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(71) Applicant (*for all designated States except US*): DANCALL TELECOM A/S [DK/DK]; P.O. Box 106, DK-9490 Pandrup (DK).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): KNUDSEN, Jasper, B. [DK/DK]; Rømøgade 5, 4. tv., DK-9000 Aalborg (DK). KÖNNE, Leif [DK/DK]; Kornelparken 270, Grindsted, DK-9310 Vodskov (DK).

(74) Agent: HOFMAN-BANG & BOUTARD, LEHMANN & REE A/S; Adelgade 15, DK-1304 Copenhagen K (DK).

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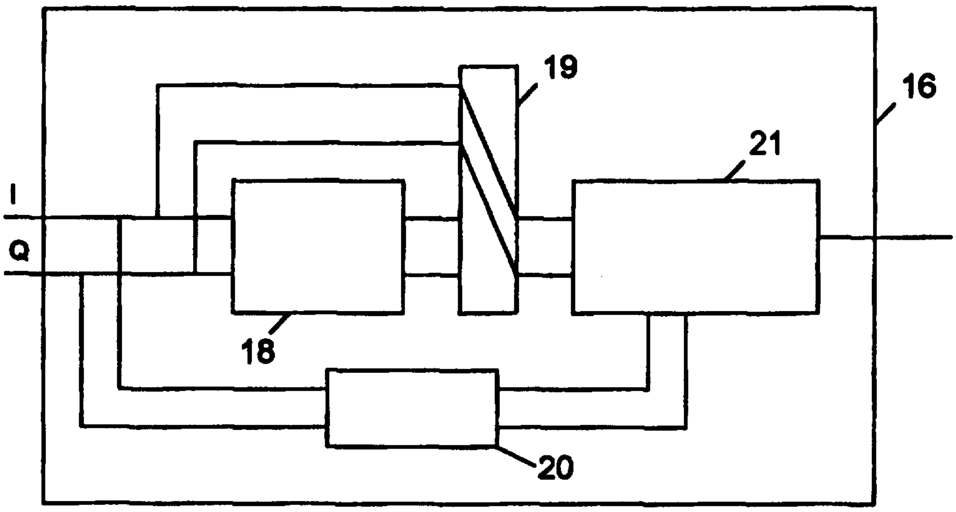

(57) Abstract

A demodulator (16) for use in a receiver for transmission systems is adapted to demodulate received signals according to a coherent principle in a first mode and to demodulate received signals according to a non-coherent principle in a second mode. The demodulator comprises a differential detector (18), an equalizer (21) and a switch (19) adapted to couple the received signals directly to the equalizer (21) in the first mode of the demodulator and to couple the received signals to the equalizer (21) via the differential detector (18) in the second mode of the demodulator.

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A demodulator for transmission systems and use of such a demodulator

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The invention concerns a demodulator for use in a receiver for transmission systems and adapted to demodulate received signals according to a coherent principle in a first mode and to demodulate received signals according to a non-coherent principle in a second mode.

It is well-known that when communicating over a mobile channel, such as e.g. in a mobile telephone system, the signal is subjected to various influences affecting amplitude and phase between transmitter and receiver. Such influences include distortion which occurs because of multipath propagation of the transmitted signal. The situation is further aggravated by the fact that the distortion constantly changes when the mobile unit moves. It is therefore necessary that so-called channel equalization on the received signal can take place in the receiver. This channel equalization is performed to equalize the distortion which may have taken place partly in the transmission channel itself and partly in the radio frequency receiver. Examples of transmission systems of the said type include mobile telephone systems, e.g. of GSM or DCS/PCS type, and transmission systems of DECT type.

Said channel equalization may be performed using a plurality of known equalization principles. These equalization or demodulation principles may be divided into coherent and non-coherent ones. In some transmission systems, such as e.g. the GSM or DCS/PCS types, the reference frequency of the receiver is so precise compared to the reference oscillator in the corresponding transmitter that it is possible to use a so-called coherent transmitter for equalizing the received signal. This receiver type requires that frequency and phase of the carrier wave of the received signal are known and constant for a given block of received data.

