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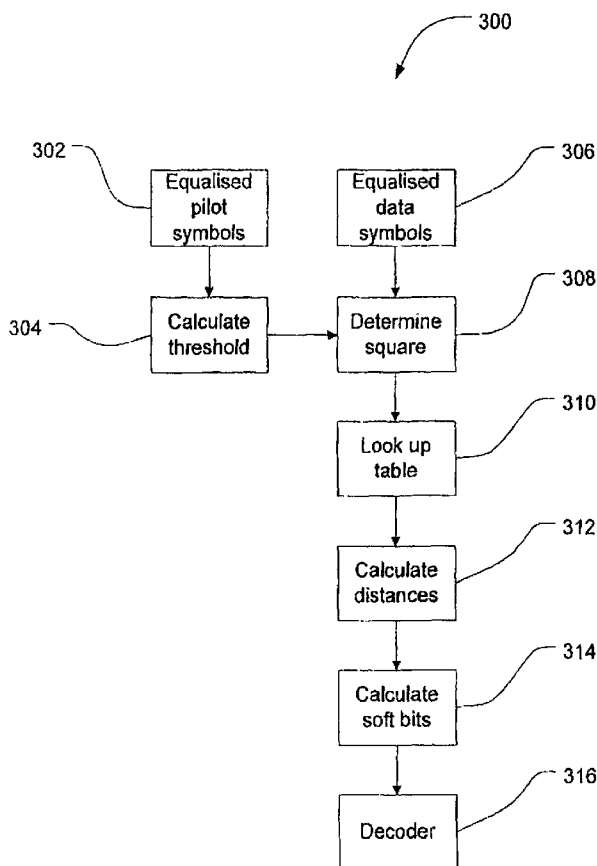
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(54) Title: DEMODULATION METHOD



(57) Abstract: A method of calculating at least one soft bit corresponding to a data symbol received by a radio receiver is described. In one form the method (300) includes, calculating an average amplitude at least one received data symbol. The method also includes calculating (304) at least one threshold amplitude in respect of the data symbol on the basis of the calculated average amplitude. Next a subset of constellation symbols is determined (310) at least partly on the basis of the at least one threshold, and for which a distance determination will be made. The distance between the position of the data symbol and each of the symbols in the subset of constellation symbols is determined (312) and then a soft bit corresponding to the received symbol is calculated (314) on the basis of said determined distances.

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## DESCRIPTION

## DEMODULATION METHOD

## 5 REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of the priorities of Australian provisional patent application No. 2006905197 filed on 20 September 2006 and Australian standard patent application filed on 31 August 2007, the disclosures of which are incorporated  
10 herein in their entirety by reference thereto.

## FIELD OF THE INVENTION

The present invention relates to methods of demodulation used in a receiver in a wireless communications network, and a device and  
15 program therefor.

It is convenient to describe the preferred examples in connection with a system that uses turbo code and quadrature amplitude modulation (QAM). However the present invention should not be  
20 considered as being limited to the use of turbo code, but should be considered as being generally applicable to systems using any type of channel encoder such that the corresponding decoder uses soft inputs to recover the transmitted information bits.

## BACKGROUND OF THE INVENTION

Communications systems often employ forward error correction in order to correct errors caused by noise generated in transport channels. For example, a communication system may use a "turbo code" for the forward error correction. At the transmitter side a turbo encoder introduces redundancy bits based on information bits. The encoded bits at the output of turbo encoder are then modulated and transmitted to the receiver. At the receiver end, the receiver demodulates the received signal and produce received encoded bits to the turbo decoder. A turbo decoder then decodes the received encoded bits to recover the information bits.

To maximize the advantage of the coding gain the receiver assigns each received encoded bit of value on a multi level scale that is representative of the probability that the bit is 1 (or 0).

One such scale is referred to as a Log-Likelihood Ratio (LLR) probability. Using LLR each bit is in general represented as a number between  $-a$  to  $a$  ( $a > 0$ ). The value close to  $a$  signifies that the transmitted bit was 0 with a very high probability, and a value of  $-a$  signifies that the transmitted bit was 1 with a very high probability. A value of 0 indicates that the logical bit value is indeterminate. The LLR value is then used as a soft bit.

The log likelihood  $L(b_i)$  for  $i$ -th bit ( $i=0,1,\dots,N$ ) can be

calculated as:

$$L(b_i) = \ln \frac{P(b_i = 0|y)}{P(b_i = 1|y)} = \ln \frac{\sum_{z|b_i=0} P(z|y)}{\sum_{z|b_i=1} P(z|y)} \approx \frac{1}{2\sigma^2} \left( \min_{z|b_i=1} |y - z|^2 - \min_{z|b_i=0} |y - z|^2 \right)$$

- 5 where  $y$  is received QAM symbol,  $z$  is a QAM symbol in the reference QAM constellation, and  $\sigma^2$  is noise variance.

From this formula, the computational complexity would involve

- Step1/ Estimation of  $\sigma^2$
- 10 Step2/ Estimation of reference QAM constellation (estimation of average amplitude of the desired signal)
- Step3/ Calculation of the distances and min searches
- Step4/ Division to get  $L(b_i)$

## 15 SUMMARY OF THE DISCLOSURE

The above mentioned 'normal LLR' method is in general too computationally complex to implement as each bit requires a minimum distance search between the received QAM symbol and all reference constellation points.

- 20 Therefore, it is an object of the present invention to provide a novel method with less computational complexity and a device therefor.

Accordingly it is an object of the present invention to address

the shortcomings of the prior art. In a preferred example it is an object of the invention to simplify the conventional LLR demodulation method by reducing the number of distance calculations needed to obtain soft bits.

5

In a first aspect, the present invention provides a method of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the method including: calculating an average amplitude for the at least one received data symbol; calculating  
10 at least one threshold amplitude in respect of the data symbol on the basis of the calculated average amplitude; determining a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance determination will be made; determining the distance between the position of the data symbol and  
15 each of the symbols in the subset of constellation symbols; and calculating a soft bit corresponding to the received symbol on the basis of said determined distances.

The step of, determining a subset of constellation symbols at  
20 least partly on the basis of the threshold, can include, determining a core constellation symbol associated with the received symbol at least partly on the basis of the threshold; and determining a plurality of additional constellation symbols associated with the core symbol.

