Chapter 3

BJT CLASS-F POWER AMPLIFIER DESIGN

This Chapter provides the simulation and experimental verification of quite low-frequency prototype of polyharmonic power amplifier operated at 1MHz. However, this frequency is one-third of transition frequency, which is 3MHz for used BJT. These allow to neglect the influence of package parasitic parameters on output current and voltage waveforms in order to better illustrate proposed theoretical results.

1. SIMULATION

The polyharmonic power amplifier equivalent circuit is shown in Fig. 3-1. The Ansoft Serenade SV 8.5 simulator was used[28]. The output network has a well-known "Third-Harmonic Peaking" construction[13].

There were parasitic resistances added to the parallel contours and in order to model the finite quality factors.

Two cases were simulated, using similar output network shown in Fig. 3-1, but different values of network components. The first case respects to classic class-F tuning summarized by C. Trask[13]. The second case realize the proposed in the Chapter 2 tuning, that takes into account BJT lag.

The collector current and collector-emitter voltage waveforms for the first case are shown in Fig. 3-2. The voltage has strong asymmetrical form. The collector efficiency is 59.5%, transistor output power is 1.72W, and dc supply power is 2.89W.

The waveforms of collector current and collector-emitter voltage for the second case are shown in Fig. 3-3.

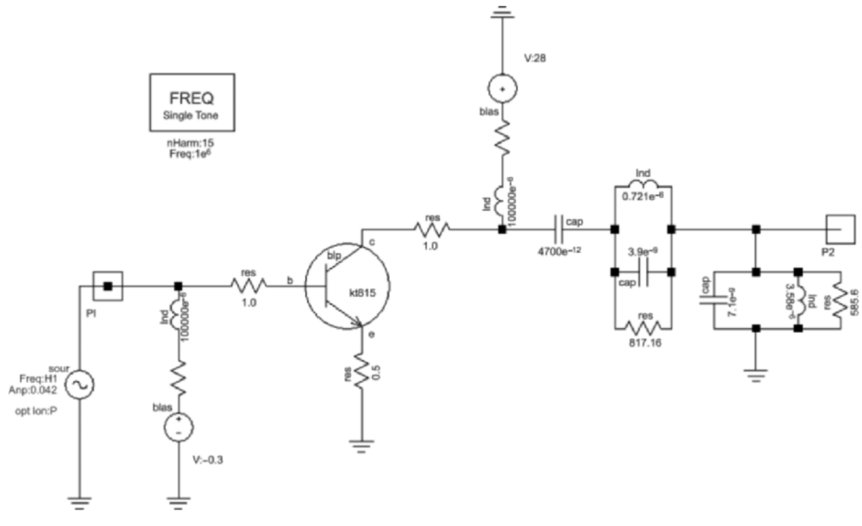

Figure 3-1. Polyharmonic power amplifier equivalent circuit.

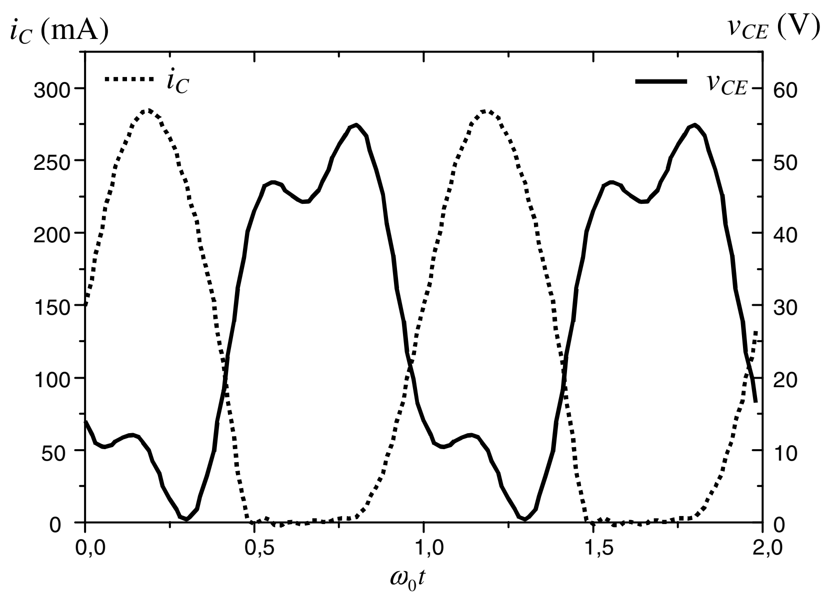

Figure 3-2. Waveforms of collector current and voltage in case of classic tuning.

