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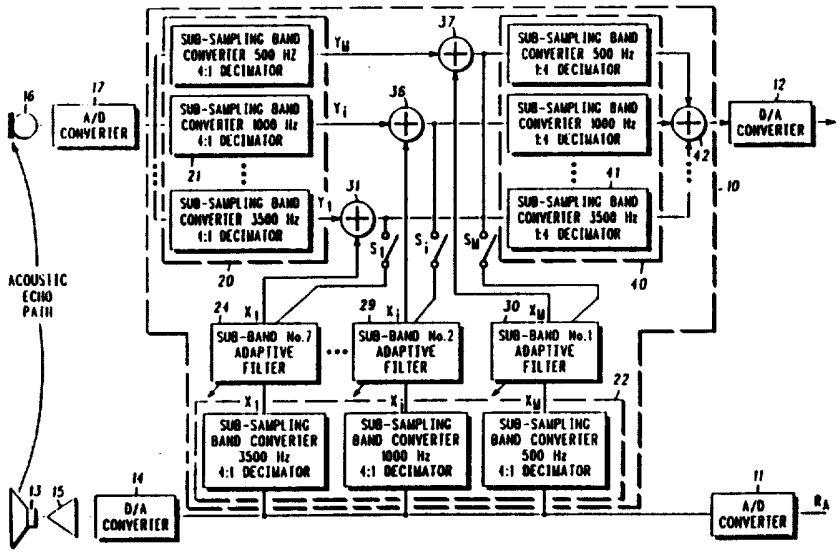
(54) Title: ECHO CANCELLER



(57) Abstrac.

This invention relates to an echo canceller such as for use in a full duplex hands free radio. The echo canceller is particularly suitable for use in a vehicle fitted with a microphone and a loudspeaker, for cancelling echos reach the radio microphone (16) from the radio loudspeaker (13). The signal paths are divided into sub-band channels (Y_1-Y_M). Each of the channels has an adaptive filter (24, 29, 30), a time delay coefficient of which is dynamically adjustable. Means are provided for cancelling echos by compensating the signal on each channel as a function of the signal from the filter, and means (S_1, S_i, S_M) are provided for initiating and suspending the adjustment of the coefficient of each channel filter as a function of the signal on that channel (X_1-X_M and/or Y_1-Y_M).

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Echo Canceller

Background to the Invention

This invention relates to an echo canceller such as for use in a full duplex hands free radio. The echo canceller is particularly suitable for use in a vehicle fitted with a microphone and a loudspeaker, for cancelling echos reaching the radio microphone from the radio loudspeaker.

The echo canceller is useful in any system having large transmission delays in the order of 100 msec particularly useful for GSM cellular subscriber equipment.

The GSM cellular radio system calls for standards in cancellation of echos not reached in previous systems. In particular, in the GSM system the up link/down link transmission delay can be of the order of 100 milliseconds, which is considerably more than in traditional cellular. The echo tends to become more annoying as the transmission delay increases so that GSM systems require improvements in this field.

Summary of the Prior Art

A method of adaptive filtering in sub-bands is described in a paper of that title by Andre Gilloire and Martin Vetterli, published in IEEE bulletin D6.6 of 1988, at page 1572. The paper concludes that the computational complexity of adaptive filtering is improved nearly proportional to the number of sub-bands, and the conversion speed is improved as well, making the scheme described attractive for application like acoustic echo cancellation. The aforesaid paper in its entirety is incorporated herein by reference.

It is an object of the present invention to provide an improved echo canceller, especially one which allows for full duplex operation with good echo suppression.

Summary of the Invention

According to the present invention, there is provided an echo canceller comprising an output path for outputting desired signals (eg. through a loudspeaker) and an input path for receiving desired signals (eg. through a microphone) together with undesired echos from the output path. The output path has at least one channel connected thereto for receipt of signals therefrom, said channel having an adaptive filter, and the input path has at least one channel and means for cancelling said echos by compensating the signal thereon as a function of the filtered signals from the filter, characterised by means for initiating and suspending the adjustment of the filter coefficient as a function of the signal on at least one path.

Adjustment of the filter coefficient (or coefficients) may be dependent on a number of factors. In a first embodiment, the adjustment is temporarily disabled when the level of the signal on the output path (the loudspeaker signal) is below a pre-determined threshold. In a second embodiment, the adjustment disabled when the level of the signal on the input path (through the microphone) is above a predetermined threshold.

