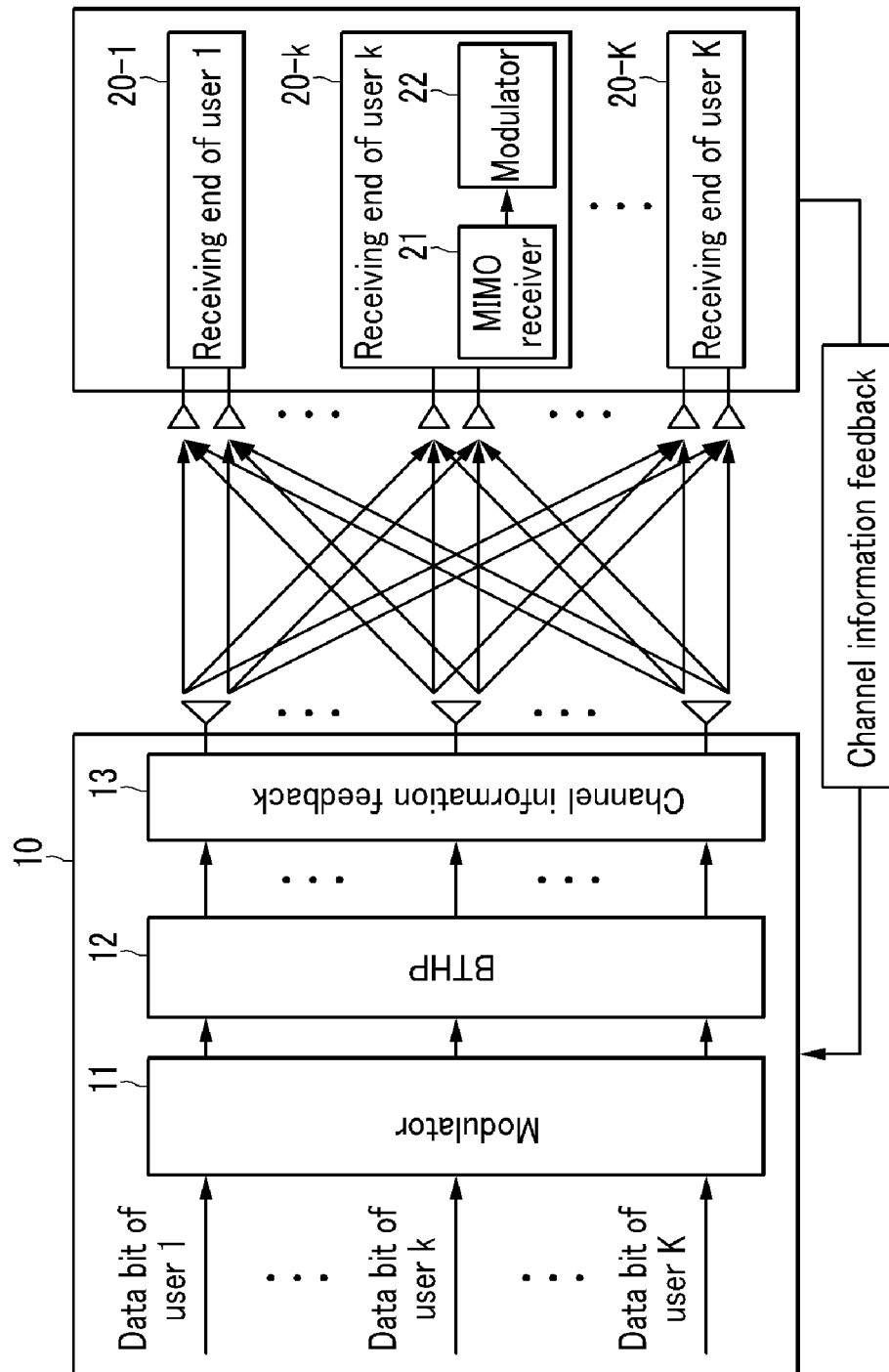
[Claim 13]

The transmitting method of claim 9, further comprising modulating the data for each user according to the channel information that is fed back from the users prior to the precoding.

