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The Performance Of SISO In Wireless Open-Access Research Platform (WARP) Using QAM Modulation

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Abstract. This paper shows the implementation of SISO communication system using QAM modulation in WARP. The performance of the proposed system is evaluated in terms of Bit-Error-Rate (BER) for different M-array level: 4, 8, and 16 in indoor and outdoor environments, both using LOS condition. In the analysis results, SISO performance with 4-QAM modulation achieves better performance compared to 8-QAM and 16-QAM for both environments. Meanwhile, SISO performance with QAM modulation in outdoor environment achieves better results compared to indoor environment for different M-array level. In indoor environment with transmitted power -26 dBm, BER achieved for 4-QAM, 8-QAM, and 16-QAM are 1.33×10^{-4} , 2.078×10^{-2} , and 8.76×10^{-2} , respectively. While in outdoor environment with the same transmitted power, BER achieved for 4-QAM, 8-QAM, and 16-QAM are $0,1.497 \times 10^{-2}$ and 5.928×10^{-2} , respectively. SISO performance using M-QAM modulation is better than using M-PSK modulation.

Keyword: SISO, WARP, BER, QAM

1. Introduction

SDR (Software Defined Radio) is an opening architecture based on modern communication theory and digital signal processing. SDR uses standardized hardware units, connected bus, and downloading software. SDR can allow the wireless devices to be reconfigured by the software update which can implement the emerging new wireless communication standards. Thereby, it can decrease the time for developing product [1] [2].

One of the SDR platform which is being developed by Rice University in America is Wireless Open Access Research Platform (WARP). WARP is an intelligent open-access platform which capable, scalable, and extensible for wireless communication research. WARP platform is designed to meet the high level performances. WARP architecture consists of 4 main components: *Hardware Custom*, *Platform Support Packages*, *Open-Access Repository*, and *Research applications*. [3][4]

WARP implementation has been applied in SISO, MIMO, MISO, and cooperative communication. [5] [6] [7] [8] All those implementation used PSK modulation which only considering the phase shift. Thus, the previous studies, shown BER values are high enough for a high transmitted power.

In this paper, SISO communication system will be implemented on the WARP module using QAM modulation. QAM modulation considering the phase and amplitude shift, therefore BER is low [9] [10] and saving energy. [11] The research will be evaluated in terms of bit-error-rate for various



transmitted power. The implementation will be conducted in real channel in indoor and outdoor environments with both using LOS condition.

The contents of this paper are organized as follows. Section II about SISO using M-QAM modulation. Section III describe the results and analysis. Section IV describe conclusions.

2. SISO Using M-QAM Modulation

SISO simulation design using M-QAM modulation is shown in Figure 1. The simulation used ideal canal with 10^3 bit transmitted. The performance analysis can be found from the comparison of transmitted and received bit as a result of BER for different E_b/N_0 .

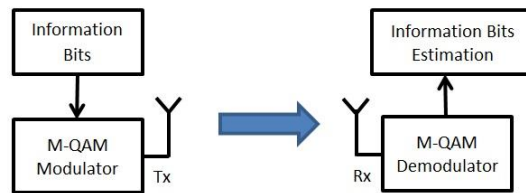


Figure 1. Simulation block of SISO with M-QAM Modulation

The next step after simulation is the implementation SISO using M-QAM modulation in WARP module. The block diagram of SISO implementation using M-QAM modulation is shown in Figure 2. The number of bit transmitted is 30000 bit. The implementation of the system consists of M-QAM modulation, additional pilot and preamble, up-sampling, filter, up-converter, normalization in transmitter side, down-converter, match filter, down-sampling, preamble detection, canal estimation, and M-QAM demodulation in receiver side.

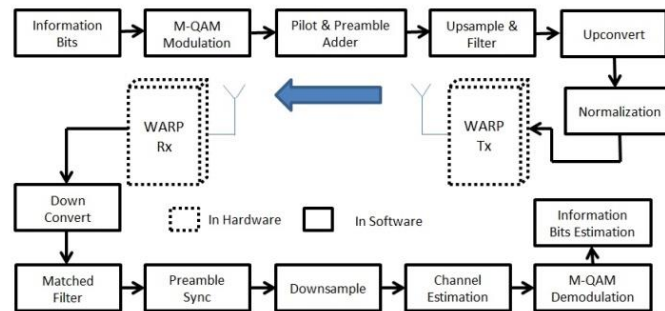


Figure 2. System implementation diagram of SISO with M-QAM Modulation

The implementation of the proposed method is following these steps. First, generating the data information in form of random bit, such as bit $u_i = [u(1)u(2) \dots u(n)]$ with n is the number of bit generated. Then form the symbols with the help of equation (1)

$$v = \sum_{i=1}^k u(i) 2^{k-i} \quad (1)$$

With $k = \log_2 M$ and M is the modulation level.

