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PN대역확장 통신 시스템에서 협대역 간섭신호의 제거방식에 관한 연구

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A study on narrowband interference rejection in PN spread spectrum communication systems

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Abstract

In this paper, a improved whitening filter for narrowband interference rejetion in PN spread spectrum communication systems is proposed. This whitening filter has the feedback from the output to the input of adaptive transversal filter and is superior to conventional LMS whitening filter in respect to SNR and power spectrum since the calculation of tap weight is based on maximum likelihood estimation.

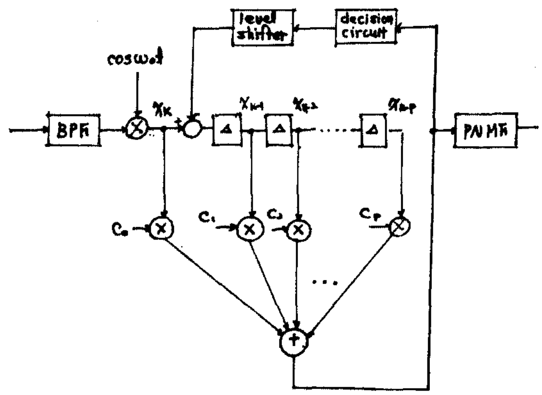

Fig. 1 system model

1. Introduction

The performance of a direct sequence spread spectrum receiver may be enhanced considerably by using linear mean square (LMS) estimation techniques for suppression of narrowband interference. This technique is conceptionally accomplished by implementing digital whitening filter hm that is equivalent to whitening the received signal (transmitted signal plus noise plus jammer). Since interference as well as signal is whitened the performence using LMS estimation is somecases inferier to that obtained using other electronic rejection circuitry. So new suppression filter suggested by the form of feedback in order to whiten interference alone.

2. System model and signal format

The system considered is a BPSK spread spectrum system shown in Fig. 1 and it is assumed that the narrowband interference is multiple CW interference and narrowband gaussian interference and SS modulation is accomplished by direct sequence (PN) method. In a narrowband interference environment the received wideband signal can be expressed as

$$x_k = s_k + g_k + n_k$$
$$= U P_k + \sum_{m=1}^{M} C_m \cos(2\pi f_m k\Delta t + \Phi_m) + n_k \qquad (1)$$

where

g_k narrowband interference

n_k zero mean white Gaussian noise with a variance σ^2

U information symbol

P_k modulated PN sequence

C_m amplitude of narrowband jamming

f_m sampling frequency of narrowband jamming

Φ_M phase of the narrowband jamming distributed uniformly over the range $(-\pi, \pi)$

Δt sampling interval

3. Coefficient Calculation

If there is no error in decision circuit of Fig.1, the equations to determine the coefficients is expressed as

$$\hat{\varepsilon}_k = \sum_{l=1}^{p} C_l \varepsilon_{k-l} = C_p C_r$$
$$= \sum_{l=1}^{p} C_l (\chi_{k-l} - d_{k-l})$$
$$\simeq \sum_{l=1}^{p} C_l (\eta_{k-l} + g_{k-l}) \quad (2)$$

where

$\{d_k\}$ independent random binary data sequences

$$C_p = [C_1, \cdots, C_p]' = [\underline{C}_{p-1}, C_p] \quad (3)$$

$$\chi_p = [\chi_k, \cdots, \chi_{k-p}] = [\underline{\chi}_{p-1}, \chi_p] \quad (4)$$

We choose that minimizes the sum of squares of the deviation $\hat{\varepsilon}_k - \varepsilon_k$, that is the mean squares of the

$$J = E\{(\hat{\varepsilon}_k - \varepsilon_k)^2\}$$

The resulting estimate obtained by setting $\frac{\partial J}{\partial \underline{C}} = 0$ is

$$C_p^* = R_p^{-1} U_p \quad (5)$$

where

$$R_p = [r_{|i-j|}]_{i=j=1,\cdots,p} = \begin{pmatrix} R_{p-1} & J r_{p-1} \\ r_{p-1}' J & r_0 \end{pmatrix} \quad (6)$$

$$= E(\chi_p, \chi_p') \quad (7)$$

$$\underline{U}_p = [U_1, U_2, \cdots, U_p] = [E(\chi_1^2), \cdots, E(\chi_p^2)]$$

The coefficients $\{C_p^*\}$ can be recursively computed by using a form of the Levinson algorithm.

4. Performance

A. Power Spectra

Power Spectra for whitening filter with feedback is shown in Fig. 2 . In this case ,the performance of a direct sequence(DS) spread spectrum receiver is enhanced by using this filters assuming the number of tones M is chosen to 100 and the order of the whitening filter is 4.

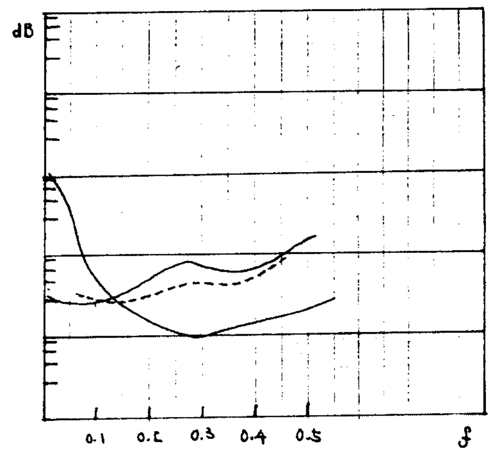

Fig.2 Power spectrum;SNR+-8dB,C_m=0.6,the number of tones is chosen to be 50.