In other transmission systems, such as e.g. DECT, however, the reference frequency is not, or not always, so precise from the transmitter side that the receiver can use the coherent principle, it being therefore necessary to use a so-called non-coherent principle. The receiver does not know the exact frequency and phase of the received data block and moreover cannot expect that frequency and shape are constant through a whole data block. Receivers of the non-coherent type are usually not resistant to multipath propagation, which results in impaired quality of the data signals received.

The ever increasing use of the various transmission systems creates a need for terminals or base stations which are capable of receiving and transmitting data information by means of several different transmission systems. If, e.g., it is desired to have a terminal capable of receiving and transmitting data information partly in one of the transmission systems allowing coherent demodulation, partly in one of the systems without this facility, it has previously been necessary to provide the terminal with two complete receivers, viz. one operating according to the coherent principle, and one operating according to the non-coherent principle. This means that it is difficult to make such terminals suitably small and easy to handle, and also adds considerably to the costs of these terminals. For base stations as well as terminals it may moreover be difficult to obtain a suitable combination of price and implementation complexity.

Such a receiver is known from IEEE Transactions on Communications, Vol. 42, No. 7, July 1994, Upamanyu Madhow et al., "Universal Receivers with Side Information from the Demodulators: An Example for Nonselective Rician Fading Channels".

US Patent Specification 4 583 048 discloses a receiver wherein, in a coherent system, a training sequence is demodulated non-coherently at the start of each block to enable adjustment of the phase, so that the rest of the block may be demodulated coherently. However, this is merely done to ensure that the coherent demodulation can take place, and the receiver is not capable of demodulating signals which can just be demodulated non-coherently.

The invention provides a demodulator which, by means of the same hardware, is capable of receiving data information and demodulating these according to the coherent principle and the non-coherent principle, respectively. Thus, it is a so-called multimode receiver which will be considerably cheaper to manufacture than a receiver containing two separate receiver circuits. Further, the receiver will have a considerably higher quality in certain physical surroundings for the transmission systems which cannot (or not always) use coherent demodulation, and in these situations a longer range of the receiver is moreover achieved.

This is achieved according to the invention in that the demodulator comprises a differential detector, an equalizer and a switch adapted to couple the received signals directly to the equalizer in the first mode of the demodulator and to couple the received signals to the equalizer via the differential detector in the second mode of the demodulator.

The use of such a configuration ensures that just a small part of the receiver circuit need be different for the two transmission systems, while all the rest of the receiver circuit may be used for both systems. As mentioned, it is contemplated either that the receiver can receive data information by means of two different transmission systems, or that, in a system where the received signals are not always sufficiently good for demodulation to take place according to the coherent principle, the receiver can demodulate according to the coherent principle when this is possible and switch to the non-coherent principle when coherent demodulation is not possible.

In an embodiment of the invention, which is described in claim 2, the demodulator is adapted to receive data which are transmitted in blocks of finite length, each said block containing a training sequence which is known beforehand by the receiver, and the equalizer here comprises a Viterbi equalizer.

When, as stated in claim 3, the demodulator is adapted to receive data signals from various transmission systems in each of the said modes, it is ensured, as mentioned, that the same receiver can serve as a receiver on two or more different transmission systems. An expedient embodiment of this receiver is adapted to receive data signals associated with transmission systems using modulation forms of MSK type, since this is a widely used modulation form.

For example, as stated in claim 5, the demodulator may be adapted to receive data signals associated with a mobile telephone system of e.g. GSM or DCS/PCS type in the first mode, i.e. when the demodulator operates as a coherent demodulator. Further, as stated in claim 6, the demodulator may be adapted to receive data signals associated with e.g. a transmission system of DECT type in the second mode, i.e. when the demodulator operates as a non-coherent demodulator. Owing to the extensive use of these transmission types a receiver capable of receiving signals of these types will be extremely expedient.

In the situation where the receiver is to receive data signals from two or more different transmission systems, it will be expedient that, as stated in claim 7, the demodulator is arranged such that switching between coherent and non-coherent demodulation is controlled by signals received from the transmitter side of the transmission system, so that it is the received signal type which decides whether coherent or non-coherent demodulation takes place.

