(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 151 081 B9

(12) # CORRECTED EUROPEAN PATENT SPECIFICATION

(15) Correction information:
Corrected version no 1 (W1 B1)
Corrections, see
Claims DE 1-16
Claims FR 1-16

(48) Corrigendum issued on:
10.10.2012 Bulletin 2012/41

(45) Date of publication and mention of the grant of the patent:
01.08.2012 Bulletin 2012/31

(21) Application number: **08774185.6**

(22) Date of filing: **20.06.2008**

(51) Int Cl.:
H04L 1/00 *(2006.01)* ***H04L 25/06*** *(2006.01)*

(86) International application number:
PCT/EP2008/057889

(87) International publication number:
WO 2009/003859 (08.01.2009 Gazette 2009/02)

(54) **Processing transmissions in a wireless communication system**

Bearbeitung von Übertragungen in drahtlosen kommunikationssystemen

Traitement de transmissions dans un système de communication sans fil

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR

(30) Priority: **29.06.2007 GB 0712701**

(43) Date of publication of application:
10.02.2010 Bulletin 2010/06

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- **"Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (FDD) (3GPP TS 25.212 version 5.10.0 Release 5); ETSI TS 125 212" ETSI STANDARDS, LIS, SOPHIA ANTIPOLIS CEDEX, FRANCE, vol. 3-R1, no. V5.10.0, 1 June 2005 (2005-06-01), XP014030539 ISSN: 0000-0001 cited in the application**

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Description

[0001] This invention relates to processing transmissions in a wireless communication system, particularly where a receiver does not have information about the transmission format.

[0002] In the 3rd Generation Partnership Project (3GPP) Wideband Code Division Multiple Access (WCDMA) forward link, multiple Dedicated Channels (DCHs) can be separately encoded and punctured, and then multiplexed for transmission over the same Dedicated Physical Channel (DPCH) (3GPP TS 25.212, "Technical Specification Group Radio Access Network; Multiplexing and Channel Coding (FDD)", June 2005, Section 4). For each DCH transport channel, a variable number of information data blocks, may be encoded and simultaneously transmitted on the DPCH. The particular format of each transmission is normally signalled to a mobile terminal or User Equipment (UE) by a Transport Format Combination Indicator (TFCI), which specifies for each DCH transport channel the transport block size (i.e. number of bits contained in each transport block) and the number of transmitted transport blocks (plus additional parameters related to puncturing and channel encoding) (3GPP TS 25.302, "Technical Specification Group Radio Access Network; Services Provided by the Physical Layer", September 2005). However, the WCDMA standard requires that, under certain conditions, the UE be able to infer the transport format used for a transmission, without explicit signalling of the transport format combination indicator TFCI. In this case, the user equipment UE should rely on specific receiver signal processing functions for blind transport format detection. When, for each transport channel, the set of possible transport formats contains only one transport format with more than zero transport blocks, the user equipment should perform a specific processing function referred to as single transport format detection (3GPP TS 25.212, "Technical Specification Group Radio Access Network; Multiplexing and Channel Coding (FDD)", June 2005, Section 4.3.1a), where the user equipment only needs to distinguish between the cases where the DCH transmission contains zero or one transport block (data rates equal to zero or full-rate).

[0003] In a WCDMA system, transmissions are made in Transmission Time Intervals (TTIs) of the duration of one or more 10ms radio frames. Each 10ms radio frame is further subdivided in 15 time slots, each containing 2560 chips. DCH data transmitted on a DPCH over one TTI can contain one transport block or multiple blocks.

[0004] A method for blind single transport format detection is suggested in 3GPP TS 25.212, "Technical Specification Group Radio Access Network; Multiplexing and Channel Coding (FDD)", June 2005, Annex A (Informative): Blind Transport Format Detection, Section A.1.1. This method is based on an estimate of the power per bit of the dedicated physical data channel DPDCH, P_{DPDCH}, which is compared against an estimate of the power per bit of the dedicated physical control channel DPCCH, P_{DPCCH}. Both power estimates are calculated per slot and averaged over one 10ms frame. If the ratio P_{DPDCH} / P_{DPCCH} exceeds some threshold T, then it is declared that the full rate transport format has been detected, else it is declared that the zero rate transport format has been detected.

[0005] In the case where code blocks of different DCH transport channels are multiplexed and transmitted on the same DPCH channel, the above approach requires the identification of the DPCH slot data that correspond to the different transport channel.

[0006] A document authored by Ramprashad, S.A., et al, Entitled "Locally Most Powerful Invariant Tests for Signal Detection" IEEE Transactions on Information Theory, Vol. 44 No. 3, 1 May 1998 was cited in the European Search Report as Background Art. It relates to a different context to that in which the present invention is set, and combines two types of tests for the presence of a signal in additive noise. Such tests, referred to in the document as locally most powerful invariant tests, are defined using a number of orthogonal linear subspaces, and the second order signal statistics in each subspace.

[0007] One aspect of the invention provides a method of processing transmissions in a wireless communication system to detect whether a transmission unit contains transmitted data, the method comprising: receiving a plurality of samples of a transmission unit; determining an average signal-to-disturbance ratio of the plurality of samples; determining for each sample one or more bit reliability indicators, which is related to the probability that the transmitted bit is a one or a zero; generating an averaged function of the reliability indicators from the plurality of received samples; and applying a test using the averaged function of the reliability indicators and the average signal-to-disturbance ratio to determine if the transmission unit contains transmitted data.

[0008] Another aspect of the invention provides a system for processing transmissions in a digital communications system to detect whether a transmission unit contains transmitted data, the system comprising: means for receiving a plurality of samples of a transmission unit; means for determining an average signal-to-disturbance ratio over the plurality of samples; means for determining for each sample one or more bit reliability indicators, which is related to the probability that the transmitted bit isa one or a zero; means for generating an average function of the bit reliability from the plurality of received samples; means for applying a test using the average function of the reliability indicators and the average signal-to-disturbance ratio to determine if the transmission unit contains transmitted data.

[0009] In the preferred embodiments, the test which is applied is formulated based on a Bayes test. Unlike the prior art blind single transport format detection techniques discussed above, the method described in the following embodiments does not rely on a comparison of power estimates for different portions of the DPCH time slot. The problem of detecting the presence of a transmitted signal of specified characteristics from observation of a set of received samples is a classical problem of detection theory, which has been widely studied in the context of detection of signal in noise and hypothesis testing (see, e.g. H.L. Van Trees, Detection, Estimation, and modulation Theory, John Wiley & Sons, 1968, A. Papoulis, Probability, Random Variables and Stochastic Processes, McGray-Hill, 1991, and references therein). The proposed method is based on a likelihood ratio test deriving from the same principles as that discussed in the classical detection theory, but differs from the classical solutions, with the specific advantage of allowing signal detection over a wider range of signal-to-noise ratios, above a threshold selected taking into account a specified error performance limit. The method has a general use, but finds particular application in single transport format detection in a 3GPP WCDMA receiver.

[0010] For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made by way of example to the accompanying drawings, in which:

Figure 1 is a schematic block diagram of a system in accordance with one embodiment of the invention;
Figure 2 is a schematic block diagram of an optimum detection technique;
Figure 3 is a schematic block diagram of an approximate detection technique;
Figure 4 is a schematic block diagram of an alternative embodiment of the invention; and
Figures 5 to 9 are graphs indicating the performance of the detection techniques discussed herein.

[0011] A block diagram including the main functionalities of a WCDMA receiver in accordance with an embodiment of the invention is illustrated in Figure 1. In Figure 1 reference numeral 2 denotes an antenna which receives a wireless transmission and supplies it in analogue form to RF and IF stages 4, themselves known in the art. A receiver front-end 6 includes the functions of analogue to digital conversion and receives root-raised cosine filtering, and a signal detector 8, which is typically implemented by a rake receiver, that descrambles and despreads the relevant downlink codes. For each time slot, the DPCH is constituted by the Dedicated Physical Data Channel (DPDCH) and the Dedicated Physical Control Channel (CPCCH). The DPDCH fields of the DPCH slot contain data symbols (user data) deriving from the code blocks of the different DCH transport channels, whereas the DPCCH fields contain control information (including pilot symbols), which is always transmitted independently of the presence of user data. The received samples corresponding to the pilot field are supplied to a power estimation block 10 and the received samples corresponding to the data fields are supplied to an LLR calculation block 12. Signal detection is followed by calculation of the bit log-likelihood ratios (LLRs) in block 12, which provide reliability information for soft-input channel decoding. The receiver also comprises a deinterleaving and demultiplexing function 14. After deinterleaving/demultiplexing, each transport channel is provided with a depuncturing and channel decoding function 16 and a CRC (cyclic redundancy check) function 18.

[0012] The receiver further includes a blind transport format detection function 20. The detection function 20 receives signal power estimates E_s and disturbance estimates N_0 from the power estimation block 10 as well as LLRs $L(y_k)$ from the LLR calculation block 12. In a manner to be described more fully herein, the blind transport format detection function makes a distinction between a zero transport block (data rate equal to zero) and a non-zero transport block (full rate data). The operations of deinterleaving, depuncturing, channel decoding and CRC check need to be performed only if the detection algorithm has identified the transmission of a non-zero size transport block.

