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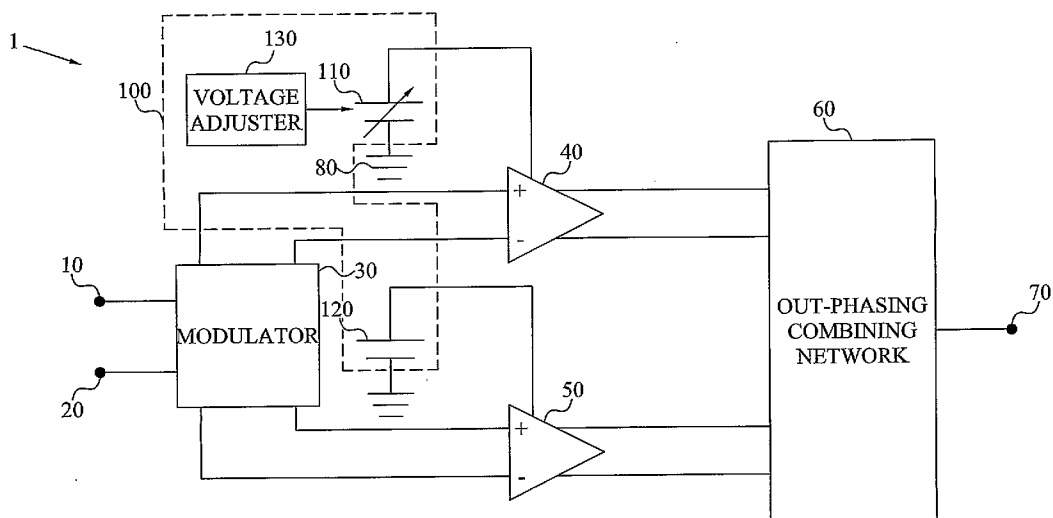
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(54) Title: LINC OUT-PHASING AMPLIFIER SYSTEM



(57) Abstract: The present invention relates to a LINC out-phasing amplifier system (1) and techniques for reducing amplifier imbalances in the amplifier system (1). An input signal is applied to a modulator (30) that splits the signal into two phasor fragments which are independently amplified in a respective branch amplifier (40, 50) and subsequently combined in an out-phasing combining network (60) into an amplified output signal. A bias system (110, 120, 140) supplies biases to the branch amplifiers (40, 50). The invention reduces the arising amplitude imbalances by independently adjusting the biases experienced by the branch amplifiers (40, 50). Due to this bias adjustment, in operation independent and different biases will be supplied to the branch amplifiers (40, 50) resulting in a cancellation of the amplitude imbalances.

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LINC OUT-PHASING AMPLIFIER SYSTEM

TECHNICAL FIELD

5 The present invention generally relates to linear amplification using nonlinear components, LINC, out-phasing amplifier systems, and in particular to improving the operation characteristics of such LINC out-phasing amplifier systems.

BACKGROUND

10 Amplifiers are used today in a wide range of applications for amplifying different signals. In for example radio communications systems a power amplifier typically amplifies a radio frequency (RF) signal in a transmitter prior to transmission to a receiver.

15 Today several different data modulations and modulation schemes are available to use together with the RF signals. This imparts new challenges to the power amplifiers utilized for amplifying the modulated signals. For example, Orthogonal Frequency Division Multiplexing (OFDM) modulation multiplexes data among 52 carriers, each of which can be modulated with
20 different modulation schemes, including Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16-level Quadrature Amplitude Modulation (16QAM) or 64QAM.

25 Several of the modulations utilized in the art, including OFDM, leads to resulting RF signals with large error vector magnitude.

30 In the wireless communications systems, a high output power (and therefore range) and high bite rate is desired for the transmitted RF signals but with low power consumption. There is traditionally a complex tradeoff between these conflicting goals. Thus, in order to obtain a high bite rate, excellent linearity is required. This is usually achieved by backing-off a linear power amplifier, e.g. class AB power amplifier, resulting in lower transmitted power. Lower transmitted power, however, results in a poorer link budget

and therefore less operating range. Higher power and therefore range can be achieved, but then at the cost of data rate and power consumption. In summary, low power consumption, high data rate and good range is desired but the traditional linear amplifiers in the art can at most simultaneously achieve only two of these three goals.

Traditional linear amplifiers can be made quite efficient when operating at their peak power, but the efficiency drops quickly at lower envelope powers. This means that such linear amplifiers are not suitable to amplify RF signals, e.g. OFDM modulated signals, for which the amplifier should operate at its peak power and peak efficiency at a broad range of output powers.

Linear amplification using nonlinear components (LINC) out-phasing amplifiers, however, provide excellent efficiency over a vast range of output powers. In operation, an input signal is provided, e.g. as an in-phase (I) and quadrature phase (Q) signal, at input ports of the LINC out-phasing amplifier. The input signals are processed in a LINC modulator to generate two signals of constant amplitude but of varying phase, sometimes denoted phasor fragments in the art. These two phasor fragments are amplified in two separate nonlinear amplifiers, typically referred to as branch amplifiers. The amplified signals are then combined in a LINC out-phasing combining network to create, at an output port, a single amplified RF signal of varying phase and amplitude. Since the branch amplifiers are operating at optimum (maximum) swing, each amplifier can always be operated at peak efficiency.

The LINC out-phasing system also comprises a supply voltage or bias source connected to the two branch amplifiers. The provided bias controls the resulting power level of the output signal.

The document [1] discloses a phase predistortion using phase control to account for phase imbalances and interactions between the two signal paths

of the LINC out-phasing amplifier system and prevent degradation of linearity.

SUMMARY

5 However, even if document [1] teaches techniques for combating phase imbalances and degradations in the LINC out-phasing amplifier system, amplitude imbalances are typically present in the amplifier system. These amplitude imbalances arise due to spread in the including components of the branch amplifiers and the combining network, resulting in that the two
10 branch amplifiers will not generate the same output power for the same bias voltage. The arising amplitude imbalance will, when the two signals are combined, degrade the linearity of the amplifier system, reduce the dynamic range of the amplifier system, result in unwanted spurious elements on adjacent frequencies and reduce the ability to back down the amplifier
15 system below a certain output power level.

There is, thus, a need for providing a simple solution that combats any amplitude imbalances of a LINC out-phasing amplifier system.

20 The present invention overcomes these and other drawbacks of the prior art arrangements.

It is a general object of the present invention to provide a LINC out-phasing amplifier system with improved operation characteristics.

25 It is another object of the invention to provide techniques for improving the operation characteristics of a LINC out-phasing amplifier system by correcting amplitude imbalance errors.

30 Yet another object of the invention is to provide a correction of amplitude imbalance errors that can be applied to different LINC out-phasing amplifier solutions without requiring usage of complex circuit components and circuitry.

These and other objects are met by the invention as defined by the accompanying patent claims.

5 Briefly, the present invention involves a LINC out-phasing amplifier system and methods and arrangements for improving the operation characteristics of the amplifier system by compensating for amplitude imbalances that arise due to the including components of the amplifier system.

10 A LINC out-phasing amplifier system according to the present invention includes a LINC modulator for modulating an input signal, e.g. RF signal, to be amplified by adding the signal to a carrier. Furthermore, the signal is split into two component or phasor signals having equal amplitude but typically different phases. The phasor signals are individually amplified in respective
15 nonlinear branch power amplifiers before they are combined in an out-phasing combining network to generate the amplified output (RF) signal.

A bias system is connected to the branch amplifiers for supplying biases or drive voltages thereto. The actual bias level experienced by the branch
20 amplifiers affects the power of the output signal.

According to the invention, the signal amplitude imbalances of the amplifier system are combated by independently adjusting the bias experienced by the branch amplifiers. This means that the supplied bias is adjusted or trimmed
25 slightly around a pre-set default value (determined based on the desired power amplification) causing a cancellation or at least a reduction of the amplitude imbalance errors.

This bias adjustment can be realized by applying a fixed (default) bias to one
30 of the branch amplifiers, whereas the other nonlinear amplifier is connected to and driven by a variable bias source. The bias supplied by this variable bias source is then adjusted by a voltage adjuster, which could be operated manually by an operator or automatically based on an adjustment

command. This bias adjustment typically starts from the same default bias level as provided by the fixed bias source. The bias level is then increased or decreased slightly until a desired output signal is obtained without any negative spurious elements caused by amplitude imbalance errors.

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In an alternative implementation, each nonlinear branch amplifier is biased by a respective variable bias or direct current voltage source. In such a case, the bias experienced by each amplifier can be independently and individually adjusted, providing an additional degree of freedom in the amplitude imbalance cancellation.

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The amplitude imbalance cancellation can be performed as a sub-process of the manufacturing or test run process of the LINC out-phasing amplifier system. In such a case, an operator monitors the output signal while he/she mechanically adjusts the bias provided by the variable bias source(s) until a desired output signal is obtained.

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Alternatively, a feedback solution could be employed. In such a solution, a signal detector is connected to the output terminal of the LINC out-phasing amplifier system and monitors the output signal. The detector then generates, based on this signal detection, a voltage adjustment command or signal that is provided to a voltage adjuster. This voltage adjuster adjusts, based on the received command, the bias delivered by the variable bias source(s) and experienced by the branch amplifier(s). This automatic adjustment can also be utilized during actual operation of the out-phasing amplifier system to correct for amplitude imbalances that arise due to temperature changes, aging and other factors that affect the characteristics of the including circuit components.

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Once desired bias levels have been defined that allow for amplitude imbalance correction as determined from monitoring the output signal, these bias levels are preferably read. In operation, the read bias levels are utilized by the bias system to provide improved operation characteristics of the LINC

out-phasing amplifier system. This means that the variable bias source(s) utilized in the adjustment procedure could actually be replaced by fixed bias source(s) set to these read bias levels. As a consequence, during operation, the branch amplifiers will be independently biased and furthermore biased at different voltage levels. In other words, a first pre-determined bias level is supplied to the first nonlinear power amplifier and a second different pre-determined bias level is supplied to the second nonlinear power amplifier. At least one of these pre-determined bias levels have been defined during the adjustment procedure and the possible other bias level could then be the default bias level.

The branch amplifiers utilized according to the present invention are nonlinear and highly power efficient amplifiers. Suitable such amplifiers include switch-mode amplifiers, such as class D, e.g. current mode class D or voltage mode class D, E or F amplifiers. Also linear amplifiers, such as class B and C amplifiers, can, when driven at saturation, be nonlinear and be utilized as branch amplifiers.

The invention offers the following advantages:

- Improves the operation characteristics of a LINC out-phasing amplifier system by correcting for amplitude imbalance errors;
- Increases the linearity of the LINC out-phasing amplifier system;
- Increases the dynamic range of the amplifier increases since also lower output power levels can be reached;
- Cancels unwanted spurious elements on adjacent frequencies in the output signal;
- The possibility of trimming and adjusting the amplifier system during production and manufacturing or continuously during operation relaxes the demands on the analogue components of the amplifier system, which enables high volume production of the LINC out-phasing amplifier system;
- Correction of amplitude imbalance errors can be realized by a very simple circuitry solution without the use of complex components; and

- Can be implemented as a part of the manufacturing process and/or be utilized during continuous operation.

Other advantages offered by the present invention will be appreciated upon reading of the below description of the embodiments of the invention.

SHORT DESCRIPTION OF THE DRAWINGS

The invention together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

Fig. 1 is a schematic block diagram of a LINC out-phasing amplifier system according to an embodiment of the present invention;

Figs. 2A, 2B; 3A, 3B and 4A, 4B are phasor diagrams, where Figs. 2A, 3A, 4A illustrate desired phasor fragments and output signals and Figs. 2B, 3B, 4B illustrate phasor fragments with amplitude imbalances resulting in incorrect output signals;

Fig. 5A is a diagram illustrating the output signal of a LINC out-phasing amplifier system with 0.1 dB signal amplitude imbalance;

Fig. 5B is a corresponding diagram illustrating the output signal of a LINC out-phasing amplifier system which has been amplitude imbalance corrected according to the present invention;

Fig. 6 is a schematic block diagram of a LINC out-phasing amplifier system according to another embodiment of the present invention;

Fig. 7 is a schematic block diagram of a LINC out-phasing amplifier system according to a further embodiment of the present invention;

Fig. 8 is a schematic block diagram of a LINC out-phasing amplifier system according to yet another embodiment of the present invention;

Fig. 9 is a block diagram of a current mode class D amplifier that can be utilized in the LINC out-phasing amplifier system according to the present invention;

Fig. 10 is a block diagram of a voltage mode class D amplifier that can be utilized in the LINC out-phasing amplifier system according to the present invention;

Fig. 11 is a block diagram of a class E amplifier that can be utilized in the LINC out-phasing amplifier system according to the present invention;

Fig. 12 is a block diagram of a class F amplifier that can be utilized in the LINC out-phasing amplifier system according to the present invention;

Fig. 13 is a block diagram of a transmitting unit comprising a LINC out-phasing amplifier system according to the present invention;

Fig. 14 is flow diagram of a method of improving the operation characteristics of a LINC out-phasing amplifier system according to the present invention;

Fig. 15 is flow diagram of a method of operating a LINC out-phasing amplifier system according to the present invention;

Fig. 16 is flow diagram illustrating the bias adjusting step of Fig. 14 and the bias applying step of Fig. 15 in more detail according to an embodiment of the present invention;

Fig. 17 is flow diagram illustrating the bias adjusting step of Fig. 14 and the bias applying step of Fig. 15 in more detail according to another embodiment of the present invention; and

Fig. 18 is a flow diagram illustrating additional steps of the method disclosed in Fig. 14 or 15 according to an embodiment of the present invention.