B. Signal-to- Noise ratio

In SS system of Fig. 1, the correlator input is

$$\varepsilon_k = \sum_{n=0}^{M} C_n (\chi_k - d_k) \quad (8)$$

assuming $d_{k-n} = P_{k-n}$ in ideal case, then

$$S = \sum_{k=1}^{L} \varepsilon_k P_k + P_k$$
$$= \sum_{k=1}^{L} \sum_{n=0}^{N} a_n P_k (P_{k-n} + g_{k-n} - P_{k-n}) + P_k \quad (9)$$

The mean of [illegible] is

$$E(S) = L \quad (10)$$

and

$$E(S^2) = E[\sum_{k=1}^{L} \sum_{n=0}^{N} \sum_{i=1}^{L} \sum_{j=0}^{N} C_n C_j P_k P_i g_{k-n} g_{i-j}]$$
$$= \sum_{k=1}^{L} \sum_{n=0}^{N} \sum_{i=1}^{L} \sum_{j=0}^{N} C_n C_j E(P_k P_i) E(g_{k-n} g_{i-j})$$
$$= L\sigma^2 \sum_{n=1}^{N} C_n^2 \quad (11)$$

since

$$E(P_k P_l) = \delta_{k-l} = \begin{cases} 1, & k = l \\ 0, & \text{otherwise} \end{cases} \quad (12)$$

$$E[P_k P_i P_{k-n} P_{i-j}] = \begin{cases} 1, & n = j = 0 \\ \delta_{n-j}, & n > 0, j > 0, i = k \\ 0, & \text{otherwise} \end{cases} \quad (13)$$

$$E(g_{k-n}) = 0 \tag{14}$$

$$E(g_{k-n} g_{i-j}) = \frac{1}{L}\sum_{m=1}^{M} C_m^2 \cos(2\pi\Delta t f_m (j-n) + \sigma^2 \delta_{j-n})$$
$$= M P_N \Delta t \Delta f + \sigma^2 \delta_{j-n} \tag{15}$$

The variance of S is

$$V(S) = E(S^2) - L^2$$
$$= \sum_{k=1}^{L}\sum_{n=0}^{N}\sum_{i=1}^{L}\sum_{j=0}^{N} a_n c_j E(P_k P_i) E(g_k g_i)$$
$$+ E(P_k P_i) - L^2$$
$$= L P_N \Delta t \Delta f M + L \sigma^2 \sum_{n=1}^{N} a_n^2 \tag{16}$$

Therefore

$$SNR = \frac{E^2(S)}{V(S)} = \frac{L}{\sigma^2 \sum_{n=1}^{N} a_n^2 + L P_N \Delta t \Delta f M} \tag{17}$$

The SNR of conventional SS spread spectrum system is

$$SNR' = \frac{L}{\frac{1}{2} L b_m^2 + \sigma^2} \tag{18}$$

in the system without feedback

$$SNR'' = \frac{L}{(1+\sigma^2)\sum_{n=1}^{N} a_n^2 + M P_N \Delta f \Delta t} \tag{19}$$

since

$$\varepsilon_k = \sum_{n=0}^{N} a_n x_{k-n} \tag{20}$$

Hense the performance is improved and plotted in Fig. 3.

4. Conclusion

This paper has proposed a feedback whitening filters that has the feedback from the output to the input of adaptive transversal filter and showed the **SNR** representation of this system. This filter can effectively suppresss narrowband jammming signals and has satisfactory performance regard to SNR and Power spectrum. Although the error probability has not derived in this paper, it is also expected to be improved because of whitening only jamming component.

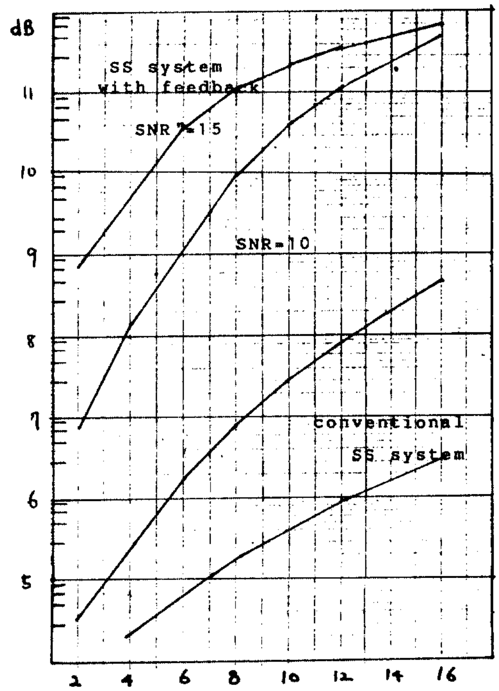

Fig.3 SNR comparison.(SNR versus The number of taps)

REFERENCE

(1) R.C.Dixon,Spread Spectrum Systems:Wiley ,1976

(2) M.Hsu and A.Giorano,"Digital Whitening Techniques for Improving Spread Spectrum Communications Perforemance in the Presence of Narrowband Jamming and Interference," IEEE Trans.Commun.,Vol.COM-26,No.2,Feb. 1978

(3) J.W.Kelchem and J.G.Proakis,"Adaptive Algorithms for Estimating and Suppressing Narrowband Interference in PN Spread Spectrum Systems,"IEEE Trans.Commun.,Vol.COM-30, pp.913-924,May 1982

(4)L.Li and L.B.Milstein,"Rejection of Narrowband Interference in PN Spread Spectrum Systems Using Transversal Filters,"IEEE Trans.Commun.,VOl.COM-30,pp.925-928,May 1982

(5) R.A.Ailtis and L.B.Milstein,"Estimation Techniques for Narrowband Interference Rejection,"ICC,pp.1582-1586,1983