Cross Post-distortion Balanced Power Amplifier

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***Abstract* — In this paper, we propose a new distortion cancellation mechanism for a balanced power amplifier (BPA) structure using the carrier cancellation loop of a feedforward (FFW) and post-distortion (PoD) technique. We use the distortion generated within a portion of a BPA to cancel the distortion generated within the whole BPA. Samples of the signal and distortion from one part of the BPA are combined with a reference signal, and then those signals destructively combine to generate the error signal. When the error signal is injected into the output of another part of the BPA with the gain and phase control, the distortion generated by both part of the BPA are cancelled. The operating frequency bands of the implemented cross PoD BPA is the IMT-2000 (f_0=2.14GHz) band. With the commercial high power amplifier of 240W PEP for base-station application, the adjacent channel leakage ratio (ACLR) measurement with WCDMA 4FA signal shows 18.6dB improvement at an average output power of 40dBm.**

***Index Terms* — Linearization, post-distortion, balanced amplifier.**

I. INTRODUCTION

High power amplifiers (HPA) are the most important devices in mobile communication systems, specifically for base-station applications. Balanced power amplifiers are a basic structure to obtaining high output power and stable isolation characteristics. However, HPA presents nonlinearities generating amplitude and phase distortions on the PA output signal due to the non-constant envelope modulations used to achieve better spectral efficiency. There are many linearization techniques to satisfy the rigid linearity requirement of the base-station HPA. Feedforward is one of the most widely used techniques with excellent linearity improvement, and its signal cancellation mechanism has been used for various applications [1]-[4]. Post-distortion is another way of distortion cancellation by injecting error signals into the output of a PA.

In this paper, we propose a new distortion cancellation mechanism in a balanced power amplifier (BPA) structure using the carrier cancellation loop of a feedforward (FFW) and post-distortion (PoD) technique. To provide the experimental verification, we implemented the cross PoD BPA, and showed the loop cancellation with ACLR improvements.

II. DESIGN OF A CROSS POST-DISTORTION BALANCED POWER AMPLIFIER

A. Circuit Configuration and Theory of Operation

A conventional 2-way BPA structure is shown in Fig. 1. Two transistors are combined in parallel with a power divider and combiner. This structure is commonly used when higher output power is needed. Since the two transistors or PA's normally have identical electrical characteristics, we conclude that the samples of the distortion signal generated from PA1 can be used to cancel the distortion generated by both part of the BPA when it is injected into the output of PA2.

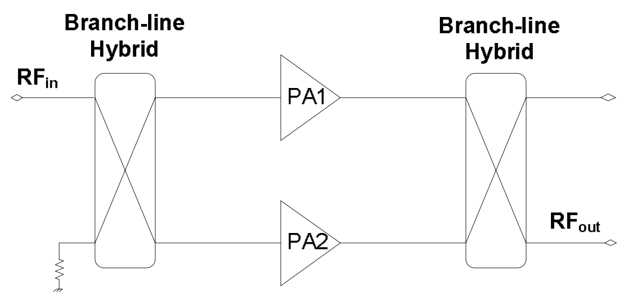

Fig.1. Conventional balanced power amplifier structure.

Fig. 2 shows the simplified block diagram of the proposed cross PoD BPA. It consists of three major loops: the carrier cancellation loop (1st loop), the balanced power amplifier loop (2nd loop), and an error-signal injection loop (3rd loop). The carrier cancellation loop extracts the error signal from the amplified signal generated at the output of PA1. The balanced power amplifier loop amplifies the input signal and generates output power. The error-signal injection loop receives distortion signals from the 1st loop, and injects these distortion signals into the output of PA2 after adequate gain and phase adjustment.

The main advantage of this structure is that we do not need any error signal generation circuit such as predistorter (PD), because PD has limitation in predicting the transfer function of a target PA resulting in the degradation of linearization performance. Also, due to the fact that two PAs have same nonlinearity, perfect distortion cancellation is possible.

