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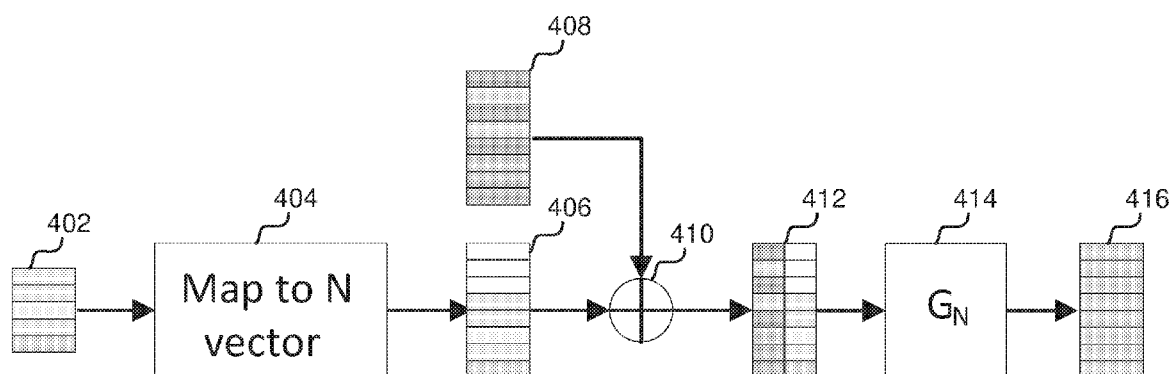


FIG. 4

(57) Abstract: A method, apparatus, and computer-readable medium for transmitting coded messages to a receiving device including constructing a data vector including a plurality of data bits, transforming the data vector into a u-domain vector, applying a mask to the u-domain vector, encoding the masked u-domain vector with polar encoding to generate a transmission vector, and transmitting, to the receiving device, the transmission vector.

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POLAR CODED HARQ-IR SCHEME

BACKGROUND

[0001] The present disclosure relates to wireless communications, and more particularly, to polar encoding masked messages.

[0002] Wireless communication networks are widely deployed to provide various communication services such as voice, video, packet data, messaging, broadcast, etc. These wireless networks may be multiple-access networks capable of supporting multiple users by sharing the available network resources. Examples of such multiple-access networks include Code Division Multiple Access (CDMA) networks, Time Division Multiple Access (TDMA) networks, Frequency Division Multiple Access (FDMA) networks, Orthogonal FDMA (OFDMA) networks, and Single-Carrier FDMA (SC-FDMA) networks.

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. For example, 5G NR (new radio) communications technology is envisaged to expand and support diverse usage scenarios and applications with respect to current mobile network generations. In an aspect, 5G communications technology includes enhanced mobile broadband addressing human-centric use cases for access to multimedia content, services and data; ultra-reliable-low latency communications (URLLC) with requirements, especially in terms of latency and reliability; and massive machine type communications for a very large number of connected devices, and typically transmitting a relatively low volume of non-delay-sensitive information. However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in 5G communications technology and beyond. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

[0004] In 5G communications, data sent by a transmitting device may not be accurately received by the receiving device. While the transmitting device may resend the entire data repeatedly until proper reception, this wastes network resources. Further, excessive retransmission may lower the overall data transmission rate of the network, which causes user equipment (UE) within the network to suffer performance degradation. Therefore, improvements in the transmission reliability may be desired.

SUMMARY

[0005] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0006] In some aspects, a method, apparatus, and computer-readable medium for transmitting coded messages to a receiving device include constructing a data vector including a plurality of data bits, transforming the data vector into a u-domain vector, applying a mask to the u-domain vector, encoding the masked u-domain vector with polar encoding to generate a transmission vector, and transmitting, to the receiving device, the transmission vector.

[0007] In other aspects, a method, apparatus, and computer-readable medium for transmitting coded messages to a receiving device include generating a first data vector having a plurality of data bits, generating a first u-domain vector by transforming the first data vector, wherein the first u-domain vector includes first active bits and first non-active bits, encoding the first u-domain vector with a polar encoder to generate a first transmission vector having a first plurality of bits and a second plurality of bits, transmitting the first plurality of bits, receiving an indication of a failed decoding of the first plurality of bits, in response to the indication of the failed decoding: generating a second data vector having a portion of the plurality of data bits, generating a mask based on the first data vector, generating a second u-domain vector by transforming the second data vector, wherein the second u-domain vector includes second active bits and second non-active bits, applying a mask to the second u-domain vector to generate an intermediate vector, encoding the intermediate vector with the polar encoder to generate a second transmission vector having a third plurality of bits and a fourth plurality of bits, and transmitting the third plurality of bits.

[0008] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The disclosed aspects will hereinafter be described in conjunction with the appended drawings, provided to illustrate and not to limit the disclosed aspects, wherein like designations denote like elements, and in which:

[0010] FIG. 1 is a schematic diagram of an example of a wireless communication network including at least one user equipment;

[0011] FIG. 2 is an example of rate-matching under repetition mode or puncture mode in HARQ;

[0012] FIG. 3 is an example of rate-matching under shorten mode in hybrid automatic repeat request (hybrid ARQ or HARQ);

[0013] FIG. 4 is an example of a block diagram of polar encoding of masked u-domain vectors;

[0014] FIG. 5 is examples of block diagrams of polar decoding of transmission vectors;

[0015] FIG. 6 is another example of a block diagram of polar encoding of masked u-domain vectors in a transmitting device.

[0016] FIG. 7 illustrates examples of masked encoders used in polar encoding of masked u-domain vectors.

[0017] FIG. 8 is an example of a matrix for generating masks for the u-domain vectors;

[0018] FIG. 9 is an example of a block diagram for active bit relocation for polar encoding with two transmissions;

[0019] FIGS. 10-21 illustrate examples of active bit relocation for polar encoding with two transmissions using two modes;

[0020] FIG. 22 is an example of a block diagram of the decoding process;

[0021] FIG. 23 a flow chart of a method for masking u-domain vectors for polar encoding;

[0022] FIG. 24 is a flow chart of an example of a method of retransmitting coded messages;

[0023] FIG. 25 is a flow chart of a method 2500 of decoding coded messages;

[0024] FIG. 26 is a schematic diagram of an example of a user equipment as described herein;

[0025] FIG. 27 is a schematic diagram of an example of a base station (BS) as described herein;

[0026] FIG. 28 is an example of a block diagram of polar encoding;

[0027] FIG. 29 is another example of a block diagram for active bit relocation for polar encoding with two transmissions.

[0028] FIG. 30 is yet another example of a block diagram for active bit relocation for polar encoding with two transmissions.

[0029] FIG. 31 shows graphs that illustrate examples of performance measurements of various transmission schemes.

[0030] FIG. 32 shows graphs that illustrate examples of performance measurements of various transmission schemes.

[0031] FIG. 33 shows graphs that illustrate examples of performance measurements of various transmission schemes.

DETAILED DESCRIPTION

[0032] Various aspects are now described with reference to the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It may be evident, however, that such aspect(s) may be practiced without these specific details. Additionally, the term “component” as used herein may be one of the parts that make up a system, may be hardware, firmware, and/or software stored on a computer-readable medium, and may be divided into other components.

[0033] The following description provides examples, and is not limiting of the scope, applicability, or examples set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Various examples may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to some examples may be combined in other examples.

[0034] It should be noted that the techniques described herein may be used for various wireless communication networks such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and other systems. The terms “system” and “network” are often used interchangeably. A CDMA system may implement a radio technology such as CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases 0 and A are commonly referred to as CDMA2000 1X, 1X, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1xEV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM™, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are new releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, and GSM are described

in documents from an organization named “3rd Generation Partnership Project” (3GPP). CDMA2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned above as well as other systems and radio technologies, including cellular (e.g., LTE) communications over a shared radio frequency spectrum band. The description below, however, describes an LTE/LTE-A and/or 5G New Radio (NR) system for purposes of example, and LTE or 5G NR terminology is used in much of the description below, although the techniques are applicable beyond LTE/LTE-A and 5G NR applications, e.g., to other next generation communication systems).

[0035] In some implementations, a transmitting device of data may use polar code to encode the data information prior to transmission. Polar code may select the most reliable transmission location after channel polarization transform and carry data bits on the most reliable transmission location. After rate-matching, polar code may work under the puncture mode, the shorten mode, and the repetition mode. Polar code, in some examples, may be used for hybrid automatic repeat request chase combining (HARQ-CC) or HARQ incremental redundancy (HARQ-IR). During HARQ-CC, the transmitting device transmits the same codeword at each re-transmission, with no coding gain at the retransmissions. During HARQ-IR, the transmitting device incrementally transmits parts of a long codeword at each retransmission, and may obtain additional coding gain after every retransmission. HARQ-CC may be easier to implement, while HARQ-IR may be more complex to decode and require a buffer at the receiving device.

[0036] In certain aspects, a mask may be applied to a data vector to relocate data bits for subsequent retransmissions in a communication system that utilizes the HARQ-IR scheme for redundancy. After the initial transmission, the communication system may receive a feedback message indicating the quality of transmission. The communication system may relocate data bits toward more reliable channels for subsequent resources by applying a mask prior to the polar encoding. The masking process may place certain data bits (i.e. ones that failed to be decoded by the receiving device) in more reliable communication channels for retransmission.

[0037] Referring to FIG. 1, in accordance with various aspects of the present disclosure, the wireless communication network 100 may include one or more base stations (BSs) 105, one or more UEs 110, and a core network 115. The BS 105 may include a number of components to implement features of the present disclosure. For example, a data component 170 within a modem 160 of the BS 105 may generate data vectors from data bits used in communicating with the UEs 110. The data vectors may contain textual, audio, and/or video information sent by the BS 105 to the UEs 110. A masking component 172 may mask the data vectors to relocate

portions of the data bits within the data vectors from one resource location to another. An encoding component 174 may apply polar encoding to the data vectors to transform the data vectors into codewords for transmission, and decode polar encoded codewords back to data vectors. A communication component 176 of the BS 105 may send and receive codewords to/from UEs 110. A decoding component 178 may decode polar-coded messages received by the BS 105.

[0038] Similarly, the UE 110 may include a number of components to implement features of the present disclosure. For example, a data component 150 within a modem 140 of the UE 110 may generate data vectors from data bits used in communicating with the BS 105. A masking component 152 may mask the data vectors to relocate portions of the data bits within the data vectors from one resource location to another. An encoding component 154 may apply polar encoding to the data vectors to transform the data vectors into codewords for transmission, and decode polar encoded codewords back to data vectors. A communication component 156 of the UE 110 may send and receive codewords to/from the BS 105. A decoding component 158 may decode polar-coded messages received by the UE 110.

[0039] The modem 160 of base station 105 may be configured to communicate with other base stations 105 and UEs 110 via a cellular network or other wireless and wired networks. The modem 140 of UE 110 may be configured to communicate via a cellular network, a Wi-Fi network, or other wireless and wired networks. The modems 140, 160 may receive and transmit data packets, via transceivers.

[0040] The core network 115 may provide user authentication, access authorization, tracking, internet protocol (IP) connectivity, and other access, routing, or mobility functions. The base stations 105 may interface with the core network 115 through backhaul links 120 (e.g., S1, etc.). The base stations 105 may perform radio configuration and scheduling for communication with the UEs 110, or may operate under the control of a base station controller (not shown). In various examples, the base stations 105 may communicate, either directly or indirectly (e.g., through core network 115), with one another over backhaul links 125 (e.g., X1, etc.), which may be wired or wireless communication links.

[0041] The base stations 105 may wirelessly communicate with the UEs 110 via one or more base station antennas. Each of the base stations 105 may provide communication coverage for a respective geographic coverage area 130. In some examples, the base stations 105 may be referred to as a base transceiver station, a radio base station, an access point, an access node, a radio transceiver, a NodeB, eNodeB (eNB), gNB, Home NodeB, a Home eNodeB, a relay, or some other suitable terminology. The geographic coverage area 130 for a base station 105 may

be divided into sectors or cells making up only a portion of the coverage area (not shown). The wireless communication network 100 may include base stations 105 of different types (e.g., macro base stations or small cell base stations, described below). Additionally, the plurality of base stations 105 may operate according to different ones of a plurality of communication technologies (e.g., 5G (New Radio or “NR”), fourth generation (4G)/LTE, 3G, Wi-Fi, Bluetooth, etc.), and thus there may be overlapping geographic coverage areas 130 for different communication technologies.

[0042] In some examples, the wireless communication network 100 may be or include one or any combination of communication technologies, including a NR or 5G technology, a Long Term Evolution (LTE) or LTE-Advanced (LTE-A) or MuLTEfire technology, a Wi-Fi technology, a Bluetooth technology, or any other long or short range wireless communication technology. In LTE/LTE-A/MuLTEfire networks, the term evolved node B (eNB) may be generally used to describe the base stations 105, while the term UE may be generally used to describe the UEs 110. The wireless communication network 100 may be a heterogeneous technology network in which different types of eNBs provide coverage for various geographical regions. For example, each eNB or base station 105 may provide communication coverage for a macro cell, a small cell, or other types of cell. The term “cell” is a 3GPP term that can be used to describe a base station, a carrier or component carrier associated with a base station, or a coverage area (e.g., sector, etc.) of a carrier or base station, depending on context.

[0043] A macro cell may generally cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs 110 with service subscriptions with the network provider.

[0044] A small cell may include a relative lower transmit-powered base station, as compared with a macro cell, that may operate in the same or different frequency bands (e.g., licensed, unlicensed, etc.) as macro cells. Small cells may include pico cells, femto cells, and micro cells according to various examples. A pico cell, for example, may cover a small geographic area and may allow unrestricted access by UEs 110 with service subscriptions with the network provider. A femto cell may also cover a small geographic area (e.g., a home) and may provide restricted access and/or unrestricted access by UEs 110 having an association with the femto cell (e.g., in the restricted access case, UEs 110 in a closed subscriber group (CSG) of the base station 105, which may include UEs 110 for users in the home, and the like). An eNB for a macro cell may be referred to as a macro eNB. An eNB for a small cell may be referred to as a small cell eNB, a pico eNB, a femto eNB, or a home eNB. An eNB may support one or multiple (e.g., two, three, four, and the like) cells (e.g., component carriers).

[0045] The communication networks that may accommodate some of the various disclosed examples may be packet-based networks that operate according to a layered protocol stack and data in the user plane may be based on the IP. A user plane protocol stack (e.g., packet data convergence protocol (PDCP), radio link control (RLC), MAC, etc.), may perform packet segmentation and reassembly to communicate over logical channels. For example, a MAC layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use HARQ to provide retransmission at the MAC layer to improve link efficiency. In the control plane, the RRC protocol layer may provide establishment, configuration, and maintenance of an RRC connection between a UE 110 and the base stations 105. The RRC protocol layer may also be used for core network 115 support of radio bearers for the user plane data. At the physical (PHY) layer, the transport channels may be mapped to physical channels.

[0046] The UEs 110 may be dispersed throughout the wireless communication network 100, and each UE 110 may be stationary or mobile. A UE 110 may also include or be referred to by those skilled in the art as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology. A UE 110 may be a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a tablet computer, a laptop computer, a cordless phone, a smart watch, a wireless local loop (WLL) station, an entertainment device, a vehicular component, a customer premises equipment (CPE), or any device capable of communicating in wireless communication network 100. Additionally, a UE 110 may be Internet of Things (IoT) and/or machine-to-machine (M2M) type of device, e.g., a low power, low data rate (relative to a wireless phone, for example) type of device, that may in some aspects communicate infrequently with wireless communication network 100 or other UEs. A UE 110 may be able to communicate with various types of base stations 105 and network equipment including macro eNBs, small cell eNBs, macro gNBs, small cell gNBs, relay base stations, and the like.

[0047] A UE 110 may be configured to establish one or more wireless communication links 135 with one or more base stations 105. The wireless communication links 135 shown in wireless communication network 100 may carry uplink (UL) transmissions from a UE 110 to a base station 105, or downlink (DL) transmissions, from a base station 105 to a UE 110. The downlink transmissions may also be called forward link transmissions while the uplink

transmissions may also be called reverse link transmissions. Each wireless communication link 135 may include one or more carriers, where each carrier may be a signal made up of multiple sub-carriers (e.g., waveform signals of different frequencies) modulated according to the various radio technologies described above. Each modulated signal may be sent on a different sub-carrier and may carry control information (e.g., reference signals, control channels, etc.), overhead information, user data, etc. In an aspect, the wireless communication links 135 may transmit bidirectional communications using frequency division duplex (FDD) (e.g., using paired spectrum resources) or time division duplex (TDD) operation (e.g., using unpaired spectrum resources). Frame structures may be defined for FDD (e.g., frame structure type 1) and TDD (e.g., frame structure type 2). Moreover, in some aspects, the wireless communication links 135 may represent one or more broadcast channels.

[0048] In some aspects of the wireless communication network 100, base stations 105 or UEs 110 may include multiple antennas for employing antenna diversity schemes to improve communication quality and reliability between base stations 105 and UEs 110. Additionally or alternatively, base stations 105 or UEs 110 may employ multiple input multiple output (MIMO) techniques that may take advantage of multi-path environments to transmit multiple spatial layers carrying the same or different coded data.

[0049] Wireless communication network 100 may support operation on multiple cells or carriers, a feature which may be referred to as carrier aggregation (CA) or multi-carrier operation. A carrier may also be referred to as a component carrier (CC), a layer, a channel, etc. The terms “carrier,” “component carrier,” “cell,” and “channel” may be used interchangeably herein. A UE 110 may be configured with multiple downlink CCs and one or more uplink CCs for carrier aggregation. Carrier aggregation may be used with both FDD and TDD component carriers. The base stations 105 and UEs 110 may use spectrum up to Y MHz (e.g., Y = 5, 10, 15, or 20 MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x = number of component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or less carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

[0050] The wireless communications network 100 may further include base stations 105 operating according to Wi-Fi technology, e.g., Wi-Fi access points, in communication with

UEs 110 operating according to Wi-Fi technology, e.g., Wi-Fi stations (STAs) via communication links in an unlicensed frequency spectrum (e.g., 5 GHz). When communicating in an unlicensed frequency spectrum, the STAs and AP may perform a clear channel assessment (CCA) or listen before talk (LBT) procedure prior to communicating in order to determine whether the channel is available.

[0051] Additionally, one or more of base stations 105 and/or UEs 110 may operate according to a NR or 5G technology referred to as millimeter wave technology. For example, mmW technology includes transmissions in mmW frequencies and/or near mmW frequencies. Extremely high frequency (EHF) is part of the radio frequency (RF) in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in this band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. For example, the super high frequency (SHF) band extends between 3 GHz and 30 GHz, and may also be referred to as centimeter wave. Communications using the mmW and/or near mmW radio frequency band has extremely high path loss and a short range. As such, base stations 105 and/or UEs 110 operating according to the mmW technology may utilize beamforming in their transmissions to compensate for the extremely high path loss and short range.

[0052] Active bit relocation using u-domain mask (ARUM) allows each transmission to have an independent encoding and rate-matching scheme. ARUM works with various rate-matching schemes and may obtain additional coding gains. The transmissions may be self-decodable. The process of masking the u-domain vectors may adhere to channel polarization transform rules and obtain desirable coding gains of polar code. In some implementations, the loss may be less than 0.2 decibel compared with theoretical transmission limit.

[0053] Referring to FIG. 2, which shows an example 200 of rate-matching under repetition mode or puncture mode in HARQ. When transmitting using the repetition mode, a data vector 210 may include active bits and non-active bits (i.e. frozen bits). A matrix 212 may transform the data vector 210 into a transmission vector 214. Some of the bits in the transmission vector 214 may be sent via the communication links 135, while other bits in the transmission vector 214 may be transmitted more than once. A receiving decoder may add the corresponding log-likelihood ratios (LLRs) of the copies of the same bits during decoding. When transmitting using the puncture mode, some of the bits in the transmission vector 214 may be sent via the communication links 135, while other bits in the transmission vector 214 may not be transmitted. A receiving decoder may set the LLRs of the bits not transmitted to zero.

[0054] Referring to FIG. 3, which shows an example 300 of rate-matching under shorten mode in HARQ. When transmitting using the puncture mode, a data vector 310 may include active bits and non-active bits, such as frozen bits and shorten bits 312. A matrix 320 may transform the data vector 310 into an transmission vector 330. Some of the bits in the transmission vector 330 may be sent via the communication links 135, while other bits in the transmission vector 330 may be zero-valued and unnecessary to transmit. A receiving decoder may set the corresponding LLRs to positive infinity because of the known zero bits. The LLR of a bit may

be calculated using the formula $LLR(b) = \log \left(\frac{P(b=0)}{P(b=1)} \right)$.

