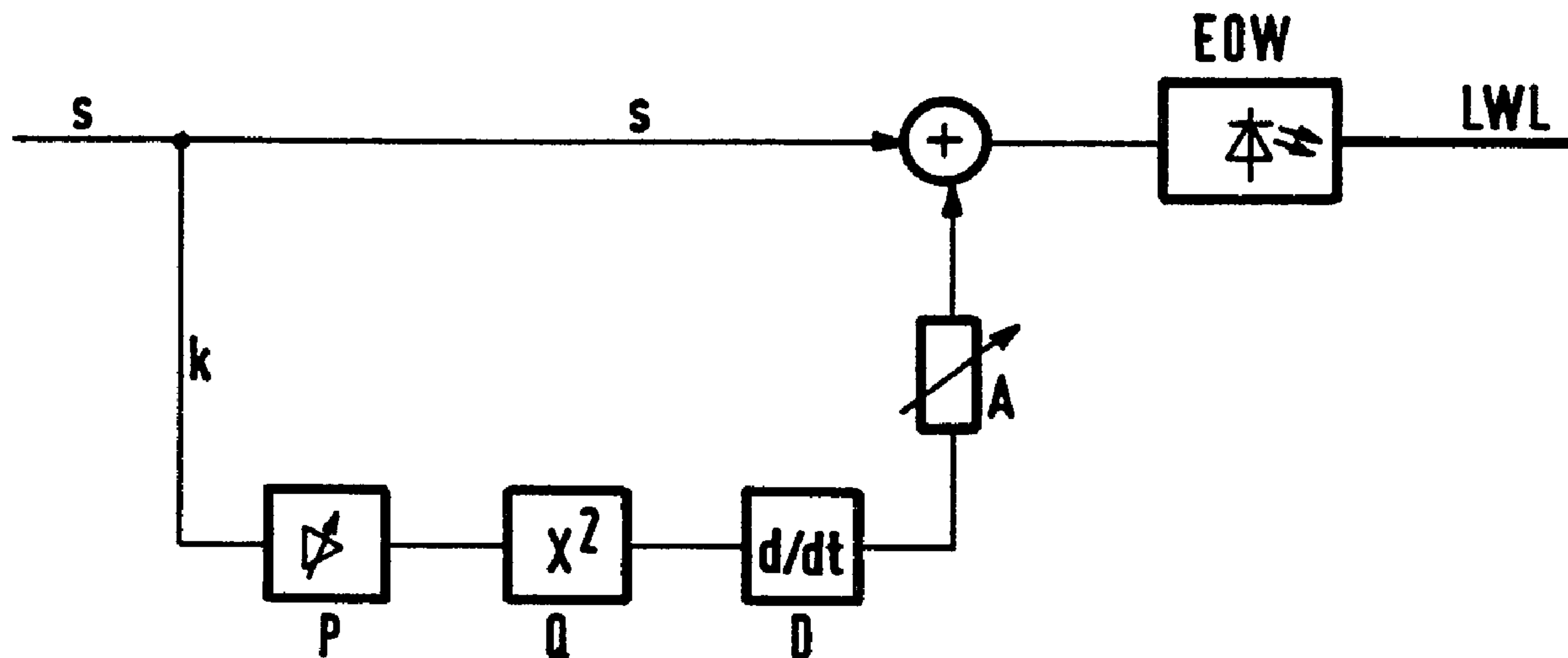




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(54) Titre : METHODE ET CIRCUIT POUR CORRIGER LA DISTORSION CAUSEE DANS LES SIGNAUX PAR LES GLISSEMENTS DE FREQUENCE LASER ET LA DISPERSION DANS LES FIBRES
 (54) Title: METHOD AND CIRCUIT ARRANGEMENT FOR ELECTRIC COMPENSATION OF SIGNAL DISTORTION CAUSED BY LASER CHIRP AND FIBER DISPERSION



(57) Abrégé/Abstract:

For the purpose of electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, a correction signal is derived from the electric transmission and/or reception signal by squaring followed by differentiation and added to the electric transmission signal and/or reception signal, respectively, after necessary attenuation.

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Abstract

5 For the purpose of electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, a correction signal is derived from the electric transmission and/or reception signal by squaring followed by differentiation and added to the electric transmission signal and/or reception signal, respectively, after necessary attenuation.

Figures 1 + 2

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TEXT TRANSLATION

Method and circuit arrangement for electric compensation of signal distortion caused by laser chirp and fiber dispersion

5 In optical telecommunication systems with signal transmission via optical fibers, the interaction of laser chirp, on the one hand, and fiber dispersion, on the other hand, leads to possibly substantial signal distortion which, in particular in the case of analog signal transmission (for example, AM-CATV) in the wavelength window around 1.55 μm via standard monomode fibers, can restrict the range of such systems to a few hundred meters.

