Abstract

Quantum entanglement acts as a resource in communication schemes, which are unexpected in classical realm. The correlations between measurement outcomes on entangled quantum systems show departure from the usual classical correlations. The richness of the quantum correlations can be established by the violation of Bell's inequality, which must be satisfied by all possible classical correlations for the specific scenario. Hence, the study of Bell inequalities plays an important role in the applications of quantum communication theory. A large part of the thesis is devoted to the study of Bell inequalities in different contexts. Using the concept of geometric multisetting Bell inequalities introduced by Zukowski [27], we develop [38] Bell inequalities for arbitrary number of spin-1 systems. We used special choice of settings which never allows Kochen-Specker 1967 contradiction [39, 40]. Theses inequalities are violated by quantum predictions.

We present [52] a theory of geometric chained Bell inequalities for higher dimensional systems based on chained inequalities derived by Pykacz and Santos [48, 49] . For the maximally entangled states the inequalities are refuted maximally by quantum mechanical predictions.

We also show that [70], staring from the geometric concept of Ref.[27] one can derive inequalities allowing to reveal the possibility of quantum steering.

ψ-epistemic models of the quantum states which are based on the concept of ``hidden states" were discussed in several papers [75, 78, 79, 80, 81, 82]. However, the experimental tests of theses models are not free form detection efficiency loophole. The Pusey-Barrett-Rudolph (PBR) theorem suffers from the same vulnerability. We calculate [77] the critical detection efficiency, below which the PBR argument for the ontic nature (this can be argued to be a manifestation of non-classicality) of quantum state within the ``hidden states" approach is inconclusive.

We analyze [101] conditions to detect entanglement for bipartite systems of arbitrary dimension $d,$ for the case of state transfer via noisy channels. We use several types of models of noise. We employ a geometrical approach [69] which is based on correlation functions. Also, we compute critical noise parameters to violate the CGLMP-Bell inequality [36]. We give analytical derivation in the asymptotic case of infinite dimension.

After discussing different aspects of quantumness, we proceed to analyze state transfer. It is a well-known routine for various systems of spins-1/2. Still, it is not well studied for chains of spins of larger magnitudes. We argue [117] that while perfect state transfer may seem impossible in spin-1 systems, it is still feasible for arrays of V-type three-level atoms. Tomography of such 1D array is also shown to be possible by measuring the first atom from such an array.