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(54) **ENHANCED DOHERTY AMPLIFIER WITH BIAS SUPPLY MODULATION**

ERWEITERTER DOHERTY-VERSTÄRKER MIT VORSPANNUNGSVERSORGUNGS-MODULATION

AMPLIFICATEUR DOHERTY AMÉLIORÉ AVEC MODULATION D'ALIMENTATION DE POLARISATION

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EP 2 342 817 B1

Description

FIELD OF THE APPLICATION

[0001] The present application relates generally to signal amplification and specifically to a device and method for controlling efficiency and performance of an amplification device.

BACKGROUND

[0002] Wireless devices use Radio Frequencies (RF) to transmit information. For example, cell phones use amplified RF to transmit voice data to base stations, which allow signals to be relayed to communications networks. Other existing wireless communication devices include Bluetooth, HomeRF and WLAN. In a conventional wireless device, the power amplifier consumes most of the power of the overall wireless system. For systems that run on batteries, a power amplifier with a low efficiency results in a reduced communication time for a given battery life. For continuous power systems, a decrease in efficiency results in increased power usage and heat removal requirements, which may increase the equipment and operating costs of the overall system.

[0003] For this reason, much effort has been expended on increasing the efficiency of RF power amplifiers. One type of amplifier that may provide increased efficiency is a Doherty-type power amplifier. A common Doherty-type power amplifier design includes a main amplifier and an auxiliary amplifier. The main amplifier is operated to maintain optimal efficiency up to a certain power level and allows the auxiliary amplifier to operate above that level. When the power amplifier is operated at a high output power level, the main amplifier will be heavily compressed such that non-linearities are introduced into the amplified signal. In common Doherty-type amplifiers, the main and auxiliary amplifiers are composed of the same type of amplifiers with the same maximum power rating. These Doherty-type amplifiers develop an efficiency peak 6 dB back of full power which in theory will be equal in magnitude to the maximum efficiency of the system.

[0004] New amplifier architectures and device technologies allow for designs wherein the location of the efficiency peak in back-off may be moved about the traditional 6 dB point and wherein magnitudes exceed the maximum compressed system efficiency. Doherty-type devices capable of an increased efficiency over a wide range of output power levels may be provided by using a main amplifier design of different size or materials than that of the auxiliary amplifier. However, the choice of materials and designs for such amplifiers must be set when a product is manufactured and only coarse, incremental changes in the location of the efficiency peak may be achieved. Due to variations in system applications and in the signals which require amplification, it would be desirable to have a Doherty-type device capable of operation and peak efficiency for various signal output power levels and peak to average signal ratios. Further, it would be desirable to have an amplification device which is dynamically configurable to meet system requirements without requiring modification to the device hardware.

[0005] WO 2004027983 discloses a power amplifier circuit that includes two amplifiers coupled in parallel. An input received by the second amplifier is a delayed version of the input received by the first amplifier. The output of the first amplifier is delayed such that the delayed output of the first amplifier is substantially in phase with the output of the second amplifier. For low output power operation, only the first amplifier is enabled. For high output power operation, both the first and the second amplifiers are enabled. The first and the second amplifiers operate as saturated amplifiers. A first variable output power control signal controls the output power of the first amplifier, and a second variable output power control signal controls the output power of the second amplifier subsection, both control signals being operated from a same battery source.

BRIEF SUMMARY

[0006] The present invention provides a signal amplifier in accordance with claim 1, a base station in accordance with claim 10 and a method of amplifying an input signal in accordance with claim 12.

[0007] The present application discloses and describes a Doherty-type amplifier having a peak efficiency point that may be adapted to various signal characteristics. The main amplifier and auxiliary amplifier are biased by separate and independent bias voltage supplies. In some embodiments, the bias voltage supplies are fixed and have different voltage levels. In some embodiments, the bias voltage supplies are variable and may be adjusted to achieve different performance characteristics.

[0008] In one aspect, the present application describes a signal amplifier. The signal amplifier includes a signal preparation unit adapted to divide an input signal into a main input signal and an auxiliary input signal, wherein the signal preparation unit includes a dual drive module configured to apply signal shaping to the main input signal and the auxiliary input signal. The signal amplifier also includes a main amplifier configured to receive the main input signal and output an amplified main signal, a main bias voltage source supplying a main bias voltage to the main amplifier, an auxiliary amplifier configured to receive the auxiliary input signal and output an amplified auxiliary signal, an auxiliary bias voltage source supplying an auxiliary bias voltage to the auxiliary amplifier, a signal combiner adapted to combine the amplified main signal and the amplified auxiliary signal into an output signal, and a voltage control module adapted to independently control the main bias voltage source and the auxiliary bias voltage source. The main bias voltage source is independent from the auxiliary bias voltage source.

[0009] In another aspect, the present application describes a base station for receiving and sending wireless RF communications. The base station includes an RF antenna, an RF transmitter connected to the RF antenna and configured to up-convert and amplify a transmit signal for propagation by the RF antenna, an RF receiver connected to the RF antenna and configured to down-convert a received RF signal from the RF antenna, and a signal controller with a network port for sending and receiving communications with a network, the signal controller being connected to and controlling the RF receiver and the RF transmitter. The RF transceiver includes the signal amplifier.

[0010] In yet another aspect, the present application describes a method of amplifying an input signal. The method includes dividing an input signal into a main input signal and an auxiliary input signal and applying signal shaping to the main input signal and the auxiliary input signal, biasing a main amplifier with a main bias voltage from a main bias voltage source, biasing an auxiliary amplifier with an auxiliary bias voltage from an auxiliary bias voltage source, amplifying the main input signal using the main amplifier to generate an amplified main signal, amplifying the auxiliary input signal using the auxiliary amplifier to generate an amplified auxiliary signal, combining the amplified main signal and the amplified auxiliary signal to create an output signal, and independently controlling the main bias voltage source and the auxiliary bias voltage source using a voltage control module. The main bias voltage source is independent from the auxiliary bias voltage source.

[0011] Further aspects and features of example embodiments are described below in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Reference will now be made, by way of example, to the accompanying drawings which show example embodiments, and in which:

Figure 1 diagrammatically shows an example embodiment of an enhanced amplifier;

Figure 2 shows a block diagram of another example embodiment of an enhanced amplifier;

Figure 3 shows a block diagram of a further embodiment of the enhanced amplifier;

Figure 4 shows a graph of gain and efficiency versus output power for an example embodiment of the enhanced amplifier; and

Figure 5 shows a block diagram of an example base station for a wireless network.

DETAILED DESCRIPTION

[0013] It should be understood at the outset that although an exemplary implementation of one embodiment of the present disclosure is illustrated below, the present system may be implemented using any number of techniques, whether currently known or in existence. The present disclosure should in no way be limited to the exemplary implementations, drawings, and techniques illustrated below, including the exemplary design and implementation illustrated and described herein, but may be modified within the scope of the appended claims along with their full scope of equivalents

[0014] It is further understood that as used herein, terms such as coupled, connected, electrically connected, in signal communication, and the like may include direct connections between components, indirect connections between components, or both, as would be apparent in the overall context of a particular embodiment. The term coupled is intended to include, but not be limited to, a direct electrical connection. The terms transmit, transmitted, or transmitting is intended to include, but not be limited to, the electrical transmission of a signal from one device to another.

[0015] Reference is first made to Figure 1, which shows a block diagram of an example embodiment of an enhanced amplifier 10. The enhanced amplifier 10 is arranged in a Doherty configuration, having a main amplifier 12 in parallel with an auxiliary amplifier 14. An input signal 16 is received by a signal preparation unit 20, which divides the input signal into a main input signal 40 and an auxiliary input signal 42 that are input to the main amplifier 12 and auxiliary amplifier 14, respectively. The main amplifier 12 outputs a main amplified signal 44 and the auxiliary amplifier 14 outputs an auxiliary amplified signal 46 to a signal combiner 21.

[0016] The signal combiner 21 includes a main amplifier impedance transformer 22 in the output path of the main amplifier 12. In most embodiments, the main amplifier impedance transformer 22 is selected to produce a 90 degree phase shift in the main amplified signal 44. The main amplifier impedance transformer 22 may also be selected for impedance matching purposes from the point of view of the output port of the enhanced amplifier 10. As known to those ordinarily skilled in the art, the output path typically is designed to provide both a phase offset of 90 degrees as well as an appropriate impedance transformation when the auxiliary amplifier 14 is off. The main amplified signal 44 and auxiliary amplified signal 46 are combined in the signal combiner 21 using techniques which will be appreciated by those skilled in the art to produce the output signal 18.