When, as stated in claim 8, switching between coherent and non-coherent demodulation is controlled by means of a detector capable of detecting whether the received signals are suitable for coherent demodulation, it is ensured that the receiver itself decides on the basis of the quality of the received signals whether to use coherent or non-coherent demodulation. This may be relevant either if the signal quality from the transmitter varies, or where transmitters having a sufficient quality for coherent demodulation to be used in the receivers as well as transmitters which do not meet this requirement, are used within the same system.

The use of the said demodulator in a mobile telephone system of e.g. GSM or DCS/PCS type, as stated in claim 9, ensures that such receivers can have an even more universal application, since they will also be capable of receiving data signals which are transmitted on other systems. The same is achieved when the receiver, as stated in claim 10, is used in a transmission system of DECT type, since this system will be widely used also in future. Here, even the quality will be improved, since receivers for this system usually do not have such a high quality as is required in the systems using coherent demodulation.

The invention will be explained more fully below with reference to the drawing, in which

fig. 1 shows two transmitters of different type and a receiver in which the invention may be applied,

fig. 2 shows the structure of a data receiver,

fig. 3 shows an example of a differential detector,

fig. 4 shows an example of a time discrete channel model,

fig. 5 shows a setup for coherent Viterbi equalizer,

fig. 6 shows a setup for a non-coherent Viterbi equalizer, and

fig. 7 shows an example of a multimode Viterbi equalizer.

Fig. 1 shows a system having a receiver 11 capable of receiving data information from two different transmission systems, and two transmitters 1, 2 representing the two different systems. The transmitter 1 may be a transmitter for a mobile telephone system of GSM or DCS 1800/DCS 1900 type. Similarly, the transmitter 2 may be a transmitter for a DECT transmission system.

Data are transmitted wirelessly in blocks from the two transmitters through a time-varying transmission channel to the receiver. In this transmission, the transmitted signal is subjected to noise as well as distortion. It is therefore necessary to perform a so-called channel equalization on the received signal in the receiver. This channel equalization is performed to equalize the distortion applied in the transmission channel and in the radio frequency receiver of the receivers. Data are transmitted in blocks of finite duration between the transmitters 1, 2 and the receiver 11. Each data block contains a sequence, a so-called training sequence, which is known to the receiver, and which enables the receiver to estimate the pulse response of the transmission channel, i.e. from the modulator of the transmitter to the demodulator of the receivers.

The transmitter 1 from a GSM or DCS system contains a bit source 3 which supplies the data to be transmitted, and a radio frequency modulator 4 which modulates the data signal by means of an oscillator 5 for the reference frequency. The modulated data signal is then emitted from an antenna 6. The transmitter 2 from a DECT system similarly contains a bit source 7, a radio frequency modulator 8, a reference frequency oscillator 9 and an antenna 10.

The receiver 11 receives data signals on the antenna 12, following which they are first processed in a radio frequency part 13 capable of receiving signals of GSM/DCS as well as DECT type. The radio frequency part 13 contains the reference frequency oscillator 14 of the receiver and a phase shift 15 ensuring that the data signals appear in a complex form on the output of the radio frequency part. This is shown in the figure by the two signals I, Q. Suitable amplification, filtering and mixing are performed in the radio frequency part to ensure sufficient selectivity and signal/noise ratios until the further processing of the data signals is performed. The data signals are passed from the radio frequency part 13 to the data receiver 16 in which the channel equalization and the detection proper take place. The radio frequency part 13 and the data receiver 16 are controlled by a control circuit 17.

Fig. 2 shows the structure of the data receiver 16. The complex signals I, Q are fed to a differential detector 18, a switch 19 and a channel estimator 20. As will be seen, the signals may be fed via the switch 19 either directly or via the differential detector 18 to an equalizer 21, which may e.g. be a Viterbi equalizer or another equalizer of MLSE type (Maximum Likelihood Sequence Estimator). By means of the training sequence received, the channel estimator 20 finds the instantaneous transmission channel pulse response, which is then used by the equalizer 21 to perform equalization, thereby allowing the received data information to be estimated.

