INVERSE ADAPTIVE MODELING OF RADIO PROPAGATION CHANNELS

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I. INTRODUCTION

The characterizations of radio propagation channels are generally based on theoretical and/or statistical models derived from propagation measurements between fixed locations over certain specified regions [1,2]. However, propagation conditions vary from time to time (e.g. diurnal and seasonal variations of the atmosphere) and from region to region (e.g. variations of geographical and terrain conditions). In particular, the propagation paths continue to change in cases of mobile communications. As a result, adaptive modeling of propagation channels become valuable for practical applications.

This paper presents an inverse adaptive modeling scheme for characterizing radio propagation channels and discusses its applications for improving radio communication systems. In Section II, an inverse adaptive modeling scheme for systems is presented. In Section III, we deal with inverse adaptive modeling of radio propagation channels based on the same concept as discussed in Section II. In Section IV, we discuss some practical applications of the inverse adaptive modeling scheme for improving radio communication systems.

II. INVERSE ADAPTIVE MODELING OF AN UNKNOWN SYSTEM

The scheme of inverse modeling of an unknown system [3] is shown in Fig. 1. The unknown system and the LMS adaptive filter are connected in cascade. The input signal s(k) drives the unknown system and serves as the reference signal r(k) of the LMS adaptive filter. The adaptive filter is a tapped-delay-line transversal filter as shown in Fig. 2.

The output signal y(k) is the weighted sum of the signal $x_i(k)$.

$$y(k) = \sum_{i=0}^{n} w_i(k)\, x_i(k)$$

$$= W(k)^T X(k) \qquad (1)$$

where $W(k) = [w_0(k)\ w_1(k)\ \dots\ w_i(k)\ \dots w_n(k)]^T$ is the weight column vector

$X(k) = [x_0(k)\ x_2(k) \dots x_i(k) \dots x_n(k)]^T$ is the input column vector.

The error signal $\in(k)$ is the difference between the reference signal r(k) and the filter output y(k).

$$\in(k) = r(k) - y(k) \qquad (2)$$

The adaptive filter minimizes the mean-square error $E[\in(k)^2]$ by adjusting its weights in accordance with the LMS algorithms [4].

$$W(k+1) = W(k) + 2\mu\epsilon(k)\, X(k) \tag{3}$$

for digital systems and

$$\frac{d}{dt} W(t) = -2\mu\epsilon(t)\, X(t) \tag{4}$$

for analog systems. Where μ is a scalar constant controlling rate of convergence and stability ($\mu < 0$).

The optimum weight vector W_{LMS} for a minimum $E[\epsilon(k)^2]$ is given by the Wiener-Hopf equation [4].

$$W_{LMS} = R^{-1} P \tag{5}$$

where $R = E[X(k)\, X(k)^T]$ is the input correlation matrix and R^{-1} is the inverse matrix of R.
$P = E\{r(k)\, X(k)]$ is the cross-correlation between the reference signal and the input signal.

In the absence of system noise, the mean-square error $E[\epsilon(k)^2]$ can be minimized to zero such that the filter output y(k) will match to the reference signal r(k). The input signal s(k) is convolved with the impulse response of the unknown system and the LMS adaptive filter deconvolves the system output x(k) to restore the original signal s(k). As a result, the overall transfer function of the system in cascade with the converged adaptive filter is unity. i.e.,

$$H_S(\omega)\, H_A(\omega) = 1 \tag{6}$$

Therefore, the transfer function of the adaptive filter $H_A(\omega)$ is the reciprocal of that of the unknown system $H_S(\omega)$, and the adaptive filter represents an inverse model of the unknown system.

III. INVERSE ADAPTIVE MODELING OF RADIO PROPAGATION CHANNELS

The proposed modeling scheme for radio propagation channels is based on the same concept of inverse adaptive modeling of an unknown system. However, in this case, the transmitter and the adaptive filter are far apart from each other. We cannot apply the same input signal s(k) to the propagation channel and to the adaptive filter at the same site as in the case of modeling an unknown system.

Fig. 3 shows the scheme of inverse adaptive modeling of radio propagation channels. In this case, a reference signal for the adaptive filter has to be generated locally at the receiver, which must be correlated with the transmitted signal and in synchronization with the transmitted signal. This can be achieved by transmitting a Pseudonoise (PN) code sequence which is known to the receiver. The same PN code can be generated at the receiver and code synchronization between the transmitter and the receiver can be accomplished by using acquisition and tracking circuits [5,6]. It should be noted that the PN code is to provide the reference signal for the LMS adaptive filter rather than serving as a spreading code as in the case of spread spectrum communication systems. A short PN code sequence may be employed to serve as training signal of the adaptive modeling scheme.

This scheme can function properly while the information is being transmitted. In this case the reference signal for the adaptive filter is generated by a signal processor as shown in Fig. 3. However, the structure of the signal processor depends on the type of modulation.

IV. APPLICATIONS OF INVERSE ADAPTIVE MODELING

The inverse adaptive modeling scheme can continue monitoring radio propagation channel and automatically provide equalization to the channel without the knowledge of atmospheric and terrain conditions. The ability of adaptive equalization depends on the speed of adaptation and the number of adjustable weights of the LMS adaptive filter. In addition, high channel noise can cause the modeling scheme to deteriorate.

