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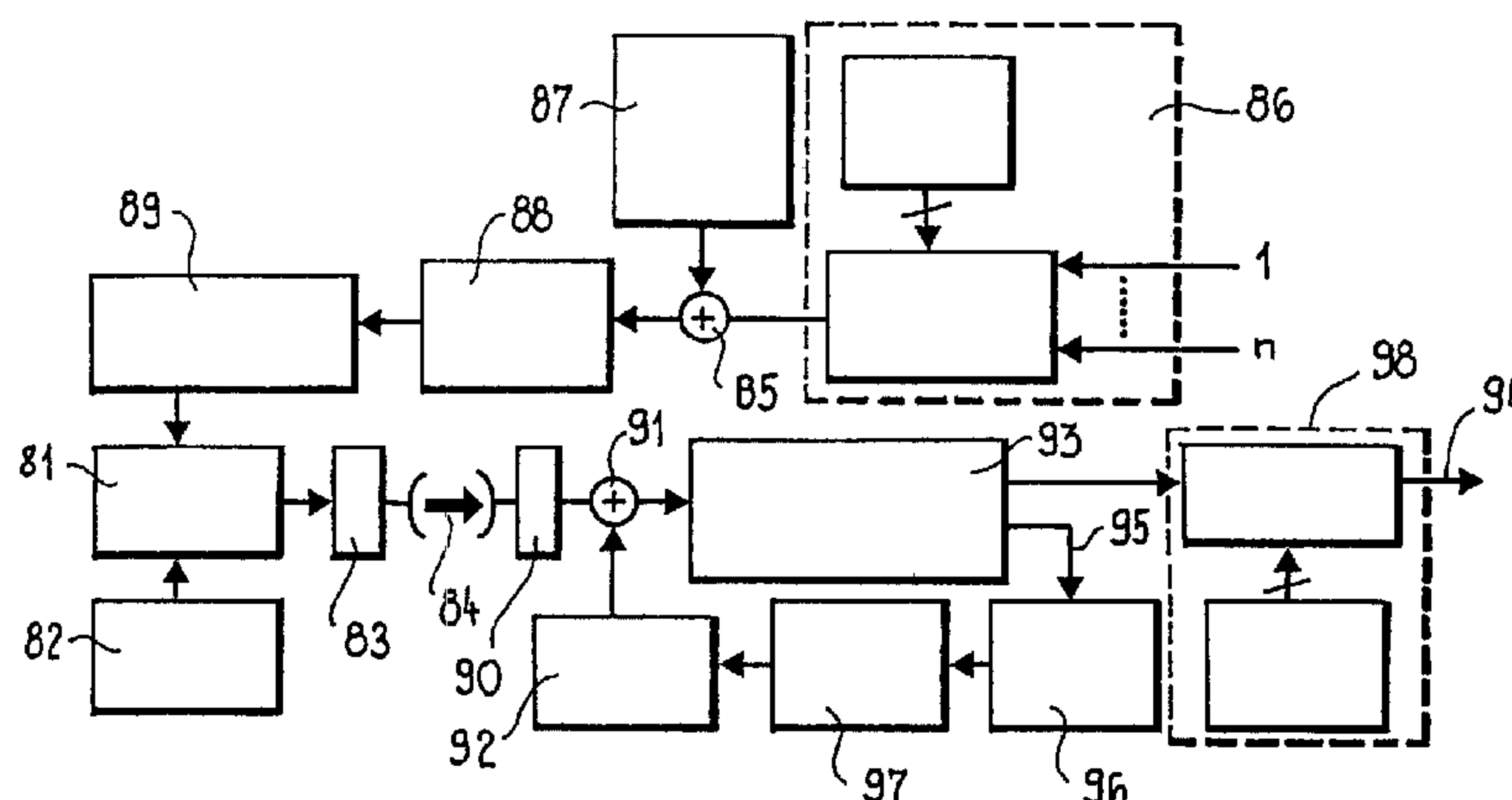
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(54) **SYSTEME DE COMMUNICATION OPTIQUE ENTRE  
SATELLITES POUR TRANSMISSION DE RAYON LASER  
MODULE**

(54) **OPTICAL INTERSATELLITE COMMUNICATIONS SYSTEM  
FOR TRANSMITTING A MODULATED LASER BEAM**



(57) The optical intersatellite communications system comprises two separate ranges of the bandwidth such, that a first range is provided for a synchronization channel of a narrow bandwidth for the transmission of synchronization frames of a fixed data rate, and a second range of a broad bandwidth is provided for a transparent link. The corresponding communications arrangement comprises an electro-optical phase modulator (81) for modulating the laser light from a TX laser (82) and for passing the modulated laser light to the one end of a transparent link, which transmits the laser beam (84). A data signal unit (86) at the transmitter end and a synchbit unit (87) are connected to a linkage circuit (85). On the output side the linkage circuit (85) is connected to an electro-optical modulator driver (88), which is connected via a linearizer (89) with the input of the electro-optical phase modulator (81). The linearizer compensates the intermodulation products of the third and fifth orders.



**ABSTRACT**

The optical intersatellite communications system comprises two separate ranges of the bandwidth such, that a first range is provided for a synchronization channel of a narrow bandwidth for the transmission of synchronization frames of a fixed data rate, and a second range of a broad bandwidth is provided for a transparent link. The corresponding communications arrangement comprises an electro-optical phase modulator (81) for modulating the laser light from a TX laser (82) and for passing the modulated laser light to the one end of a transparent link, which transmits the laser beam (84). A data signal unit (86) at the transmitter end and a synchbit unit (87) are connected to a linkage circuit (85). On the output side the linkage circuit (85) is connected to an electro-optical modulator driver (88), which is connected via a linearizer (89) with the input of the electro-optical phase modulator (81). The linearizer compensates the intermodulation products of the third and fifth orders.

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**Optical Intersatellite Communications System  
for Transmitting a Modulated Laser Beam**

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The present invention relates to an optical intersatellite communications system for transmitting a modulated laser beam.

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Optical intersatellite communications systems are known, which operate with digital data at a fixed bit rate of, for example, 1.5 Gbits/s  $\pm$  3%. Analog optical communications systems are also known in many variations. In the case of a digital signal, the pulse shape of the signal is always specified within a narrow tolerance range, because otherwise the system could not function. A main problem in connection with the coherent homodyne transmission arises in the synchronization of the local oscillator laser, whose phase is to be secured to or locked with the received light wave for detection and demodulation purposes. With digital systems with a fixed data rate, there is a simple way to achieve synchronization by employing the so-called syncbit method, wherein the data flow contains a syncbit which, after seventeen bits of "zeros" and "ones", is in a third state "0.5".

It is now the object of the present invention to provide an improved optical intersatellite communications system in accordance with claim 1.

Accordingly, the system in accordance with the invention permits the transmission  
5 of almost arbitrary analog and digital signals at various data rates up to a defined bandwidth over optical intersatellite links, and this in contrast to known systems, which only permit the transmission of digital signals at a fixed prescribed data rate.

Advantageous embodiments of the invention are recited in the dependent claims.

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The invention will be explained in greater detail in what follows by means of drawings. Shown therein are in:

**Fig. 1**, a schematic representation of an optical intersatellite communications  
15 system in accordance with the invention, having a transmitting element and a receiving element,

**Fig. 2**, a diagram of the degradation of the signal/noise ratio in such a  
communications system,

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**Fig. 3**, schematic representations of a synchbit frame in the frequency range and the time range,

**Figs. 4 and 5**, block circuit diagrams for explaining the multiplexing of different  
25 sub-channels of a base band channel, or respectively a microwave channel,

**Fig. 6**, a block circuit diagram of a so-called RFE circuit,

**Fig. 7**, a diagram to be used for correcting the non-linearities of the third and fifth  
30 order,

**Fig. 8**, a block circuit diagram of an optical intersatellite communication system in accordance with the invention,

35 **Fig. 9**, a schematic representation to explain the correction of non-linearities,

**Fig. 10**, a block circuit diagram of a first circuit for producing such a correction,

Fig. 11, a block circuit diagram of a second circuit for producing such a correction, and

5 Fig. 12, a diagram for the optimization of such a linearity correction.

The analog system in accordance with Fig. 1, having a transmitting element 1 and a receiving element is defined in the customary manner as a function of the CNR value (carrier-to-noise ratio) and the CIM value (carrier-to-intermodulation ratio). A signal  $S_e$  with a signal-to-noise ratio  $SNR_{in}$  is supplied to the transmitting element, and the  
10 receiving element provides an output signal  $S_o$  with a signal-to-noise ratio  $SNR_{out}$ . The total SNR value, which determines the dynamic range DR of the link, relates to the incoherent addition of noise and intermodulation. Sine-shaped signals are used for measuring these analog values, while digital links are specified by digital signals and SNR  
15 or BER values. It is therefore necessary to specify the analog links also in regard to the intermodulation. The bit error probability in a digitally modulated sub-channel at the output of the system is greater than at its input because of a finite SNR value. Fig. 2 shows by way of example the CNRlink requirements for a given SNR Input value, and an acceptable SNR degradation  $SNR_{out} - SNR_{in}$  because of the finite SNR value of the link.  
20 With the majority of applications, a sub-channel modulation is used in analog systems. The sub-channels themselves normally transmit digital data. However, the entire system is considered to be analog, because the interferences between the sub-channels reduce their SNR factor which, because of the non-linearity of the system, is a property of an analog system which is not specified in digital systems. In contrast to this, the invention  
25 provides a band-limited "transparent" channel, which constitutes an ideal analog system. Communications satellites in geostationary orbits have a frequency band between 10.7 and 12.75 GHz, wherein most likely a frequency band between 21.4 and 22.0 GHz will probably also be employed in the future.

