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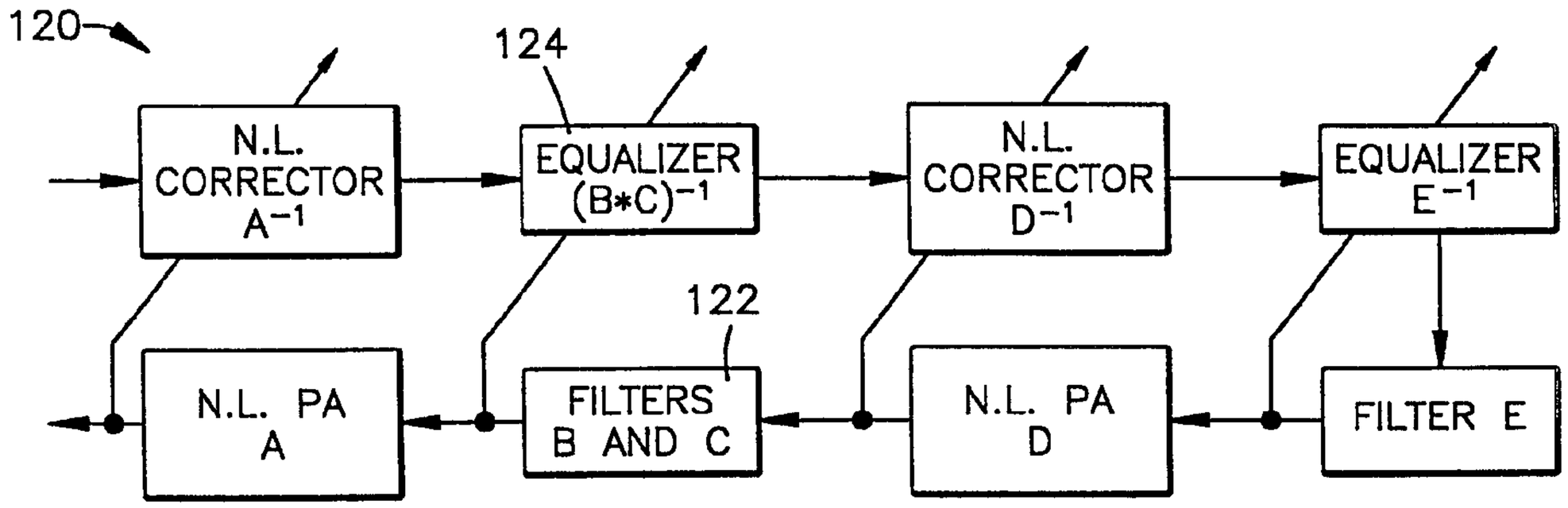
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(54) Title: BROADCAST TRANSMISSION SYSTEM WITH DISTRIBUTED CORRECTION



(57) Abrégé/Abstract:
A transmission system (14) broadcasts an information signal. Within the system (14), several components (e.g., 20-24) cause distortion to the information signal as the signal is processed and proceeds toward a broadcast antenna. The group of distortion causing components (20-24) is identified as a first group, and is arranged in a sequence along a signal path (12) toward the antenna. The first group of components (20-24) performs various functions, including amplification, but each subjects the information signal to distortion shifts away from intended values. A second group of components (e.g., 28-32) modifies the information signal to compensate for the distortion shifts imposed by the first group of components (20-24). The second group of components (28-32) is located upstream of the first group of components (20-24). The second group of components (28-32) is arranged in a sequence to modify the information signal to compensate for the distortions in an order inverse to the occurrence of the distortions.

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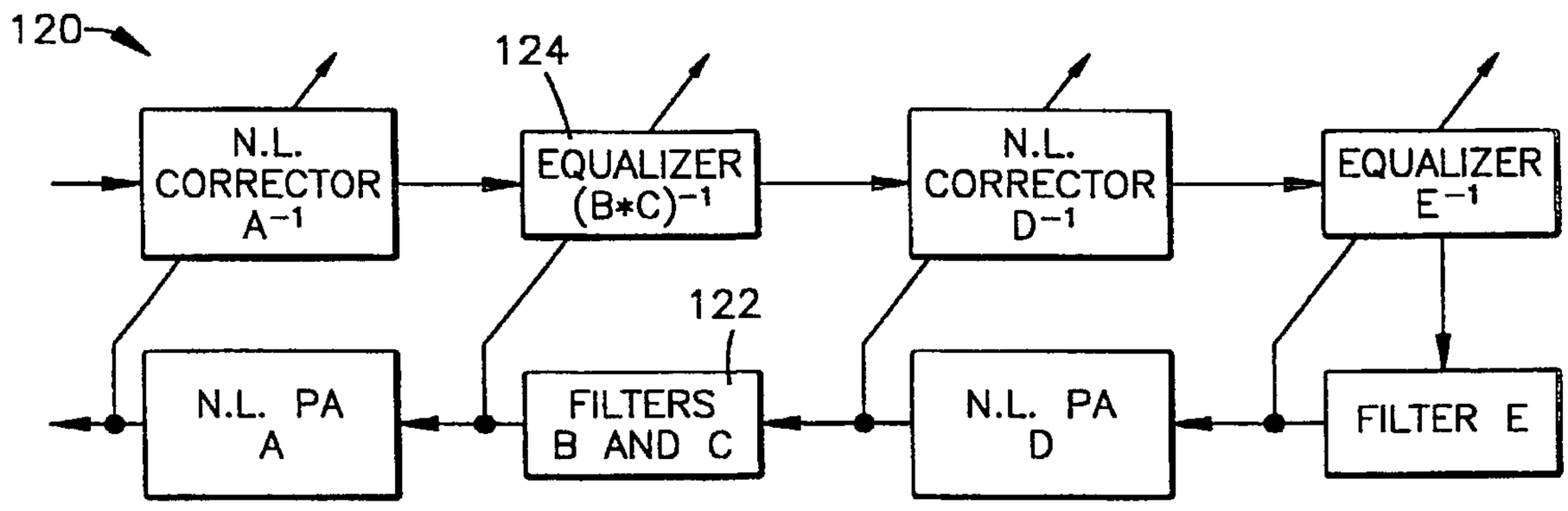
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(54) Title: BROADCAST TRANSMISSION SYSTEM WITH DISTRIBUTED CORRECTION



(57) Abstract: A transmission system (14) broadcasts an information signal. Within the system (14), several components (e.g., 20-24) cause distortion to the information signal as the signal is processed and proceeds toward a broadcast antenna. The group of distortion causing components (20-24) is identified as a first group, and is arranged in a sequence along a signal path (12) toward the antenna. The first group of components (20-24) performs various functions, including amplification, but each subjects the information signal to distortion shifts away from intended values. A second group of components (e.g., 28-32) modifies the information signal to compensate for the distortion shifts imposed by the first group of components (20-24). The second group of components (28-32) is located upstream of the first group of components (20-24). The second group of components (28-32) is arranged in a sequence to modify the information signal to compensate for the distortions in an order inverse to the occurrence of the distortions.

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BROADCAST TRANSMISSION SYSTEM WITH DISTRIBUTED CORRECTION

The present invention relates to broadcast transmission systems and is particularly directed to compensation of distortion within a digital transmission system, such as a digital TV ("DTV") transmission system.

A high-speed broadcast transmission system such as a DTV broadcast system includes components that distort an information signal away from intended values. Specifically, the system includes a power amplifier that imposes non-linear distortion upon the signal, as the signal is amplified. Also, the broadcast transmission system includes filters, such as band-limiting filters, that impose linear distortion upon the information signal as the signal is filtered.

As a result of such distortions within the transmission system, instantaneous amplitude and phase variations (AM/AM, AM/PM) and frequency dependent amplitude and phase variations (frequency response and group delay) occur. It is to be appreciated that within a phase-amplitude modulated system, amplitude and phase integrity of the system must be preserved for optimum system performance.

Traditional equalization for television systems has been accomplished by analog, pre-distortion equalizers and correctors that are static (non-adaptive). Such equalizers and correctors require factory adjustments to provide a desired amount of pre-distortion (pre-equalization). Aging of the equalizers and correctors, and temperature change cause drift in the amount of pre-distortion that is imposed by the equalizers and correctors. Occasional field adjustments are required.