25 Preferably the step of determining a plurality of additional

constellation points associated with the core symbol is performed using a look up table.

Preferably when the received data symbol is modulated with 16  
5 QAM, the subset of constellation symbols for which a distance determination is made includes 5 symbols.

Preferably, when the received data symbol is modulated with 64  
QAM, the subset of constellation symbols for which a distance  
10 determination is made includes 7 symbols.

In a second aspect, the present invention provides a method of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the method including; determining a  
15 subset of constellation symbols at least partly on the basis of one or more threshold values calculated at least partly on the basis of the equalised received symbol, and for which a distance determination will be made; determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols;  
20 calculating a soft bit corresponding to the equalised received symbol on the basis of said determined distances.

In a third aspect, the present invention provides a device for calculating at least one soft bit corresponding to a data symbol  
25 received by a radio receiver, including: means for calculating an

average amplitude for the at least one equalised received data symbol;  
means for calculating at least one threshold amplitude in respect of the  
data symbol on the basis of the calculated average amplitude; means  
for determining a subset of constellation symbols at least partly on the  
5 basis of the at least one threshold, and for which a distance  
determination will be made; and means for determining the distance  
between the position of the data symbol and each of the subset of  
constellation symbols; means for calculating a soft bit corresponding to  
the equalised received symbol on the basis of said determined  
10 distances.

The device can further include a look up table for use in  
determining the subset of constellation symbols for which distance  
determinations will be made.

15

As a fourth aspect, the present invention provides a device for  
calculating at least one soft bit corresponding to a data symbol  
received by a radio receiver, including; an average amplitude  
calculating unit that calculates an average amplitude for the at least  
20 one received data symbol; a threshold amplitude calculating unit that  
calculates at least one threshold amplitude in respect of the data  
symbol on the basis of the calculated average amplitude; a subset  
determining unit that determines a subset of constellation symbols at  
least partly on the basis of the at least one threshold, and for which a  
25 distance determination will be made; a distance determining unit that

determines the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and a soft bit calculating unit that calculates a soft bit corresponding to the received symbol on the basis of said determined distances.

5

In a fifth aspect, the present invention provides a communication receiver including a device according to the third aspect of the present invention.

10 In a sixth aspect, the present invention provides computer readable programs which can process the method or operate the device of the present invention. Particularly, the program includes the processing steps as mentioned in the methods according to the first or second aspect.

15 The program may be stored on a recording medium or available through a communication network.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 Examples of the present invention will now be described by way of non-limiting example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a communication system including a communication receiver in accordance with one example of the present invention;

25 Figure 2 is a diagram illustrating a 16-QAM signal constellation

mapping;

Figure 3 is a flowchart depicting the main steps in a preferred example of the present invention;

Figure 4 depicts a diagram of a 16-QAM signal constellation mapping showing a received symbol and the constellation reference symbols over which distances will be calculated in an example of the present invention; and

Figure 5 depicts a diagram of a 64-QAM signal constellation mapping showing a received symbol and the constellation reference symbols over which distances will be calculated in another example of the present invention.

#### PREFERRED MODES

In broad concept modes for implementing a method according to the present invention simplify the conventional LLR demodulation method by reducing the number of distance calculations needed to obtain soft bits. In a preferred mode this is achieved by first determining the region, e.g. a square, on the I-Q grid in which the equalised received symbol should lie. The area is found from thresholds that are calculated from pilot symbols.

Once the region is determined, distances are calculated between the equalized received symbol and a fraction of the reference constellation points. The reference constellation points used are preferably pre-defined in a look up table and the distances calculated

are directly used to calculate soft bits.

Figure 1 shows generally a communication system 10 including a transmitter 11, connected to a digital source 12. The transmitter 11 configured to receive binary input data from the digital source 12. The transmitter 11 generates and transmits a modulated signal 13 for reception by a receiver 14. The receiver 14 demodulates the received signal and attempts to recover decoded binary data which is then forwarded to a destination 15. The transmitter 11 includes an encoder 16, which may use turbo code or other Viterbi based encoding method such as convolutional codes to encode the binary input data 22. The transmitter also includes a signal mapping block 17 and modulator 18. The receiver includes a demodulator 19, log-likelihood estimator 20 and decoder 21. In a similar fashion to the encoder, the decoder 21 may use turbo code or other Viterbi based decoding scheme.

Binary input data 22 to be transmitted is encoded with a suitable code by the encoder 16, which generates a sequence of binary symbols 23 referred to as encoded bits. Several encoded bits are blocked together and mapped to a point on a signal constellation by the signal mapping block 17, thereby generating a sequence of complex-valued modulation symbols 24. This sequence is applied to the modulator 18, which generates a continuous time domain waveform for transmission to the receiver 14.

The demodulator 19 demodulates the received modulated signal and generates a sequence of complex-valued soft symbol 25. Each soft symbol represents an estimate of a modulation symbol that was transmitted by the transmitter 11. These estimates are used by the log-likelihood estimator 20 to extract log-likelihood metrics (soft bits) 26 associated with the given modulation symbol. The decoder 21 uses the sequence of log-likelihood metrics (soft bits) to decode the binary data that was originally transmitted and recover decoded binary data 27.

10

## [EXAMPLE 1]

A first example of the present invention will be described in the context of a signal modulated using 16-QAM. Figure 2 depicts the square 16-QAM constellation. The constellation 200 has an index  $m=2$  and is defined to be a signal constellation with  $4^m$  points. The square 16-QAM constellation shown in Figure 2 has an index  $m=2$  and is defined to be a signal constellation with  $4^m$  points. Each signal point is denoted by its index  $(i,j)$  where  $0 \leq i,j < 2^m$ . The position of each  $i,j$  point on the constellation is given by the following formula:

20

$$C_{i,j} = \{(2^m - 1 - 2i) \Delta, (2^m - 1 - 2j) \Delta\} \text{ where } \Delta = \sqrt{\frac{3}{4^m - 1} \left(\frac{1}{2}\right)}$$

The above formula ensures that the average energy of the signal constellation is normalised to one, where  $\Delta$  is a normalisation

parameter for a square-QAM constellation. For a 16-QAM constellation,  $m=2$  and  $\Delta = \frac{1}{\sqrt{10}}$ . For other square-QAM constellations, the value of both  $m$  and  $\Delta$  will change. Accordingly, for a 64-QAM constellation,  $m=3$  and  $\Delta = \frac{1}{\sqrt{42}}$ , whilst for a 256-QAM constellation,  $m=4$  and  $\Delta = \frac{1}{\sqrt{170}}$ .

