The Fifth Conference on
Information Theory and Complex Systems TINKOS 2017,
November 9-10, 2017

Book of abstracts

(ISBN: 978-86-80593-61-6)

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Kraus operators for a pair of interacting qubits: a case study

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Keywords

microscopic model; quantum entanglement; Kraus decomposition

Summary

The Kraus form of the completely positive dynamical maps is appealing from the mathematical and the point of the diverse applications of the open quantum systems theory.

The “integral”, i.e. so-called, Kraus form [1] of a completely positive dynamical map for an open quantum system [2, 3] is appealing for the mathematical reasons. Mathematical existence of the Kraus form for such processes is guaranteed by the Kraus theorem, universally [1-3]. On the other hand, a Kraus-form (KF) may be regarded as a solution to a differential master equation (ME) for the open system's statistical operator (density matrix); a case when no ME exists for the process can be found e.g. in Refs. [4,5].

The Kraus operators are often constructed due to some physical assumptions or understanding of the underlying physical processes [6]. Nevertheless, such derivations may not provide the full physical (e.g. microscopic) details [7]. One way to obtain a proper KF for the open system's dynamics is derivation from the related master equation for the process [7,8]–if such an ME exists [4,5]. To this end, it is important to note: phenomenological derivations of MEs may also be unreliable–often there appear certain subtleties of both mathematical and physical nature as well as unexpected pitfalls [9,10].

Unfortunately, the Kraus operators are poorly known for the two-qubit processes. Having this in mind as well as the above-distinguished usefulness of KF, in this paper we derive the Kraus operators starting from a microscopically derived master equation for a pair of two-level systems (qubits). We are concerned with an ancilla qubit interacting with another qubit, which is subjected to a $\hat{S}_x$ spin-projection quantum measurement, while the strength of the interaction is arbitrary. Usefulness of the KF for the process is emphasized by application of our results in investigating the dynamics of entanglement in the qubits system. The obtained results are applied to calculate the dynamics of the initial entanglement in the qubits system. We obtain the loss of the correlations in the finite time interval; the stronger the inter-qubit interaction, the longer lasting entanglement in the system.

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*The author is financially supported by the Ministry of education, science and technology Serbia under the grant no. 171028.