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(56) Related Art
US 5453976
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ABSTRACT

Echo Canceller

Digital filters are used to simulate the transmission function of a real system with echo cancellers. A digital signal processor with high processing speed and large memory is required to then calculate said filters and update the filter coefficients. To reduce the effort for the echo canceller, the invention provides a block autocorrelation, i.e. the correlation of a block from a defined number of sample values of the transmitted signal and received echo signals originating therefrom, which determines time intervals, in which an echo arrives and in which an update of the filter coefficients is carried out. The number of filter coefficients to be calculated and the effort to do this are reduced considerably, so that echo cancellers for telecommunication terminals can be produced at low costs.

Figure 4

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Regulation 3.2

AUSTRALIA

Patents Act 1990

ORIGINAL
COMPLETE SPECIFICATION
STANDARD PATENT

Invention Title:

" ECHO CANCELLATION METHOD AND CIRCUIT"

The following statement is a full description of this invention, including the best method of performing it known to us:-

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This invention relates to an echo canceller, which is used in transmission systems with 2-wire/4wire bridges, for example in communication systems according to the DECT standard (Digital European Cordless Telecommunications Standard). 2-wire/4-wire junctions are implemented with hybrids, where technical mismatching can never be completely avoided, resulting in signal reflections, which effectively lower the transmission quality). The implementation of an echo canceller is also possible in handsfree units of communication terminals, where an acoustic coupling between the loudspeaker above the surrounding room and the microphone leads to unwanted transmission of the received signal to the speaker at the far end of the transmission path and which is then perceived as an interfering echo.

It is fundamentally known to cancel the effect of echoes with echo cancellers, compare R. Wehrmann and others: Signal processing methods to improve speech communication on handsfree units in the magazine "Der Femmelde -Ingenieur", 48th year, October 1994, pages 27 - 28. With an echo canceller, the transmission function of the real system transmit-line. receive-line. which are electrically coupled by mismatched hybrids, is simulated as closely as possible. With handsfree units the transmission function of the real system loudspeaker-room -microphone is simulated as closely as possible. The signal arriving at the subscriber's passes through both the real system as well as the system simulated by the echo canceller, and subsequently the output signal of the echo canceller is subtracted from the echo-containing real system signal, so that the echo is compensated.

Digital filters whose filter coefficient, for example, can be determined according to the Normalized Least Mean Square Algorithm, or NLMS-algorithm, are used to realize echo cancellers, compare T. Huhn, H.J. Jentschel: Combination of noise reduction and echo combination during handsfree speech, published in Nachrichtentechnik Elektronik, Berlin 43 (1993), pages 274-280. The necessary filter length is determined by the sampling frequency and the echo transmission time. The filter coefficients must be updated continuously corresponding to the changing echo signal. For example, in a transmission system where a new sample value of the signal to be transmitted is made available every 125,us, and in which the echo transmission time is 70 ms, 560 sample values must he stored and processed, i.e

$$70\ ms \cdot \frac{8\ sample\ values}{1\ ms} \cdot 560\ sample\ values$$

To receive a useful approximation to the echo time function, a digital signal processor with high processing speed and large memory is necessary to realize the echo canceller, so that the technical implementation of this idea is coupled with high costs. Due to their complexity and expense, the known solutions are unsuitable to meet, particularly, the commercial requirements of a satisfactory quality for handsfree units.

One difficulty in determining the filter coefficients is, to determine the current pulse reply of the simulated system only when no interfering influences are present. Therefore, using a digital filter, there is the requirement to determine reliably between local echoes and sounds or active local speaker, and between line echoes and active remote speaker, to determine filter coefficients only with silent local speaker and silent remote speaker , because mainly only echo signal are received at that time. It is known to take a correlation measurement between received echo signal and transmitted echo signal, to determine the most suitable time to determine the filter coefficient, compare DE 43 05 256 Al. This publication describes how the correlation analysis is used to determine when an acoustic coupling factor is determined as measure for an echo signal. The practical application however fails, due to the fact that the amount of computation required for the correlation analysis is very large.

