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(54) **Title:** A DEVICE FOR CROSSTALK CANCELLATION IN OPTICAL TRANSCEIVERS

(57) **Abstract:** A device useful for cancellation of crosstalk in an optical transceiver, integrating transmission of an output signal and reception of an input signal comprising:a tunable filter for cancelling the crosstalk component from the transmitter to the receiver; a delay element for closing the gap between the input signal and cancelled crosstalk component; and an adaptation circuit for adjusting to the changing characteristics of the device, such as the signal to noise and distortion ratio and the relative amounts of electrical and optical crosstalk, such that the crosstalk component from the transmitter to the receiver is more fully cancelled.

A DEVICE FOR CROSSTALK CANCELLATION IN OPTICAL TRANSCEIVERS

FIELD OF THE INVENTION

The present invention generally relates to optical transceivers. More specifically, the present invention relates to a device for crosstalk cancellation in optical transceivers.

BACKGROUND

A bi-directional optical transceiver, which transmits and receives optical data, becomes a key component in optical links such as Passive Optical Networks (PON). Integration of the transmitter and receiver into one module reduces the cost of the system, of which the transceiver is one of the most expensive parts.

However, integration has its own price. Optical and electrical crosstalk may reach the receiver, and degrade its performance. Reduction of crosstalk has been achieved using expensive techniques, such as optical filtering and electrical separation, which achieve high crosstalk attenuation.

The crosstalk in optical transceivers can limit the performance of the receiver in that transceiver. In order to prevent performance degradation, or to improve the situation, a higher price must be paid. In the case of optical crosstalk, the price of a double filter must be paid. In the case of electrical crosstalk, a more expensive size and material design is needed.

Therefore, there is a need to provide an optical transceiver that overcomes the disadvantages of prior art technology.

SUMMARY OF THE INVENTION

The object of the invention is to have a new architecture for optical transceivers. The invention will improve the receiver sensitivity by implementing new crosstalk cancellation techniques.

It is another object of the present invention to provide better performance receivers. By improving the receiver sensitivity the invention enables longer distance optical communication and/or higher rate optical communication at lower cost.

It is a further object of the present invention to provide a new technique called crosstalk cancellation, which improves the receiver performance by improving the Signal to Noise and Distortion (SNDR).

The present invention provides a device useful for cancellation of crosstalk in an optical transceiver, integrating transmission of an output signal and reception of an input signal comprising:

a tunable filter for cancelling the crosstalk component from the transmitter to the receiver;

a delay element for closing the gap between the input signal and cancelled crosstalk component; and

an adaptation circuit for adjusting to the changing characteristics of the device, such as the signal to noise and distortion ratio and the relative amounts of electrical and optical crosstalk,

such that the crosstalk component from the transmitter to the receiver is more fully cancelled.

In certain embodiments, the tunable filter is a linear filter. In such case, in certain embodiments the adaptation circuit has a zero-forcing algorithm. In other embodiments the adaptation circuit has a least mean squares algorithm.

In certain embodiments the tunable filter is a non-linear filter. In this case, in certain embodiments the filter incorporates analog techniques. In other embodiments the filter incorporates digital techniques.

In certain embodiments the tunable filter is a combination of linear and nonlinear filters.

In certain embodiments the crosstalk between the transmitter and the receiver is electrical crosstalk.

In certain embodiments the crosstalk between the transmitter and the receiver is optical crosstalk.

Other features and advantages of the invention will become apparent from the following drawings and description.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention with regard to the embodiments thereof, reference is made to the accompanying drawings, in which like numerals designate corresponding elements or sections throughout, and in which:

Fig. 1 is a schematic block diagram of a general prior art optical transceiver, which consists of a bi-directional optical module and the electrical circuitry;

Fig. 2 is a schematic block diagram illustrating the implementation of crosstalk cancellation in an optical transceiver, constructed and operated in accordance with the principles of the present invention;

Fig. 3 is a schematic block diagram illustrating the implementation of crosstalk cancellation in an optical transceiver using a linear type tunable filter, constructed and operated in accordance with the principles of the present invention; and

Fig. 4 is a schematic block diagram illustrating the implementation of crosstalk cancellation in an optical transceiver using a non-linear type tunable filter, constructed and operated in accordance with the principles of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to fig. 1, which is a schematic block diagram of a general prior art optical transceiver 100, which consists of a bi-directional optical module 110 and the electrical circuitry 120. The crosstalk in optical transceivers can limit the performance of the receiver in that transceiver. In order to prevent performance degradation, or to improve the situation, a higher price must be paid. In the case of optical crosstalk, the price of a double filter must be paid. See, for example, "A 1.3/1.55μm BI-DIRECTIONAL TRANSCEIVER FOR ATM-PON ONU WITH –40dBm FULL-DUPLEX SENSITIVITY USING A NOVEL DOUBLE-FILTER 1.55μm-PIN-PD", Yoshiki Kuhara, Hiromi Nakanishi, Takeshi Okada, Jiro Shinkai, Hitoshi Terauchi, ECOC 2000.

