Bit Error Rate Analysis for BPSK Modulation in Presence of Noise and Two Co-channel Interferers

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Summary
In this paper the bit error rate (BER) analysis of binary phase shift keying (BPSK) modulated signal detection in presence of two BPSK modulated co-channel interfering signals and additive white Gaussian noise is presented. The detection of a desired signal with minimum achievable BER in co-channel interfering environment with two interferers was analyzed. The minimum achievable BER was obtained at interferers gain less than -10dB. Noise effect of AWGN channel can be observed using scatter plot rather than BER values.
Key words:
BPSK, co-channel interference, wireless cellular systems

1. Introduction

The interference signals in wireless cellular systems can be classified in two categories: those caused by natural phenomena, and those manmade signals that can be attenuated or controlled such as inter-modulation interference; inter-symbol interference; near end to far end ratio Interference; adjacent interference and Co-channel interference (CCI).
Inter-modulation interference caused by nonlinear system components, especially in analog cellular systems. Inter-symbol interference is the unwanted signal, which is the interference contribution of other symbols to the symbol under consideration. Near end to far end ratio Interference appears when the distance between a mobile unit and the base station transmitter becomes critical with respect to another mobile unit that is close enough to override the desired base station signal. The adjacent channel interference can be classified as either inband or out of band interference. The term inband is applied when the center of the interfering signal bandwidth falls within the bandwidth of the desired signal. The term out of band is applied when the center of the interfering signal bandwidth falls outside the bandwidth of the desired signal.

Co-channel interference is defined as the interfering signal that has the same carrier frequency as the useful base station signal. Co-channel cells are those cells using the same frequency channels in different clusters of cellular system, and the interference between signals from these cells is called co-channel Interference, which can be reduced by increasing the distance between co-channel cells.
In modern wireless cellular systems (3G, 4G) most interference types can be reduced to acceptable communication levels using special techniques such as power control, soft handoff and digital filters, when adjacent channel interference is compared with co-channel interference at the same level of interfering power the effects of the adjacent channel interference are always less, so co-channel interference is still the most effective type.
The problem of detecting BPSK signal in the presence of one interferer and noise has been introduced by several papers. In [1] the BER performance analysis for an un-coded binary BPSK system in two-wave with diffused power fading channels was presented. In [2] the effect of CCI on the performance of partially coherent BPSK and quadrature phase shift keying (QPSK) in uncorrelated L-branch equal-gain combining systems was studied. In [3] the performance of wideband communication systems in the presence of narrowband interference (NBI) was evaluated. In [4] The problem of detecting a desired BPSK modulated bit in the presence of only a second BPSK modulated interfering signal and additive white Gaussian noise is considered.
The objective of this paper is to analyze the effect of co-channel interference on BPSK modulated signal in the presence of more than one co-channel interfering signal and additive white Gaussian noise.

2. Error Probability for BPSK

Because the information in BPSK is contained in the carrier phase, it is necessary to use coherent detection in order to have an accurately demodulated BPSK. The phase of a constant amplitude carrier signal is switched between two values according to the two possible signals, corresponding to binary 1 and 0, respectively. Usually, the two phases are separated by 180°, and if the sinusoidal

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carrier has an amplitude A_c and energy per bit E_b we can write [5]:

$$E_b \quad (1/2)A^2_c T_b \qquad (1)$$

Where T_b is the bit duration; then the transmitted BPSK signal can be one of the following waveforms:

$$v_{BPSK0}(t) \quad A_c \sin(2\pi f_c t \quad \varphi_c) \quad \text{for} \quad 0 \quad t \quad T_b \qquad (2)$$

$$v_{BPSK1}(t) \quad - A_c \sin(2\pi f_c t \quad \varphi_c) \quad \text{for} \quad 0 \quad t \quad T_b \qquad (3)$$

Equations (2) and (3) can be rewritten as:

$$v_{BPSK}(t) \quad P A_c \sin(\pi f_c t \quad \varphi_c) \qquad (4)$$

Where P represents the phase changing of BPSK signal P=1 for bit 1 and P=0 for bit 0. The probability of bit error for coherent detection of BPSK from [5] is:

$$P_b = Q(\frac{d_{\min}}{\sqrt{2N_0}}) \qquad (5)$$

Where d_{min} the minimum distance of the two signals constellation; N_0 is the power spectral density of the noise The signal constellation for BPSK in terms of energy per bit from (1) is given by $S_0 = \sqrt{E_b}$, and $S_1 = -\sqrt{E_b}$. This yield the minimum distance $d_{\min} = 2A_c = 2\sqrt{E_b}$ Substituting this into (5) yields:

$$P_b = Q(\frac{2\sqrt{E_b}}{\sqrt{2N_0}}) = Q(\sqrt{\frac{2E_b}{N_0}}) \qquad (6)$$

