行政院國家科學委員會補助專題研究計畫成果報告

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基於排線式遞迴類神經網路展頻分碼多工窄頻干擾消除研究

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計畫類別：☒個別型計畫　□整合型計畫
計畫編號：NSC 89－2213－E009－087－－
執行期間：88年8月1日至89年7月31日

計畫主持人：張柏榮
共同主持人：

本成果報告包括以下應繳交之附件：
- □赴國外出差或研習心得報告一份
- □赴大陸地區出差或研習心得報告一份
- □出席國際學術會議心得報告及發表之論文各一份
- □國際合作研究計畫國外研究報告書一份

執行單位：國立交通大學電信工程學系

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mean(ACM) filter 架構[6]。進而整合軟決策回饋機制(soft decision feedback)，以上非線性 ACM filter 干擾消除技術有另外一個假設，即窄頻干擾信號是建立在自我回歸模型上(autogressive model)。同時 ACM filter 干擾消除器必須知道自我回歸模型的相關參數。反之則會大大降低系統效能。因此 Vijayan 與 Poo[4]採用 LMS(Least Mean square) 適應性信號處理機制預估自我回歸模型中未知的參數，以便提高系統效能。但是以上的窄頻干擾消除技術均局限在單純的展頻通訊上。最近，Rusch 及 Poor[5]，延伸適應性 ACM filter 干擾消除技術於展頻分碼多工通訊上。但是他們的技術確有兩個明顯的缺點，即系統必需知道使用者的人數及頻道統計特性。然而行動使用者接收器並無法知道目前同時使用者的人數。因此本計畫擬採用具有非線性特性的類神經網路技術進行展頻分碼多工窄頻干擾消除，以期解決使用者人數及頻道特性未知所產生的缺失。過去 Bijjani 與 Das[8]曾採用多階層感知類神經網路技術(multilayer perceptron(MLP) neural networks)進行單純展頻窄頻干擾消除。但是多階層認知類神經網路的學習及收斂速率相當慢，而無法達到無線通訊上即時窄頻干擾消除的要求。因此本計畫擬採用源自於 Haykin[9] 所提出具有即時運算能力的排線式遞迴類神經網路 (Pipelined recurrent neural networks)進行展頻分碼多工窄頻干擾消除。同時本計畫也將進一步利用整合競爭強化學習速率退火技術(Competitive reinforcement learning-rate annealing schedule)與延伸式遞迴最小平方誤差機制(extended recursine least squares, ERLS)進一步提高該類神經網路的收斂速率，以便達到無線通訊即時處理的要求。

三、 研究方法與成果

本計研究畫進行步驟可以分成以下四個階段：(1) 建立十九個細胞的展頻分碼多工通訊軟體模擬架構，(2)建立基於排線式遞迴類神經網路之展頻分碼多工窄頻干擾消除軟體機制，(3)研發競爭強化學習速率退火(Competitive reinforcement learning-rate annealing schedule) 技術提高排線式遞迴類神經網路的收斂速率，(4)與目前其他窄頻干擾消除技術如：線性適應性濾波器、卡門濾波器 (kalman filtering)以及適應性 ACM 濾波器，針對收斂速率，信號雜訊比增益效能(SNR improvement)及位元錯誤率(bit error rate)互相比較。

