BPSK system

1 Introduction

This document describes the simulation BPSK system in back-to-back configuration.

2 Functional Description

A simplified diagram of the system being simulated is presented in the Figure 1. The system simulated takes a random binary string and encodes it in an optical bandpass signal, signal that afterwards is decoded in order to re-obtain the original binary string.

The decoding of the optical signal is accomplished by an homodyne receiver, which combines the signal with a local oscillator with a user-determined phase. The homodyne receiver block output is then fed into a block that compares it with the original binary string and computes the Bit Error Rate (BER) along with it's upper and lower bounds for a certain user defined confidence level.

Figure 1: Overview of the BPSK system being simulated.

System Blocks	netxpto Blocks
BPSK Transmitter	MQamTransmitter
BPSK Receiver	HomodyneReceiver
BER Estimator	BitErrorRate

3 System Input Parameters

This system takes into account the following input parameters:

~~netxpto~~ Parameters	Description
NumberOfBits	Gives the number of bits in the encoded string
SamplesPerSymbol	Establishes the number of samples each bit in the string is given
pLength	Sets the bit generator pattern length
iqAmplitudesValues	Sets the state constellation
outOpticalPower_dBm	Sets the optical power, in units of dBm, of the sent signal
LOoutOpticalPower_dBm	Sets the optical power, in units of dBm, of the local oscillator used in the homodyne detector
LocalOscillatorPhase	Sets the initial phase of the local oscillator used in the homodyne detector
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 detector
Amplification	Sets the amplification of the trans-impedance amplifier used in the homodyne detector
NoiseAmplitude	Sets the amplitude of the gaussian thermal noise added in the homodyne detector
Delay	Sets the delay factor of the homodyne detector
PosReferenceValue	Set the positive and negative reference values for the bit decision block
NegReferenceValue	
Confidence	Sets the confidence interval for the calculated QBER
MidReportSize	Sets the number of bits between generated QBER mid-reports

4 Inputs

This system takes no inputs.

5 Outputs

This system outputs the following objects:

- Signals:
  - Initial Binary String; ($MQAM_0$)
  - Optical Signal with coded Binary String; (S_{00})
  - Decoded Binary String; (S_{01})
- Other:
  - Bit Error Rate report in the form of a .txt file. (BER.txt)

6 Simulation Results

We consider the following scenarios:

- 6.1 Basic BPSK back to back with normally distributed thermal noise.

6.1 BPSK with thermal noise

The following results were obtained from the simulation using the following input parameters:

NumberOfBits=	1000
SamplesPerSymbol=	16
pLength=	5
iqAmplitudesValues=	{ { 1, 0 }, { -1, 0 } }
outOpticalPower_dBm=	-20
LOoutOpticalPower_dBm=	-10
LocalOscillatorPhase=	0
TransferMatrix=	{ { 1/sqrt(2), 1/sqrt(2), 1/sqrt(2), -1/sqrt(2) } }
Responsivity=	1
Amplification=	1e6
NoiseAmplitude=	15.397586549153788
Delay=	9

The system took the binary string presented in Figure 2 and encoded it into the optical signal in Figure 3. Notice the BPSK constelation of the signal, presented in Figure 4.

