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EXPERIMENTAL INVESTIGATION OF HIGH FREQUENCY CLASS-E POWER AMPLIFIER WITH PARALLEL AND SERIES SHUNT FILTERS

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High frequency high efficiency power amplifiers remain one of the main competitive goals in designing of radio transmitter for wireless information technology, «Internet-of-Things» (IoT) devices, distributed network systems, especially for portable devices because power amplifier is the main power consumption component of the whole radio transmitting system.

Class E power amplifier together with the class F and many of their variations are widely used in radio transmitters because of their high efficiency, which can reach out 100 % and losses substantially determined by losses in active device at high frequencies [1]. Some of those classes have their own advantages. One has higher Cp (power utilize factor), another one has wider frequency band of operation. The aim of this work is to experimentally investigate the possibility of obtaining flat drain voltage waveforms using series shunt filter tuned with frequency higher than operation frequency that can lead this scheme to operation as class EF power amplifier adding harmonics of the main frequency in the proper phase ratio [2, 3].

The proposed schematic is shown at fig. 1.

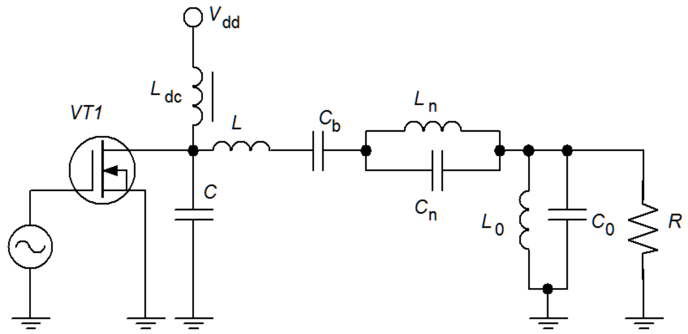

Fig. 1. Class-EF power amplifier schematic

It consists of an active device VT1, acts as a switch between "ON" and "OFF" states at input frequency, load resistance *R*, shunt filter L_0C_0 that resonate at signal frequency and shunt filter L_nC_n connected in series with inductance L and is used to provide necessary signal harmonic amplitude and phase shift for obtaining flat drain voltage waveform. Inductance L_{dc} acts as an RF-choke and transmits only DC current from supply V_{dd} and capacitor C_b acts as DC-block capacitor.

Firstly for class-E operation of the proposed scheme elements values for DC supply voltage of 24 V and desired output power of 5 W at 1 MHz operation frequency were calculated to be: *R*=51.3 Ohm, *C*=917 pF, L=9.81 uH, C_n=1148 pF, L_n=2.45 uH, C_0=16130 pF, L_0=1.57 uH.

Experimentally obtained output power and efficiency dependences versus frequency are shown below at fig. 2. As can be seen, experimental prototype shown 3.8 W of output power with 91 % of drain efficiency at 1 MHz. Drain voltage and current waveforms were obtained with storage digital oscilloscope using small ferrite ring inductor directly at the drain pin and are shown at fig. 3. As can be seen drain voltage corresponds to class E power amplifier.

The next step was to change resonant frequency of L_nC_n shunt filter by changing capacitance C_n to obtain flat drain voltage waveforms with smaller peak factor. The obtained drain voltage and current waveforms for different C_n values are shown at fig. 4–5.

