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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 July 2008 (24.07.2008)

PCT

(10) International Publication Number
WO 2008/088194 A1

(51) International Patent Classification:
H04B 7/04 (2006.01)

(21) International Application Number:
PCT/KR2008/000327

(22) International Filing Date: 18 January 2008 (18.01.2008)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
10-2007-0005715 18 January 2007 (18.01.2007) KR

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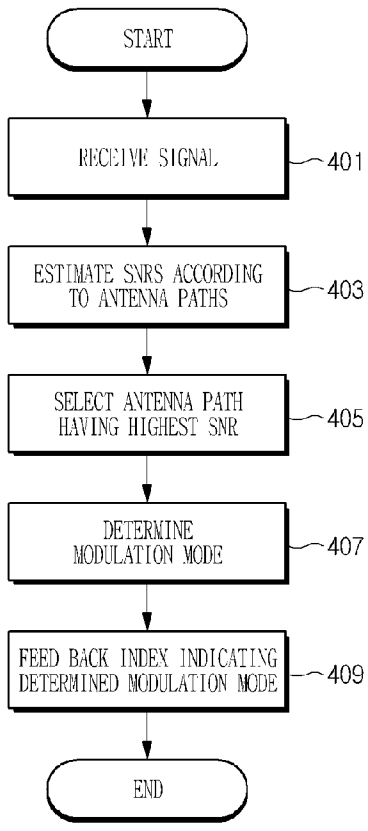
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, 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, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, 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: METHOD AND APPARATUS FOR TRANSMITTING AND RECEIVING A SIGNAL IN A COMMUNICATION SYSTEM

[Fig. 4]



(57) Abstract: A method and apparatus for transmitting and receiving a signal in a communication system are provided. The method includes setting a range of a Signal-to-Noise Ratio (SNR) having a varying threshold value according to a target Bit Error Rate (BER), receiving a signal from the transmitter through the wireless channel, measuring SNRs of all the antennas, selecting an antenna having the highest SNR among the measured antenna- specific SNRs, determining a range corresponding to the SNR of the selected antenna on the basis of the target BER and the set SNR range, and determining a modulation mode according to the range, and transmitting the determined modulation mode to the transmitter.

WO 2008/088194 A1

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, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

Description

METHOD AND APPARATUS FOR TRANSMITTING AND RECEIVING A SIGNAL IN A COMMUNICATION SYSTEM

Technical Field

[1] The present invention relates to a method and an apparatus for transmitting and receiving a signal in a communication system, and more particularly, to a method and an apparatus for selecting a path of a receiving antenna, applying an adaptive modulation scheme according to the selected path, and transmitting and receiving a signal in a communication system in which a receiver has a plurality of receiving antennas.

Background Art

[2] Current mobile communication systems are developing into next-generation mobile communication systems for providing service capable of transmitting and receiving a large amount of data at high speed. In a wireless channel environment of mobile communication systems, unlike in a wired channel environment, errors occur due to various reasons, such as multipath interference, shadowing, attenuation of electric waves, time-varying noise, interference and fading, etc. For this reason, not only data is lost, but also the available frequency band of a wireless channel is limited.

[3] Therefore, next-generation mobile communication systems must use limited frequency band and power resources for the sake of a high transmission rate and reliable transmission in a channel of a varying wireless environment. Adaptive modulation and antenna diversity are the most important factors making such technology possible in the next-generation mobile communication systems. The adaptive modulation scheme serves to improve frequency efficiency in a wireless channel environment. To use a varying channel while maintaining an instantaneous error rate below a reference value, the adaptive modulation scheme adaptively applies a modulation scheme by adjusting a modulation parameter such as a constellation size and a coding rate. In general, a modulation mode is selected based on a comparison result between some previously determined reference values and received signal intensity. In other words, a transmitter receives channel state information of a transceiver channel fed back from a receiver. Here, when the channel state is good, the transmitter may use a modulation scheme having a high transmission rate to transmit a signal. On the other hand, when the channel state is not good, the transmitter may use a modulation scheme having a low transmission rate to reduce an error rate.

[4] Meanwhile, diversity techniques are being used to remove instability of communication due to fading. According to an antenna diversity scheme among the

diversity techniques, a receiver has a plurality of antennas to transmit and receive a signal using an antenna having a good channel or through multiple paths.

[5] When there are a plurality of receiving antennas, the optimum antenna combining method among antenna diversity schemes is well-known Maximum Ratio Combining (MRC). An output of a receiving end processed by MRC is a signal into which all diversity antenna signals are combined to maximize a Signal-to-Noise Ratio (SNR). However, the more diversity paths, the higher the execution complexity of MRC. MRC requires as many Radio Frequency (RF) chains as the number of available diversity paths and must simultaneously obtain complete channel state information of respective diversity paths. To reduce execution complexity of an MRC diversity combiner, Generalized Selection Combining (GSC) has been proposed and is being widely researched. A GSC receiver combines a predetermined number of the best diversity paths according to the rule of the optimum MRC scheme. As GSC schemes, there are Minimum Selection GSC (MS-GSC) and Output-Threshold MRC (OT-MRC). However, MRC and GSC involve high complexity to combine signals, and thus selection diversity or switched diversity may be used to reduce the complexity.

[6] However, such conventional diversity combining schemes have not only been researched separately from the adaptive modulation scheme but also never been considered in association with the adaptive modulation scheme. But today, to efficiently use limited resources of wireless channels and improve reliability, it is necessary to combine the diversity schemes with the adaptive modulation scheme.

Disclosure of Invention

Technical Problem

[7] The present invention is directed to a method and apparatus for transmitting and receiving a signal in a communication system which combine an adaptive modulation scheme with a switched diversity scheme and thus can efficiently transmit data while ensuring reliability.

Technical Solution

[8] One aspect of the present invention provides a method of transmitting and receiving a signal at a receiver connected with a transmitter through a wireless channel and including a plurality of antennas, the method including: setting a range of a Signal-to-Noise Ratio (SNR) having a threshold value varying according to a target Bit Error Rate (BER); receiving a signal from the transmitter through the wireless channel; measuring SNRs of all the antennas; selecting an antenna having the highest SNR among the measured antenna-specific SNRs; determining a range corresponding to the SNR of the selected antenna on the basis of the target BER and the set SNR range, and determining a modulation mode according to the range; and transmitting the

determined modulation mode to the transmitter.

[9] The method may further include receiving a signal modulated according to the determined modulation mode and transmitted by the transmitter. Determining the modulation mode may include comparing the SNR of the selected antenna with a threshold value

γ_{T_n}

(n =N, N-1, ..., 2) for determining the modulation mode, and determining n as the modulation mode when the SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

.

[10] Another aspect of the present invention provides a method of transmitting and receiving a signal at a receiver connected with a transmitter through a wireless channel and including a plurality of antennas, the method including: receiving a signal from the transmitter through the wireless channel; measuring an SNR of a current antenna among the antennas; comparing the measured SNR with a predetermined reference value; determining the measured SNR as an output SNR when the measured SNR is greater than or equal to the reference value as a result of the comparison, and switching to another antenna and determining an SNR of the switched antenna as an output SNR when the measured SNR is less than the reference value; determining a modulation mode using the determined output SNR and transmitting the determined modulation mode to the transmitter.

[11] The current antenna may be an antenna previously used to receive a signal from the transmitter. The method may further include receiving a signal modulated according to the determined modulation mode and transmitted by the transmitter. Determining the modulation mode may include comparing the SNR of the selected antenna with a threshold value

γ_{T_n}

(n = N, N-1, ..., 2) for determining the modulation mode, and determine n as the modulation mode when the SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

.

[12] Still another aspect of the present invention provides a method of transmitting and receiving a signal at a receiver connected with a transmitter through a wireless channel and including a plurality of antennas, the method including: receiving a signal from the transmitter through the wireless channel; measuring an SNR of a current antenna among the antennas; comparing the measured SNR with a predetermined reference value; determining the measured SNR as an output SNR when the measured SNR is greater than or equal to the reference value as a result of the comparison, switching to another antenna when the measured SNR is less than the reference value, and determining an SNR of the switched antenna as an output SNR when the SNR of the switched antenna is greater than or equal to the reference value; determining a modulation mode using the determined output SNR; and transmitting the determined modulation mode to the transmitter.

[13] Determining the output SNR may include determining an SNR of the latest switched antenna as the output SNR when SNRs of all the antennas are less than the reference value. Determining the output SNR may include determining the highest SNR among SNRs of all the antennas as the output SNR when the SNRs of all the antennas are less than the reference value. The method may further include receiving a signal modulated according to the determined modulation mode and transmitted by the transmitter. Determining the modulation mode may include comparing the SNR of the selected antenna with a threshold value

γ_{T_n}

(n = N, N-1, ..., 2) for determining the modulation mode, and determining n as the modulation mode when the SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

. The reference value may be a threshold value

γ_{T_N}

. The reference value may be a threshold value

γ_{T_2}

. Determining the output SNR may include requesting, at the receiver, the transmitter to transmit a signal using a Quadrature Phase Shift Keying (QPSK) modulation scheme when SNRs of all the antennas are less than a threshold value

γ_{T_2}

. Determining the output SNR may include transmitting, at the receiver, a request to store data and wait for a next guard period to the transmitter when SNRs of all the antennas are less than a threshold value

γ_{T_2}

. The signal may include a guard period.

[14] Yet another aspect of the present invention provides an apparatus for transmitting and receiving a signal, including: a transmitter modulating a signal according to a modulation mode fed back from a receiver and transmitting the modulated signal; and a receiver including a plurality of antennas, selecting an antenna to receive the signal transmitted from the transmitter among the antennas, determining a modulation mode corresponding to an SNR of the selected antenna, and feeding back the modulation mode to the transmitter.

[15] The receiver may include: a transceiver for receiving the signal and transmitting the determined modulation mode to the transmitter through the antennas; an SNR measurer for measuring SNRs of the antennas with respect to the received signal; an antenna path selector for selecting the antenna to receive the signal and a modulation mode determiner for determining the modulation mode using the SNR of the antenna selected by the antenna path selector.

