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I, Gerard P. Grenier, am over twenty-one (21) years of age. I have never been convicted of a felony, and I am fully competent to make this declaration. I declare the following to be true to the best of my knowledge, information and belief:

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A.	D. Kim, et. al., "High efficiency and wideband envelope tracking power amplifier with sweet spot tracking" 2010 IEEE Radio Frequency Integrated Circuits Symposium, May 23 – 25, 2010.
B.	P.G. Blanken, et. al., "A 50MHz bandwidth multi-mode PA supply modulator for GSM, EDGE and UMTS application" 2008 IEEE Radio Frequency Integrated Circuits Symposium, June 17, 2008.
C.	T. Kwak, et. al., "A 2 W CMOS Hybrid Switching Amplitude Modulator for EDGE Polar Transmitters" IEEE Journal of Solid-State Circuits, Vol. 42, Issue 12, December 2007.
D.	W. Chu, et. al., "A 10 MHz Bandwidth, 2 mV Ripple PA Regulator for CDMA Transmitters" IEEE Journal of Solid-State Circuits, Vol. 43, Issue 12, December 2008.

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11. D. Kim, et. al., "High efficiency and wideband envelope tracking power amplifier with sweet spot tracking" was published in the 2010 IEEE Radio Frequency Integrated Circuits Symposium. The 2010 IEEE Radio Frequency Integrated Circuits Symposium was held from May 23 – 25, 2010. Copies of the conference proceedings were made available no later than the last day of the conference. The article is currently available for public download from the IEEE digital library, IEEE Xplore.

12. P.G. Blanken, et. al., "A 50MHz bandwidth multi-mode PA supply modulator for GSM, EDGE and UMTS application" was published in the 2008 IEEE Radio Frequency Integrated Circuits Symposium. The 2008 IEEE Radio Frequency Integrated Circuits Symposium was held on June 15-17, 2008. Copies of the conference proceedings were made available no later than the last day of the conference. The article is currently available for public download from the IEEE digital library, IEEE Xplore.

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15. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

I declare under penalty of perjury that the foregoing statements are true and correct.

Executed on: 25 May 2018

EXHIBIT A

High efficiency and wideband envelope tracking power amplifier with sweet spot tracking

4 Author(s) Dongsu Kim ; Jinsung Choi ; Daehyun Kang ; Bumman Kim View All Authors

Abstract:
This paper describes the implementation of a high efficiency and wideband envelope tracking power amplifier with sweet spot tracking. By modulating supply voltage of power amplifier (PA), efficiency can be increased significantly. And linearity is improved by envelope shaping and sweet spot tracking. The supply modulator has a combined structure of a switching amplifier and a linear amplifier to achieve high efficiency as well as wide bandwidth. The measurement results show efficiencies of 36.4/34.1 % for 10/20 MHz long term evolution (LTE) signals with peak to average power ratio (PAPR) of 7.5/7.42 dB.

Published in: Radio Frequency Integrated Circuits Symposium (RFIC), 2010 IEEE

Date of Conference: 23-25 May 2010

INSPEC Accession Number: 11360746

Date Added to IEEE *Xplore*: 03 June 2010

DOI: 10.1109/RFIC.2010.5477260

ISBN Information:

Publisher: IEEE

ISSN Information:

Conference Location: Anaheim, CA, USA

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SECTION I.
Introduction

As wireless communication systems provide high data rate services, the channel bandwidth and PAPR of the signals are increased and the efficiency for the power amplifier is decreased. In the case of conventional PA with fixed supply voltage (Fig. 1a), the PA should be operated in the back off power region to linearly amplify the modulated signal with high PAPR and its efficiency is much lower than its peak value as shown in Fig. 2. On the other hand, the envelope tracking PA (Fig. 1b) operates under modulated supply voltage according to its output power level and its efficiency is degraded slightly.

Because overall efficiency of the envelope tracking PA is proportional to efficiency of the supply modulator and its linearity is affected by linearity of the supply modulator, a realization of the

high PAPR signals. In [2], a switching amplifier is used as a supply modulator. Although it achieves high efficiency, it requires high order passive filter and its bandwidth is too narrow to use for wide bandwidth signals such as LTE and WiMAX. To achieve high efficiency and wide bandwidth, we use hybrid switching supply modulator combining the advantages of two supply modulators [3][7]. To improve the performance of power amplifier, a boost converter is added to the supply modulator as shown in Fig. 3. By boosting the supply voltage of the linear amplifier from 3.4V to 5V, the output voltage of the supply modulator is increased up to 4.5V and the power amplifier shows higher gain, efficiency, output power and wider bandwidth.