DETAILED DESCRIPTION

Throughout the drawings, the same reference characters will be used for corresponding or similar elements.

The present invention relates to linear amplification using nonlinear components (LINC) out-phasing amplifier systems and in particular to techniques for improving the operation characteristics of such LINC out-phasing amplifier systems by correcting for present amplitude imbalances.

The inventor has discovered that the including components of the LINC out-phasing amplifier systems of today causes amplitude imbalances between the two amplified signals. For example, spread in transistor parameters and surrounding components of the two branch amplifiers in the LINC out-phasing amplifier system implies that the two branch amplifiers will not generate equal output power for equal applied bias or supply voltage. Furthermore, the load experienced by the two branch amplifiers is typically not constant but changes during operation. This causes amplitude imbalances when the two amplified phasor signal are combined. Furthermore, the combining network that is utilized for this signal combination will typically also contribute to the emergence of amplitude imbalances.

The amplitude imbalances will degrade the linearity of the LINC out-phasing amplifier system when driving it with modulated signals and furthermore reduce the dynamic range of the amplifier system and the ability to back down the amplifier system below a certain level. The imbalances also results, during signal combination, in incomplete cancellation of unwanted elements in the wideband phase-modulated signal. As a result, a large number of unwanted spurious products appear in the output spectrum, which will be illustrated further below.

The present invention solves these problems by affecting the bias level experienced by the branch amplifiers of the LINC out-phasing system, or affecting the bias level experienced by at least one of the amplifiers. As a consequence, independent biases are provided, according to the invention, to the nonlinear power amplifiers of the LINC out-phasing amplifier system. The different levels of these two biases have been determined in an adjustment and correction procedure and are set to allow cancellation or at least reduction of the amplifier imbalances of the LINC out-phasing amplifier system.

Fig. 1 is schematic block diagram of a first embodiment of a LINC out-phasing amplifier system 1 according to the present invention. The amplifier system 1 generally includes a first 10 and second 20 input port or terminal, respectively, that are adapted for receiving a respective input signal. The input signal could generally be represented by an in-phase (I) signal, e.g. applied to the first input port 10, and a quadrature (Q) phase signal, e.g. applied to the second input port 20.

As is well known to the person skilled in the art, a source (bandpass) signal is typically separated into two (out-phased) constant-envelope signals by a signal component separator (SCS) or digital signal processor (DSP) (not separately illustrated in the figure). The two constant-envelope signals can then be digital-to-analogue (D/A) converted to a respective I and Q signal, which are provided at the input ports 10, 20 of the LINC out-phasing amplifier system (1).

The I and Q signals are then preferably processed in a LINC modulator 30 for generating two phase-modulated carrier signals to be separately amplified by two branch amplifiers 40, 50. The operation of this LINC modulator 30 can mathematically be expressed, if the original band-limited source signal is expressed as $s(t) = a(t)e^{j\theta(t)}$, where $0 \leq a(t) \leq V_m$, as $s_1(t) = s(t) - e(t) = V_m a(t) e^{j[\theta(t) - \psi(t)]}$

and $s_2(t) = s(t) + e(t) = V_m a(t) e^{j[\theta(t) + \psi(t)]}$, where $\psi(t) = \arccos\left(\frac{a(t)}{V_m}\right)$ and the quadrature

signal $e(t)$ is defined by $e(t) = js(t) \sqrt{\frac{V_m^2}{a^2(t)} - 1}$. In an alternative description of the

operation of the modulator 30, the input I and Q signals are transformed from rectangular coordinates into polar coordinates, resulting in a r , $[-1 \leq r \leq 1]$,

and φ component. Two phases are then generated according to $\varphi_1 = \varphi + \arccos(r)$ and $\varphi_2 = \varphi - \arccos(r)$. These two phase components are, each together with a r component of 1, transformed back to rectangular coordinates, resulting in two I and Q pairs, I_1 , Q_1 and I_2 , Q_2 . I/Q modulation are then performed on the I/Q pairs to generate the two broadband phasor signals to be input at the branch amplifiers 40, 50.

The modulator 30 of the LINC out-phasing amplifier system 1 of the present invention can be realized with any of the available modulator implementations available in the art. The actual choice of modulator solution does generally not have any impact on the feasibility of the present invention.

The two broadband signals have equal (constant) amplitude but typically different (varying) phase.

The two branch amplifiers 40, 50 separately amplify the phasor fragments or signals to generate two amplified signals that are to be combined. The amplifiers 40, 50 are highly nonlinear and power-efficient amplifiers. Suitable amplifiers 40, 50 to utilize according to the present invention will be described in more detail herein.

An out-phasing combiner or combining network 60 is connected to the two power amplifiers 40, 50 and is arranged for receiving and combining the two individually amplified signals to generate a single output signal at an output port 70. If this combining network 60 provides isolation between the amplifiers 40, 50, the resulting amplifier system 1 typically provides poor efficiency

because of loss in the combiner 60. However, if a low-loss combiner that cannot provide isolation is used, the overall system 1 can be very efficient.

5 The combiner 60 of the LINC out-phasing amplifier system 1 according to the invention can, at least partly, be based on a balun or hybrid combiner. Furthermore, a passive combiner could be utilized. This combiner imposes a load impedance on the branch amplifiers 40, 50 that varies with the envelope so that the branch amplifiers 40, 50 are driving a high impedance load when low output power is required. This swinging impedance forces the amplifiers
10 40, 50 to draw less current when less radio frequency (RF) power is required, allowing high efficiency to be maintained at back-off.

15 Actually the teachings of the present invention can be applied to any LINC out-phasing amplifier system 1 irrespectively of the actual combining network implementation employed. However, since the out-phasing combining network 60 itself can introduce and negatively effect amplitude imbalances, a combining network solution 60 that has a low amplitude imbalance introducing effect is preferably employed according to the present invention.

20 The two branch amplifiers 40, 50 are connected to a bias system represented by a variable bias or voltage source 110 and a fixed bias or voltage source 120 in the figure. In clear contrast to the prior art solutions, this bias system 110, 120 provides independent biases or supply voltages to the two power amplifiers 40, 50. In other words, the two branch amplifiers 40, 50 are
25 individually and independently biased.

The variable bias source 110 is connected between electrical ground 80 and the first nonlinear power amplifier 40 and the fixed bias source 120 is similarly connected between electrical ground 80 and the second nonlinear
30 power amplifier 50.

The inventor has discovered that the arising signal amplitude imbalances caused by said LINC out-phasing amplifier system (1) can be corrected by

individually trimming or adjusting the biases experienced by the power amplifiers 40, 50.

5 The two bias sources 110, 120 form part of an amplitude imbalance corrector 100 according to the present invention. This amplitude imbalance corrector 100 includes, in the illustrative embodiment depicted in Fig. 1, a voltage or bias adjuster 130 operating on the variable bias source 110 to thereby adjust the bias delivered by the bias source 110 and experienced by the first nonlinear power amplifier.

10 The amplitude imbalances imparted by the LINC out-phasing amplifier system 1 are preferably corrected during a correction or adjusting procedure. This correction procedure is typically and preferably performed as a part of the manufacturing process or the subsequent test operation process of the LINC out-phasing amplifier system 1. In such a case, the amplitude imbalance
15 problem can be combated already before the actual use or operation of the out-phasing amplifier system 1. However, the correction procedure could alternatively, or in addition, be performed during operation to cope with amplitude imbalances that arise during operation due to factors, e.g.
20 temperature and aging, that affects the including components of the amplifiers system 1.

Generally, in this correction procedure, the fixed bias source 120 delivers a default bias to the second power amplifier 50 and the variable bias source 110
25 also delivers a default bias, preferably of the same voltage level as the bias of the fixed source 120, but to the first nonlinear power amplifier 40. These (same) bias levels are preferably determined and selected based on the desired output power level of the signal at the output port 70.

30 The output signal at the port or terminal 70 is monitored as the bias experienced by the first amplifier 40 is adjusted, by the voltage adjuster 130, slightly around this default bias level. This bias adjustment performed by the voltage adjuster 130 is continued until the amplitude imbalances have been

eliminated or at least a desired reduction in the amplitude imbalances has been obtained as determined from the output signal monitoring. Once this desired amplitude imbalance correction has been obtained, the variable bias source is (temporarily) locked to the bias level that resulted in the amplitude imbalance elimination.

It is anticipated by the present invention, that an operator can manually adjust the bias of the bias source 110, e.g. by mechanically affecting a voltage relay 130. Alternatively, the voltage adjuster 130 could automatically and possibly dynamically adjust the variable bias source 110 in response to an adjustment command, as is discussed in more detail below.

In operation of the LINC out-phasing combining network 1, the fixed voltage source 120 provides the default bias to the second nonlinear power amplifier 50. The first power amplifier 40, however, experiences the adjusted bias level that resulted in amplitude imbalance elimination or minimization. This bias level could be provided by the variable bias source 110 utilized during the correction procedure. Alternatively, during operation, the variable bias source 110 could be replaced by a fixed bias source that provides, to the first power amplifier 40, the bias level determined during the correction procedure. Since this determined bias level reduces and preferably minimizes the amplitude imbalance problem, there is generally no need during operation for varying the bias experienced by the first power amplifier 40.

As a consequence, during operation the bias system 110, 120 will provide individual and independent biases to the branch amplifiers 40, 50. In addition, the first amplifier 40 experiences a first pre-defined bias level (as determined during the correction procedure) and the second amplifier 50 experiences a second different pre-defined bias level (the default bias level determined based on the desired output power level).

It is evident from the discussion above that, during operation, the amplitude imbalance corrector 100 and the voltage adjuster 130 can be omitted so that

only the bias system 110, 120 remains besides the including components 30 to 60 of the LINC out-phasing amplifier 1.

5 Figs. 2A to 4B are vector diagrams schematically illustrating the problems that can arise when amplitude imbalances are present. In these figures, Figs. 2A, 3A, 4A illustrate how two correct constant voltage, variable phase signals 92, 94 are combined to produce the desired output signal 96 of arbitrary amplitude. Figs. 2B, 3B, 4B illustrate the corresponding situations but where the amplitude imbalances affect the total amplitude of at least one of the phasor signals 93, 95. Due to these imbalances, when the two phasor signals are combined in Figs. 2B, 3B, 4B, incorrect output signals 97 are obtained. Compared to the desired correct combined signals 96, the incorrect signals 97 can be both out of phase and have incorrect amplitude.

10
15 For example, a LINC out-phasing amplifier system marred by amplitude imbalances can have reduced dynamic range implying that certain output power levels (zero as in Fig. 3A) cannot be obtained (see Fig. 3B).

20 As was noted in the foregoing, amplitude imbalances can cause incomplete cancellation of unwanted elements in the wideband phase-modulated signals. This is schematically illustrated in Fig. 5A, which represents the output voltage of a LINC out-phasing amplifier system with 0.1 dB amplitude imbalance or error. Note that the incomplete cancellation of wideband components leaves a residue in adjacent channels (frequency) outside of the fundamental/output frequency of 2 GHz. This will then introduce adjacent channel interference (ACI).

25
30 Fig. 5B is a corresponding diagram of the output voltage of the same LINC out-phasing amplifier system that has been bias adjusted and therefore amplitude imbalance corrected according to the present invention. In this diagram, the unwanted elements have been totally cancelled.

In Fig. 1, the variable bias source 110 has been connected to the first power amplifier 40 and the fixed bias source 120 is connected to the second power amplifier 50. However, it is evident for the skilled person that the variable bias source 110 could alternatively be connected to the second power amplifier 50, leaving the fixed bias source 120 in connection with first power amplifier 40.

Fig. 6 illustrates a LINC out-phasing amplifier system 1 having a different bias system 110, 140 and amplitude imbalance corrector 100 compared to the embodiment illustrated in Fig. 1. The bias system 1 includes a first variable bias source 110 connected between electrical ground 80 and the first nonlinear power amplifier 40. A second variable bias source 140 of the bias system is similarly connected between electrical ground 80 and the second nonlinear amplifier 50. The single voltage adjuster 130 of the amplitude imbalance corrector 100 then operates on both variable bias sources 110, 140. Alternatively, this single adjuster 130 could be replaced by two voltage or bias adjusters, each of which operates on and adjusts the bias provided by one of the bias sources 110, 140.

In the adjustment or correction procedure, the provided bias levels of the two bias sources 110, 140 are preferably both initially set to the default bias level that optimally (in the absence of any amplitude imbalances) would result in the desired output signal. The output signal at the output port 70 is then monitored as the voltage adjuster 130 individually adjusts or trims the biases delivered by the respective bias sources 110, 140 and experienced by the respective branch amplifiers 40, 50. Once a desired output signal has been reached, e.g. as illustrated by starting from the output signal depicted in Fig. 5A and ending with the signal depicted in Fig. 5B, the bias or voltage settings of the two bias sources 110, 140 are read and will be utilized during operation.

In operation, the bias level determined during the correction procedure are utilized and applied to the respective branch amplifiers 40, 50 of the LINC

out-phasing amplifier system 1. In such a case, the variable bias sources 110, 140 used in the correction procedure could be employed for delivering the two different bias levels. Alternatively, one or both of the variable bias sources 110, 140 can be replaced by a respective fixed bias source set to the
5 corresponding determined bias level.