[0055] FIG. 4 shows an example of a block diagram 400 of polar encoding of masked u-domain vectors, or an intermediate vector. A data vector 402 may include a number of data bits. By transforming the data vector 402 with a mapping matrix 404, the data vector 402 is transformed to a u-domain vector 406. The u-domain vector 406 may be N-bit vector that results from ratematching the data vector 402. The u-domain vector 406 may include more bits than the data vector 402. A bit-wise addition 410 may be performed on the u-domain vector 406 and a masking vector 408 to create an intermediate vector 412. The bit-wise addition 410 may be a masking process that relocates one or more bits in the u-domain vector 406 from one resource location to another. For example, the masking process may relocate the one or more bits in the u-domain vector 406 from a resource location having low transmission reliability to another resource location having high transmission reliability. The intermediate vector 412 may be transformed to a transmission vector 416 by a polar encoding matrix 414. The polar encoding matrix 414 may perform a polar encoding transformation. The transmission vector 416 may be sent to a receiving device. Throughout the figures of the present application different bits may be indicated with different colors. The same information identifying the different bits may also be conveyed using different patterns.

[0056] FIG. 5 shows an example of a block diagram 500 of polar decoding of transmission vectors with unknown mask and an example of a block diagram 550 of polar decoding of transmission vectors with known mask. A masking vector 504 may be transformed by a polar encoding matrix 506 and transmitted across a channel 508 into a LLR mask vector 510. The receiving device may perform a LLR check 512 of a transmission vector 502 and the LLR mask vector 510. The result of the LLR check 512 is inputted into a polar decoder 514 to generate a received data vector 516. The received data vector 516 may include data bits sent by the transmitting device.

[0057] Still referring to FIG. 5, a masking vector 564 may be transformed by a polar encoding matrix 566 into a second mask vector 570. The receiving device may perform a sign flip 572 of a transmission vector 562 and the second mask vector 570. The result of the sign flip 572 is inputted into a polar decoder 574 to generate a received data vector 576. The received data vector 576 may include data bits sent by the transmitting device.

[0058] Referring now to FIG. 6, which illustrates another example of a block diagram 600 of polar encoding of masked u-domain vectors in a transmitter. In some implementations, the transmitting device attaches 604 cyclic redundancy check (CRC) bits to data bits 602 to generate a data vector 606 having k_1 bits. The data vector 606 is transformed by a masked encoder 608 into an intermediate vector 610 having N_1 bits. The intermediate vector 610 may be transformed by a rate match matrix 612 to generate a first transmission vector 614 having M_1 bits.

[0059] Still referring to FIG. 6, if the transmitting device receives an indication of failed decoding of some bits within the data bits 602, a bit selection 680 may be performed to select data bits 622 for a first repeated transmission. In certain implementations, the transmitting device attaches 624 CRC bits to data bits 622 to generate a data vector 626 having k_2 bits. The data vector 626 is transformed by a masked encoder 628 into an intermediate vector 630 having N_2 bits. The intermediate vector 630 may be transformed by a rate match matrix 632 to generate a second transmission vector 634 having M_2 bits.

[0060] Referring again to FIG. 6, if the transmitting device receives another indication of failed decoding of some bits within the data bits 602, a bit selection 680 may be performed to select data bits 642 for a second repeated transmission. In certain implementations, the transmitting device attaches 644 CRC bits to data bits 642 to generate a data vector 646 having k_3 bits. The data vector 646 is transformed by a masked encoder 648 into an intermediate vector 650 having N_3 bits. The intermediate vector 650 may be transformed by a rate match matrix 652 to generate a second transmission vector 654 having M_3 bits.

[0061] Referring to FIG. 6, if the transmitting device receives yet another indication of failed decoding of some bits within the data bits 602, a bit selection 680 may be performed to select data bits 662 for a third repeated transmission. In certain implementations, the transmitting device attaches 664 CRC bits to data bits 662 to generate a data vector 666 having k_4 bits. The data vector 666 is transformed by a masked encoder 668 into an intermediate vector 670 having N_4 bits. The intermediate vector 670 may be transformed by a rate match matrix 672 to generate a second transmission vector 674 having M_4 bits. More or fewer retransmissions than those shown in FIG. 6 may be supported.

[0062] Turning to FIG. 7, which illustrates examples of masked encoders 608, 628, 648, 668 used in polar encoding of masked u-domain vectors. In some implementations, the data vectors 606, 626, 646, 666 may be input of the masked encoders 608, 628, 648, 668. Mapping matrices may map the data vectors 606, 626, 646, 666 to N_{MAX} vectors 712, 722, 732, 742. The N_{MAX} vectors 712, 722, 732, 742 may each include N_{MAX} bits. During the initial transmission, the N_{MAX} vector 712 may be truncated by selecting 714 last N_1 bits of the N_{MAX} bits to generate an intermediate vector 716. The intermediate vector 716 may have N_1 bits, where N_1 may be less than or equal to N_{MAX} . Next, the intermediate vector 716 may be transformed by a polar encoding matrix 718.

[0063] Still referring to FIG. 7, during the first repeated transmission, the N_{MAX} vector 722 may be masked by the N_{MAX} vector 712 using a bit-wise addition operation 750. After the masking process, the masked N_{MAX} vector 722 may be truncated by selecting 724 last N_2 bits of the N_{MAX} bits to generate an intermediate vector 726. The intermediate vector 726 may have N_2 bits, where N_2 may be less than or equal to N_{MAX} . Next, the intermediate vector 726 may be transformed by a polar encoding matrix 728.

[0064] Referring again to FIG. 7, during the second repeated transmission, the N_{MAX} vector 732 may be masked by the N_{MAX} vector 712 using a bit-wise addition operation 752. After the masking process, the masked N_{MAX} vector 732 may be truncated by selecting 734 last N_3 bits of the N_{MAX} bits to generate an intermediate vector 736. The intermediate vector 736 may have N_3 bits, where N_3 may be less than or equal to N_{MAX} . Next, the intermediate vector 736 may be transformed by a polar encoding matrix 738.

[0065] Referring still to FIG. 7, during the third repeated transmission, the N_{MAX} vector 742 may be masked by the N_{MAX} vectors 712, 732 using bit-wise addition operations 754, 756. After the masking process, the masked N_{MAX} vector 742 may be truncated by selecting 744 last N_4 bits of the N_{MAX} bits to generate an intermediate vector 746. The intermediate vector 746 may have N_4 bits, where N_4 may be less than or equal to N_{MAX} . Next, the intermediate vector 746 may be transformed by a polar encoding matrix 748.

[0066] Turning to FIG. 8, which illustrates an example of a matrix 800 for generating masks for the u-domain vectors. The mask for the u-domain vector for the i -th transmission may be expressed as $v_i = [u_1, u_2, \dots, u_{i-1}] \times S_i$ where $S_i = \text{kron}(R_{[1:i-1,i]}, I_{N_{max}}) = R_{[1:i-1,i]} \otimes I_{N_{max}}$. Here, R is a matrix $R = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}^{\otimes T}$, T is the maximum transmission times. $I_{N_{max}}$ is the N_{max} by N_{max} sized identity matrix. In the block diagram 800, masks 802, 804 are the masks for the u-domain vectors for the third and fifth transmissions. In some examples, the first, second, third, fourth,

fifth, sixth, seventh, and eighth masks may be 0, u_1 , u_1 , $u_1+u_2+u_3$, u_1 , $u_1+u_2+u_5$, $u_1+u_3+u_5$, and $u_1+u_2+u_3+u_4+u_5+u_6+u_7$, respectively.

[0067] FIG. 9 illustrates an example of a block diagram 900 for active bit relocation for polar encoding with two transmissions. To achieve active bit relocation, the best K indices are picked out from all the $N_1 + N_2 + \dots + N_t$ polarized channels, and where K_t active-bits from block $[1, 2, t-1]$ are relocated to block t . During the first transmission, a u-domain vector 910 is transformed by a polar encoding matrix 934 into a transmission vector 940. The u-domain vector 910 may include one or more data bits 912, a repeated bit 914 in an unreliable transmission location 916. After the transmission of the transmission vector 940, a second transmission may be initiated due to the failed decoding of the repeated bit 914. During the second transmission, a u-domain vector 920 may include the repeated bit 914 at a reliable transmission location 922. The u-domain vector 920 may be bit-wisely added 928 with the u-domain vector 910 to form an intermediate vector 930. The intermediate vector 930 may be transformed by a polar encoding matrix 932 into a transmission vector 950. The repeated bit 914 may be relocated to the reliable transmission location 922 having a higher transmission reliability than the unreliable transmission location 916. For example, the unreliable transmission location 916 may be a resource location where information transmitted has a low probability (e.g. 10% for every transmission) of being decoded by receiving device. The reliable transmission location 922 may be a different resource location where information transmitted has a high probability (e.g. 99% for every transmission) of being decoded by receiving device. At the receiving device, the u-domain vector 920 may be decoded before the u-domain vector 910.

[0068] FIGS. 10-21 illustrate examples of active bit relocation for polar encoding with two transmissions using two modes.

[0069] Referring now to FIG. 10, which shows an example of a block diagram 1000 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize puncture or repetition mode, and the second transmission may utilize puncture or repetition mode. For example, during the first transmission, a u-domain vector 1010, or an intermediate vector 1012 may be transformed, via a polar encoding matrix 1014, into a transmission vector 1016. In puncture mode, bits 1018 in the transmission vector 1016 may not be transmitted. During the second transmission, a u-domain vector 1020 may be bit-wisely added with the u-domain vector 1010 to produce an intermediate vector 1022. The intermediate vector 1022 may be transformed by a polar encoding matrix 1024 into a transmission vector 1026. In repetition mode, bits 1028 in the transmission vector 1026 may not be transmitted during

retransmission while remaining bits in the transmission vector 1026 are retransmitted. A legend 1050 indicates the types of bits and their associated colors.

[0070] Referring now to FIG. 11, which shows an example of a block diagram 1100 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize puncture or repetition mode, and the second transmission may utilize puncture or repetition mode. For example, during the first transmission, a u-domain vector 1110 or an intermediate vector 1112 may be transformed, via a polar encoding matrix 1114, into a transmission vector 1116 having N bits. In puncture mode, bits 1118 in the transmission vector 1016 may not be transmitted. During the second transmission, a u-domain vector 1120 may be bit-wised added with the u-domain vector 1110 to produce an intermediate vector 1122. The intermediate vector 1122 may be shortened to produce a shortened intermediate vector 1124. The intermediate vector 1124 may be transformed by a polar encoding matrix 1116 into a transmission vector 1128 having N/2 bits. In repetition mode, bits 1130 in the transmission vector 1128 may not be transmitted during retransmission while remaining bits in the transmission vector 1128 are retransmitted.

[0071] Referring now to FIG. 12, which shows an example of a block diagram 1200 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize puncture or repetition mode, and the second transmission may utilize puncture or repetition mode. For example, during the first transmission, a u-domain vector 1210 may be mapped to an intermediate vector 1212. The intermediate vector 1212 may be shortened into a shortened intermediate vector 1214 by removing a portion of the bits in the intermediate vector 1212. Next, the shortened intermediate vector 1214 may be transformed, via a polar encoding matrix 1216, into a transmission vector 1218 having N bits. In puncture mode, bits 1219 in the transmission vector 1218 may not be transmitted. During the second transmission, a u-domain vector 1220 may be bit-wised added with the u-domain vector 1210 to produce an intermediate vector 1222. The intermediate vector 1222 may be transformed by a polar encoding vector 1224 into a transmission vector 1226 having 2N bits. In repetition mode, bits 1228 in the transmission vector 1126 may not be transmitted during retransmission while remaining bits in the transmission vector 1226 are retransmitted.

[0072] Referring now to FIG. 13, which shows an example of a block diagram 1300 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize puncture or repetition mode, and the second transmission may utilize shorten mode. For example, during the first transmission, a u-domain vector 1310, or an intermediate vector 1312 may be transformed, via a polar encoding matrix 1314, into a transmission vector 1316. During

the second transmission, a u-domain vector 1320 may be bit-wised added with the u-domain vector 1310 to produce an intermediate vector 1322. The intermediate vector 1322 may be transformed by a polar encoding matrix 1324 into a transmission vector 1326. In shorten mode, bits 1328 in the transmission vector 1326 may be zero-valued and unnecessary to transmit.

[0073] Referring now to FIG. 14, which shows an example of a block diagram 1400 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize puncture or repetition mode, and the second transmission may utilize shorten mode. For example, during the first transmission, a u-domain vector 1410 or an intermediate vector 1412 may be transformed, via a polar encoding matrix 1414, into a transmission vector 1416 having N bits. During the second transmission, a u-domain vector 1420 may be bit-wised added with the u-domain vector 1410 to produce an intermediate vector 1422. The intermediate vector 1422 may be shortened to produce a shortened intermediate vector 1424. The intermediate vector 1424 may be transformed by a polar encoding matrix 1426 into a transmission vector 1428 having N/2 bits. In shorten mode, bits 1430 in the transmission vector 1428 may be zero-valued and unnecessary to transmit.

[0074] Referring now to FIG. 15, which shows an example of a block diagram 1500 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize puncture or repetition mode, and the second transmission may utilize shorten mode. For example, during the first transmission, a u-domain vector 1510 may be mapped to an intermediate vector 1512. The intermediate vector 1512 may be shortened into a shortened intermediate vector 1514 by removing a portion of the bits in the intermediate vector 1512. Next, the shortened intermediate vector 1514 may be transformed, via a polar encoding matrix 1516, into a transmission vector 1518 having N bits. During the second transmission, a u-domain vector 1520 may be bit-wised added with the u-domain vector 1510 to produce an intermediate vector 1522. The intermediate vector 1522 may be transformed by a polar encoding vector 1524 into a transmission vector 1526 having 2N bits. In shorten mode, bits 1528 in the transmission vector 1526 may be zero-valued and unnecessary to transmit.

[0075] Referring now to FIG. 16, which shows an example of a block diagram 1600 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize shorten mode, and the second transmission may utilize puncture or repetition mode. For example, during the first transmission, a u-domain vector 1610, or an intermediate vector 1612 may be transformed, via a polar encoding matrix 1614, into a transmission vector 1616. In shorten mode, bits 1618 in the transmission vector 1616 may be zero-valued and unnecessary to transmit. During the second transmission, a u-domain vector 1620 may be bit-wised added

with the u-domain vector 1610 to produce an intermediate vector 1622. The intermediate vector 1622 may be transformed by a polar encoding matrix 1624 into a transmission vector 1626.

[0076] Referring now to FIG. 17, which shows an example of a block diagram 1700 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize shorten mode, and the second transmission may utilize puncture or repetition mode. For example, during the first transmission, a u-domain vector 1710 or an intermediate vector 1712 may be transformed, via a polar encoding matrix 1714, into a transmission vector 1716 having N bits. In repetition mode, bits 1718 in the transmission vector 1716 may be zero-valued and unnecessary to transmit. During the second transmission, a u-domain vector 1720 may be bit-wised added with the u-domain vector 1710 to produce an intermediate vector 1722. The intermediate vector 1722 may be shortened to produce a shortened intermediate vector 1724. The intermediate vector 1724 may be transformed by a polar encoding matrix 1726 into a transmission vector 1728 having N/2 bits.

[0077] Referring now to FIG. 18, which shows an example of a block diagram 1800 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize shorten mode, and the second transmission may utilize puncture or repetition mode. For example, during the first transmission, a u-domain vector 1810 may be mapped to an intermediate vector 1812. The intermediate vector 1812 may be shortened into a shortened intermediate vector 1814 by removing a portion of the bits in the intermediate vector 1812. Next, the shortened intermediate vector 1814 may be transformed, via a polar encoding matrix 1816, into a transmission vector 1818 having N bits. In shorten mode, bits 1819 in the transmission vector 1818 may be zero-valued and unnecessary to transmit. During the second transmission, a u-domain vector 1820 may be bit-wised added with the u-domain vector 1810 to produce an intermediate vector 1822. The intermediate vector 1822 may be transformed by a polar encoding vector 1824 into a transmission vector 1826 having 2N bits.

[0078] Referring now to FIG. 19, which shows an example of a block diagram 1900 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize shorten mode, and the second transmission may utilize shorten mode. For example, during the first transmission, a u-domain vector 1910, or an intermediate vector 1912 may be transformed, via a polar encoding matrix 1914, into a transmission vector 1916. In shorten mode, bits 1918 in the transmission vector 1916 may be zero-valued and unnecessary to transmit. During the second transmission, a u-domain vector 1920 may be bit-wised added with the u-domain vector 1910 to produce an intermediate vector 1922. The intermediate vector 1922 may be

transformed by a polar encoding matrix 1624 into a transmission vector 1926. In shorten mode, bits 1928 in the transmission vector 1926 may be zero-valued and unnecessary to transmit. Here, bits 1918 and bits 1928 have the same lengths, i.e. transmission vectors 1916, 1926 have the same number of shortened bits.

[0079] Referring now to FIG. 20, which shows an example of a block diagram 2000 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize shorten mode, and the second transmission may utilize shorten mode. For example, during the first transmission, a u-domain vector 2010 or an intermediate vector 2012 may be transformed, via a polar encoding matrix 2014, into a transmission vector 2016. In shorten mode, bits 2018 in the transmission vector 2016 may be zero-valued and unnecessary to transmit. During the second transmission, a u-domain vector 2020 may be bit-wised added with the u-domain vector 2010 to produce an intermediate vector 2022. The intermediate vector 2022 may be transformed by a polar encoding matrix 2024 into a transmission vector 2026. In shorten mode, bits 2028 in the transmission vector 2026 may be zero-valued and unnecessary to transmit. Here, bits 2018 and bits 2028 have different lengths, i.e. the transmission vector 2016 has a smaller number of shortened bits than the transmission vector 2026.

[0080] Referring now to FIG. 21, which shows an example of a block diagram 2100 for active bit relocation for polar encoding with two transmissions. The first transmission may utilize shorten mode, and the second transmission may utilize shorten mode. For example, during the first transmission, a u-domain vector 2110 or an intermediate vector 2112 may be transformed, via a polar encoding matrix 2114, into a transmission vector 2116. In shorten mode, bits 2118 in the transmission vector 2116 may be zero-valued and unnecessary to transmit. During the second transmission, a u-domain vector 2120 may be bit-wised added with the u-domain vector 2110 to produce an intermediate vector 2122. The intermediate vector 2122 may be transformed by a polar encoding matrix 2124 into a transmission vector 2126. In shorten mode, bits 2128 in the transmission vector 2126 may be zero-valued and unnecessary to transmit. Here, bits 2118 and bits 2128 have different lengths, i.e. the transmission vector 2116 has a larger number of shortened bits than the transmission vector 2126.

[0081] Turning now to FIG. 22, which illustrates an example of a block diagram 2200 of the decoding process. The receiving device receives a first LLRs during the first reception and a second LLRs during the second reception. After receiving the first LLRs, the receiving device performs a de-ratematch 2202 on the first LLRs to produce a first N_1 LLRs. The receiving device also performs a de-ratematch 2206 on the second LLRs to produce a first N_2 LLRs. Depending on the length of the N_1 LLRs and N_2 LLRs, a duplication or truncation 2204 is

performed on the N_1 LLRs to generate a second N_2 LLRs. The first N_2 LLRs and second N_2 LLRs are combined using a LLR domain check 2208 to create a final N_2 LLRs. The final N_2 LLRs is decoded with a decoding matrix 2210 to extract the k_2 bits.

[0082] Still referring to FIG. 22, the extracted k_2 bits may be encoded with a encoding matrix 2212 to obtain N_2 bits. Next, the sign of the first N_2 LLRs is flipped 2214 and padded or folded 2216 to generate a second N_1 LLRs. The first and second N_1 LLRs are then added 2218 to create a final N_1 LLRs, which may be decoded with a decoding matrix 2220 to obtain the original k bits from the transmitting device. The duplication (Dup), truncation (Trunc), padding (Pad), and Folding (Fold) processes are displayed at the bottom of FIG. 22.

