Optimal Encoding of Classical Information on Passive Linear Thermal Operations

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The amount of information that a noisy channel can transmit has been one of the primary subjects of interest in classical information theory. We extend this study to the quantum regime for a practically-motivated family of the quantum channels we call the thermal channels, which consist simply of a mixing interaction with an environment at a certain temperature followed by a phase-shifting operation, both requiring no external energy source. As the measure of quantum channel information capacity, we investigate conditions to maximize the Holevo information of the thermal channel over encoding procedures distributing the channel's mixing and phase-shift parameters, given an input quantum state with finite energy and a certain environment temperature. We show that the maximum Holevo information can be achieved by a family of encoding procedures that uniformly distributes the channel's phase-shift parameter. Moreover, for a large family of input quantum states, any maximizing encoding necessarily and sufficiently has finite support over the channel mixing parameter, forming a finite number of rings around the origin in the phase space as visualized in Figure 1. Other properties pertaining to its information capacity given different families of input states, environment temperature, and energy constraints are investigated analytically and numerically.

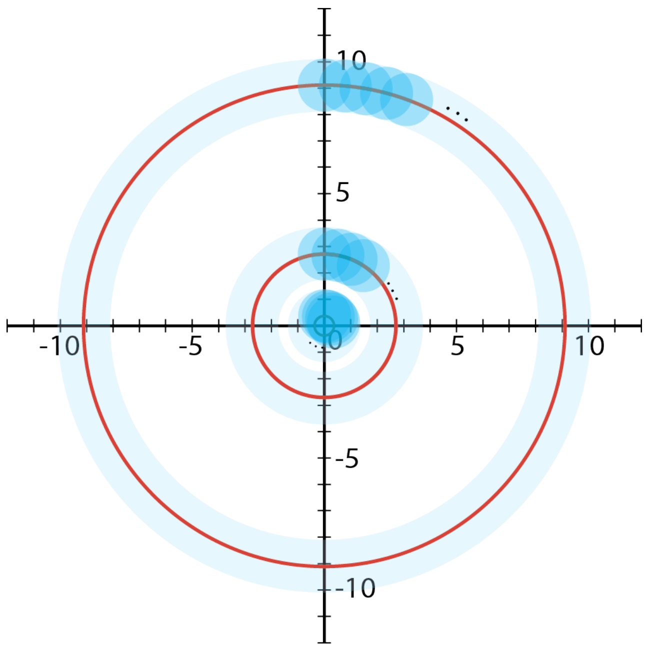

Figure 1: Phase-space visualization of an optimal encoding given a coherent state input and zero-temperature environment