In the case of electrical crosstalk, a more expensive design in size and material is needed. See, for example, "AN ONU TRANSCEIVER MODULE USING PLC FOR 622Mbit/s-DOWNSTREAM ATM-PON SYSYTEM", H.Yanagisawa, A.Goto, R.Nomura, N.Kitamura, Y.Fukutomi, J.Yokoyama, M.Kunitsugu and K.Kaede, ECOC 2000.

Bi-directional module 110 comprises laser diode 112, Positive Intrinsic Negative (PIN) diode 114 and Wave Division Multiplex (WDM) filter 116 and/or beam splitter 118. Laser diode 112 converts the electrical current, which contains the transmitted information, into optical power, which is coupled to the fiber.

PIN diode 114 converts the received optical power, which contains the received information, into electrical current. The Avalanche Photo Diode (APD) can alternatively be used for more sensitive and more expensive receivers.

Beam splitter 118 directs the output optical power of laser diode 112 to the fiber, but part of the output power flows to PIN diode 114 or the APD alternative optical input. This part is the optical crosstalk.

The optical WDM filter 116, which reduces the optical crosstalk, can also be used for better performance.

The other part of the receiver shown in figure 1 is electrical circuitry 120. In the transmit side 121, it is the laser diode driver 122, which converts the transmitted data stream into current which drive laser diode 112.

The receive side 125 comprises a pre-amplifier 126, a limiter amplifier 127 and a clock data recovery circuit (CDR) 128. Pre amplifier 126 is a low noise amplifier, usually a trans impedance amplifier that amplifies the low electrical current at the output of PIN diode 114. Limiter amplifier 127 discriminates the noisy signal into a 2-level signal. CDR 128 estimates the timing of the stream, and samples the data at the right points. Feedback methods, such as Phase Lock Loop (PLL) or feed forward methods can be used for CDR 128.

Since the electrical current of transmitted data 121 is much larger than the electrical current of received data 125, the transmitted current is induced to the receive circuitry. This induction happens via common electrical connections and via radiation. This induction is the electrical crosstalk.

The common methods that are used to attenuate the electrical crosstalk are careful design for maximum separation between the electrical output and electrical input. This makes the electrical component more expensive.

In all the known designs, the optical crosstalk attenuation is limited to less than 50dB while the electrical crosstalk attenuation is limited to less than 100dB. That means that using an expensive and sensitive detector Avalanche Photo Diode (APD), will not improve the transceivers' performance because of the crosstalk.

Referring to Fig. 2, a schematic block diagram is shown illustrating the implementation of crosstalk cancellation 200 in an optical transceiver, constructed and operated in accordance with the principles of the present invention.

The gray blocks in fig. 2 implement the crosstalk cancellation. These blocks are the tunable filter 210, the delay element 220 and the adaptation circuit 230.

In reality, the received signal 255 consists of the wanted received signal 250 and the crosstalk (optical and electrical) components 257. Crosstalk components 257 can be modeled as a transmitted data signal 240, which passes through filter 210, and which can have linear and nonlinear components, as detailed accordingly hereinbelow in fig.3 and fig. 4.

In order to cancel the crosstalk, the transmitted data 245 is passed through tunable filter 210 and then subtracted 252 from wanted received signal 250. Tunable filter 210 can be of 2 basic types:

a linear type;

a nonlinear type; or

a combination of linear and non linear.

A linear type tunable filter is a tapped delay line (FIR – Finite Impulse Response) with programmable or tunable coefficients.

Referring to Fig. 3, a schematic block diagram is shown, illustrating the implementation of crosstalk cancellation in an optical transceiver using a linear type tunable filter 300, constructed and operated in accordance with the principles of the present invention.

