

BIT ERROR RATE PERFORMANCE OF 12QAM IN THE PRESENCE OF UNCOMPENSATED TRANSMITTER NONLINEARITY

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1. Introduction

Noda proposes the optimum bit mapping in binary to symbol coding for 12QAM and calculates its theoretical bit error rate (BER) performance to find that 12QAM outperforms 8PSK by 0.5 dB in E_b/N_0 at BER of 10^{-6} [1]. This short paper further studies BER performance of 12QAM, in comparison with 8PSK and 16QAM, when transmitter high power amplifier (HPA) is operated with low output back-off (OBO). We seek the optimum OBO that maximizes the system gain [2].

2. Transmitter HPA Nonlinearity

The memoryless HPA nonlinearity is modeled as given below, based on a solid-state HPA characteristic [2].

$$F(|z|) = A_F(|z|) \exp[j\theta_F(|z|)]$$

with AM-AM conversion

$$A_F(|z|) = g_F |z| / (1 + \gamma_F |z|^{2p})^{1/2p} \quad (\text{Rapp model})$$

and AM-PM conversion

$$\theta_F(|z|) = \theta_F |z|^2 / (1 + \tau_F |z|^2) \quad (\text{Saleh model}),$$

where z is normalized input, $p = 1.5$, γ_F is an OBO-related parameter, g_F is a gain parameter, $\tau_F = \gamma_F^{1/p} \tau$ ($\tau = 0.8$) and $\theta_F = \gamma_F^{1/p} \theta$ ($\theta = 0.5$ radian) are AM-PM conversion parameters.

3. Spectrum Efficiency and Roll-off Factor

Spectrum efficiency R_b/W (R_b : bit rate, W : full bandwidth), as a measure for efficiency in frequency utilization, is related to roll-off factor α as follows.

$$\begin{aligned} R_b/W &= \eta_{12} / (1 + \alpha_{12}) & \eta_{12} &= 3.5 \text{ bit/symbol for 12QAM} \\ &= \eta_8 / (1 + \alpha_8) & \eta_8 &= 3 \text{ bit/symbol for 8PSK, and} \\ &= \eta_{16} / (1 + \alpha_{16}) & \eta_{16} &= 4 \text{ bit/symbol for 16QAM.} \end{aligned}$$

In this paper, we assume that the three modulation schemes have the same spectrum efficiency, and we choose $\alpha_{12} = 0.3125$, $\alpha_8 = 0.125$ and $\alpha_{16} = 0.5$ for $R_b/W = 2.67$ bit/sec/Hz.

4. System Gain

System gain of a radio transmission system is discussed in [2], and it is shown that the system gain is maximized when the quantity "Required $E_b/N_0 + \text{OBO}$ " is minimized. Required E_b/N_0 is such E_b/N_0 that provides a given BER.

5. Required $E_b/N_0 + \text{OBO}$ versus OBO

Fig. 1 shows simulated Required $E_b/N_0 + \text{OBO}$ versus OBO at BER of 10^{-6} for 12QAM and 8PSK. We find that there exists the optimum OBO (about 4 dB for 12QAM and 2 dB for 8PSK) that minimizes Required $E_b/N_0 + \text{OBO}$ (or maximizes the system gain). Fig. 2 compares 12QAM with 16QAM, where the optimum OBO is also about 4 dB for 16QAM. At these optima, Required E_b/N_0 values are 15.5 dB, 16.8 dB and 17.1 dB for 12QAM, 8PSK and 16QAM, respectively. Therefore, for the optimum OBO, 12QAM outperforms both 8PSK and 16QAM by more than 1 dB.

6. BER Performance for the Optimum OBO

Fig. 3 shows BER versus E_b/N_0 for 12QAM, 8PSK and 16QAM without nonlinearity and with nonlinearity of the respective optimum OBO values.

7. Conclusion

It is found that for the optimum OBO that maximizes the system gain, 12QAM outperforms 8PSK, even when transmitter HPA nonlinearity is present. 16QAM still requires larger E_b/N_0 .

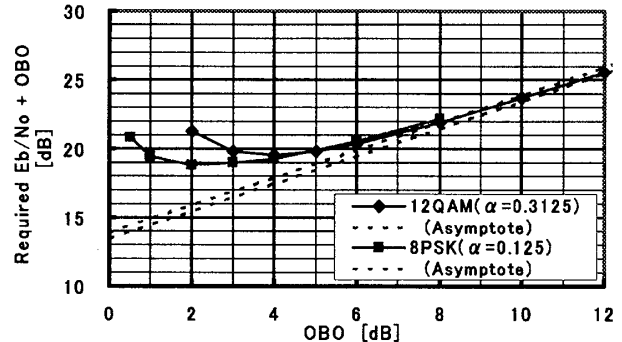


Fig. 1 Req. $E_b/N_0 + \text{OBO}$ vs. OBO for 12QAM and 8PSK.

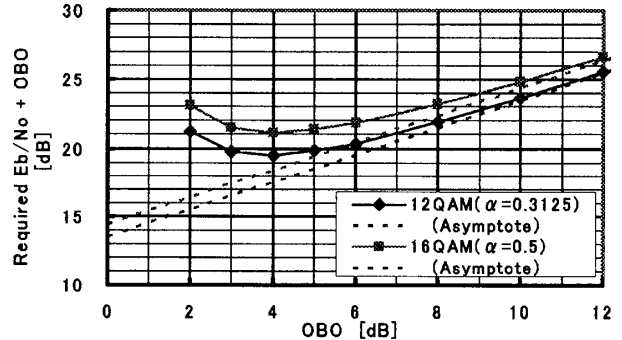


Fig. 2 Req. $E_b/N_0 + \text{OBO}$ vs. OBO for 12QAM and 16QAM.

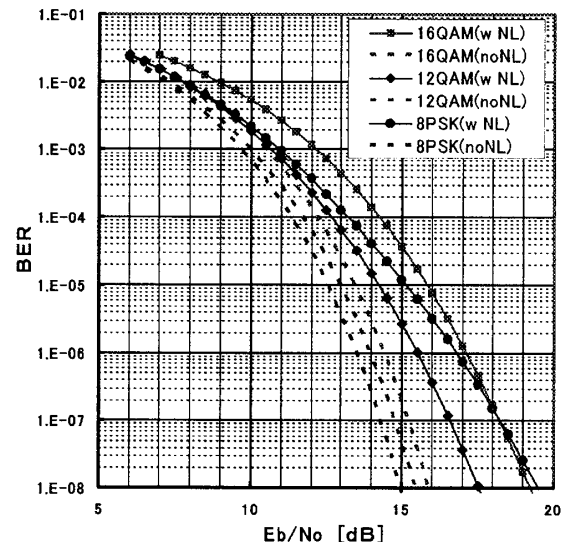


Fig. 3 BER vs. E_b/N_0 for 12QAM, 8PSK and 16QAM.

References

- [1] S. Noda, "Study of bit mapping optimization on 12QAM," in *Proc. IEICE General Conf. 2004*, March 2004, B-5-202 (text in Japanese)
- [2] S. Koike and S. Noda, "Performance of 6PSK and 8PSK systems in the presence of transmitter nonlinearity," in *Proc. IEICE Society Conf. 2006*, Sept. 2006, B-5-100.