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Performance Evaluation of Coherent and Non-Coherent Detectors for the Reception of Quadrature Amplitude Modulation (QAM) Signals

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Abstract

Several methods have been employed to eliminate the problem of high error rates associated with wireless communication systems especially with transmission of signals using Quadrature Amplitude Modulation scheme. This research work has examined critically the effective contribution of using Coherent detector over Non-coherent detector in the reception of QAM signals by evaluating their performances in terms of bit error rates (BER) with respect to the signal-to-noise ratio (SNR) and their amplitude characteristics in the transmission of the QAM signals over the Additive White Gaussian Noise (AWGN). This is achieved by using MATLAB/SIMULINK software package. The simulation results give a considerably smaller BER in the Coherent detection method as compared to the Non-coherent detection method at all SNRs. This shows the advantage of using Coherent detector over the Non-coherent detector.

Keywords: Coherent detector, Non-coherent detector, QAM signals and Bit error rate.

Introduction

The communication system is a concatenation of modulation, a noisy medium, and demodulation schemes [1]. In response to the ever increasing demand in transmission capacity of a communication system, future telecommunication systems that will operate at 100 Gb/s are already under development. Field trials have been realized over existing deployed systems using a conventional direct detection approach [2-3]. A most important challenge at such high speed transmission is the spectral efficiency required to increase the transmission capacity over existing transmission links. New methods based on Coherent detection appear as the most promising [4-5]. Through modulation of signals or digital signal processing in electrical domain, they enable polarization multiplexing [6] and the mitigation of transmission impairment [7-8].

Modulation is the process of converting information carrying signals into forms that can be transmitted over a very long distance without loss in meaning and with very little loss in quality [9]. The need for modulation arises from the need for practicability of antennas and also to ensure different signals in the same frequency range can be transmitted over a long range of distance without interference. Modulation is a widely used phenomenon in communication engineering and takes different forms. Analogue modulation techniques such as amplitude modulation and frequency modulation are employed in analogue transmission of audio and video signals while digital modulation techniques such as on-off keying and phase shift keying are used to send audio and video signals from digital transmitters to digital receivers. In amplitude modulation, the information signal is superimposed on a higher frequency carrier signal which is used to carry the information from the sending end to the receiving end.

Quadrature Amplitude Modulation (QAM) is one of widely used modulation techniques because of its efficiency in power and bandwidth. In QAM system, two amplitude-modulated (AM) signals are combined into a single channel, thereby doubling the effective bandwidth. Also QAM is a modulation scheme which is carried out by changing the amplitude of two waves and it is often used to transmit large amount of data, under limited bandwidth. Digital QAM is a combination of amplitude and phase modulation. A QAM signal can be decoded using Coherent or Non-coherent detection. QAM detector requires the recovery of a Quadrature phase receiver, it can also be used to combat the problem of phase ambiguity in the recovered carrier, and it is greatly complicated by the presence of the amplitude component of the data symbols.

The detector is a baseband multi-level symbol set [10]. It undergoes matched filtering for optimum performance in noise, before being passed through a bank of comparators to determine the level from each demodulator at the sampling instant, and hence decode the corresponding bit pattern. Coherent detection refers to the radio technique of amplifying, down converting, and filtering a signal prior to detection [11]. With the fast development of modern communication techniques, the demand for reliable high data rate transmission has increased significantly, which stimulate much interest in modulation techniques. Different modulation techniques allow you to send different bits per symbol and thus achieve different throughputs or efficiencies. In this research work, the performances of Coherent and Non-coherent detectors for the reception of QAM signals are investigated over the Additive White Gaussian Noise (AWGN) using MATLAB/SIMULINK software package.

Materials and Methods

System Model

In this research work more attention was focused on the bit error rate of the received signal so as to measure the performance of the Coherent detector and Non-coherent detector in the reception of QAM signal. The mathematical model considered is shown in equations (1) and (2).

Assuming that Gaussian noise is the only channel disturbance, the received signal:

$$y(t) = x(t) + n(t) \quad (1)$$

Where $x(t)$ is the transmitted signal and $n(t)$ refers to the additive noise Ignoring the noise; $y(t)$ is written as

$$y(t) = u_I(t)\cos(2\pi f_c t + \phi_c) - u_Q(t)\sin(2\pi f_c t + \phi_c) \quad (2)$$

where u_I and u_Q are the In-phase and Quadrature amplitudes of the information-bearing signal of the carrier respectively. f_c and ϕ_c are the carrier frequency and phase respectively.