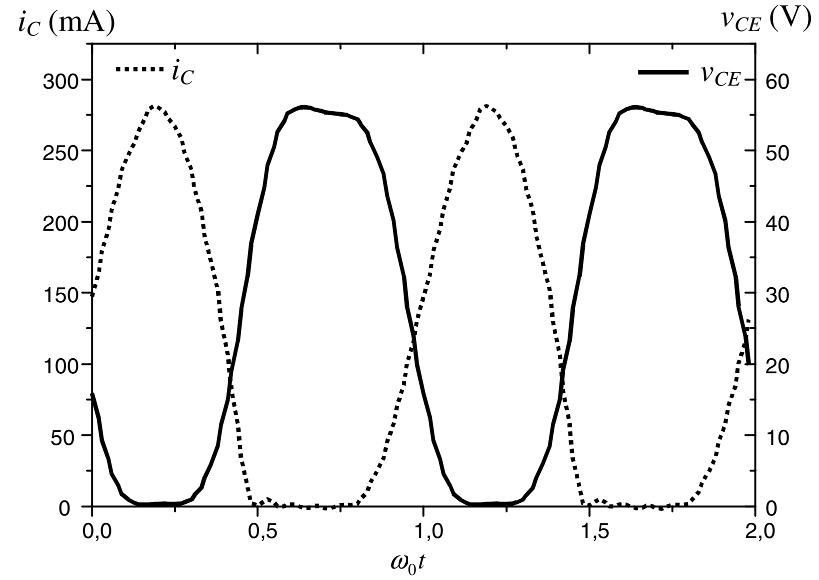

Figure 3-3. Waveforms of collector current and voltage with tuning described in Chapter 2.

The voltage has almost symmetrical flat form. The collector efficiency is 75.4%, transistor output power is 2.15W, and dc supply power is 2.85W.

The customary class-C amplifier was simulated in order to compare performances with the above cases and demonstrate the advantages of the second case. The bias, supply and driving power conditions were the same, while class-C output network was realized by shortening the C3-L3-R3 contour.

The collector current and collector-emitter voltage of simulated class-C amplifier are shown in Fig. 3-4. The collector efficiency is 65%, transistor output power is 1.88W, dc supply power is 2.89W.

Therefore, classic class-F tuning of output network leads even to decrease in efficiency comparing with customary class-C amplifier for almost the same input power, bias and supply. This unexpectedness is caused by the stretching effect of collector current impulse at the operating frequency comparable with transition frequency of BJT. The stretched impulse has changed spectral content. Particularly, the phase shift other than just out-of-phase exists between the fundamental component and the third harmonic. In order to obtain better efficiency, this phase shift needs to be compensated for by proper tuning of output network.

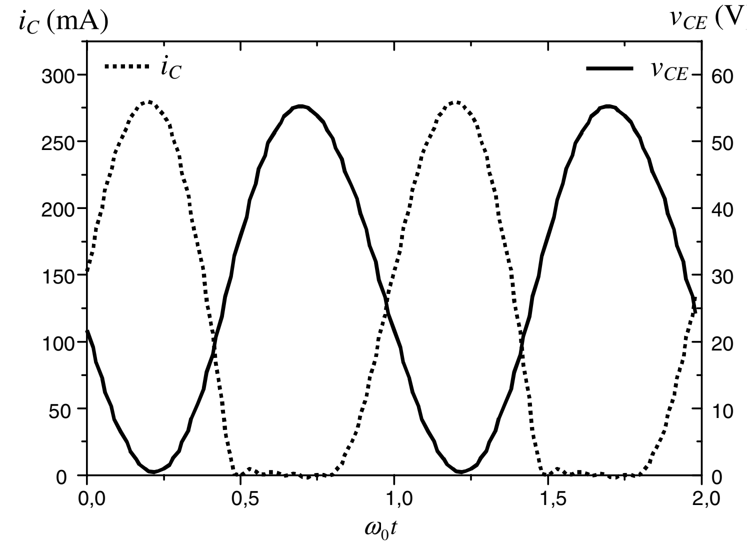

Figure 3-4. Waveforms of collector current and voltage of class-C power amplifier.

