Optimize BER Offset QPSK Baseband Modulation-Demodulation featuring AWGN and OFDM

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***Abstract*— In communication system, being fastest not always the best option because of much great error probabilities. Complex architecture also cost high for the component maintenances. An optimal OQPSK modem is provide for friendly use and affordable model in academic purposes. The proposed method is moderate way with twice data size than the conventional method, but error calculation is exactly constant. Good and optimal BER measurements from simulated binary data useful for academic learning purpose.**

Keywords*— *Additive White Gaussian Noise, Bit Error Rate, Offset Quadrature Phase Shift Keying, Orthogonal Frequency Division Multiplexing

I. Introduction

The Institute of Electrical and Electronics Engineers (IEEE) provides a lot of support for study and development of wireless communication technology through official regulations. Since its release in 2003, the IEEE 802.15.4 regulation on wireless communication has become very popular as a reference for wireless sensor and actuator networks (WSANs) products [1]. However, wireless sensor and actuator networks products on the market, for example, Bit Error Rate (BER) measuring instruments have price tag above tens millions Indonesian Rupiah (IDR). This is certainly a barrier against academic institutions with limited funding.

Numerous study about practicum module wireless communication [2, 3] specifically at modulation model development has been carried out starting from the basic binary phase-shift keying (BPSK) modulation technique used in two low-speed data bits, to the offset quadrature phase shift keying (OQPSK) modulation used for the higher data rate version. From some study results, OQPSK has a more constant waveform, thus enabling a more efficient nonlinear power gain to be used to minimize power consumption.

In the next study, experiments were conducted to evaluate and compare the resistance to interference of the OQPSK and Orthogonal Frequency Division Multiplexing (OFDM) showing that the OFDM provides significant benefits compared to OQPSK in terms of interference resistance [4].

Overall, this shows that the selection of OQPSK as main modulation technique featuring channel OFDM physical layer is appropriate when applying it to low-power wireless networks for module implementation in the academic purposed. Additive White Gaussian Noise (AWGN) will also implement as noise error correction method [5]. The study is mainly focused on BER calculation to optimize modem OFDM-OQPSK performance.

On this paper, the author wants to know about generate point-to-point wireless signals communication through a computer simulation using MATLAB. Implementing carrier signal OFDM simulation into OQPSK baseband modulation, while adding AWGN through in-phase and quadrature channel to able perform signal detection for good and optimal BER measurements from simulated random binary data streams.

II. Methods

A. Signal Representation and Propagation Models

Define signal representation as baseband versus passband that would satisfy formula below

$$s_p(t) = Re\, s_b(t) e^{j2\pi fct}$$

Baseband signal usually convenient for multiple purpose such as digital signal processing and mathematical analysis. While passband signal, have equivalent amount as electromagnetic wave of frequency carrier that is transmitted and received through medium.

Point-to-point wireless channel models commonly have three main effects, such as path loss due to diffraction and finite area of antennas that mainly happen at large scale effect (around kilometers), signal attenuation or shadowing due to signal absorption, scattering, refection as medium scale effect (tens of meters), and fading due to phase cancellation, reinforcement from multipath combining and doppler effect that occurs in small scale in centimeters [6, 7].

B. Capacity of Flat Channel

Capacity is a maximum achievable rate with no errors, with maximum mutual information ovel all input distribution. Can be calculated by proving matching lower and upper bounds, quite easy to detect but hard to prove. Some notion of capacity commonly used in wireless systems, there are AWGN Capacity, CSI at RX, TX, and so on [8, 9].

Additive White Gaussian Noises is capacity of fixed channel with no fading. Satisfy formula below:

$$C = B\, log2(1 + \gamma)$$

AWGN capacity used because availability to detect other settings. For deterministic response, as statistical models below

$$h(t,\tau) = \sum_i a_i(t) e^{-j2\pi(t-\tau_i(t))} \delta(t - \tau_i(t))$$

With no movement because of doppler effect, the equations become time invariant response called LTI system as variable time become linear with doppler effect and variable delay become linear with variable frequency.

C. Digital Modulation and Detection

Modulation is about translating signal from lowpass into bandpass.

The transmitted signal s(t) can be represented as:

$$s(t) = Re\{u(t)e^{j2\pi fct}\}$$

$$s(t) = Re\{u(t)\}cos2\pi fct - Im\{u(t)\}sin(2\pi fct)$$

The received signal r(t) is obtain from the convolution of the input signal u(t) with the equivalent low-pass time-varying channel impulse response c(τ, t) from the channel and then converting those into the carrier frequency, as follow:

$$r(t) = Re\left\{\left(\int_{-\infty}^{\infty} c(\tau,t)u(\tau - t)d\tau\right) e^{j2\pi fct}\right\}$$

Detection idea is to use the estimate of the instantaneous channel state fed back to the transmitter. There are some problems that maybe occurs while estimate of the channel, such as inaccurate due to receiver measurement error and delayed due to non-zero delay of the feedback link.

