Performance Analysis Of Multi Level Frequency Hopping For Cdma Systems

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Abstract:
Frequency hopping is performed by changing carrier frequencies while communicating. Spread spectrum techniques have become more prevalent in modern communication systems and the demand for the efficient usage of available spectrum. In this paper multi level frequency hopping is proposed for CDMA systems. The performance analysis shows that this provides better spectral efficiency and support more users at higher data rates. The results were compared against Goodman's FSK based FH-CDMA scheme at maintained constraints.

Keywords: Code division multiple access(CDMA), code modulation, frequency hopping(FH), spectral efficiency(SE), multiple access interference (MAI).

1. Introduction

Spread spectrum differs from a classical narrow-band or broadband system in that the signal energy is spread over a much wider frequency range, reducing the power spectral density of the signal and providing several advantages:

• Low Probability of Intercept, meaning that it is harder to detect the RF signals
• Higher tolerance to narrow-band noise sources, the anti-jamming property
• Reduction of sensitivity to interference from multi-path reflections
• Possibility of CDMA (Code-division multiple access) operation, where several cooperating transmitters using different frequency hopping patterns can transmit in the same frequency range without disturbing each other [9]

a) Direct-Sequence Spread Spectrum

There are two forms of spread-spectrum techniques, direct-sequence (DSSS) and frequency hopping (FHSS). Direct sequence spread spectrum involves transmitting at a much higher rate than the data-rate, and convoluting the data with a spreading code. At the receiver, the signal can be decoded by using correlation techniques, comparing the incoming signal with the spreading codes. DSSS is more complex to implement than frequency hopping, and is not suitable to low-power systems due to the high data rates involved.

b) Frequency Hopping

Frequency hopping, as implied by the name, is performed by changing carrier frequencies while communicating. In a typical system, the frequency hopping will be of the so-called slow variety, which means that several data symbols (bits) are transmitted during each hop. A rate between 50 and several hundred hops per second is practical. The lock time of the PLL when changing frequencies is 100us-200us (depending on the loop filter); while the time required reprogramming the needed registers using a 1 MHz clock is on the order of 50-60us. The time during a hop when data cannot be received or transmitted is termed the blanking interval. The dwell time is the time spent in each channel. Since spread-spectrum technology has its roots in military applications, much of the terminology refers to enemy "jammers" of varying complexity. In commercial systems, intelligent jamming is not a primary threat. Most of the time, the "jamming" signal will merely be another device trying to utilise the same frequency band for communicating. These devices will typically not be as devious as intelligent enemy jammers might be, so the security requirements can be eased a bit compared to military applications. The so-called "narrowband jammer" is probably the most representative threat seen in civilian applications. Interference from multi-path reflections is also a serious threat. These reflections can cause large frequency- and location-dependent drops in signal strength. Frequency hopping combats multi-path reflections by ensuring frequency diversity[2] [3]. In FH-CDMA, the available transmission bandwidth is divided into L carrier frequency-bands and each frequency band is used to convey one element of an L×N FH pattern, according to the address signature of the intended receiver, where L is the number of frequencies and N is the number of time slots. To apply M-ary FSK, each carrier frequency band is further subdivided into a set of M frequencies. There are totally ML frequencies, grouped into L sections (i.e., frequency-bands) of M frequencies each. The same M frequencies in each section are used to represent the M symbols in M-ary FSK, and the same j^{th} frequency in every section is used to transmit the j^{th} symbol, where j € [0;M - 1]. By using MFSK on top of FH-CDMA, the data rate is increased because each symbol represents [$\log_2 M$] data bits. In FH-CDMA scheme every frequency-band use a different frequency to represent the transmitting symbol, and the pick of the frequency in a frequency-band is controlled by a prime sequence. The prime/FH-CDMA scheme supported higher data rate than the MFSK/FH-CDMA scheme for the same number of frequencies per frequency band, at the expense of poor performance. It was because a squared number of prime sequences (i.e., symbols) by relaxing the cross-correlation functions from zero (in MFSK) to one[5][4]. In this paper a multi level FH-CDMA system is proposed for providing frequency diversity for more users at higher data rates over fading channels. This paper is organized as follows, section II describes about the proposed multi level frequency hopping method, section III gives the probability of detection for different channels and performance evaluation.

