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(54) **SYSTEM AND METHOD FOR TRANSPORT BLOCK SIZE DESIGN FOR MULTIPLE-INPUT, MULTIPLE-OUTPUT (MIMO) IN A WIRELESS COMMUNICATIONS SYSTEM**

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H04L 27/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 27/0008*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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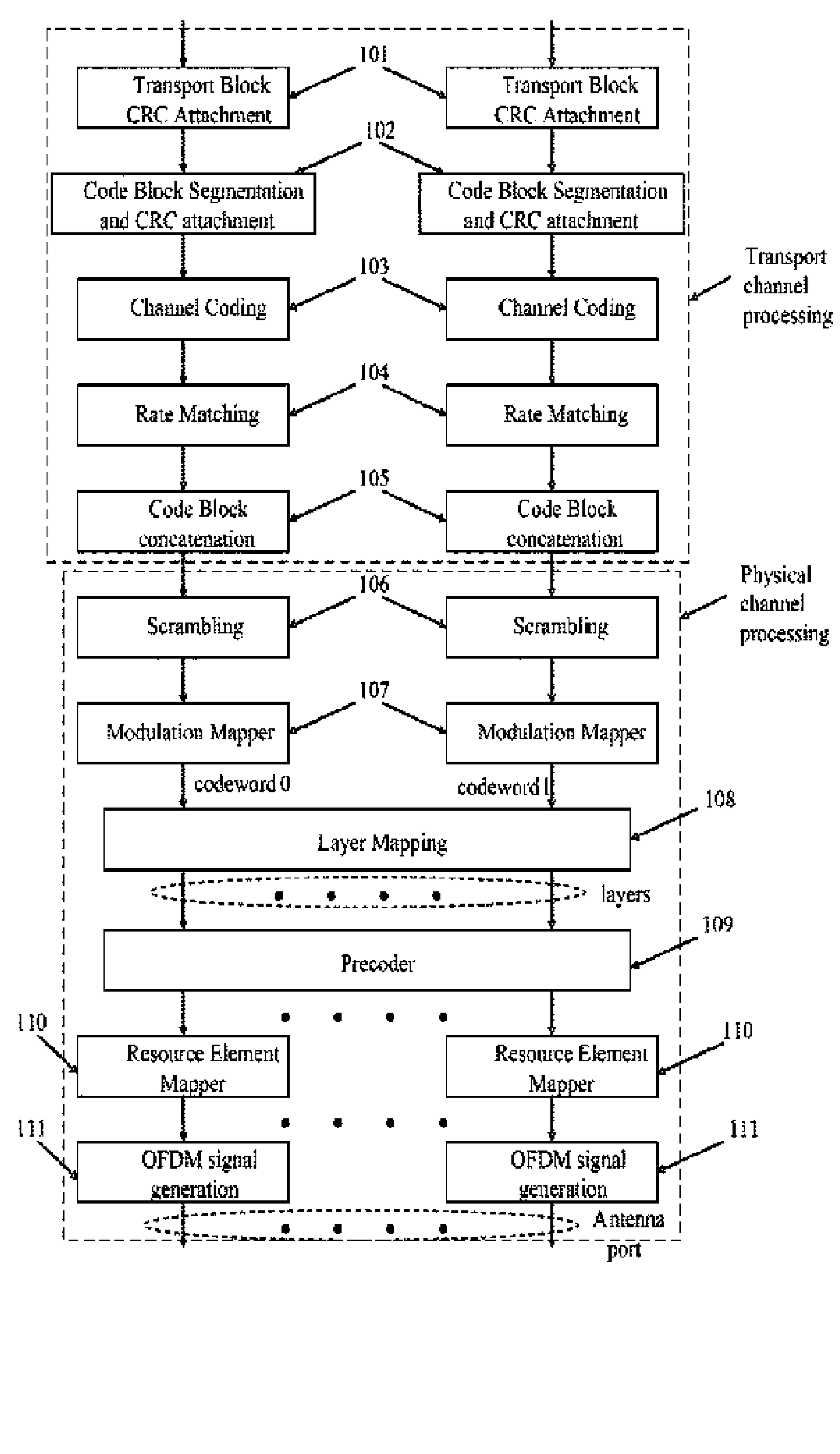
(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

(57) **ABSTRACT**

In one embodiment, a method for transmitting information includes processing a downlink transport channel to generate a transport block (TB) having a TB size. The TB size is selected by selecting a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}). The TB size for the selected I_{TBS} and N_{PRB} is selected so that an effective code rate at an user equipment (UE) does not exceed a specified threshold. The effective code rate is defined as a number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by a number of physical channel bits on Physical Downlink Shared Channel (PDSCH). The transport block is mapped to multiple spatial layers. The number of spatial layers N is greater than or equal to three. The multiple spatial layers are transmitted to the UE.

43 Claims, 7 Drawing Sheets



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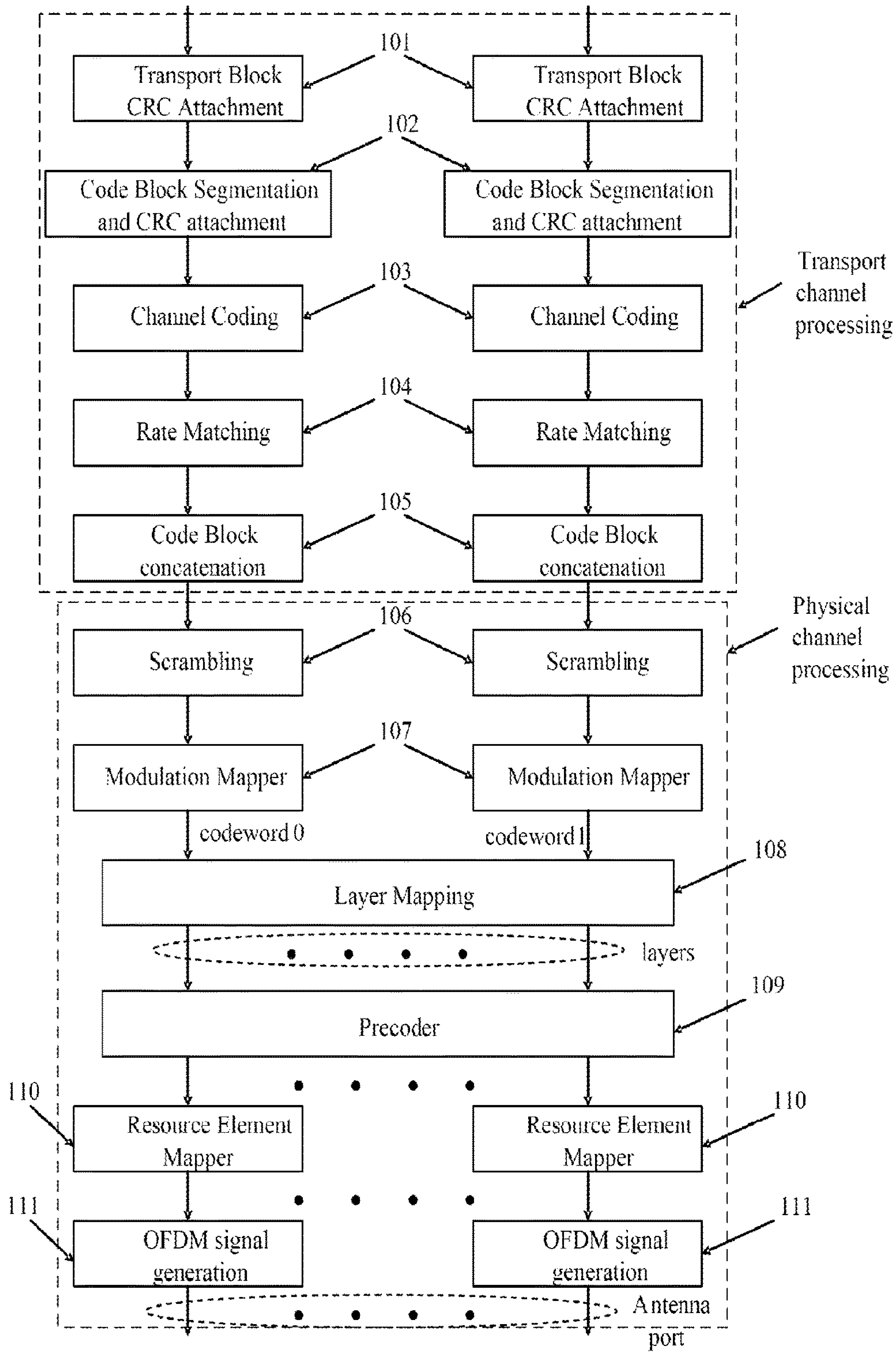
101
Transport Block CRC Attachment
Transport Block CRC Attachment
102
Code Block Segmentation and CRC attachment
Code Block Segmentation and CRC attachment
103
Channel Coding
Channel Coding
104
Rate Matching
Rate Matching
105
Code Block concatenation
Code Block concatenation
Transport channel processing
106
Scrambling
Scrambling
107
Modulation Mapper
Modulation Mapper
codeword 0
codeword 1
Physical channel processing
108
Layer Mapping
layers
109
Precoder
110
Resource Element Mapper
110
Resource Element Mapper
111
OFDM signal generation
111
OFDM signal generation
Antenna port