Digital signal processing techniques provide improved performance of the pre-distortion of the information signal. Specifically, digital signal processing can be used in an adaptive correction and equalization approach. Such an adaptive approach can eliminate the factory and field adjustments.

It is known to perform adaptive correction of a signal within a signal stream proceeding toward an antenna. However, in a relatively fast data system, the correction requires a relatively large amount of processing in a short period of time. In one known technique, all of the distortion (i.e., linear and non-linear) is corrected in a single step.

In another technique, the correction for the distortion imposed within the system is done component by component proceeding in a direction toward the antenna. Specifically, for each component, the signal that is output from that component is monitored to determine the amount of distortion imposed by that component. A correction is then developed for that

component. Subsequently, the next subsequent component is monitored to develop the correction for that component. However, such a technique is time consuming and is often unsuitable for high data rate streams. Further, within such a system, amplitude or group delay variations over frequency can be misinterpreted to be instantaneous amplitude and phase variations.

WO99/05869 discloses a transmission system for broadcasting a digital signal comprising a non-linear power amplifier, a pre-amplification analog filter and digital signal correctors to compensate the digital information signal for non-linear and linear distortions imposed by the different analog circuits of the transmission path. This known arrangement discloses that a non-linear corrector and a linear pre-equalizer are adaptively controlled by an adaptive equalization determination circuit which receives an analog feedback signal detected at the output of the power amplifer.

Thus, there is a need for a high-speed technique for adaptive correction of linear and non-linear distortion within a digital broadcast transmission system.

According to the present invention, there is provided a transmission system for broadcasting an information signal and having a signal path along which the information signal proceeds towards an antenna, comprising: a first plurality of components located on the signal path, said first plurality of components including a first component and a second component for performing respective functions on the information signal, said first component subjecting the information signal to non-linear distortion shifts away from intended values and said second component subjecting the information signal to linear distortion shifts away from intended values; and a second plurality of components, located on the signal path upstream of the first plurality of

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components, said second plurality of components including a third component and a fourth component for modifying the information signal to compensate for the non-linear and linear distortion shifts imposed on the information signal by said first plurality of components; characterized in that said third component and said fourth component are respectively responsive to the output signal of said first component and the output signal of said second component to modify the information signal to compensate for the non-linear distortion caused by said first component and to compensate for the linear distortion caused by said second component, respectively, said third component and said fourth component being arranged in the second plurality of components in a sequence to modify the information signal to compensate for the distortions in an order inverse to the order in which the distortions occur in the first plurality of components.

In an embodiment of the invention: the first plurality of components includes a fifth component which subjects the information signal to linear distortion shifts away from intended values; the second plurality of components includes a sixth component for modifying the information signal to compensate for the linear distortion caused by the fifth component; and the upstream/downstream location of said sixth component with respect to said third and fourth components is the inverse of the upstream/downstream location of said fifth component with respect to said first and second components.

Said second component and said fifth component may be grouped together either upstream or downstream of the first component; and said fourth component and said sixth component may be grouped together downstream or upstream of the third component.

A radio frequency transmitter system embodying the invention has an input circuit for processing digital signals to be transmitted from an antenna, a digital-to-analog converter for converting the digital signals into analog form, and an up converter for modulating a radio frequency carrier by the analog signals, the first plurality of components being connected in the data path between said up converter and said antenna, and the second plurality of components being connected in the data path between said input circuit and said digital analog converter.

In this embodiment of the invention: said first component comprises a power amplifier; said second component comprises a pre-amplification filter; said third component comprises a non-linear corrector; and said fourth component comprises a first linear equilizer.

~~and the digital-to-analog converter for processing the digital signals to be applied to the digital-~~ to-analog converter. The adaptive digital signal distortion compensation ~~circuitry is~~ responsive to the digital signals from the analog-to-digital converter corresponding to the outputs of the filter and amplifier circuits for modifying the digital television signals to provide linear and non-linear compensation to the digital television signals. The compensation sequence applied to the digital television signals is such that it is inverse to the order in which the filter and ~~amplifier circuits are connected.~~

The present invention will now be described, by way of example, with reference to the accompanying drawings in which:

Fig. 1 is a function block diagram of components arranged in a sequence in accordance with the present invention;

Fig. 2 is a block diagram of an example device in which the present invention is utilized;

Fig. 3 is a plot of an amplifier transfer curve;

Fig. 4 is a plot of a correction provided to linearize the amplifier output;

Fig. 5 is a block diagram of a portion of the device shown in Fig. 2, which details an arrangement in accordance with the present invention;

Fig. 6 is a function block diagram of another embodiment in accordance with the present invention;

Fig. 7 is a function block diagram of yet another embodiment in accordance with the present invention;

Fig. 8 is a function block diagram of still another embodiment in accordance with the present invention; and

Figs. 9-12 are illustrations of mathematical models of cascaded systems.

One representation of the present invention is an apparatus 10 shown in function block format in Fig. 1 as a plurality of components that are located sequentially along a data stream path 12. The data stream 12 is for an information data signal that is transmitted at a relatively high rate. Further, the data signal typically has a relatively wide band (i.e., 18 MHz).

The high data rate and bandwidth are related to the system environment in which the apparatus 10 is located. Specifically, the apparatus 10 is preferably part of a high definition ("HD") digital television ("DTV") system 14 as shown in Fig. 2. Preferably, the DTV broadcasts signals in the radio range of frequencies. In one embodiment, the broadcast signal is in the ultrahigh frequency range (300-3000 MHz), and is preferably in the range of 470-860 MHz. In pertinent part, the DTV system 14 includes an 8VSB exciter 16 and a transmitter 18.

The components of the apparatus 10 shown in Fig. 1 are located within the 8VSB exciter

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16 and the transmitter 18 of Fig. 2. Specifically, the transmitter 18 (Fig. 1) includes a power amplifier 20, a pre-amplification filter 22 located upstream of the amplifier and a post-amplification filter 24 located downstream of the amplifier. Herein, the pre-amplification filter 22 is referred to as an input filter, and the post-amplification filter is referred to as a high power filter. It is to be appreciated that the transmitter 18 may include other components.

The power amplifier 20 amplifies the information signal to a power level that is suitable for broadcast transmission of a RF signal. In one example, the amplified power level is 50 kilowatts. Also, the power amplifier 20 may be comprised of an array of amplifying devices. If a plurality of amplifying devices is present within the power amplifier 20, a combiner device is located adjacent to the high power filter 24 to combine amplifier device outputs. It is to be understood that various amplifier configurations could be employed, and the high power filter would encompass suitable additional components, such as combiner circuitry.

Focusing now upon a theoretical "ideal" system, all of the components of a transmitter would be ideal. Specifically, a power amplifier of the system would be ideal and the transfer curve for the ideal amplifier would be linear. A dashed line in Fig. 3 shows an example of such an ideal transfer curve. Thus, within such an ideal system, an information signal having a given pre-amplification power level would be amplified to a predetermined power level by the amplifier, based solely upon a linear relationship that dictates the amount of amplification. Also, filters of the ideal system would not impose any distortions.

The actual power amplifier 20 of the apparatus 10 is, however, not ideal, and the actual power transfer curve of the amplifier is not linear. A non-linear distortion is imposed by the power amplifier 20 upon the information signal during amplification of the information signal. Specifically, the non-linear distortion is directed to changes in instantaneous amplitude and phase variations. A solid line in Fig. 3 shows an example of an actual transfer curve. Accordingly, a correction must be imposed upon the information signal to compensate for the distortion caused by the power amplifier 20. The solid line in Fig. 4 shows an example of the correction.

In addition, the filters 22 and 24 of the transmitter 18 impose linear deformations to the information signal. The input filter 22 imposes a first linear distortion and the high power filter 24 imposes a second linear distortion to the information signal. Specifically, the distortion imposed by high power filter 24 is directed to group delay and amplitude response (i.e., amplitude variation versus frequency). Thus, for each of the several components 20-24 within the transmitter 18, an amount of correction or equalization must be imposed upon the information signal to compensate.