In the case of a linear filter 310 the adaptation can be performed using some known algorithms, like Zero-Forcing or Least Mean Squares (LMS) or others. See, for example, "The Theory and Practice of MODEM Design", John A.C. Bingham. Adaptive filters are a subset of digital filters, which are a digital signal processing technique used to alter the characteristics of a signal. The advantage of adaptive filters is that they can adjust to the changing characteristics of the system. Linear filter 310 improves on the simple FIR delay line by allowing the system to choose a single optimal time-constant by minimizing the Mean Squared Error of the system. The tapped delay line is an FIR filter, used in nearly all digital interference canceling applications due to its inherent stability. The time delay taps 320 are scaled by weighting coefficients 330, and then summed 340 to form FIR linear filter 310.

In figure 3 the implementation can be digital or analog. In the case of digital implementation a Digital to Analog Converter (DAC) is required at the filter's output.

Nonlinear type tuned filter is described in figure 4.

Referring to Fig. 4, a schematic block diagram is shown, illustrating the implementation of crosstalk cancellation in an optical transceiver using a non-linear type tunable filter 400, constructed and operated in accordance with the principles of the present invention. In the case of non-linear filtering, the data sequence determines the pulse-shape 457 to be subtracted from the received signal 450. Also in this case, analog and digital techniques can be used.

The delay component in both implementations is used to ensure that precursor and post cursor bits will determine the signal to be cancelled.

CLAIMS:

1. A device useful for cancellation of crosstalk in an optical transceiver, integrating transmission of an output signal and reception of an input signal comprising:

a tunable filter for cancelling the crosstalk component from the transmitter to the receiver;

a delay element for closing the gap between the input signal and cancelled crosstalk component; and

an adaptation circuit for adjusting to the changing characteristics of the device, such as the signal to noise and distortion ratio and the relative amounts of electrical and optical crosstalk,

such that the crosstalk component from the transmitter to the receiver is more fully cancelled.

2. A device according to claim 1, wherein the tunable filter is a linear filter.

3. A device according to claim 2, wherein the adaptation circuit has a zero-forcing algorithm.

4. A device according to claim 2, wherein the adaptation circuit has a least mean squares algorithm.

5. A device according to claim 1, wherein the tunable filter is a non-linear filter.

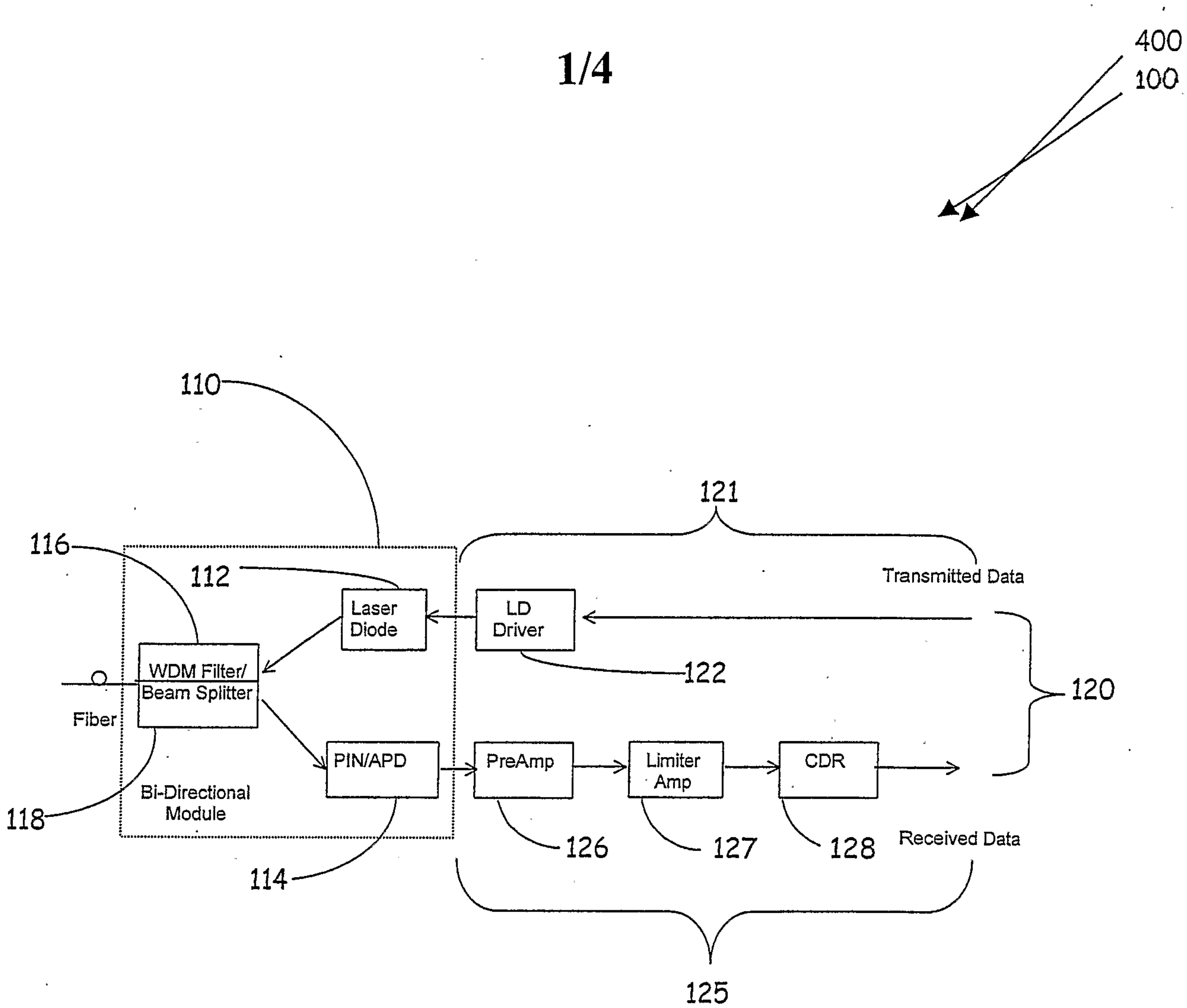
6. A device according to claim 5, wherein said filter incorporates analog techniques.

