15th INTERNATIONAL SYMPOSIUM on POWER ELECTRONICS - Ee 2009
XV Međunarodni simpozijum Energetska elektronika – Ee 2009
NOVI SAD, REPUBLIC OF SERBIA, October 28th - 30th, 2009

COMPARATIVE STUDY OF TWO MULTILEVEL CONVERTERS FOR ENVELOPE AMPLIFIER

Miroslav Vasić, Oscar Garcia, Jesus Angel Oliver, Pedro Alou, Daniel Diaz, Jose Antonio Cobos
Universidad Politécnica de Madrid, Centro de Electrónica Industrial, Madrid, Spain
José Gutierrez Abacal 2, 28006 Madrid, +34 913 363 191
miroslav.vasic@upm.es

Abstract: *Modern transmitters usually have to amplify and transmit signals with simultaneous envelope and phase modulation. Due to this property of the transmitted signal, linear power amplifiers (class A, B or AB) are usually used as a solution for the power amplifier stage. These amplifiers have high linearity, but suffer from low efficiency when the transmitted signal has low peak-to-average power ratio. The Kahn envelope elimination and restoration (EER) technique is used to enhance efficiency of RF transmitters, by combining highly efficient, nonlinear RF amplifier (class D or E) with a highly efficient envelope amplifier in order to obtain linear and highly efficient RF amplifier. This paper compares two solutions for the envelope amplifier based on a combination of multilevel converter and linear regulator. The solutions are compared regarding their efficiency, size and weight. Both solutions can reproduce any signal with maximal spectral component of 1 MHz and give instantaneous maximal power of 50 W. The efficiency measurements show that when the signals with low average value are transmitted, the implemented prototypes have up to 20% higher efficiency than linear regulator that is used as a conventional solution.*

Key Words: ***Power Amplifiers, Kahn's Tehcnique, Envelope Amplifiers***

1. INTRODUCTION

In the modern world of today, the demand for broadband and wireless services is growing on a daily basis. One of direct consequences of this growth is certainly the growth of the networks that have to provide these services and the problem is their energy consumption. Some estimations showed that a 1% of planet's global energy consumption in 2007 was made by telecommunication industry [1]. In [2] is explained that the efficiency of the first generation 3G radio base stations is just few percents, and that the efficiency of the employed power amplifiers is just 6%. The impact of power amplifier's efficiency can be seen in the information that if the power amplifiers could improve its efficiency by 10% the overall efficiency would be raised by 6%.

One of the reason for very low efficiency of linear power amplifiers is the transmitted signal's statistics. The major part of the transmitted signals have high Peak-to-Average-Power-Ratio (PAPR) and it means that the working point of linear power amplifiers usually is area where they have low efficiency. The Kahn envelope elimination and restoration (EER) technique is used to enhance efficiency of RF transmitter. Fig. 1 shows block diagram of one EER transmitter. This technique combines a highly efficient, but nonlinear RF PA (class D or class E for example) with a highly efficient envelope amplifier to implement high-efficiency linear RF PA [3].

An envelope amplifier based on a multilevel converter in series with a linear regulator is presented in [4]. It is shown that this solution can reproduce 2 MHz sine wave, with low spectral distortion and providing 50W of instantaneous power. This topology operates at relatively low switching frequency and without additional output filter because the linear regulator filters all the noise and ripple that comes from the multilevel convert.

In this paper two different implementations of this topology are compared regarding its efficiency, complexity, size and possibility of integration.

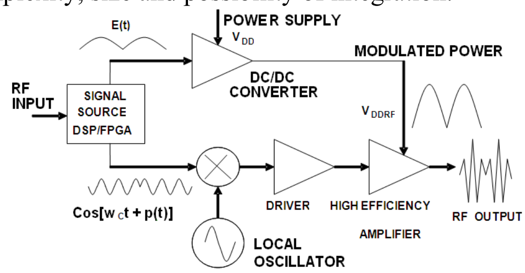

Fig. 1. *Block Scheme of Kahn-technique Transmitter*

2. ARCHITECTURE OF THE ENVELOPE AMPLIFIER

The topology that is used for the envelope amplifier consists of a multilevel converter in series with a high slew rate linear regulator. The main idea of the solution can be seen in Fig. 2. The multilevel converter has to supply the linear regulator and it has to provide discrete voltage levels that are as close as possible to the output voltage of the envelope amplifier. If this is fulfilled, the power losses on the linear regulator will be minimal, because they are directly proportional to the difference of its input and output voltage. However, in order to guarantee correct work of the linear regulator, the output voltage of the multilevel converter always has to be higher than the output voltage of the linear regulator. Similar solution, but for lower frequencies and higher power is presented in [5].

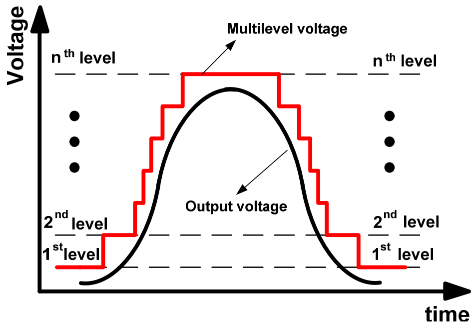

Fig. 2. *Time diagrams of the proposed envelope amplifier*

There are several possibilities to implement the multilevel converter for this application. The first one, architecture one, is to provide all the voltages that are needed at its output, and then to use a switching network as an analog multiplexer to select each one when it is necessary, Fig. 3. The second solution is to use independent voltage cells that are put in series, and then to generate the output voltage as a combination of its voltages. These cells can be implemented to give just positive voltage (two-level cell, architecture two), or to produce positive and negative voltage (three-level cell, architecture three), Fig.4.

