(CONVENTION. Company.) Form 8

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DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT OR PATENT OF ADDITION

(1) Here insert (in full) Name of Company.

In support of the Convention Application made by(1) Telefonaktiebolaget LM Ericsson, of S-126 25 STOCKHOLM SWEDEN

(hereinafter referred to as the applicant) for a Patent

(2) Here insert title of Invention.

for an invention entitled:(2) A METHOD FOR AVOIDING SELF-OSCILLATION IN CONJUNCTION WITH ECHO CANCELLATION

(3) Here insert full Name and Address, of Company official authorized to make declaration.

I,(3) Mr Tage Lövgren, Mickelsbergsvägen 134, S-126 63 HÄGERSTEN SWEDEN

of Mr Erling Blommé, Gimlevägen 2, S-182 64 DJURSHOLM SWEDEN

do solemnly and sincerely declare as follows:

1. ~~I am~~ We are authorised by the applicant for the patent to make this declaration on its behalf.

(4) Here insert basic Country or Countries followed by date or dates and basic Applicant or Applicants.

2. The basic application as defined by Section 141 of the Act was made in(4) Sweden on the 9th day of April 19 92, by Telefonaktiebolaget LM Ericsson

on the day of 19, by

(5) Here insert (in full) Name and Address of Actual Inventor or Inventors.

3.(5) Mr Bengt Gustav Löfmark, Torpgläntan 4, S-127 41 SKÄRHOLMEN SWEDEN

is/are the actual inventor of the invention and the facts upon which the applicant is entitled to make the application are as follow:

The applicant is the assignee of Mr Bengt Gustav Löfmark

4. The basic application referred to in paragraph 2 of this Declaration was the first application made in a Convention country in respect of the invention the subject of the application.

DECLARED at Stockholm, Sweden

this 20th day of August 19 94

TELEFONAKTIEBOLAGET LM ERICSSON

(6) Signature.

(6) Erling Blommé, Senior Vice President and General Counsel; Tage Lövgren, Manager of Patent and Trademark Department

To: The Commissioner of Patents

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(56) Prior Art Documents
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(57) Claim

1. A method for avoiding self-oscillation in a four-wire loop in conjunction with echo cancellation effected with the aid of an adaptive filter (15), c h a r a c t e r i z e d by restricting the permitted range of the coefficients of the adaptive filter in a manner such that the absolute value of the filter transfer function, $|H_{ca}|$, is restricted according to the following condition: $|H_{ca}| < 1/|H_{fa}| - |H_{ne}|$, where H_{fa} is the echo transfer function in the far-end (13) of the loop and H_{ne} is the echo transfer function in the near-end (14) of the loop; and by reducing the values of said coefficients when said condition is not fulfilled.

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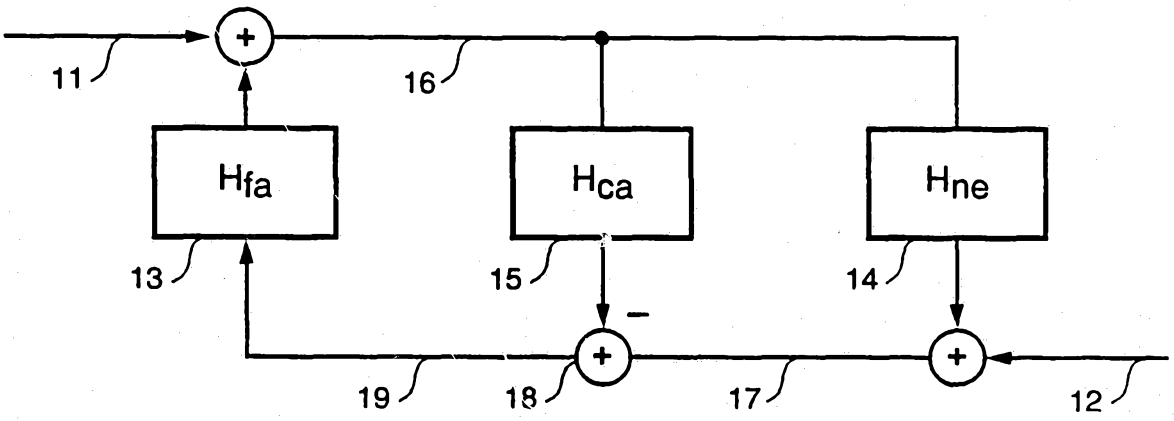

(57) Abstract

The invention relates to a method for avoiding self-oscillation in a four-wire loop in conjunction with echo cancellation effected with the aid of an adaptive filter (15). Self-oscillation is avoided for both long and short connections and also when signaling with narrow-band signals, by restricting the permitted range of the coefficients of the adaptive filter in a manner such that the absolute value of the filter t ansfer function will be sufficiently small for amplication in the four-wire loop to be less than one. This is achieved by limiting the absolute value of the filter transfer function $|H_{ca}|$, to a value which is smaller than a determined function of the echo transfer function (H_{fa}) in the far-end (13) of the loop and the echo transfer function H_{ne} in the near-end (14) of the loop.