When the data receiver is used for receiving GSM/DCS 1800/DCS 1900 signals, the reference frequency of the receivers is so precise compared to the reference oscillator in the corresponding transmitter that it will be possible to use a so-called coherent receiver for equalizing the signal received. This receiver type requires that frequency and phase of the carrier wave of the received signal are known and constant for a block of received data. When this is the case, a so-called Viterbi equalizer may be used, it being understood that the receiver has full knowledge of the frequency and phase of the received carrier wave.

The channel pulse response is first estimated in the channel estimator 20 on the basis of the known sequence of the signal which is received. This estimate of the channel distortion is then used in the unit 21, which performs equalization and estimation of the bits which are received. The coherent version of the data receiver does not use the differential detector, as mentioned, and the complex baseband signal is therefore just bypassed, as shown.

When, on the other hand, the data receiver is used for a DECT signal, the reference frequency is not so precise as to enable the receiver to employ the coherent principle. Therefore, a so-called non-coherent principle is used. The reason is that the reference oscillator in the DECT transmitter 2 according to the DECT specification has very lenient frequency stability requirements, so that it cannot be expected that it is appropriate to implement a coherent receiver solution. The basis of the non-coherent principle is that the receiver does not know the exact frequency and phase of the received block, and that frequency and phase are not necessarily constant through a whole block.

In this situation, estimation of the channel pulse response on the basis of the known sequence in the received signal takes place first, like before. The received signal is passed through the differential detector 18 prior to being fed to the equalizer 21. Fig. 3 shows an example of how the differential detector 18 may be constructed. The detector contains a time delay element 22 and an element 23 which performs complex conjugation of the signals, which are still in a complex form (I, Q). The resulting signal is then mixed with the original signal in the mixing stage 24. It should be noted that various differential detectors are available, and the detector shown in fig. 3 is merely an example of such a differential detector. After the differential detection the received signal is fed via the switch 19 to the equalizer 21, which is capable of performing so-called differential Viterbi equalization of the received signal by means of the estimated channel pulse response. This type of equalization is basically the same as the differential one, but with a few modifications because of the inclusion of the differential detector in the receiver chain.

As mentioned, the pulse response of the channel is estimated in this type of transmission systems by means of a special bit sequence in the transmitted blocks. This makes it possible to generate a so-called time discrete channel model in the receiver which describes the influence of the channel on the transmitted signal.

An example of such a model is shown in fig. 4. This figures shows an example of an estimated channel pulse response with L+1 taps, called $h_0, \ldots, h_L$. The values I_k are the symbols transmitted from the transmitter, which may generally take on complex values. It is assumed that I_k can take on a total of M different values. This description of the channel model means that it can be described as a state machine, in which the states can take on the values $s_k=(I_{k-1}, I_{k-2}, \ldots, I_{k-L})$. This results in a state machine having a total of M^L states described by various combinations of the symbols I in the state description s_k.

It is assumed below that L=1 to simplify the description of the algorithms. In accordance with the above, this gives rise to two values of h, viz. h_0 and h_1. This moreover means that the state machine of the channel can take on M_1=M states.

Fig. 5 shows the setup of input signal to the coherent Viterbi equalizer, while fig. 6 correspondingly shows the setup for input signal to the non-coherent Viterbi equalizer. In the said example, the coherent signal receives the following signal:

$$r_k=h_0 \cdot I_k+h_1 \cdot I_{K-1}$$

The corresponding expression for the non-coherent receiver will be:

$$I_k=(h_0 \cdot I_k+h_1 \cdot I_{k-1}) \cdot (h_0 \cdot I_{k-1}+h_1 \cdot I_{k-2})^*$$

$$r_k=|h_0|^2 I_k I_{k-1}^*+|h_1|^2 I_{k-1} I_{k-2}^*+h_0 h_1^* I_k I_{k-2}^*+h_1 h_0^* |I_{k-1}|^2$$

For the modulation form used in the DECT system, $I_k=j\ b_k\ I_{k-1}$, and hence with substitution in the above formula:

$$r_k=j \cdot b_k |h_0|^2+j \cdot |h_1|^2 b_{k-1}-b_k b_{k-1} h_0 h_1+h_0^* \cdot h_1$$

This means that the coherent and non-coherent Viterbi equalizations may be implemented such that just a single block must be capable of making calculations corresponding to either the coherent or the non-coherent receiver solution, while all the other blocks are common to the two solutions.