Bit Error Rate

The transmission BER is the number of detected bits that are incorrect before error correction, divided by the total number of transferred bits (including redundant error codes). The information BER, approximately equal to the decoding error probability, it is the number of decoded bits that remain incorrect after the error correction, divided by the total number of decoded bits (the useful information). Normally the transmission BER is larger than the information BER. In a communication system, the receiver side BER may be affected by transmission channel noise, interference, distortion, bit synchronization problems, attenuation, wireless multipath-fading [9]. The BER may be improved by choosing a strong signal strength (unless this causes cross-talk and more bit errors), by choosing a slow and robust modulation scheme or line coding scheme, and by applying channel coding schemes such as redundant forward error correction codes.

Research methodology

In order to evaluate the performance of the Non-coherent and Coherent detectors for the reception of the QAM signal, the systems were modeled using SIMULINK as shown in Figure 1. The difference in their development is in the receiver frequency. A change of carrier frequency at receiver from 2.5 MHz to 2.5 kHz for the Non-coherent detector The numerical simulations were performed and graphs plotted. Collection of data was done by generating sufficient number of independent random realizations of the system's parameters. The development of the data needed for the performance evaluations follow a general steps

- Defining the mathematical model that represent the system's parameters
- Determining the constraints and conditions needed for the simulation

- Writing the algorithm
- Selecting and organizing the right data structure and functions
- Writing the main code in steps
- Debugging the code and making modifications in steps
- Simulate the final program.

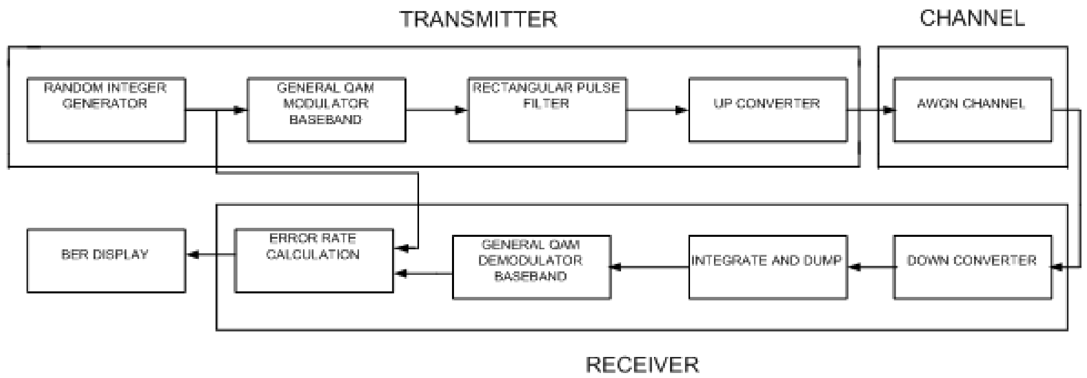

Figure 1: Generalized Simulink model for the Coherent/Non-coherent detection of QAM signals.

Simulation Parameters

The simulation parameters were as stated

Modulation scheme: 4-QAM
Sample period: $10^{-3}/8$

Samples per frame: 100
Transmitter filter: Rectangular pulse filter
Receiver filter: Integrate and dump
Carrier frequency: 2.5MHz
Channel: AWGN
Phase offset: $\pi/8$
Signal-to-noise ratio: 0 to 14 (dB)

Results and Discussion

The simulation results have shown the performance of the detectors. This is achieved by generating random integers and transmitting them over Additive White Gaussian Noise (AWGN) channel. Figures 2 and 3 show the wave form of the transmitted and the received signals for coherent and Non-coherent detections of QAM signal respectively. Table 1 shows the numerical results indicating that the amplitude of the received signal for both coherent reception and non-coherent reception is smaller than the amplitude of the transmitted signals. However amplitude of received signals for coherent reception is larger than that of non-coherent reception for the same transmit signal level. It is desirable to state here that the values of QAM signals give a substantial increase in strength with coherent reception, the received signals with non-coherent signaling is considerably lower which consequently result in weak signal reception with low quality and distortion of sent signals.