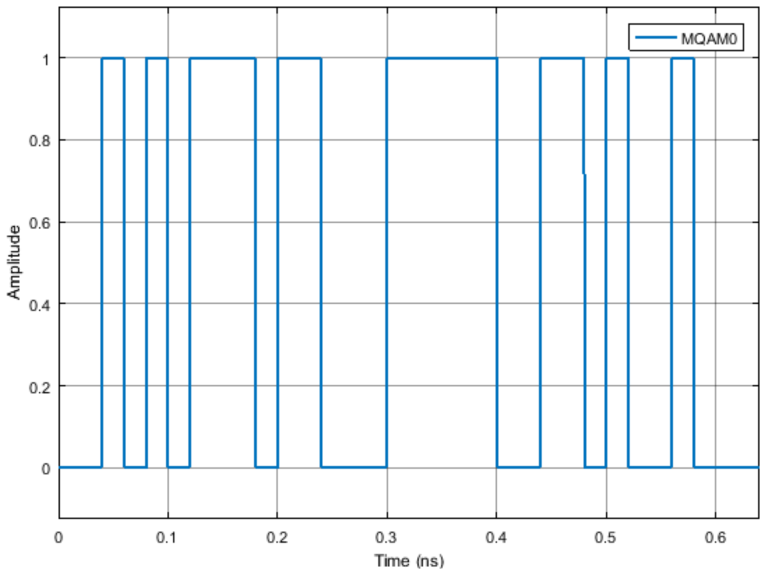

Figure 2: Sent binary key.

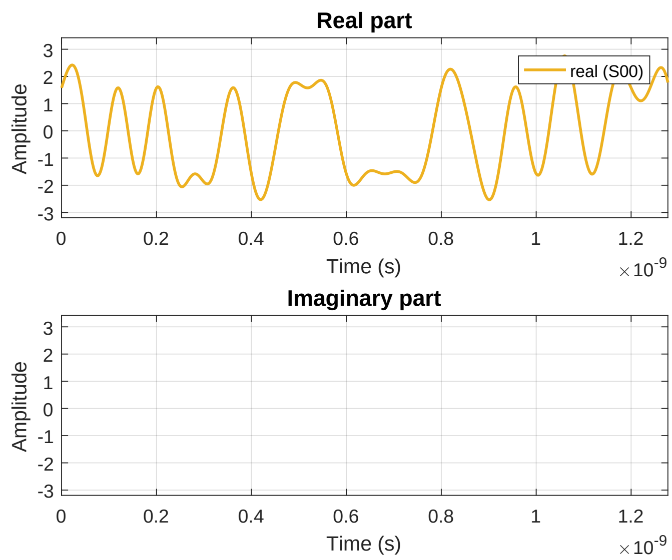

Figure 3: Sent signal.

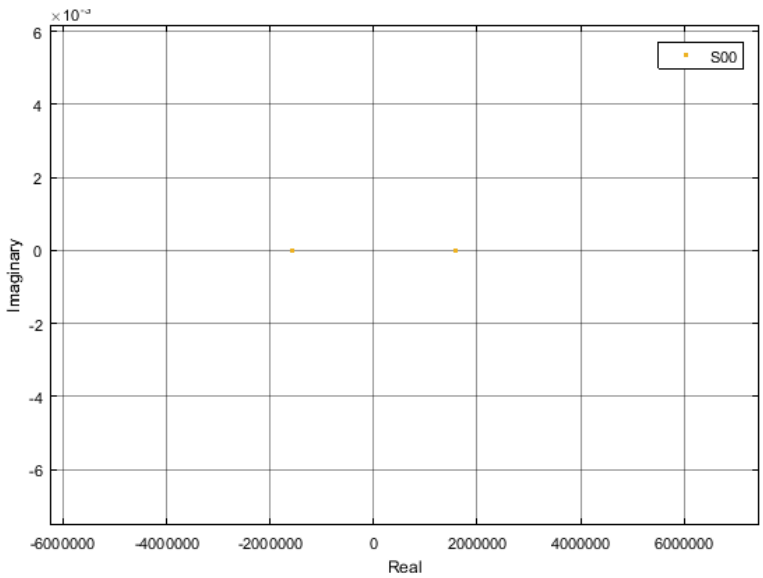

Figure 4: Constellation of the sent signal.

Homodyne detection is then performed, using to that effect the local oscillator signal presented in Figure 5. Figures 6 and 7 show the addition of noise to the signal.