Turning again to the theoretical ideal system, any action (i.e., amplification or filtering) imposed upon the information signal would be time-invariant). Specifically, in the ideal system, the actions imposed upon the information signal would not change over time. Thus, for a given input stimulus, the ideal system always produces the same output, independent of the time at which the stimulus occurs.

However, in actuality, the transmitter 18 is time-variant. Specifically, for a given input stimulus, the output that is provided by the transmitter 18 changes over time. One reason for time-variance is thermal effects within the transmitter 18. The thermal effects cause variations in the amount of signal deformation caused by the power amplifier 20 and the filters 22 and 24 to the information signal. Thus, it is desirable to compensate for all of the deformation (i.e., linear and non-linear), and adapt to changes in the deformation.

The apparatus 10 in accordance with the present invention provides three corrector or equalizer components 28-32 within the 8VSB exciter 16 for the three distortion causing components 20-24 within the transmitter 18. Specifically, an adaptive non-linear corrector 28 (e.g., pre-equalization circuitry) imposes a pre-distortion onto the signal to compensate for the non-linear distortion caused by the power amplifier 20. An adaptive linear equalizer 30 (e.g., pre-correction circuitry) imposes a pre-distortion onto the information signal to compensate for the linear distortion caused by the input filter 22. An adaptive linear equalizer 32 (e.g., pre-equalization circuitry) imposes a pre-distortion onto the information signal to compensate for the linear distortion caused by the high power filter 24. Collectively, the linear equalizer 32, the non-linear corrector 28, and the linear equalizer 30 function as adaptive digital signal distortion compensation circuitry.

The linear equalizer 32, the non-linear corrector 28, and the linear equalizer 30 are arranged in a sequence such that the pre-distortions (or pre-corrections) are imposed in a sequential order that is the inverse of the order that distortion occurs. Specifically, because the linear distortion caused by the high power filter 24 occurs last (i.e., at a downstream location from all of the other distortions), the linear pre-distortion imposed by the linear equalizer 32 occurs first. The non-linear pre-distortion imposed by the non-linear corrector 28 occurs second because the non-linear distortion imposed by the power amplifier 20 occurs second. The linear pre-distortion imposed by the linear equalizer 30 occurs third (i.e., after the pre-distortion from the linear equalizer 32 and the pre-distortion of the non-linear corrector 28) because the distortion caused by the input filter 22 occurs first (i.e., prior to the distortion caused by the power amplifier 20 and the high power filter 24).

Inverse order pre-distortion, in accordance with the present invention, is based upon

several issues. First, linear effects and non-linear effects do not retain the property of superposition (i.e., they are not interchangeable) when they are mixed together. Second linear functions, by themselves, do maintain the property of superposition when non-linear effects are not present. Third, an ideal "system" (a "system" being one or more components grouped for consideration) can be intermingled, at will, with either a linear system or a non-linear system. In other words, superposition holds with ideal systems and any other type of system. In order to demonstrate these issues, a digression into mathematics is provided. A nonlinear element, such as a power amplifier can be modeled by the following:

$$y(t) = a_1x(t) + a_2x^2(t) + a^3(t) + \ldots$$

Let x(t) be an arbitrary modulated signal given by...

$$x(t) = p(t)\cos(\omega + \theta)$$

where:

p(t) is the baseband modulation signal

ω is the carrier frequency

q is a fixed phase offset.

Assuming only a 3rd order system for simplicity, then:

$$y(t) = 1/2a_2p^2(t) + [a_1p(t) = a_3p^3(t)]\cos(\omega t+\theta) + 1/2a_2p^2(t)\cos[2(\omega\tau+\theta)]$$
$$+1/2a_3p^3(t)\cos[3(\omega t+\theta)]$$

Only odd order products contribute to the fundamental amplitude. Assuming bandpass filtering is used to eliminate the DC term and harmonic terms, the general system can be reduced to a signal given as follows:

$$Y(t) = [\Sigma a_kp^k(t)]\cos(\omega t+\theta)$$
$$\{k=1,3,5,\ldots\}$$

For moderately non-linear to linear systems, the a_k terms approach zero faster than the $p^k(t)$ terms approach infinity. This sets a limit on the order of the system. Given this model, characterization of this type of system is rather straight-forward and requires a relatively small number of coefficient identifiers.

A cascaded correction system is shown in Fig. 9. Choosing w(t) to be a second order non-

linear system given by:

$$w(t)=a_1x(t)+a_2x^2(t)$$

Also, if it is assumed that v(t) is an arbitrary order non-linear polynomial corrector given by:

$$v(t)=b_1x(t)+b_2x^2(t)+b_3x^3(t)+...$$

If it is desired that the output of the cascaded system is a linear function of the input, namely y(t)=Ax(t), where A is some scalar value (assumed to be unity simplicity).

The system transfer function is given by:

$$y(t)=x(t)=a_1v(t)+a_2v^2(t)$$

$$x(t)=a_1[b_1x(t)+b_2x^2(t)+b_3x^3(t)+...]+a_2[b_1x(t)+b_2x^2(t)+b_3x^3(t)...]^2$$

$$x(t)=a_1b_1x(t)+[a_1b_2+a_2b_1^2]x^2(t)+....$$

There is no exact solution to the equation, but an approximation can be made to a specified order. An approximate second order solution would be:

$$a_1=1/b_1$$

$$a_2=-b_2/b_1^3$$

Although this approximate solution cancels the second order term, it generates higher order product terms. In general, this correction technique compensates for non-linear artifiacts less than or equal to the order of pre-correction. Higher order artificates are generated, the highest of which is the sum of both the pre-correction and the non-linear system combined. This approximation is useful to the extent that the higher order products are small.

Turning now to a linear system, any linear system can be modeled by a general auto-regressive moving average process:

$$G(z)=(\Sigma bz^{-k})/(1-\Sigma a_kz^{-k})$$

Correction for these systems requires the inverse function, namely:

$$H(z)=1/G(z)$$

For any polynomial of the form given by G(z), there exists an inverse H(z). However, there is no guarantee that the inverse will be stable. A common practice is to implement an all-pole approximation of the inverse system assuring stability. The order of the inverse system becomes a matter of performance and processing resources.

The correction of cascaded linear and non-linear systems provides a more difficult challenge. The most difficult problem is controlling the order of the system corrector. The order becomes multiplicative rather than additive for these types of systems. For example, the classic Volterra series expansion for both non-linear and frequency dependent systems is given in general discrete form as:

$$y(n) = \Sigma\Sigma \ldots \Sigma h_k(\tau_1 \ldots \tau_k)\, x(n-\tau_1) \ldots x(n-\tau_k)$$

Summations in order are:

$$k = 1 \ldots infinite;$$
$$\tau_1 = 0 \ldots N_1$$
$$\vdots$$
$$\tau_k = o \ldots N_k$$

These types of systems require much higher order modeling which is expensive and complex in high speed systems such as HDTV.

An example of a cascaded linear and non-linear system is given in Fig. 12, where h(n) is a linear system of order m+1. Its transfer function can be written as:

$$u(n) = x(n)\, h_0 + x(n-1)\, h_1 + x(n-2)\, h_2 + \ldots x(n-m)\, h_m$$

The system w(n) is assumed to be a nonlinear system of order k+1. Its transfer function is written as:

$$w(n) = a_1 u(n) + a_2 u^2(n) + a_3 u^3(n) = + \ldots + a_k u^k(n)$$

Then in general, the transfer function of the cascaded system is:

$$\begin{aligned} y(n) = {} & a_{0,0} x(n) + a_{0,1} x(n-1) + a_{0,2} x(n-1) + \ldots + a_{0,m} x(n-m) \\ & + a_{1,0} x(n) + a_{1,1} x(n-1) + a_{1,2} x(n-1) + \ldots + a_{1,m} x(n-m) \\ & \ldots \\ & + a_{k,0} x(n) + a_{k,1} x(n-1) + a_{k,2} x(n-1) + \ldots + a_{k,m} x(n-m) \end{aligned}$$

The order of the system is (k+1)(m+1) rather than k+m+2. Cost and complexity become prohibitive for high speed systems of significant order. The problem that the above mixed system imposes can be avoided to a large degree by distributing the system correction.