[0083] FIG. 23 is a flow chart of a method 2300 for masking u-domain vectors for polar encoding. At block 2302, the method 2300 may construct a data vector including a plurality of data bits. For example, the data component 150 of the UE 110 may construct a data vector including a plurality of data bits. The data bits may include audio, video, textual, or other information that the UE 110 uploads to the BS 105.

[0084] At block 2304, the method 2300 may transform the data vector into a u-domain vector. For example, the encoding component 154 of the UE 110 may transform the data vector into a u-domain vector. The transformation may include multiplying the data vector by a matrix. The u-domain vector may include more bits than the data vector.

[0085] At block 2306, the method 2300 may mask the u-domain vector with a mask. For example, the masking component 152 of the UE 110 may mask the u-domain vector with a mask. The masking component 152 may also generate the mask depending on the order of transmission. For example, during the initial transmission of the data vector, the masking component 152 may select a mask having all zero bits. For the first and second retransmissions, the masking component 152 may select a mask having identical bits as the data vector. For the third retransmission, the masking component 152 may select a mask equal to the sum of the previous data vectors.

[0086] At block 2308, the method 2300 may encode the masked u-domain vector with polar encoding to generate a transmission vector. For example, the encoding component 154 of the UE 110 may encode the masked u-domain vector with polar encoding to generate a transmission vector.

[0087] At block 2310, the method 2300 may transmit, to a receiving device, the transmission vector. For example, the communication component 156 of the UE 110 may transmit the transmission vector to the communication component 176 of the BS 105.

[0088] FIG. 24 is a flow chart of an example of a method 2400 of retransmitting coded messages. At block 2402, the method 2400 may generate a first data vector having a plurality of data bits. For example, the data component 150 may generate a first data vector having a plurality of data bits.

[0089] At block 2404, the method 2400 may generate a first u-domain vector by transforming the first data vector, wherein the first u-domain vector includes first active bits and first non-active bits. For example, the encoding component 154 may generate a first u-domain vector by transforming the first data vector, wherein the first u-domain vector includes first active bits and first non-active bits.

[0090] At block 2406, the method 2400 may encode the first u-domain vector with a polar encoder to generate a first transmission vector having a first plurality of bits and a second plurality of bits. For example, the encoding component 154 may encode the first u-domain vector with a polar encoder to generate a first transmission vector having a first plurality of bits and a second plurality of bits.

[0091] At block 2408, the method 2400 may transmit the first plurality of bits. For example, the communication component 158 may transmit the first plurality of bits.

[0092] At block 2410, the method 2400 may receive an indication of a failed decoding of the first plurality of bits. For example, the communication component 158 may receive an indication of a failed decoding of the first plurality of bits.

[0093] At block 2412, in response to the indication of the failed decoding, the method 2400 may generate a second data vector having a portion of the plurality of data bits. For example, the data component 150 may generate a second data vector having a portion of the plurality of data bits.

[0094] At block 2414, the method 2400 may generate a mask based on the first data vector. For example, the masking component 152 may generate a mask based on the first data vector.

[0095] At block 2416, the method 2400 may generate a second u-domain vector by transforming the second data vector, wherein the second u-domain vector includes second active bits and second non-active bits. For example, the encoding component 154 may generate a second u-domain vector by transforming the second data vector, wherein the second u-domain vector includes second active bits and second non-active bits.

[0096] At block 2418, the method 2400 may mask the second u-domain vector with the mask to generate an intermediate vector. For example, the masking component 152 may mask the second u-domain vector with the mask to generate an intermediate vector.

[0097] At block 2420, the method 2400 may encode the intermediate vector with the polar encoder to generate a second transmission vector having a third plurality of bits and a fourth plurality of bits. For example, the encoding component 154 may encode the intermediate vector with the polar encoder to generate a second transmission vector having a third plurality of bits and a fourth plurality of bits.

[0098] At block 2422, the method 2400 may transmit the third plurality of bits. For example, the communication component 158 may transmit the third plurality of bits.

[0099] FIG. 25 is a flow chart of a method 2500 of decoding coded messages. The method 2500 may be implemented, partly or completely, by decoders illustrated in FIGS. 5 and 22. At block 2502, the method 2500 may de-ratematch 2502 received bits. For example, the decoding component 158 may de-ratematch 2502 received LLR vectors sent by a transmitting device.

[0100] At block 2504, the method 2500 may scale the received LLR vectors to size- N_C vectors $[x_1, x_2, \dots, x_T]$. For example, the decoding component 158 may scale the received LLR vectors to size- N_C vectors $[x_1, x_2, \dots, x_T]$.

[0101] At block 2506, the method 2500 may initialize $i=T$. For example, the decoding component 158 may initialize $i=T$.

[0102] At block 2508, the method 2500 may soft combine LLR for i -th transmission. For example, the decoding component 158 may soft combine LLR for i -th transmission.

[0103] At block 2510, the method 2500 may collect known info bits from decoding results for $[T, T-1, i+1]$ -th transmissions. For example, the decoding component 158 may collect known info bits from decoding results for $[T, T-1, i+1]$ -th transmissions.

[0104] Next, at block 2512, the method 2500 may soft combine LLRs from $[T, T-1, i+1]$ -th transmissions. For example, the decoding component 158 may soft combine LLRs from $[T, T-1, i+1]$ -th transmissions.

[0105] At block 2514, the method 2500 may decode (N_i, K_i) code. For example, the decoding component 158 may decode (N_i, K_i) code.

[0106] At block 2516, the method 2500 may determine if $i=1$. For example, the decoding component 158 may determine if $i=1$.

[0107] At block 2518, if i does not equal to 1, the method 2500 may re-encode (N_i, K_i) and flip signs of LLRs of block T . For example, the encoding component 154 may re-encode (N_i, K_i) and flip signs of LLRs of block T .

[0108] At block 2520, the method 2500 may set $i=i-1$. For example, the decoding component may set $i=i-1$.

[00109] At block 2522, if the method 2500 determines that $i=1$ at block 2516, the method 2500 may output the decoded bits. For example, the communication component 156 may output the decoded bits.

[00110] In some implementations, the methods 2300, 2400, and 2500 may be implemented by the BS 105 and its corresponding components.

[00111] Referring to FIG. 26, one example of an implementation of the UE 110 may include a variety of components, some of which have already been described above, but including components such as one or more processors 2612 and memory 2616 executing one or more functions relating to polar encoding and decoding, and transceiver 2602 in communication via one or more buses 2644, which may operate in conjunction with modem 140 and the communication component 150 to enable one or more of the functions described herein related to controlling data packet transmission reliability. Further, the one or more processors 2612, modem 140, memory 2616, transceiver 2602, RF front end 2688 and the antenna system 2665, may be configured to support voice and/or data calls (simultaneously or non-simultaneously) in one or more radio access technologies.

[00112] In an aspect, the one or more processors 2612 can include a modem 140 that uses one or more modem processors. The various functions related to the communication component 150 may be included in modem 140 and/or processors 2612 and, in an aspect, can be executed by a single processor, while in other aspects, different ones of the functions may be executed by a combination of two or more different processors. For example, in an aspect, the one or more processors 2612 may include any one or any combination of a modem processor, or a baseband processor, or a digital signal processor, or a transmit processor, or a receiver processor, or a transceiver processor associated with transceiver 2602. In other aspects, some of the features of the one or more processors 2612 and/or modem 140 associated with the data component 150 may be performed by transceiver 2602.

[00113] Memory 2616 can include any type of computer-readable medium usable by a computer or at least one processor 2612, such as random access memory (RAM), read only memory (ROM), tapes, magnetic discs, optical discs, volatile memory, non-volatile memory, and any combination thereof. In an aspect, for example, memory 2616 may be a non-transitory computer-readable storage medium that stores one or more computer-executable codes defining the communication component 156 and/or one or more of its subcomponents, and/or data associated therewith, when UE 110 is operating at least one processor 2612 to execute the communication component 156 and/or one or more of its subcomponents.

[00114] Transceiver 2602 may include at least one receiver 2606 and at least one transmitter 2608. Receiver 2606 may include hardware, firmware, and/or software code executable by a processor for receiving data, the code comprising instructions and being stored in a memory (e.g., computer-readable medium). Receiver 2606 may be, for example, a radio frequency (RF) receiver. In an aspect, receiver 2606 may receive signals transmitted by at least one base station 105. Additionally, receiver 2606 may process such received signals, and also may obtain measurements of the signals, such as, but not limited to, E_c/I_o , SNR, RSRP, RSSI, etc. Transmitter 2608 may include hardware, firmware, and/or software code executable by a processor for transmitting data, the code comprising instructions and being stored in a memory (e.g., computer-readable medium). A suitable example of transmitter 2608 may including, but is not limited to, an RF transmitter.

[00115] Moreover, in an aspect, the UE 110 may include RF front end 2688, which may operate in communication with the antenna system 2665 and transceiver 2602 for receiving and transmitting radio transmissions, for example, wireless communications transmitted by at least one BS 105 or wireless transmissions transmitted by other BS 105 and UE 110. RF front end 2688 may be connected to the antenna system 2665 and can include one or more low-noise amplifiers (LNAs) 2690, one or more switches 2692, one or more power amplifiers (PAs) 2698, and one or more filters 2696 for transmitting and receiving RF signals.

[00116] In an aspect, LNA 2690 can amplify a received signal at a desired output level. In an aspect, each LNA 2690 may have a specified minimum and maximum gain values. In an aspect, RF front end 2688 may use one or more switches 2692 to select a particular LNA 2690 and its specified gain value based on a desired gain value for a particular application.

[00117] Further, for example, one or more PA(s) 2698 may be used by RF front end 2688 to amplify a signal for an RF output at a desired output power level. In an aspect, each PA 2698 may have specified minimum and maximum gain values. In an aspect, RF front end 2688 may use one or more switches 2692 to select a particular PA 2698 and its specified gain value based on a desired gain value for a particular application.

[00118] Also, for example, one or more filters 2696 can be used by RF front end 2688 to filter a received signal to obtain an input RF signal. Similarly, in an aspect, for example, a respective filter 2696 can be used to filter an output from a respective PA 2698 to produce an output signal for transmission. In an aspect, each filter 2696 can be connected to a specific LNA 2690 and/or PA 2698. In an aspect, RF front end 2688 can use one or more switches 2692 to select a transmit or receive path using a specified filter 2696, LNA 2690, and/or PA 2698, based on a configuration as specified by the transceiver 2602 and/or processor 2612.

[00119] As such, the transceiver 2602 may be configured to transmit and receive wireless signals through the antenna system 2665 via RF front end 2688. In an aspect, transceiver may be tuned to operate at specified frequencies such that UE 110 can communicate with, for example, one or more BSs 105 or one or more cells associated with one or more base stations 105. In an aspect, for example, modem 140 can configure the transceiver 2602 to operate at a specified frequency and power level based on the BS configuration of the UE 110 and the communication protocol used by modem 140.

[00120] In an aspect, modem 140 can be a multiband-multimode modem, which can process digital data and communicate with transceiver 2602 such that the digital data is sent and received using transceiver 2602. In an aspect, modem 140 can be multiband and be configured to support multiple frequency bands for a specific communications protocol. In an aspect, modem 140 can be multimode and be configured to support multiple operating networks and communications protocols. In an aspect, modem 140 can control one or more components of UE 110 (e.g., RF front end 2688, transceiver 2602) to enable transmission and/or reception of signals from the network based on a specified modem configuration. In an aspect, the modem configuration can be based on the mode of the modem and the frequency band in use. In another aspect, the modem configuration can be based on BS configuration information associated with UE 110 as provided by the network.

[00121] Referring to FIG. 27, one example of an implementation of the BS 105 may include a variety of components, some of which may be similar to the UE components already described above in connection with FIG. 26, but including components such as one or more processors 2712 and memory 2716, e.g., executing one or more functions relating to polar encoding and decoding, and transceiver 2702 in communication via one or more buses 2744, which may operate in conjunction with modem 160 and the communication component 176 to enable one or more of the functions described herein.

[00122] FIG. 28 shows an example of a block diagram 2800 of polar encoding. A data vector 2802 may include a number of data bits. By transforming the data vector 2802 with a mapping matrix 2804, the data vector 2802 is transformed to a u-domain vector 2806. The u-domain vector 2806 may include more bits than the data vector 2802. The u-domain vector 2806 may be transformed to a transmission vector 2816 by a polar encoding matrix 2814. The polar encoding matrix 2814 may perform a polar encoding transformation. The transmission vector 2816 may be sent to a receiving device.

[00123] FIG. 29 illustrates another example of a block diagram 2900 for active bit relocation for polar encoding with two transmissions. The block diagram 2900 may be equivalent to the

block diagram 900. During the first transmission, a u-domain vector 2910 is transformed by a polar encoding matrix 2934 into a transmission vector 2940. The u-domain vector 2910 may include one or more data bits 2912, a repeated bit 2914 in an unreliable transmission location 2916. After the transmission of the transmission vector 2940, a second transmission may be initiated due to the failed decoding of the repeated bit 2914. During the second transmission, a u-domain vector 2920 may include the repeated bit 2914 at a reliable transmission location 2922. The transformed (by a polar encoding matrix 2932) u-domain vector 2920 may be bit-wised added 2928 with the transmission vector 2940 to form an transmission vector 2950. The repeated bit 2914 may be relocated to the reliable transmission location 2922 having a higher transmission reliability than the unreliable transmission location 2916. For example, the unreliable transmission location 2916 may be a resource location where information transmitted has a low probability (e.g. 50% for every transmission) of being decoded by receiving device. The reliable transmission location 2922 may be a different resource location where information transmitted has a high probability (e.g. 90% for every transmission) of being decoded by receiving device. At the receiving device, the transmission vector 2950 may be decoded before the transmission vector 2940.

[00124] FIG. 30 illustrates yet another example of a block diagram 3000 for active bit relocation for polar encoding with two transmissions. The block diagram 3000 may also be equivalent to the block diagram 900. During the first transmission, a u-domain vector 3010 is transformed by a polar encoding matrix 3034 into a transmission vector 3040. The u-domain vector 3010 may include one or more data bits 3012, a repeated bit 3014 in an unreliable transmission location 3016. After the transmission of the transmission vector 3040, a second transmission may be initiated due to the failed decoding of the repeated bit 3014. During the second transmission, a u-domain vector 3020 may include the repeated bit 3014 at a reliable transmission location 3022. The transformed (by a polar encoding matrix 3032) u-domain vector 3020 may be bit-wised added by an adder 3028 with the transmission vector 3040 to form an transmission vector 3050. The repeated bit 3014 may be relocated to the reliable transmission location 3022 having a higher transmission reliability than the unreliable transmission location 3016. For example, the unreliable transmission location 3016 may be a resource location where information transmitted has a low probability (e.g. 20% for every transmission) of being decoded by receiving device. The reliable transmission location 3022 may be a different resource location where information transmitted has a high probability (e.g. 95% for every transmission) of being decoded by receiving device. At the receiving device, the transmission vector 3050 may be decoded before the transmission vector 3040. In some

implementations, the polar encoding matrices 3032, 3034 and the adder 3028 may be implemented by an equivalent polar encoding matrix 3060.

[00125] FIG. 31 illustrates graphs 3100, 3150 showing examples of performance measurements of various transmission schemes. In the graph 3100, the values of M1 and M2 equal to 512. In the graph 3150, the values of M1 equals to 512 and the values of M2 equals to 256.

[00126] FIG. 32 illustrates graphs 3200, 3250 showing examples of performance measurements of various transmission schemes. In the graph 3200, the values of M1 and M2 equal to 432 and the ARUM works in “shorten+shorten” modes. In the graph 3250, the values of M1 and M2 equal to 432 and the ARUM works in “puncture+puncture” modes.

[00127] FIG. 33 illustrates graphs 3300, 3350 showing examples of performance measurements of various transmission schemes. In the graph 3300, the value of M1 is smaller than the value of M2 and the ARUM works in “shorten+shorten” modes. In the graph 3250, the value of M1 is greater than the value of M2 and the ARUM works in “shorten+shorten” modes.

[00128] The above detailed description set forth above in connection with the appended drawings describes examples and does not represent the only examples that may be implemented or that are within the scope of the claims. The term “example,” when used in this description, means “serving as an example, instance, or illustration,” and not “preferred” or “advantageous over other examples.” The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and apparatuses are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

[00129] Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, computer-executable code or instructions stored on a computer-readable medium, or any combination thereof.

[00130] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a specially-programmed device, such as but not limited to a processor, a digital signal processor (DSP), an ASIC, a FPGA or other programmable logic device, a discrete gate or transistor logic, a discrete hardware component, or any combination thereof designed to perform the functions described herein. A specially-programmed processor may be a microprocessor, but in the alternative, the processor may be

any conventional processor, controller, microcontroller, or state machine. A specially-programmed processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00131] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a non-transitory computer-readable medium. Other examples and implementations are within the scope and spirit of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a specially programmed processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, “or” as used in a list of items prefaced by “at least one of” indicates a disjunctive list such that, for example, a list of “at least one of A, B, or C” means A or B or C or AB or AC or BC or ABC (i.e., A and B and C).

[00132] Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[00133] The previous description of the disclosure is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the common principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Furthermore, although elements of the described aspects may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated. Additionally, all or a portion of any aspect may be utilized with all or a portion of any other aspect, unless stated otherwise. Thus, the disclosure is not to be limited to the examples and designs described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of transmitting coded messages to a receiving device, comprising:
constructing a data vector including a plurality of data bits;
transforming the data vector into a u-domain vector;
applying a mask to the u-domain vector;
encoding the masked u-domain vector with a polar encoding to generate a transmission vector; and
transmitting, to the receiving device, the transmission vector.
2. The method of claim 1, further comprising receiving an indication that the receiving device failed to decode the data bits, wherein the data bits include a first portion that is in a reliable transmission location and a second portion that is in an unreliable transmission location.
3. The method of claim 2, further comprising:
constructing a redundant data vector including the second portion of the data bits by relocating the second portion of the data bits from the unreliable transmission location to the reliable transmission location;
transforming the redundant data vector into a redundant u-domain vector;
masking the redundant u-domain data vector with a redundant mask;
encoding the masked redundant u-domain vector with the polar encoding to generate a redundant transmission vector; and
transmitting, to the receiving device, the redundant transmission vector.
4. The method of claim 3, wherein the redundant mask includes the u-domain vector.
5. The method of claim 3, wherein the data vector further includes one or more first cyclic redundancy check (CRC) bits and the redundant data vector includes one or more second CRC bits.
6. The method of claim 1, wherein transforming the data vector into the u-domain vector includes converting a portion of bits in the u-domain vector into frozen bits.

7. A user equipment, comprising:
 - a memory;
 - a transceiver; and
 - a processor in communication with the memory and the transceiver and configured to:
 - construct a data vector including a plurality of data bits;
 - transform the data vector into a u-domain vector;
 - applying a mask to the u-domain vector;
 - encode the masked u-domain vector with polar encoding to generate a transmission vector; and
 - transmit, to a receiving device, the transmission vector.
8. The user equipment of claim 7, wherein the processor is further configured to perform the methods of any of claims 1-6.
9. A computer-readable medium having instructions stored therein that, when executed by one or more processors, cause the one or more processors to:
 - construct a data vector including a plurality of data bits;
 - transform the data vector into a u-domain vector;
 - applying a mask to the u-domain vector;
 - encode the masked u-domain vector with polar encoding to generate a transmission vector; and
 - transmit, to a receiving device, the transmission vector.
10. The computer-readable medium of claim 9, further comprising instructions to cause the processor to perform the method of any of claims 1-6.
11. A method of retransmitting coded messages, comprising:
 - generating a first data vector having a plurality of data bits;
 - generating a first u-domain vector by transforming the first data vector, wherein the first u-domain vector includes first active bits and first non-active bits;
 - encoding the first u-domain vector with a polar encoder to generate a first transmission vector having a first plurality of bits and a second plurality of bits;
 - transmitting the first plurality of bits;

receiving an indication of a failed decoding of the first plurality of bits;
in response to the indication of the failed decoding:

- generating a second data vector having a portion of the plurality of data bits;
- generating a mask based on the first data vector;
- generating a second u-domain vector by transforming the second data vector,
wherein the second u-domain vector includes second active bits and second non-active
bits;
- applying a mask to the second u-domain vector to generate an intermediate
vector;
- encoding the intermediate vector with the polar encoder to generate a second
transmission vector having a third plurality of bits and a fourth plurality of bits; and
- transmitting the third plurality of bits.

12. The method of claim 11, wherein:

the first non-active bits and the second non-active bits include frozen bits; and
the first plurality of bits and the third plurality of bits are identical.