[0017] The enhanced amplifier 10 features differential bias control for the main amplifier 12 and auxiliary amplifier 14. This feature offers greater flexibility in establishing the peak efficiency point to adapt to particular signal and network conditions. In the example shown in Figure 1, the main amplifier 12 is connected to a main bias voltage source 30 to receive a main bias voltage 31, and the auxiliary amplifier 12 is connected to an auxiliary bias voltage source 32 to receive an auxiliary bias voltage 33. The main bias voltage 31 is separate and independent from the auxiliary bias voltage 33. In most implementations the main bias voltage 31 is set to a different voltage level than the auxiliary bias voltage 33.

[0018] In many embodiments, the main bias voltage 31 and auxiliary bias voltage 33 may be preselected or predetermined based on the expected characteristics of the input signal 16 and/or output signal 18. For example, the determination of the bias voltages 31, 33 may be based upon the expected average output power of the output signal 18 and/or the peak-to-average ratio (PAR) of the output signal 18. Other characteristics may be used in addition to or instead of average power and PAR to determine the appropriate bias voltages 31, 33, for a given application. If the bias voltages 31, 33 are predetermined for a particular implementation, then the main bias voltage source 30 and auxiliary bias voltage source 32 may be static DC voltage sources. In some embodiments, the sources 30, 32 may include voltage rails configured to supply the preselected voltage level and derived from an external voltage source. In another embodiment, the sources 30, 32 may include one or more voltage sources specifically dedicated to the enhanced amplifier 10. Those ordinarily skilled in the art will appreciate the range of possible electrical mechanisms for implementing the two independent bias voltage sources 30, 32.

[0019] In one example embodiment, the main amplifier 12 and auxiliary amplifier 14 may be semiconductor devices of different material compositions, different designs, or both different material compositions and different designs. The use of a first semiconductor device for the main amplifier 12 and a second semiconductor device for the auxiliary amplifier 14, wherein the first semiconductor device is not the same as the second semiconductor device, can be used to enhance the efficiency of enhanced amplifier 10. Use of a main amplifier 12 having a different amplifier design from auxiliary amplifier 14 may enhance the operational efficiency of the enhanced amplifier 10.

[0020] The use of two different bias voltages on the main and auxiliary amplifiers 12, 14 may exacerbate non-linearities that can be created in the amplification process. A Doherty-configured amplifier typically exhibits non-linearities since the main amplifier is biased in Class AB and the auxiliary amplifier is biased in Class C, both of which exhibit input-to-output non-linearity. If the main amplifier 12 and auxiliary amplifier 14 are different devices (different materials or different designs) then the non-linearity may be further exacerbated. Accordingly, the signal preparation unit 20 may be adapted to compensate for non-linearities in the amplification stage by performing signal preparation prior to amplification. For example, in some embodiments, the signal preparation unit 20 may be configured to perform signal shaping to partly compensate for non-linearities in the amplification stage. Signal shaping allows appropriate portions of the signal to be separated and routed to the main and auxiliary amplifiers 12, 14. In another example, the signal preparation unit 20 may be configured to perform predistortion linearization, adding to or subtracting from the input signal 16 to try to offset the resulting non-linear effects of the amplifier stage. Other pre-amplification non-linear compensation techniques or operations may also be employed. Various operations and configurations for offsetting or compensating for non-linearities in a Doherty amplifier are described in US patent application serial no. 11/537,084, entitled Enhanced Doherty Amplifier with Asymmetrical Semiconductors, filed September 29, 2006.

[0021] Reference is now made to Figure 2, which shows another embodiment of the enhanced amplifier 10. The main bias voltage source 30 and the auxiliary bias voltage source 32 provide independent bias voltage supplies for the main amplifier 12 and auxiliary amplifier 14, respectively. In this embodiment, the bias voltage sources 30, 32 are variable voltage supplies. The enhanced amplifier 10 includes a voltage control module 34 coupled to the bias voltage sources 30, 32 to independently control the setting of the main bias voltage 31 and the auxiliary bias voltage 33. The voltage control module 34 may output a main control signal 35 to the main bias voltage source 30 to set the main bias voltage 31, and it may output an auxiliary control signal 36 to the auxiliary bias voltage source 32 to set the auxiliary bias voltage 33. The bias voltage sources 30, 32 may be varied during system operation to adapt to changing signal characteristics or system conditions or they may be initialized following a reset or powering-on condition.

[0022] The enhanced amplifier 10 may include a feedback loop. A feedback signal 60 from the output signal 18 may be returned to the signal preparation unit 20. The feedback signal 60 provides information regarding the output signal 18 and may allow the signal preparation unit 20 to monitor various signal characteristics based upon which it may control various parameters or operations in the signal preparation unit 20. For example, using the feedback signal 60, the signal preparation unit 20 may monitor the power level of the output signal 18, and may collect statistics regarding average output power, peak-to-average ratio, etc. Based on these statistics, it may adjust its signal shaping or pre-distortion linearization operations, if any.

[0023] As shown in Figure 2, the voltage control module 34 may also receive the feedback signal 60. This enables the voltage control module 34 to adjust the bias voltages 31, 33 to react to changes in the signal characteristics of the output signal 18. In some embodiments, the feedback signal 60 may not be directly received by the voltage control module 34, which may instead receive or obtain signal statistics information or data from the signal preparation unit 20. It will also be appreciated that the voltage control module 34 is not necessarily implemented as a stand-alone module separate from the signal preparation unit 20, and may be incorporated within the signal preparation unit 20 in some embodiments. Other variations will be appreciated by those skilled in the art.

[0024] Main and auxiliary bias voltage sources 30, 32 may comprise high efficiency variable voltage source designs as can be readily achieved by those skilled in the art. For example, a 60W amplifier that is 40% efficient would require an average DC supply of 150W or approximately 5.4A, to provide a 28V bias voltage. In many embodiments, the efficiency of the variable voltage sources should be high such that they do not degrade the efficiency of the main and auxiliary amplifiers 12, 14. Those ordinarily skilled in the art will appreciate the appropriate characteristics of a variable voltage source for a particular application.

[0025] With the ability to independently control or vary the main bias voltage 30 and the auxiliary bias voltage 32, the operation of the enhanced amplifier 10 may be scaled to provide an optimal efficiency and gain at a predetermined output power (Pout) level. For example, in some systems or implementations which do not experience a high average power, the bias voltages 31, 33 may be varied to provide an efficiency peak at a lower power level.

[0026] Reference is now made to Figure 3, which shows a further embodiment of the enhanced amplifier 10. In this embodiment, the voltage control module 34 is shown as being implemented with the signal preparation unit 20. The signal preparation unit 20 receives the feedback signal 60 and collects statistics, such as, for example, average output power and PAR, based upon which it controls predistortion and signal shaping operations within the signal preparation unit 20. Some of the same statistics may be used by the voltage control module 34 to control the bias voltage sources 30, 32. In one embodiment, the magnitude of the main bias voltage 31 may be made proportional to the average output power, Pout (avg), and the auxiliary bias voltage 33 may be made proportional to the peak output power, $P_{out(peak)}$.

[0027] As shown in Figure 3, the signal preparation unit 20 is configured to divide the input signal 16 into the main input signal 40 and the auxiliary input signal 42. In the course of dividing the input signal 16, the signal preparation unit 20 may perform certain operations to compensate for non-linearities introduced by the asymmetric Doherty configuration of the main and auxiliary amplifiers 12, 14.

[0028] The signal preparation unit 20 includes a signal divider 24 for dividing the input signal 16 into a main portion 50 and an auxiliary portion 52. The signal divider 24 does not necessarily split the input signal 16 into equal portions. In fact, the signal divider 24 may unevenly divide the input signal 16 and alter the division depending on the state of the main and auxiliary amplifiers 12, 14. In particular, all or most of the input signal 16 may be initially directed to the main amplifier 12 until it is driven into compression; after which the signal divider 24 may alter the division to increase the magnitude of the auxiliary portion 52.

