A Study on Digital RF Repeaters with Interference Cancellation System

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Abstract— **In this paper, the adaptive interference cancellation system (ICS) in order to cancel the feedback signal in the wireless communication system is proposed. We cancel the interference with the attenuation signal corresponding to the feedback signal and estimate the feedback signal by using Normalized Least Mean Square (NLMS) algorithm. The proposed scheme showed a better performance of interference cancellation in the measurement results.**

Index Terms— **ICS, NLMS algorithm, Radio Frequency (RF) repeater.**

I. INTRODUCTION

In case of a radio repeater that uses the same frequency for transmitting and receiving signals, the feedback signal from transmit antenna comes back to the receive antenna and this feedback signal becomes the source of an interference. Performance of the receiver is determined by the feedback signal. Some analog interference cancellation techniques estimate the amplitude, phase, and delay of the feedback signal included in the input signal to the repeater. And cancel the feedback signal with the signal generated from the estimated amplitude, phase, and delay [1,2].

In this paper, we propose an adaptive interference cancellation system which prevents the receiver system from oscillation let the receiver maintains maximum output power of the power amplifier. The final aim is to reduce the overall hardware complexity of the interference cancellation repeater. In order to do so, an interpolation is applied to the implementation of the input and output filters for frequency band selection and spectrum control as well as the adaptive filter is used for interference cancellation.

The rest of this paper is organized as follows. The structure of a radio interference cancellation repeater and the interference cancellation algorithm are briefly described in chapter 2. Chapter 3 presents the proposed interference cancellation scheme for Wideband Code Division Multiple Access (WCDMA) in Radio Frequency (RF) repeaters. The computational complexity and performance of the proposed scheme are compared with those of the conventional scheme in chapter 4. Finally, conclusion follows in chapter 5.

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II. FUNDAMENTAL OF INTERFERENCE CANCELLATION SYSTEM

The structure of the radio interference cancellation RF repeater, which relays the signal from a base station to mobile stations, is shown in Fig 1. The analog signal can propagate through a feedback channel and, it is processed in the RF repeater. Interference canceller generates the counterpart signal to cancel the feedback signals and the counterpart signal has the same amplitude and phase. This system can not control all the feedback signals with time-varying factors. So, only one feedback signal which has same variable factors as the primary setting is cancelled out. Adaptive counterpart signal is generated by adaptive detector, method of adaptive counterpart signal generation and the adaptive feedback algorithm in the interference cancellation system (ICS) [3-6].

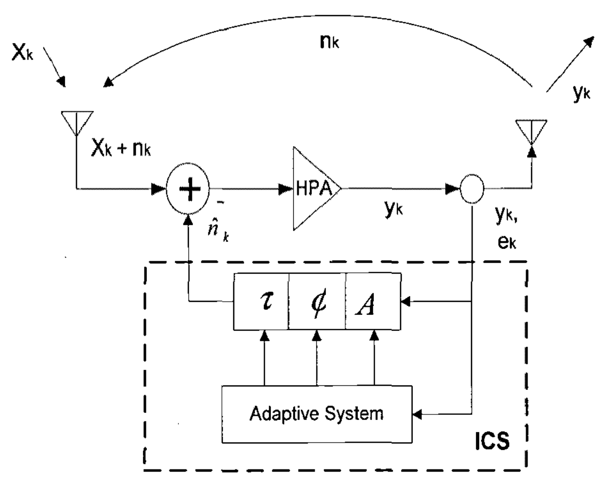

Fig. 1. The structure of RF repeater using interference cancellation system.

The Least Mean Square (LMS) algorithm, which was firstly proposed by Widrow and Hoff in 1960 [2], is the most widely used adaptive filtering algorithm. A significant feature of the LMS algorithm is its simplicity and robustness to signal statistics. Moreover, it required neither correlation functions nor matrix inversion. The LMS algorithm is a stochastic implementation of the steepest descent algorithm. We can develop the following Eq.(1).

$$w_{k+1} = w_k - \mu \nabla J \tag{1}$$

Where w_k is weight vector and μ is step size, ∇J is gradient vector.

Using steepest descent algorithm, to develop an estimate of the gradient vector ∇J, the most obvious strategy is to substitute estimates of the correlation matrix R and the cross-correlation vector P between the filter input and the desired output, which is expressed as Eq.(2).

$$\nabla J = 2Rw - 2P \tag{2}$$

The simplest choices of estimator for R and P are the instantaneous estimates of the sample values. Hence, we write as Eq.(3),(4).

$$R_{ins} = X_k X_k^T \tag{3}$$

$$P_{ins} = d_k X_k \tag{4}$$

Where d_k is desired signal and X_k is input signal .