30 Fig. 3 shows that in accordance with the present invention two separate ranges of the bandwidth are used. A first range is reserved for a synchronization channel 31 of a narrow bandwidth between 0 and some MHz, i.e. for synchronization frames at fixed data rates, wherein in Fig. 3 the spectral output density PSD is represented as a function of the frequency  $f$ , and the modulation signal amplitude as a function of time. The  
35 synchronization channel 31 contains data, i.e. zeros and ones, and syncbits in the status "0.5" for the local oscillator of the receiver. In connection with a phase modulation (BPSK: binary phase shift keying) of the lightwave, a data bit "0" will modulate the phase

of the lightwave 33 for example by  $\pm 90^\circ$  in the optical modulator on the transmitter end, while a "1" adds an amount of  $90^\circ$  to the phase of the lightwave 34. In contrast thereto, the "0.5", or respectively the syncbit, adds the amount  $0^\circ$  to the phase of the lightwave 35. The receiver can then extract the  $0^\circ$  phase states, i.e. the syncbits, and can perform the  
5 synchronization of the local oscillator.

In this connection it should be noted, that the syncbit must be surrounded by bits of symmetrical phase states, because otherwise it could not be detected in the receiver. In addition to various sub-channels 1 to n, a syncbit frame channel is additionally  
10 provided, through which first signaling bits 36, at least one syncbit 35 and second signaling bits 37 are for example transmitted. This syncbit channel 31 is per se similar to the syncbit channel of a digital system, but has a much narrower bandwidth, for example of a magnitude of some Mbits/s, instead of Gbits/s.

15 The difference between digital operation and analog operation lies in the different optical phase-locking loops used for synchronization, or OPLL loops (optical phase-lock loop synchronization). In a system with a fixed data rate, the OPLL loop is performed with the aid of syncbits having the length of a data bit, which are respectively inserted after the predetermined number of data bits mentioned. In analog operation, a synchronization  
20 frame of a small bit rate with the syncbits and other auxiliary data is transmitted, spectrally separated from the actual useful data. Thus, in accordance with the present invention, both modes of operation differ only in the processing of syncbits, in a few filter functions and in the processing of the received signal, such as, for instance, with the clock and data retrieval in the course of digital operation with a fixed data rate.

25 On the other hand, a large bandwidth 32 between 10 MHz and 1 GHz is available for the "transparent link" 32 in the course of this. Within this transparent band 32, each signal which spectrally fits in it, can be transmitted, regardless of its shape, by means of such a transparent link. In any case, synchronization takes place by means of the narrow  
30 channel 31 below the transparent channel 32. The synchronization channel must have a frame with syncbits and data bits in symmetrical states, so that the local oscillator can achieve the synchronization state.

The syncbit method can be performed with the aid of FPGAs (field-programmable  
35 gate arrays), which are considerably more cost-efficient than the RFASICs (radio frequency application- specific integrated circuits), which are required for syncbit processing in digital systems with fixed data rates.

The known digital systems are not transparent in the sense of the present invention, since they must have a stable data rate, for which only deviations of a few percent are permissible, and also, because the pulses should be more or less rectangular, so that the so-called analog signals of arbitrary wave shapes - for a defined bandwidth - or digital signals with a data rate different than the data rate provided, are basically neither permissible nor transmittable.

The transparent channel has a much greater bandwidth and can transmit every signal, whose spectrum fits into the channel. If it is necessary to transmit several digital or analog signals, such as is the case with TV satellite communications, this channel has several sub-channels. As represented in Fig. 4, the signals are transmitted over the transparent channel 41. A signal can modulate the respective carrier in the multiplexing device 42 on the transmitter end in each sub-channel 1, ... n, before it is passed on to the optical link. These modulated carriers can then be multiplexed, and the sub-channels are then de-multiplexed and again down-mixed in a demultiplexing device 43 at the end of the link. The syncbit frame 44 on the transmitter end is preferably conducted via a low bandpass filter to a multiplexer 45 of the device 42, and the syncbit frame 46 on the receiver end is preferably retrieved via a low bandpass filter by a demultiplexer 47 of the device 43.

In a satellite, the sub-channels can already be multiplexed into microwave carriers of a magnitude of 10 GHz. As represented in Fig. 5, the signals are transmitted via the transparent channel 51. On the transmitter end, the sub-channels 52 multiplexed on the microwave carriers can be conducted to a multiplex device 53 on the transmitter end. Since the band occupied by the sub-channels is relatively narrow, for example less than 1 GHz, this is preferably performed in such a way that initially the modulated microwave signal is down-mixed into a band of approximately 10 MHz to 1 GHz. Such a band is transmitted via the optical transparent intersatellite link 51 from one satellite to another, where a demultiplexer device 55 retrieves the syncbit frame 58 by demultiplexing. The signal is again up-mixed into the microwave range in order to make possible a further microwave transmission, for example from a satellite to the ground. In place of n base band signals or sub-channels of a relatively narrow bandwidth, it is also possible to transmit a broadband analog or digital base band signal at a high bit rate.

The link interface consists of several parallel base band inputs/outputs, or respectively of a single broadband input/output. If necessary, base band processors at the inputs and outputs can convert the parallel, narrow band channels into sub-channels, which have been appropriately multiplexed with sub-carriers. The single input broad band plan is used in particular when a signal, which was multiplexed with sub-carriers, had already been delivered to the input and therefore additional signal processing is no longer necessary, or when a single analog signal of large bandwidth, or a digital data signal at a high bit rate, has to be transmitted.

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The homodyne RFE receiver (receiver front end) in accordance with Fig. 6 consists, for example, of a conventional balanced receiver. The received light 61 and the laser light 62 of a local oscillator 63 are coupled in an optical hybrid coupler 64 and thereafter detected by means of two photodiodes 651, 652. The photo flows from these photodiodes are then added in an adder 66 and converted in a transimpedance amplifier 67 into a voltage. An AGC (automatic gain control) amplifier 68 finally provides the amplified signal 69. A signal 631 from a syncbit processing and OPLL control unit is provided to the local oscillator.

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The diagram in Fig. 7 is used for calculating the increase of the intermodulation IM in dB in the band center as a function of the number n of carriers through a link, which has non-linearities of the third and fifth order, for which the following equations, which can be used for  $n > 9$ , also apply:

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$$IM3 = 10 \cdot \log_{10}(1.5 \cdot n^2) \quad (3rd \text{ Order})$$

$$IM5 = 10 \cdot \log_{10}(0.24 \cdot n^{4.8}) \quad (5th \text{ Order})$$

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The approximation values of the third and fifth order are identified by \*, or respectively in Fig. 7. The solid lines correspond to the exact values. Conventional optical communications systems operate with direct or indirect intensity modulation. In the first case, the laser diode injection flow is modulated. With indirect or external intensity modulation the laser acts as a CW source, and the beam is modulated by means of an external modulator, for example of the Mach-Zehnder type. Detection is performed either by measuring the intensity of the modulated light by means of a photodiode (direct detection or DD), or coherently, i.e. with the aid of a local oscillator and subsequent mixing in a photodiode. Such DD systems are not very sensitive in actual use.

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In connection with links having large losses, for example with intersatellite links, only coherent systems can assure the required sensitivity. If the resultant intermediate frequency of the coherent mixing process is zero, this is called "homodyne" detection, if not, it is called a heterodyne one. Homodyne designs are generally more sensitive, but the heterodyne ones are easier to construct. The most sensitive known type is the homodyne phase modulation (PM).

The communications system in Fig. 8 comprises an electro-optical phase modulator 81 for modulating the laser light of a TX laser 82, and for forwarding the modulated light to the end 83 of a transmission system or link, which transmits the laser beam 84. A data signal unit 86 on the transmitter end and a syncbit unit 87 are connected to the linkage circuit 85. On the output side, the circuit 85 is connected with an electro-optical modulator driver 88, which is connected via a correcting circuit 89 with the input of the electro-optical phase modulator 81. The data signal unit 86 on the transmitter end can have a converter with the required mixers, filters and local oscillators in order to up-mix the sub-channel signals 1, ... n on the input side. The syncbit unit 87 is provided for syncbit generation and filtering. The modulator driver 88 comprises an amplifier with a preamplifier, and the correcting circuit 89 is preferably employed as a pre-distortion linearizer. A coupling circuit 91, which is also connected with a local oscillator laser, or LO laser, 92 at the input side, and whose output signals are provided to an optical RX receiver pre-stage 93 which, besides the data signals 94, also provides a syncbit signal 95, which is passed on via a filter 96 to a syncbit OPLL circuit 97, is connected to the other end 90 of the link. A data signal unit 98 on the receiver end can be provided for these data signals, which also has a converter with the required mixers, filters and local oscillators in order to down-mix the sub-channel signals on the output side. The most important distortion source because of intermodulation results from the so-called Mach-Zehnder interferometer, consisting of a phase modulator and EFC (front end coupler)/photodiodes. The most important noise source is the shot noise of the RFE (receiver front end)/LO laser.