As a consequence, during operation the bias system 110, 140 will provide individual and independent biases to the branch amplifiers 40, 50. In addition, the first amplifier 40 experiences a first pre-defined bias level (as
10 determined during the correction procedure) and the second amplifier 50 experiences a second different pre-defined bias level (also determined during the correction procedure).

Fig. 7 schematically illustrates a further embodiment of a LINC out-phasing amplifier system 1 with a different bias system 110 and amplitude imbalance corrector 100. In this embodiment, a single bias source, preferably variable bias source 110, supplies biases to both branch amplifiers 40, 50. However, due to the presence of a variable bias or voltage consuming unit 150 present between the first amplifier 40 and the bias source 110, the bias level
15 experienced by the first amplifier 40 is different from the bias level of the second amplifier 50.

In the figure, the bias consuming unit has non-limitedly been exemplified as a variable resistance 150. A resistance adjuster 160 is then arranged in the
25 amplitude imbalance corrector 100 for operating on and adjusting the resistance value of this variable resistance 150. A further, fixed or optionally variable, resistance 180 is preferably likewise arranged connected to the bias source 110 and the second power amplifier 50.

30 In this embodiment, the out-phasing combining network 60 is preferably an isolating combining network so that the two branch amplifiers 40, 50 is caused to always consume the same current irrespectively of their respective delivered output power. However, as was noted above, such an isolation is

typically marred by low efficiency and an amplitude imbalance corrector according to Fig. 1 or Fig. 6 is typically superior to this solution.

5 In the correction procedure, the bias level of the (optionally variable) bias source 110 and the resistance value of the resistor 150 are preferably set so the first amplifier 40 experience the pre-defined, or at least close to the pre-defined, bias level. The other amplifier 50 preferably also experiences a bias level at least close to the default level. The resistance value of the variable resistance 150 is then adjusted (increased or decreased) as the output signal
10 at the port 70 is monitored. Once a desired output signal is obtained the current adjusted resistance value is read.

15 In operation the variable resistance 150 can be replaced by a fixed resistance having a resistance value equal to (or at least close to) the read adjusted resistance value.

20 It is anticipated by the present invention that other bias/voltage consuming circuit elements and circuitries could be utilized instead of the variable resistance 150 to realize the bias adjusting function of the amplitude imbalance correction of the present invention.

25 Fig. 8 schematically illustrates the LINC out-phasing amplifier system 1 according to Fig. 1 equipped with a feedback solution for dynamically adjusting the bias experienced by at least one of the branch amplifiers 40, 50 during operation.

30 An output detector 170 is arranged for measuring the output signal from the out-phasing combining network 60 of the LINC out-phasing amplifier system 1. Based on the measured signal, the output detector 170 generates a control signal that is transmitted to the voltage adjuster 130. The control signal causes the adjuster 130 to change, adjust or tune the bias supplied by the variable bias source 110 and experienced by the first power amplifier 40.

The output detector 170 could, for example, generate the control signal based on a difference of the current output signal and a desired output signal. Alternatively, or in addition, the control signal can be generated based on the magnitude of the undesired spurious elements present on adjacent frequencies.

The automatic and dynamic bias adjustment or tuning provided by the embodiment disclosed in Fig. 8 can be utilized both during the correction and adjustment procedure and during actual operation of the LINC out-phasing amplifier system 1. In such a case, a suitable adjusted bias level is preferably determined during the correction procedure and is then initially utilized during operation. However, in operation external factors, e.g. temperature, and/or other factors, e.g. aging, can affect the properties of the including components 30 to 60 of the amplifier system 1 so that amplitude imbalances once more arise or the compressed amplitude imbalances become worse. In such a case, the output detector 170 generates a new control signal that causes the adjuster 130 to adjust the bias experienced by the first power amplifier to combat these new amplitude imbalances.

In operation, the output detector 170 could continuously monitor the output signal and therefore be able to finely tune the delivered bias level. However, in such a case there may be a risk of over-adjusting the bias source 110 by switching back and forth between different supplied bias levels. In order to reduce this risk, the output detector 170 could alternatively be configured for periodically or intermittently, e.g. at pre-defined time instances, monitor and investigate the output signal to determine whether any bias adjustment is required. Also different hysteresis solutions are possible.

It is anticipated by the present invention that the feedback solution presented in Fig. 8 could also be applied to the LINC out-phasing amplifier system disclosed in Fig. 6 or 7. In the former case, the output detector 170 generates a control signal that causes the voltage adjuster 130 to adjust the

supplied bias of the first bias source, supplied bias of the second bias source or the supplied bias of the first and second bias source. In the latter case, the output detector 170 is in connection with the resistance adjuster that adjusts the variable resistance based on reception of a control signal.

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The circuitry solutions of the present invention discussed above and exemplified in Figs. 1, 6, 7 and 8 that allow correction for amplitude imbalance in the LINC out-phasing amplifier system and allow operating the imbalance-corrected LINC out-phasing amplifier system with no or reduced amplitude imbalance problems provide several advantageous of the prior art. Firstly, the linearity and the dynamic range of the amplifier increase since also lower output power levels can be reached. Furthermore, the amplitude imbalance correction causes cancellation of the unwanted spurious elements and a more "clean" output signal. The possibility of trimming and adjusting the amplifier system during production and manufacturing or continuously during operation relaxes the demands on the analogue components of the amplifier system, which enables high volume production of the LINC out-phasing amplifier system. In addition, this compensation of amplitude imbalance errors of the invention can be realized by a very simple circuitry solution without the use of complex components.

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The power amplifiers utilized as branch amplifiers in the LINC out-phasing amplifier system according to the present invention are nonlinear but power efficient power amplifiers. Several different amplifier solutions that fulfill these requirements can be utilized. For example, generally the nonlinear power amplifier could be regarded as operating as a switched amplifier or switch-mode amplifier. These switch-mode amplifiers have the potential for very high efficiency with drain efficiency theoretically approaching 100 %. Typical switch-mode amplifiers that can be utilized according to the present invention include class D, E and F amplifiers and hybrids thereof. However, also potentially linear amplifiers driven at saturation to thereby become nonlinear, e.g. class B and C amplifiers, could be utilized as branch amplifiers.

In a preferred embodiment of the present invention the two branch amplifiers are of a same class, implying that if the first branch amplifier is, for example, a class D amplifier the second branch amplifier is preferably also a class D amplifier.

Fig. 9 is a schematic block diagram of a preferred realization of a branch amplifier 200 according to the present invention represented as a current mode class D (CMCD) amplifier 200.

Class D amplifiers 200 have been widely used at low frequencies in power converters and are now becoming more frequent also in RF and microwave applications. The amplifier 200 acts as a switch synchronized by a driver that can deliver power from a direct current (DC) supply terminal 280 to an alternate current (AC) load network 290 at the switching frequency and its harmonics. A 100 % efficiency would be possible if there were no switch dissipation and no power wasted in harmonics. The CMCD amplifier 200 allows partial or full absorption of the transistors' 230, 240 output capacitance into the resonator network. This means that the output capacitances are alternately grounded by the complementary switches so the capacitances appear in parallel with a filter 250, forming a resonant tank. Thus, it will be possible to utilize transistors 230, 240 with higher output capacitances but also higher breakdown voltages in the CMCD configuration at higher frequencies and power levels.

The CMCD amplifier 200 includes two transistors 230, 240 represented as two general FETs (field effect transistors) 230, 240, arranged for processing in an input (RF) signal (phasor fragment) present at the input ports 210, 220. The transistors 230, 240 could independently be of any FET design, such as JFET (junction FET), IGFET (insulated gate FET), MESFET (metal semiconductor FET) or MOSFET (metal oxide semiconductor FET). Furthermore, other types of transistors, including bipolar transistors, and

circuit components that has switching functionality could replace the first FET 230 and/or second FET 240.

5 The first FET 230 comprises a gate 232, source 234 and drain 236 electrode. The gate or input electrode 210 is adapted for receiving the input signal and is, in operation, connected to a first input port or terminal 210. During operation, the source electrode 234 of the first transistor 230 is connected to electrical ground 80. Correspondingly, the drain electrode 236 is arranged for connection with a current source, represented by a supply voltage or bias
10 terminal 280 and an inductor 260, arranged between the bias terminal 280 and the drain electrode 236.

15 The second FET 240 has its gate electrode 242 in connection with a second input port or terminal 220. The source electrode 244 of the second transistor 240 is, in operation, connected to electrical ground 80. Finally, the drain electrode 246 is interconnected by the bias terminal 280 through a second inductor 270.

20 The output load 290, which schematically illustrates the out-phasing combining network, is connected between the drain electrodes 236, 246 of the transistors 230, 240. A filter circuit 250 is also connected between the drain electrodes 236, 246 parallel with the load 290. This filter 250 has resonant frequency set to the carrier frequency of the input signal. This means that the filter 250 could be regarded as an open circuit for the output frequency and a
25 short circuit for all harmonics.

For more discussion and illustration of CMCD amplifiers and their operation, refer to the documents [1, 2].

30 The variable or fixed bias source utilized in the bias system and amplitude imbalance corrector of the LINC out-phasing amplifier system supplies the bias at the bias terminal 280. This means that adjusting or trimming the bias of a branch amplifier in this case is realized by adjusting or trimming

the drain voltage of the FET transistors 230, 240 in the CMCD branch amplifier(s) 200.

For a CMCD amplifier 200, the output power is proportional to the square of the drain or collector voltage of the transistors 230, 240 used in the CMCD design. Therefore, by adjusting the supplied drain/collector voltage, the output power can be adjusted and any amplitude imbalances be suppressed.

This output power is generally given by $P_{load} = \frac{\pi^2}{2R_{load}} V_{cc}^2$, where R_{load} is the impedance of the load 290 as seen by the CMCD amplifier 200 and V_{cc} is the applied supply voltage. This means that the output power is proportional to the square of the supply voltage. This can be utilized to change the output power to compensate amplitude imbalance errors.

Fig. 10 is a schematic layout of another class D amplifier 300 that can be utilized as branch amplifier according to the present invention. This amplifier 300 is a voltage mode class D (VMCD) amplifier 300, the switching transistors 330, 340 of which controls the voltage instead of the current (as the CMCD amplifier). The two switching transistors 330, 340 may be driven 180 degrees out of phase by applying a bias (drain voltage) at the bias terminals 380, 385.

Correspondingly, to Fig. 9, the gate electrodes 332, 342 of the transistors 330, 340 are in connection with the input terminals 310, 320 over which the phasor signal is applied. The respective source electrodes 334, 344 of the transistors 330, 340 are each connected to one of the bias terminals 380, 385. The two drain electrodes 336, 346 are interconnected and are further connected to the output load 390 (out-phasing combining network) through a filter 350. This filter has a resonant frequency set to the center frequency of the signal.

One of the bias terminals, preferably the bias terminal 385, could be connected to electrical ground 80. In such a case, the bias adjustment

according to the present invention is performed by adjusting the bias provided at the bias terminal 380.

5 In an alternative embodiment, the first bias terminal 380 is connected to a first bias source, preferably providing a positive DC voltage, and the second bias terminal 385 is connected to a second bias source, preferably providing a negative DC voltage. The bias adjustment according to the present invention can then be provided by adjusting the bias provided at the first bias terminal 380, the bias provided at the second bias terminal 385 or
10 adjusting (a combined adjustment or an individual/independent adjustment) the bias provided at the first terminal 380 and the bias provided at the second terminal 385.

15 In contrast to the CMCD amplifier, the output capacitance of the transistors 330, 340 in the VMCD amplifier 300 must be charged or discharged to the DC bias through the transistor 330, 340. This leads to a loss of energy for each switching cycle. As a consequence, the VMCD amplifier 300 is marred by capacitance discharge loss that is unfavorable.

20 Fig. 11 schematically illustrates a class E amplifier 400 that can be utilized as branch amplifier according to the present invention. A transistor 430, non-limitedly exemplified as a general FET transistor in the figure, has its gate electrode 432 in connection with the first input port 410 and its source electrode in connection with electrical ground 80. The drain electrode is
25 connected for receiving a DC bias at a bias terminal 480 through a first inductor 460. The drain electrode 436 is further in connection, through a second inductor 470 and a band-pass filter 450, with the output load 490. A capacitance 440 is further preferably connected between the drain electrode 436 and ground 80.

30 In a class E amplifier, when the transistor 430 turns on and the switch closes, the voltage across the transistor 430 is always zero so the output capacitance discharge loss is avoided. A disadvantage in the GHz range is

that variable duty-cycle, nonlinear capacitances and other parasitic components degrade the class E operation. For more information of class E amplifiers reference are made e.g. to the document [3].

5 The bias adjustment according to the present invention is performed at the bias terminal 480 of the amplifier 400 in the figure.

Fig. 12 is a schematic drawing of an amplifier 500 operating according to class F. The amplifier 500 comprises a transistor 530, e.g. a FET transistor, with a gate electrode 532 in connection with a first input terminal 510, whereas the source gate 534 is connected to electrical ground 80. A bias terminal 580 is connected to the drain electrode 536 through an inductor 560. The drain electrode 536 is further connected to the load 590 through a filter 550. This filter is an open circuit at the fundamental frequency (carrier frequency), presents infinite impedance at odd harmonics and is a short circuit at other frequencies.

The bias terminal 580 is connected to the bias system of the present invention.

