(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 April 2011 (28.04.2011)

PCT

(10) International Publication Number
WO 2011/049367 A1

(51) International Patent Classification:
H04B 7/14 (2006.01) *H04B 7/155* (2006.01)

(21) International Application Number:
PCT/KR2010/007196

(22) International Filing Date:
20 October 2010 (20.10.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/604,290 22 October 2009 (22.10.2009) US

(71) Applicant: **KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY** [KR/KR]; 373-1, Gusong-dong, Yuseong-gu, Daejeon 305-701 (KR).

(72) Inventor: **JUNG, Bang Chul**; KAIST Institute for IT Convergence, 335 Gwahangno, Yuseong-gu, Daejeon 305-701 (KR).

(74) Agent: **PARK, Jun Seok**; MA.P.S Intellectual Property Law Firm, 11th Floor, Seongdo Bldg., 587-23, Sinsa-dong, Gangnam-gu, Seoul 135-747 (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, KR, 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, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, ZA, ZM, ZW.

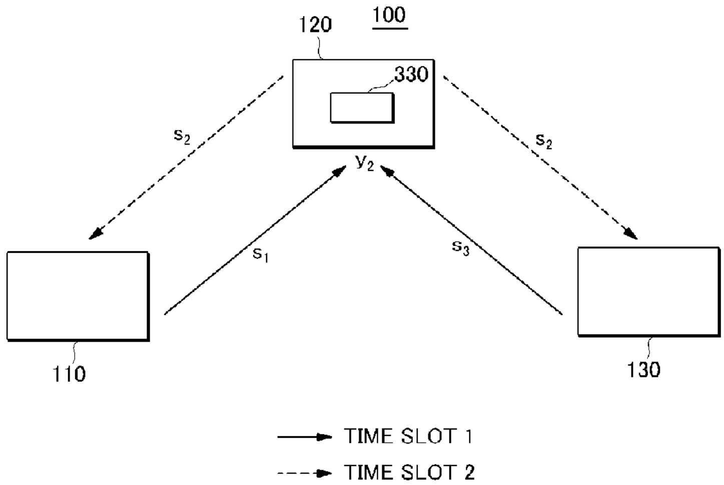
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: COMMUNICATION DEVICE

[Fig. 1]



(57) Abstract: A communication device includes an RF receiver that receives a combined signal including a first signal transmitted from a first node and a second signal transmitted from a second node, a channel estimator that estimates first channel information of the first signal and second channel information of the second signal, respectively, a multiuser detector that detects original signal values of the combined signal using the estimated first and second channel information and an RF transmitter that transmits a signal generated based on the values detected by the multiuser detector to the first node and the second node during a predetermined period.

WO 2011/049367 A1

Description

Title of Invention: COMMUNICATION DEVICE

Background Art

[1] Wireless communication systems are widely deployed to provide mobile devices with various contents, such as voice, text, image, and moving pictures. For example, multiple channel access techniques allow multiple users to share system resources, such as bandwidth and transmission power. Examples of multiple channel access techniques include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, or orthogonal frequency division multiple access (OFDMA) systems. Such multiple channel access techniques can simultaneously support communication between multiple mobile devices.

Disclosure of Invention

Technical Problem

[2] Various embodiments of communication devices and communication methods are disclosed herein. In one embodiment, a communication device includes an RF receiver that receives a combined signal including a first signal transmitted from a first node and a second signal transmitted from a second node, a channel estimator that estimates first channel information of the first signal and second channel information of the second signal, respectively, a multiuser detector that detects original signal values of the combined signal using the estimated first and second channel information, and an RF transmitter that transmits a signal generated based on the original signal values detected by the multiuser detector to the first node and the second node during a predetermined period.

Solution to Problem

[3] In another embodiment, a communication method includes estimating first channel information of a first signal and second channel information of a second signal transmitted simultaneously from different nodes, detecting original signal values of a combined signal including the first signal and the second signal based on the estimated first and second channel information by a multiuser detector, and transmitting a signal generated based on the detected original signal values to the different nodes during a predetermined period.

[4] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

Brief Description of Drawings

[5] FIG. 1 shows a schematic diagram of an illustrative embodiment of a communication system.

[6] FIG. 2 shows a schematic block diagram illustrating components of the communication devices of the communication system of FIG. 1.

[7] FIG. 3 shows a schematic diagram of symbol candidates of the signal received by the relay node shown in FIGS. 1 and 2.

[8] FIG. 4 shows a detailed block diagram of an illustrative embodiment of the relay node shown in FIGS. 1 and 2.

[9] FIG. 5 shows a detailed block diagram of another illustrative embodiment of the relay node shown in FIGS. 1 and 2.

[10] FIG. 6 is a flow diagram explaining an illustrative embodiment of a communication method.

[11] FIG. 7 is a flow diagram explaining another illustrative embodiment of a communication method.

Mode for the Invention

[12] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[13] In one embodiment, the present disclosure provides a communication device including a multiuser detector that detects values of a combined signal. The combined signal includes a first signal transmitted from a first node and a second signal transmitted from a second node using estimated first and second channel information.

[14] FIG. 1 is a schematic diagram of an illustrative embodiment of a communication system. FIG. 2 is a schematic block diagram illustrating components of the communication devices of the communication system of FIG. 1. As depicted in FIG. 1, a communication system 100 includes multiple communication devices 110, 120 and 130. Each communication device 110, 120 or 130 can transmit, receive or relay signals, and act as either a source node or a relay node. Various types of handheld communication apparatuses such as, but not limited to, mobile phones, smart phones or Personal

Digital Assistants (PDAs) can be used for communication devices 110, 120 and 130. For the purpose of description, it is assumed hereinafter that communication devices 110 and 130 each act as a source node (for example, first node 110 and second node 130), and communication device 120 acts as a relay node. However, one of ordinary skill in the art will appreciate that any of communication devices 110, 120 and 130 can act as a source node, a relay node, or a combination thereof.

[15] As depicted in FIG. 1, first node 110 and second node 130, as source nodes, substantially simultaneously transmit signals s_1 and s_3 to relay node 120 during a time slot 1 (as depicted by a solid directional line in FIG. 1). As used herein the time slot 1 can be defined as an uplink slot during which signals s_1 and s_3 of first and second nodes 110 and 130 are transmitted to relay node 120 based on a predetermined communication protocol.

[16] The transmitted first and second signals s_1 and s_3 are combined on a physical layer such as, but not limited to, air interface, to generate a combined signal y_2. Combined signal y_2 is received at relay node 120. When combined signal y_2 is distorted after passing through multi path fading channel, the original signal values of combined signal y_2 can be detected by a multiuser detector 330 of relay node 120, which will be further described in detail hereinafter. As used herein, the original signal values of combined signal y_2 refer to the values of combined signal y_2 in which no distortion is occurred. Relay node 120 then transmits signal s_2 generated based on the detected original signal values of combined signal y_2 to first node 110 and second node 130 during a time slot 2 (as depicted by a broken or dashed directional line in FIG. 1). As used herein, the time slot 2 can be defined as a downlink slot during which signal s_2 is received at first and second nodes 110 and 130 based on the predetermined communication protocol.

[17] As depicted in FIG. 2, first node 110 includes a first encoder 111, a first decoder 113 and a first XOR (exclusive or) operator 115. Second node 130 includes a second encoder 131, a second decoder 133 and a second XOR (exclusive or) operator 135.

