임펄스잡음 및 동일채널간섭환경하에서의 QAM신호와 PSK신호의 오율특성 비교

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The Comparison of PSK vs QAM Error Performance with Impulsive Noise and Cochannel Interference

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Abstract

The error rate performance of PSK transmission system versus QAM transmission system has been compared in the environment of impulsive noise and cochannel interference.

1. Introduction

In digital signal transmission the modulation method used in any particular application depends on the available channel bandwidth and is generally a compromise between simplicity of instrumentation and high efficiency transmission.

For medium bandwidth efficiency, coupled with moderately simple signal generation and detection, phase-shift keying(PSK) is a good modulation choice. It has been used for high-speed data transmission(20 Mbps) over radio frequency channels.

In voiceband data transmission for high-speed (4800-9600 bps), quadrature amplitude modulation (QAM) is attractive. Accordingly, PSK scheme which is representative technique in digital transmission and QAM scheme which has some analog characteristics have become the subject of interest by many authors.

However the ever increasing demand and supply for communication channel in the radio frequency (RF) bands causes a serious problem of electromagnetic interference(EMI). Consequently, as the RF band is limited, the reuse of the existing band in use has been considered by many investigators.

And, in accordance with citifying, impulsive noise which is generated by many electromechanical devices and the ignition spark of automobile, etc. has also become a serious degradation factor to the receiving system.

In this paper, we compared PSK receiving system to QAM system or QAM system to PSK system with one interferer and impulsive noise environment. The statistical characteristics of impulsive noise is also clarified.

2. Analysis Model

(1) PSK Signal

M-ary PSK signal can be represented as

$$s(t)=S\cos(2\pi f_0 t + 2\pi\lambda/M) \qquad (1)$$

where

S; amplitude of signal
f_0; carrier frequency
M; the number of levels
$\lambda(=0,1,\cdots,M-1)$; M-ary information.

Here the probability of occurrence of each information is assumed to be same.

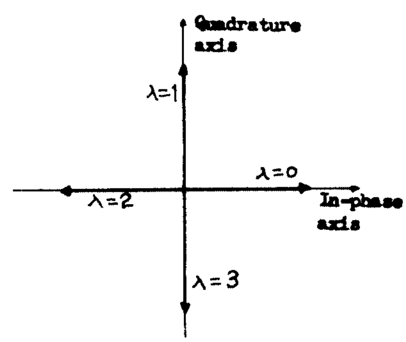

Fig.1 Phasor of the quaternary PSK signal.

(2) QAM Signal

Typical representation of QAM signal has been provided as

$$s(t)=A_j\cos\omega_c t + B_k\sin\omega_c t \qquad (2)$$

where

$A_j, B_k \in \{\pm d, \pm 3d, \cdots, \pm(2L-1)d\}$

d; 2d is the distance between adjacent signals.

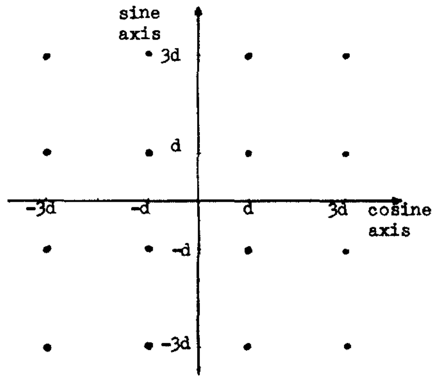

Fig.2 16-ary QAM signal.

(3) Interferer

PSK interferer, which is generated by the reuse of existing band, is given as

$$i(t)=I\cos(2\pi f_0 t + 2\pi\nu/M + \phi) \qquad (3)$$

where

I; amplitude of the interferer

$\nu(=0,1,\cdots,M-1)$; the information of the interferer

ϕ; relative initial phase difference to the desired signal.

QAM cochannel interferer can be represented as

$$i(t)=C_j\cos(\omega_c t + \psi) + D_k\sin(\omega_c t + \psi) \qquad (4)$$

(4) Impulsive Noise

The probability density function(p.d.f.) of envelope of class A impulsive noise has been proposed by Middleton as

$$P(E)=e^{-A}\sum_{i=0}^{\infty}\frac{A^i}{i!}\frac{2E}{\sigma_i^2}e^{-\frac{E^2}{\sigma_i^2}} \qquad (5)$$

where

$E(=E'/\sqrt{2(\sigma_G^2+\Omega_A)})$; normalized noise envelope

$\sigma_i^2=(i/A+\Gamma')/(1+\Gamma')$

$\Gamma'(=\sigma_G^2/\Omega_A)$; Gaussian noise power($\sigma_G^2$) to impulsive noise power(Ω_A) ratio

A; impulsive index.