As was mentioned in the foregoing, also amplifiers in saturation and class B or C operation could also be utilized as branch amplifier according to the present invention. Furthermore, depending on the including components of the branch amplifiers, e.g. FET or bipolar transistor, the amplitude imbalances can be reduced by adjusting or trimming the drain or collector voltage of the transistor(s) in the branch amplifiers. As a consequence, in these implementations, adjusting the bias experienced by a branch amplifier would then imply adjusting the DC drain or collector voltage of the transistor(s) in the branch amplifier. Correspondingly, during operation the two branch amplifiers are biased independently by preferably applying a first bias level at the first branch amplifier and applying a second different bias level at the second branch amplifier. This would then represent applying a first DC drain/collector voltage to the transistor(s) of the first branch

amplifier and applying a second different DC drain/collector voltage to the transistor(s) of the second amplifier.

Fig. 13 schematically illustrates a portion of a radio communications unit or transmitter 900 comprising a signal processing unit 920 with a LINC out-phasing amplifier system 1 according to the present invention. The transmitter 900 includes a signal source 910 that provides signals, e.g. RF signals, to the amplifier system 1 of the signal processing unit 920. The signal output of the amplifier system 1 is provided to an antenna 940 for transmission to a receiver. An optional predistorter or linearizer 930 may be provided in the processing unit 920, preferably positioned between the signal source 910 and the amplifier system 1 so that the output signal of the signal source 910 passes through the predistorter 930 prior reaching the amplifier system 1. The predistorter 930 can then predistort the amplifier input signal to compensate for the (amplitude and/or phase) nonlinearities of the amplifier system 1. This means that the predistorter 930 could be employed for correcting phase imbalances in the LINC out-phasing amplifier system 1 according to the present invention. The amplitude imbalance combating function of the present invention that forms an integral part of the amplifier system 1 in the figure could be complemented by further amplitude imbalance operations of the predistorter 930.

The transmitter 900 disclosed in Fig. 13 can of course include additional units in the signal line from the signal source 910 to the antenna 940. The transmitter 900 according to the present invention can be arranged in any type of (radio) communication unit including stationary units such as base stations and mobile units such as mobile telephones, mobile terminals and mobile communicators.

Fig. 14 is a flow diagram of a method of correcting for amplitude imbalances in a LINC out-phasing amplifier system according to the present invention. This correcting method could be implemented as a part of the manufacturing/production process or a subsequent test driving.

Furthermore, the correction method can actually be performed during operation of the LINC out-phasing amplifier system to combat amplitude imbalances arising due to external factors (temperature) or other sources (aging) that affects the components in the amplifier system.

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The method starts with the optional step S1 which basically represents selecting the including components of the LINC out-phasing amplifier system. This step is performed during the manufacturing phase, in which the actual LINC modulator, branch amplifiers and out-phasing combining network to utilize is selected. As is evident from the foregoing discussion, there are several different modulator, branch amplifier and combining network solutions available in the art and the actual choice of these components depends on the particular circumstances of the usage of the amplifier system. For example, the particular (RF) signal to be amplified has most often a large impact of the suitability of the different available components. As the teachings of the present invention can be applied to different out-phasing amplifier systems, the actual choice of components is mainly performed based on other criterion determined by the person skilled in the art. However, components having a low tendency to cause amplitude (and phase) imbalances are of course preferred.

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In a next step S2, a (test) input signal is applied to the LINC out-phasing amplifier system and the amplified output signal is monitored. If this step S2 is performed as part of the manufacturing or test phase, the applied input signal preferably resembles as close as possible a typical "real" input signal that could be utilized during operation of the amplifier system. Any equipment that are utilized in the art for monitoring signals amplified by a LINC out-phasing amplifier system can be utilized in this step S2.

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In a next step, the biases (DC drain/collector voltage) supplied by the bias system and experienced by the branch amplifiers are adjusted or trimmed slightly from the initially utilized default value. In this adjustment, it could be possible to only adjust the bias experienced by one of the branch

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amplifiers while the bias of the other amplifier is kept fixed. Alternatively, the biases experienced by both branch amplifiers could be adjusted in this step S3. In such a case, the biases are preferably independently and individually adjusted, implying that different bias levels may be provided to the two branch amplifiers.

The bias adjustment could be realized by starting from e.g. the initial default biases and then adjusting the variable bias source(s) in small steps and detect the output signal of the amplifier to see if the amplitude imbalances have been reduced. For example, one can start by increasing the supplied bias in small steps. If no improvement is seen in the output signal, the supplied bias could then instead be decreased in small steps. If the bias of both bias sources can be adjusted an extra degree of freedom is available. In this case, it could actually be enough to increase (or decrease) the bias of only one of the bias sources. Alternatively, the bias of one of the bias sources could be increased (or decreased) while the bias supplied by the other source is increased or decreased.

It is quite easy to determine when suitable bias levels have been reached by investigating the output signal as is evident from a comparison of Fig. 5A (0.1 dB amplitude error) and Fig. 5B (no amplitude imbalance). Thus, the cancellation of the unwanted spurious elements on adjacent frequencies is a good indication of amplitude imbalance correction. The (small) changes in bias voltage are continued until a (close to) maximum or at least adequate amplitude imbalance cancellation has been obtained. This procedure could be performed manually by an operator that then investigates the amplifier output and adjusts the provided DC biases based on this signal output investigation. In an alternative implementation, an automatic adjustment could be used. In such a case, a unit is arranged for detecting the amplifier output and generating voltage adjustment commands or signals based on this output detection. The adjustment commands are then forwarded to the respective variable bias sources that will adjust the delivered DC biases based on the adjustment commands.

Also more sophisticated methods and techniques such as Monte Carlo simulation or neural networks could be employed for adjusting and providing correct biases that will generate a satisfactory amplitude imbalance reduction.

The procedure performed in steps S2 and S3 are preferably continued, as schematically illustrated by the line L1, until a desired result has been obtained.

The settings of the bias sources when the amplitude imbalance cancellation or reduction has been achieved are then read. These bias levels should then be utilized during operation of the LINC out-phasing amplifier system.

It is evident for the skilled person that the difference between the resulting adjusted bias levels and the initial default biases is relatively small when compared to the default biases. This means that the bias adjustment performed according to the present invention most often only results in small voltage changes of up to a few percentages. If the biases would be changed to much the output power level of the amplified signal would be incorrect.

The method then ends.

Fig. 15 is a flow diagram of operating a LINC out-phasing amplifier system according to the present invention. The method starts in step S10, where independent biases are applied to the two branch amplifiers. These two different biases are preferably determined in the correction method discussed above and disclosed in Fig. 14. As a consequence, a first pre-determined bias level (the default bias level determined based on the required power level of the output signal or the adjusted default bias level determined in the correction method) is supplied to the first branch amplifier and a second different pre-determined bias level (the default bias level

determined based on the required power level of the output signal or the adjusted default bias level determined in the correction method) is supplied to the second branch amplifier.

5 In a next step S11, the input signal is applied to the LINC out-phasing amplifier system. Due to the careful choice of supplied biases, no or at least reduced amplitude imbalances are present and a correct amplification of the input signal can be performed.

10 It is anticipated by the present invention that for most applications no further bias adjustment or refinement is typically needed during operation. However, temperature changes, component aging and other factors could affect the components in the LINC out-phasing amplifier system and in particular the components of the nonlinear amplifiers and the combining
15 network. In such a case, the amplitude imbalance problem can reemerge once more. A further bias adjustment during operation, or performed when the LINC out-phasing amplifier system is temporarily taken out of operation, could then be beneficial.

20 The method then ends.

Fig. 16 is a flow diagram illustrating an embodiment of the adjusting step S3 of Fig. 14 and an embodiment of the applying step S10 of Fig. 15 in more detail. The method starts from step S2 of Fig. 14 or from start in Fig. 15. In a
25 next step S20, a default bias is applied to the first branch power amplifier. This default bias is set to provide a correct amplification of the input signal. The next step S21 applies a constant bias to the second nonlinear amplifier. This constant bias is typically equal to the default bias. In step S22, the default bias supplied to the first amplifier is adjusted as was discussed in
30 connection with step S2 of Fig. 14. This means that in this embodiment, only the bias of one bias source and experienced by one amplifier is adjusted to cope with the amplitude imbalances. The method then continues to end in Fig. 14 or step S11 in Fig. 15.

Fig. 17 is a flow diagram illustrating an embodiment of the adjusting step S3 of Fig. 14 and an embodiment of the applying step S10 of Fig. 15 in more detail. The method starts from step S2 of Fig. 14 or from start in Fig. 15. In a next step S30, a default bias is applied to the first branch power amplifier. The next step S31 applies a default bias to the second nonlinear amplifier. These two default biases are typically equal and set to provide a correct amplification of the input signal. In step S32, the default biases supplied to the two amplifiers are individually adjusted as was discussed in connection with step S2 of Fig. 14. This means that in this embodiment, the biases of two bias sources and experienced by both amplifier are adjusted to cope with the amplitude imbalances. The method then continues to end in Fig. 14 or step S11 in Fig. 15.

Fig. 18 is a flow diagram illustrating additional steps of the method disclosed in Fig. 14 or 15 according to an embodiment of the present invention. The method starts from step S2 of Fig. 14 or from step S11 in Fig. 15. In a next step S40, the output signal of the LINC out-phasing amplifier system is detected by a signal detector. This signal detector then generates a voltage or bias adjustment command in step S41 based on the detected output signal. The signal detector could, for example, generate the adjustment command based on a difference between the actual output signal and a desired signal and/or based on a magnitude of unwanted spurious elements present in the output signal on adjacent frequencies.

The adjustment command is then provided to one or two bias adjuster that adjusts the supplied bias of one or two controllable variable bias sources.

The actual bias adjustment to be performed based on the detected output signal and, thus, the form of the adjusting command is preferably determined from test experiments performed on LINC out-phasing amplifier systems. More complex techniques such as Monte Carlo simulation or neural networks

could be utilized to determine a suitable bias adjustment and adjustment command based on a given detected output signal.

5 Note further that the output detector could monitor/detect the output signal for a period of time before generating the adjustment command. This means the command could then be regarded as generated based on the average output signal during the time period.

10 The method then continues to step S3 Fig. 14 or step S10 in Fig. 15, where the bias(es) are adjusted based on the generated command.

15 It will be understood by a person skilled in the art that various modifications and changes may be made to the present invention without departure from the scope thereof, which is defined by the appended claims.

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CLAIMS

1. A linear amplification using nonlinear components, LINC, out-phasing amplifier system (1) comprising:

5 - a first nonlinear power amplifier (40) arranged for amplifying a first signal;

 - a second nonlinear power amplifier (50) arranged for amplifying a second signal, said first and second signal having equal amplitude; and

10 - a signal combining unit (60) connected to said first (40) and second (50) nonlinear power amplifier and arranged for combining said first amplified signal and said second amplified signal into an amplified output signal,

characterized by:

15 - an amplitude imbalance corrector (100) comprising a bias system (110, 120; 140) for independently biasing said first (40) and second (50) nonlinear power amplifier to correct for signal amplitude imbalances caused by said LINC out-phasing amplifier system (1).

2. The amplifier system according to claim 1, **characterized in** that said bias system (110, 120; 140) provides a first predetermined bias to said first nonlinear power amplifier and a second predetermined bias to said second nonlinear power amplifier (50), a voltage level of said second predetermined bias being different from a voltage level of said first predetermined bias.

3. The amplifier system according to claim 1 or 2, **characterized in** that said bias system (110, 120) comprises:

25 - a variable bias source (110) for providing an adjustable bias to said first nonlinear power amplifier (40); and

30 - a fix bias source (120) arranged for providing a constant bias to said second nonlinear power amplifier (50), and said amplitude imbalance corrector (100) comprises means (130) for adjusting said bias provided by said variable bias source (110) and experienced by said first nonlinear power amplifier (40).

4. The amplifier system according to claim 1 or 2, **characterized in** that said bias source (110, 140) comprises:

- a first variable bias source (110) arranged for providing an adjustable bias to said first nonlinear power amplifier (40); and

5 - a second variable bias source (140) arranged for providing an adjustable bias to said second nonlinear power amplifier (50), and said amplitude imbalance corrector (100) comprises means (130) for individually adjusting said bias provided by said first variable bias source (110) and experienced by said first nonlinear power amplifier (40) and said bias provided
10 by said second variable bias source (140) and experienced by said second nonlinear power amplifier (50).

5. The amplifier system according to claim 3 or 4, **characterized in** that said amplitude imbalance corrector (100) comprises a signal detector (170)
15 arranged for detecting said amplified output signal and for generating a bias adjustment command based on said detected amplified output signal, and said adjusting means (130) adjusts said bias experienced by said first nonlinear power amplifier (40) based on said bias adjustment command.

20 6. The amplifier system according to any of the claims 1 to 5, **characterized in** that said first nonlinear power amplifier (40) is a first switched-mode power amplifier (200; 300; 400) and said second nonlinear power amplifier (50) is a second switched-mode power amplifier (200; 300; 400).

25 7. The amplifier system according to claim 6, **characterized in** that said first nonlinear power amplifier (40) is a first current mode class D power amplifier (200) and said second nonlinear power amplifier (50) is a second current mode class D power amplifier (200).

30 8. The amplifier system according to any of the claims 1 to 7, **characterized by** a LINC modulator (30) connected to said first (40) and second (50) nonlinear power amplifier and arranged for generating said first and second signal based an alternate current input signal.