In a third embodiment adjustment is temporarily disabled when there is a desired signal on the input path and no desire signal on the output path (ie. the near end talker is active alone).

In a fourth embodiment, adjustment is suspended when there is a desired signal on the output path and a desired signal, other than echos, on the input path ie both the near end and far end talkers are active.

A preferred embodiment of the invention will be described, with reference to the accompanying drawings, in which:

Fig 1 shows an echo canceller in accordance with the invention and

Fig 2 shows a block diagram of a control algorithm for control of the adaptive filtering in the echo canceller of Fig 1.

Detailed description of the preferred embodiment

Referring to Fig 1, there is shown an echo canceller as part of a duplex GSM mobile radio. The echo canceller is shown in dotted outline 10 and is implemented in a digital signal processor such as a DSP 56001 of Motorola Inc or two such processors as necessary. The echo canceller is connected to a transceiver (not shown) at the right hand side of the figure by means of analog-to-digital converter 11 and digital-to-analog converter 12 and is connected to a microphone 13 by means of digital-to- analog converter and power amplifier 15 and to a microphone 16 by means of analog-to-digital converter 17. The converters 11 and 14, the amplifier 15 and the loudspeaker 13 make up the "output path". The microphone 16, converter 17, echo canceller 10 and converter 12 make up the "input path". There is an acoustic echo path between the loudspeaker 13 and the microphone 16 which gives rise to unwanted echos at the microphone 16. It is the purpose of the echo canceller 10 to suppress echos received at the microphone from the loudspeaker.

The inventors have found that the performance of the echo canceller is improved if the speech frequency band is divided into seven sub-bands covering the area from 250 Hz to 3750 Hz giving 500 Hz sub bands. Each sub band has associated with it a complete echo canceller system and a synthesize filter. In the figure, the sub-bands are referred to as 1 to M. The echo canceller 10 comprises an analyse filter bank 20 made up of seven sub-sampling-band (SSB) converters 21, each having a 4:1 decimator. There is a similar analyse filter bank 22 comprising seven SSB converters and 4:1 decimators connected for receipt of signals from the A/D converter 11 on the

output path. The signals X1 to XM from the analyse filter bank 22 are passed to seven sub band adaptive FIR filters 24 to 30. These filters delay the signals X1 to XM by up to 30 milliseconds. The signals from the filters 24 to 30 are subtracted from the signals from the analyse filter banks by means of mixers 31 to 37. The analyse filter bank 20 is designed to be equal to analyse filter bank 22. Provided that the response of filter 24-30 matches the combined response of loudspeaker, echo path, microphone, and filter bank, the subtraction of these signals will provide echo suppression. From the resulting signals, a final signal is synthesized in synthesize filter bank 40. This filter bank comprises seven SSB converters 41 each providing 1:4 interpolation. The signals from the seven sub-bands are added in mixer 42 and converted to analog form in D/A converter 12, for transmission in the GSM mobile transmitter (not shown).

Each of the sub-band FIR filters 21 to 30 is adaptive, in that the coefficients of those filters are dynamically adjustable in accordance with the above mentioned paper by Gilloire and Vetterli. In the preferred embodiment of the present invention, feedback is provided within each sub band from the output of the mixers 31 to 37 to the sub-band FIR filters 24 to 30. The feedback in each sub band causes the adaptive FIR filter in that sub-band to update its coefficients as a function of the signal on the input path in that sub band after echo suppression. The update algorithm is based on the least mean square of the signal, as described in "A Stochastic Approximation Method", Annals of Mathematical Statistics, Vol 22, pp400-407, 1959, M.Robbins, & S.Monroe. A control algorithm is provided to temporarily disable updating of the coefficients in each of the FIR filters. (To put this another way, the state of the FIR filter is temporarily frozen). This is represented in Fig 1 by switches S1 to SM, however, it will be understood that these "switches", as with all the other elements shown within

the dotted line of the echo canceller 10, are implemented in software.

The algorithm controlling the suspension of coefficient updating is shown in block diagram form in Fig 2 as algorithm 50. The algorithm has as its inputs the signals from the analyse filter bank 20 (signals Y1 to YM), the signals from the sub-band adaptive FIR filters 24 to 30 (signals X1 to XM) and the inputs from the analyse filter bank 22 (signals X1 to XM).