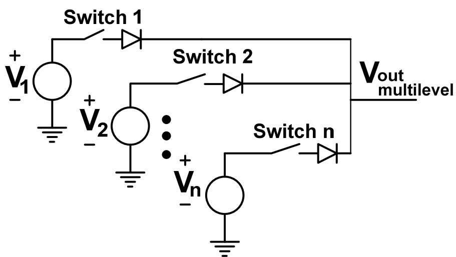

Fig. 3. *Multilevel converter realized with independent supplies and analog multiplexer*

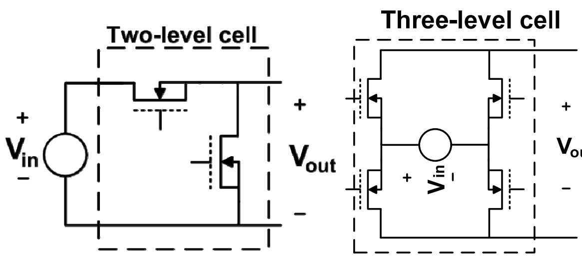

Fig. 4. *Voltage cells that could be used as a solution to implement a multilevel converter*

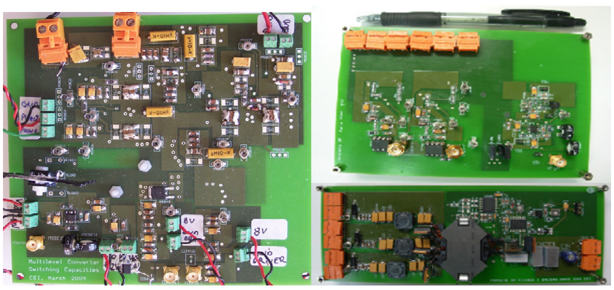

Fig. 5. *Photographs of implemented envelope amplifiers (architectures one and two from left to right)*

In this paper, the first architecture is implemented using voltage dividers based on switching capacities and the second architecture using a flyback converter as a power source that supplies independent voltage cells, Fig. 5.

3. EXPERIMENTAL RESULTS

The efficiency of the system for both prototypes is measured for different sine waves and the results are summarized in Table 1. The measured efficiency is compared with theoretical efficiency of the linear regulator supplied by a constant voltage.

Fig. 6 and Fig. 7 show waveforms of the both implemented envelope amplifiers.

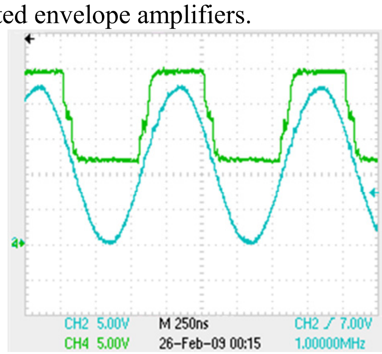

Fig. 6. *Waveforms of multilevel converter's voltage and output voltage at 1MHz (architecture one)*

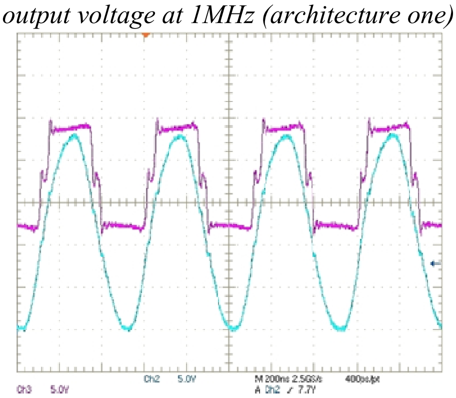

Fig. 7 *Waveform of multilevel's output voltage and linear regulator's output voltage at 2MHz (architecture two)*

Table 1. *Measured efficiency of the implemented envelope amplifiers for different sine waves compared with the theoretical efficiency of an ideal linear regulator supplied by 23 V*

Vsin(V)	*Sine wave frequency (MHz)*	*Measured efficiency of the architecture one*	*Measured efficiency of the architecture two*	*Theoretical efficiency of an ideal linear regulator supplied by 23V*
0-9	*1*	*49.9%*	*43.9%*	*29.3%*
5-14	*1*	*64.7%*	*58.5%*	*45.9%*
0-22.5	*1*	*74.3%*	*70.6%*	*73.4%*
0-9	*0.5*	*49.1%*	*43.6%*	*29.3%*
5-14	*0.5*	*65.3%*	*59.5%*	*45.9%*
0-22.5	*0.5*	*75.5%*	*71.2%*	*73.4%*

4. REFRENCES

[1] S.Roy, "Energy Logic for Telecommunications", white paper for Emerson Network Power, September 2008

[2] G.Pierre, "Power System Efficiency in Wireless Communication", APEC '06, special presentations

[3] F.H. Raab, P. Asbeck, S. Cripps, P.B. Kenington, Z.B. Popovic, N. Pothecary, J.F. Sevic, N.O. Sokal, "Power Amplifiers and Transmitters for RF and Microwave"

[4] M.Vasic, O.Garcia, J.A.Oliver, P.Alou, D.Diaz, J.A.Cobos, "Multilevel Power Supply for High Efficiency RF Amplifier", APEC '09, February 2009

[5] Gong, G., Ertl, H., Kolar, J. W., "A Multi-Cell Cascaded Power Amplifier", APEC '06 2006