Fig. 1

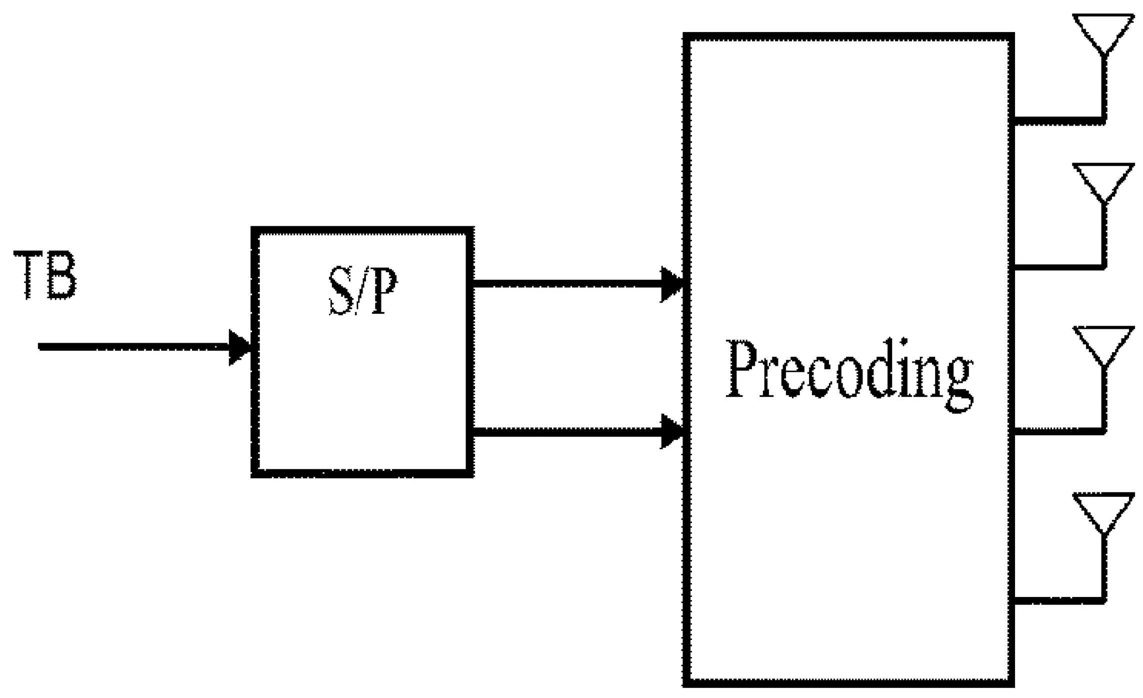

Fig. 2a

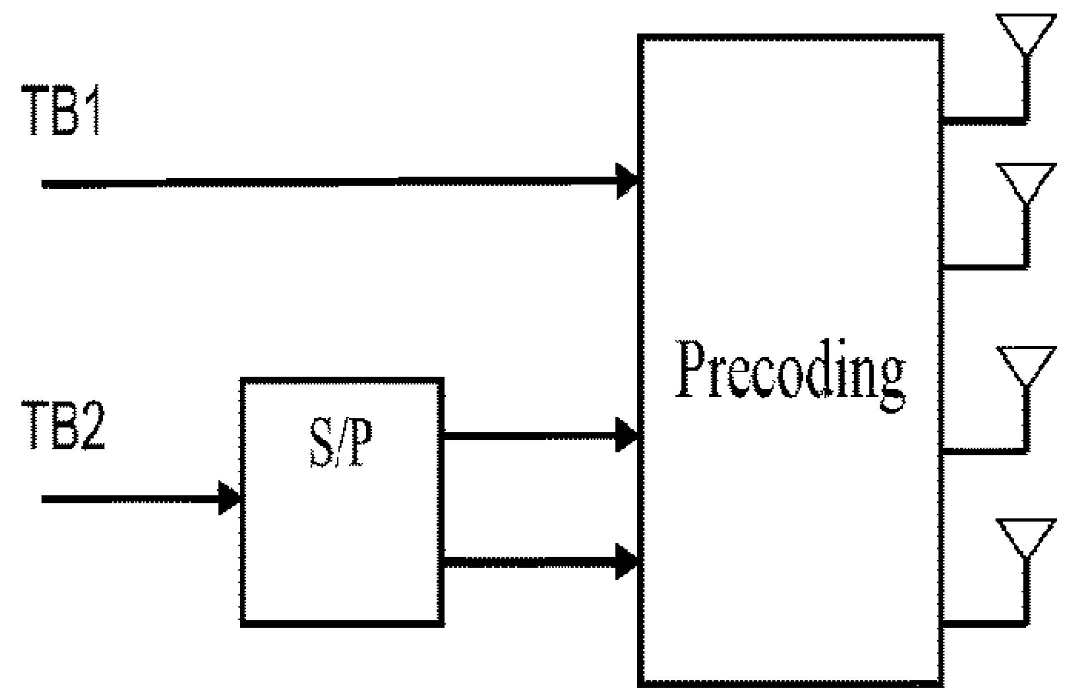

Fig. 2b

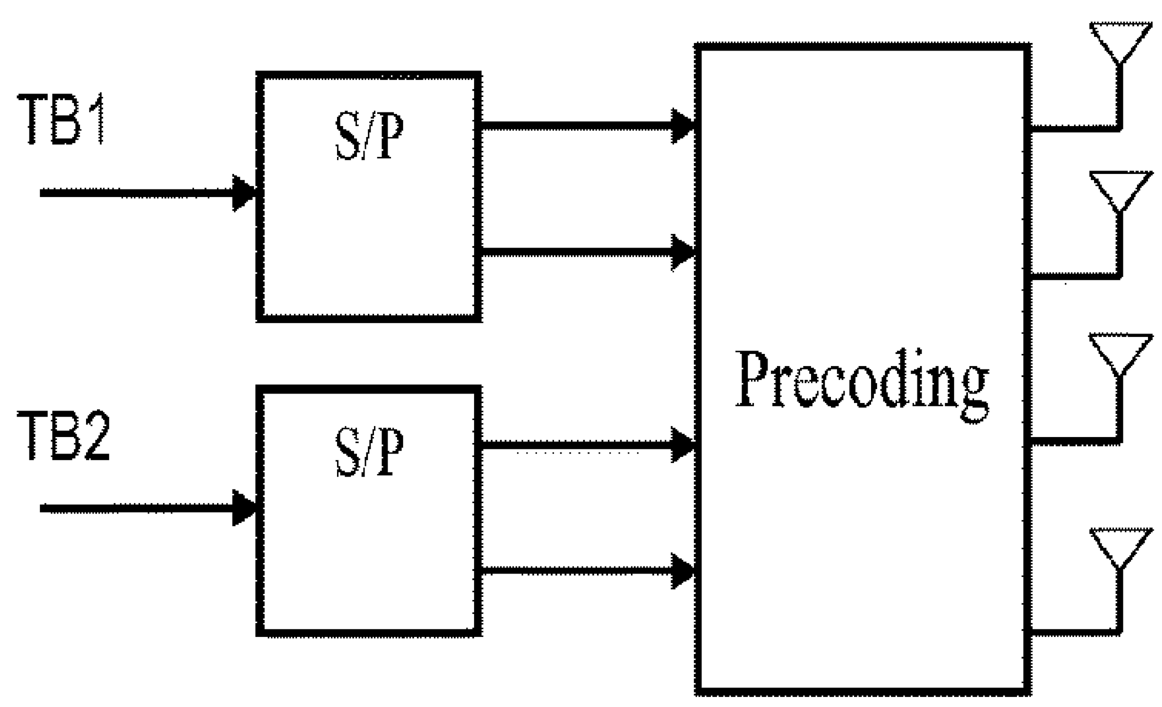

Fig. 2c

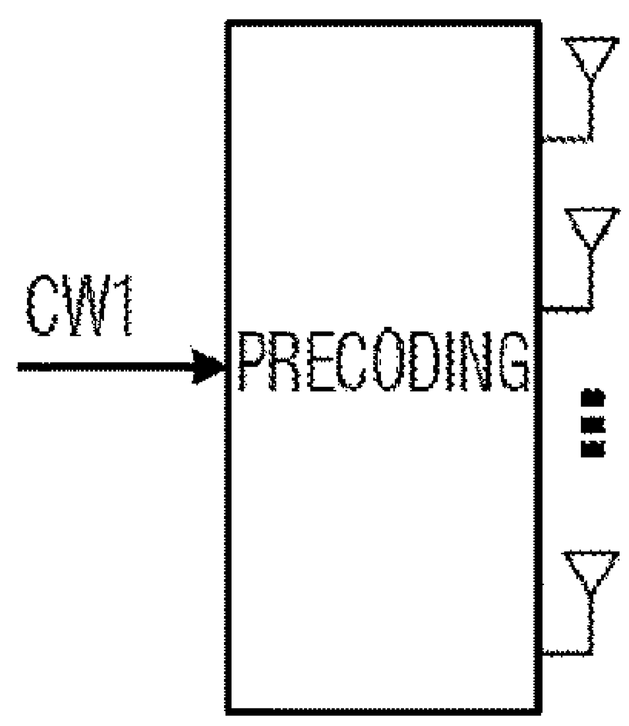

Fig. 3a

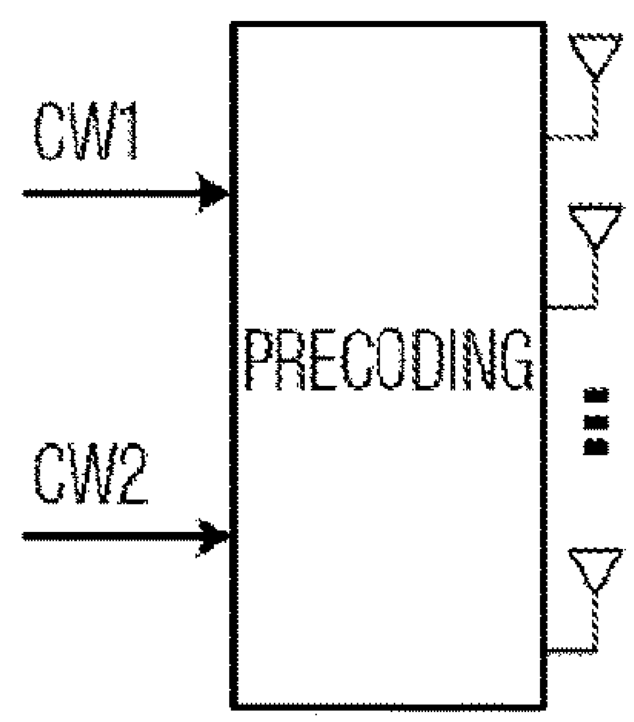

Fig. 3b

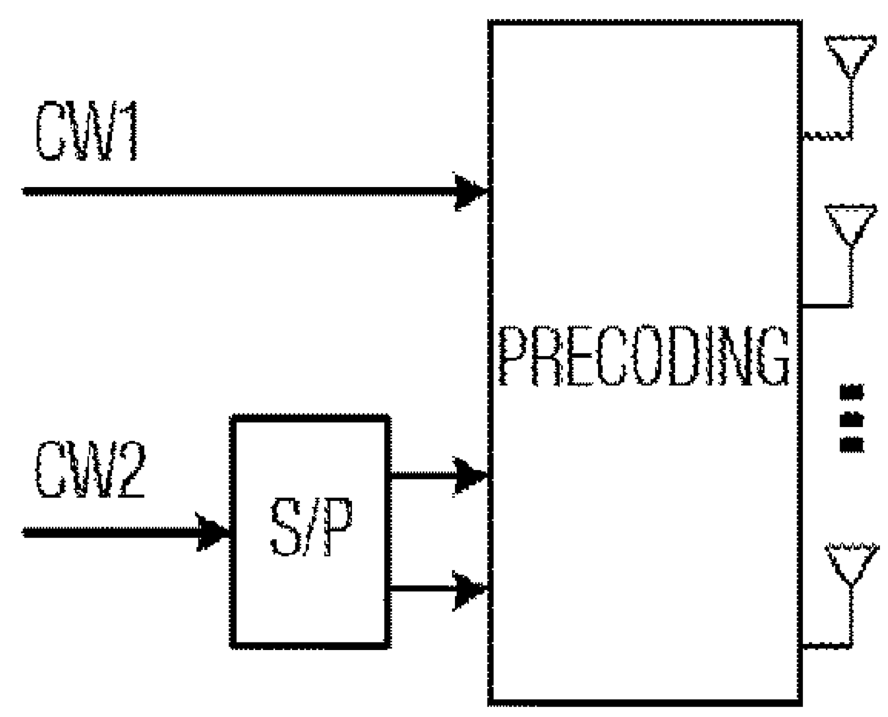

Fig. 3d

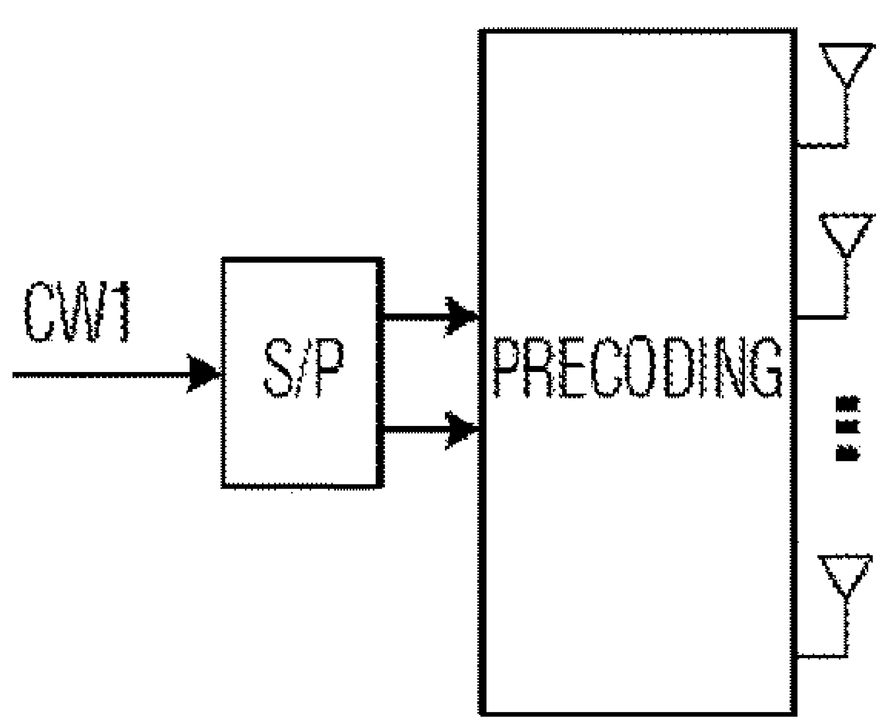

Fig. 3c

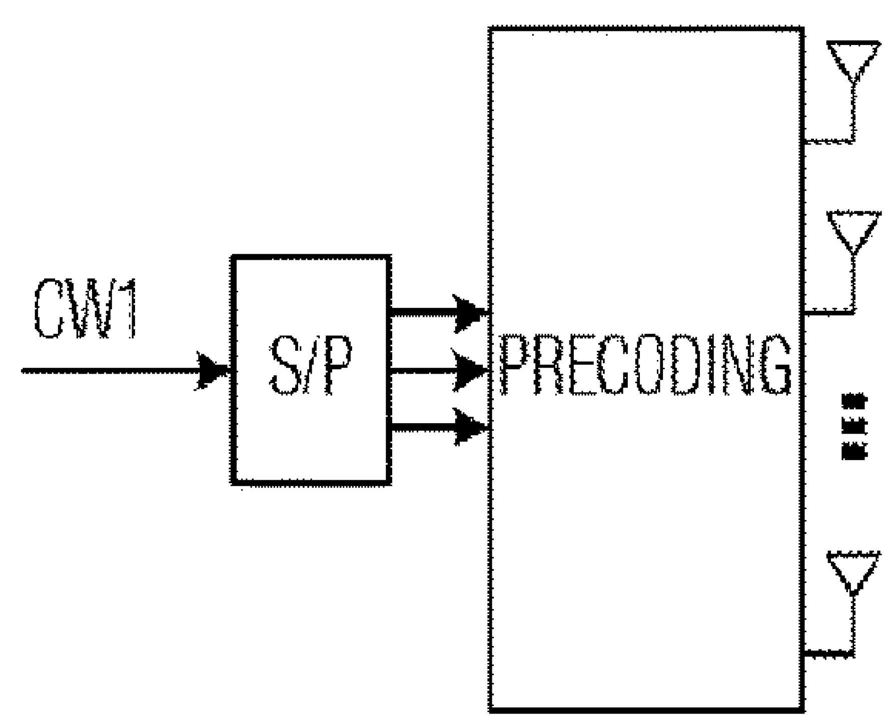

Fig. 3e

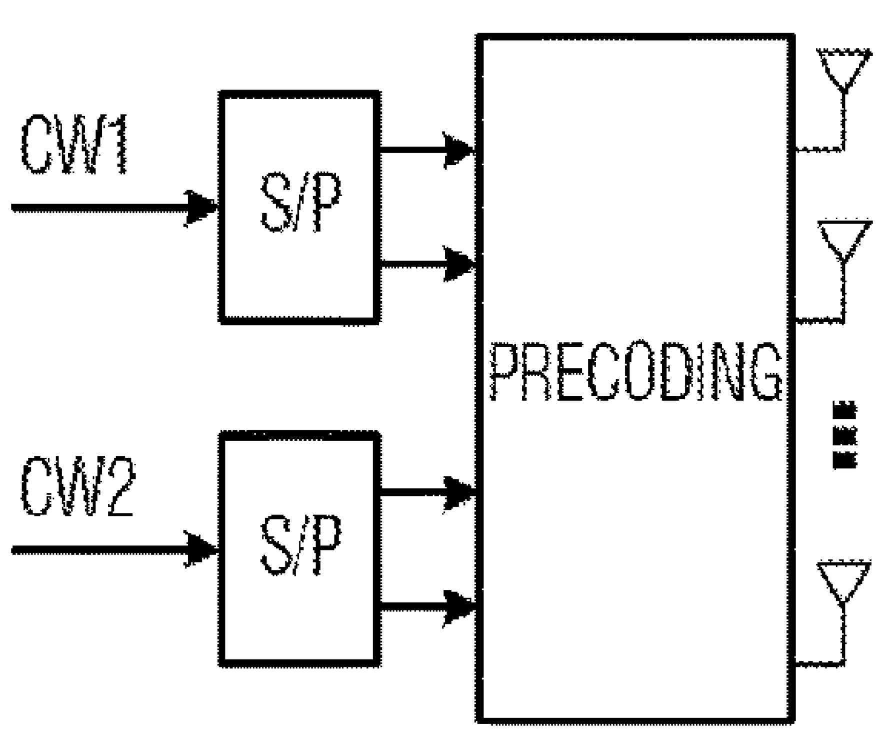

Fig. 3f

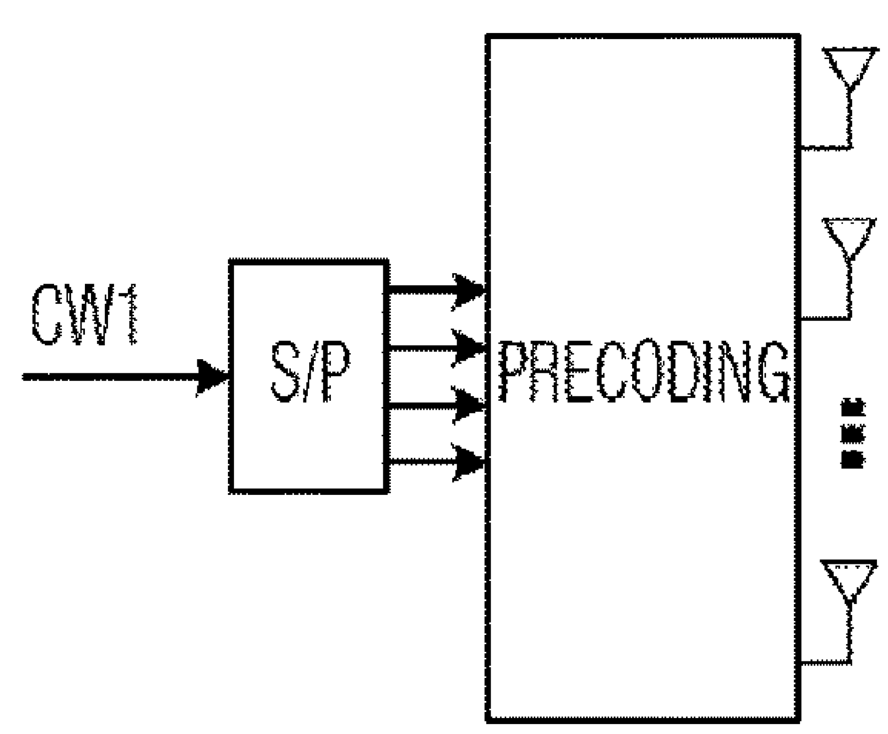

Fig. 3g

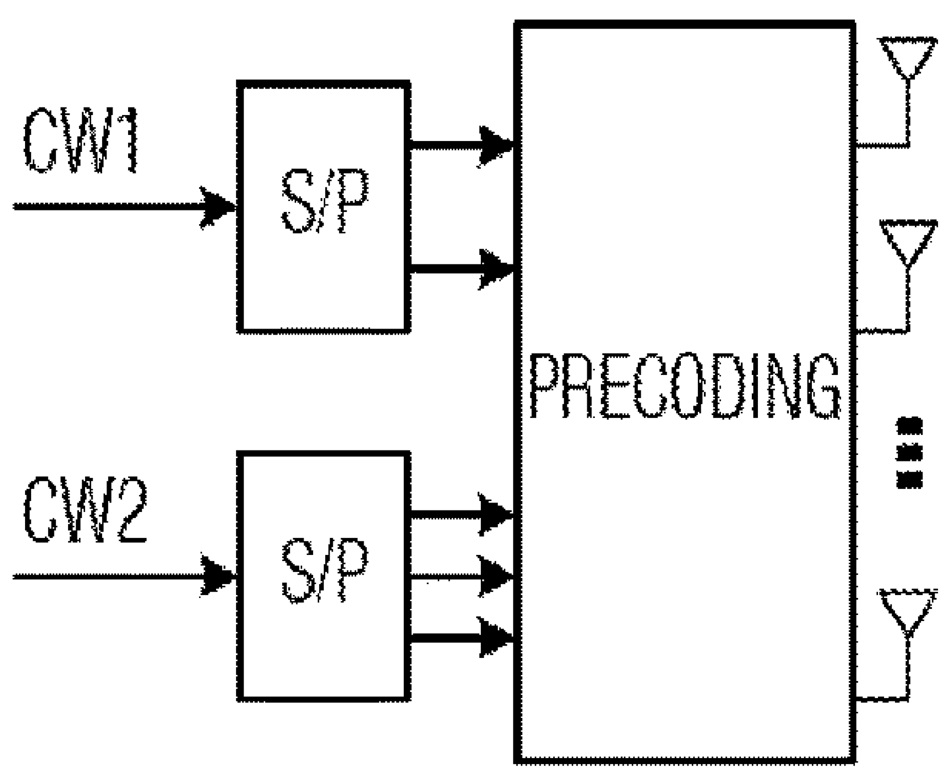

Fig. 3h

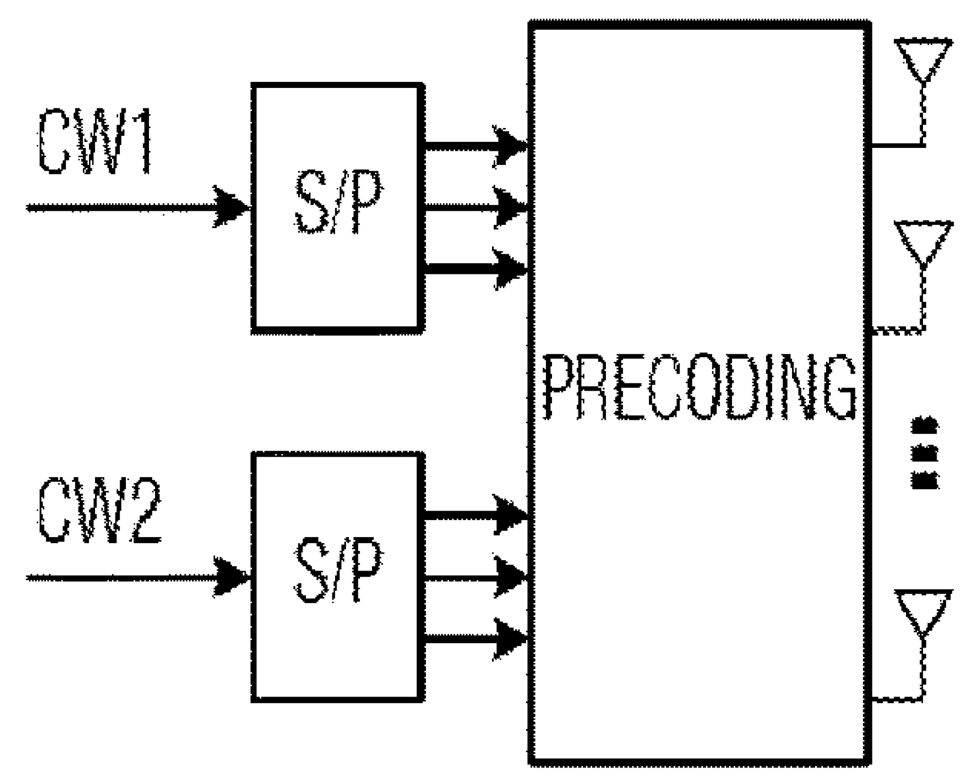

Fig. 3i

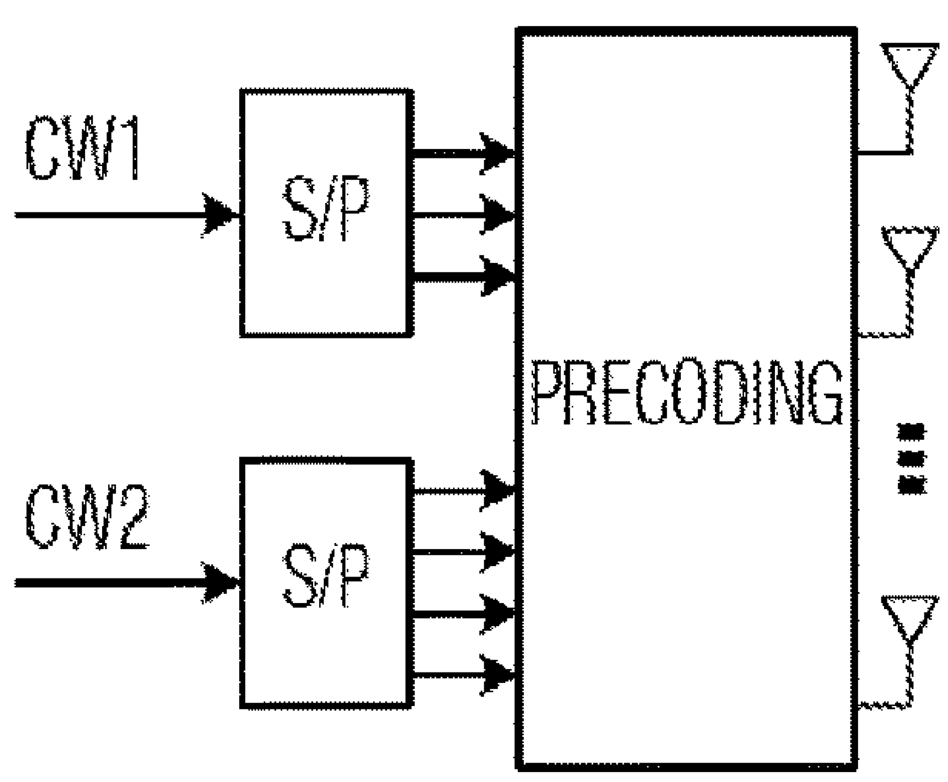

Fig. 3j

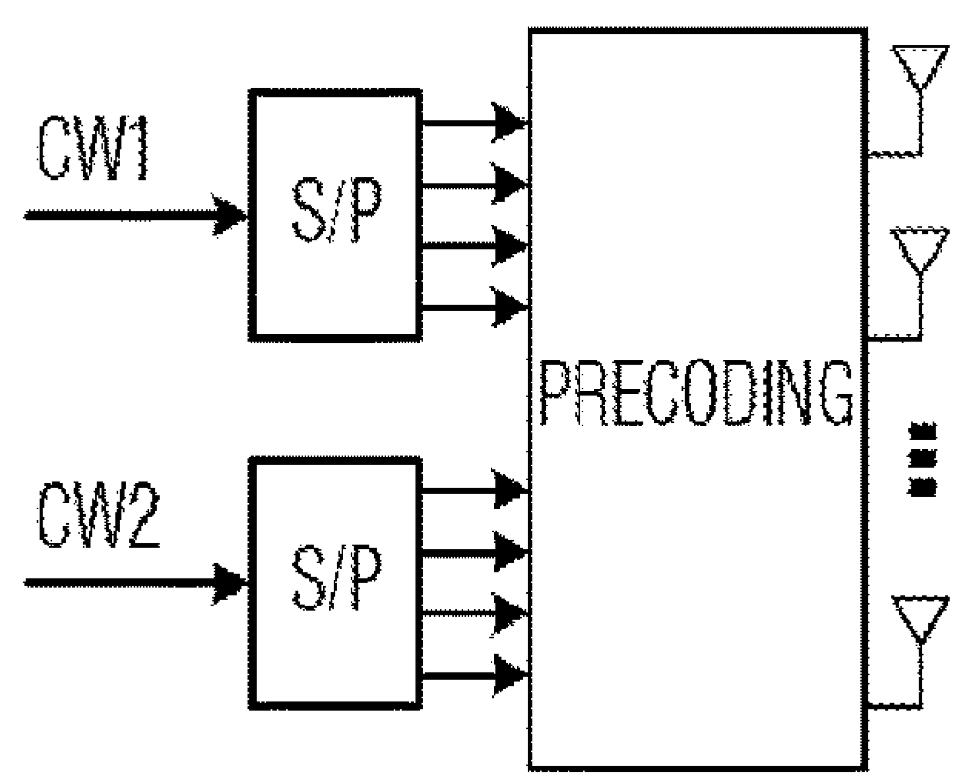

Fig. 3k

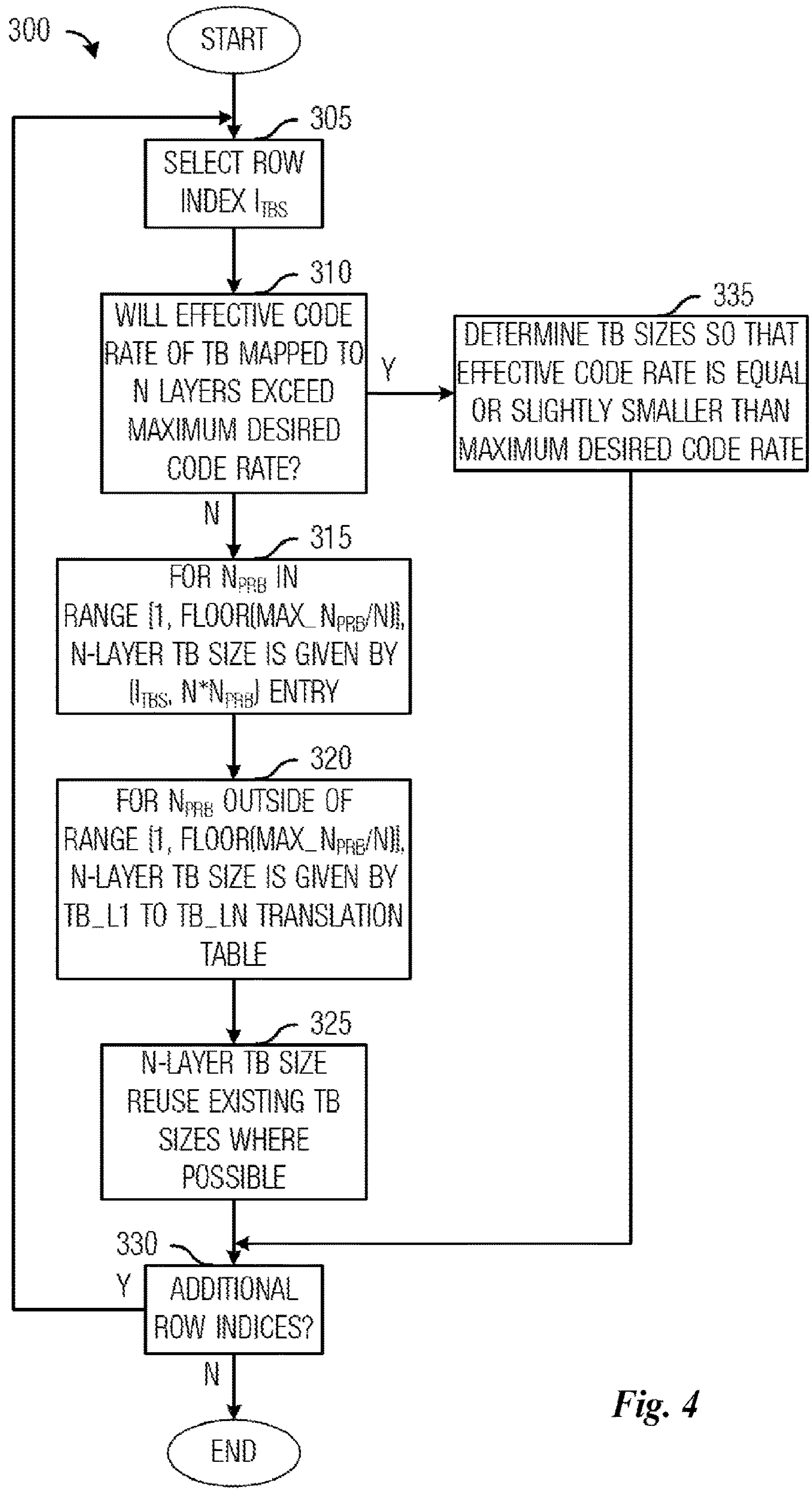
300
START
305
SELECT ROW INDEX I_TBS
310
WILL EFFECTIVE CODE RATE OF TB MAPPED TO N LAYERS EXCEED MAXIMUM DESIRED CODE RATE?
Y
335
DETERMINE TB SIZES SO THAT EFFECTIVE CODE RATE IS EQUAL OR SLIGHTLY SMALLER THAN MAXIMUM DESIRED CODE RATE
N
315
FOR N_PRB IN RANGE [1, FLOOR(MAX_N_PRB/N)], N-LAYER TB SIZE IS GIVEN BY (I_TBS, N*N_PRB) ENTRY
320
FOR N_PRB OUTSIDE OF RANGE [1, FLOOR(MAX_N_PRB/N)], N-LAYER TB SIZE IS GIVEN BY TB_L1 TO TB_LN TRANSLATION TABLE
325
N-LAYER TB SIZE REUSE EXISTING TB SIZES WHERE POSSIBLE
330
Y
ADDITIONAL ROW INDICES?
N
END

Fig. 4

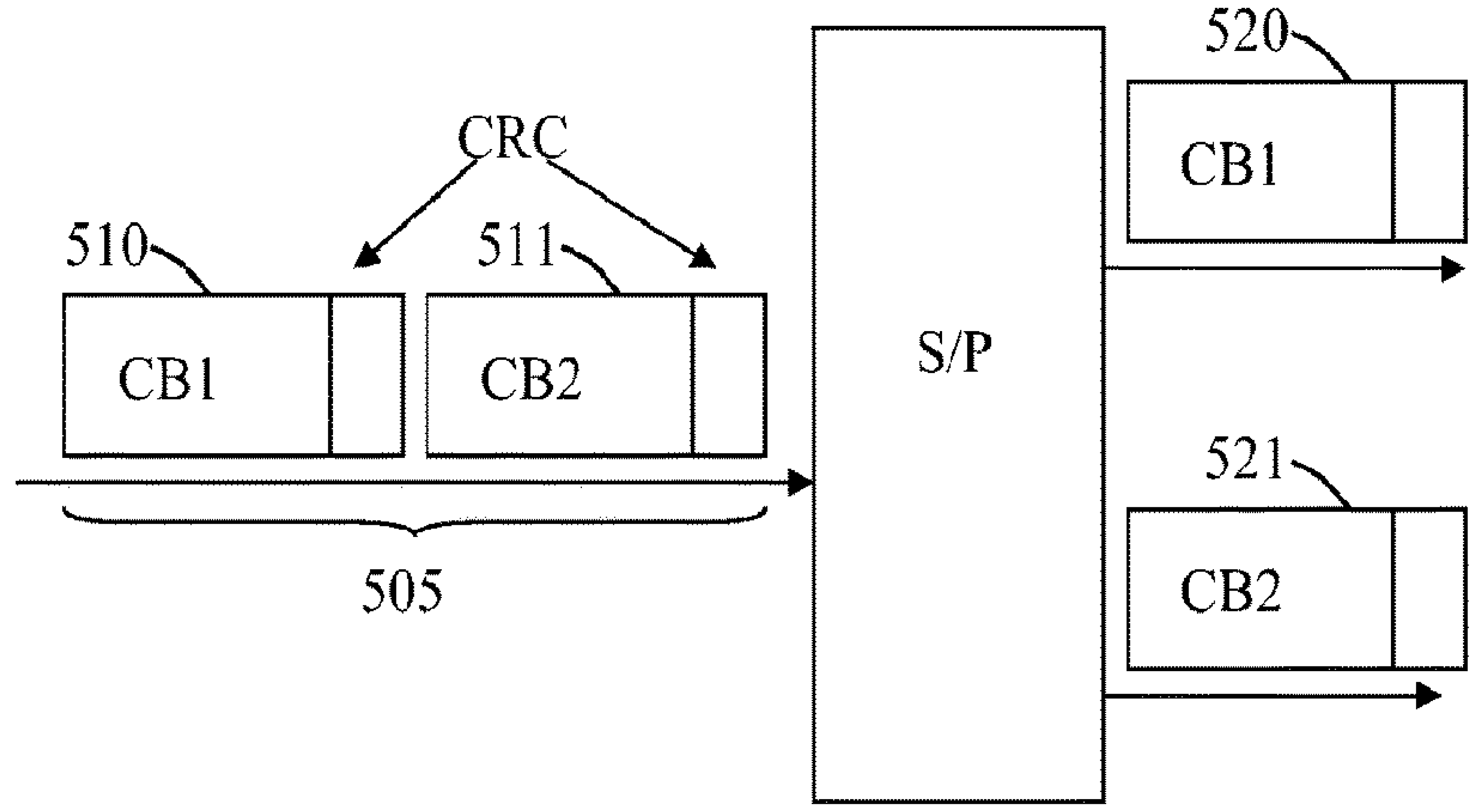
CRC
510
511
CB1
CB2
505
S/P
520
CB1
521
CB2

Fig. 5a

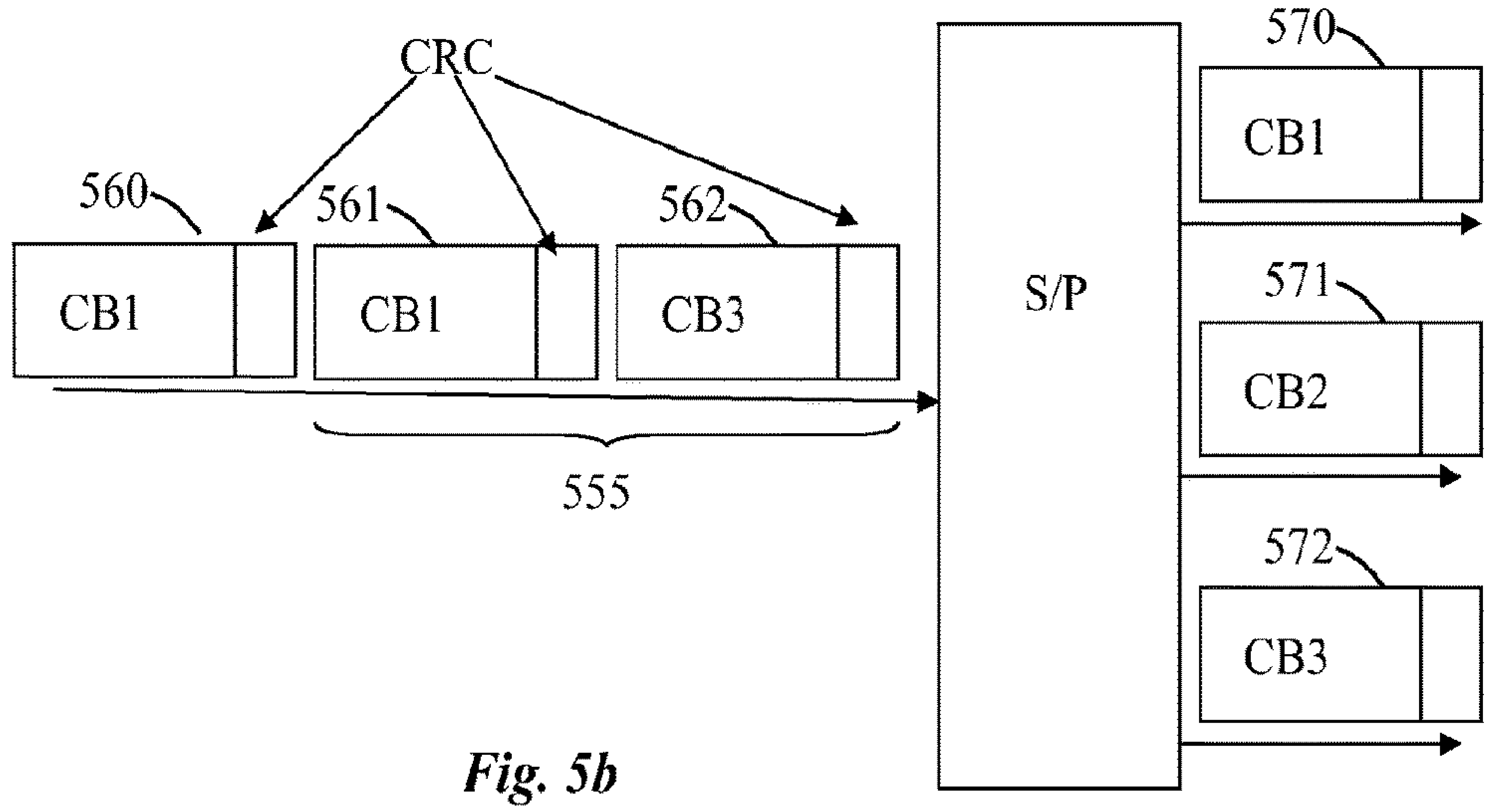
CRC
560
561
562
CB1
CB1
CB3
555
S/P
570
CB1
571
CB2
572
CB3

Fig. 5b

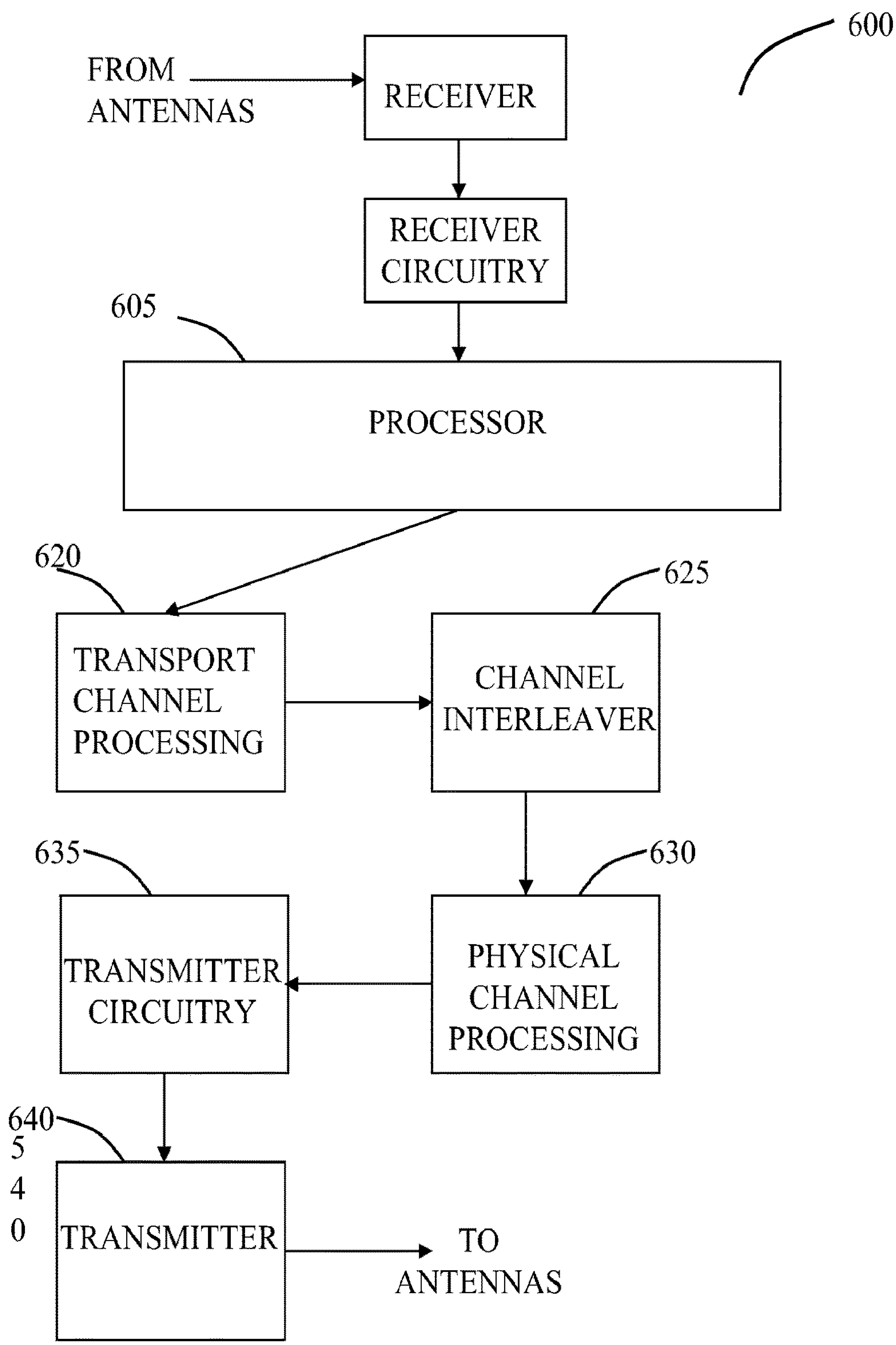
600
FROM ANTENNAS
RECEIVER
RECEIVER CIRCUITRY
605
PROCESSOR
620
625
TRANSPORT CHANNEL PROCESSING
CHANNEL INTERLEAVER
635
630
TRANSMITTER CIRCUITRY
PHYSICAL CHANNEL PROCESSING
640
5
4
0
TRANSMITTER
TO ANTENNAS

Fig. 6

SYSTEM AND METHOD FOR TRANSPORT BLOCK SIZE DESIGN FOR MULTIPLE-INPUT, MULTIPLE-OUTPUT (MIMO) IN A WIRELESS COMMUNICATIONS SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

This application claims the benefit of U.S. Provisional Application No. 61/183,481, filed on Jun. 2, 2009, entitled "System and Method for Transport Block Size Design for Downlink Multiple-Input, Multiple-Output (MIMO) in a Wireless Communications System," and U.S. Provisional Application No. 61/219,321 filed on Jun. 22, 2009, entitled "Transport Block Size Design for LTE-A Uplink MIMO," which applications are hereby incorporated herein by reference.