13. The method of claim 11, wherein:

the first non-active bits and the second non-active bits include frozen bits; and
the second plurality of bits and the fourth plurality of bits are not transmitted.

14. The method of claim 11, wherein:

the first non-active bits and the second non-active bits include frozen bits; and
the second plurality of bits and the fourth plurality of bits are zero-valued.

15. The method of claim 11, wherein:

the first non-active bits include frozen bits or zero-valued bits; and
the first plurality of bits and the third plurality of bits are identical.

16. The method of claim 11, wherein:

the first non-active bits include frozen bits or zero-valued bits; and
the second plurality of bits and the fourth plurality of bits are not transmitted.

17. The method of claim 11, wherein:

the first non-active bits and the second non-active bits include frozen bits or zero-valued bits; and

the second plurality of bits and the fourth plurality of bits are zero-valued.

18. The method of claim 11, wherein a length of the first transmission vector is identical to a length of the second transmission vector.

19. The method of claim 11, wherein a length of the first transmission vector is longer than a length of the second transmission vector.

20. The method of claim 11, wherein a length of the first transmission vector is shorter than a length of the second transmission vector.

21. The method of claim 11, wherein:
the second plurality of bits and the fourth plurality of bits are zero-valued; and
a number of the second plurality of bits is the same to a number of the fourth plurality of bits.

22. The method of claim 11, wherein:
the second plurality of bits and the fourth plurality of bits are zero-valued; and
a number of the second plurality of bits is longer than a number of the fourth plurality of bits.

23. The method of claim 11, wherein:
the second plurality of bits and the fourth plurality of bits are zero-valued; and
a number of the second plurality of bits is shorter than a number of the fourth plurality of bits.

24. A user equipment, comprising:
a memory;
a transceiver;
a processor coupled to the memory and the transceiver and configured to:
generate a first data vector having a plurality of data bits;

generate a first u-domain vector by transforming the first data vector, wherein the first u-domain vector includes first active bits and first non-active bits;

encode the first u-domain vector with a polar encoder to generate a first transmission vector having a first plurality of bits and a second plurality of bits;

transmit the first plurality of bits;

receive an indication of a failed transmission of the first plurality of bits;

in response to the failed transmission:

generate a second data vector having a portion of the plurality of data bits;

generate a mask based on the first data vector;

generate a second u-domain vector by transforming the second data vector, wherein the second u-domain vector includes second active bits and second non-active bits;

apply a mask to the second u-domain vector to generate an intermediate;

encode the intermediate vector with the polar encoder to generate a second transmission vector having a third plurality of bits and a fourth plurality of bits; and

transmit the third plurality of bits.

25. The user equipment of claim 24, wherein the processor is further configured to perform the methods of any of claims 12-23.

26. A computer-readable medium having instructions stored therein that, when executed by one or more processors, cause the one or more processors to:

generate a first data vector having a plurality of data bits;

generate a first u-domain vector by transforming the first data vector, wherein the first u-domain vector includes first active bits and first non-active bits;

encode the first u-domain vector with a polar encoder to generate a first transmission vector having a first plurality of bits and a second plurality of bits;

transmit the first plurality of bits;

receive an indication of a failed transmission of the first plurality of bits;

in response to the failed transmission:

generate a second data vector having a portion of the plurality of data bits;

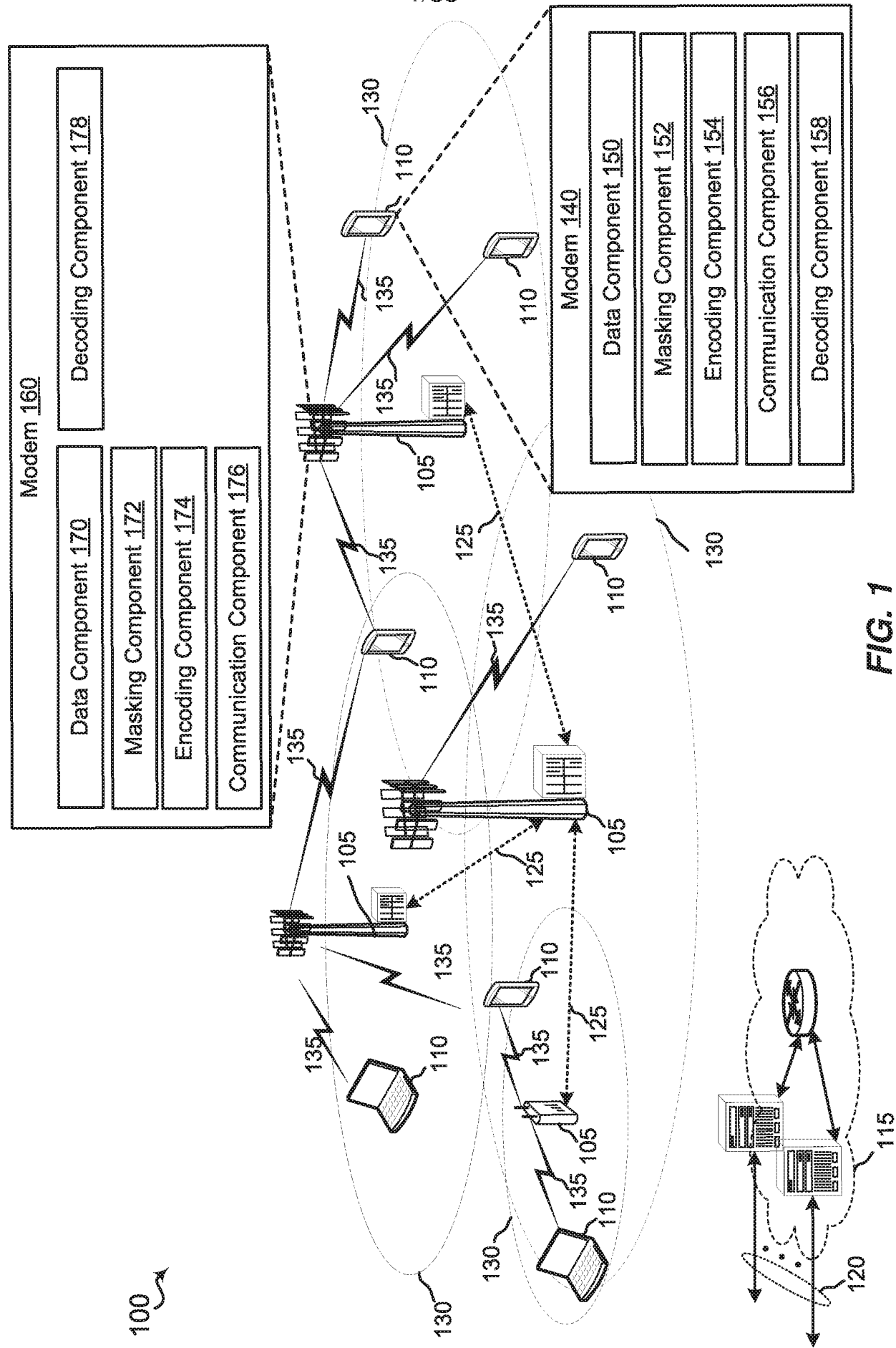
generate a mask based on the first data vector;

generate a second u-domain vector by transforming the second data vector, wherein the second u-domain vector includes second active bits and second non-active bits;

apply a mask to the second u-domain vector to generate an intermediate vector;

encode the second u-domain vector with the polar encoder to generate a second transmission vector having a third plurality of bits and a fourth plurality of bits; and transmit the third plurality of bits.

27. The computer-readable medium of claim 26, further comprising instructions to cause the processor to perform the method of any of claims 12-23.



200

210

$$\begin{bmatrix} u_1 & u_2 & u_3 & u_4 & u_5 & u_6 & u_7 & u_8 \end{bmatrix}$$

$\times$

212

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

$=$

214

$$\begin{bmatrix} x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & x_8 \end{bmatrix}$$

FIG. 2

300

310

$$\begin{bmatrix} u_1 & u_2 & u_3 & u_4 & u_5 & u_6 & u_7 & u_8 \end{bmatrix}$$

312

$\times$

320

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

$=$

330

$$\begin{bmatrix} x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & x_8 \end{bmatrix}$$

332

FIG. 3

400 ↗

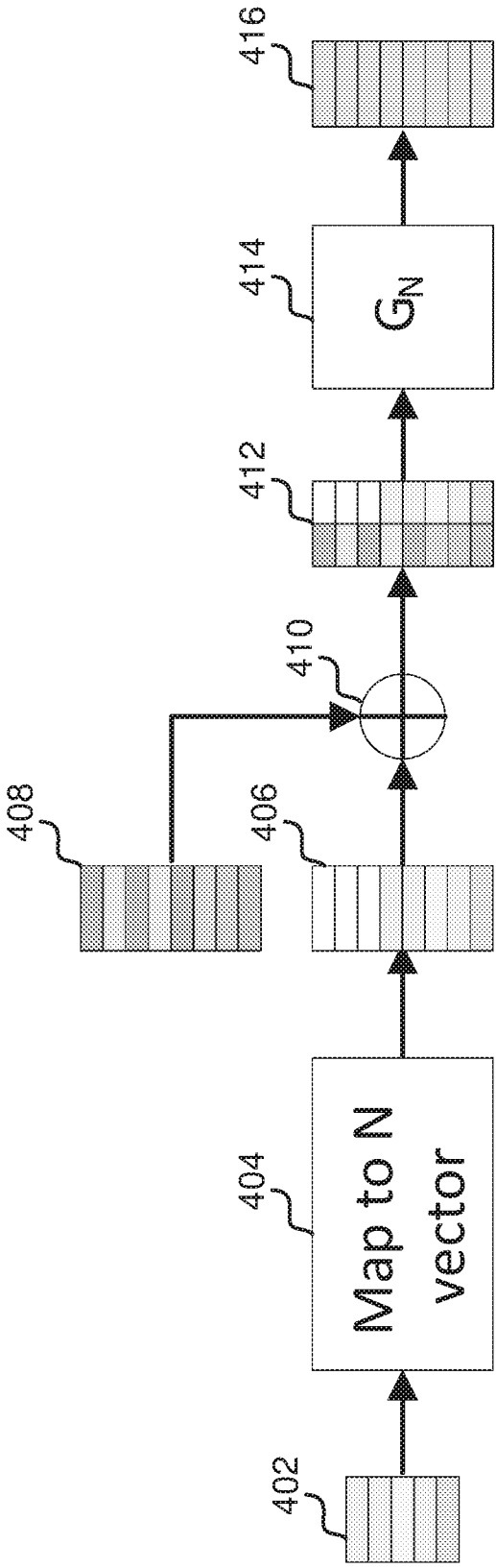


FIG. 4

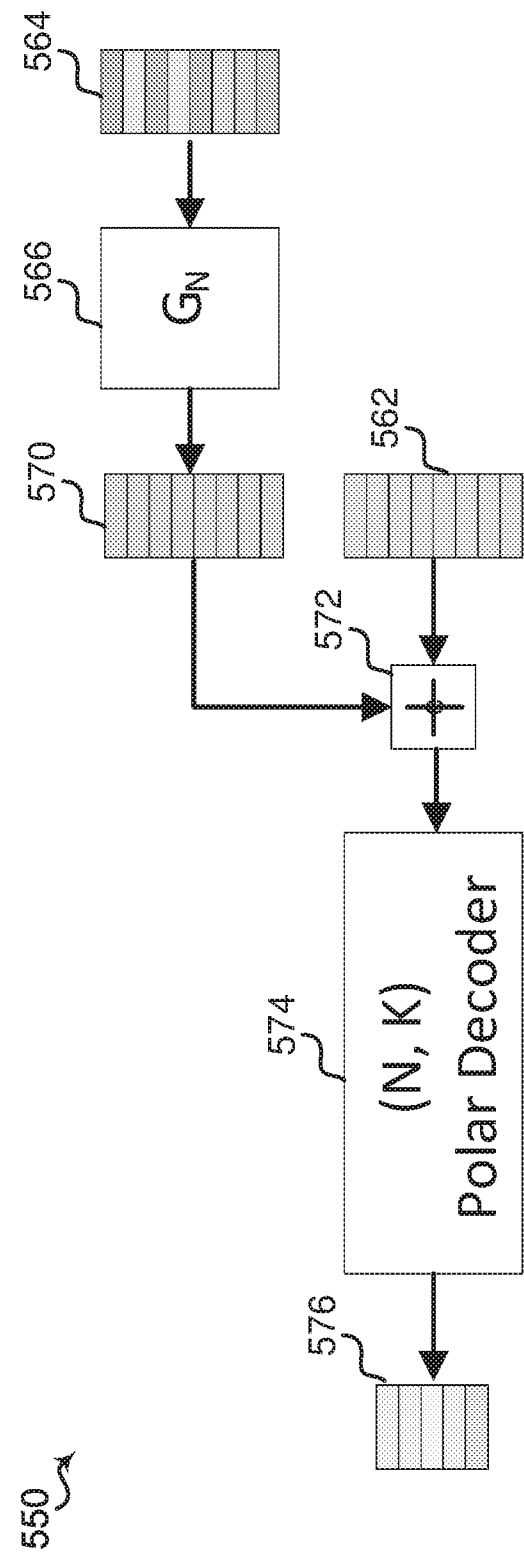
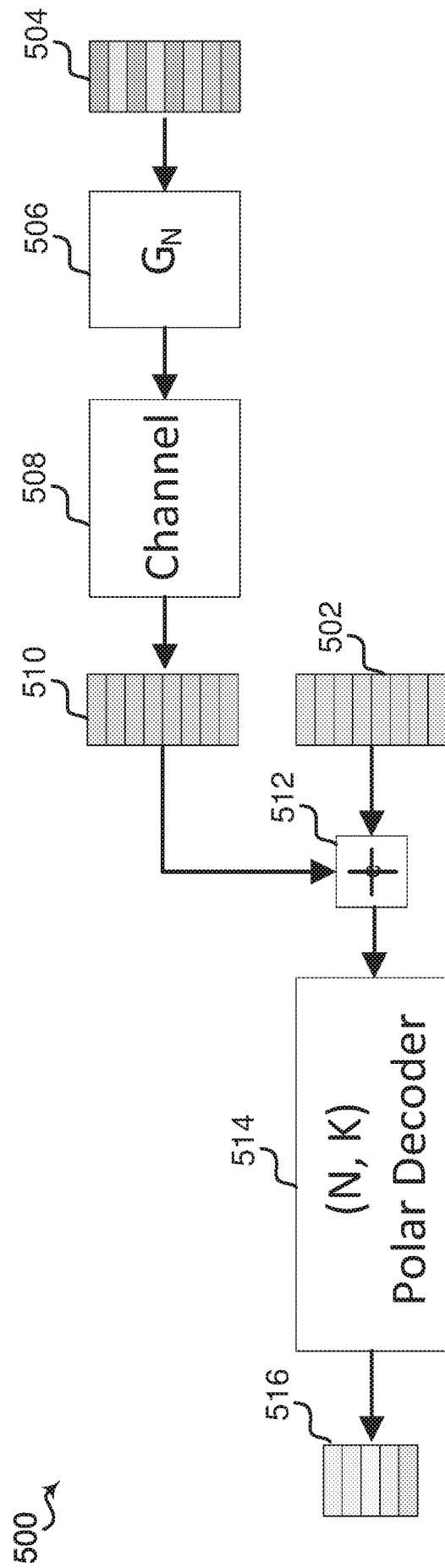


FIG. 5

600

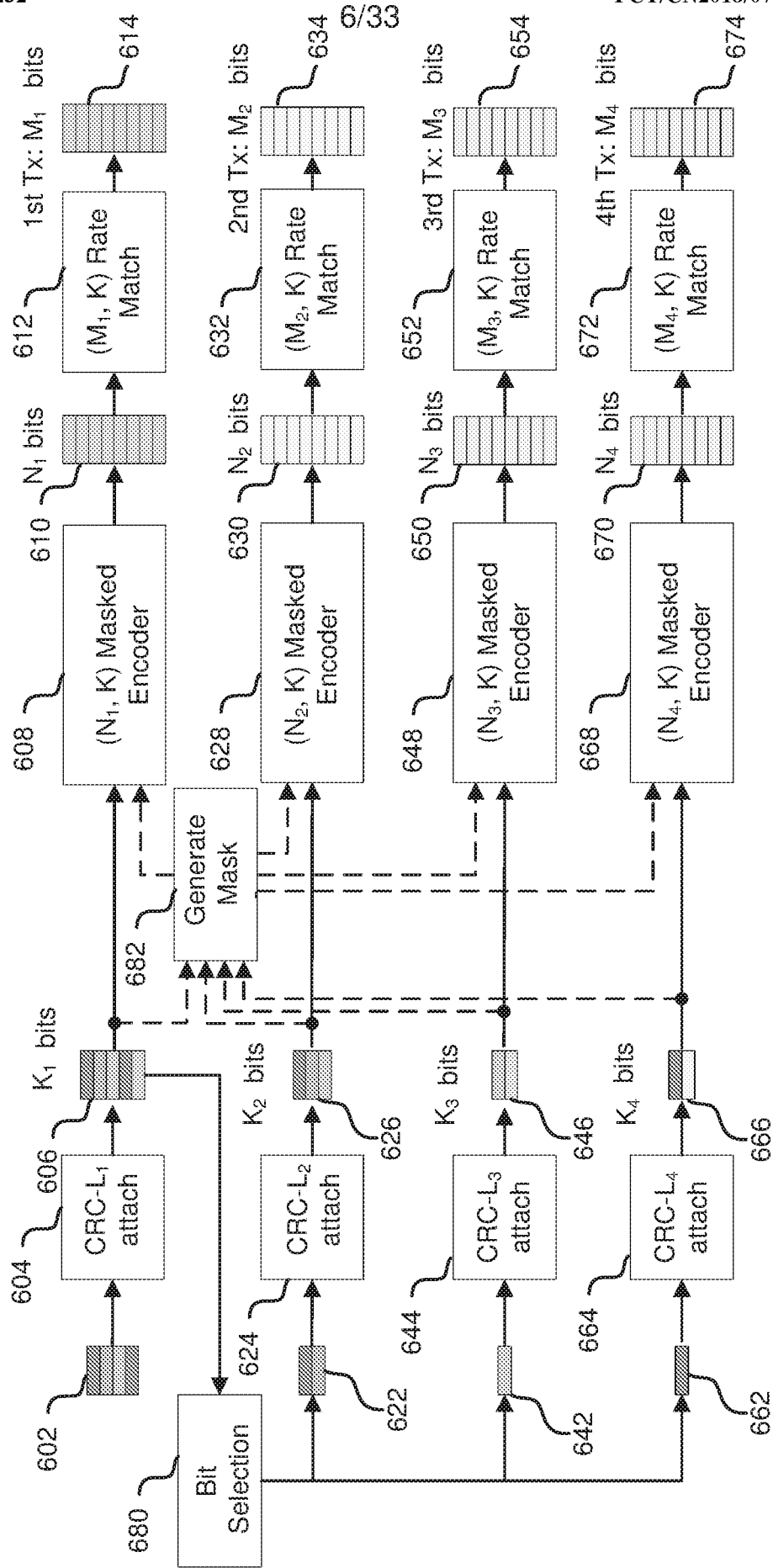


FIG. 6

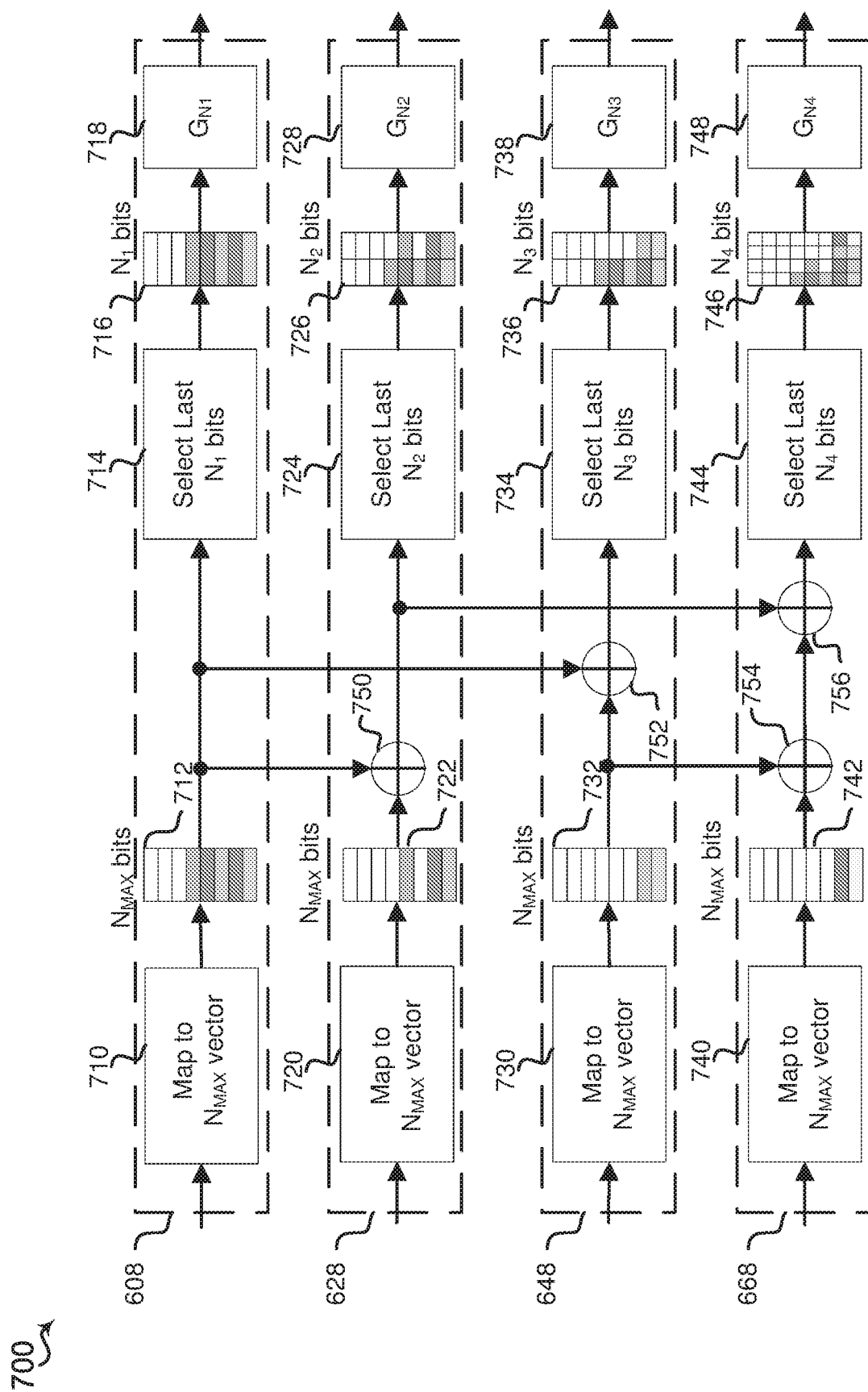


FIG. 7

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800

		802		804			
1	1	1	1	1	1	1	1
0	1	0	1	0	1	0	1
0	0	1	1	0	0	1	1
0	0	0	1	0	0	0	1
0	0	0	0	1	1	1	1
0	0	0	0	0	1	0	1
0	0	0	0	0	0	1	1
0	0	0	0	0	0	0	1