我們的展頻分碼多工窄頻干擾消除的系統架構基本上採用 Poor 與 Rusch[7]提出如圖(一)所示的先預估窄頻干擾信號再由原信號減去的系統模型(Estimator/Subtractor model)。剩餘的信號則送入展頻分碼多工檢測器分離出所需要的位元信息。因此我們發展如圖(二)所示的適應性排線式遞迴類神經網路窄頻干擾信號預估次系統。該次系統架構源自於排線式遞迴類神經網路獨特的 nested nonlinearity 特性。Li 與 Haykin[9][10]指出排線式遞迴類神經網路可以近似任何系統(universal approximator)當延遲單元個數增加或內部神經元個數(hidden neurous)足夠多。本計畫也將提出如何判定可以維持極佳非線性預估能力所需最少的模組數目及內部神經元個數的機制。該機制延伸系統判認(System identification)理論中模式位階(model order)判定所採用的最小信息 方法(minimum information entropy)。如此將可減少排線式遞迴類神經網路所需模組數目及內部神經元個數因而達到硬體建構成本降低。網路排線式遞迴類神經網路串接一序列具有低運算複雜度的相似規模單純遞迴類神經網路模組而成一排線式鎖鏈如圖(三)所示。其中各模組均可以平行獨立運作極適於平行處理器的電路模型。輸入信號 $\phi(z)$ 由右上端進入一序列延遲傳輸線(tapped delay line)產生個別延遲信號以便輸入各個遞迴類神經網路模組。最左端的模組除了內部神經元回饋外同時也有該模組輸出信號的回饋。如此形成無線遞迴 nest nonlinearity 的特性以期提高預估效能。最後預估信號 ϕ 則由靠右中間輸出。一般遞迴類神經網路採用遞迴學習法則(real-time recurrent learning (RTRL) algorithm)進行網路上神經鍵強度值的調整。Haykin 及 Li[9]延伸即時遞迴學習法則機制並且應用在排線式類神經網路上。然而爲了進一步提高收斂速度以達到無線通訊即時處理的要求，我們研發整合競爭強化學習機制及學習速度模擬退火的優點以期提高排線式遞迴類神經網路各個模組的收斂速度。同時融入延伸式遞迴最小平方誤差機制的優點使得各個模組的學習演算機制達到最佳的效能。圖（四）及圖五分別是排線式遞迴類神經網路窄頻干擾消除機制(PRNN)與 Rusch 及 Poor[5]所提出兩種不同基於 ACM filter 之非線性預估濾波器(nonlinear predictor filter, NLP)窄頻干擾消除機制，NLP1 及 NLP2 效能比較。NLP1 及 NLP2 效能隨著未知人數干擾強度變大而降低（最高未知人數爲 50 人）。然而本計畫所提出排線式遞迴類神經網路窄頻干擾消除效能接近理論最佳上限值同時不隨著未知人數增加而降低。

四、 結論與討論

本計畫所完成工作項目及具體成果主要包括以下數點：1.完成基於排線式遞迴類神經網路展頻分碼多工窄頻干擾消除軟體機制。2.完成競爭強化學習速率退火應用在排線式遞迴類神經網路上的軟體機制。3.與其它現有窄頻消除技術針對收斂速率，信號雜訊比增益效能及位元錯誤率互相比較。本計畫研究成果也即將在 IEEE Trans. Vehicular Technology 上發表。

五、 參考文獻

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[3] L. M. Li and L. B. Milstein, "Rejection of pulsed CW interference in PN spread-spectrum systems using complex adaptive filters," *IEEE Trans. Commun.*, vol. COM-31, pp. 10-20. 1983.

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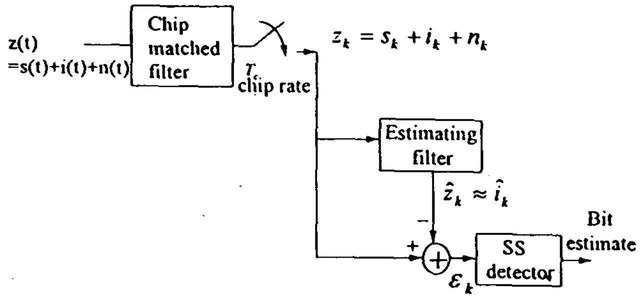

Fig. 1. Estimator/subtractor model for NBI rejection in SS-CDMA systems.