TECHNICAL FIELD

The present invention relates generally to wireless communication, and more particularly to a system and method for transport block size (TBS) design for MIMO in a wireless communication system.

BACKGROUND

The Third Generation Partnership Project (3GPP) has decided that Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (E-UTRA) evolve in future releases in order to meet 3GPP operator requirements for the evolution of E-UTRA and a need to meet/exceed the capabilities of International Mobile Telecommunications (IMT) Advanced. Accordingly, Long Term Evolution (LTE) is in the progress of evolving to LTE-Advanced.

Changes in LTE-Advanced over LTE include a target peak data rate for a downlink (DL) to be about 1 Gbps for LTE-Advanced as compared to 100 Mbps for LTE. In order to support such high data rates, DL spatial multiplexing with up to eight layers is considered for LTE-Advanced (see 3GPP TR 36.814 V0.4.1(2009-02), "Further Advancements for E-UTRA; Physical Layer Aspects; (Release 9), which is incorporated herein by reference), while in LTE, DL spatial multiplexing with up to four layers is available. As a result, changes may have to be made to facilitate the higher layer DL spatial multiplexing for LTE-Advanced, such as redesigning control signaling, reference signal patterns, transport block size per DL component carrier, and so forth.

As specified in LTE-Advanced, in the DL 8-by-X single user spatial multiplexing, up to two transport blocks may be transmitted to a scheduled User Equipment (UE) in a subframe per DL component carrier. Each transport block may be assigned its own modulation and coding scheme.

With an increase in the number of supported layers for DL spatial multiplexing in LTE-advanced, a new codeword-to-layer mapping needs to be designed to accommodate the larger number of layers (eight as opposed to four). Furthermore, the size of the transport blocks may be significantly increased for the allocated resource blocks.