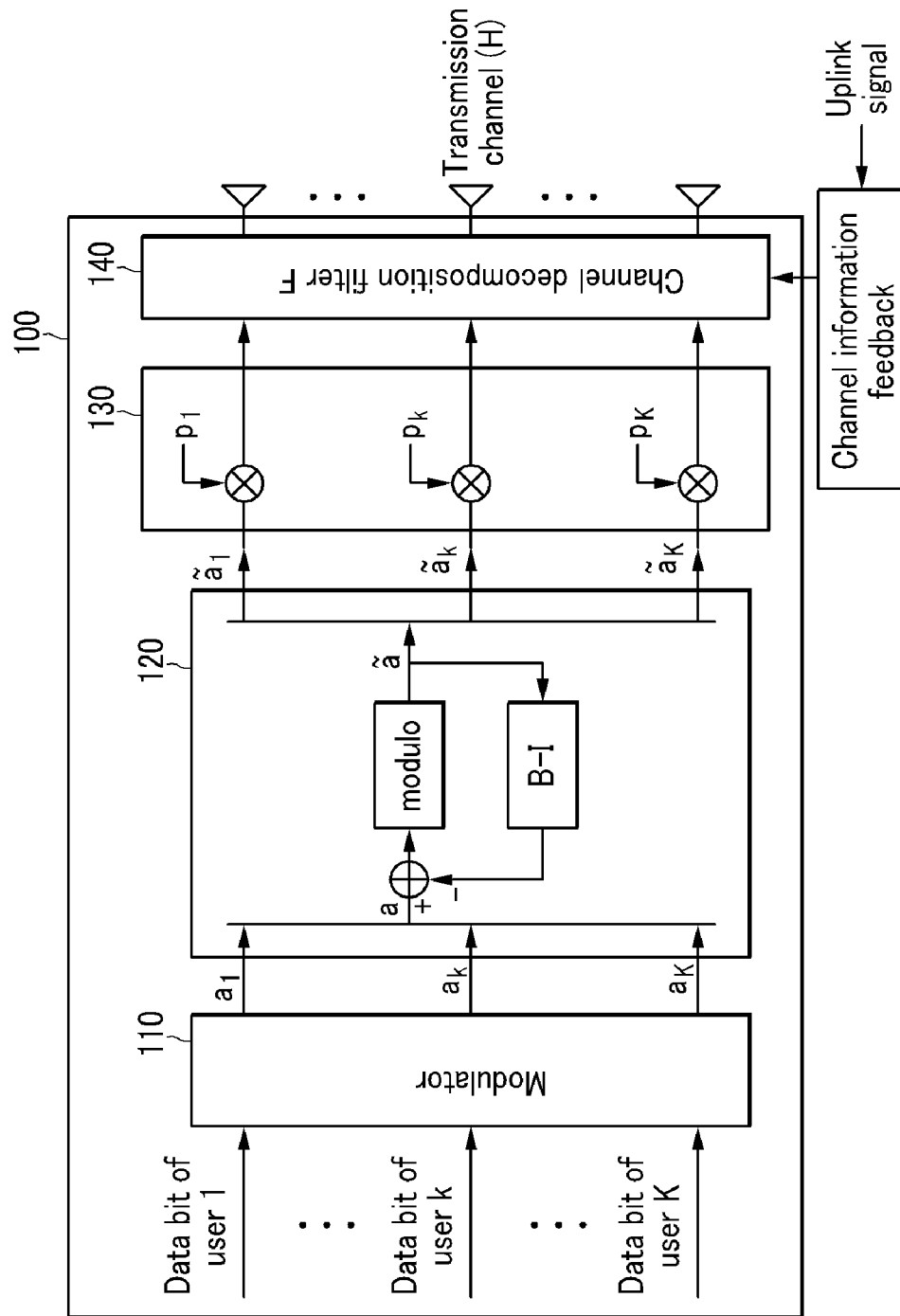
[Fig. 1]



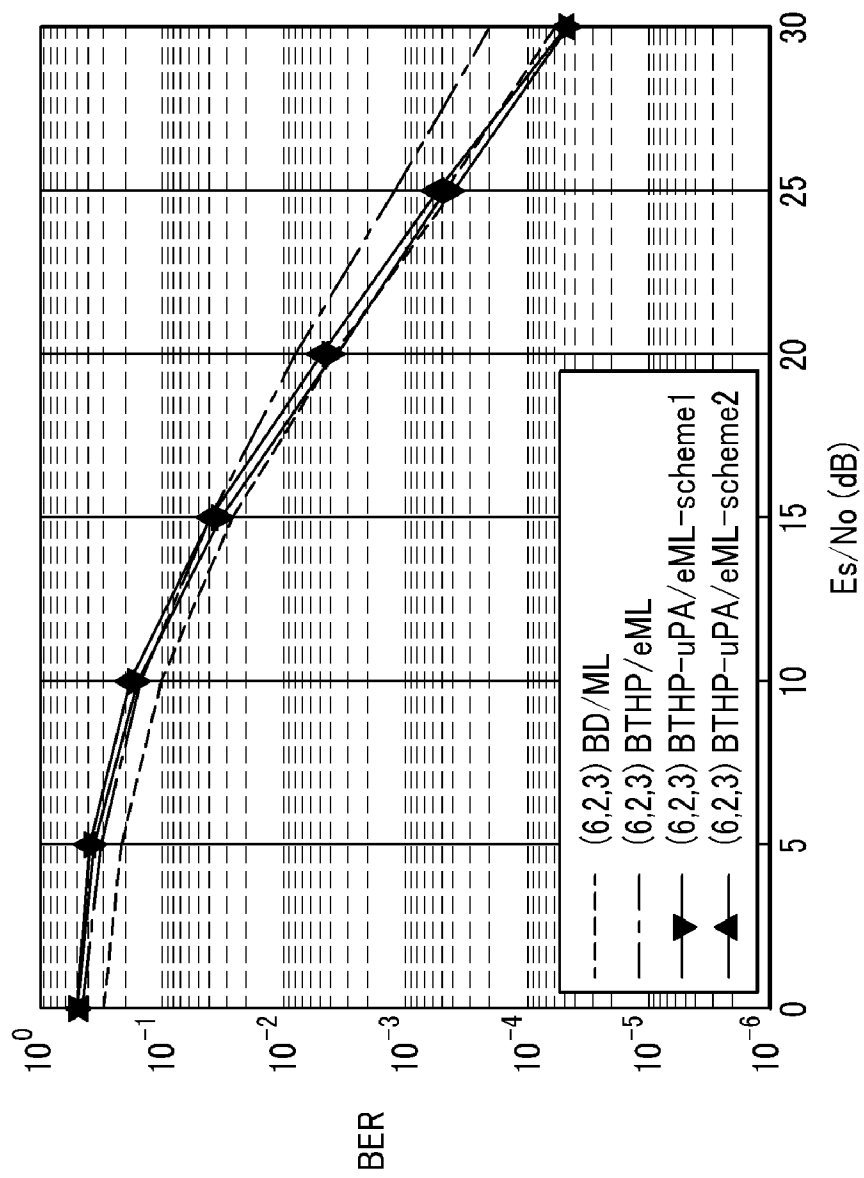
[Fig. 2]



[Fig. 3]



[Fig. 4]



[Fig. 5]