It is an object of the present invention to provide an echo canceller with a digital filter so that the number of filter coefficients to be determined and the expenditure for their calculation becomes so small that the echo canceller can be implemented as low-cost component in a communication systems according to the DECT standard.

According to the invention there is provided an echo canceller which is connected between a transmit line and a receive line in a communications system whose transfer function is determined by a digital filter, wherein the transfer function is updated when the result of a correlation between a block formed from a selected number of sample values of transmitted signals and a received echo signal originating therefrom exceeds a defined threshold.

The essence of the invention is that a block autocorrelation, which means the correlation of a block from a defined number of samples values of the transmitted signals with a received echo signal originating therefrom, determines the time intervals, in which echoes occur and in which an update of the digital filter coefficients occurs.

According to a further aspect of the invention there is provided a method of echo cancellation in a communications system, whose transfer function is determined by a digital filer, including the steps of:

performing a correlation between a block formed from a selected number of sample values of transmitted signals and a received echo signal originating therefrom ;

comparing the result of the correlation with a defined threshold; and

updating the transfer function when the result of the correlation exceeds the defined threshold.

In order that the invention may be readily carried into effect, embodiments thereof will now be described in relation to the accompanying drawings, in which:

Fig. 1 is a schematic display of the autocorrelation,

Fig. 2 is a schematic display of the block autocorrelation,

Fig. 3 is a function diagram of a block autocorrelator and

Fig. 4 is a function diagram of an echo canceller with a block autocorrelator.

It is possible in principle, to determine the time interval of an echo by autocorrelation.

According to Fig. 1, the average time value of the product is formed from the function x(t) with the same function 4(t-T) displaced by time T. This determines the autocorrelation between transmitted signal and received echo.

To limit a large amount of computation required for the autocorrelation of individual sample values, an autocorrelation of selected blocks is conducted according to the invention and as shown in Fig. 2. In Fig. 2, the function x(t) consists of, for example, five representative values, which are each determined from one block. An average block value is determined by block autocorrelation with the echo signal r(t), whose greatest value specifies the block with the greatest echo. This also generally enables determination of the time intervals in which echo signals occur.

According to Fig. 3, the block autocorrelator is connected between the transmit line 1 and the receive line 2. A determined number m of sample values x(k) of the transmit signal, for example m = 8, is combined into a block B[n], which consists of elements X[n,m], where n = number of blocks. For each block B[n] a representative block value is calculated from the number m of the sample values x(k). This is calculated according to the following equation:

$$B_t[i] = (1 - \alpha) * B_{t-1}[i] + \alpha * X[i,1] \qquad (1)$$

where $0 < \alpha < 1$
and $1 \leq i \leq n$,
where $B_t[i]$ is the current representative block value and $B_{t-1}[i]$ is the previously determined block value.

For this calculation (1) only the first element X[i,l] of a block B[i] is required. The factor α specifies the influence of the second addend on the representative block value and therefore the speed of change of the representative block value. In the practical case $\alpha \approx 2^{-4}$ is often selected.

It is also possible to determine the representative block value from the first element X[i,1] and the last element X[i,m] of a block B [i]. The representative value calculation is then carried out according to the following equation:

$$B_t[i] = B_{t-1}[i] + X[i,l] - X[i,m] \qquad (2)$$

Each representative block value $B_t[i]$ is multiplied by the sample values r(k) of the received transmit echo signal originating from there. An average block value $A_t[i]$ is calculated for each block from the products according to the following equation:

$$A_t[i] = (1 - \beta) A_{t-1}[i] + \beta * B_t[i] \frac{r(k)}{const} \qquad (3)$$

where $0 < \beta < 1$
and $1 \leq i \leq n$,
where β is selected according to the same considerations as previously stated for α.

The average block values $A_t[1] \ldots A_t[n]$ and a logic circuit 3 are used to determine the time intervals in which an echo canceller is to be effective. The average block values $A_1[1] \ldots A_1[n]$ are the result of block autocorrelation between the signals transmitted in a block and the echo signals.