[18] First and second encoders 111 and 131 perform channel coding on signals s_1 and s_3 to generate encoded signals w_1 and w_3, respectively. In some embodiments, first and second encoders 111 and 131 perform the channel coding by selectively inserting redundant bits into signals s_1 and s_3. By inserting redundant bits, bit errors of signals s_1 and s_3 can be detected and corrected so that reliable signal transmission is achieved. First node 110 and second node 130 transmit encoded signals w_1 and w_3, respectively, for reception by relay node 120. Prior to reception by relay node 120, encoded signals w_1 and w_3 are combined on a physical layer, such as an air interface.

[19] Relay node 120 receives combined signal y_2 including encoded signals w_1 and w_3. Further, relay node 120 detects original signal values of combined signal y_2 using

multiuser detector 330 and generates signal s_2 using the original signal values, which will be further described hereinafter. Relay node 120 transmits signal s_2 to both first node 110 and second node 130.

[20] First decoder 113 of first node 110 decodes signal s_2 and second decoder 133 of second node 130 decodes signal s_2. First and second decoders 113 and 133 provide decoded signal $\hat{s}_2$ to first and second XOR operators 115 and 135, respectively.

[21] First XOR operator 115 of first node 110 performs an XOR operation on decoded signal $\hat{s}_2$ and first signal s_1 to generate second signal s_3 that has been transmitted from second node 130. Since decoded signal $\hat{s}_2$ is the decoded signal of signal s_2 which is generated using combined signal y_2, it includes first signal s_1 and second signal s_3. Thus, first node 110 can receive second signal s_3 transmitted from second node 130 using the XOR operation.

[22] Second XOR operator 135 of second node 130 performs an XOR operation on decoded signal $\hat{s}_2$ and second signal s_3 to generate first signal s_1 that has been transmitted from first node 110. Since decoded signal $\hat{s}_2$ includes first signal s_1 and second signal s_3, as described above, second node 130 can receive first signal s_1 using the XOR operation.

[23] In the illustrative embodiment, signals (for example, signal s_1 and signal s_3) can be transmitted and received between first and second nodes 110 and 130 which are far away from each other during relatively short time periods, for example, two time slots (for example, time slots 1 and 2).

[24] In the above-stated illustrative embodiment, the channel codes used by encoders 111 and 131 and decoders 113 and 133 have linearity. For example, the channel codes may include Linear Block Codes, such as Hamming codes, Golay codes, BCH codes, Reed Solomon codes and (Linear) Convolution Codes. However, the channel codes used by encoders 111 and 131 and decoders 113 and 133 are not limited thereto and any channel code having linearity may be employed.

[25] FIG. 3 is a schematic diagram of symbol candidates of a signal received by the relay node of FIGS. 1 and 2. A combined signal including multiple signals is expressed with information of signals each transmitted from a multiple number of nodes and channel information of the transmitted signals. The channel information includes a channel coefficient of an ith node at a certain time slot and an average received power level at the ith node. By way of example, but not limitation, the channel coefficient may be an independent and identically-distributed (i.i.d.) complex Gaussian random variable with variance one (1). Further, noise is added to the combined signal. The noise may be Additive White Gaussian Noise (AWGN) whose power spectral density is N_0, but the noise is not limited thereto.

[26] For example, the combined signal received by relay node 120 (see FIG. 1) is

expressed by Equation 1 as follows.

[27] [Equation 1]

[28]
$$y_2 = h_1\sqrt{P_1}x_1 + h_3\sqrt{P_3}x_3 + n$$

[29] Here, x_1 denotes a symbol value of first signal s_1 transmitted from first node 110 (see FIG. 1), x_3 denotes a symbol value of second signal s_3 transmitted from second node 130 (see FIG. 1) and y_2 denotes the combined signal received by relay node 120. Further, h_1 and h_3 respectively denote channel coefficients of first signal s_1 and second signal s_3, and P_1 and P_3 respectively denote average received power levels at first node 110 and second node 130. Furthermore, n denotes Additive White Gaussian Noise (AWGN) added to first signal s_1 and second signal s_3.

[30] For example, if first node 110 and second node 130 transmit BPSK (Binary Phase Shift Keying) modulated signals, symbol values x_1 and x_3 are minus one (-1) or one (1). Accordingly, combined signal y_2 has four possible symbol candidates as expressed in the following Equation 2.

[31] [Equation 2]

[32]
$$\begin{aligned} C_{00} &= h_1\sqrt{P_1} + h_3\sqrt{P_3},\ C_{10} = -h_1\sqrt{P_1} + h_3\sqrt{P_3}, \\ C_{11} &= -h_1\sqrt{P_1} - h_3\sqrt{P_3},\ C_{01} = h_1\sqrt{P_1} - h_3\sqrt{P_3} \end{aligned}$$

[33] In Equation 2, C_{00} is a possible symbol candidate when symbol value x_1 of first signal s_1 is one (1) and symbol value x_3 of second signal s_3 is one (1). C_{10} is a possible symbol candidate when symbol value x_1 of first signal s_1 is minus one (-1) and symbol value x_3 of second signal s_3 is one (1). C_{11} is a possible symbol candidate when symbol value x_1 of first signal s_1 is minus one (-1) and symbol value x_3 of second signal s_3 is minus one (-1). C_{01} is a possible symbol candidate when symbol value x_1 of first signal s_1 is one (1) and symbol value x_3 of second signal s_3 is minus one (-1).

[34] Referring to FIG. 3 and Equation 2, combined signal y_2 is determined as one (1) if the symbol of combined signal y_2 is detected as C_{10} or C_{01}. Further, combined signal y_2 is determined as zero (0) if the symbol of combined signal y_2 is detected as C_{00} or C_{11}. Since, first signal s_1 and second signal s_3 are combined during time slot 1 (as depicted by a solid arrow in FIG. 1), symbol value x_1 of first signal s_1 and symbol value x_3 of second signal s_3 are XOR operated each other. Accordingly, if symbol value x_1 and x_3 are the same, combined signal y_2 is one (1) and if symbol value x_1 and x_3 are different, combined signal y_2 is zero (0).

[35] Although the BPSK modulation signals have been illustrated above, it will be apparent to those skilled in the art that any modulation method, such as M-QAM (Quadrature Amplitude Modulation) method can also be used.

[36] FIG. 4 is a detailed block diagram of an illustrative embodiment of the relay node shown in FIGS. 1 and 2. In the illustrative embodiment, relay node 120 includes an RF (Radio Frequency) receiver 310, a channel estimator 320, a multiuser detector 330, a decoder 340 (optional), an encoder 350 (optional) and an RF transmitter 360.

[37] RF receiver 310 receives combined signal y_2 including first signal s_1 transmitted from first node 110 (see FIG. 1) and second signal s_3 transmitted from second node 130 (see FIG. 1) during time slot 1 (as depicted by a solid directional line in FIG. 4). As discussed in the paragraphs [18], first signal s_1 and second signal s_3 may be encoded signals and they can be combined on a physical layer. RF receiver 310 provides combined signal y_2 to multiuser detector 330. Further, RF receiver 310 receives first and second pilot signals (not shown) from first and second nodes 110 and 130 and provides the received first and second pilot signals to channel estimator 320.

