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Datasheet for the decision
of 15 February 2019

Case Number: T 1255/16 - 3.5.07

Application Number: 05749661.4

Publication Number: 1850484

IPC: H03M13/00

Language of the proceedings: EN

Title of invention:
Basic matrix based on irregular LDPC, codec and generation
method thereof

Applicant:
ZTE Corporation

Headword:
Irregular LDPC code/ZTE

Relevant legal provisions:
EPC Art. 56, 113(2)

Keyword:
Basis of decision - pending requests
Inventive step - (no)

Decisions cited:
T 0255/05, T 1312/13

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Case Number: T 1255/16 - 3.5.07

D E C I S I O N
of Technical Board of Appeal 3.5.07
of 15 February 2019

Appellant: (Applicant)	ZTE Corporation ZTE Plaza, Keji Road South Hi-Tech Industrial Park Nanshan, Shenzhen Guangdong 518057 (CN)
Representative:	Bergmeier, Werner Canzler & Bergmeier Patentanwälte Partnerschaft mbB Friedrich-Ebert-Straße 84 85055 Ingolstadt (DE)
Decision under appeal:	Decision of the Examining Division of the European Patent Office posted on 9 December 2015 refusing European patent application No. 05749661.4 pursuant to Article 97(2) EPC

Composition of the Board:

Chairman	R. Moufang
Members:	R. de Man
	C. Barel-Faucheux

Summary of Facts and Submissions

I.   The applicant (appellant) appealed against the decision
        of the Examining Division refusing European patent
        application No. 05749661.4, which claims a priority
        date of 23 January 2005 and was filed in Chinese as
        PCT/CN2005/000671 and published in English under
        Article 158(3) EPC 1973 as EP 1 850 484 A1.

II.   The decision cited the following document:

        D1: R. Xu et al.: "High girth LDPC coding for OFDMA
            PHY", IEEE C802.16e-04/423, IEEE 802.16 Broadband
            Wireless Access Working Group, 3 November 2004,
            retrieved from http://www.ieee802.org/16/tge/
            contrib/C80216e-04_423.pdf.

        The Examining Division decided that the subject-matter
        of claims 1 and 7 of the then sole substantive request
        infringed Article 123(2) EPC and that claims 1 and 7
        were neither clear nor concise within the meaning of
        Article 84 EPC.

III.   In its statement of grounds of appeal, the appellant
        replaced its sole substantive request with a main
        request and an auxiliary request.

IV.   In a communication accompanying a summons to oral
        proceedings, the Board expressed the preliminary view
        that neither the main request nor the auxiliary request
        complied with Articles 84 and 123(2) EPC and that the
        subject-matter of claim 1 of both requests lacked
        inventive step over document D1.

V.   In a letter dated 15 January 2019, the appellant filed
        a set of amended claims based on the main request

submitted with the statement of grounds of appeal. It
gave arguments in support of their allowability and
stated that it would not attend the oral proceedings.
It requested that a communication pursuant to
Rule 71(3) EPC be issued.

It also submitted the following two documents:

D4: US 8 185 797 B2, published on 22 May 2012; and
D5: R. Xu et al.: "High Girth LDPC Coding for OFDMA
    PHY", IEEE C802.16e-05/031r1, IEEE 802.16 Broadband
    Wireless Access Working Group, 25 January 2005.

VI.   In a further communication, the Board informed the
        appellant that it understood the appellant's intention
        to have been that the newly filed claims replaced the
        previously pending substantive requests as a sole
        substantive request. The appellant did not comment on
        this communication.

VII.   Oral proceedings were held on 15 February 2019 in the
        appellant's absence. At the end of the oral
        proceedings, the chairman pronounced the Board's
        decision.

