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Performance Study of Maximum-Likelihood Receivers and Transversal Filters for the Detection of Direct-Sequence Spread-Spectrum Signal in Narrowband Interference

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Abstract - Linear least squares estimation techniques can be used to enhance suppression of narrowband interference in direct-sequence spread-spectrum systems. Nonlinear techniques for this purpose have also been investigated recently. Here, we derive maximum-likelihood receivers for direct-sequence signal in Gaussian interference with known second order characteristics. It is shown that if the receiver uses samples from outside the bit interval, then the receiver structure (called ML II)is nonlinear. The bit error rate performances of these ML receivers are compared to those of linear receivers employing one-sided and two-sided least squares estimation filters, for the case of Gaussian autoregressive interference. It is shown that the ML II receiver outperforms the matched filter, the one sided and the two sided transversal filters.

I. INTRODUCTION

Direct-sequence spread-spectrum systems offer an inherent capability of rejecting narrowband interference. This is achieved by modulating the bit waveform with a PN signal before transmission and correlating the received signal with a replica of the PN signal. In this way, interfering signals, whose bandwidths are narrow compared to the spread signal, are attenuated by the receiver. Processing the received signal prior to correlating with the PN sequence has been employed to improve the suppression of narrowband interference. Linear least squares estimation techniques to estimate and subtract the narrowband interference have been studied [1]. Nonlinear techniques for interference suppression in spread-spectrum systems have been investigated in [2]. Here, we study the performance of maximum-likelihood receivers for direct sequence spread spectrum signals received in Gaussian interference with known second order statistics. When the receiver operates on the observations in the bit duration only, the receiver is the well known linear detector known as the matched filter. When the observation interval extends outside the bit interval, the receiver structure is shown to be nonlinear. The nonlinearity arises not due to the modeling of the binary chip sequence as as random as in [2], but due to the uncertainty on the bits adjacent to the bit being tested.

II. MAXIMUM-LIKELIHOOD RECEIVERS

We consider here the performance of maximum-likelihood receivers for the following problem . We shall restrict to the case where an entire maximal length PN code sequence is embedded in each bit (so called short PN sequences). A similar analysis can be easily done for the case of long PN sequences. Let the received signal be processed by a chip-matched-filter and sampled at the chip rate of the PN sequence to yield [2]:

$$z_k = s_k + n_k + j_k \qquad (1)$$

where $s_k = S\, b_k\, c_k$. Without loss of generality,the signal strength S is assumed to be 1.0. c_k is the kth chip of the PN sequence with chip interval τ_c. c_k for $k < 0$ or $k > L-1$ is taken modulo L. $b_k \varepsilon \{+1,-1\}$ is the binary information with bit duration $T_b = L\tau_c$, L is the processing gain given as the number of PN chips per message bit. Note that $b_k = b \;\varepsilon\; \{\pm 1\}$ for all k in the same bit interval. n_k is a sequence of zero mean i.i.d. Gaussian noise with known variance σ_n^2. j_k is a sequence of narrowband interference modeled as a zero mean Gaussian process with autocovariance $R_j(k)$. The detection problem is: all b_k over the current bit (i.e. b) =

$$\begin{cases} -1: & H_0 \\ +1: & H_1 \end{cases} \qquad (2)$$

Let $v_k = n_k + j_k$ be the white noise plus the interference with autocovariance $R_v(m)=\sigma_n^2\,\delta(m) + R_j(m)$. Let Λ be the L×L covariance matrix of $\{v_k\}$. The maximum-likelihood detector for the detection problem in (2) is given by :

$$\underline{z}^T \Lambda^{-1} \underline{c} \underset{-1}{\overset{+1}{\gtrless}} 0 \qquad (3)$$

where $\underline{z}^T = [z_0, z_1, \ldots, z_{L-1}]$, $\underline{c}^T = [c_0, c_1, \ldots, c_{L-1}]$. Call this the ML I receiver.

2.1 ML II Receiver and its Bit Error Rate.

Now consider the observation vector to consist of the chips corresponding to the bit under test appended with some chips from the previous bit, i.e. the receiver has to test the present bit but uses observation samples from the present bit interval and a part of the previous bit interval. Let $\underline{r}^T = [\bar{\underline{z}}^T \;\; \underline{z}^T]$ where $\bar{\underline{z}}^T = [\bar{z}_{L-i}, \bar{z}_{L-i+1}, \ldots, \bar{z}_{L-1}]$ is the vector of the last i chip samples from the previous bit, $i \le L$. The likelihood ratio, $\lambda(\underline{r})$, and the corresponding maximum-likelihood detector for the detection problem in (2) is then given by:

$$\lambda(\underline{r}) = \frac{\displaystyle\sum_{d \varepsilon \{\pm 1\}} \exp\{\underline{s}^T_{d,+1} \Lambda^{-1} (\underline{r} - \tfrac{1}{2}\, \underline{s}_{d,+1})\}}{\displaystyle\sum_{d \varepsilon \{\pm 1\}} \exp\{\underline{s}^T_{d,-1} \Lambda^{-1} (\underline{r} - \tfrac{1}{2}\, \underline{s}_{d,-1})\}} \underset{-1}{\overset{+1}{\gtrless}} 1 \qquad (4)$$

where Λ is the $(L+i)\times(L+i)$ covariance matrix of the sequence $\{v_k\}$, and $\underline{s}^T_{d,b} = [dc_{L-i}, dc_{L-i+1}, \ldots, dc_{L-1}, bc_0, bc_1, \ldots, bc_{L-1}]$, the subscript d indicates the previous bit, $d \;\varepsilon\; \{\pm 1\}$. Using straightforward calculations involving partitioned vectors and matrices, it can be shown that the bit error probability for the detector in (4) is given by:

$$P_e = \Pr\{\sinh(\theta_1) > \gamma \sinh(\theta_2) \mid H_0\} \qquad (5)$$

where $\theta_1 = \underline{s}^T_{+1,+1} \Lambda^{-1} \underline{r}$. $\theta_2 = \underline{s}^T_{-11,+1} \Lambda^{-1} \underline{r}$. γ is a negative constant obtained from the entries in Λ^{-1} matrix and $\underline{s}_{+1,+1}$ vector The test statistic given by (4) is nonlinear in observations. The receiver based on (4) will be called ML II.

III. PERFORMANCE COMPARISON

The bit error rate performances of the ML I and ML II receivers are evaluated numerically and compared to the performances of the one-sided and two-sided transversal filters. The narrowband interference is modeled as a second order zero mean Gaussian autoregressive process with known parameters. As expected, both the maximum-likelihood receivers and the transversal filters perform better when the power spectral density is peaky. The nonlinear ML II receiver outperforms the matched filter receiver and the one-sided and two-sided transversal filters.

REFERENCES

[1] L. B. Milstein, "Interference rejection techniques in spread spectrum communications,'Proc. IEEE, vol. 76, No.6, June 1988, pp 657-671.

[2] R. Vijayan and H. Vincent Poor, "Nonlinear techniques for interference suppression in spread-spectrum systems," IEEE Trans. on Commun., Vol. 38, No. 7, July 1990, pp 1060-1065.