2. EXPERIMENTAL RESULTS

The prototype of class-F power amplifier was implemented on the basis of the medium power KT815 transistor, which transition frequency is 3MHz. The above mentioned output network (see Fig. 3-1) with the proposed tuning taking into account BJT lag was used. The equivalent circuit of prototype is shown in Fig. 3-5.

The G3-112 oscillator produced the necessary input power at the operating frequency 1 MHz. The 53 Ohm resistor in the BJT base terminal circuit limits the input current and prevents thermal runaway effect. The TEC-18 stable voltage source sets the bias voltage. Inductances Ld and Ldk act as RF-Chokes. The Ri1 and Ri2 resistors are used in order to get the oscillograms of base and collector currents, respectively. The Re resistor is thermostabilizing.

The measured collector efficiency and output power dependencies on base-emitter RMS voltage for –0.45 V bias are presented in Table 3-1. The negative bias was used in order to set proper cut-off angle, acceptable for class-F operation near transition frequency (see Fig. 2-3). As was expected, the efficiency dependence has flat maximum at the input voltage value for which first and third harmonics are out-of-phase, since the stretching effect is taken into account in tuning of output network.

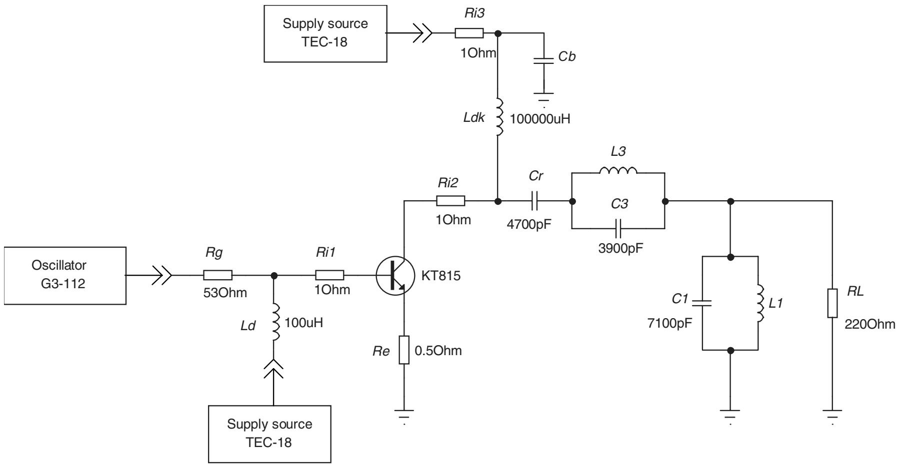

Figure 3-5. Equivalent circuit of class-F amplifier prototype.

Table 3-1. Measured efficiency and output power of amplifier prototype

Base-emitter RMS voltage (V)	Efficiency (%)	Output power (W)
1.5	62.9	1.75
1.55	64.3	1.81
1.6	63.7	1.87
1.65	63.2	1.93
1.7	63.3	1.97
1.75	62.8	1.99
1.8	62.3	2.0

The oscillograms of collector-emitter voltage and load voltage are shown in Fig. 3-8. The collector-emitter voltage has almost symmetrical form close to target for the third harmonic peaking class-F amplifier.

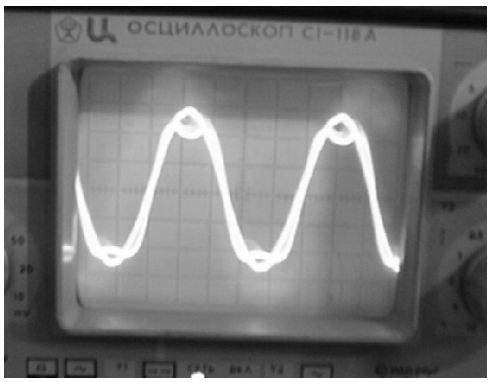

Figure 3-6. The collector-emitter and load voltages' waveforms.

3. SUMMARY

The two variants of polyharmonic class-F power amplifiers and customary class-C amplifier are simulated in order to illustrate the theoretical results of Chapter 2.

The classic tuning case of class-F amplifier does not provide the amplifier efficiency increase at the frequencies comparable with transition one. On the contrary, it leads to the poorer performance compared with appropriate class-C amplifier.

The experimental investigation of third-harmonic peaking class-F power amplifier confirms the simulation results.