[0013] Reference will now be made to Figures 2 and 3 to discuss two different detection processes. One is referred to as an optimum detection process (Figure 2), and the other is referred to as an approximate detection process (Figure 3). Either or both of these detection processes can be implemented in the blind TF detection block 20. The choice of which detection process is implemented, and if they are both implemented the choice of which process to use in any particular circumstances is discussed more fully in the following. Both processes derive from a detection algorithm which will now be discussed.

[0014] The single transport format detection algorithm is based on an approximation of the optimum Bayes test (known as the likelihood ratio test) for detection of a transmitted signal in noise. The following derivation refers to the case of a Quadrature Phase Shift Keying (QPSK) modulated signal, which is relevant for the DPCH channel of 3GPP WCDMA, but it will be appreciated that straightforward modification allows the extension of the algorithm to different signal modulation formats.

[0015] Under the hypothesis of transmitted signal, we assume a QPSK data sequence with independent identically distributed (i. i.d) in-phase and quadrature symbols $a_k \in \{+1/\sqrt{2}, -1/\sqrt{2}\}$. Denoting by y_k the k-th in-phase or quadrature received signal sample, the aim is to discriminate between the two hypotheses:

$$H_0 : y_k = n_k$$

$$H_1 : y_k = a_k \sqrt{E_s^{(k)}} + n_k \qquad \text{Equation (1)}$$

where $E_s^{(k)}$ represents the k-th received symbol energy, and n_k is an additive white Gaussian noise process with zero mean and variance $\sigma_n^2 = N_0/2$. The hypotheses H_0 and H_1 are assumed to have the same a priori probability Pr (H_0)=Pr(H_1)=1/2.

[0016] Let $\Lambda(y_k)$ indicate the quantity:

$$\Lambda(y_k) = \ln \frac{\Pr(H_1 \mid y_k)}{\Pr(H_0 \mid y_k)}. \qquad \text{Equation (2)}$$

[0017] A Bayes test based on the observation y_k selects hypothesis H_1 if $\Lambda(y_k)>0$, and H_0 if $\Lambda(y_k) < 0$. Modelling H_0 and H_1 in Equation (1) as the events $\{a_k = 0\}$ and $\{a_k = \pm 1/\sqrt{2}\}$, respectively, Equation (2) can be rewritten as:

$$\Lambda(y_k) = \ln \frac{\Pr(a_k = \pm 1/\sqrt{2} \mid y_k)}{\Pr(a_k = 0 \mid y_k)}. \qquad \text{Equation (3)}$$

[0018] Then, assuming Pr(H_0)=Pr(H_1)=1/2, $\Pr(a_k = +1/\sqrt{2} \mid H_1) = \Pr(a_k = -1/\sqrt{2} \mid H_1) = 1/2$ and applying Bayes' rule:

$$\Lambda(y_k) = \ln \frac{(1/2)p(y_k \mid a_k = +1/\sqrt{2}) + (1/2)p(y_k \mid a_k = -1/\sqrt{2})}{p(y_k \mid a_k = 0)}$$

$$= \ln \frac{1}{2} + \ln \frac{\exp[-(y_k - \sqrt{E_s^{(k)}}/\sqrt{2})^2/N_0] + \exp[-(y_k + \sqrt{E_s^{(k)}}/\sqrt{2})^2/N_0]}{\exp[-y_k^2/N_0]}$$

$$= -\frac{1}{2}\frac{E_s^{(k)}}{N_0} + \ln\cosh(\sqrt{2}y_k \frac{\sqrt{E_s^{(k)}}}{N_0}) \qquad \text{Equation (4)}$$

and we have the likelihood ratio test:

$$\ln\cosh(\sqrt{2}y_k \frac{\sqrt{E_s^{(k)}}}{N_0}) \gtrless \frac{1}{2}\frac{E_s^{(k)}}{N_0}. \qquad \text{Equation (5)}$$

[0019] To derive the Bayes test based on the observation set y = $\{y_0, y_1, ..., y_{N-1}\}$, in place of Equation (2) we define:

$$\Lambda(\mathbf{y}) = \ln \frac{\Pr(H_1 \mid y_0, y_1, \ldots, y_{N-1})}{\Pr(H_0 \mid y_0, y_1, \ldots, y_{N-1})} . \qquad \text{Equation (6)}$$

[0020] In this case, Equation (4) becomes:

$$\Lambda(\mathbf{y}) = \ln \frac{\prod_{k=0}^{N-1} [(1/2)p(y_k \mid a_k = +1/\sqrt{2}) + (1/2)p(y_k \mid a_k = -1/\sqrt{2})]}{\prod_{k=0}^{N-1} p(y_k \mid a_k = 0)}$$

$$= -\frac{1}{2} \sum_{k=0}^{N-1} \frac{E_s^{(k)}}{N_0} + \sum_{k=0}^{N-1} \ln\cosh(\sqrt{2} y_k \frac{\sqrt{E_s^{(k)}}}{N_0}) . \qquad \text{Equation (7)}$$

[0021] Therefore, the likelihood ratio test $\Lambda \gtrless 0$ can be implemented as:

$$\frac{1}{N} \sum_{k=0}^{N-1} \ln\cosh(\sqrt{2} y_k \frac{\sqrt{E_s^{(k)}}}{N_0}) \gtrless \frac{1}{2} \frac{E_s}{N_0} \qquad \text{Equation (8)}$$

where $E_s = (1/N) \sum_{k=0}^{N-1} E_s^{(k)}$, or equivalently, letting $L(y_k) = \sqrt{2} y_k \sqrt{E_s^{(k)}} / N_0$

$$\frac{1}{N} \sum_{k=0}^{N-1} \ln\cosh[L(y_k)] \gtrless \frac{1}{2} \frac{E_s}{N_0} . \qquad \text{Equation (9)}$$

[0022] Note that, in the case where each noise sample n_k is modelled as a Gaussian random variable with zero mean and variance $\sigma_{n(k)}^2 = N_0^{(k)} / 2$ (*non-stationary* noise process), the quantities E_s/N_0 and $L(y_k)$ of Equation (9) should be redefined as $E_s / N_0 = (1/N) \sum_{k=0}^{N-1} (E_s^{(k)} / N_0^{(k)})$ and $L(y_k) = \sqrt{2} y_k \sqrt{E_s^{(k)}} / N_0^{(k)}$ ..

[0023] The process of Equation (9) is the optimum process illustrated in Figure 2. To implement the optimum test (9), the receiver comprises a division function 30, which receives values of the received symbol energy $E_s^{(k)}$ and the estimated noise $N_0^{(k)}$ for each received sample from the power estimation block 10. The function 30 takes the ratio of these values for each sample and supplies them to estimation block 32 which provides an averaged ratio E_s/N_0 over *N* samples (observation interval). In this way, the estimation function 30 and average block 32 derive an estimate of the parameter E_s/N_0 over the observation interval *N*. (If the noise is stationary (i.e., if $N_0^{(k)} := N_0$), the received symbol energy $E_s^{(k)}$ is applied at the input of the average block 32. The output of block 32 and the estimated average noise N_0 are then input to the function 30, which finally provides the averaged ratio E_s/N_0.) The LLR calculation block 10 computes the log-likelihood ratios $L(y_k)$ from the samples $\{y_0, y_1, ..., y_{N-1}\}$ from the same observation interval. The LLR values $L(y_k)$ are passed through a nonlinearity ln cosh(·), function 38, which may be implemented by means of a look-up table. The detection metric on the left-hand side of Equation (9) can be then obtained by averaging in block 40 the output of the nonlinearity over the observation set.

[0024] The metric on the right hand side of Equation 9 can be determined by multiplying the summed ratio E_s / N_0 by the fixed value 1/2 using multiplier 34. The inequality can be then determined at block 36, which selects hypothesis H_0 or H_1.

[0025] For moderate to high signal-to-noise ratios, from Equation (7) we also write:

$$\Lambda(\mathbf{y}) = \sum_{k=0}^{N-1} \{\ln\frac{1}{2} - \frac{1}{2}\frac{E_s^{(k)}}{N_0} + \ln(\exp[L(y_k)] + \exp[-L(y_k)])\}$$

$$\approx N(\ln\frac{1}{2} - \frac{1}{2}\frac{E_s}{N_0}) + \sum_{k=0}^{N-1} |L(y_k)| \qquad \text{Equation (10)}$$

and the optimum test Equation (9) is approximated as:

$$\frac{1}{N}\sum_{k=0}^{N-1} |L(y_k)| \gtrless \frac{1}{2}\frac{E_s}{N_0} - \ln\frac{1}{2}. \qquad \text{Equation (11)}$$

[0026] More generally, the approximate test may be written as:

$$\frac{1}{N}\sum_{k=0}^{N-1} |L(y_k)| \gtrless \frac{1}{2}\frac{E_s}{N_0} + \eta \qquad \text{Equation (12)}$$

where η is a constant. Figure 3 illustrates the approximate test of equation 12. Like numerals in Figure 3 denote like parts as in Figure 2. In place of the lncosh(·) function 38, a modulus function 42 is applied to the LLRs $L(y_k)$. The summation block 40 sums the absolute values of the LLRs over the observation interval N and supplies the resulting values to selection block 36.

