CLAIMS

1. A method of encoding information, by a transmitting device using a parity check matrix of a low-density parity-check code, for transmission over a communication channel, the method comprising:

determining, by the transmitting device, the parity check matrix comprising at least $5Z$ rows and $27Z$ columns,

wherein the parity check matrix comprises a plurality of submatrices that each has dimensions of $Z \times Z$ for a non-zero integer Z, and wherein a submatrix (m, n) of the parity check matrix, which is a m-th one in a row direction of the parity check matrix and a n-th one in a column direction of the parity check matrix, is:

for $m = 0$ and for $n = \{0, 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{223, 16, 94, 91, 74, 10, 0, 205, 216, 21, 215, 14, 70, 141, 198, 104, 81, 1, 0\}$ by Z,

for $m = 1$ and for $n = \{0, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14, 15, 16, 17, 19, 21, 22, 23, 24\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{141, 45, 151, 46, 119, 157, 133, 87, 206, 93, 79, 9, 118, 194, 31, 187, 0, 0, 0\}$ by Z,

for $m = 2$ and for $n = \{0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 17, 18, 19, 20, 24, 25\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among

$\{207, 203, 31, 176, 180, 186, 95, 153, 177, 70, 77, 214, 77, 198, 117, 223, 90, 0, 0\}$ by Z,

for $m = 3$ and for $n = \{0, 1, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22, 25\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{201, 18, 165, 5, 45, 142, 16, 34, 155, 213, 147, 69, 96, 74, 99, 30, 158, 1, 0\}$ by Z, and

for $m = 4$ and for $n = \{0, 1, 26\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{170, 10, 0\}$ by Z,

generating encoded data, by the transmitting device, based on encoding the information with the determined parity check matrix; and

transmitting the encoded data.

2. The method according to claim 1, wherein

for $m = 0$ and for n other than $n = \{0, 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$,

for $m = 1$ and for n other than $n = \{0, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14, 15, 16, 17, 19, 21, 22, 23, 24\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$,

for $m = 2$ and for n other than $n = \{0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 17, 18, 19, 20, 24, 25\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$,

for $m = 3$ and for nother than

$n = \{0, 1, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22, 25\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$, and

for $m = 4$ and for n other than $n = \{0, 1, 26\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$.

3. The method according to claim 1, wherein the parity check matrix has at least $46Z$ rows comprising 46 $Z \times Z$-sized submatrices that are indexed by m (where $0 \leq m \leq 45$) in the row direction of the parity check matrix and at least $68Z$ columns comprising 68 $Z \times Z$-sized submatrices that are indexed by n (where $0 \leq n \leq 67$) in the column direction of the parity check matrix,

wherein for $m = 5, \ldots, 45$ and for$n = 27, \ldots, 67$:

each submatrix $(m, m + 22)$ is an un-shifted identity matrix of size $Z \times Z$, and

each submatrix except for the submatrix $(m, m + 22)$ is an all-zero matrix of size $Z \times Z$.

4. The method according to claim 1, wherein generating the encoded data, by the transmitting device, based on encoding the information with the determined parity check matrix comprises:

generating, based on the information and the parity check matrix, a plurality of parity bits $\vec{\boldsymbol{p}}$ that satisfy:

$$H \cdot (\vec{\boldsymbol{x}} \quad \vec{\boldsymbol{p}})^T = 0,$$

where H is the parity check matrix, and $\vec{\boldsymbol{x}}$ is the information.

5. The method according to claim 1, wherein Z is related to a size of the

information that is encoded by the transmitting device.

6. The method according to claim 5, wherein Z represents a lifting value that is any one of 7, 14, 28, 56, 112, or 224.

7. The method according to claim 1, further comprising:

determining a base matrix of size at least 46×68 in which an element at location (m, n) of the base matrix indicates whether the submatrix (m, n) is equal to a matrix obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by the shift index value $a_{m,n}$.

8. The method according to any one of claims 1 to 7, wherein the parity check matrix has at least $46Z$ rows comprising 46 $Z \times Z$-sized submatrices that are indexed by m (where $0 \leq m \leq 45$) in the row direction of the parity check matrix, and

wherein:

for $m = 5$ and for $n = \{0, 1, 3, 12, 16, 21, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{164, 59, 86, 80, 182, 130, 153\}$ by Z,

for $m = 6$ and for $n = \{0, 6, 10, 11, 13, 17, 18, 20\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{158, 119, 113, 21, 63, 51, 136, 116\}$ by Z,

for $m = 7$ and for $n = \{0, 1, 4, 7, 8, 14\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index

value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{17, 76, 104, 100, 150, 158\}$ by Z,