Each signal point in the constellation is labelled with a binary string that denotes a block of encoded bits associated with the modulation symbol. A grey code mapping is used to associate the modulation symbols with blocks of encoded bits. In this case, each of the points in the constellation is identified by a 4 bit grey code having bits  $b_0$ ,  $b_1$ ,  $b_2$  and  $b_3$ . In other square-QAM constellations, the number of bits in the grey code will vary. For example, in a 64-QAM constellation, each point is identified by a 6 bit grey code as will be seen in the second example described below.

Figure 3 depicts a flowchart of the main steps in the preferred example of the present invention. As can be seen the method 300 begins with the reception and equalisation of one or more pilot symbols in step 302. The pilot symbols are used in step 304 to compute one or more threshold values to be applied to the received equalised data symbols in a manner to be described below.

In the preferred mode the threshold in step 304 is determined on the basis of the average data symbol amplitude,  $A_{data}$ . The average data symbol amplitude  $A_{data}$  can be calculated in a known manner, e.g. calculated in the conventional LLR method above mentioned above. One preferred way of calculating  $A_{data}$  is to use received pilot signals and a known ratio between power of pilot and data. For example following expression can be used to calculate  $A_{data}$  :

$$10 \quad A_{data} = \sqrt{\frac{1}{P_{PD}} \left( \frac{1}{N} \sum_{k=1}^N \hat{y}_{k,p} \right)^2} ,$$

where  $P_{PD}$  is the pilot to data power ratio,  $N$  is the number of pilots in the sample set and  $\hat{y}_{k,p}$  are the equalised pilots assuming that all pilots are the same i.e.

15

$$y_{1,p} = y_{2,p} = \dots = y_{N,p} .$$

Using the average data symbol amplitude  $A_{data}$  the threshold  $T_j$  can be calculated using the expression:

20

$$T_j = A_{data} \times C_j ;$$

where  $C_j$  is given by:

$$C_j = 2 \times j \times \Delta;$$

and where  $j$  is the number of thresholds needed ( $j=1$  for 16-QAM and  $j=\{1,2,3\}$  for 64-QAM). The scaling factor  $\Delta$  is a normalisation parameter for a square-QAM constellation calculated as described above. For convenience, when using 16-QAM and 64-QAM, the values used for  $\Delta$  are:

$$\Delta = \begin{cases} \frac{1}{\sqrt{10}} & \text{for 16-QAM} \\ \frac{1}{\sqrt{42}} & \text{for 64-QAM} \end{cases}$$

10

Next, in step 308 a core symbol which will be used as the basis for later distance calculations, is determined.

The 4 bits of the core symbol ( $b_0 \dots b_3$ ) are determined using the following criteria:

Table 1 : Criteria for determining centre of region with 16-QAM

$b_0$	$b_1$	$b_2$	$b_3$
If $y_i \geq 0$ $b_0=0$	If $y_q \geq 0$ $b_1=0$	If $\text{abs}(y_i) \leq T1$ $b_2=0$	If $\text{abs}(y_q) \leq T1$ $b_3=0$
Else $b_0=1$	Else $b_1=1$	Else $b_2=1$	Else $b_3=1$

where  $y_i$  and  $y_q$  are the I and Q components respectively of received symbol  $y$ ,  $T1$  is threshold determined as shown above.

20

As an example, take the situation depicted in Figure 4, which shows a 16QAM constellation diagram 400. The circle 402 represents the equalised received symbol,  $y$ . The circle 406 represents the reference constellation symbol that is closet to symbol  $y$ , and is referred to as the "core symbol". The circles 408 are a series of reference symbols associated with the core symbol 406.

In the example of figure 4, using the criteria in Table 1, the four bits  $b_0, b_1, b_2, b_3$  of the core symbol, are determined to be 0000.

10

In step 310 of Figure 3, a series of additional symbols surrounding the core symbol are determined using a look up table. The look up table is defined by finding the symbols nearest to the core symbol whose  $i$ -th bit is the opposite of the core symbol's  $i$ -th bit. This is illustrated in Figure 4. In this example the core symbol (0000) is surrounded by reference symbols 408 (0001, 0010, 0100, 1000), which only differ from the core symbol (0000) by one bit. The following table sets out an exemplary look up table A for use with a 16-QAM example of the present invention.

<Look up Table A>

Core symbol	Surrounding reference symbols	Core symbol	Surrounding reference Symbols
0000	0001 1000 0100 0010	1000	0000 1100 1010 1001
0001	1001 0100 0011 0000	1001	0001 1100 1011 1000
0010	1000 0110 0000 0011	1010	0000 1110 1000 1011
0011	1001 0110 0001 0010	1011	0001 1110 1001 1010
0100	1100 0000 0110 0101	1100	0100 1000 1110 1101
0101	1101 0000 0111 0100	1101	0101 1000 1111 1100
0110	1100 0010 0100 0111	1110	0100 1010 1100 1111
0111	1101 0010 0101 0110	1111	0101 1010 1101 1110

The look up table defines a group of reference symbols that are associated with the core symbol. Together with the core symbol they  
 5 define a subset of reference symbols for which the distances from the received symbol y are calculated in step 312 of the method of Figure 3. By limiting the distance calculations to this subset of the I-Q reference

symbols instead of full set of 16 I-Q reference symbols, the total number of distance calculations performed is greatly reduced, thus reducing the overall complexity of the algorithm.

5 In a preferred form of the present invention the distance metric used for the distance calculation is the Euclidean distance,  $d$ , which is calculated as follows:

$$d = |\hat{y} - z|^2$$

10

where  $\hat{y}$  and  $z$  denote the received equalised and reference symbol respectively. However other distance metrics could potentially be used, such as,

$$s = \hat{y} - z; q = \max(\text{Re}(s), \text{Im}(s)) + 0.5 \min(\text{Re}(s), \text{Im}(s)); d = q^2 .$$

15

Next in step 314, soft bits are calculated. The soft bits are calculated directly from the distances between the equalised received symbol and the set of reference constellation symbols defined in the look up table. The soft bits  $\tilde{b}_i$ , are determined by:

20 If  $b_i$  of  $z_c = 0$ ,

$$\tilde{b}_i = d_i - d_c$$

else

$$\tilde{b}_i = d_c - d_i$$

25 where  $\hat{y}$  is the received equalised symbol,  $z_c$  is the core symbol,  $z_i$  is

the  $i$ -th surrounding reference symbol,  $d_c$  is the distance between  $\hat{y}$  and  $z_c$ , and  $d_i$  is the distance between  $\hat{y}$  and  $z_i$ .