A METHOD FOR AVOIDING SELF-OSCILLATION IN CONJUNCTION WITH ECHO CANCELLATION

TECHNICAL FIELD

The present invention relates to a method for avoiding self-oscillation in a four-wire loop in conjunction with echo cancellation effected with the aid of an adaptive filter.

BACKGROUND ART

In telecommunication systems in which adaptive echo cancellation is effected with the aid of an adaptive filter in a four-wire loop, in certain operational cases problems occur with self-oscillation, so-called "bursting". This phenomenon is caused by the presence in the four-wire loop of a feedback from the output of the adaptive filter to its input, via the far-end of the loop. In this way, a near-end signal is able to pass around the loop and appear as a far-end signal at the filter input and thereby influence the setting of the adaptive filter. The risk of self-oscillation is greater in the case of shorter connections, for instance when so-called adaptive hybrids are used, than in the case of longer connections, for instance when so-called trunk echo cancelers are used. This is because the near-end signal passing around the loop is decorrelated as a result of the large delay that occurs in long connections.

The "bursting" phenomenon and a method of reducing the risk of "bursting", i.e. self-oscillation, is described in W.A. Sethares, C.R. Johnson JR. and C.E. Rohrs: "Bursting in Adaptive Hybrids", IEEE Transactions on Communications, Vol. 37, No. 8, August 1989, pages 791-799.

According to the known method there is used a so-called double-talk detector and the updating of an adaptive filter used for echo cancellation is interrupted when signals from a near-end are detected. The method can be relatively successful in the case of trunk echo cancelers which are localized in a network so that the

echo path will be relatively heavily attenuated, e.g. more than 6 dB. However, attenuation of the echo is poorer in the case of an adaptive hybrid which lies in the actual 2/4-wire transition, and consequently the detector has a more difficult task. Furthermore, there is a risk that any self-oscillation will be interpreted as a strong near-end signal, causing updating to be interrupted. In this case, any self-oscillation that had commenced would become permanent, which is unacceptable.

It has also been found that when the signals are narrow band signals, e.g. when they are comprised of pure tones, a weak near-end signal may also have a pronounced disturbing effect on the adaptive filter, and therewith result in self-oscillation. Tone signalling is found, for instance, in modem traffic. Consequently, when applying the known method there is a risk that self-oscillation cannot be avoided when transmitting narrow band signals.

Another method for avoiding self-oscillation in conjunction with echo cancellation is described in J.W. Cook and R. Smith: "An integrated circuit for analogue line interfaces with adaptive transmission and extra facilities", British Telecom. Technol. J., Vol 5, No. 1, January 1987, pages 32-42. According to this method, the adaptive filter is comprised of one of 24 predetermined filters. However, this merely provides highly limited possibilities of effectively canceling echoes. Consequently, it is probable that the method can only be used for adaptive hybrids, due to the relatively low requirement of echo cancellation that then exists.

It is also known in conjunction with adaptive control to enhance the stability of an adaptive system, by limiting the permitted range for the coefficients of an adaptive filter. In this regard, it is necessary to be aware of the requirements that the adaptive filter must fulfil in order for the system to be stable, and to ensure that the coefficients are restricted in a manner which will fulfil these requirements. When the requirements for preventing self-oscillation are known and can be transferred to the coefficient space, i.e. to the value of the coefficients, it is

possible, of course, to guarantee stability. However, a difficulty resides in finding a criterion which can readily be transformed to the coefficient space and which does not require undue calculation and which will not excessively restrict the permitted range. Excessive limitation of the range would unnecessarily impair performance under the normal conditions in which no such limitation is required.

One example of the restriction of the permitted range for filter coefficients is found described in A. Krieger and E. Masry: "Constrained Adaptive Filtering Algorithms: Asymptotic Convergence Properties for Dependent Data", IEEE Transactions on Information Theory, Vol. 35, No. 6, November 1989, pages 1166-1176.

DISCLOSURE OF THE INVENTION

The object of the present invention is to provide a method of avoiding self-oscillation in a four-wire loop in conjunction with echo cancellation with the aid of an adaptive filter. The method shall be effective in both long and short connections and also when signalling with narrow-band signals. In brief, this is achieved by restricting the permitted range of the coefficients of the adaptive filter in a manner such that the absolute value of the filter transfer function will be sufficiently small for the amplification in the four-wire loop to be less than one.

In addition, particular methods are proposed for limiting the filter coefficients in a manner such that the aforesaid method will only require an moderate calculation-demanding procedure.

The invention is characterized by the features set forth in the following claims.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will now be described in more detail with reference to the accompanying drawing, in which Figure 1 is a

block schematic illustrating a four-wire loop which includes a trunk echo canceller; Figure 2 is a block schematic equivalent to the block schematic shown in Figure 1; and Figure 3 illustrates an equivalent block schematic for a four-wire loop which incorporates an adaptive hybrid.

