Detection of Code – Division Multiple Access Signals based on Neural Network

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Abstract

Artificial Neural Networks are employed for demodulation of spread spectrum signals in a multiple – access environment. In fact, the conventional matched filter receiver, when used in multi-user system, suffers from the interfering signals, so that when reducing this problem, we need to make the receiver in optimum state. This receiver is too complex for practical use. Two simple structures employing multilayer nodes are produced for demodulation of spread-spectrum signals. The Neural Networks are trained for the demodulation of signals by using back propagation type algorithms. A comparative analysis of the two receivers, the conventional and that employing Neural Network, has been presented.

الخلاصة

استخدمت في هذا البحث الشبكات العصبية الصناعية (ANN) لاعادة التضمين (Demodulation) للأشارات ذات النطاق المنتشر في محيط متعدد الاستخدامات وله مستفيدون عديدون. ان المرشح الاعتيادي نوع الموائم (Matched Filter) عند استخدامه في المستلم يعاني من اشارات التداخل، لذا عند تقليل هذه المشكلة نحتاج الى جعل المستلم بأقل حال من طاقته الاسمية. وفي هذه الحالة، فأن منظومة المستلم تكون معقدة عند الاستخدام العملي في تضخيم الموجات المايكروية. وثمة مقترح لتشكيلة بسيطة (Multilayer) باستخدام عقدة ذات مستويين لأعادة تضمين هذه الاشارة . ولقد تم تدريب الشبكات العصبية لأعادة تضمين هذه الإشارة بواسطة خوارزمية الانتشار الخلفي (Back propagation) . وتم إجراء مقارنة تحليلية لعمل المستلم في كلتا الحالتين: الكلاسيكية، وباستخدام الشبكات العصبية الذي تم التوصل اليه في هذا البحث .

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1. Introduction

Multiple accessing in the code domain is achieved by spreading the spectrum of the transmitted signals using reassigned code wave forms (1).

The definition of spread spectrum may be stated in two parts:

Spread spectrum is a means of transmission in which the data of interest occupies a bandwidth in excess of the minimum necessary to send the data.

The spectrum spread is accomplished by means of a code that is independent of the data sequence.

The basic modulation techniques used in the spread spectrum system are as follows:

- Direct sequence (DS) modulation
- Frequency hopping (FH)
- Time hopping (TH)
- Pulse – FM
- Hybrids form (2)

System description

In the multiple access network of interest, transmitters are assumed to share a radio band in combination of the time and code.

One way of multiple accessing in the code domain is spread spectrum, which is a signaling scheme that uses much bandwidth than necessary for a given data rate.

Let us assume that in a given time interval, there are K active transmitters in the network.

In a general CDMA system, the signal at a given receiver is the super position of the K transmitted signals in additive channel noise (3):

$$r(t) = \sum_{i}^{p}\sum_{k=2}^{k} B_k^{(i)} S_k(t - iT - \tau_k) + n_t \quad \text{.....} \quad (1)$$

Where

2P+1 : is the paket length .

BK $^{(1)}$: The K^{TH} user information bit in the I^{TH} interval .

K: 1,2,…. K

$n/_T$: Additive channel noise

SK (I): The modulated signal wave form of the produced neural net of multi-user detector. We present the application to binary (DS) direct–sequence signals. So that:

$$S_k(t) = A_k Q_k(t) COS(W_c t + \theta_k) \quad \text{.....} \quad (2)$$

d_K : signal amplitude

W_C: carrier frequency

$_K$: The phase angle

A_K: Time – limited code wave form

$$a_k(t) = \sum_{j=0}^{M-1} a_j^{(K)} \pi(t - jT_c) \quad \text{.....} \quad (3)$$

Where

$aj^{(K)}$ { =1,-1 } : is a code symbol

π (t) : The unit rectangular pulse of

duration TC

N: The length of spreading sequence

$$T = NT_c \text{ ……} \quad (4)$$

3. Neural net receivers

We employed Neural Network for classifying different signals in both synchronous and a synchronous for the neural net receivers considered.

(A): One for demodulation of the signal of one user or several users. These configurations are shown in Figures 1 and 2.

(B): The other for demodulation of signals of several users in the presence of interfering users.

These configurations are shown in Figures 1 and 2.

From Fig. 3 we employ a feed-forward Neural Network with continuous input values. These networks consist of an input layer of nodes, one or more layers of hidden nodes and layers of output nodes. Each node in a given layer is connected to all the nodes of the next layer.

Therefore, in a L- layer protection, the O/P of the (I TH) node of the (L TH) layer takes the value:-

$$V_i^{(l)} = g\left(\sum_{j=1}^{M_{l-1}} W_{ji}^{(l)} V_j^{(l-1)} - W_{oi}^{(l)}\right) \ldots \quad (5)$$

L= 1,2,3,….. , L

I= 1,2,3,……, M_L

M_L = No. of nodes in the L TH layer.

$W_{JI}^{(L)}$ = The weight associated with connection between the J^{TH} node of the L-1^{ST} layer to the I^{TH} node of the L^{TH} layer .

$W_{OI}^{(L)}$: Threshold

Non linear ties which are commonly used for the activated function G (.).

$W_J^{(O)}$: j TH input to the network .

M_o : The total No. of inputs .