[38] Channel estimator 320 estimates channel information including a received power level and a channel coefficient by using the first and second pilot signals received by RF receiver 310. For example, channel estimator 320 estimates first channel information including a first received power level and a first channel coefficient of first signal s_1 by using the first pilot signal transmitted from first node 110 through RF receiver 310. Further, channel estimator 320 estimates second channel information including a second received power level and a second channel coefficient of second signal s_3 by using the second pilot signal transmitted from second node 130 through RF receiver 310. Then, channel estimator 320 provides the estimated first and second channel information to multiuser detector 330.

[39] Multiuser detector 330 detects original signal values of combined signal y_2 received from RF receiver 310 using the estimated first and second channel information received from channel estimator 320. The values detected by multiuser detector 330 may be, but not limited to, one (1) or zero (0), and can be varied depending on a modulation method.

[40] Multiuser detector 330 employs various detecting methods such as, but not limited to, a joint ML (maximum likelihood) detecting method and any other multiuser detecting method.

[41] To detect the original signal values of combined signal y_2, multiuser detector 330 is configured to execute LLR (log likelihood ratio) computation of combined signal y_2. For example, if BPSK is used as a modulation method, the LLR (log likelihood ratio) value is calculated by Equation 3 as follows.

[42] [Equation 3]

[43]
$$\Lambda_{s_2} = \log \frac{\mathbf{P}\left(s_2 = 0 | y_2\right)}{\mathbf{P}\left(s_2 = 1 | y_2\right)} = \log \frac{\mathbf{P}\left(s_1 = 0, s_3 = 0 | y_2\right) + \mathbf{P}\left(s_1 = 1, s_3 = 1 | y_2\right)}{\mathbf{P}\left(s_1 = 1, s_3 = 0 | y_2\right) + \mathbf{P}\left(s_1 = 0, s_3 = 1 | y_2\right)},$$

[44] Here, Λ_{s2} denotes the LLR (log likelihood ratio) value, and P(A) denotes a probability of occurrence of an event A. For example, $P(s_1=0, s_3=0 \mid y_2)$ is a probability of occurrence of an event in which, when combined signal y_2 is received, the values of first signal s_1 and second signal s_3 are zero (0), respectively. If Λ_{s2} is equal to or less than zero (0), the original signal value of combined signal y_2 is determined as one (1). If Λ_{s2} is larger than zero (0), the original signal value of combined signal y_2 is determined as zero (0).

[45] Further, assuming that a first probability (the value of first signal s_1 is zero (0)) and a second probability (the value of first signal s_1 is one (1)) are equal; and that a third probability (the value of second signal s_3 is zero (0)) and a fourth probability (the value of second signal s_3 is one (1)) are equal, Equation 3 is expressed by the following Equation 4 according to Bayes' rule.

[46] [Equation 4]

[47]
$$\Lambda_{s_2} = \log \frac{\mathbf{p}(y_2|s_1=0,s_3=0)+\mathbf{p}(y_2|s_1=1,s_3=1)}{\mathbf{p}(y_2|s_1=1,s_3=0)+\mathbf{p}(y_2|s_1=0,s_3=1)}$$
$$= \log \frac{\exp\left(-\frac{|y_2-C_{00}|^2}{2\sigma^2}\right)+\exp\left(-\frac{|y_2-C_{11}|^2}{2\sigma^2}\right)}{\exp\left(-\frac{|y_2-C_{10}|^2}{2\sigma^2}\right)+\exp\left(-\frac{|y_2-C_{01}|^2}{2\sigma^2}\right)},$$

[48] Here, $p(\alpha)$ denotes a probability density function of α. For example, $p(y_2 \mid s_1=0, s_3=0)$ is a probability density function of combined signal y_2 when the value of first signal s_1 is zero (0) and the value of second signal s_3 is zero (0). σ^2 denotes a variance, and C_{00}, C_{01}, C_{10} and C_{11} denote the symbol candidates of combined signal y_2 as expressed in Equation 2, respectively.

[49] Multiuser detector 330 produces a vector L_2 composed of the values detected as a result of the LLR (log likelihood ratio) computation and provides vector L_2 to decoder 340.

[50] Although relay node 120 has been described to execute the LLR (log likelihood ratio) computation on BPSK modulated signals, it will be apparent to those skilled in the art that the LLR (log likelihood ratio) computation can also be applied to another signals modulated by another modulation method, such as M-QAM.

[51] As described above, multiuser detector 330 produces vector L_2 with a multiuser detecting method, such as a joint ML (maximum likelihood) detecting method. Therefore, relay node 120 can decrease multi path fading even if a pre-equalizer, which is used to compensate the multi path fading, is not provided.

[52] Decoder 340 receives vector L_2 having the LLR (log likelihood ratio) values and decodes vector L_2 using a first channel code to generate decoded vector $\widehat{s}_2$. Further, decoder 340 provides decoded vector $\widehat{s}_2$ to encoder 350.

[53] Encoder 350 receives decoded vector $\hat{s}_2$ from decoder 340 and encodes decoded vector $\hat{s}_2$ using a second channel code to generate an encoded vector $\hat{w}'_2$. Then, encoder 350 provides encoded vector $\hat{w}'_2$ to RF transmitter 360. As described in the paragraph [24], the first and second channel codes have linearity, and various channel codes having linearity can be used for the first and second channel codes.

[54] RF transmitter 360 modulates encoded vector $\hat{w}'_2$ into signal s_2 and transmits signal s_2 to first node 110 and second node 130 during time slot 2 (as depicted by a broken arrow in FIG. 4).

[55] In another embodiment, relay node 120 is configured without decoder 340 and encoder 350. Since decoder 340 and encoder 350 are omitted, the decoding and encoding of vector L_2 are also omitted in this embodiment. Particularly, in response to combined signal y_2 transmitted from RF receiver 310 and the first and second channel information estimated by channel estimator 320, multiuser detector 330 generates vector L_2, and provide it to RF transmitter 360. In response to vector L_2, RF transmitter 360 generates signal s_2 without the above-mentioned decoding and encoding processes, and transmits generated signal s_2 to first and second nodes 110 and 130. First node 110 and second node 130 decodes signal s_2 using decoder 113 and 133 (See FIG. 2) as discussed in the paragraph [20].

[56] Accordingly, as discussed in the paragraphs [21] and [22], first and second nodes 110 and 130 obtain signals s_3 and s_1 respectively by XOR operations of the decoded signals of signal s_2 and their own signals s_1 and s_3. Since all of the channel codes used by first and second nodes 110 and 130, decoder 340 and encoder 350 have linearity, the decoded signals of signal s_2 satisfies linearity with respect to signals s1 and s_3 and signals s_1 and s_3 can be obtained respectively by the XOR operation.

[57] FIG. 5 is a detailed block diagram of another illustrative embodiment of the relay node shown in FIGS. 1 and 2. In this embodiment, a relay node 400 includes an RF (Radio Frequency) receiver 410, a channel estimator 420, a multiuser detector 430, a first decoder 440, a second decoder 450, an XOR operator 460, an encoder 470 and an RF transmitter 480. Since the function and operation of RF receiver 410, channel estimator 420, encoder 470 and RF transmitter 480 in FIG. 5 are substantially identical or similar to those of RF receiver 310, channel estimator 320, encoder 350 and RF transmitter 360 respectively in FIG. 4, redundant description thereof will be omitted herein.

