

Design of QAPM Modulation System with High Power Efficiency and SIMULINK Evaluation

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Abstract— Studies of low power consumption modulation schemes are based on FSK and PPM. But, these methods require more bandwidth for high data rate transmit. In this paper, we analyse the QAPM modulation for low power consumption and improving bandwidth efficiency modulation method. A QAPM method is an extension of the QAM and the power efficiency of the transmitter is improved by 3dB. In this paper, we compare PSSK and QAPM regard to bit error rate and throughput.

Keywords— PSSK, QAPM, Power efficiency, Bandwidth efficiency, Power efficiency.

I. INTRODUCTION

Recently, the low power consumption communication technique has been actively studied in according to miniaturization of electronic. From among these, WPAN and WBAN are actively studies. The WPAN systems are composed of short range high data rate communication system such as UWB and a sensor network system such as Bluetooth and Zigbee. A UWB system is required low transmitted power for in order to reduce interference with other wireless devices. Also, the sensor network systems are required low power consumption for the running time.

The WBAN systems are composed of in-body and on-body systems. And the in-body applications which interconnect the implanted apparatus in the human body and the apparatus sticking on the human body support a wide range of medical applications. Therefore WBAN devices require a high degree of miniaturization and long operation time periods before maintenance. Because the system with small sized battery inside the body and the battery is not easy to change.

Studies of low power consumption communication systems are based on the FSK, PPM and PWM scheme [1]-[3]. But, these modulation schemes are bandwidth efficiency less than PSK and QAM. Therefore PSSK modulation scheme is proposed for improve bandwidth efficiency [4]. PSSK method is to improve bandwidth efficiency than FSK and power efficiency better than PSK. And this method is better about 6dB than PSK at BER 10^{-6} . These characteristic are suitable manner for capsule-endoscope that is required low power consumption and high data rate communication system [5].

PSPM method is extension from PSSK technique. And bandwidth efficiency is half than PSSK, but performance of BER is better about 5dB than PSSK. Also, power efficiency of

PSPM is improved than PSK and PSSK because every symbol of PSPM has a zero-envelope period like PPM technique.

In this paper, we design and analyse QAPM modulation scheme. QAPM method is an extension QAM technique, unlike PSSK and PSPM. M-ary QAPM are determines the silence-envelope position of the symbol using the first but data, and $(\log_2 M) - 1$ bits determine the Quadrature amplitude of symbol. This method requires twice the bandwidth of QAM and the same bandwidth as PSSK. However, its BER performance is better about 2~4dB than that of QAM. Also, the power efficiency of the transmitter is improved about 3dB. We are proved form the simulation results.

This paper is organized as follow. Section II analyses QAPM modulation scheme and described system model. And then, a QAPM modulation scheme is simulated and the results are shown in Section III.

II. QAPM MODULATION SCHEME

QAPM modulation scheme is transmitting two QAM symbol of orthogonal waveform. As shown in figure 1, 16QAPM constellation. 16QAM is transmitting 4-ary data of one symbol, but 16QAPM transmitting 4-ary data of two 8QAM orthogonal symbols.