VIII.   Claim 1 of the amended claims filed by letter of
        15 January 2019 reads as follows:

        "An encoder based on irregular low density parity
        check, LDPC, codes based on a unit matrix and its
        cyclic shift matrix comprising an encoding operation
        module, a basic matrix storage module and an extension
        module, characterized in that:
            said basic matrix storage module is configured to
        store a basic matrix H_b consisting of an M×(N-M) block
        A corresponding to information bits and an M×M block B

corresponding to check bits; in the basic matrix H_b, for all cycles with length of 4, any element of i, j, k and l constituting the cycle in anti-clockwise or clockwise order always satisfies an inequality: mod (i-j+k-l, z) ≠ 0, wherein mod represents a modulo operation, and z is an extension factor, z=L/N, L is a length of codeword, N is a number of columns in the basic matrix H_b, L, M, and N are integers that are greater than 0;

and said basic matrix H_b also satisfies one of following conditions:

1) supposing the number of columns with the largest weight in the basic matrix H_b is r, then in each new basic matrix formed by deleting random r-1 columns herein, for all cycles with length of 4, any element of i, j, k and l constituting the cycle in anti-clockwise or clockwise order always satisfies the inequality: mod (i-j+k-l, z) ≠ 0, and in the each new basic matrix, for all cycles with length of 6, any element of i, j, k, l, m and n constituting the cycle in anti-clockwise or clockwise order always satisfies an inequality: mod (i-j+k-l+m-n, z) ≠ 0; or

2) supposing the number of the columns with the largest weight in the basic matrix H_b is r, then in each new basic matrix formed by deleting random r-1 columns and all columns with weight of 3 therein, for all cycles with length of 4, any element of i, j, k and l constituting the cycle in an anti-clockwise or clockwise order always satisfies the inequality: mod (i-j+k-l, z) ≠ 0, and in the each new basic matrix, for all cycles with length of 6, any element of i, j, k, l, m and n constituting the cycle in an anti-clockwise or clockwise order always satisfies the inequality: mod (i-j+k-l+m-n, z) ≠ 0; wherein i, j, k, l, m, n∈H_b, and i, j, k, l, m, n are integers equal to or greater than 0 and less than or equal to z-1;

said extension module is configured to extend said
basic matrix H_b according to the extension factor z and
a z×z basic permutation matrix to obtain a (M×z) ×
(N×z) parity check matrix of LDPC codes; and
said encoding operation module is configured to
perform an encoding operation on source data of (N-M)×z
bits to obtain a codeword of N×z bits based on the
(M×z) × (N×z) parity check matrix obtained from
extension of said basic matrix H_b;
wherein weight of the column represents the number
of non-negative elements in the column."

IX.   The appellant's arguments, where relevant to the
        decision, are discussed in detail below.

Reasons for the Decision

1.   The appeal complies with the provisions referred to in
        Rule 101 EPC and is therefore admissible.

2.   *The appellant's requests - Article 113(2) EPC*

2.1   In its letter of 15 January 2019, the appellant did not
        state whether it maintained or withdrew the main
        request and the auxiliary request filed with the
        statement of grounds of appeal. The absence of an
        explicit statement to the effect that pending
        substantive requests are maintained normally cannot be
        taken to mean that those requests are withdrawn.

2.2   In the present case, however, the letter lacks any
        argument in support of the previously filed requests
        and merely gives reasons why the newly filed amended
        claims comply with the EPC. In the Board's view, this

is an indication that the appellant meant to replace its pending requests with the newly filed claims.

2.3   Moreover, if it were to be assumed that the main request and the auxiliary request were maintained, the appellant's letter would leave the Board in doubt about the order in which it was to consider its requests: the appellant referred to the newly filed claims only as "amendments", not as "a new main request" or "a second auxiliary request". Under Article 113(2) EPC, the EPO is to examine, and decide upon, the European patent application only in the text submitted to it, or agreed, by the applicant. In the case of multiple substantive requests, this means that it is the responsibility of the applicant or appellant to specify the order in which its requests are to be examined (see decisions T 255/05 of 18 October 2005, reasons 17; T 1312/13 of 6 December 2017, reasons 2.3).

2.4   In view of these considerations, the Board informed the appellant, in its further communication, that it assumed that the previously filed requests had been withdrawn and that the amended set of claims formed the basis for the appellant's sole substantive request. Since the appellant did not express disagreement with this observation, the Board now considers it to have been established that the main request and the auxiliary request filed with the statement of grounds of appeal are no longer maintained and that the appellant requests that the decision under appeal be set aside and that a patent be granted on the basis of the claims filed with the letter of 15 January 2019. The Board is therefore in a position to proceed with the examination of the appeal without infringing Article 113(2) EPC.