BEST MODE OF CARRYING OUT THE INVENTION

Figure 1 is a block schematic which constitutes an example of a four-wire loop incorporating an echo canceler which may function as a so-called trunk echo canceler for instance. Reference numerals 11 and 12 identify a two-wire line at a far-end and at a near-end respectively. Each of the lines is connected to a respective two/four-wire hybrid 13 and 14. The echo canceler includes a digital adaptive filter 15 which is normally referred to as a balance filter in connection with echo canceling. The filter is coupled between a branch 16 with the transmission direction to the right, and a branch 17, 19 with the transmission direction to the left. An echo estimate is formed in the filter 15 and subtracted from a signal in the branch 17 in a subtraction means 18.

Figure 2 illustrates a block schematic which is equivalent to the schematic shown in Figure 1 and in which the transfer functions of different blocks have been marked. The same reference signs as those used in Figure 1 have also been used in Figure 2. The echo transfer functions for the two/four-wire hybrids 13, 14 and the transfer function for the balance filter 15 are called H_{fa}, H_{ne} and H_{ca}, which stand for H_{far}, H_{near} and H_{cancel} respectively.

A trunk echo canceler is normally placed at a location where echo loss is greater than 6 dB. Consequently, in one such particular case the following will apply for the echo transfer function,

at the near-end: $|H_{ne}| \leq 0.5$ (1)

and at the far-end: $|H_{fa}| \leq 0.5$ (2)

The resultant echo transfer function H_{re} for the hybrid 14 and the echo canceler 15 is:

$$H_{re} = H_{ne} - H_{ca} \quad (3)$$

A sufficient condition for the stability is that the amplification in the four-wire loop is smaller than one, which gives:

$$|H_{fa}*(H_{ne}-H_{ca})| = |H_{fa}|*|H_{ne}-H_{ca}| < 1 \quad (4)$$

Equation (4) together with equation (2) gives:

$$|H_{ne}-H_{ca}| < 2 \quad (5)$$

However the following applies:

$$|H_{ne}-H_{ca}| \leq |H_{ne}| + |H_{ca}| \quad (6)$$

Equation (4) together with equation (6) gives the following stability condition:

$$|H_{ca}| < 1/|H_{fa}| - |H_{ne}| \quad (7)$$

Equation (7) thus gives a general and adequate stability condition for an echo canceler according to Figures 1 and 2. This condition will guarantee stability when the absolute value of the balance filter transfer function is limited to being smaller than a given function of the echo transfer function in the far-end of the loop and in its near-end. One method of guaranteeing that $|H_{ca}|$ is restricted is to calculate the value of $|H_{ca}|$, for instance by fourier transformation, and if this value is too large by multiplying all of the coefficients in H_{ca} with one and the same positive number which is smaller than one, so as to return $|H_{ca}|$ to the permitted range.

In the particular case according to equations (1) and (2), an adequate stability condition is:

$$|H_{ne}| + |H_{ca}| < 2 \quad (8)$$

With regard to equation (1), this condition is always fulfilled when

$$|H_{ca}| < 1.5 \qquad (9)$$

In order to ensure safely that the stability condition will be fulfilled, it is sufficient to fulfil the equation (7). Naturally, it is possible to calculate $|H_{ca}|$ and to interrupt updating of the balance filter when the equation (7) is not fulfilled. The calculations required herefor, however, are excessive, since it involves a fourier transformation of the transfer function. Furthermore, an interruption in the updating of the balance filter means that an optimum cannot definitely be achieved, with regard to the boundary condition. Instead of reaching an optimum, the updating is perhaps interrupted when reaching the boundary according to equation (7).

Suggested below are also methods which are less requiring of calculations than the aforesaid fourier transformation and which result in the definite achievement of an optimum with regard to the boundary condition, and according to which the filter coefficients are returned automatically to the permitted range should they assume random values for some reason or other, for instance as a result of disturbance on the supply voltage.

The most common type of adaptive filter in an echo canceler is an FIR-filter. This filter has the following transfer function:

$$H_{ca} = \Sigma\{b_v * z^{-v}\} \qquad (10)$$

where b_v represents the adaptive coefficients and $z = e^{j\omega T}$. In the expression for z, $T = 1/f_s$, where f_s is the sampling frequency.

The following relationship always applies: $|z| = 1$. The following relationship therefore applies for the transfer function H_{ca}:

$$|H_{ca}| \leq \Sigma|b_v| \qquad (11)$$

which shows that when the coefficients are restricted during the updating process in accordance with

$$|H_{ca}| \leq \Sigma|b_v| \leq 1.5 \qquad (12)$$

the stability condition will be fulfilled. It can be mentioned that the value 1.5 is appropriate for a trunk echo canceler. Another value which fulfills the conditions according to equation (7) should be chosen in other applications.

The condition according to equation (12) is simple to calculate, since it solely requires a summation of the absolute values of the coefficients.