15 Laser chirp, that is to say the modulation-dependent frequency deviation of a laser, can be circumvented by the use of external modulators, but this entails an appreciable outlay. An attempt can be made to combat fiber dispersion, that is to say the wavelength-dependent spread of the signal propagation time in the optical fiber, by splicing in fiber pieces having a dispersion opposite to that of the standard fiber, but it is then necessary to accept an appreciable additional attenuation. A further approach to a solution is offered by electronic compensation measures; thus, an all-pass and a low-pass filter structure (with a varactor diode) 20 for compensating the fiber dispersion by corresponding signal delays are known from ELECTRONICS LETTERS 27(1991)5 dated 28.02.1991, pages 421 to 423.

25 By contrast, the invention adopts a different approach for the purpose of electric compensation of signal distortion in an optical telecommunication system 30 caused by laser chirp and fiber dispersion.

The invention relates to a method and a circuit arrangement for electric compensation of signal distortion caused by laser chirp and fiber dispersion. The method is characterized in that a correction signal is derived from the electric transmission and/or reception signal by squaring followed by differentiation and is added to the electric transmission signal and/or reception signal, respectively, after a level correction necessary per se in the form of a signal attenuation; the circuit arrangement is characterized according to the invention in that, branching from the electric transmission and/or reception signal path is a correction signal path which has a squaring element and a downstream differentiating element and opens out again into the electric signal path after a downstream level correction circuit via an adding input, it being the case that in a further embodiment of the invention a level adapting circuit can be connected upstream of the squaring element in the correction signal path.

The invention, which proceeds from a relationship between the light output and the optical frequency of the laser which is linear and phase-locked at least to a good approximation, and is based on the finding that a signal occurring at the end of a dispersive transmission link essentially comprises the original signal and an interference term which can be simulated electrically in a very simple way, is attended by the advantage that signal distortion caused by laser chirp and fiber dispersion can be compensated electrically at the receiving end and/or (given a defined length of link) at the transmission end in a very effective way independently of the mean signal level with a very low outlay on circuitry.

The invention is explained in still further detail with the aid of the drawings, in which Figure 1 shows a circuit arrangement for electric compensation at the transmission end, and

Figure 2 shows a circuit arrangement for electric compensation at the reception end of signal distortion induced by laser chirp and fiber dispersion.

5 Represented diagrammatically in Figure 1 to an extent required in order to understand the invention is an exemplary embodiment of a circuit arrangement for electric compensation of signal distortions in an optical telecommunication system caused by laser chirp and fiber
10 dispersion, in which an electric transmission signal path s leads to an optical fiber LWL via an electro-optic transducer EOW formed by a laser diode. Branching off from the electric transmission signal path s is a correction signal path k which has a squaring element Q and a
15 downstream differentiating element D and which opens out again into the electric signal path s after a downstream signal attenuating element A via an adding input; as may be seen from Figure 1, a level adapting circuit P can be connected upstream of the squaring element Q in the
20 correction signal path k depending on the type of the squaring element.

Owing to the fact that a correction signal is derived from the electric transmission signal by squaring followed by differentiation and added to the electric
25 transmission signal after a necessary attenuation, signal distortion caused in the optical telecommunication system containing the optical fiber LWL by the interaction of laser chirp and fiber dispersion is electrically compensated:

30 The starting point is assumed to be a relationship between the light output of the laser EOW and the optical frequency thereof, which is at least approximately linear and phase-locked and can be described by means of

$$35 \quad \Delta f = \frac{\delta}{P_0} P(t) \quad (1)$$

wherein

Δf is the frequency deviation of the laser from the mean value given at the mean light output P_0 ,

α is the ratio of the change in output to the change in current of the laser,

δ is the ratio of the change in frequency to the change in current of the laser, and

5 $P(t)$ is the change in output of the laser caused by modulation.

Owing to this (linear) relationship between light output and optical frequency, in the case of a dispersive optical fiber LWL the - frequency-dependent - signal
10 propagation time on the optical fiber depends on the signal amplitude; if the fiber dispersion is denoted by D and the fiber length by L , the signal propagation time deviates from the mean value τ_0 given in the case of the mean light output P_0 by

