PROBABILITY BOUNDS ON THE PEAK INTENSITY OF ULTRASHORT LIGHT PULSE CDMA

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ABSTRACT

Optical CDMA is being proposed as a suitable multiaccess technique to take advantage of the large bandwidth available in single-mode fiber-optic communications. In a CDMA system the communication link is shared by a number of users each of which has a unique address code, called signature. Recently an all-optical CDMA system based upon encoding and decoding coherent ultrashort pulses was introduced [1]. In the proposed optical CDMA system the transmitter consists of a bandlimited signal source, that generates a train of ultrashort light pulses. The output of the bandlimited source is multiplied by a data source that takes values 0 or 1 (ON-OFF Keying). If the data is 0, then no energy is transmitted. If the data is 1, then the ultrashort pulse is sent to the spectral-phase encoder which adds a determinate phase shift to each spectral component of the ultrashort pulse. When a pseudorandom set of spectral phase shifts is selected, spectral phase coding spreads the incident ultrashort pulse into a longer, lower intensity pseudonoise burst [1]. The receiver is assumed to be a correlation receiver which is matched to the desired signal. The correlation process (optical decoder) is similar to that of the optical encoder, except that the decoder's spectral-phase code is the complex conjugate of the encoder's spectral-phase code. Thus a pulse is properly decoded when the encoding and decoding masks are a complex conjugate pair, in which case the spectral phase shifts are removed and the original pulse is recovered. On the other hand, when the encoding and decoding masks do not match, the spectral phase shifts are rearranged but not removed, and the output remains a low intensity pseudonoise burst. A threshold device is set to detect data corresponding to intense, properly decoded pulses and to reject low intensity, improperly decoded, pseudonoise bursts.

An important factor in the performance of the proposed CDMA system is the peak intensity of the encoded signals. We consider using random signatures for the phase encoding of the phase pulses in the system and prove that they result in a fairly low peak intensity of the signals. We assume that the ultra-short light pulses are characterized by an ideal rectangular spectrum with bandwidth W. The ultrashort light pulse has peak intensity P_0 and duration $t_c \approx \frac{2\pi}{W}$. Pulses of this form had been used in the experiments reported in [1]. The encoding is taking place in the frequency domain. The signal bandwidth is divided into $N_0 = 2N+1$ chips, each of length $B = W/N_0$. Due to the encoding done through a pair of diffraction gratings and a phase mask, the spectral components in the interval $[nB,(n+1)B)$, $n = -N,\ldots,N$, experience a phase shift shift of $e^{i\phi_n}$, where $\overline{\phi} = \{\phi_n\}_{n=-N}^{N}$ is the signature of the transmitter. In the time domain the encoded signal is the product

$$G(t)\cdot V(t,\overline{\phi}),$$

where

$$V(t,\overline{\phi}) = \frac{1}{N_0}\sum_{n=-N}^{N}\exp\{-j(nBt+\phi_n)\},$$

and

$$G(t) = \sqrt{P_0}\ \mathrm{sinc}\ (Bt/2).$$

Note that $G(t)$ varies much slower in time than the signal $V(t,\overline{\phi})$ and can be viewed as the envelope of the encoded signal. We prove that if the ϕ_i's , are i.i.d. and equal to 0 ar π with probability 0.5 then for any $\lambda > 0$, $\rho \in (0,1)$ and $k > 4$,

$$\Pr(\overline{\phi} : \|V(t,\overline{\phi})\|_\infty \geq \lambda) \leq \left(4kN_0\cdot\exp\left(-N_0E(\frac{k-\pi}{k}\lambda)\right)\right)^{\rho}, \tag{1}$$

where $\|\cdot\|_\infty$ is the supremum norm over t and

$$E(\mu) = \frac{\mu}{2^{3/2}}\ln\left(\frac{\sqrt{2}+\mu}{\sqrt{2}-\mu}\right) - \frac{1}{2}\ln\left(\frac{2}{2-\mu^2}\right) = \frac{\mu^2}{4}+\frac{\mu^4}{48}+\frac{\mu^6}{240}+\cdots \tag{2}$$

The proof of (1) is based on the Chernoff bound. The exponent given in (2) is greater than the exponent found in [2] based on another approach.

REFERENCE

[1] J. A. Salehi, A. M. Weiner, J. P. Heritage, "Coherent Ultrashort Light Pulse Code Division Multiple Access Communication Systems", Journal of Lightwave Technology, Vol. 8, No.3, pp. 478-491, March 1990.

[2] D. J. Hajela, J. A. Salehi, "Limits to the Encoding of Coherent Ultrashort Light Pulses", Proceedings of 1990 Conference on Information Sciences and Systems, Princeton University, pp. 869-873, March 1990.