

ERROR PATH CONTROL FOR FEED-FORWARD AMPLIFIER

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FIELD OF THE INVENTION

10 The present invention relates generally to feed-forward amplifiers and more particularly, to controlling an error path in a feed-forward amplifier.

BACKGROUND OF THE INVENTION

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The methods used to tune the error path in feed-forward amplifiers have limitations imposed by the dynamic range of the detector used to form the basis for controlling the error path. For example, in the
20 conventional pilot tone approach, the input level to the pilot tone receiver must be maintained at a sufficiently low level to ensure that the IM generated in the pilot tone receiver is below that of the corrected LPA. While this is not very difficult to overcome in relaxed intermodulation (IM)
25 product environments, strict IM products requirements can present a more difficult problem.

One method to solve this problem is to provide a direct analog-to-digital (A/D) conversion of the output signal and use signal processing techniques to determine
30 which "spurs" are IM products. Such a prior art feed-forward amplifier is shown in FIG. 1. Referring to FIG. 1, a signal 101 is input into a radio frequency (RF) coupler 103 which has as an output a signal entering a main gain/phase control block 106. Output from the block 106 is input into a
35 main amp 109 which has an output into another RF coupler

112. In the preferred embodiment, the main amp 109 is a Class AB amplifier as is well known in the art. The main gain/phase control block 106 and the main amp 109 generally comprise a main path 107 for the signal 101 to propagate.

Also output from the RF coupler 103 is a signal which enters a main delay block 115. The amount of time delay presented by the main delay block 115 is approximately equal to the amount of time delay the input signal 101 experiences as it propagates through the main path 107. The signal exiting the main delay block 115 enters RF coupler 118. Also input into RF coupler 118 is an output from RF coupler 112. Since each signal entering RF coupler 118 is substantially in phase, the main signal component in each of the input signals will be canceled, thus leaving (theoretically) only an error signal 119 exiting the RF coupler 118.

The error signal 119 exiting the RF coupler 118 is input into an error path 123 which generally comprises an error gain/phase control 121 and an error amplifier 124. In the preferred embodiment, the error amp 124 is a Class A amplifier as is well known in the art. The error gain/phase control block 121 provides fine tune adjustment of both the gain and the phase of the error signal 119 exiting the RF coupler 118. Exiting the error amp 124 is thus an error signal which has been gain and phase controlled by a controller 137. In this prior art implementation, the controller 137 includes a down converter 139 and an analog-to-digital (A/D) 136.

The signal exiting the RF coupler 127 is a signal which contains both a main signal component and an error component, and this signal is input into an error delay block 127 which provides a time delay which is substantially equal to the time delay the error signal 119 experiences as it

propagates through the error path 123. The signal exiting the error delay block 127 is input into the RF coupler 130, as is the gain and phase controlled error signal exiting the error amplifier 124. Again, since each signal entering the RF coupler 130 is in phase, the two signals entering the RF coupler 130 will be combined such that the error signal is substantially canceled. Thus, the signal 131 exiting the RF coupler 130 has (theoretically) only the main component of the original input signal therein. Signal 131 is input into the RF coupler 133 which provides not only the eventual output signal but also a signal 134 used by the controller 137 to eventually control the error path 123.

One of the biggest problems with the above-described approach is that a high dynamic range A/D converter 136 to control the error path 123 is required. For example, if signal 134 has a 70 dB dynamic range, the A/D converter 136 must be a minimum of a 12-bit A/D converter. To be capable of digitizing entire cellular bands, such a 12-bit A/D converter would have to operate at a very high sampling rate to digitize the entire bandwidth. Another problem with this approach is that the down conversion process would also be required to have IM performance more than the desired IM performance of the overall feed-forward LPA - typically -60 dBc IM performance for the AMPS cellular band.

Thus, a need exists for a improved method and apparatus for controlling an error path in a feed-forward amplifier with a reduce dynamic range requirement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 generally depicts a prior art feed-forward amplifier.

5 FIG. 2 generally depicts a feed-forward amplifier having improved error path control in accordance with the invention.

10 FIG. 3 generally depicts an alternate embodiment of a feed-forward amplifier having improved error path control in accordance with the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

15 A feed-forward amplifier bases control of an error path within the feed-forward amplifier on an output signal after performing carrier cancellation to remove the carrier signal. The feed-forward amplifier implements couplers, a carrier cancellation gain/phase control block and a carrier
20 cancellation delay block to cancel the carrier signal. By basing the control of the error path on a signal without the carrier signal, controlling of the error path does not suffer from the effects of high dynamic range presented by the carrier signal, thus improving overall control of the feed-
25 forward amplifier.

 Stated generally, a method of controlling an error path in a feed-forward amplifier is disclosed. The feed-forward amplifier includes both a main path and the error path and amplifies a carrier signal for transmission to a
30 destination. By first canceling the carrier signal and then controlling the error path of the feed-forward amplifier based on the canceled carrier output signal, control of the feed-forward amplifier is improved.