15
$$\Delta\tau = D \cdot L \cdot \Delta f \quad (2)$$

In the case of a change in optical output

$$P(t) = P_0 \cdot m \cdot \sum_{i=1}^n \cos(w_i t), \quad (3)$$

caused by modulation, wherein $w_i/2\pi$ is the carrier frequency of the i th transmission channel, the result at the
20 far end of the optical fiber LWL is thus a light output of

$$P^*(t - \tau_0) \sim P_0 \cdot m \cdot \sum_{i=1}^n \cos(w_i (t - \Delta\tau)) = P_0 \cdot m \cdot \sum_{i=1}^n \cos(w_i t - w_i D L \frac{\delta}{\alpha} P(t)), \quad (4)$$

wherein m is the modulation index (identical for all signal channels). In practice, in the case of slight
25 interference, it holds that $w_i \cdot D \cdot L \cdot \frac{\delta}{\alpha} \cdot P(t) \ll 1$; for example, in the case of a standard monomode fiber it can be that $D = 1.18 \cdot 10^{-25} \text{ s}^2/\text{m}$ (at a wavelength of $1.55 \mu\text{m}$) and $L = 10,000 \text{ m}$

and in the case of a laser (Fujitsu FLD 150 F2KP)

30 $\alpha = 0.04 \text{ mW/mA}$ and $\delta = 550 \text{ MHz/mA}$,

from which it follows that $D \cdot L \cdot \frac{\delta}{\alpha} = 1.77 \cdot 10^{-11} \text{ s/mW}$.

Using $\cos(u-v) = \cos u \cdot \cos v + \sin u \cdot \sin v$
(addition theorem)

and $\cos v = 1$ for $v \ll 1$,

$\cos v = v$ for $v \ll 1$

5 and $\frac{d}{dt} \cos wt = -\sin wt$,

$\frac{d}{dt} \cos^2 wt = -2w \cdot \cos wt \cdot \sin wt$,

it is also possible to write

$$\begin{aligned}
 P^*(t - \tau_0) &\sim P_0 \cdot m \cdot \sum_{i=1}^n \cos(w_i t - w_i \Delta t) = P_0 \cdot m \cdot \sum_{i=1}^n \left\{ \cos w_i t \right. \\
 &\quad \left. + w_i DL \frac{\delta}{\alpha} P(t) \cdot \sin w_i t \right\} \quad (6) \\
 &= P(t) \\
 &\quad + w_i DL \frac{\delta}{\alpha} P(t) \cdot \left(-\frac{d}{dt} P(t) \right) \\
 &= P(t) - \frac{1}{2} w_i DL \cdot \frac{\delta}{\alpha} \cdot \frac{d}{dt} P^2(t).
 \end{aligned}$$

instead of equation (4), when substituting equation (3)
in equation (4).

The position and intensity of the interference term is obtained as

$$D \cdot L \cdot \frac{\delta}{\alpha} \cdot \frac{d}{dt} P^2(t) = \frac{1}{2} \cdot D \cdot L \cdot \frac{\delta}{\alpha} \cdot P_0^2 \cdot m^2 \cdot \left\{ \sum_{i=1}^n w_i \cdot \sin(2w_i t) + \sum_{i=1}^n \sum_{j=i+1}^n (w_i + w_j) \cdot \sin((w_i + w_j)t) + (w_j - w_i) \cdot \sin((w_j - w_i)t) \right\} \quad (7)$$

by substituting equation (3) in equation (6).

n(n+1)/2 interference lines occur. The signal at the far end of the optical fiber is composed of the original signal and an interference signal orthogonal thereto. This interference signal is proportional not only to the optical fiber length, dispersion and chirp, but also to the frequency at which the interference occurs.

By squaring and subsequent differentiation of the transmission signal P(t), the correction signal is obtained, after attenuation in accordance with the factor $\frac{1}{2} w_i D L \frac{\delta}{\alpha}$, for electric compensation of the signal distortions caused by the interaction of laser chirp and fiber dispersion.

Since the signal distortion term is very small per se (approximately 40 to 60 dB below the useful signal level), it is also possible to use the disturbed reception signal to generate the correction signal by using squaring and subsequent differentiation to derive from the electric reception signal a correction signal which is added to the electric reception signal after a level

correction which is necessary per se in the form of signal attenuation.

Figure 2 represents an exemplary embodiment of a circuit arrangement for electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, in which an optical fiber LWL leads to an electric reception signal path e via an optoelectric transducer OEW. Branching from the electric reception path e is a correction signal path k which has a squaring element Q and a downstream differentiating element D and which opens out again into the electric signal path e after a downstream signal attenuating element A; a level adapting circuit P can be connected in turn upstream of the squaring element Q in the correction signal path k, depending on the squaring element used.

As follows from the above explanation of the invention, the correction signal formed by squaring followed by differentiation further requires a level adaptation, specifically in principle in the form of a signal attenuation; in the case of poor efficiency of the squaring element and differentiating element and an excessively low correction signal level resulting therefrom, however, a level correction in the form of a correction signal amplification can also become necessary on occasion.