The soft bits thus calculated are then passed to the decoder to  
5 decode the bits (in step 316 of Figure 3) in a conventional manner.

[EXAMPLE 2]

The present Invention can be realized with higher order  
modulation schemes such as 64-QAM. Generally speaking the process  
10 followed in this case is the same as for 16-QAM, with the following  
changes:

- As noted above, more thresholds are calculated.
- For 64-QAM a different set of constellation reference symbols is  
15 used, meaning that a different grey code is needed. This necessitates  
the use of a different set of criteria for determining the core symbol in  
step 308. For 64-QAM, given the constellation definition as shown in  
Figure 5, the 6 bits for the core symbol ( $b_0$  -  $b_5$ ) are determined using  
the following criteria:

Table 2: Criteria for determining core symbol with 64-QAM

$b_0$	$b_1$	$b_2$
If $y_i \geq 0$ $b_0=0$ Else $b_0=1$	If $y_q \geq 0$ $b_1=0$ Else $b_1=1$	If $\text{abs}(z_i) \leq T2$ $b_2=0$ Else $b_2=1$
$b_3$	$b_4$	$b_5$
If $\text{abs}(z_q) \leq T2$ $b_3=0$ Else $b_3=1$	If $T1 \leq \text{abs}(z_i) \leq T3$ $b_4=0$ Else $b_4=1$	If $T1 \leq \text{abs}(z_q) \leq T3$ $b_5=0$ Else $b_5=1$

• A different look up table is needed for determining which surrounding reference symbols are to be used for distance calculations.

5 In the example of Figure 5 the following look up table B is used:

<Look up Table B>

Square/core symbol	Surrounding reference symbols	Square/core symbol	Surrounding reference symbols
101111	000111 111011 100101 101010 101101 101110	101101	000111 111001 100101 101000 101111 101100
101110	000110 111011 100100 101010 101100 101111	101100	000110 111001 100100 101000 101110 101101
101010	000010 111011 100000 101110 101000 101011	101000	000010 111001 100000 101100 101010 101001
101011	000011 111011 100001 101110 101001 101010	101001	000011 111001 100001 101100 101011 101000

111111	010111 101011 110101 111010 111101 111110	111101	010111 101001 110101 111000 111111 111100
111110	010110 101011 110100 111010 111100 111111	111100	010110 101001 110100 111000 111110 111101
111010	010010 101011 110000 111110 111000 111011	111000	010010 101001 110000 111100 111010 111001
111011	010011 101011 110001 111110 111001 111010	111001	010011 101001 110001 111100 111011 111000
001111	100111 011011 000101 001010 001101 001110	001101	100111 011001 000101 001000 001111 001100
001110	100110 011011 000100 001010 001100 001111	001100	100110 011001 000100 001000 001110 001101
001010	100010 011011 000000 001110 001000 001011	001000	100010 011001 000000 001100 001010 001001
001011	100011 011011 000001 001110 001001 001010	001001	100011 011001 000001 001100 001011 001000

011111	110111 001011 010101 011010 011101 011110	011101	110111 001001 010101 011000 011111 011100
011110	110110 001011 010100 011010 011100 011111	011100	110110 001001 010100 011000 011110 011101
011010	110010 001011 010000 011110 011000 011011	011000	110010 001001 010000 011100 011010 011001
011011	110011 001011 010001 011110 011001 011010	011001	110011 001001 010001 011100 011011 011000
100111	000111 110011 101101 100010 100101 100110	100101	000111 110001 101101 100000 100111 100100
100110	000110 110011 101100 100010 100100 100111	100100	000110 110001 101100 100000 100110 100101
100010	000010 110011 101000 100110 100000 100011	100000	000010 110001 101000 100100 100010 100001
100011	000011 110011 101001 100110 100001 100010	100001	000011 110001 101001 100100 100011 100000

110111	010111 100011 111101 110010 110101 110110	110101	010111 100001 111101 110000 110111 110100
110110	010110 100011 111100 110010 110100 110111	110100	010110 100001 111100 110000 110110 110101
110010	010010 100011 111000 110110 110000 110011	110000	010010 100001 111000 110100 110010 110001
110011	010011 100011 111001 110110 110001 110010	110001	010011 100001 111001 110100 110011 110000
000111	100111 010011 001101 000010 000101 000110	000101	100111 010001 001101 000000 000111 000100
000110	100110 010011 001100 000010 000100 000111	000100	100110 010001 001100 000000 000110 000101
000010	100010 010011 001000 000110 000000 000011	000000	100010 010001 001000 000100 000010 000001
000011	100011 010011 001001 000110 000001 000010	000001	100011 010001 001001 000100 000011 000000

010111	110111 000011 011101 010010 010101 010110	010101	110111 000001 011101 010000 010111 010100
010110	110110 000011 011100 010010 010100 010111	010100	110110 000001 011100 010000 010110 010101
010010	110010 000011 011000 010110 010000 010011	010000	110010 000001 011000 010100 010010 010001
010011	110011 000011 011001 010110 010001 010010	010001	110011 000001 011001 010100 010011 010000

As can be seen in Figure 5 the equalised symbol 502 is found to be closest to the core symbol 101100. Using the look up table it can be seen that the reference symbols associated with this core symbol, 5 illustrated in grey on Figure 5, are: 000110, 111001, 100100, 101000, 101110 and 101101. Thus a subset of the total I-Q constellation containing the core symbol and corresponding associated symbols is defined and the distance between the received symbol y and each symbol in the subset can then be calculated.

10

[EXTENDED APPLICABILITIES]

It should be noted that, whist the illustrative examples have been described in the context of square 16-QAM and 64-QAM modulation schemes the method can be applied to higher order-QAM

constellations (e.g. 256-QAM) or to constellations with different definitions.