[0029] The signal preparation unit 20 also includes a main signal shaper 26 and an auxiliary signal shaper 28. The signal shapers 26, 28, apply signal shaping techniques to improve the efficiency of the enhanced amplifier 10 and, in some cases, the signal preparation unit 20 may apply filtering or other predistortion functions to the main portion 50 and auxiliary portion 52 to compensate for non-linearities. In one embodiment, the signal shapers 26, 28 are configured such that the main signal shaper 26 shapes the main portion 50 into a base portion of the input signal 16 for amplification by the main amplifier 12 and the auxiliary signal shaper 28 shapes the auxiliary portion 52 into a peak portion of the input signal 16 for amplification by the auxiliary amplifier 14. Other shaping and compensation operations will be appreciated by those of ordinary skill in the art.

[0030] The signal divider 24 and the signal shapers 26, 28 may collectively be referred to as a dual drive module 90. The dual drive module 90 may be implemented using analog components in some embodiments. In many embodiments, the dual drive module 90 may be implemented digitally. For example, the dual drive module 90 may be implemented using a digital signal processor (DSP), a suitable programmed microcontroller, or an application specific integrated circuit (ASIC). The suitable programming of such a device to achieve the functionality described herein will be within the skill of a person of ordinary skill in the art.

[0031] In many embodiments, the dual drive module 90 is configured to operate on a baseband analog signal or a digital signal. Accordingly, the signal preparation unit 20 may include a main up-converter 80 and an auxiliary up-converter 82 for generating the RF main input signal 40 and the RF auxiliary input signal 42. Alternatively, the signal preparation unit 20 may be implemented using a direct RF solution with the signals being converted directly from digital to radio frequency to provide the RF main input signal 40 and the RF auxiliary input signal 42.

[0032] The signal preparation unit 20 may further include a pre-distortion linearizer 70. The pre-distortion linearizer 70 applies pre-distortion to the input signal 16 to compensate for or offset non-linearities causes by the non-linear operation of the enhanced amplifier 10. The feedback signal 60 may provide information for dynamically adjusting or configuring the pre-distortion linearizer 70.

[0033] In a given implementation of the enhanced amplifier 10, the location of the peak efficiency may be determined through use of a power sweep. In one example embodiment, the main and auxiliary amplifiers 12,14 may be asymmetrical in terms of maximum power rating with the main amplifier 12 having approximately 100W capability and the auxiliary amplifier 14 having approximately 200W capability. The main amplifier 12 may include LDMOS FETs and may be biased in Class AB based on a standard 28V supply and the main drain bias voltage varied from 5 to 35V. The auxiliary amplifier 14 may include LDMOS FETs and may be biased in "deep" class C (Vgs = 0.50 V) with the auxiliary drain bias voltage held at a constant 28V. As the main drain bias voltage is increased, the location of peak efficiency in back-off increases from approximately 34dBm to just above 50dBm. The magnitude of the efficiency peak in back-off increases with the increase in main drain bias voltage and the gain magnitude also increases. Maximum achievable power increases marginally as the main drain bias voltage is increased.

[0034] In another example embodiment, with the main amplifier 12 having approximately 100W capability and the auxiliary amplifier 14 having approximately 200W capability, the auxiliary drain bias voltage may be varied. In this embodiment, the main amplifier 12 may include LDMOS FETs and may be biased in Class AB and the main drain bias voltage held at a constant 28V. The auxiliary amplifier 14 may include LDMOS FETs and may be biased in "deep" class C (Vgs = 0.50 V) based on a standard 28V supply and the auxiliary drain bias voltage varied from 5 to 35V. In this case, once a certain threshold is achieved, at about 15V, gain and efficiency in back-off remain constant. The maximum achievable power increases significantly as the auxiliary amplifier drain bias voltage is increased. The location and depth of the transition trough also increase as the auxiliary amplifier drain bias voltage increases.

[0035] In another embodiment, the main and auxiliary amplifiers may be asymmetrical in terms of maximum power rating with the main amplifier 12 having approximately 100W capability and the auxiliary amplifier 14 having approximately 200W capability. The main amplifier may include LDMOS FETs and may be biased in Class AB and the main drain bias voltage held at a reduced level of 15V. The auxiliary amplifier 14 may include LDMOS FETs and may be biased in "light" class C (Vgs = 3.30V) with the auxiliary drain bias voltage held constant at an increased level of 35V. In this case, with input signal shaping, gain in back-off is held above standard Doherty levels. Reference is now made to Figure 4, which shows a graph 100 of gain versus output power and a graph 102 of efficiency versus output power. As shown in the graph 102, the location of the first efficiency peak 104 in back-off is reduced to approximately 41dbm and the magnitude of the first efficiency peak 104 in back-off is decreased to between 35-40%. The magnitude of gain during Doherty transition is held somewhat constant for an approximately 15dB range and the maximum compressed power level Pmax is increased by approximately 2dB to more than 57 dBm. In this embodiment, using components which provide typically a 7.78dB separation, a 16dB efficiency peak separation is provided without physical design variations.

[0036] In the embodiments described above and illustrated in the Figures, as the performance of the main and auxiliary amplifiers 12, 14 is varied, delay and phase variations also are introduced in the amplified signals. The output signal 18 which is created from the main amplified signal 44, main amplifier impedance transformer 22 and the auxiliary amplified signal 46 should be in phase. This may be accomplished in any way known to one skilled in the art, including, but not limited to, realigning the phasing using baseband/digital delay techniques. Baseband/digital delay techniques are intended to refer to any delay techniques that include, but are not limited to, those that digitally delay the transmission of signals. Use of baseband/digital techniques in the signal preparation unit 20 provide for dynamic control of the input signals to account for the non-linearities and variations introduced by varying the main and auxiliary bias voltage sources 12, 14. Feedback signal line 60 allows signal preparation unit 20 to monitor the signal leaving enhanced amplification unit 10, and to make adjustments to pre-distortion linearizer 70 or dual drive module 90. In some embodiments, an auxiliary path phase offset may be introduced using a suitable component (not shown). The auxiliary path phase offset may be fixed or variable.

[0037] Reference is now made to Figure 5, which shows a block diagram of a wireless network base station 130 incorporating the enhanced amplifier 144. Base station 130 is a medium to high-power multi-channel, two-way radio in a fixed location. It may typically be used by low-power, single-channel, two-way radios or wireless devices such as mobile phones, portable phones and wireless routers. Base station 130 may comprise a signal controller 132 that is coupled to a transmitter 134 and a receiver 136. Transmitter 134 and receiver 136 (or combined transceiver) is further coupled to an antenna 138. In base station 130, digital signals are processed in signal controller 132. The digital signals may be signals for a wireless communication system, such as signals that convey voice or data intended for a mobile terminal (not shown). Base station 130 may employ any suitable wireless technologies or standards such as 2G, 2.5G, 3G, GSM, IMT-2000, UMTS, iDEN, GPRS, EV-DO, EDGE, DECT, PDC, TDMA, FDMA, CDMA, W-CDMA, TD-CDMA, TD-SCDMA, GMSK, OFDM, etc. Signal controller 132 then transmits the digital signals to transmitter 134, which includes a channel processing circuitry 140. Channel processing circuitry 140 encodes each digital signal, and a radio frequency (RF) generator 142 modulates the encoded signals onto an RF signal. The RF signal is then amplified in an enhanced amplification unit 10. The resulting output signal is transmitted over antenna 138 to the mobile terminal. Antenna 138 also receives signals sent to base station 130 from the mobile terminal. Antenna 138 transmits the signals to receiver 136 that demodulates them into digital signals and transmits them to signal controller 132 where they may be relayed to an external network 146. Base station 130 may also comprise auxiliary equipment such as cooling fans or air exchangers for the removal of heat from base station 130.

[0038] In one embodiment, the enhanced amplifier 10 (Fig. 3) may be incorporated into base station 130 in lieu of parts, if not all, of blocks 142 and 144, which may decrease the capital costs and power usage of base station 130. The power amplifier efficiency measures the usable output signal power relative to the total power input. The power not used to create an output signal is typically dissipated as heat. In large systems such as base station 130, the heat generated by amplification may require cooling fans and other associated cooling equipment that may increase the cost of base station 130, require additional power, increase the overall size of the base station housing, and require frequent maintenance. Increasing the efficiency and improving control over the enhanced amplifier 10 in base station 130 may eliminate the need for some or all of the cooling equipment. Further, the supply power to enhanced amplifier 10 may be reduced since it may more efficiently be converted to a usable signal. The space and resources required to implement separate bias voltage sources 12, 14 in the enhanced amplifier 10 are offset by the control over device performance and efficiency characteristics. The physical size of base station 130 and the maintenance requirements may also be reduced due to the reduction of cooling equipment. This may enable base station 130 equipment to be moved to the top of a base station tower, allowing for shorter transmitter cable runs and reduced costs. In an embodiment, base station 130 has an operating frequency ranging from 800 MHz to 3.5 GHz.