The controller algorithm is based on calculating the signal energy of the different sub band signals. These calculations are based on averaging the sub band signals by filtering the absolute value of the samples in a second order IIR filter, with cut off frequency FC=50Hz.

The coefficients of the FIR filters are not up dated when:

1. The level of the loudspeaker signal is below a fixed threshold;.
2. The level of the microphone signal is above a fixed threshold;.
3. The near end talker is active alone; or
4. Both the near end and the far end talker are active - double talk.

In order to meet the conditions 1 and 2, the sub band energies are compared with fixed thresholds. A time delay is added to prevent sudden spikes and low level samples from stopping the updating process.

Double talk, as described under points 3 and 4 above, is detected by calculating the cross correlation between the microphone sub band signal Yi and the sub band signal Xi estimated by the echo canceller - see Figure 1. The cross correlation is calculated from:

$$Si = \frac{E[Xi(n) \cdot Yi(n)]}{\sqrt{E[Xi^2(n)] \cdot E[Yi^2(n)]}} \quad ; i = 1,2..M$$

The normalization is performed in order to make the correlation independent of the absolute signal levels and to limit the correlation to the interval [0;1]. E[.] symbolizes the aforementioned energy calculation.

In order to decide whether the current sub-band contains double talk or not, the cross correlation factor is compared to a fixed threshold. The value of the threshold is chosen with respect to the current sub-band. Updating is performed whenever the cross correlation is greater than the threshold.

The invention has the advantage that by controlling each sub band separately, it is possible to stop updating the coefficients in only those frequency bands where double talk is actually present. Thereby, it is possible to achieve echo cancelling even under conditions were the full band echo canceller would have stopped updating. As a result, the invention provides an improved echo canceller.

It will, of course, be understood that the above description has been given by way of example only, and that modifications of detail can be made within the scope of the invention.

Claims

1. An echo canceller comprising an output path (11, 14, 15, 13) for outputting desired signals and an input path (16, 17, 10, 12) for receiving desired signals together with undesired echos from the output path, the output path having a plurality of sub-band channels (X_1-X_M) connected thereto for receipt of signals therefrom, each of said channels having an adaptive filter (24, 29,30), a time delay coefficient of which is dynamically adjustable, and the input path having a plurality of sub-band channels (Y_1-Y_M) and means for cancelling said echos by compensating the signal on each channel as a function of the signal from the filter, characterised by means (S_1, S_i, S_M) for initiating and suspending the adjustment of the said coefficient of each channel filter as a function of the signal on that channel (X_1-X_M and/or Y_1-Y_M).

2. An echo canceller according to claim 1, wherein means are provided for measuring the signal level on a channel of the output path and suspending adjustment of said coefficient when said signal is below a predetermined threshold.

3. An echo canceller according to claim 1 or 2, wherein means are provided for measuring the signal level on a channel (Y_1-Y_M) of the input path and suspending adjustment of the filter coefficient when the signal on that path is above a predetermined second threshold.

4. An echo canceller according to claim 1, wherein manes are provided for measuring the signals on a channel of the output and input paths and suspending adjustment of said coefficient when there is a desired signal on the input path channel (Y_1-Y_M) and no desired signal on the output path channel (X_1-X_M).

5. An echo canceller according to claim 1, wherein means are provided for measuring the signals on a channel of the output and input paths and suspending adjustment of said coefficient when there is a desired signal on the output path channel and a desired signal, other than echos, on the input path channel.

6. An echo canceller according to any one of the preceding claims, characterised in that there are from four to twelve channels connected to the output path and an equal number of channels in the input path.

7. An each canceller according to claim 6, wherein there are from six to eight such channels.

8. An echo canceller according to claim 6 or 7, wherein the channels span the frequency range from about 250 Hz to about 3750 Hz in approximately equal sub-bands.

9. An echo canceller according to any one the preceding claims in combination with a duplex transceiver, wherein the output path includes a loudspeaker (13) for audio output of received signals, the input path includes a microphone (16) for audio input of signals for transmission, the echo canceller is arranged to cancel echos in the microphone originating from the loudspeaker, and the means for initiating and suspending the adjustment of the filter coefficient is arranged to suspend said adjustment during full duplex operation.