[0027] Instead of supplying the value $(1/2)E_s/N_0$ directly to the selection block 36, the value is summed at summer 44 with the value η. The quantity $|L(y_k)|+\ln(1/2)$ is a good approximation of $\ln\cosh[L(y_k)]$ for moderate to high values of E_s/N_0. At low E_s/N_0, however, $|L(y_k)|+\ln(1/2)$ is smaller than $\ln\cosh[L(y_k)]$. It is possible to see that, below a given value of E_s/N_0, the function $(1/N)\sum_{k=0}^{N-1} |L(y_k)| + \ln(1/2)$ is always smaller than $(1/2)E_s/N_0$ even in the presence of a transmitted signal. This behaviour reduces the range of signal-to-noise ratios over which it is possible to perform detection using the approximate test (Equation 11). In a 3GPP WCDMA system, this may degrade the receiver error performance at low signal-to-noise ratios, and it may affect the correct operation of the CPCH downlink fast power control. WCDMA downlink power control is based on an outer loop power control algorithm, which uses information on the number of successfully and unsuccessfully decoded DCH data blocks, determined by the pass or fail of the Cyclic Redundancy Check (CRC) that relies on parity bits appended to each data block before encoding. In the outer loop power control algorithm, CRC pass/fail is employed to control a target signal-to-interference ratio (SIR), according to the DCH quality (block-error rate) target set by the network. This SIR target is then used by the inner loop power control algorithm, to derive a power control command to be transmitted in the uplink, which requests an increase or decrease of the downlink DPCH power. CRC failures drive the SIR target upwards, so that the user equipment requests an increase of the transmitted power, in an effort to improve the error performance towards the target block-error rate. For this algorithm to function correctly, the transmitted blocks must be detected, regardless of whether they can subsequently be successfully decoded or not (CRC pass/fail). For low values of E_s/N_0, the use of the approximate test Equation (11) leads to consistent failures to detect blocks, which prevents the possibility of identifying unsuccessful decoding (CRC fail). As a consequence, the outer loop power control would be unable to drive an increase of the DPCH downlink power transmitted to the UE. To avoid this pathological situation, a suitable constant η in Equation (12) may be selected using select block 46 such that the detection range can be extended to low signal-to-noise ratios.

[0028] It is worth noting that the value of η chosen on the basis of the required detection range may degrade the probability of false alarm at higher signal-to-noise ratios. To circumvent this problem, η can be made a function of the measured E_s/N_0, for instance setting η to different constant values for different intervals of E_s/N_0. In this case, $\eta = \eta(E_s/N_0)$ may be chosen equal to -ln(1/2) for values of the measured E_s/N_0 greater than a suitable threshold.

[0029] In a WCDMA receiver, the quantity E_s/N_0 can be obtained from estimates of $E_s^{(k)}$ and $N_0^{(k)}$ derived from the DPCCH dedicated pilot symbols transmitted on each downlink DPCH slot. As shown in Figure 1, the set of LLRs $L(y_k)$ can be computed from the set of DPDCH signal samples $\{y_0, y_1, ..., y_{N-1}\}$, and the estimates of $E_s^{(k)}$ and $N_0^{(k)}$ for the slots in which each DPDCH symbol is received. The transport format detection algorithm then uses the set of $L(y_k)$ to derive the detection metric $(1/N)\sum_{k=0}^{N-1}|L(y_k)|$ of equation (12). Once $E_s^{(k)}$, $N_0^{(k)}$ and $L(y_k)$ have been calculated, the actual received DPCH samples are no longer needed for the algorithm.

[0030] For a WCDMA receiver, in the case where different code blocks are multiplexed and transmitted on the same DPCH physical channel, with the approach shown in Figure 1 the LLRs $L(y_k)$ to be used for transport format detection are collected per slot, before deinterleaving and code block demultiplexing. This requires the identification of the values y_k of the DPCH slot that correspond to the different code blocks. In this respect, it may be advantageous to collect the LLRs for transport format detection after deinterleaving and code block demultiplexing, as shown in Figure 4. The reason for this is that the LLRs represent the signal quality which is affected by transmission conditions. It is very likely to be the case therefore that a particular subset of adjacent samples (multiplexed from different channels) will nevertheless have similar LLRs which would be unrepresentative of later samples. By deinterleaving the channels before taking the LLR values, this ensures that the LLRs are randomly distributed so that an average of the first number of samples (for example 32) can be considered as representative of that block.

[0031] An additional advantage of the implementation of Figure 4 is that it allows a simple way to reduce complexity by estimating the detection metric of Equation (12) over a subset N' of the N LLR values of a given code block. In fact, since the LLRs are collected after deinterleaving, one can compute $(1/N')\sum_{k=0}^{N'-1}|L(y_k)|$, where $N' << N$ can be chosen in order not to appreciably affect the required detection performance.

[0032] The performance of the approximated test Equation (12) can be quantified in terms of probability of detection P_D and probability of false alarm P_F. Using the approximate detection measure $\gamma = (1/N)\sum_{k=0}^{N-1}|L(y_k)|$ and the detection threshold $\theta=(1/2)E_s/N_0 + \eta$, we write:

$$P_D = \int_{0}^{\infty} p(\gamma \mid H_1)d\gamma \qquad \text{Equation (13)}$$

$$P_F = \int_{0}^{\infty} p(\gamma \mid H_0)d\gamma \qquad \text{Equation (14)}$$

[0033] Since the number of observations N is usually relatively large, the function γ can be modelled as a Gaussian random variable. Under this assumption, letting $d_1 = E\{\gamma|H_1\}$ and $\sigma_1^2 = E\{(\gamma - E\{\gamma \mid H_1\})^2 \mid H_1\}$, we have:

$$P_D = \frac{1}{\sqrt{2\pi\sigma_1}} \int_{\theta}^{\infty} \exp[\frac{(\gamma - d_1)^2}{2\sigma_1^2}] d\gamma = \frac{1}{2} erfc(\frac{\theta - d_1}{\sqrt{2\sigma_1}}) \qquad \text{Equation (15)}$$

and letting $d_0 = E\{\gamma|H_0\}$ and $\sigma_0^2 = E\{(\gamma - E\{\gamma|H_0\})^2|H_0\}$

$$P_F = \frac{1}{\sqrt{2\pi\sigma_0}} \int_{\theta}^{\infty} \exp[\frac{(\gamma - d_0)^2}{2\sigma_0^2}] d\gamma = \frac{1}{2} erfc(\frac{\theta - d_0}{\sqrt{2\sigma_0}}) \; . \qquad \text{Equation (16)}$$

[0034] An example of the performance of the approximate test Equation (12) calculated using Equations (15) and (16) is shown in Figure 5 and Figure 6. The figures give the probability of detection P_D and probability of false alarm P_F as a function of the constant η of Equation (12), for different values of E_s/N_0. The curves of Figure 5 have been obtained computing Equation (15) and Equation (16) with N =10 and E_s/N_0 values from -3dB and 3dB, while Figure 6 assumes N =20 and E_s/N_0 from -9dB to -6dB. From the results of Figure 5, the modified algorithm Equation (12) gives values of 1-P_D and P_F below 2.10^{-4} for $E_s/N_0 \geq$ 0dB, using only N=10 observation samples. As shown in Figure 6, increasing the number of observations to N =20 one obtains probabilities 1-P_D and P_F below $2 \cdot 10^{-4}$ for $E_s/N_0 \geq$ -9dB.

[0035] The behaviour of the optimum and approximate detection algorithms Equation (9) and Equation (12) is compared in Figures 7-9. The curves have been obtained by generating the signal samples y_k under the hypotheses H_0 and H_1, with a noise power $N_0/2$=1/2 and for different values of average symbol energy E_s. The detection metrics of Equation (9), Equation (11) and Equation (12) have been computed for each sample y_k, and the results have been averaged over N =1000 observations.

[0036] In Figure 7, the optimum detection measure under hypotheses H_0 and H_1 is compared with the threshold (1/2) E_s/N_0, where in Figure 8 and Figure 9, the measure $(1/N)\sum_{k=0}^{N-1} | L(y_k) |$ is compared with the thresholds (1/2) E_s/N_0 -ln(1/2) and (1/2)E_s/N_0 +0.5, respectively. As shown in Figure 8, the modified test of Equation (11) without selectable constant η does not allow signal detection for E_s/N_0 < 0dB, where from Figure 9 using the constant η=0.5 in Equation (12) disables signal detection only for E_s/N_0 < -2dB, thus giving a wider range of signal-to-noise ratios over which the outer loop power control can correctly operate.

[0037] While the invention has been described in the context of the above-referenced embodiments, we appreciate that alternatives are possible and that the scope of this invention is limited only by the accompanying claims.

Claims

1. A method of processing transmissions in a wireless communication system to detect whether a transmission unit contains transmitted data, the method comprising:

   receiving a plurality of samples (y_k) of a transmission unit; and
   determining (32) an average signal-to-disturbance ratio of the plurality of samples; **characterised by**
   using reliability indicators determined for the samples to determine if the transmission unit contains transmitted data, by
   generating (38, 40) an average of ln cosh (·) values for the reliability indicators from the plurality of received samples; and
   applying a test (36) to compare the reliability indicator average with a factor proportional to the average signal-to-disturbance ratio.