[0039] While the enhanced amplifier has been described in conjunction with illustrated embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the scope of the invention.

Claims

1. A signal amplifier, comprising:

a signal preparation unit (20) adapted to divide an input signal (16),into a main input signal (40) and an auxiliary input signal (42), wherein the signal preparation unit (20) includes a dual drive module configured to apply signal shaping to the main input signal (40) and the auxiliary input signal (42);
a main amplifier (12) configured to receive the main input signal (40) and output an amplified main signal (44);
a main bias voltage source (30) supplying a main bias voltage (31) to the main amplifier (12);
an auxiliary amplifier (14) configured to receive the auxiliary input signal (42) and output an amplified auxiliary signal (46);
an auxiliary bias voltage source (32) supplying an auxiliary bias voltage (33) to the auxiliary amplifier (14);
a signal combiner (21) adapted to combine the amplified main signal (44) and the amplified auxiliary signal (46) into an output signal (18); and
a voltage control module (34) adapted to:

independently control the main bias voltage source (30) and the auxiliary bias voltage source (32), wherein the main bias voltage source (30) is independent from the auxiliary bias voltage source (32); and
adjust the main bias voltage (31) and the auxiliary bias voltage (33) according to one or more signal characteristics of the output signal (18);
wherein the signal preparation unit (20) is adapted to control parameters or operations in the signal preparation unit (20) according to the one or more signal characteristics of the output signal.

2. The signal amplifier claimed in claim 1, wherein the voltage control module (34) is configured to output a main control signal (35) to the main bias voltage source (30) to set the main bias e the main i voltage (31), and to output an auxiliary control signal (36) to the auxiliary bias voltage source (32) to set the auxiliary bias voltage (33).

3. The signal amplifier claimed in claim 1 or claim 2, wherein the main bias voltage (31) differs from the auxiliary bias voltage (33).

4. The signal amplifier claimed in any one of claims 1 to 3, further including a feedback path (60) to the signal preparation unit (20) for supplying the signal preparation unit (20) with the output signal (18), and wherein the signal preparation unit (20) is configured to calculate the one or more output signal characteristics.

5. The signal amplifier claimed in any one of claims 1 to 4, wherein the signal combiner (21) includes a main path phase offset impedance (22) for adjusting the phase of the amplified main signal (44).

6. The signal amplifier claimed in any one of claims 1 to 5, wherein the signal preparation unit (20) includes a pre-distortion linearizer (70).

7. The signal amplifier claimed in any one of claims 1 to 6, wherein the main amplifier (12) and auxiliary amplifier (14) comprise RF power amplifiers, wherein the output signal (18) comprises an RF signal, and wherein the signal preparation unit (20) includes a main up-converter (80) adapted to up-convert the main input signal (40) to a main RF input signal and an auxiliary up-converter (82) adapted to up-convert the auxiliary input signal (42) to an auxiliary RF input signal.

8. An RF transmitter comprising the signal amplifier claimed in any of claims 1 to 7.

9. An RF transceiver comprising the signal amplifier claimed in any of claims 1 to 7.

10. A base station for receiving and sending wireless RF communications, the base station comprising:

an RF antenna (138);
an RF transmitter (134) connected to the RF antenna (138) and configured to up-convert and amplify a transmit signal for propagation by the RF antenna (138);
an RF receiver (136) connected to the RF antenna (138) and configured to down-convert a received RF signal from the RF antenna (138); and
a signal controller (i32) with a network port for sending and receiving communications with a network (146), the signal controller (132) being connected to and controlling the RF receiver (136) and the RF transmitter (132), and
wherein the RF transmitter includes an enhanced signal amplifier, the enhanced signal amplifier comprising the signal amplifier claimed in anyone of claims 1 to 7.

11. The base station claimed in claim 10, wherein the RF transmitter and the RF transceiver are combined in a transceiver.

12. A method of amplifying an input signal, comprising:

dividing an input signal into a main input signal and an auxiliary input signal and applying signal shaping to the main input signal and the auxiliary input signal;
biasing a main amplifier with a main bias voltage from a main bias voltage supply source;
biasing an auxiliary amplifier with an auxiliary bias voltage from an auxiliary bias voltage source;
amplifying the main input signal using the main amplifier to generate an amplified main signal;
amplifying the auxiliary input signal using the auxiliary amplifier to generate an amplified auxiliary signal;
combining the amplified main signal and the amplified auxiliary signal to create an output signal; and
independently controlling the main bias voltage supply source and the auxiliary bias voltage source using a voltage control module, comprising adjusting, by the voltage control module, the main bias voltage and the auxiliary bias voltage according to one or more signal characteristics of the output signal, wherein the main bias voltage supply source is independent from the auxiliary bias voltage supply source; and
controlling parameters or operations in the signal preparation unit according to the one or more signal characteristics of the output signal.

13. The method claimed in claim 12, further comprising supplying a main control signal from the voltage control module to the main bias voltage source to set the main bias voltage, and supplying an auxiliary control signal from the voltage control module to the auxiliary bias voltage source to set the auxiliary bias voltage.

14. The method claimed in claim 12 or claim 13, wherein the main bias voltage is substantially different from the auxiliary bias voltage.

15. The method claimed in any one of claims 12 to 14, further comprising calculating the one or more signal characteristics of the output signal from the output signal.

Patentansprüche

1. Signalverstärker, umfassend:

eine Signalvorbereitungseinheit (20), die dazu eingerichtet ist, ein Eingangssignal (16) in ein Haupteingangssignal (40) und ein Hilfseingangssignal (42) aufzuteilen, wobei die Signalvorbereitungseinheit (20) ein Dualantriebsmodul umfasst, das dazu eingerichtet ist, eine Signalformung auf das Haupteingangssignal (40) und das Hilfseingangssignal (42) anzuwenden;
einen Hauptverstärker (12), der dazu eingerichtet ist, das Haupteingangssignal (40) zu empfangen und ein verstärktes Hauptsignal (44) auszugeben;
eine Hauptvorspannungsquelle (30), die dem Hauptverstärker (12) eine Hauptvorspannung (31) zuführt;
einen Hilfsverstärker (14), der dazu eingerichtet ist, das Hilfseingangssignal (42) zu empfangen und ein verstärktes Hilfssignal (46) auszugeben;
eine Hilfsvorspannungsquelle (32), die dem Hilfsverstärker (14) eine Hilfsvorspannung (33) zuführt;
einen Signalkombinierer (21), der dazu eingerichtet ist, das verstärkte Hauptsignal (44) und das verstärkte Hilfssignal (46) in ein Ausgangssignal (18) zu kombinieren; und
ein Spannungssteuerungsmodul (34), das eingerichtet ist zum:

unabhängigen Steuern der Hauptvorspannungsquelle (30) und der Hilfsvorspannungsquelle (32), wobei die Hauptvorspannungsquelle (30) von der Hilfsvorspannungsquelle (32) unabhängig ist; und
Einstellen der Hauptvorspannung (31) und der Hilfsvorspannung (33) entsprechend einem oder mehreren Signalmerkmalen des Ausgangssignals (18);
wobei die Signalvorbereitungseinheit (20) dazu eingerichtet ist, Parameter oder Vorgänge in der Signalvorbereitungseinheit (20) entsprechend dem einen oder den mehreren Signalmerkmalen des Ausgangssignals zu steuern.

2. Signalverstärker nach Anspruch 1, bei welchem das Spannungssteuerungsmodul (34) dazu eingerichtet ist, ein Hauptsteuerungssignal (35) an die Hauptvorspannungsquelle (30) auszugeben, um die Hauptvorspannung (31) einzustellen, und ein Hilfssteuerungssignal (36) an die Hilfsvorspannungsquelle (32) auszugeben, um die Hilfsvorspannung (33) einzustellen.

3. Signalverstärker nach Anspruch 1 oder Anspruch 2, bei welchem sich die Hauptvorspannung (31) von der Hilfsvorspannung (33) unterscheidet.