7. A device according to claim 5, wherein said filter incorporates digital techniques.

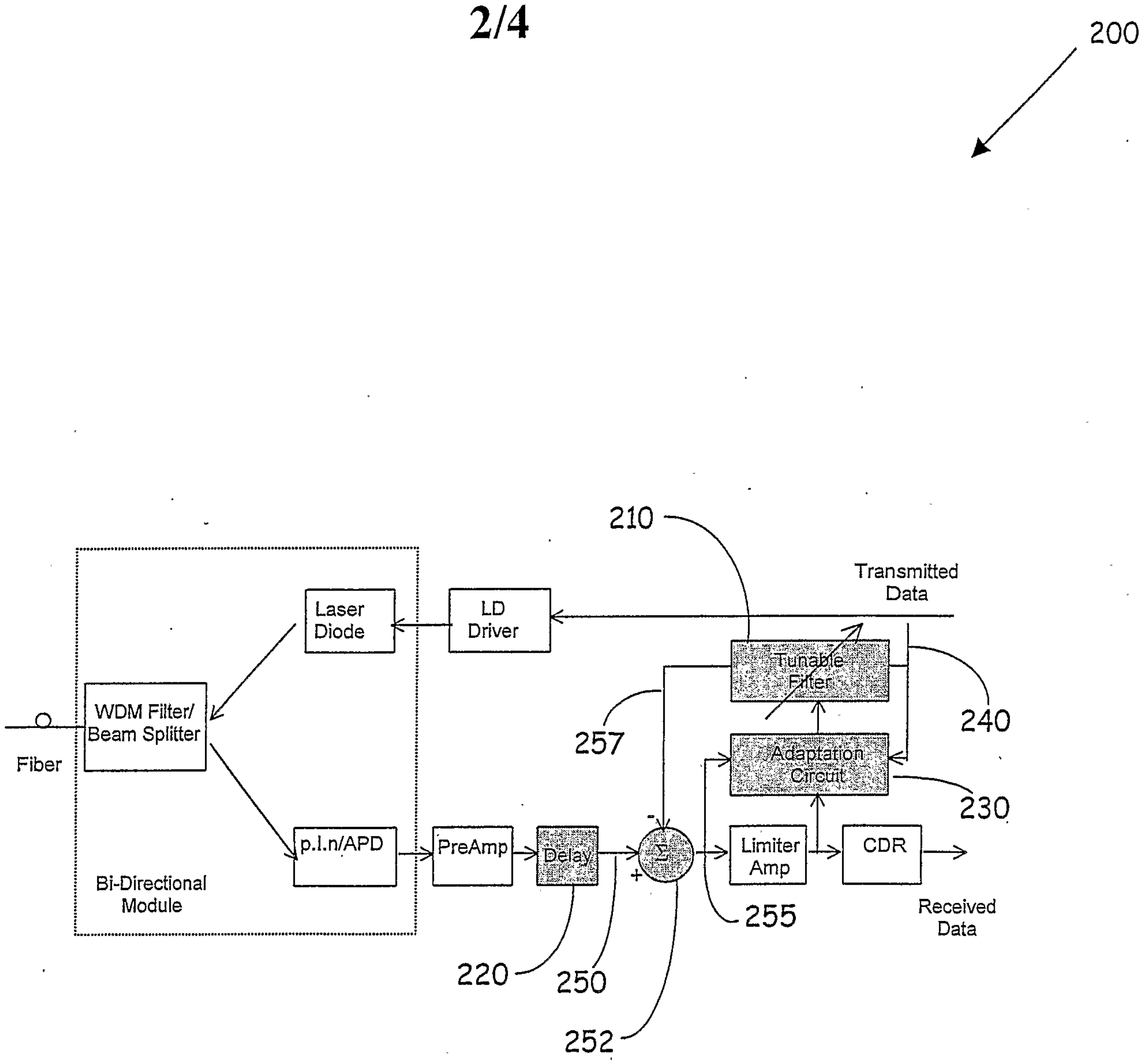
8. A device according to claim 1, wherein the tunable filter is a combination of linear and nonlinear filters.