The communications system in accordance with the present invention comprises an optical phase-locking loop, also called OPLL (optical phase-lock loop), and a local oscillator, for whose synchronization in case of an analog modulation two methods are provided, wherein in accordance with one of these a residual pilot carrier is used, and with the other a so-called syncbit technique. With the preferred syncbit technique, synchronization bits as well as reference bits are transmitted in a narrow spectral window

outside of the transmission bandwidth in order to achieve an OPLL phase synchronization. This synchronization channel can also be used for signaling and network control purposes.

5           Since the system in accordance with the invention is designed for transmitting any arbitrary signals, higher demands are preferably made on linearity than with employment with digital signals of a fixed transmission rate. If, for example, two main carrier signals of the frequency  $f_1$ , or respectively  $f_2$ , and a further carrier signal of the frequency  $f_3 = 2 \cdot f_2 - f_1$ , are transmitted, an intermodulation product of the frequency  $f_3$  is generated by a  
10           system non-linearity of a non-even order. In a digital system with a fixed data rate, or in a system operating in a digital mode in accordance with the present invention, such static non-linearities do not cause any loss in the transmission quality, even if they are very strong, such as when limiters are used. However, the digital systems with a fixed data rate must be low-noise in order to achieve great ranges. But the analog systems must be  
15           low-noise and very linear at the same time, i.e. they must have a great dynamic range.

          In accordance with the present invention, a coherent optical phase modulation is preferably employed for both cases to achieve a high degree of sensitivity. In connection with systems with fixed data rates, this is then called coherent BPSK (coherent binary  
20           phase shift keying), in contrast to coherent phase modulation (coherent PM) in the analog case. In the case of a coherent transmission, the receiver must down-mix the received phase-modulated lightwave to an intermediate frequency with the aid of a local oscillator. If this intermediate frequency is zero, the lightwave is demodulated in accordance with the so-called homodyne method with the aid of a photodetector directly following the mixing  
25           with the local oscillator. In accordance with the present invention, this homodyne method is preferably used in both cases - analog and digital -, since it is the most sensitive.

          To increase the dynamic range of the link, the optical phase modulator **81**, in which the non-linearity mainly is created, can be linearized with the aid of an electronic,  
30           broadband pre-distortion linearization circuit **89** which, for compensating the sine-like characteristics of the mixing/detection process, has an arc-sine transmission characteristic.

The non-linearity of the phase modulator/receiver combination results from the mixture in the balanced receiver photodiodes.

The following applies for the received laser light field:

$$5 \quad E_{in}(t) = E_{in,o} \sin[\omega_{in}t + \varphi(t)]$$

wherein  $\varphi(t)$  is the modulated phase.

The following applies for the local oscillator laser field:

$$E_{Lo}(t) = E_{Lo,o} \sin[\omega_{Lo}t]$$

10 The photo flow, i.e. the intensity detection of  $E_{in}(t) + E_{Lo}(t)$

$$i_{det}(t) = i_{det,o} \sin[(\omega_{in} - \omega_{Lo})t + \varphi(t)]$$

When the phase lock loop has achieved synchronization,  $\omega_{in}$  and  $\omega_{Lo}$  are equal, so  
15 that  $(\omega_{in} - \omega_{Lo})$  disappears:

$$i_{det,sync}(t) = i_{det,o} \sin[\varphi(t)]$$

The detected signal or the photo flow are not proportional to the modulation voltage, which corresponds to the phase  $u_{mod}(t) = \varphi(t)$ , but to a sine. It is distorted in a  
20 non-linear manner. The sine-shaped distorted signal approximately results from a Taylor series, as follows:

$$i_{det,sync} = i_{det,o} \sin[\varphi] = i_{det,o} [\varphi - \varphi^3/3! + \varphi^5/5! - \dots] = b_1 x + b_3 x^3 + b_5 x^5 + \dots$$

If the modulation signal, which is proportional to the phase  $\varphi$ , is pre-distorted by  
25 means of an arc sine function, the detected flow will be a linear function of the modulation:

$$i_{det,sync,pred} = i_{det,o,pred} \sin[\arcsin(\varphi)] = \varphi$$

30

The arc sine function also results from a Taylor series, as follows:

$$\begin{aligned} u_{mod,pred}(t) &= u_{mod,o,pred} \arcsin[u_{mod,pred}(t)/u_{mod,o,pred}] = u_{mod,o,pred} \arcsin[x] = \\ &= u_{mod,o,pred} [x + x^3/6 + 3x^5/40 + \dots] = a_1 x + a_3 x^3 + a_5 x^5 + \dots \end{aligned}$$

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Fig. 9 shows an approximation of the functions 890 and 810 of the linearizer, or respectively of the modulator/receiver, which result in a linearized combination. The signal 891 corresponds to the input voltage of the circuit 89 (Fig. 8), and the signal 811 to the output voltage of the phase modulator 81 (Fig. 8), or respectively of the receiver.

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In order to compensate the distortions of the third and fifth order, the relationship between the coefficients  $a_1$ ,  $a_3$  and  $a_5$  are of importance. The following three approximation methods can be employed for the pre-distortion linearization:

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a) Antiparallel Schottky diode circuit as the non-linearity:

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As represented in Fig.10, the input signal 101 is divided into a linear branch 110 and a non-linear branch 120, in which the non-linearities of the third and fifth order are generated by a pair of antiparallel Schottky diodes 103. Since the non-linearity of a Schottky diode has an exponential behavior, the non-linearity of an antiparallel Schottky diode pair also has an exponential course, namely without even terms and therefore in the form:

$$x + x^3/3! + x^5/5!$$

20

Two damping members 102 and 104 with amplification factors  $g_2$ , or respectively  $g_4$ , are also present in the non-linear branch 120, which permit the control of the coefficients of the third and fifth order:

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$$a_3 = g_2^3 g_4 / 3! \quad a_5 = g_2^5 g_4 / 5!$$

30

Known linearizers of the third order only use one damping member corresponding to the attenuator 104. Therefore the non-linearity of the fifth order cannot be compensated, except if the circuit to be linearized has an exponential non-linearity. An attenuator 105, a variable phase shifter 104, and a variable delay circuit 107 have been connected in series in the linear branch 110. The attenuator 104, as well as the phase shifter 104, and the delay circuit 107 permit a compensation of the coefficients  $a_1$  of the first order. In accordance with the invention, the circuit with the attenuator 102, known per se for a linearization of the third order, permits the use of an exponential non-polarity for the generation of any arbitrary positive non-linearities of the third and fifth order, and therefore the compensation of circuits having almost arbitrary non-linearities of the third and fifth order, in order to supply a linearized output signal 109.

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b) Compensation of a rather weak non-linearity by means of a negative sine-shaped non-linearity in accordance with Fig. 11, which shows an approximation of the functions 895 and 815 of the linearizer, or respectively of the modulator/receiver, for resulting in a linearized combination. The signal 896 corresponds to the input voltage of the circuit 89 (Fig. 8), and the signal 816 to the output voltage of the phase modulator 81 (Fig. 8), or respectively of the receiver. A sine-shaped non-linearity can be approximated by a tanh function. The tanh function can be produced by a cascaded circuit of two bipolar differential amplifiers, wherein the first one is excited non-linearly, and the second linearly. The difference between two collector currents with a constant sum, which are exponentially dependent from the input voltage, produces the approximation  $\tanh = \text{sine}$ . In accordance with the present invention, such a "sine" circuit, known per se, can be used for improving the linearity in accordance with the structure represented in Fig. 11.

c) CMOS circuit. The integrated CMOS (cross-coupled differential pairs) circuits have a voltage/current non-linearity of the form

$$i(u) = c_1 u - u[(1 - u^2/c_2)]^2$$

which, with a suitable selection of the coefficients  $c_1$  and  $c_2$  by means of transistor scaling, approximate the arc sine function:

$$i(u) = u + u^3/6 + 3u^5/40 + \dots$$

Fig. 12 shows the dynamic SNR range as a function of the optical modulation index OMI, wherein  $\text{OMI} = 1$  corresponds to a phase angle of  $90^\circ$ . The representation in Fig. 12 relates to fixed values of the signal output (-53 dB), of the output of the local oscillator (3 mW), the number of sub-channels (12) and the bandwidth (36 MHz; total bandwidth = 500 MHz). In the diagram in accordance with Fig. 12, CIM is the carrier/intermodulation ratio, CNR is the carrier/noise ratio, and  $\text{CNR}_{\text{tot}}$  the ratio between the carrier and the sum of noise and intermodulation, namely  $\text{CNR}_{\text{tot}(\text{lin})}$  linearized,  $\text{CNR}_{\text{tot}(\text{unlin})}$  non-linearized, and  $\text{CNR}_{\text{tot}(\text{req})}$  desired. In Fig. 12, the maximum of the curve  $\text{CNR}_{\text{tot}(\text{lin})}$  is clearly greater than the maximum of the curve  $\text{CNR}_{\text{tot}(\text{unlin})}$ . From this results the possibility of a transmission via the "transparent" channel in accordance with the present invention, which therefore permits a simultaneous suppression of the intermodulation products of the third and fifth order to a large degree.