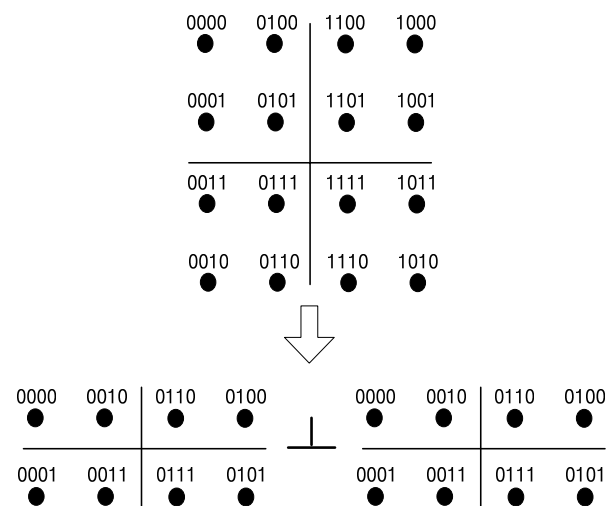


Figure 1. 16QAPM constellation

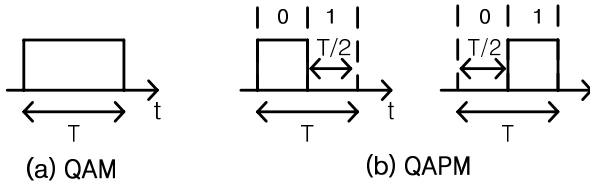


Figure 2. 16QAPM symbol duration

In figure 2(a), QAM symbol duration is T which is symbol period, but QAPM symbol duration is $T/2$ as figure 2(b). The symbol position of QAPM determines using the first bit data. This method is double portion of bandwidth more than QAM.

M-ary QAPM signal is represented as follows.

$$s_m(t) = \{(A_I + A_J)A_m + (A_I + A_J)B_m\} [\alpha(t)(\cos 2\pi f_c t - \sin 2\pi f_c t) + \beta(t)(\cos 2\pi f_c t + \sin 2\pi f_c t)] \quad (0 \leq t < T) \quad (1)$$

where f_c is carrier frequency, A_I is in-phase amplitude and A_J is quadrature amplitude.

$$A_m = \begin{cases} 1, & 0 \leq m \leq \frac{M}{2} - 1 \\ 0, & \frac{M}{2} \leq m \leq M - 1 \end{cases} \quad (2)$$

$$\alpha(t) = u(t) - u(t - 0.5T), \quad \beta(t) = \alpha(t - 0.5T) \quad (3)$$

where A_m and B_m are position of symbol in symbol period, $\alpha(t)$ and $\beta(t)$ are unit step functions that determine the carrier frequency of the symbol. Therefore transmit signal $s_m(t)$ can be written equation (4).

$$s_m(t) = s_m^T \mathbf{f}_x = (A_m A_I) \alpha(t) \cos 2\pi f_c t - (A_m A_J) \alpha(t) \sin 2\pi f_c t + (B_m A_I) \beta(t) \cos 2\pi f_c t - (B_m A_J) \beta(t) \sin 2\pi f_c t. \quad (4)$$

QAPM signal maintains orthogonal property of the symbol and symbol location decide by A_m and B_m .

The figure 3 presents M-QAPM coherent receiver. As shown equation (5), the coherent receiver receives the signal $s_m(t) + n(t)$, where $n(t)$ is the complex AWGN with power spectral density N_0 .

$$s_r(t) = s_m(t) + n(t) \quad (5)$$

In the first, received signal $s_m(t) + n(t)$ multiplication $\alpha(t)$ and $\beta(t)$ for determine symbol position in period. The unit step function $\alpha(t)$ and $\beta(t)$ have orthogonal characteristic as shown equation (6).

$$\alpha(t)^2 = \beta(t)^2 = 1, \quad \alpha(t) \times \beta(t) = 0. \quad (6)$$

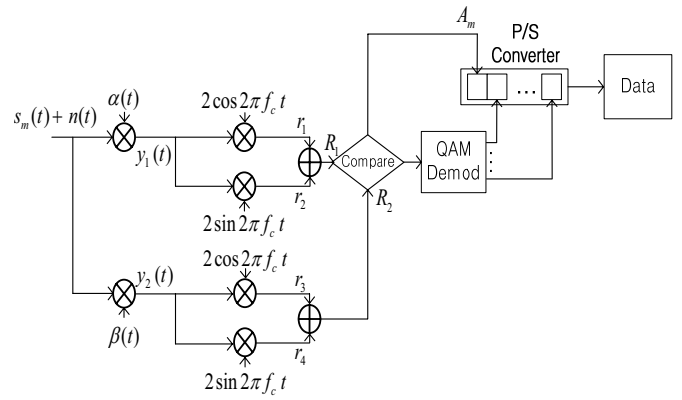


Figure 3. QAPM receiver structure.