For uplink, the target peak data rate is 50 Mb/s in LTE system, but for LTE-Advanced the target peak data rate of uplink is increased to 500 Mb/s. Uplink spatial multiplexing of up to four layers is considered for LTE-Advanced to support the higher data rates according to 3GPP TR 36.814 V0.4.1(2009-02), "Further Advancements for E-UTRA; Physical Layer Aspects; (Release 9)," which is incorporated herein by reference. In contrast only a single layer is used for LTE uplink. Therefore, many changes have to be made to facilitate the higher layer uplink spatial multiplexing for LTE-Advanced, such as redesigning control signaling, reference signal patterns, transport block size per uplink component carrier, and so on.

Hence, transport block size design for uplink and downlink are needed for increasing peak data rate in uplink and downlink transmission.

SUMMARY OF THE INVENTION

These and other problems are generally solved or circumvented, and technical advantages are generally achieved, by embodiments of a system and method for transport block size design for downlink MIMO in a wireless communication system.

In accordance with an embodiment, a method for transmitting information comprises processing a downlink transport channel to generate a transport block (TB) having a TB size. The TB size is selected by selecting a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}). The TB size for the selected I_{TBS} and N_{PRB} is selected so that an effective code rate at a user equipment (UE) does not exceed a specified threshold. The effective code rate is defined as a number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and/or code block CRC bits divided by a number of physical channel bits on Physical Downlink Shared Channel (PDSCH). The transport block is mapped to multiple spatial layers. The number of spatial layers N is greater than or equal to three. The multiple spatial layers are transmitted to the UE.

In another embodiment, a method for transmitting information comprises processing a uplink transport channel to generate a transport block (TB) having a TB size. The TB size is selected by selecting a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}). The TB size for the I_{TBS} and the N_{PRB} is selected so that the number of code blocks in the TB size is one (1) or a multiple of a number of spatial layers N. The transport block is mapped to the N spatial layers, and the N spatial layers transmitted to a receiver.

In an alternative embodiment, a communications device comprises a transmitter to be coupled to at least one transmit antenna. The transmitter is configured to transmit signals with the at least one transmit antenna. A transport channel processing unit is coupled to a processor. The transport channel processing unit is configured to provide transport channel processing to a transport block (TB) provided by the processor. The TB size of the TB is selected by selecting a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}), and setting the TB size for the selected I_{TBS} and N_{PRB} so that the effective code rate at a user equipment (UE) does not exceed a specified threshold. The effective code rate is defined as the number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by the number of physical channel bits on Physical Downlink Shared Channel (PDSCH). A physical channel processing unit is coupled to the transmitter. The physical channel processing unit is configured to provide physical channel processing to a plurality of transport blocks provided by the transport channel processing unit.

In yet another, a communications device comprises a transmitter to be coupled to at least one transmit antenna. The transmitter is configured to transmit signals with the at least one transmit antenna. A transport channel processing unit is coupled to a processor. The transport channel processing unit is configured to provide transport channel processing to a transport block (TB) provided by the processor. The TB size of the TB is selected by selecting a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}), and selecting the TB size for the I_{TBS} and N_{PRB} so that the number of code blocks in the TB size is one (1) or a multiple of a number of spatial layers N. A channel interleaver is coupled to the transport channel processing unit. The channel interleaver is configured to interleave modulation symbols of a plurality of transport blocks. A physical channel processing unit is coupled to the channel interleaver and to the transmitter. The physical channel processing unit is configured to provide physical channel processing to the interleaved modulation symbols provided by the channel interleaver.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the embodiments that follow may be better understood. Additional features and advantages of the embodiments will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the embodiments, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a flow diagram of LTE Advanced downlink physical layer processing;

FIGS. **2**a through **2**c are diagrams of three cases of transmit blocks (TBs) to downlink layer mappings, with a number of downlink layers being equal to two (FIG. **2**a), three (FIG. **2**b), and four (FIG. **2**c), where a single TB is mapped to two layers;

FIGS. **3**a through **3**k are diagrams of codeword-to-layer mappings in LTE-Advanced;

FIG. **4** is a flow diagram of operations in the design of TB sizes for a codeword-to-N-layer mapping, where N is greater than or equal to three in accordance with embodiments of the invention;

FIG. **5**, which includes FIGS. **5**a and **5**b, illustrates mapping a transport block to multiple uplink layers, wherein FIG. **5**a illustrates mapping of a transport block having two code blocks to two layers, and wherein FIG. **5**b illustrates mapping of a transport block having three code blocks to three layers, in accordance with embodiments of the invention; and

FIG. **6** illustrates a communications device using embodiments of the invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and using of the embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

The embodiments will be described in a specific context, namely a Third Generation Partnership Project (3GPP) Long Term Evolution Advanced (LTE-Advanced) communications system. The invention may also be applied, however, to other communications systems, such as UMB, WiMAX compliant communications systems, that support transport block (TB) mapping to multiple MIMO layers, both uplink (UL) and downlink (DL). Therefore, the discussion of LTE and LTE-Advanced wireless communications systems should not be construed as being limiting to either the scope or the spirit of the embodiments.

In 3GPP LTE and LTE-Advanced compliant communications systems, data from upper network layers arrive at a physical layer as transport blocks (TBs). At each transmission instance (for example, a subframe in LTE), up to two TBs may be scheduled. At the physical layer, each TB undergoes processing such as channel coding, rate matching, scrambling, modulation, before it is mapped to MIMO layers and sent out from the antennas. In LTE, the set of code bits/modulation symbols corresponding to a TB is called a MIMO codeword. Conceptually, the codeword refers to a TB and may be used interchangeably.

In accordance with embodiments of the invention, a downlink transport block size design will be first described, followed by an uplink transport block design.

FIG. **1** is a flow diagram of LTE-Advanced downlink physical layer processing.

As illustrated in FIG. **1**, up to two transport blocks (TB) are input and for each TB, a cyclic redundancy check (CRC) is attached to the TB at Transport block CRC attachment unit **101**. If the size of the TB is larger than a preset threshold, Code block segmentation and Code block CRC attachment unit **102** is used to split the TB into multiple code blocks (CB) and a CRC is attached to each CB. If the TB is not larger than the preset threshold, then the TB may not be split into multiple CBs and the output of unit **101** are sent to unit **103**.

Then, each CB is turbo-encoded in Channel Coding unit **103**. In Rate matching unit **104**, the coded bits of each CB is interleaved and the redundancy version (RV) for hybrid automatic repeat request (HARM) is obtained from high layer signaling. The CBs may be concatenated in a Code block concatenation unit **105** and the coded symbols to be transmitted is scrambled in a Scrambling unit **106** to randomize the transmission bits. The transport block size is defined within the transport channel processing within steps **101**-**105** and no further definition of the transport block size occurs during steps **106** and beyond.

Before mapping codewords to layers, the scrambled bits may be modulated into complex-valued symbols using Quadrature Phase Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (QAM) or 64QAM in a Modulation Mapper unit **107**. The complex-valued modulation symbols for each codeword to be transmitted are mapped onto one or several layers in a Layer Mapping unit **108**. While, a Precoder unit **109** takes as input the vector comprising one symbol from each layer and generates a block of vector to be mapped onto resources on each of the antenna ports.

In a Resource Element Mapper unit **110**, the precoded symbols are mapped into time-frequency domain resource element of each antenna port and then converted to orthogonal frequency division multiplexing (OFDM) baseband signal in an OFDM signal generation unit **111**. The baseband signal is then upconverted to a carrier frequency for each antenna port.

There may be several combinations of codeword-to-layer mapping in LTE. Codeword-to-layer mapping is discussed herein in the context of spatial multiplexing.

Let M_{symbol}^{layer} denote a number of modulation symbols per layer transmitted in a LTE subframe. Due to the parallel nature of the multiple antenna techniques used, the same number of modulation symbols are transmitted in each layer. Let M_{symbol}^{q}, $q\in\{1,2\}$ be a total number of modulation symbols per transport block q. When the modulation symbols for each of the code words are mapped onto a layer, $M_{symbol}^{layer}=M_{symbol}^{q}$, $q\in\{1,2\}$.

When the modulation symbols for a codeword are mapped onto two layers, the number of antenna ports must be four (see 3GPP TS 36.211 V8.6.0 (2009-03), "Physical Channels and Modulation (Release 8), which is incorporate herein by reference).

FIGS. **2**a through **2**c are diagrams of three cases of transmit blocks (TBs) to downlink layer mappings, with a number of downlink layers being equal to two (FIG. **2**a), three (FIG. **2**b), and four (FIG. **2**c). In FIG. **2**, a single TB is mapped to two layers.

FIG. **2**a illustrates a single transport block (TB) mapped onto two layers, wherein after codeword-to-layer mapping, $M_{symbol}^{layer}=M_{symbol}^{1}/2$. FIG. **2**b illustrates two transport blocks mapped onto three layers, wherein after codeword-to-layer mapping, $M_{symbol}^{layer}=M_{symbol}^{1}=M_{symbol}^{2}/2$. FIG. **2**c illustrates two transport blocks mapped onto four layers, wherein after codeword-to-layer mapping, $M_{symbol}^{layer}=M_{symbol}^{1}/2=M_{symbol}^{2}/2$.

FIG. **3**, which includes FIGS. **3**a-**3**k illustrates codeword-to-layer mappings in LTE-Advanced, wherein FIGS. **3**c, **3**e, and **3**g illustrate single codeword retransmissions when an initial transmission comprises more than one codeword. In LTE-Advanced, DL spatial multiplexing of up to eight layers is considered. In order to avoid increasing the uplink (UL) overhead without a significant loss in performance, up to two transport blocks (TBs) can be transmitted to a scheduled UE in a subframe per DL component carrier.

As illustrated in FIGS. **3**a-**3**k, codeword one (CW**1**) is a modulation symbol sequence corresponding to TB one (TB**1**). Similarly, codeword two (CW**2**) is a modulation symbol sequence corresponding to TB two (TB**2**). There is a one-to-one relationship between a TB and its modulation symbol sequence, given the modulation order and code rate. Although the transport blocks (e.g., TB**1**, TB**2**) are not directly mapped to the spatial layers, rather the modulation symbol sequence (e.g., CW**1**, CW**2**) are mapped to the spatial layers, it is understood that in discussion of mapping to spatial layers, CW**1** and TB**1** may be used interchangeably, and CW**2** and TB**2** may be used interchangeably. There are one-layer TBs, two-layer TBs (i.e., one TB mapped to two layers), three-layer TBs (i.e., one TB mapped to three layers), and four-layer TBs (i.e., one TB mapped to four layers) in LTE-Advanced.

In particular, a TB may be mapped to three layers or four layers when spatial multiplexing of five to eight layers is used for transmission (as illustrated in FIGS. **3**h through **3**k). For example, for the five layer (FIG. **3**h) and seven layer (FIG. **3**j) situations, the following relationships exist:

For five layers, TB**1** is mapped to two layers and TB**2** is mapped to three layers, thus, $M_{symbol}^{layer}=M_{symbol}^{1}/2=M_{symbol}^{2}/3$.

For seven layers, TB**1** is mapped to three layers and TB**2** is mapped to four layers, thus, $M_{symbol}^{layer}=M_{symbol}^{1}/3=M_{symbol}^{2}/4$. Similar relationships exist for six layer and eight layer situations.

One-layer TB sizes and two-layer TB sizes, as defined for LTE, are being reused in LTE-Advanced. One-layer TB size table and two-layer TB size table are defined in LTE (see 3GPP TS 36.213 V8.6.0 (2009-03), "Physical layer procedures (Release 8), which is incorporated herein by reference), with a first being a one-layer TB size (TBS) table of size 27×110, referred to as a one-layer TBS table, and a second being a one-layer to two-layer TBS translation table, referred to as a two-layer TBS table. Design principles for one-layer TB sizes and two-layer TB sizes in LTE are described in detail below (see 3GPP TS 36.212 V8.6.0 (2009-03), "Multiplexing and channel coding (Release 8);" 3GPP TS 36.213 V8.6.0 (2009-03), "Physical layer procedures (Release 8);" R1-081638, "TBS and MCS Signalling and Table;" R1-082211,—"Remaining details of MCS/TBS signaling;" and R1-082719, "Remaining Issues with TBS & MCS Settings;" which are incorporated herein by reference).

Several factors are taken into consideration in designing the one-layer TB sizes. First, in order to avoid padding and reduce receiver complexity, the one-layer TB sizes are defined so that the code block sizes, with transport block CRC bits and code block CRC bits attached, are aligned with Quadratic Permutation Polynomial (QPP) sizes for turbo codes.

Second, some preferred Media Access Control (MAC) sizes should be contained for system requirements in designing one-layer TB sizes, such as 16, 24, 40, 56, 72, 104, 120, 152, 296, 344, 392, 440, 488, and 536 bits.

Third, one-layer TB sizes are computed from the Modulation and Coding Scheme (MCS) table using the reference configuration of one (1) Orthogonal Frequency Division Multiplexed (OFDM) symbol for control region and the four antenna ports configuration. The one-layer TBS table is invariant of control region sizes and antenna configurations.

Fourth, the UE may be unable to decode if the effective code rate is greater than 1. In particular, since the UE may skip decoding a TB in an initial transmission if the effective code rate is higher than 0.930, this factor should be considered for designing TB sizes with higher modulation orders, where the effective code rate is defined as the number of DL information bits (including TB CRC bits and code block CRC bits) divided by the number of physical channel bits on Physical Downlink Shared Channel (PDSCH).

Fifth, every one-layer TB size should occur with sufficient number of times, thus providing the desired flexibility in (re)transmission schedule.

Sixth, the one-layer TB sizes with highest MCS level for every allocated physical resource blocks lead to consistent peak rate scaling across different bandwidths.

The one-layer TB sizes may be designed with consideration of the above listed factors and placed in tabular form, wherein a row index I_{TBS} is obtained from the MCS table and a column index N_{PRB} denotes the number of allocated physical resource blocks.

For $1\le N_{PRB}\le 110$, the TB size (TBS) may be given by (I_{TBS}, N_{PRB}) entry of the one-layer TBS table. The size of the one-layer TBS table used in LTE is 27×110, wherein each of the 27 rows corresponds to a distinct spectral efficiency, and each of the 110 columns corresponds to a given number of physical resource blocks (RB).

To signal the transmit format, including the TB size of a TB, Downlink Control Information (DCI) is used which contains a 5-bit MCS field. The MCS field points to the 32 rows in the MCS table. In the MCS table, three MCS states are reserved for signaling modulation orders for retransmission, and two overlapped MCSs for transitioning from QPSK to 16-QAM, and from 16-QAM to 64-QAM, respectively. Thus there are 27 distinct spectral efficiency levels (i.e., MCS levels), corresponding to the 27 rows of the one-layer TBS table. With the MCS field and the RB allocation, the TB size is obtained by looking up the 27×110 one-layer TBS table.

For a given combination of resources blocks and spectral efficiency, two-layer TB sizes are two times one-layer TB sizes in principle with some adjustment given for CRC bits. Most two-layer TB sizes occur in the one-layer TBS table, thus providing the desired flexibility in (re)transmission schedule.

A method for obtaining the two-layer TBS table based on the one-layer TBS table is described as follows.

First, for $1 \le N_{PRB} \le 55$, the two-layer transport block sizes are given by the (I_{TBS}, $2 \cdot N_{PRB}$) entry of the one-layer TBS table. Second, for $56 \le N_{PRB} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS}, N_{PRB}) entry of one-layer TBS table, which is then translated into TBS_L2 using the mapping rule shown in Table 1 below. The two-layer transport block sizes are given by TBS_L2.

Although the two-layer TB sizes are defined by two categories above, collectively an equivalent 27×110 two-layer TB sizes is effectively defined, similar to the explicitly defined 27×110 one-layer TB size table.

TABLE 1

One-layer to two-layer transport block sizes translation table

TBS_L1	TBS_L2
1544	3112
1608	3240
1672	3368
1736	3496
1800	3624
1864	3752
1928	3880
1992	4008
2024	4008
2088	4136
2152	4264
2216	4392
2280	4584
2344	4776
2408	4776
2472	4968
2536	5160
2600	5160
2664	5352
2728	5544
2792	5544
2856	5736
2984	5992
3112	6200
3240	6456
3368	6712
3496	6968
3624	7224
3752	7480
3880	7736
4008	7992
4136	8248

TABLE 1-continued

One-layer to two-layer transport block sizes translation table

TBS_L1	TBS_L2
4264	8504
4392	8760
4584	9144
4776	9528
4968	9912
5160	10296
5352	10680
5544	11064
5736	11448
5992	11832
6200	12576
6456	12960
6712	13536
6968	14112
7224	14688
7480	14688
7736	15264
7992	15840
8248	16416
8504	16992
8760	17568
9144	18336
9528	19080
9912	19848
10296	20616
10680	21384
11064	22152
11448	22920
11832	23688
12216	24496
12576	25456
12960	25456
13536	27376
14112	28336
14688	29296
15264	30576
15840	31704
16416	32856
16992	34008
17568	35160
18336	36696
19080	37888
19848	39232
20616	40576
21384	42368
22152	43816
22920	45352
23688	46888
24496	48936
25456	51024
26416	52752
27376	55056
28336	57336
29296	59256
30576	61664
31704	63776
32856	66592
34008	68808
35160	71112
36696	73712
37888	76208
39232	78704
40576	81176
42368	84760
43816	87936
45352	90816
46888	93800
48936	97896
51024	101840
52752	105528
55056	110136
57336	115040

TABLE 1-continued

One-layer to two-layer transport block sizes translation table	
TBS_L1	TBS_L2
59256	119816
61664	124464
63776	128496
66592	133208
68808	137792
71112	142248
73712	146856
75376	149776

A three-layer table may be designed in accordance with an embodiment of the invention as described below. In various embodiments, three-layer TB sizes are defined so that the code block sizes, with TB CRC bits and code block CRC bits attached, are aligned with QPP sizes for turbo codes. The three-layer TB sizes are about three times one-layer TB sizes with adjustment given for CRC bits. Advantageously, most three-layer transport block sizes occur in the one-layer TBS table and the two-layer TBS table, thus providing the desired flexibility in (re)transmission schedule. Since the UE may skip decoding a TB in an initial transmission if the effective code rate is higher than 0.930, the effective code rates should be smaller than 0.930. This should be particularly considered for the highest spectral efficiency, i.e., $I_{TBS}=26$.

To be able to calculate the effective code rates, the system configurations for up to eight layers in LTE-Advanced is discussed below in accordance with embodiments of the invention. The number of resource elements for data transmission is estimated, based on which the effective code rates can then be obtained.

In 3GPP 56bis, there are two kinds of reference signals, a Channel State Information-Reference Signal (CSI-RS) for measurement and a Demodulation-Reference Signal (DM-RS) for demodulation. For CSI-RS, the periodicity of its transmissions may be specified in terms of an integer number of subframes. For rank three through eight transmissions, a maximum of 24 Resource Elements (Res) (total) is assigned to DM-RS in each Resource Block (RB).

Therefore, assuming one OFDM symbol is used for the control region, eight REs per RB for LTE cell-specific RS (i.e., one antenna port for cell-specific RS), and 24 REs per RB for demodulation reference signals, the effective code rate can be calculated as follows:

$$R_{eff}=(TBS+24+N_{CB}\times 24)/(N_{PRB}\times((168-10-8-24)\times N_{layer}\times Q_m)), \quad (1)$$

considering the specific layout of a RB in 3GPP LTE and LTE-Advanced system. In equation (1), TBS denotes the transport block size, N_{CB} denotes the number of codeblocks in the transport block, N_{layer} denotes the number of spatial layers that the TB is mapped to, Q_m denotes the modulation order which can be obtained from the MCS table. In the numerator of equation (1), the two instances of 24 refer to the length-24 codeblock-level CRC, and the length-24 TB-level CRC, respectively. In the denominator of equation (1), 168 is the total number of REs in a RB assuming a normal cyclic prefix; 10 is the number of REs for downlink control in a RB; 8 is the number of REs for LTE cell-specific reference signals assuming one antenna port; and 24 is the number of DM-RS in a RB. In equation (1), the CSI-RS is not considered since it is sparse and most subframes are not expected to contain CSI-RS. Equation (1) will be used to calculate the effective code rates in the transport block size design. Note that equation (1) ignores the scenario where a TB is composed of a single CB, and only considers the scenario where a TB is composed of multiple CBs. This is acceptable since most TB sizes have multiple CBs when it is mapped to multiple layers.