[58] Relay node 400 includes two decoders (for example, first decoder 440 and second decoder 450), while relay node 120 depicted in FIG. 4 includes one decoder 340. Further, relay node 400 includes XOR operator 460 in association with first and second decoders 440 and 450.

[59] As in relay node 120 depicted in FIG. 4, multiuser detector 430 receives combined

signal y_2 from RF receiver 410 and estimated first and second channel information from channel estimator 420. While multiuser detector 330 depicted in FIG. 4 detects original signal values of combined signal y_2, multiuser detector 430 depicted in FIG. 5 detects the values of first signal s_1 and second signal s_3 respectively from combined signal y_2. Then, the original signal values of combined signal y_2 are generated using the detected values of first signal s_1 and second signal s_3. Specifically, multiuser detector 430 detects values of first signal s_1 based on first channel information and second channel information estimated by channel estimator 420. Further, multiuser detector 430 detects values of second signal s_3 based on the first channel information and the second channel information. At this time, the values detected by multiuser detector 430 may be, but not limited to, one (1) or zero (0), and can be varied depending on the modulation method. Furthermore, multiuser detector 430 generates two vectors (first and second vectors L_1 and L_3) for first and second signals s_1 and s_3, respectively.

[60] Particularly, multiuser detector 430 executes LLR (log likelihood ratio) computation of first signal s_1 and second signal s_3. For example, if BPSK is used as a modulation method, the LLR (log likelihood ratio) value of first signal s_1 is expressed by the following Equation 5.

[61] [Equation 5]

[62]
$$\Lambda_{s_1} = \log\frac{\mathbf{P}(s_1=0,\ s_3=0|y_2)+\mathbf{P}(s_1=0,\ s_3=1|y_2)}{\mathbf{P}(s_1=1,\ s_3=0|y_2)+\mathbf{P}(s_1=1,\ s_3=1|y_2)}$$

[63] Further, the LLR (log likelihood ratio) value of second signal s_3 is expressed by the following Equation 6.

[64] [Equation 6]

[65]
$$\Lambda_{s_3} = \log\frac{\mathbf{P}(s_1=0,\ s_3=0|y_2)+\mathbf{P}(s_1=1,\ s_3=0|y_2)}{\mathbf{P}(s_1=0,\ s_3=1|y_2)+\mathbf{P}(s_1=1,\ s_3=1|y_2)}$$

[66] In Equations 5 and 6, P(A) denotes a probability of occurrence of an event A. For example, $P(s_1=0, s_3=0 \mid y_2)$ is a probability of occurrence of an event in which, when combined signal y_2 is received, the values of first signal s_1 and second signal s_3 are respectively zero (0). If the LLR (log likelihood ratio) Λ_{s1} or Λ_{s3} is equal to or less than zero (0), the value of first signal s_1 or second signal s_3 is determined as one (1). If Λ_{s1} or Λ_{s3} is larger than zero (0), the value of first signal s_1 or second signal s_3 is determined as zero (0).

[67] Further, multiuser detector 430 produces a first vector L_1 composed of the LLR (log likelihood ratio) values of first signal s_1 and provides first vector L_1 to first decoder 440. Furthermore, multiuser detector 430 produces a second vector L_3 composed of the LLR (log likelihood ratio) values of second signal s_3 and provides second vector L_3 to second decoder 450.

[68] First decoder 440 receives first vector L_1 composed of the LLR (log likelihood ratio) values of first signal s_1 and decodes first vector L_1 using a first channel code. Further, first decoder 440 provides a decoded vector $\hat{s}_1$ to XOR operator 460.

[69] Second decoder 450 receives second vector L_3 composed of the LLR (log likelihood ratio) values of second signal s_3 and decodes second vector L_3 using a second channel code. Further, second decoder 450 provides a decoded vector $\hat{s}_3$ to XOR operator 460.

[70] XOR operator 460 performs an XOR operation on decoded vector $\hat{s}_1$ and decoded vector $\hat{s}_3$. Accordingly, XOR operator 460 generates a combined vector $\hat{s}_2$ and then provides combined vector $\hat{s}_2$ to encoder 470.

[71] Encoder 470 encodes combined vector $\hat{s}_2$ using a third channel code and then transmits an encoded vector $\hat{w}'_2$ to RF transmitter 480. RF transmitter 480 modulates encoded vector $\hat{w}'_2$ into signal s_2 and transmits signal s_2 to both first node 110 (see FIG. 1) and second node 130 (see FIG. 1). As described in the paragraph [24], the first, second and third channel codes have linearity, and various channel codes having linearity can be used for the first, second and third channel codes.

[72] Although first decoder 440, second decoder 450 and encoder 470 are shown in FIG. 4, they are optional and may be omitted in certain embodiments. In an example embodiment in which relay node 400 is configured without first decoder 440, second decoder 450 and encoder 470, XOR operator 460 performs an XOR operation directly on first vector L_1 and second vector L_3, each received from multiuser detector 430, and RF transmitter 480 transmits a signal generated by the XOR-operation without the above-mentioned decoding and encoding processes.

[73] FIG. 6 is a flow diagram explaining an illustrative embodiment of a communication method. Referring to FIGS. 1, 2, 4 and 6, an example embodiment of a communication method is illustrated. A signal (for example, a combined signal y_2) is received in a communication device (for example, relay node 120) during a certain time period (for example, time slot 1) (Operation 510). The signal includes two encoded signals (for example, first signal s_1 transmitted from first node 110 and second signal s_3 transmitted from second node 130, which is combined on a physical layer).

[74] Channel information is estimated by using a pilot signal received by RF receiver 310 (Operation 520). The channel information includes a received power level and a channel coefficient. For example, first channel information is estimated using a first pilot signal transmitted from first node 110. The first channel information includes a first received power level and a first channel coefficient of first signal s_1. Further, second channel information is estimated using a second pilot signal transmitted from second node 130. The second channel information includes a second received power level and a second channel coefficient of second signal s_3.

[75] Original signal values of combined signal y_2 received in operation 510 are detected using the first and second channel information estimated in operation 520 (Operation 530). Further, vector L_2 composed of the original signal values is produced by executing LLR (log likelihood ratio) computation (Operation 530). The values detected in operation 530 may be, but not limited to, one (1) or zero (0), and can be varied depending on the modulation method. Since the detailed process for detecting the original signal values of combined signal y_2 has already been discussed in the paragraphs [41] and [45] with reference to FIG. 4, redundant description thereof will be omitted herein.

[76] Vector L_2 is decoded using a first channel code to generate vector $\hat{s}_2$ (Operation 540). Vector $\hat{s}_2$ decoded in operation 540 is encoded using a second channel code to generate vector $\hat{w}'_2$ (Operation 550). Vector $\hat{w}'_2$ encoded in operation 550 is modulated into signal s_2 and signal s_2 is transmitted to first node 110 and second node 130 during a predetermined period (for example, time slot 2) (Operation 560).

[77] Signal s_2 is decoded into decoded vector $\hat{s}_2$ at first node 110 and first node 110 performs XOR-operation on decoded vector $\hat{s}_2$ and signal s_1 to obtain or generate second signal s_3 that has been transmitted from second node 130. Further, signal s_2 is decoded into decoded vector $\hat{s}_2$ at second node 130 and second node 130 performs XOR-operation on decoded vector $\hat{s}_2$ and signal s_3 to obtain or generate first signal s_1 that has been transmitted from first node 110.