for $m = 8$ and for $n = \{0, 1, 3, 12, 16, 19, 21, 22, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{33, 95, 4, 217, 204, 39, 58, 44, 201\}$ by Z,

for $m = 9$ and for $n = \{0, 1, 10, 11, 13, 17, 18, 20\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{9, 37, 213, 105, 89, 185, 109, 218\}$ by Z,

for $m = 10$ and for $n = \{1, 2, 4, 7, 8, 14\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{82, 165, 174, 19, 194, 103\}$ by Z,

for $m = 11$ and for $n = \{0, 1, 12, 16, 21, 22, 23\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{52, 11, 2, 35, 32, 84, 201\}$ by Z,

for $m = 12$ and for $n = \{0, 1, 10, 11, 13, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{142, 175, 136, 3, 28, 182\}$ by Z,

for $m = 13$ and for $n = \{0, 3, 7, 20, 23\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{81, 56, 72, 217, 78\}$ by Z,

for $m = 14$ and for $n = \{0, 12, 15, 16, 17, 21\}$, each submatrix (m, n) is obtained

by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{14, 175, 211, 191, 51, 43\}$ by Z,

for $m = 15$ and for $n = \{0, 1, 10, 13, 18, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{90, 120, 131, 209, 209, 81\}$ by Z,

for $m = 16$ and for $n = \{1, 3, 11, 20, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{154, 164, 43, 189, 101\}$ by Z,

for $m = 17$ and for $n = \{0, 14, 16, 17, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{56, 110, 200, 63, 4\}$ by Z,

for $m = 18$ and for $n = \{1, 12, 13, 18, 19\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{199, 110, 200, 143, 186\}$ by Z,

for $m = 19$ and for $n = \{0, 1, 7, 8, 10\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{8, 6, 103, 198, 8\}$ by Z,

for $m = 20$ and for $n = \{0, 3, 9, 11, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{105, 210, 121, 214, 183\}$ by Z,

for $m = 21$ and for $n = \{1, 5, 16, 20, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{192, 131, 220, 50, 106\}$ by Z,

for $m = 22$ and for $n = \{0, 12, 13, 17\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{53, 0, 3, 148\}$ by Z,

for $m = 23$ and for $n = \{1, 2, 10, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{88, 203, 168, 122\}$ by Z,

for $m = 24$ and for $n = \{0, 3, 4, 11, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{49, 157, 64, 193, 124\}$ by Z,

for $m = 25$ and for $n = \{1, 6, 7, 14\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{1, 166, 65, 81\}$ by Z,

for $m = 26$ and for $n = \{0, 2, 4, 15\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{107, 176, 212, 127\}$ by Z,

for $m = 27$ and for $n = \{1, 6, 8\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{208, 141, 174\}$ by

Z,

for $m = 28$ and for $n = \{0, 4, 19, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{146, 153, 217, 114\}$ by Z,

for $m = 29$ and for $n = \{1, 14, 18, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{150, 11, 53, 68\}$ by Z,

for $m = 30$ and for $n = \{0, 10, 13, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{34, 130, 210, 123\}$ by Z,

for $m = 31$ and for $n = \{1, 7, 22, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{175, 49, 177, 128\}$ by Z,

for $m = 32$ and for $n = \{0, 12, 14, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{192, 209, 58, 30\}$ by Z,

for $m = 33$ and for $n = \{1, 2, 11, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{114, 49, 161, 137\}$ by Z,

for $m = 34$ and for $n = \{0, 7, 15, 17\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index

value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{82, 186, 68, 150\}$ by Z,

for $m = 35$ and for $n = \{1, 6, 12, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{192, 173, 26, 187\}$ by Z,

for $m = 36$ and for $n = \{0, 14, 15, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{222, 157, 0, 6\}$ by Z,

for $m = 37$ and for $n = \{1, 13, 23\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{81, 195, 138\}$ by Z,

for $m = 38$ and for $n = \{0, 9, 10, 12\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{123, 90, 73, 10\}$ by Z,

for $m = 39$ and for $n = \{1, 3, 7, 19\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{12, 77, 49, 114\}$ by Z,

for $m = 40$ and for $n = \{0, 8, 17\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{67, 45, 96\}$ by Z,

for $m = 41$ and for $n = \{1, 3, 9, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index

value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{23, 215, 60, 167\}$ by Z,

for $m = 42$ and for $n = \{0, 4, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{114, 91, 78\}$ by Z,

for $m = 43$ and for $n = \{1, 16, 18, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{206, 22, 134, 161\}$ by Z,

for $m = 44$ and for $n = \{0, 7, 9, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{84, 4, 9, 12\}$ by Z, and

for $m = 45$ and for $n = \{1, 6, 10\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{184, 121, 29\}$ by Z.