The integer symbols will be processed as modulation input and translated into complex number that corresponding with the modulation in use. The results of the modulation is the complex number which have real and imaginary value. The symbols from the results of modulation can be described as

$$v_m = [v_1 v_2 v_3 \dots v_{(n/k)}] \quad (2)$$

The pilot symbol is added as a canal estimation response. The pilot symbol is inserted in every 12 symbol periodically. In receiver side, the process of symbol detection is done with canal estimation using pilot method. In this process, there are many assumption, such as canal is assumed has a flat

fading type and the number of tap is one. The convolution operation between transmitted symbols with response canal can be minimized into multiplying operation because the number of tap is one. The canal estimation scheme is, in the transmitter side, the information symbols is inserted with a pilot symbol (estimator) which placed periodically. In the receiver side, the received symbols multiplied with the same scale from transmitter side. The value of symbols is known as the results of multiplying with estimator because the assumption of flat fading canal. For the canal estimation of the other symbols are done by point regression in estimator. The received symbols then used as linier point regression which is known as interpolation process.

Those symbols then added with preamble symbols to determine the location of the first information symbol in the receiver side. The number of preamble symbols are 13 symbols. The first symbol detection is done based on the higher correlation between the received signal sample and preamble sample. The next process is upsample. Upsample is used to improve the sampling rate of the transmitted data. This process is done by passing the symbols of the previous process into *Squared Root Raised Cosine* (SRRC) filter with oversampling rate 8. In receiver side, used match filter to eliminated high frequency.

The next process is upconvert in transmitter side and downconvert in receiver side. Each of signal samples from pulse-shaping filter output is then multiplied by each cosine and sine signal samples with frequency of 5 MHz. The upconvert and downconvert processes are consecutively expressed, as follow:

$$\begin{aligned} & \exp(\sqrt{-1} \times 2\pi f_c t) \\ & \exp(-\sqrt{-1} \times 2\pi f_c t) \end{aligned} \tag{3}$$

with f_c is sampling frequency, t is time.

The measurement of SISO communication system with QAM modulation is conducted in two differents environment: indoor and outdoor. Every enviroment is set to have LOS condition, The transmitter and receiver nodes are separated with 6 meters and antennas are put on 40 cm above the floor.

3. Analysis and Result

In this section, the result of SISO communication system with M-QAM simulation and implementation are elaborated. Simulation and implementation refer to diagram blok in Figure 1 and Figure 2, respectively. M-ary level modulations are 4, 8, and 16.

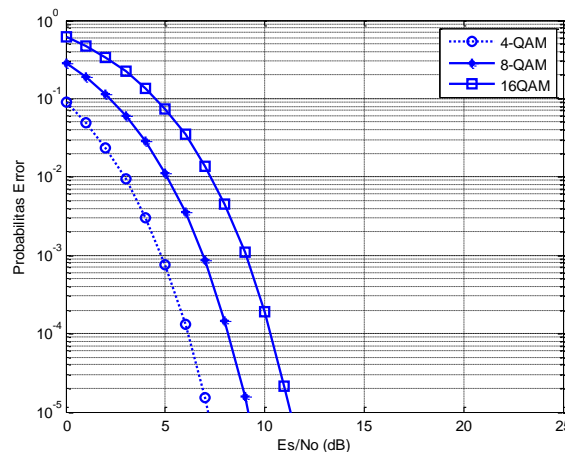


Figure 3. BER Vs Eb/No for SISO with M-QAM Modulation simulation

In the simulation, 4-QAM, 8-QAM, and 16-QAM performances are compared in terms of BER for several E_b/N_0 , which are represented in Figure 3. From the figure 4, it can be described that 4-QAM is better than 8-QAM and 16-QAM, with BER values of 7.5×10^{-4} , 1.12×10^{-2} , and 7.4×10^{-2} , respectively, at E_b/N_0 of 5 dB. When the value E_b/N_0 is increased, 4-QAM is better achieved. The next, the results of performance measurement of SISO communication system with 4-QAM, 8-QAM, and 16-QAM in indoor environment are shown in Figure 4.