Advantageous Effects

[16] According to the present invention, an adaptive modulation scheme is combined with a switched diversity scheme, and thus it is possible to provide a method and an apparatus for transmitting and receiving a signal in a communication system which can efficiently transmit data while ensuring reliability.

[17] The method and apparatus for transmitting and receiving a signal according to the present invention, in which an adaptive modulation scheme and a switched diversity scheme are combined in various ways, have low execution complexity and may be used in a Wireless Personal Area Network (WPAN) system based on oncoming Millimeter (MM) waves.

Brief Description of the Drawings

[18] FIG. 1 is a block diagram of an apparatus for transmitting and receiving a signal according to an exemplary embodiment of the present invention.

[19] FIG. 2 is a block diagram of a receiver according to an exemplary embodiment of the present invention.

[20] FIG. 3 is a signal flowchart between a transmitter and a receiver according to an exemplary embodiment of the present invention.

[21] FIG. 4 is a flowchart showing a signal transmitting and receiving process to which an adaptive modulation scheme is applied by Selection Combining (SC) according to a first exemplary embodiment of the present invention.

[22] FIG. 5 is a flowchart showing a signal transmitting and receiving process to which an adaptive modulation scheme is applied by Switched-and-Stay Combining (SSC) according to a second exemplary embodiment of the present invention.

[23] FIG. 6 is a flowchart showing a signal transmitting and receiving process to which an adaptive modulation scheme is applied by Switch-and-Examine Combining (SEC) according to a third exemplary embodiment of the present invention.

[24] FIG. 7 is a graph showing average frequency efficiency based on SC according to an exemplary embodiment of the present invention.

[25] FIG. 8 is a graph showing an average error rate based on SC according to an exemplary embodiment of the present invention.

[26] FIG. 9 is a graph showing average frequency efficiency based on an SEC-based minimum estimation scheme according to an exemplary embodiment of the present invention.

[27] FIG. 10 is a graph showing an average error rate based on an SEC-based minimum estimation scheme according to an exemplary embodiment of the present invention.

[28] FIG. 11 is a graph showing average frequency efficiency based on an SEC-based bandwidth-efficient scheme according to an exemplary embodiment of the present invention.

[29] FIG. 12 is a graph showing an average error rate based on an SEC-based bandwidth-efficient scheme according to an exemplary embodiment of the present invention.

[30] FIGS. 13 to 16 are graphs showing performance and frequency efficiency of SEC with post-examining selection (SECps) based on a minimum estimation scheme and a bandwidth-efficient scheme according to an exemplary embodiment of the present invention.

Best Mode for Carrying Out the Invention

[31] Hereinafter, an exemplary embodiment of the present invention will be described in detail with reference to the accompanying drawings. However, the present invention is not limited to the exemplary embodiment disclosed below, but can be implemented in various types. Therefore, the present exemplary embodiment isprovided for complete disclosure of the present invention and to fully inform the scope of the present invention to those ordinarily skilled in the art.

[32] FIG. 1 is a block diagram of an apparatus for transmitting and receiving a signal according to an exemplary embodiment of the present invention.

[33] Referring to FIG. 1, the apparatus for transmitting and receiving a signal according to an exemplary embodiment of the present invention includes a transmitter 101 and a receiver 110. The transmitter 101 includes a modulator 102 and an antenna 104, and the receiver 110 includes a plurality of antennas 112 and a diversity combiner 114. A signal to be transmitted from the transmitter 101 to the receiver 110 is modulated by the modulator 102 and transmitted through the antenna 104. The transmitted signal passed through a wireless channel is input to the diversity combiner 114 through the receiving antennas 112. The diversity combiner 114 detects the transmitted original signal using one of various diversity techniques.

[34] The modulator 102 performs an adaptive modulation scheme according to an environment of the wireless channel. Here, M-ary Quadrature Amplitude Modulation (M-QAM) is applied according to the wireless channel environment. Unlike a conventional adaptive modulation scheme, according to the adaptive modulation scheme of the present invention, a modulation mode determined in the receiver 110 is fed back to the transmitter 101, and then adaptive modulation is performed according to the determined modulation mode. In particular, when Signal-to-Noise Ratios (SNRs) are classified into N regions, an SNR of a final output signal from the diversity combiner 114 belongs to one of the N regions. More specifically, when the SNR of the final output signal from the diversity combiner 114 belongs to an n-th region

$(\gamma_{T_n}, \gamma_{T_{n+1}})$

among the N regions, the receiver 110 feeds back a modulation mode index of n to the transmitter 101, and the transmitter 101 performs 2^n-QAM. Here, n has a value of 2 to N, and a constellation size is denoted by $2^n = M$.

[35] Respective threshold values

γ_{T_n}

of the N regions vary according to a target Bit Error Rate (BER). In the cases of the target BER being 1 %, 0.1 % and 0.01%, threshold values by which respective modulation levels are classified are shown in Table 1 below.

[36] Table 1

n	γ_{T_n} [dB] for $\mathrm{BER}_0 = 10^{-2}$	γ_{T_n} [dB] for $\mathrm{BER}_0 = 10^{-3}$	γ_{T_n} [dB] for $\mathrm{BER}_0 = 10^{-4}$
2	7.33	9.64	11.35
3	11.84	13.32	16.07
4	13.90	16.63	18.23
5	17.83	19.79	22.29
6	19.73	22.86	24.30
7	23.85	25.91	28.24
8	25.43	28.94	30.23

[37] Meanwhile, the receiver 110 receives a signal transmitted from the transmitter 101 through the L antennas 112, and the diversity combiner 114 determines a receiving antenna path among paths of the antennas 112. The receiver 110 estimates an output SNR of the antenna path determined by the diversity combiner 114 and determines a modulation mode according to the output SNR. The receiver 110 feeds back an index indicating the determined modulation mode to the transmitter 101. Here, a short guard period preferably be inserted in the signal in consideration of a time for determining a diversity antenna path for the received signal and the modulation mode by the receiver 110.

[38] FIG. 2 is a block diagram of a receiver according to an exemplary embodiment of the present invention.

[39] Referring to FIG. 2, the receiver includes a transceiver 201, an SNR measurer 203, an antenna path selector 205 and a modulation mode determiner 207. Here, the SNR measurer 203, the antenna path selector 205 and the modulation mode determiner 207 may correspond to the diversity combiner 114 of the receiver 110 shown in FIG. 1.

[40] The transceiver 201 includes a plurality of antennas, receives a signal transmitted from a transmitter through the antennas, and transfers the signal to the SNR measurer 203 and the antenna path selector 205. In addition, the transceiver 201 serves to transfer information on a modulation mode determined by the modulation mode determiner 207.

[41] The SNR measurer 203 measures SNRs of the signal received by the transceiver 201 according to antenna paths, and transfers the measured antenna-path-specific SNRs to the antenna path selector 205. The antenna path selector 205 determines an antenna path for receiving the transmitted signal on the basis of the antenna-path-specific SNRs measured by the SNR measurer 203. There are three methods for the antenna path selector 205 to select an antenna path.

[42] A first method is Selection Combining (SC), which compares SNRs of all the

antennas of the transceiver 201 to select an antenna path having the highest SNR. A second method is Switched-and-Stay Combining (SSC), which switches a current antenna path to another antenna path when an SNR of the current antenna path becomes less than a specific threshold value. A third method is Switch-and-Examine Combining (SEC), which searches for and switches to an antenna path having a higher SNR than a specific threshold value when an SNR of a current antenna path becomes less than the threshold value, and selects the latest antenna path when SNRs of all antenna paths are less than the threshold value. SEC with post-examining selection (SECps), which is a modified SEC scheme, selects and switches to an antenna path having the highest SNR when SNRs of all antenna paths are less than a specific threshold value. The first one among the antenna path selection methods belongs to a selection-diversity scheme, and the second and third methods belong to switched diversity schemes. Respective embodiments using the three schemes will be described later in detail with reference to FIGS. 4 to 6.

[43] The modulation mode determiner 207 determines a modulation mode using an SNR, i.e., an output SNR, of the antenna path determined by the antenna path selector 205. Here, the method for the modulation mode determiner 207 to determine a modulation mode has been described above in detail with reference to FIG. 1. A modulation mode index indicating the modulation mode determined by the modulation mode determiner 207 is fed back to the transmitter through the transceiver 201. In a next period, the transmitter modulates a signal according to the fed-back modulation mode and transmits the modulated signal.

[44] FIG. 3 is a signal flowchart between a transmitter and a receiver according to an exemplary embodiment of the present invention.

[45] Referring to FIG. 3, the transmitter modulates a signal to be transmitted and then transmits the modulated signal to the receiver (step 301). Here, the receiver receives the signal through a plurality of antennas. Subsequently, the receiver selects an antenna path for receiving a signal among the antennas and determines a modulation mode according to an SNR of the selected antenna path (step 303). Then, the receiver transmits information on the determined modulation mode to the transmitter (step 305). Here, the modulation mode information may be the modulation mode index described with reference to FIG. 1. The transmitter receiving the modulation mode information modulates a signal according to the modulation scheme determined by the receiver and then transmits the modulated signal to the receiver (step 307).

[46] <First exemplary embodiment>

[47] SC and adaptive modulation are applied to a first exemplary embodiment. Since SC compares SNRs of all the received signals through all the antennas of a transceiver to select an antenna path having the highest SNR, it is possible to select an antenna with

the best signal quality at all times. However, SC requires high complexity to select an antenna.

[48] FIG. 4 is a flowchart showing a signal transmitting and receiving process to which SC and the adaptive modulation scheme are applied according to the first exemplary embodiment of the present invention.

[49] Referring to FIG. 4, a receiver receives a signal transmitted from a transmitter through a plurality of antennas (step 401). The receiver measures SNRs according to respective antenna paths (step 403).

[50] When the number of antennas of the receiver is L, the respective antenna-path-specific SNRs are

$\gamma_1, \gamma_2, \cdots, \gamma_l$

. A diversity combiner of the receiver selects an antenna path corresponding to the highest of the antenna-path-specific SNRs (step 405). The receiver determines the highest value

γ_c

among

$\gamma_1, \gamma_2, \cdots, \gamma_l$

as an output SNR, and compares the output SNR with an SNR threshold value

γ_{T_n}

(n = N, N-1, …, 2) shown in Table 1 to determine a modulation mode (step 407). When the output SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

, the receiver determines 2^n-QAM as a modulation mode.