Therefore, equation (4) is represented as follows equation (7).

$$\begin{aligned} y_1(t) &= (s_m(t) + n(t)) \times \alpha(t) \\ &= A_m (A_I \cos 2\pi f_c t - A_J \sin 2\pi f_c t) + n(t) \alpha(t) \quad (7) \\ y_2(t) &= (s_m(t) + n(t)) \times \beta(t) \\ &= A_m (A_I \cos 2\pi f_c t - A_J \sin 2\pi f_c t) + n(t) \beta(t) \end{aligned}$$

Secondly, multiplication of equation (7) and carrier frequency that is obtainable information signals.

$$\begin{aligned} r_1 &= A_m A_I + n(t) \alpha(t), \quad r_2 = A_m A_J + n(t) \alpha(t), \\ r_3 &= B_m A_I + n(t) \beta(t), \quad r_4 = B_m A_J + n(t) \beta(t) \end{aligned} \quad (8)$$

Finally, we can detect the symbol position in period. The equation (8) is sum of in-phase amplitude and quadrature amplitude. The signal power compares R_1 and R_2 that is determining symbol position.

$$\begin{aligned} R_1 &= A_m A_I + A_m A_J + n(t) \alpha(t) = A_m (A_I + A_J) + n(t) \alpha(t) \\ R_2 &= B_m A_I + B_m A_J + n(t) \beta(t) = B_m (A_I + A_J) + n(t) \beta(t) \end{aligned} \quad (9)$$

If is $R_1 > R_2$, than A_m is 1. And if is $R_1 < R_2$, than A_m is 0. Therefore QAPM signal be able to demodulation by sum A_m and QAM demodulation data. M-ary QAPM is one bit determines the silence-envelope position of the symbol, and $(\log_2 M) - 1$ bits QAM symbol.

QAPM modulation scheme is to transmit QAM symbol mapping. Therefore probability of error of QAPM is deriving from probability of error of QAM.

$$P_{s-QAM} \cong 4 \frac{\sqrt{M}-1}{\sqrt{M}} Q \left[\sqrt{\frac{3}{M-1}} \cdot \frac{kE_b}{N_0} \right] - 4 \left(\frac{\sqrt{M}-1}{\sqrt{M}} \right)^2 Q^2 \left(\sqrt{\frac{3}{M-1}} \cdot \frac{kE_b}{N_0} \right) \quad (10)$$

$$P_{b-QAM} \cong \frac{4IJ - 2I - 2J}{M} Q \left(\sqrt{\frac{6 \log_2(IJ)}{(I^2 + J^2 - 2)}} \cdot \frac{E_b}{N_0} \right) - \frac{4}{M} (1 + IJ - I - J) Q^2 \left(\sqrt{\frac{6 \log_2(IJ)}{(I^2 + J^2 - 2)}} \cdot \frac{E_b}{N_0} \right) \quad (11)$$

The equation (10) is received symbol probability error for M-ary square QAM and equation (11) is received symbol probability error of M-ary $I \times J$ rectangular QAM [7]. The M-ary QAPM signal transmits $M/2$ QAM. Therefore probability of bit error is deriving equation (12).

$$P_{b-QAPM} = \frac{1}{\log_2 M} \times P_{s-QAM} \left(\frac{1}{2} M \right) \quad (12)$$

Also, as shown equation (13), SNR value is changed because QAPM signal transmits $M/2$ QAM.

$$SNR = \frac{E_b}{N_0} = \frac{A^2}{N_0 B_p} \quad (13)$$

The A is signal amplitude and B_p transmits bit. As the above equation, SNR is affect by transmission power of the signal and transmission bit. Therefore SNR of QAPM can be derived by using equation (14).

$$\frac{E_b}{N_0 (QAPM)} = \frac{\log_2 M}{\log_2 M - 1} \times \frac{E_b}{N_0 (QAM)} \quad (14)$$

The bit error rate P_b for several M is expressed in table 1.

