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# Interference Cancellation Algorithm for 2 × 2 MIMO System without Pilot in LTE

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## ABSTRACT

Interference cancellation system (ICS) for 3GPP/LTE system is the broadband cancellation system, which receives forward signal through the donor antenna. We proposed new algorithm of received signal with pilot and non-pilot design. Although repeater design needs our project, so in this paper we discuss about interference cancellation algorithm for 2x2 MIMO systems without pilot in LTE. First explain the general principle structure of 3GPP/LTE, next determine our new design and algorithm. Finally, we simulated our mathematic extraction of proposed new algorithm on MATLAB.

**Keywords:** MMSE; Lookup-table; Threshold; Cost Function; Viterbi Algorithm

## 1. Introduction

Interference cancellation system (ICS) for the donor and service antenna amplifies the received signals and sends them to base station and mobile to get stronger signal. During this process, it cancels the interference signal between the donor and receiving antenna. There are using types of cancellation algorithms, some existing adaptive cancellation algorithms work in the frequency domain, using the reference tones carried in the OFDM signal. Other algorithms use the time domain methods like the LMS. In general these algorithms are classified by interference cancellation algorithm with and without pilot signals. We described interference cancellation algorithm without pilot signals in this paper. It is feasible to implement ICS in OFDMA systems such as LTE. Although IC techniques can be applied to both downlink and uplink of LTE, due to complexity considerations, IC is considered mainly as a technique for the UL and implemented in the base station receiver. ICS techniques can be used to cancel both intra-cell and inter-cell interference.

## 2. Proposed Channel Estimation Method and Equalization

### 2.1. Non Pilot Channel Estimation

The MMSE estimator minimizes the MSE of the channel estimates, but the complexity is high compared to the ML or LS estimators. The LS and MMSE method were compared in and for OFDM systems and the MMSE was found to outperform the ML in low SNRs. The calculation of the MMSE estimate requires a large matrix inversion. The complexity of the MMSE estimator can also be reduced by considering only the high energy channel taps.

Transform domain techniques may also be used for obtaining the channel estimates for the whole bandwidth. The inverse FFT transforms the channel frequency response into time domain where the low power taps can be eliminated and the noise reduced channel can be transformed back to frequency domain with the FFT. MMSE filtering can also be used to predict the channel of the current OFDM symbol based on channel estimates from previous symbols, i.e. time and frequency domain correlation of the channel frequency response can be exploited in the channel estimation. For improved performance in MIMO-OFDM systems, the spatial correlation can be included in the MMSE channel estimation.

### 2.2. Equalization Techniques

In general, there are three categories of equalization techniques. Our technique is the time–frequency domain equalization with channel shortening. A time-domain equalizer is inserted to reduce the MIMO channels to the ones with the channel length shorter than or equal to the

 

CP length, and then, a one-tap frequency-domain equalizer is applied to each subcarrier. When the MIMO channels are shortened by the time-domain equalizer, residual ICI and ISI are introduced. They cannot be eliminated by the subsequent frequency-domain equalizer and, thus, limit the performance.

This has resulted in new receiver concepts using different equalization techniques. These techniques are briefly explained below.

- *Time-domain equalizer (TEQ)*

The time domain equalization (TEQ) is a short FIR filter at the receiver input that is designed to shorten the duration of the channel impulse response (L). Thus it allows a reduction in the guard interval length. Using a filter with up to 20 coefficients, the effective channel impulse response of a typical AWGN channel can easily be reduced by a factor of 10. Different cost functions such as minimum mean squared error, maximum shortening signal-to-noise ratio (SNR), and minimum inter-symbol interference (ISI), and maximum bit rate have been proposed to design the time domain equalizer (TEQ).

### 2.3. Iterative Algorithm

In OFDM, channel estimation can be performed with a blind or a non-blind technique. The blind channel estimation method does not require the use of training sequences or pilot symbols and enables a more efficient use of the available bandwidth. The channel estimates are obtained using the statistical properties of the received data which is collected over a certain time period.

ML equalizer, and can be used to compute the coefficients of suboptimal but lower-complexity equalizers such as the minimum mean-squared error (MMSE) linear equalizer (LE). Even though the MMSE-LE can be estimated directly, having the channel estimates allows us to choose which equalizer is more appropriate for the channel.