Consider the two systems shown in Figs. 11 and 12. The system in Fig. 11 uses a single block to pre-correct for both the linear and non-linear system functions. The pre-correction $V^{-1}[h(n),w(n)]$ represents the inverse of the equation given above for the cascaded linear and non-linear system. The order required for this correction would be (k+1)(m+1) as indicated above. The system of Fig. 12 distributes the correction between a linear and non-linear block $w^{-1}(n)$ and $h^{-1}(n)$, respectively.

The $h^{-1}(n)$ corrector need only provide linear correction for h(n). Although equalizers vary, for discussion purposes, it is assumed that the order used is equal to the order of h(n). In this example the order is given as m. Given that $h^{-1}(n)$ has corrected for h(n) perfectly, the residual system behavior is entirely non-linear. This allows for a much lower order corrector. It must be noted that the order of equalizer needed depends on many things including type of filter, performance needed, stability, etc. Also, the order of the non-linear corrector required is a function of the higher order effects (speed which a_1 goes to zero). A typical rule of thumb is twice the order of the non-linear system. For high order systems, the benefit of this approach is easily seen.

A more detailed example of the apparatus 10 in accordance with the present invention functioning within the system 14 is shown in Fig. 5. Specifically, other exciter components 36 within the 8VSB exciter 16 are shown providing the signal to the linear equalizer 32. In one embodiment, the information data stream input into the linear equalizer 30 is comprised of 32 byte words defined within a phase amplitude modulated electrical signal.

The linear equalizer 32 is preferably a FIR digital filter that has suitable structure for pre-compensating or pre-equalizing the information signal to compensate for the linear distortion caused by the high power filter 24. The linear equalizer 32 may be comprised of, or include, a microprocessor that performs a program process and/or may be comprised of, or include, discrete "hard-wired" circuitry. It is to be appreciated that other filter types can be employed (e.g., IIR, a combination of FIR and IIR, or even an analog filter).

The information signal passes from the linear equalizer 32 to the non-linear corrector 28. The non-linear corrector 28 may have any suitable structure for pre-distorting (i.e., pre-compensating or pre-equalizing) the signal to compensate for the non-linearities caused by the power amplifier 20. Specifically, the non-linear corrector 28 may impose a linear piecewise correction curve that employs an iterative or empirical approach to routinely update a set of

correction values within a memory. Thus, the non-linear corrector may be comprised of, or include, a microprocessor that performs a program process and/or may be comprised of, or include, discrete "hard-wired" circuitry.

The output of the non-linear corrector 28 is provided to the linear equalizer 30. The linear equalizer 30 may have any suitable components for pre-distorting the signal to compensate for the linear distortion caused by the input filter 22. In one embodiment, the structure and function of the linear equalizer 30 is similar to the structure and function of the linear equalizer 32, except that different pre-distortions are imposed. The output of the linear equalizer 30 is provided to a digital-to-analog converter (DAC) 40.

The information signal proceeds through the DAC 40 and through an up converter 42, which is driven by a local oscillator 44 to provide the information signal as a modulated radio frequency signal. The modulation is via the output of the DAC 40. The information signal then proceeds through the input filter 22, the power amplifier 20, and the high power filter 24.

The system 14 includes an adaptive determinations function 46 which facilitates the selection of various sample points of the signal so that the equalizer 32, the corrector 28, and the equalizer 30 can provide pre-correction. Any suitable adaptation may be utilized for each of the three pre-distortion components 28-32. In order for the adaptation to operate, a first sample signal 50 is coupled off within the transmitter 18 subsequent to filtering by the input filter 22. A second sample signal 52 is coupled off within the transmitter 18 subsequent to amplification by the power amplifier 20. A third sample signal 54 is coupled off within the transmitter 18 subsequent to filtering by the high power filter 24.

Fig. 1 shows the simplified block diagram of the system of Fig. 7. It can be seen that the system is a cascade linear and non-linear system that can take advantage of a distributed correction scheme.

The function block diagram of Fig. 6 shows another example of an apparatus 60 in accordance with the present invention. Specifically, the apparatus 60 includes a non-linear corrector A^{-1} 62, a linear equalizer B^{-1} 64, a linear equalizer C^{-1} 66, a non-linear corrector D^{-1} 68, and a linear equalizer E^{-1} 70. These components 62-70 pre-distort a supplied information signal to compensate for distortion caused by the downstream components of a filter E 72, a non-linear power amplifier D 74, a filter C 76, a filter B 78, and a non-linear power amplifier A 80. A compensating component (e.g., linear equalizer C^{-1} 66) exists for each distorting component (e.g., filter C 76). Each compensating component has an inverse effect with regard to distortion of the information signal. Hence, the alphabetic identifiers are paired to indicated a distorting action (e.g., A) and the inverse action of compensating (e.g., A^{-1}).

The location of each compensating component is at the "inverse" of the location of the associated distorting component. Thus, the order of pre-distortion is in a reverse order of the distortions caused by the filter E 72, the non-linear power amplifier D 74, the filter C 76, the filter B 78, and the non-linear power amplifier A 80. For example, the first compensating component (i.e., the non-linear corrector A^{-1} 62) is associated with the last distorting component (i.e., the non-linear power amplifier A 80).

The function block diagram of Fig. 7 shows another example of an apparatus 90 in accordance with the present invention. The apparatus 90 is a variation of the apparatus 60 of Fig. 6. The apparatus 90 (Fig. 7) illustrates that a sequence of pre-distorting components can be rearranged such that the sequence is not an exact inverse of the sequence by which distortion occurs, so long as transposition of linear pre-distortion does not extend beyond the location of any non-linear pre-distortion.

Specifically, in the example shown in Fig. 7, a non-linear corrector A^{-1} 92 compensates for the non-linear distortion that is caused by the non-linear power amplifier A 94. A linear equalizer B^{-1} 96 compensates for the linear distortion caused by a filter B 98. A linear equalizer C^{-1} 100 compensates for the linear distortion caused by the filter C 102. A non-linear corrector D^{-1} 104 compensates for the non-linear distortion caused by the non-linear power amplifier D 106. A linear equalizer E^{-1} 108 compensates for the linear distortion caused by the filter E 110.

The order of distortion is E, D, C, B, and A, but the order of pre-distortion compensation is A^{-1}, C^{-1}, B^{-1}, D^{-1}, and E^{-1}. The linear equalizer C^{-1} 100 is located upstream (i.e., prior) to the linear equalizer B^{-1} 96. The arrangement A^{-1}, C^{-1}, B^{-1}, D^{-1}, and E^{-1} properly compensates for the distortion. The order of a group of components that compensates for a sequence segment of linear distortion is rearrangable so long as the rearrangement does not move a component for linear compensation past a component for non-linear compensation. In the illustrated example, the linear equalizer E^{-1} 108 could not be rearranged with either the linear equalizer B^{-1} 96 or the linear equalizer C^{-1} 100 because the rearrangement would cross the non-linear corrector D^{-1} 104.

The block diagram of Fig. 8 illustrates an apparatus 120 in accordance with the present invention. The apparatus 120 is a variation of the apparatus 60 of Fig. 6 and illustrates that groups of like-kind distortion can be handled as an aggregate. Within Fig. 8, filters B and C are combined into a single filter block 122. The filters B and C still impose linear distortion onto the information signal. However, the linear pre-distortion that compensates for the linear distortion of the filters B and C is combined into a single step within a linear equalizer $(B*C)^{-1}$ 124.

Such combining is useful especially for the apparatus 120, which is adaptive. The apparatus 120 uses feedback to calculate/generate compensation values, which are used within

the correctors and equalizers. Thus, as shown by Fig. 8, four feedback loops are required, as opposed to five. The reduced number of feedbacks requires a lesser amount of hardware and calculation/computation, and memory compared to the situation in which separate correction occurs for filter B and filter C.