This is outlined in fig. 7, in which an example of a multimode Viterbi equalizer is shown.

In the shown implementation of the multimode Viterbi equalizer, the block "generation of reference received signal" must be capable of handling both the coherent setup and the non-coherent setup shown in figs. 5 and 6. All other blocks are the same for the two receiver types.

P a t e n t C l a i m s :

1. A demodulator (16) for use in a receiver for transmission systems and adapted to demodulate received signals according to a coherent principle in a first mode and to demodulate received signals according to a non-coherent principle in a second mode, c h a r a c t e r i z e d in that the demodulator comprises a differential detector (18), an equalizer (21) and a switch (19) adapted to couple the received signals directly to the equalizer (21) in the first mode of the demodulator and to couple the received signals to the equalizer (21) via the differential detector (18) in the second mode of the demodulator.

2. A demodulator according to claim 1, c h a r a c t e r i z e d in that it is adapted to demodulate data which are transmitted in blocks of finite length, each said block containing a training sequence which is known beforehand by the receiver, and that the equalizer (21) comprises a Viterbi equalizer.

3. A demodulator according to claim 1 or 2, c h a r a c t e r i z e d in that it is adapted to demodulate data signals associated with a specific transmission system in each of said states.

4. A demodulator according to claims 1-3, c h a r a c t e r i z e d in that it is adapted to demodulate data signals associated with transmission systems using modulation forms of MSK type.

5. A demodulator according to claims 1-4, c h a r a c t e r i z e d in it is adapted to demodulate data signals associated with a mobile telephone system of e.g. GSM or DCS/PCS type in said first mode.

6. A demodulator according to claims 1-5, c h a r a c - t e r i z e d in that it is adapted to demodulate data signals associated with e.g. a transmission system of DECT type in said second mode.

7. A demodulator according to claims 1-6, c h a r a c - t e r i z e d in that said switch (19) switching between between coherent and non-coherent demodulation is controlled by signals which are received from the transmitter side of the transmission system.

8. A demodulator according to claims 1-6, c h a r a c - t e r i z e d in that said switch (19) switching between coherent and non-coherent demodulation is controlled by a detector capable of detecting whether the received signals are suitable for using coherent demodulation.