In [8], they analyze nonlinear distortion of envelope tracking PA. Because of knee voltage and nonlinear capacitance, AM-AM and AM-PM distortion are generated. By adopting envelope shaping and sweet spot tracking, linearity can be improved.

In this paper, we implement a high efficiency and wideband envelope tracking PA for LTE applications using a hybrid switching supply modulator, HBT PA, envelope shaping, and sweet spot tracking.

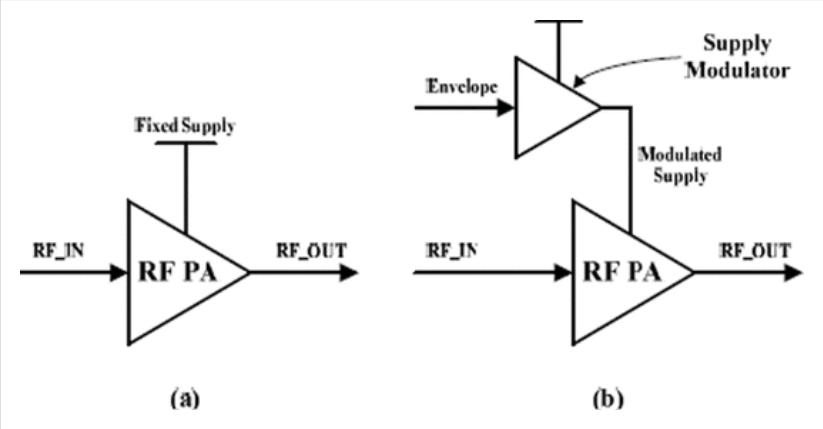


Fig. 1. (a) Conventional PA with fixed supply voltage. (b) Envelope tracking PA with modulated supply voltage.

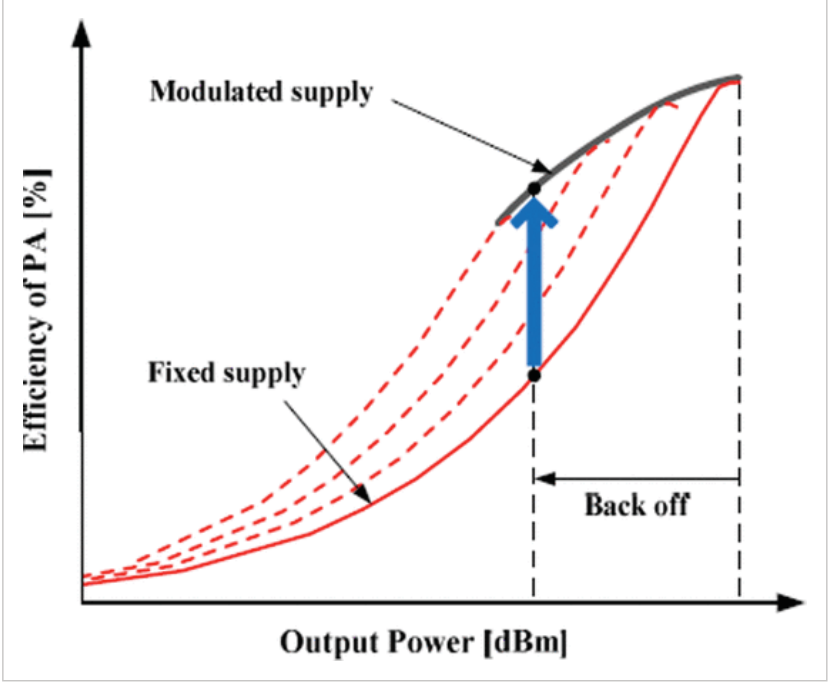
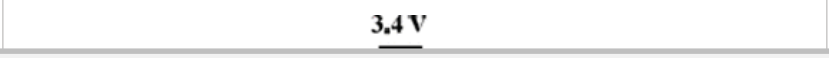


Fig. 2. PA's efficiency curves with fixed supply voltage and modulated supply voltage.



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