2. A method according to claim 1, wherein the test is implemented using the following:

$$\frac{1}{N}\sum_{k=0}^{N-1}\ln\cosh[L(y_k)] \gtrless \frac{1}{2}\frac{E_s}{N_0},$$

where N is the number of samples, $L(y_k)$ is a reliability indicator for the kth sample, E_s/N_0 is the average signal to noise ratio.

3. A method of processing transmissions in a wireless communication system to detect whether a transmission unit contains transmitted data, the method comprising:

receiving a plurality of samples of a transmission unit;
determining (32) an average signal-to-disturbance ratio of the plurality of samples;
characterised by using reliability indicators determined for the samples to determine if the transmission unit contains transmitted data, by
generating (42, 40) an average of the absolute values of the reliability indicators from the plurality of received samples; and
applying a test (36) to compare the reliability indicator average with a value which is the sum of a factor proportional to the average signal-to-disturbance ratio and a selectable constant.

4. A method according to claim 3, wherein the test which is applied is as follows:

$$\frac{1}{N}\sum_{k=0}^{N-1}|L(y_k)| \gtrless \frac{1}{2}\frac{E_s}{N_0}+\eta,$$

where N is the number of samples, $L(y_k)$ is a reliability indicator for the kth sample, E_s/N_0 is the average signal to noise ratio and η is the selectable constant.

5. A method according to claim 3 or 4, where the constant η is selected based on the average signal-to-disturbance ratio.

6. A method according to claim 1, in which a plurality of channels are multiplexed in said transmission, and wherein the step of generating the average function of the reliability indicators is effected for the multiplexed transmission.

7. A method according to claim 1, wherein a plurality of channels are multiplexed in each transmission, the method comprising the step of demultiplexing said channels prior to the step of generating an average function of the reliability indicators, wherein said average function is generated for each channel.

8. A system for processing transmissions in a digital communications system to detect whether a transmission unit contains transmitted data, the system comprising:

means for receiving a plurality of samples of a transmission unit; and
means (32) for determining an average signal-to-disturbance ratio over the plurality of samples; **characterised by**
means for using reliability indicators determined from the samples to determine if a transmission unit contains transmitted data, comprising:

means (38, 40) for generating an average of ln cosh (·) values for the reliability indicators determined from the plurality of received samples; and
means (36) for applying a test to compare the reliability indicator average with a factor proportional to the average signal-to-disturbance ratio.

9. A system for processing transmissions in a digital communications system to detect whether a transmission unit contains transmitted data, the system comprising:

means for receiving a plurality of samples of a transmission unit;
means (32) for determining an average signal-to-disturbance ratio over the plurality of samples; **characterised by**
means (12) for using reliability indicators determined for the samples to determine if a transmission unit contains transmitted data, comprising:

means (42, 40) for generating an average of the absolute values of the reliability indicators of the bit reliability indicators from the plurality of received samples; and
means (36) for applying a test to compare the reliability indicator average with a value which is a sum of a factor proportional to the average signal to disturbance ratio and a selectable constant.

10. A system according to claim 8 or 9, wherein the means for receiving a plurality of samples comprises a radio frequency receiver arranged to receive an analogue wireless signal and to convert said analogue wireless signal into said plurality of samples.

11. A system according to claim 10, wherein said means for receiving a plurality of samples comprises means for demultiplexing and deinterleaving a plurality of channels from a transmission in which a plurality of channels are multiplexed, said plurality of samples being derived from each said channel prior to the step of generating an average function of the reliability indicators.

12. A system according to claim 10, wherein said means for generating an average function of the reliability indicator is adapted to operate on a transmission in which a plurality of channels are multiplexed.

13. A system according to claim 8 or 9, which is a wide band code division multiple access system.

14. A system according to claim 8 or 9, comprising means for generating a signal estimate and a disturbance estimate from pilot symbols.

15. A system according to claim 9, comprising means for selecting the selectable constant based on the average signal-to-disturbance ratio.

16. A computer readable media comprising a computer program having a sequence of instructions which when executed by a computer implement a method of processing transmissions in a wireless communications system, the method in accordance with any of claims 1 to 7.

Patentansprüche

1. Ein Verfahren zum Verarbeiten von Übertragungen in einem drahtlosen Kommunikationssystem, um zu erfassen, ob eine Übertragungseinheit übertragene Daten enthält, wobei das Verfahren umfasst:

Empfangen einer Mehrzahl von Datensätzen (y_k) einer Übertragungseinheit;
Bestimmen (32) eines durchschnittlichen Signal-Störungs-Verhältnisses der Mehrzahl von Datensätzen; **gekennzeichnet durch**
Verwenden von Zuverlässigkeitsindikatoren, die für die Datensätze bestimmt werden, um zu bestimmen, ob die Übertragungseinheit übertragene Daten enthält, **durch**
Generieren (38, 40) eines Durchschnitts von In cosh (·) Werten für die Zuverlässigkeitsindikatoren aus der Mehrzahl empfangener Datensätze; und
Anwenden eines Tests (36) für den Vergleich des Zuverlässigkeitsindikatordurchschnitts mit einem Faktor, der zu dem durchschnittlichen Signal-Störungs-Verhältnis proportional ist.

2. Ein Verfahren nach Anspruch 1, wobei der Test unter Verwendung des folgenden implementiert wird:

$$\frac{1}{N}\sum_{k=0}^{N-1}\ln\cosh[L(y_k)] \gtrless \frac{1}{2}\frac{E_s}{N_0},$$

wobei N die Zahl der Datensätze ist, $L(y_k)$ ein Zuverlässigkeitsindikator für den $k$ten Datensatz ist, E_s/N_0 das durchschnittliche Signal/Rauschverhältnis ist.

3. Ein Verfahren zum Verarbeiten von Übertragungen in einem drahtlosen Kommunikationssystem, um zu erfassen, ob eine Übertragungseinheit übertragene Daten enthält, wobei das Verfahren umfasst:

Empfangen einer Mehrzahl von Datensätzen einer Übertragungseinheit;
Bestimmen (32) eines durchschnittlichen Signal/Störungsverhältnisses der Mehrzahl von Datensätze;
gekennzeichnet durch Verwenden von Zuverlässigkeitsindikatoren, die für die Datensätze bestimmt werden, um zu bestimmen, ob die Übertragungseinheit übertragene Daten enthält, **durch**
Generieren (42, 40) eines Durchschnitts der Absolutwerte der Zuverlässigkeitsindikatoren aus der Mehrzahl empfangener Datensätze; und
Anwenden eines Tests (36), um den Durchschnitt des Zuverlässigkeitsindikators mit einem Wert zu vergleichen, welcher die Summe aus einem zu dem durchschnittlichen Signal/Störungsverhältnis proportionalen Faktor und einer auswählbaren Konstante ist.

4. Ein Verfahren nach Anspruch 3, wobei der Test, der angewandt wird, wie folgt ist:

$$\frac{1}{N}\cdot\sum_{k=0}^{N-1}|L(y_k)| \gtrless \frac{1}{2}\frac{E_s}{N_0}+\eta,$$

wobei N die Zahl der Datensätze ist, $L(y_k)$ ein Zuverlässigkeitsindikator für den $k$ten Datensatz ist, E_s/N_0 das durchschnittliche Signal/Rauschverhältnis ist und η eine auswählbare Konstante ist.

5. Ein Verfahren nach Anspruch 3 oder 4, wobei die Konstante η auf der Basis des durchschnittlichen Signal/Störungsverhältnisses ausgewählt wird.

6. Ein Verfahren nach Anspruch 1, bei dem eine Mehrzahl von Kanälen in der Übertragung gemultiplext wird, und wobei der Schritt des Generierens der Durchschnittsfunktion der Zuverlässigkeitsindikatoren für die gemultiplexte Übertragung durchgeführt wird.

7. Ein Verfahren nach Anspruch 1, wobei eine Mehrzahl von Kanälen in jeder Übertragung gemultiplext wird, wobei das Verfahren den Schritt des Demultiplexens der Kanäle vor dem Schritt der Generierung einer Durchschnittsfunktion der Zuverlässigkeitsindikatoren umfasst, wobei die Durchschnittsfunktion für jeden Kanal generiert wird.

8. Ein System zur Verarbeitung von Übertragungen in einem digitalen Kommunikationssystem, um zu erfassen, ob eine Obertragungseinheit übertragene Daten enthält, wobei das System umfasst:

Mittel zum Empfangen einer Mehrzahl von Datensätzen einer Übertragungseinheit;
Mittel (32) zum Bestimmen eines durchschnittlichen Signal/Störungsverhältnisses über die Mehrzahl von Datensätzen; **gekennzeichnet durch**
Mittel zum Verwenden von Zuverlässigkeitsindikatoten, die für die Datensätze bestimmt werden, um zu bestimmen, ob die Übertragungseinheit übertragene Daten enthält,
Mittel (38, 40) zum Generieren eines Durchschnitts von In cosh (·) Werten für die Zuverlässigkeitsindikatoren, die aus der Mehrzahl empfangener Datensätze bestimmt werden; und
Mittel (36) zum Anwenden eines Tests für den Vergleich des Zuverlässigkeitsindikatordurchschnitts mit einem Faktor, der zu dem durchschnittlichen Signal/Störungsverhältnis proportional ist.