[51] The receiver feeds back an index indicating the determined modulation mode to the transmitter (step 409). The transmitter modulates a subsequent data signal according to the modulation mode and transmits the modulated data signal to the receiver. Meanwhile, when the SNRs of all the antenna paths are less than

γ_{T_2}

, that is, the output SNR is less than

γ_{T_2}

, the receiver may operate according to one of two options in step 409. The receiver may request the transmitter to transmit a signal using the lowest modulation mode in violation of a target BER, i.e., a Quadrature Phase Shift Keying (QPSK) modulation scheme (option 1). Otherwise, the receiver may request the transmitter to store data in a buffer and wait for a better channel environment until a next guard period (option 2).

[52] FIG. 7 is a graph showing average frequency efficiency based on SC according to the two options. Here, L denotes the number of antennas of a receiver. As illustrated in FIG. 7, the more the antennas, the higher the average frequency efficiency. When there is the same number of antennas, the two options have almost the same performance in a high SNR region. On the other hand, option 1 has higher frequency efficiency than option 2 in a low SNR region. This is because when a channel state is not good, option 1 violates a target BER condition to transmit data while option 2 stores data in a buffer and waits.

[53] It is possible to observe violation of a BER condition in FIG. 8. FIG. 8 is a graph showing an average error rate based on SC. Referring to FIG. 8, an average BER of option 1 is greater than a target BER of 10^{-3} in a low SNR region. According to option 1, an increase in the number of antennas considerably reduces an SNR section violating a BER condition. On the other hand, according to option 2, an increase in the number of antennas renders high performance with respect to a BER in a very high SNR section only.

[54] <Second exemplary embodiment>

[55] SSC and adaptive modulation are applied to a second exemplary embodiment. In comparison with SC, SSC does not compare all antenna paths but measures an SNR of a current antenna alone, and thus complexity for a receiver to select an antenna is reduced. However, SSC cannot ensure signal quality of a switched antenna. SSC is based on an assumption that signal quality of one antenna is probably good when signal quality of the other antenna is poor. SSC may be of no use when the number of antennas is three or more.

[56] FIG. 5 is a flowchart showing a signal transmitting and receiving process to which SSC and the adaptive modulation scheme are applied according to the second exemplary embodiment of the present invention.

[57] Referring to FIG. 5, a receiver receives a signal transmitted from a transmitter through a plurality of antennas (step 501). The receiver determines whether an SNR of a current antenna path with respect to the received signal is greater than or equal to a specific reference value (step 503).

[58] When it is determined that the current SNR is greater than or equal to the reference value as a result of the comparison, the process proceeds to step 507. On the other hand, when it is determined that the current SNR is less than the reference value, the

process proceeds to step 505. In step 505, that is, when the current SNR is less than the reference value, the receiver switches the current antenna path to another antenna path and then performs step 507 and subsequent steps.

[59] In step 507, the receiver determines an SNR of the current antenna path as an output SNR. Subsequently, the receiver determines a modulation mode corresponding to the output SNR (step 509). Here, the receiver determines a modulation mode in the same method as described in step 407 of FIG. 4. Subsequently, the receiver feeds back an index indicating the determined modulation mode to the transmitter (step 511).

[60] <Third exemplary embodiment>

[61] SEC and adaptive modulation are applied to a third exemplary embodiment. SEC is a scheme of searching for and switching to an antenna path having a higher SNR than a reference value when signal quality, that is, a reception SNR becomes less than the reference value. SSC is different from SEC in that a current antenna is switched to another antenna without consideration of an SNR of another antenna when a reception SNR is less than a reference value. Meanwhile, according to SEC, an antenna having a higher SNR than the reference SNR may not be found though a receiver switches to all antennas. In this case, the receiver selects the latest antenna. Here, the receiver may select and switch to an antenna path having the highest SNR, which is referred to as SECps.

[62] The third exemplary embodiment of the present invention may use a minimum estimation scheme and a bandwidth-efficient scheme according to what the reference value is.

[63] First, the minimum estimation scheme will be described below.

[64] The minimum estimation scheme is intended to minimize the number of times that a receiver estimates a path to select a path. Here, the receiver sets the lowest reference value

γ_{T_2}

as a reference value for SEC. When an SNR of a current antenna is greater than or equal to the reference value

γ_{T_2}

, the receiver determines the SNR of the current antenna path as an output SNR and compares it with threshold values

$\gamma_{T_3}, \gamma_{T_4}, \cdots, \gamma_{T_n}$

for determining a modulation mode. When the output SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

, the receiver determines n as a modulation mode. Here, the modulation scheme becomes 2^n-QAM. The receiver feeds back the determined modulation mode to a transmitter, and the transmitter modulates a subsequent data burst according to the fed-back modulation scheme.

[65] Meanwhile, when SNRs of all antenna paths are lower than

γ_{T_2}

, that is, the output SNR is less than

γ_{T_2}

, the receiver may perform one of two options below. The receiver may request the transmitter to transmit a signal using the lowest modulation mode in violation of a target BER, i.e., the QPSK modulation scheme (option 1). Otherwise, the receiver may request the transmitter to store data in a buffer and wait for a better channel environment until a next guard period (option 2). According to option 1, the receiver receives a signal via the latest antenna path in the case of SEC, and searches for the best antenna path and receives a signal via the antenna path in the case of SECps.

[66] Next, the bandwidth-efficient scheme will be described below.

[67] The bandwidth-efficient scheme is intended to maximize frequency efficiency. To increase frequency efficiency, a receiver needs the highest modulation mode in a process of combining antenna diversity. More specifically, the receiver determines the highest value

γ_{T_N}

as a reference value in a process of performing SEC or SECps. When an SNR of a current antenna path is greater than or equal to the reference value

γ_{T_N}

, the receiver stops path estimation and received data through the current antenna. In addition, the receiver requests a transmitter to modulate a subsequent data burst using 2^n-QAM and transmit the modulate data burst. When the SNR of the current antenna path becomes less than the reference value

γ_{T_N}

, the receiver searches for and switches to an antenna path having an SNR greater than or equal to the reference value

γ_{T_N}

. When SNRs of all antennas are less than the reference value

γ_{T_N}

, the receiver determines an SNR of the latest antenna path as an output SNR in the case of SEC, and compares the SNRs of all antennas and determines the highest SNR as an output SNR in the case of SECps. The receiver compares the output SNR with threshold values

$\gamma_{T_{N-1}}, \gamma_{T_{N-2}}, \cdots, \gamma_{T_2}$

for determining a modulation mode, and determines n as a modulation mode when the output SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

. Subsequently, the receiver feeds back the determined modulation mode to the transmitter for modulation of the subsequent data burst.

[68] Meanwhile, in the worst case, that is, when the SNRs of all the antenna paths are less than

γ_{T_2}

, the bandwidth-efficient scheme may operate according to two options in the same manner as the minimum estimation scheme. The receiver may request the transmitter to transmit a signal using the lowest modulation mode in violation of a target BER, i.e., the QPSK modulation scheme (option 1). Otherwise, the receiver may request the transmitter to store data in a buffer and wait for a better channel environment until a next guard period (option 2).

[69] A process of transmitting and receiving a signal according to the third exemplary embodiment of the present invention including the minimum estimation scheme and the bandwidth-efficient scheme is shown in FIG. 6. FIG. 6 is a flowchart showing a signal transmitting and receiving process to which SEC and an adaptive modulation scheme are applied according to a third exemplary embodiment of the present invention.

[70] Referring to FIG. 6, a receiver receives a signal transmitted from a transmitter through a plurality of antennas (step 601). The receiver determines whether an SNR of a current antenna path with respect to the received signal is greater than or equal to a

specific reference value (step 603).

[71] When it is determined that the SNR of the current antenna path is greater than or equal to the reference value, the process proceeds to step 611. On the other hand, when it is determined that the SNR of the current antenna path is less than the reference value, the process proceeds to step 605. In step 605, the receiver determines whether another antenna path exists. When another antenna path exists, the receiver performs step 607. On the other hand, when another antenna path does not exist, the receiver performs step 609.

[72] In step 607, the receiver selects another antenna path and estimates an SNR of the selected antenna path. Subsequently, the receiver determines whether the estimated SNR is greater than or equal to the reference value in step 603. Step 609 is performed when SNRs of all antenna paths are less than the reference value, and may be omitted in the case of minimum estimation scheme. In step 609, the receiver selects an antenna path having the highest SNR among the SNRs of all the antenna paths less than the reference value.

[73] In step 611, the receiver determines an SNR of the current antenna path as an output SNR. Subsequently, the receiver determines a modulation mode corresponding to the output SNR (step 613), and then feeds back an index indicating the determined modulation mode to the transmitter (step 615).

[74] The above-described embodiments employing adaptive modulation and switched combining are in a trade-off relation between frequency efficiency and average BER.

[75] FIG. 9 is a graph showing average frequency efficiency based on an SEC-based minimum estimation scheme according to an exemplary embodiment of the present invention. In a high SNR region, average frequency efficiency graphs of the two options overlap each other regardless of the number of antennas. This is because when a channel state is good, an SNR of a first path is greater than or equal to a reference value and thus is probably used for selecting a modulation mode. In addition, it can be seen from FIG. 9 that an increase in the number of receiving antennas according to option 2 increases efficiency more than an increase in the number of receiving antennas according to option 1 in a low-to-medium SNR region. According to option 2, a probability that data cannot be transmitted is reduced according to the increase in the number of receiving antennas.

[76] In a low SNR region, option 1 has higher frequency efficiency than option 2. This is because when a channel state is not good, option 1 violates a target BER condition to transmit data while option 2 stores data in a buffer and waits. It is possible to observe violation of a BER condition in FIG. 10. FIG. 10 is a graph showing an average error rate according to an SEC-based minimum estimation scheme. In a low-to-medium SNR region, option 1 violates a target BER at all times, but option 2 satisfies a target

BER condition. In addition, an increase in the number of receiving antennas considerably reduces BER violation according to option 1 but is no use for BER performance according to option 2.