**WHAT IS CLAIMED IS**

5           1. An optical intersatellite communications system for transmitting a modulated  
laser beam (3),  
**characterized in that**

10 two separate ranges of the bandwidth are used such, that a first range is provided  
for a synchronization channel (31) of a narrow bandwidth for the transmission of  
synchronization frames of a fixed data rate, and a second range of a broad  
bandwidth (32) is provided for a transparent link, wherein the synchronization  
channel (31) contains syncbits for the local oscillator of the receiver.

15           2. The optical intersatellite communications system in accordance with claim  
**1, characterized in that**

the transparent link is designed for transmitting analog signals of any arbitrary  
wave shapes, or digital signals with a data rate which is different from a given one.

20           3. The optical intersatellite communications system in accordance with claims  
**1 or 2, characterized in that**

syncbits are transmitted with the aid of FPGAs (field programmable gate  
arrays).

25           4. The optical intersatellite communications system in accordance with one of  
claims 1 to 3,  
**characterized in that,**

30 in a multiplexer device (42) on the receiver end, a signal in sub- channels (1,  
... n) modulates a corresponding carrier before the latter is passed on to the  
optical transparent link, that these modulated carriers are multiplexed, and that the  
sub-channels are demultiplexed at the end of the link in a demultiplexer device  
(43) on the receiver end.

5. The optical intersatellite communications system in accordance with one of claims 1 to 4,

**characterized in that**

5 the syncbit frame (44) at the transmitter end is conducted via a low bandpass filter to a multiplexer (45) of the device (42), and that the syncbit frame (46) at the receiver end is retrieved via a low bandpath filter from a demultiplexer (47) of the demultiplexer device (43) at the receiver end.

10 6. The optical intersatellite communications system in accordance with one of claims 1 to 5,

**characterized in that**

15 in a satellite the sub-channels are multiplexed in a multiplexer device (53) at the transmitter end into microwave carriers in the GHz range, that first the modulated microwave signal is down-mixed at least approximately into a band in the MHz range, that such a band is transmitted via the optical transparent intersatellite link (51) from one satellite to another, where the syncbit frame (56) is retrieved in a demultiplexer device (55) by means of demultiplexing, that the signal is again up-mixed into the microwave range in order to permit a further microwave  
20 transmission.

7. The optical intersatellite communications system in accordance with one of claims 1 to 6,

25 **characterized in that,**

a number n of base band signals or sub-channels of a relatively narrow bandwidth, or a broadband analog or digital base band signal of a high bit rate are transmitted.

8. The optical intersatellite communications system in accordance with one of claims 1 to 7,

**characterized in that**

5 a homodyne balanced RFE receiver is provided, in which the received light (61) and the laser light (62) of a local oscillator (63, 92) are coupled in an optical hybrid coupler (64, 91), and are thereafter detected by two photodiodes (651, 652), that the photo flows from these photodiodes are added in an adder (66) and are converted in a transimpedance amplifier (67) into a voltage, and that the local  
10 oscillator (63, 92) is acted upon by a signal (631) from a syncbit processing and OPLL control unit (97).

9. The optical intersatellite communications system in accordance with one of  
15 claims 1 to 8,

**characterized in that,**

for increasing the dynamic range of the link, an electronic broadband pre-distortion linearization circuit (89) is connected upstream of the optical phase modulator (81) which, for compensating the sine- shaped characteristic of the  
20 mixing/detection process, has an arc sine transmission characteristic.

10. The optical intersatellite communications system in accordance with claim  
25 9, characterized in that

pre-distortion linearization circuit (89) is designed for suppressing intermodulation products of the third and fifth orders.