Table 1: Amplitude Modulation with Coherent and Non-Coherent Detection of QAM signals

Transmit signals	Received QAM signals	
	Coherent detection	Non- Coherent detection
0	0	0
0.6628	0.1379	-0.0226
0.9795	0.3983	-0.0226
0.9048	0.4727	-0.0095
0.4503	0.2585	0.0110
-0.3417	-0.1819	0.0195
-0.8858	-0.4364	-0.0161
-0.9874	-0.4525	-0.0289
-0.6713	-0.1783	-0.0402
-0.0136	-0.2452	-0.0049

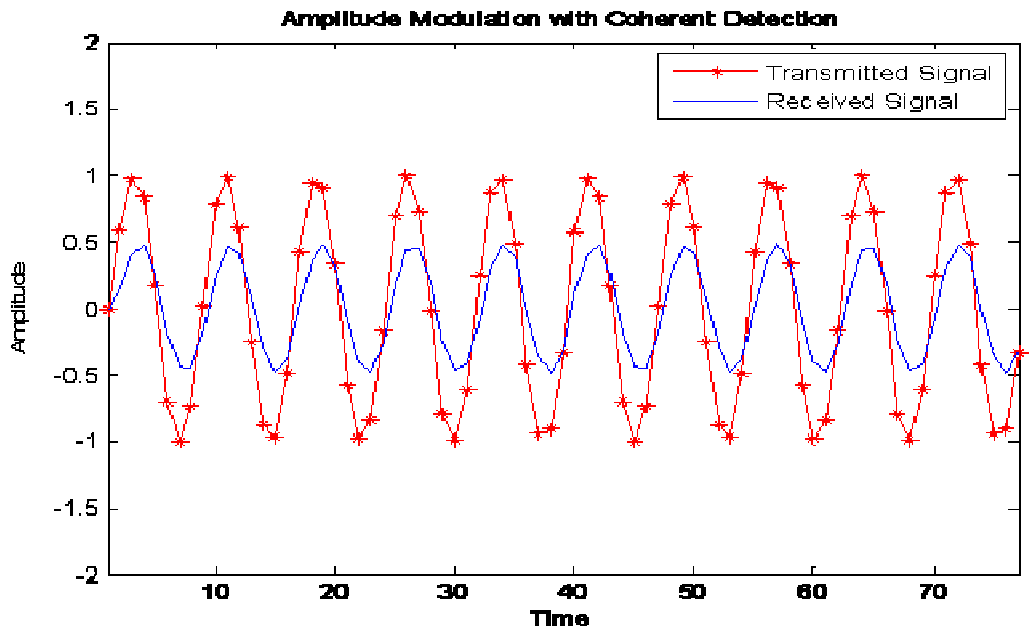

Figure 2: Simulation of Amplitude modulation of QAM signals with coherent detection

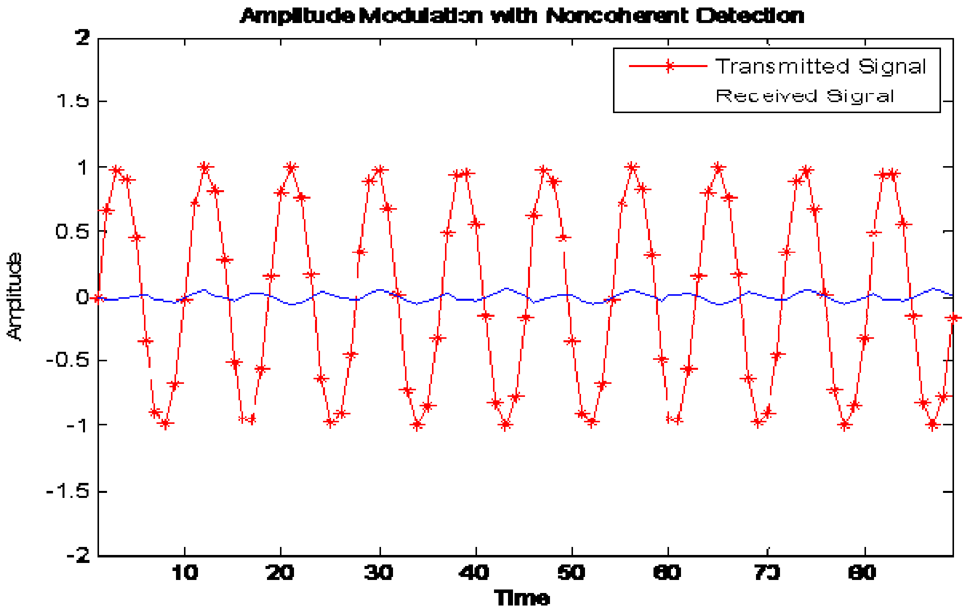

Figure 3: Simulation of Amplitude modulation of QAM signals with non-coherent detection