9. A transmitting device configured to encode, based on a parity check matrix of a low-density parity-check code, information for transmission over a communication channel, the transmitting device comprising:

at least one processor; and

at least one computer memory operably connectable to the at least one processor and storing instructions that, when executed, cause the at least one processor to perform operations comprising:

determining, by the transmitting device, the parity check matrix comprising at least

$5Z$ rows and $27Z$ columns,

wherein the parity check matrix comprises a plurality of submatrices that each has dimensions of $Z \times Z$ for a non-zero integer Z, and wherein a submatrix (m, n) of the parity check matrix, which is a m-th one in a row direction of the parity check matrix and a n-th one in a column direction of the parity check matrix, is:

for $m = 0$ and for $n = \{0, 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{223, 16, 94, 91, 74, 10, 0, 205, 216, 21, 215, 14, 70, 141, 198, 104, 81, 1, 0\}$ by Z,

for $m = 1$ and for $n = \{0, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14, 15, 16, 17, 19, 21, 22, 23, 24\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{141, 45, 151, 46, 119, 157, 133, 87, 206, 93, 79, 9, 118, 194, 31, 187, 0, 0, 0\}$ by Z,

for $m = 2$ and for $n = \{0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 17, 18, 19, 20, 24, 25\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among
$\{207, 203, 31, 176, 180, 186, 95, 153, 177, 70, 77, 214, 77, 198, 117, 223, 90, 0, 0\}$
by Z,

for $m = 3$ and for $n = \{0, 1, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22, 25\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value

among $\{201, 18, 165, 5, 45, 142, 16, 34, 155, 213, 147, 69, 96, 74, 99, 30, 158, 1, 0\}$ by Z, and

for $m = 4$ and for $n = \{0, 1, 26\}$, obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{170, 10, 0\}$ by Z,

generating encoded data based on encoding the information with the determined parity check matrix; and

transmitting the encoded data.

10. The transmitting device according to claim 9, wherein

for $m = 0$ and for n other than $n = \{0, 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$,

for $m = 1$ and for n other than $n = \{0, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14, 15, 16, 17, 19, 21, 22, 23, 24\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$,

for $m = 2$ and for n other than $n = \{0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 17, 18, 19, 20, 24, 25\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$,

for $m = 3$ and for nother than $n = \{0, 1, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21, 22, 25\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$, and

for $m = 4$ and for n other than $n = \{0, 1, 26\}$, each submatrix (m, n) is equal to an all-zero matrix of size $Z \times Z$.

11. The transmitting device according to claim 9, wherein the parity check matrix has at least $46Z$ rows comprising 46 $Z \times Z$-sized submatrices that are indexed by *m* (where $0 \leq m \leq 45$) in the row direction of the parity check matrix and at least $68Z$ columns comprising 68 $Z \times Z$-sized submatrices that are indexed by *n* (where $0 \leq n \leq 67$) in the column direction of the parity check matrix,

wherein for $m = 5, \ldots, 45$ and for$n = 27, \ldots, 67$:

each submatrix $(m, m + 22)$ is an un-shifted identity matrix of size $Z \times Z$, and

each submatrix except for the submatrix $(m, m + 22)$ is an all-zero matrix of size $Z \times Z$.

12. The transmitting device according to claim 9, wherein Z is related to a size of the information that is encoded by the transmitting device.

13. The transmitting device according to claim 12, wherein Z represents a lifting value that is any one of 7, 14, 28, 56, 112, or 224.

14. The transmitting device according to any one of claims 9 to 13, wherein the parity check matrix has at least $46Z$ rows comprising 46 $Z \times Z$-sized submatrices that are indexed by *m* (where $0 \leq m \leq 45$) in the row direction of the parity check matrix, and

wherein:

for $m = 5$ and for $n = \{0, 1, 3, 12, 16, 21, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{164, 59, 86, 80, 182, 130, 153\}$ by Z,

for $m = 6$ and for $n = \{0, 6, 10, 11, 13, 17, 18, 20\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{158, 119, 113, 21, 63, 51, 136, 116\}$ by Z,

for $m = 7$ and for $n = \{0, 1, 4, 7, 8, 14\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{17, 76, 104, 100, 150, 158\}$ by Z,

for $m = 8$ and for $n = \{0, 1, 3, 12, 16, 19, 21, 22, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{33, 95, 4, 217, 204, 39, 58, 44, 201\}$ by Z,

for $m = 9$ and for $n = \{0, 1, 10, 11, 13, 17, 18, 20\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{9, 37, 213, 105, 89, 185, 109, 218\}$ by Z,

for $m = 10$ and for $n = \{1, 2, 4, 7, 8, 14\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{82, 165, 174, 19, 194, 103\}$ by Z,

for $m = 11$ and for $n = \{0, 1, 12, 16, 21, 22, 23\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{52, 11, 2, 35, 32, 84, 201\}$ by Z,

for $m = 12$ and for $n = \{0, 1, 10, 11, 13, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among