9. A device according to claim 1, wherein the crosstalk between the transmitter and the receiver is electrical crosstalk.

10. A device according to claim 1, wherein the crosstalk between the transmitter and the receiver is optical crosstalk.



Prior art Fig. 1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210
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Laser Diode
LD Driver
Tunable Filter
WDM Filter/ Beam Splitter
Fiber
257
240
Adaptation Circuit
230
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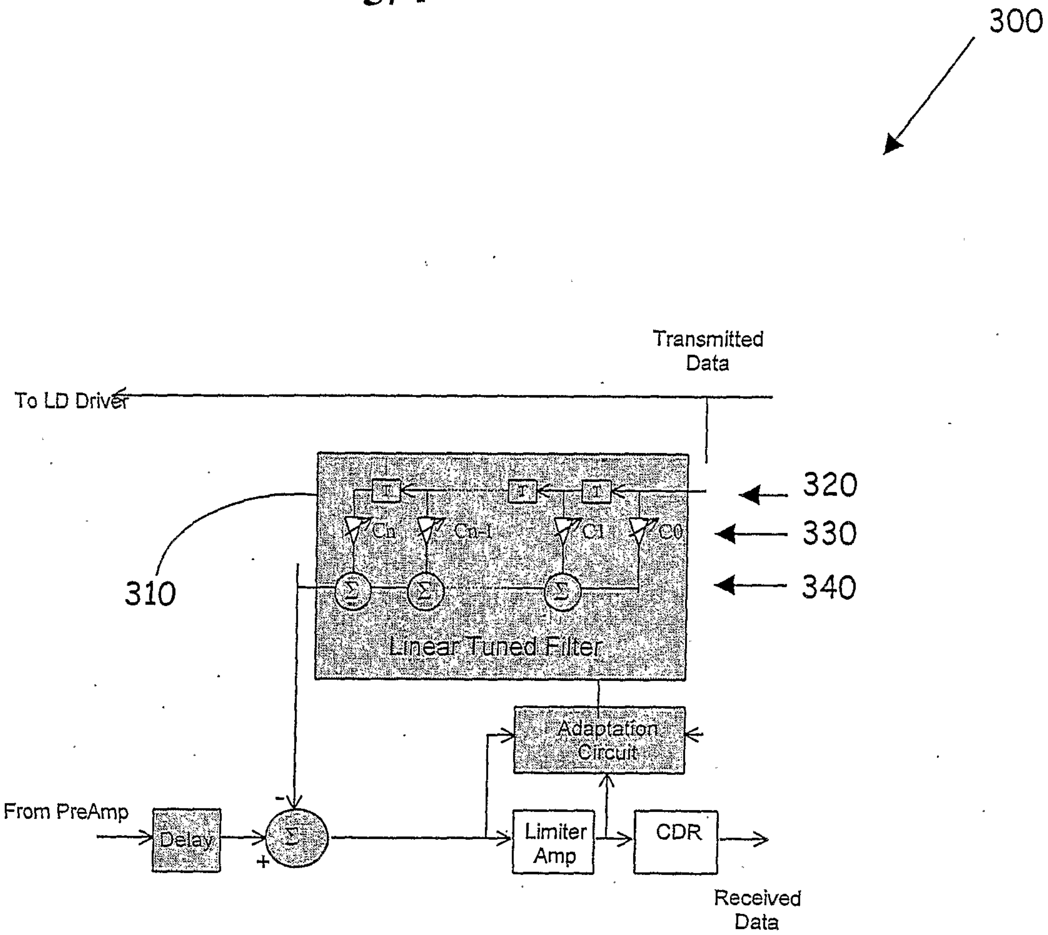
PreAmp
Delay
Σ
Limiter Amp
CDR
Bi-Directional Module
255
Received Data
220
250
252