4. Signalverstärker nach einem der Ansprüche 1 bis 3, weiterhin umfassend einen Feedbackpfad (60) an die Signalvorbereitungseinheit (20) zum Zuführen des Ausgangssignals (18) an die Signalvorbereitungseinheit (20), und wobei die Signalvorbereitungseinheit (20) dazu eingerichtet ist, das eine oder die mehreren Ausgangssignalmerkmale zu berechnen.

5. Signalverstärker nach einem der Ansprüche 1 bis 4, bei welchem der Signalkombinierer (21) eine Hauptpfadphasenverschiebungsimpedanz (22) zum Einstellen der Phase des verstärkten Hauptsignals (44) umfasst.

6. Signalverstärker nach einem der Ansprüche 1 bis 5, bei welchem die Signalvorbereitungseinheit (20) einen Vorverzerrungslinearisierer (70) umfasst.

7. Signalverstärker nach einem der Ansprüche 1 bis 6, bei welchem der Hauptverstärker (12) und der Hilfsverstärker (14) HF-Leistungsverstärker umfassen, wobei das Ausgangssignal (18) ein HF-Signal umfasst, und wobei die Signalvorbereitungseinheit (20) einen Haupthochkonvertier (80), der dazu eingerichtet ist, das Haupteingangssignal (40) in ein Haupt-HF-Eingangssignal hochzukonvertieren, und einen Hilfshochkonvertier (82) umfasst, der dazu eingerichtet ist, das Hilfseingangssignal (42) in ein Hilfs-HF-Eingangssignal hochzukonvertieren.

8. HF-Sender umfassend den Signalverstärker nach einem der Ansprüche 1 bis 7.

9. HF-Sende-Empfänger umfassend den Signalverstärker nach einem der Ansprüche 1 bis 7.

10. Basisstation zum Empfangen und Senden von drahtlosen HF-Kommunikationen, wobei die Basisstation Folgendes umfasst:

eine HF-Antenne (138);
einen HF-Sender (134), der mit der HF-Antenne (138) verbunden und dazu eingerichtet ist, ein Sendesignal zur Ausbreitung durch die HF-Antenne (138) hochzukonvertieren und zu verstärken;
einen HF-Empfänger (136), der mit der HF-Antenne (138) verbunden und dazu eingerichtet ist, ein empfangenes HF- Signal von der HF-Antenne (138) herunterzukonvertieren; und
eine Signalsteuerung (132) mit einem Netzwerkanschluss zum Senden und Empfangen von Kommunikationen mit einem Netzwerk (146), wobei die Signalsteuerung (132) mit dem HF-Empfänger (136) und dem HF-Sender (132) verbunden ist und sie steuert; und
wobei der HF-Sender einen erweiterten Signalverstärker umfasst, wobei der erweiterte Signalverstärker den Signalverstärker nach einem der Ansprüche 1 bis 7 umfasst.

11. Basisstation nach Anspruch 10, bei welcher der HF-Sender und der HF-Sende-Empfänger in einem Sende-Empfänger kombiniert sind.

12. Verfahren zum Verstärken eines Eingangssignals, umfassend:

Aufteilen eines Eingangssignals in ein Haupteingangssignal und ein Hilfseingangssignal und Anwenden einer Signalformung auf das Haupteingangssignal und das Hilfseingangssignal;
Vorspannen eines Hauptverstärkers mit einer Hauptvorspannung von einer Hauptvorspannungszuführungsquelle;
Vorspannen eines Hilfsverstärkers mit einer Hilfsvorspannung von einer Hilfsvorspannungsquelle;
Verstärken des Haupteingangssignals mittels des Hauptverstärkers, um ein verstärktes Hauptsignal zu erzeugen;
Verstärken des Hilfseingangssignals mittels des Hilfsverstärkers, um ein verstärktes Hilfssignal zu erzeugen;
Kombinieren des verstärkten Hauptsignals und des verstärkten Hilfssignals, um ein Ausgangs-

signal zu erzeugen; und
unabhängiges Steuern der Hauptvorspannungszuführungsquelle und der Hilfsvorspannungsquelle mittels eines Spannungssteuerungsmoduls, umfassend das Einstellen, durch das Spannungssteuerungsmodul, der Hauptvorspannung und der Hilfsvorspannung entsprechend einem oder mehreren Signalmerkmalen des Ausgangssignals, wobei die Hauptvorspannungszuführungsquelle von der Hilfsvorspannungszuführungsquelle unabhängig ist; und Steuern von Parametern oder Vorgängen in der Signalvorbereitungseinheit entsprechend dem einen oder den mehreren Signalmerkmalen des Ausgangssignals.

13. Verfahren nach Anspruch 12, weiterhin umfassend das Zuführen eines Hauptsteuerungssignals vom Spannungssteuerungsmodul an die Hauptvorspannungsquelle, um die Hauptvorspannung einzustellen, und Zuführen eines Hilfssteuerungssignals vom Spannungssteuerungsmodul an die Hilfsvorspannungsquelle, um die Hilfsvorspannung einzustellen.

14. Verfahren nach Anspruch 12 oder Anspruch 13, bei welchem die Hauptvorspannung sich wesentlich von der Hilfsvorspannung unterscheidet.

15. Verfahren nach einem der Ansprüche 12 bis 14, weiterhin umfassend das Berechnen des einen oder der mehreren Signalmerkmale des Ausgangssignals aus dem Ausgangssignal.

Revendications

1. Un amplificateur de signal, comprenant :

une unité de préparation de signal (20) apte à diviser un signal d'entrée (16) en un signal d'entrée principal (40) et un signal d'entrée auxiliaire (42), l'unité de préparation de signal (20) comprenant un module de pilotage double configuré pour appliquer une conformation de signal au signal d'entrée principal (40) et au signal d'entrée auxiliaire (42) ;
un amplificateur principal (12) configuré pour recevoir le signal d'entrée principal (40) et délivrer en sortie un signal principal amplifié (44) ;
une source de tension de polarisation principale (30) délivrant une tension de polarisation principale (31) à l'amplificateur principal (12) ;
un amplificateur auxiliaire (14) configuré pour recevoir le signal d'entrée auxiliaire (42) et délivrer en sortie un signal auxiliaire amplifié (46) ;
une source de tension de polarisation auxiliaire (32) délivrant une tension de polarisation auxiliaire (33) à l'amplificateur auxiliaire (14) ;
un combineur de signaux (21) apte à combiner le signal principal amplifié (44) et le signal auxiliaire amplifié (46) en un signal de sortie (18) ; et
un module de contrôle de tension (34) apte à :

contrôler indépendamment la source de tension de polarisation principale (30) et la source de tension de polarisation auxiliaire (32), la source de tension de polarisation principale (30) étant indépendante de la source de tension de polarisation auxiliaire (32) ; et
ajuster la tension de polarisation principale (31) et la tension de polarisation auxiliaire (33) en fonction d'une ou plusieurs caractéristiques de signal du signal de sortie (18) ;
dans lequel l'unité de préparation de signal (20) est apte à contrôler les paramètres des opérations de l'unité de préparation de signal (20) en fonction des une ou plusieurs caractéristiques de signal du signal de sortie.

2. L'amplificateur de signal de la revendication 1, dans lequel le module de contrôle de tension (34) est configuré pour délivrer en sortie un signal de contrôle principal (35) à la source de tension de polarisation principale (30) pour régler la tension de polarisation principale (31), et pour délivrer en sortie un signal de contrôle auxiliaire (36) à la source de tension de polarisation auxiliaire (32) pour régler la tension de polarisation auxiliaire (33).

3. L'amplificateur de signal selon la revendication 1 ou la revendication 2, dans lequel la tension de polarisation principale (31) est différente de la tension de polarisation auxiliaire (33).

4. L'amplificateur de signal de l'une des revendications 1 à 3, comprenant en outre un trajet de rétroaction (60) vers l'unité de préparation de signal (20) pour délivrer à l'unité de préparation de signal (20) le signal de sortie (18), et dans lequel l'unité de préparation de signal (20) est configurée pour calculer les une ou plusieurs caractéristiques du signal de sortie.

5. L'amplificateur de signal de l'une des revendications 1 à 4, dans lequel le combineur de signaux (21) comprend une impédance de déphasage de trajet principal (22) pour ajuster la phase du signal principal amplifié (44).

6. L'amplificateur de signal de l'une des revendications 1 à 5, dans lequel l'unité de préparation de signal (20) comprend un linéariseur de prédistorsion (70).