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CLAIMS:

1. A method for electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, characterized in that a correction signal is derived from the electric transmission signal by squaring followed by differentiation and is added to the electric transmission signal after a level correction necessary per se in the form of a signal attenuation.
2. The method for electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, as claimed in Claim 1, characterized in that a correction signal is derived from the electric reception signal by squaring followed by differentiation and is added to the electric transmission signal after a level correction necessary per se in the form of a signal attenuation.
3. A circuit arrangement for electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, characterized in that, branching from the electric transmission signal path (s) is a correction signal path (k) which has a squaring element (Q) and a downstream differentiating element (D) and opens out again into the electric signal path (s) after a downstream level correction circuit (A) via an adding input.
4. The circuit arrangement for electric compensation of signal distortion in an optical telecommunication system caused by laser chirp and fiber dispersion, as claimed in Claim 3, characterized in that, branching from the electric reception signal path (e) is a correction signal path (k) which has a squaring element (Q) and a downstream differentiating element (D) and opens out again into the

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electric signal path (e) after a downstream level correction circuit (A) via an adding input.

5. The circuit arrangement as claimed in Claim 3 or 4, characterized in that a level adapting circuit (P) is
5 connected upstream of the squaring element (Q) in the correction signal path (k).

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PATENT AGENTS

FIG 1

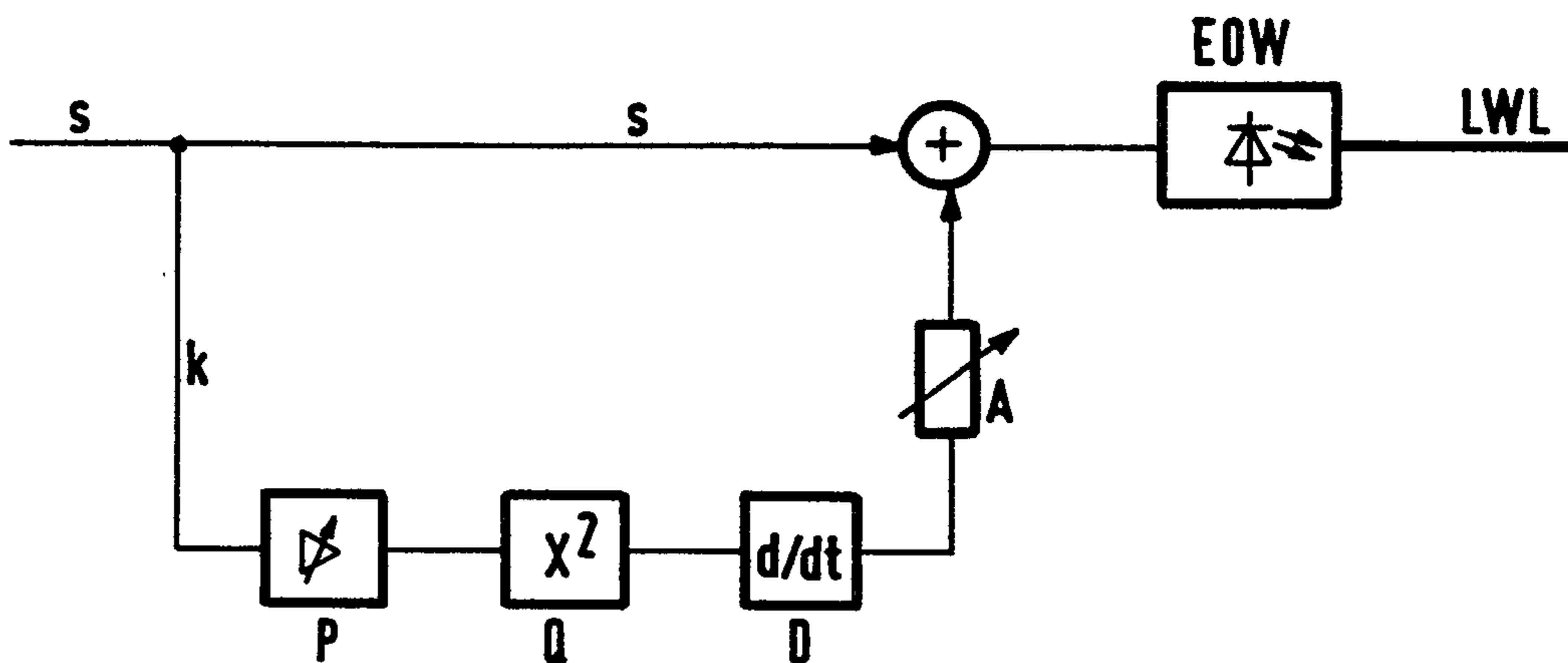


FIG 2