10. An echo canceller and transceiver according to claim 9, when installed in a vehicle.

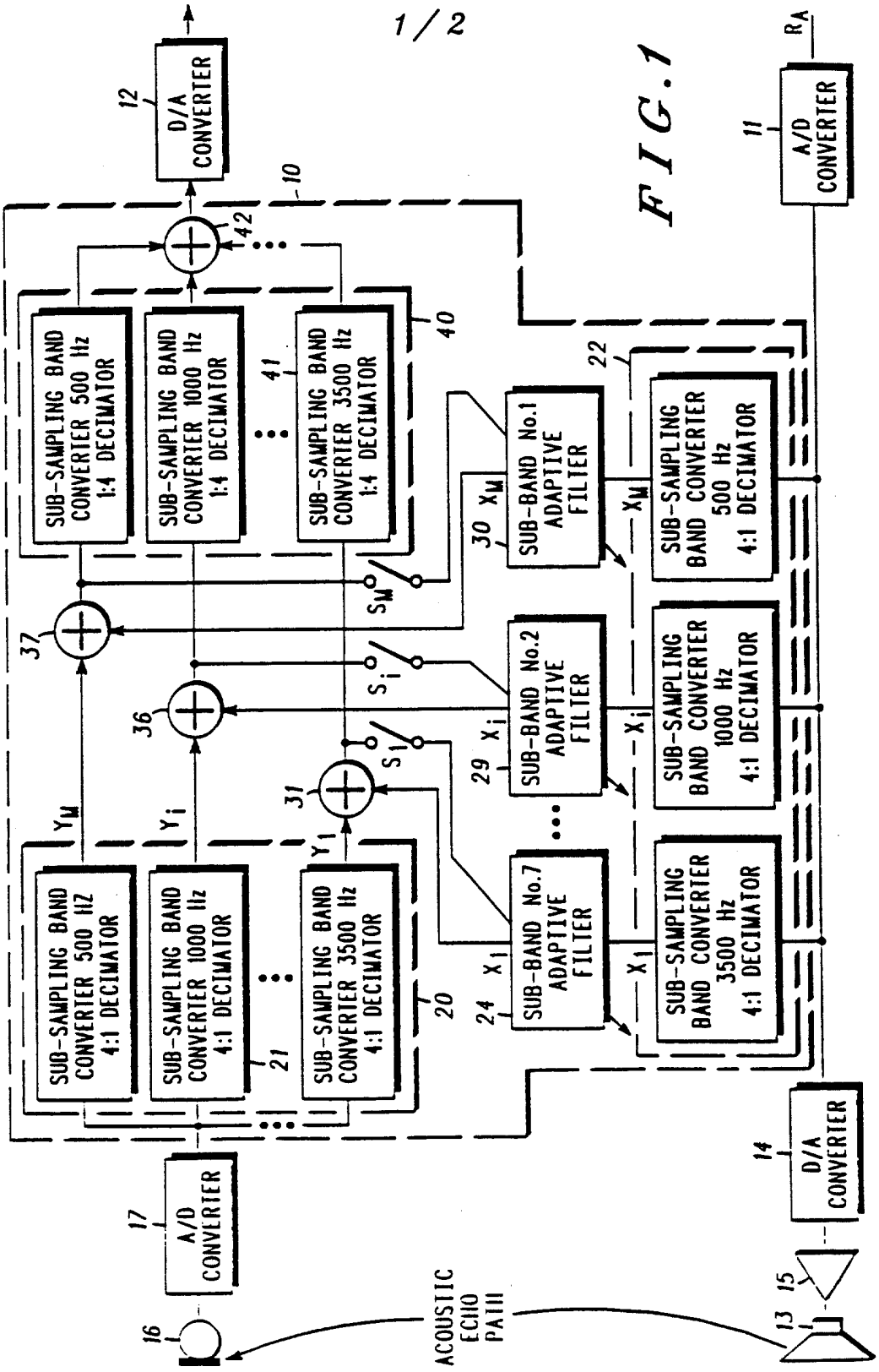
D/A CONVERTER
12
A/D CONVERTER
11
R_A
10
SUB-SAMPLING BAND CONVERTER 500 Hz 1:4 DECIMATOR
SUB-SAMPLING BAND CONVERTER 1000 Hz 1:4 DECIMATOR
SUB-SAMPLING BAND CONVERTER 3500 Hz 1:4 DECIMATOR
40
41
42
SUB-BAND No.1 ADAPTIVE FILTER
SUB-BAND No.2 ADAPTIVE FILTER
SUB-BAND No.7 ADAPTIVE FILTER
30 X_M
29 X_i
24 X_1
22
X_M
$-X_i$
X_1
SUB-SAMPLING BAND CONVERTER 500 Hz 4:1 DECIMATOR
SUB-SAMPLING BAND CONVERTER 1000 Hz 4:1 DECIMATOR
SUB-SAMPLING BAND CONVERTER 3500 Hz 4:1 DECIMATOR
SUB-SAMPLING BAND CONVERTER 500 Hz 4:1 DECIMATOR
SUB-SAMPLING BAND CONVERTER 1000 Hz 4:1 DECIMATOR
SUB-SAMPLING BAND CONVERTER 3500 Hz 4:1 DECIMATOR
20
21
Y_M
Y_i
Y_1
37
36
31
S_M
S_i
S_1
A/D CONVERTER
17
D/A CONVERTER
14
16
15
13
ACOUSTIC ECHO PATH