7. L'amplificateur de signal de l'une des revendications

1 à 6, dans lequel l'amplificateur principal (12) et l'amplificateur auxiliaire (14) comprennent des amplificateurs de puissance RF, dans lequel le signal de sortie (18) comprend un signal RF, et dans lequel l'unité de préparation de signal (20) comprend un convertisseur élévateur principal (80) apte à convertir le signal d'entrée principal (40) en l'élevant en un signal d'entrée RF principal et un convertisseur élévateur auxiliaire (82) apte à convertir le signal d'entrée auxiliaire (42) en l'élevant en un signal d'entrée RF auxiliaire.

8. Un émetteur RF comprenant l'amplificateur de signal de l'une des revendications 1 à 7.

9. Un émetteur/récepteur RF comprenant l'amplificateur de signal de l'une des revendications 1 à 7.

10. Une station de base pour recevoir et envoyer des communications RF sans fil, la station de base comprenant :

une antenne RF (138) ;
un émetteur RF (134) relié à l'antenne RF (138) et configuré pour convertir en l'élevant et amplifier un signal d'émission pour qu'il soit propagé par l'antenne RF (138) ;
un récepteur RF (136) relié à l'antenne RF (138) et configuré pour convertir en l'abaissant un signal RF reçu en provenance de l'antenne RF (138) ; et
un contrôleur de signal (132) avec un port réseau pour envoyer et recevoir des communications avec un réseau (146), le contrôleur de signal (132) étant relié au récepteur RF (136) et à l'émetteur RF (132) et les contrôlant, et
dans laquelle l'émetteur RF comprend un amplificateur de signal renforcé, l'amplificateur de signal renforcé comprenant l'amplificateur de signal de l'une des revendications 1 à 7.

11. La station de base de la revendication 10, dans laquelle l'émetteur RF et l'émetteur/récepteur RF sont combinés en un émetteur/récepteur.

12. Un procédé d'amplification d'un signal d'entrée, comprenant :

la division d'un signal d'entrée en un signal d'entrée principal et un signal d'entrée auxiliaire et l'application d'une conformation de signal au signal d'entrée principal et au signal d'entrée auxiliaire ;
la polarisation d'un amplificateur principal avec une tension de polarisation principale provenant d'une source d'alimentation en tension de polarisation principale ;
la polarisation d'un amplificateur auxiliaire avec une tension de polarisation auxiliaire provenant d'une source de tension de polarisation auxiliaire ;
l'amplification du signal d'entrée principal en utilisant l'amplificateur principal pour générer un signal principal amplifié ;
l'amplification du signal d'entrée auxiliaire en utilisant l'amplificateur auxiliaire pour générer un signal auxiliaire amplifié ;
la combinaison du signal principal amplifié et du signal auxiliaire amplifié pour créer un signal de sortie ; et
le contrôle indépendant de la source d'alimentation de tension de polarisation principale et de la source de tension de polarisation auxiliaire en utilisant un module de contrôle de tension, comprenant l'ajustement, par le module de contrôle de tension, de la tension de polarisation principale et de la tension de polarisation auxiliaire en fonction d'une ou plusieurs caractéristiques de signal du signal de sortie, la source d'alimentation en tension de polarisation principale étant indépendante de la source d'alimentation de tension de polarisation auxiliaire ; et
le contrôle de paramètres ou d'opérations dans l'unité de préparation de signal en fonction des une ou plusieurs caractéristiques de signal du signal de sortie.

13. Le procédé de la revendication 12, comprenant en outre la délivrance d'un signal de contrôle principal du module de contrôle de tension vers la source de tension de polarisation principale pour ajuster la tension de polarisation principale, et la délivrance d'un signal de contrôle auxiliaire du module de contrôle de tension à la source de tension de polarisation auxiliaire pour ajuster la tension de polarisation auxiliaire.

14. Le procédé de la revendication 12 ou de la revendication 13, dans lequel la tension de polarisation principale est substantiellement différente de la tension de polarisation auxiliaire.

15. Le procédé de l'une des revendications 12 à 14, comprenant en outre le calcul des une ou plusieurs caractéristiques de signal du signal de sortie à partir du signal de sortie.

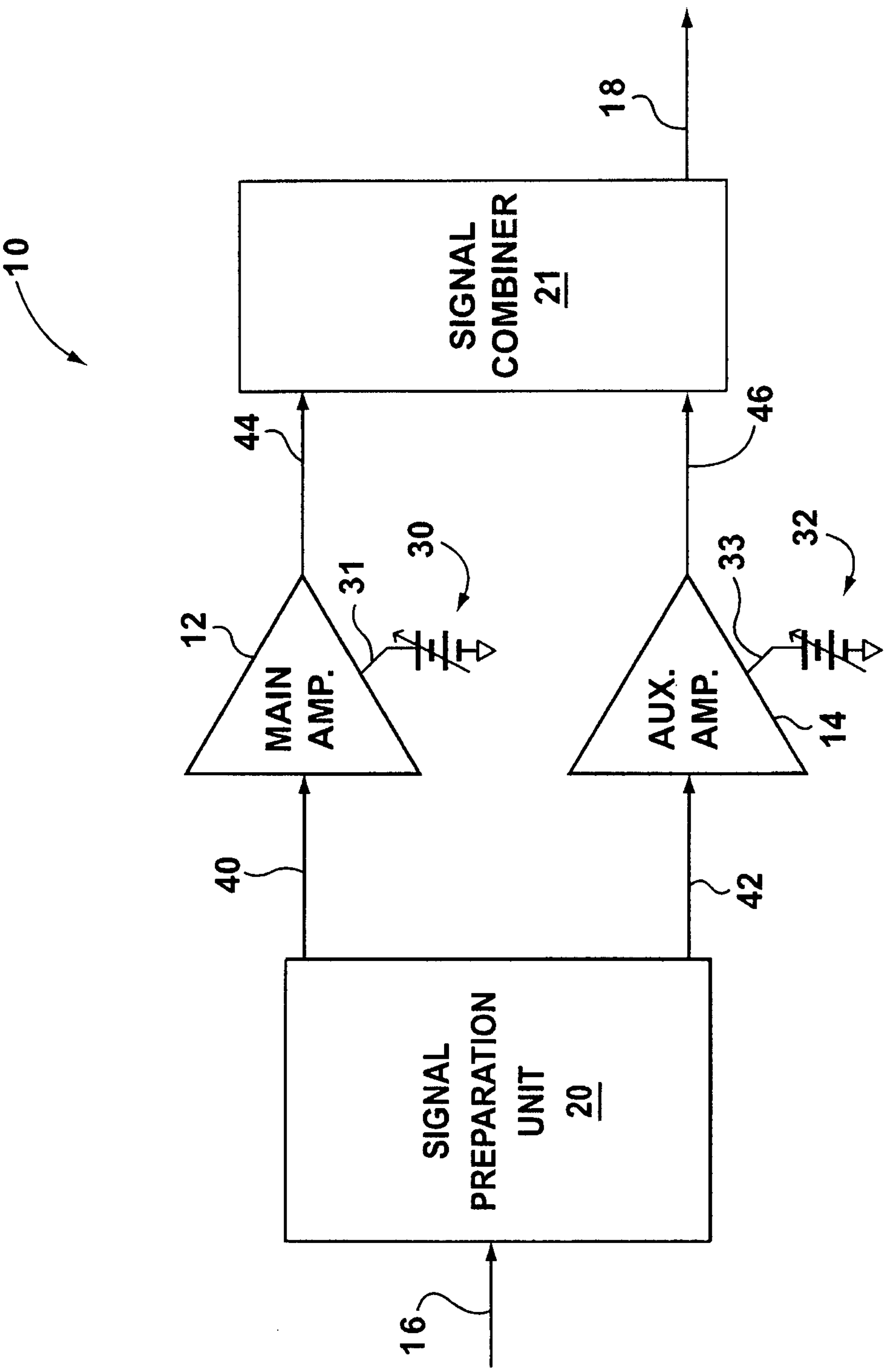
10
SIGNAL PREPARATION UNIT 20
SIGNAL COMBINER 21
MAIN AMP.
AUX. AMP.
12
14
16
18
30
31
32
33
40
42
44
46