2. MULTI LEVEL FREQUENCY HOPPING

The available transmission bandwidth is divided into M_h frequency bands with M_m carrier frequencies in each band, giving a total of $M_m M_h$ carrier frequencies. In the first (modulation) level, a number of serial data bits is grouped together and represented by a symbol. Each symbol is, in turn, represented by a modulation code of dimension $M_m \times L_m$ and weight (i.e., number of elements) w_m, where M_m is the number of frequencies, Lm is the number of time slots (i.e., code length). The number of data bits that can be represented by a symbol depends on the number of available modulation codes. If there are ϕm available modulation codes, each symbol can represent up to $\lfloor \log 2\ \phi_m \rfloor$ data bits, where $\lfloor \cdot \rfloor$ is the floor function [6].
In the second (FH) level, each user is assigned a unique FH pattern of dimension $M_h \times L_h$ and weight (i.e., number of elements) w_h, where M_h is the number of frequencies, L_h is the number of time slots (i.e., pattern length). The elements in the modulation codes and FH patterns determine the carrier frequencies of the final FH-CDMA signals. While an element of a modulation code defines the carrier frequency used in a frequency band in a given time slot, an element of the FH pattern determines which frequency band (out of M_h bands) to use. In our scheme, we can choose any families of ($M_m \times L_m$, w_m, $\lambda_{a,m}$, $\lambda_{c,m}$) modulation codes and ($M_h \times L_h$, w_h, $\lambda_{a,h}$, $\lambda_{c,h}$) FH patterns as long as $w_h \geq L_m$, where $\lambda_{a,m}$ ($\lambda_{a,h}$) and $\lambda_{c,m}$ ($\lambda_{c,h}$) denote the maximum autocorrelation side lobes and cross-correlation values of the modulation codes (FH patterns), respectively. For example the FH patterns with different prime sequences for different users is encoded shown pictorially in the figure 1

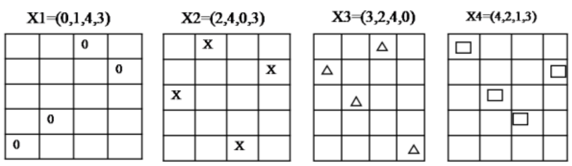

Figure 1) a) FH patterns for different users

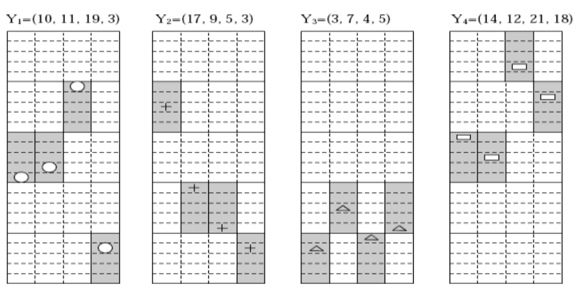

Figure 1) b) Encoded FH patterns the shaded columns in the transmitting signals; represent the frequency bands specified by the corresponding FH patterns.The decoding process is explained in the figure2

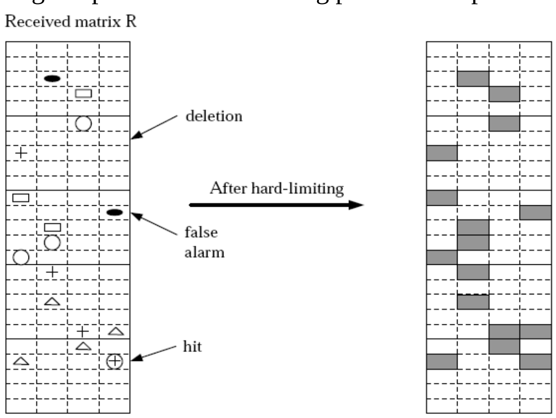

Figure 2: Decoding Process

3. Performance Analysis

In the analysis of the FH-CDMA scheme, we focus on the effects of multiple access interference (MAI) and Rayleigh fading. MAI depends on the cross-correlation functions of the FH patterns, which are related to the code length, code weight, and number of available frequencies. For the proposed FH-CDMA scheme, the cross-correlation functions of the prime sequences add extra interference and need to be considered. Overall, in the absence of fading, a decision error may occur if MAI creates additional entries representing a wrong symbol. An error may occur due to fading, which causes a frequency to be falsely detected when none has been transmitted (i.e., false alarm), or causes a received frequency to be missed (i.e. deletion). In the following analysis, we assume that the hopping frequencies are separated large enough in frequency so that the de-hopped signals at a receiver suffer from independent Rayleigh fading symbol-by-symbol. For each symbol, fading is also assumed to be frequency nonselective [8].Assume that one-hit FH patterns of dimension $M_h \times L_h$ are used and the transmission band is divided into $M_m M_h$ frequencies, in which M_m frequencies are used to carry the modulation codes of weight w_m Assume that there are K simultaneous users, the probability that the de-hopped signal contains n entries in an undesired