3. Co-channel interference Analysis Methodology

One of the main design goals in the wireless cellular systems is to provide high capacity in combination with the required quality of service. Due to the architectural structure of these systems, a very vital issue is the determination methodologies for analyzing the nature and the influence of any kind of interference. Various analysis tools have been developed, which take into consideration interference not only as an additive distorting agent but also as a multiplicative agent, as in fading. The main objective is then to analyze how the interference as a general distortion agent affects well-accepted criteria of performance of wireless cellular systems, such as carrier to interference (C/I) or signal to interference (S/I) and BER, and then proceed to develop optimal or suboptimal design tools that lead to practical system implementation and that satisfy predetermined minimum performance levels. Thus the analysis methodology that is involved in order to achieve our objective it takes, as a basic analysis tool, the determination of BER as functions of SNR as critical design parameter.

4. Simulation System

The simulation models the effects of co-channel interference on a BPSK modulated signal. The model includes two interferers, Interferer1 and Interferer2 and can modify the power gain of each interferer. The simulation adds interference to BPSK modulated original signal created by the transmitter (Tx) using a sum block, noise is added by AWGN channel. BER is measured after filtering and demodulating the received signal in the receiver (Rx). Figure (1) shows simulation structure:

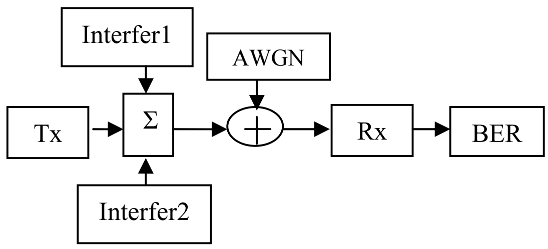

Fig. 1 simulation structure

The two interfering signals have phase angles φ_1 and φ_2 which are assumed to be independent and uniformly distributed, the original and interfering signals are bit synchronized. The combined BPSK received signal can be written as:

$$v_{BPSK}(t) = \sum_{i=1}^{3} P_i A_i \sin(2\pi f_i t + \varphi_i) + n(t)$$
$$for....0 \le t \le T_b ....(7)$$

Where A_1, A_2, A_3 and f_1, f_2, f_3 are the amplitudes and frequencies of the original and the first and second interfering signals respectively, n(t) is the noise signal. P_1, P_2, P_3 represent the phase changing of the original and the first and second interfering signals respectively.

5. Results and Discussion

Figure (2) shows simulation results of BER versus SNR for different values of interferers gain. The results show that BER is decreasing by increasing the interferers gain in negative values, also BER is not affected by improving SNR. SNR effect can be shown from scatter plots in figures (3) and (4), where the plots are becoming smoother by increasing the SNR from 10 to 20 dB, which means the decreasing of noise effect.

The scatter plots in figures (5) and (6) show the received constellation for one orthogonal interferer (fig.5) or both interferers (fig.6), only six plots can be seen for the three input signals because of high gain of interferers. The all eight possible plots (2^3) can be observed after decreasing the interferers gain to -10 dB with at least one interferer is orthogonal as shown in figure (7), which means the detection of a desired signal with minimum achievable BER at interferers gain less than -10dB.

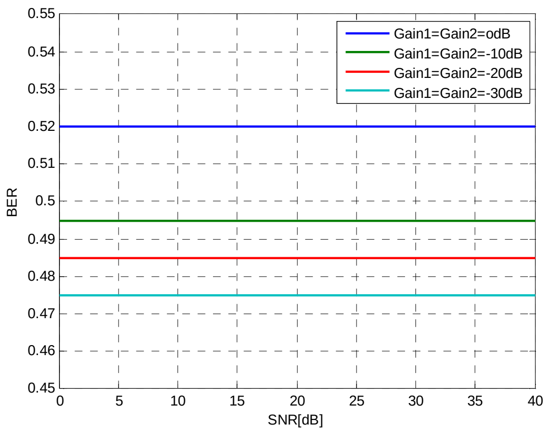

Fig. 2 BER versus SNR

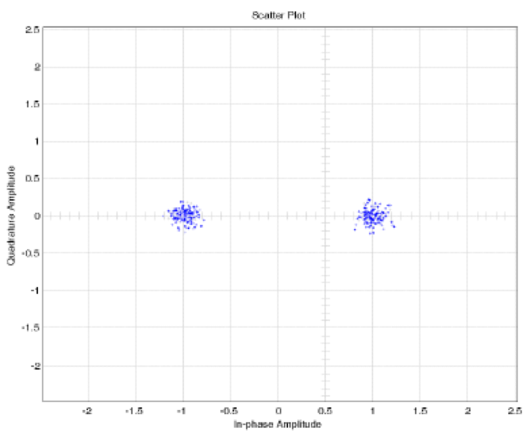

Fig. 3 Scatter plot of Received constellation for SNR=10dB; Gain1=Gain2= 0dB; φ1=φ2=0o