[MERITORIOUS EFFECTS]

5           As can be seen from the foregoing, in the preferred examples the computational reduction offered by the invention, may be significant, for example, with 16-QAM, the number of distance calculations for each received symbol can be reduced from 16 to 5 and for 64-QAM, the number of distance calculations can be reduced from 64 to 7.

10

[PROGRAMS]

          According to seventh aspect, the methods of the present invention can be implemented by way of a computer which is operated by a corresponding program or programs including specific processing  
15 steps corresponding to the steps of the method. The processing unit (or units) may be implemented in a device of transmitter or receiver, respectively.

          It will be understood that the invention disclosed and defined in  
20 this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

25           It will also be understood that the term "comprises" (or its

grammatical variants) as used in this specification is equivalent to the term "includes" and should not be taken as excluding the presence of other elements or features.

## CLAIMS:

1. A method of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the method including:
  - calculating an average amplitude for the at least one received
  - 5 data symbol;
  - calculating at least one threshold amplitude in respect of the data symbol on the basis of the calculated average amplitude;
  - determining a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance
  - 10 determination will be made;
  - determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and
  - calculating a soft bit corresponding to the received symbol on the basis of said determined distances.
  - 15
2. A method of calculating a soft bit corresponding to a data symbol as claimed in claim 1 wherein the step of, determining a subset of constellation symbols at least partly on the basis of the threshold, includes;
  - 20 determining a core constellation symbol associated with the received symbol at least partly on the basis of the threshold; and
  - determining a plurality of additional constellation symbols associated with the core symbol.
- 25 3. A method of calculating a soft bit corresponding to a data

symbol as claimed in claim 2 wherein the step of determining a plurality of additional constellation points associated with the core symbol is performed using a look up table.

5 4. A method of calculating a soft bit corresponding to a data symbol as claimed in any one of claims 1 to 3, wherein the received data symbol is modulated with 16 QAM and the subset of constellation symbols for which a distance determination is made includes 5 symbols.

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5. A method of calculating a soft bit corresponding to a data symbol as claimed in any one of claims 1 to 3, wherein the received data symbol is modulated with 64 QAM and the subset of constellation symbols for which a distance determination is made includes 7  
15 symbols.

6. A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver, including:

means for calculating an average amplitude for the at least one  
20 received data symbol;

means for calculating at least one threshold amplitude in respect of the data symbol on the basis of the calculated average amplitude;

means for determining a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a  
25 distance determination will be made;

means for determining the distance between the position of the data symbol and each symbol of the subset of constellation symbols;

means for calculating a soft bit corresponding to the received symbol on the basis of said determined distances.

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7. A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver as claimed in claim 6 wherein the device further includes a look up table for use in determining the subset of constellation symbols for which distance determinations will  
10 be made.

8. A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver as claimed in either of claims 6 or 7 wherein the means for determining a subset of constellation  
15 symbols is configured to

determine a core constellation symbol associated with the received symbol at least partly on the basis of the threshold; and

determine a plurality of additional constellation symbols associated with the core symbol.

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9. A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver as claimed in any one of claims 6 to 8 wherein the received data symbol is modulated with 16 QAM and the subset of constellation symbols for which a distance  
25 determination is made includes 7 symbols.

10. A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver as claimed in any one of claims 6 to 8, wherein the received data symbol is modulated with 64 QAM and the subset of constellation symbols for which a distance determination is made includes 7 symbols.

11. A communication receiver including the device according to any one of claims 6 to 10.

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12. A method of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the method including:

determining a subset of constellation symbols at least partly on the basis of one or more threshold values calculated at least partly on the basis of the received symbol, and for which a distance determination will be made;

determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and

calculating a soft bit corresponding to the received symbol on the basis of said determined distances.

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13. A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver, including:

an average amplitude calculating unit that calculates an average amplitude for the at least one received data symbol;

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a threshold amplitude calculating unit that calculates at least one threshold amplitude in respect of the data symbol on the basis of the calculated average amplitude;

a subset determining unit that determines a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance determination will be made;

a distance determining unit that determines the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and

a soft bit calculating unit that calculates a soft bit corresponding to the received symbol on the basis of said determined distances.

14. A device for calculating at least one soft bit corresponding to a data symbol as claimed in claim 13, wherein the device further includes a look up table for use in determining the subset constellation symbols for which distance determinations will be made.

15. A program of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the program comprising processing steps of:

calculating an average amplitude for the at least one received data symbol;

calculating at least one threshold amplitude in respect of the data symbol on the basis of the calculated average amplitude;

determining a subset of constellation symbols at least partly on

the basis of the at least one threshold, and for which a distance determination will be made;

determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and

5 calculating a soft bit corresponding to the received symbol on the basis of said determined distances.

16. The program as claimed in claim 15, wherein said processing step of, determining a subset of constellation symbols at least partly on  
10 the basis of the threshold, includes further processing steps of;

determining a core constellation symbol associated with the received symbol at least partly on the basis of the threshold; and

determining a plurality of additional constellation symbols associated with the core symbol.

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17. The program as claimed in claim 16, wherein the processing step of determining a plurality of additional constellation points associated with the core symbol is performed using a look up table.

20 18. The program as claimed in any one of claims 15 to 17, wherein the received data symbol is modulated with 16 QAM and the subset of constellation symbols for which a distance determination is made includes 5 symbols.

25 19. The program as claimed in any one of claims 15 to 17, wherein

the received data symbol is modulated with 64 QAM and the subset of constellation symbols for which a distance determination is made includes 7 symbols.

5 20. A program of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the program comprising processing steps of:

determining a subset of constellation symbols at least partly on the basis of one or more threshold values calculated at least partly on  
10 the basis of the received symbol, and for which a distance determination will be made;

determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and

calculating a soft bit corresponding to the received symbol on  
15 the basis of said determined distances.

**AMENDED CLAIMS**

**[received by the International Bureau on 10 January 2008 (10.01.2008)]**

the received data symbol is modulated with 64 QAM and the subset of constellation symbols for which a distance determination is made includes 7 symbols.

5 20. A program of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the program comprising processing steps of:

determining a subset of constellation symbols at least partly on the basis of one or more threshold values calculated at least partly on  
10 the basis of the received symbol, and for which a distance determination will be made;

determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols; and

calculating a soft bit corresponding to the received symbol on  
15 the basis of said determined distances.