Substituting the above values into Eq.(2) and the combining Eq.(1) and Eq.(2), we obtain:

$$\begin{aligned} w_{k+1} &= w_k + 2\mu X_k \{d_k - X_k^T w_k\} \\ &= w_k + 2\mu X_k \{d_k - w_k^T X_k\} \\ &= w_k + 2\mu X_k e_k \end{aligned} \tag{5}$$

Where y_k is output signal and e_k is error signal as given in Eq. (6), Eq.(7).

$$y_k = w_k^T X_k \tag{6}$$

$$e_k = d_k - y_k = d_k - w_k X_k \tag{7}$$

The algorithm described by Eq.(5), Eq.(6) and Eq.(7) constitutes the adaptive LMS algorithm. Eq.(6) is referred to as filtering. Eq.(7) is used to calculate the estimation error. Eq.(5) is the tap-weight adaptation recursion. Eq. (6), Eq.(7) and Eq.(5), in this order, specify the three steps required to complete each iteration of the LMS algorithm. The algorithm requires that X_k, d_k, w_k are known at the each iteration [7].

III. PRPPOSED INTERFERENCE CANCELLATION SCHEME

The structure of the proposed ICS is shown in Fig 2. The proposed ICS input is a mixed signal of feedback signal and signal from the base station. After cancellation of the feedback signal, we obtain output signal.

Two interference cancellation schemes based on the interference cancellation method are adapted. At the first cancellation, system controller produces attenuation signal $\hat{n}_k$, the estimate of feedback signal with same amplitude and time delay but the negative phase to cancel the feedback signal n_k . In the second cancellation, adaptive normalized LMS (NLMS) algorithm is used to cancel out the remained the feedback signal.

The adaptive NLMS algorithm described by Eq. (5) is realized by the μ as Eq.(7).

$$\mu = \frac{\alpha}{X_k^T(n) X_k(n) + \beta}, 0 < \alpha < 2 \tag{7}$$

Where α is a positive constant used to ensure stabile convergence, β is a positive constant used to avoid that the denominator results in zero values.

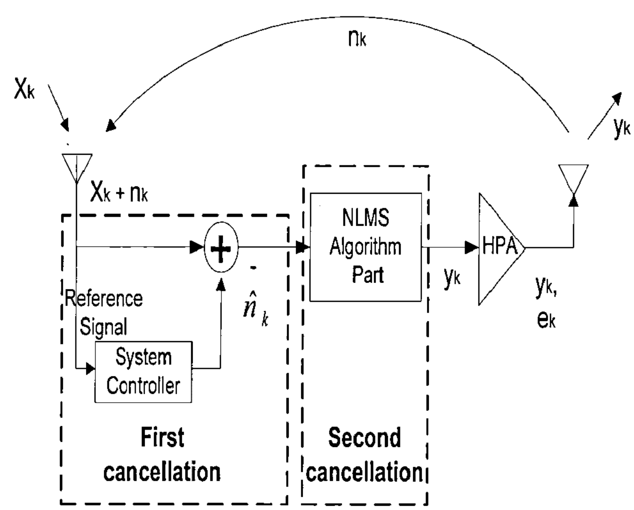

Fig. 2. The structure of the proposed ICS.

Table 1 shows the specification of the RF system. The repeater system for WCDMA band is designed based on the present communication service. Ref. [8] derives a radio repeater interference model for mobile communication system.

IV. PERFORMANCE MEASUREMENT

TABLE I
SPECIFICATION OF THE RF SYSTEM

	Uplink	Downlink
Frequency Range	1940 ~ 1960 MHz	2130 ~ 2150 MHz
Band	3 dBp-p	3 dBp-p
Input power range	-50 dBm/Total	-68 ~ -38 dBm/FA
Maximum output	27 dBm/Total	37 dBm/FA 43 dBm/Total
System Gain	70~100 dB	75~105 dB
Bandwidth	20 MHz	
Antenna Isolation	≤110 dB	
Impedance	50 Ω	
Signal to Noise Ratio (SNR)	≤23 dB	
Output Power	43 Watt	
Spurious Level	50 dBc	
Cancelation Rejection	27 dB	
Noise Figure	4.5 dB	
Input Output SNR	23 dB	
Operation Temperature	-25 ~ 55°C	

The method employed is NLMS to cancel interference and feedback signal. Fig. 3 shows the system setup block diagram to test ICS performance of the feedback interference cancellation. And Fig. 4 is actual hardware setup to test ICS performance.