FIG. 8

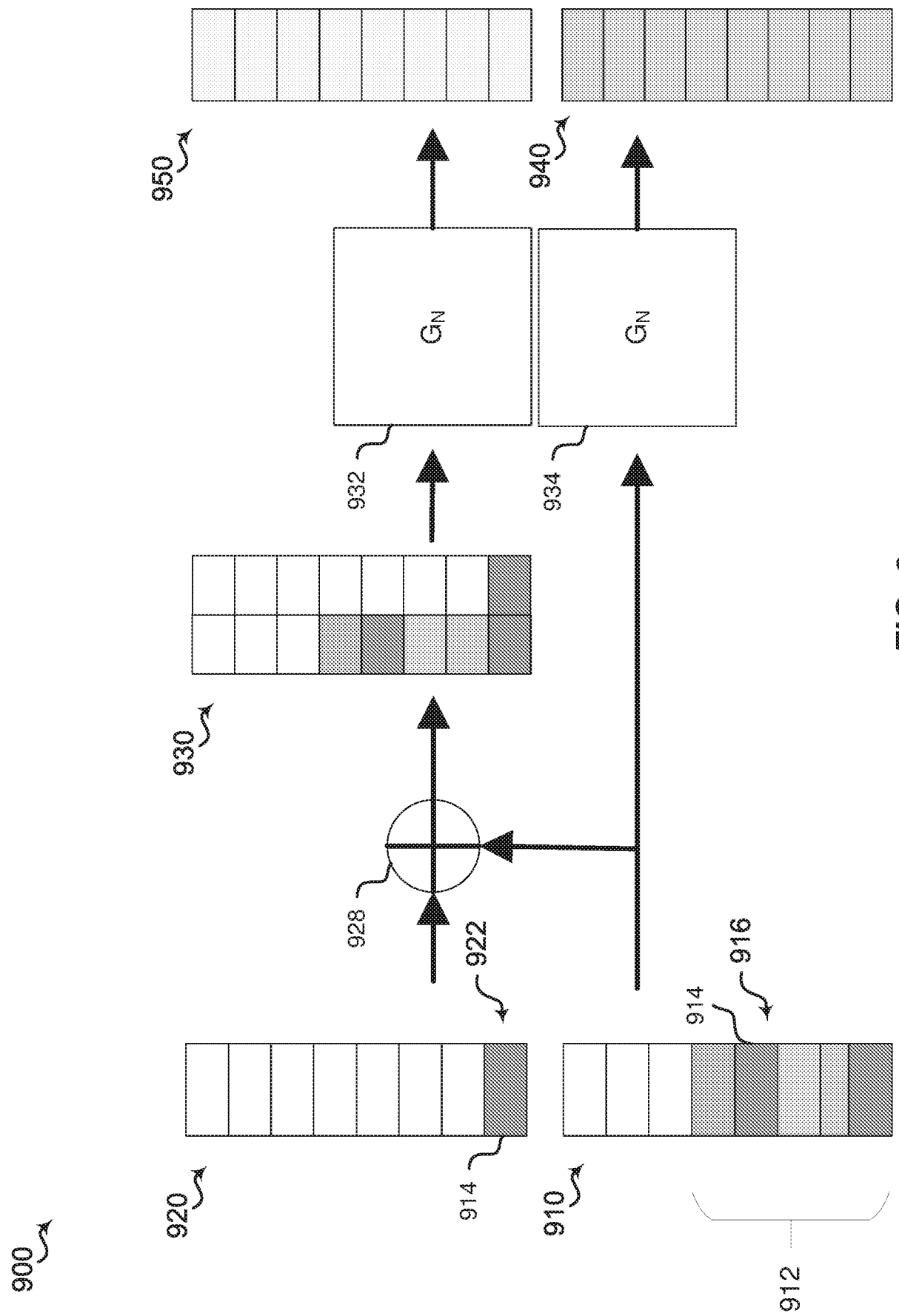


FIG. 9

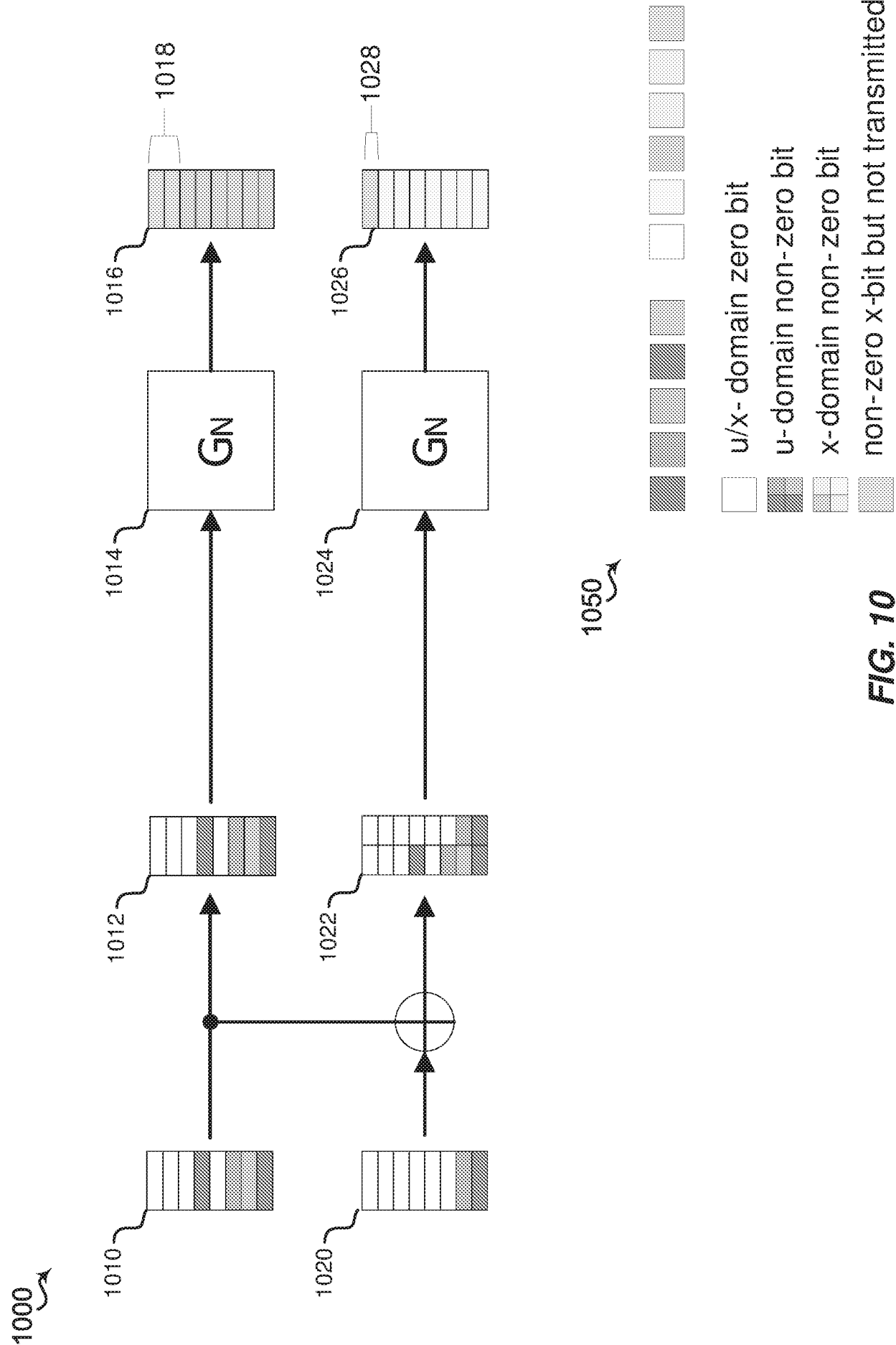


FIG. 10

1100

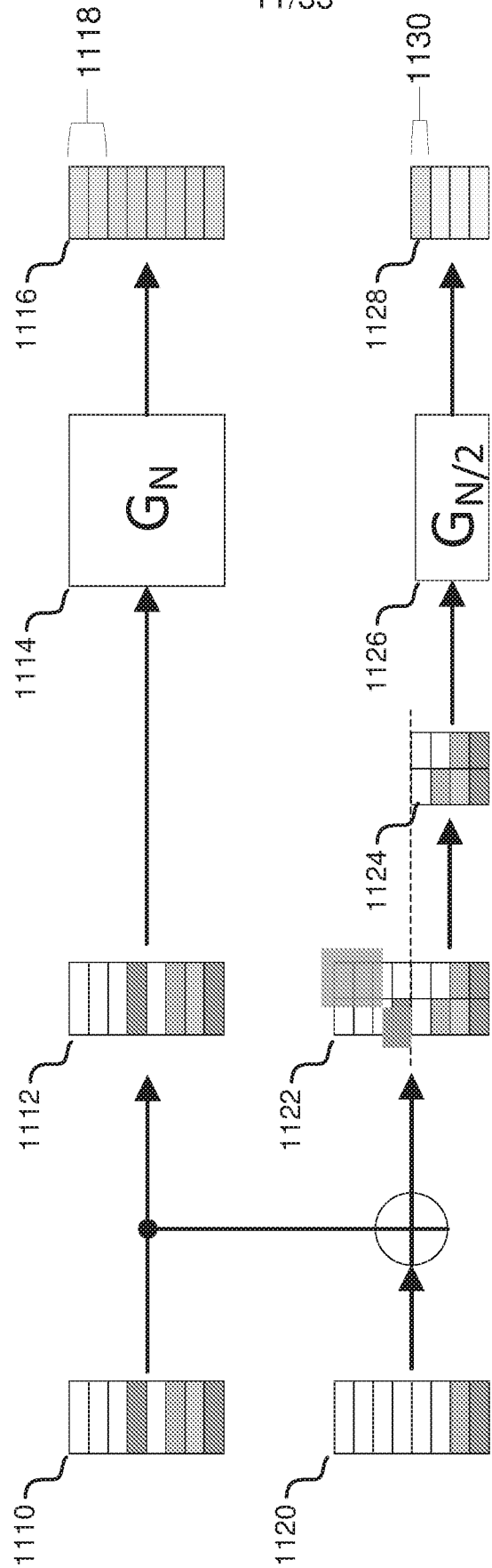


FIG. 11

1200

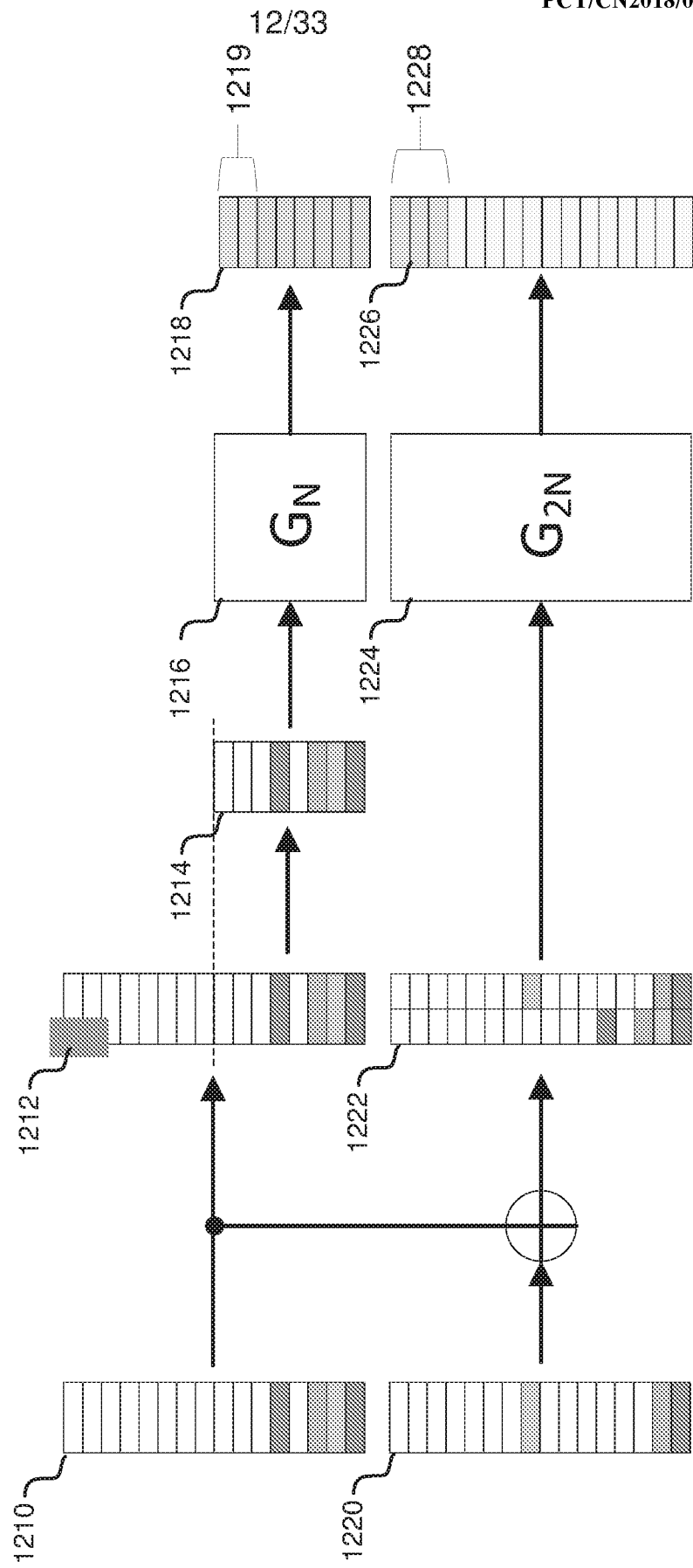


FIG. 12

1300

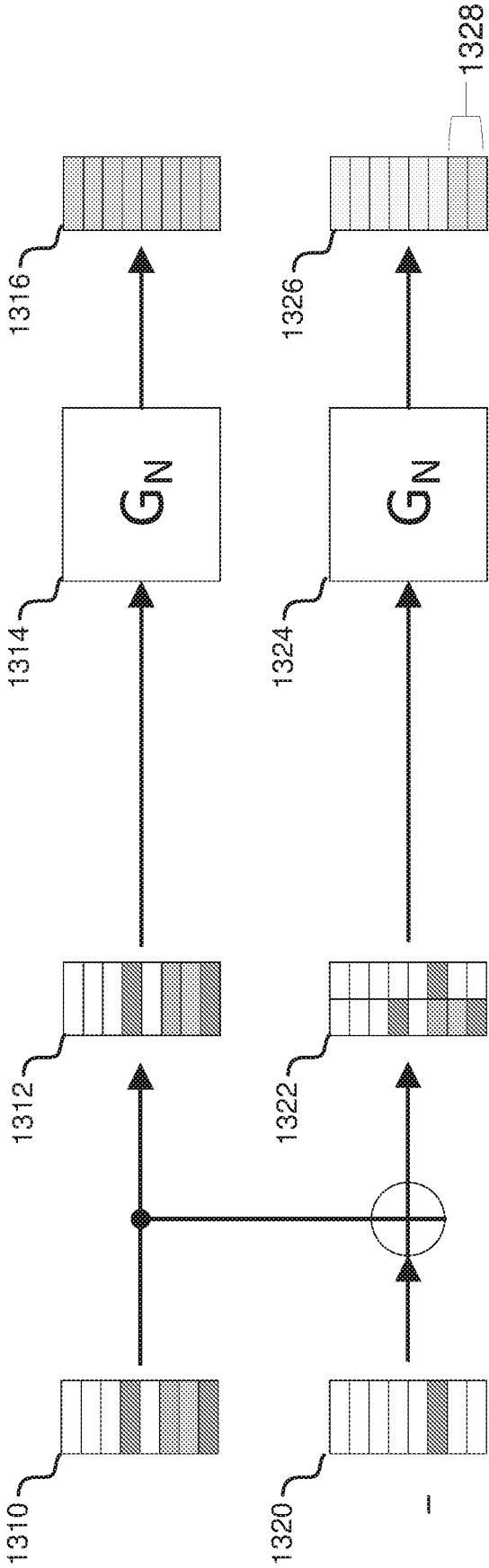