The equals sign in equation (11), i.e. $\text{Max}|\Sigma\{b_v * z^{-v}\}| = \Sigma|b_v|$ applies, inter alia, in the following cases:

- Only one coefficient is different to zero (all frequencies).
- All coefficients have the same sign (f=o, i.e. direct current).
- Each alternate coefficient is negative ($f=f_s/2$).
- Each alternate coefficient is zero and each alternate coefficient of the remainder is negative and each alternate coefficient positive ($f=f_s/4$).

It has been found that cases similar to those above can occur when both the near-end signals and the far-end signals consist of pure tones. The requirement for a summation of the absolute values is thus not unrealistically hard, but must generally be fulfilled in order to guarantee stability.

It is desirable to attain an optimum as quickly as possible even when introducing a boundary condition, even though this optimum lies on the boundary. By calculating the new values of the coefficients when updating the adaptive filter and not proceeding with the updating when these new values do not fulfil the condition, the result, under all circumstances, will be a slow convergence on the boundary and perhaps prevent an optimum being achieved. Such

a method is therefore unsuitable. In order to guarantee a rapid convergence and to achieve an optimum it is desirable that the influence of the updating procedure effected on the basis of different boundary conditions is perpendicular thereto.

The most common adaptive filter updating method is the LMS-method. When practicing this method, the filter coefficients are updated in accordance with the following equation:

$$b_v(k+1) = b_v(k) + u*x_v(k)*e(k+1) \quad (13)$$

where $x_v(k)$ is the signal and $e(k+1)$ is the error, this updating process endeavoring to reduce the correlation between said signal and said error, and u is an updating constant which determines the speed and the accuracy of the updating process. Variants of this algorithm in which the error sign and/or the signal sign are used are also common.

One method of obtaining rapid convergence and an influence which is perpendicular to the boundary condition when using the limit value according to equation (9) is to proceed as follows. A check is made in conjunction with each updating process to ascertain whether the boundary condition has been fulfilled or not.

Form E in accordance with: $E = \Sigma|b_v| - B_{sum}$ (14)

where B_{sum} corresponds to the limit value 1.5 in equation (9).

When E is greater than 0, updating is effected in accordance with the following equation:

$$b_v(k+1) = b_v(k) - SIGN\,[b_v(k)]*E/Nv + u*x_v(k)*e(k+1) \quad (15)$$

where Nv is the number of coefficients and $SIGN[b_v(k)]$ is the sign on the coefficient. Equation (15) implies that the coefficients are returned to the permitted range at right angles to the condition according to equation (14).

If E is smaller than 0, updating is effected in a usual manner according to equation (13).

Equation (15) is very similar to the normal updating equation, i.e. equation (13), and implies that the absolute sum of each coefficient is reduced by an equally as large sum. If so desired, the equation (15) can be modified in a normal manner to obtain the sign algorithm or sign/sign-algorithm. The additional calculation required is moderate and the factor E/Nv is the same for all coefficients and need therefore only be calculated once with each updating process and then added to or subtracted from each coefficient, depending on the sign of the coefficient.

The updating algorithm according to equation (15) returns the coefficients to the permitted range in one step when all

$$|b_v| > E/Nv \qquad (16)$$

However, should one or more coefficients not fulfil the condition according to equation (16), these coefficients will be updated to opposite signs and thereafter slowly converge to zero with changing signs. This is unsuitable because the more coefficients that lie close to zero the slower the convergence towards the desired range. If all coefficients are almost zero with the exception of one, the error will first increase and then decrease with each updating process with a factor 1-2/Nv. When there is a large number of coefficients, a very slow convergence will result. In this case, an updating algorithm according to equation (29) below can be used, this algorithm not exhibiting this convergence problem. However, a true optimum is not achieved when this lies on the border of the limitation condition.

A limitation of the range in which the coefficients are permitted to move in accordance with the aforegoing, will, of course, also imply a limitation to the possible extent of echo cancellation. The following will apply when canceling the echo of one side, i.e. the near-end echo:

$$H_{ne} + H_{ca} = 0 \qquad (17)$$

Thus, with regard to equation (1) the transfer function of an echo canceler must be capable of fulfilling the following conditions in order to be able to cancel all conceivable echo paths:

$$\text{Max}(|H_{ca}|) \geq 0.5 \qquad (18)$$

In order to be able to cancel the one echo path and not induce self-oscillation in the four-wire loop, the transfer function of the echo canceler must therefore be capable of fulfilling the following conditions:

$$0.5 \leq \text{Max}(|H_{ca}|) \leq 1.5 \qquad (19)$$

A calculation of the impulse response of two PCM-filters plus a highpass filter in cascade with end terminals corresponding to USA's nominal impedance and loaded and non-loaded cable with the subsidiary condition that the total loss is greater than 6 dB has resulted in a sum which is smaller than 1.5 in all three cases. Investigations indicate that the requirement of suppressing the echo and also the stability against self-oscillation are both achieved with the proposed method. When the limit value chosen is greater than 1.5, stability against self-oscillation cannot be strictly proven, but the probability of self-oscillation occurring is considerably lower than if there was no limitation of the transfer function. This particularly applies to the case when "double-talk"-detectors are used to prevent updating from taking place solely with respect to a near-end signal.