[78] FIG. 7 is a flow diagram explaining another illustrative embodiment of a communication method. Referring to FIGS. 1, 2, 5 and 7, an example embodiment of a communication method is illustrated. Since the function and process of operation 610 and 620 in FIG. 7 may be similar to those of operation 510 and 520 respectively in FIG. 6, redundant description thereof will be omitted herein.

[79] As compared to operation 530 in FIG. 6 in which the values of one combined signal y_2 are detected, the values of two signals (first signal s_1 and second signal s_3) are detected, respectively (Operation 630). The values of first signal s_1 are detected using first channel information and second channel information estimated in operation 620 and the values of second signal s_3 are detected using the first channel information and the second channel information estimated in operation 620. The values of first signal s_1 and second signal s_3 can be detected using, but not limited to, LLR (log likelihood ratio) computation of first signal s_1 and second signal s_3, respectively. Since the detailed process for detecting the values of first signal s_1 and values of second signal s_3 is already discussed in the paragraph [60] with reference to FIG. 5, redundant description thereof will be omitted herein.

[80] Further, first vector L_1 is produced by executing LLR (log likelihood ratio) computation of first signal s_1 and second vector L_3 is produced by executing LLR (log

likelihood ratio) computation of second signal s_3, respectively (Operation 640). The detected values may be, but not limited to, one (1) or zero (0), and can be varied depending on the modulation method.

[81] First vector L_1 is decoded using a first channel code and second vector L_3 is decoded using a second channel code (Operation 650). Accordingly, decoded vectors $\hat{s}_1$ and $\hat{s}_3$ are generated.

[82] An XOR operation is performed on decoded vectors $\hat{s}_1$ and $\hat{s}_3$ and thus combined vector $\hat{s}_2$ is generated (Operation 660). Then, combined vector $\hat{s}_2$ is encoded to generate vector $\hat{w}_2'$ using a third channel code (Operation 670). Encoded vector $\hat{w}_2'$ is modulated into signal s_2 and signal s_2 is transmitted to both first node 110 and second node 130 during a predetermined period (for example, time slot 2) (Operation 680).

[83] One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are only provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

[84] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[85] In an illustrative embodiment, any of the operations, processes, etc. described herein can be implemented as computer-readable instructions stored on a computer-readable medium. The computer-readable instructions can be executed by a processor of a mobile unit, a network element, and/or any other computing device.

[86] There is little distinction left between hardware and software implementations of aspects of systems; the use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software can become significant)

a design choice representing cost vs. efficiency tradeoffs. There are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

[87] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a CD, a DVD, a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[88] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering

practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein can be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system generally includes one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[89] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable", to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[90] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[91] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at

least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., " a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., " a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[92] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[93] As will be understood by one skilled in the art, for any and all purposes, such as in

terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a second third, middle third and first third, etc. As will also be understood by one skilled in the art all language such as “up to,” “at least,” and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[94] From the foregoing, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

Claims

[Claim 1] A communication device comprising:
an RF receiver that receives a combined signal including a first signal transmitted from a first node and a second signal transmitted from a second node;
a channel estimator that estimates first channel information of the first signal and second channel information of the second signal, respectively;
a multiuser detector that detects original signal values of the combined signal using the estimated first and second channel information; and
an RF transmitter that transmits a signal generated based on the original signal values detected by the multiuser detector to the first node and the second node during a predetermined period.

[Claim 2] The communication device of claim 1, wherein the multiuser detector is a joint-ML (maximum likelihood) detector.

[Claim 3] The communication device of claim 1, further comprising:
a decoder that decodes a vector composed of the original signal values detected by the multiuser detector using a first channel code; and
an encoder that encodes the decoded vector using a second channel code.

[Claim 4] The communication device of claim 3, wherein the first channel code and the second channel code have linearity.

[Claim 5] The communication device of claim 3, wherein the multiuser detector is configured to execute LLR (log likelihood ratio) computation of the combined signal.

[Claim 6] The communication device of claim 3, wherein the first channel information includes a received power level and a channel coefficient of the first signal, and the second channel information includes a received power level and a channel coefficient of the second signal.

[Claim 7] A communication device comprising:
an RF receiver for receiving a combined signal including a first signal transmitted from a first node and a second signal transmitted from a second node;
a channel estimator for estimating first channel information of the first signal and second channel information of the second signal, respectively;
a multiuser detector for detecting values of the first signal and the

second signal from the combined signal using the estimated first and second channel information;
an XOR (exclusive-or) operator for performing an XOR-operation on the values of the first signal and the values of the second signal; and
an RF transmitter for transmitting a signal generated based on the XOR-operation to the first node and the second node during a predetermined period.

[Claim 8] The communication device of claim 7, wherein the multiuser detector is a joint-ML (maximum likelihood) detector.

[Claim 9] The communication device of claim 7, further comprising:
a first decoder for decoding a first vector composed of the detected values of the first signal using a first channel code;
a second decoder for decoding a second vector composed of the detected values of the second signal using a second channel code; and
an encoder for encoding the XOR-operated values using a third channel code
wherein the XOR operator performs the XOR-operation on the decoded first vector and the decoded second vector.

[Claim 10] The communication device of claim 9, wherein the first channel code, the second channel code and the third channel code have linearity.

[Claim 11] The communication device of claim 9, wherein the multiuser detector is configured to execute LLR (log likelihood ratio) computation of the first signal and the second signal.

[Claim 12] The communication device of claim 9, wherein the first channel information includes a received power level and a channel coefficient of the first signal, and the second channel information includes a received power level and a channel coefficient of the second signal.

[Claim 13] A communication method comprising:
estimating first channel information of a first signal and second channel information of a second signal transmitted substantially simultaneously from different nodes;
detecting original signal values of a combined signal including the first signal and the second signal based on the estimated first and second channel information by a multiuser detecting method; and
transmitting a signal generated based on the detected original signal values to the different nodes during a predetermined period.

[Claim 14] The communication method of claim 13, wherein the multiuser detecting method is a joint-ML (maximum likelihood) detecting method.

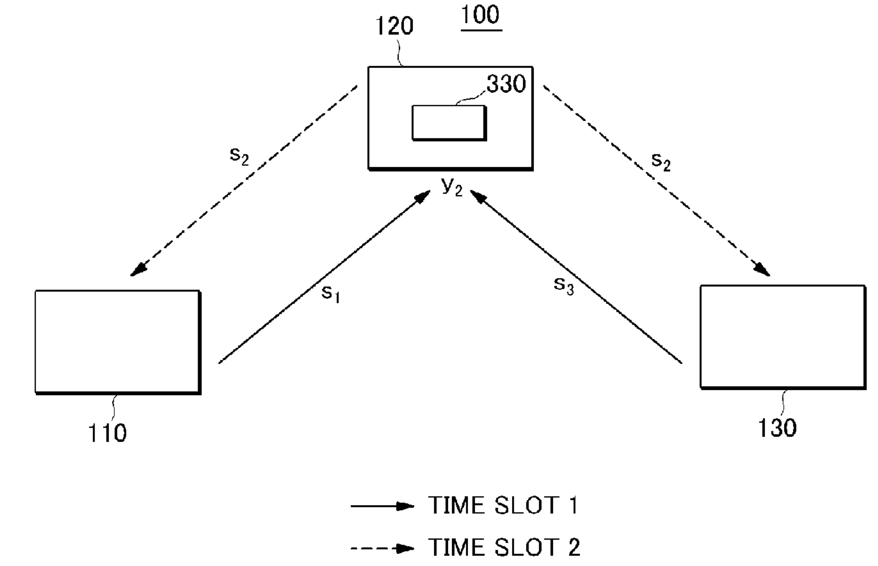
[Claim 15] The communication method of claim 13, further comprising:
decoding a vector composed of the detected original signal values of the combined signal using a first channel code; and
encoding the decoded vector using a second channel code.

