

ENCODING AND DECODING METHOD AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Chinese Patent Application No. 202110748075.8, filed with the China National Intellectual Property Administration on July 2, 2021 and entitled "ENCODING AND DECODING METHOD AND APPARATUS", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This application relates to the field of communication technologies, and in particular, to an encoding method, a decoding method, and an apparatus.

BACKGROUND

[0003] The most typical three communication scenarios of a 5th generation (5th generation, 5G) communication system include an enhanced mobile broadband (enhanced mobile broadband, eMBB), massive machine type communication (massive machine type communication, mMTC), and ultra-reliable low-latency communication (ultra-reliable low-latency communication, URLLC). As a most basic radio access technology, encoding is one of important research objects to meet a 5G communication requirement. A polar code (Polar Code) is selected as a control encoding scheme in a 5G standard. The polar code may also be referred to as a Polar code, and is the first and only known encoding method that can be strictly proved to "achieve" a channel capacity. For different code lengths, particularly for limited codes, performance of the polar code is much better than that of a turbo code and a low density parity check (low density parity check, LDPC) code. In addition, the polar code has low computational complexity in encoding and decoding. The advantages enable the polar code to have a great development and application prospect in 5G.

[0004] In a polar code encoding process, an information sub-channel may be first determined,

and then a to-be-encoded bit sequence is encoded based on the information sub-channel. Currently, a common construction method is, for example, bit-interleaved coded modulation (bit-interleaved coded modulation, BICM). The BICM mainly constructs an information sub-channel based on lower-order modulation such as quadrature phase shift keying (quadrature phase shift keying, QPSK) or binary phase shift keying (binary phase shift keying, BPSK). In a construction process, it may be assumed that energy of all bits in a symbol is consistent. However, in higher-order modulation such as pulse amplitude modulation (pulse amplitude modulation, PAM) 16, energy of four bits included in one symbol is inconsistent. If the BICM is used for generating a polar code under the higher-order modulation, there is a problem that a construction result does not match a modulation scheme.

[0005] Currently, a polar code generation manner applicable to the higher-order modulation needs to be urgently provided.

SUMMARY

[0006] This application provides an encoding method, a decoding method, and an apparatus, to generate a polar code that matches higher-order modulation.

[0007] According to a first aspect, this application provides an encoding method. The method may be performed by a communication apparatus. The communication apparatus is, for example, a terminal device, a network device, or an Internet of Things device, or may be a module (for example, a chip) in a network device, or may be a module (for example, a chip) in a terminal device. An entity for executing the method is not specifically limited herein in this application, and the encoding method provided in this application can be performed provided that a transmitter is disposed in a communication device.

[0008] The encoding method includes: obtaining an information bit quantity K and an encoding bit quantity L ; determining a symbol quantity S based on the encoding bit quantity L and an energy level quantity B , where S is S_1 or S_2 , $S_1=L/B$, and $S_2=L/2B$; determining K information sub-channels from an encoding sequence based on the symbol quantity S , the energy level quantity B , and a reliability sequence; and encoding K information bits and outputting a bit sequence based on the K information sub-channels, where the encoding sequence includes $B_{\max}$ sub-sequences, the $B_{\max}$ sub-sequences respectively correspond to $B_{\max}$ energy levels, each sub-sequence in the

B_{max} sub-sequences includes S_{max} sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence; the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are S₁ sub-channels or 2×S₂ sub-channels in a sub-sequence whose energy level is i; and K, L, B, S, S₁, S₂, B_{max}, and S_{max} are all positive integers, S_{max} is greater than or equal to S, B_{max} is greater than or equal to B, and i is greater than or equal to 0 and less than B.

[0009] In the foregoing technical solution, the reliability sequence is constructed based on correlation between bits in a same symbol, and in a construction process, different energy levels of different bits in the same symbol are further considered. When sending information, a transmitting end may determine the information sub-channel from the encoding sequence based on the reliability sequence, and the transmitting end encodes the information bit based on the determined information sub-channel, to obtain a bit sequence that matches higher-order modulation. Correspondingly, a receiving end may determine the information sub-channel from the encoding sequence based on the reliability sequence, and decode the bit sequence based on the information sub-channel, to obtain information that needs to be actually sent by the transmitting end. In this manner, a coding gain of about 0.5 dB to 1.5 dB can be increased. In addition, designs of an encoder and a decoder do not need to be changed. This helps reduce costs.

[0010] In addition, the reliability sequence may be a double nested structure, to be specific, a sequence including S_{max}×B_{max} sub-channels that jointly correspond to the preset symbol quantity S_{max} and the preset energy level quantity B_{max}. The reliability sequence may be applicable to different symbol quantities or different energy levels. The transmitting end may determine the candidate sub-channels based on a symbol quantity and an energy level corresponding to a to-be-sent information bit and the reliability sequence. Then, the information sub-channel and a frozen sub-channel are determined from the candidate sub-channels. In this way, there is no need to set different reliability sequences for modulation corresponding to each energy level quantity. This helps reduce costs.

[0011] In a possible implementation, the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

[0012] In the foregoing technical solution, the punctured sub-channel, the shortened sub-

channel, and the pre-frozen sub-channel are excluded from the candidate sub-channels, and the information sub-channels are selected from remaining candidate sub-channels in descending order of reliability, to ensure that reliability of all sub-channels used for carrying the information bit is high, and help improve accuracy in information transmission.

5 **[0013]** In a possible implementation, the punctured sub-channel or the shortened sub-channel is determined based on the energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B.

10 **[0014]** In the foregoing technical solution, the mother code length in the symbol is determined based on an energy level (namely, a bit quantity in the symbol). In other words, the mother code length is determined from two dimensions: an inter-symbol dimension and an intra-symbol dimension, to help determine a candidate sub-channel corresponding to the energy level quantity B and the symbol quantity S.

15 **[0015]** In a possible implementation, after the encoding K information bits and outputting a bit sequence based on the K information sub-channels, the method further includes: performing rate matching and modulation on the output bit sequence to obtain S to-be-sent symbols; and performing interleaving processing on the S to-be-sent symbols.

20 **[0016]** In the foregoing technical solution, the symbol-level interleaving processing is performed on the modulated S to-be-sent symbols, to ensure that correlation among a plurality of bits in the symbols is not damaged, and help improve anti-interference performance of the to-be-sent symbols in response to burst continuous noise in a sending process.

25 **[0017]** In a possible implementation, the modulation includes: sequentially selecting one bit from each sub-sequence of B sub-sequences in an ascending order of energy levels and mapping the bit to one to-be-sent symbol. In a possible implementation, a $(j_1 \times B + j_2)^{\text{th}}$ bit in the bit sequence may be mapped to a j_2^{th} bit in a j_1^{th} to-be-sent symbol, where j_1 is a positive integer less than S, and j_2 is a positive integer less than B.

[0018] In a possible implementation, for quadrature amplitude modulation (quadrature amplitude modulation, QAM) 256, the modulation further includes: exchanging mapping orders of a bit selected from a sub-sequence corresponding to a third energy level and a bit selected from a sub-sequence corresponding to a fourth energy level in the ascending order of energy levels.

30 **[0019]** In the foregoing technical solution, the mapping orders of the bit selected from the sub-sequence corresponding to the third energy level and the bit selected from the sub-sequence

corresponding to the fourth energy level are exchanged to obtain a symbol. This can help improve transmission performance of the symbol in a channel.

[0020] In a possible implementation, the encoding is polar code encoding.

[0021] According to a second aspect, this application provides a decoding method. The method may be performed by a communication apparatus. The communication apparatus is, for example, a terminal device, a network device, or an Internet of Things device, or may be a module (for example, a chip) in a network device, or may be a module (for example, a chip) in a terminal device. An entity for executing the method is not specifically limited herein in this application, and the decoding method provided in this application can be performed provided that a receiver is disposed in a communication device.

[0022] The decoding method includes: receiving S symbols, where a symbol quantity S is $S1$ or $S2$; and demodulating and decoding the S symbols based on the symbol quantity S , an energy level quantity B , a reliability sequence, and an encoding sequence to obtain L bits, where the L bits include K information bits, and $L=S1 \times B$, or $L=2 \times S2 \times B$, where the encoding sequence includes $B_{\max}$ sub-sequences, the $B_{\max}$ sub-sequences respectively correspond to $B_{\max}$ energy levels, each sub-sequence in the $B_{\max}$ sub-sequences includes $S_{\max}$ sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence; the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are $S1$ sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i ; and K , L , B , S , $S1$, $S2$, $B_{\max}$, and $S_{\max}$ are all positive integers, $S_{\max}$ is greater than or equal to S , $B_{\max}$ is greater than or equal to B , and i is greater than or equal to 0 and less than B .

[0023] In the foregoing technical solution, the reliability sequence is constructed based on correlation between bits in a same symbol, and in a construction process, different energy levels of different bits in the same symbol are further considered. When sending information, a transmitting end may determine the information sub-channel from the encoding sequence based on the reliability sequence, and the transmitting end encodes the information bit based on the determined information sub-channel, to obtain a bit sequence that matches higher-order modulation. Correspondingly, a receiving end may determine the information sub-channel from the encoding sequence based on the reliability sequence, and decode the bit sequence based on the information sub-channel, to obtain information that needs to be actually sent by the transmitting

end. In addition, designs of an encoder and a decoder do not need to be changed. This helps reduce costs.

[0024] In addition, the reliability sequence may be a double nested structure, to be specific, a sequence including $S_{\max} \times B_{\max}$ sub-channels that jointly correspond to the preset symbol quantity $S_{\max}$ and the preset energy level quantity $B_{\max}$. The reliability sequence may be applicable to different symbol quantities or different energy levels. The transmitting end may determine the candidate sub-channels based on a symbol quantity and an energy level corresponding to a to-be-sent information bit and the reliability sequence. Then, the information sub-channel and a frozen sub-channel are determined from the candidate sub-channels. In this way, there is no need to set different reliability sequences for modulation corresponding to each energy level quantity. This helps reduce costs.

[0025] In a possible implementation, the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

[0026] In a possible implementation, the punctured sub-channel or the shortened sub-channel is determined based on an energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B .

[0027] In a possible implementation, before the demodulating and decoding the S symbols based on the symbol quantity S , the energy level quantity B , a reliability sequence, and an encoding sequence to obtain L bits, the method further includes: performing de-interleaving processing on the S symbols.

[0028] In a possible implementation, the demodulation includes: sequentially mapping B bits included in each symbol in the S symbols to B sub-sequences sorted in ascending order of energy levels.

[0029] In a possible implementation, for QAM256, the demodulation further includes: exchanging mapping orders of a third bit and a fourth bit included in each symbol in the S symbols.

[0030] In a possible implementation, the encoding is polar code encoding.

[0031] According to a third aspect, this application provides a communication apparatus. The communication apparatus is, for example, a terminal device, a network device, or an Internet of Things device, or may be a module (for example, a chip) in a network device, or may be a module (for example, a chip) in a terminal device. The communication apparatus includes an input/output

unit and a processing unit.

[0032] In a possible implementation, the input/output unit is configured to obtain an information bit quantity K and an encoding bit quantity L ; and the processing unit is configured to determine a symbol quantity S based on the encoding bit quantity L and an energy level quantity B , where S is S_1 or S_2 , $S_1=L/B$, and $S_2=L/2B$, where the processing unit is further configured to:
5 determine K information sub-channels from an encoding sequence based on the symbol quantity S , the energy level quantity B , and a reliability sequence; and the processing unit is further configured to encode K information bits and output a bit sequence based on the K information sub-channels, where the encoding sequence includes $B_{\max}$ sub-sequences, the $B_{\max}$ sub-sequences
10 respectively correspond to $B_{\max}$ energy levels, each sub-sequence in the $B_{\max}$ sub-sequences includes $S_{\max}$ sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence; the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are S_1 sub-channels or $2 \times S_2$ sub-channels in a sub-sequence whose energy level is i ; and
15 K , L , B , S , S_1 , S_2 , $B_{\max}$, and $S_{\max}$ are all positive integers, $S_{\max}$ is greater than or equal to S , $B_{\max}$ is greater than or equal to B , and i is greater than or equal to 0 and less than B .

[0033] In a possible implementation, the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

[0034] In a possible implementation, the punctured sub-channel or the shortened sub-channel is determined based on the energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B .

[0035] In a possible implementation, after encoding the K information bits and outputting a bit sequence based on the K information sub-channels, the processing unit is further configured to:
25 perform rate matching and modulation on the output bit sequence to obtain S to-be-sent symbols; and perform interleaving processing on the S to-be-sent symbols.

[0036] In a possible implementation, the processing unit is specifically configured to sequentially select one bit from each sub-sequence of B sub-sequences in an ascending order of energy levels and map the bit to one to-be-sent symbol.

[0037] In a possible implementation, for QAM256, the processing unit is further configured to exchange mapping orders of a bit selected from a sub-sequence corresponding to a third energy

level and a bit selected from a sub-sequence corresponding to a fourth energy level in the ascending order of energy levels.

[0038] In a possible implementation, the encoding is polar code encoding.

[0039] According to a fourth aspect, this application provides a communication apparatus. The communication apparatus is, for example, a terminal device, a network device, or an Internet of Things device, or may be a module (for example, a chip) in a network device, or may be a module (for example, a chip) in a terminal device. The communication apparatus includes an input/output unit and a processing unit.

[0040] In a possible implementation, the input/output unit is configured to receive S symbols, where a symbol quantity S is S_1 or S_2 ; and the processing unit is configured to: demodulate and decode the S symbols based on the symbol quantity S , an energy level quantity B , a reliability sequence, and an encoding sequence to obtain L bits, where the L bits include K information bits, and $L=S_1 \times B$, or $L=2 \times S_2 \times B$, where the encoding sequence includes $B_{\max}$ sub-sequences, the $B_{\max}$ sub-sequences respectively correspond to $B_{\max}$ energy levels, each sub-sequence in the $B_{\max}$ sub-sequences includes $S_{\max}$ sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence; the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are S_1 sub-channels or $2 \times S_2$ sub-channels in a sub-sequence whose energy level is i ; and K , L , B , S , S_1 , S_2 , $B_{\max}$, and $S_{\max}$ are all positive integers, $S_{\max}$ is greater than or equal to S , $B_{\max}$ is greater than or equal to B , and i is greater than or equal to 0 and less than B .

[0041] In a possible implementation, the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

[0042] In a possible implementation, the punctured sub-channel or the shortened sub-channel is determined based on an energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B .

[0043] In a possible implementation, before demodulating and decoding the S symbols based on the symbol quantity S , the energy level quantity B , the reliability sequence, and the encoding sequence to obtain the L bits, the processing unit is further configured to perform de-interleaving processing on the S symbols.

[0044] In a possible implementation, the processing unit is specifically configured to sequentially map B bits included in each symbol in the S symbols to B sub-sequences sorted in ascending order of energy levels.

[0045] In a possible implementation, for QAM256, the processing unit is further configured to exchange mapping orders of a third bit and a fourth bit included in each symbol in the S symbols.

[0046] In a possible implementation, the encoding is polar polar code decoding.

[0047] For the third aspect or the fourth aspect, it should be understood that the input/output unit may be referred to as a transceiver unit, a communication unit, or the like. When the communication apparatus is a terminal device, the input/output unit may be a transceiver, and the processing unit may be a processor. When the communication apparatus is a module (for example, a chip) in a terminal device, the input/output unit may be an input and output interface, an input and output circuit, an input and output pin, or the like, or may be referred to as an interface, a communication interface, an interface circuit, or the like. The processing unit may be a processor, a processing circuit, a logic circuit, or the like.

[0048] According to a fifth aspect, this application provides a communication apparatus, including at least one processor and a memory. The memory is configured to store a computer program or instructions. When the communication apparatus runs, the processor executes the computer program or the instructions stored in the memory, so that the communication apparatus performs the method according to any one of the first aspect or the possible implementations of the first aspect, or performs the method according to any one of the second aspect or the possible implementations of the second aspect. In an optional implementation, the processor and the memory may be integrated into a same chip, or may be separately integrated into different chips.

[0049] According to a sixth aspect, embodiments of this application further provide a computer-readable storage medium. The computer-readable storage medium stores computer-readable instructions, and when the computer-readable instructions are run on a computer, the computer is enabled to perform the method according to any one of the first aspect or the possible implementations of the first aspect, or perform the method according to any one of the second aspect or the possible implementations of the second aspect.

[0050] According to a seventh aspect, this application provides a computer program product including instructions. When the computer program product runs on a computer, the computer is enabled to perform the method according to any one of the first aspect or the possible

implementations of the first aspect, or perform the method according to any one of the second aspect or the possible implementations of the second aspect.

[0051] According to an eighth aspect, embodiments of this application provide a chip system. The chip system includes a processor, and may further include a memory, and is configured to implement the method according to any one of the first aspect or the possible implementations of the first aspect, or configured to perform the method according to any one of the second aspect or the possible implementations of the second aspect. The chip system may include a chip, or may include a chip and another discrete component.

[0052] According to a ninth aspect, embodiments of this application provide a communication system. The communication system includes a transmitting end and a receiving end, where the transmitting end is configured to perform the method according to any one of the first aspect or the possible implementations of the first aspect, and the receiving end is configured to perform the method according to any one of the second aspect or the possible implementations of the second aspect.

[0053] For technical effects that can be achieved by the second aspect to the ninth aspect, refer to descriptions of technical effects that can be achieved by corresponding possible implementations in the first aspect. Details are not described herein again in this application.

BRIEF DESCRIPTION OF DRAWINGS

[0054] FIG. 1 is an example of a communication system applicable to a polar encoding method and a polar decoding method according to this application;

[0055] FIG. 2 is a schematic flowchart of an example of sending a signal by a transmitting end according to this application;

[0056] FIG. 3 is an example of a specific encoding process according to this application;

[0057] FIG. 4 is a schematic diagram of an example of decoding a plurality of bits in a received symbol by a receiving end according to this application;

[0058] FIG. 5a and FIG. 5b are schematic diagrams of examples of bit correlation in a group of symbols according to this application;

[0059] FIG. 6 is a schematic flowchart of an example of determining a reliability sequence according to this application;

[0060] FIG. 7a is a schematic diagram of an example of an encoding sequence according to this application;

[0061] FIG. 7b is a schematic diagram of an example of a reliability sequence according to this application;

[0062] FIG. 8 is a schematic flowchart of an example of encoding and decoding according to this application;

[0063] FIG. 9 is a schematic diagram of an example of constructing an information sub-channel and a frozen sub-channel according to this application;

[0064] FIG. 10 is a schematic flowchart of an example of sending a symbol by a transmitting end according to this application;

[0065] FIG. 11a and FIG. 11b are schematic diagrams of examples of comparison between a group of CAP and BICM according to this application;

[0066] FIG. 12a and FIG. 12b are schematic diagrams of examples of comparison between another group of CAP and BICM according to this application;

[0067] FIG. 13 is a schematic diagram of an example of comparison between CAP and MLC according to this application;

[0068] FIG. 14 is a schematic diagram of a structure of a first communication apparatus according to an embodiment of this application;

[0069] FIG. 15 is a schematic diagram of a structure of a second communication apparatus according to an embodiment of this application; and

[0070] FIG. 16 is a schematic diagram of a structure of a third communication apparatus according to an embodiment of this application.

DESCRIPTION OF EMBODIMENTS

[0071] In the field of wireless communication technologies, a communication device (for example, a terminal device or a network device) may perform encoding in a polar code manner. A polar code is designed based on channel polarization (channel polarization), and is the first constructive encoding scheme that can be proved through a strict mathematical method to achieve a channel capacity.

[0072] The wireless communication field may include but is not limited to a 5G

communication system, a future communication system (such as a 6G communication system), a satellite communication system, a narrowband Internet of Things (narrow band-internet of things, NB-IoT) system, a global system for mobile communications (global system for mobile communications, GSM), an enhanced data rate for GSM evolution (enhanced data rate for GSM evolution, EDGE) system, a wideband code division multiple access (wideband code division multiple access, WCDMA) system, a code division multiple access 2000 (code division multiple access, CDMA2000) system, a time division-synchronous code division multiple access (time division-synchronization code division multiple access, TD-SCDMA) system, a long term evolution (long term evolution, LTE) system, and three typical application scenarios of the 5G mobile communication system: eMBB, URLLC, and mMTC.

[0073] FIG. 1 is an example of a communication system applicable to a polar encoding method and a polar decoding method according to this application. The communication system includes a transmitting end 101 and a receiving end 102. The transmitting end 101 may be a network device or a terminal device, and the receiving end 102 may be a network device or a terminal device.

[0074] Optionally, when the transmitting end 101 is the network device, the receiving end 102 may be the terminal device; or when the receiving end 102 is the network device, the transmitting end 101 may be the terminal device.

[0075] The transmitting end 101 may include an encoder. The transmitting end 101 may encode a to-be-encoded bit sequence by using the encoder, and output an encoded bit sequence. A to-be-sent symbol is obtained through rate matching, interleaving, and modulation performed on the encoded bit sequence, and the to-be-sent symbol may be transmitted to the receiving end 102 on a channel. The receiving end 102 may include a decoder. The receiving end 102 may receive and demodulate the symbol from the transmitting end 101. After performing demodulation and de-interleaving on the received symbol, the receiving end 102 may perform decoding by using the decoder.

[0076] A terminal device in this application includes a device that provides a voice and/or data connectivity for a user. Specifically, the terminal device includes a device that provides a voice for the user, includes a device that provides data connectivity for the user, or includes a device that provides a voice and data connectivity for the user. For example, the terminal device may include a handheld device with a wireless connection function, or a processing device connected to a wireless modem. The terminal device may include user equipment (user equipment, UE), a

wireless terminal device, a mobile terminal device, a device-to-device (device-to-device, D2D) communication terminal device, a vehicle-to-everything (vehicle to everything, V2X) terminal device, a machine-to-machine/machine-type communication (machine-to-machine/machine-type communications, M2M/MTC) terminal device, an Internet of Things (internet of things, IoT) terminal device, a subscriber unit (subscriber unit), a subscriber station (subscriber station), a mobile station (mobile station), a remote station (remote station), an access point (access point, AP), a remote terminal device (remote terminal), an access terminal device (access terminal), a user terminal device (user terminal), a user agent (user agent), a user device (user device), a satellite, a drone, a balloon, an airplane, or the like. For example, the terminal device may include a mobile phone (or referred to as a "cellular" phone), a computer with a mobile terminal device, or a portable, pocket-sized, handheld, or computer built-in mobile apparatus. For example, it may be a device such as a personal communication service (personal communication service, PCS) phone, a cordless telephone set, a session initiation protocol (session initiation protocol, SIP) phone, a wireless local loop (wireless local loop, WLL) station, or a personal digital assistant (personal digital assistant, PDA). The terminal device may alternatively include a limited device, for example, a device with low power consumption, a device with a limited storage capability, or a device with a limited computing capability. For example, the terminal device includes an information sensing device such as a barcode, radio frequency identification (radio frequency identification, RFID), a sensor, a global positioning system (global positioning system, GPS), or a laser scanner. As an example instead of a limitation, in embodiments of this application, the terminal device may alternatively be a wearable device. The wearable device may also be referred to as a wearable intelligent device, an intelligent wearable device, or the like, and is a general term of wearable devices that are intelligently designed and developed for daily wear by using a wearable technology. If the various terminal devices described above are located in a vehicle (for example, placed in the vehicle or installed in the vehicle), the terminal devices may be all considered as vehicle-mounted terminal devices. For example, the vehicle-mounted terminal devices are also referred to as on-board units (on-board unit, OBU).

[0077] The network device in this application includes, for example, an access network (access network, AN) device such as a base station (for example, an access point), and may be a device that is in an access network and that communicates with a wireless terminal device over an air interface through one or more cells. Alternatively, a network device is, for example, a road side

unit (road side unit, RSU) in a vehicle-to-everything (vehicle-to-everything, V2X) technology. For example, the network device may include a next-generation NodeB (next generation NodeB, gNB) in a 5th generation (5th generation, 5G) mobile communication technology and a new radio (new radio, NR) system (also referred to as an NR system for short), or may include a central unit (central unit, CU) and a distributed unit (distributed unit, DU) in a cloud access network (cloud radio access network, Cloud RAN) system, a satellite, a drone, a balloon, an airplane, and the like. This is not limited in embodiments of this application.

[0078] A polar code is a linear block code. A generator matrix of the polar code is G_N , and an encoding process of the polar code is $x_1^N = u_1^N G_N$, where $u_1^N = (u_1, u_2, \dots, u_N)$, and is a binary row vector, and a length is N (namely, a code length); and G_N is an $N \times N$ matrix, and $G_N = F_2^{\otimes (\log_2(N))}$, where $F_2 = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$, and $F_2^{\otimes (\log_2(N))}$ is defined as a Kronecker (Kronecker) product of $\log_2 N$ matrices F_2 .

[0079] In a polar code encoding process, some bits in u_1^N are used for carrying information and are referred to as information bits, and a set of indexes of the bits is denoted as A . Some other bits are set to fixed values that are pre-agreed on by a transmitting end and a receiving end (where the bits are referred to as fixed bits or frozen bits), and a set of indexes of the bits is represented by a complementary set A^c of A . Generally, the fixed bits are usually set to 0. A sequence of the fixed bits may be randomly set provided that the transmitting end and the receiving end reach an agreement in advance. Therefore, encoding output of the polar code may be simplified as: $x_1^N = u_A G_N(A)$, where u_A is a set of the information bits in u_1^N , u_A is a row vector with a length of K , that is, $|A| = K$, where $|\cdot|$ represents a quantity of elements in the set, K is an information block size, $G_N(A)$ is a sub-matrix obtained by using rows corresponding to indexes in the set A in the matrix G_N , and $G_N(A)$ is a $K \times N$ matrix. A polar code construction process is a selection process of the set A , and the selection process of the set A determines performance of the polar code.

[0080] Refer to FIG. 2. An example of a process of sending a signal by a transmitting end is illustrated. The transmitting end may construct an information sub-channel and a frozen sub-channel in advance based on manners such as density evolution (density evolution, DE), Gaussian approximation (Gaussian approximation, GA), and polarization weight (polarization weight, PW).

Channel encoding is performed on a to-be-encoded bit sequence based on the constructed information sub-channel and frozen sub-channel, to obtain an encoded bit sequence. Because energy of bits in a modulation symbol is inconsistent, the encoded bit sequence may be input to an interleaver to perform interleaving. An interleaved bit sequence is modulated into a plurality of symbols. The transmitting end sends the symbol to a receiving end.

[0081] FIG. 3 shows an example of a specific encoding process. The left side may be understood as a to-be-encoded side, and the right side may be understood as an encoded side. A process from left to right is a process in which a transmitting end encodes a to-be-encoded bit sequence. On the to-be-encoded side, the to-be-encoded bit sequence may be represented by a vector u , where the vector u is $(0, 0, 0, u_4, 0, u_6, u_7, u_8)$. The vector u is encoded based on a generator matrix G_N , to obtain an encoded bit sequence. Refer to FIG. 3. The encoded bit sequence may be represented as $(1, 1, 0, 0, 0, 0, 1, 1)$, where a high-reliability sub-channel is used for mapping an information bit, and a low-reliability sub-channel is used for mapping a frozen bit. As shown in FIG. 3, four information bits are respectively mapped to information sub-channels, frozen sub-channels are set to 0, and a bit sequence with a length of 8 is generated after an encoding process $x_1^N = u_1^N G_N$.

[0082] Further description may be made with reference to FIG. 3. In the encoding process, two adjacent columns are an encoding layer, bits in a left column are input bits of the encoding layer, and bits in a right column are output bits of the encoding layer. For example, in the leftmost encoding layer, an input bit sequence is $(0, 0, 0, 1, 0, 1, 0, 1)$, and an output bit sequence is $(0, 0, 1, 1, 1, 1, 1, 1)$. An operation symbol " $\oplus$ " in the middle of the encoding layer represents an exclusive OR operation, " $\oplus$ " represents an exclusive OR operation between a bit in a row in which " $\oplus$ " is located and a bit in a row which " $\oplus$ " reaches, and a bit on the right side of " $\oplus$ " is an operation result. For example, in the leftmost encoding layer, a " $\oplus$ " operation is performed on the first input bit (with a value of 0) and the second input bit (with a value of 0) to obtain the first output bit (with a value of 0).

[0083] Currently, a common construction method is, for example, BICM. The BICM mainly constructs an information sub-channel based on lower-order modulation such as QPSK or BPSK. In a construction process, it may be assumed that energy of bits in a lower-order modulation symbol is consistent. However, in higher-order modulation, for example, QAM16, energy of bits

in a symbol is inconsistent. If the BICM is used for generating a polar code under the higher-order modulation, there is a problem that a constructed information sub-channel does not match a modulation scheme.

[0084] In view of this, this application provides an encoding method, a decoding method, and an apparatus, to construct an information sub-channel and a frozen sub-channel by using correlation between bits in a symbol under the higher-order modulation, and generate a polar code under the higher-order modulation based on the constructed information sub-channel and frozen sub-channel. This helps improve channel transmission reliability.

[0085] The correlation between a plurality of bits in a same symbol under the higher-order modulation is explained in advance.

[0086] When a transmitting end sends the symbol to a receiving end through a channel, the plurality of bits in the same symbol are subject to same noise interference in the channel. Distribution of received information of the plurality of bits in the same symbol received by the receiving end is correlated. FIG. 4 is a schematic diagram of decoding a plurality of bits in a received symbol by a receiving end, where a modulation scheme is, for example, amplitude shift keying (amplitude shift keying, ASK) 16, and four bits in one symbol are correlated.

[0087] It should be noted in advance that, in FIG. 4, a_0 , a_1 , a_2 , a_3 , b_0 , b_1 , b_2 , b_3 , and the like all represent bits, and each bit corresponds to a value of the bit. In a decoding process, a plurality of times of decoding may be included, each time of decoding may correspond to one decoding layer, and one decoding layer includes an input bit and an output bit. For example, at the outermost decoding layer, the receiving end may decode a_0 , a_1 , a_2 , and a_3 to obtain b_0 , b_1 , b_2 , and b_3 , where a_0 , a_1 , a_2 , and a_3 are the input bits, and b_0 , b_1 , b_2 , and b_3 are the output bits. For ease of description, a layer at which a_0 , a_1 , a_2 , and a_3 are located may be referred to as a first layer, a layer at which b_0 , b_1 , b_2 , and b_3 are located is referred to as a second layer, a layer at which c_0 , c_1 , c_2 , and c_3 are located is referred to as a third layer, the first layer and the second layer form a first decoding layer, the second layer and the third layer form a second decoding layer, and so on.

[0088] In the example shown in FIG. 4, the receiving end may receive four symbols, and each symbol includes four bits. In other words, the receiving end may receive a bit sequence including 16 bits. Further, a_0 , a_1 , a_2 , and a_3 in the bit sequence are all bits in the first symbol. In a sending process, because a_0 , a_1 , a_2 , and a_3 are subject to same noise interference in a same symbol (namely, the first symbol), a_0 , a_1 , a_2 , and a_3 are correlated.

[0089] Correspondingly, the receiving end may decode a_0 , a_1 , a_2 , and a_3 in the first symbol to obtain intermediate results, where the intermediate results are respectively b_0 , b_1 , b_2 , and b_3 . Because b_0 , b_1 , b_2 , and b_3 still correspond to the first symbol, and are subject to the same noise interference in the same symbol, b_0 , b_1 , b_2 , and b_3 are correlated.

[0090] The receiving end may continue to decode b_0 , b_1 , b_2 , and b_3 to obtain intermediate results, where the intermediate results are respectively c_0 , c_1 , c_2 , and c_3 . Because c_0 , c_1 , c_2 , and c_3 still correspond to the first symbol, and are subject to the same noise interference in the same symbol, c_0 , c_1 , c_2 , and c_3 are correlated.

[0091] Herein, it should be noted that the receiving end performs two-layer decoding on a_0 , a_1 , a_2 , and a_3 in the first symbol, to obtain c_0 , c_1 , c_2 , and c_3 . For probability density functions respectively corresponding to a_0 , a_1 , a_2 , and a_3 , refer to FIG. 5a. The probability density functions respectively corresponding to a_0 , a_1 , a_2 , and a_3 are correlated. For probability density functions respectively corresponding to c_0 , c_1 , c_2 , and c_3 , refer to FIG. 5b. The probability density functions respectively corresponding to c_0 , c_1 , c_2 , and c_3 are also correlated.

[0092] As shown in FIG. 4, the receiving end may continue to decode c_0 , c_1 , c_2 , and c_3 , to obtain intermediate decoding results. It can be learned from a correspondence between bits at all layers in FIG. 4 that bits obtained by decoding c_0 , c_1 , c_2 , and c_3 no longer correspond to a same symbol, that is, the obtained bits are no longer correlated.

[0093] Based on the foregoing descriptions of the correlation, this application provides a manner of constructing a reliability sequence. The reliability sequence may be obtained based on the correlated plurality of bits in the same symbol in the foregoing decoding process.

[0094] In construction of the reliability sequence, a preset symbol quantity $S_{\max}$ and a preset modulation order $B_{\max}$ may be determined in advance, and both $S_{\max}$ and $B_{\max}$ are positive integers. The preset modulation order indicates a quantity of bits included in one symbol, and a plurality of bits in one symbol respectively correspond to respective energy levels. It may be understood that in this application, values of the preset modulation order, a preset bit quantity, and a preset energy level quantity are the same, and the three may be interchanged in some embodiments.

[0095] A schematic flowchart of generating a reliability sequence is described with reference to FIG. 6. The procedure may be performed by a reliability sequence generation apparatus, and the reliability sequence generation apparatus may be a receiving end, a transmitting end, or another

apparatus.

[0096] Step 601: Determine a joint distribution probability density function of transmitted symbols and received symbols based on a preset signal-to-noise ratio and a preset modulation order, where the transmitted symbol may be represented as x , the received symbol may be represented as y , and the joint distribution probability density function of the transmitted symbols and the received symbols may be represented as $f(y, x)$.

[0097] In this application, a quantity of transmitted symbols may be equal to the preset symbol quantity $S_{\max}$, and a quantity of received symbols may also be equal to the preset symbol quantity $S_{\max}$. In other words, the joint distribution probability density function of the transmitted symbols and the received symbols may be determined based on $S_{\max}$ transmitted symbols and $S_{\max}$ received symbols.

[0098] For example, the joint distribution probability density function of the transmitted symbols and the received symbols $f(y, x)$ meets a formula:

$$f(y, x) = X(x, \sigma^2) \times P(x)$$

[0099] $x_0, x_1, \dots, x_{\max-1}$ are a value range of a value of the transmitted symbol, and the value range of the value of the transmitted symbol is related to the preset modulation order $B_{\max}$. For example, in a case of ASK8, the preset modulation order is 3, and the value range of the value of the transmitted symbol is $x_0, x_1, \dots, x_7$. For example, in a case of ASK16, the preset modulation order is 4, and the value range of the value of the transmitted symbol is $x_0, x_1, \dots, x_{15}$. $X(x, \sigma^2)$ is Gaussian distribution that complies with $N(x, \sigma^2)$, and σ^2 is noise power density. $P(x)$ is a prior probability that an amplitude of the transmitted symbol is equal to $x_0, x_1, \dots, x_{\max-1}$.

[00100] Step 602: Determine an expression of an LLR of a first bit in the received symbols based on the received symbols and the transmitted symbols.

[00101] The first bit may be an input bit of the outermost decoding layer in a decoding process of the received symbols. A same received symbol may include $B_{\max}$ first bits, and the $B_{\max}$ first bits may be respectively represented as $a_0, a_1, \dots, a_{B_{\max}-1}$. For example, in the ASK16 shown in FIG. 4, there are four received symbols, and the outermost decoding layer corresponding to each received symbol includes four first bits. The first received symbol is used as an example for description. The four first bits included in the first received symbol may be respectively represented as a_0, a_1, a_2 , and a_3 .

[00102] It is noted in advance that the transmitted symbol may be a joint expression of a

plurality of bits, and the transmitted symbol may be expressed as $(b_0b_1 \dots b_{B_{\max}-1})_2$ in binary, where $b_0, b_1, \dots, b_{B_{\max}-1}$ are values of all bits of the transmitted symbol in a binary expression.

[00103] Specifically, a prior probability $P(\tilde{x})$ may be determined first, and a likelihood probability $P(y|\tilde{x})$ is determined based on the received symbols, where $\tilde{x}$ is a possible transmitted symbol when the likelihood probability is calculated. Then, expressions of LLRs of a plurality of first bits are determined based on the prior probability $P(\tilde{x})$ and the likelihood probability $P(y|\tilde{x})$.

[00104] For example, in the plurality of first bits, an LLR of a k^{th} first bit may be expressed as:

$$\text{LLR}_k(y, x) = \log \frac{\sum_{b_k=\tilde{b}_k} P(y|\tilde{x}) \times P(\tilde{x})}{\sum_{b_k \neq \tilde{b}_k} P(y|\tilde{x}) \times P(\tilde{x})}$$

[00105] A value range of k is $0, 1, \dots, B_{\max}-1$; b_k is a value of the k^{th} first bit in x ; and $\tilde{b}_k$ is a value of the k^{th} first bit in $\tilde{x}$.

[00106] In a construction process, $\text{LLR}_k(y, x)$ may be used to represent whether the k^{th} first bit is correctly decoded. For example, when the LLR is greater than 0, it indicates that the k^{th} first bit is correctly decoded; or when the LLR is less than 0, it indicates that the k^{th} first bit is incorrectly decoded. A probability that the k^{th} first bit is correctly decoded may be obtained based on an integral of a (y, x) combination with $\text{LLR}_k(y, x)$ greater than 0 in $f(y, x)$.

[00107] In this application, the receiving end receives $S_{\max}$ received symbols, and each received symbol includes $B_{\max}$ first bits. To be specific, a bit sequence received by the receiving end includes $N_{\max}$ first bits, where $N_{\max}$ equals to the preset symbol quantity $S_{\max}$ multiplied by the preset modulation order $B_{\max}$. Correspondingly, the receiving end may determine LLRs of the $N_{\max}$ first bits, that is, expressions of the LLRs of the $N_{\max}$ first bits with respect to (y, x) . In the example in FIG. 4, the preset symbol quantity $S_{\max}$ is 4, and the preset modulation order $B_{\max}$ is 4. In other words, the bit sequence received by the receiving end includes 16 first bits. Correspondingly, the receiving end may obtain expressions of LLRs of the 16 first bits with respect to (y, x) based on the 16 (y, x) combinations.

[00108] Step 603: Determine an expression of an LLR of a second bit based on the expression of the LLR of the first bit in the received symbol. The second bit is an intermediate bit in a process of decoding the first bit.

[00109] Specifically, for any received symbol, the expression of the LLR of the second bit may be determined based on the expression of the LLR of the first bit in the received symbol. One received symbol includes $B_{\max}$ first bits. LLRs of the $B_{\max}$ first bits in the received symbol are

decoded, to obtain LLRs of Bmax second bits, and the Bmax second bits also correspond to the received symbol. In this application, the Bmax second bits may be respectively represented as c_0 , c_1 , ..., and $c_{B_{\max}-1}$.

[00110] For example, in the ASK16 shown in FIG. 4, symbol decoding operation is performed on LLRs (to be specific, LLRs of a_0 , a_1 , a_2 , and a_3) in the four first bits in the first received symbol, to obtain LLRs in four second bits corresponding to the first received symbol. The four second bits may be respectively represented as c_0 , c_1 , c_2 , and c_3 .

[00111] An example in which a_0 , a_1 , a_2 , and a_3 are first bits, and c_0 , c_1 , c_2 , and c_3 are second bits is used for specifically explaining a process of determining expressions of LLRs of the second bits based on expressions of LLRs of the first bits in this application.

[00112] Step 1: Obtain expressions of LLRs of b_0 , b_1 , b_2 , and b_3 based on the expressions of the LLRs of a_0 , a_1 , a_2 , and a_3 .

[00113] For example, the expressions of the LLRs of b_0 , b_1 , b_2 , and b_3 may be as follows:

$$LLR_{b_0}(y, x) = (LLR_{a_0}(y, x) \blacksquare LLR_{a_2}(y, x))$$

$$LLR_{b_1}(y, x) = (LLR_{a_1}(y, x) \blacksquare LLR_{a_3}(y, x))$$

$$LLR_{b_2}(y, x) = (LLR_{a_0}(y, x) + LLR_{a_2}(y, x))$$

$$LLR_{b_3}(y, x) = (LLR_{a_1}(y, x) + LLR_{a_3}(y, x))$$

[00114] In the expression, $LLR_{a_0}(y, x)$, $LLR_{a_1}(y, x)$, $LLR_{a_2}(y, x)$, and $LLR_{a_3}(y, x)$ indicate the expressions of the LLRs of a_0 , a_1 , a_2 , and a_3 respectively; and $LLR_{b_0}(y, x)$, $LLR_{b_1}(y, x)$, $LLR_{b_2}(y, x)$, and $LLR_{b_3}(y, x)$ indicate the expressions of the LLRs of b_0 , b_1 , b_2 , and b_3 respectively. $\blacksquare$ indicates a boxplus operation. For example, boxplus may also be replaced by an expression $a \blacksquare b = \left(1 - 2^{\text{sign}(a)\text{sign}(b)}\right) \times \min(\text{abs}(a), \text{abs}(b))$. In the expression, sign indicates a sign operation, 0 is output for a positive number, and 1 is output for a negative number. abs indicates an operation of obtaining an absolute value, and min indicates an operation of obtaining a minimum value.

[00115] Step 2: Obtain the expressions of the LLRs of c_0 , c_1 , c_2 , and c_3 based on the expressions of the LLRs of b_0 , b_1 , b_2 , and b_3 .

[00116] For example, the expressions of the LLRs of c_0 , c_1 , c_2 , and c_3 may be as follows:

$$\text{LLR}_{c_0}(y, x) = (\text{LLR}_{b_0}(y, x) \blacksquare \text{LLR}_{b_1}(y, x))$$

$$\text{LLR}_{c_1}(y, x) = (\text{LLR}_{b_0}(y, x) + \text{LLR}_{b_1}(y, x))$$

$$\text{LLR}_{c_2}(y, x) = (\text{LLR}_{b_2}(y, x) \blacksquare \text{LLR}_{b_3}(y, x))$$

$$\text{LLR}_{c_3}(y, x) = (\text{LLR}_{b_2}(y, x) + \text{LLR}_{b_3}(y, x))$$

5 **[00117]** In the expression, $\text{LLR}_{c_0}(y, x)$, $\text{LLR}_{c_1}(y, x)$, $\text{LLR}_{c_2}(y, x)$, and $\text{LLR}_{c_3}(y, x)$ indicate the LLRs of c_0 , c_1 , c_2 , and c_3 respectively.

[00118] Further, based on the expressions of the LLRs of c_0 , c_1 , c_2 , and c_3 with respect to the LLRs of b_0 , b_1 , b_2 , and b_3 and the expressions of the LLRs of b_0 , b_1 , b_2 , and b_3 with respect to the LLRs of a_0 , a_1 , a_2 , and a_3 , the expressions of the LLRs of c_0 , c_1 , c_2 , and c_3 with respect to the LLRs
10 of a_0 , a_1 , a_2 , and a_3 may be obtained:

$$\text{LLR}_{c_0}(y, x) = (\text{LLR}_{a_0}(y, x) \blacksquare \text{LLR}_{a_2}(y, x)) \blacksquare (\text{LLR}_{a_1}(y, x) \blacksquare \text{LLR}_{a_3}(y, x))$$

$$\text{LLR}_{c_1}(y, x) = (\text{LLR}_{a_0}(y, x) \blacksquare \text{LLR}_{a_2}(y, x)) + (\text{LLR}_{a_1}(y, x) \blacksquare \text{LLR}_{a_3}(y, x))$$

$$\text{LLR}_{c_2}(y, x) = (\text{LLR}_{a_0}(y, x) + \text{LLR}_{a_2}(y, x)) \blacksquare (\text{LLR}_{a_1}(y, x) + \text{LLR}_{a_3}(y, x))$$

$$\text{LLR}_{c_3}(y, x) = (\text{LLR}_{a_0}(y, x) + \text{LLR}_{a_2}(y, x)) + (\text{LLR}_{a_1}(y, x) + \text{LLR}_{a_3}(y, x))$$

15 **[00119]** It should be supplemented that the foregoing descriptions are merely provided by using the ASK16 as an example. However, in another scenario, for example, ASK4 or ASK8, the expressions of the LLRs of the second bits may also be determined based on the expressions of the LLRs of the first bits.

[00120] For example, in the ASK8:

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$$\text{LLR}_{c_0}(y, x) = (\text{LLR}_{a_0}(y, x) \blacksquare \text{LLR}_{a_2}(y, x)) \blacksquare (\text{LLR}_{a_1}(y, x))$$

$$\text{LLR}_{c_1}(y, x) = (\text{LLR}_{a_0}(y, x) \blacksquare \text{LLR}_{a_2}(y, x)) + (\text{LLR}_{a_1}(y, x))$$

$$\text{LLR}_{c_2}(y, x) = (\text{LLR}_{a_0}(y, x) + \text{LLR}_{a_2}(y, x))$$

[00121] It should be further supplemented that, in the ASK16 or the ASK8, two-layer decoding needs to be performed on the LLRs of the first bits, to obtain the LLRs of the second bits. However,
25 in the ASK4, the LLRs of the second bits may be obtained by performing only one-layer decoding on the LLRs of the first bits. In other words, in this application, a decoding layer quantity for decoding from the LLRs of the first bits to the LLRs of the second bits (which may be referred to

as a first decoding layer quantity) may be related to a preset modulation order. For example, the first decoding layer quantity equals to $\log_2 B_{\max}$. For example, the preset modulation order is 4, and the first decoding layer quantity is 2; or the preset modulation order is 2, and the first decoding layer quantity is 1.

[00122] In this application, the receiving end may determine expressions of LLRs of $N_{\max}$ second bits, to be specific, the expressions of the LLRs of the $N_{\max}$ second bits with respect to (y, x) . In the example in FIG. 4, the preset symbol quantity $S_{\max}$ is 4, and the preset modulation order $B_{\max}$ is 4. In other words, the bit sequence received by the receiving end includes 16 second bits. Correspondingly, the receiving end may obtain expressions of LLRs of the 16 second bits with respect to (y, x) based on 16 (y, x) combinations.

[00123] Step 604: Determine LLR distribution of the second bits based on the expressions of the LLRs of the second bits.

[00124] The LLR distribution of the second bits may be obtained based on the following expression:

$$f_c(\text{LLR} = L) = \int_{\text{LLR}_c(y,x)=L} f(y, x)$$

[00125] $f_c(\text{LLR} = L)$ is the LLR distribution of the second bits. Thus, the LLR distribution of the second bits is a distribution function related to the LLRs of the second bits. In this application, LLR distribution of the $N_{\max}$ second bits may be obtained.

[00126] Step 605: Determine LLR distribution of third bits based on the LLRs distribution of the second bits.

[00127] The third bit is a final bit (equivalent to a to-be-encoded bit of the transmitting end) in the decoding process, and the plurality of third bits may be used by the receiving end to determine information bits actually sent by the transmitting end. For example, in the ASK16 shown in FIG. 4, the last layer is final bits obtained through decoding, and the final bits include 16 third bits.

[00128] For a co-color block, LLR distribution of two output bits in the co-color block may be determined based on LLR distribution of two input bits in the co-color block. Still using FIG. 4 as an example, LLR distribution of d_0 and d_4 may be determined based on LLR distribution of c_0 and c_4 . For details, refer to the following relational expression:

$$f_{d_0}(\text{LLR} = L) = \int_{L=L_0 \blacksquare L_4} f_{c_0}(L_0) \times f_{c_4}(L_4)$$

$$f_{d_4}(\text{LLR} = L) = \int_{L=L_0+L_4} f_{c_0}(L_0) \times f_{c_4}(L_4)$$

[00129] $f_{c_0}(L)$ and $f_{c_4}(L)$ are the LLR distribution of c_0 and c_4 respectively, and $f_{d_0}(L)$ and $f_{d_4}(L)$ are the LLR distribution of d_0 and d_4 respectively.

[00130] In this way, LLR distribution of bits at a fourth layer in the decoding process may be obtained based on LLR distribution of bits at a third layer in the decoding process. Further, LLR distribution of bits at a fifth layer in the decoding process is determined based on the LLR distribution of the bits at the fourth layer in the decoding process, and by analogy, LLR distribution of bits at the last layer in the decoding process (that is, the LLR distribution of the third bits) is obtained.

[00131] In this application, LLR distribution of Nmax third bits may be obtained.

[00132] It should be supplemented that, in the decoding process, the LLR distribution of the third bits is determined based on the LLR distribution of the second bits, where a decoding layer quantity is related to the preset symbol quantity Smax. In other words, a decoding layer quantity for decoding from the second bits to the third bits (which may be referred to as a second decoding layer quantity) may be related to the preset symbol quantity Smax. For example, the second decoding layer quantity equals to $\log_2 S_{\text{max}}$. For example, the preset symbol quantity is 4, and the second decoding layer quantity is 2; or the preset symbol quantity is 8, and the second decoding layer quantity is 3.

[00133] Step 606: Determine a reliability sequence based on the LLR distribution of the third bits.

[00134] The following may be performed on each of the Nmax third bits: Perform integration on a part that is in the LLR distribution of the third bits and whose LLR is greater than 0, to obtain decoding accuracy of the third bits.

[00135] Optionally, the decoding accuracy of the third bits may be obtained with reference to the relational expression $P_u = \int_{L>0} f_u(L)$, where u represents the third bits, $f_u(L)$ represents the LLR distribution of the third bits, and P_u represents the decoding accuracy of the third bits.

[00136] After the accuracy of the third bits is determined, reliability of the third bits may be determined based on the accuracy of the third bits. For example, the accuracy of the third bits may be used as the reliability of the third bits. Then, a reliability sequence is determined based on

reliability of the Nmax third bits. In determining the reliability sequence, specifically, the Nmax third bits may be sorted based on the reliability respectively corresponding to the Nmax third bits, to obtain the reliability sequence.

[00137] With reference to the method for determining the reliability sequence shown in the example in FIG. 6, in this application, a joint probability density function $f(y, x)$ corresponding to a bit may be converted into discrete probability distribution, and an actual operation is completed in a manner of probability distribution summation. For ease of description, the example of the ASK16 shown in FIG. 4 is still used for description.

[00138] Step 1: Perform discretization processing on the received symbols to obtain discretized values $\hat{y}$, where $\hat{y}$ has $2n + 1$ items, and is represented as $[\hat{y}_{-n}, \hat{y}_{-(n-1)}, \dots, \hat{y}_{-1}, \hat{y}_0, \hat{y}_1, \dots, \hat{y}_{(n-1)}, \hat{y}_n]$, and n is a positive integer. Further, $\hat{y}_i = i \times z$, $i \in [-n, -(n-1), \dots, -1, 0, 1, \dots, n-1, n]$, where z represents a positive number.

[00139] Then, the probability density function $f(y, x)$ is converted into a discrete probability distribution $P(\hat{y}_i, x) = P(x) \times \int_{\hat{y}_a}^{\hat{y}_b} X(x, \sigma^2)$, where $x_0, x_1, \dots, x_{\max-1}$ is a value range of a value of a transmitted symbol, $\hat{y}_a = \begin{cases} -\infty, & i = -n \\ z \times (i - 0.5), & i \neq -n \end{cases}$, $\hat{y}_b = \begin{cases} +\infty, & i = n \\ z \times (i + 0.5), & i \neq n \end{cases}$, and $P(x)$ is a prior probability that the transmitted symbol is equal to $x_0, x_1, \dots, x_{\max-1}$.

[00140] Step 2: Determine a likelihood probability $P(\hat{y}|\tilde{x})$ based on the received symbol $\hat{y}$, and determine the expressions of the LLRs of the first bits in the received symbol $\hat{y}$ based on the likelihood probability $P(\hat{y}|\tilde{x})$ and the prior probability $P(\tilde{x})$.

[00141] The LLR of the k^{th} first bit may be expressed as $\text{LLR}_k(\hat{y}, x) = \log \frac{\sum_{b_k=\tilde{b}_k} P(\hat{y}|\tilde{x}) \times P(\tilde{x})}{\sum_{b_k' \neq \tilde{b}_k} P(\hat{y}|\tilde{x}) \times P(\tilde{x})}$,

where the value of k is one of 0, 1, 2, or 3; b_k is the value of the k^{th} first bit in x ; and $\tilde{b}_k$ is the value of the k^{th} first bit in $\tilde{x}$. To facilitate calculation, the foregoing expression $\text{LLR}_k(\hat{y}, x)$ may be simplified as follows:

$$\text{LLR}_k(\hat{y}, x) = \max_{b_k=\tilde{b}_k} (P(\hat{y}|\tilde{x}) \times P(\tilde{x})) - \max_{b_k' \neq \tilde{b}_k} (P(\hat{y}|\tilde{x}) \times P(\tilde{x}))$$

[00142] The max operation indicates obtaining the maximum value.

[00143] Correspondingly, the receiving end may obtain the expressions of the LLRs of the 16 first bits with respect to (y, x) based on the 16 (y, x) combinations.

[00144] Step 3: Determine the expressions of the LLRs of the second bits based on the expressions of the LLRs of the first bits in the received symbol $\hat{y}$, including the following step.

[00145] Based on the expressions of the LLRs of a_0 , a_1 , a_2 , and a_3 , the obtained expressions of the LLRs of c_0 , c_1 , c_2 , and c_3 is as follows:

$$\text{LLR}_{c_0}(\hat{y}, x) = (\text{LLR}_{a_0}(\hat{y}, x) \blacksquare \text{LLR}_{a_2}(\hat{y}, x)) \blacksquare (\text{LLR}_{a_1}(\hat{y}, x) \blacksquare \text{LLR}_{a_3}(\hat{y}, x))$$

$$\text{LLR}_{c_1}(\hat{y}, x) = (\text{LLR}_{a_0}(\hat{y}, x) \blacksquare \text{LLR}_{a_2}(\hat{y}, x)) + (\text{LLR}_{a_1}(\hat{y}, x) \blacksquare \text{LLR}_{a_3}(\hat{y}, x))$$

$$\text{LLR}_{c_2}(\hat{y}, x) = (\text{LLR}_{a_0}(\hat{y}, x) + \text{LLR}_{a_2}(\hat{y}, x)) \blacksquare (\text{LLR}_{a_1}(\hat{y}, x) + \text{LLR}_{a_3}(\hat{y}, x))$$

$$\text{LLR}_{c_3}(\hat{y}, x) = (\text{LLR}_{a_0}(\hat{y}, x) + \text{LLR}_{a_2}(\hat{y}, x)) + (\text{LLR}_{a_1}(\hat{y}, x) + \text{LLR}_{a_3}(\hat{y}, x))$$

[00146] $\blacksquare$ represents the boxplus operation, and consistent with Gaussian approximation, the LLRs is represented by correct decoding and incorrect decoding in this case, so that a G function is simplified to addition. To simplify the calculation, the boxplus can alternatively be replaced by an expression $a \blacksquare b = \left(1 - 2^{\text{sign}(a)\text{sign}(b)}\right) \times \min(\text{abs}(a), \text{abs}(b))$. In the expression, sign indicates a sign operation, 0 is output for a positive number, and 1 is output for a negative number. abs indicates an operation of obtaining an absolute value, and $\min$ indicates an operation of obtaining a minimum value.

[00147] Step 4: Determine the LLR distribution of the second bits based on the expressions of the LLRs of the second bits.

[00148] Specifically, LLR distribution of any second bit may be represented as $P_c(\text{LLR} = \hat{L}) = \sum_{\text{LLR}_c(\hat{y}_i, x) = \hat{L}} P(\hat{y}_i, x)$, where $\hat{L}$ is a discretized value of the LLR, $\hat{L}$ has $2m + 1$ items, and is represented as $[\hat{L}_{-m}, \hat{L}_{-(m-1)}, \dots, \hat{L}_{-1}, \hat{L}_0, \hat{L}_1, \dots, \hat{L}_{(m-1)}, \hat{L}_m]$, and m is a positive integer. Specifically, $\hat{L}_i = i \times z$, $i \in [-m, -(m-1), \dots, -1, 0, 1, \dots, m-1, m]$.

[00149] Step 5: Determine the LLR distribution of the third bits based on the LLR distribution of the second bits.

[00150] Density evolution may be performed on a basic in the co-color block, to obtain output distribution of $P_{d_0}(\hat{L})$ and $P_{d_4}(\hat{L})$ when distribution of $P_{c_0}(\hat{L})$ and $P_{c_4}(\hat{L})$ is input, and an expression is as follows:

$$P_{d_0}(\text{LLR} = \hat{L}) = \sum_{\hat{L} = f(\hat{L}_i, \hat{L}_j)} P_{c_0}(\hat{L}_i) \times P_{c_4}(\hat{L}_j),$$

$$P_{d_4}(\text{LLR} = \hat{L}) = \sum_{\hat{L} = \hat{L}_i + \hat{L}_j} P_{c_0}(\hat{L}_i) \times P_{c_4}(\hat{L}_j),$$

where $f(\hat{L}_i, \hat{L}_j) \triangleq (1 - 2^{\text{sign}(\hat{L}_i) \wedge \text{sign}(\hat{L}_j)}) \times \min(\text{abs}(\hat{L}_i), \text{abs}(\hat{L}_j))$.

[00151] Step 6: Determine the reliability sequence based on the LLR distribution of the third bits.

[00152] Specifically, the accuracy of each third bit may be determined with reference to a relational expression $P_u = \sum P_u(\hat{L} > 0) + 0.5 \times P_u(\hat{L} = 0)$. The reliability of each third bit is determined based on the accuracy of each third bit. Then, the reliability sequence is determined based on the reliability of each third bit. Herein, the reliability sequence may include the 16 third bits sorted based on the reliability.

[00153] In this application, the third bit may also be referred to as a polarized sub-channel, and the polarized sub-channel is used for mapping a to-be-encoded bit in polar encoding, so that the polarized sub-channel may be referred to as a sub-channel for short. In a possible implementation, a quantity of sub-channels may be N_{max} (to be specific, $S_{\text{max}} \times B_{\text{max}}$), N_{max} sub-channels may form an encoding sequence, and each sub-channel in the encoding sequence corresponds to a sequence number based on a location of the sub-channel. For example, a preset symbol quantity $S_{\text{max}}=16$. To be specific, the encoding sequence includes 16 symbols, and the 16 symbols may be represented as a symbol 0 to a symbol 15. A preset modulation order $B_{\text{max}}=4$. To be specific, each symbol corresponds to four bits. The quantity of sub-channels N_{max} is $16 \times 4=64$, and 64 sub-channels may be represented as a sub-channel 0 to a sub-channel 63. For example, for the encoding sequence, refer to FIG. 7a. The sub-channel 0, the sub-channel 16, the sub-channel 32, and the sub-channel 48 may correspond to the symbol 0, and the sub-channel 1, the sub-channel 17, the sub-channel 33, and the sub-channel 49 may correspond to the symbol 1, and the like.

[00154] Alternatively, the location of the sub-channel in the encoding sequence may be represented by using a sequence number of a symbol in which the sub-channel is located and a sequence number of the sub-channel in the symbol. For example, a sub-channel (0, 0) represents that the sub-channel is the sub-channel 0 in the symbol 0, namely, the first sub-channel in the first symbol. For another example, a sub-channel (0, 1) represents that the sub-channel is the sub-channel 1 in the symbol 0, namely, the second sub-channel in the first symbol. For another example, a sub-channel (1, 0) represents that the sub-channel is the sub-channel 0 in the symbol 1, namely, the first sub-channel in the second symbol. For another example, a sub-channel (1, 1) represents that the sub-channel is the sub-channel 1 in the symbol 1, namely, the second sub-channel in the

second symbol.

[00155] For ease of description, the following uses the sequence number of the sub-channel to represent the location of the sub-channel in the encoding sequence for example.

[00156] The $N_{\max}$ sub-channels may be sorted in a descending order based on reliability of the $N_{\max}$ sub-channels, to obtain the reliability sequence. The reliability sequence may be divided into $B_{\max}$ sub-sequences based on energy levels, and each sub-sequence corresponds to one energy level. Further, each sub-sequence includes $S_{\max}$ sub-channels.

[00157] FIG. 7b is a schematic diagram of an example of a reliability sequence according to this application. The reliability sequence corresponds to the example of the encoding sequence shown in FIG. 7a. In the reliability sequence, reliability of sub-channels from top to bottom gradually increases, and reliability of sub-channels from left to right gradually increases. For example, reliability of a sub-channel 62 is greater than reliability of a sub-channel 56, and reliability of the sub-channel 62 is greater than reliability of a sub-channel 61.

[00158] Further, the reliability sequence may include four sub-sequences, and each sub-sequence corresponds to one energy level. For example, the four sub-sequences are represented as a sub-sequence 0, a sub-sequence 1, a sub-sequence 2, and a sub-sequence 3, and respectively correspond to an energy level 0, an energy level 1, an energy level 2, and an energy level 3. The energy levels are sorted in ascending order as follows: the energy level 0, the energy level 1, the energy level 2, and the energy level 3. Each sub-sequence includes 16 sub-channels, where the sub-sequence 0 may include 16 sub-channels corresponding to a pattern 1, the sub-sequence 1 may include 16 sub-channels corresponding to a pattern 2, the sub-sequence 2 may include 16 sub-channels corresponding to a pattern 3, and the sub-sequence 3 may include 16 sub-channels corresponding to a pattern 4.

[00159] Herein, it should be supplemented that, in FIG. 7b, the 16 sub-channels included in the sub-sequence 0, namely, sub-channels 0 to 15, correspond to sub-channels in the first row in FIG. 7a. It may also be understood that the sub-channels included in the first row in FIG. 7a form the sub-sequence 0. Similarly, in FIG. 7a, sub-channels included in the second row form the sub-sequence 1, sub-channels included in the third row form the sub-sequence 2, and sub-channels included in the fourth row form the sub-sequence 3.

[00160] Based on the constructed reliability sequence, during encoding at a transmitting end, the transmitting end may determine an information sub-channel and a frozen bit from the encoding

sequence based on a symbol quantity and a modulation order in current encoding and reliability of the sub-channels in the reliability sequence, and encode to-be-encoded information based on the information sub-channel and the frozen bit.

5 **[00161]** To better explain this embodiment of this application, a bit sequence and a sub-channel used in an encoding process in this application are first explained and described. In this application, when the transmitting end needs to send K information bits to a receiving end, the transmitting end may obtain a sending length L based on an information bit quantity K and a bit rate R , where the sending length L is a bit quantity actually sent by the transmitting end to the receiving end.

10 **[00162]** The sending length L corresponds to a mother code length N , the mother code length N may be less than or equal to a maximum mother code length $N_{\max}$, and the maximum mother code length $N_{\max}$ may be understood as a quantity of sub-channels included in the reliability sequence. In this case, an area between the mother code length N and the maximum mother code length $N_{\max}$ is an unavailable area, and the unavailable area cannot be used by the transmitting end to determine the information sub-channel. It may also be understood that an area
15 corresponding to the mother code length N is an available area, and an area other than the available area in an area corresponding to the maximum mother code length $N_{\max}$ is the unavailable area.

[00163] Further, the mother code length N may be greater than or equal to the sending length L , and the transmitting end can match the sending length L with the mother code length N in a rate matching manner. On a to-be-encoded side, when selecting the information sub-channel from the
20 available area, the transmitting end selects a shortened sub-channel or a punctured sub-channel at the same time. The shortened sub-channel or the punctured sub-channel corresponds to a pre-frozen sub-channel on the to-be-encoded side, and the shortened sub-channel or the punctured sub-channel may be deleted by the transmitting end on an encoded side. Further, on the to-be-encoded side, after excluding the shortened sub-channel or the punctured sub-channel from the available
25 area, the transmitting end may obtain a candidate area, and the transmitting end may select the information sub-channel from the candidate area. A sub-channel other than the information sub-channel in the candidate area may be set as a frozen sub-channel, and the frozen sub-channel may be used to place the frozen bit.

30 **[00164]** FIG. 8 is a schematic flowchart of an example of encoding and decoding according to this application.

[00165] Step 801: A transmitting end obtains an information bit quantity K and an encoding bit

quantity L.

[00166] When the transmitting end needs to send an information bit sequence, the transmitting end may determine the encoding bit quantity L based on the information bit quantity K and a bit rate R that are included in the information bit sequence. Optionally, the encoding bit quantity L equals to the information bit quantity K divided by the bit rate R, where K and L are both positive integers, and R is less than or equal to 1.

[00167] Step 802: The transmitting end determines a symbol quantity S based on the encoding bit quantity L and an energy level quantity B, where the symbol quantity S is S1 or S2, $S1=L/B$, and $S2=L/2B$. S1, S2, and B are positive integers.

[00168] This embodiment of this application may be applicable to a plurality of modulation schemes, such as PAM, QAM, ASK, and PSK.

[00169] For single-channel modulation (where a symbol includes only a real part), for example, the PAM or the ASK, the transmitting end may determine the symbol quantity S1 based on the encoding bit quantity L and the energy level quantity B, where $S1=L/B$.

[00170] For two-channel modulation (where the symbol includes the real part and an imaginary part), for example, the QAM or the PSK, the transmitting end may determine the symbol quantity S2 based on the encoding bit quantity L and the energy level quantity B, where $S2=L/2B$.

[00171] Step 803: The transmitting end determines K information sub-channels from an encoding sequence based on the symbol quantity S, the energy level quantity B, and a reliability sequence. The K information sub-channels are sub-channels used to place K information bits.

[00172] In an optional implementation, the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels. Specifically, the K information sub-channels may be selected from the candidate sub-channels in descending order of reliability of the candidate sub-channels. Further, the candidate sub-channels are S1 sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i, where i may be an integer from 0 to B-1. In other words, an energy level 0 to an energy level quantity B-1 correspond to B sub-sequences, and the transmitting end may determine the S1 sub-channels or the $2 \times S2$ sub-channels from each of the B sub-sequences.

[00173] In this application, the transmitting end may determine a mother code length of the symbol S' based on the symbol quantity S, and determine a mother code length in the symbol B' based on the energy level quantity B (namely, a bit quantity B in the symbol). The mother code

length of the symbol S' and the mother code length in the symbol B' may be used for determining a mother code length N . Optionally, the mother code length N is a product of the mother code length of the symbol S' and the mother code length in the symbol B' .

[00174] For example, the mother code length of the symbol S' may be obtained based on a formula $S' = 2^{\lceil \log_2(S) \rceil}$. For example, when the symbol quantity S equals to 14, the mother code length of the symbol $S' = 2^{\lceil \log_2(14) \rceil} = 16$; and for another example, when the symbol quantity S equals to 7, the mother code length of the symbol $S' = 2^{\lceil \log_2(7) \rceil} = 8$.

[00175] The mother code length in the symbol B' may be obtained based on a formula $B' = 2^{\lceil \log_2(B) \rceil}$. For example, when the bit quantity in the symbol B equals to 3, the mother code length in the symbol $B' = 2^{\lceil \log_2(3) \rceil} = 4$; and for example, when the bit quantity in the symbol B equals to 2, the mother code length in the symbol $B' = 2^{\lceil \log_2(2) \rceil} = 2$.

[00176] When the mother code length of the symbol S' is less than a preset symbol quantity $S_{\max}$, and/or the mother code length in the symbol B' is less than a preset energy level quantity $B_{\max}$, the transmitting end may set a pre-frozen sub-channel, and the pre-frozen sub-channel may be processed as a frozen bit in an encoding and decoding process. The pre-frozen sub-channel may also be referred to as an unavailable sub-channel. It may be understood that the pre-frozen sub-channel corresponds to an unavailable area in the encoding sequence, and an area other than the unavailable area in the encoding sequence may be an available area.

[00177] For an implementation in which the transmitting end determines the pre-frozen sub-channel, refer to the following example 1 to example 3.

[00178] Example 1: When the mother code length of the symbol S' is less than the preset symbol quantity $S_{\max}$, the transmitting end may determine the unavailable sub-channel based on the mother code length of the symbol S' and the preset symbol quantity $S_{\max}$. Refer to the example of the encoding sequence shown in FIG. 7a. For example, the preset symbol quantity $S_{\max}$ equals to 16, and assuming that the mother code length of the symbol $S' = 8$, the transmitting end may determine that all sub-channels corresponding to a symbol 8 to a symbol 15 are unavailable sub-channels.

[00179] Example 2: When the mother code length in the symbol B' is less than the preset energy level quantity $B_{\max}$, the transmitting end may determine the unavailable sub-channel based on the mother code length in the symbol B' and the preset energy level quantity $B_{\max}$. Refer to the example of the encoding sequence shown in FIG. 7a. For example, the preset energy level

quantity $B_{\max}$ equals to 4, and assuming that the mother code length in the symbol $B' = 2$, the transmitting end may determine that a third sub-channel and fourth sub-channel in each symbol are unavailable sub-channels.

[00180] Example 3: When the mother code length of the symbol S' is less than the preset symbol quantity $S_{\max}$, and the mother code length in the symbol B' is less than the preset energy level quantity $B_{\max}$, the transmitting end may determine the unavailable sub-channel based on the mother code length of the symbol S' and the preset symbol quantity $S_{\max}$, and based on the mother code length in the symbol B' and the preset energy level quantity $B_{\max}$. Refer to the example of the encoding sequence shown in FIG. 7a. For example, the preset symbol quantity $S_{\max}$ equals to 16, the preset energy level quantity $B_{\max}$ equals to 4, and assuming that the mother code length of the symbol $S' = 8$, and the mother code length in the symbol $B' = 2$, the transmitting end may determine the sub-channels corresponding to the symbol 8 to the symbol 15, and both a third sub-channel and a fourth sub-channel of each symbol in a symbol 0 to a symbol 7 are unavailable sub-channels.

[00181] It is clear that when the mother code length of the symbol S' is equal to the preset symbol quantity $S_{\max}$, and the mother code length in the symbol B' is equal to the preset energy level quantity $B_{\max}$, the transmitting end may not need to perform the step of determining the available area (or in other words, the transmitting end may not need to perform the step of determining the unavailable area).

[00182] In an optional implementation, when the symbol quantity S is less than the mother code length of the symbol S' , and/or the energy level quantity B is less than the mother code length in the symbol B' , the transmitting end may determine the pre-frozen sub-channel from the available area based on the symbol quantity S and the energy level quantity B . The pre-frozen sub-channel is a sub-channel corresponding to a punctured sub-channel or a shortened sub-channel on a to-be-encoded side. After excluding the pre-frozen sub-channel from a candidate area, the transmitting end obtains the candidate area, where the candidate area includes a plurality of candidate sub-channels, and the transmitting end may obtain the information sub-channel from the plurality of candidate sub-channels. A specific rate matching manner is not within the protection scope of this application. Therefore, for ease of description, in this application, a manner of determining a shortened sub-channel when rate matching is shortening may be used as an example for description. A manner of determining a punctured sub-channel when the rate matching is puncturing is similar

to that of determining the shortened sub-channel, and details are not described again.

[00183] For an implementation in which the transmitting end determines the pre-frozen sub-channel corresponding to the shortened sub-channel, refer to the following example a to example c.

5 **[00184]** Example a: When the bit quantity in the symbol B is less than the mother code length in the symbol B', the transmitting end may determine, from the available area based on the bit quantity in the symbol B and the mother code length in the symbol B', the pre-frozen sub-channel corresponding to the shortened sub-channel, where the pre-frozen sub-channel may be used for intra-symbol rate matching. For example, in QAM64, a one-channel signal (for example, an I-channel signal or a Q-channel signal) includes three bits. In other words, the bit quantity in the symbol B equals to 3, and the mother code length in the symbol B' = 4. It may be determined that a pre-frozen sub-channel corresponding to the shortened sub-channel in the symbol is a fourth sub-channel. For another example, in QAM1024, a one-channel signal (for example, an I-channel signal or a Q-channel signal) includes five bits, the bit quantity in the symbol B equals to 5, and the mother code length in the symbol B' = 8. It may be determined that pre-frozen sub-channels corresponding to the shortened sub-channel in the symbol are a fourth sub-channel, a sixth sub-channel, and an eighth sub-channel.

10 **[00185]** Example b: When the symbol quantity S is less than the mother code length of the symbol S', the transmitting end may determine, from the available area based on the symbol quantity S and the mother code length of the symbol S', the pre-frozen sub-channel corresponding to the shortened sub-channel, where the pre-frozen sub-channel may be used for inter-symbol rate matching. For example, if the symbol quantity is 14 and the mother code length of the symbol S' is 16, it may be determined that, in a symbol 0 to a symbol 15, sub-channels corresponding to the symbol 14 and the symbol 15 are pre-frozen sub-channels corresponding to the shortened sub-channel.

20 **[00186]** Example c: When the bit quantity in the symbol B is less than the mother code length in the symbol B', and the symbol quantity S is less than the mother code of the symbol S', the transmitting end may determine, from the available area, a pre-frozen sub-channel corresponding to the shortened sub-channel based on the bit quantity in the symbol B and the mother code length in the symbol B', and based on the symbol quantity S and the mother code of the symbol S'. For example, in the QAM64, if the bit quantity in the symbol B equals to 3, the mother code length in

the symbol $B' = 4$, the symbol quantity is 14, and the mother code length of the symbol S' is 16, the sub-channels corresponding to the symbol 14 and the symbol 15 in the symbol 0 to the symbol 15 and a fourth sub-channel in each symbol of the symbol 0 to the symbol 13 is a pre-frozen sub-channel corresponding to the shortened sub-channel. In this example, the pre-frozen sub-channel used for inter-symbol rate matching may be represented as $P_s=[14, 15]$, and a pre-frozen sub-channel used for intra-symbol rate matching may be represented as $P_b=[3]$.

[00187] It is clear that when the symbol quantity S is equal to the mother code length of the symbol S' , and when the bit quantity in the symbol B is equal to the mother code length in the symbol B' , the transmitting end may not need to determine the pre-frozen sub-channel corresponding to the shortened sub-channel.

[00188] After determining shortened sub-channels and pre-frozen sub-channels corresponding to the shortened sub-channels, the transmitting end may exclude the sub-channels from the available area, to obtain the candidate area. Then, in the plurality of candidate sub-channels in the candidate area, whether each candidate sub-channel is the pre-frozen sub-channel is sequentially determined based on descending order of reliability, and if the candidate sub-channel is the pre-frozen sub-channel, skip the candidate sub-channel, or if the candidate sub-channel is not the pre-frozen sub-channel, determine the candidate sub-channel as the information sub-channel.

[00189] In a possible manner, if determining that a sequence number of a sub-channel meets a formula $\frac{x}{s'} \in P_b$ or meets a formula $\text{mod}(x, s') \in P_s$, the transmitting end determines that the sub-channel is the pre-frozen sub-channel.

[00190] With reference to the reliability sequence shown as an example in FIG. 7b, it is assumed that an information bit quantity K that need to be sent by the transmitting end equals to 21, a code rate R equals to 0.5, a modulation order B equals to 3, and a symbol quantity S equals to 14. In this case, the transmitting end needs to determine 21 information sub-channels from the encoding sequence based on the reliability sequence. In this example, if the symbol quantity S equals to 14, sub-channels corresponding to the symbol 14 and the symbol 15 are pre-frozen sub-channels, and if the modulation order B equals to 3, sub-channels corresponding to the pattern 4 in FIG. 7b (in other words, a fourth sub-channel in each symbol in the symbol 0 to the symbol 13) are pre-freeze sub-channels. For example, the transmitting end may determine, in descending order of reliability, that a first sub-channel (namely, a sub-channel 63) to a ninth sub-channel (namely, a sub-channel 54) are the pre-frozen sub-channels, a tenth sub-channel (namely, a sub-channel 47) is the

information sub-channel, an eleventh sub-channel (namely, a sub-channel 53) is the pre-frozen sub-channel, and so on, until the 21 information sub-channels are determined. Then, remaining sub-channels are used as frozen sub-channels. For locations of the constructed information sub-channels and frozen sub-channels, refer to FIG. 9. A pattern 1 represents a pre-frozen sub-channel corresponding to a shortened sub-channel. A pattern 2 represents an information sub-channel, and is used for carrying 21 bits in a to-be-encoded bit sequence. A pattern 3 represents a frozen sub-channel. For example, a value of each frozen sub-channel may be set to 0.

[00191] In another possible manner, the transmitting end may obtain L candidate sub-channels after excluding the determined pre-frozen sub-channels from the encoding sequence. It also may be understood that the transmitting end determines the L candidate sub-channels from the encoding sequence based on the symbol quantity S and the energy level quantity B. When a modulation scheme is single-channel modulation, the L candidate sub-channels are $S1 \times B$ sub-channels. When the modulation scheme is two-channel modulation, the L candidate sub-channels are $2 \times S2 \times B$ sub-channels. Then, the transmitting end may determine K information sub-channels from the L candidate sub-channels based on reliability of each candidate sub-channel in descending order of reliability, where the K information sub-channels may be used for carrying K information bits. Remaining $L-K$ sub-channels in the L candidate sub-channels may be used for carrying $L-K$ frozen bits. Further, the $L-K$ sub-channels and the determined pre-frozen sub-channels may be used as frozen sub-channels.

[00192] With reference to the reliability sequence shown as an example in FIG. 7b, it is assumed that the information bit quantity K that need to be sent by the transmitting end equals to 21, the code rate R equals to 0.5, the modulation order B equals to 3, and the symbol quantity S equals to 14. The encoding bit quantity L equals to the information bit quantity K divided by the code rate R and equals to 42. The transmitting end may determine the sub-sequence 0, the sub-sequence 1, and the sub-sequence 2 from the encoding sequence, and separately determine 14 sub-channels from each of the sub-sequence 0, the sub-sequence 1, and the sub-sequence 2. For example, the transmitting end may determine a sub-channel 0 to a sub-channel 13 in each sub-sequence of the sub-sequence 0, the sub-sequence 1, and the sub-sequence 2 as candidate sub-channels, to obtain 42 candidate sub-channels. Then, in descending order of reliability of the candidate sub-channels, 21 information sub-channels are determined from the 42 candidate sub-channels, where the 21 information sub-channels are used for carrying 21 information bits, and the remaining 21 candidate

sub-channels may be used for carrying 21 frozen bits.

[00193] Step 804: The transmitting end encodes the K information bits and outputs a bit sequence based on the K information sub-channels.

[00194] The transmitting end may respectively place the K information bits in the K information sub-channels, and set both the L–K frozen sub-channels and the pre-frozen sub-channels to 0, to obtain a to-be-encoded bit sequence whose length is N (the mother code length of the symbol $S' \times$ the mother code length in the symbol B'). For an encoding process, refer to the process from left to right in FIG. 3, or refer to the process from bottom to top in FIG. 4. The encoding may be an encoding scheme in which an existing polar code is used, and details are not described again.

[00195] Step 805: The transmitting end performs rate matching and modulation on the output bit sequence, to obtain S to-be-sent symbols.

[00196] After outputting an encoded bit sequence, the transmitting end may perform rate matching on the output encoded bit sequence, where the rate matching may be a bit corresponding to an unsent shortened sub-channel. The embodiment corresponding to FIG. 9 is used for description. All sub-channels corresponding to the pattern 1 are shortened sub-channels. When performing rate matching, the transmitting end may not send bits corresponding to the sub-channels. A bit sequence obtained through rate matching performed by the transmitting end may be referred to as a to-be-modulated bit sequence, and the transmitting end may perform modulation on the to-be-modulated bit sequence to obtain a to-be-sent symbol (which may be referred to as a symbol to be sent). In addition, this application does not exclude a case in which the transmitting end does not need to perform rate matching on the encoded bit sequence. In this case, the transmitting end modulates the encoded bit sequence as the to-be-modulated bit sequence into the to-be-sent symbol.

[00197] In this application, the to-be-modulated bit sequence may correspond to B sub-sequences, and S sub-channels included in each sub-sequence respectively correspond to S bits. In the to-be-modulated bit sequence, in ascending order of energy levels, one bit is sequentially selected from the bits corresponding to each sub-sequence and mapped to one to-be-sent symbol, that is, S to-be-sent symbols are obtained by mapping. In a possible implementation, the transmitting end may map the to-be-modulated bit sequence into the S to-be-sent symbols. For example, a $(j_1 \times B + j_2)^{\text{th}}$ bit in the to-be-modulated bit sequence may be mapped to a j_2^{th} bit in a j_1^{th} to-be-sent symbol, where j_1 is a positive integer less than S, and j_2 is a positive integer less than B.

[00198] Refer to FIG. 9. For example, S equals to 14, and B equals to 3, the to-be-modulated bit sequence includes $14 \times 3 = 42$ bits, and the transmitting end may map the 42 bits to 14 to-be-sent symbols. Specifically, in the ascending order of energy levels, a bit 0, a bit 16, and a bit 32 that respectively correspond to a sub-channel 0, a sub-channel 16, and a sub-channel 32 may be mapped to a symbol 0, a bit 1, a bit 17, and a bit 33 that respectively correspond to a sub-channel 1, a sub-channel 17, and a sub-channel 33 are mapped to a symbol 1, and by analogy, the 42 to-be-modulated bits are mapped to the 14 to-be-sent symbols.

[00199] Optionally, after the S to-be-sent symbols are obtained through modulation, symbol-level interleaving processing may be performed on the S to-be-sent symbols. For example, the transmitting end modulates the bit sequence into the 14 to-be-sent symbols (represented as the symbol 0 to a symbol 13), and a sequence in which the transmitting end sends the symbols to a receiving end may be: the symbol 0, a symbol 7, the symbol 1, a symbol 8, a symbol 2, a symbol 9, a symbol 3, a symbol 10, a symbol 4, a symbol 11, a symbol 5, a symbol 12, a symbol 6, and the symbol 13. Therefore, this helps improve anti-interference performance of the to-be-sent symbols in response to burst continuous noise in a sending process.

[00200] In this application, not only the S to-be-sent symbols may be interleaved after the modulation, but also the bit sequence may be interleaved before the modulation. To ensure that a correlated bit is still mapped to a same to-be-sent symbol, when interleaving processing is performed on the bit sequence, a same interleaved sequence may be used for the bit corresponding to the sub-channel in each sub-sequence. For example, in FIG. 9, a sub-sequence 0 includes the sub-channel 0 to a sub-channel 13, and the sub-channel 0 to the sub-channel 13 respectively correspond to the bit 0 to a bit 13; a sub-sequence 1 includes the sub-channel 16 to a sub-channel 29, and the sub-channel 16 to the sub-channel 29 respectively correspond to the bit 16 to a bit 29; and a sub-sequence 2 includes the sub-channel 32 to a sub-channel 45, and the sub-channel 32 to the sub-channel 45 respectively correspond to the bit 32 to a bit 45. For example, in interleaving of the 14 bits corresponding to the sub-sequence 0, a sequence of the bits after the interleaving may be: the bit 0, the bit 7, the bit 1, the bit 8, the bit 2, the bit 9, the bit 3, the bit 10, the bit 4, the bit 11, the bit 5, the bit 12, the bit 6, and the bit 13. Correspondingly, the sub-sequence 1 and the sub-sequence 2 perform the same interleaving. For example, in the interleaving of the 14 bits corresponding to the sub-sequence 1, a sequence of the bits after the interleaving may be: the bit 16, the bit 23, the bit 17, the bit 24, the bit 18, the bit 25, the bit 19, the bit 26, the bit 20, the bit

27, the bit 21, the bit 28, the bit 22, and the bit 29.

[00201] In this application, different sub-sequences correspond to different energy levels. When a plurality of bits are mapped to a same symbol, energy levels of the plurality of bits in the same symbol are sorted in an order.

5 **[00202]** In an example in which ASK is used for explanation, when an energy level quantity is 2, two bits may be mapped to a constellation of ASK4, and corresponding energy levels are respectively an energy level 0 and an energy level 1; when the energy level quantity is 3, three bits may be mapped to a constellation of ASK8, and corresponding energy levels are respectively the energy level 0, the energy level 1, and an energy level 2; and when the energy level quantity is 4,
10 four bits may be mapped to a constellation of ASK16, and corresponding energy levels are respectively the energy level 0, the energy level 1, the energy level 2, and an energy level 3.

[00203] Further, in an example in which QAM is used for explanation, when the energy level quantity is 2, two bits may be mapped to a constellation of QAM16, and corresponding energy levels are respectively the energy level 0 and the energy level 1; when the energy level quantity is
15 3, three bits may be mapped to a constellation of QAM64, and corresponding energy levels are respectively the energy level 0, the energy level 1, and the energy level 2; and when the energy level is 4, four bits may be mapped to a constellation of QAM256, and corresponding energy levels are respectively the energy level 0, the energy level 1, the energy level 2, and the energy level 3.

20 **[00204]** Energy corresponding to the energy level 0, the energy level 1, the energy level 2, and the energy level 3 is in the ascending order.

[00205] In addition, when the energy level is 4, for example, in the ASK16 or the QAM256, mapping orders of the bit in the sub-sequence corresponding to the energy level 2 and the bit in the sub-sequence corresponding to the energy level 3 may be exchanged. For example, the four bits are mapped to the constellation of the ASK16, and the corresponding energy levels are
25 respectively the energy level 0, the energy level 1, the energy level 3, and the energy level 2. For another example, the four bits are mapped to the constellation of the QAM256, and the corresponding energy levels are respectively the energy level 0, the energy level 1, the energy level 3, and the energy level 2. In this manner, transmission performance of the symbol in a channel can be improved.

30 **[00206]** Step 806: The transmitting end sends S symbols to the receiving end. The receiving end receives the S symbols from the transmitting end.

[00207] Step 807: The receiving end demodulates and decodes the S symbols based on the symbol quantity S, the energy level quantity B, the reliability sequence, and the encoding sequence to obtain L bits, where the L bits include the K information bits.

[00208] In this application, the receiving end and the transmitting end may pre-agree on the energy level, the reliability sequence, the encoding sequence, and the like. Therefore, after receiving the S symbols from the transmitting end, the receiving end may perform demodulation and decoding based on the pre-agreed energy level, the reliability sequence, the encoding sequence, and the like. Specifically, the receiving end may perform demodulation processing on the S symbols based on the symbol quantity S and the energy level quantity B, to obtain L demodulated LLRs, where the L LLRs correspond to L to-be-decoded bits. For example, when the LLR is greater than 0, a value of the to-be-decoded bit corresponding to the LLR is 1; and when the LLR is less than 0, a value of the to-be-decoded bit corresponding to the LLR is 0. Then, the receiving end determines the K information sub-channels based on the symbol quantity S, the reliability sequence, and the encoding sequence, and the K information sub-channels correspond to the K information bits in the L to-be-decoded bits. Therefore, the receiving end may obtain information actually sent by the transmitting end to the receiving end. In this application, for a manner of determining the K information sub-channels by the receiving end, refer to the manner of determining the K information sub-channels by the transmitting end in step 803. Details are not described again.

[00209] In a demodulation process at the receiving end, the receiving end may sequentially map B bits included in each of the S symbols to the B sub-sequences whose energy levels are sorted in the ascending order. For example, in FIG. 9, S equals to 14, B equals to 3, the bit 0, the bit 16, and the bit 32 included in the symbol 0 are respectively mapped to first sub-channels of the sub-sequence 0, the sequence 1, and the sequence 2, and the bit 1, the bit 17, and the bit 33 included in the symbol 1 are respectively mapped to second sub-channels of the sub-sequence 0, the sequence 1, and the sequence 2, and so on, to obtain the sequence 0, the sequence 1, and the sequence 2. The 14 sub-channels included in each sequence respectively correspond to the 14 bits. For example, the 14 sub-channels included in the sequence 0 respectively correspond to the bit 0 to the bit 13.

[00210] It should be noted that when the energy level quantity is 4, for example, in the ASK16 or the QAM256, the transmitting end may exchange a sequence between the sub-sequence corresponding to the energy level 2 and the sub-sequence corresponding to the energy level 3

during mapping. Correspondingly, during demodulation, the receiving end also needs to exchange mapping orders of two bits in the symbol, map a third bit in the symbol to the sub-sequence corresponding to the energy level 3, and map a fourth bit in the symbol to the sub-sequence corresponding to the energy level 2, so that the receiving end can demodulate a correct bit sequence.

5 **[00211]** It should be further noted that, if the transmitting end interleaves the S symbols, after receiving the S symbols, the receiving end may first perform de-interleaving on the S symbols, and then perform demodulation and decoding on the S symbols. If the transmitting end interleaves the bits in the symbol, after performing demodulation on the S symbols, the receiving end may perform de-interleaving on the bits in the symbol, and then perform decoding.

10 **[00212]** FIG. 10 is a schematic flowchart of an example of sending a symbol by a transmitting end according to this application. The transmitting end determines a symbol quantity and a modulation order; the transmitting end determines a pre-frozen sub-channel from an encoding sequence based on the symbol quantity and the modulation order; and then, the transmitting end excludes the pre-frozen sub-channel from the encoding sequence, and determines an information sub-channel and a frozen sub-channel from remaining sub-channels based on a reliability sequence. The transmitting end performs code construction based on the determined information sub-channel, the frozen sub-channel, and a to-be-sent information bit, to obtain a to-be-encoded bit sequence. The transmitting end performs polar code encoding on the to-be-encoded bit sequence, to obtain an encoded bit sequence. The transmitting end then performs rate matching on the encoded bit sequence based on the pre-frozen sub-channel. The transmitting end determines a mapping relationship between bits and symbols in the bit sequence obtained through rate matching based on a mapping pattern. The transmitting end modulates the bit sequence into a plurality of to-be-sent symbols in higher order based on the mapping relationship between the bits and the symbols. The transmitting end performs symbol interleaving on the plurality of to-be-sent symbols, and then sends a plurality of interleaved symbols to a receiving end through a channel.

25 **[00213]** In this embodiment of this application, the transmitting end may determine the information sub-channel and the frozen sub-channel from the encoding sequence based on an information bit quantity of to-be-sent information, an encoding bit quantity of corresponding to the information bit quantity, and the reliability sequence, and encode the information bit based on the information sub-channel and the frozen sub-channel. In this manner, the reliability sequence is constructed based on correlation between bits in a same symbol, and in a construction process,

different energy levels of different bits in the same symbol are further considered. The information bit is encoded based on the information sub-channel determined by the reliability sequence, and the bit sequence that matches higher-order modulation may be obtained. Correspondingly, after receiving the symbol, the receiving end may also determine the information sub-channel based on the reliability sequence, and decode an accurate information bit. Designs of an encoder and a decoder do not need to be changed. This helps reduce costs.

[00214] Further, the reliability sequence may be a double nested structure, to be specific, a sequence including sub-channels that jointly correspond to a preset symbol quantity and a preset energy level quantity. The reliability sequence may be applicable to different symbol quantities or different energy levels. The transmitting end may determine candidate sub-channels based on a symbol quantity and an energy level corresponding to the to-be-sent information bit and the reliability sequence. Then, the information sub-channel and the frozen sub-channel are determined from the candidate sub-channels. For example, modulation corresponding to different energy levels, for example, ASK4, ASK8, and ASK16, may all correspond to a same reliability sequence, and there is no need to set different reliability sequences for the modulation corresponding to each energy level. This helps reduce costs.

[00215] This application provides a new information sub-channel construction method. The method may be referred to as a polar code construction method based on bit correlation, may be represented as correlation aware polar in English, and may be represented as CAP for short in English.

[00216] In this application, for different modulation orders and different bit sequence lengths, performance comparison between the CAP and an existing construction manner shows that a gain of 1 dB to 1.5 dB can be obtained without changing an encoder and a decoder when the CAP is used.

[00217] The following provides examples of comparison charts between a plurality of performance evaluations.

[00218] Performance evaluation 1: In a case of QAM16 and $N=1024$, for comparison between the CAP and BICM, refer to FIG. 11a; and in a case of QAM16 and $N=4096$, for comparison between the CAP and the BICM, refer to FIG. 11b.

[00219] Performance evaluation 2: In a case of QAM256 and $N=1024$, for comparison between the CAP and the BICM, refer to FIG. 12a; and in a case of QAM256 and $N=4096$, for comparison

between the CAP and the BICM, refer to FIG. 12b.

[00220] Performance evaluation 3: In a case of QAM256 and $N=1024$, for comparison between the CAP and multilevel coded modulation (multilevel coded modulation, MLC), refer to FIG. 13.

[00221] Based on the foregoing content and a same concept, FIG. 14 and FIG. 15 are schematic diagrams of structures of possible communication apparatuses according to this application. The communication apparatuses may be configured to implement functions of the transmitting end or the receiving end in the foregoing method embodiments, and therefore can also implement beneficial effects of the foregoing method embodiments. In this application, the communication apparatus may be the transmitting end 101 shown in FIG. 1, or may be the receiving end 102 shown in FIG. 1.

[00222] When the communication apparatus is the transmitting end, the communication apparatus includes an input/output unit 1401 and a processing unit 1402.

[00223] In a possible implementation, the input/output unit 1401 is configured to obtain an information bit quantity K and an encoding bit quantity L ; and the processing unit 1402 is configured to determine a symbol quantity S based on the encoding bit quantity L and an energy level quantity B , where S is $S1$ or $S2$, $S1=L/B$, and $S2=L/2B$, where the processing unit 1402 is further configured to: determine K information sub-channels from an encoding sequence based on the symbol quantity S , the energy level quantity B , and a reliability sequence; and the processing unit 1402 is further configured to encode K information bits and output a bit sequence based on the K information sub-channels, where the encoding sequence includes B_{max} sub-sequences, the B_{max} sub-sequences respectively correspond to B_{max} energy levels, each sub-sequence in the B_{max} sub-sequences includes S_{max} sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence; the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are $S1$ sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i ; and K , L , B , S , $S1$, $S2$, B_{max} , and S_{max} are all positive integers, S_{max} is greater than or equal to S , B_{max} is greater than or equal to B , and i is greater than or equal to 0 and less than B .

[00224] In a possible implementation, the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

[00225] In a possible implementation, the punctured sub-channel or the shortened sub-channel is determined based on the energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B.

[00226] In a possible implementation, after encoding the K information bits and outputting a bit sequence based on the K information sub-channels, the processing unit 1402 is further configured to: perform rate matching and modulation on the output bit sequence to obtain S to-be-sent symbols; and perform interleaving processing on the S to-be-sent symbols.

[00227] In a possible implementation, the processing unit 1402 is specifically configured to sequentially select one bit from each sub-sequence of B sub-sequences in an ascending order of energy levels and map the bit to one to-be-sent symbol.

[00228] In a possible implementation, for QAM256, the processing unit 1402 is further configured to exchange mapping orders of a bit selected from a sub-sequence corresponding to a third energy level and a bit selected from a sub-sequence corresponding to a fourth energy level in the ascending order of energy levels.

[00229] In a possible implementation, the encoding is polar code encoding.

[00230] When the communication apparatus is the receiving end, the communication apparatus includes an input/output unit 1401 and a processing unit 1402.

[00231] In a possible implementation, the input/output unit 1401 is configured to receive S symbols, where a symbol quantity S is S1 or S2; and the processing unit 1402 is configured to: demodulate and decode the S symbols based on the symbol quantity S, an energy level quantity B, a reliability sequence, and an encoding sequence to obtain L bits, where the L bits include K information bits, and $L=S1 \times B$, or $L=2 \times S2 \times B$, where the encoding sequence includes Bmax sub-sequences, the Bmax sub-sequences respectively correspond to Bmax energy levels, each sub-sequence in the Bmax sub-sequences includes Smax sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence; the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are S1 sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i; and K, L, B, S, S1, S2, Bmax, and Smax are all positive integers, Smax is greater than or equal to S, Bmax is greater than or equal to B, and i is greater than or equal to 0 and less than B.

[00232] In a possible implementation, the K information sub-channels are selected in a

descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

[00233] In a possible implementation, the punctured sub-channel or the shortened sub-channel is determined based on an energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B.

[00234] In a possible implementation, before demodulating and decoding the S symbols based on the symbol quantity S, the energy level quantity B, the reliability sequence, and the encoding sequence to obtain the L bits, the processing unit 1402 is further configured to perform de-interleaving processing on the S symbols.

[00235] In a possible implementation, the processing unit 1402 is specifically configured to sequentially map B bits included in each symbol in the S symbols to B sub-sequences sorted in ascending order of energy levels.

[00236] In a possible implementation, for QAM256, the processing unit 1402 is further configured to exchange mapping orders of a third bit and a fourth bit included in each symbol in the S symbols.

[00237] In a possible implementation, the encoding is polar code decoding.

[00238] In addition, as shown in FIG. 15, this application further provides a communication apparatus 1500. For example, the communication apparatus 1500 may be a chip or a chip system. Optionally, in this embodiment of this application, the chip system may include a chip, or may include a chip and another discrete component.

[00239] The communication apparatus 1500 may include at least one processor 1510. The communication apparatus 1500 may further include at least one memory 1520, configured to: store a computer program, program instructions, and/or data. The memory 1520 is coupled to the processor 1510. The coupling in this embodiment of this application may be an indirect coupling or a communication connection between apparatuses, units, or modules in an electrical form, a mechanical form, or another form, and is used for information exchange between the apparatuses, the units, or the modules. The processor 1510 may operate in collaboration with the memory 1520. The processor 1510 may execute the computer program stored in the memory 1520. Optionally, the at least one memory 1520 may also be integrated with the processor 1510.

[00240] The communication apparatus 1500 may further include a transceiver 1530, and the communication apparatus 1500 may exchange information with another device by using the

transceiver 1530. The transceiver 1530 may be a circuit, a bus, a transceiver, or any other apparatus that may be configured to exchange information.

[00241] In a possible implementation, the communication apparatus 1500 may be the foregoing transmitting end or the foregoing receiving end. The memory 1520 stores a necessary computer program, program instructions, and/or data for implementing the functions in any one of the foregoing embodiments. The processor 1510 may execute the computer program stored in the memory 1520, to complete the method in any one of the foregoing embodiments.

[00242] In this embodiment of this application, a specific connection medium among the transceiver 1530, the processor 1510, and the memory 1520 is not limited. In this embodiment of this application, the memory 1520, the processor 1510, and the transceiver 1530 are connected by using a bus in FIG. 15. The bus is represented by using a bold line in FIG. 15. A manner of connection between other components is merely an example for description, and cannot be construed as a limitation. The bus may be classified into an address bus, a data bus, a control bus, and the like. For ease of representation, only one bold line is used for representing the bus in FIG. 15, but this does not mean that there is only one bus or only one type of bus. In this embodiment of this application, the processor may be a general-purpose processor, a digital signal processor, an application-specific integrated circuit, a field programmable gate array or another programmable logic device, a discrete gate or transistor logic device, or a discrete hardware component, and may implement or perform the methods, steps, and logical block diagrams disclosed in embodiments of this application. The general-purpose processor may be a microprocessor or any conventional processor or the like. The steps of the method disclosed with reference to embodiments of this application may be directly performed by a hardware processor, or may be performed by using a combination of hardware in the processor and a software module.

[00243] In this embodiment of this application, the memory may be a nonvolatile memory, for example, a hard disk drive (hard disk drive, HDD) or a solid-state drive (solid-state drive, SSD), or may be a volatile memory (volatile memory) such as a random access memory (random-access memory, RAM). The memory may alternatively be any other medium that can be configured to carry or store expected program code in a form of instructions or a data structure and that can be accessed by a computer. This is not limited thereto. The memory in this embodiment of this application may alternatively be a circuit or any other apparatus that can implement a storage function, and is configured to: store the computer program, the program instructions, and/or the

data.

[00244] Based on the foregoing embodiments, refer to FIG. 16. An embodiment of this application further provides another communication apparatus 1600, including an interface circuit 1610 and a logic circuit 1620. The interface circuit 1610 may be understood as an input/output interface, and may be configured to perform operation steps the same as those of the input/output unit 1401 shown in FIG. 14 or the transceiver 1530 shown in FIG. 15. Details are not described herein again in this application. The logic circuit 1620 may be configured to run code instructions to perform the method in any one of the foregoing embodiments, may be understood as the processing unit 1402 in FIG. 14 or the processor 1510 in FIG. 15, and may implement a same function as the processing unit or the processor. Details are not described herein again in this application.

[00245] Based on the foregoing embodiments, an embodiment of this application further provides a readable storage medium. The readable storage medium stores instructions. When the instructions are executed, the method executed by the security detection method in any one of the foregoing embodiments is implemented. The readable storage medium may include any medium that can store program code, such as a USB flash drive, a removable hard disk, a read-only memory, a random access memory, a magnetic disk, or a compact disc.

[00246] A person skilled in the art should understand that embodiments of this application may be provided as a method, a system, or a computer program product. Therefore, this application may use a form of hardware only embodiments, software only embodiments, or embodiments with a combination of software and hardware. In addition, this application may use a form of a computer program product that is implemented on one or more computer-usable storage media (including but not limited to a disk memory, a CD-ROM, an optical memory, and the like) that include computer-usable program code.

[00247] This application is described with reference to the flowcharts and/or block diagrams of the method, the apparatus (system), and the computer program product according to this application. It should be understood that computer program instructions may be used to implement each process and/or each block in the flowcharts and/or the block diagrams and a combination of a process and/or a block in the flowcharts and/or the block diagrams. These computer program instructions may be provided to a general-purpose computer, a dedicated computer, an embedded processor, or a processor of another programmable data processing apparatus to generate a

machine, so that the instructions executed by the computer or the processor of the another programmable data processing apparatus generate an apparatus for implementing a function specified in one or more processes in the flowcharts and/or in one or more blocks in the block diagrams.

5 **[00248]** These computer program instructions may be alternatively stored in a computer-readable memory that can instruct a computer or another programmable data processing apparatus to work in a specific manner, so that the instructions stored in the computer-readable memory generate an artifact that includes an instruction apparatus. The instruction apparatus implements a function specified in one or more processes in the flowcharts and/or in one or more blocks in the
10 block diagrams.

[00249] These computer program instructions may be alternatively loaded onto a computer or another programmable data processing apparatus, so that a series of operations and steps are performed on the computer or the another programmable apparatus, to generate computer-implemented processing. Therefore, the instructions executed on the computer or the another
15 programmable apparatus provide steps for implementing a function specified in one or more processes in the flowcharts and/or in one or more blocks in the block diagrams.

CLAIMS

What is claimed is:

1. An encoding method, comprising:

obtaining an information bit quantity K and an encoding bit quantity L ;

5 determining a symbol quantity S based on the encoding bit quantity L and an energy level quantity B , wherein S is $S1$ or $S2$, $S1=L/B$, and $S2=L/2B$;

determining K information sub-channels from an encoding sequence based on the symbol quantity S , the energy level quantity B , and a reliability sequence; and

10 encoding K information bits and outputting a bit sequence based on the K information sub-channels, wherein

the encoding sequence comprises B_{max} sub-sequences, the B_{max} sub-sequences respectively correspond to B_{max} energy levels, each sub-sequence in the B_{max} sub-sequences comprises S_{max} sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence;

15 the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are $S1$ sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i ; and

K , L , B , S , $S1$, $S2$, B_{max} , and S_{max} are all positive integers, S_{max} is greater than or equal to S , B_{max} is greater than or equal to B , and i is greater than or equal to 0 and less than B .

20 2. The method according to claim 1, wherein the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

25 3. The method according to claim 2, wherein the punctured sub-channel or the shortened sub-channel is determined based on the energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B .

4. The method according to claim 1, wherein after the encoding K information bits and outputting a bit sequence based on the K information sub-channels, the method further comprises:

performing rate matching and modulation on the output bit sequence to obtain S to-be-sent symbols; and

30 performing interleaving processing on the S to-be-sent symbols.

5. The method according to claim 4, wherein the modulation comprises: sequentially selecting one bit from each sub-sequence of B sub-sequences in an ascending order of energy levels and mapping the bit to one to-be-sent symbol.

6. The method according to claim 5, wherein for quadrature amplitude modulation QAM256, the modulation further comprises: exchanging mapping orders of a bit selected from a sub-sequence corresponding to a third energy level and a bit selected from a sub-sequence corresponding to a fourth energy level in the ascending order of energy levels.

7. The method according to any one of claims 1 to 6, wherein the encoding is polar code encoding.

8. A decoding method, comprising:
receiving S symbols, wherein a symbol quantity S is S1 or S2; and
demodulating and decoding the S symbols based on the symbol quantity S, an energy level quantity B, a reliability sequence, and an encoding sequence to obtain L bits, wherein the L bits comprise K information bits, and $L=S1 \times B$, or $L=2 \times S2 \times B$, wherein

the encoding sequence comprises Bmax sub-sequences, the Bmax sub-sequences respectively correspond to Bmax energy levels, each sub-sequence in the Bmax sub-sequences comprises Smax sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence;

the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are S1 sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i; and

K, L, B, S, S1, S2, Bmax, and Smax are all positive integers, Smax is greater than or equal to S, Bmax is greater than or equal to B, and i is greater than or equal to 0 and less than B.

9. The method according to claim 8, wherein the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

10. The method according to claim 9, wherein the punctured sub-channel or the shortened sub-channel is determined based on an energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B.

11. The method according to claim 8, wherein before the demodulating and decoding the S symbols based on the symbol quantity S, the energy level quantity B, a reliability sequence, and

an encoding sequence to obtain L bits, the method further comprises:

performing de-interleaving processing on the S symbols.

12. The method according to claim 11, wherein the demodulation comprises: sequentially mapping B bits comprised in each symbol in the S symbols to B sub-sequences sorted in ascending order of energy levels.

13. The method according to claim 12, wherein for quadrature amplitude modulation QAM256, the demodulation further comprises: exchanging mapping orders of a third bit and a fourth bit comprised in each symbol in the S symbols.

14. The method according to any one of claims 8 to 13, wherein the encoding is polar code decoding.

15. A communication apparatus, comprising:

an input/output unit, configured to obtain an information bit quantity K and an encoding bit quantity L; and

a processing unit, configured to determine a symbol quantity S based on the encoding bit quantity L and an energy level quantity B, wherein S is S1 or S2, $S1=L/B$, and $S2=L/2B$, wherein

the processing unit is further configured to: determine K information sub-channels from an encoding sequence based on the symbol quantity S, the energy level quantity B, and a reliability sequence; and

the processing unit is further configured to encode K information bits and output a bit sequence based on the K information sub-channels, wherein

the encoding sequence comprises Bmax sub-sequences, the Bmax sub-sequences respectively correspond to Bmax energy levels, each sub-sequence in the Bmax sub-sequences comprises Smax sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence;

the K information sub-channels are selected from candidate sub-channels based on an order of reliability of the candidate sub-channels, and the candidate sub-channels are S1 sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i; and

K, L, B, S, S1, S2, Bmax, and Smax are all positive integers, Smax is greater than or equal to S, Bmax is greater than or equal to B, and i is greater than or equal to 0 and less than B.

16. The apparatus according to claim 15, wherein the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel,

a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

17. The apparatus according to claim 16, wherein the punctured sub-channel or the shortened sub-channel is determined based on the energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B.

5 18. The apparatus according to claim 15, wherein after encoding the K information bits and outputting a bit sequence based on the K information sub-channels, the processing unit is further configured to:

perform rate matching and modulation on the output bit sequence to obtain S to-be-sent symbols; and

10 perform interleaving processing on the S to-be-sent symbols.

19. The apparatus according to claim 18, wherein the processing unit is specifically configured to:

sequentially select one bit from each sub-sequence of B sub-sequences in an ascending order of energy levels and map the bit to one to-be-sent symbol.

15 20. The apparatus according to claim 19, wherein for quadrature amplitude modulation QAM256, the processing unit is further configured to exchange mapping orders of a bit selected from a sub-sequence corresponding to a third energy level and a bit selected from a sub-sequence corresponding to a fourth energy level in the ascending order of energy levels.

20 21. The apparatus according to any one of claims 15 to 20, wherein the encoding is polar polar code encoding.

22. A communication apparatus, comprising:

an input/output unit, configured to receive S symbols, wherein a symbol quantity S is S1 or S2; and

25 a processing unit, configured to: demodulate and decode the S symbols based on the symbol quantity S, an energy level quantity B, a reliability sequence, and an encoding sequence to obtain L bits, wherein the L bits comprise K information bits, and $L=S1 \times B$, or $L=2 \times S2 \times B$, wherein

the encoding sequence comprises Bmax sub-sequences, the Bmax sub-sequences respectively correspond to Bmax energy levels, each sub-sequence in the Bmax sub-sequences comprises Smax sub-channels, and the reliability sequence indicates an order of reliability of sub-channels in the encoding sequence;

30 the K information sub-channels are selected from candidate sub-channels based on an order

of reliability of the candidate sub-channels, and the candidate sub-channels are S1 sub-channels or $2 \times S2$ sub-channels in a sub-sequence whose energy level is i ; and

K, L, B, S, S1, S2, Bmax, and Smax are all positive integers, Smax is greater than or equal to S, Bmax is greater than or equal to B, and i is greater than or equal to 0 and less than B.

23. The apparatus according to claim 22, wherein the K information sub-channels are selected in a descending order of reliability from sub-channels that are other than a punctured sub-channel, a shortened sub-channel, and a pre-frozen sub-channel and that are in the candidate sub-channels.

24. The apparatus according to claim 23, wherein the punctured sub-channel or the shortened sub-channel is determined based on the energy level quantity B and a mother code length in a symbol corresponding to the energy level quantity B.

25. The apparatus according to claim 22, wherein before demodulating and decoding the S symbols based on the symbol quantity S, the energy level quantity B, the reliability sequence, and the encoding sequence to obtain the L bits, the processing unit is further configured to:

perform de-interleaving processing on the S symbols.

26. The apparatus according to claim 25, wherein the processing unit is specifically configured to sequentially map B bits comprised in each symbol in the S symbols to B sub-sequences sorted in ascending order of energy levels.

27. The apparatus according to claim 26, wherein for quadrature amplitude modulation QAM256, the processing unit is further configured to exchange mapping orders of a third bit and a fourth bit comprised in each symbol in the S symbols.

28. The apparatus according to any one of claims 22 to 27, wherein the encoding is polar code encoding.

29. A communication apparatus, comprising at least one processor and a memory, wherein the memory is configured to store a computer program or instructions; and

the at least one processor is configured to execute the computer program stored in the memory, so that the communication apparatus performs the method according to any one of claims 1 to 7 or the method according to any one of claims 8 to 14.

30. A computer-readable storage medium, wherein the computer-readable storage medium stores instructions, and when the instructions are executed, a computer is enabled to perform the method according to any one of claims 1 to 7 or the method according to any one of claims 8 to 14.

31. A computer program product, wherein the computer program product comprises a computer program or instructions, and when the computer program or the instructions are executed by a communication apparatus, the method according to any one of claims 1 to 7 or the method according to any one of claims 8 to 14 is implemented.

5

32. A communication system, comprising the communication apparatus according to any one of claims 15 to 21 and the communication apparatus according to any one of claims 22 to 28.