A transmission system (14) broadcasts an information signal. Within the system (14), several components (e.g., 20-24) cause distortion to the information signal as the signal is processed and proceeds toward a broadcast antenna. Specifically, the group of distortion causing components (20-24) is identified as a first group, and is arranged in a sequence along a signal path (12) toward the antenna. The first group of components (20-24) performs various functions, including amplification, but each subjects the information signal to distortion shifts away from intended values. A second group of components (e.g., 28-32) modifies the information signal to compensate for the distortion shifts imposed by the first group of components (20-24). The second group of components (28-32) is located upstream of the first group of components (20-24). The second group of components (28-32) is arranged in a sequence to modify the information signal to compensate for the distortions in an order inverse to the occurrence of the distortions.

CLAIMS

1. A transmission system (10, 60, 90 or 120) for broadcasting an information signal and having a signal path along which the information signal proceeds towards an antenna, comprising: a first plurality of components (18) located on the signal path, said first plurality of components (18) including a first component (20, 80 or 94) and a second component (22, 78 or 98) for performing respective functions on the information signal, said first component (20, 80 or 94) subjecting the information signal to non-linear distortion shifts away from intended values and said second component (22, 78 or 98) subjecting the information signal to linear distortion shifts away from intended values; and a second plurality of components (16), located on the signal path upstream of the first plurality of components, said second plurality of components (16) including a third component (28, 62 or 92) and a fourth component (30, 64 or 96) for modifying the information signal to compensate for the non-linear and linear distortion shifts imposed on the information signal by said first plurality of components; characterized in that said third component (28, 62 or 92) and said fourth component (30, 64 or 96) are respectively responsive to the output signal of said first component (20, 80 or 94) and the output signal of said second component (22, 78 or 98) to modify the information signal to compensate for the non-linear distortion caused by said first component and to compensate for the linear distortion caused by said second component, respectively, said third component (28, 62 or 92) and said fourth component (30, 64 or 96) being arranged in the second plurality of components (16) in a sequence to modify the information signal to compensate for the distortions in an order inverse to the order in which the distortions occur in the first plurality of components (18).

2. A system as claimed in claim 1, wherein: the first plurality of components (18) includes a fifth component (24, 76 or 102) which subjects the information signal to linear distortion shifts away from intended values; the second plurality of components (16) includes a sixth component (32, 66 or 100) for modifying the information signal to compensate for the linear distortion caused by the fifth component (24, 76 or 102); and the upstream/downstream location of said sixth component (32, 66 or 100) with respect to said third and fourth components (28, 62 or 92; 30, 64 or 100) is the inverse of the upstream/downstream location of said fifth component (24, 76 or 102) with respect to said first and second components (20, 80 or 94; 22, 78 or 98).

3. A system as claimed in claim 2, wherein: said second component (78 or 98) and said fifth component (76 or 102) are grouped together either upstream or downstream of the first component (80 or 94); and said fourth component (64 or 96) and said sixth component (66 or 100) are grouped together downstream or upstream of the third component (62 or 92).

4. A system as claimed in claim 3, wherein said fourth component (64 or 96) and said sixth components (66 or 100) are combined to compensate simultaneously for the linear distortion caused by said second and fifth components (78 or 98; 76 or 102).

5. A system as claimed in any preceding claim, wherein: the system comprises a radio frequency transmitter system having an input circuit for processing digital signals to be transmitted from an antenna, a digital-to-analog converter (40) for converting the digital signals into analog form, and an up converter (42) for modulating a radio frequency carrier by the analog signals; the first plurality of components (18) are connected in the data path between said up converter (42) and said antenna; and the second plurality of

components (16) are connected in the data path between said input circuit and said digital-to-analog converter (40).

6. A system as claimed in claim 5, wherein said first component (20, 80 or 94) comprises a power amplifier; said second component (22, 78 or 98) comprises a pre-amplification filter; said third component (28, 62 or 92) comprises a non-linear corrector; and said fourth component (30, 64 or 96) comprises a first linear equalizer.

7. A system as claimed in any one of claims 2 to 5, wherein: the system comprises a radio frequency transmitter system having an input circuit for processing digital signals to be transmitted from an antenna, a digital-to-analog converter (40) for converting the digital signals into analog form, and an up converter (42) for modulating a radio frequency carrier by the analog signals; the first plurality of components (18) are connected in the data path between said up converter (42) and said antenna; and the second plurality of components (16) are connected in the data path between said input circuit and said digital-to-analog converter (40); said first component (20, 80 or 94) comprises a power amplifier; said second component (22, 78 or 98) comprises a first filter; said third component (28, 62 or 92) comprises a non-linear corrector; said fourth component (30, 64 or 96) comprises a first linear equalizer; said fifth component (24, 76 or 102) comprises a second filter; and said sixth component (32, 66 or 100) comprises a second linear equalizer.

8. A system as claimed in claim 7, including: a down converter (46) for receiving output signals from said first, second and fifth components (20, 80 or 94; 22, 78 or 98; 24, 76 or 102) for down converting said output signals; an analog-to digital converter (46) for converting the down converted analog signals into digital form and supplying said digital signals to the respective

components (28, 62 or 92; 30, 64 or 96; 32, 66 or 100) of the second plurality of components (16).