3.   *The application*

3.1   The application relates to encoding and decoding data
        using low-density parity-check (LDPC) error-correcting
        codes. Such codes are defined by a sparse parity-check
        matrix. Because these matrices can be very large, the
        application considers parity-check matrices H that are
        constructed by "expanding" a smaller basic matrix H_b.
        In this expansion process, each element j of the basic
        matrix H_b is replaced with a z×z matrix that is either
        the z×z zero matrix (if j = -1) or the jth power of a
        cyclic right shift of the z×z unit matrix (if j ≥ 0)
        (see paragraphs [0051] to [0053] and [0093] of the A1
        publication). The integer z is referred to as the
        "expansion factor".

3.2   An LDPC parity-check matrix can be represented as a
        bipartite graph (known as the "Tanner graph") on N
        "variable nodes" corresponding to the columns of the
        matrix, and M "check nodes" corresponding to the rows
        of the matrix, a variable node being connected to a
        check node by an edge if the element in the
        corresponding row and column of the matrix is a
        "1" (paragraph [0048]). The "girth" of this graph, i.e.
        the length of its shortest cycle, is an indicator for
        the error-correcting performance of the LDPC code. As
        explained in paragraph [0050] of the application,
        ideally the girth of the graph is as large as possible,
        and the number of cycles in the graph having a length
        equal to the girth is as low as possible.

        The Board notes that since the "Tanner graph" is
        bipartite (because there are no edges between variable
        nodes or between check nodes), the length of each cycle
        in the graph is necessarily even.

3.3   Paragraph [0055] of the application explains that the
        girth of the parity-check matrix H is related to the
        girth of the basic matrix H_b. The application then
        lists "sufficient and necessary conditions" in terms of
        conditions on the basic matrix H_b and the expansion
        factor z for the girth of the parity-check matrix H to
        be at least six (in paragraph [0056]), at least eight
        (in paragraph [0057]) and at least ten (in paragraph
        [0058]).

        In particular, paragraph [0056] states that for the
        girth of the matrix H to be at least six, it is
        sufficient and necessary that "in its basic matrix, for
        all girths with length of 4, any element of i, j, k and
        l constituting the basic matrix in anti-clockwise or
        clockwise (the effect is equivalent for clockwise order
        and anti-clockwise order) always satisfies: mod (i-j+k-
        l, z) ≠ 0, wherein mod is modular operation, and z is
        the extension factor, an even number".

        And paragraph [0057] states for the girth of the matrix
        H to be at least eight, it is sufficient and necessary
        that "in its basic matrix, for all girths with length
        of 4, any element of i, j, k and l constituting the
        basic matrix in anti-clockwise or clockwise always
        satisfies: mod (i-j+k-l, z) ≠ 0; and for all girths
        with length of 6, any element of i, j, k, l, m and n
        constituting the basic matrix in anti-clockwise or
        clockwise always satisfies: mod (i-j+k-l+m-n, z) ≠ 0".

3.4   To understand these somewhat cryptically formulated
        conditions, it is helpful to consider Figures 4 and 5
        of the application, which show - according to paragraph
        [0049] - "the general forms of girths with length of 4
        and 6 respectively in the LDPC parity check matrix",

and to realise that what is meant is "cycles of length
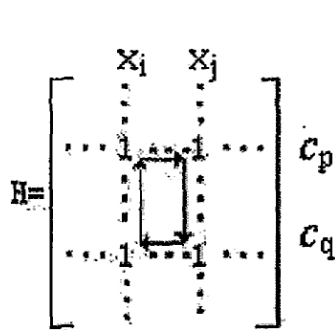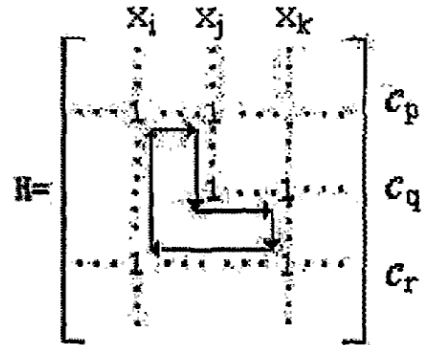4 and 6" rather than "girths with length 4 and 6".