[77] FIG. 11 is a graph showing average frequency efficiency according to an SEC-based bandwidth-efficient scheme. Referring to FIG. 11, an increase in the number of receiving antennas does not remarkably increase frequency efficiency in a low-to-medium SNR region according to either of the two options, unlike the minimum estimation scheme. For the same reason as described above, option 1 has higher frequency efficiency than option 2. In a high SNR region, an increase in the number of receiving antennas may considerably increase frequency efficiency according to both of the two options. This is because an increasing number of receiving antennas upon a good channel state increases a probability that a constellation size of a modulation scheme increases. On the other hand, when the channel state is not good, it is difficult to use the largest constellation size, and a receiver uses a constellation size based on the latest-searched path at all times. Consequently, a system cannot obtain a receiving antenna diversity effect.

[78] FIG. 12 is a graph showing an average error rate based on an SEC-based bandwidth-efficient scheme according to an exemplary embodiment of the present invention. While option 1 violates a required BER in a low SNR region, option 2 satisfies the required BER at all times. In addition, an increase in the number of receiving antennas improves BER performance of option 1 but hardly has influence on BER performance of option 2 in a high SNR region.

[79] FIGS. 13 to 16 are graphs showing performance and frequency efficiency of SECps based on the minimum estimation scheme and the bandwidth-efficient scheme.

[80] Referring to FIGS. 13 and 14, the SECps-based minimum estimation scheme has very similar frequency efficiency and performance to the SEC-based minimum estimation scheme. On the other hand, under the SECps-based minimum estimation scheme error performance in a low SNR region according to option 1 can be expected to be improved. This is because an undesirable path is occasionally switched to the best path.

[81] Referring to FIG. 15, unlike the SEC-based bandwidth-efficient scheme, the SECps-based bandwidth-efficient scheme has performance improving according to an increase in the number of antennas in the entire SNR region. When a modulation scheme having the largest constellation cannot be used, the SECps-based bandwidth-efficient scheme uses the best path and thus can use a modulation scheme having a larger constellation than the SEC-based bandwidth-efficient scheme. Comparing FIGS. 15 and 7, the SECps-based bandwidth-efficient scheme can have almost the same frequency efficiency as SC. Referring to FIG. 16, with an increase in the number of

receiving antennas, BER performance of the SECps-based bandwidth-efficient scheme considerably increases according to option 1 rather than option 2. As illustrated in FIG. 8, the SECps-based bandwidth-efficient scheme has similar BER performance to SC according to option 1.

[82] While the invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

[1] A method of transmitting and receiving a signal at a receiver which is connected with a transmitter through a wireless channel and includes a plurality of antennas, the method comprising:
setting a range of a Signal-to-Noise Ratio (SNR) having a threshold value varying according to a target Bit Error Rate (BER);
receiving a signal from the transmitter through the wireless channel;
measuring SNRs of all the antennas;
selecting an antenna having the highest SNR among the measured antenna-specific SNRs;
determining a range corresponding to the SNR of the selected antenna on the basis of the target BER and the setSNR range, and determining a modulation mode according to the range; and
transmitting the determined modulation mode to the transmitter.

[2] The method of claim 1, further comprising:
receiving a signal modulated according to the determined modulation mode and transmitted by the transmitter.

[3] The method of claim 1, wherein determining the modulation mode comprises comparing the SNR of the selected antenna with a threshold value

γ_{T_n}

(n = N, N-1, ..., 2) for determining the modulation mode, and determining n as the modulation mode when the SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

.

[4] A method of transmitting and receiving a signal at a receiver connected with a transmitter through a wireless channel and including a plurality of antennas, the method comprising:
receiving a signal from the transmitter through the wireless channel;
measuring a Signal-to-Noise Ratio (SNR)of a current antenna among the antennas;
comparing the measured SNR with a predetermined reference value;
determining the measured SNR as an output SNR when the measured SNR is greater than or equal to the reference value as a result of the comparison, and

switching to another antenna and determining an SNR of the switched antenna as an output SNR when the measured SNR is less than the reference value;
determining a modulation mode using the determined output SNR; and
transmitting the determined modulation mode to the transmitter.

[5] The method of claim 4, wherein the current antenna is an antenna previously used to receive a signal from the transmitter.

[6] The method of claim 4, further comprising:
receiving a signal modulated according to the determined modulation mode and transmitted by the transmitter.

[7] The method of claim 4, wherein determining the modulation mode comprises comparing the SNR of the selected antenna with a threshold value

γ_{T_n}

(n = N, N-1, ..., 2) for determining the modulation mode, and determining n as the modulation mode when the SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

.

[8] A method of transmitting and receiving a signal at a receiver connected with a transmitter through a wireless channel and including a plurality of antennas, the method comprising:
receiving a signal from the transmitter through the wireless channel;
measuring a Signal-to-Noise Ratio (SNR) of a current antenna among the antennas;
comparing the measured SNR with a predetermined reference value;
determining the measured SNR as an output SNR when the measured SNR is greater than or equal to the reference value as a result of the comparison, switching to another antenna when the measured SNR is less than the reference value, and determining an SNR of the switched antenna as an output SNR when the SNR of the switched antenna is greater than or equal to the reference value;
determining a modulation mode using the determined output SNR; and
transmitting the determined modulation mode to the transmitter.

[9] The method of claim 8, wherein determining the output SNR comprises determining an SNR of the latest switched antenna as the output SNR when SNRs of all the antennas are less than the reference value.

[10] The method of claim 8, wherein determining the output SNR comprises de-

termining the highest SNR among SNRs of all the antennas as the output SNR when the SNRs of all the antennas are less than the reference value.

[11] The method of claim 8, further comprising:
receiving a signal modulated according to the determined modulation mode and transmitted by the transmitter.

[12] The method of claim 8, wherein determining the modulation mode comprises comparing the SNR of the selected antenna with a threshold value

γ_{T_n}

(n = N, N-1, ..., 2) for determining the modulation mode, and determining n as the modulation mode when the SNR is less than

$\gamma_{T_{n+1}}$

and greater than or equal to

γ_{T_n}

.

[13] The method of claim 12, wherein the reference value is a threshold value

γ_{T_N}

.

[14] The method of claim 12, wherein the reference value is a threshold value

γ_{T_2}

.

[15] The method of claim 12, wherein determining the output SNR comprises requesting, at the receiver, the transmitter to transmit a signal using a Quadrature Phase Shift Keying (QPSK) modulation scheme when SNRs of all the antennas are less than a threshold value

γ_{T_2}

.

[16] The method of claim 12, wherein determining the output SNR comprises transmitting, at the receiver, a request to store data in a buffer and wait for a next guard period to the transmitter when SNRs of all the antennas are less than a threshold value

γ_{T_2}

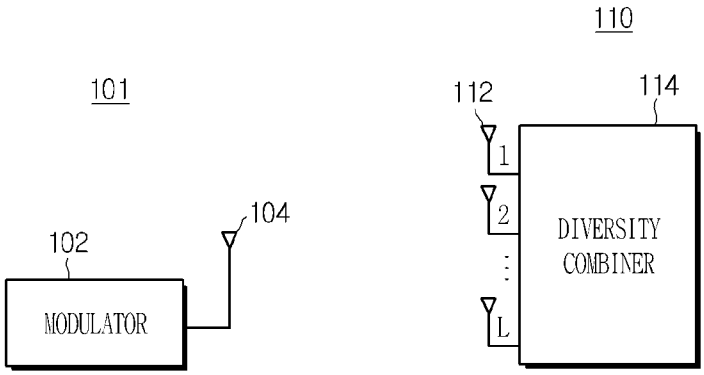
.

[17] The method of claim 8, wherein the signal comprises a guard period.

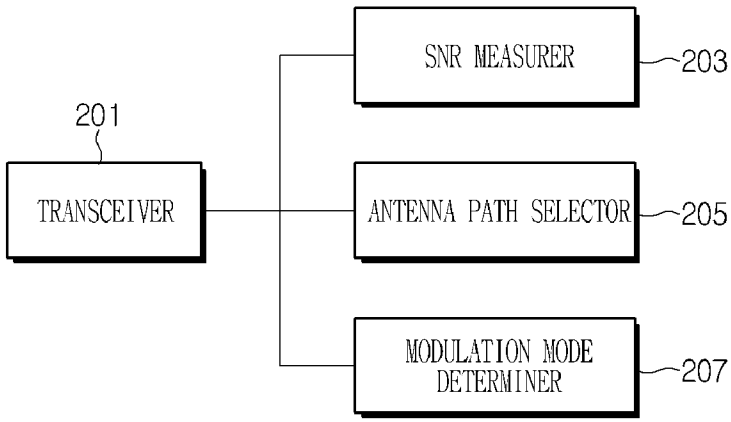
[18] An apparatus for transmitting and receiving a signal, comprising:
a transmitter for modulating a signal according to a modulation mode fed back from a receiver and transmitting the modulated signal; and
the receiver including a plurality of antennas, selecting an antenna to receive the signal transmitted from the transmitter among the antennas, determining a modulation mode corresponding to a Signal-to-Noise Ratio (SNR) of the selected antenna, and feeding back the modulation mode to the transmitter.

[19] The apparatus of claim 18, wherein the receiver comprises:
a transceiver for receiving the signal and transmitting the determined modulation mode to the transmitter through the antennas;
an SNR measurer for measuring SNRs of the antennas with respect to the received signal;
an antenna path selector for selecting an antenna to receive the signal; and
a modulation mode determiner for determining the modulation mode using the SNR of the antenna selected by the antenna path selector.