Under the assumption that an echo mainly occurs in only one block, the greatest average block value $A_1[i]_{max}$ is determined by means of logic circuit 3, which therefore shows the presence of an echo. The sample values in the so determined block are then used to calculate the transmission function of the echo canceller. Depending on the block size and calculating speed of a digital signal processor, and depending on required accuracy, it is possible to use further blocks $A_1[i]$, neighbouring the block with the greatest average value, to calculate the transmission function of the echo canceller. Whether only the block with the greatest average value $A_1[i]_{max}$ or further blocks $A_1[i]$ neighbouring this block, are used to calculate the transmission function of the echo canceller, depends on the size of the threshold with which the average block values are evaluated by logic circuit 3. The smaller the threshold, the greater the probability that more than one block will be used to calculate the transmission function of the echo canceller.

For the case where the echo arrives at different times, not only the maximum average block value $A_1[i]_{max}$ is determined. but also a number of i blocks with the greatest average block values $A_1[i]$ is determined from the n blocks.

Fig. 4 shows the connection of a block auto correlator 4 with an echo canceller 5. Echo function e(k) is now simulated for selected blocks i, which is subtracted from the echo-containing receive signal r(k). A gate circuit 6 ensures that only the sample values $x_i(k)$ of the selected blocks i are used to calculate the transmission function of echo canceller 5. The transmission function of the echo canceller 5 is formed by a digital filter, in which, and according to equation (4), the sum is formed from the products X[i,p] of the selected blocks i and the corresponding filter coefficients C [i,p]; p specifies the number of sample values within a block.

$$e(k) = \sum_{p=1}^{m} X[i,p] * C[i,p] \qquad (4)$$

Selecting the blocks X[i,p] relevant for the echo cancellation saves computation time which makes a favourable comparison with the prior art. It is not necessary, as was previously the case, to get the sum of the products of all sample values x(k) and the filter coefficients. Furthermore, the solution according to the invention reduces the number of filter coefficients which need to be calculated.

The claims defining the invention are as follows:

1. An echo canceller connected between a transmit line and a receive line in a communications system said echo canceller having a transfer function determined by a digital filter, wherein the transfer function is updated when the result of a correlation between

(a) a value formed from a combination formed from a block of sample values of transmitted signals, and;

(b) a received echo signal originating from said transmitted signal

exceeds a predetermined threshold.

2. An echo canceller connected between a transmit line and a receive line in a communications system whose transfer function is determined by a digital filter, including:

first sampling means to sample transmitted signals transmitted over the transmit line;

first store means to store a block formed from a predetermined number of the sample values from the transmitted signals;

second sampling means to sample a received echo signal;

second store means to store sample values of the echo signal;

correlation means to perform a correlation between the sample values of the transmitted signals and the echo signal;

comparison means to generate an update signal when the result of the correlation exceeds a predetermined threshold, whereby the transfer function is updated.

3. An echo canceller as claimed in claim 1 or claim 2, wherein the correlation is performed by grouping the sample values of the transmitted signal into a number of blocks, calculating a representative value for each of the blocks from the sample values, and multiplying each representative block value by the echo signal to obtain a number of average block values, from which a logic circuit selects at least one average block value which exceeds a defined threshold.

4. An echo canceller as claimed in claim 3, wherein in the case of a singular echo, the updating of the transfer function of the digital filter takes place in the block whose average block value is determined by the singular echo, and that when required, at least one block

preceding said block in time and at least one block following said block in time are additionally used for updating the transfer function of the digital filter.

5. An echo canceller as claimed in claim 2, wherein in the case of a number q of echo signals distributed over time, the respective greatest average block values originating from the q echo signals, and, thus, those blocks are determined which are used to update the transfer function of the digital filter.

6. An echo canceller arrangement substantially as herein described with reference to the accompanying drawings.

7. A method of echo cancellation in a communications system, whose transfer function is determined by a digital filter, including the steps of:

performing a correlation between a block formed from a selected number of sample values of transmitted signals and a received echo signal originating therefrom;

comparing the result of the correlation with a defined threshold; and

updating the transfer function when the result of the correlation exceeds the defined threshold.