$\{142, 175, 136, 3, 28, 182\}$ by Z,

for $m = 13$ and for $n = \{0, 3, 7, 20, 23\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{81, 56, 72, 217, 78\}$ by Z,

for $m = 14$ and for $n = \{0, 12, 15, 16, 17, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{14, 175, 211, 191, 51, 43\}$ by Z,

for $m = 15$ and for $n = \{0, 1, 10, 13, 18, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{90, 120, 131, 209, 209, 81\}$ by Z,

for $m = 16$ and for $n = \{1, 3, 11, 20, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{154, 164, 43, 189, 101\}$ by Z,

for $m = 17$ and for $n = \{0, 14, 16, 17, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{56, 110, 200, 63, 4\}$ by Z,

for $m = 18$ and for $n = \{1, 12, 13, 18, 19\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{199, 110, 200, 143, 186\}$ by Z,

for $m = 19$ and for $n = \{0, 1, 7, 8, 10\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index

value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{8, 6, 103, 198, 8\}$ by Z,

for $m = 20$ and for $n = \{0, 3, 9, 11, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{105, 210, 121, 214, 183\}$ by Z,

for $m = 21$ and for $n = \{1, 5, 16, 20, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{192, 131, 220, 50, 106\}$ by Z,

for $m = 22$ and for $n = \{0, 12, 13, 17\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{53, 0, 3, 148\}$ by Z,

for $m = 23$ and for $n = \{1, 2, 10, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{88, 203, 168, 122\}$ by Z,

for $m = 24$ and for $n = \{0, 3, 4, 11, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{49, 157, 64, 193, 124\}$ by Z,

for $m = 25$ and for $n = \{1, 6, 7, 14\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{1, 166, 65, 81\}$ by Z,

for $m = 26$ and for $n = \{0, 2, 4, 15\}$, each submatrix (m, n) is obtained by

circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{107, 176, 212, 127\}$ by Z,

for $m = 27$ and for $n = \{1, 6, 8\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{208, 141, 174\}$ by Z,

for $m = 28$ and for $n = \{0, 4, 19, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{146, 153, 217, 114\}$ by Z,

for $m = 29$ and for $n = \{1, 14, 18, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{150, 11, 53, 68\}$ by Z,

for $m = 30$ and for $n = \{0, 10, 13, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{34, 130, 210, 123\}$ by Z,

for $m = 31$ and for $n = \{1, 7, 22, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{175, 49, 177, 128\}$ by Z,

for $m = 32$ and for $n = \{0, 12, 14, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{192, 209, 58, 30\}$ by Z,

for $m = 33$ and for $n = \{1, 2, 11, 21\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{114, 49, 161, 137\}$ by Z,

for $m = 34$ and for $n = \{0, 7, 15, 17\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{82, 186, 68, 150\}$ by Z,

for $m = 35$ and for $n = \{1, 6, 12, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{192, 173, 26, 187\}$ by Z,

for $m = 36$ and for $n = \{0, 14, 15, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{222, 157, 0, 6\}$ by Z,

for $m = 37$ and for $n = \{1, 13, 23\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{81, 195, 138\}$ by Z,

for $m = 38$ and for $n = \{0, 9, 10, 12\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{123, 90, 73, 10\}$ by Z,

for $m = 39$ and for $n = \{1, 3, 7, 19\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among

$\{12, 77, 49, 114\}$ by Z,

for $m = 40$ and for $n = \{0, 8, 17\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{67, 45, 96\}$ by Z,

for $m = 41$ and for $n = \{1, 3, 9, 18\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{23, 215, 60, 167\}$ by Z,

for $m = 42$ and for $n = \{0, 4, 24\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{114, 91, 78\}$ by Z,

for $m = 43$ and for $n = \{1, 16, 18, 25\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{206, 22, 134, 161\}$ by Z,

for $m = 44$ and for $n = \{0, 7, 9, 22\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{84, 4, 9, 12\}$ by Z, and

for $m = 45$ and for $n = \{1, 6, 10\}$, each submatrix (m, n) is obtained by circularly shifting columns of an identity matrix of size $Z \times Z$ to the right by a shift index value $a_{m,n}$ that is defined by taking a modulo operation to a respective value among $\{184, 121, 29\}$ by Z.