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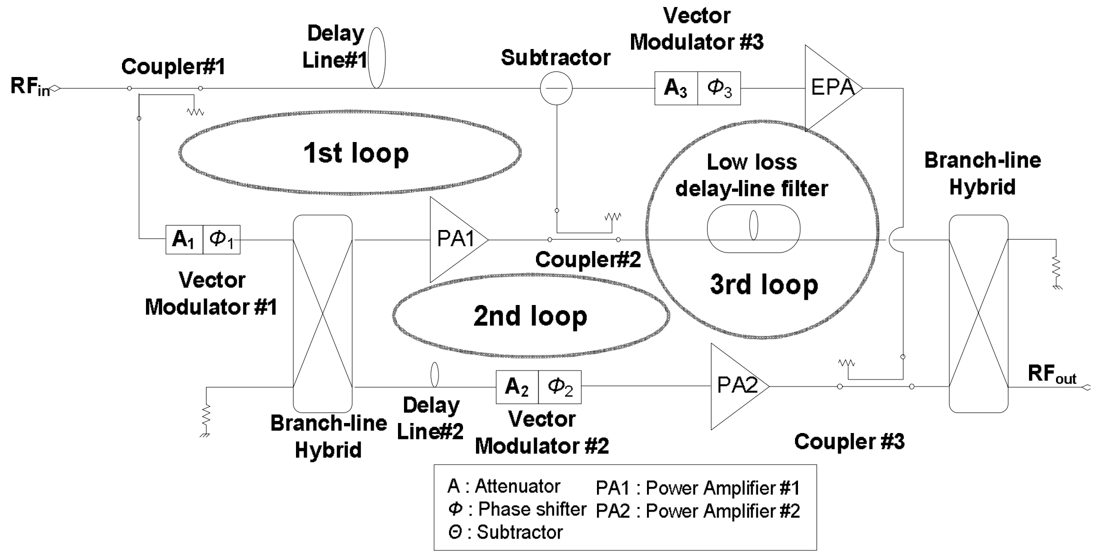


Fig. 2. Block diagram of the proposed cross post-distortion balanced power amplifier.

Moreover, because of the structural similarity with feedforward technique, this configuration would have linearity improvement through wide dynamic range. As compared with a feedforward technique which has a lossy delay-line filter at the output of a main PA introducing considerable power loss, the proposed cross PoD BPA has a lossy delay-line filter only at the output of one part of a BPA structure, reducing the total output power loss considerably.

B. Carrier Cancellation Loop (1st loop)

Fig. 3 shows the error-signal generation procedure of a carrier cancellation loop. Some portion of the input signal is then coupled to the PA1 path through coupler #1, and the other portion is transmitted through delay line #1 as a reference signal. Delay line #1 compensates time delay due to PA1 and vector modulator #1. The output of PA1 has carrier signal with distortion generated by the nonlinearity of PA1. When this output signal is destructively combined with the reference signal, the only signal remaining as an error signal is the distortion signal. To achieve perfect signal cancellation, group delay matching is critical, as well as amplitude and phase matching. We designed an equal group delay signal canceller to obtain broadband signal cancellation [5].

C. Balanced Power Amplifier Loop (2nd loop)

Fig. 4 shows the balanced power amplifier loop. A low loss delay-line filter at the output of PA1 is used to compensate for the time delay due to the error power amplifier (EPA) from the 3rd loop, where we should compensate the PA2 path with delay-line #2 to maintain the balance of two paths. A small signal amplifier is needed because vector modulator #2 has some insertion loss at the center of variation range. At the isolation port of a BPA, denoted as signal cancellation port, we can monitor the balance of a BPA loop.

C. Error Signal Injection Loop (3rd loop)

An error-signal injection loop is shown in Fig.5. The gain and the phase of an error signal generated at the 1st loop are adjusted with the vector modulator #3 and EPA so that it can cancel the distortion components generated by both PA's of BPA structure when injected into the output of PA2. The error signal injected into the output of PA2 cancels not only the distortion generated from the PA2, but also the distortion from PA1 at the output port of a BPA, denoted as RF_{out}. Thus, we cannot measure the loop cancellation of the 3rd loop.

The power capability of an EPA should be high enough not to generate any additional nonlinearity for itself. The output of an EPA, denoted as "A", is connected to the output of PA2 through coupler #3.

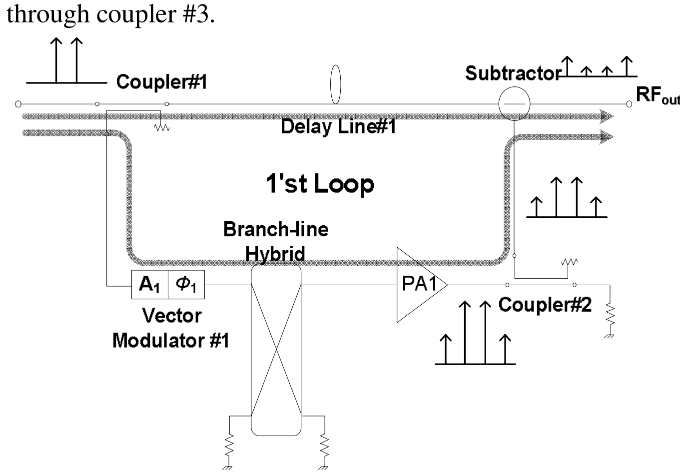


Fig. 3. Carrier cancellation loop.

