Wireless Repeater with Adaptive Equalizer and Phase Noise Compensator for LTE-Advanced Uplink

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Abstract — **In this paper, we propose adaptive equalizer and phase noise compensator in order to effectively cancel feedback channel and phase noise in wireless repeater system based on LTE-Advanced uplink system. In a repeater system, the performance got worse caused by feedback channel and phase noise. In order to cancel feedback channel, we use adaptive equalizer such as NLMS and RLS. And block type pilot is a common pilot pattern in LTE-Advanced uplink standard. So the phase noise compensator exploits block type pilot. Instead of estimating phase noise in other algorithms, the proposed method directly estimates the interference components caused by phase noise and improves estimation accuracy. After that, we reconstruct the interference matrix and suppress the interferences by the inverse matrix method. BER performance of proposed method is satisfied with 12.5dB at 10-4.**

Index Terms — **Ceramics, coaxial resonators, delay filters, delay-lines, power amplifiers.**

I. Introduction

When the gain of a wireless repeater is larger than the isolation between transmit and receive antennas of the repeater, the feedback signal that comes into the receive antenna from the transmit antenna of the repeater causes the repeater to go into feedback oscillation regardless of the input signal [1]-[5]. In this case, repeater system may be unstable because of the feedback. Also, the phase noise effect can exist in up and down converter of wireless repeater. If there are phase noise effects, the performance of system will get worse. Therefore, we propose adaptive equalizer and phase noise compensator here.

II. System Model

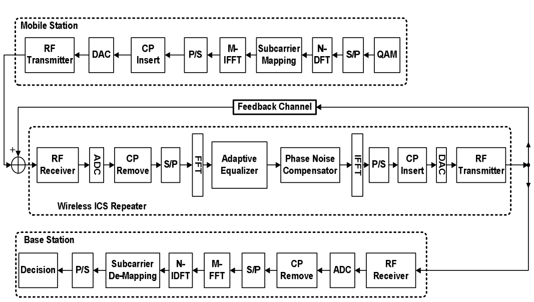

Fig. 1. Block diagram of wireless repeater system.

Figure 1 is the block diagram of wireless repeater system. The phase noise exists in RF transmitter and RF receiver among base station, mobile station and wireless repeater respectively. We estimate unknown channel and evaluate the performance of wireless repeater system.

$$y_F(n) = h(n) * x(n) + n(n), \; (where\ h(n) = \sum_l \alpha_l \cdot \delta(n - \tau_l)). \quad (1)$$

where α is feedback gain, τ is delay, and $n(n)$ is AWGN. Because the input signal is far smaller than feedback signal $\alpha > 1$.

III. Adaptive Equalizer in Repeater System

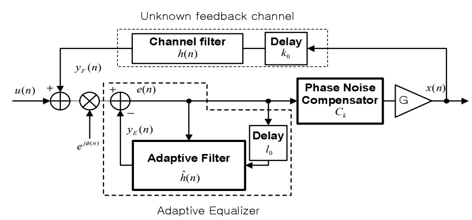

Fig. 2. Block diagram of adaptive equalizer and phase noise compensator.

The interference effects of feeback signal may cause the distortion in repeater system, because of the existence of feedback channel. Therefore, interference cancellation system is implemented by adaptive equalizer. The error of estimated signal is as follows.

$$\begin{aligned} e(n) &= i(n) \cdot e^{j\phi(n)} + y_F(n) \cdot e^{j\phi(n)} - y_E(n) \\ &= i(n) \cdot e^{j\phi(n)} + h(n) * x(n-k_0) \cdot e^{j\phi(n)} - w(n) * e(n-k_0) \end{aligned} . \quad (2)$$

A.RLS Adaptive Filter

The RLS algorithm is derived from the minimization of the sum of weighted least-square error which is expressed as follows :

$$J_{LS}(n) = \sum_{l=1}^{n} \lambda^{n-l} e^2(n), \quad (3)$$

where λ is the forgetting factor, which has a value more than 0 and below 1. Therefore, RLS algorithm can be expressed as following equation.