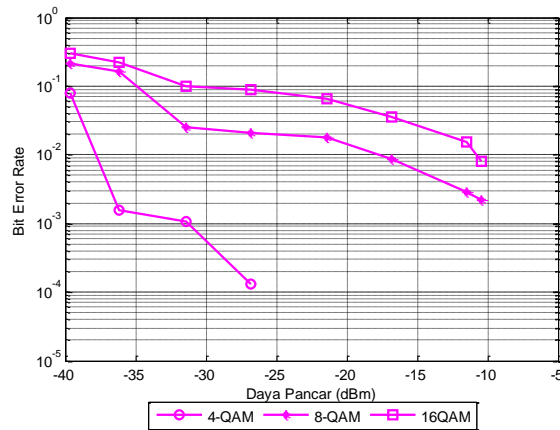


Figure 4. Performance comparison of 4-QAM, 8-QAM, and 16-QAM in indoor with LOS condition

From the measurement, it can be described that the performance 4-QAM is better than 8-QAM and 16-QAM for all various transmitted power. At transmit power -26 dBm, 4-QAM, 8-QAM, and 16-QAM have BER value of each 1.33×10^{-4} , 2.078×10^{-2} , 8.76×10^{-2} , respectively. The form of slopping curve in simulation and measurement results is different because of the multipath condition that occur in measurement process. The results of performance measurement of SISO communication system with 4-QAM, 8-QAM, and 16-QAM in outdoor environment are shown in Figure 5.

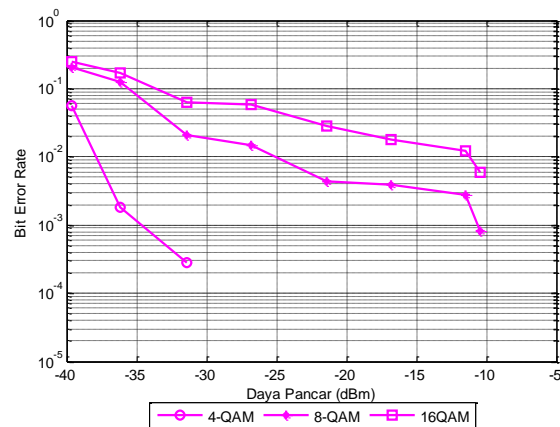


Figure 5. Performance comparison of 4-QAM, 8-QAM, and 16-QAM in outdoor with LOS condition

From the measurement, it can be described that the performance 4-QAM is better than 8-QAM and 16-QAM for all various transmitted power. At transmit power -26 dBm, 4-QAM, 8-QAM, and 16-QAM have BER value of each 0, 1.497×10^{-2} , 5.928×10^{-2} , respectively. The form of slopping curve in simulation and measurement results is different because of the multipath condition that occur in measurement process.

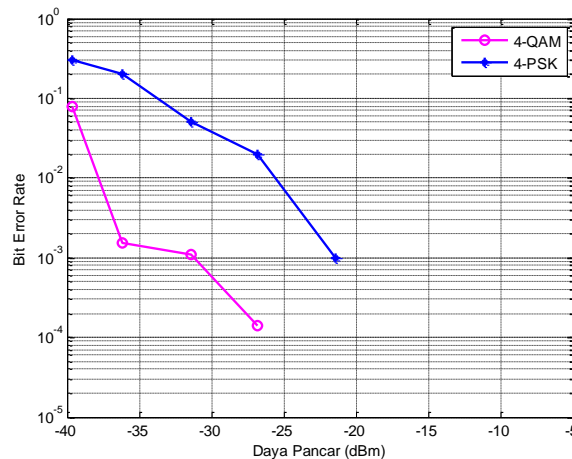


Figure 6. Performance comparison of 4-QAM and 4-PSK in indoor with LOS condition

The comparison performance of 4-PSK and 4-QAM are shown in Figure 6. The result of 4-PSK is conducted in previous research. [5] The measurement, described that the performance 4-QAM is better than 4-PSK for all various transmitted power. At transmitter power -26 dBm, 4-QAM BER value is 1.33×10^{-4} , while 4-PSK BER value is 2×10^{-2} . At another transmitter power, BER value of 4-QAM always smaller than 4-PSK.

4. Conclusion

The implementation with SISO communication using M-QAM modulation has been shown. The performance of the system is evaluated by BER for 4-QAM, 8-QAM, and 16-QAM modulation in indoor and outdoor environment using LOS condition. From the measurements, the best performance is achieved by using SISO with 4-QAM modulation in outdoor environment. The implementation using 4-QAM produce smaller BER value than using 4-PSK modulation. Thus, SISO using M-QAM can repair the performance of M-PSK, this is indicated by low BER value and saving transmitter power.

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