9. A system as claimed in any preceding claim, wherein the system is a digital television transmitter system (14).

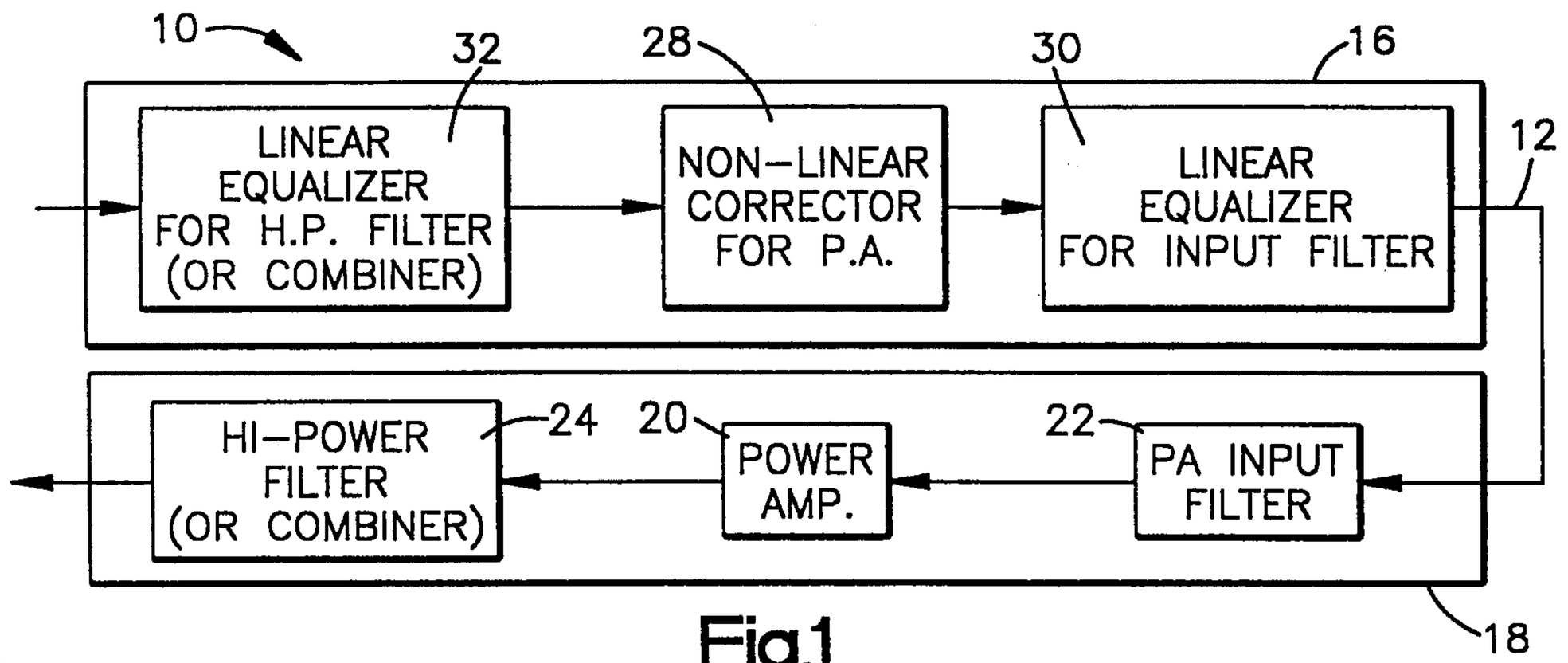


Fig.1

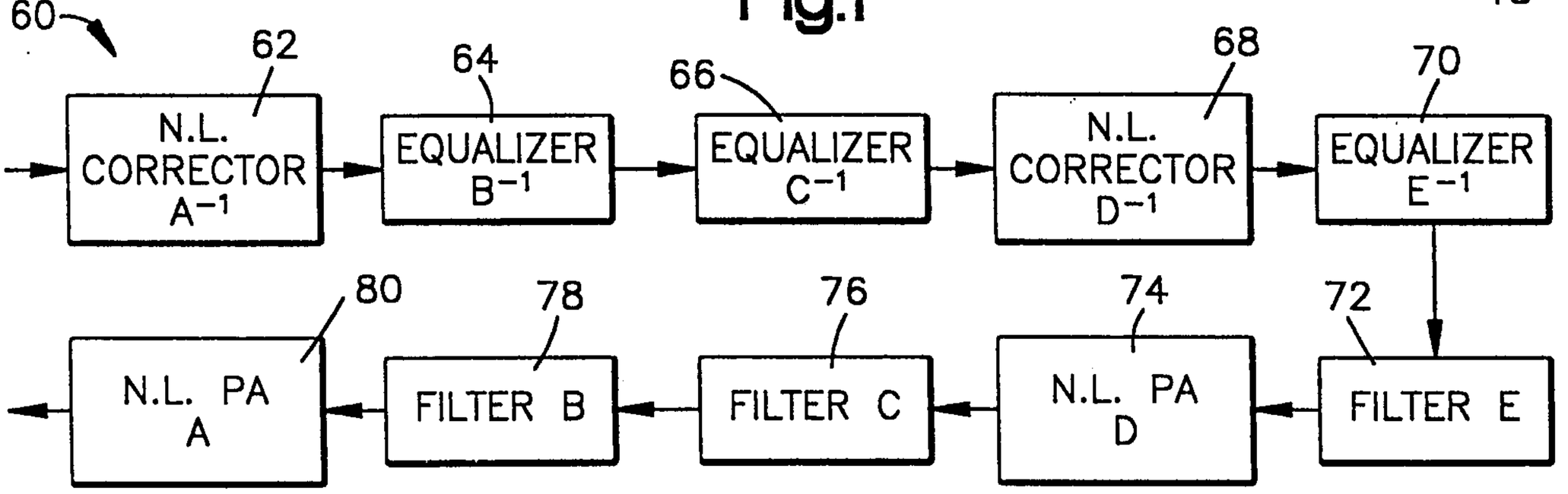


Fig.6

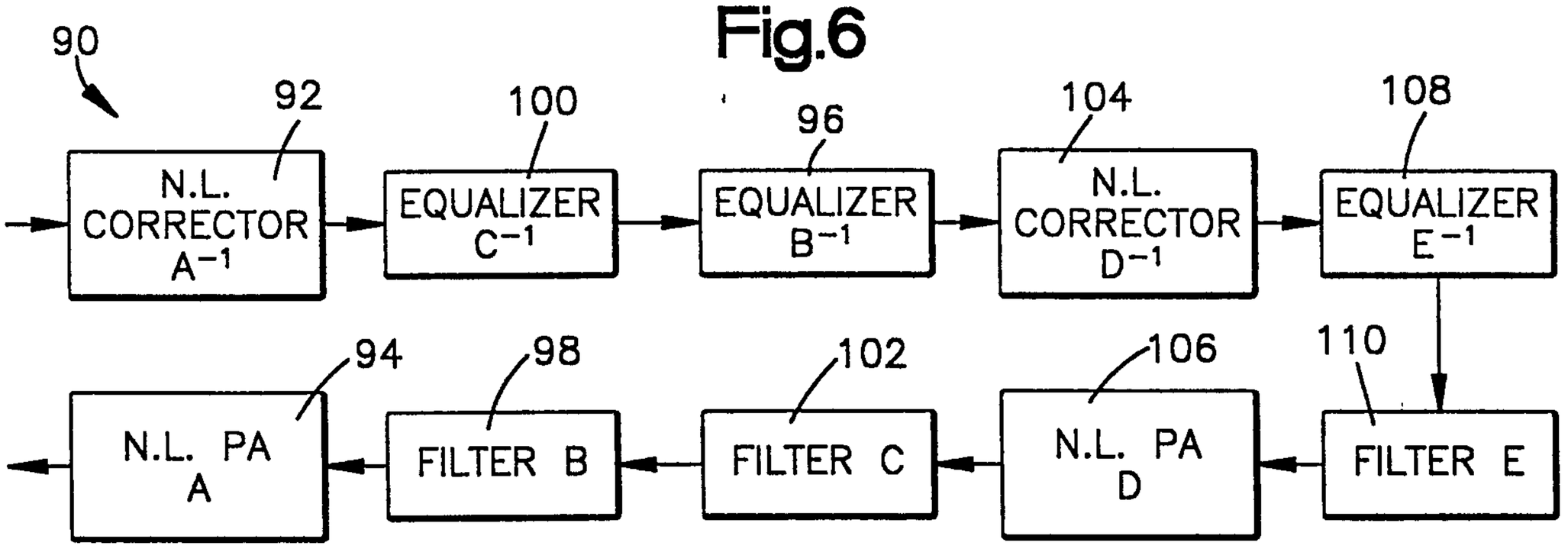


Fig.7

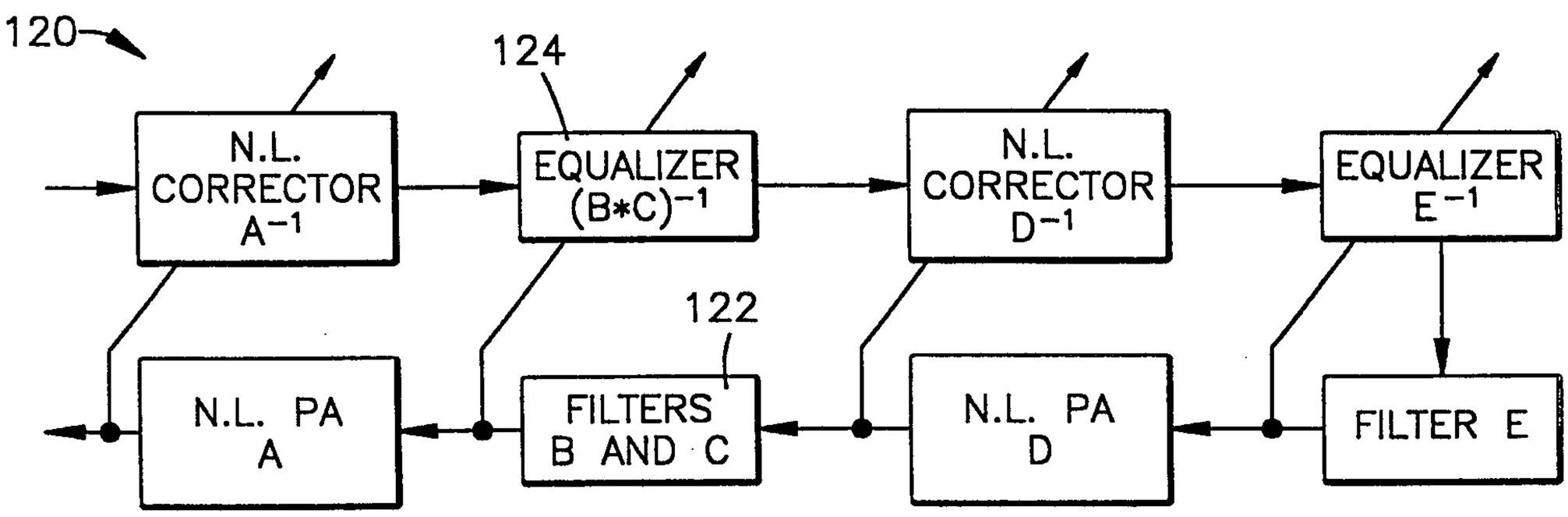


Fig.8

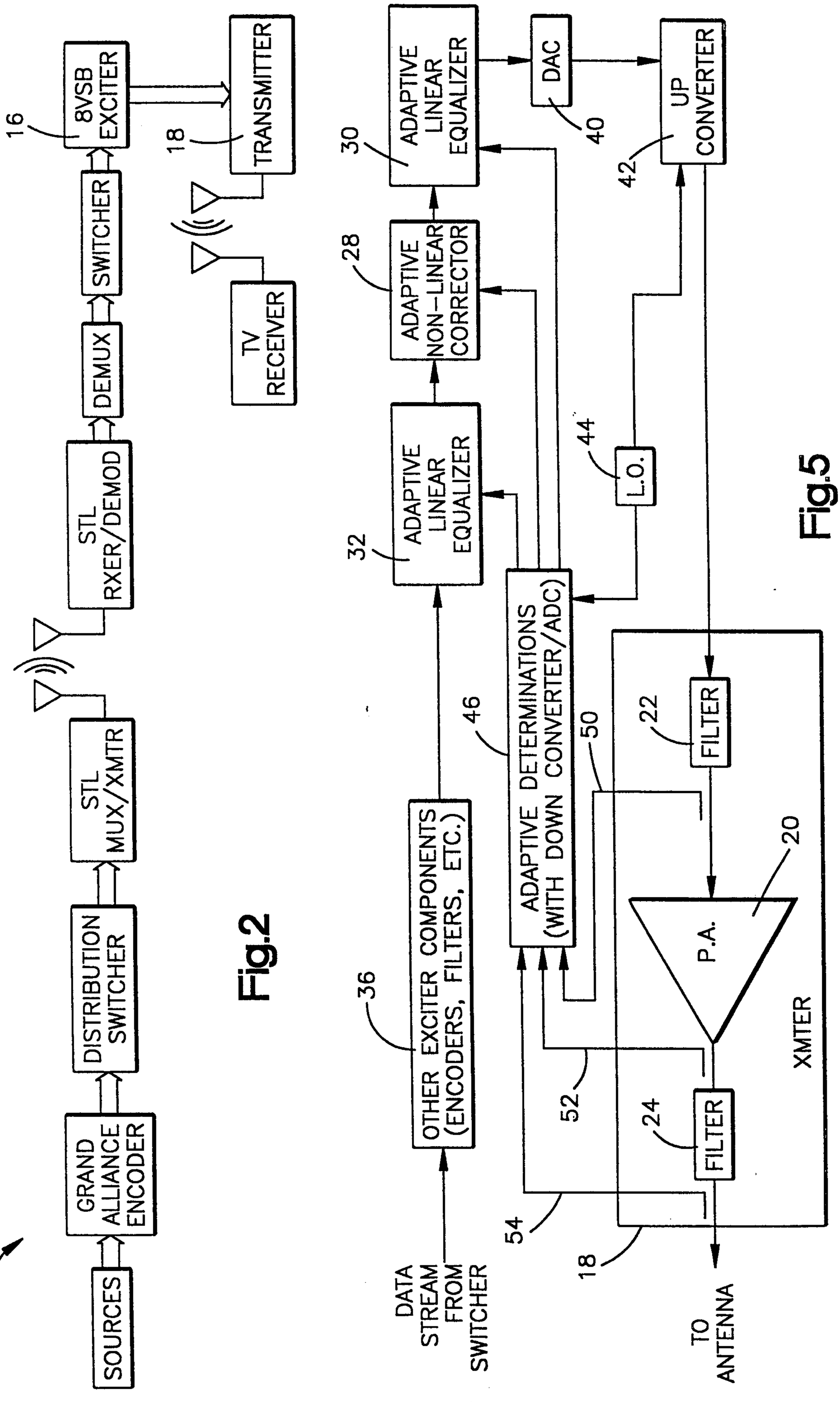

16
8VSB EXCITER
18
TRANSMITTER
TV RECEIVER
SWITCHER
DEMUX
STL RXER/DEMOD
STL MUX/XMTR
DISTRIBUTION SWITCHER
GRAND ALLIANCE ENCODER
SOURCES
14
30
ADAPTIVE LINEAR EQUALIZER
DAC
40
UP CONVERTER
42
28
ADAPTIVE NON-LINEAR CORRECTOR
32
ADAPTIVE LINEAR EQUALIZER
44
L.O.
ADAPTIVE DETERMINATIONS (WITH DOWN CONVERTER/ADC)
46
50
22
FILTER
P.A.
20
XMTER
52
24
FILTER
54
18
36
OTHER EXCITER COMPONENTS (ENCODERS, FILTERS, ETC.)
DATA STREAM FROM SWITCHER
TO ANTENNA