FIG. 1

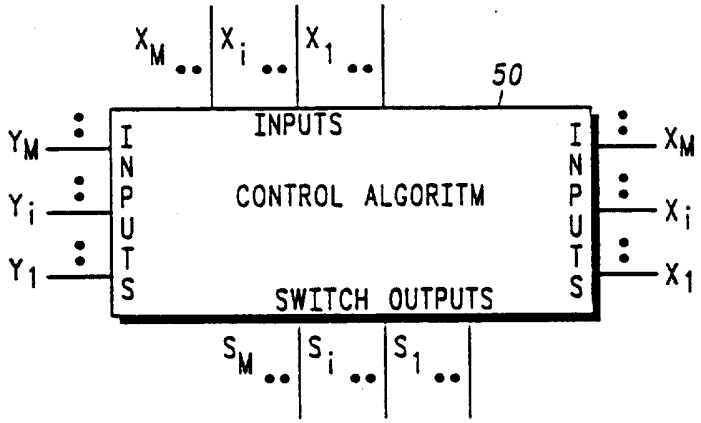
X_M .. X_i .. X_1 ..
50
INPUTS
Y_M
Y_i
Y_1
INPUTS
CONTROL ALGORITM
INPUTS
X_M
X_i
X_1
SWITCH OUTPUTS
S_M .. S_i .. S_1 ..

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/EP 90/02264

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 04 B 3/23, H 04 M 9/08

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	H 04 B, H 04 M

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	EP, A1, 0333581 (ETAT FRANCAIS REPRESENTE PAR LE MINISTRE DES POSTES, DES TELECOMMUNICATIONS ET DE L'ESPACE (CENTRE NATIONAL D'ETUDES DES TELECOMMUNICATIONS)) 20 September 1989, see column 1, line 1 - column 4, line 28; column 6, line 62 - column 7, line 4; figures 1-2	1,3,6-8
Y		5
	--	
Y	EP, A1, 0301627 (N.V. PHILIPS' GLOEILAMPENFABRIEKEN) 1 February 1989, see column 10, line 55 - column 11, line 55; abstract; figure 2	5
	--	

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
15th April 1991	21. 05. 91
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	EP, A1, 0107122 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 2 May 1984, see figures 1,7; claims 1,5	1-10
A	US, A, 4578543 (LE BOURLOT ET AL) 25 March 1986, see abstract	1-10
A	EP, A1, 0282393 (CONNAN, JEAN-LOUIS) 14 September 1988, see abstract; figures 1-3	1-10

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/EP 90/02264

SA 43474

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 23/03/91 The European Patent office is in no way liable for theseparticulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A1- 0333581	20/09/89	FR-A-B-	2628918	22/09/89
		US-A-	4956838	11/09/90
EP-A1- 0301627	01/02/89	JP-A-	1034021	03/02/89
		NL-A-	8701633	01/02/89
		US-A-	4903247	20/02/90
EP-A1- 0107122	02/05/84	CA-A-	1201541	04/03/86
		JP-A-	59080029	09/05/84
		US-A-	4644108	17/02/87
US-A- 4578543	25/03/86	CA-A-	1196434	05/11/85
		EP-A-B-	0082529	29/06/83
		FR-A-B-	2518853	24/06/83
EP-A1- 0282393	14/09/88	FR-A-B-	2612029	09/09/88
		JP-A-	63299436	06/12/88
		US-A-	4984265	08/01/91