SUPER ONE-WAY INFORMATION DEFICIT FOR A TWO-PARAMETER CLASS OF STATES IN $2 \otimes D$ QUANTUM SYSTEMS

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(*Received August 24, 2015 – Revised September 29, 2015*)

So far, the super one-way deficit in weak measurement has been calculated explicitly only for a limited set of two-qubit quantum states and expressions for more general states are not known. In this paper, we extend the previous studies to $2 \otimes d$ quantum systems and derive an analytical expression for a two-parameter class of states for $d \geq 3$. We compare quantum discord and super one-way deficit for qubit-qutrit systems. We find that super one-way deficit is smaller than the quantum discord. On the other hand, by tuning the weak measurement continuously to the projective measurement, both super one-way deficit and quantum discord converge to the same value.

Keywords: super one-way deficit, quantum discord, weak measurement, $2 \otimes d$ quantum systems.

1. Introduction

Quantum states are sensitive to quantum measurements. When we measure an arbitrary quantum state in some orthogonal basis (projective measurement), we lose its coherence. Nevertheless, when we perform measurement which couples the system and the measuring device weakly, then the system will be perturbed slowly and may not lose its coherence entirely. This scheme was introduced by Aharonov–Albert–Vaidman [1] in the weak measurement formalism. This gives a weak value of an observable which can take values outside the spectrum of the observable. In recent years, it is been found that weak-value amplification has several applications. For instance, weak measurements have been used for interrogating quantum systems in a coherent manner [2], in understanding the role of the uncertainty principle in the double-slit experiment [3, 4], in understanding the macrorealism [5, 6]. On the practical applications, this has been used for observation of photonic version of the spin Hall effect [7], to amplify the detection of optical beam in the Sagnac interferometer [8], in the feedback control of quantum systems [9] and even direct measurement of wavefunction of single photon [10]. Recently, it has been found that weak measurements can help in protecting quantum entanglement from decoherence [11].

The quantum correlation of quantum states consists of entanglement and other types of nonclassical correlations. It is well accepted that quantum correlations are more general than entanglement [12, 13]. A canonical measure of quantum correlation is the quantum discord [14, 15] which characterizes the quantumness of correlations. It determines how much a system can be disrupted when we observe it to acquire the classical information. There are some precise expressions for quantum discord for two-qubit states, such as for the X states [16, 17].

Beside quantum discord, a lot of other measures of quantum correlation have been presented, such as the quantum deficit [18], measurement-induced disturbance [15], geometric discord [19, 20], and continuous-variable discord [21]. Amongst them, the work deficit [18] has operational approach to quantify quantum correlation. From the physical point of view, quantum deficit originates in describing a process which tries to extract work by nonlocal operation from a correlated system coupled to a heat bath in the case of pure states. Moreover, the definition of the one-way deficit is given by the relative entropy over all local von Neumann measurements on one subsystem which reveals the fundamental role of quantum correlations as a resource for the distribution of entanglement [22]. Quantum discord and the one-way deficit both are quantum correlations based on von Neumann measurement. Because of the basic role of weak measurement, it is interesting to know what those quantum correlations will be for weak measurement? It is shown that weak measurement performed on one of the subsystems can lead to super quantum discord that is always larger than the normal discord [23]. It is natural to ask whether weak measurements can always reveal more quantumness of correlations. If they can, then one can exploit this extra quantum correlation for information processing. Recently, Y. K. Wang et al. [24] have introduced the definition of the super one-way deficit for bipartite quantum state with weak measurement on one subsystem and calculated the super one-way deficit for Werner states. However, expressions for more general quantum states are not known. In this paper, we endeavour to calculate the super one-way deficit for a two-parameter class of states in $2\otimes d$ quantum systems. As an example, we study the qubit-qutrit system and compare the super one-way deficit and the quantum discord.

This paper is organized as follows. In Section 2 we discuss super one-way deficit. We describe two-parameter class of states in Section 3 and calculate the super one-way deficit for them. Moreover, in Section 4 we apply the results for qubit-qutrit system and study the relation between the quantum discord and super one-way deficit. A brief summary is given in Section 5.

2. Super one-way deficit in weak measurements

The definition of the super one-way deficit in weak measurement on the subsystem B is given by [24]

$$\Delta_w^{\rightarrow}(\rho_{AB}) = \min_{\{\Pi_k\}} S\Big(\sum_{\pm x}(I \otimes P^B(\pm x))\rho_{AB}(I \otimes P^B(\pm x))\Big) - S(\rho_{AB}) \tag{1}$$

with the minimization going over all projective-valued measurement Π_k, where $S(\rho) = -\mathrm{Tr}(\rho \log_2 \rho)$ is the von Neumann entropy of a quantum state ρ. The above