21. (New) A method of calculating at least one soft bit corresponding to a data symbol received by a radio receiver, the method including:

20 calculating at least one threshold amplitude in respect of the data symbol on the basis of an average amplitude;

determining a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance determination will be made; and

25 determining the distance between the position of the data symbol

and each of the symbols in the subset of constellation symbols.

22. (New) A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver, including:

5 means for calculating at least one threshold amplitude in respect of the data symbol on the basis of an average amplitude;

means for determining a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance determination will be made; and

10 means for determining the distance between the position of the data symbol and each symbol of the subset of constellation symbols.

23. (New) A device for calculating at least one soft bit corresponding to a data symbol received by a radio receiver, including:

15 a threshold amplitude calculating unit that calculates at least one threshold amplitude in respect of the data symbol on the basis of an average amplitude;

20 a subset determining unit that determines a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance determination will be made; and

a distance determining unit that determines the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols.

25 24. (New) A program of calculating at least one soft bit

corresponding to a data symbol received by a radio receiver, the program comprising processing steps of:

- calculating at least one threshold amplitude in respect of the data symbol on the basis of an average amplitude;
- 5 determining a subset of constellation symbols at least partly on the basis of the at least one threshold, and for which a distance determination will be made; and
- determining the distance between the position of the data symbol and each of the symbols in the subset of constellation symbols.

## Statement under Article 19(1)

The additional new claims 21 to 24 are based on the Written Opinion of the ISA, Box No. V, 2. Citations and explanations, which mentions:

— In particular, "calculating at least one threshold amplitude in respect of ..." and "determining a subset of constellation symbols..." are not disclosed in D1 - D4. —

Based on these novel features, added new claims 21-24 are formulated.