fig. 4

fig. 5

3.5   A cycle of length 4 in the Tanner graph of the LDPC
        matrix H corresponds to two columns/variable nodes x_i
        and x_j and two rows/check nodes c_p and c_q for which the
        matrix H has 1s at their four intersections (as shown
        in Figure 4). These 1s in the matrix H are part of
        right-shifted z×z unit matrices and therefore
        correspond to non-negative elements in the basic matrix
        H_b. These non-negative elements corresponding to the
        four 1s in the LDPC matrix H form themselves a "cycle
        of length 4" in the basic matrix H_b in the sense that
        they are in the same configuration as the 1s in
        Figure 4. The elements "i, j, k and l" of girths/cycles
        of length 4 "in the basic matrix" hence refer to any
        four non-negative elements in matrix H_b in this
        configuration. The condition formulated in paragraph
        [0056] requires that any such four non-negative
        elements i, j, k and l in matrix Hb satisfy mod (i-j+k-
        l, z) ≠ 0 (meaning that the number i-j+k-l is not
        evenly divisible by z).

        The conditions on cycles of length 6 can likewise be
        understood with the help of Figure 5.

3.6   An LDPC code is commonly classified as being either
        "regular", meaning that its LDPC matrix has both
        identical row weights and identical column weights, or
        "irregular". Paragraph [0006] of the present
        application mentions regular and irregular LDPC codes
        but also a further category of "semi-regular" codes,
        for which the row weights and column weights are
        identical only for the "information bits" of the LDPC
        matrix, i.e. for the left-hand side of an LDPC matrix
        having the shape shown in Figure 7:
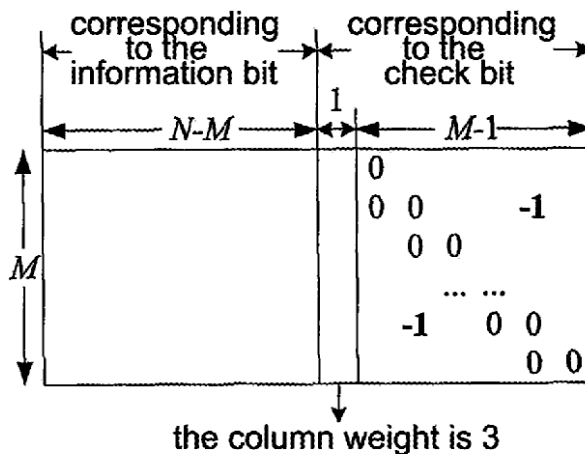

fig. 7

        According to paragraph [0006], an irregular LDPC code
        has "totally different row weight and column weight of
        parity check matrix, and column weight of the
        information bits of the parity check matrix is also
        different". However, it is easy to verify that not all
        the row weights and column weights are "totally
        different" for the examples of irregular codes given in
        the application, for instance the irregular LDPC code
        corresponding to the basic matrix H_b of size 6×24
        defined in original claim 13 (the (24-6)×z "information
        bits" columns having either weight three or weight
        six). The Board therefore understands an "irregular"

LDPC code within the meaning of the application to be an LDPC code that is neither regular nor semi-regular.

4.   *Interpretation of claim 1*

4.1   Independent claim 1 is directed to an LDPC encoder comprising an encoding-operation module, a basic-matrix-storage module and an extension module.

The basic-matrix-storage module holds a basic matrix H_b consisting of an information part of size M×(N-M) and a parity part of size M×M.

The extension module is configured to extend the basic matrix H_b to obtain an LDPC matrix of size (M×z) × (N×z) in the manner explained in point 3.1 above.

The encoding-operation module is configured to encode (N-M)×z bits of source data to obtain a codeword having N×z bits on the basis of the (M×z) × (N×z) LDPC matrix.

Claim 1 requires the LDPC code defined by the LDPC matrix to be irregular.

4.2   Claim 1 imposes a number of inequality conditions on the basic matrix H_b.

In particular, any four non-negative elements i, j, k, l of the basic matrix Hb forming a cycle with length four (in the sense discussed in point 3.5 above) must satisfy mod (i-j+k-l, z) ≠ 0.

