



- (51) **International Patent Classification:**
H04B 7/005 (2006.01) *H04B 7/06* (2006.01)
- (21) **International Application Number:**
PCT/IB2015/051881
- (22) **International Filing Date:**
15 March 2015 (15.03.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
61/969,948 25 March 2014 (25.03.2014) US
14/639,140 5 March 2015 (05.03.2015) US
- (71) **Applicant:** MARVELL WORLD TRADE LTD.
[BB/BB]; L'Horizon, Gunsite Road, Brittons Hill, St. Michael, BB14027 (BB).
- (72) **Inventors:** MELZER, Ezer; 17A Moyal Street, 69351 Tel Aviv (IL). YELLIN, Daniel; 71 Herzl Street, 43353 Ra'anana (IL).
- (74) **Agent:** D. KLIGLER I.P. SERVICES LTD.; P.O. 57651, 61576 Tel Aviv (IL).
- (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, BN, 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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- with amended claims and statement (Art. 19(1))

Date of publication of the amended claims and statement: 10 December 2015

- (54) **Title:** LOW-COMPLEXITY COMMUNICATION TERMINAL WITH ENHANCED RECEIVE DIVERSITY

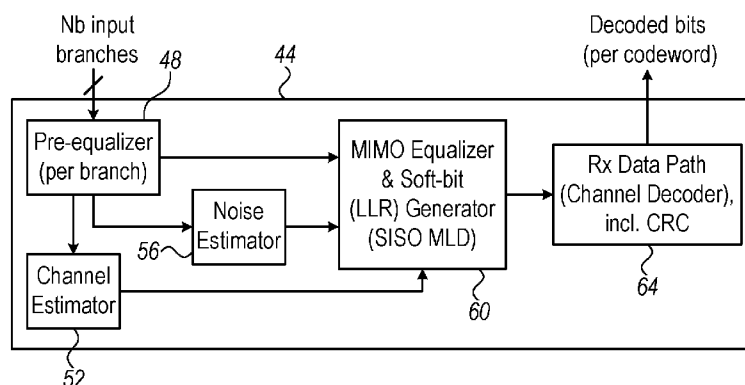


FIG. 2A

(57) **Abstract:** A method includes, in a receiver (20), receiving a signal carrying data using multiple antennas (24A...24D), so as to produce multiple respective input signals (S1... S4). The input signals are divided into two or more subsets. The input signals within each of the subsets are combined in a first diversity-combining stage (88, 96), to produce respective intermediate signals. In a second diversity-combining stage (92, 104), the intermediate signals are combined to produce an output signal. The output signal is decoded so as to reconstruct the data carried by the received signal.

AMENDED CLAIMS

received by the International Bureau on 22 October 2015 (22.10.2015)

1. A method, comprising:
 - in a receiver, receiving a signal carrying data using multiple antennas, so as to produce multiple respective input signals;
 - dividing the input signals into two or more subsets, by assessing a characteristic of a communication channel over which the signal is received and assigning the input signals to the subsets based on the characteristic;
 - in a first diversity-combining stage, combining the input signals within each of the subsets, to produce respective intermediate signals;
 - in a second diversity-combining stage, combining the intermediate signals to produce an output signal; and
 - decoding the output signal so as to reconstruct the data carried by the received signal.
2. The method according to claim 1, wherein combining the input signals comprises evaluating a respective error measure for one or more of the input signals, and selecting an input signal having a lowest error measure.
3. The method according to claim 1, wherein combining the intermediate signals comprises evaluating a respective error measure for one or more of the intermediate signals, and selecting an intermediate signal having a lowest error measure.
4. The method according to claim 1, wherein combining the input signals comprises generating a respective sequence of soft bits for each subset, and wherein combining the intermediate signals comprises combining the sequences of the soft bits.
5. The method according to claim 1, wherein combining the input signals comprises generating a respective sequence of soft symbols for each subset, and wherein combining the intermediate signals comprises combining the sequences of the soft symbols.
6. The method according to claim 5, wherein generating the soft symbols comprises estimating respective Signal-to-Noise Ratios (SNRs) for the soft symbols, and wherein combining the sequences comprises combining the soft symbols in accordance with the SNRs.
7. The method according to claim 1, wherein receiving the signal comprises estimating a noise covariance matrix for the multiple input signals, and wherein dividing the input signals into the subsets comprises nulling off-diagonal elements of the noise covariance matrix that are associated with pairs of the input signals that belong to different subsets.

