Transmission system study

1 Introduction

This document describes a simple emission and detection system that uses coherent states as it's means?? of transmission???.
The transmitted information consists in a binary sequence which is ??translated?? in a sequence of coherent states. In this simulation, the used constellation is formed by the states $\{|\alpha\rangle, |i\alpha\rangle, |-\alpha\rangle, |-i\alpha\rangle\}$, in which α is defined as $\langle n\rangle = |\alpha|^2$ ($\langle n\rangle$ is the expected number of photons in a state). (METER MELHOR)

One of the main effects studied in this system is quantum noise, which is an intrinsic effect?? to coherent states(VER MARK FOX). In principle???? (VER REFERENCIAS) the variance of a coherent state is given by $\Delta X_1 \Delta X_2 = {}^1/_4$.

But, given that we combine two photocurrents to obtain an output current, then the total noise will have a combined value of SOMETHING??? Procurar referencias.

Therefore, assuming Gaussian?? (WHY GAUSSIAN?) shot noise, for each quadrature we want $\mathrm{Var}(X_i) = {}^1/_4$?????
(TENHO DE PROCURAR REFERENCIAS)

In this simulation, we introduce quantum noise in the photodiodes. We know that a coherent state has an expected number of photons distributed by a Poisson distribution, which has an average number equal to it's variance. Therefore, when the photodiode detects the power of signal, which is proportional to the number of photons, then it's variance must also be proportional to the number of photons.

In fact the last step in detecting the resulting signal introduces an difference between currents, but that only will increase the variance. Assuming the independence between detections, and it's intrinsic noise (PROCURAR MELHOR PALEIO), then:

$$\mathrm{Var}(I_{out}) = \mathrm{Var}(I_1) + \mathrm{Var}(I_2)$$

Therefore, the best result we can achieve will be $\mathrm{Var}(X) = {}^1/_4$???? (PROCURAR PALEIO SOBRE ISTO)

2 Functional Description

The simulation setup is described by diagram in figure 1. We start by generating a state from one of the four available ones.???? Then, the signal is received in a Hybrid Detector??? where the signal is compared with a local oscillator giving four different signals in it's output. Two of those signals are detected by a photodiode which output will be the difference of the two photocurrents. The other two signals will be also be detected by another photodiode, which will obtain the other quadrature of the signal.????? (TEM QUE FICAR MELHOR EXPLICADO).

System Blocks	netxpto Blocks
-	MQAM
-	LocalOscillator
-	Hybrid??
-	Photodiode??
-	Sampler ??

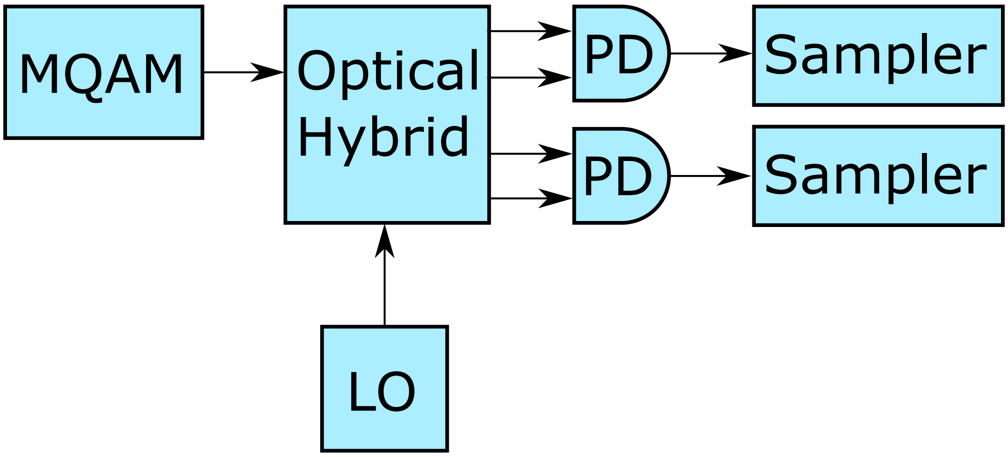

Figure 1: Overview of the optical system being simulated.