FIG. 1

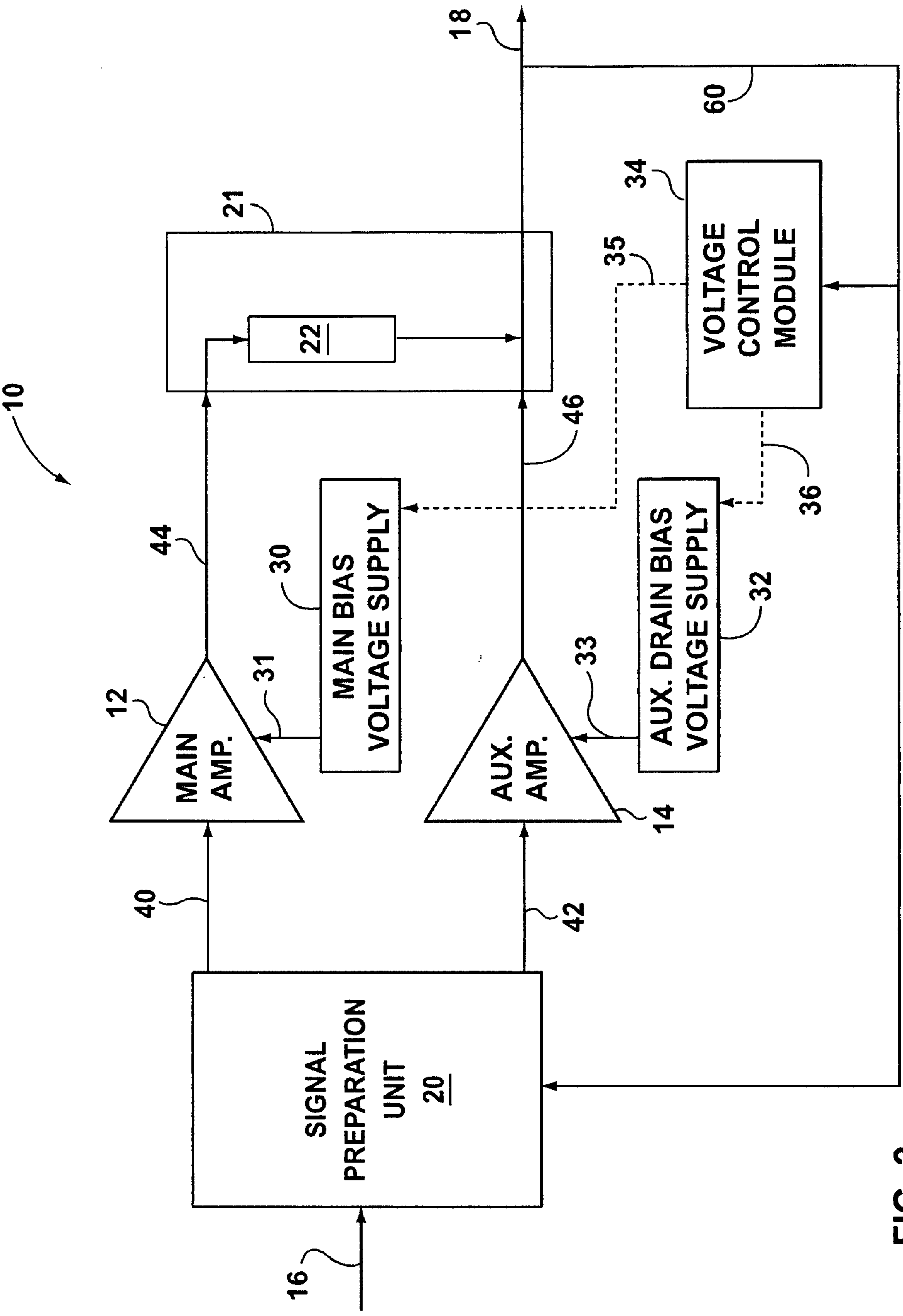
10
SIGNAL
PREPARATION
UNIT
20
MAIN
AMP.
AUX.
AMP.
MAIN BIAS
VOLTAGE SUPPLY
AUX. DRAIN BIAS
VOLTAGE SUPPLY
VOLTAGE
CONTROL
MODULE
22
12
14
16
18
21
30
31
32
33
34
35
36
40
42
44
46
60

FIG. 2

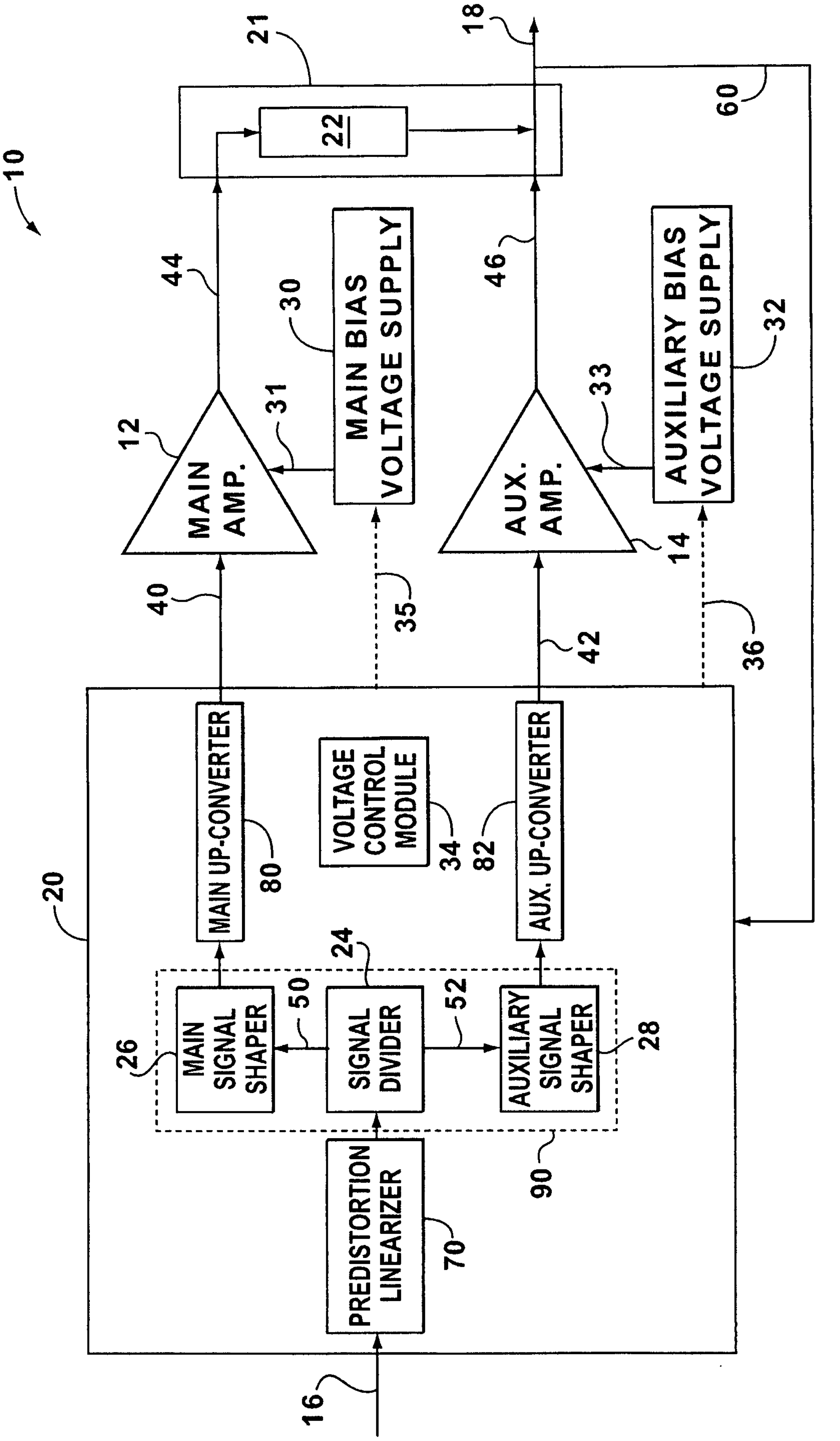
10
20
21
22
18
60
44
46
30
MAIN BIAS VOLTAGE SUPPLY
31
12
MAIN AMP.
40
35
AUX. AMP.
14
33
AUXILIARY BIAS VOLTAGE SUPPLY
32
42
36
MAIN UP-CONVERTER
80
VOLTAGE CONTROL MODULE
34
AUX. UP-CONVERTER
82
MAIN SIGNAL SHAPER
26
50
SIGNAL DIVIDER
24
52
AUXILIARY SIGNAL SHAPER
28
90
PREDISTORTION LINEARIZER
70
16