Figure 3 illustrates an example of an equivalent block schematic illustrating a four-wire loop having an echo canceler in the form of an adaptive hybrid. This block schematic includes a balance filter which is located much closer to the near-end hybrid, e.g. on the same circuit board as said hybrid, than is normal in the case described above. Those components and transfer functions which have correspondence in Figures 1 and 2 have been identified in the same manner as in the earlier case. The balance filter is divided into an adaptive part 150 having the transfer function H_{ca} and a fixed, non-adaptive part 151 having the transfer function

H_{co}. The output from the adaptive part 150 of the balance filter is connected to a subtraction means 180, whereas the output from the fixed part 151 of said filter is connected to a subtraction means 181. The fixed filter part is a non-adaptive path, which, for instance, corresponds to the echo when the line is terminated with the nominal impedance of the line circuit, whereas the adaptive filter part can be considered in the same manner as the balance filter 15 in the example illustrated in Figures 1 and 2. The resultant echo transfer function downstream of the adaptive filter part 150, i.e. for the near-end hybrid 14 and the fixed filter part 151, has been marked symbolically with the reference sign H'_{ne} in the Figure and can be said to correspond to H_{ne} in Figure 2, whereas the adaptive filter part, H_{ca}, correspond to H_{ca} in Figure 2.

The relationship $H'_{ne} = H_{ne} - H_{co}$ (20)
applies for H'_{ne}.

In this case, a general stability condition corresponding to the condition according to equation (7) for the echo canceler 15 in accordance with the aforegoing is:

$$|H_{ca}| < 1/|H_{fa}| - |H'_{ne}| \quad (21)$$

When H'_{ne} is replaced in accordance with equation (20), the general condition can be instead written as:

$$|H_{ca}| < 1/|H_{fa}| - |H_{ne}-H_{co}| \quad (22)$$

Thus, in this case, stability is guaranteed because the absolute value of the transfer function of the adaptive filter part is caused to be smaller than a given function of the echo transfer function in the far-end of the loop and the resultant echo transfer function downstream of the adaptive filter part, i.e. for the fixed filter part together with the echo transfer function in the near-end of the loop. The condition according to equation (7) is actually a special case of the condition according to equation

(22), since the balance filter 15 of the embodiment illustrated in Figures 1 and 2 does not include a non-adaptive part.

Some differences exist with respect to the case according to Figures 1 and 2. One difference is that echo loss in the near-end can be lower than 6 dB, possibly only one or two dB. Another difference is that the total echo loss required is much lower, since the adaptive hybrid need only be as good as or only slightly better than a suitable compromise balance, which implies loss of the echo by slightly more than 10 dB. Furthermore, loss of the echo in the far-end may also be lower than 6 dB, particularly in the USA where one and the same input and output level is used in a local station, so that no loss occurs in the four-wire loop.

When taken together, these differences imply that a lower limit value than 1.5 must be used for the sum of the absolute values of the coefficients in order to guarantee stability. This is also possible, due to the smaller demand on echo loss in this application, and because the echo frequency response is smoother. It has been found that the echo loss requirement can be fulfilled when a limit value of about 0.7 is chosen.

For instance, the following relationships apply when the echo loss in the near-end and the far-end are greater than 3 dB, and when $B_{sum} \leq 0.7$:

$|H'_{ne}| \leq 0.707$, $|H_{fa}| \leq 0.707$ and $|H_{ca}| \leq 0.7$, which give:

$$|H_{fa}|*(|H'_{ne}|+|H_{ca}|) \leq 0.707*(0.707+0.7) < 1$$

which results in stability, since the loop amplification is lower than one.

Several alternative methods are conceivable for limiting the filter coefficients in the cases aforedescribed. One possibility is to use a weighted sum in accordance with the following:

$$\Sigma|q_v*b_v| \leq B_{sum} \qquad (23)$$

where q_v represents weighting factors.

In this case, the following updating algorithm can be used in order to influence updating perpendicularly to the border condition:

$$b_v(k+1) = b_v(k) - SIGN[b_v(k)]*E/(q_v*Nv) + u*x_v(k)*e(k+1) \quad (24)$$

Another possibility is this. When the adaptive filter also includes an IIR-part, i.e. a recursive part, e.g. having the following transfer function:

$$H_{ca} = \Sigma\{b_v*z^{-v}\} + z^{-(Nv+1)}*\Sigma\{c_w/(1+a_w*z^{-1})\} \quad (25)$$

where c_w represents coefficients in the recursive part, and a_w represents the recursive pole positions, the following will apply:

$$|H_{ca}| \leq \Sigma|b_v| + \Sigma\{|c_w|/(1-|a_w|)\} \quad (26)$$

which gives the condition:

$$\Sigma|b_v| + \Sigma\{|c_w|/(1-|a_w|)\} \leq B_{sum} \quad (27)$$

Equation (27) resembles equation (23). A suitable updating of the c-coefficients is obtained in accordance with the following equation:

$$c_w(k+1) = c_w(k) - SIGN[c_w(k)]*E*(1-|a_w|)/Nv + u*x_w(k)*e(k+1) \quad (28)$$

Alternatively, the transfer function can be realized in accordance with:

$$H_{ca} = \Sigma\{b_v*z^{-v}\} + z^{-(Nv+1)}*\Sigma\{c_w*(1-|a_w|)/(1+a_w*z^{-1})\} \quad (29)$$

wherein the same updating as that achieved according to equation (15) can be used for b_v and c_w.