FIG. 13

1400

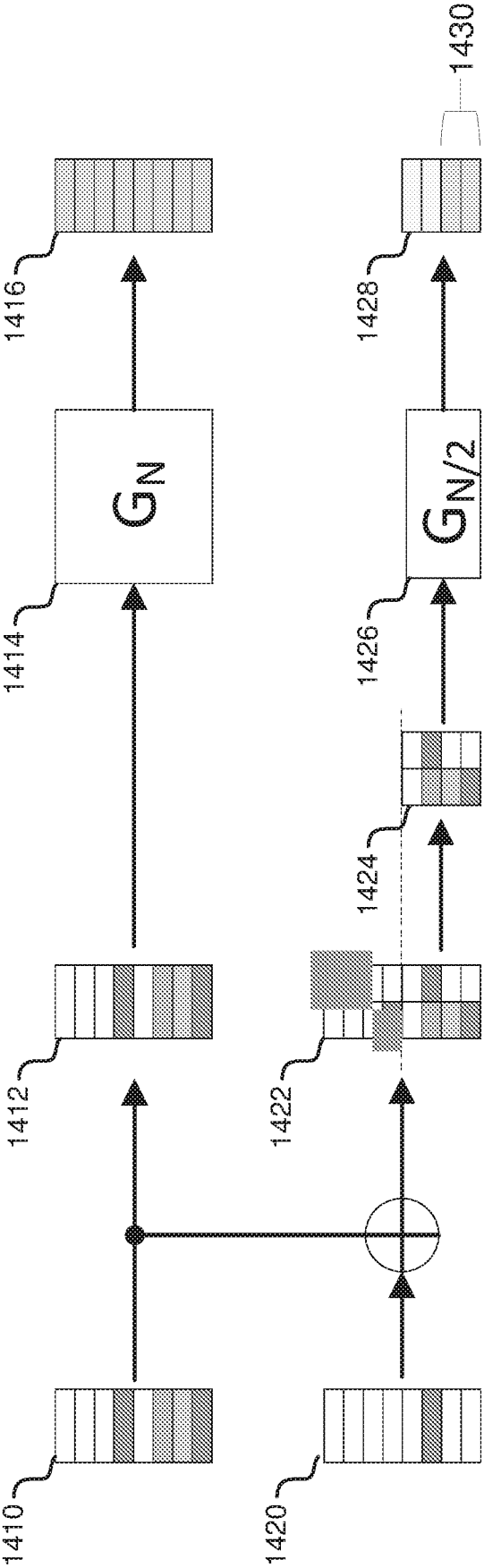


FIG. 14

1500

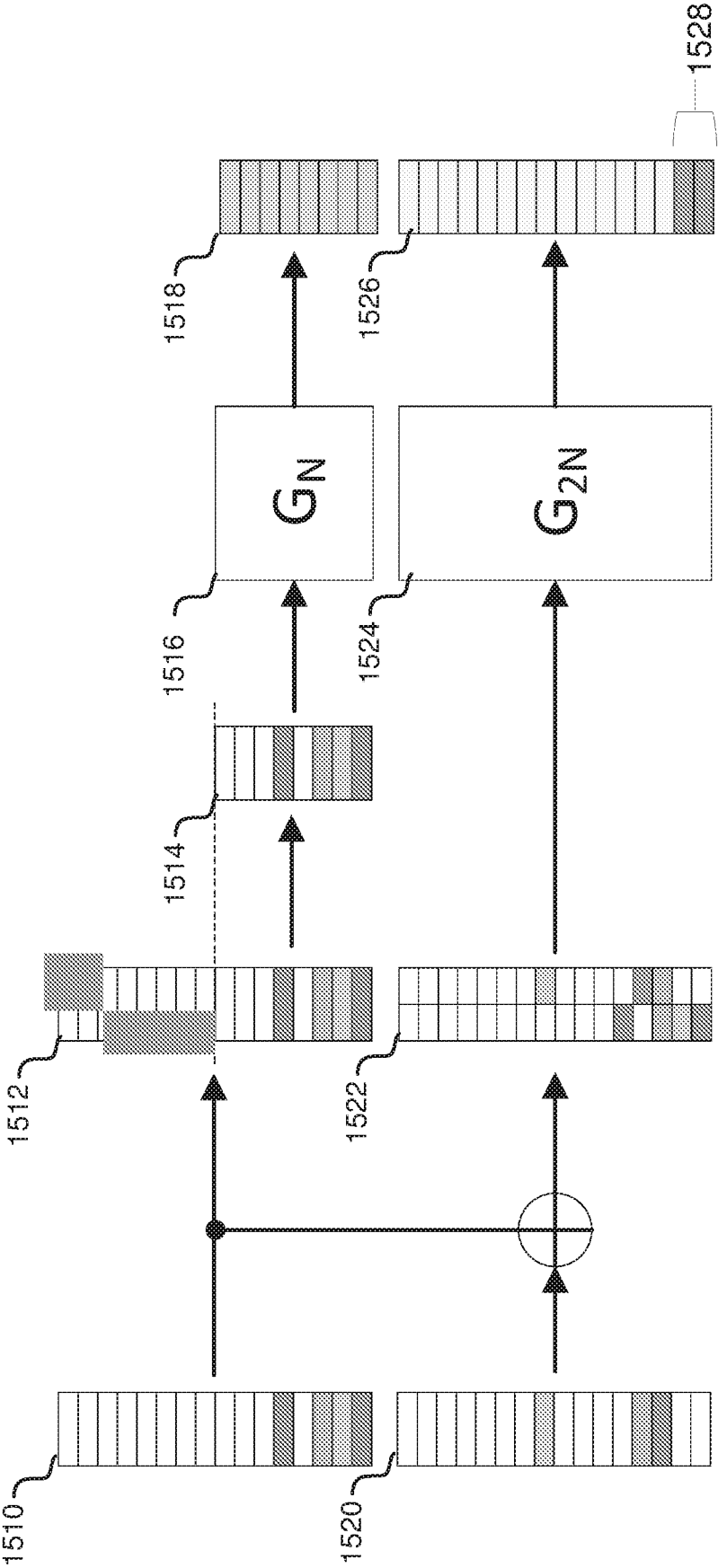


FIG. 15

1600

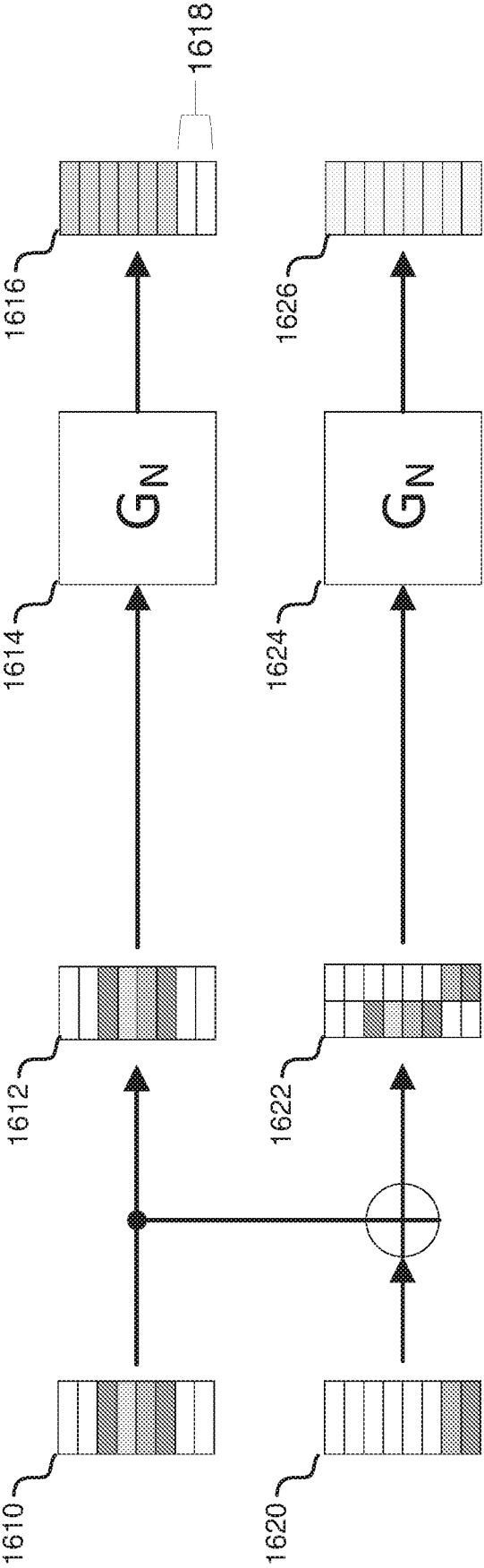


FIG. 16

1700

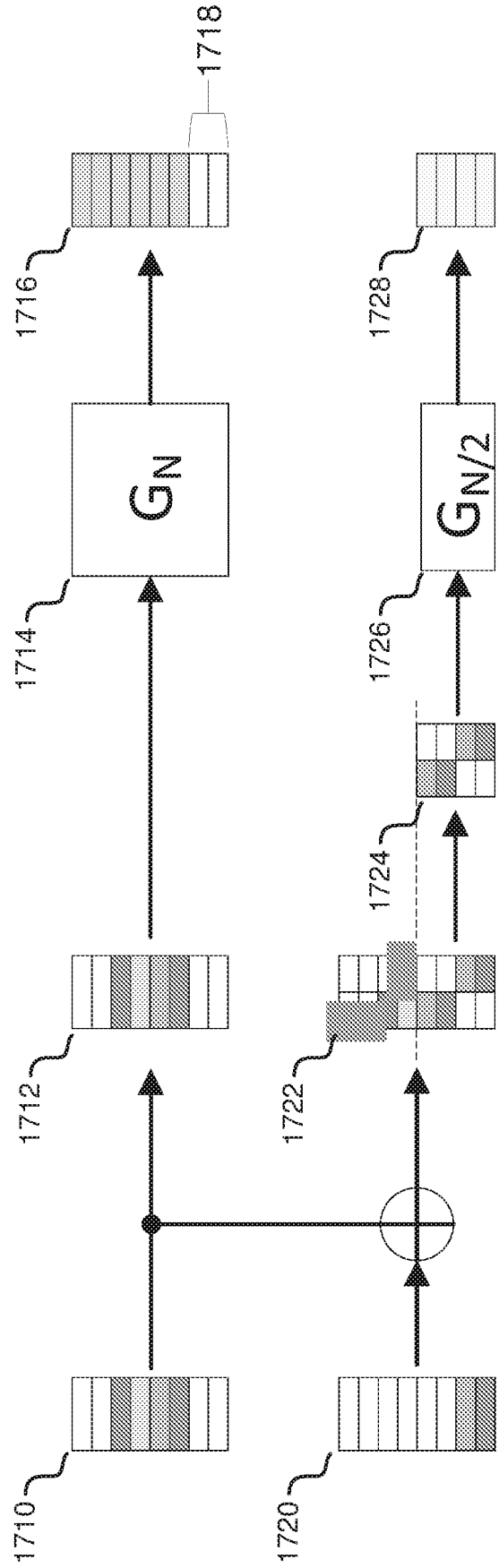
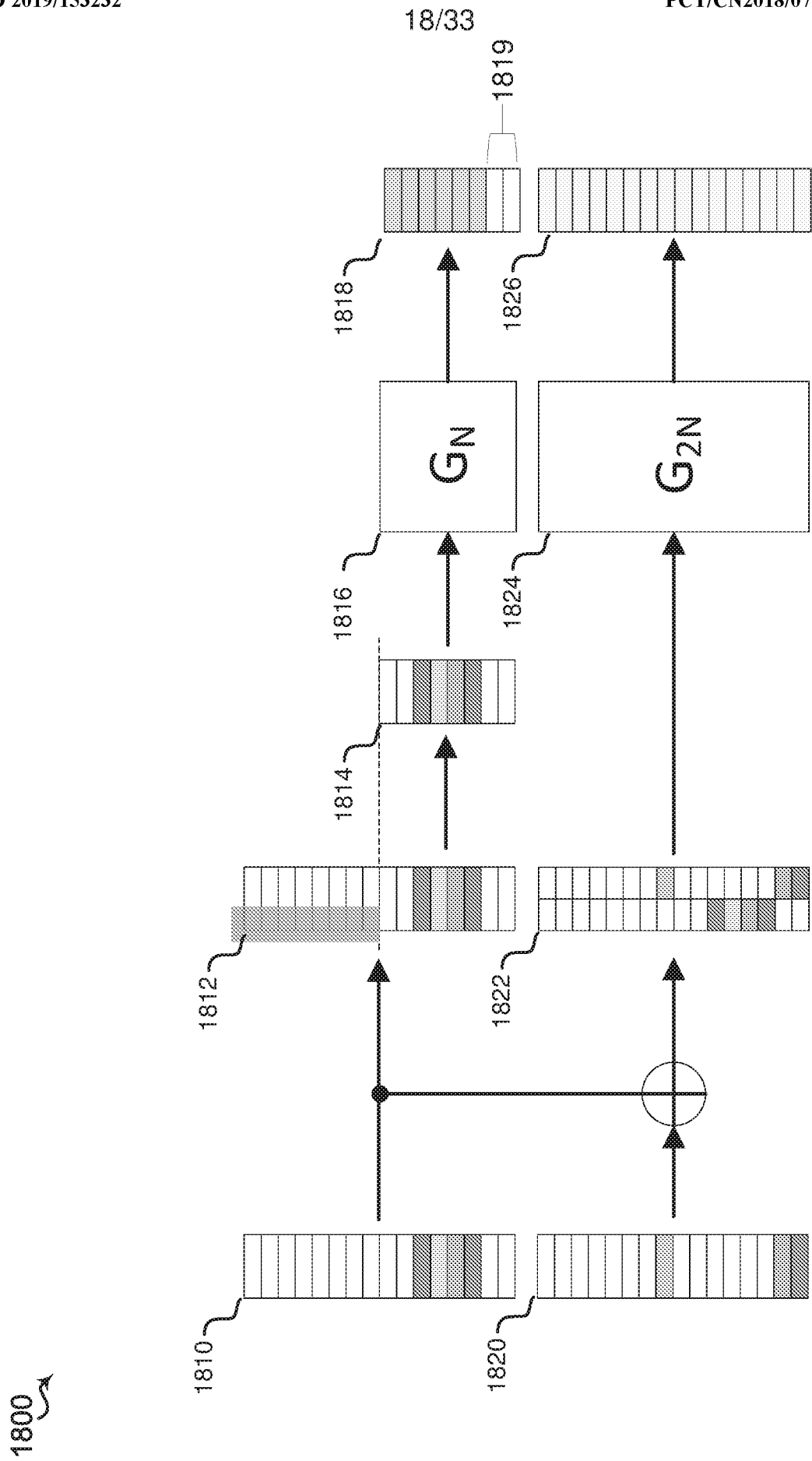