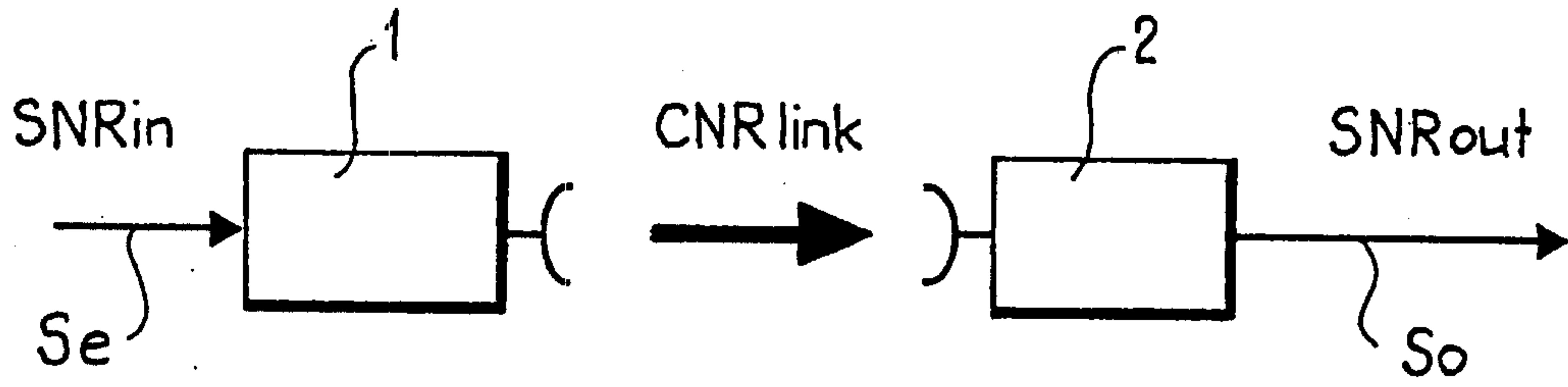


Fig.1

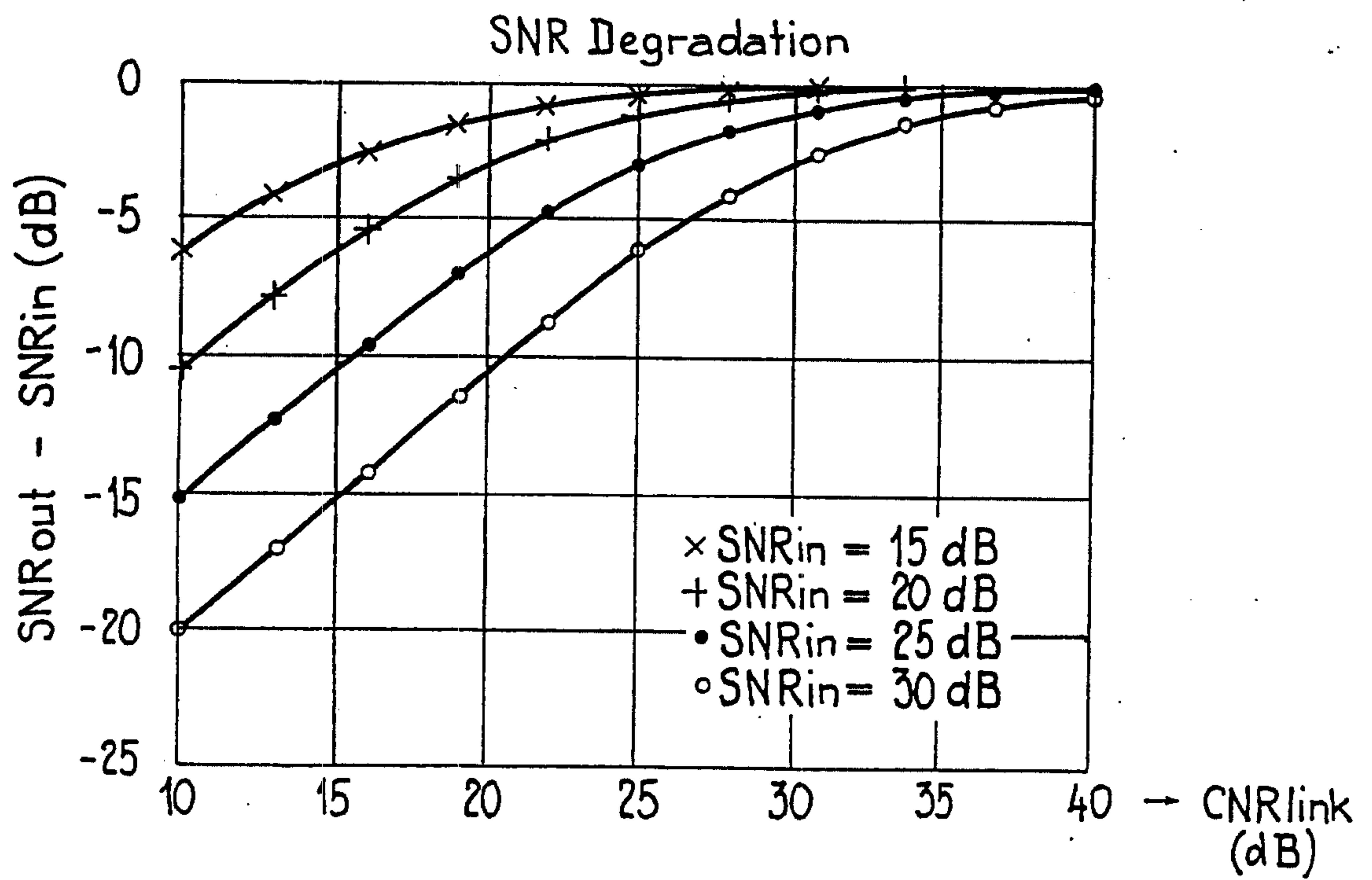


Fig.2

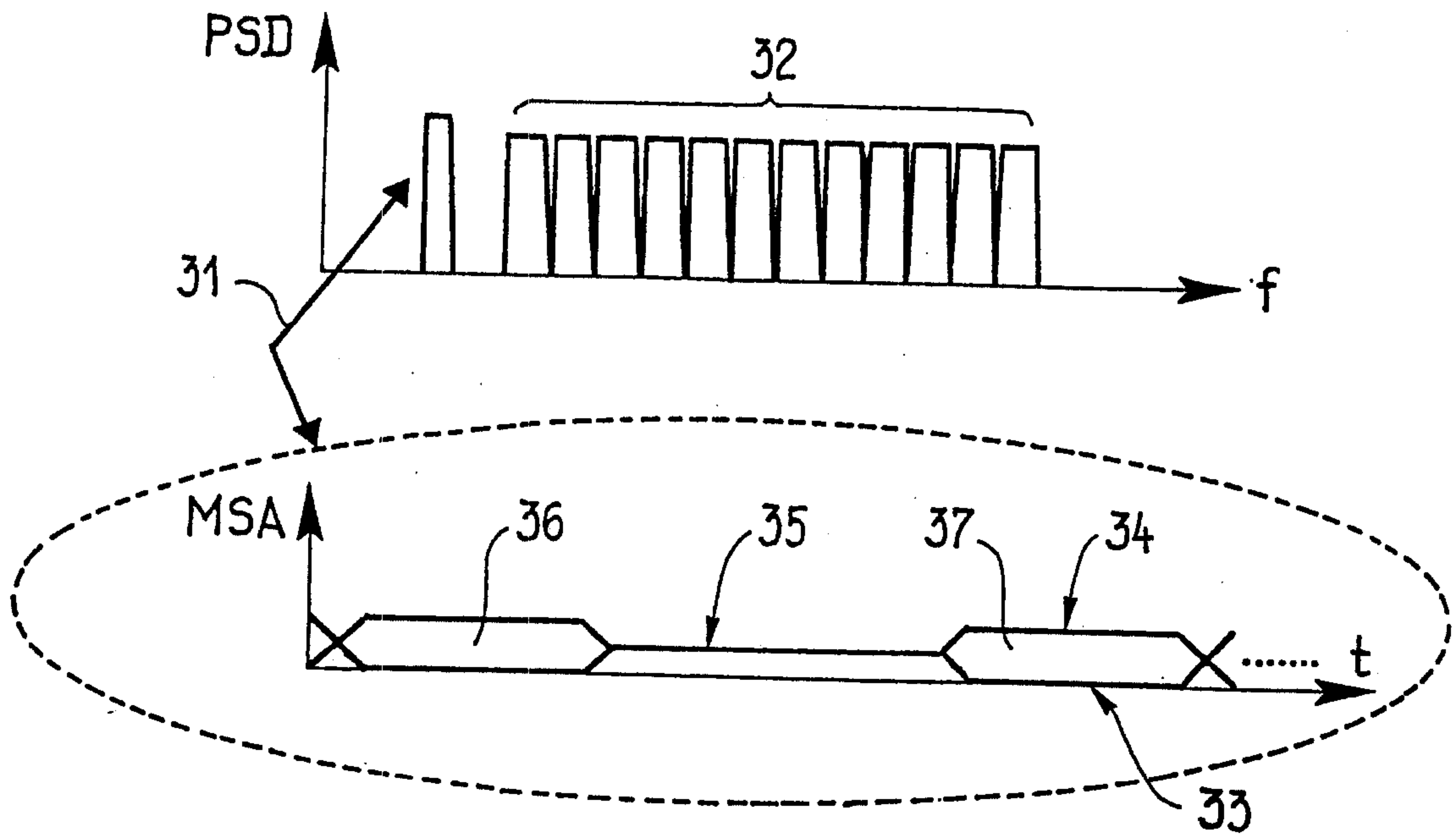


Fig. 3

