The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

Workshop on
NEW TRENDS IN QUANTUM DYNAMICS AND ENTANGLEMENT
21 - 25 February 2011

Estimating Capacities of Gaussian Quantum Channels

Stefano MANCINI
School of Science and Technology
University of Camerino, 62032 Camerino, Italy
and INFN Sezione di Perugia, 06123 Perugia, Italy

Abstract:

Quantum channels are every means that convey quantum systems on whose states information is encoded. Formally they are quantum maps mapping input to output states. The maximum rate at which information can be reliably transmitted through a quantum channel defines its capacity. Actually one can define several capacities depending on the kind of information transmitted (classical or quantum) and on the additional resources used in transmission. Evaluation of quantum channels capacities is one of the most important and difficult problems of quantum information theory. Gaussian channels, which maps input Gaussian states into output Gaussian states, are among the simplest models allowing capacities investigation.
A paradigmatic example of quantum Gaussian channel is the lossy bosonic channel where states lose energy en route from the sender to the receiver. The term bosonic arises because each input (respectively output) is represented by a bosonic field mode. In turn, the effect of losses is usually modelled by letting each input mode to interact with an environment mode through a rotation (beam splitter) transform whose angle (transmissivity) determines the loss rate. The classical capacity, the classical assisted capacity, and the quantum capacity for such a channel were evaluated by assuming each environment mode in the vacuum state. However, when more general states of environment are taken into account, even non factorized ones which give rise to memory effect, the evaluation of capacities becomes much more demanding.
We present the analytical solution for the optimization problem corresponding to finding the maximum of Holevo information overall Gaussian states for the lossy bosonic channel. We then analyze the dependence of the classical capacity from the lossy channel's parameters providing full classification of possible cases and singling out critical and supercritical behaviours. We account for both memoryless and memory cases and we demonstrate the existence of mode symmetry violation which gives rise to the problem of optimal channel memory.
The devised approach results very powerful since it is applicable to other capacities (besides classical one) and other Gaussian channels (besides lossy one). Moreover, within it, we are able to derive the most relevant information transmission rates, by treating them as logarithmic approximations of the capacities.