Adaptive schemes also used in systems using tunable parameters that can be applied, such as adaptive modulation from latest commercial 802.11ac Wi-fi standard uses BPSK, QPSK, and OQPSK, then adaptive power in multiuser systems power control in OFDM systems, discussing point to point channels [10, 11].

D. In-Phase and Quadrature Signal

The received signal can be written in the form of in-phase and quadrature as follow:

$$r(t) = r_I(t)\cos(2\pi fct) + r_Q(t)\sin(2\pi fct)$$

E. Performance of Digital Modulation over Wireless Channel

QPSK modulation consists of BPSK modulation on both in-phase and quadrature components of the signal. To obtain perfect phase and carrier recovery, the received signal components corresponding to each of these branches are orthogonal. Therefore, the bit error probability on each branch is the same as for BPSK.

F. Multicarrier Modulation

Main idea is to divide large bandwidth into smaller chunks and perform narrowband signals. Some advantage, there are take care of inter-symbol interference (ISI), able to multiplexing subcarriers (OFDM) and signal processing become more extremely efficient [12-14].

An alternate analysis for OFDM is based on a matrix representation of the system. Consider a discrete-time equivalent lowpass channel with FIR h[n], $0 \leq n \leq \mu$, input $\tilde{x}[n]$, noise ν[n], and output $y[n] = \tilde{x}[n] * h[n] + \nu[n]$. Denote the nth element of these sequences as $h_n = h[n]$, $\tilde{x}_n = \tilde{x}[n]$, $\nu_n = \nu[n]$, and $y_n = y[n]$.

III. Result and Discussion

A. Result

MATLAB used in this chapter to simulate QPSK and OQPSK each other. As follow from the simulation diagram block can be seen simulation block diagram respectively. By using 1024 bits random data and crate sampling interval parameter to be set around of 1:10000 and so on as precise as possible. At this section, only use one signal sample number for modulation ease, and setting value of signal to noise ratio ranges from 0-10 dB.

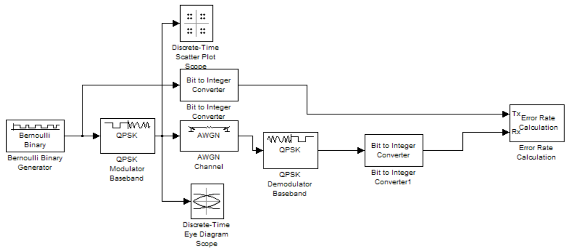

Fig. 1. QPSK Diagram Algorithm

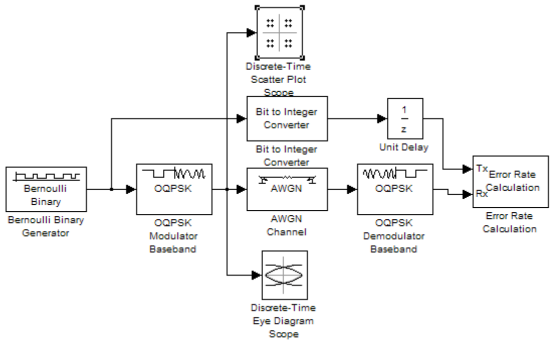

Fig. 2. OQPSK Diagram Algorithm

To validate the modulation works properly, figure out the mapping result, by create scatter plot of 1024 bits data into modulator, and there is the result:

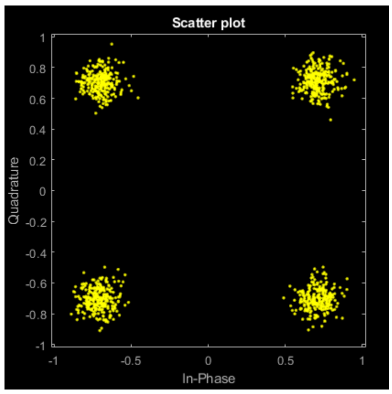

Fig. 3. Bit Data Scatter Plot

Then signal through the channel into demodulator would be divided into two channels, there are in-phase and quadrature as received signal for further process. These two received signals modulated through each matched filter respectively and then back into demanded formatted data. So, from each channel can produced information record as binary data, and then combine into one formatted.

Thus, those 1024 bits data could be detected. Its schematic diagram can be seen below.