TABLE 1. BER OF QAPM MODULATION CLOSED FORM

Modulation Level	Bit error rate
M=16	$\left(\frac{1}{4} \right) \times \left[\frac{5}{4} \operatorname{erfc} \left(\sqrt{\frac{2}{3} \cdot \frac{E_b}{N_0}} \right) - \frac{1}{12} \operatorname{erfc}^2 \left(\sqrt{\frac{2}{3} \cdot \frac{E_b}{N_0}} \right) \right]$
M=32	$\left(\frac{1}{5} \right) \times \left[\frac{3}{2} \operatorname{erfc} \left(\sqrt{\frac{1}{2} \cdot \frac{E_b}{N_0}} \right) - \frac{9}{4} \operatorname{erfc}^2 \left(\sqrt{\frac{1}{2} \cdot \frac{E_b}{N_0}} \right) \right]$
M=64	$\left(\frac{1}{6} \right) \times \left[\frac{13}{8} \operatorname{erfc} \left(\sqrt{\frac{288}{975} \cdot \frac{E_b}{N_0}} \right) - \frac{21}{16} \operatorname{erfc}^2 \left(\sqrt{\frac{288}{975} \cdot \frac{E_b}{N_0}} \right) \right]$

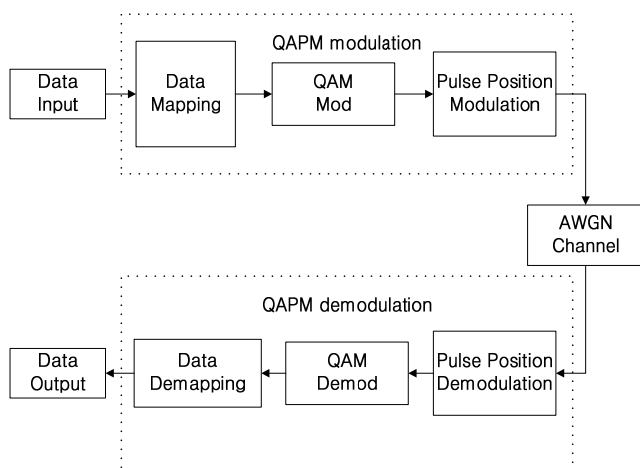


Figure 4. QAPM system block

As shown Figure 4, QAPM modulation method will be conducted by a three step process. QAPM method send N bit data to N-1 bit data symbols and 1 bit symbol is position data. Therefore, data mapping block is N bit data convert into N-1 bit data. After that, N-1 data are modulating QAM method and determine the pulse position using one bit data. And QAPM demodulation method is detect the symbol position in signal period. And symbol data is demodulating the QAM method. After that, QAM demodulate data is converted into QAPM data using symbol position data.

III.SIMULATION RESULTS AND DISCUSSION

The Figure 5 is simulation results of QAPM modulation SER performance using SIMULINK Monte-Carlo method. The performance of 8QAPM is 9dB at SER 10^{-6} . And performance of 16QAPM is 12.5dB also, 32QAPM is 14dB at SER 10^{-6} .

The figure 6 is BER performance of 16-ary modulation. It shows that the performance of 16-ary QAPM is better about 0.5 dB than 16-ary PSSK, also better about 2.3 dB than 16-ary QAM at BER 10^{-6} . Because that basically BER performance of QAM is better than PSK. And figure 7 is BER performance of 32-ary QAPM, PSSK, QAM and PSK in AWGN channel. It shows that, the performance of 32-ary QAPM is better about 4dB than PSSK. In these results, we show that the performance of QAPM is better than PSSK and 32-ary modulation performance gap is much wider than 16-ary modulation. Because BER performance of QAM is better than PSK as increases the modulation level.

Basically the performance of 8QAM is better about 0.5dB than 8PSK, but 16QAM is better about 4dB than 16PSK. In this reason, QAPM modulation is more useful than PSSK according to increase of modulation level.