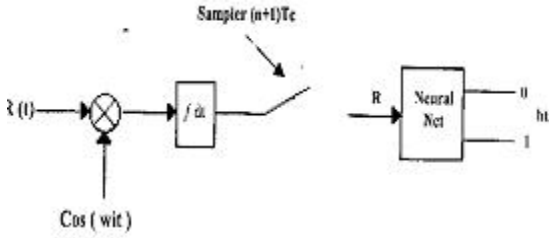

Fig (1)
Structure of neural Net multi use receiver for single – use demodulator

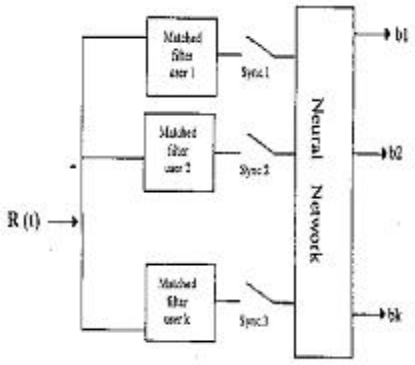

Fig (2)
Structure of neural Net multi-user receiver for multi-user demodulation

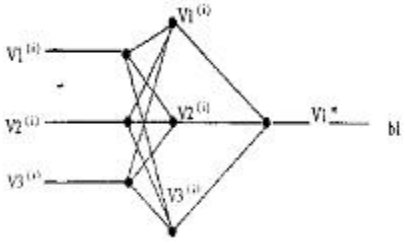

Fig (3)
Afwo – Layer preceptron

In our research, the multi layer perception was trained to demodulate spread spectrum signals. The training is an interactive process of modifying weights and thresholds to minimize an error function.

The back-propagation algorithm is training algorithm that has been applied to many classifications that minimize an empirical error function; the error function is defined as the sum of errors due to each exemplary pattern:

$$\varepsilon(w) = \sum_{p} \varepsilon_p \quad \text{(6)}$$

At any step the interaction in the weights is in the direction of the negative gradient of the error:-

$$\Delta w_{ji}^{(l)} \alpha - \frac{\partial \varepsilon_p}{\partial w_{ji}^{(l)}} \quad \text{(7)}$$

Where the initial values of the weights and WJI $^{(L)}$ (O) are chosen to be some small random numbers.

Numerical Results

The performances of the conventional and Neural Networks receivers are compared. Consider demodulation of a single user in a synchronous twp–users with near– far problem where :-

- $E_2 / E_1 = 6$ dB
- Spreading sequence $a^{(1)} = (1,1,1)$ + $a^{(2)} = (1,-1,1)$
- Length N=3

Two-layer is employed with three input nodes, three nodes in hidden layer and one output node, so that the average bit–error probabilities of the two receivers (conventional, neural net) are plotted versus the (SNR) of the first user (SNR1):

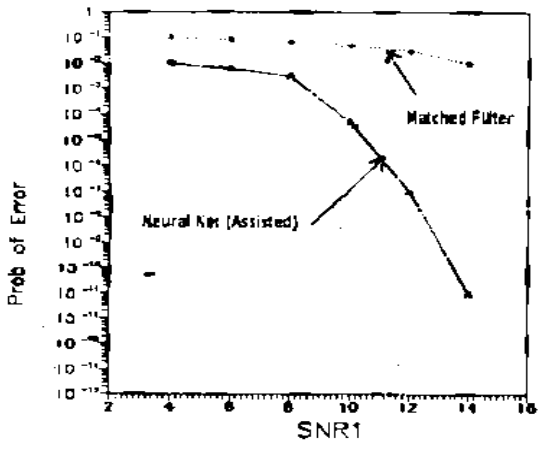

Fig. 4

Fig. 4 Show the error probabilities versus the relative energies of two users (E_2/ E_1) :-

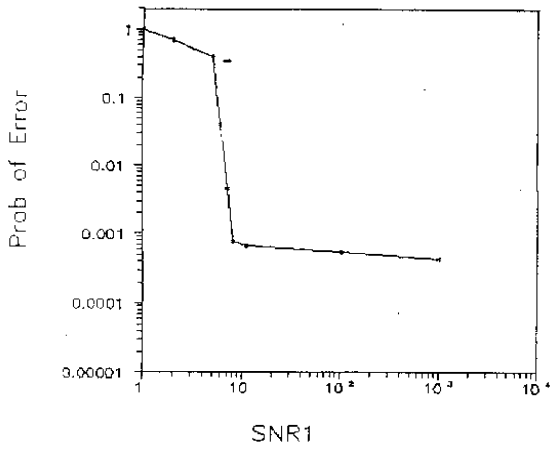

Fig. 5

Fig. (5) Show the relation between the average rate versus the length of the training period for this two – user.

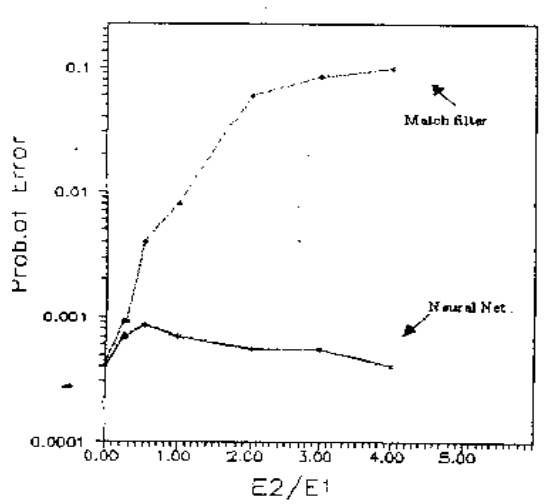

Fig. 6

5. Conclusions

We considered the near–far problems of demodulating spread– spectrum signals in multiple access. The following points are deduced:

The performance of the conventional receiver (matches filter) is very sensitive to the strength of the interfering users.

- The error probability of Neural Network receiver is independent of the strength of the other users.
- The performance of the Neural Network receivers comparable to that of the optimum receivers.
- The training can be terminated after approximately 500 exemplary input.
- For demodulation of information bit, the Neural Network receiver relies on parallel computation in each layer which implies constant demodulation time complexity and exponential hardware complexity in the number of users.

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