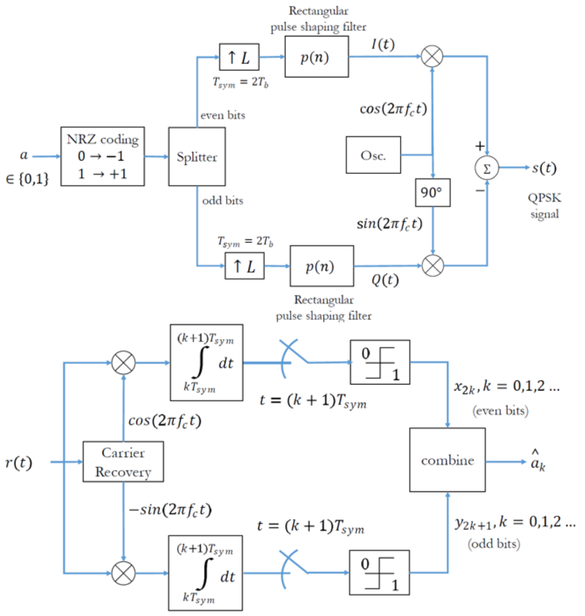

Fig. 4. QPSK Modulation-Demodulation Diagram Algorithm

The modulation demodulation combination performance can be computed and display on MATLAB. As mentioned on chapter before, the theory QPSK signal equivalent two orthogonally modulated BPSK signals. So that, result curves performance graph for BER of QPSK same as that of conventional BER of BPSK but with twice data rate.

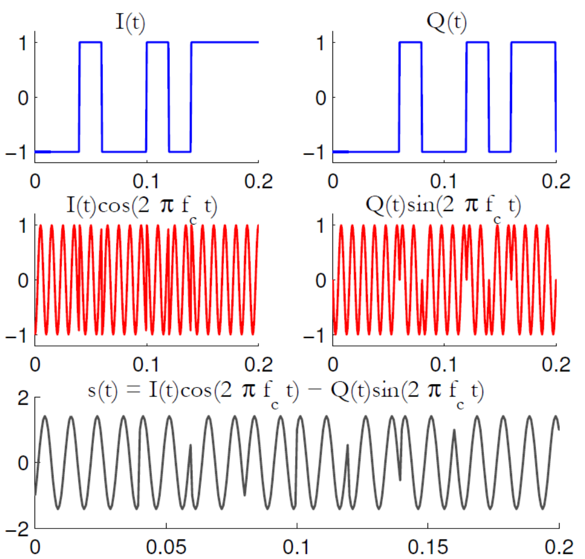

Fig. 5. QPSK simulated waveform

After bits data detection work properly, then calculate how much bit error per total data. As it can be seen from the comparative performance, BER of QPSK produce smallest curve among all.

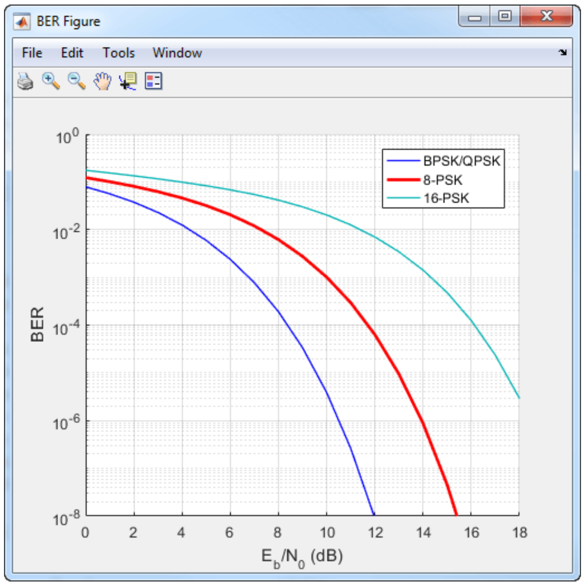

Fig. 6. BER of QPSK vs Higher Orde-PSK

Thus, the theory that say as per modulation higher than 4 states, BER graph performance of phase shift keying method in AWGN channel become worse is correct.

Furthermore, at Offset QPSK have specific orthogonal components that due to delay circuits as much as half symbol offset in the Q-channel could not change states at the same time, because the components only able to change states at the middle of the symbol periods. Within the elimination of 180^0 phase shifts and the phase change only limited into 0^0 or 90^0 on every symbol in Offset QPSK would bring more advantages than conventional QPSK.