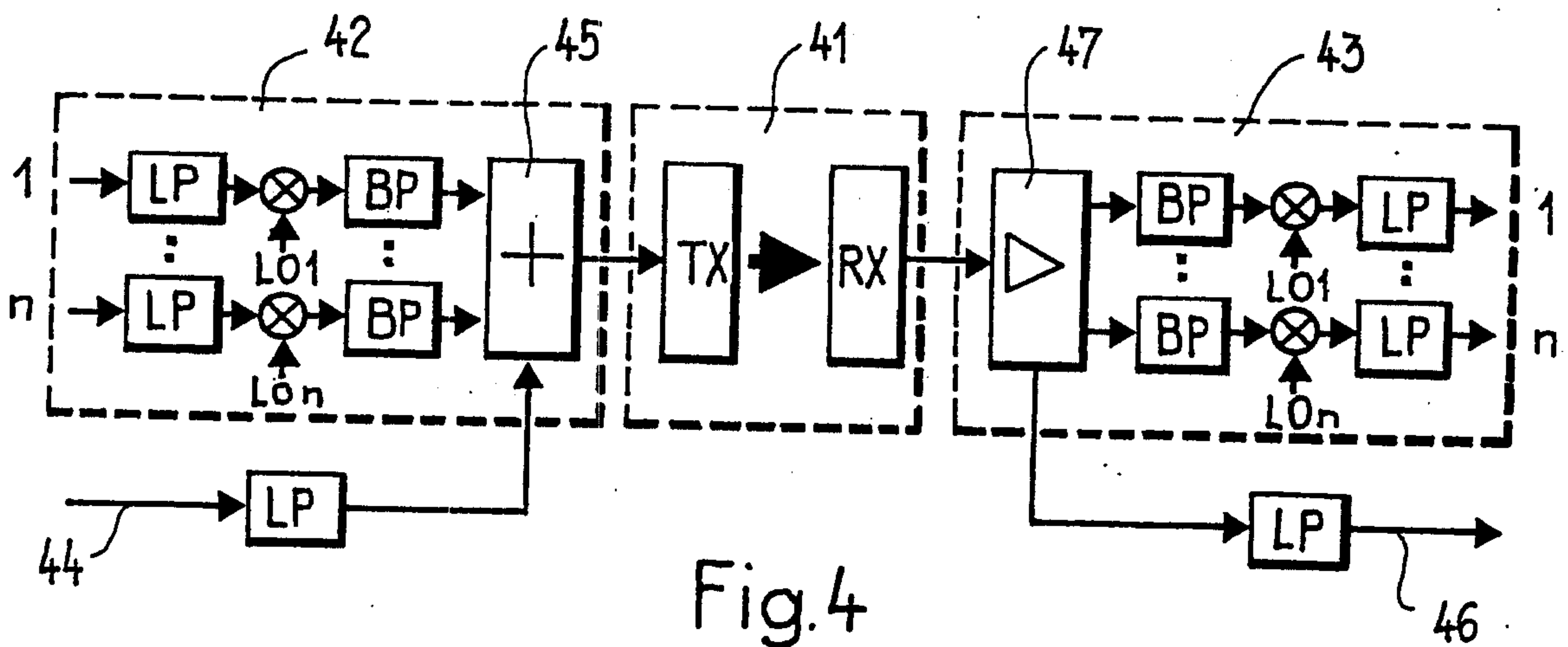


Fig. 4

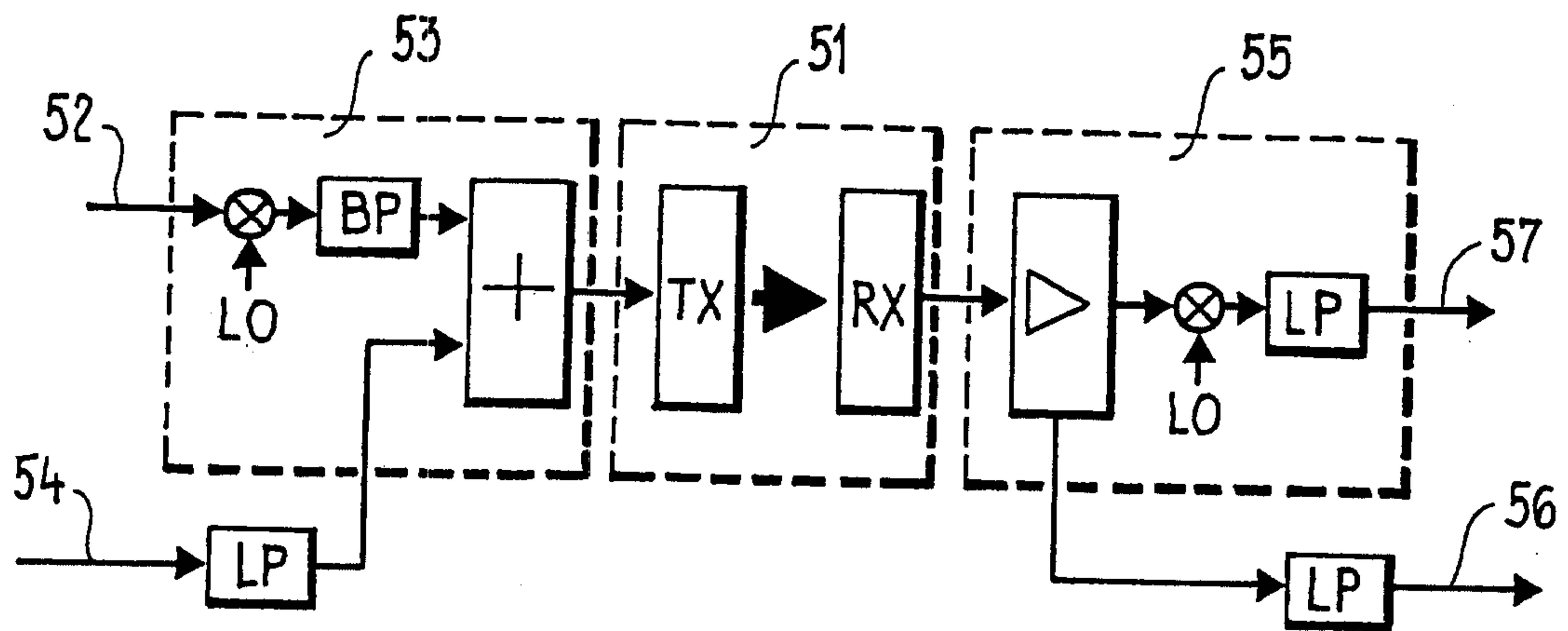


Fig. 5

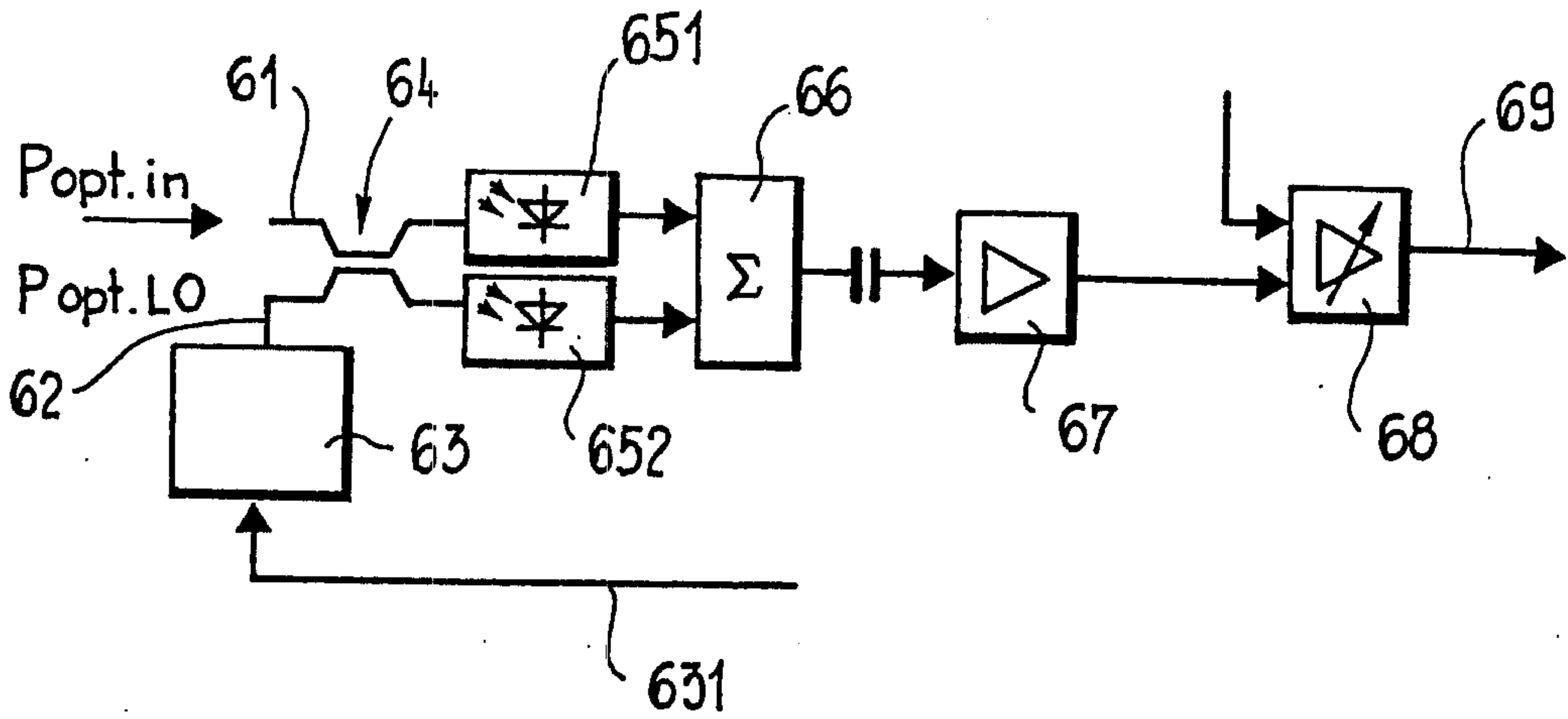


Fig.6