For $I_{TBS}=26$, the DL target spectral efficiency is 5.55, which is a combination of 64-QAM with code rate 0.9250. With REs taken out for RS and control region, it is found that the effective code rate of a TB mapped to three layers is higher than 0.930 if the $I_{TBS}=26$ sizes in the one-layer TBS table are scaled three times.

Therefore, in various embodiments, the three-layer TB sizes can be divided into two parts within the row index and two parts within the column index N_{PRB}. Each of the four parts are designed independently.

First, for $0\leq I_{TBS}\leq 25$, the three-layer TB sizes are three times the one-layer TB sizes in principle with some adjustment given for CRC bits.

For $1\leq N_{PRB}\leq 36$ and $0\leq I_{TBS}\leq 25$, where $36=\lfloor 110/3\rfloor$, the three-layer TB sizes are given by the $(I_{TBS}, 3\cdot N_{PRB})$ entry of the one-layer TBS table. This is because for $1\leq N_{PRB}\leq 36$ and $0\leq I_{TBS}\leq 25$, the effective code rates for every MCS levels are less than 0.930 if the scaled one-layer table is used. Therefore, in various embodiments, for $1\leq N_{PRB}\leq 36$ and $0\leq I_{TBS}\leq 25$, the three-layer TB sizes are given by the $(I_{TBS}, 3\cdot N_{PRB})$ entry of the one-layer TBS table.

Second, for $I_{TBS}=26$, the three-layer TB sizes are determined so that the effective code rate is 0.930 or slightly lower. Similarly, for $1\leq N_{PRB}\leq 36$ and $I_{TBS}=\leq 26$, many of the effective code rates are found to be higher than 0.930 if the $(I_{TBS}, 3\cdot N_{PRB})$ entry of the one-layer TBS table is used. Thus the TB sizes are redesigned so that the effective code rates calculated based on Equation (1), with $N_{layer}=3$ and $Q_m=6$ (64-QAM), should be smaller than 0.930. The final TB sizes for $1\leq N_{PRB}\leq 36$ and $I_{TBS}=26$ is shown in Table 2. In Table 2, for each N_{PRB}, two candidate TBS values are provided; the larger value is listed in the row labelled 26, and the smaller of the two is listed in the row labelled 26'. If only one candidate TBS value is provided for a N_{PRB}, then the value is used in both row 26 and row 26'.

For each $_{NPRB}$, either TBS candidate (in row 26 or row 26') may be used. It is preferable to use the larger value in row 26, so that a slightly higher efficiency may be achieved. Alternatively, in some embodiments, the smaller value in the row 26' can be used, so that the TB can be received with relatively higher reliability. In some embodiments, it is also possible to use values in row 26 for a subset of the $_{NPRB}$, and use values in row 26' for the rest. In various embodiments, all the TBS values in Table 2 are chosen from the existing values for the one-layer and the equivalent two-layer TBS table. This allows flexible scheduling for the (re)transmission of a TB size. However, in some embodiments, one of the two candidate values listed in Table 2 may be pre-selected, e.g., by the telecommunication operator.

TABLE 2

Three-layer transport block sizes table with $1 \le N_{PRB} \le 36$ and $I_{TBS} = 26$ in accordance with an embodiment of the invention.

I_{TBS}	N_{PRB} 1	2	3	4	5	6	7	8	9	10
26	2024	4136	6200	8248	10296	12216	14112	16416	18336	20616
26'	1992	4008	5992	7992	9912	11832	13536	15840	17568	19848

I_{TBS}	N_{PRB} 11	12	13	14	15	16	17	18	19	20
26	22920	24496	26416	29296	30576	32856	35160	36696	39232	40576
26'	22152	23688	25456	28336	29296	31704	34008	35160	37888	39232

I_{TBS}	N_{PRB} 21	22	23	24	25	26	27	28	29	30
26	43816	45352	46888	48936	51024	52752	55056	57336	59256	61664
26'	42368	43816	45352	46888	48936	51024	52752	55056	57336	59256

I_{TBS}	N_{PRB} 31	32	33	34	35	36
26	63776	66592	68808	71112	71112	75376
26'	61664	63776	66592	68808	68808	75376

Additionally, for $37 \le N_{PRB} \le 110$, since many of the effective code rates for $I_{TBS}=26$ can be higher than 0.930, three-layer TB sizes are separately designed for $0 \le I_{TBS} \le 25$ and $I_{TBS}=26$.

For $37 \le N_{PRB} \le 110$ and $0 \le I_{TBS} \le 25$, a TB_L1 to TB_L3 translation table is defined for each unique TB_L1 size in the 37-110 columns of the one-layer TBS table. A baseline TBS_L1 is taken from the (I_{TBS}, N_{PRB}) entry of the one-layer TBS table, then 3×TBS_L1 is compared with all entries of the one-layer and two-layer TBS table, and the most adjacent entry will be chosen as TBS_L3. When there are two entries that are equidistant from 3×TBS_L1, one value may be chosen from the two based on considerations such as the effective code rates, data rate and times of occurrence, and so on. Overall, there are 12 TBS_L1 values which have two equidistant entries in the one-layer and two-layer TBS table. These 12 TBS_L1 values are 2280, 2536, 2792, 2984, 3112, 3240, 3368, 3496, 3624, 3752, 3880 and 4008. Both equaldistant options are listed in Table 3 for these 10 TBS_L1 values. Either choice can be used as TBS_L3 in various embodiments. The larger one between these two entries, underscored in Table 3 (shown below), may be preferred due to the slightly higher data rate.

Furthermore, some 3×TBS_L1 are larger than all the entries in the one-layer and two-layer TBS table, there are 10 entries which do not have the adjacent entries in the one-layer and two-layer TBS table that can be used as TBS_L3. These TBS_L1 values are 51024, 52752, 55056, 57336, 59256, 61664, 63776, 66592, 68808, and 71112. For these entries, three-layer TB sizes are three times of TBS_L1 with some adjustment given for CRC bits and should be aligned with QPP sizes for turbo codes. The 10 entries of TBS_L1 and their corresponding TBS_L3 are shown boldfaced in Table 3. Also in Table 3, the two largest TBS_L1 values of 73712 and 75376 do not have a corresponding TBS_L3 value specified, because 73712 and 75376 are used only for $I_{TBS}=26$ for one-layer TB sizes.

Combining the smaller TBS_L3 that can be looked up in the one-layer and two-layer TBS table and the larger TBS_L3 that are constructed, the one-layer to 3-layer translation table is shown in Table 3.

TABLE 3

One-layer to three-layer TBS translation table with $37 \le N_{PRB} \le 110$ and $0 \le I_{TBS} \le 25$ in accordance with an embodiment of the invention.

TBS_L1	TBS_L3
1032	3112
1064	3240
1096	3240
1128	3368
1160	3496
1192	3624
1224	3624
1256	3752
1288	3880
1320	4008
1352	4008
1384	4136
1416	4264
1480	4392
1544	4584
1608	4776
1672	4968
1736	5160
1800	5352
1864	5544
1928	5736
1992	5992
2024	5992
2088	6200
2152	6456
2216	6712
2280	6712/6968
2344	6968
2408	7224
2472	7480
2536	7480/7736
2600	7736

TABLE 3-continued

One-layer to three-layer TBS translation table with $37 \leq N_{PRB} \leq 110$ and $0 \leq I_{TBS} \leq 25$ in accordance with an embodiment of the invention.

TBS_L1	TBS_L3
2664	7992
2728	8248
2792	8248/8504
2856	8504
2984	8760/9144
3112	9144/9528
3240	9528/9912
3368	9912/10296
3496	10296/10680
3624	10680/11064
3752	11064/11448
3880	11448/11832
4008	11832/12216
4136	12576
4264	12960
4392	12960
4584	13536
4776	14112
4968	14688
5160	15264
5352	15840
5544	16416
5736	16992
5992	18336
6200	18336
6456	19080
6712	19848
6968	20616
7224	21384
7480	22152
7736	22920
7992	23688
8248	24496
8504	25456
8760	26416
9144	27376
9528	28336
9912	29296
10296	30576
10680	31704
11064	32856
11448	34008
11832	35160
12216	36696
12576	37888
12960	39232
13536	40576
14112	42368
14688	43816
15264	45352
15840	46888
16416	48936
16992	51024
17568	52752
18336	55056
19080	57336
19848	59256
20616	61664
21384	63776
22152	66592
22920	68808
23688	71112
24496	73712
25456	76208
26416	78704
27376	81176
28336	84760
29296	87936
30576	90816
31704	93800
32856	97896
34008	101840
35160	105528
36696	110136

TABLE 3-continued

One-layer to three-layer TBS translation table with $37 \leq N_{PRB} \leq 110$ and $0 \leq I_{TBS} \leq 25$ in accordance with an embodiment of the invention.

TBS_L1	TBS_L3
37888	115040
39232	119816
40576	119816
42368	128496
43816	133208
45352	137792
46888	142248
48936	146856
51024	**154104**
52752	**157432**
55056	**165216**
57336	**171888**
59256	**177816**
61664	**185728**
63776	**191720**
66592	**199824**
68808	**205880**
71112	**214176**
73712	N/A
75376	N/A

For the situation where N_{PRB}={38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72}, each (I_{TBS},N_{PRB}) entry for the three-layer TBS table can also be given by the

$$\left(I_{TBS},\ \frac{3\cdot N_{PRB}}{2}\right)$$

entry in the equivalent 27×110 two-layer TBS table which can be constructed by the one-layer to two-layer TB size translation table. The TBS subset thus obtained is different from the TBS obtained via the TB_L1 to TB_L3 translation table defined above in Table 3 in some embodiments. However, since these N_{PRB} values are not consecutive, it may be more difficult to specify or implement than using a table like Table 3 for an entire set of consecutive N_{PRB} values.

Again for I_{TBS}=26 and $37 \leq N_{PRB} \leq 110$, the three-layer TB sizes are redesigned based on system configurations so that the effective code rates should be smaller than 0.930. Equation (1) is used to calculate the effective code rates, assuming the associated reference configuration and with N_{layer}=3 and Q_m=6. The final TB sizes are given in Table 4. In Table 4, for each N_{PRB}, two candidate TBS values are provided; the larger value listed in the row labelled 26, and the smaller listed in the row labelled 26'. If only one candidate TBS value is provided for a N_{PRB}, then the value is used in both row 26 and row 26'. For each N_{PRB}, either TBS candidate (in row 26 or row 26') may be used. In various embodiments, it is advantageous to use the larger value in row 26, so that a slightly higher efficiency may be achieved. Alternatively, in some embodiments, the smaller value in the row 26' may be used, so that the TB can be received with relatively higher reliability. Alternatively, some embodiments may use values in row 26 for a subset of the N_{PRB}, and use values in row 26' for the rest.

In various embodiments, all the TBS values in Table 4 less than or equal to 149776 are chosen from the existing values for the one-layer and two-layer TB size table. Advantageously, this allows flexible scheduling for the (re)transmission of a TB size. For values greater than 149776 in Table 4, values in Table 3 are reused where appropriate.

TABLE 4

Three-layer transport block sizes with 37 ≤ N_{PRB} ≤ 110 and I_{TBS} = 26 in accordance with an embodiment of the invention.

I_{TBS}	N_{PRB} 37	38	39	40
26	76208	78704	81176	81176
26'	75376	76208	78704	78704

I_{TBS}	N_{PRB} 41	42	43	44	45	46	47	48	49	50
26	84760	84760	87936	90816	90816	93800	97896	97896	101840	101840
26'	81176	81176	84760	87936	87936	90816	93800	93800	97896	97896

I_{TBS}	N_{PRB} 51	52	53	54	55	56	57	58	59	60
26	105528	105528	110136	110136	115040	115040	115040	119816	119816	119816
26'	101840	101840	105528	105528	110136	110136	110136	115040	115040	115040

I_{TBS}	N_{PRB} 61	62	63	64	65	66	67	68	69	70
26	124464	124464	128496	128496	133208	133208	133208	142248	142248	146856
26'	119816	119816	124464	124464	128496	128496	128496	137792	137792	142248

I_{TBS}	N_{PRB} 71	72	73	74	75	76	77	78	79	80
26	146856	146856	152976	152976	152976	152976	160032	160032	160032	167752
26'	142248	142248	151376	151376	151376	151376	159096	159096	159096	165960

I_{TBS}	N_{PRB} 81	82	83	84	85	86	87	88	89	90
26	167752	167752	173744	173744	173744	179736	179736	179736	185728	185728
26'	165960	165960	171888	171888	171888	177816	177816	177816	183744	183744

I_{TBS}	N_{PRB} 91	92	93	94	95	96	97	98	99	100
26	185728	191720	191720	191720	197712	197712	197712	203704	203704	209696
26'	183744	189696	189696	189696	195816	195816	195816	201936	201936	208056

I_{TBS}	N_{PRB} 101	102	103	104	105	106	107	108	109	110
26	209696	209696	214176	214176	214176	214176	221680	221680	221680	221680
26'	208056	208056	209696	209696	209696	209696	214176	214176	214176	214176

A four-layer table may be designed in accordance with an embodiment of the invention as described below. In various embodiments, a four-layer TB sizes are defined so that the code block sizes, with TB CRC bits and code block CRC bits attached, are aligned with QPP sizes for turbo codes. In various embodiments, four-layer TB sizes are two times two-layer TB sizes with some adjustment given for CRC bits. Most four-layer TB sizes occur in the one-layer TBS table, the two-layer TBS table, and the three-layer TBS table, thus providing the desired flexibility in (re)transmission schedule. Since the UE may skip decoding a TB in an initial transmission if the effective code rate is higher than 0.930, the effective code rates should be smaller than 0.930. This should be particularly considered for the highest spectral efficiency, i.e., I_{TBS}=26.

Similar to three-layer TB size design, it is found that the effective code rate of a TB mapped to four layers is higher than 0.930 if the I_{TBS}=26 sizes in the one-layer TBS table are scaled four times (or if the I_{TBS}=26 sizes in the equivalent two-layer TBS table are scaled twice). Therefore, in various embodiments, the four-layer TB size can be divided into two parts: $0 \le I_{TBS} \le 25$ and I_{TBs}=26, and again into two parts: $1 \le N_{PRB} \le 55$ and $56 \le N_{PRB} \le 110$.

In the first part, for $0 \le I_{TBS} \le 25$, the four-layer transport block sizes are twice the two-layer transport block sizes in principle with some adjustment given for CRC bits.

For $1 \le N_{PRB} \le 55$ and $0 \le I_{TBS} \le 25$, where 55=110/2, the four-layer TB sizes are given by the (I_{TBS},$2 \cdot N_{PRB}$) entry of the two-layer TBS table. This is because the effective code rates for every MCS levels are checked and are found to be less than 0.930.

For $56 \le N_{PRB} \le 110$ and $0 \le I_{TBS} \le 25$, a TB_L2 to TB_L4 translation table, as described below, is defined for each unique TB_L2 size in the 56-110 columns of the two-layer TBS table.

In the second part, for $I_{TBS}=26$, the four-layer TB sizes are determined so that the effective code rate is 0.930 or slightly lower.

For $1 \le N_{PRB} \le 55$ and $I_{TBS}=26$, many of the effective code rates are found to be higher than 0.930 if the $(I_{TBS}, 2 \cdot N_{PRB})$ entry of the two-layer TBS table is used. Thus the TB sizes are redesigned so that the effective code rates calculated based on Equation (1), with $N_{layer}=4$ and $Q_m=6$ (64-QAM), should be smaller than 0.930. The final TB sizes for $1 \le N_{PRB} \le 55$ and $I_{TBS}=26$ is shown in Table 5. In Table 5, for each N_{PRB}, two candidate TBS values are provided, the larger value is listed in the row labelled 26, and the smaller of the two is listed in the row labelled 26'. If only one candidate TBS value is provided for a N_{PRB}, then the value is used in both row 26 and row 26'. For each N_{PRB}, either TBS candidate (in row 26 or row 26') may be used. It is preferable to use the larger value in row 26, so that a slightly higher efficiency may be achieved. Alternatively, in some embodiments, the smaller value in the row 26' can be used, so that the TB can be received with relatively higher reliability. Some embodiments may use values in row 26 for a subset of the N_{PRB}, and use values in row 26' for the rest. In one or more embodiments, all the TBS values in Table 5 are chosen from the existing values for the one-layer, the equivalent two-layer, and the three-layer TBS tables. Advantageously, this allows flexible scheduling for the (re)transmission of a TB size.

TABLE 5

Four-layer TB sizes table with $1 \le N_{PRB} \le 55$ and $I_{TBS} = 26$ in accordance with an embodiment of the invention

	N_{PRB}									
I_{TBS}	1	2	3	4	5	6	7	8	9	10
26	2728	5544	8248	11064	13536	16416	19080	22152	24496	27376
26'	2664	5352	7992	10680	12960	15840	18336	21384	23688	26416

	N_{PRB}									
I_{TBS}	11	12	13	14	15	16	17	18	19	20
26	30576	32856	35160	37888	40576	43816	46888	48936	52752	55056
26'	29296	31704	34008	36696	39232	42368	45352	46888	51024	52752

	N_{PRB}									
I_{TBS}	21	22	23	24	25	26	27	28	29	30
26	57336	59256	63776	66592	68808	71112	75376	76208	81176	81176
26'	55056	57336	61664	63776	66592	68808	73712	75376	78704	78704

	N_{PRB}									
I_{TBS}	31	32	33	34	35	36	37	38	39	40
26	84760	87936	90816	93800	97896	97896	101840	105528	105528	110136
26'	81176	84760	87936	90816	93800	93800	97896	101840	101840	105528

	N_{PRB}									
I_{TBS}	41	42	43	44	45	46	47	48	49	50
26	110136	115040	119816	119816	124464	128496	128496	133208	133208	137792
26'	105528	110136	115040	115040	119816	124464	124464	128496	128496	133208

	N_{PRB}				
I_{TBS}	51	52	53	54	55
26	142248	142248	146856	149776	149776
26'	137792	137792	142248	149776	149776

For $56 \le N_{PRB} \le 110$, since many of the effective code rates for $I_{TBS}=26$ can be higher than 0.930, four-layer transport block sizes are separately designed for $0 \le I_{TBS} \le 25$ and $I_{TBS}=26$.

For $0 \le I_{TBS} \le 25$, in order to ensure that TB sizes occur sufficient times, the relationships for one-layer TB sizes translated to two-layer TB sizes are reused as much as possible by two-layer TB sizes translated to four-layer transport block sizes. The translation relationship from one-layer TB sizes to two-layer TB sizes is given in Table 1 (shown previously).

Table 1 includes unique two-layer TB size for $56 \le N_{PRB} \le 110$ under columns labeled TBS_L2, where TBS_L1 denotes one-layer TB sizes and TBS_L2 denotes two-layer TB sizes. For the i-th TBS_L2 entry TBS_L2(i) in Table 1, TBS_L2(i) is used to look up the TBS_L1 entries in Table 1. When the TBS_L1(j) is located where TBS_L1(j)=TBS_L2(i), then TBS_L4(i)=TBS_L2(j). After the search, only twenty entries of TBS_L2(i) do not have the corresponding TBS_L1(j) in Table 1.