8. A method as claimed in claim 7, wherein the correlation is performed by grouping the sample values of the transmitted signal into a number of blocks, calculating a representative value for each of the blocks by averaging the sample values, and multiplying each representative value by the echo signal to obtain a number of average block values, from which a logic circuit selects at least one average block value which exceeds a defined threshold.

9. A method as claimed in claim 8, wherein in the case of a singular echo, the updating of the transfer function of the digital filter takes place in the block whose average block value is determined by the singular echo, and that when required, at least one block preceding said block in time and at least one block following said block in time are additionally used for updating the transfer function of the digital filter.

10. A method as claimed in claim 8, wherein in the case of a number q of echo signals distributed over time, the respective greatest average block values originating from the q echo signals and, thus, those blocks are determined which are used to update the transfer function of the digital filter.

11. A method of echo cancellation substantially as herein described with reference to the accompanying drawings.

Dated this 7th day of March 2000

ALCATEL N.V.

by its attorneys

Freehills Patent Attorneys

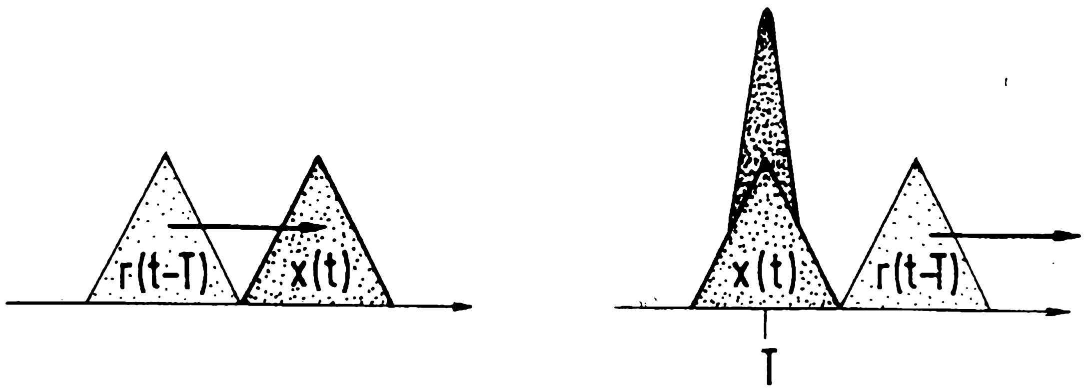

Fig.1

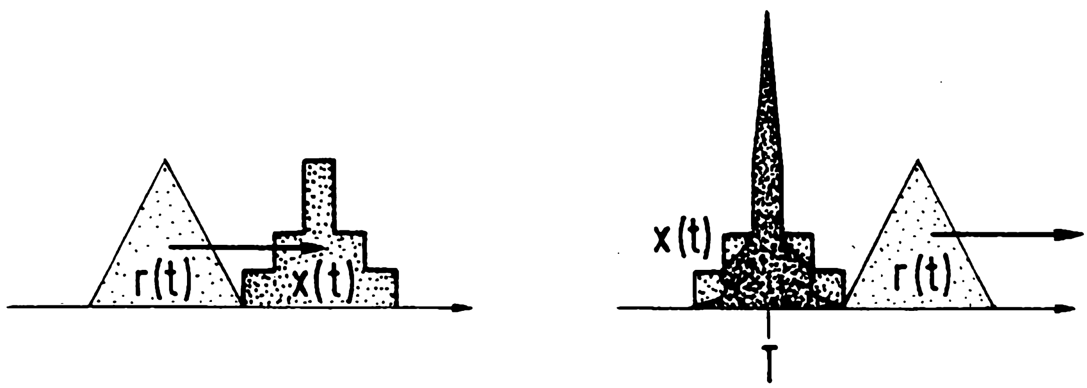

Fig.2

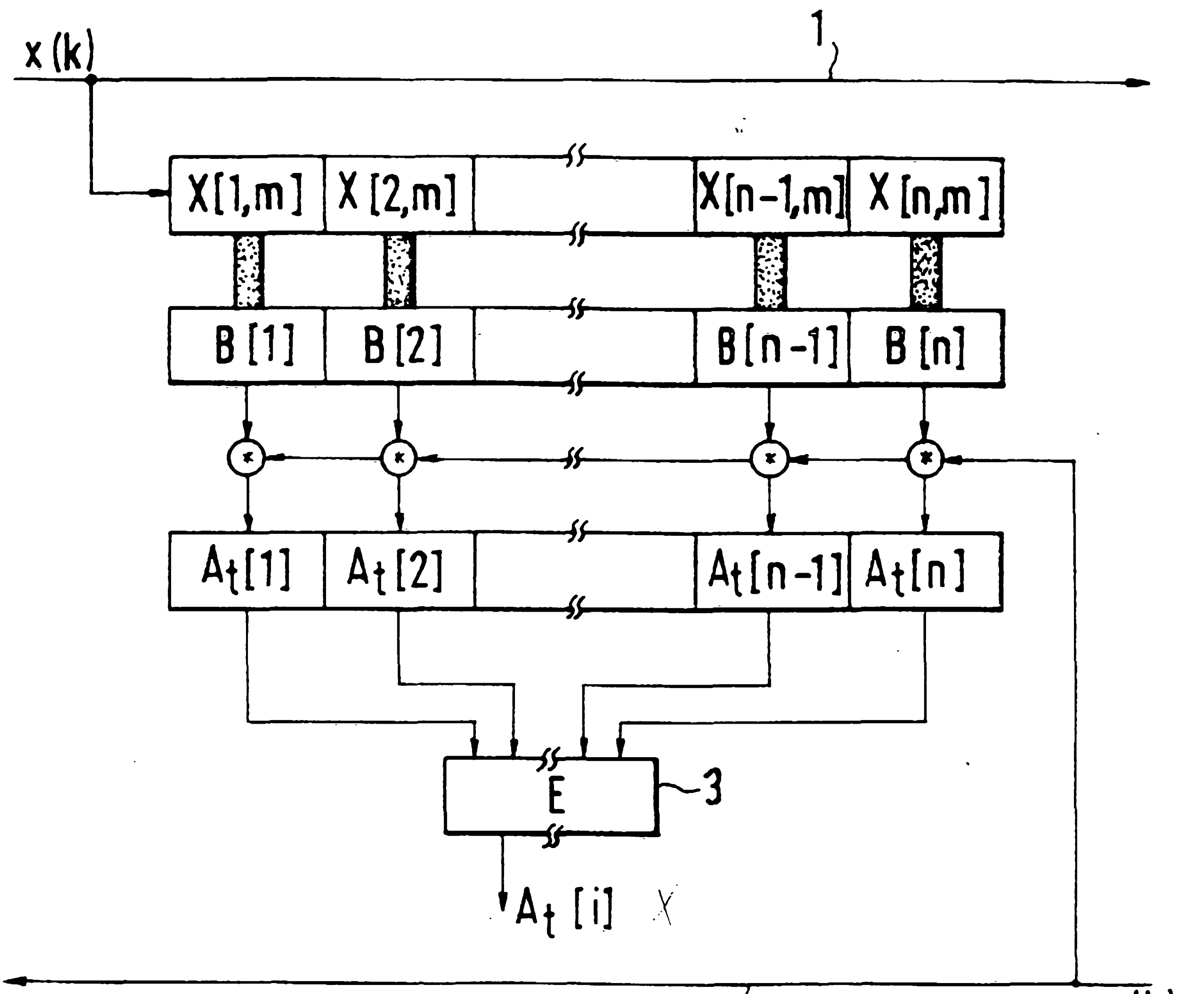

Fig.3

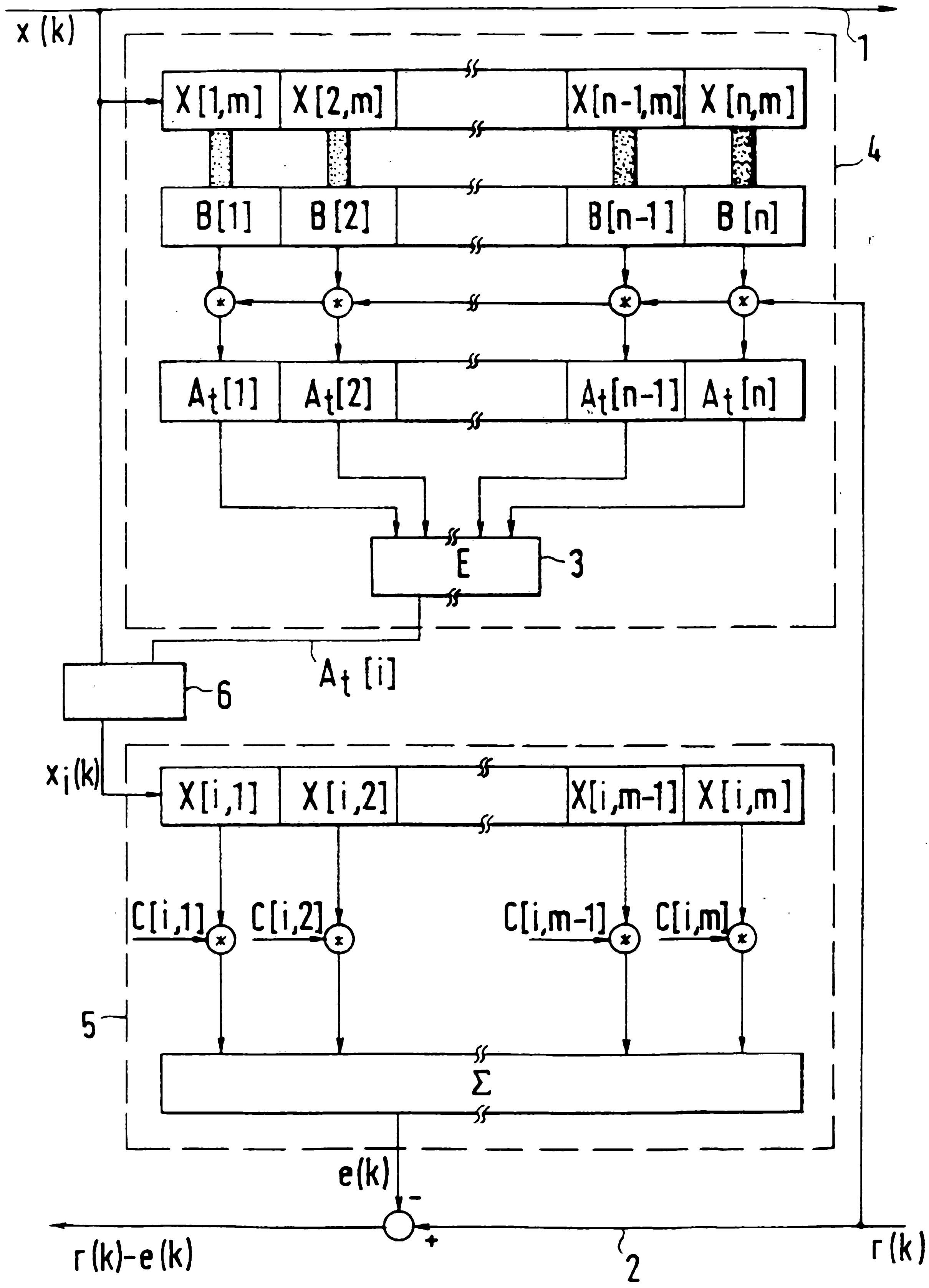
x (k)
1
X [1,m]
X [2,m]
X [n-1,m]
X [n,m]
4
B [1]
B [2]
B [n-1]
B [n]
A_t [1]
A_t [2]
A_t [n-1]
A_t [n]
E
3
A_t [i]
6
x_i (k)
X [i,1]
X [i,2]
X [i,m-1]
X [i,m]
C [i,1]
C [i,2]
C [i,m-1]
C [i,m]
5
Σ
e (k)
r (k)-e (k)
2
r (k)

Fig. 4