FIG. 3

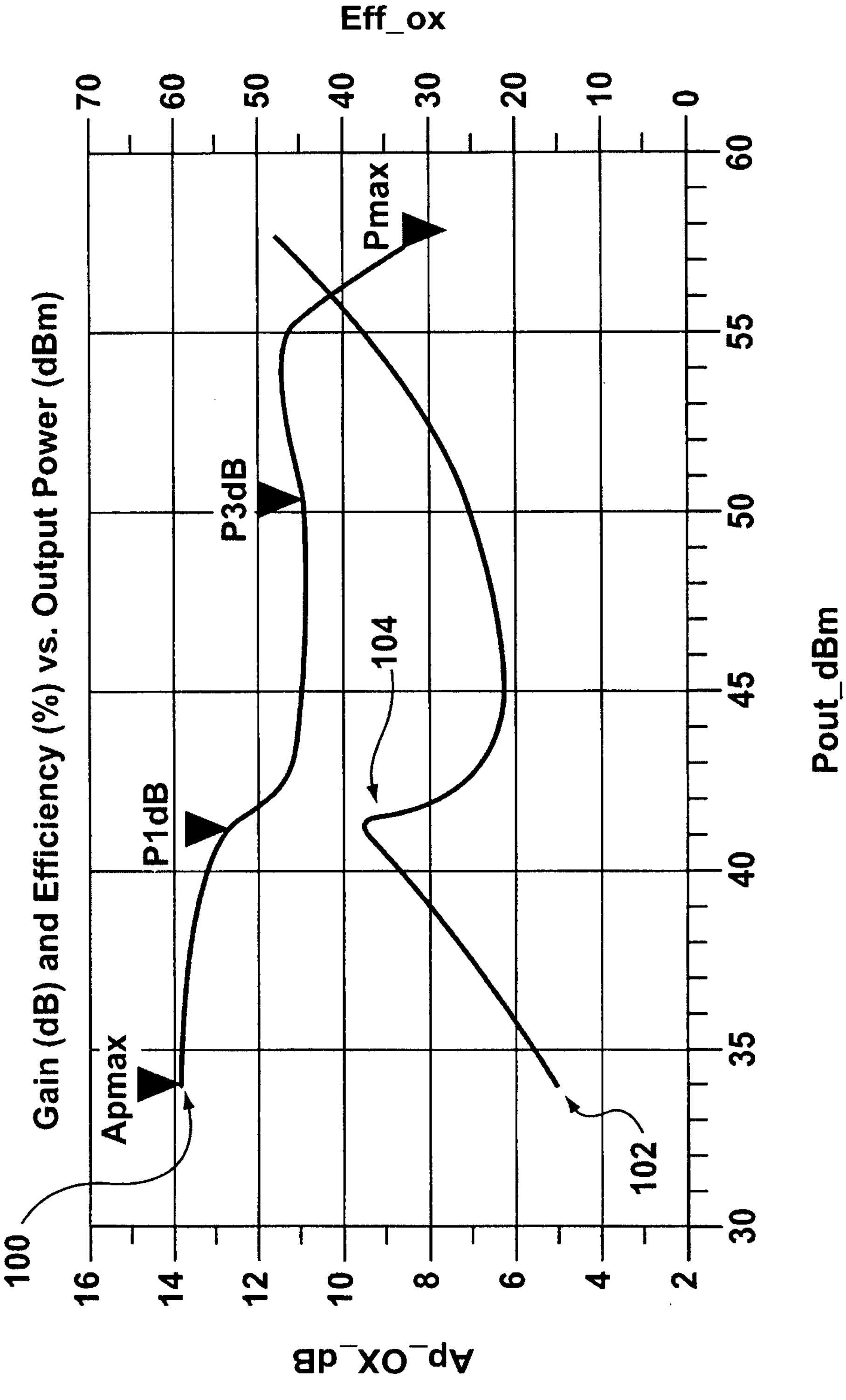
Gain (dB) and Efficiency (%) vs. Output Power (dBm)
Eff_ox
Ap_OX_dB
Pout_dBm
70
60
50
40
30
20
10
0
16
14
12
10
8
6
4
2
30
35
40
45
50
55
60
Apmax
P1dB
P3dB
Pmax
100
102
104

FIG. 4

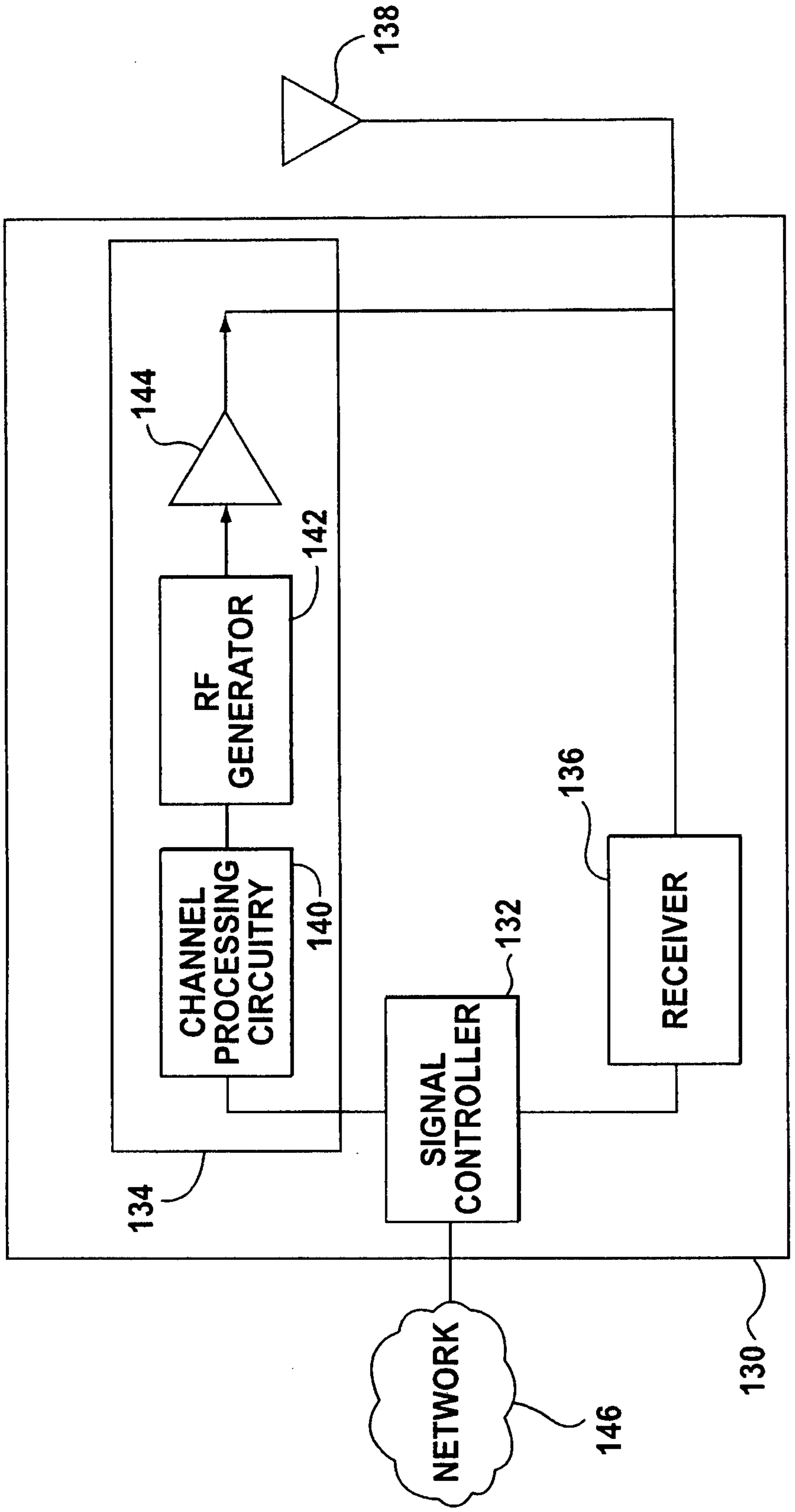
138
144
142
RF GENERATOR
CHANNEL PROCESSING CIRCUITRY
140
136
RECEIVER
132
SIGNAL CONTROLLER
134
130
NETWORK
146

FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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