3 Required files

Header Files

File	**Description**
netxpto.h	Generic purpose simulator definitions.
m_qam_transmitter.h	—
local_oscillator.h	Generates continuous coherent signal.
optical_hybrid.h	—
photodiode.h	—
sampler.h	—
sink.h	Closes any unused signals.

Source Files

File	**Description**
netxpto.cpp	Generic purpose simulator definitions.
m_qam_transmitter.cpp	—
local_oscillator.cpp	Generates continuous coherent signal.
optical_hybrid.cpp	—
photodiode.cpp	—
sampler.cpp	—
sink.cpp	Closes any unused signals.

4 System Input Parameters

This system takes into account the following input parameters:

System Parameters	Description
numberOfBitsGenerated	Gives the number of bits to be simulated
bitPeriod	Sets the time between adjacent bits
wavelength	Sets the wavelength of the local oscillator in the MQAM????
samplesPerSymbol	Establishes the number of samples each bit in the string is given
localOscillatorPower1	Sets the optical power, in units of W, of the local oscillator inside the MQAM
localOscillatorPower2	Sets the optical power, in units of W, of the local oscillator used for Bob's measurements
localOscillatorPhase	Sets the initial phase of the local oscillator used in the detection
transferMatrix	Sets the transfer matrix of the beam splitter used in the homodyne detector
responsivity	Sets the responsivity of the photodiodes used in the homodyne detectors
bufferLength	Sets the length of the buffer used in the signals
iqAmplitudeValues	Sets the amplitude of the states used in the MQAM????
shotNoise	Chooses if quantum shot noise is used in the simulation
samplesToSkip	Sets the number of samples to skip when writing out some of the signal files.

5 Inputs

This system takes no inputs.

6 Outputs

The system outputs the following objects:

- Signals:
  - Binary Sequence used in the MQAM; (S_0)
  - Local Oscillator used in the MQAM; (S_1)
  - Local Oscillator used in the detection; (S_2)
  - Optical Hybrid Outputs; (S_3, S_4, S_5, S_6)
  - In phase Photodiode output; (S_7)
  - Quadrature Photodiode output; (S_8)
  - In phase Sampler output; (S_9)
  - Quadrature Sampler output; (S_{10})

7 Simulation Results

The objective of this simulation was to get the (quantum noise???) associated to the detection of coherent states.

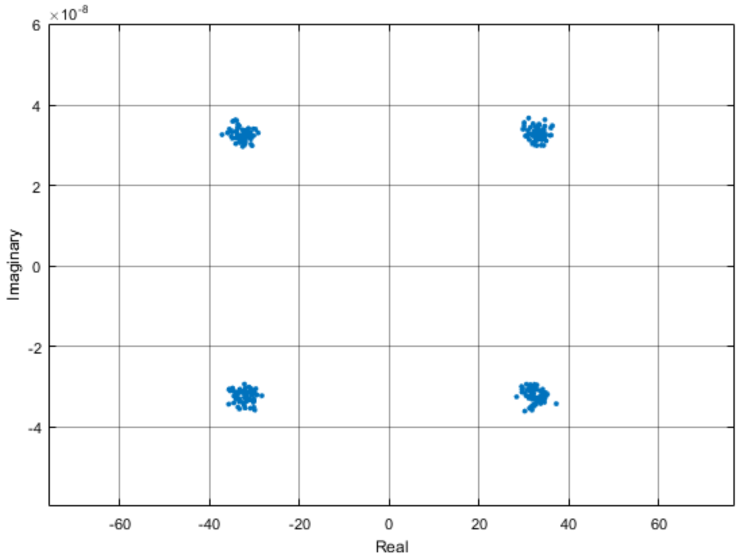

Figure 2: Simulation of a constelation of 4 states (n = 100)

We expect that the variance is invariant with the number of photons sent from Alice. The plot in 3 show that the simulation also shows this invariance with the number of photons.

