On the Design of Quantum Communication Systems with non-Gaussian States

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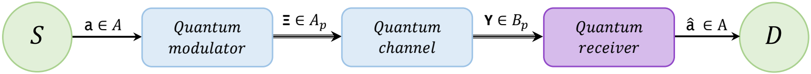
Motivation

- Communications are becoming ever more important and widespread.
- Classical physics is only a special case of quantum physics.
- The use of quantum non-Gaussian states can significantly improve the performance of a communication system.

Contents

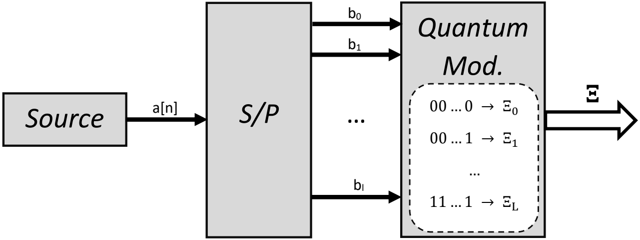
Quantum Communication System



Block chain of a quantum communication system.

Quantum Communication System

Quantum modulation



Quantum Communication System

Quantum modulation

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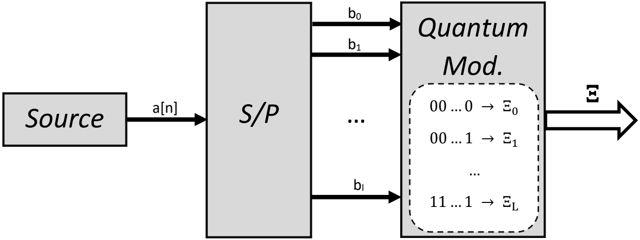


OOK

$$\Xi_0 = \Xi_{th}$$
$$\Xi_1 = \Xi_{th}(\mu)$$

BPSK

$$\Xi_0 = \Xi_{th}(-\mu)$$
$$\Xi_1 = \Xi_{th}(\mu)$$

Coherent state

$$\boldsymbol{A}\left|\mu\right\rangle = \mu\left|\mu\right\rangle$$
$$\left|\mu\right\rangle = \boldsymbol{D}_\mu\left|0\right\rangle$$

Squeezed state

$$\left|\mu,\zeta\right\rangle = \boldsymbol{D}_\mu \boldsymbol{S}_\zeta\left|0\right\rangle$$

Thermal noise state

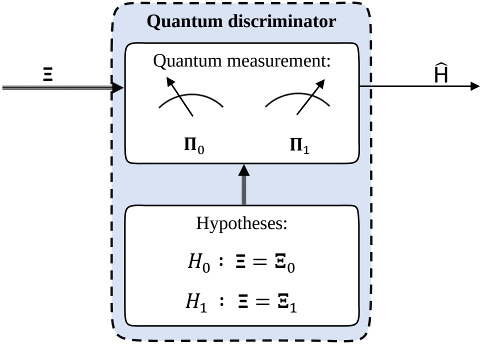
$$\boldsymbol{\Xi}_{\mathrm{th}} = (1-v)\sum_{n=0}^{\infty} v^n \left|n\right\rangle\left\langle n\right|$$
$$v = \frac{\bar{n}}{\bar{n}+1}; \qquad \bar{n} = \left(\exp\left\{\frac{\hbar\omega}{k_B T}\right\} - 1\right)^{-1}$$

Photon added states

$$\boldsymbol{\Xi}^{(k)} = \frac{(\boldsymbol{A}^\dagger)^k \boldsymbol{\Xi} \boldsymbol{A}^k}{\mathrm{tr}\left\{(\boldsymbol{A}^\dagger)^k \boldsymbol{\Xi} \boldsymbol{A}^k\right\}}$$

Quantum Communication System

Quantum receiver



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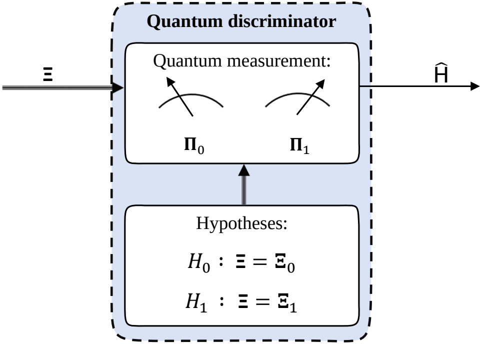


Distribution error probability

$$P_e = 1 - \left(p_0 \operatorname{tr}\{\Xi_0 \Pi_0\} + p_1 \operatorname{tr}\{\Xi_1 \Pi_1\}\right)$$

Helstrom Bound: Minium distribution error probability

$$\breve{P}_e = \frac{1}{2}\left(1 - \left\| p_1 \Xi_1 - p_0 \Xi_0 \right\|_1\right)$$