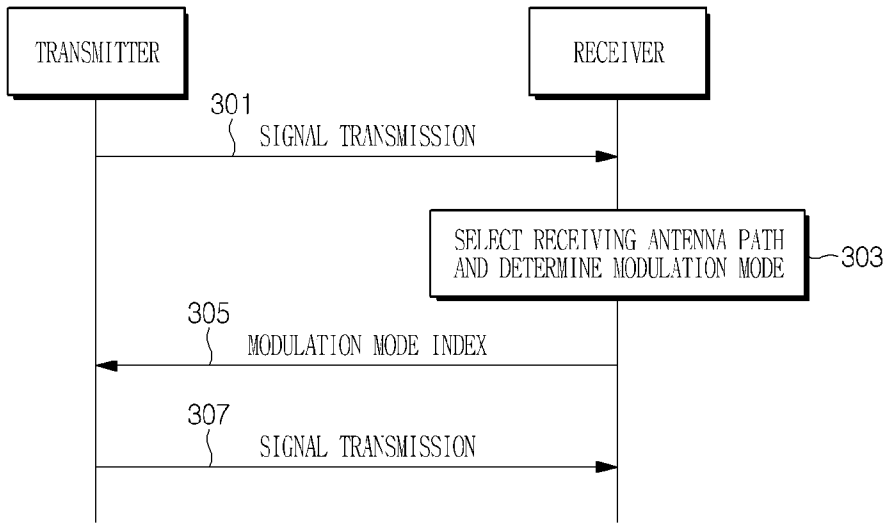
[Fig. 1]



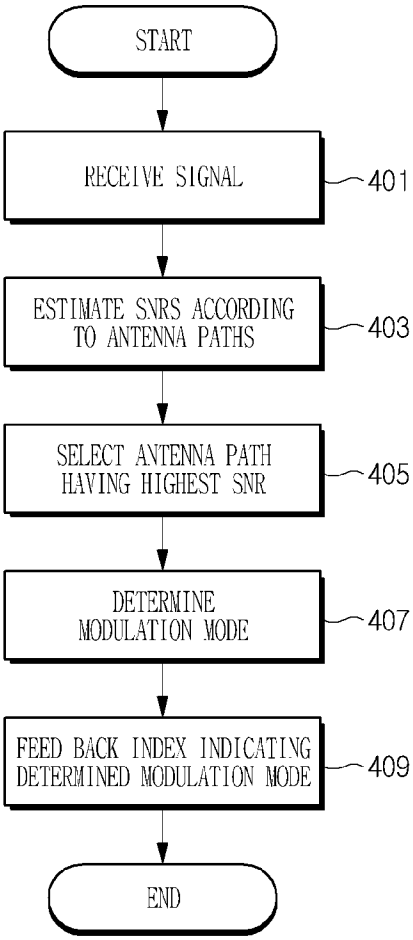
[Fig. 2]



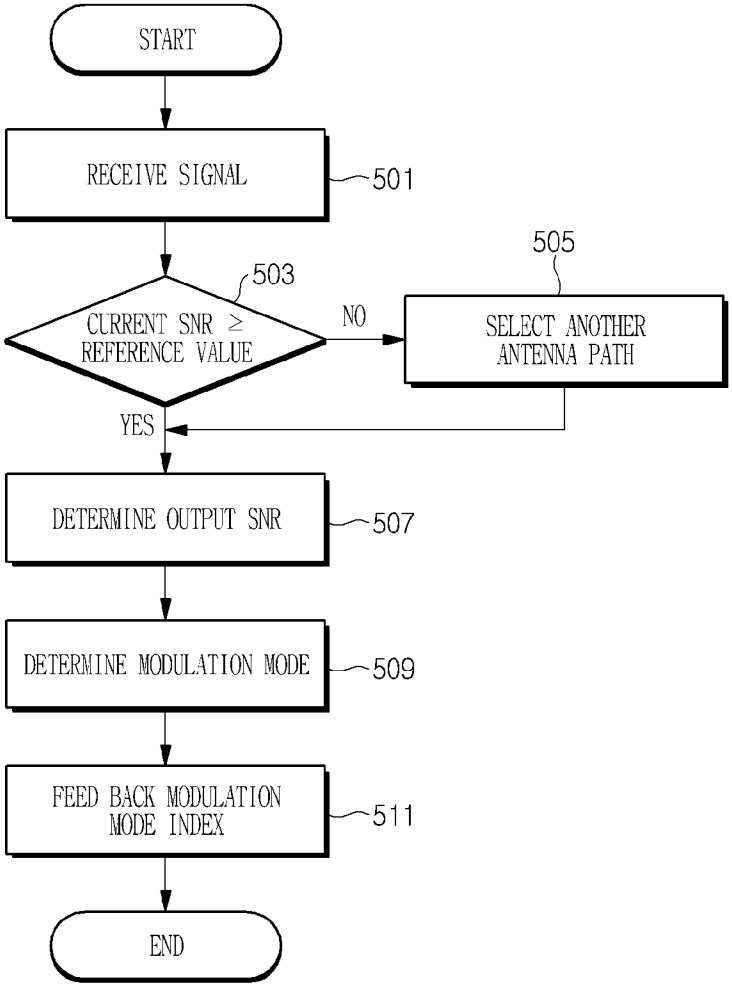
[Fig. 3]



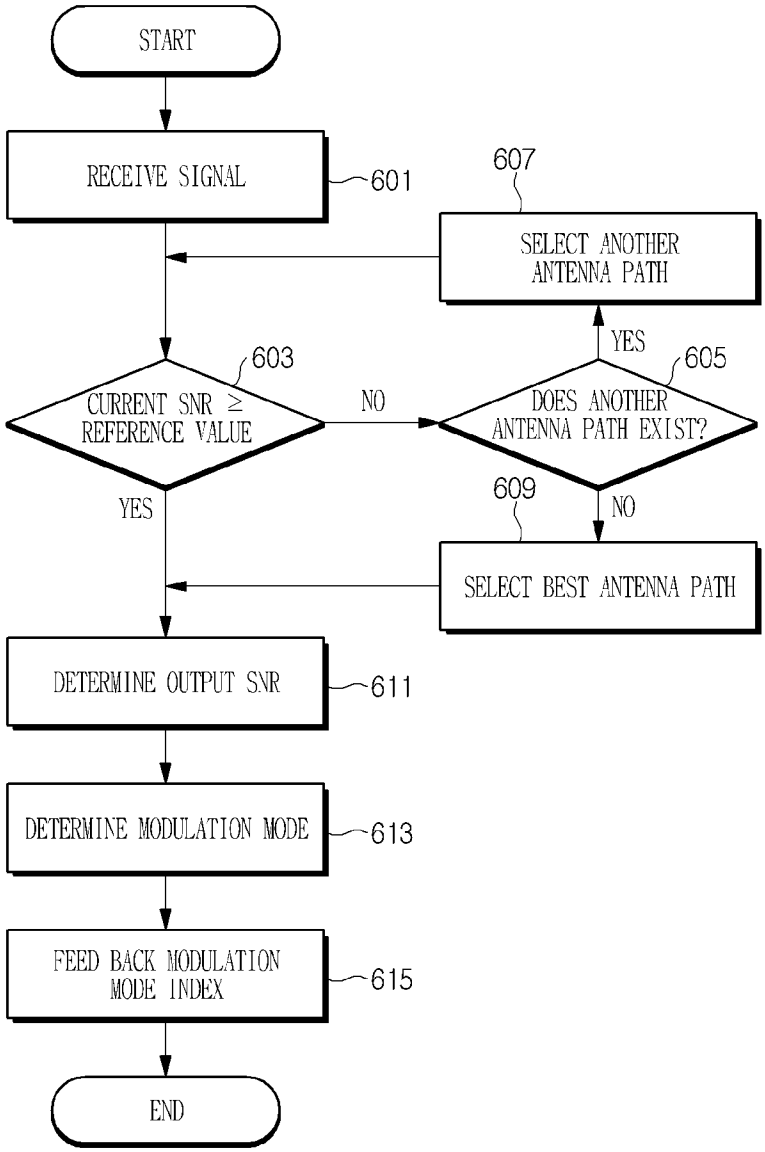
[Fig. 4]


START
RECEIVE SIGNAL
401
ESTIMATE SNRS ACCORDING TO ANTENNA PATHS
403
SELECT ANTENNA PATH HAVING HIGHEST SNR
405
DETERMINE MODULATION MODE
407
FEED BACK INDEX INDICATING DETERMINED MODULATION MODE
409
END

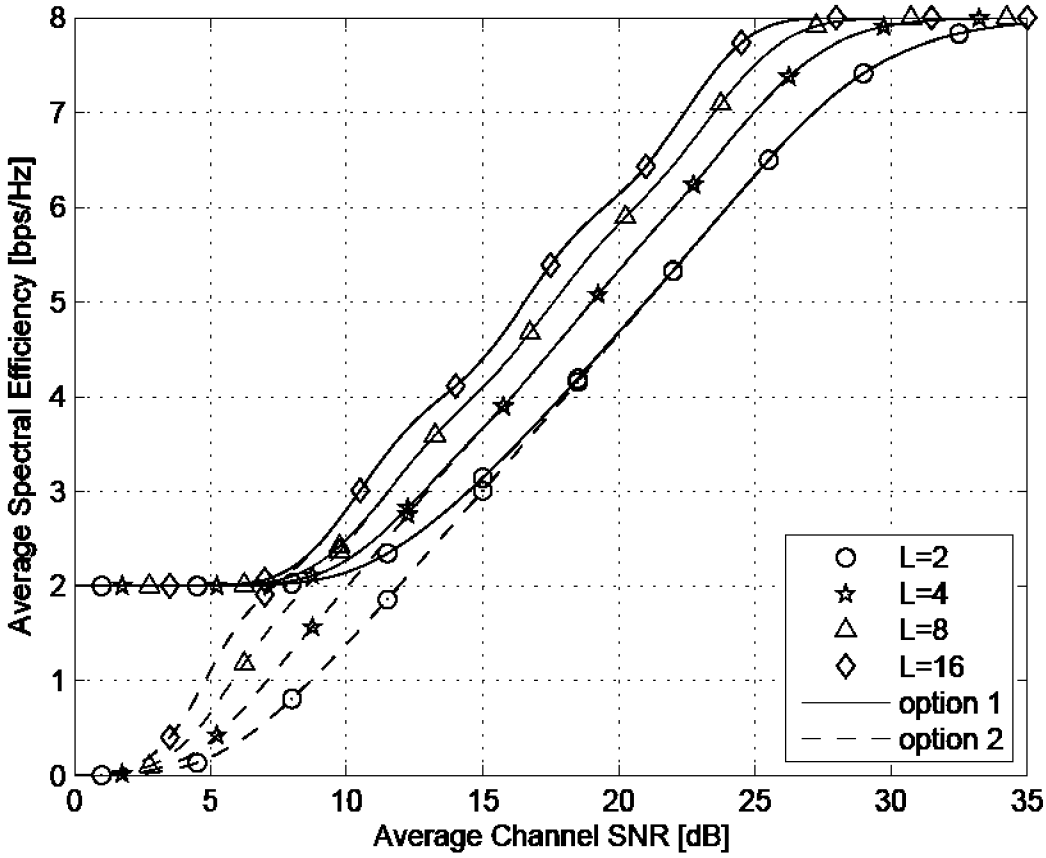
[Fig. 5]


