Channel Estimation Techniques for Multicarrier OFDM 5G Wireless Communication Systems

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***Abstract*—The fifth-generation (5G) communication system is supposed to include a huge amount of mobile data traffic and number of wireless connections, for improved spectrum efficiency, quality of service (QoS), reliability, and security. This paper studies channel estimation techniques in multicarrier orthogonal frequency-division-multiplexing (OFDM) 5G wireless communication systems in Rayleigh and Rician channels. Proposed M-estimator based channel estimation technique in comparison with classical least squares (LS) and linear minimum mean-squared error (LMMSE) estimation is studied and analyzed. An M- estimator is proposed for robustification of channel estimation technique in Rayleigh and Rician fading channels. Simulation results are provided and the comparison shows the performance gains achieved by the proposed technique over LS and MMSE estimation in multicarrier OFDM 5G wireless communication systems.**

Index Term*—*channel estimation; internet of things; least squares; M-estimator.

I. Introduction

5G wireless communication systems must handle various situations and meet the increasing demand for data rates and QoS [1]. Transmitted symbols can be recovered by proper channel estimation to fix the channel impulse response (CIR) and to identify the effect of the channel on the transmitted symbols [2]. Hence, better reconstruction of transmitted symbols is required. Various channel estimation techniques were studied for wireless communication systems [3]. Channel parameters estimation in OFDM and generalized frequency division multiplexing (GFDM) were studied in [4] and [5] respectively. Robust multiuser detection using *M*-estimation in wireless communication systems was analyzed in [6]. LS and LMMSE based estimation techniques for channel parameters were compared in [7].

Different channel estimation techniques are generally used for massive multiple-input multiple-output (MIMO) systems, which are studied in [8]. [9] Outlines MMSE based OFDM systems for channel estimation. In [10], channel estimation technique for OFDM systems with fading (rapid dispersive) channels is proposed. [11] Proposes a scheme for analyzing OFDM systems performance over Rayleigh fading channels in the presence of phase noise, carrier frequency offset and jitter. Recently, mMIMO time-varying channels of OFDM systems are proposed in [12-14].

In this paper, Section II outlines system model, Section III explains *M*-estimator, Section IV describes the proposed channel estimation technique, simulation results are included in Section V and Section V contains some concluding remarks followed by references.

II. System Model

OFDM is one of the efficient modulation formats used in present 5G wireless communication systems. Fig. 1 shows block diagram of OFDM (cyclic prefix (CP)) system with FFT.

The New Radio (NR) 5G standard uses OFDM on uplink and downlink. The carrier spacing can be 15kHz, 30 kHz, 60 kHz, 120 kHz, 240 kHz, and 480 kHz with subcarriers up to 3300. BPSK, QPSK, 16QAM, 64QAM or 256QAM may be used for the subcarrier modulation. The received signal (at the receiver) may be described by

$$\mathbf{Y} = \mathbf{HX} + \mathbf{W} \tag{1}$$

where $\mathbf{H} = \left[H[0],\ H[1],\ \cdots,\ H[N-1]\right]^T$ is the vector form of channel, $\mathbf{W} = \left[W[0],\ W[1],\ \cdots,\ W[N-1]\right]^T$ is the vector form of noise with 0 mean and υ^2 variance and

$$X = \begin{bmatrix} X(0) & 0 & \cdots & 0 \\ 0 & X(1) & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & X(N-1) \end{bmatrix}.$$

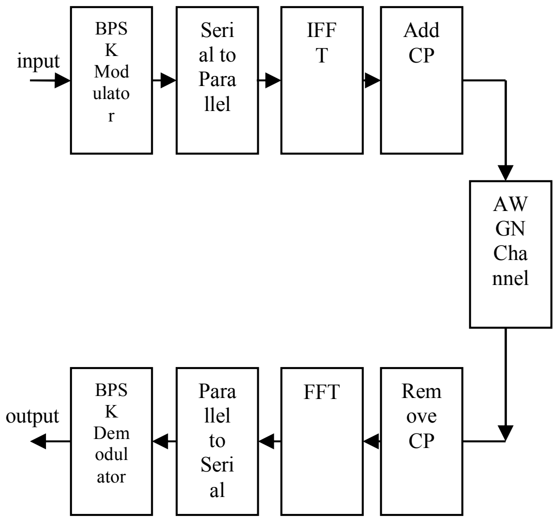


Figure1. Block diagram of OFDM system with FFT.