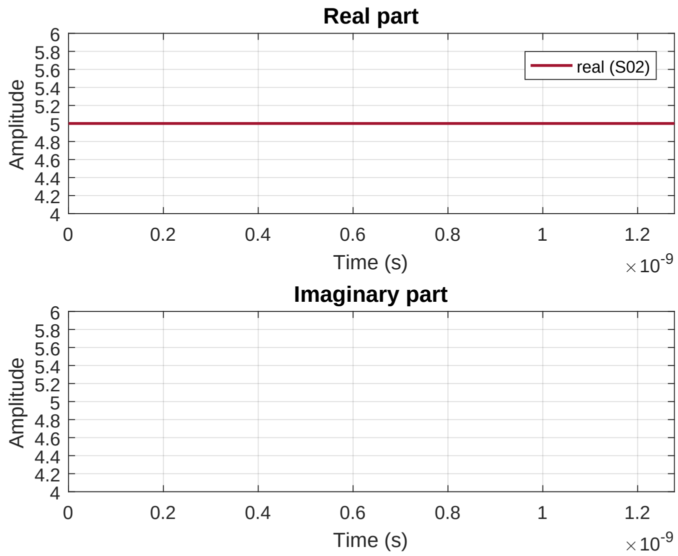

Figure 5: Homodyne receiver internal signal: local oscillator used for Homodyne detection.

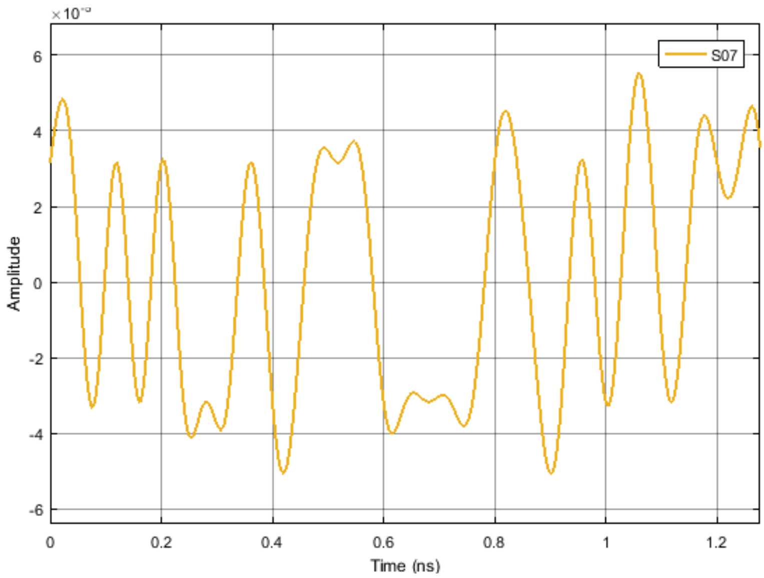

Figure 6: Homodyne receiver internal signal: subtraction of the signals outputted by the photodiodes.

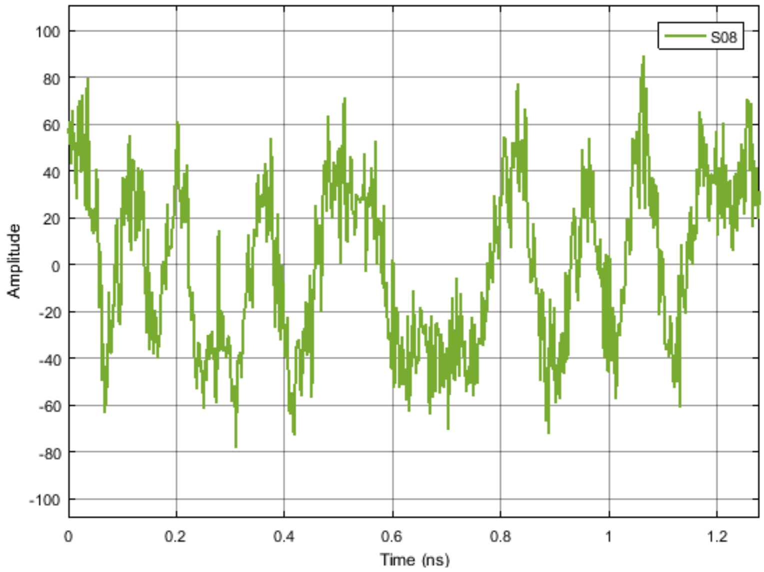

Figure 7: Homodyne receiver internal signal: amplification of the signal in Figure 6 with added noise.