## 3. Mathematic Extraction for Non Pilot Channel Estimation

We assume a single UE receiving desired signal from the serving BS as well as inter-cell interference signals from neighboring BSs. The BSs from different cells are assumed to be synchronized in time and frequency. The UE has NR receive antennas which are used for performing inter-cell interference suppression. Each BS has one antenna to transmit one stream of information.

We define s as the vector that stands for the d pilot symbols, which are multiplexed with s to form a block of N=Nd+Np transmitted symbols s. For simplicity, we

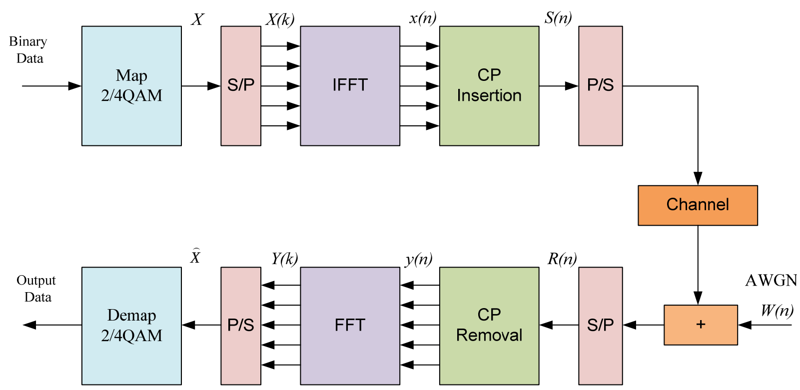


**Figure 1. The block diagram of an OFDM system.**

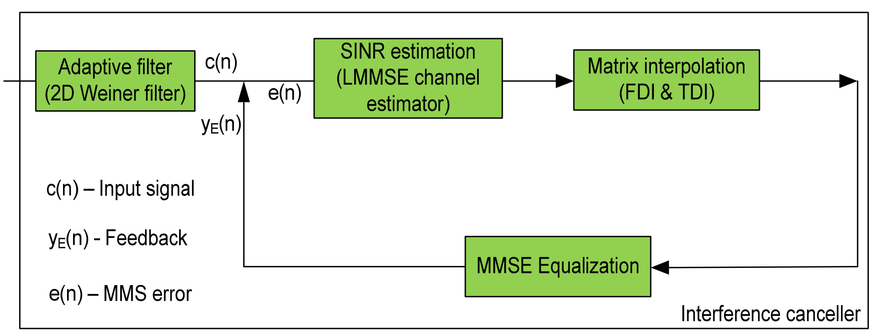


**Figure 2. Proposed Iterative model for MIMO receiver.**

 