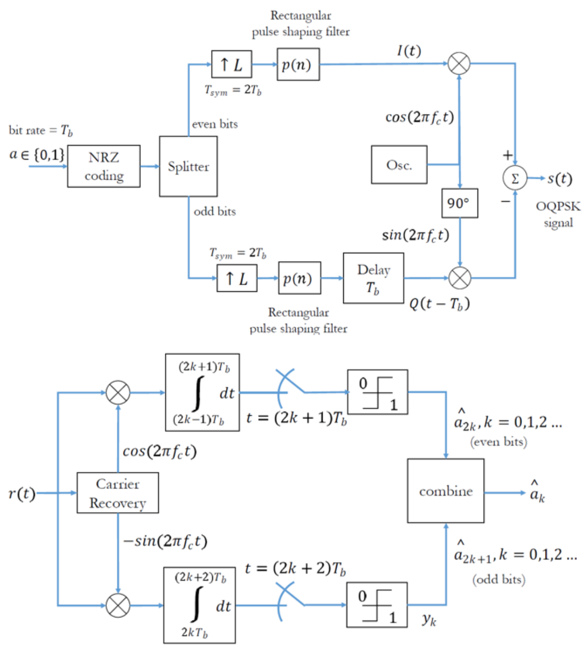

Fig. 7. OQPSK Modulation-Demodulation Diagram Algorithm

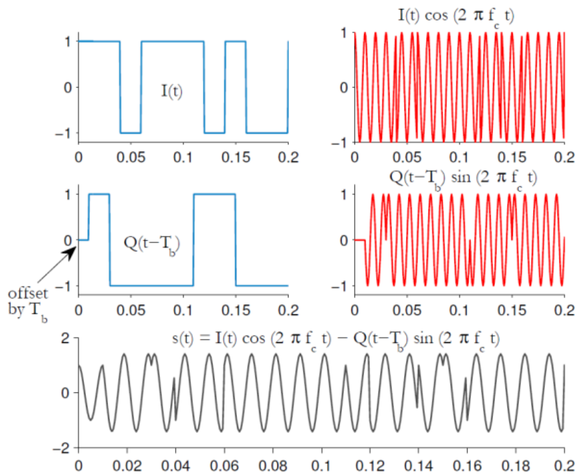

Fig. 8. OQPSK simulated waveform

From the theory Offset QPSK is typically equivalent as QPSK, the different is there are orthogonal carrier signals on the Q-channel that are delayed in time, where the I-channel is same timing with conventional QPSK.

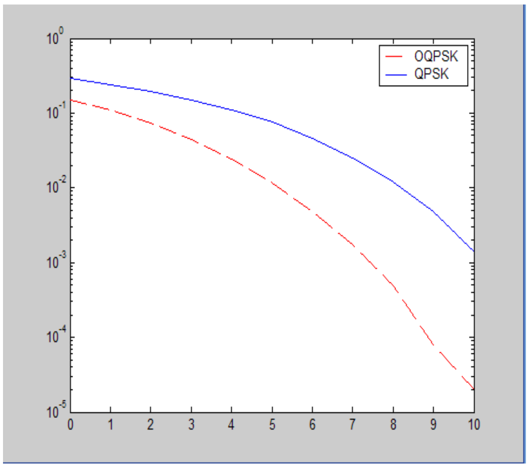

Fig. 9. BER of QPSK vs OQPSK

The different is only at Q-channel but would greatly affect simulation, it can be seen by made comparative graph of conventional QPSK and Offset QPSK in the AWGN channel, where BER of Offset QPSK is less than conventional QPSK.

B. Discussion

Although OFDM is a multicarrier scheme found in many common wireless communications standards such as WIFI, LTE, and 5G [15]. The author can only perform OFDM to make BER comparative graph between theorical calculation and simulation.

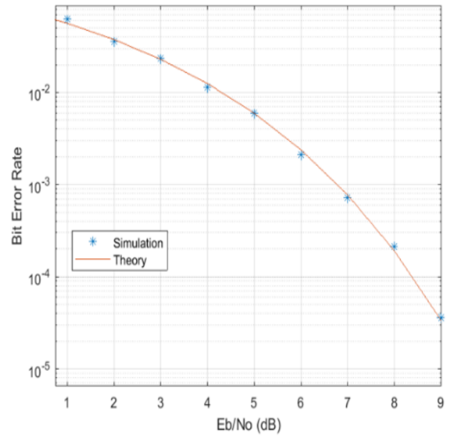

Fig. 10. BER QPSK-OFDM Theorical vs Simulation

IV. Conclusion

Based on the results of the study conducted, it can generate signals through a computer simulation using MATLAB. Implementing carrier signal OFDM baseband simulation into Offset QPSK modulator, to perform AWGN between in-phase signal and quadrature as signal mapping for good and optimal BER measurements from simulated binary data streams in real-time. It can also predict the result based on theorical calculation, which is useful for academic learning purpose as main goals.

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