9. Ein System zum Verarbeiten von Übertragungen in einem digitalen Kommunikationssystem, um zu erfassen, ob eine Übertragungseinheit übertragene Daten enthält, wobei das System umfasst:

Mittel zum Empfangen einer Mehrzahl von Datensätzen einer Übertragungseinheit;
Mittel (32) zum Bestimmen eines durchschnittlichen Signal/ Störungsverhältnisses über die Mehrzahl von Datensätzen; **gekennzeichnet durch**
Mittel (12) zum Verwenden von Zuverlässigkeitsindikatoren, die für die Datensätze bestimmt werden, um zu

bestimmen, ob die Übertragungseinheit übertragene Daten enthält, umfassend:

Mittel (42, 40) zum Generieren eines Durchschnitts der Absolutwerte der Zuverlässigkeitsindikatoren der Bit-Zuverlässigkeitsindikatoren aus der Mehrzahl empfangener Datensätze; und
Mittel (36) zum Anwenden eines Tests, um den Zuverlässigkeitsindikatordurchschnitt mit einem Wert zu vergleichen, weicher eine Summe eines Faktors, der proportional zu dem durchschnittlichen Signal/ Störungsverhältnis ist, und einer auswählbaren Konstante ist.

10. Ein System nach Anspruch 8 oder 9, wobei die Mittel zum Empfangen einer Mehrzahl von Datensätzen einen Radiofrequenzempfänger aufweisen, der dazu vorgesehen ist, ein analoges drahtloses Signal zu empfangen und das analoge drahtlose Signal in die Mehrzahl von Datensätzen zu konvertieren.

11. Ein System nach Anspruch 10, wobei die Mittel zum Empfangen einer Mehrzahl von Datensätzen Mittel zum Demultiplexen und Entschachteln einer Mehrzahl von Kanälen aus einer Übertragung aufweisen, bei welcher mehrere Kanäle gemultiplext sind, wobei die mehreren Datensätze von jedem der Kanäle vor dem Schritt der Generierung einer Durchschnittsfunktion der Zuverlässigkeitsindikatoren abgeleitet werden.

12. Ein System nach Anspruch 10, wobei die Mittel zum Generieren einer Durchschnittsfunktion des Zuverlässigkeitsindikators dazu angepasst sind, an einer Transmission zu arbeiten, in welcher mehrere Kanäle gemultiplext sind.

13. Ein System nach Anspruch 8 oder 9, welches ein Breitband-Codedivisions-Mehrfachzugriffssystem ist.

14. Ein System nach Anspruch 8 oder 9, mit Mitteln zum Generieren einer Signalschätzung und einer Störungsschätzung aus Pilotsymbolen.

15. Ein System nach Anspruch 9, mit Mitteln zum Auswählen der auswählbaren Konstante auf der Basis des durchschnittlichen Signal/ Störungsverhältnisses.

16. Ein Computer lesbares Medium mit einem Computerprogramm, welches eine Befehlssequenz aufweist, die, wenn sie durch einen Computer ausgeführt wird, ein Verfahren zum Verarbeiten von Übertragungen in einem drahtlosen Kommunikationssystem implementiert, wobei das Verfahren einem der Ansprüche 1 bis 7 entspricht.

Revendications

1. Procédé de traitement de transmissions dans un système de communication sans fil destiné à détecter si une unité de transmission contient des données transmises, le procédé comprenant :

la réception d'une pluralité d'échantillons (y_k) d'une unité de transmission ; et
la détermination (32) d'un rapport signal sur perturbation moyen de la pluralité d'échantillons ; **caractérisé par** :

l'utilisation d'indicateurs de fiabilité déterminés pour les échantillons, afin de déterminer si l'unité de transmission contient des données transmises, en
générant (38, 40) une moyenne des valeurs ln cosh (.) pour les indicateurs de fiabilité à partir de la pluralité d'échantillons reçus ; et
l'application d'un test (36) pour comparer l'indicateur de fiabilité moyen avec un facteur proportionnel au rapport signal sur perturbation moyen.

2. Procédé selon la revendication 1, dans lequel le test est mis en oeuvre en utilisant la relation suivante :

$$\frac{1}{N}\sum_{k=0}^{N-1}\ln\cosh[L(y_k)] \gtrless \frac{1}{2}\frac{E_s}{N_0},$$

où N est le nombre d'échantillons, $L(y_k)$ est un indicateur de fiabilité pour le $k^{\text{-ième}}$ échantillon, E_s/N_0 est le rapport signal sur bruit moyen.

3. Procédé de traitement de transmissions dans un système de communication sans fil destiné à détecter si une unité de transmission contient des données transmises, le procédé comprenant :

la réception d'une pluralité d'échantillons d'une unité de transmission ;
la détermination (32) d'un rapport signal sur perturbation moyen de la pluralité d'échantillons ;
caractérisé par l'utilisation d'indicateurs de fiabilité déterminés pour les échantillons, afin de déterminer si l'unité de transmission contient des données transmises, en
générant (42, 40) une moyenne des valeurs absolues des indicateurs de fiabilité à partir de la pluralité d'échantillons reçus ; et
l'application d'un test (36) pour comparer l'indicateur de fiabilité moyen avec une valeur qui est la somme d'un facteur proportionnel au rapport signal sur perturbation moyen et d'une constante sélectionnable.

4. Procédé selon la revendication 3, dans lequel le test qui est appliqué est comme suit :

$$\frac{1}{N}\sum_{k=0}^{N-1}|L(y_k)| \gtrless \frac{1}{2}\frac{E_s}{N_0}+\eta,$$

où N est le nombre d'échantillons, $L(y_k)$ est un indicateur de fiabilité pour le $k^{\text{-ième}}$ échantillon, E_s/N_0 est le rapport signal sur bruit moyen et η est la constante sélectionnable.

5. Procédé selon la revendication 3 ou 4, dans lequel la constante η est sélectionnée sur la base du rapport signal sur perturbation moyen.

6. Procédé selon la revendication 1, dans lequel une pluralité de canaux sont multiplexés dans ladite transmission, et dans lequel l'étape de génération de la fonction moyenne des indicateurs de fiabilité est effectuée pour la transmission multiplexée.

7. Procédé selon la revendication 1, dans lequel une pluralité de canaux sont multiplexés dans chaque transmission, le procédé comprenant l'étape de démultiplexage desdits canaux avant l'étape de génération d'une fonction moyenne des indicateurs de fiabilité, ladite fonction moyenne étant générée pour chaque canal.

8. Système de traitement de transmissions dans un système de communication numérique destiné à détecter si une unité de transmission contient des données transmises, le système comprenant :

un moyen pour recevoir une pluralité d'échantillons d'une unité de transmission ; et
un moyen (32) pour déterminer un rapport signal sur perturbation moyen sur la pluralité d'échantillons ; **caractérisé par**
un moyen pour utiliser des indicateurs de fiabilité déterminés à partir des échantillons, afin de déterminer si une unité de transmission contient des données transmises, comprenant :

un moyen (38, 40) pour générer une moyenne des valeurs ln cosh (.) pour les indicateurs de fiabilité déterminés à partir de la pluralité d'échantillons reçus ; et
un moyen (36) pour appliquer un test afin de comparer l'indicateur de fiabilité moyen avec un facteur proportionnel au rapport signal sur perturbation moyen.

9. Système de traitement de transmissions dans un système de communication numérique destiné à détecter si une unité de transmission contient des données transmises, le système comprenant :

un moyen pour recevoir une pluralité d'échantillons d'une unité de transmission ;
un moyen (32) pour déterminer un rapport signal sur perturbation moyen sur la pluralité d'échantillons ; **caractérisé par**
un moyen (12) pour utiliser les indicateurs de fiabilité déterminés pour les échantillons, afin de déterminer si

une unité de transmission contient des données transmises, comprenant :

un moyen (42, 40) pour générer une moyenne des valeurs absolues des indicateurs de fiabilité des indicateurs de fiabilité de bits à partir de la pluralité d'échantillons reçus ; et
un moyen (36) pour appliquer un test afin de comparer l'indicateur de fiabilité moyen avec une valeur qui est une somme d'un facteur proportionnel au rapport signal sur perturbation moyen et d'une constante sélectionnable.

10. Système selon la revendication 8 ou 9, dans lequel le moyen pour recevoir une pluralité d'échantillons comprend un récepteur de radiofréquence agencé pour recevoir un signal sans fil analogique et pour convertir ledit signal sans fil analogique en ladite pluralité d'échantillons.

11. Système selon la revendication 10, dans lequel ledit moyen pour recevoir une pluralité d'échantillons comprend un moyen pour démultiplexer et désentrelacer une pluralité de canaux d'une transmission dans laquelle une pluralité de canaux sont multiplexés, ladite pluralité d'échantillons étant déduits de chaque dit canal avant l'étape de génération d'une fonction moyenne des indicateurs de fiabilité.

12. Système selon la revendication 10, dans lequel ledit moyen pour générer une fonction moyenne de l'indicateur de fiabilité est conçu pour agir sur une transmission dans laquelle une pluralité de canaux sont multiplexés.