The twenty TBS_L2(i) values are the largest 20 TBS_L2 in Table 1. However only 18 TBS_L2 values need to have the translation relationship to TBS_L4, since the largest two TBS_L2 values {146856, 149776}, corresponding to TBS_L1 values {73712, 75376}, are only used for I_{TBS}=26. Thus the following 18 TBS_L2 values need to have the TBS_L4 value defined from scratch: 76208, 78704, 81176, 84760, 87936, 90816, 93800, 97896, 101840, 105528, 110136, 115040, 119816, 124464, 128496, 133208, 137792, and 142248. For these 18 TBS_L2 values, the TBS_L4 values are found which corresponds to 2×TBS_L2 with some adjustment given for CRC bits and should be aligned with QPP sizes for turbo codes. These 18 TBS_L2 values, together with their corresponding TBS_L1 and TBS_L4 values are boldfaced in Table 6.

In Table 6, the TBS_L2 to TBS_L4 translation relationship is shown. Table 6 repeats the TBS_L1 to TBS_L2 translation relationship shown in Table 1.

TABLE 6

Two-layer to four-layer TB sizes translation table with $55 \leq N_{PRB} \leq 110$ and $0 \leq I_{TBS} \leq 25$ in accordance with an embodiment of the invention

TBS_L1	TBS_L2	TBS_L4
1544	3112	6200
1608	3240	6456
1672	3368	6712
1736	3496	6968
1800	3624	7224
1864	3752	7480
1928	3880	7736
1992	4008	7992
2024	4008	7992
2088	4136	8248
2152	4264	8504
2216	4392	8760
2280	4584	9144
2344	4776	9528
2408	4776	9528
2472	4968	9912
2536	5160	10296
2600	5160	10296
2664	5352	10680
2728	5544	11064
2792	5544	11064
2856	5736	11448
2984	5992	11832
3112	6200	12576
3240	6456	12960
3368	6712	13536
3496	6968	14112
3624	7224	14688
3752	7480	14688
3880	7736	15264
4008	7992	15840
4136	8248	16416
4264	8504	16992
4392	8760	17568
4584	9144	18336
4776	9528	19080
4968	9912	19848
5160	10296	20616
5352	10680	21384
5544	11064	22152
5736	11448	22920
5992	11832	23688
6200	12576	25456
6456	12960	25456
6712	13536	27376
6968	14112	28336
7224	14688	29296
7480	14688	29296
7736	15264	30576
7992	15840	31704
8248	16416	32856
8504	16992	34008
8760	17568	35160
9144	18336	36696
9528	19080	37888
9912	19848	39232
10296	20616	40576
10680	21384	42368
11064	22152	43816
11448	22920	45352
11832	23688	46888
12216	24496	48936
12576	25456	51024
12960	25456	51024
13536	27376	55056
14112	28336	57336
14688	29296	59256
15264	30576	61664
15840	31704	63776
16416	32856	66592
16992	34008	68808
17568	35160	71112
18336	36696	73712
19080	37888	76208
19848	39232	78704
20616	40576	81176
21384	42368	84760
22152	43816	87936
22920	45352	90816
23688	46888	93800
24496	48936	97896
25456	51024	101840
26416	52752	105528
27376	55056	110136
28336	57336	115040
29296	59256	119816
30576	61664	124464
31704	63776	128496
32856	66592	133208
34008	68808	137792
35160	71112	142248
36696	73712	146856
37888	**76208**	**152976**
39232	**78704**	**157432**
40576	**81176**	**161760**
42368	**84760**	**169544**
43816	**87936**	**175600**
45352	**90816**	**181656**
46888	**93800**	**187712**
48936	**97896**	**195816**
51024	**101840**	**203704**
52752	**105528**	**211936**
55056	**110136**	**220296**
57336	**115040**	**230104**
59256	**119816**	**239656**
61664	**124464**	**248272**
63776	**128496**	**257016**
66592	**133208**	**266440**
68808	**137792**	**275608**
71112	**142248**	**284608**
73712	146856	N/A
75376	149776	N/A

For I_{TBS}=26, the four-layer TB sizes are redesigned based on system configurations so that the effective code rates should be smaller than 0.930. Equation (1) is used to calculate the effective code rates, assuming the associated reference configuration and with N_{layer}=4 and Q_m=6. The final TB sizes are found and given in Table 7. In Table 7, for each N_{PRB}, two candidate TBS values are provided; the larger value listed in the row labelled 26, and the smaller listed in the row labelled 26'. If only one candidate TBS value is provided for a then the value is used in both row 26 and row 26'. For each N_{PRB}, either TBS candidate (in row 26 or row 26') may be used. It is preferable to use the larger value in row 26, so that a slightly higher efficiency may be achieved. Alternatively, the smaller value in the row 26' can be used, so that the TB can be received with relatively higher reliability. It is also possible to use values in row 26 for a subset of the N_{PRB}, and use values in row 26' for the rest.

TABLE 7

Four-layer TB sizes with $55 \le N_{PRB} \le 110$ and $I_{TBS} = 26$ in accordance with an embodiment of the invention.

I_{TBS}	N_{PRB} 56	57	58	59	60
26	155768	159096	159096	165216	165216
26'	154104	157432	157432	163488	163488

I_{TBS}	N_{PRB} 61	62	63	64	65	66	67	68	69	70
26	169544	169544	175600	175600	181656	181656	181656	189696	189696	195816
26'	167752	167752	173744	173744	179736	179736	179736	187712	187712	193768

I_{TBS}	N_{PRB} 71	72	73	74	75	76	77	78	79	80
26	195816	195816	203704	203704	203704	203704	214176	214176	214176	224048
26'	193768	193768	201936	201936	201936	201936	211936	211936	211936	221680

I_{TBS}	N_{PRB} 81	82	83	84	85	86	87	88	89	90
26	224048	224048	230104	230104	230104	239656	239656	239656	248272	248272
26'	221680	221680	227672	227672	227672	238656	238656	238656	245648	245648

I_{TBS}	N_{PRB} 91	92	93	94	95	96	97	98	99	100
26	248272	257632	257632	257632	263624	263624	263624	272496	272496	278552
26'	245648	257016	257016	257016	263136	263136	263136	269616	269616	275608

I_{TBS}	N_{PRB} 101	102	103	104	105	106	107	108	109	110
26	278552	278552	284608	284608	284608	284608	296720	296720	296720	296720
26'	275608	275608	278552	278552	278552	278552	284608	284608	284608	284608

The four-layer TB sizes can be alternatively designed by setting the four-layer TB sizes to be four times the one-layer TB sizes. The above discussed design of four-layer TB sizes that are twice the two-layer TB sizes. Theoretically, this is equivalent to designing four-layer TB sizes that are four times the one-layer TB sizes. However, because the two-layer TB sizes are not exactly twice the one-layer TB sizes, a translation table based on four times the one-layer TB sizes may be different from Table 6 for some TBS_L1 values. On the other hand, the I_{TBS}=26 values in Table 6 and Table 7 does not change because they are determined based on the effective code rates.

For TBS_L1 values in the range of 1544≤TBS_L1≤36696, there are four TBS_L1 values that map to different TBS_L4 values with that in Table 6 if TBS_L4 is taken to be the closest value to 4×TBS_L1 in one-layer and two-layer TB sizes. The four TBS_L1 values are: 3752, 6200, 6712, and 29296. The relevant translation to TBS_L4 is shown in Table 8.

For TBS_L1 values greater than 36696, the TBS_L4 values are computed rather than looked up from existing one-layer and two-layer TBS table. If TBS_L4 is taken to be the closest value to 4×TBS_L1, TBS_L4 entries different from those in Table 6 may be found. For example, five TBS_L1 values, {37888, 59256, 61664, 63776, and 68808} have TBS_L4 translations different from Table 6, as shown in Table 8. Overall, Table 8contains the TBS_L4 translation entries different with those in Table 6. Translation for the rest of the sizes is the same as Table 6.

TABLE 8

Alternative one-layer to four-layer TB sizes translation table in accordance with an embodiment of the invention

TBS_L1	TBS_L2	TBS_L4
3752	7480	15264
6200	12576	24496
6712	13536	26416
29296	59256	115040
37888	**76208**	**151376**
59256	**119816**	**236160**
61664	**124464**	**245648**
63776	**128496**	**254328**
68808	**137792**	**275376**

FIG. **4** illustrates a flow diagram of operations **300** in the design of TB sizes for a codeword-to-N-layer mapping, where N is greater than or equal to three (3). Operations **300** may be indicative of operations taking place in a processor or a computer used to map codewords to N-layers, producing a N-layer TBS table.

Operations **300** may begin with a processor selecting a row index (I_{TBS}) from a set of possible row indices, such as from a MCS table (block **305**). The row index specifies a modulation and coding scheme to be used. The processor may have a list of row indices and may start at one end of the list and continue towards the other end of the list, for example. The processor may check to determine if the effective code rate of a TB mapped onto N-layers using the selected modulation and coding scheme will exceed a maximum desired code rate (block **310**).

If the effective code rate does not exceed the maximum desired code rate, then for entries of the N-layer TBS table associated with the row index I_{TRS} and column index N_{PRB}, where N_{PRB} is an integer within a range of [1, floor (max_N_{PRB}/N)], the TB size may be given by the (I_{TBS}, $N \times N_{PRB}$) entry of the one-layer TBS table (block 315). Here max_N_{PRB} is the max number of physical resource blocks that can be allocated. For example, if the one-layer TBS table is of size 27×110, and N=3, then for entries of the three-layer TBS table within range [1 to 36], where max_N_{PRB}=110 and floor (max_N_{PRB}/N)=36, the entries are given by entry (I_{TBS}, $3 \cdot N_{PRB}$) of the one-layer TBS table.

For entries where N_{PRB} is an integer outside of the range of [1, floor(max_N_{PRB}/N)], the TB size may be defined using a translation table, such as Table 3 shown above (block **320**). If possible, the entries in the translation table may be defined so that the N-layer TBS reuses existing TB sizes, such as values in the one-layer and two-layer TBS table (block **325**). Furthermore, some N×TBS_L1 entries are larger than all the entries in the one-layer and two-layer TBS table. In one embodiment when N=3, there are 10 entries which do not have adjacent entries in the one-layer and two-layer TBS table that can be used as the N-layer TBS. For a three-layer table, these TBS_L1 values are 51024, 52752, 55056, 57336, 59256, 61664, 63776, 66592, 68808, and 71112. For these entries, three-layer TB sizes are three times of TBS_L1 with some adjustment given for CRC bits and should be aligned with QPP sizes for turbo codes. The 10 entries of one-layer TBS (TBS_L1) and their corresponding three-layer TBS (TBS_L3) are shown boldfaced in Table 3. If there are additional row indices to process (block **330**), the processor may return block **305** to select another row index, else operations **300** may terminate.

If the effective code rate exceeds the maximum desired code rate (block **310**), then entries of the N-layer TBS table that exceed the maximum desired code rate may be redesigned so that the effective code rate does not exceed the maximum desired code rate (block **335**). If there are additional row indices to process (block **330**), the processor may return block **305** to select another row index, else operations **300** may terminate.

Embodiments of the invention for uplink MIMO will next be described.

Uplink spatial multiplexing of up to four layers is considered for LTE-Advanced while only a single layer is allowed in LTE. As specified in 3GPP TS 36.814, in the uplink single user spatial multiplexing, up to two transport blocks can be transmitted from a scheduled UE in a subframe per uplink component carrier. Each transport block is likely to have its own MCS level. Depending on the number of transmission layers, the modulation symbols associated with each of the transport blocks are mapped onto one or two layers according to the same principle as in Rel-8 E-UTRA downlink spatial multiplexing.

Since in Rel-8 uplink transport block sizes are defined for one spatial layer only, there is a need to define the uplink transport block sizes which are mapped to two layers in Rel-10. While it is possible to reuse the Rel-10 two-layer TB sizes defined for DL, it is shown below that this is not conducive to the implementation of per-layer successive interference cancellation (SIC).

As described below, embodiments of the invention provide improved design for TB size allocation for improving uplink performance. In various embodiments, the new transport block sizes for uplink are designed for LTE-Advanced to facilitate successive interference cancellation in the receiver.

Code block segmentation and successive interference cancellation receiver will be first described because of their implications in designing a two-layer table. A transport block generated by MAC layer is passed to the physical layer for channel coding and other processing before transmission over the air. As described in 3GPP TS 36.212 V8.6.0 (2009-03), Multiplexing and channel coding, which is incorporated herein by reference, each TB is first attached with L=24 TB-level CRC bits. Then code block segmentation is performed on a TB to form code blocks (CBs). The turbo encoder individually encode each code blocks.

Let B be the TB size plus the TB-level CRC bits, i.e., B=TBS+L, where TBS refers to the transport block size. If B is smaller than Z, the entire TB including the TB-level CRC bits is treated as one code block (CB) and passed to turbo encoder. If B is larger than the maximum code block size Z, segmentation of the input bit sequence is performed and an additional CRC sequence of L=24 bits is attached to each code block. Here the maximum code block size is Z=6144 which is the largest QPP turbo interleaver length. As agreed for 3GPP LTE, the TB sizes are chosen such that no filler bits are necessary, and the code blocks are all of the same size.

Total number of code blocks C is determined by:

```
if B ≤ Z
    L = 0
    Number of code blocks: C = 1
     B' = B
else
    L = 24
    Number of code blocks: C = ⌈B /(Z − L)⌉.
     B' = B + C · L
end if
```

The code block sizes are B'/C.

When MIMO is used, modulation symbols of a TB is mapped to the spatial layers before transmitted by the multiple transmit antennas. At the receiver end, the received symbols of a TB are processed in the receiver to estimate the transmitted TB. To facilitate SIC, it is proposed in R1-091093, "Uplink SU-MIMO in LTE-Advanced," Ericsson, 3GPP TSG-RAN WGI #56, Athens, Greece, February 9-Feb. 13, 2009, which is incorporated herein by reference, that "One CRC per layer" should be used, taking advantage of the "functionality of one CRC per code block". This leads to a proposed codeword-to-layer mapping for uplink spatial multiplexing, as shown in Table 1. In Table 1, a codeword refers to the sequence of modulation symbols corresponding to a TB, M_{symbol}^{layer} denotes the number of modulation symbols per layer transmitted in a LTE subframe, $d^{(i)}$ denotes the modulation symbols of the i-th TB, $x^{(i)}$ denotes the modulation symbol on the i-th antenna port.

TABLE 9

Codeword-to-layer mapping for UL spatial multiplexing in accordance with an embodiment of the invention		
Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \ldots, M_{symb}^{layer} - 1$
2	1	$x^{(0)}(i) = d^{(0)}(i)$ $\quad M_{symb}^{layer} = M_{symb}^{(0)}/2$ $x^{(1)}(i) = d^{(0)}(M_{symb}^{layer} + i)$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $\quad M_{symb}^{layer} = M_{symb}^{(0)} = M_{symb}^{(1)}/2$ $x^{(1)}(i) = d^{(1)}(i)$ $x^{(2)}(i) = d^{(1)}(M_{symb}^{layer} + i)$
4	2	$x^{(0)}(i) = d^{(0)}(i)$ $\quad M_{symb}^{layer} = M_{symb}^{(0)}/2 = M_{symb}^{(1)}/2$ $x^{(1)}(i) = d^{(0)}(M_{symb}^{layer} + i)$ $x^{(2)}(i) = d^{(1)}(i)$ $x^{(3)}(i) = d^{(1)}(M_{symb}^{layer} + i)$

This mapping allows per-layer SIC, considering that a transport block goes through the code block segmentation process, as defined in 3GPP TS 36.212. As defined in 3GPP TS 36.212, a TB is appended with 24 TB-level CRC bits and passed to the code block segmentation process. For a TB (including CRC bits) greater than 6144 bits, the TB is segmented into code blocks. Each code block is appended with CB-level CRC bits. Each code block (including CB-level CRC bits) is then turbo encoded individually. With the mapping in Table 1, the CB-level CRC can be utilized to form a per-layer CRC check, thus allowing per-layer SIC.

Without channel interleaving to mix bits of code blocks, the codeword to layer mapping in Table 9 would keep bits of a given code block together, except possibly at the end of the first layer and the beginning of the second layer. For a TB composed of an even number of code blocks, the method maps an integer number of code blocks to a layer, thus no CB will be divided between two layers.

FIG. **5**, which includes FIGS. **5**a and **5**b, illustrates mapping a transport block to multiple uplink layers, wherein FIG. **5**a illustrates mapping of a transport block having two code blocks to two layers, and wherein FIG. **5**b illustrates mapping of a transport block having three code blocks to three layers, in accordance with embodiments of the invention.

FIG. **5**a illustrates a mapping of a TB **505** with two code blocks to two layers. As shown in FIG. **5**a, TB **505** includes two code blocks (CB**1** **510** and CB**2** **511**). Each of the two code blocks also includes a CB-level CRC. The mapping results in one code block in each of the two uplink layers (shown as CB**1** **520** and CB**2** **521**). Additionally, each uplink layer has one CRC due to a per-code block CRC defined in the LTE Rel-8.

Although shown in FIG. **5**a (and in other figures discussed herein) as being a single contiguous code block on a single layer when an entire code block is mapped onto the single layer for simplicity reasons (for example, CB**1** **520**), in an actual communications system, the code block may be spread over a layer. For example, modulation symbols of the code block may not be in a proper order (such as due to interleaving or some other information dispersal technique), modulation symbols may not be contiguous (such as due to insertion of control information, error correction/detection information, bit puncturing, and so forth). Therefore, the illustration of a single contiguous code block should not be construed as being limiting to either the spirit or the scope of the embodiments.

In general, if a TB comprises an even number of code blocks (denoted 2C), each uplink layer may be assigned C code blocks and each code block would have a CRC. Therefore, each uplink layer has an equivalent CRC and an uplink layer may be deemed correct if all C code block-level CRC checks correctly, while an uplink layer may be deemed incorrect if one or more of the C code block-level CRC checks incorrectly. SIC may then be facilitated as an entire set of bits of a first layer (e.g., layer one) and can be used for interference cancellation of bits of a second layer (e.g., layer two) when the first layer's CRC checks correctly, and vice versa.

For C=1, i.e., the TB size is smaller than or equal to 6120 bits, and not segmented into code blocks. In this case, only TB-level CRC bits are attached to the TB, without any CB-level CRC bits. In this case, the receiver may use MMSE or ML algorithm.

While the discussion focuses on the case where channel interleaving is not used, the same discussion holds if per-layer channel interleaving is used. With channel interleaving where bits of different layer are interleaved separately, and an even number of CBs, bits of a given code block will be kept in the same layer with the codeword to layer mapping in Table 9.

The basic SIC receiver can be enhanced to exploit the fact that each code block in LTE has CB-level CRC. One possible way of performing SIC is discussed below for the case of one TB being mapped to two layers. Due to the presence of CB-level CRC, a fraction or the whole of a layer is protected by CRC bits, if a TB is composed of two or more code blocks. Rather than requiring the correctness of the entire layer being confirmed before interference cancellation as required by the basic SIC, a partial interference cancellation can be carried out as long as correctness of any part of the layer is confirmed.

One way to perform the enhanced SIC receiver is described here. First a 2×2 MMSE is first performed at the receiver. The layer with higher SINR is identified and decoded.

(a) After turbo decoding, CBs that are fully contained in the stronger layer are CRC checked. The CBs that are deemed correctly received can be used to reconstruct interference. The interference can then be cancelled from the buffered receive samples. The data of second layer can then be estimated and decoded. Note that this is different from the basic SIC processing that part of the bits, vs. all the bits, of the layer can be used for cancellation. For example, if the stronger layer carries 2.5 CBs, and only one CB is correctly received, the correct CB can be used for cancellation.

