Design and numerical simulation of Josephson traveling-wave parametric amplifier using new circuit simulator

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Superconducting traveling wave parametric amplifier (TWPA) is essential in quantum sensing and quantum computers. Although standard coupled-mode theory can explain the amplification of the signal, it fails to describe complex behavior beyond the approximations utilized by the theory. In order to simulate a response of TWPA model, it is necessary to solve a system comprising many nonlinear equations numerically. The most common program that allows a simulation of such systems is WRspice. This program has already been successfully used to design some amplifiers [1],[2]. In this work, we used the new program JoSIM [3], which uses a different numerical scheme for solving Josephson junctions circuits.

We developed a novel Josephson Junction Resonantly phase-matched TWPA design based on the already known one [4] using a nonlinear resonant element instead of a linear one. Our innovations allow us to achieve high gain and make our designs realistic for manufacturing. The impedance matching of the amplifier is ensured by a novel taper consisting of Josephson Junctions. We showed that such a taper suppresses ripples in the gain profile. The design was modeled using JoSIM and WRspice programs,
considering realistic Josephson Junctions critical current spread in TWPA. Both programs provide similar gain magnitude, although slightly different gain profile. However, JoSIM simulates circuits much faster than WRspice.

References

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