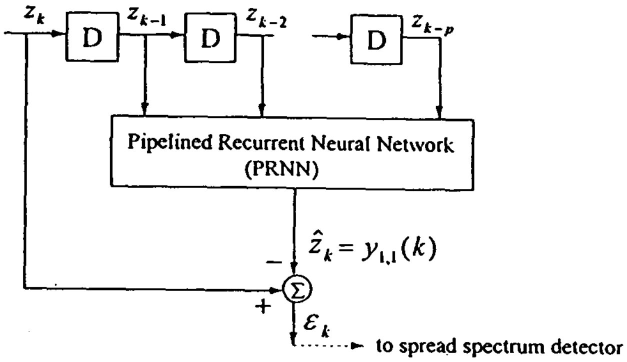

Fig. 2 Adaptive PRNN predictor.

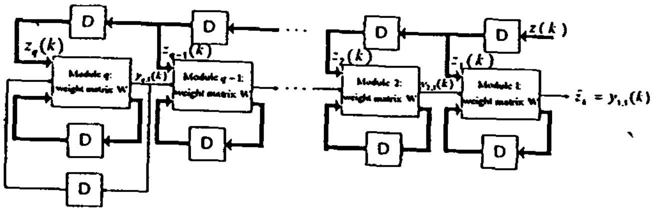

Fig.3.a A pipelined recurrent neural network (PRNN) with *q* modules

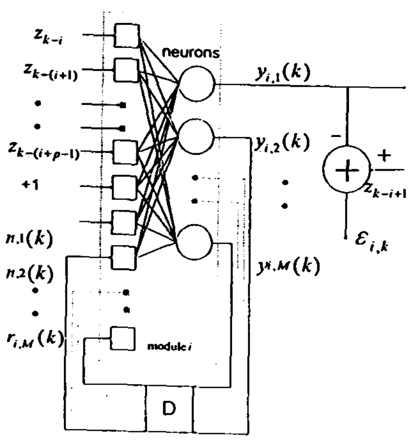

Fig.3.b Detailed architechure of module *i* of the PRNN

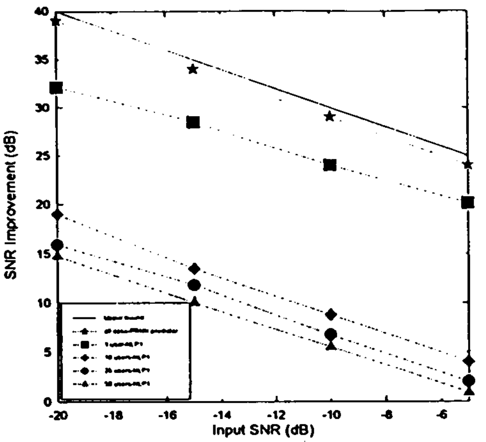

Fig. 4 Adaptive predictor performance for AR interference-multiple CDMA users when PRNN and NLP1 did not know the number of users.

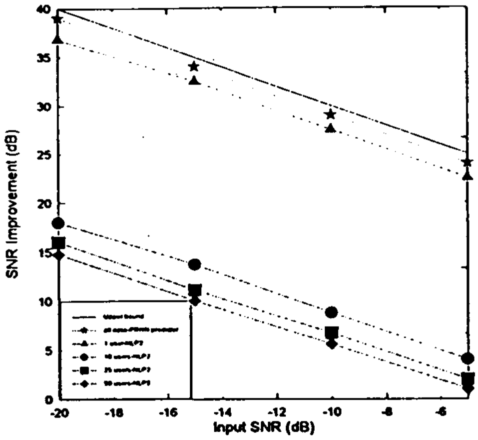

Fig. 5 Adaptive predictor performance for AR interference-multiple CDMA users when PRNN and NLP2 did not know the number of users.