13. Système selon la revendication 8 ou 9, qui est un système d'accès multiple par répartition en code à large bande.

14. Système selon la revendication 8 ou 9, comprenant un moyen pour générer une estimation de signal et une estimation de perturbation à partir de symboles pilotes.

15. Système selon la revendication 9, comprenant un moyen pour sélectionner la constante sélectionnable sur la base du rapport signal sur perturbation moyen.

16. Support lisible par un ordinateur comprenant un programme d'ordinateur comportant une séquence d'instructions qui, lorsqu'elles sont exécutées par un ordinateur, exécutent un procédé de traitement de transmissions dans un système de communication sans fil, le procédé étant selon l'une quelconque des revendications 1 à 7.

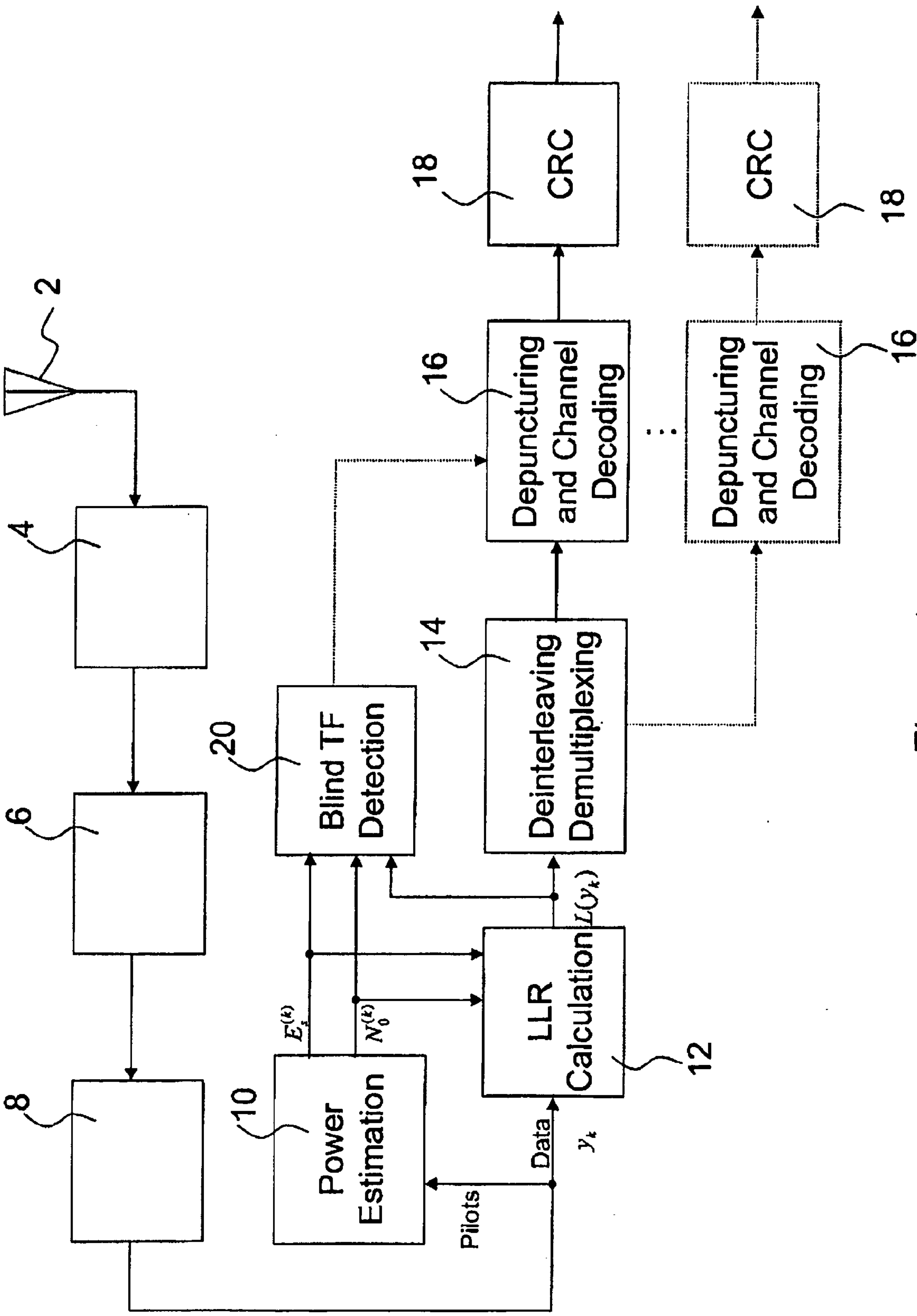

2
4
6
8
10
Power Estimation
Pilots
Data
y_k
$E_s^{(k)}$
$N_0^{(k)}$
12
LLR Calculation
$L(y_k)$
20
Blind TF Detection
14
Deinterleaving Demultiplexing
16
Depuncturing and Channel Decoding
16
Depuncturing and Channel Decoding
18
CRC
18
CRC

Figure 1

OPTIMUM DETECTION eq.(9)

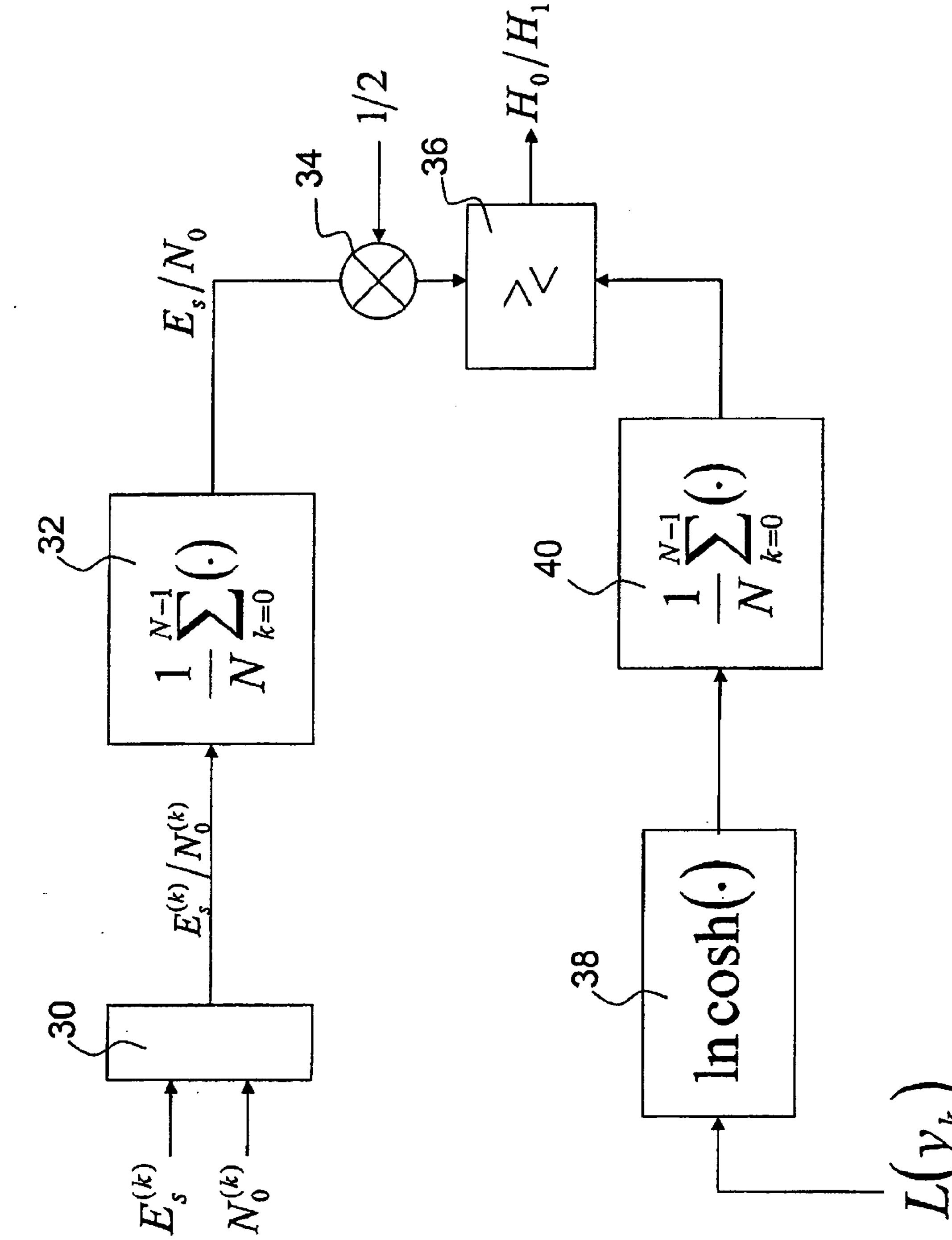


Figure 2

APPROXIMATE DETECTION eq.(12)