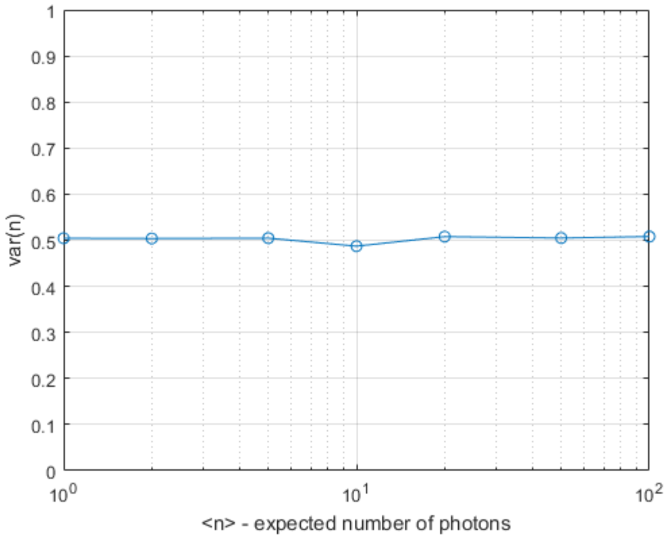

Figure 3: Simulation of the variance of n.

..... We can conclude that the expected variance will give us Var(X) = $^1/_2$.
The results obtained in our simulations are in accordance with the theoretical prevision???

8 Block Description

8.1 MQAM mapper???

M-QAM Mapper

Input Parameters

- m
- iqAmplitudes

Functional Description

This block does the mapping of the binary signal using a m-QAM modulation. It atributes to each pair of bits a point in the I-Q space. The constellation is defined by the *iqAmplitudes* vector.

Input Signals

Number: 1
Type: Binary (DiscreteTimeDiscreteAmplitude)

Output Signals

Number: 2
Type: Sequence of 1's and -1's (DiscreteTimeDiscreteAmplitude)

Examples

— MISSING IMAGE —

Sugestions for future improvement

8.2 Local Oscillator

Local Oscillator

Input Parameters

- LocalOscillatorPhase
- LocalOscillatorOpticalPower
- LocalOscillatorOpticalPower_dBm

Functional Description

This blocks outputs a complex signal with a user defined length, phase and power. The phase and optical power are defined by the values of *LocalOscillatorPhase* and *LocalOscillatorOpticalPower* respectively.

Input Signals

Number: 0

Output Signals

Number: 1
Type: Complex or Complex_XY optical signal (ContinuousTimeContinuousAmplitude)
1

8.3 Optical Hybrid

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8.4 Photodiode

Photodiode

Input Parameters

- setResponsivity
- useNoise

Functional Description

This block accepts two complex signals and outputs one real signal built from an evaluation of the power of the input signals and their subsequent subtraction. The responsivity is defined by the value of *Responsivity*. This block also adds random gaussian distributed shot noise with an amplitude defined by the power of the inputs. The shot noise is activated by the boolean variable set by the *useNoise* parameter.

Input Signals

Number: 2
Type: Complex signal (ContinuousTimeContinuousAmplitude)

Output Signals

Number: 1
Type: Real signal (ContinuousTimeContinuousAmplitude)

8.5 Sampler

Sampler

Input Parameters

- setSamplingRate
- setDelay

Functional Description

This block accepts one real continuous signal and outputs one real discrete signal built from a sampling of the input signal with a predetermined sampling rate. The sampling rate is defined by the value *SamplingRate*. This block also allows for a controlled adjustment of the starting point of the output signal, defined by the value *Delay*

Input Signals

Number: 1
Type: Real signal (ContinuousTimeContinuousAmplitude)

Output Signals

Number: 1
Type: Real signal (DiscreteTimeContinuousAmplitude)

9 Known Problems

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