Realistic Non-Gaussian Receivers for Long Distance Continuous-Variable Quantum Key Distribution

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Abstract. *Reception strategies based on non-Gaussian detectors can be used to improve the performance of various quantum information processing tasks. In this work, we investigate the performance of two non-Gaussian receivers with imperfect detectors for long distance CV-QKD protocol. We show that both receivers outperform the ideal homodyne detection scheme even under realistic conditions, providing a robust alternative for enhancing long-distance CV-QKD.*

1. Introduction

Conventional CV-QKD protocols rely on Gaussian measurements, such as homodyne or heterodyne detections, due to their compatibility with current infrastructure and established security proofs [Laudenbach et al. 2018]. Nevertheless, non-Gaussian measurements can hold significant importance for certain protocols, as they can outperform conventional detection schemes regarding fundamental figures of merit in quantum communications [Kennedy 1973, Takeoka and Sasaki 2008, Izumi et al. 2020]. In this work, we investigate two non-Gaussian discrimination schemes — the Kennedy receiver and the optimized displaced receiver — within the framework of binary coherent state modulation CV-QKD with reverse reconciliation. By explicitly incorporating detector imperfections, we demonstrate that these non-Gaussian strategies enhance the secret key rate, surpassing the ideal homodyne detection even under imperfect realistic scenarios.

2. Results and Discussion

Figure 1 compares the secret key rate across the analyzed receivers. The top row illustrates the performance of the Kennedy receiver for various efficiencies γ and dark count levels ν. This scheme (top row) proves robust to reduced detection efficiency, with only a 5 km decrease in secure distance at $\gamma = 0.7$, outperforming ideal homodyne detection for $\gamma \geq 0.9$. In contrast, it is highly sensitive to dark counts (ν) (top row, right panel), which reduce the secure distance by ≈ 50 km at $\nu \approx 10^{-3}$. For the optimized displacement receiver, we observe an overall enhancement compared to the Kennedy receiver. These results are shown in the bottom row for the same parameters. As indicated, the optimized displacement receiver reacts in a qualitatively similar, though consistently better, way to reductions in detection efficiency than the Kennedy scheme (bottom row, left panel). More importantly, it exhibits a pronounced robustness against dark count noise (bottom row, right panel), maintaining a positive secret key rate beyond 200 km for all

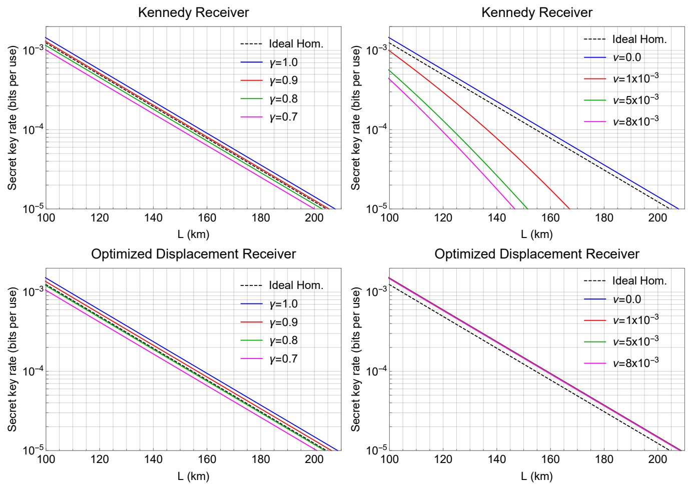

Figura 1. Top row (bottom row): Secret key rate for the Kennedy receiver (Optimized displacement receiver) as a function of distance for different values of detection efficiency γ and dark counts noise ν.

noise levels considered. Moreover, this receiver surpasses ideal homodyne detection for almost all combinations of imperfection parameters, with a lower performance only when the detection efficiency drops below 80%.

3. Conclusion

We analyze two non-Gaussian receivers with imperfect detectors in a binary coherent-state CV-QKD protocol with reverse reconciliation. In the ideal scenario ($\gamma = 1, \nu = 0$), both non-conventional strategies outperform standard homodyne detection. While dark counts significantly reduce the Kennedy receiver's secure distance (≈ 50km), the optimized displacement receiver remains robust, surpassing the ideal homodyne across all noise levels studied. Regarding efficiency, the Kennedy receiver maintains a superior secret key rate for $\gamma \geq 0.9$, whereas the optimized displacement receiver outperforms the homodyne for $\gamma > 0.8$.

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