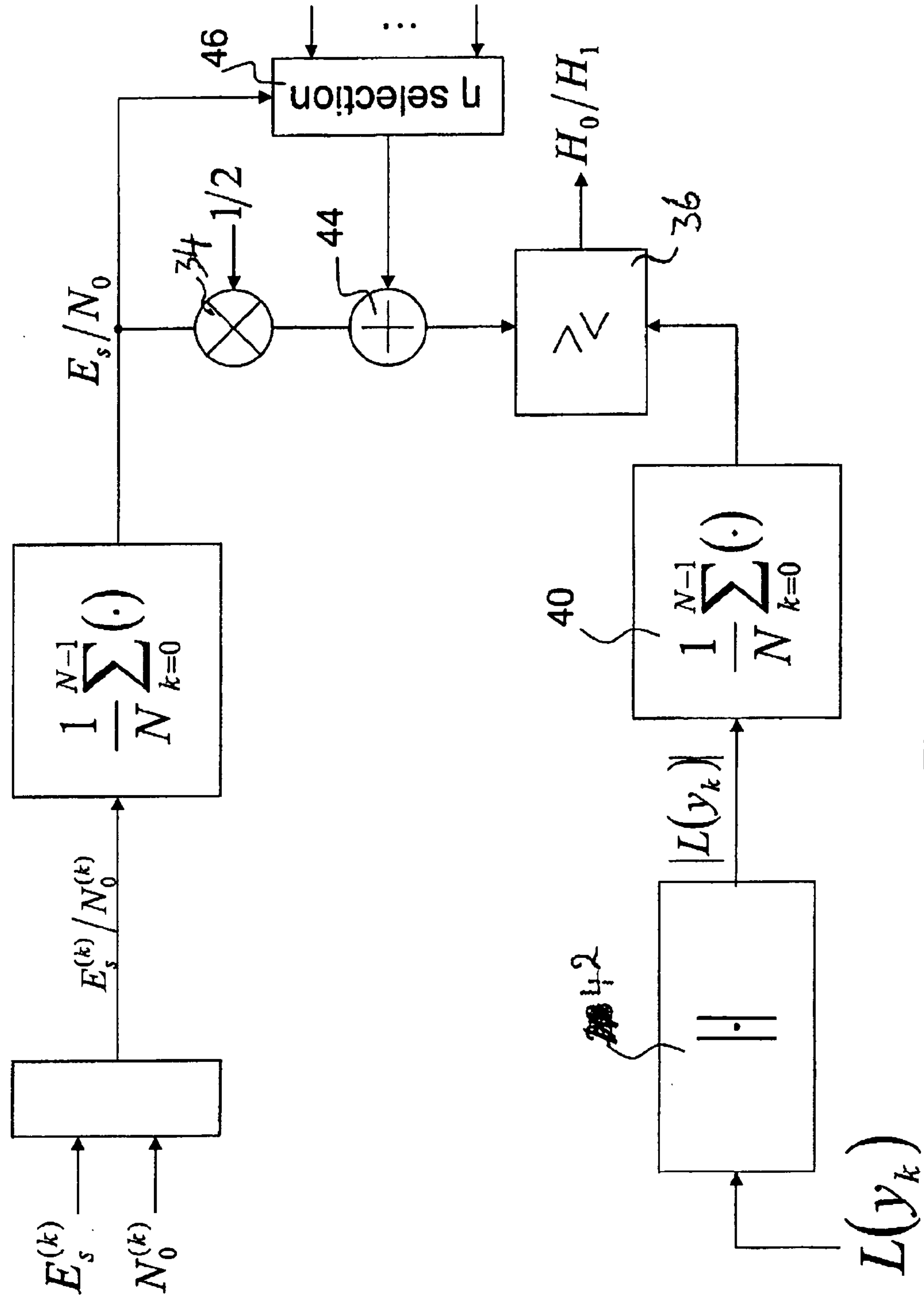
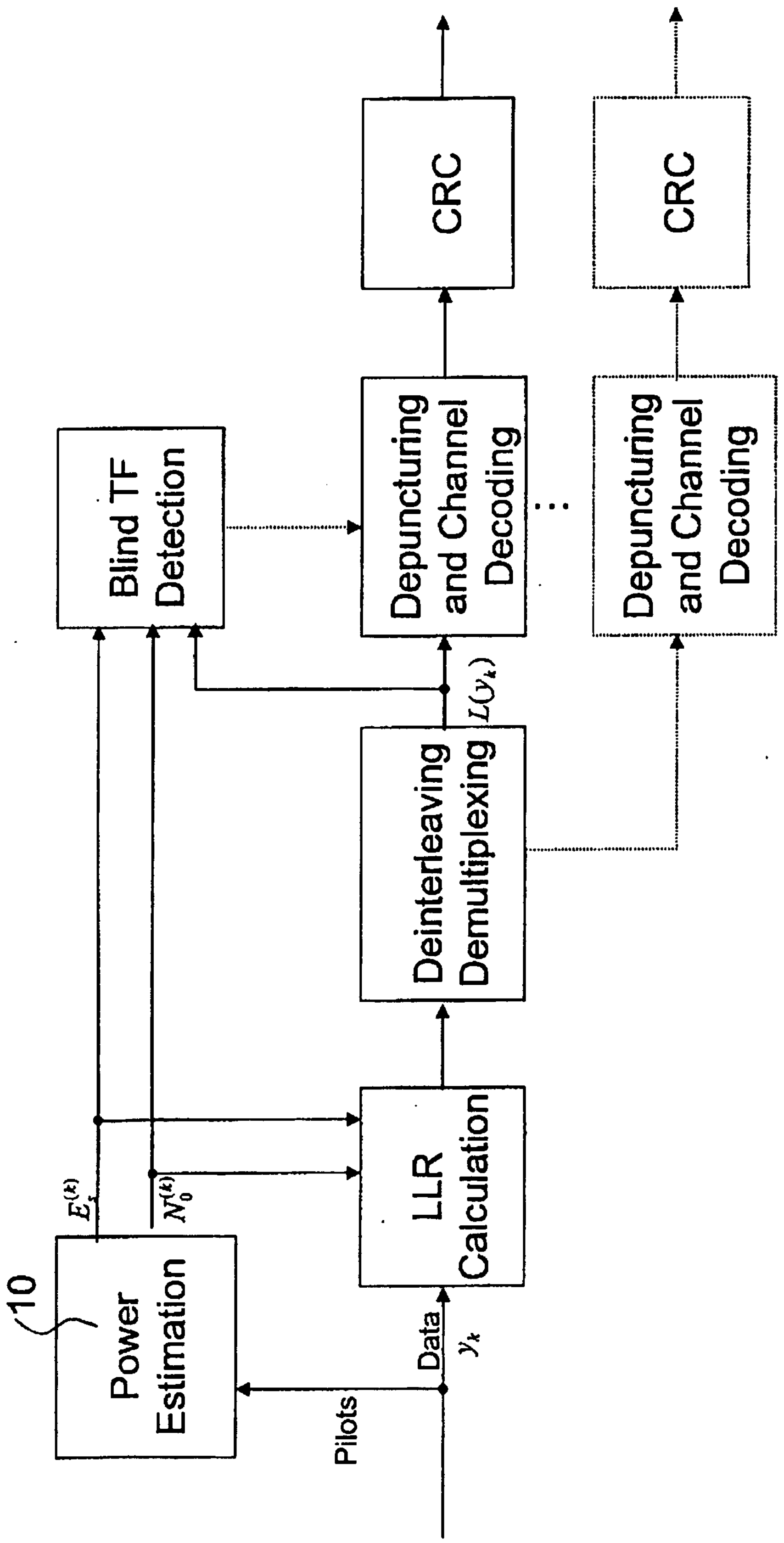


Figure 3



10
Power Estimation
Pilots
Data
y_k
$E_s^{(k)}$
$N_0^{(k)}$
LLR Calculation
Deinterleaving Demultiplexing
$L(y_k)$
Blind TF Detection
Depuncturing and Channel Decoding
Depuncturing and Channel Decoding
CRC
CRC