In addition, the matrix must satisfy one of conditions 1) and 2).

4.3   Condition 1) refers to a "each new basic matrix formed
        by deleting random r-1 columns" from the basic matrix
        H_b, where r is the number of columns with the largest
        weight in matrix H_b. In each such (hypothetically
        created) new basic matrix, non-negative elements i, j,
        k and l forming a cycle of length four must satisfy mod
        (i-j+k-l, z) ≠ 0; and non-negative elements i, j, k, l,
        m and n forming a cycle of length six must satisfy mod
        (i-j+k-l+m-n, z) ≠ 0.

4.4   Condition 2) is similar to condition 1) but considers
        "each new basic matrix" formed by deleting, from the
        basic matrix H_b, random r-1 columns and all columns
        with weight three.

5.   *Clarity*

        In its communication, the Board expressed doubts as to
        whether claim 1 of both the main request and the
        auxiliary request was clear, in particular in respect
        of the features referring to "elements i, j, k and l"
        and to "cycles" in the basic matrix H_b.

        Although the appellant has amended the wording of
        claim 1 in this respect, it may be questioned whether
        the amended claim actually overcomes the Board's
        clarity objection. In fact, the appellant considered it
        necessary to submit post-published document D4 "for the
        Board to more clearly understand i, j, k, l of the
        short cycle".

        The Board will leave this question open since it can
        decide the case on the basis of the inventive-step
        objection which was raised in the Board's communication
        against claim 1 of the previous main request and

auxiliary request and which still applies to the
amended claim 1.

6.   *Inventive step*

6.1   Before considering the prior art, the Board notes that
        the condition discussed in point 4.2, second paragraph,
        above corresponds to the sufficient and necessary
        condition on the basic matrix H_b for the girth of the
        expanded LDPC matrix to be at least six (see points 3.3
        to 3.5).

        Moreover, since the columns of each "new basic matrix"
        considered in conditions 1) and 2) form a subset of the
        columns of the basic matrix H_b, each cycle of length
        four or six in each "new basic matrix" corresponds to a
        cycle of length four or six in the basic matrix H_b.
        This means that if the girth of the expanded LDPC
        matrix is at least eight, the non-negative integers i,
        j, k, l or i, j, k, l, m, n corresponding to a cycle of
        length four or six in each "new basic matrix" satisfy
        the inequality mod (i-j+k-l, z) ≠ 0 or mod (i-j+k-l+m-
        n, z) ≠ 0.

        Hence, if the girth of the expanded LDPC matrix is at
        least eight, then the basic matrix H_b satisfies all the
        inequality conditions listed in claim 1.

6.2   Document D1, in section 8.4.9.2.5.1, discloses the
        construction of a parity-check matrix H by expansion of
        a model matrix H_{bm}. Each blank or negative value in the
        model matrix H_{bm} (values -1 in the sample model
        matrices on pages 4, 5 and 6) is replaced with the z×z
        zero matrix, and each non-negative value corresponds to
        a "circular shift size $p(i,j)≥0$" and is replaced with a
        circular right shift by the same amount of the z×z unit

matrix. It is undisputed that this expansion method corresponds to the functionality of the "extension module" as disclosed in the present application (see point 3.1 above).

On page 2, fourth to sixth paragraphs, document D1 discloses that high-girth LDPC codes have good performance characteristics. The "Rate 1/2" model matrices H_{bm} disclosed on page 4 of document D1 are said to have girth eight for $z < 80$ and girth ten for $z \geq 80$. They thus satisfy the inequality conditions on the "basic matrix" specified in claim 1.

6.3   Document D1, in section 8.4.9.2.5.2, discloses an encoder for encoding source data using the parity-check matrix obtained by expanding the model matrix H_{bm}. In the Board's view, this encoder comprises implicitly disclosed encoding-operation, basic-matrix-storage and extension modules as claimed.