START
RECEIVE SIGNAL
501
503
CURRENT SNR ≥ REFERENCE VALUE
NO
505
SELECT ANOTHER ANTENNA PATH
YES
DETERMINE OUTPUT SNR
507
DETERMINE MODULATION MODE
509
FEED BACK MODULATION MODE INDEX
511
END

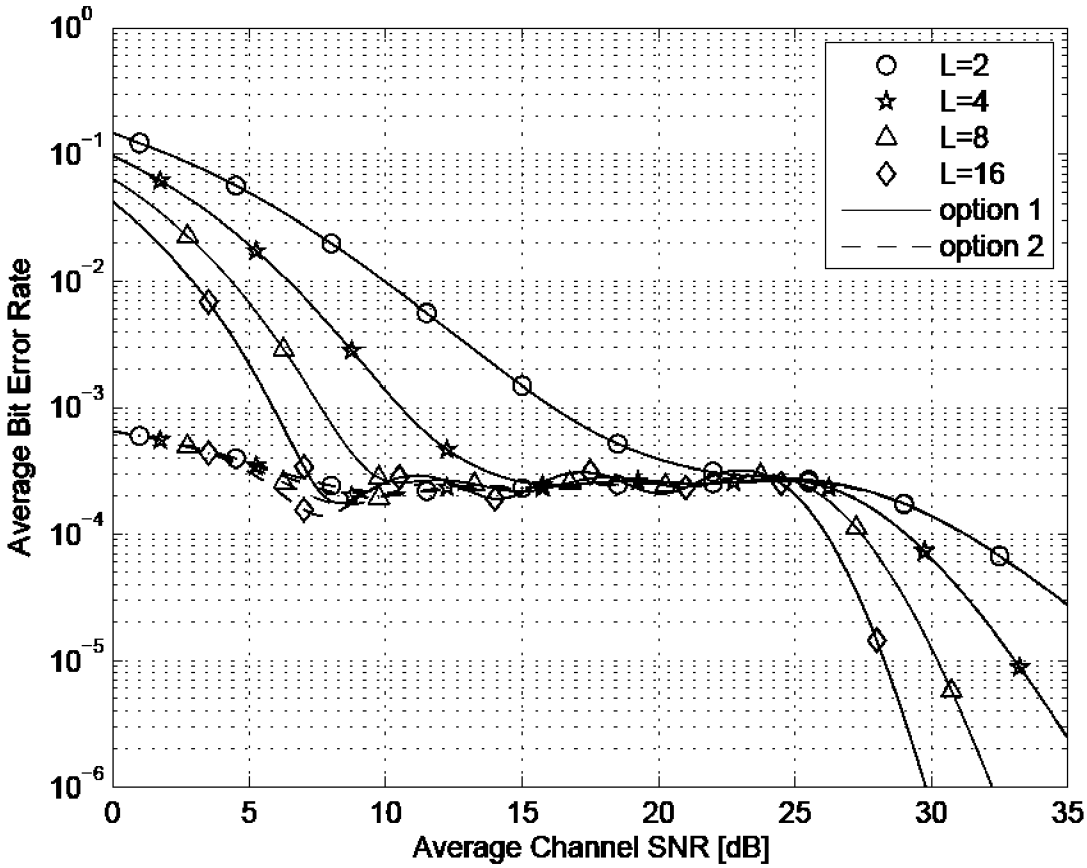
[Fig. 6]


START
RECEIVE SIGNAL
601
607
SELECT ANOTHER ANTENNA PATH
YES
603
CURRENT SNR ≥ REFERENCE VALUE
NO
605
DOES ANOTHER ANTENNA PATH EXIST?
609
NO
YES
SELECT BEST ANTENNA PATH
DETERMINE OUTPUT SNR
611
DETERMINE MODULATION MODE
613
FEED BACK MODULATION MODE INDEX
615
END

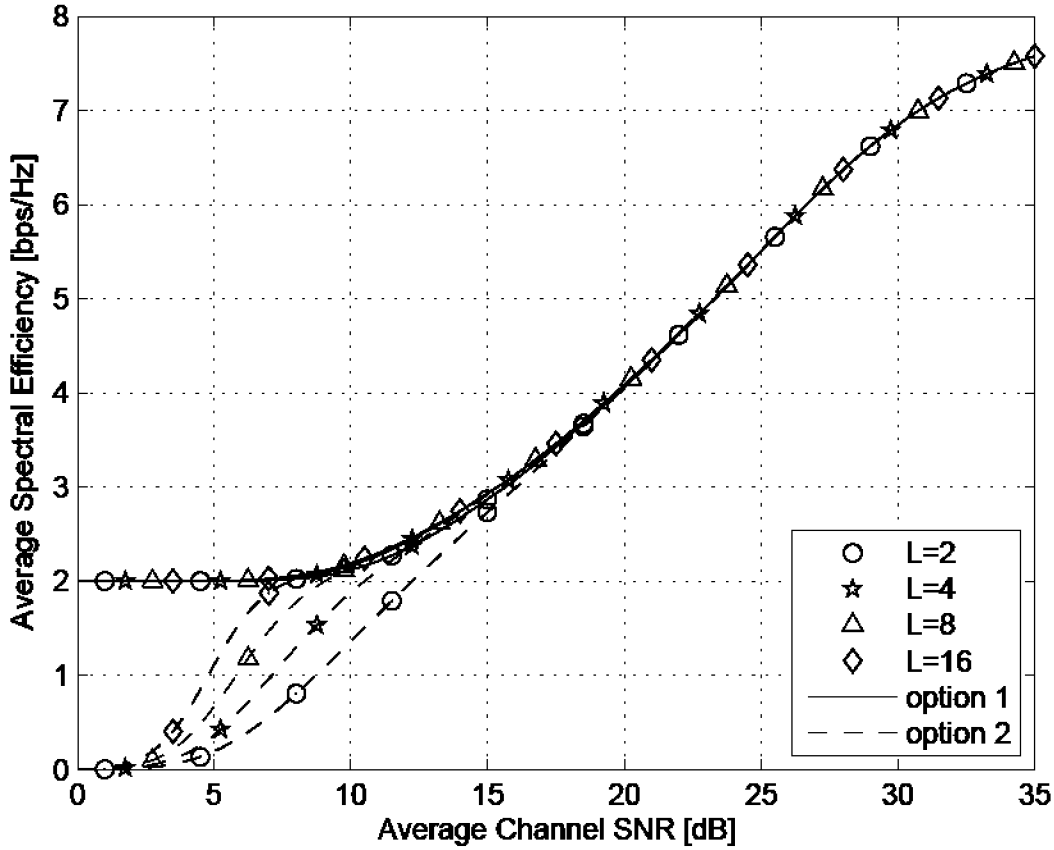
[Fig. 7]


Average Spectral Efficiency [bps/Hz]
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

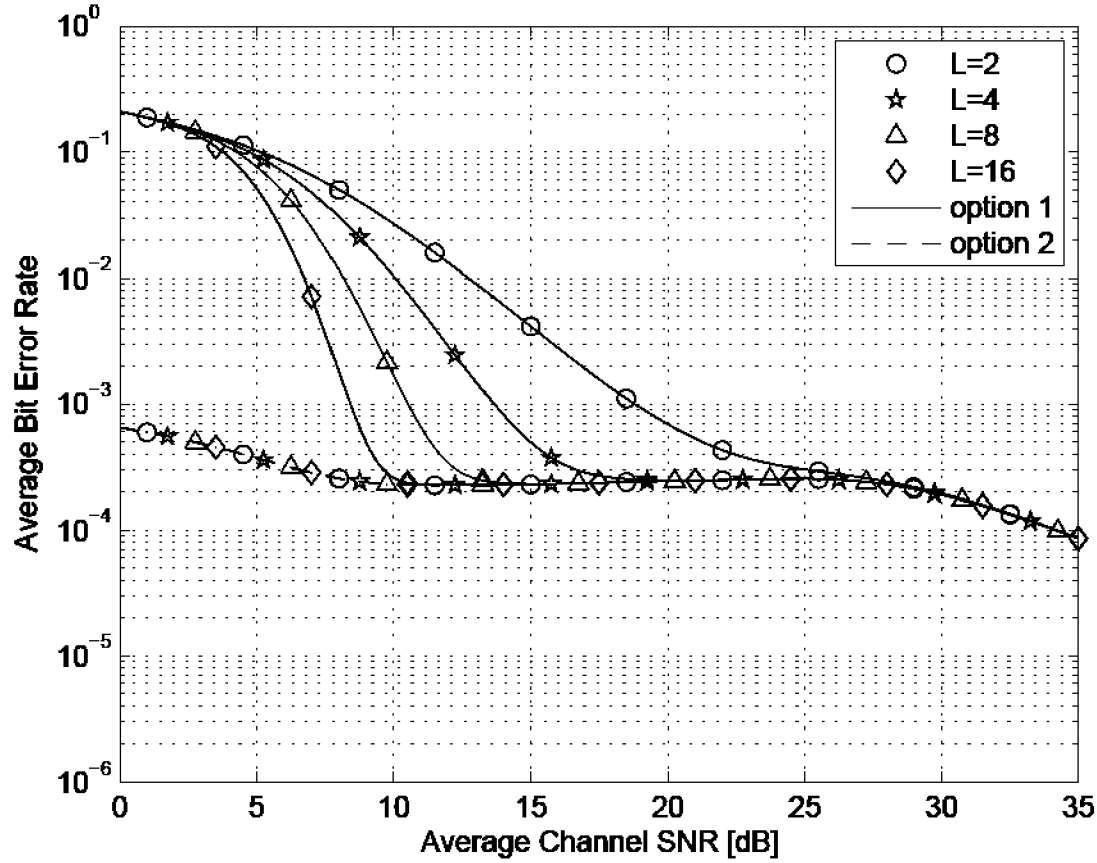
[Fig. 8]