[Claim 16] The communication method of claim 13, wherein detecting original signal values of the combined signal includes:
detecting values of the first signal using the first and second channel information; and
detecting values of the second signal using the first and second channel information.

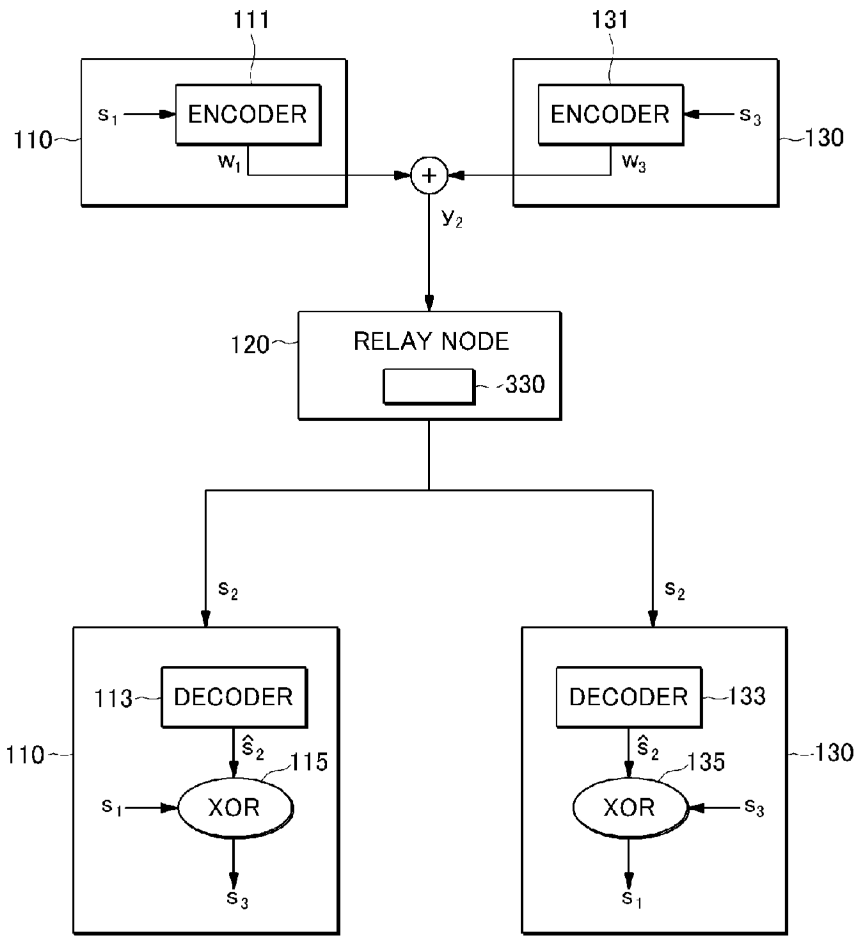
[Claim 17] The communication method of claim 16, wherein detecting original signal values of the combined signal further includes:
performing XOR-operation on the detected values of the first signal and the detected values of the second signal.

[Claim 18] The communication method of claim 17, further comprising:
encoding a vector generated by the XOR-operation by using a second channel code.

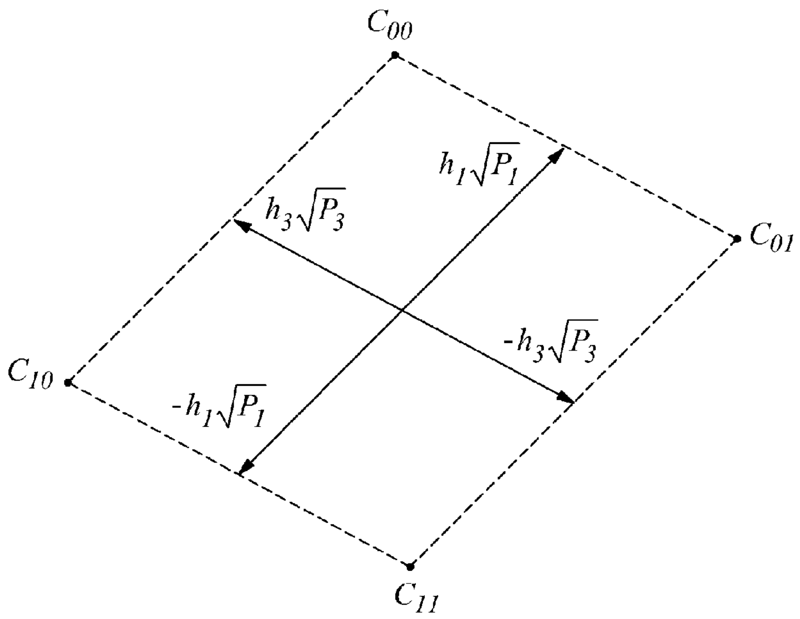
[Fig. 1]


120
100
330
s_2
s_2
y_2
s_1
s_3
110
130
TIME SLOT 1
TIME SLOT 2

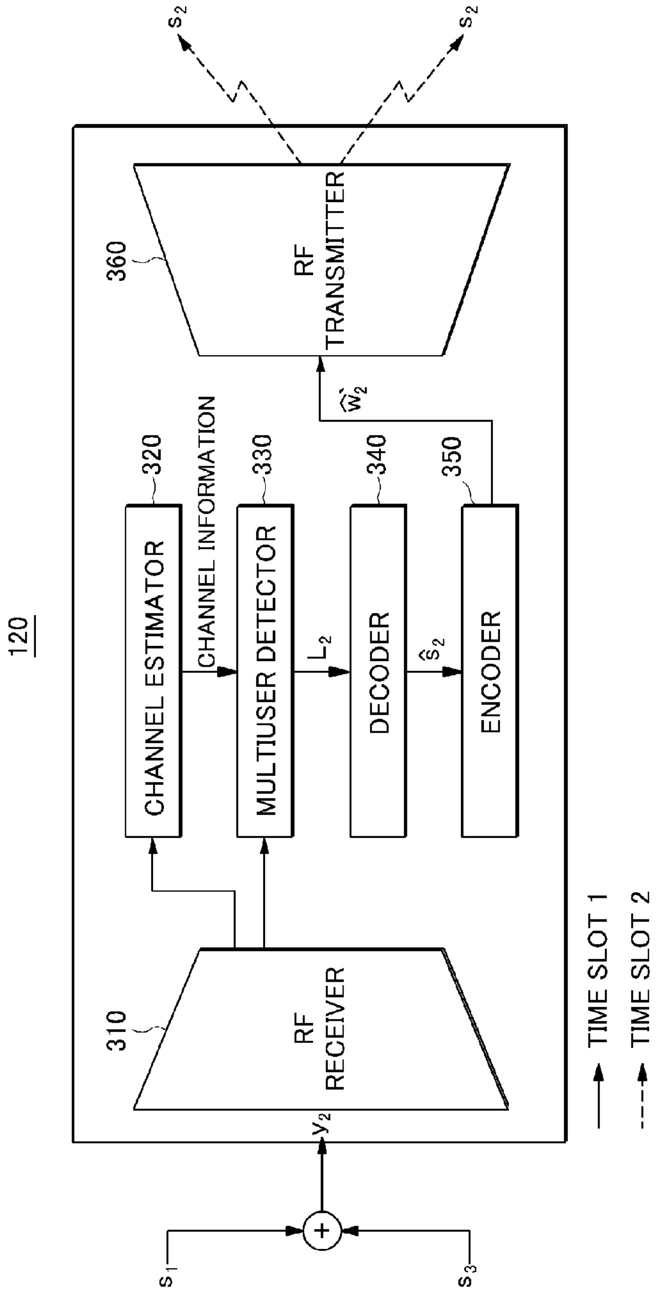
[Fig. 2]