The result of the homodyne detection is the binary string presented in 8, which is then compared to the original binary string by the BER block, which outputs the report presented in Figure 9.

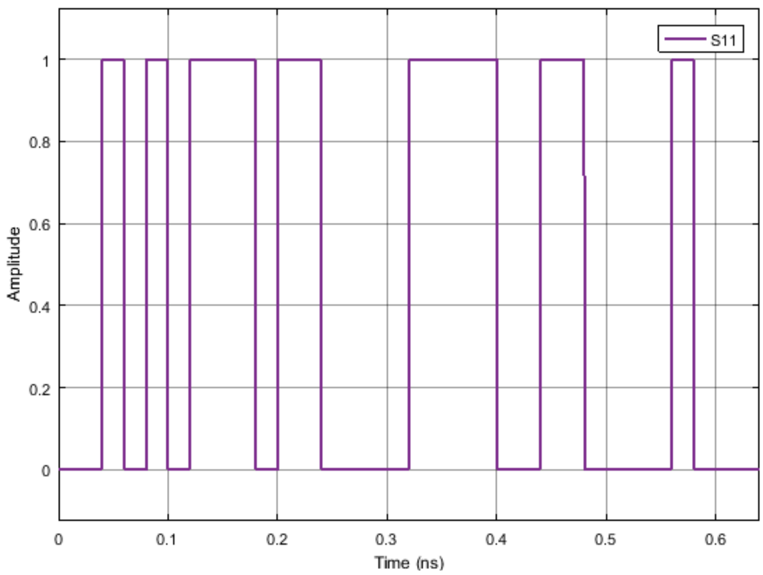

Figure 8: Decoded binary string, output of the Homodyne receiver block.

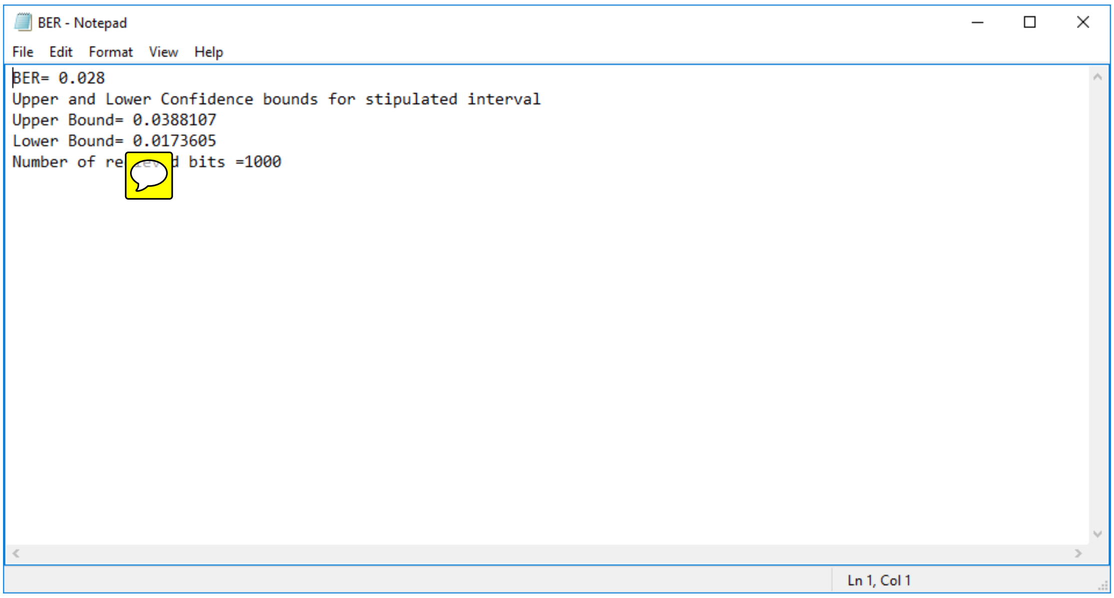

Figure 9: Bit-Error-Rate report.

