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Quantum Coding with Finite Resources

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The quantum capacity of a memoryless channel determines the maximal rate at which we can code reliably over asymptotically many uses of the channel. Here we argue that this asymptotic characterization is often insufficient in practice where decoherence severely limits our ability to manipulate large quantum systems in the encoder and decoder. For all practical purposes we should instead focus on the optimal trade-off between three parameters: the rate of the code, the size of the quantum devices at the encoder and decoder, and the fidelity of the transmission. Towards this goal, we find approximate and exact characterizations of this tradeoff for various channels, including dephasing, depolarizing and erasure channels. In each case the tradeoff is parametrized by the capacity and a second channel parameter, the quantum channel dispersion. In the process we develop several general bounds that are valid for all finite-dimensional quantum channels and can be computed efficiently.