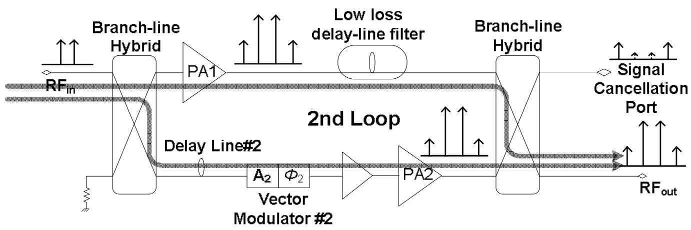


Fig. 4. Balanced power amplifier loop.

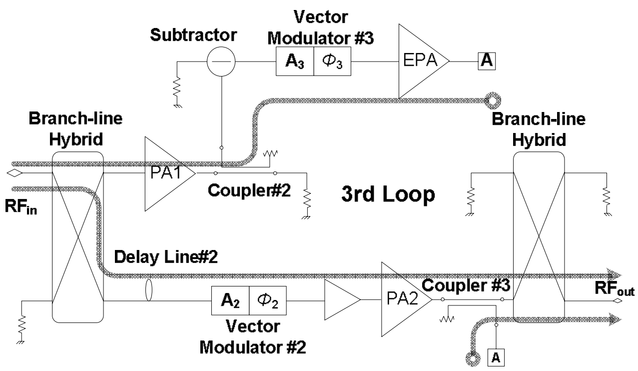


Fig. 5. Error signal injection loop.

III. Implementation and Measurements

To prove the validity of the proposed configuration, we implemented cross PoD BPA for IMT-2000 band and measured the performance of the implemented linearization system with the commercial power amplifiers of 120W PEP for base-station. PA's used in this configuration were STA2100 series commercial base-station power amplifier of 120W PEP of Sewon Teletech, Inc.

Fig. 6(a) shows the loop suppression result of the 1st loop measured with network analyzer. An equal group delay signal canceller cancels input signal more than 23dB for 2.11~2.17GHz. Bandwidth of signal cancellation could be broader than the result shown here since the operation bandwidth of the PA is limited to 60MHz in this case. Fig. 6(b) shows the loop suppression result of the BPA loop monitored at the signal cancellation port (isolation port of a BPA) with a network analyzer. It shows over 28dB cancellation for 2.11~2.17GHz. From the result, we can conclude that the BPA loop is well-balanced and operates as a balanced power amplifier.

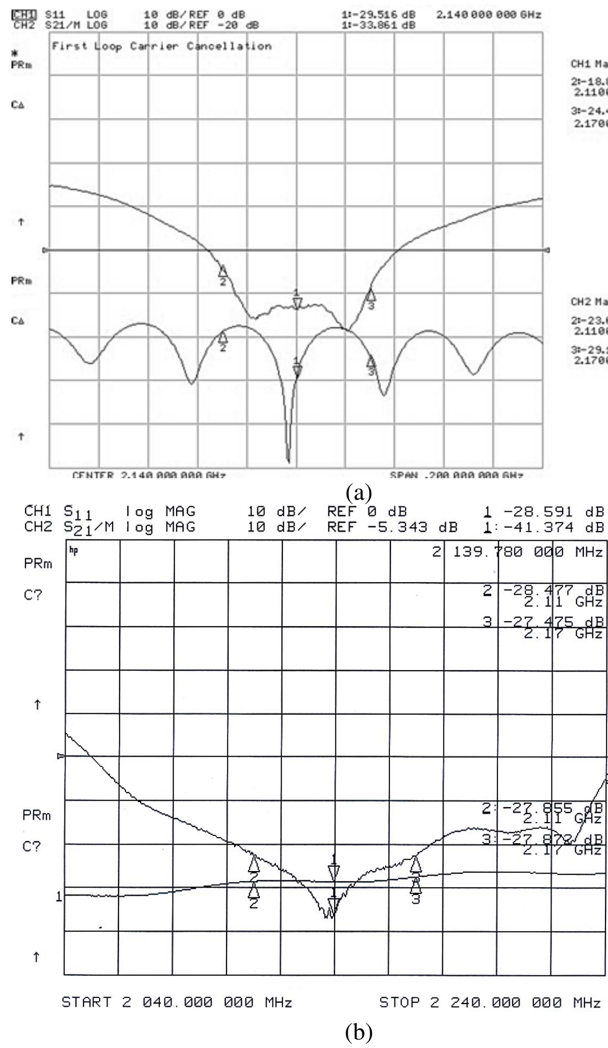
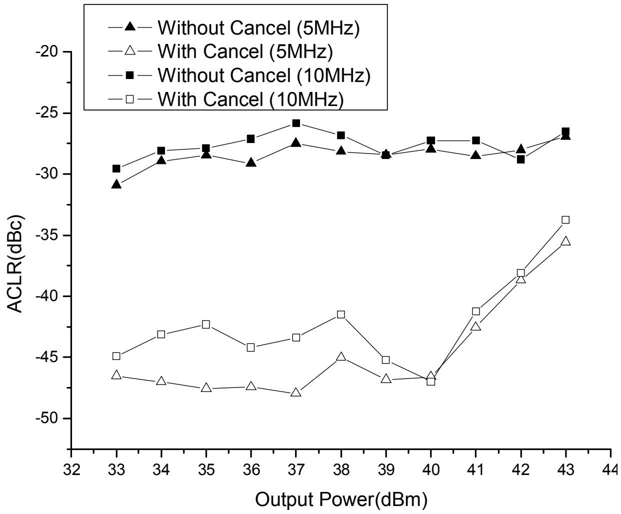