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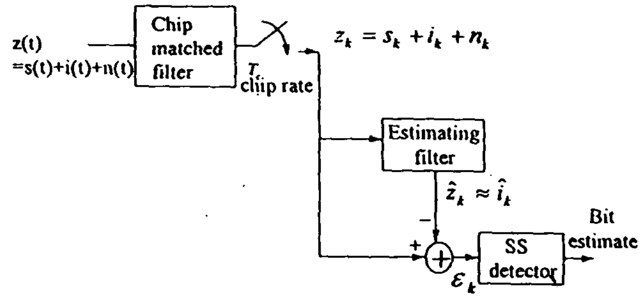

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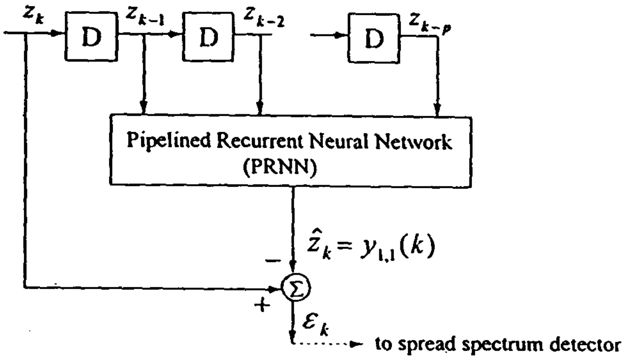

Fig. 2 Adaptive PRNN predictor.

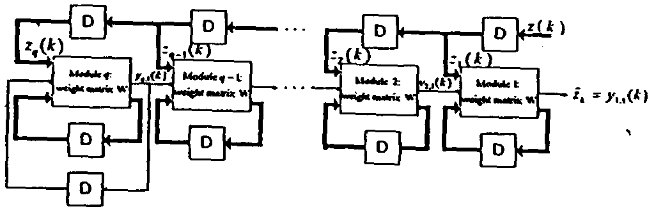

Fig.3.a A pipelined recurrent neural network (PRNN) with *q* modules

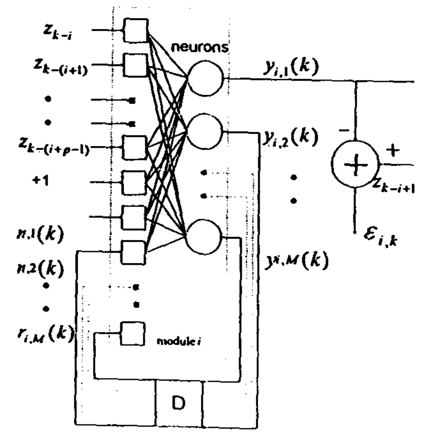

Fig.3.b Detailed architechure of module *i* of the PRNN

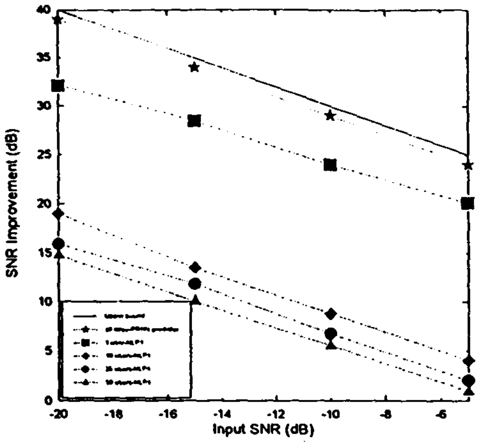

Fig. 4 Adaptive predictor performance for AR interference-multiple CDMA users when PRNN and NLP1 did not know the number of users.

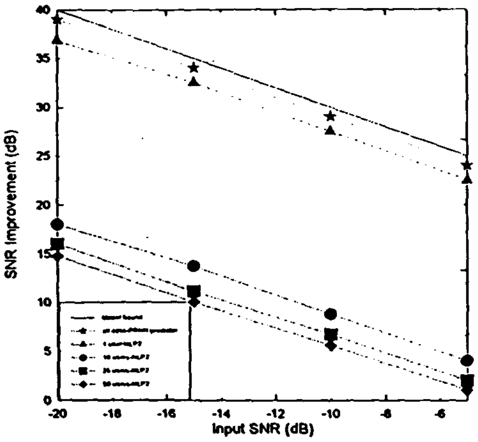

Fig. 5 Adaptive predictor performance for AR interference-multiple CDMA users when PRNN and NLP2 did not know the number of users.