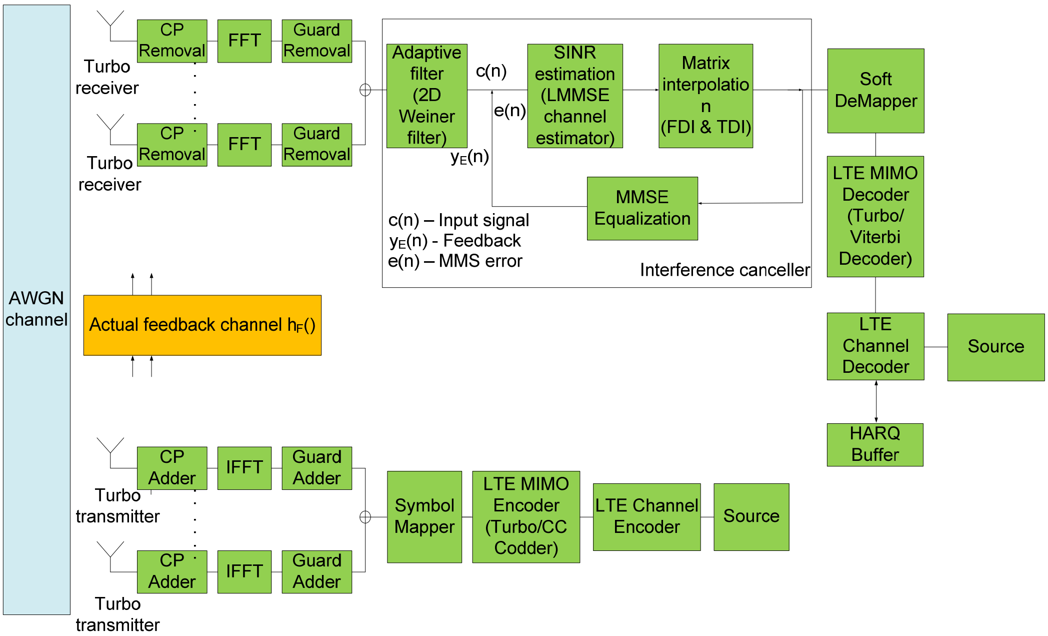


**Figure 3. Proposed system model of ICS Repeater without Pilot signal for 3GPP/LTE.**

consider unit-energy QPSK with the symbol alphabet αk, k=1,…,4, which are used for desired signal as well as all other interference signals. In this work, the receiver is assumed to have perfect CSI between the serving BS and the UE. If SIC is applied, the UE also requires knowledge about the interference link, e.g., the channel between the UE and the interfering BS and the modulation scheme of the interference signals. Notice that the pilot symbols here are only used to calculate the beam forming weights, not for performing channel estimation.

## 3.1. MMSE Estimator

This effectively equalizes the frequency-selective channel. First, consider the infinite length filter case: The output of the equalizer is

$$\hat{x}[n] = \sum_{k=-\infty}^{\infty} \omega_{n-k} t[k] = \sum_{k=-\infty}^{\infty} q_{n-k} x[k] + \sum_{k=-\infty}^{\infty} \omega_k \eta[n-k]$$

Is where the equalized channel IR is

$$q_n = \sum_{j=-\infty}^{\infty} \omega_j f_{n-j}$$

The difference between the Tx.ed data and the equalizer output is:

$$\varepsilon[n] = x[n] - \hat{x}[n]$$

and the MMSE cost function is:

$$J = E\{|\varepsilon[n]|^2\} = E\{|x[n] - \hat{x}[n]|^2\}$$

Principle of orthogonality:

$$E\{t[n-k]\varepsilon^*[n]\} = 0, -\infty < k < \infty$$

We can calculate the MMSE equalizer by either minimizing *J* over *w*:

$$J = E\{|\varepsilon[n]|^2\} = E\{x[n] - \hat{x}[n]|^2\}$$

$$= E\{|x[n] - \sum_{k=-\infty}^{\infty} \omega_k t[n-k]|^2\}$$

$$= E\left\{|x[n] - \sum_{k=-\infty}^{\infty} \omega_k \left(\sum_{l=0}^{L-1} f_l x[l-(n-k)] + v[n-k]\right)|^2\}\right\}$$

Then Jmin is,

$$J = E\{|\varepsilon[n]|^2\} = E\{\varepsilon[n]\varepsilon^*[n]\} = E\{\varepsilon[n](x^*[n] - \hat{x}^*[n])\}$$

Due to the principle of orthogonality,

$$E\{\varepsilon[n]\hat{x}^*[n]\} = 0 \text{ then}$$

$$J_{\min} = E\{\varepsilon[n]x^*[n]\}$$

$$= E\{|x[n]|^2\} - \sum_{k=-\infty}^{\infty} \omega_k E\{t[n-k]x^*[n]\}$$

$$= 1 - \sum_{k=-\infty}^{\infty} \omega_j f_{-k} = b_0$$

## 3.2. MMSE Calculation

$$\hat{x}[n] = q_0 x[n] + \sum_{k \neq n} q_{n-k} x[k] + \sum_{k=-K}^{K} \omega_k \eta[n-k]$$

where the WMF output/equalizer input is

$$q_n = \sum_{j=-\infty}^{\infty} \omega_j f_{n-j}$$

and the convolution of the equalizer and the equivalent channel IRs is

$$t[n] = \sum_{k=-\infty}^{\infty} f_k x[n-k] + \eta[n]$$

Obviously, the variance of noise is

$$\sigma_n{}^2 = N_0 \sum_{k=-k}^{k} c_k{}^2$$

The ISI terms are

$$D = \sum_{k \neq n} q_{n-k} x[k]$$

For a fixed sequence of information symbols

$$x_j = \{x[k]\}, D = D_j$$

Then, the probability of error for this sequence is

$$P_M(D_j) = 2\frac{M-1}{M} P\{(D_j + N) > q_0\}$$

$$= 2\frac{M-1}{M} Q\left(\sqrt{\frac{(q_0 - D_j)^2}{\sigma_n{}^2}}\right)$$

$$N = \sum_{k=-K}^{K} \omega_k \eta[n-k]$$

Average probability is found by averaging over all $D_J$

$$P_M = \sum_{xj} P_M\{D_j\} \quad P\{x_j\}$$

$P_M\{D_J\}$ is dominated by the sequence yielding highest $D_J$ which occurs when $x[n]= \pm(M\text{-}1)$ and the signs of $x[n]$'s match the corresponding $\{qn\}$.