Average Bit Error Rate
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

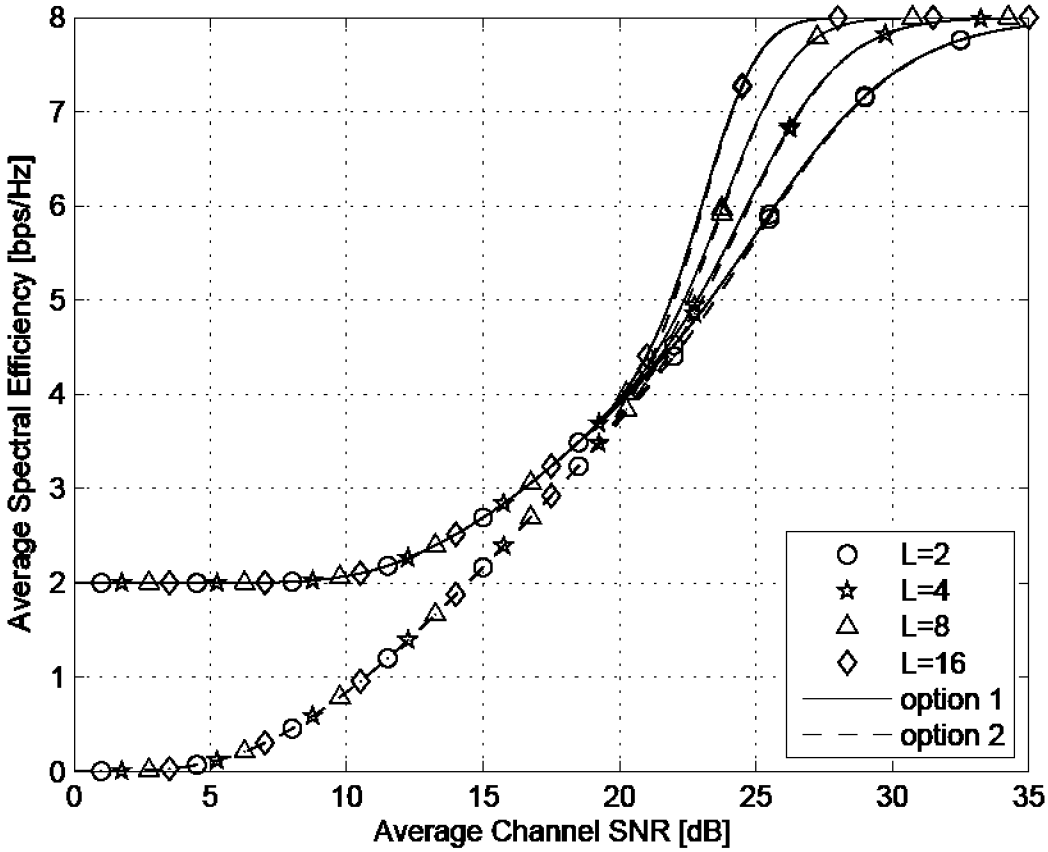
[Fig. 9]


Average Spectral Efficiency [bps/Hz]
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

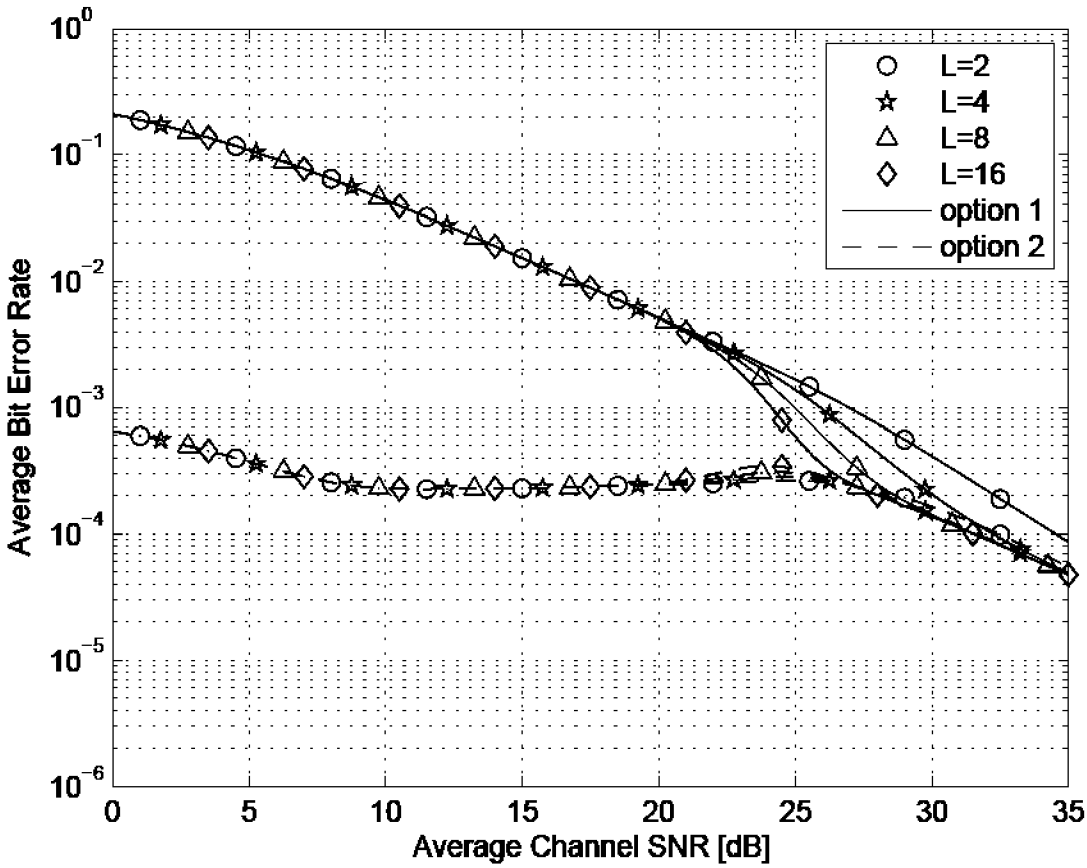
[Fig. 10]


Average Bit Error Rate
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

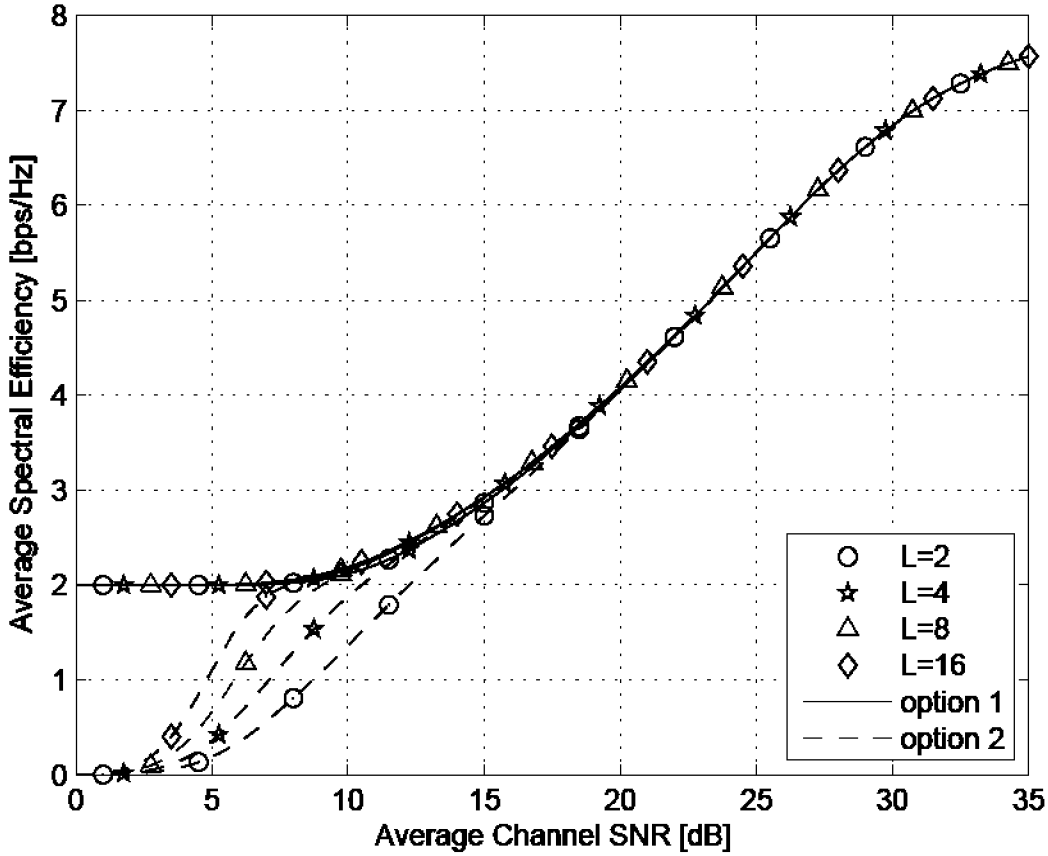
[Fig. 11]


Average Spectral Efficiency [bps/Hz]
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