3. Statistical Characteristics of the Composite Wave

(1) PSK

When the terminal of composite vector, in the M-ary PSK system, lies in the error region(the shaded portion of Fig.3), an error is made by the receiver.

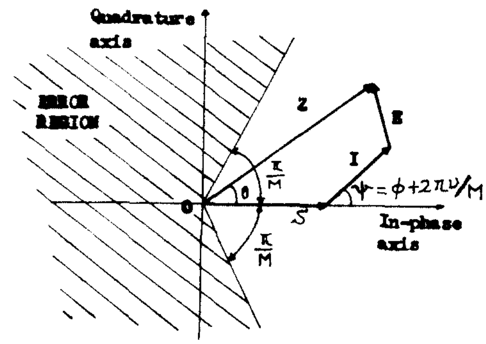

Fig.3 Phasor diagram of received PSK signal.

The error probability of M-ary PSK signal is derived as

$$P_e=(1-\frac{1}{M})-\sum_{n=1}^{\infty}\sum_{i=0}^{\infty}\frac{1}{\pi}\cdot\sin\frac{n\pi}{M}\cdot\frac{e^{-A}A^i}{i!}\cdot \cos n\left[\tan^{-1}\frac{\sin(\phi+2\pi\nu/M)}{\sqrt{\beta}+\cos(\phi+2\pi\nu/M)}\right] \frac{1}{(\sigma_i^2)^{n/2}}\cdot\frac{\Gamma(n/2)}{\Gamma(n+1)}\cdot[\alpha+2\alpha\cos(\phi+2\pi\nu/M)/\sqrt{\beta} +\alpha/\beta]^{n/2}\,{}_1F_1[n/2;n+1;-(\sigma_i^2)^{-1}\{\alpha+2\alpha\cdot \cos(\phi+2\pi\nu/M)/\sqrt{\beta}+\alpha/\beta\}] \qquad (6)$$

where

α; carrier to noise power ratio(CNR)

β; carrier to interferer power ratio(CIR)

The total probability of error is the sum of M cases. Thus,

$$PE=\frac{1}{M}\left(P_e\big|_{\nu=0}+P_e\big|_{\nu=1}+\cdots+P_e\big|_{\nu=M-1}\right) \qquad (7)$$

(2) QAM

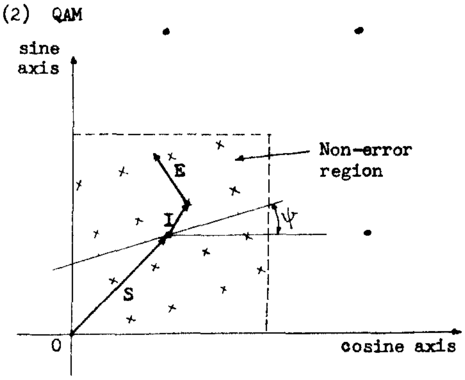

Fig.4 Phasor representation of the received QAM signal.

When the terminal of the composite phasor goes over the non-error region, in QAM receiving system, an error is made. The error probability of 16-ary QAM signal is derived as

$$P_E = \frac{2L-1}{2L}\,\frac{e^{-A}}{\pi}\sum_{i=0}^{\infty}\frac{A^i}{i!}\left\{(1-X)\,e^{-\frac{\alpha}{\sigma_i^2}(1-X)^2} - (1+X)\,e^{-\frac{\alpha}{\sigma_i^2}(1+X)^2}\right\} \qquad (8)$$

where

$$X = \sqrt{r}\,\sqrt{(2j-1)^2 + (2k-1)^2}\,\sin\left(\psi + \tan^{-1}\frac{2j-1}{2k-1}\right)$$

α; CNR

r; r^{-1} = CIR

4. Numerical Calculation and Discussion

The graphical results for the bit error rate(BER) of received BPSK signal and 16-ary QAM signal which is evaluated in CNR, CIR, impulsive index and the phase difference between signal and interferer have been shown in Fig.5~Fig.8.

The BER for a fixed value of A and with the variation of Γ' are shown in Fig.6. At low CNR, the major factor causing the bit error is the Gaussian noise but, at high CNR, the impulsive noise causes more errors than Gaussian noise in PSK system. In Fig.7, in QAM system, the error probability is nearly independent on impulsiveness, but in PSK system the error probability is dependent on impulsive noise at high CNR. It can be considered that the reason is the QAM system has some analog characteristics of amplitude modulation and the PSK system has typical digital characteristics. The interesting result, however, is shown in Fig.8. It is the best case, in PSK system that the signal and the interferer meet with orthogonal phase. The authors, at these results, believe if we lock the phase difference to 90° in PSK system, we shall get noteworthy improvement of error rate. And QAM system is superior to PSK system in the environment of heavy impulsive noise.