7 Block Description

7.1 MQAM Transmitter

7.2 Homodyne Receiver

Introduction

This super-block compresses the function of the following blocks:

- Local Oscillator;
- Balanced Beamsplitter;
- Photodiode;
- Subtractor;
- Amplifier;
- Discretizer;
- Delayer
- Bit Decider;

This compression allows for a cleaner code.

Input Parameters

- LocalOscillatorOpticalPower
- LocalOscillatorOpticalPower_dBm
- LocalOscillatorPhase
- TransferMatrix
- Responsivity
- Amplification
- NoiseAmplitude
- SamplingRate
- Delay
- ReferenceValue

Functional Description

The input signal is evaluated and a binary string is generated from this evaluation.

A diagram of the blocks that constitute this super-block, with the corresponding relations is presented in Figure 10.

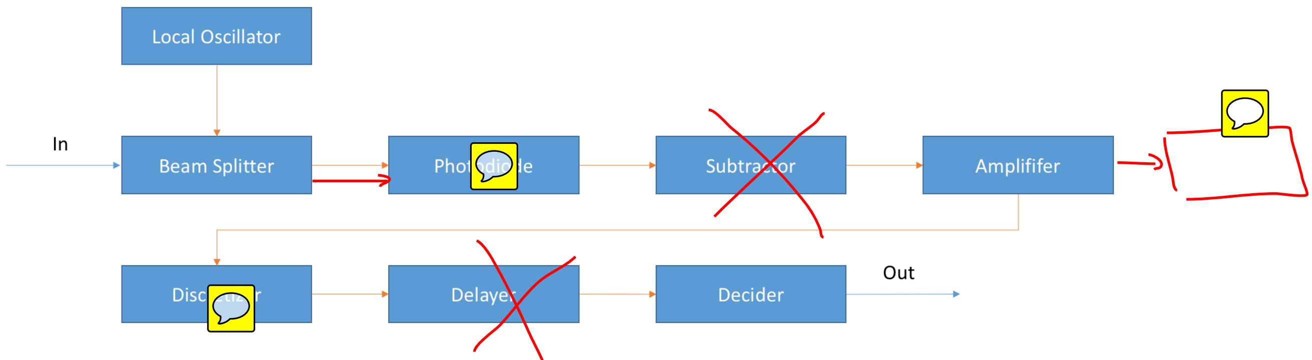

Figure 10: Homodyne Receiver Block Diagram.

Inputs

Number: 1
Type: Sequence of impulses modulated by the filter (OpticalSignal)

Outputs

Number: 1
Type: Binary String (Binary)

7.3 Bit Error Rate

Input Parameters

- setConfidence
- setMidReportSize

Functional Description

This block accepts two binary strings and outputs a binary string, outputting a 1 if the two input samples are equal to each other and 0 if not. This block also outputs *.txt* files with a report of the calculated BER as well as the estimated Confidence bounds for a given probability P. The block allows for mid-reports to be generated, the number of bits between reports is customizable, if it is set to 0 then the block will only output the final report.

Input Signals

Number: 1
Type: Binary (DiscreteTimeDiscreteAmplitude)

Output Signals

Number: 1
Type: Binary (DiscreteTimeDiscreteAmplitude)

7.4 Local Oscillator

Input Parameters

- LocalOscillatorPhase
- LocalOscillatorOpticalPower
- `LocalOscillatorOpticalPower_dBm`

Functional Description

This blocks accepts a complex signal (either with XY polarization or a simple Band Pass signal) and outputs a phase constant complex signal with the same length as the input signal. The phase and optical power are defined by the values of *LocalOscillatorPhase* and *LocalOscillatorOpticalPower* respectively.

Input Signals

Number: 1
Type: Complex signal (ContinuousTimeContiousAmplitude)

Output Signals

Number: 2
Type: Complex signal (ContinuousTimeContiousAmplitude)

7.5 Beam Splitter

Input Parameters

- setTransferMatrix

Functional Description

This block accepts two complex signals and outputs two complex signals built from a mixture of the two inputs according to a pre-determined and user defined transfer matrix.