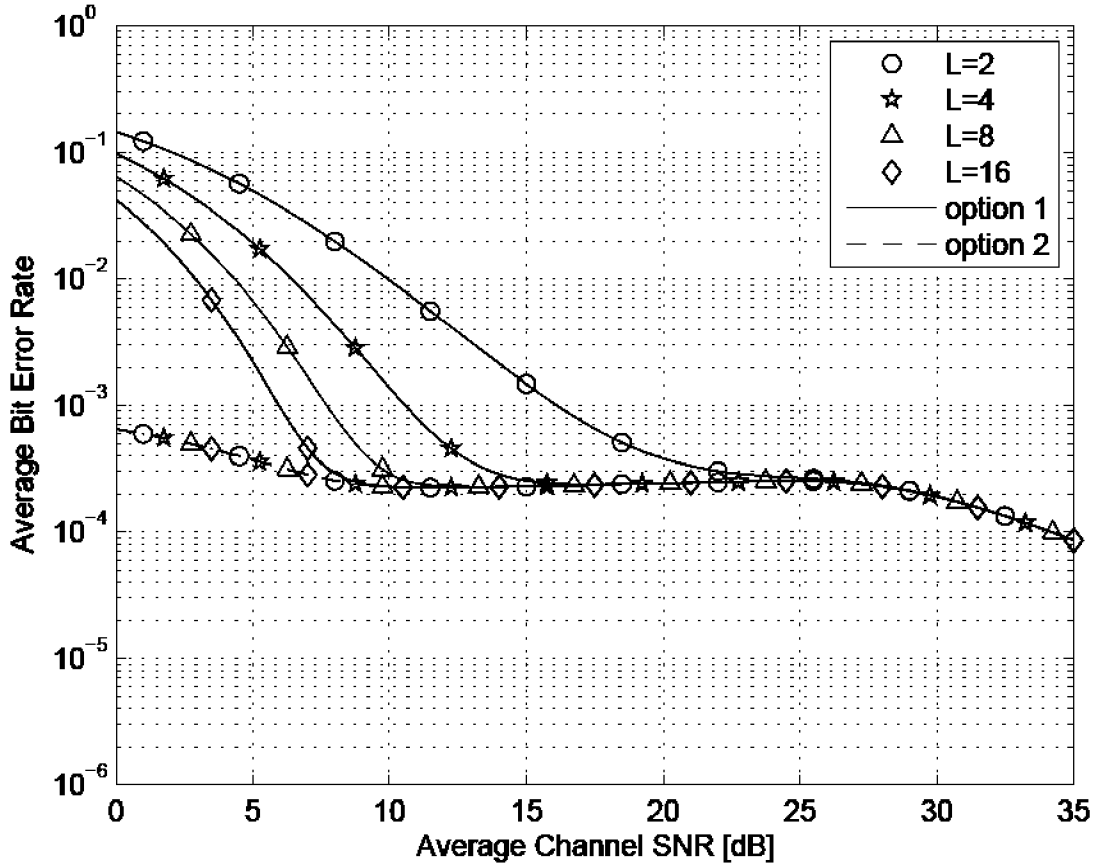
[Fig. 12]


Average Bit Error Rate
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

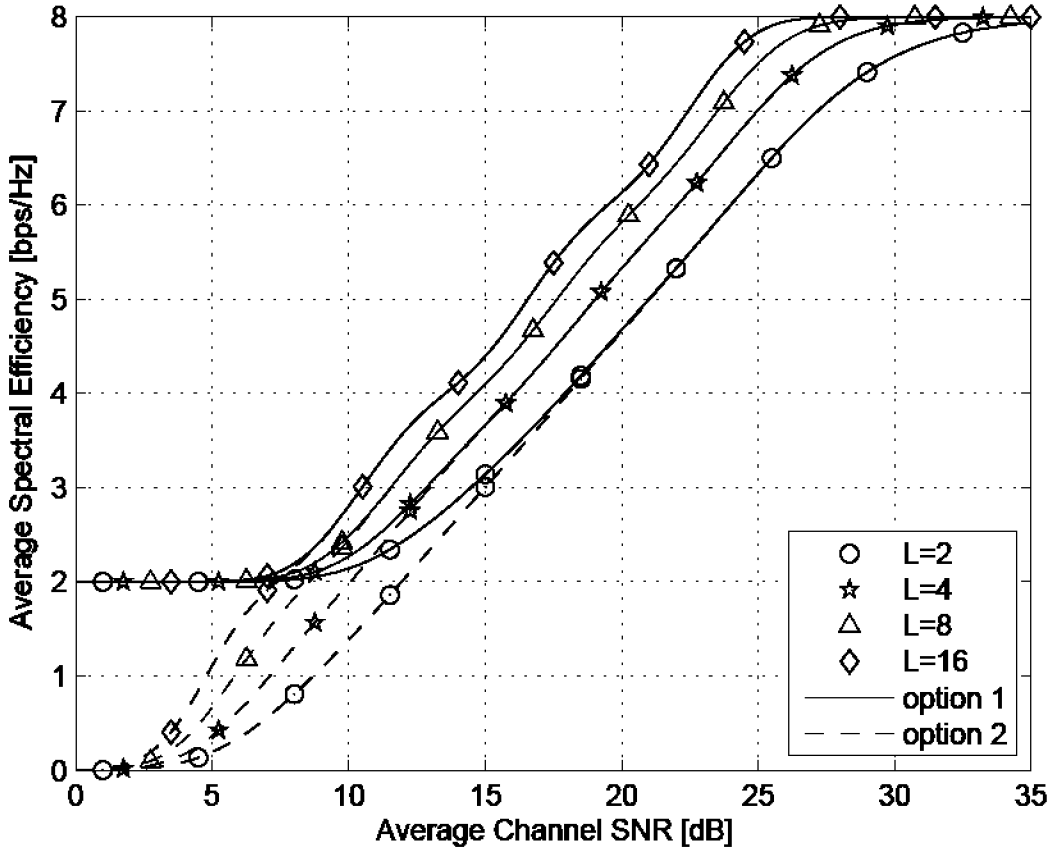
[Fig. 13]


Average Spectral Efficiency [bps/Hz]
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

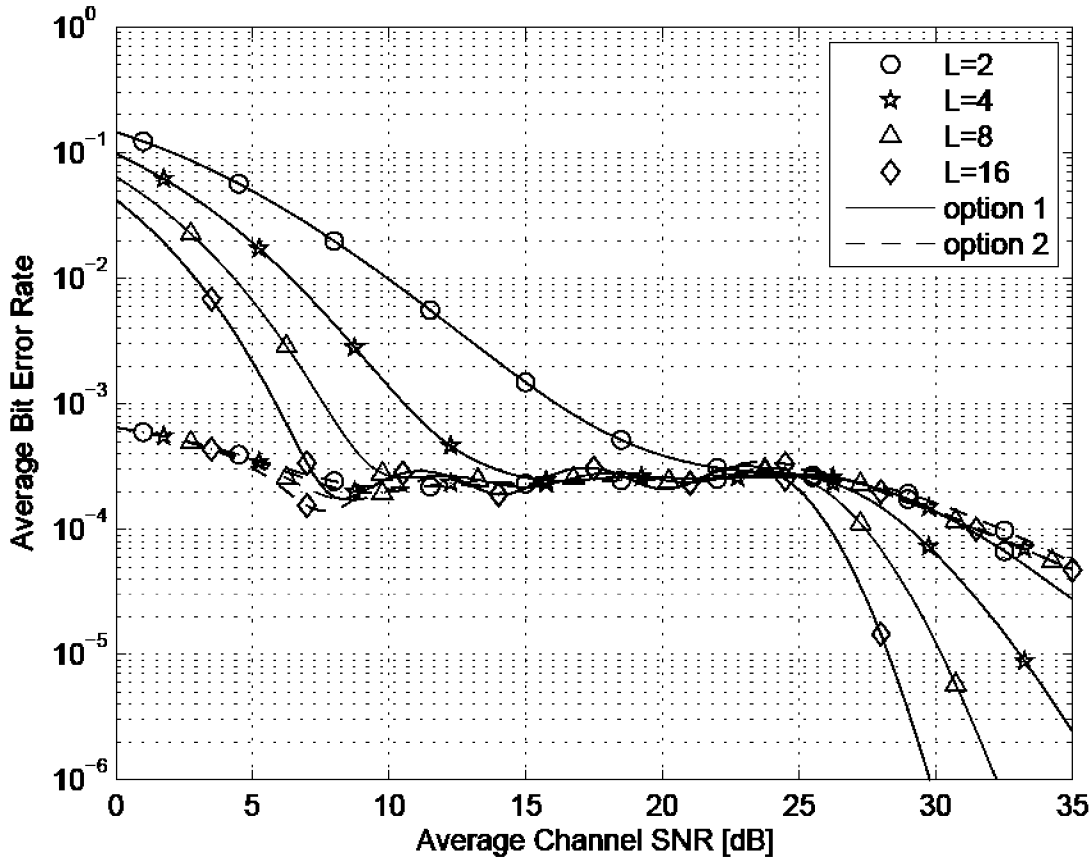
[Fig. 14]


Average Bit Error Rate
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

[Fig. 15]


Average Spectral Efficiency [bps/Hz]
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

[Fig. 16]


Average Bit Error Rate
Average Channel SNR [dB]
L=2
L=4
L=8
L=16
option 1
option 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2008/000327

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/04(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 H04B, H04J, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

KOREAN UTILITY MODELS AND APPLICATIONS FOR UTILITY MODELS SINCE 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS, DELPHION, ESPACENET & Keywords : adaptive modulation, diversity, modulation mode 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.
Y	US 2005/135497 A1 (KIM, KWANG SOON. et al.) 23 June 2005 * see abstract, claims 1-5, figures 1,6,7 *	1-19
Y	KR 2003-0083489 A (SAMSUNG ELECTRONICS CO., LTD.) 30 October 2003 * see abstract, claims 1, 4, 6, 8, page 3 line 39 - page 4 line 38, figures 3-4 *	1-19
A	WO 2006/020434 A2 (INTERDIGITAL TECHNOLOGY CORPORATION) 23 February 2006 * see abstract, claims 1-7,10 figure 14 *	1-19
A	US 2003/0231706 A1 (HWANG, IN TAE) 18 December 2003 * see abstract, paragraphs [52]-[64], claims 1, 5, 9-13, figure 8 *	1-19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 APRIL 2008 (30.04.2008)	**30 APRIL 2008 (30.04.2008)**

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Authorized officer

KIM Byeong Gyun

Telephone No. 82-42-481-8300

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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