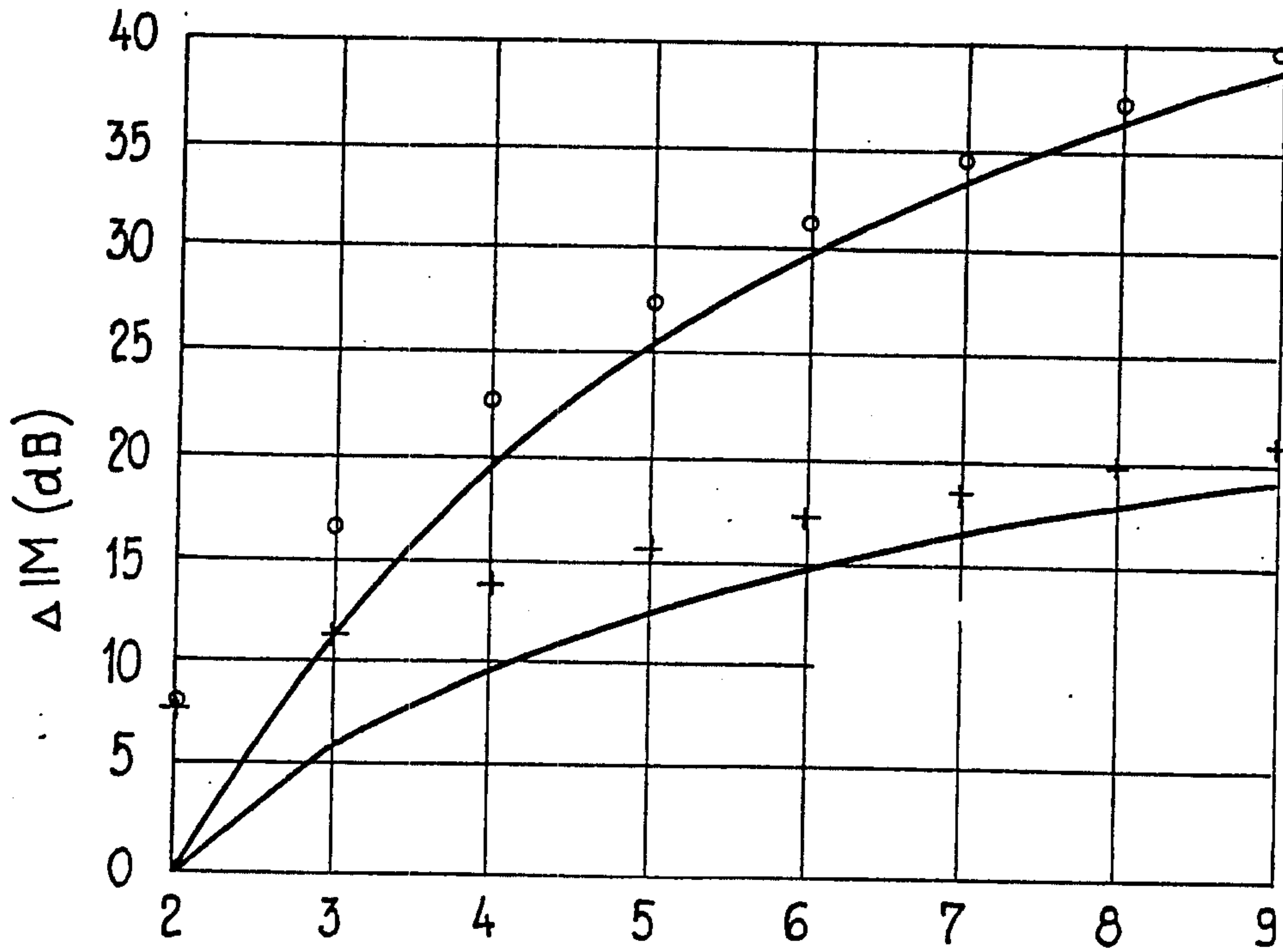
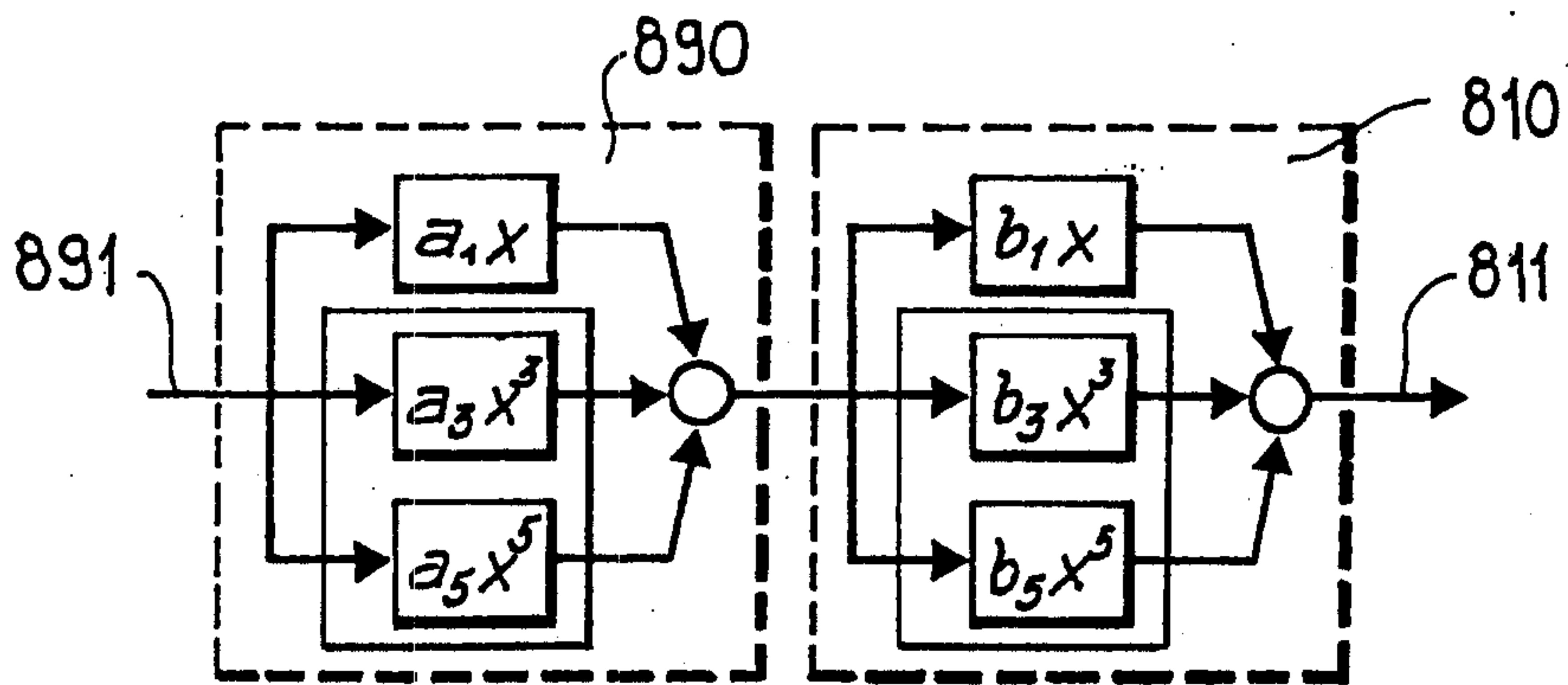
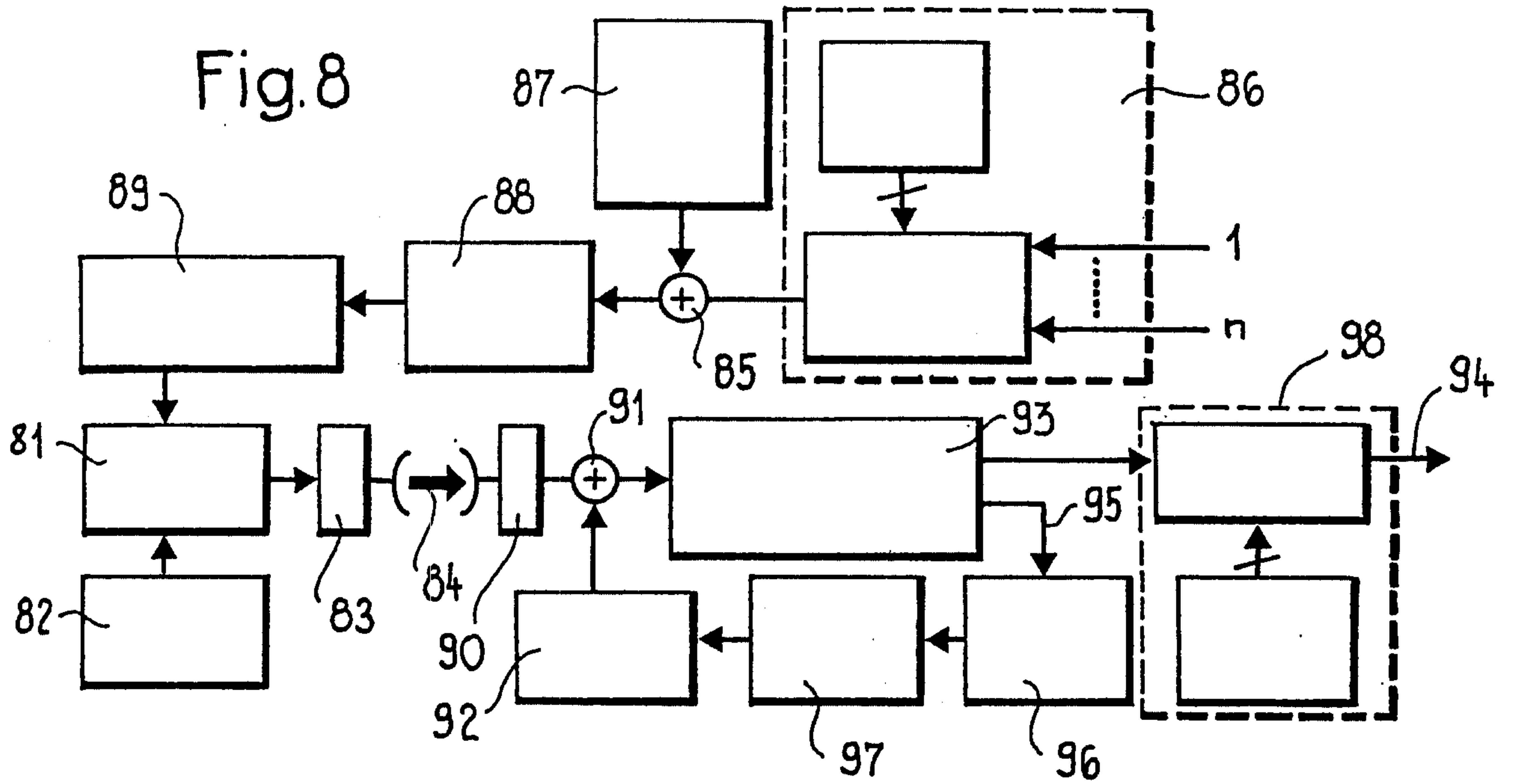
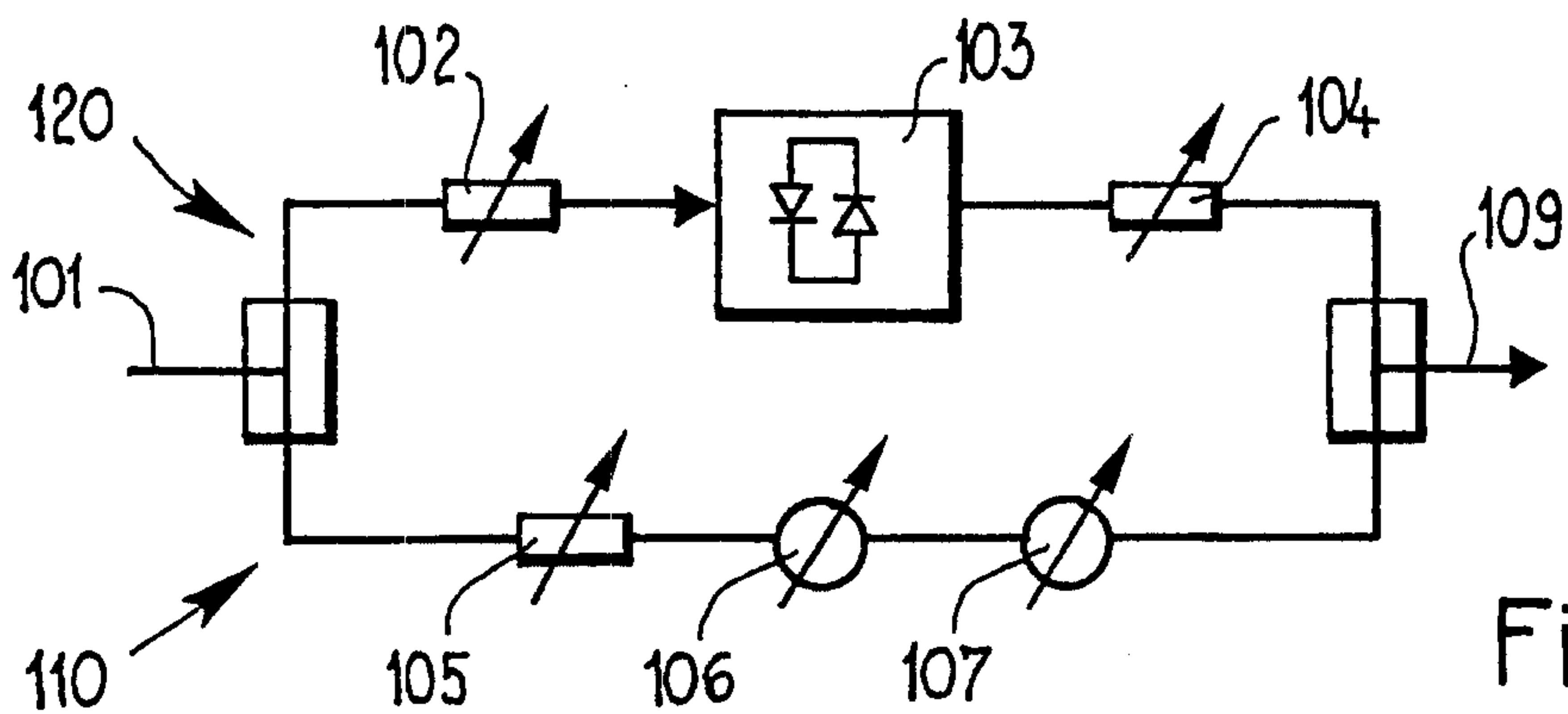