9. The amplifier system according to any of the claims 1 to 8, **characterized in** that said biases are direct current drain or collector bias voltages of at least one transistor (230, 240; 330, 340; 430, 440; 530) of said first (40) and second (50) nonlinear power amplifier.

10. A transmitter (900) comprising:

- an antenna (940) for transmitting a radio frequency signal; and
- a linear amplification using nonlinear components, LINC, out-phasing amplifier system (1) according to any of the claims 1 to 9 for amplifying said radio frequency signal input to said antenna (940).

11. A base station comprising a transmitter according to claim 10.

12. A mobile unit comprising a transmitter according to claim 10.

13. Use of a linear amplification using nonlinear components, LINC, out-phasing amplifier system (1) according to any of the claims 1 to 9 for amplifying an input signal.

14. The use according to claim 13, **characterized in** that said input signal is a radio frequency input signal.

15. An arrangement (100) for improving operation characteristics of a linear amplification using nonlinear components, LINC, out-phasing amplifier system (1) comprising a first nonlinear power amplifier (40) arranged for amplifying a first signal, a second power amplifier (50) arranged for amplifying a second signal, said first and second signal having equal amplitude, a bias system (110, 120; 140) for providing a respective bias to said first (40) and second (50) nonlinear power amplifier, and a signal combining circuitry (60) for combining said first and second amplified signal into an amplified output signal, **characterized by** an amplitude imbalance corrector (100) for correcting signal amplitude imbalances caused by said LINC out-phasing

amplifier system (1) and thereby improve the operation characteristics of said LINC out-phasing amplifier system (1) by individually adjusting said bias experienced by at least one of said first (40) and second (50) nonlinear power amplifier.

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16. The arrangement according to claim 15, **characterized in** that said bias system (110, 120) comprises:

- a variable bias source (110) for providing an adjustable bias to said first nonlinear power amplifier (40); and

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- a fix bias source (120) arranged for providing a constant bias to said second nonlinear power amplifier (50), and said amplitude imbalance corrector (100) comprises means (130) for adjusting said bias provided by said variable bias source and experienced by said first nonlinear power amplifier (40).

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17. The arrangement according to claim 15, **characterized in** that said bias system (110, 140) comprises:

- a first variable bias source (110) arranged for providing an adjustable bias to said first nonlinear power amplifier (40); and

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- a second variable bias source (140) arranged for providing an adjustable bias to said second nonlinear power amplifier (50), and said amplitude imbalance corrector (100) comprises means (130) for individually adjusting said bias provided by said first variable bias source (110) and experienced by said first nonlinear power amplifier (40) and said bias provided by said second variable bias source (140) and experienced by said second nonlinear power amplifier (50).

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18. The arrangement according to claim 16 or 17, **characterized in** that said amplitude imbalance corrector (100) comprises a signal detector (170) arranged for detecting said amplified output signal and for generating a bias adjustment command based on said detected amplified output signal, and said adjusting means (130) adjusts said bias experienced by said first nonlinear power amplifier based on said bias adjustment command.

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19. The arrangement according to any of the claims 15 to 18, **characterized in** that said biases are direct current drain or collector bias voltages of at least one transistor (230, 240; 330, 340; 430, 440; 530) of said first (40) and second (50) nonlinear power amplifier.

20. A method for improving operation characteristics of a linear amplification using nonlinear components, LINC, out-phasing amplifier system (1) comprising a first nonlinear power amplifier (40) for amplifying a first signal, a second power amplifier (50) for amplifying a second signal, said first and second signal having equal amplitude, a bias system (110, 120; 140) for providing a respective bias to said first (40) and second (50) nonlinear power amplifier, and a signal combining circuitry (60) for combining said first and second amplified signal into an amplified output signal, **characterized by** correcting for signal amplitude imbalances caused by said LINC out-phasing amplifier system (1) and thereby improving the operation characteristics of said LINC out-phasing amplifier system (1) by individually adjusting said bias experienced by at least one of said first (40) and second (50) nonlinear power amplifier.

21. The method according to claim 20, **characterized by**:

- applying a default bias to said first nonlinear power amplifier (40); and
- applying a constant bias to said second nonlinear power amplifier (50), and said correcting step comprises correcting for amplitude imbalances by adjusting said bias applied to said first nonlinear power amplifier (40).

22. The method according to claim 20, **characterized by** applying a respective default bias to said first (40) and second (50) nonlinear power amplifier, and said correcting step comprises correcting for amplitude imbalances by individually adjusting said biases applied to said first (40) and second (50) nonlinear power amplifier.

23. The method according to claim 21 or 22, **characterized by**:

- detecting said amplified output signal; and
- generating a bias adjustment command based on said detected

amplified output signal, and said correcting step comprises correcting for
said amplitude imbalances by adjusting said bias experienced by said first
nonlinear power amplifier based on said bias adjustment command.

24. A method of operating a linear amplification using nonlinear components,
LINC, out-phasing amplifier system (1) comprising a first nonlinear power
amplifier (40) for amplifying a first signal, a second power amplifier (50) for
amplifying a second signal, said first and second signal having equal
amplitude, and a signal combining circuitry (60) for combining said first and
second amplified signal into an amplified output signal, **characterized by**
applying independent biases to said first (40) and second (50) nonlinear power
amplifier to correct for signal amplitude imbalances caused by said LINC out-
phasing amplifier system (1).

25. The method according to claim 24, **characterized in** that said applying
step comprises the steps of:

- applying a first predetermined bias to said first nonlinear power
amplifier; and
- applying a second predetermined bias to said second nonlinear
power amplifier (50), a voltage level of said second predetermined bias being
different from a voltage level of said first predetermined bias.

26. The method according to claim 24 or 25, **characterized in** that said
applying step comprises the steps of:

- applying a default bias to said first nonlinear power amplifier (40);
- applying a constant bias to said second nonlinear power amplifier
(50); and
- adjusting said bias experienced by said first nonlinear power
amplifier (40) to correct for said amplitude imbalances.

27. The method according to claim 24 or 25, **characterized in** that said applying step comprises the steps of:

- applying a respective default bias to said first (40) and second (50) nonlinear power amplifier;

- individually adjusting said biases experienced by said first (40) and second (50) nonlinear power amplifier to correct for said amplitude imbalances.

28. The method according to claim 26 or 27, **characterized by:**

- detecting said amplified output signal; and

- generating a bias adjustment command based on said detected amplified output signal, and said adjusting step comprises adjusting said bias experienced by said first nonlinear power amplifier (40) based on said bias adjustment command.

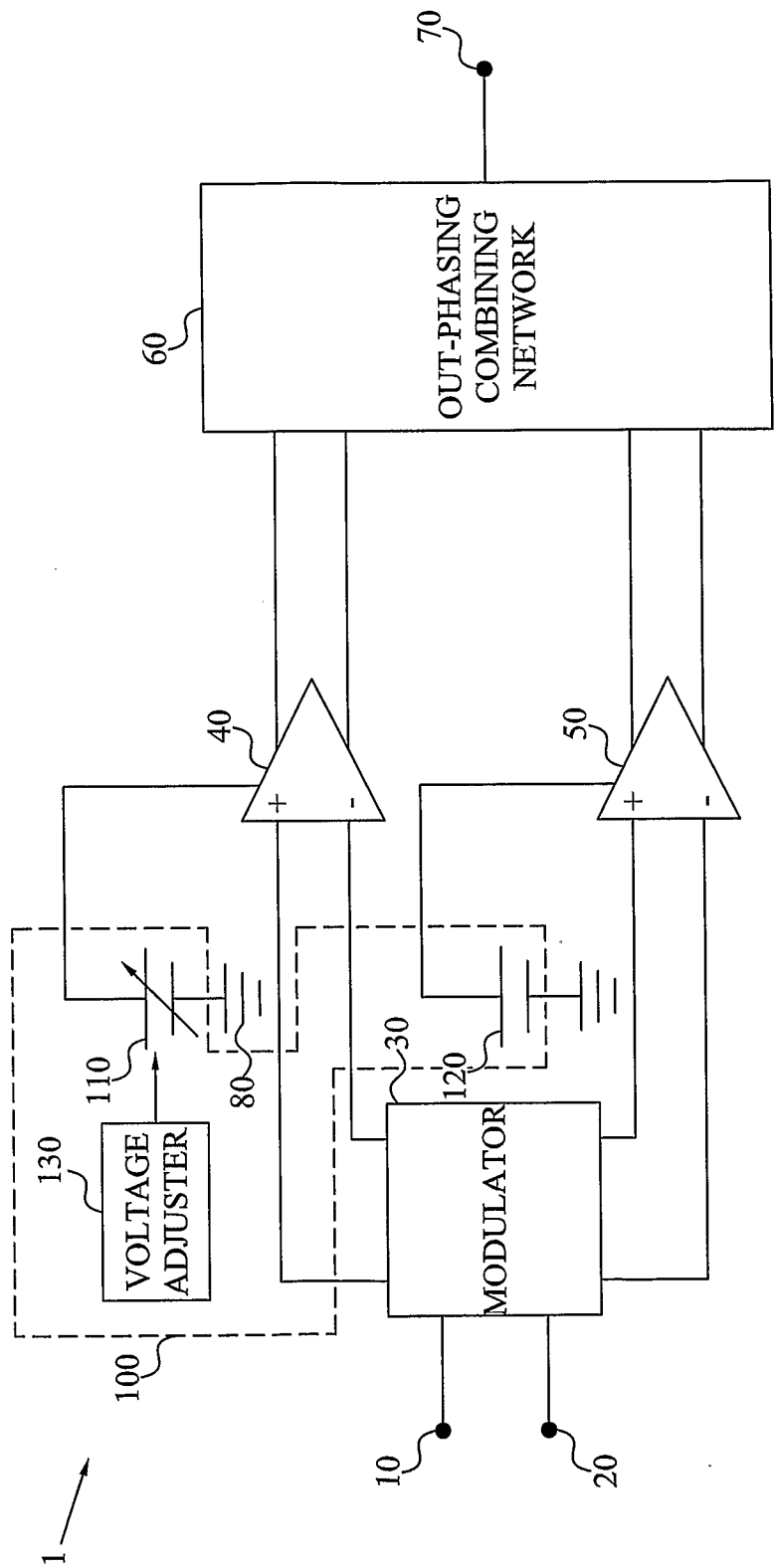


Fig. 1

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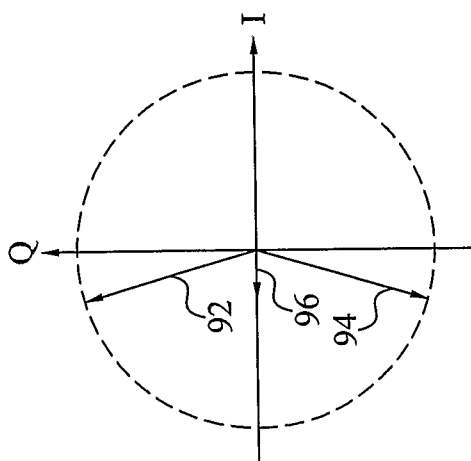