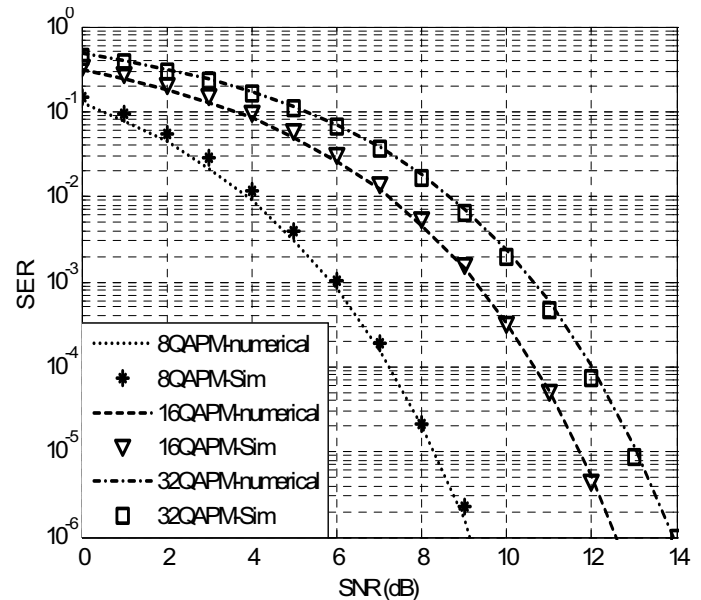


Figure 5. SER performance of QAPM.

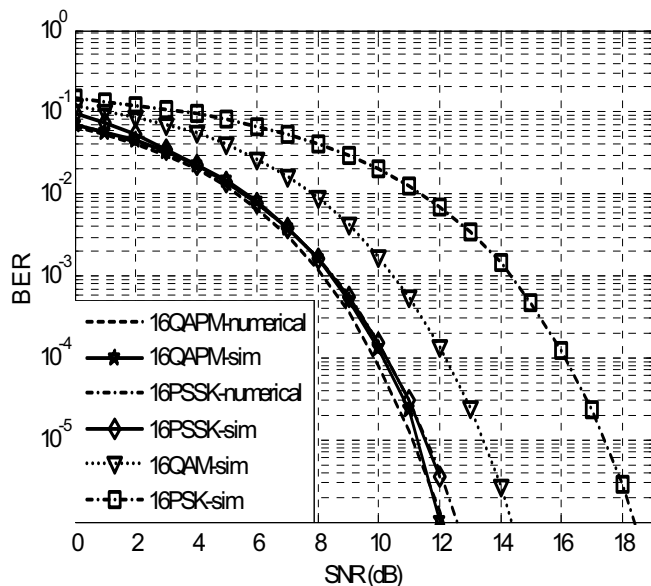


Figure 6. BER performance of 16-ary modulations

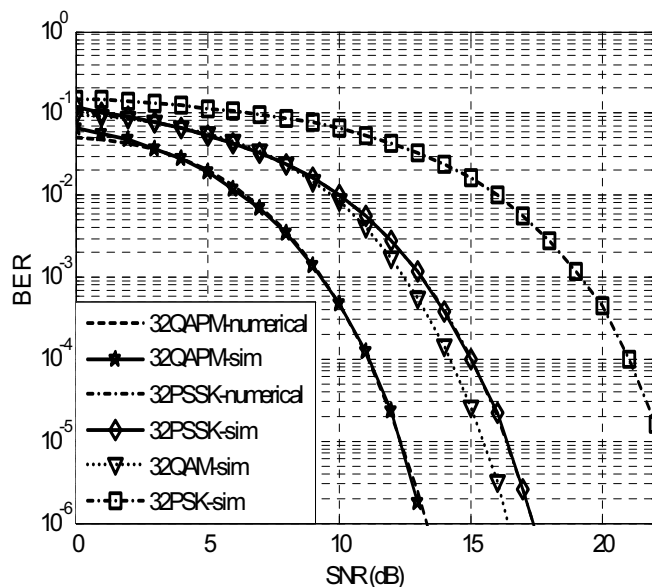


Figure 7. BER performance of 32-ary modulations

IV. CONCLUSION

In this paper, we design and analyse QAPM scheme extension method in order to increase power efficiency. And we evaluate QAPM system by using SIMULINK. From the simulation results, we can see that BER performance of QAPM and PSSK are better than QAM and PSK in AWGN channel. As a result, BER performance of QAPM modulation scheme is better about 0.5~4dB than PSSK modulation. Therefore a QAPM scheme could be identified as a more good a modulation scheme than the PSSK scheme.

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