Helstrom Bound: Minium distribution error probability

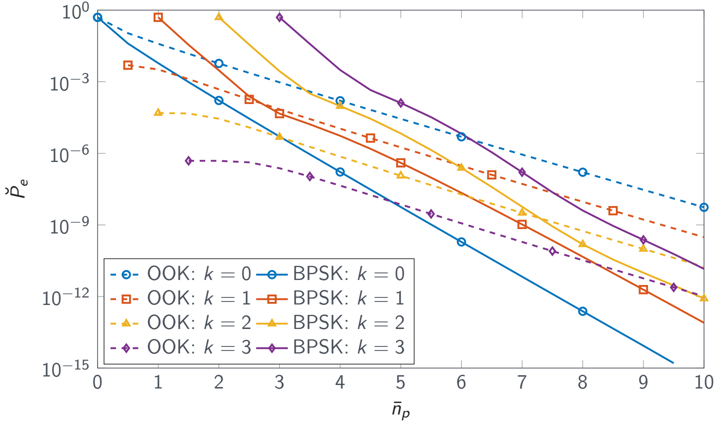
$$\breve{P}_e = \frac{1}{2}\left(1 - \|p_1 \Xi_1 - p_0 \Xi_0\|_1\right)$$

MDEP for pure states

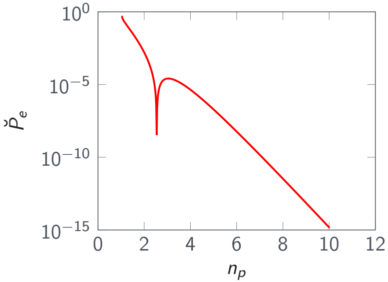
$$\breve{P}_e = \frac{1}{2}\left(1 - \sqrt{1 - 4 p_0 p_1 |\langle\psi_0|\psi_1\rangle|^2}\right)$$

Discrimination of Photon Added States

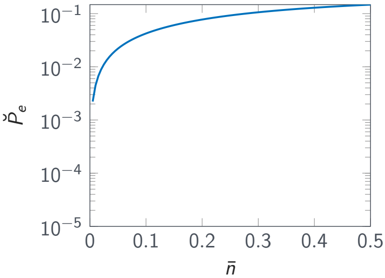
Noisy PACS discrimination



BPSK and OOK comparison in terms of MDEP as function of $\bar{n}_p$ with $N = 45$, $\bar{n} = 10^{-2}$, $p_0 = p_1 = 1/2$.



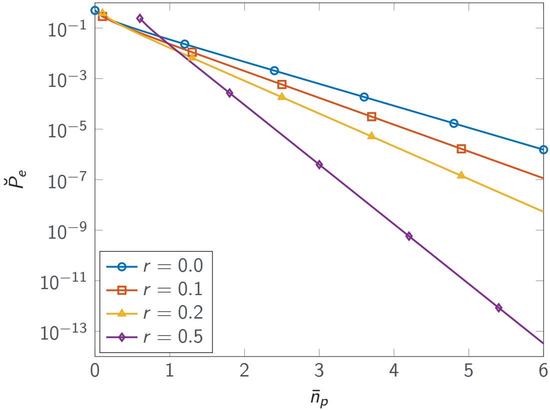
MDEP of quantum BPSK as function of n_p, in absence of noise with $N = 30$ and $k = 1$.



MDEP for $\mu = 0.54$ (value of the zero) in terms of $\bar{n}$.

Discrimination of Photon Added States

Squeezed States discrimination: BPSK



MDEP of a QBPSK system with squeezed states in terms of the mean photon number in the system $\bar{n}_p$.

$N = 30$; $\bar{n} = 0$; $p_0 = p_1 = 1/2$

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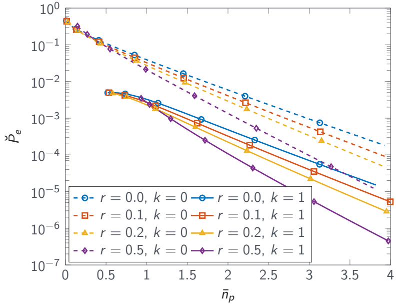
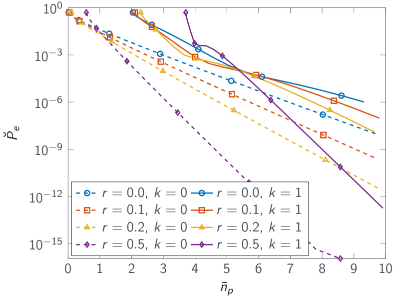
$$N = 45;\ \bar{n} = 10^{-2};\ \theta = \pi;\ p_0 = p_1 = 1/2$$



MDEP of a QOOK system with PASS in terms of the mean photon number in the system $\bar{n}_p$.



MDEP of a QBPSK system with PASS in terms of the mean photon number in the system $\bar{n}_p$.

Conclusion

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- We can design a quantum equivalent of a classical communication system.
- The use of PACSs or PASS improves the performance of the quantum state discriminator for QOOK systems.
- The use of PASSs in particular can leads to significant benefits in terms of MDEP.