Fig. 4A

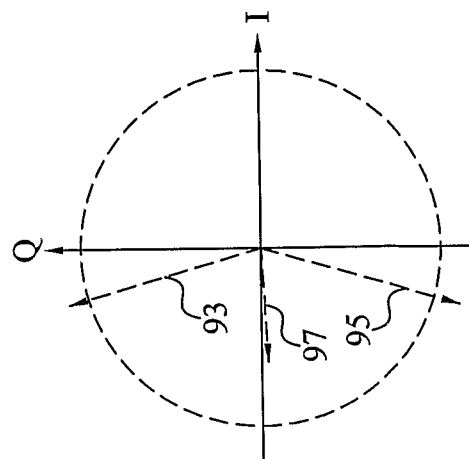


Fig. 4B

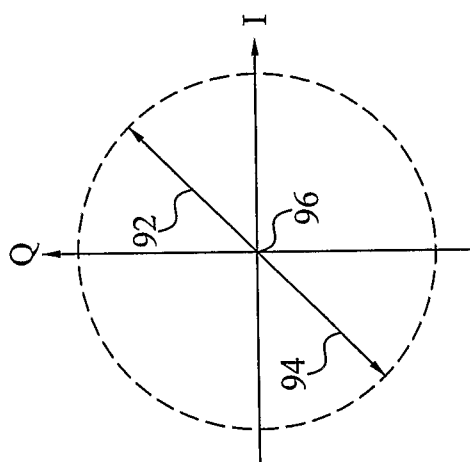


Fig. 3A

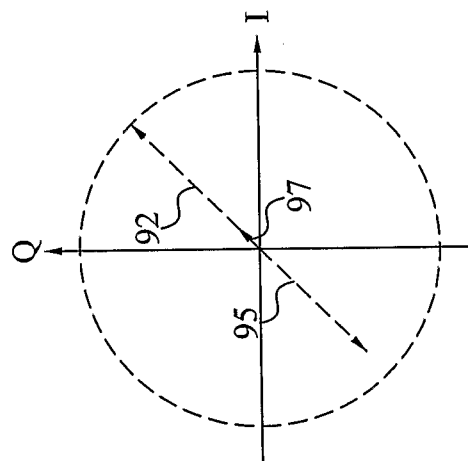


Fig. 3B

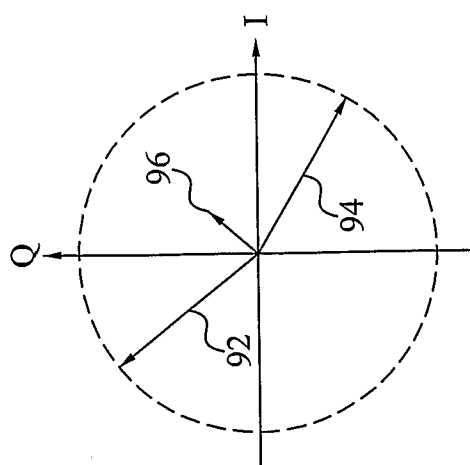


Fig. 2A

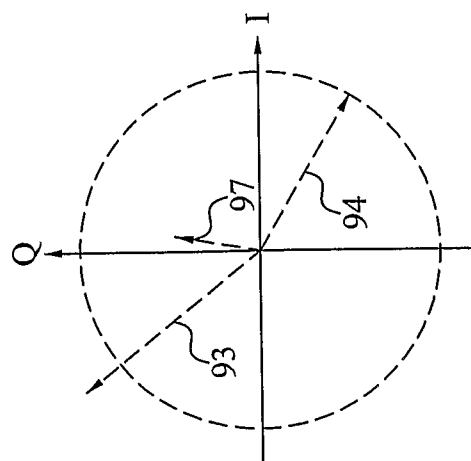


Fig. 2B

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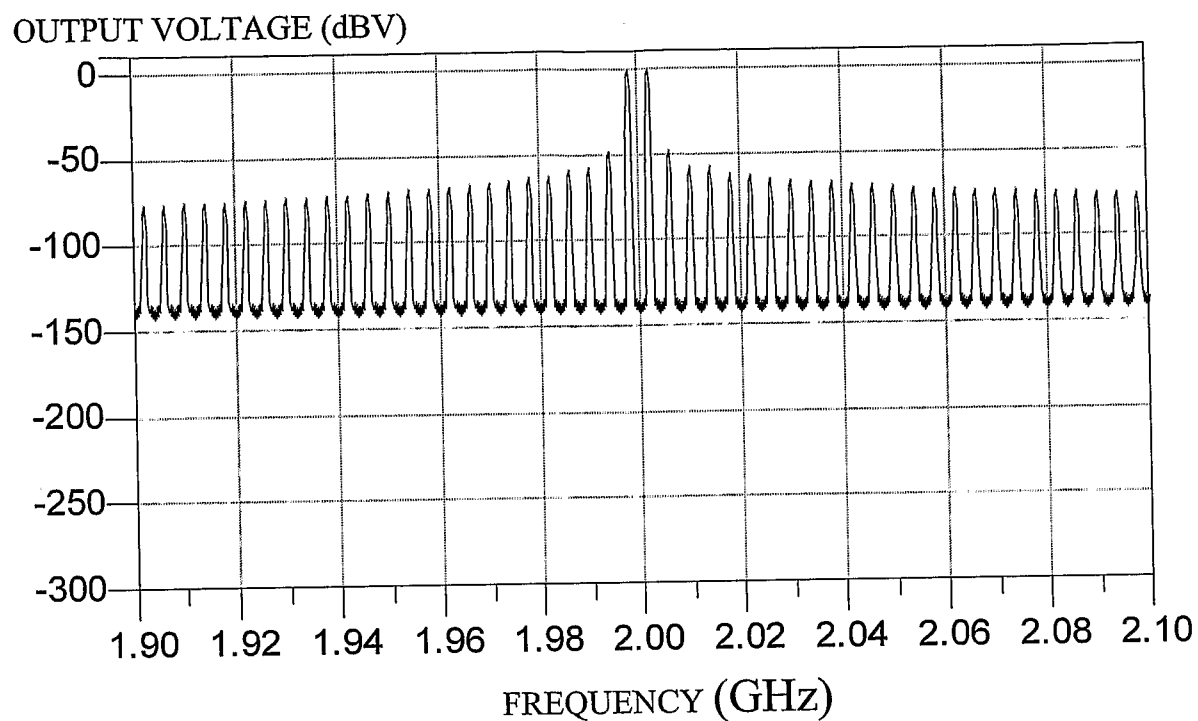