FIG . 1

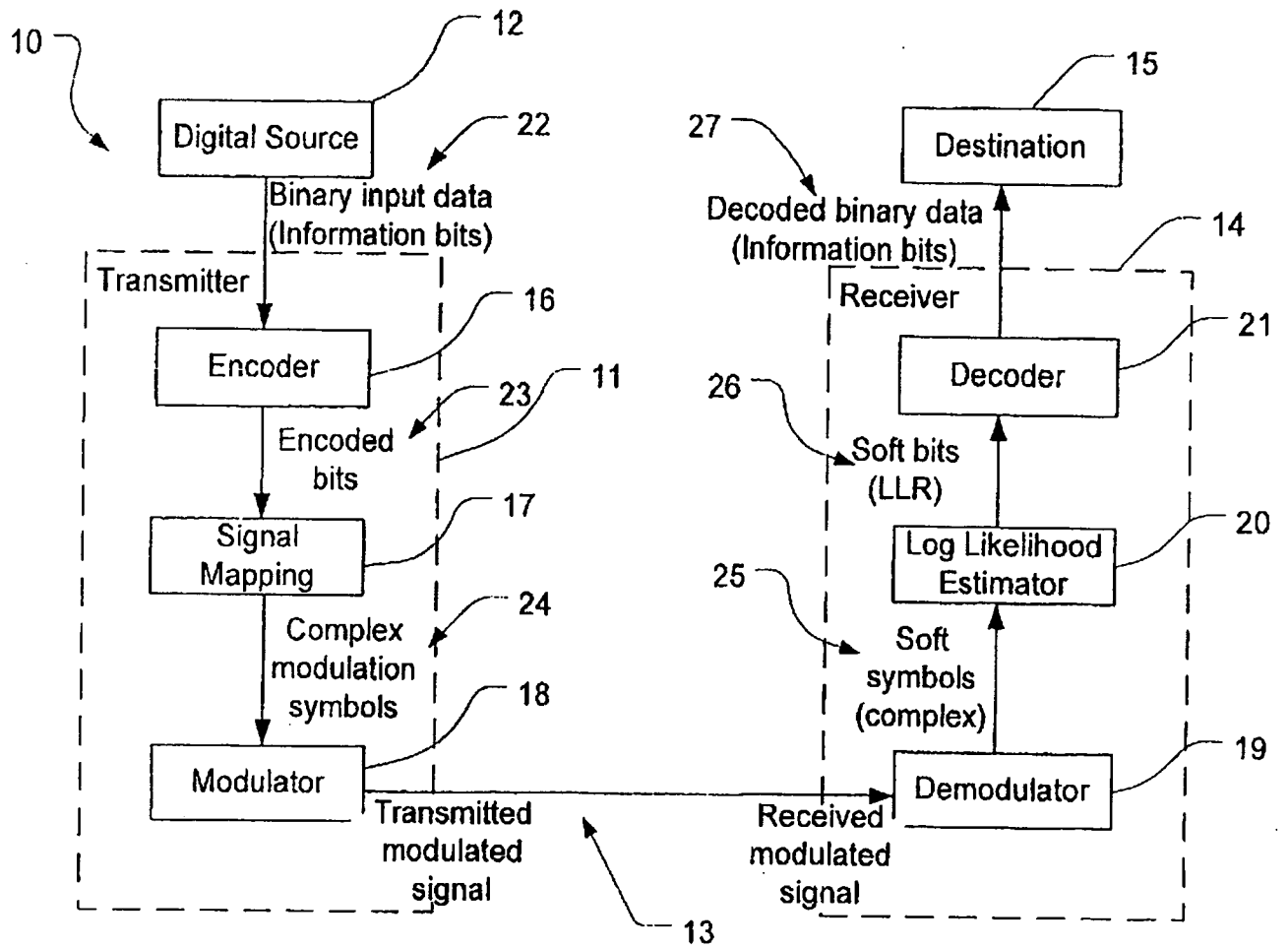


FIG . 2

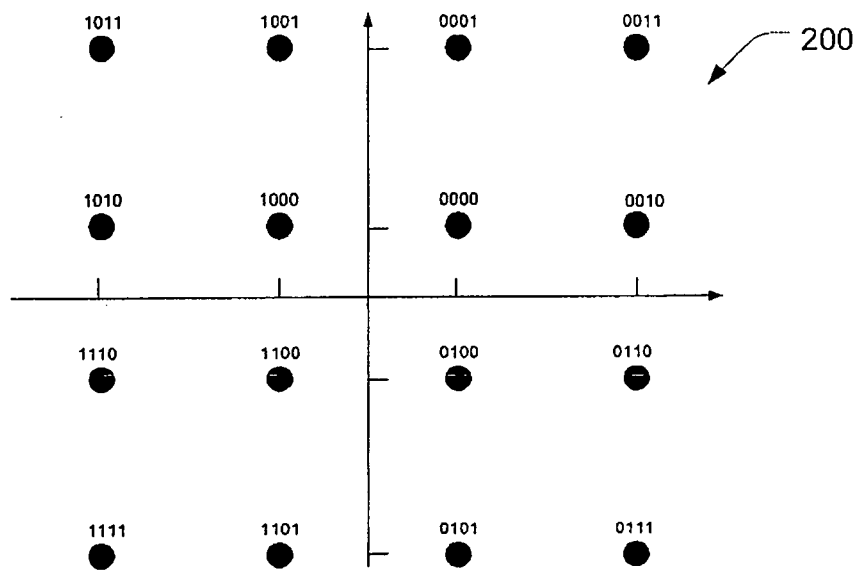


FIG . 3

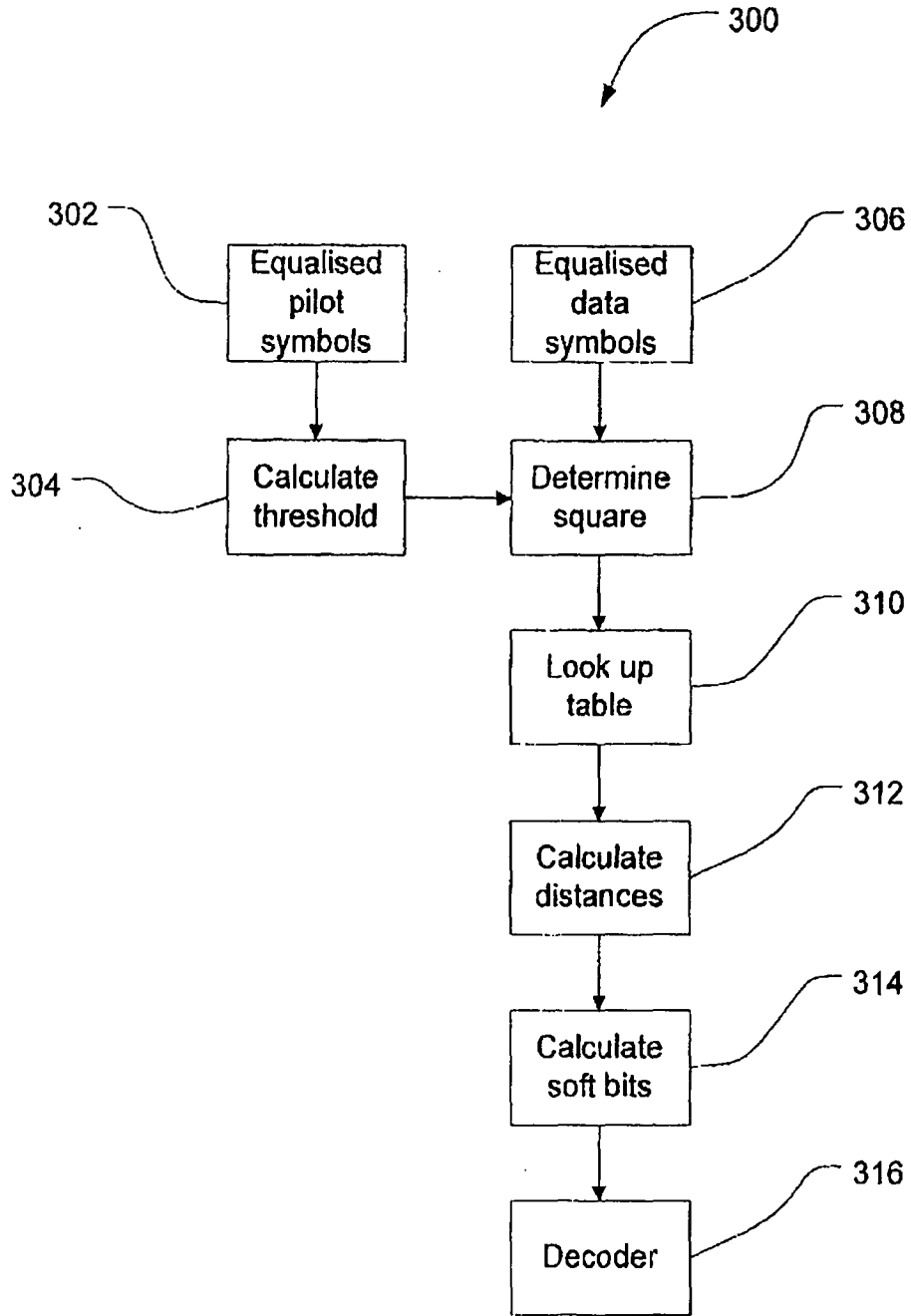


FIG. 4

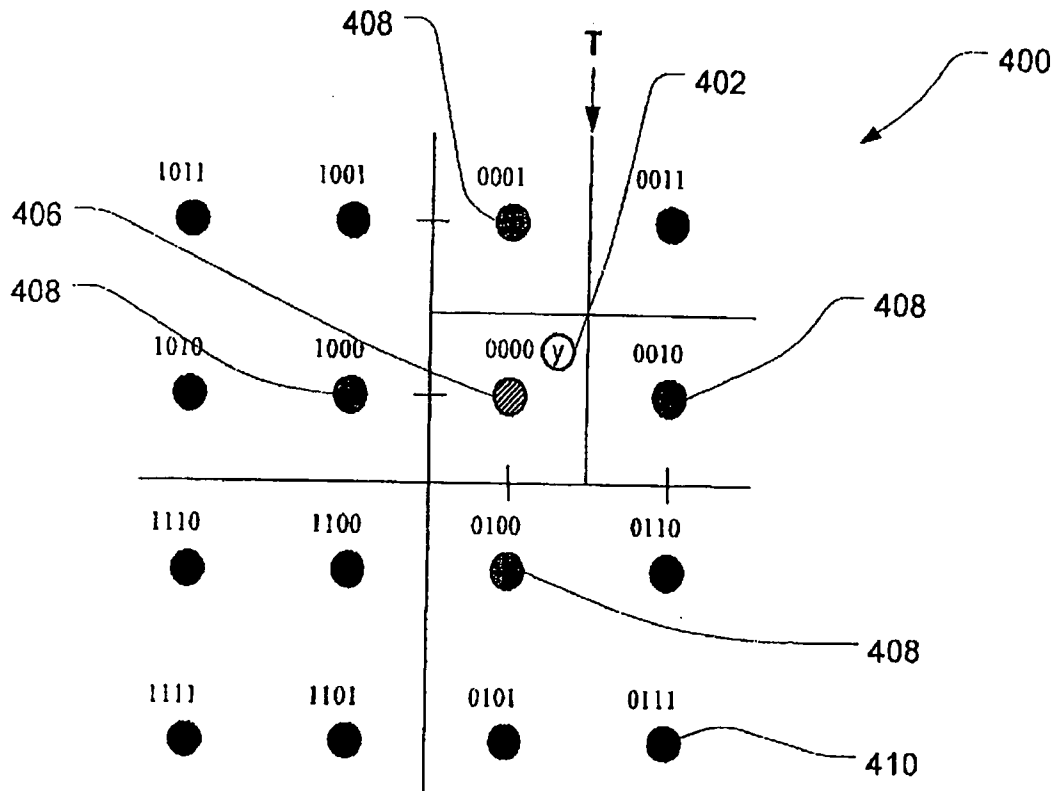
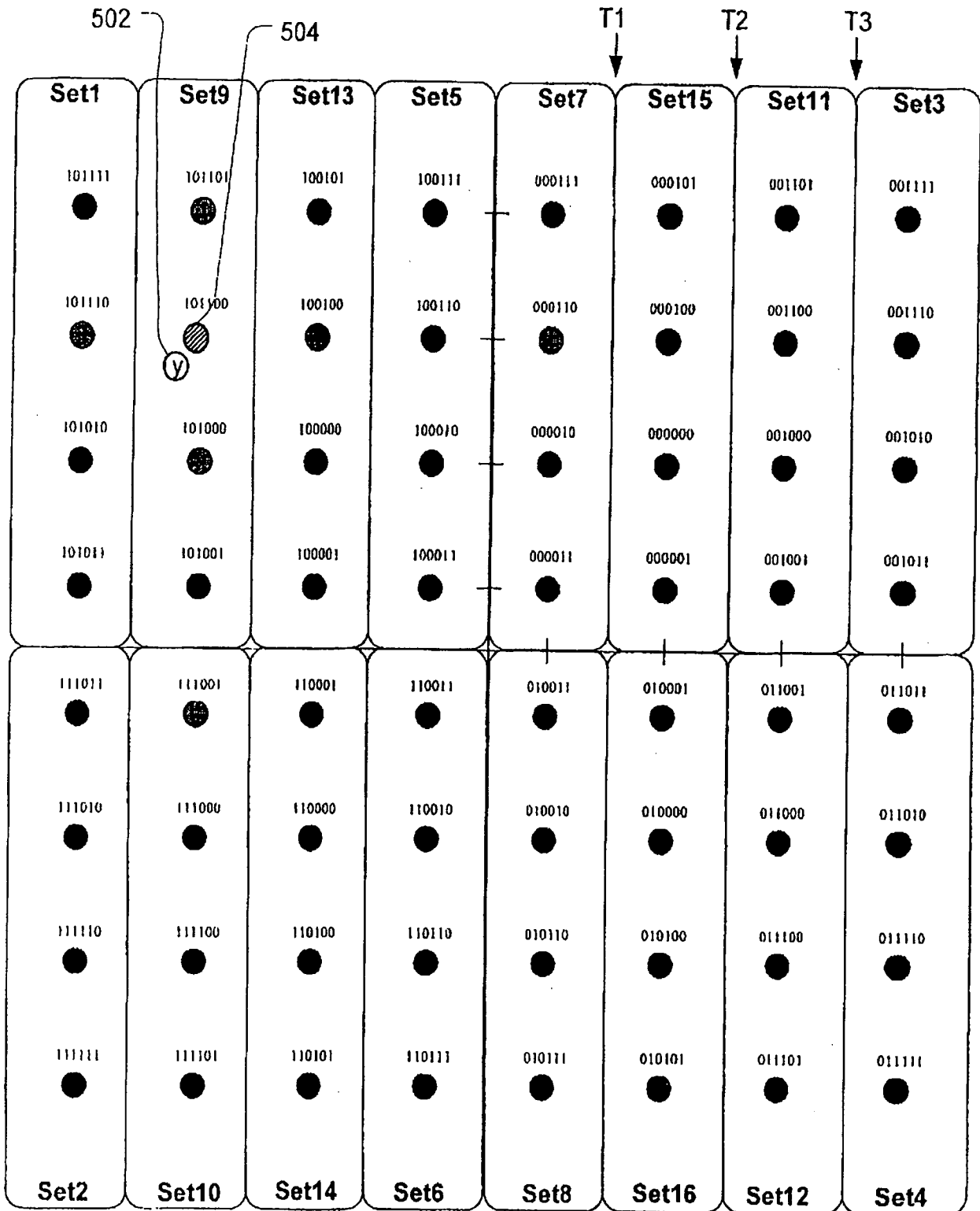


FIG . 5



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/068742

A. CLASSIFICATION OF SUBJECT MATTER		
Int.Cl. H04L27/00 (2006.01) i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Int.Cl. H04L27/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2007 Registered utility model specifications of Japan 1996-2007 Published registered utility model applications of Japan 1994-2007		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
IEEE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-522375 A (KONINKLIJKE PHILIPS ELECTRONICS N.V.) 2004.07.22, see abstract & US 2003-0053566 A1 & WO 03/007529 A1	1-20
A	JP 2002-271211 A (HITACHI, Ltd.) 2002.09.20, [0039]-[0046], FIG.6, (Family :none)	1-20
A	JP 2004-104188 A (MATSUSHITA ELECTRIC INDUSTRIAL Co., Ltd) 2004.04.02, [0004], FIG.39, FIG.40, (Family :none)	1-20
A	JP 2004-165937 (NTT DoCoMo, Inc.) 2004.06.10, [0041]-[0044], FIG.3 & US 2004-0096015 A1 & EP 1420558 A1	1-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
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