(a) (b)

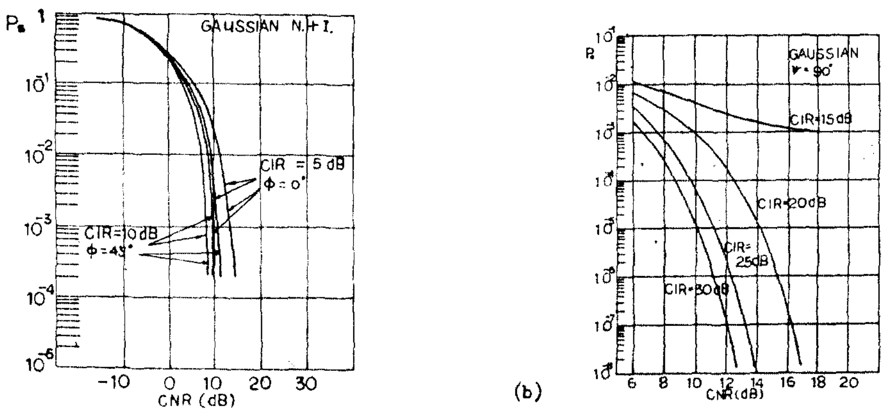

Fig.5 BER of (a)BPSK signal, (b)16-ary QAM signal interfered by one interferer and Gaussian noise.

(a) (b)

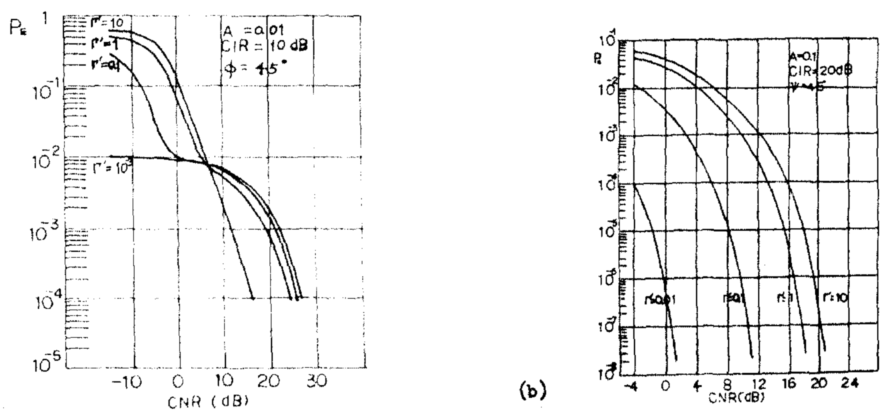

Fig.6 BER of (a)BPSK signal, (b)16-ary QAM signal interfered by one interferer and impulsive noise(with the change of Γ').

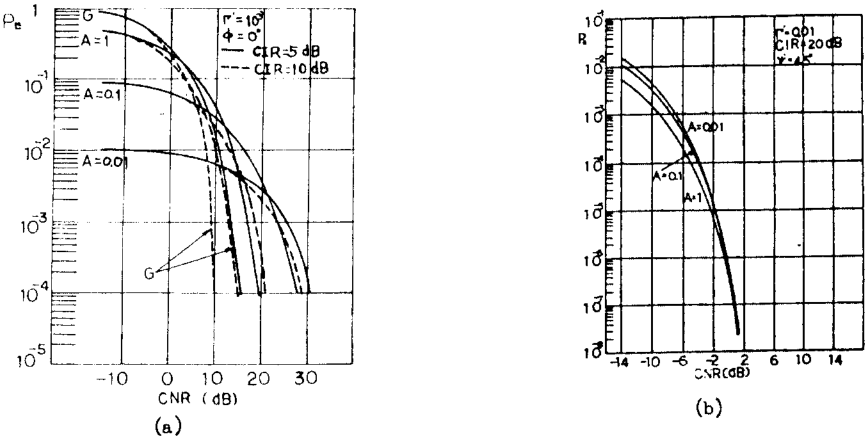

Fig.7 BER of (a)BPSK signal, (b)16-ary QAM signal interfered by one interferer and impulsive noise(with the change of A).

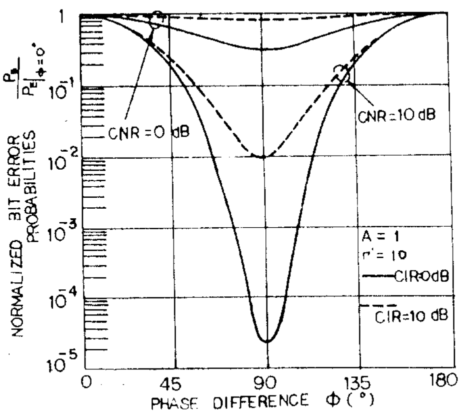

Fig.8 Normalized bit error probabilities by the worst case($\phi=0^\circ$) in PSK system.

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