Fig. 2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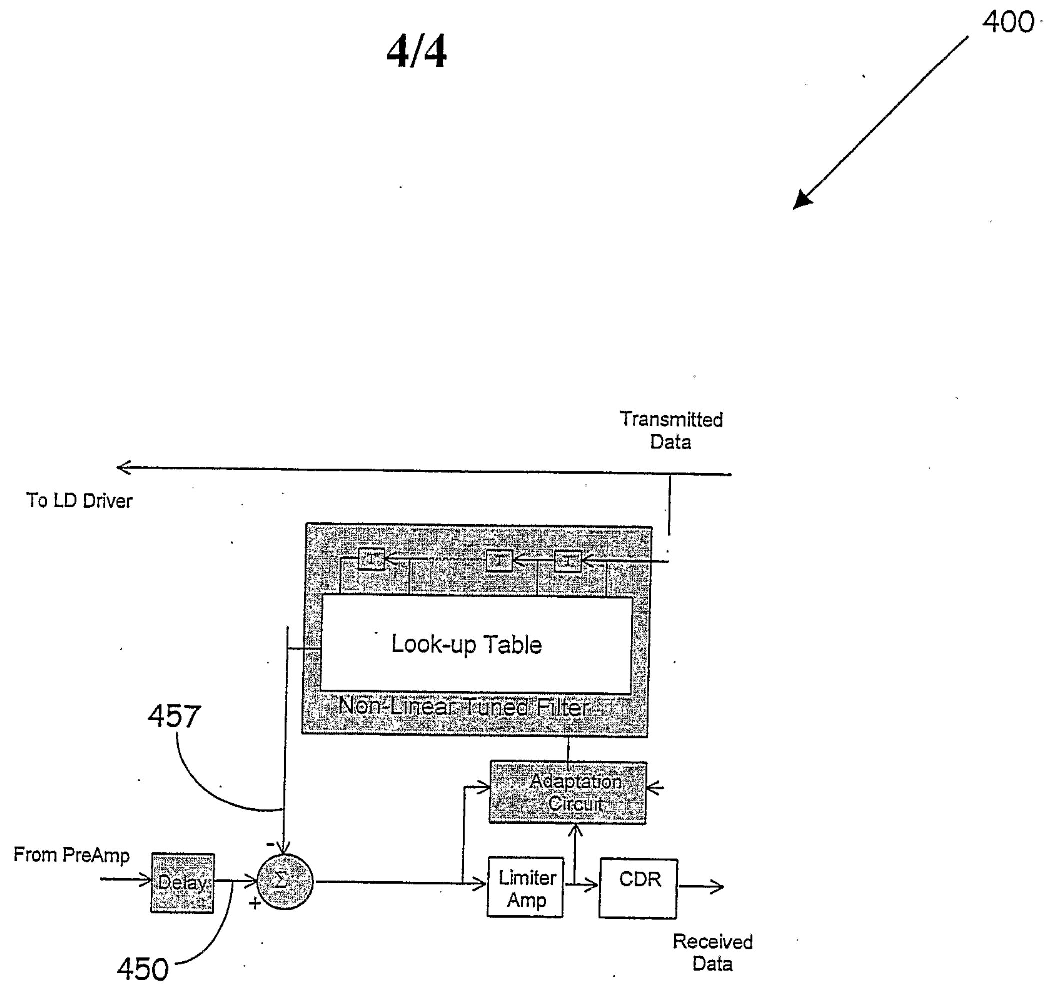
330
340
310
Cn
Cn-1
C1
C0
Linear Tuned Filter
Adaptation Circuit
From PreAmp
Delay
Limiter Amp
CDR
Received Data

Fig. 3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Adaptation Circuit
From PreAmp
Delay
Σ
Limiter Amp
CDR
450
Received Data

Fig. 4