In the case of earth-space propagation, which passes through the tropospheric and ionospheric regions of the atmosphere, the propagation effects can be greatly reduced by the adaptive modeling scheme. As a result, the scheme can improve the performances of satellite communication systems. The transmission of digital signals through dispersive channels can cause serious intersymbol interference without appropriate equalization. Therefore, adaptive modeling techniques become essential when channel characteristics are unknown and time-varying.

V. CONCLUSION

An inverse adaptive modeling scheme has been introduced for characterizing and equalizing radio propagation channels. This scheme can monitor and compensate the propagation channel such that a signal can be transmitted through the channel as if propagation effects were not present or greatly reduced. As a result, this scheme can cope with unpredictable propagation conditions and can significantly improve the performances of radio communication systems.

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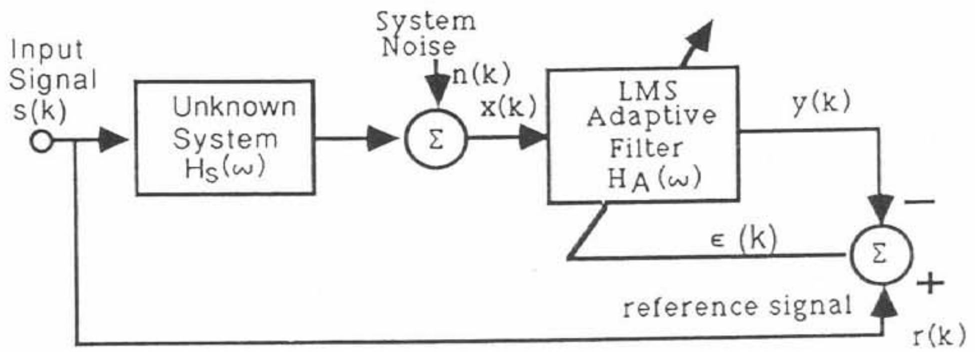

Fig. 1. **Inverse Adaptive Modeling of an Unknown System**

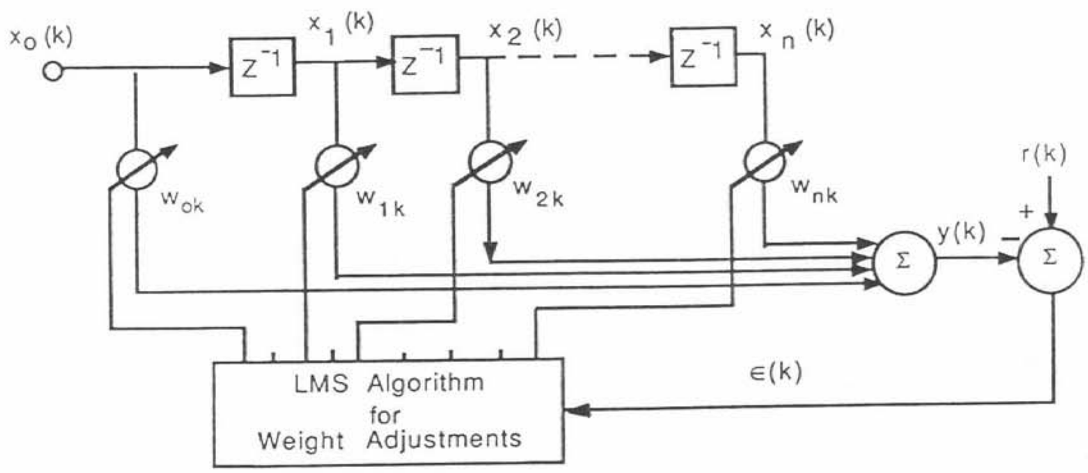

Fig. 2 **Tapped-delay-line LMS Adaptive Filter**

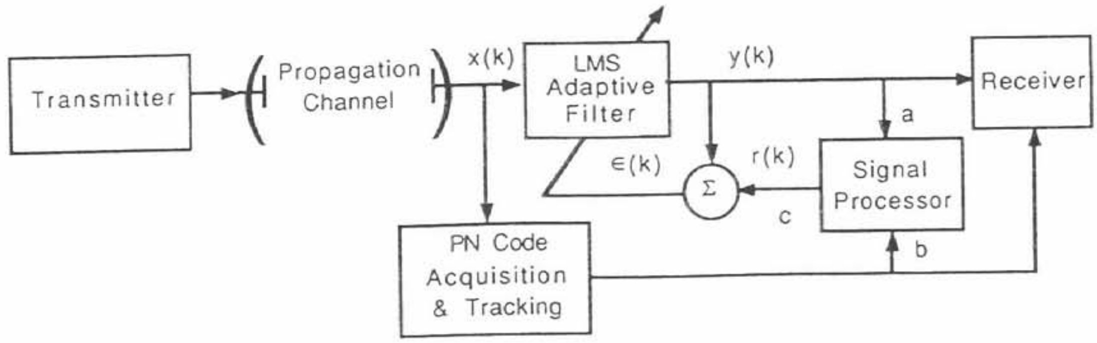

Fig. 3 **Inverse Adaptive Modeling of a propagation channel while information is being transmitted**