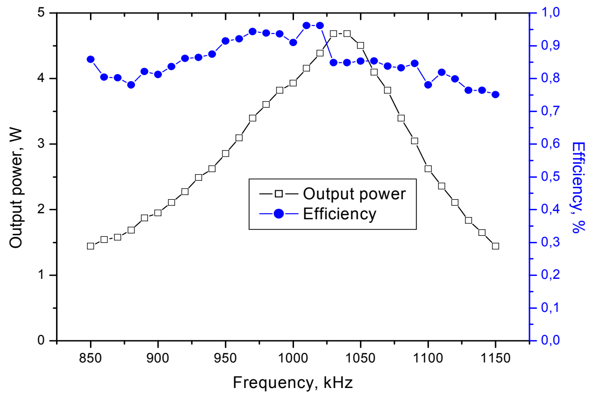

Fig. 2. Class E output power and efficiency versus frequency

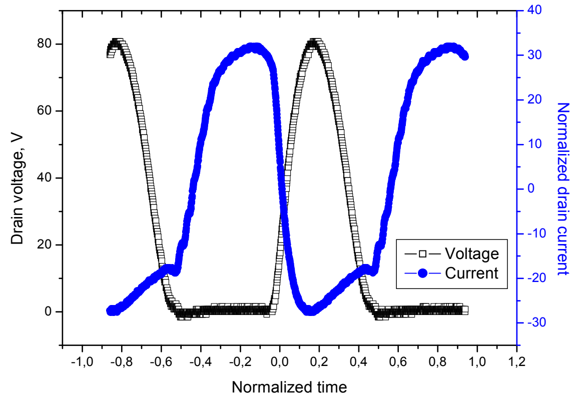

Fig. 3. Drain voltage and current waveforms for C_n=1230 pF

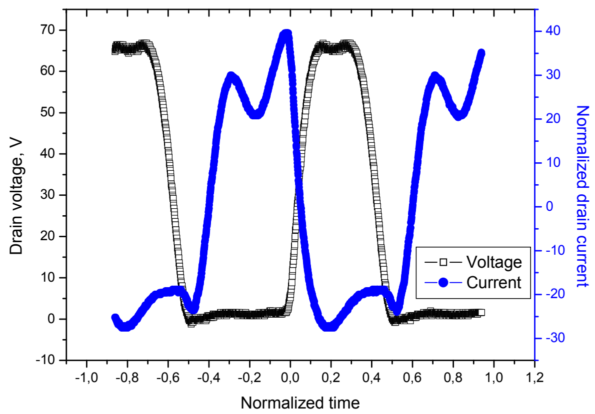

Fig. 4. Drain voltage and current waveforms for C_n=1342 pF

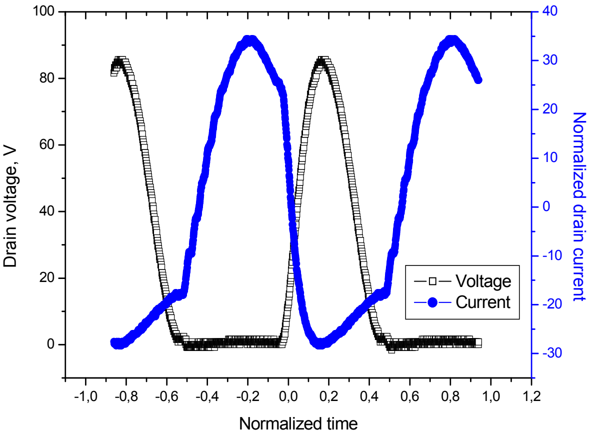

Fig. 5. Drain voltage and current waveforms for C_n=864 pF

As can be seen at fig. 4 we obtain flat drain voltage waveform with its peak value of 67 volts, while at fig. 5 with C_n=864 pF we have 88 volts drain peak voltage both maintaining zero-voltage switch conditions.

As a conclusion we can say that it was experimentally shown a possibility to vary from one drain voltage waveform (class E waveform) to another drain voltage waveform (flat waveform with lower peak factor) by changing resonant frequency of L_nC_n shunt filter. Also efficiency remains in high values range with zero-voltage switching conditions fulfillment and still give wide opportunities to developer for obtaining desirable type of operation.

References

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3. Mediano A., Sokal N. O. "A Class-E RF power amplifier with a flat-top transistor-voltage waveform," IEEE Trans. on Power Electronics, Vol. 28, No. 11, Nov. 2013, pp. 5215–5221.