FIG. 2 generally depicts a feed-forward amplifier 200 having improved error path control in accordance with the invention. FIG. 2 has a substantial number of blocks in common with FIG. 1, and thus like blocks are identified with like numerals. Different from FIG. 1 is the addition of a means for canceling 207 the carrier signal, such means including the RF coupler 203, a carrier cancellation gain/phase control block 206, a carrier cancellation block 209 and another RF coupler 212.

10 Note that in FIG. 2, the signal coupled off of the RF coupler 133 is not directly input into the means for controlling 216, but is instead input into the RF coupler 212. Via the RF coupler 203 in combination with the carrier cancellation gain/phase control block 206 and the carrier cancellation delay block 209, the signal 219 exiting the RF coupler 212 does not have the main component of the input signal (i.e., the carrier signal) therein. In fact, the signal exiting the RF coupler 212 has only an error signal therein.

15 Since the main component of the input signal, which had the wide dynamic range, is no longer utilized for controlling the error path 123, the means for controlling 216 of FIG. 2 no longer suffers from the effects of a wide dynamic control signal as in the prior art. When the signal exiting the RF coupler 212 is input into the down converter 218 and the A/D 215, no adverse effects due to the control signal (in this case, signal 219) are experienced. As such, A/D converter 215 can be implemented as a much smaller A/D converter. For a -60 dBc type AMPS amplifier, an 8-bit converter can thus be implemented to provide improved control of the error path in accordance with the invention.

20 FIG. 3 generally depicts an alternate embodiment of a feed-forward amplifier having improved error path control in accordance with the invention. As shown in FIG. 3, a switchable attenuator 303 is implemented to disable the

means for canceling 207 from the circuitry, thus allowing for easy identification of the desired carrier frequencies. By disabling the means for canceling 207 and switching the attenuator 303 via the switch 306, the desired carriers will
5 be much larger than the IM products and thus easily identifiable for use in subsequent intermodulation (IM) product determination. With this information, the location of the undesired IM products are then determined to aid in their identification when the means for canceling 207 is
10 enabled back into the feed-forward amplifier 300 during normal operation.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various
15 changes in form and details may be made therein without departing from the spirit and scope of the invention. In fact, the invention can be implemented with virtually any error path control method that uses the error portion of the output signal, including methods that do not digitize the
20 output signal with an A/D converter as described above. The corresponding structures, materials, acts and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or acts for performing the functions in
25 combination with other claimed elements as specifically claimed.

Claims



1. A method of improving error path control in a feed-forward amplifier, the feed-forward amplifier having a
5 main path and the error path and amplifying a carrier signal for transmission to a destination, the method comprising the steps of:

canceling the carrier signal from a signal output from
10 the feed-forward amplifier to produce a control signal; and
controlling the error path of the feed-forward amplifier based on the control signal.
2. The method of claim 1, wherein the step of controlling
15 the error path further comprises controlling the amplitude and phase of an input error signal.



3. An apparatus for improving error path control in a feed-forward amplifier, the feed-forward amplifier having a main path and the error path and amplifying a carrier signal for transmission to a destination, the apparatus
5 comprising:

means for canceling the carrier signal from a signal output from the feed-forward amplifier to produce a control signal; and

10 means for controlling the error path of the feed-forward amplifier based on the control signal.

4. The apparatus of claim 3, wherein the means for canceling the carrier signal further comprises, in series, a
15 first radio frequency (RF) coupler, a carrier cancellation gain/phase control block, a carrier cancellation delay block and a second RF coupler.

5. The apparatus of claim 3, wherein the means for
20 controlling the error path of the feed-forward amplifier based on the control signal further comprises a downconverter and an analog-to-digital (A/D) converter.

6. The apparatus of claim 5, wherein the analog-to-
25 digital (A/D) converter further comprises, at most, an 8-bit analog-to-digital (A/D) converter.



7. A feed-forward amplifier for use in a wireless communication system, the feed-forward amplifier comprising:

5 a main path for amplifying an input signal having a carrier signal and an error signal;

an error path, coupled to the main path, for adjusting the error signal;

10 a carrier cancellation block, having as an input a signal output from the feed-forward amplifier, for canceling the carrier signal from the signal output from the feed-forward amplifier to produce a control signal; and

a controller, coupled to the carrier cancellation block, for controlling the error path utilizing the control signal.

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8. The feed-forward amplifier of claim 7, wherein the controller for controlling the error path further comprises a controller for controlling the amplitude and phase of an error signal input into the error path.

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9. The feed-forward amplifier of claim 7, wherein the controller further comprises a downconverter and an analog-to-digital (A/D) converter having, at most, 8-bit resolution.



10. A feed-forward amplifier for use in a wireless communication system, the feed-forward amplifier comprising:

- 5 a main path for amplifying an input signal having a carrier signal and an error signal;
 - an error path, coupled to the main path, for adjusting the error signal;
 - a carrier cancellation block for canceling the carrier
- 10 signal from a signal output from the feed-forward amplifier to produce a control signal;
 - a switch, having as inputs the signal output from the feed-forward amplifier and the control signal, for disabling the carrier cancellation block to aid in identification of the
- 15 carrier for subsequent intermodulation (IM) product determination and for enabling the carrier cancellation block to aid in control of the error path; and
 - a controller for controlling the error path utilizing the control signal when the carrier cancellation block is enabled
- 20 by the switch.