The result obtained in terms of BER in respect to SNR (dB) for Coherent detection of QAM signals as compared with the Non-coherent detection QAM signals are given in Table 2. It can be seen clearly from Table 2 that BER with Coherent detection per frame size at the receiver is considerably less than that encountered when Non-coherent detection was used. Figure 4 compares the BER versus SNR for the coherent detection reception with BER for the non-coherent detection reception method using 4-QAM modulation scheme. In the simulation 100 samples of symbols per frame were transmitted over AWGN channel for SNR values of 0 to 14dB. It was observed that the BER reduces as the SNR increases for both the Coherent detection reception method and Non-coherent reception method. However, the plot for that of the Non-coherent detection does not show a significant reduction in the values of BER as SNR increases. Also, the numerical values reveal that, the mean value of BER for coherent detection and non-coherent detection receptions are 0.6135or 61.35%, and 0.7401 or 74.01% respectively. This actually shows BER value difference of about 13%.

Table 2: BER values of Coherent and Non-coherent reception signals at a particular SNR (dB).

SNR(dB)	BER	
	Coherent	Non-coherent
0	0.6933	0.7617
2	0.6755	0.7610
4	0.6547	0.7589
6	0.6327	0.7575
8	0.6071	0.7573
10	0.5789	0.7562
12	0.5492	0.7078
14	0.5167	0.6606

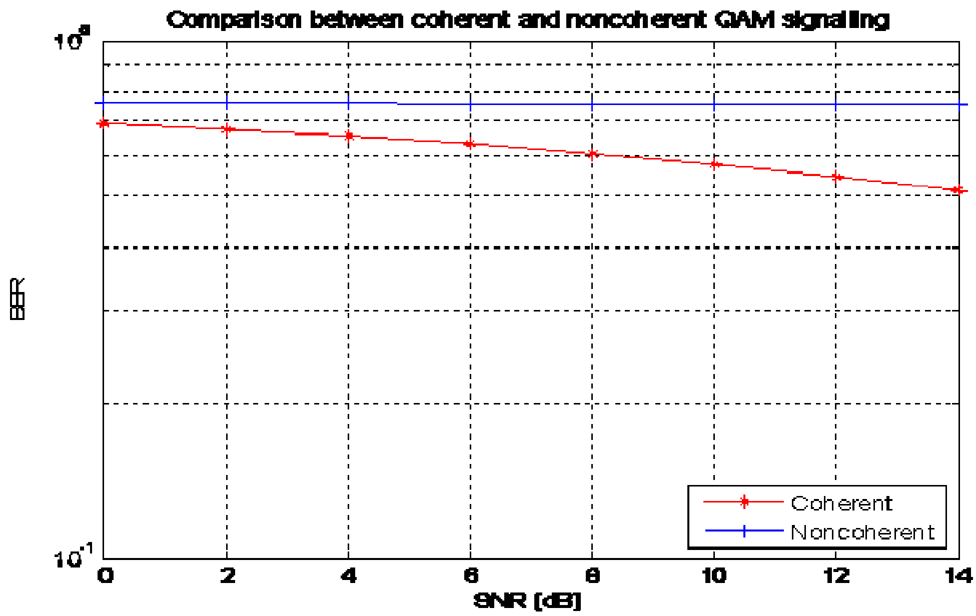

Figure 4: Simulation of BER versus SNR of coherent detection and non- coherent detection for the reception of QAM signal.

Conclusion

A comparative analysis of the two methods (Coherent and Non-coherent detectors) for reception of QAM signals has been carried out. It is evident from the result that the non-coherent detection method produces a substantially higher value of BER than the coherent detection method for the same value of SNR. This increase in BER value can be attributed to carrier phase mismatch at the receiver, and in terms of propagation could be due to carrier phase offset in the received signal when using non-coherent detectors for the reception of QAM signals.

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