Fig.2

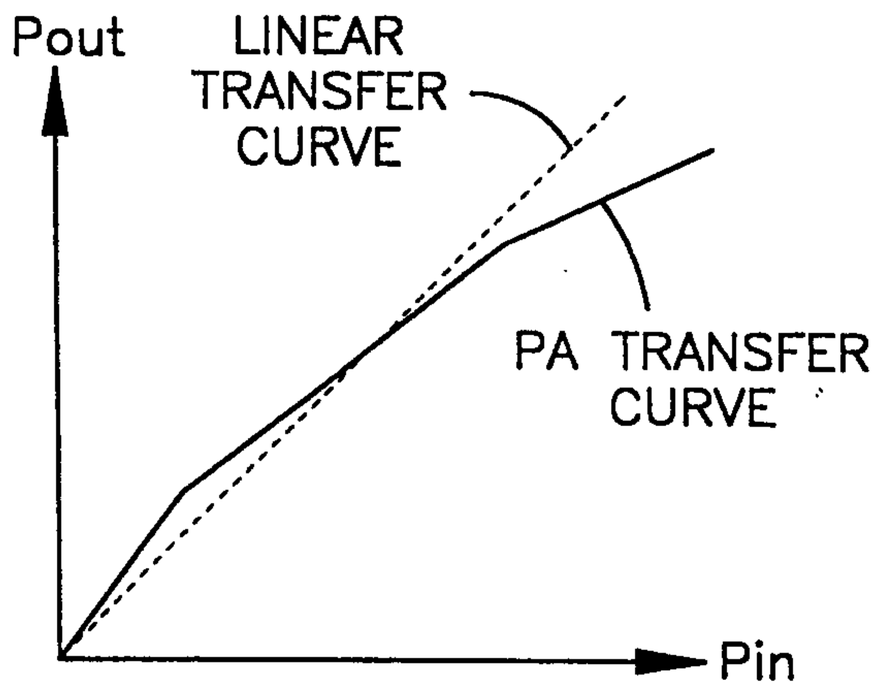

Pout
LINEAR
TRANSFER
CURVE
PA TRANSFER
CURVE
Pin

Fig.3

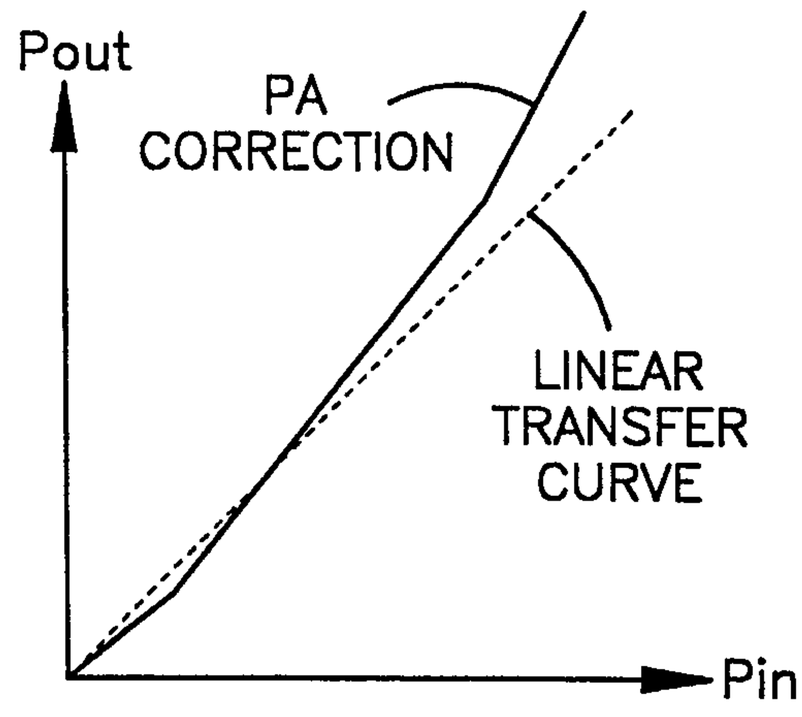

Pout
PA
CORRECTION
LINEAR
TRANSFER
CURVE
Pin

Fig.4

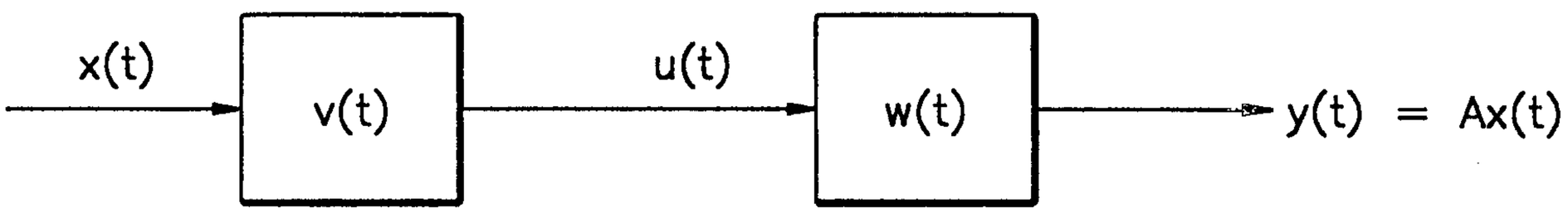


Fig.9

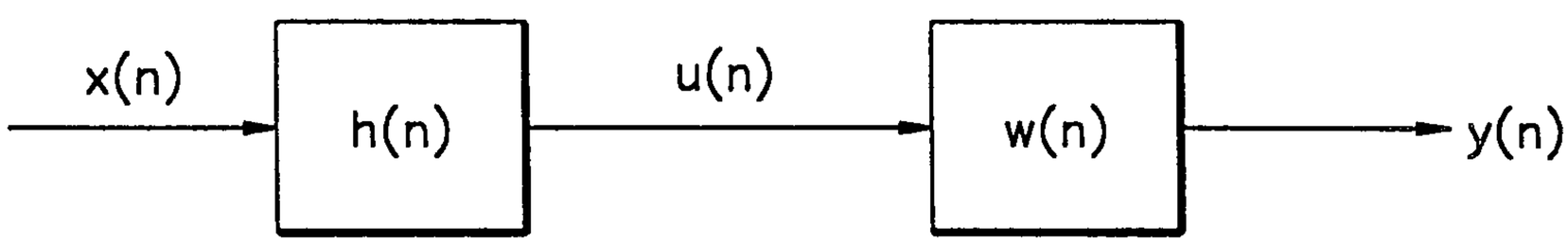


Fig.10

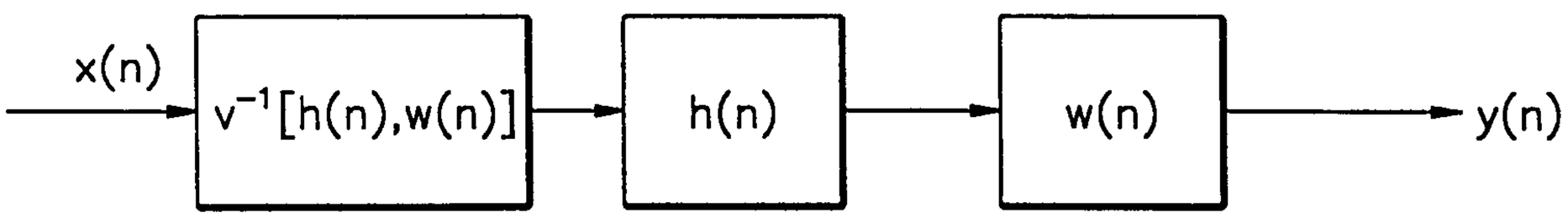


Fig.11

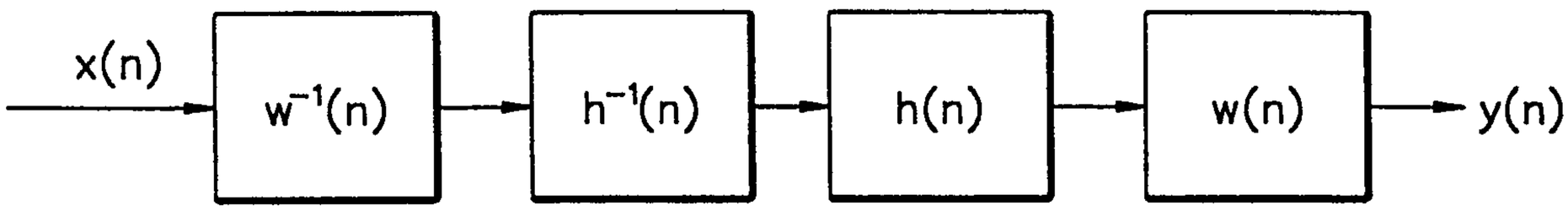
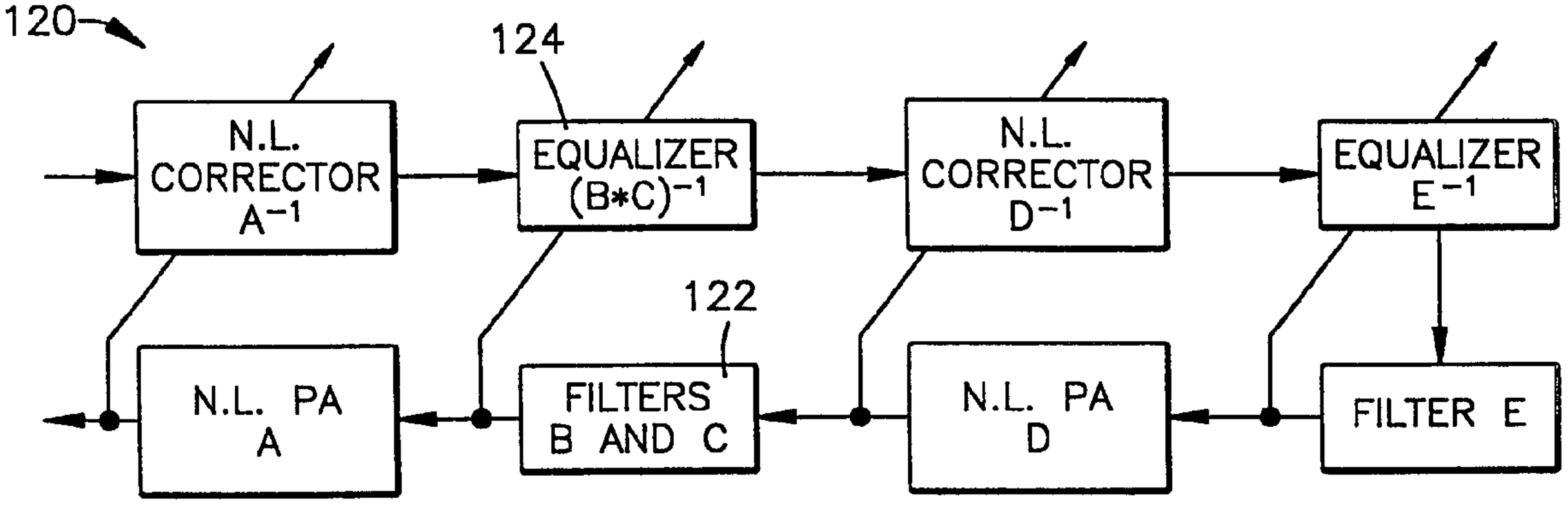


Fig.12


120
124
N.L.
CORRECTOR
A-1
EQUALIZER
(B*C)-1
N.L.
CORRECTOR
D-1
EQUALIZER
E-1
122
N.L. PA
A
FILTERS
B AND C
N.L. PA
D
FILTER E