Fig. 5A

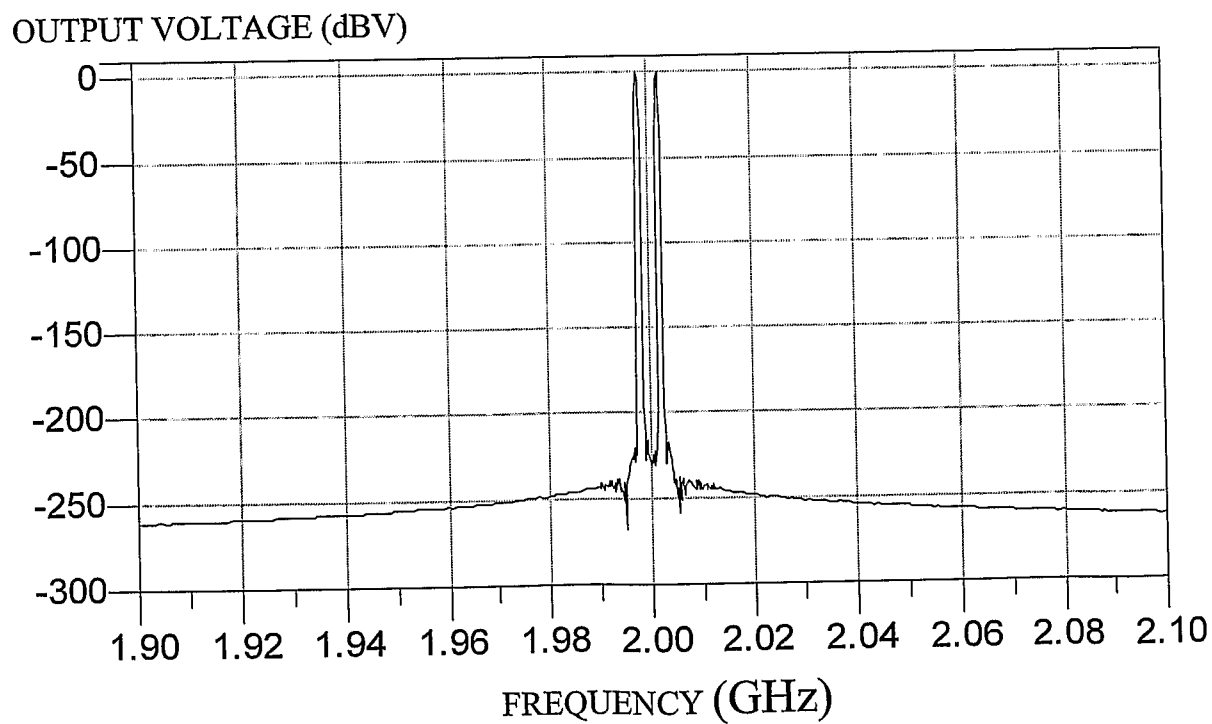


Fig. 5B

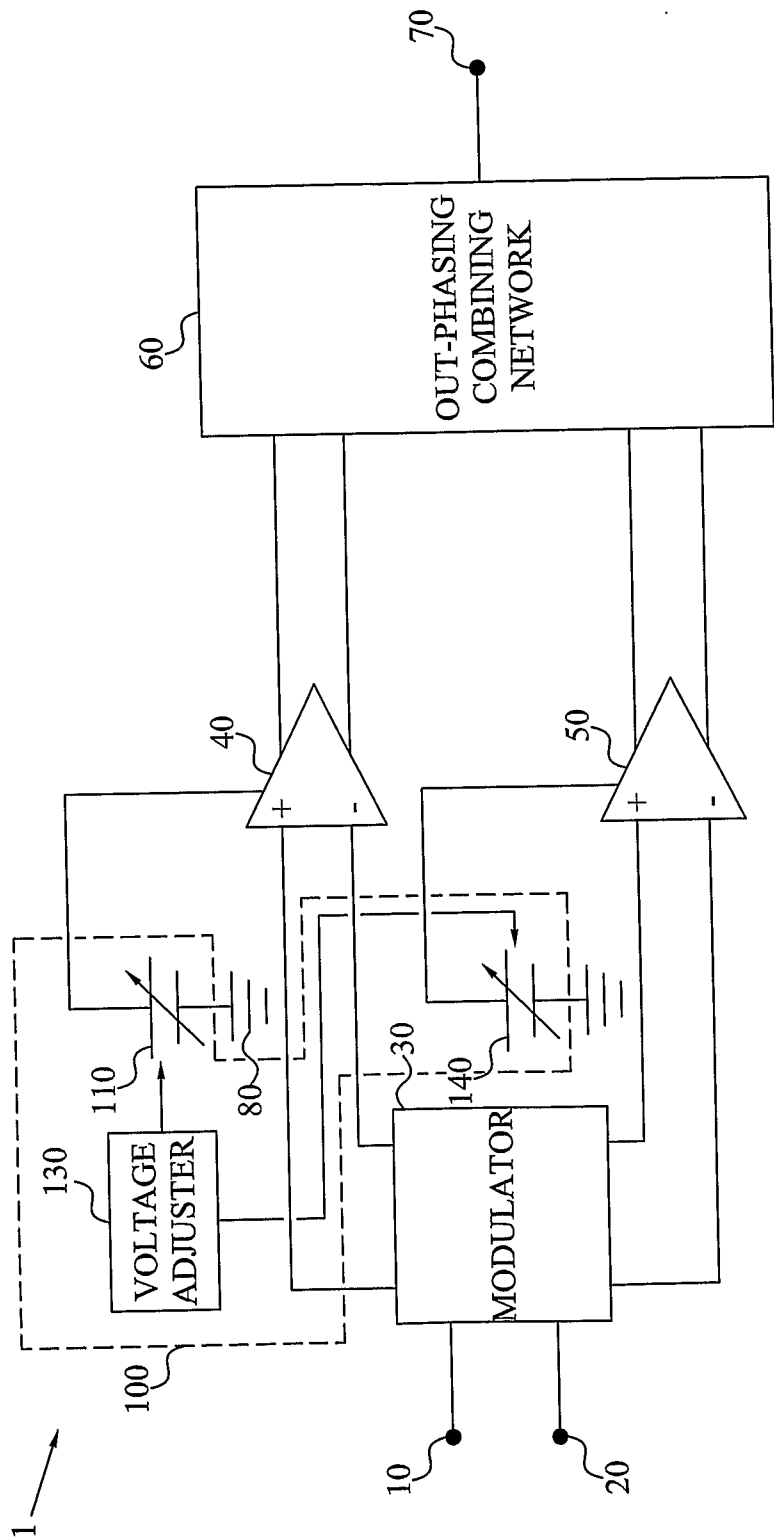


Fig. 6

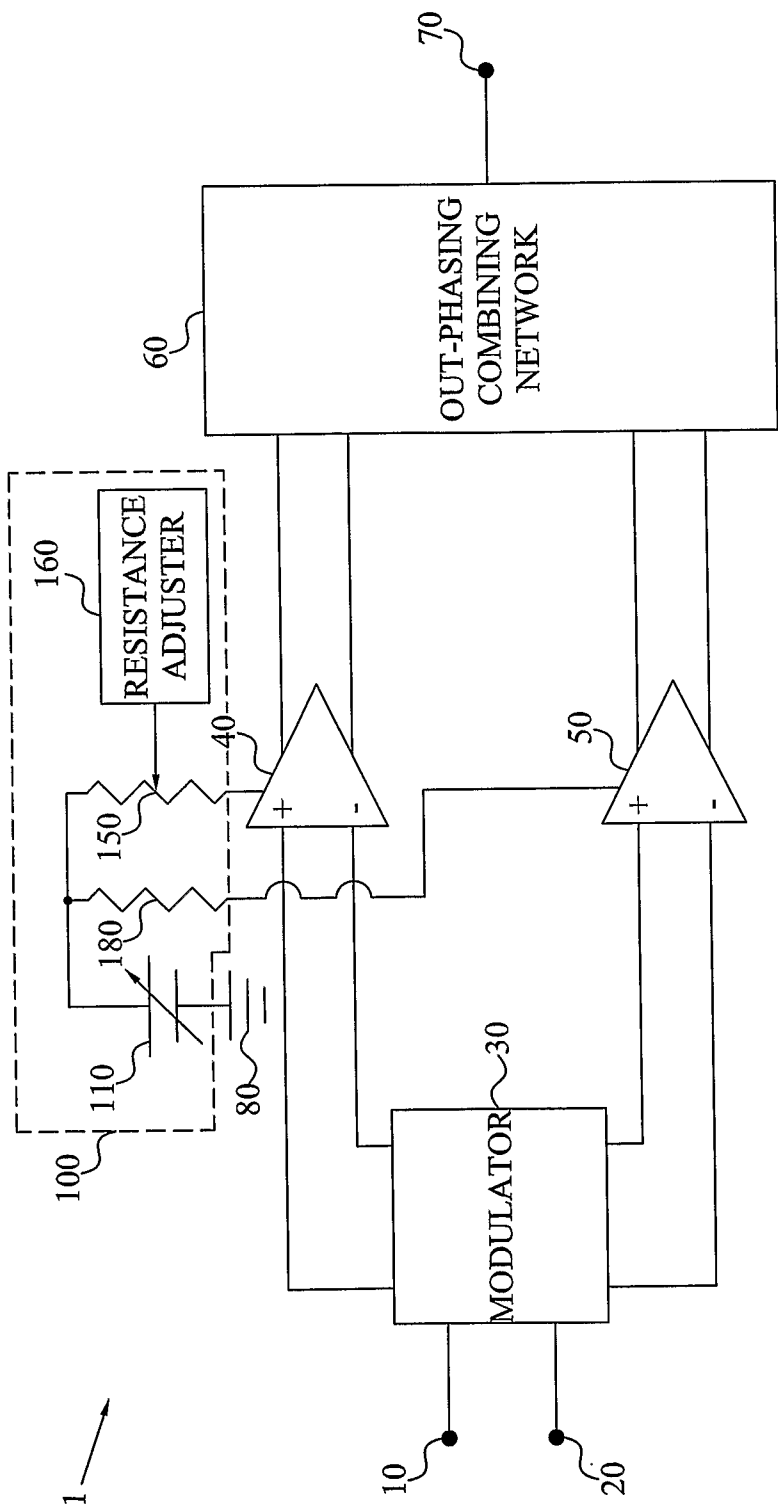


Fig. 7

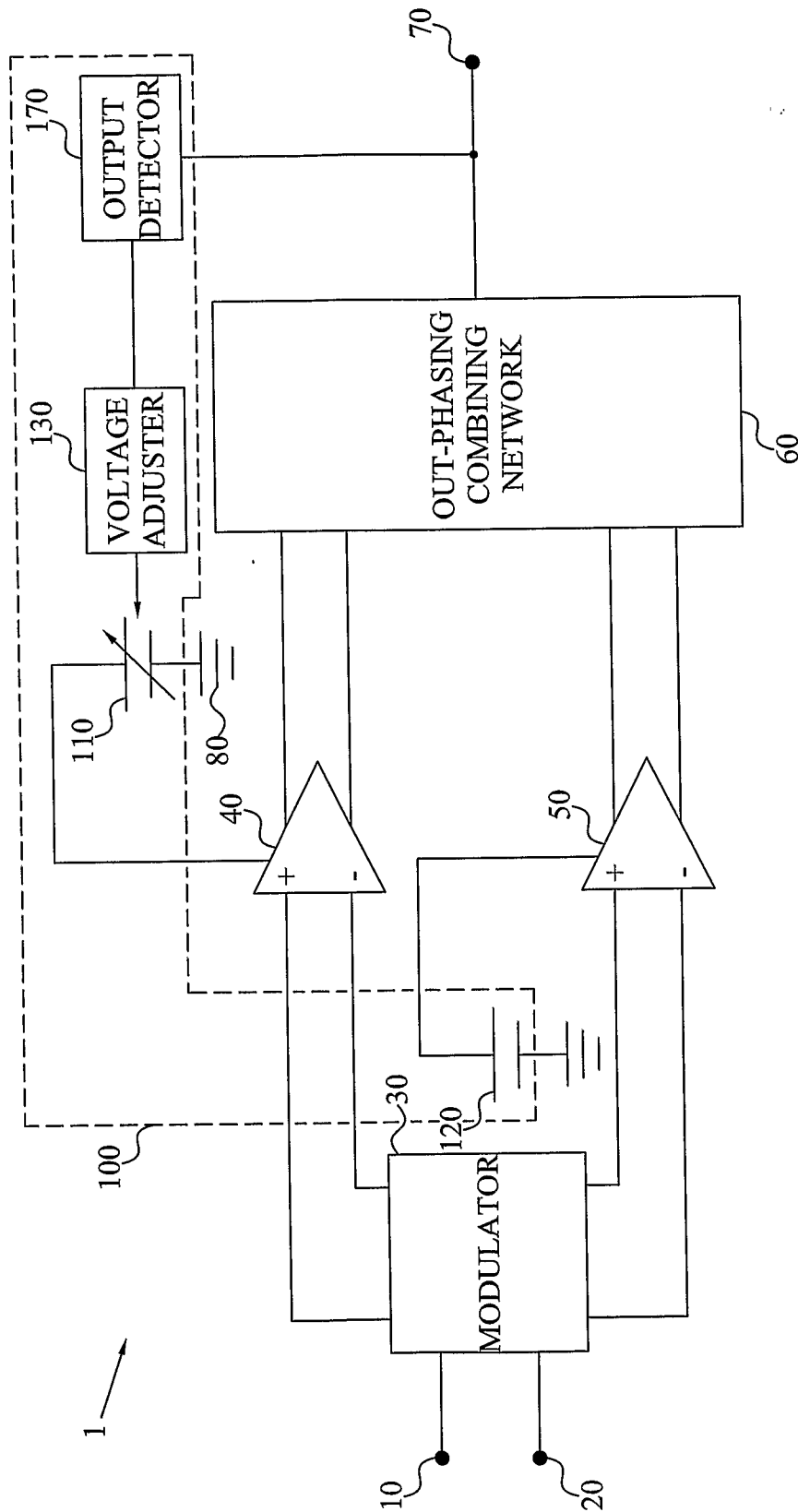


Fig. 8

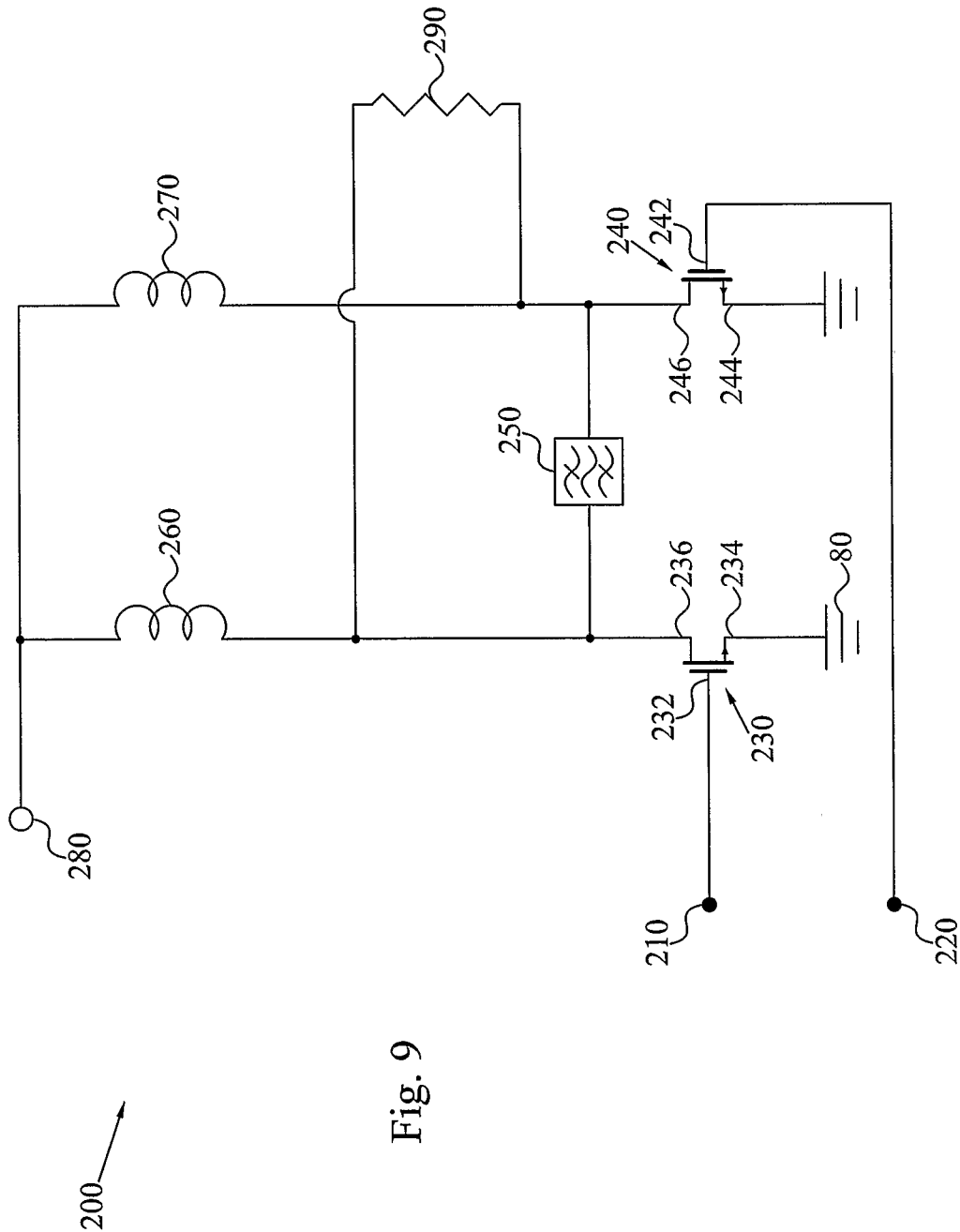
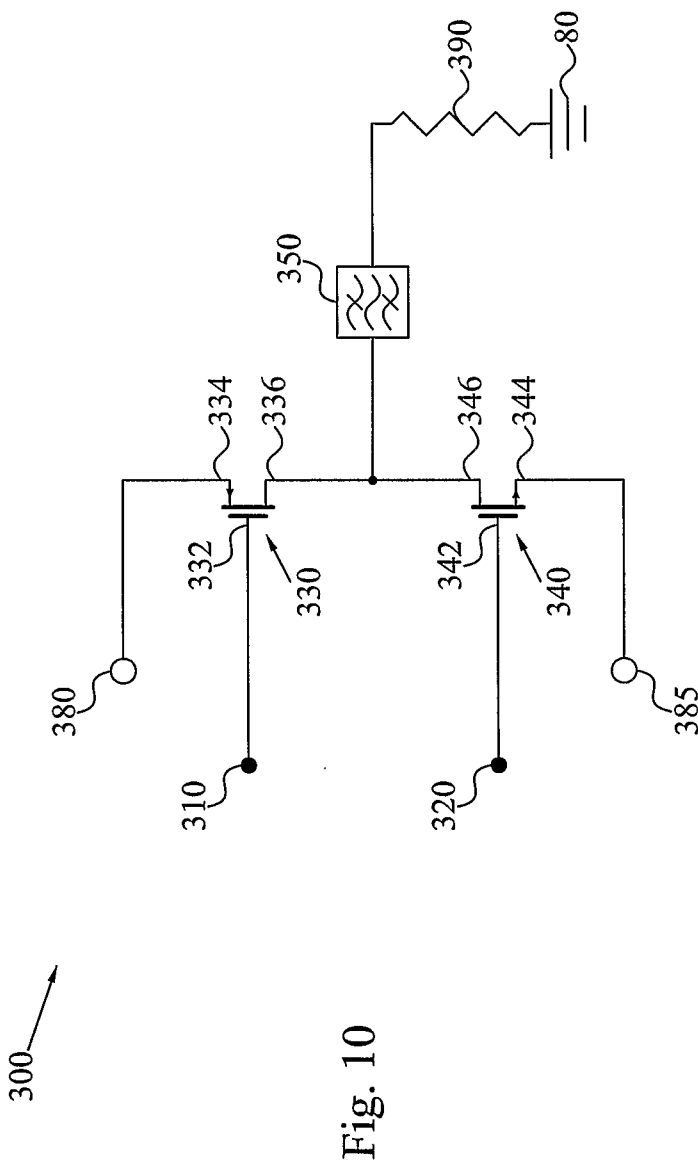
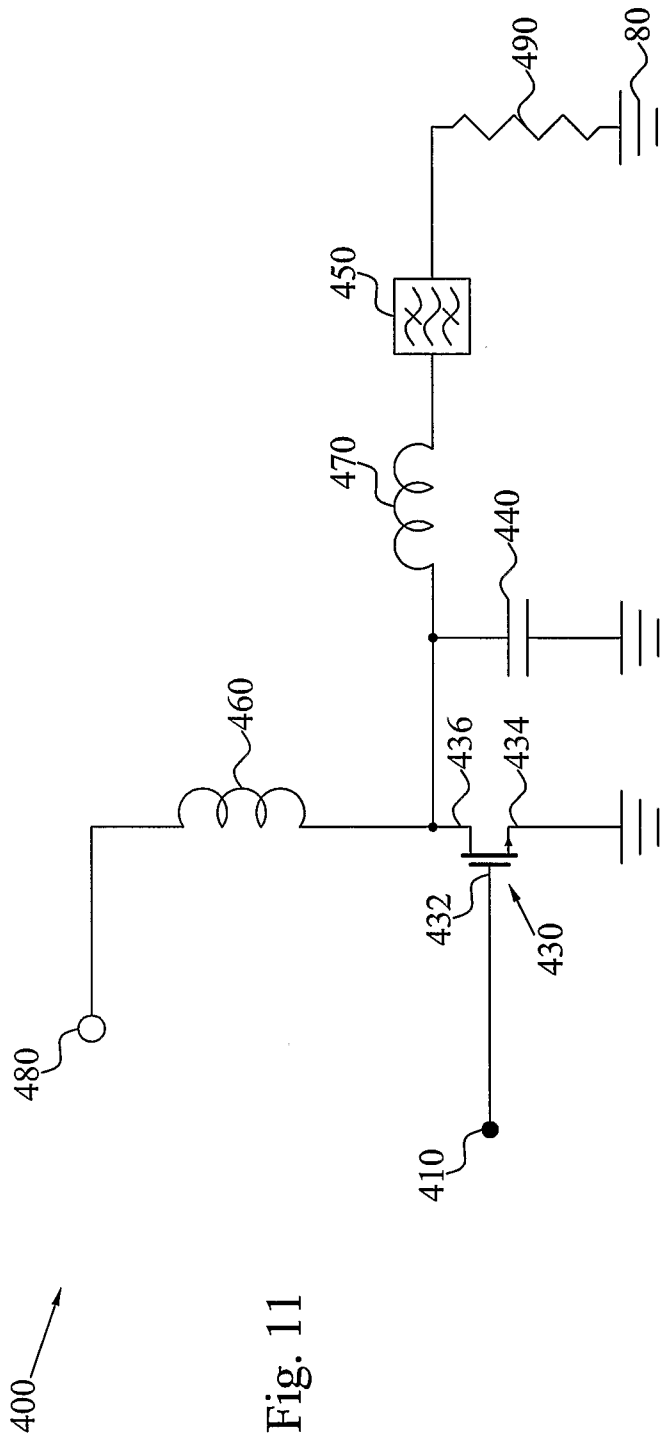