A third possibility is to apply non-perpendicular updating. The same limitation of the transfer function can be obtained by using the aforesaid criteria but with another updating algorithm. However, the convergence along the boundary condition is changed so that true optimum cannot be achieved. However, such a method may be applied to advantage, when it reduces calculation requirements. An example of one such updating algorithm is given below.

A multiplicator is formed, $Mult = 1 - E/B_{sum}$, where E is formed in accordance with equation (14). The multiplicator is truncated to zero if it becomes negative and is set to one for negative values of E. Updating is effected in accordance with the following equation:

$$b_v(k+1) = b_v(k)*Mult + u*x_v(k)*e(k+1) \qquad (30)$$

In equation (30) all coefficients are multiplied by the same factor. This implies that if the condition $E < 0$ is not fulfilled, there is introduced a leakage of such large magnitude as to return the coefficients to the permitted range. It can be mentioned that leakage is a measure used to achieve stabilization, in that in the updating process the adaptive coefficients are given a contribution which moves them towards zero or some other predetermined value. Multiplication of the coefficients by the same factor may, for instance, be advantageous when the sign operator is lacking among the routines of the signal processor. If optimum lies outside the boundary condition, updating will proceed towards that point on the border where the direction to the origin of the coordinates is perpendicular to the level curve of the error criterium.

An alternative method, which is particularly beneficial when the filter has many coefficients, is to introduce a new, common coefficient and to multiply the total signal by this common coefficient. The transfer function for H_{ca} will then be:

$$H_{ca} = b_{com} * \Sigma(b_v * z^{-v}) \quad (31)$$

where b_{com} is normally 1.0 but is reduced when E is greater than zero.

The coefficients b_v are updated in the usual manner, irrespective of the stability condition, whereas b_{com} is multiplied by Mult when E is greater than zero. However, it is necessary to return b_{com} to the value 1.0, which is its normal state value. This can be achieved by adding a small number "e" when the coefficient is smaller than one. Updating of b_{com} is then:

$$b_{com}(k+1) = Mult * b_{com}(k) + e \quad \text{for } E>0 \quad (32)$$

and

$$b_{com}(k+1) = b_{com}(k) + e \quad \text{for } E<0 \quad (33)$$

when b_{com} is limited so as to be smaller than or equal to 1.0.

It is well known that self-oscillations will occur most readily in the four-wire loop at frequencies close to the band edges, because echo loss is poorest at these frequencies. Consequently, it is advisable to check the conditions at the band-edge frequencies with extra care. As will be evident from the aforegoing, simple conditions prevail between the coefficients and the absolute value of the transfer function at given frequencies, primarily at the frequency zero and at half the sampling frequency. Since these frequencies lie very close to the band edges, separate criteria for these frequencies can be used, whereby the region for the transfer function in precisely these frequency ranges can be further restricted.

When f=0 : $|\Sigma(b_v * z^{-v})| = |\Sigma(b_v)|$ (34)

When $f=f_s/2$: $|\Sigma(b_v * z^{-v})| = |\Sigma(b_v * (-1)^v)|$ (35)

For these frequencies it is possible to use a stricter criterion than that used for $\Sigma|b_v|$ without reducing the possibility of

obtaining desired echo cancellation. For instance, if a separate criterion, called $B_{sum\ 0}$ is used at the frequency f=0, the following procedure is followed when updating perpendicularly:

Form E according to: $E = \Sigma\{b_v\} - B_{sum\ 0}$

If E is greater than 0, updating is effected according to:

$$b_v(k+1) = b_v(k) - E/Nv + u*x_v(k)*e(k+1) \qquad (36)$$

When E is smaller than 0, a new value of E is formed according to: $E = \Sigma\{b_v\} + B_{sum\ 0}$

If the new value of E is smaller than 0, updating is effected according to equation (36).

If E is greater than 0, updating is effected in the usual manner, i.e. according to equation (13).

Updating can also be effected in the same manner as that described with reference to equations (30) - (33).

As will be understood from the above description referring to equation (16), a slow convergence can occur in some cases. In view of this, it may be beneficial to ensure that no individual coefficient has an absolute value which is greater than B_{sum}. In this way, a slow convergence is avoided when all coefficients are close to zero with the exception of one coefficient. This can be achieved either by trunking or by updating.