FIG. 17



18

1900

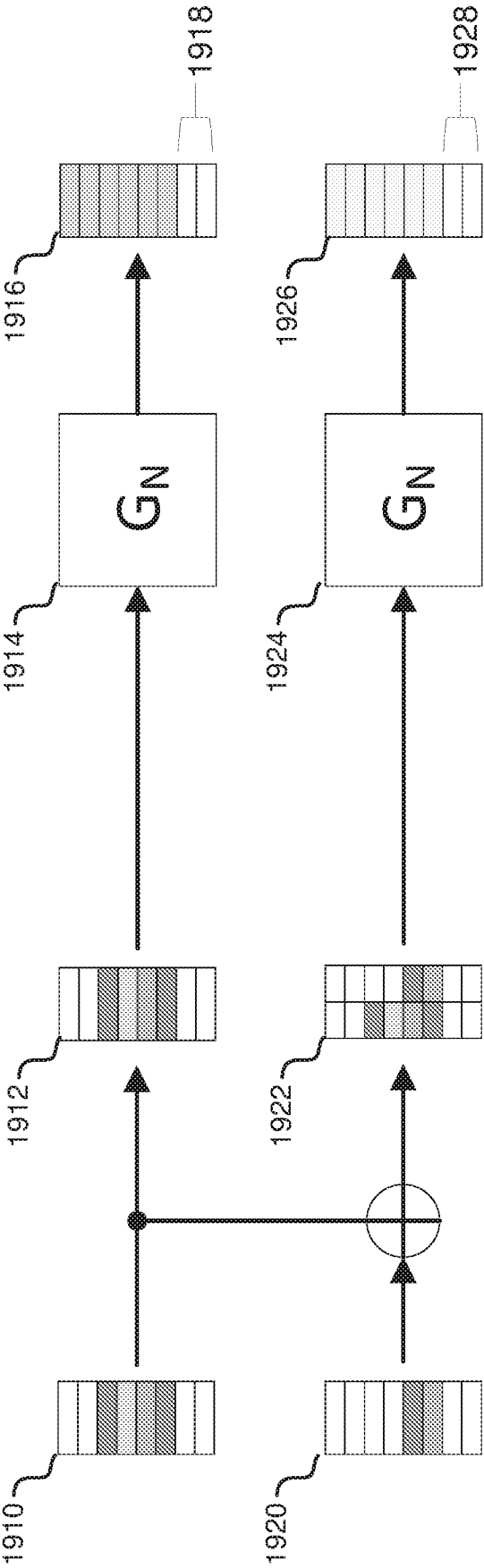


FIG. 19

2000

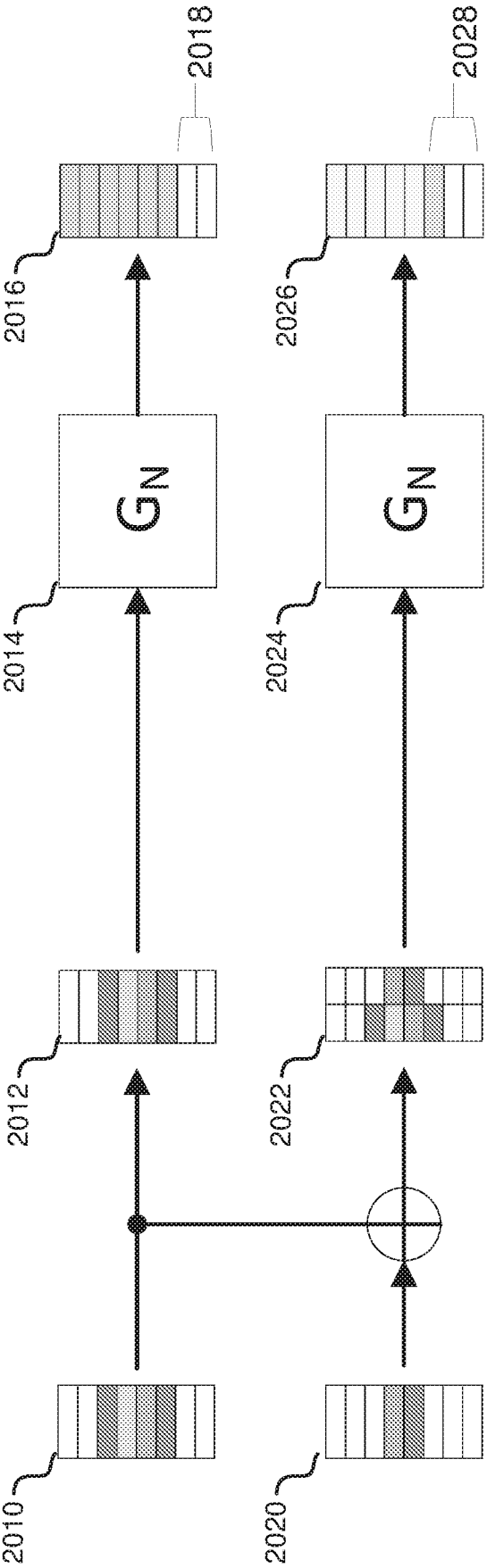


FIG. 20

2100

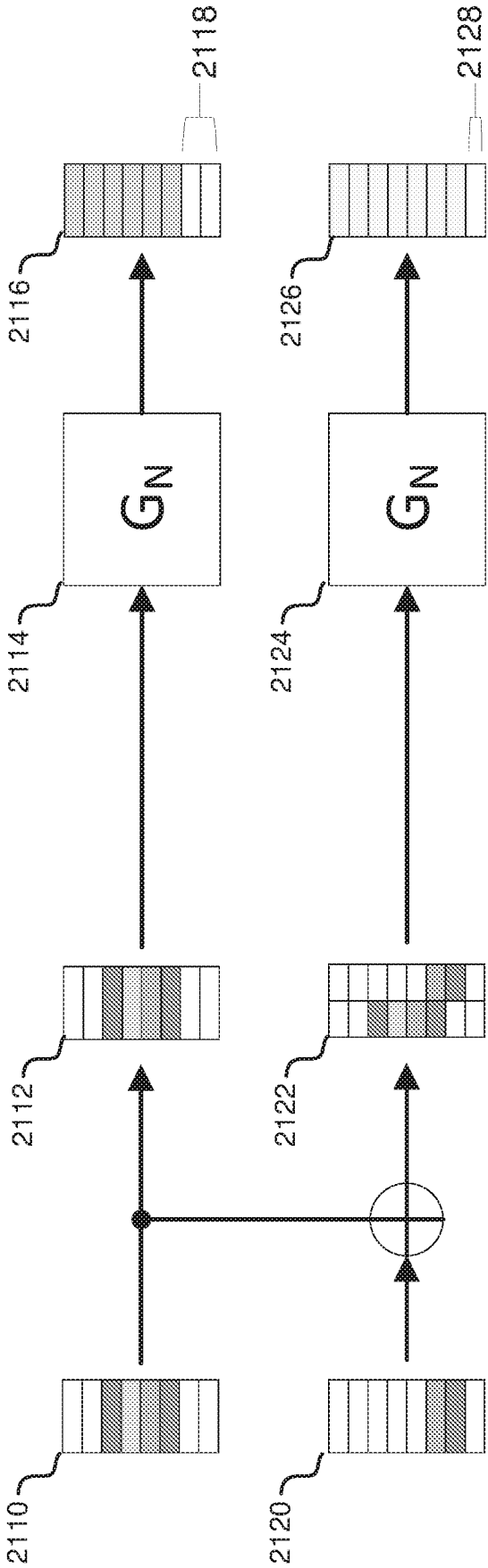


FIG. 21

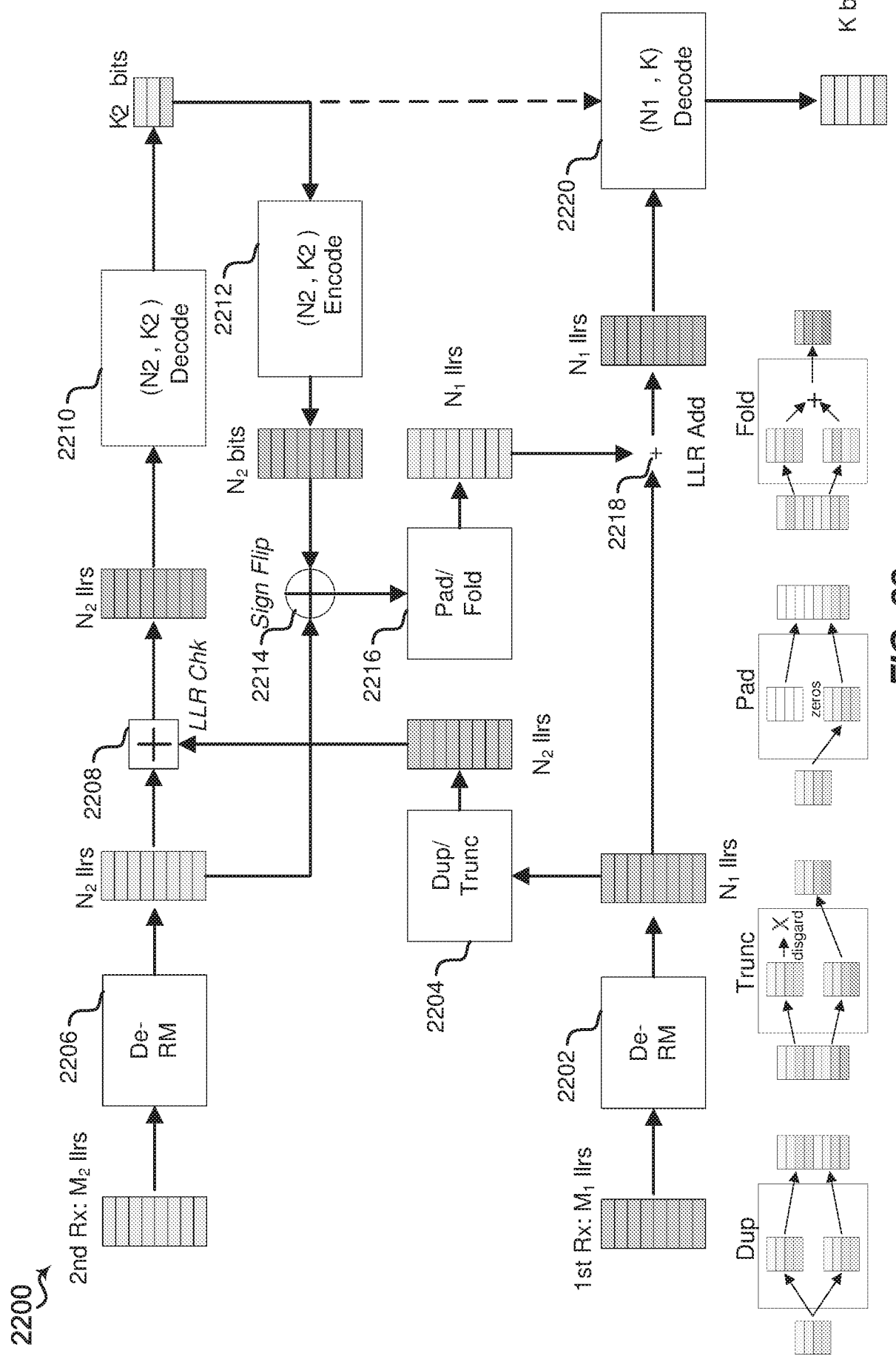
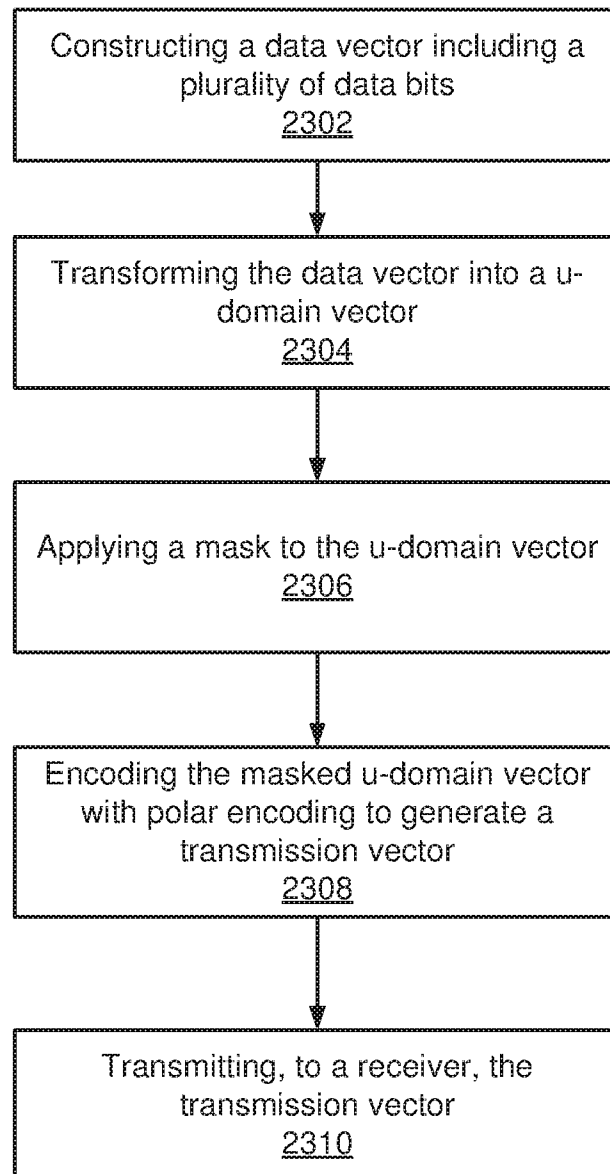


FIG. 22

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2300

**FIG. 23**

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2400

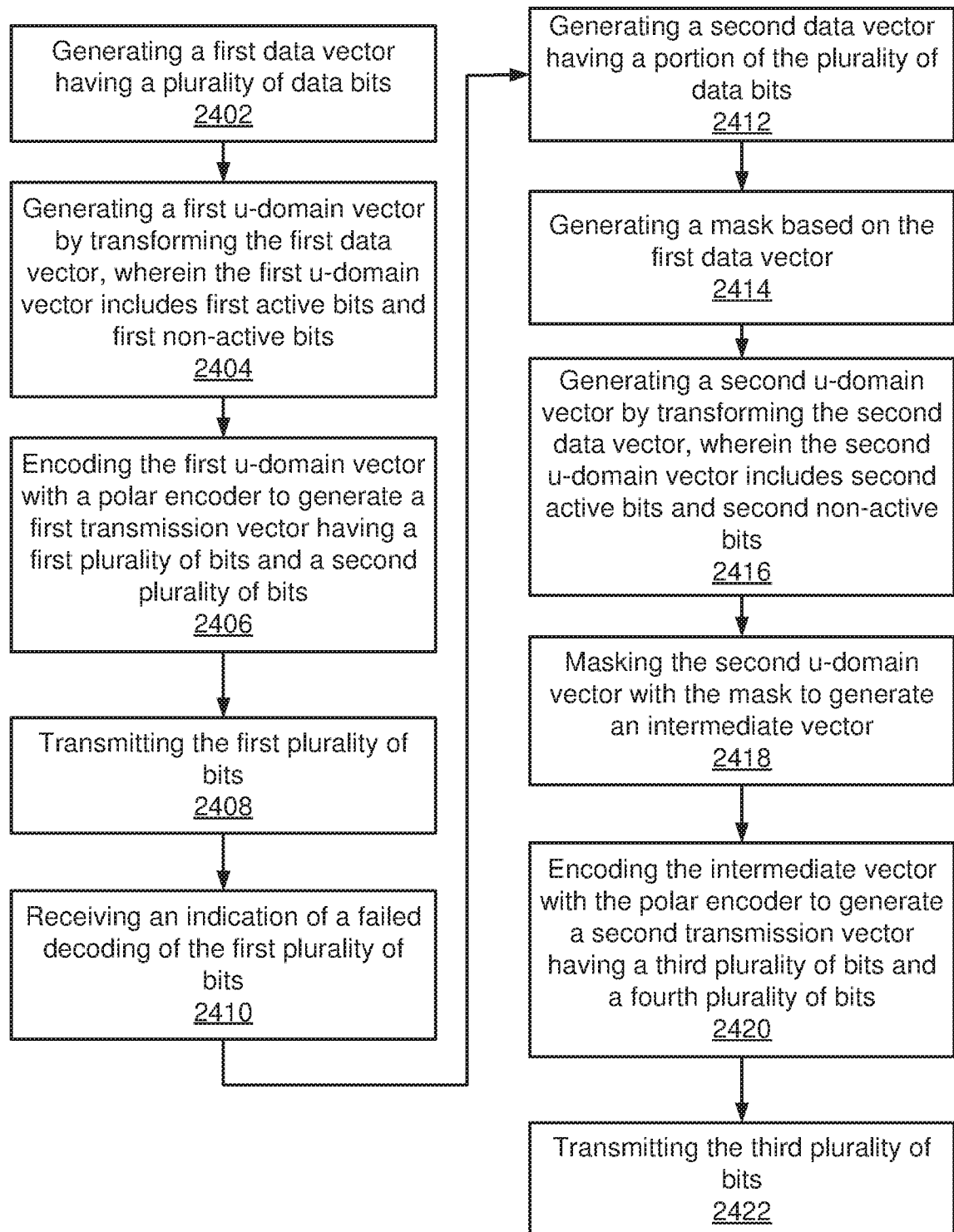


FIG. 24

2500

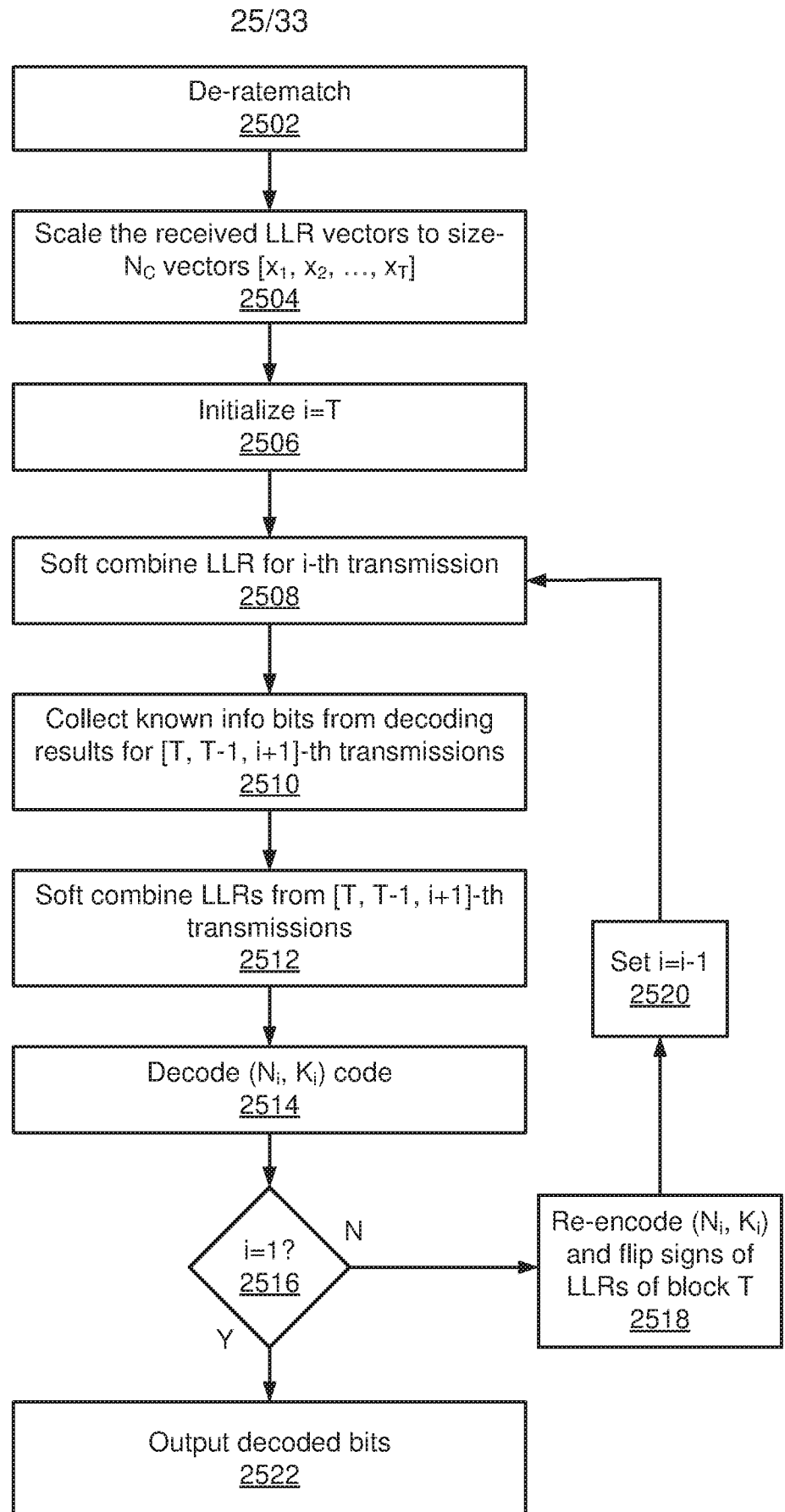
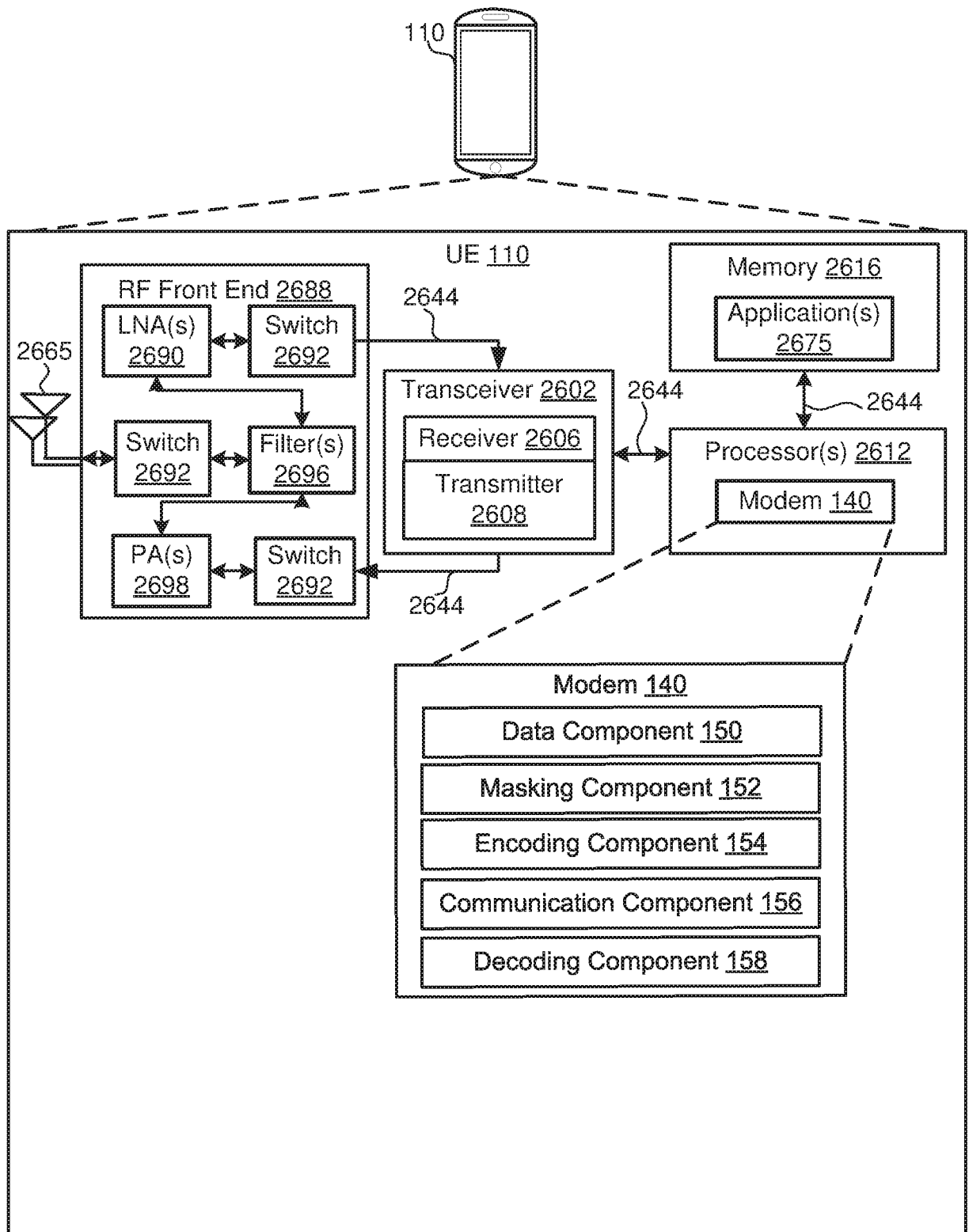


FIG. 25

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**FIG. 26**

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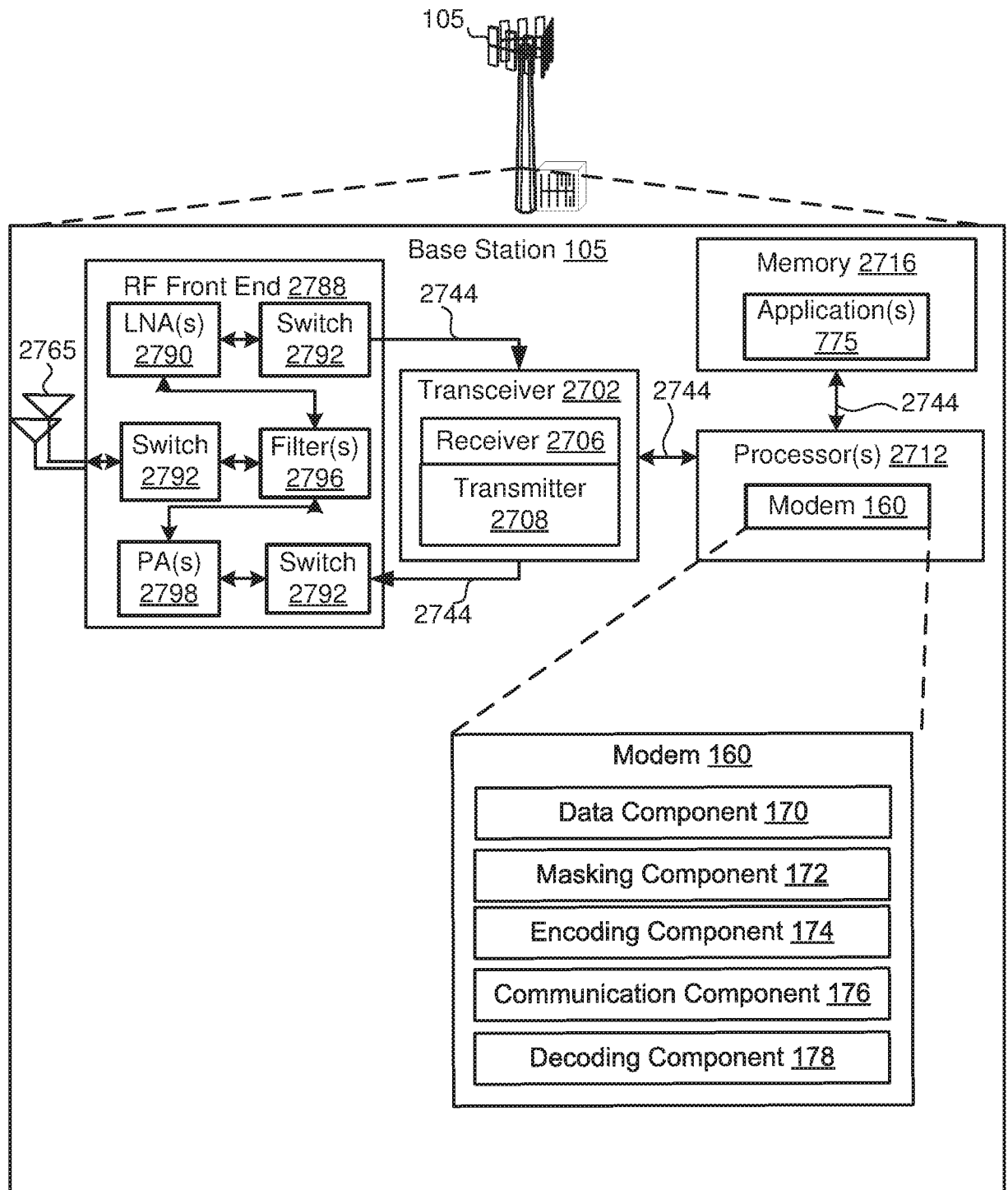