III. *M*-ESTIMATOR

An *M*-estimator [15] is used to robustify the channel estimation technique for 5G wireless communication systems. Penalty, influence and weight functions of the proposed *M*-estimator for channel estimation in 5G multicarrier wireless communications in Rayleigh and Rician fading channels (see Fig.2, 3 and 4 also) are given by

$$\rho_{PROPOSED}(x) = \begin{cases} \dfrac{x^2}{2} & for \quad |x| \le a \\ a^2 - a|x| & for \quad a < |x| \le b \\ \dfrac{-ab}{2}\exp\left(1-\dfrac{x^2}{b^2}\right)+d & for \quad |x| > b \end{cases} \tag{2}$$

$$\psi_{PROPOSED}(x) = \begin{cases} x & for \quad |x| \le a \\ a sign(x) & for \quad a < |x| \le b \\ \dfrac{a}{b} x \exp\left(1-\dfrac{x^2}{b^2}\right) & for \quad |x| > b \end{cases} \tag{3}$$

$$w_{PROPOSED}(x) = \begin{cases} 1, for \quad |x| \le a \\ \dfrac{a \operatorname{sgn}(x)}{x}, for \quad a < |x| \le b \\ \dfrac{a}{b}\exp\left(1-\dfrac{x^2}{b^2}\right), for \quad |x| > b \end{cases} \tag{4}$$

where a and b are any constants and x is any data. From an influence function, robustness measures are derived and a $(=kv^2)$ and b $(=2kv^2)$ are selected (where k is any constant). *M*-estimators reduce the outcome of outliers with $\min \sum_i \rho(x_i)$, where $\rho(.)$ is penalty function, $\psi(x) = \dfrac{d\rho(x)}{dx}$ is the influence function and $w(x) = \dfrac{\psi(x)}{x}$ is the weight function.

IV. CHANNEL ESTIMATION

LS channel estimation for 5G multicarrier wireless communications in Rayleigh and Rician fading channels is given by

$$\hat{\mathbf{H}}_{\mathbf{LS}} = \left(\mathbf{X}^{\mathbf{H}}\mathbf{X}\right)^{-1}\mathbf{X}^{\mathbf{H}}\mathbf{Y} = \mathbf{X}^{-1}\mathbf{Y} \tag{5}$$

where estimate of $\mathbf{H}$ is $\hat{\mathbf{H}}$ and $\mathbf{X}^{\mathbf{H}}$ is the Hermitian matrix of $\mathbf{X}$.

MMSE channel estimation for 5G multicarrier wireless communications in Rayleigh and Rician fading channels is given by

$$\hat{\mathbf{H}}_{MMSE} = \mathbf{R}_{HH}\left[\mathbf{R}_{HH} + \left(\mathbf{X}\mathbf{X}^{H}\right)^{-1}\mathbf{W}\upsilon^2\right]^{-1}\hat{\mathbf{H}}_{LS} \tag{6}$$

where $\mathbf{R}_{HH}$ is the matrix form of auto-covariance of $\mathbf{X}$.

Proposed technique estimates channel parameters for 5G multicarrier wireless communications in Rayleigh and Rician fading channels using

$$\hat{\mathbf{H}}_{\mathbf{PROPOSED}} = \left(\mathbf{X}^{\mathbf{H}}\boldsymbol{\psi}(\mathbf{x})\mathbf{X}\right)^{-1}\mathbf{X}^{\mathbf{H}}\mathbf{Y} \tag{7}$$

where $\psi(x)$ is influence function of the estimator described in above section.

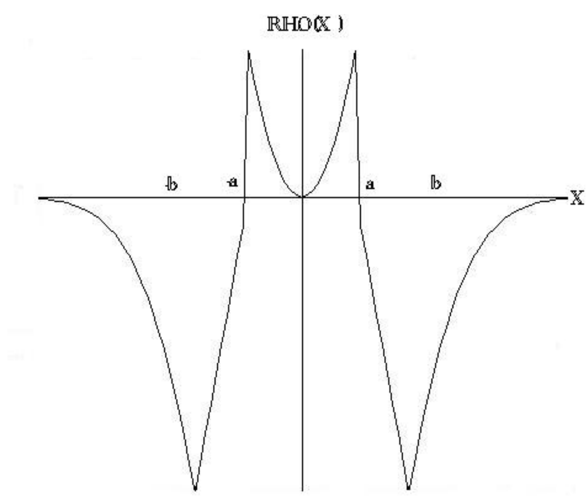


Figure 2. Proposed *M*-estimator penalty function.

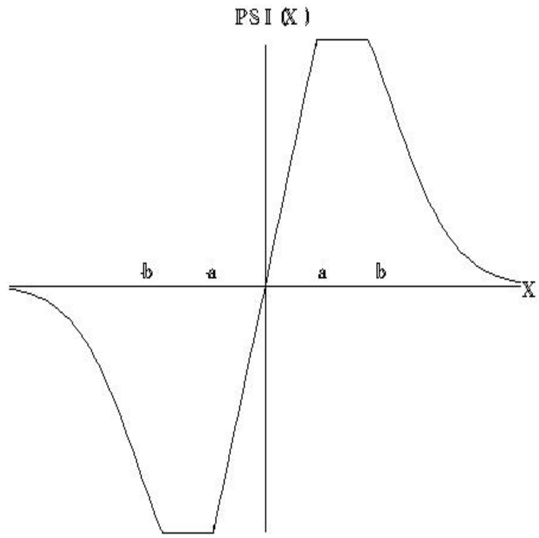


Figure 3. Proposed *M*-estimator influence function.

