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

Supervisor:

Chiar.mo Prof. Andrea Conti

Co-Supervisor:

Dott. Ing. Stefano Guerrini

Candidate:

Federico Forzano

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Motivation

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- 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

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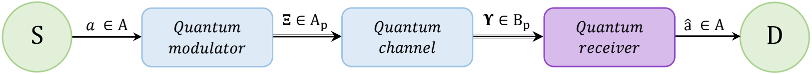
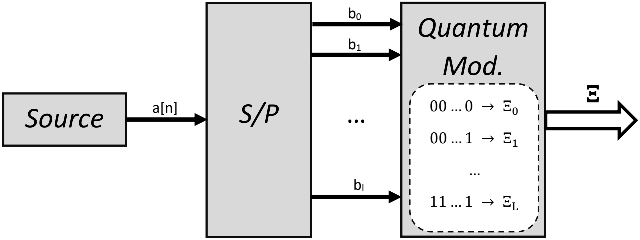
Quantum Communication System



Block chain of a quantum communication system.

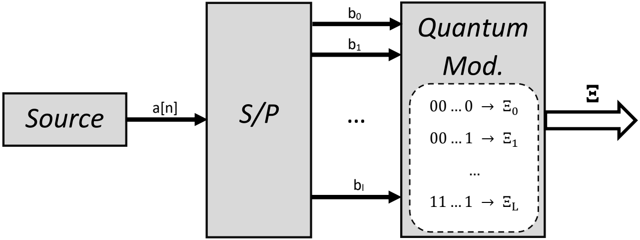
Quantum Communication System

Quantum modulation



Quantum Communication System

Quantum modulation



OOK

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

BPSK

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

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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

$$\boldsymbol{\Xi}_{th} = (1-v)\sum_{n=0}^{\infty} v^{n}\left|n\right\rangle\left\langle n\right|$$

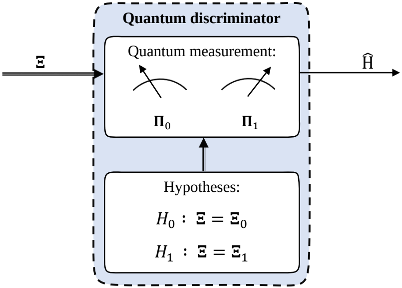
$$v = \frac{\bar{n}}{\bar{n}+1}; \qquad \bar{n} = \left(\exp\left\{\frac{\hbar\omega}{k_B T}\right\} - 1\right)^{-1}$$

Photon added states

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

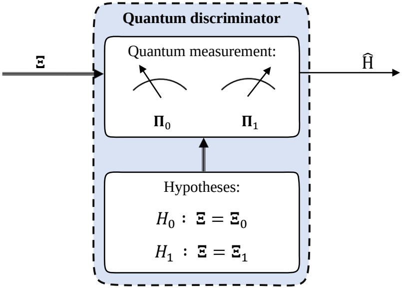
Quantum Communication System

Quantum receiver



Quantum Communication System

Quantum receiver



Distribution error probability

$$P_e = 1 - (p_0 tr\{\mathbf{\Xi}_0 \mathbf{\Pi}_0\} + p_1 tr\{\mathbf{\Xi}_1 \mathbf{\Pi}_1\})$$

Helstrom Bound: Minium distribution error probability

$$\breve{P}_e = \frac{1}{2}\left(1 - \left\| p_1 \boldsymbol{\Xi}_1 - p_0 \boldsymbol{\Xi}_0 \right\|_1\right)$$

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Helstrom Bound: Minium distribution error probability