111
131
110
ENCODER
ENCODER
s_1
s_3
130
w_1
w_3
+
y_2
120
RELAY NODE
330
s_2
s_2
113
DECODER
DECODER
133
110
$\hat{s}_2$
115
$\hat{s}_2$
135
130
s_1
XOR
XOR
s_3
s_3
s_1

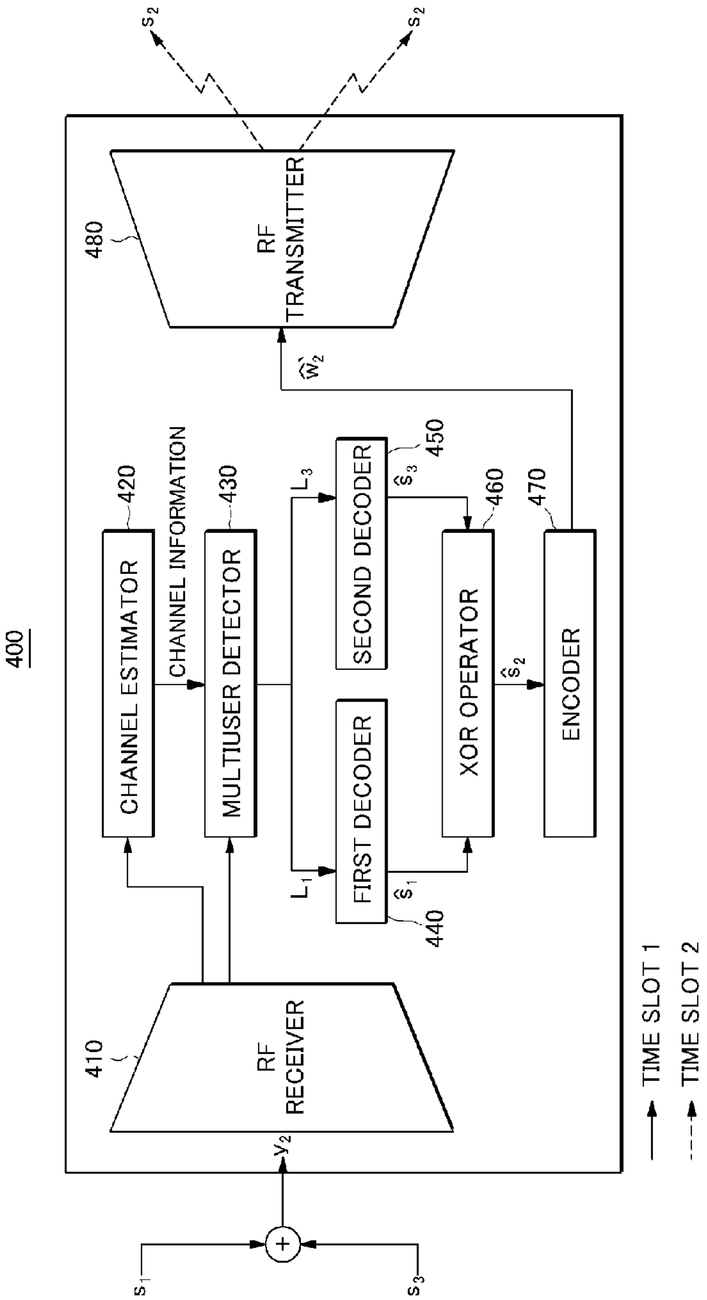
[Fig. 3]



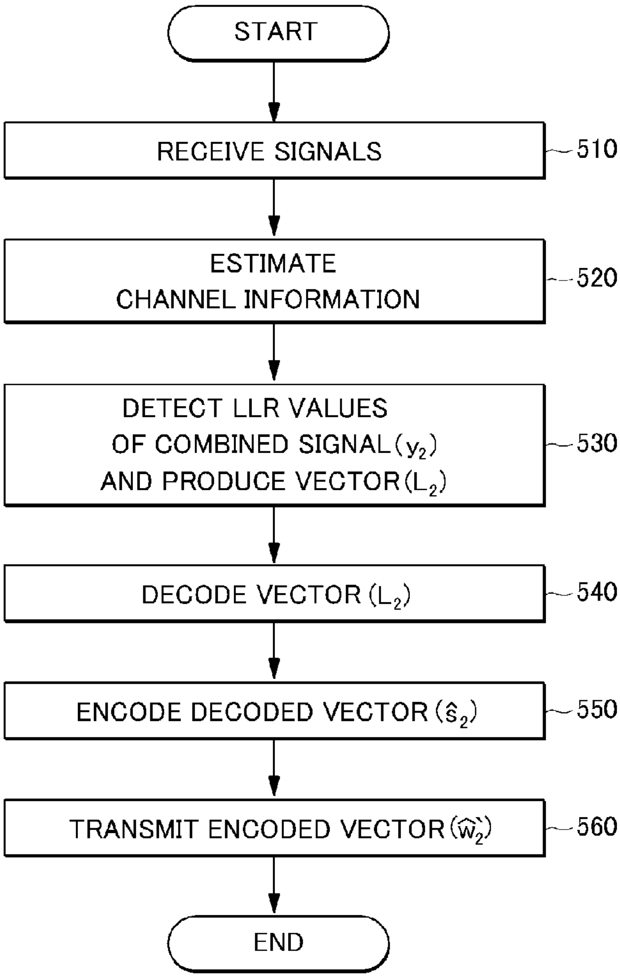
[Fig. 4]


120
s_2
s_2
360
RF TRANSMITTER
$\hat{w}_2$
320
CHANNEL ESTIMATOR
CHANNEL INFORMATION
330
MULTIUSER DETECTOR
L_2
340
DECODER
$\hat{s}_2$
350
ENCODER
310
RF RECEIVER
y_2
s_1
s_3
TIME SLOT 1
TIME SLOT 2