CLAIMS

1. A method for avoiding self-oscillation in a four-wire loop in conjunction with echo cancellation effected with the aid of an adaptive filter (15), characterized by restricting the permitted range of the coefficients of the adaptive filter in a manner such that the absolute value of the filter transfer function, $|H_{ca}|$, is restricted according to the following condition: $|H_{ca}| < 1/|H_{fa}| - |H_{ne}|$, where H_{fa} is the echo transfer function in the far-end (13) of the loop and H_{ne} is the echo transfer function in the near-end (14) of the loop; and by reducing the values of said coefficients when said condition is not fulfilled.

2. A method according to Claim 1, characterized in that the criterion for restricting the permitted range of said coefficients consists of a limitation of a sum of the absolute values of the coefficients ($\Sigma|b_v|$).

3. A method according to Claim 1, characterized in that a criterion for restricting the permitted range of said coefficients consists in a limitation of a weighted sum of the absolute values of the coefficients ($\Sigma|q_v*b_v|$).

4. A method according to Claim 1, characterized in that a criterion for restricting the permitted range of said coefficients consists in a limitation of the absolute value of a summation of the coefficients ($|\Sigma b_v|$).

5. A method according to Claim 1, characterized in that a criterion for restricting the permitted range of said coefficients consists in a limitation of the absolute value of a summation of the coefficients, where each alternate coefficient is multiplied by minus one ($|\Sigma\{b_v*(-1)^v\}|$).

6. A method for avoiding self-oscillation in a four-wire loop in conjunction with echo cancellation effected with the aid of a filter which includes an adaptive part (150) and a non-adaptive

part (151), c h a r a c t e r i z e d by restricting the permitted range of the coefficients in the adaptive filter part (150) in a manner such that the absolute value of the transfer function, $|H_{ca}|$, of the adaptive part will be restricted in accordance with the following condition: $|H_{ca}| < 1/|H_{fa}| - |H_{ne}-H_{cc}|$, where H_{fa} is the echo transfer function in the far-end (13) of the loop, H_{ne} is the echo transfer function in the near-end (14) of the loop, and H_{co} is the transfer function in the non-adaptive part (151) of the filter; and by reducing the values of the said coefficients when said condition is not fulfilled.

7. A method according to Claim 6, c h a r a c t e r i z e d in that a criterion for restricting the permitted range of said coefficients consists in a limitation of a summation of the absolute values of the coefficients ($\Sigma|b_v|$).

8. A method according to Claim 6, c h a r a c t e r i z e d in that a criterion for restricting the permitted range of said coefficients consists in a limitation of a weighted summation of the absolute values of the coefficients ($\Sigma|q_v*b_v|$).

9. A method according to Claim 6, c h a r a c t e r i z e d in that a criterion for restricting the permitted range of said coefficients consists in a limitation of the absolute value of a summation of the coefficients ($|\Sigma b_v|$).

10. A method according to Claim 6, c h a r a c t e r i z e d in that a criterion for restricting the permitted range of said coefficients consists in a limitation of the absolute value of a summation of the coefficients, where each alternate coefficient is multiplied by minus one ($|\Sigma(b_v*(-1)^v)|$).

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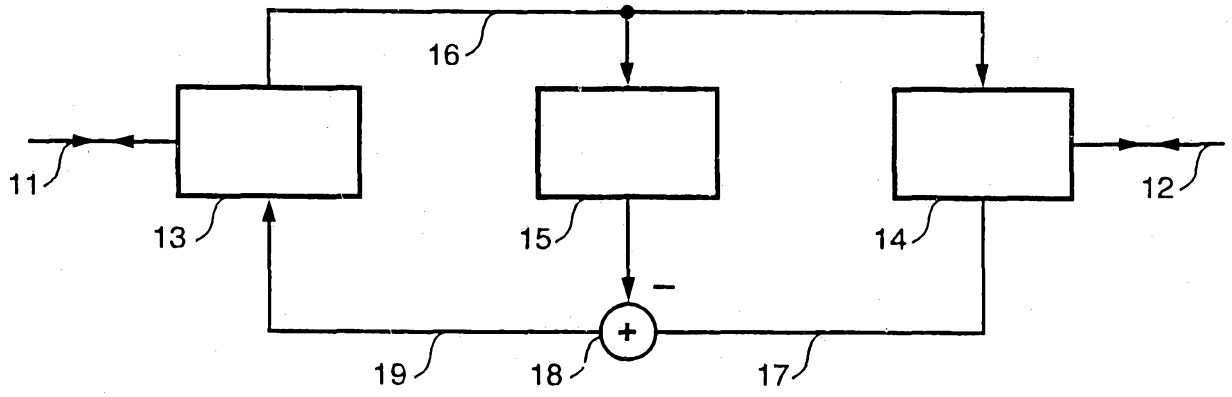