Fig. 9





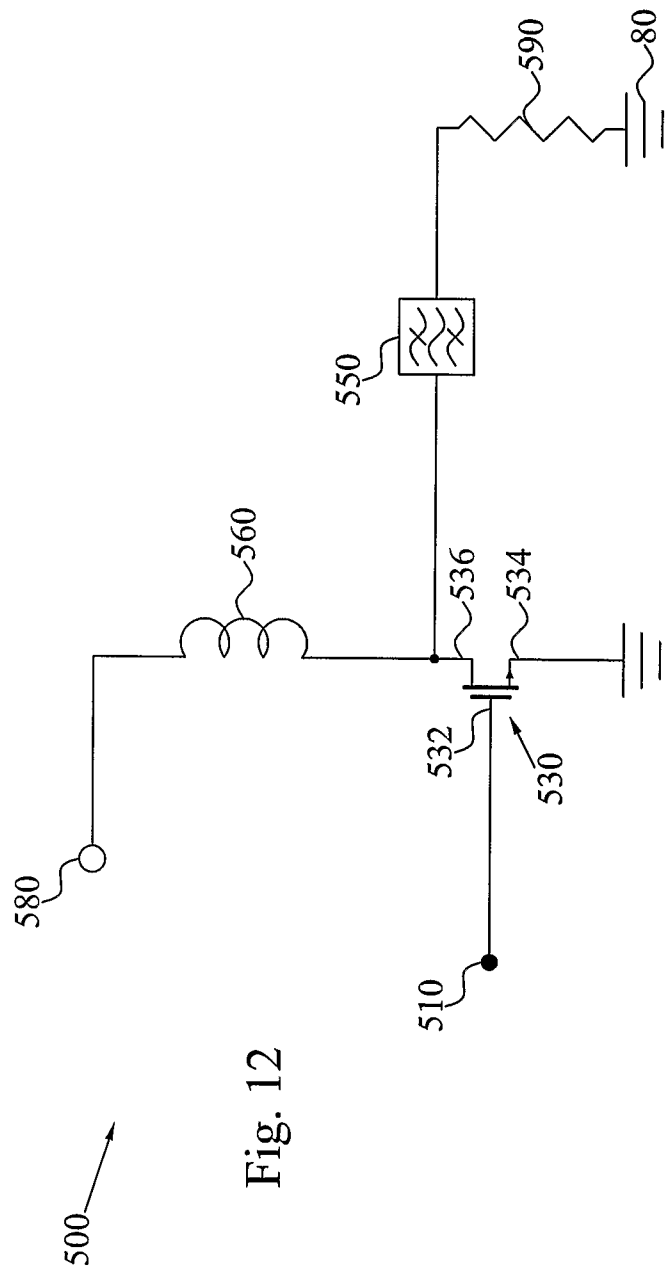
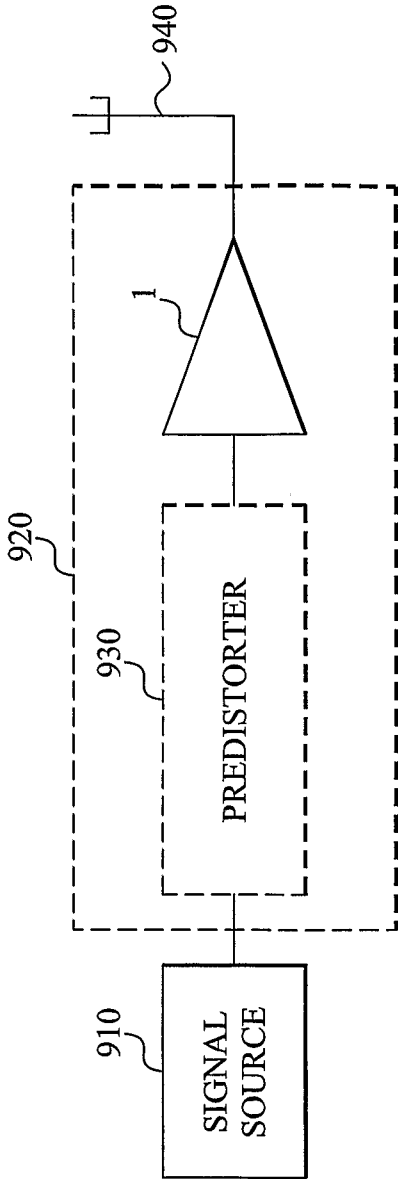


Fig. 12



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Fig. 13

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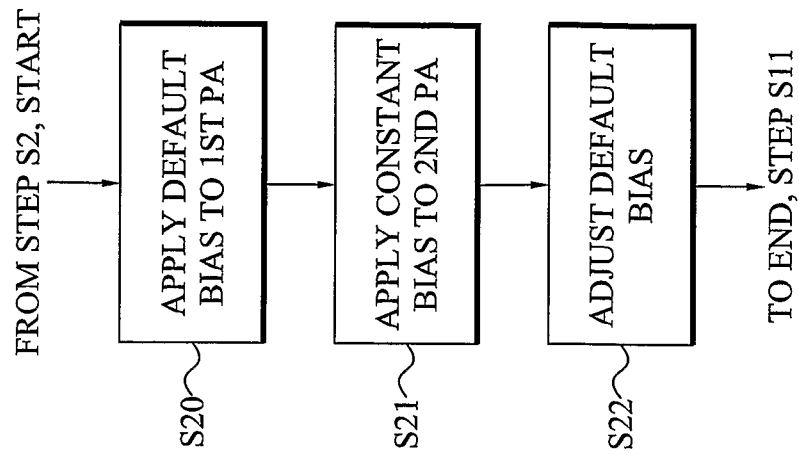


Fig. 16

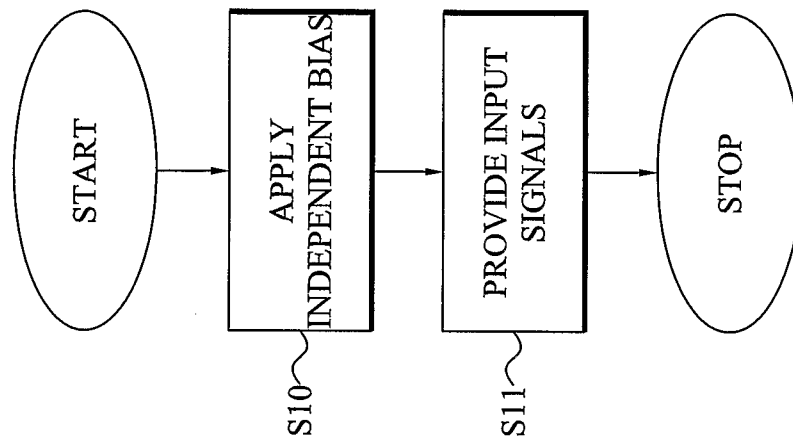


Fig. 15

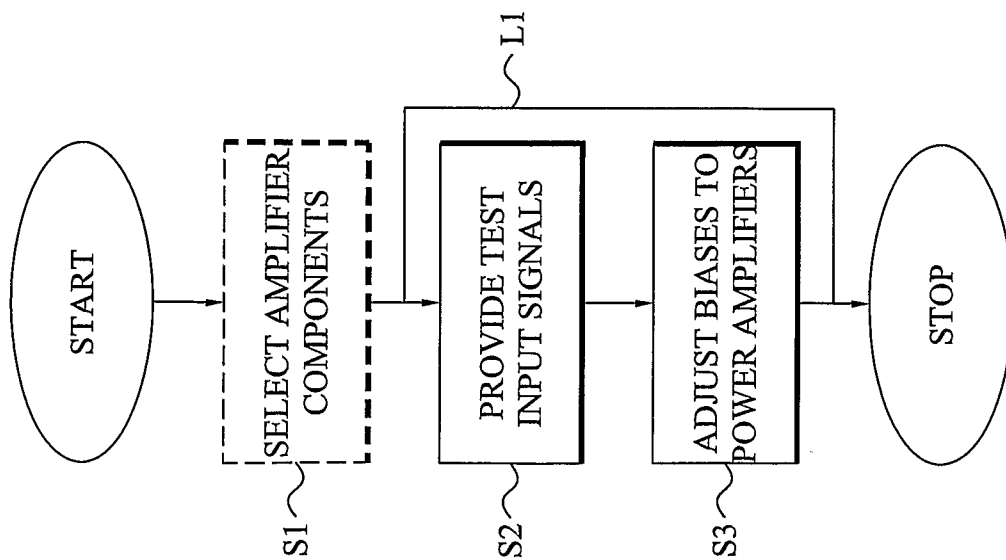
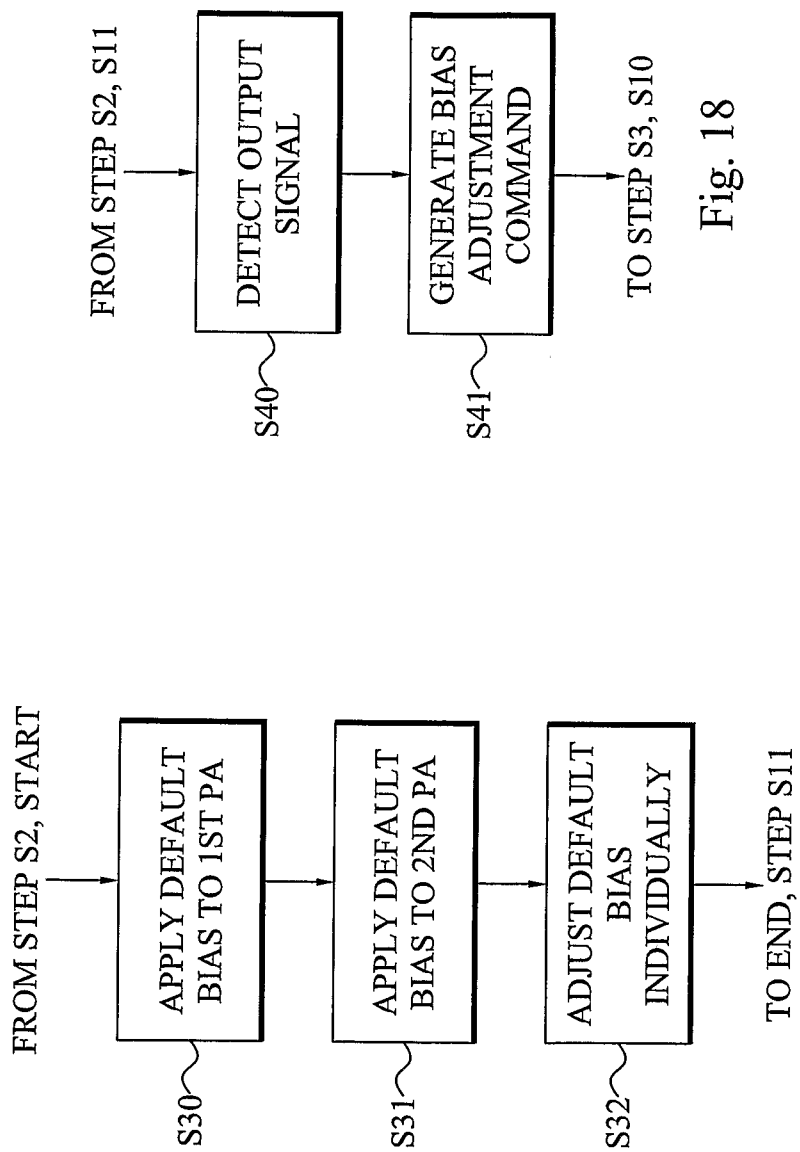


Fig. 14

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2006/000096

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9966637 A1 (DATUM TELEGRAPHIC INC.), 23 December 1999 (23.12.1999), page 46, line 14 - page 47, line 16, figure 33, claim 7, abstract --	1-28
X	US 5901346 A (R.E.STENGEL ET AL), 4 May 1999 (04.05.1999), column 3, line 16 - column 4, line 16; column 6, line 34 - line 45, figure 2 --	1-28
A	Paloma Garcia et al An Adaptive Digital Method of Imbalances Cancellation in LINC Transmitters IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 54, NO. 3, MAY 2005 sid.879-888 --	1-28



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Date of the actual completion of the international search

31 August 2006

Date of mailing of the international search report

10-10-2006

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2006/000096

International patent classification (IPC)

H03F 1/02 (2006.01)

H03F 1/32 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

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Information on patent family members

04/03/2006

International application No.

PCT/SE2006/000096

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