$$P(n) = \binom{w}{n} \sum_{i=0}^{n} (-1)^i \binom{n}{i} (1 - \frac{w^2}{L_h M_m M_h} + \frac{n}{w} . \frac{w^2}{L_h M_h M_m} - \frac{i}{w} \frac{w^2}{L_h M_m M_h})^{k-1} \quad (1)$$

Over AWGN, and Rayleigh and Rician fading channels, false alarms and deletions may introduce detection errors to the received FH-CDMA signals. A false-alarm probability, p_f, is the probability that a tone is detected in a receiver when none has actually been transmitted. A deletion probability, p_d, is the probability that a receiver missed a transmission tone.

For AWGN channel

$$P_d = 1 - Q(\sqrt{2\left(\frac{E_b}{N_0}\right).\left(\frac{k_b}{w_m}\right)}, \beta_0 \quad (2)$$

Where Q is Marcum's Q-function and

$$\beta_0 = \sqrt{2 + \frac{\left(\frac{E_b}{N_0}\right).\left(\frac{k_b}{w_m}\right)}{2}}$$

For Rayleigh channel

$$P_d = 1 - exp\left\{\frac{-\beta^2}{2+2\left(\frac{E_b}{N_0}\right)\left(\frac{k_b}{w_m}\right)}\right\} \quad (3)$$

For Raician channel

$$P_d = 1 - Q(\sqrt{\frac{2\rho\left(\frac{E_b}{N_0}\right).\left(\frac{k_b}{w_m}\right)}{1+\rho+\left(\frac{E_b}{N_0}\right).\left(\frac{k_b}{w_m}\right)}}, \beta_1 \quad (4)$$

Where

$$\beta_1 = \frac{\beta_0}{\sqrt{1+\frac{\left(\frac{E_b}{N_0}\right)\left(\frac{k_b}{w_m}\right)}{(1+\rho)}}}$$

Below are the experimental results obtained when w_m=4,$M_m \times L_h$=4×11,,$Mh \times L_h$=11×47,ρ=12 Eb/N_0=25dB.From the results we can conclude that the proposed method outperforms over Goldman's method for spectral efficiency about 5% achieving an error rate about 10^{-3} .

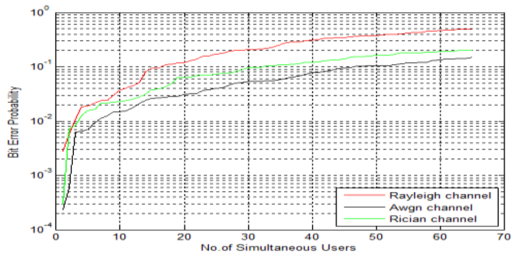

Figure 3: Performance Analysis of proposed method

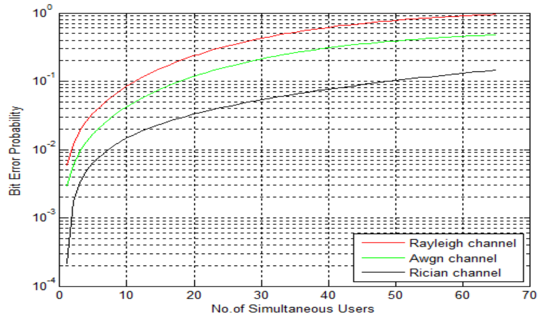

Figure 4: Performance analysis of Goldman's under different channels

4. Conclusion

In this paper, we proposed a new Multi level frequency hopping for CDMA systems. The prime/FH-CDMA and RS/FH-CDMA schemes were special cases of our scheme. The performance analyses showed that the Multi -level FH-CDMA scheme provided a trade-off between performance and data rate. The partitioned Multi-level FH-CDMA scheme increased the number of possible users and exhibited higher data rate and greater SE than Goodman's scheme. In summary, the new scheme offered more flexibility in the design of FH-CDMA systems to meet different operating requirements

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6. References

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