

The aim of this work is to investigate projection operator method of derivation of equations of motion for reduced density matrix and apply it to a model open quantum system. We gradually pass from quantum mechanical model of a molecule with one vibrational degree of freedom to an example of open quantum system relevant in the theory of nonlinear spectroscopy. In the thesis we present results of numerical simulations of the time evolution of the open quantum system performed with a program written for this purpose. We are specially concerned with simulations of the solution of the time-convolutionless generalized master equation up to the a second order of the perturbation expansion, and we show that under certain conditions it provides an exact solution of the problem. The text also contains derivation of the recurrence relations for the Franck-Condon factors for the most general case of two quantum harmonic oscillators in one space dimension, i. e. transformation matrix between two bases of the $\mathcal{L}^2(\mathbb{R})$ space determined by the solutions of the time-independent Schrödinger equation appropriate for these oscillators.