Input Signals

Number: 2
Type: Complex signal (ContinuousTimeContiousAmplitude)

Output Signals

Number: 2
Type: Complex signal (ContinuousTimeContiousAmplitude)

7.6 Photodiode

Input Parameters

- setResponsivity

Functional Description

This block accepts two complex signals and outputs two real signals built from an evaluation of the power of the input signals.

Input Signals

Number: 2
Type: Complex signal (ContinuousTimeContiousAmplitude)

Output Signals

Number: 2
Type: Real signal (ContinuousTimeContiousAmplitude)

7.7 Subtractor

Input Parameters

This block has no input parameters.

Functional Description

This block accepts two real signals and outputs one real signals built from subtracting the value of the input signals.

Input Signals

Number: 2
Type: Real signal (ContinuousTimeContiousAmplitude)

Output Signals

Number: 1
Type: Real signal (ContinuousTimeContiousAmplitude)

7.8 Amplifier

Input Parameters

- setAmplification
- setNoiseAmplitude

Functional Description

This block accepts one real signal and outputs one real signal built from multiplying the input signals by a predetermined value. This block also adds random gaussian distributed noise with a user defined amplitude. The multiplying factor and noise amplitude are defined by the values of *Amplification* and *NoiseAmplitude* respectively.

Input Signals

Number: 1
Type: Real signal (ContinuousTimeContiousAmplitude)

Output Signals

Number: 1
Type: Real signal (ContinuousTimeContiousAmplitude)

7.9 Discretizer

Input Parameters

- setSamplingRate

Functional Description

This block accepts one real continuous signal and outputs one real discrete signal built from a sampling of the input signals with a predetermined sampling rate. The sampling rate is defined by the value *SamplingRate*.

Input Signals

Number: 1
Type: Real signal (ContinuousTimeContiousAmplitude)

Output Signals

Number: 1
Type: Real signal (DiscreteTimeContiousAmplitude)

7.10 Delayer

Input Parameters

- setDelay

Functional Description

This block accepts one real discrete signal and outputs one real discrete signal discarding a predetermined number of samples of the beginning of the input signal. The number of samples discarded rate is defined by the value *Delay*.

Input Signals

Number: 1
Type: Real signal (DiscreteTimeContiousAmplitude)

Output Signals

Number: 1
Type: Real signal (DiscreteTimeContiousAmplitude)

7.11 Bit Decider

Input Parameters

- setPosReferenceValue
- setNegReferenceValue

Functional Description

This block accepts one real discrete signal and outputs a binary string, outputting a 1 if the input sample is above the predetermined reference level and 0 if it is below another reference value The reference values are defined by the values of *PosReferenceValue* and *NegReferenceValue*.

Input Signals

Number: 1
Type: Real signal (DiscreteTimeContiousAmplitude)

Output Signals

Number: 1
Type: Binary (DiscreteTimeDiscreteAmplitude)

7.12 Bit Error Rate

Input Parameters

- setConfidence
- setMidReportSize

Functional Description

This block accepts two binary strings and outputs a binary string, outputting a 1 if the two input samples are equal to each other and 0 if not. This block also outputs *.txt* files with a report of the calculated BER as well as the estimated Confidence bounds for a given probability P. The block allows for mid-reports to be generated, the number of bits between reports is customizable, if it is set to 0 then the block will only output the final report.

Input Signals

Number: 1
  Type: Binary (DiscreteTimeDiscreteAmplitude)

Output Signals

Number: 1
  Type: Binary (DiscreteTimeDiscreteAmplitude)

8 Known Problems

- Homodyne Super-Block not functioning (problem in inputting signal into it)
- MQAM Transmitter PDF needs to be written
- 8 bits being lost of every signal
- If the bit string length is larger than 512, this first 512 bits are lost
- I don't think it is possible to declare nested subfiles, so I can't put the sub blocks into the homodyne receiver super block manual