(b) After the processing of the stronger layer, likely with a certain degree of interference cancelled for the weaker layer, then the weaker layer is turbo decoded and CRC checked. If the weaker layer (or part of it) passes the CRC check, then the weaker layer can be used to cancel interference for the stronger layer, if the corresponding part of the stronger layer was not detected correctly.

(c) Iterate (a) and (b) until both layers are correctly decoded, or no improvement is observed, or a predefined number of iterations are reached. If both layers fail the CRC checks after a predefined number of iterations, then both TBs are declared to be in error.

In the above, the description included the case where a TB is segmented into an odd number of CBs and a CB may be mapped to layers. However, if a TB is segmented into an even number of CBs, the SIC receiver can be simplified because no layer contains a partial CB.

While the procedure above only discusses SIC between layers corresponding to a TB, the same principle can be applied between TBs if two TBs are used as in the case of 3 and 4 layers in Table 9. Since each TB has TB-level CRC, the SIC receiver can utilize both the CB-level CRC and the TB-level CRC.

FIG. **5**b illustrates a mapping of a TB **555** with three code blocks to three layers. As shown in FIG. **5**b, TB **555** includes three code blocks (CB**1 560**, CB**2 561**, and CB**3 562**). Each of the three code blocks include a CB-level CRC. The mapping results in one code block in each of the three uplink layers (shown as CB**1 570**, CB**2 571**, and CB**3 573**). The use of code blocks that are multiples of three in the TB **555** ensures enhanced SIC as described above for the two-layer case. Similar to the two layer case, for C=1, i.e., the TB size is smaller than or equal to 6120 bits, and not segmented into code blocks.

The design of uplink two-layer transport block sizes will now be described in accordance with an embodiment of the invention.

Uplink transport block sizes are defined and signaled similar to downlink. For uplink, to signal the transmit format, including the TB size of a TB, the DCI (downlink control information) is used which contains a 5-bit MCS field. The MCS field points to the 32 rows in the MCS Table, "Modulation, TBS index and redundancy version table for PUSCH," in 3GPP TS 36.213. In the MCS table, three MCS states are reserved for signaling redundancy version for retransmission, and two overlapped MCSs for transitioning from QPSK to 16-QAM, and from 16-QAM to 64-QAM, respectively. Thus there are 27 distinct spectral efficiency levels (i.e., MCS levels), corresponding to the 27 rows of the Table of one-layer transport block sizes. With the MCS field and the RB allocation, the TB size is obtained by looking up the 27×110 one-layer transport block size table. As currently defined in 3GPP TS 36.213, the uplink one-layer TB size table is the same as the downlink one-layer TB size table. Although nominally, the uplink TBS table reuses the DL TBS table and thus contains TBS for N_{PRB} from 1 to 110, only a subset of the N_{PRB} values are actually used for uplink, as shown below.

While the uplink TB size table appears to be of the same dimension as the downlink TB size table, in reality on the uplink only certain N_{PRB} values are valid. As specified in 3GPP TS 36.211 V8.5.0 (2008-12), Physical Channels and Modulation, which is incorporated herein by reference, the variable $M_{sc}^{PUSCH}=M_{RB}^{PUSCH}\cdot N_{sc}^{RB}$, where M_{RB}^{PUSCH} represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfill

$$M_{RB}^{PUSCH}=2^{\alpha_2}\cdot 3^{\alpha_3}\cdot 5^{\alpha_5}\leq N_{RB}^{UL}$$

where $\alpha_2,\alpha_3,\alpha_5$ is a set of non-negative integers.

Since for 3GPP LTE, the maximum N_{RB}^{UL} defined is 110, the valid M_{RB}^{PUSCH} values are:

$$\{1\ 2\ 3\ 4\ 5\ 6\ 8\ 9\ 10\ 12\ 15\ 16\ 18\ 20\ 24\ 25\ 27\ 30\ 32\ 36\ 40\ 45\ 48\ 50\ 54\ 60\ 64\ 72\ 75\ 80\ 81\ 90\ 96\ 100\ 108\} \quad (2)$$

M_{RB}^{PUSCH} in 3GPP TS 36.211 is equivalent to N_{PRB} which is the column index of the TB size table. Thus for the uplink TB size table design, only N_{PRB} of the above values need to be considered.

Similar to downlink, the method for obtaining uplink two-layer transport block sizes based on one-layer transport block sizes can be given below.

(a) For $1\leq N_{PRB}\leq 55$, the two-layer transport block sizes are given by the $(I_{TBS},2\cdot N_{PRB})$ entry of Table for one-layer transport block sizes.

(b) For $56\leq N_{PRB}\leq 110$, a baseline TBS_L1 is taken from the (I_{TBS},N_{PRB}) entry of Table for one-layer transport block sizes, which is then translated into TBS_L2 using a mapping rule (e.g., using Table 1). The two-layer transport block sizes are given by TBS_L2.

However, unlike downlink transmission, for both (a) and (b), if the transport block size is greater than 6120, the two-layer TBS need to contain an even number of code blocks when segmented, to facilitate SIC. Thus the TBS_L2 values obtained from the TBS tables defined for downlink may need to be replaced by another value TBS_L2'. Below the two-layer TBS design for $5\leq N_{PRB}\leq 110$ is shown in details, as an example of designing the entire uplink two-layer TBS. In other words, a one-layer to two-layer TBS translation table is designed below for the TBS in the following N_{PRB} columns in the one-layer TBS table:

$$N_{PRB}=\{60, 64, 72, 75, 80, 81, 90, 96, 100, 108\} \quad (3)$$

For N_{PRB} values in (3), a baseline TBS_L1 is taken from the (I_{TBS},N_{PRB}) entry of Table for one-layer transport block sizes, which is then translated into TBS_L2 using the one-layer to two-layer TBS translation table.

If the TBS_L1 to TBS_L2 translation relationship in Table 1 is reused, the translation table for uplink MIMO would be as shown in Table 10, where N_{cb}_L2 column shows the number of code blocks segmented from TBS_L2. Note that certain TBS_L1 values in Table 1 are not included in Table 10, due to the fact that only N_{PRB} values in (3) need to be considered for uplink.

For TBS_L2 values with odd N_{cb}_L2 values and N_{cb}_L2>2 in Table 10, the TBS_L2 need to be redesigned to facilitate per-layer SIC receiver. The results of the redesign is shown in Table 11, where TBS_L2' shows the proposed two-layer TB size, and N_{cb}_L2' shows the number of code blocks segmented from TBS_L2'. For each TBS_L1 entry, the corresponding TBS_L2' value is found by using the TBS of an even number of CBs that is closest to (2×TBS_L1).

In an embodiment of the invention, the TBS_L2' values for uplink are found using the following steps:

i) Find TBS_L2 as defined for downlink in 3GPP TS 36.213;

ii) Use code block segmentation procedure to find C, the number of CBs for TBS_L2.

a) If C is even, TBS_L2 defined for downlink is used for uplink also, i.e., TBS_L2'=TBS_L2.

b) If C is odd, TBS_L2' value is found by using the TBS of an even number of CBs that is closest to (2×TBS_L1).

TABLE 10

One-layer to two-layer transport block sizes translation table using relationship in Table 1 in accordance with an embodiment of the invention.

TBS_L1	TBS_L2	N_{cb}_L2
1672	3368	1
1800	3624	1
1992	4008	1
2088	4136	1
2152	4264	1
2216	4392	1
2280	4584	1
2344	4776	1
2536	5160	1
2600	5160	1
2664	5352	1
2728	5544	1
2792	5544	1
2856	5736	1
2984	5992	1
3240	6456	2
3368	6712	2
3496	6968	2
3624	7224	2
3752	7480	2
4008	7992	2
4264	8504	2
4392	8760	2
4584	9144	2
4776	9528	2
5160	10296	2
5352	10680	2
5544	11064	2
5736	11448	2
6200	12576	3
6456	12960	3
6712	13536	3
6968	14112	3
7224	14688	3
7480	14688	3
7736	15264	3
7992	15840	3
8248	16416	3
8504	16992	3
8760	17568	3
9144	18336	3
9528	19080	4
9912	19848	4
10296	20616	4
10680	21384	4
11064	22152	4
11448	22920	4
11832	23688	4
12216	24496	5
12576	25456	5
12960	25456	5
13536	27376	5
14112	28336	5
14688	29296	5
15264	30576	5
15840	31704	6
16416	32856	6
16992	34008	6
17568	35160	6
18336	36696	6
19080	37888	7
19848	39232	7
20616	40576	7
21384	42368	7
22152	43816	8
22920	45352	8
23688	46888	8
24496	48936	8
25456	51024	9
26416	52752	9
27376	55056	9
28336	57336	10
29296	59256	10
30576	61664	11

TABLE 10-continued

One-layer to two-layer transport block sizes translation table using relationship in Table 1 in accordance with an embodiment of the invention.

TBS_L1	TBS_L2	N_{cb}_L2
31704	63776	11
32856	66592	11
34008	68808	12
35160	71112	12
36696	73712	13
37888	76208	13
39232	78704	13
40576	81176	14
42368	84760	14
43816	87936	15
45352	90816	15
46888	93800	16
48936	97896	16
51024	101840	17
52752	105528	18
55056	110136	18
57336	115040	19
59256	119816	20
61664	124464	21
63776	128496	21
66592	133208	22
68808	137792	23
71112	142248	24
75376	149776	25

TABLE 11

One-layer to two-layer transport block sizes translation table: Redesigned Subset of Table 10 in accordance with an embodiment of the invention.

TBS_L1	TBS_L2	Ncb_L2	TBS_L2'	Ncb_L2'
6200	12576	3	12216	2
6456	12960	3	12216	2
6712	13536	3	12216	2
6968	14112	3	12216	2
7224	14688	3	12216	2
7480	14688	3	12216	2
7736	15264	3	18568	4
7992	15840	3	18568	4
8248	16416	3	18568	4
8504	16992	3	18568	4
8760	17568	3	18568	4
9144	18336	3	18568	4
12216	24496	5	24456	4
12576	25456	5	24456	4
12960	25456	5	24456	4
13536	27376	5	24456	4
14112	28336	5	30936	6
14688	29296	5	30936	6
15264	30576	5	30936	6
19080	37888	7	36696	6
19848	39232	7	36696	6
20616	40576	7	43304	8
21384	42368	7	43304	8
25456	51024	9	48936	8
26416	52752	9	55416	10
27376	55056	9	55416	10
30576	61664	11	61176	10
31704	63776	11	61176	10
32856	66592	11	68040	12
36696	73712	13	73416	12
37888	76208	13	73416	12
39232	78704	13	80280	14
43816	87936	15	85656	14
45352	90816	15	92776	16
51024	101840	17	104376	18

TABLE 11-continued

One-layer to two-layer transport block sizes translation table: Redesigned Subset of Table 10 in accordance with an embodiment of the invention.

TBS_L1	TBS_L2	Ncb_L2	TBS_L2'	Ncb_L2'
57336	115040	19	117256	20
61664	124464	21	122376	20
63776	128496	21	128984	22
68808	137792	23	134616	22
75376	149776	25	154104	26

Similar to N_{PRB} values in (3), the two-layer TBS corresponding to values N_{PRB} smaller than 56 are also found using the steps in i) and ii). Overall, the entire two-layer TB size table is shown below in Table 12 for all the N_{PRB} values in (2).

TABLE 12

Uplink two-layer transport block size table of size 27 × 35 in accordance with an embodiment of the invention.

	N_{PRB}									
I_{TBS}	1	2	3	4	5	6	8	9	10	12
0	32	88	152	208	256	328	424	488	536	648
1	56	144	208	256	344	424	568	632	712	872
2	72	176	256	328	424	520	696	776	872	1064
3	104	208	328	440	568	680	904	1032	1160	1384
4	120	256	408	552	696	840	1128	1288	1416	1736
5	144	328	504	680	872	1032	1384	1544	1736	2088
6	176	392	600	808	1032	1224	1672	1864	2088	2472
7	224	472	712	968	1224	1480	1928	2216	2472	2984
8	256	536	808	1096	1384	1672	2216	2536	2792	3368
9	296	616	936	1256	1544	1864	2536	2856	3112	3752
10	328	680	1032	1384	1736	2088	2792	3112	3496	4264
11	376	776	1192	1608	2024	2408	3240	3624	4008	4776
12	440	904	1352	1800	2280	2728	3624	4136	4584	5544
13	488	1000	1544	2024	2536	3112	4136	4584	5160	6200
14	552	1128	1736	2280	2856	3496	4584	5160	5736	6968
15	600	1224	1800	2472	3112	3624	4968	5544	6200	7224
16	632	1288	1928	2600	3240	3880	5160	5992	6456	7736
17	696	1416	2152	2856	3624	4392	5736	6456	7224	8760
18	776	1544	2344	3112	4008	4776	6200	7224	7992	9528
19	840	1736	2600	3496	4264	5160	6968	7736	8504	10296
20	904	1864	2792	3752	4584	5544	7480	8248	9144	11064
21	1000	1992	2984	4008	4968	5992	7992	9144	9912	12216
22	1064	2152	3240	4264	5352	6456	8504	9528	10680	12216
23	1128	2280	3496	4584	5736	6968	9144	10296	11448	12216
24	1192	2408	3624	4968	5992	7224	9912	11064	12216	12216
25	1256	2536	3752	5160	6200	7480	10296	11448	12216	12216
26	1480	2984	4392	5992	7480	8760	11832	12216	12216	18568

	N_{PRB}									
I_{TBS}	15	16	18	20	24	25	27	30	32	36
0	808	872	1000	1096	1320	1384	1480	1672	1800	1992
1	1064	1160	1288	1416	1736	1800	1992	2152	2344	2600
2	1320	1416	1608	1800	2152	2216	2408	2664	2856	3240
3	1736	1864	2088	2344	2792	2856	3112	3496	3752	4264
4	2152	2280	2600	2856	3496	3624	3880	4264	4584	5160
5	2664	2792	3112	3496	4264	4392	4776	5352	5736	6200
6	3112	3368	3752	4136	4968	5160	5736	6200	6712	7480
7	3624	3880	4392	4968	5992	6200	6712	7224	7736	8760
8	4264	4584	4968	5544	6712	6968	7480	8504	9144	9912
9	4776	5160	5736	6200	7480	7992	8504	9528	10296	11448
10	5352	5736	6200	6968	8504	8760	9528	10680	11448	12216
11	5992	6456	7224	7992	9528	9912	11064	12216	12216	12216
12	6712	7224	8248	9144	11064	11448	12216	12216	12216	18568
13	7736	8248	9144	10296	12216	12216	12216	18568	18568	18568
14	8504	9144	10296	11448	12216	12216	18568	18568	18568	20616
15	9144	9912	11064	12216	12216	18568	18568	18568	19848	22152
16	9912	10296	11832	12216	18568	18568	18568	19848	20616	23688
17	10680	11448	12216	12216	18568	18568	19848	21384	22920	24456
18	11832	12216	12216	18568	19080	19848	21384	23688	24456	30936
19	12216	12216	18568	18568	20616	21384	22920	24456	24456	30936
20	12216	12216	18568	18568	22152	22920	24456	30936	30936	34008
21	12216	18568	18568	19848	24456	24456	24456	30936	31704	36696

TABLE 12-continued

Uplink two-layer transport block size table of size 27 × 35 in accordance with an embodiment of the invention.

22	18568	18568	19080	21384	24456	24456	30936	32856	34008	36696
23	18568	18568	20616	22920	24456	30936	30936	34008	36696	43304
24	18568	19848	22152	24456	30936	30936	32856	36696	36696	43816
25	19080	20616	22920	24456	30936	31704	34008	36696	43304	45352
26	22152	23688	24456	30936	35160	36696	36696	43816	46888	55416

	N_{PRB}									
I_{TBS}	40	45	48	50	54	60	64	72	75	80
0	2216	2536	2664	2792	2984	3368	3624	4008	4136	4392
1	2856	3240	3496	3624	4008	4264	4776	5160	5544	5736
2	3624	4008	4264	4584	4776	5352	5736	6456	6712	7224
3	4776	5352	5544	5736	6200	6968	7480	8504	8760	9528
4	5736	6456	6968	7224	7736	8504	9144	10296	10680	11448
5	6968	7992	8504	8760	9528	10680	11448	12216	12216	12216
6	8248	9528	9912	10296	11448	12216	12216	12216	18568	18568
7	9912	11064	11832	12216	12216	12216	18568	18568	18568	19848
8	11064	12216	12216	12216	12216	18568	18568	19848	21384	22152
9	12216	12216	12216	18568	18568	19080	20616	22920	23688	24456
10	12216	18568	18568	18568	19080	21384	22920	24456	24456	30936
11	18568	18568	19080	19848	22152	24456	24456	30936	30936	32856
12	18568	20616	22152	22920	24456	24456	30936	32856	34008	36696
13	20616	22920	24456	24456	30936	30936	32856	36696	36696	43304
14	22920	24456	24456	30936	30936	34008	36696	43304	43304	45352
15	24456	24456	30936	30936	32856	36696	36696	43816	45352	48936
16	24456	30936	31704	32856	35160	36696	43304	46888	48936	55416
17	30936	32856	35160	36696	36696	43304	45352	55416	55416	59256
18	31704	35160	36696	36696	43304	46888	48936	57336	59256	61176
19	34008	36696	43304	43816	46888	48936	55416	61176	68040	68808
20	36696	43304	45352	46888	48936	57336	59256	68808	71112	73416
21	36696	45352	48936	48936	55416	61176	61176	73416	73416	81176
22	43816	48936	48936	55416	59256	68040	68808	80280	81176	85656
23	45352	48936	55416	57336	61176	68808	73416	81176	85656	92776
24	48936	55416	59256	61176	68040	73416	80280	85656	92776	97896
25	48936	57336	61176	61176	68808	73416	81176	92776	93800	104376
26	59256	68040	71112	73416	81176	85656	93800	105528	110136	119816

	N_{PRB}				
I_{TBS}	81	90	96	100	108
0	4584	5160	5352	5544	5992
1	5992	6456	6968	7224	7992
2	7224	7992	8504	9144	9528
3	9528	10680	11064	11448	12216
4	11448	12216	12216	12216	18568
5	12216	18568	18568	18568	19080
6	18568	19080	19848	20616	22920
7	19848	22152	23688	24456	24456
8	22920	24456	24456	30936	30936
9	24456	30936	30936	31704	34008
10	30936	31704	34008	35160	36696
11	32856	36696	36696	36696	43816
12	36696	43304	43816	45352	48936
13	43304	45352	48936	48936	55416
14	45352	48936	55416	57336	61176
15	48936	55416	59256	61176	68040
16	55416	59256	61176	68040	71112
17	59256	68040	71112	73416	80280
18	61176	71112	73416	80280	84760
19	71112	80280	81176	85656	93800
20	73416	84760	92776	93800	104376
21	81176	92776	97896	104376	110136
22	85656	97896	104376	110136	119816
23	93800	104376	110136	117256	122376
24	97896	110136	119816	122376	133208
25	104376	117256	122376	128984	134616
26	119816	133208	142248	154104	154104

FIG. **6** illustrates a communications device **600** in accordance with embodiments of the invention. Communications device **600** may be a base station (or a mobile station) communicating using spatial multiplexing on a DL (or on an UL for a mobile station). Communications device **600** includes a processor **605** that may be used to execute applications and programs. Communications device **600** includes a receive chain and a transmit chain.

The transmit chain of communications device **600** includes a transport channel processing unit **620** that may provide transport channel processing such as applying CRC data to a transport block, segmenting, channel coding, rate matching, concatenating, and so on, to information to be transmitted.

