Single-tone Jamming Mitigation in MC-CDMA and Coordinated Jamming Communications System

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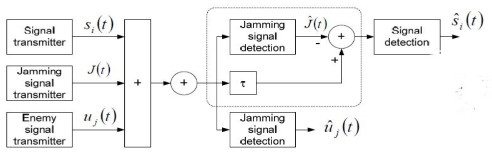
Introduction

In this paper, we consider coordinated jamming and communications (CJamCom) technique in associate with multicarrier (MC) code division multiple access (CDMA) netwroks, where the narrow-band interference (NBI) considered is a single-tone jamming. We present analysis of jamming autocorrelation matrix and give its estimated value based on jamming pattern. We then analyze the decoding performance of both honest user and enemy user combining the estimated jamming autocorrelation matrix and MMSE detector. Moreover, we will clarify the effects of MMSE detector demodulated results under different jamming pattern conditions.

Coordinated Jamming and Communications (CJamCom)



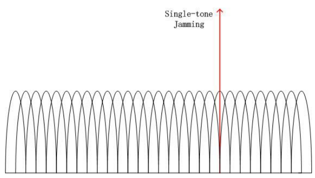
For the CJamCom system, basicly we uppose that there are two types of user: honest user and enemy user. In order to suppress those malicious user's transmission, a jammer was added during transmission, only the honest user knows the jamming pattern and can eliminate or suppress it during decoding the signal. While the enemy user suffered great transmission performance degradation due to without knowing the characteristics of the jamming.

System Model

Consider a baseband MC-CDMA system with P subcarriers and K users, processing gain of each user is P. A P-point Inverse Fast Fourier transform (IFFT) operation will be included when generate the transmission signal. The transmitted signal during mth symbol interval can be expressed as

$$\mathbf{y}(m)=\sum_{k=1}^{K} d_k(m)\sqrt{P_k}\mathbf{C}_k\mathbf{F}\mathbf{h}_k(m)+\sqrt{P_J}\mathbf{B}_J(m)\mathbf{F}_J h_J(m)+\mathbf{n}(m)$$

In frequency domain, the entire band is divided into P orthogonal sub-channels. For the single-tone jammer, it will generate a impulse choosing one of the sub-channels. Between different symbol intervals the jammer will choose different sub-channel to transmit, such jamming pattern changing information only can be obtained by the honest user.



Linear MMSE Approach and Jamming Matrix Estimation

The minimum mean-square error (MMSE) linear multiuser detector has been proved effective in the process of suppressing multiple-access interference (MAI) in conventional CDMA networks. The MMSE detector for single user in our work will be

$$\mathbf{G}^*=\frac{1}{1+\left[\mathbf{s}_1^{\mathrm{H}}\left(\mathbf{R}_J+\sigma_n^2\mathbf{I}\right)^{-1}\mathbf{s}_1\right]}\left(\left(\mathbf{R}_J+\sigma_n^2\mathbf{I}\right)^{-1}\mathbf{s}_1\right)$$

In order to better demodulate signal, the detected user needs to know the content of the jamming auto-variance matrix, which can be expressed as

$$\mathbf{R}_J^q=\frac{1}{M}P_J\sum_{m=1}^{M}\mathrm{I}(m,q)a_m^2 \qquad \mathrm{I}(m,q)=\begin{cases}1, & \text{if } m\text{th symbol interval jammer occupy } q\text{th subchannel}\\ 0, & \text{otherwise}\end{cases}$$

since we consider rayleigh fading model, the distribution of a bunch of such variable will follow gamma distribution we can estimate the jamming auto-variance matrix only based on the knowledge of jamming pattern. The estimated jamming matrix is

$$\mathbf{R}_J^q\cong\frac{1}{M}P_J Q_q\cdot 2\sigma^2$$

Impact of Different Jamming Patterns on the Demodulated Results

When considering both the multiple-access interference (MAI) and single-tone jamming, the 1st user output SINR of the MMSE detector is

$$\mathrm{SINR}=\mathbf{s}_1^{\mathrm{H}}\left(\sum_{k=2}^{K}\mathbf{s}_k\mathbf{s}_k^{\mathrm{H}}+\mathbf{R}_J+\sigma_n^2\mathbf{I}\right)^{-1}\mathbf{s}_1$$

To simplify our analysis we ignore the effect of MAI and insert the jamming estimated auto-variance matrix, the output SINR can be rewritten as

$$\mathrm{SINR}=\sum_{i=1}^{P}\left(\mathbf{s}_1^{(i)*}\mathbf{s}_1^{(i)}\right)\cdot\left(\frac{1}{\sigma_n^2+\dfrac{2P_J\sigma^2}{M}Q_i}\right)$$

We then have a following optimization problem:

$$\max\ \sum_{i=1}^{P}\frac{1}{\sigma_n^2+\dfrac{2P_J\sigma^2}{M}Q_i} \qquad s.t.\ \ \sum_{i=1}^{P}Q_i=M,\ Q_i\geq 0\ (Q_i \text{ is integer})$$

Through Karush-Kuhn-Tucker (KKT) conditions we have the conclusion that in order to achieve relatively higher SINR value of honest user, best way for the single-tone jammer is just occupy one subchannel and never hopping. However this will increase the risk that the interference be detected. The trade off will be select relatively few channels (say 10 subchannel) to hop, and each subchannel has the equal opportunity to be accessed throughout the transmission.

Simulation Results

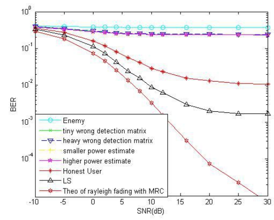


Fig.1

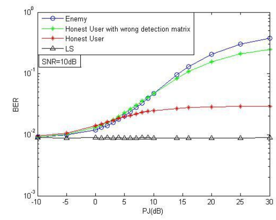


Fig.2

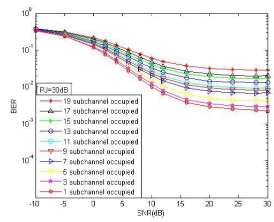


Fig.3

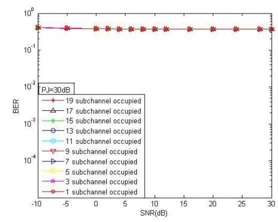


Fig.4

Fig.1 presents the BER performance of different user type versus the SNR value under the condition that the jamming power is fixed as 30dB. In order to better comparison, we consider the least-square (LS) detector under the condition that the honest user perfect eliminate the single-tone jamming. Honest user's BER performance greatly outperform the decoding results of the enemy user.

Fig.2 presents the BER performance of different user type versus the jamming power under the condition that the SNR value is fixed as 10dB. The BER performance of enemy user will getting worse and worse with the increase of the jamming power, when the jamming power arrived at relatively higher point the curve becomes stable.

Fig.3 shows the honest user BER performance with different jamming pattern versus the SNR under the fixed jamming power condition, which elaborate that in order to achieve better BER performance of honest user, best way for the single-tone jammer is just occupy one subchannel and never hopping.

Fig.4 shows the enemy user BER performance with different jamming pattern versus the SNR under the fixed jamming power. It is obviously to see that the enemy user's BER performance is not affected by different jamming pattern.

Conclusion

In our work, we consider a CJamCom system under MC-CDMA network. Honest user can generate a single-tone jamming to suppress the performance of the enemy user. With jamming matrix estimation honest user can still achieve relatively good demodulation results.