9. Use of a demodulator according to claims 1-8 in a mobile telephone system of e.g. GSM or DCS/PCS type.

10. Use of a demodulator according to claims 1-8 in a transmission system of DECT type.

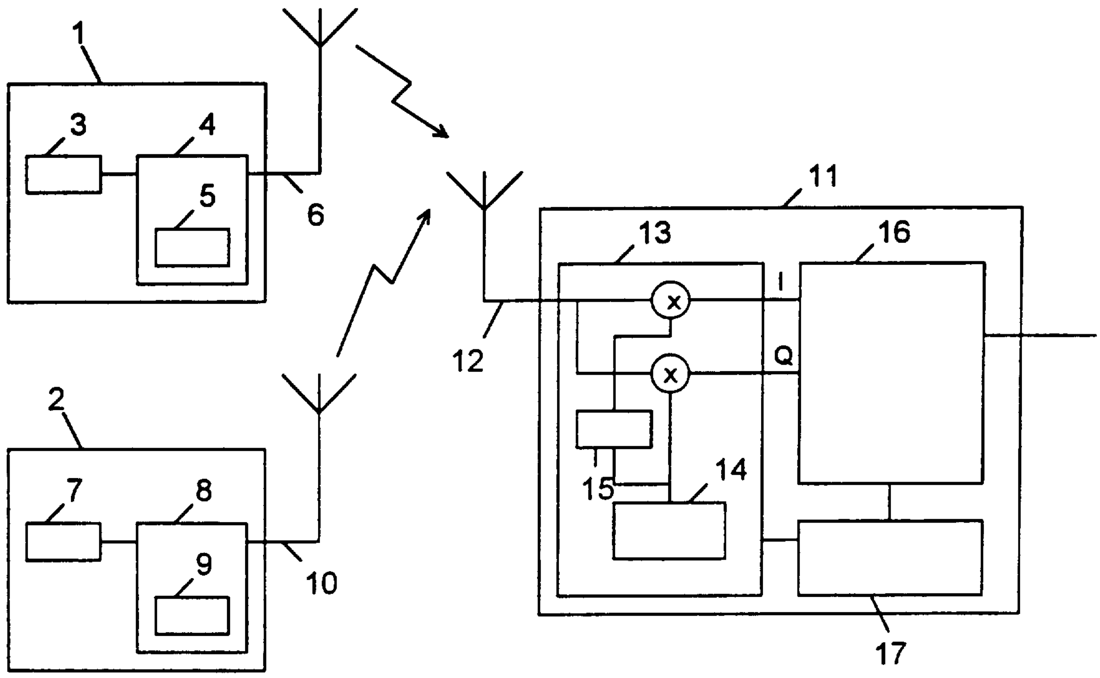


Fig. 1

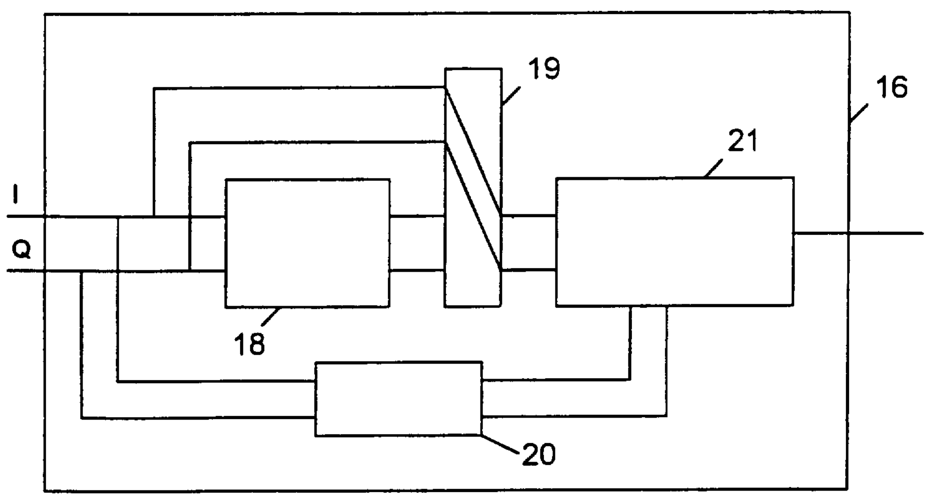


Fig. 2

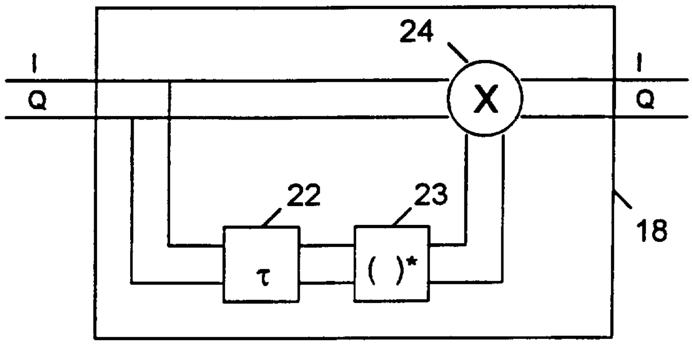


Fig. 3

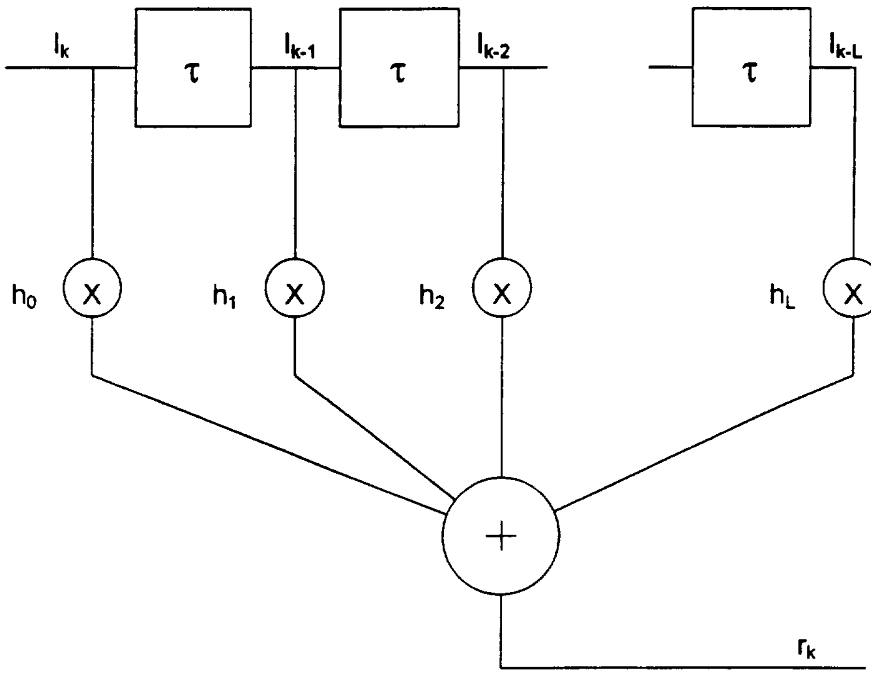


Fig. 4

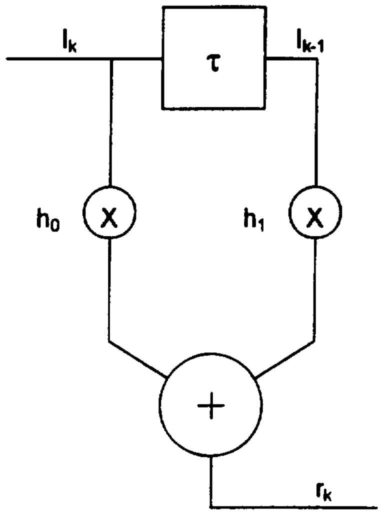


Fig. 5

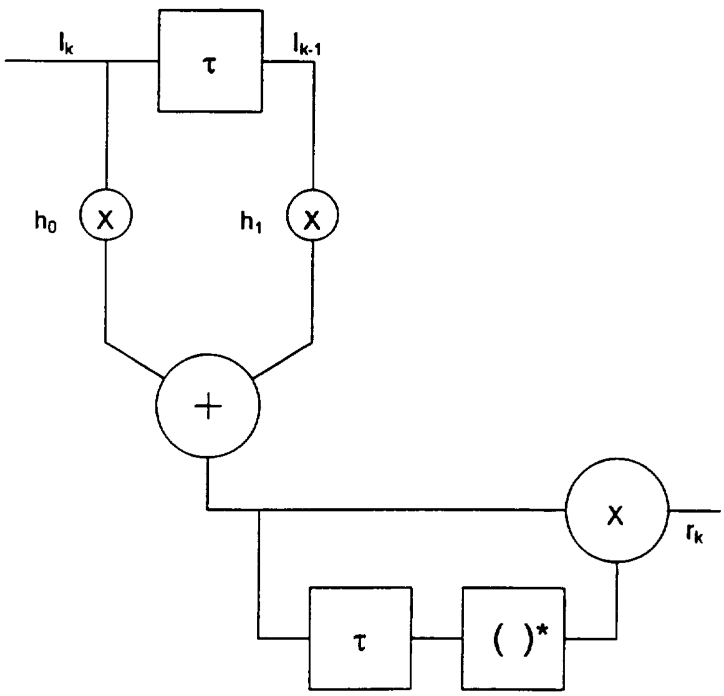
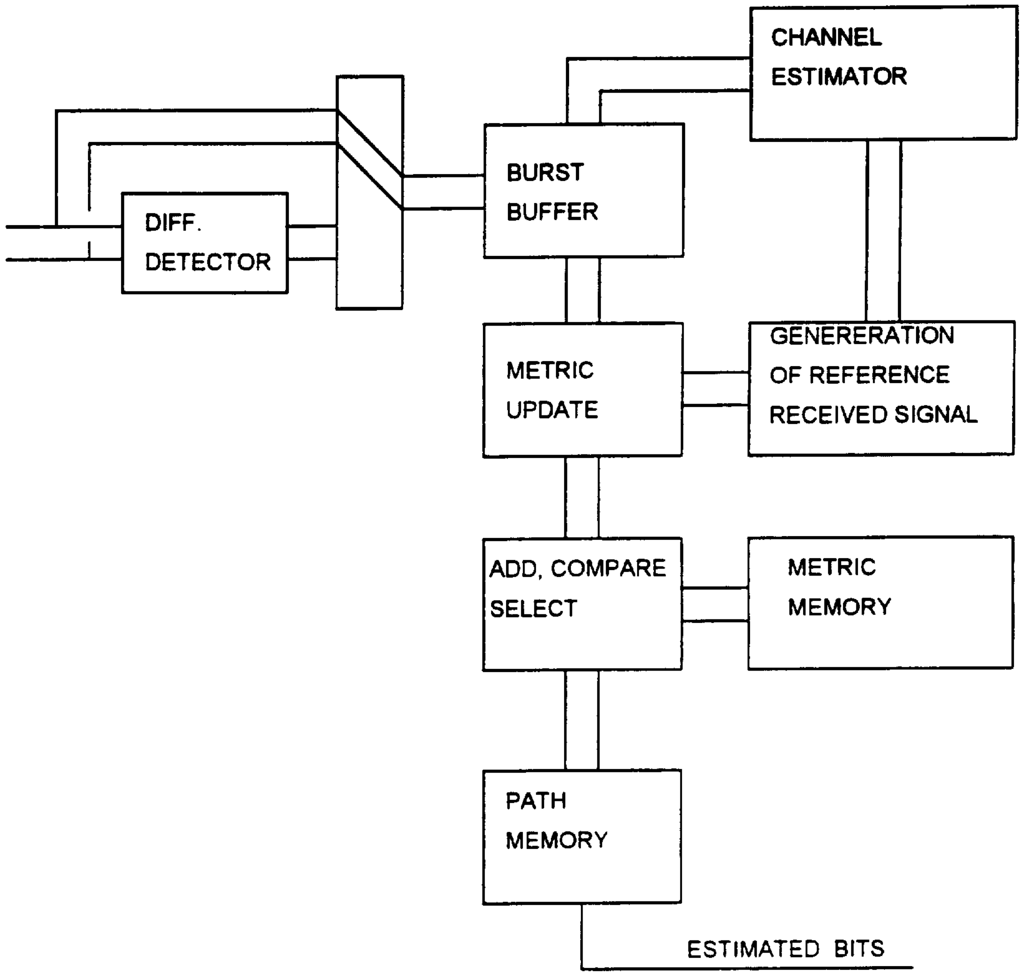


Fig. 6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DETECTOR
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UPDATE
GENERERATION
OF REFERENCE
RECEIVED SIGNAL
ADD, COMPARE
SELECT
METRIC
MEMORY
PATH
MEMORY
ESTIMATED BITS

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 96/00162

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 27/22
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)

IPC6: H04L, H03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	IEEE Transactions on communications, Volume 42, No 7, July 1994, Upamanyu Madhow et al, "Universal receivers with side information from the demodulators: An example for nonselective rician fading channels", page 2395 - page 2405, page 2395, left column, first paragraph - page 2396, left column, first paragraph, abstract	1,3-6,9,10
A		2,7,8
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Y	US 5375143 A (H.L KAZECKI ET AL), 20 December 1994 (20.12.94), column 2, line 37 - column 3, line 20, figure 1	1,3-6,9,10
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 July 1996	18 -07- 1996
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Christian Rasch Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 96/00162

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

01/07/96

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WO-A1- 9513677	18/05/95	NONE	