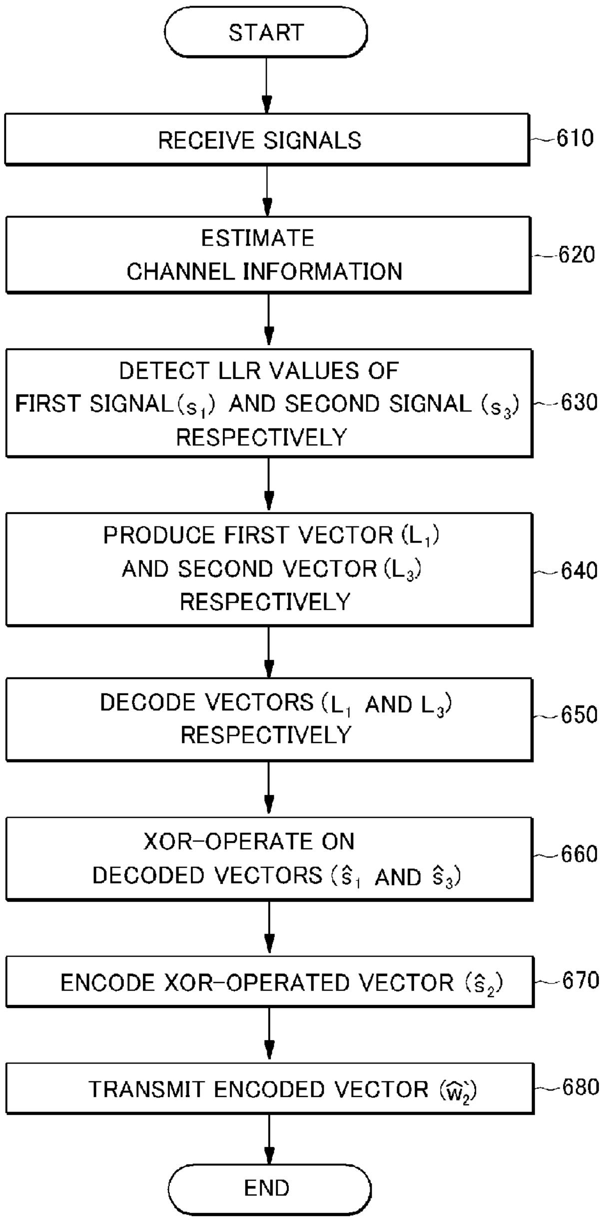
[Fig. 5]


400
410
RF RECEIVER
420
CHANNEL ESTIMATOR
CHANNEL INFORMATION
430
MULTIUSER DETECTOR
440
FIRST DECODER
450
SECOND DECODER
460
XOR OPERATOR
470
ENCODER
480
RF TRANSMITTER
TIME SLOT 1
TIME SLOT 2

[Fig. 6]


START
RECEIVE SIGNALS
510
ESTIMATE CHANNEL INFORMATION
520
DETECT LLR VALUES OF COMBINED SIGNAL (y_2) AND PRODUCE VECTOR (L_2)
530
DECODE VECTOR (L_2)
540
ENCODE DECODED VECTOR ($\hat{s}_2$)
550
TRANSMIT ENCODED VECTOR ($\hat{w}_2'$)
560
END

[Fig. 7]


START
RECEIVE SIGNALS
610
ESTIMATE CHANNEL INFORMATION
620
DETECT LLR VALUES OF FIRST SIGNAL (s_1) AND SECOND SIGNAL (s_3) RESPECTIVELY
630
PRODUCE FIRST VECTOR (L_1) AND SECOND VECTOR (L_3) RESPECTIVELY
640
DECODE VECTORS (L_1 AND L_3) RESPECTIVELY
650
XOR-OPERATE ON DECODED VECTORS ($\hat{s}_1$ AND $\hat{s}_3$)
660
ENCODE XOR-OPERATED VECTOR ($\hat{s}_2$)
670
TRANSMIT ENCODED VECTOR ($\hat{w}_2$)
680
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2010/007196

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H04B 7/14 (2006.01) ***H04B 7/155*** (2006.01)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC,WPI, TXTE (multiuser, detect, joint, channel, estimation, relay, likelihood and similar terms)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 2008/0125032 A1 (JUNG et al.) 29 May 2008	
X Y	Whole document, especially paragraphs 17-19, 22-24, 29, 50-78, 91-94, 127,139, figures 5, 6, 9, 11, claims 1, 4, 10, 17, 22	1, 7, 13, 16, 17 18
	EP 2081313 A2 (INTEL CORPORATION) 22 July 2009	
X	figure 2 , paragraphs 34 to 41, 52-56	1, 2, 13,14
Y	Whole document, especially paragraph 40	3-6, 15
	WO 2006/071187 A2 (TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]) 6 July 2006	
X	Abstract, figure 2, page 5 lines 3-8, figures 5A, 5B, page 11 line 19 to page 12 line 22, page 15 lines 5-12, page 16 line 30 to page 18 line 16, page 22 lines 9-22, page 24 line 3 to page 25 line 16, claims	1, 2, 7, 8, 13, 14
	US 2007/0211786 A1 (SHATTIL) 13 September 2007	
X	Abstract, claim 1, figures 14, 59A, 59B, 109A, 109B, 110A, 110B paragraphs 411, 438, 439, 459, 460, 652, 653, 709-719, 779-788, 819-822, 1179,	1, 3-6, 13, 15
A	Figures 23A, 23B, 24 , paragraphs 779 to 807	9

[X] Further documents are listed in the continuation of Box C [X] 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 relevance

"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 another 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 relevance; 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 relevance; 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	Date of mailing of the international search report
19 January 2011	25 JAN 2011

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	**DALE E. SIVER** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2196

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ZHANG, S. et al. "Channel coding and decoding in a relay system operated with physical-layer network coding" 12 June 2009 IEEE Journal on Selected Areas of Communication Vol. 27, Issue 5 Abstract, Introduction, pages 9-11, Section IV	3-6 15, 18
X	ROSSETTO F. et al. "ON THE DESIGN OF PRACTICAL ASYNCHRONOUS PHYSICAL LAYER NETWORK CODING" IEEE 10th Workshop on Signal Processing Advances in Wireless Communication, SPAWC 21-24 June 2009 Abstract, Introduction, Section 1, Figures 1 and 2, Section 2 and Section 4	1, 7, 13
Y	Whole document, especially figure 2 and Section 2.	3
A	KATTI, S., "XORs in the Air: Practical Wireless Network Coding" June 2008 IEEE/ACM Transactions on Networking, Vol. 16, No. 3 June 2008 Whole document, especially figures 1 and 2	1, 7, 13

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	2008125032	KR	20080048584				
EP	2081313	CN	101534181	US	2009185521		
WO	2006071187	CN	101128997	EP	1834422	US	2009268662
US	2007211786	AU	26681/99	AU	59045/00	BR	9907892
		CA	2321748	CN	1296684	EP	1053615
		EP	1198903	ID	25666	US	5955992
		US	2002034191	US	6686879	US	6888887
		US	7010048	US	7076168	US	2004086027
		US	7317750	US	2003147655	US	7406261
		US	2004141548	US	7418043	US	7430257
		US	7593449	US	2004213351	US	7639597
		US	2004100897	US	7787514	US	2005232182
		US	7835455	US	2006227851	US	7839941
		US	2002150070	US	2007025421	US	2008310484
		US	2009110033	WO	0103330	WO	9941871

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX