



(51) International Patent Classification:

H03M 13/13 (2006.01) *H03M 13/00* (2006.01)

(21) International Application Number:

PCT/US2017/032546

(22) International Filing Date:

12 May 2017 (12.05.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/336,422 13 May 2016 (13.05.2016) US

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

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

(54) Title: POLAR CODE CONSTRUCTION AND ENCODING

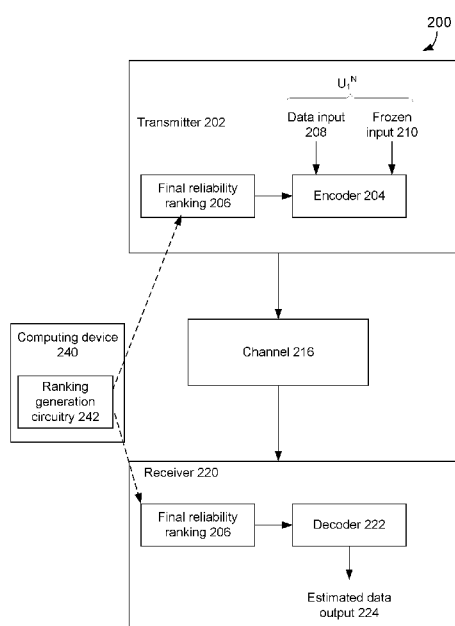


Fig. 2

(57) Abstract: Described is an apparatus. The apparatus may comprise a first circuitry, a second circuitry, and a third circuitry. The first circuitry may be operable to select a set of coding rates comprising a plurality of coding rates. The second circuitry may be operable to, for each coding rate of the plurality of coding rates, estimate a corresponding reliability ranking, such that a plurality of reliability rankings is estimated for the corresponding plurality of coding rates. The third circuitry may be operable to estimate a final reliability ranking, based at least in part on the plurality of reliability rankings. A transmitter is to encode data in accordance with polar coding, based at least in part on the final reliability ranking.

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

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

POLAR CODE CONSTRUCTION AND ENCODING

CLAIM OF PRIORITY

[0001] The present application claims priority under 35 U.S.C. § 119(e) to United States Provisional Patent Application Serial Number 62/336,422, filed May 13, 2016 and entitled “METHOD OF POLAR CODING FOR WIRELESS SYSTEMS,” which is herein incorporated by reference in its entirety.

BACKGROUND

[0002] Wireless communication may be encoded using one or more appropriate coding techniques. In information theory, a polar code is a linear block error correcting code. The polar code may be constructed, e.g., based on a multiple recursive concatenation of a short kernel code. Polar code may be used for encoding data for wireless communication.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. However, while the drawings are to aid in explanation and understanding, they are only an aid, and should not be taken to limit the disclosure to the specific embodiments depicted therein.

[0004] **Fig. 1A** illustrates an encoding operation using polar codes at an encoder, and **Fig. 1B** illustrates a decoding operation using polar codes at a decoder.

[0005] **Fig. 2** schematically illustrates a system for constructing a polar code for transmission over a channel, based at least in part on a final reliability ranking, in accordance with some embodiments of the disclosure.

[0006] **Fig. 3** illustrates a method to construct a plurality of reliability rankings for a corresponding plurality of coding rates, where the plurality of reliability rankings may be used to generate a final reliability ranking, in accordance with some embodiments of the disclosure.

[0007] **Fig. 4** illustrates a method to generate a final reliability ranking, in accordance with some embodiments of the disclosure.

[0008] **Fig. 5** illustrates an Evolved Node-B (eNB) and a UE, in accordance with some embodiments of the disclosure.

[0009] **Fig. 6** illustrates hardware processing circuitries for an eNB that may encode data using polar code based on a final reliability ranking, and transmit a code word to a UE, in accordance with some embodiments of the disclosure.

[0010] **Fig. 7** illustrates hardware processing circuitries for a UE for performing LBT prior to UL transmission in unlicensed spectrum, in accordance with some embodiments of the disclosure.

[0011] **Fig. 8** illustrates a computing device, a smart device, a computing device or a computer system or a SoC (System-on-Chip), which may generate a final reliability ranking, in accordance with some embodiments of the disclosure.

[0012] **Fig. 9** illustrates methods for generating a final reliability ranking, where the final reliability ranking may be used for encoding and/or decoding in accordance with polar coding, in accordance with some embodiments of the disclosure.

[0013] **Fig. 10** illustrates methods for a UE or an eNB to encode an input vector using polar coding, where the input vector may be generated based on a final reliability ranking, in accordance with some embodiments of the disclosure.

[0014] **Fig. 11** illustrates an architecture of a system of a network, in accordance with some embodiments of the disclosure.

[0015] **Fig. 12** illustrates example components of a device, in accordance with some embodiments of the disclosure.

[0016] **Fig. 13** illustrates example interfaces of baseband circuitry, in accordance with some embodiments of this disclosure.

DETAILED DESCRIPTION

[0017] A central topic of information theory is the transmission of data through a noisy medium. Typically, to make communication reliable in the presence of noise, redundancy in the data may be added before transmission, as the intended receiver only has access to a noisy version of the data. If the redundancy is added through coding, then it may be possible to reconstruct the original data at the receiver in the presence of noise. Coding is a central element in any communication systems, including wireless communication systems. However, adding this redundancy comes at the cost of reducing the effective rate of data transmission for a given data transmission rate, e.g., as in addition to the data the redundancy may also have to be transmitted.

[0018] Polar codes were proposed by Arikan E. Arikan, "Channel Polarization: A Method for Constructing Capacity-Achieving Codes for Symmetric Binary-Input

Memoryless Channels” (IEEE Trans. on Inf. Theory, Vol. 55, pp. 3051-3073). Polar codes may asymptotically achieve the capacity of binary-input symmetric memoryless channels with increasing code length.

[0019] A polar code is a linear block error-correcting code designed for a specific discrete-input, memoryless channel. Such codes may be used in forward error correction (FEC) and applied to transmitting data on a communications channel such that errors in the communication can be corrected and/or detected by the receiving circuit of a message block.

[0020] **Fig. 1A** illustrates an encoding operation using polar codes at an encoder, and **Fig. 1B** illustrates a decoding operation using polar codes at a decoder (although the encoder and decoder are not illustrated in **Figs. 1A-1B**). For the example of Fig. 1, assume $N=2^n$ is the code length, where $n = 3$, and $N = 8$. Let $U_1^N = (u_0, u_1, \dots, u_{N-1})$ and $X_1^N = (x_0, x_1, \dots, x_{N-1})$, denote an input vector comprising input bits to an encoder and the corresponding code word output by the encoder, respectively. The encoding operation, depicted in **Fig. 1A** for $N=8$, may have a butterfly structure similar to that of a fast Fourier transform (FFT).

[0021] The resulting code word X_1^N , generated by encoding the input vector U_1^N , may be sent over a communications channel (e.g., wireless communications channel) through N distinct utilizations of the communications channel. The corresponding channel output is denoted by $Y_1^N = (y_0, y_1, \dots, y_{N-1})$. Decoding of this channel output Y_1^N may be performed by means of a successive cancellation (SC) decoder, where for a given Y_1^N , the decoder may sequentially attempt to deduce the value of u_0 , then u_1 , all the way to u_{N-1} . Accordingly, the decoding of u_i may be based on the prior estimation of $(u_0, u_1, \dots, u_{i-1})$, denoted as $\hat{U}_1^N = (\hat{u}_0, \hat{u}_1, \dots, \hat{u}_{i-1})$. The probability that Y_1^N was received is denoted as $\Pr(y|\hat{u}_0^{i-1}, u_i=b)$ for $b \in \{0,1\}$, given that $u_0^{i-1} = \hat{u}_0^{i-1}$; $u_i=b$; and that $(u_{i+1}, u_{i+2}, \dots, u_{N-1})$ are independent random variables with Bernoulli distribution of parameter 0.5. The estimated value $\hat{u}_i$ may be chosen in accordance with any appropriate decoding algorithm.

[0022] **Figs. 1A-1B** is known to those skilled in the art, e.g., has been discussed in U.S. Patent Publication No. 2013/0117344, and hence, will not be discussed in further details herein. U.S. Patent Publication No. 2013/0117344 is incorporated in reference in its entirety herein.

[0023] As the code length N increases, the probability that a bit u_i is correctly decoded, given that all previous bits were correctly decoded, may approach either about 1 or about 0.5. The proportion of bits whose probability of successful decoding approaches 1 tends towards the capacity of the underlying channel as N increases. This information

regarding the reliability of those bits may be used to select a high-reliability subset of U_1^N to store data bits, while the rest of U_1^N , called the frozen-bit set (or frozen set), may be set to a fixed, pre-determined value (e.g., all zeros, all ones, or a combination of zeros and ones).

The frozen set is known by the encoder and the decoder, which forces $\hat{u}_i$ to the corresponding pre-determined value of u_i , e.g., if i is part of the frozen set.

[0024] In polar code construction, the encoder may take as input the length- N binary vector U_1^N , and may compute $X_1^N = U_1^N \cdot G_n$, where G_n is the n -th Kronecker power of a 2×2 matrix $\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$, where $U_1^N = (u_0, u_1, \dots, u_{N-1})$, $X_1^N = (x_0, x_1, \dots, x_{N-1})$, and $N = 2^n$.

Various coding rates may be achieved by setting the desired number of encoder inputs U_1^N to data bits, and freezing the remaining bit values to the predetermined values. For example, to encode a rate $\frac{1}{2}$ code, half of the U_1^N 's may be set to data bits, and the rest frozen to their predetermined values.

[0025] When the received vectors are decoded using a Successive Cancellation (SC) decoder, every estimated bit $\hat{u}_i$ may have a predetermined error probability given that bits u_0^{i-1} were correctly decoded, that tends towards either 0 or 0.5. Moreover, the proportion of estimated bits with a low error probability tends towards the capacity of the underlying channel. Polar codes exploit this phenomenon, called channel polarization, by using the most reliable K bits to transmit information, while setting, or freezing, the remaining $(N-K)$ bits to the predetermined values. The choice of which bit indices to freeze (and to what values) and which bits to use for data is fixed before transmission, and revealed to both the encoder and the decoder.

[0026] An aspect of polar code word construction may be to determine, for a given coding rate, a subset of the input U_1^N for using as data bits, and the remaining of the input U_1^N as frozen bits.

[0027] In the following description, numerous details are discussed to provide a more thorough explanation of embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring embodiments of the present disclosure.

[0028] Note that in the corresponding drawings of the embodiments, signals are represented with lines. Some lines may be thicker, to indicate a greater number of constituent signal paths, and/or have arrows at one or more ends, to indicate a direction of information

flow. Such indications are not intended to be limiting. Rather, the lines are used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit or a logical unit. Any represented signal, as dictated by design needs or preferences, may actually comprise one or more signals that may travel in either direction and may be implemented with any suitable type of signal scheme.

[0029] Throughout the specification, and in the claims, the term "connected" means a direct electrical, mechanical, or magnetic connection between the things that are connected, without any intermediary devices. The term "coupled" means either a direct electrical, mechanical, or magnetic connection between the things that are connected or an indirect connection through one or more passive or active intermediary devices. The term "circuit" or "module" may refer to one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" may refer to at least one current signal, voltage signal, magnetic signal, or data/clock signal. The meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0030] The terms "substantially," "close," "approximately," "near," and "about" generally refer to being within +/- 10% of a target value. Unless otherwise specified the use of the ordinal adjectives "first," "second," and "third," etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0031] It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

[0032] The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions.

[0033] For the purposes of the present disclosure, the phrases "A and/or B" and "A or B" mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0034] In addition, the various elements of combinatorial logic and sequential logic discussed in the present disclosure may pertain both to physical structures (such as AND gates, OR gates, or XOR gates), or to synthesized or otherwise optimized collections of

devices implementing the logical structures that are Boolean equivalents of the logic under discussion.

[0035] In addition, for purposes of the present disclosure, the term “eNB” may refer to a legacy eNB, a next-generation or 5G eNB, an Access Point (AP), a Base Station or an eNB communicating on the unlicensed spectrum, and/or another base station for a wireless communication system. For purposes of the present disclosure, the term “UE” may refer to a legacy UE, a next-generation or 5G UE, an STA, and/or another mobile equipment for a wireless communication system.

[0036] Various embodiments of eNBs and/or UEs discussed below may process one or more transmissions of various types. Some processing of a transmission may comprise receiving, encoding, decoding, and/or otherwise handling a transmission that has been received. In some embodiments, an eNB or UE processing a transmission may determine or recognize the transmission’s type and/or a condition associated with the transmission. For some embodiments, an eNB or UE processing a transmission may act in accordance with the transmission’s type, and/or may act conditionally based upon the transmission’s type. An eNB or UE processing a transmission may also recognize one or more values or fields of data carried by the transmission. Processing a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission that has been received by an eNB or a UE through one or more layers of a protocol stack.

[0037] Various embodiments of eNBs and/or UEs discussed below may also generate one or more transmissions of various types. Some generating of a transmission may comprise receiving, encoding, decoding, and/or otherwise handling a transmission that is to be transmitted. In some embodiments, an eNB or UE generating a transmission may establish the transmission’s type and/or a condition associated with the transmission. For some embodiments, an eNB or UE generating a transmission may act in accordance with the transmission’s type, and/or may act conditionally based upon the transmission’s type. An eNB or UE generating a transmission may also determine one or more values or fields of data carried by the transmission. Generating a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission to be sent by an eNB or a UE through one or more layers of a protocol stack.

[0038] **Fig. 2** schematically illustrates a system 200 for constructing a polar code for transmission over a channel, based at least in part on a final reliability ranking, in accordance

with some embodiments of the disclosure. System 200 comprises, in some embodiments, a transmitter 202 and a receiver 220. Transmitter 202 may transmit data (e.g., encoded in code words) over a channel 216 to receiver 220. Channel 216 may be, for example, a wireless communication channel.

[0039] In some embodiments, one of transmitter 202 and receiver 220 may be a eNB, and another of transmitter 202 and receiver 220 may be a UE. For example, system 200 may correspond to a eNB transmitting to a UE over the channel 216, or vice versa. In some other embodiments, transmitter 202 and receiver 220 may correspond to any wireless transmitter and receiver communicating using any appropriate wireless communication standard or protocol.

[0040] In some embodiments, transmitter 202 may comprise an encoder 204. Encoder 204 may receive data input 208 and frozen input 210. Data input 208 may comprise data bits that transmitter 202 may intend to transmit to receiver 220. Frozen input 210 may comprise frozen bits that may be frozen or set to pre-determined values (e.g., all zeros, all ones, a combination of zeros and ones, etc.). Encoder 204 may generate one more code words based on data input 208 and frozen input 210.

[0041] For constructing a codeword of length N , a number of bits in data input 208 and the number of bits in frozen input 210 may be based on a coding rate of the polar code. As an example, if the coding rate is $1/2$, then data input 208 may have $N/2$ bits, and frozen input 210 may have $N/2$ bits. In another example, if $N = 8$ and coding rate is $2/8$, then data input 208 may have 2 bits, and frozen input 210 may have 6 bits. As previously discussed herein, the choice of which bit indices to freeze (and to what values) and which bits to use for data may be fixed before transmission, and revealed to both encoder 204 and to a decoder 206.

[0042] In some embodiments, transmitter 202 may receive a final reliability ranking 206 (also referred to as “reliability ranking 206”). In some embodiments, final reliability ranking 206 may be generated by a computing device 240 (e.g., by a ranking generation circuitry 242), and computing device 240 may transmit final reliability ranking 206 to transmitter 202 and receiver 220. For example, transmitter 202 may store final reliability ranking 206 (e.g., in a memory of transmitter 202, where the memory is not illustrated in **Fig. 2**). In an example, receiver 220 may store final reliability ranking 206 (e.g., in a memory of receiver 220, where the memory is not illustrated in **Fig. 2**).

[0043] As discussed herein with respect to **Fig. 1**, encoder 204 may receive a length- N binary input vector U_1^N as input, and may compute code word $X_1^N = U_1^N \cdot G_n$, where G_n

is the n -th Kronecker power of a 2×2 matrix $\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$, where $U_1^N = (u_0, u_1, \dots, u_{N-1})$, $X_1^N = (x_0, x_1, \dots, x_{N-1})$, and $N = 2^n$ (e.g., in **Fig. 1**, N is 8). In some embodiments, some of the bits of input vector U_1^N may comprise bits from data input 208, and remaining of the bits of input vector U_1^N may comprise bits from frozen input 210. In some embodiments, final reliability ranking 206 may rank various positions of the input vector U_1^N , e.g., based on a reliability of the corresponding bits to be transmitted correctly over the channel and decoded by decoder 222.

[0044] Merely as a simple example of $N = 8$, final reliability ranking 206 may be [7, 5, 6, 3, 4, 2, 1, 0] (although such a ranking is merely an example). For such an example, position 7 (or bit number 7) of input vector U_1^N may have a highest probability of being correctly decoded by decoder 222, position 5 (or bit number 5) of input vector U_1^N may have a second highest probability of being correctly decoded by decoder 222, position 6 (or bit number 6) of input vector U_1^N may have a third highest probability of being correctly decoded by decoder 222, and so on.

[0045] In this example of final reliability ranking 206 being [7, 5, 6, 3, 4, 2, 1, 0], if coding rate is $1/8$, then a single bit of data input 208 may be in position 7 of input vector U_1^N , and remaining bits of input vector U_1^N may be frozen bits. In another example, if coding rate is $2/8$, then data input 208 may comprise two bits in positions 7 and 5 of input vector U_1^N , and remaining bits of input vector U_1^N may be frozen bits. In another example, if coding rate is $4/8$, then data input 208 may comprise four bits in positions 7, 5, 6, and 3 of input vector U_1^N , and remaining bits of input vector U_1^N may be frozen bits.

[0046] Thus, in some embodiments, encoder 204 may select appropriate positions for the data bits of data input 208 in input vector U_1^N , based on final reliability ranking 206. Put differently, in some embodiments, data input 208 and frozen input 210, in combination, may form input vector U_1^N received by encoder 204, where positions of the data bits of data input 208 in input vector U_1^N may be based on final reliability ranking 206. In some embodiments, decoder 222 may also have access to final reliability ranking 206, based on which decoder 222 may decode the output from the channel 216, and generate estimated data output 224.

[0047] As previously discussed herein, final reliability ranking 206 may be generated by computing device 240. Computing device 240 may be a part of transmitter 202 and/or receiver 220, or may be separate from transmitter 202 and/or receiver 220. For example, computing device 240 may generate final reliability ranking 206 in advance, and

communicate final reliability ranking 206 to transmitter 202 and/or receiver 220 prior to communication between transmitter 202 and/or receiver 220.

[0048] **Fig. 3** illustrates method 300 to construct a plurality of reliability rankings for a corresponding plurality of coding rates, where the reliability rankings may be used to generate a final reliability ranking (e.g., final reliability ranking 206 of **Fig. 2**), in accordance with some embodiments of the disclosure. For example, with reference to **Fig. 3**, methods that may relate to computing device 240 are discussed below. Although the actions in the method of **Fig. 3** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 3** may be optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[0049] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause computing device 240 to perform an operation comprising the method of **Fig. 3**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[0050] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the method 300 of **Fig. 3**.

[0051] Returning to **Fig. 3**, various methods may be used in accordance with the various embodiments discussed herein. The method 300 may comprise, at 304, choosing a block length N (e.g., at computing device 240). For example, input vector U_1^N received by encoder 204 may comprise N bits, and the code words generated by encoder 204 may comprise N bits. In some embodiments, N is 2^n , where n is a positive integer. Thus, N may be equal to 2, 4, 8, 16, 32, 64, 128, 256, 1024, 2048, or the like. Merely as an example, method 300 may be used for $N = 1024$, and may be repeated for $N = 2048$, and so on.

[0052] At 308, a reference set of coding rates R may be chosen (e.g., at computing device 240), where the set of coding rates $R = \{R_1, R_2, \dots, R_k\}$, and where $R_1 < R_2 < \dots < R_k$. Merely as an example, for $N = 128$, the set R may be $\{1/128, 2/128, 3/128, \dots, 128/128\}$, which may lead to 128 number of iterations of some operations of the method 300.

In another example, to reduce a number of iterations, elements of the set R may be incremented by a factor of 4. For example, in the example of $N = 128$, the set R may be $\{4/128, 8/128, 12/128, \dots, 128/128\}$. In some embodiments, a number of data bits (and a number of frozen bits) in input vector U_1^N may be based on a coding rate selected from the set R .

[0053] At 312, a first coding rate R_1 may be selected from the set R , and a coding rate R_i may be selected (e.g., at computing device 240) to be R_1 (e.g., a count i may be initialized to 1). Operations at blocks 316 to 336 may correspond to this coding rate R_i .

[0054] At 316, N bits of input vector U_1^N (e.g., all the bits of input vector U_1^N) may be set (e.g., at computing device 240) to corresponding pre-determined values, e.g., all zeros, all ones, some to zeros and some to ones, or the like.

[0055] At 320, a code word of length N (e.g., code word X_1^N) may be generated by, for example, encoding input vector U_1^N using polar codes. The encoding operation may be performed in a simulated environment, e.g., by computing device 240. Merely as an example, if N bits of input vector U_1^N is set to all zero at 316, then the code word at 320 may also be all zero.

[0056] At 324, a channel (e.g., the channel 216) may be simulated at computing device 240, and noise samples according to design signal to noise ratio (SNR) may be generated. For example, if the code word is actually transmitted over the channel 216, receiver 220 may receive a noise-added version of the code word due to noise and interface. The simulation at 324 may output such a noise-added version of the code word. The added noise may be in accordance with the design SNR.

[0057] At 328, the noise-added version of the code word may be decoded by a decoder at computing device 240. For example, the received code word, which contains errors due to noise samples for the coding rate R_i , may be decoded. In some embodiments, the decoding may be based on the coding rate R_i . For example, in decoding, a value of decoding of a first bit may affect a decoding of a second bit, and so on. So, decoding of a frozen bit may affect decoding of a data bit, and vice versa. Thus, the manner in which the noise affect the code word and the manner in which the decoding is performed may be based on the coding rate R_i .

[0058] At 332, an average bit error rate for each bit index from $0:(N-1)$ after decoding may be calculated (e.g., at computing device 240). For example, some of the bit index may have a higher probability of successful transmission and decoding than others, and these bits

may be marked to have higher reliability. A bit index may be a position of a bit in the input vector U_1^N .

[0059] At 336, the bit indexes may be sorted according to their corresponding reliabilities, using the average bit error rate, to generate a sorted index of reliability ranking I_i for the coding rate R_i . Merely as an example, assume for $N = 8$, the sorted index of reliability ranking I_1 for a coding rate R_1 of $1/8$ may be $[7, 5, 6, 3, 4, 2, 1, 0]$. This may indicate that for the one data bit in the code word, the highest reliable bit index or bit position in input vector U_1^N is 7.

[0060] At 340, it may be determined if R_i is less than R_k (e.g., determine if all the code rates in the set R has been considered). If so, computing device 240 may increment the code rate R_i by one (e.g., $R_i = R_i + 1$) at 344, and may loop back to block 316 of method 300. Thus, the loop in the method 300 may be iterated, e.g., until all code rates $R_1, R_2, \dots, R_k$ in the set R has been processed.

[0061] Once all code rates $R_1, R_2, \dots, R_k$ in set R has been processed (e.g., when $R_i = R_k$), then block 340 may output a “yes.” As all code rates $R_1, R_2, \dots, R_k$ in the set R has been processed, the reliability rankings $I_1, I_2, \dots, I_k$ has been generated at various iterations of the block 336. Accordingly, at 348, computing device 240 may store the set of reliability rankings $I_1, I_2, \dots, I_k$ corresponding to the set of coding rates $R_1, R_2, \dots, R_k$, and the method 300 may end.

[0062] As discussed herein above, the SNR experienced by the transmission of an encoded code word and/or the decoding of the encoded code word may be based on an associated coding rate. For example, for coding rates R_1 and R_2 of **Fig. 3**, the corresponding SNRs and/or the corresponding decoding operations may be different. Accordingly, in some embodiments, reliability ranking I_1 corresponding to coding rate R_1 may be different from reliability ranking I_2 corresponding to coding rate R_2 . Put differently, the highest reliable bit indexes in input vector U_1^N (e.g., as estimated by method 300) may be based on the corresponding coding rate, and may change as the coding rate changes. This may lead to individual ones of sorted indices of reliability rankings $I_1, I_2, \dots, I_k$ potentially being different.

[0063] Henceforth, the reliability rankings $I_1, I_2, \dots, I_k$ are also referred to simply as rankings $I_1, I_2, \dots, I_k$, and individual ones of these reliability rankings are also referred to as rankings.

[0064] **Fig. 4** illustrates method 400 to generate a final reliability ranking (e.g., final reliability ranking 206 of **Fig. 2**), in accordance with some embodiments of the disclosure.

For example, with reference to **Fig. 4**, methods that may relate to computing device 240 are discussed below. Although the actions in the method of **Fig. 4** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 4** may be optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur.

Additionally, operations from the various flows may be utilized in a variety of combinations.

[0065] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause computing device 240 to perform an operation comprising the method of **Fig. 4**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[0066] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the method 400 of **Fig. 4**.

[0067] Returning to **Fig. 4**, various method may be in accordance with the various embodiments discussed herein. The method 400 may comprise, at 404, setting a count i to be 1. Also, for ranking R_i (e.g., R_1 , as generated in the method 300), let first N_{D1} positions in the ranking I_1 represent data bit indices. For example, for $N = 128$ and $R_1 = 4/128$, N_{D1} may be four (e.g., the first four positions of the ranking I_1 , which may correspond to the first four bits of input vector U_1^N). Also at 404, for all rankings $I_2, \dots, I_k$, the first N_{D1} positions in each of these rankings may be set (e.g., by computing device 240) to the first N_{D1} positions of the ranking R_1 . It is to be noted that the rankings $I_1, I_2, \dots, I_k$ of **Fig. 4** may be generated by method 300 of **Fig. 3**.

[0068] For example, assume that $N = 128$ (e.g., input vector U_1^N may have N bits), and assume the set of coding rates $R_1, R_2, \dots, R_k$ is given by $[4/128, 8/128, 12/128, \dots, 128/128]$. Merely as an example, assume that $I_1 = [127, 126, 125, 123, 111, 112, 115, 120, 118, 116, \dots]$, $I_2 = [127, 125, 119, 111, 126, 95, 123, 63, 109, 110, \dots]$, $I_3 = [127, 123, 111, 119, 47, 126, 79, 125, 95, 55, 63, 31, 87, \dots]$, and so on. Also, let coding rate R_1 be $4/128$. Thus, the first four bit indices in I_1 may represent indices for data bits, and the remaining bit indices in I_1 may represent indices for frozen bits. In some embodiments, in accordance with operations at 404, for all rankings $I_2, \dots, I_k$, the first four positions in each of these rankings

may be set to the first four positions of the ranking I1. Thus, in accordance with operations at 404, the rankings I2 and I3 may be modified such that the first four positions of these rankings may respectively be set to [127, 126, 125, 123] (e.g., set to the first four positions of the ranking I1). Thus, the rankings I2 and I3 may be modified such that a modified ranking I2 = [127, 126, 125, 123, 119, 111, 95, 63, 109, 110, ...], a modified ranking I3 = [127, 126, 125, 123, 111, 119, 47, 79, 95, 55, 63, 31, 87, ...]. Rankings I4, ..., Ik may also be modified in a similar manner.

[0069] Referring again to **Fig. 4**, the method 400 may then proceed to 408, where the count i may be incremented by one. Thus, after a first iteration of 408, the count i may be two.

[0070] At 412, for ranking I $_i$, let first N_{Di} positions in I $_i$ represent data bit indices. For example, for $i = 2$ and coding rate $R_2 = 8/128$, N_{Di} positions may represent the first eight positions of ranking I2, and the first eight positions in I2 may represent data bit indices. Also, for ranking I $_{(i-1)}$, let first $N_{D(i-1)}$ positions in I $_{(i-1)}$ represent data bit indices. For example, count $(i-1)$ is one, and for ranking I1, the first four positions (e.g., first N_{D1} positions) in I1 may represent data bit indices.

[0071] In some embodiments, in accordance with 412 of method 400, for all rankings I1, ..., I $_{(i-1)}$, I $_{(i+1)}$, ..., Ik, the positions $(N_{D(i-1)}+1)$, ..., N_{Di} in each of these rankings may be respectively set to the positions $(N_{D(i-1)}+1)$, ..., N_{Di} of the ranking Ri.

[0072] For example, for $i = 2$, N_{Di} is eight and $N_{D(i-1)}$ is four. Thus, the 5th, 6th, 7th, and 8th positions of rankings I1, I3, I4, ..., Ik may be respectively set to the 5th, 6th, 7th, and 8th positions of the ranking I2. In the above discussed example, the ranking I2 (e.g., after being modified at 404) may be [127, 126, 125, 123, 119, 111, 95, 63, 109, 110, ...]. The 5th, 6th, 7th, and 8th positions of the ranking I2 is [119, 111, 95, 63]. Thus, in some embodiments, in each of the rankings I1, I3, I4, ..., Ik, the 5th, 6th, 7th, and 8th positions may be set to [119, 111, 95, 63]. Thus, for example, ranking I1 may now be I1 = [127, 126, 125, 123, 119, 111, 95, 63, 112, 115, 120, 118, 116, ...], the ranking I3 may now be I3 = [127, 126, 125, 123, 119, 111, 95, 63, 47, 79, 55, 31, 87, ...], and so on. The ranking I2 may remain unchanged at [127, 126, 125, 123, 119, 111, 95, 63, 109, 110, ...].

[0073] In some embodiments, while, for example, setting the 5th, 6th, 7th, and 8th positions of the ranking I3, relative positions of other bit indices may not be altered in the ranking I3. For example, in the original I3 (e.g., at an end of the method 300 of **Fig. 3**), bit indices 47, 79, 55, 31, 87 occurred in order (e.g., although there were intervening bit indices in between these bit indices). This relative position of the bit indices 47, 79, 55, 31, 87 may

be preserved while various positions are set during 404 and also during the first iteration of 412 (e.g., although the absolute position of one or more of these bit indices 47, 79, 55, 31, 87 may be altered during 404 and/or during the first iteration of 412).

[0074] Referring again to method 400, at 416, it may be determined if count i is less than count k (e.g., determine if all the coding rates $R_1, \dots, R_k$ have been considered). If “yes” at 416, the method 400 may loop back to 408, where the count i may be incremented by one. For example, for the second iteration of 408, count i may be incremented to 3.

Similarly, during the second iteration, 412 may be repeated.

[0075] For example, for the second iteration of 412, for $i = 3$, N_{Di} (e.g., N_{D3}) is twelve and $N_{D(i-1)}$ (e.g., N_{D2}) is eight. Thus, the 9th, 10th, 11th, and 12th positions of rankings $I_1, I_2, I_4, \dots, I_k$ may be respectively set to the 9th, 10th, 11th, and 12th positions of the ranking I_3 . In the above discussed example, the ranking I_3 (e.g., after being modified at the first iteration of 412) may be [127, 126, 125, 123, 119, 111, 95, 63, 47, 79, 55, 31, 87, ...]. The 9th, 10th, 11th, and 12th positions of the ranking I_3 is [47, 79, 55, 31]. Thus, in some embodiments, in each of the rankings $I_1, I_3, I_4, \dots, I_k$, the 9th, 10th, 11th, and 12th positions may be set to [47, 79, 55, 31]. Thus, for example, ranking I_1 may now be $I_1 = [127, 126, 125, 123, 119, 111, 95, 63, 47, 79, 55, 31, 112, 115, 120, 118, 116, \dots]$, and the ranking I_2 may now be $I_2 = [127, 126, 125, 123, 119, 111, 95, 63, 47, 79, 55, 31, 109, 110, \dots]$.

[0076] It is to be noted that the modification to the rankings $I_1, \dots, I_k$, as discussed with respect to 412 of method 400, may progressively set the starting positions of these rankings to be similar. For example, after the first iteration 412, the first eight positions of each of the rankings $I_1, \dots, I_k$ may be similar; after the second iteration 412, the first twelve positions of each of the rankings $I_1, \dots, I_k$ may be similar; and so on.

[0077] Referring again to method 400, if “no” at 416 (e.g., after all the coding rates $R_1, \dots, R_k$ has been considered, and after 412 has been executed for $(k-1)$ times), the method 400 may proceed to 420. It may be noted that at 420, each of the rankings $I_1, \dots, I_k$ may be similar. In some embodiments, at 420, the final reliability ranking (e.g., final reliability ranking 206) may be set to any of the rankings $I_1, I_2, \dots, I_k$.

[0078] At 424, the final reliability ranking (e.g., final reliability ranking 206) may be transmitted (e.g., by computing device 240) to an encoder (e.g., encoder 204) and/or a decoder (e.g., decoder 222), e.g., to facilitate encoding and decoding in accordance with polar coding, based on the final reliability ranking.

[0079] For example, assume that the encoder has access to final reliability ranking 206, and let final reliability ranking 206 for $N = 128$ be [127 126 125 123 119 111 95 63 47

79 55 31 87 103 59 91 107 61 93 115 109 62 15 117 94 23 39 110 27 71 121 43 118 75 29 51 45 83 122 77 53 30 99 124 85 46 57 101 78 89 54 7 86 105 11 58 102 19 90 113 13 35 106 60 92 114 21 67 108 37 14 25 69 22 116 41 38 73 26 49 70 120 81 42 74 28 97 50 3 44 82 76 5 52 98 9 84 56 100 6 88 17 10 33 104 18 65 112 12 34 20 66 36 24 68 40 1 72 48 80 2 96 4 8 16 32 64 0]. Now, if encoder 204 is to encode input vector U_1^N with a coding rate of 4/128, then encoder 204 may use positions [127 126 125 123] (e.g., the first four positions of final reliability ranking 206) of input vector U_1^N for data input 208, and use the remaining positions of input vector U_1^N for frozen input 210.

[0080] In another example, if encoder 204 is to encode input vector U_1^N with a coding rate of 8/128, then encoder 204 may access the first 8 positions from final reliability ranking 206, and use the first 8 positions of input vector U_1^N for data input 208 and use the remaining positions of input vector U_1^N for frozen input 210.

[0081] In yet another example, if encoder 204 is to encode input vector U_1^N with a coding rate of 64/128, then encoder 204 may access the first 64 positions from final reliability ranking 206, and use the first 64 positions of input vector U_1^N for data input 208 and use the remaining positions of input vector U_1^N for frozen input 210.

[0082] Decoder 222 may know a coding rate that encoder 204 is using for a code word, and decoder 222 may also have access to final reliability ranking 206. Accordingly, once decoder 222 receives a code word and a corresponding coding rate, decoder 222 may be aware of relative positions of data input 208 and frozen input 210 in input vector U_1^N .

Decoder 222 may attempt to decode the received code word, based at least in part on such knowledge of relative positions of data input 208 and frozen input 210 in input vector U_1^N .

[0083] In some embodiments, transmitter 202, including encoder 204, may be a part of one of an eNB or a UE; and receiver 220, including decoder 222, may be a part of another of the eNB or the UE.

[0084] In some embodiments, using methods 300 and 400 of **Figs. 3-4**, an example final reliability ranking 206 for $N = 128$ (where N is a number of bits in the input vector U_1^N) may be: [127 126 125 123 119 111 95 63 47 79 55 31 87 103 59 91 107 61 93 115 109 62 15 117 94 23 39 110 27 71 121 43 118 75 29 51 45 83 122 77 53 30 99 124 85 46 57 101 78 89 54 7 86 105 11 58 102 19 90 113 13 35 106 60 92 114 21 67 108 37 14 25 69 22 116 41 38 73 26 49 70 120 81 42 74 28 97 50 3 44 82 76 5 52 98 9 84 56 100 6 88 17 10 33 104 18 65 112 12 34 20 66 36 24 68 40 1 72 48 80 2 96 4 8 16 32 64 0].

[0085] In some embodiments, using methods 300 and 400 of **Figs. 3-4**, an example final reliability ranking 206 for $N = 256$ may be: [255 254 253 251 247 245 243 239 237 235

231 223 221 219 215 207 191 190 189 187 183 175 159 151 143 127 126 125 123 119 111
 103 95 87 79 63 59 55 47 31 222 238 91 249 199 167 107 155 246 61 171 93 115 203 157
 179 109 173 211 250 62 117 205 15 94 181 227 23 158 110 39 213 27 121 174 71 252 43
 185 135 118 206 229 75 182 217 214 233 122 51 29 139 186 45 83 230 147 77 218 241 99
 53 141 30 163 85 124 46 234 188 149 57 195 101 78 89 54 220 165 142 7 242 153 86 105
 197 11 236 244 150 169 102 58 201 166 113 90 177 154 198 106 248 60 209 170 19 92 13
 114 35 202 156 225 21 178 67 108 37 131 172 14 210 25 69 116 22 41 204 133 180 38 73
 226 26 49 70 137 212 120 81 42 134 184 145 74 28 97 228 50 3 138 216 161 44 82 232 76
 146 193 52 98 140 240 5 162 84 148 9 56 194 100 6 88 164 17 152 104 196 10 33 168 18 65
 112 12 200 129 34 176 20 66 208 36 130 24 68 224 40 132 1 72 48 136 80 2 144 96 4 160
 192 8 16 32 64 128 0].

[0086] In some embodiments, using methods 300 and 400 of **Figs. 3-4**, an example final reliability ranking 206 for N = 512 may be: [511 510 509 507 505 503 502 501 499 495
 494 493 491 487 479 478 477 475 471 463 459 455 447 446 445 443 439 435 431 427 423
 415 413 411 407 399 383 382 381 379 375 371 367 363 359 351 349 347 343 335 319 317
 315 311 303 287 255 254 253 251 247 243 239 237 235 231 223 221 219 215 207 191 189
 187 183 175 159 127 125 123 119 111 95 63 55 47 31 467 365 143 126 429 190 79 318 271
 87 506 245 222 151 373 103 461 279 59 350 91 167 437 414 483 238 295 155 366 199 107
 249 283 469 171 327 61 430 377 299 508 246 93 391 115 203 441 157 374 462 179 331 485
 109 285 307 438 173 473 395 211 62 15 250 301 339 117 94 205 23 470 378 181 227 333
 158 489 403 39 110 309 442 355 497 486 474 252 174 397 380 286 213 490 419 121 341
 444 229 185 405 302 313 206 118 357 334 182 451 217 476 27 71 310 421 345 135 43 398
 214 498 233 409 263 75 122 342 361 29 453 51 139 186 492 230 83 406 45 267 314 425 147
 358 77 218 241 99 53 275 141 346 369 422 30 124 163 85 457 269 500 234 46 410 188 291
 149 433 195 57 362 454 316 465 426 504 220 348 242 101 370 277 78 458 323 165 89 412
 54 236 293 481 142 434 387 364 153 86 197 105 270 281 150 325 428 169 102 58 244 466
 278 297 7 389 90 166 113 201 372 460 11 154 177 294 329 106 198 436 19 282 482 305 60
 326 209 170 393 13 248 35 92 337 298 21 468 376 114 67 390 202 156 225 37 108 178 131
 440 484 401 330 472 353 284 306 172 394 210 417 300 338 116 204 488 25 14 180 69 259
 226 332 402 449 41 22 308 354 133 212 396 73 38 261 120 49 418 340 26 496 137 184 70
 228 404 81 312 42 265 134 450 356 216 145 74 262 97 28 344 50 273 138 420 161 44 82
 232 266 408 289 76 146 360 193 452 3 52 98 140 274 321 424 240 162 84 268 5 368 385
 290 148 456 56 194 9 100 432 276 88 6 322 164 17 152 464 10 292 386 104 33 196 280 18
 168 324 65 480 12 112 296 129 34 388 200 257 20 176 66 328 304 36 208 130 392 24 258

336 68 224 400 40 132 352 1 260 416 72 48 448 136 264 2 80 144 96 272 4 160 288 192 320
384 8 16 32 256 64 128 0].

[0087] In some embodiments, using methods 300 and 400 of **Figs. 3-4**, an example final reliability ranking 206 for N = 1024 may be: [1023 1022 1021 1019 1018 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981 979 975 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923 919 911 903 895 894 893 891 889 887 885 883 879 878 877 875 871 863 862 861 859 855 847 839 831 830 829 827 823 815 807 799 795 791 783 767 766 765 763 761 759 757 755 751 750 749 747 743 735 734 733 731 727 719 711 703 702 701 699 695 687 683 679 671 667 663 655 639 638 637 635 631 627 623 619 615 607 603 599 591 575 573 571 567 559 543 511 510 509 507 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 455 447 446 445 443 439 431 423 415 411 407 399 383 382 381 379 375 367 363 359 351 349 347 343 335 319 317 315 311 303 287 255 254 253 251 247 243 239 235 231 223 221 219 215 207 191 189 187 183 175 159 127 125 123 119 111 95 63 942 605 505 459 427 371 237 47 811 715 31 1020 758 669 435 365 974 953 79 886 413 691 190 997 126 797 143 843 55 429 621 467 819 318 685 87 950 271 723 222 245 985 506 574 151 527 907 373 279 350 103 59 461 813 762 629 167 717 851 606 91 535 437 483 414 238 982 295 155 890 693 670 199 739 366 845 107 551 283 915 1001 249 327 622 469 61 171 821 539 867 798 954 377 430 583 299 725 93 909 246 508 633 391 115 686 998 203 555 157 441 374 764 647 931 853 179 331 462 109 485 697 285 814 986 630 1009 307 587 173 718 775 438 892 541 741 62 15 1002 963 956 917 869 857 846 825 822 729 726 694 473 489 378 250 988 910 470 395 211 933 745 301 921 563 442 854 1010 651 634 339 557 205 595 117 965 779 333 181 698 403 227 94 873 486 742 659 158 355 589 918 309 1004 826 474 497 397 110 611 213 286 937 565 252 870 730 787 753 653 341 419 174 121 542 380 23 675 597 185 858 302 39 781 636 881 229 405 206 118 490 934 558 27 444 313 451 71 803 969 357 661 217 182 334 746 700 43 569 707 1012 135 922 613 345 590 310 945 75 789 421 263 476 398 214 874 828 835 966 29 566 601 51 139 122 233 677 519 654 409 732 342 498 45 83 267 186 361 453 665 598 977 938 805 899 754 230 782 77 147 860 406 523 617 314 492 709 99 53 1016 425 993 970 924 882 748 946 876 358 793 614 681 940 662 500 241 218 837 570 369 422 790 756 678 457 346 809 978 625 901 602 713 433 124 410 234 884 806 666 362 275 454 188 689 141 972 163 841 531 85 316 618 269 710 30 291 794 426 465 817 220 948 525 149 572 46 195 994 504 547 838 57 721 682 242 101 348 905 277 323 78 760 165 604 89 370 533 54 579 458 142 236 849 412 810 293 153 626 387 902 481 86 980 888 714 270 197 364 434 668 105 549 281 643 737 150 526 620 325 690 169 913 537 58 102 842 796 428 7 278 952 771 581 297

865 244 466 90 113 166 389 818 684 201 11 534 996 553 372 722 906 154 645 294 177 329
 460 19 929 812 198 106 628 984 282 550 305 13 60 436 585 850 716 482 692 738 844 773
 961 248 914 1000 326 393 209 170 468 561 538 820 376 866 582 649 337 92 298 724 908
 390 114 632 35 202 593 156 554 440 225 777 646 21 401 178 67 108 930 330 852 284 484
 696 353 37 657 306 131 1008 586 172 774 540 14 740 210 25 394 609 472 69 562 824 259
 916 417 300 785 116 962 22 650 338 41 728 204 868 133 856 932 488 673 744 556 594 920
 778 332 226 180 402 449 801 872 308 354 964 658 588 705 396 212 564 610 515 496 652
 786 120 418 340 833 73 936 261 38 752 184 49 674 596 26 137 70 517 780 228 404 312 81
 42 265 880 450 897 134 802 356 216 660 568 145 968 521 706 74 262 612 97 344 28 50 273
 420 788 944 138 518 600 834 161 232 44 676 408 976 360 664 452 804 898 529 82 266 616
 708 289 792 424 146 76 522 193 240 545 98 52 836 680 274 140 992 321 368 162 84 530
 268 3 456 577 808 624 385 290 900 148 524 432 712 56 5 194 100 641 546 276 688 88 322
 9 840 164 532 769 464 6 578 152 816 17 292 386 104 720 196 904 280 10 548 642 33 168
 324 480 848 536 18 770 65 580 112 296 736 12 388 200 912 34 129 552 176 644 864 328 20
 257 66 304 772 584 928 513 208 392 36 560 130 648 24 336 960 258 68 224 592 776 514
 400 40 132 352 656 608 260 72 784 416 1 516 48 672 136 448 800 704 80 264 2 832 520
 144 896 96 272 528 4 160 288 544 192 320 8 576 384 640 768 16 0 512 32 64 256 128].

[0088] In some embodiments, using methods 300 and 400 of **Figs. 3-4**, an example final reliability ranking 206 for N = 2048 may be: [2047 2046 2045 2044 2043 2042 2041 2039 2038 2037 2035 2031 2030 2029 2027 2025 2023 2021 2019 2015 2014 2013 2011 2009 2007 2006 2005 2003 1999 1998 1997 1995 1991 1983 1982 1981 1979 1977 1975 1974 1973 1971 1967 1966 1965 1963 1959 1951 1950 1949 1947 1943 1939 1935 1931 1927 1919 1918 1917 1915 1913 1911 1910 1909 1907 1903 1902 1901 1899 1895 1891 1887 1886 1885 1883 1879 1875 1871 1869 1867 1863 1855 1854 1853 1851 1847 1845 1843 1839 1837 1835 1831 1823 1821 1819 1815 1807 1791 1790 1789 1787 1786 1785 1783 1782 1781 1779 1775 1774 1773 1771 1767 1763 1759 1758 1757 1755 1751 1747 1743 1741 1739 1735 1727 1726 1725 1723 1719 1717 1715 1711 1709 1707 1703 1695 1693 1691 1687 1679 1663 1662 1661 1659 1655 1653 1651 1647 1645 1643 1639 1631 1630 1629 1627 1623 1615 1599 1598 1597 1595 1591 1583 1575 1567 1559 1551 1535 1534 1533 1531 1530 1529 1527 1526 1525 1523 1519 1518 1517 1515 1511 1507 1503 1502 1501 1499 1495 1493 1491 1487 1485 1483 1479 1471 1470 1469 1467 1463 1461 1459 1455 1453 1451 1447 1439 1438 1437 1435 1431 1423 1407 1406 1405 1403 1399 1397 1395 1391 1389 1387 1383 1375 1374 1373 1371 1367 1359 1343 1342 1341 1339 1335 1327 1319 1311 1307 1303 1295 1279 1278 1277 1275 1271 1269 1267 1263 1262

1261 1259 1255 1247 1246 1245 1243 1239 1231 1223 1215 1214 1213 1211 1207 1199
1191 1183 1179 1175 1167 1151 1150 1149 1147 1143 1135 1131 1127 1119 1115 1111
1103 1087 1085 1083 1079 1071 1055 1023 1022 1021 1019 1018 1017 1015 1014 1013
1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981 979 975 973 971 967 959 958
957 955 951 949 947 943 941 939 935 927 926 925 923 919 911 895 894 893 891 887 885
883 879 878 877 875 871 863 862 861 859 855 847 831 830 829 827 823 815 807 799 795
791 783 767 766 765 763 761 759 758 757 755 751 750 749 747 743 735 734 733 731 727
719 711 703 702 701 699 695 687 679 671 667 663 655 639 638 637 635 631 623 619 615
607 603 599 591 575 573 571 567 559 543 511 510 509 507 505 503 501 499 495 494 493
491 487 479 478 477 475 471 463 455 447 446 445 443 439 431 423 415 411 407 399 383
382 381 379 375 367 363 359 351 349 347 343 335 319 317 315 311 303 287 255 254 253
251 247 239 235 231 223 221 219 215 207 191 189 187 183 175 159 127 125 123 119 111
95 63 1978 1914 1694 1646 1563 1401 1390 1351 1273 1195 1117 839 683 605 427 371 243
1822 1749 1607 903 811 715 1710 1323 1020 942 889 627 459 237 1532 1454 669 502 365
31 1139 413 47 1415 1270 1933 886 435 2022 1788 1181 1227 126 1657 1579 691 1671 953
1877 1398 974 843 79 1465 621 1955 997 429 797 1355 143 1486 190 55 1203 1133 1509
1721 318 819 1309 1838 685 1654 271 87 467 2010 950 222 245 2033 1611 723 907 1742
1331 574 527 1799 1197 151 985 1916 506 1462 350 1765 373 103 1419 1565 1497 813 279
59 461 1086 1235 762 1941 1039 1849 629 1587 851 1325 167 1718 1274 606 717 535 91
1987 437 1753 1675 1870 982 483 1141 1363 238 414 1118 890 295 1893 1229 155 1047
693 1980 739 670 1581 366 845 1494 199 107 1402 551 283 2026 915 1001 249 1846 1619
1205 1251 622 1182 327 1357 1803 61 171 469 1881 1063 821 539 1427 1513 867 954 377
798 430 1750 1658 1934 583 1134 725 93 1957 2036 2034 2028 2012 2001 1993 1990 1989
1969 1962 1961 1958 1946 1945 1942 1905 1898 1897 1894 1884 1882 1878 1859 1852
1850 1827 1813 1811 1805 1777 1770 1769 1766 1756 1754 1731 1724 1722 1701 1699
1689 1685 1683 1678 1677 1660 1637 1635 1625 1621 1614 1613 1593 1589 1582 1566
1543 1522 1521 1514 1510 1500 1498 1475 1468 1466 1445 1443 1429 1422 1421 1404
1381 1379 1369 1366 1365 1358 1337 1334 1333 1326 1310 1287 1276 1257 1254 1253
1241 1238 1237 1230 1209 1206 1198 1159 1145 1142 1099 1095 1067 1053 1051 1010
1009 1004 1002 998 988 986 965 963 956 933 931 921 917 910 909 892 873 869 857 853
846 825 822 814 775 764 745 741 729 726 718 697 694 686 647 634 633 630 595 587 563
555 541 508 489 486 485 473 470 462 442 441 438 395 391 378 374 339 331 307 299 285
250 246 211 203 179 157 115 109 2040 1923 1806 1778 1622 1590 1516 1477 1433 1210
1163 1075 854 742 698 651 557 497 301 205 181 62 1829 1385 1146 1107 1069 918 826

779 403 227 173 117 1733 1641 1430 1101 659 1291 937 870 753 333 1382 474 355 158
1338 730 1547 589 397 94 1906 1242 1171 858 1817 309 110 1772 1686 611 213 565 1594
252 1994 1449 380 286 1265 653 1948 1705 1861 341 1123 881 787 419 1077 1638 121
2017 1165 636 15 1299 542 174 934 597 1370 1900 969 1393 675 490 302 1446 444 185
1970 1054 1187 405 1814 781 1012 1148 229 23 1109 1481 1555 206 746 558 118 1293 451
922 803 313 700 1833 1626 1649 39 945 661 1524 357 1258 217 1702 182 1070 334 1315
707 1434 1212 1925 569 1737 27 1457 71 1549 1173 613 874 966 590 828 1219 476 310
345 789 1081 421 1964 1780 43 2018 2004 2002 1996 1976 1972 1937 1929 1926 1912
1908 1873 1866 1865 1862 1842 1841 1834 1830 1818 1784 1761 1745 1738 1734 1714
1713 1706 1692 1690 1667 1650 1644 1642 1628 1603 1596 1573 1571 1561 1557 1528
1505 1489 1482 1478 1458 1452 1450 1436 1411 1394 1388 1386 1372 1347 1340 1317
1305 1301 1294 1266 1260 1244 1221 1189 1177 1166 1129 1125 1113 1110 1078 1016 993
978 977 970 946 940 938 924 899 882 876 860 837 835 805 793 790 754 748 732 709 681
677 665 662 654 617 601 598 566 498 492 453 425 422 409 406 398 361 358 342 233 230
214 186 122 2020 1889 1820 1550 1490 1396 1349 1302 1268 1225 1174 1126 1102 1082
901 782 756 713 678 614 500 457 346 314 218 135 83 51 1930 1746 1708 1605 1321 1193
1114 884 809 602 570 369 267 241 124 75 1137 1031 806 519 234 139 1795 1413 625 433
410 263 29 1190 972 45 841 454 188 147 1558 666 523 77 1953 1577 1484 1318 1652 1201
689 2008 1836 1669 1353 1178 362 948 710 53 99 618 465 1035 141 1222 275 994 316 426
794 1874 817 1130 220 1460 572 504 1329 531 1740 269 163 85 1506 721 1574 1306 905
242 30 682 838 149 348 1043 760 291 1609 1084 525 1797 1350 1417 1194 195 46 1233
1272 1716 101 1762 547 604 57 1562 370 1585 849 1037 277 1868 980 323 458 1985 810
888 412 165 236 1059 78 626 89 1938 1116 533 902 1606 481 1673 714 1361 1492 1322
579 54 1400 434 2024 668 142 364 1844 1138 1414 293 387 153 1045 737 1890 1226 1091
86 197 270 913 690 620 105 1180 549 1617 1748 1578 281 643 1249 952 842 1932 1656
796 150 1801 428 1670 325 1202 1425 526 1132 865 169 1061 1464 1954 1876 1720 996
2032 1377 1354 1308 1508 1681 466 684 984 818 1330 1764 1196 906 244 1798 1610 722
1418 1564 1496 1633 460 929 1848 1940 1155 812 1986 372 1234 850 1586 537 581 58
1441 628 102 1038 1324 297 1809 1752 278 771 716 1892 1049 389 1674 436 201 1093 166
1283 1362 482 1140 113 534 90 1228 553 1697 692 645 294 1580 738 329 844 177 1046
1000 154 1065 914 961 1618 1157 1539 1204 198 1880 248 1250 1356 106 305 550 585
1802 7 282 773 1512 468 1426 820 1473 393 326 866 1956 209 376 170 60 1097 561 1825
1062 11 538 1285 724 908 1332 1612 1378 582 649 337 1768 1729 632 1682 298 92 1073
1050 19 390 1236 1420 440 114 1094 1541 202 1944 1161 593 1144 930 1588 554 13 852

156 1634 225 35 777 646 401 484 178 696 330 1105 108 1008 1676 1442 1988 1896 1364
 1810 1520 1857 1960 1208 740 1620 916 1698 824 1776 962 1804 472 1252 1066 1289
 1336 353 1158 657 1428 868 284 1474 728 586 1921 306 774 172 1240 1169 394 1380 609
 210 540 1545 1098 1826 562 1684 1904 1286 785 1592 417 856 1121 300 67 21 1052 650
 1730 338 1074 932 488 1636 116 1297 1992 204 37 673 1368 131 556 1542 1162 594 1444
 744 778 1812 180 1185 332 25 226 14 402 69 1068 449 259 1553 920 1106 801 1624 1968
 1858 1290 1256 308 588 354 41 22 658 515 133 705 1700 1432 872 1313 396 212 964 1100
 564 610 73 38 1170 1027 261 120 1217 1546 1384 652 418 786 340 496 1476 49 833 1688
 26 1569 1076 1122 137 517 70 1922 1828 184 1164 936 1298 674 596 2000 752 81 1345
 1640 228 42 780 265 1029 1732 134 404 312 1448 1186 1108 1264 1816 880 1860 1704
 2016 1392 968 897 1554 1292 450 1601 802 356 1480 660 216 568 1409 706 944 1832 1648
 1314 1172 612 1548 344 1924 1080 1456 788 1218 420 1736 145 1124 1665 521 1570 834
 600 74 262 97 1300 676 232 28 408 273 50 1712 1033 1346 1112 138 518 976 1188 161
 1864 360 452 664 529 44 82 1556 1793 804 898 1030 266 1488 1602 289 616 1041 1176
 708 146 76 1840 1316 193 522 1410 424 792 545 98 1128 52 240 1220 1744 274 140 1034
 1928 321 1304 680 836 1572 1057 1666 992 162 3 368 84 530 268 577 1192 1348 456 1560
 385 1504 1872 290 808 624 148 5 1042 524 1089 56 900 1794 194 432 712 100 1604 641
 546 1320 1136 276 1036 1760 9 1412 88 322 688 1224 1153 164 1058 1936 840 532 6 1576
 769 1200 464 578 17 1668 152 1888 292 816 386 1352 1044 1281 104 196 1090 10 720 904
 280 33 1328 548 1796 642 1608 1537 1952 1232 168 324 1416 536 1060 480 18 848 1154
 1584 65 770 580 112 1048 296 12 1672 1360 736 388 1984 1282 200 129 34 1092 912 552
 1248 1616 176 1800 644 1538 864 1424 20 328 257 1064 66 1156 1376 304 772 1680 584
 513 928 208 392 1632 36 1284 130 560 1025 1096 1808 1440 24 648 1540 1072 336 960
 1696 258 68 1160 1472 224 592 776 1824 514 400 1728 1104 40 1288 1026 132 352 1856
 656 1544 1168 608 1920 260 784 1 72 416 1120 1296 516 48 672 1552 1028 1184 136 448
 800 1312 704 80 264 1216 1568 2 832 520 1344 1032 1600 144 896 1408 96 272 1664 1792
 528 160 288 4 1024 1056 1040 192 64 8 1280 1088 32 640 384 768 128 1536 1152 0 16 320
 544 256 512 576].

[0089] **Fig. 5** illustrates an eNB and a UE, in accordance with some embodiments of the disclosure. **Fig. 5** includes block diagrams of an eNB 510 and a UE 530 which are operable to co-exist with each other and other elements of an LTE network. High-level, simplified architectures of eNB 510 and UE 530 are described so as not to obscure the embodiments. It should be noted that in some embodiments, eNB 510 may be a stationary

non-mobile device. In some embodiments, the UE 530 of **Fig. 5** may correspond to any UE discussed herein.

[0090] In some embodiments, the eNB 510 is coupled to one or more antennas 505, and UE 530 is similarly coupled to one or more antennas 525. However, in some embodiments, eNB 510 may incorporate or comprise antennas 505, and UE 530 in various embodiments may incorporate or comprise antennas 525.

[0091] In some embodiments, antennas 505 and/or antennas 525 may comprise one or more directional or omni-directional antennas, including monopole antennas, dipole antennas, loop antennas, patch antennas, microstrip antennas, coplanar wave antennas, or other types of antennas suitable for transmission of RF signals. In some MIMO (multiple-input and multiple output) embodiments, antennas 505 are separated to take advantage of spatial diversity.

[0092] eNB 510 and UE 530 are operable to communicate with each other on a network, such as a wireless network (e.g., using licensed or unlicensed spectrum). eNB 510 and UE 530 may be in communication with each other over a wireless communication channel 550, which has both a downlink path from eNB 510 to UE 530 and an Uplink path from UE 530 to eNB 510.

[0093] As illustrated in **Fig. 5**, in some embodiments, eNB 510 may include a physical layer circuitry 512, a MAC (media access control) circuitry 514, a processor 516, a memory 518, and a hardware processing circuitry 520. A person skilled in the art will appreciate that other components not shown may be used in addition to the components shown to form a complete eNB.

[0094] In some embodiments, physical layer circuitry 512 includes a transceiver 513 for providing signals to and from UE 530. Transceiver 513 provides signals to and from UEs or other devices using one or more antennas 505. In some embodiments, MAC circuitry 514 controls access to the wireless medium. Memory 518 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Hardware processing circuitry 520 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 516 and memory 518 are arranged to perform the operations of hardware processing circuitry 520, such as operations described herein with reference to logic devices and circuitry within eNB 510 and/or hardware processing circuitry 520.

[0095] Accordingly, in some embodiments, eNB 510 may be a device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device.

[0096] As is also illustrated in **Fig. 5**, in some embodiments, UE 530 may include a physical layer circuitry 532, a MAC circuitry 534, a processor 536, a memory 538, a hardware processing circuitry 540, a wireless interface 542, and a display 544. A person skilled in the art would appreciate that other components not shown may be used in addition to the components shown to form a complete UE.

[0097] In some embodiments, physical layer circuitry 532 includes a transceiver 533 for providing signals to and from eNB 510 (as well as other eNBs). Transceiver 533 provides signals to and from eNBs or other devices using one or more antennas 525. In some embodiments, MAC circuitry 534 controls access to the wireless medium. Memory 538 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Wireless interface 542 may be arranged to allow the processor to communicate with another device. Display 544 may provide a visual and/or tactile display for a user to interact with UE 530, such as a touch-screen display. Hardware processing circuitry 540 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 536 and memory 538 may be arranged to perform the operations of hardware processing circuitry 540, such as operations described herein with reference to logic devices and circuitry within UE 530 and/or hardware processing circuitry 540.

[0098] Accordingly, in some embodiments, UE 530 may be a device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display.

[0099] Elements of **Fig. 5**, and elements of other figures having the same names or reference numbers, can operate or function in the manner described herein with respect to any such figures (although the operation and function of such elements is not limited to such descriptions). For example, **Figs. 2 and 6-7** also depict embodiments of eNBs, hardware processing circuitry of eNBs, UEs, and/or hardware processing circuitry of UEs, and the embodiments described with respect to **Fig. 5** and **Figs. 2 and 6-7** can operate or function in the manner described herein with respect to any of the figures.

[00100] In addition, although eNB 510 and UE 530 are each described as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements and/or other hardware elements. In some embodiments of this disclosure, the functional elements can refer to one or more processes operating on one or more processing elements. Examples of software and/or hardware configured elements include Digital Signal Processors (DSPs), one or more microprocessors, DSPs, Field-Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), Radio-Frequency Integrated Circuits (RFICs), and so on.

[00101] **Fig. 6** illustrates hardware processing circuitries for an eNB that may encode data using polar code based on a final reliability ranking, and transmit a code word to a UE, in accordance with some embodiments of the disclosure. In some embodiments, the eNB of **Fig. 6** may also receive a code word that is encoded using polar code from a UE, and decode the received code word based on the final reliability ranking, according to some embodiments.

[00102] With reference to **Fig. 5**, an eNB may include various hardware processing circuitries discussed below, which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 5**, eNB 510 (or various elements or components therein, such as hardware processing circuitry 520, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00103] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 516 (and/or one or more other processors which eNB 510 may comprise), memory 518, and/or other elements or components of eNB 510 (which may include hardware processing circuitry 520) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 516 (and/or one or more other processors which eNB 510 may comprise) may be a baseband processor.

[00104] Returning to **Fig. 6**, an apparatus of eNB 510 (or another eNB or base station), which may be operable to communicate with one or more UEs on a wireless network, may comprise hardware processing circuitry 600. In some embodiments, hardware processing circuitry 600 may comprise one or more antenna ports 605 operable to provide various

transmissions over a wireless communication channel (such as wireless communication channel 550). Antenna ports 605 may be coupled to one or more antennas 607 (which may be antennas 505). In some embodiments, hardware processing circuitry 600 may incorporate antennas 607, while in other embodiments, hardware processing circuitry 600 may merely be coupled to antennas 607.

[00105] Antenna ports 605 and antennas 607 may be operable to provide signals from an eNB to a wireless communications channel and/or a UE, and may be operable to provide signals from a UE and/or a wireless communications channel to an eNB. For example, antenna ports 605 and antennas 607 may be operable to provide transmissions from eNB 510 to wireless communication channel 550 (and from there to UE 530, or to another UE). Similarly, antennas 607 and antenna ports 605 may be operable to provide transmissions from a wireless communication channel 550 (and beyond that, from UE 530, or another UE) to eNB 510.

[00106] Hardware processing circuitry 600 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 6**, hardware processing circuitry 600 may comprise a first circuitry 610, a second circuitry 620, and a third circuitry 630.

[00107] In some embodiments, first circuitry 610 may be operable to receive a final reliability ranking from a computing device (e.g., computing device 240). Second circuitry 620 may be operable to encode an input vector in accordance with the final reliability ranking using polar coding, to generate an encoded code word. Third circuitry 630 may transmit the encoded code word to a UE.

[00108] In some embodiments, first circuitry 610 may be operable to receive the final reliability ranking from the computing device. Third circuitry 630 may receive an encoded code word from a UE. Second circuitry 620 may be operable to decode the received code word using polar coding, based at least in part on the final reliability ranking, to generate data bits from the decoded code word.

[00109] In some embodiments, hardware processing circuitry 600 may be coupled to a transceiver circuitry for at least one of: generating transmissions, scheduling transmissions, encoding transmissions, processing transmissions, or decoding transmissions.

[00110] In some embodiments, first circuitry 610, second circuitry 620, and/or third circuitry 630 may be implemented as separate circuitries. In other embodiments, first circuitry 610, second circuitry 620, and/or third circuitry 630 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00111] **Fig. 7** illustrates hardware processing circuitries for a UE for performing LBT prior to UL transmission in unlicensed spectrum, in accordance with some embodiments of the disclosure. With reference to **Fig. 5**, a UE may include various hardware processing circuitries discussed below, which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 5**, UE 530 (or various elements or components therein, such as hardware processing circuitry 540, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00112] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 536 (and/or one or more other processors which UE 530 may comprise), memory 538, and/or other elements or components of UE 530 (which may include hardware processing circuitry 540) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 536 (and/or one or more other processors which UE 530 may comprise) may be a baseband processor.

[00113] Returning to **Fig. 7**, an apparatus of UE 530 (or another UE or mobile handset), which may be operable to communicate with one or more eNBs on a wireless network, may comprise hardware processing circuitry 700. In some embodiments, hardware processing circuitry 700 may comprise one or more antenna ports 705 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 550). Antenna ports 705 may be coupled to one or more antennas 707 (which may be antennas 525). In some embodiments, hardware processing circuitry 700 may incorporate antennas 707, while in other embodiments, hardware processing circuitry 700 may merely be coupled to antennas 707.

[00114] Antenna ports 705 and antennas 707 may be operable to provide signals from a UE to a wireless communications channel and/or an eNB, and may be operable to provide signals from an eNB and/or a wireless communications channel to a UE. For example, antenna ports 705 and antennas 707 may be operable to provide transmissions from UE 530 to wireless communication channel 550 (and from there to eNB 510, or to another eNB). Similarly, antennas 707 and antenna ports 705 may be operable to provide transmissions from a wireless communication channel 550 (and beyond that, from eNB 510, or another eNB) to UE 530.

[00115] Hardware processing circuitry 700 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 7**, hardware processing circuitry 700 may comprise a first circuitry 710, a second circuitry 720, and/or a third circuitry 730.

[00116] In some embodiments, first circuitry 710 may be operable to receive a final reliability ranking from a computing device (e.g., computing device 240). Second circuitry 720 may be operable to encode an input vector in accordance with the final reliability ranking using polar coding, to generate an encoded code word. Third circuitry 730 may transmit the encoded code word to an eNB.

[00117] In some embodiments, first circuitry 710 may be operable to receive the final reliability ranking from the computing device. Third circuitry 730 may receive an encoded code word from an eNB. Second circuitry 720 may be operable to decode the received code word using polar coding, based at least in part on the final reliability ranking, to generate data bits from the decoded code word.

[00118] In some embodiments, first circuitry 710, second circuitry 720, and/or third circuitry 730 may be implemented as separate circuitries. In other embodiments, first circuitry 710, second circuitry 720, and third circuitry 730 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00119] **Fig. 8** illustrates a computing device 800, a smart device, a computing device or a computer system or a SoC (System-on-Chip) 800, which may generate a final reliability ranking, in accordance with some embodiments of the disclosure. In some embodiments, the computing device 800 can be used to implement computing device 240 of **Fig. 2**. It is pointed out that those elements of **Fig. 8** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[00120] In some embodiments, computing device 800 represents an appropriate computing device, such as a computing tablet, a mobile phone or smart-phone, a laptop, a desktop, an IOT device, a server, a set-top box, a wireless-enabled e-reader, or the like. It will be understood that certain components are shown generally, and not all components of such a device are shown in computing device 800.

[00121] In some embodiments, computing device 800 includes a first processor 810. The various embodiments of the present disclosure may also comprise a network interface within 870 such as a wireless interface so that a system embodiment may be incorporated into a wireless device, for example, cell phone or personal digital assistant.

[00122] In one embodiment, processor 810 can include one or more physical devices, such as microprocessors, application processors, microcontrollers, programmable logic devices, or other processing means. The processing operations performed by processor 810 include the execution of an operating platform or operating system on which applications and/or device functions are executed. The processing operations include operations related to I/O (input/output) with a human user or with other devices, operations related to power management, and/or operations related to connecting the computing device 800 to another device. The processing operations may also include operations related to audio I/O and/or display I/O.

[00123] In one embodiment, computing device 800 includes audio subsystem 820, which represents hardware (e.g., audio hardware and audio circuits) and software (e.g., drivers, codecs) components associated with providing audio functions to the computing device. Audio functions can include speaker and/or headphone output, as well as microphone input. Devices for such functions can be integrated into computing device 800, or connected to the computing device 800. In one embodiment, a user interacts with the computing device 800 by providing audio commands that are received and processed by processor 810.

[00124] Display subsystem 830 represents hardware (e.g., display devices) and software (e.g., drivers) components that provide a visual and/or tactile display for a user to interact with the computing device 800. Display subsystem 830 includes display interface 832, which includes the particular screen or hardware device used to provide a display to a user. In one embodiment, display interface 832 includes logic separate from processor 810 to perform at least some processing related to the display. In one embodiment, display subsystem 830 includes a touch screen (or touch pad) device that provides both output and input to a user.

[00125] I/O controller 840 represents hardware devices and software components related to interaction with a user. I/O controller 840 is operable to manage hardware that is part of audio subsystem 820 and/or display subsystem 830. Additionally, I/O controller 840 illustrates a connection point for additional devices that connect to computing device 800 through which a user might interact with the system. For example, devices that can be attached to the computing device 800 might include microphone devices, speaker or stereo systems, video systems or other display devices, keyboard or keypad devices, or other I/O devices for use with specific applications such as card readers or other devices.

[00126] As mentioned above, I/O controller 840 can interact with audio subsystem 820 and/or display subsystem 830. For example, input through a microphone or other audio

device can provide input or commands for one or more applications or functions of the computing device 800. Additionally, audio output can be provided instead of, or in addition to display output. In another example, if display subsystem 830 includes a touch screen, the display device also acts as an input device, which can be at least partially managed by I/O controller 840. There can also be additional buttons or switches on the computing device 800 to provide I/O functions managed by I/O controller 840.

[00127] In one embodiment, I/O controller 840 manages devices such as accelerometers, cameras, light sensors or other environmental sensors, or other hardware that can be included in the computing device 800. The input can be part of direct user interaction, as well as providing environmental input to the system to influence its operations (such as filtering for noise, adjusting displays for brightness detection, applying a flash for a camera, or other features).

[00128] In one embodiment, computing device 800 includes power management 850 that manages battery power usage, charging of the battery, and features related to power saving operation. Memory subsystem 860 includes memory devices for storing information in computing device 800. Memory can include nonvolatile (state does not change if power to the memory device is interrupted) and/or volatile (state is indeterminate if power to the memory device is interrupted) memory devices. Memory subsystem 860 can store application data, user data, music, photos, documents, or other data, as well as system data (whether long-term or temporary) related to the execution of the applications and functions of the computing device 800.

[00129] Elements of embodiments are also provided as a machine-readable medium (e.g., memory 860) for storing the computer-executable instructions (e.g., instructions to implement any other processes discussed herein). The machine-readable medium (e.g., memory 860) may include, but is not limited to, flash memory, optical disks, CD-ROMs, DVD ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, phase change memory (PCM), or other types of machine-readable media suitable for storing electronic or computer-executable instructions. For example, embodiments of the disclosure may be downloaded as a computer program (e.g., BIOS) which may be transferred from a remote computer (e.g., a server) to a requesting computer (e.g., a client) by way of data signals via a communication link (e.g., a modem or network connection).

[00130] Connectivity 870 includes hardware devices (e.g., wireless and/or wired connectors and communication hardware) and software components (e.g., drivers, protocol stacks) to enable the computing device 800 to communicate with external devices. The

computing device 800 could be separate devices, such as other computing devices, wireless access points or base stations, as well as peripherals such as headsets, printers, or other devices.

[00131] Connectivity 870 can include multiple different types of connectivity. To generalize, the computing device 800 is illustrated with cellular connectivity 872 and wireless connectivity 874. Cellular connectivity 872 refers generally to cellular network connectivity provided by wireless carriers, such as provided via GSM (global system for mobile communications) or variations or derivatives, CDMA (code division multiple access) or variations or derivatives, TDM (time division multiplexing) or variations or derivatives, or other cellular service standards. Wireless connectivity (or wireless interface) 874 refers to wireless connectivity that is not cellular, and can include personal area networks (such as Bluetooth, Near Field, etc.), local area networks (such as Wi-Fi), and/or wide area networks (such as WiMax), or other wireless communication.

[00132] Peripheral connections 880 include hardware interfaces and connectors, as well as software components (e.g., drivers, protocol stacks) to make peripheral connections. It will be understood that the computing device 800 could both be a peripheral device ("to" 882) to other computing devices, as well as have peripheral devices ("from" 884) connected to it. The computing device 800 commonly has a "docking" connector to connect to other computing devices for purposes such as managing (e.g., downloading and/or uploading, changing, synchronizing) content on computing device 800. Additionally, a docking connector can allow computing device 800 to connect to certain peripherals that allow the computing device 800 to control content output, for example, to audiovisual or other systems.

[00133] In addition to a proprietary docking connector or other proprietary connection hardware, the computing device 800 can make peripheral connections 880 via common or standards-based connectors. Common types can include a Universal Serial Bus (USB) connector (which can include any of a number of different hardware interfaces), DisplayPort including MiniDisplayPort (MDP), High Definition Multimedia Interface (HDMI), Firewire, or other types.

[00134] In some embodiments, the computing device 800 can be used to implement computing device 240 of **Fig. 2**. In some embodiments, the computing device 800 may comprise ranking generation circuitry 890. In some embodiments, ranking generation circuitry 890 may comprise hardware (e.g., may utilize at least part of processor 810). In some embodiments, ranking generation circuitry 890 may comprise a combination of hardware and software (e.g., instructions stored in the memory subsystem 860 and executed

by the processor 810). In some embodiments, ranking generation circuitry 890 may generate rankings $I_1, \dots, I_k$, e.g., as discussed throughout this disclosure (e.g., and discussed also with respect to **Fig. 3**). In some embodiments, ranking generation circuitry 890 may also generate final reliability ranking 242, e.g., as discussed throughout this disclosure (e.g., and discussed also with respect to **Fig. 4**). In some embodiments, ranking generation circuitry 890 may transmit final reliability ranking 242 to a transmitter and/or a decoder, e.g., as discussed throughout this disclosure.

[00135] **Fig. 9** illustrates methods for generating a final reliability ranking, where the final reliability ranking may be used for encoding and/or decoding in accordance with polar coding, in accordance with some embodiments of the disclosure. Although the actions in the method of **Fig. 9** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 9** are optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00136] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause computing device 240 to perform an operation comprising the method of **Fig. 9**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00137] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods 900 of **Fig. 9**.

[00138] Returning to **Fig. 9**, various methods may be in accordance with the various embodiments discussed herein. The method 900 comprises, at 904, selecting a set of coding rates. In some embodiments, the set of coding rates comprises a plurality of coding rates.

[00139] At 908, for each coding rate of the plurality of coding rates, a corresponding reliability ranking may be estimated. In some embodiments, a plurality of reliability rankings may be estimated for the corresponding plurality of coding rates.

[00140] At 912, a final reliability ranking may be estimated, based at least in part on the plurality of reliability rankings. In some embodiments, a transmitter may encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00141] In some embodiments, one or more of the plurality of reliability rankings may be modified to generate a plurality of modified reliability rankings, and the final reliability ranking may be estimated based at least in part on the plurality of modified reliability rankings.

[00142] In some embodiments, a reliability ranking may be estimated by receiving an input vector. From the input vector, a code word corresponding to a first coding rate may be generated using polar coding. Noise may be added to the code word, to simulate transmission of the code word over a wireless channel, to generate a corrupted code word. In some embodiments, the corrupted code word may be decoded at a decoder. Bit positions of the input vector may be ranked in accordance with reliability of bits in the respective bit positions of the input vector being successfully decoded at the decoder. In some embodiments, the reliability ranking may be estimated based at least in part on ranking the bit positions of the input vector.

[00143] In some embodiments, a first reliability ranking corresponding to a first coding rate may be accessed, where the first coding rate may be a lowest coding rate in the set of coding rates. A first N_1 positions of the first reliability ranking may correspond to data bits and remaining positions of the first reliability ranking correspond to frozen bits. In some embodiments, first one or more of the plurality of reliability rankings may be first modified, e.g., such that first N_1 positions of each of the plurality of reliability rankings are set to the first N_1 positions of the first reliability ranking.

[00144] In some embodiments, a second reliability ranking may be accessed subsequent to the first modifying. The second reliability ranking may correspond to a second coding rate, where the second coding rate may be higher than the first coding rate, and where a first N_2 positions of the second reliability ranking may correspond to data bits and remaining positions of the second reliability ranking may correspond to frozen bits. In some embodiments, second one or more of the plurality of reliability rankings may be modified, such that position (N_1+1) to position N_2 of each of the plurality of reliability rankings are respectively set to position (N_1+1) to position N_2 of the second reliability ranking.

[00145] In some embodiments, an i^{th} reliability ranking may be accessed, where the i^{th} reliability ranking may correspond to an i^{th} coding rate, where the i^{th} coding rate may be higher than an $(i-1)^{\text{th}}$ coding rate, where a first N_i positions of the i^{th} reliability ranking may

correspond to data bits and remaining positions of the i^{th} reliability ranking may correspond to frozen bits, and where a first $N(i-1)$ positions of an $(i-1)^{\text{th}}$ reliability ranking may correspond to data bits and remaining positions of the second reliability ranking may correspond to frozen bits. In some embodiments, third one or more of the plurality of reliability rankings may be modified, such that position $(N(i-1) + 1)$ to position N_i of each of the plurality of reliability rankings are respectively set to position $(N(i-1) + 1)$ to position N_i of the i^{th} reliability ranking.

[00146] In some embodiments, the i^{th} coding rate may be a highest coding rate in the set of coding rates. In some embodiments, the final reliability ranking may be estimated, subsequent to the third modifying the third one or more of the plurality of reliability rankings. In some embodiments, the final reliability ranking may be to be equal to the i^{th} reliability ranking, subsequent to the third modifying the third one or more of the plurality of reliability rankings.

[00147] **Fig. 10** illustrates methods for a UE or an eNB to encode an input vector using polar coding, where the input vector may be generated based on a final reliability ranking, in accordance with some embodiments. With reference to **Fig. 10**, methods that may relate to UE 530 and hardware processing circuitry 700, or eNB 510 and hardware processing circuitry 600 are discussed below. Put differently, in some embodiments, the method of **Fig. 10** may be performed by UE 530 and hardware processing circuitry 700; and in some other embodiments, the method of **Fig. 10** may be performed by eNB 510 and hardware processing circuitry 600.

[00148] Although the actions in the method of **Fig. 10** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 10** are optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00149] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause UE 530 and/or hardware processing circuitry 700 (or eNB 510 and/or hardware processing circuitry 600) to perform an operation comprising the method of **Fig. 10**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g.,

conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00150] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods 1000 of **Fig. 10**.

[00151] Returning to **Fig. 10**, various methods may be in accordance with the various embodiments discussed herein. A method 1000 may comprise, at 1004, receiving a final reliability ranking. In some embodiments, the final reliability ranking may be generated based on a plurality of reliability rankings corresponding to a plurality of coding rates, e.g., as discussed with respect to **Figs. 3-4**. At 1008, data may be encoded in accordance with polar coding, based at least in part on the final reliability ranking. For example, an input vector may be generated, where the input vector may comprise data bits and frozen bits. In some embodiments, positions of the data bits in the input vector may be based on the final reliability ranking. In some embodiments, the input vector may be encoded in accordance with polar coding.

[00152] **Fig. 11** illustrates an architecture of a system 1100 of a network in accordance with some embodiments of the disclosure. The system 1100 is shown to include a user equipment (UE) 1101 and a UE 1102. The UEs 1101 and 1102 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks), but may also comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

[00153] In some embodiments, any of the UEs 1101 and 1102 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[00154] The UEs 1101 and 1102 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) 1110 — the RAN 1110 may be, for example, an

Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs 1101 and 1102 utilize connections 1103 and 1104, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 1103 and 1104 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

[00155] In this embodiment, the UEs 1101 and 1102 may further directly exchange communication data via a ProSe interface 1105. The ProSe interface 1105 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[00156] The UE 1102 is shown to be configured to access an access point (AP) 1106 via connection 1107. The connection 1107 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.11 protocol, wherein the AP 1106 would comprise a wireless fidelity (WiFi®) router. In this example, the AP 1106 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[00157] The RAN 1110 can include one or more access nodes that enable the connections 1103 and 1104. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The RAN 1110 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 1111, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 1112.

[00158] Any of the RAN nodes 1111 and 1112 can terminate the air interface protocol and can be the first point of contact for the UEs 1101 and 1102. In some embodiments, any

of the RAN nodes 1111 and 1112 can fulfill various logical functions for the RAN 1110 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

[00159] In accordance with some embodiments, the UEs 1101 and 1102 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 1111 and 1112 over a multicarrier communication channel in accordance various communication techniques, such as, but not limited to, an Orthogonal Frequency-Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[00160] In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 1111 and 1112 to the UEs 1101 and 1102, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[00161] The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 1101 and 1102. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 1101 and 1102 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 1002 within a cell) may be performed

at any of the RAN nodes 1111 and 1112 based on channel quality information fed back from any of the UEs 1101 and 1102. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 1101 and 1102.

[00162] The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, $L=1, 2, 4$, or 8).

[00163] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[00164] The RAN 1110 is shown to be communicatively coupled to a core network (CN) 1120 —via an S1 interface 1113. In embodiments, the CN 1120 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN. In this embodiment the S1 interface 1113 is split into two parts: the S1-U interface 1114, which carries traffic data between the RAN nodes 1111 and 1112 and the serving gateway (S-GW) 1122, and the S1-mobility management entity (12E) interface 1115, which is a signaling interface between the RAN nodes 1111 and 1112 and 12Es 1121.

[00165] In this embodiment, the CN 1120 comprises the 12Es 1121, the S-GW 1122, the Packet Data Network (PDN) Gateway (P-GW) 1123, and a home subscriber server (HSS) 1124. The 12Es 1121 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The 12Es 1121 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 1124 may comprise a database for network users, including subscription-related

information to support the network entities' handling of communication sessions. The CN 1120 may comprise one or several HSSs 1124, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 1124 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[00166] The S-GW 1122 may terminate the S1 interface 1113 towards the RAN 1110, and routes data packets between the RAN 1110 and the CN 1120. In addition, the S-GW 1122 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

[00167] The P-GW 1123 may terminate an SGi interface toward a PDN. The P-GW 1123 may route data packets between the EPC network 1123 and external networks such as a network including the application server 1130 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 1125. Generally, the application server 1130 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 1123 is shown to be communicatively coupled to an application server 1130 via an IP communications interface 1125. The application server 1130 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 1101 and 1102 via the CN 1120.

[00168] The P-GW 1123 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 1126 is the policy and charging control element of the CN 1120. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 1126 may be communicatively coupled to the application server 1130 via the P-GW 1123. The application server 1130 may signal the PCRF 1126 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 1126 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow

template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 1130.

[00169] **Fig. 12** illustrates example components of a device 1200, in accordance with some embodiments of the disclosure. In some embodiments, the device 1200 may include application circuitry 1202, baseband circuitry 1204, Radio Frequency (RF) circuitry 1206, front-end module (FEM) circuitry 1208, one or more antennas 1210, and power management circuitry (PMC) 1212 coupled together at least as shown. The components of the illustrated device 1200 may be included in a UE or a RAN node. In some embodiments, the device 1200 may include less elements (e.g., a RAN node may not utilize application circuitry 1202, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 1200 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[00170] The application circuitry 1202 may include one or more application processors. For example, the application circuitry 1202 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 1200. In some embodiments, processors of application circuitry 1202 may process IP data packets received from an EPC.

[00171] The baseband circuitry 1204 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1204 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 1206 and to generate baseband signals for a transmit signal path of the RF circuitry 1206. Baseband processing circuitry 1204 may interface with the application circuitry 1202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1206. For example, in some embodiments, the baseband circuitry 1204 may include a third generation (3G) baseband processor 1204A, a fourth generation (4G) baseband processor 1204B, a fifth generation (5G) baseband processor 1204C, or other baseband processor(s) 1204D for other existing generations, generations in

development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 1204 (e.g., one or more of baseband processors 1204A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1206. In other embodiments, some or all of the functionality of baseband processors 1204A-D may be included in modules stored in the memory 1204G and executed via a Central Processing Unit (CPU) 1204E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1204 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1204 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[00172] In some embodiments, the baseband circuitry 1204 may include one or more audio digital signal processor(s) (DSP) 1204F. The audio DSP(s) 1204F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1204 and the application circuitry 1202 may be implemented together such as, for example, on a system on a chip (SOC).

[00173] In some embodiments, the baseband circuitry 1204 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1204 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1204 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[00174] RF circuitry 1206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1206 may include switches, filters, amplifiers, etc. to facilitate

the communication with the wireless network. RF circuitry 1206 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1208 and provide baseband signals to the baseband circuitry 1204. RF circuitry 1206 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1204 and provide RF output signals to the FEM circuitry 1208 for transmission.

[00175] In some embodiments, the receive signal path of the RF circuitry 1206 may include mixer circuitry 1206a, amplifier circuitry 1206b and filter circuitry 1206c. In some embodiments, the transmit signal path of the RF circuitry 1206 may include filter circuitry 1206c and mixer circuitry 1206a. RF circuitry 1206 may also include synthesizer circuitry 1206d for synthesizing a frequency for use by the mixer circuitry 1206a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1206a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1208 based on the synthesized frequency provided by synthesizer circuitry 1206d. The amplifier circuitry 1206b may be configured to amplify the down-converted signals and the filter circuitry 1206c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 1204 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1206a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00176] In some embodiments, the mixer circuitry 1206a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1206d to generate RF output signals for the FEM circuitry 1208. The baseband signals may be provided by the baseband circuitry 1204 and may be filtered by filter circuitry 1206c.

[00177] In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a may be arranged for direct

downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path may be configured for super-heterodyne operation.

[00178] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1206 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1204 may include a digital baseband interface to communicate with the RF circuitry 1206.

[00179] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[00180] In some embodiments, the synthesizer circuitry 1206d may be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1206d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00181] The synthesizer circuitry 1206d may be configured to synthesize an output frequency for use by the mixer circuitry 1206a of the RF circuitry 1206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1206d may be a fractional N/N+1 synthesizer.

[00182] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1204 or the applications processor 1202 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1202.

[00183] Synthesizer circuitry 1206d of the RF circuitry 1206 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay

elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[00184] In some embodiments, synthesizer circuitry 1206d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 1206 may include an IQ/polar converter.

[00185] FEM circuitry 1208 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1206 for further processing. FEM circuitry 1208 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1206 for transmission by one or more of the one or more antennas 1210. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 1206, solely in the FEM 1208, or in both the RF circuitry 1206 and the FEM 1208.

[00186] In some embodiments, the FEM circuitry 1208 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1206). The transmit signal path of the FEM circuitry 1208 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1210).

[00187] In some embodiments, the PMC 1212 may manage power provided to the baseband circuitry 1204. In particular, the PMC 1212 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 1212 may often be included when the device 1200 is capable of being powered by a battery, for example, when

the device is included in a UE. The PMC 1212 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[00188] While **Fig. 12** shows the PMC 1212 coupled only with the baseband circuitry 1204. However, in other embodiments, the PMC 1212 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 1202, RF circuitry 1206, or FEM 1208.

[00189] In some embodiments, the PMC 1212 may control, or otherwise be part of, various power saving mechanisms of the device 1200. For example, if the device 1200 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 1200 may power down for brief intervals of time and thus save power.

[00190] If there is no data traffic activity for an extended period of time, then the device 1200 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 1200 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 1200 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

[00191] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[00192] Processors of the application circuitry 1202 and processors of the baseband circuitry 1204 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 1204, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 1204 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As

referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[00193] **Fig. 13** illustrates example interfaces of baseband circuitry, in accordance with some embodiments of this disclosure. As discussed above, the baseband circuitry 1204 of **Fig. 11** may comprise processors 1204A-1204E and a memory 1204G utilized by said processors. Each of the processors 1204A-1204E may include a memory interface, 1304A-1304E, respectively, to send/receive data to/from the memory 1204G.

[00194] The baseband circuitry 1204 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 1312 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 1204), an application circuitry interface 1314 (e.g., an interface to send/receive data to/from the application circuitry 1202 of **Fig. 12**), an RF circuitry interface 1316 (e.g., an interface to send/receive data to/from RF circuitry 1206 of **Fig. 12**), a wireless hardware connectivity interface 1318 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 1320 (e.g., an interface to send/receive power or control signals to/from the PMC 1212).

[00195] Reference in the specification to "an embodiment," "one embodiment," "some embodiments," or "other embodiments" means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least some embodiments, but not necessarily all embodiments. The various appearances of "an embodiment," "one embodiment," or "some embodiments" are not necessarily all referring to the same embodiments. If the specification states a component, feature, structure, or characteristic "may," "might," or "could" be included, that particular component, feature, structure, or characteristic is not required to be included. If the specification or claim refers to "a" or "an" element, that does not mean there is only one of the elements. If the specification or claims refer to "an additional" element, that does not preclude there being more than one of the additional element.

[00196] Furthermore, the particular features, structures, functions, or characteristics may be combined in any suitable manner in one or more embodiments. For example, a first embodiment may be combined with a second embodiment anywhere the particular features, structures, functions, or characteristics associated with the two embodiments are not mutually exclusive.

[00197] While the disclosure has been described in conjunction with specific embodiments thereof, many alternatives, modifications and variations of such embodiments will be apparent to those of ordinary skill in the art in light of the foregoing description. For example, other memory architectures e.g., Dynamic RAM (DRAM) may use the embodiments discussed. The embodiments of the disclosure are intended to embrace all such alternatives, modifications, and variations as to fall within the broad scope of the appended claims.

[00198] In addition, well known power/ground connections to integrated circuit (IC) chips and other components may or may not be shown within the presented figures, for simplicity of illustration and discussion, and so as not to obscure the disclosure. Further, arrangements may be shown in block diagram form in order to avoid obscuring the disclosure, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the present disclosure is to be implemented (i.e., such specifics should be well within purview of one skilled in the art). Where specific details (e.g., circuits) are set forth in order to describe example embodiments of the disclosure, it should be apparent to one skilled in the art that the disclosure can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

[00199] The following clauses pertain to further embodiments. Specifics in the clauses may be used anywhere in one or more embodiments. All optional features of the apparatus described herein may also be implemented with respect to a method or process.

[00200] Clause 1. An apparatus comprising: a memory for storing instructions; one or more processors to: select a set of coding rates comprising a plurality of coding rates; estimate a plurality of reliability rankings respectively corresponding to the plurality of coding rates; and estimate a final reliability ranking based at least in part on the plurality of reliability rankings, wherein a transmitter is to encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00201] Clause 2. The apparatus of clause 1, wherein the one or more processors are to: modify one or more of the plurality of reliability rankings to generate a plurality of modified reliability rankings; and estimate the final reliability ranking based at least in part on the plurality of modified reliability rankings.

[00202] Clause 3. The apparatus of any of clauses 1-2, wherein to estimate a reliability ranking, the one or more processors are to: receive an input vector having a plurality of bits in a respectively corresponding plurality of bit positions; generate, from the input vector, a code

word corresponding to a first coding rate using polar coding; generate a corrupted code word by adding noise to the code word, to simulate transmission of the code word over a wireless channel; decode, at a decoder, the corrupted code word; generate a set of ranked bit positions of the input vector based upon a plurality of reliabilities respectively corresponding to the plurality of bits, the plurality of reliabilities being based upon decoding at the decoder the respectively corresponding plurality of bits; and estimate the reliability ranking, based at least in part on the set of ranked bit positions of the input vector.

[00203] Clause 4. The apparatus of one of clauses 1-3, wherein the one or more processors are to: access a first reliability ranking corresponding to a first coding rate, wherein the first coding rate is a lowest coding rate in the set of coding rates, and wherein a number $N1$ of first positions of the first reliability ranking correspond to data bits and remaining positions of the first reliability ranking correspond to frozen bits; and modify, in a first modifying, first one or more of the plurality of reliability rankings such that a number $N1$ of first positions of each of the plurality of reliability rankings are set to the number $N1$ of first positions of the first reliability ranking.

[00204] Clause 5. The apparatus of clause 4, wherein the one or more processors are to: access a second reliability ranking subsequent to the first modifying, wherein the second reliability ranking corresponds to a second coding rate, wherein the second coding rate is higher than the first coding rate, and wherein a number $N2$ of first positions of the second reliability ranking correspond to data bits and remaining positions of the second reliability ranking correspond to frozen bits; and modify, in a second modifying, second one or more of the plurality of reliability rankings such that a position $(N1+1)$ to a position $N2$ of each of the plurality of reliability rankings are respectively set to a position $(N1+1)$ to a position $N2$ of the second reliability ranking.

[00205] Clause 6. The apparatus of clause 5, wherein the one or more processors are to: access an i^{th} reliability ranking subsequent to the second modifying, wherein the i^{th} reliability ranking corresponds to an i^{th} coding rate, wherein the i^{th} coding rate is higher than an $(i-1)^{\text{th}}$ coding rate, wherein a number N_i of first positions of the i^{th} reliability ranking correspond to data bits and remaining positions of the i^{th} reliability ranking correspond to frozen bits, and wherein a number $N(i-1)$ of first positions of an $(i-1)^{\text{th}}$ reliability ranking correspond to data bits and remaining positions of the $(i-1)^{\text{th}}$ reliability ranking correspond to frozen bits; and modify, in a third modifying, one or more of the plurality of reliability rankings such that a position $(N(i-1) + 1)$ to a position N_i of each of the plurality of reliability

rankings are respectively set to a position $(N(i-1) + 1)$ to a position N_i of the i^{th} reliability ranking.

[00206] Clause 7. The apparatus of clause 6, wherein the i^{th} coding rate is a highest coding rate in the set of coding rates, and wherein to estimate the final reliability ranking, the one or more processors are to: estimate the final reliability ranking subsequent to the third modifying.

[00207] Clause 8. The apparatus of any of clauses 6 or 7, wherein to estimate the final reliability ranking, the one or more processors are to: estimate the final reliability ranking to be equal to the i^{th} reliability ranking subsequent to the third modifying.

[00208] Clause 9. The apparatus of any of clauses 1 to 8, wherein: the transmitter is to encode data to generate a code word having a length of 128; and the final reliability ranking comprises the ordered list of bit indices: [127 126 125 123 119 111 95 63 47 79 55 31 87 103 59 91 107 61 93 115 109 62 15 117 94 23 39 110 27 71 121 43 118 75 29 51 45 83 122 77 53 30 99 124 85 46 57 101 78 89 54 7 86 105 11 58 102 19 90 113 13 35 106 60 92 114 21 67 108 37 14 25 69 22 116 41 38 73 26 49 70 120 81 42 74 28 97 50 3 44 82 76 5 52 98 9 84 56 100 6 88 17 10 33 104 18 65 112 12 34 20 66 36 24 68 40 1 72 48 80 2 96 4 8 16 32 64 0].

[00209] Clause 10. The apparatus of any of clauses 1 to 8, wherein: the transmitter is to encode data to generate a code word having a length of 256; and the final reliability ranking comprises the ordered list of bit indices: [255 254 253 251 247 245 243 239 237 235 231 223 221 219 215 207 191 190 189 187 183 175 159 151 143 127 126 125 123 119 111 103 95 87 79 63 59 55 47 31 222 238 91 249 199 167 107 155 246 61 171 93 115 203 157 179 109 173 211 250 62 117 205 15 94 181 227 23 158 110 39 213 27 121 174 71 252 43 185 135 118 206 229 75 182 217 214 233 122 51 29 139 186 45 83 230 147 77 218 241 99 53 141 30 163 85 124 46 234 188 149 57 195 101 78 89 54 220 165 142 7 242 153 86 105 197 11 236 244 150 169 102 58 201 166 113 90 177 154 198 106 248 60 209 170 19 92 13 114 35 202 156 225 21 178 67 108 37 131 172 14 210 25 69 116 22 41 204 133 180 38 73 226 26 49 70 137 212 120 81 42 134 184 145 74 28 97 228 50 3 138 216 161 44 82 232 76 146 193 52 98 140 240 5 162 84 148 9 56 194 100 6 88 164 17 152 104 196 10 33 168 18 65 112 12 200 129 34 176 20 66 208 36 130 24 68 224 40 132 1 72 48 136 80 2 144 96 4 160 192 8 16 32 64 128 0].

[00210] Clause 11. The apparatus of any of clauses 1 to 8, wherein: the transmitter is to encode data to generate a code word having a length of 512; and the final reliability ranking comprises the ordered list of bit indices: [511 510 509 507 505 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 459 455 447 446 445 443 439 435 431 427 423

415 413 411 407 399 383 382 381 379 375 371 367 363 359 351 349 347 343 335 319 317
 315 311 303 287 255 254 253 251 247 243 239 237 235 231 223 221 219 215 207 191 189
 187 183 175 159 127 125 123 119 111 95 63 55 47 31 467 365 143 126 429 190 79 318 271
 87 506 245 222 151 373 103 461 279 59 350 91 167 437 414 483 238 295 155 366 199 107
 249 283 469 171 327 61 430 377 299 508 246 93 391 115 203 441 157 374 462 179 331 485
 109 285 307 438 173 473 395 211 62 15 250 301 339 117 94 205 23 470 378 181 227 333
 158 489 403 39 110 309 442 355 497 486 474 252 174 397 380 286 213 490 419 121 341
 444 229 185 405 302 313 206 118 357 334 182 451 217 476 27 71 310 421 345 135 43 398
 214 498 233 409 263 75 122 342 361 29 453 51 139 186 492 230 83 406 45 267 314 425 147
 358 77 218 241 99 53 275 141 346 369 422 30 124 163 85 457 269 500 234 46 410 188 291
 149 433 195 57 362 454 316 465 426 504 220 348 242 101 370 277 78 458 323 165 89 412
 54 236 293 481 142 434 387 364 153 86 197 105 270 281 150 325 428 169 102 58 244 466
 278 297 7 389 90 166 113 201 372 460 11 154 177 294 329 106 198 436 19 282 482 305 60
 326 209 170 393 13 248 35 92 337 298 21 468 376 114 67 390 202 156 225 37 108 178 131
 440 484 401 330 472 353 284 306 172 394 210 417 300 338 116 204 488 25 14 180 69 259
 226 332 402 449 41 22 308 354 133 212 396 73 38 261 120 49 418 340 26 496 137 184 70
 228 404 81 312 42 265 134 450 356 216 145 74 262 97 28 344 50 273 138 420 161 44 82
 232 266 408 289 76 146 360 193 452 3 52 98 140 274 321 424 240 162 84 268 5 368 385
 290 148 456 56 194 9 100 432 276 88 6 322 164 17 152 464 10 292 386 104 33 196 280 18
 168 324 65 480 12 112 296 129 34 388 200 257 20 176 66 328 304 36 208 130 392 24 258
 336 68 224 400 40 132 352 1 260 416 72 48 448 136 264 2 80 144 96 272 4 160 288 192 320
 384 8 16 32 256 64 128 0].

[00211] Clause 12. The apparatus of any of clauses 1 to 8, wherein: the transmitter is to encode data to generate a code word having a length of 1024; and the final reliability ranking comprises the ordered list of bit indices: [1023 1022 1021 1019 1018 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981 979 975 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923 919 911 903 895 894 893 891 889 887 885 883 879 878 877 875 871 863 862 861 859 855 847 839 831 830 829 827 823 815 807 799 795 791 783 767 766 765 763 761 759 757 755 751 750 749 747 743 735 734 733 731 727 719 711 703 702 701 699 695 687 683 679 671 667 663 655 639 638 637 635 631 627 623 619 615 607 603 599 591 575 573 571 567 559 543 511 510 509 507 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 455 447 446 445 443 439 431 423 415 411 407 399 383 382 381 379 375 367 363 359 351 349 347 343 335 319 317 315 311 303 287 255 254 253 251 247 243 239 235 231 223 221 219 215 207 191 189 187

183 175 159 127 125 123 119 111 95 63 942 605 505 459 427 371 237 47 811 715 31 1020
758 669 435 365 974 953 79 886 413 691 190 997 126 797 143 843 55 429 621 467 819 318
685 87 950 271 723 222 245 985 506 574 151 527 907 373 279 350 103 59 461 813 762 629
167 717 851 606 91 535 437 483 414 238 982 295 155 890 693 670 199 739 366 845 107
551 283 915 1001 249 327 622 469 61 171 821 539 867 798 954 377 430 583 299 725 93
909 246 508 633 391 115 686 998 203 555 157 441 374 764 647 931 853 179 331 462 109
485 697 285 814 986 630 1009 307 587 173 718 775 438 892 541 741 62 15 1002 963 956
917 869 857 846 825 822 729 726 694 473 489 378 250 988 910 470 395 211 933 745 301
921 563 442 854 1010 651 634 339 557 205 595 117 965 779 333 181 698 403 227 94 873
486 742 659 158 355 589 918 309 1004 826 474 497 397 110 611 213 286 937 565 252 870
730 787 753 653 341 419 174 121 542 380 23 675 597 185 858 302 39 781 636 881 229 405
206 118 490 934 558 27 444 313 451 71 803 969 357 661 217 182 334 746 700 43 569 707
1012 135 922 613 345 590 310 945 75 789 421 263 476 398 214 874 828 835 966 29 566
601 51 139 122 233 677 519 654 409 732 342 498 45 83 267 186 361 453 665 598 977 938
805 899 754 230 782 77 147 860 406 523 617 314 492 709 99 53 1016 425 993 970 924 882
748 946 876 358 793 614 681 940 662 500 241 218 837 570 369 422 790 756 678 457 346
809 978 625 901 602 713 433 124 410 234 884 806 666 362 275 454 188 689 141 972 163
841 531 85 316 618 269 710 30 291 794 426 465 817 220 948 525 149 572 46 195 994 504
547 838 57 721 682 242 101 348 905 277 323 78 760 165 604 89 370 533 54 579 458 142
236 849 412 810 293 153 626 387 902 481 86 980 888 714 270 197 364 434 668 105 549
281 643 737 150 526 620 325 690 169 913 537 58 102 842 796 428 7 278 952 771 581 297
865 244 466 90 113 166 389 818 684 201 11 534 996 553 372 722 906 154 645 294 177 329
460 19 929 812 198 106 628 984 282 550 305 13 60 436 585 850 716 482 692 738 844 773
961 248 914 1000 326 393 209 170 468 561 538 820 376 866 582 649 337 92 298 724 908
390 114 632 35 202 593 156 554 440 225 777 646 21 401 178 67 108 930 330 852 284 484
696 353 37 657 306 131 1008 586 172 774 540 14 740 210 25 394 609 472 69 562 824 259
916 417 300 785 116 962 22 650 338 41 728 204 868 133 856 932 488 673 744 556 594 920
778 332 226 180 402 449 801 872 308 354 964 658 588 705 396 212 564 610 515 496 652
786 120 418 340 833 73 936 261 38 752 184 49 674 596 26 137 70 517 780 228 404 312 81
42 265 880 450 897 134 802 356 216 660 568 145 968 521 706 74 262 612 97 344 28 50 273
420 788 944 138 518 600 834 161 232 44 676 408 976 360 664 452 804 898 529 82 266 616
708 289 792 424 146 76 522 193 240 545 98 52 836 680 274 140 992 321 368 162 84 530
268 3 456 577 808 624 385 290 900 148 524 432 712 56 5 194 100 641 546 276 688 88 322
9 840 164 532 769 464 6 578 152 816 17 292 386 104 720 196 904 280 10 548 642 33 168

324 480 848 536 18 770 65 580 112 296 736 12 388 200 912 34 129 552 176 644 864 328 20
 257 66 304 772 584 928 513 208 392 36 560 130 648 24 336 960 258 68 224 592 776 514
 400 40 132 352 656 608 260 72 784 416 1 516 48 672 136 448 800 704 80 264 2 832 520
 144 896 96 272 528 4 160 288 544 192 320 8 576 384 640 768 16 0 512 32 64 256 128].

[00212] Clause 13. The apparatus of any of clauses 1 to 8, wherein: the transmitter is to encode data to generate a code word having a length of 2048; and the final reliability ranking comprises the ordered list of bit indices: [2047 2046 2045 2044 2043 2042 2041 2039 2038 2037 2035 2031 2030 2029 2027 2025 2023 2021 2019 2015 2014 2013 2011 2009 2007 2006 2005 2003 1999 1998 1997 1995 1991 1983 1982 1981 1979 1977 1975 1974 1973 1971 1967 1966 1965 1963 1959 1951 1950 1949 1947 1943 1939 1935 1931 1927 1919 1918 1917 1915 1913 1911 1910 1909 1907 1903 1902 1901 1899 1895 1891 1887 1886 1885 1883 1879 1875 1871 1869 1867 1863 1855 1854 1853 1851 1847 1845 1843 1839 1837 1835 1831 1823 1821 1819 1815 1807 1791 1790 1789 1787 1786 1785 1783 1782 1781 1779 1775 1774 1773 1771 1767 1763 1759 1758 1757 1755 1751 1747 1743 1741 1739 1735 1727 1726 1725 1723 1719 1717 1715 1711 1709 1707 1703 1695 1693 1691 1687 1679 1663 1662 1661 1659 1655 1653 1651 1647 1645 1643 1639 1631 1630 1629 1627 1623 1615 1599 1598 1597 1595 1591 1583 1575 1567 1559 1551 1535 1534 1533 1531 1530 1529 1527 1526 1525 1523 1519 1518 1517 1515 1511 1507 1503 1502 1501 1499 1495 1493 1491 1487 1485 1483 1479 1471 1470 1469 1467 1463 1461 1459 1455 1453 1451 1447 1439 1438 1437 1435 1431 1423 1407 1406 1405 1403 1399 1397 1395 1391 1389 1387 1383 1375 1374 1373 1371 1367 1359 1343 1342 1341 1339 1335 1327 1319 1311 1307 1303 1295 1279 1278 1277 1275 1271 1269 1267 1263 1262 1261 1259 1255 1247 1246 1245 1243 1239 1231 1223 1215 1214 1213 1211 1207 1199 1191 1183 1179 1175 1167 1151 1150 1149 1147 1143 1135 1131 1127 1119 1115 1111 1103 1087 1085 1083 1079 1071 1055 1023 1022 1021 1019 1018 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981 979 975 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923 919 911 895 894 893 891 887 885 883 879 878 877 875 871 863 862 861 859 855 847 831 830 829 827 823 815 807 799 795 791 783 767 766 765 763 761 759 758 757 755 751 750 749 747 743 735 734 733 731 727 719 711 703 702 701 699 695 687 679 671 667 663 655 639 638 637 635 631 623 619 615 607 603 599 591 575 573 571 567 559 543 511 510 509 507 505 503 501 499 495 494 493 491 487 479 478 477 475 471 463 455 447 446 445 443 439 431 423 415 411 407 399 383 382 381 379 375 367 363 359 351 349 347 343 335 319 317 315 311 303 287 255 254 253 251 247 239 235 231 223 221 219 215 207 191 189 187 183 175 159 127 125 123 119 111

95 63 1978 1914 1694 1646 1563 1401 1390 1351 1273 1195 1117 839 683 605 427 371 243
1822 1749 1607 903 811 715 1710 1323 1020 942 889 627 459 237 1532 1454 669 502 365
31 1139 413 47 1415 1270 1933 886 435 2022 1788 1181 1227 126 1657 1579 691 1671 953
1877 1398 974 843 79 1465 621 1955 997 429 797 1355 143 1486 190 55 1203 1133 1509
1721 318 819 1309 1838 685 1654 271 87 467 2010 950 222 245 2033 1611 723 907 1742
1331 574 527 1799 1197 151 985 1916 506 1462 350 1765 373 103 1419 1565 1497 813 279
59 461 1086 1235 762 1941 1039 1849 629 1587 851 1325 167 1718 1274 606 717 535 91
1987 437 1753 1675 1870 982 483 1141 1363 238 414 1118 890 295 1893 1229 155 1047
693 1980 739 670 1581 366 845 1494 199 107 1402 551 283 2026 915 1001 249 1846 1619
1205 1251 622 1182 327 1357 1803 61 171 469 1881 1063 821 539 1427 1513 867 954 377
798 430 1750 1658 1934 583 1134 725 93 1957 2036 2034 2028 2012 2001 1993 1990 1989
1969 1962 1961 1958 1946 1945 1942 1905 1898 1897 1894 1884 1882 1878 1859 1852
1850 1827 1813 1811 1805 1777 1770 1769 1766 1756 1754 1731 1724 1722 1701 1699
1689 1685 1683 1678 1677 1660 1637 1635 1625 1621 1614 1613 1593 1589 1582 1566
1543 1522 1521 1514 1510 1500 1498 1475 1468 1466 1445 1443 1429 1422 1421 1404
1381 1379 1369 1366 1365 1358 1337 1334 1333 1326 1310 1287 1276 1257 1254 1253
1241 1238 1237 1230 1209 1206 1198 1159 1145 1142 1099 1095 1067 1053 1051 1010
1009 1004 1002 998 988 986 965 963 956 933 931 921 917 910 909 892 873 869 857 853
846 825 822 814 775 764 745 741 729 726 718 697 694 686 647 634 633 630 595 587 563
555 541 508 489 486 485 473 470 462 442 441 438 395 391 378 374 339 331 307 299 285
250 246 211 203 179 157 115 109 2040 1923 1806 1778 1622 1590 1516 1477 1433 1210
1163 1075 854 742 698 651 557 497 301 205 181 62 1829 1385 1146 1107 1069 918 826
779 403 227 173 117 1733 1641 1430 1101 659 1291 937 870 753 333 1382 474 355 158
1338 730 1547 589 397 94 1906 1242 1171 858 1817 309 110 1772 1686 611 213 565 1594
252 1994 1449 380 286 1265 653 1948 1705 1861 341 1123 881 787 419 1077 1638 121
2017 1165 636 15 1299 542 174 934 597 1370 1900 969 1393 675 490 302 1446 444 185
1970 1054 1187 405 1814 781 1012 1148 229 23 1109 1481 1555 206 746 558 118 1293 451
922 803 313 700 1833 1626 1649 39 945 661 1524 357 1258 217 1702 182 1070 334 1315
707 1434 1212 1925 569 1737 27 1457 71 1549 1173 613 874 966 590 828 1219 476 310
345 789 1081 421 1964 1780 43 2018 2004 2002 1996 1976 1972 1937 1929 1926 1912
1908 1873 1866 1865 1862 1842 1841 1834 1830 1818 1784 1761 1745 1738 1734 1714
1713 1706 1692 1690 1667 1650 1644 1642 1628 1603 1596 1573 1571 1561 1557 1528
1505 1489 1482 1478 1458 1452 1450 1436 1411 1394 1388 1386 1372 1347 1340 1317
1305 1301 1294 1266 1260 1244 1221 1189 1177 1166 1129 1125 1113 1110 1078 1016 993

978 977 970 946 940 938 924 899 882 876 860 837 835 805 793 790 754 748 732 709 681
677 665 662 654 617 601 598 566 498 492 453 425 422 409 406 398 361 358 342 233 230
214 186 122 2020 1889 1820 1550 1490 1396 1349 1302 1268 1225 1174 1126 1102 1082
901 782 756 713 678 614 500 457 346 314 218 135 83 51 1930 1746 1708 1605 1321 1193
1114 884 809 602 570 369 267 241 124 75 1137 1031 806 519 234 139 1795 1413 625 433
410 263 29 1190 972 45 841 454 188 147 1558 666 523 77 1953 1577 1484 1318 1652 1201
689 2008 1836 1669 1353 1178 362 948 710 53 99 618 465 1035 141 1222 275 994 316 426
794 1874 817 1130 220 1460 572 504 1329 531 1740 269 163 85 1506 721 1574 1306 905
242 30 682 838 149 348 1043 760 291 1609 1084 525 1797 1350 1417 1194 195 46 1233
1272 1716 101 1762 547 604 57 1562 370 1585 849 1037 277 1868 980 323 458 1985 810
888 412 165 236 1059 78 626 89 1938 1116 533 902 1606 481 1673 714 1361 1492 1322
579 54 1400 434 2024 668 142 364 1844 1138 1414 293 387 153 1045 737 1890 1226 1091
86 197 270 913 690 620 105 1180 549 1617 1748 1578 281 643 1249 952 842 1932 1656
796 150 1801 428 1670 325 1202 1425 526 1132 865 169 1061 1464 1954 1876 1720 996
2032 1377 1354 1308 1508 1681 466 684 984 818 1330 1764 1196 906 244 1798 1610 722
1418 1564 1496 1633 460 929 1848 1940 1155 812 1986 372 1234 850 1586 537 581 58
1441 628 102 1038 1324 297 1809 1752 278 771 716 1892 1049 389 1674 436 201 1093 166
1283 1362 482 1140 113 534 90 1228 553 1697 692 645 294 1580 738 329 844 177 1046
1000 154 1065 914 961 1618 1157 1539 1204 198 1880 248 1250 1356 106 305 550 585
1802 7 282 773 1512 468 1426 820 1473 393 326 866 1956 209 376 170 60 1097 561 1825
1062 11 538 1285 724 908 1332 1612 1378 582 649 337 1768 1729 632 1682 298 92 1073
1050 19 390 1236 1420 440 114 1094 1541 202 1944 1161 593 1144 930 1588 554 13 852
156 1634 225 35 777 646 401 484 178 696 330 1105 108 1008 1676 1442 1988 1896 1364
1810 1520 1857 1960 1208 740 1620 916 1698 824 1776 962 1804 472 1252 1066 1289
1336 353 1158 657 1428 868 284 1474 728 586 1921 306 774 172 1240 1169 394 1380 609
210 540 1545 1098 1826 562 1684 1904 1286 785 1592 417 856 1121 300 67 21 1052 650
1730 338 1074 932 488 1636 116 1297 1992 204 37 673 1368 131 556 1542 1162 594 1444
744 778 1812 180 1185 332 25 226 14 402 69 1068 449 259 1553 920 1106 801 1624 1968
1858 1290 1256 308 588 354 41 22 658 515 133 705 1700 1432 872 1313 396 212 964 1100
564 610 73 38 1170 1027 261 120 1217 1546 1384 652 418 786 340 496 1476 49 833 1688
26 1569 1076 1122 137 517 70 1922 1828 184 1164 936 1298 674 596 2000 752 81 1345
1640 228 42 780 265 1029 1732 134 404 312 1448 1186 1108 1264 1816 880 1860 1704
2016 1392 968 897 1554 1292 450 1601 802 356 1480 660 216 568 1409 706 944 1832 1648
1314 1172 612 1548 344 1924 1080 1456 788 1218 420 1736 145 1124 1665 521 1570 834

600 74 262 97 1300 676 232 28 408 273 50 1712 1033 1346 1112 138 518 976 1188 161
 1864 360 452 664 529 44 82 1556 1793 804 898 1030 266 1488 1602 289 616 1041 1176
 708 146 76 1840 1316 193 522 1410 424 792 545 98 1128 52 240 1220 1744 274 140 1034
 1928 321 1304 680 836 1572 1057 1666 992 162 3 368 84 530 268 577 1192 1348 456 1560
 385 1504 1872 290 808 624 148 5 1042 524 1089 56 900 1794 194 432 712 100 1604 641
 546 1320 1136 276 1036 1760 9 1412 88 322 688 1224 1153 164 1058 1936 840 532 6 1576
 769 1200 464 578 17 1668 152 1888 292 816 386 1352 1044 1281 104 196 1090 10 720 904
 280 33 1328 548 1796 642 1608 1537 1952 1232 168 324 1416 536 1060 480 18 848 1154
 1584 65 770 580 112 1048 296 12 1672 1360 736 388 1984 1282 200 129 34 1092 912 552
 1248 1616 176 1800 644 1538 864 1424 20 328 257 1064 66 1156 1376 304 772 1680 584
 513 928 208 392 1632 36 1284 130 560 1025 1096 1808 1440 24 648 1540 1072 336 960
 1696 258 68 1160 1472 224 592 776 1824 514 400 1728 1104 40 1288 1026 132 352 1856
 656 1544 1168 608 1920 260 784 1 72 416 1120 1296 516 48 672 1552 1028 1184 136 448
 800 1312 704 80 264 1216 1568 2 832 520 1344 1032 1600 144 896 1408 96 272 1664 1792
 528 160 288 4 1024 1056 1040 192 64 8 1280 1088 32 640 384 768 128 1536 1152 0 16 320
 544 256 512 576].

[00213] Clause 14. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including: an encoder to receive input data, and to generate a code word using polar coding, wherein the encoder is to generate the code word based at least in part on the final reliability ranking of any of clauses 1 through 13.

[00214] Clause 15. An Evolved Node-B (eNB) device comprising an application processor, a memory, one or more antennas, and a wireless interface for allowing the application processor to communicate with another device, the eNB device including: an encoder to receive input data, and to generate a code word using polar coding, wherein the encoder is to generate the code word based at least in part on the final reliability ranking of any of clauses 1 through 13.

[00215] Clause 16. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including: a decoder to receive a code word that is encoded using polar coding, and to decode the code word based at least in part on the final reliability ranking of any of clauses 1 through 13.

[00216] Clause 17. An Evolved Node-B (eNB) device comprising an application processor, a memory, one or more antennas, and a wireless interface for allowing the application processor to communicate with another device, the eNB device including: a decoder to receive a code word that is encoded using polar coding, and to decode the code word based at least in part on the final reliability ranking of any of clauses 1 through 13.

[00217] Clause 18. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors to perform an operation comprising: select a set of coding rates comprising a plurality of coding rates; estimate a plurality of reliability rankings respectively corresponding to the plurality of coding rates; and estimate a final reliability ranking, based at least in part on the plurality of reliability rankings, wherein a transmitter is to encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00218] Clause 19. The machine readable storage media of clause 18, the operation comprising: modify one or more of the plurality of reliability rankings to generate a plurality of modified reliability rankings; and estimate the final reliability ranking based at least in part on the plurality of modified reliability rankings.

[00219] Clause 20. The machine readable storage media of clause 18, the operation comprising: receive an input vector having a plurality of bits in a respectively corresponding plurality of bit positions; generate, from the input vector, a code word corresponding to a first coding rate using polar coding; generate a corrupted code word by adding noise to the code word, to simulate transmission of the code word over a wireless channel; decode, at a decoder, the corrupted code word; generate a set of ranked bit positions of the input vector based upon a plurality of reliabilities respectively corresponding to the plurality of bits, the plurality of reliabilities being based upon successful decoding at the decoder the respectively corresponding plurality of bits; and estimate the reliability ranking, based at least in part on the set of ranked bit positions of the input vector.

[00220] Clause 21. The machine readable storage media of any clauses 18 through 20, the operation comprising: access a first reliability ranking corresponding to a first coding rate, wherein the first coding rate is a lowest coding rate in the set of coding rates, and wherein a number N1 of first positions of the first reliability ranking correspond to data bits and remaining positions of the first reliability ranking correspond to frozen bits; and modify, in a first modifying, one or more of the plurality of reliability rankings such that a number N1 of first positions of each of the plurality of reliability rankings are set to the number N1 of first positions of the first reliability ranking.

[00221] Clause 22. The machine readable storage media of clause 21, the operation comprising: access a second reliability ranking subsequent to the first modifying, wherein the second reliability ranking corresponds to a second coding rate, wherein the second coding rate is higher than the first coding rate, and wherein a number N_2 of first positions of the second reliability ranking correspond to data bits and remaining positions of the second reliability ranking correspond to frozen bits; and modify, in a second modifying, one or more of the plurality of reliability rankings such that a position (N_1+1) to a position N_2 of each of the plurality of reliability rankings are respectively set to a position (N_1+1) to a position N_2 of the second reliability ranking.

[00222] Clause 23. The machine readable storage media of clause 22, the operation comprising: access an i^{th} reliability ranking, wherein the i^{th} reliability ranking corresponds to an i^{th} coding rate, wherein the i^{th} coding rate is higher than an $(i-1)^{\text{th}}$ coding rate, wherein a Number N_i of first positions of the i^{th} reliability ranking correspond to data bits and remaining positions of the i^{th} reliability ranking correspond to frozen bits, and wherein a number $N(i-1)$ of first positions of an $(i-1)^{\text{th}}$ reliability ranking correspond to data bits and remaining positions of the $(i-1)^{\text{th}}$ reliability ranking correspond to frozen bits; and modify, in a third modifying, one or more of the plurality of reliability rankings such that a position $(N(i-1) + 1)$ to a position N_i of each of the plurality of reliability rankings are respectively set to a position $(N(i-1) + 1)$ to a position N_i of the i^{th} reliability ranking.

[00223] Clause 24. The machine readable storage media of clause 21, wherein the i^{th} coding rate is a highest coding rate in the set of coding rates, and wherein the operation comprises: estimate the final reliability ranking subsequent to the third modifying.

[00224] Clause 25. The machine readable storage media of any of clauses 23 through 24, the operation comprising: estimate the final reliability ranking to be equal to the i^{th} reliability ranking, subsequent to the third modifying.

[00225] Clause 26. The machine readable storage media of any of clauses 18 through 25, wherein: the transmitter is to encode data to generate a code word having a length of 128; and the final reliability ranking comprises the ordered list of bit indices: [127 126 125 123 119 111 95 63 47 79 55 31 87 103 59 91 107 61 93 115 109 62 15 117 94 23 39 110 27 71 121 43 118 75 29 51 45 83 122 77 53 30 99 124 85 46 57 101 78 89 54 7 86 105 11 58 102 19 90 113 13 35 106 60 92 114 21 67 108 37 14 25 69 22 116 41 38 73 26 49 70 120 81 42 74 28 97 50 3 44 82 76 5 52 98 9 84 56 100 6 88 17 10 33 104 18 65 112 12 34 20 66 36 24 68 40 1 72 48 80 2 96 4 8 16 32 64 0].

[00226] Clause 27. The machine readable storage media of any of clauses 18 through 25, wherein: the transmitter is to encode data to generate a code word having a length of 256; and the final reliability ranking comprises the ordered list of bit indices: [255 254 253 251 247 245 243 239 237 235 231 223 221 219 215 207 191 190 189 187 183 175 159 151 143 127 126 125 123 119 111 103 95 87 79 63 59 55 47 31 222 238 91 249 199 167 107 155 246 61 171 93 115 203 157 179 109 173 211 250 62 117 205 15 94 181 227 23 158 110 39 213 27 121 174 71 252 43 185 135 118 206 229 75 182 217 214 233 122 51 29 139 186 45 83 230 147 77 218 241 99 53 141 30 163 85 124 46 234 188 149 57 195 101 78 89 54 220 165 142 7 242 153 86 105 197 11 236 244 150 169 102 58 201 166 113 90 177 154 198 106 248 60 209 170 19 92 13 114 35 202 156 225 21 178 67 108 37 131 172 14 210 25 69 116 22 41 204 133 180 38 73 226 26 49 70 137 212 120 81 42 134 184 145 74 28 97 228 50 3 138 216 161 44 82 232 76 146 193 52 98 140 240 5 162 84 148 9 56 194 100 6 88 164 17 152 104 196 10 33 168 18 65 112 12 200 129 34 176 20 66 208 36 130 24 68 224 40 132 1 72 48 136 80 2 144 96 4 160 192 8 16 32 64 128 0].

[00227] Clause 28. The machine readable storage media of any of clauses 18 through 25, wherein: the transmitter is to encode data to generate a code word having a length of 512; and the final reliability ranking comprises the ordered list of bit indices: [511 510 509 507 505 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 459 455 447 446 445 443 439 435 431 427 423 415 413 411 407 399 383 382 381 379 375 371 367 363 359 351 349 347 343 335 319 317 315 311 303 287 255 254 253 251 247 243 239 237 235 231 223 221 219 215 207 191 189 187 183 175 159 127 125 123 119 111 95 63 55 47 31 467 365 143 126 429 190 79 318 271 87 506 245 222 151 373 103 461 279 59 350 91 167 437 414 483 238 295 155 366 199 107 249 283 469 171 327 61 430 377 299 508 246 93 391 115 203 441 157 374 462 179 331 485 109 285 307 438 173 473 395 211 62 15 250 301 339 117 94 205 23 470 378 181 227 333 158 489 403 39 110 309 442 355 497 486 474 252 174 397 380 286 213 490 419 121 341 444 229 185 405 302 313 206 118 357 334 182 451 217 476 27 71 310 421 345 135 43 398 214 498 233 409 263 75 122 342 361 29 453 51 139 186 492 230 83 406 45 267 314 425 147 358 77 218 241 99 53 275 141 346 369 422 30 124 163 85 457 269 500 234 46 410 188 291 149 433 195 57 362 454 316 465 426 504 220 348 242 101 370 277 78 458 323 165 89 412 54 236 293 481 142 434 387 364 153 86 197 105 270 281 150 325 428 169 102 58 244 466 278 297 7 389 90 166 113 201 372 460 11 154 177 294 329 106 198 436 19 282 482 305 60 326 209 170 393 13 248 35 92 337 298 21 468 376 114 67 390 202 156 225 37 108 178 131 440 484 401 330 472 353 284 306 172 394 210 417 300 338 116 204 488 25 14 180 69 259 226 332 402 449 41 22 308 354 133 212 396 73 38 261 120 49 418

340 26 496 137 184 70 228 404 81 312 42 265 134 450 356 216 145 74 262 97 28 344 50
 273 138 420 161 44 82 232 266 408 289 76 146 360 193 452 3 52 98 140 274 321 424 240
 162 84 268 5 368 385 290 148 456 56 194 9 100 432 276 88 6 322 164 17 152 464 10 292
 386 104 33 196 280 18 168 324 65 480 12 112 296 129 34 388 200 257 20 176 66 328 304
 36 208 130 392 24 258 336 68 224 400 40 132 352 1 260 416 72 48 448 136 264 2 80 144 96
 272 4 160 288 192 320 384 8 16 32 256 64 128 0].

[00228] Clause 29. The machine readable storage media of any of clauses 18 through 25, wherein: the transmitter is to encode data to generate a code word having a length of 1024; and the final reliability ranking comprises the ordered list of bit indices: [1023 1022 1021 1019 1018 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981 979 975 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923 919 911 903 895 894 893 891 889 887 885 883 879 878 877 875 871 863 862 861 859 855 847 839 831 830 829 827 823 815 807 799 795 791 783 767 766 765 763 761 759 757 755 751 750 749 747 743 735 734 733 731 727 719 711 703 702 701 699 695 687 683 679 671 667 663 655 639 638 637 635 631 627 623 619 615 607 603 599 591 575 573 571 567 559 543 511 510 509 507 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 455 447 446 445 443 439 431 423 415 411 407 399 383 382 381 379 375 367 363 359 351 349 347 343 335 319 317 315 311 303 287 255 254 253 251 247 243 239 235 231 223 221 219 215 207 191 189 187 183 175 159 127 125 123 119 111 95 63 942 605 505 459 427 371 237 47 811 715 31 1020 758 669 435 365 974 953 79 886 413 691 190 997 126 797 143 843 55 429 621 467 819 318 685 87 950 271 723 222 245 985 506 574 151 527 907 373 279 350 103 59 461 813 762 629 167 717 851 606 91 535 437 483 414 238 982 295 155 890 693 670 199 739 366 845 107 551 283 915 1001 249 327 622 469 61 171 821 539 867 798 954 377 430 583 299 725 93 909 246 508 633 391 115 686 998 203 555 157 441 374 764 647 931 853 179 331 462 109 485 697 285 814 986 630 1009 307 587 173 718 775 438 892 541 741 62 15 1002 963 956 917 869 857 846 825 822 729 726 694 473 489 378 250 988 910 470 395 211 933 745 301 921 563 442 854 1010 651 634 339 557 205 595 117 965 779 333 181 698 403 227 94 873 486 742 659 158 355 589 918 309 1004 826 474 497 397 110 611 213 286 937 565 252 870 730 787 753 653 341 419 174 121 542 380 23 675 597 185 858 302 39 781 636 881 229 405 206 118 490 934 558 27 444 313 451 71 803 969 357 661 217 182 334 746 700 43 569 707 1012 135 922 613 345 590 310 945 75 789 421 263 476 398 214 874 828 835 966 29 566 601 51 139 122 233 677 519 654 409 732 342 498 45 83 267 186 361 453 665 598 977 938 805 899 754 230 782 77 147 860 406 523 617 314 492 709 99 53 1016 425 993 970 924 882 748 946 876 358 793 614 681 940 662 500 241 218 837 570 369 422

790 756 678 457 346 809 978 625 901 602 713 433 124 410 234 884 806 666 362 275 454
 188 689 141 972 163 841 531 85 316 618 269 710 30 291 794 426 465 817 220 948 525 149
 572 46 195 994 504 547 838 57 721 682 242 101 348 905 277 323 78 760 165 604 89 370
 533 54 579 458 142 236 849 412 810 293 153 626 387 902 481 86 980 888 714 270 197 364
 434 668 105 549 281 643 737 150 526 620 325 690 169 913 537 58 102 842 796 428 7 278
 952 771 581 297 865 244 466 90 113 166 389 818 684 201 11 534 996 553 372 722 906 154
 645 294 177 329 460 19 929 812 198 106 628 984 282 550 305 13 60 436 585 850 716 482
 692 738 844 773 961 248 914 1000 326 393 209 170 468 561 538 820 376 866 582 649 337
 92 298 724 908 390 114 632 35 202 593 156 554 440 225 777 646 21 401 178 67 108 930
 330 852 284 484 696 353 37 657 306 131 1008 586 172 774 540 14 740 210 25 394 609 472
 69 562 824 259 916 417 300 785 116 962 22 650 338 41 728 204 868 133 856 932 488 673
 744 556 594 920 778 332 226 180 402 449 801 872 308 354 964 658 588 705 396 212 564
 610 515 496 652 786 120 418 340 833 73 936 261 38 752 184 49 674 596 26 137 70 517 780
 228 404 312 81 42 265 880 450 897 134 802 356 216 660 568 145 968 521 706 74 262 612
 97 344 28 50 273 420 788 944 138 518 600 834 161 232 44 676 408 976 360 664 452 804
 898 529 82 266 616 708 289 792 424 146 76 522 193 240 545 98 52 836 680 274 140 992
 321 368 162 84 530 268 3 456 577 808 624 385 290 900 148 524 432 712 56 5 194 100 641
 546 276 688 88 322 9 840 164 532 769 464 6 578 152 816 17 292 386 104 720 196 904 280
 10 548 642 33 168 324 480 848 536 18 770 65 580 112 296 736 12 388 200 912 34 129 552
 176 644 864 328 20 257 66 304 772 584 928 513 208 392 36 560 130 648 24 336 960 258 68
 224 592 776 514 400 40 132 352 656 608 260 72 784 416 1 516 48 672 136 448 800 704 80
 264 2 832 520 144 896 96 272 528 4 160 288 544 192 320 8 576 384 640 768 16 0 512 32 64
 256 128].

[00229] Clause 30. The machine readable storage media of any of clauses 18 through 25, wherein: the transmitter is to encode data to generate a code word having a length of 2048; and the final reliability ranking comprises the ordered list of bit indices: [2047 2046 2045 2044 2043 2042 2041 2039 2038 2037 2035 2031 2030 2029 2027 2025 2023 2021 2019 2015 2014 2013 2011 2009 2007 2006 2005 2003 1999 1998 1997 1995 1991 1983 1982 1981 1979 1977 1975 1974 1973 1971 1967 1966 1965 1963 1959 1951 1950 1949 1947 1943 1939 1935 1931 1927 1919 1918 1917 1915 1913 1911 1910 1909 1907 1903 1902 1901 1899 1895 1891 1887 1886 1885 1883 1879 1875 1871 1869 1867 1863 1855 1854 1853 1851 1847 1845 1843 1839 1837 1835 1831 1823 1821 1819 1815 1807 1791 1790 1789 1787 1786 1785 1783 1782 1781 1779 1775 1774 1773 1771 1767 1763 1759 1758 1757 1755 1751 1747 1743 1741 1739 1735 1727 1726 1725 1723 1719 1717 1715

1711 1709 1707 1703 1695 1693 1691 1687 1679 1663 1662 1661 1659 1655 1653 1651
1647 1645 1643 1639 1631 1630 1629 1627 1623 1615 1599 1598 1597 1595 1591 1583
1575 1567 1559 1551 1535 1534 1533 1531 1530 1529 1527 1526 1525 1523 1519 1518
1517 1515 1511 1507 1503 1502 1501 1499 1495 1493 1491 1487 1485 1483 1479 1471
1470 1469 1467 1463 1461 1459 1455 1453 1451 1447 1439 1438 1437 1435 1431 1423
1407 1406 1405 1403 1399 1397 1395 1391 1389 1387 1383 1375 1374 1373 1371 1367
1359 1343 1342 1341 1339 1335 1327 1319 1311 1307 1303 1295 1279 1278 1277 1275
1271 1269 1267 1263 1262 1261 1259 1255 1247 1246 1245 1243 1239 1231 1223 1215
1214 1213 1211 1207 1199 1191 1183 1179 1175 1167 1151 1150 1149 1147 1143 1135
1131 1127 1119 1115 1111 1103 1087 1085 1083 1079 1071 1055 1023 1022 1021 1019
1018 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981
979 975 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923 919
911 895 894 893 891 887 885 883 879 878 877 875 871 863 862 861 859 855 847 831 830
829 827 823 815 807 799 795 791 783 767 766 765 763 761 759 758 757 755 751 750 749
747 743 735 734 733 731 727 719 711 703 702 701 699 695 687 679 671 667 663 655 639
638 637 635 631 623 619 615 607 603 599 591 575 573 571 567 559 543 511 510 509 507
505 503 501 499 495 494 493 491 487 479 478 477 475 471 463 455 447 446 445 443 439
431 423 415 411 407 399 383 382 381 379 375 367 363 359 351 349 347 343 335 319 317
315 311 303 287 255 254 253 251 247 239 235 231 223 221 219 215 207 191 189 187 183
175 159 127 125 123 119 111 95 63 1978 1914 1694 1646 1563 1401 1390 1351 1273 1195
1117 839 683 605 427 371 243 1822 1749 1607 903 811 715 1710 1323 1020 942 889 627
459 237 1532 1454 669 502 365 31 1139 413 47 1415 1270 1933 886 435 2022 1788 1181
1227 126 1657 1579 691 1671 953 1877 1398 974 843 79 1465 621 1955 997 429 797 1355
143 1486 190 55 1203 1133 1509 1721 318 819 1309 1838 685 1654 271 87 467 2010 950
222 245 2033 1611 723 907 1742 1331 574 527 1799 1197 151 985 1916 506 1462 350 1765
373 103 1419 1565 1497 813 279 59 461 1086 1235 762 1941 1039 1849 629 1587 851 1325
167 1718 1274 606 717 535 91 1987 437 1753 1675 1870 982 483 1141 1363 238 414 1118
890 295 1893 1229 155 1047 693 1980 739 670 1581 366 845 1494 199 107 1402 551 283
2026 915 1001 249 1846 1619 1205 1251 622 1182 327 1357 1803 61 171 469 1881 1063
821 539 1427 1513 867 954 377 798 430 1750 1658 1934 583 1134 725 93 1957 2036 2034
2028 2012 2001 1993 1990 1989 1969 1962 1961 1958 1946 1945 1942 1905 1898 1897
1894 1884 1882 1878 1859 1852 1850 1827 1813 1811 1805 1777 1770 1769 1766 1756
1754 1731 1724 1722 1701 1699 1689 1685 1683 1678 1677 1660 1637 1635 1625 1621
1614 1613 1593 1589 1582 1566 1543 1522 1521 1514 1510 1500 1498 1475 1468 1466

1445 1443 1429 1422 1421 1404 1381 1379 1369 1366 1365 1358 1337 1334 1333 1326
1310 1287 1276 1257 1254 1253 1241 1238 1237 1230 1209 1206 1198 1159 1145 1142
1099 1095 1067 1053 1051 1010 1009 1004 1002 998 988 986 965 963 956 933 931 921 917
910 909 892 873 869 857 853 846 825 822 814 775 764 745 741 729 726 718 697 694 686
647 634 633 630 595 587 563 555 541 508 489 486 485 473 470 462 442 441 438 395 391
378 374 339 331 307 299 285 250 246 211 203 179 157 115 109 2040 1923 1806 1778 1622
1590 1516 1477 1433 1210 1163 1075 854 742 698 651 557 497 301 205 181 62 1829 1385
1146 1107 1069 918 826 779 403 227 173 117 1733 1641 1430 1101 659 1291 937 870 753
333 1382 474 355 158 1338 730 1547 589 397 94 1906 1242 1171 858 1817 309 110 1772
1686 611 213 565 1594 252 1994 1449 380 286 1265 653 1948 1705 1861 341 1123 881 787
419 1077 1638 121 2017 1165 636 15 1299 542 174 934 597 1370 1900 969 1393 675 490
302 1446 444 185 1970 1054 1187 405 1814 781 1012 1148 229 23 1109 1481 1555 206 746
558 118 1293 451 922 803 313 700 1833 1626 1649 39 945 661 1524 357 1258 217 1702
182 1070 334 1315 707 1434 1212 1925 569 1737 27 1457 71 1549 1173 613 874 966 590
828 1219 476 310 345 789 1081 421 1964 1780 43 2018 2004 2002 1996 1976 1972 1937
1929 1926 1912 1908 1873 1866 1865 1862 1842 1841 1834 1830 1818 1784 1761 1745
1738 1734 1714 1713 1706 1692 1690 1667 1650 1644 1642 1628 1603 1596 1573 1571
1561 1557 1528 1505 1489 1482 1478 1458 1452 1450 1436 1411 1394 1388 1386 1372
1347 1340 1317 1305 1301 1294 1266 1260 1244 1221 1189 1177 1166 1129 1125 1113
1110 1078 1016 993 978 977 970 946 940 938 924 899 882 876 860 837 835 805 793 790
754 748 732 709 681 677 665 662 654 617 601 598 566 498 492 453 425 422 409 406 398
361 358 342 233 230 214 186 122 2020 1889 1820 1550 1490 1396 1349 1302 1268 1225
1174 1126 1102 1082 901 782 756 713 678 614 500 457 346 314 218 135 83 51 1930 1746
1708 1605 1321 1193 1114 884 809 602 570 369 267 241 124 75 1137 1031 806 519 234
139 1795 1413 625 433 410 263 29 1190 972 45 841 454 188 147 1558 666 523 77 1953
1577 1484 1318 1652 1201 689 2008 1836 1669 1353 1178 362 948 710 53 99 618 465 1035
141 1222 275 994 316 426 794 1874 817 1130 220 1460 572 504 1329 531 1740 269 163 85
1506 721 1574 1306 905 242 30 682 838 149 348 1043 760 291 1609 1084 525 1797 1350
1417 1194 195 46 1233 1272 1716 101 1762 547 604 57 1562 370 1585 849 1037 277 1868
980 323 458 1985 810 888 412 165 236 1059 78 626 89 1938 1116 533 902 1606 481 1673
714 1361 1492 1322 579 54 1400 434 2024 668 142 364 1844 1138 1414 293 387 153 1045
737 1890 1226 1091 86 197 270 913 690 620 105 1180 549 1617 1748 1578 281 643 1249
952 842 1932 1656 796 150 1801 428 1670 325 1202 1425 526 1132 865 169 1061 1464
1954 1876 1720 996 2032 1377 1354 1308 1508 1681 466 684 984 818 1330 1764 1196 906

244 1798 1610 722 1418 1564 1496 1633 460 929 1848 1940 1155 812 1986 372 1234 850
1586 537 581 58 1441 628 102 1038 1324 297 1809 1752 278 771 716 1892 1049 389 1674
436 201 1093 166 1283 1362 482 1140 113 534 90 1228 553 1697 692 645 294 1580 738
329 844 177 1046 1000 154 1065 914 961 1618 1157 1539 1204 198 1880 248 1250 1356
106 305 550 585 1802 7 282 773 1512 468 1426 820 1473 393 326 866 1956 209 376 170 60
1097 561 1825 1062 11 538 1285 724 908 1332 1612 1378 582 649 337 1768 1729 632 1682
298 92 1073 1050 19 390 1236 1420 440 114 1094 1541 202 1944 1161 593 1144 930 1588
554 13 852 156 1634 225 35 777 646 401 484 178 696 330 1105 108 1008 1676 1442 1988
1896 1364 1810 1520 1857 1960 1208 740 1620 916 1698 824 1776 962 1804 472 1252
1066 1289 1336 353 1158 657 1428 868 284 1474 728 586 1921 306 774 172 1240 1169 394
1380 609 210 540 1545 1098 1826 562 1684 1904 1286 785 1592 417 856 1121 300 67 21
1052 650 1730 338 1074 932 488 1636 116 1297 1992 204 37 673 1368 131 556 1542 1162
594 1444 744 778 1812 180 1185 332 25 226 14 402 69 1068 449 259 1553 920 1106 801
1624 1968 1858 1290 1256 308 588 354 41 22 658 515 133 705 1700 1432 872 1313 396
212 964 1100 564 610 73 38 1170 1027 261 120 1217 1546 1384 652 418 786 340 496 1476
49 833 1688 26 1569 1076 1122 137 517 70 1922 1828 184 1164 936 1298 674 596 2000
752 81 1345 1640 228 42 780 265 1029 1732 134 404 312 1448 1186 1108 1264 1816 880
1860 1704 2016 1392 968 897 1554 1292 450 1601 802 356 1480 660 216 568 1409 706 944
1832 1648 1314 1172 612 1548 344 1924 1080 1456 788 1218 420 1736 145 1124 1665 521
1570 834 600 74 262 97 1300 676 232 28 408 273 50 1712 1033 1346 1112 138 518 976
1188 161 1864 360 452 664 529 44 82 1556 1793 804 898 1030 266 1488 1602 289 616
1041 1176 708 146 76 1840 1316 193 522 1410 424 792 545 98 1128 52 240 1220 1744 274
140 1034 1928 321 1304 680 836 1572 1057 1666 992 162 3 368 84 530 268 577 1192 1348
456 1560 385 1504 1872 290 808 624 148 5 1042 524 1089 56 900 1794 194 432 712 100
1604 641 546 1320 1136 276 1036 1760 9 1412 88 322 688 1224 1153 164 1058 1936 840
532 6 1576 769 1200 464 578 17 1668 152 1888 292 816 386 1352 1044 1281 104 196 1090
10 720 904 280 33 1328 548 1796 642 1608 1537 1952 1232 168 324 1416 536 1060 480 18
848 1154 1584 65 770 580 112 1048 296 12 1672 1360 736 388 1984 1282 200 129 34 1092
912 552 1248 1616 176 1800 644 1538 864 1424 20 328 257 1064 66 1156 1376 304 772
1680 584 513 928 208 392 1632 36 1284 130 560 1025 1096 1808 1440 24 648 1540 1072
336 960 1696 258 68 1160 1472 224 592 776 1824 514 400 1728 1104 40 1288 1026 132
352 1856 656 1544 1168 608 1920 260 784 1 72 416 1120 1296 516 48 672 1552 1028 1184
136 448 800 1312 704 80 264 1216 1568 2 832 520 1344 1032 1600 144 896 1408 96 272

1664 1792 528 160 288 4 1024 1056 1040 192 64 8 1280 1088 32 640 384 768 128 1536
1152 0 16 320 544 256 512 576].

[00230] Clause 31. An apparatus of a User Equipment (UE) operable to communicate with an Evolved Node-B (eNB) on a wireless network, comprising: a memory for storing instructions; and one or more processors to: receive a final reliability ranking, wherein the final reliability ranking is generated based on a plurality of reliability rankings respectively corresponding to a plurality of coding rates; and encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00231] Clause 32. The apparatus of clause 31, wherein the one or more processors are to: generate an input vector comprising data bits and frozen bits, wherein positions of the data bits in the input vector are based on the final reliability ranking; and encode the input vector.

[00232] Clause 33. The apparatus of any of clauses 31 through 32, comprising a transceiver circuitry for generating transmissions and processing transmissions.

[00233] Clause 34. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of clauses 31 through 33.

[00234] Clause 35. An apparatus of an Evolved Node-B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: a memory for storing instructions; and one or more processors to: receive a final reliability ranking, wherein the final reliability ranking is generated based on a plurality of reliability rankings respectively corresponding to a plurality of coding rates; and encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00235] Clause 36. The apparatus of clause 35, wherein the one or more processors are to: generate an input vector comprising data bits and frozen bits, wherein positions of the data bits in the input vector are based on the final reliability ranking; and encode the input vector.

[00236] Clause 37. The apparatus of any of clauses 35 through 36, comprising a transceiver circuitry for generating transmissions and processing transmissions.

[00237] Clause 38. An Evolved Node-B (eNB) device comprising an application processor, a memory, one or more antennas, and a wireless interface for allowing the application processor to communicate with another device, the eNB device including the apparatus of any of clauses 35 through 37.

[00238] Clause 39. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors to perform an operation comprising: receive, for a User Equipment (UE), a final reliability ranking, wherein the final reliability ranking is generated based on a plurality of reliability rankings respectively corresponding to a plurality of coding rates; and encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00239] Clause 40. Machine readable storage media of clause 39, the operation comprising: generate an input vector comprising data bits and frozen bits, wherein positions of the data bits in the input vector are based on the final reliability ranking; and encode the input vector.

[00240] Clause 41. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors to perform an operation comprising: receive, for an Evolved Node-B (eNB), a final reliability ranking, wherein the final reliability ranking is generated based on a plurality of reliability rankings respectively corresponding to a plurality of coding rates; and encode data in accordance with polar coding, based at least in part on the final reliability ranking.

[00241] Clause 42. Machine readable storage media of clause 41, the operation comprising: generate an input vector comprising data bits and frozen bits, wherein positions of the data bits in the input vector are based on the final reliability ranking; and encode the input vector.

[00242] An abstract is provided that will allow the reader to ascertain the nature and gist of the technical disclosure. The abstract is submitted with the understanding that it will not be used to limit the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

We claim:

1. An apparatus comprising:
 - a memory for storing instructions;
 - one or more processors to:
 - select a set of coding rates comprising a plurality of coding rates;
 - estimate a plurality of reliability rankings respectively corresponding to the plurality of coding rates; and
 - estimate a final reliability ranking based at least in part on the plurality of reliability rankings,
 - wherein a transmitter is to encode data in accordance with polar coding, based at least in part on the final reliability ranking.
2. The apparatus of claim 1, wherein the one or more processors are to:
 - modify one or more of the plurality of reliability rankings to generate a plurality of modified reliability rankings; and
 - estimate the final reliability ranking based at least in part on the plurality of modified reliability rankings.
3. The apparatus of any of claims 1-2, wherein to estimate a reliability ranking, the one or more processors are to:
 - receive an input vector having a plurality of bits in a respectively corresponding plurality of bit positions;
 - generate, from the input vector, a code word corresponding to a first coding rate using polar coding;
 - generate a corrupted code word by adding noise to the code word, to simulate transmission of the code word over a wireless channel;
 - decode, at a decoder, the corrupted code word;
 - generate a set of ranked bit positions of the input vector based upon a plurality of reliabilities respectively corresponding to the plurality of bits, the plurality of reliabilities being based upon decoding at the decoder the respectively corresponding plurality of bits; and
 - estimate the reliability ranking, based at least in part on the set of ranked bit positions of the input vector.

4. The apparatus of one of claims 1-3, wherein the one or more processors are to:
 - access a first reliability ranking corresponding to a first coding rate, wherein the first coding rate is a lowest coding rate in the set of coding rates, and wherein a number $N1$ of first positions of the first reliability ranking correspond to data bits and remaining positions of the first reliability ranking correspond to frozen bits; and
 - modify, in a first modifying, first one or more of the plurality of reliability rankings such that a number $N1$ of first positions of each of the plurality of reliability rankings are set to the number $N1$ of first positions of the first reliability ranking.
5. The apparatus of claim 4, wherein the one or more processors are to:
 - access a second reliability ranking subsequent to the first modifying, wherein the second reliability ranking corresponds to a second coding rate, wherein the second coding rate is higher than the first coding rate, and wherein a number $N2$ of first positions of the second reliability ranking correspond to data bits and remaining positions of the second reliability ranking correspond to frozen bits; and
 - modify, in a second modifying, second one or more of the plurality of reliability rankings such that a position $(N1+1)$ to a position $N2$ of each of the plurality of reliability rankings are respectively set to a position $(N1+1)$ to a position $N2$ of the second reliability ranking.
6. The apparatus of claim 5, wherein the one or more processors are to:
 - access an i^{th} reliability ranking subsequent to the second modifying, wherein the i^{th} reliability ranking corresponds to an i^{th} coding rate, wherein the i^{th} coding rate is higher than an $(i-1)^{\text{th}}$ coding rate, wherein a number N_i of first positions of the i^{th} reliability ranking correspond to data bits and remaining positions of the i^{th} reliability ranking correspond to frozen bits, and wherein a number $N(i-1)$ of first positions of an $(i-1)^{\text{th}}$ reliability ranking correspond to data bits and remaining positions of the $(i-1)^{\text{th}}$ reliability ranking correspond to frozen bits; and
 - modify, in a third modifying, one or more of the plurality of reliability rankings such that a position $(N(i-1) + 1)$ to a position N_i of each of the plurality of reliability rankings are respectively set to a position $(N(i-1) + 1)$ to a position N_i of the i^{th} reliability ranking.

7. The apparatus of claim 6, wherein the i^{th} coding rate is a highest coding rate in the set of coding rates, and wherein to estimate the final reliability ranking, the one or more processors are to:

estimate the final reliability ranking subsequent to the third modifying.

8. The apparatus of any of claims 6 or 7, wherein to estimate the final reliability ranking, the one or more processors are to:

estimate the final reliability ranking to be equal to the i^{th} reliability ranking subsequent to the third modifying.

9. The apparatus of any of claims 1 to 8, wherein:

the transmitter is to encode data to generate a code word having a length of 128; and

the final reliability ranking comprises the ordered list of bit indices: [127 126 125 123

119 111 95 63 47 79 55 31 87 103 59 91 107 61 93 115 109 62 15 117 94 23 39 110 27 71

121 43 118 75 29 51 45 83 122 77 53 30 99 124 85 46 57 101 78 89 54 7 86 105 11 58 102

19 90 113 13 35 106 60 92 114 21 67 108 37 14 25 69 22 116 41 38 73 26 49 70 120 81 42

74 28 97 50 3 44 82 76 5 52 98 9 84 56 100 6 88 17 10 33 104 18 65 112 12 34 20 66 36 24

68 40 1 72 48 80 2 96 4 8 16 32 64 0].

10. The apparatus of any of claims 1 to 8, wherein:

the transmitter is to encode data to generate a code word having a length of 256; and

the final reliability ranking comprises the ordered list of bit indices: [255 254 253 251

247 245 243 239 237 235 231 223 221 219 215 207 191 190 189 187 183 175 159 151 143

127 126 125 123 119 111 103 95 87 79 63 59 55 47 31 222 238 91 249 199 167 107 155 246

61 171 93 115 203 157 179 109 173 211 250 62 117 205 15 94 181 227 23 158 110 39 213

27 121 174 71 252 43 185 135 118 206 229 75 182 217 214 233 122 51 29 139 186 45 83

230 147 77 218 241 99 53 141 30 163 85 124 46 234 188 149 57 195 101 78 89 54 220 165

142 7 242 153 86 105 197 11 236 244 150 169 102 58 201 166 113 90 177 154 198 106 248

60 209 170 19 92 13 114 35 202 156 225 21 178 67 108 37 131 172 14 210 25 69 116 22 41

204 133 180 38 73 226 26 49 70 137 212 120 81 42 134 184 145 74 28 97 228 50 3 138 216

161 44 82 232 76 146 193 52 98 140 240 5 162 84 148 9 56 194 100 6 88 164 17 152 104

196 10 33 168 18 65 112 12 200 129 34 176 20 66 208 36 130 24 68 224 40 132 1 72 48 136

80 2 144 96 4 160 192 8 16 32 64 128 0].

11. The apparatus of any of claims 1 to 8, wherein:

the transmitter is to encode data to generate a code word having a length of 512; and

the final reliability ranking comprises the ordered list of bit indices: [511 510 509 507

505 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 459 455 447 446 445
443 439 435 431 427 423 415 413 411 407 399 383 382 381 379 375 371 367 363 359 351
349 347 343 335 319 317 315 311 303 287 255 254 253 251 247 243 239 237 235 231 223
221 219 215 207 191 189 187 183 175 159 127 125 123 119 111 95 63 55 47 31 467 365 143
126 429 190 79 318 271 87 506 245 222 151 373 103 461 279 59 350 91 167 437 414 483
238 295 155 366 199 107 249 283 469 171 327 61 430 377 299 508 246 93 391 115 203 441
157 374 462 179 331 485 109 285 307 438 173 473 395 211 62 15 250 301 339 117 94 205
23 470 378 181 227 333 158 489 403 39 110 309 442 355 497 486 474 252 174 397 380 286
213 490 419 121 341 444 229 185 405 302 313 206 118 357 334 182 451 217 476 27 71 310
421 345 135 43 398 214 498 233 409 263 75 122 342 361 29 453 51 139 186 492 230 83 406
45 267 314 425 147 358 77 218 241 99 53 275 141 346 369 422 30 124 163 85 457 269 500
234 46 410 188 291 149 433 195 57 362 454 316 465 426 504 220 348 242 101 370 277 78
458 323 165 89 412 54 236 293 481 142 434 387 364 153 86 197 105 270 281 150 325 428
169 102 58 244 466 278 297 7 389 90 166 113 201 372 460 11 154 177 294 329 106 198 436
19 282 482 305 60 326 209 170 393 13 248 35 92 337 298 21 468 376 114 67 390 202 156
225 37 108 178 131 440 484 401 330 472 353 284 306 172 394 210 417 300 338 116 204
488 25 14 180 69 259 226 332 402 449 41 22 308 354 133 212 396 73 38 261 120 49 418
340 26 496 137 184 70 228 404 81 312 42 265 134 450 356 216 145 74 262 97 28 344 50
273 138 420 161 44 82 232 266 408 289 76 146 360 193 452 3 52 98 140 274 321 424 240
162 84 268 5 368 385 290 148 456 56 194 9 100 432 276 88 6 322 164 17 152 464 10 292
386 104 33 196 280 18 168 324 65 480 12 112 296 129 34 388 200 257 20 176 66 328 304
36 208 130 392 24 258 336 68 224 400 40 132 352 1 260 416 72 48 448 136 264 2 80 144 96
272 4 160 288 192 320 384 8 16 32 256 64 128 0].

12. The apparatus of any of claims 1 to 8, wherein:

the transmitter is to encode data to generate a code word having a length of 1024; and

the final reliability ranking comprises the ordered list of bit indices: [1023 1022 1021

1019 1018 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983
981 979 975 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923
919 911 903 895 894 893 891 889 887 885 883 879 878 877 875 871 863 862 861 859 855
847 839 831 830 829 827 823 815 807 799 795 791 783 767 766 765 763 761 759 757 755

751 750 749 747 743 735 734 733 731 727 719 711 703 702 701 699 695 687 683 679 671
667 663 655 639 638 637 635 631 627 623 619 615 607 603 599 591 575 573 571 567 559
543 511 510 509 507 503 502 501 499 495 494 493 491 487 479 478 477 475 471 463 455
447 446 445 443 439 431 423 415 411 407 399 383 382 381 379 375 367 363 359 351 349
347 343 335 319 317 315 311 303 287 255 254 253 251 247 243 239 235 231 223 221 219
215 207 191 189 187 183 175 159 127 125 123 119 111 95 63 942 605 505 459 427 371 237
47 811 715 31 1020 758 669 435 365 974 953 79 886 413 691 190 997 126 797 143 843 55
429 621 467 819 318 685 87 950 271 723 222 245 985 506 574 151 527 907 373 279 350
103 59 461 813 762 629 167 717 851 606 91 535 437 483 414 238 982 295 155 890 693 670
199 739 366 845 107 551 283 915 1001 249 327 622 469 61 171 821 539 867 798 954 377
430 583 299 725 93 909 246 508 633 391 115 686 998 203 555 157 441 374 764 647 931
853 179 331 462 109 485 697 285 814 986 630 1009 307 587 173 718 775 438 892 541 741
62 15 1002 963 956 917 869 857 846 825 822 729 726 694 473 489 378 250 988 910 470
395 211 933 745 301 921 563 442 854 1010 651 634 339 557 205 595 117 965 779 333 181
698 403 227 94 873 486 742 659 158 355 589 918 309 1004 826 474 497 397 110 611 213
286 937 565 252 870 730 787 753 653 341 419 174 121 542 380 23 675 597 185 858 302 39
781 636 881 229 405 206 118 490 934 558 27 444 313 451 71 803 969 357 661 217 182 334
746 700 43 569 707 1012 135 922 613 345 590 310 945 75 789 421 263 476 398 214 874
828 835 966 29 566 601 51 139 122 233 677 519 654 409 732 342 498 45 83 267 186 361
453 665 598 977 938 805 899 754 230 782 77 147 860 406 523 617 314 492 709 99 53 1016
425 993 970 924 882 748 946 876 358 793 614 681 940 662 500 241 218 837 570 369 422
790 756 678 457 346 809 978 625 901 602 713 433 124 410 234 884 806 666 362 275 454
188 689 141 972 163 841 531 85 316 618 269 710 30 291 794 426 465 817 220 948 525 149
572 46 195 994 504 547 838 57 721 682 242 101 348 905 277 323 78 760 165 604 89 370
533 54 579 458 142 236 849 412 810 293 153 626 387 902 481 86 980 888 714 270 197 364
434 668 105 549 281 643 737 150 526 620 325 690 169 913 537 58 102 842 796 428 7 278
952 771 581 297 865 244 466 90 113 166 389 818 684 201 11 534 996 553 372 722 906 154
645 294 177 329 460 19 929 812 198 106 628 984 282 550 305 13 60 436 585 850 716 482
692 738 844 773 961 248 914 1000 326 393 209 170 468 561 538 820 376 866 582 649 337
92 298 724 908 390 114 632 35 202 593 156 554 440 225 777 646 21 401 178 67 108 930
330 852 284 484 696 353 37 657 306 131 1008 586 172 774 540 14 740 210 25 394 609 472
69 562 824 259 916 417 300 785 116 962 22 650 338 41 728 204 868 133 856 932 488 673
744 556 594 920 778 332 226 180 402 449 801 872 308 354 964 658 588 705 396 212 564
610 515 496 652 786 120 418 340 833 73 936 261 38 752 184 49 674 596 26 137 70 517 780

228 404 312 81 42 265 880 450 897 134 802 356 216 660 568 145 968 521 706 74 262 612
 97 344 28 50 273 420 788 944 138 518 600 834 161 232 44 676 408 976 360 664 452 804
 898 529 82 266 616 708 289 792 424 146 76 522 193 240 545 98 52 836 680 274 140 992
 321 368 162 84 530 268 3 456 577 808 624 385 290 900 148 524 432 712 56 5 194 100 641
 546 276 688 88 322 9 840 164 532 769 464 6 578 152 816 17 292 386 104 720 196 904 280
 10 548 642 33 168 324 480 848 536 18 770 65 580 112 296 736 12 388 200 912 34 129 552
 176 644 864 328 20 257 66 304 772 584 928 513 208 392 36 560 130 648 24 336 960 258 68
 224 592 776 514 400 40 132 352 656 608 260 72 784 416 1 516 48 672 136 448 800 704 80
 264 2 832 520 144 896 96 272 528 4 160 288 544 192 320 8 576 384 640 768 16 0 512 32 64
 256 128].

13. The apparatus of any of claims 1 to 8, wherein:

the transmitter is to encode data to generate a code word having a length of 2048; and

the final reliability ranking comprises the ordered list of bit indices: [2047 2046 2045

2044 2043 2042 2041 2039 2038 2037 2035 2031 2030 2029 2027 2025 2023 2021 2019
 2015 2014 2013 2011 2009 2007 2006 2005 2003 1999 1998 1997 1995 1991 1983 1982
 1981 1979 1977 1975 1974 1973 1971 1967 1966 1965 1963 1959 1951 1950 1949 1947
 1943 1939 1935 1931 1927 1919 1918 1917 1915 1913 1911 1910 1909 1907 1903 1902
 1901 1899 1895 1891 1887 1886 1885 1883 1879 1875 1871 1869 1867 1863 1855 1854
 1853 1851 1847 1845 1843 1839 1837 1835 1831 1823 1821 1819 1815 1807 1791 1790
 1789 1787 1786 1785 1783 1782 1781 1779 1775 1774 1773 1771 1767 1763 1759 1758
 1757 1755 1751 1747 1743 1741 1739 1735 1727 1726 1725 1723 1719 1717 1715 1711
 1709 1707 1703 1695 1693 1691 1687 1679 1663 1662 1661 1659 1655 1653 1651 1647
 1645 1643 1639 1631 1630 1629 1627 1623 1615 1599 1598 1597 1595 1591 1583 1575
 1567 1559 1551 1535 1534 1533 1531 1530 1529 1527 1526 1525 1523 1519 1518 1517
 1515 1511 1507 1503 1502 1501 1499 1495 1493 1491 1487 1485 1483 1479 1471 1470
 1469 1467 1463 1461 1459 1455 1453 1451 1447 1439 1438 1437 1435 1431 1423 1407
 1406 1405 1403 1399 1397 1395 1391 1389 1387 1383 1375 1374 1373 1371 1367 1359
 1343 1342 1341 1339 1335 1327 1319 1311 1307 1303 1295 1279 1278 1277 1275 1271
 1269 1267 1263 1262 1261 1259 1255 1247 1246 1245 1243 1239 1231 1223 1215 1214
 1213 1211 1207 1199 1191 1183 1179 1175 1167 1151 1150 1149 1147 1143 1135 1131
 1127 1119 1115 1111 1103 1087 1085 1083 1079 1071 1055 1023 1022 1021 1019 1018
 1017 1015 1014 1013 1011 1007 1006 1005 1003 999 995 991 990 989 987 983 981 979 975
 973 971 967 959 958 957 955 951 949 947 943 941 939 935 927 926 925 923 919 911 895

894 893 891 887 885 883 879 878 877 875 871 863 862 861 859 855 847 831 830 829 827
823 815 807 799 795 791 783 767 766 765 763 761 759 758 757 755 751 750 749 747 743
735 734 733 731 727 719 711 703 702 701 699 695 687 679 671 667 663 655 639 638 637
635 631 623 619 615 607 603 599 591 575 573 571 567 559 543 511 510 509 507 505 503
501 499 495 494 493 491 487 479 478 477 475 471 463 455 447 446 445 443 439 431 423
415 411 407 399 383 382 381 379 375 367 363 359 351 349 347 343 335 319 317 315 311
303 287 255 254 253 251 247 239 235 231 223 221 219 215 207 191 189 187 183 175 159
127 125 123 119 111 95 63 1978 1914 1694 1646 1563 1401 1390 1351 1273 1195 1117 839
683 605 427 371 243 1822 1749 1607 903 811 715 1710 1323 1020 942 889 627 459 237
1532 1454 669 502 365 31 1139 413 47 1415 1270 1933 886 435 2022 1788 1181 1227 126
1657 1579 691 1671 953 1877 1398 974 843 79 1465 621 1955 997 429 797 1355 143 1486
190 55 1203 1133 1509 1721 318 819 1309 1838 685 1654 271 87 467 2010 950 222 245
2033 1611 723 907 1742 1331 574 527 1799 1197 151 985 1916 506 1462 350 1765 373 103
1419 1565 1497 813 279 59 461 1086 1235 762 1941 1039 1849 629 1587 851 1325 167
1718 1274 606 717 535 91 1987 437 1753 1675 1870 982 483 1141 1363 238 414 1118 890
295 1893 1229 155 1047 693 1980 739 670 1581 366 845 1494 199 107 1402 551 283 2026
915 1001 249 1846 1619 1205 1251 622 1182 327 1357 1803 61 171 469 1881 1063 821 539
1427 1513 867 954 377 798 430 1750 1658 1934 583 1134 725 93 1957 2036 2034 2028
2012 2001 1993 1990 1989 1969 1962 1961 1958 1946 1945 1942 1905 1898 1897 1894
1884 1882 1878 1859 1852 1850 1827 1813 1811 1805 1777 1770 1769 1766 1756 1754
1731 1724 1722 1701 1699 1689 1685 1683 1678 1677 1660 1637 1635 1625 1621 1614
1613 1593 1589 1582 1566 1543 1522 1521 1514 1510 1500 1498 1475 1468 1466 1445
1443 1429 1422 1421 1404 1381 1379 1369 1366 1365 1358 1337 1334 1333 1326 1310
1287 1276 1257 1254 1253 1241 1238 1237 1230 1209 1206 1198 1159 1145 1142 1099
1095 1067 1053 1051 1010 1009 1004 1002 998 988 986 965 963 956 933 931 921 917 910
909 892 873 869 857 853 846 825 822 814 775 764 745 741 729 726 718 697 694 686 647
634 633 630 595 587 563 555 541 508 489 486 485 473 470 462 442 441 438 395 391 378
374 339 331 307 299 285 250 246 211 203 179 157 115 109 2040 1923 1806 1778 1622
1590 1516 1477 1433 1210 1163 1075 854 742 698 651 557 497 301 205 181 62 1829 1385
1146 1107 1069 918 826 779 403 227 173 117 1733 1641 1430 1101 659 1291 937 870 753
333 1382 474 355 158 1338 730 1547 589 397 94 1906 1242 1171 858 1817 309 110 1772
1686 611 213 565 1594 252 1994 1449 380 286 1265 653 1948 1705 1861 341 1123 881 787
419 1077 1638 121 2017 1165 636 15 1299 542 174 934 597 1370 1900 969 1393 675 490
302 1446 444 185 1970 1054 1187 405 1814 781 1012 1148 229 23 1109 1481 1555 206 746

558 118 1293 451 922 803 313 700 1833 1626 1649 39 945 661 1524 357 1258 217 1702
182 1070 334 1315 707 1434 1212 1925 569 1737 27 1457 71 1549 1173 613 874 966 590
828 1219 476 310 345 789 1081 421 1964 1780 43 2018 2004 2002 1996 1976 1972 1937
1929 1926 1912 1908 1873 1866 1865 1862 1842 1841 1834 1830 1818 1784 1761 1745
1738 1734 1714 1713 1706 1692 1690 1667 1650 1644 1642 1628 1603 1596 1573 1571
1561 1557 1528 1505 1489 1482 1478 1458 1452 1450 1436 1411 1394 1388 1386 1372
1347 1340 1317 1305 1301 1294 1266 1260 1244 1221 1189 1177 1166 1129 1125 1113
1110 1078 1016 993 978 977 970 946 940 938 924 899 882 876 860 837 835 805 793 790
754 748 732 709 681 677 665 662 654 617 601 598 566 498 492 453 425 422 409 406 398
361 358 342 233 230 214 186 122 2020 1889 1820 1550 1490 1396 1349 1302 1268 1225
1174 1126 1102 1082 901 782 756 713 678 614 500 457 346 314 218 135 83 51 1930 1746
1708 1605 1321 1193 1114 884 809 602 570 369 267 241 124 75 1137 1031 806 519 234
139 1795 1413 625 433 410 263 29 1190 972 45 841 454 188 147 1558 666 523 77 1953
1577 1484 1318 1652 1201 689 2008 1836 1669 1353 1178 362 948 710 53 99 618 465 1035
141 1222 275 994 316 426 794 1874 817 1130 220 1460 572 504 1329 531 1740 269 163 85
1506 721 1574 1306 905 242 30 682 838 149 348 1043 760 291 1609 1084 525 1797 1350
1417 1194 195 46 1233 1272 1716 101 1762 547 604 57 1562 370 1585 849 1037 277 1868
980 323 458 1985 810 888 412 165 236 1059 78 626 89 1938 1116 533 902 1606 481 1673
714 1361 1492 1322 579 54 1400 434 2024 668 142 364 1844 1138 1414 293 387 153 1045
737 1890 1226 1091 86 197 270 913 690 620 105 1180 549 1617 1748 1578 281 643 1249
952 842 1932 1656 796 150 1801 428 1670 325 1202 1425 526 1132 865 169 1061 1464
1954 1876 1720 996 2032 1377 1354 1308 1508 1681 466 684 984 818 1330 1764 1196 906
244 1798 1610 722 1418 1564 1496 1633 460 929 1848 1940 1155 812 1986 372 1234 850
1586 537 581 58 1441 628 102 1038 1324 297 1809 1752 278 771 716 1892 1049 389 1674
436 201 1093 166 1283 1362 482 1140 113 534 90 1228 553 1697 692 645 294 1580 738
329 844 177 1046 1000 154 1065 914 961 1618 1157 1539 1204 198 1880 248 1250 1356
106 305 550 585 1802 7 282 773 1512 468 1426 820 1473 393 326 866 1956 209 376 170 60
1097 561 1825 1062 11 538 1285 724 908 1332 1612 1378 582 649 337 1768 1729 632 1682
298 92 1073 1050 19 390 1236 1420 440 114 1094 1541 202 1944 1161 593 1144 930 1588
554 13 852 156 1634 225 35 777 646 401 484 178 696 330 1105 108 1008 1676 1442 1988
1896 1364 1810 1520 1857 1960 1208 740 1620 916 1698 824 1776 962 1804 472 1252
1066 1289 1336 353 1158 657 1428 868 284 1474 728 586 1921 306 774 172 1240 1169 394
1380 609 210 540 1545 1098 1826 562 1684 1904 1286 785 1592 417 856 1121 300 67 21
1052 650 1730 338 1074 932 488 1636 116 1297 1992 204 37 673 1368 131 556 1542 1162

594 1444 744 778 1812 180 1185 332 25 226 14 402 69 1068 449 259 1553 920 1106 801
 1624 1968 1858 1290 1256 308 588 354 41 22 658 515 133 705 1700 1432 872 1313 396
 212 964 1100 564 610 73 38 1170 1027 261 120 1217 1546 1384 652 418 786 340 496 1476
 49 833 1688 26 1569 1076 1122 137 517 70 1922 1828 184 1164 936 1298 674 596 2000
 752 81 1345 1640 228 42 780 265 1029 1732 134 404 312 1448 1186 1108 1264 1816 880
 1860 1704 2016 1392 968 897 1554 1292 450 1601 802 356 1480 660 216 568 1409 706 944
 1832 1648 1314 1172 612 1548 344 1924 1080 1456 788 1218 420 1736 145 1124 1665 521
 1570 834 600 74 262 97 1300 676 232 28 408 273 50 1712 1033 1346 1112 138 518 976
 1188 161 1864 360 452 664 529 44 82 1556 1793 804 898 1030 266 1488 1602 289 616
 1041 1176 708 146 76 1840 1316 193 522 1410 424 792 545 98 1128 52 240 1220 1744 274
 140 1034 1928 321 1304 680 836 1572 1057 1666 992 162 3 368 84 530 268 577 1192 1348
 456 1560 385 1504 1872 290 808 624 148 5 1042 524 1089 56 900 1794 194 432 712 100
 1604 641 546 1320 1136 276 1036 1760 9 1412 88 322 688 1224 1153 164 1058 1936 840
 532 6 1576 769 1200 464 578 17 1668 152 1888 292 816 386 1352 1044 1281 104 196 1090
 10 720 904 280 33 1328 548 1796 642 1608 1537 1952 1232 168 324 1416 536 1060 480 18
 848 1154 1584 65 770 580 112 1048 296 12 1672 1360 736 388 1984 1282 200 129 34 1092
 912 552 1248 1616 176 1800 644 1538 864 1424 20 328 257 1064 66 1156 1376 304 772
 1680 584 513 928 208 392 1632 36 1284 130 560 1025 1096 1808 1440 24 648 1540 1072
 336 960 1696 258 68 1160 1472 224 592 776 1824 514 400 1728 1104 40 1288 1026 132
 352 1856 656 1544 1168 608 1920 260 784 1 72 416 1120 1296 516 48 672 1552 1028 1184
 136 448 800 1312 704 80 264 1216 1568 2 832 520 1344 1032 1600 144 896 1408 96 272
 1664 1792 528 160 288 4 1024 1056 1040 192 64 8 1280 1088 32 640 384 768 128 1536
 1152 0 16 320 544 256 512 576].

14. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including:

an encoder to receive input data, and to generate a code word using polar coding,

wherein the encoder is to generate the code word based at least in part on the final reliability ranking of any of claims 1 through 13.

15. An Evolved Node-B (eNB) device comprising an application processor, a memory, one or more antennas, and a wireless interface for allowing the application processor to communicate with another device, the eNB device including:

an encoder to receive input data, and to generate a code word using polar coding, wherein the encoder is to generate the code word based at least in part on the final reliability ranking of any of claims 1 through 13.

16. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including:

a decoder to receive a code word that is encoded using polar coding, and to decode the code word based at least in part on the final reliability ranking of any of claims 1 through 13.

17. An Evolved Node-B (eNB) device comprising an application processor, a memory, one or more antennas, and a wireless interface for allowing the application processor to communicate with another device, the eNB device including:

a decoder to receive a code word that is encoded using polar coding, and to decode the code word based at least in part on the final reliability ranking of any of claims 1 through 13.

18. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors to perform an operation comprising:

select a set of coding rates comprising a plurality of coding rates;

estimate a plurality of reliability rankings respectively corresponding to the plurality of coding rates; and

estimate a final reliability ranking, based at least in part on the plurality of reliability rankings,

wherein a transmitter is to encode data in accordance with polar coding, based at least in part on the final reliability ranking.

19. The machine readable storage media of claim 18, the operation comprising:

modify one or more of the plurality of reliability rankings to generate a plurality of modified reliability rankings; and

estimate the final reliability ranking based at least in part on the plurality of modified reliability rankings.

20. The machine readable storage media of claim 18, the operation comprising:
- receive an input vector having a plurality of bits in a respectively corresponding plurality of bit positions;
 - generate, from the input vector, a code word corresponding to a first coding rate using polar coding;
 - generate a corrupted code word by adding noise to the code word, to simulate transmission of the code word over a wireless channel;
 - decode, at a decoder, the corrupted code word;
 - generate a set of ranked bit positions of the input vector based upon a plurality of reliabilities respectively corresponding to the plurality of bits, the plurality of reliabilities being based upon successful decoding at the decoder the respectively corresponding plurality of bits; and
 - estimate the reliability ranking, based at least in part on the set of ranked bit positions of the input vector.
21. The machine readable storage media of any claims 18 through 20, the operation comprising:
- access a first reliability ranking corresponding to a first coding rate, wherein the first coding rate is a lowest coding rate in the set of coding rates, and wherein a number N1 of first positions of the first reliability ranking correspond to data bits and remaining positions of the first reliability ranking correspond to frozen bits; and
 - modify, in a first modifying, one or more of the plurality of reliability rankings such that a number N1 of first positions of each of the plurality of reliability rankings are set to the number N1 of first positions of the first reliability ranking.
22. An apparatus of a User Equipment (UE) operable to communicate with an Evolved Node-B (eNB) on a wireless network, comprising:
- a memory for storing instructions; and
 - one or more processors to:
 - receive a final reliability ranking, wherein the final reliability ranking is generated based on a plurality of reliability rankings respectively corresponding to a plurality of coding rates; and
 - encode data in accordance with polar coding, based at least in part on the final reliability ranking.

23. The apparatus of claim 22, wherein the one or more processors are to:
- generate an input vector comprising data bits and frozen bits, wherein positions of the data bits in the input vector are based on the final reliability ranking; and
 - encode the input vector.
24. An apparatus of an Evolved Node-B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising:
- a memory for storing instructions; and
 - one or more processors to:
 - receive a final reliability ranking, wherein the final reliability ranking is generated based on a plurality of reliability rankings respectively corresponding to a plurality of coding rates; and
 - encode data in accordance with polar coding, based at least in part on the final reliability ranking.
25. The apparatus of claim 24, wherein the one or more processors are to:
- generate an input vector comprising data bits and frozen bits, wherein positions of the data bits in the input vector are based on the final reliability ranking; and
 - encode the input vector.

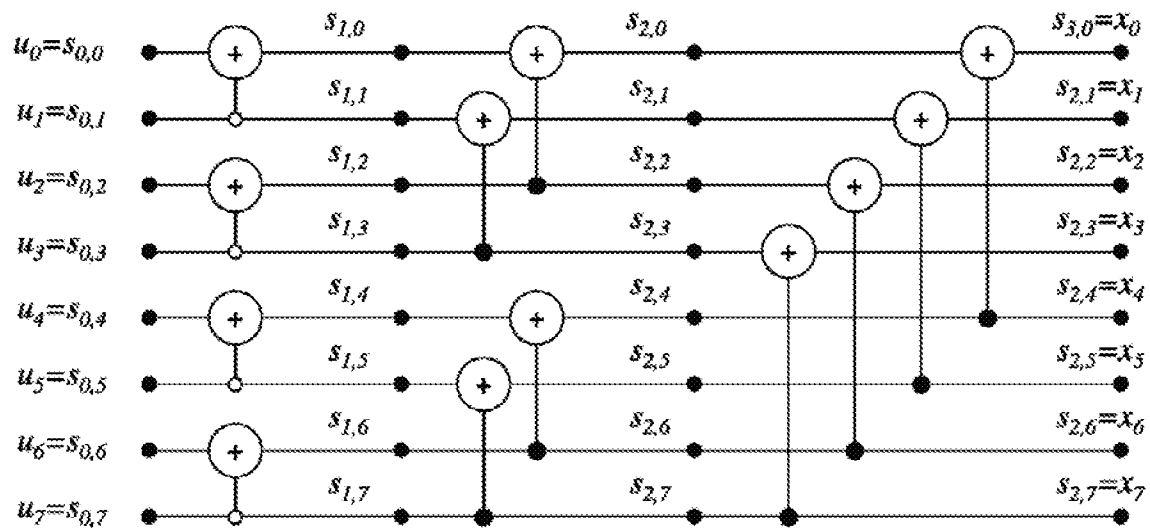


Fig. 1A

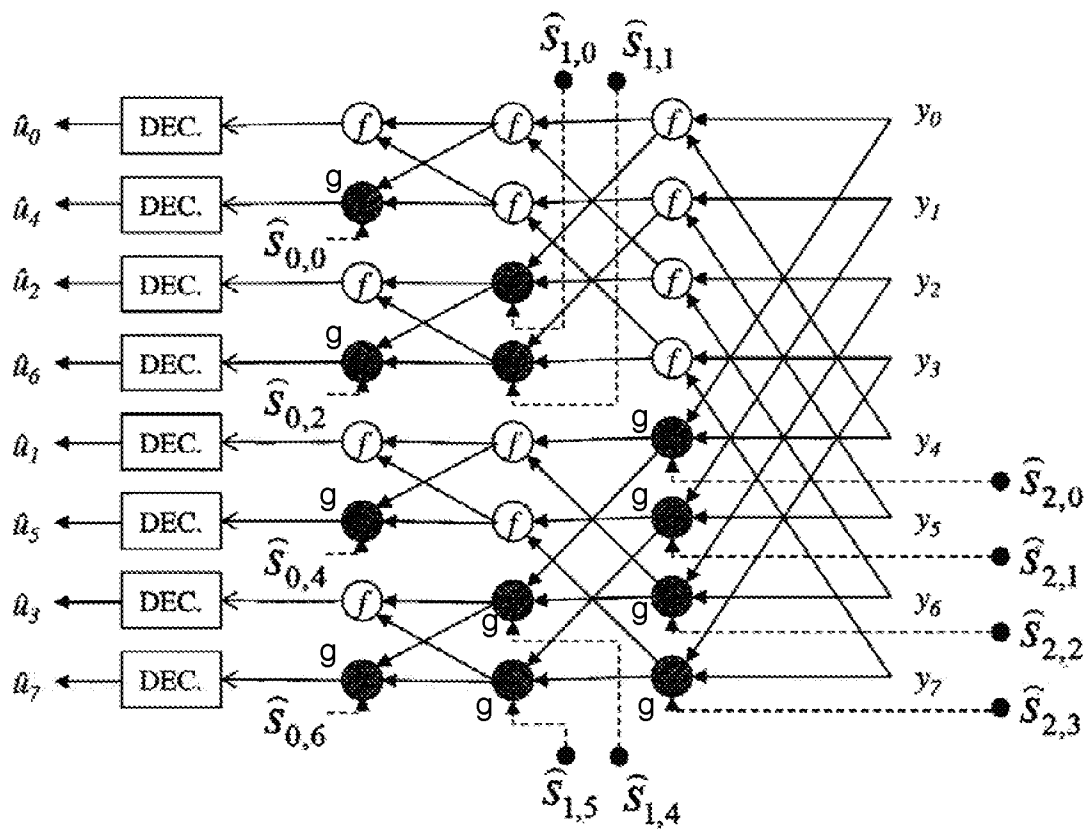
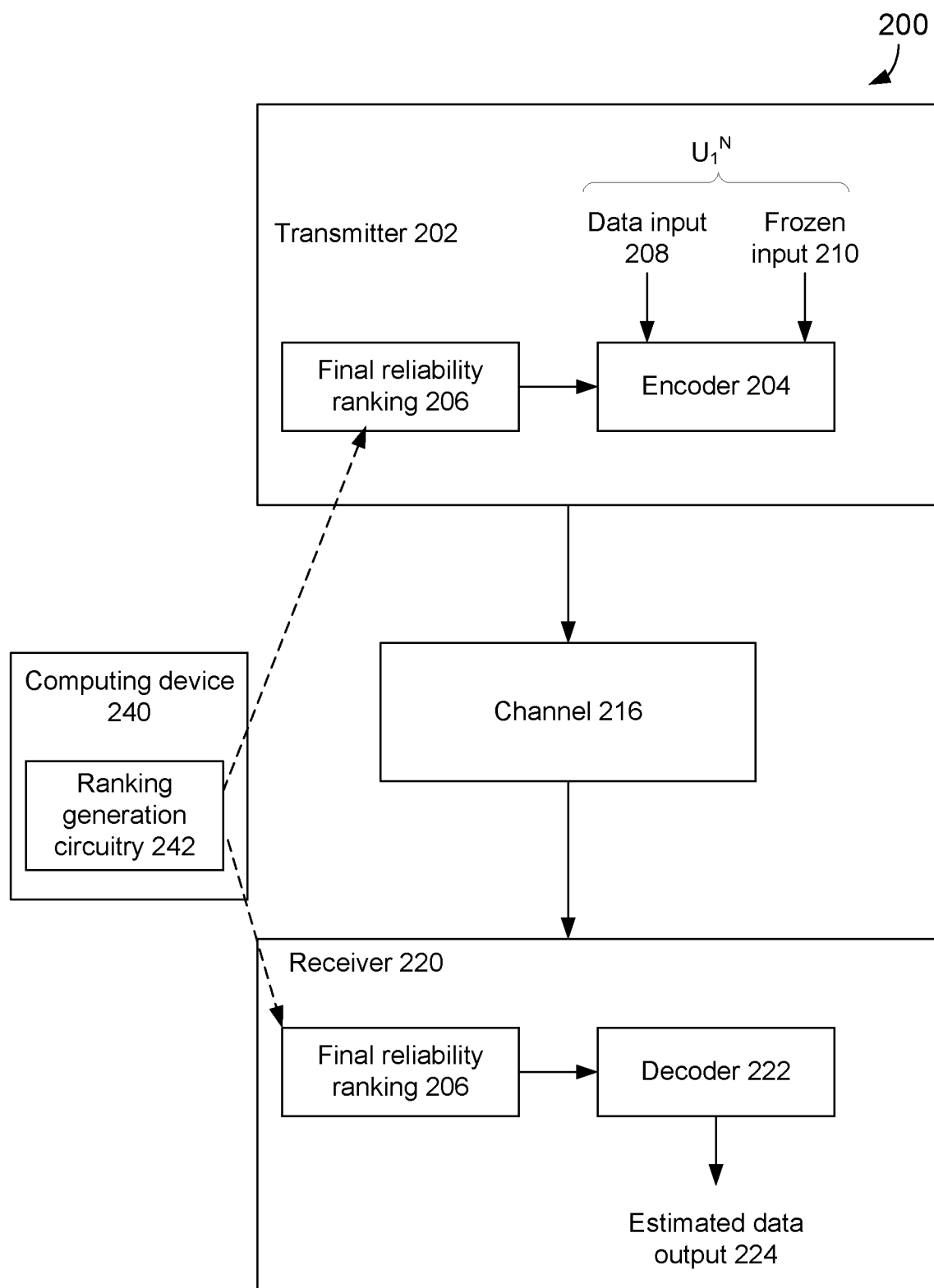
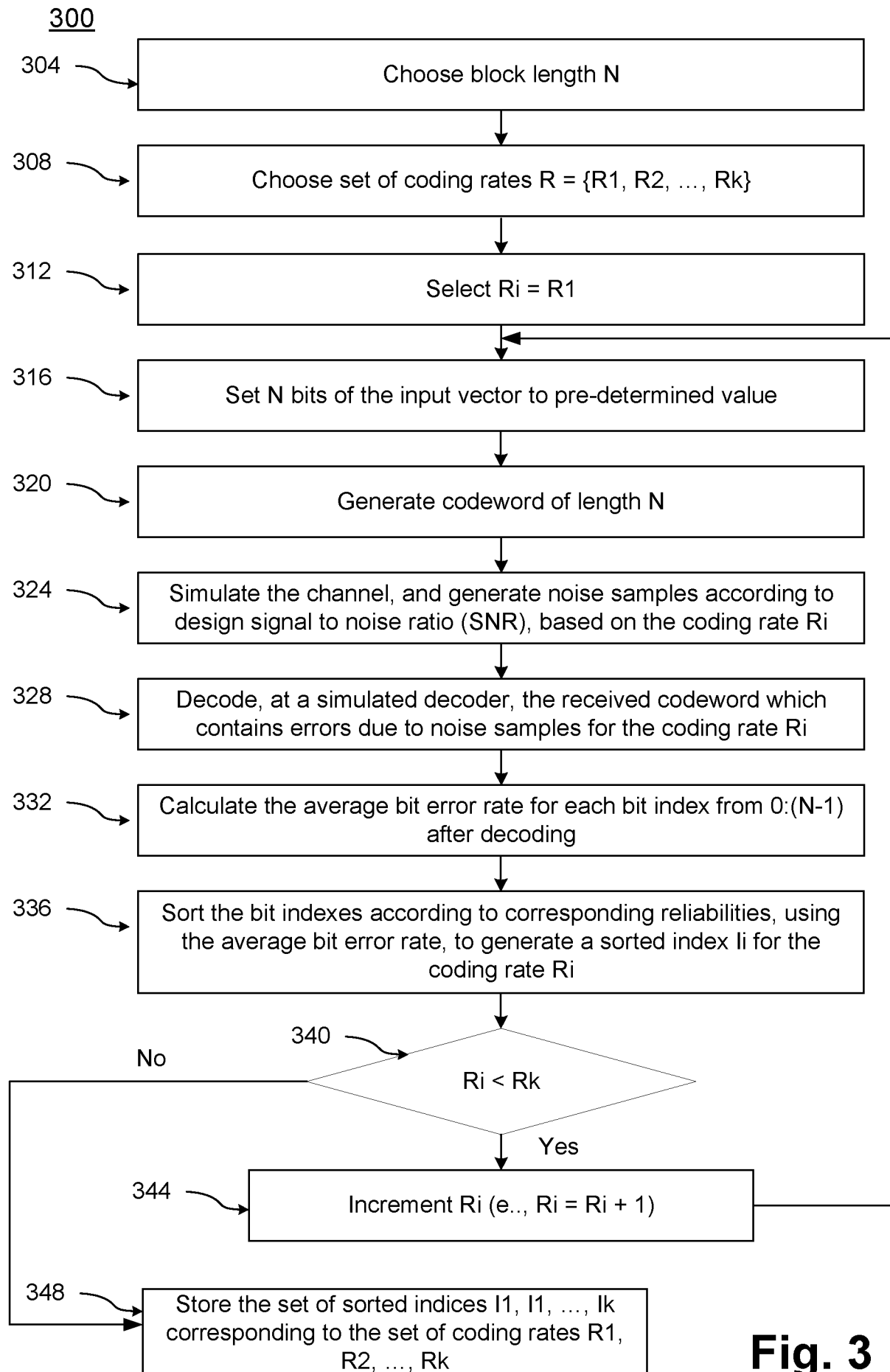
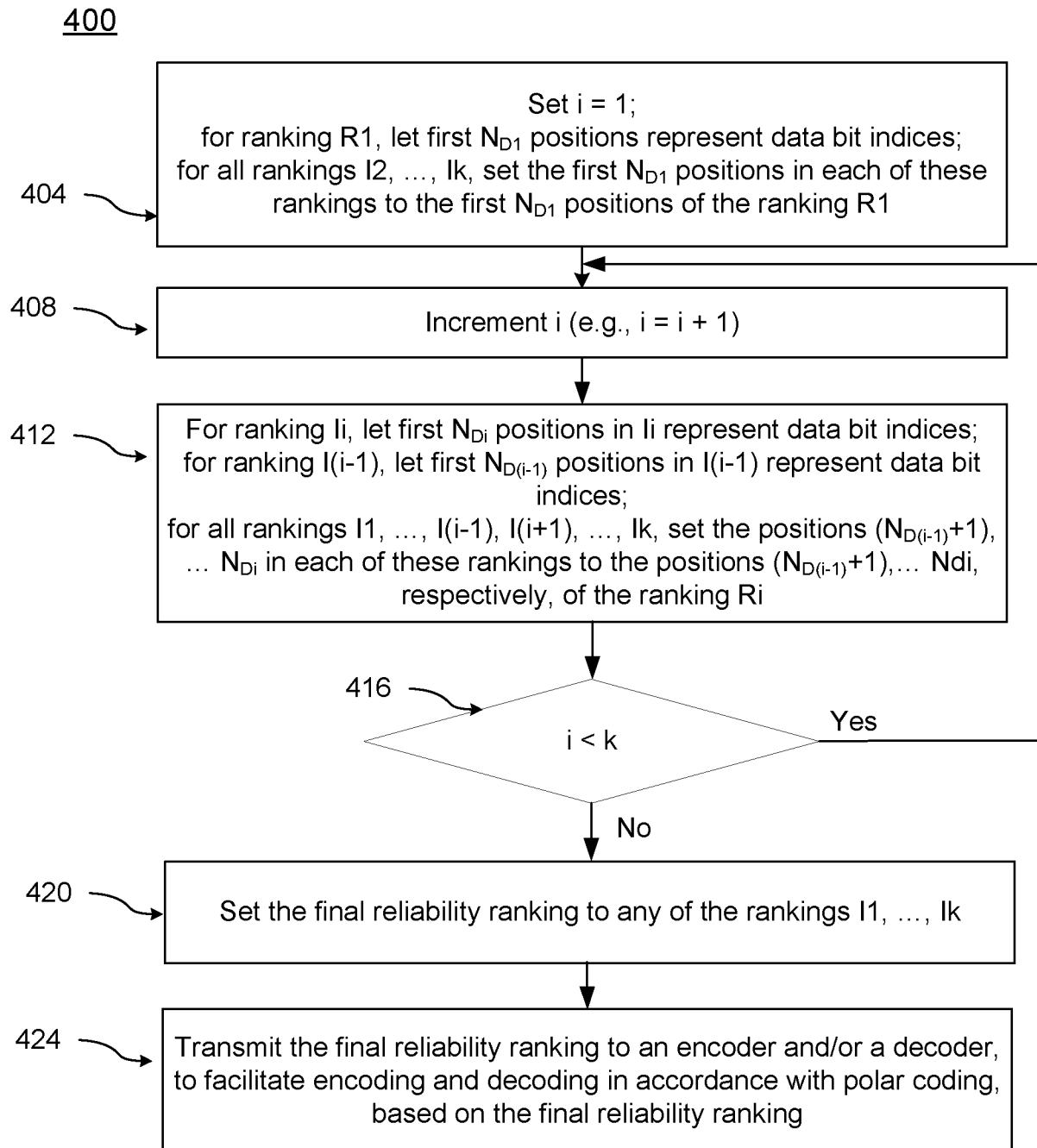