Figure 4

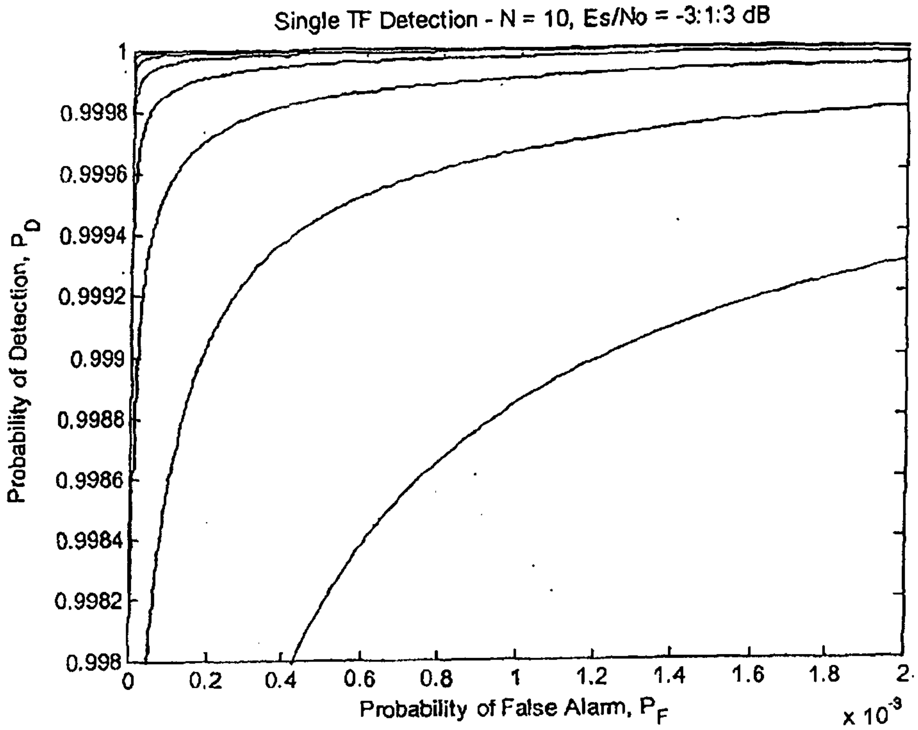


Figure 5

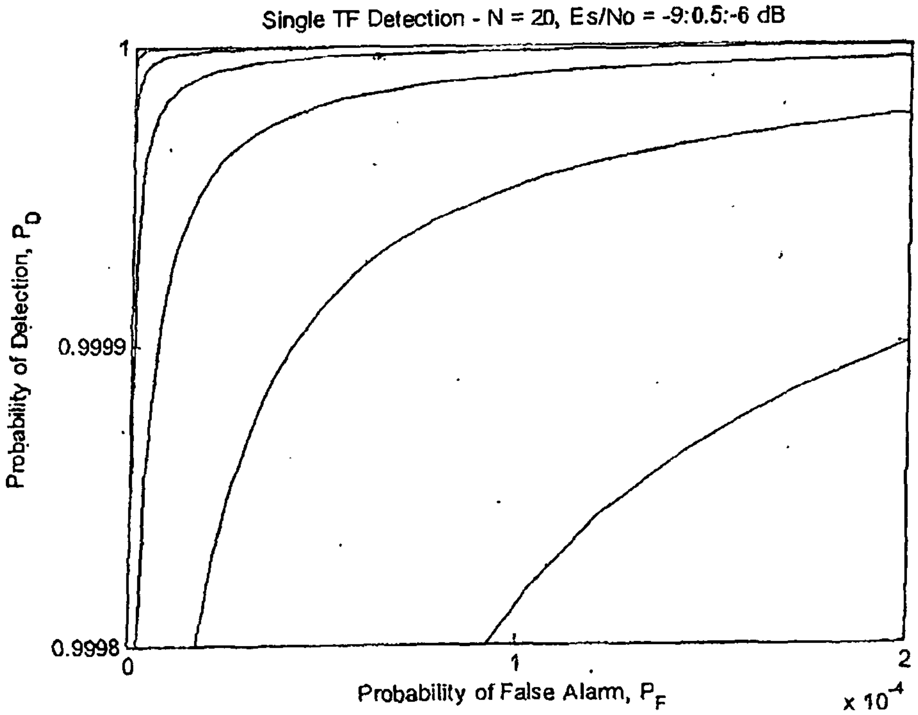


Figure 6

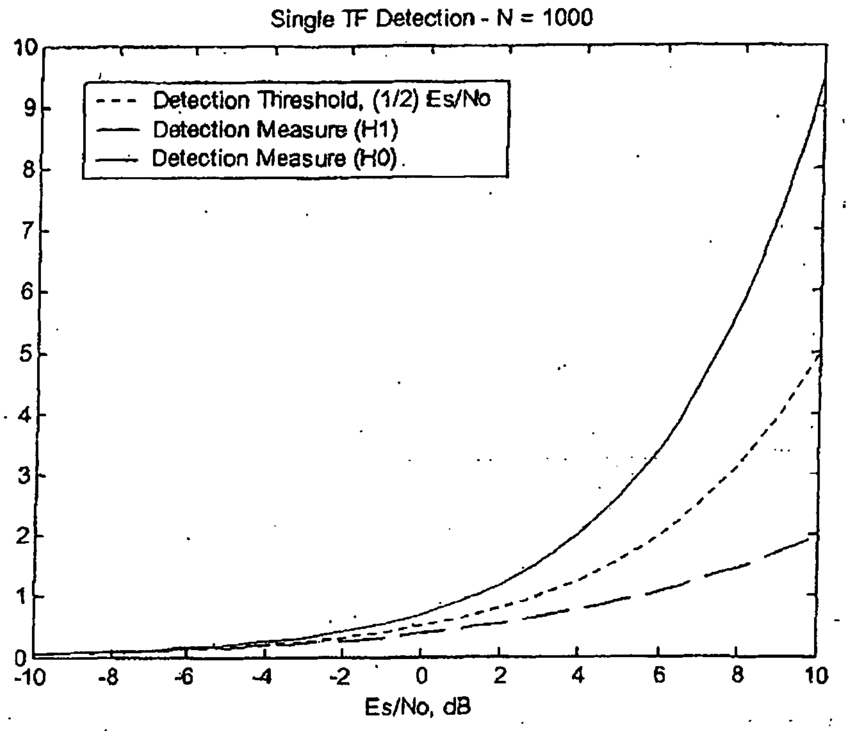

Single TF Detection - N = 1000
Detection Threshold, (1/2) Es/No
Detection Measure (H1)
Detection Measure (H0)
10
9
8
7
6
5
4
3
2
1
0
-10
-8
-6
-4
-2
0
2
4
6
8
10
Es/No, dB

Figure 7

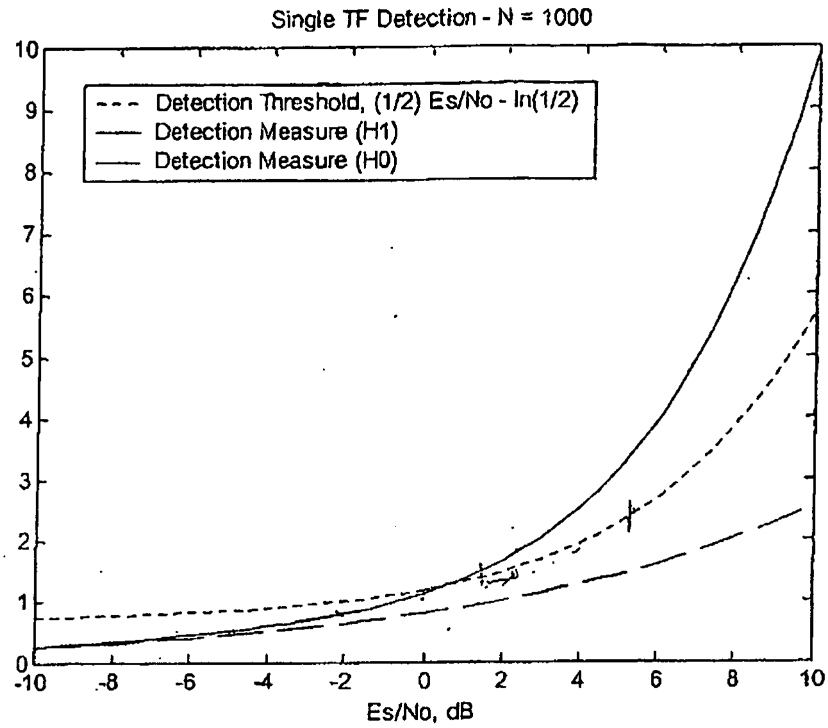


Figure 8

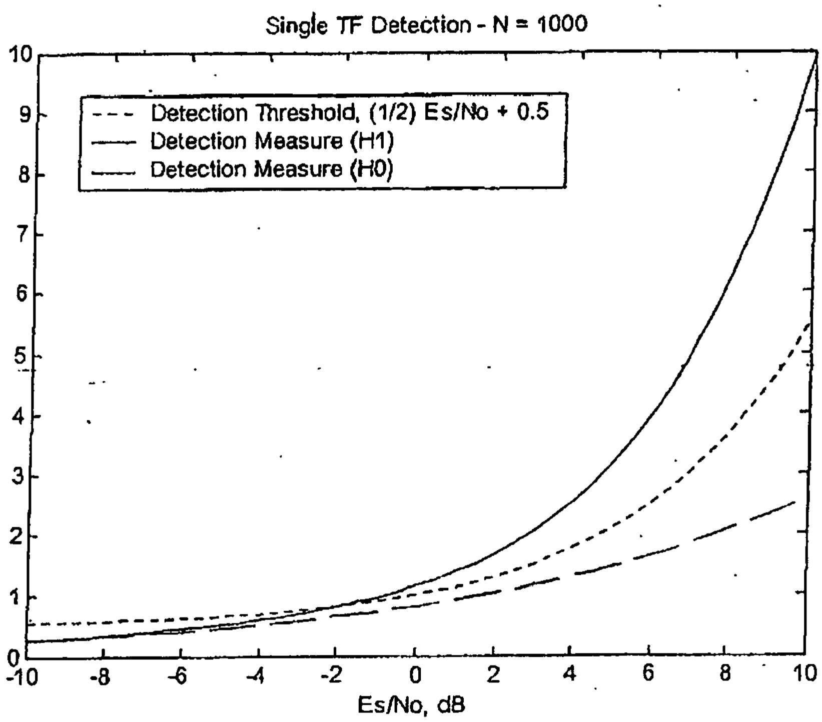


Figure 9

REFERENCES CITED IN THE DESCRIPTION

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