Transmit chain of communications device **600** also includes a channel interleaver **625**. Channel interleaver **625** may be implemented as a multi-layer channel interleaver with a plurality of sub-channel interleavers, wherein there may be as many sub-channel interleavers as there are layers that a codeword may be mapped onto. Channel interleaver **625** may follow any of a variety of interleaver, such as a block interleaver, bit reversal interleaver, and so forth, while the sub-channel interleavers may be modulation-symbol or bit level interleavers, for example.

Transmit chain of communications device **600** further includes a physical channel processing unit **630**, transmitter circuitry **635**, and a transmitter **640**. Physical channel processing unit **630** may provide the codeword-to-layer mapping function, such as those described previously. Physical channel processing unit **630** may provide other physical channel processing such as scrambling, modulation/coding scheme selection and mapping, signal generating, and so forth. Transmitter circuitry **635** may provide processing such as parallel to serial converting, amplifying, filtering, and so on. Transmitter **640** may transmit the information to be transmitted using one or more transmit antennas.

Although shown in FIG. **6** as being located immediately ahead of physical channel processing unit **630**, channel interleaver **625** may be placed in any of a variety of positions in the transmit chain of communications device **600**. Preferably the channel interleaver **625** is placed before a layer mapping unit (part of physical channel processing unit **630**). Alternatively it may be placed after the layer mapping unit. In general, the position of channel interleaver **625** may be relatively position independent as long as it achieves the desired interleaving effect together with the layer mapping unit of physical channel processing unit **630**.

In various embodiments, the uplink and downlink tables including translation tables described above may be transferred and stored in the communications device **600** prior to beginning of the transmission. Consequently, the receiving device can use the corresponding uplink or downlink tables to determine the transport block size of the received transmission.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. For example, many of the features and functions discussed above can be implemented in software, hardware, or firmware, or a combination thereof.

Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

What is claimed is:

1. A method for transmitting information, the method comprising:

[processing a downlink transport channel to generate a transport block (TB) having a TB size, wherein the TB size is selected by:]

selecting a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}), [and]

setting [the] *a transport block* (TB) size for the selected I_{TBS} and N_{PRB} wherein an effective code rate at a user equipment (UE) does not exceed a specified threshold, wherein the effective code rate is defined as a number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by a number of physical channel bits on *a* Physical Downlink Shared Channel (PDSCH);

mapping the transport block to multiple spatial layers, wherein the number of spatial layers N is greater than or equal to three; and

transmitting the multiple spatial layers to the UE.

2. The method of claim **1**, wherein setting the TB size comprises defining the TB size so that code block sizes with TB CRC bits and code block CRC bits attached are aligned with Quadratic Permutation Polynomial (QPP) sizes for turbo codes.

3. The method of claim **1**, wherein the TB size is identical to another entry in an one-layer TB size table or a two-layer TB size table.

4. The method of claim **1**, wherein the number of spatial layers N is equal to three, and wherein the setting the TB size for the selected I_{TBS} and N_{PRB} comprises:

selecting the TB size by a (I_{TBS},$3 \cdot N_{PRB}$) entry of a one-layer TBS table if $1 \le N_{PRB} \le 36$; and

selecting the TB size from a translation table if $37 \le N_{PRB} \le N_{MAX}$, wherein N_{MAX} is the maximum number of physical resource blocks that can be allocated.

5. The method of claim **4**, wherein the translation table comprises translations from a one-layer TB size to a three-layer TB size.

6. The method of claim **4**, wherein the translation table is obtained by:

obtaining a one-layer TB size (TBS_L1) by selecting a (I_{TBS},N_{PRB}) entry from the one-layer TBS table and calculating 3×TBS_L1; and

obtaining a three-layer TB size (TBS_L3) by selecting the TB size in the one-layer table or a two-layer table that is most adjacent to a calculated 3×TBS_L1.

7. The method of claim **6**, wherein if the calculated 3×TBS_L1 is larger than all entries in the one-layer and two-layer table, the three-layer TB size is selected to be 3×TBS_L1 with adjustments for CRC bits and alignment with Quadratic Permutation Polynomial (QPP) sizes for turbo coding.

8. The method of claim **4**, wherein if N_{PRB}={38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72} and $0 \le I_{TBS} \le 25$, the TB size is selected by a

$$\left(I_{TBS}, \frac{3 \cdot N_{PRB}}{2}\right)$$

entry in an equivalent 27×110 two-layer TBS table constructed by a one-layer to two-layer TB size translation table.

9. The method of claim **4**, further comprising receiving the transmitted multiple spatial layers at the UE, and using the one-layer TBS table, or the translation table to determine a transmitted size of the transport block.

10. The method of claim **4**, wherein the translation table is

TBS_L1	TBS_L3
1032	3112
1064	3240
1096	3240
1128	3368
1160	3496
1192	3624
1224	3624
1256	3752
1288	3880
1320	4008
1352	4008
1384	4136
1416	4264
1480	4392
1544	4584
1608	4776
1672	4968
1736	5160
1800	5352
1864	5544
1928	5736
1992	5992
2024	5992
2088	6200
2152	6456
2216	6712
2280	6712/6968
2344	6968
2408	7224
2472	7480
2536	7480/7736
2600	7736
2664	7992
2728	8248
2792	8248/8504
2856	8504
2984	8760/9144
3112	9144/9528
3240	9528/9912
3368	9912/10296
3496	10296/10680
3624	10680/11064
3752	11064/11448
3880	11448/11832
4008	11832/12216
4136	12576
4264	12960
4392	12960
4584	13536
4776	14112
4968	14688
5160	15264
5352	15840
5544	16416
5736	16992
5992	18336
6200	18336
6456	19080
6712	19848
6968	20616
7224	21384
7480	22152
7736	22920
7992	23688
8248	24496
8504	25456
8760	26416
9144	27376
9528	28336
9912	29296
10296	30576
10680	31704
11064	32856

-continued

TBS_L1	TBS_L3
11448	34008
11832	35160
12216	36696
12576	37888
12960	39232
13536	40576
14112	42368
14688	43816
15264	45352
15840	46888
16416	48936
16992	51024
17568	52752
18336	55056
19080	57336
19848	59256
20616	61664
21384	63776
22152	66592
22920	68808
23688	71112
24496	73712
25456	76208
26416	78704
27376	81176
28336	84760
29296	87936
30576	90816
31704	93800
32856	97896
34008	101840
35160	105528
36696	110136
37888	115040
39232	119816
40576	119816
42368	128496
43816	133208
45352	137792
46888	142248
48936	146856
52752	157432
55056	165216
57336	171888
59256	177816
61664	185728
63776	191720
66592	199824
68808	205880
71112	214176.

11. The method of claim **1**, wherein the number of spatial layers N is equal to four, and wherein the setting the TB size for the selected I_{TBS} and N_{PRB} comprises:

selecting the TB size from a translation table if $56 \leq N_{PRB} \leq N_{MAX}$, wherein N_{MAX} is the maximum number of physical resource blocks that can be allocated.

12. The method of claim **11**, wherein the translation table is

TBS_L1	TBS_L4	TBS_L1	TBS_L4
1544	6200		
1608	6456	3880	15264
1672	6712	4008	15840
1736	6968	4136	16416
1800	7224	4264	16992
1864	7480	4392	17568
1928	7736	4584	18336
1992	7992	4776	19080
2024	7992	4968	19848
2088	8248	5160	20616
2152	8504	5352	21384
2216	8760	5544	22152

-continued

TBS_L1	TBS_L4	TBS_L1	TBS_L4
2280	9144	5736	22920
2344	9528	5992	23688
2408	9528		
2472	9912	6456	25456
2536	10296		
2600	10296	6968	28336
2664	10680	7224	29296
2728	11064	7480	29296
2792	11064	7736	30576
2856	11448	7992	31704
2984	11832	8248	32856
3112	12576	8504	34008
3240	12960	8760	35160
3368	13536	9144	36696
3496	14112	9528	37888
3624	14688	9912	39232
10296	40576	28336	115040
10680	42368		
11064	43816	30576	124464
11448	45352	31704	128496
11832	46888	32856	133208
12216	48936	34008	137792
12576	51024	35160	142248
12960	51024	36696	146856
13536	55056		
14112	57336	39232	157432
14688	59256	40576	161760
15264	61664	42368	169544
15840	63776	43816	175600
16416	66592	45352	181656
16992	68808	46888	187712
17568	71112	48936	195816
18336	73712	51024	203704
19080	76208	52752	211936
19848	78704	55056	220296
20616	81176	57336	230104
21384	84760		
22152	87936		
22920	90816		
23688	93800	66592	266440
24496	97896		
25456	101840	71112	284608
26416	105528		
27376	110136.		

13. The method of claim **11**, wherein the translation table comprises translations from a one-layer TB size to a four-layer TB size.

14. The method of claim **11**, wherein the translation table is obtained by:

locating a two-layer TB size (TBS_L2(i)) for an one-layer TB size (TBS_L1(i)) in an i^{th} row of an one-layer to two-layer translation table, the TBS_L1(i) being an (I_{TBS},N_{PRB}) entry of an one-layer TBS table;

in a j^{th} row of the one-layer to two-layer translation table identifying an one-layer TB size (TBS_L1(j)) having a TB size equal to TBS_L2(i)); and

setting the four-layer TB size for the i^{th} row in the one-layer to four-layer translation to the two-layer TB size of the j^{th} row (TBS_L2(j)).

15. The method of claim **14**, wherein the four-layer TB size for the i^{th} row in the one-layer to four-layer translation is set to 2×TBS_L2(i) with adjustment for CRC bit and alignment with QPP sizes for turbo codes if no one-layer TB size (TBS_L1(j)) has a TB size equal to TBS_L2(i)).

16. The method of claim **11**, wherein the translation table is

TBS_L1	TBS_L4
3752	15264
6200	24496
6712	26416
29296	115040
37888	151376
59256	236160
61664	245648
63776	254328
68808	275376.

17. A communications device comprising:

a transmitter to be coupled to at least one transmit antenna, the transmitter configured to transmit signals with the at least one transmit antenna;

a transport channel **[**processing unit coupled to a**]** processor, the transport channel **[**processing unit**]** *processor* configured to **[**provide transport channel processing to a transport block (TB) provided by the processor, wherein a TB size of the TB is selected by**]**:

[selecting**]** *select* a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}), and

[selecting the**]** *select a transport block* (TB) size for the selected I_{TBS} and N_{PRB}, wherein the effective code rate for a user equipment (UE) does not exceed a specified threshold for the selected TB size, wherein the effective code rate is defined as the number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by the number of physical channel bits on *a* Physical Downlink Shared Channel (PDSCH); and

a physical channel **[**processing unit**]** *processor* coupled to the transmitter, the physical channel **[**processing unit**]** *processor* configured to provide physical channel processing to a plurality of transport blocks provided by the transport channel **[**processing unit**]** *processor*.

18. The communications device of claim **17**, wherein the transport channel processing comprises appending error check data to a transport block, segmenting, channel coding, rate matching, concatenating, or a combination thereof.

19. The communications device of claim **17**, wherein the physical channel processing comprises scrambling, modulation/coding scheme selection, codeword-to-layer mapping, signal generating, or a combination thereof.

20. The communications device of claim **17**, wherein the physical channel **[**processing unit**]** *processor* is further configured to map a transport block of the plurality of transport blocks to multiple spatial layers, wherein the number of spatial layers N is greater than or equal to three.

21. A communications device comprising:

a transmitter to be coupled to at least one transmit antenna, the transmitter configured to transmit signals with the at least one transmit antenna;

a **[**processing unit to process a downlink transport channel to generate a transport block (TB) having a TB size, wherein the processing unit is**]** *processor* configured to **[**select the TB size by**]**:

[selecting**]** *select* a modulation and coding scheme index (I_{TBS}) and a physical resource block index (N_{PRB}), and

[setting the**]** *set a transport block* (TB) size for the selected I_{TBS} and N_{PRB} wherein an effective code rate for a user equipment (UE) does not exceed a specified threshold, wherein the effective code rate is defined as a number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by a number of physical channel bits on *a* Physical Downlink Shared Channel (PDSCH); and

a layer **[**mapping unit**]** *mapper* to map the transport block to multiple spatial layers, wherein the number of spatial layers N is greater than or equal to three, wherein the transmitter is configured to transmit the multiple spatial layers to the UE.

22. The communications device of claim **21**, wherein setting the TB size comprises defining the TB size so that code block sizes with TB CRC bits and code block CRC bits attached are aligned with Quadratic Permutation Polynomial (QPP) sizes for turbo codes.

23. The communications device of claim **21**, wherein the TB size is identical to another entry in an one-layer TB size table or a two-layer TB size table.

24. The communications device of claim **21**, wherein the number of spatial layers N is equal to three, and wherein the setting the TB size for the selected I_{TBS} and N_{PRB} comprises:

selecting the TB size by a $(I_{TBS}, 3 \cdot N_{PRB})$ entry of a one-layer TBS table if $1 \le N_{PRB} \le 36$; and

selecting the TB size from a translation table if $37 \le N_{PRB} \le N_{MAX}$, wherein N_{MAX} is the maximum number of physical resource blocks that can be allocated.

25. The communications device of claim **24**, wherein the translation table comprises translations from a one-layer TB size to a three-layer TB size.

26. The communications device of claim **24**, wherein the translation table is obtained by:

obtaining a one-layer TB size (TBS_L1) by selecting a (I_{TBS}, N_{PRB}) entry from the one-layer TBS table and calculating 3×TBS_L1; and

obtaining a three-layer TB size (TBS_L3) by selecting the TB size in the one-layer table or a two-layer table that is most adjacent to a calculated 3×TBS_L1.

27. The communications device of claim **26**, wherein if the calculated 3×TBS_L1 is larger than all entries in the one-layer and two-layer table, the three-layer TB size is selected to be 3×TBS_L1 with adjustments for CRC bits and alignment with Quadratic Permutation Polynomial (QPP) sizes for turbo coding.

28. The communications device of claim **24**, wherein if N_{PRB}={38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72} and $0 \le I_{TBS} \le 25$, the TB size is selected by a

$$\left(I_{TBS}, \frac{3 \cdot N_{PRB}}{2}\right)$$

entry in an equivalent 27×110 two-layer TBS table constructed by a one-layer to two-layer TB size translation table.

29. The communications device of claim **21**, wherein the number of spatial layers N is equal to four, and wherein the setting the TB size for the selected I_{TBS} and N_{PRB} comprises selecting the TB size from a translation table if $56 \le N_{PRB} \le N_{MAX}$, wherein N_{MAX} is the maximum number of physical resource blocks that can be allocated.

30. The communications device of claim **29**, wherein the translation table comprises translations from a one-layer TB size to a four-layer TB size.

31. The communications device of claim **29**, wherein the translation table is obtained by:

locating a two-layer TB size (TBS_L2(i)) for an one-layer TB size (TBS_L1(i)) in an i^{th} row of an one-layer to two-layer translation table, the TBS_L1(i) being an (I_{TBS}, N_{PRB}) entry of an one-layer TBS table;

in a j^{th} row of the one-layer to two-layer translation table identifying an one-layer TB size (TBS_L1(j)) having a TB size equal to TBS_L2(i)); and

setting the four-layer TB size for the i^{th} row in the one-layer to four-layer translation to the two-layer TB size of the j^{th} row (TBS_L2(j)).

32. The communications device of claim **31**, wherein the four-layer TB size for the i^{th} row in the one-layer to four-layer translation is set to 2×TBS_L2(i) with adjustment for CRC bit and alignment with QPP sizes for turbo codes if no one-layer TB size (TBS_L1(j)) has a TB size equal to TBS_L2(i)).

33. A method for transmitting information, the method comprising:

selecting a modulation and coding scheme index (ITBS) and a physical resource block index (NPRB) for a transport block (TB), and

setting the TB size for the selected ITBS and NPRB wherein an effective code rate at a user equipment (UE) does not exceed a specified threshold, wherein the effective code rate is defined as a number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by a number of physical channel bits on Physical Downlink Shared Channel (PDSCH);

mapping the transport block to multiple spatial layers, wherein the number of spatial layers N is greater than or equal to three; and

transmitting the multiple spatial layers to the UE, wherein the number of spatial layers N is equal to three, and wherein the setting the TB size for the selected ITBS and NPRB comprises:

selecting the TB size by a $(I_{TBS}, 3 \cdot N_{PRB})$ *entry of a one-layer TBS table if 1≤NPRB≤36; and*

selecting the TB size from a translation table if 37≤NPRB≤NMAX, wherein NMAX is the maximum number of physical resource blocks that can be allocated.

34. The method of claim 33, wherein the translation table comprises:

TBS_L1	*TBS_L3*
1032	*3112*
1064	*3240*
1096	*3240*
1128	*3368*
1160	*3496*
1192	*3624*
1224	*3624*
1256	*3752*
1288	*3880*
1320	*4008*
1352	*4008*
1384	*4136*
1416	*4264*
1480	*4392*
1544	*4584.*

35. The method of claim 33, wherein the translation table comprises:

TBS_L1	*TBS_L3*
3752	*11064/11448*
3880	*11448/11832*

-continued

TBS_L1	*TBS_L3*
4008	*11832/12216*
4136	*12576*
4264	*12960*
4392	*12960*
4584	*13536*
4776	*14112*
4968	*14688*
5160	*15264*
5352	*15840*
5544	*16416.*

36. The method of claim 33, wherein the translation table is

TBS_L1	*TBS_L3*
16992	*51024*
17568	*52752*
18336	*55056*
19080	*57336*
19848	*59256*
20616	*61664*
21384	*63776*
22152	*66592*
22920	*68808.*

37. The method of claim 33, wherein the translation table comprises

TBS_L1	*TBS_L3*
1544	*4584*
1608	*4776*
1672	*4968*
1736	*5160*
1800	*5352*
1864	*5544*
1928	*5736*
1992	*5992.*

38. The method of claim 33, wherein the translation table is

TBS_L1	*TBS_L3*
27376	*81176*
28336	*84760*
29296	*87936*
30576	*90816*
31704	*93800*
32856	*97896*
34008	*101840*
35160	*105528*
36696	*110136*
37888	*115040.*

39. The method of claim 33, wherein setting the TB size comprises defining the TB size so that code block sizes with TB CRC bits and code block CRC bits attached are aligned with Quadratic Permutation Polynomial (QPP) sizes for turbo codes.

40. The method of claim 33, wherein the TB size is identical to another entry in an one-layer TB size table or a two-layer TB size table.

41. A user equipment (UE) comprising:

a transmitter to be coupled to at least one transmit antenna, the transmitter configured to transmit signals with the at least one transmit antenna;

a processor configured to select a transport block (TB) size by:

selecting a modulation and coding scheme index (ITBS) and a physical resource block index (NPRB), and

setting the TB size for the selected ITBS and NPRB wherein an effective code rate for a communications device does not exceed a specified threshold, wherein the effective code rate is defined as a number of downlink (DL) information bits including TB cyclic redundancy check (CRC) bits and code block CRC bits divided by a number of physical channel bits on Physical Downlink Shared Channel (PDSCH); and

a layer mapper to map the transport block to multiple spatial layers, wherein the number of spatial layers N is greater than or equal to three, wherein the transmitter is configured to transmit the multiple spatial layers to the communications device.

42. The UE of claim 41, wherein setting the TB size comprises defining the TB size so that code block sizes with TB CRC bits and code block CRC bits attached are aligned with Quadratic Permutation Polynomial (QPP) sizes for turbo codes.

43. The UE of claim 41, wherein the TB size is identical to another entry in an one-layer TB size table or a two-layer TB size table.

* * * * *