Fig. 1

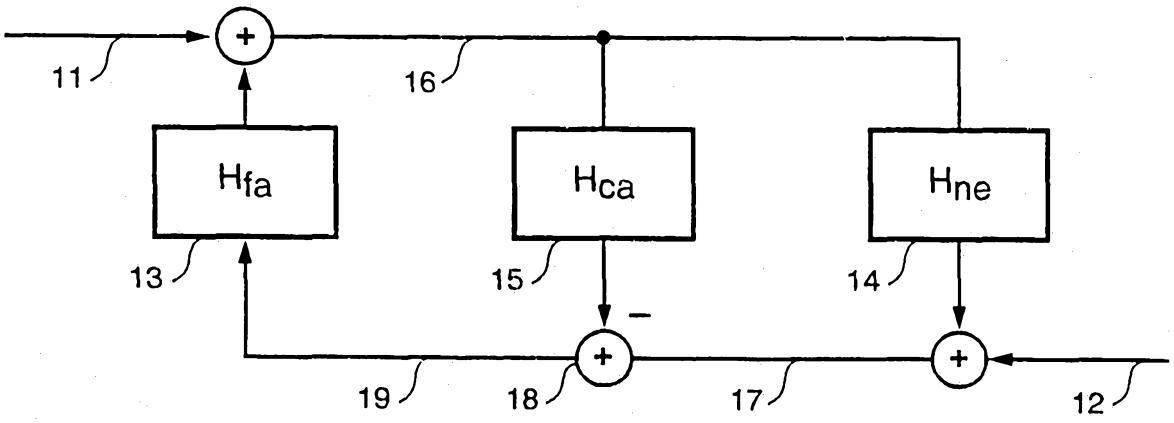

Fig. 2

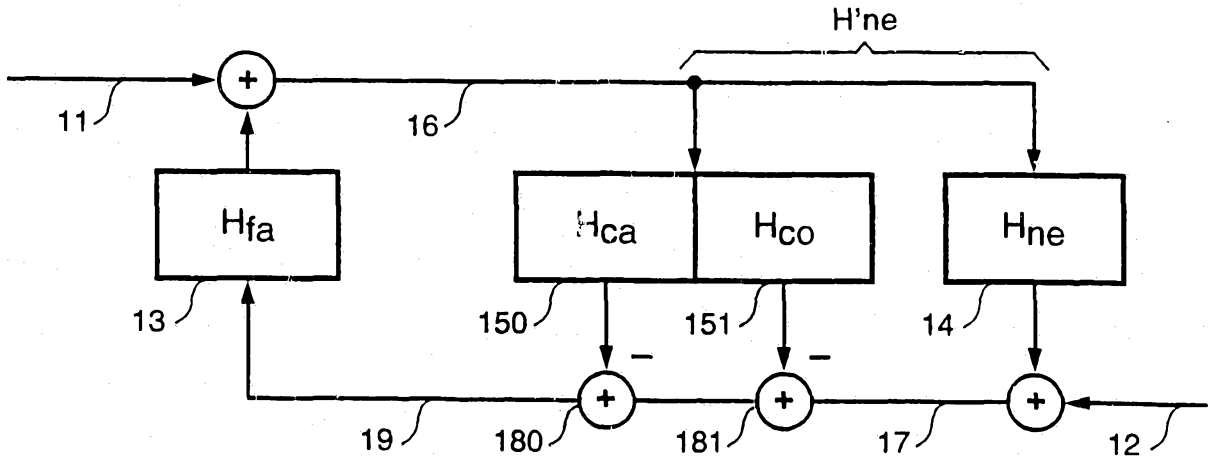

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00218

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: H04B 3/23
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)

IPC5: H04B

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

SE,DK,FI,NO classes as above

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

DIALOG: CLAIMS, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4894820 (RYOICHI MIYAMOTO ET AL), 16 January 1990 (16.01.90), column 15, line 59 - column 19, line 24, figures 12,13 --	1-10
A	US, A, 4811261 (MASAKI KOBAYASHI ET AL), 7 March 1989 (07.03.89), column 1, line 45 - column 2, line 49, figures 1-3, abstract --	1-10
A	Patent Abstracts of Japan, Vol 13,No 181, E-750, abstract of JP, A, 1-7821 (OKI ELECTRIC IND CO LTD), 11 January 1989 (11.01.89) --	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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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
7 May 1993	09 -07- 1993
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 Michael Felhendler Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, Vol 13,No 493, E-842, abstract of JP, A, 1-198154 (OKI ELECTRIC IND CO LTD), 9 August 1989 (09.08.89)	1-10

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INTERNATIONAL SEARCH REPORT

Information on patent family members

31/03/93

International application No.
PCT/SE 93/00218

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4894820	16/01/90	GB-A,B- 2202717	28/09/88
		JP-A- 63236132	03/10/88
		JP-A- 63238727	04/10/88
		JP-A- 1007822	11/01/89
US-A- 4811261	07/03/89	JP-C- 1626623	28/11/91
		JP-B- 2053963	20/11/90
		JP-A- 61200713	05/09/86
		JP-A- 62149213	03/07/87