Fig.7



**Fig. 9**



**Fig. 10**

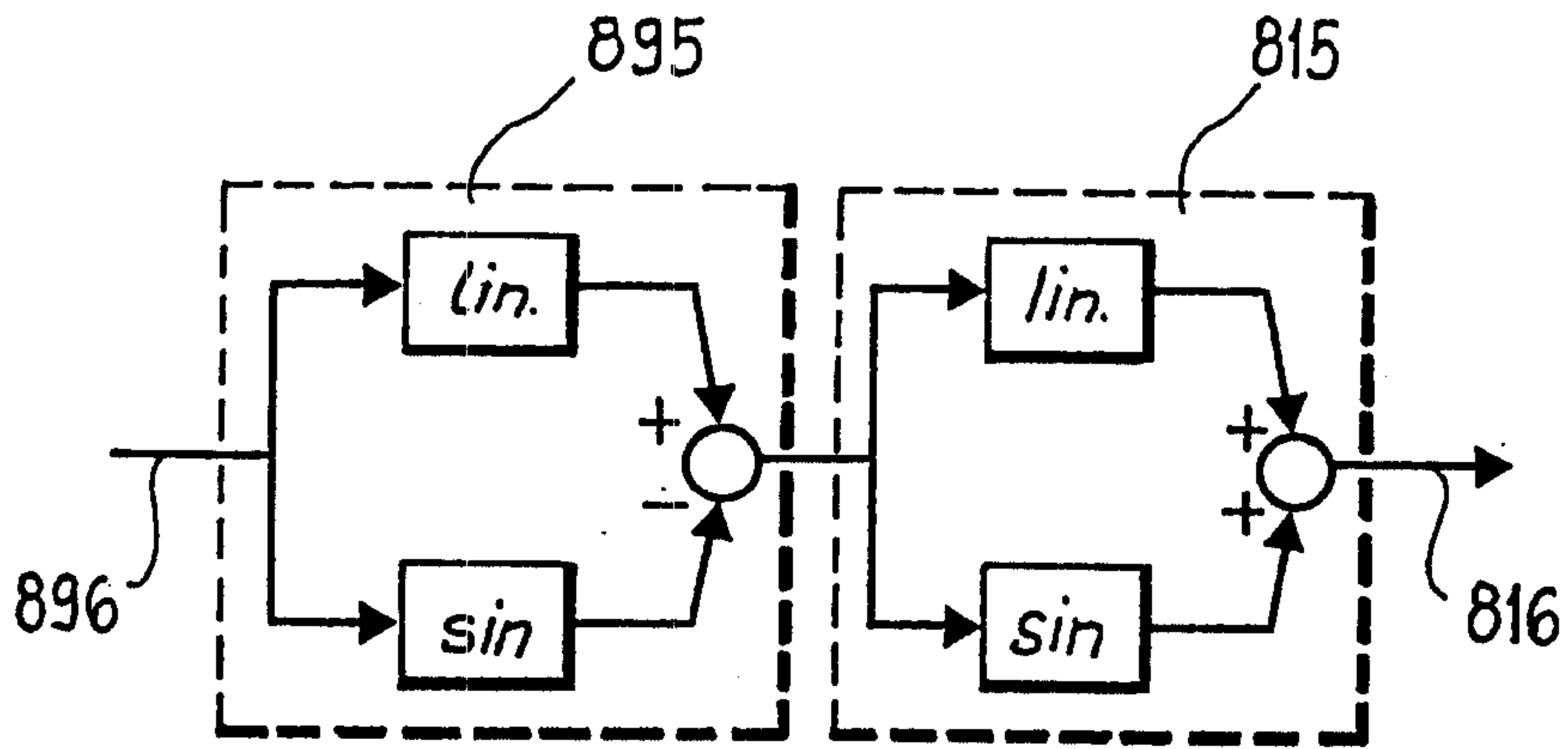


Fig.11

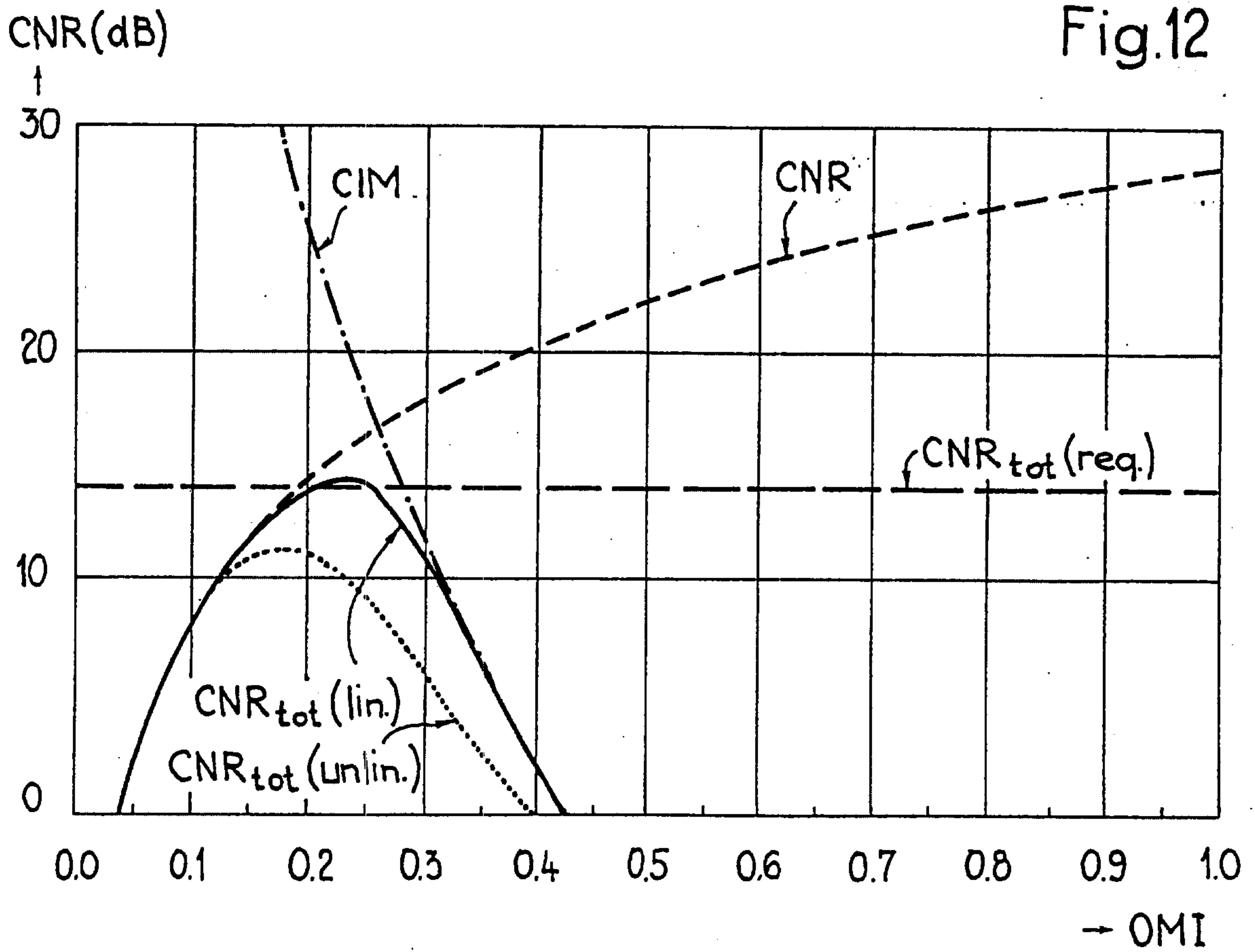


Fig.12