FIG. 27

2800

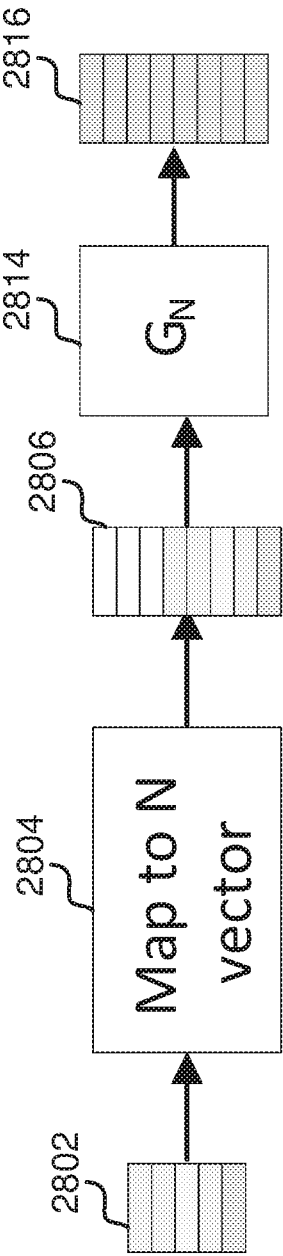


FIG. 28

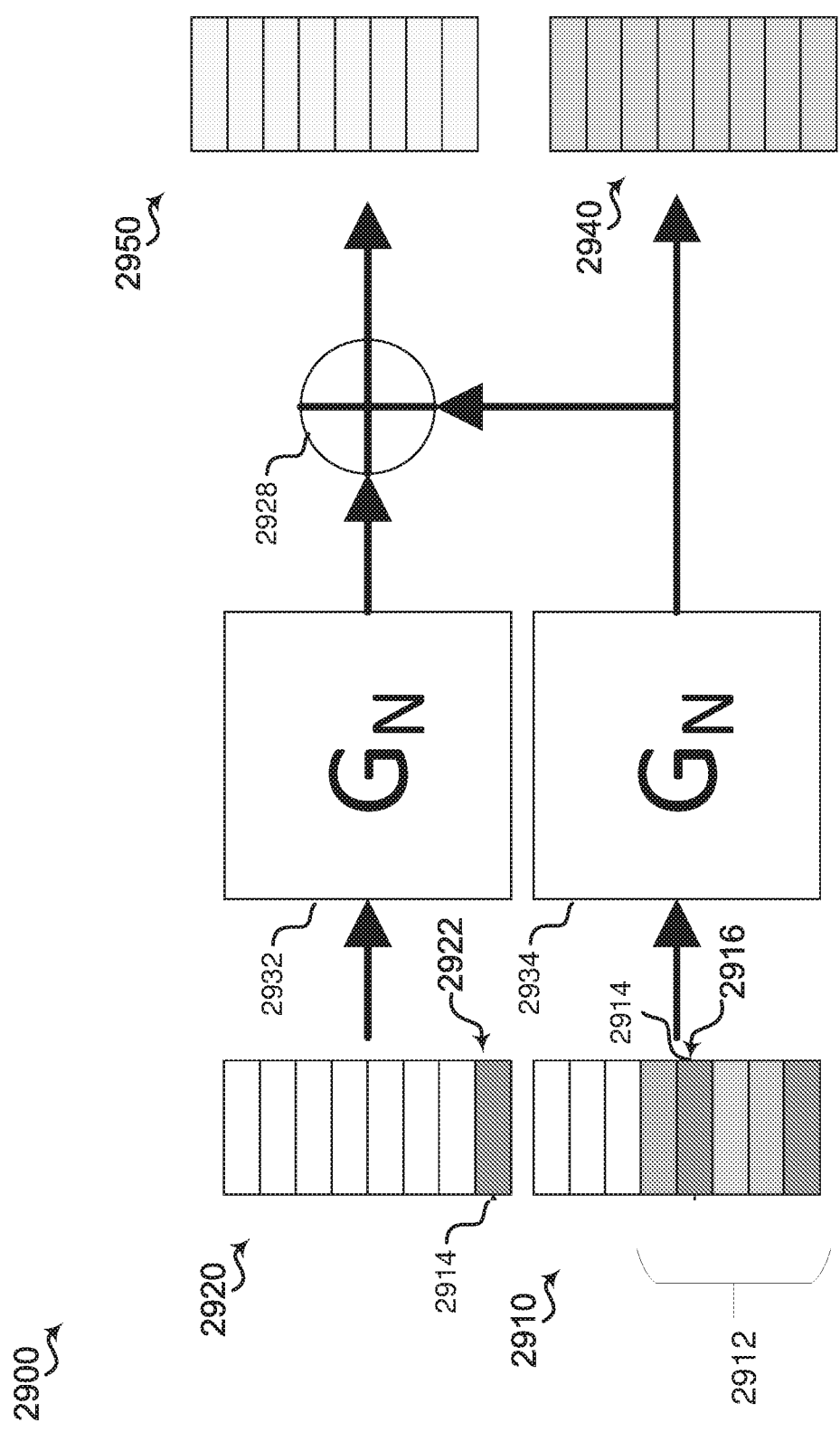


FIG. 29

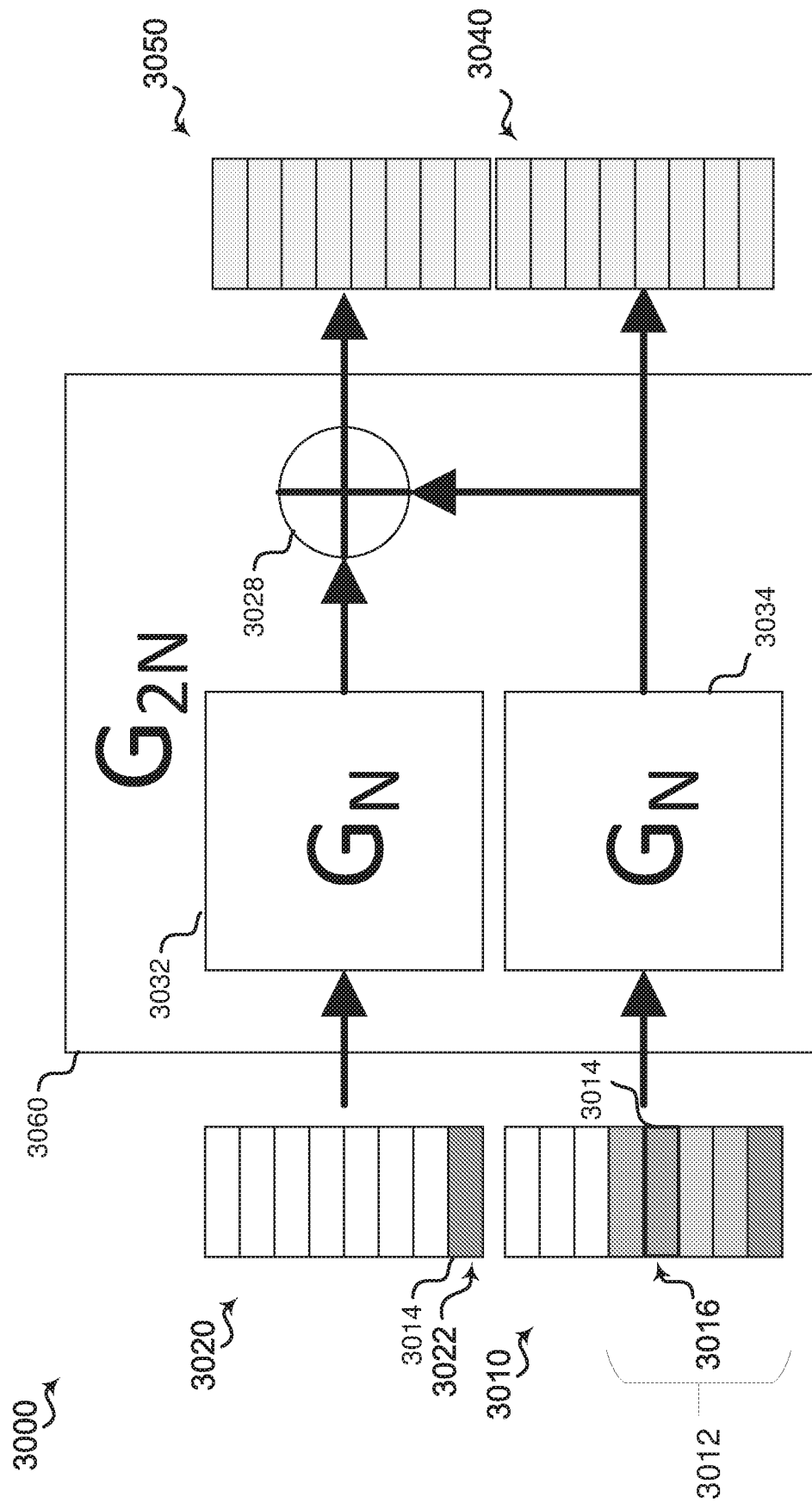


FIG. 30

3100 ↗

3150 ↗

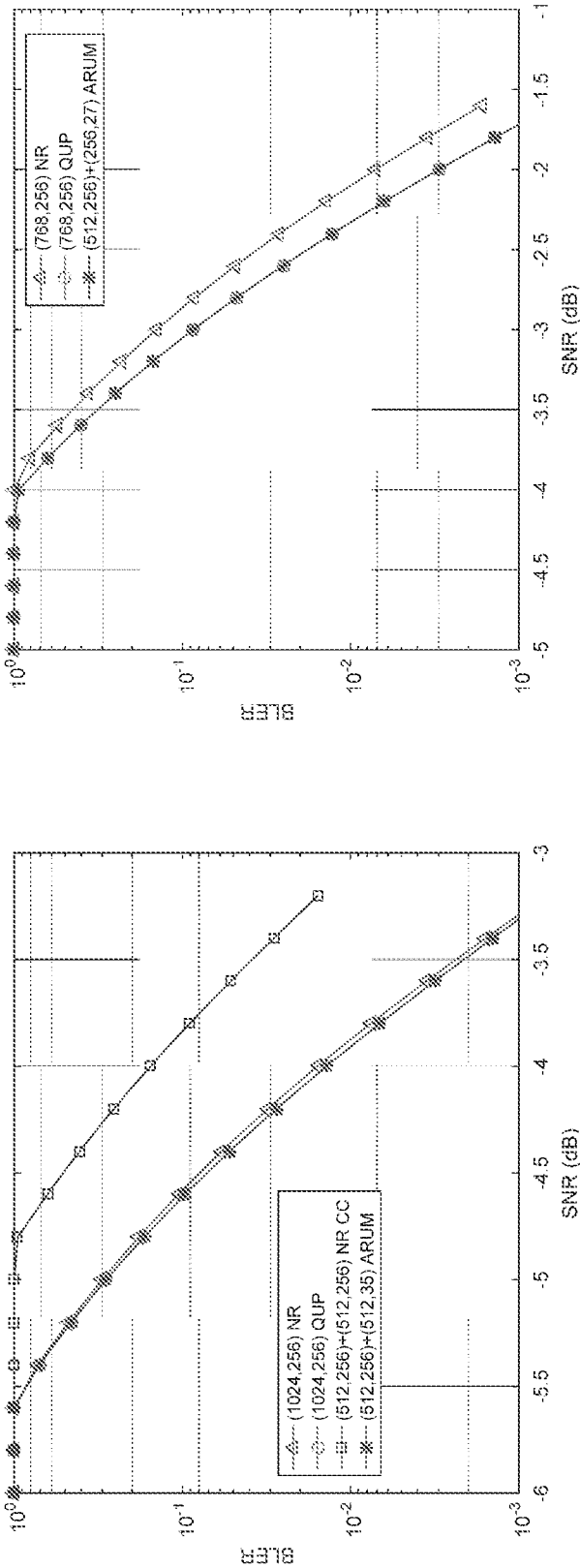


FIG. 31

3200 ↗

3250 ↗

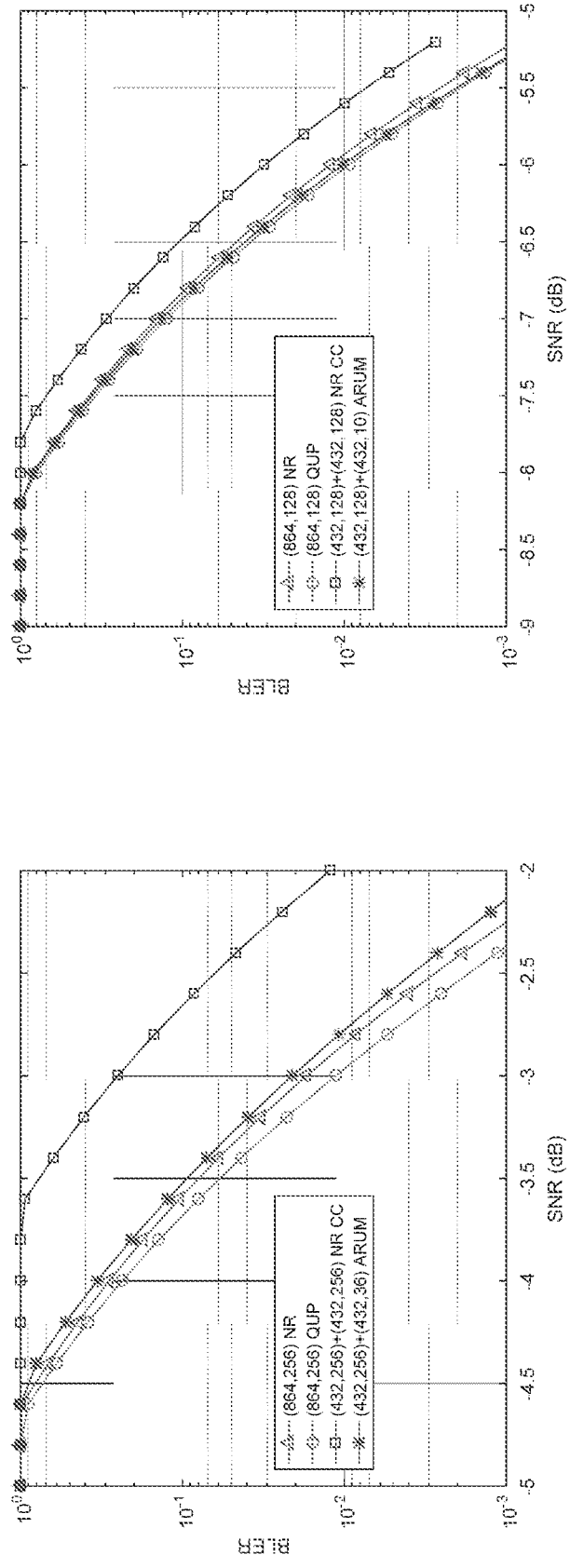


FIG. 32

3300 ↗

3350 ↗

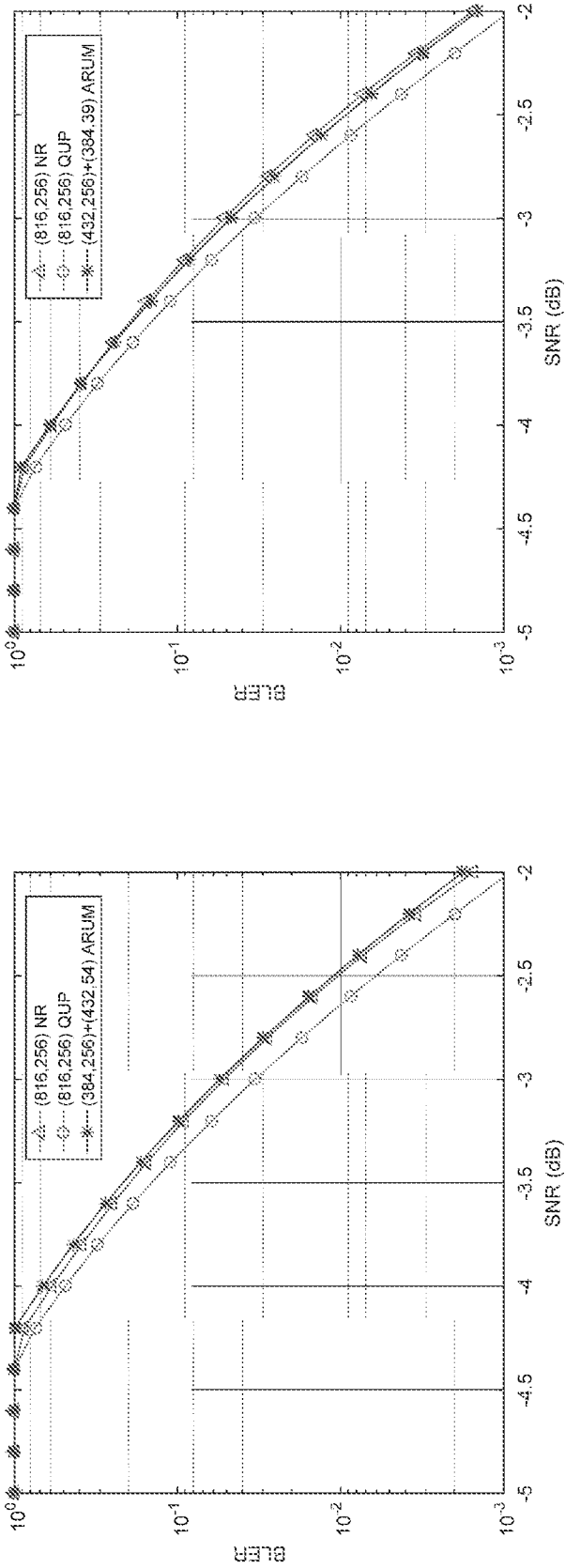


FIG. 33

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/075950

A. CLASSIFICATION OF SUBJECT MATTER H04L 1/00(2006.01)i; H03M 13/13(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04L; H04W; H04Q; 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) CNPAT, WPI, EPODOC, CNKI, 3GPP: polar, mask+, cod+, encod+, vector, rate, match+, active, frozen, CRC, HARQ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017215486 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 21 December 2017 (2017-12-21) description, paragraphs [0140]-[0157], figures 18-21	1-27
A	CN 102916763 A (HUAWEI TECHNOLOGIES CO., LTD. ET AL.) 06 February 2013 (2013-02-06) the whole document	1-27
A	US 2016380763 A1 (LG ELECTRONICS INC.) 29 December 2016 (2016-12-29) the whole document	1-27
A	QUALCOMM INCORPORATED. "Polar HARQ" 3GPP TSG-RAN WG1 #86 R1-166371, 26 August 2016 (2016-08-26), the whole document	1-27
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 15 October 2018		Date of mailing of the international search report 02 November 2018
Name and mailing address of the ISA/CN STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China Facsimile No. (86-10)62019451		Authorized officer GUO,Haibo Telephone No. 86-(10)-53961730

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2017215486	A1	21 December 2017	US	2017366199	A1	21 December 2017
CN	102916763	A	06 February 2013	None			
US	2016380763	A1	29 December 2016	None			