Fig. 1B

**Fig. 2**

**Fig. 3**

**Fig. 4**

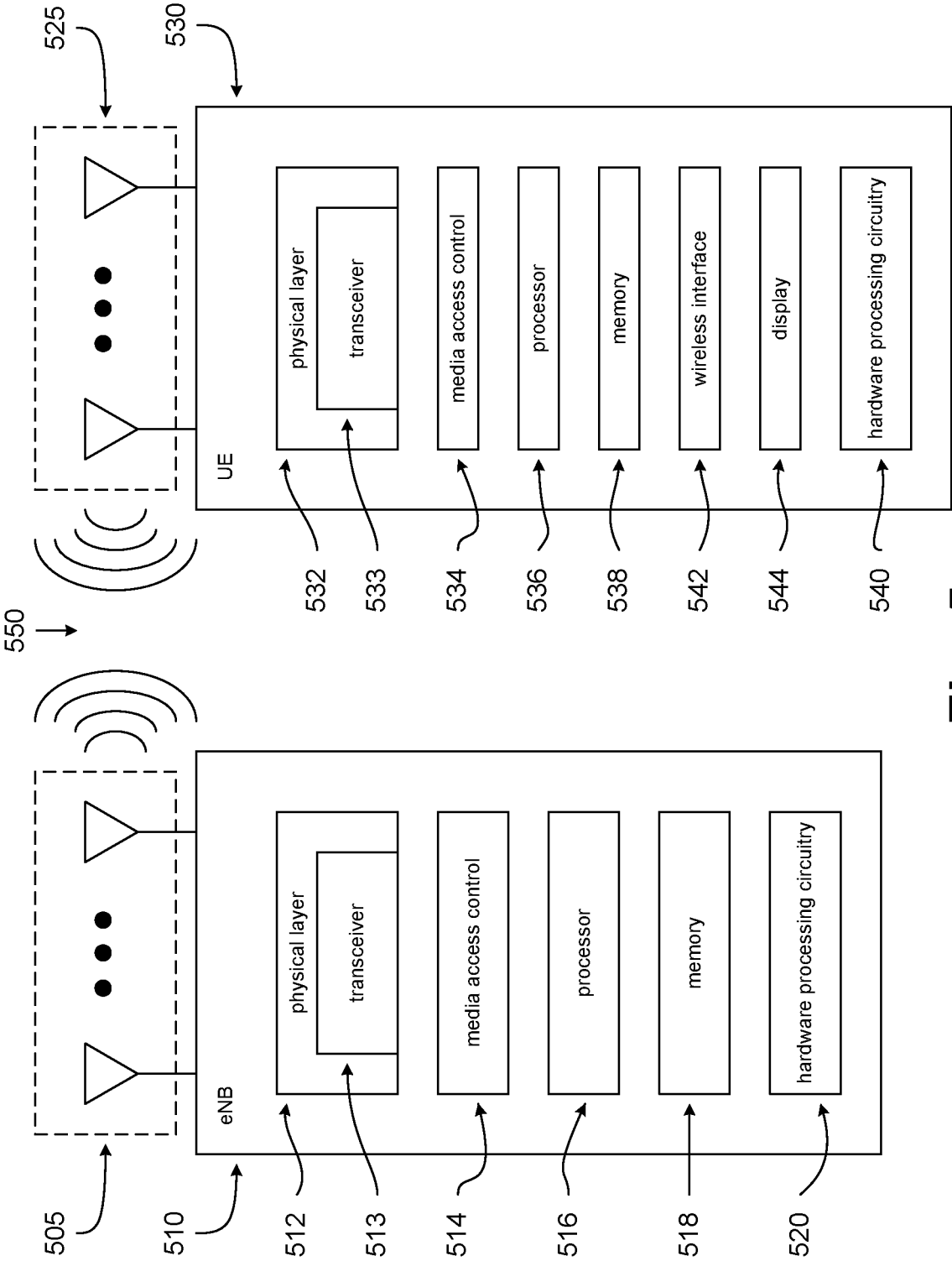


Fig. 5

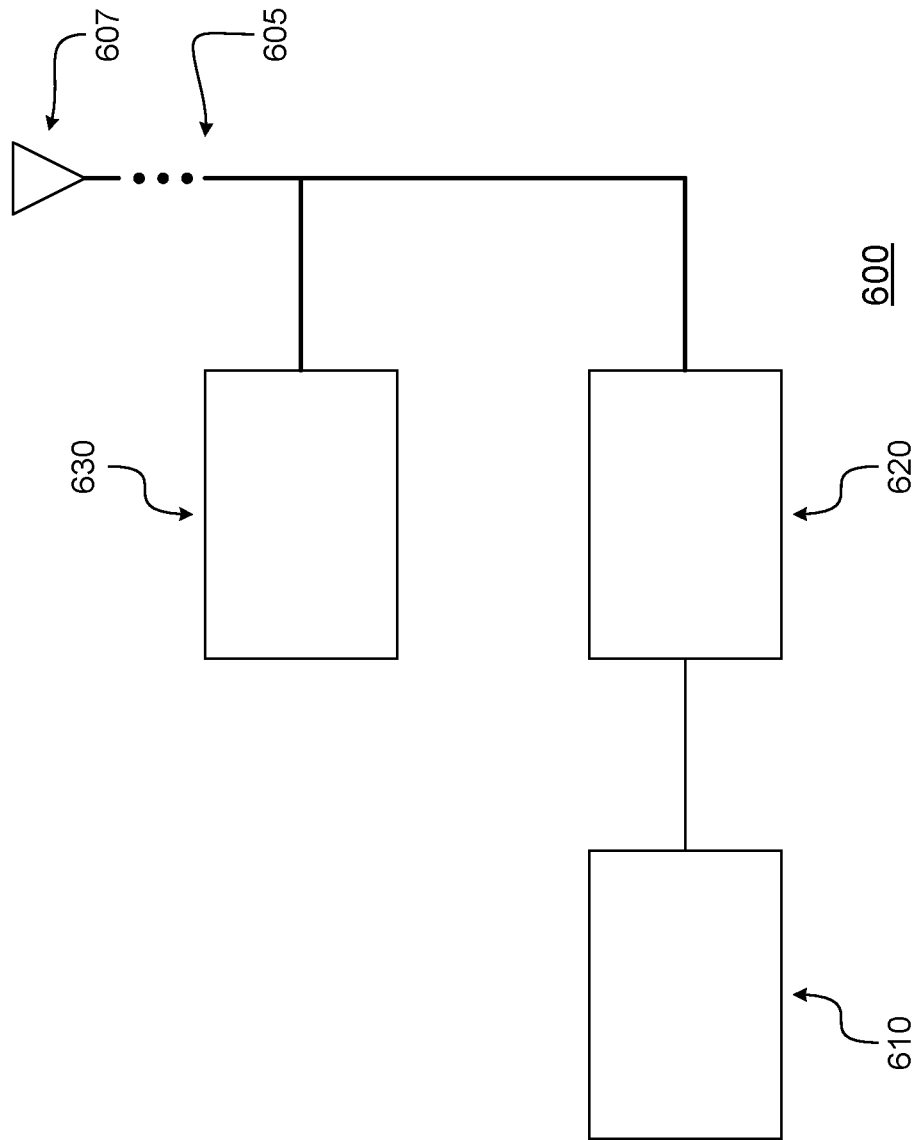


Fig. 6

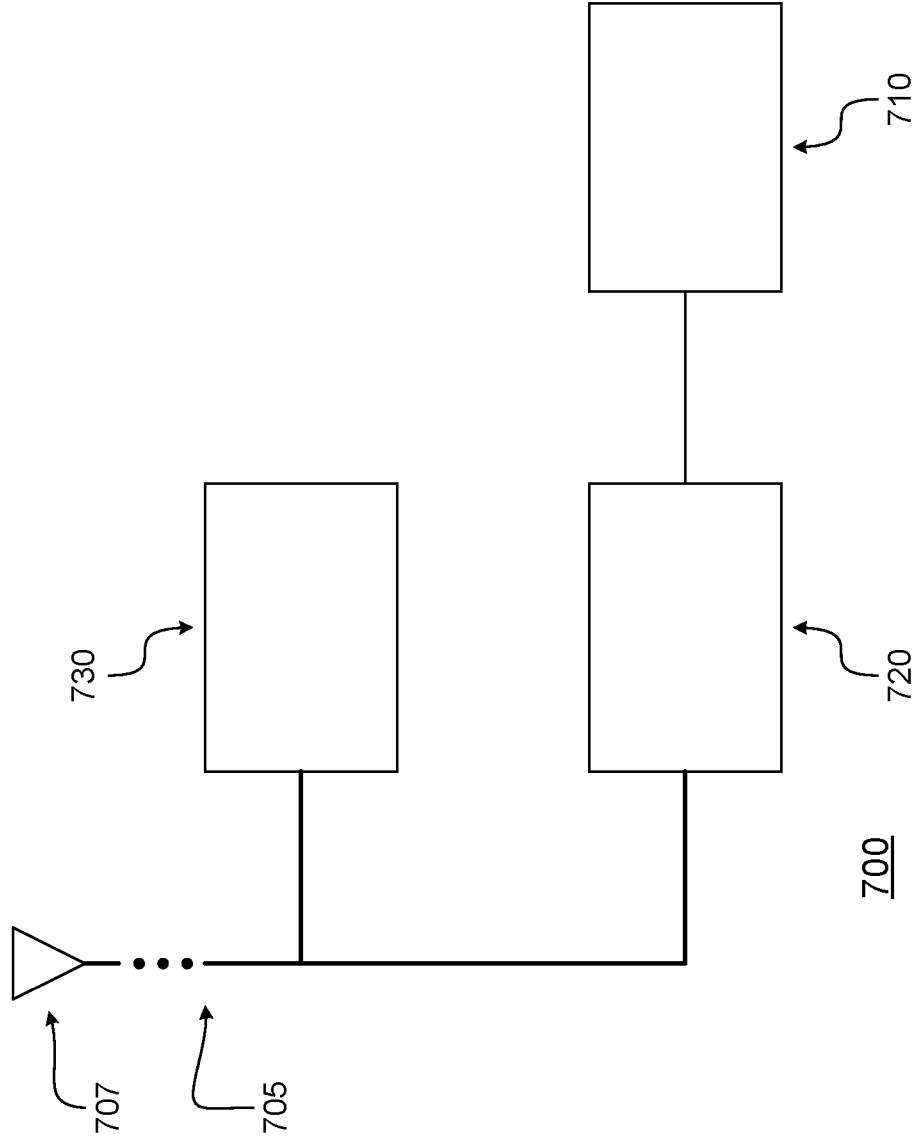


Fig. 7

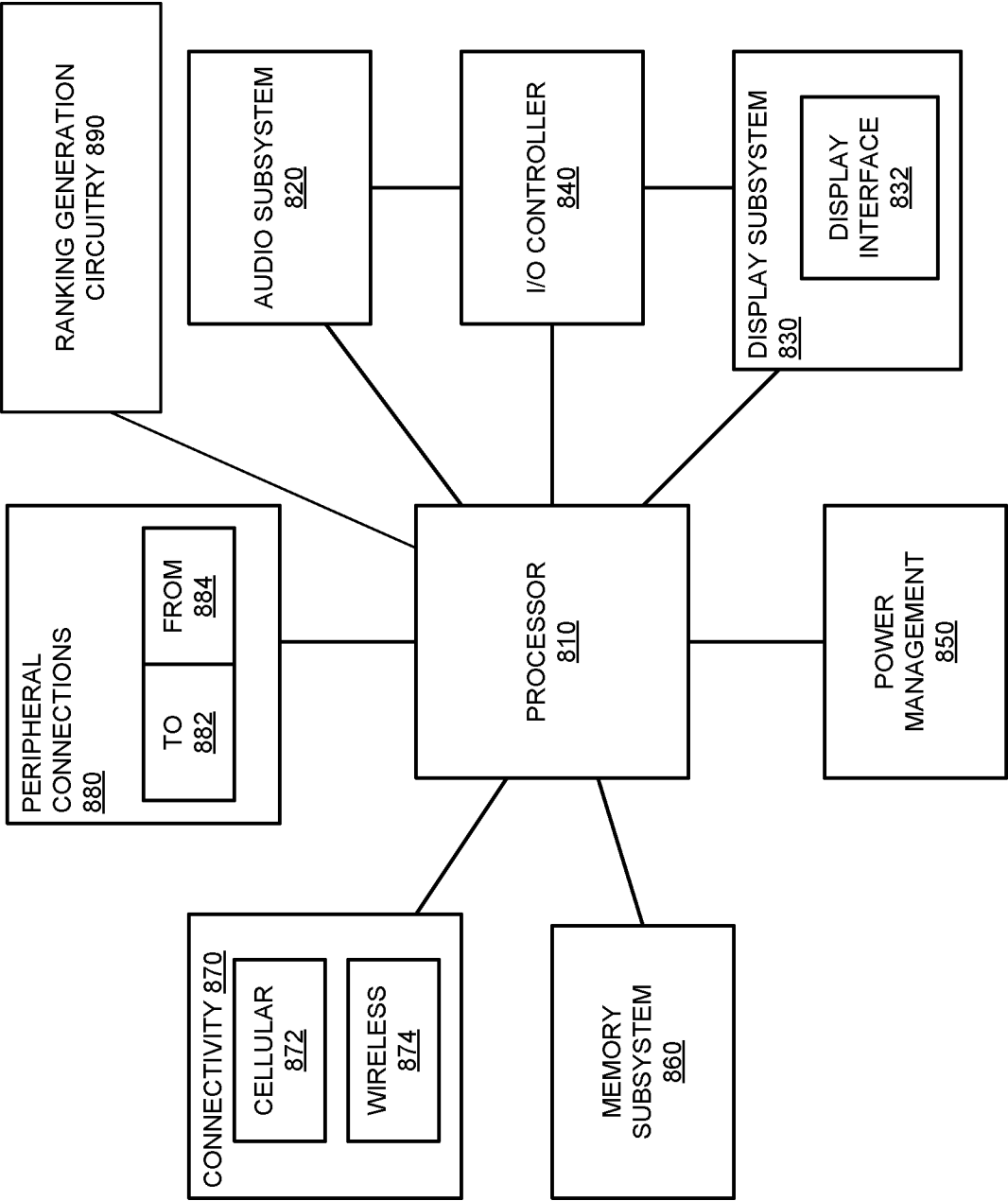


Fig. 8

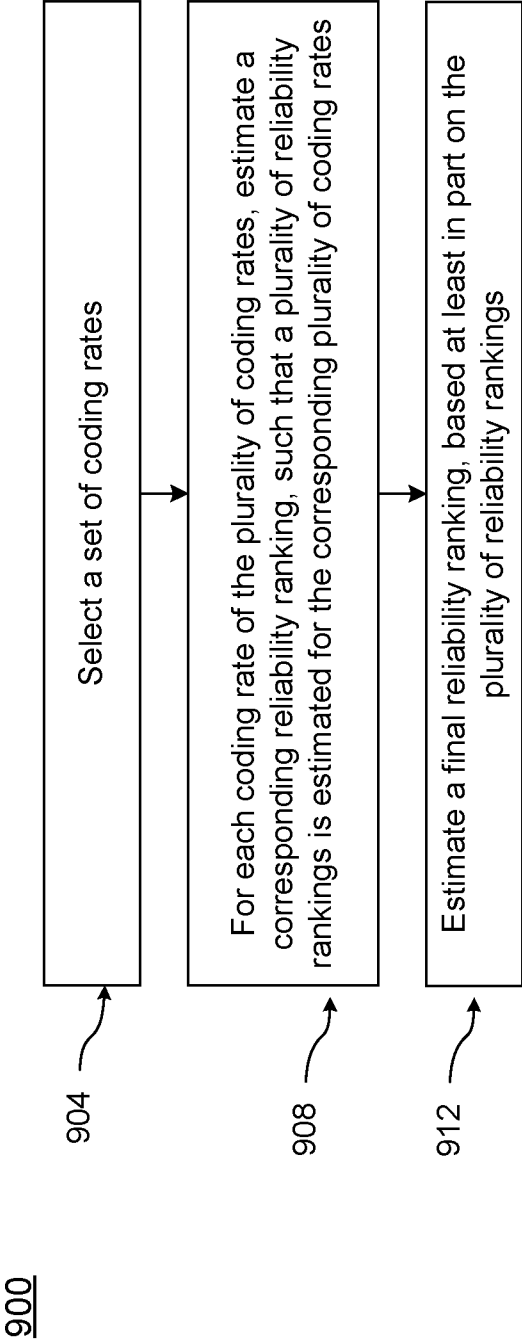


Fig. 9

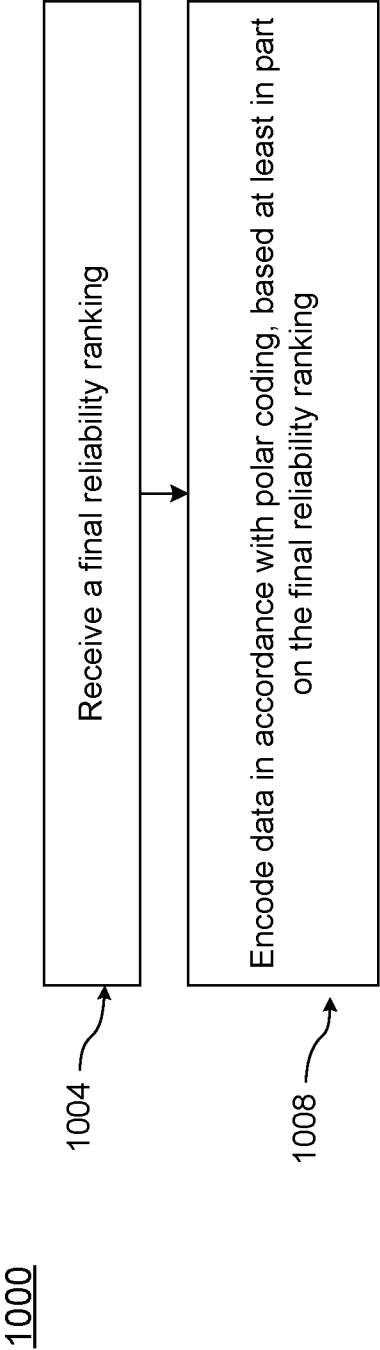


Fig. 10

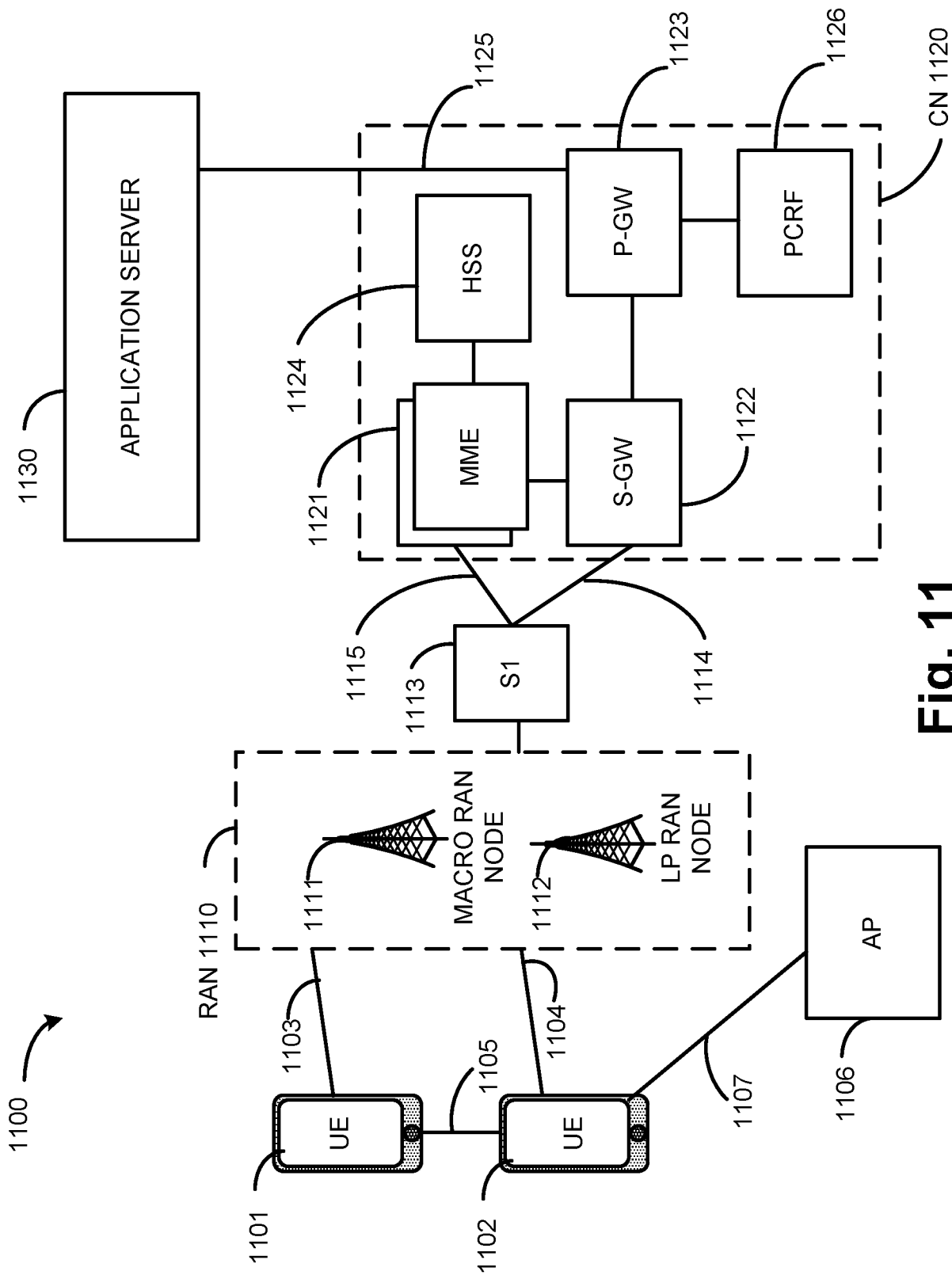


Fig. 11

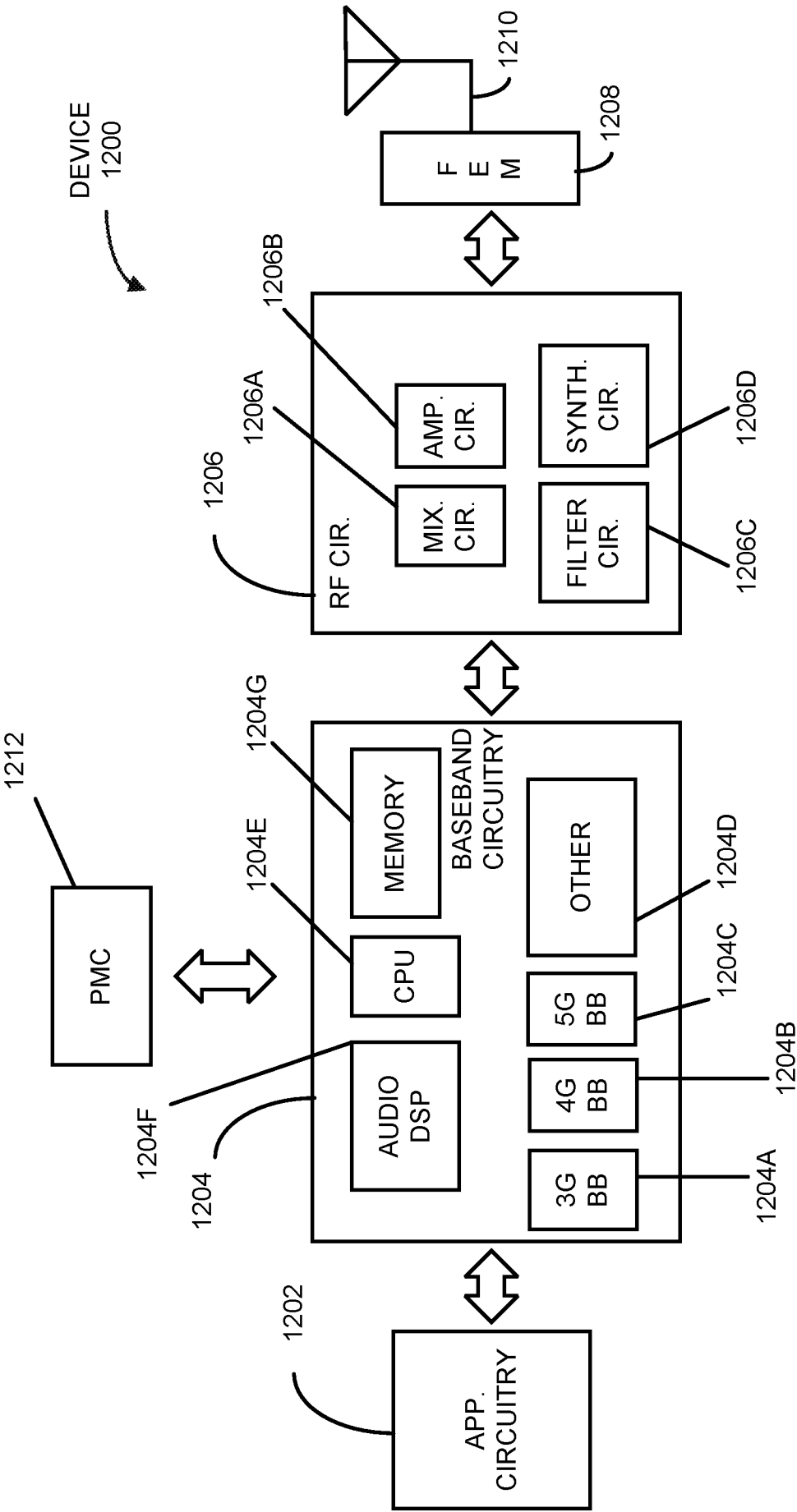


Fig. 12

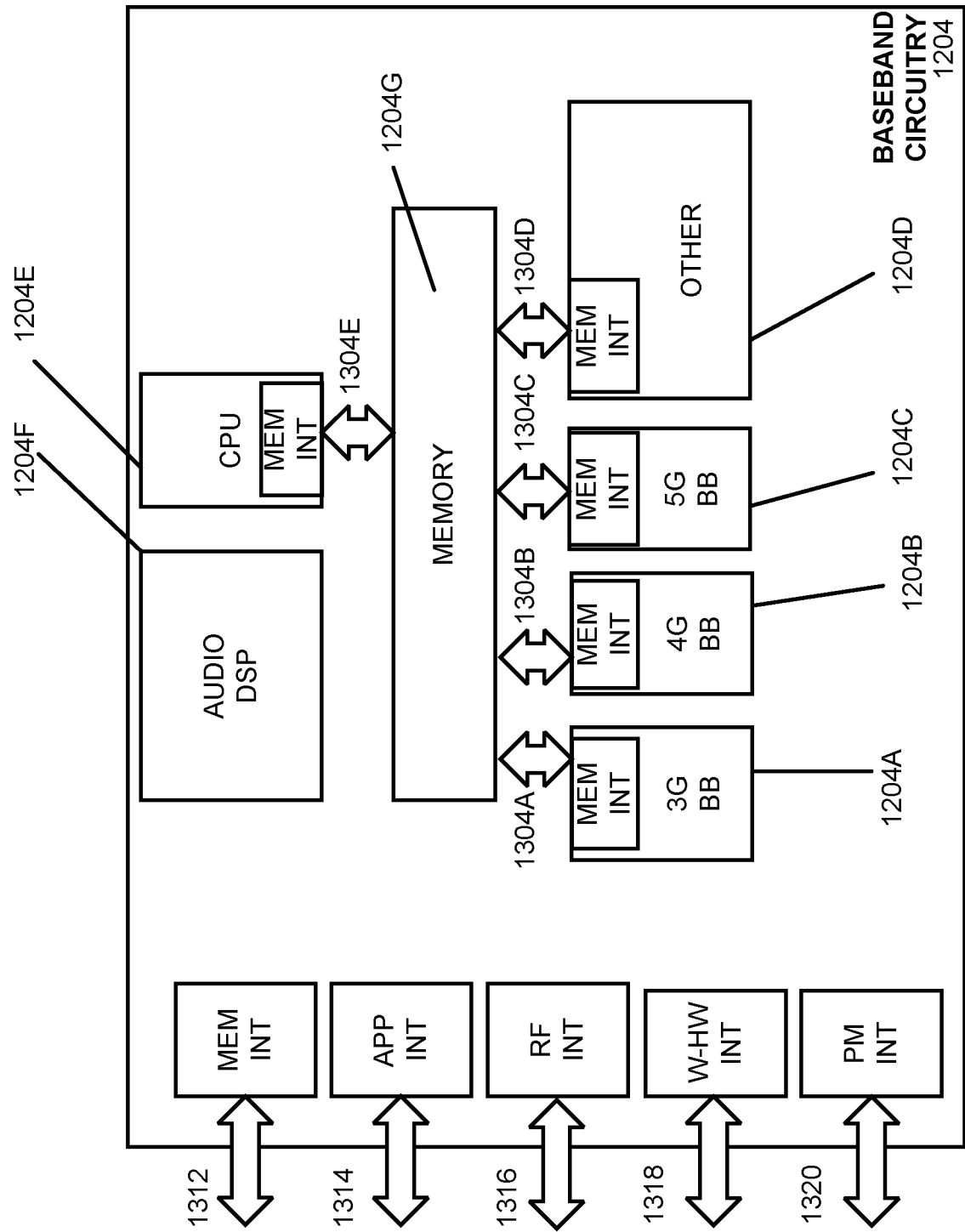


Fig. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/032546

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03M13/13 H03M13/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H03M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/092886 A1 (IONITA CORINA IOANA [US] ET AL) 2 April 2015 (2015-04-02)	1,3, 9-18,20, 22-25
Y A	paragraph [0016] - paragraph [0056]; figures 1A, 1B, 2, 6 claims 9-10	2,19 4-8,21
Y	----- HASSANI S HAMED ET AL: "Universal polar codes", 2014 IEEE INTERNATIONAL SYMPOSIUM ON INFORMATION THEORY, IEEE, 29 June 2014 (2014-06-29), pages 1451-1455, XP032635600, DOI: 10.1109/ISIT.2014.6875073 [retrieved on 2014-08-08] section 1.A. Preliminaries section 1.B. Base polar scheme ----- -/-	2,19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

10 August 2017

Date of mailing of the international search report

23/08/2017

Name and mailing address of the ISA/

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Authorized officer

Farman, Thomas

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/032546

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LI YUE ET AL: "A study of polar codes for MLC NAND flash memories", 2015 INTERNATIONAL CONFERENCE ON COMPUTING, NETWORKING AND COMMUNICATIONS (ICNC), IEEE, 16 February 2015 (2015-02-16), pages 608-612, XP032752610, DOI: 10.1109/ICCNC.2015.7069414 [retrieved on 2015-03-26] section V: "Adaptive Decoding". -----	1-25
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A	ALI ESLAMI ET AL: "A Practical Approach to Polar Codes", ARXIV.ORG, CORNELL UNIVERSITY LIBRARY, 201 OLIN LIBRARY CORNELL UNIVERSITY ITHACA, NY 14853, 27 July 2011 (2011-07-27), XP080517802, DOI: 10.1109/ISIT.2011.6033837 section IV: "Rate-Compatible Polar Codes"; the whole document -----	1-25

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/032546

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WO 2015066925	A1	14-05-2015	CN 105684316 A 15-06-2016
			EP 3054599 A1 10-08-2016
			US 2016254876 A1 01-09-2016
			WO 2015066925 A1 14-05-2015