$$D_j{}^* - (M-1)\sum_{k \neq 0} |q_k|$$

### 3.3. Error Model

MMSE equalizer aims at minimizing

$$J = E\left\{\left|\varepsilon[n]^2\right|\right\} = E\left\{\left\{\left|x[n-\delta] - \hat{x}[n]\right|\right\}^2\right\}$$

$$= E\left\{\left|e_\delta^T x[n] - \hat{x}[n]\right|^2\right\}$$

$$x[n] = \begin{bmatrix} x[n] \\ x[n-1] \\ \vdots \\ x[n-(N+L-2)] \end{bmatrix}$$

Expanding the cost function

$$J = E\left\{\left|e_\delta^T x[n] - \hat{x}[n]\right|^2\right\} = E\left\{\left|e_\delta^T x[n] - w^T \eta[n]\right|^2\right\}$$

$$= E\Big\{\left(\left(e_\delta^T - w^T F\right)x[n] - w^T \eta[n]\right)$$

$$\left(x^H[n]\left(e_\delta - F^H w^*\right) - \eta^H[n] w^*\right)\Big\}$$

Optimum equalizer coefficients are:

$$\nabla_{w^*} J = 2\left(w_0^T R - p^H\right) = 0$$

$$w_0^T = p^H R^{-1} = \sigma_x^2 e_\sigma^T F^H \left(\sigma_x^2 F F^H + \sigma_\eta^2 I\right)^{-1}$$

Substituting back to the MSE term

$$J_{\min} = \sigma_x^2 - p^H R^{-1} p \sigma_x^2$$

$$= \sigma_x^2 - \sigma_x^2 e_\delta^T F^H \left(\sigma_x^2 F F^H + \sigma_\eta^2 I\right)^{-1} \sigma_x^2 F e_\delta$$

$$= e_\delta^T \left(\frac{1}{\sigma_\delta^2} I + \frac{1}{\sigma_\eta^2} F^H F\right)^{-1} e_\delta$$

## 4. Flowchart of Proposed Signal Processing Technique without Pilot Signal for ICS

In result section, the simulations of the algorithms developed two cases. Our proposed design implemented both cases, which are pilot and non-pilot receiver simulated on MATLAB. **Figure 5** shows non-pilot design for 2-2 Tx-Rx MIMO system. This figure included TDI and FDI based matrix interpolation that requires modulation