6.4   As the appellant pointed out in its statement of grounds of appeal, the examples in document D1 relate to semi-regular LDPC codes. Indeed, each of the 12 leftmost columns of the "Rate 1/2" family of model matrices includes four non-negative elements, which means that the $12 \times z$ columns in the information part of the corresponding LDPC matrices all have weight four. These LDPC codes are therefore not irregular LDPC codes (see point 3.6 above).

6.5   Hence, the subject-matter of claim 1 of the main request differs from the encoder of document D1 only in that the LDPC code is irregular.

6.6   According to paragraph [0004] of the application, it was known at the priority date that irregular codes

have performance advantages over regular codes. And
document D1, in the paragraph bridging pages 2 and 3,
states that the method for designing high-girth LDPC
codes can be used to design both regular and irregular
LDPC codes. It adds that "any matrix structure with
given code rate, codeword length and degree
distribution can be obtained by our method".

At the priority date of the invention, it was therefore
obvious for the skilled person to consider applying the
techniques of document D1 to irregular codes.

6.7   In its letter of 15 January 2019, the appellant argued
that irregular codes were "completely different" from
the codes disclosed in document D1 "due to different
densities of non-zero elements". For irregular codes,
it was "impossible to find the extension matrix H with
girth of 8".

The Board cannot agree that it is impossible to find a
basic matrix H_b for which the expanded LDPC matrix H
has a girth of at least eight and which defines an
irregular LDPC code. In fact, any of the "Rate 1/2"
model matrices of document D1 can be made irregular by
replacing a single non-negative element in the
information part of H_{bm} with the element -1 (causing
the weights of its "information bits" columns and rows
to be different from the other weights), and such a
modified model matrix continues to have a girth of at
least eight (since such a modification removes edges
from the Tanner graph and thus can only remove cycles
and not introduce new cycles). Such basic matrices H_b
therefore exist and thus can be found, if not by the
aforementioned modification, then at least by a
straightforward computer search.

The Board hence concludes that the skilled person, starting from document D1, would not only be motivated to look for a basic matrix H_b for which the expanded LDPC matrix is irregular but still has girth eight or higher, but would also succeed in finding one. He would thereby arrive at the subject-matter of claim 1 without the exercise of inventive skill.

6.8   The appellant submitted that "in our example, a column weight of r=3 columns reaches 12, which is much larger than the maximum column weight of the semi-regular code which is 4, so we can't design an irregular matrix with girth of 8, but can only design an overall matrix with a girth of 6". The appellant appears to be referring to the sample basic matrix of size 12×24 shown in paragraph [0077] of the A1 publication, which indeed includes three columns of weight 12.

Since claim 1 does not require the basic matrix H_b to have columns of a particular (largest) weight, the appellant's submission has no bearing on the Board's reasoning.

6.9   The appellant further argued that document D5 gave evidence of good coding performance achieved by the three sample basic matrices shown in paragraphs [0077], [0084] and [0098]. A high-girth structured LDPC code with optimal performance was first proposed in the present application. The design of the semi-regular LDPC code of document D1 was completely different from the design of the irregular code of the application.

However, claim 1 is not limited to any of the sample matrices of the present application. As explained in point 6.1 above, claim 1 encompasses all basic matrices for which the expanded LDPC matrix H is irregular and

has a girth of at least eight. It was already known at
the priority date that high girth and irregularity of
the LDPC matrix were advantageous.

6.10   The appellant requested the Board to provide evidence
        that the features of claim 1 defining the various
        inequality conditions were common general knowledge.

        The Board notes that, for the subject-matter of claim 1
        to lack inventive step, it is sufficient that the
        skilled person would have arrived at something falling
        within the terms of the claim, i.e. at a basic matrix
        H_b that corresponds to an irregular LDPC code and that
        satisfies the inequality conditions specified in
        claim 1. Those inequality conditions are satisfied if
        the expanded LDPC code has a girth of at least eight.
        There is no need for the Board to show that the skilled
        person would have arrived at the **wording** of the claim,
        since that is not what Article 56 EPC is about.

6.11   Hence, the subject-matter of claim 1 lacks inventive
        step (Article 56 EPC).

7.   *Conclusion*

        Since the sole substantive request cannot be allowed,
        the appeal is to be dismissed.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

I. Aperribay   R. Moufang

Decision electronically authenticated