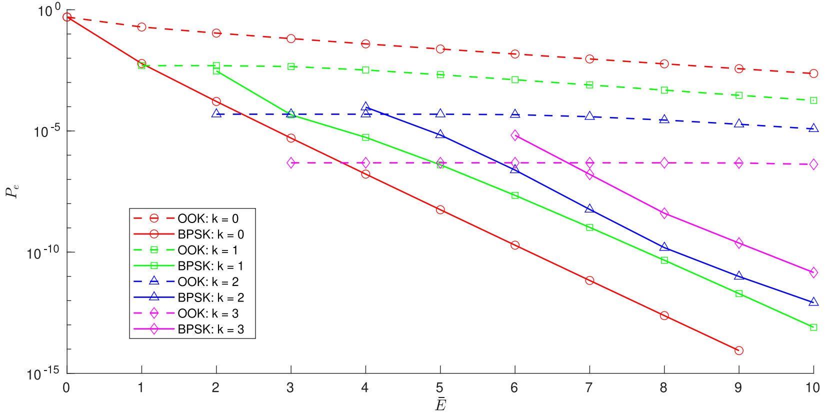
$$\breve{P}_e = \frac{1}{2}\left(1 - \left\|p_1 \Xi_1 - p_0 \Xi_0\right\|_1\right)$$

MDEP for pure states

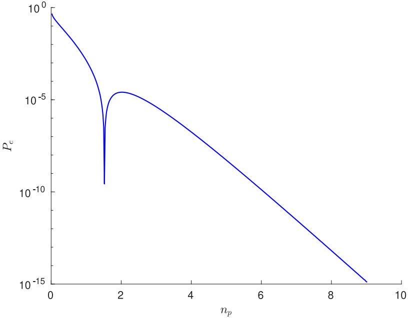
$$\breve{P}_e = \frac{1}{2}\left(1 - \sqrt{1 - 4 p_0 p_1 \left|\langle \psi_0 | \psi_1 \rangle\right|^2}\right)$$

Discrimination of Photon Added States

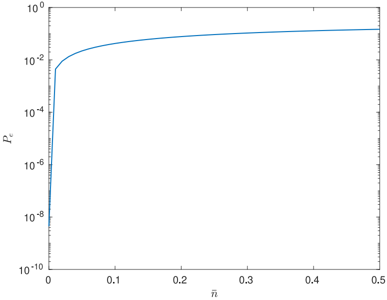
Noisy PACS discrimination



MDEP comparison of a QOOK and QBPSK systems with PACS in terms of the mean energy of the system $\bar{E}$.
$N = 45$; $\bar{n} = 10^{-2}$; $p_0 = p_1 = 1/2$



MDEP of a QBPSK with PACSs, without noise. $k = 1$.



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

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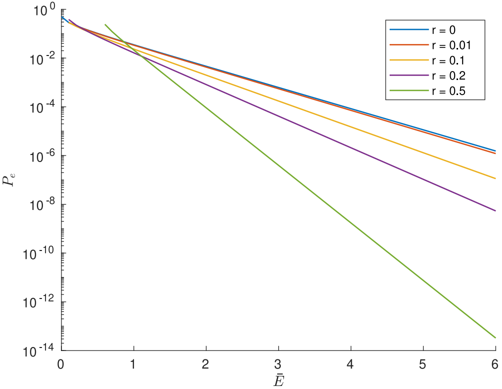
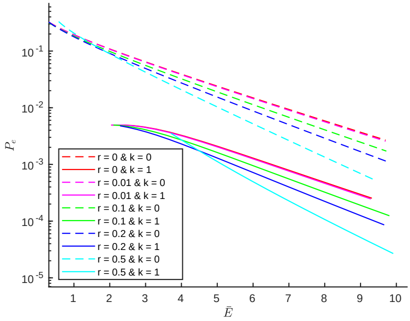
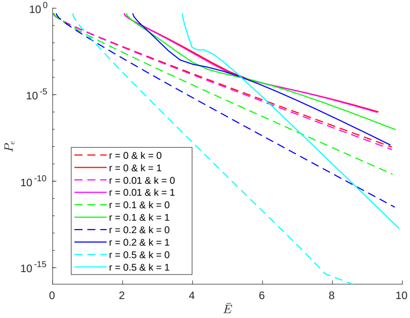


MDEP of a QBPSK system with squeezed states in terms of the mean energy of the system $\bar{E}$.
$N = 30$; $\bar{n} = 0$; $p_0 = p_1 = 1/2$

$$N = 30;\ \bar{n} = 10^{-2};\ \theta = \pi;\ p_0 = p_1 = 1/2$$



MDEP of a QOOK system with PASS in terms of the mean photon number n_p.



MDEP of a QBPSK system with PASS in terms of the mean energy of the system $\bar{E}$.

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.