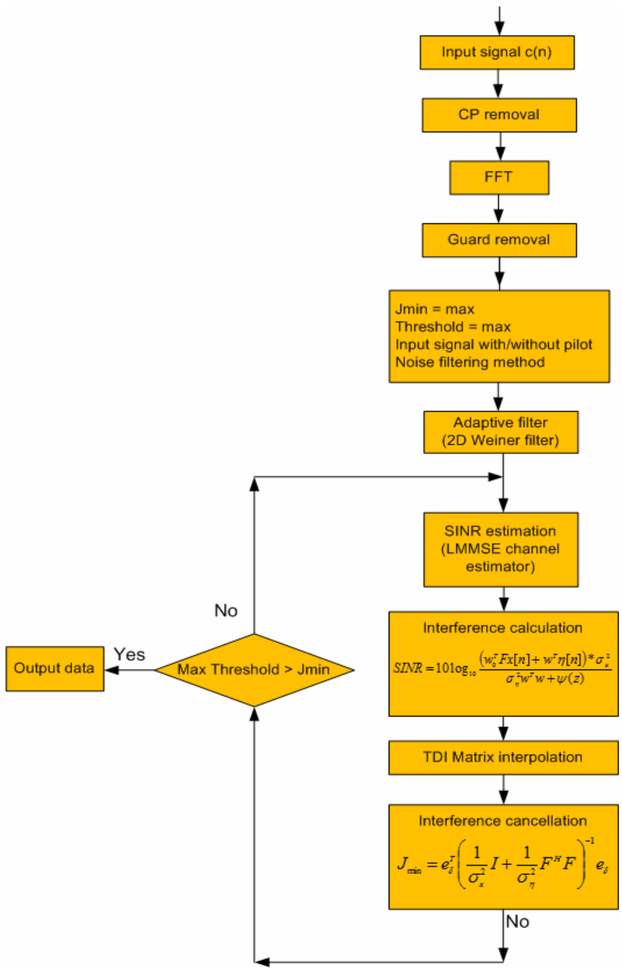


**Figure 4. Proposed combination signal processing technique of ICS for 3GPP/LTE.**

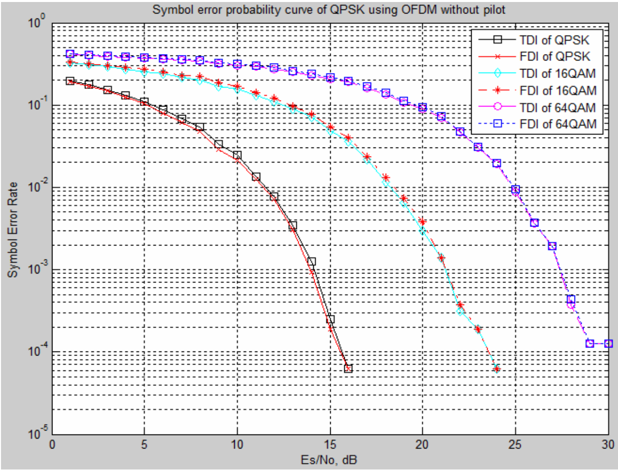


**Figure 5. The symbol error rate comparison of the proposed non-pilot technique with that of a 2Tx−2Rx at the MMSE receiver.**

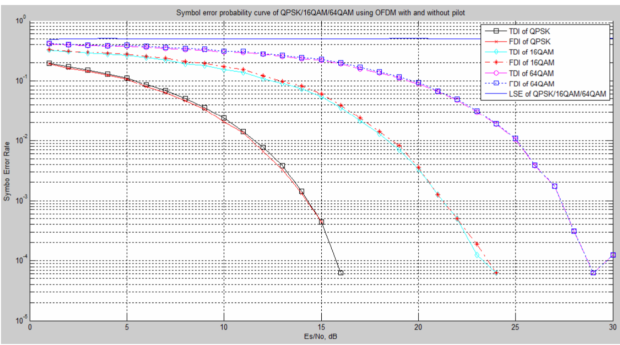


**Figure 6. The symbol error rate comparison of the proposed non-pilot and pilot technique with any modulation order at the receiver.**

**Table 1. Simulation parameters.**

| Parameter | Value |
|---|---|
| Modulation schemes | QPSK,16QAM,64QAM |
| Cyclic prefix | Normal |
| FFT/IFFT block size | 1024 |
| Number of iterations | 6< |
| Threshold | 1.2 |
| Packet size in symbols | 10^3 |
| Channel tape | 6 |
| Channel estimator with pilot | MLSE using Viterbi algorithm |
| Channel estimator without pilot | MMSE |
| Channel equalizer with pilot | Least Square equalizer |
| Channel equalizer without pilot | Linear MMSE equalizer |
| Receiver antenna | MMSE receiver |

QPSK, 16QAM, 64QAM. The first iterative step ended to check maximum threshold is larger than $J_{min}$ value. If true no more iterative step, otherwise next iterative step continue. Proposed methods based two cases of ICS receiver structure. So we define only one general algorithm, which is used to any system with ICS block. If system determined input signal with pilot, then signal go to matched filtering block, otherwise select to adaptive filter.

## 5. Conclusions and Future Works

In finally, linear MMSE time-domain equalization technique has been proposed for general MIMO-OFDM systems. The added CP at the end of each MIMO-OFDM symbol converts the *linear convolution* in the channel into *circular convolution*. Simulations have demonstrated that the proposed MMSE time domain equalizer technique is effective in suppressing ICI and ISI and robust against the number of shifts in excess of the CP length. Finally, in this project the MMSE equalization used to non-pilot system, LS equalization used to pilot system, that are mainly considered as proved by any works. It would be very interesting to extend the ideas of the polynomial approach and transceiver/repeater designs to new practical system based channel interference cancellation methods.

## 6. Acknowledgements

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