8. The method according to claim 1, comprising computing and transmitting from the receiver Channel State Information (CSI) feedback that reflects performance of the first and second diversity-combining stages.
9. Apparatus, comprising:
reception circuitry, which is configured to receive a signal carrying data using multiple antennas, so as to produce multiple respective input signals; and
baseband processing circuitry, which is configured to divide the input signals into two or more subsets by assessing a characteristic of a communication channel over which the signal is received and assigning the input signals to the subsets based on the characteristic, to combine the input signals within each of the subsets in a first diversity-combining stage so as to produce respective intermediate signals, to combine the intermediate signals in a second diversity-combining stage so as to produce an output signal, and to decode the output signal so as to reconstruct the data carried by the received signal.
10. The apparatus according to claim 9, wherein the baseband processing circuitry is configured to generate a respective sequence of soft bits or soft symbols for each subset, and to combine the sequences of the soft bits or soft symbols.
11. The apparatus according to claim 9, wherein the baseband processing circuitry is configured to estimate a noise covariance matrix for the multiple input signals, and to null off-diagonal elements of the noise covariance matrix that are associated with pairs of the input signals that belong to different subsets.
12. A mobile communication terminal comprising the apparatus of claim 9.
13. A chipset for processing signals in a mobile communication terminal, comprising the apparatus of claim 9.
14. A method, comprising:
in a receiver that includes multiple antennas and multiple receiver chains, evaluating a criterion and, based on the criterion, selecting a mode from:
a first mode, in which one or more of the antennas are disconnected, and at least one of the remaining antennas is connected to more than one of the receiver chains; and
a second mode, in which each of the antennas is connected to a respective receiver chain; and

receiving a signal using the multiple receiver chains in accordance with the selected mode.

15. The method according to claim 14, wherein evaluating the criterion comprises selecting the first mode when the signal comprises a Carrier Aggregation (CA) signal, and selecting the second mode when the signal comprises a non-CA signal.

16. The method according to claim 14, wherein receiving the signal comprises, when the selected mode comprises the second mode, diversity-combining the signal received via two or more of the receiver chains.

17. Apparatus, comprising:

reception circuitry, comprising multiple receiver chains coupled to multiple antennas; and

baseband processing circuitry, which is configured to evaluate a criterion, to select based on the criterion a mode from among a first mode, in which one or more of the antennas are disconnected and at least one of the remaining antennas is connected to more than one of the receiver chains, and a second mode in which each of the antennas is connected to a respective receiver chain, and to receive a signal using the multiple receiver chains in accordance with the selected mode.

18. The apparatus according to claim 17, wherein, when the selected mode comprises the second mode, the baseband processing circuitry is configured to diversity-combine the signal received via two or more of the receiver chains.

STATEMENT UNDER ARTICLE 19(1)

Applicant submits herewith an amendment to claims 1-20 in this application.

Independent claim 1 has been amended to incorporate the features of dependent claim 2, further reciting that dividing the input signals into the two or more subsets comprises assessing a characteristic of a communication channel over which the signal is received and assigning the input signals to the subsets based on the characteristic. There is no teaching or suggestion of the features in the references that were cited in the International Search Report. Original claim 2 has been canceled. Original claims 3-9 have been renumbered 2-8 and dependencies were amended as appropriate.

Original Independent claim 10 has been renumbered 9, and amended to incorporate the features of original dependent claim 11, further reciting that the baseband processing circuitry is configured to divide the input signals into the two or more subsets by assessing a characteristic of a communication channel over which the signal is received and assigning the input signals to the subsets based on the characteristic. There is no teaching or suggestion of the features in the references that were cited in the International Search Report. Original claim 11 has been canceled. Original claims 12-20 have been renumbered 10-18 and dependencies were amended as appropriate.