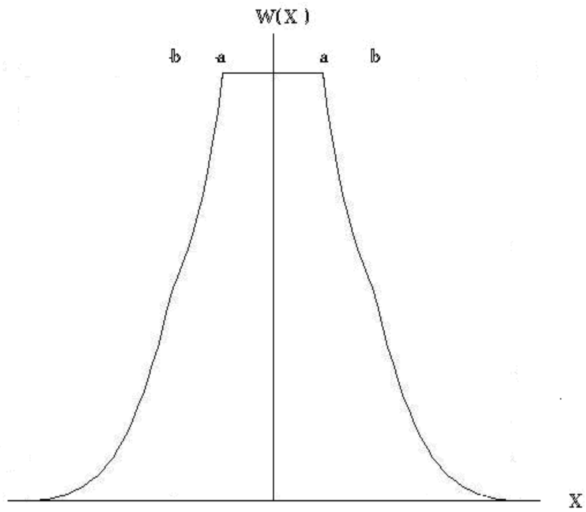


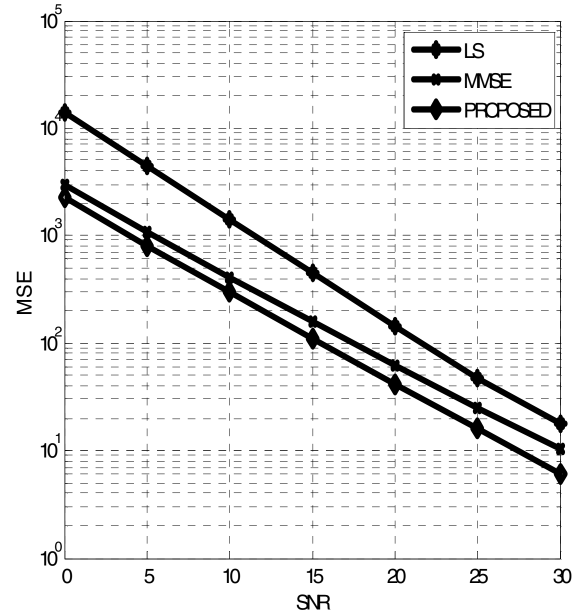
Figure 4. Proposed *M*-estimator weight function.

V. Simulation Results

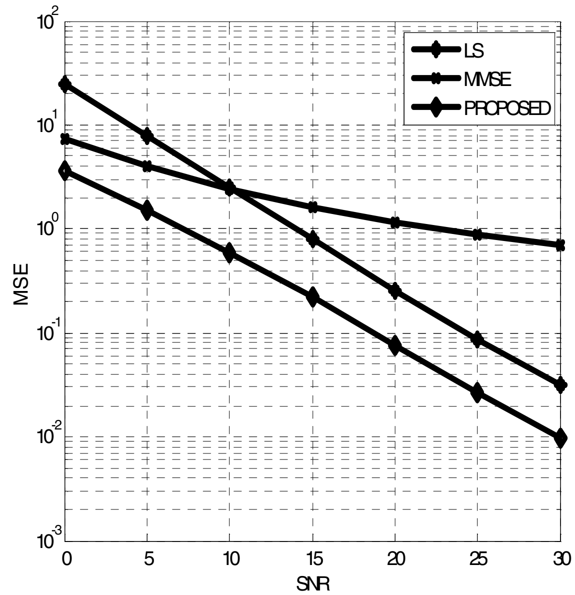
In simulations, channel estimation techniques based on LS and proposed *M*-estimator are compared and shown in Fig. 4. Simulation parameters used are pilot separation 4, number of sub carriers 128, modulation of subcarriers is BPSK and cyclic prefix is 8. A tapped-delay line channel is modeled whose power delay profile is (1, 0.5, 0.25, 0.125) for the fractional delays (0, 2.7, 3.1, 4.9) samples, each tap is modeled by a Gaussian distribution. MSE versus SNR is plotted in simulation results for all the considered channel estimation techniques. From these simulation plots, it is observed that the proposed *M*-estimator based channel estimation technique offers better performance over LS and MMSE techniques.

VI. Concluding Remarks

M-estimator based channel estimation technique for 5G multicarrier OFDM wireless communication systems in Rayleigh and Rician fading channels is analyzed in this paper. A new *M*-estimator is used for optimizing the channel estimation technique. Simulation results are provided to compare the performance gains offered by the proposed technique with that of LS and MMSE techniques for channel estimation. Observations from simulation results imply that the proposed *M*-estimator based channel estimation technique for 5G multicarrier OFDM wireless communication systems offers better performance than LS and MMSE techniques in Rayleigh and Rician fading channels.



(a)



(b)

Figure. 5. BER vs. SNR Performance of LS, MMSE and Proposed channel estimators in (a) Rayleigh and (b) Rician fading channels.

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