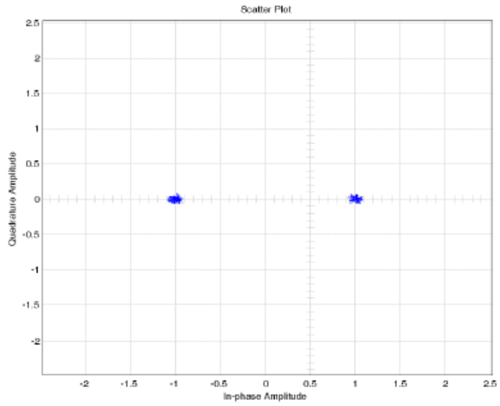

Fig.4 Scatter plot of Received constellation for SNR=20dB; Gain1=Gain2= 0dB; φ1=φ2=0o

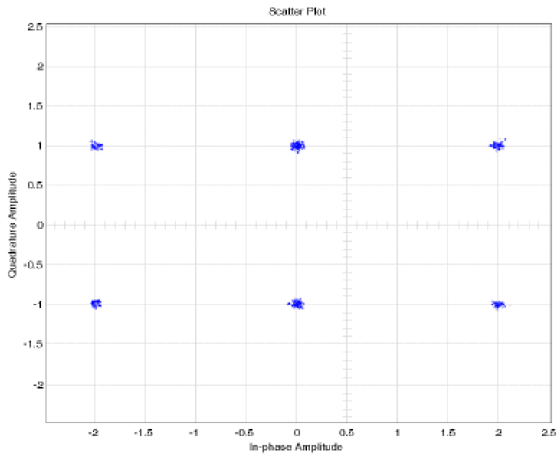

Fig. 5 Scatter plot of Received constellation for SNR=20dB; Gain1=Gain2=0dB; φ1=90o; φ2=0o

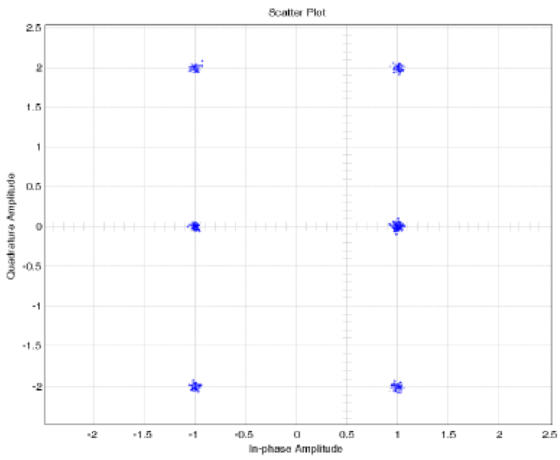

Fig. 6 Scatter plot of Received constellation for SNR=20dB; Gain1=Gain2=0dB; φ1=90o; φ2=90o

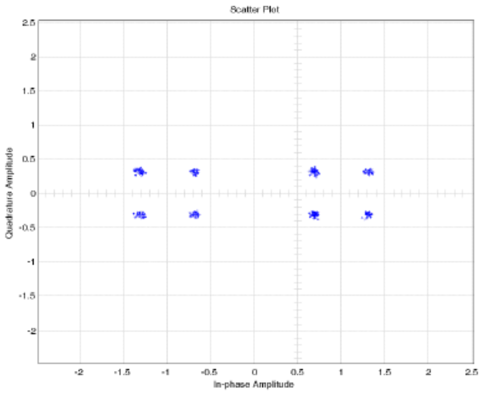

Fig. 7 Scatter plot of Received constellation for SNR=20dB; Gain1=Gain2= -10dB; φ1=0o; φ2=90o

Conclusions

Bit error rate of BPSK modulated signal detection in presence of two BPSK modulated co-channel interfering signals and additive white Gaussian noise was analyzed. The minimum achievable BER was obtained at interferers gain less than -10dB. Noise effect of AWGN channel can be observed using scatter plot rather than BER values.

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References
[1] S. H. Oh and Kwok H. Li, "BER Performance of BPSK Receivers over Two-Wave with Diffuse Power Fading Channels", IEEE Transaction on wireless communications, vol. 4, No. 4, July 2005
[2] M. A. Smadi, V. K. Prabhu and S. O. Al-Jazzar, " Analytical Study on the Effect of Co-channel Interference on Partially Coherent Diversity Systems", ", IEEE Transaction on communications Vol. 57, No. 1, January 2009
[3] A. Giorgetti, M. Chiani and M. Z. Win, " The Effect of Narrowband Interference on Wideband Wireless Communication Systems", IEEE Transaction on communications Vol. 53, No. 12, December 2005
[4] R. Kwan and C. Leung," Optimal Detection of a BPSK Signal Contaminated by Interference and Noise", IEEE communications Letters, Vol. 6, NO. 6, June 2002
[5] A. Goldsmith, "Wireless Communications", Cambridge University Press, 2005

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