Fig. 5 shows the input signal to ICS. The feedback interference signal and original signal in the WCDMA systems are shown. Fig. 6 shows the output signal spectrum after cancelling the feedback signal by adaptive LMS algorithm in the ICS. From Fig. 6, we can the feedback interference cancellation of about 5dB. Fig 7 shows the output signal spectrum after cancelling the feedback signal by the proposed two interference cancellation schemes in the ICS. From Fig. 7, we can see the feedback interference cancellation of about 18dB.

The Mean Square Error (MSE) performances of the LMS algorithm and NLMS algorithm is shown in Fig. 8, Fig. 9. When compared at the iteration number of 1000, MSE of LMS algorithm is about -5.8dBm and that of the NLMS algorithm is -10.7dBm. The NLMS algorithm shows the better steady state MSE performance.

We remove the interference by system controller with reference signal, and again cancel the feedback signal by using NLMS algorithm. So, the scheme has a good performance for cancelling the interference signal.

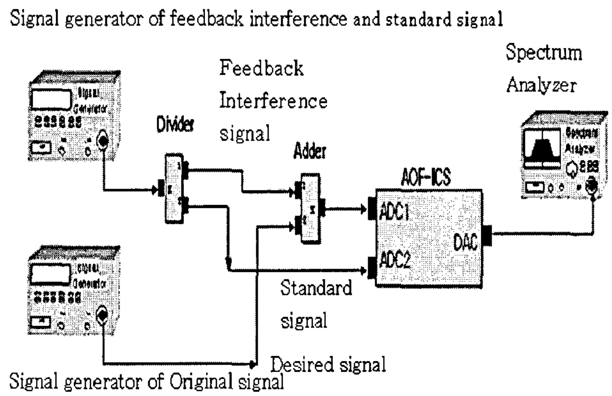

Fig. 3. System setup block diagram.

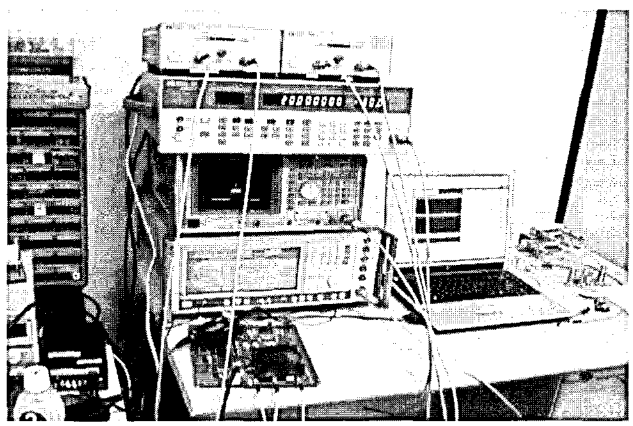

Fig. 4. Photograph of the hardware setup.

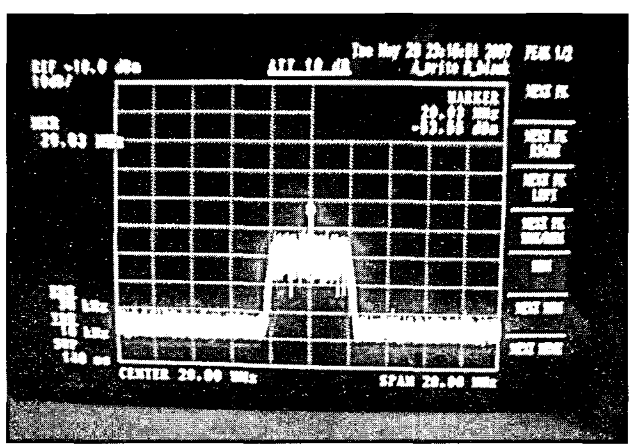

Fig. 5. The input signal to ICS.