$$\hat{h}_l(n+1) = \hat{h}_l(n) + g(n)e(n), \quad (4)$$

where the updating vector is defined as

$$g(n) = r(n) / \left(1 + x^T(n) r(n)\right), \quad (5)$$

and

$$r(n) = \lambda^{-1} P(n-1) x(n), \quad (6)$$

where *P(n)* is the inverse correlation matrix of input data.

$$P(n) \equiv R^{-1}(n) = \left(\sum_{l=1}^{n} \lambda^{n-l} x(l) x^T(l) \right)^{-1},$$

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can be computed recursively as

$$P(n) = \lambda^{-1} P(n-1) - g(n) r^{T}(n) \cdot \qquad (7)$$

IV. Phase Noise Compensator

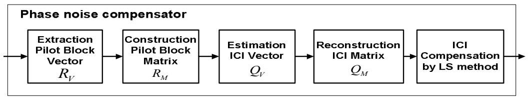

Fig. 3. Block diagram of phase noise compensator.

In this section, we propose a phase noise compensator, which is based on block type pilot. The ICI components are caused by phase noise. We estimate the ICI components directly from the received pilot block, instead of estimating phase noise process that is fairly difficult to get accurate estimation results. Then, by reconstructing the ICI matrix, we can make suppression to the interferences by inverse matrix method. Finally, then, we can improve performance of system. We extract pilot block vector, and construct pilot block matrix by using pilot block vector. And then, we estimate ICI vector by using pilot block matrix. And we reconstruct ICI matrix, and finally, we compensate ICI effects by LS method. We assume that the phase noise has a high correlation with the pilot block and the following data block. Since symbol period and frame size are usually very short in wireless communications, this assumption is feasible. Therefore, the influence of phase noise on the data block can be easily suppressed by LS method.

V. Simulation Results

TABLE I. The simulation parameters.

Number of Subcarriers	128
Modulation	16QAM
Channel	AWGN + Feedback channel
Phase noise variance	0.005, 0.01, 0.05

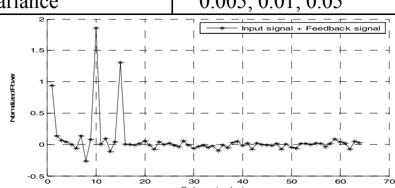

Fig. 4. Signal compositions of input and feedback signal in time domain.

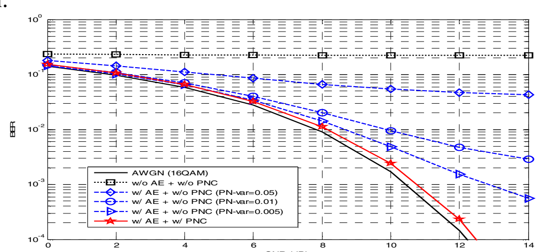

Fig. 5. BER performance of proposed algorithm (16QAM).

The table 1 is the simulation parameters. We have simulated for feedback channel which is shown as follows.

Case of feedback channel: $h_1 = 1.8\delta(n-10) + 1.2\delta(n-15)$.

Figure 4 shows signal compositions of input signal and feedback signal in time domain. For evaluation, we used NMSE method which is

$$MSE = 10\log_{10}\left\{\left(\sum_{l=1}^{n}\left(y_F(l) - y_E(l)\right)^2\right) / \left(\sum_{l=1}^{n} y_F(l)^2\right)\right\}$$

It is clear as simulation results, the convergence speed of RLS is faster than NLMS for both channels. Figure 5 is the BER performance of adaptive equalizer and phase noise compensator in case of 16QAM. In figure 5, an AE means the adaptive equalizer, and a PNC means the phase noise compensator. The feedback channel and phase noise are compensated by adaptive equalizer and phase noise compensator. BER performance of proposed method is satisfied with 12.5dB at 10^{-4}.

VI. Conclusions

In this paper, we propose adaptive equalizer and phase noise compensator in wireless repeater system. In order to cancel feedback channel, we use adaptive equalizer such as NLMS and RLS. Also, in LTE-Advanced uplink standard, block type pilot is a common pattern. So the phase noise compensator exploits block type pilot. Instead of estimating phase noise in other algorithms, the proposed method directly estimates the interference components caused by phase noise and improves estimation accuracy. After that, we reconstruct the interference matrix and suppress the interferences by the inverse matrix method. BER performance of proposed method is satisfied with 12.5dB at 10^{-4}.

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