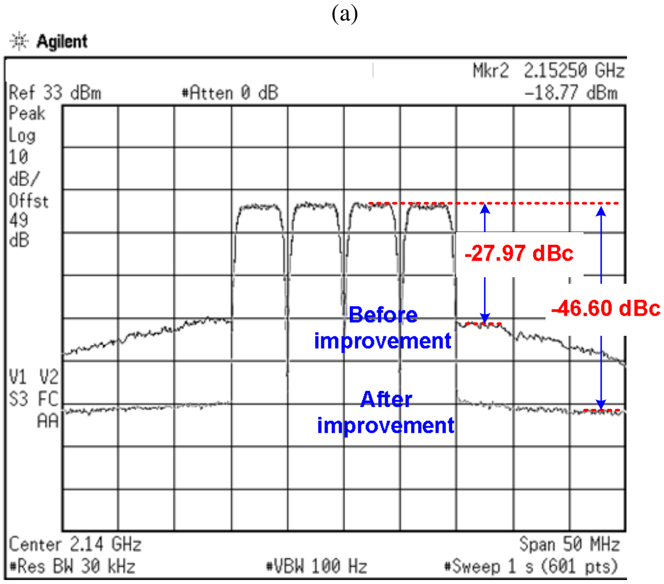
Fig. 6. Loop cancellation results measured with network analyzer. (a) Carrier cancellation loop, (b) Balanced power amplifier loop.

We have measured the output power spectral density of the cross PoD BPA with and without an error signal injection loop using a WCDMA 4-carrier signal for IMT-2000 band.

Measurement results are shown in Fig. 7. ACLRs at a 5MHz and 10MHz offset are shown through output dynamic range at IMT-2000 band in Fig. 7(a). The proposed system shows excellent linearity throughout the dynamic range. Fig. 7(b) shows the measured power spectral density of the implemented cross PoD BPA at an average output power of 40dBm before and after cancellation. The ACLR at 5MHz offset is -46.6dBc, an improvement of about 18.6dB by the cancellation.



(a)



(b)

Fig. 7. ACLR characteristic and power spectral density of the cross PoD BPA before and after linearization. (a) ACLR characteristics through the output dynamic range, (b) Power spectral density at an average output power of 41.5dBm.

IV. Conclusion

In this paper, we proposed a new distortion cancellation mechanism in a balanced power amplifier (BPA) structure using a carrier cancellation loop of a feedforward (FFW) and post-distortion (PoD) technique. We used the distortion generated within a portion of a BPA to cancel the distortion generated within the whole BPA. Samples of the signal and distortion from one part of the BPA are combined with a reference signal, and then those signals destructively combine to generate the error signal. When the error signal is injected into the output of another part of the BPA with the gain and phase control as well as group delay matching, the distortion generated by both part of the BPA are cancelled.

To prove the validity of the proposed design technique, we implemented cross PoD BPA for IMT-2000 band and measured the performance of the implemented linearization system with the commercial power amplifiers of 240W PEP for base-station application.

The proposed design method of cross PoD BPA can be extended to the BPA structure with more than two PA's to cancel the distortion generated by all parts of a BPA. Therefore, it is expected that the proposed system would show its superior ability as a base-station high power amplifier in the broadband multimedia communication environment. There are several additional advantages such as low power loss, excellent linearity improvement, wide dynamic range, and simple structure.

V. Acknowledgment

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