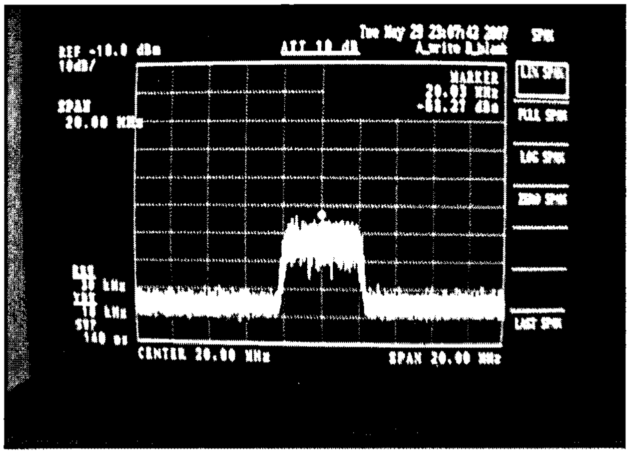

Fig. 6. The output signal spectrum after cancelling the feedback signal by Adaptive LMS algorithm.

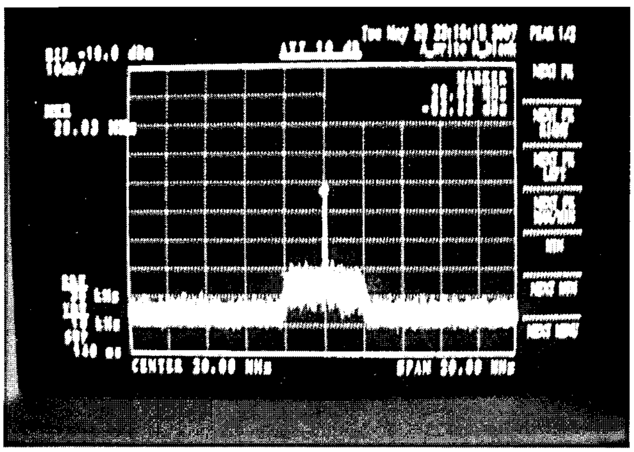

Fig. 7. The output signal spectrum after cancelling the feedback signal by the proposed scheme.

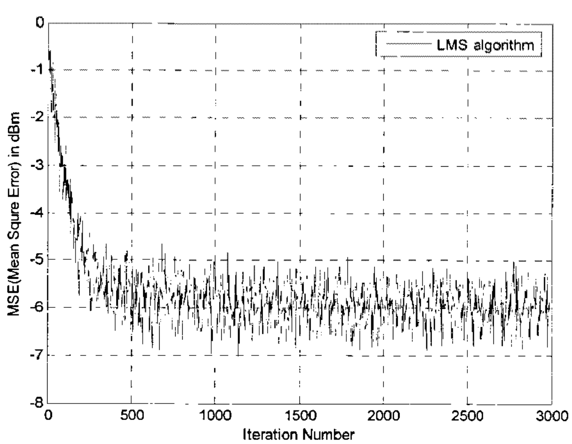

Fig. 8. MSE performance of the LMS algorithm.

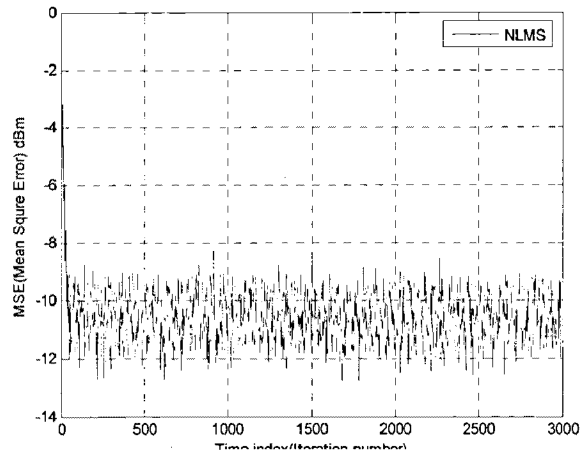

Fig. 9. MSE performance of the NLMS algorithm.

V. CONCLUSIONS

We proposed an adaptive interference cancellation system for a radio repeater. The proposed ICS consists of two stages of cancellation. First, attenuation signal is used to cancel the interference. And NLMS algorithm is employed in the second stage. We investigated the performance and compared with LMS algorithm employed system. The proposed scheme was implemented with digital signal processing (DSP) chip and showed a better performance of interference cancellation in the measurement. Test setup was carried out for WCDMA system environment.

Performance of the proposed ICS is suitable for interference cancellation in wireless communication systems.

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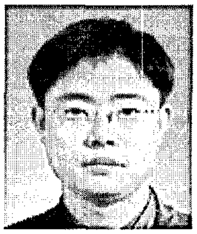

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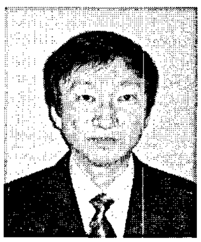

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